Environmental Assessment of the Alaskan Continental Shelf

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April - June 1976 quarterly reports from Principal Investigators participating in a multi-year program of environmental assessment related to petroleum development on the Alaskan Continental Shelf. The program is directed by the National Oceanic and Atmospheric Administration under the sponoroship of the Bureau of Land Management.

ENVIRONMENTAL RESEARCH LABORATORIES
Boulder, Colorado
September 1976

VOLUME II

CONTENTS

EFFECTS

EFFECTS

QUARTERLY REPORT

I. Study of Effects of Acute and Chronic Exposure to Hydrocarbons on Shallow Water Bering Sea Fishes

II. Both field and laboratory activities were conducted this quarter

A. Ship schedule

1. OCSEAP RP-4-MF-76A-Leg II Eastern Bering Sea
April 24-May 13, 1976
R/V Miller Freeman

B. Dr. A.L. DeVries
Physiological Research Laboratory
Scripps Institution of Oceanography
La Jolla, California, 92093

and

Mr. Scott Graves
Staff Research Associate
Physiological Research Laboratory
Scripps Institution of Oceanography
La Jolla, California, 92093

Role: Perform physiological observations on dermersal fish survey

C. Methods and sample localities--Fishes were collected by trawl at several depths at temperatures between -0.5 and +4°C in Sub area III of the Eastern Bering Sea (Figure 1). Fishes were kept alive in tanks on the deck of the Miller Freeman. Sea water was continually circulated through the tanks and fishes survived with out problems under these conditions even when seas were rough. When sea conditions permitted fishes were transferred to 60 gallon tanks which contained naphthalene at concentrations between 3 and 10 ppm. The times when the fishes first showed stress and when they died were recorded. Observations were not made for periods longer than 48 hours because of the short duration of the cruise.

Blood samples were also taken from several species of Bering Sea fishes and the freezing and melting points of their blood determined. A large difference between these two parameters indicates the presence of antifreeze. This survey was done in order to determine which fishes should be shipped to Scripps Institution of Oceanography for further studies on the effect of naphthalene on the synthesis of the antifreeze proteins. Observations were also made to determine which fishes were hardy enough to stand 30 hours of transport in an ice chest by air.

III. Results and Interpretation--Short term exposure to high concentrations of naphthalene (5ppm or greater) produced death quickly in all species examined. At concentrations of less than 3 ppm several sculpins survived for at least 48 hours. However at these concentrations the pacific cod and yellow fin sole quickly died indicating a greater susceptibility to this toxicant. The data for the sculpins are in accord with those obtained for the tide pool sculpin which occurs in the rocky tide pools of the Pacific Ocean near La Jolla, California and lives at higher temperatures (+15°C). Only preliminary short term toxicity studies were done aboard the Miller Freeman because of the lack of aquarium space, large size of specimens (weights greater than 400 grams) and the short duration of the cruise.

More sophisticated studies could be done aboard ship with a flow through system in which larger numbers of fishes could be handled. Such studies appear feasible to me and would increase the reliability of the results which indicate differences between the sculpins and cods.

The preliminary short term studies were done in order to establish concentration limits below which Bering Sea fishes would not die during 48 hours. This was done so that we would have some idea of what levels of naphthalene could be tolerated for long term exposure studies to be done at Scripps.

Freezing and melting points of the blood serums of a few specimens of all of the Bering Sea fishes caught during the fish survey were also determined. Only 5 of the species examined showed a large difference between the freezing and melting point indicating the presence of an antifreeze system. A summary of those fishes examined is given in Table I. Of those fishes possessing antifreeze, only the sculpin appeared sufficiently hardy to transport by air to Scripps for long term studies. About 40 of the sculpin, Myoxocephalus verrucosus were shipped to Scripps and of these 28 survived. Those which died apparently suffered internal damage when caught in the trawl and the damage was not apparent for several weeks. The 28 remaining fish are all feeding and are in good condition. Several of these fishes are being exposed to naphthalene in a flow through system at concentrations of 1 ppm at +4°C. At this temperature, unexposed control fish retain their orginal level of antifreeze. The naphthalene exposed fish have not been sampled to date but will be after three weeks of exposure. Thus far the only change noted is that they are no longer interested in feeding. Before exposure they were fed pieces of yellowtail fish every other day.

IV. Estimate of funds expended $37, 641

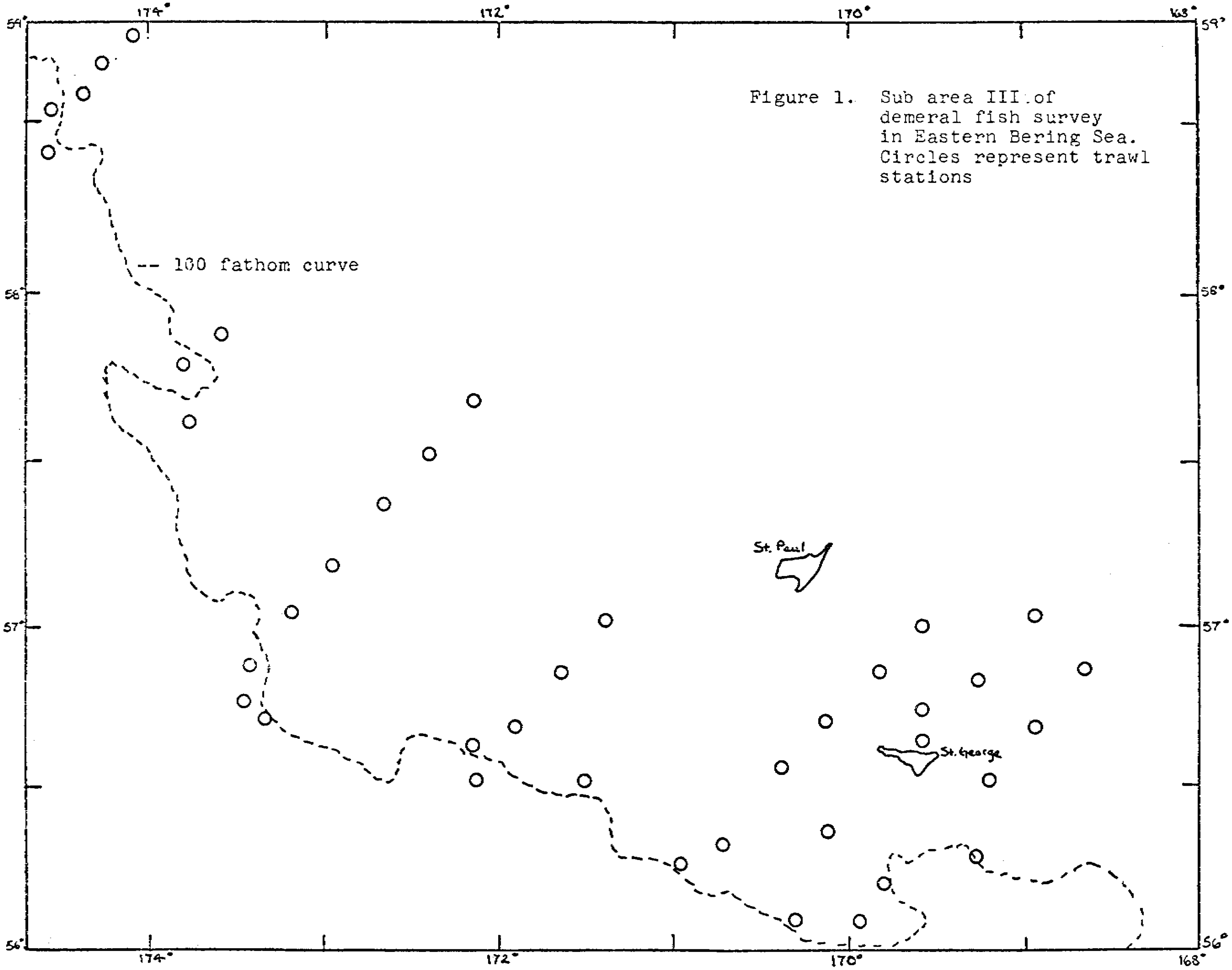

Figure 1. Sub area III of demeral fish survey in Eastern Bering Sea. Circles represent trawl stations

Table I. Survey of antifreezes in Eastern Bering Sea fishes. Presence of antifreeze was detected by determining the difference between the freezing and melting points of the blood serum.

Species	Antifreeze Present
Alaskan Plaice	Yes
Polar Eel Pout	Yes
Shorthorn Sculpin	Yes
Great Sculpin	Yes
Starry Flounder	Yes
Pacific Herring	?
Pollock	No
Pacific Cod	No
Arrow Tooth Flounder	No
Greenland Turbot	No
Pacific Halibut	No
Yellow Fin Sole	No
Rock Sole	No
Black Cod	No
Capelin	No
Atka Mackeral	No
Yellow Irish Lord	No

Quarterly Report

Contract #

Research Unit #71

Reporting Period

4/1/76 to 6/30/76

Number of Pages 3

Effects of Oil on Marine Mammals

Co-Principal Investigator Roger Gentry

Co-Principal Investigator Bruce McAlister

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Northwest Fisheries Center
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June 1976

Quarterly Report

RU 71 - Physiological Impact of Oil on Marine Mammals

I. Task Objective

A. To determine the thermal conductance of both normal and oiled fur seal pelts.

B. To measure the effects of oil fouling on the number, depth and frequency of dives made during feeding excursions.

C. To measure the impact of oil fouling on the metabolic rates of fur seals in air and in water.

II. Field and Laboratory

A. Laboratory - to July 1, 1976
The contract physiologist has rebuilt 10 depth-time (D-T) recorders following the original field tests. The metabolic chamber has been constructed and tested. Approximately 100 hours of test time on four fur seals has been conducted at several temperatures. Heat flux measurements have been completed on five raw pelts of various phocids, one otariid, one walrus and two sea otters. These are control samples. Oiled samples will be run the following quarter. All equipment has been tested, packed and shipped for field work on the Pribilof Islands.

B. Scientific Party
Dr. G. L. Kooyman, Mr. Jack Sarno, SIO, (assistant), Randy Drus, SIO, (assistant) Dr. R.L. Gentry, NMFS Marine Mammal Division (Principal Investigator) and Mr. G. McGloshan (field assistant).

C. Field Methods:
No field testing or sampling this quarter.

D. Sample Localities
No field testing or sampling this quarter.

E. Data Collected and Analyzed

The preliminary data from last summer has been further analyzed and a report prepared and accepted for publication in Science. Copies will be provided as soon as available. Pelt data has been reduced to final form, but report will not be prepared until oiled comparisons are available.

III. Results

No final results available for this quarter

IV. Preliminary Interpretation of Results

Depth-time data has been previously reported upon. Preliminary analysis suggests that sea otter pelts provide better insulations than other pelts. The one oiled sea otter pelt did not appear to differ significantly from the non-oiled pelt in thermal insulation and efficiency.

Although resting metabolism rates appear similar over a temperature range, activity appears to be greater at lower temperature with associated greater consumption. Further testing and analysis will be necessary to verify any of these results.

Shallow dive tests on sea lions (10 to 20 m.) were repeated and identified as real and not instrument artifacts.

V. Problems Encountered

A. D-T recorder. Has been redesigned to obtain proper control on calibrations.

VI. Estimated Funds Expended

Contract with University of California (Scripps	$ (8,900)	NMFS
Institution of Oceanography	73,600	
Travel	1,300	
Salaries (Field help on Pribilof Islands)	10,300	
Overhead	5,400	
	$ 90,600	

QUARTERLY REPORT

Contract #
Research Units #72, 331, 334
Reporting Period April 1, 1976 - June 30, 1976
Number of Pages 14

ACUTE AND CHRONIC TOXICITY, UPTAKE AND DEPURATION, AND SUBLETHAL METABOLIC RESPONSE OF ALASKAN MARINE ORGANISMS TO PETROLEUM HYDROCARBONS

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June 22, 1976

I. Task Objectives

A. General Tasks

1. Determine the acute and chronic effects of crude oil, its component fractions, and other petroleum-associated chemicals on physiological and behavioral mechanisms of selected arctic and subarctic organisms.

2. Conduct laboratory and field studies to determine recovery rates of selected organisms and ecosystems from perturbations resulting from either contamination or other disturbances associated with petroleum development.

B. Specific Objectives and Studies

1. Determine acute toxicity of previously untested species such as amphipods, mysids, sandlances, and others.

2. Determine acute toxicity at different temperatures with several species such as scallops, pink salmon, and shrimp.

3. Determine the chronic toxicity to shrimp and herring eggs and the effects of oil on newly extruded eggs of crabs.

4. Determine the uptake and depuration of oil components for previously untested species.

5. Determine the effect of temperature on oil component uptake and depuration.

6. Determine the effect of oil on metabolic rate of fish and invertebrates.

7. Determine the effect of oil on scallop growth and behavior.

8. Determine the effect of oil on crab autotomy response.

9. Determine histopathology effects of oil using routine histology, enzyme histochemistry, and electron microscopy.

II. Laboratory Activities

A. General Methods

Standard bioassay techniques, modified by the special requirements of working with hydrocarbons, are used in the majority of our experiments. Animals exposed to oil are monitored for death, sublethal physiological effects, behavioral changes, and metabolism of hydrocarbons.

All laboratory work was done at the Auke Bay facility. The majority of organisms for our studies were collected in the vicinity of Auke Bay, Alaska. Exceptions to this were limpets collected at Cape Yakataga.

Cook Inlet oil was obtained from Shell Oil Company in 55-gallon drums. No. 2 fuel was taken from the laboratory heating system fuel tanks. Benzene, toluene, and naphthalene were reagent grade.

1. Mixing

Water-soluble fractions were prepared depending on the volume needed by mixing a 1% oil to water mixture in either an 18-liter bottle, a 100-liter glass aquarium, a 55-gallon polyethylene-lined oil barrel, or an 800-liter fiberglass tank. In each case, suitable electric motors with mixing paddles were adjusted to the proper mixing energy to allow the oil vortex to descend one-third of the depth of the container. The mixing continued for 20 hours followed by a 3-hour settling period. The WSF was then siphoned off from beneath the oil slick and diluted for use in exposure.

2. Exposure

Most exposures were static, aerated, and at a tissue-to-volume ratio of 1 gram per liter or less. Oil concentrations are measured analytically at the beginning of the exposures. Organism responses (mortality or some other parameter) are analyzed by computerized probit statistics. For several studies repetitive dosing was used. Periodically the oil concentration was monitored (UVOD) and brought up to the initial concentration by addition of 100% water-soluble fraction. The concentration deviation is minimized by frequent redosing.

3. Analytical Methods

Our oil-water solutions (WSF's) are routinely analyzed by infrared (IR) and ultraviolet (UV) spectrophotometry, as well as by gas-liquid chromatography (GC).

The IR method is from Gruenfeld (1973), and involves determining the absorbance of light at 3412 nanometer wavelength by the oil-derived hydrocarbons. Aliphatic compounds, which are not very toxic, absorb most strongly at this wavelength. The method does not measure toxic aromatic or polar compounds. We use this method as a general indication of relative differences between successive WSF preparations, and as a means of comparing our work with that of previous investigations. Despite its limitations, this method of determining oil in water is far superior to measuring only the volume of oil added to water, since the amount of oil that enters the water column is very dependent on the mixing energy and duration.

A second method that we routinely employ is a modified version of the UV method of Neff and Anderson (1975). This method involves determining the absorbance of oil-derived hydrocarbons at 221 nanometers. Naphthalene and methyl-substituted naphthalenes absorb most strongly at this wavelength, although high concentrations of mononuclear aromatics (such as benzene, toluene, xylene, etc.) can also cause appreciable absorption. The naphthalenes have been implicated in several toxicity studies. We use this method principally as a means of predicting the toxicity of successive WSF preparations. Since the different methyl-substituted naphthalenes have slightly different molar absorptivities at 221 nanometers, we report results by this method as naphthalene equivalents. This is the amount of pure naphthalene that would account for most of the absorbance observed in a given sample at 221 nanometers.

The third method we employ routinely involves gas-liquid chromatography (GLC). We use a column suggested by Supelco, Inc., which is especially suited for separating aromatic hydrocarbons. In this method we extract the WSF with two aliquots of methylene chloride, and then analyze from 1 to 10 microliters of the combined extracts immediately by GLC for mononuclear aromatics. Then we concentrate the extract to 500 microliters, and analyze from 1 to 10 microliters again by GLC for the higher aromatics.

We have established the identity of most of the aromatic peaks by comparing retention times with known standards, by spiking WSF's with known aromatics, and by mass spectroscopic (MS) identification of selected samples. The results from these different methods have always been in agreement. The MS study (conducted at the Northwest Fisheries Center in Seattle) also established that both normal and some branched paraffins elute from our column, and in some cases they elute simultaneously with some of the aromatic compounds. On the basis of this information we are now able to correct for this interference.

4. Bioassay Statistics

When possible, all of our bioassay results are analyzed by a computerized probit analysis by Finney (1971). This statistical technique calculates a maximum likelihood estimation of the oil concentration that would cause 50%

of the exposed animals to respond after exposure to the WSF for some given time.*

Usually the response is death, although we do note certain other behavioral responses as well.

In addition, the probit analysis estimates a 95% fiducial limit about this TLm, and a slope function and 95% fiducial limit about this slope function. The slope function is the rate at which the proportion of animals responding changes with changing oil concentrations in the WSF. From it, one can estimate the most likely proportion of animals that would respond at WSF oil concentrations other than the TLm. It is related to the tolerance distribution of the species being tested.

In some cases our bioassay results are not amenable to probit analysis. Probit analysis requires at least two dose levels of WSF at which the proportion of animals responding is observed to be between zero and one. Occasionally our dose levels will be so distributed that none of the animals respond in some set of lower doses, and all of them respond in the next highest dose and all higher doses. Or, there will be only one dose at which the proportion of animals responding is observed to lie between zero and one. In the former case we estimate the TLm as the antilog of the sum of the log of the highest dose where no animals respond, plus the log of the lowest dose where all of the animals respond, divided by two. In the latter case we estimate the TLm by plotting the dose versus the percent of the animals responding, and noting the dose level that corresponds to 50% response. This is the method of Doudoroff et al. (1951).

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*We call this concentration of oil in the WSF the median tolerance limit, or TLm.

All of our data are being stored on punched computer cards, as well as in our record books.

B. Methods of Specific Experiments (Laboratory)

1. Static Acute Bioassays

a. Bioassays were conducted with several organisms and developmental stages at temperatures ranging from 4-8°C. Water-soluble fractions of crude oils were prepared as described before. Oil exposures were monitored by chemical analyses, i.e. IR, UV, and GC. Mortalities were noted daily and the results were analyzed as described previously (probit statistics with 95% fiducial limits). Sublethal quantifiable behavioral responses were used when possible as an additional indicator of effect.

b. Special assays with scallops and hermit crabs were run to determine long-term effects and extent of recovery after acute exposure to Cook Inlet WSF. Scallops and hermit crabs were exposed to three concentrations of Cook Inlet WSF for 10 exposure time periods and then put in clean flowing seawater where their condition (lethal and sublethal responses) was monitored for three months. This was repeated three times with scallops and was duplicated (two replicates) with hermit crabs.

c. Stages I through III coonstripe shrimp larvae were assayed with Cook Inlet WSF. Mortality, inhibition of molting, and frequency (or success) of molting were monitored.

2. Static Acute Bioassays at Different Temperatures

a. Temperature assays were run using acute exposures at 4°, 8°, and 12°C with pink salmon, scallops, _Eualus_ shrimp, and _Pandalus_ shrimp. Benzene, naphthalene, and Cook Inlet WSF were used in these tests. The three temperatures were run simultaneously with the same initial mix to minimize variability. Animals were temperature-acclimated before testing.

b. In order to explain temperature effects on oil toxicity, a separate study was done to test the effect of temperature on the persistence of individual mono- and dinuclear aromatic hydrocarbons from a Cook Inlet WSF during a 96-hour assay situation. Replicate 18-liter bioassay jars containing one identical Cook Inlet WSF dose were subject to the following conditions at 4°, 8°, and 12°C:

(1) No aeration, no mercuric chloride (nonspecific microorganism poison).

(2) No aeration, mercuric chloride present.

(3) Aeration, no mercuric chloride.

(4) Aeration, mercuric chloride present.

Aeration was a controlled variable, to test the effect of temperature on the persistence of the more volatile compounds. Mercuric chloride was used to eliminate losses from biodegradation by microorganisms. The result was 12 unique experimental conditions (three temperatures, four conditions at each temperature). The concentration of mono- and dinuclear aromatic hydrocarbons was determined daily by gas chromatographic analyses of water samples. UV and IR analyses of the water samples were also made to determine effects on "total" oil measurements. Total bacteria counts were made daily for each condition.

3. Long-term Bioassays

a. A chronic Cook Inlet WSF assay was completed on the eggs of *Eualus suckleyi* attached to the female shrimp. Doses were replenished every 48 hours for one month, until hatching began. Hatching then took place over the next two months. Number of larvae per female and general condition of larvae were recorded, as well as post-parturition molting success and size of females. The relationships between WSF concentrations and hatch size per size of female, condition of hatched larvae, condition of female, and time of hatching are being analyzed.

b. Herring roe on Fucus fronds were assayed using both single 48-hour doses and four doses over nine days. Visible egg death, hatching success, and survival of larvae for 48 hours were monitored.

c. The effects of naphthalene on newly extruded tanner crab eggs were determined. Crabs without eggs (prior to egg extrusion) or with newly extruded eggs were exposed to several doses of naphthalene for 20 hours, then egg samples were examined daily for cell division and development.

4. Hydrocarbon Uptake

The uptake of ^{14}C naphthalene-spiked Cook Inlet WSF in pink salmon fry and king crab eggs was determined over a nine-day period. Pink salmon fry and king crab eggs were exposed statically for 48 hours then placed in clean running water to monitor depuration. Samples were taken periodically for isotope analyses by liquid scintillation counting (measures ^{14}C naphthalene and/or metabolites) and for gas chromatographic analyses of aromatic hydrocarbons by Scott Warner. All samples were whole organism (pink salmon) or groups of eggs (king crab).

5. Hydrocarbon Uptake at Different Temperatures

These experiments are scheduled for July 1976.

6. Effect of Oil on Metabolic Rate of Fish and Invertebrates

These experiments are not scheduled this quarter.

7. Effect of Oil on Scallop Growth and Behavior

An attempt was made to determine the effects of Cook Inlet WSF on the growth rate of scallops. Two groups of scallops were measured and marked, then exposed statically to five doses of Cook Inlet WSF for 48 hours. One group was then held in the lab and measured biweekly, while the other group was placed in framed net enclosures in Auke Bay and measured likewise.

A third group of scallops was exposed to five doses of Cook Inlet WSF for 24 hours at weekly intervals. The scallops were measured biweekly and held in running water in the lab between the static exposures.

Length-weight curves were developed for the scallops initially and are to be repeated at the termination of the study.

8. Effect of Oil on Crab Autotomy Response

Post-molt juvenile tanner crabs were measured, then exposed to several doses of Cook Inlet WSF, benzene, or naphthalene at varying times after molting. Leg loss was monitored in each experiment.

9. Effect of Oil on Gross Histology

Histology samples are being processed as outlined in the annual report.

10. Effect of Oil on Field Mortality of Limpets

An experiment to determine the effects of sublethal oil exposure on the survival of limpets in the field has been started. Seven hundred-twenty five limpets at a site on north Douglas Island have been successfuly marked, mapped, and monitored, then collected, exposed to three doses of Cook Inlet WSF in the laboratory for 24 hours, and returned to their homesites in the field. Control and exposed limpets are being monitored for survival in the field at monthly intervals.

III. Results

1. Acute Bioassays

The following 96-hour acute bioassays were completed this quarter:

Species	Stage	Cook Inlet WSF	Fuel Oil WSF
Protothaca staminea (littleneck clam)	Juvenile	X	X
Cucumaria vega (sea cucumber)	Adult	X	X
Acmaea scutum (limpet)	Adult	X	X
Acmaea persona (limpet)	Adult	X	X
Mytilus edulis (mussel)	Adult	X	X

The results of the above assays plus previous OCS assays (in 1975 annual report) will be presented at the American Institute of Biological Sciences symposium in Washington, D.C., August 1976. With the coming of favorable weather many more species will be collected and assayed this summer.

Data from the scallop recovery assays have been written up as a manuscript to be presented at the 1977 Fate and Effects of Oil symposium in New Orleans, Louisiana in March 1977. Results of the hermit crab recovery study are being analyzed.

A manuscript covering the shrimp stage I-III assays has been completed for presentation at the NOAA symposium in Seattle, Washington in November 1976.

2. Acute Bioassays at Different Temperatures

The following temperature assays at 4°, 8°, and 12°C were completed this quarter:

Species	Stage	Cook Inlet WSF	Benzene	Naphthalene
Oncorhynchus gorbuscha (pink salmon)	Juvenile	X	X	X
Chlamys spp. (bay scallop)	Juvenile			X
Pandalus goniurus (humpback shrimp)	Adult	X	X	X
Eualis spp. (shrimp)	Adult	X	X	X

This completes the temperature assay series for pink salmon, shrimp, and scallops exposed to Cook Inlet WSF, benzene, and naphthalene at 4°, 8°, and 12°C. A manuscript is being prepared and will be published and presented at the 1976 NOAA symposium at Seattle, Washington in November. A second manuscript titled "The effects of temperature on the persistence of aromatic hydrocarbons in seawater" will also be presented at the NOAA symposium.

3. Long-term Bioassays

Data are being analyzed from the chronic shrimp egg, shrimp larvae, herring egg, and crab egg exposures.

4. Hydrocarbon Uptake

The results of the uptake study with pink salmon fry and king crab eggs will not be available until analyses are completed by Scott Warner of Battelle-Columbus in the fall of 1976.

A large contract is being issued to Scott Warner for tissue analyses of the above experiment and a temperature uptake study is scheduled for July 1976.

5. Hydrocarbon Uptake at Different Temperatures

Scheduled for July 1976.

6. Oil Effects on Metabolic Rate

Additional determinations of the effects of Cook Inlet WSF, toluene, and naphthalene at two temperatures on the metabolism of pink salmon are scheduled for July-August 1976. The study to determine the uptake of oil and effects on metabolism in shrimp is scheduled for August 1976.

7. Scallop Growth

Scallops exhibit a very slow growth rate. In the two-month period, April-June, control scallops did not show measureable growth. Because of this, data collection regarding the two groups of scallops dosed one time has been terminated. The third group dosed weekly will continue to be dosed and measured through the summer. This experiment will be re-started at a later date if scallops grow a measureable amount when the water warms up.

8. Crab Autotomy

Data from the crab autotomy experiment are being analyzed with additional studies pending.

9. Histology

Histology data analyses are proceeding.

10. Field Mortality Experiments

The limpet study will continue through the summer with data analysis slated for this fall.

IV. Interpretation

No interpretations are available at this time. Interpretation of results will occur in reviewed manuscripts.

V. Problems Encountered

1. Acute assays with invertebrates must be followed by a recovery period to determine delayed mortality. This is now being done in all acute assays.

2. Continuous-flow stable dosing assays and exposures are needed to eliminate the decreasing oil component concentrations. This is proposed in our FY 1977 proposals.

3. The addition of a sample oxidizer proposed for next year will eliminate most isotope tissue preparation problems and allow for a greater output. We are going to freeze samples in future uptake studies for processing by the oxidizer in the fall of 1976.

4. A simple method to separate isotope-labeled aromatic compounds from metabolites of the compound was needed. The method of Roubal (1976) will be used in future uptake studies to determine whether the isotope label represents the parent compound or a metabolite.

5. Using scallops in growth studies must be further considered after this season's data collection. No growth in field or lab specimens has occurred to date, but observations are continuing to see if growth occurs in mid to later summer when temperatures are warmer. Additional animals are being tested as alternates for growth studies.

VI. Estimate of Funds Expended

Budget summary as of June 20, 1976 and for the period July 1 - September 30, 1976.

	Annual Plan ending 6/30/76	Projected Costs to 6/30 based on budget report to 5/31/76	Plan for 3 months (7/1 - 9/30)	Total 15 month Plan*
Salary costs	97.5k	96.9k	42.8k	139.7k
Travel	4.6	4.7	2.2	6.9
Contracts	2.8	2.9	35.0	37.9
Equipment & Supplies	20.5	23.0	6.5	29.4
Other Direct Costs	8.2	6.2	2.6	8.8
Support Costs	31.3	31.3	15.6	46.9
Totals	164.9k	165.0k	104.7k	269.6k

*Includes July 1, 1975 - September 30, 1976.

OCSEAP QUARTERLY REPORT

Research Unit: 73
Reporting Period: April-June 1976
Number of Pages: 13

SUBLETHAL EFFECTS AS REFLECTED BY MORPHOLOGICAL, CHEMICAL, PHYSIOLOGICAL, AND BEHAVIORAL INDICES

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June 1976

I. Task Objectives

The objective of these studies is to identify and evaluate in selected marine organisms the effects of chronic exposure to petroleum hydrocarbons and trace metals. Particular emphasis in this past quarter has been on alterations in physiochemical properties of mucus and on chemosensory perturbations. Progress and results in the two other studies under R.U. 73 (disruptions in larval development and changes in tissue and cell structure) will be discussed in detail in the next reporting period.

II. Field or Laboratory Activities

C. Methods - laboratory analysis

1. Chemosensory

Olfactory electrophysiological studies were conducted on yearling coho salmon adapted to saltwater. Standard experimental procedures and recording techniques were used to monitor the electrical response from the olfactory bulb (Hara, 1973). Amino acid stimulants (L-serine, L-alanine and L-methionine at 10^{-5} M) and selected aromatic fractions of petroleum hydrocarbons were dissolved in filtered seawater. Concentrations of undiluted stock solutions of aromatic hydrocarbons were determined by gas chromatography.

Extracts of Prudhoe Bay crude oil were prepared by shaking microliter quantities of oil in 50 ml of filtered saltwater for five minutes. The mixture was allowed to stand for one hour and the water soluble fraction drawn off.

2. Mucus and skin

Salmon (Oncorhynchus kisutch) of average weight of 200 g and flatfish (Platichthys stellatus) of average weight of 25 g, were exposed to 3 and 150 ppb of lead (Pb^{210}) and cadmium (Cd^{109}) at 4° and 10°C.

The fish were exposed to 3 ppb of metals for 30 days and to 150 ppb for 15 days. Samples of mucus and skin were collected at three equal intervals during the exposure period and twice during the depuration period.

Analytical Techniques: Three test fish were taken from each exposure interval for collection of body and gill mucus, skin and scales. Sample collection methods are described in the previous report. From flatfish both dorsal and ventral skin samples were taken for analyses. The level of metal in the mucus was assessed by liquid scintillation spectrometry.

The ability of the test and control mucus solutions to reduce friction relative to that of seawater was ascertained by measuring viscosity of these samples at a Reynolds number of 8000 (Rosen and Cornford, 1971). This measurement simulates natural conditions when fish swim rapidly inducing turbulence which causes boundary layers between mucus and water to break down. This results in small amounts of mucus dissolving in surrounding water.

Mucus samples were also analyzed by fluorescence spectrometry. Protein content of each sample was determined by the method of Lowry et al. (1951).

III. Results

A. Chemosensory

Upon perfusion of the salmons' olfactory sac with stimulant the background electrical activity of the olfactory bulb immediately changed to an oscillatory pattern as shown in Figure 1a. This increased amplitude response was terminated by rinsing with filtered seawater.

The event marks in Figure 1a do not denote duration of the stimulus, but only initiation of stimulus or rinsing. The delay of 1.0 to 1.5 seconds between start of stimulus and the electroencephalographic (EEG) response reflected the time required for the solutions to pass through the capillary pipette used to perfuse the naris. The duration of this delay interval is an important factor in interpretation of results as discussed in Section IV.

Figure 1b depicts the olfactory EEG response after infusion of the naris with 1.5 ppm naphthalene for 25 seconds, followed immediately by 1.0 ppm L-serine. The response to naphthalene rapidly diminished as compared to the sustained activity induced by L-serine. Exposure of the olfactory epithelium to naphthalene (0.2 to 17.0 ppm) did not reduce or inhibit the subsequent response to L-serine, L-methionine, or L-alanine.

When one part of 1.5 ppm naphthalene was mixed with an equal part of 1.0 ppm L-serine the EEG response approximates that of the unmixed L-serine solution, being of slightly less amplitude for the appropriate dilution.

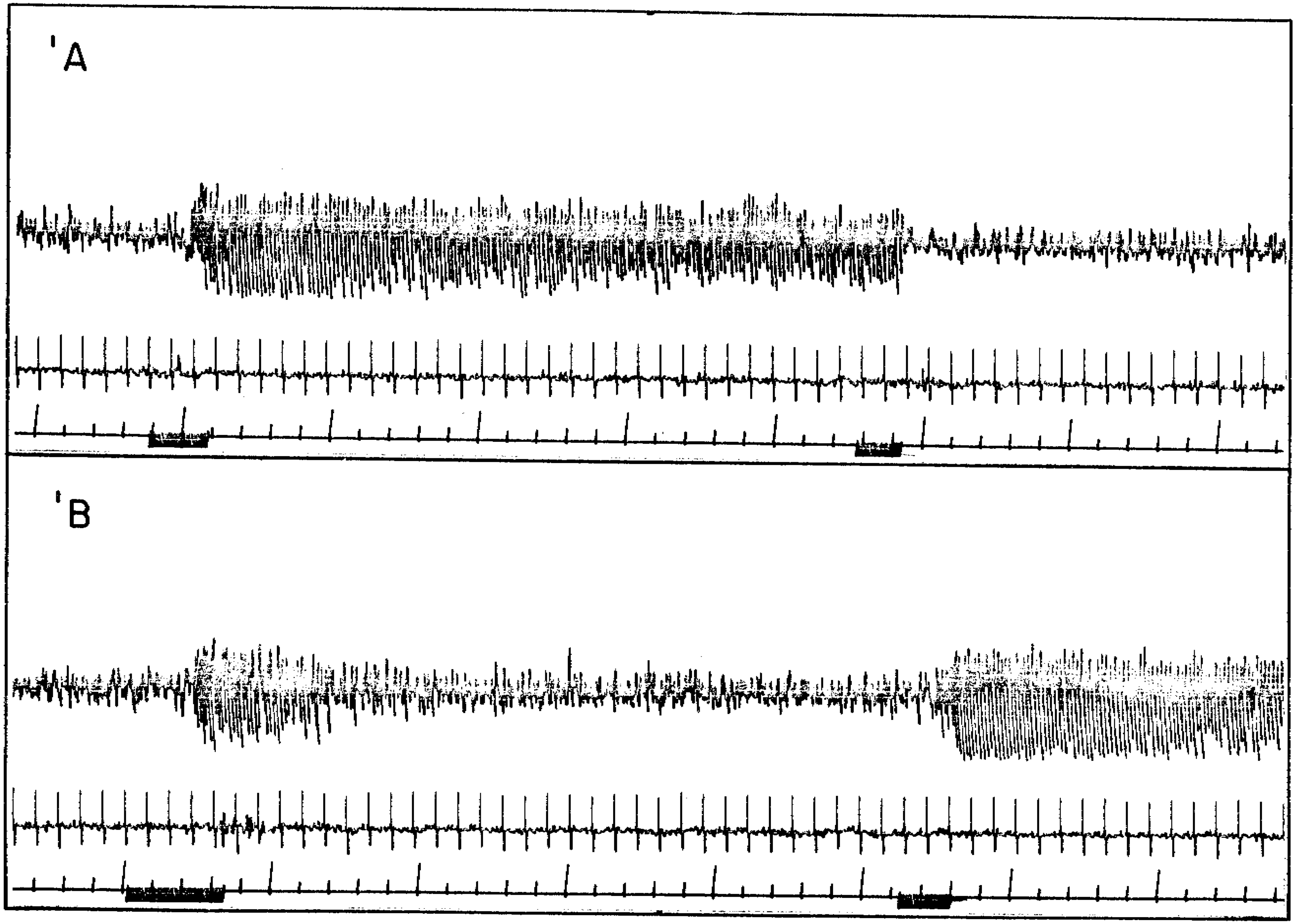

Figure 1. A. EEG response to 10^{-5} M (1 ppm) L-serine for 25 seconds followed by rinse (top trace). Middle trace is EKG, and event marks at bottom indicate initiation of stimulus and rinse. Time scale, 1 second divisions. B. Continuation of part A. Exposure to 1.5 ppm naphthalene for 25 seconds followed by 1 ppm L-serine.

There was no evidence of detection of 2,6-dimethylnaphthalene, or 2,3,6-trimethylnaphthalene at levels of 0.2 to 2.0 ppm. The EEG response to these aromatics was similar to that from flushing the naris with filtered seawater; that is, there was a slight temporary decrease in baseline activity.

Exposing the naris to benzene at 0.2 to 2.0 ppm resulted in the same EEG pattern as naphthalene (Fig. 1b). Also, as with naphthalene, there was no effect on the subsequent responses when amino acid stimuli were applied.

Water-soluble fractions of whole Prudhoe Bay crude oil (20.0 to 1.8 ppm initial concentrations) were discriminated by the fish from filtered seawater as shown in Figure 2. Here again, there was no decrement in subsequent responses to amino acids. Threshold concentrations for discrimination were not determined in this series of experiments.

Perfusion of the naris with 1-2 ppm naphthalene or benzene for 10 minutes did not consistently alter the response to amino acids. In several instances there appeared to be a delay in recovery of up to 40 seconds.

B. Mucus and skin

Preliminary findings on the uptake and discharge of lead and cadmium in mucus and skin of coho salmon and starry flounder at 4° and 10°C are given in Tables 1 and 2. From initial studies, it was apparent that levels of metals in gill mucus were similar to that in the body mucus, therefore, in later studies gill mucus was not collected separately. Rheological measurements were made only on coho salmon as it was not possible to get sufficient mucus (3 to 4 g) from flatfish.

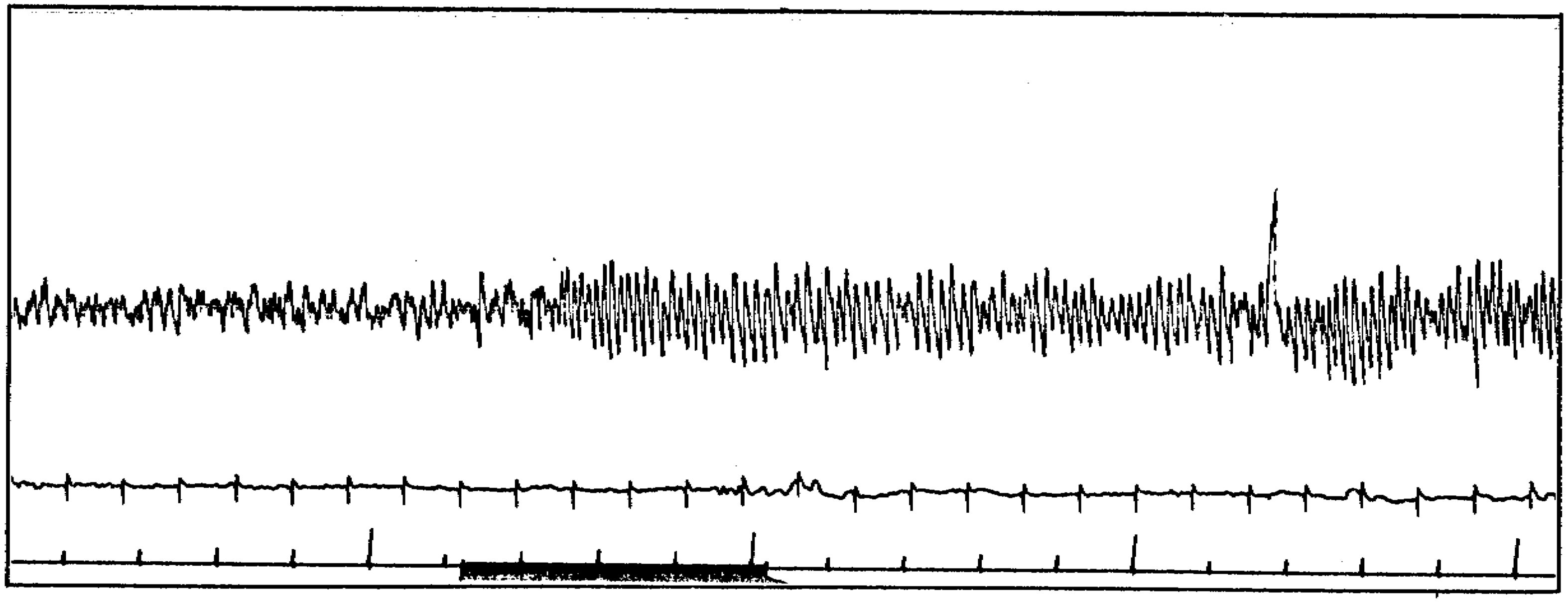

Figure 2. EEG response to water-soluble extract of Prudhoe Bay crude oil (concentration of 1.8 ppm). Time scale, 1 second divisions.

Table 1.

Uptake and Discharge of Trace Metals (Pb and Cd) from Epidermal Mucus and Skin of Coho Salmon (*Oncorhynchus kisutch*) at 4° and 10°C * +

Time (days)	3 ppb Pb^{210}		Time (days)	150 ppb Pb^{210}		150 ppb Pb^{210}		150 ppb Cd	
	4°C			4°C		10°C		10°C	
Exposure	Mucus	Skin	Exposure	Mucus	Skin	Mucus	Skin	Mucus	Skin
10	2.2	1.2	4	237	**	206	87	130	27
20	5.6	1.4	9	257	77	250	118	142	**
30	6.3	2.6	14	268	**	252	326	192	44
Depuration			Depuration						
7	0.80	2.3	3	86	28	-	-	-	-
14	0.50	3.3	7	78	41	-	-	-	-

* Values are expressed in ppb.

** Samples are being analyzed.

\+ Levels of metals based on dry weight of sample are being calculated.

Table 2.

Uptake and Discharge of Trace Metals (Pb and Cd) in the Mucus and Skin of Starry Flounder (*Platichthys stellatus*) at 4° and 10°C[*][++]

Time (days)	150 ppb Pb				150 ppb Cd	
	4°C		10°C		10°C	
Exposure	Mucus	Skin[+]	Mucus	Skin	Mucus	Skin
4	**	223	1,766	151	2,148	68
9	3,880	251	787	322	**	*
14	832	311	310	333	214	200
Depuration						
7	317	770	**	**	**	**

[+] Top skin, some samples of the bottom skin are being evaluated for the levels of accumulated metal.

[*] Values are expressed in ppb.

[**] Samples are being analyzed.

[++] Levels of metal based on dry weight of sample are being calculated.

The data in Table 1 demonstrate that the epidermal mucus and skin of coho salmon accumulate lead and cadmium. In salmon mucus there is a biomagnification factor of about 2 for lead, and a value of 1.3 for cadmium. From other short-term exposure studies, carried out in our laboratories, we found that the rate of uptake of metals in the mucus is very rapid; in fact, within a few hours substantial amounts of metal is accumulated. Moreover, the fact that the biomagnification factor for both exposure levels (3 and 150 ppb) were quite similar suggests a possibility that the metal is accumulated in the mucus via passive diffusion.

The levels of both lead and cadmium increased in the skin of coho salmon during exposure. Lead was accumulated to a much greater extent than cadmium. For example, at 150 ppb exposure at 10°C, biomagnification factors of 2.2 and 0.3 were obtained for lead and cadmium, respectively. It appears that skin retains significant levels of lead even after 14 days of depuration.

Preliminary observations indicate that the mucus of starry flounder (Table 2) accumulated extremely large amounts of lead and cadmium during the first few days (biomagnification factor about 12 to 14). These initially high levels declined steeply during the rest of the exposure period. The skin of flatfish accumulated increasing levels of both lead and cadmium during exposure. It is not yet known whether dorsal and ventral skin of flatfish accumulate similar levels of metal. We are currently processing these samples.

Measurements on fluorescence spectra of mucus indicated, in most cases, no detectable change in the intensities or position of excitation peaks on control and test mucus. There was some decrease in the intensity of excitation, however, in the lead-exposed mucus. Whether this is due to a quenching effect of lead or an alteration in the structure of mucus remains to be determined. We are currently investigating possible alterations in metal-exposed mucus with ESR techniques.

Assessment of rheometric data indicates that mucus of salmon exposed to 150 ppb of lead exhibit certain alterations in viscoelastic properties. That is, friction reducing ability of the test mucus was considerably less than the value obtained for the controls. There is some indication that lead may induce aggregation of macromolecules present in the mucus and thus alter its rheometric properties.

IV. Preliminary interpretation of results

A. Chemosensory

Recent literature has stressed that one adverse effect of petroleum pollution may be its action on the chemosensory system. Of the petroleum hydrocarbons the aromatic fractions are the most suspect for causing chemosensory disruption (Takahashi and Kittredge, 1973). The mechanism of this disruption is unknown, but it has been suggested that contaminants may mask the chemoreceptive sites, thus blocking incoming chemical signals at the receptor level (Sutterlin, 1974). Our preliminary data indicate that the receptor sites responsive to certain amino acids are not masked by specific aromatic petroleum hydrocarbons as a result of short-term exposure.

The neural activity elicited by naphthalene and benzene may be, however, of a different origin than that resulting from an amino acid stimulation. For naphthalene and benzene solutions the delay from introduction of the sample and EEG activity was about double that for amino acid elicited response. As discussed by Hara (1974) a delay in reaction suggests activity taking place not at the chemosensory receptor sites, but is more likely a nonspecific irritant effect deeper in the olfactory epithelium. Thus, chronic exposure may have a disruptive effect which has not shown up in these short-term exposure experiments. To test this, electrophysiological studies on chronically-exposed coho salmon are planned for the next reporting period.

B. Mucus and skin

The levels of lead and cadmium used in these experiments did not cause apparent gross behavioral changes or increased mortality during exposure periods of up to one month.

Salmon epidermal mucus and skin accumulated much more lead than cadmium; however, flatfish mucus accumulated both metals to a similar extent. Moreover, the levels of metal accumulated in flatfish mucus were much greater than those found in salmonid mucus.

It appears that metals in mucus may be accumulated primarily via passive diffusion in salmonids but by a different mechanism in flatfish.

Levels of lead and cadmium increased steadily during exposure in the skin of both salmonids and flatfish. Also, both coho salmon and starry flounder accumulate more lead than cadmium in the skin. Interestingly, levels of lead increased in skin during depuration indicating that skin may play an important role in excretion of metals.

Preliminary assessment of data shows that the presence of lead in mucus causes structural alterations as indicated by rheological measurements. This finding suggests that lead may complex with macromolecules present in the mucus.

In summary, our studies so far have resulted in several potentially important findings for the well-being and long-term survival of fish exposed to trace metals:

1. We have found a considerable bioaccumulation of metals in mucus, especially in flatfish. Moreover, metals persist in the skin of fish long after they are transferred to clean water. This may result in changes in disease susceptibility of fish; studies are in progress to attempt to determine if this occurs.

2. Clear alterations in rheological properties of fish mucus have been observed after trace metal exposure. This is interpreted as potentially causing increased friction between fish body surface and water which could result in decreased ability of fish to capture prey or escape predators.

V. Problems Encountered/Recommended Changes: N/A

VI. Estimate of Funds Expended

As of May 31, 1976, the research has spent 84.7 K.

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OCSEAP QUARTERLY REPORT

Research Unit: 74

Reporting Period: April-June 1976

Number of Pages: 18

IDENTIFICATION OF MAJOR PROCESSES IN BIOTRANSFORMATIONS OF PETROLEUM HYDROCARBONS AND TRACE METALS

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OCSEAP QUARTERLY REPORT - R.U. 74

I. Task Objectives

A. Petroleum Hydrocarbons

Studies encompass a preliminary investigation of (a) the degree to which different compounds accumulate in biota from continuous exposure to non-lethal doses of hydrocarbons, (b) effects of environmental conditions, such as temperature and exposure concentrations on accumulations, (c) whether or not specific sites exist in fish where accumulation results in damage to normal physiology, and (d) the metabolic stability (biological half-life) of selected aromatic compounds in test organisms.

B. Trace Metals

Studies with trace metals encompass a preliminary investigation of (a) uptake and accumulation of lead and cadmium in salmon and flatfish employing both radioactive and non-radioactive metals, (b) the relative distributions of lead and cadmium in key tissues (e.g., liver, kidney, gills) in salmon and flatfish, and (c) interactions of lead and cadmium with cellular components.

C. Detoxifying Enzymes in Biota from Norton Sound and Chukchi Sea

Examine and report on the ability of biota in pristine areas to adapt metabolically to an environment with added contaminants from oil operations. Determine the current levels of detoxifying enzymes in a broad spectrum of biota from Norton Sound and the Chukchi Sea.

II. Field or Laboratory Activities

C. Methods - laboratory analysis

1. Biotransformation of petroleum hydrocarbons and trace metals

a. Hydrocarbons

Shrimp and crab larvae: Marine larval invertebrates, spot shrimp (*Pandalus platyceros*) and Dungeness crab (*Cancer magister*), were exposed in flowing seawater to 8-12 ppb of naphthalene-1-^{14}C or naphthalene-1-^{14}C complexed with Bovine serum albumin (BSA). The spot shrimp and Dungeness crab were hatched in the laboratory from ovigerous females. The shrimp larvae hatched during each day were kept separately in holding tanks and fed brine shrimp. Animals employed in the experiments were newly metamorphosed larval stages. Exposure periods varied from 24 to 36 hr and studies of tissue depuration were carried out for periods of up to 108 hr. Larval tissues were examined for both accumulated naphthalene-1-^{14}C and carbon-14 labeled metabolites. Total carbon-14 in the animals was determined by digesting tissues for 1 hr at 25°C followed by analysis of the sample by liquid scintillation spectrometry (Roubal *et al*., 1976). Total metabolites of naphthalene-1-^{14}C were determined by employing formic acid and solvent extraction procedures described previously (Roubal *et al*., 1976).

Marine fish: The metabolism of aromatic hydrocarbons in coho salmon (*Oncorhynchus kisutch*) was studied as follows: Benzene-U-^{14}C, naphthalene-1-^{14}C and anthracene-9-^{14}C were administered in food and by intraperitoneal injection to juvenile salmon. In feeding studies, the benzene, naphthalene, and anthracene were incorporated into Oregon Moist Pellets (OMP). All fish received a daily amount of the OMP equal to approximately 1% of their body weight. In separate tests, salmonids were fasted for 3 days and then fed 5 μCi of individual hydrocarbons impregnated in OMP. Sampling began 24 hr afterwards, which allowed tissues ample time to accumulate parent hydrocarbons and metabolic products. Additional samples were taken at 72, 168, and 336 hr to evaluate the composition of aromatic compounds over an extended period of time. In these experiments, brain, liver, gall bladder, heart, muscle, and "carcass" were examined. Concentrations of parent hydrocarbons and metabolic products were determined by previously described procedures (Roubal et al., 1976).

In addition to the radioisotope studies, coho salmon were exposed to a water-soluble fraction (WSF) of Prudhoe Bay crude oil in seawater under continuous flow-through bioassay conditions. The exposure system comprises a mixer module into which crude petroleum is churned into an incoming stream of seawater. Insoluble oil suspensions formed in the system were removed from the "soluble" hydrocarbons by a multi-channeled baffle assembly. The clear water solutions of WSF were metered to individual aquaria after dilution to the desired concentration of hydrocarbons. The solutions were not recirculated, but directed to a scrubbing unit, which removes all water-soluble hydrocarbons. The concentrations of total hydrocarbons in the flowing seawater were found to be 0.5 ppm by infrared spectrophotometry. The individual components of the system were analyzed by gas-liquid chromatography/mass spectrometry (GLC/MS) and found to be enriched in low molecular weight aromatic compounds. Details of the composition of the exposure water will be given in the final report.

In this study, the salmonids were exposed to the WSF for up to 6 weeks and then transferred to clean flowing seawater to evaluate depuration of hydrocarbons. All samples have now been collected. Analyses of gill, liver, and muscle tissue are in progress employing GLC/MS techniques in conjunction with a modification of the digestion and separation technique of Warner (1976).

b. Trace metals

Marine fish: Coho salmon (average weight, 200 g) and starry flounder (average weight, 25 g) were exposed to 3 and 150 ppb of lead and cadmium at 4° and 10°C. Examined in the present work were gills, liver, kidney, erythrocytes, and brain after perfusion. The blood and plasma were also examined.

2. Detoxifying enzymes in biota from Norton Sound and Chukchi Sea

In keeping with contract objectives, protocols applicable to sample handling aboard the Miller Freeman will be established during the next reporting period and made available to Mr. Gronlund by August 1, 1976.

3. Histology

Tissue samples of skin, gill, liver, and kidney were taken from four control and four experimental fish after two weeks of exposure to the WSF. The tissues were prepared for light microscopy as well as for scanning and transmission electron microscopy.

The liver was sectioned at 1μ and stained with Richardson's (azure II and methylene blue) for examination with the light microscope. Then sections (500 Å) were prepared on copper grids and stained with lead citrate for electron microscopy.

III. Results

A. Biotransformation of petroleum hydrocarbons and trace metals

1. Hydrocarbons

Shrimp and crab larvae: The findings indicated that naphthalene-1-^{14}C and naphthalene-1-^{14}C-BSA complex at 8 to 12 ppb in flowing seawater brought about 100% mortality in 24 to 36 hr in Dungeness crab zoea and Stage I and Stage V spot shrimp. Maximum accumulation of naphthalene-1-^{14}C in Stage V spot shrimp exposed to this hydrocarbon was nearly four times greater than in shrimp exposed to naphthalene-1-^{14}C-BSA complex (820 ppb versus 220 ppb). Thus, magnifications of 25 to 100 times the exposure levels were found. Metabolic products of naphthalene-1-^{14}C (as 1-naphthol), in experiments with complexed and non-complexed naphthalene reached maximum values of 21% and 9%, respectively, of total radioactive compounds. Naphthalene-1-^{14}C was almost entirely depurated from tissues in 24 to 36 hr, whereas metabolic products were strongly resistent to depuration.

Marine fish:[1/] The incorporation of ^{14}C-labeled benzene, naphthalene and anthracene into brain, liver, gall bladder, muscle and "residual carcass" is presented in Table I. In each case the animals received an intraperitoneal injection of 62.8 μg of hydrocarbon. The maximum accumulation of benzene occurred in the liver in 24 hr and represented 5.5 ng/mg dry wt of tissue. Naphthalene was found to accumulate in the gall bladder to the extent of 9.5 ng/mg dry wt of tissue in 24 hr. However, with the exception of gall bladder, the maximum accumulation of naphthalene occurred in the "residual carcass" which had a maximum of 6.4 ng/mg dry wt of tissue in 24 hr. The data from the anthracene experiment indicated that 167 ng/mg dry wt of tissue occurred in the gall bladder in 24 hr. A maximum anthracene accumulation of 20.6 ng/mg dry wt of tissue occurred in the residual carcass at 24 hr. We conclude from the overall data that benzene, naphthalene, and anthracene are metabolized in coho salmon.

The gall bladder and liver appear to be major sites for the accumulation of metabolic products. Nevertheless, substantial amounts of metabolic products also appear in the brain, muscle, and residual carcass in 72 to 144 hr after intraperitoneal injection. A detailed quantitative examination of the individual aromatic metabolites was undertaken, with coho salmon receiving naphthalene-1-^{14}C via intraperitoneal injection. The 1-naphthol and 1-naphthyl-β-glucoronic acid derivatives were found in significant amounts in brain, liver, and gall bladder, together with lesser amounts of other derivatives such as 1,2-dihydro-2-dihydroxynaphthalene (Table II).

[1/] Studies on marine fish were supported in part by NWFC base funds.

Table I

Distribution of Hydrocarbons and Aromatic Metabolites in Coho Salmon Receiving Hydrocarbons (62.8 μg) via Intraperitoneal Injection

Hydrocarbon	Time after injection (in hours)	TISSUE																			
		BRAIN				LIVER				GALLBLADDER				MUSCLE***				RESIDUAL CARCASS****			
		picograms HC per mg dry tissue	% administered dose (HC)	UN* %	MET %	picograms HC per mg dry tissue	% administered dose	UN %	MET %	picograms HC per mg dry tissue	% administered dose	UN %	MET %	picograms HC per mg dry tissue	% administered dose	UN %	MET %	picograms HC per mg dry tissue	% administered dose	UN %	MET %
Benzene	6	155	0.0027	98	2	702	0.016	68	32	888	0.00022	37	63	85	0.066	100	0	849	6.20	100	0
	24	29	0.00036	100	0	5510	0.0004	58	42	256	0.00041	29	71	7	0.006	100	0	61	0.22	100	0
Naphthalene	24	3980	0.059	98	2	2670	0.080	87	13	9460	0.073	28	72	1580	1.60	96	4	6430	15.2	99	1
	72	962	0.011	76	24	984	0.023	55	45	**	--	--	--	973	0.722	86	14	1940	3.03	89	11
	144	487	0.0080	80	20	294	0.011	59	41	--	--	--	--	238	0.348	87	13	1320	4.78	92	8
Anthracene	24	50200	0.764	98	2	17700	0.432	36	64	167000	0.80	10	90	12100	10.1	87	13	20600	33.0	97	3
	72	5240	0.052	96	4	2150	0.076	42	58	--	--	--	--	1210	1.35	99	1	20200	40.0	86	14
	144	2000	0.025	91	9	1220	0.047	31	69	--	--	--	--	385	0.421	54	46	4420	12.0	60	40

*Values shown are percentages of parent hydrocarbon (UN) and total aromatic metabolites (MET) based on distribution of 14_C between each group of compounds.

**Analysis not performed.

***Muscle samples were a combination of dark and light muscle from the left anterior of the fish.

****Tissue remaining after all other samples had been taken.

Table II

DISTRIBUTION OF NAPHTHALENE METABOLITES IN COHO SALMON 24 HOURS AFTER INJECTION OF 125.6 μg NAPHTHALENE

Compound	Brain	Liver	Gall Bladder	Muscle
1-naphthol	29*	156	537	34
1,2-dihydro-1,2-dihydroxynaphthalene	5	48	604	6
1-naphthyl sulfate	24	12	238	29
1-naphthyl mercapturic acid	20	172	1,380	9
1-naphthyl-β-glucuronic acid	70	217	12,800	22

* Values are given as picograms of compound per milligram dry tissue.

Coho salmon were also force-fed naphthalene-1-^{14}C in purified salmon oil. The accumulation of radioactivity into brain, liver, kidney, gall bladder, dark muscle, light muscle, gut contents, gut and blood were evaluated for up to 48 hr. Maximum accumulations of radioactivity occurred in gall bladder and liver, representing 5.3 ng/mg dry wt of tissue (hr) and 4.7 ng/mg dry wt of tissue (8 hr), respectively (Table III). Interestingly, dark muscle, kidney, and brain also accumulated relatively large amounts of naphthalenic metabolites. The concentrations of metabolites in the tissues, 16 hr after the administration of naphthalene-1-^{14}C, are the following (expressed as % of carbon-14 in the form of 1-naphthol):

Liver	1.5; 3.6
Kidney	5.4; 9.7
Gall bladder	9.1; 24.4
Dark muscle	1.0; 1.3
Light muscle	1.0; 2.2
Gut contents	2.1; 5.3
Gut	1.4; 2.7
Blood	0.3; 3.5

The wide variability in the concentrations of metabolites is consistent with other current findings from our laboratories, and will be discussed at greater length in the final report for R.U. 74.

The composition of the WSF of Prudhoe Bay crude oil has been determined. The following compounds were detected: toluene, xylene (three isomers), alkylated benzene (three-carbon substituent; six isomers), alkylated benzene (four-carbon substituent; one isomer), naphthalene, methylnaphthalene (two isomers), alkylated naphthalene (two-carbon substituent; one isomer), fluorene, phenanthrene and/or anthracene, and alkylated phenanthrenes (two

Table III

UPTAKE AND DISTRIBUTION OF NAPHTHALENE IN FORCE-FED COHO SALMON

	Brain		Liver		Kidney		Gall Bladder		Dark Muscle		Light Muscle		Gut Contents		Gut		Blood	
Time after feeding (hours)	picograms hydrocarbon per milligram dry tissue*	% administered dose**	picograms hydrocarbon per milligram dry tissue	% administered dose	picograms hydrocarbon per milligram dry tissue	% administered dose	picograms hydrocarbon per milligram dry tissue	% administered dose	picograms hydrocarbon per milligram dry tissue	% administered dose	picograms hydrocarbon per milligram dry tissue	% administered dose	picograms hydrocarbon per milligram dry tissue	% administered dose	picograms hydrocarbon per milligram dry tissue	% administered dose	picograms hydrocarbon per milligram dry tissue	% administered dose
2	91	0.00286	178	0.0347	11	<.001	31	<.001	19	0.0111	8	0.252	NA***	92.0	81	0.101	39	0.0977
8	2900	0.105	4670	1.48	1440	0.145	5310	0.180	1550	0.827	336	2.31	NA	55.0	9080	12.1	333	0.305
16	2200	0.105	2580	1.16	841	0.161	4600	0.285	2410	2.27	435	5.37	NA	18.3	5720	9.89	2368	3.46
48	191	0.00716	175	0.0590	123	0.0293	5100	0.252	433	0.361	36	0.441	NA	1.41	80	0.231	38	0.0558

* Values shown represent a combination of both parent naphthalene and aromatic metabolites, based on molecular weight of naphthalene

** Based on ^{14}C

*** Not applicable

and three-carbon substituents; one of each). In addition, phenol and several isomers of hydroxytoluene were identified. A final quantitative analysis of the WSF will be completed shortly.

The possible accumulation of hydrocarbons in gill, liver, and muscle of salmonids exposed to the WSF of Prudhoe Bay crude oil is presently under investigation. The results of this work will be included in the next report.

2. Trace metals

About two-thirds of the metal exposure studies for this contract year have been completed. Data obtained on the uptake of lead and cadmium by coho salmon and starry flounder at 4^o and 10^oC are given in Tables IV and V. Gills, liver, kidney, blood, erythrocytes, plasma, and brain were examined. The findings indicate that exposure of coho salmon to 3 ppb of lead for 30 days results in significant accumulations of lead in gill and kidney, representing magnification factors of 20 and 23, respectively. Similar trends were obtained on exposure of coho salmon to 150 ppb of lead at 4° and 10°C; however, almost twice as much lead accumulated in gills and kidney at 10°C than at 4°C, indicating that a tendency to accumulate lead from surrounding water is substantially decreased at low temperatures. Data on exposure of coho salmon to 150 ppb of cadmium for 15 days at 10°C indicated that gills, kidney, and liver were major sites of deposition. The greatest magnification (5.7 X) of cadmium occurred in the gills.

Table V gives results on the uptake of metal by starry flounder exposed to 150 ppb of lead and cadmium. In the studies with lead, temperatures of 4° and 10°C were employed. The tendency for lead

Table IV

ACCUMULATION OF LEAD AND CADMIUM IN COHO SALMON (*ONCORHYNCHUS KISUTCH*) IN 15 DAY EXPOSURE*

Metal Concentration	3 ppb Pb**	150 ppb Pb		150 ppm Cd
Temperature	4°C	4°C	10°C	10°C
Length of Exposure (days)	30	15	15	15
Gills	58 ppb	1060 ppb	1940 ppb	850 ppb
Liver	10	230	480	290
Kidney	70	680	1100	448
Blood	19	200	160	15
Erythrocytes	38	500	560	45
Plasma	2.04	37	30	9
Brain	0.61	4	10	1.5

* Data is preliminary and provisional.

** Data will be expressed on wt/dry wt tissue basis at a later time.

Table V

ACCUMULATION OF LEAD AND CADMIUM IN STARRY FLOUNDER (*PLATICHTHYS STELLATUS*) IN 15 DAY EXPOSURE*

Metal Concentration (ppb)	150 ppb Pb**		150 ppb Cd
Temperature	4°C	10°C	10°C
Gills	980 ppb	1750 ppb	930 ppb
Liver	550	850	1440
Kidney	668	2340	230
Blood	260	580	
Brain	130	600	5

* Data is preliminary and provisional.

** Data will be expressed on a wt/dry wt of tissue basis at a later time.

to be substantially magnified in gills, kidney, and liver is reminiscent to results obtained with coho salmon. However, in contrast to coho salmon, a relatively large amount of lead (magnification = 4.0 X) accumulates in the brain at both 4° and 10°C. Comparative results with cadmium in an exposure of coho salmon to 150 ppb at 10°C show that cadmium accumulates in the brain to a relatively small degree; the major sites of deposition are gills and liver. Accordingly, the data in Table V show that substantial differences exist between coho salmon and starry flounder with respect to the degree of accumulation of both lead and cadmium in key tissues, notably brain.

3. Detoxifying enzymes in biota from Norton Sound and Chukchi Sea

In the two weeks that this phase of R.U. 74 has been operational, two aspects of the work were carried out as follows: A 7-cubic foot ultra-low temperature freezer was purchased and upon arrival will be placed aboard the Miller Freeman in time for the ship's departure.

A test was made of holding several small flounder in a net pen in seawater to determine whether or not we can keep the fish alive incaptivity. After about 3 weeks, most fish died. A couple of surviving fish appeared unhealthy and were released to the environment. An obvious requirement exists to be able to hold fish captive and healthy so as to perform the required prototype exposure experiments with petroleum oils.

4. Histology

The findings from microscopic examinations are being evaluated and will be described in the final report.

IV. Preliminary Interpretation of Results

A. Biotransformations of petroleum hydrocarbons and trace metals

1. Hydrocarbons

Shrimp and crab larvae: The findings suggest that naphthalene and naphthalene bound to protein have high acute toxicities to Stage I and Stage V spot shrimp and newly hatched Dungeness crab zoea in the low ppb range. The findings also suggest that Stage I and Stage V of spot shrimp are capable of accumulating from 25 to 100 times environmental concentrations of naphthalene, depending upon whether the naphthalene is free or protein-bound. Bioaccumulated naphthalene is readily depurated from Stage I and Stage V spot shrimp; however, metabolites are strongly resistant to depuration, suggesting that greater attention should be focused on the accumulation and toxicological properties of naphthalene derivatives in larval forms.

Marine fish: The studies indicated that anthracene, naphthalene and benzene are readily deposited in key tissue sites upon entering the body. Concentrations were found to increase in key tissues, such as liver and brain, in the order of anthracene> naphthalene > benzene. This finding suggests the possibility that, within certain molecular weight ranges, the persistence of aromatic hydrocarbons in salmonid tissues may be directly related to the number of benzenoid rings in the molecule. Substantial reductions in the concentrations of hydrocarbons occur after removal of the source of hydrocarbons; however, such depurations are followed by a tendency to increase concentrations of metabolites for days thereafter. The metabolites, although classically associated with excretion, appear in significant amounts in all tissues examined, including the brain. Thus a general picture arises which implies that a substantial decline in accumulations of hydrocarbons is accompanied by a steady increase in the formation of metabolic products in all of the tissues and body fluids examined.

A special effort was made this year to establish a fully operational system for the exposure of marine organisms to constant levels of WSF under continuous flow-through bioassay conditions. In the next report we will provide data on the accumulation of the components of WSF in tissues of both coho salmon and flatfish. Now that the flow-through system is operational, the acquisition of important data on marine organisms becomes possible in relation to the accumulation, metabolism, and discharge of WSF of petroleum oil.

2. Trace metals

The findings indicate that both coho salmon and starry flounder are capable of magnifying both lead and cadmium in key organs, notably gill, kidney, and liver. Interestingly, substantial differences appear to exist between the accumulations in each of these species. A notable feature of the data is the obvious tendency for starry flounder to accumulate substantial amounts of lead in the brain. The capability of these animals to depurate both lead and cadmium will be the subject of a future report.

3. Detoxifying enzymes in biota from Norton Sound and Chukchi Sea

The initial studies carried out during the short period of work described in this report suggest that another way must be found to hold experimental flatfish alive during challenge experiments with petroleum. This matter is currently under investigation.

For flounder, it is planned to place a firm plastic sheet on the bottom of net pens so that the fish can rest and feed from a non-porous surface. Different food sources will be evaluated so as to determine a suitable form of food by which petroleum oil can be given to the fish in the diet.

V. Problems Encountered/Recommended Changes

Job vacancies for a chemist and a physical science technician have not been filled for the new aspects of the work dealing with detoxifying enzymes. These vacancies will be filled as soon as possible. No other problems exist.

VI. Estimate of Funds Expended

As of May 31, 1976, the research has spent $37,500.

REFERENCES

Roubal, W.T., T.K. Collier and D.C. Malins.
1976. Accumulation and metabolism of carbon-14 labeled benzene, naphthalene and anthracene by young coho salmon (*Oncorhynchus kisutch*). Arch. Environ. Contamin. Toxicol. (In press).

Warner, J.S.
1976. Determination of aliphatic and aromatic hydrocarbons in marine organisms. Anal. Chem. 48, 578.

Quarterly Report

Research Unit #75
Reporting Period 4/1-6/30/76
Number of Pages 2

Assessment of available literature on effects of oil pollution on biota in arctic and subarctic waters

Principal Investigators: Donald C. Malins
Maurice E. Stansby
Northwest Fisheries Center
National Marine Fisheries Service
Seattle, Washington 98112

June 16, 1976

QUARTERLY REPORT

I. Task Objectives

To prepare a critical review of the present state of knowledge of effects of oil pollution upon biota after surveying published reports in the literature.

II. Field or Laboratory Activities

The task of locating pertinent literature references has been completed. Preparation of a first draft of the critical review is underway by several staff members. This first draft is approximately 80% completed. A firm arrangement has been made with Academic Press to publish the final critical review in book form. Mr. Frank Piskur has begun the editing of the critical reviews so that portions prepared by different scientists will appear in relatively similar format and style. Much of the work in the next (final) quarter will consist of completion of the editing and revision toward the goal of producing the final report.

III. Results

Results of this research unit are in terms of descriptive reports prepared rather than that of data collected. With the first draft of the manuscript being about 80% complete, the project is right on schedule.

IV. Preliminary Interpretation of Results

There are many reports already in the literature regarding the general effects of petroleum pollution in temperate waters. The number of reports dealing with effects in arctic and contiguous waters are, however, very few in number. We would have to say at this stage of the project that very likely a major achievement of this research unit will probably be to point up research areas where great gaps in knowledge occur and where additional research must be undertaken before any sound conclusions as to effects of petroleum pollution in the arctic can be reached.

V. Problems Encountered/Recommended Changes

None other than the paucity of information on research in arctic waters alluded to under IV above.

VI. Estimate of Funds Expended

Approximately ___% of the funds for this research unit have been expended or obligated.

QUARTERLY REPORT

Contract 03-5-022-56
Task Order Number 18
Quarter Ending -
3 June 1976

EFFECTS OF CRUDE OIL ON HERRING ROE

Dr. Ronald L. Smith
Associate Professor of Zoology
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

June 30, 1976

QUARTERLY REPORT

I. Task Objectives

Objectives for this quarter included the following:

A. Complete experimental design.

B. Obtain newly spawned herring roe.

C. Conduct experiment.

II. Field and Laboratory Activities

A. Field

A float plane was chartered to fly us to the site of kelping activity. We were able to obtain fronds of algae covered with fertilized herring eggs through the efforts of Mr. Len Weimer, I.M.S., Seward. Egg covered fronds were flown back to Seward in two 4 gallon plastic buckets with lids. I estimate the time from harvest to initiation of thermal equilibration in Seward at four hours. During this time, the water temperature surrounding the eggs varied less than 2^oC.

B. Laboratory

Laboratory experiments were conducted in which 21 one gallon containers were used to incubate samples of about 200 eggs each. Three containers each were utilized for controls (no oil-seawater exposure), 4 hr., 8 hr., 12 hr., 24 hr., 48 hr., and 6 day exposures. All experimental containers were filled with seawater which had been equilibrated with Prudhoe Bay crude oil.

The equilibrated mixture was prepared as follows:

1. Three 12 gallon glass carboys received 42 1. seawater each.
2. 500 ml crude added.
3. Vigorous mixing via electric motors/stainless steel paddles for a 24 hr. period.
4. Allow settling for a 24 hr. period.
5. Syphon off seawater from below oil slick via stainless steel syphon

Water changes were carried out at the termination of each of the various exposure times and every 48 hrs. When oil exposure ended for an experimental jar the frond was carefully removed and placed in a clean jar with clean seawater. Water samples for hydrocarbon analysis were taken periodically through the experiment.

When hatching began (day 14) we removed larvae daily from all jars. We also counted them, enumerated those obviously deformed and preserved some for photography and E.M. Other larvae were frozen for hydrocarbon analysis.

For additional details of these activities, please consult Don Day's written log of our conversations of June 21, 1976.

III. Results

Although we have not run statistical analyses, it appears that exposure times up to 48 hrs. have no significant effect on hatching success. None of the embryos hatched from the 6 day exposure jars. Increasing exposure time appears to successively retard embryonic development and increase the percentage of morphological abnormalities.

IV. Problems Encountered

We are still running behind schedule on the hydrocarbon analyses due to John Pearson's untimely accident. At present, we have not begun to gas chromatography but are proceeding with the thin layer chromatographic analyses. I have had no word on my request for an extension without additional funds for this project.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: June 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 18 R.U. NUMBER: 123

PRINCIPAL INVESTIGATOR: Dr. R. L. Smith

No environmental data are to be taken by this task order as indicated in the Data Management Plan. A schedule of submission is therefore not applicable[1].

NOTE: [1] Data Management Plan has been approved and made contractual.

Department of
Fisheries and Wildlife

Oregon
State
University

Marine Science Center
Newport, Oregon 97365 (503) 867-3011

July 23, 1976

Dr. Donald Day
NOAA Environmental Research
Laboratories
Outer Continental Shelf Energy Program
Juneau Project Office
P.O. Box 1808
Juneau, Alaska 99802

Re: Research Unit #183,OCSEP

Dear Dr. Day:

In view of the recent submission date for our annual report, May 27, 1976, this letter is intended to serve as an update on the project in lieu of the 5th quarter report.

Subsequent to our writing of the annual report we have initiated two additional chronic exposure experiments employing Dungeness crab zoeae and the seawater soluble fraction of Alaskan crude oil, benzene, and naphthalene as toxicants. One of these experiments was begun in mid May and the second in late June. Regretably we have continued to experience poorer survival of the cultures than we had originally anticipated. However, I feel that the results of the several experiments taken together do satisfactorily define the concentration of these toxicants that the larvae can tolerate for extended periods of time.

Since the writing of the annual report we have also conducted two additional studies; one to evaluate the effects of the seawater soluble fraction of crude oil, naphthalene, and benzene on hatching of Dungeness crab eggs and development of the larvae through the short prezoeae stage; and the second to determine the acute toxicity of a large number of aromatic compounds which are normally encountered in seawater soluble fractions of crude oil. These include a variety of methyl and ethyl substituted benzenes and naphthalenes. For the remainder of our work we will determine the hexane/seawater partition coefficients for the aforementioned compounds as an aid to understanding their relative toxicities and we may attempt a partial characterization of the aromatic components in our seawater soluble fraction to allow some assessment of the relative contribution of each of the major aromatics to the toxicity of the whole fraction.

Yours sincerely,

Richard S. Caldwell

Richard S. Caldwell
Assistant Professor of Fisheries

RSC:ej

QUARTERLY REPORT

Contract 03-5-022-56
Task Order Number 17
Quarter Ending -
30 June 1976

SUBLETHAL EFFECTS - EFFECTS ON SEAGRASS

Dr. John G. Pearson
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

June 30, 1976

QUARTERLY REPORT

I. Task Objectives

The objectives of this study are currently being revised. New experimental designs will be submitted as a Task Order Modification.

II. Field and Laboratory Activities

Due to illness, the principal investigator, John Pearson, is unable to continue in this project. The above mentioned experimental modification is due to and accompanied by a request to name associate investigator, C. P. McRoy, as principal investigator.

III. Results

None.

IV. Problems Encountered

See Activities II.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: June 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 17 R.U. NUMBER: 305

PRINCIPAL INVESTIGATOR: Dr. J. G. Pearson

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]		
	From	To	Batch 1	2	
Cordova Area	12/9/75	12/12/75	None[2]		

Notes: [1] Data Management Plan has been approved and made contractual.

[2] As stated in quarterly report, all samples were apparently lost in transit by Alaska Airlines.

OCSEAP QUARTERLY REPORT

Research Unit: 332

Reporting Period: April-June 1976

Number of Pages: 26

DETERMINE THE FREQUENCY AND PATHOLOGY OF MARINE FISH AND INVERTEBRATES IN THE BERING, BEAUFORT, CHUKCHI SEAS, GULF OF ALASKA, AND NORTON SOUND

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June 1976

QUARTERLY REPORT

I. Task Objectives

Task A-28. Determine by field and literature studies the incidence and pathology of disease presently existing in fish, shellfish, birds, and mammals for use in evaluating future impacts of petroleum-related activity.

II. Field and Laboratory Activities

A. Ship Schedule

Vessel: NOAA Ship *Miller Freeman*

Cruise: M761

Dates: Leg I: March 28 to April 21, 1976

Leg II: April 24 to May 13, 1976

Leg III: May 18 to June 4, 1976

B. Scientific Party

Leg I: Bruce B. McCain, PhD
University of California, Davis, California
Role: Party Chief. Assisted in the examination of fish for pathological conditions, collected tissue specimens, photographed affected animals, isolated bacteria and fungi, and prepared cruise report.

William D. Gronlund
NMFS, NOAA, NWFC
Role: Assisted in the examination of fish for pathological conditions, and processed biological data.

Legs II & III: Mark S. Myers
University of California, Davis, California
Role: Party Chief. Examined fish for pathological conditions, collected tissue specimens, isolated bacteria, processed biological data, and prepared cruise reports.

C. Methods

1. Field procedures

Examination of Hauls. After fish were sorted according to species and subsamples were selected by members of OCSEAP R.U. 175, the fish in each subsample were examined for externally visible pathological conditions and, when feasible, for readily recognizable internal disorders. In cases where an entire subsample could not be examined, the number of fish examined was recorded. Following the processing of each haul, the following information was recorded in the Haul Data Sheet: haul number; date; number of fish examined for each species, usually listed according to sex (this data was usually obtained from the length-frequency records of R.U. 175); the type of pathological conditions observed; and the number of fish with each type of condition for each species and usually each sex.

Examination of Individual Fish. Fish with pathological conditions were processed while still alive or freshly dead. Each fish was assigned a specimen number and the following information was recorded on an Individual Data Sheet: species, sex, length, weight, type of disease, method of age determination (otolith or scale), general health of the fish, and location and size of the pathological condition(s). If specimens were to be taken from an individual, then it was photographed, and either the diseased tissue alone or in combination with the major internal organs was preserved in either 10% formalin with phosphate-buffered saline (for light microscope histology), or a fixative for electron microscopy (Hawkes, 1974). In some cases, tissue was frozen at -20°C or in liquid nitrogen (-196°C) for later microbiological procedures. The presence of bacteria or fungi inside lesions, tumors, and internal organs was determined by cauterizing the surface of the tissue to be sampled, opening the tissue with a sterile scapel, removing an inoculum with a sterile loop, and streaking the inoculum in petri dishes with Ordal's Seawater Cytophaga Agar (OSCA), brain-heart infusion agar (Difco, dissolved in seawater), or potatoe dextrose agar (Difco) containing penicillin and streptomycin (for isolation of fungi). Representative colonies were purified by restreaking, stored in tubes containing OSCA, and returned to the laboratory for further tests. In addition to streaking the inoculum onto agar media, a portion of each inoculum was spread onto a glass microscope slide and gram stained.

2. Laboratory procedures

Laboratory activities were mainly concerned with processing the specimens and data obtained during Leg I of Cruise M761. Tissue specimens to be examined histologically were matched with the photographic colored slides showing the gross pathology of the original pathological condition, and histological procedures were initiated.

Bacterial isolates were characterized using standard taxonomic criteria, such as, cell morphology, colony color and morphology, oxidase activity, behavior in oxidation-fermentation media, and motility.

Scales and otoliths from diseased fish were examined and age determinations were made. This data was added to the information contained on the Individual Data Sheets.

The Haul Data and Individual Data Sheets were analyzed, the data summarized, and in some cases compared with similar data obtained by R.U. 175 for the same hauls. Length frequencies, sex ratios, and length/weight and age/length relationships of diseased and total populations were compared.

D. Sample localities

The sampling stations at which fish were examined are the same as those used by R.U. 175 during Legs I, II, and III, Cruise M761 of the NOAA ship Miller Freeman.

E. Data collected

1. Number and types of samples:

36,417 individual fish were examined; 1461 cases of pathological abnormalities were found and the biological characteristics (sex, length, weight, etc.) of affected fish were determined.

2. Number and types of analyses:

266 specimens were collected for histopathological examination, including light and electron microscopy; 60 bacterial isolates were obtained and purified; approximately 50 tissue specimens were frozen in liquid nitrogen (liquid nitrogen container is presently onboard the NOAA ship Miller Freeman).

III. Results

A. Field Activities

Of the 26 species of demersal fishes examined aboard the NOAA ship Miller Freeman during Legs I to III of Cruise M761, four had pathological conditions which were observed at more than five sampling stations and with an overall frequency equal to or greater than 1.0% (Tables 1,2). The affected species, associated pathological conditions, and the overall average frequencies of each condition were as follows: Pacific cod (Gadus macrocephalus), pseudobranchial tumors, 8.7%; Pacific cod, skin ulcers, 1.6%; pollock (Theragra chalcogramma), pseudobranchial tumors, 1.7%; yellowfin sole (Limanda aspera), lymphocystis, 2.8%; and rock sole (Lepidopsetta bilineata), epidermal papillomas, 1.3%. Additional information concerning the prevalence of these abnormalities is given in Table 2.

The pseudobranchial tumors of cod were very similar in appearance to those found by us in the Bering Sea during the 1975 cruise of the NOAA ship Miller Freeman. All of the cod tumors observed in 1975 and 1976 were bilateral with one possible exception. The distribution of this disease as yet shows no discernable geographic pattern (Figures 1, 2,3; Table 3). The overall average frequency at stations where this condition was found ranged from 1.1 to 73.3%. Lengths of tumor-bearing cod captured in Leg I ranged from 29 to 71 cm. Also, approximately the same percentage of male cod had tumors as females.

Two main types of Pacific cod skin ulcers were observed, a generally circular, hemorrhagic, open type; and a raised, round, yellow-white-colored type with an amorphous covering of mucoid-like material and often having hemorrhagic foci. Bacteria with very similar cellular staining properties and morphology, and colonial color and shape were routinely isolated from cauterized ulcers (see Laboratory Activities for more information). Intermediate and larger cod seemed most affected by this condition, with few fish under 40 cm having ulcers. Approximately the same percentage of males as females had this condition. The range of frequencies of occurrence at stations where affected fish were caught was from 1.1 to 35.2%. The distribution of the highest disease frequencies followed a southernly pattern in the Bering Sea (Fig. 4, Table 3).

Pseudobranchial tumors in pollock differed from the cod tumors in four main ways: (1) male pollock had tumors about twice as frequently as did females; (2) smaller pollock over a narrower size range, between about 20 to 40 cm, had tumors; (3) several pollock had unilateral tumors; and (4) the pollock tumors were grossly more invasive than cod tumors with two possible cases of metastases being observed. The percentage of tumor-bearing pollock ranged from 0.1 to 13.2% at stations where this disease was detected. Stations with the highest disease frequencies followed a southernly pattern (Figs. 5,6; Table 3).

The virus-caused lymphocystis growths observed this year on yellowfin sole were essentially similar to those observed last year in the Bering Sea. Last year all of the growths were found on the "blind" side; however, this year a significant number of growths were observed on the "eyed"side. About 10% of the fish with lymphocystis had fin erosion associated with fins containing growths. The number of males with this disease was very similar to the number of diseased females. At stations where infected yellowfin were observed, the disease frequencies ranged from 2.3 to 31.3%. Also, the highest frequencies of disease occurrence were found in the southeastern part of the Bering Sea (Figs. 7,9; Table 3).

Epidermal papillomas observed on rock sole this year were similar to those described last year. Males had approximately three times the frequency of tumors as did females. In addition, about 85% of the males with tumors were less than 20 cm in length, while 30% of the females with tumors were less than 20 cm. The frequencies of tumor-bearing fish ranged from 0.4 to 58.9% at stations where affected fish were found. The distribution of tumor-bearing rock sole appeared to be depth related, with the shallowest stations having the highest frequencies (Fig. 9, Table 3).

Several pathological conditions observed to occur at low frequencies included the following: (1) gill-associated tumors of pollock, (2) skin ulcers of halibut (*Hippoglossus stenolepis*), (3) various cyst-like structures beneath the skin of four species of flounders, (4) green liver disease in cod and pollock, (5) fin erosion in cod, pollock, flathead sole (*Hippoglossiides elassodon*) and long-head dab (*Limanda proboscidea*), (6) a systemic bacterial infection of cod; and (7) deep, round, hemorrhagic skin lesions in cod and pollock probably caused by leeches, lampreys, or hagfishes. In addition, two types of copepod gill parasites were often observed in cod and pollock. One of these types of copepods was sometimes attached to gill arches with considerable associated gill necrosis.

B. Laboratory activities

1. Data analysis

Much of the sex/length/age frequency data mentioned above was from data obtained in the field and analyzed in the laboratory.

2. Bacteriology

Bacterial isolates from skin ulcers of six different Pacific cod have so far behaved identically in taxonomic tests. They appear to be a *Pseudomonas* sp. Additional tests are being performed to determine if a single bacterial species was common to the ulcers of all six fish. Other bacterial isolates from cod skin ulcers and internal organs are also being tested.

C. Activities related to the Chukchi Sea, Norton Sound baseline studies

1. A graduate student from the College of Fisheries, University of Washington, with a strong background in fisheries biology and invertebrate pathology was selected to participate in shipboard field activities.
2. Changes in ADP computer format for individual animals were initiated in order to record characteristics of invertebrates with pathological conditions. Mr. Dean Dale, PMEL, Seattle, is assisting us in this matter.
3. The P.I.'s have been performing an extensive review of the literature concerned with invertebrate pathology.

IV. Preliminary Interpretation of Results

The general distribution of the three diseases, epidermal papillomas of rock sole, pseudobranchial tumors of cod, and lymphocystis of yellowfin sole, was found this year to resemble the pattern of these diseases found by us in the Bering Sea last year. The highest disease frequencies of rock sole papillomas appeared to follow the shallower depths along the north to eastern edge of the Bering Sea. This distribution did not seem to correspond to the densities of rock sole populations; in fact, the highest numbers of tumor-bearing rock sole appeared to be located on the fringe of rock sole populations. Thus, as has been mentioned in our previous reports, rock sole with papillomas may have difficulty competing with normal rock sole of their same age and must move to less competitive waters. Alternatively, environmental factors and/or other behavior patterns of rock sole may have created disease "hot spots." The overall disease frequency this year was very similar to last year (1.3% versus 1.0%).

In contrast to tumor-bearing rock sole, yellowfin with lymphocystis seemed to be closely associated with high population densities of yellowfin sole. The overall frequency this year (2.8%) was also similar to last year (2.1%). The mode of transmission of this viral disease is not yet known. The results of last year indicated that the lymphocystis growths occured only on the blind side, suggesting that perhaps abrasive contact with objects on the bottom sediment may allow entry of the lymphocystis virus. However, our observations this year have shown that some growths occur on the eyed-side; therefore, the mode of virus entry may be more complex than we hypothesized previously, possibly related to the high population densities in which this species is often found.

Pollock with pseudobranchial tumors seemed to be distributed in a pattern much the same as cod with these tumors. Also, our observation of these tumors in pollock strongly suggests that all members of the family Gadidea may be predisposed to this disease. The finding of unilateral tumors in pollock and possibly one cod suggests that the mechanism of tumor induction in these two species may be similar. If histological examination of the above-mentioned apparent metastasized pollock pseudobranchial tumors is confirmed, then some of these tumors may be malignant and therefore very harmful to the affected pollock. This finding may also explain why smaller pollock tended to have a higher frequency of tumors than larger pollock; tumor development in young pollock could cause death.

The prevalence of pseudobranchial tumors in Pacific cod this year (8.7%) was slightly higher than last year (7.4%). Juvenile cod (fish less than 20 cm in length) have not yet been found with this condition. Either this condition does not develop until a certain age, or the neoplastic condition is not grossly recognizable in young fish; the latter hypothesis is favored at this time. The ulcerative skin condition of cod did not appear to be connected with pseudobranchial tumors. The two types of ulcers may be different stages of the same disease, as both types were often found on the same fish. Approximately six cod were observed to have numerous ulcers, and be lighter colored and more flaccid than normal. Three such fish were sampled bacteriologically and found to have bacteria in their ulcers, peritoneal fluid and the liver and/or kidney. The bacterial isolates from the internal organs and fluids have not yet been tested sufficiently to compare them with the bacterial isolates from the ulcers. If they are found to be the same organisms, then it is possible that the skin ulcers may be associated with a systemic bacterial disease.

V. Problems Encountered and Recommended Changes

One recommendation concerns the assignment of species of particular interest to scientific personnel aboard research vessels. During Cruise M761, some of the species having major diseases were assigned to other vessels. Therefore, when we want to compare the biological data of diseased fish to that of the whole population of that species, we must use data from fish caught by a different vessel, at a different time, and different geographical station. A better situation would be to coordinate the assignment of species by resource assessment investigators with the needs of the pathology group.

VI. Estimate of Funds Expended

General Assistance		$10,729
Employee Benefits		923
Supplies and Expenses		5,361
Travel		4,078
Overhead		4,076
	Total	$25,167

REFERENCES

Hawkes, Joyce.
1974. The structure of fish skin. I. General organization. Cell Tiss. Res. 149, 147-158.

Table 1

SPECIES EXAMINED EXHIBITING NO SIGNIFICANT PATHOLOGY

Species	Number Examined	Number of Stations Where Examined
Flathead sole *Hippoglossoides elassodon*	2977	47
Arrowtooth flounder *Atheresthes stomias*	2416	35
Halibut *Hippoglossus tenolepsis*	513	28
Greenland turbot *Reinhandtius hippoglossoides*	979	26
Alaska plaice *Pleuronectes quadrituberculatus*	728	21
Longhead dab *Limanda proboscidea*	169	5
Pacific Ocean perch *Sebastes alutus*	149	9
Pacific sandfish *Trichodon trichodon*	10	1
Black cod *Anoplopoma fimbria*	18	3
Herring *Clupea harengus pallasi*	175	4
Rainbow smelt *Osmerus mordax dentex*	20	1
Capelin *Mallotus villosus*	100	1
Wattled eelpout *Lycodes palearis*	2	1
Dogfish *Squalus acanthius*	1	1
Snailfish *Careproctus* sp.	3	1
Starry flounder *Platichthys stellatus*	41	9
Dover sole *Microstomus pacificus*	1	1
Sturgeon poacher *Agonus acipenseris*	1	1
Gynnocanthus sp.	1	1
Myoxocephalus sp.	9	1
Myoxocephalus jaok	1	1
Myoxocephalus polyacanthocephalus	1	1
	8,417	

Table 2

THE OVERALL AVERAGE FREQUENCY, THE NUMBERS OF HAULS OUT OF 117 TOTAL HAULS IN WHICH A DISEASED SPECIES WAS CAPTURED, AND THE AVERAGE FREQUENCY OF THE HAULS IN WHICH DISEASED FISH WERE PRESENT FOR EACH OF THE FIVE PATHOLOGICAL CONDITIONS

Species and Disease	No. of Fish Examined	No. of Fish Affected	Overall Average Frequency (%)	No. of Hauls with Species	No. of Hauls with Affected Fish	Average of Hauls with Affected Fish (%)
Pacific Cod Pseudobranchial tumors	4654	403	8.7	85	57	14.9
Pacific Cod Skin ulcers	4654	73	1.6	85	19	7.8
Walleye Pollock Pseudobranchial tumors	9173	156	1.7	75	34	3.1
Yellowfin Sole Lymphocystis	8036	228	2.8	50	17	9.7
Rock Sole Epidermal papillomas	6440	87	1.3	70	10	11.1

Table 3.--Summary of data (by haul number) for the five major pathological conditions observed on NOAA ship *Miller Freeman* Cruise B761, Legs 1, II and III.

	Pacific Cod					Pollock			Yellowfin Sole			Rock Sole		
Haul or station #	Number examined	Number with tumors	Frequency of tumors	Number with skin ulcers	Frequency of skin ulcers	Number examined	Number with tumors	Frequency of tumors	Number examined	Number with lymphocystis	Frequency of lymphocystis	Number examined	Number with epidermal papilloma	Frequency of epidermal papilloma
1	109	18	16.5%	0	0%	-	-	-%	-	-	-%	163	0	0%
2	131	16	12.2	0	0	56	0	0	-	-	-	182	0	0
3	67	15	22.4	0	0	114	1	0.9	1	0	0	227	1	0.4
4	24	6	25.0	1	4.2	231	0	0	-	-	-	120	0	0
5	25	2	8.0	1	4.0	62	0	0	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	3	0	0	0	0	12	0	0	269	33	12.3	146	1	0.6
9	-	-	-	-	-	-	-	-	68	7	10.3	170	65	38.2
10	-	-	-	-	-	-	-	-	42	12	28.6	17	10	58.9
11	37	1	2.7	13	35.1	71	0	0	-	-	-	-	-	-
12	-	-	-	-	-	6	0	0	-	-	-	-	-	-
13	17	0	0	1	5.9	76	0	0	-	-	-	-	-	-
14	94	3	3.2	5	5.3	-	-	-	-	-	-	-	-	-
15	14	1	7.1	0	0	-	-	-	-	-	-	-	-	-
16	72	3	4.2	12	16.7	200	5	2.5	-	-	-	196	0	0
17	37	3	8.1	7	18.9	331	2	0.6	-	-	-	28	0	0
18	99	11	11.1	10	10.1	175	8	4.6	-	-	-	203	0	0
19	45	14	31.0	3	6.7	265	9	3.4	-	-	-	82	0	0
20	-	-	-	-	-	67	5	7.5	-	-	-	217	1	0.5
21	5	3	60.0	0	0	42	2	4.8	249	8	3.2	56	4	7.1
22	-	-	-	-	-	6	0	0	128	4	3.1	6	0	0
23	-	-	-	-	-	-	-	-	37	3	8.1	-	-	-
24	15	3	20.0	0	0	202	12	5.9	158	8	5.1	62	1	1.6
25	9	3	33.3	0	0	193	6	3.1	12	0	0	99	0	0
26	44	10	22.7	1	2.3	117	3	2.6	-	-	-	175	0	0
27	20	2	10.0	0	0	85	6	7.1	-	-	-	18	0	0
28	14	1	7.1	0	0	205	2	1.0	-	-	-	-	-	-
29	25	3	12.0	2	8.0	257	3	1.2	-	-	-	-	-	-
30	60	2	3.3	3	5.0	334	0	0	-	-	-	-	-	-
31	28	0	0	0	0	149	1	0.7	-	-	-	-	-	-
32	63	0	0	1	1.6	146	2	1.4	-	-	-	-	-	-
33	1	0	0	0	0	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35	158	10	6.3	5	3.2	149	1	0.7	-	-	-	110	0	0
36	88	1	1.1	1	1.1	163	0	0	-	-	-	53	0	0
37	63	0	0	0	0	95	1	1.1	-	-	-	-	-	-
38	18	0	0	2	11.7	63	0	0	-	-	-	-	-	-
39	52	2	3.8	2	3.8	118	0	0	-	-	-	86	0	0
40	51	0	0	0	0	53	1	1.9	-	-	-	70	0	0
41	105	6	5.7	2	1.9	127	0	0	-	-	-	58	0	0
42	16	1	6.3	0	0	126	2	1.6	-	-	-	115	0	0
43	14	1	7.1	0	0	36	2	5.6	192	6	3.1	164	2	1.2
44	13	1	7.7	0	0	112	0	0	-	-	-	134	0	0
45	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46	3	0	0	0	0	-	-	-	-	-	-	-	-	-
47	57	8	13.6	0	0	159	0	0	-	-	-	44	0	0
48	234	33	14.1	0	0	440	0	0	-	-	-	166	0	0
49	22	2	9.1	0	0	96	2	2.1	-	-	-	163	0	0
50	29	3	10.3	0	0	128	1	0.8	96	30	31.3	113	0	0

Table 3 - continued

	Pacific Cod					Pollock			Yellowfin Sole			Rock Sole		
Haul or station #	Number examined	Number with tumors	Frequency of tumors	Number with skin ulcers	Frequency of skin ulcers	Number examined	Number with tumors	Frequency of tumors	Number examined	Number with lymphocystis	Frequency of lymphocystis	Number examined	Number with epidermal papilloma	Frequency of epidermal papilloma
51	38	1	2.6%	0	0%	205	27	13.2	178	29	16.3	125	0	0
52	6	3	50.0	0	0	169	14	8.3	100	9	9.0	106	0	0
53	-	-	-	-	-	-	-	-	-	-	-	-	-	-
54	-	-	-	-	-	-	-	-	-	-	-	-	-	-
55	17	0	0	0	0	7	0	0	118	13	11.0	-	-	-
56	-	-	-	-	-	-	-	-	256	6	2.3	18	1	0.5
57	-	-	-	-	-	-	-	-	221	15	6.8	-	-	-
58	97	6	6.2	0	0	124	1	0.1	-	-	-	112	0	0
59	147	19	12.9	0	0	-	-	-	-	-	-	-	-	-
60	33	9	27.2	0	0	125	0	0	94	0	0	131	0	0
61	12	3	25.0	0	0	-	-	-	136	0	0	121	0	0
62	15	11	73.3	0	0	41	1	2.4	129	0	0	64	0	0
63	-	-	-	-	-	-	-	-	-	-	-	-	-	-
64	148	37	25.0	0	0	-	-	-	6	0	0	25	0	0
65	18	0	0	0	0	62	0	0	-	-	-	-	-	-
66	-	-	-	-	-	-	-	-	-	-	-	-	-	-
67	659	51	27.7	0	0	-	-	-	-	-	-	110	0	0
68	-	-	-	-	-	-	-	-	-	-	-	133	0	0
69	-	-	-	-	-	-	-	-	-	-	-	130	0	0
70	-	-	-	-	-	-	-	-	4	0	0	-	-	-
71	-	-	-	-	-	-	-	-	108	0	0	1	0	0
72	(juv) 125	0	0	0	0	-	-	-	200	0	0	50	1	2.0
73	59	2	3.4	0	0	11	0	0	183	0	0	111	0	0
74	(juv) 80	0	0	0	0	2	0	0	189	0	0	182	0	0
75	(juv) 54	0	0	0	0	-	-	-	197	0	0	53	0	0
76	25	7	28.0	0	0	61	0	0	-	-	-	110	0	0
77	48	10	20.8	0	0	31	0	0	14	0	0	71	0	0
78	105	8	7.6	0	0	403	4	1.0	3	0	0	41	0	0
79	39	0	0	0	0	31	0	0	-	-	-	-	-	-
80	5	0	0	0	0	90	0	0	12	0	0	-	-	-
81	23 (11 juv)	0	0	0	0	231	4	1.7	548	0	0	81	0	0
82	12	0	0	0	0	266	13	4.9	105	0	0	39	0	0
83	11	1	9.1	0	0	165	6	3.6	191	0	0	1	0	0
84	30	2	6.7	0	0	82	1	1.2	88	0	0	3	0	0
85	8	0	0	0	0	281	0	0	147	0	0	-	-	-

Table 3- continued

	Pacific Cod					Pollock			Yellowfin Sole			Rock Sole		
Haul or station #	Number examined	Number with tumors	Frequency of tumors	Number with skin ulcers	Frequency of skin ulcers	Number examined	Number with tumors	Frequency of tumors	Number examined	Number with lymphocystis	Frequency of lymphocystis	Number examined	Number with epidermal papilloma	Frequency of epidermal papilloma
86	52	3	5.8	0	0	26	0	0	-	-	-	10	0	0
87	64	2	3.1	0	0	240	0	0	-	-	-	41	0	0
88	2	0	0	0	0	13	0	0	-	-	-	3	0	0
89	26	1	3.8	0	0	294	0	0	3	0	0	138	0	0
90	44	6	13.6	0	0	265	2	0.1	-	-	-	54	0	0
91	-	-	-	0	0	13	0	0	-	-	-	7	0	0
92	6	0	0	0	0	7	0	0	-	-	-	2	0	0
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	41	2	4.9	0	0	11	0	0	-	-	-	5	0	0
96	16	0	0	0	0	50	0	0	-	-	-	25	0	0
97	42	3	7.1	0	0	13	0	0	-	-		5	0	0
98	(juv) 3	0	0	0	0	53	0	0	-	-	-	36	0	0
99	-	-	-	-	-	23	0	0	-	-	-	2	0	0
100	2	0	0	0	0	56	3	5.3	608	0	0	-	-	-
101	(juv) 33	0	0	0	0	-	-	-	104	0	0	12	0	0
MB 13	55	15	27.3	0	0	215	0	0	171	29	16.9	374	0	0
MB 12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MB 4	(juv) 18	0	0	0	0	-	-	-	112	6	5.4	4	0	0
MB 9	-	-	-	-	-	-	-	-	543	0	0	-	-	-
MB 25	-	-	-	-	-	-	-	-	250	0	0	-	-	-
MB 22	-	-	-	-	-	-	-	-	433	0	0	-	-	-
MB 10	(juv) 342	0	0	0	0	-	-	-	88	0	0	-	-	-
MB 19	-	-	-	-	-	-	-	-	240	0	0	-	-	-
MB 16	36	2	5.5	1	2.8	12	0	0	-	-	-	-	-	-
MB 55-A	-	-	-	-	-	-	-	-	75	0	0	-	-	-
MB 69	12	3	25.0	0	0	120	3	2.5	-	-	-	-	-	-
MB 86B	18	1	5.5	0	0	41	0	0	9	0	0	8	0	0
MB 46	-	-	-	-	-	-	-	-	517	0	0	-	-	-
MB 37	-	-	-	-	-	-	-	-	79	0	0	-	-	-
MB 28	-	-	-	-	-	-	-	-	137	0	0	-	-	-
MB 18-A	47	7	14.9	0	0	67	0	0	188	10	5.3	453	0	0
TOTALS	4,654	403	Ave. 8.7%	73	Ave. 1.6%	9,173	156	Ave. 1.7%	8,036	228	Ave. 2.8%	6,440	87	Ave. 1.3%

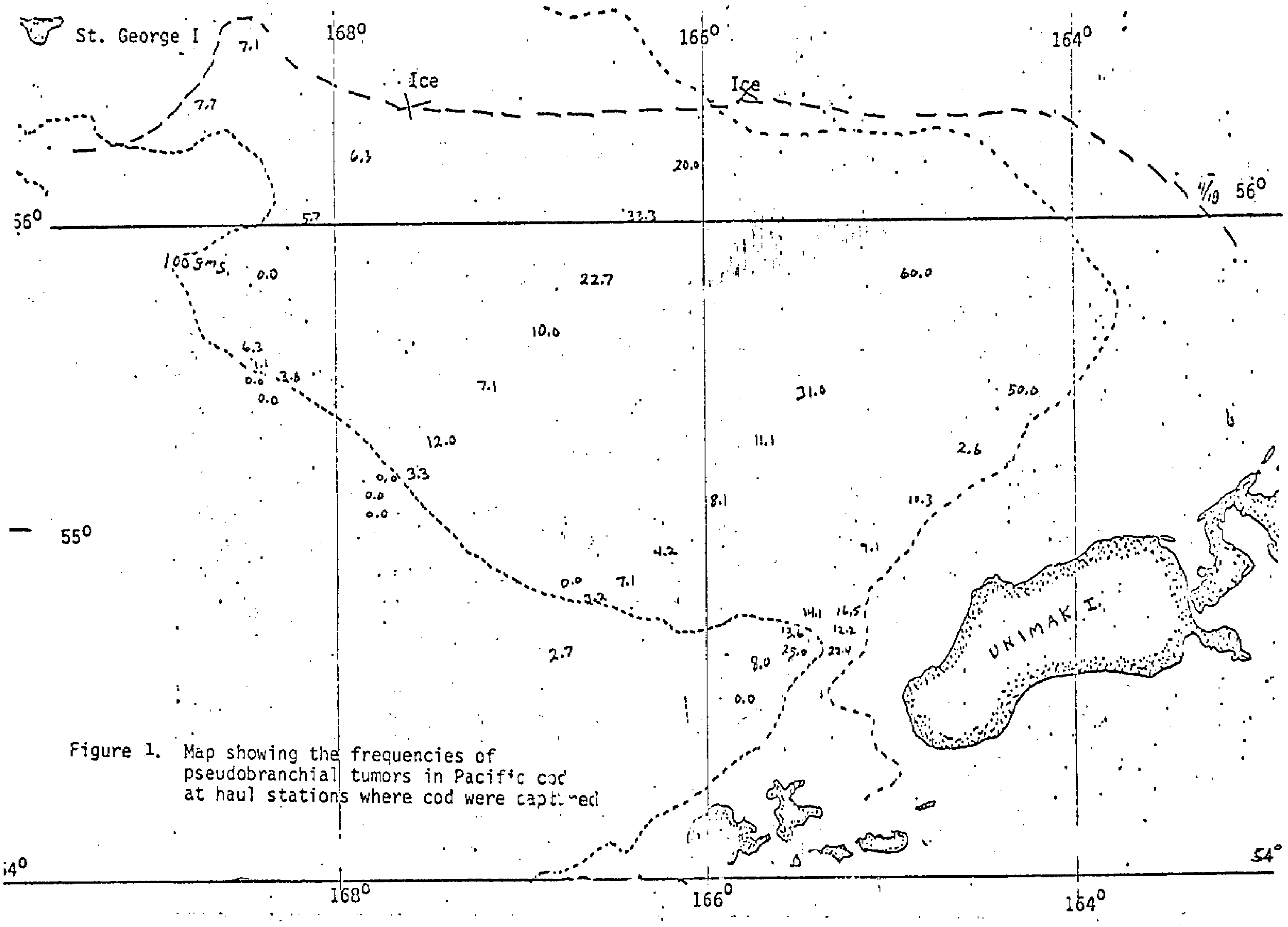


Figure 1. Map showing the frequencies of pseudobranchial tumors in Pacific cod at haul stations where cod were captured

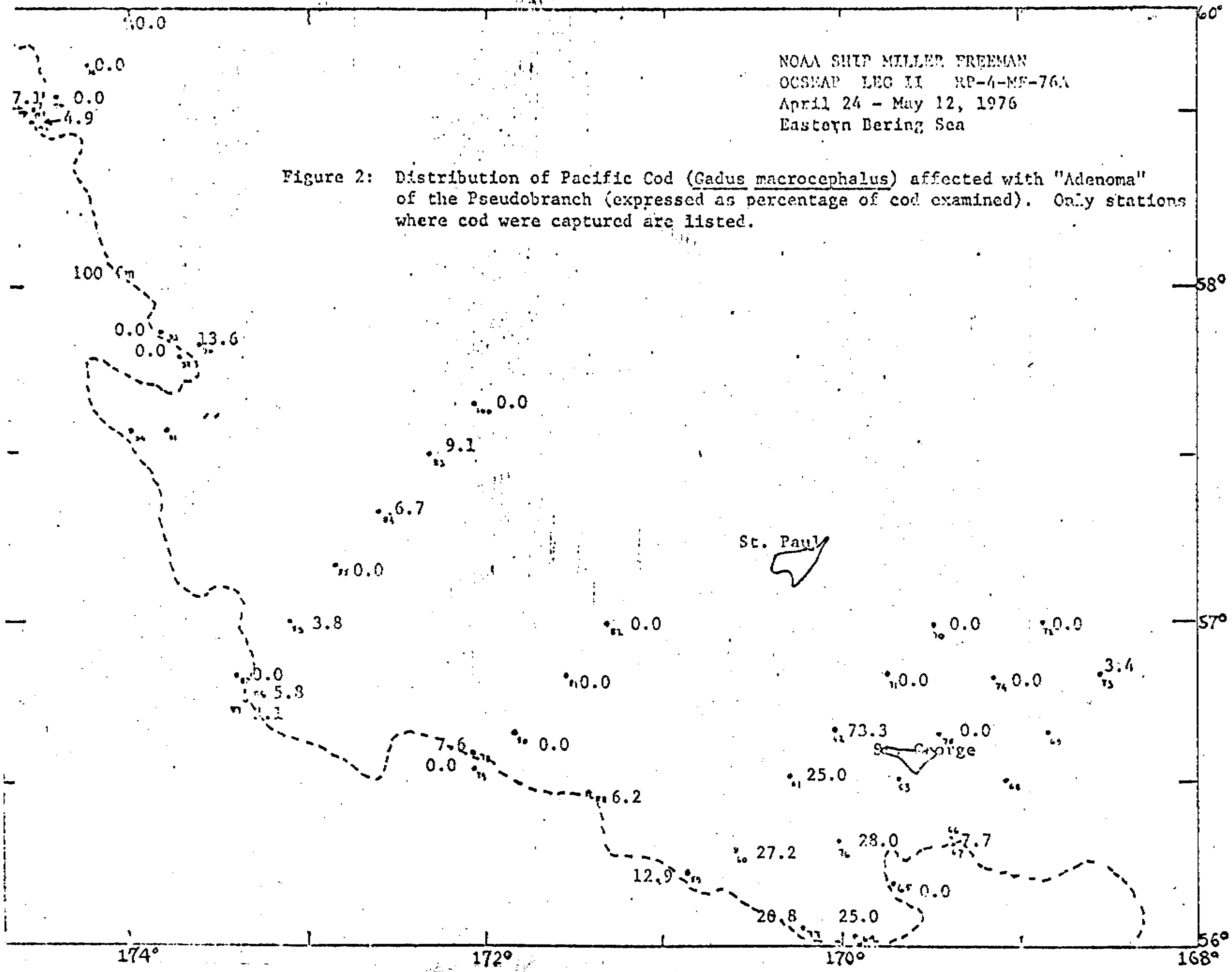


Figure 2: Distribution of Pacific Cod (Gadus macrocephalus) affected with "Adenoma" of the Pseudobranch (expressed as percentage of cod examined). Only stations where cod were captured are listed.

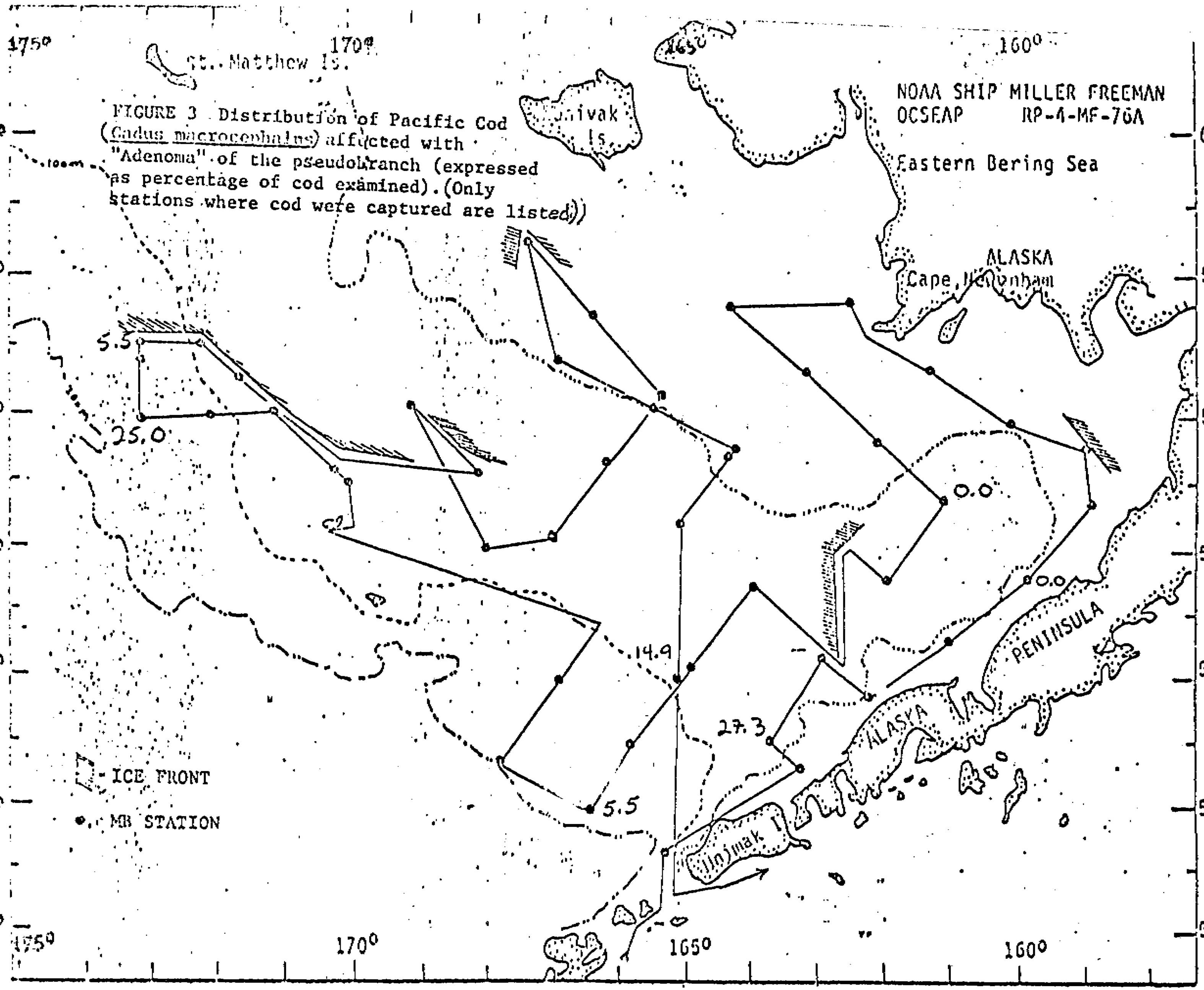


FIGURE 3 Distribution of Pacific Cod (*Gadus macrocephalus*) affected with "Adenoma" of the pseudobranch (expressed as percentage of cod examined). (Only stations where cod were captured are listed)

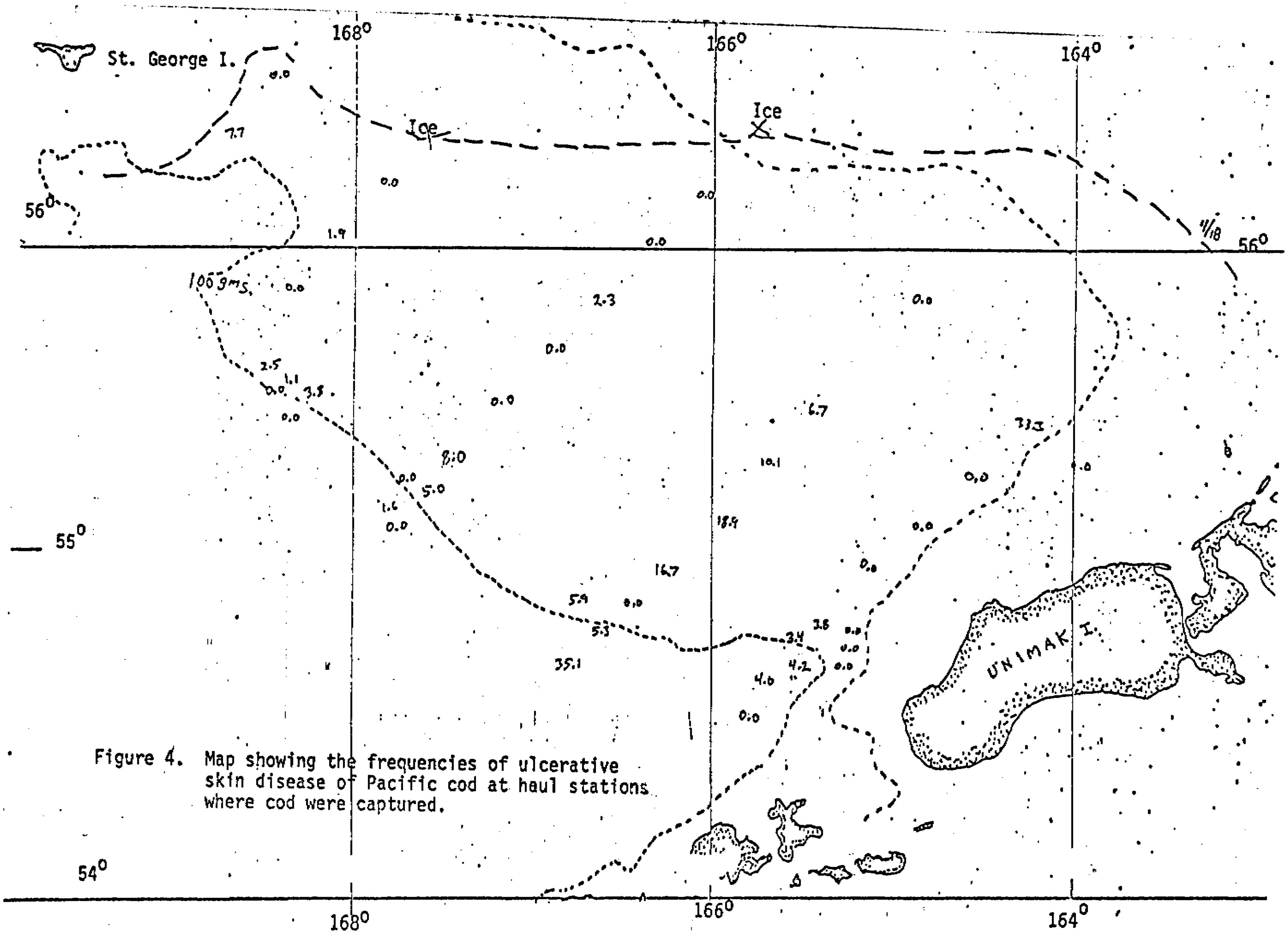


Figure 4. Map showing the frequencies of ulcerative skin disease of Pacific cod at haul stations where cod were captured.

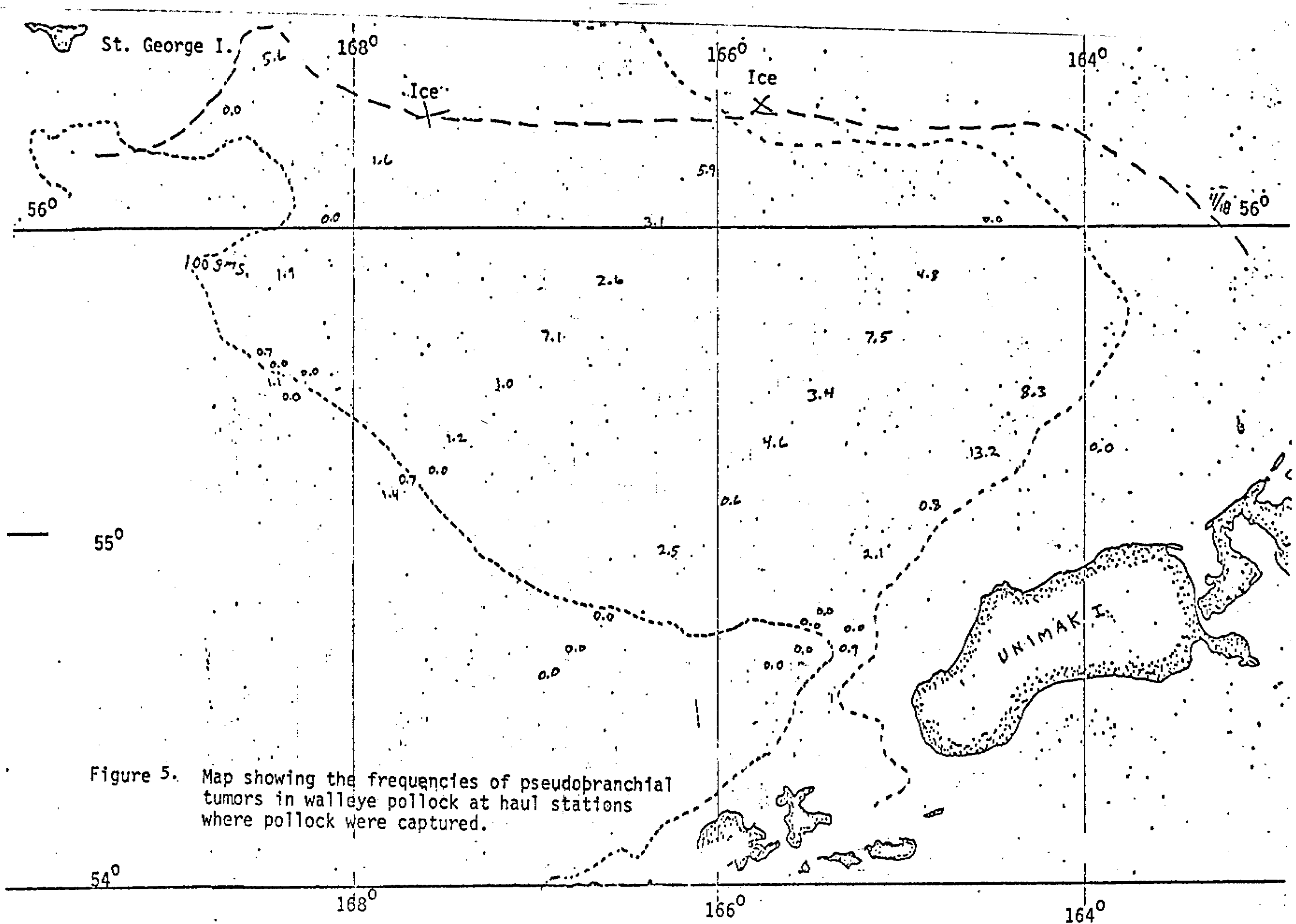
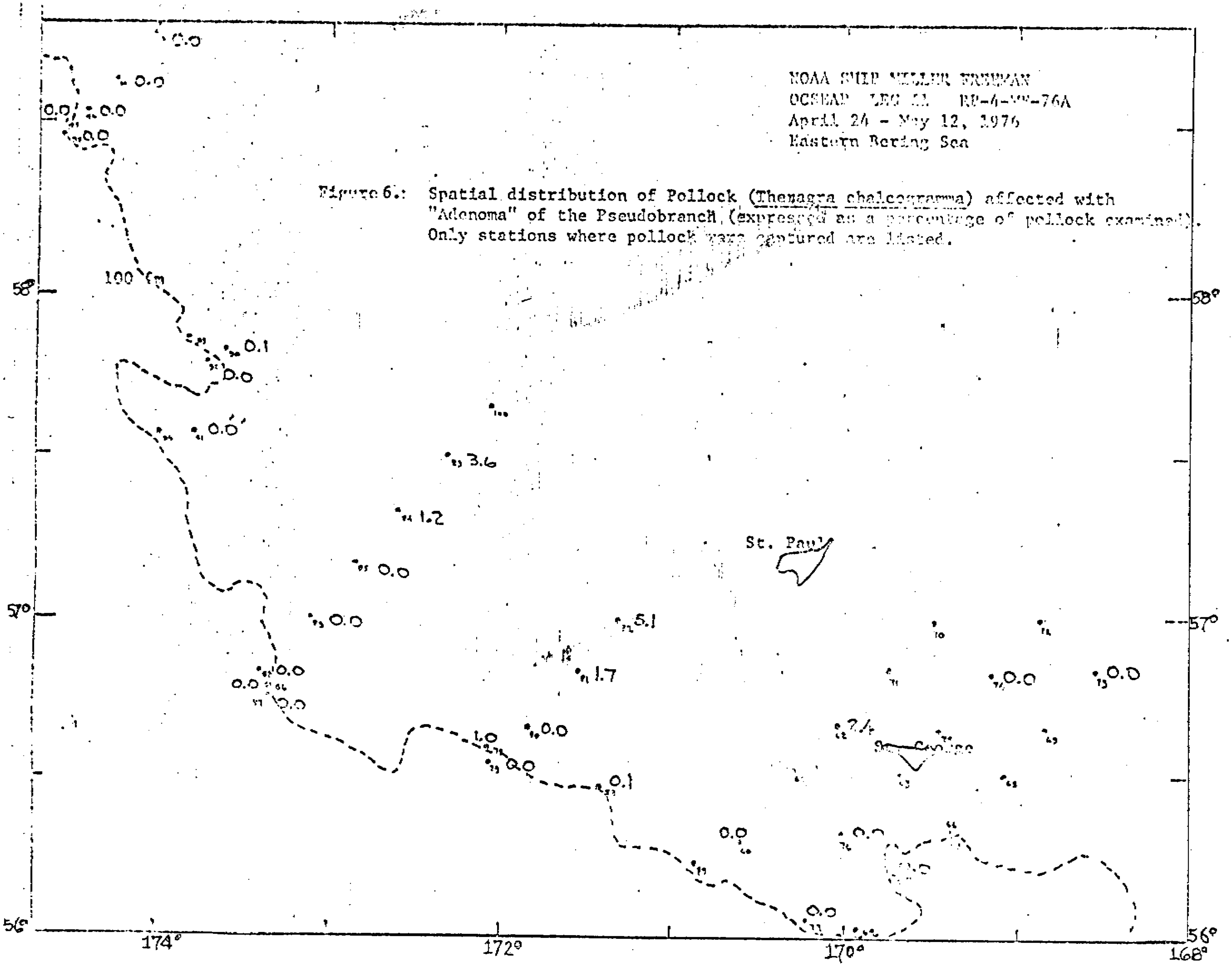


Figure 5. Map showing the frequencies of pseudobranchial tumors in walleye pollock at haul stations where pollock were captured.



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OCSEAP LEG II RP-4-MF-76A
April 24 - May 12, 1976
Eastern Bering Sea

Figure 6.: Spatial distribution of Pollock (*Theragra chalcogramma*) affected with "Adenoma" of the Pseudobranch (expressed as a percentage of pollock examined). Only stations where pollock were captured are listed.

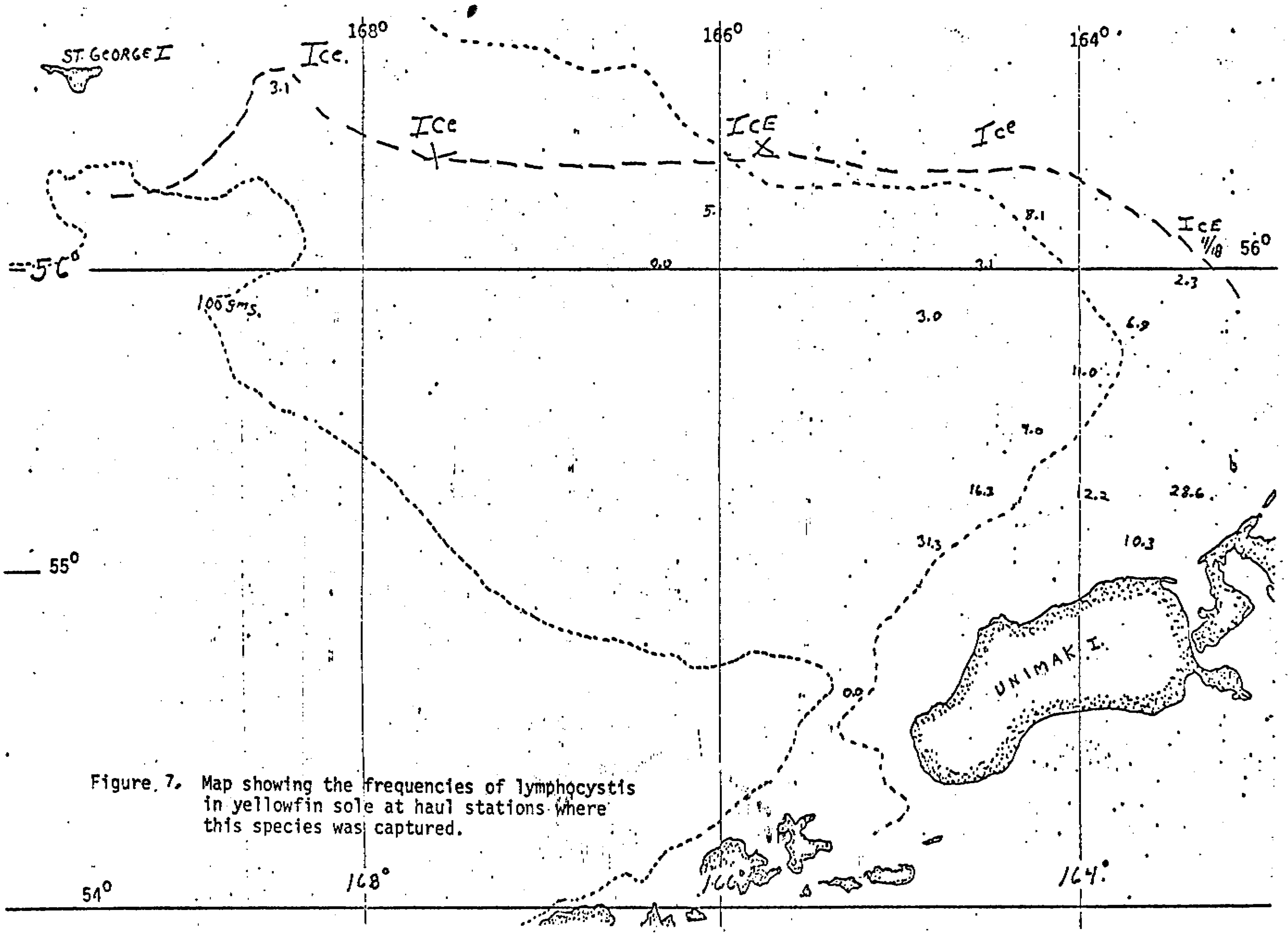

Figure 7. Map showing the frequencies of lymphocystis in yellowfin sole at haul stations where this species was captured.

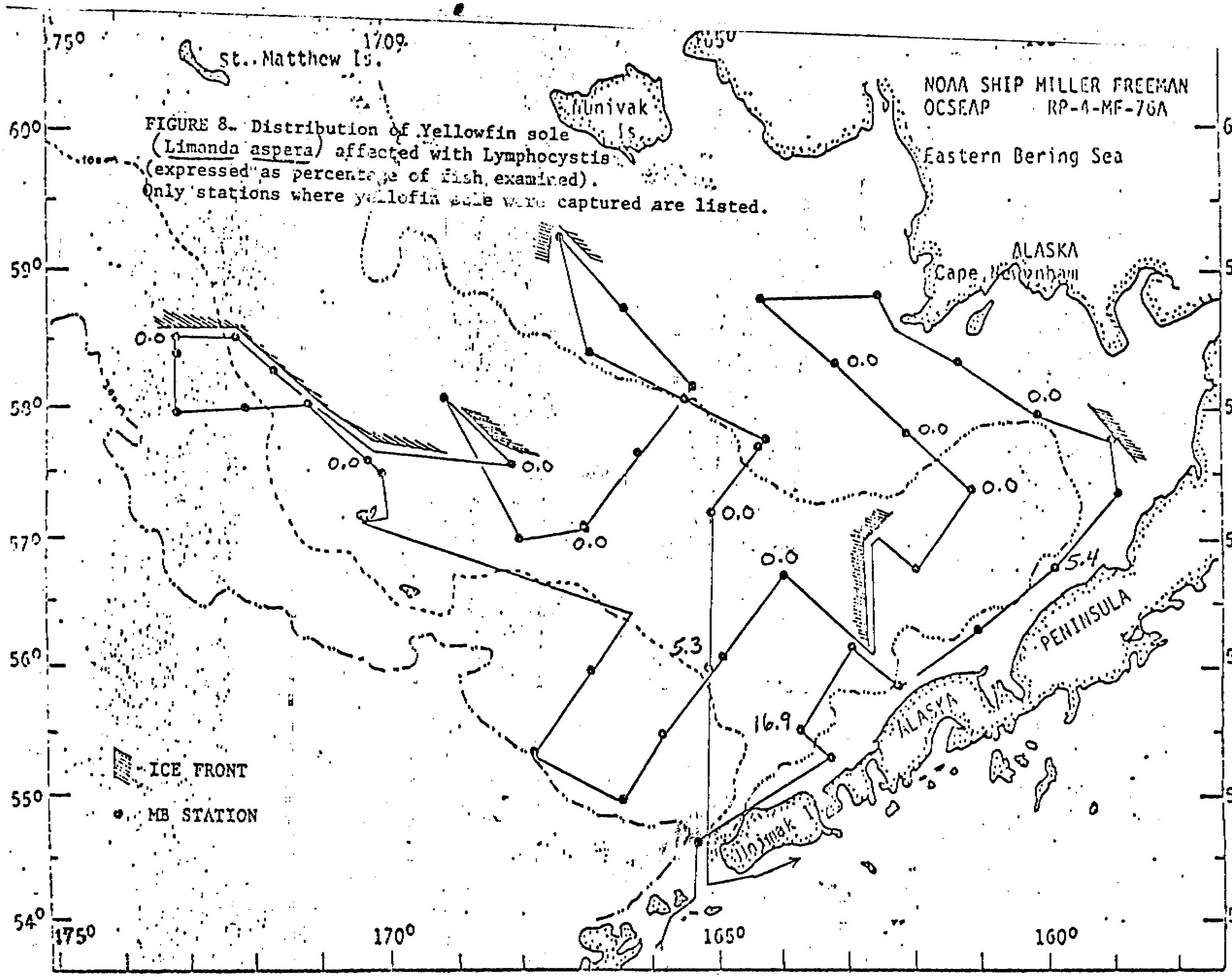

FIGURE 8. Distribution of Yellowfin sole (*Limanda aspera*) affected with Lymphocystis (expressed as percentage of fish examined). Only stations where yellofin sole were captured are listed.

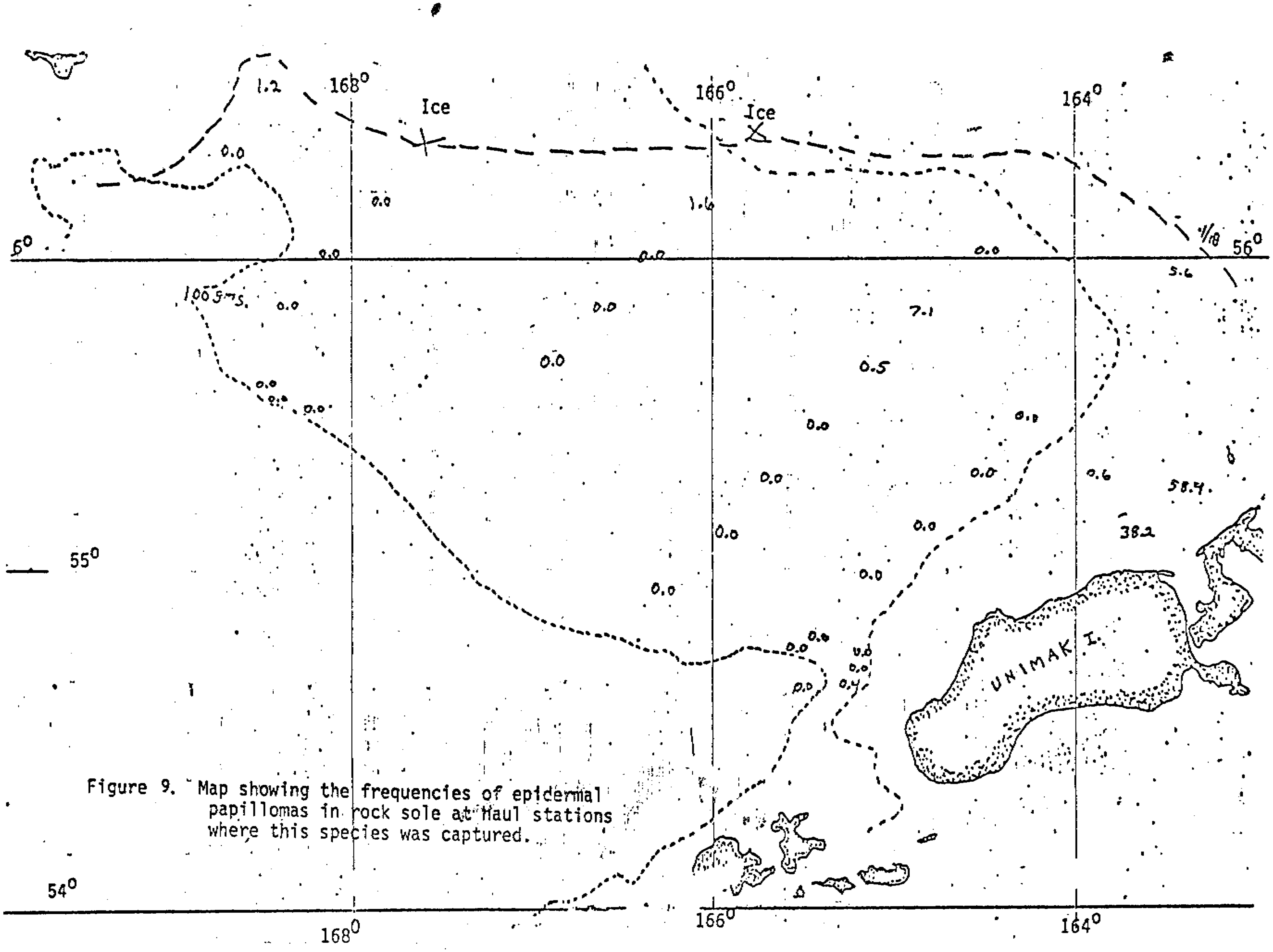

Figure 9. Map showing the frequencies of epidermal papillomas in rock sole at haul stations where this species was captured.

CHEMISTRY AND MICROBIOLOGY

CHEMISTRY AND MICROBIOLOGY

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Not In Bibl

Quarterly Report

Contract # 03-5-022-85
Research Unit 29
Period 4/1 - 6/30

Assessment of Potential Interactions of Microorganisms and Pollutants Resulting from Petroleum Development on the Outer Continental Shelf in the Beaufort Sea

Submitted by: Ronald M. Atlas
Principal Investigator
Department of Biology
University of Louisville
Louisville, Kentucky 40208

July 1, 1976

I. Task Objectives

A. To characterize marine microbiological communities in sufficient detail to establish a baseline description of microbiological community characteristics on a seasonal basis.

B. To determine the role of microorganisms in the biodegradation of petroleum hydrocarbons.

II. Field and Laboratory Activities

A. Field Schedule

March 28 - May 20, 1976

Helicopter

B. Scientific Party

Dr. Tatsuo Kaneko

Mr. George Roubal

Mrs. Teiko Kaneko

Department of Biology
University of Louisville
Louisville, Kentucky 40208

C. Methods

Water and sediment samples were collected through holes drilled in the ice as described in previous reports. Surface ice samples were also collected aseptically. Microorganisms were enumerated as described in previous reports. Laboratory activities to characterize isolated microorganisms using 400 tests were also continued.

For rates hydrocarbon biodegradation studies, radiolabelled hexadecane spiked crude oil was incubated for 40 days with collected samples. The reaction was stopped by addition of acid and the ^{14}C was quantitated by liquid scintillation counting.

D. Sample Locations

Sediment, water and ice samples were collected at the numbered sites shown in Figure 1. Beach samples were collected at Plover Point. Latitudes and longitudes of sample collections are shown in Table I.

E. Data Collected

The water, sediment and ice samples collected, including location and abiotic parameters, are shown in Table I. Ten different enumeration techniques were performed on the microorganisms in the samples. Eight hundred microorganisms were isolated for characterization.

III. Results

A. Characterization of microorganisms isolated from August-September sampling.

Characterization tests were completed for 700 microorganisms isolated from the August-September samples. Two searchable files, Nos. 100191 and 100102, now exist at the National Institute of Health for organisms isolated at 4 and 20 C respectively. NODC has been notified of the NIH information and retrieval system. Analyses have not yet been performed on this data.

B. Enumeration of micoorganisms from March-April sampling.

Enumeration of micoorganisms from ice, water and sediment samples are shown in Table II.

IV. Interpretation of Results

No new interpretation of analyses were made during this period.

V. Problems Encountered

A lack of continued funding threatens to prevent adequate further sampling and any complete analysis of collected organisms and interpretation of results, thus greatly reducing the value of the large effort that has been conducted to date to gather a data base on the microorganisms of this region.

VI. Estimate of Funds

It is estimated tht 75% of all funds were expended as of 5/1/76.

Table I

Sample Locations and Abiotic Parameters

Sample#	Latitude	Longitude	Depth(m)	Temp.(C)	Salinity(°/oo)
		Water			
103	71°39'	155°04'	1	-2.0	19.2
104	71 21	156 21	1	-2.0	24.5
105	71 23	155 56	1	-2.0	25.0
106	71 23	155 26	1	-2.0	22.0
107	71 23	154 54	1	-2.0	17.0
108	71 21	156 27	1	-2.0	31.0
109	71 21	156 21	1	-2.0	29.0
110	71 08	146 30	1	-2.0	23.0
111	70 32	148 22	1	-1.5	28.0
112	70 31	147 24	1	-2.0	28.0
113	70 28	147 30	1	-1.5	29.0
114	70 17	147 00	1	-2.0	17.0
116	71 36	152 12	1	-2.0	24.0
117	71 46	151 52	1	-2.0	20.5
118	71 26	152 22	1	-2.0	19.0
119	71 19	152 33	1	-2.0	19.8
120	71 08	152 55	1	-2.0	25.5
121	71 23	153 50	1	-2.0	28.0
122	71 23	154 22	1	-2.0	29.0
123	71 34	155 35	1	-1.5	28.0
		Ice			
101	71°31'	156°06'	0	0	-
102	71 34	155 35	0	0	-
103	71 39	155 04	0	0	-
104	71 21	156 21	0	0	-
105	71 23	155 56	0	0	-
106	71 23	155 26	0	0	-
107	71 23	154 54	0	0	-
108	71 21	156 27	0	0	-
109	71 21	156 21	0	0	-
110	71 08	146 30	0	0	3.2
111	70 32	148 22	0	0	-
112	70 31	147 24	0	0	-
113	70 28	147 30	0	0	-
114	70 47	147 00	0	0	23.8
115	70 22	148 20	0	0	1.0
116	71 36	152 12	0	0	6.0
117	71 46	151 52	0	0	2.5
118	71 26	152 22	0	0	11.0

Sample#	Latitude	Longitude	Depth(m)	Temp.(C)	Salinity(°/oo)
		Ice (cont'd.)			
119	71°19'	152°33'	0	0	8.5
120	71 08	152 55	0	0	3.5
121	71 23	153 50	0	0	5.0
122	71 23	154 22	0	0	5.0
123	71 34	155 35	0	0	4.0
		Sediment			
101	71°23'	155°56'	6.0	0	-
102	71 23	155 25	6.0	0	-
103	71 23	154 54	7.0	0	-
104	71 21	156 27	5.0	0	-
105	71 21	156 21	5.0	0	-
106	70 32	148 22	8.0	0	-
107	70 31	147 24	14.0	0	-
108	70 28	147 30	3.5	0	-
109	70 47	147 00	26.0	0	-
110	70 22	148 20	2.0	0	-
111	71 26	152 22	50.0	0	-
112	71 19	152 33	30.0	0	-
113	71 08	152 55	9.0	0	-
114	71 23	153 50	22.0	0	-
115	71 23	154 22	13.0	0	-

Table II

Enumeration of Microorganisms

Sample#		Heterotrophs				"Vibrio"				
		Aerobic		Anaerobic						
	Direct Count	Marine Agar	Marine Agar	Marine Agar	Marine Agar	TCBS	TCBS	Pseudosel	Oil	Oil
Water		4 C	20 C	4 C	20 C	4 C	20 C	20 C	4 C	20 C
103	$6.4x10^{5}$	$1.3x10^{1}$	0	0	0	$5.0x10^{0}$	0	0	$0.22x10^{0}$	$0.18x10^{0}$
104	$6.2x10^{4}$	$2.0x10^{1}$	$1.6x10^{1}$	$3.0x10^{0}$	0	$1.5x10^{1}$	$2.5x10^{0}$	0	$0.08x10^{0}$	$0.04x10^{0}$
105	$7.0x10^{4}$	$4.7x10^{1}$	$2.0x10^{0}$	$1.7x10^{1}$	$1.0x10^{2}$	$4.3x10^{1}$	$2.5x10^{0}$	0	$0.20x10^{0}$	$0.05x10^{0}$
106	$1.6x10^{5}$	$5.0x10^{1}$	$1.0x10^{1}$	$6.7x10^{0}$	$3.0x10^{0}$	$3.5x10^{1}$	$5.0x10^{0}$	$8.0x10^{-4}$	$0.18x10^{0}$	$0.26x10^{0}$
107	$1.0x10^{5}$	$4.0x10^{1}$	$1.3x10^{1}$	$1.6x10^{1}$	$6.6x10^{0}$	$3.0x10^{1}$	$5.0x10^{0}$	0	$0.24x10^{0}$	$0.02x10^{0}$
108	$2.8x10^{5}$	$1.4x10^{3}$	$2.6x10^{3}$	$1.3x10^{1}$	$2.6x10^{2}$	$1.4x10^{2}$	$1.5x10^{1}$	$2.0x10^{-2}$	$3.14x10^{0}$	$0.10x10^{0}$
109	$3.6x10^{5}$	$8.1x10^{2}$	$2.2x10^{3}$	$3.3x10^{1}$	$2.8x10^{2}$	$1.4x10^{2}$	$5.0x10^{2}$	$2.0x10^{-2}$	$0.24x10^{0}$	$0.54x10^{0}$
110	$1.7x10^{5}$	$5.7x10^{0}$	$0.9x10^{0}$	$3.0x10^{0}$	$0.6x10^{0}$	$1.0x10^{0}$	$2.0x10^{0}$	0	$0.02x10^{0}$	$0.06x10^{0}$
111	$1.5x10^{5}$	$6.2x10^{1}$	$3.2x10^{4}$	$7.5x10^{0}$	$2.6x10^{4}$	$9.8x10^{1}$	$2.0x10^{0}$	0	$0.66x10^{0}$	$0.50x10^{0}$
112	$2.8x10^{5}$	$3.0x10^{1}$	$5.0x10^{1}$	$4.4x10^{0}$	$3.7x10^{0}$	$9.5x10^{1}$	0	0	$0.04x10^{0}$	$0.40x10^{0}$
113	$1.1x10^{5}$	$3.3x10^{1}$	$1.1x10^{1}$	$5.0x10^{0}$	$1.0x10^{1}$	$6.4x10^{1}$	$1.0x10^{0}$	0	$0.16x10^{0}$	$0.86x10^{0}$
114	$7.0x10^{4}$	$2.0x10^{1}$	$1.0x10^{0}$	$1.1x10^{1}$	$0.5x10^{0}$	$2.2x10^{1}$	0	0	$0.04x10^{0}$	$0.04x10^{0}$
116	$2.3x10^{5}$	$1.0x10^{1}$	0	0	$3.0x10^{0}$	$1.0x10^{0}$	$2.0x10^{0}$	0	$0.06x10^{0}$	$0.02x10^{0}$
117	$1.2x10^{5}$	$9.1x10^{3}$	$1.6x10^{4}$	$4.8x10^{3}$	$1.6x10^{4}$	$3.3x10^{1}$	$3.3x10^{1}$	$0.13x10^{0}$	$0.04x10^{0}$	-
118	$7.8x10^{4}$	$8.3x10^{0}$	$9.4x10^{0}$	$1.0x10^{1}$	$6.7x10^{0}$	0	0	$0.84x10^{0}$	$0.02x10^{0}$	$2.20x10^{1}$
119	$1.6x10^{5}$	$7.1x10^{2}$	$9.1x10^{2}$	$7.1x10^{2}$	$1.0x10^{3}$	$1.2x10^{1}$	0	-	$0.16x10^{0}$	-
120	$9.3x10^{4}$	$1.3x10^{1}$	$1.3x10^{1}$	$1.0x10^{1}$	$6.7x10^{0}$	$2.0x10^{1}$	$1.0x10^{0}$	0	$0.12x10^{0}$	$0.22x10^{0}$
121	$9.3x10^{4}$	$3.3x10^{0}$	$0.2x10^{0}$	$3.8x10^{0}$	$0.1x10^{0}$	$2.7x10^{1}$	0	0	$0.32x10^{0}$	$0.02x10^{0}$
122	$1.6x10^{5}$	$1.2x10^{1}$	$2.2x10^{0}$	$4.2x10^{0}$	$3.3x10^{0}$	$4.2x10^{1}$	0	0	-	$0.04x10^{0}$
123	$1.6x10^{5}$	$1.3x10^{1}$	$1.5x10^{0}$	$3.3x10^{1}$	$3.3x10^{0}$	$4.4x10^{1}$	0	0	$0.42x10^{0}$	$0.04x10^{0}$
Ice										
103	$1.0x10^{5}$	$3.7x10^{1}$	0	$3.3x10^{0}$	0	0	0	-	$0.02x10^{0}$	$0.04x10^{0}$
104	$1.9x10^{5}$	$7.3x10^{1}$	$3.7x10^{1}$	$2.0x10^{1}$	$1.0x10^{1}$	0	0	-	$0.02x10^{0}$	$0.02x10^{0}$
105	$1.6x10^{5}$	$1.6x10^{1}$	$8.0x10^{1}$	$1.5x10^{0}$	$1.0x10^{0}$	$2.8x10^{1}$	0	0	$0.02x10^{0}$	$0.02x10^{0}$
106	$8.5x10^{4}$	$1.1x10^{1}$	$6.0x10^{1}$	$1.2x10^{0}$	$7.0x10^{1}$	0	0	0	$0.11x10^{0}$	$0.36x10^{0}$
107	$7.8x10^{4}$	$0.3x10^{0}$	$2.7x10^{2}$	0	$3.3x10^{0}$	0	$3.0x10^{0}$	0	$0.02x10^{0}$	$0.42x10^{0}$
108	$7.0x10^{4}$	$1.6x10^{1}$	$0.5x10^{0}$	0	$0.6x10^{0}$	0	$1.5x10^{2}$	$0.66x10^{0}$	$0.02x10^{0}$	$0.06x10^{0}$

	Direct Count	Marine Agar 4 C	Marine Agar 20 C	Marine Agar 4 C	Marine Agar 20 C	TCBS 4 C	TCBS 20 C	Pseudosel 20 C	Oil 4 C	Oil 20 C
Ice (cont'd.)										
109	1.9x10^5	7.7x10^1	1.7x10^2	1.9x10^1	-	8.7x10^1	1.3x10^1	0	0.30x10^0	0.10x10^0
110	8.5x10^4	0	0.3x10^0	0	0.4x10^0	0	0	0	0.10x10^0	0.02x10^0
111	1.5x10^5	5.5x10^2	3.1x10^3	1.9x10^2	4.8x10^2	0	1.0x10^0	0	1.22x10^1	0.70x10^0
112	7.8x10^4	9.9x10^0	1.1x10^1	2.7x10^0	7.8x10^0	0	0	0	0.02x10^0	0.02x10^0
113	1.3x10^5	4.0x10^1	1.0x10^0	1.0x10^0	1.8x10^2	0	0	0	0.02x10^0	0.30x10^0
114	7.8x10^4	6.0x10^1	1.3x10^0	1.5x10^1	1.7x10^0	1.2x10^1	1.0x10^0	0	0.06x10^0	0.12x10^0
115	1.1x10^5	2.9x10^2	2.0x10^2	4.5x10^1	3.2x10^1	0	1.0x10^0	0	1.10x10^0	0.36x10^0
116	4.6x10^4	3.8x10^1	2.8x10^1	0.5x10^0	5.0x10^1	2.0x10^2	0	-	0.08x10^0	-
117	5.4x10^4	6.3x10^1	5.2x10^0	0.1x10^0	2.1x10^1	0	0	0.48x10^0	0.02x10^0	1.95x10^1
118	7.8x10^4	5.7x10^0	2.2x10^1	0	4.9x10^0	0	1.0x10^0	6.00x10^{-1}	0.02x10^0	9.00x10^0
119	9.3x10^4	1.0x10^1	1.9x10^0	0	1.2x10^0	0	0	1.30x10^0	0.02x10^0	0.18x10^0
120	7.8x10^4	0	0.8x10^0	0.1x10^0	3.3x10^0	0	0	0	0.06x10^0	0.02x10^0
121	7.8x10^4	1.6x10^0	0	0	0	0	0	0	0.02x10^0	0.02x10^0
122	1.0x10^5	5.0x10^0	0.2x10^0	0.3x10^0	0	0	0	0	0.02x10^0	0.02x10^0
123	4.6x10^4	2.0x10^1	1.7x10^0	0	0	0	0	0	0.02x10^0	0.02x10^0
Sediment										
101	1.1x10^1	2.8x10^5	1.2x10^5	8.8x10^5	9.6x10^4	1.2x10^5	2.2x10^4	0	-	0.10x10^0
102	4.4x10^9	1.9x10^6	7.2x10^4	2.6x10^5	4.1x10^4	5.2x10^4	2.1x10^4	-	0.30x10^0	3.70x10^0
103	5.5x10^9	2.0x10^5	3.6x10^4	4.8x10^4	1.4x10^3	5.7x10^3	1.7x10^3	0	1.00x10^0	1.00x10^0
104	1.9x10^9	6.4x10^5	1.7x10^5	1.0x10^5	5.2x10^4	4.6x10^3	2.0x10^2	0	3.00x10^0	1.70x10^0
105	1.3x10^9	1.1x10^5	6.8x10^4	1.7x10^4	1.1x10^4	2.4x10^3	0	0	1.50x10^0	2.50x10^1
106	3.2x10^7	6.3x10^4	3.9x10^4	5.5x10^3	1.3x10^4	1.9x10^3	1.7x10^2	0	1.60x10^0	1.70x10^0
107	5.3x10^7	3.4x10^4	5.0x10^3	4.0x10^3	1.3x10^3	4.7x10^2	6.2x10^1	0	3.30x10^0	2.00x10^0
108	7.2x10^8	1.9x10^5	3.7x10^5	4.8x10^5	3.6x10^5	1.2x10^4	2.7x10^3	-	-	-
109	1.4x10^1	1.1x10^5	1.5x10^4	5.4x10^4	1.3x10^5	8.9x10^3	1.8x10^2	0	0.10x10^0	0.10x10^0
110	1.4x10^8	5.4x10^4	1.3x10^5	2.8x10^4	3.2x10^4	4.2x10^0	0	0	1.10x10^1	0.90x10^0
111	2.3x10^8	7.7x10^4	3.8x10^3	2.5x10^4	1.5x10^3	6.9x10^3	1.4x10^2	0	0.70x10^0	-
112	2.2x10^8	1.4x10^4	4.8x10^2	2.3x10^2	7.6x10^2	1.1x10^3	0	3.0x10^0	1.60x10^0	0.10x10^0
113	2.3x10^8	7.6x10^3	4.2x10^3	2.2x10^4	2.8x10^3	2.2x10^3	4.6x10^3	0	7.80x10^0	0.10x10^0
114	7.5x10^7	2.7x10^4	2.0x10^3	1.8x10^4	1.2x10^3	7.5x10^3	6.0x10^0	0	4.70x10^0	0.10x10^0
115	1.4x10^8	1.8x10^3	2.4x10^2	1.4x10^2	1.2x10^2	5.0x10^2	1.9x10^0	0	0.10x10^0	0.40x10^0

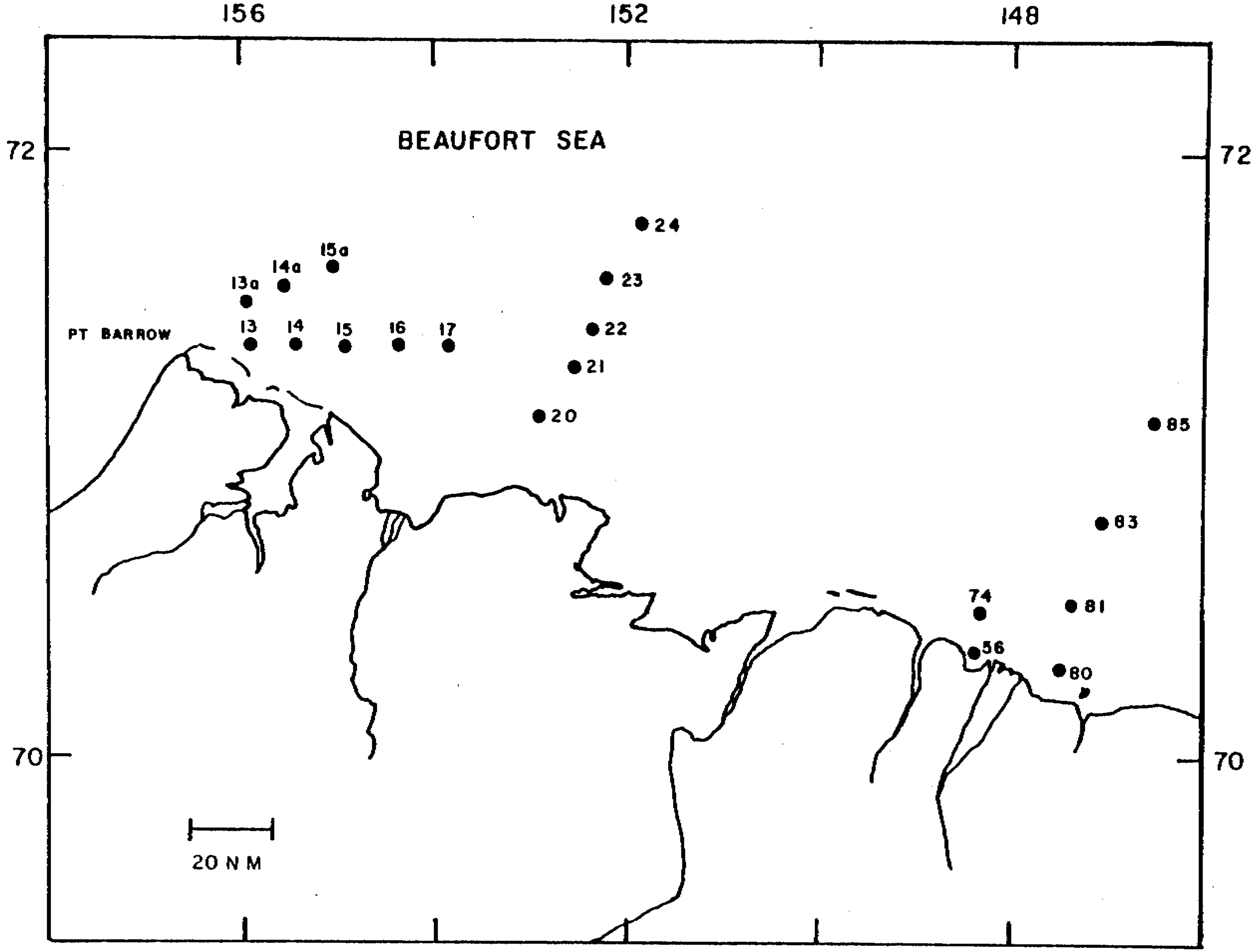

Fig.1 Map showing sampling locations.

Quarterly Report

Contract # 03-6-022-35109
Research Unit 30
Period 4/1 - 6/30

Assessment of Potential Interactions of Microorganisms and Pollutants Resulting from Petroleum Development in the Gulf of Alaska

Submitted by: Ronald M. Atlas
Principal Investigator
Department of Biology
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July 1, 1976

I. Task Objectives

A. To characterize marine microbiological communities in sufficient detail to establish a baseline description of microbiological community chracteristics on a seasonal basis.

B. To determine the role of microorganisms in the biodegradation of petroleum hydrocarbons.

II. Field and Laboratory Activities

A. Field Schedule

March 18 - March 27, 1976

NOAA vessel <u>Discoverer</u>

B. Scientific Party

Dr. James Hauxhurst

Mr. George Roubal

Mr. Craig Short

Department of Biology
University of Louisville
Louisville, Kentucky 40208

C. Methods

Water and sediment samples were collected as described in previous reports. Beach samples were also collected aseptically. Microorganisms were enumerated as described in previous reports. Laboratory activities to characterize isolated microorganisms using 400 tests were also continued.

For rates of hydrocarbon biodegradation studies, radiolabelled hexadecane spiked Prudhoe crude oil was incubated for 40 days with collected samples. The reaction was stopped by addition of acid and the $^{14}CO_2$ released was trapped in hyamine hydroxide. The ^{14}C was quantitated by liquid scintillation counting.

D. Sample Locations

Sediment and water samples were collected at the numbered sites shown in Figure 1. Beach samples were collected at lettered sites. A beach sample was also collected on Kodiak Island. Latitudes and longitudes of sample collections are shown in Table I.

Crab samples were collected by Alaska's Department of Fish and Game on March 2 and 30. The locations were 17 miles SE off Cape Chiniak and 3 miles off Long Island, 9 miles off Cape Chinak respectively.

E. Data Collected

The water and sediment samples collected, including location and abiotic parameters, are shown in Table I. Eight different enumeration techniques were performed on the microorganisms in the samples. One thousand microorganisms were isolated for characterization. Seven enumeration procedures were used for micoorganisms from Tanner crab samples.

III. Results

A. Characterization of microorganisms isolated from October sampling.

Characterization tests were completed for microorganisms isolated from the October cruise in the northwest Gulf of Alaska. A searchable file, No. 100190, now exists at the National Institute of Health. NODC has been notified of the NIH information storage and retrieval system. Analyses have not yet been performed on this data.

B. Enumeration of microorganisms from March sampling.

Enumerations of microorganisms from sediment and water samples collected during the March cruise in the northeast Gulf of Alaska are shown in Table II.

Enumerations of microorganisms from crab samples collected during March are shown in Table III.

C. Hydrocarbon biodegradation experiments.

The radioactive counts released from the radiolabelled hydrocarbon are shown in Table IV.

IV. Interpretation of Results

No new interpretation of analyses were made during this period.

V. Problems Encountered

A lack of continued funding threatens to prevent adequate further sampling and any complete analysis of collected organisms and interpretation of results, thus greatly reducing the value of the large effort that has been conducted to date to gather a data base on the microorganisms of this area.

VI. Estimate of Funds

It is estimated that 75% of all funds were expended as of 5/1/76.

Table I

Sample Locations and Abiotic Parameters

Sample#	Latitude	Longitude	Depth(m)	Temp.(C)	Salinity(°/oo)
		Water			
201	57°39'	152°30'	0	2.0	31.41
202	59 50	149 30	2	3.0	31.67
203	59 24	149 04	2	3.5	32.23
204	58 58	148 39	2	3.5	32.26
206	59 17	147 15	2	4.0	32.16
207	59 45	146 31	2	4.0	32.11
209	60 06	149 33	2	3.0	31.10
210	59 23	146 54	2	3.0	31.83
211	59 32	147 00	2	3.0	31.81
212	60 08	145 02	2	3.2	31.78
213	59 47	145 10	2	3.4	31.84
214	59 54	143 52	2	4.1	32.08
216	59 16	142 56	2	4.5	32.46
217	59 46	142 44	2	4.5	32.13
218	59 44	141 29	2	3.8	31.72
219	59 27	141 48	2	4.5	32.16
220	59 44	140 07	0	3.0	30.76
221	59 33	139 49	0	4.0	30.80
222	59 34	140 06	2	4.2	31.97
223	59 26	140 19	2	4.7	32.19
224	59 18	140 29	2	4.8	32.17
225	60 21	146 38	0	5.0	31.12
226	60 21	146 39	0	5.0	30.74
227	60 21	146 37	0	3.2	31.28
		Sediment			
202	59°50'	149°30'	190	4.3	32.41
203	59 24	149 04	183	4.6	32.75
204	58 58	148 39	217	5.0	33.80
206	59 17	147 15	252	5.3	33.77
207	59 45	146 31	70	4.3	32.25
210	59 23	146 54	302	4.9	32.55
211	59 32	147 00	308	5.1	32.72
212	60 08	145 02	45	3.7	31.91
213	59 47	145 10	158	4.6	32.27
214	59 54	143 52	76	4.4	32.10
216	59 16	142 56	2282	2.1	34.62
217	59 46	142 44	128	4.8	32.17
218	59 44	141 29	40	4.2	31.87
219	59 27	141 48	175	5.8	33.17
223	59 26	140 19	226	5.8	33.11
224	59 18	140 29	124	5.6	32.79

Table II

Enumeration of Microorganisms

Sample#	Direct Count	Heterotrophs Marine Agar 4 C	Heterotrophs Marine Agar 20 C	"Vibrio" TCBS 4 C	"Vibrio" TCBS 20 C	Pseudosel 20 C	Oil 4 C	Oil 20 C
Water								
201	$2.6x10^{5}$	$2.2x10^{4}$	$2.0x10^{4}$	$4.5x10^{1}$	$2.7x10^{1}$	$1.7x10^{0}$	-	-
202	$9.3x10^{4}$	$3.3x10^{1}$	$3.9x10^{1}$	$1.0x10^{0}$	$3.8x10^{0}$	$2.6x10^{-1}$	$5.50x10^{0}$	$0.68x10^{0}$
203	$3.3x10^{5}$	$2.1x10^{1}$	$2.0x10^{1}$	$3.0x10^{-2}$	$<1.0x10^{-2}$	$5.0x10^{-3}$	$0.50x10^{0}$	$0.68x10^{0}$
204	$3.0x10^{5}$	$3.1x10^{1}$	$2.2x10^{2}$	$2.2x10^{-1}$	$1.0x10^{-1}$	$5.8x10^{-2}$	$0.20x10^{0}$	$0.40x10^{0}$
206	$9.3x10^{4}$	$1.4x10^{1}$	$1.7x10^{1}$	$4.0x10^{-2}$	$4.0x10^{-2}$	$<5.0x10^{-3}$	$0.20x10^{0}$	$0.61x10^{0}$
207	$1.0x10^{5}$	$9.7x10^{0}$	$2.7x10^{1}$	$5.3x10^{-1}$	$3.7x10^{-1}$	$2.5x10^{-2}$	$0.20x10^{0}$	$0.12x10^{0}$
209	$2.7x10^{5}$	$1.0x10^{3}$	$9.9x10^{2}$	$8.2x10^{0}$	$2.0x10^{-1}$	$1.9x10^{0}$	-	$1.00x10^{0}$
210	$4.6x10^{4}$	$5.9x10^{1}$	$2.6x10^{1}$	$7.4x10^{-1}$	$5.8x10^{-1}$	$1.1x10^{0}$	-	$0.45x10^{0}$
211	$9.3x10^{4}$	$3.6x10^{1}$	$3.2x10^{1}$	$6.1x10^{-1}$	$3.1x10^{-1}$	$5.5x10^{-2}$	-	$0.30x10^{0}$
212	$2.4x10^{5}$	$7.2x10^{1}$	$1.0x10^{2}$	$6.2x10^{-1}$	$1.2x10^{0}$	$1.1x10^{-1}$	$3.90x10^{0}$	$0.30x10^{0}$
213	-	$3.1x10^{1}$	$6.7x10^{0}$	$1.3x10^{-1}$	$7.6x10^{-1}$	$2.6x10^{-1}$	$1.00x10^{0}$	$0.19x10^{0}$
214	$5.4x10^{4}$	$1.0x10^{2}$	$3.2x10^{1}$	$1.4x10^{0}$	$2.6x10^{0}$	$1.6x10^{-1}$	$0.40x10^{0}$	$0.04x10^{0}$
216	$6.2x10^{4}$	$3.2x10^{1}$	$3.6x10^{1}$	$1.5x10^{0}$	$1.1x10^{0}$	-	-	$0.05x10^{0}$
217	$1.6x10^{5}$	$2.3x10^{1}$	$3.1x10^{1}$	$3.9x10^{1}$	$4.3x10^{0}$	-	$0.20x10^{0}$	$0.01x10^{0}$
218	$1.5x10^{5}$	$3.3x10^{1}$	$3.2x10^{1}$	$4.1x10^{-1}$	$6.2x10^{-1}$	-	$0.20x10^{0}$	$0.01x10^{0}$
219	$1.2x10^{5}$	$1.2x10^{1}$	$5.8x10^{1}$	$4.8x10^{-1}$	$9.0x10^{-1}$	-	-	$0.01x10^{0}$
220	$4.6x10^{4}$	$3.8x10^{2}$	$3.8x10^{2}$	$1.7x10^{0}$	$5.4x10^{0}$	-	-	$0.08x10^{0}$
221	$1.2x10^{5}$	$3.0x10^{1}$	$4.6x10^{1}$	$9.5x10^{-1}$	$8.1x10^{-1}$	-	-	-
222	$1.0x10^{5}$	$1.5x10^{1}$	$1.8x10^{1}$	$7.2x10^{-1}$	$9.3x10^{0}$	-	$1.40x10^{0}$	$1.38x10^{0}$
223	$7.0x10^{4}$	$6.0x10^{0}$	$1.7x10^{1}$	$6.0x10^{-2}$	$9.1x10^{-1}$	-	-	$1.22x10^{0}$
224	$3.1x10^{4}$	$3.0x10^{1}$	$2.6x10^{1}$	$8.1x10^{-1}$	$1.7x10^{0}$	-	-	$0.79x10^{0}$
225	$1.0x10^{5}$	$7.7x10^{2}$	$2.9x10^{3}$	$7.1x10^{0}$	$1.3x10^{0}$	-	-	$0.12x10^{0}$
226	$2.2x10^{5}$	-	-	-	-	-	-	$4.23x10^{0}$
227	$7.8x10^{4}$	-	-	-	-	-	-	$0.90x10^{0}$
Sediment								
201	$1.1x10^{6}$	$1.8x10^{5}$	$2.4x10^{5}$	$9.0x10^{2}$	$5.5x10^{2}$	$8.0x10^{1}$	-	-
202	$3.3x10^{9}$	$5.2x10^{5}$	$2.1x10^{5}$	$3.6x10^{4}$	-	$5.4x10^{1}$	$5.60x10^{0}$	$0.10x10^{0}$

	Direct Count	Marine Agar	Marine Agar	TCBS	TCBS	Pseudosel	Oil	Oil
		4 C	20 C	4 C	20 C	20 C	4 C	20 C
Sediment (cont'd.)								
203	$6.2x10^{9}$	$1.1x10^{5}$	$3.5x10^{4}$	$2.4x10^{3}$	$6.0x10^{2}$	$1.3x10^{1}$	$1.00x10^{0}$	$0.20x10^{0}$
204	$2.5x10^{9}$	$6.7x10^{4}$	$8.5x10^{4}$	$2.1x10^{3}$	$3.6x10^{2}$	$1.2x10^{1}$	$0.70x10^{0}$	$0.10x10^{0}$
206	$2.7x10^{9}$	$2.4x10^{4}$	$1.4x10^{4}$	$2.1x10^{3}$	$1.4x10^{2}$	$4.2x10^{1}$	-	$0.50x10^{0}$
207	$3.3x10^{9}$	$4.2x10^{5}$	$3.1x10^{5}$	$6.9x10^{3}$	$9.4x10^{1}$	$4.5x10^{1}$	$0.60x10^{0}$	-
210	$2.8x10^{9}$	$3.0x10^{6}$	$6.1x10^{6}$	$5.2x10^{3}$	$8.2x10^{1}$	-	$1.26x10^{1}$	$0.10x10^{0}$
211	$5.2x10^{9}$	$1.5x10^{5}$	$2.4x10^{5}$	$6.1x10^{3}$	$1.4x10^{2}$	$9.7x10^{1}$	-	$0.10x10^{0}$
212	$3.3x10^{9}$	$1.7x10^{5}$	$4.7x10^{5}$	$4.7x10^{3}$	$2.9x10^{1}$	$2.9x10^{1}$	$6.00x10^{0}$	$0.10x10^{0}$
213	-	$1.7x10^{5}$	$6.7x10^{5}$	$1.3x10^{4}$	$2.3x10^{1}$	$7.2x10^{1}$	$1.20x10^{0}$	$0.10x10^{0}$
214	$1.9x10^{9}$	$1.1x10^{6}$	$7.7x10^{5}$	$1.7x10^{4}$	$5.3x10^{1}$	$1.6x10^{1}$	$3.80x10^{0}$	$0.90x10^{0}$
216	$8.2x10^{8}$	$3.7x10^{3}$	$3.3x10^{3}$	$1.6x10^{2}$	$2.0x10^{3}$	$2.3x10^{1}$	-	$2.30x10^{0}$
217	$1.6x10^{9}$	$1.5x10^{5}$	$5.2x10^{4}$	$4.0x10^{1}$	$1.5x10^{2}$	-	$1.90x10^{0}$	$0.70x10^{0}$
218	$4.0x10^{8}$	$5.8x10^{3}$	$1.2x10^{5}$	$8.5x10^{1}$	$2.9x10^{1}$	-	$1.50x10^{0}$	$0.30x10^{0}$
219	$5.6x10^{9}$	$1.1x10^{5}$	$6.0x10^{4}$	$3.2x10^{2}$	$1.5x10^{1}$	-	-	-
220	$6.1x10^{7}$	$1.5x10^{3}$	$4.4x10^{3}$	$9.9x10^{1}$	$8.3x10^{1}$	-	-	$0.01x10^{0}$
223	$1.8x10^{9}$	$1.2x10^{5}$	$1.1x10^{5}$	$7.5x10^{3}$	$7.2x10^{1}$	-	-	$0.20x10^{0}$
224	$1.8x10^{9}$	$4.4x10^{5}$	$2.5x10^{5}$	$8.0x10^{3}$	$1.1x10^{2}$	-	-	-
225	$4.1x10^{9}$	$4.0x10^{6}$	$1.7x10^{7}$	$3.0x10^{4}$	$1.6x10^{3}$	-	-	-
226	$3.4x10^{9}$	$9.0x10^{6}$	$3.2x10^{7}$	$4.8x10^{5}$	$1.4x10^{3}$	-	-	$0.40x10^{0}$

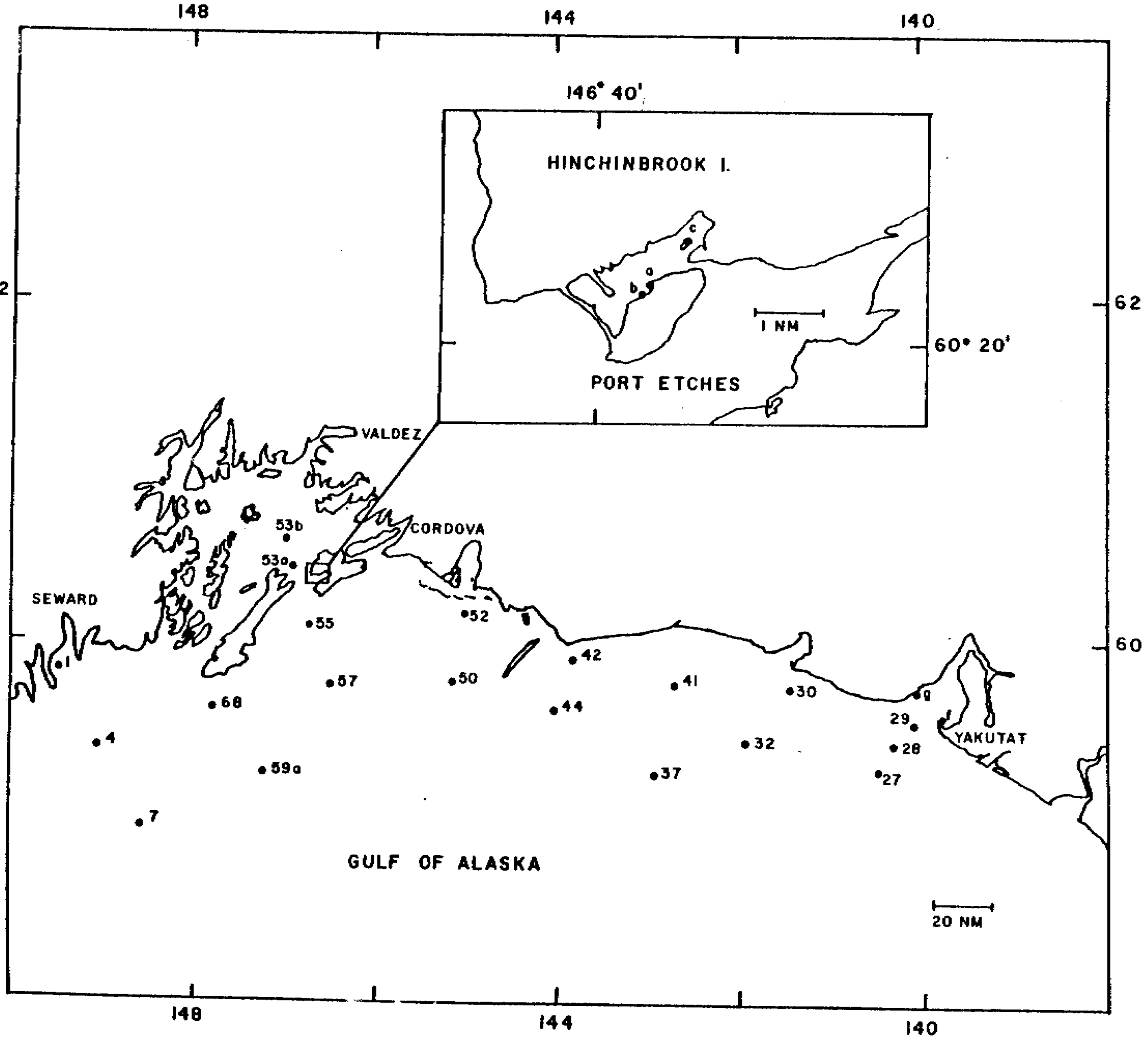

Fig. 1 Map showing sampling locations.

Table III

Bacterial Counts from Tanner Crabs/gm wet weight

		TSA 20 C	TSA 37 C	TSA + Marine Salts 25 C	TSA + Marine Salts 37 C	TCBS 25 C	Anaerobes
Sample 1	Gill	$2.6x10^5$	$6.0x10^3$	$3.0x10^5$	$2.0x10^4$	0	50
March 4	Leg Muscle	80	20	80	20	0	25
	Inside Muscle	$6.0x10^2$	$5.0x10^2$	$7.0x10^2$	$8.0x10^2$	0	25
Sample 2	Gill	$1.0x10^5$	$1.8x10^4$	$1.6x10^5$	$1.6x10^4$	0	250
March 4	Leg Muscle	$2.8x10^3$	$3.8x10^4$	$2.9x10^3$	$4.0x10^3$	0	0
	Gut	$1.0x10^2$	$1.0x10^3$	$1.0x10^2$	$5.0x10^2$	0	0
Sample 3	Gill	$1.0x10^6$	$1.0x10^6$	$1.0x10^6$	$1.6x10^6$	$7.0x10^3$	$3.0x10^5$
March 30	Leg Muscle	$2.4x10^2$	$1.5x10^2$	$4.0x10^4$	$1.3x10^2$	0	20
	Gut	$8.0x10^3$	$6.5x10^3$	$2.8x10^3$	$2.6x10^3$	50	$2.2x10^3$

Table IV

^{14}C Counts Released from Radiolabelled Oil - Estimate of Rates of Hydrocarbon Biodegradation

Sample #	CPM Control	CPM Experimental
Water		
201	277	10,770
202	327	7,298
203	258	5,397
204	306	8,006
206	316	8,734
207	307	4,026
209	287	-
210	328	5,235
211	314	5,594
212	271	5,971
213	319	4,262
214	284	6,698
216	290	2,852
217	292	5,472
218	324	6,005
219	331	5,317
220	305	3,078
221	292	3,398
222	281	4,777
223	300	4,619
224	324	1,136
225	290	3,252
226	324	3,179
227	306	5,578
Sediment		
201	325	12,295
202	299	4,173
203	277	7,010
204	300	3,851
206	285	3,342
207	304	1,905
210	330	4,021
212	291	4,808
213	333	5,258
214	321	5,003
216	301	3,377
217	321	6,641
218	353	8,004
219	347	1,990
220	299	2,510
223	303	7,159
224	314	7,297
225	285	5,680
226	304	3,121

RU# 43,44,45

NO REPORT SUBMITTED

The principal investigator is in the field.

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Fifth Quarter Report

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DISTRIBUTION OF LIGHT HYDROCARBONS, C_1-C_4, IN THE NORTHEAST GULF OF ALASKA AND THE SOUTHEASTERN BERING SHELF

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July 1, 1976

I. OBJECTIVES

The low molecular weight hydrocarbon program was initiated in the OCS of Alaska in response to the environmental guidelines set forth in the Environmental Study Plan for the Gulf of Alaska, Southeastern Bering Sea, and the Beaufort Seas (January 1975). Briefly, the purpose was to establish the spatial and temporal variations (seasonal and diurnal) in the dissolved hydrocarbon fraction composed of methane, ethane, ethylene, propane, propylene, isobutane and n-butane. These data are being collected in order to establish baseline levels of naturally-occurring hydrocarbons in the lease areas prior to exploration, development, and production of fossil fuel reserves. These components have proven to be valuable indicators of petroleum input arising from drilling, production, and transportation of crude oil and refined products.

In support of the basic objectives, attention is being given to natural hydrocarbon sources, namely gas and oil seeps, production of hydrocarbons from near-surface sediments, and biogenic sources within the euphotic zone.

II. FIELD AND LABORATORY ACTIVITIES

A. Field Schedule

During the reporting period, we participated on a single cruise to Lower Cook Inlet and the Northeast Gulf of Alaska aboard the NOAA research vessel Discoverer. The cruise to Lower Cook Inlet was hastily organized and piggybacked on a cruise being fielded by the biological oceanographers of PMEL. It does not represent a complete survey of the hydrocarbon distributions in Lower Cook Inlet.

Region	Cruise Identification	Dates
LCI	RP-4-0I-76A-III	5 Apr.-12 Apr. 76
NEGOA	RP-4-0I-76A-IV	13 Apr.-30 Apr. 76

B. Scientific Party

The participants on the cruise were:

LCI - Mr. Anthony Young
NEGOA - Mr. Anthony Young
- Lt. Larry Keister
- Mr. Lee Ohler

C. Field Sampling and Shipboard Analysis

Water is drawn from either 5- or 10-liter Niskin® bottles and stored in 1-liter glass-stoppered bottles. To retard bacterial growth, approximately 100 mg of sodium azide is added.

Dissolved gases are stripped from the solution using the procedure recommended by Swinnerton and Linnenbom (1967). A diagram of the gas phase equilibrator is shown in figure 1.

Hydrocarbons are removed in a stream of ultra-pure He (120 ml/min) and condensed on an activated alumina trap maintained at -196°C. Approximately 12 min of stripping are required to quantitatively remove the hydrocarbons (> 98%) from solution, after which time the trap is warmed to 90-100°C and the absorbed gases are allowed to pass into the gas chromatograph (GC).

The hydrocarbons are chromatographed on a column (3/16" x 8') of Poropak® Q, 60-80 mesh, supplemented with an activated alumina column (3/16" x 2") impregnated with 1% silver nitrate by weight. Components are detected as they emerge from the column with an FID. The GC is a Hewlett Packard Model® 5711, equipped with dual FID's. Chromatographic analysis of saturates and unsaturates requires approximately 6 min when columns are temperature programmed from 110°-150° C.

D. Cruise Tracks

The sampling grids in Lower Cook Inlet and the Northeast Gulf of Alaska are shown in figures 2 and 3.

E. Data Collected and Analyzed

Survey Region	No. Stations/Samples	No. Analysis*	Trackline (km)
LCI	9/38	38	1,560
NEGOA	47/355	355	3,100

* Each analysis includes the identification and determination of the concentration of the components: methane, ethane, ethylene, propane, propylene, iso- and n-butanes.

III. RESULTS AND DISCUSSION

A. NEGOA

The spatial distribution of low molecular weight hydrocarbons (LMWH) were determined during the month of April as a continuation of our seasonal sampling program on the OCS. The preliminary results of these observations are recorded in figures 5-13 in terms of areal distributions.

Methane: Figures 5-7 reveal the concentration of methane in nl/liter (STP) for the surface layers, the 58-m surface, and the surface 5 m from the bottom. The salient feature in the surface layer is a large clockwise gyre west of Kodiak Island advecting methane-rich water from the vicinity of Kayak Island toward the west. The source of this methane is probably organic-rich sediments in the Kayak Trough (fig. 4) where relatively high concentrations of methane are observed near the bottom (fig. 7). Nearshore waters are highly supersaturated with methane (saturation concentrations ≈ 80 nl/liter), indicating a strong in situ source of methane. This source is presumably the bottom sediments, but surface biological activity cannot be ruled out at this time. Note that surface offshore values are approaching equilibrium saturation values.

The concentration of methane on the 58-m surface in the region of Tarr Bank is shown in figure 6. This surface is just above the top of Tarr Bank and also reveals the clockwise gyre not unlike that observed in the surface layers. The source of this methane appears to be the Kayak Island slope and Kayak Trough.

Concentrations of methane near the bottom reflects both microbial activity in organic-rich sediments and topographic control. Hinchinbrook Sea Valley and the Kayak Trough appear to be strong sources of biogenic methane. In contrast, Tarr Bank, a topographic high composed of relict Holocene sediments, is apparently not a source of methane.

The near-bottom distribution of methane is in sharp contrast to the observations conducted in October-November 1975, when a large plume of methane was observed to propagate from west to east across Tarr Bank (see fig. 8). If the source of this methane was Hinchinbrook Sea Valley, then the sharp departure from conditions observed last fall must be attributable to a systematic change in the near-bottom mean circulation. We have not had the opportunity to corroborate these suspicions with physical oceanographic observations.

Ethane and Ethylene: The concentration of ethane in the surface layers and near the bottom is shown in figures 9 and 10. In general, concentrations of ethane in the surface layers are higher near shore, although the nature of the source is not known at this time. There is little variation in ethane over the entire region, concentrations ranging from a low near 0.2 nl/liter to a high of 0.4 nl/liter.

The distribution of ethane near the bottom is regionally uniform, showing little or no horizontal structure in contrast to the distribution of methane.

Surface ethylene concentrations are revealed in figure 11. Salient features include a moderately strong plume south of Kayak Island in the direction of mean flow. The core of ethylene production seems to be centered between Kayak Island and Icy Bay, the highest value observed being 1.5 nl/liter. Although no productivity measurements were available during this cruise, the general concensus is that ethylene production and productivity are correlative (Lamontagne et al., 1973).

Near-bottom concentrations of ethylene on the shelf are uniform, not unlike the distribution observed for ethane (fig. 12). Elevated values near 0.6 nl/liter were observed around the perimeter of Tarr Bank with significantly lower values found over the bank (0.5 nl/l). Like ethane, these concentrations probably reflect a low-level flux from the underlying sediments resulting from the low temperature degradation of organic matter (Brooks and Sackett, 1973).

Propane, Propylene, iso- and n-Butanes: Analytical difficulties were encountered with the electronic integration of propane and propylene peaks. This data will be processed manually and is not ready for presentation at this time.

The concentrations of iso-butane and n-butane were uniformly low over the entire survey region. Concentrations did not exceed the detection limit of 0.04 nl/liter in but a few samples, and these may have been the result of discrete contamination from the ship.

Time Series - Station 15

A 55-hr time study was conducted at station 15, located at the shelf break south of Icy Bay (see fig. 3). The results of the methane distribution in the surface layers and at depth are shown in figure 13. With exception of the observation taken at 2200 hrs 24 April 1976 (GMT), the observed variability in the surface layers is not more than ± 5% of a mean value of 100 nl/liter. This is only a few percent greater than the analytical precision of the method. Toward the end of the observational period, there is a systematic increase in the mean concentration of methane to approximately 120 nl/liter.

The concentration of methane in the near-bottom waters is highly variable. Fluctuations of more than 100 nl/liter in 12 hrs are not uncommon. As noted in the surface layers, there is a systematic increase in the mean concentration of methane from approximately 140 nl/liter early in the period to over 230 nl/liter near the end of the time series. The increase in the surface layers is probably the result of vertical exchange with methane-rich water from below.

B. Lower Cook Inlet

The spatial distributions of LMWH were determined in lower Cook Inlet during the month of April. Because this effort was piggybacked along with a phytoplankton and primary productivity study by PMEL, only cursory coverage was possible. Preliminary results are depicted in figures 14-23.

Methane: The surface and near-bottom concentrations of methane are shown in figures 14 and 15. High surface concentrations are observed near the Forelands, and in Kamishak and Kachemak Bays. Unusually high concentrations of methane near the Forelands are believed to be the result of seep activity or drilling operations in Upper Cook Inlet.

High surface concentrations in Kamishak and Kachemak Bays do not appear to be supported by a sediment source as the concentrations near the bottom are lower. This would necessarily imply a near-surface source, but these are too few data to be precise about the cause at this time.

The concentration of methane in equilibrium with the atmosphere for this region is approximately 80-90 nl/liter, hence it would appear that the surface layers near the Forelands are nearly twentyfold supersaturated! For FY-77, we are proposing to study this area more intensely to determine the source of the methane.

Ethane and Ethylene: The surface and near-bottom concentrations of ethane and ethylene are shown in figures 16-19. Concentrations of ethane, both surface and bottom, in the lower part of the inlet are rather similar to those observed in the open Gulf of Alaska. Surface and near-bottom ethane values average 0.4 nl/liter in the lower part of the inlet, increasing dramatically to 1.2 nl/liter near the Forelands. Near-bottom values are also significantly higher at 0.85 nl/liter. It is our view, based on these very preliminary results, that the elevated concentrations of methane and ethane in the northern portion of the Inlet are the result of seep or drilling activity.

Surface ethylene concentrations in the lower inlet range from zero in the north to 1.5 nl/liter in Kachemak Bay. Presumably the higher concentrations are in response to biological activity in the surface layers. The zero concentration levels of ethylene near the Forelands again is also indicative of a petroleum source for methane and ethane.

Propane and Propylene: Surface and near-bottom concentrations of propane are shown in figures 20 and 21. Unusually high surface concentrations of propane were observed in Kachemak Bay (0.5-1 nl/liter), but not in the near-bottom waters. The average concentration of propane in the near-bottom waters is 0.2 nl/liter. The source of propane is unknown, but may be related to shipping and transportation activities at Homer.

Surface and near-bottom concentrations of propylene are shown in figures 22 and 23. As before, the highest concentrations are observed in Kachemak Bay with zero concentrations near the Forelands. Concentrations of propylene throughout Lower Cook Inlet are not unusually high, being quite similar to those observed in the open Gulf.

V. PROBLEMS ENCOUNTERED

Analytical difficulties were encountered during the Cook Inlet cruise due to contamination of GC column packings and water absorbents with propane from a leaking cylinder. Several days of valuable ship time were expended in the cleanup procedure, resulting in a significant number of incomplete analyses.

We also incurred difficulties with peak area integrations for propane and propylene. These data, not shown in this report, will be processed from the analog traces and will be included in the next report.

VI. ESTIMATE OF FUNDS EXPENDED THROUGH 30 JUNE 1976

	Allocated	Expended to Date	Balance
Salaries and overhead	83.5 k*	55.6 k	27.9 k
Major equipment	27.3 k*	26.0 k	1.3 k
Expendable supplies	13.7 k*	11.7 k	2.0 k
Travel and per diem	7.5 k*	2.7 k	4.8 k
Shipping	3.5 k*	2.5 k	1.0 k
Publications	2.0 k*	1.0 k	1.0 k
TOTALS	137.5 k*	99.5 k	38.0 k

* New funds allocated amounting to 15.5 k and old funds reallocated to pay future salaries.

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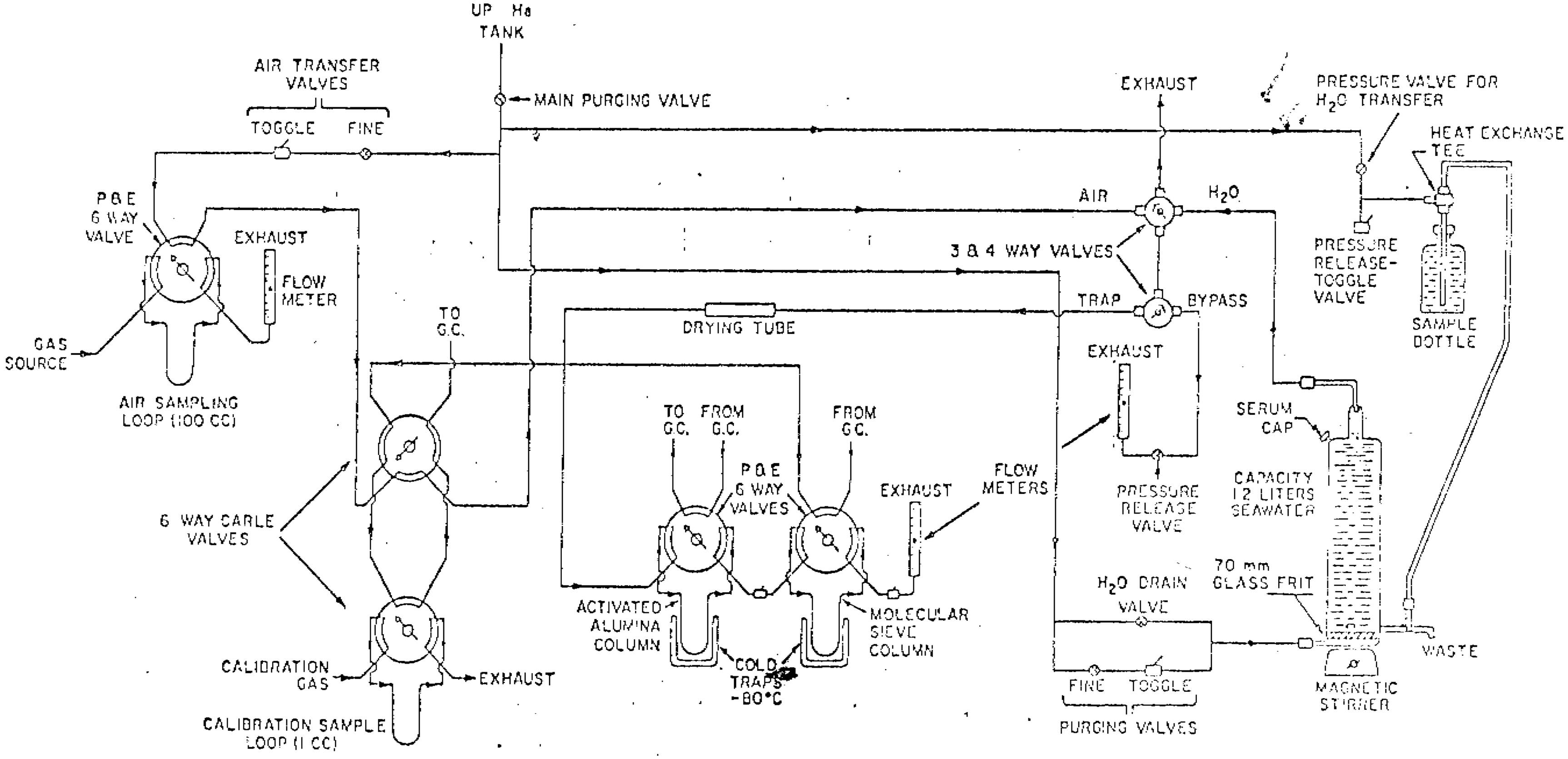

Figure 1. Low molecular weight hydrocarbon extraction system (Swinnerton and Linnenbom, 1967; Swinnerton *et al*., 1968). The extraction system shown is a recent modification given to us by Mr. R. Lamontagne of the Naval Research Laboratories, Washington, D. C.

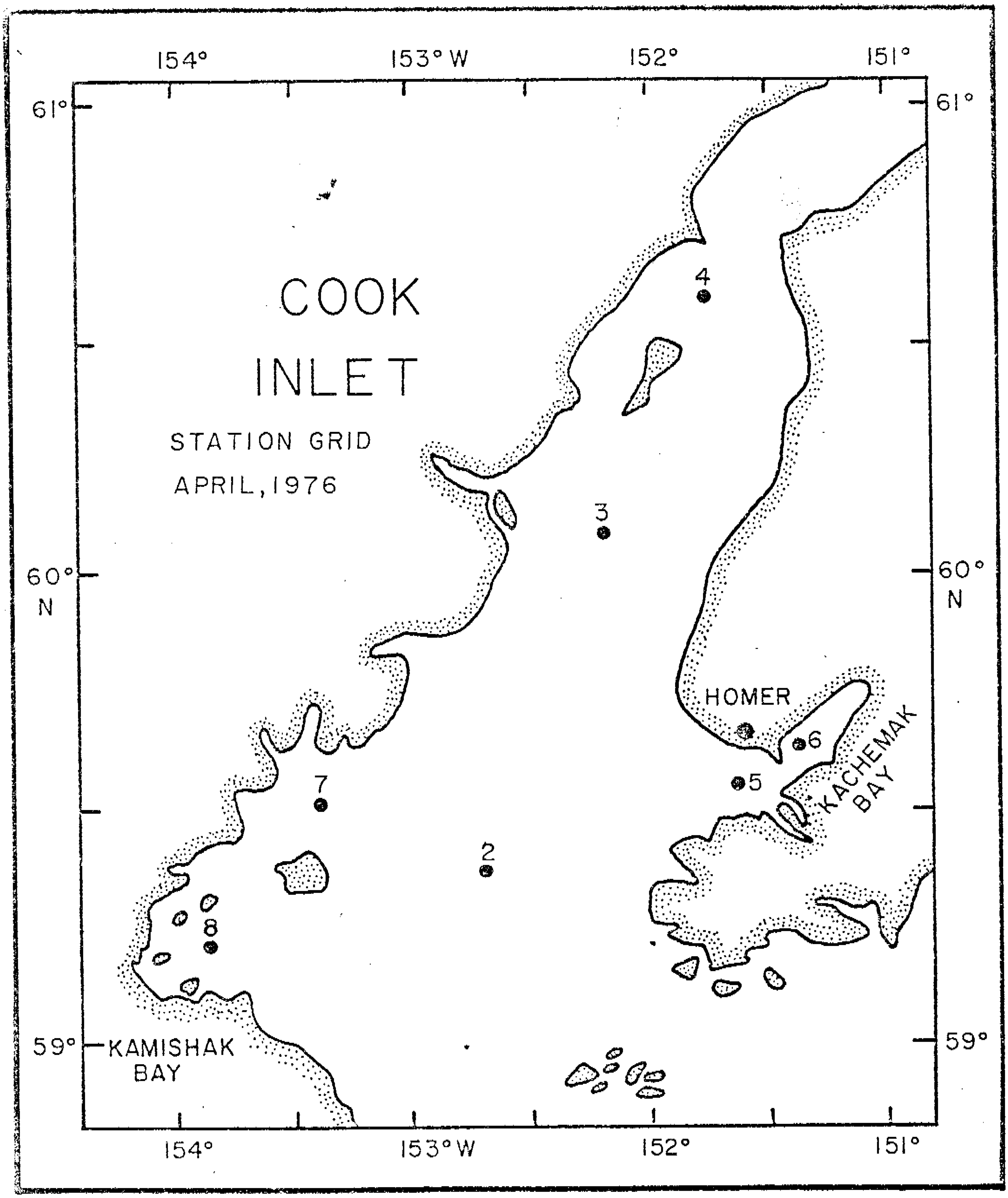

Figure 2. Sample locations in Lower Cook Inlet.

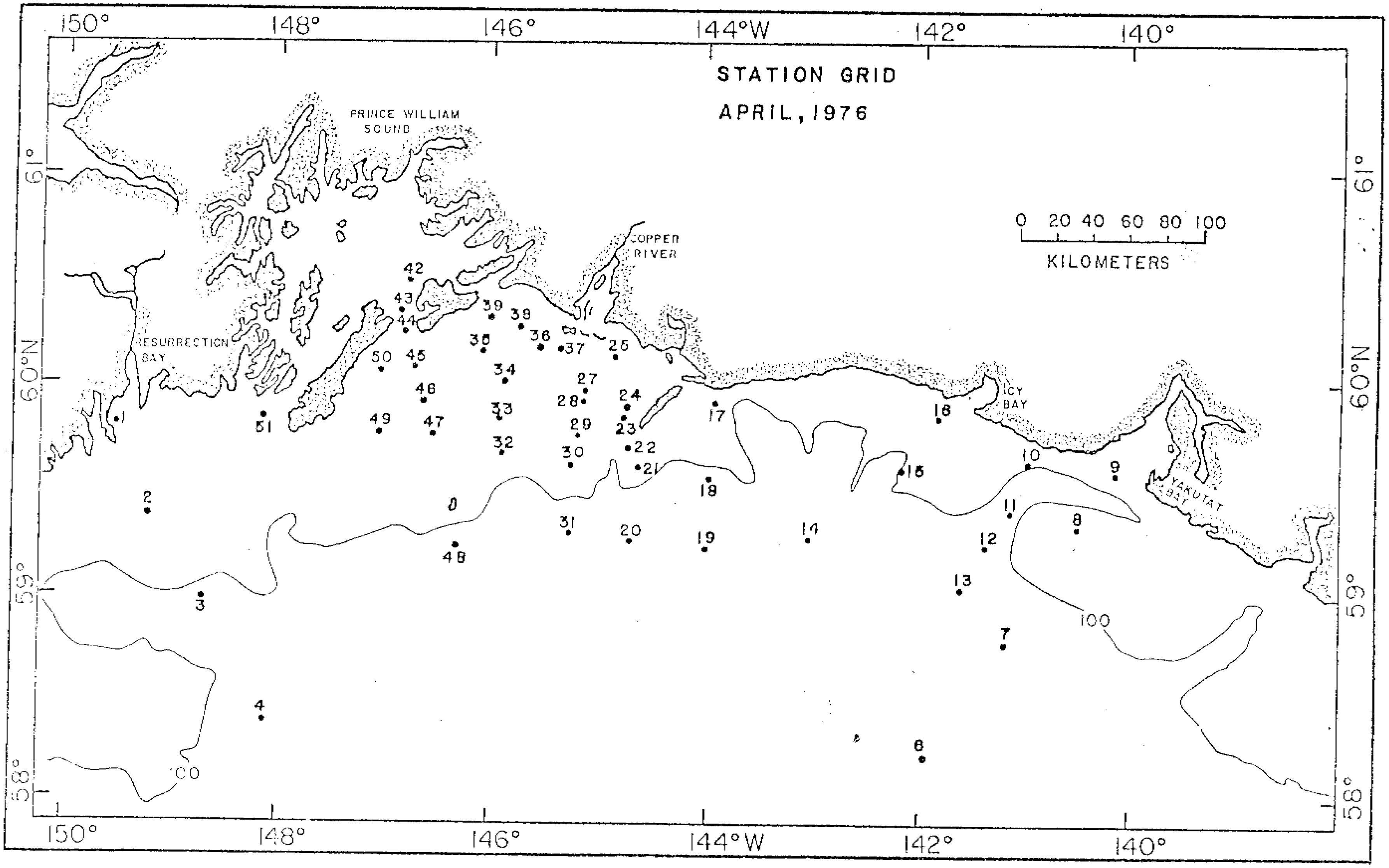

Figure 3. Sample locations in the Northeast Gulf of Alaska (NEGOA).

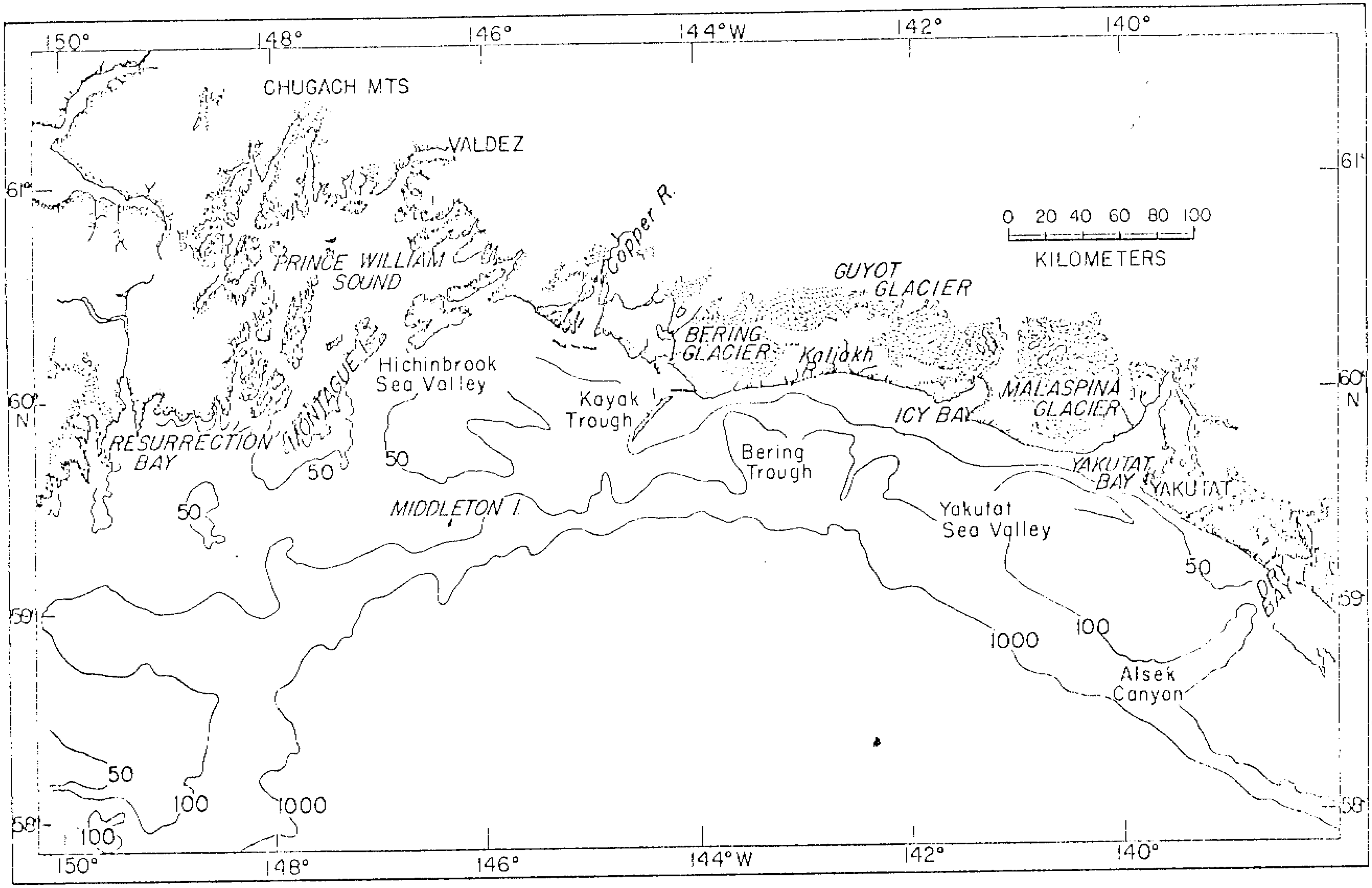

Figure 4. Bottom topography, NEGOA shelf.

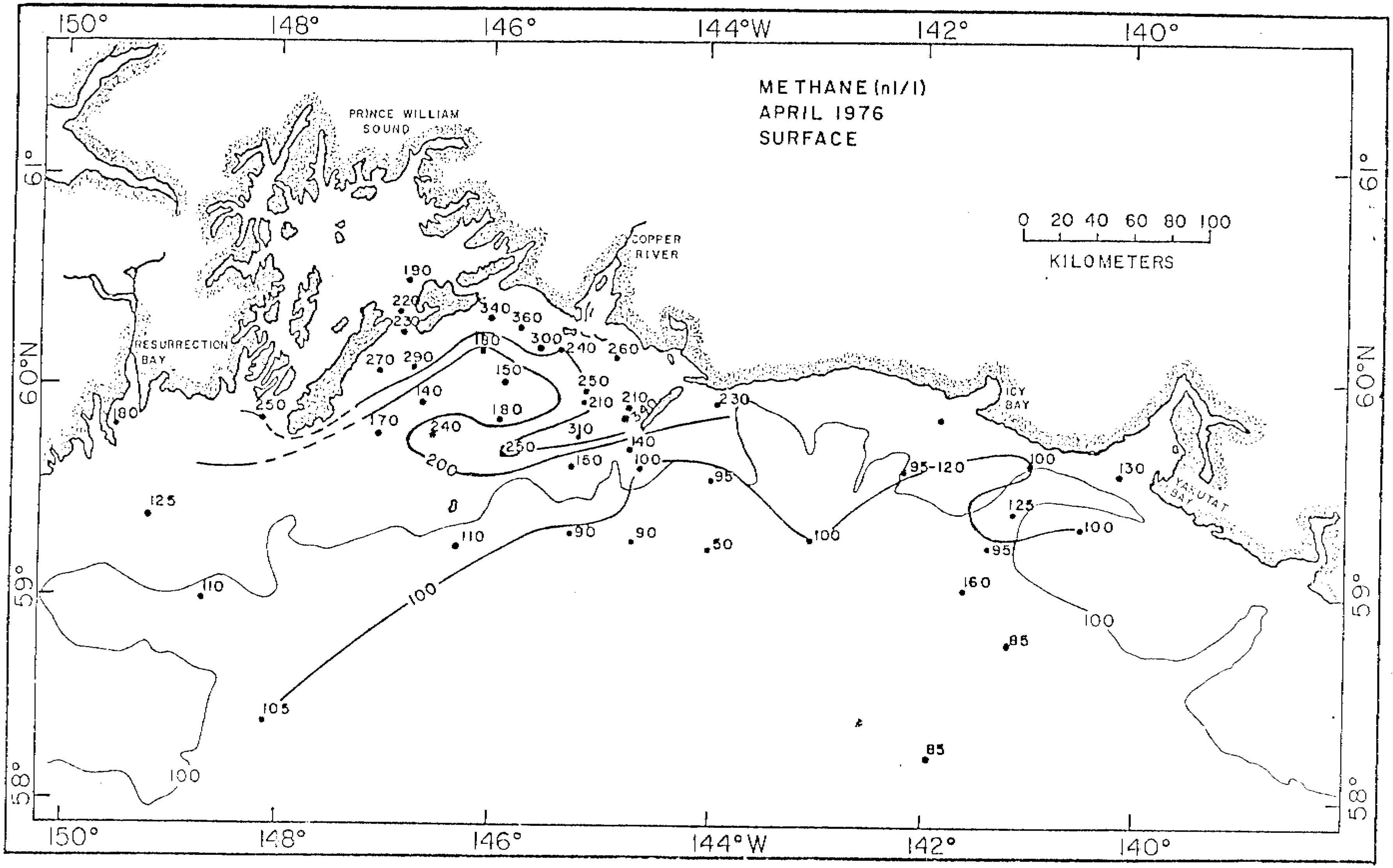

Figure 5. Surface concentration of methane (nl/liter) in NEGOA during April 1976. Concentrations rounded to nearest 5 nl/liter.

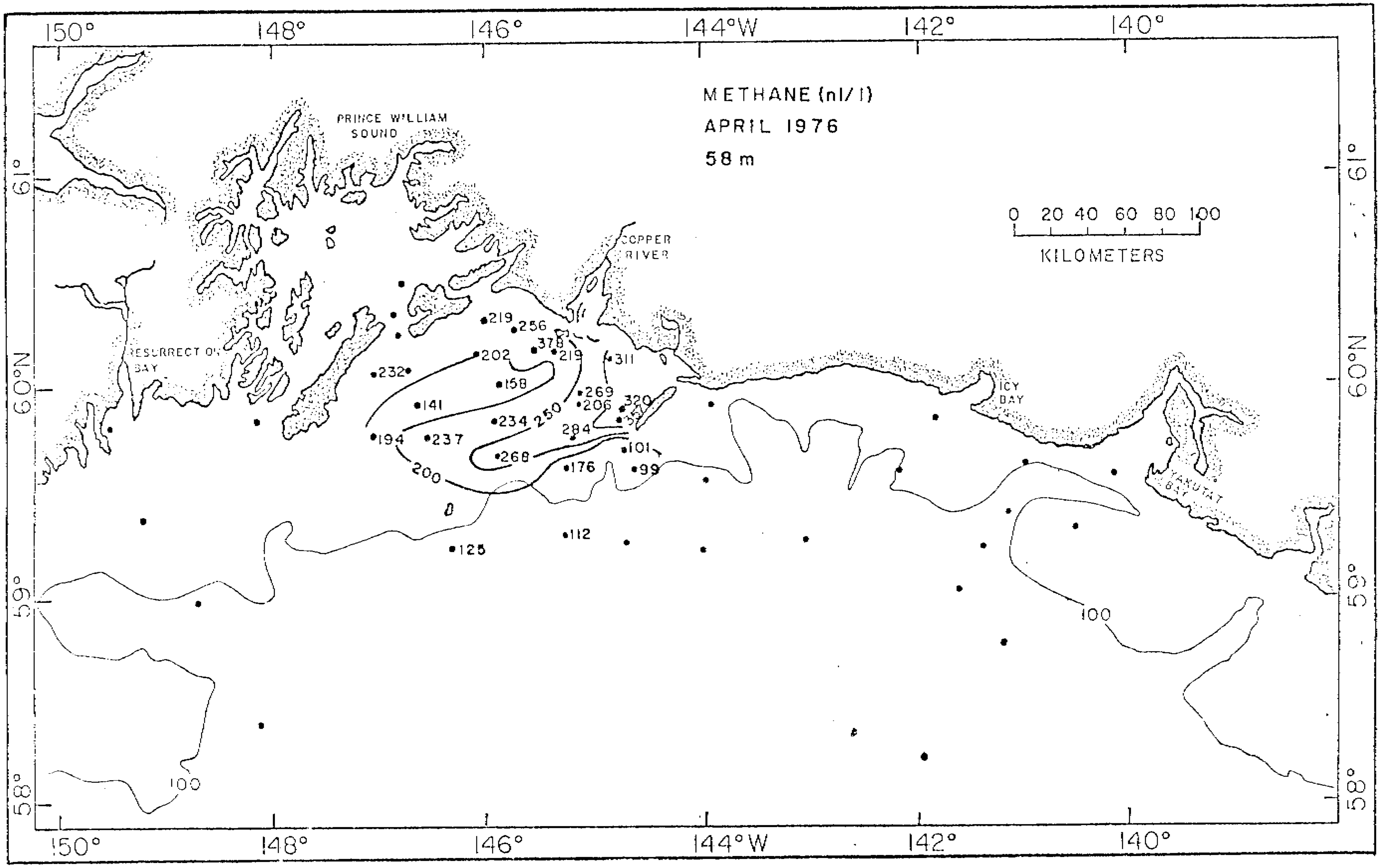

Figure 6. Concentration of methane (nl/liter) on the 58-m surface in NEGOA during April 1976.

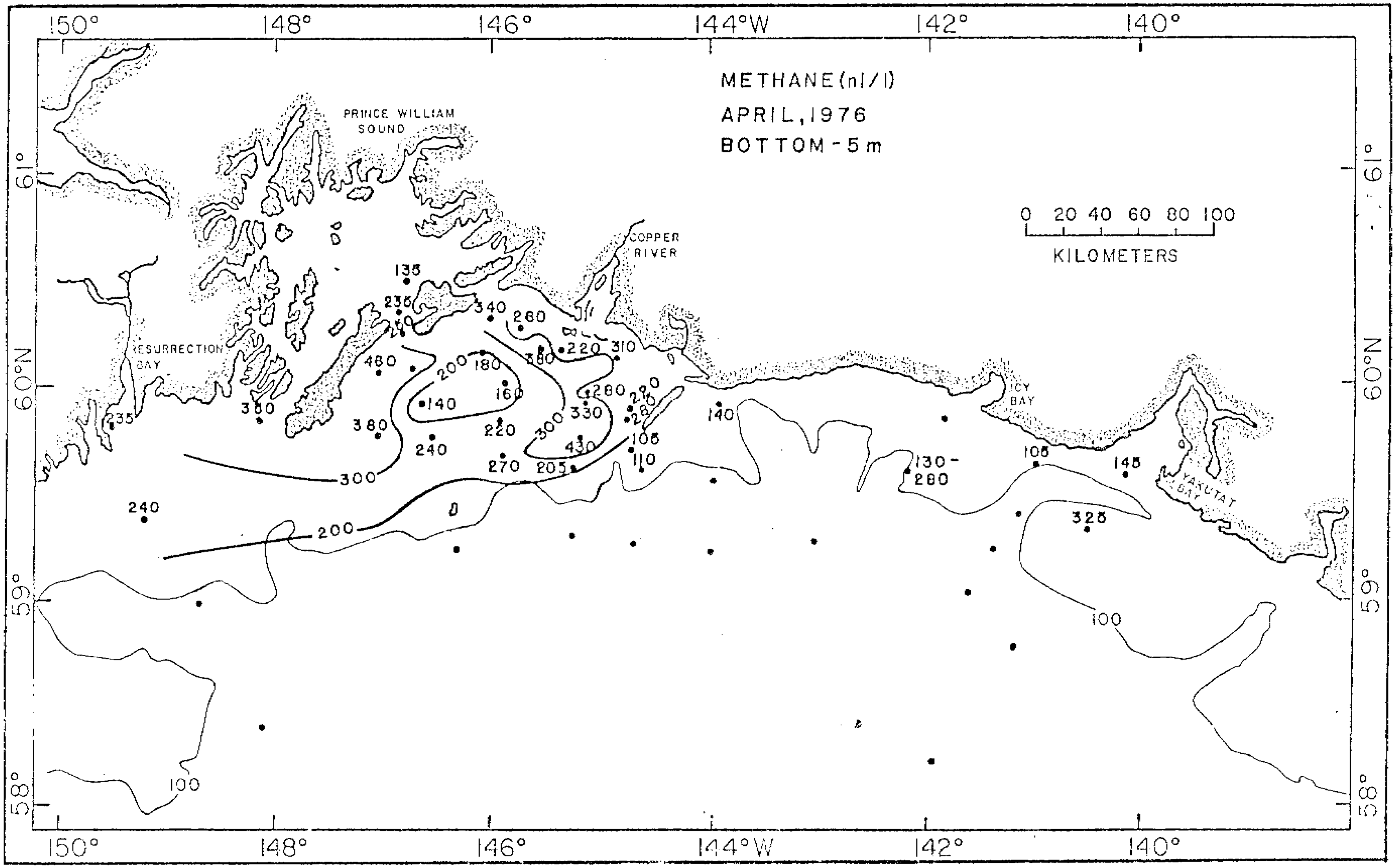

Figure 7. Concentration of methane (nl/liter) within 5 m of the bottom on the NEGOA shelf during April 1976.

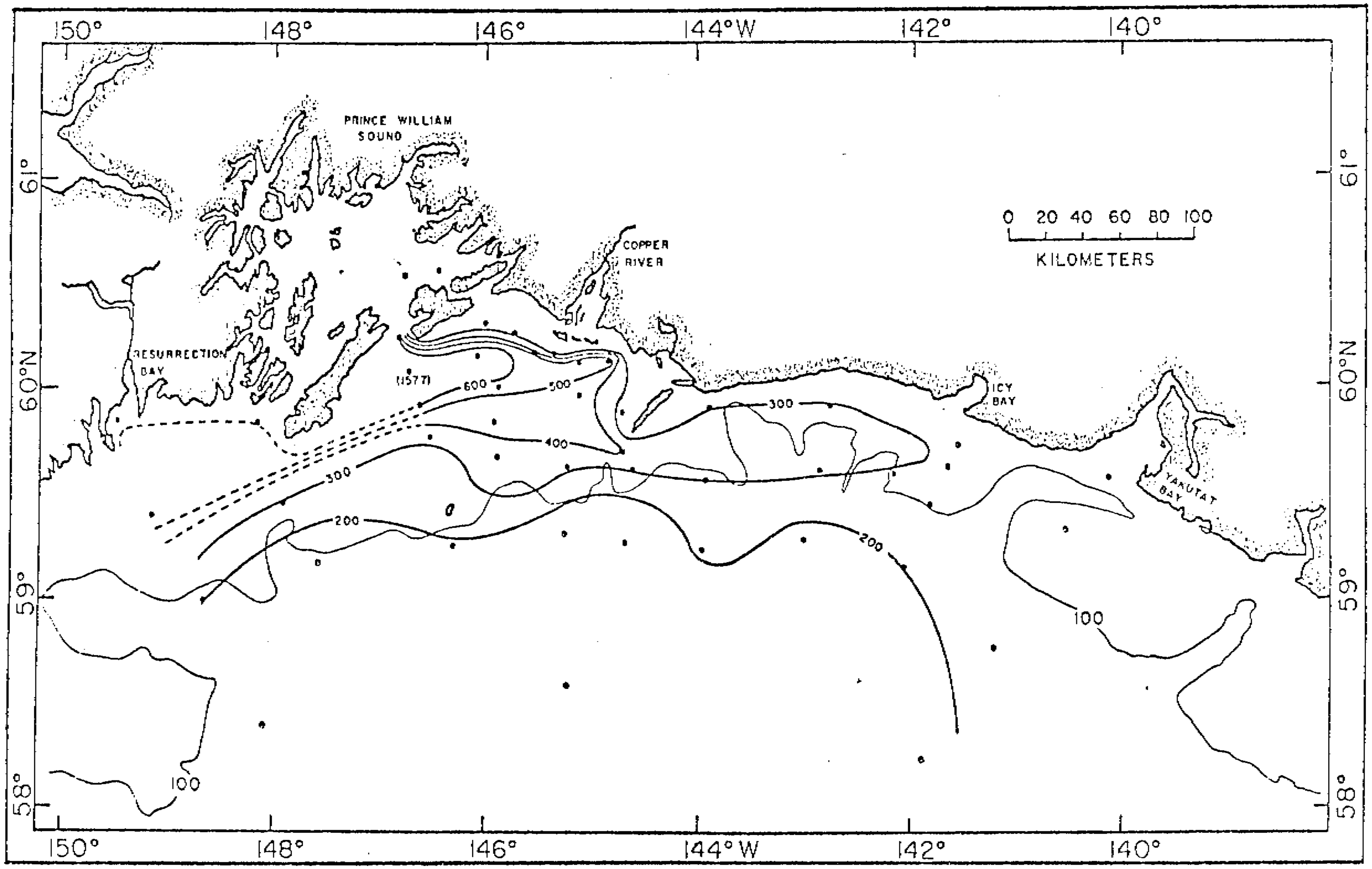

Figure 8. Concentration of methane (nl/liter) within 5 m of the bottom on the NEGOA shelf during October-November 1975.

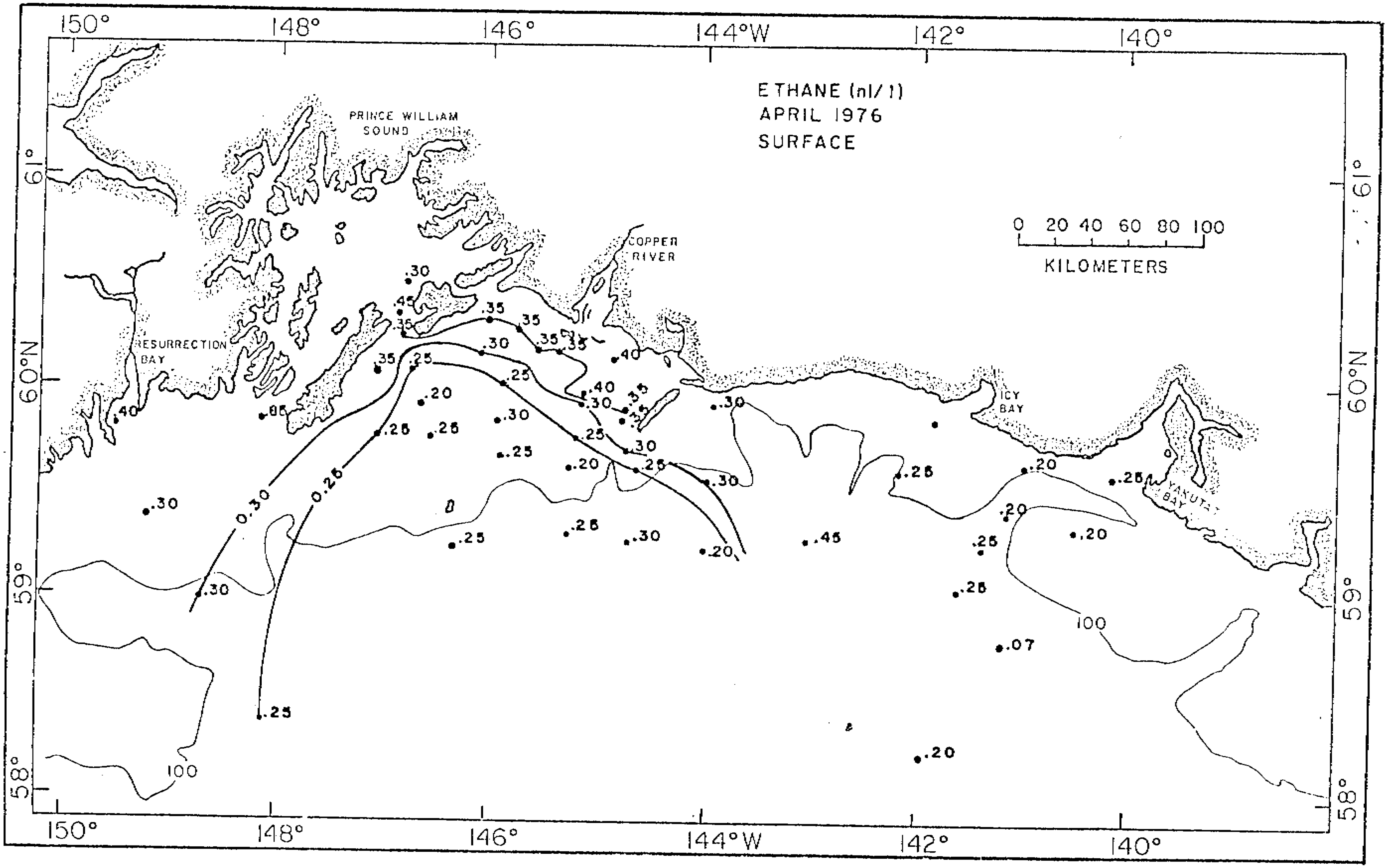

Figure 9. Surface concentration of ethane (nl/liter) in NEGOA during April 1976.

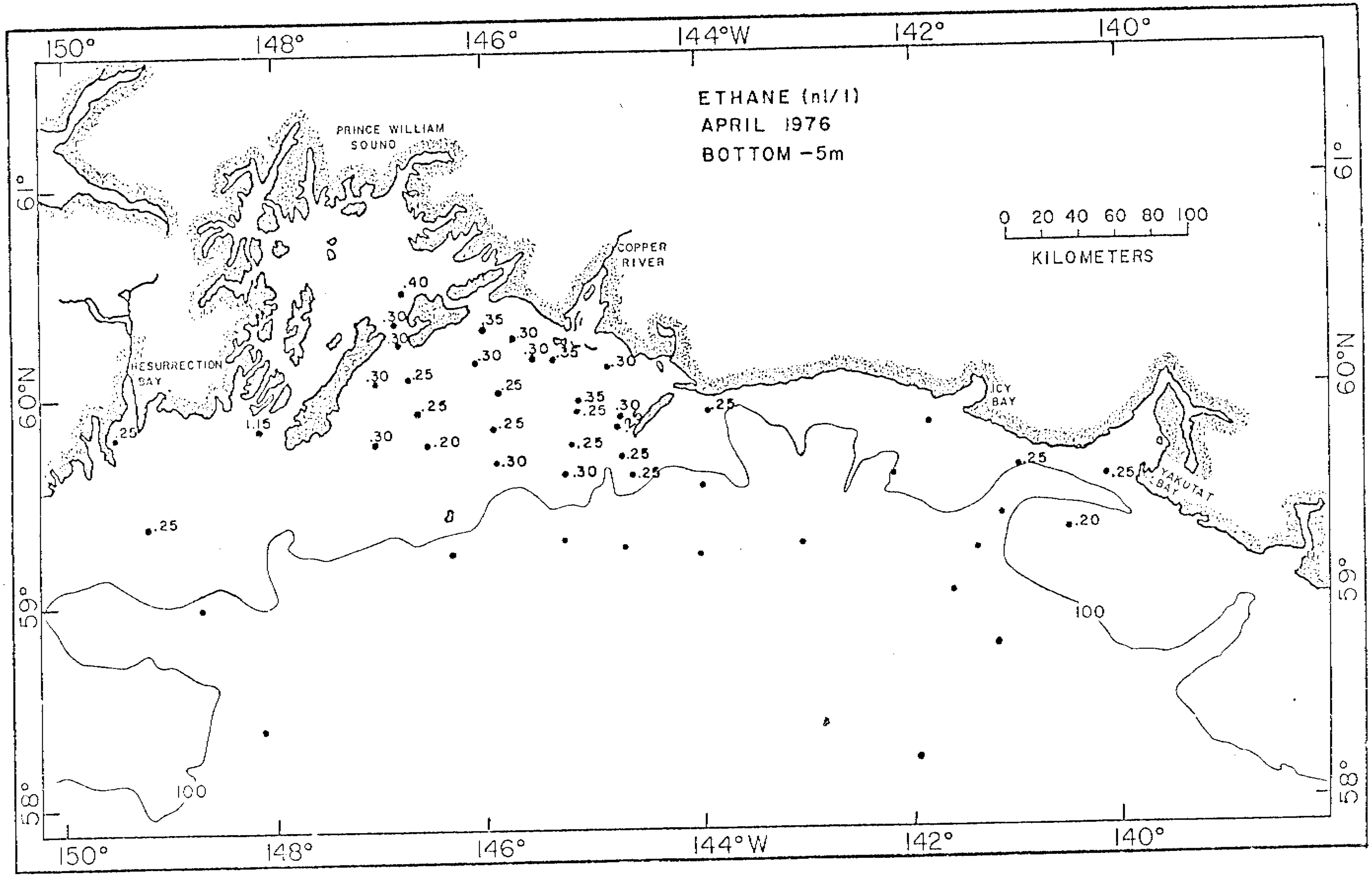

Figure 10. Concentration of ethane (nl/liter) within 5 m of the bottom on the NEGOA shelf during April 1976.

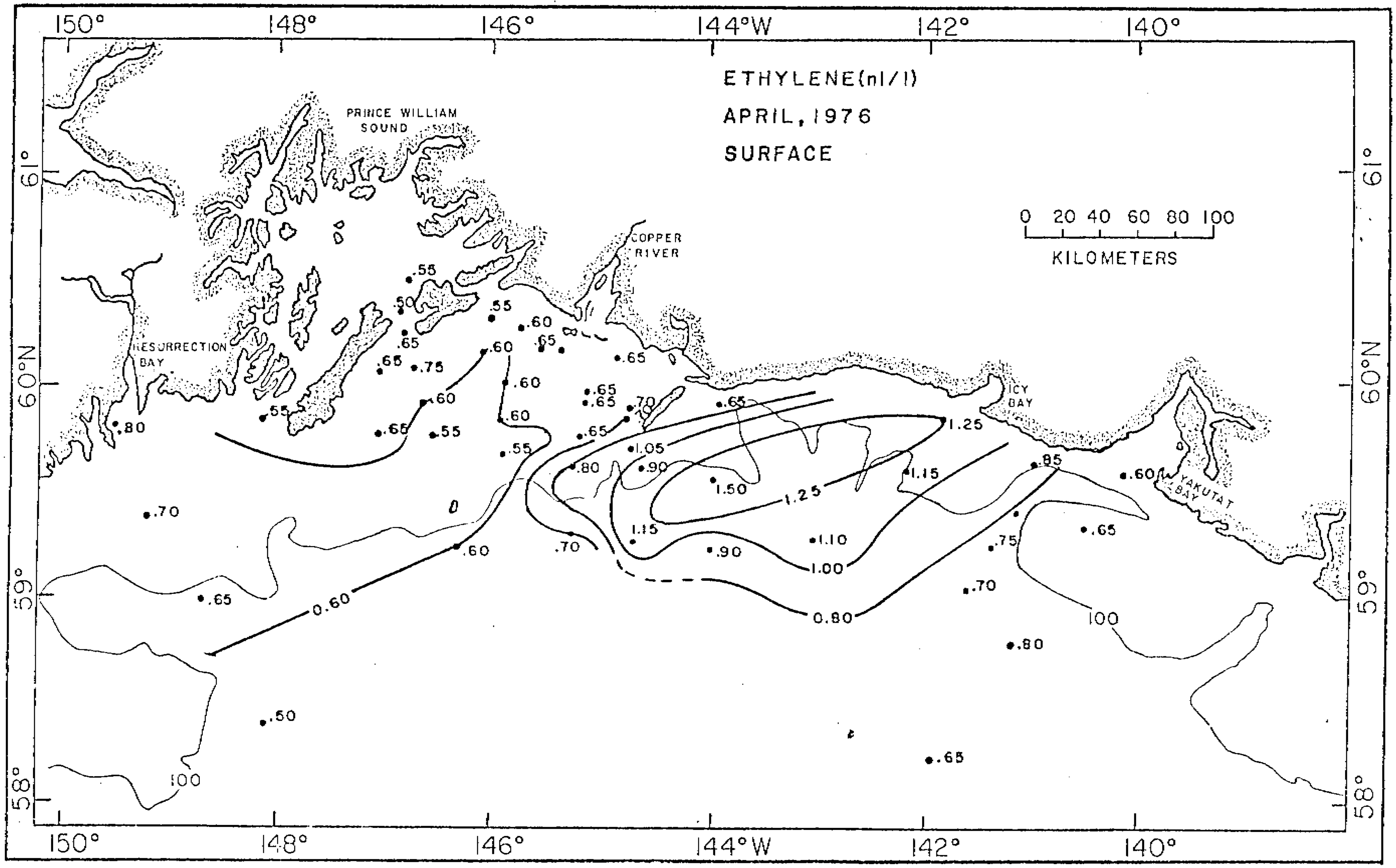

Figure 11. Surface concentration of ethylene (nl/liter) in NEGOA during April 1976.

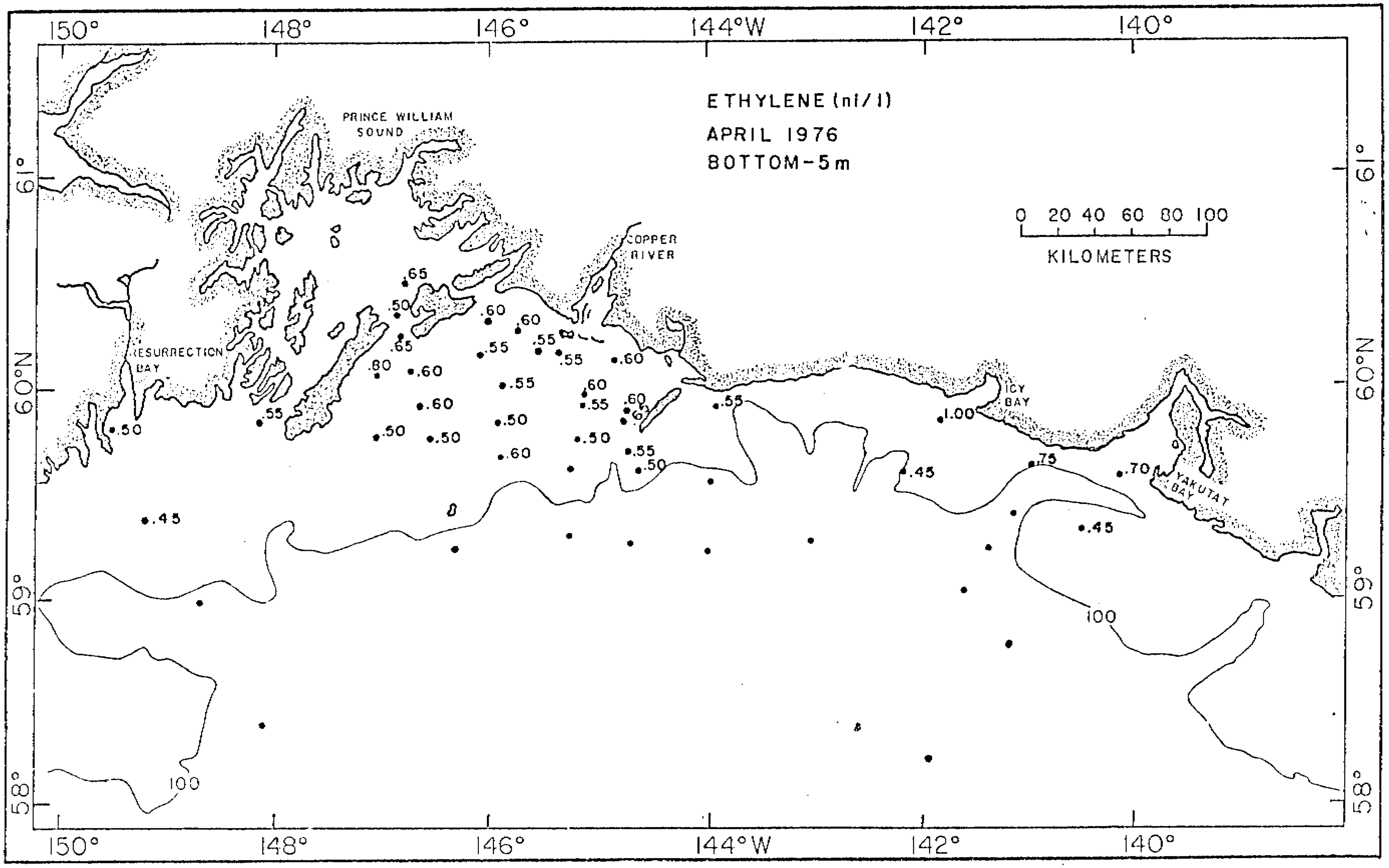

Figure 12. Concentration of ethylene (nl/liter) within 5 m of the bottom on the NEGOA shelf during April 1976.

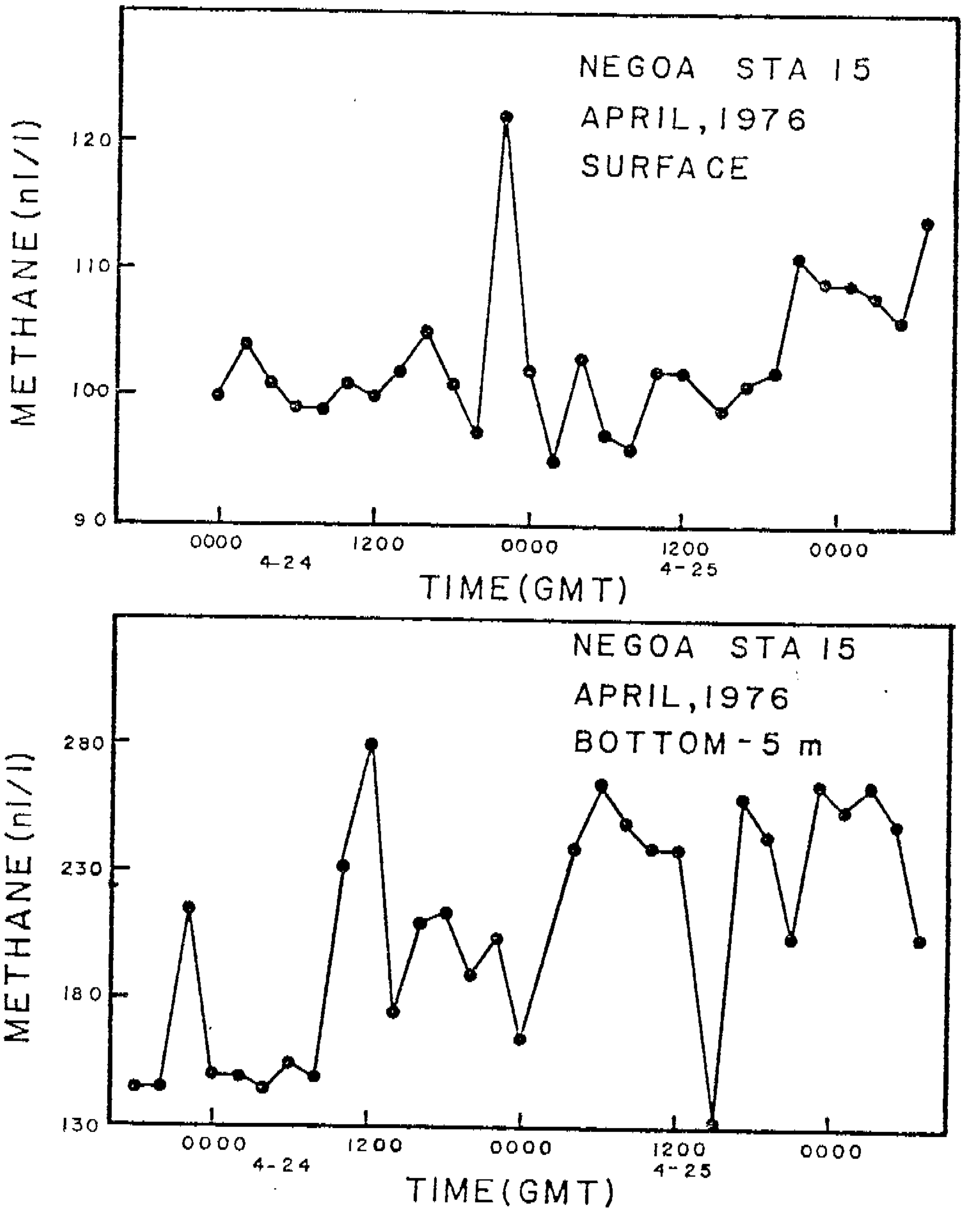

Figure 13. Diurnal variation of the concentration of methane (nl/liter) in the surface layers and within 5 m of the bottom at station 15. Sampling occurred every 2 hrs.

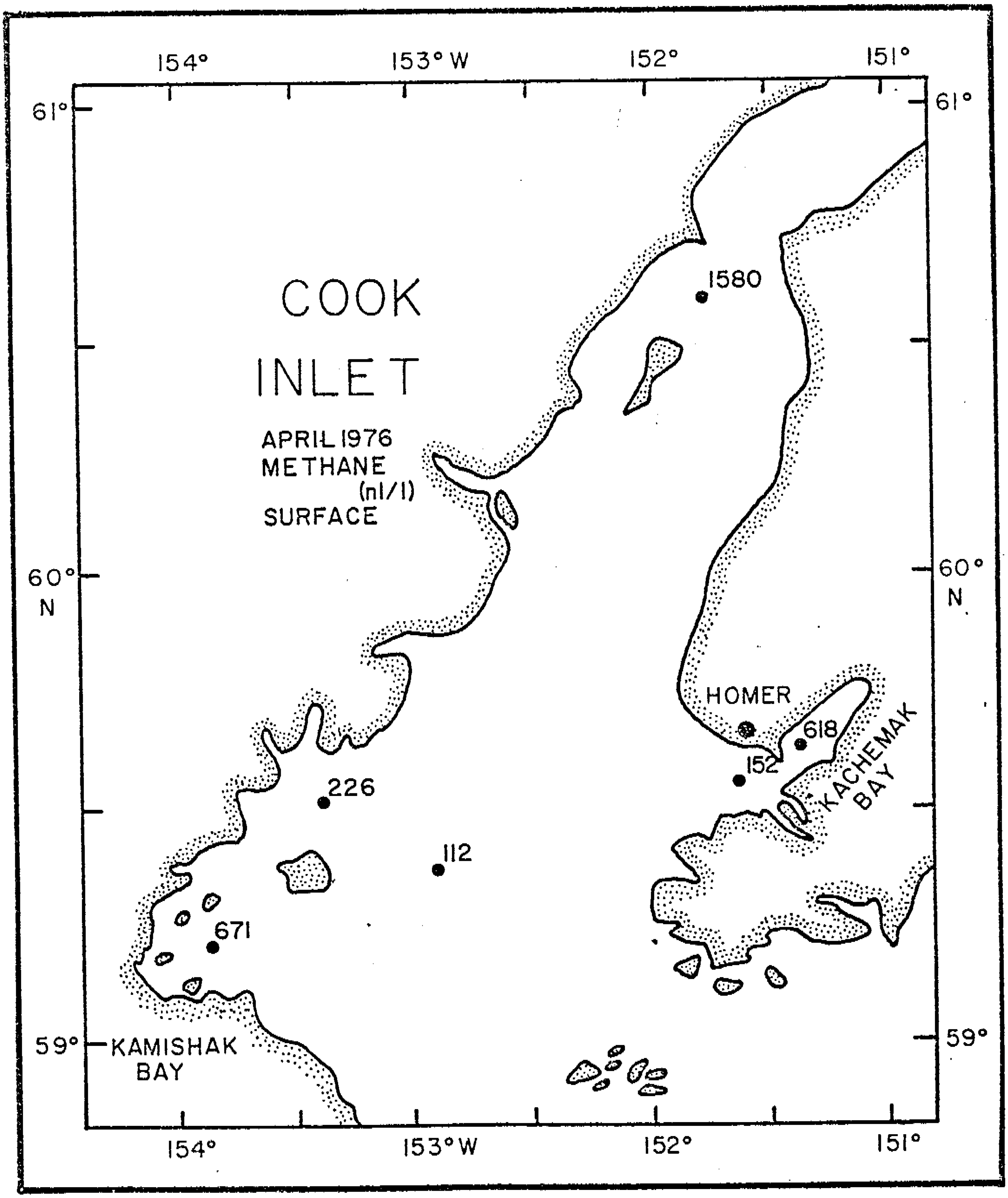

Figure 14. Surface concentration of methane (nl/liter) in Lower Cook Inlet during April 1976.

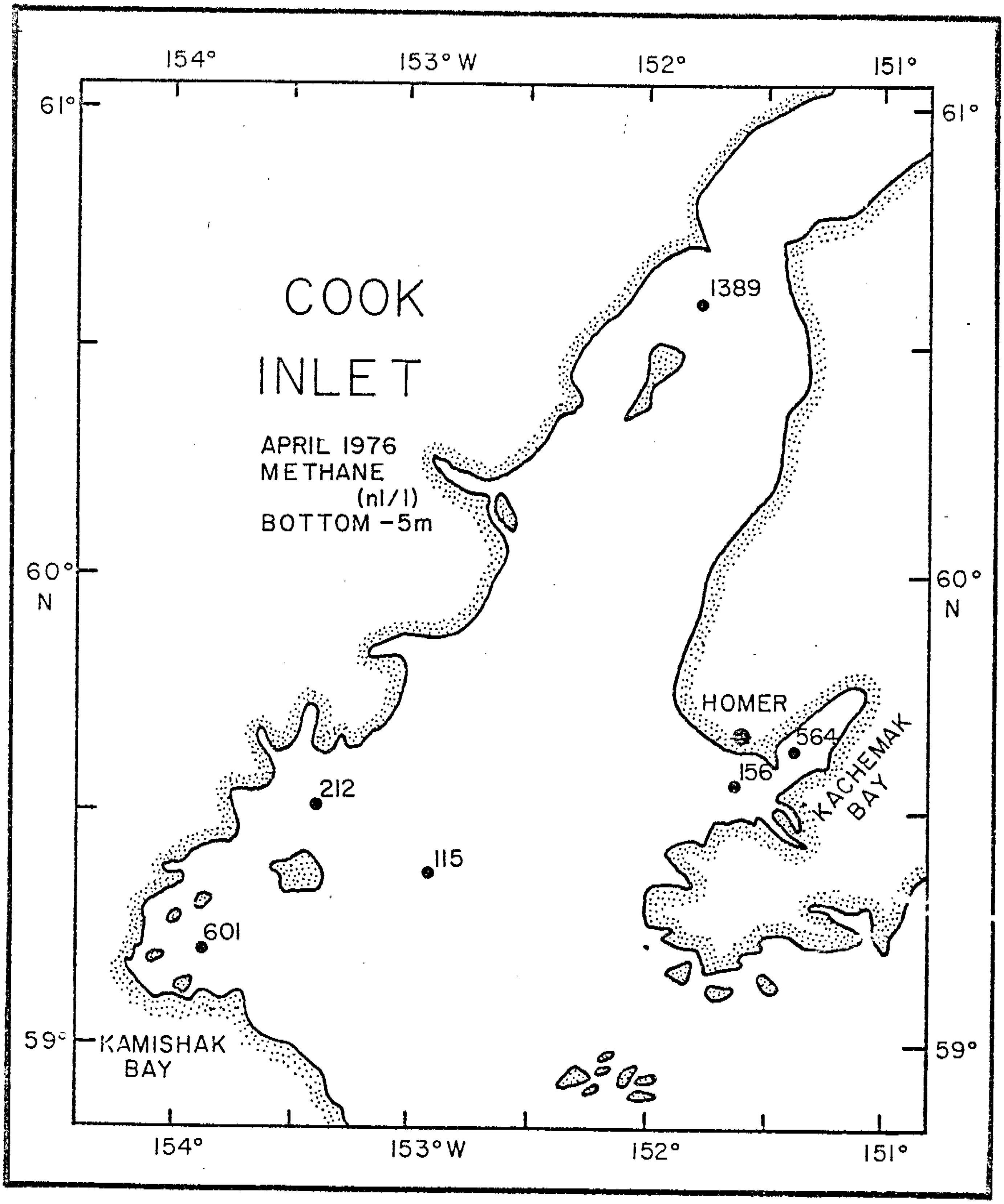

Figure 15. Concentration of methane (nl/liter) within 5 m of the bottom in Lower Cook Inlet during April 1976.

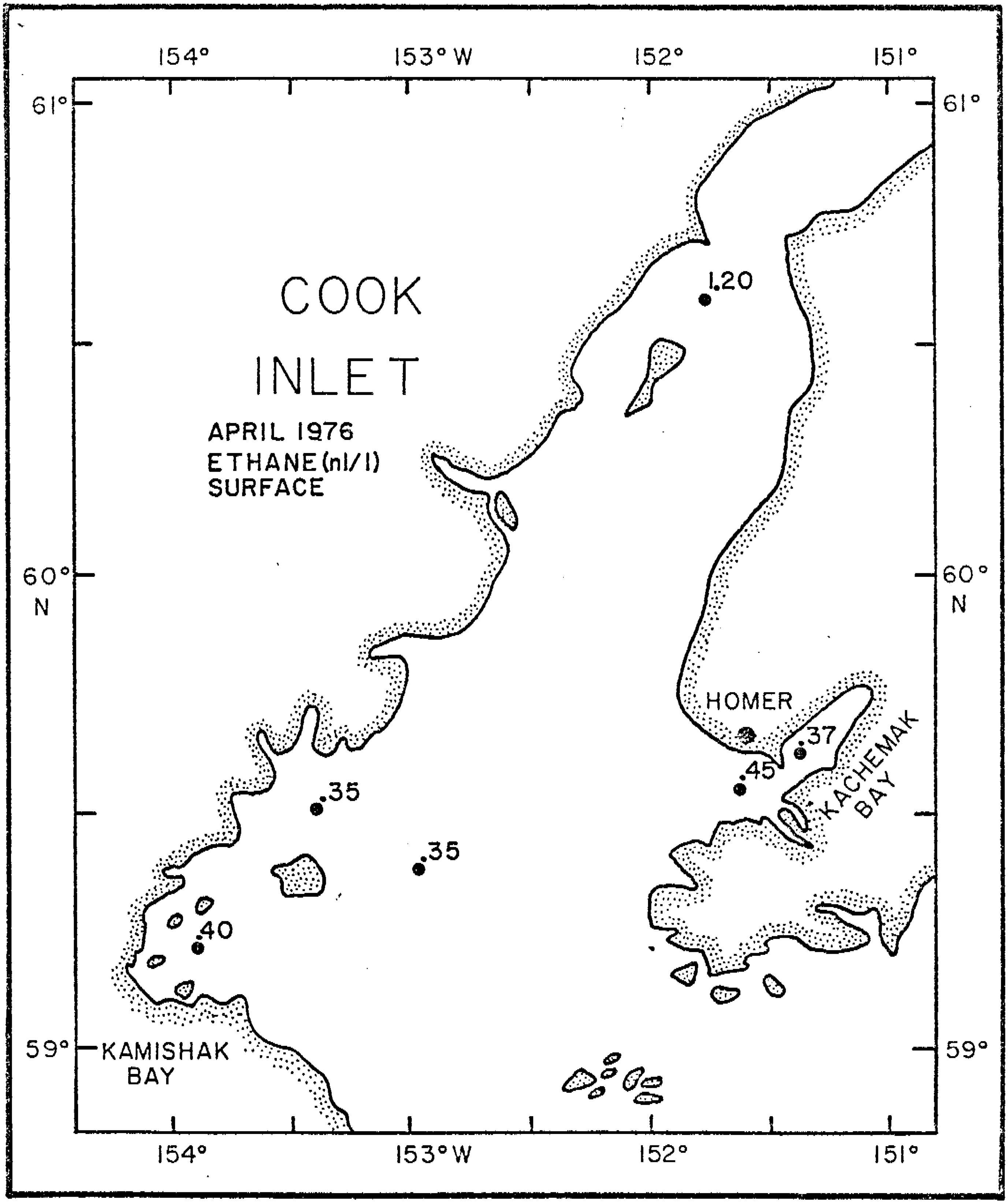

Figure 16. Surface concentration of ethane (nl/liter) in Lower Cook Inlet during April 1976.

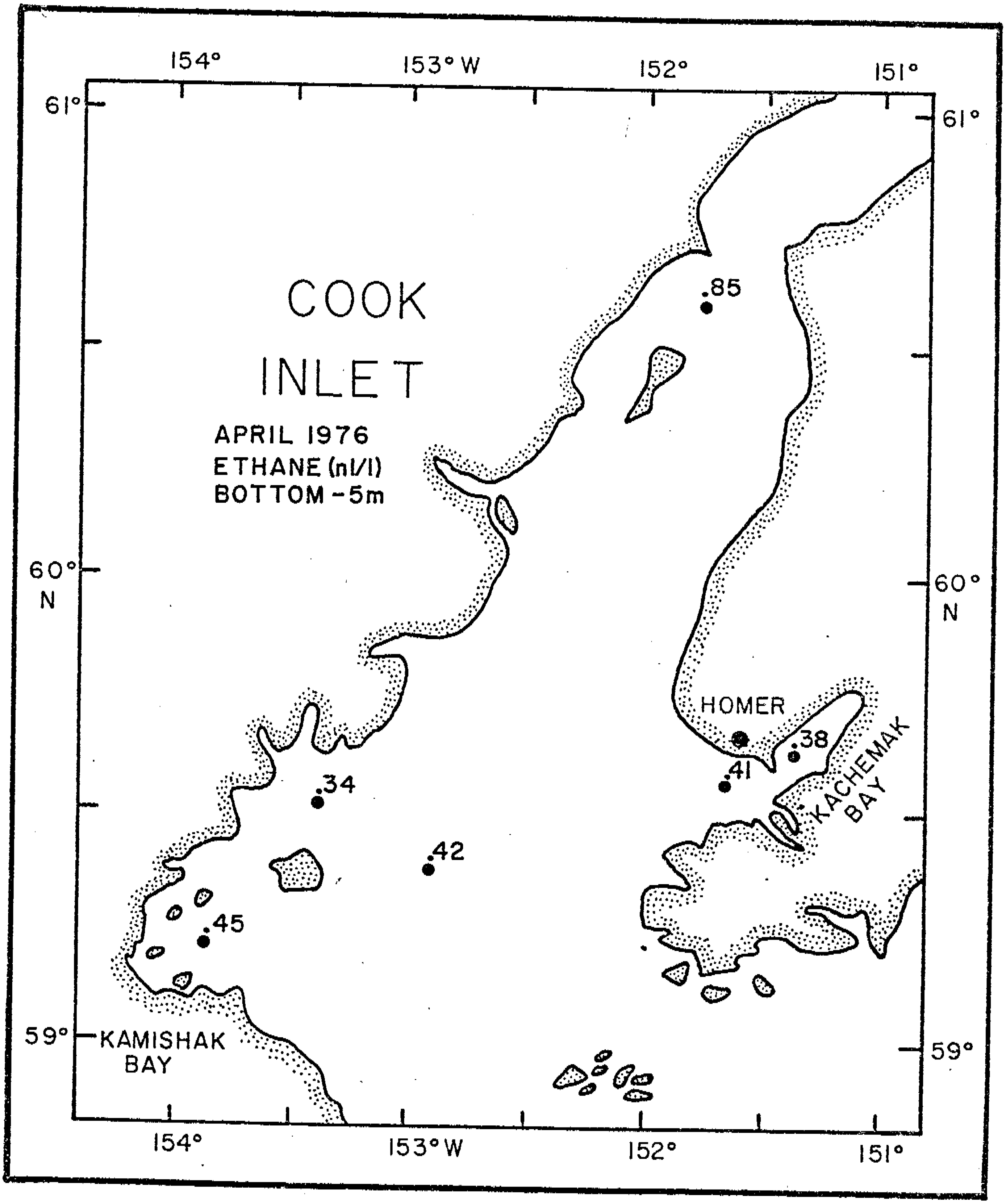

Figure 17. Concentration of ethane (nl/liter) within 5 m of the bottom in Lower Cook Inlet during April 1976.

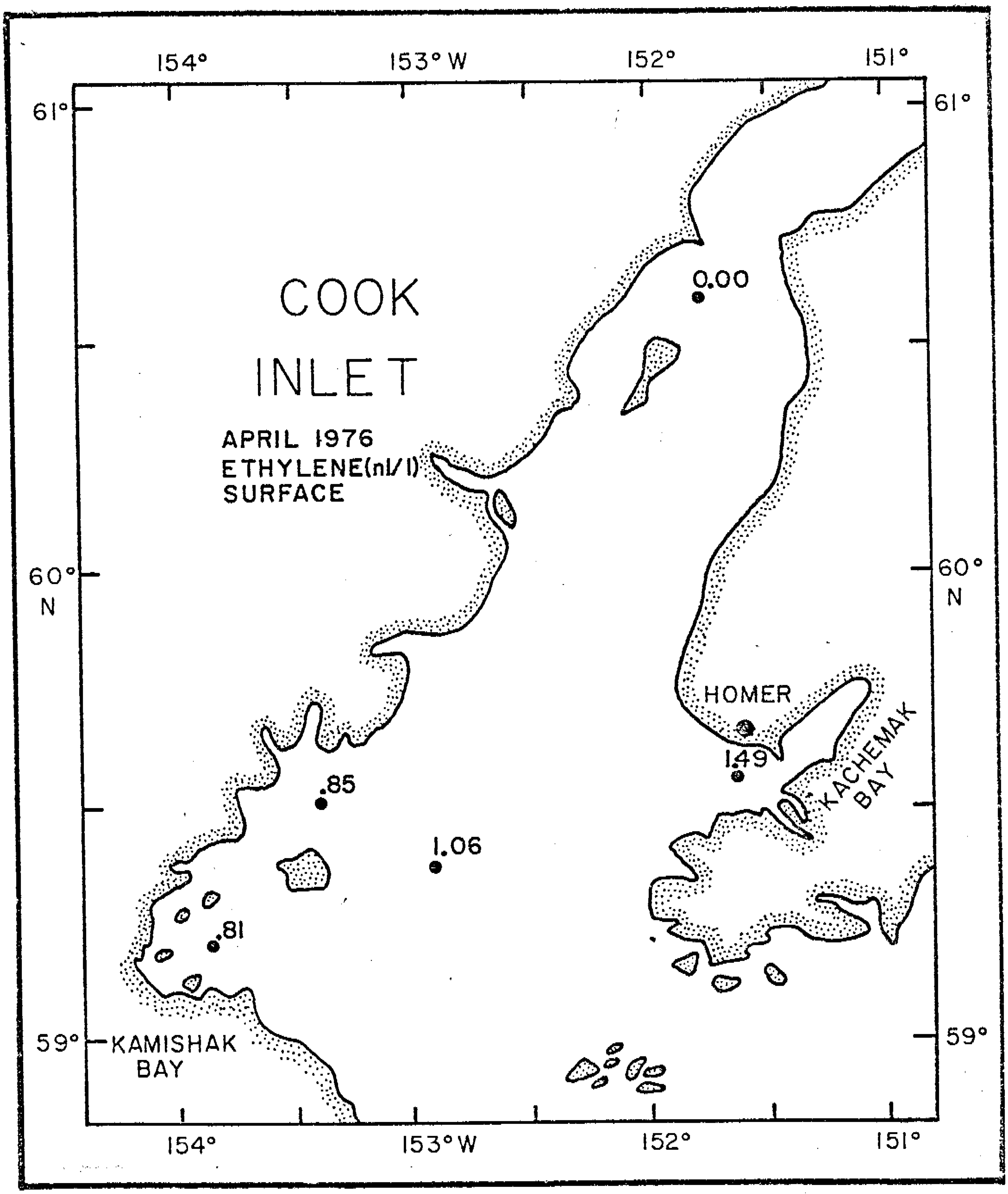

Figure 18. Surface concentration of ethylene (nl/liter) in Lower Cook Inlet during April 1976.

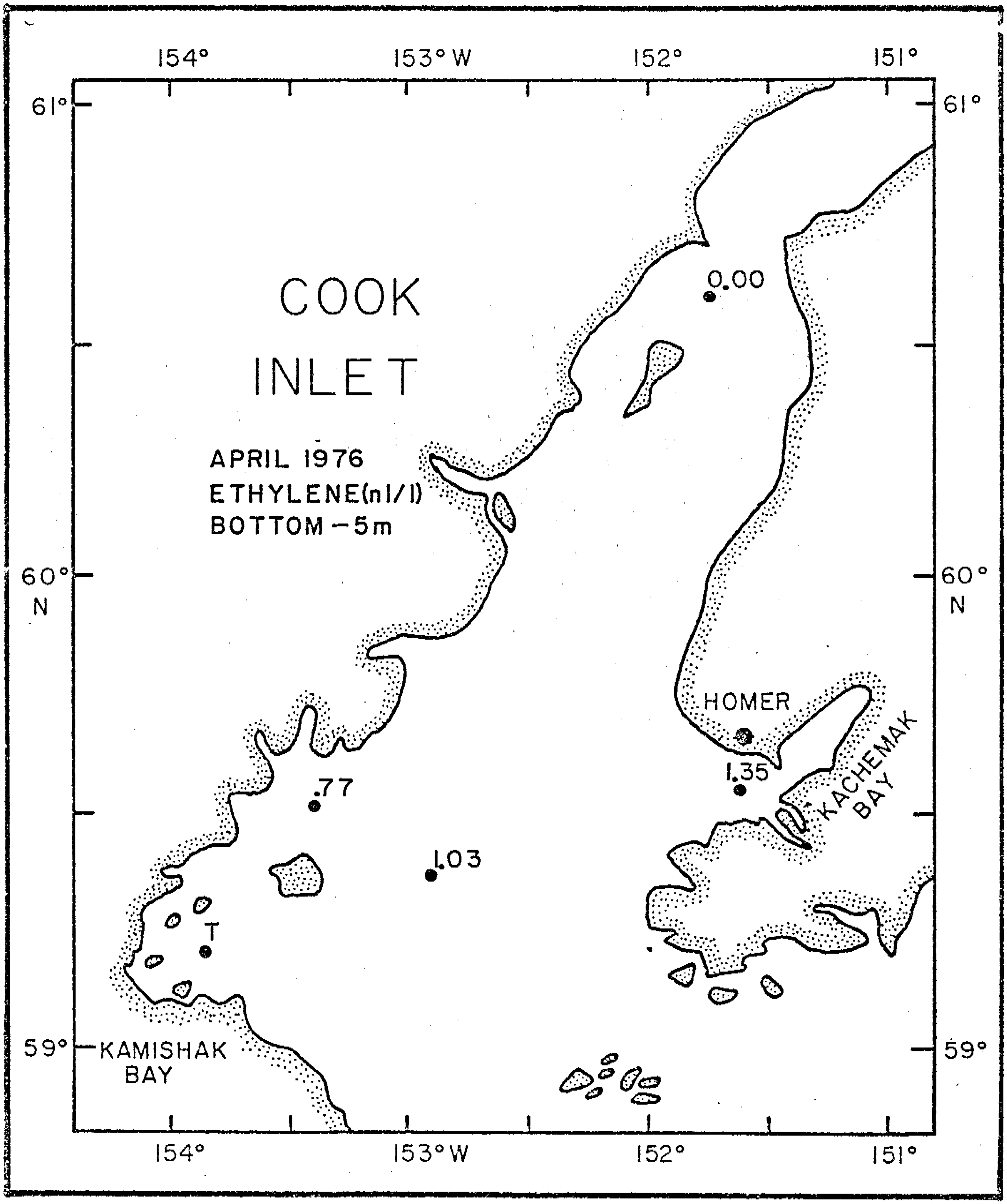

Figure 19. Concentration of ethylene (nl/liter) within 5 m of the bottom in Lower Cook Inlet during April 1976.

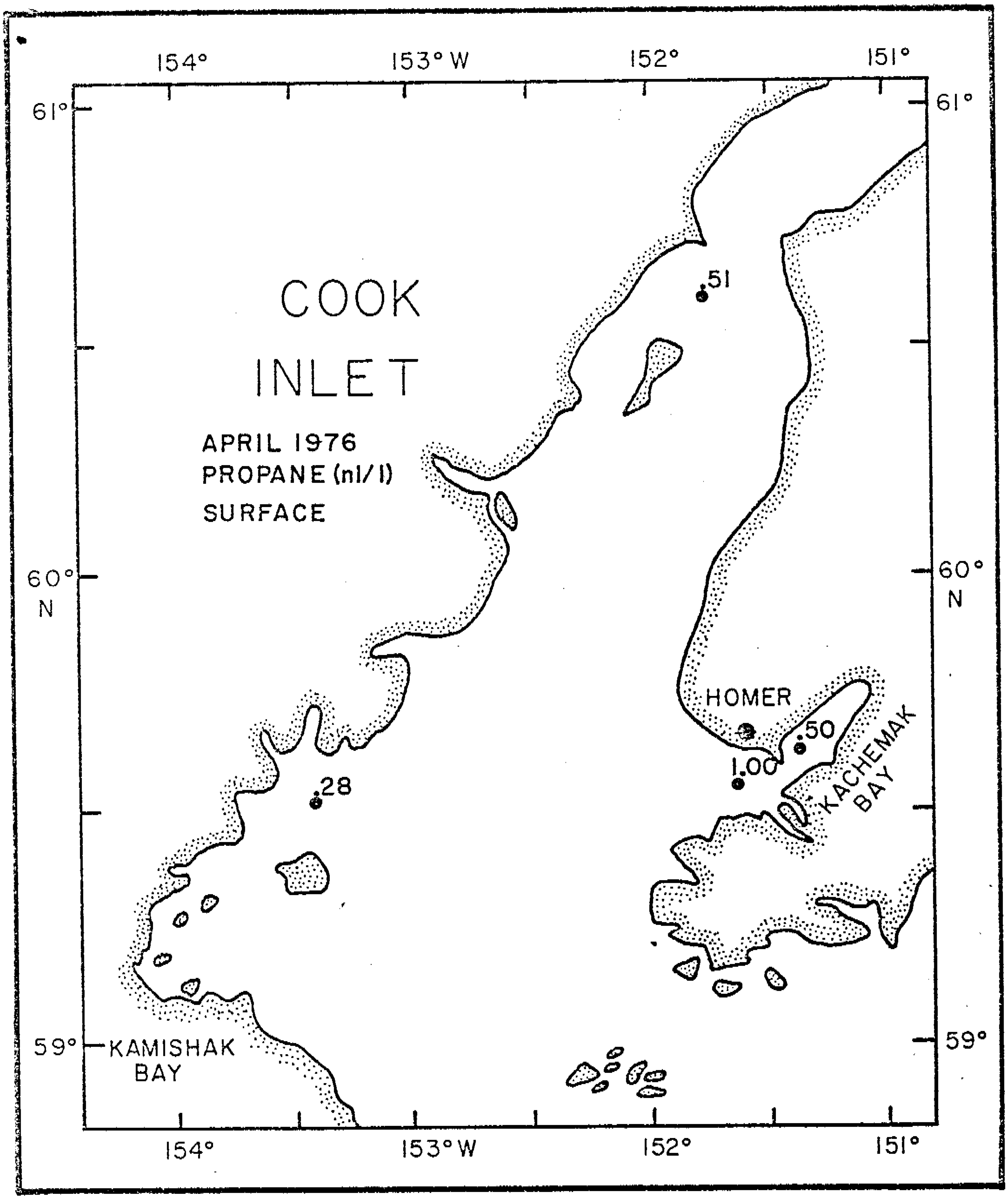

Figure 20. Surface concentration of propane (nl/liter) in Lower Cook Inlet during April 1976.

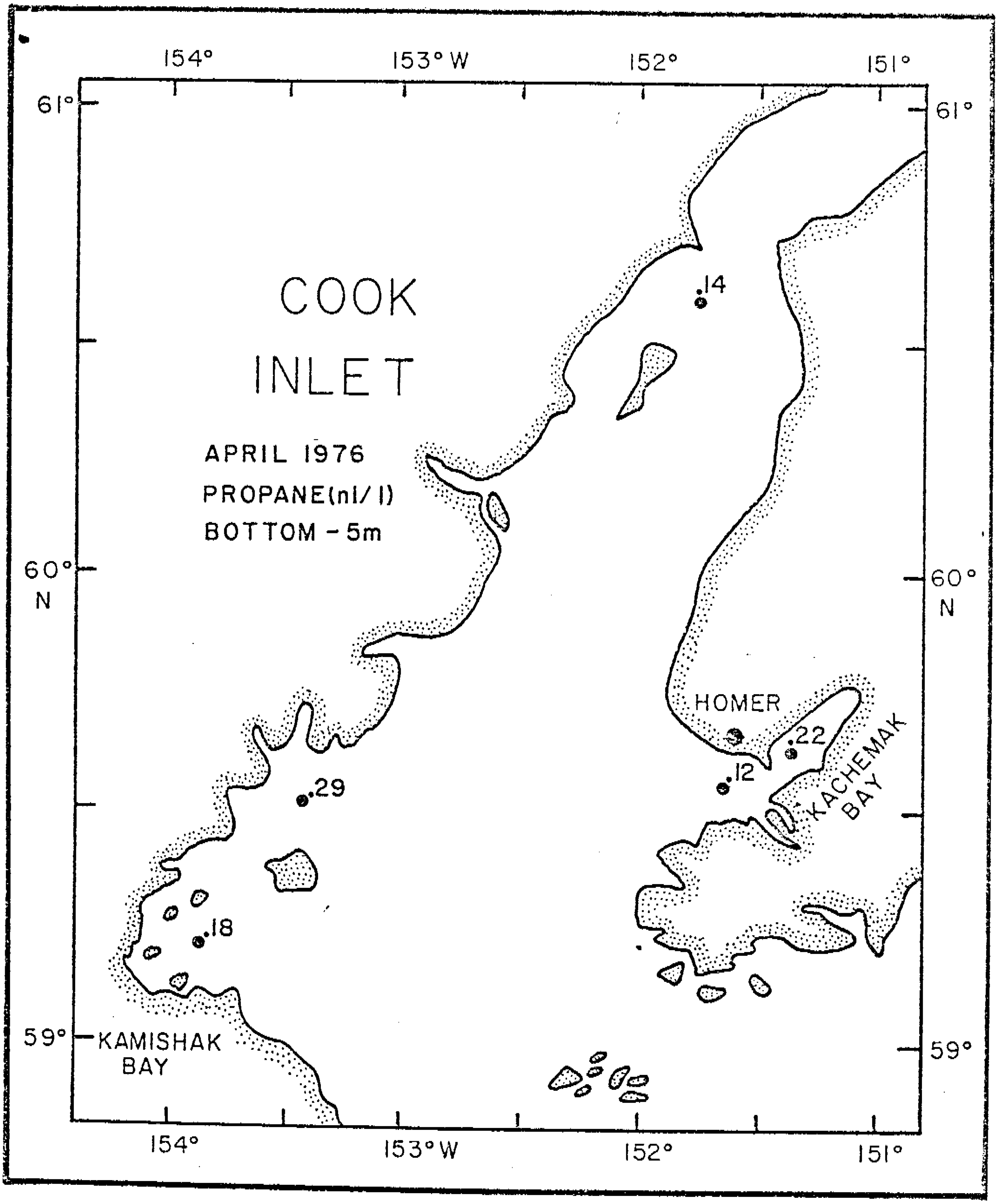

Figure 21. Concentration of propane (nl/liter) within 5 m of the bottom in Lower Cook Inlet during April 1976.

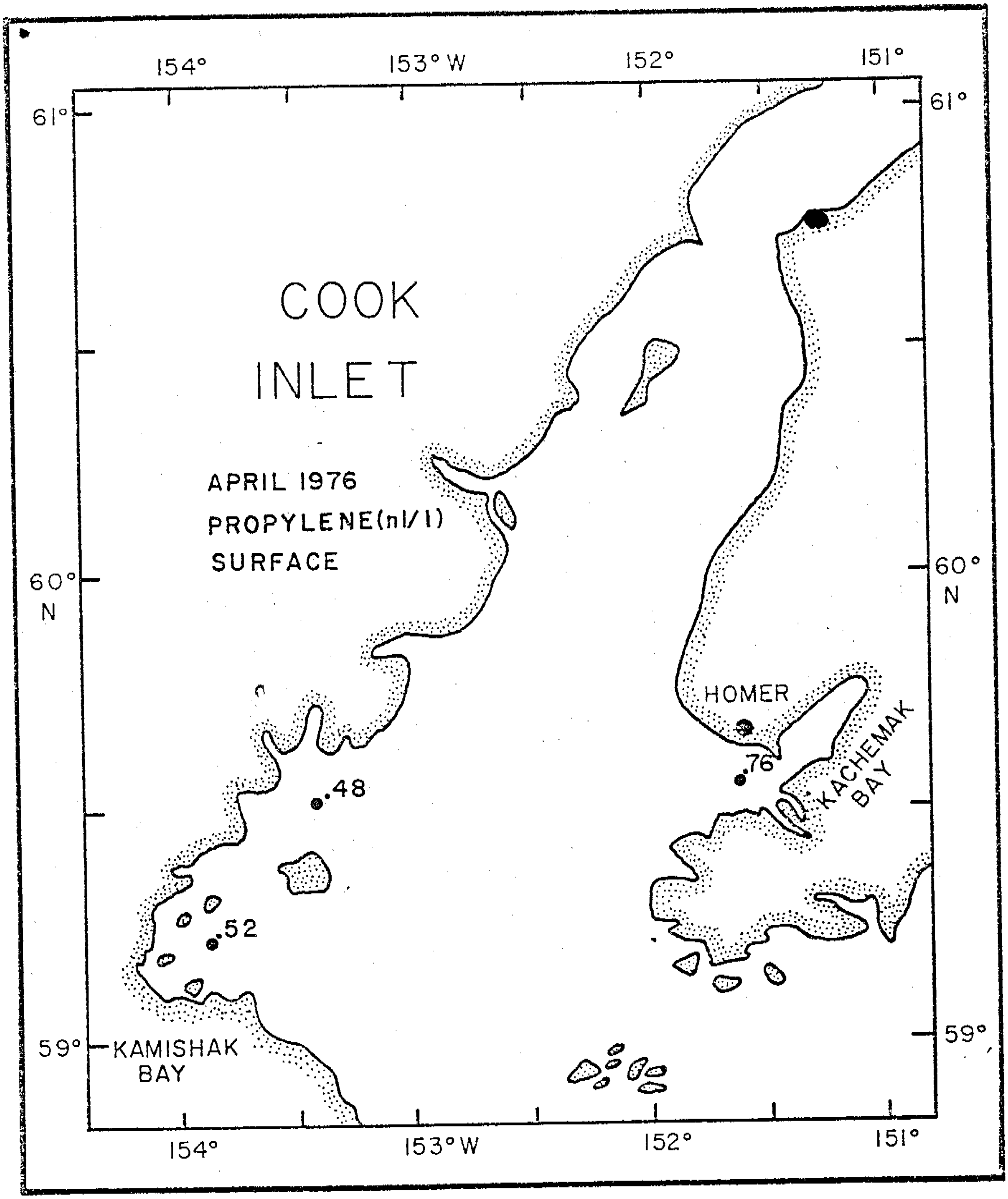

Figure 22. Surface concentration of propylene (nl/liter) in Lower Cook Inlet during April 1976.

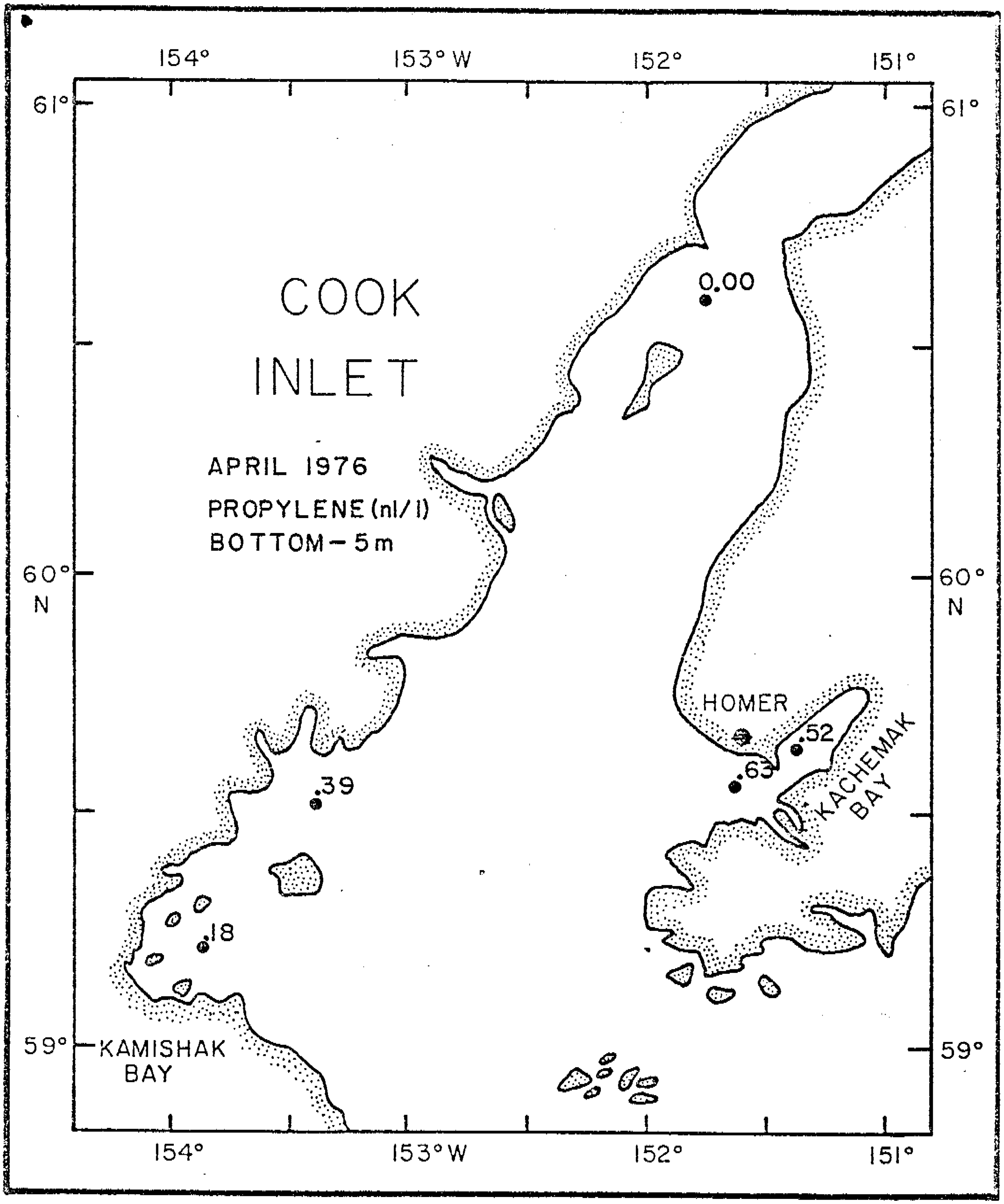

Figure 23. Concentration of propylene (nl/liter) within 5 m of the bottom in Lower Cook Inlet during April 1976.

QUARTERLY REPORT

Contract 03-5-022-56
Task Order Number 12
Quarter Ending -
30 June 1976

NATURAL DISTRIBUTION AND ENVIRONMENTAL BACKGROUND OF TRACE HEAVY METALS IN ALASKAN SHELF AND ESTUARINE AREAS

(Title modification April 16, 1976)

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June 30, 1976

QUARTERLY REPORT

I. Task Objectives

The primary objective of the program is to characterize the trace metal contents of sea water, sediment and selected indigenous animal and plant species in the three defined study areas: the Gulf of Alaska, the Bristol Bay Basin region of the Bering Sea and the Beaufort Basin region of the Beaufort Sea, as defined in the above referenced Task Order Work Statement. The program also incorporates sediment grain-size analysis, clay mineralogical projects and "previous work" literature searches as described in that work statement.

II. Field and Laboratory Activities

A. Field Work

1. Bering Sea

A second batch of sub-tidal trawl samples was collected by Dr. Feder's group on the *Miller Freeman* in the Bering Sea in April. Those samples are to replace the previously collected batch which thawed and was lost during storage due to a local power failure (see January - March quarterly report). The new samples were received in Fairbanks at the beginning of June and have not yet been sorted and distributed to the various sub-projects. Localities and types of samples collected are given in Tables I and II. It should be noted that the station grid occupied by the NMFS personnel, who were the primary operators of this cruise, bears no relationship to the grids previously established by the benthic and chemistry programs (see Annual Report).

2. Lower Cook Inlet

Moana Wave cruise, March 31 - April 15, 1976. We attempted to respond to a last minute request to obtain samples from this area for the heavy metal program. G. Landreth was dispatched on the above referenced benthic biology cruise and collected sediment samples as shown in Table III. Sediment suitable for trace metal analysis could not be collected on most stations because of the nature of the bottom. Water could not be obtained on this cruise and there was no request for biota at that time.

R/V Acona cruise June 25 - July 2, 1976. We have requested collection of *Mytilus* and *Fucus* samples by Dr. Shaw's group who will be present on this cruise.

3. Beaufort Sea

Glacier cruise; project for August 1976. Supplies and equipment have been dispatched to Long Beach, California, for loading on the *Glacier* for this cruise. Participants scheduled at this time from this program are:

TABLE I

S. Bering Sea
Miller Freeman April 1976

Station numbering system & localities

Project station #	Tow #	NMFS Grid #	Sample #	Locality	
				Lat N	Long N
3	1	Z-5 (1)	1	54 48.3	165 16.2-
			2	54 47.3	165 18.3
			3		
5	3	Z-5 (3)	4	54 44.7	165 18.6-
			5	54 43.6	165 17.2
7	5	Z-4 (2)	6	54 40.4	165 42.0-
				54 34.6	165 39.5
18	9	A/B-7/8	7	55 09.8	163 44.1-
			8	55 09.8	163 41.3
19	10	B - 7	9	55 19.8	163 24.0-
				55 18.2	163 25.2
24	13	Z - 2 (3)	10	55 53.5	166 44.0-
				55 53.8	166 41.9
25	14	Z - 2 (4)	11	54 50.4	166 35.8-
			12	54 51.8	166 34.1
27	16	A - 3	13	54 59.7	166 17.8-
			14	55 00.0	166 15.2
			15		
29	17	A/B - 3/6	16	55 09.3	166 02.0-
			17	55 10.2	166 00.3
			18		
			19		
30	18	B - 6	20	55 18.5	165 43.8-
			21	55 20.1	165 42.5
			22		
			23		
31	19	B/C-6/5	24	55 30.5	165 27.9-
			25	55 32.1	165 26.0
			26		
32	20	C - 5	27	55 39.4	165 11.5-

TABLE I (Continued)

Station numbering system & localities

Project station #	Tow #	NMFS Grid #	Sample #	Locality	
				Lat N	Long N
			28	55 41.0	165 09.8
			29		
38	24	D/E-3/4	30	56 10.2	166 05.9-
			31	56 10.7	166 08.6
			32		
39	25	D - 3	33	56 01.6	166 19.2-
			34	56 00.2	166 21.8
			35		
48	29	B - 1	36	55 20.1	167 27.8-
			37	55 18.3	167 28.9
			38		
49	30	A/B-18/1 (2)	39	55 14.0	167 36.3-
			40	55 15.4	167 37.7
			41		
56	35	C-19 (2)	42	55 35.7	168 29.1-
			43	55 34.0	168 26.8
57	36	C-19 (3)	44	55 32.1	168 23.9-
			45	55 31.2	168 21.2
58	37	C-19 (4)	46	55 31.3	168 26.0-
				55 32.5	168 27.7
60	39	C-19 (6)	47	55 31.2	168 17.6
				55 30.0	168 15.6
64	40	CD-18/19	48	55 48.2	168 24.8-
			49	55 49.6	168 21.0
80	49	A - 5	50	54 59.8	165 08.9-
				54 58.2	165 09.7

TABLE II

S. Bering Sea
Miller Freeman April 1976

Samples collected for heavy metal program.

NMFS Grid #	Trawl #	Sample #	Depth (m)	Date 1976	Species
Z-5 (1)	1	1	167.6-	4.1	Pollock
		2	161.9		Rock sole
		3			Tanner
Z-5 (3)	3	4	167.9	4.1	Pollock
		5			Rock sole
Z-4 (2)	5	6	409.5-	4.1	Pollock
			420.4		
A/B-7/8	9	7	83.1-	4.3	Tanner
		8	84.8		Rock sole
B-7	10	9	98.3	4.3	Tanner
			99.9		
Z-2 (3)	13	10	249.3-	4.6	Tanner
			252.9		
Z-2 (4)	14	11	183.8-	4.6	Pollock
		12	200.2		Tanner
A-3	16	13	144.7-		Rock sole
		14	166.5		Tanner
		15			Neptunea
A/B-3/4	17	16	134.6-	4.9	Tanner
		17	132.8		Pollock
		18			Rock sole
		19			Neptunea
B-4	18	20	121.9-	4.9	Tanner
		21	104.6		Pollock
		22			Neptunea
		23			Rock sole
B/C-6/5	19	24	114.3	4.9	Rock sole
		25			Pollock
		26			Tanner
C-5	20	27	112.8-	4.9	Rock sole

TABLE II (Continued)

Samples collected for heavy metal program.

NMFS Grid #	Trawl #	Sample #	Depth (m)	Date 1976	Species
		28	119.9		Pollock
		29			Tanner
D/E-3/4	24	30	109.2-	4.10	Rock sole
		31	111.0		Neptunea
		32			Tanner
D-3	25	33	124.2-		Tanner
		34	126.4		Rock sole
		35			Pollock
B-1	29	36	149.2	4.11	Pollock
		37	151.0		Tanner
		38			Rock sole
A/B-18/1 (2)	30	39	176.5-		Pollock
		40	178.3		Tanner
		41			Rock sole
C-19 (2)	35	42	167.4-	4.12	Pollock
		43	169.2		Rock sole
C-19 (3)	36	44	249.3		Rock sole
		45			Pollock
C-19 (4)	37	46	338.5-	4.12	Pollock
			340.3		
C-19 (6)	39	47	196.7-	4.12	Rock sole
			202.0		
CD-18/19	40	48	143.7	4.13	Tanner
		49			Pollock
A-s	49	50	116.4	4.16	Neptunea

TABLE III

Moana Wave March 31 - April 15

Operations - Lower Cook Inlet

Station No.	Bottom depth (m)	Sediment sample
04	26	Haps
10	25	Haps
11	29	Haps
12	38	Haps
18	133	Van Veen
19	100	Van Veen
25	55	Van Veen
26	64	Haps
30	71	Haps

Leg I - early August - H. V. Weiss
Leg II - late August - T. A. Gosink
G. Landreth

4. Northeast and Northwest Gulf

Intertidal biota samples -- *Fucus* and *Mytilus* -- have been collected for us by Dr. Zimmermann's group. Sample batches were received by us in Fairbanks on March 25 and June 24th. Samples and localities are shown in Tables IV and V.

B. Field Collection Methods

Sample collections and storage methods have been essentially as described in the Annual Report. Specific deviations are noted in the following section.

C. Laboratory Analysis Programs

1. Voltammetry (Dr. D. C. Burrell)

Cd, Cu and Pb analysis of Gulf of Alaska water samples are shown in Tables VI and VII. These samples were filtered at 0.4 mμ at sea and acidified to pH4 prior to storage and transportation to the laboratory. In the laboratory, the samples were further acidified (to pH2) using Ultrex HCL. The data on Tables VI and VII are means of duplicate determinations. Standard additions have been applied to each sample.

Locations of intra- and inter-laboratory calibration localities are given in Tables VI and VII. This was a special set of samples which will be used to standardize various analysis techniques. Considerable efforts are currently being devoted, for example, to comparing carbon filament atomic spectrometore and thin-film regular and differential pulse reverse voltammetric techniques for Cd, Pb and Cu.

The zinc data of Table VIII has been determined by inverse voltammetry at pH8; this is discussed further below. Samples were adjusted from the storage pH2 with NaOH.

2. Neutron Activation Analysis (Dr. D. E. Robertson)

Haps core samples from the south Bering Sea and the northeast and northwest Gulf regions were sectioned at 2 cm intervals shipboard and stored frozen in plastic jars. In the laboratory, these sediments samples were dried, weighed, and encapsuled in polyethylene vials prior to "rabbit" irradiation and Ge(Li) gamma spectrometric determination of the heavy metals Mn and V. Data for those elements are given in Tables IX - XI for the So. Bering Sea and northeast and northwest Gulf regions respectively. (As always, station number are standard as given in the Annual Report.)

TABLE IV

N. W. Gulf Region

Intertidal biota sample localities.

Locality	Species
Lagoon Point	Mytilus Fucus
Cape Pasagshak	Mytilus Fucus
Cape Lupin (Unimak)	Mytilus Fucus
Sennett Point (Unimak)	Mytilus Fucus
Eider Point	Mytilus
Unalaska Island	Fucus
Low Cape	Mytilus

TABLE V

N. E. Gulf of Alaska

Intertidal biota sample localities.

Locality	Species
Port Dick	Mytilus Fucus
Sundstrom Island	Mytilus Fucus
Cape Nukshak	Mytilus Fucus
Otter Island	Mytilus Fucus
La Touche Point	Mytilus Fucus
Kagak Island	Fucus
Anchor Cove	Fucus
Spectacle Island	Fucus
Boswell Bay	Mytilus Fucus
Makushin Bay	Mytilus Fucus
Katalia	Mytilus Fucus
Day Harbor	Mytilus

TABLE VI

N.E. Gulf of Alaska
Discoverer Leg III 23 November-2 December 1975

Heavy metal contents of filtered (0.4 μm) water (μg/ℓ)

Station No.	Depth (m)	Cd	Pb	Cu
02	10	-	0.03	0.18
	178	-	0.02	0.16
05	10	0.02	0.045	0.26
	162	0.035	0.03	0.16
08	10	-	0.03	0.14
	276	0.035	0.04	0.37
11	10	0.02	0.06	0.14
	1350	*	*	*
15	10	0.09	0.13	0.14
	1500	*	*	*
24	10	-	-	-
	410	*	*	*
26	10	(0.08)	(0.27)	0.15
	136	-	(0.35)	(>1.0)
29	71	0.035	(0.15)	(1.0)
30	42	0.025	0.06	0.25
33	10	0.03	0.04	0.10
	205	0.03	0.45	0.20
44	10	0.02	0.045	0.45
	165	0.04	0.06	0.36
48	10	0.02	0.07	0.20
	447	0.055	0.06	0.20
49	10	0.02	0.03	0.26
	120	0.02	0.05	0.16
50	10	0.02	0.04	0.40
	167	0.02	0.04	0.21
51	10	0.025	0.04	0.28
	133	-	0.035	-

TABLE VI (Continued)

Heavy metal contents of filtered (0.4 μm) water (μg/ℓ)

Station No.	Depth (m)	Cd	Pb	Cu
52	74	0.02	0.03	0.22
53	10	-	(>1.0)	-
	284	0.04	(1.0)	(0.48)
54	10	0.02	0.06	0.23
	202	-	0.02	0.16
55	10	0.03	0.09	0.52
	110	0.025	0.03	0.21
56	58	-	0.17	0.13
57	67		0.06	-
58	82	0.025	0.06	0.20
59A	10	-	-	-
	370	-	-	-

* Intercalibration station: Analysis not yet complete.

TABLE VII

N.W. Gulf of Alaska
Discoverer Leg III 23 November-2 December 1975

Heavy metal contents of filtered (0-4 μm) water (μg/ℓ)

Station No.	Depth (m)	Cd	Pb	Cu
106	81	0.025	0.035	0.16
108	10	-	0.07	0.16
	226	0.025	0.025	0.15
110	10	0.03	0.025	0.15
	173	*	*	*

* Intercalibration station: Analysis not yet complete.

TABLE VIII

S. Bering Sea
Discoverer 2-19 June 1976

Free zinc (see text) contents at pH 8 in unfiltered water (μg/ℓ)

Station No.	Depth (m)	Zn (μg/ℓ)	Station No.	Depth (m)	Zn (μg/ℓ)
02	0	0.60	21	0	-
	40	1.2		40	0.56
06	0	0.36	24	0	0.40
	40	0.35		40	1.1
08	0	0.40	26	0	0.50
	15	(4.0)		45	0.47
10	0	0.45	30	0	1.7
	60	0.48		125	-
12	0	0.88	62	0	0.19
	75	1.5		45	0.42
13	0	(>5)	64	80	0.20
	75	0.58	65	0	-
14	0	1.2		100	0.60
	130	0.57	69	0	-
17	0	0.60		105	1.0
	110	1.0			
19	0	0.75			
	65	0.40			

TABLE IX

S. Bering Sea
Discoverer June 2-19, 1975
D. E. Robertson, Analyst

Total heavy metal contents of bottom sediments (mg/kg dry weight).

Station	Depth Interval (cm)	Mn	V
8	0-2	720 ± 38	126 ± 26
	4-6	567 ± 36	87 ± 25
	8-10	715 ± 43	165 ± 29
	12-14	629 ± 37	90 ± 25
12	0-3	573 ± 49	118 ± 25
19	0-2	628 ± 43	93 ± 27
28	0-3	524 ± 50	92 ± 25
29	0-4	572 ± 45	77 ± 23
30	0-4	571 ± 43	112 ± 24
	4-8	574 ± 38	114 ± 25
	8-12	574 ± 43	106 ± 27
37	0-2	358 ± 42	85 ± 23
	4-6	360 ± 38	85 ± 21
41	0-2		
43	0-2		
	4-6		
56	0-2	–	–
	4-6	425 ± 38	83 ± 32
	8-10	427 ± 45	86 ± 23
	12-18	427 ± 49	98 ± 23
59	0-2	366 ± 42	77 ± 22
	4-6	393 ± 40	77 ± 20
64	0-2	397 ± 48	82 ± 24
	4-6	414 ± 22	87 ± 43
	8-10	403 ± 47	89 ± 23
	12-14	422 ± 45	96 ± 24
	16-20	420 ± 46	89 ± 23
	20-24	422 ± 45	89 ± 23

TABLE X

N. W. Gulf of Alaska
Discoverer Leg IV. October 8 - 16, 1975.
D. E. Robertson, Analyst

Total heavy metal contents of bottom sediments (mg/kg dry weight).

Station	Depth Interval	Mn	V
104	0-2	846 ± 39	72 ± 19
	4-6	546 ± 48	108 ± 24
	8-10	570 ± 42	94 ± 22
119	0-2	991 ± 48	130 ± 29
	4-6	802 ± 45	137 ± 27
	8-10	724 ± 47	119 ± 28
120	0-2	1066 ± 51	164 ± 31
	4-6	958 ± 47	123 ± 28
	8-10	997 ± 57	167 ± 32
	12-14	1074 ± 52	150 ± 30
	16-18	931 ± 49	144 ± 28
121	0-2	782 ± 53	118 ± 26
	4-6	690 ± 50	121 ± 29
	8-10	744 ± 44	114 ± 26
122	0-2	312 ± 31	27 ± 15
124	0-2	489 ± 47	83 ± 25
	4-6	541 ± 45	88 ± 23
	8-10	464 ± 45	70 ± 22
133	Surf.	1170 ± 50	173 ± 28
134	0-2	711 ± 54	126 ± 27
	4-6	651 ± 52	124 ± 25
	8-10	844 ± 56	148 ± 28
	12-14	804 ± 46	147 ± 27
	16-18	742 ± 51	118 ± 30
135	0-2	806 ± 56	129 ± 28
	4-6	900 ± 45	140 ± 27
	8-10	906 ± 45	132 ± 27

TABLE XI

N. E. Gulf of Alaska
Discoverer Leg III, Nov. 23-Dec. 2, 1975
D. E. Robertson, Analyst

Total heavy metal contents of bottom sediments (mg/kg).

Station	Depth Interval (cm)	Mn	V
2	0-2	738 ± 49	150 ± 29
	6-8	847 ± 48	190 ± 28
	10-12	845 ± 55	173 ± 29
	14-16	995 ± 48	185 ± 28
	18-20	817 ± 46	170 ± 28
5	8-10	777 ± 48	165 ± 29
	14-16	774 ± 49	181 ± 28
26	0-2	924 ± 51	92 ± 16
	4-6	879 ± 48	147 ± 25
	8-10	836 ± 48	141 ± 24
	12-14	810 ± 53	135 ± 30
30	0-2	600 ± 51	91 ± 26
33	0-2	635 ± 45	108 ± 24
	4-6	432 ± 40	75 ± 20
	8-10	562 ± 42	108 ± 20
44	0-2	851 ± 43	146 ± 26
	4-6	786 ± 18	174 ± 30
48	0-2	799 ± 44	161 ± 27
	4-6	812 ± 46	143 ± 27
	8-10	756 ± 56	174 ± 28
49	0-2	776 ± 51	157 ± 28
	4-6	746 ± 40	168 ± 27
	8-10	731 ± 41	165 ± 27
	12-14	731 ± 38	145 ± 25
	16-18	713 ± 40	166 ± 27
50	0-2	776 ± 40	163 ± 27
	4-6	812 ± 43	183 ± 28
	8-10	782 ± 45	169 ± 29
	12-14	740 ± 39	169 ± 26
	18-20	763 ± 40	166 ± 27

TABLE XI (Continued)

Total heavy metal contents of bottom sediments (mg/kg).

Station	Depth Interval (cm)	Mn	V
51	0-2	969 ± 50	179 ± 30
	4-6	912 ± 46	177 ± 28
52	0-2	936 ± 41	165 ± 27
	4-6	889 ± 46	183 ± 31
	8-10	825 ± 45	180 ± 30
	12-14	816 ± 40	166 ± 27
	14-16	852 ± 44	152 ± 29
56	0-2	734 ± 41	138 ± 25
	4-6	621 ± 46	158 ± 27
	8-10	933 ± 43	151 ± 27
	12-14	886 ± 45	197 ± 26
57	0-2	878 ± 51	152 ± 26
	4-6	747 ± 44	144 ± 27
58	0-2	951 ± 47	176 ± 29
	4-6	789 ± 44	149 ± 27
	8-10	779 ± 49	167 ± 29
59A	Surf.*	858 ± 57	155 ± 30

*Samples from Station 59A collected in van Veen grab.

These analytical procedures also produced concurrently the data for the major ions Al and Ca given in Tables XII - XIV. Inter-laboratory standardization and precision dates will be discussed in a later report.

3. Atomic Spectrometric Determination of Soluble Mercury

(Dr. H. V. Weiss)

This is a procedure which has not been previously utilized in this program so that full details are included below. Water samples were collected at the standard northeast and northwest Gulf of Alaska stations and filtered (0.4 mμ) in the faction described previously. Aliquots of each sample have been U.V. irradiated to oxidize any metal found in organic complexes so that the data of Tables XV and XVI are for the dissolved inorganic and total soluble fractions respectively. Details of the analysis procedure used follow:

Reagents

Compressed nitrogen gas, ultrapure.

Stannous chloride solution: 200 g of reagent grade $SnCl_2.2H_2O$ was added to 60 ml of conc. HCl. This mixture was heated until complete dissolution. The volume was raised to 1-litter with 3 N H_2SO_4.

Mercury Standard

A 10 part per billion mercury standard was prepared by dilution of a 1000 part per million commercial standard (F&J Scientific) with 1.6 N HNO_3.

Instrument

Measurements were made with the Mercury Monitor (Laboratory Data Control, Riviera Beach, Fla.). This instrument was coupled to a Perkin Elmer recorder for quantification of the response.

Apparatus

A bubbler flask (250-ml) served as the sample container in which the mercury reduction occurred. One arm of the flask was attached to the source of pure nitrogen while the other to a drying tube charged with silica gel (6-16 mesh). The drying tube was connected to the entrance port of the Mercury Monitor.

A constant temperature bath (50^oC) was used to warm the sample prior to reduction and during the time of nitrogen sweep.

TABLE XII

S. Bering Sea
Discoverer Leg II June 2-19, 1975
D. E. Robertson, Analyst

Total major cation contents of bottom sediments (% dry weight).

Station	Depth interval (cm)	Al (%)	Ca (%)
08	0-2	7.29 ± 0.03	3.69 ± 0.84
	4-6	7.18 ± 0.03	3.29 ± 0.65
	8-10	9.38 ± 0.04	3.22 ± 0.37
	12-14	7.23 ± 0.03	2.92 ± 0.04
12	0-3	6.66 ± 0.03	1.93 ± 0.80
19	0-2	7.94 ± 0.03	4.63 ± 0.70
28	0-3	6.05 ± 0.03	2.31 ± 1.03
29	0-4	5.91 ± 0.02	2.09 ± 0.33
30	0-4	6.10 ± 0.07	2.97 ± 1.34
	6-8	6.26 ± 0.03	1.80 ± 1.25
	8-12	6.09 ± 0.04	2.45 ± 1.63
37	0-2	5.50 ± 0.03	2.32 ± 1.00
	4-6	5.75 ± 0.02	2.37 ± 0.70
	8-11		
41	0-2		
43	0-2		
	4-6		
56	0-2		
	4-6	5.23 ± 0.03	2.82 ± 0.53
	8-10	5.42 ± 0.03	1.61 ± 1.13
	12-18	5.60 ± 0.03	2.55 ± 1.25
59	0-2	5.10 ± 0.02	2.08 ± 0.47
	4-6	4.97 ± 0.02	1.87 ± 0.69
64	0-2	5.10 ± 0.07	3.73 ± 1.25
	4-6	5.44 ± 0.16	2.20 ± 1.66
	8-10	5.49 ± 0.03	2.82 ± 1.02
	12-14	5.81 ± 0.03	2.52 ± 0.89
	14-20	5.66 ± 0.03	2.62 ± 0.89
	20-24	5.89 ± 0.02	1.96 ± 0.73

TABLE XIII

N. W. Gulf of Alaska
Discoverer Leg IV, October 8-16, 1975
D. E. Robertson, Analyst

Total major ion contents of bottom sediments (% dry weight).

Station	Depth Interval (cm)	Al(%)	Ca(%)
104	0-2	2.40 ± 0.01	15.74 ± 0.79
	4-6	6.21 ± 0.02	10.66 ± 1.10
	8-10	5.13 ± 0.02	11.40 ± 1.05
119	0-2	7.36 ± 0.04	2.54 ± 1.07
	4-6	7.58 ± 0.03	2.53 ± 1.17
	8-10	7.66 ± 0.04	2.59 ± 0.75
120	0-2	7.57 ± 0.04	1.16 ± 1.69
	4-6	7.06 ± 0.04	2.06 ± 1.22
	8-10	7.48 ± 0.04	1.94 ± 1.37
	12-14	7.64 ± 0.04	1.71 ± 0.95
	16-18	7.24 ± 0.04	1.42 ± 1.53
121	0-2	6.95 ± 0.03	1.9 ± 1.2
	4-6	6.61 ± 0.04	<1.6%
	8-10	6.89 ± 0.04	1.97 ± 1.02
122	0-2	2.06 ± 0.02	26.9 ± 1.3
124	0-2	6.07 ± 0.03	1.8 ± 1.3
	4-6	5.63 ± 0.03	2.2 ± 0.9
	8-10	5.55 ± 0.02	2.6 ± 0.7
133	Surf.	8.13 ± 0.04	7.7 ± 1.0
134	0-2	6.69 ± 0.03	3.2 ± 1.4
	4-6	5.98 ± 0.03	3.4 ± 1.2
	8-10	7.36 ± 0.03	2.8 ± 1.2
	12-14	7.05 ± 0.04	3.2 ± 1.2
	16-18	6.75 ± 0.04	2.7 ± 1.4
135	0-2	7.46 ± 0.03	3.6 ± 1.4
	4-6	7.46 ± 0.03	3.9 ± 0.9
	8-10	7.73 ± 0.03	3.9 ± 1.1

TABLE XIV

N.E. Gulf of Alaska
Discoverer Leg III 23 November-2 December 1975
D. E. Robertson, Analyst

Total major cation contents of bottom sediments (% dry weight).

Station	Depth interval (cm)	Al (%)	Ca (%)
02	0- 2	7.11 ± 0.04	1.89 ± 0.82
	6- 8	7.91 ± 0.04	2.47 ± 0.80
	10-12	7.73 ± 0.03	1.86 ± 0.76
	14-16	7.85 ± 0.03	2.44 ± 1.03
	18-20	7.86 ± 0.04	2.70 ± 0.73
05	8-10	7.61 ± 0.04	4.33 ± 1.37
	14-16	7.24 ± 0.04	2.51 ± 0.98
26	0- 2	6.19 ± 0.03	5.29 ± 0.92
	4- 6	6.68 ± 0.03	6.93 ± 1.03
	8-10	6.38 ± 0.03	5.52 ± 0.97
	12-14	6.81 ± 0.04	5.46 ± 1.25
30	0- 2	6.70 ± 0.03	1.56 ± 1.27
33	0- 2	4.06 ± 0.03	9.62 ± 1.11
	4- 6	4.17 ± 0.02	7.42 ± 1.20
	8-10	5.16 ± 0.02	12.65 ± 0.60
44	0- 2	7.15 ± 0.03	3.81 ± 0.68
	4- 6	7.32 ± 0.12	2.45 ± 1.15
48	0- 2	7.63 ± 0.03	3.29 ± 1.06
	4- 6	7.52 ± 0.03	4.24 ± 1.22
	8-10	7.72 ± 0.03	4.39 ± 0.74
49	0- 2	7.07 ± 0.03	3.42 ± 1.32
	4- 6	7.78 ± 0.03	3.07 ± 0.77
	8-10	8.29 ± 0.04	4.22 ± 0.69
	12-14	7.77 ± 0.03	3.98 ± 0.92
	16-18	7.76 ± 0.03	2.43 ± 0.99

TABLE XIV (Continued)

Total major cation contents of bottom sediments (% dry weight).

Station	Depth interval (cm)	Al (%)	Ca (%)
50	0- 2	7.52 ± 0.04	3.34 ± 1.41
	4- 6	8.45 ± 0.04	3.14 ± 0.97
	8-10	8.08 ± 0.04	2.61 ± 1.41
	12-14	7.77 ± 0.03	2.51 ± 1.21
	18-20	7.89 ± 0.03	2.16 ± 1.04
51	0- 2	8.20 ± 0.04	2.32 ± 1.15
	4- 6	7.10 ± 0.04	2.46 ± 1.06
52	0- 2	8.07 ± 0.04	3.79 ± 1.24
	4- 6	8.76 ± 0.04	3.13 ± 0.69
	8-10	8.69 ± 0.04	3.38 ± 0.64
	12-14	8.14 ± 0.04	3.46 ± 1.23
	14-16	8.39 ± 0.04	3.18 ± 1.15
56	0- 2	6.73 ± 0.03	7.52 ± 1.08
	4-6	8.25 ± 0.04	7.93 ± 1.20
	8-10	7.78 ± 0.03	3.33 ± 0.72
	12-14	8.10 ± 0.03	3.46 ± 1.16
57	0- 2	7.06 ± 0.03	6.00 ± 1.07
	4- 6	7.41 ± 0.04	5.31 ± 0.84
58	0- 2	8.52 ± 0.04	2.81 ± 1.32
	4- 6	7.41 ± 0.03	3.31 ± 0.89
	8-10	7.96 ± 0.04	2.72 ± 1.19
59A	Surf.*	7.92 ± 0.03	2.51 ± 0.83

*Samples from Station 59A collected in van Veen grab.

TABLE XV

N. W. Gulf of Alaska
Discoverer Leg III Nov 23 - Dec 2, 1975
H. V. Weiss, Analyst.

Soluble mercury contents of filtered (0.6 μm) water (ng/1).

Station	Depth (m)	Inorganic	Total
108	226	4	4
110	10	3.9 ± 0.4 (a)	9
	273*	9	6

* Intercalibration station

(a) Duplicate

TABLE XVI

N. E. Gulf of Alaska
Discoverer Leg III Nov 23 - Dec 2, 1975
H. V. Weiss, Analyst

Soluble mercury contents of filtered (0.4 μm) water (ng/l).

Station	Depth (m)	Inorganic	Total
2	178	13	32
5	162	4	5
8	276	4	2
11	10	11	12
	1350*	4	2
15	10	24	16
	1500*	22	-
24	10	7.2 ± 0.5 (a)	2
	410*	6	7
26	10	6	4
	136	3	5
33	10	7	4
	205	3	3
44	10	27	33
	165	19.8 ± 0.5 (a)	-
48	10	11	9
	447	19	11
49	10	21	23
	120	5.5 ± 1.2 (b)	4
50	10	27	33
	107	24	26
51	10	10	10
	133	8	7
52	74	4	2
53	10	5.6 ± 0.7 (a)	5
	784	5.1 ± 0.5 (a)	2
54	10	4	4

TABLE XVI (Continued)

Soluble mercury contents of filtered (0.4 μm) water (ng/1).

Station	Depth (m)	Inorganic	Total
	202	4	5
55	10	3	3
	110	6	2
56	58	8.0 ± 1.5 (b)	3
57	67	2	-
58	82	16	2
59A	10	2	4
	370	6	3

*Intercalibration stations

(a) Duplicate

(b) Triplicate

Ultraviolet Irradiation

For the aliquots of the samples to be irradiated with ultraviolet rays, a 100 ml aliquot was placed in a quartz tube fitted with a ground quartz cap. Two drops of H_2O_2 were added and the sample was irradiated for 1-hour. The intensity of the ultraviolet source was such that mercury in the compound, methyl mercuric chloride, was quantitatively released for reduction with stannous chloride after a 1-minute irradiation.

Procedure

Samples were usually thawed at room temperature overnight and analyzed during the course of the following day. A 100-ml aliquot of the untreated or irradiated sample was transferred to the bubbler flask and the flask was immersed in the water bath for 3-5 minutes. Stannous chloride reagent (0.5 ml) was added, mixed and the apparatus was completely assembled. Nitrogen gas was passed through the solution at a rate of 1600 ml/min. The gas flow was continued until the recorded response returned to the background value.

To the mercury depleted solution a volume of mercury standard was added and the process described above was repeated. The quantity of mercury in the sample was determined by comparison of the initial with the subsequent peak-height response.

The error associated with this procedure is 20 percent, 10 percent and 6 percent at 5, 10, and 30 ng/liter levels of concentration.

4. Se & Cr by gas chrometography (Dr. T. A. Gosink)

Dr. Gosink reports no laboratory analysis work this quarter.

5. Clay mineral analysis program (Dr. A. S. Naidu)

During the last quarter, the less than 2 mμ as well as the 1 mμ (e.s.d.) fractions of 27 sediment samples from the Gulf of Alaska have been saturated separately with 1 N solutions of Mg and K, and mounted on porous porcelain plates. X-ray diffraction analyses on all of the less than 2 mμ fractions have been completed. At present X-ray analysis on the less than 1 mμ (e.s.d.) fractions of the above sediments have been half-way completed. For each of the size fractions of the above clays, at least 8 X-ray diffraction patterns are being obtained. prior and subsequent to K^+ & Mg^{++} treatments, glycolation, and heat treatments.

Treatments of the less than 2 mμ size fraction of 20 sediment samples from the southeast Bering Sea with 1N solutions of Kcl and $MgCl_2$ have been completed. The samples thus treated have been mounted on porcelain plates and are ready to be X-rayed. The less than 1 mμ fractions of the above sediments have been separated and need to be treated chemically.

6. Heavy Metal Contents of Sediment Extracts (Dr. D. C. Burrell)

Heavy metal data (mg/kg dry weight) for extracts from sediments for the south Bering Sea, northwest Gulf of Alaska and Lower Cook Inlet are given in Tables XVII - XIX. The extract technique used has been described and discussed in the Annual Report. These data were obtained at too late a date for a discussion of their significance to be included here.

III. Results

Results obtained during this quarter have been given in Tables VI - XIX above. A preliminary discussion is given in the following section.

IV. Preliminary Interpretation of Results

A. Zinc in Sea Water (Dr. D. C. Burrell)

The zinc data of Table VIII are not directly comparable with other published compilations. Total soluble zinc in open ocean waters is generally considered to be in excess of 1 μg/l. Zirino and Henley (1971), for example, have given a range of 1-2 - 2-2 μg/l for unfiltered northeast tropical Pacific waters; their values for filtered samples are frequently less than this however. By running the voltammetric analysis at *in situ* pH values we have attempted to obtain a more meaningful value for the free (uncompleted) zinc present, i.e., the fraction usually considered to be "available" to marine biota. The procedure used has been designed to minimize, as far as possible, removal of soluble hydrolized species which tend to sorb onto the container surfaces. Time series tests seem to confirm that we have been successful in this. Too few data are available at this stage of the project to warrant a detailed discussion.

B. Cd, Cu and Pb in Sea Water (Dr. D. C. Burrell)

We have accumulated a considerable volume of data now for these elements in open ocean water. Again, however, we wish to defer a more detailed discussion until the end of the contract period. Cadmium values are generally in the range 0.02 μg/l or lower (close to the detection limit by this method) and possibly show an increase with depth. Work on this important element is currently progressing in other parts of the U. S. also (e.g., by Martin off the California coast) and there are indications of correlations with the indigenous biota. This will be discussed further later. Copper and lead are generally enhanced at the surface. This latter could be due in part to contamination due to the proximity of the ship, although samples were collected from 10 m depth.

TABLE XVII

S. Bering Sea
Discoverer June 2-19, 1975

Heavy metal contents of sediment extracts (mg/kg).

Station	Cd	Cu	Ni	Zn	Fe	Mn
6	<0.25	<2.5	<2.5	6.4	-	-
8	<0.25	7.9	6.4	21.3	-	-
10	<0.25	<2.5	<2.5	7.2	-	-
12	<0.25	<2.5	<2.5	12.2	-	-
13	<0.25	<2.5	2.5	9.3	-	-
14	<0.25	<2.5	2.5	9.5	-	-
17	<0.25	<2.5	<2.5	12.2	1920	26.0
19	<0.25	<2.5	<2.5	6.1	1920	26.0
21	<0.25	<2.5	<2.5	12.0	-	-
26	<0.25	<2.5	<2.5	6.8	-	-
28	<0.25	<2.5	2.5	9.9	1850	22.7
30	<0.25	2.5	7.3	23.9	-	-
31	0.25	<2.5	<2.5	7.1	637	9.0
41	0.25	<2.5	<2.5	6.4	1466	22.7
43	0.25	<2.5	2.5	6.3	-	-
44	0.25	<2.5	<2.5	5.9	1040	16.2
57	0.25	<2.5	<2.5	6.8	-	-
59	0.25	<2.5	<2.5	4.8	1555	18.2
60	0.25	<2.5	<2.5	12.0	-	-
62	0.25	<2.5	<2.5	9.7	-	-
63	0.25	<2.5	<2.5	13.3	1756	27.3
64	0.25	<2.5	<2.5	12.0	1350	20.9
65	0.25	2.5	<2.5	10.5	915	18.8
69	0.25	<2.5	<2.5	12.5	985	21.3
56	0.25	9.9	8.2	19.3	-	-

TABLE XVIII

N. E. Gulf of Alaska
Discoverer Leg III, Nov 23-Dec 2, 1975

Heavy metal contents of sediment extracts (mg/kg).

Station	Cd	Cu	Ni	Zn
2	<0.25	6.2	5.5	30.6
5	<0.25	7.1	6.4	20.6
33	<0.25	7.2	2.0	12.3
44	<0.25	10.8	3.9	12.8
49	<0.25	12.4	11.2	37.2
51	<0.25	19.5	11.0	32.6
52	<0.25	17.3	12.6	39.2
53	<0.25	10.8	8.3	21.6
54	<0.25	13.5	8.2	22.2
55	<0.25	11.9	11.1	34.5

TABLE XIX

Lower Cook Inlet
Moana Wave March 31-April 15, 1976

Heavy metal contents of sediment extracts (mg/kg).

Station	Cd	Cu	Ni	Zn
4	<0.25	16.8	3.7	13.7
10	<0.25	16.9	7.9	34.3
11	<0.25	17.2	5.9	17.8
12	<0.25	15.1	4.1	14.7
18	<0.25	3.6	1.8	10.5
19	<0.25	3.0	<1.2	5.2
25	<0.25	3.0	1.3	11.6
26	<0.25	11.9	2.9	10.0
30	<0.25	6.7	2.9	19.6

C. Heavy metals and Major Ions in Bottom Sediments (Dr. D. E. Robertson)

These data (Tables IX - XIV) are for whole rock analyses and are hence not directly comparable with the extract data of Tables XVII - XIX (see discussion in Annual Report).

No significant systematic trends were observed in the depth distributions of V, Mn, Al, and Ca in the sediment cores. The vertical distribution of these elements to depths of up to 24 cm normally does not vary outside of the analytical uncertainty. However, there does exist significant geographical variations in the distribution of these metals. Surface sediments in the Bering Sea have average V and Mn concentrations of 95 and 514 ppm, respectively. In the northeast Gulf of Alaska the average V and Mn concentrations are 146 and 813 ppm, respectively. Similar values were also observed in the western Gulf of Alaska.

Calcium and aluminum concentrations in the northeastern Gulf of Alaska sediments are also slightly higher compared to Bering Sea sediments, averaging approximately 3.5 percent and 7.5 percent, respectively.

Within each study area significant geographical variability in the metal concentrations in the sediments frequently exist between stations. The variability appears to be somewhat random but may be strongly related to the mineralogy and texture of the sediments. No definite concentration gradients for these elements appear to extend from near-shore to offshore on the continental shelf in both the Gulf of Alaska and Bering Sea. The concentrations of these metals are quite similar to values reported for continental shelf sediments from temperate regions.

D. Mercury in Sea Water (Dr. H. V. Weiss)

These data, by atomic spectrometric analysis, are given in Tables XV and XVI.

The concentration of mercury in seawater from the Gulf of Alaska ranges from a few nanograms to several tens of nanograms per liter. The higher values appear to be situated in the region covered in the leg of the cruise extending from Station 44 to 50 via Station 15. Correlation between the concentration of mercury in surface and bottom waters at a specific location could not be established.

The treatment of water with ultraviolet rays did not provide evidence for further release of mercury. This observation suggests that the mercury in seawater exists in the free ionic readily reducible form.

E. Heavy Metals of Beaufort Sea Sediments (Dr. A. S. Naidu)

A total of 33 sediment samples from the Alaskan half of the Beaufort Sea continental shelf have been selected for analysis of Fe, Mn, Cu, Ni, Zn, and V on the gross sediments as well as on the nonlithogenous (relatively more "mobile") phases. Thus, 13 more samples have been taken up for analysis than the contract stipulated.

Subsequent to submitting the Annual Report, vanadium has been analyzed.

The following table contains summarized results of the heavy metal analysis carried out to date and partition patterns of Fe, Mn, Cu, Ni and Zn in the lithogenons and non-lithogenous sediment components of the Beaufort Sea shelf.

	Average	Average	Average per
Element	Conc. in gross sediments*	Conc. in nonlithogenous component*	Cent. nonlithogenous component in gross sediments
Fe	2.21	0.56	25
Mn	413	280	68
Cu	29	6	21
Ni	89	25	28
Zn	49	6	12

*Concentrations of Fe are expressed in wt. percents, whereas those of Mn, Cu, Ni, and Zn are in parts per million.

Thus, it would seem that except for Mn, large proportions of the other heavy metals are partitioned in the detrital sediment component, presumably 'tightly' bound in the lattice structure of silicates.

In order to understand the partition patterns of Fe, Mn, Cu, Ni, Zn, and V in the nonlithogenous components, each of the above 37 sediment samples has been treated with a mild acid/reducing agent, as suggested by Chester and Hugh (1967). Analyses of Cu and Zn have been completed on all of these leachates. Iron and Mn have been analyzed on 17 of the 33 samples, while Ni analysis on 33 leachate samples are being performed now. Aliquots of the 33 leachate samples have been retained for the purpose of conducting vanadium analysis by neutron activation at the Naval Undersea Center, San Diego. Visit by Dr. A. S. Naidu to the latter center has been scheduled for the second week of July. Aliquots of all leachate samples have been provided to Dr. Gosink for chronium analysis.

The concentrations of Fe, Mn, Cu, Ni, and Zn on all gross sediments and leachates analyzed to date have been calculated, and the percentages for the lithogenous and nonlithogenous components have been conducted for precision measurement, which has not been calculated as yet.

F. Clay Mineralogy of Northeast and Northwest Gulf and South Bering Sea (Dr. A. S. Naidu)

Preliminary analysis of bottom sediment samples by X-ray diffraction has resulted in the recognition of differences between the clay mineral ($<2\mu$ equivalent spherical diameter layer silicates) assemblages from the northeast and northwest Gulf of Alaska and the south Bering Sea. Northeast Gulf of Alaska suites are characterized by predominant illitic (40-50%) and chloritic (40-50%) components, with a subordinate (generally <10%) glycol-expandable component, and only occasional traces of kaolinite. While the northwestern Gulf of Alaska sediments are not too dissimilar in aspect, there does seem to be somewhat more (∿10%) smectite glycol-expandable components in this region, together with a slightly greater (50-60%) proportion of illite, and correspondingly less (30-40%) chlorite. These slight but discernible differences would seem most likely to be attributable to the differing general character of the proximal land-masses, (i.e., predominantly metamorphic terrane of the Chugach Mts. vs. the Alaska Peninsula, where volcanic materials are more abundant). The clay minerals of the southeastern Bering Sea are comprised of somewhat greater (20-40%) proportions of glycol-expandable components, most likely smectitic in nature, together with illitic material (20-50%), and chlorite (30-40%), while a kaolinite component also is commonly discernible (generally in amounts of 10% or less) as well as noteworthy amounts of an undetermined amorphous inorganic phase. The greater amounts of smectitic material in this region presumably represent contributions from the predominantly volcanic terranes of the Aleutian Islands, Pribilof Islands, and Nunivak Island, perhaps at least in part in the form of volcanic ash (cf. the amorphous inorganic components of these sediments), some of which may have undergone subsequent modification to a smectitic phase(s). Presumably the kaolinitic component is introduced into the area from the adjacent land-mass of mainland Alaska, most likely by the Kuskokwim River - Nushagak River system.

Thus, the generalizations regarding clay mineral compositions seem most readily attributable to differences in the nature of the source materials for the areas studied, with current patterns presumably representing additional modifying effects. However, there are some instances in which local factors may be dominant, resulting in minor deviations from the larger-scale regional clay mineral patterns. Although these regional patterns are reasonably distinct from one another, there are a few cases where the differences are less notable.

Results of the X-ray diffraction analysis of the K^+ and Mg^{++} saturated clays suggest that significant portions of the glycol-expandable mineral components are degraded illites.

Additional work is in progress, endeavoring to characterize the clay mineral components more thoroughly, in hopes of increasing our understanding of the sedimentologic, mineralogic, and geochemical relationships in these portions of the continental shelf of Alaska.

V. Problems Encountered

A. Problems obtaining biological samples continue. After considerable effort we managed to obtain a set of sub-tidal trawl samples from the Bering Sea but this was ruined when power to the storage freezer was lost. A second batch has now been obtained due to the good offices of Dr. Feder's group. This has only recently arrived, as noted above, and no laboratory work has yet been possible. Dr. Zimmermann has faithfully supplied us with intertidal material but we have received nothing from the major biological programs (NMFS and ADFG).

B. Cruises and station localities appear to be uncoordinated. As noted above, the sample grid occupied by the NMFS cruises appear to bear no obvious relationship to the standard grids used by most of the University of Alaska investigators.

C. Logistic problems continue. Dr. Gosink was cancelled from his scheduled *Surveyor* cruise April 27 - May 8 to the northeast Gulf of Alaska. Other contractual committments have prevented him from going at another time. It would appear, therefore, that no Se or Cr data will be obtained for this region.

Similarly, the *Glacier* schedule has only recently been formalized (?) and prior committments now prevent Dr. Naidu's participation.

The schedule for the *Discoverer* cruise to Norton Sound and the Chukchi Sea has recently been changed to that it now coincides with Beaufort Sea operations. We are having difficulties allocating the few available personnel.

D. Crash programs to work in areas not originally included in the Work Statement have caused endless problems. We have, for example, attempted to mount operations (at the time, unfunded) in Lower Cook Inlet but the program was hastily conceived and and unsatisfactory. We are still unclear as to the scope of the program required here; initial indicators were for sediment only, recent correspondence has included biota.

E. The major problems confronting the heavy metal program at the present time are a direct consequence of the drastic reduction of the program which will occur from October. We have, for example, the strange situation of having several sampling cruises scheduled and funded but no support for subsequent analysis. The impact on the skilled technical personnel is of greater concern, however. We have devoted considerable effort to finding and training chemical technicians especially for the OCSEAP program. The budget projected for FY '77 will necessitate many of these people being dismissed. One technician, faced with the prospect of termination in September, has already resigned and we have, obviously, been unable to find a suitable replacement for a period of these months only.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: June 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 12 R.U. NUMBER: 162/163/288/293/312

PRINCIPAL INVESTIGATOR: Dr. D. C. Burrell

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 1	2	3	4
Discoverer Leg II #808	6/2/75	6/19/75	*	9/30/76	None	*
Silas Bent Leg I #811	8/31/75	9/14/75	None	None	None	None
Discoverer Leg IV #812	10/8/75	10/16/75	*	9/30/76	None	*
Miller Freeman	8/16/75	10/20/75	None	None	Unknown	None
Discoverer Leg III #810	9/12/75	10/3/75	None	None	None	*
North Pacific	4/25/75	8/7/75	None	None	Unknown	None
Intertidal Biota		1975	None	None	Unknown	None
Discoverer #816	11/12/75	12/2/75	*	9/30/76	None	9/30/76
Contract 03-5-022-34	Last	Year	*	None	None	None

Note: [1] Data Management Plan has been approved by M. Pelto, we await approval by the Contract Officer.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 5	6	7	8
Discoverer Leg II 808	6/2/75	6/19/75	*	None	None	None
Silas Bent Leg I 811	8/31/75	9/14/75	None	None	None	None
Discoverer Leg IV 812	10/8/75	10/16/75	9/30/76	*	None	None
Miller Freeman	8/16/75	10/20/75	None	Lost	9/30/76	*
Discoverer Leg III 810	9/12/75	10/3/75	None	*	None	None
North Pacific	4/25/75	8/7/75	None	Lost	Lost	Lost
Intertidal Biota		1975	None	None	*	*
Discoverer 816	11/23/75	12/2/75	9/30/76	None	None	None
Contract 03-5-022-34	Last	year	*	None	*	*

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]	
	From	To	Batch 9	10
Discoverer Leg II 808	6/2/75	6/19/75	*	9/30/76
Silas Bent Leg I 811	8/31/75	9/14/75	9/30/76	*
Discoverer Leg IV 812	10/8/75	10/16/75	9/30/76	*
Miller Freeman	8/16/75	10/20/75	none	none
Discoverer Leg III 810	9/12/75	10/3/75	none	none
North Pacific	4/25/75	8/7/75	none	none
Intertidal Biota		1975	none	none
Discoverer 816	11/23/75	12/2/75	*	*
Contract 03-5-022-34	Last	year	*	none
Moana Wave	3/76	4/15/76	*	none
Beaufort Sea Sediments			*	*

* These data have been submitted in tabular form in the Annual and Quarterly Reports for T/O 12 including the Final report of contract 03-5-022-34.

Fifth Quarterly Report

RU # 190
Contract # 03-5-022-68
Research Units # A-27, B-9, C-2
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Baseline study of microbial activity in the Beaufort Sea and Gulf of Alaska and analysis of crude oil degradation by psychrophilic bacteria.

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I. Task Objectives

A. General nature and scope of study

Our objective was to study the baseline levels of microbial activity in the Beaufort Sea and Gulf of Alaska during both the summer and winter seasons. In addition, we were to evaluate the effects of crude oil on microbial activity and to analyze the process of hydrocarbon degradation by psychrophilic hydrocarbon utilizing bacteria isolated from the Beaufort Sea.

B. Specific objectives

1. Determination of the relative heterotrophic potential in natural marine microbial populations (task number A-27). Studies include representitive samples of both water and sediments in different geological locations and under contrasting seasonal conditions. These studies were to be designed to give an estimate of the natural variations to be expected in microbial activity in the waters and sediments of the Beaufort Sea and Gulf of Alaska.

2. Isolation and characterization of psychrophilic hydrocarbon utilizing marine bacteria which are capable of degrading and/or emulsifying crude oil at relatively high rates under the conditions found in the Beaufort Sea (task number B-9). Strains of bacteria having the above characteristics were to be isolated from crude oil enrichment cultures using natural samples taken from the Beaufort Sea as the inoculum. After isolation and purification, the strains were to be subjected to a number of basic physiological studies which would determine the function of these organisms under the conditions found in the Beaufort Sea.

3. Determination of the acute effects of crude oil on the heterotrophic activity of the natural microbial populations found in the Beaufort Sea (task number C-2). These studies were to be supplemented with longer term studies which would be designed to obtain information about how crude oil affects the natural population and how, in turn, the natural population alters the crude oil.

4. Coordination of our studies with the microbial studies of Dr. Atlas and his associates to obtain the most comprehensive data possible on the role of marine bacteria in the marine ecosystems in both the Beaufort Sea and the Gulf of Alaska. To accomplish this end, our baseline studies were to be made using the same samples. In addition, a close liaison was to be established to insure the least possible duplication of effort. In addition, we were to collect subsamples to be analyzed for inorganic nutrient concentrations by Dr. Alexander.

C. Suggested objectives for future research

1. Potential *in situ* rates of crude oil degradation and emulsification by microbial processes.

To date, there have been very few studies of crude oil biodegradation in polar marine ecosystems. This information is absolutely required if informed managerial decisions are to be made concerning the best possible course of action to take in the event of an oil spill and to properly assess the potential long term effects of a spill under a given set of circumstances. These types of data are currently being collected by our research team but a great deal more must be learned before a comprehensive picture is obtained.

2. The effects of crude oil on the bacteria involved in nutrient and geochemical cycles.

Bacteria are the single most important factor in the recycling of sulfur, phosphorous, nitrogen, and carbon in the marine ecosystem. It is also important in such vital functions as nitrogen fixation and the degradation of relatively recalcitrant compounds such as chitin. At the present time, very little is known about the effects of crude oil on the function of the bacteria involved in these transformations. It is possible that crude oil may perturb one or more of these vital functions which would, in turn, greatly affect the potential recovery of the entire ecosystem. Without information about these vital functions, long term effects of crude oil spills on primary productivity and biological activity at the higher trophic levels will be impossible to assess.

3. Assessment of the long term effects of crude oil pollution on restricted ecosystems.

An interdisciplinary study of the potential long term impact of crude oil on a well defined representative ecosystem should be attempted. Since the function of bacteria in such a system is basic to what will eventually occur at higher trophic levels, an assessment of bacterial function must be made.

II. Field and Laboratory Activities

A. Field trip schedule

1. During this period, we participated in two field trips. The first was a cruise on board the NOAA ship Discoverer from March 16, 1976 to March 27, 1976.

2. The second field trip was conducted at NARL (Barrow, AK) from March 31, 1976 to April 21, 1976. Transects were run using the chartered ERA helicopter on April 5, 7, 10, 16, and 18, 1976 and using the NOAA helicopter stationed at Prudhoe Bay on April 12 and 14. One station was taken using a truck on April 9, 1976.

B. Scientific party

1. All of the personnel involved in this project are in the Department of Microbiology, Oregon State University. Dr. Griffiths was the only person participating in the field trips mentioned above. The other two were conducting related laboratory studies at Oregon State University.

2. Personnel:

Dr. Robert P. Griffiths, Co-Investigator
Dr. Thomas Goodrich, Post-Doctorate Research Associate
Mr. Thomas McNamara, Technician

C. Methods

1. Sampling procedures

a. Discoverer cruise

The water samples were taken in sterile Niskin plastic water sample bags fitted on Niskin "butterfly" water samplers. All samples were taken within two meters of the surface and were processed within two hours after they were collected.

All sediment samples except the beach samples taken at stations a, b, d and f were taken with a Van Veen grab. Approximately 150 grams of surface sediment were taken as a representitive sample at each station.

b. Beaufort Sea field trip

Nine inch holes were drilled through the ice using a power head and 9 inch auger. Water samples were taken using the Niskin "butterfly" water samplers in all but four samples (#BW101, 102, 103 and 104). These four samples were taken using a sterile vacuum flask sampler (our own design). The water samples were kept in an ice chest from the time they were taken to the time they were received at NARL for processing. This procedure prevented the samples from freezing while enroute to the laboratory. All samples were processed within four hours after they were taken.

The sediment samples were taken with a Kahl scientific mud snapper. One or two grap samples were taken at the same time and location and combined with the seawater within the grab. These samples were placed into sterile 250 ml wide mouth glass sample bottles for transport to the laboratory. All samples were maintained at or slightly below the *in situ* temperature during sampling and transport.

Ice samples were taken from the ice shavings that resulted from drilling the hole through the ice. These samples were placed into sterile sample bags for transport to and storage at the laboratory. The ice samples were melted at 5 C for 24 hours prior to processing.

2. Heterotrophic potential studies

The techniques used in this study were basically those of Hobbie and Crawford (1969) as further modified by Harrison, Wright, and Morita (1971). This procedure involves the addition of different concentrations of U-^{14}C labeled substrate to identical subsamples. After addition of the subsample, the 50 ml serum bottles that were used for reaction vessels were sealed with rubber serum bottle caps fitted with plastic rod and cup assemblies (Kontes Glass Co., Vineland, N.J.:K-882320) containing 25 x 50 mm strips of fluted Whatman #1 chromatography paper. The samples were incubated in the dark within 0.5 C of the in situ temperature. After the incubation period, the bottles were injected through the septum with 0.2 ml of 5N H_2SO_4 in order to stop the reaction and release the $^{14}CO_2$. After the addition of the acid, 0.15 ml of the CO_2 absorbent, β-phenethylamine, was injected onto the filter paper. The bottles were then shaken on a rotary shaker at 200 rpm for at least 45 minutes at room temperature to facilitate the absorption of CO_2. The filter papers containing the $^{14}CO_2$ were removed from the cup assemblies and added to scintillation vials containing 10 ml of toleune based scintillation fluor (Omnifluor, New England Nuclear).

The subsamples were filtered through a 0.45 μm membrane filter (Millipore). The trapped cells on the filter were washed with three 10 ml portions of seawater at 0-3 C. The filters were dried and then added to scintillation vials containing 10 ml of the above mentioned fluor. The vials were counted in a Beckman model LS-100 C liquid scintillation counter located in the field laboratory or they were counted on a Nuclear Chicago Mark I liquid scintillation counter located in our laboratory at Oregon State University.

In the sediment samples, a 1.0 ml subsample was diluted with a 32 o/oo (w/v) solution of sterile artificial seawater. After dilution, the sediment sample was treated the same way as a water sample. Duplicate one ml subsamples of the sediment slurry were dried and weighed to determine the dry weights. These dry weights were used to calculate the V_{max} values in terms of grams dry weight of sediment.

During the Discoverer cruise, (U-^{14}C) L-glutamic acid with a specific activity of 230 mCi/mmole (New England Nuclear) was used in all water samples. The range of glutamic acid concentrations in the reaction vessels was from 0.6 μg/liter to 4.6 μg/liter. With the exception of sediment sample number 101GB, all sediment samples were exposed to glutamic acid concentrations in the range of 10.5 μg/liter to 84 μg/liter using (U-^{14}C) L-glutamic acid with a specific activity of 10 mCi/mmole. Duplicate subsamples were used at each of four substrate concentrations. The average incubation temperature used during the cruise was 4 C which was within 1 C of the in situ surface water temperature. The length of incubation varied from 9 to 12 hours.

During the Beaufort Sea study, all sediment and water samples were exposed to glutamic acid with a specific activity of 230 mCi/mmole. The range of glutamic acid concentrations in the reaction vessels was from 0.6 μg/liter to 4.6 μg/liter. The average incubation temperature used was -1.0 C and the length of incubation varied from 8 to 11 hours. All samples were incubated in the dark.

3. Calculations

Calculation of the kinetic parameters was made from the relationship:

$$\frac{Cut}{c} = \frac{K_t + S_n}{V_{max}} + \frac{A}{V_{max}}$$

where c = radioactivity assimulated plus that respired as $^{14}CO_2$ by the heterotrophic population in disintegrations/min; S_n = the natural substrate concentration in µg/liter; A = the added substrate in µg/liter; C = 2.2 x 10^6 µCi of ^{14}C; u = amount of ^{14}C labeled substrate added/sample bottle in µCi; t = incubation time in hours; V_{max} = the maximum velocity of uptake in µg x liter^{-1} x h^{-1}; and K_t = the transport constant in µg/liter. From this equation can also be calculated the time (T_t) in hours required by the natural microbial population to utilize the natural substrate in the seawater sample. For the derivation of this equation and the assumptions on which it is based, see Wright and Hobbie (1966). Saturation curves were converted to the best fitting straight line using least squares and a modified Lineweaver-Burk equation.

The percent respired was calculated by dividing the amount of labeled carbon associated with the CO_2 fraction by the total amount of substrate taken up by the cells (both cell and $^{14}CO_2$ radioactivity) and multiplying this ratio by 100.

4. Temperature study

The water sample used in this study was taken from station #3 in Elson Lagoon. Duplicate subsamples were prepared as described above and incubated at each of the temperatures indicated in Figure 3. In cases where there were fluctuations in the incubation temperature, the temperature reported is the mean temperature (in most cases, the temperature range was less than one degree C). In order to reduce the chance of significantly altering the substrate concentrations during the course of the experiment, the incubation time for samples incubated at high temperatures was reduced. Samples at the following temperatures were incubated for the following periods: 20, 15 and 10 C, 6 hours; 4 and -1 C, 8.5 hours.

5. Acute effects of crude oil extract on the observed heterotrophic potential

Five ml of crude oil taken from Prudhoe Bay was added to 45 ml of sterilized seawater in a 150 ml separatory funnel. The mixture was shaken and allowed to separate for three hours at 5 C. The aqueous phase was removed into another separatory funnel and allowed to set for an additional 1/2 hour before dispensing one ml subsamples of the aqueous phase into the reaction mixtures. Each reaction vessel contained 9 ml of the seawater sample to be tested and one ml of the crude oil extract. In the controls, the one ml of crude oil extract was replaced by one ml of sterile seawater. Heterotrophic potential was measured using labeled glutamic acid as described above.

6. Direct Cell Counts

Ten ml of seawater was fixed in the field laboratory by adding it to 0.6 ml of membrane (0.45 μm) filtered formaldehyde (37%). The vials containing the fixed water samples were sealed and stored until they could be counted in our laboratory at Oregon State University. In the sediment studies, the final dilution of the sediments in the heterotrophic potential studies was used and treated the same as the seawater samples.

From 5 to 17 ml of sample were filtered through a 0.2 μm Nuclepore filter. When a relatively high number of organisms was present, the samples were diluted with membrane filtered artificial seawater. The number of organisms per field was kept within acceptable limits and the volume filtered was kept above 5 ml. Controls were run using filtered artificial seawater and all of the reagents used in the staining and mounting procedure. These counts were no more than 5% of those found in the samples and were considered insignificant.

The staining procedure used was that of Zimmermann and Meyer-Reil (1974). This procedure involves staining the cells trapped on the membrane filter with acridine orange and then destaining with iso-propyl alcohol. The membranes were dried and mounted on microscopic slides with a mounting medium of cinnamaldehyde and eugenol (2:1).

The bacterial cells were counted using a Zeiss IV Fl epi-fluorescence condenser microscope fitted with filters KP 500, KP 490, FT 510, and LP 520. The eyepiece used was Kpt W 12.5 x and the objective was plan 100 x. Approximately 50 restriction fields were counted per sample. Representative fields were counted from the center of the membrane filter to the outside edge of the filtration circle.

Only bodies with distinct fluorescence (either orange or green), clear outline and recognizable bacterial shape were counted as being bacterial cells.

7. Biochemical studies of arctic bacterial isolates

The methods and taxonomic key used in this study are those of Bain and Shewan (1969).

8. References

Bain, N. and J. M. Shewan. 1969. Identification of Aeromonas, Vibrio, and related organisms. In B. M. Gibbs and D. A. Shapton (ed.), Identification Methods for Microbiologists, Part B. pp 79-84.

Harrison, M. J., R. T. Wright, and R. Y. Morita. 1971. Method for measuring mineralization in lake sediments. Appl. Microbiol. 21: 698-702.

Hobbie, J. E., and C. C. Crawford. 1969. Respiration corrections for bacterial uptake of dissolved organic compounds in natural waters. Limnol. Oceanogr. 14:528-532.

Zimmermann, R., and L.-A. Meyer-Reil. 1974. A new method for fluorescence staining of bacterial populations on membrane filters. Kieler Meeresforschungen. 30:24-27.

D. Sample Locations

The locations and sampling dates for all work in the Gulf of Alaska are given in Table 1. The sampling sites are graphically illustrated in Figure 1. All sample were taken from the NOAA ship Discoverer during leg 2 of project number RP-4-01-76A.

The sample locations and dates for all work in the Beaufort Sea area are listed in Table 5. The sampling sites are illustrated in Figure 2.

E. Data collected

During the Gulf of Alaska cruise, we measured heterotrophic potential and bacterial concentrations in 27 water samples and 20 sediment samples. Of these samples 7 water samples and 4 sediment samples were taken along the beach.

During the Beaufort Sea study, 23 water and 14 sediment samples were studied. In addition, three ice melt samples were analyzed.

Approximately 200 miles of trackline were covered during the Beaufort Sea studies and about 660 miles were covered during the Gulf of Alaska cruise.

III. Results

A. Gulf of Alaska

During the period March 16 to March 27, 1976 we participated in an oceanographic cruise on board the NOAA ship Discoverer. Twenty-seven water and twenty sediment samples were taken at the stations shown in Figure 1. The date of sampling, station and sample numbers, position and distance from shore of each station are given in Table 1. Measurements of salinity, temperature, the maximum potential glutamic acid uptake (V_{max}) and percent respiration are given for all water samples in Table 2. The average V_{max} value for offshore water samples was 1.4×10^{-3} µg glutamic acid x liter^{-1} x hr^{-1} and the range was from 0.3×10^{-3} to 3.4×10^{-3} (Table 3). The average percent respiration was 72 with a range of 53 to 93. The average water sample temperature was 3.8°C with a range of 2 to 5 and the average salinity was 31.9 o/oo with a range of 30.7 to 32.5.

The V_{max} values for glutamic acid uptake in the sediment samples are still being calculated; however, the average percent respiration was 44 with a range of 30 to 72 (Table 4). Subsamples of both water and sediment samples were fixed for direct bacterial count measurements using epifluorescent microscopy. These data are still being processed.

B. Beaufort Sea

During our 1976 winter field study period in the Beaufort Sea, we collected and analyzed 23 water, 14 sediment and 3 ice samples. The location of the stations sampled are shown in Figure 2. The date of sampling, the station number, sample number, position, and distance from shore are given for all samples in Table 5. Measurements of salinity, temperature, V_{max} and percent respiration are given for all water samples tested (Table 6). The average V_{max} value was 3.1×10^{-3} μg x liter^{-1} x hr^{-1} and the range was from 0.2×10^{-3} to 14×10^{-3} (Table 3). The average percent respiration in the water samples was 85 and the range was from 52 to 100 percent. The average water sample temperature was -1.9°C with a range of -2.0 to -1.5. The average salinity was 24 o/oo with a range of 17 to 29. The average percent respiration in the sediment samples was 45 and the range was from 35 to 87 percent.

Three ice samples were analyzed for heterotrophic activity using the same techniques used in the water samples. The average V_{max} was 2.3×10^{-3} μg glutamic acid x liter^{-1} x hr^{-1}. The average percent respiration for these samples was 98%.

The effect of incubation temperature on the apparent V_{max} in a water sample was tested. The results of this experiment are given in Figure 3.

C. Laboratory studies at Oregon State University

Work has continued on the characterization of selected psychrophilic or psychrotrophic strains of bacteria which were isolated from oil enrichment cultures taken from the Beaufort Sea. The growth temperature profiles for all strains listed in Table 7 except strains G-3 and G-6 were presented in the first annual report. The other characteristics tested to date are presented in Table 7. We do not have enough information at this time to give a positive identification to the genus level on all of the strains listed but the following tentative identifications can be made. Strains 30, 45 and 47 probably belong to the genus *Vibrio*; strains 52, 53, and 59 belong to the Arthrobacter-Coryneform group; strain G-3 is most probably of the genus *Pseudomonas*; strain G-6 belongs to the Vibrio-Aeromonas group.

We have just recently received our gas chromatograph and as a result we do not have any data to report on the effects of certain key environmental factors on hydrocarbon utilization by these strains. Work has progressed on the long term experiments on the effects of crude oil on natural microbial populations. These data will be presented in a subsequent report after enough data has been accumulated to insure a reasonably accurate interpretation of the results.

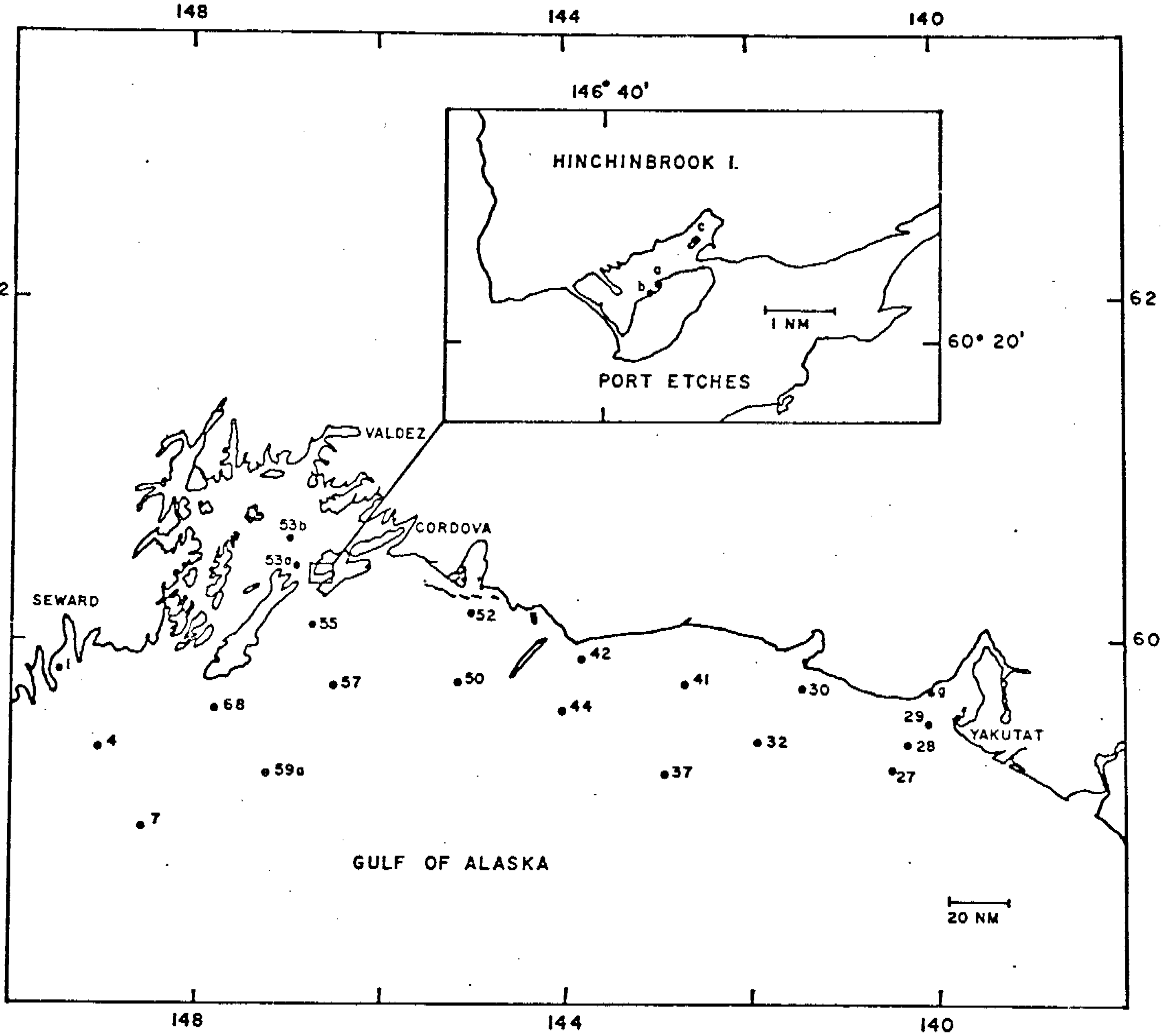

Figure 1. Stations sampled in the Gulf of Alaska during the March, 1976 cruise on the NOAA ship Discoverer.

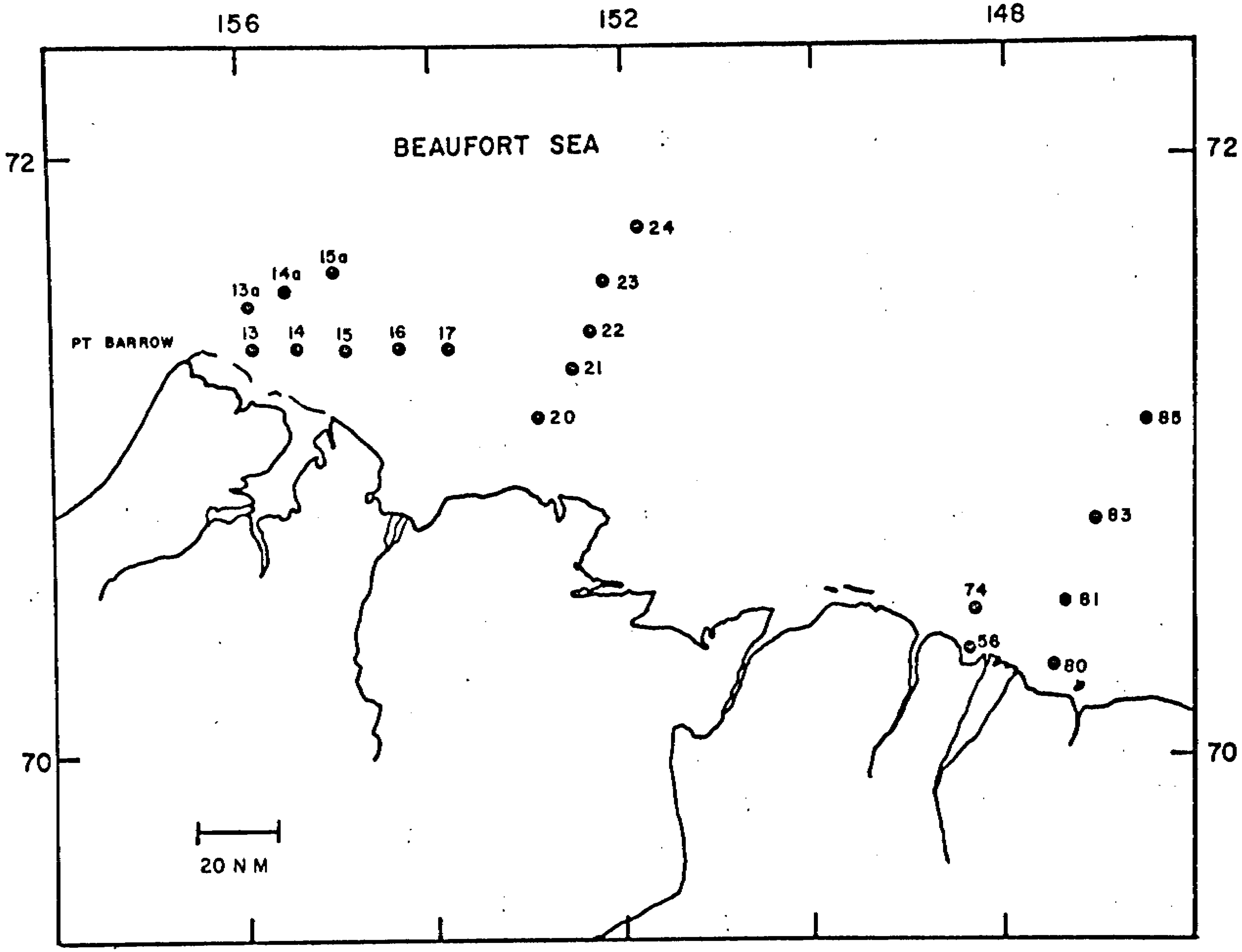

Figure 2. Stations sampled in the Beaufort Sea during April, 1976.

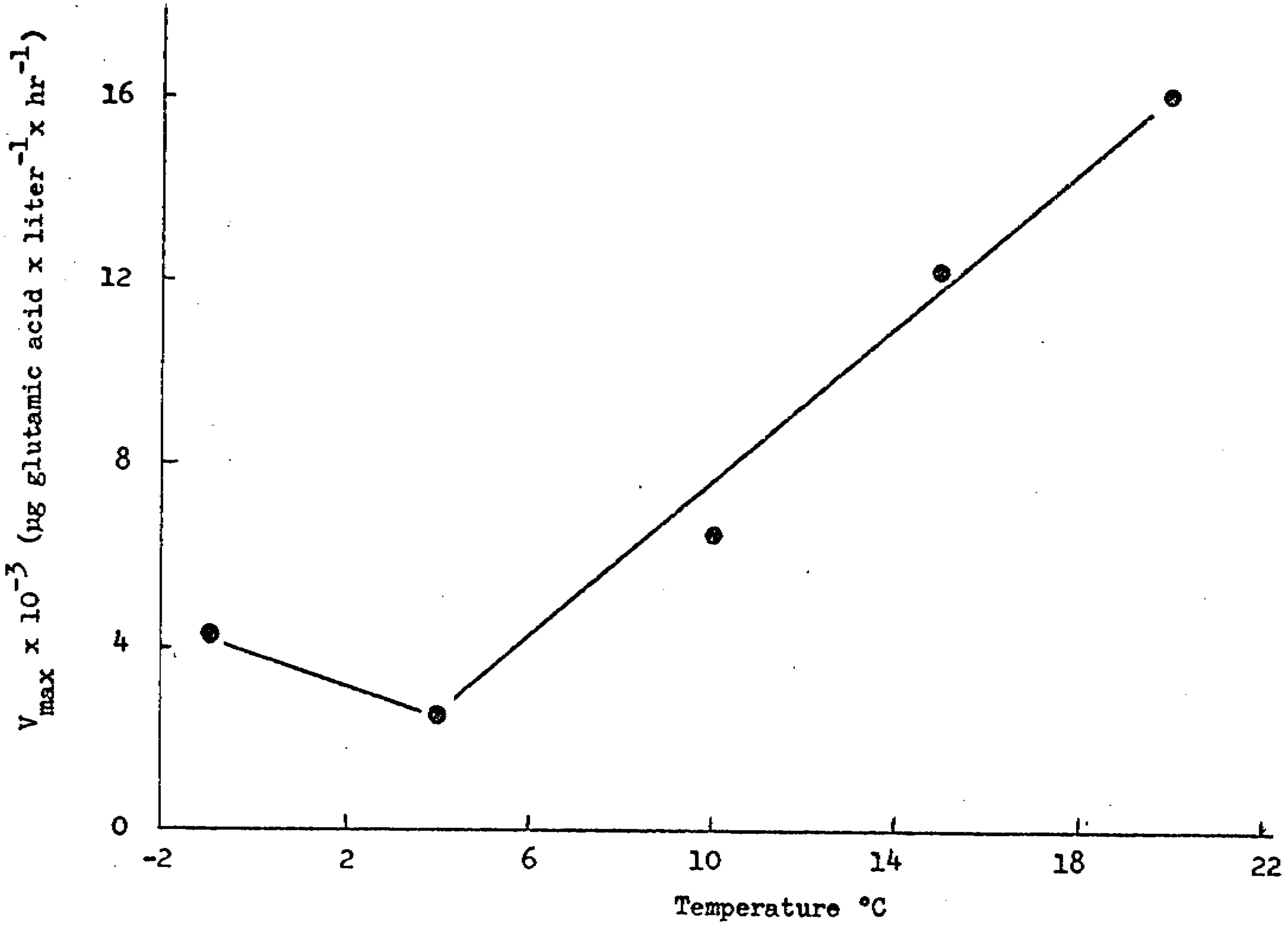

Figure 3. The effects of incubation temperature on apparent V_{max} values.

Table 1. Date of sampling, sample number, station number and position information on samples taken in the Gulf of Alaska during the Discoverer cruise.

DATE	STATION NUMBER	WATER SAMPLE NUMBER	SEDIMENT NUMBER	LAT.		LONG.		DISTANCE FROM SHORE IN NM
3/15	d	GW 201	GB 201	57°	39'	152°	30'	0
3/17	1	GW 202	GB 202	59	50.3'	149	30.4'	4
3/18	4	GW 203	GB 203	59	24.6'	149	04.2'	25
3/18	7	GW 204	GB 204	58	58.8'	148	39.5'	55
3/18	68	GW 205	---	59	38.3'	147	48.0'	10
3/19	59a	GW 206	GB 206	59	17.2'	147	15.6'	37
3/19	57	GW 207	GB 207	59	45.5'	146	31.0'	30
3/19	55	GW 208	---	60	04.7'	146	44.4'	11
3/20	e	GW 209	---	60	06.8'	149	33.2'	0
3/21	53a	GW 210	GB 210	60	23.3'	146	54.5'	4
3/21	53b	GW 211	GB 211	60	32.5'	147	00.6'	10
3/21	52	GW 212	GB 212	60	08.8'	145	02.2'	6
3/21	50	GW 213	GB 213	59	47.0'	145	10.2'	17
3/22	42	GW 214	GB 214	59	54.3'	143	52.3'	6
3/22	44	GW 215	---	59	38.1'	144	02.0'	19
3/22	37	GW 216	GB 216	59	16.7'	142	56.9'	49
3/23	41	GW 217	GB 217	59	45.9'	142	44.0'	21
3/23	30	GW 218	GB 218	59	44.2'	141	29.0'	8
3/23	32	GW 219	GB 219	59	27.1'	141	48.5'	31
3/24	f	GW 220	GB 220	59	32.2'	139	47.1'	0
3/24	g	GW 221	---	59	44.7'	140	07.5'	0
3/25	29	GW 222	---	59	34.5'	140	06.6'	9
3/25	28	GW 223	GB 223	59	26.7'	140	19.0'	16
3/25	27	GW 224	GB 224	59	18.4'	140	29.6'	24
3/26	a	GW 225	GB 225	60	20.8'	146	38.4'	0
3/26	b	GW 226	GB 226	60	20.6'	146	38.5'	0
3/26	c	GW 227	---	60	21.4'	146	37.4'	0

Table 2. Summary of physical and heterotrophic potential data collected for all water samples taken from the Gulf of Alaska during the March, 1976 Discoverer cruise. The V_{max} is the maximum potential velocity for both macromolecular synthesis and respiration, reported as μg x $liter^{-1}$ x hr^{-1}. The substrate used in these studies was (U-^{14}C) L glutamic acid. (*) indicates those samples taken from the beach. (low) indicates those samples with activities that were too low to give an accurate estimate of V_{max}. (high) indicates those samples with such high activity that no saturation curve could be established.

Sample number	Station number	Sample temp. ^oC	Salinity o/oo	Vmax x 10^{-3}	Percent respiration
*GW201	d	2.0	31.4	113	62
GW202	1	3.0	31.7	low	57
GW203	4	3.5	32.2	0.9	58
GW204	7	3.5	32.3	2.0	65
GW205	68	3.5	32.1	1.5	77
GW206	59a	4.0	32.2	low	73
GW207	57	4.0	32.1	1.0	71
GW208	55	4.0	31.9	0.9	93
*GW209	e	3.0	31.1	9.7	76
GW210	53a	3.0	31.8	1.9	71
GW211	53b	3.0	31.8	1.1	64
GW212	52	3.2	31.7	low	80
GW213	50	3.4	31.8	0.6	81
GW214	42	4.1	32.1	low	86
GW215	44	3.0	32.2	1.5	74
GW216	37	4.5	32.5	3.4	64
GW217	41	5.0	32.2	2.4	69
GW218	30	3.8	31.7	0.7	81
GW219	32	4.5	32.2	0.3	71
*GW220	f	3.0	32.2	49.4	78
GW221	g	4.0	30.7	1.3	53
GW222	29	4.2	31.9	erratic	89
GW223	28	4.7	32.2	low	89
GW224	27	4.8	32.2	1.7	69
*GW225	a	5.0	31.1	89.4	63
*GW226	b	5.0	30.7	high	55
*GW227	c	3.2	31.3	53.3	64

Table 3. Data summary of the average values measured during all field studies.

Factor	Units	Beaufort Sea Summer 1975		Beaufort Sea Winter 1976		Gulf of Alaska Winter 1976	
		Ave.	Range	Ave.	Range	Ave.	Range
$V_{max} \times 10^{-3}$ (Offshore water)	$\mu g \times liter^{-1} \times hr^{-1}$	40	4 to 118	3.1	0.2 to 14	1.4	0.3 to 3.4
$V_{max} \times 10^{-3}$ (Beach water)	$\mu g \times liter^{-1} \times hr^{-1}$	-	- -	-	- -	63.0	9.7 to 113
Percent Respiration (water)	%	59	44 to 76	85	52 to 100	72	53 to 93
Percent Respiration (sediments)	%	43	32 to 71	45	35 to 87	44	30 to 72
Sample Temperature	°C	1.2	-0.8 to 3.2	-1.9	-2.0 to -1.5	3.8	2.0 to 5.0
Sample Salinity (water)	o/oo	20.5	9.0 to 26.5	24	17 to 29	31.9	30.7 to 35.5

Table 4. Percent respiration observed in sediment samples taken from the Beaufort Sea and Gulf of Alaska.

Beaufort Sea		Gulf of Alaska	
Sample Number	Percent Respiration	Sample Number	Percent Respiration
BB101	53	GB201	41
BB102	56	GB202	35
BB103	87	GB203	34
BB104	36	GB204	33
BB105	38	GB206	40
BB106	39	GB207	27
BB107	38	GB210	36
BB108	41	GB211	30
BB109	43	GB212	41
BB111	47	GB213	42
BB112	35	GB214	45
BB113	44	BG216	69
BB114	37	GB217	40
BB115	40	GB218	72
		GB219	49
		GB220	59
		GB223	49
		GB224	39
		GB225	50
		GB226	46

Table 5. Sampling date, sample number, station number and position information on samples taken in the Beaufort Sea during April, 1976.

DATE	STATION NUMBER	WATER SAMPLE NUMBER	SEDIMENT NUMBER	LAT.	LONG.	DISTANCE FROM SHORE IN NM
4/5	13a	BW 101	___	71° 30'	156° 06'	18
4/5	14a	BW 102	___	71 34.5'	155 35'	28
4/5	15a	BW 103	___	71 39'	155 04'	37
4/5	3	BW 104	___	71 21.6'	156 21.0'	0.5
4/7	13	BW 105	BB 101	71 23'	155 56'	11
4/7	14	BW 106	BB 102	71 23'	155 26'	17
4/7	15	BW 107	BB 103	71 23'	154 54'	18
4/9	3	BW 107a	___	71 21.6'	156 21.0'	0.5
4/10	2	BW 108	BB 104	71 21.4'	156 27'	1.5
4/10	3	BW 109	BB 105	71 21.6'	156 21'	0.5
4/12	81	BW 112	BB 107	70 31'	147 24'	22
4/12	80	BW 113	BB 108	70 18'	147 30'	7
4/12	74	BW 111	BB 106	70 32'	148 27'	11
4/14	85	BW 110	___	71 08'	146 30'	72
4/14	83	BW 114	BB 109	70 47'	147 00'	42
4/16	24	BW 116	___	71 46'	151 52'	72
4/16	23	BW 117	___	71 36'	152 12'	56
4/16	22	BW 118	BB 111	71 26'	152 22'	43
4/16	21	BW 119	BB 112	71 19'	152 33'	37
4/18	20	BW 120	BB 113	71 08'	152 55'	18
4/18	17	BW 121	BB 114	71 23'	153 50'	33
4/18	16	BW 122	BB 115	71 23'	154 22'	25
4/18	14a	BW 123	___	71 34.5'	155 35'	28

Table 6. Summary of physical and heterotrophic potential data collected in the Beaufort Sea during the April, 1976 field study period. The Vmax is the maximum potential velocity for both macromolecular synthesis and respiration reported as μg glutamic acid x $liter^{-1}$ x hr^{-1}. (p) indicates that these stations are located near Prudhoe Bay. (pp) indicates that these stations are located in the Pitt Point area. All other stations were located near Point Barrow.

Sample number	Station number	Sample temp. °C	Salinity o/oo	Vmax x 10^{-3}	Percent respiration
BW101	13a	-1.6	28	14	98
BBW102	14a	-2.0	22	12	96
BW103	15a	-2.0	19	4.2	96
BW104	3	-2.0	25	5.4	81
BW105	13	-2.0	25	5.4	96
BW106	14	-2.0	22	2.0	100
BW107	15	-2.0	17	0.9	99
BW107a	3	-2.0	25	4.3	69
BW108	2	-2.0	31	1.1	68
BW109	3	-2.0	29	0.7	54
BW110	85 (p)	-2.0	23	4.2	98
BW111	74 (p)	-1.5	28	2.8	90
BW112	81 (p)	-2.0	28	0.5	94
BW113	80 (p)	-1.5	29	0.7	85
BW114	83 (p)	-2.0	17	1.0	97
BW116	24 (pp)	-2.0	24	0.4	78
BW117	23 (pp)	-2.0	21	0.2	69
BW118	22 (pp)	-2.0	19	0.2	52
BW119	21 (pp)	-2.0	20	low	73
BW120	20 (pp)	-2.0	26	2.1	93
BW121	17	-2.0	28	1.4	94
BW122	16	-2.0	29	2.1	88
BW123	14a	-1.5	28	low	90

Table 7. Biochemical and growth characteristics of psychrophilic and psychrotrophic bacterial strains isolated from crude oil agar plates.

	Strain number							
Characteristic	30	45	47	52	53	59	G-3	G-6
gram reaction	-	-	-	+	+	+	-	-
growth on broth								
pellicle	-	-	-	-	-	-	+	-
ring	+	+	+	+	+	+	-	+
granular	-	-	-	-	-	-	+	-
even	+	+	+	+	+	+	-	+
slight	-	-	-	+	+	+	-	-
heavy	+	+	+	-	-	-	+	+
growth at various salinities								
0% NaCl	-	-	-	+	+	+	+	+
3% NaCl	+	+	+	-	#	-	+	+
10% NaCl	-	-	-	-	-	-	+	+
3.5% (W/V) Rila Salts	+	+	+	+	+	+	+	+
growth on special media								
Hugh Liefson (aerobic)	@	@	@	@	@	@	@	@
Hugh Liefson (anaerobic)	@	@	@	-	-	-	-	@
Simmon's citrate	+	+	+	-	-	-	#	#
antibiotic sensitivity								
penicillin	-	-	-	-	-	-	-	-
pteridine 0-129	-	-	-	-	-	-	-	-
enzyme production								
oxidase	+	+	+	-	-	-	+	+
catalase	*	*	*	*	*	*	#	+
chitinase	+	+	+	-	-	-	-	-
lipase	+	+	+	-	-	-	+	+
lysine decarboxylase	#	#	#	-	-	-	-	#
arginine "	-	-	-	-	-	-	-	-
ornithine "	-	-	-	-	-	-	-	-
gelatinase	+	+	+	#	#	#	+	+
nitrate reduction	+	+	+	-	-	-	#	+
indole production	+	+	+	-	-	-	-	-

#	marginal or weak reaction
@	growth with acid production
*	very strong reaction

IV. Preliminary interpretation of results

The maximum potential uptake of glutamic acid (V_{max}) was measured in water samples taken in both the Gulf of Alaska and the Beaufort Sea. The overall average V_{max} value measured in water samples taken offshore in the Gulf of Alaska was approximately one half that observed in the Beaufort Sea a few weeks later. Although direct count data from these samples is not yet available to us, Dr. Atlas observed that the concentration of bacteria as determined by both direct and indirect counts was significantly higher in the Beaufort Sea than in the Gulf of Alaska during his fall 1975 field study period. This same trend was observed in the indirect counts made on the same samples used in this study (R. M. Atlas, personal communication). These data suggest that, in general, the relative microbial activity in the Gulf of Alaska may be significantly lower than that found in the Beaufort Sea.

There was a marked difference between the V_{max} values observed in the 7 beach water samples and the offshore water samples taken in the Gulf of Alaska (Table 2 and 3). All of the samples taken on the beach showed much higher activity than any of those observed in the offshore samples (the average values were 63×10^3 and 1.4×10^3, respectively). The main factor affecting the level of activity in the beach water did not appear to be the proximity to potential sources of pollution but rather the degree of mixing with the sediment. Of the beach water samples tested, the one showing the lowest activity was taken a few meters from the ferry pier at Seward (station e, sample GW209). This was the only beach sample taken from a rocky beach. The samples taken from an area which should have been least influenced by pollution from population centers (stations a, b, and c) showed very high activity. One water sample was taken within 50 meters of the beach in Yakutat Bay and showed a V_{max} value which was the same as the average value for offshore water samples. Of course it is difficult to say much about one observation but it seems quite likely that the high values observed in beach water samples may be restricted to a relatively narrow zone along the beach. How this high activity along the beach might affect the potential for oil biodegradation in this region remains to be studied. We have shown in our work in the Beaufort Sea last summer that the activity in the sediments in shallow waters are much greater than that found in the water column itself. It thus seems reasonable that along the shoreline where the water and sediment are constantly being mixed and where nutrients are likely to accumulate, there should be relatively high microbial activity.

During our studies in the Beaufort Sea, we were able to measure the heterotrophic potential at the same station at different times. These studies were conducted in an attempt to determine the magnitude of the variation that naturally occurs at a given location. The heterotrophic potential of the microflora in water samples taken from station #3 in Elson Lagoon was measured on three different occasions (Table 6). The observed values ranged from 0.7×10^3 to 5.4×10^{-3} μg x liter^{-1} x hr^1. The other station where a similar comparison was made was number 14a. When tested on 4/5/76, the V_{max} was one of the highest observed in this area (1.2×10^{-2}); yet when the same location was sampled again 13 days later, the activity was too low to obtain an accurate measurement.

Another factor which was measured in both water and sediment samples was the percent respiration which is analogous to microbial mineralization of substrate. The percent respiration observed in the sediments was approximately the same in both the Beaufort Sea and the Gulf of Alaska, and there was also very little difference between the percentages observed in the summer and winter in the Beaufort Sea (Table 3). In contrast to this homogeneity, there were differences seen between the percent respiration observed in the water samples tested in the Beaufort Sea (85%) and the Gulf of Alaska (72%) in the winter and that observed in the summer in the Beaufort Sea (59%). In all cases, the average percent respiration found in the water samples was significantly higher than that found in the sediments. The very high percent respiration observed in the winter Beaufort Sea samples suggest that these organisms may be in a dormant state since, on the average, most of the glutamic acid that was taken up was being used for energy production and not for the biosynthesis of new cellular material.

There were also some significant differences in the average salinity and temperatures observed in the Beaufort Sea and the Gulf of Alaska. The average salinity in the Beaufort Sea was 24 o/oo and it was about 32 o/oo in the Gulf of Alaska; the later figure is closer to what one would expect in open ocean water. There was also a significant difference in the average water sample temperature observed in these two regions (-1.9 in the Beaufort Sea and 3.8 in the Gulf of Alaska).

The effects of incubation temperature on the apparent V_{max} values measured in a sample taken from Elson Lagoon produced a pattern similar to that observed in the ocean water samples tested last summer (see the first annual report). It is difficult to state whether or not the relatively high value at $-1^{o}C$ is an artifact or a true value (Figure 3).

An analysis of heterotrophic potential in three ice melt samples showed that there was very little difference between the V_{max} value observed in the ice melt and that observed in the underlying water. Even though the average percent respiration in these three samples was relatively high (98%), these values were within the range found in the water samples. This confirms a trend noted during the summer sampling period, namely, there was little or no difference between the V_{max} and percent respiration values observed in float ice melt and that found in the surrounding seawater.

The immediate effect of the addition of an aqueous crude oil extract on the uptake and respiration of glutamic acid by the microflora in a water sample was also tested. The results were similar to those observed in a set of experiments conducted last summer in the Beaufort Sea. No significant difference was observed between the samples that were exposed to the crude oil extract and those that were not.

V. Problems encountered, recommended changes and acknowledgments

A. Problem areas

1. Our only major logistic problem has come from freight handling mixups with Wein Airlines.

2. Due to purchasing and funding delays, we have just received our new gas chromatograph. We will now be able to proceed with our studies of hydrocarbon biodegradation by psychrophilic and psychrotrophic Arctic marine bacteria.

B. Recommended changes

1. We recommend that certain representative sampling sites be established and that interdisciplinary studies be planned which would continue without interruption for 2 to 3 years.

2. One of the most important questions to be answered by this program is the long term effects of crude oil pollution on environment. At the present time, there is no information on how long it will take for an oil perturbed environment to return to its natural state. Central to this problem is the biodegradation of crude oil; a reaction which, as far as we now know, is exclusively carried out by microorganisms. Virtually nothing is known about this process in Arctic marine water and sediments. This is a question to which both our group and Dr. Atlas's group have attempted to address ourselves, but this will require a sustained level of funding which will allow us to conduct basic research on these problems.

C. Acknowledgments

1. We would like to extend a special thanks to the officers and crew of the NOAA ship Discoverer for their excellent assistance during our March 1976 cruise in the Gulf of Alaska. Their "can do" attitude was very much appreciated and made it possible for us to accomplish more than we had even hoped.

2. During our field study period at NARL, Barrow, AK, we received excellent logistic support. We would like to extend a special thanks to the NOAA logistic coordinator, Ted Fletcher, for his many "logistic miracles" and to Sally Manning for her excellent laboratory support.

VI. Estimate of funds expended through June 30, 1976

Salary and Wages		$33,434
Other Payroll Expenses (OPE)		4,943
Supplies		11,171
Travel		3,075
Equipment		29,990
Indirect Costs		9,280
	Total	$91,893

QUARTERLY REPORT

Contract 03-5-022-56
Task Order Number 5
Quarter Ending -
30 June, 1976

HYDROCARBONS: NATURAL DISTRIBUTION AND DYNAMICS ON THE ALASKAN OUTER CONTINENTAL SHELF

Dr. D. G. Shaw
Assistant Professor of Marine Science
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

June 30, 1976

QUARTERLY REPORT

I. Task Objectives

The primary objectives of this program are to produce data on the kinds and amounts of hydrocarbons in waters, biota and sediments of the Alaskan OCS areas and to develop a quantative understanding of factors that control those distributions.

II. Field and Laboratory Activities

A. Field

1. Surface water samples (47) and seston (20) were collected in the Gulf of Alaska on a cruise of the *R/V Moana Wave* during the period.

2. Samples of biological materials (29) were collected in the Bering Sea on a cruise of the *FR/V Miller Freeman* during the period.

3. As this report is being transmitted a cruise of the *R/V Acona* is collecting surface water, seston and intertidal organisms and sediment from lower Cook Inlet.

B. Laboratory

1. Analysis of biota, water, and seston are all proceeding satisfactorially.

2. Our investigation of hydrocarbon-sediment interactions is continuing to make progress.

3. The GC-MS-data system is now operational.

III. Results

Biological collections and analyses are now focusing on comparison of various tissues within species. Initial results indicate considerable variation among tissues of an individual and between individuals. No aromatic hydrocarbons have yet been detected. Water analyses show levels somewhat higher than those found during the winter, but still on the order of μg/kg.

IV. Problems

The intercalibration program remains dormant.

V. Subcontractor Activities

A quarterly report describing I. R. Kaplan's progress in sediment collection and analysis will be forwarded when available.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: June 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 5 R.U. NUMBER: 275/276/294

PRINCIPAL INVESTIGATOR: Dr. D. G. Shaw

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]		
	From	To	Batch 1	2	3
Silas Bent Leg I #811	8/31/75	9/14/75	None	submitted	submitted
Discoverer Leg III #810	9/12/75	10/3/75	None	None	submitted
Discoverer Leg IV #812	10/3/75	10/16/75	9/30/76	None	submitted
Surveyor #814	10/28/75	11/17/75	None	submitted	None
North Pacific	4/25/75	8/7/75	submitted	None	None
Contract 03-5-022-34	Last	Year	submitted	submitted	submitted
Moana Wave MW 001	2/21/76	3/5/76	None	9/30/76	9/30/76
Miller Freeman	5/17/76	6/4/76	9/30/76	None	None

Note: [1] Data Management plan has been approved and made contractual.

QUARTERLY REPORTS

Contract 03-5-022-56
Task Order Number 7
Quarter Ending -
30 June 1976

MICROBIAL RELEASE OF SOLUBLE TRACE METALS FROM OIL IMPACTED SEDIMENTS

Dr. Robert J. Barsdate
Professor of Marine Science
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

June 30, 1976

QUARTERLY REPORT

I. Task Objectives

The object of this work is to determine by the use of experimental laboratory techniques whether or not changes in the concentration of dissolved trace metals in the interstitial waters of sediments are likely to occur as a result of introduction of crude oil. A further objective is to relate such metal changes to variations in microbial activity or other biological or chemical perturbations taking place within the sediments. For this quarter the immediate objectives have been to perform lead and cadmium analyses on experiments run in the previous quarter (Bering Sea sediments). An additional objective has been to initiate work on eelgrass detritus from Izembek Lagoon.

II. Field Activities

None.

III. Results

Lead analyses of the water from experimental flasks containing Bering Sea sediments and seawater with and without petroleum crude were made. The copper data from these experiments were reported and discussed briefly in the last quarterly report. For copper the results suggest that slightly higher metal concentrations are present following the addition of oil, and the results for lead are quite similar. The increase in lead concentration was apparent within 24 hours after the oil addition, suggesting (as in the case of copper) a physio-chemico rather than a microbial trace metal release mechanism.

Cadmium analyses were attempted on these same samples, but in all cases the concentrations in solution were low and within the range of possible contamination from laboratory sources. From these data we will be able to conclude only that there has been no large increase in cadmium in solution following the addition of oil.

Work was initiated on eelgrass (*Zostera marina L.*) detritus, and the initial results indicate perhaps two separate phenomena: (a) an initial metal release similar to that observed in the more inorganic Bering Sea sediments, and (b) a fairly slow but long-term release of metal to the water which presumably results from leaching and/or microbial mineralization. Following the addition of oil this leaching or mineralization takes place slowly relative to controls, ultimately resulting in a lower metal concentration in the oil-treated samples.

IV. Problems Encountered

None.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: June 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 7 R.U. NUMBER: 178

PRINCIPAL INVESTIGATOR: Dr. Robert J. Barsdate

No environmental data are to be taken by this task order as indicated in the Data Management Plan. A schedule of submission is therefore not applicable[1].

NOTE: [1] Data Management Plan has been approved and made contractural.

PHYSICAL OCEANOGRAPHY

PHYSICAL OCEANOGRAPHY

Research Unit	Proposer	Title	Page
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81	G. L. Hufford U. S. Coast Guard	Beaufort Shelf Surface Currents	241
91	K. Aagaard Dept. of Ocean. U. of Wash. D. P. Haugen Applied Physics Lab. U. of Wash.	Current Measurements in the Beaufort Sea	243
111	Robert Carlson Inst. of Water Res. U. of Alaska	Seasonability and Variability of Streamflow in Nearshore Coastal Areas	248
138/ 139/ 147	Stanley P. Hayes James D. Schumacher PMEL	Gulf of Alaska Study of Mesoscale Oceanographic Processes (GAS-MOP)	253
140/ 146/ 149/ 31	J. A. Galt PMEL	Numerical Studies of Alaskan OCS	287
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PHYSICAL OCEANOGRAPHY

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335	R. J. Callaway Chester Koblinsky Coastal Pollution Br./EPA	Transport of Pollutants in the Vicinity of Prudhoe Bay, Alaska	452
347	Harold W. Searby AEIDC William A. Brower NCC	Marine Climatology of the Gulf of Alaska and the Bering and Beaufort Seas	461
357	F. Favorite NMFS/NWFC J. H. Johnson NMFS/PEG	Physical Oceanography of the Gulf of Alaska	489
367	Bernard Walter Robert Reynolds PMEL	Near-Shore Atmospheric Modification in NEGOA	625

FIFTH QUARTER REPORT

RU48 - Development and Operation of HF Current-Mapping Radar Units -- Physical Oceanography

I. Task Objectives

The primary objectives of the proposed program are twofold: (i) to implement a proven radar concept into a transportable, easily assembled and operated pair of units capable of producing a map of near-surface currents on location in real time, and to calibrate the system as to its accuracy; (ii) to operate the radars at coastal areas of interest along the Gulf of Alaska seacoast in support of the OCSEAP objectives in physical oceanography. It is presently planned that the first Alaskan operations of the radar unit-pair will be in the Lower Cook Inlet, with one site near Anchor Point (above Homer), and the other at Point Naskowhak (near Seldovia). Operational areas beyond this will be arranged with OCSEAP based upon their lease sale schedules. Experiments may be conducted in other areas of Alaska and the continental United States in conjunction with other research groups for specific scientific purposes, such as correlation of observed oil trajectories with the output of our radar.

II. Field and Laboratory Activities

1. Laboratory Activities. Nearly all activities since the beginning of the program have been of a laboratory nature, viz., the analysis, design, simulation, and construction of a pair of current-sensing radar units. Mr. Michael Evans was designated Project Leader of the overall program, under Dr. Donald Barrick, Chief of the Sea State Studies Program Area of the Wave Propagation Laboratory. Karl Sutterfield has been with the program since its inception, in charge of the effective utilization of the computer systems for the operation, support, and control of the radars. Mr. Jack Riley joined the team February 1975, and is in charge of developing the graphic and display software for the system. Dr. Bob Weber is implementing all of the software for the reduction and mathematical processing of the received radar signal data. Mr. Don Lund joined the group in August 1975, and at present is primarily responsible for the construction of several of the RF elements of the system. In March 1976, LT Craig Blasingame was assigned to this project; he is currently in charge of all logistics arrangements in support of our upcoming field operations. Messrs. Wally St. John, Dan Law, Jack Hawkins, and William Everard have been assisting on a part-time basis in the design and assembly of the various digital and RF hardware components of the system. Finally, several of the hardware construction and assembly tasks have been contracted out to engineers of Astro Engineering Corporation and ERBTEC Associates, who are located close by.

2. Field Activities. The decision was made in August 1975 that the first unit pair would be field tested near Miami, Florida. The primary reasons for this decision were: (i) The relatively well-known current patterns of the Gulf Stream should facilitate the assessment of the accuracy

of the system. (ii) Logistic and technical support for these tests has been offered by Nova University and the University of Miami. The radar units left Boulder by van for Florida the last week in June, 1976. During the first month, both units were assembled and checked out at Nova University (near Fort Lauderdale, about 40 km north of Miami). The correct operation of all of the RF and digital hardware for both units was verified on a sequential, step-by-step basis. The transmitting and receiving antennas were assembled on the roof. (The building is about 300 m from the coast.) After proper operation of the individual components was ascertained, sea-echoes were received and digitally processed by the units. Finally, beginning August 15, the entire radar unit was operated from the van on the beach near Fort Lauderdale, operating entirely from a small gasoline generator in the same mode anticipated for the Alaskan operations.

III. Results

A. System Design, Construction, and Calibration.

1. Designs. All system-level designs have been completed. All of the hardware components being constructed in-house have been designed.

2. Procurements. Major hardware items which have been purchased commercially include: (i) the electronic laboratory test gear; (ii) computer support facilities; (iii) the radar receivers; (iv) the minicomputers for the field units. All of these major hardware items have been delivered.

3. In-House Fabrication. Several hardware items have been designed and constructed in-house. These include: (i) transmitter-drivers; (ii) transmitter power amplifiers; (iii) receiving antennas; (iv) transmitting antennas; (v) radio telemetry gear (between sites); (vi) fast Fourier-transform digital hardware; (vii) array-processing digital hardware; (viii) data-acquisition board, consisting of the sample and hold circuits, the analog-to-digital converters, and the digital pre-averaging circuits; (ix) semi-conductor buffer memory; (x) graphic display hardware; (xi) systems-integration hardware, including special high-efficiency power supplies, power sequencing circuitry, and fault-analysis circuitry. All of these items have been built and checked out in their final form for the field units.

4. System Integration. All of the hardware items which have either been procured or fabricated in-house have been assembled into the two units constituting the radar pair; this assembly was completed 15 June. The only item which was not integrated into the field units is the fast-Fourier transform processor; for the present, this function is being done by minicomputer software. Each radar unit consists of two weather-proof fiberglass cases containing shock-mounted racks; these racks contain all of the RF and digital gear necessary for producing real-time current maps in the field. Each case stands 44 inches high and weighs about 175 pounds, capable of being handled in the field by two men.

5. System Performance Analyses. Based upon the system design specifications, an analysis of system performance has been completed. This study shows that the maximum range from each radar unit should be of the order of 70 km. An analysis of azimuthal angle-of-arrival accuracy shows that insignificant position errors will result when signal-to-noise ratio exceeds 10 decibels. An optimization study indicates that the ideal separation between the two units is approximately 40 km.

6. System Software. Integration of operating-system software for control of the various hardware components is essentially completed. Graphics and display software (for making on-site current maps) has been completed. The radar-signal data-processing software has also been completed and checked out. Much of the software has already operated satisfactorily in the field.

7. System Simulation. Using the graphics/display software and the signal data-processing software, simulations have been run in the laboratory. These simulations -- instead of using actual radar signals -- employ simulated signals consisting of the (random) sea-echo signal and a (random) noise signal, as would be received by the actual radar at each of the three antenna terminals. The sea-echo signal includes the effect of the current pattern on the Doppler shift. Any desired current pattern can be inserted on the signal. These simulated signals are then processed by the same software to be used in the field. Hence, such simulations permit one to: (i) debug and check out the system software before actually going into the fields; (ii) obtain a feel for the accuracy of the output product (i.e., the current maps); (iii) modify and improve the system software where certain inaccuracies and weaknesses are detected from the simulations.

8. Antennas. The transmitting antenna system was conceived to be moderately directive, so that (i) higher signals could be obtained from desired ocean regions, and (ii) signals from unwanted areas (for example, behind the radar) could be eliminated. A design study contract was given to Lawrence Livermore Laboratories, which has an international reputation in the area of numerical antenna analysis. Based on their study (now completed), we selected and constructed Yagi monopole antennas consisting of both three vertical elements (for a wider pattern) and four vertical elements (for a narrower pattern). (The vertical elements are about 9 feet high, and the entire device can be erected on the beach in about 1/2 hour.) The antenna has been checked out electrically, and the measured parameters agree very closely with those predicted by Livermore. (The agreement was far better than expected.)

The receiving antenna system consists of three short elements. While one version has been built and checked out, we are re-designing (in-house) this antenna system to be much smaller and more lightweight. The receiving antenna dimensions are much less critical than those of the transmitting antenna.

9. Operating Frequencies. We have recently received frequency allocations from IRAC for all of our upcoming operations. We are permitted to select any frequencies in the band between 25.330 and 28.000 MHz; these allocations we presently consider satisfactory for all of our operations.

10. Theoretical Analyses. Several non-system, oceanographic factors will limit the accuracy of the system for measuring near-surface currents. One of these is the nonlinear interactions of surface waves, which generate Doppler-shift errors that are not associated with the currents. Examination of this mechanism theoretically shows that such errors -- expressed in terms of radial current velocity -- can always be expected to be less than 10 cm/s, with typical errors of the order of 5 cm/s.

B. Field Tests.

1. A major milestone point in the Florida field tests was reached on 24 July: namely, experimental evidence that the field radar system works! A summary of the details of accomplishment is the following. Signals were broadcast and received through the antenna system, converted to digital bit streams, filtered, and Fourier-transformed in the field in real time. The outputs are digital sea-echo Doppler spectra for different ranges. These spectra contain all of the information about the surface currents, which are deduced therefrom by mathematical formulas already tested in software form in the laboratory. The several sets of Doppler spectra we measured thus far contain all of the identifying features of the Gulf Stream, indicating that the basic operation of the system is proper. The project team is very proud that they reached this milestone point after only two weeks in the field with no major setbacks!

2. A second major field event consisted in moving the entire radar unit to the beach and operating it from a van with power from a portable gasoline generator; field operations in this mode were conducted for nearly one week, with no serious interruptions due to hardware failures. Of further interest is the fact that the team continued these operations throughout a tropical storm (which later became a hurricane), with winds of 50 knots and waves of 15 feet. Much of the time the antennas on the beach were awash, but data continued to be recorded. Sea-echo signals were detected to ranges exceeding 90 km. The very harsh conditions encountered during this three-day period in Florida will most likely exceed those anticipated in Alaska. Hence the continued operation of the radar during this period gives us confidence that the system should function well in the future.

C. Reporting Activities.

A major technical report has been prepared and published relating to the present system. This report describes the theory behind the concept, the system design as presently configured, analyses predicting system performance, and system simulations showing current-field maps produced by the actual radar field software using realistic input signals. The report was published July 1976, and is entitled "Implementation of Coastal Current-Mapping HF Radar System. Progress Report No. 1" (D. E. Barrick and M. W. Evans, authors; NOAA Technical Report ERL 373-WPL 47). A copy of the report is attached.

IV. Preliminary Interpretation of Results

Interpretation of the data recorded in Florida thus far indicates that the system performs according to predictions. In particular, the theoretically predicted range of 70 km has actually been exceeded. The mathematics derived specifically for the three-antenna receiving system (which relate the signal azimuthal angle of arrival to the radial current velocity) have been verified by comparisons with radar measurements for the Gulf Stream.

V. Problems Encountered/Recommended Changes

We anticipate no major redesign of the system hardware based upon our Florida field tests. Minor hardware items which should be improved involve primarily modification of the antennas and RF cables/connectors so that they will better withstand the corrosive environment of the seashore. Software improvements will continue to be made as field experience is obtained.

One recommended course of action -- based upon conversations with OCSEAP personnel and interested outside physical oceanographers -- involves conducting several well-planned scientific tests with our radar instrument. The oceanographic community feels that this device will revolutionize the measurement of near-surface coastal current patterns, providing a wealth of data over time and space scales heretofore unavailable by any other means. However, because the instrument is revolutionary compared with conventional physical oceanographic tools, claims relating to its measurements will undoubtedly be disputed by some. While we "radio-oceanographers" (having a background in radar and scattering theory as well as physical oceanography) -- based upon years of analysis and development of this technique -- have no doubt that it will work and provide map-like patterns related to surface circulation, conventional oceanographers who do not understand radio physics will require many tests supported by independent "ground-truth" observations of surface currents before they will accept the results of our instrument. There would be nothing worse than for an oil company to produce an oceanographer as an "expert witness," testifying that radar current maps introduced as evidence in court have neither been proven nor accepted as a reliable technique because of the absence of adequate independent validating measurements. Such an event could seriously impugn BLM and demolish the credibility of radar data for some time to come.

Hence it is recommended that a series of small-scale tests be planned for this upcoming Winter season -- when operations in Alaska may be difficult -- to verify the accuracy of our instrument and assist in further interpretation of its output data. These should be planned in conjunction with OCSEAP personnel and supported by independent oceanographic observations. There are many areas around the continental U.S. where such winter operations would be feasible, including Puget Sound, Florida, the Gulf of Mexico, and Southern California.

VI. Estimate of Funds Expended

(1 March 1975 - 30 June 1976)

1. Funds Expended (Salaries and Other Objects) $595,000

2. Funding Obtained to Date

a) NOAA/ERL	
FY 75	$ 40 K
b) OCSEAP	
FY 75	240 K
FY 76	215 K
c) Coast Guard	
FY 75	50 K
d) ERDA	
FY 76	50 K

RU# 81

NO REPORT SUBMITTED

The principal investigator is in the field.

QUARTERLY REPORT

Contract No.:

02-5-022-67, TA 3

Research Unit No.:

91

Reporting Period:

1 April 1976 - 30 June 1976

Number of Pages:

3

Current Measurements in the Beaufort Sea

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30 June 1976

I. Objectives

The general objective of this research unit is to provide long-term Eulerian time series of currents at selected locations on the outer shelf and the slope of the Beaufort Sea, so as to describe and understand the circulation and dynamics of the outer shelf and slope.

II. Field/Laboratory Activities

A. Field trip schedule

1. 19-30 April 1976.
2. 205 Helicopter.
3. Charter ERA Helicopter; Anchorage.

B. Scientific party

1. Dr. Knut Aagaard, Department of Oceanography, University of Washington, Chief Scientist.
2. Mr. Clark Darnall.
3. Mr. Fred Karig, Applied Physics Laboratory, University of Washington.

C. Methods

Mooring No. 1 was deployed in Barrow Canyon at 190 meters water depth. This mooring consisted of two Aanderaa RCM-4 current meters and a transponding acoustic release (AMF Model 395).

Mooring No. 2 was deployed at 225 meters water depth on the outer continental shelf off Oliktok Point. This mooring consisted of two Aanderaa RCM-4 current meters, a mid-water transponder, and an acoustic release (AMF Model 242).

Mooring No. 3 was deployed at 1135 meters water depth on the outer shelf slope off Oliktok Point. This mooring consisted of two Aanderaa RCM-4 current meters, and a transponding acoustic release.

D. Station locations

See atached listing for pertinent mooring information.

E. Data collected

The current meters are collecting temperature, current speed and direction at a timing interval of 30 minutes.

III. Results

Mooring recovery is planned for the period 1 August - 31 October 1976.

IV. Preliminary Interpretation of Results

None

V. Problems encountered

See Annual Report.

VI. Estimate of Funds Expended (May 30, 1976)

A. Original Allocation

1.	Aagaard, Oceanography:	$ 74,651
2.	Haugen, APL:	100,349
3.	Total	175,000

B. Estimate of Funds Expended: Aagaard

1.	Salaries	$ 5,391
2.	Benefits	639
3.	Indirect Costs	2,361
4.	Supplies, Other Direct Costs, Equipment & Travel	57,855
	Total	66,246
	Remaining Balance	8,405

C. Estimate of Funds Expended: Haugen

1.	Salaries	37,900
2.	Benefits & Indirect Costs	37,700
3.	Purchases, Travel & Supplies	21,100
	Total	96,700
	Remaining Balance	3,649

Mooring No. 1 - Barrow Canyon

position: 71°35.0'N, 155°58.8'W
sounding: 190 m
time of deployment (GMT): 0835, 24 April 1976
current meter depths: 65 m, 140 m
other component instruments: transponding acoustic release
total mooring length: 132 m
in situ anchor weight: 1152 lb.

Mooring No. 2 - Oliktok outer shelf

position: 71°12.6'N, 149°53'W
sounding: 225 m
time of deployment (GMT): 0206, 29 April 1976
current meter depths: 100 m, 175 m
other component instruments: mid-water transponder, acoustic release
total mooring length: 132 m
in situ anchor weight: 929 lb.

Mooring No. 3 - Oliktok slope

position: 71°15.6'N, 149°53'W
sounding: 1136 m
time of deployment (GMT): 1011, 29 April 1976
current meter depths: 136 m, 611 m
other component instruments: transponding acoustic release
total mooring length: 1007 m
in situ anchor weight: 1393 lb.

QUARTERLY REPORT

R.U. # 111
Contract 03-5-022-56
Task Order Number 4
Quarter Ending -
30 June 1976

SEASONABILITY AND VARIABILITY OF STREAMFLOW IN NEARSHORE COASTAL AREAS

Dr. Robert F. Carlson
Director
Institute of Water Resources
University of Alaska
Fairbanks, Alaska 99701

June 30, 1976

I. Task Objectives

The overall objective of this project has been the determination and assessment of seasonal streamflow variations in coastal streams as they relate to probable offshore development activities. The stream characterization is outlined on the flow chart which follows on the next page (Table 1).

II. Field or Laboratory Activities

None

III. Results

The 1, 3, 7, 10, 30 day duration series ratios are completed for all the rivers of interest. Flow mass curves are being plotted presently using a computer plotting scheme. The flow duration curves and exceedance series will be completed pending receipt of a computer run from the U. S. Army Corps of Engineers in Anchorage. The statistical streamflow parameters are determined. Characteristic hydrographs remain to be plotted. The snowmelt characterization is partially completed, and NOAA satellite imagery has been received for the 1976 snowmelt period (April 15 - June 13, 1976). Hypsometric curves (area-elevation curves) are also nearly completed for all the rivers and streams of interest.

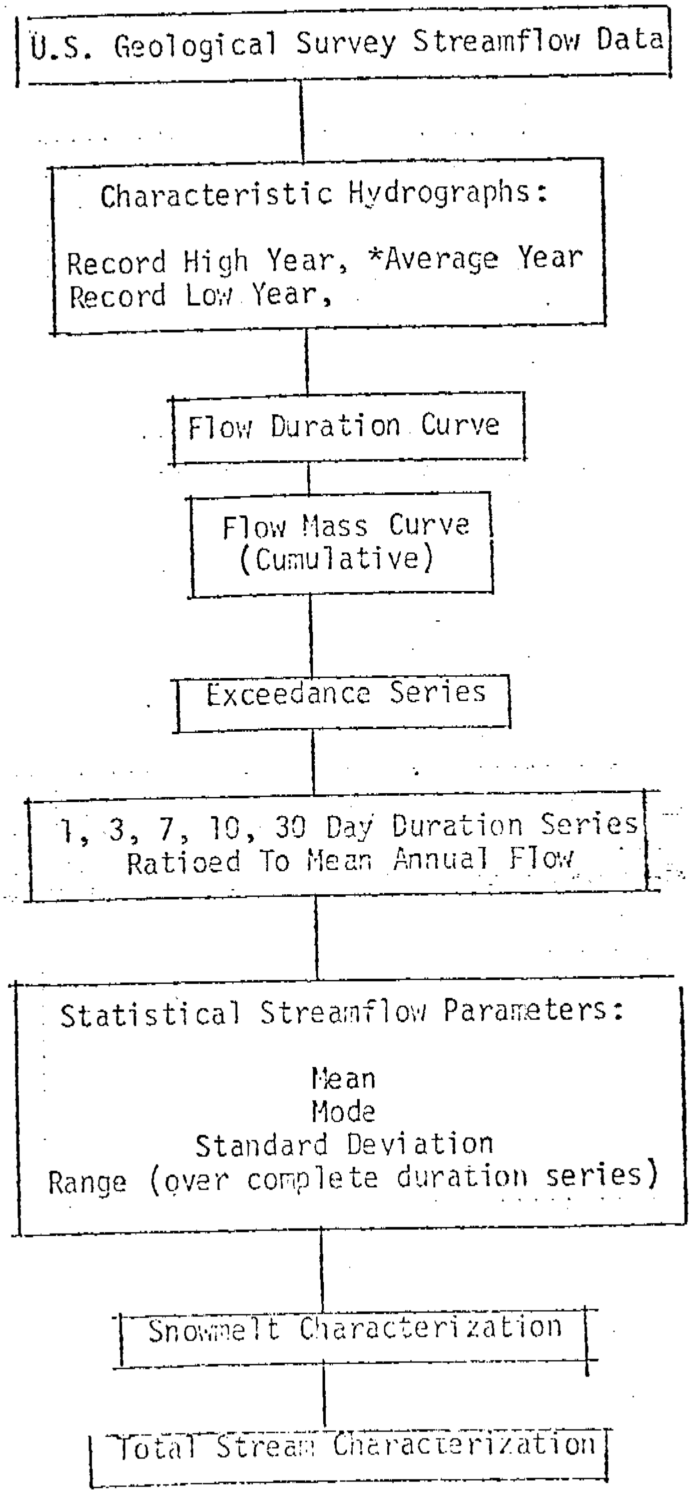
IV. Preliminary interpretation of results:

Briefly, patterns of snowmelt and streamflow variability are related regionally and also very dependent on basin area, as was expected. Results of these investigations will be reported by grouping the rivers according to the regions of O.C.S. interest, i.e. Gulf of Alaska, S. Bering, N. Bering-Chukchi, and Beaufort Sea regions. Because of the climatic similarities within these regions, discussion of the stream variability assumes a more meaningful perspective in this type of grouping.

North Slope rivers are the extreme of variability, with rapid break-up and runoff in the spring and early freeze-up in autumn. Variability decreases in relation to climatic severity. The less severe the climate, the less variability there is in streamflow. Following the coast in a counterclockwise direction from the Beaufort sea to the Chukchi, Bering and into the Gulf of Alaska, both climate and streamflow become less seasonal.

Table 1

FLOW CHART - O.C.S. STREAM CHARACTERIZATION



*Average Year is that year during which the mean annual flow was closest to the mean annual flow for the length of record.

The presence of large lakes in a river basin also is an important influence in regulating streamflow. Both the Kvichak (Lake Iliamna) and the Wood Rivers (Lakes Beverly, Nerka, and Aleknagik) have very small degrees of annual variability in streamflow. This factor is attributed to lake storage and subsequent regular outflow.

Other factors resulting from or affecting spring breakup include the anomalous North Slope snowmelt patterns and the flooding of sea ice by fresh river runoff water during spring breakup. Both of these factors will be discussed at length in the final report.

V. Problems Encountered

None

VI. Estimate of funds expended

	Budget	Encumbered	Spent	Balance
Salaries	$26,200	$	$19,592	$ 6,608
Travel	855		679	176
Supplies	200		202	(2)
Services	3,700	454	433	2,813
Other			37	(37)
Overhead	14,987		11,207	3,780
Salaries/Benefits	4,430		3,331	1,099
Total	$50,372	$ 454	$35,481	$14,437

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: June 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 4 R.U. NUMBER: 111

PRINCIPAL INVESTIGATOR: Dr. Robert F. Carlson

No environmental data are to be taken by this task order as indicated in the Data Management Plan. A schedule of submission is therefore not applicable[1].

NOTE: [1] Data Management Plan has been approved and made contractual.

QUARTERLY REPORT

Contract #R7120846
#R7120847

Research Unit #138, 139, 147

Reporting Period: 1 April -
30 June 1976

Number of Pages : 33

GULF OF ALASKA STUDY OF MESOSCALE OCEANOGRAPHIC PROCESSES (GAS-MOP)

Dr. S. P. Hayes

Dr. J. D. Schumacher

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3711 - 15th Avenue, N. E.
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July 1, 1976

I. TASK OBJECTIVES

- Eulerian measurements of the velocity field at several positions and levels
- Measurement of the along- and cross-shelf sea surface slope
- Process study to understand the interrelations among the velocity field, the bottom pressure gradient, the density field, and the wind field in order to determine the dynamics of the circulation on the continental shelf.

II. FIELD OR LABORATORY ACTIVITIES

A. Cruises:

1. NOAA ship *DISCOVERER* RP-4-D1-76A LEG VI (11-20 May 1976)

Scientific Party:

John Glenn	Chief Scientist	PMEL
John Piety	Sea Surface Slope, CTD	UW
Roger Osland	Sea Surface Slope	UW
Carl Pearson	Current Meter Arrays	PMEL
Dave Pashinski	Satellite Tracked Buoys/ Current Meter Arrays	AOML

2. NOAA ship *MILLER FREEMAN* RP-4-MF-76A LEG IV (7-23 June 1976)

Scientific Party:

Pat Laird	Chief Scientist	PMEL
Dick Tripp	Current meters	UW
Steve Harding	Current meters	UW

B. Methods:

Plessey 9040 CTD

Plessey 8400 Digital Data Logger

Aanderaa RCM-4 current meters

PTG pressure temperature gauges

AMF releases

C. Sample Localities:

SLS-8	59° 39.0'N ,	141° 41.0'W
SLS-9	59° 18.76'N,	142° 02.37'W
SLS-13	59° 45.3'N ,	141° 33.8'W
SLS-14	59° 39.6'N ,	141° 42.0'W
SLS-15	59° 19.15'N,	142° 6.25'W
STA 62	59° 37.6'N ,	142° 6.2'W
STA 60	60° 7.8'N ,	145° 48.7'W
STA 61	59° 32.6'N ,	145° 49.7'W
STA 69	59° 50.0'N ,	145° 43.3'W
WGC-1	54° 03.0'N ,	163° 06.5'W
WGC-2	57° 34.6'N ,	150° 98.6'W
WGC-3	55° 11.5'N ,	156° 58.0'W

D. Data Collected or Analyzed:

1.

SLS-8	Recovered - 3 current meters, PTG
SLS-9	Recovered - 3 current meters, PTG
STA 62G	Recovered - 4 current meters, nephelometer
STA 60B	Recovered - 3 current meters
STA 61B	Recovered - 3 current meters
STA 69A	Recovered - 2 current meters
WGC-1C	Recovered - 4 current meters
WGC-2C	Recovered - 4 current meters, PTG

SLS-13	Deployed - PTG
SLS-14	Deployed - 2 current meters, PTG
SLS-15	Deployed - PTG
STA 60C	Deployed - 3 current meters
STA 61C	Deployed - 4 current meters
STA 62H	Deployed - 4 current meters
STA 69B	Deployed - 3 current meters
WGC-1D	Deployed - 3 current meters
WGC-2D	Deployed - 3 current meters
WGC-3B	Deployed - 3 current meters

2. 80 CTD casts were taken, tapes have been translated and are being processed.

III. RESULTS

These new data sets are being processed and analyzed. Results of previous analyses are contained in the Annual Report and in the appended manuscript.

IV. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

Moorings SLS-7 and WGC-3A failed to respond to a release command. Attempts may be made to recover these arrays by dragging.

V. ESTIMATE OF FUNDS EXPENDED (1 July 1975 - 30 June 1976)

Salaries and Overhead	$ 73,300
Equipment	36,000
Supplies and Materials	26,700
Calibration	10,400
Contractual Services	33,400
Travel	16,800
Transportation	14,400
Total	$211,000

Preliminary Description of Circulation on the Continental Shelf in the N. E. Gulf of Alaska: February-May 1975

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1 ~~March~~ 1976
May

ABSTRACT

Results of a preliminary study of the circulation on the continental shelf in the Northeast Gulf of Alaska are presented. Wind, current, and bottom pressure measurements for the period February to May 1975 are described. The bottom pressure measured at 100 m depth agrees well with the adjusted sea level calculated from a nearby coastal tide gauge. The circulation divides into a winter and a spring regime. This seasonal change is most clearly seen in the bottom pressure and its correlation with the alongshore wind and current. The monthly mean bottom pressure drops by 12 cm from February to April. Comparable changes are not observed in the onshelf density field. During February the wind, bottom pressure, and currents are mutually coherent. A simple linear correlation between bottom pressure and alongshore current accounts for much of the variance. However, during March and April the coherences are low and the linear correlation is no longer valid. The data suggest that offshelf processes or non-local effects become more important.

From February to May, 1975 a pilot experiment was conducted in the Northeast Gulf of Alaska to study the circulation on the continental shelf and its relation to wind, bottom pressure, and density distribution. The mean current in this region flows westward, generally parallel to the coastline, and is associated with the Alaskan Current (Dodimead, *et al.*, 1963). In winter, the Aleutian Low dominates the weather system. This yields northeasterly winds and, often, severe storms (Danielsen, *et al.*, 1957). The wind pattern produces on shore Ekman transport and a downwelling situation (Royer, 1975). There are indications of a wintertime increase in the westward transport of the Alaskan Current (Favorite, 1974; Galt and Royer, 1975). During summer the North Pacific High influences the Gulf of Alaska. Lighter winds and a relaxation of the wintertime set up ensue (Dodimead *et al.*, 1963; Royer, 1975).

The time period of the experiment includes a winter month (February) and what appears to be a spring transition period. Throughout the experiment the stratification on the continental shelf was weak. The purpose of this paper is to examine the low frequency (f < .025 cph) fluctuations in the currents and to relate them to wind and bottom pressure changes. In addition, bottom pressure measurements made offshore will be compared with inferred bottom pressures from a coastal sea level gauge. The representativeness of the coastal record is discussed.

The experiment was located offshore of Icy Bay Alaska (Figure 1). Mooring SLS-1, in 100 m depth, had an E. G. and G. Geodyne 850 current meter at 90 m depth and an Aanderaa TG-2A pressure gauge anchored to the bottom. The floatation was 80 m below the surface. The pressure gauge utilized a

Paroscientific quartz crystal pressure transducer. Its resolution is equivalent to approximately 3 mm of water level change and its long term stability is better than 3 cm of water level change per year. The gauge was calibrated before and after deployment; the relative calibrations agreed to within the accuracy of the dead weight tester used (.025%). A summary of SLS-1 data was reported in Holbrook, *et al.*, (1976).

Mooring 62B, in 185 m depth, had Aanderaa RCM4 current meters at 20, 50, and 100 m depths. The floatation was 15 m below the surface. A summary of the data records, calibration procedures, and mooring diagrams are reported in Reynolds *et al.*, (1976).

The data from the moored array were supplemented with coastal sea level, winds, and atmospheric pressure measured at Yakutat. In addition, winds calculated from the 6-hourly synoptic surface atmospheric pressure analyses produced by Fleet Numerical Weather Central (Bakun, 1975) were analyzed. The coastal topography is extremely mountainous in the vicinity of Icy Bay and Yakutat. Thus, the measured winds at Yakutat are not representative of the winds over the Gulf of Alaska. While the calculated winds probably represent the largescale wind field reasonably well, significant local variations can be expected to occur.

Density Field

At deployment and recovery of the moorings salinity, temperature, and depth (STD) measurements were taken with a Plessey 9006 STD. Measurements were made along the lines 1 and 2 and at the position of SLS-1 (Figure 1). The change in water properties on the continental shelf is shown by the profiles in Figure 2. The stratification was weak in both cases; the sigma-t change from surface to bottom was only 0.2 units in February and 0.5 units in May. The May profile indicates denser near bottom water has moved onto the shelf. This is consistent with a relaxation of the winter downwelling.

The density sections along lines 1 and 2 are shown in Figure 3. All four sections show similar stratification on the shelf. The isopycnals slope downward as one proceeds shoreward from the shelf break. The intrusion of denser water onto the shelf is again seen in the May sections. The density sections seaward of the shelf break are more complex. In February, the sections along lines 1 and 2 are quite different. Line 1 indicates a baroclinic flow to the southeast while line 2 indicates flow to the northwest. Based on time series measurements the vertical displacements of the isopycnals are too large to be due to tidal oscillations. The density field may indicate an eddy; however, no other density measurements are available which further resolve this circulation. In any case, the structure does not extend far onto the shelf where all sections indicate a baroclinic flow to the northwest.

Time Series

Current and bottom pressure time series were low pass filtered using a symetrical cosine filter with a half power point at 40 hours. The 6-hourly calculated winds were filtered with a Fourier filter with a 40 hour cut off. Wind velocities rather than wind stress were used throughout the analysis. Comparison of results using wind stress showed no significant differences. All vector series were rotated into an approximate onshore-alongshore coordinate system. This system was checked by calculating the principal axis (Fofonoff, 1969) and its stability (Gonella, 1972). For SLS-1, the 90 m currents had a principal axis direction of 300°T in agreement with the local bathemetry. The stability of the elipse was above the 95% significant level for the low frequency band considered here, thus indicating linear polarization. However, at 62B the bathemetry makes it difficult to assign an alongshore direction. The principal axis is at roughly 315°T for all depths; but, the stability is low (significant at the 80% confidence level). For the analysis, 315°T was considered to be the alongshore direction at 62B.

The equivalent bottom pressure at Yakutat was constructed by adding the observed sea level and atmospheric pressure assuming one milli-bar equaled one centimeter. This bottom pressure has only 30% of the low frequency variance observed in the sea level record by itself. For comparisons, the mean was removed from the bottom pressure before plotting.

Figure 4 shows the low pass filtered time series for alongshore winds and currents and for the two bottom pressure series. During February, several periods of high winds occurred. These storms were separated by periods with light winds and occasional wind reversals. In general, the strong winds were alongshore to the Northwest and Figure 4 gives an indication of their speed. From 2 February until 11 February, wind measurements from a moored buoy and from the NOAA Ship *Oceanographer* were available at the experimental site (Holbrook, *et al.*, 1975). They agree, qualitatively, with the calculated winds. The alongshore water velocity and the bottom pressure responded rapidly to the wind structure.

Storm associated alongshore velocity changes of roughly 40 cm/sec were observed at the 20 and 50 m levels, while changes of 30 cm/sec occurred at 90 and 100 m depths. These velocity changes were accompanied by increases in bottom pressure of about 15 cm. The current and pressure fluctuations appear to be in phase during the storm events. The winds generally lead the oceanic response.

After March 1, the frequency and intensity of storm winds diminished. The mean wind speed dropped by a factor of 2.5 from 11.0 m/sec in February to 4.4 m/sec in March-April. Between the two periods, the mean bottom pressure at SLS-1 decreased 12 cm. The alongshore velocities did not mirror this bottom pressure change; at the 90 m depth only a 2 cm/sec change was observed from February to March-April. The relationship between the fluctuations in current and bottom pressure was also complex during the March-April period. For example, on March 20 and 23 the current meter records at all levels on 62B show large increases. Neither the bottom pressure nor the currents on SLS-1 show similar variations. On March 30 the 62B currents and the SLS-1 bottom pressure appear correlated; however, the 90 m currents show little change. Thus, qualitatively, the relationships among the measurements seems simpler in February than in the subsequent period.

Analysis

Bottom Pressure Comparison. The similarity between the bottom pressure measured at SLS-1 and inferred from the Yakutat sea level and atmospheric pressure data is apparent from Figure 4. The 100 m depth contour is about

20 km offshore at Icy Bay; whereas it is less than 5 km off Yakutat. Thus, one might expect the two pressure measurements to closely agree. The linear correlation coefficient between the records is .96 with a regression coefficient of 1.25 indicating that the Yakutat bottom pressure fluctuations are on average 25% greater than those at SLS-1. The coherence between SLS-1 and Yakutat bottom pressures (Figure 5) is high throughout the low frequency band. The signals are in phase. The decreased coherence towards the high frequency end of the band may be due to localized effects in Yakutat Bay. In general, it appears that the Yakutat sea level measurements are reasonably representative of the offshore bottom pressure.

Both bottom pressure series show the decrease in mean pressure from February to March. From historical data, the seasonal change in the monthly mean sea level is 25.2 cm at Yakutat (Pattullo *et al.*, 1955). The highest mean sea level is in December and the lowest is in May. This seasonal excursion is reduced by about 50% when atmospheric pressure effects are included (Reid *et al.*, 1975). Comparing adjusted sea level to the available hydrographic data Reid *et al.* (1975), conclude that the seasonal sea level change is a consequence of the change in steric level of the deep water. Thus, a wintertime increase in the Alaskan Current is reflected in higher sea levels at Yakutat (Favorite, 1974).

The present data does not resolve the connection between steric adjustment and adjusted sea level (bottom pressure) seasonal change. On the continental shelf at SLS-1 the dynamic height of the surface relative to 75 d bar did not change significantly from February to May. Offshore, the density section on line 2 shows only a 2-cm decrease in the dynamic height of the surface relative to 1000 d bar. However, line 1 shows a 25 cm decrease in this dynamic height. Since both lines are equally close to SLS-1 (*i.e.*, 25 km), the seasonal change in steric level is not resolved.

Geostrophy: Baroclinic Shear. At SLS-1 we had only a single measurement of the velocity; thus, the vertical shear of the alongshore flow must be inferred from the STD sections (Figure 3). These indicate a shear from the surface to the bottom of 1.2 cm/sec in February and 3.0 cm/sec in May. The expected error in these geostrophic shears can be estimated from the dynamic height fluctuations observed during a 24-hr anchor station (standard deviation 0.2 dynamic cm) and the expected error in position (1 km). These numbers yield a ± 2 cm/sec velocity uncertainty.

At 62B the directly measured currents can also be compared with the geostrophic shear. In February the mean measured shear from 20 m to 100 m was 5.8 ± 7.2 cm/sec. The calculated shear was 5.9 cm/sec. Similarly, in April the measured average shear was 6.8 ± 6.7 cm/sec compared to a 5.5 cm/sec geostrophic shear. However, when the geostrophic shear was compared to the average measured shear on the day of the STD section, the agreement was poor. For example, the average measured shear on February 5 was 13.6 cm/sec rather than the geostrophic 5.9 cm/sec. It is likely that the station spacing (20 km) did not resolve the shorter period fluctuations.

Geostrophy: Barotropic component. The alongshore velocities at 62B (Figure 4) indicate that much of the variability is depth independent throughout the upper 100 m. The variance of the shear between 20 m and 100 m is less than half of the variance of the 100 m alongshore velocity. These results and the weak geostrophic shear at SLS-1 lead one to interpret the 90 m current in terms of barotropic velocity. In this case the bottom pressure variations should be linearly related to the velocity.

In a simple linear regression between the two time series the regression coefficient can be related to a length scale for the pressure gradient (Collins, 1964)

$$v = \left(\frac{g}{fL} \right) p + b \qquad (1)$$

v is the alongshore velocity, p is the pressure, f is the Coriolis parameter, and L is the desired length scale of the pressure gradient. Of course, the barotropic assumption and hence the length scale, L, only make sense when the correlation coefficient is large.

Table 1 gives the correlation coefficients, the 95% confidence level, the regression coefficients, and, where appropriate, the length scale. The confidence level was computed assuming that the number of degrees of freedom was given by the number of days of data. The results show a definite seasonal change. The February velocity and pressure are linearly correlated and the length scale corresponds to the shelf width. However, the March-April records (which exclude the bottom pressure trend observed near the beginning of March) do not show significant linear correlation. The February data are consistent with a simple barotropic model in which the oceanic response is confined to the continental shelf (Beardsley and Butman, 1974). The spring data suggest that baroclinic effects or a variety of length scales are important during this period.

Spectral properties. The frequency space representation of the time series was used to look for dominant time scales and to compare the spectral shape observed on the Alaskan continental shelf with that observed in the summer off Oregon. In order to obtain reasonable frequency resolution, the spectra were calculated over the 3-month record length. The time series were too short for a detailed investigation of possible seasonal non-stationarity. The seasonal trend was removed by end point detrending (Frankignoul, 1974).

Figure 6 shows the kinetic energy density spectra for the calculated wind and the 90 and 100 m currents. The variance density spectrum for the SLS-1 bottom pressure is also shown. In the wind spectrum the energy density rises rapidly as the frequency decreases from the filter cut off. There is a peak or plateau near .02 cph. This is followed by a second rapid energy density increase and a peak near .01 cph. The energy density, then, continues to increase with a reduced slope. The structures near .01 and .02 cph are also observed in the oceanic response to the winds. The .01 cph peak is most pronounced in the 62B-100 m spectra where it amounts to a factor of five increase in energy density. The SLS-1 90 m currents and bottom pressure spectra also show the peaks. The structures in the wind spectra appear to be associated with the severe storms during February (Figure 4). In his analysis of the calculated wind field for eight winters, Bakun (1975) computed the power spectra for the coastal upwelling index. There was no indication of the structures at .01 and .02 cph in his spectra. The features observed in our data may relate only to the specific time period of the experiment.

Comparison of the Alaskan shelf current spectra with those measured during the summer at 90 m depth in 100 m of water off Oregon (Halpern, *et al.*, 1976) shows that the Alaskan currents have a slower fall off of energy density with increasing frequency. The dot dash line in Figure 6 indicates the slope and energy level observed off Oregon. At low frequencies (periods of one month) the energy densities at the two locations agree. However, as the frequency increases the energy densities diverge. For periods near 100 hours there is an order of magnitude greater energy density on the Alaskan shelf. The band from 40 hours to 200 hours (2-8 days) where the large discrepancy between the spectra occurs corresponds to the time scale for the storm systems seen in Figure 4.

The correlation between the wind and the oceanic response is further described by the coherence between bottom pressure and wind. In Figure 7 both measured winds at Yakutat and calculated winds are compared with the SLS-1 bottom pressure. The bottom pressure-wind coherence is displayed rather than current-wind coherence since both have a similar shape, but the latter is smaller. The 90% confidence level (Carter, *et al.*, 1973) for the coherence is shown by the dashed line. Both wind records show a similar shape to the coherence; however, the calculated winds give higher values. The alongshore coherence (Figure 7a) is significant in the low frequency region and has peaks near 100 and 50 hour, corresponding to the peaks observed in the kinetic energy spectra. The phase between alongshore wind and the bottom pressure (Figure 7b) has the wind leading the bottom pressure. At 100 hours the phase shift is 25° (7 hours) and near 50 hours the phase is 70° (10 hours). The confidence limits on the phase depend on knowing the true coherence (Stegan and Van Atta, 1970). Assuming the measured coherence (0.9) is the true coherence, then the 95% confidence limits for ten degrees of freedom is ± 26°. Thus the 100 hour response could actually be in phase, whereas at 50 hours a phase lag appears real. Figure 7c shows the on/offshore winds compared with the bottom pressure. This coherence is smaller than that of the alongshore winds. Similar results have been observed elsewhere (Cragg, *et al.*, 1974). The onshore Ekman transport caused by alongshore winds is more effective than the direct wind stress in producing sea level set up.

The high coherence between the SLS-1 bottom pressure and the Yakutat bottom pressure noted in Figure 5 allows us to extend the comparison of the alongshore wind and the oceanic response. In Figure 8 the coherence between the calculated alongshore wind and the Yakutat bottom pressure is shown for the winter period January and February, 1975 and for the spring period April and May, 1975. The two periods are quite different. In winter the bottom pressure and the wind are closely coupled and coherent over much of the low frequency spectral band. In spring the observed coherences are low. A larger fraction of the bottom pressure variations must be associated with other forcing. Candidates include offshelf baroclinic changes and non-local wind effects.

The coherences among the velocity series have also been computed. In this case rotory coherences (Mooers, 1973) were calculated so that the results would be coordinate system independent. These coherences are not shown since they add little to the qualitative understanding obtained from visual inspection. The 20 m and 100 m data from 62B were significantly coherent over a broad frequency range. The phase difference was not significantly different from zero. These results are consistent with a barotropic interpretation for the flow. The cross shelf coherence between 62B 100 m velocity and SLS-1 90 m velocity was not significantly (at the 95% confidence level) different from zero for any frequencies below the low pass cut-off. This low cross shelf coherence is consistent with measurements off Washington and Oregon (Huyer *et al.*, 1975).

The final set of coherences calculated related the measured alongshore velocities and the SLS-1 bottom pressure. The linear correlation and barotropic response observed during February indicate that the winter time velocity and pressure series are coherent and in phase. In order to calculate the frequency dependence of the coherence (with a reasonable degree of resolution) the entire record was analyzed. The results are shown in Figure 9. There is again significant coherence near 50 and 100 hours. In these regions the phase is small.

Figures 6-9 indicate that there are regions of the spectrum where energy is transferred from the wind field to the ocean currents in a coherent manner. Increased energy density in these spectral bands appears to be present in the forcing functions and in the response. The selectivity of the response is similar to results observed off Oregon and Washington (Smith, 1974; Huyer, *et al.*, 1975) where shelf waves have been suggested. However, the shortness of the time series and the apparent winter-spring nonstationarity limit further speculation at this time.

Conclusions

This preliminary study on the continental shelf in the Northeast Gulf of Alaska suggests that the February to May circulation can be divided into a winter period and a spring transition. The separation is not obvious in the density field on the shelf, although some relaxation of the winter downwelling is observed. The bottom pressure and its correlation with wind and alongshore velocities shows the most clear evidence for the two regimes. During winter the increased wind stress to the northwest causes a set up of the sea level and downwelling. However, when the winds lessen in the spring, the sea level rapidly drops. This spring set down is observed in the bottom pressure, but it is not apparent in the alongshore flow. Hence, it appears to be related to offshelf processes. The present data set is not sufficient to define whether these deep water processes are baroclinic or barotropic.

Superimposed on the seasonal changes are the 2-10 day wind, current, and bottom pressure variations. During winter these are dominated by the storm events. In this case the response of the shelf circulation is largely consistent with a barotropic model which has a length scale equal to the shelf width. There is some evidence of a selective transfer of energy from the wind field to the currents at frequencies near .01 and .02 cph. In these spectral bands the wind, bottom pressure, and alongshore currents are all mutually coherent. During spring the interpretation of the shelf circulation becomes complex. No longer are the bottom pressure and the alongshore currents linearly related. In addition the wind and bottom pressure become less coherent. It should be recognized that even during the spring isolated events can be found where the various parameters all respond in a coherent manner. It is only in an average sence that the coherences are insignificant.

Acknowledgments

We appreciate the helpful comments of D. Halpern and J. R. Holbrook. We are indebted to A. Bakun for calculating the wind field at the experimental site. The research was supported by the Environmental Research Laboratories of the National Oceanic and Atmospheric Administration.

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Interval	CC	CL 95%	RC (sec^{-1})	L (km)
5 Feb - 18 Apr	.35	.26	0.31	250
5 Feb - 1 Mar	.74	.41	1.51	52
8 Mar - 15 Apr	.14	.31	0.26	--

Table 1. Linear correlation between velocity (90 m) and bottom pressure at SLS-1. CC is the correlation coefficient, CL is the confidence level, RC is the regression coefficient, and L is the length scale discussed in the text.

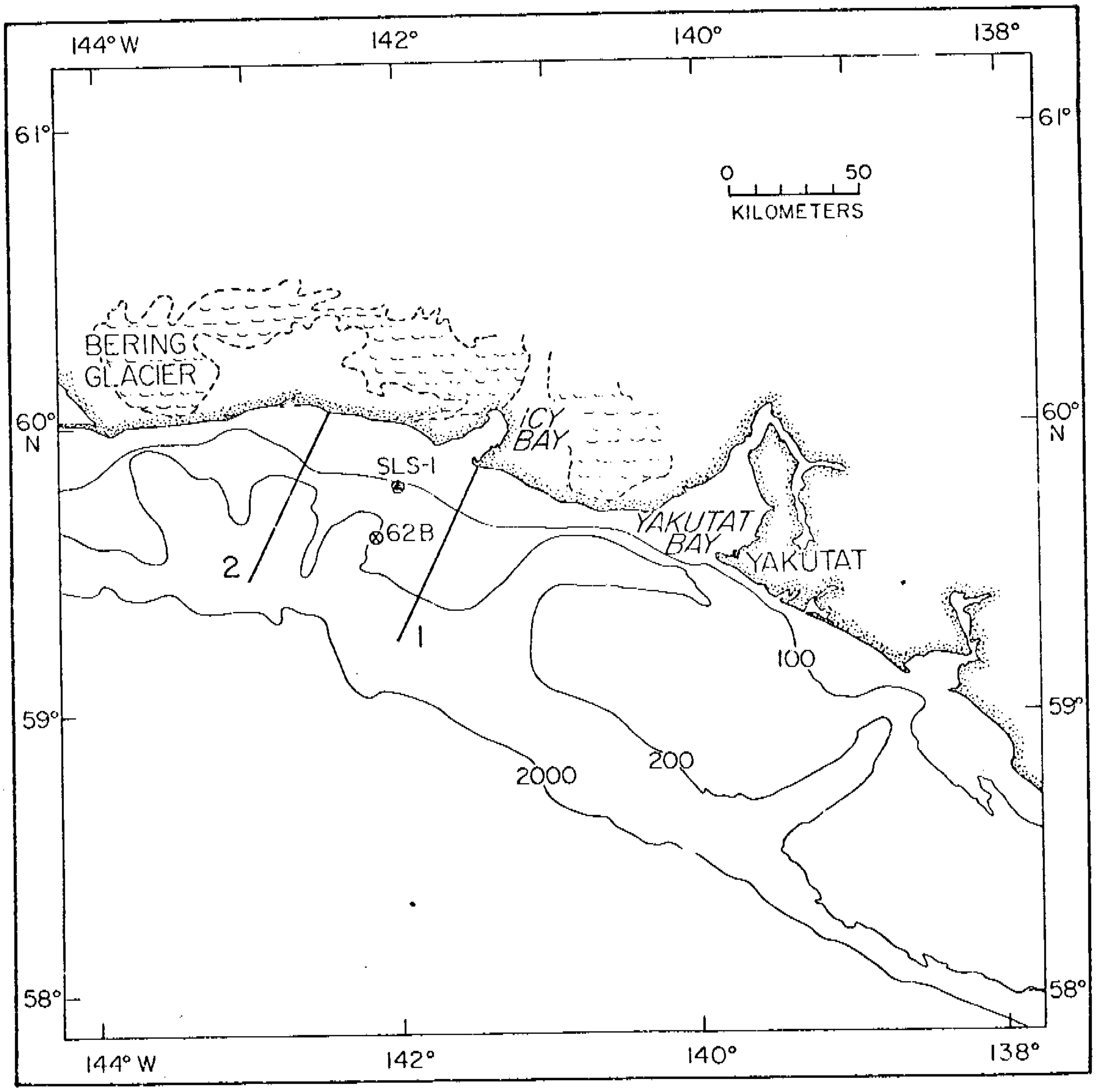


Figure 1. Location of the experiment. Mooring SLS-1 had a bottom pressure gauge and current meter; mooring 62B had three current meters. Hydrographic measurements were made along lines 1 and 2.

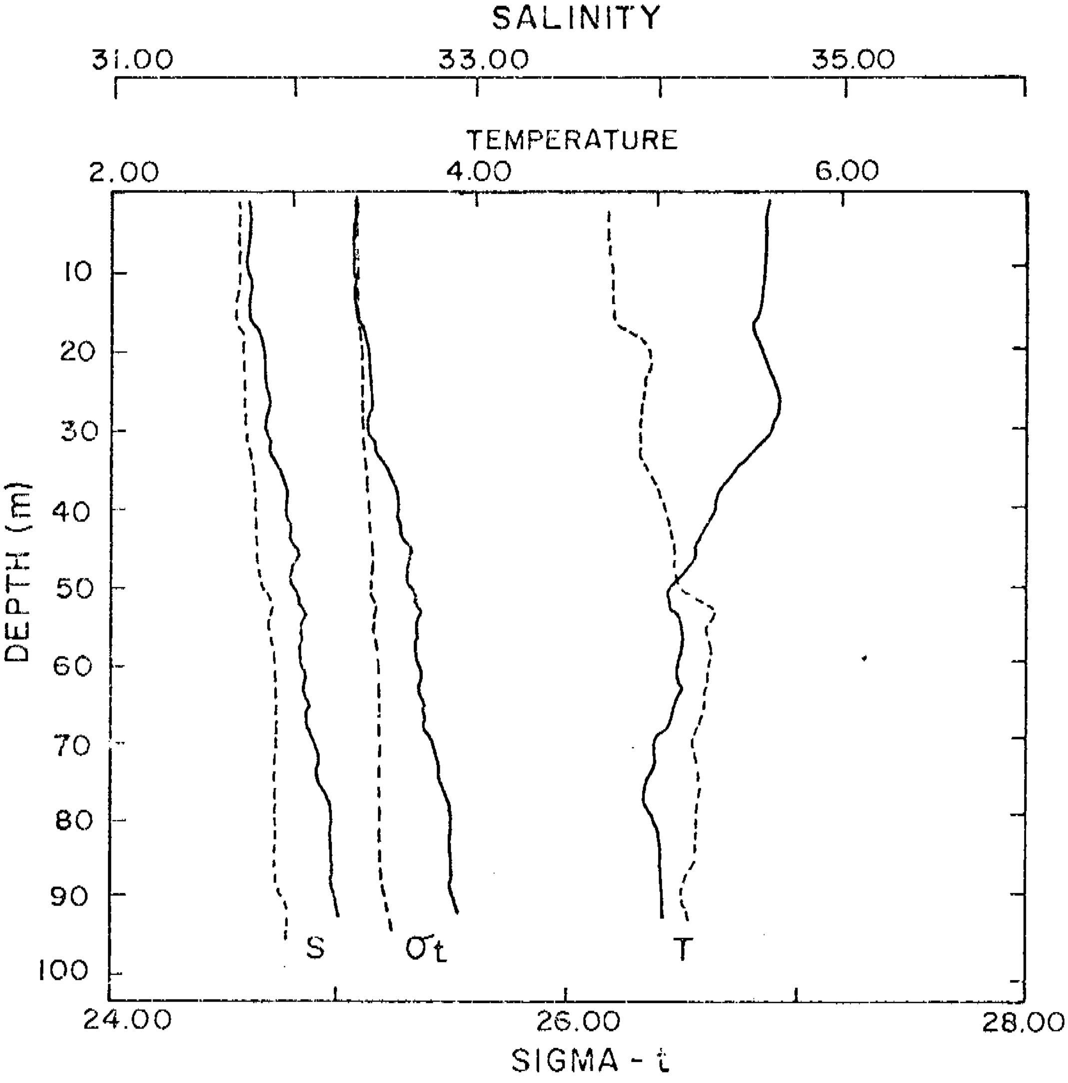


Figure 2. Vertical profiles of temperature (T), salinity (S), and sigma-t (σ_T) at mooring SLS-1 during February (dashed) and May (solid).

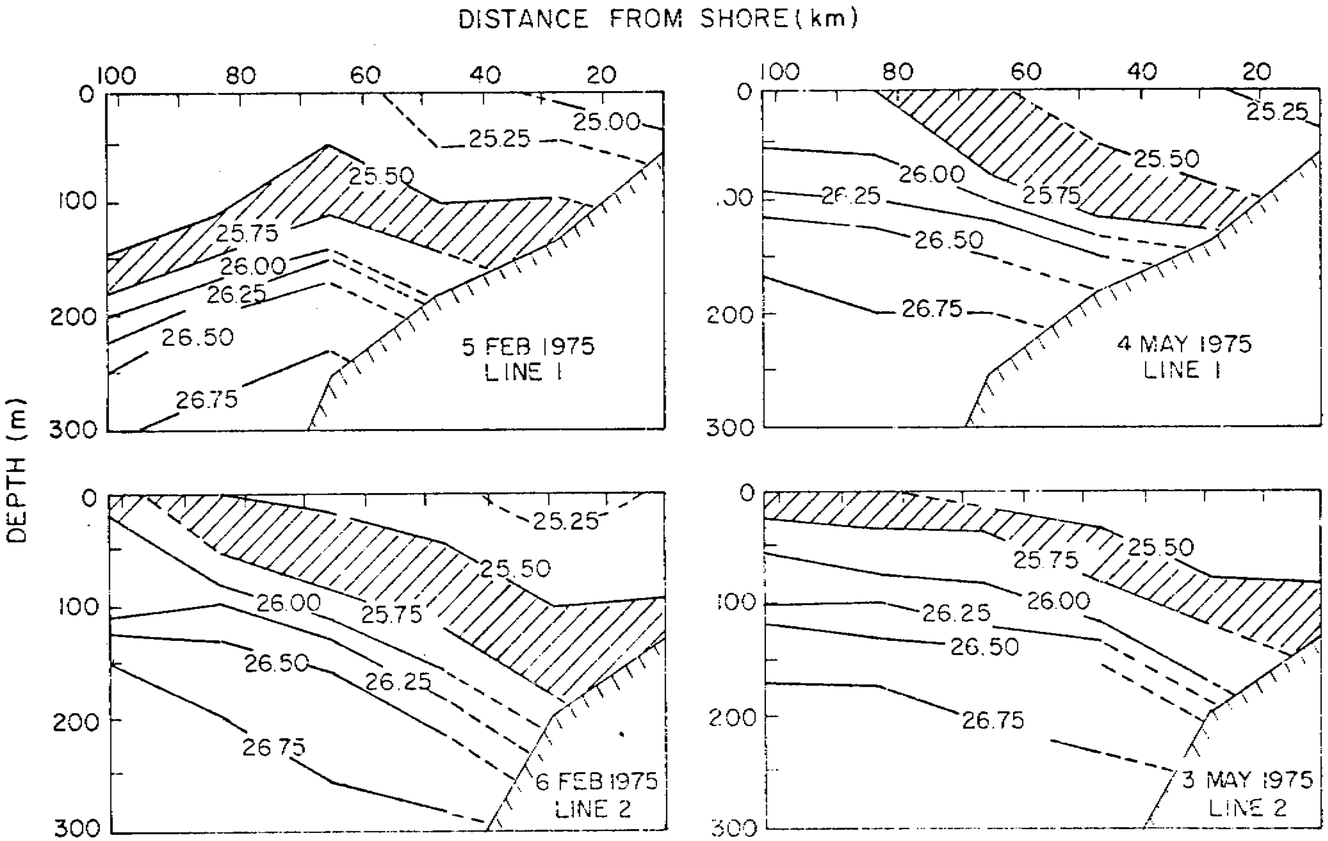


Figure 3. Vertical sections of sigma-t along lines 1 and 2 during February and May.

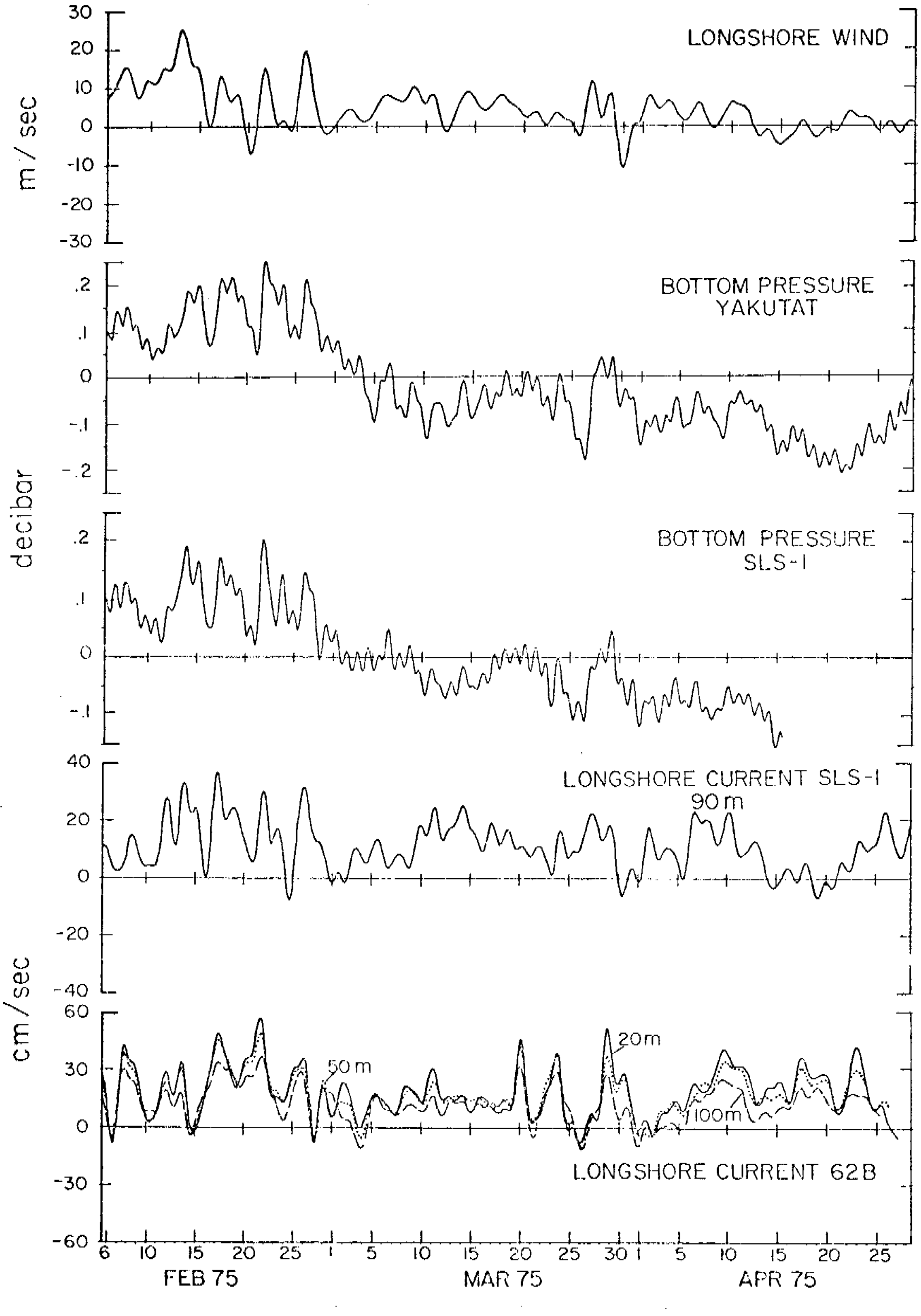


Figure 4. Low pass filtered (half-power frequency .025 cph) alongshore wind, current and bottom pressure.

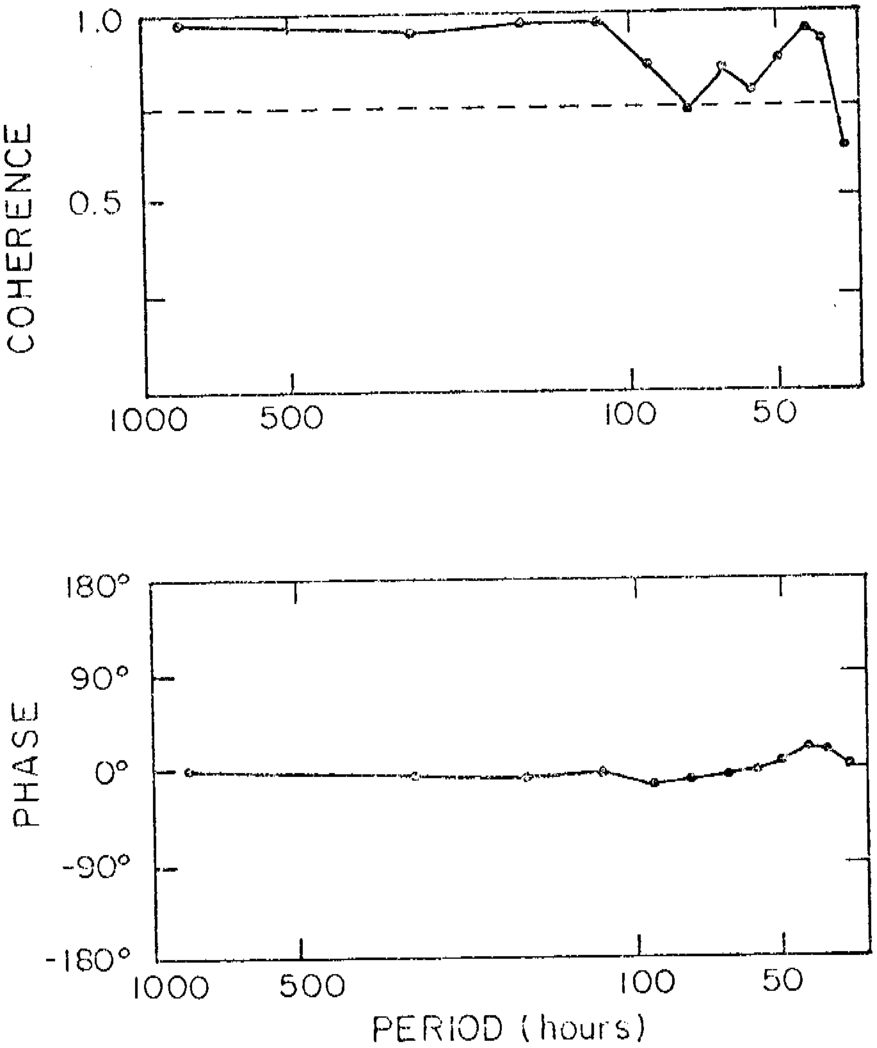


Figure 5. The coherence and phase between Yakutat bottom pressure and SLS-1 bottom pressure.

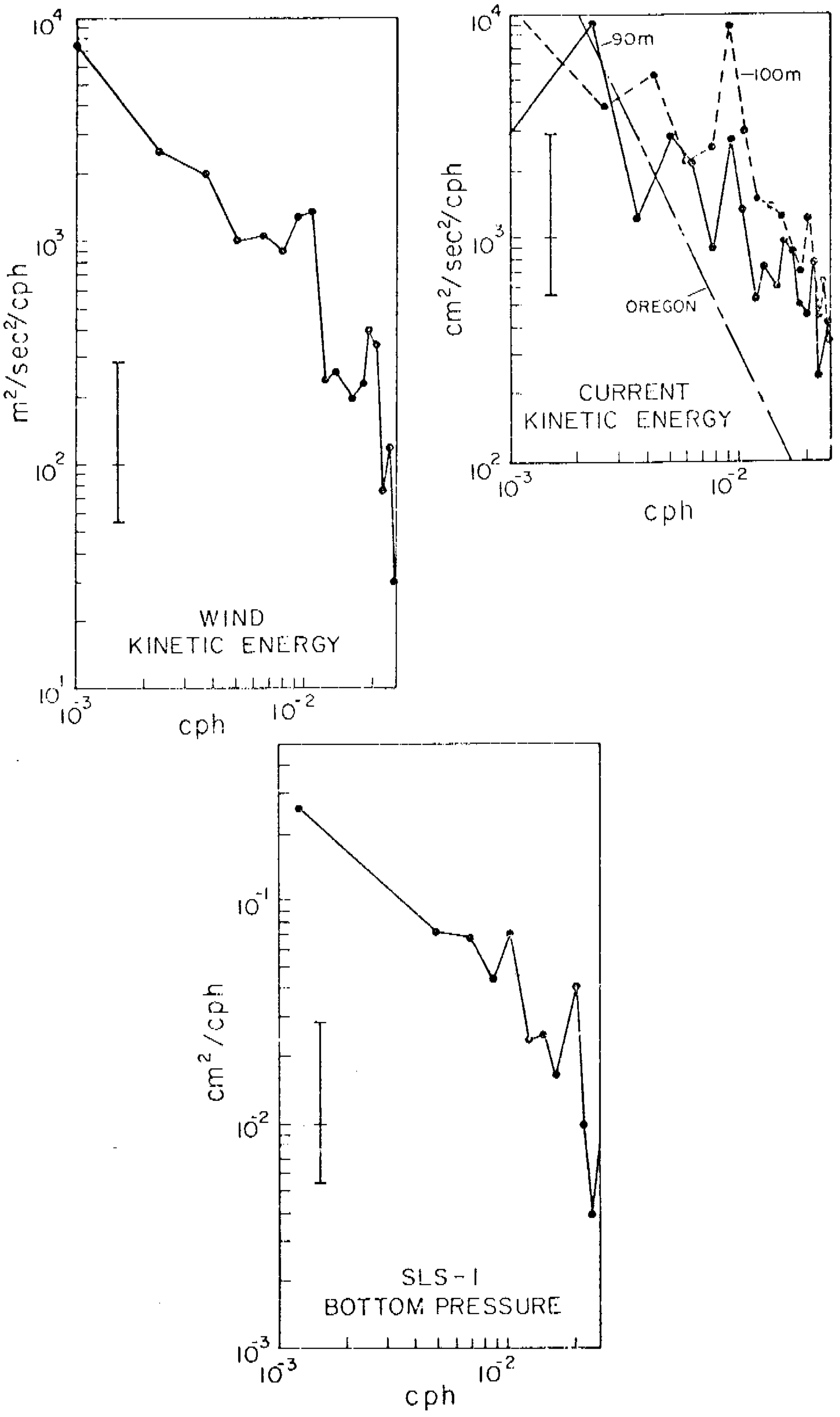


Figure 6. Kinetic energy density spectrum for calculated winds and for currents at SLS-1 and 62B. Variance density for SLS-1 bottom pressure.

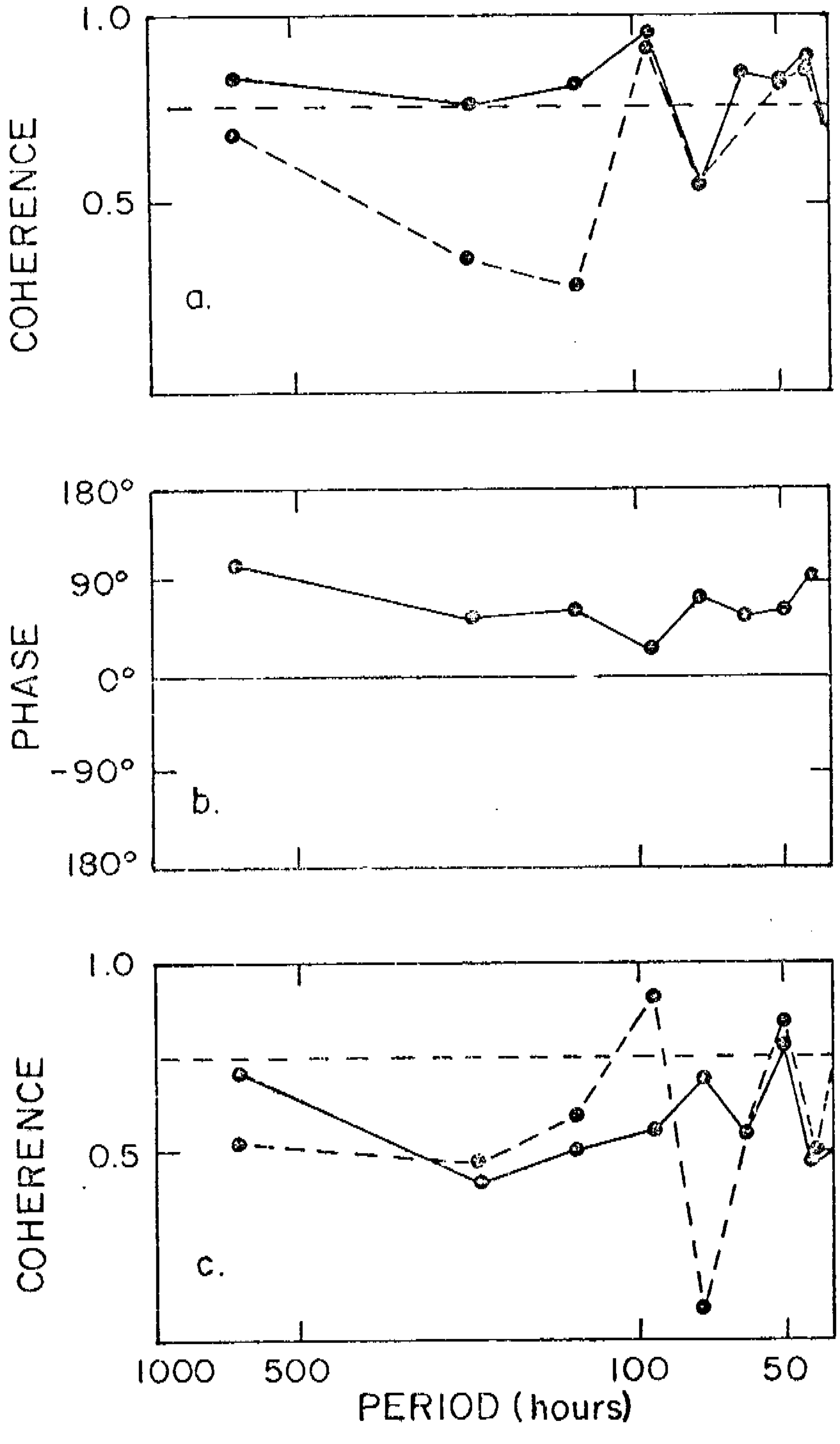


Figure 7. Coherence between calculated wind (solid) or measured Yakutat wind (dashed) and SLS-1 bottom pressure. (a) alongshore wind coherence (b) alongshore winds (calculated) phase (c) onshore wind coherence.

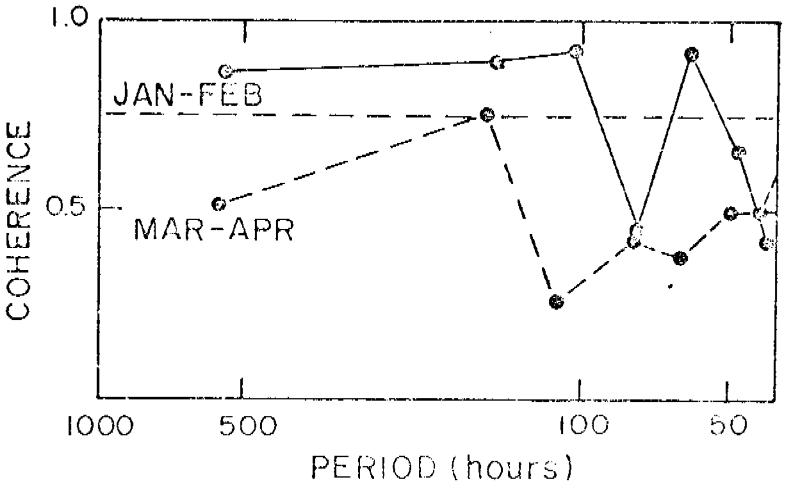


Figure 8. Coherence between calculated alongshore winds and Yakutat bottom pressure for the winter and the spring periods.

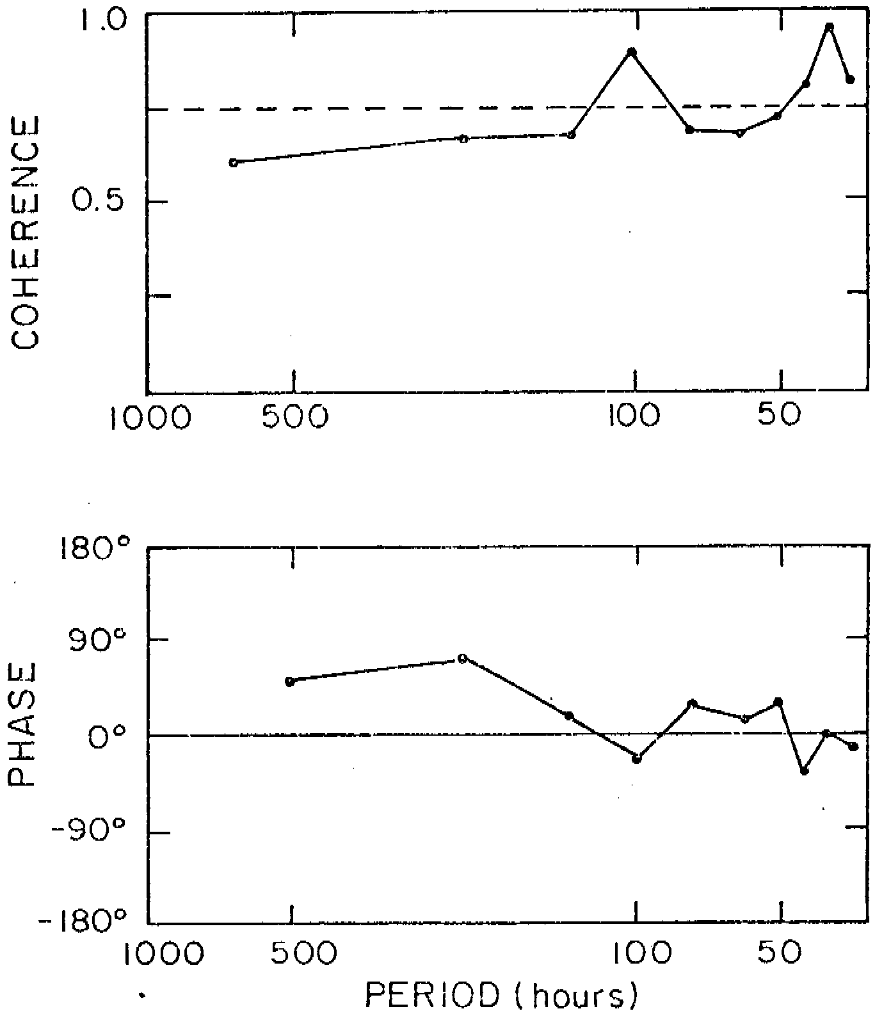


Figure 9. Coherence and phase between SLS-1 bottom pressure and current at 90 m depth.

RU# 140/146/149/31

NO REPORT SUBMITTED

The principal investigator is in the field.

QUARTERLY REPORT

Contract No.:

03-5-022-67, TA 4

Research Unit Nos.:

141, 145, 148

Reporting Period:

1 April 1976 - 30 June 1976

Number of Pages:

3

Bristol Bay Oceanographic Processes (B-BOP)

L. K. Coachman

Department of Oceanography
University of Washington

J. D. Schumacher
Pacific Marine Environmental Laboratory

30 June 1976

I. Objectives

This study is a joint program with Pacific Marine Environmental Laboratory, ERL, NOAA to provide water mass circulation information over the eastern Bering Sea shelf region for the Outer Continental Shelf Environmental Assessment Program. This program is outlined in detail in Dr. J. Schumacher's report.

II. Field Activities

A. See attached cruise reports.

B. Scientific party

See attached.

C. Methods

See attached.

D. Station location / cruise track

See attached.

E. Data collected (U of W)

1. Pressure gauge 9-7-75 to 10-4-75

   Mooring BC-4A

   Mooring BC-2A 9-8-75 to 10-5-75

   NODC Accession Number 76-0748

2. Mooring BC-4A

   Current Meter 1011/3 T = 20 min.

   Current Meter 1013/2 T = 20 min.

   NODC Accession Number 76-0745

3. Mooring BC-4B 10-4-75 to 6-14-76

   Current Meter 734/07

4. Mooring BC-12A 3-19-76 to 6-12-76

   Current Meter 1011/4

   Current Meter 1013/3

5. Moorings deployed (UW)

BC-4C	2 cm + 1 PG
BC-8A	2 cm
BC-9A	2 cm
BC-10A	1 cm + 1 PG
BC-11A	1 PG

III. Results

Data from Mooring BC-4B and BC-12A are now being processed. The reduction and processing of the C-T-D is under Dr. Schumacher's supervision.

IV. Preliminary Interpretation of Results

A scientific paper titled, "Finestructure Instability in Outer Bristol Bay," by L. K. Coachman and R. L. Charnell is in preparation.

V. Problems Encountered

As yet we do not have any C-T-D data taken from NOAA ship *Discoverer* to reduce to analyze.

VI. Estimate of Funds Expended (May 30, 1976)

Original Allocation: $197,500

A.	Salaries	$ 24,338
B.	Benefits	2,823
C.	Indirect costs	10,660
D.	Supplies & Other Direct Costs	33,320
E.	Equipment	66,418
F.	Travel	7,692
	Total Expenditures	145,251
	Balance	52,249

QUARTERLY REPORT

Contract No.:
R7120849

Research Unit Nos.:
141, 145, 148

Reporting Period:
1 April 1976 - 30 June 1976

Number of Pages:
1

Bristol Bay Oceanographic Processes
(B-BOP)

J.D. Schumacher
Pacific Marine Environmental Laboratory

L.K. Coachman
Department of Oceanography
University of Washington

15 July 1976

Task Title: BRISTOL BAY OCEANOGRAPHIC PROCESSES (B-BOP)

PI: Dr. James D. Schumacher
NOAA/PMEL
3711 15th Avenue N.E.
Seattle, WA 98105

Dr. L.K. Coachman
Dept. of Oceanography
University of Washington
Seattle, WA 98195

Report Period 1 April - 30 June 1976

I. Task Objectives:

1) Determine spatial and temporal variability in the velocity-field and obtain indications of spatial coherence at various length scales across Bristol Bay.
2) Determination of sea level perturbation time and length scales.
3) Examination of meteorological factors related to observed pulses in mean flow.
4) Characterization of temporal and spatial variability of hydrographic properties.

II. Field and Laboratory Activities:

A. Cruises: See attached cruise reports

B. Laboratory Activities: Meetings among PI's were held at the Sandpoint facility on 13-14 May to coordinate plans for FY77 and to discuss this year's work. In attendance were: Drs. L.K. Coachman, K. Aagard and R. Tripp (UW), T. Royer and R. Muench (U of A), J. Galt, R. Charnell, J. Schumacher, S. Hayes (PMEL) and R. Overstreet (ERL).

III. Results

Data from mooring BC-2B are now being processed. CTD data from cruise RP-4-MW-76A of the OCSEAP Bering Sea Project (casts 1-32, 10-23 March 1976) have been transmitted to the Project Office.

IV. Preliminary Interpretation of Results

A scientific paper titled, "Fine Structure Instability in Outer Bristol Bay" by L.K. Coachman and R.L. Charnell, based on the 10-23 March 1976 CTD data is in preparation.

BRISTOL BAY OCEANOGRAPHIC PROCESSES

1. *Objectives*

This study is a joint program with the Pacific Marine Environmental Laboratory (PMEL), ERL, NOAA to provide water mass and circulation information over the southeastern Bering Sea shelf region for the Outer Continental Shelf Environmental Assessment Program (OCSEAP). The objective of Leg VI of Cruise RP-4-MW-76A was to deploy twelve and to recover six instrument moorings, and to deploy three near-surface drifters. The objective of Leg VII was to occupy CTD stations on the Bristol Bay Oceanographic Processes (B-BOP) grid.

2. *Cruise Track and Narrative*

The R/V *Moana Wave* departed Kodiak, Alaska at 1700 26 May (all times herein are GMT) and proceeded to the Bering Sea to commence Leg VI (Fig. 1). Mooring deployment and recovery proceeded as follows (also see Appendices A and B):

1)	Station BC-3B	Recovered two current meters and one pressure gauge at 0509 29 May.
	Station BC-3C	Deployed two current meters at 0542 29 May
2)	Station BC-12A	Attempted to recover two current meters at 1430 29 May, but the release failed to respond to either firing or interrogation signals on channels 7-10 (the release was set on 7; nearby moorings at lower channels). After spending eight hours in a box search pattern, the ship departed the area. NOAA ship *Miller Freeman* recovered this mooring at 1730 12 June after normal release response.
3)	Station BC-7A	Recovered two current meters and one pressure gauge at 0002 30 May.
4)	Station BC-14A	Deployed two current meters and one pressure gauge at 0532 30 May.
5)	Station BC-6A	Recovered two current meters and one pressure gauge at 1535 30 May.
6)	Drifters	Launched two near-surface drifters to be tracked by satellite as follows:

PRL #1
NASA ID 0503
56-37.7 N 1800 30 May (about)
162-44.0 W

PRL #2
NASA ID 0535
56-42.2 N 1800 30 May (about)
162-51.3 W

7) Station BC-5A Deployed two current meters at 2008 30 May.

Drifter Launched one near surface drifter to be tracked by satellite as follows:

PRL #3
NASA ID 0544
56-49.2 N 2030 30 May (about)
163-06.6 W

8) Station BC-2B Recovered two current meters and one pressure gauge at 2236 30 May.

Station BC-2C Deployed two current meters and one pressure gauge at 0025 31 May.

9) Station BC-15A Deployed two current meters and one pressure gauge at 0458 31 May.

10) Station BC-10A Deployed one current meter and one tide gauge at 0632 1 June.

11) Station BC-8A Deployed two current meters at 1505 1 June.

12) Station BC-4B Attempted to recover two current meters and one pressure gauge at 1930 1 June. The release responded properly to interrogate signals, but failed to respond to firing signals. The NOAA ship *Miller Freeman* recovered the upper current meter by dragging at 1610 14 June.

Station BC-4C Deployed two current meters and one pressure gauge at 2000 1 June.

13) Station BC-9A Deployed two current meters at 0019 2 June.

14) Station BC-11A Deployed one pressure gauge at 0415 2 June.

About 2300 2 June Doug Causey, USFWS, embarked until about 2130 4 June for bird observations in the vicinity of the Pribilof Islands. At 2300 2 June the ship moored at Dutch Harbor, Alaska, to await a new tape deck for the CTD. The old unit had failed on 1 June at Station BC-10. Leg VI was terminated, although Station BC-13 had yet to be done.

The new tape deck arrived on a Reeves Aleutian Airlines flight at 0330 6 June and the ship was underway to commence Leg VII at 0500 6 June (see Fig. 2).

1) Station BC-13A Recovered two current meters and one pressure gauge at 1438 6 June.

Station BC-13B Deployed two current meters at 1636 6 June.

2) CTD Grid

About 0000 7 June the ship commenced occupying CTD stations on the master B-BOP grid. Between stations 70-71-72-73, 104-94-84 and 137-138-139-140-141 intermediate stations were occupied at intervals of approximately 5 nautical miles. Stations were occupied in the following order: 70-73, 83-80, 90-93, 103-100, 110-113, 117-114, 125-129, 118-120, 131, 121, 132, 133, 122, 123, 108-104, 94, 84, 85, 95, 96, 86, 87, 97, 98, 88, 137-141, 78-74, 63-58, 46-50, 40-35, 25-30 and 20-15.

University of Washington (UW) participation ended at Dutch Harbor at 0730 18 June.

3. *Methods*

Aanderaa RCM-4 current meters set to record at 20-minute intervals were used on each mooring. UW instruments record current speed, direction and temperature while PMEL instruments also record conductivity and pressure. AanderaaTG-2 (pressure) or TG-3 (pressure and temperature)gagues were put in wells in the anchors at the appropriate moorings. CTD stations were taken after each deployment and recovery, except when the CTD was inoperable (see above). A Nansen bottle temperature and salinity sample was obtained at the bottom of each cast, except at the intermediate stations. A Plessy Model 9041 CTD was used and data collected on 7-track magnetic tape for reduction ashore. Salinity samples were analyzed on board ship using a Beckman RS7-C portable salinometer.

4. *Personnel*

J. Haslett	Chief Scientist	PMEL
T. Kinder	Student	UW
R. Newman	Technician	PMEL
D. Ripley	Student Helper	UW
K. Metzner	Student	USFWS
D. Causey	Student	USFWS
W. King	Master	R/V *Moana Wave*

5. *Summary*

moorings deployed	12	
moorings recovered	4	
moorings not recovered	2	(see Note)
current meters deployed	25	
current meters recovered	10	
current meters not recovered	4	(see Note)
tide gauges deployed	7	
tide gauges recovered	4	
tide gauges not recovered	1	
CTD stations occupied	152	
salinity samples	106	

Note: Two current meters from BC-12A and one current meter from BC-4B were recovered subsequently by NOAA ship *Miller Freeman*.

APPENDIX A

UW Deployment Summary

	BC-10A	BC-8A (1)	BC-4C	BC-9A (1)	BC-11A (2)
Sounding (m)	66	73	58	39	31
Down Time (GMT)	0631 1 June	1505 1 June	2000 1 June	0019 2 June	0415 2 June
Latitude (N) Longitude (W)	57-16.6 169-32.8	57-58.5 168-49.5	58-35.8 168-20.7	59-14.0 167-36.1	59-40.9 167-13.6
Loran C	48274.3(Z) 33926.6(Y)	47872.1(Z) 33379.5(Y)	47565.2(Z) 32894.0(Y)	47222.0(Z) 32400.6(Y)	47001.9(Z) 32025.1(Y)
CM ser depth (m)	355 49	1922 26	1920 25	1925 17	- -
CM ser depth (m)	- -	1923 54	1921 52	1927 27	- -
TG ser depth (m)	115 65	- -	111 57	- -	184 30
Release ser chn	502085 6	500954 1	138 7	501054 2	502285 8

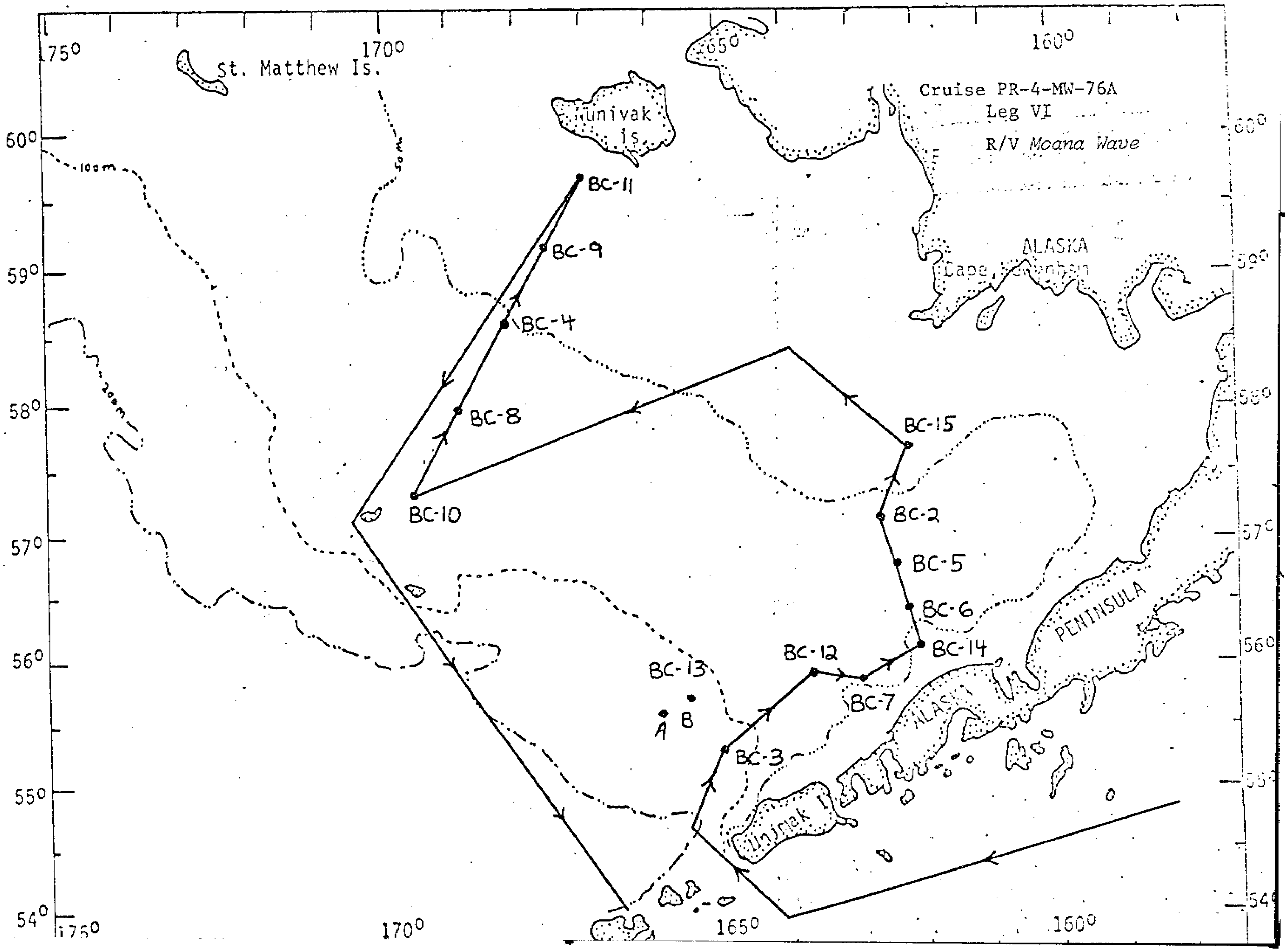
Note 1. BC-8A and BC-9A used a galvinized to stainless steel connection to connect to PMEL anchor.

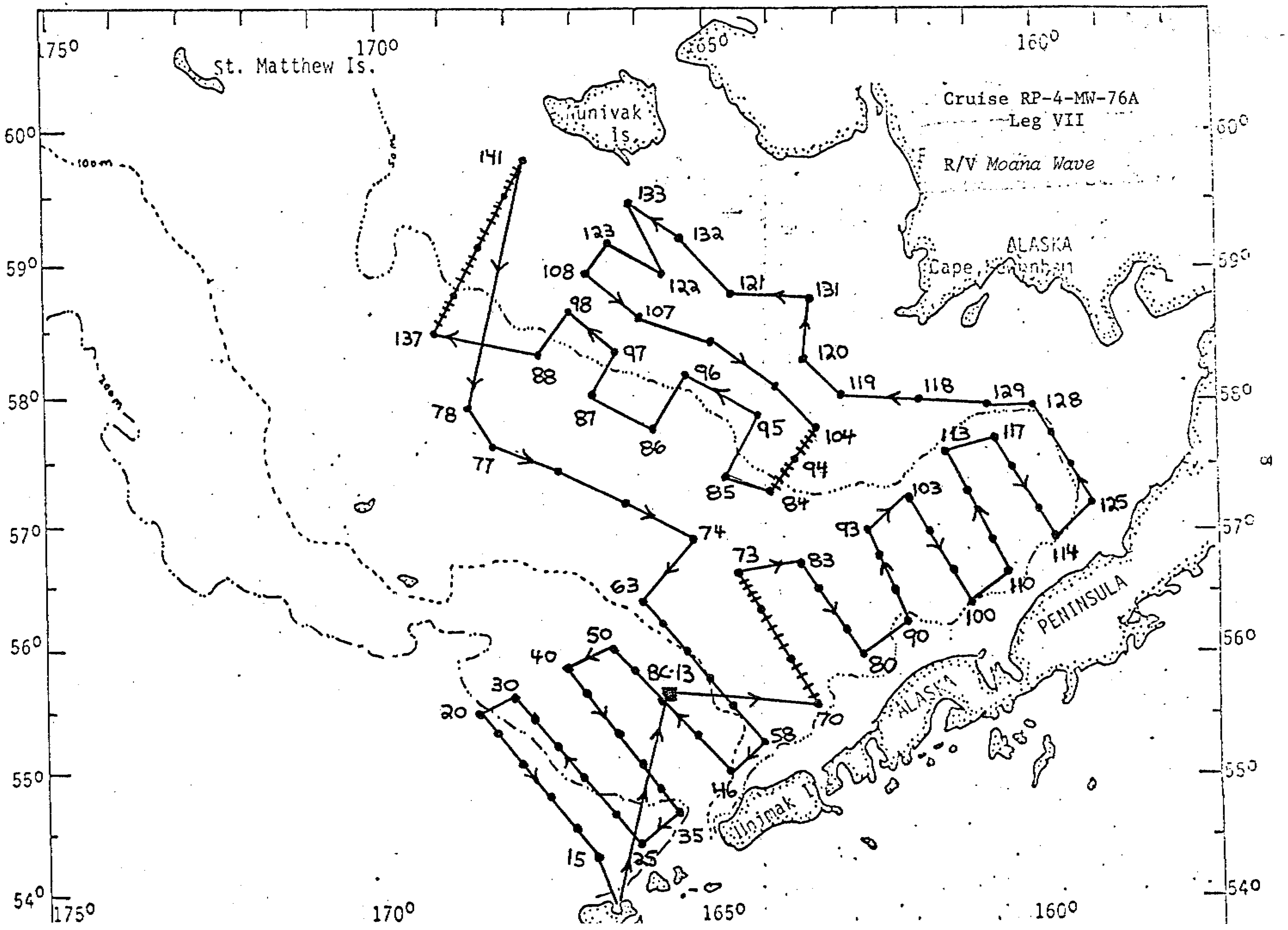
Note 2. BC-11A used 6 glass spheres for flotation. They were originally black, but were painted a sickly yellow-orange to improve visibility.

APPENDIX B

PMEL Deployment Summary

Station	INST	Latitude (N)	Longitude (W)	Loran C	Depth (m)	Channel
BC-2C	2CM + 1PG	57-03.7	163-21.3	32796.5(Y) 45799.8(Z)	65	6
BC-3C	2CM	55-01.8	165-09.8	18355.5(X) 46343.1(Z)	114	8
BC-5A	2CM	56-49.2	163-06.6	32822.9(Y) 45678.8(Z)	70	2
BC-6A	2CM	56-32.1	162-35.3	32824.2(Y) 45451.8(Z)	76	3
BC-13B	2CM + 1PG	55-30.1	165-49.4	33600.0(Y) 46647.0(Z)	117	1
BC-14A	2CM + 1PG	56-02.3	161-50.0	32832.7(Y) 45101.4(Z)	51	1
BC-15A	2CM + 1PG	57-36.4	162-45.2	32484.3(Y) 45559.7(Z)	51	4


Cruise PR-4-MW-76A
Leg VI
R/V *Moana Wave*
St. Matthew Is.
Nunivak Is.
ALASKA
Cape Newenham
PENINSULA
ALASKA
Unimak I.
100m
200m
50m
BC-11
BC-9
BC-4
BC-8
BC-10
BC-15
BC-2
BC-5
BC-6
BC-14
BC-12
BC-7
BC-13
A
B
BC-3
175°
170°
165°
160°
60°
59°
58°
57°
56°
55°
54°


Cruise RP-4-MW-76A
Leg VII
R/V Moana Wave
St. Matthew Is.
Nunivak Is.
ALASKA
Cape Newenham
PENINSULA
ALASKA
Unimak I.
100m
50m
175°
170°
165°
160°
60°
59°
58°
57°
56°
55°
54°
141
137
133
132
123
108
122
121
131
98
107
120
119
118
129
128
88
97
96
87
86
95
104
78
77
85
84
94
113
117
125
103
93
114
74
73
83
110
100
63
90
80
50
40
BC-13
70
30
20
58
46
35
25
15

BRISTOL BAY OCEANOGRAPHIC PROCESSES

1. *Objectives*

This study is a joint program with Pacific Marine Environmental Laboratory, ERL, NOAA to provide water mass circulation information over the eastern Bering Sea shelf region for the Outer Continental Shelf Environmental Assessment Program (OCSEAP).

The Leg II portion of Cruise RP-4-MW-76A on the R/V *Moana Wave* was the third phase in the program directed towards accomplishing this research. The objectives of this cruise were: 1) the recovery and deployment of current meter and pressure gauge moorings in the eastern Bering Sea; 2) the recovery and deployment of current meter moorings, between south of Kodiak Island and Unimak Pass, for the NEGOA project; 3) a series of C-T-D stations selected from the Bristol Bay Oceanographic Processes (B-BOP) program master grid and near the ice edge.

2. *Cruise Track and Narrative*

The R/V *Moana Wave* departed Kodiak, Alaska at 0337 GMT, 9 March 1976 and proceeded to the survey area (Fig. 1).

The following moorings were recovered and deployed as follows:

1)	Station WGC-2B	did not respond to interrogation at latitude 57°26.7' North; longitude 150°29.4' West. A six-hour search pattern was initiated between 1700 and 2300 GMT, 9 March 1976.
	Station WGC-2C	deployed at 0054 GMT, 10 March 1976 in 186 meters water depth at latitude 57°26.92 North; longitude 150°29.59' West. Loran-C rates were 31204.2 (Y) and 42132.6 (Z). This mooring consisted of four current meters, a pressure gauge and an acoustic release (Channel 1).
2)	Station WGC-3A	deployed at 2225 GMT, 11 March 1976 in 184 meters water depth at latitude 55°04.9' North; longitude 157°09.5' West. Loran-C rates were 32427.7 (Y) and 18558.7 (X). This mooring consisted of four current meters, a pressure gauge, and an acoustic release (Channel 3).
3)	Station WGC-1B	released at 1926 GMT and recovered at 2045 GMT, 12 March 1976.
	Station WGC-1C	deployed at 0115 GMT, 13 March 1976 in 183 meters water depth at latitude 54°01.0' North; longitude 163°02.8' West. Loran-C rates were 45479.5 (Z) and 18231.0 (X). This mooring consisted of four current meters and acoustic release (Channel 2).

4) Station BC-3A released at 1804 GMT and recovered at 1837 GMT, 16 March 1976.

Station BC-3B deployed at 2026 GMT, 16 March 1976 in 116 meters water depth at latitude 55°01.3' North; longitude 165°04.8' West. The Loran-C rates were 46345.9 (Z) and 18354.3 (X). This mooring consisted of two current meters, a pressure gauge, and acoustic release (Channel 6).

5) Station BC-1B did not respond to interrogation at 1825 GMT, 17 March 1976. The weather freshened with heavy icing so no search was attempted at that time.

A positive interrogation was made at 1130 GMT, 22 March 1976 at latitude 55°23.161 North; longitude 167°55.773 West (approximately 5 mi SE of deployment). The Loran-C rates were 42371.20 (Z) and 33925.7 (Y). Various courses were steered in an attempt to close in on the mooring. It was found that the mooring could only be interrogated from one quadrant, suggesting that the acoustic release was lying on its side minus the rest of the mooring. This was further substantiated upon firing when the mooring did not surface. The presence of heavy trawling in the area is fairly indicative of what happened to the mooring.

6) Station BC-12A deployed at 1932 GMT, 19 March 1976 in 95 meters water depth at latitude 55°48.16' North; longitude 163°53.62' West. The Loran-C rates were 45929.03 (Z) and 33222.77 (Y). This mooring (Fig. 2) consisted of two current meters, and acoustic release (Channel 7).

7) Station BC-7A deployed at 0440 GMT, 20 March 1976 in 67 meters water depth at latitude 55°42.3' North; longitude 163°01.3' West. The Loran-C rates were 45577.0 (Z) and 33108.6 (Y). This mooring consisted of two current meters, a pressure gauge and acoustic release (Channel 4).

8) Station BC-13A deployed at 0153 GMT, 22 March 1976 in 122 meters water depth at latitude 55°30.2' North; longitude 166°01.7' West. The Loran-C rates were 46724.81 (Z) and 33630.00 (Y). This mooring consisted of two current meters and acoustic release (Channel 5).

Hydrographic stations were occupied at the following B-BOP C-T-D master grid stations: Nos. 70, 59, 58, 47, 46, 35, 36, 37, 48, 39, 29, 18, 17, 16, 15, 25 and 35. Six other C-T-D stations were occupied near the ice edge. In addition, C-T-D casts were accomplished near moorings WGC-2C, WGC-3A, WGC-1C, BC-3B, BC-12A, BC-7A, and BC-1B.

A total of 24 salinity samples and temperature measurements were collecte for calibration of the C-T-D data.

The R/V *Moana Wave* docked at the ferry pier Kodiak, Alaska 1900 GMT, 25 March 1976. A total of 2192 nautical miles were logged on Leg II of this cruise.

3. *Methods*

Aanderaa RCM-4 current meters were employed on each mooring, set to record data (current speed and direction, temperature, conductivity and pressure) at a timing interval of 20 minutes. The meters on mooring BC-12A do not have a conductivity or pressure sensor. An Aanderaa TG-2A pressure gauge was housed in an anchor well on five of the moorings (not WGC-1C, BC-12A, and BC-13A). These units integrate total pressure over 100 seconds and record every 15 minutes.

C-T-D casts were taken on each hydrographic station utilizing a Plessy Model 9050 Environmental Profiling System. Data were stored on 7-track magnetic tape for reduction ashore. In order to determine field correction factors for the conductivity and temperature sensors, a Nansen bottle was attached 1 meter above sensors.

Salinity samples were analyzed aboard ship on a Beckman Instruments Model RS-7C Portable Inductive Salinometer Serial No. 28951.

4. *Personnel*

Mr. J. Haslett	Chief Scientist	PMEL/ERL/NOAA
Mr. D. Spell	Electronics Technician	
Mr. R. B. Tripp	Principal Oceanographer	University of Washingt
Ms. B. Hogarty	Research Technologist	

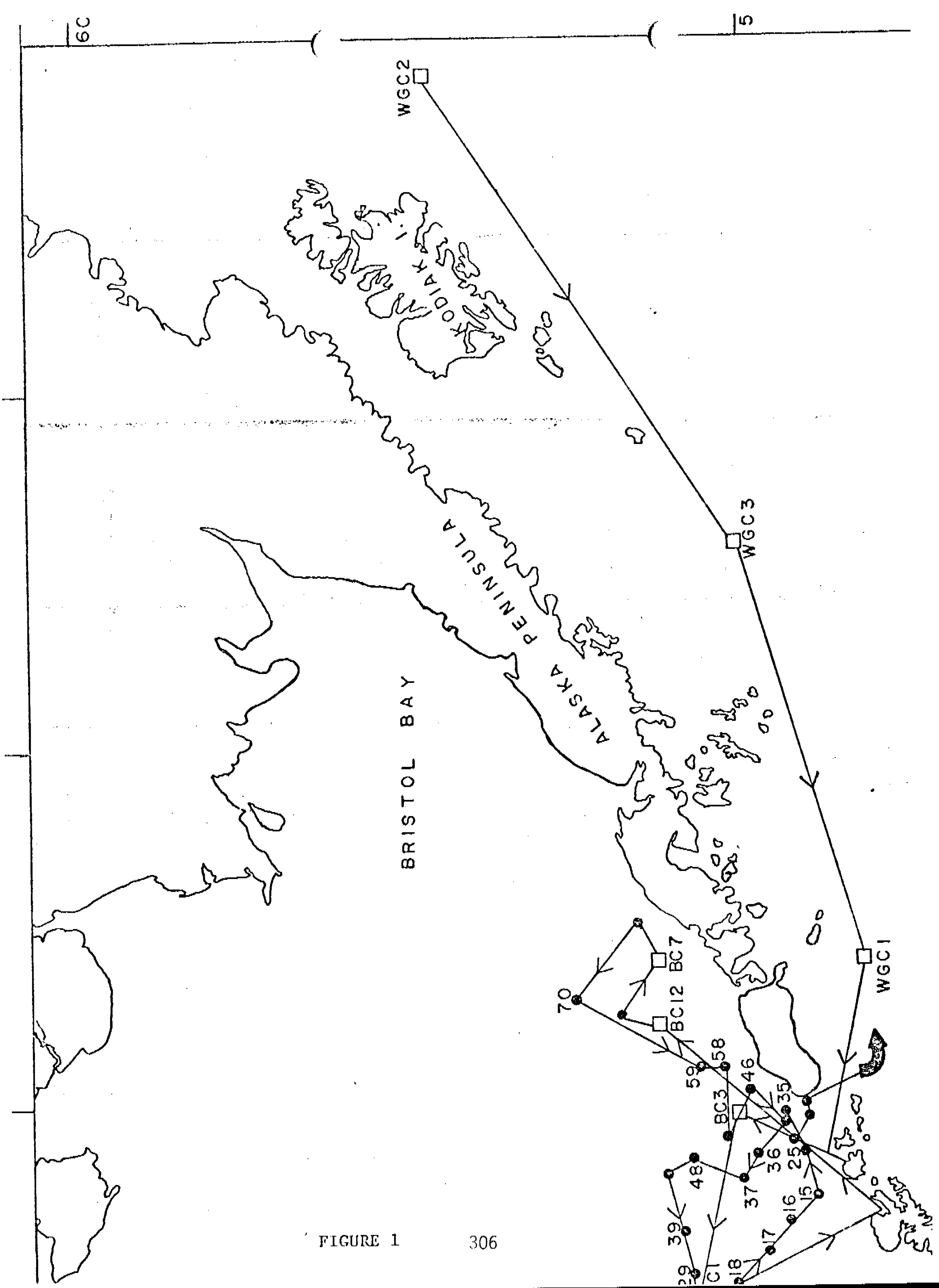
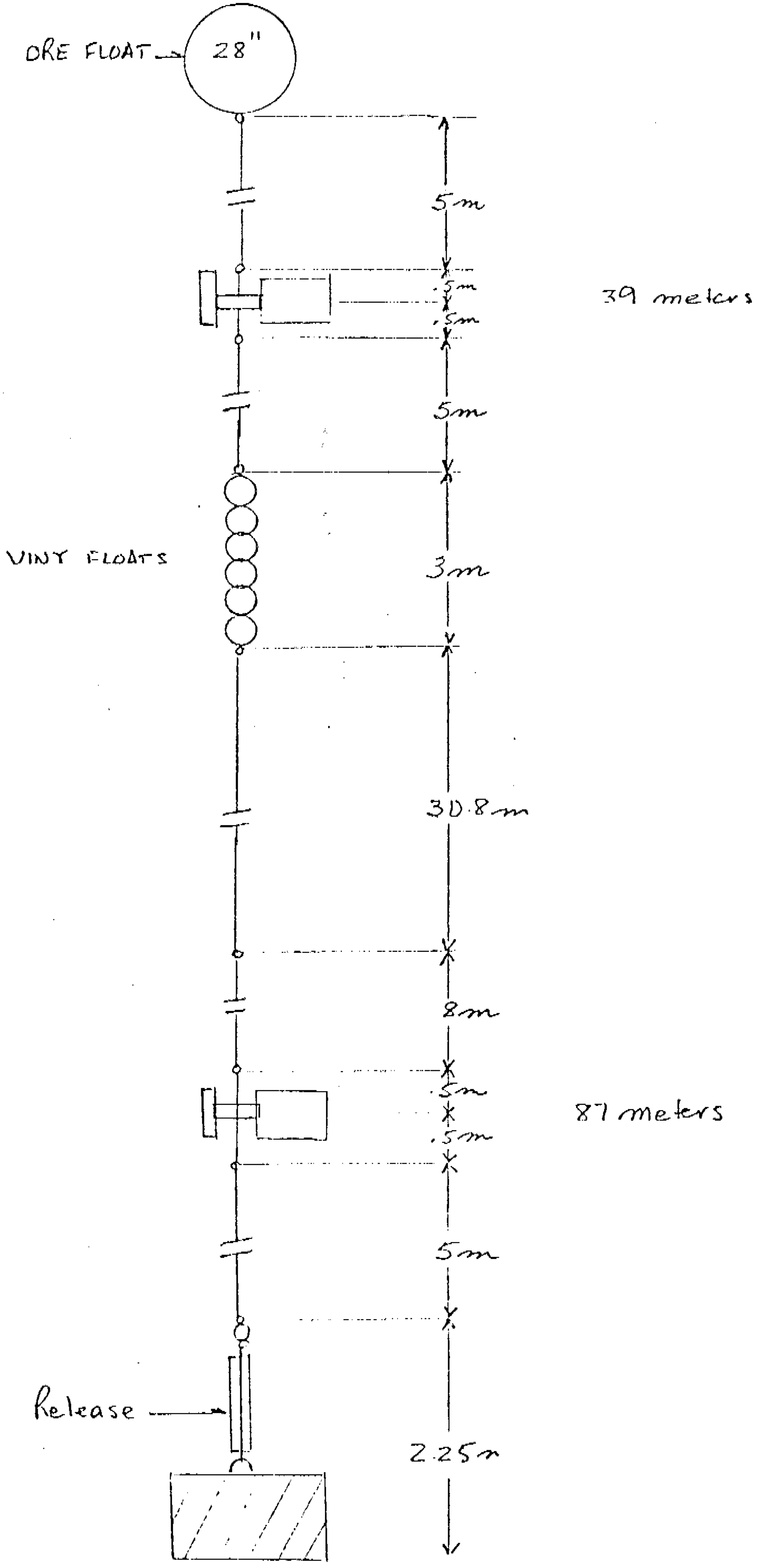

6C
5
WGC2
KODIAK I.
WGC3
ALASKA PENINSULA
BRISTOL BAY
WGC1
BC7
BC12
70
58
59
46
35
BC3
36
25
48
37
15
16
39
17
C1
18

FIGURE 1

FIGURE 2


ORE FLOAT
28"
5m
.5m
.5m
39 meters
5m
VINY FLOATS
3m
30.8m
8m
.5m
.5m
87 meters
5m
Release
2.25m

APPENDIX A

C-T-D Station Summary

Station No.	Grid No.	Time GMT	Date GMT 1976	Latitude N	Longitude W	Depth (m)
1	WGC-2	0141	3/10	57°27.4'	150°30.5'	173
2	WGC-3	2205	3/12	55°04.7'	157°10.0'	184
3	WGC-1	0133	3/13	54°01.0'	163°02.8'	180
5	BC-3	0300	3/16	55°01.6'	165°09.4'	100
6	BC-12	1954	3/19	55°42.2'	163°53.6'	85
7		2158	3/19	55°48.2'	163°53.6'	83
8	BC-7	0455	3/20	55°41.6'	163°01.9'	53
10		2120	3/20	55°48.1'	162°22.4'	40
11	BB-70	0128	3/21	56°29.9'	163°32.1'	62
12	BB-59	0435	3/21	55°22.9'	164°30.5'	92
13	BB-58	0514	3/21	55°11.2'	164°14.4'	59
14	BB-47	1020	3/21	55°08.0'	165°16.0'	103
15	BB-46	1238	3/21	54°55.6'	164°50.6'	53
16	BB-35	1525	3/21	54°42.0'	165°22.2'	193
17	BB-36	1720	3/21	54°52.2'	165°46.0'	130
18	BB-37	1905	3/21	55°03.1'	166°04.9'	127
19	BB-48	2130	3/21	55°24.0'	165°43.9'	108
20		2330	3/21	55°37.2'	166°02.0'	113
21	BB-39	0438	3/22	55°30.1'	166°53.6'	127
22	BB-29	0644	3/22	55°24.2'	167°26.0'	129
23	BC-1	0855	3/22	55°23.9'	167°56.2'	168
24	BB-18	2325	3/22	55°05.3'	167°35.2'	277
25	BB-17	0242	3/23	54°49.1'	167°07.5'	350
26	BB-16	0323	3/23	54°37.4'	166°43.6'	385
27	BB-15	0705	3/23	54°23.0'	166°20.0'	670
28	BB-25	0947	3/23	54°29.3'	165°43.8'	380
29	BB-35	1206	3/23	54°43.1'	165°20.7'	174
30		1425	3/23	54°22.5'	165°31.0'	87
31		1548	3/23	54°28.0'	165°13.0'	156
32		1658	3/23	54°31.0'	165°00.5'	75

APPENDIX A (cont.)

MOORING STATION SUMMARY

Mooring No.	Time GMT	Date GMT 1976	Latitude N	Longitude W	Depth (m)	Loran-C			Receiver Code No.
						X-Rate	Y-Rate	Z-Rate	
WGC-2C	0054	10/3	57°26.92'	150°29.59'	186		31204.2	42132.6	1
WGC-3A	2225	11/3	55°04.9'	157°09.5'	184	18558.7	32427.7		3
WGC-1C	0115	13/3	54°01.0'	163°02.8'	183	18231.0		45479.5	2
BC-3B	2026	16/3	55°01.3'	165°04.8'	116	18354.3		46345.9	6
BC-12A	1932	19/3	55°48.16'	163°53.62'	95		33222.77	45929.03	7
BC-7A	0440	20/3	55°42.3'	163°01.3'	67		33108.6	45577.0	4
BC-13A	0153	22/3	55°30.2'	166°01.7'	122		33630.0	46724.81	5

BRISTOL BAY OCEANOGRAPHIC PROCESSES

1. *Objectives*

This study is a joint program with Pacific Marine Environmental Laboratory, ERL, NOAA to provide water mass circulation information over the eastern Bering Sea shelf region for the Outer Continental Shelf Environmental Assessment Program (OCSEAP).

The Leg IV portion of Cruise RP-4-MF-76A on the NOAA ship *Miller Freeman* was the fourth phase in the program directed towards accomplishing this research. The objectives of this cruise were: 1) the recovery and deployment of three current meter moorings, between east of Kodiak Island and Unimak Pass, for the NEGOA project; 2) a search for Station WGC-2B east of Kodiak Island; 3) a search for Station BC-12A located north of Unimak Island; 4) a search for Station BC-4B located between Nanivak Island and St. Paul Island; 5) a series of C-T-D stations selected from the Bristol Bay Oceanographic Processes (B-BOP) program master grid

2. *Cruise Track and Narrative*

The NOAA ship *Miller Freeman* departed Kodiak, Alaska at 0500 GMT, 8 June 1976 and proceeded to the survey area (Fig. 1).

The following moorings were recovered and/or deployed as follows:

1) Station WGC-2C	released at 1332 GMT, 8 June 1976 at latitude 57°26.92' North; longitude 150°29.59' West.
Station WGC-2D	deployed at 1547 GMT, 8 June 1976 in 92 meters water depth at latitude 57°34.6' North; longitude 150°48.6'West Loran-C rates were 31195.29 (Y) and 42165.32 (Z). This mooring consisted of three current meters and a Model 242 accoustic release (Channel 8).
Station WGC-2B	did not respond to interrogation at the deployment position. The mooring was interrogated using all possibl combinations of power settings at eight locations along the 100 fathom line (five locations northeast of the deployment position and three on the southwest side) with negative results. Two sweeps of the area using wire and grapnel hooks were also accomplished with negative results. The search was terminated at 2313 GMT, 8 June 1976.
2) Station WGC-3A	did not respond to interrogation at 0105 GMT, 10 June 1976. The search was temporarily suspended at 0330 GMT, 10 June 1976 to deploy Station WGC-3B. At 0530 GMT, 10 June 1976 the search was resumed. We attempted to fire at three likely locations along the 101 fathom line.

Negative results — Interrogations were made at 22 sites. Dragging was undertaken till 2030 GMT, 10 June 1976. Negative results.

Station WGC-3B — deployed at 0510 GMT, 10 June 1976 in 11.6 meters water depth at latitude 55°11.5' North; longitude 156°58.0' West Loran-C rates were 32377.90 (Y), 32377.98 (Y), 18574.60 (X) and 43219.44 (Z). This mooring consisted of three current meters and a Model 242 accoustic release (Channel 7).

3) Station WGC-1C — released at 1635 GMT, 11 June 1976 at latitude 54°00.3' North; longitude 163°02.9' West.

Station WCC-1D — deployed at 1831 GMT, 11 June 1976 in 89.6 meters water depth at latitude 54°03.0' North; longitude 163°06.05' West. Loran-C rates were 18238.53 (X), 33396.42 (Y), and 45502.88 (Z). The GP was obtained using the X and Y rates. The Z rate plotted slightly east. This mooring consisted of three current meters and a Model 242 accou release (Channel 4).

At 1839 GMT, 11 June 1976 proceeded to Dutch Harbour, Alaska to pick up ship's equipment. We arrived at 0350 GMT, and departed 0415 GMT, 12 J 1976 to return to the survey area (Fig. 2).

4) Station BC-12A — released at 1546 GMT, and recovered at 1730 GMT, 12 Jun 1976 at latitude 55°48.5 North; longitude 163°54.1' Wes in 96.9 meters water depth.

5) Station BC-4B — On station at 0840 GMT, 13 June 1976. Responded to interrogation but would not fire. A total of sixteen interrogations were made to home in on the mooring. A marker buoy was set and dragging operations began. The mooring was snagged on the twenty-fifth trawl at 1610 G 14 June 1976. The top current meter and the midwater floation were retrieved. Although the release (and remaining instrumentation) now void of any floation lay the bottom, it still responded to interrogation. Draggi operations continued for the remains of the mooring. An additonal twenty-seven sets were made. The remains were snagged on two separate occasions. On one of these the weight passed through the trawl net. Further recovery attempts were terminated at 1001 GMT, 16 June 1976.

Hydrographic stations were occupied at the following B-BOP C-T-D master grid stations: Nos. 69, 68, 56, 67, 66, 65, 64, 51, 52, 53, 54, 55, 44A, 44, 43, 42, 41, 31, and 19.

A total of 19 salinity samples and temperature measurements were collected from the Niskin bottle 1 meter above the C-T-D unit for calibrating the sensors.

The NOAA ship *Miller Freeman* docked at Dutch Harbour, Alaska at 0400 GMT, 18 June 1976 to disembark scientific personnel. A total of 1850 nautical miles were logged on this portion of the cruise.

3. *Methods*

Aanderaa RCM-4 current meters were employed on each mooring, set to record data (current speed and direction, temperature, conductivity and pressure) at a timing interval of 20 minutes.

C-T-D casts were taken on each hydrographic station utilizing a Plessy Model 9040 Environmental Profiling System Serial No. 6211 (calibrated at NRCC March 1976). Data were stored on 7-track magnetic tape for reduction ashore. In order to determine field correction factors for the conductivity and temperature sensors, a 10-liter Niskin bottle was attached to the rosette sampler.

The salinity samples were analyzed aboard ship using a Hytech Model 621 Portable Inductive Salinometer Serial No. 1043 (calibrated 12 March 1976).

4. *Personnel*

PMEL/ERL/NOAA	
Mr. N. P. Laird	Chief Scientist
University of Washington	
Mr. R. B. Tripp	Principal Oceanographer
Mr. S. Harding	Technician

APPENDIX A

C-T-D Station Summary

Station No.	Grid No.	Time GMT	Date GMT 1976	Latitude N	Longitude W	Depth (m)
1	BB-69	1524	6/16	57°53.8'	169°18.2'	69
2	BB-68	1830	6/16	57°32.1'	169°02.4'	73
3	BB-56	2025	6/16	57°10.7'	169°15.2'	75
4	BB-67	2300	6/16	57°05.9'	168°29.7'	80
5	BB-66	0050	6/17	56°55.1'	167°57.7'	88
6	BB-65	0232	6/17	56°46.4'	167°30.1'	93
7	BB-64	0430	6/17	56°35.2'	166°57.6'	102
8	BB-51	0717	6/17	56°06.0'	167°11.4'	138
9	BB-52	0931	6/17	56°20.3'	167°43.4'	136
10	BB-53	1121	6/17	56°29.0'	168°09.5'	126
11	BB-54	1319	6/17	56°38.8'	168°35.7'	112
12	BB-55	1522	6/17	56°51.2'	169°06.3'	85
13	BB-44A	1723	6/17	56°30.6'	169°23.2'	86
14	BB-44	1913	6/17	56°27.9'	169°08.7'	106
15	BB-43	2050	6/17	56°19.1'	168°44.0'	133
16	BB-42	2237	6/17	56°08.0'	168°17.0'	165
17	BB-41	0039	6/18	55°55.9'	167°46.1'	135
18	BB-31	0259	6/18	55°49.3'	168°18.6'	144
19	BB-19	0530	6/18	55°19.1'	167°56.0'	298

APPENDIX A (cont.)

MOORING STATION SUMMARY

Mooring No.	Time GMT	Date GMT 1976	Latitude N	Longitude W	Depth (m)	Loran-C			Receiver Code No.
						X-Rate	Y-Rate	Z-Rate	
WGC-2D	1547	6/8	57°34.6'	150°48.6'	92		31195.29	42165.32	8
WGC-3B	0510	6/10	55°11.5'	156°58.0'	111.6	18574.60	32377.90 32377.98	43219.44	7
WGC-1D	1831	6/11	54°03.0'	163°06.05'	89.6	18238.53	33396.42	45502.88	4

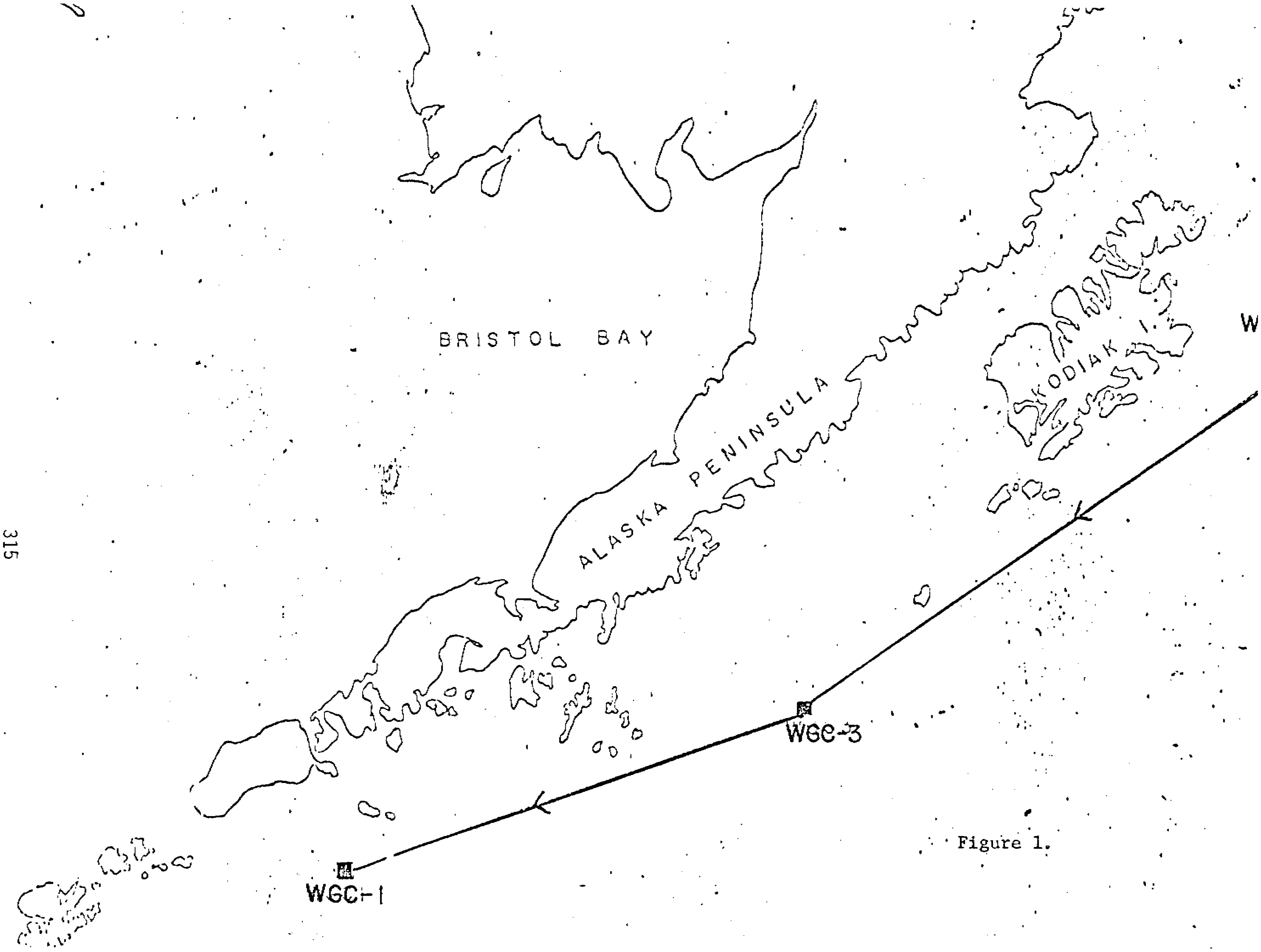


Figure 1.

QUARTERLY REPORT

Contract No.:

03-5-022-67, TA 1

Research Unit No.:

151

Reporting Period:

1 April 1976 - 30 June 1976

Number of Pages:

STD Mappings of the Beaufort Sea Shelf

Knut Aagaard

Department of Oceanography
University of Washington
Seattle, Washington 98195

30 June 1976

I. Objectives

To provide seasonally distributed temperature-salinity mappings of the Beaufort Sea Shelf and the dynamically related region of the slope. Such mappings are an essential prerequisite to, and component of, all physical oceanographic studies on the shelf. These mappings are necessary input for the accomplishments of task elements B-2 to B-4.

II. Field/Laboratory Activities

A. Field trip schedule

1. 19-29 May 1976 (GMT)
2. 205 Helicopter
3. Charter ERA Helicopter, Anchorage

B. Scientific party

1. Mr. Clark Darnall, University of Washington Cruise Leader.
2. Mr. Dennis Hanzlick, University of Washington.

C. Methods

Field sampling utilizing a Plessy Model 9400 Conductivity/Temperature/Depth profiling system.

D. Station locations

See attached listing.

E. Data collected

22 CTD stations. Parameters sampled between surface and bottom or between surface and 600 meters, whichever is greater.

III. Results

Data is being processed.

IV. Preliminary Interpretation of Results

See Annual Report

V. Problems Encountered

We are having data reduction difficulties due to instrument problems (sensor failure, leaking, drift etc). We anticipate solving the problems in the very near future. These sensor problems have brought about much more programming and re-running of data tapes than we had anticipated.

VI. Estimate of Funds Expended (May 30, 1976)

Original Allocation:	$ 51,726
A. Salaries	5,589
B. Benefits	606
C. Indirect Costs	2,448
D. Supplies & Other Direct Costs	18,964
E. Equipment	20,863
Total	48,470
Remaining Balance	3,256

CTD STATION LISTING - BEAUFORT SEA

Station/ Cast No.	Date (GMT) May 1976	Latitude °N	Longitude °W	Sounding m
1	19	71°07.8'	152°46.5'	26
2	19	71°11.8'	152°44.0'	31
3	19	71°17.5'	152°36.5'	49
4	19	71°23.0'	152°28.5'	113
5	19	71°28.4'	152°20.5'	119
6	19	71°33.7'	152°12.3'	305
7	19	71°38.0'	152°06.0'	874
8	20	71°43.5'	151°57.5'	1050
9	23	70°35.0'	147°12.0'	37
10	23	70°40.5'	147°04.2'	40
11	23	70°46.0'	146°56.0'	48
12	23	70°52.5'	146°47.8'	91
13	23	70°57.0'	146°41.0'	613
14	23	71°03.2'	146°33.0'	1452
15	23	71°07.9'	146°25.5'	1821
16	25	70°12.6'	142°14.1'	46
17	28	70°33.8'	141°44.0'	406
18	29	70°28.5'	141°51.4'	71
19	29	70°23.1'	141°59.0'	59
20	29	70°17.8'	142°06.1'	53
21	29	70°07.0'	142°21.5'	37
22	29	70°07.0'	142°21.5'	37

RU# 217

NO REPORT SUBMITTED

The principal investigator is in the field.

LINKAGE OF THE BENGTSSON LIMITED AREA FORECAST MODEL AND THE OPTIMIZED HYDRODYNAMICAL-NUMERICAL MODEL OF W. HANSEN TYPE

by

R.Bauer, S. Larson, T. Laevastu and A.Stroud

Northwest Fisheries Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112
July 1976

Abstract

The operational quasi-geostrophic three-parameter model developed by Dr. L. Bengtsson for the Swedish Meteorological and Hydrological Institute has been linked with the optimized multi-layer hydrodynamical-numerical model based on the work of Professor W. Hansen at the University of Hamburg, Germany for use in the study of the wind and tide driven circulation along the southern Alaskan coast, sponsored by the Outer Continental Shelf Energy Programme (BLM/NOAA).

The Bengtsson forecast model was used to increase the resulution of the surface pressure field to a 74.08 km grid in an area where the coastal elevations are a major determining factor. The initial states and the variable boundaries were prescribed for the Bengtsson model by extracting data from the Fleet Numerical Weather Central (FNWC) archived files for two storm periods in June and November, 1973.

This document describes the programs and procedures used to link the FNWC fields to the Bengtsson model and the Bengtsson model to the Hydrodynamical-Numerical (HN) model, and provides supplemental information for the Bengtsson and HN models described fully in references (1) and (2).

INDEX

LIST OF FIGURES

FIGURE

LIST OF TABLES

ACKNOWLEDGEMENTS

The authors wish to thank Dr. L. Bengtsson, who spent a very difficult week with us testing his model in its revised form, and LT. Byron Maxwell, who provided us with a carefully documented listing and his notes on the Bengtsson model.

1. INTRODUCTION

This report describes the linking of the Naval Environmental Prediction Research Facility (NEPRF) version of the Bengtsson three parameter quasi-geostrophic atmospheric (AT) model for limited area forecasting and the NEPRF Optimized version of the Hydrodynamical-Numerical (HN) model for use in the Gulf of Alaska.

The AT model has been tested in a hindcast mode using initial and variable boundary conditions computed from the northern hemisphere 63x63 polar stereographic Fleet Numerical Weather Central (FNWC) grids. The AT model was used to compute the surface winds over the Gulf of Alaska at 6 hour intervals in a 74.08 kilmeter grid for two periods beginning 1 June and 17 November 1973. The wind fields were converted to the smaller HN model area grids with grid spaces of 14.816 kilometers by extracting and reanalyzing the relative wind U and V components and then interpolating them to one hour intervals. Winds were introduced into the HN models after a six hour initialization period and updated each hour.

1.1 OVERVIEW OF THE AT-HN MODEL LINKAGE

There are three separate programs in the existing linkage between the models. Two of these, the grid preparation and data extraction programs, were written for the NEPRF CDC 3100 computer and are used to prepare FNWC 63x63 data for input into the AT field analysis program. The third program in the linkage started as the field analysis program on the CDC 3100 but was later converted to a dual function program on the CDC 6500. The field analysis program analyzes the FNWC grid values into AT fields and also analyzes the AT generated wind component fields into the smaller HN grids. Figure 1 shows the program sequencing. Program ANOMALY calculates the M,N coordinates for each polar stereographic I,J grid point in a specified range of I and J points and punches the I,J and HN M,N grid values on cards. Program COAMDAT reads a tape containing FNWC 63x63 fields, extracts an I,J value from each field for each coordinate card in its input deck and generates the COAM tape containing values at I,J points with their HN M,N coordinates. The COAM tape is read by the ATANAL program which analyzes the FNWC values into the AT fields. The AT model in turn generates a wind component tape which is processed by ATANAL into the coastal grid HN wind fields.

1.2 DESCRIPTION OF GRID CONVENTIONS

One of the confusing factors in dealing with the programs in this sequence arises because each program borrowed code from a different source and these elements do not have common grid conventions. Figure 2 is presented to reduce the confusion. The arrows within the grid indicate the sequence in which the elements are stored in the arrays and show the array limits and principal indices.

To further complicate the matter there are actually four different HN grids involved. The original AT model grid was developed as a compromise grid for both the AT and HN models. Although the 74.08 kilometer HN model was not used the input and output tapes for and from the AT model are formatted in terms of the 74.08 kilometer HN model. The three HN models that are a part of the BLM Gulf of Alaska project all

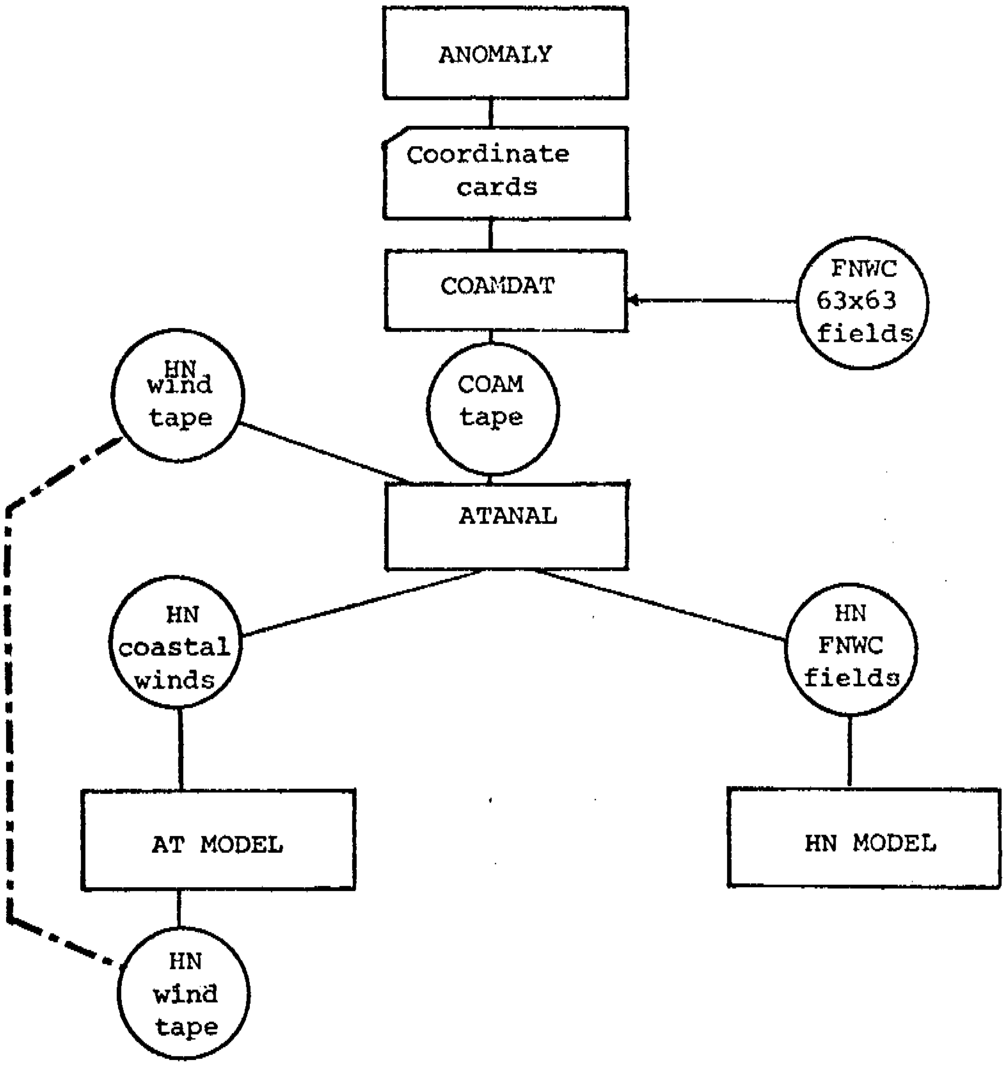
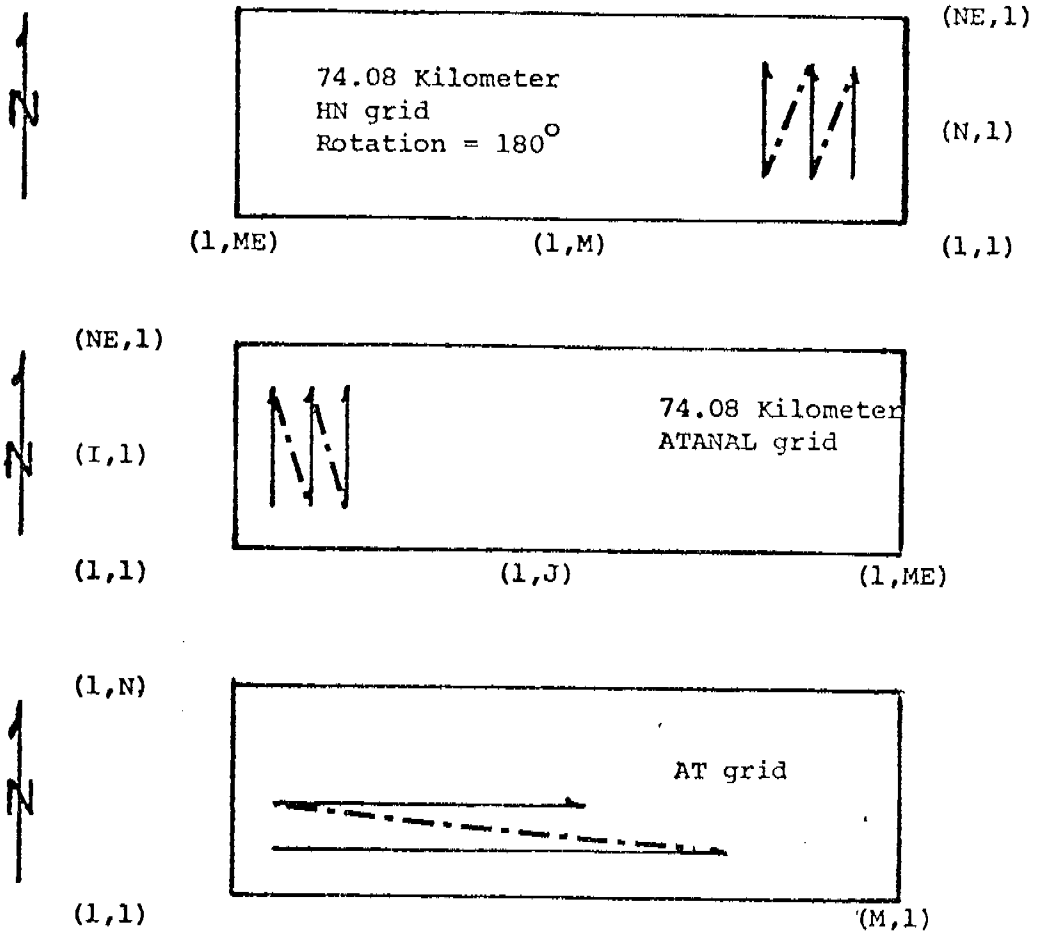


Figure 1. Program sequence



Arrows show order of data storage in a single dimensioned array.

Figure 2. Grid conventions

have 14.816 kilometer grids. To distinguish between the HN models the 74.08 kilometer grid will be assumed unless the area is also specified.

Programs ANOMALY and COAMDAT both use HN grid M,N coordinates. FNWC 63x63 grid points in the programs are in FNWC standard I,J notation. The HN convention is for the upper left corner of the grid to be identified as (1,1) with the row index varying faster. However, the 74.08 kilometer HN grid was rotated 180° so that (1,1) is in the southeast corner.

The HN grid convention indices are used on all tapes in the linkage. The input sections of the ATANAL and AT programs convert from the HN coordinate sequence to the indices used in the models. The output sections of these programs restore the local indices to the HN grid conventions. In the case of ATANAL when the wind fields are being processed the outputted fields match the HN grids for the three coastal areas.

Within the ATANAL program the row index varies faster and the origin is in the southwest corner. The AT model has the same origin as the ATANAL program but the column index varies faster.

All three coastal grids are rotated HN grids. The east coastal grid is rotated counterclockwise 309° with the northern corner as the origin. The western and central grids are rotated 39° so their western corners are their origin.

1.2.1 Description of the 74.08 Kilometer Grid

The 74.08 kilometer grid is defined by the base lines 40° North and center line 143.86333333° West, which corresponds to row 1 and column

TABLE 1

HN Grid Relationships

	HN	HN Western	HN Central	HN Eastern
Model Number	1000	100	70	1
Grid Length (Kilometers)	74.08	14.816	14.816	14.816
Rotation Angle	180	39	39	309
No. Rows	32	27	32	18
No. Columns	47	60	50	40

24, as shown in Figure 3. The distance between rows is 2/3° latitude (74.08 kilometers) and columns are spaced at 2/3° of latitude intervals measured out from the center line. This grid preserves distance measurements but distorts angles at the edge of the grid. This distortion was not considered important.

1.2.2 Description of the Coastal Grids

The coastal grids have grid lengths of 14.816 kilometers and overlap. The specifications for the grids are given in Table 1 and are shown in Figures 4 through 6.

1.3 TAPE FORMATS

There are three tape formats involved in the sequence. The first is an extract of FNWC 63x63 fields. The second is the COAM tape and the third is the HN format tapes. All tapes are recorded at 556 BPI in 7 tracks, in binary mode, as a single file.

1.3.1 FNWC 63x63 Field Tapes

The field format on the FNWC tapes is described in the FNWC User Guide (6). The fields required by the AT model in order for a date-time group set are: the sea temperature (TSEA), the 1000 mb pressure level (D1000), the 500 mb pressure level (D500), the 300 mb pressure level (D300) and the dew point depression (TP850).

1.3.2 The COAM Tape

The COAM tape format is shown in Figure 7. The file contains reocrds which are all identical in length but the length may vary

Figure 4. HN 14.816 kilometer western grid

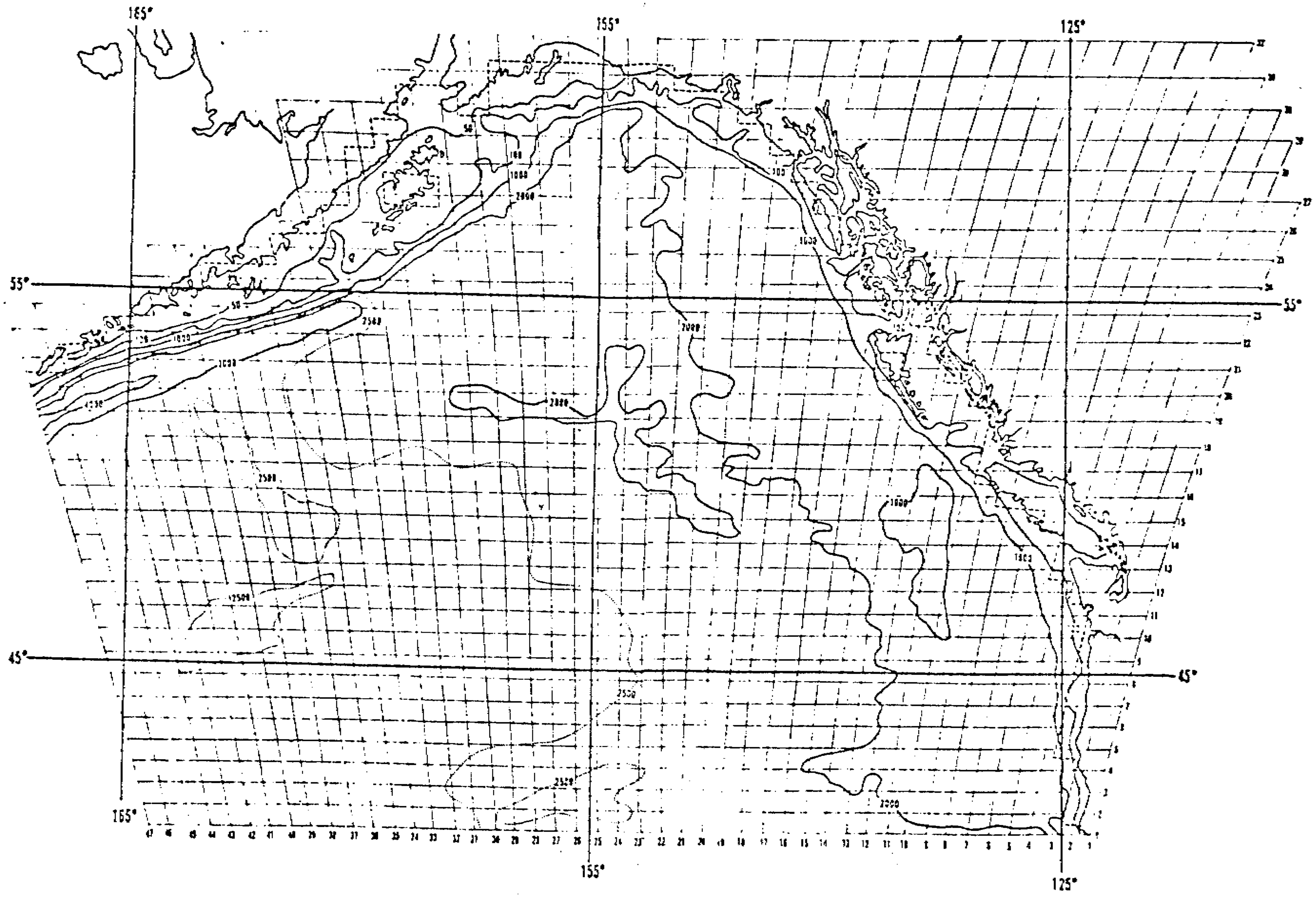
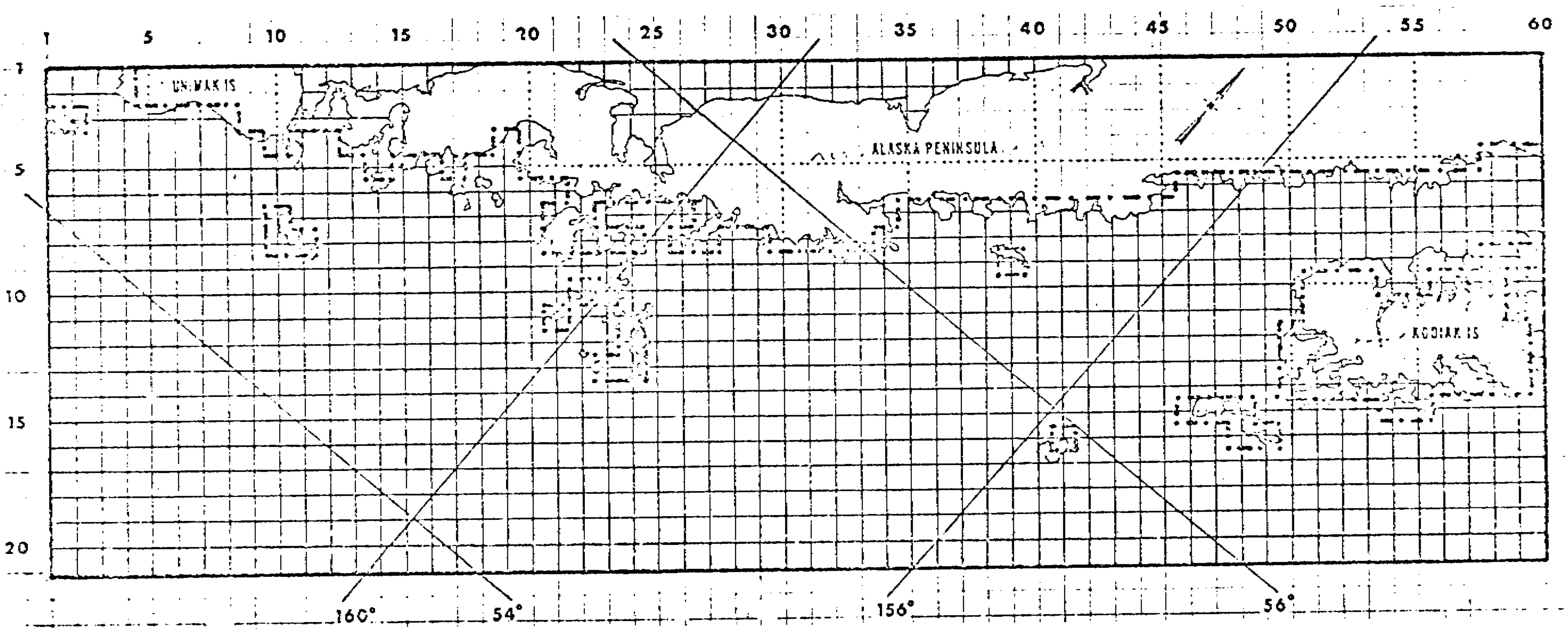


Figure 3. HN 74.08 kilometer grid


1
5
10
15
20
25
30
35
40
45
50
55
60
1
5
10
15
20
UNIMAK IS
ALASKA PENINSULA
KODIAK IS
160°
54°
156°
56°

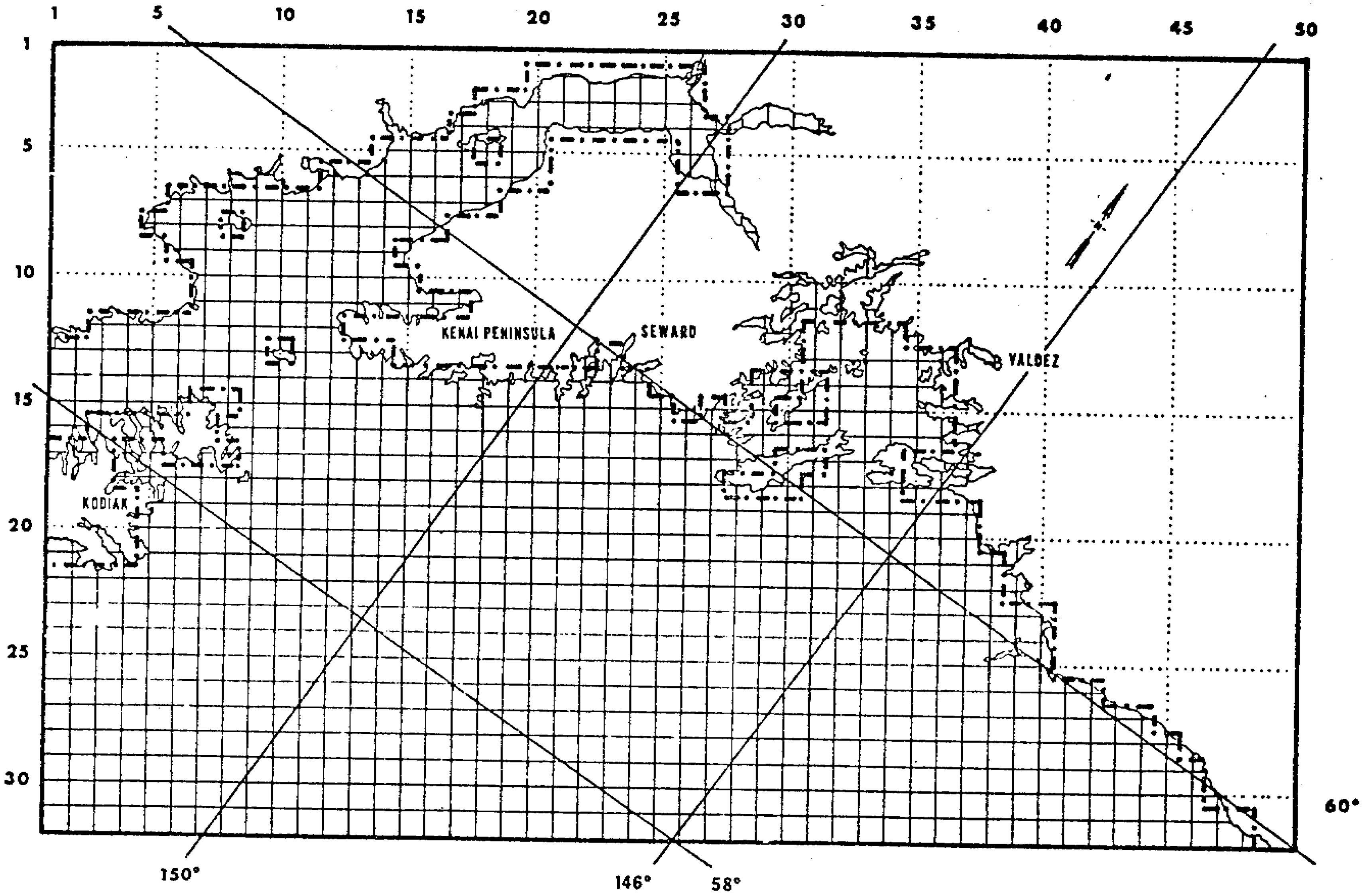


Figure 5. HN 14.816 kilometer center grid

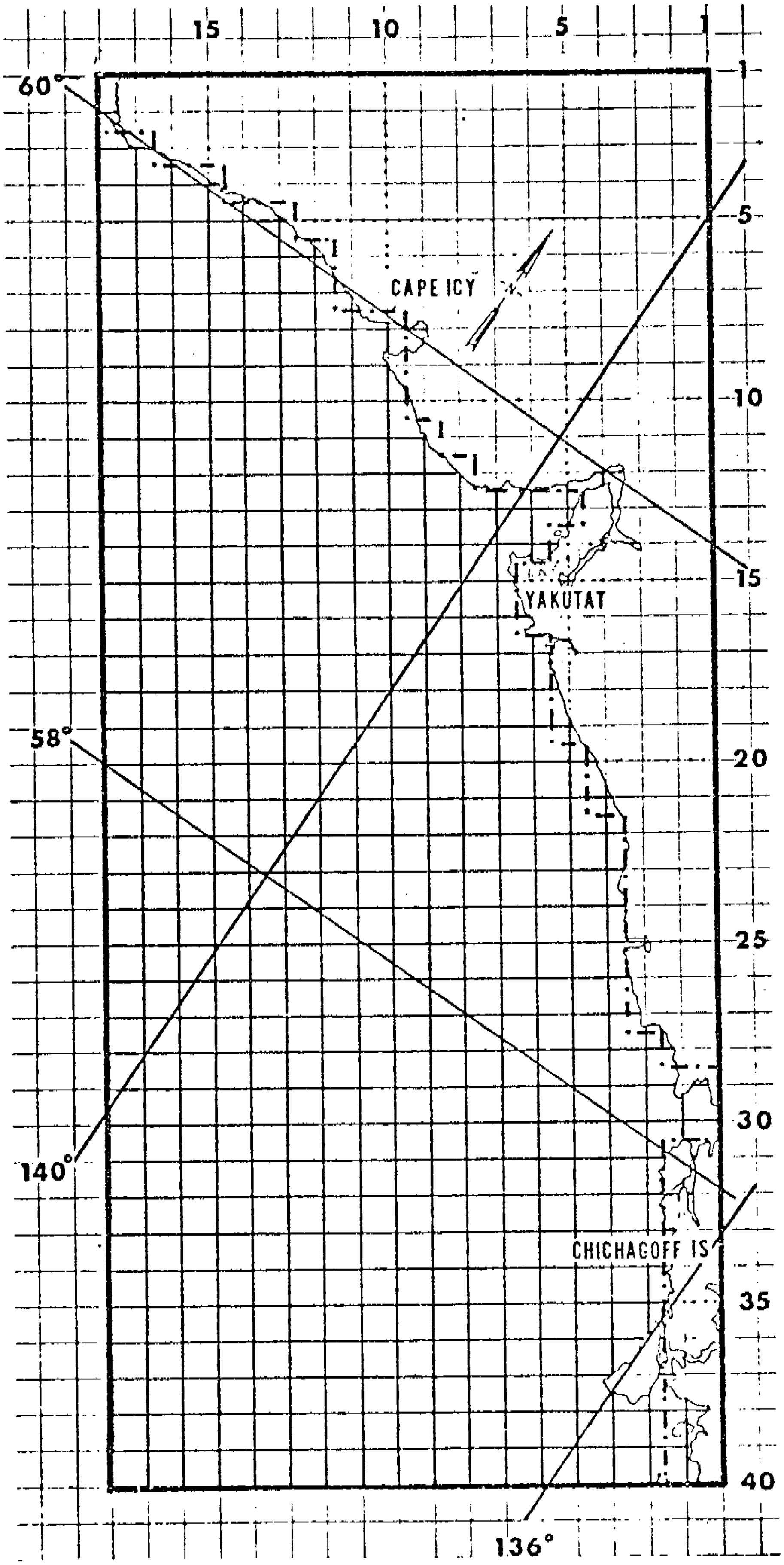
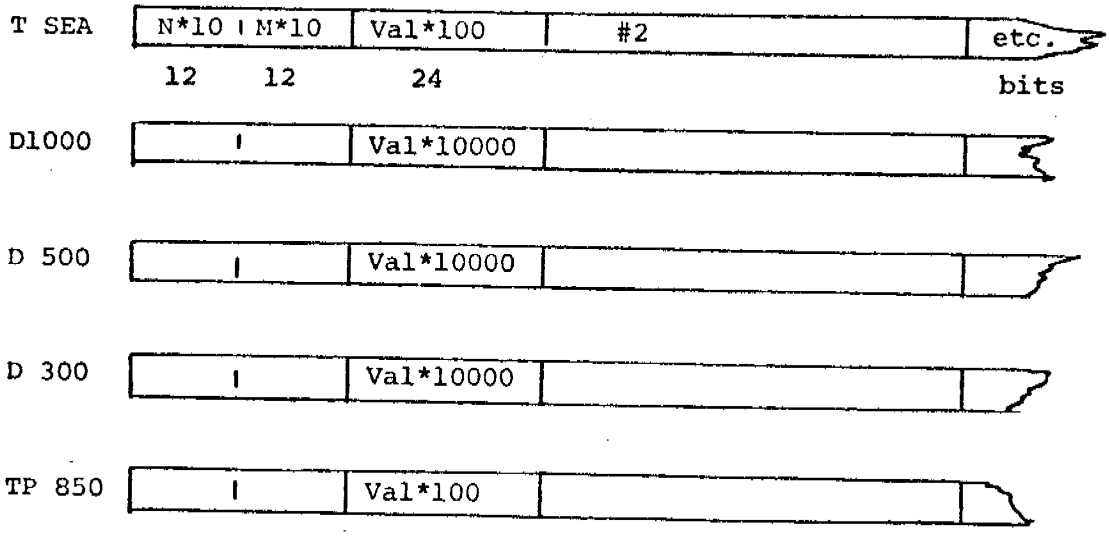


Figure 6. HN 14.816 kilometer eastern grid

556 BPI
Odd parity
48 bit logical record blocked so that there is 1 field in each physical record.
1 file on each tape

For Gulf of Alaska grid there are 75 logical records per physical record.



All fields are binary integers

0 = N = NE+1

0 = M = ME+1

Val maybe + or -. Final Val = Val * Scale + offset

	"	"	
T SEA	.01	.0	°C
D1000	.0001	111.	Z height Meters
D 500	.0001	5574.	"
D 300	.0001	9164.	"
TP 850	.01	.0 ,	°C

Figure 7. COAM format

depending on the number of coordinate cards in the COAMDAT deck. The file consists of a single record for each FNWC field processed and is composed of 48 bit fields with the M,N coordinate and the value in two 12 and one 24 bit field. All fields represent scaled integers. The coordinate fields are always positive but the value field may be positive or negative. The COAM tape presently serves as a bridge between the 24 bit CDC 3100 computer and the 60 bit CDC 6500 computer.

1.3.3 HN Tape Format

The HN tape has records which are of variable length from 144 bits to 30000 bits with a fixed length header of 120 bits. The header bits, as shown in Figure 8, are divided into 24 and 12-bit fields. All values in the header are positive binary integers. The header is followed by from 1 to 1245, 24-bit fields. These data fields contained scaled integers which may be positive or negative. Negative numbers are expressed in CDC 1's complement (in octal (B):0001B=1, 0000B=0, 7777B=-0, 7776B=-1).

A logical record will require more than one physical record if the grid contains more than 1245 values. Any number of physical records can make up a logical record but no logical records share a physical record. Records with type numbers less than 8 are assumed to be grouped logical records with 3 logical records per group. In grouped records, since all logical records have identical headings, the Z logical record must be first followed by the U and then the V logical record.

Logical records are ordered on the tape in ascending type sequence within the time group.

HEADER FORMAT

TIME in seconds	LAYER or LEVEL	TYPE*	ROWS	COLS	MODEL NO.	
24	24	24	12	12	24	No of bits

Layer or Level	Type		Scaling
1 2 3	1 = sumbolic HTZ, depth HTU and HTV 2 = water height Z, U and V vectors		*10 *1000
0	8	Wind component U and V	*10
0	11	TSEA	*10
1000	12	D1000	*10000
500	12	D500	*10000
300	12	D300	*10000
0	14	TP850	*10

*types 1-7 reserved for grouped records (Z,U,V)

Value = tape field integer/scale

Figure 8. HN tape format

Type 8 records are reserved for wind components and are paired with the U component field followed by the V component field.

2. HINDCAST DATA PREPARATION

The two sets of hindcast data selected for this trial effort consist of two storm periods in the Gulf of Alaska from 1-7 June 1973 and 17-23 November 1973. The FNWC 63x63 fields for these periods at 0000 and 1200 GMT were processed through the sequence into the HN format tape for input to the AT model. The AT model runs were started at 0000, 1 July 1973 and 0000 17 November 1973, using as the initial state the analyzed grid obtained from the FNWC values. The edge values for variable boundary conditions were interpolated between the 12 hour pressure fields for each time step. The TSEA and TP850 were not considered in the variable boundary conditions.

The AT model was run out to 36 hours saving the wind component fields at 6 hour intervals in HN format. The wind components were then analyzed into the coastal grids at 6 hour intervals and linearly interpolated into 1 hour fields for input to the coastal HN models starting at 6 hours.

The three linking programs required to prepare the hindcast data are described in this section. The AT model and HN model instructions are described in the following sections of this report.

2.1 GENERAL PROGRAM NOTES

All programs are written in FORTRAN and could be modified to run on other configurations by revising the relatively small sections involving input and output activities that are computer word size dependent. The general description of the programs, the grid convention and the tape formats has already been given in section 1 of this report. This section contains the run instructions, program organization, methods and variable description.

After the conversion of the analysis program from the CDC 3100 to the CDC 6500 computer was completed, the need for separating the grid calculation, data extraction steps and data analysis steps disappeared, but in the present research effort there was nothing to be gained by converting and combining the functions of the grid preparation and extraction procedures with the input phase of the AT field generation. Consequently, streamlining of procedures will have to await a new application.

2.2 PROGRAM ANOMALY

Program ANOMALY was borrowed from another project and was modified to compute the HN grid values from the FNWC I,J latitude longitude coordinates. The program produces both a listing and a deck of coordinate cards.

The relevant part of program ANOMALY consists of the main program ANOMALY, routines IJTOLL and TOLL.

2.2.1 Run Instructions

To run program ANOMALY the user must determine the FNWC I,J grid window containing the area to be extracted. When choosing the I,J minimum and maximum values the user should be sure to include the I,J points that lie within one grid cell interval outside the final grid to be used by the AT model. Values in this band outside the grid row and column are used to determine the boundary values in the final grid and to minimize the distortion on the edge caused by relaxation in the ATANAL program.

The I,J limits are used as limits on loops 999 in program ANOMALY. The parameters given in the call to TOST (an initialization entry for TOLL) specifies the base line latitude, the center line longitude, the HN grid row number for the base latitude and the HN grid column number for the center line. The spacing is set in routine TOLL.

This program punches extra cards that are outside the final grid by more than one row and column. These cards are discarded.

2.2.2 Routine Descriptions

ANOMALY

This is the main program. It calls routine TOLL twice: once through entry TOST to start the calculations and once for each coordinate point through entry TOMN to get the HN M,N coordinates for a latitude longitude pair. The routine calls IJTOLL once each for each coordinate point to convert from FNWC I,J coordinate indices to latitude longtidue. The routine lists the coordinates and punches coordinate cards for use in program COAMDAT.

IJTOLL

This routine is given an I,J index in the FNWC northern hemisphere polar stereographic grid and then it returns the latitude longitude coordinates in degrees.

TOLL

This routine computes the HN grid M,N index for the Gulf of Alaska grid. It is not a general purpose routine in the normal sense; since the indices are computed directly for the HN grid rotated 180°. The routine requires an initial call giving the correspondence between latitude-longitude base and center lines and the N,M grid numbers. In the Gulf of Alaska grid these are 40°N=row 1, 143.863333=column 24. In successive calls to TOMN the routine computes the M,N coordinates using the method described in Bowditch (3) to compute distance along a latitude line.

2.2.3 Variables

I,J	FNWC Northern Hemisphere polar stereographic grid indices
XLAT,YLONG	Latitude and longitude of an FNWC grid point
XN,YM	HN grid indices
N,M	Scaled HN grid values=XN*10,YM*10
X1 Y1	Factors to compute distances between longtiudes from Bowditch (3).

2.3 PROGRAM COAMDAT

Program COAMDAT was written to extract the required I,J values from the tape containing FNWC 63x63 fields using a preexisting standard NEPRF subroutine, READ63. The program as it presently exists processes the PS and D850 fields which are not needed by the AT model. This

IEXT3=1 or=0	Option to include the vertical advection of vorticity and divergence terms
IEXT4=1 or=0	Option to include the twisting term in the vorticity equation
ITIME=0	Initial time on the HN tape in seconds
NTIME=0	Initial time for computation (matching ITIME) in hours

Variables set in INITIAL

For the real data case no variables need be set in INITIAL unless the grid size is changed to 14.816E+4 meters. In this case the grid indices are modified before calls to INOUT and the number of grid points is reduced by the elimination of every other grid point. The reduced grid has been used for a number of tests during the project since it more closely matches the Atlantic grid size for which the model was developed.

Input Tape Rules

The two input tapes used for the project contain a single set of data for either the 1 June 1973 or 17 November 1973 cases and since they contain only relative times they could be used interchangeably by simply changing the tape assigned to logical unit 1. The relative time of the initial fields must match the time specified by ITIME. When variable boundary conditions are used the input tape must have fields in the proper sequence at 12 hour intervals. To have the proper calls 12 must be an integer multiple of NBLOCK.

Output Tape Rules

The output tape is used to store the wind components and is called from within MAP3P. It is called each time the surface pressure field is printed when the first parameter in the call sequence to MAP3P is equal to 2. The data are written directly on the tape if a tape is preassigned to TAPE2.

Land Elevation Table

The land elevation table is read by routine INITIAL when it is entered for the real data case. The land elevation table has been read from a card deck where each card represents a row of the Gulf of Alaska grid and each column is a column in the grid. Punches in the land elevation table are the index to the surface pressure table STANPS, which gives the pressure for 0, 200, 500, 1000, 2000, 3000, 4,000 5,000 6,000 and 7,000 meters--the levels on the MONACO charts for the Gulf of Alaska.

3.2.2 Channel Case Checklist

Setting	Meaning
KIND=1	Channel case
IVAR=0	The boundaries are not updated with real data. The channel is connected on the right-left ends.
DS=200km or 100 km	Grid sides used in experimental grids
N=15	Number of rows
M=30	Number of columns
MODEL=0	No input tape is used so the model number does not matter

ROT=0	This does not matter if the winds are not computed.
NEND=36 or 72	Length of forecast period in hours
NTSTEP=12 NBLOCK=6	Number of time steps in the forecast interval and forecast period
MAPHOUR=0, 72,6	Start printout at time 0. Printout at 6 hour intervals until NEND hours or 72 hours have passed.
NSMUTT, MSMUTT=72,0,0	In the channel cases no smoothing is used
LETACC NELLIPT MELLIPT	All must be set to even multiples of NBLOCK
IEXT3=1 or 0 IEXT4=1 or 0	Option to include or exclude extended calculations
ITIME=0 NTIME=0	Time counters should both be equal =0 for the channel case start

For the channel case all data are generated during the execution of routine INITIAL. The calls to routine GENCH are used to create the initial stream function and the calls to FILL are used to generate the surface pressure and temperature fields.

Table 2 shows several test cases using the channel option that were used in conjunction with the optional extended calculations and heating. The dimensions of the in core arrays must be large enough to contain the M*N array.

Test Cases Variable	1 (Barotropic)	2	3 (Baroclinic 2 wave)	4
UPS	30.	7.	5.,5.	0.,3.,4.,6., 5.,4.,3.,2., 0.
UPM	30.	20.	35.,35.	0.,12.22,16.26, 21.31,18.31,15.31 12.12,8.92,0.
UP1	30.	35.	50.,50.	0.,24.,32.,42., 36.,30.,24.,17., 0.
PSIS	0.			.2E7
PSIM	5.4E8			5.144E8
PSI1	9.2E8			9.04E8
FIM	50.			60.
BETA	1.14542E-11		16.E-12	1.14542E-11
NWAVE	1		2	0
NU	1		2	9
NX	1		1,4	0
NY	0		1,1	0
PSIC	0.		0.,0.	0.
PSIS	0.		1.5E5,1.5E5	0.
LAMC	0.		0.,0.	0.
LAMS	0.		-90.,-90.	0.
DS	200./100.			
M	30/60			
N	15/30			
IDIM	450/1800			
IEXT3	0/1			
IEXT4	0/1			

Table 2. Specifications of channel test cases

3.3 DESCRIPTION OF ROUTINES

The following routines are described in the order shown in the program organization, Figure 9.

PROG3P

This is the main program which contains most of the DATA statements that control the functioning of the program. The program sequence is to set initial constants, call INITIAL to read or generate the time 0 fields, convert the initial fields into the forms required by the computation, initialize and store initial fields in ECS fields and then loop for each forecast interval. Within the forecast loop the fields are mixed with boundary values, smoothed, checked for ellipticity and printed.

BMOVE

This routine is used to impose the cyclic boundary on the channel computation. It is used when KIND=0. It moves the next to last column in the array to the first column, and the second column to the last column position.

XMIT

This routine is used to move data vectors and zero data arrays within core.

RANWT/RANRD

Routine to link the program with an external storage device capable of storing the work arrays. Presently used to transmit to and read data from ECS.

FIELD

Debugging aid that prints the entire set of incore work arrays F1-F10.

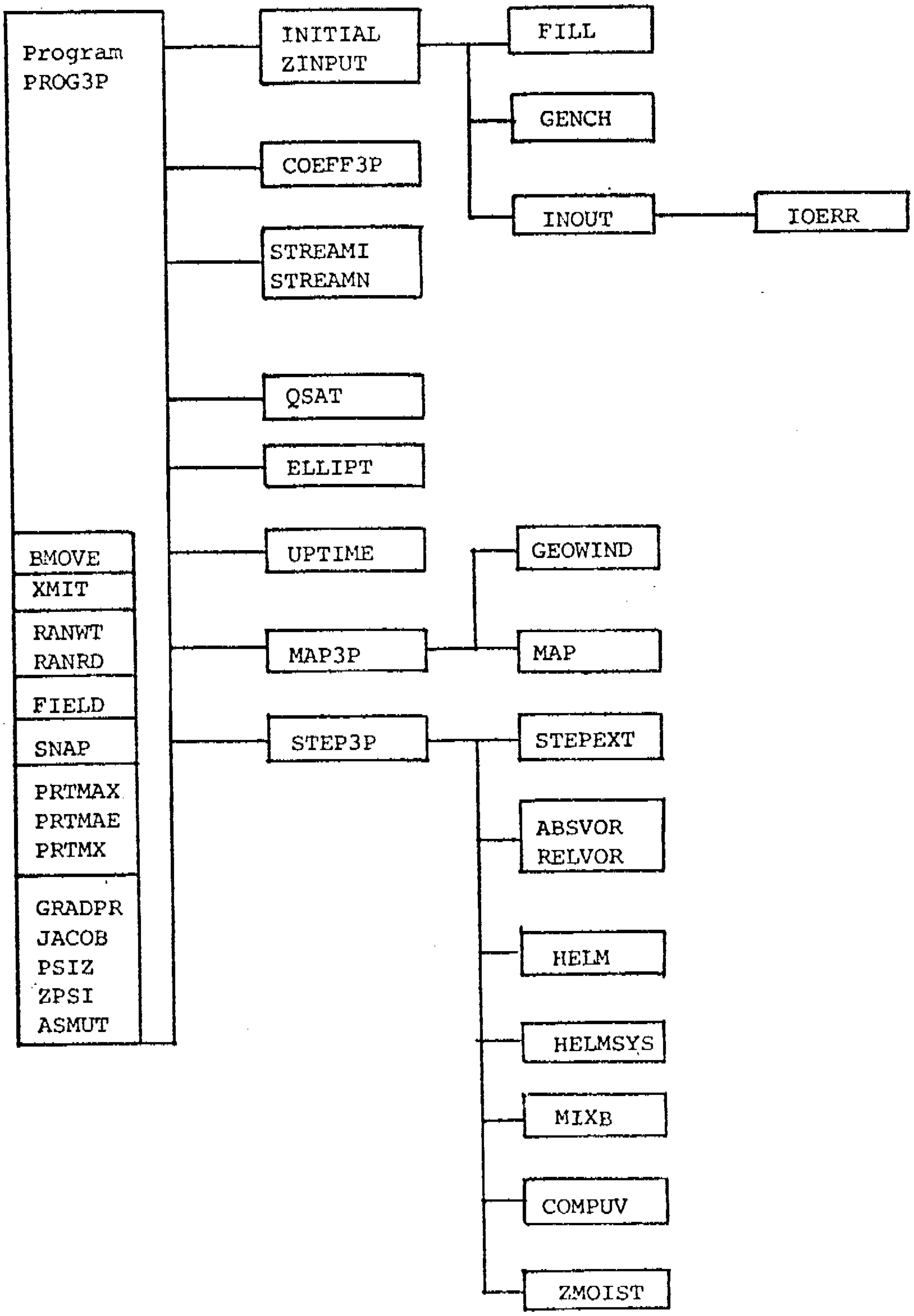


Figure 9. AT model call sequences

SNAP

Debugging aid. Prints a 10x10 corner of the specified sequential set of the work arrays F1-F10.

PRTMAX/PRTMAE/PRTMX

Routine to print an array with title, row and column numbers. The three entires provide F12.2, E12.6 and I12 formats for the array values.

GRADPR/JACOB/PSIZ/ZPSI/ASMUT

This routine combines a number of array to array mathematical processes. Entry GRADPR computes $\nabla A \cdot \nabla B$ as a finite difference.

```
GRADPR(I,J)  = (A(I+1,J)-A(I,J))*(B(I+1,J)-B(I,J))+(A(I,J)
               -A(I-1,J))*(B(I,J)-B(I-1,J))+(A(I,J+1)
               -A(I,J))*(B(I,J+1)-B(I,J))+(A(I,J)
               -A(I,J-1))*(B(I,J)-B(I,J-1))
```

Entry JACOB computes the Jacobian operator

```
J(A,B)  = ((A(I+1,J)-A(I-1,J))*(B(I,J+1)-B(I,J-1))
          -((B(I+1,J)-B(I-1,J))*A(I,J+1)-A(I,J-1))
```

Entry PSIZ converts heights to thicknesses.

Entry ZPSI converts thicknesses to heights.

Entry ASMUT smooths the field

INITIAL/ZINPUT

This routine contains the portion of the initialization process not included in program PROG3P. The data statements in this subroutine are used to control the generation of "canned" channel cases or the reading of real data.

In the real data case (KIND=1) the surface elevations are read and converted to pressures, the input tape is read and the vapor pressure is computed from the 850 mb dew point temperature. The MARK, MY and F arrays are created and selected data are printed. In the variable boundary cases (IVAR=1) the routine is re-entered through ZINPUT to read the boundary fields that are to be mixed with the forecast field.

In the canned data case, the MARK, MY and F fields are computed and then routine GENCH is called to generate the height fields. Routine FILL is used to create the surface temperatue and pressure fields.

FILL

This routine is used to fill a selected part of an array with a value that is constant for each column and may vary with the row index by a constant interval.

GENCH

This routine is used to generate a 2 dimensional array containing a sine-cosine wave form.

INOUT

This routine is used to read and write the fields in or out to tape. The tape format used is described separately. The routine is called by INITIAL to read data and by GEOWIND to write the wind component tape.

IOERR

This routine is called by INOUT whenever a parity error or end of file is detected on input or output tapes.

COEFF3P

This routine precomputes the simple variable constants used by STEP3P and STEPEXT.

STREAMI/STREAMN

This routine rescales pressure fields by the constant g/f.

QSAT

Computes the integrated mixing ratio at saturation given the mean temperature.

ELLIPT

Modifies the array so that the criterion of ellipticity is satisfied.

UPTIME

Increments the action time by the time interval and then sets the time to a large number if the new time is greater than the end time specified.

MAP3P

Retrieves desired fields from ECS and calls MAP to print the zebra grid points for selected fieelds. Also calls GEOWIND.

GEOWIND

Routine using Larson formula to compute wind components, speed and direction for use in the HN model.

MAP

Routine to make zebra pattern grid printouts.

STEP3P

Main computation forecasting routine.

STEPEXT

Routine for extended terms

RELVOR

Computes relative and absolute vorticity terms

HELMSYS

Solves the couble set of Helmholz equations

HELM

Solves the single Helmholz equations

MIXB

Mixes the forecast field with the input fields on the outer three rows and columns.

COMPUV

Computes the heating effects from the sea surface temperature in the surface layer if the air temperature is colder than the sea.

ZMOIST

Routine to simulate sensible heating based on the sea surface temperature. It is the elevation in meters at which the wind or stream function representative of the wind is calculated, essentially the midpoint of the surface layer (≈ 750 mb).

3.4 DESCRIPTION OF VARIABLES

A	A formal parameter array in GRADPR, XMIT, BMOVE	
AB4	Intermediate variable used in solving HELMSYS	
ADIFF	Diffusion coefficient for humidity	
ALFA	Overrelaxation coefficient	
ALFAM	Overrelaxation coefficient used in HELM	
ALFAPSI	Not used	
ANG	Latitude in degress of a grid point used in GEOWIND	
ARG	Ratios of pressure level used in COEFF3P to compute the ALOG of the ratios	
AX	Angle between pure geostrophic and surface wind vectors	
A1	Used in computation of divergence, a_1	$=2.0828\ 10^{-3}$
A2	a_2	$=1.3546\ 10^{-3}$
A3	a_3	$=0.044374$
B	Output array in XMIT Input array in GRADPR	
BETA	Constant used to compute Beta plane for channel case	
B1	Used in computation of divergence, b_1,	$=1.0475\ 10^{-3}$
B2	b_2	$=1.6261\ 10^{-3}$
B3	b_3	$=0.012258$

C	Formal parameter used in GRADPR call sequence for result and work arrays. Constant in COMPUV	= .12
CC1	1./TO	
CC2	$e \cdot L/R$	
CC3	$e \cdot L/C_p$	
CC4	CC2•CC3	
CC5	DEL1•DEL2	
CF	Friction over land or over ocean =FCONT or FOCEAN	
CK	Constant used in COMPUV	= .35
CLX	Height of a print character on a CDC printer in meters	= .00425
CLY	Width of a print character on a CDC printer in meters	= .00254
CO	Cosine of geostrophic wind vectors	
CONV	Convergence parameter used in ELLIPT	= .43
COS1	Cosine of angle between geostrophic and surface wind vectors	
CP	Specific heat at constant pressure C_p	=1004.
CX	Interpolation interval for computing values at zebra grid print position	
CY	Interpolation interval for computing values at zebra grid print position	
C1	$c_1 = \frac{2P_m}{2P_0 - P_1} = \frac{10}{17}$	=0.588235

C2	$c_2 = \frac{2(P_0-P_m)}{2P_0-P_1} = \frac{10}{17}$	=0.588235
C3	$c_3 = \frac{6P_0-4P_1}{6P_0-3P_1} = \frac{48}{51}$	=0.941176
C4	$c_4 = \frac{6P_m-2P_1}{6P_0-3P_1} = \frac{24}{51}$	=0.470588
C5	$c_5 = \frac{8P_0-8P_m}{6P_0-3P_1} = \frac{40}{51}$	=0.784314
C6	$c_6 = \frac{8P_m}{6P_0-3P_1} = \frac{40}{51}$	=0.784314
C7	$c_7 = \frac{P_1}{6P_0-3P_1} = \frac{3}{51}$	=0.0588235
C8	$c_8 = \frac{2}{2P_0-P_1} = \frac{2}{170}$	=0.0117647
D	Combined scaling constant in MAP	
DELP	Δ_p used to compute rainfall	
DELT	Time step in seconds Δt=NBLOCK·3600/NTSTEP	
DEL1	∂_2 tolerance	=.0001
DEL2	∂_2 tolerance	=.001
DEW	Used in advection formula in COMPUV	
DIV	M1·N2-N2·M2	
DIV1	ECS storage array for divergence field D_1	
DIV 2	ECS storage array for divergence field D_2	
DEPS	Time between fields being integrated = DELT·EPS	
DS	Grid distance (meters)	

DSS	.5/DS used in GEOWIND	
DT	Time step in hours =DELT/3600.	
DX	North-South dimension of a cell in meters represented by a print character in the zebra grid print	
DY	East-West dimension of a zebra cell in meters	
D1	Wind contraction factor	
E	Entry flag used in INITIAL to distinguish between the initial entry and calls to ZINPUT 1.=INITIAL entry 0.=ZINPUT entry	
EC2	ECS address of forecast field to be mixed	
EC3	ECS address of boundary value field to be mixed	
EE	E	=.622
EM	Coefficient for computing mean stream function, e_m	=0
EPS	Number of time steps between fields in the time integration	
EP	E_0	=.611
E1	Coefficients for computing mean stream functions, e_1	=-1.3589
E2	e_2	=0
F	Coriolis parameter field =F_0•2.•SIN (lat degrees)	
FA	Array contains data to be written on the output tape or array to be filled from data on the input tape.	
FACT	Time ratio used to mix boundary values into field at each integration step	

FCONT	Friction coefficient over land	=1.
FF	In routine INITIAL latitude in degrees, Coriolis parameter at a grid point	
FIM	Mid-latitude of channel	
FLD	Surface pressure field given to GEOWIND	
FM	Mean latitude Coriolis parameter used in computing Beta plane for channel case	
FMY	f^2/M	
FOCEAN	Friction coefficient over oceans	=.62
FORC	2D array for the forcing function	
FORC1 FORC2	Formal parameters in HELMSYS routine representing forcing function arrays	
FO	Radial velocity of the earth	=1.03E-4
FOFO	FO squared	
F1-F10	In core work arrays. All must be of equal size equal to IDIM words	
G	Gravity	=9.806
GDFO	g/F_0	
HEAT	ECS storage array for Heating	
HL	L	$=2.5.10^6$
HM3	ECS storage array for the twisting terms for the mean field	
HUM1	ECS storage array for humidity field	
HUM2	ECS storage array for humidity field	

H1	$h_1 = \frac{R}{4c_p} \ln (\frac{p_0}{p_m})$	$=0.495351 \cdot 10^{-1}$
H2	$h_2 = \frac{2f_0}{R \ln (\frac{p_0}{p_m})} \left(1 + \frac{0.75\ R(p_0 - p_m)}{c_p(p_0 + p_m)}\right)$	$=0.110953 \cdot 10^{-5}$
H3	h_3	$=1.03552 \cdot 10^{-6}$
H4	h_4	$=0$
H6	h_6	$=1.03552 \cdot 10^{-6}$
H13	ECS storage array for the twisting terms for the thickness field 1	
H23	ECS storage array for the twisting terms for the thickness field 2	
IA	Increment for array index for the array data is being taken from in XMIT	
IB	Increment for array index for the array data is placed into in XMIT	
IDAY	Day number	
IDIM	True dimensional size of the arrays	
ID1 ID2	Two word ident used to find data on input tapes and to identify output records	
IERR	Index to tape messages in IOERR 1=parity error on input 2=eof input 3=parity error on output 4=eof output	
IEXT3	Switch to include or exclude the vertical advection of vorticity, $\omega\ \partial\zeta / \partial P$, in forecasting equation 0=exclude 1=include	

IEXT3=1 or=0	Option to include the vertical advection of vorticity and divergence terms
IEXT4=1 or=0	Option to include the twisting term in the vorticity equation
ITIME=0	Initial time on the HN tape in seconds
NTIME=0	Initial time for computation (matching ITIME) in hours

Variables set in INITIAL

For the real data case no variables need be set in INITIAL unless the grid size is changed to 14.816E+4 meters. In this case the grid indices are modified before calls to INOUT and the number of grid points is reduced by the elimination of every other grid point. The reduced grid has been used for a number of tests during the project since it more closely matches the Atlantic grid size for which the model was developed.

Input Tape Rules

The two input tapes used for the project contain a single set of data for either the 1 June 1973 or 17 November 1973 cases and since they contain only relative times they could be used interchangeably by simply changing the tape assigned to logical unit 1. The relative time of the initial fields must match the time specified by ITIME. When variable boundary conditions are used the input tape must have fields in the proper sequence at 12 hour intervals. To have the proper calls 12 must be an integer multiple of NBLOCK.

Output Tape Rules

The output tape is used to store the wind components and is called from within MAP3P. It is called each time the surface pressure field is printed when the first parameter in the call sequence to MAP3P is equal to 2. The data are written directly on the tape if a tape is preassigned to TAPE2.

Land Elevation Table

The land elevation table is read by routine INITIAL when it is entered for the real data case. The land elevation table has been read from a card deck where each card represents a row of the Gulf of Alaska grid and each column is a column in the grid. Punches in the land elevation table are the index to the surface pressure table STANPS, which gives the pressure for 0, 200, 500, 1000, 2000, 3000, 4,000 5,000 6,000 and 7,000 meters--the levels on the MONACO charts for the Gulf of Alaska.

3.2.2 Channel Case Checklist

Setting	Meaning
KIND=1	Channel case
IVAR=0	The boundaries are not updated with real data. The channel is connected on the right-left ends.
DS=200km or 100 km	Grid sides used in experimental grids
N=15	Number of rows
M=30	Number of columns
MODEL=0	No input tape is used so the model number does not matter

ROT=0	This does not matter if the winds are not computed.
NEND=36 or 72	Length of forecast period in hours
NTSTEP=12 NBLOCK=6	Number of time steps in the forecast interval and forecast period
MAPHOUR=0, 72,6	Start printout at time 0. Printout at 6 hour intervals until NEND hours or 72 hours have passed.
NSMUTT, MSMUTT=72,0,0	In the channel cases no smoothing is used
LETACC NELLIPT MELLIPT	All must be set to even multiples of NBLOCK
IEXT3=1 or 0 IEXT4=1 or 0	Option to include or exclude extended calculations
ITIME=0 NTIME=0	Time counters should both be equal =0 for the channel case start

For the channel case all data are generated during the execution of routine INITIAL. The calls to routine GENCH are used to create the initial stream function and the calls to FILL are used to generate the surface pressure and temperature fields.

Table 2 shows several test cases using the channel option that were used in conjunction with the optional extended calculations and heating. The dimensions of the in core arrays must be large enough to contain the M*N array.

Test Cases Variable	1 (Barotropic)	2	3 (Baroclinic 2 wave)	4
UPS	30.	7.	5.,5.	0.,3.,4.,6.,5.,4.,3.,2.,0.
UPM	30.	20.	35.,35.	0.,12.22,16.26,21.31,18.31,15.31 12.12,8.92,0.
UP1	30.	35.	50.,50.	0.,24.,32.,42.,36.,30.,24.,17.,0.
PSIS	0.			.2E7
PSIM	5.4E8			5.144E8
PSI1	9.2E8			9.04E8
FIM	50.			60.
BETA	1.14542E-11		16.E-12	1.14542E-11
NWAVE	1		2	0
NU	1		2	9
NX	1		1,4	0
NY	0		1,1	0
PSIC	0.		0.,0.	0.
PSIS	0.		1.5E5,1.5E5	0.
LAMC	0.		0.,0.	0.
LAMS	0.		-90.,-90.	0.
DS	200./100.			
M	30/60			
N	15/30			
IDIM	450/1800			
IEXT3	0/1			
IEXT4	0/1			

Table 2. Specifications of channel test cases

3.3 DESCRIPTION OF ROUTINES

The following routines are described in the order shown in the program organization, Figure 9.

PROG3P

This is the main program which contains most of the DATA statements that control the functioning of the program. The program sequence is to set initial constants, call INITIAL to read or generate the time 0 fields, convert the initial fields into the forms required by the computation, initialize and store initial fields in ECS fields and then loop for each forecast interval. Within the forecast loop the fields are mixed with boundary values, smoothed, checked for ellipticity and printed.

BMOVE

This routine is used to impose the cyclic boundary on the channel computation. It is used when KIND=0. It moves the next to last column in the array to the first column, and the second column to the last column position.

XMIT

This routine is used to move data vectors and zero data arrays within core.

RANWT/RANRD

Routine to link the program with an external storage device capable of storing the work arrays. Presently used to transmit to and read data from ECS.

FIELD

Debugging aid that prints the entire set of incore work arrays F1-F10.

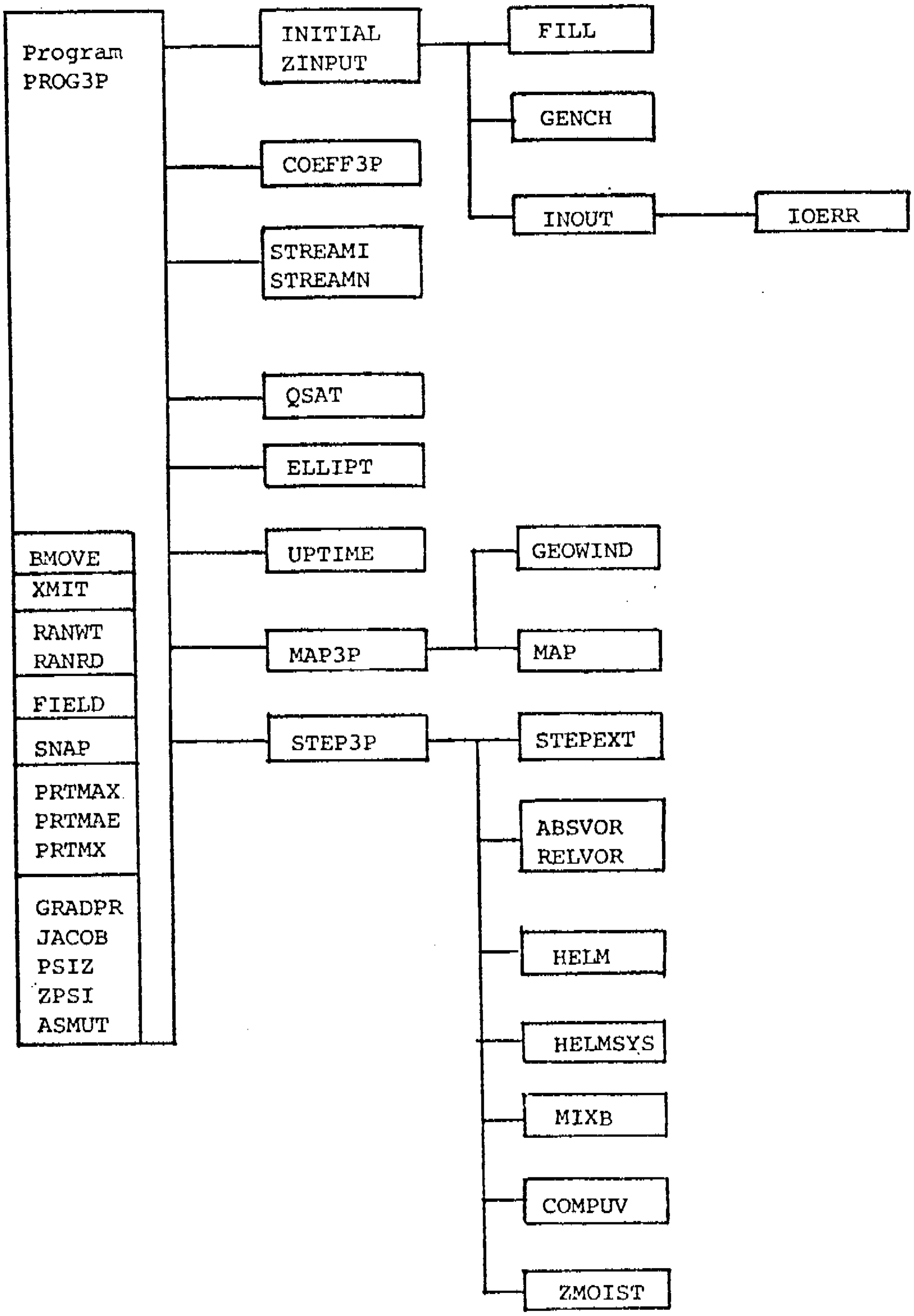


Figure 9. AT model call sequences

SNAP

Debugging aid. Prints a 10x10 corner of the specified sequential set of the work arrays F1-F10.

PRTMAX/PRTMAE/PRTMX

Routine to print an array with title, row and column numbers. The three entires provide F12.2, E12.6 and I12 formats for the array values.

GRADPR/JACOB/PSIZ/ZPSI/ASMUT

This routine combines a number of array to array mathematical processes. Entry GRADPR computes $\nabla A \cdot \nabla B$ as a finite difference.

$$\begin{aligned} \mathrm{GRADPR}(I,J) = {} & (A(I+1,J)-A(I,J))*(B(I+1,J)-B(I,J))+(A(I,J) \\ & -A(I-1,J))*(B(I,J)-B(I-1,J))+(A(I,J+1) \\ & -A(I,J))*(B(I,J+1)-B(I,J))+(A(I,J) \\ & -A(I,J-1))*(B(I,J)-B(I,J-1)) \end{aligned}$$

Entry JACOB computes the Jacobian operator

$$\begin{aligned} J(A,B) = {} & ((A(I+1,J)-A(I-1,J))*(B(I,J+1)-B(I,J-1)) \\ & -((B(I+1,J)-B(I-1,J))*A(I,J+1)-A(I,J-1)) \end{aligned}$$

Entry PSIZ converts heights to thicknesses.

Entry ZPSI converts thicknesses to heights.

Entry ASMUT smooths the field

INITIAL/ZINPUT

This routine contains the portion of the initialization process not included in program PROG3P. The data statements in this subroutine are used to control the generation of "canned" channel cases or the reading of real data.

In the real data case (KIND=1) the surface elevations are read and converted to pressures, the input tape is read and the vapor pressure is computed from the 850 mb dew point temperature. The MARK, MY and F arrays are created and selected data are printed. In the variable boundary cases (IVAR=1) the routine is re-entered through ZINPUT to read the boundary fields that are to be mixed with the forecast field.

In the canned data case, the MARK, MY and F fields are computed and then routine GENCH is called to generate the height fields. Routine FILL is used to create the surface temperatue and pressure fields.

FILL

This routine is used to fill a selected part of an array with a value that is constant for each column and may vary with the row index by a constant interval.

GENCH

This routine is used to generate a 2 dimensional array containing a sine-cosine wave form.

INOUT

This routine is used to read and write the fields in or out to tape. The tape format used is described separately. The routine is called by INITIAL to read data and by GEOWIND to write the wind component tape.

IOERR

This routine is called by INOUT whenever a parity error or end of file is detected on input or output tapes.

COEFF3P

This routine precomputes the simple variable constants used by STEP3P and STEPEXT.

STREAMI/STREAMN

This routine rescales pressure fields by the constant g/f.

QSAT

Computes the integrated mixing ratio at saturation given the mean temperature.

ELLIPT

Modifies the array so that the criterion of ellipticity is satisfied.

UPTIME

Increments the action time by the time interval and then sets the time to a large number if the new time is greater than the end time specified.

MAP3P

Retrieves desired fields from ECS and calls MAP to print the zebra grid points for selected fieelds. Also calls GEOWIND.

GEOWIND

Routine using Larson formula to compute wind components, speed and direction for use in the HN model.

MAP

Routine to make zebra pattern grid printouts.

STEP3P

Main computation forecasting routine.

STEPEXT

Routine for extended terms

RELVOR

Computes relative and absolute vorticity terms

HELMSYS

Solves the couble set of Helmholz equations

HELM

Solves the single Helmholz equations

MIXB

Mixes the forecast field with the input fields on the outer three rows and columns.

COMPUV

Computes the heating effects from the sea surface temperature in the surface layer if the air temperature is colder than the sea.

ZMOIST

Routine to simulate sensible heating based on the sea surface temperature. It is the elevation in meters at which the wind or stream function representative of the wind is calculated, essentially the mid-point of the surface layer (≈ 750 mb).

3.4 DESCRIPTION OF VARIABLES

A	A formal parameter array in GRADPR, XMIT, BMOVE	
AB4	Intermediate variable used in solving HELMSYS	
ADIFF	Diffusion coefficient for humidity	
ALFA	Overrelaxation coefficient	
ALFAM	Overrelaxation coefficient used in HELM	
ALFAPSI	Not used	
ANG	Latitude in degress of a grid point used in GEOWIND	
ARG	Ratios of pressure level used in COEFF3P to compute the ALOG of the ratios	
AX	Angle between pure geostrophic and surface wind vectors	
A1	Used in computation of divergence, a_1	$=2.0828\ 10^{-3}$
A2	a_2	$=1.3546\ 10^{-3}$
A3	a_3	$=0.044374$
B	Output array in XMIT Input array in GRADPR	
BETA	Constant used to compute Beta plane for channel case	
B1	Used in computation of divergence, b_1,	$=1.0475\ 10^{-3}$
B2	b_2	$=1.6261\ 10^{-3}$
B3	b_3	$=0.012258$

C	Formal parameter used in GRADPR call sequence for result and work arrays. Constant in COMPUV	= .12
CC1	1./TO	
CC2	e • L/R	
CC3	e • L/C_p	
CC4	CC2•CC3	
CC5	DEL1•DEL2	
CF	Friction over land or over ocean =FCONT or FOCEAN	
CK	Constant used in COMPUV	= .35
CLX	Height of a print character on a CDC printer in meters	= .00425
CLY	Width of a print character on a CDC printer in meters	= .00254
CO	Cosine of geostrophic wind vectors	
CONV	Convergence parameter used in ELLIPT	= .43
COS1	Cosine of angle between geostrophic and surface wind vectors	
CP	Specific heat at constant pressure C_p	=1004.
CX	Interpolation interval for computing values at zebra grid print position	
CY	Interpolation interval for computing values at zebra grid print position	
C1	$c_1 = \frac{2P_m}{2P_0 - P_1} = \frac{10}{17}$	=0.588235

C2	$c_2 = \frac{2(P_0-P_m)}{2P_0-P_1} = \frac{10}{17}$	=0.588235
C3	$c_3 = \frac{6P_0-4P_1}{6P_0-3P_1} = \frac{48}{51}$	=0.941176
C4	$c_4 = \frac{6P_m-2P_1}{6P_0-3P_1} = \frac{24}{51}$	=0.470588
C5	$c_5 = \frac{8P_0-8P_m}{6P_0-3P_1} = \frac{40}{51}$	=0.784314
C6	$c_6 = \frac{8P_m}{6P_0-3P_1} = \frac{40}{51}$	=0.784314
C7	$c_7 = \frac{P_1}{6P_0-3P_1} = \frac{3}{51}$	=0.0588235
C8	$c_8 = \frac{2}{2P_0-P_1} = \frac{2}{170}$	=0.0117647
D	Combined scaling constant in MAP	
DELP	Δ_P used to compute rainfall	
DELT	Time step in seconds Δt=NBLOCK·3600/NTSTEP	
DEL1	∂_2 tolerance	=.0001
DEL2	∂_2 tolerance	=.001
DEW	Used in advection formula in COMPUV	
DIV	M1·N2-N2·M2	
DIV1	ECS storage array for divergence field D_1	
DIV 2	ECS storage array for divergence field D_2	
DEPS	Time between fields being integrated = DELT·EPS	
DS	Grid distance (meters)	

DSS	.5/DS used in GEOWIND	
DT	Time step in hours =DELT/3600.	
DX	North-South dimension of a cell in meters represented by a print character in the zebra grid print	
DY	East-West dimension of a zebra cell in meters	
D1	Wind contraction factor	
E	Entry flag used in INITIAL to distinguish between the initial entry and calls to ZINPUT 1.=INITIAL entry 0.=ZINPUT entry	
EC2	ECS address of forecast field to be mixed	
EC3	ECS address of boundary value field to be mixed	
EE	E	=.622
EM	Coefficient for computing mean stream function, e_m	=0
EPS	Number of time steps between fields in the time integration	
EP	E_0	=.611
E1	Coefficients for computing mean stream functions, e_1	=-1.3589
E2	e_2	=0
F	Coriolis parameter field $=F_0 \cdot 2. \cdot$SIN (lat degrees)	
FA	Array contains data to be written on the output tape or array to be filled from data on the input tape.	
FACT	Time ratio used to mix boundary values into field at each integration step	

FCONT	Friction coefficient over land	=1.
FF	In routine INITIAL latitude in degrees, Coriolis parameter at a grid point	
FIM	Mid-latitude of channel	
FLD	Surface pressure field given to GEOWIND	
FM	Mean latitude Coriolis parameter used in computing Beta plane for channel case	
FMY	f^2/M	
FOCEAN	Friction coefficient over oceans	=.62
FORC	2D array for the forcing function	
FORC1 FORC2	Formal parameters in HELMSYS routine representing forcing function arrays	
FO	Radial velocity of the earth	=1.03E-4
FOFO	FO squared	
F1-F10	In core work arrays. All must be of equal size equal to IDIM words	
G	Gravity	=9.806
GDFO	g/F_0	
HEAT	ECS storage array for Heating	
HL	L	$=2.5.10^6$
HM3	ECS storage array for the twisting terms for the mean field	
HUM1	ECS storage array for humidity field	
HUM2	ECS storage array for humidity field	

H1	$h_1 = \frac{R}{4c_p} \ln (\frac{p_0}{p_m})$	$=0.495351 \cdot 10^{-1}$
H2	$h_2 = \frac{2f_0}{R \ln (\frac{p_0}{p_m})} \left(1 + \frac{0.75\ R(p_0-p_m)}{c_p(p_0+p_m)}\right)$	$=0.110953 \cdot 10^{-5}$
H3	h_3	$=1.03552 \cdot 10^{-6}$
H4	h_4	$=0$
H6	h_6	$=1.03552 \cdot 10^{-6}$
H13	ECS storage array for the twisting terms for the thickness field 1	
H23	ECS storage array for the twisting terms for the thickness field 2	
IA	Increment for array index for the array data is being taken from in XMIT	
IB	Increment for array index for the array data is placed into in XMIT	
IDAY	Day number	
IDIM	True dimensional size of the arrays	
ID1 ID2	Two word ident used to find data on input tapes and to identify output records	
IERR	Index to tape messages in IOERR 1=parity error on input 2=eof input 3=parity error on output 4=eof output	
IEXT3	Switch to include or exclude the vertical advection of vorticity, $\omega\ \partial\zeta / \partial P$, in forecasting equation 0=exclude 1=include	

IEXT4	Swith to include or exclude the twisting term in the forecasting equation o=exclude 1=include
IFMT	Array used for variable format in PRTMAX
IMM	Simple index = (1,n)
IND	Simple index to locate the two points before and following a grid point I in the row or column. Used in GEOWIND to compute the second order approximation to the gradient.
IP	Simple index = (I+1,J)
IPOINT	Number of points that fail the criterion of ellipticity in ELLIPT
IPP	Simple index = (M,n)
IQ	Print value and then the position index in the zebra grid print row
IREC	Number of records read from input tape
IS	Line spacing control in PRTMAX 1H‸ no extra spacing 1H0 double space
ISL	Index used to build LS table
IT	Time in seconds of the desired input field
ITIME	Time in seconds when reading or writing tapes. Time in hours during remainder of the program
ITY	Type of field on tape -indicates field is to be read +indicates field is to be written 11=FNWC Sea temperature field T SEA 12=FNWC Pressure field D1000,D500 or D300 14=FNWC TP850 field 8=U or V wind component

IVAR	Indicator for constant or variable boundary conditions 0=constant boundaries 1=variable boundaries
IW	500 word buffer used to read and write tape
IWW	The word that is presently being packed or unpacked for or from the tape buffer in INOUT
I1	In QSAT index to precomputed values of integrated mixing ratios in the range 1 to 71 from temperature in the range -20 to +50. InPROG3P =0 if no smoothing this time step =1 if smoothing is required In GRADPR=beginning point in array for storing smoothed values. Excludes first rows from computation.
I2	In PROG3P =0 if ellipticity is bypassed this time step =1 if fields are modified to meet ellipticity criterion In GRADPR=end point in array for storing smoothed values. Excludes last row from computation
	Indicator for when zebra grids are to be printed 0=no print, 1=print
I1	Surface pressure (2=print and call GEOWIND)
I2	Height for level p_m
I3	Height for level p_1
I4	Thickness $(p_m - p_1)$
I5	Lower vertical velocity $\bar{\omega}_1$
I6	Precipitable water
I7	Accumulated precipitation
I8	Relative humidity
I9	Stream function for level p_s
I10	Stream function for level p_m
I11	Stream function for level p_1
JJ	Row number in PRTMAX

JK	Index to first column being printed on the page in PRTMAX	
JMA	Maximum row index for the page	
JMI	Minimum row index for the page	
JMP	Number of column being printed in this page of the zebra grid print	
J3	ECS storage array for $J_3=J(\Psi_m;\Psi_1)$	
J4	ECS storage array for $J_4=J(\Psi_m;\Psi_2)$	
J12	ECS storage array for $J_1+J_2=$ $J(\Psi_m;\zeta_1)+J(\Psi_1;\beta_2)$	
J56	ECS storage array for $J_5+J_6=$ $J(\Psi_m;\zeta_2)+J(\Psi_2;\beta_6)$	
J789	ECS storage array for $J_7+J_8+J_9=$ $J(\Psi_m;\beta_7)+J(\Psi_1;\beta_8)+J(\Psi_2;\beta_9)$	
KIND	Type of run flag 1=canned data channel case (cyclic boundary conditions) 0=real data	
KT	In STEP3P Index in the integration loop In MAP Array of print characters used for the zebra print	
K1	$k_1 = c_2(c_2-\frac{4}{3})$	=-0.438291
K2	$k_2 = -c_2c_4$	=-0.276816
K3	$k_3 = c_2c_7$	=-0.034602
K4	$k_4 = -c_1c_2$	=-0.346020
K10	$k_{10} = 2t_2c_8$	=-0.438294
K11	$k_{11} = -2(t_3+t_7)c_8$	=-0.276817
K12	$k_{12} = -t_7c_8$	=0.034602
K13	$k_{13} = -2t_3c_8$	=-0.346021

K14	$k_{14} = 2(t_5-t_8)c_8$	=-0.507498
K15	$k_{15} = -t_8c_8$	=0.083045
K16	$k_{16} = 2t_1c_8$	=0.016609
K17	$k_{17} = 2(t_4-t_6)c_8$	=0.005536
K18	$k_{18} = -t_6c_8$	=-0.000692
K19	$k_{19} = 2t_2c_8$	=-0.438293
K20	$k_{20} = 2t_3c_8$	=-0.346021
K21	$k_{21} = 2t_1c_8$	=0.016609
K22	$k_{22} = -2(t_3+t_7)c_8$	=-0.276817
K23	$k_{23} = 2(t_5-t_8)c_8$	=-0.507497
K24	$k_{24} = 2(t_4-t_6)c_8$	=0.005536
K25	$k_{25} = -t_7c_8$	=0.034602
K26	$k_{26} = -t_8c_8$	=0.083045
K27	$k_{27} = -t_6c_8$	=-0.000692
K31	$k_{31} = -\dfrac{t_{10}}{(p_0-p_m)}$	=0.411765
K32	$k_{32} = -\dfrac{t_{11}}{(p_0-p_m)}$	=0.588235
K33	$k_{33} = \dfrac{1-t_9}{(p_0-p_m)}$	=0.0117647
K36	$k_{36} = \dfrac{t_{10}-t_{13}}{(p_m-p_1)}$	=-0.588235
K37	$k_{37} = \dfrac{t_{11}-t_{14}}{(p_m-p_1)}$	=-0.411765
K38	$k_{38} = \dfrac{t_9-t_{12}}{(p_m-p_1)}$	=0.0117647
LAMC	Phase differences for the cosine functions (λc)	

LAMS	Phase differences for the sine functions (λ_s).
LCM	Address of ECS where array transfer starts
LEN	Length of input output buffer in INOUT=500 words on CDC 6000-7000 series machine
LETACC	(1) Times when the accumulated precipitation shall be interrupted in hours (multiple of NBLOCK) (2) End time after which no interruption takes place (3) Time interval between interruption (multiple of NBLOCK)
LEV	Level in tape record header 300 for D300 500 for D500 1000 for D1000 0 for all other fields
L	Counter used in COMPUV indicating the number of times the routine has been entered
LS	ECS array contains the flag field used by COMPUV
LU	Logical unit number for output tape in INOUT, for zebra grid prints in MAP
M	Row dimension
MAPHOUR	(1) Time when forecast is to be printed in hours (multiple of NBLOCK) (2) Time of last printout desired (3) Time interval between forecast printouts (multiple of NBLOCK)

MARK	Flag field used to control computations in the outside 3 rows and columns of the arrays defined as follows (origin of grid=lower left corner): 20 10 10 10 10 10 10 19 14 -9 -8 -8 -8 -8 -7 6 14 -9-10-10-10-10 -7 6 14 -9-10 -1 -1-10 -7 6 14 -9-10 -1 -1-10 -7 6 14 -9-10-10-10-10 -7 6 14 -9 -6 -6 -6 -6 -7 6 17 2 2 2 2 2 2 18
MAXNAME	Maximum number of words in matrix header line = 10
MELLIPT	(1) Time at which ellipticity correction is to be made in hours (multiple of NBLOCK) (2) Time of last correction (3) Time interval between corrections (multiple of NBLOCK)
MF	Index to the first column being printed on the page in PRTMAX
MI	In FILL number of columns to be filled
ML	Index to last column being printed on the page in PRTMAX
MN	Number of elements used in the arrays=number of rows times number of columns
MODEL	Model number used when reading or writing tapes. Used to uniquely define the data tapes.
MSMUTT	Same as NSMUTT for a second time sequence except it cannot be used to control smoothing at time 0.

MT	UPTIME parameter (1) Time action desired (multiple of NBLOCK) (2) Last time action desired (3) Time interval between actions (multiple of NBLOCK)	
MY	Map scale factor μ	
M1	Number of columns-1, m_1	=-826.330
M2	m_2	=-688.40
M12	12 bit mask used to pack and unpack tapes	
M24	24 bit bask used in packing and unpacking takes	
N	Column dimension	
NAME	Page header word in SNAP and FIELD	
NAME1	Header for the matrix printout NC characters in length 1 to 80 characters long	
NBLOCK	Forecast interval in hours (usually 6)	
NC	Number of characters in NAME1 header line $1 \leq NC \leq 80$	
NCNT	Counter for the number of times SNAP has been called	
NCPW	Number of characters per word=10	
ND	NTSTEP+1 Number of times the integration loop is executed during one forecast computation	
NELLIPT	Same as MELLIPT but used for a second time sequence	
NEND	End time for forecast in hours	

NI	In FILL number of rows to be filled	
NN	Number of print column available for zebra print grid	
NOP	Number of pages required to print a matrix in PRTMAX	
NSMUTT	(1) Time of the first smoothing, may be 0 if the initial fields are to be smoothed (in hours) (2) Last time for a smoothing operation (3) Time interval between smoothing operations	
NTIME	Time in hours	
NTSTEP	Number of time steps for an integration interval	
NU	Resolution of zonal wind speed	
NW	Number of words being packed or unpacked in INOUT, in PRTMAX number of words in heading	
NWAVE	Number of waves	
NX	Wave numbers as a function of channel length in X direction (nx)	
NY	Wave numbers as a function of channel width in Y direction (ny)	
N1	Number of rows-1, n_1	=-532.92
N2	n_2	
OFFSET	Constant added to input values from tape after the values are scaled and subtracted from output values before scaling	
PI	Radians in 180°	=3.141593
PNIVM	Pressure level p_m	=50CB

PNIVS	Pressure level P_0	=100CB
PNIV1	Pressure level P_1	=30CB
PM	P_m Intermediate pressure level that divides the atmosphere into 2 layers	=50CB
PMEAN	$.5 \cdot P_m + P_s$	
PP	Intermediate value used in STEP3P computations. Ratio of time step to grid size used in COMPUV	
PPM	$2./(P_0 - P_m)$	
PQ	Intermediate value used in STEP3P computation	
PREC	ECS storage array for accumulated precipitation	
PS	ECS storage array for surface pressure field	
PSI	Result field Ψ field Array being modified to satisfy the criterion of ellipticity in ELLIPT	
PSIC	Amplitudes of the cosine functions (Ψc)	
PSIM1	ECS storage array for Ψ_m at time 1	
PSIM2	ECS storage array for Ψ_m at time 2	
PSIPM	Pressure levels for channel case	
PSIPS		
PSIP1		
PSIS	Amplitudes of the sine function (Ψs)	
PSI11	ECS storage array for Ψ_1 at time 1	

PSI12	ECS storage array for Ψ_1 at time 2	
PSI21	ECS storage array for Ψ_2 at time 1	
PSI22	ECS storage array for Ψ_2 at time 2	
P0	P_0 Lower pressure level near the surface of the earth	=100 CB
P1	P_1 Upper pressure level near the tropopause	= 30 CB
Q	Field to be printed	
QD	Resolution indicator for isolines	
QZ	Isoline corresponding to 000 on the printed grid	
R	Gas constant for air	=287.
RESIDUE	Formal parameter in HELMSYS=RESM Formal parameter in HELMSYS= RESSYS	
RESM	Allowed residual in the HELM routine	$=.5 \cdot 10^5$
RESPSI	Not used	
RESSYS	Allowed residual in the HELMSYS routine	$=.5 \cdot 10^5$
RESZ	Not used	
RMAX	Maximum residual remaining at the end of an iteration in HELM	
ROT	Grid rotation defined as counter clockwise angle from the North to the +Y axis in degrees	
RPD	Radians per degree. Constant used to convert to and from degrees	
RW	Precomputed values mixing ratios at saturation	

S	Array to be printed in PRTMAX Vorticity term at one grid point in ABSVOR	
SATUR	Saturation temperature	
SCALE	Map scale factor for grid print (unit 10° m) Scale factor in INOUT = .01 for all input fields except for ITY=12 (D300, D500, D1000) when the factor is .0001	
SCM	Beginning word of an array to be transferred to or from ECS	
SI	Sine of the geostrophic wind vector	
SIN1	Sine of the angle between the geostrophic and surface wind vectors	
SS1	Coefficients for computing mean divergences	$=E1+EM \cdot C2$
SS2		$=E2-EM \cdot C1$
SS3		$=-EM \cdot C8$
STANPS	Standard pressures at mean levels defined on Monoco charts.	
SURPS	Standard atmospheric pressure at sea level	=101.325 CB
STAB1	$(\Gamma_d-\Gamma)_1$ the dry adiabatic lapse rate-lapse rate; assume	=.422222
STAB2	$(\Gamma_d-\Gamma)_2$ $\Gamma=.75_d$	=.511111
S1	Used in computations of divergence, s_1	=28.230856
S2	s_2.	=10.645832
TA	ECS storage array for the air temperature	

TERM1	Values used in the computation of divergence.	
TERM2		
TM	Temperature in °K	
TOL	Tolerance	
TS	ECS storage array for surface temperature in °K	
TWT	Air-sea temperature difference	
TO	Conversion factor to convert from °C to Kelvin=273.	
T1	$t_1 = \frac{p_0+p_m-p_1}{2p_0-p_1}$	=0.705882
T2	$t_2 = \frac{1}{3} \frac{(2p_1-3p_m-p_0)(p_0-p_m)}{2p_0-p_1}$	=-18.627500
T3	$t_3 = \frac{p_m(p_0-p_m)}{2p_0-p_1}$	=14.705900
T6	$t_6 = c_8 \frac{p_1}{6}$	=0.0588235
T7	$t_7 = -c_2 \frac{p_1}{6}$	=-2.941175
T8	$t_8 = (c_1-2) \frac{p_1}{6}$	=-7.058825
T10	$t_{10} = (c_2-1)(p_0-p_m)$	=-20.588250
T11	$t_{11} = -c_1(p_0-p_m)$	=-29.411750
T12	$t_{12} = c_8 \frac{p_1}{2}$	=0.176471
T13	$t_{13} = -c_2 \frac{p_1}{2}$	=-8.823525

T14	$t_{14} = (c_1-2)\frac{p_1}{2}$	=-21.176475
U	Zonal wind speed	
UKUA	Air temperature gradient in the U direction	
UKUW	Water temperature gradient in the U direction	
UPM	Zonal wind profiles at the levels p_s, p_m and p_1 for the initial fields in the channel case	
UPS		
UP1		
V	In FILL value placed in the row	
VKVA	Air temperature gradient in the V direction	
VKVW	Water temperature gradient in the V direction	
VI	In FILL value that the initial value is incremented by when incrementing to next row	
VM	ECS storage array for the velocity potential for the mean field	
VOR	η or ζ field	
VS	In FILL initial value to be placed in the row	
V1	ECS storage array for the velocity potential for the thickness field 1	
V2	ECS storage array for the velocity potential for the thickness field 2	
WF	Weighting factor used to interpolate between boundary value fields in time	

	Weights for mixing the boundary fields
WGT1	Outside row or column
WGT2	Next inner row or column
WGT3	Third row or column inside boundary
WI	Easterly component of wind vector
WJ	Northerly component of wind vector
WS	ECS sotrage array for ω_s, the vertical velocity at the lower boundary
WT	Wind speed
WX	Adjustment of wave near rigid boundaries Boundary WX=0 +1 row from the boundary, wx=0.33 +2 rows from the boundary, wx=.64 +3 or more rows from the boundary, wx=1.
XIX	Row in index-1 used to compute latitude in GEOWIND
XP	Midpoint in a zebra grid print position
YP	Midpoint in a zebra grid print position
YZ	Midpoint in a zebra grid print position
Z	Formal parameter in STREAM1 routine= height field
ZD	Wind direction computed in GEOWIND
ZM	Data array used to store precomputed values for ZMOIST

ZM1	Z_m fields stored in ECS for boundary mixing at times 1 and 2
ZM2	
ZS	Wind speed computed in GEOWIND
Z1	Arrays used in HELMSYS
Z2	
Z11	Z_1 fields stored in ECS for boundary mixing at times 1 and 2
Z12	$Z_1=.5(Z_m-Z_{1000})$
Z21	Z_2 fields stored in ECS for boundary mixing at times 1 and 2
Z22	$Z_2=.5(Z_{300}-Z_m)$

4. HYDRODYNAMICAL-NUMERICAL MODEL

The Optimized HN model run instructions are contained in Bauer (1) and additional documentation of the model is in preparation for the Environmental Protection Agency, Corvallis Environmental Research Laboratory so it is not repeated in this report. Figure 10 is an overview of the HN model program sequence showing where the AT model links in. The HN model requires a preprocessed initial grid contained on an HN format tape. This tape is prepared by a program on the NEPRF CDC 3100 computer by Phase I. The HN model reads the initial tape and the optional wind component tape generated by the ATANAL program from the water heights and and velocity fields. The output tape can then be processed by the display program Phase III which produces pen plots on CalComp plotters, by HNCNTR which produces contour plots of the fields on the NEPRF 3100 Varian plotter or by ADVECT which is a program to advect pollutants based on the velocity fields.

4.1 SUMMARY OF CHANGES

The HN model reported in (1) has undergone a number of revisions since the report was prepared. Most of the changes were to add capabilities to the model or to alter the boundary conditions that are treated in detail in the forthcoming EPA report. The only change made specifically for this project was the addition of the variable wind input option. This change was made using the CDC UPDATE system to replace the source program statements that converted the WIND card parameters

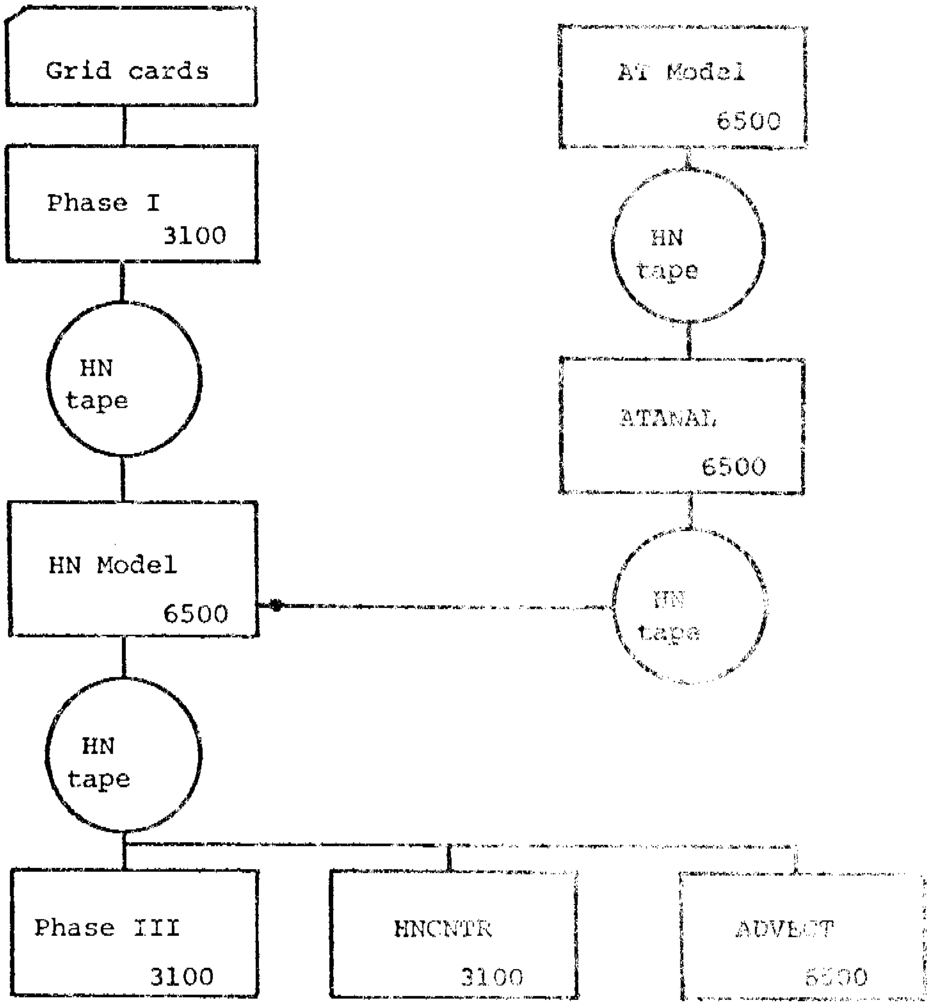


Figure 10. HN program sequence

into constant wind fields with a call to INPOUT to read the wind component fields, to add the capability to INPOUT to read a second tape, and to update the field each hour once it is turned on. The facilities of starting and ending the wind field were left under the control of the WIND card.

4.2 ADDITIONAL NOTES ON VARIABLE WIND DATA INPUT

The wind component tape contains components of the wind expressed as force vectors relative to the HN model grid and does not require additional rotations. The start time and update times, grid size, and model number must all match those supplied to the Phase I card ATANAL programs or the records will be bypassed by INPOUT routine. Normally the wind is not started in the HN model until at least 6 hours to avoid initial program shock which can cause the HN model to become numerically unstable.

TIDAL CURRENTS AND POLLUTANT DISPERSAL IN THE WESTERN GULF OF ALASKA AS DERIVED FROM A HYDRODYNAMICAL-NUMERICAL MODEL

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1. INTRODUCTION

The computation of tides and currents using hydrodynamical-numerical (HN) models was originally proposed in 1938 by Professor Walter Hansen of the University of Hamburg. However, it was not until the advent of the electronic computer that this approach became feasible. These models, based on the equations of motion modified to operate on vertically integrated mass transport, have been well tested over the past 20 years for single-layer cases. Since 1967, in collaboration with Professor Hansen, Dr. Taivo Laevastu of the Oceanography Department, Naval Environmental Prediction Research Facility, has extended these models to allow multiple open boundaries, multiple layers, and various auxiliary computations [1-5]. The analysis and prediction of advection and diffusion of pollutants is easily incorporated into the HN formulation since current components are computed in short time intervals.

An optimized multilayer HN model [6], in two-layer mode, was applied to three overlapping areas in the Gulf of Alaska. The results described here concern the westernmost grid which extends along the Alaskan Peninsula from eastern Kodiak Island, southwestward to Unimak Pass and offshore to an approximate distance of 300 km (Figure 1).

The project was funded by the Outer Continental Shelf Energy Project of NOAA. The Project Officer was Dr. Mauri Pelto, OCSEP office of NOAA. Appreciation is expressed to the following members of the NEPRF staff for the technical support services noted: Mrs. P. Mousseau and Mrs. W. Carlisle, manuscript typing; Mr. R. Clark, graphics; Mr. S. Myrick, photography; and Mr. S. Bishop, editing.

2. THE EQUATION SET

The basic set of equations includes: (a) vertically integrated equations of motion for each layer; (b) two interdependent continuity equations, one for each layer; and (c) the equations setting the boundary conditions.

(a) Equations of Motion:

$$\dot{U}1 + \frac{r\sqrt{U1^2 + V1^2}}{H_u} U1 - fV1 + g\zeta_{1x} = K^{(x)}$$

(Layer 1)

$$\dot{V}1 + \frac{r\sqrt{U1^2 + V1^2}}{H_{v1}} V1 + fU1 + g\zeta_{1y} = K^{(y)}$$

$$\dot{U}2 + \frac{r\sqrt{U2^2 + V2^2}}{H_{u2}} U2 - fV2 + g\frac{\rho_1}{\rho_2} \zeta_{1x} +$$

$$g(1 - \frac{\rho_1}{\rho_2}) \zeta_{2x} = 0$$

(Layer 2)

$$\dot{V}2 + \frac{r\sqrt{U2^2 + V2^2}}{H_{v2}} V2 + fU2 + g\frac{\rho_1}{\rho_2} \zeta_{1y} +$$

$$g(1 - \frac{\rho_1}{\rho_2}) \zeta_{2y} = 0$$

(b) Continuity Equations:

$\dot{\zeta}_1 - \dot{\zeta}_2 + (H_1\ U1)_x + (H_1\ V1)_y = 0$ (Layer 1)

$\dot{\zeta}_2 + (H_2\ U2)_x + (H_2\ V2)_y = 0$ (Layer 2) where:

ζ_1 = surface elevation

ζ_2 = deviation of MLD (mixed layer depth) from its mean (initially prescribed) depth

U1, V1 = u,v components in first layer

U2, V2 = u,v components in second layer

r = friction coefficient (internal friction)

f = Coriolis parameter

r_b = bottom friction coefficient

g = acceleration of gravity

H = layer thickness

ρ_1, ρ_2 = densities of the respective layers

$K^{(x)}, K^{(y)}$ = external forces

$(\ )_x$ = partial with respect to x = $\frac{\partial()}{\partial x}$

Detailed descriptions of these equations as well as their finite difference formulations are available in [1].

(c) Boundary Conditions

For the two-layer mode of the optimized HN model used in the Gulf of Alaska region, the boundary conditions were: (1) No normal flow at land-sea boundaries; and (2) flow through open boundaries, as computed internally one grid distance from the boundary.

Wind stress on the surface layer was parameterized using

$$\tau^{(x)} = \lambda \frac{\omega_x \sqrt{\omega_x^2 + \omega_y^2}}{H}$$

$$\tau^{(y)} = \lambda \frac{\omega_y \sqrt{\omega_x^2 + \omega_y^2}}{H}$$

where:

λ = the drag coefficient

ω = the wind speed

ω_x, ω_y = components of wind vector

$\tau^{(x)}, \tau^{(y)}$ = components of the stress vector

Water surface elevations of several grid boundary locations were specified as the driving force for tidal currents within the area. Because of a lack of actual tidal data along the boundaries, values from Kodiak Island and Sanak Island were utilized as described below and depicted in Figure 4.

Kodiak tides were used along the Shelikof Straits boundary and Sanak tides were used through the Unimak Pass. For the offshore oceanic grid boundary parallel to the Alaska Peninsula, a linearly interpolated tide from southwest to northeast was specified using Sanak tides at the westernmost corner and Kodiak tides at the easternmost corner. The amplitude, phase speed and phase angle of each component of the Sanak and Kodiak tides are given in Table 1. The eastern grid boundary south of Kodiak and the western grid boundary are not externally forced. Due to the extreme thickness of the second layer (relative to the first) over the Aleutian

Table 1. Values of tidal components.

Location	Component	Amplitude (cm)	Phase Angle (deg)	Phase Speed (deg/hr)
Kodiak Is. 57°47'N 152°24'W	M_2	98.4	8	28.984
	K_1	40.5	139	15.041
	O_1	27.3	122	13.943
	S_2	32.8	41	30.000
Sanak Is. 54°23'N 162°38'W	M_2	58.6	355	28.984
	K_1	41.6	124	15.041
	O_1	23.6	97	13.943
	S_2	22.1	18	30.000

Trench, water surface elevations specified at the forced boundaries were assumed to result solely from tidally induced variations in the thickness of the second layer. A general and more complete discussion of boundary conditions for HN models can be found in Kagan [7].

3. DIFFUSION AND ADVECTION [1]

Diffusion in water bodies has been presented in many formulas, a few of which are given here (neglecting vertical diffusion).

The general diffusion formula is

$$\frac{\partial^2 S}{\partial x^2} + \frac{\partial^2 S}{\partial y^2} - \frac{1}{A}\frac{\partial S}{\partial t} = 0 \;;$$

the basic dispersion formula is

$$\frac{\partial S}{\partial t} = Y - \frac{S}{n} - \frac{\partial}{\partial x}(U_x + pS_x) - \frac{\partial}{\partial y}(U_y + pS_y) \;;$$

and the Fickian equation is

$$\frac{\partial S}{\partial t} = Y - \frac{S}{n} + K\nabla^2 S - \frac{\partial}{\partial x}(S_u U) - \frac{\partial}{\partial y}(S_v V);$$

where:

Y = addition (release)
n = decay
S = concentration
$pS_{x,y}$ = concentration velocity component
t = time
K (coefficient) = $\beta a v_r$ (a = depth; $v_r = u^2 + v^2$; $\beta = 0.003$)
S_u, S_v = concentration gradients in u and v direction
A = diffusion coefficient (Austausch coefficient)

The Lagrangian approach of diffusion in finite difference form was adopted by Wolff, Hansen and Joseph [8]:

$$S_{n,m}^{t+\tau} = S_{n,m}^{t} \left(1 - \frac{4\tau A}{\ell^2}\right) + \frac{A\tau}{\ell^2} \left(S_{n-1,m}^{t} + S_{n+1,m}^{t} + S_{n,m-1}^{t} + S_{n,m+1}^{t} - 4S_{n,m}^{t}\right)$$

where:

t = time
τ = time step
ℓ = grid size
S = concentration
A = diffusion coefficient
n,m = grid coordinates

The above finite equation deviates from the usual finite difference diffusion formula only in the addition of the last term (-4S), which makes the solution similar to the solution of the "Laplacian" ($K\nabla^2 S$). Also, the advection is computed linearly in finite difference form:

$$S^{t+\tau}_{n,m} = S^{t}_{n,m} - \tau \left| U^{t+\tau}_{n,m} \right| \frac{(S^{t}_{n,m} - S^{t}_{n,m\pm 1})}{\ell} -$$

$$- \tau \left| V^{t+\tau}_{n,m} \right| \frac{(S^{t}_{n,m} - S^{t}_{n\pm 1,m})}{\ell}$$

where Sn,m-1 or n,m+1 (respectively n-1, n+1) are used, depending on the direction (sign) of U and V.

The Lagrangian approach used by Wolff, Hansen and Joseph [8], though reproducing the diffusion process well, does not conserve absolutely the amount of the dispersing substance. The following modified formula, however, was found to be conservative, provided the proper A (Austausch coefficient) is chosen and corresponds to the chosen time step and grid size:

$$S^{t+\tau}_{n,m} = S^{t}_{n,m} - \frac{4\tau A}{\ell^2} S^{t}_{n,m} + \frac{\tau A}{\ell^2} (S^{t}_{n-1,m} + S^{t}_{n,m-1}$$

$$+ S^{t}_{n+1,m} + S^{t}_{n,m+1} - 4S^{t}_{n,m}) + \frac{\tau A}{\ell^2} (S^{t}_{n-1,m-1}$$

$$+ S^{t}_{n-1,m+1} + S^{t}_{(n+1,m-1)} + S^{t}_{(n+1,m+1)})$$

It should be mentioned that the transport equation used in NEPRF programs is very similar to the "upwind" difference scheme used in air pollution problems (Pandolfo et al. [9]). This scheme requires that $\frac{U\Delta t}{\Delta \ell} < 1$.

The Austausch coefficient (A) is a function of grid size and time step. In an experiment designed to investigate the conservation of diffusing substances, one of the main criteria was found to be a relationship between grid size and time step. This relation of A to grid size with a 1,000 sec time step is shown in Figure 2. The correct value of A is found from this graph and from the relation, $A = \frac{1,000}{\Delta t}$ A (graph). With a small time step, the value of A approaches that found empirically by Okubo and Ozmidov [10] and Kullenberg [11]. An idea of the proper A to be used in different grid sizes can be obtained also from the Joseph and Sendner [12] formulation. There is still some slight uncertainty about the dependence of the horizontal Austausch coefficient (K_h) on the length scale, $K_H = k_1 \times 10^{-3} \ell^{k2}$. Kullenberg [11] gives the values for the coefficients $k_1 = 1.3$ and $k_2 = 1.31$, whereas Okubo [13] gives the corresponding values as 1.03 and 1.15. Both lines are shown in Figure 2.

4. INPUTS AND RESULTS

Case 1 is a 48-hour, tides-only (no wind) run. Beginning at approximately high tide, hour 29 (104400 s), a continuous source of pollutants is input at row 12, column 47, approximately 56°50'N, 155°W (Figure 1). The amount of continuous source is 1000 units/day, input into the model as 0.463 units per 40-second time step. Case 1 is considered to be a summer case with the thickness of the first layer (mixed layer depth) as 20 m.

A time series of layer 1 surface currents (cm/s) and tidal heights (cm) at point 12,47 for Case 1 is given in Figure 6. The circled times on the x-axis are those at which layer 1 and 2 currents (cm/s) and height deviations (cm) are presented over the whole grid (Figures 7 through 15).

Case 2 is indentical to Case 1 except a constant wind of 10 m/s from 320° true is used to force the surface layer over the whole grid. The wind is started at hour 24 (86400 s) and is continued through the remainder of the run. Considering current flow during the no-winds condition, winds from 320° true were chosen as a worst case situation with respect to pollutant landfall originating from a source at point 12,47.

Figure 16 is a time series of layer 1 surface currents (cm/s) and tidal heights (cm) at point 12,47 for Case 2. Circled times on the x-axis are those for which layer 1 and 2 currents (cm/s) and height deviations (cm) are presented over the entire grid (Figures 17 through 25). Pollutant distribution at hours 42 and 48, after initializing the continuous source at hour 29, are shown in Figures 26 and 27 for Cases 1 and 2 respectively.

In Figures 7-15 and 17-27, contour intervals are as follows: layer 1 plots, 5 cm; layer 2 plots, 50 cm; and pollutant plots, 200 arbitrary units. Layer 1 and 2 currents are represented by current barbs at every-other grid point. Each flag on a current barb indicates 10 cm/s; thus a barb with two and one-half flags represents a current of 25 cm/s (approximately one-half knot).

Values of the various constants input into this particular Gulf of Alaska model are given in Table 2.

Table 2. Constant parameters for computations of flow in the western Gulf of Alaska.

Constants	Values
Number of Rows	21
Number of Columns	60
Grid Step (cm)	1481600
Rotation Angle* (deg)	39
Wind Drag Coefficient	3.2×10^{-6}
Mid-latitude of Grid (deg)	55.5
Bottom Friction Coefficient	0.003
Austausch Coefficient	5.25×10^{5}
Time Step (sec)	40
Number of Layers	2
Layer 1 Smoothing Parameter	0.99
Layer 2 Smoothing Parameter	0.98
Layer 1 Density (gr/cm^3)	1.023
Layer 2 Density (gr/cm3)	1.025

*Counterclockwise angle between north and positive Y axis of the computational grid

5. VERIFICATION AND DISCUSSION

The work of Favorite et al. [14] describes surface flow in the vicinity of Kodiak Island using dynamic methods to obtain geostrophic currents. These methods, however, do not intrinsically resolve the tidal currents and currents due to sea level fluctuations which dominate in coastal waters.

Until adequate current measurements are obtained so that proper tuning and verification of the western grid Gulf of Alaska model can be accomplished, previously used and less satisfactory verification methods must be employed [5].

A harmonic prediction of surface heights, based on tidal station data within the grid but not used to drive the model, is compared to computed model output (Case 1) for the given location. Figure 5 demonstrates the comparison of a harmonic prediction from King Cove (55°04'N, 162°19'W) and computed data from row 5, column 15; it indicates good agreement between the harmonic prediction and computed data.

Three features should be noted in the current and height fields of Figures 7-15 and 17-25: (1) the extremes in surface height deviation (layer 1) off the southwest edge (row 9, column 9) of Sanak Island; (2) the apparent convergence zone (except in Case 2, layer 1) in the Shelikof Strait off the western tip of Kodiak Island; and (3) the apparent incoherence of the second layer height deviations.

The first feature off Sanak Island is probably caused by the juxtaposition of steep bottom topography arising out of the Aleutian Trench (Figure 3) and the relatively shallow bank to the southwest of Sanak.

The second feature, which appears in all but the winds case layer 1, is probably also due to bottom topography. Off the western corner of Kodiak Island, the 200 m contour (Figure 3) indicates a narrow channel which originates from the Aleutian Trench to the south and into but not completely through the Shelikof Straits. Further support of this feature off Kodiak is found in drift bottle studies [15] which indicate this area as a convergence zone. Persistence of these features off Sanak and Kodiak Islands, using various boundary prescriptions of the tidal inputs, also indicates that these features are of topographic origin rather than simply interactive effects caused by the given boundary prescriptions.

The third feature, the irregularities of the second layer height deviations, are possibly caused by topographic effects, but they may just as likely be caused by insufficient tuning of the model by means of the second layer smoothing parameters.

It would be of interest to attempt verification of the three features noted above to evaluate the extent of further tuning required.

Study of the actual numerical output of pollutant distributions is necessary for the best understanding of the dispersion of a continuous pollutant source in Cases 1 and 2 described previously. An indication of the numerical outputs is given in the pollutant contour plots for hours 42 and 48 for Case 1 (Figure 26) and Case 2 (Figure 27).

A southwestward trend of pollutant movement is observed in both Cases 1 and 2 with this tendency accentuated as expected in the case that includes winds from the northwest. Pollutant landfall in Cases 1 and 2 from a release at point 12,47 apparently occurs in the Trinity Islands to the southwest of Kodiak at least 22 hours after the start of continuous pollutant release.

The cause of the apparent slow dispersal from this particular release point is reasonable when the current velocities and grid step are compared. If one assumes the maximum current speed of 30 cm/s at point 12,47 is constant in the area, the grid step of 1481600 cm yields a simple advection speed of 13.7 hours per grid step. Diffusion hastens the spreading somewhat, but the speed is not a sustained 30 cm/s and the direction is also variable. The combination of these factors yields the apparent slow pollutant dispersal.

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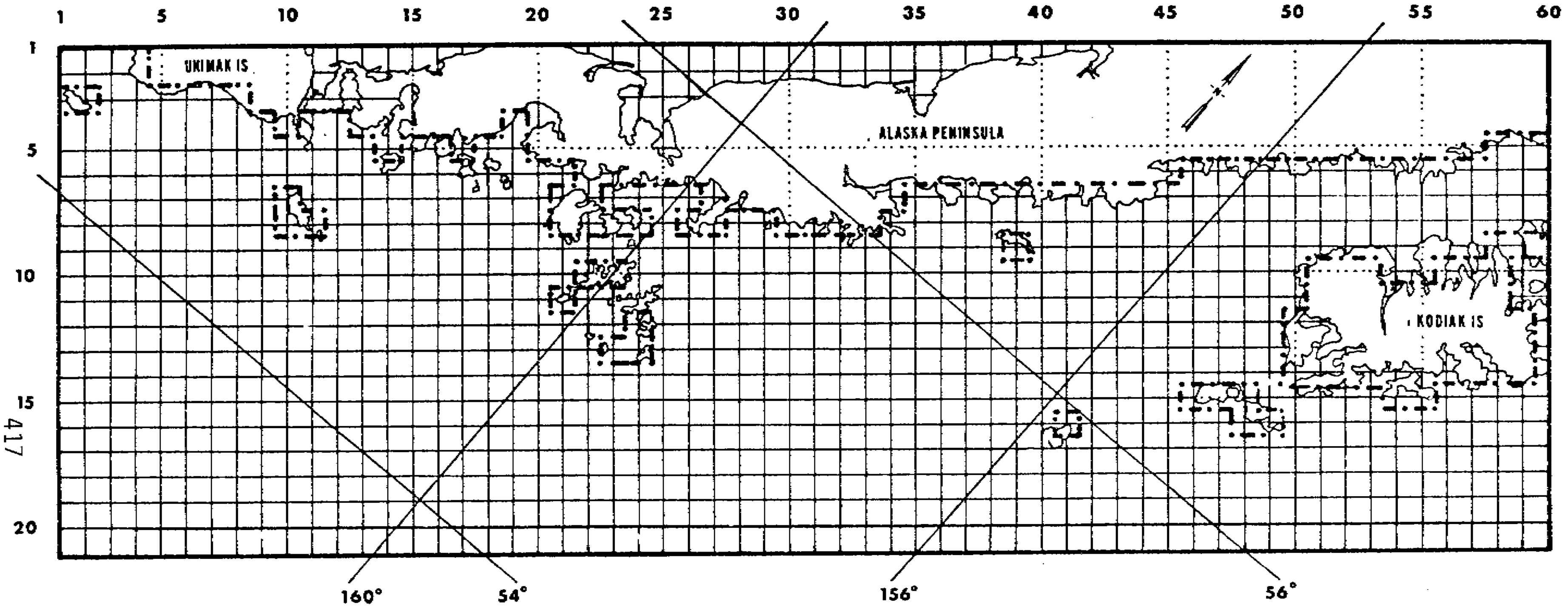
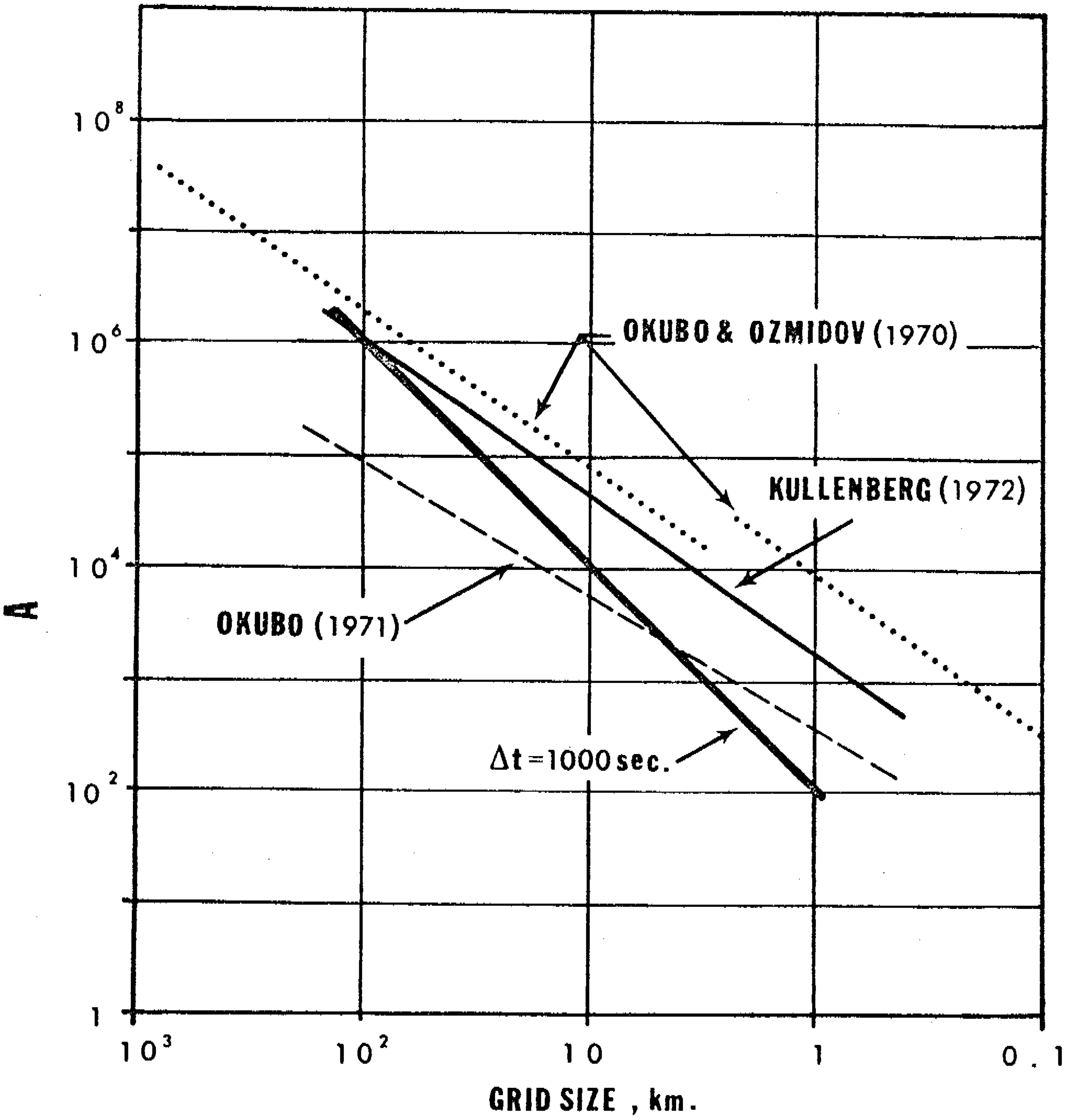
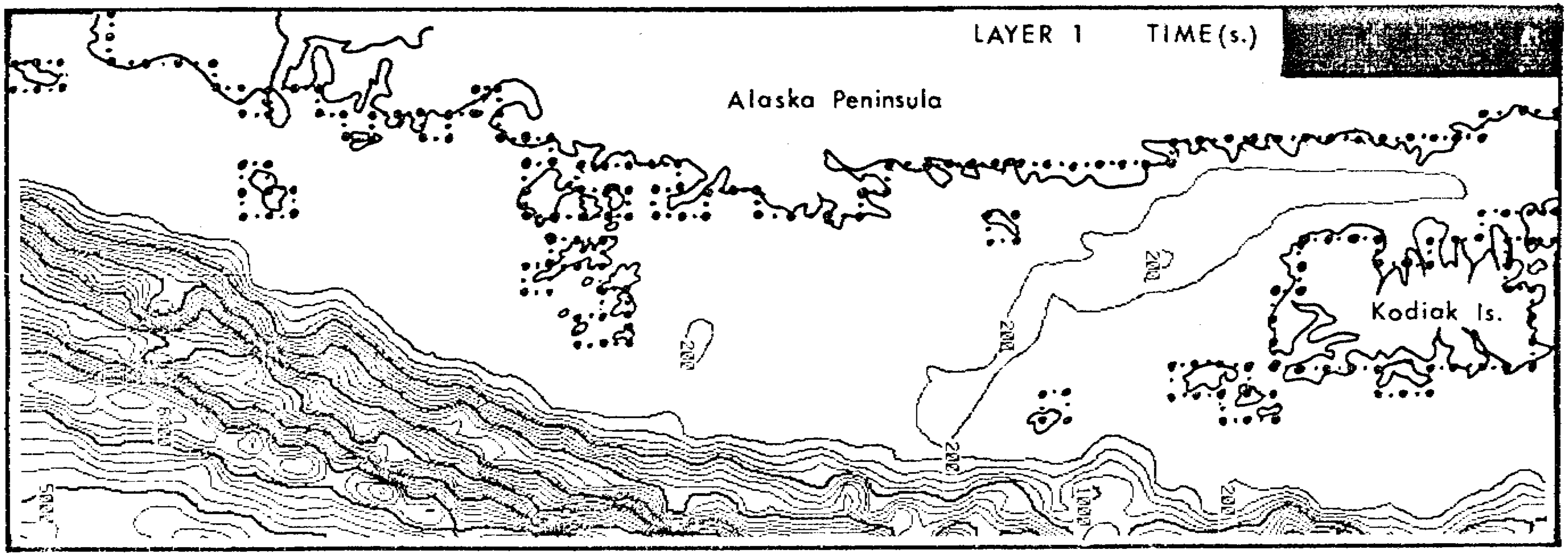


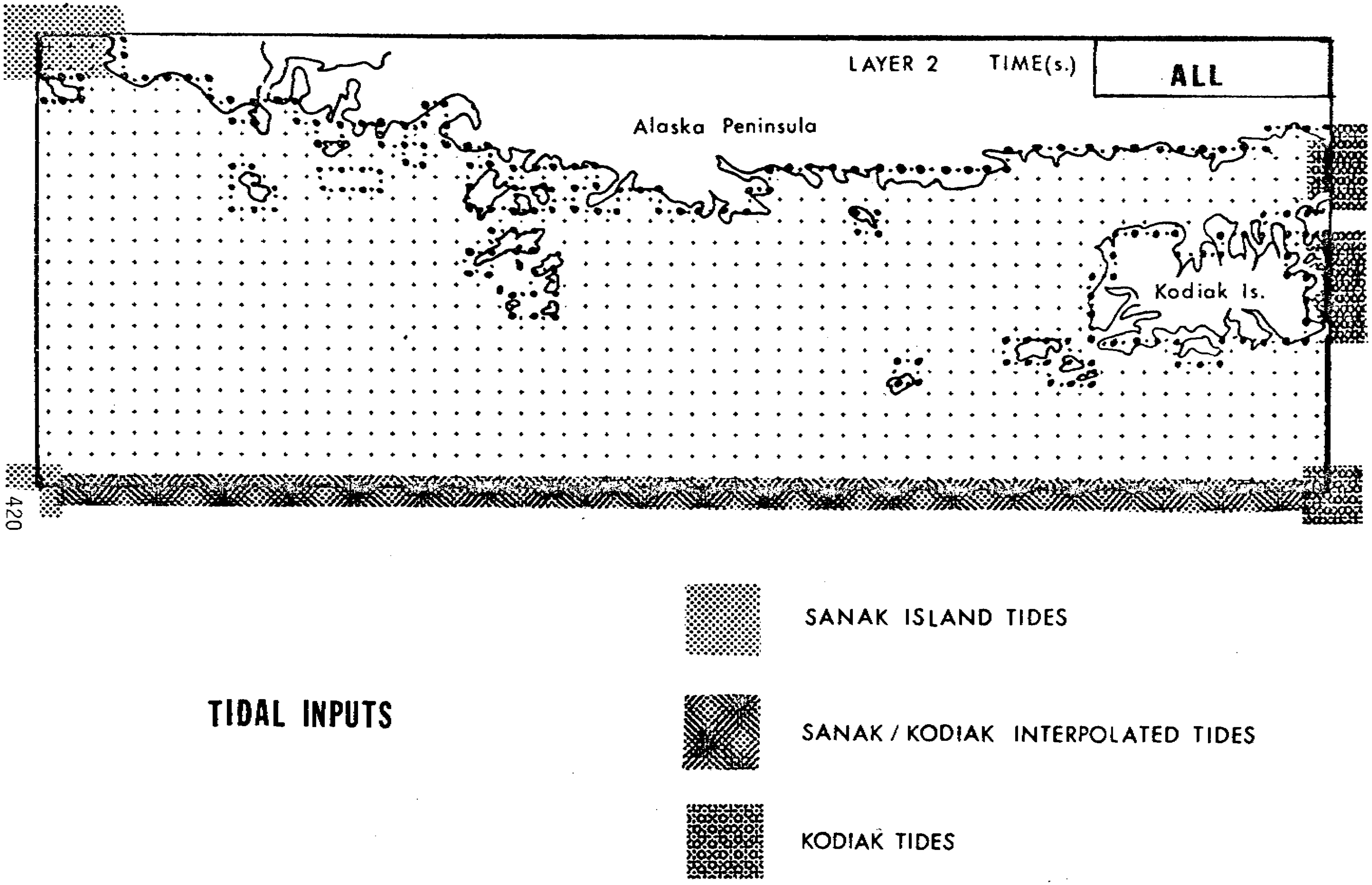
1. Gulf of Alaska, western grid.



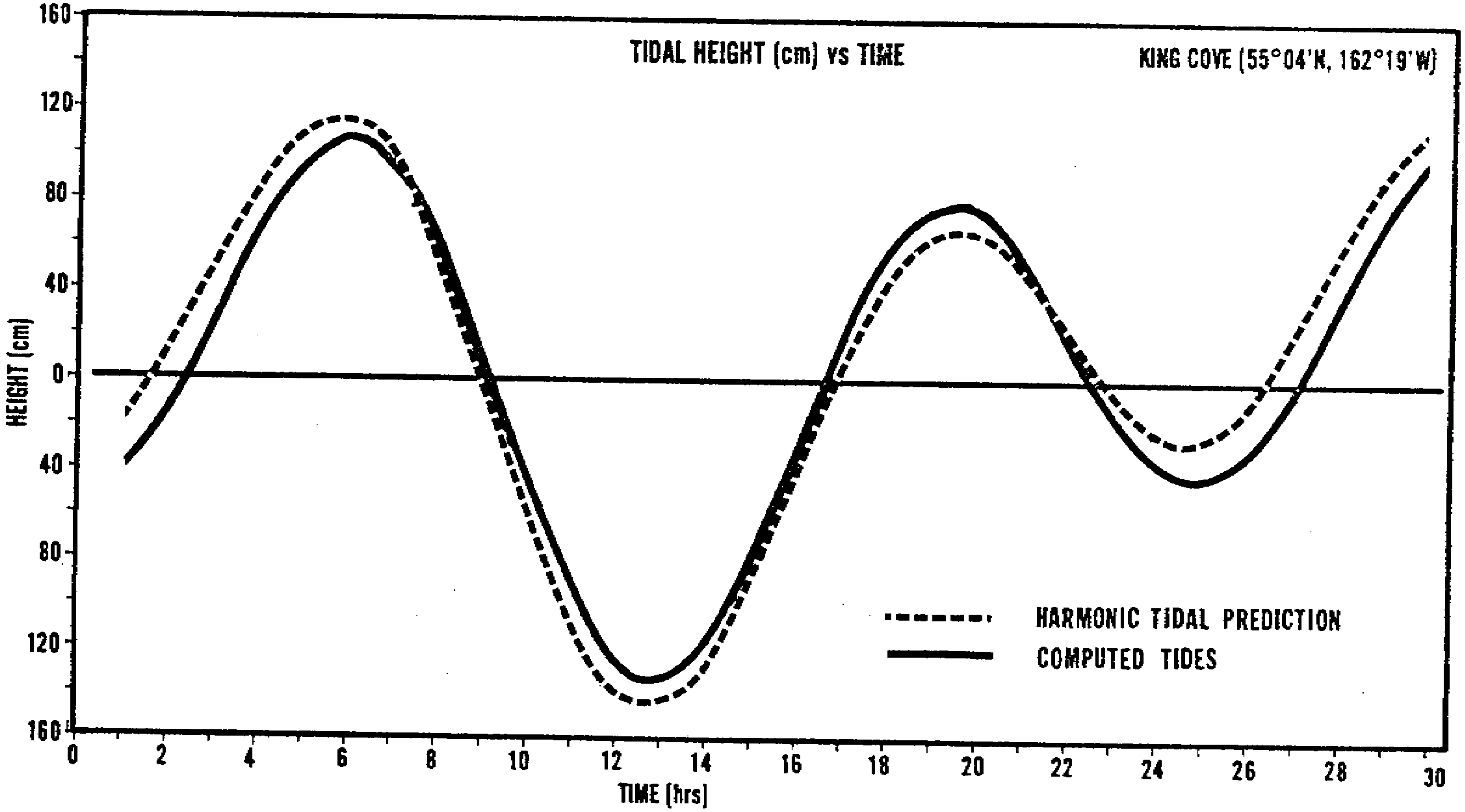
2. Austausch coefficient (A) vs. grid size (km) for t = 1000 s.



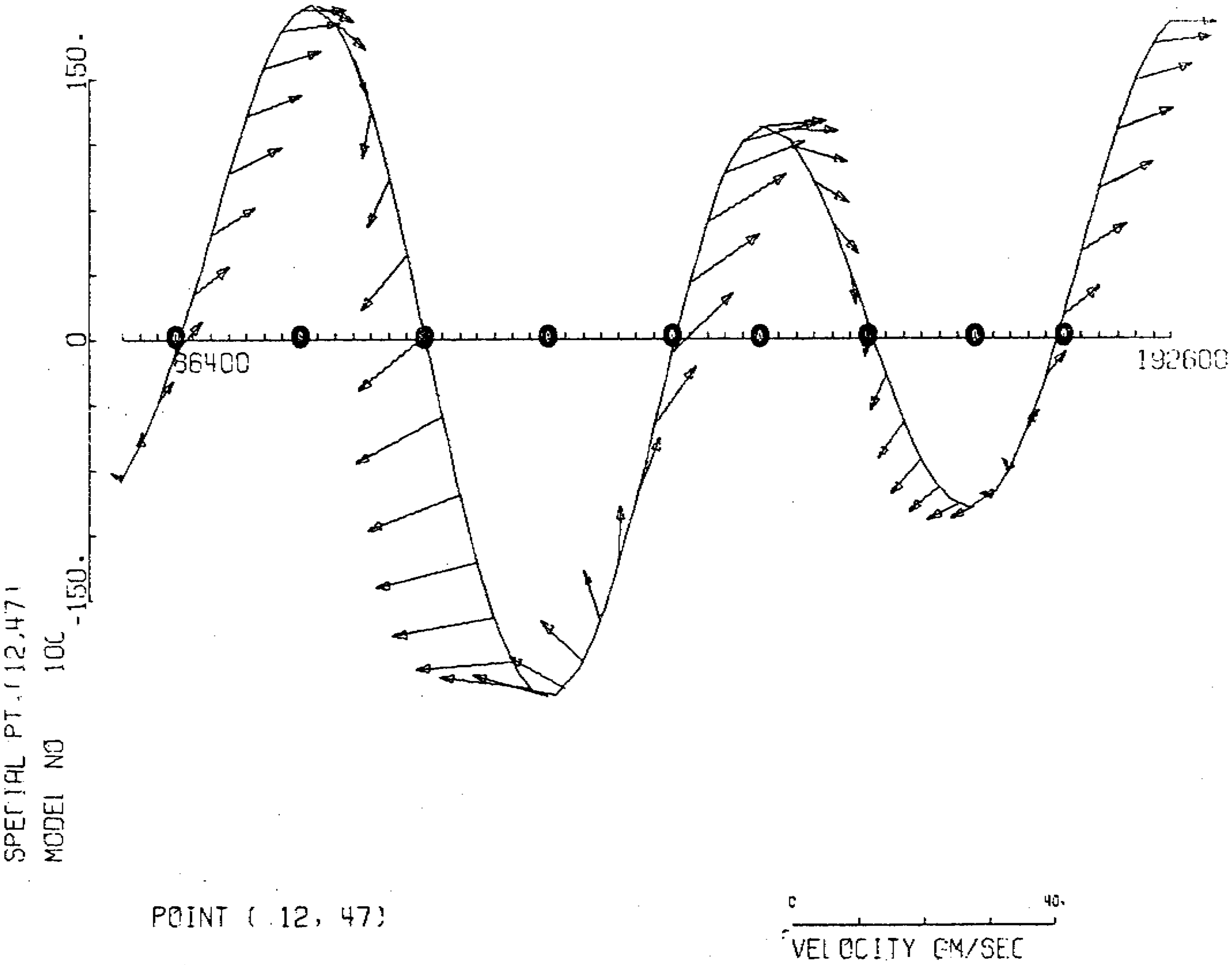
3. Bottom topography (m), Gulf of Alaska, western grid.



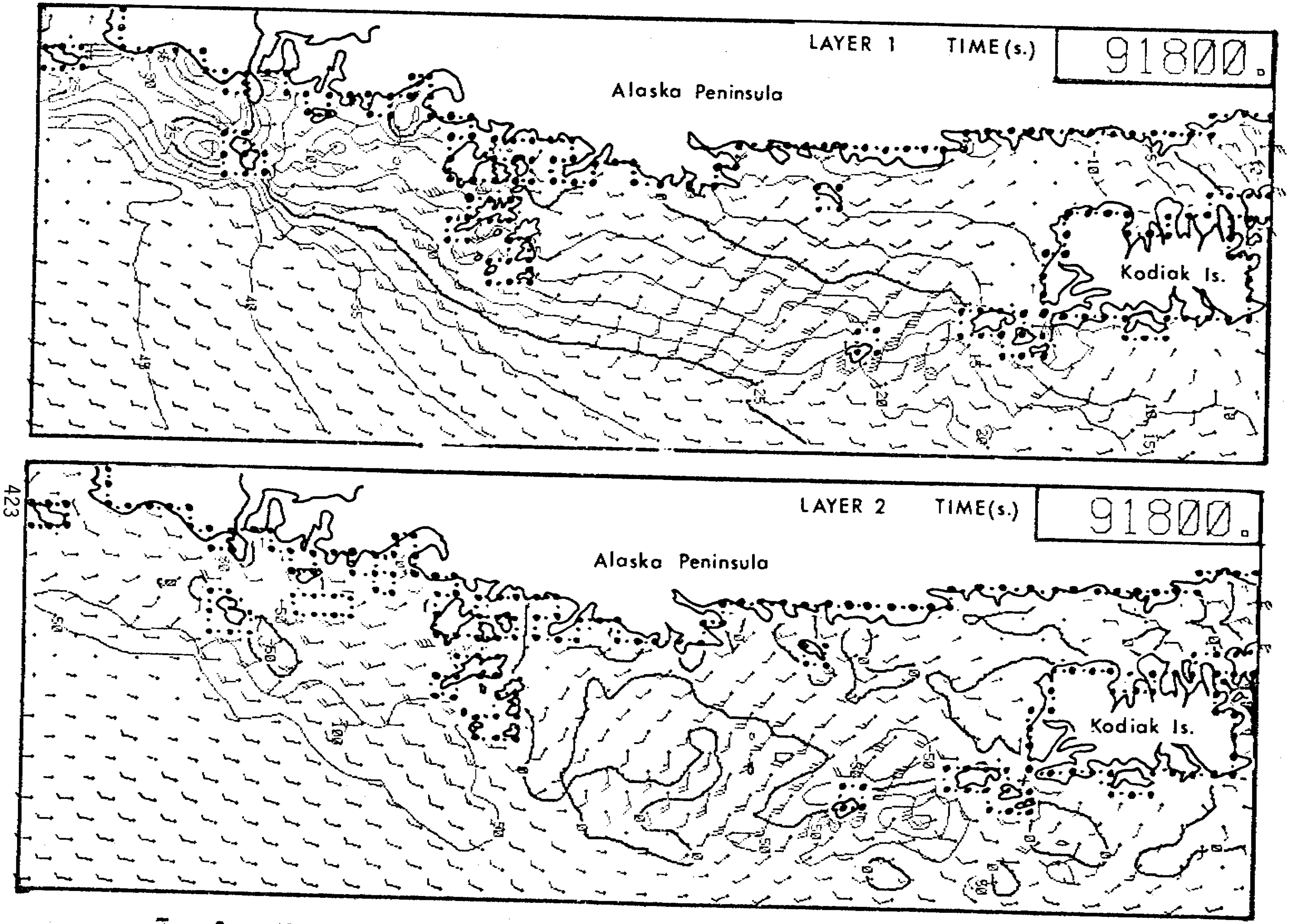
4. Tidal specifications at grid boundaries.



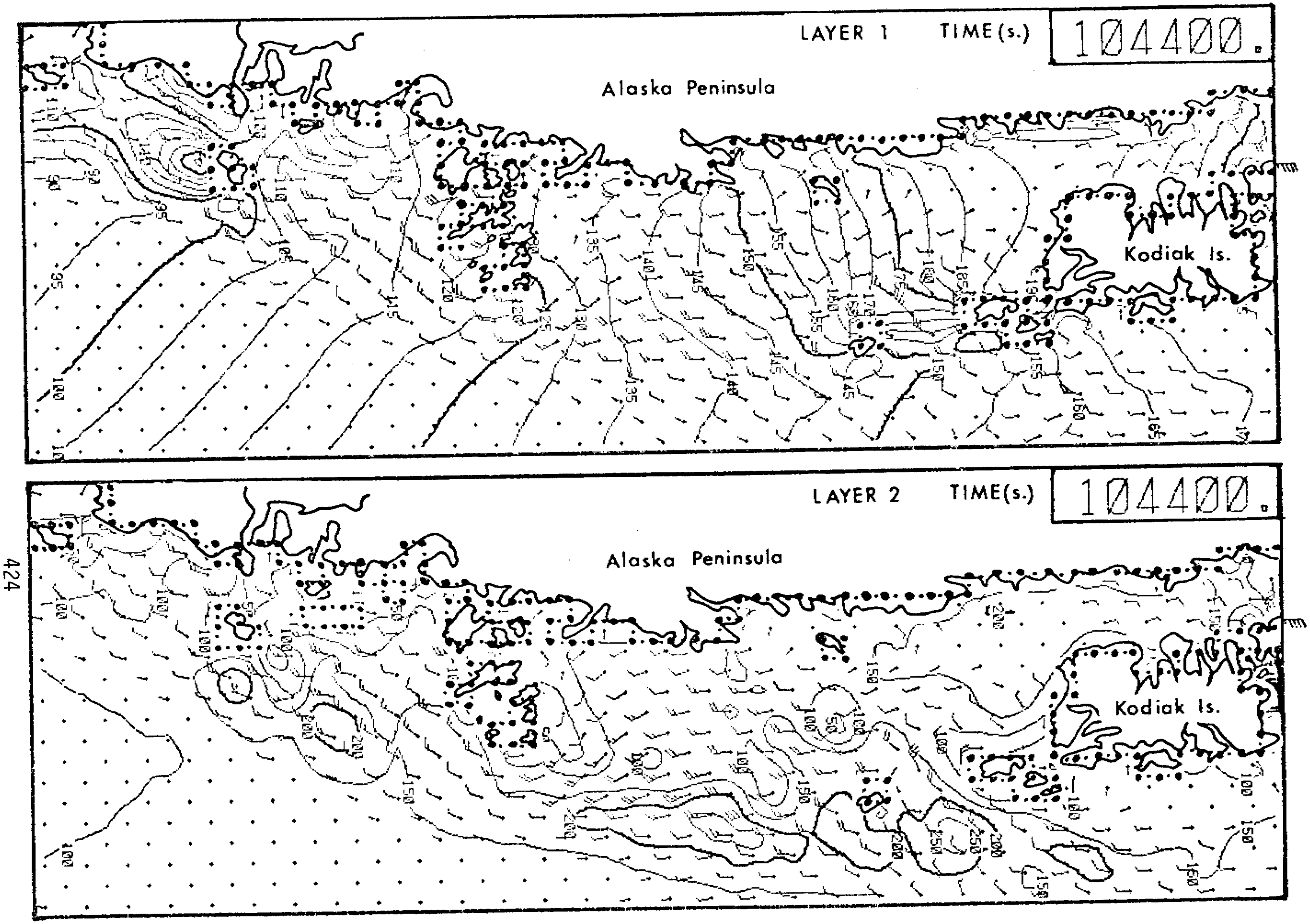
5. Harmonically predicted vs. computed tidal heights (cm) at King Cove (55°04'N, 162°19'N).



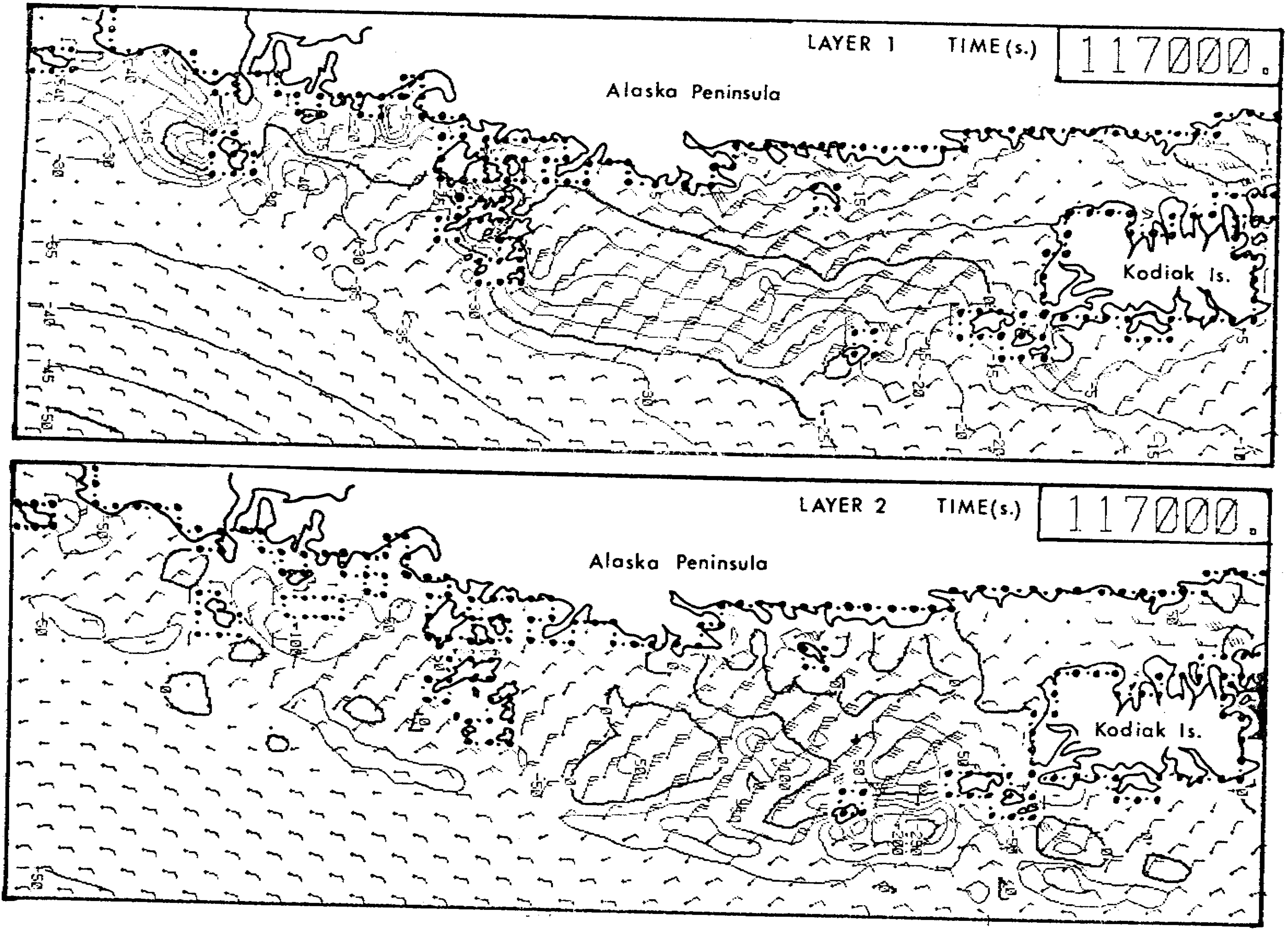
6. TIDAL HEIGHTS AND CURRENTS WITHOUT WINDS
LAYER3. OPTIMIZED H-N MODEL FOR B.L.M. GULF OF ALASKA, WESTERN GRID.



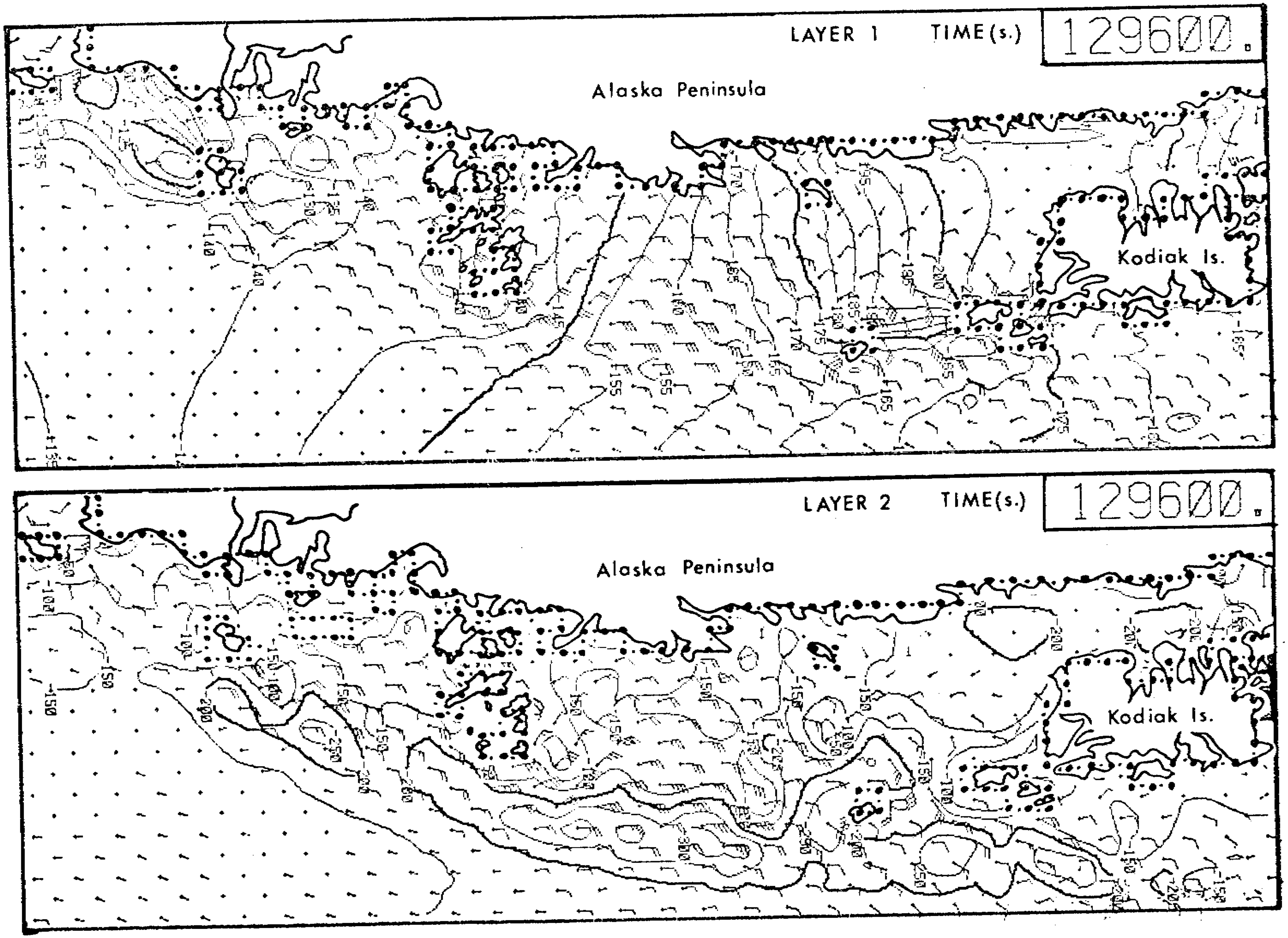
7. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 25 1/2 hours (91800 s).



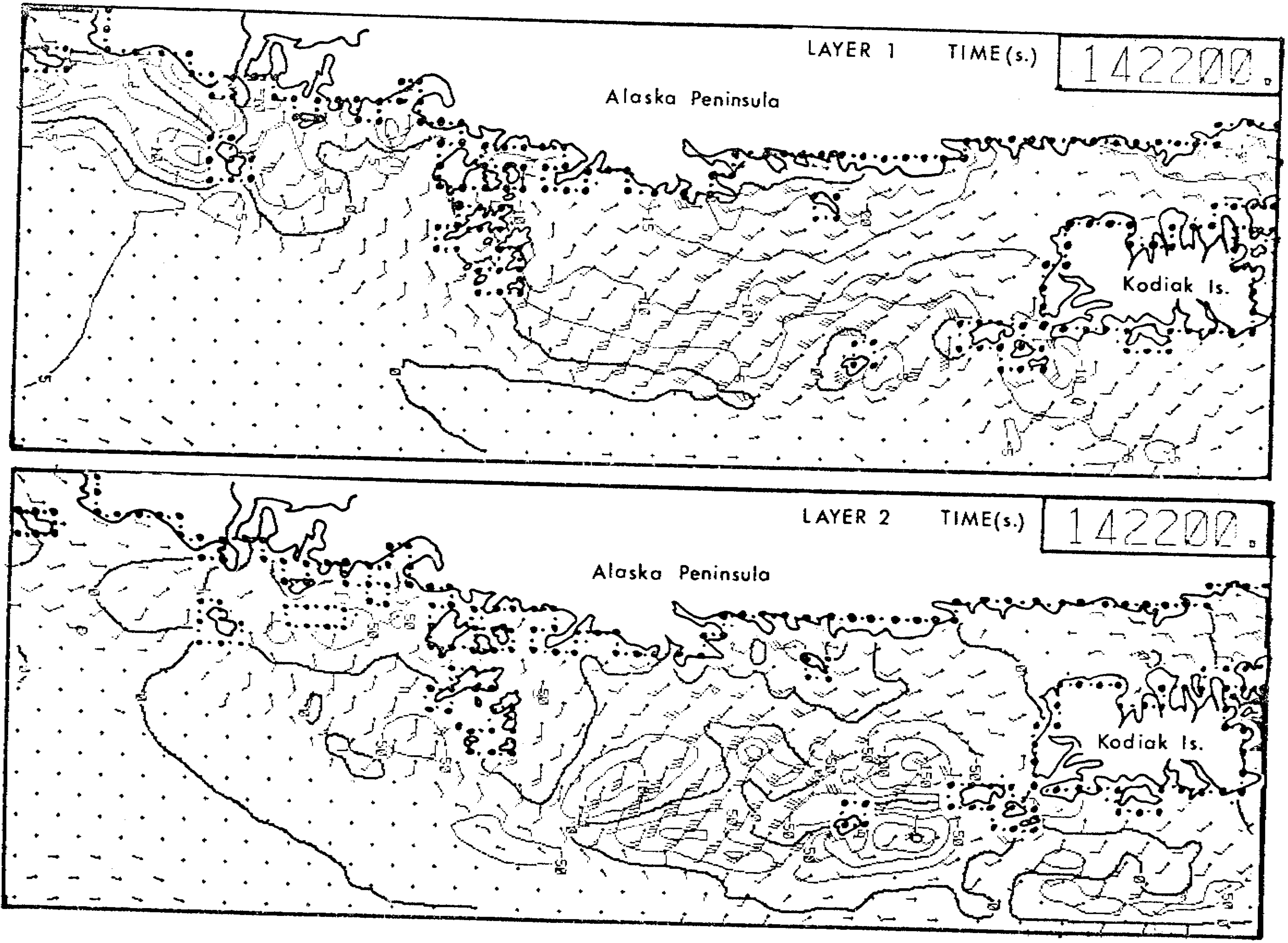
8. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 29 hours (104400 s).



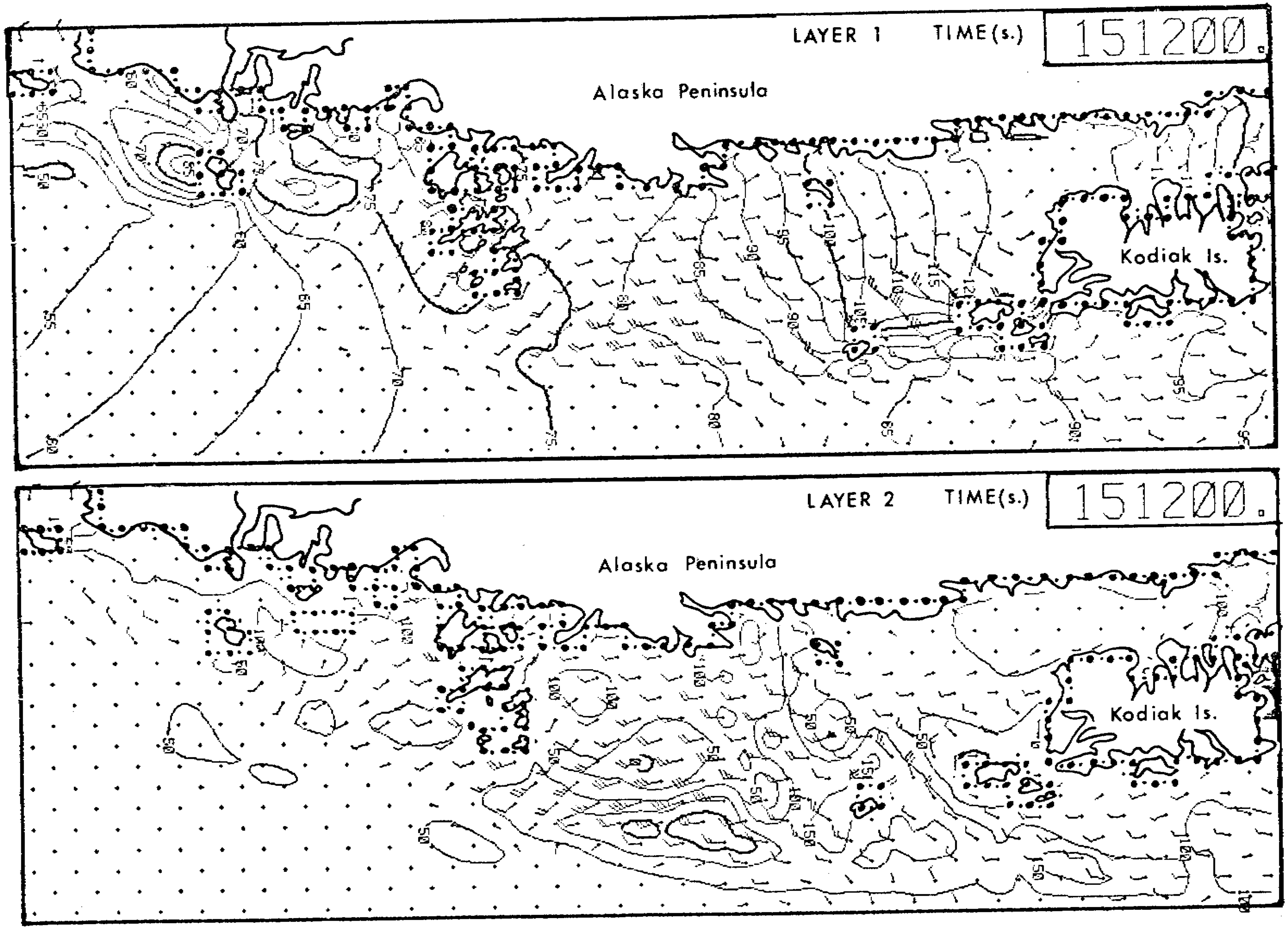
9. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 32 1/2 hours (11700 s).



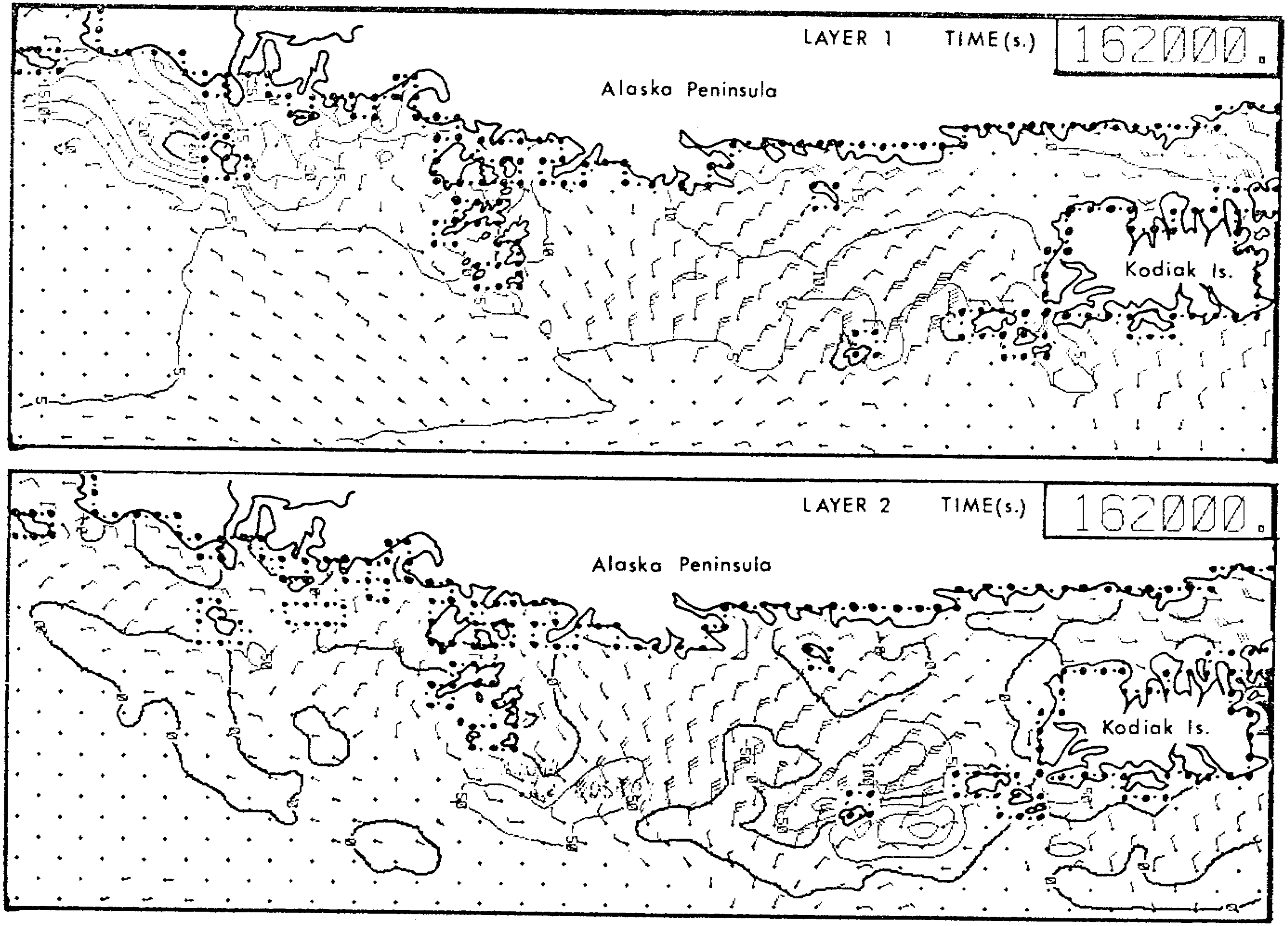
10. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 36 hours (129600 s).



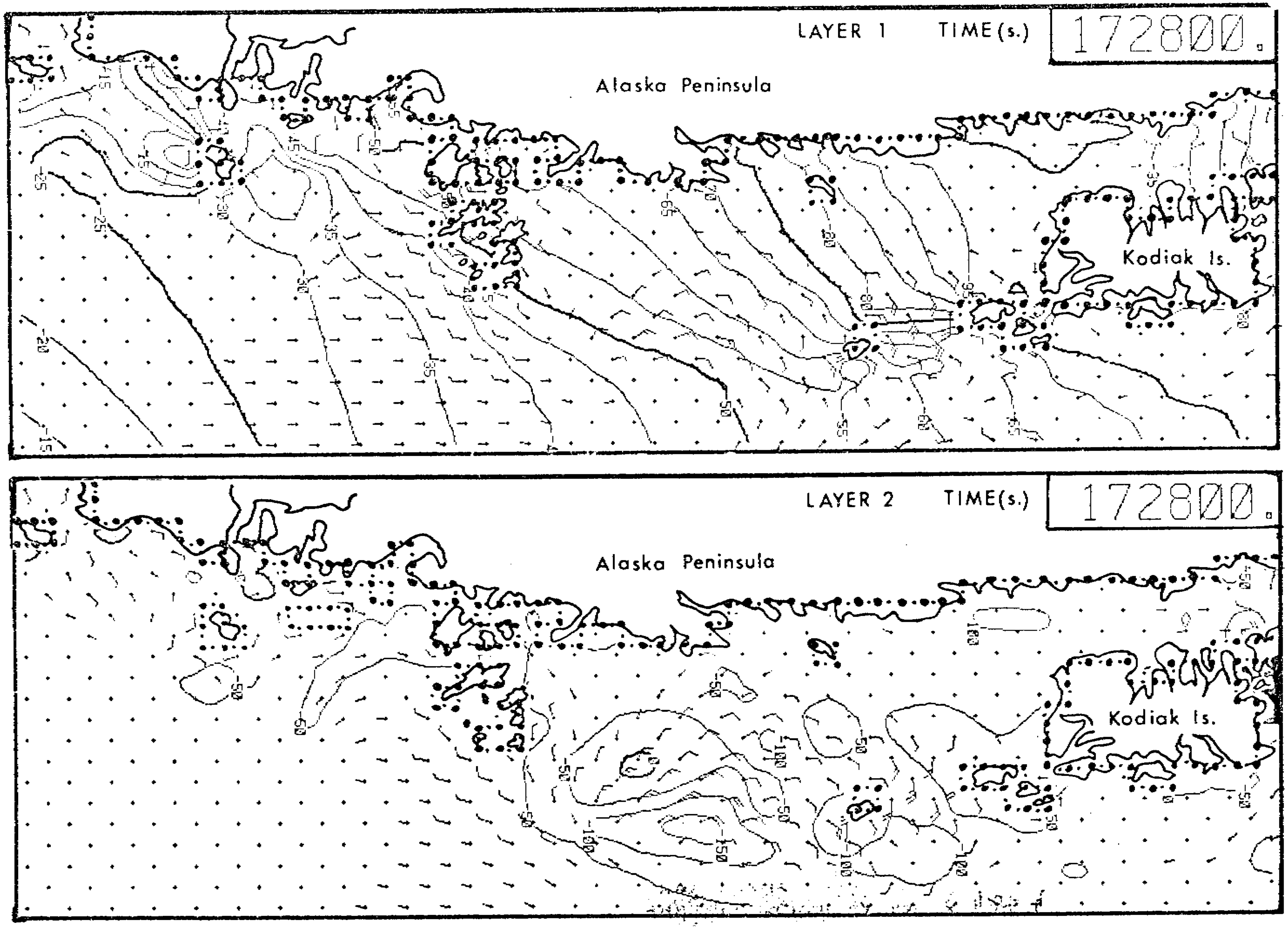
11. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 39 1/2 hours (142200 s).



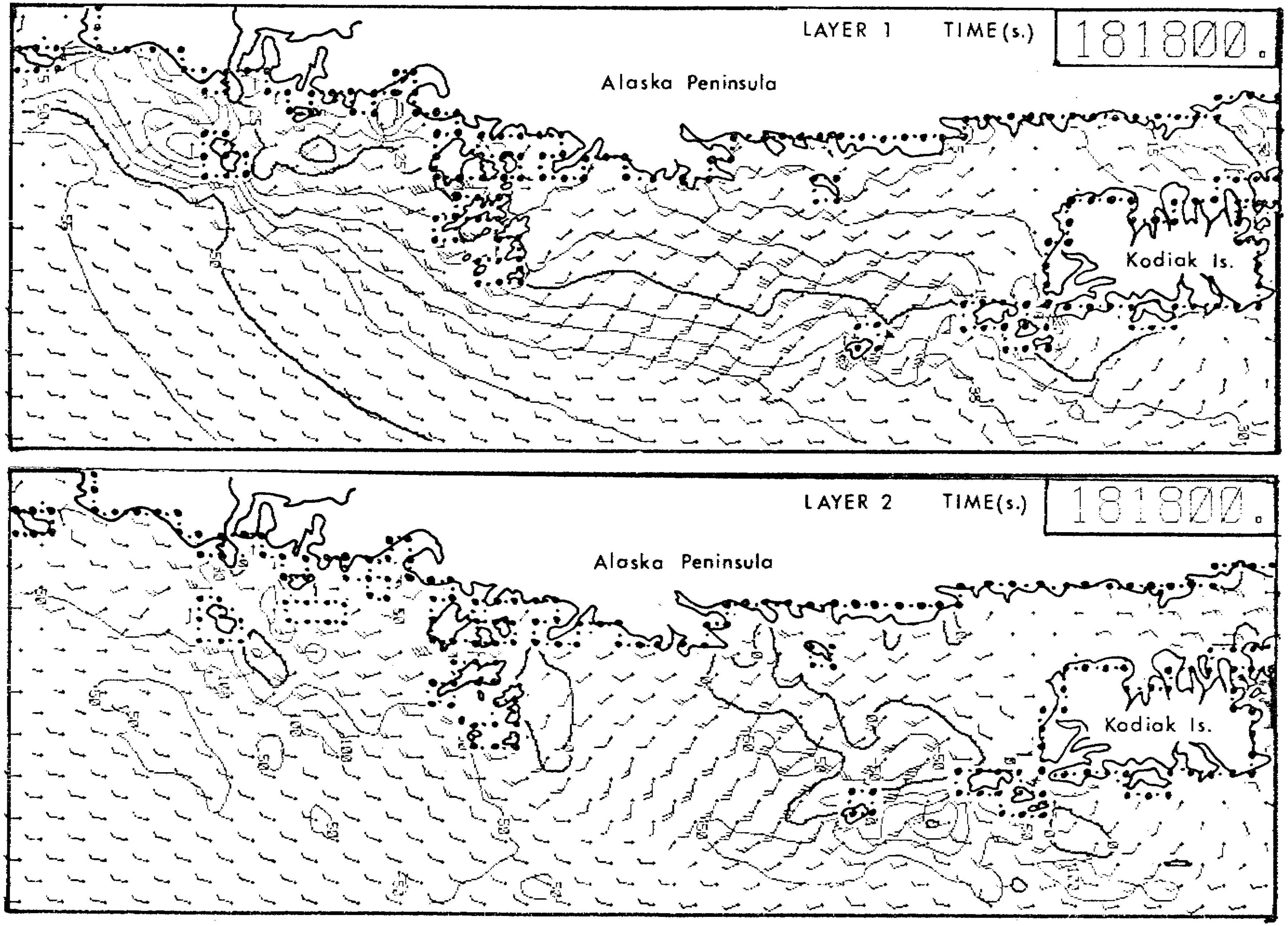
12. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 42 hours (151200 s).



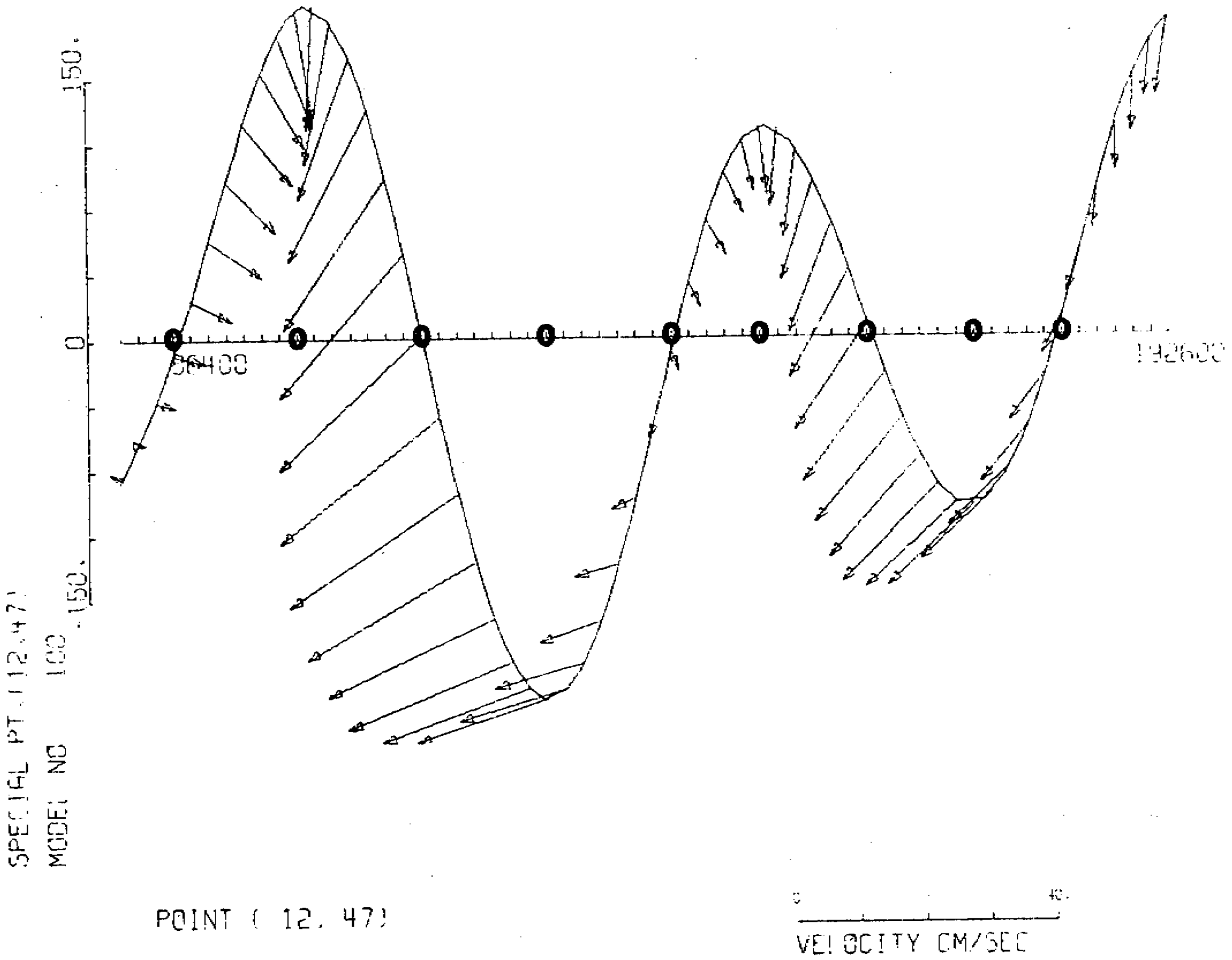
13. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 45 hours (162000 s).



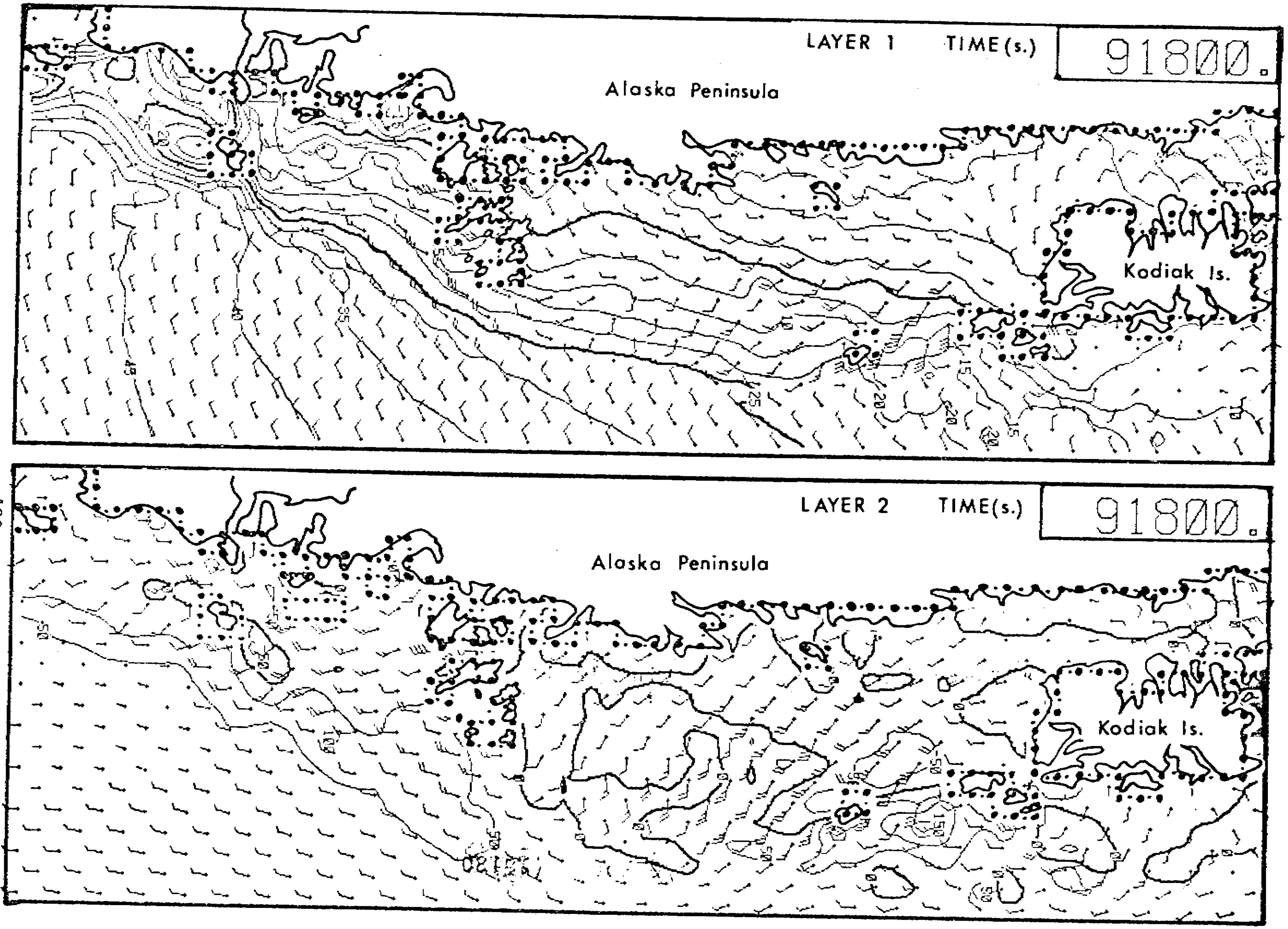
14. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 48 hours (172800 s).



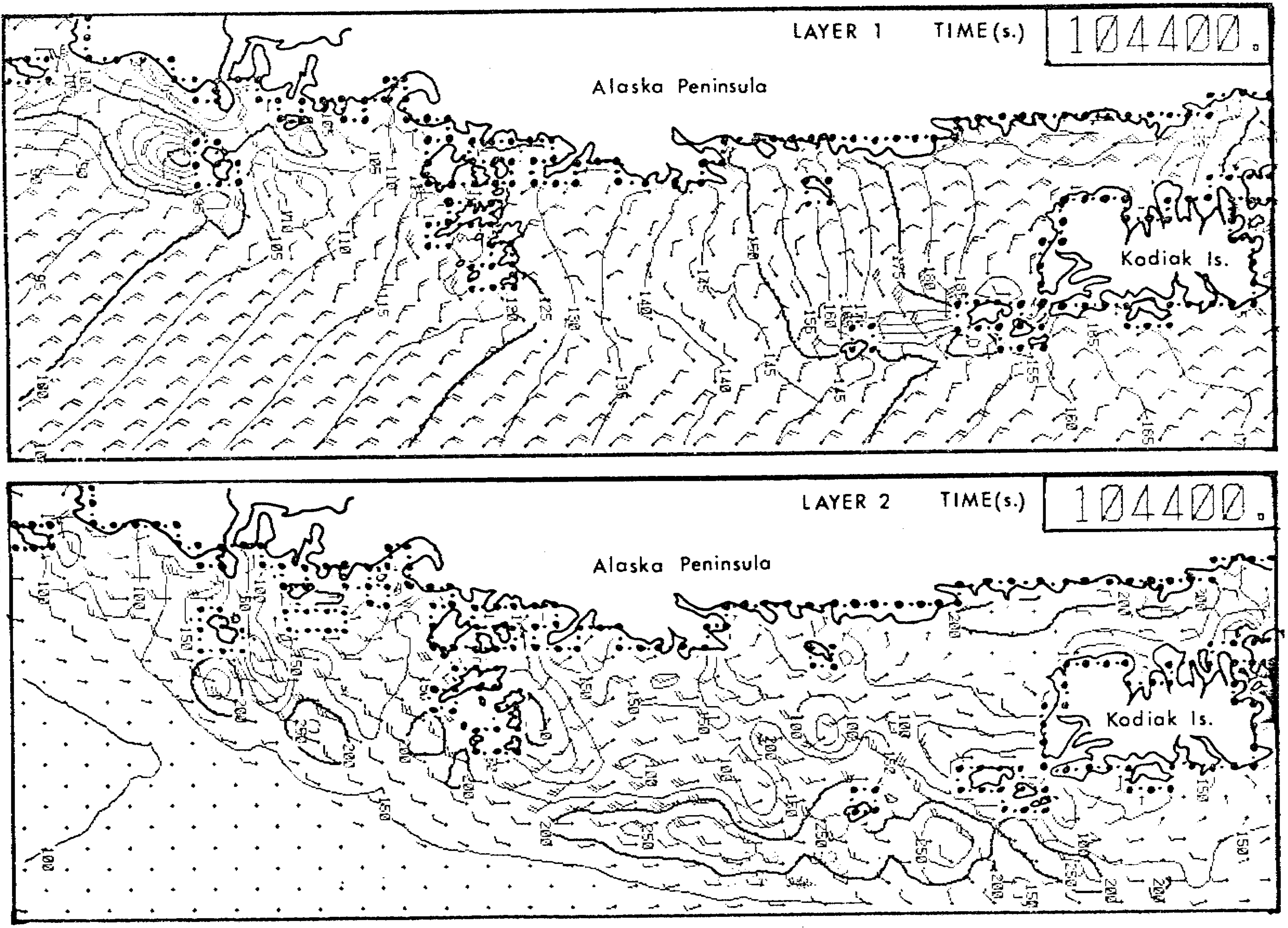
15. Case 1, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 50 1/2 hours (181800 s).



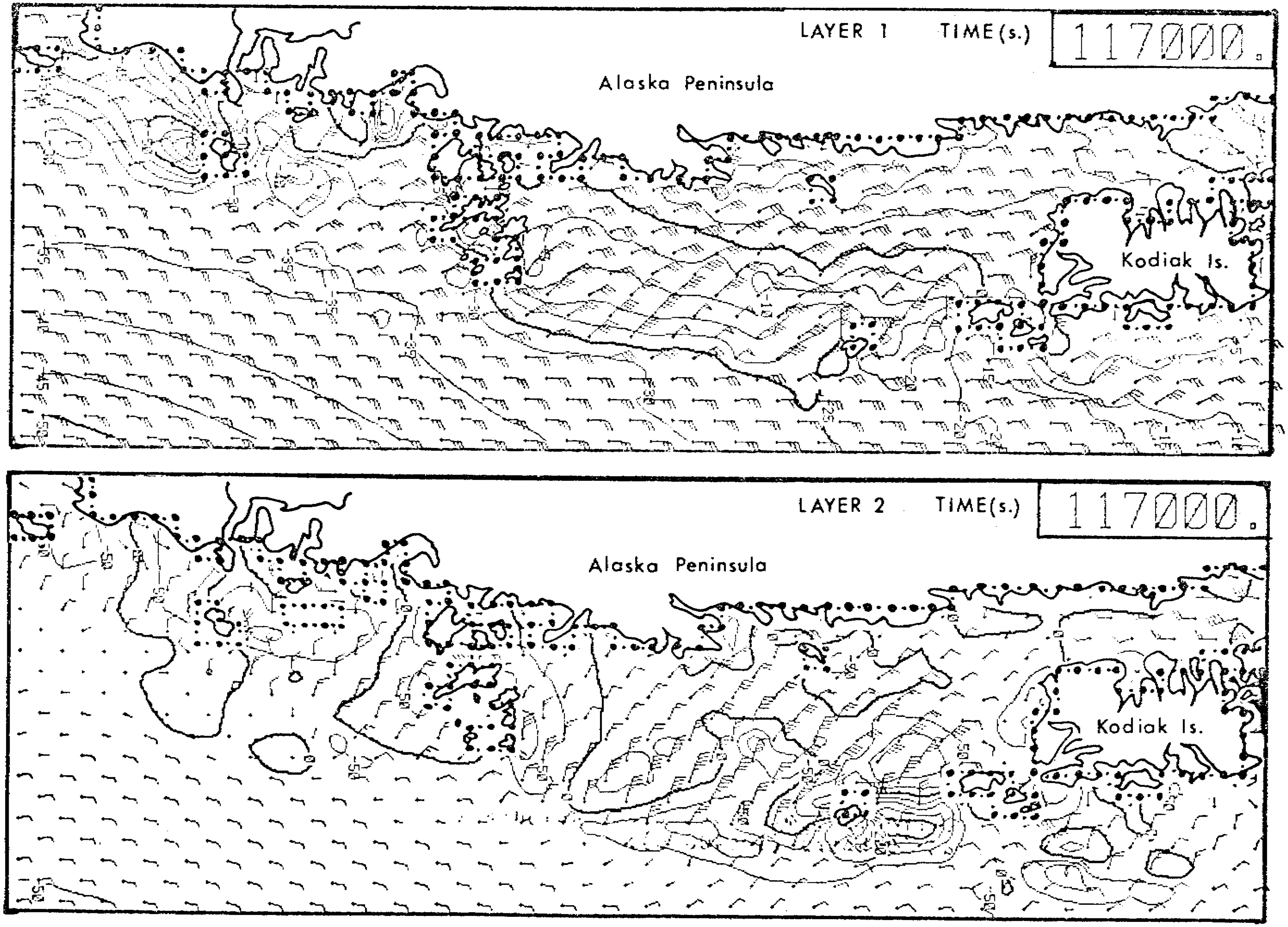
16. TIDAL HEIGHTS AND CURRENTS WITH NW WINDS
LAYER3, OPTIMIZED H-N MODEL FOR B.L.M. GULF OF ALASKA, WESTERN GRID.



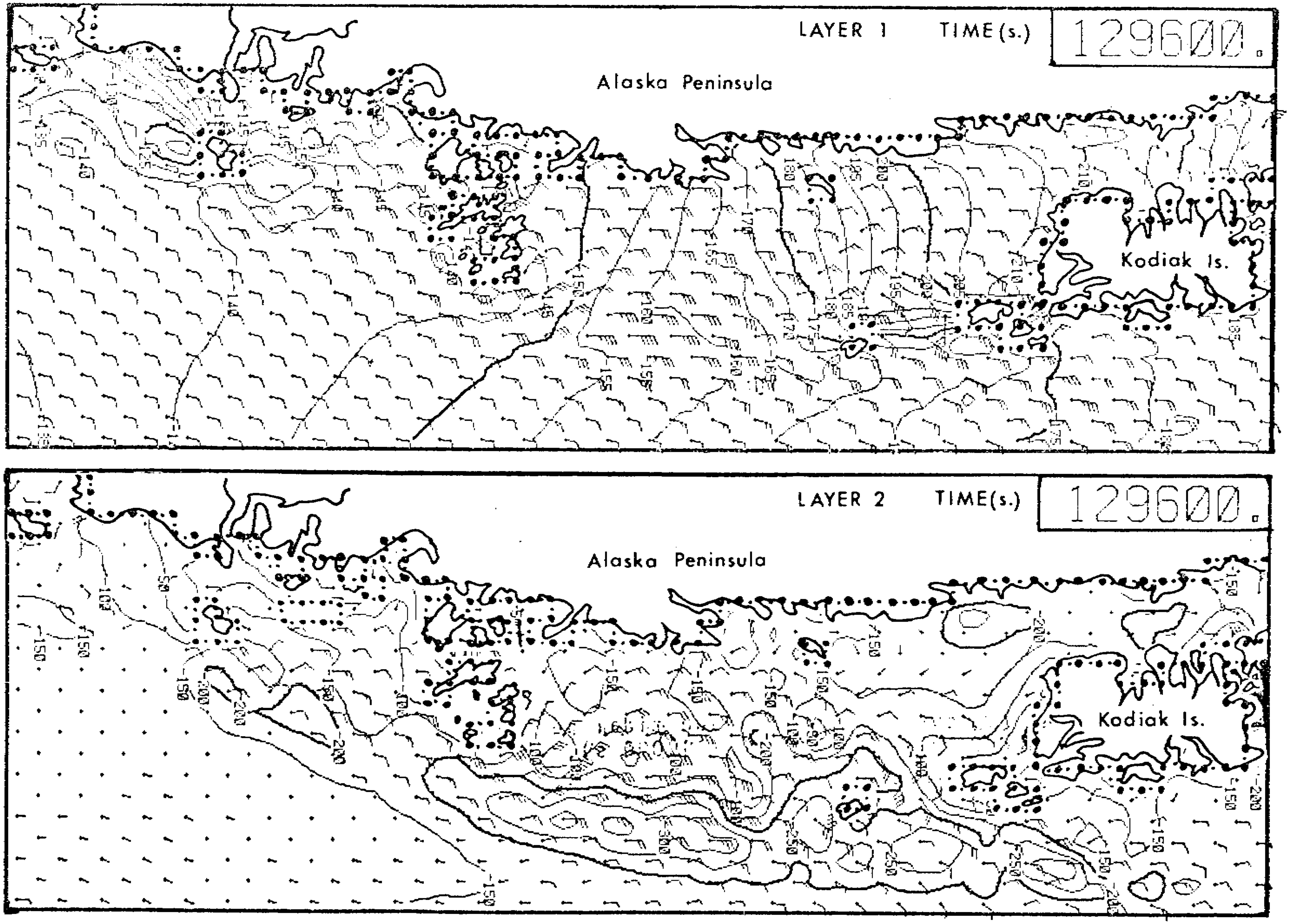
17. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 25 1/2 hours (91800 s).



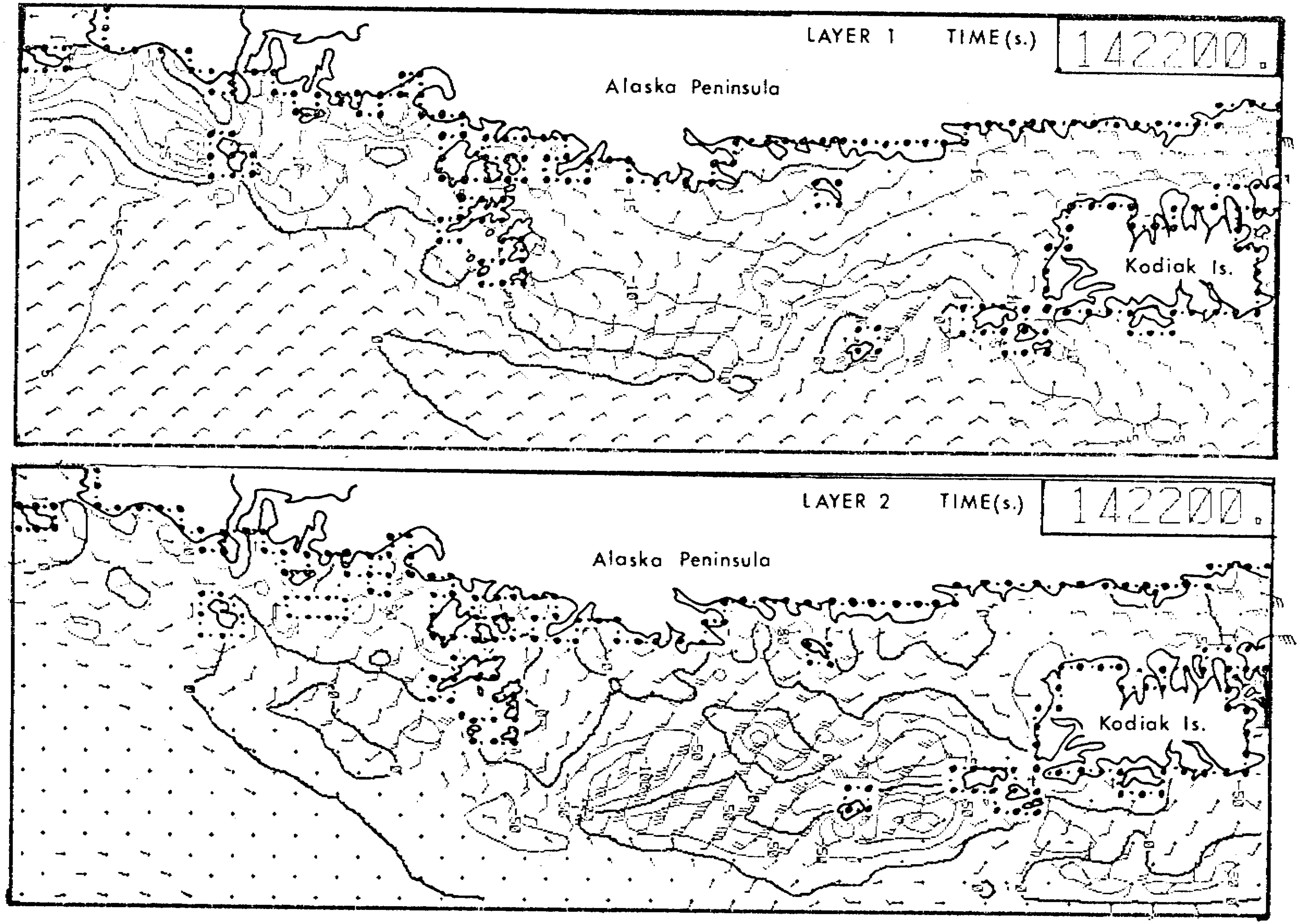
18. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 29 hours (104400 s).



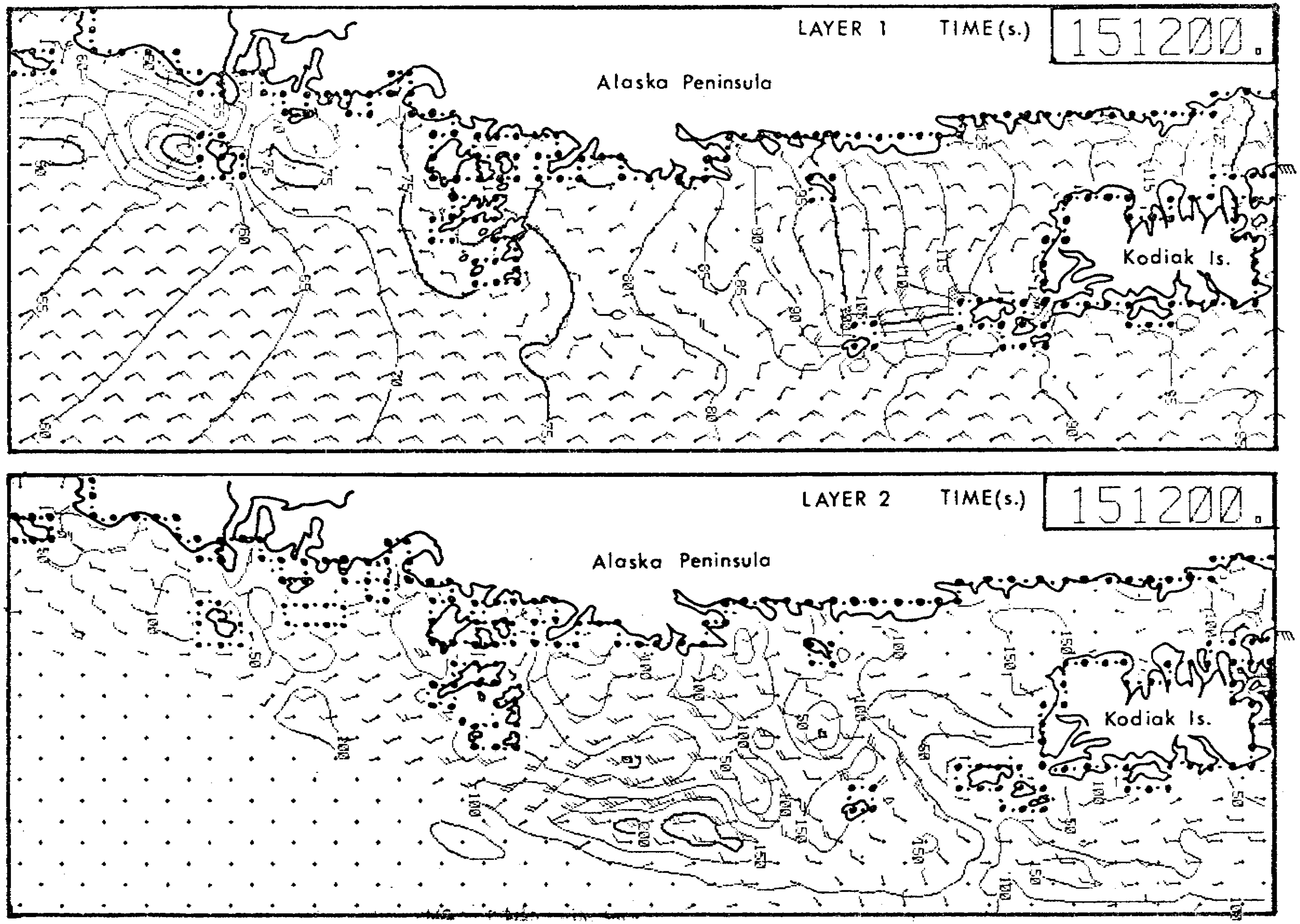
19. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 32 1/2 hours (117000 s).



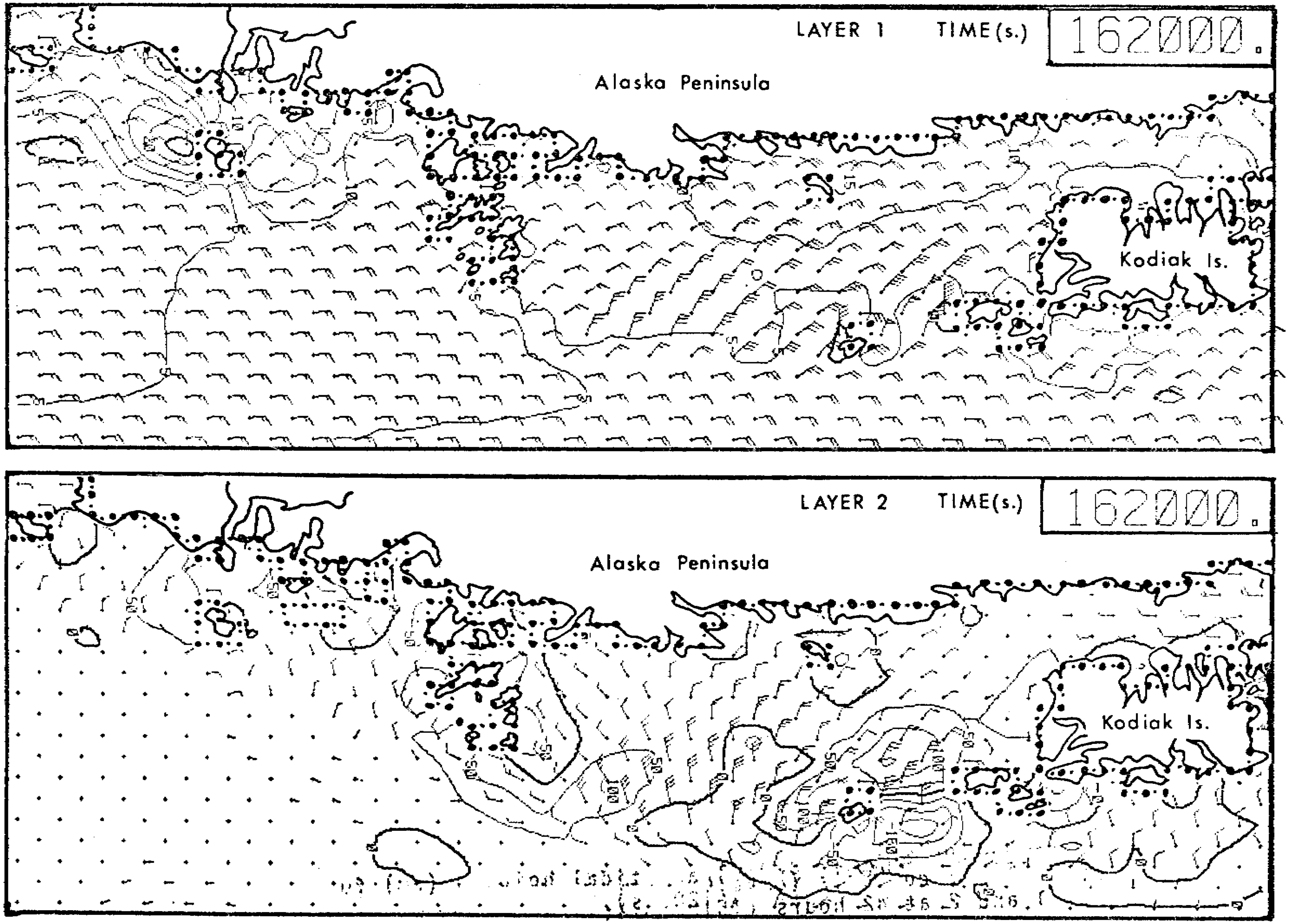
20. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 36 hours (129600 s).



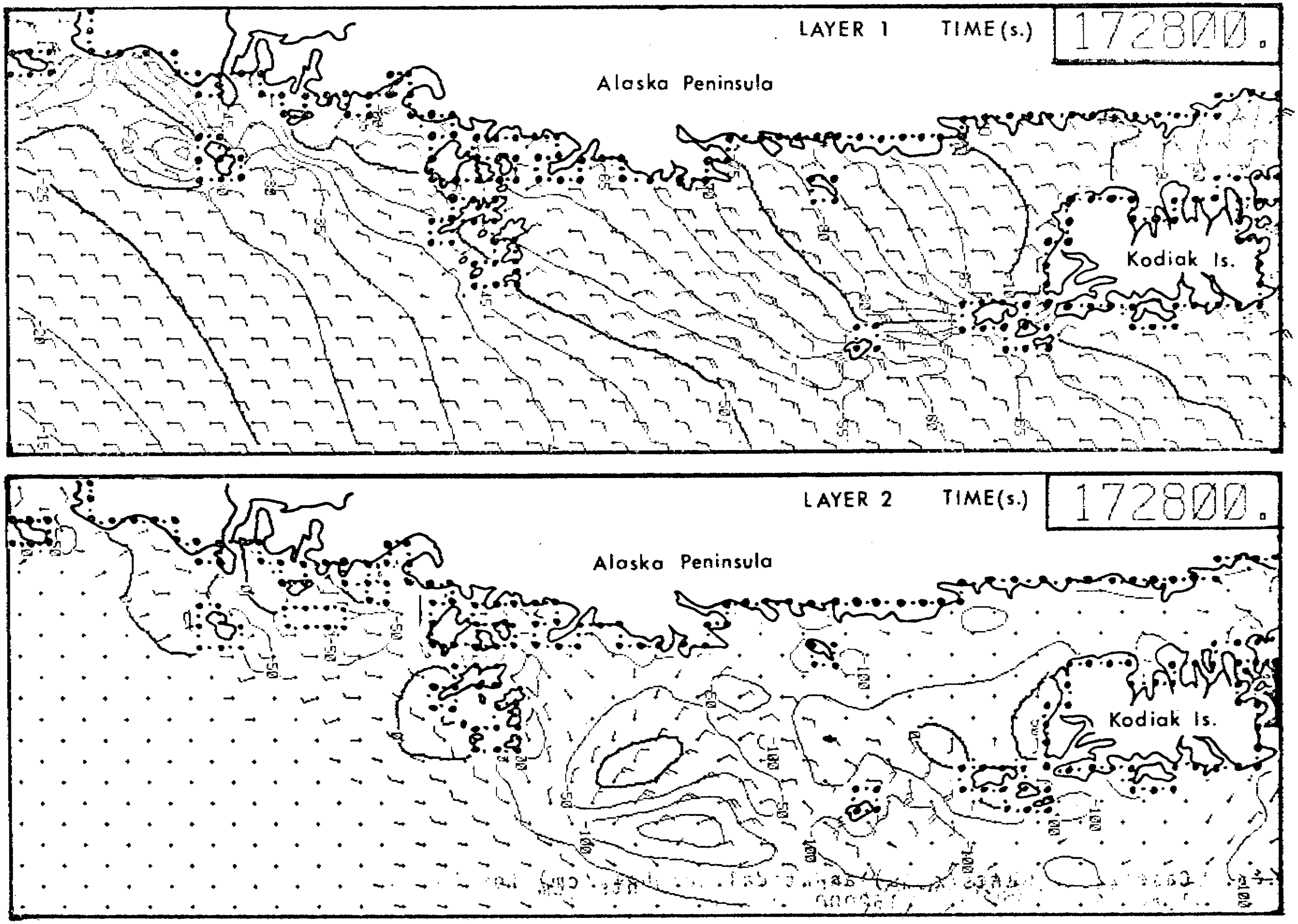
21. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 39 1/2 hours (142200 s).



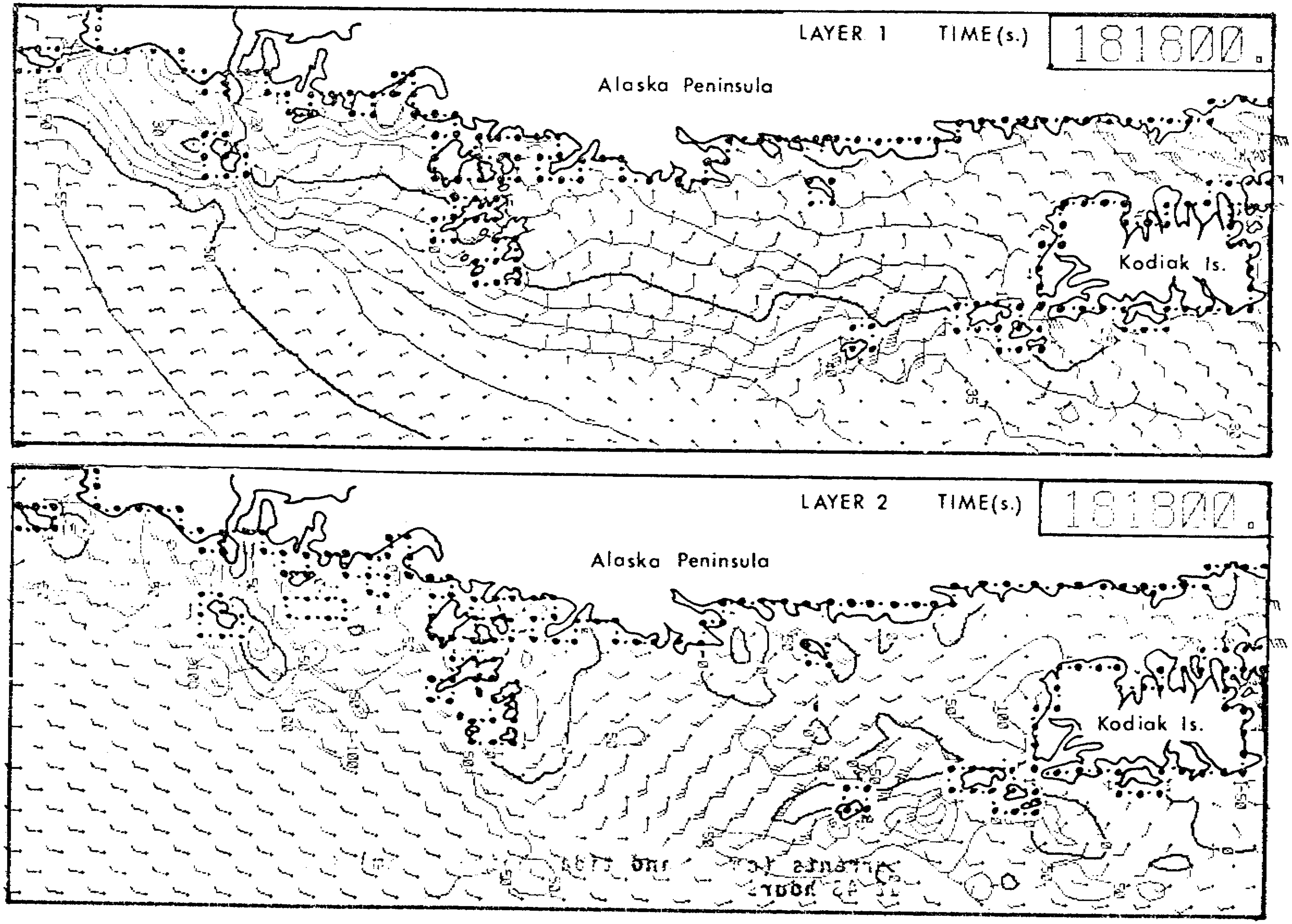
22. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 42 hours (151200 s).



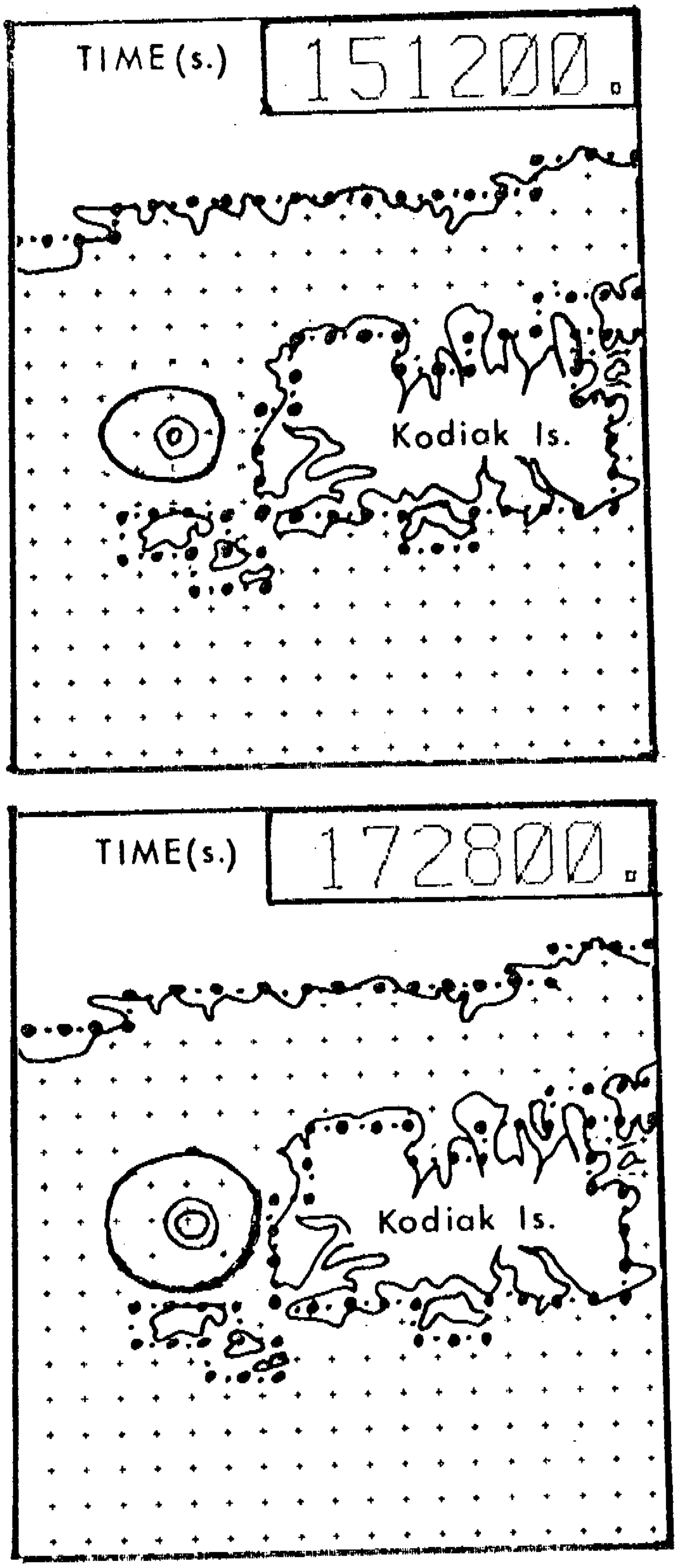
23. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 45 hours (162000 s).



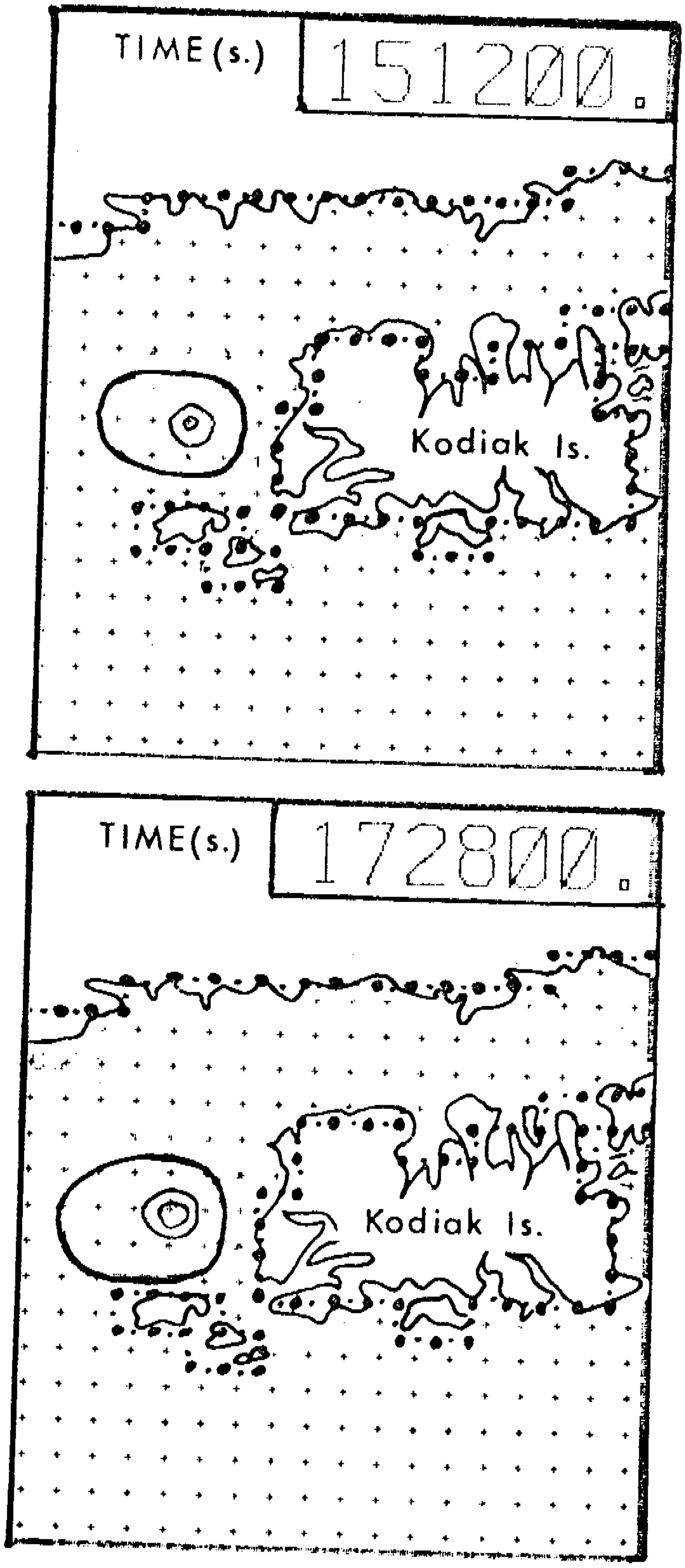
24. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 48 hours (172800 s).



25. Case 2, currents (cm/s) and tidal heights (cm) for layers 1 and 2 at 50 1/2 hours (181800 s).



26. Case 1, pollutant distribution (arbitrary units) at 42 hours (151200 s) and 48 hours (172800 s) after starting continuous source at 29 hours (104400 s).



27. Case 2, pollutant distribution (arbitrary units) at 42 hours (151200 s) and 48 hours (172800 s) after starting continuous source at 29 hours (104400 s).

QUARTERLY REPORT

Contract 03-5-022-56
Task Order Number 19
Quarter Ending -
30 June 1976

MESOSCALE CURRENTS AND WATER MASSES IN THE GULF OF ALASKA

Thomas C. Royer
Associate Professor of Marine Science
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

June 30, 1976

QUARTERLY REPORT

I. Task Objectives

To continue gathering hydrographic data over the continental shelf region of the Gulf of Alaska in the eastern portion (GASSE), western portion (GASSO) and the Kodiak Island region. To continue to monitor currents and sea level at a permanent station location in the Gulf of Alaska.

II. Field Activities

Both grids were occupied using the *R/V Moana Wave* from 19 April to 21 May 1976. A total of 62 stations were occupied on the eastern grid and 48 stations of the western grid with five stations in Prince William Sound. CTD measurements were made at all of these stations. Another current meter mooring with five meters and bottom pressure guage was deployed at station nine (58°41.1'N, 148°19.6'W). An 81 station grid of CTD in the Kodiak Island area was occupied.

III. Results

The receipt of Middleton Island weather data has begun. We now have those data for February 1975 through March 1976. We also have the data for EB-03 weather buoy (57°N, 148°W) for October 1972 through December 1975. Approximately 10 transects of the U. S. Coast Guard section lines in the North Pacific are now on hand.

Analysis of both the hydrographic and current meter data is continuing. A paper entitled "Sea surface temperature observations in the Gulf of Alaska" was presented at an American Meteorological Society Conference on air-sea interactions. The continuation proposal for this project has been written and submitted.

IV. Problems Encountered

The major problems of this quarter are the conversion of our data processing programs to the new computer system and the final processing of the CTD data gathered aboard the *Surveyor* in November 1975. The program conversion should be completed by 30 June. The latter problem involves the station holding ability of the *Surveyor*. On 12 percent of the CTD casts on cruise 814 the wire angle was 350° or greater with 39 percent at 30° or greater. With the CTD system this causes problems when attempts are made to gather water samples for calibration purposes. The wire angle changes resulting in depth changes of the bottle position between the time that the bottle was tripped and the calibration information read from the CTD system. This error could be minimized through the use of a Rosette-type water sampler. This sampler decreases the time between the bottle tripping and reading of the system.

The effect of the drifting ship on the computation of geostrophic currents is now being considered in order to evaluate the upcoming cruise scheduled for September aboard the *Surveyor*.

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: June 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 19 R.U. NUMBER: 289

PRINCIPAL INVESTIGATOR: Dr. T. C. Royer

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]		
	From	To	Batch 1	2	3
Acona #193	7/1/74	7/9/74	submitted	None	None
Acona #200	10/8/74	10/14/74	submitted	None	None
Acona #202	11/18/74	11/20/74	submitted	None	None
Acona #205	2/12/75	2/14/75	submitted	None	None
Acona #207	3/21/75	3/27/75	submitted	None	None
Acona #212	6/3/75	6/13/75	7/20/76		
Oceangrapher #805	2/1/75	2/13/75	7/20/76	None	None
Silas Bent #811	8/31/75	9/28/75	Submitted		
Discoverer #812	10/3/75	10/16/75	(a)		
Surveyor #814	10/28/75	11/17/75	submitted		
Discoverer #816	11/23/75	12/2/75	(b)	None	None
Station 60	6/2/74	9/10/74	None	7/30/76	None
Station 64	4/28/75	5/20/75	None	7/30/76	None
Station 9	Current meter, not available in field.				
Station 9	Pressure gauge, not available in field.				
Moana Wave MW 001	2/21/76	3/5/76	submitted		
Moana Wave MW 003/004	4/20/76	5/21/76	8/31/76		

Note:

[1] Data Management Plan and Data Formats have been approved and are considered contractual.

(a) Parent tapes were coded in PODAS format, tapes were submitted to F. Cava as requested.

(b) Data useless due to malfunction of shipboard data logger.

QUARTERLY REPORT

Contract 03-5-022-56
Task Order Number 14
Quarter Ending -
30 June 1976

HISTORICAL AND STATISTICAL DATA ANALYSIS AND SHIP OF OPPORTUNITY PROGRAM

Dr. Robin D. Muench
Associate Professor of Marine Science
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

June 30, 1976

QUARTERLY REPORT

I. Task Objectives

To obtain temperature, salinity, dissolved oxygen, nutrient and meteorological data on an opportunity (not-to-interfere) basis from oceanographic vessels operating in the southeastern Bering Sea region, to analyze this data and to incorporate it into the ongoing analysis of historical data.

II. Field Activities

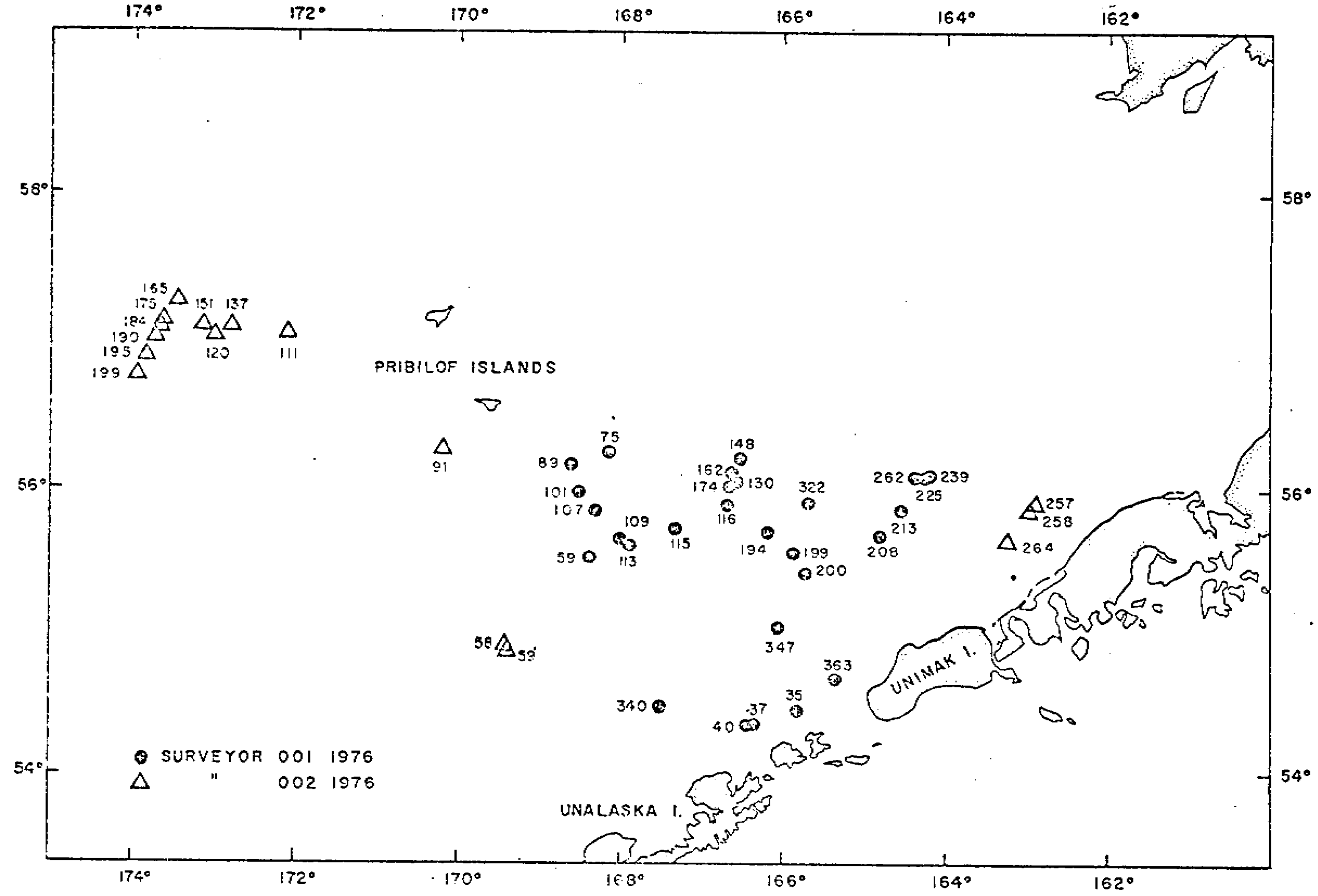
A six-week cruise was carried out from late March-April aboard the *R/V Surveyor*. Locations of oceanographic stations were controlled in large part by weather and position of the ice edge; most stations were along the ice edge or along the shelf break (see Figure). Temperature and salinity were measured at all stations, while dissolved oxygen and nutrient concentrations were measured at selected stations. Routine meteorological observations were made at all stations. Satellite photos obtained during the cruise documented the position of the ice edge, which was unusually far south for the time of year.

Oceanographic observations during this cruise were hampered by malfunctions of the vessel's running gear; the cruise was prematurely terminated by loss of the main propulsion system.

III. Results

Analysis of historical data from southeastern Bering Sea region east of 165°W has been completed and the resulting information compiled into an M.S. thesis now in the final stages of preparation. The zone of apparant upwelling in central Bristol Bay has been further documented using the historical data, and a theory explaining this upwelling in terms of Ekman suction is elaborated upon. The temperature and salinity structure of the waters is discussed, using data primarily from summer 1969-1972; only during these times was spatial coverage sufficient to define the fields. Where possible, however, scattered data from other years have been used to support these distributions. The data show a two-layered system wherein cold dense water formed during winter convection underlies warmer, lower salinity water, in agreement with previous work in the region. Some details in the distribution and discussed, and it is noted that the results support the concept of a cyclonic circulation along isobaths in inner Bristol Bay.

Temperature and salinity data from stations within selected sub-areas just inside the shelf edge are being analyzed for long-term (from 1934 to 1971) variations in heat and salt content. Computations are being carried out for the water column both above and below the summer thermocline. Preliminary analyses of the results show large (2-3°C) year-to-year variations. These variations, in conjunction with spatial variations, poor station coverage, and numerous years for which no data are available, complicate attempts to detect long-term variations. Ongoing work addresses these problems and also those of large scale horizontal distribution of temperature and salinity for certain years from which adequate data are available.



Stations occupied during legs one and two of the March-April 1976 cruise of R/V *Surveyor*.

The dissolved oxygen and nutrient data from the November 1975 cruise of the *R/V Miller Freeman* were received late in this study period. Preliminary analysis of these data suggest that vertical convection was occurring to the bottom. Many of the stations were occupied in and adjacent to regions of actively forming ice, and it is hoped that these data will be useful, in conjunction with satellite photos, for study of ice formation in the Bering Sea. Unfortunately, due to malfunctioning of the shipboard data acquisition equipment, the vertical temperature and salinity values were unreliable. Only the surface and bottom values of temperature and salinity, obtained from discrete bottle samples, were judged to be of sufficient validity for inclusion in the analysis.

Satellite imagery has been obtained on a nearly daily basis from the Bering Sea region during the study period. This has made it possible to fully document ice coverage during what has been an unusually severe ice year. During April the ice edge was some 60 n mi south of the Pribilofs, and in early June there was still a considerable quantity of ice remaining south of Saint Lawrence Island. It will be of interest to test whether this severe ice cover has a detectable effect upon the water column as observed both during April and later during the coming summer.

IV. Problems Encountered

No reliable vertical temperature or salinity profiles were obtained on the November 1975 *Miller Freeman* cruise due to malfunctioning of the data logger. We are still attempting to retrieve some of this data. Data acquisition on the March-April *Surveyor* cruise was severely curtailed by mechanical problems which eventually terminated the cruise several days early.

V. Estimate of Funds Expended

See attached sheet.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: June 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 14 R.U. NUMBER: 307

PRINCIPAL INVESTIGATOR: Dr. R. D. Muench

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 1			
Acona #197	7/20/75	7/30/75	7/20/76			
Discoverer Leg I & II #808	5/15/75	6/19/75	7/20/76			
Discoverer Leg I #810	8/9/75	8/28/75	(a)			
Miller Freeman #815	11/19/75	11/26/75	submitted			
Surveyor 001/002	3/76	4/76	8/31/76			

NOTE: [1] Data Management Plan and Data Format have been approved and are considered contractual.

(a) Parent tapes were coded in PODAS format, tapes were submitted to F. Cava as requested.

Interagency Agreement: R5-0813, R6-0813
Research Unit: 335
Reporting Period: April-June, 1976
Number of Pages: 2+6 figs.

TRANSPORT OF POLLUTANTS IN THE VICINITY OF PRUDHOE BAY, ALASKA

Richard J. Callaway
Chester Koblinsky

Marine and Freshwater Ecology Branch
Corvallis Environmental Research Laboratory
Environmental Protection Agency
200 S.W. 35th Street
Corvallis, Oregon 97330

July 1, 1976

I. Task Objectives

Determine flushing rates, retention times, and potential pollutant transport in the vicinity of Prudhoe Bay, Alaska. A numerical model, based on work by Hansen and Laevastu, is employed for determination of circulation features.

II. Laboratory Activities

A. Preparation for Field Studies

Because of space committments on board the GLACIER, this season's field verification phase is to be conducted by others. Mr. Hufford, of the USCG Oceanographic Research Unit, was asked to install and retrieve our current meters. Meters, transducers and mooring gear were assembled and tested in Corvallis and shipped to Long Beach for loading on the GLACIER.

B. Personnel

Mr .Callaway visited with Mr. Hufford in Groton, Connecticut, while on a trip to Boston. Field installation procedure was reviewed.

C. Methods

Figure 1 shows the installation scheme to be used to moor two strings of (two each) Aanderaa current Meters.

D. Sample Localities

The instruments will be placed in about 10 fathoms (shallowest depth the GLACIER normally operates in) at the locations shown in figure 4.

E. Data Collected or Analyzed

NA

III. Results

This section discusses modifications made in model schematization and subsidiary work preparatory to final model production runs.

A. Bottom Topography Analysis

Because of the shallow depths in Beaufort coastal waters, bottom topography and friction play a significant role in determining current velocity. It was felt that additional emphasis in the effects of topography was required; figure 2 shows the analysis flow chart used in two schematizations to filter and assess the magnitude of different wave bands as they relate to the numerical integration scheme employed in the HN model.

B. Schematization

Various methods were employed to examine the topography of the area. Figure 3, for instance, shows a perspective diagram of the large scale grid--Oliktok Point to Challenge Entrance (figure 4). The grid employed in the annual report was refined; figure 4 shows the lateral extent of the new grid; bottom topography was also redigitized. Several offshore islands have been added and more realistic detail included in the delta regions. Gross results presented in the annual report should remain unchanged, however.

Figure 5 shows the new grid for Prudhoe Bay. In order to remove boundary effects near the interior area of interest, the offshore and westward boundaries were extended from those shown in the annual report. The extension of the ARCO wharf is also a new feature on the grid schematization.

Figure 6 shows the Simpson Lagoon schematization; this is unchanged from that shown in the annual report.

IV. Preliminary Interpretation of Results

This quarter was used primarily to arrive at a decision as to the suitability of our schematizations and a reexamination of the data available to us. Final computer runs will be based on the data now in hand.

V. Problems Encountered

No insurmountable problems were encountered aside from a decided disappointment in not being allotted space on the GLACIER for installation of instruments. Whether this creates problems for the future can only be determined after the field season.

VI. Estimate of Funds Expended

$800--Computer

$200--Shipping Instruments

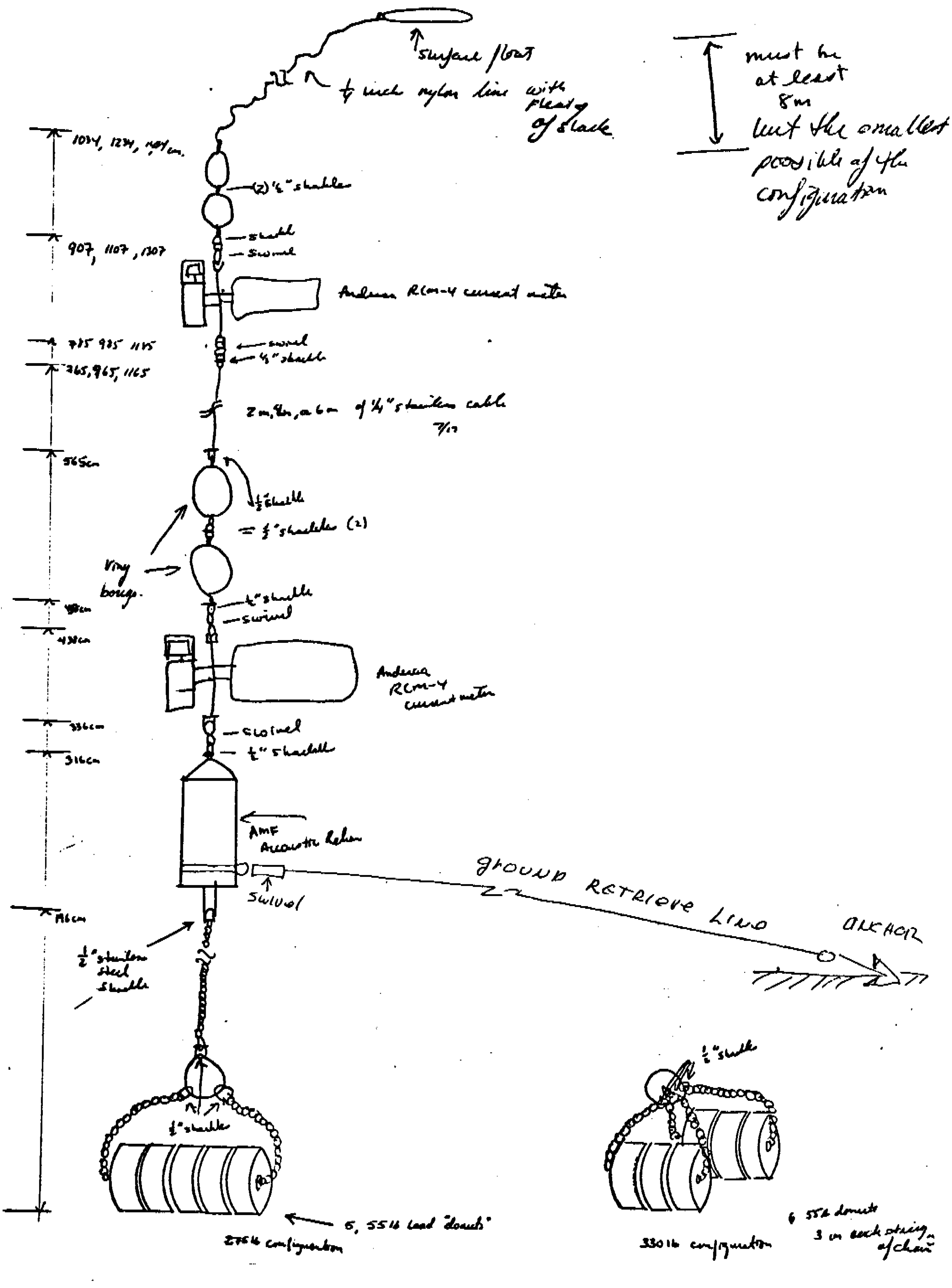


Fig. 1. Aanderaa Installation

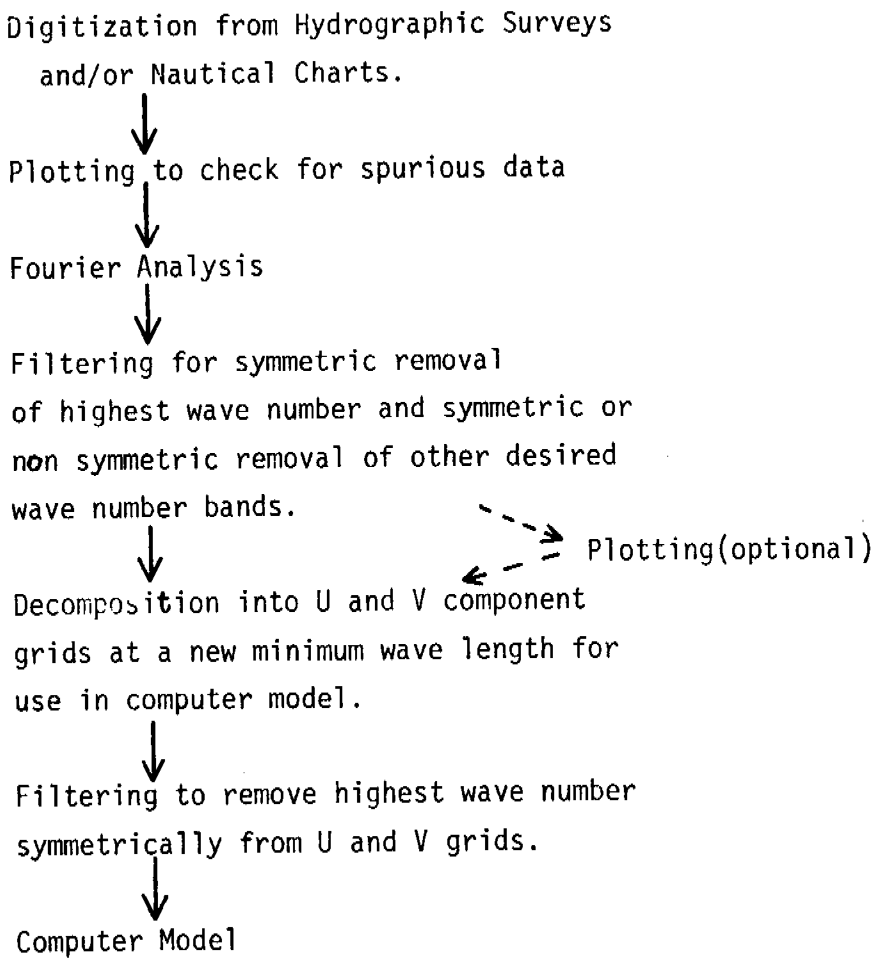


Fig. 2. Bottom Topography Analysis Flow Chart.

Horizontal to Vertical exaggeration = 3281:1

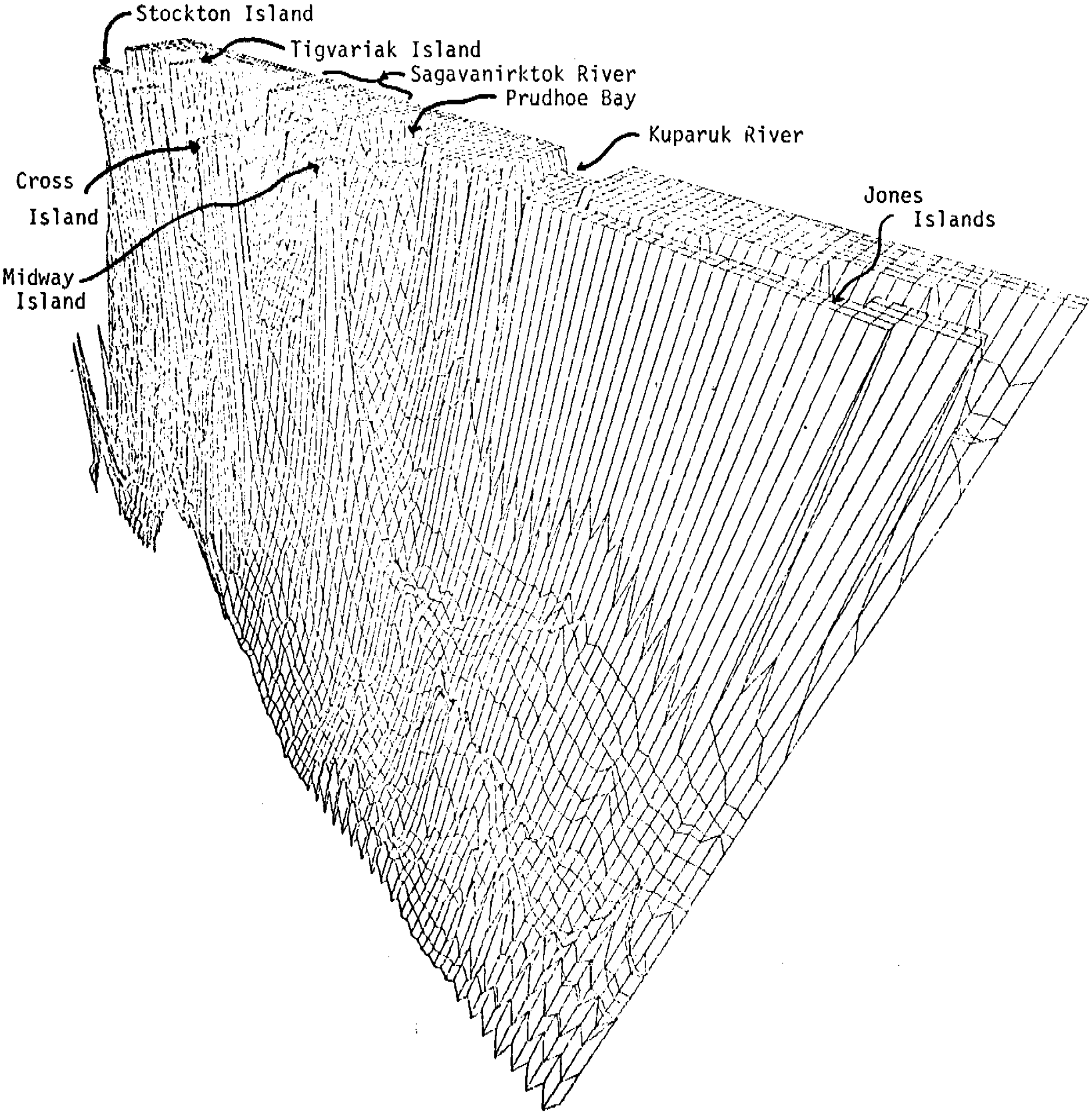


Fig. 3. Perspective diagram of the Oliktok Point to the Challenge Entrance grid. The vantage point is looking southeast from the northwest corner of the grid.

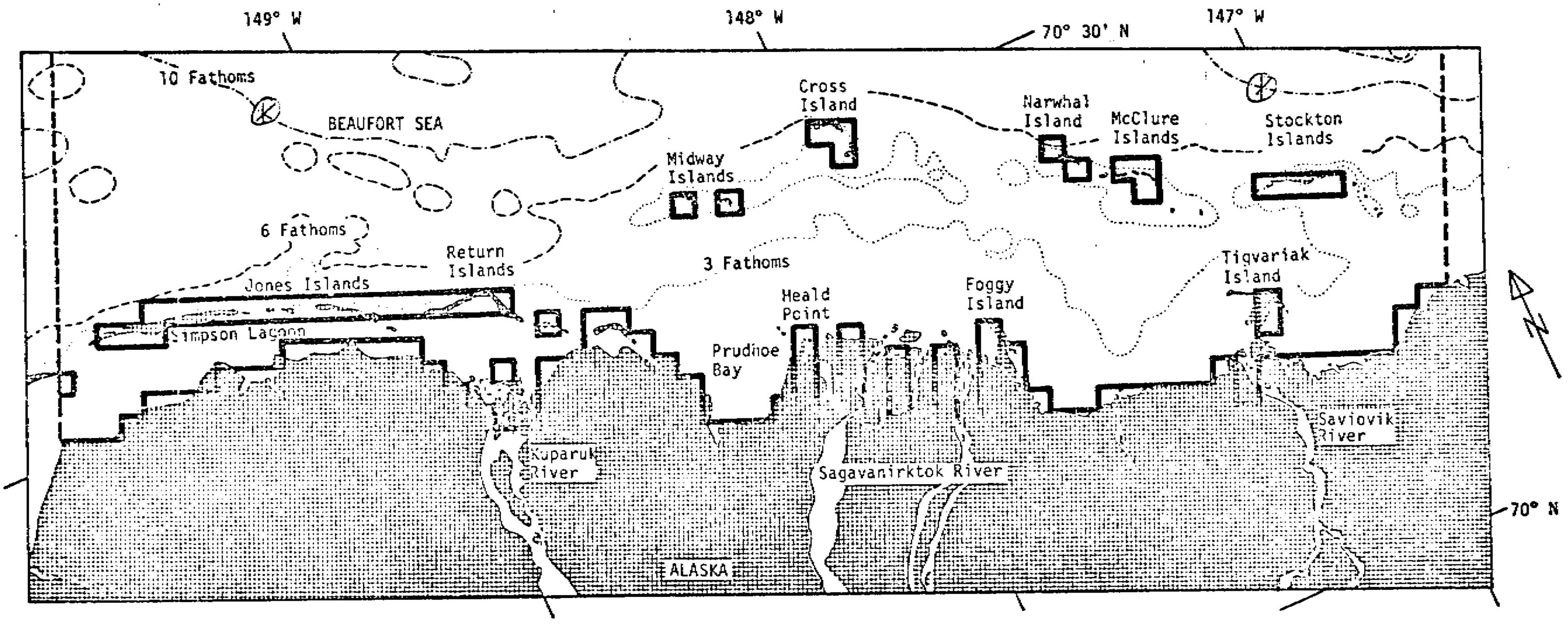


Fig. 4. OLIKTOK POINT TO THE CHALLENGE ENTRANCE

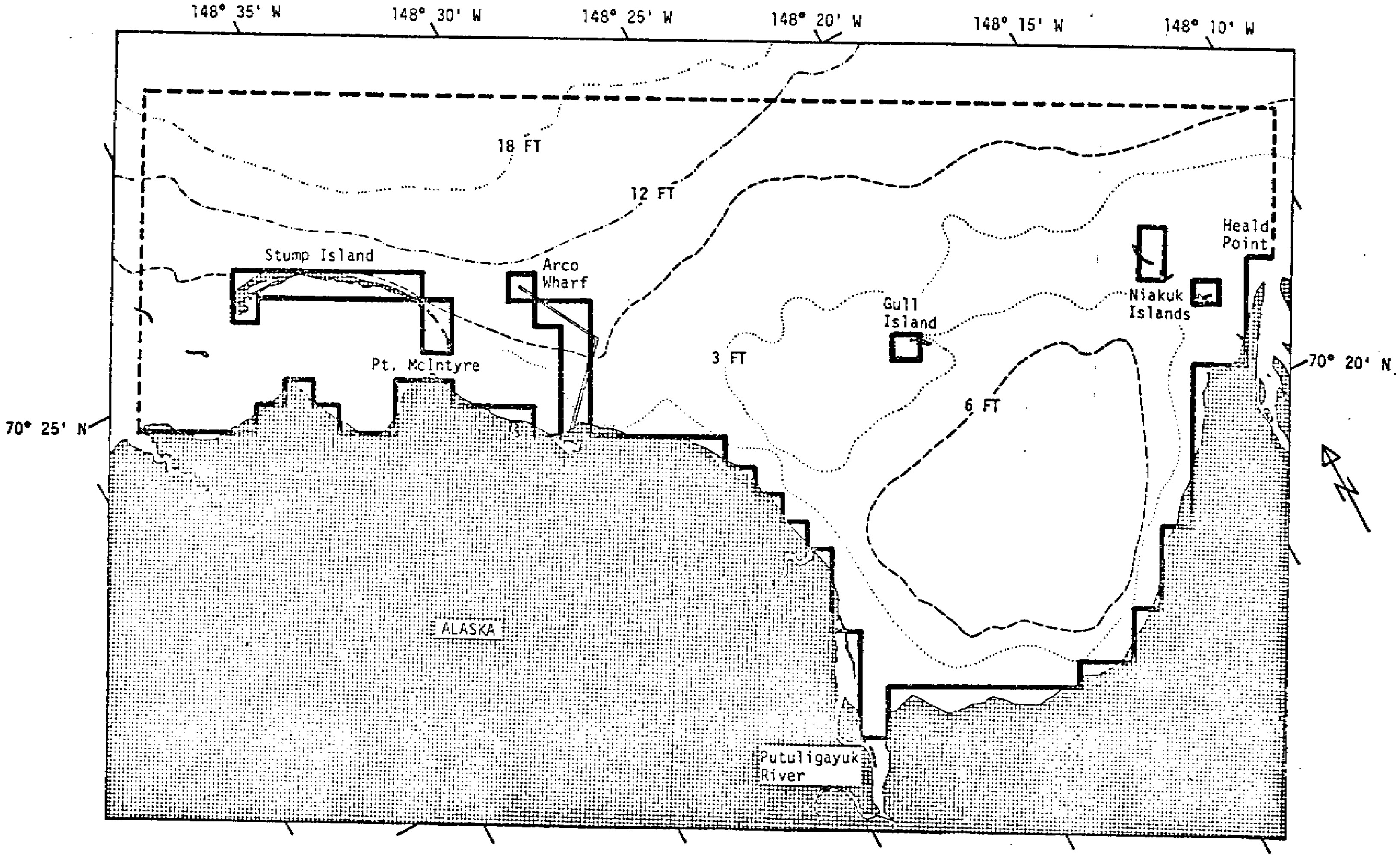


Fig. 5. PRUDHOE BAY

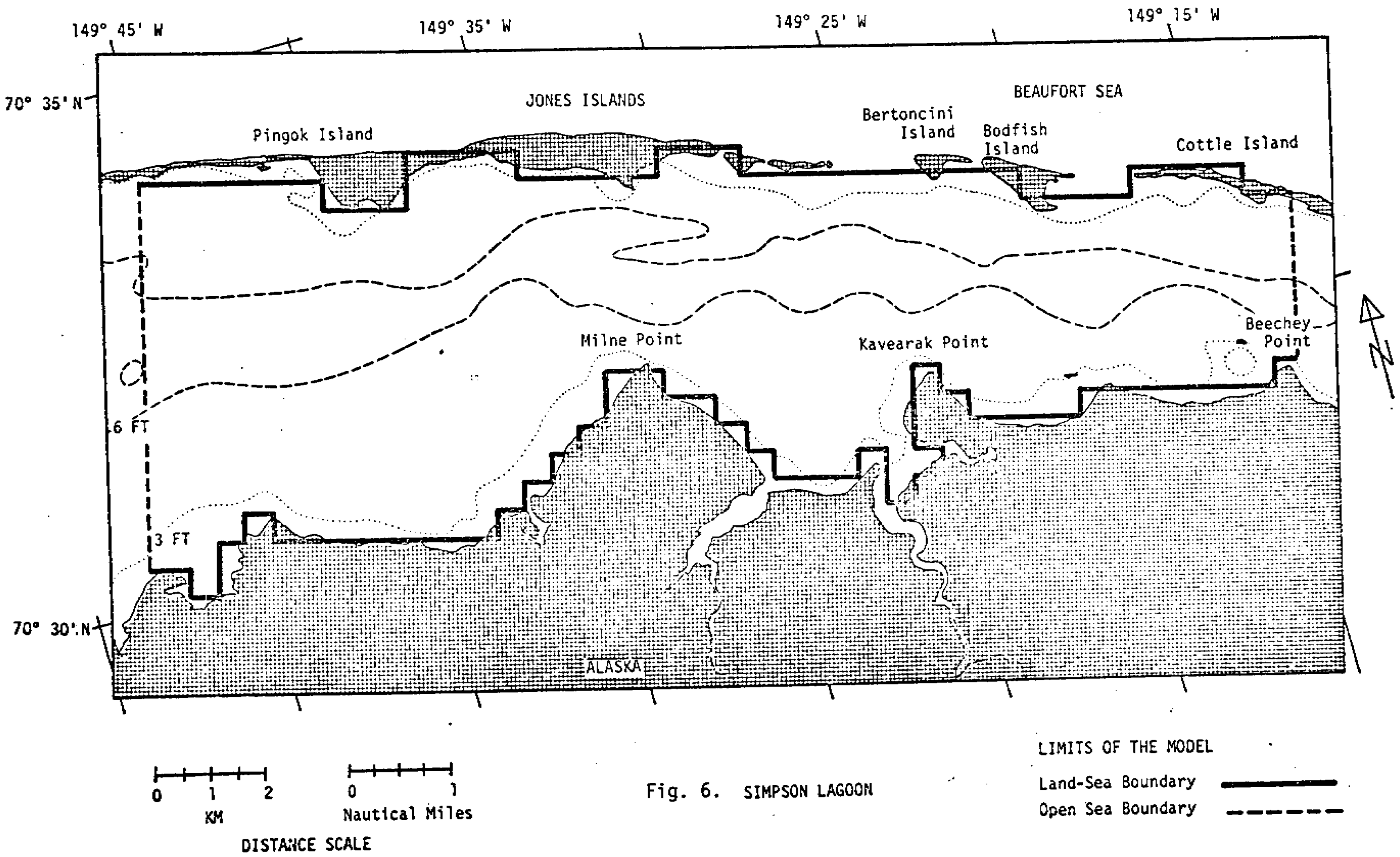


Fig. 6. SIMPSON LAGOON

Quarterly Report

Contract No: N/A
Research Unit No: 347
Reporting Period: April 1, 1976;
through June 30, 1976
Number of Pages: 2

"Marine Climatology of the Gulf of Alaska and the Bering and Beaufort Seas"
Climatic Atlases (3)

Principal Investigators

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QUARTERLY REPORT

I. Task Objectives

To compile and publish a descriptive climatology of that portion of the Alaskan waters and coastal areas that are important to resource development of the outer continental shelf (OCS).

II. Field and Laboratory Activities

This project has no field or laboratory activities. It is a joint effort by the AEIDC and the NCC to produce a climatic atlas for each of three Alaskan marine and coastal areas: the Gulf of Alaska (50°-65°N, 130°-165°W); the Bering Sea (50°-65°N, 155°-180°W); and the Beaufort Sea (65°-75°N, 140°-180°W).

NCC is to provide monthly climatological analyses in the form of 360 isopleth charts and 9,540 statistical graphs (see attachments). The analyses are to be based on 600,000 surface marine observations and two million (3-hourly) observations for 49 (selected) coastal stations contained in NCC's digital data base. AEIDC is to provide extremes of all weather elements and information on coastal damage resulting from wind generated weather elements, check analysis work done by NCC, and prepare all materials for publication. (AEIDC will provide an independent quarterly report).

III. Results

Computer processing of the digital data is complete. This includes the computer-to-microfilm production of the 9,540 statistical graphs and the computer plotting of the 360 charts. All graphs have been photo processed; some 55% of these have been edited and forwarded to AEIDC and the remainder should be ready for mailing in July. About 75% of the isopleth charts have been analyzed by meteorologists; however, progress has been slowed for lack of funds (see Item V below).

IV. Preliminary Interpretation of Results

The U.S. Navy Marine Climatic Atlas of the World, Vol.II, North Pacific Ocean (1959), one of eight volumes in a series of atlases of the world which is currently being updated by the Navy, has had wide acceptance as an authoritative reference for large scale operational planning and research.

The present study will provide three atlases to represent the total of the Alaskan waters in greater detail and each will be based on more than 20 years of additional data. Also, as marine data are typically sparse in the near coastal zone, a zone of sharp gradients and complex climate, data for the 49 coastal stations were included. Such a combination should provide the best possible climatological picture for the coastal waters of Alaska.

V. Problems Encountered

A computer-visual inventory of the digital surface marine data file disclosed a sparcity of data north of 60° latitude. To permit a better climatic description of the Bering and Beaufort Seas, marine observations were digitized from manuscript forms archived at NCC for the period 7/73-12/74 and digital data for 22 additional coastal stations held in NCC's file were combined with data of the 27 stations originally selected. As little data for the area east of Barter Island are available in NCC's digital file (see attached sample of data plot), a climatic description of the Mackenzie Bay Area is dependent on the approval of the AEIDC/NCC Mackenzie Proposal. This would permit us to purchase digital data from Canada for computer processing and analysis to include the marine area 125°-140°W in the Beaufort Sea Atlas.

Because of the increased data processing and analysis requirements, the NCC in April requested and received an additional $10K. In May, after the full impact of increased requirements was known, the NCC requested, but did not receive, an additional $25K for FY-76 (see Item VI below).

VI. Estimate of Funds Expended

As of 6/15, all of the $84.5K allotted for FY-76, 76T have been expended and continuation of work is dependent upon the approval of two work statements submitted by the NCC in April, the Mackenzie Bay Proposal in FY-76T ($25K) and the Continuation of the current Task in FY-77 (additional $25K).

ATTACHMENT I

PROPOSED

ALASKAN COASTAL ZONE ATLAS

Provisional

TABLE OF CONTENTS

I. Foreword, Introduction, Geographic Reference Chart.

II. General Climatology (Special items to be covered in text and/or presented in graph, table or chart form).

- A. "Annual March" of selected elements
- B. Fog information
- C. Extratropical cyclone information
- D. Storm surges
- E. High wind and wave recurrence intervals
- F. Potential superstructure icing
- G. Tides - type, range, etc.
- H. Surface currents - speed/direction
- I. Topography - land and sea
- J. Coastal flooding

III. Discussion of the Data Base, Discussion of the Charts and Graphs, Notes to Users, References.

IV. Climatic Charts with Graphs of Marine Areas and Selected Coastal Stations - to be displayed (monthly or seasonally, as appropriate) on a base map that locates land stations and marine areas and includes isopleth analyses when appropriate.

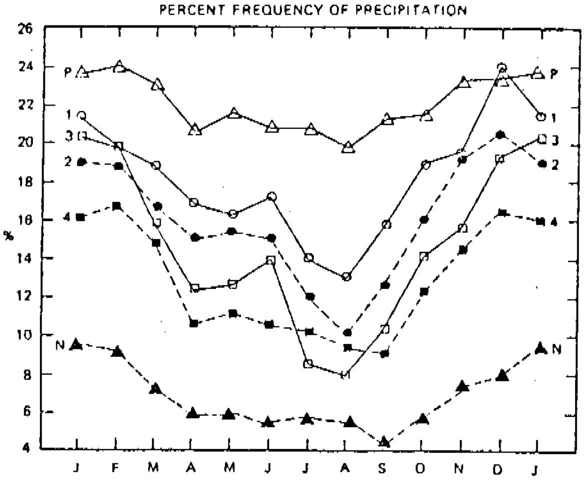
- A. Cloud Cover - Wind Direction
- B. Visibility - Wind Direction
- C. Low Cloud Ceiling - Visibility
- D. Precipitation - Wind Direction
- E. Precipitation Types
- F. Air Temperature - Wind Direction
- G. Air Temperature - Wind Speed
- H. Wet Bulb Temperature - Relative Humidity
- I. Sea Surface Temperature
- J. Wave Height - Direction
- K. Wave Height - Period
- L. Wind Speed - Direction
- M. Sea-Level Pressure
- N. Hours Duration of Gales - Days Interval Between Gales

Detailed Provisional Contents of Alaskan Coastal Climatology Atlas *

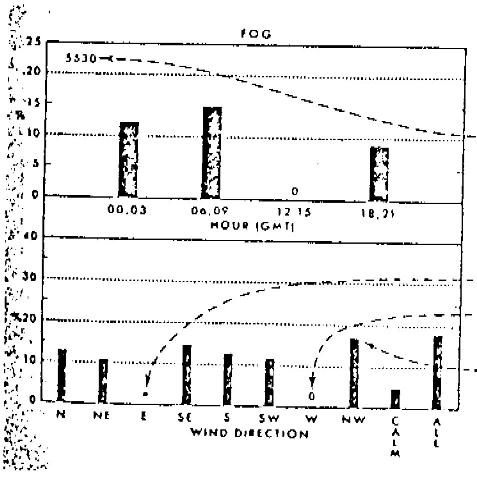
I. Introduction Material
Foreword, Introduction, Geographic Reference Chart

II. General Climatology
Items of special interest are covered here.

A. Annual march of selected elements include monthly graphs to show annual variations of such items as cloud cover, visibility, fog, precipitation, air temperature, sea surface temperature, waves, wind and sea level pressure. A sample graph appears below:



B. Fog information for fog-prone areas (If fog is extremely prevalent, fog material is covered in the "Climatic Charts" section).



Fog

Number of observations.

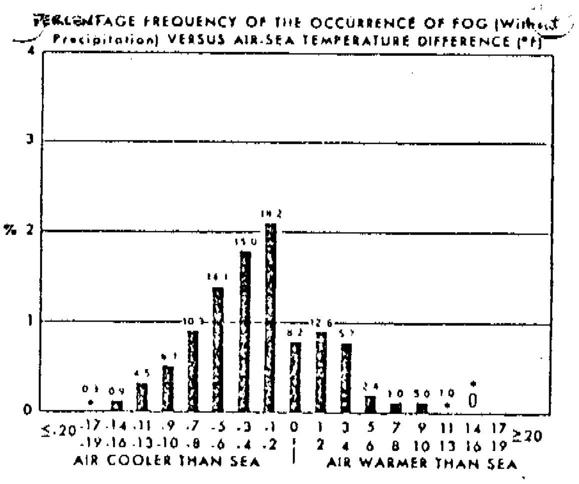
Bar graphs represent percent frequency of Fog (without precipitation) for various hour groupings and wind directions. Data are based on 100% for each hour-group and direction category.

• indicates < 05% but >0.

0 indicates no fog occurred with the wind direction.

(Data show that 17% of all NW winds were accompanied by Fog (without precipitation).)

*Sample graphs are based on dummy data and are not necessarily representative of U.S. Coastal Areas.



C. Principal extratropical cyclone tracks and frequencies are presented on small-scale charts.

D. Storm surges are documented on a map of the area.

E. High wind and wave recurrence intervals give estimates of 5, 10, 25, 50 and 100 year return periods of these phenomena.

F. Superstructure icing potential is shown via small-scale seasonal charts.

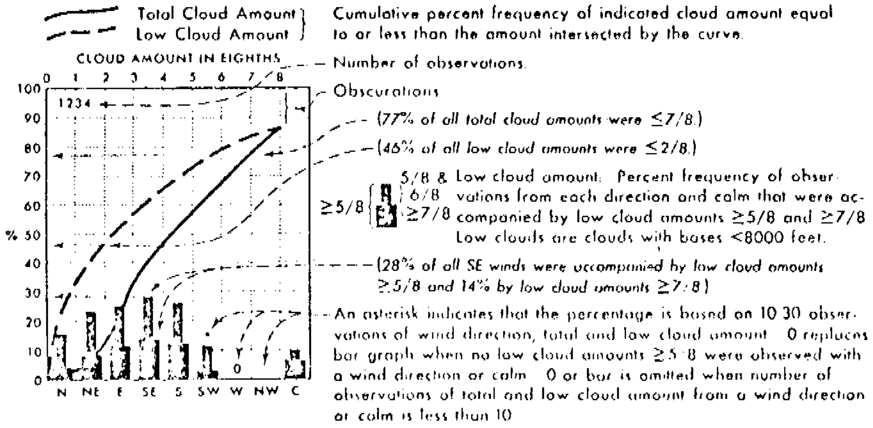
G. Other pertinent topics of a local nature are covered. These may include major drainage areas, ice free shipping seasons, major coastal geographic features, extreme observed wave heights and winds, wind chill table, immersion hypothermia table (or shown on chart), etc.

III. Discussions of the data base, charts, graphs and special notes to users are narrative descriptions. Notes will mention the use of marine data, which is not abundant in some marine areas (a chart of obs per 1° will be included). Use of "off-the-shelf" data is explained.

References will be of standard form.

IV. Major climatic charts. Chart types and sample legends are shown below.

A. Cloud Cover-Wind Direction



Cumulative percent frequency of indicated cloud amount equal to or less than the amount intersected by the curve.

(77% of all total cloud amounts were ≤7/8.)

(46% of all low cloud amounts were ≤2/8.)

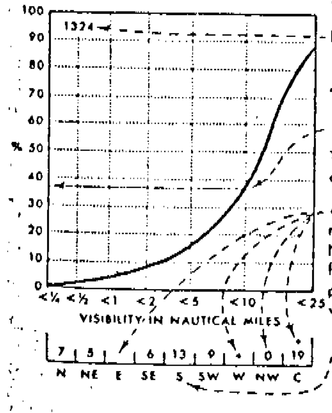
Low cloud amount: Percent frequency of observations from each direction and calm that were accompanied by low cloud amounts ≥5/8 and ≥7/8. Low clouds are clouds with bases <8000 feet.

(28% of all SE winds were accompanied by low cloud amounts ≥5/8 and 14% by low cloud amounts ≥7/8.)

An asterisk indicates that the percentage is based on 10-30 observations of wind direction, total and low cloud amount. 0 replaces bar graph when no low cloud amounts ≥5/8 were observed with a wind direction or calm. 0 or bar is omitted when number of observations of total and low cloud amount from a wind direction or calm is less than 10.

Isopleths: Percent frequency of total cloud amount ≤ 2/8. Percent frequency of low cloud amount ≥ 5/8.

B. Visibility - Wind Direction



Visibility.

Number of observations.

Cumulative percent frequency of visibilities less than the visibility intersected by the curve.

(37% of all visibilities reported were <10 nautical miles.)

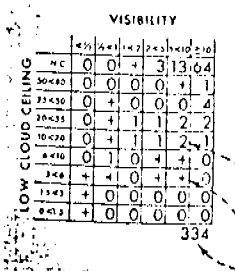
The table below the graph indicates percent frequency of occurrence of visibility <2 nautical miles versus wind direction.

+ indicates <.5% but >0; 0 indicates that no visibilities <2 nautical miles were observed with winds from a direction or calm. No percentage is given if less than 10 observations are available for visibility and wind direction. An asterisk indicates that the percentage was based on 10-30 observations of visibility and wind direction.

(13% of all S winds were accompanied by visibilities <2 nautical miles.)

Isopleths: Percent frequency of visibility < 2 nautical miles. Percent frequency of visibility ≥ 5 nautical miles.

C. Low Cloud Ceiling - Visibility



VISIBILITY

LOW CLOUD CEILING

	<½	½<1	1<2	2<5	5<10	≥10
N C	0	0	+	3	13	64
50<80	0	0	0	0	+	1
35<50	0	+	0	0	0	4
20<35	0	+	1	1	2	2
10<20	0	+	1	1	2	1
6<10	0	1	0	+	+	0
3<6	+	+	0	+	+	0
1.5<3	+	0	0	0	0	0
0<1.5	+	0	0	0	0	0

334

Low cloud ceiling - Visibility.

Percent frequency of simultaneous occurrence of specified low cloud ceilings (hundreds of feet) and visibilities (nautical miles).

Low cloud ceiling heights are estimated from the height of low clouds (h) when low cloud amount (N_h) is ≥5/8.

Obscurations are included under ceiling "0 <1.5".

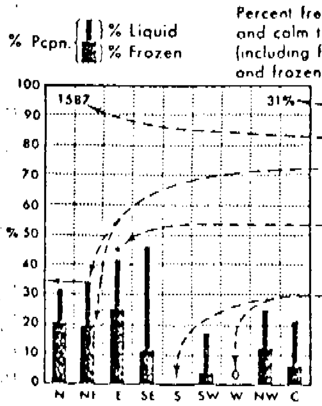
"N C" (no ceiling) includes bases of clouds ≥8000 feet as well as occurrences of N_h <5/8.

(2% of all observations reported ceiling ≥1000 but <2000 feet simultaneously with visibility ≥5 but <10 nautical miles.)

+ indicates <.5% but >0.

Number of observations.

D. Precipitation - Wind Direction



Percent frequency of observations with surface winds from each direction and calm that were accompanied by precipitation, subdivided into liquid type (including freezing rain and freezing drizzle) and frozen type (including liquid and frozen types falling simultaneously).

Percentage of present weather reporting precipitation.

Number of observations.

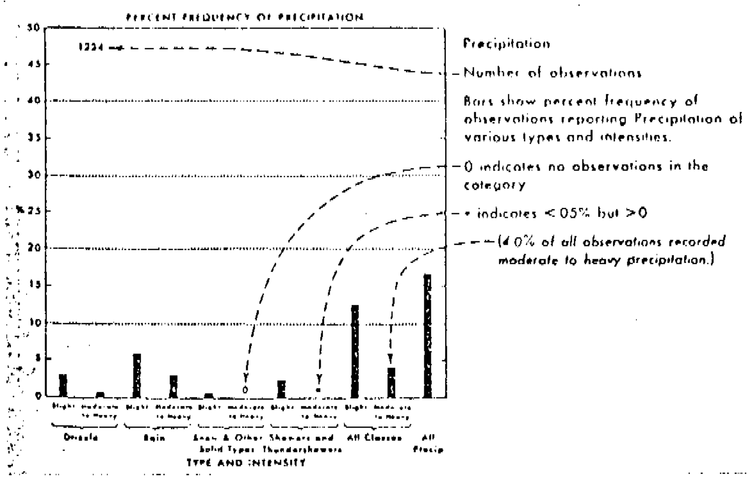
(34% of all NE winds were accompanied by precipitation, of which 14% was liquid and 20% was frozen.)

An asterisk in the column for a given direction (or calm) indicates percentages were based on 10-30 observations of present weather and wind direction.

0 replaces bar when no precipitation was observed with winds from a given direction (or calm). No bar graph is presented if less than 10 observations containing present weather are reported for a given direction (or calm).

Isopleths: Percent frequency of precipitation. (Note-display monthly mean precipitation values at selected coastal stations).

E. Precipitation Types



Precipitation

Number of observations

Bars show percent frequency of observations reporting Precipitation of various types and intensities.

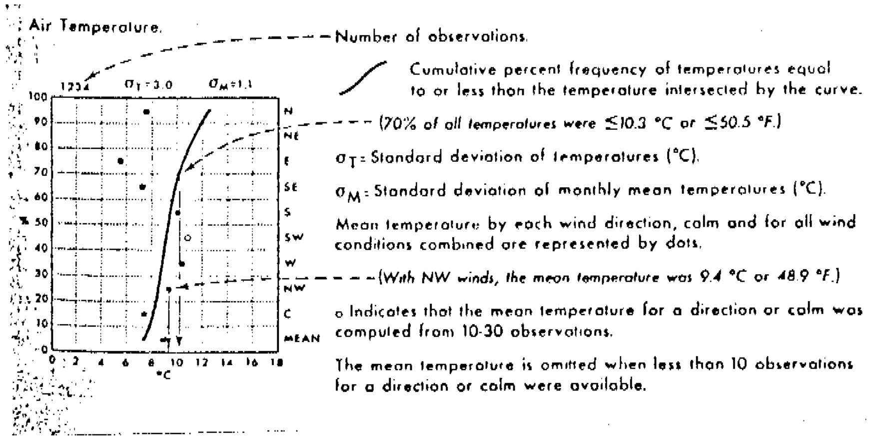
0 indicates no observations in the category

* indicates < 05% but > 0

(4 0% of all observations recorded moderate to heavy precipitation.)

Isopleths: Percent frequency of frozen precipitation. (Note-display monthly mean snowfall amounts at selected coastal stations).

F. Air Temperature - Wind Direction



Number of observations.

Cumulative percent frequency of temperatures equal to or less than the temperature intersected by the curve.

(70% of all temperatures were ≤10.3 °C or ≤50.5 °F.)

σ_T = Standard deviation of temperatures (°C).

σ_M = Standard deviation of monthly mean temperatures (°C).

Mean temperature by each wind direction, calm and for all wind conditions combined are represented by dots.

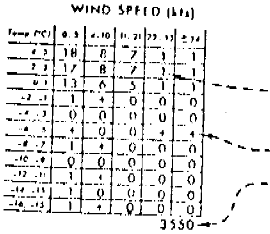
(With NW winds, the mean temperature was 9.4 °C or 48.9 °F.)

o Indicates that the mean temperature for a direction or calm was computed from 10-30 observations.

The mean temperature is omitted when less than 10 observations for a direction or calm were available.

Isopleths: Mean Air Temperature

G. Air Temperature - Wind Speed



WIND SPEED (kts)

Temp (°C)	0-3	4-10	11-21	22-33	≥34
4 5	18	8	7	1	1
2 3	17	8	7	1	1
0 1	13	6	5	1	1
-2 -1	1	+	0	0	0
-4 -3	0	0	0	0	0
-6 -5	+	0	0	+	+
-8 -7	1	+	0	0	0
-10 -9	0	0	0	0	0
-12 -11	1	+	0	0	0
-14 -13	1	0	0	0	0
-16 -15	1	+	0	0	0

3550

Wind speed and air temperature

Percent frequency of simultaneous occurrence of specified temperature (°C) and wind speed (knots).

(1% of all observations reported temperature 2-3°C simultaneously with wind speed of 22-33 kts.)

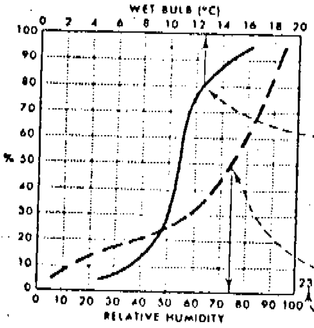
Indicates <.5% but >0.

Number of observations.

Use of this table in determination of Potential Superstructure Icing is explained in the text.

Isopleths: 1% and 99% air temperatures.

H. Wet Bulb Temperature - Relative Humidity



Wet bulb - Relative humidity.

Cumulative percent frequency of wet bulb temperatures equal to or less than the temperature intersected by the curve (top scale).

Wet bulb.

(80% of all observed wet bulb temperatures were ≤12.5°C or 54.5°F.)

Cumulative percent frequency of relative humidities equal to or less than the humidity intersected by the curve (bottom scale).

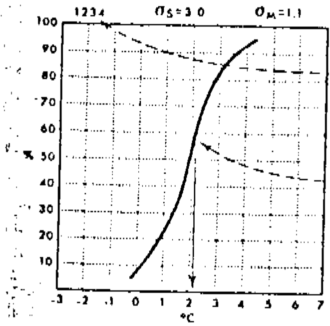
Relative humidity.

(50% of all observed relative humidities were ≤74%.)

Number of observations.

Isopleths: Percent frequency of Temperature-Humidity Index (THI) ≥ 24°C.

I. Sea Surface Temperature



Sea surface temperature.

Number of observations.

Cumulative percent frequency of sea surface temperatures equal to or less than the temperature intersected by the curve.

(60% of all observed sea surface temperatures were ≤2.1°C or ≤35.8°F.)

σ_S: Standard deviation of sea surface temperatures (°C).

σ_M: Standard deviation of monthly mean sea surface temperatures (°C).

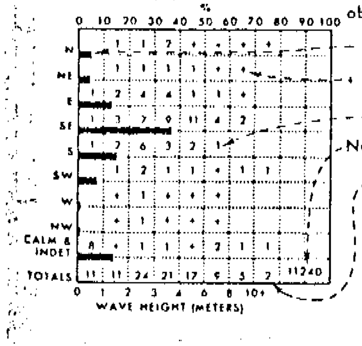
Isopleths: Mean 1% and 99% Sea Surface Temperature

J. Wave Height - Direction

Wave direction and height.

Direction frequency (top scale): Bars represent percent frequency of waves from each direction.

Height frequency (bottom scale): Printed figures represent percent frequency of wave heights observed from each direction.



(5% of all waves were from the N.)

+ indicates <.5% but >0.

(1% of all waves were from the S with heights from 6-7.5 meters.)

Number of observations.

(2% of the waves from all directions had heights from ≥10 meters.)

WAVE HEIGHT INTERVAL

Feet	0-2	3-6	7-9	10-12	13-19	20-25	26-32	≥33
Meters	0-.5	1-1.5	2-2.5	3-3.5	4-5.5	6-7.5	8-9.5	≥10
	0	1	2	3	4	6	8	10+

Printed scale on bottom of chart

Isopleths: Percent frequency of waves less than 1.5 meters.
Percent frequency of waves less than 2.5 meters.

K. Wave Height - Period

PERIOD (Seconds)

HEIGHT (meters)	<6	6-7	8-9	10-11	12-13	>13	[illegible]
0-.5	21	3	1	+	+	1	6
1-1.5	22	16	6	2	1	+	+
2-2.5	3	6	4	3	1	+	+
3-3.5	+	1	1	1	1	+	+
4-5.5	+	+	+	+	+	+	0
6-7.5	0	+	+	0	0	+	0
8-9.5	0	0	0	+	0	0	0
≥10	0	0	0	0	0	+	0

4010

Percent frequency of occurrence of wave height and period.

(2% of observed waves had a height of 1-1.5 meters and a period of 10-11 seconds.)

+ indicates <.5% but >0.

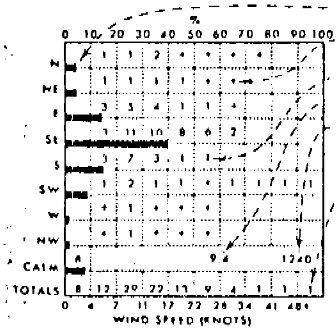
Number of observations.

Waves are selected on the basis of the higher of sea and swell when both are reported. If both heights are equal, the longer period is selected.

Isopleths: Percent frequency of waves ≥ 3.5 meters.
Percent frequency of waves ≥ 6.0 meters.
(Note-display observed extreme wave heights at observation points

L. Wind Speed - Direction

Direction frequency (top scale): Bars represent percent frequency of winds observed from each direction. Speed frequency (bottom scale): Printed figures represent percent frequency of wind speeds observed from each direction.



(4% of all winds were from the N.)

+ indicates < 5% but >0.

(1% of all winds were from the S and had wind speed 22-27 knots.)

The scalar mean speed was 9.4 knots.

Number of observations.

(1% of winds from all directions had wind speed ≥48 knots.)

WIND SPEED INTERVAL (KNOTS)

0-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	≥48
0	4	7	11	17	22	28	34	41	48+

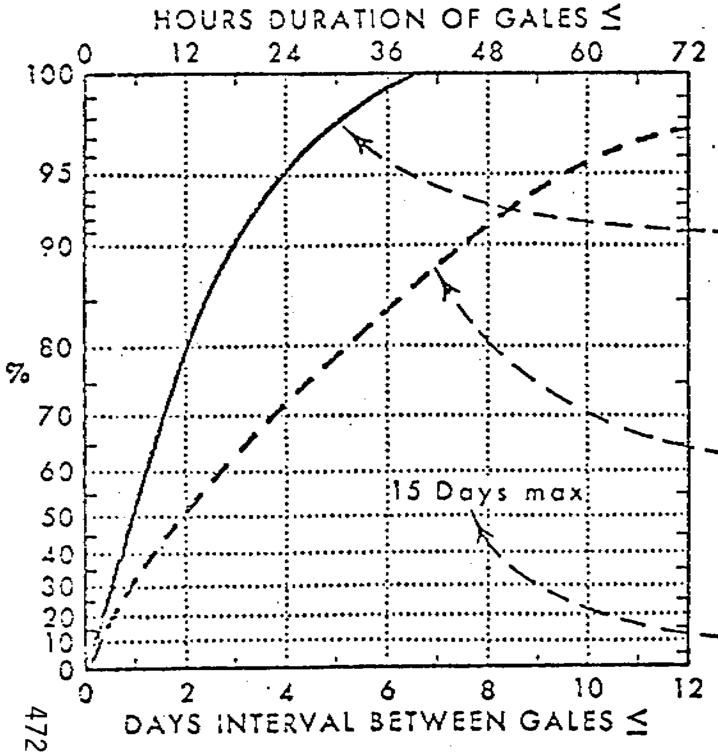
Printed scale on bottom of chart

Isopleths: Scalar mean wind speed. (Note-display observed extremes at observation points).

M. Sea Level Pressure
Graphs: Percent frequency of sea level pressure similar to the sea surface temperature graphs.

Isopleths: Mean sea level pressure. (Note-display primary/ secondary storm tracks).

N. Hours Duration of Gales - Days Interval Between Gales (see attached page)



Hours duration of gales - Days interval between gales.

Cumulative percent frequency of hours duration of gales equal to or less than the number of hours intersected by the solid curve (based on gales which began in this month).

----(*98% of gales had a duration ≤30 hours.*)

Cumulative percent frequency of days interval between gales equal to or less than the number of days intersected by the broken curve (based on gales which ended in this month).

----(*88% of gales were followed by another gale in 7 days or less.*)

The maximum value(s) of hours duration and/or days interval will be displayed when the graph limits are exceeded.

----(*100% of gales were followed by another gale in 15 days or less.*)

Where observations of gales are few, cumulative percent frequencies of hours duration of gales and days interval between gales are provided in tables.

Percentage frequency of gale force winds (≥34 knots)

BEAUFORT SEA

ATLAS LOCATOR	(WMO NO.) WBAN NO.	NAME	LAT° LON°	P.O.R.	GRAPH II
1	(21982)	OSTROV VRANGELJA	70°-58'N; 178°-32'W	1/59 - 6/71	82 / 1982
2	(25173)	MYS SMIDTA	68°-55'N; 179°-29'W	1/59 - 6/71	73 / 5173
3	(25286)	OSTROV KOLYUCHINO	67°-28'N; 174°-36'W	1/59 - 12/63	86 / 5286
	"	" "		1/69 - 6/71	" "
4	(25399)	MYS UZLEN	66°-10'N; 169°-50'W	1/59 - 6/71	91 / 5399
5	26634	TIN CITY	65°-34'N: 167°-55'W	5/53 - 12/71	27 / 6634
6	26616	KOTZEBUE	66°-52'N: 162°-38'W	1/45 - 12/74	20 / 6611
7	26631	CAPE LIZBURNE	68°-53'N; 166°-06'W	8/52 - 12/71	24 / 6631
8	26638	POINT LAY/LIZ-2	69°-44'N; 163°-01'W	8/57 - 11/75	31 / 6638
9	27508	WAINWRIGHT/LIZ-3	70°-37'N; 159°-51'W	8/57 - 11/75	33 / 7568
10	27502	BARROW	71°-18'N: 156°-47'W	7/48 - 12/74	30 / 7502
11	27512	LONELY POINT/POW-1	70°-55'N; 153°-14'W	7/57 - 11/75	34 / 7512
12	27403	OLIKLOK/POW-2	70°-30'N; 149°-53'W	8/57 - 11/75	32 / 7403
13	27401	BARTER ISLAND	70°-08'N; 143°-38'W	1/49 - 12/74	29 / 7401
14	26156	KOMAKUK BEACH	69°-35'N; 140°-11'W	8/73 - 10/75	
15	26392	SHINGLE ~~BEACH~~ POINT	68°-57'N; 137°-12'W	8/73 - 10/75	
16	26394	TUKTOYAKTUK	69°-27'N; 133°-00'W	1/58 - 12/75	
* 17	26291	NICHOLSON PENINSULA	69°-57'N; 128°-55'W	8/73 - 10/75	
18	27202	CAPE PARRY	70°-10'N; 124°-41'W	1/56 - 12/75	
19	27201	SACHS HARBOUR	71°-57'N; 124°-44'W	11/55 - 12/75	
	AREA NO.	MARINE AREAS			
A	13		70°-75°N; 180°-155°W	1872 - 1974	62
B	14		75°-COAST; 155°-130°W	" "	64
C	12		65°-70°N; 180°W COAST	" "	63

* Canadian stations to be included if MacKenzie Bay Proposal is approved for FY-76 T

1 Ostrov Vrangelja

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	•	0	0
20.21	•	•	•	0	0
18.19	•	•	•	•	0
16.17	•	1	1	•	0
14.15	•	2	4	1	•
12.13	1	5	11	4	•
10.11	2	10	15	6	•
8.9	1	7	12	5	1
6.7	•	3	3	2	•
4.5	•	•	•	•	•
2.3	0	•	•	•	0

4511

2 Mys Smidta

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	•	0	0	0
20.21	0	•	•	•	0
18.19	•	•	•	•	0
16.17	•	1	2	•	0
14.15	1	4	5	1	•
12.13	1	10	12	3	•
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	•	1	1	1	•
4.5	•	•	•	•	0
2.3	0	0	0	0	0

6054

3 Ostrov Kolyvchino

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
26.27	0	•	0	0	0
24.25	•	•	•	0	0
22.23	•	•	•	•	0
20.21	•	1	1	•	0
18.19	1	5	5	1	•
16.17	2	12	13	2	•
14.15	2	11	12	2	•
12.13	1	8	10	3	•
10.11	•	2	2	1	•
8.9	•	•	•	•	•
6.7	0	0	•	0	0

7176

4 Mys Uzlew

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	•	•	•	0	0
20.21	2	6	4	•	0
18.19	4	24	26	2	•
16.17	1	10	18	2	•
14.15	•	•	•	•	0
12.13	0	•	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5515

5 Tin City

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
26.27	0	•	0	0	0
24.25	•	•	•	0	0
22.23	•	•	•	•	0
20.21	•	1	1	•	0
18.19	1	5	5	1	•
16.17	2	12	13	2	•
14.15	2	11	12	2	•
12.13	1	8	10	3	•
10.11	•	2	2	1	•
8.9	•	•	•	•	•
6.7	0	0	•	0	0

7176

6 Kotzebue

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	•	•	•	0	0
20.21	2	6	4	•	0
18.19	4	24	25	2	•
16.17	1	10	18	2	•
14.15	•	•	•	•	0
12.13	0	•	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5616

7 Cape Lisburne

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	•	0	0	0
20.21	0	•	•	•	0
18.19	•	•	•	•	0
16.17	•	1	2	•	0
14.15	1	4	5	1	•
12.13	1	10	12	3	•
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	•	1	1	1	•
4.5	•	•	•	•	0
2.3	0	0	0	0	0

6054

8 Point Lay

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	•	0	0
20.21	•	•	•	0	0
18.19	•	•	•	•	0
16.17	•	1	1	•	0
14.15	•	2	4	1	•
12.13	1	6	11	4	•
10.11	2	10	15	6	•
8.9	1	7	12	5	1
6.7	•	3	3	2	•
4.5	•	•	•	•	•
2.3	0	•	•	•	0

4511

9 Wainwright

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	•	0	0
20.21	•	•	•	0	0
18.19	•	•	•	•	0
16.17	•	1	1	•	0
14.15	•	2	4	1	•
12.13	1	6	11	4	•
10.11	2	10	15	6	•
8.9	1	7	12	5	1
6.7	•	3	3	2	•
4.5	•	•	•	•	•
2.3	0	•	•	•	0

4511

10 Barrow

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	•	0	0	0
20.21	0	•	•	•	0
18.19	•	•	•	•	0
16.17	•	1	2	•	0
14.15	1	4	5	1	•
12.13	1	10	12	3	•
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	•	1	1	1	•
4.5	•	•	•	•	0
2.3	0	0	0	0	0

6054

11 Lonely Point

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	•	•	•	0	0
20.21	2	6	4	•	0
18.19	4	24	25	2	•
16.17	1	10	18	2	•
14.15	•	•	•	•	0
12.13	0	•	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5616

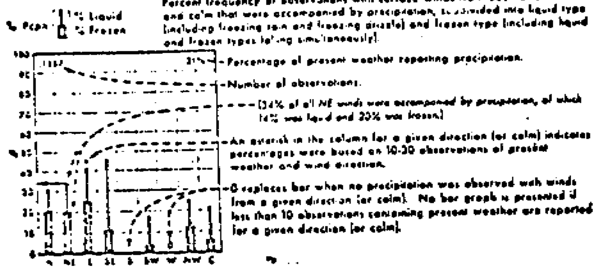
12 Oliktok

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
26.27	0	•	0	0	0
24.25	•	•	•	0	0
22.23	•	•	•	•	0
20.21	•	1	1	•	0
18.19	1	5	5	1	•
16.17	2	12	13	2	•
14.15	2	11	12	2	•
12.13	1	8	10	3	•
10.11	•	2	2	1	•
8.9	•	•	•	•	•
6.7	0	0	•	0	0

7175

Legend



Percent frequency of observations with surface winds from each direction and calm that were accompanied by precipitation, subdivided into liquid type (including freezing rain and freezing drizzle) and frozen type (including liquid and frozen types falling simultaneously).

Percentage of present weather reporting precipitation.

Number of observations.

(34% of all NE winds were accompanied by precipitation, of which 14% was liquid and 20% was frozen)

An asterisk in the column for a given direction (or calm) indicates percentages were based on 10-30 observations of present weather and wind direction.

0 replaces bar when no precipitation was observed with winds from a given direction (or calm). No bar graph is presented if less than 10 observations containing present weather are reported for a given direction (or calm).

13 Barter Island

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
28.29	•	•	0	0	0
26.27	0	•	•	0	0
24.25	•	•	•	•	0
22.23	1	3	2	•	•
20.21	1	6	6	•	0
18.19	1	11	12	1	•
16.17	2	11	13	2	•
14.15	1	6	7	1	•
12.13	1	3	3	1	•
10.11	•	•	•	•	•
8.9	0	•	0	•	0

5121

14 Komakuk Beach

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	•	0	0
20.21	•	•	•	0	0
18.19	•	•	•	•	0
16.17	•	1	1	•	0
14.15	•	2	4	1	•
12.13	1	6	11	4	•
10.11	2	10	15	6	•
8.9	1	7	12	5	1
6.7	•	3	3	2	•
4.5	•	•	•	•	•
2.3	0	•	•	•	0

4511

BEAUFORT SEA

ATLAS LOCATOR	(WMO NO.) WBAN NO.	NAME	LAT°' LON°'	P.O.R.	GRAPH II
1	(21982)	OSTROV VRANGELJA	70°-58'N; 178°-32'W	1/59 - 6/71	82 / 1982
2	(25173)	MYS SMIDTA	68°-55'N; 179°-29'W	1/59 - 6/71	73 / 5173
3	(25286)	OSTROV KOLYUCHINO	67°-28'N; 174°-36'W	1/59 - 12/63	86 / 5286
	"	" "		1/69 - 6/71	" "
4	(25399)	MYS UZLEN	66°-10'N; 169°-50'W	1/59 - 6/71	91 / 5399
5	26634	TIN CITY	65°-34'N; 167°-55'W	5/53 - 12/71	27 / 6634
6	26616	KOTZEBUE	66°-52'N; 162°-38'W	1/45 - 12/74	20 / 6611
7	26631	CAPE LIZBURNE	68°-53'N; 166°-06'W	8/52 - 12/71	24 / 6631
8	26638	POINT LAY/LIZ-2	69°-44'N; 163°-01'W	8/57 - 11/75	31 / 6638
9	27508	WAINWRIGHT/LIZ-3	70°-37'N; 159°-51'W	8/57 - 11/75	33 / 7568
10	27502	BARROW	71°-18'N; 156°-47'W	7/48 - 12/74	30 / 7502
11	27512	LONELY POINT/POW-1	70°-55'N; 153°-14'W	7/57 - 11/75	34 / 7512
12	27403	OLIKLOK/POW-2	70°-30'N; 149°-53'W	8/57 - 11/75	32 / 7403
13	27401	BARTER ISLAND	70°-08'N; 143°-38'W	1/49 - 12/74	29 / 7401
14	26456	KOMAKUK BEACH	69°-35'N; 140°-11'W	8/73 - 10/75	
15	26392	SHINGLE ~~BEACH~~ POINT	68°-57'N; 137°-12'W	8/73 - 10/75	
16	26394	TUKTOYAKTUK	69°-27'N; 133°-00'W	1/58 - 12/75	
* 17	26291	NICHOLSON PENINSULA	69°-57'N; 128°-55'W	8/73 - 10/75	
18	27202	CAPE PARRY	70°-10'N; 124°-41'W	1/56 - 12/75	
19	27201	SACHS HARBOUR	71°-57'N; 124°-14'W	11/55 - 12/75	
	AREA NO.	MARINE AREAS			
A	13		70°-75°N; 180°-155°W	1872 - 1974	62
B	14		75°-COAST; 155°-130°W	" "	64
C	12		65°-70°N; 180°W-COAST	" "	63

* Canadian stations to be included if MacKenzie Bay Proposal is approved for FY-76T

1 Ostrov Vrangelja

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	+	0	0
20.21	+	+	+	0	0
18.19	+	+	+	+	0
16.17	+	1	1	+	0
14.15	+	2	4	1	+
12.13	1	6	11	4	+
10.11	2	10	15	6	+
8.9	1	7	12	5	1
6.7	+	3	3	2	+
4.5	+	+	+	+	+
2.3	0	+	+	+	0

4511

2 Mys Smidta

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	+	0	0	0
20.21	0	+	+	+	0
18.19	+	+	+	+	0
16.17	+	1	2	+	0
14.15	1	4	5	1	+
12.13	1	10	12	3	+
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	+	1	1	1	+
4.5	+	+	+	+	0
2.3	0	0	0	0	0

6054

3 Ostrov Kolyvchino

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
26.27	0	+	0	0	0
24.25	+	+	+	0	0
22.23	-	+	+	+	0
20.21	-	1	1	+	0
18.19	1	5	5	1	+
16.17	2	12	13	2	+
14.15	2	11	12	2	+
12.13	1	8	10	3	+
10.11	+	2	2	1	+
8.5	+	+	+	+	+
6.7	0	0	+	0	0

7176

4 Mys Uzlew

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	+	+	+	0	0
20.21	2	6	4	+	0
18.19	4	24	26	2	+
16.17	1	10	18	2	+
14.15	+	+	+	+	0
12.13	0	+	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5515

5 Tin City

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
26.27	0	+	0	0	0
24.25	+	+	+	0	0
22.23	-	+	+	+	0
20.21	+	1	1	+	0
18.19	1	5	5	1	+
16.17	2	12	13	2	+
14.15	2	11	12	2	+
12.13	1	8	10	3	+
10.11	+	2	2	1	+
8.9	+	+	+	+	+
6.7	0	0	+	0	0

7176

6 Kotzebue

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	+	+	+	0	0
20.21	2	6	4	+	0
18.19	4	24	26	2	+
16.17	1	10	18	2	+
14.15	+	+	+	+	0
12.13	0	+	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5616

7 Cape Lisburne

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	+	0	0	0
20.21	0	+	+	+	0
18.19	+	+	+	+	0
16.17	+	1	2	+	0
14.15	1	4	5	1	+
12.13	1	10	12	3	+
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	+	1	1	1	+
4.5	+	+	+	+	0
2.3	0	0	0	0	0

6054

8 Point Lay

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	+	0	0
20.21	+	+	+	0	0
18.19	+	+	+	+	0
16.17	+	1	1	+	0
14.15	-	2	4	1	+
12.13	1	6	11	4	+
10.11	2	10	15	6	+
8.9	1	7	12	5	1
6.7	+	3	3	2	+
4.5	+	+	+	+	+
2.3	0	+	+	+	0

4511

9 Wainwright

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	+	0	0
20.21	+	+	+	0	0
18.19	+	+	+	+	0
16.17	+	1	1	+	0
14.15	+	2	4	1	+
12.13	1	6	11	4	+
10.11	2	10	15	6	+
8.9	1	7	12	5	1
6.7	+	3	3	2	+
4.5	+	+	+	+	+
2.3	0	+	+	+	0

4511

10 Barrow

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	+	0	0	0
20.21	0	+	+	+	0
18.19	+	+	+	+	0
16.17	+	1	2	+	0
14.15	1	4	5	1	+
12.13	1	10	12	3	+
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	+	1	1	1	+
4.5	+	+	+	+	0
2.3	0	0	0	0	0

6054

11 Lonely Point

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	+	+	+	0	0
20.21	2	6	4	+	0
18.19	4	24	26	2	+
16.17	1	10	18	2	+
14.15	+	+	+	+	0
12.13	0	+	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5616

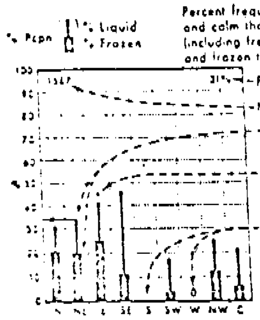
12 Oliktok

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
26.27	0	+	0	0	0
24.25	+	+	+	0	0
22.23	+	+	+	+	0
20.21	+	1	1	+	0
18.19	1	5	5	1	+
16.17	2	12	13	2	+
14.15	2	11	12	2	+
12.13	1	8	10	3	+
10.11	+	2	2	1	+
8.5	+	+	+	+	+
6.7	0	0	+	0	0

7176

Legend



Percent frequency of observations with surface winds from each direction and calm that were accompanied by precipitation, subdivided into liquid type (including freezing rain and freezing drizzle) and frozen type (including liquid and frozen types falling simultaneously).

–Percentage of present weather reporting precipitation.

–Number of observations.

–(34% of all NE winds were accompanied by precipitation, of which 14% was liquid and 20% was frozen.)

–An asterisk in the column for a given direction (or calm) indicates percentages were based on 10-30 observations of present weather and wind direction.

–0 replaces bar when no precipitation was observed with winds from a given direction (or calm). No bar graph is presented if less than 10 observations containing present weather are reported for a given direction (or calm).

13 Barter Island

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-32	≥ 34
28.29	+	+	0	0	0
26.27	0	+	+	0	0
24.25	+	+	+	+	0
22.23	1	3	2	+	+
20.21	1	6	6	+	0
18.19	1	11	12	1	+
16.17	2	11	13	2	+
14.15	1	6	7	1	+
12.13	1	3	3	1	+
10.11	+	+	+	+	+
8.9	0	+	0	+	0

5121

14 Komakuk Beach

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	+	0	0
20.21	+	+	+	0	0
18.19	+	+	+	+	0
16.17	+	1	1	+	0
14.15	+	2	4	1	+
12.13	1	6	11	4	+
10.11	2	10	15	6	+
8.5	1	7	12	5	1
6.7	+	3	3	2	+
4.5	+	+	+	+	+
2.3	0	+	+	+	0

4511

Precipitation; January

SHINGLE POINT
WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	[illegible]
22.23	0	0	+	0	0
20.21	+	+	+	0	0
18.19	+	+	+	+	0
16.17	+	1	1	+	0
14.15	+	2	4	1	+
12.13	1	6	11	4	+
10.11	2	10	15	6	+
8.5	1	7	12	5	1
6.7	+	3	3	2	+
4.5	+	+	+	+	+
2.3	0	+	+	+	0

4511

16 Tuktoyaktuk
WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	+	0	0	0
20.21	0	+	+	+	0
18.19	+	+	+	+	0
16.17	+	1	2	+	0
14.15	1	4	5	1	+
12.13	1	10	12	3	+
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	+	1	1	1	+
4.5	+	+	+	+	0
2.3	0	0	0	0	0

6054

17 Nicholson PENINSULA
WIND SPEED

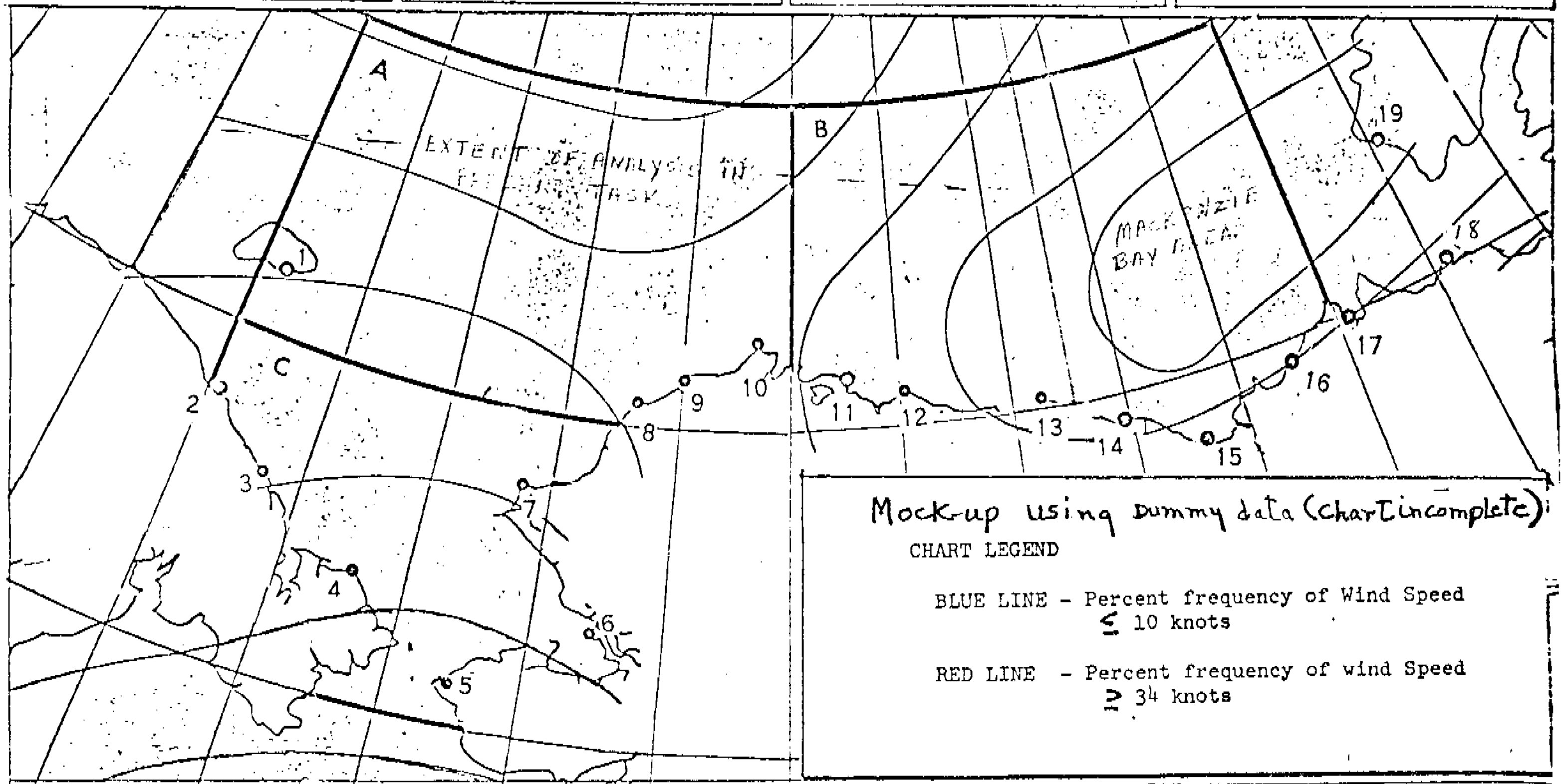
TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	+	+	+	0	0
20.21	2	6	4	+	0
18.19	4	24	26	2	+
16.17	1	10	18	2	+
14.15	+	+	+	+	0
12.13	0	+	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5616

18 Cape Parry
WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
25.27	0	+	0	0	0
24.25	+	+	+	0	0
22.23	-	+	+	+	0
20.21	+	1	1	+	0
18.19	1	5	5	1	+
15.17	2	12	13	2	+
14.15	2	11	12	2	+
12.13	1	8	10	3	+
10.11	+	2	2	1	+
8.5	+	+	+	+	+
6.7	0	0	+	0	0

7176



Mock-up using Dummy data (Chart incomplete)

CHART LEGEND

BLUE LINE - Percent frequency of Wind Speed ≤ 10 knots

RED LINE - Percent frequency of wind Speed ≥ 34 knots

19 Sachs Harbour
WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
25.27	0	+	0	0	0
24.25	+	+	+	0	0
22.23	-	+	+	+	0
20.21	+	1	1	+	0
18.19	1	5	5	1	+
16.17	2	12	13	2	+
14.15	2	11	12	2	+
12.13	1	8	10	3	+
10.11	+	2	2	1	+
8.5	+	+	+	+	+
6.7	0	0	+	0	0

7176

A Beaufort ~~Marine~~ Sea
WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	+	+	+	0	0
20.21	2	6	4	+	0
18.19	4	24	26	2	+
16.17	1	10	18	2	+
14.15	+	+	+	+	0
12.13	0	+	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
5.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5616

B Beaufort ~~Marine~~ Sea
WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	+	0	0	0
20.21	0	+	+	+	0
18.19	+	+	+	+	0
16.17	+	1	2	+	0
14.15	1	4	5	1	+
12.13	1	10	12	3	+
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	+	1	1	1	+
4.5	+	+	+	+	0
2.3	0	0	0	0	0

6054

C Beaufort ~~Marine~~ Sea
WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	+	0	0
20.21	+	+	+	0	0
18.19	+	+	+	+	0
16.17	+	1	1	+	0
14.15	+	2	4	1	+
12.13	1	6	11	4	+
10.11	2	10	15	6	+
8.9	1	7	12	5	1
6.7	+	3	3	2	+
4.5	+	+	+	+	+
2.3	0	+	+	+	0

4511

ANALYSIS OF MACKENZIE BAY AREA WILL BE INCLUDED PENDING APPROVAL OF AEIDC/NCC MACKENZIE PROPOSAL FOR FY-76T

BERING SEA

TLAS OCATOR	(WMO NO.) WBAN NO.	NAME	LAT°' LON°'	P.O.R.	GRAPH ID
1	(25594)	BUHTA PROVIDENIJA	64°-26'N; 173°-14'W	1/59-6/71	94/5594
2	26703	GAMBELL	63°-46'N; 171°-45'W	7/48-6/53	28/6703
3	26632	NORTHEAST CAPE	63°-19'N; 168°-58'W	1/53-11/68	25/6632
4	26617	NOME	64°-30'N; 165°-26'W	1/45-12/74	21/6617
5	26620	MOSES POINT	64°-12'N; 162°-03'W	7/48-6/67	22/6620
6	26627	UNALAKLEET	63°-53'N; 160°-48'W	7/48-12/$\overset{7}{6}$4	23/6627
7	26633	CAPE ROMANZOF	61°-47'N; 166°-02'W	3/53-11/68	26/6633
8	26615	BETHEL	60°-47'N; 161°-48'W	7/48-12/71	19/6615
9	25623	CAPE NEWENHAM	58°-39'N; 162°-04'W	7/53-12/70	9/5623
10	25503	KING SALMON	58°-41'N; 156°-39'W	1/49-12/74	6/5503
11	25713	ST. PAUL ISLAND	57°-09'N; 170°-13'W	1/56-12/74	14/5713
12	25625	PORT MOLLOR	56°-00'N; 160°-31'W	6/59-11/68	11/5625
13	25515	DRIFTWOOD BAY	53°-58'N; 166°-51'W	7/59-5/69	8/5515
14	25626	NIKOLSKI	52°-55'N; 168°-47'W	6/59-11/68	12/5626
15	25704	ADAK	51°-53'N; 176°-38'W	1/49-12/74	13/5704

	AREA NO.	MARINE AREAS			
A	11		60°-65°N; 180°W COAST	1872-1974	61
B	9		55°-60°N; 175°-167°W	" "	59
C	10		55°-60°N; 167°W COAST	" "	60
D	8		50°-55°N; 180°-172°W	" "	58
E	7		50°-55°N; 172°-165°W	" "	57

1 Buhta Providenija

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	+	0	0	0
20.21	0	+	+	+	0
18.19	+	+	+	+	0
16.17	+	1	2	+	0
14.15	1	4	5	1	+
12.13	1	10	12	3	+
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	+	1	1	1	+
4.5	+	+	+	+	0
2.3	0	0	0	0	0

6054

2 Gambell

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	+	0	0
20.21	+	+	+	0	0
19.15	+	+	+	+	0
15.17	+	1	1	+	0
14.15	+	2	4	1	+
12.13	1	6	11	4	+
10.11	2	10	15	6	+
8.9	1	7	12	5	1
6.7	+	3	3	2	+
4.5	+	+	+	+	+
2.3	0	+	+	+	0

4511

3 Northeast Cape

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
26.27	0	+	0	0	0
24.25	+	+	+	0	0
22.23	+	+	+	+	0
20.21	+	1	1	+	0
18.19	1	5	5	1	+
16.17	2	12	13	2	+
14.15	2	11	12	2	+
12.13	1	8	10	3	+
10.11	+	2	2	1	+
8.9	+	+	+	+	+
6.7	0	0	+	0	0

7176

Nome

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	+	+	+	0	0
20.21	2	6	4	+	0
18.19	4	24	26	2	+
16.17	1	10	18	2	+
14.15	+	+	+	+	0
12.13	0	+	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5616

5 Moses Point

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
25.27	0	+	0	0	0
24.25	+	+	+	0	0
22.23	+	+	+	+	0
20.21	+	1	1	+	0
18.19	1	5	5	1	+
16.17	2	12	13	2	+
14.15	2	11	12	2	+
12.13	1	8	10	3	+
10.11	+	2	2	1	+
8.9	+	+	+	+	+
6.7	0	0	+	0	0

7176

6 Unalakleet

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	+	+	+	0	0
20.21	2	6	4	+	0
18.19	4	24	26	2	+
15.17	1	10	18	2	+
14.15	+	+	+	+	0
12.13	0	+	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5616

7 Cape Romanzof

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	+	0	0
20.21	+	+	+	0	0
18.19	+	+	+	+	0
16.17	+	1	1	+	0
14.15	+	2	4	1	+
12.13	1	6	11	4	+
10.11	2	10	15	6	+
8.9	1	7	12	5	1
6.7	+	3	3	2	+
4.5	+	+	+	+	+
2.3	0	+	+	+	0

4511

8 Bethel

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	+	0	0	0
20.21	0	+	+	+	0
18.19	+	+	+	+	0
16.17	+	1	2	+	0
14.15	1	4	5	1	+
12.13	1	10	12	3	+
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	+	1	1	1	+
4.5	+	+	+	+	0
2.3	0	0	0	0	0

6054

9 Cape Newenham

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	+	0	0	0
20.21	0	+	+	+	0
18.19	+	+	+	+	0
16.17	+	1	2	+	0
14.15	1	4	5	1	+
12.13	1	10	12	3	+
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	+	1	1	1	+
4.5	+	+	+	+	0
2.3	0	0	0	0	0

6054

10 King Salmon

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	+	0	0
20.21	+	+	+	0	0
18.19	+	+	+	+	0
16.17	+	1	1	+	0
14.15	+	2	4	1	+
12.13	1	6	11	4	+
10.11	2	10	15	6	+
8.9	1	7	12	5	1
6.7	+	3	3	2	+
4.5	+	+	+	+	+
2.3	0	+	+	+	0

4511

11 St. Paul Island

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	+	0	0	0
20.21	0	+	+	+	0
18.19	+	+	+	+	0
16.17	+	1	2	+	0
14.15	1	4	5	1	+
12.13	1	10	12	3	+
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	+	1	1	1	+
4.5	+	+	+	+	0
2.3	0	0	0	0	0

6054

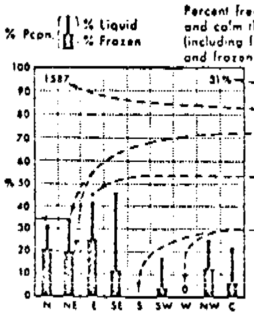
12 Port Moller

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
26.27	0	+	0	0	0
24.25	+	+	+	0	0
22.23	+	+	+	+	0
20.21	+	1	1	+	0
18.19	1	5	5	1	+
16.17	2	12	13	2	+
14.15	2	11	12	2	+
12.13	1	8	10	3	+
10.11	+	2	2	1	+
8.9	+	+	+	+	+
6.7	0	0	+	0	0

7176

Legend



Percent frequency of observations with surface winds from each direction and calm that were accompanied by precipitation, [illegible] divided into liquid type (including freezing rain and freezing drizzle) and frozen type (including liquid and frozen types falling simultaneously).

–Percentage of present weather reporting precipitation.

–Number of observations.

– – –(34% of all NE winds were accompanied by precipitation, of which 14% was liquid and 20% was frozen.)

–An asterisk in the column for a given direction (or calm) indicates percentages were based on 10-30 observations of present weather and wind direction.

–0 replaces bar when no precipitation was observed with winds from a given direction (or calm). No bar graph is presented if less than 10 observations containing present weather are reported for a given direction (or calm).

13 Driftwood Bay

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
28.29	+	+	0	0	0
26.27	0	+	+	0	0
24.25	+	+	+	+	0
22.23	1	3	2	+	+
20.21	1	6	6	+	0
18.19	1	11	12	1	+
16.17	2	11	13	2	+
14.15	1	6	7	1	+
12.13	1	3	3	1	+
10.11	+	+	+	+	+
8.9	0	+	0	+	0

5121

14 Nikolski

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
24.25	+	+	+	0	0
22.23	1	5	4	+	0
20.21	4	16	20	1	0
18.19	2	16	25	2	0
16.17	+	1	2	+	0
14.15	+	0	0	0	0
12.13	0	0	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0

5545

15 Adak

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
14.15	0	+	+	0	0
12.13	+	1	1	1	+
10.11	1	5	9	4	+
8.9	3	16	28	14	1
6.7	1	3	7	4	+
4.5	0	0	+	+	+
2.3	0	0	0	0	0
0.1	0	0	0	0	0
-2.-1	0	0	0	0	0
-4.-3	0	0	0	0	0
-6.-5	0	0	0	0	0

A Bering Sea

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	+	0	0	0
20.21	0	+	+	+	0
18.19	+	+	+	+	0
16.17	+	1	2	+	0
14.15	1	4	5	1	+
12.13	1	10	12	3	+
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	+	1	1	1	+
4.5	+	+	+	+	0
2.3	0	0	0	0	0

6054

B Bering Sea

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	+	0	0
20.21	+	+	+	0	0
18.19	+	+	+	+	0
16.17	+	1	1	+	0
14.15	+	2	4	1	+
12.13	1	6	11	4	+
10.11	2	10	15	6	+
8.9	1	7	12	5	1
6.7	+	3	3	2	+
4.5	+	+	+	+	+
2.3	0	+	+	+	0

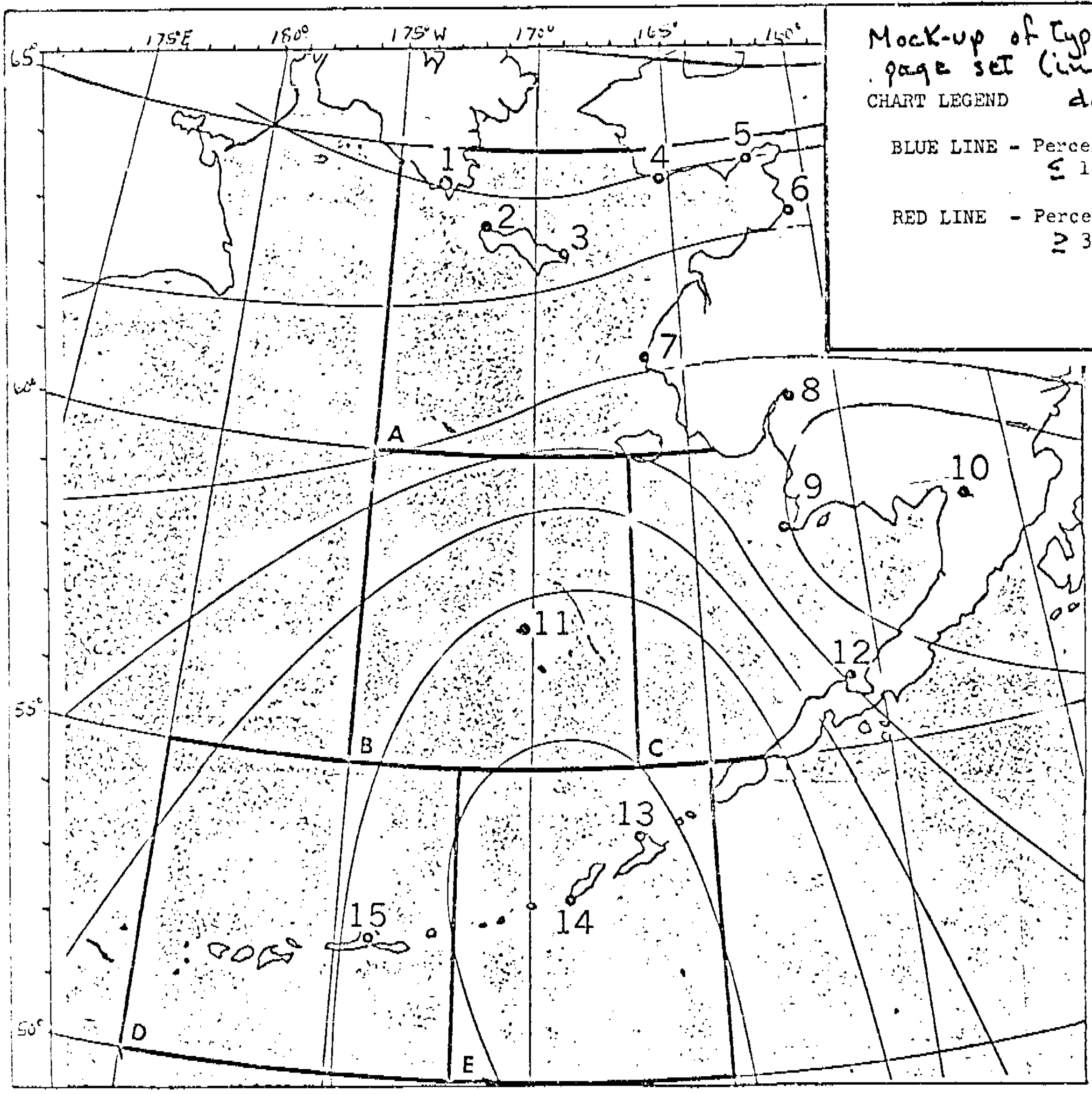
4511

C Bering Sea

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
26.27	0	+	0	0	0
24.25	+	+	+	0	0
22.23	+	+	+	+	0
20.21	+	1	1	+	0
18.19	1	5	5	1	+
16.17	2	12	13	2	+
14.15	2	11	12	2	+
12.13	1	8	10	3	+
10.11	+	2	2	1	+
8.9	+	+	+	+	+
6.7	0	0	+	0	0

7176



Mock-up of typical Atlas graphs-chart page set (incomplete - using dummy data)

CHART LEGEND

BLUE LINE - Percent frequency of Wind Speed ≤ 10 knots

RED LINE - Percent frequency of wind Speed ≥ 34 knots

D Bering Sea

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	+	+	+	0	0
20.21	2	6	4	+	0
18.19	4	24	25	2	+
16.17	1	10	18	2	+
14.15	+	+	+	+	0
12.13	0	+	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5616

E Bering Sea

WIND SPEED (KTS)

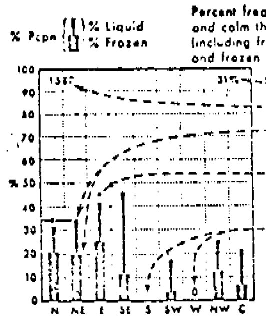
TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
26.27	0	+	+	0	0
24.25	0	+	+	0	0
22.23	0	+	+	+	0
20.21	+	+	+	0	0
18.19	+	2	2	+	+
16.17	1	6	6	1	+
14.15	2	11	11	2	+
12.13	2	13	15	3	+
10.11	1	6	8	2	+
8.9	+	1	1	+	+
6.7	+	+	+	0	0

6741

GULF OF ALASKA

ATLAS LOCATOR	WBAN No.	NAME	LAT °′ LON °′	P.O.R.	GRAPH I.D.
1	26524	COLd BAY	55°-12′N; 162°-43′W	7/55 - 12/74	10 / 5624
2	25501	KodiAK	57°-45′N; 152°-20′W	11/45 - 12/74	5 / 5501
3	25507	HOMER	59°-38′N; 151°-30′W	7/48 - 12/74	7 / 5507
4	26523	KENAi	60°-34′N; 151°-15′W	7/48 - 1/71	18 / 6523
5	26451	ANCHORAGE	61°-10′N; 149-59′W	11/52 - 12/74	17 / 6451
6	26410	CORdOVA	60°-30′N; 145°-30′W	1/45 - 1/71	15 / 6410
7	25403	MiddLETON ISLANd	59°-27′N; 146°-19′W	7/48 - 6/63	4 / 5403
8	26445	YAKATAGA	60°-05′N; 142°-30′W	7/48 - 5/68	16 / 6445
9	25339	YAKuTAT	59°-31′N; 139°-40′W	8/48 - 12/74	3 / 5339
10	25333	SiTKA	57°-04′N; 135°-21′W	7/48 -- 1/71	2 / 5333
11	25308	ANNETTE ISLANd	55°-02′N; 131°-134′W	7/42 - 12/74	1 / 5308
	AREA No.	MARINE AREAS			
A	6		52°N COAST; 165°-156°W	1872 - 1974	56
B	5		54°-57°N; 156°-150°W	" "	55
C	4		57°N-COAST; COAST-150°W	" "	54
D	3		56°N-COAST; 150°-144°W	" "	53
E	2		56°N-COAST; 144°-137°W	" "	52
F	1		54°N-COAST; 137°W COAST	" "	51

Legend



Percent frequency of observations with surface winds from each direction and calm that were accompanied by precipitation, subdivided into liquid type (including freezing rain and freezing drizzle) and frozen type (including liquid and frozen types falling simultaneously).

Percentage of present weather reporting precipitation.

Number of observations.

(34% of all NE winds were accompanied by precipitation, of which 14% was liquid and 20% was frozen.)

An asterisk in the column for a given direction (or calm) indicates percentages were based on 10-30 observations of present weather and wind direction.

0 replaces bar when no precipitation was observed with winds from a given direction (or calm). No bar graph is presented if less than 10 observations containing present weather are reported for a given direction (or calm).

1 Cold Bay

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	*	0	0
20.21	*	*	*	0	0
18.19	*	*	*	*	0
16.17	*	1	1	*	0
14.15	*	2	4	1	*
12.13	1	6	11	4	*
10.11	2	10	15	6	*
8.9	1	7	12	5	1
6.7	*	3	3	2	*
4.5	*	*	*	*	*
2.3	0	*	*	*	0

4511

2 Kodiak

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	*	0	0	0
20.21	0	*	*	*	0
18.19	*	*	*	*	0
16.17	*	1	2	*	0
14.15	1	4	5	1	*
12.13	1	10	12	3	*
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	*	1	1	1	*
4.5	*	*	*	*	0
2.3	0	0	0	0	0

6054

3 Homer

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	*	0	0
20.21	*	*	*	0	0
18.19	*	*	*	*	0
16.17	*	1	1	*	0
14.15	*	2	4	1	*
12.13	1	6	11	4	*
10.11	2	10	15	6	*
8.9	1	7	12	5	1
6.7	*	3	3	2	*
4.5	*	*	*	*	*
2.3	0	*	*	*	0

4511

4 Kenai

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
25.27	0	*	0	0	0
24.25	*	*	*	0	0
22.23	*	*	*	*	0
20.21	*	1	1	*	0
18.19	1	5	5	1	*
16.17	2	12	13	2	*
14.15	2	11	12	2	*
12.13	1	8	10	3	*
10.11	*	2	2	1	*
8.9	*	*	*	*	*
6.7	0	0	*	0	0

7176

5 Anchorage

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	*	*	*	0	0
20.21	2	6	4	*	0
18.19	4	24	26	2	*
16.17	1	10	18	2	*
14.15	*	*	*	*	0
12.13	0	*	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5616

6 Cordova

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
25.27	0	*	0	0	0
24.25	*	*	*	0	0
22.23	*	*	*	*	0
20.21	*	1	1	*	0
18.19	1	5	5	1	*
16.17	2	12	13	2	*
14.15	2	11	12	2	*
12.13	1	8	10	3	*
10.11	*	2	2	1	*
8.9	*	*	*	*	*
6.7	0	0	*	0	0

7176

7 Middleton Island

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	*	*	*	0	0
20.21	2	6	4	*	0
18.19	4	24	25	2	*
16.17	1	10	18	2	*
14.15	*	*	*	*	0
12.13	0	*	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5616

8 Yakataga

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	*	0	0	0
20.21	0	*	*	*	0
18.19	*	*	*	*	0
16.17	*	1	2	*	0
14.15	1	4	5	1	*
12.13	1	10	12	3	*
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	*	1	1	1	*
4.5	*	*	*	*	0
2.3	0	0	0	0	0

6054

9 Yakutat

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	*	0	0
20.21	*	*	*	0	0
18.19	*	*	*	*	0
16.17	*	1	1	*	0
14.15	*	2	4	1	*
12.13	1	6	11	4	*
10.11	2	10	15	6	*
9.9	1	7	12	5	1
6.7	*	3	3	2	*
4.5	*	*	*	*	*
2.3	0	*	*	*	0

4511

10 Sitka

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	*	0	0
20.21	*	*	*	0	0
18.19	*	*	*	*	0
16.17	*	1	1	*	0
14.15	*	2	4	1	*
12.13	1	6	11	4	*
10.11	2	10	15	6	*
8.9	1	7	12	5	1
6.7	*	3	3	2	*
4.5	*	*	*	*	*
2.3	0	*	*	*	0

4511

11 Annette Isl.

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	*	0	0	0
20.21	0	*	*	*	0
18.19	*	*	*	*	0
16.17	*	1	2	*	0
14.15	1	4	5	1	*
12.13	1	10	12	3	*
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	*	1	1	1	*
4.5	*	*	*	*	0
2.3	0	0	0	0	0

6054

A Gulf of Alaska

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
26.27	0	*	0	0	0
24.25	*	*	*	0	0
22.23	*	*	*	*	0
20.21	*	1	1	*	0
18.19	1	5	5	1	*
16.17	2	12	13	2	*
14.15	2	11	12	2	*
12.13	1	8	10	3	*
10.11	*	2	2	1	*
8.9	*	*	*	*	*
6.7	0	0	*	0	0

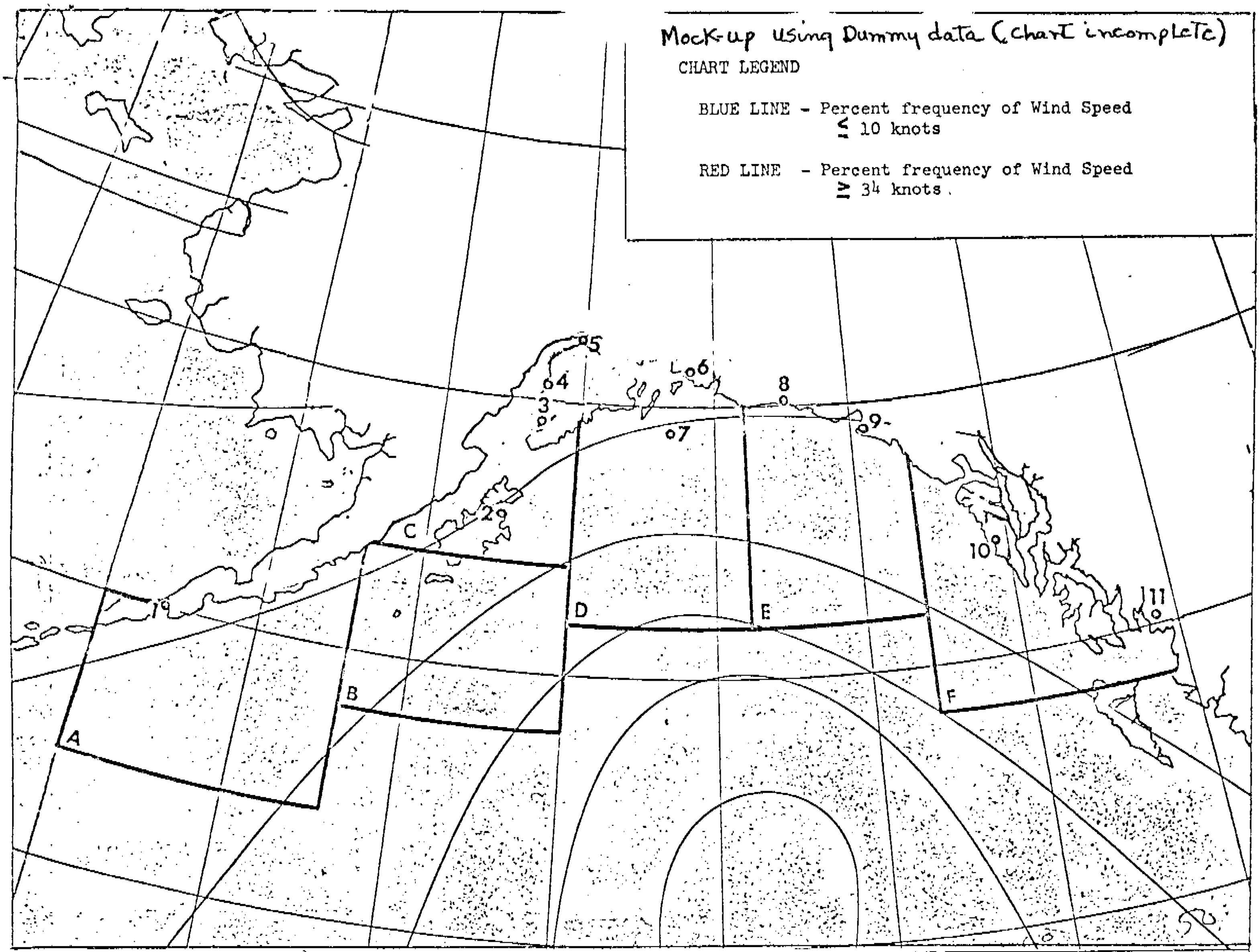
7176

B Gulf of Alaska

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	*	*	*	0	0
20.21	2	6	4	*	0
18.19	4	24	26	2	*
16.17	1	10	18	2	*
14.15	*	*	*	*	0
12.13	0	*	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5616



Mock-up using Dummy data (chart incomplete)

CHART LEGEND

BLUE LINE - Percent frequency of Wind Speed ≤ 10 knots

RED LINE - Percent frequency of Wind Speed ≥ 34 knots.

C Gulf of Alaska

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
25.27	0	+	0	0	0
24.25	+	+	+	0	0
22.22	+	+	+	+	0
20.21	+	1	1	+	0
18.19	1	5	5	1	+
16.17	2	12	13	2	+
14.15	2	11	12	2	+
12.13	1	8	10	3	+
10.11	+	2	2	1	+
8.9	+	+	+	+	+
6.7	0	0	+	0	0

7176

D Gulf of Alaska

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	0	+	0	0
20.21	+	+	+	0	0
18.19	+	+	+	+	0
16.17	+	1	1	+	0
14.15	+	2	4	1	+
12.13	1	6	11	4	+
10.11	2	10	15	6	+
8.9	1	7	12	5	1
6.7	+	3	3	2	+
4.5	+	+	+	+	+
2.3	0	+	+	+	0

4511

E Gulf of Alaska

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	0	+	0	0	0
20.21	0	+	+	+	0
18.19	+	+	+	+	0
16.17	+	1	2	+	0
14.15	1	4	5	1	+
12.13	1	10	12	3	+
10.11	2	11	15	4	1
8.9	1	7	10	3	1
6.7	+	1	1	1	+
4.5	+	+	+	+	0
2.3	0	0	0	0	0

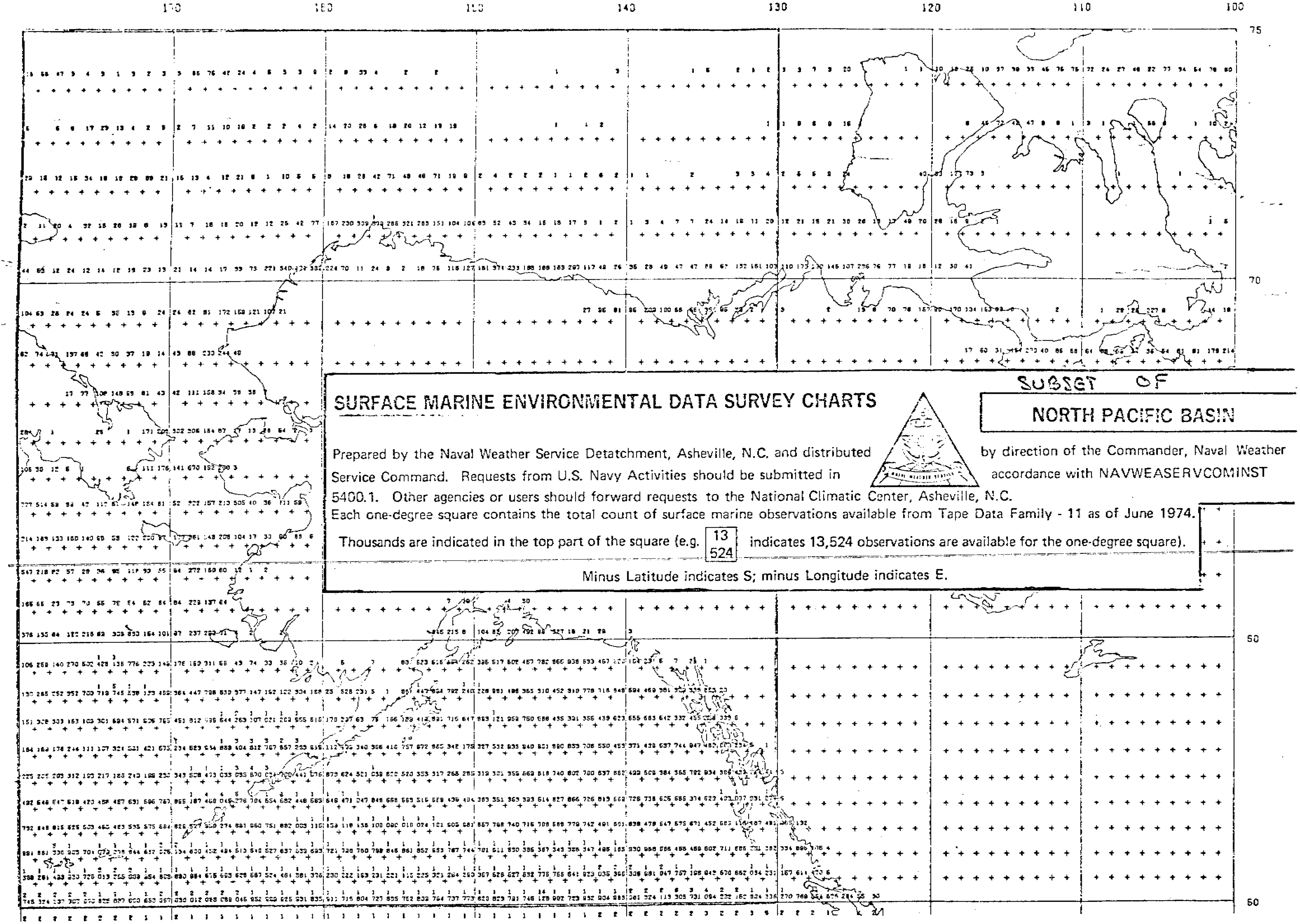
6054

F Gulf of Alaska

WIND SPEED (KTS)

TEMP (°C)	0-3	4-10	11-21	22-33	≥ 34
22.23	+	+	+	0	0
20.21	2	6	4	+	0
18.19	4	24	25	2	+
16.17	1	10	18	2	+
14.15	+	+	+	+	0
12.13	0	+	0	0	0
10.11	0	0	0	0	0
8.9	0	0	0	0	0
6.7	0	0	0	0	0
4.5	0	0	0	0	0
2.3	0	0	0	0	0

5616



SUBSET OF

NORTH PACIFIC BASIN

SURFACE MARINE ENVIRONMENTAL DATA SURVEY CHARTS

Prepared by the Naval Weather Service Detatchment, Asheville, N.C. and distributed by direction of the Commander, Naval Weather Service Command. Requests from U.S. Navy Activities should be submitted in accordance with NAVWEASERVCOMINST 5400.1. Other agencies or users should forward requests to the National Climatic Center, Asheville, N.C.

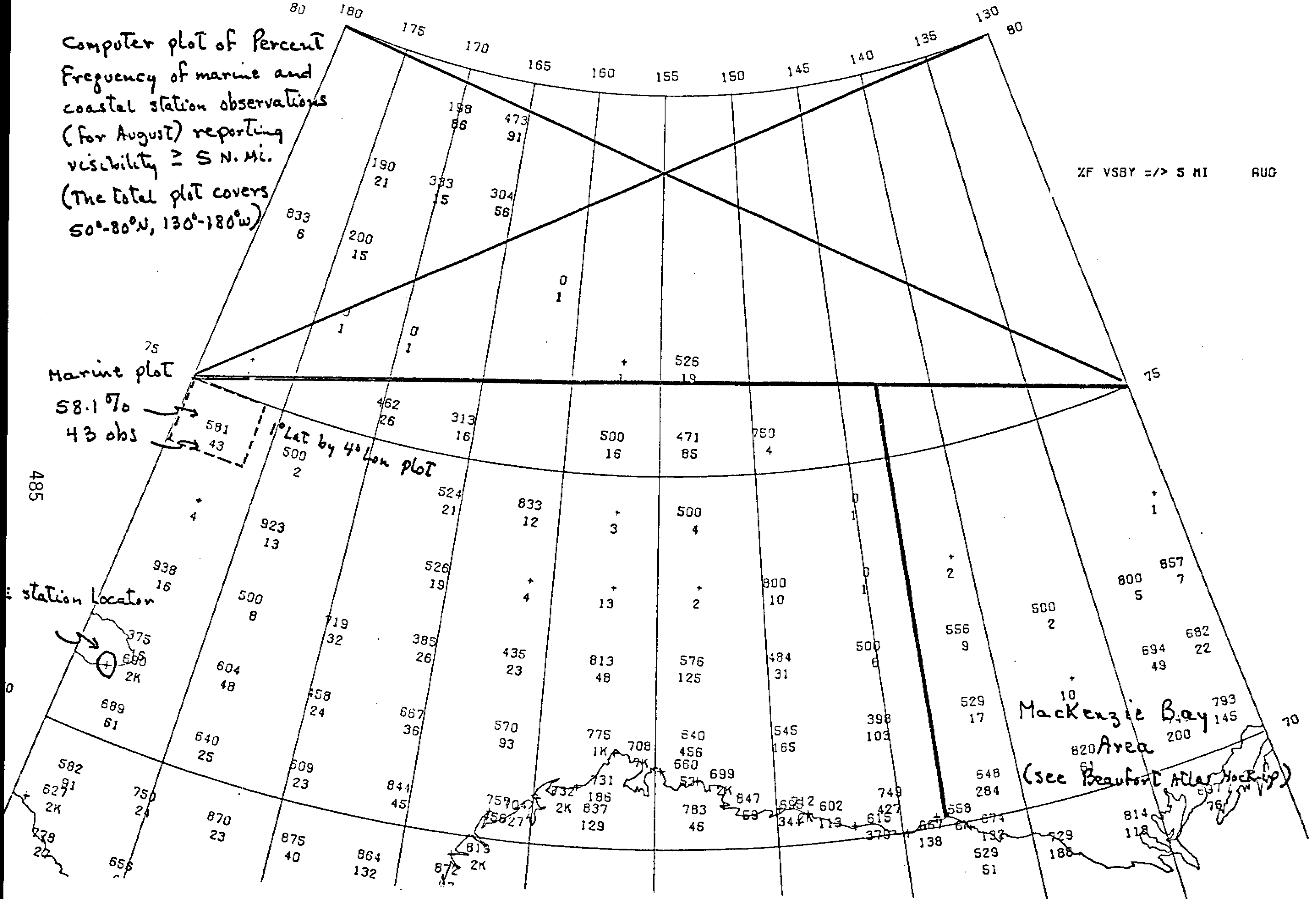
Each one-degree square contains the total count of surface marine observations available from Tape Data Family - 11 as of June 1974.

Thousands are indicated in the top part of the square (e.g. $\boxed{\begin{array}{c}13\\524\end{array}}$ indicates 13,524 observations are available for the one-degree square).

Minus Latitude indicates S; minus Longitude indicates E.

ALASKAN MARINE AREA (50°-75°N ; 130°-180°W)

Computer plot of Percent Frequency of marine and coastal station observations (for August) reporting visibility ≥ 5 N. Mi. (The total plot covers 50°-80°N, 130°-180°W)



Marine plot 58.1% 43 obs

1° Lat by 4° Lon plot

station Location

MacKenzie Bay Area (see Beaufort Atlas Mock-up)

QUARTERLY REPORT

RU 347-A
Contract 03-5-022-56
Task Order Number 25
Quarter Ending -
30 June 1976

MARINE CLIMATOLOGY OF THE GULF OF ALASKA AND THE BERING AND BEAUFORT SEAS

Harold Searby
Climatologist
Arctic Environmental Information & Data Center
University of Alaska
Anchorage, Alaska 99501

June 30, 1976

QUARTERLY REPORT

I. Task Objectives

To determine and publish the knowledge of the climatological conditions of that portion of Alaska that is important to OCS development.

II. Field and Laboratory Activities

This portion of the project has no field or laboratory activities. It is a joint project with the National Climatic Center (NCC) in Asheville, North Carolina. Arctic Environmental Information & Data Center responsibilities are to provide extremes of all weather elements, information on coastal damage resulting from wind generated storm flooding, check analysis work done at NCC, and through our graphics department, prepare materials for publication, including contracting for and supervising the publication of the three marine atlases.

III. Results

To date about 95 percent of the extremes data has been compiled, and additional storm surge information is being sought. Approximately 10 percent of the data analysis work from the NCC has been received. Our graphics department has completed two of the three base maps to be used in the publication. The third map of the Beaufort Sea is awaiting completion depending on whether or not to include the Mackenzie Delta locations. For the most part, graphics work has been slow due to the pressure of high priority internal projects; however, graphics work will proceed faster during the next quarter. A coordination trip was made this quarter to NCC and another is anticipated within the next six months.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: June 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 25 R.U. NUMBER: 347

PRINCIPAL INVESTIGATOR: Mr. Harold W. Searby

No environmental data are to be taken by this task order as indicated in the Data Management Plan. A schedule of submission is therefore not applicable[1].

NOTE: [1] Data Management Plan has been approved and made contractual.

QUARTERLY REPORT

Research Unit #357
Reporting Period 4/1/76-6/30/76
Number of Page 1 + 132

PHYSICAL OCEANOGRAPHY OF THE GULF OF ALASKA

Co-Principal Investigators:

F. Favorite, NOAA, NMFS, NWFC

and

J. H. Johnson, NOAA, NMFS, PEG

July 1, 1976

QUARTERLY REPORT

I. Task Objectives

A concise summary of the physical oceanography of the Gulf of Alaska with emphasis on water circulation and transport is compiled to provide background information for OCSEAP field programs which should assist in determining the location and intensity of direct current measurements required to define patterns in this highly complex flow regime.

II. Field or Laboratory Activities

Analysis completed.

III. Results

Final report completed and attached.

IV. Preliminary Interpretation of Results

See attached report .

V. Problems Encountered/Recommended Changes

Final report submitted one quarter early.

VI. Estimate of Funds Expended

Account exhausted, contract complete.

NORTHWEST FISHERIES CENTER

PROCESSED REPORT

JULY 1976

PHYSICAL OCEANOGRAPHY OF THE GULF OF ALASKA

by

W. J. Ingraham, Jr., A. Bakun and F. Favorite

FINAL REPORT

RU - 357

ENVIRONMENTAL ASSESSMENT of the ALASKAN CONTINENTAL SHELF

Sponsored by

UNITED STATES DEPARTMENT of INTERIOR

Bureau of Land Management

Prepared by:
Northwest Fisheries Center
National Marine Fisheries Service
2725 Montlake Boulevard E.
Seattle, Washington 98112

PHYSICAL OCEANOGRAPHY OF THE GULF OF ALASKA

PHYSICAL OCEANOGRAPHY OF THE GULF OF ALASKA

INTRODUCTION

Although extensive oceanographic investigations have been carried out in the Gulf of Alaska in the last two decades, our knowledge of actual conditions and processes and their cause and effect is still inadequate to permit any accurate short- or long-term forecasts of oceanic conditions. However, a fairly extensive data base exists, and the purpose of this report is to summarize the state of our knowledge concerning the physical environment of offshore areas of the Gulf of Alaska prior to the commencement of present OCSEAP[1] investigations. The Gulf of Alaska is considered to extend southward from the coast to a line from Dixon Entrance to Unimak Pass, essentially 54°N.

It should be recognized at the outset that the ocean is a turbulent regime that can be characterized only by statistical techniques based on extensive time-series data on water properties and direct current measurements collected on appropriate space scales. Such data are not available for the Gulf of Alaska area. Physical oceanographic studies up to the present time have been limited to aperiodic, widely-spaced station data of an exploratory nature obtained primarily to provide background information on general flow and ranges of environmental conditions related to specific aspects of fisheries investigations (Favorite, 1975). The most recent and comprehensive are those of the International North Pacific Fisheries Commission (INPFC). General environmental conditions in the Subarctic Pacific Region for the years 1953 to 1971 have been summarized by Dodimead, Favorite and Hirano (1963), and Favorite, Dodimead and Nasu (1976); the latter provides an extensive bibliography that is not reproduced in this

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[1] Outer Continental Shelf Environmental Assessment Program.

report. There is also extensive but fragmentary information available in reports of results of Soviet fishing activities (e.g. Moiseev,1963-70).[2/] Although the presently available station data are extensive, they are aperiodic, non-synoptic and lack the close grid spacing, wide area coverage, repetitive observations, and direct current measurements necessary to characterize the specific nature of flow.

A general assessment of oceanographic conditions can be made from knowledge of meteorology and bathymetry. With respect to water properties, we can expect seasonal changes in both temperature and salinity. Northward flow into the gulf brings unseasonably warm water into the gulf year round. Winter cooling will gradually erode the high temperatures in surface layer, but these will quickly be restored by seasonal warming in spring and summer. The vertical extent of winter cooling or convective overturn will depend on the stability of the water column, and this is affected primarily by the distribution of salinity with depth. Because there is an excess of precipitation over evaporation and extensive dilution in spring and summer from the extensive coastal watershed, a dilute surface layer can be expected to be underlain by a halocline. The readjustment of mass as a result of the general cyclonic flow around the gulf will result in a horizontal divergence and an upward vertical transfer in the center of the gulf. This is manifested in a doming or ridging of isolines of water properties in that area resulting in high salinities and low temperatures at the surface, particularly during winter when this process is most active.

There is a general eastward surface flow across the North Pacific Ocean composed of the northern sector of the anticyclonic flow in the central North Pacific gyre driven by winds associated with the Eastern Pacific high pressure system, and the southern sector of the general cyclonic flow of

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[2/] See also Bogdanov (1961), Plakhotnik (1962), and Filatova (1973).

the Subarctic Pacific gyre, driven by interactions of the Aleutian Low pressure system. This confluence and the subsequent eastward advection of meridional admixtures of subarctic and subtropic waters is subjected to various bathymetric conditions on reaching the eastern side of the ocean: first, a gradual shoaling, reducing the water column by half (from 6,000 - 3,000 m); second, the interference of numerous seamounts, (some extending to within 500 m of the surface); and, finally, an abrupt continental shelf. This results in marked changes in the fields of acceleration, vorticity and turbulence, as well as a predominant separation of flow into northward and southward components and associated disturbances of vertical strata. The northward branch, increasing in planetary vorticity, impinges on the head of the Gulf of Alaska where it is constrained by the land mass and is forced southwestward along the Alaska Peninsula. In order to accomplish this it must displace the northeastward flow into the gulf offshore, away from the continental slope. The vorticity balance of this southwestward flow is altered not only as a result of southward displacement, but also as a result of increasing depth (5,000 - 7,000 m) on encountering the eastern end of the Aleutian Trench. Further, we can anticipate that frictional and tidal effects on the shallow continental shelf will result in considerably reduced flow over the shelf compared to flow along and seaward of the continental slope, and that flow along the edge of the shelf will be complicated by internal waves and horizontal shelf waves.

The greatest fluctuations in flow conditions will be associated with the intensification of winds in winter. The center of the Aleutian Low travels in an anticyclonic pattern; present in late spring and summer in the northern Bering Sea, it occurs in the Gulf of Alaska in late fall, and in the western Aleutian area in winter. Thus, maximum cyclonic winds occur in the Gulf of Alaska from November to January. Maximum Ekman transport will occur at this time, piling up water along the coast and resulting in a seaward flow along the bottom. Maximum total transport also occurs at this time greatly increasing northward flow into the gulf. In summer, a northward displacement of the Eastern Pacific High results in anticyclonic winds resulting in an offshore component of Ekman transport at the surface and a compensatory onshore flow over the continental shelf. Minimum overall transport also occurs at this time.

Thus there is a potential for considerable complexity and great variability in actual conditions, and it is these time-dependent phenomena that we are most interested in. All data available will be used to define physical conditions in the gulf as accurately and completely as possible.

It is difficult to assess how representative the oceanographic data being collected or analyzed are in defining conditions in a particular area unless some measure of variability over extended time periods is available. About a century ago it was recognized that oceanic conditions in the gulf were considerably warmer than corresponding latitudes at the western side of the ocean (Dall, 1882) and this was attributed to the influence of the "Kuro Siwo" because of the known analogous effects of the Gulf Stream in the Atlantic Ocean on the climate of Europe. Although data from the "China steamers" between San Francisco, Yokohama and Hong Kong in the 1870's provided extensive data on conditions in the central Pacific Ocean, even the gold rushes and subsequent commercial traffic to Alaska failed to provide a data base documenting oceanographic conditions in the gulf. There are surface temperature data for the Gulf of Alaska from the 19th century, presumably from government and commercial vessels, but these are too fragmentary in time and space to establish climatic trends. Nevertheless, there are historical records of monthly mean air temperatures at Sitka that began when this location, called New Archangel, was controlled by the Russian-America Company (Dall, 1879) that are fairly complete to this date. Considering all years data are available since 1828 (Fig. 1), positive annual anomalies of greater than 1.5C° were recorded in 1829, 1869, 1915, 1926, 1940 and 1941; whereas, only in 1955 did a negative anomaly greater than 1.5C° occur. Cycles of 4-5 year duration are apparent in the data from 1850-71. The period from 1920 to 1947 was characterized by above normal conditions; however, there was a marked decline of over 3C° from 1940 to 1950. Below normal conditions have occurred from 1965 to the present. Perhaps the most significant aspect of these data is that the annual mean temperature for 1828-76 is precisely the same as the present day mean compiled and used by the National Weather Service, 6.3°C (43.3°F). Thus, both short-term fluctuations of 1-4 years and long-term trends, such as the cooling evident from 1940-55 have occurred. Although we have acquired sea level pressure data as far back as 1900, sea level data prior to 1930 are available only at Ketchikan, and oceanographic station data are generally available only since 1950. The longer records will be utilized where applicable, but most comparisons and interactions will of necessity be based on data from the 25-year period 1950-74.

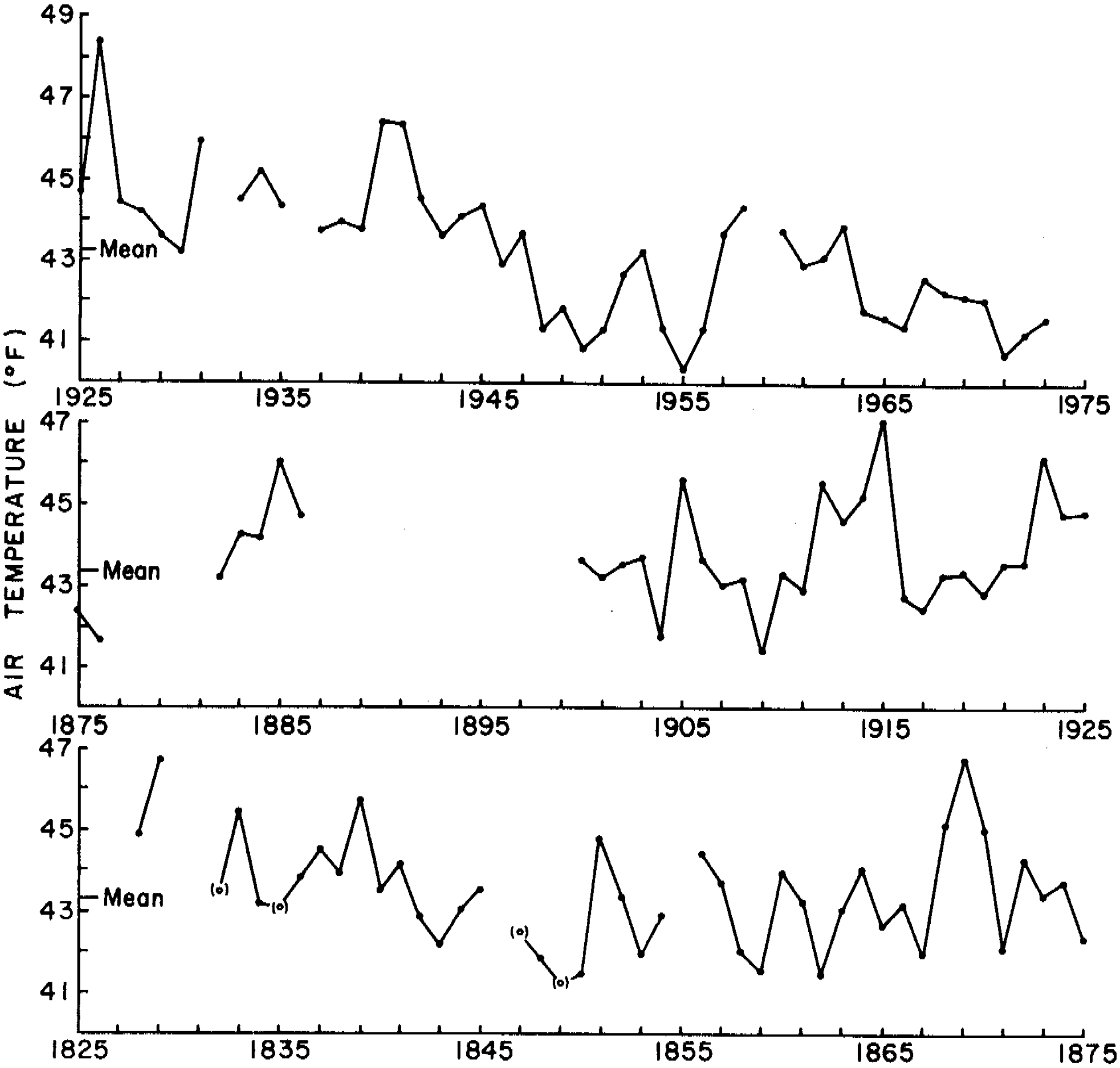

Figure 1. Air temperatures at Sitka (New Archangel) 1828-1974.

II. WATER PROPERTIES

Abrupt changes from normal conditions are usually quickly detected, but gradual changes over long periods often pass unnoticed; nevertheless, quantification of either requires an adequate data base. Reasonably complete time-series data in the gulf are available at shore stations, but none is available at specific locations in oceanic areas of the gulf[3/]. In the latter case, in order to obtain any semblance of time-series data, observations over extensive areas must be averaged over large intervals; such data provide an indication of trends but, obviously, numerous spacial and temporal phenomena are masked by the averaging process.

A. Temperature

Although observations at shore stations are the most complete source of temperature data, only surface values are obtained. Monthly mean values (referred to 1950-74 mean, where data are available) for Ketchikan, Sitka, Yakutat, Seward, Kodiak and Dutch Harbor indicate a progressively colder regime from southeastern Alaska around the gulf to the end of the Alaska Peninsula with one exception, that temperatures in winter at Dutch Harbor are about 2 or 3 C^o higher than at Kodiak (Fig. 2a). In southeastern Alaska the seasonal temperature range is about 9 C^o (from 5 - 14°C at Ketchikan and 3 - 12° at Seward), but the range increases to 11 C^o at Kodiak (1 - 12°) and decreases to 8 C^o at Dutch Harbor. Minima occur in January at Kodiak and in February at all other locations, maxima occur in July at Seward and in August at all other locations.

There are a number of oceanographic atlases of large areas of the Pacific Ocean that permit a general assessment of mean temperatures in the offshore waters of the Gulf of Alaska (e.g. LaViolette and Seim (1969)) present monthly mean, minimum and maximum sea surface temperatures based on a

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[3/] Extensive data are available at Ocean Station "P" southward of the gulf -50^ON, 145^OW (e.g. Tabata 1965 and Fofonoff and Tabata 1966).

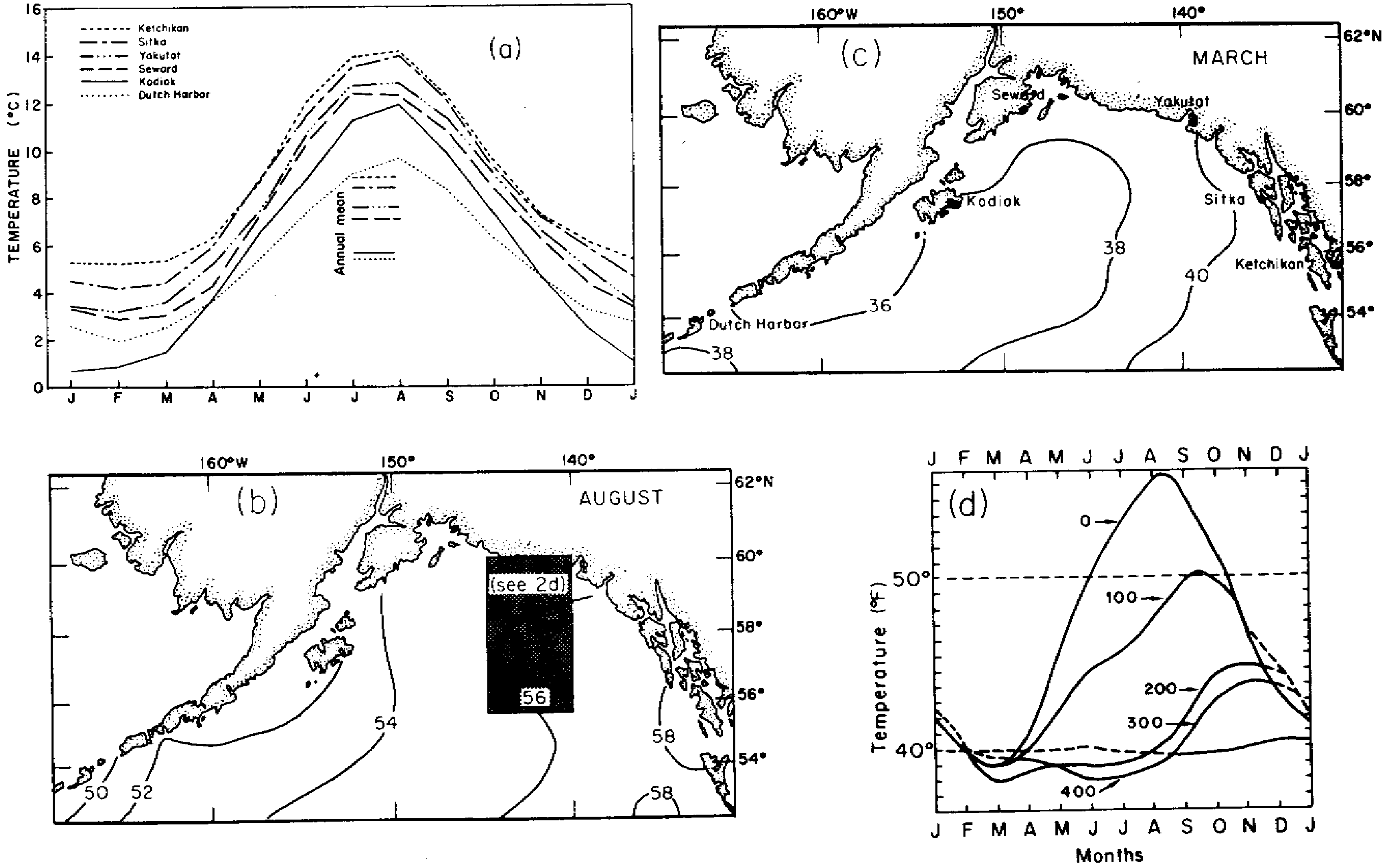

Figure 2. Sea temperature data: (a) monthly mean (1950-74) sea surface temperatures at the indicated coastal stations; (b and c) surface temperature distributions August and March (from Robinson and Bauer, 1971); and (d) monthly mean temperatures at 100 ft (30.5m) intervals to 400 ft (121.9m) in 5x5° Marsden quadrant 195-3, 55-60°N, 140-145°W (from Robinson, 1957).

1 x 1° grid), and there are also a few that are limited specifically to the gulf and adjacent area--e.g. Robinson (1957), Giovando and Robinson (1965) and Robinson and Baur (1971). These data are not only easily accessible, but adequately representative of mean conditions; thus, there is little need for an extensive summary here. It should be pointed out, however, that such atlases are representative only of offshore areas where mixing and stirring moderate the extreme conditions that occur in shallow inshore areas which are influenced by ice-melt in winter and spring, and runoff and warming over tidal shoals in spring and summer[4/]. Maximum surface temperature, 14°C, occurs in August, but conditions are sufficiently similar in September to consider either month as representative, and minimum surface temperature, 3.5°C, occurs in March (Fig. 2b and c) - temperatures of 0°C, or lower, can be found in Prince William Sound and Cook Inlet depending on the extent of ice cover.

A representative seasonal temperature cycle to a depth of 122 m (400 ft) is afforded by a compilation of station and bathythermograph (BT) data in the 5 x 5° quadrangle from 55-60°N, 140-145°W (Fig. 2d). Near isothermal conditions are present from the surface to approximately 100 m during January-March and represent the vertical extent of convective turnover during winter. This process not only determines the extent of the surface layer in winter, but results in the formation of a temperature-minimum stratum (~3°C) at depths of 75 to 150 m when surface waters are warmed in spring and summer. Wind mixing and stirring result in the formation of a warm surface layer in summer of 20-30 m thickness that is underlain by a sharp thermocline extending to the depth of winter overturn. Subsequent downward diffusion in spring, summer and autumn gradually erodes but

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[4/] See Muench and Schmidt (1975) for a discussion of conditions in Prince William Sound.

seldom eliminates the temperature-minimum stratum, particularly in the central part of the gulf. The effects of this process are evident until November. However, year round temperatures of 4.5 to 5.0°C occur near 122 m around the periphery of the gulf, over the continental shelf and slope. These temperatures, 1-2C° higher than those in the temperature-minimum stratum, appear as a mesothermal, or temperature-maximum, stratum, but are merely representative of conditions in the water column below the influence of local seasonal effects.

Further information on conditions at 122 m is provided by a plot of the geographical extent of selected isotherms (Fig. 3a): the zonal trends south of 50°N suggest an eastward flow toward the coast; the abrupt northward trend of the 4.4°C isotherm boundaries west of 140°W suggests a broad variable northward flow into the gulf east of 150°W; the westward continuation of this feature south of the Alaska peninsula suggests a westward return flow in that area; and, finally, the tongue-like area westward of 147°W between 51° and 54° suggests the presence of an eastward intrusion of cold water from the west or an area of upward vertical transfer of cold water from depth, or both. A vertical temperature profile along 145°W (Fig. 3b) based on long-term mean temperatures from all station data (2 x 2° grid) clearly exhibits a ridging of the 4 and 5° isotherms in the zone between 48-57°N; and the effects of temperature on geostrophic flow dictate an eastward, onshore flow to the south of this zone and a westward return flow north of the zone.

Mean temperature distributions below the range of the shallow bathythermograph (450' or 137 m) must be obtained from station data and are not

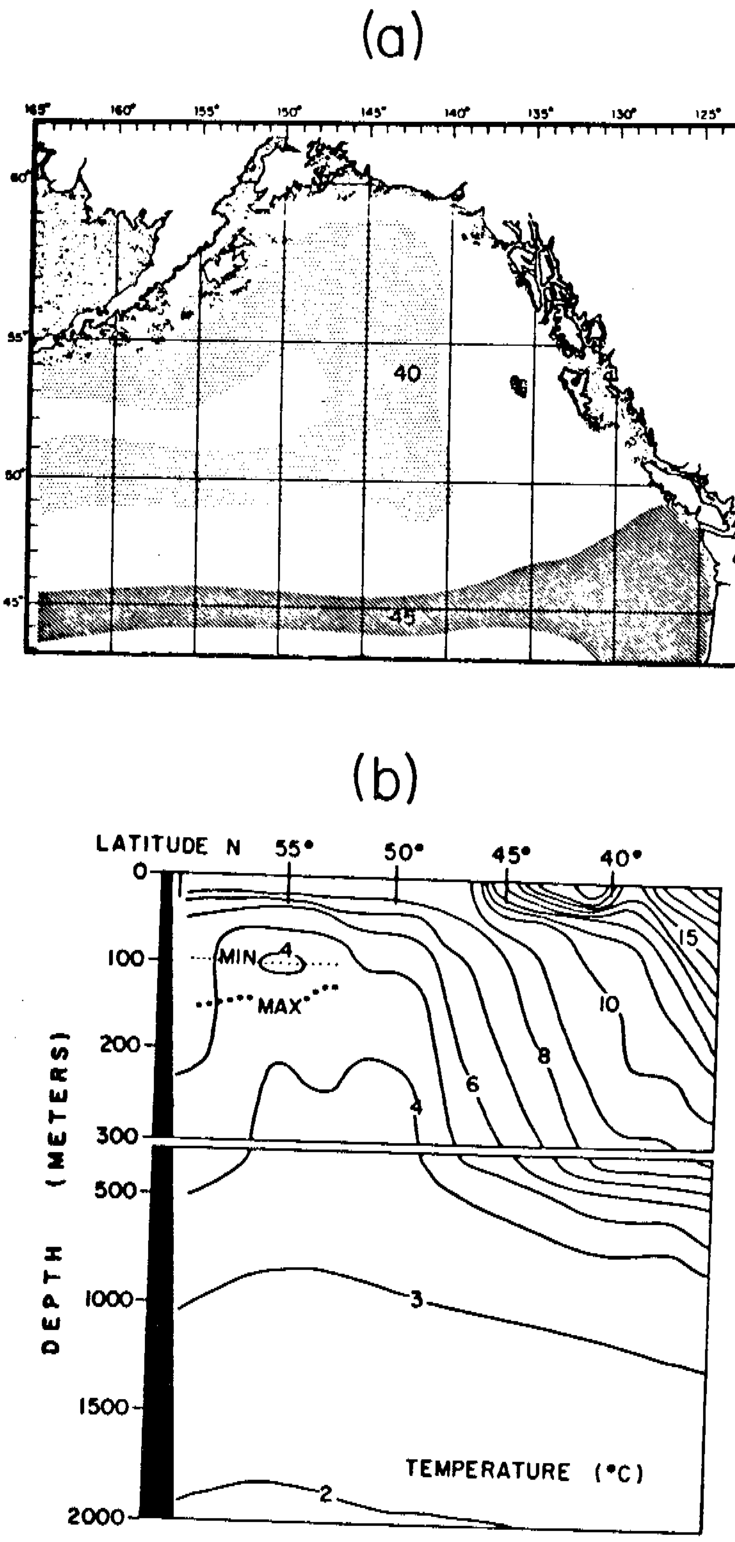


Figure 3. Geographic range of selected isotherms (°F) at 400 ft (121.9m) (from Robinson, 1957), and vertical section of long-term mean temperatures (based on 2x2° grid) along 145°W.

readily accessible. Plots based on long-term mean data (2 x 2° grid) at depths of 200, 500, 1000 and 2000 m (Fig. 4) clearly indicate the northward sweep of warm water into the gulf on the eastern side and the permanence of the cold intrusion isolated offshore on the western side; the two features exist at all levels. It should be noted that data averaged in this manner (2 x 2° grid) do not adequately represent temperature fields in the narrow boundary current at the western side of the gulf, particularly south of the Alaska Peninsula, but the gradual lowering of temperature from 5 - 4°C in an east-west direction around the gulf at 200 m, which is considered the seaward limit of the continental shelf, is fairly representative of actual conditions as far west as Kodiak Island. A grid of less than 1/2 x 1/2° would be required to show continuity of isotherms west of this area, and the paucity of data prevent this. Data obtained east of Kodiak Island in spring 1972 (Fig. 5) indicate characteristics of the distribution of 4-5°C water near 200 m in this area; and there are numerous examples of the continuity of this temperature-maximum stratum from the gulf westward out along the Aleutian Islands (e.g. Ingraham and Favorite, 1968) based on closely spaced station data from individual cruises.

At all levels from 200 to 2000 m the mean temperature distributions suggest a confluence of cold oceanic water entering the gulf in a northeasterly direction and warm water entering in a northwesterly direction. There is also a perturbation evident in isotherms in the eastern side of the gulf at 200, 500 and 1000 m that appears to suggest that flow related to the former has a blocking effect on flow related to the latter. These phenomena are discussed in later Sections on Water Properties and Currents.

Anomalies from monthly mean surface temperatures at shore stations around the gulf indicate that marked short-term deviations occur at indi-

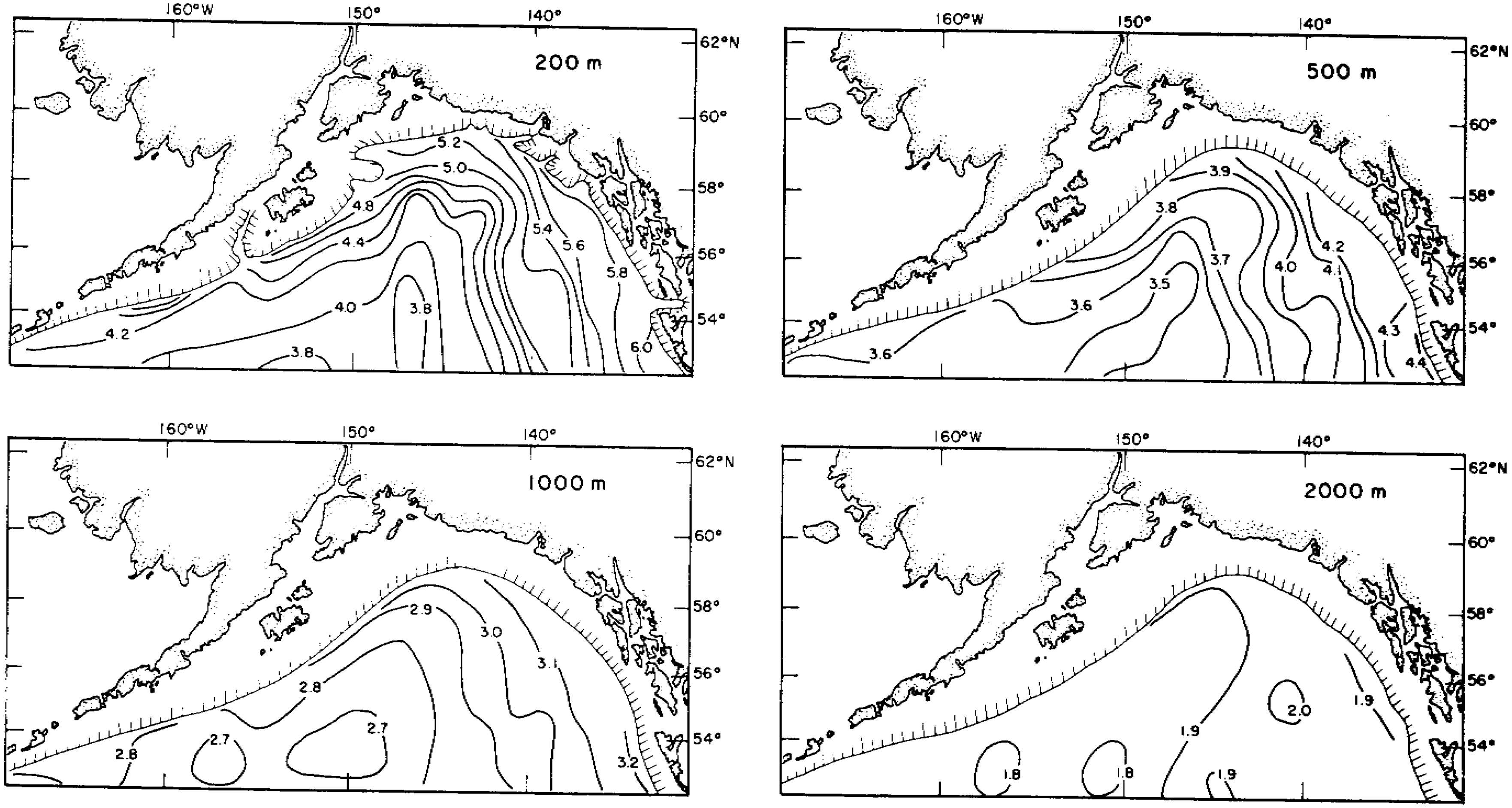


Figure 4. Long-term mean temperature distributions (based on 2x2° grid) at 200, 500, 1000 and 2000 m.

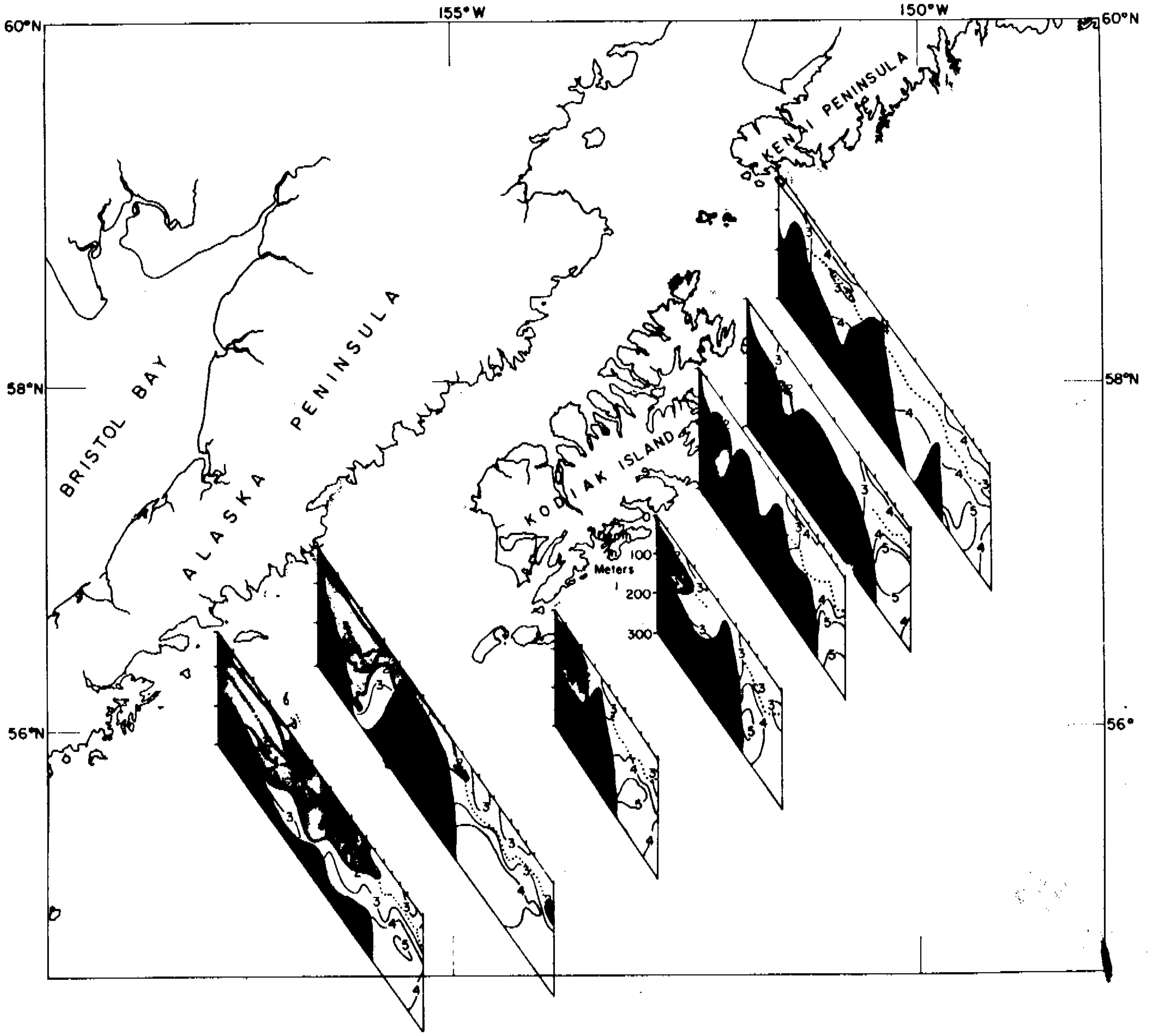


Figure 5. Vertical sections of temperature (°C) along lines of stations (RV *George B. Kelez*, April-May 1972 - Ticks indicate station locations) normal to the shelf edge indicating temperature-minimum stratum (dotted), and temperature-maximum (4-5°C) seaward of the shelf edge.

vidual stations that are not manifested at others. There is a similarity in the medium - term (1-3 years) trends, that is not apparent in the long-term trends (Fig. 6). For example, only at Dutch Harbor and Sitka is there evidence of a prolonged cooling period, 1958-73. The 12-month running mean clearly indicates cold periods centered around 1955 and 1972, and warm periods around 1958, 1963 and 1968. Similar trends in the oceanic area (5 x 5° Marsden quadrant 195-3; 55-60°N, 140-145°W) are evident (Fig. 7), and the transpacific occurrence of large areas of positive and negative anomalies at periods of 5-6 years has been pointed out by (Favorite and McLain, 1973). There are sufficient station data in offshore areas during the period 1955-1963 to indicate temperature changes that can occur at depth during cold and warm periods. Comparison of data in summer 1956 and 1958 indicates that values in the temperature-minimum stratum were over 1C° lower in 1956 over a wide area in the gulf (Fig. 8). Assuming winter convective overturn to 100 m, this represents a difference of 10,000 cal/cm^2 (of sea surface), a significant change in the heat content of the water column and the heat budget of the area.

Temperature anomalies in the water column are related also to advective processes. It is difficult to isolate the effects of winter turnover from advection in the upper 100 m or so, but at depths below seasonal influences there are secular changes that can be detected even with fragmentary data. Favorite (1975) has shown the apparent eastward intrusion of cold water from the west into the gulf indicated by the distribution of temperature on the salinity surface = 34.0 $^0/oo$ (which occurs at about 250 m) from 1955 to 1962. Any consideration of flow at depth in the gulf must take into

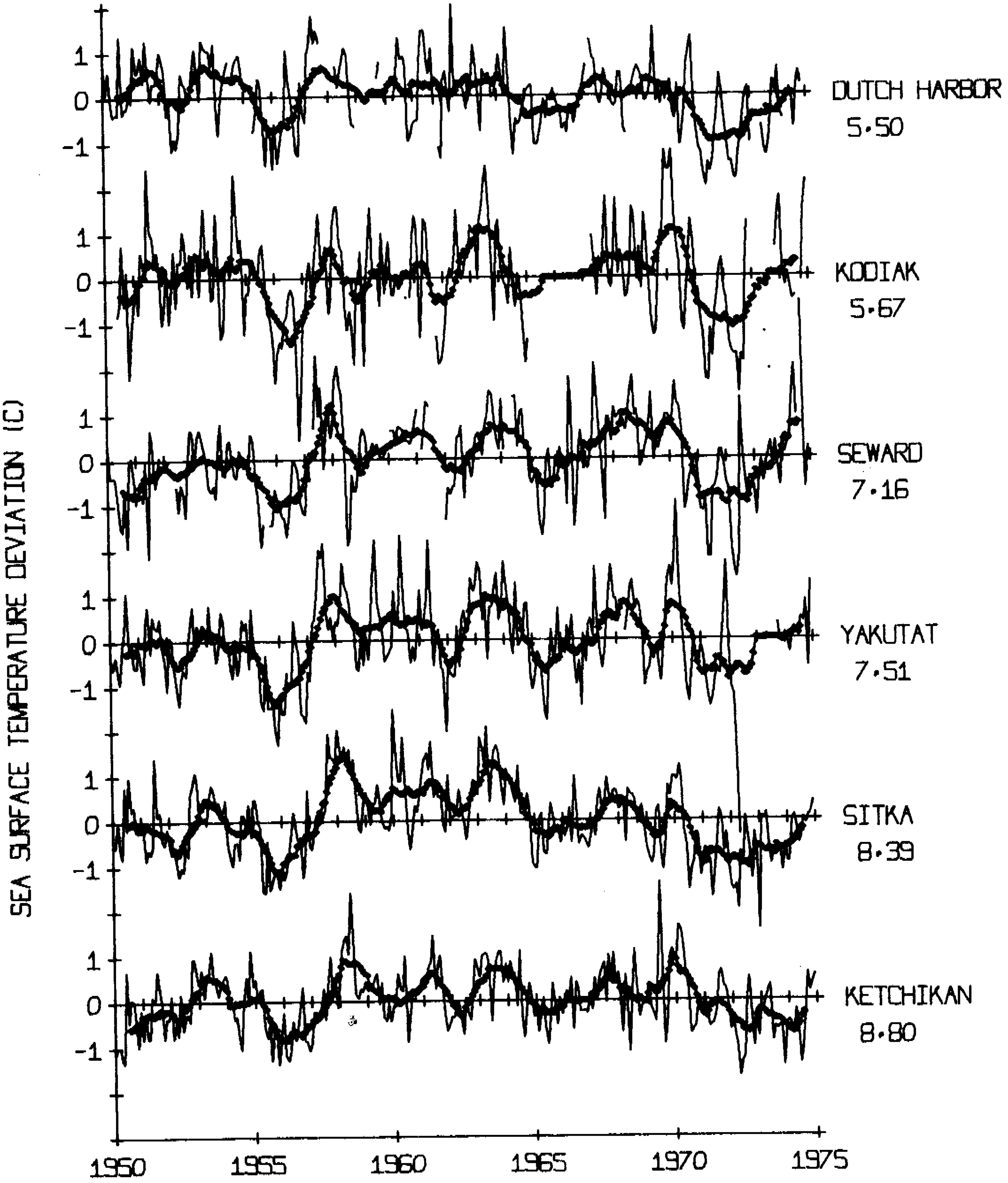


Figure 6. Deviations (C°) in sea surface temperature from monthly mean (1950-74) values at the indicated coastal stations; dotted segment indicates 12-month running mean.

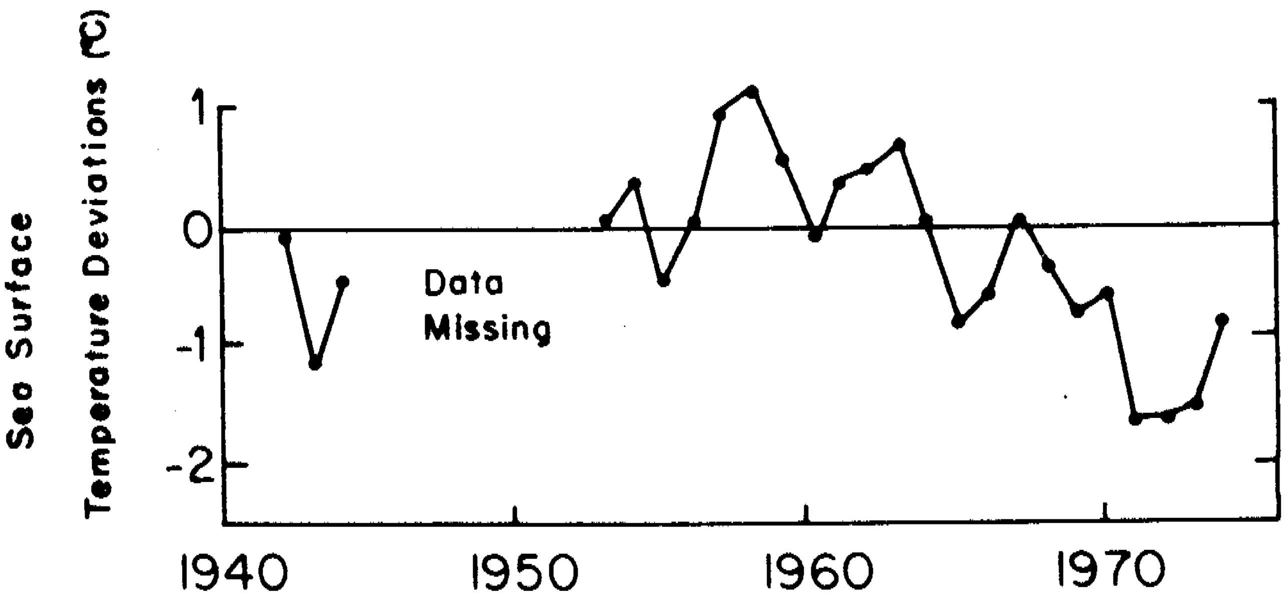


Figure 7. Deviations (C°) in sea surface temperature from annual mean (1948-67) values in 5x5° Marsden quadrant 195-3 (see Fig. 2) reflecting a cooling trend since 1958.

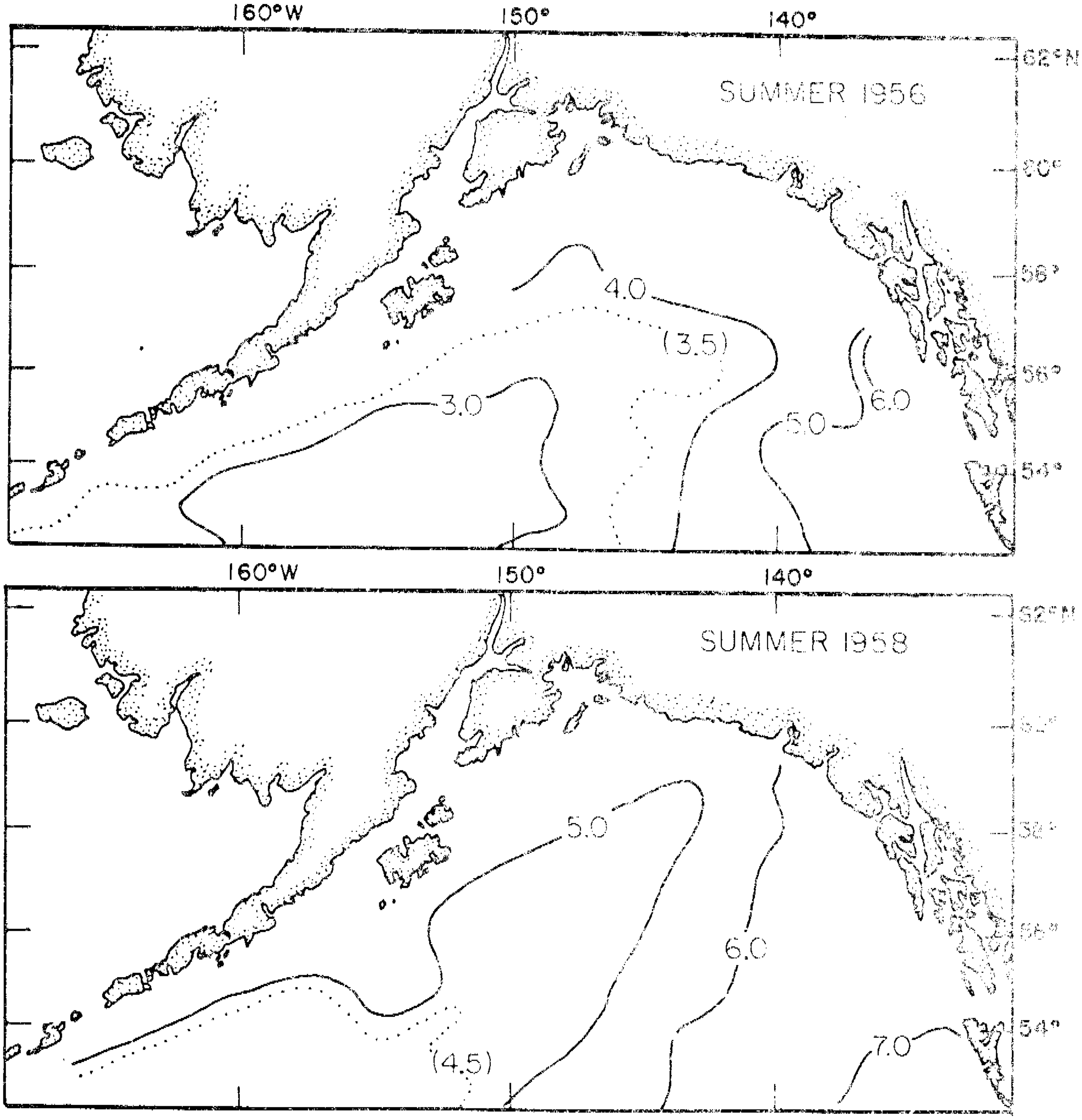


Figure 8. Temperatures (°C) in the subsurface temperature-minimum stratum (∼75-125m) indicating much warmer conditions in summer 1958 compared to summer 1956 (from Dodimead et al, 1963).

consideration the fact that this anomalously cold water intruded nearly to the continental shelf in the eastern part of the gulf in 1961 (Fig. 9).

B. Salinity

Atlases depicting salinity distributions (e.g. Muromtsev, 1958; Barkley, 1968) provide limited information on actual conditions because of the paucity of these data. This is unfortunate because in many instances extensive salinity data, particularly near the surface, would provide more information concerning flow than temperature data. Because of a net excess of precipitation over evaporation (Jacobs, 1951) and extensive runoff, Tully and Barber (1960) have likened the oceanic regime to an estuarine system.

Although extensive runoff around the gulf in spring and summer dilutes coastal waters, this flow is difficult to quantify. Some clues as to the timing of this phenomenon are available from data on the monthly mean discharge from the Copper River, the dominant system in the area. Minimum discharge occurs from December to April; flow increases in May and reaches a maximum in July (Fig. 10). The effects of coastal runoff on offshore conditions is evident in station data averaged by season and 2 x 2° quadrangles (Fig. 11). Spring and summer data are the most complete but, although values as low as 16-18 $^{0}/oo$ occur in inshore areas, the 2 x 2° grid is too coarse to reflect precise inshore minima. Nevertheless, the seasonal offshore movement of coastal dilution is evident, specifically, the 32.0 $^{0}/oo$ isohaline, which moves offshore as much as 200 km in summer compared to its position in winter. Also evident is a region of high salinity in the southwestern part of the gulf reflecting vertical divergence.

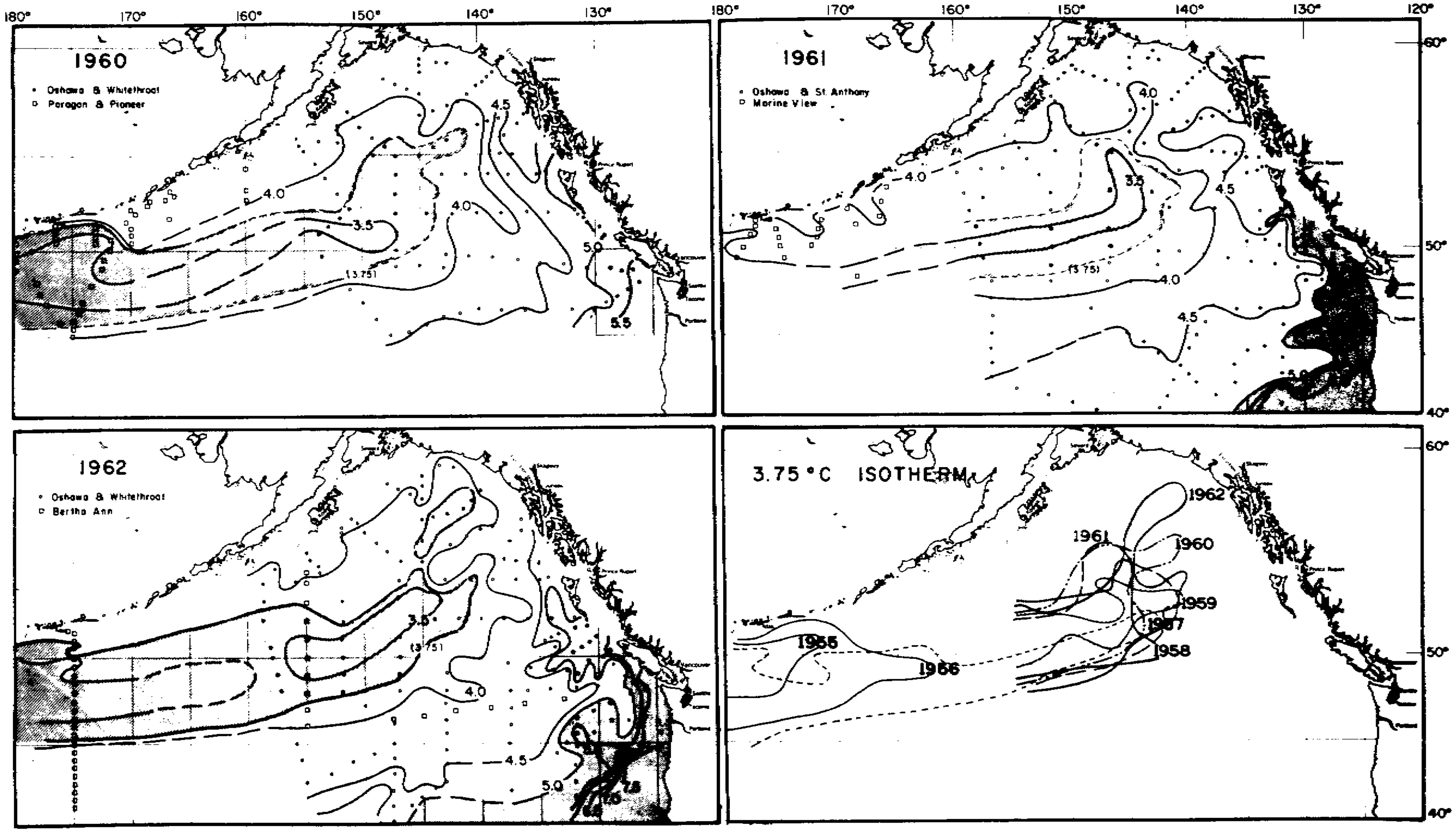


Figure 9. Temperatures (°C) on surface of salinity = 34.0 °/oo (~300m) in 1960, 61 and 62; and the configuration of the 3.75°C isotherm in 1955, 56, 57, 58, 59, 60, 61 and 1962.

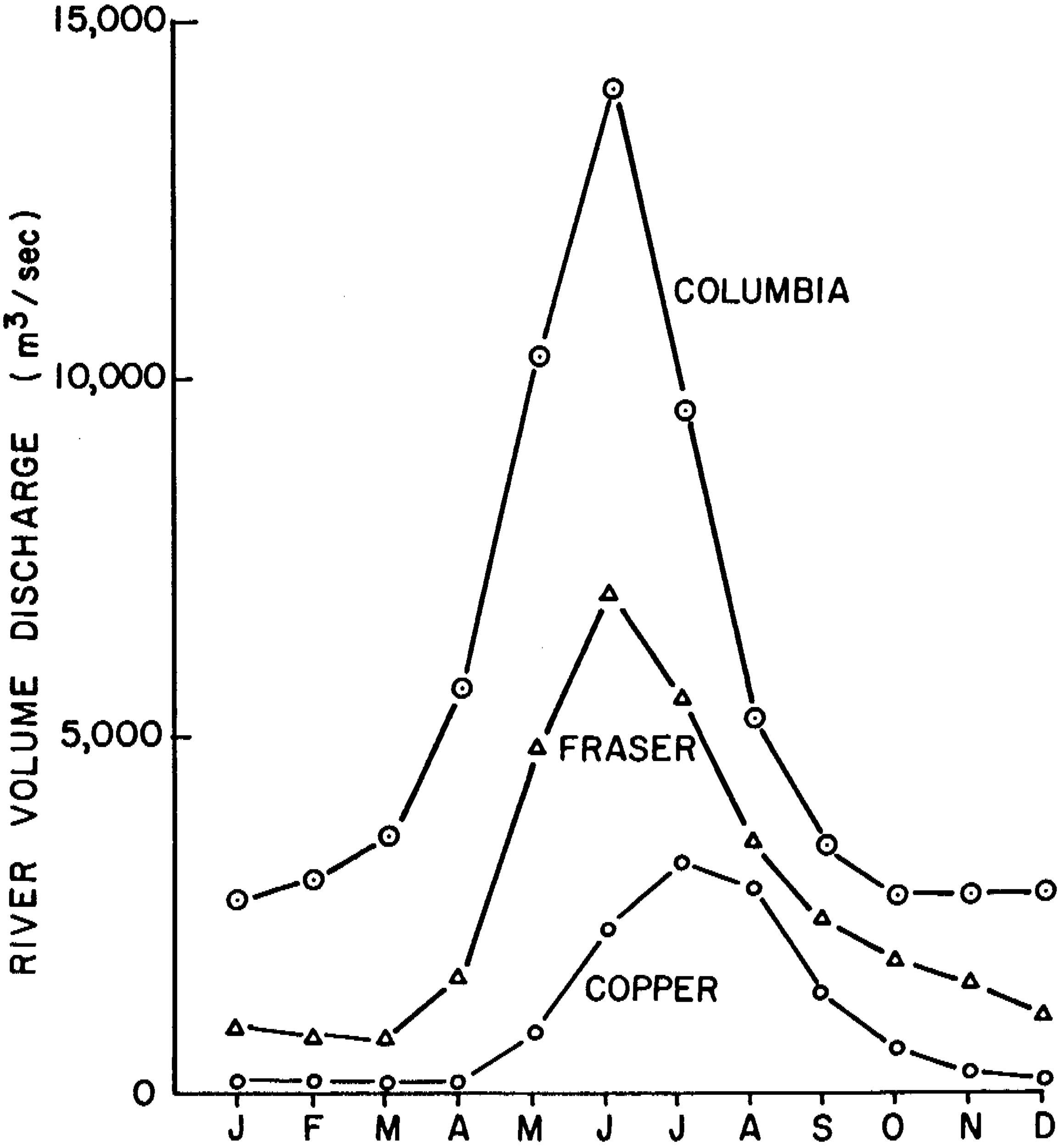


Figure 10. Monthly mean discharge (m^3/sec) from the Columbia, Fraser and Copper Rivers showing relative volume and month of peak runoff.

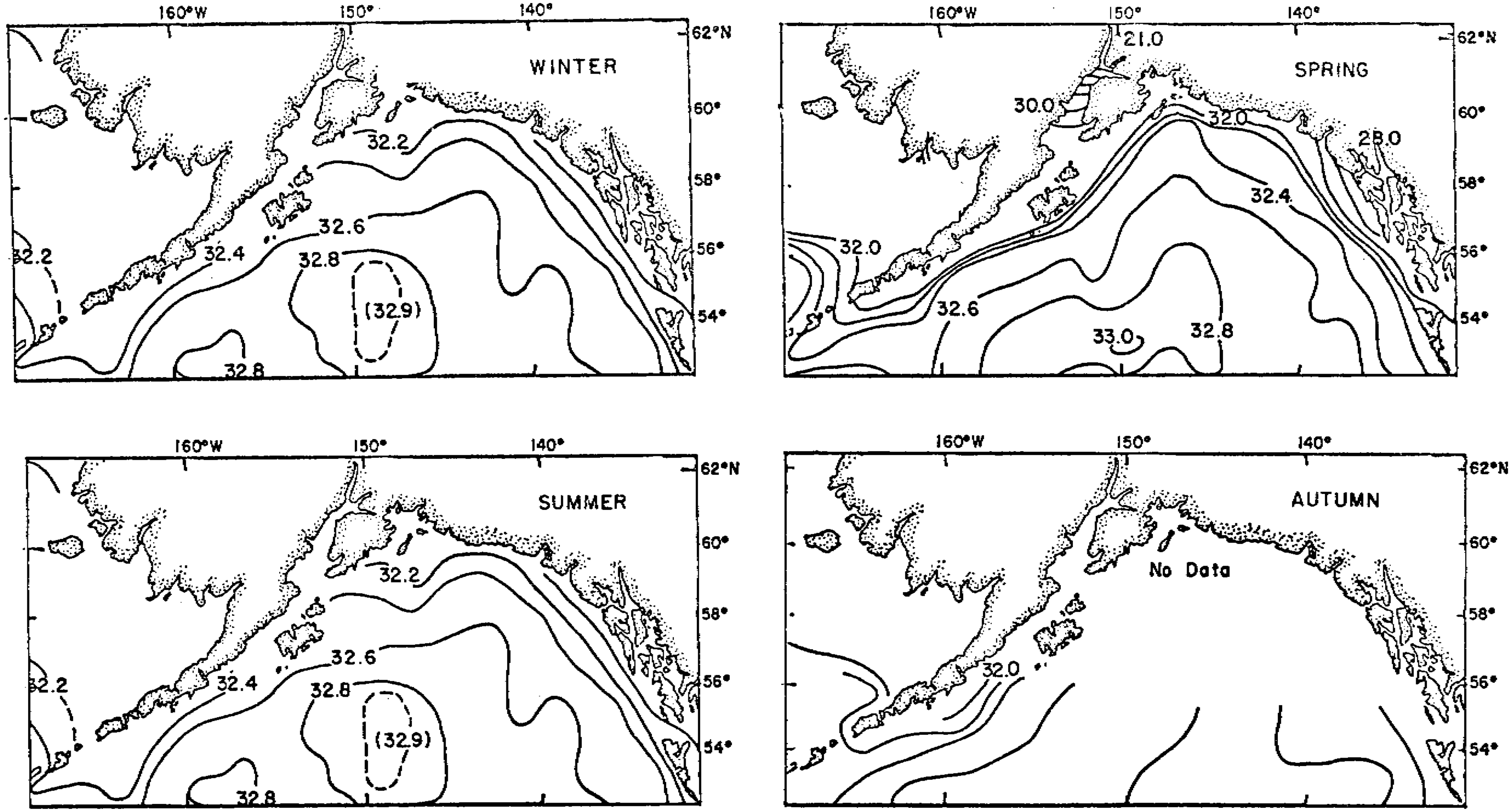


Figure 11. Long-term mean seasonal surface salinity distributions (based on a 2x2° grid) showing marked coastal dilution in summer and maximum values in southwest part of the gulf.

Maximum values (>33.0 $^{0}/oo$) in this area are evident in spring rather than as might be expected in winter, but this is believed due to limited data in the winter period.

Associated with the dilute surface layer is the marked halocline between 100-200 m (Fig. 12) evident in a vertical profile along 145°W. This feature gives a marked stability to the water column and greatly influences the vertical extent of winter convection and, thus, effects the vertical distribution of temperature and other water properties.

The salinity data are inadequate to show convincingly any anomalous salinity distributions in the gulf either in time or space. This does not mean that they do not occur. Considerable variability in the timing and volume discharge of coastal runoff takes place. An example of the variability possible is evident in the distributions of surface salinity off southeastern Alaska in summer 1957 and 1958 (Fig. 13). Considerable offshore dilution is evident in the 1958 distribution compared to that in 1957. However, the distributions represent mean fields over 3 month periods constructed from various data points, and it is difficult to ascertain which, if either, represents average or anomalous conditions.

There has always been speculation as to the existence of a frontal zone at the edge of the continental shelf indicating not only boundary processes such as shelf waves, but a simple separation of dilute coastal from saline oceanic water. Data from a continuously recording surface salinograph (Fig. 14) obtained during numerous transects of a short line of stations normal to the shelf edge eastward of Kodiak Island in spring 1972 (Favorite and Ingraham, 1976a) prove the existence of such a frontal

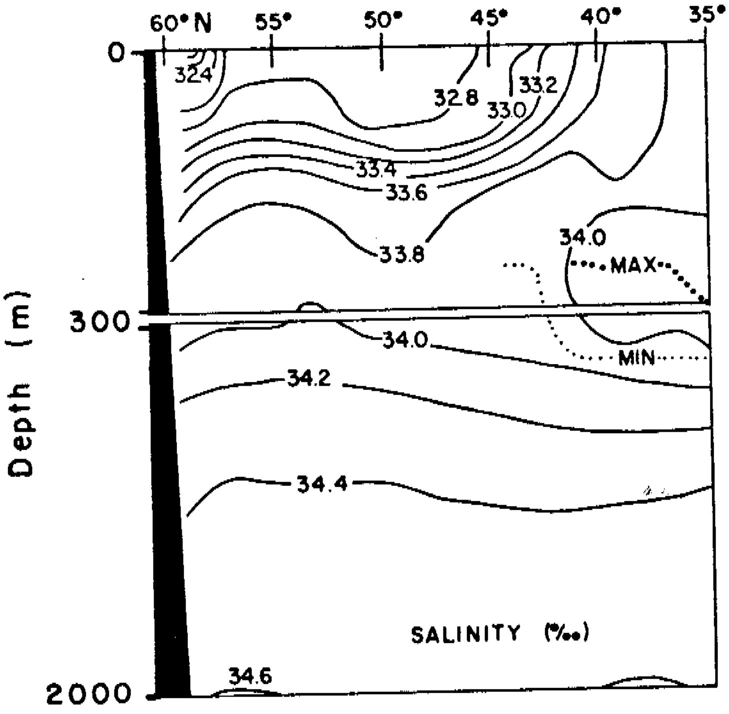


Figure 12. Vertical section of long-term mean salinities (based on 2x2° grid) along 145°W showing: the dilute surface layer north of 45°N, particularly near 60°N; the ridging or doming of isolines at 55°N; and, the halocline between 100-200 m.

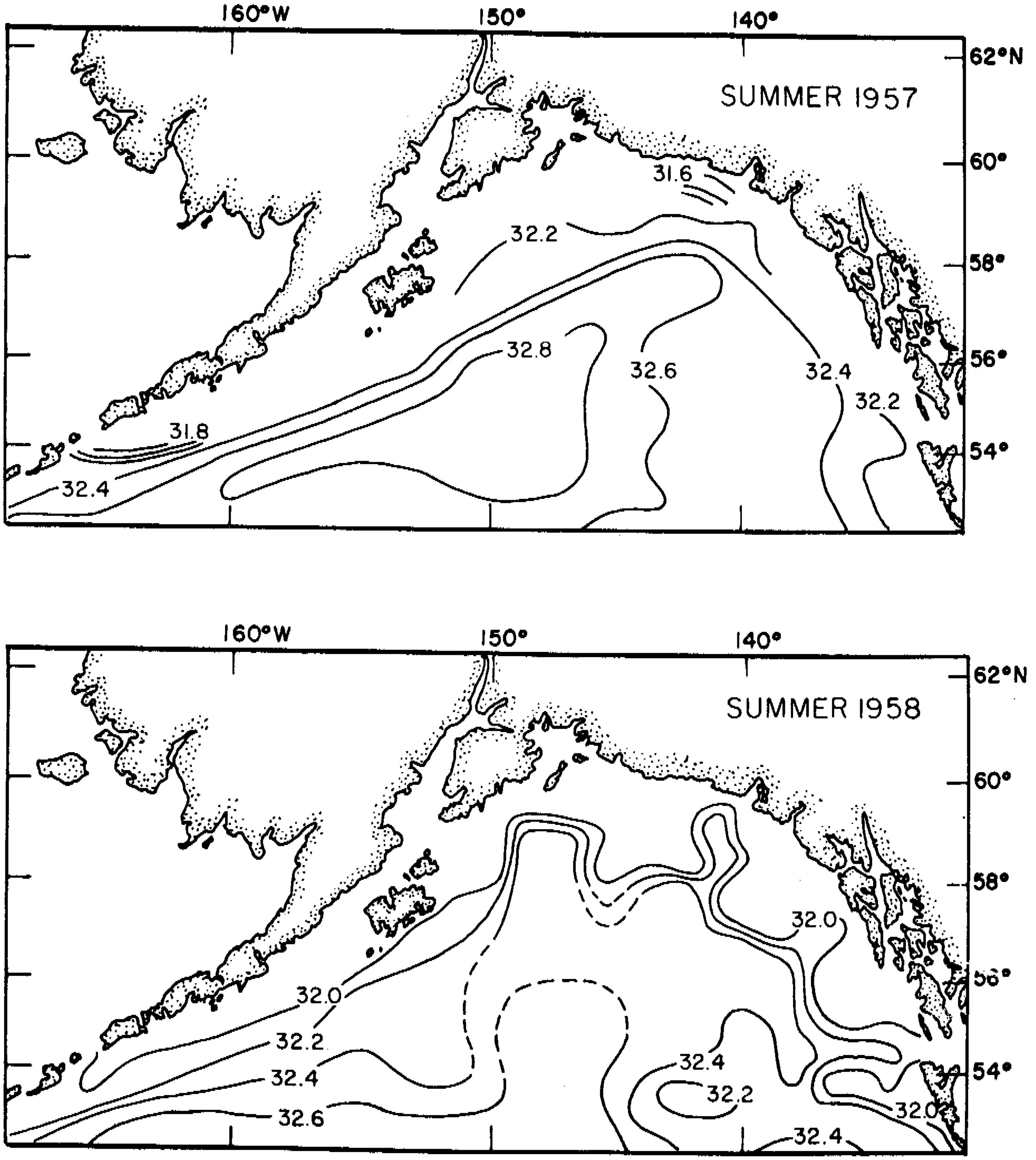


Figure 13. Surface salinity during summer 1957 and 1958 showing the extensive dilution off southeastern Alaska in the latter period reflecting the highly variable conditions that can occur in the surface layer (from Dodimead et al, 1963).

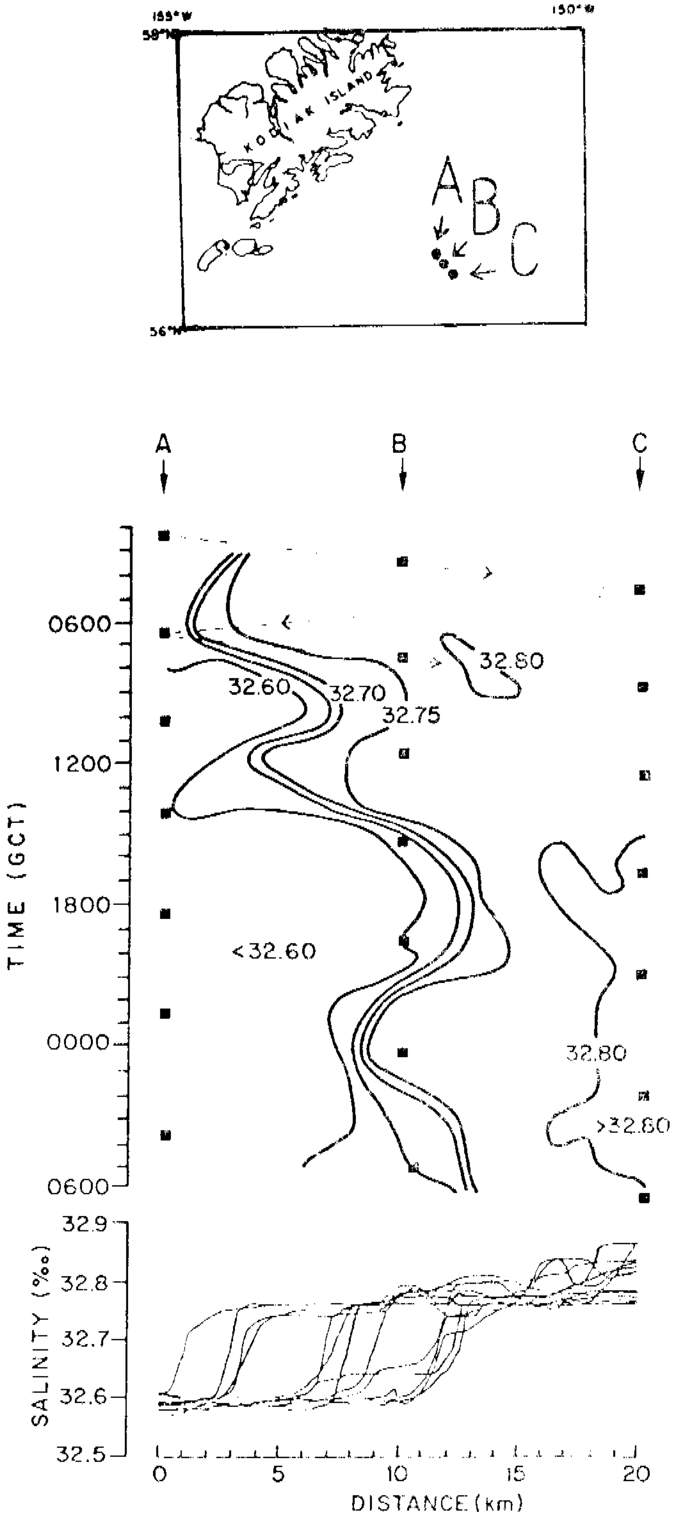


Figure 14. Surface salinity front detected seaward of Kodiak Island in the vicinity of the edge of the continental shelf (RV George B. Kelez, May 5-6, 1972) using constantly recording salinograph while occupying repetitive stations: A, B, C (dashed lines indicate vessel movement).

zone. Salinity distributions at 200, 500, 1000 and 2000 m (Fig. 15) reflect primarily the presence of the surface divergence in the offshore portion of the western gulf and the suggestion of cyclonic circulation found in the temperature distributions. There is also an obvious area of dilution off Cape Spencer in the 200 m temperature field.

C. Water Masses

All oceanic waters attain marked characteristics when they are in contact with the atmosphere and these characteristics are subsequently altered by lateral and vertical mixing. When discrete temperature and corresponding salinity values of a water parcel below the depth of seasonal influences are plotted against each other a well-defined temperature-salinity (T-S) curve results that is characteristic of a given area and defines a water mass (Sverdrup, Johnson and Fleming, 1942). Such a curve defines the Subarctic Water Mass, characteristic of the area lying generally north of 50°N in the eastern North Pacific Ocean.

The low temperatures and salinities that distinctly define this curve are due in part to the waters moving eastward at depth from the Okhotsk Sea, a general vertical movement of intermediate water due to the Ekman divergence at the surface, and an undetermined northward transport of deep water in the Pacific basin that is deflected upward in this area by the land boundaries in the gulf and the Aleutian-Commander island arc. Modifications to this basic T-S curve are caused by a northward flow of warm water on the eastern side of the gulf that originates not only from eastward flow south of 50°N, but also from northward flow in the California Undercurrent. The latter is manifested at the surface in winter, but is overridden at the surface in summer by a southward flow stemming from the southern branch of the easterly onshore flow.

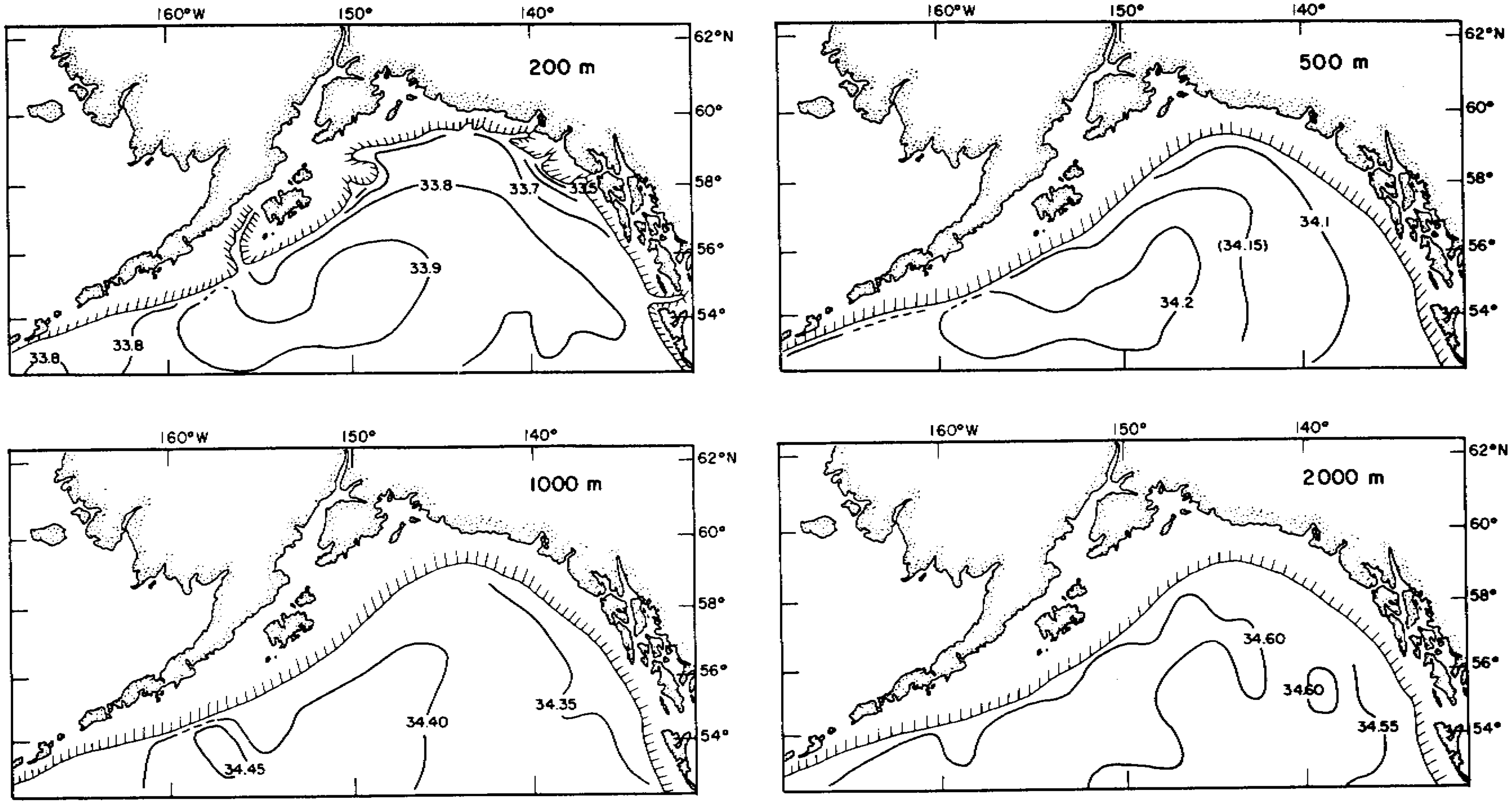


Figure 15. Long-term mean salinity distributions (based on 2x2° grid) at 200, 500, 1000 and 2000 m.

Monthly mean, as well as maximum and minimum, values of temperature and salinity at standard depths were computed from all station data by 2 x 2° quadrangles and are presented in the form of T-S curves at 4 selected locations at which winter and summer data were available (Figs. 16 and 17). Because of the paucity of data, in some instances only 3 stations, the curves and extreme values must be considered as only indicative of conditions rather than representing precise values and ranges. The water mass at the head of the gulf (area A) is formed from the merging of three major water masses moving northward into the gulf. In general, all have equivalent surface temperatures during the periods of maximum heating (summer, 13-14°C) and cooling (winter, 4-5°C), except in area B where winter temperatures of 3°C are evident, and there is a noticeable decrease in surface salinity shoreward from areas B to D, the greatest dilution occurring in area A. The elimination in winter of the temperature gradient, or thermocline, evident in the upper 50-75 m of the water column during summer is readily apparent in all areas. There are marked differences in temperatures from 100 and 300 m, about 3C°, between areas B and D; conditions at these depths in areas C and A reflect an admixture of the water masses in areas B and D, although the temperature maximum between 150 and 250 m is maintained. There is also a suggestion of a downward diffusion of summer heating below 125 m during winter. Below 300 m the T-S curves in areas A, B and C are similar and follow the trend of the general Subarctic Water Mass curve, however, there is a significant departure from this curve in area D attributed to northward flow along the coast. As might be expected, variability in temperature and salinity conditions is largely

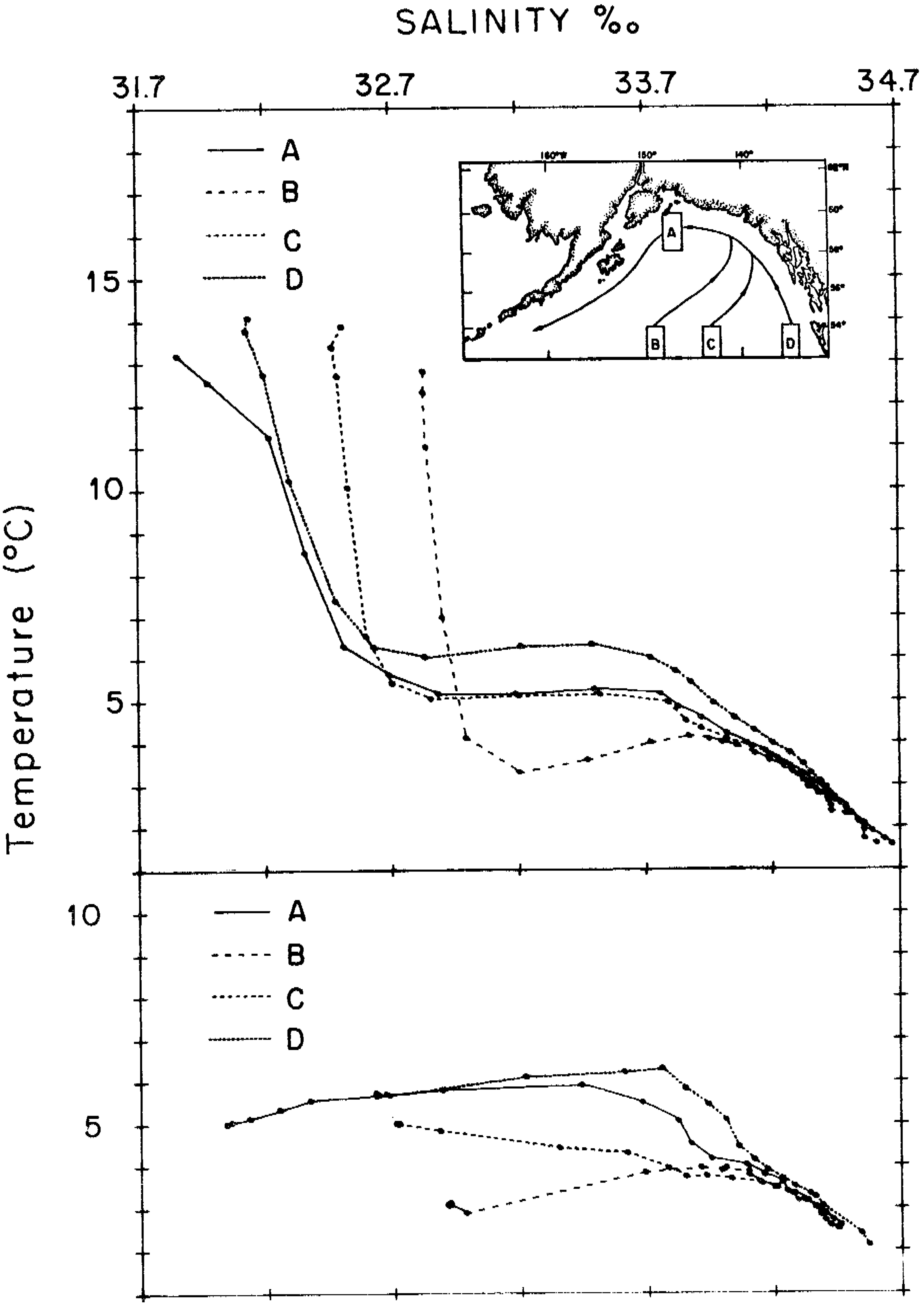


Figure 16. Long-term summer and winter mean temperature-salinity (T-S) relations at standard depths in the indicated 2x2° guadrangles showing characteristics of the various water masses funneling into the gulf.

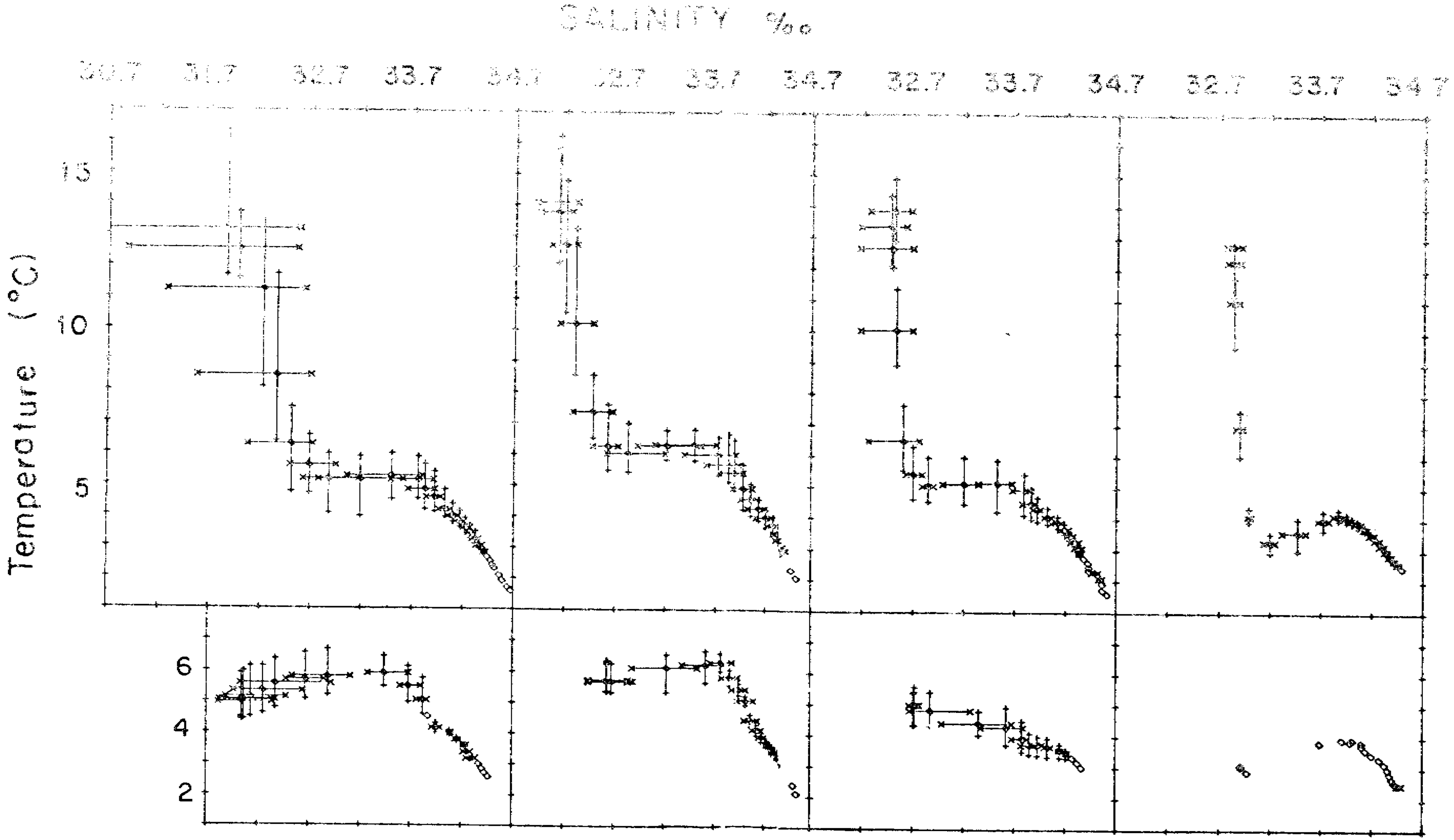


Figure 17. Maximum and minimum temperature-salinity (T-S) values at standard depths for the T-S curves shown in Figure 16.

limited to the upper 300 m of the water column and the greatest ranges occur in area A, primarily because that 2 x 2° quadrangle encompasses part of the continental shelf and is subjected to coastal runoff. Obviously conditions at the head of the gulf are dependent upon the relative components of flow in these three water masses.

III. CURRENTS

Bering, Chirikof, Cook, Clerke, Portlock, Dixon and countless other early explorers of the coastline around the gulf encountered the treacherous winds and coastal currents that exist in the area, and such information reported by mariners is constantly updated in the Alaska Coast Pilots. There are also early papers that synthesize this information. Wild (1877) presented a Current Chart of the Ocean that showed northward flow into the gulf stemming from a bifurcation of eastward onshore flow into northward and southward trending branches that occurred well seaward of Vancouver Island. Dall (1899) reported that the zone of separation was just seaward of Vancouver Island. Schultz (1911) indicated that only in summer did the separation occur at this latitude; during winter it occurred off the California coast near 41°N. Such schemes were largely based on sporadic reports and data from ship's logs, but the absence in the gulf of extensive commercial vessel traffic, whose daily observations of set and drift have provided an extensive historical data base on circulation in other areas, has resulted in a paucity of specific information concerning flow. Drift bottle studies provide information concerning gross circulation patterns, however, only the release and recovery points are known and actual trajectories are subject to various interpretations. The computation of geostrophic currents in which the relative field of currents is derived from the observed field of mass in the ocean, provides an indirect method of estimating oceanic flow. This method has several shortcomings and requires extensive synoptic observations at sea which are not possible to obtain from present platforms. Nevertheless, this method permits the calculation of relative currents and transports that provide considerable insight into oceanic flow throughout the area observations are made. No significant direct current measurements have been made in offshore waters of the gulf prior to OCSEAP studies. However, measurements off the west coast of Vancouver Island where a similar climate occurs reveals interesting patterns of onshore and offshore flow that are probably duplicated in gulf waters (Dodimead et al. 1963).

Long before planned drift bottle or drift float programs were instigated, the presence of debris from Japanese fishing operations and remnants of California redwood trees on the southeast Alaskan coast signaled two widely differing sources of water flowing into the gulf. Although there have been a number of recoveries of bottles or floats from a variety of experiments, there are several studies that provide most of the basic information that can be deduced by such studies.

The first extensive study was conducted by the International Fisheries Commission, (IFC)--predecessor to the International Pacific Halibut Commission (Fig. 18); over 4,000 bottles were released from 1930-34 (Thompson and Van Cleve, 1936). Those released along an east-west line across the gulf from Baranof to Kodiak Island and at several locations inshore along the Alaska Peninsula in spring 1930 indicated a broad northward flow into the head of the gulf, with recoveries only at Cape St. Elias and Cook Inlet, and a southwestward drift along the Alaska peninsula and through Unimak Pass. Releases just east of Kodiak Island were recovered only along the southern coast of the island and on the Alaska peninsula to the west and north of the island; releases from three locations inshore along the Alaska Peninsula indicated a southwestward drift along the coast. Releases off the west coast of the

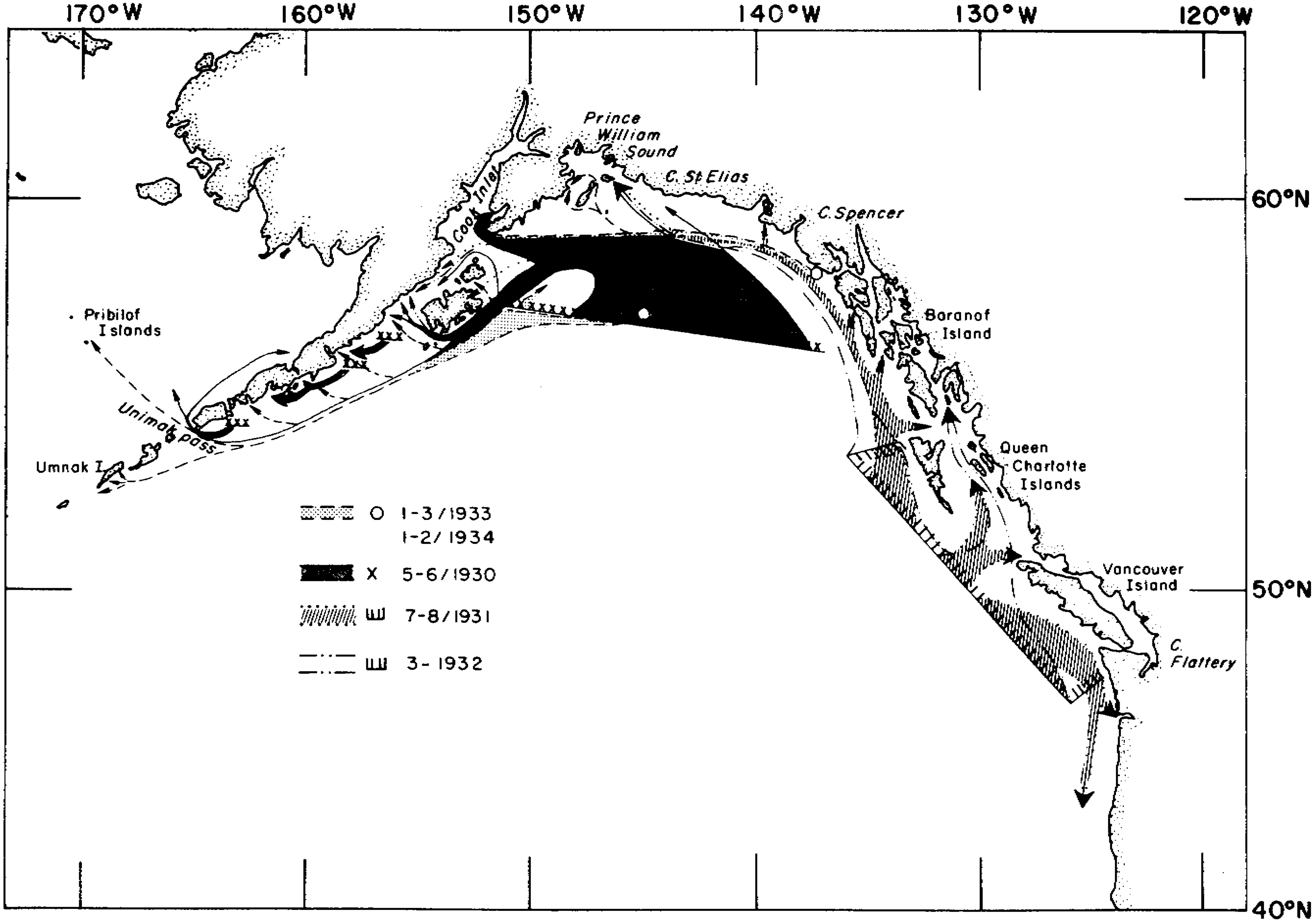


Figure 18. Schematic diagram of significant results of drift bottle studies conducted by the International Fisheries Commission (IFC) 1930-34 (adapted from Thompson and Van Cleve, 1936).

Queen Charlotte and Vancouver Islands in summer 1931 indicated a marked bifurcation of onshore flow at the northern end of Vancouver Island. Two bottles in the northern component of flow were recovered near Cape Spencer and one on Kodiak Island. In a similar experiment in spring 1932, except for one recovery at Cape Flattery (directly east of the release point), all recoveries were made northward of the release points, at various locations around the gulf. The western most recovery was made in Shelikof Strait and numerous recoveries were made in Prince William Sound where none was recovered in the 1930 and 1931 experiments. Releases north of 50°30'N and recovered north of 57°N were estimated to travel 9.4 miles per day. In winter 1933 and 1934, releases just north of Cape Spencer were recovered in Prince William Sound, along the west coast of the gulf, and on the Pribilof and Umnak Islands. These studies reflected a southward shift in winter of the zone of separation of the onshore flow off Vancouver Island that had been indicated earlier (Schutz, 1911). The northward branch, which moves cyclonically around the gulf, had a general drift of about 20 cm/sec and an inherent onshore component. Although a large cyclonic gyre encompassing the entire gulf at the latitude of Kodiak Island was inferred, there is no evidence other than delays between release and recovery to justify such a conclusion. The authors noted that, although westerly flow was predominant, at the head of the gulf, the currents were not regular or constant.

A subsequent experiment was conducted by the Pacific Oceanographic Group (POG), Nanaimo, from August 1956 to August 1959 (Dodimead and Hollister, 1962). Forty-two releases (33,869 bottles) were made from Ocean Station "P" (50°N, 145°W) and surrounding locations. Twenty-three of the releases were made at Ocean Station "P" at approximately 6-week intervals and these indicated a fairly complicated pattern in drift currents between the station and the North American coast. For example, of 998 bottles released on August 25, 1956 only one of the 114 recoveries was made north of Ketchikan and it was made on Middleton Island; whereas of 1,008 bottles released on August 24, 1957, all of the 39 recoveries were made at or west of Middleton Island. Of particular interest to the present study are the 5 releases north of Ocean Station "P", especially the 2 that were made north of 55°N. At the 3 locations south of 55°N between 155 and 160°W, an esterly set was indicated, recoveries being made throughout the head of the gulf. However, recoveries from the two releases north of 55°N (approx. 142°W) made on February 17, 1957 and August 17, 1957 were made only at the western side. Perhaps of more significance is that recoveries from the winter release (Fig. 19) were recovered as far north as the Pribilof Islands, as far west in the Aleutian area as Amchitka Island, as far east as the Washington-Oregon-California coast, and as far south as the Hawaiian Islands and Wake Islands--a tremendous dispersal that requires considerable thought when one contemplates possible oil pollution in the head of the gulf and the subsequent formation of floating tar balls.

Whereas the IFC studies were concerned with coastal drift [5/] and the POG studies largely with onshore drift from discrete offshore locations, the studies conducted by the National Marine Fisheries Service Northwest Fisheries Center (formerly Bureau of Commercial Fisheries Biological Laboratory) extended over a large area of the northern North Pacific Ocean.

[5/] See Ingraham and Hastings (1974) for results of seabed drifter study off Kodiak Island in May 1972.

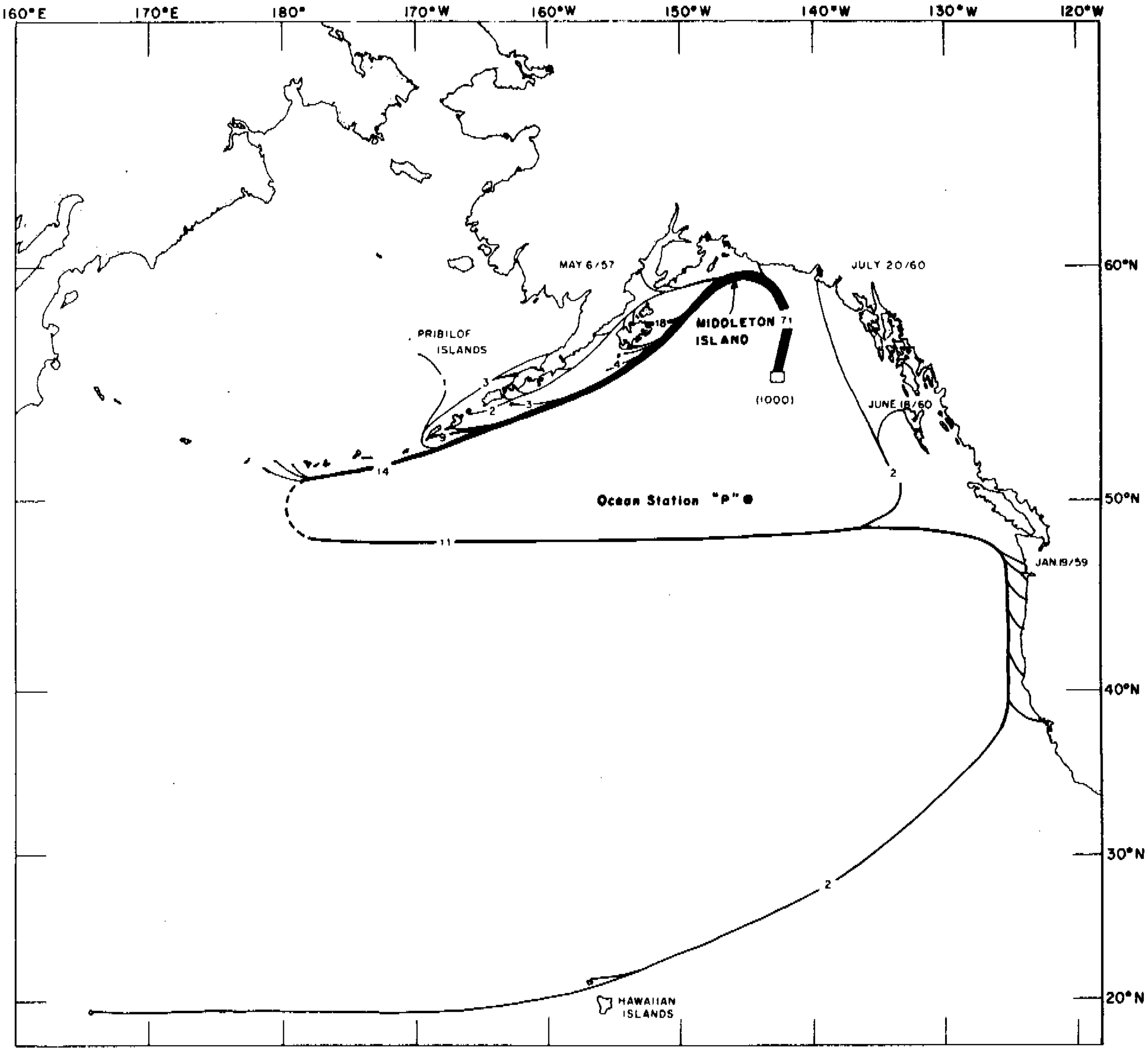


Figure 19. Release and recovery locations of drift bottles released by the Pacific Oceanographic Group (Nanaimo) in February 1957 showing the wide dispersal to the Bering Sea, the Aleutian Islands, Washington-Oregon-California coast, the Hawaiian Islands and Wake Island (from Dodimead and Hollister, 1962).

The two experiments that pertain to flow in the gulf were conducted in 1962 (Favorite, 1964) and in 1964 (Fisk, 1971); releases made along extended north-south and east-west cruise tracks (Fig. 20) indicated the broad north-south oceanic boundaries of eastward surface flow that moves directly into the gulf or toward the coasts of British Columbia, Washington, and Oregon where, in winter, a northward flow surfaces along the coast (Reid, Roden and Wyllie, 1958; Burt and Wyatt, 1964; and others).

B. Geostrophic Flow

The geostrophic (dynamic) method has been thoroughly described and evaluated (e.g. Fomin, 1964); basically, the method, which requires a balance between Coriolis and pressure gradient forces permits the computation of current relative to that at an arbitrary and perhaps fictional depth, selected in the belief that it is deep enough for isopleths of density and pressure to be parallel and thus a depth or level at which no motion exists (a zero reference level); no accelerations or physical boundaries are permitted. Fleming (1955) has presented a chart showing the locations in the northern North Pacific Ocean where the oceanographic station data required by his method had been obtained prior to 1955, and Dodimead et al (1963) showed station locations from 1955-59, as well as winter and summer fields of geopotential topography. McEwen, Thompson and Van Cleve (1930) and Thompson, McEwen and Van Cleve (1936) were the first to use this method in the Gulf of Alaska and found a westward flow in excess of 50 cm/sec at the edge of the continental shelf. The complexity of geostrophic flow in this area was evident in the closely spaced station data obtained by Doe (1955). Roden (1969) and Thomson (1972) have contributed to present knowledge of flow around the gulf.

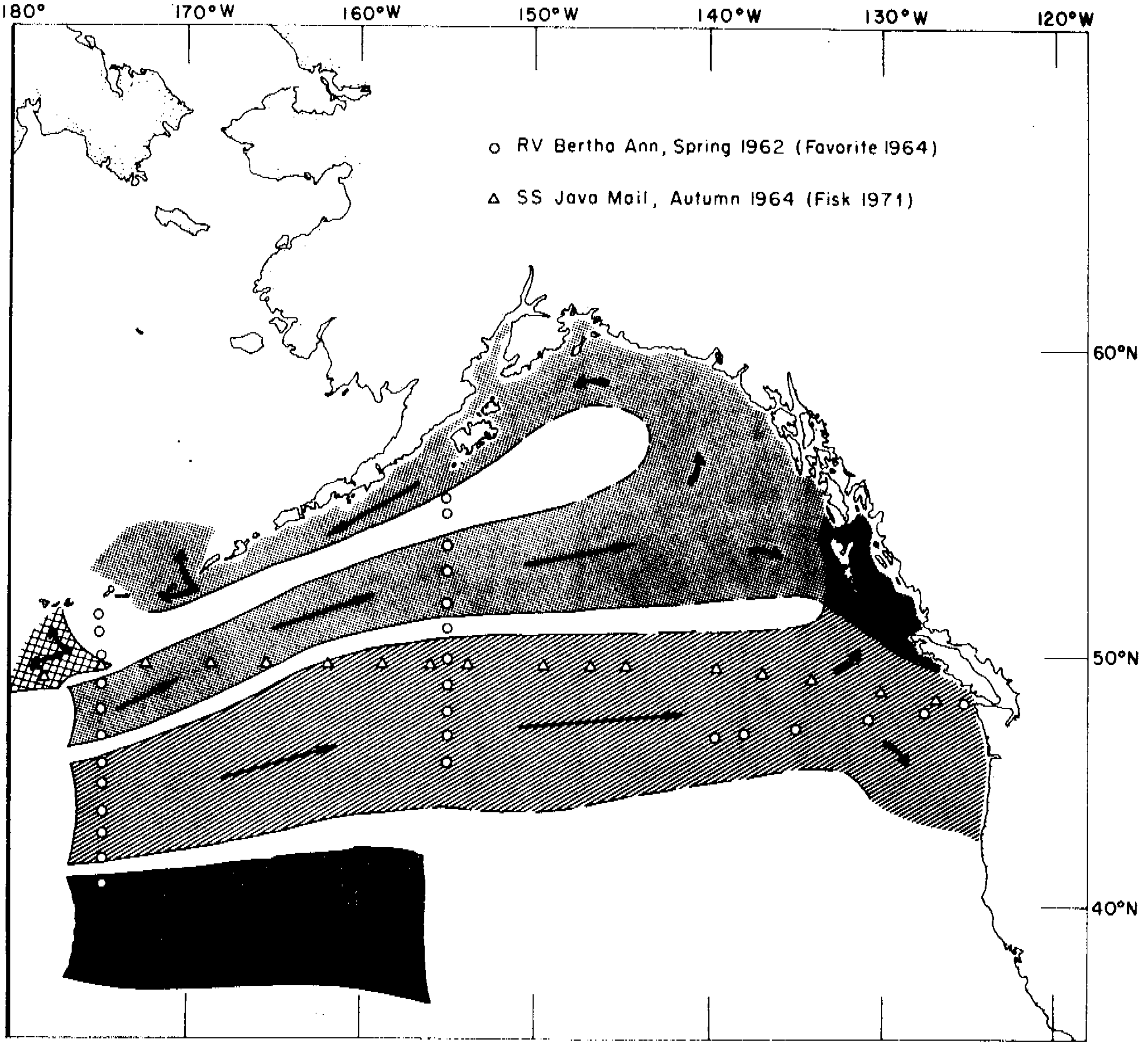


Figure 20. Schematic diagram of results of drift bottle studies by the Northwest Fisheries Center (Seattle) in 1962 and 1964 showing the general nature of easterly onshore drift.

The locations of all oceanographic station data on file at NODC (prior to OCSEAP studies) and used in this report are shown in Figure 21. Current speeds normal to a line between two oceanographic stations are obtained by the Sandstrom Helland-Hansen equation:

$$V = \frac{10}{f\Delta x}\left[\int_0^D \delta_1\,dp - \int_0^D \delta_2\,dp\right] \qquad (1)$$

where D is the accepted depth-of-no-motion expressed in decibars; δ, the geopotential anomaly; x, distance between stations; f, Coriolis acceleration; and, p, pressure.

Computations of geopotential anomalies at all stations were averaged by 2 x 2° quadrangles to obtain long-term means and seasonal (winter, spring, summer and autumn) means for the depth intervals 0/300 db, considered to be the layer of seasonal influence, and 0/2000 db, where 2000 db is considered to represent a level-of-no-motion. Mean values over such large areas (over 20,000 km) cannot be expected to reflect boundary currents over the narrow continental slope but general circulation patterns are evident. Data for winter, spring and summer are sparse, from 1 to 30 or more observations per quadrangle, with an average of about 10; data for autumn are only 20% available. At Ocean Station "P", observations are more numerous and provide at least a qualitative check on surrounding data. For example, in the mean summer data there are 112 observations at the quadrangle associated with Ocean Station "P"; mean value 0.53 dyn cm; although there are only 11 observations in the quadrangle to the west, and 10 in the quadrangle to the east, the mean values are 0.52 and 0.53 dyn cm respectively.

The seasonal mean fields of geopotential topography for the depth interval 0/300 db (Fig. 22) are quite similar. The longitude of the topographic low, 149°W is the same for all seasons but the latitude shifts

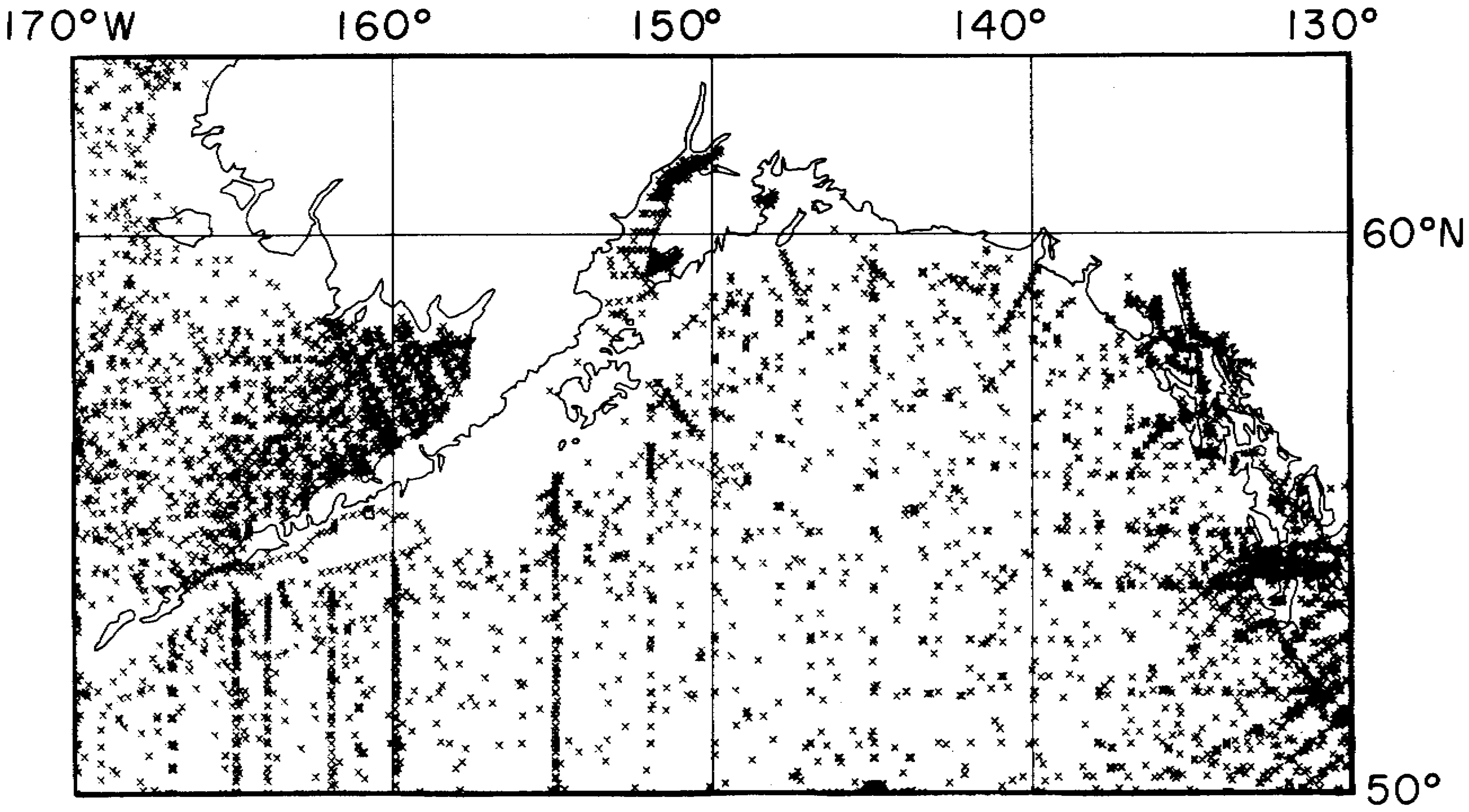


Figure 21. Locations of oceanographic stations in National Oceanographic Data Center geofile.

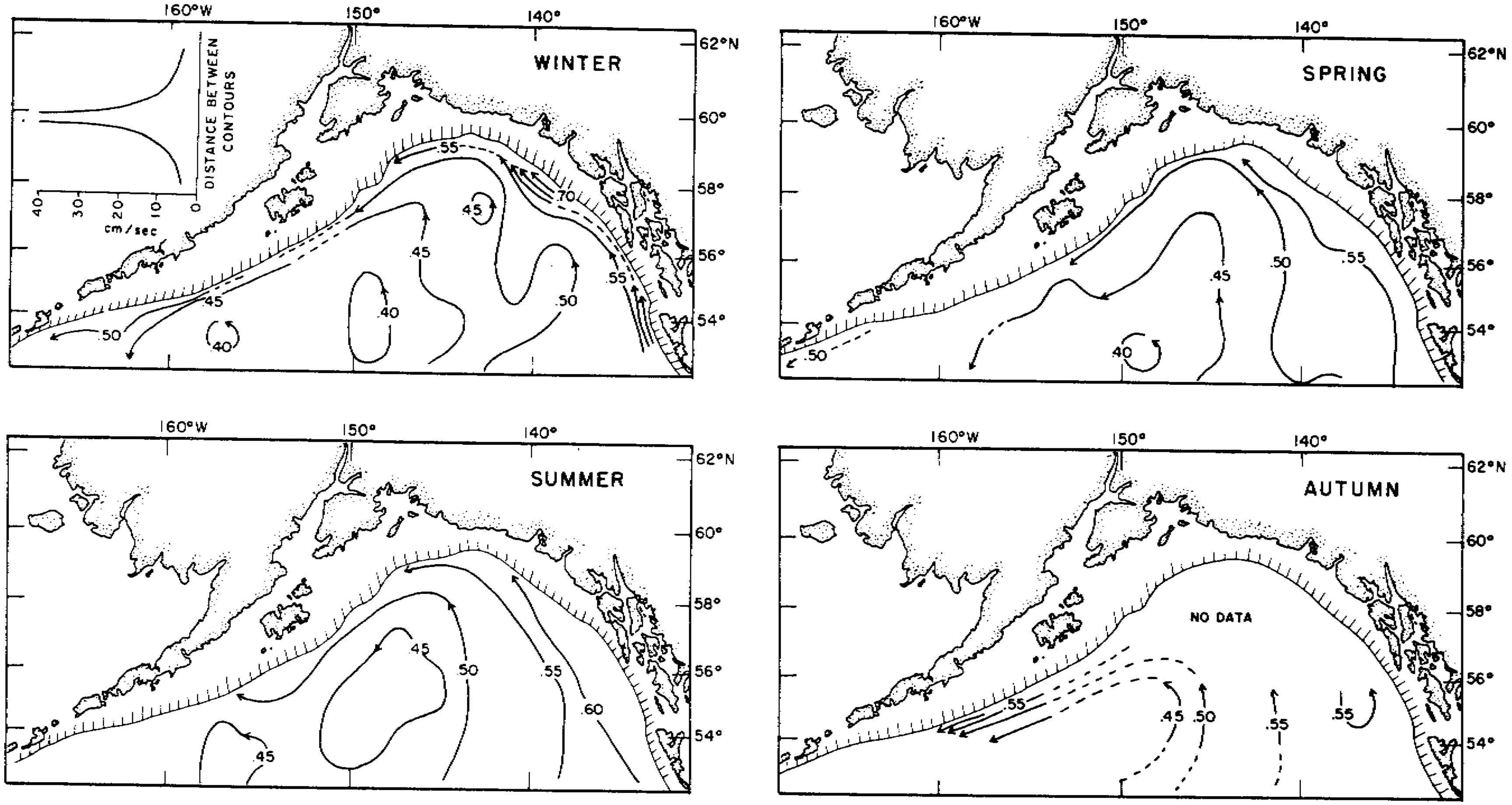


Figure 22. Long-term seasonal mean geopotential topographies, 0/300 db, (based on 2x2° grid) showing variability in geostrophic flow particularly the high velocities at the eastern side of the gulf (the broad grid spacing prevents showing the boundary current at the western side).

from 53^{o}N in spring to 55^{o}N in summer while winter is intermediate at 54^{o}N (autumn data is lacking). Although numerous variations in the configurations of the respective isopleths occur, there is a difference of 15-20 dyn cm between the topographic low in the southwestern part of the gulf and the topographic high near the coast at the eastern edge of the gulf. Further, isopleths are not continuous around the gulf but, rather than representing a discontinuity in flow, as will be shown in the next section, this is primarily due to narrow width of the boundary current in the northern and western part of the gulf. Speeds of 3 - 5 miles per day and a northward transport, east of the topographic low, of 3 Sv are indicated.

The winter and summer mean fields of geopotential topography for 0/2000 db (Fig. 23) are generally similar to those for 0/300 db. The position of the topographic low remains near 55^{o}N, 149^{o}W. The difference in topography across the eastern side of the gulf changes from 35-40 dyn cm in summer to 50 dyn cm in winter indicating some winter acceleration; speeds are 20 and 25 cm/sec and transports are 12 and 15 Sv, respectively. Isopleths at northern and western sides of the gulf are discontinuous as before. As might be expected from the foregoing, the long-term mean field of geopotential topography for 0/2000 db is not much different from either of the above and the apparent conclusion one can draw is that in winter the baroclinic mode reflects an increase in flow of about 20 percent, and this increase stems largely from adjustment in the mass field below 300 m.

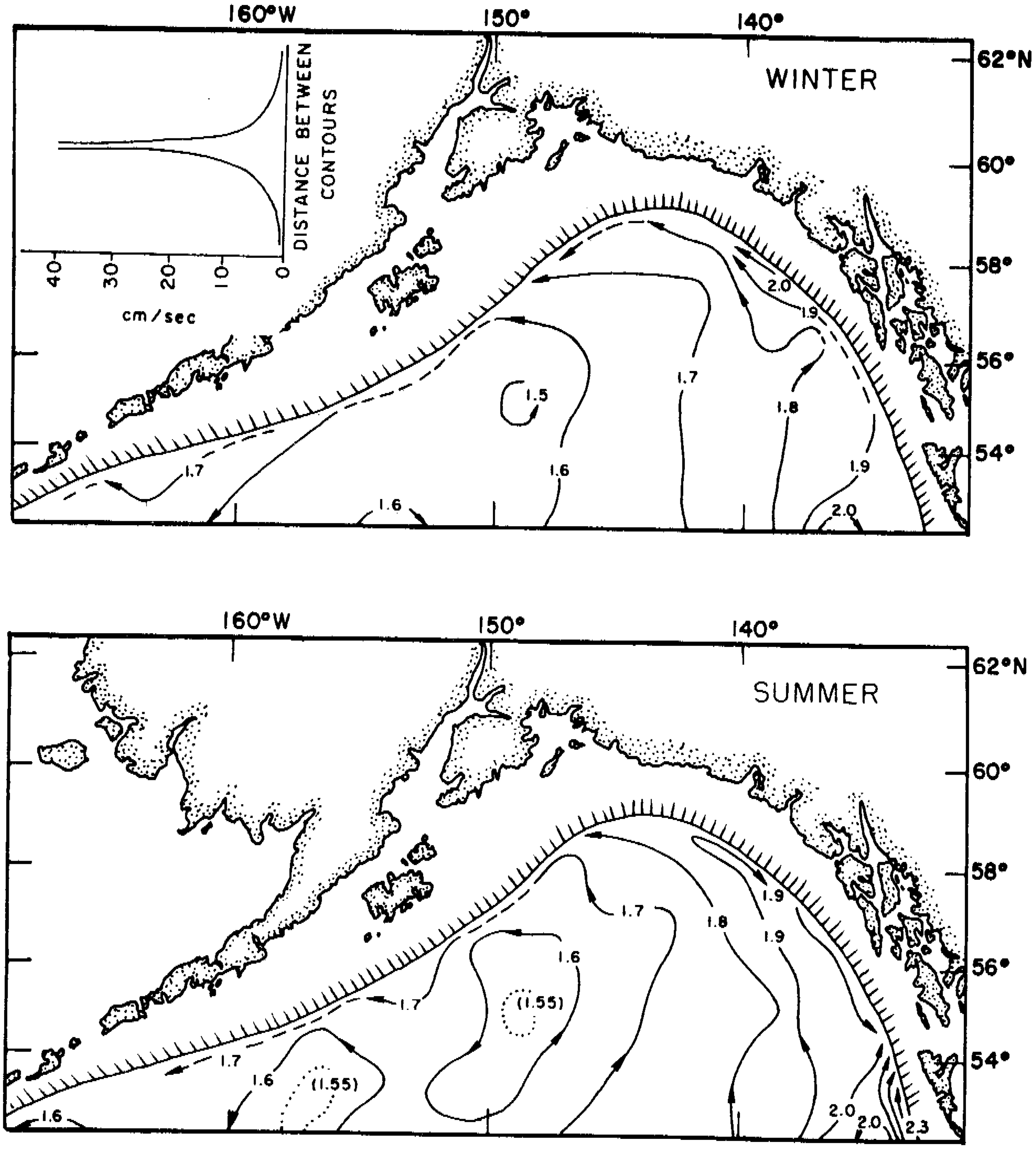


Figure 23. Long-term seasonal geopotential topographies 0/2000 db (based on $2x2^\circ$ grid) showing generally similar features of cyclonic flow.

Because of the paucity and non-synoptic nature of the station data in the gulf, it is difficult to ascertain if irregularities in geopotential topographies are real or caused by the lack of synoptic data. However, there are three aspects that can be explored: are there patterns in individual years that are not obvious in the mean flow; what are the apparent fluctuations in transport, and do accelerations in the boundary current result in discontinuities in geostropic flow on the western side of the gulf? Because most of the data that permit answering these questions were obtained in the period 1955-63 and many of the observations were limited to 1000 m at that time (even though this was not considered a realistic level-of-no-motion), some comparisons must be made in reference to this level.

One pattern that is represented in one form or another is an extensive perturbation in the northward flow at the eastern side of the gulf. Examples of this are found in the geopotential topography (0/1000 db) for winter and summer 1957 (Fig. 24). The configuration of the isopleths suggests a possible blockage of westward flow at the head of the gulf resulting in a seaward plume that extends over 500 km in a southwesterly direction. The apparent effect of this phenomenon is a convergence of isopleths, and thus an acceleration of northward flow, at the eastern side of the gulf. Unfortunately neither closely spaced or repetitive stations have ever been made in this area so the actually physical nature or cause of this feature cannot be ascertained. This is also true of features at the western side of the gulf. At times there is an

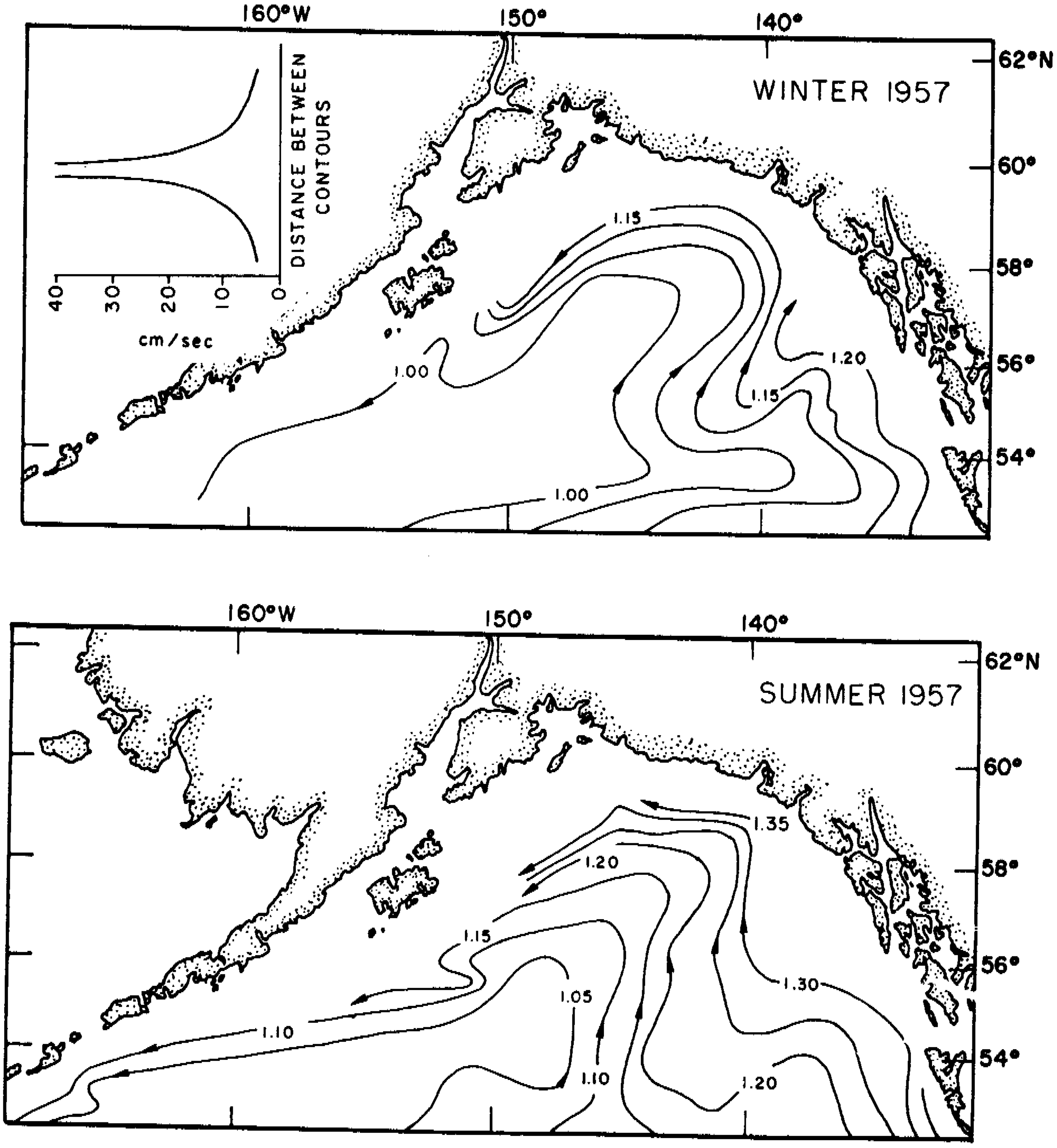


Figure 24. Geopotential topographies, 0/1000 db, winter and summer 1957 showing perturbation in flow at eastern side of the gulf.

indication of eddies breaking off to the east of the boundary current seaward of Kodiak Island (Dodimead et al, 1963), but there is also evidence that this is not a permanent feature of flow in this area.

The question as to whether or not there is continuity of geostrophic flow around the gulf would require extensive observations and extensive direct current measurements. However, some new insight into the boundary flow was obtained in 1972 when closely spaced observations were made on transects of the continental shelf and slope approximately 100 km apart east of Kodiak Island (Favorite and Ingraham, 1976a). It was discovered that approximately 70% of the westward flow out of the gulf occurred within 50 km of the shelf. Geostrophic velocities of 50 cm/sec (referred to 1000 db) occurred in a narrow band approximately 20 km wide and in one instance, velocities of 100 cm/sec (referred to 1500 db) were estimated within a 10 km band. Little evidence of any major perturbations were evident in the nearly 600 km stretch along the continental slope in this area. Thus, it would appear that when appropriate observations are made, fairly reasonable continuity may be obtained.

C. Volume Transports

Fluctuations in transport can be estimated by the difference in geopotential topography across the eastern part of the gulf. Data from 1954-62 (Table 1) indicates that the mean transport from 0 - 1000 m is approximately 8 Sv and individual values range from about 6 - 12 Sv, with no particular pattern to winter or summer values. Bennett (1958) reported that when observations are available to 2000 m the transport nearly doubles to approximately 15 Sv, with individual values ranging

Table 1. Northward volume transport (0 to 1000 m - to the nearest 0.5 Sv) into the gulf across 55°N, computed from geopotential topography (the lowest value in the Alaskan Gyre versus the inshore value at the location of the 1000-m isobath at the eastern side of the gulf).

Period	Transport (Sv)
1954 (summer)	9.0
1955 (summer)	9.0
1956 (summer)	7.5
1957 (winter)	6.5
1957 (summer)	7.0
1959 (winter)	8.5
1959 (summer)	9.0
1960 (winter)	12.0
1960 (summer)	8.0
1961 (spring)	6.5
1962 (spring)	6.5
Mean	8.1

from 13.5 - 16 Sv, and again no particular pattern to winter and summer values is evident. Thus, it would appear that the year to year seasonal fluctuations may be as great or greater than the within year seasonal ones.

IV. WIND STRESS-TRANSPORTS

Because of the paucity of data on actual winds, the wind-stress at the sea surface is obtained from distributions of sea level pressure. It should be noted at the outset that there is an unavoidable bias in long-term sea level pressure data because of not only the varying intensity and location of reports from shipping, but because of modern devices and techniques. The establishment of Ocean Station "P" in the mid-forties, the availability of satellite imagery showing cloud patterns in the mid-sixties, and the placement of ocean data buoys in the mid-seventies, all permit an increasingly better estimate of the sea level pressure fields and associated gradients. Several grid spacings are used in this report and each will be defined as encountered.

A. Pressure Fields

In order to obtain an initial assessment of variability of pressure, the historical sea level pressure data at 5 x 5^0 grid points were obtained from the National Center for Atmospheric Research (NCAR) and monthly mean fields (composed of 12 hourly and in some instances 24 hourly data) from 1899-1972 were plotted to ascertain the relative frequency at which the central pressure of the Aleutian low falls within the selected low pressure intervals (Fig. 25). In 6 instances the monthly mean pressure was less than 985 mb, these occurred in either December or January; in 32 instances it was less than 990 mb, all occurred from October to March; and in 91 instances it was less than 995 mb, all occurred from September to April. Although it appears that data from 1899-1950 are fairly representative of the period 1950-1972, we are concerned with the curl of the wind-stress and therefore details of the first and second derivative fields, and not

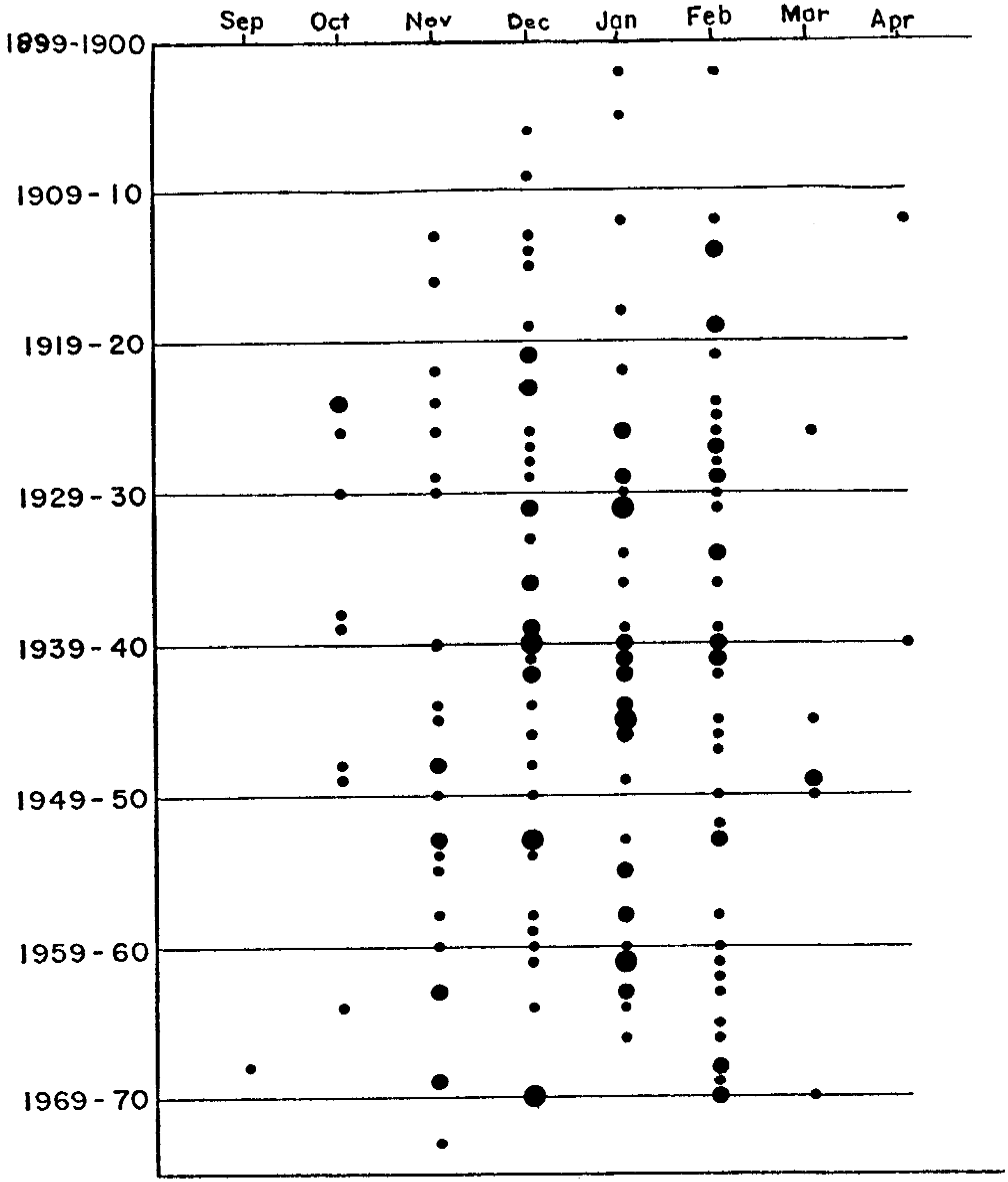


Figure 25. Frequency of monthly mean sea level pressure minima of the Aleutian low: <995 mb (●), <990 mb (●), and <985 mb (●).

merely the absolute value of pressure minima. If we choose 55^{O}N, 155^{O}W near the approximate center of the Alaskan Gyre, data at this grid point, deviations from monthly means, 12-month running means and power spectrum provide an indication of the general variability of sea level pressures. Deviations from monthly mean pressures do not exceed ± 5 mb and, except for the extended period, roughly 12 years, of positive deviations from 1901-1912 (which may be due to limited data), departures from normal are generally of 1-4 years duration. Particularly noticeable is the extended period of below normal pressures centered around 1940. The power spectrum (cycles less than 1.5 years not shown because of the obvious annual periodicity) based on annual mean values reflect cycles of 2.7, 6.7 and 13.3 years (Fig. 26). The 6.7 years is the approximate periodicity of oceanic temperature cycles (5.6 years) found by Favorite and McLain (1973). The 13.3 years suggests an influence of the sunspot cycle of 12.3 years. Favorite and Ingraham (1976b) have shown that if mean pressures from October to March for the three years centered around the period of sunspot maxima and minima from 1899 - 1972 are calcualted, with only one exception (1958), the center of the Aleutian low occurs in the central Aleutian area during periods of the sunspot maxima and in the Gulf of Alaska during periods of the sunspot minima; mean pressures are 2 mb lower during the latter period.

B. Transport Fields

Total integrated transports (wind-stress transports) are derived from the mean pressure fields by deriving a wind field that is transformed into a stress field. The nature of the coupling of energy between wind-stress and water transport is not precisely known and certainly varies under different conditions. When the water is warmer than the air, a

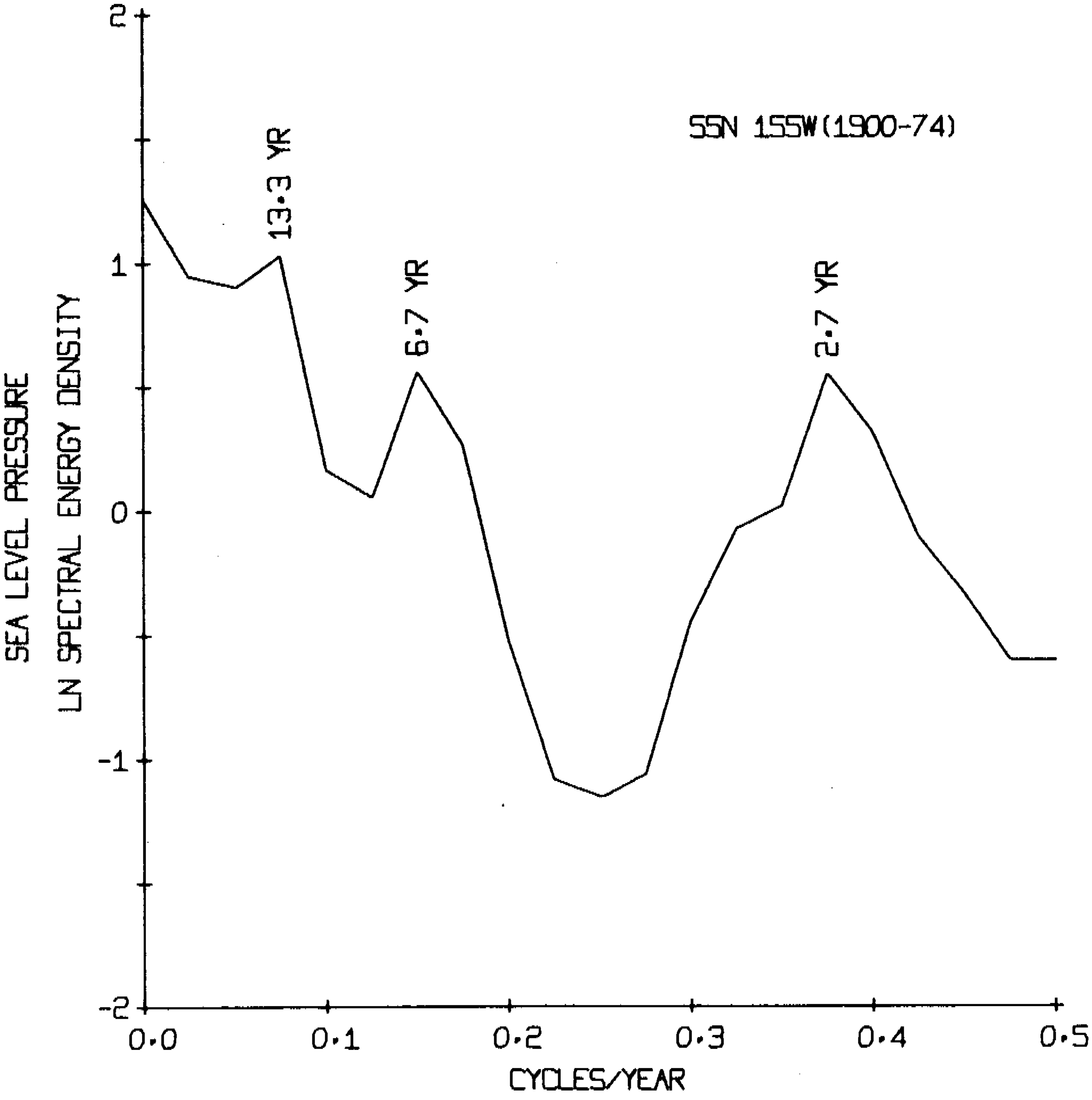


Figure 26. Spectral energy density, annual mean sea level pressure at 55°N, 155°W 1900-74 (20 lags) indicating cycles of 2.6, 6.7 and 13.3 years.

turbulent boundary layer exists and exchange of energy is more effective than when the water is colder than the air and a stable layer exists at the air-sea interface. Further, when interpolation and averaging processes are taken into account, caution must be exercised in interpreting results. However, a number of authors (e.g. Wyrtki, 1964) have indicated the usefulness of this technique in estimating flow.

Sverdrup (1947), by including the pressure gradient term in the Ekman transport equation, arrived at the following:

$$-f v = \frac{1}{\rho}\frac{\partial p}{\partial x} + \frac{\partial}{\partial z}\left(A_z \frac{\partial u}{\partial z}\right) \qquad (2)$$

$$f u = -\frac{1}{\rho}\frac{\partial p}{\partial y} + \frac{\partial}{\partial z}\left(A_z \frac{\partial v}{\partial z}\right) \qquad (3)$$

After cross differentiating and integrating from the surface to an unspecified depth-of-no-motion one obtains the transport equation:

$$M_y = \left(\frac{\partial \tau_y}{\partial x} - \frac{\partial \tau_x}{\partial y}\right) / \beta \qquad (4)$$

where τ is the wind stress and β the variation of the Coriolis parameter with latitude $\left(\frac{\partial f}{\partial y}\right)$. This shows for steady non-divergent flow the total meridional transport, M_y, is directly related to the curl of the wind stress and independent of the details of the mass distribution as long as the pressure gradient is baroclinically compensated at depth.

Using the technique devised by Fofonoff (1962) and the program constructed by Bakun (1973), geostrophic winds were computed from sea level pressure values (interpolated from the 5 x 5° field) computed on an equilateral triangular grid, 222 km on a side, centered at 47°N, 170°W. Pressure data archived on magnetic tape were arranged on the computation grid surrounding each selected location using Bessel's central difference formula. Finite difference first and second derivatives were formed and the geostrophic wind field was computed in spherical coordinates:

$$u_g = -\frac{1}{\rho R f} \frac{\partial p}{\partial \phi} \qquad (5)$$

$$\frac{\partial u_g}{\partial \phi} = -\frac{1}{\rho R f} \left(\frac{\partial^2 p}{\partial \phi^2} - \frac{\partial p}{\partial \phi} \cot \phi \right) \qquad (6)$$

$$\frac{\partial u_g}{\partial \lambda} = -\frac{1}{\rho R f} \frac{\partial^2 p}{\partial \lambda^2} \qquad (7)$$

$$v_g = \frac{1}{\rho R f \cos \phi} \frac{\partial p}{\partial \lambda} \qquad (8)$$

$$\frac{\partial v_g}{\partial \phi} = \frac{1}{\rho R f \cos \phi} \left(\frac{\partial^2 p}{\partial \phi \partial \lambda} + \frac{\partial p}{\partial \lambda} [\tan \phi - \cot \phi] \right) \qquad (9)$$

$$\frac{\partial v_g}{\partial \lambda} = \frac{1}{\rho R f \cos \phi} \frac{\partial^2 p}{\partial \lambda^2} \qquad (10)$$

where ϕ and λ are the latitude and longitude coordinates respectively, u_g and v_g are the eastward and northward components of geostrophic wind, p is the atmospheric pressure, ρ is the density of air (considered to be a constant equal to 0.00122 gm/cm), R is the mean radius of the earth and f is the Coriolis parameter.

These are transformed to estimates of the wind field near the sea surface by rotating the geostrophic wind 15 degrees to the left and contacting it by 30 percent to approximate, in a simplified manner, the effect of friction in the planetary boundary layer:

$$u = a_1 u_g + b_1 v_g \qquad (11)$$

$$\frac{\partial u}{\partial \phi} = a_1 \frac{\partial u_g}{\partial \phi} + b_1 \frac{\partial v_g}{\partial \phi} \qquad (12)$$

$$v = a_2 u_g + b_2 v_g \qquad (13)$$

$$\frac{\partial v}{\partial \lambda} = a_2 \frac{\partial u_g}{\partial \lambda} + b_2 \frac{\partial v_g}{\partial \lambda} \qquad (14)$$

where u and v are the eastward and northward components of surface wind, $\vec{V}$, and the transformation coefficients are: $a_1 = 0.7 \cos (15°)$,

$b_1 = 0.7 \sin(15°)$, $a_2 = -0.7 \sin(15°)$, $b_2 = 0.7 \cos(15°)$.

Derivatives of surface wind speed, $|\vec{V}| = \sqrt{u^2 + v^2}$ are computed according to:

$$\frac{\partial|\vec{V}|}{\partial\phi} = \left(u\frac{\partial u}{\partial\phi} + v\frac{\partial v}{\partial\phi}\right)\frac{1}{|\vec{V}|} \qquad (15)$$

$$\frac{\partial|\vec{V}|}{\partial\lambda} = \left(u\frac{\partial u}{\partial\lambda} + v\frac{\partial v}{\partial\lambda}\right)\frac{1}{|\vec{V}|} \qquad (16)$$

The stress on the sea surface, $\vec{\tau}$, was computed using a relatively high value, 0.0026, of the constant drag coefficient to partially offset the effect of using mean data:

$$\vec{\tau} = \rho\, C_D\, |\vec{V}|\, \vec{V} \qquad (17)$$

$$\frac{\partial\tau_\phi}{\partial\lambda} = \rho\, C_D\left(v\frac{\partial|\vec{V}|}{\partial\lambda} + |\vec{V}|\frac{\partial v}{\partial\lambda}\right) \qquad (18)$$

$$\frac{\partial\tau_\lambda}{\partial\phi} = \rho\, C_D\left(u\frac{\partial|\vec{V}|}{\partial\phi} + |\vec{V}|\frac{\partial u}{\partial\phi}\right) \qquad (19)$$

where τ_ϕ and τ_λ are the northward and eastward components of $\vec{\tau}$. The curl of the wind stress is then determined as

$$\nabla \times \vec{\tau} = \frac{1}{R}\left(\frac{1}{\cos\phi}\frac{\partial\tau_\phi}{\partial\lambda} - \frac{\partial\tau_\lambda}{\partial\phi} + \tau_\lambda \tan\phi\right) \qquad (20)$$

Integration of wind-stress curl along a parallel of latitude from an eastern boundary, in this case the west coast of North America, to successive grid points results in a total transport across that parallel of latitude; and eastward flow is obtained by satisfying continuity between grid points along two parallels of latitude. Welander (1959) has shown that wind-stress transport in a semi-enclosed basin (such as the Gulf of Alaska) must flow out in the form of a western boundary jet because eastern boundary currents are excluded, thus, northward transports across 55°N are considered to exit the gulf along the western shore.

When one considers the nature of the variability in location and frequency of ship reports that make up the bulk of these pressure data, the averaging processes involved, and the theory employed, there are severe limitations associated with this method of obtaining flow, but it provides an indication of the continuity of events that is unattainable from the fragmentary station data obtained only aboard research vessels. Mean (1950-74) seasonal integrated total transports (Fig. 27) indicate a maximum northward transport in excess of 19 Sv into the gulf in winter and an accompanying closed circulation in the gulf area. Northward transport drops to less than 5 Sv in spring and summer and is concentrated at the western side of the gulf, whereas there is a suggestion of southward flow (< 1 Sv) at the eastern side. Intense northward transport greater than 15 Sv is reestablished in autumn, but the closed circulation evident in winter east of 155°W is not developed.

There are marked departures from mean conditions and these are most readily apparent in winter. Two winter periods, in 1963 and 1969, have been selected to reflect the range in values obtained in the period 1950-74 (Fig. 28). Computed northward transport in 1963 was less than 10 Sv, whereas, in 1969 it was nearly 3 times as great, in excess of 25 Sv Thus, considerable variability in flow is indicated not only seasonally, but annually and marked deviations from the smoothed isopleths presented must occur. One can only conclude that, although a basic cyclonic flow

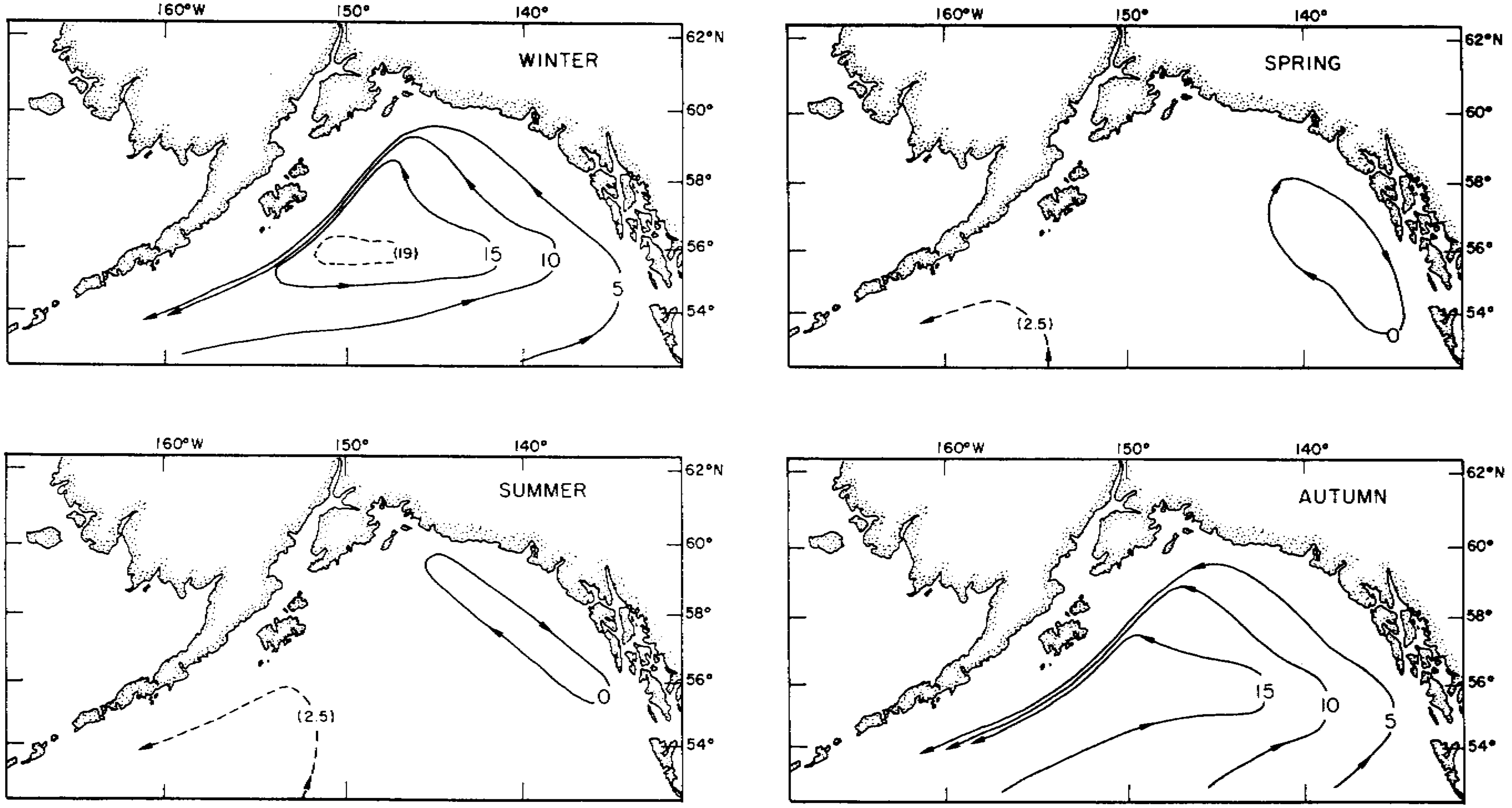


Figure 27. Seasonal mean (1950-74) integrated total transports (Sv) indicating general cyclonic flow with marked winter intensification of flow.

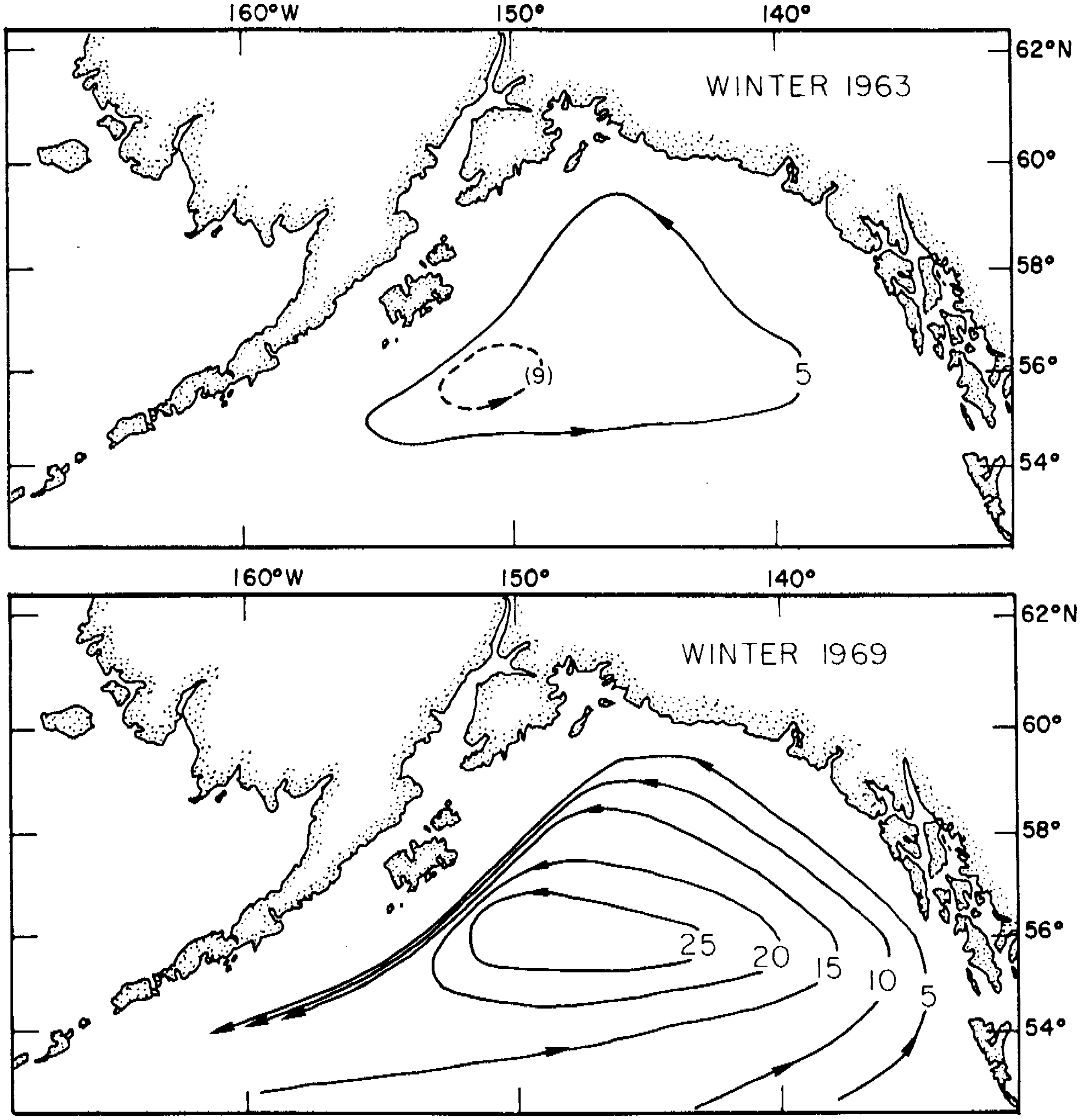


Figure 28. Total integrated transports for winter (Jan. Feb. Mar.) 1963 and 1969 indicating variability in winter flow.

exists in the gulf, the variations and perturbations in flow due to variable wind-stresses result in a highly complex flow regime.

C. Numerical Model

Further refinements of estimates of water transport in the gulf, over those obtained by integrated total transport method, are obtained by expanding basic assumptions in the total integrated transport method to permit inclusion of variable bathymetry and to incorporate analyses in a numerical model first devised by Galt (1973) for an enclosed basin. This was configured to fit the North Pacific Ocean, Bering Sea, and Okhotsk Sea on the 222 km equilateral triangular grid mentioned in the previous section. Although limited to the barotropic flow assumption, the model provides an inital look at actual isopleths of flow considering the great increase in complexity of designing a baroclinic or multilayer model. Because of problems associated with specifying initial stream lines and vorticity on an arbitrary mid-ocean southern boundary for the Gulf of Alaska, the larger ocean area with a southern boundary far away from the area of interest was selected for the model. This exploratory version would show if a more detailed grid within the Gulf of Alaska as a subset of this large area model would be informative.

The basic model outputs are time dependent solutions of the transport stream function which, when presented in maps and contoured, give transport stream lines of flow. As before, the wind stress curl field is computed from sea level pressure; the bathymetry is scaled relative to the mean depth from flat bottom (0%) to actual bathymetry (100%) to simulate the effect of stratification; and coefficients may be selected which govern the character of the solution by scaling the importance of nonlinear advection (α), lateral friction (β), and bottom friction (γ). As the model spins up from zero initial stream function and vorticity, maps may be obtained at any time interval which is a multiple of the time step (6 hours or less) to show the development of flow which in most cases reaches near steady state after about 60 days or 240 time steps. Caution must be taken when interpreting the results because of the barotropic assumption which allows minor changes in deep bathymetry to affect flow. Further, short (one month or less) periods of unusually intense wind stress curl patterns give unrealistically high transports if run to a steady solution a considerable time beyond their actual duration.

The model is based on a nondimensionalized vorticity equation (1) which is obtained by cross differentiation and subtraction of the vertically integrated equations of motion:

$$\frac{\partial \xi}{\partial t} = (\nabla \times \psi \vec{k}) \cdot \left(\frac{\alpha \xi + f}{h}\right) + \beta \nabla^2 \xi - \frac{\gamma}{h}\left[\xi + \nabla\psi \cdot \nabla\left(\frac{1}{h}\right)\right] + \nabla \times \left(\frac{\tau}{h}\right), \quad (21)$$

where ξ is the vertical component of vorticity $\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$; u and v are the horizontal components of velocity; h is the depth, f is the Coriolis parameter; α , β , and γ are constants that specify the effectiveness of the nonlinear advection, horizontal and vertical frictional forces respectively; τ is the wind stress; and ψ is the transport stream function defined by $-hu = \frac{\partial \psi}{\partial y}$ and $hv = \frac{\partial \psi}{\partial x}$. The continuity equation

$$\frac{\partial (hu)}{\partial x} + \frac{\partial}{\partial y}(hv) = 0 , \quad (22)$$

and finally a relationship between stream function and vorticity

$$\nabla\left(\frac{1}{h}\nabla\psi\right)=\xi \quad , \qquad (23)$$

complete the basic equations of the model. For further information on finite difference forms see Galt (1973).

A typical run of the model includes the following sequence of events throughout the 17 x 42 point array over the area from 33-61°N and 140°E-120°W. Initially the vorticity (ξ) and stream function (ψ) values are set to zero at each of the 714 grid points. Then the rate of change of vorticity ($\frac{\partial\xi}{\partial t}$) is computed at each grid point from equation (21) and integration of the rate of change over one time step interval (6 hours) gives a new vorticity value at each grid point. Using equation (23), new values for the transport stream function are computed from the new vorticity values by an over-relaxation technique, and streamfunction values at each grid point are contoured to indicate the new magnitude and direction of flow. This sequence is repeated. The model approaches steady conditions when the gradients are such that the terms on the right hand side of equation (21) approach zero indicating a balance between vorticity dissipation (by advection of potential vorticity, lateral friction, and bottom friction) and vorticity input at each grid point (the wind stress curl field).

Using the 25 year mean annual wind stress and a 10% bathymetry factor, the model after 60 days spin up shows the generally accepted features of flow around the Gulf of Alaska (Fig. 29). The cyclonic flow, western boundary intensification, and magnitude of transport (about 20 Sv) generally agree with the geostrophic calculations from field measurements

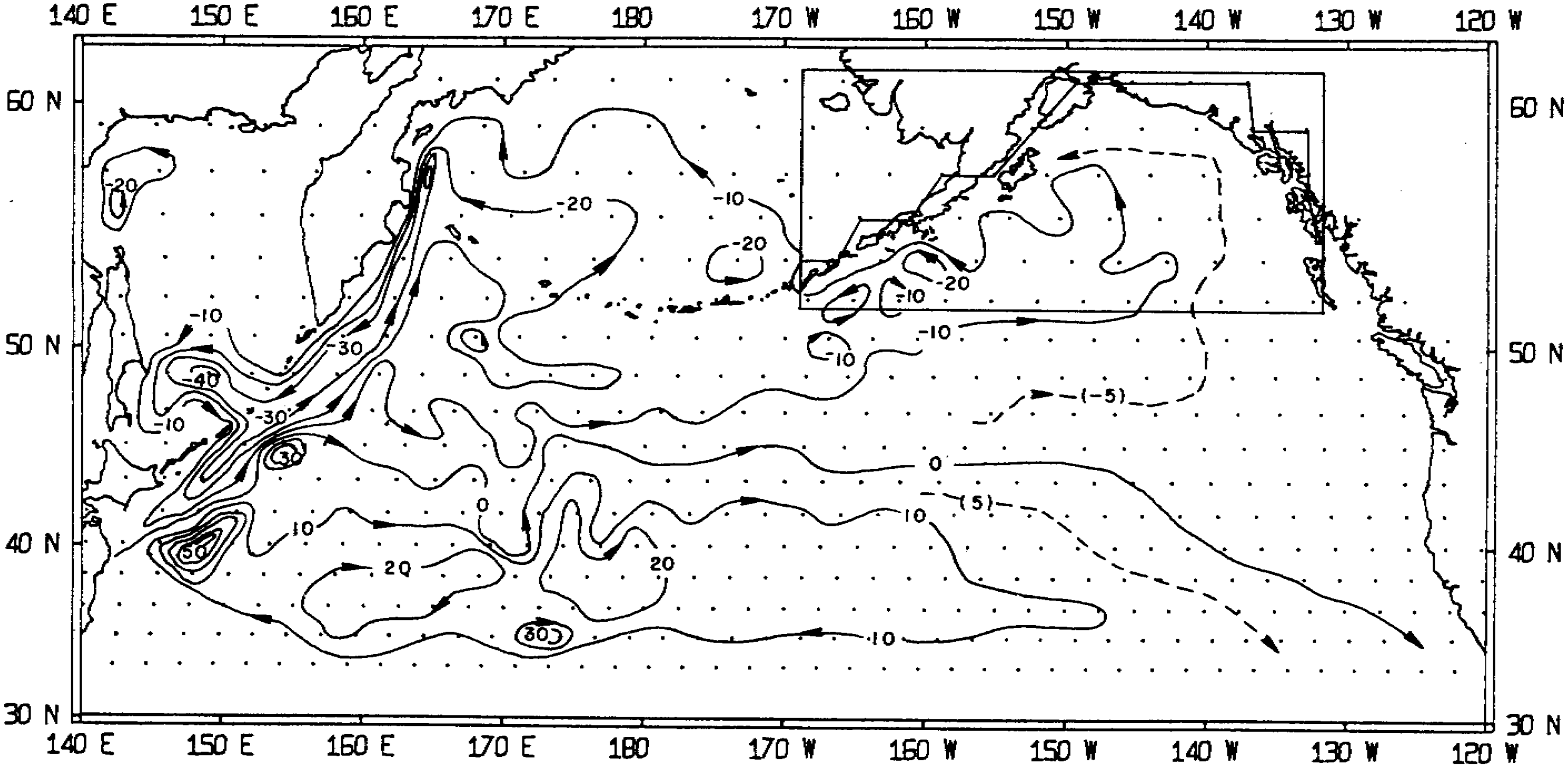


Figure 29. Numerical model of Transpacific ocean transports (Sv) using annual mean (1950-74) wind stress, 10% bathymetry factor, and α , β , γ coefficients.

of temperature and salinity if a reference level-of-no-motion of about 2000 db is used. Next the sea level pressure data were averaged by seasons to observe the effect of variable wind-stress. All factors except wind stress input were kept the same for each of the four runs which were driven by the seasonal mean (1950-74) wind-stresses, only the gulf portion of the model is presented (Fig. 30). As expected, the autumn and winter transport patterns are much more intense than the annual mean pattern, and the maximum transport of 63 Sv across 54°N (between 130° and 160°W) occurred for autumn conditions; the winter transport was 51 Sv followed by summer with 13 Sv and spring with 11 Sv. The general asymmetric cylonic features of flow were quite similar during both of the high transport seasons and both of the low transport seasons, but details were considerably different.

During autumn and winter an intense boundary current develops on the western side of the gulf, about 2 grid lengths offshore, over the continental slope. Eddy-like features form south of the boundary current. The lack of synopticity and closely spaced stations in historical oceanographic data has precluded detecting the existence of these eddies, other than perhaps isolated instances, which have been generally overlooked. At the eastern side of the gulf, the streamlines of easterly flow converge indicating higher velocities near Yakutat. The flow remains about the same magnitude zonally across the head of the gulf and intensifies as it is forced southwestward by the land boundary off Kodiak Island and the Alaska Peninsula.

During the spring and summer low wind stress period, flow is considerably reduced in magnitude, and the center of cyclonic flow shifts southward.

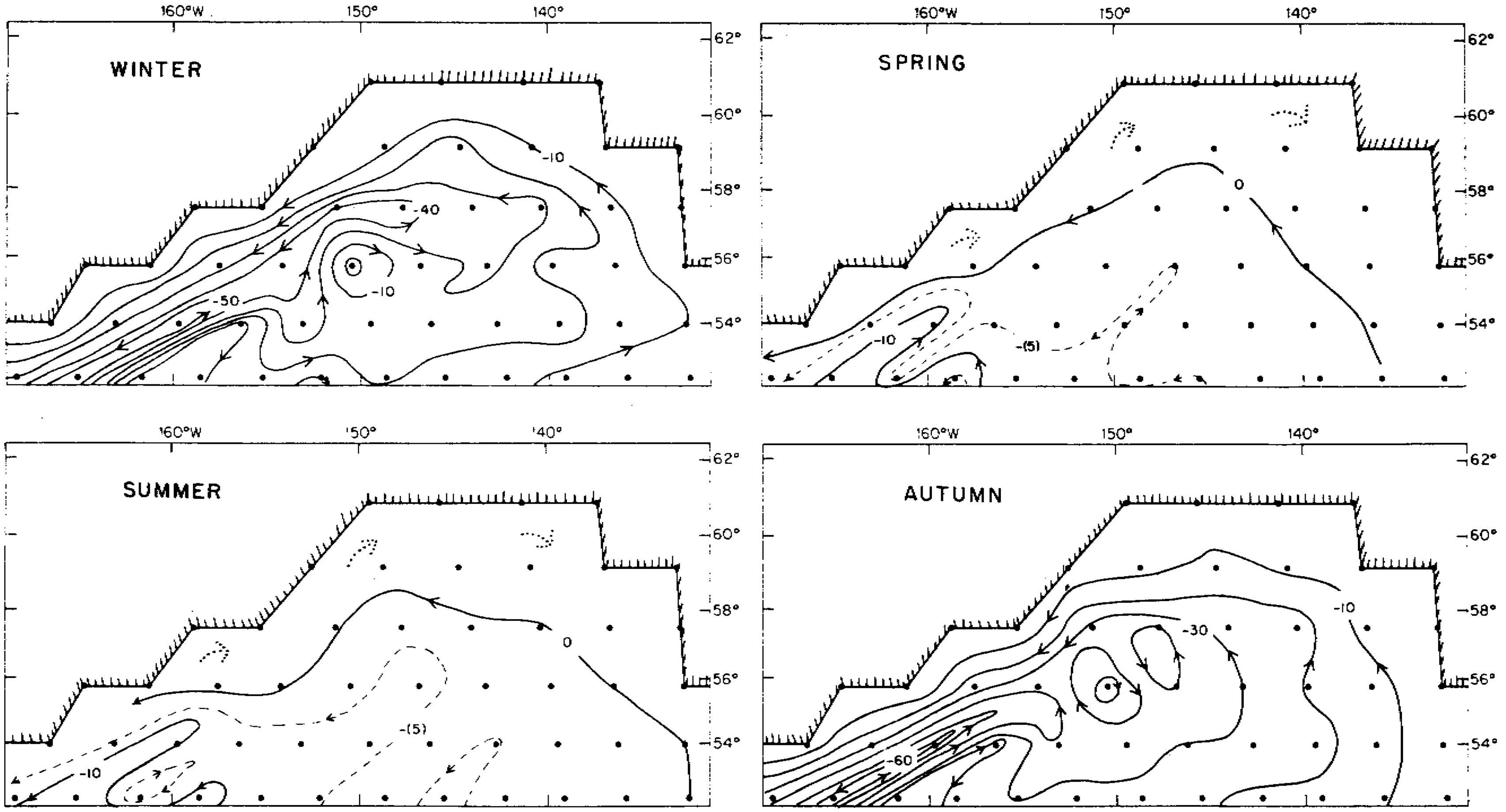


Figure 30. Seasonal mean transports (Sv) in the gulf obtained from numerical model studies suggesting a greater complexity in flow than evident in Fig. 27.

A new feature appears in the form of an inshore return flow of 1-3 Sv over the shelf that is not evident in the 10 (or 5) Sv contour interval shown. This is perhaps much more significant in terms of mean velocity considering that the transport in this area is confined to within a depth interval of 200m compared to the offshore depth interval of about 4000m. Other features of spring and summer transports include weak eddies or meanders, a broad northerly flow at the east side of the gulf, and a slight intensification of the southwesterly flow at the western side of the gulf.

Computed wind-stress fields for winter 1963 and 1969 (based upon extremes in the integrated total transport (wind-stress transport) time series)were selected to show the variability that may be expected during the high wind stress period (Fig. 31). The general features of the mean winter condition are clearly present, with 1969 having a high transport value of 83 Sv compared to only 22 Sv in 1963. The greatest departure in 1969 from mean conditions occurs in the eastern gulf where the easterly flow is contained about 400 farther south than normal, resulting in a more intense northwesterly flow along the coast. This was apparently associated with unusually strong positive wind-stress curl in the eastern gulf.

These numerical model studies suggest that flow in the gulf does not appear to be of a typically uniform cyclonic nature, but rather a funneling of northward flow into the head of the gulf that exists as a narrow boundary flow at the western side. Closure may well occur in nature (see Surface Salinity section) in the surface layer, which is generally isolated from the deeper flow by the halocline at 100-300m. Future studies should take into account the stratification or baroclinic effects.

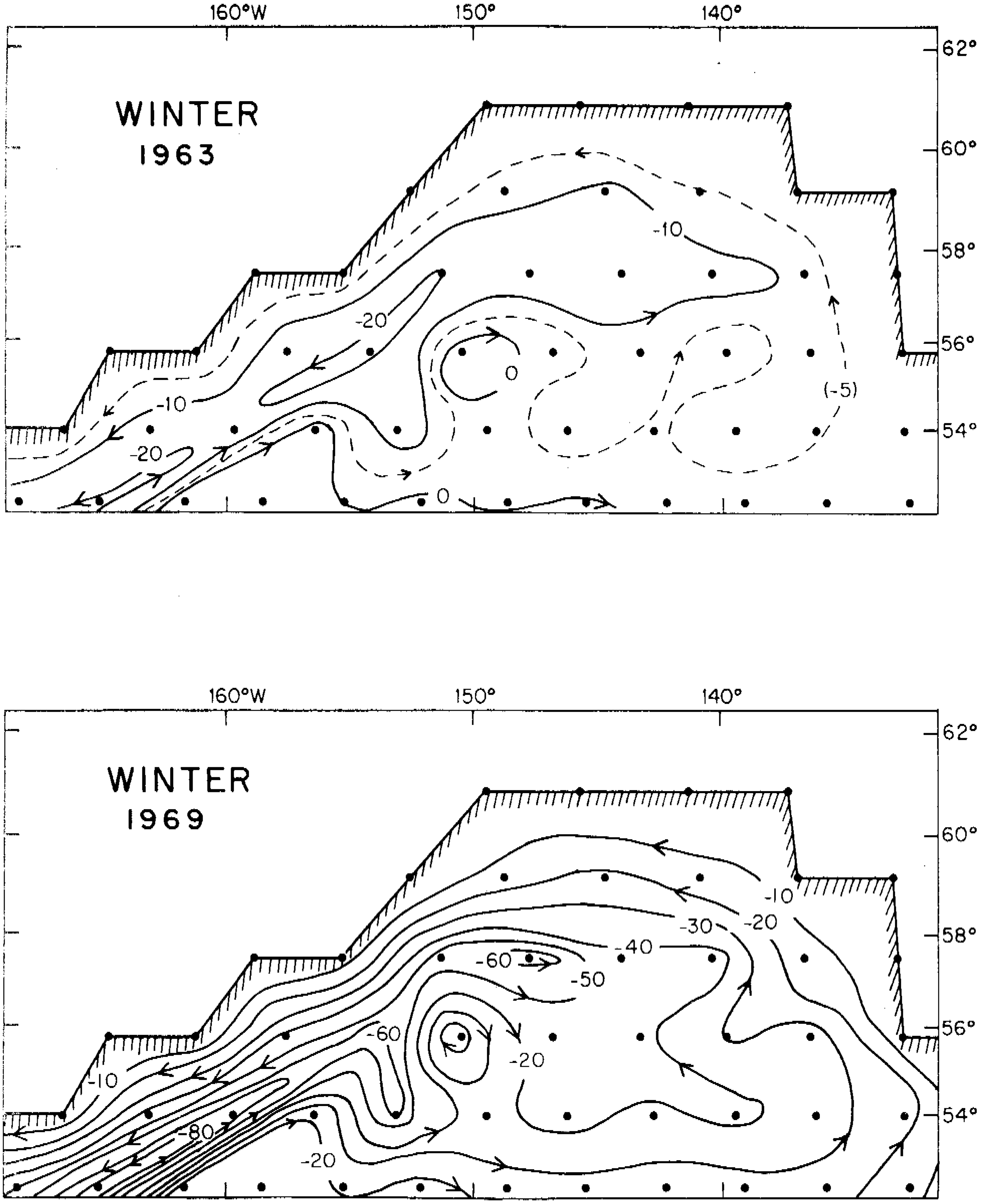


Figure 31. Numerical model transports (streamline interval 10 Sv) for winter (Jan. Feb. Mar.) 1963 and 1969 suggesting greater complexity in flow than evident in Fig. 28.

V. COASTAL SEA LEVELS

The geopotential topography computed from hydrographic data provides a relative indication of sea surface slopes but observations at shore stations are a direct measurement of actual sea level. Daily means of hourly heights referred to a local datum are recorded at selected coastal stations and the data are on file at NOAA Headquarters (Rockville). Although weekly and even daily departures from normal sea level have shown good correlations with coastal flow regimes in the Coastal Upwelling Experiments (CUE) off Oregon, monthly mean sea level data are appropriate for discussing the seasonal and longer-term variations which are the focus of this chapter. Distortions caused by changes in atmospheric pressure are corrected as follows:

$$\delta h = \frac{1}{\rho g} \delta p \qquad (24)$$

where h is the change in sea level, ρ the density of water, g the acceleration of gravity and p the atmospheric pressure. Steric effects which may result in seasonal differences as great as 6 cm are not compensated for because usually only departures from monthly means are considered.

LaFond (1939) showed that nearly all variations in sea level on the west coast of the United States could be accounted for by changes in the geopotential topography of the ocean off the coast and thus, were directly related to ocean currents. Jacobs (1939) reported that such relations were not due to changes in the density of surface water but actual slopes caused by atmospheric interactions. Pattullo et al (1955) found that in the northern North Pacific isostatic adjustments (steric and pressure effects) did not account for all seasonal departures from mean sea level, and Pattullo (1960) noted that in low latitudes sea level was high in summer but north of 40°N there was a distinct change of phase and sea levels around the Gulf of Alaska were highest in December. Local effects of river discharge on sea level at the mouth of the Columbia River were noted by Roden (1960) in a study of non-seasonal variations in sea level along the west coast of North America; only a moderate to poor coherence in relation to local sea surface temperatures were found. Sea level data south of Ketchikan were studied by Saur (1962) and deviations from isostacy were attributed to variability in ocean currents. Favorite (1974) showed that the anomalous increase in sea level at Yakutat during winter could be explained by an accompanying increase in northward wind-stress transports, and Reid and Mantyla (1975) have indicated that the winter increase in sea level along the entire coast of the northern North Pacific Ocean is due to increased flow in the overall subarctic cyclonic gyre.

A. Sea Level Pressures

A general gradual increase in monthly mean sea level pressure is evident at Ketchikan, Sitka, Yakutat, Seward, Kodiak and Dutch Harbor form February to July (Fig. 32) and this is followed by an abrupt decrease from July to October. Somewhat constant but low pressures prevail from November until January when an anomalous secondary maxima occurs that is probably caused in part by a westward shift in the center of the Aleutian low from the gulf to the central Aleutian Islands that occurs at this time.

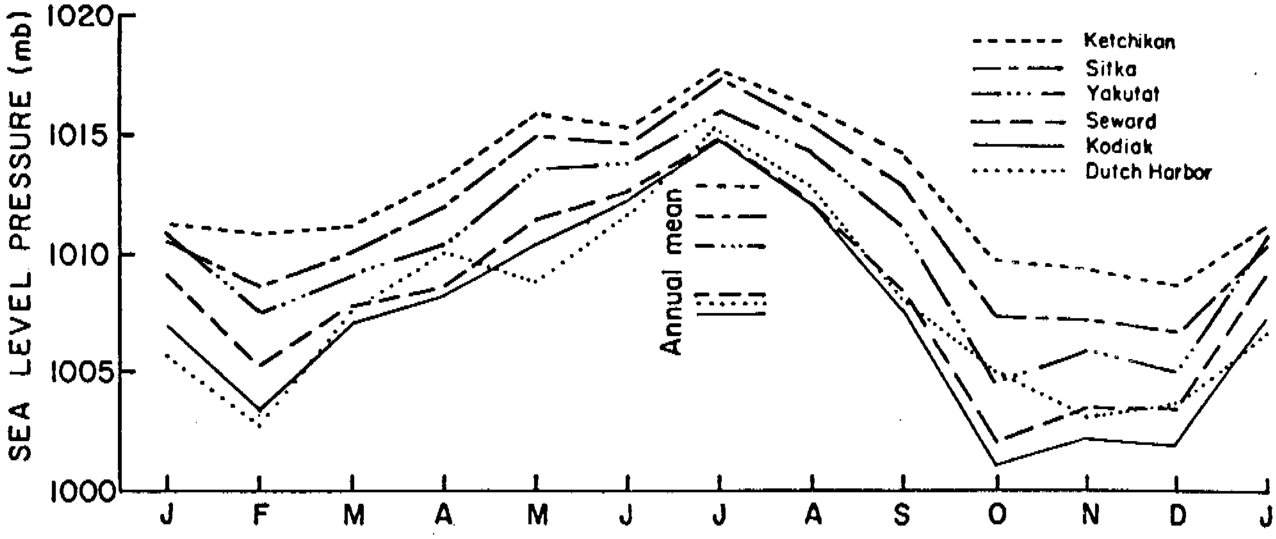


Figure 32. Monthly mean (1950-74) sea level pressure (mb) at the indicated coastal stations indicating maxima in July and minima in October.

Deviations from monthly means, and 12-month running means of sea level pressures for the 6 locations for 1950-74 (Fig. 33) indicate a marked similarity that is even reflected in abrupt anomalies of only a month or so duration. The abrupt increase in pressure in late 1950 at Dutch Harbor was evident at all stations, although decreasing in intensity to the south. In 1957 an abrupt increase and a subsequent decrease was evident at all locations and other examples are evident. Thus, there is a general response throughout the area to short or prolonged events but periods of positive or negative anomalies appear to be limited to from one month to about a year.

Spectral energy densities were computed for monthly mean values at each of the coastal stations over the period 1950-74 using a lag time of approximately 13 percent of the record length (40 lags over a continuous record of 300 data points). All locations exhibit maximum energy density at a frequency of approximately .085 cy/mo or 1 year (Fig. 34). Although the limited number of data points prohibits meaningful analysis of lower frequencies, there is an indication that the total energy distribution at these frequencies increases from Ketchikan to Dutch Harbor and a consistent indication of an energy peak at .025 cy/mo or 3.3 years. A coherency test using the coherence square technique shows a maximum coherence at a frequency of 1 year at all stations. Comparisons of data at all locations with those at Ketchikan indicates that there is also a good spatial coherence around the gulf (Fig. 35).

B. Mean Sea Levels

Monthly mean (1950-74) sea levels corrected for atmospheric pressure at Ketchikan, Sitka, Yakutat, Seward, Kodiak and Dutch Harbor (Fig. 36) reflect considerable coherence. Unfortunately there is no horizontal

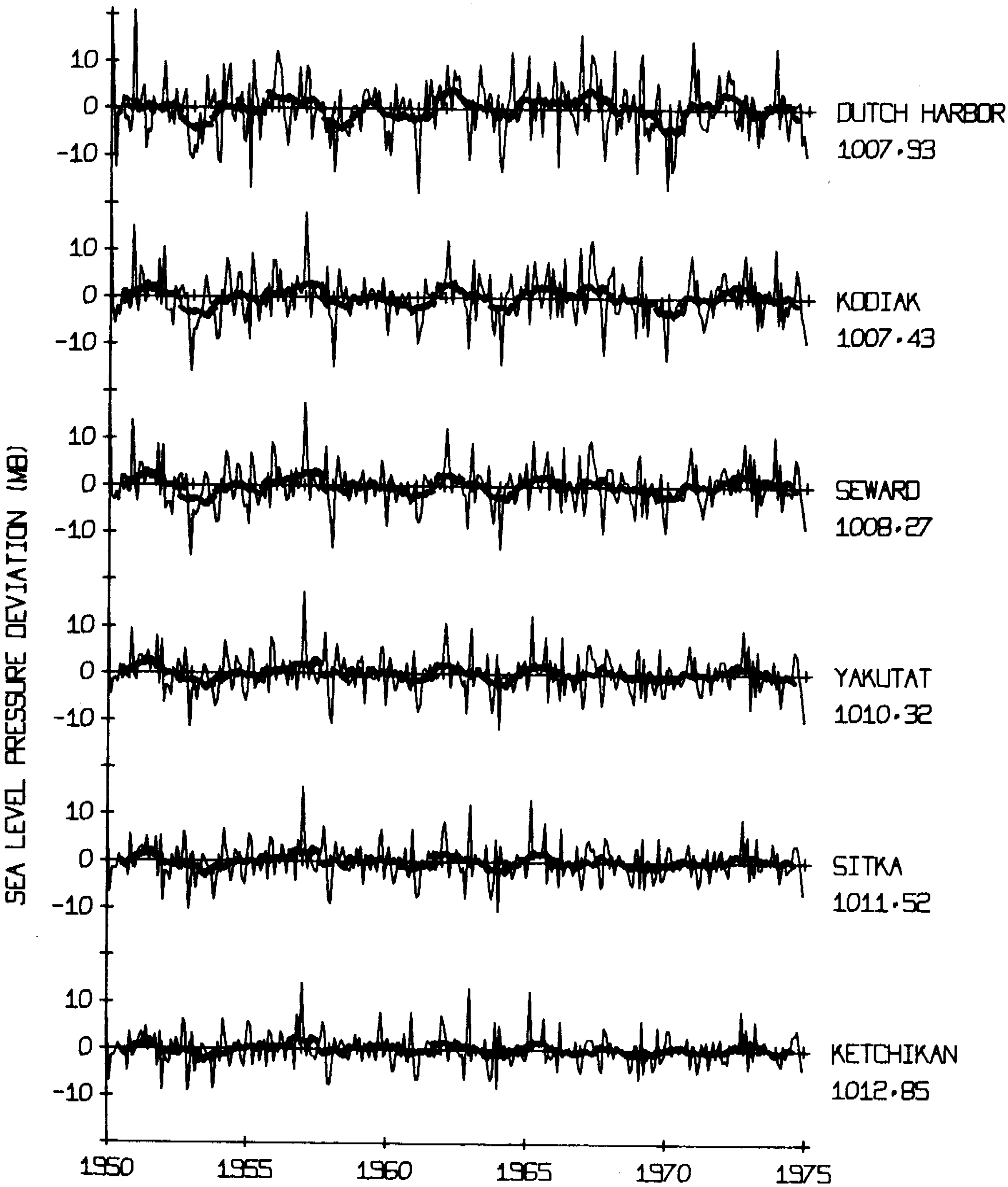


Figure 33. Deviations in sea level pressure (mb) from monthly mean (1950-74) values at the indicated coastal stations and 12-month running mean (dotted line).

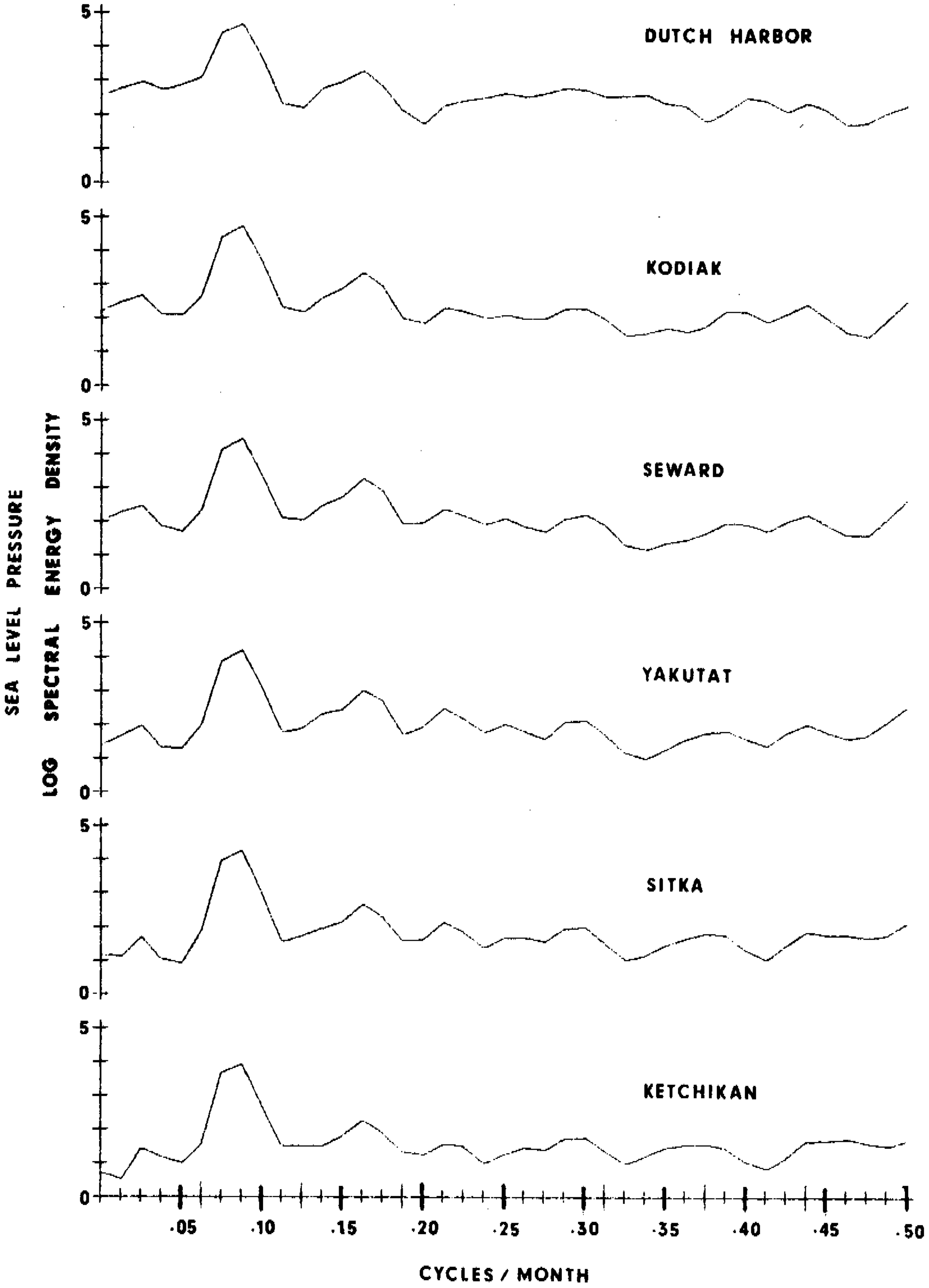


Figure 34. Spectral energy densities (40 lags) for sea level pressure at the indicated coastal stations indicating dominant annual cycle.

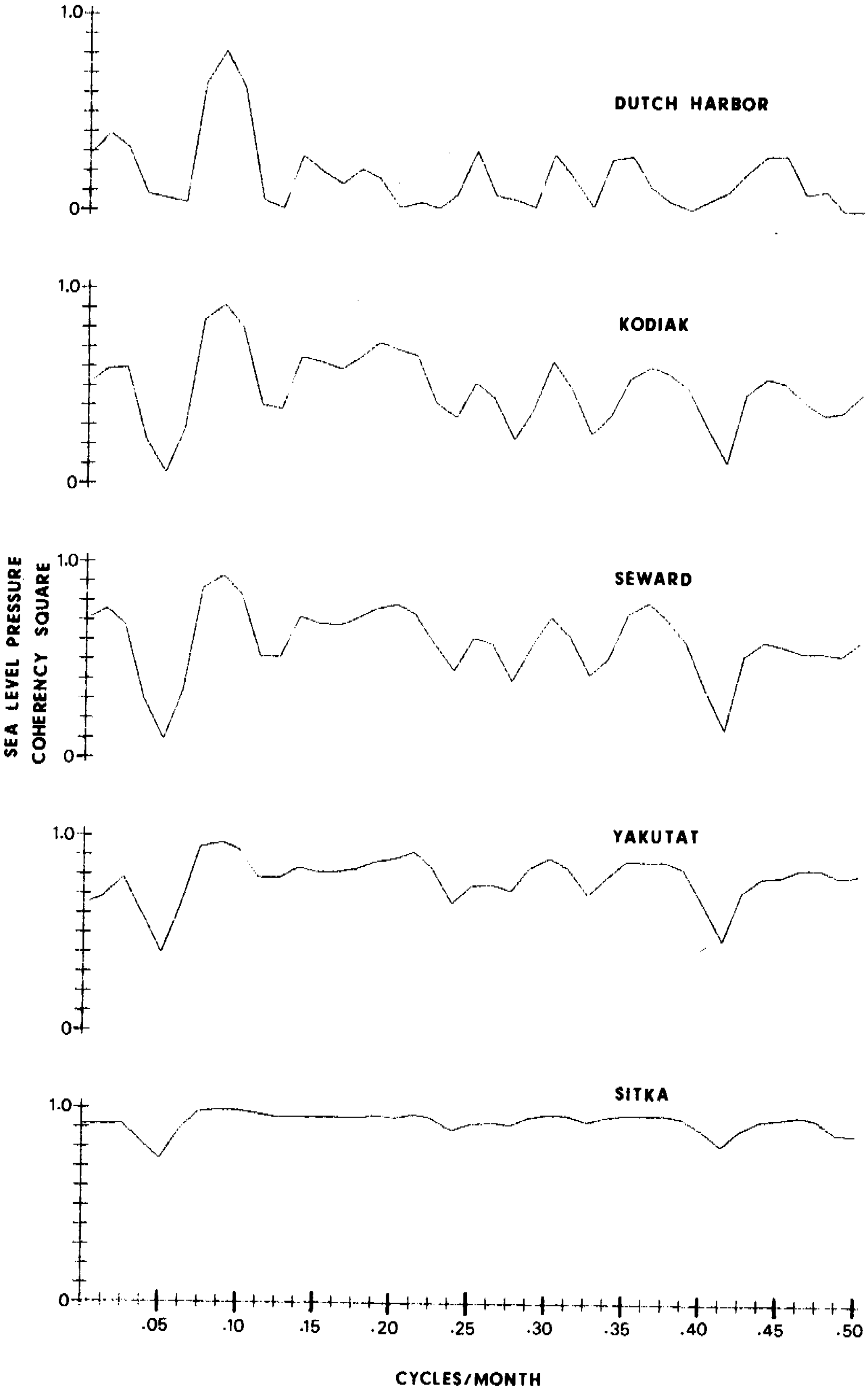


Figure 35. Coherence in sea level pressure at the indicated coastal stations, using Ketchikan as reference station, showing good coherence (>0.9) for annual cycle (.085 cy/mo).

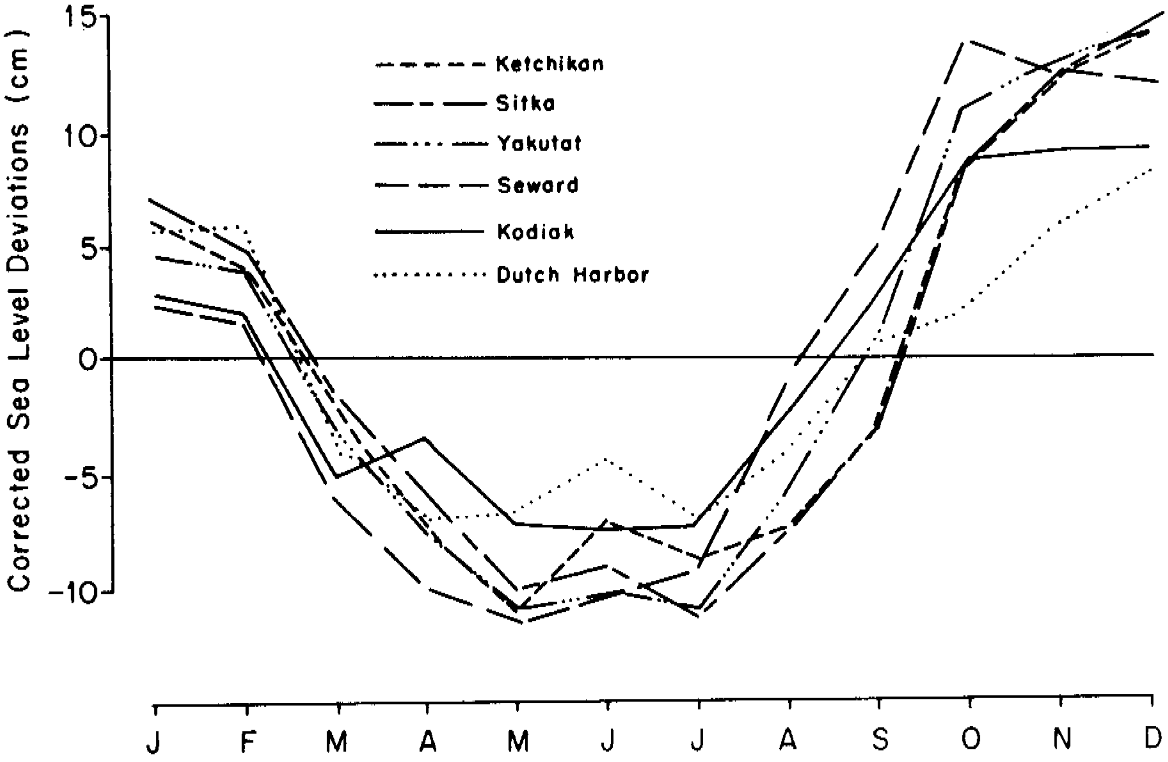


Figure 36. Deviations in monthly mean corrected (for atmospheric pressure) sea level (cm) from long term mean (1950-74) values at the indicated coastal stations showing increase in sea level in winter.

control between the various stations that would permit relating levels at the various sites to a common datum which would permit ascertaining relative levels. Deviations from monthly mean sea level for 1950-74 and 12-month running mean corrected sea level were compiled (Fig. 37). Here again there is continuity in short pulses (e.g. November 1952, January 1958, and others). However, positive and negative anomalies extend for longer periods up to 4 years. Well above normal sea level was evident at Dutch Harbor from 1957-61 and at Ketchikan from 1966-70. The apparent progressive lowering of sea level at Dutch Harbor from 1957 to 1974 is not evident at the other stations, but the below normal levels are evident from 1970 to 1974. These data can be grossly summarized for the area Sitka to Kodiak as follows: 1950-54 above normal, 1955-57 below normal, 1958-62 above normal, 1963 below normal, 1964-69 normal, 1970-74 below normal. As might be anticipated, power spectral analysis (40 lags) for corrected sea level at the coastal stations exhibits the 1 year frequency (Fig. 38). Data at Dutch Harbor, Seward, Yakutat and Ketchikan indicate significant energy densities at periods of less than one year and there is a high coherence (>.9) at this frequency at all stations compared to Ketchikan (Fig. 39). In contrast to sea level pressure, there is a marked coherence at 0.5 cy/mo. As before, the limited data points do not permit clear definition of periods greater than 1 year.

C. Relation to Transport

An increase in sea level normally signifies an increase in northward flow into the gulf. Such considerations can only be made when equivalent transport data are available. Obviously this cannot be obtained from

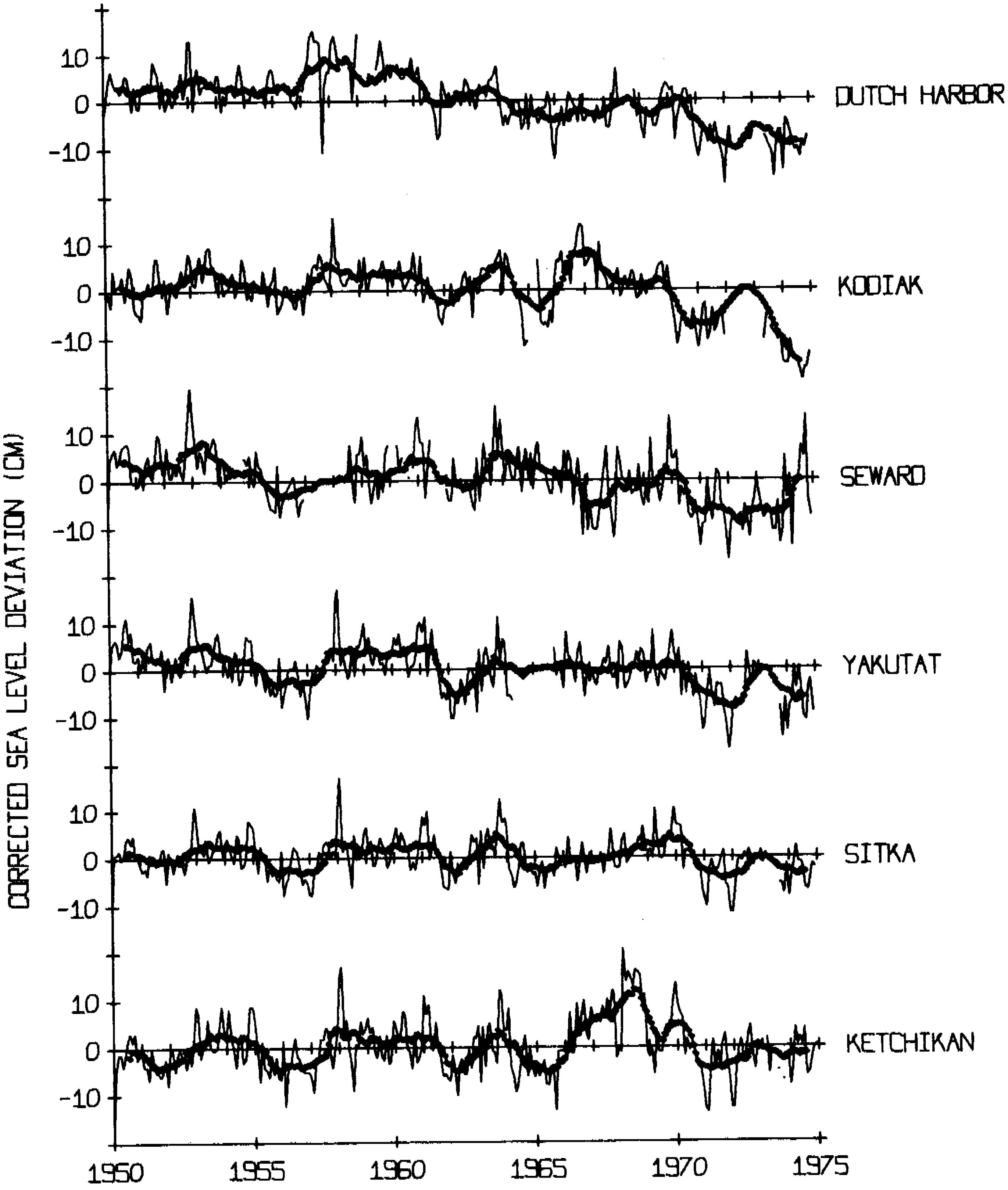


Figure 37. Deviations in corrected sea level (cm) from monthly mean (1950-74) values at the indicated coastal stations and 12-month running mean (dotted line).

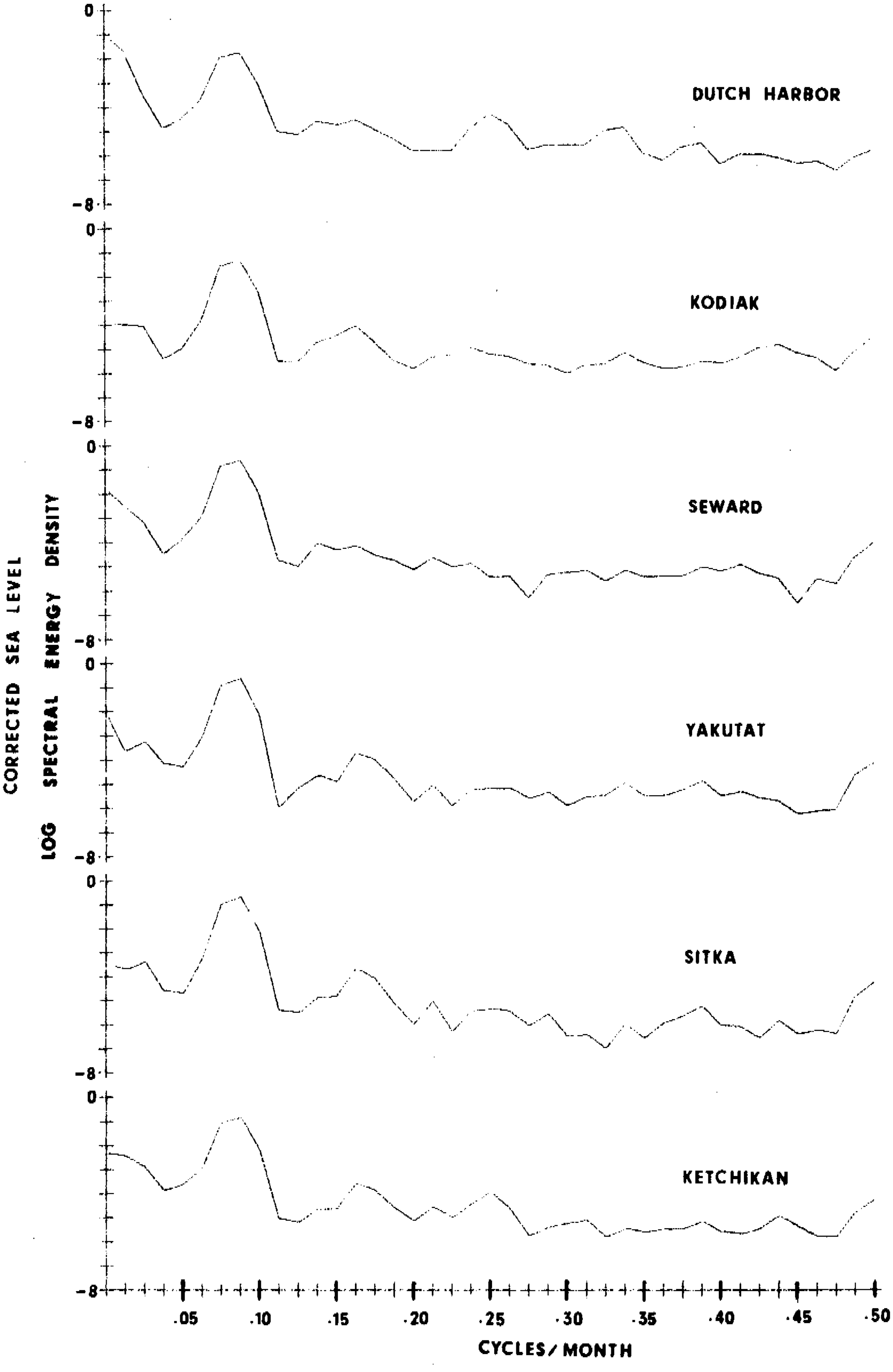


Figure 38. Spectral energy densities (40 lags) for corrected sea level at the indicated coastal stations showing the dominant 1 year cycle.

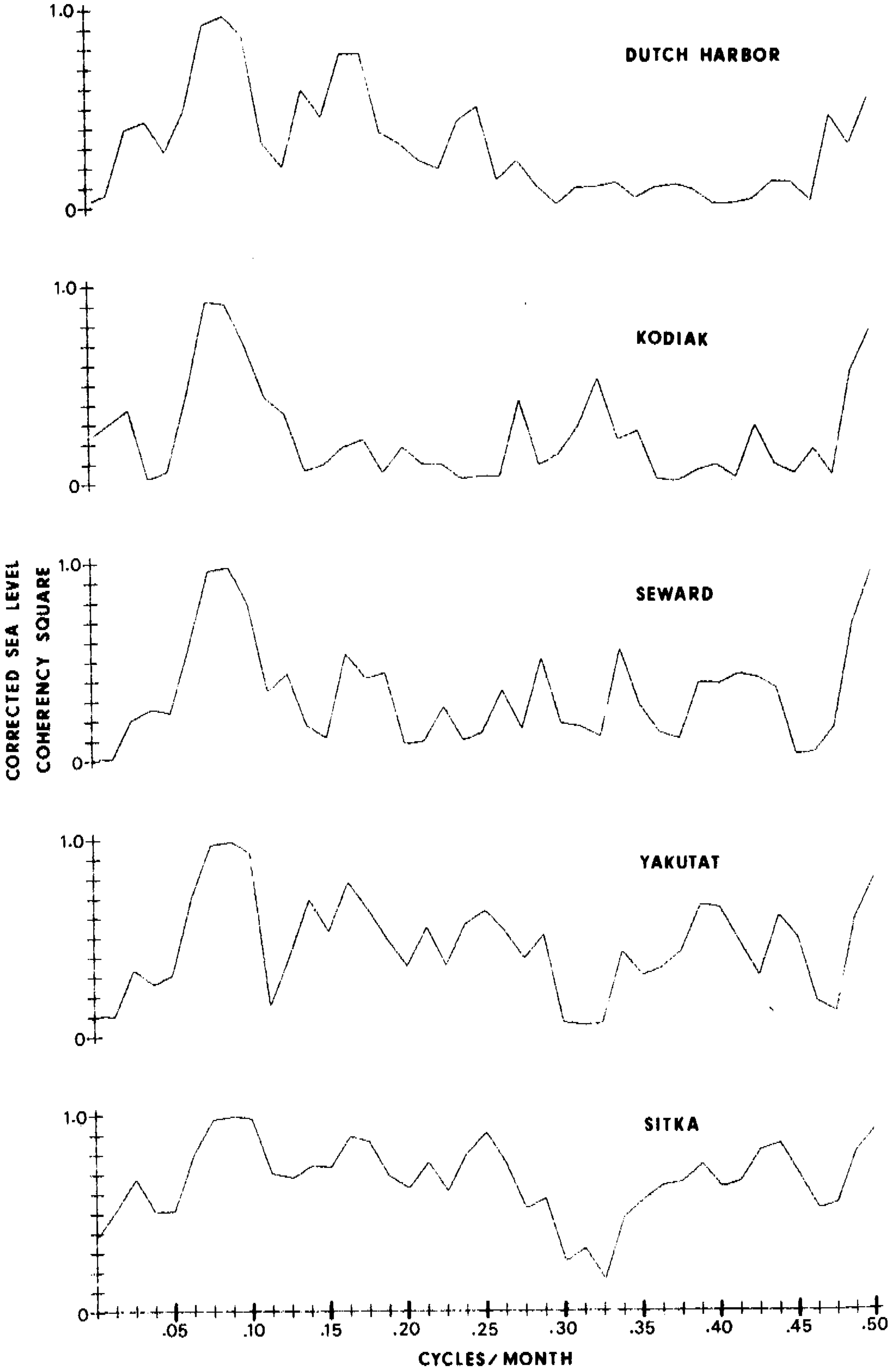


Figure 39. Coherence in corrected sea level at the indicated coastal st using Ketchikan as a reference station, showing good cohere (>0.9) for annual cycle.

station data which are available only for one or two months in a limited number of years. However, comparisons can be made with wind-stress transports. Monthly mean wind-stress transports across 55°N (+northward; - southward) computed for the years 1900-74 indicate a mean transport of 11.22 Sv (Fig. 40). There is a progressive increase in the 25-year mean values from 8.39 to 10.90 to 14.35 Sv that is probably primarily, if not almost entirely, due to progressively better definition of sea level pressure fields; thus, limited comparisons between past and more recent data can be made. Further, the high monthly mean wind-stresses in winter are **not** of sufficient duration for the calculated transports to become established, but the presence of additional energy is indicated.

The individual monthly mean transports in 1950-74 have a greater range (~ 80 Sv) than in the previous two 25-year periods (~60 Sv). The following winters stand out as having high northward transport: 1908-09, 1949-50, 1955-56, 1958-59 and 1965-66. Anomalous southward transports are indicated in: fall 1900, winter 1920, winter 1929, fall 1930, summer 1936, summer 1958 and fall 1965.

Transport ranges reflected in the 12-month running means are quite similar (~ 12 Sv) for the three 25-year periods. Except for the years 1950-1965 when there is evidence of an approximate 3-year cycle there is no immediately apparent suggestion of any other periodicities. The long data record (900 data points) provides the first substantial look at periods greater than one year and spectral analyses using 80 and 160 lags substantiate the peak near 3 years.

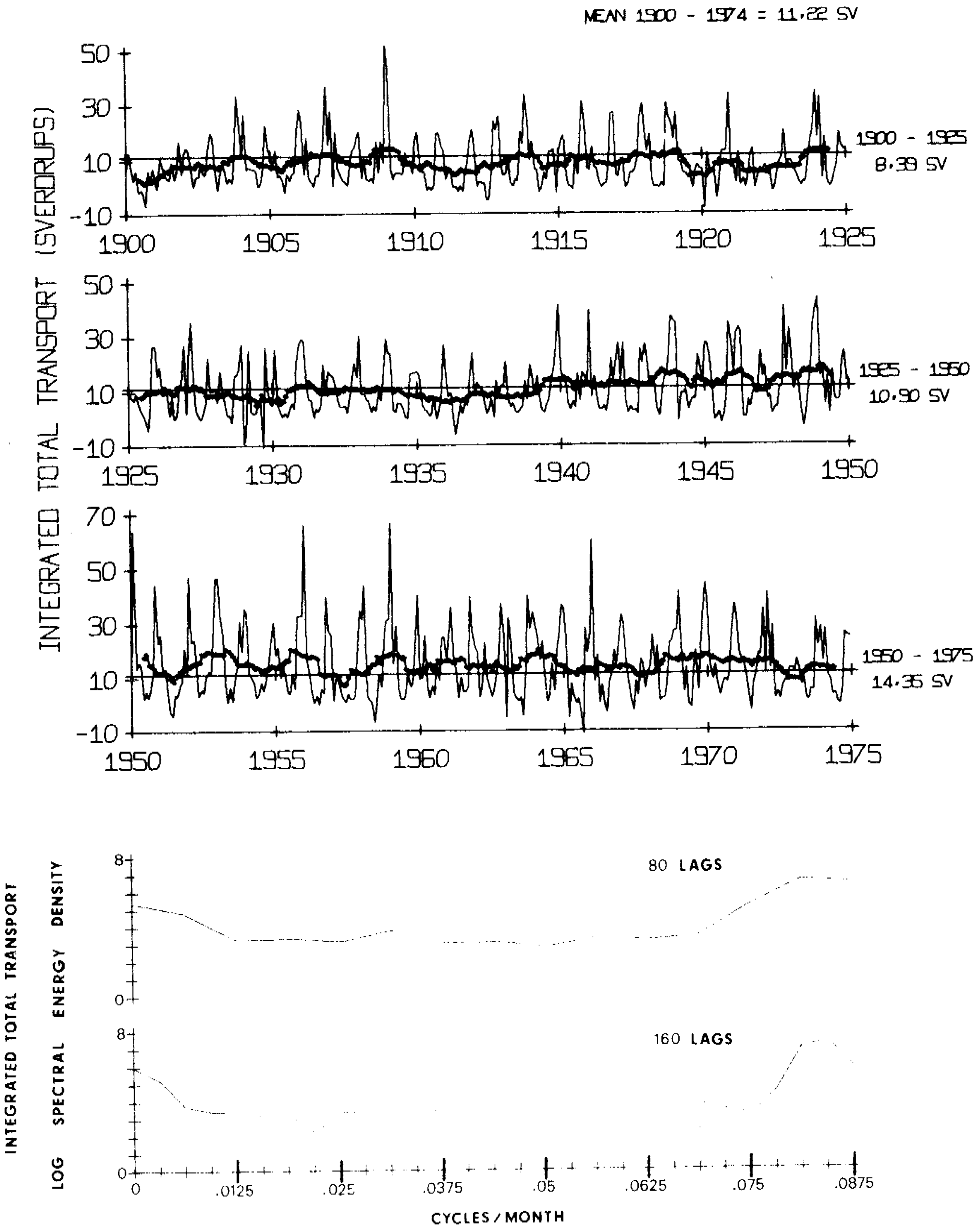


Figure 40. Monthly integrated total transports (Sv) across 55°N (+northward, -southward) 1900-74, 12-month running mean (dotted line), and spectral energy density (80 and 160 lags).

VI. SURFACE CONVERGENCE AND DIVERGENCE

The surface wind drift, i.e. the water carried along in the very surface layer of the ocean under the direct action of the wind, usually contributes only slightly to the surface velocity field, and because of its limited vertical extent is nearly always negligible in terms of total mass transport. However, the surface drift field can contain very large convergences and divergences, which may fluctuate rapidly, both in pattern and intensity. These convergences and divergences create pressure gradients and redistributions of mass which alter the underlying geostrophic currents. Because it is likely that these alterations are highly important on the scales of interest to OCSEAP field programs, a rather detailed study of the convergence-divergence pattern in the surface waters of the Gulf of Alaska has been made.

The energetic winter season dominates the annual cycle. Typically, positive wind stress curl associated with an atmospheric low pressure system induces divergent surface drift. Where the coastal boundary of the Gulf presents a barrier to this drift, convergence and intense downwelling result (Bakun, 1975). Such a situation would act to intensify the characteristic ridging of the density structure in the interior of the Gulf and to steepen the plunge of the isopycnals toward the coast. This "pumping" between the coastal and offshore areas would tend to build up baroclinicity through the winter season, which apparently would dissipate during the more relaxed portion of the year.

In order to investigate the coupled system, indices of divergence of wind-induced surface flow at 6-hourly intervals from January, 1967 through December 1975 were generated at 15 locations indicated in Figure 41. The surface flow field is approximated as Ekman Transport and an

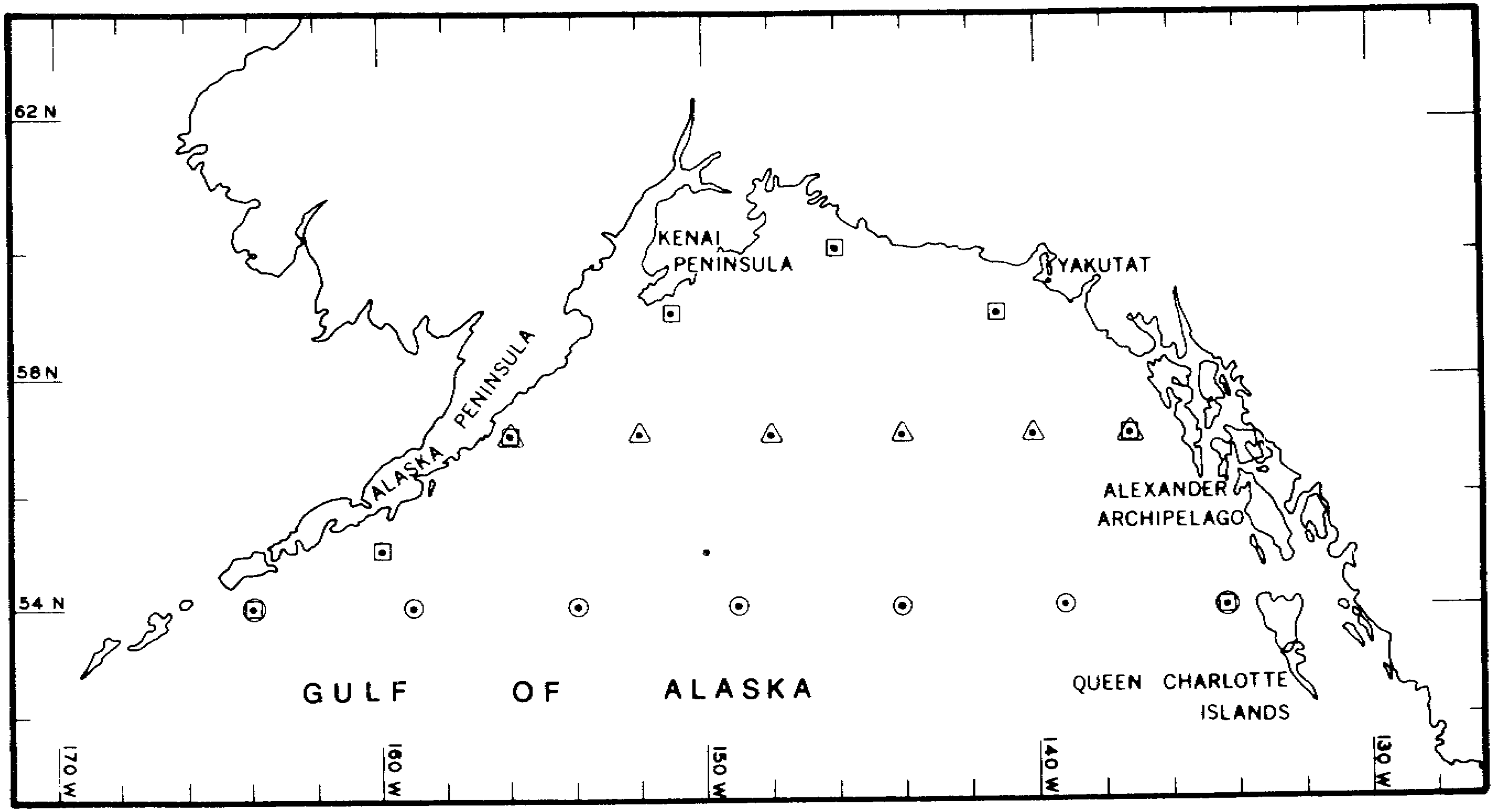


Figure 41 - Chart of the Gulf of Alaska region, showing locations at which time series of surface convergence-divergence indices were computed.

example segment of the time series at one location is shown (Fig. 42).

In the previous sections data fields averaged over a month or longer have been discussed. This is because attention has been focused on lower frequency, relatively slowly changing components of the variations, either because we are not equipped to deal with the shorter term variability or because sparsity of data requires that we collect observations over some time interval in order to get an adequate sample. Now an attempt will be made to deal with the synoptic scale. Such an approach is called for in this case because the extremely large variance of the surface divergence field on short time scales requires that proper interpretation of even the longer period variations be made within the framework of the process as it is actually occurring on the synoptic scale.

On this scale attention shifts from such mean pressure features as the Aleutian Low, or a Continental High, to individual traveling storm systems. Major winter storm tracks cut directly across the gulf from the southwest toward the northeast. Mean speeds of storm movement along these tracks are of the order of 25 knots (Klein, 1957). During the summer a larger proportion of storms turn northward through the Bering Sea and so are not felt with full intensity in the Gulf of Alaska. In addition, the summer storms are normally much less intense than the winter storms. The available reports of wind speed and direction for an area such as the gulf tend to be sparse and unevenly distributed. Example distributions of reports (Fig. 43) show that major fraction of available reports come from shore stations which, being subject to topographical influences, may not be completely representative of conditions offshore. The distribution of the observations taken at sea changes continually, and for any single observation, random errors in measurement or position may introduce

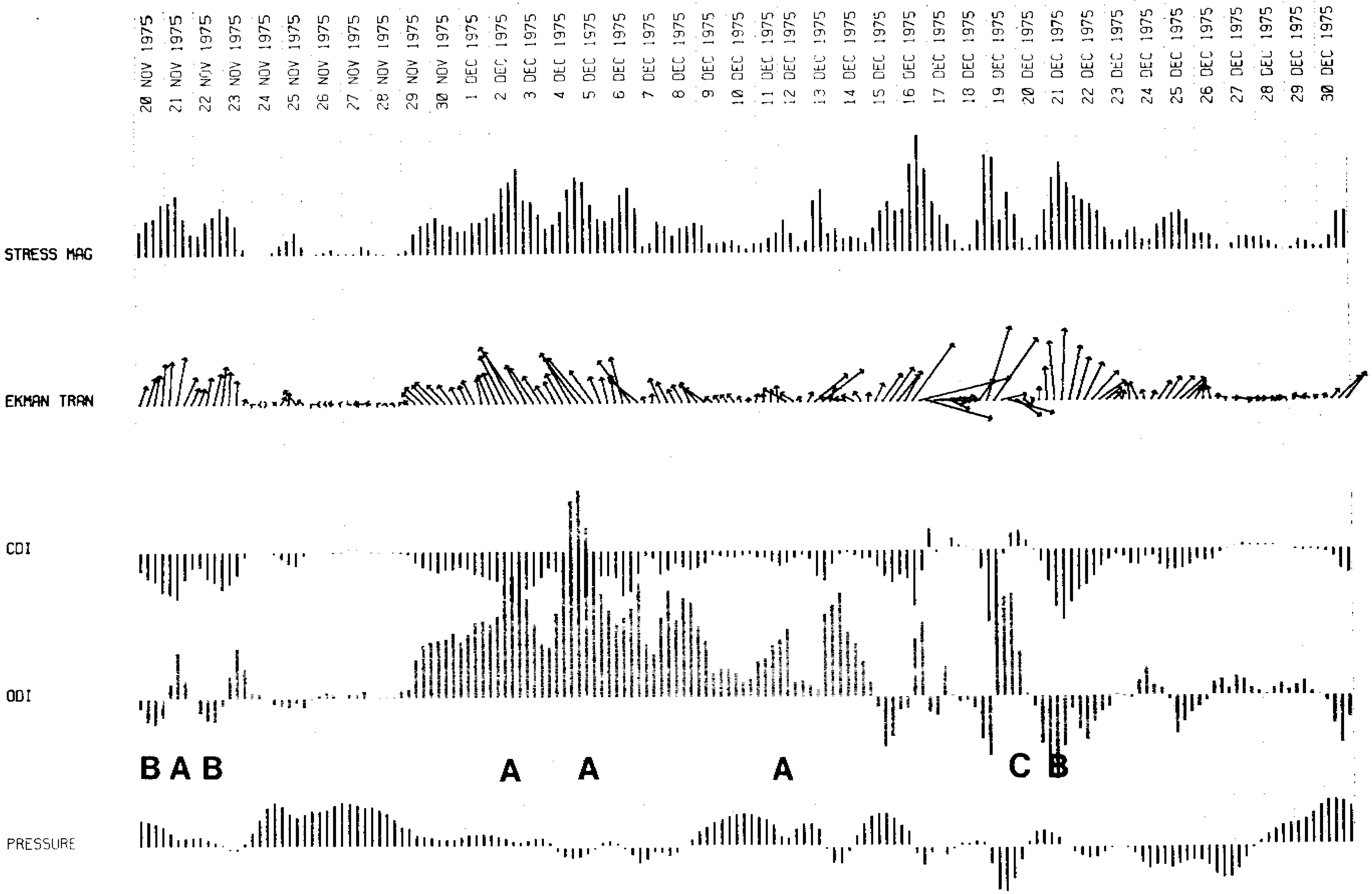
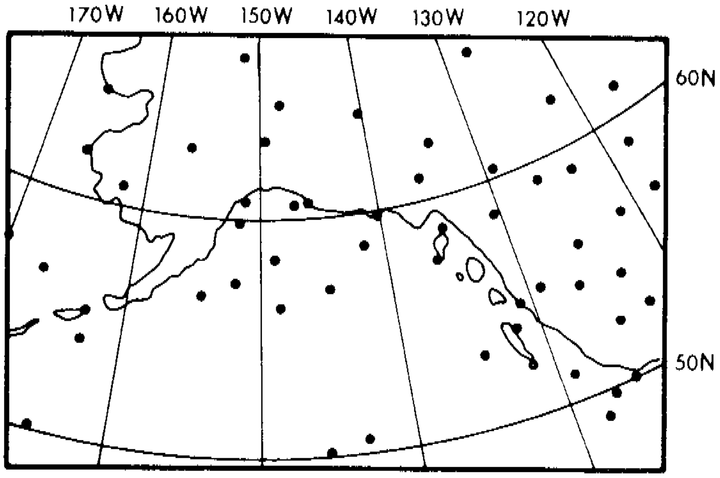


Figure 42 - Example time series segment (49N, 141W, Dec. 1, 1974 - Jan. 15, 1975). Upper graph indicates the stress magnitude at each 6-hourly synoptic sampling. Second graph indicates the magnitude and direction of Ekman transport; north is toward the top, etc. Third graph indicates the coastal divergence index (CDI). Fourth graph indicates the offshore divergence index (ODI). Large letters refer to type of event according to classification of Fig. 44.



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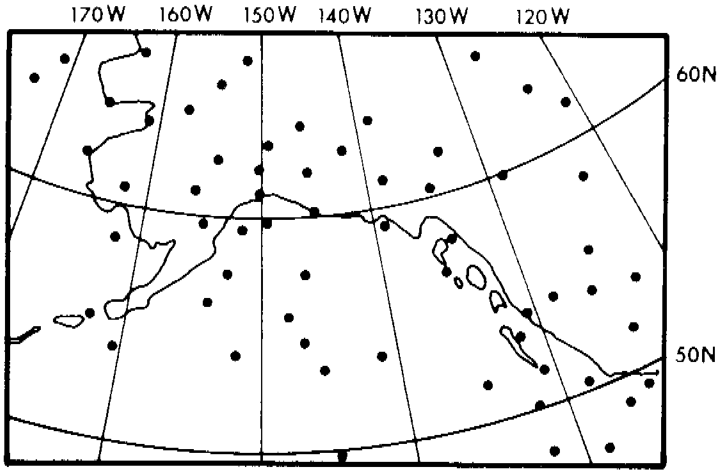

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Figure 43 - Distribution of observations made at 1800 GMT, 5 January 1974, which arrived at Fleet Numerical Weather Central in time for incorporation in the operational surface pressure analysis.

variability which is greater than the variability in the process itself (Nelson, 1974).

One way to arrive at a fairly consistent time series is to make use of analysed products produced by meteorological agencies. For this portion of the study 6-hourly synoptic surface atmospheric pressure analyses produced by Fleet Numerical Weather Central (FNWC) have been used. These analyses incorporate all available wind reports in the form of equivalent pressure gradients. The use of the pressure reports, which are linked to the wind field through well-known relationships, effectively increases the data base.

The method of atmospheric pressure analysis presently in use at FNWC is described by Holl and Mendenhall (1972). The basic steps in the analysis are as follows:

- Preparation of "first guess" field: The pressure analysis for the previous synoptic sampling, 6 hours earlier, is extropolated forward using a computation of 6-hour upper air movement and a 6-hour surface forecast using the FNWC primative equation computer forecast model.
- Assembly of new information: new reports are compared to the first guess field, subjected to a gross error check, and assigned a reliability value; surface wind reports are assembled in a gradient field.
- Blending for pressure: a blending equation of 61 terms which take into account the pressure, gradient, second-differences, cross differences, and Laplacians, plus the reliability value of each of these, is used to assemble a "best fit" pressure field.

- , Computation of reliability field: depending on the amount and reliability of information available, each grid-point value is assigned a reliability.
- Reevaluation and lateral rejection: reports are again compared to blended pressure field and reliability field and assigned new reliability values; those failing to meet criteria are rejected.
- Recycling: a new assembly is made according to the new first guess field and assigned reliabilities. The whole process is then repeated a third time to gain further accuracy.

In order to produce the computed indices discussed in this section pressure data from FNWC fields archived on magnetic tape were arranged on a 3-degree computational grid and the curl of the wind stress, $\nabla \times \vec{\tau}$ derived as shown in equations 5-20, except that constant drag coefficient of 0.0013, appropriate for synoptic rather than mean data, was used. The Ekman transport, $\vec{E}$, is derived as

$$\vec{E} = \frac{1}{f} \vec{\tau} \times \vec{k} \qquad (25)$$

where $\vec{k}$ is a unit vector directed vertically upward.

The divergence of Ekman transport integrated over the width of the coastal upwelling-downwelling boundary zone, per unit length of coast, is given, to a high degree of approximation, by the offshore component. Bakun (1973) called this by the term <u>upwelling index</u>. In this report we refer to it as the <u>coastal divergence index</u>, abbreviated as CDI.

$$CDI = \vec{E} \cdot \vec{n} \qquad (26)$$

where $\vec{n}$ is a unit vector normal to the coast. Units used are metric tons per second per 100-meter length of coast.

Away from the boundary zone the divergence of Ekman transport is computed as

$$\mathrm{ODI} = \nabla \cdot \vec{E} = \frac{1}{f} \nabla \times \vec{\tau} - \frac{\beta}{f} \vec{E} \cdot \vec{j} \qquad (27)$$

where β indicates the meridional derivative of f · ODI stands for offshore divergence index. The values presented in this report are in terms of vertical velocity (millimeters per day) through the bottom of the Ekman layer required to balance the computed divergence.

A. Vicinity of the coastal boundary

Various combinations of coastal and offshore convergence or divergence occur near the coastal boundary (Fig. 44). Both types A and B are characterized by coastal convergence (negative CDI) in the coastal boundary zone; surface water is piled up toward the coast with a resulting depression of the isopycnals, tending to intensify counter-clockwise flow along the border of the gulf. In the case of type A, divergence immediately offshore of the boundary zone (positive ODI) would favor confinement of the intensification to a narrow zone next to the coast. In the type B situation continued convergence offshore of the boundary zone (negative ODI) would spread the effect toward the interior of the Gulf.

Under situations C and D, coastal divergence (positive CDI) would favor clockwise circulation·along the boundary of the Gulf (or deceleration of counter-clockwise flow, etc.). Correspondingly, type C (positive ODI) would tend to spread the effect, while type D (negative ODI) would tend to confine it to the immediate boundary zone.

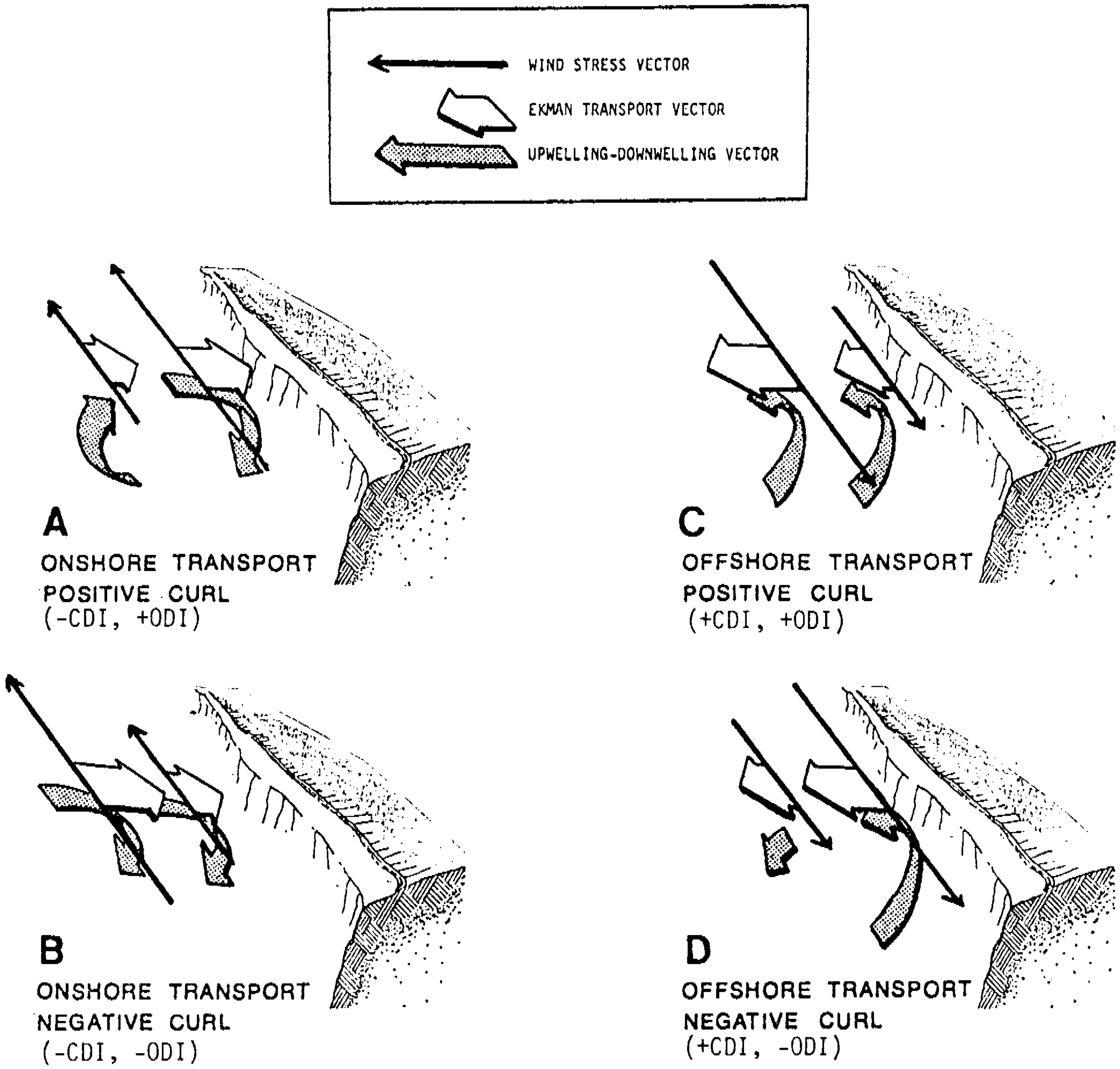

Figure 44 - Classification of indicated events according to combination of coastal and offshore convergence or divergence. A. Onshore Ekman transport and positive wind stress curl; convergence and downwelling at the coast, divergence and upwelling offshore. B. Onshore Ekman transport and negative wind stress curl; convergence and downwelling at the coast, continued convergence offshore. C. Offshore Ekman transport and positive wind stress curl; divergence and upwelling at the coast, continued divergence offshore. D. Offshore Ekman transport and negative wind stress curl; divergence and upwelling at the coast, convergence offshore.

The monthly frequency distributions of coastal divergence indices (CDI), at the near coastal locations (surrounded by squares in Fig. 41) show strongly negative mean values during the winter, indicating convergence and resulting downwelling at the coast (Fig. 45). The area of greatest intensity extends from the Kenai Peninsula (59°N, 151W) to the Alexander Archipelago (57N, 137W), reaching a maximum near Yakutat (59N, 141W). This situation relaxes during the remainder of the year; coastal divergence (positive CDI) is indicated on average over much of the gulf during summer. This "summer upwelling season" is longest in the southwest portion, extending from April to December near the extremity of the Alaska Peninsula and exhibiting three separate maxima (April, August, and November). The season of mean upwelling becomes progressively shorter and less intense with distance clockwise around the gulf, lasting three months off the Kenai Peninsual and essentially vanishing off the Alexander Archipelago.

The maximum variance corresponds in season and location to maximum absolute values of the mean. Standard deviations are larger than the means. Thus the winter season is characterized by highly energetic pulsations and relaxations of coastal convergence. In other seasons, the general trend is for the variance to decrease with the mean. The most stable situation appears to be the summer season in the northern gulf (59N, 151W; 60N, 146W; 59N, 141W). The three separate maxima exhibiting fairly similar mean positive CDI values off the lower Alaska Peninsula (54N, 164W; 55N, 160W) appear quite distinct in terms of variance. The August maximum in the mean shows the lowest variance, whereas, the November maximum exhibits standard deviations nearly three times those of August. Thus, the mean

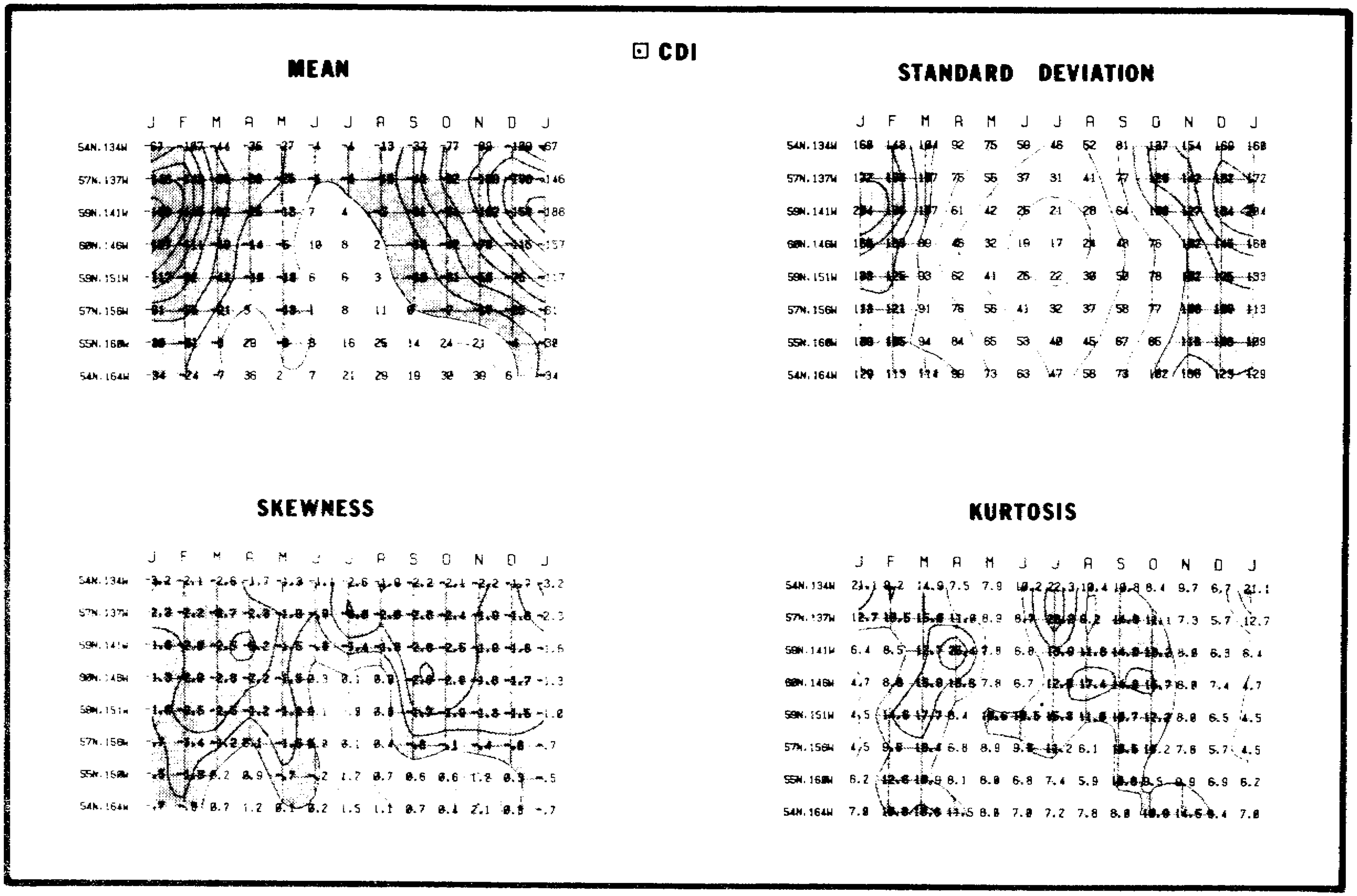

Figure 45 - Moments of the frequency distributions of coastal divergence indices (CDI) grouped by month at the near-coastal locations indicated by triangles in Fig. 41. Mean: units are cubic meters per second transported off each 100-meter width of coast; contour interval is 25. Standard Deviation: units and contour interval are the same as for the mean. Skewness: contour interval is one normalized unit. Kurtosis: contour interval is 5 normalized units.

upwelling indicated for November represents an energetic mix of upwelling and downwelling events, with the balance tipped slightly toward upwelling.

The skewness tends to have the same sign as the mean; i.e. extreme events during downwelling seasons tend to be downwelling events, and those during upwelling seasons to be upwelling events. Some modification of this general pattern appears in the northern gulf where the distribution of skewness shows a tendency to be more negative than the mean (i.e. a considerable contribution from relatively extreme downwelling events even during seasons of mean upwelling). Off the lower Alaska Peninsula an expansion of the period of positive skewness beyond that of positive mean value indicates relative importance of extreme upwelling events, most probably related to very intense storms centered north of the Alaska Peninsula.

In all months and locations the kurtosis is larger than 3.0 indicating that there appears to be a much larger contribution of extreme events than would be the case in a Gaussian process. The details of the distribution of kurtosis are controlled to some extent by the fact that the kurtosis is normalized against the variance; thus, the winter season exhibits relatively low kurtosis because the variance is high (i.e. events which would be "extreme" at other seasons are the norm during winter). When a winter-type storm appears in the spring, for example, it contributes to a higher kurtosis because the general level of activity is lower. The relatively high kurtosis during the summer season indicates that the generally stable situation is interrupted only infrequently. Large contributions to the variance from extreme events are indicated for the lower Alaska Peninsula area during the fall season.

The monthly frequency distributions of offshore divergence indices (ODI) at the near coastal locations (Fig. 46) have mean values which are positive, indicating divergence on the average offshore of the coastal upwelling-downwelling zone, except during January in the southwestern Gulf and during the summer from the Kenai Peninsual eastward. Strongest divergence on average occurs near Yakutat during winter, corresponding in season and location to the maximum negative CDI values.

The ODI variance is largest in winter, but rather than corresponding in location to the mean as was the case for the CDI values, there is a double maximum (59N, 151W; 57N, 137W) with a relative minimum in the area of the maximum mean values. In the southwestern Gulf the period of maximum variance shifts to the fall.

The skewness of the monthly ODI distributions tends to be positive; extreme events are characterized by divergent surface drift associated with cyclonic storms. Some of the monthly distributions in the northern and eastern gulf exhibit a slight negative skewness in the spring or summer. The kurtosis indicates major contributions to the variance from infrequent, extreme events.

Comparison of mean CDI and ODI values confirms that, in a mean sense, the preeminent situation along the coastal boundary of Gulf is type "A" (see Fig. 44). The extreme energy of the downwelling at the coast and divergence offshore associated with winter storm systems completely dominates the annual cycle. Table 2 lists the "types" corresponding to the monthly mean situation at the various locations. Type D is restricted to the extremely low-energy summer situation in the northern gulf. The

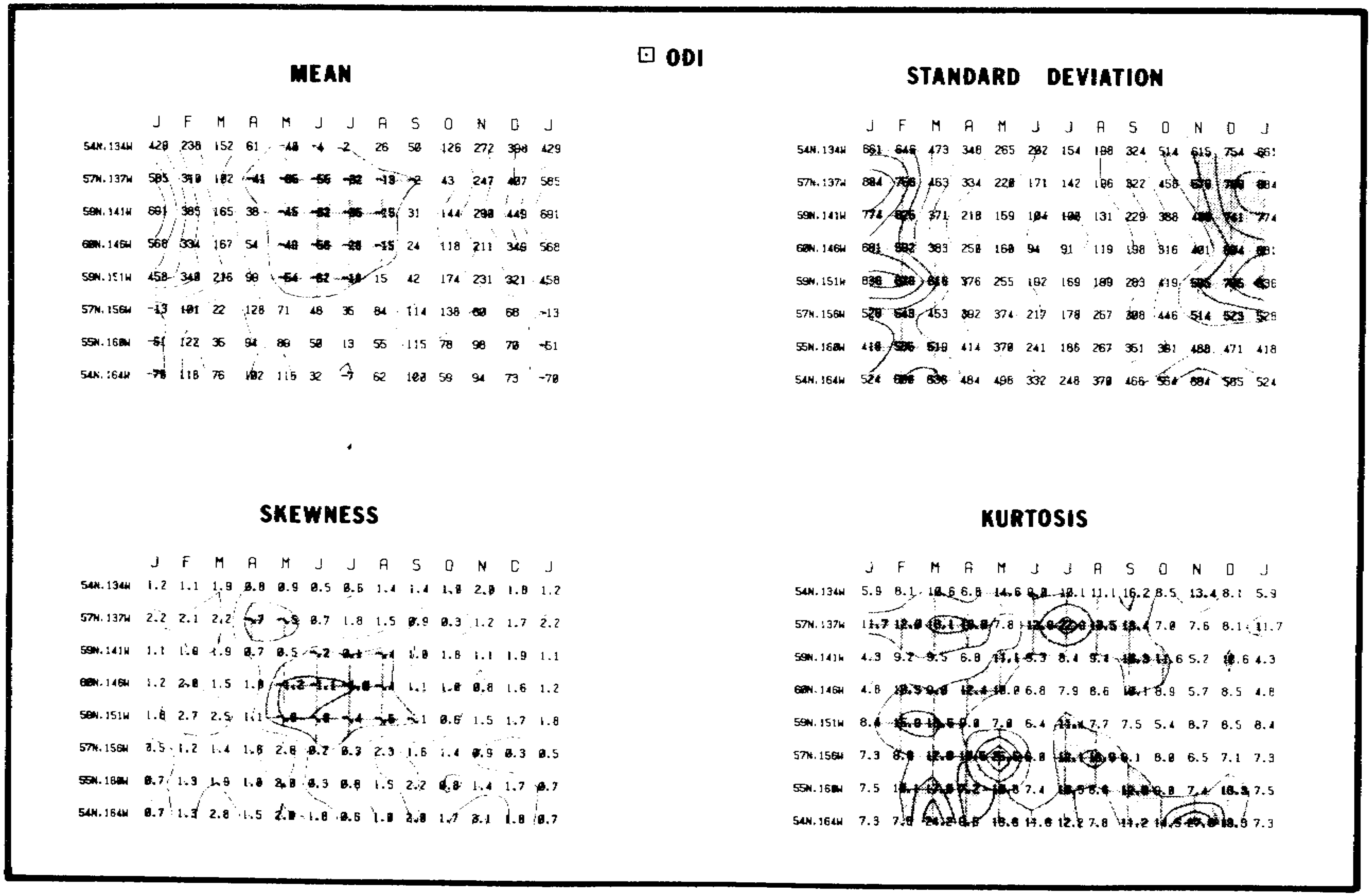

Figure 46 - Moments of the frequency distributions of offshore divergence indices (ODI) grouped by month at the near-coastal locations indicated by squares in Fig. 41. Mean: units are millimeters per day upward velocity through the bottom of the Ekman layer required to balance the indicated divergence; contour interval is 100. Standard deviation: units and contour interval is one normalized unit. Kurtosis: contour interval is 5 normalized units.

TABLE 2 - Monthly mean "types" of convergence-divergence couple, according to the classification of Figure 44, characterizing the near-coastal locations indicated by squares in Figure 41.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
54N, 164W	B	A	A	C	C	C	C	C	C	C	C	C
55N, 160W	B	A	A	C	A	C	C	C	C	C	C	A
57N, 156W	B	A	A	C	A	C	C	C	C	A	A	A
59N, 151W	A	A	A	A	B	D	D	C	A	A	A	A
60N, 140W	A	A	A	A	B	D	D	D	A	A	A	A
59N, 141W	A	A	A	A	B	D	D	B	A	A	A	A
57N, 137W	A	A	A	B	B	B	B	B	B	A	A	A
54N, 134W	A	A	A	A	B	B	A	A	A	A	A	A

coastal area of the lower Alaska Peninsula is, on average, under a type C situation over much of the year; considering this surface drift effect alone, the net tendency would seem to be to break down some of the baroclinicity built up in the type A situation further east.

The fraction of 6-hourly samplings during each month characterized by the various event types are summarized for several locations (Fig. 47). The seasonal shift from type A to type D at 59N, 141W is well illustrated. In this presentation, all periods, even where the index values were so small as to be negligibly different from zero, were included in calculating the percentages. When the weaker events are excluded the percentage of the dominant event type increases. By progressively increasing the required intensity the percentages of the less common types would eventually approach zero.

In order to perform spectral analysis on seasonal time series of substantial length, we have constructed composite winter and summer time series of the indices at each location. For example, winter time series were formed of all values within weeks of which the first day falls within the months of December, January, or February. Thus, the first week of December, 1974 follows directly after the last week in February, 1973. Summer series were similarly formed from values within weeks which begin in June, July, or August, etc. This procedure affects only the longer period spectral estimates which tend to be lost in the unresolvable seasonal and climatic scale energy. The results effectively summarize the features observed from analysis of the various short, properly continuous, seasonal segments of the time series.

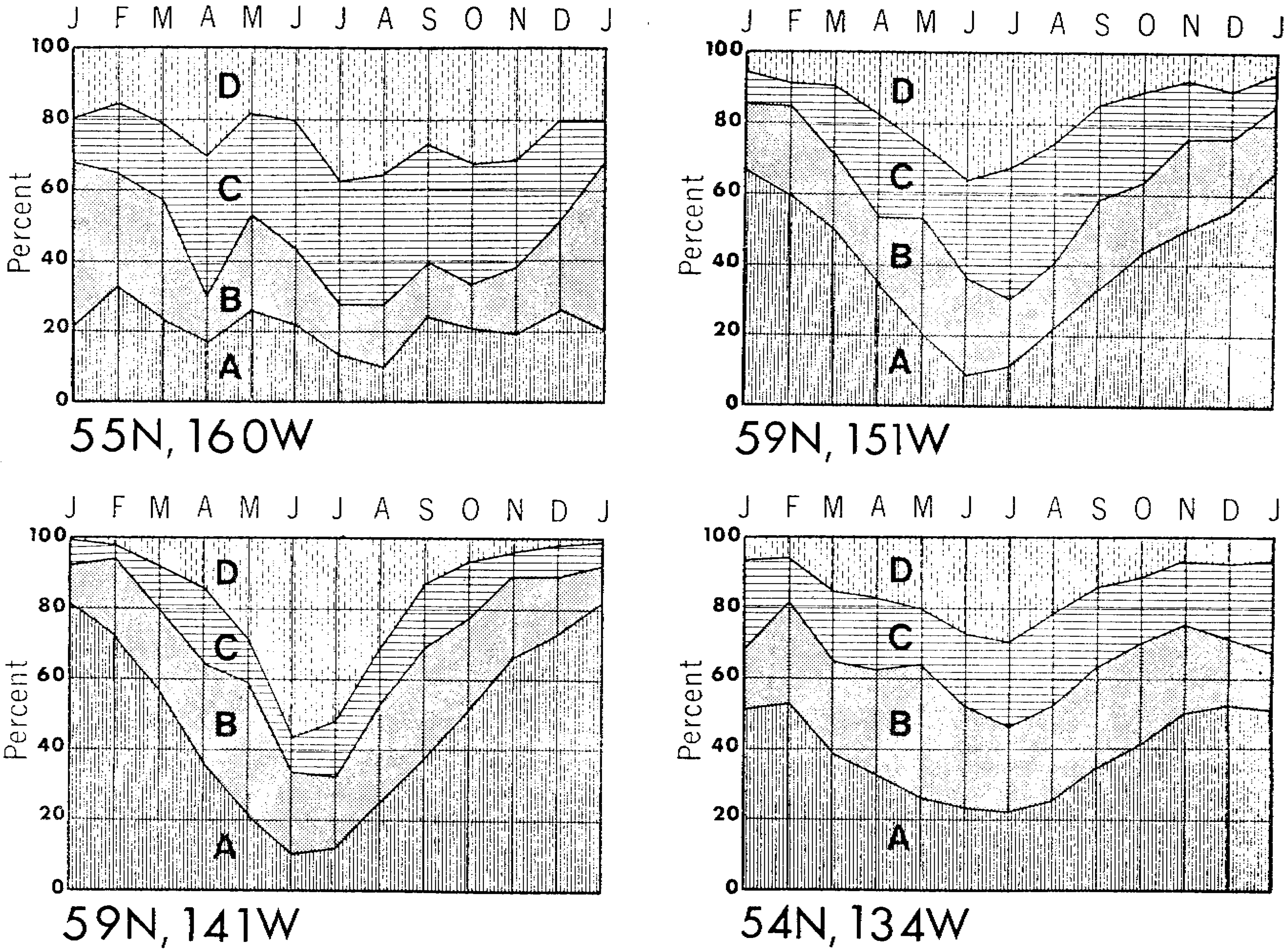

Figure 47 - Percentages, by month, of 6-hourly synoptic samplings characterized by each of the "event types" classified in Fig. 44.

Autocorrelation functions were computed from the CDI series (Fig. 48) and from the ODI series (Fig. 49). In all cases autocorrelation drops off rapidly within the first several days; time scales of individual events are characteristically short. A diurnal fluctuation, most marked in the CDI series, is apparent during summer (and less markedly in spring) at near-coastal locations in the northern and eastern Gulf. A somewhat lower frequency oscillation, indicating the "event" scale, is visible in many of the functions.

Examples of cross correlations between the CDI indices and ODI indices at the same location (Fig. 50) show that cross correlation tends to be negative for short lag periods, most markedly in the winter in the northeastern Gulf where the type A situation (negative CDI, positive ODI) predominates. Indications of negative cross correlations during summer in the same area are related to the predominance of Type D. Off the Alaska Peninsula cross correlation is low, indicating a rather complex mixture of event types and intensities.

Power spectra corresponding to the autocorrelation functions (see Figs. 48 and 49) have been constructed (Figs. 51 and 52) based on 100 lags of seasonal data series containing over 3000 data points each. This translates to about 66 degrees of freedom, representing considerable stability in the resulting spectral estimates. The spectra are similar in general form, resembling "red noise" spectra. Such spectra, which are characterized by a general decrease in energy from lower to higher frequencies, are indicative of temporal persistence within the series.

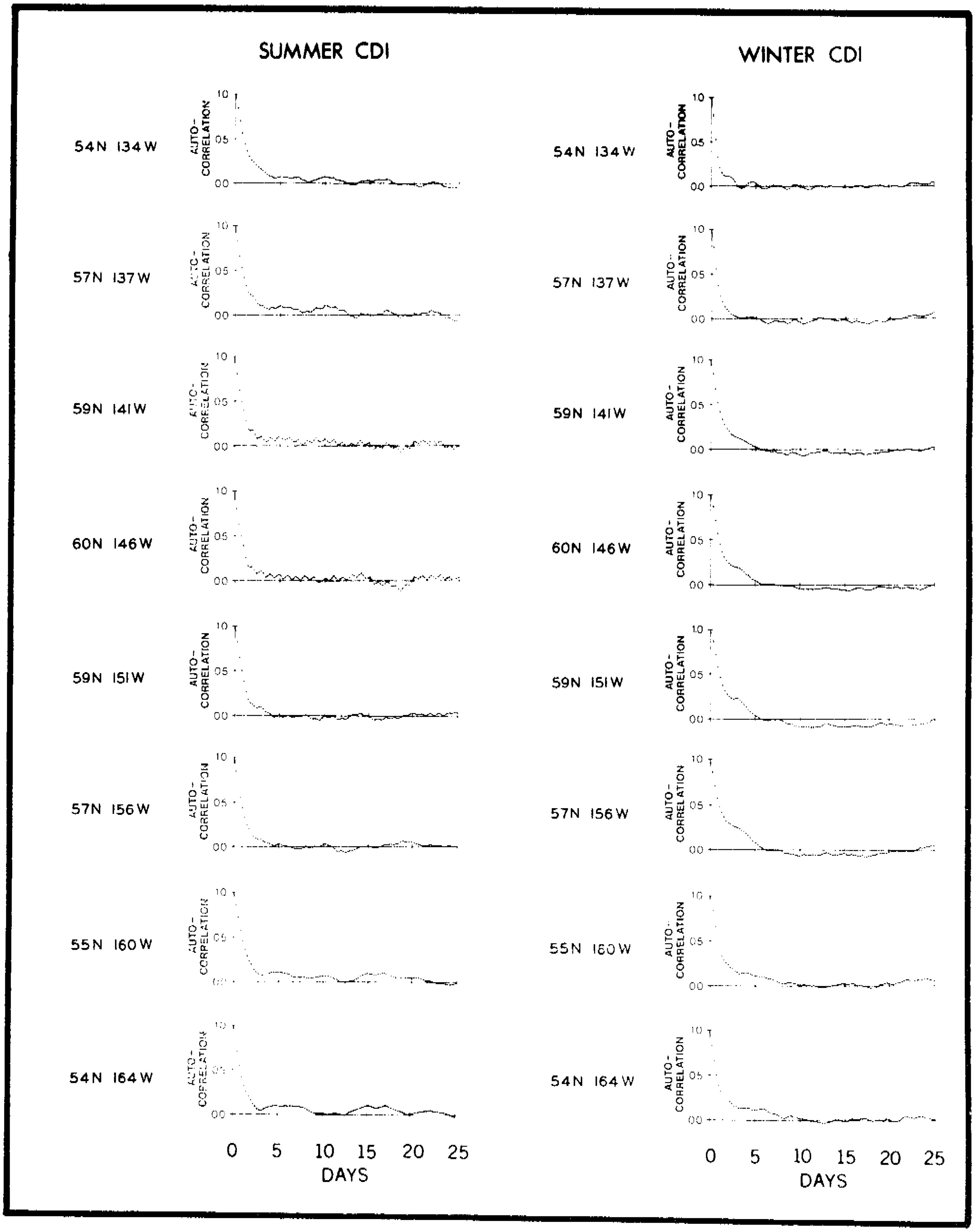

Figure 48 - Autocorrelation functions for coastal divergence indices (CDI) at the near-coastal locations.

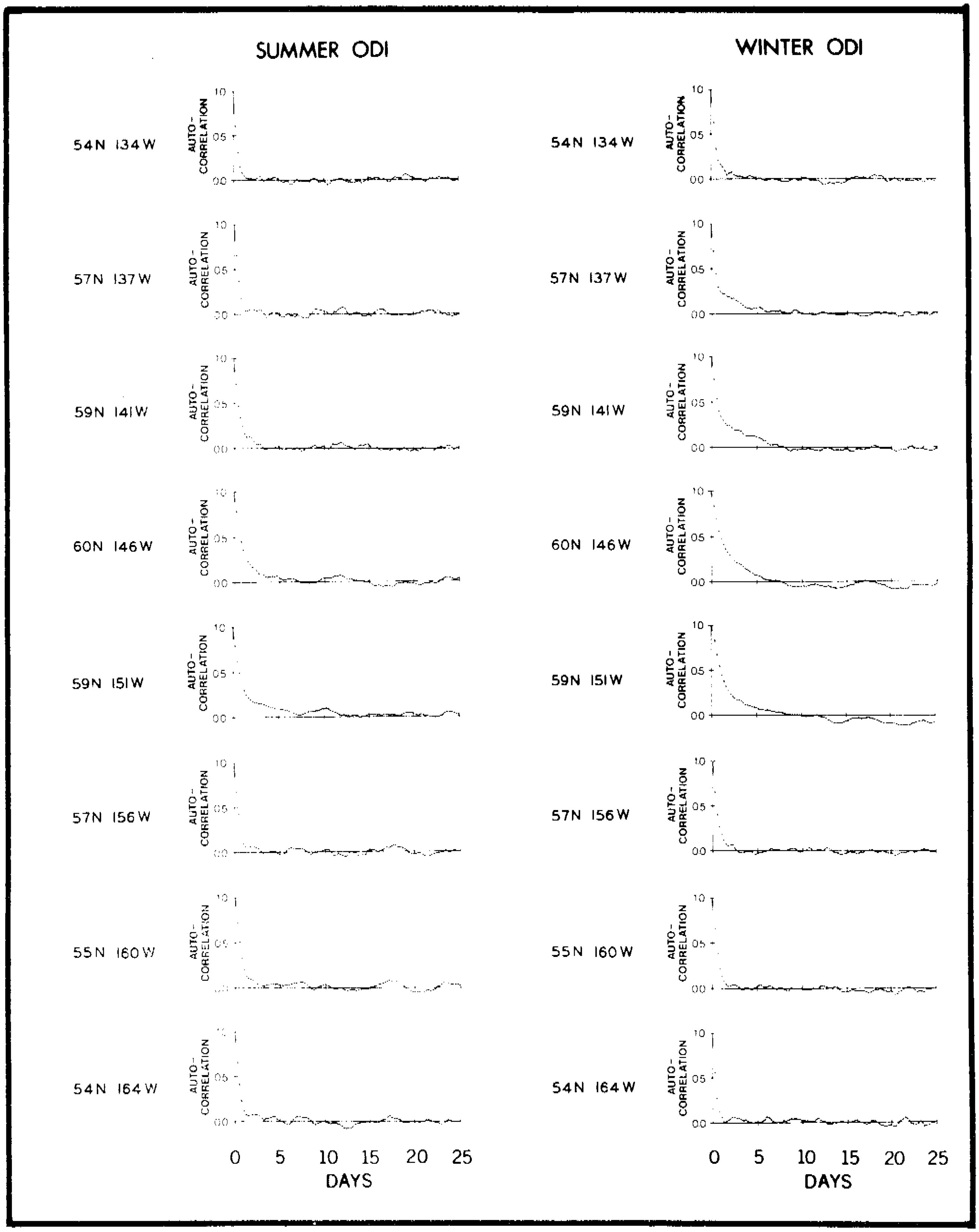

Figure 49 - Autocorrelation functions for offshore divergence indices (ODI) at the near-coastal locations.

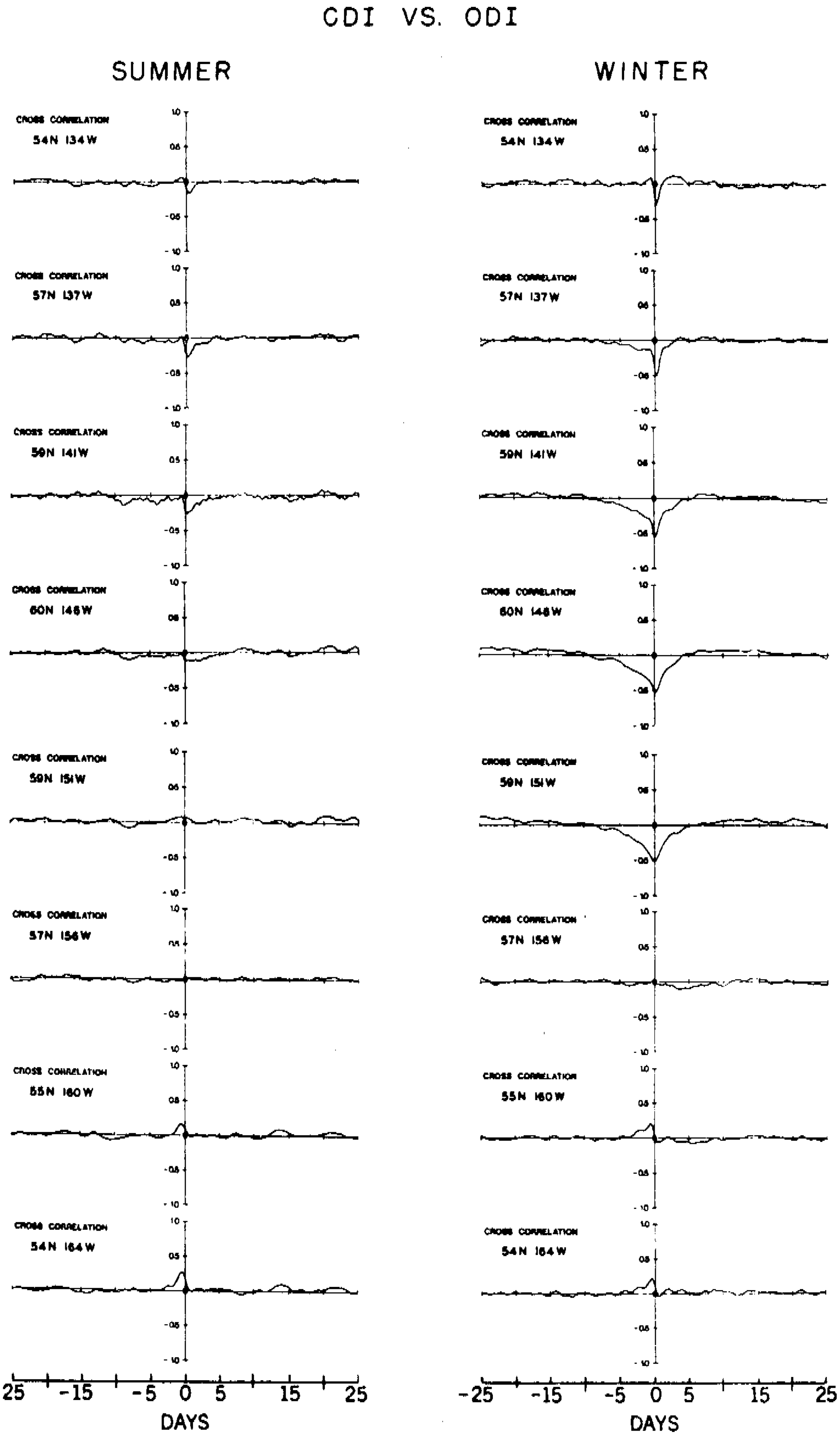

Figure 50 - Cross correlation functions for coastal divergence indices (CDI) v.s. offshore divergence indices at the near-coastal locations. Summer functions are on the left; winter functions on the right.

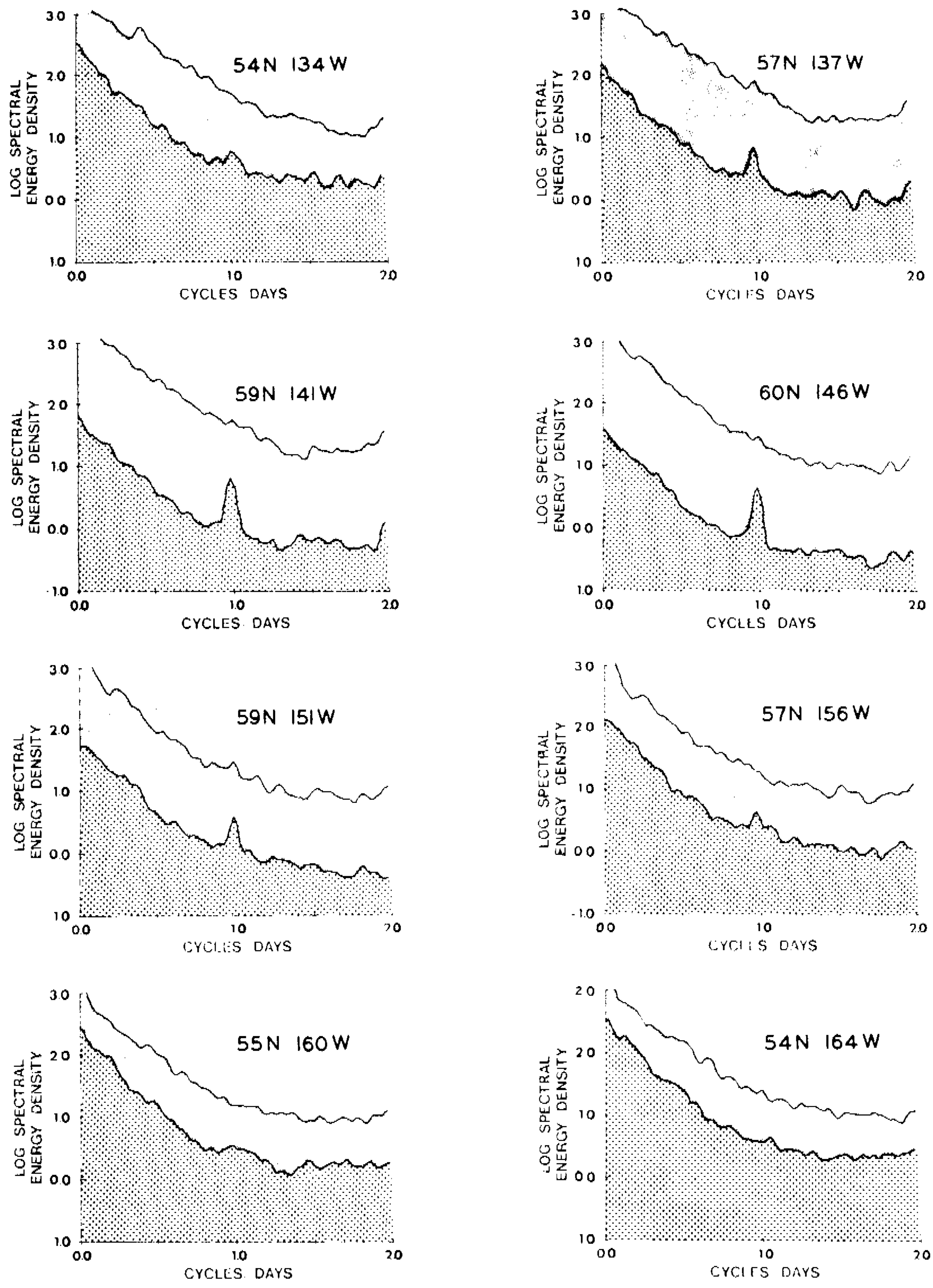

Figure 51 - Power spectra for coastal divergence indices (CDI). Winter and summer spectra at each location are superimposed. Higher energy (upper) trace plots the winter spectrum.

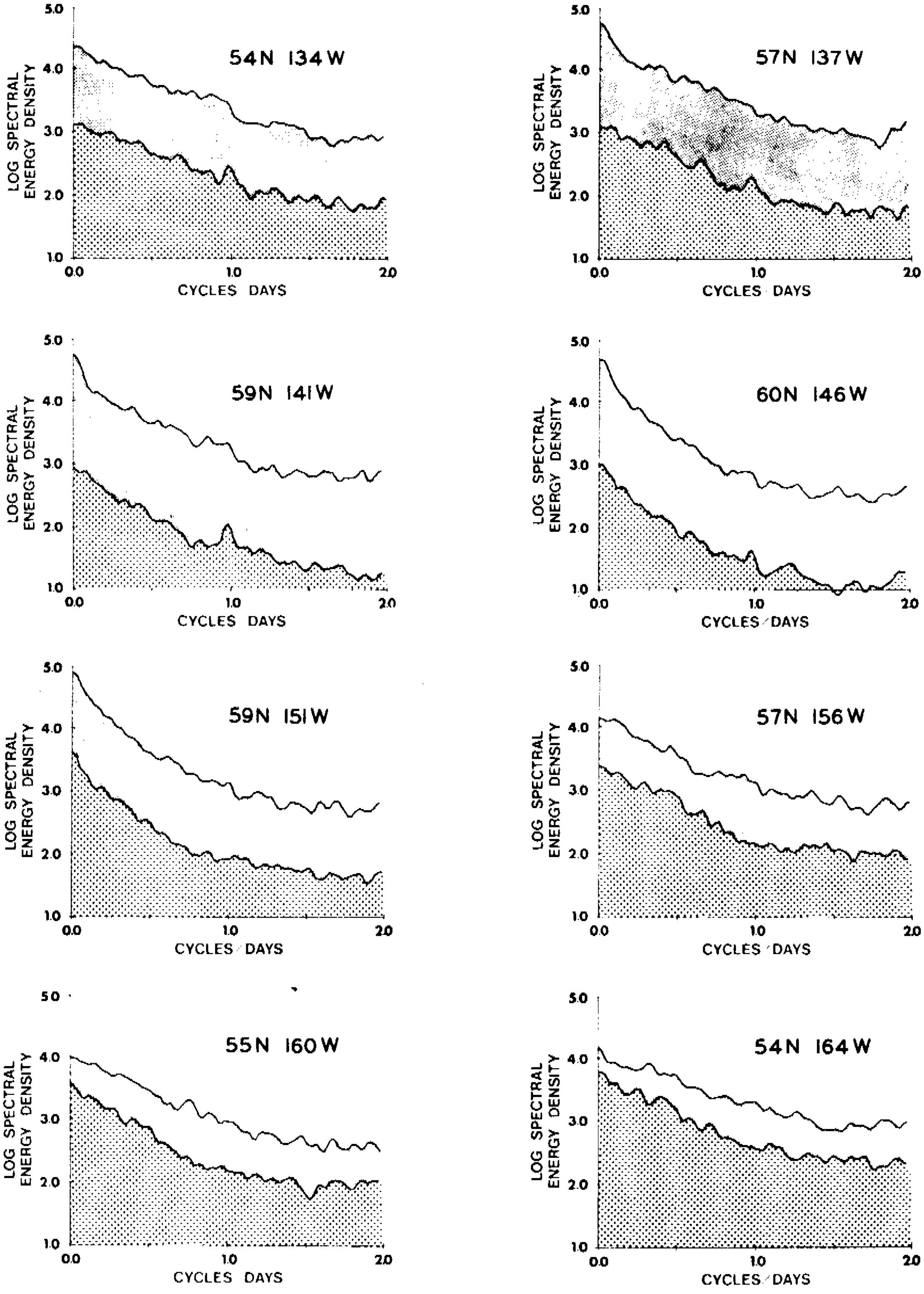

Figure 52 - Power spectra for offshore divergence indices (ODI) at near-coastal locations. Winter and summer spectra at each location are superimposed. Higher energy (upper) trace plots the winter spectrum.

Superimposed are several other features of interest. Considerable energy is spread over the "event scale" of periods of somewhat greater than a day to a week or more. In certain of the series this stands out as a broad hump representing a quasi-periodicity, that is a definite rhythm, albeit somewhat irregular. The only true periodicity is the diurnal fluctuation which stands out as a definite spike in the spring and summer spectra at locations in the northern and eastern gulf. The smaller spike at the semi-diurnal frequency appears merely because the diurnal variation is not perfectly sinusoidal, the morning to afternoon intensification being generally more rapid than the evening to morning relaxation.

Coherence functions for the CDI v.s. the ODI winter series (Fig. 53) indicate maximum coherence at the "event" and longer frequency bands in the "type A" area in the northern and eastern Gulf. Coherence is progressively less toward the southwest. During the summer coherence is minimal except at the diurnal frequency. In general, coherence between the CDI and ODI series at the same location is small compared to, for example, the coherence between series of the same type of index at adjacent locations (Fig. 54). The indication is that the CDI and ODI signals act as semi-independent variables, less so in the fairly well defined "type A" situation of cyclonic winter storms moving through the northern and eastern Gulf, and more so in the Alaska Peninsula area where the various combinations of angle of storm movement in relation to the coast, position of storm center north or south of the coastal boundary, etc., introduces a much larger degree of randomness.

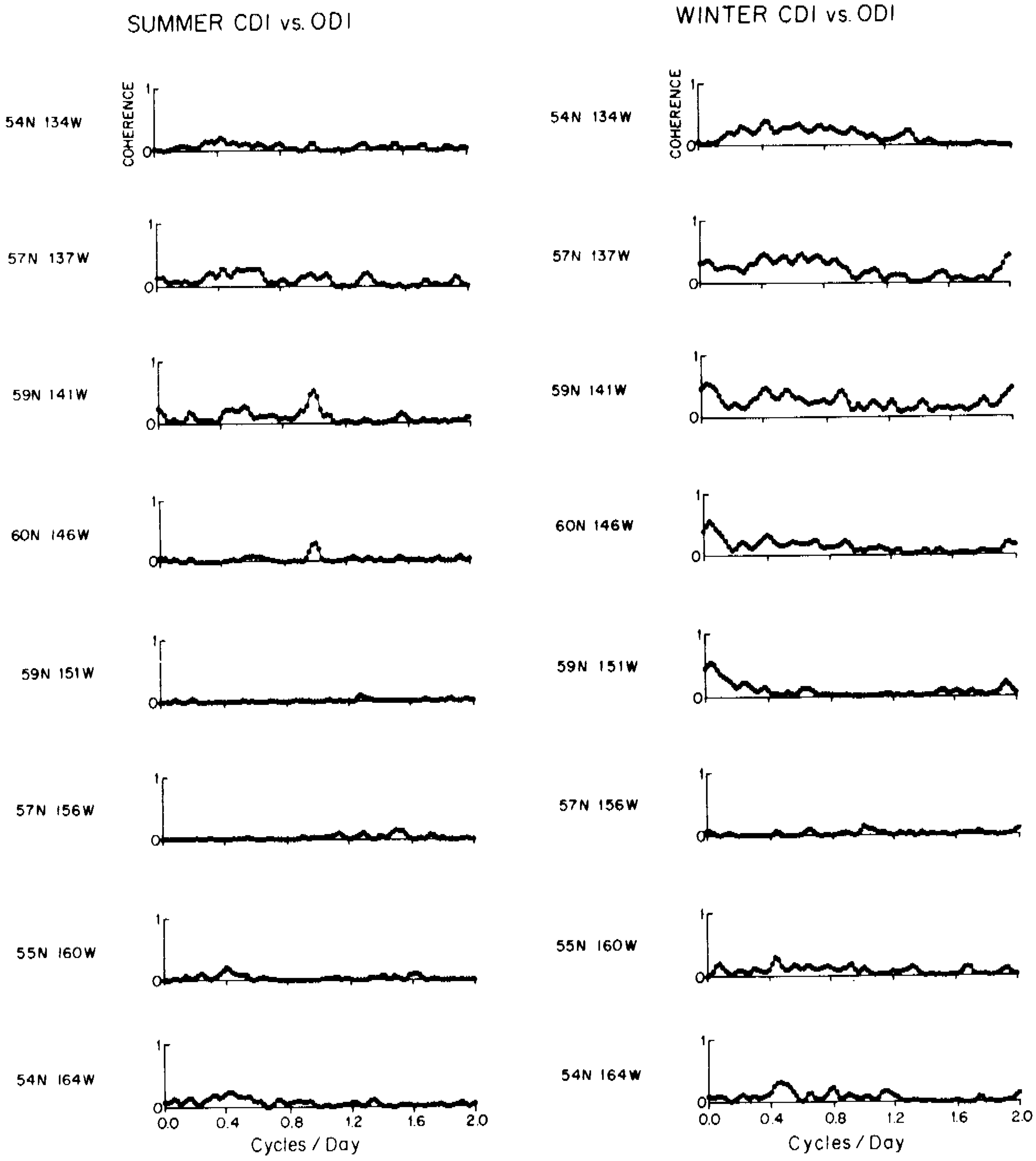

Figure 53 - Coherence functions for coastal divergence indices (CDI) v.s. offshore divergence indices (ODI).

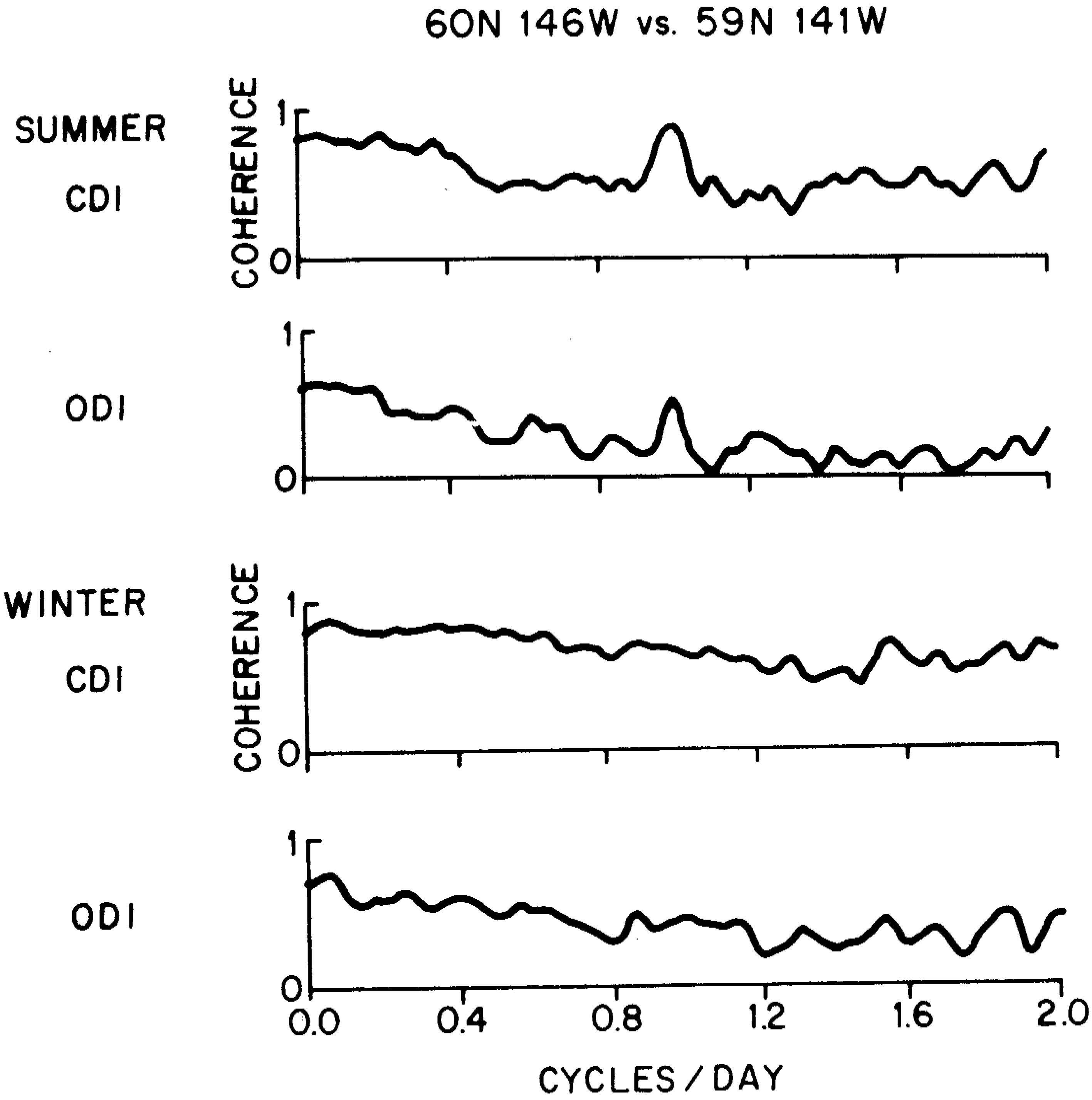

Figure 54 - Coherence functions between index series at adjacent locations: 60N, 146W v.s. 59N, 141W.

B. Interior of the Gulf

Away from the influence of the coastal boundary the CDI computations are, of course, not applicable; the distribution of surface divergence is indicated by the ODI series. The monthly frequency distributions of ODI series along 57°N (Fig. 55) and along 54°N (Fig. 56) show strongly positive mean ODI values during winter in the eastern portion of the gulf, reaching a maximum at 57N, 140W. This location thus appears as the point of maximum intensity of winter divergence. Intensity decreases from this location in all directions, but least rapidly to the north where the intersection of the lobe of intense divergence with the coast results in the maximum type A offshore divergence - coastal downwelling couple at 59N, 141W, described in the previous section. The mean intensities along 54N are much lower than at 57N.

The maximum mean negative values during the summer are likewise at 57N, 140W. The period of mean summer convergence (negative ODI values) which lasts from May through August along the coast in the northern and eastern Gulf (see Fig. 46) becomes progressively shorter westward along 57N, finally disappearing near 150W longitude. Along 57N mean convergence appears only during May and June at the near coastal location, 54N, 134W (Fig. 57).

The series at 57N, 140W also exhibits the greatest variance (see Fig. 56) during winter of any of the locations studied. Thus this location appears to mark a region of "maximum energy" in the surface divergence field of the Gulf of Alaska, both in the sense of amplitude of the seasonal mean signal and in the "spectral energy" sense of

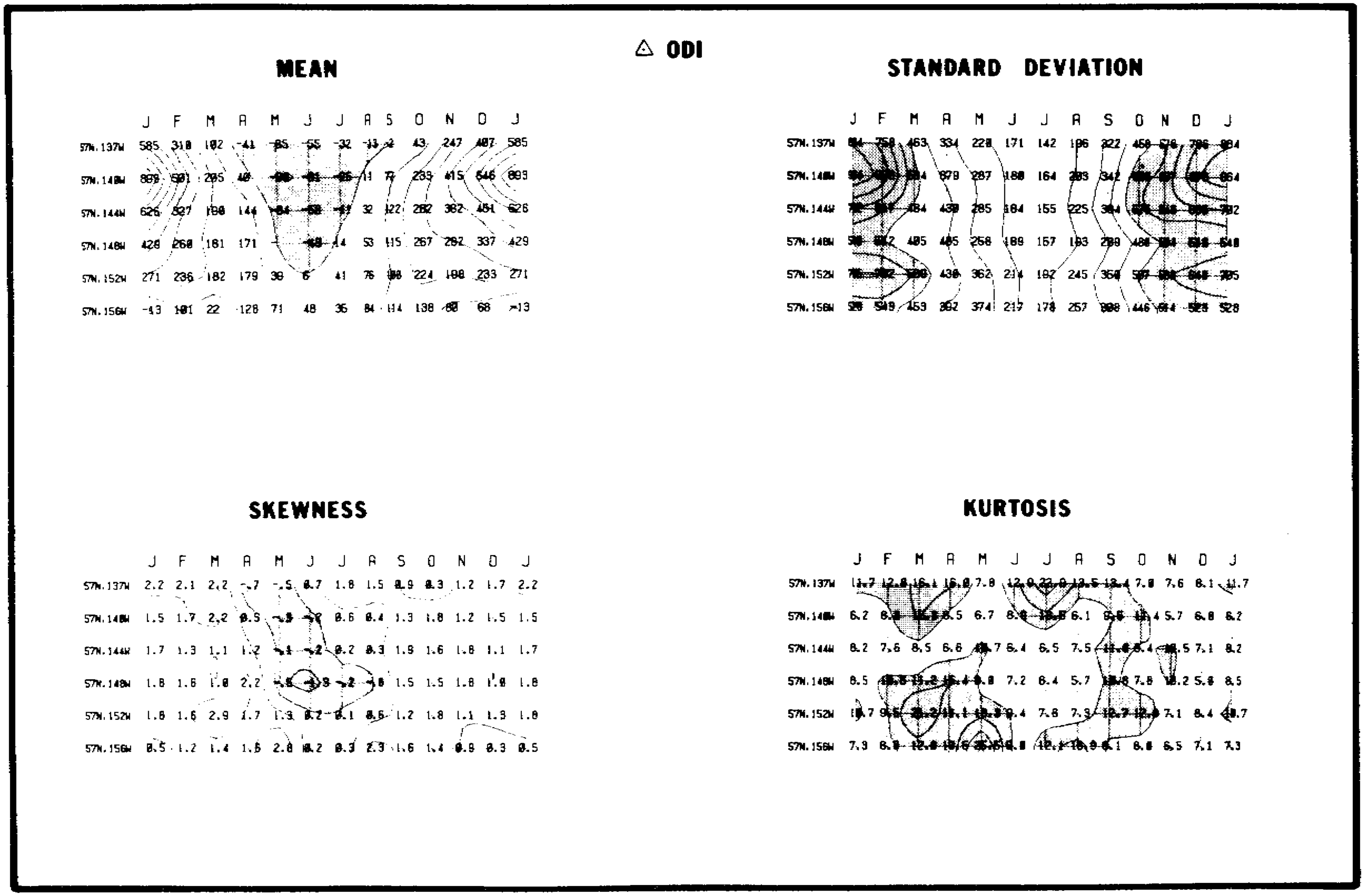

Figure 55 - Moments of the frequency distributions of offshore divergence indices (ODI) grouped by month at the locations along 57N indicated by triangle symbols in Fig. 41. Mean: units are millimeters per day upward velocity through the bottom of the Ekman layer required to balance the indicated divergence; contour interval is 100. Standard deviation: units and contour interval are as for the mean. Skewness: contour interval is one normalized unit. Kurtosis: contour interval is 5 normalized units.

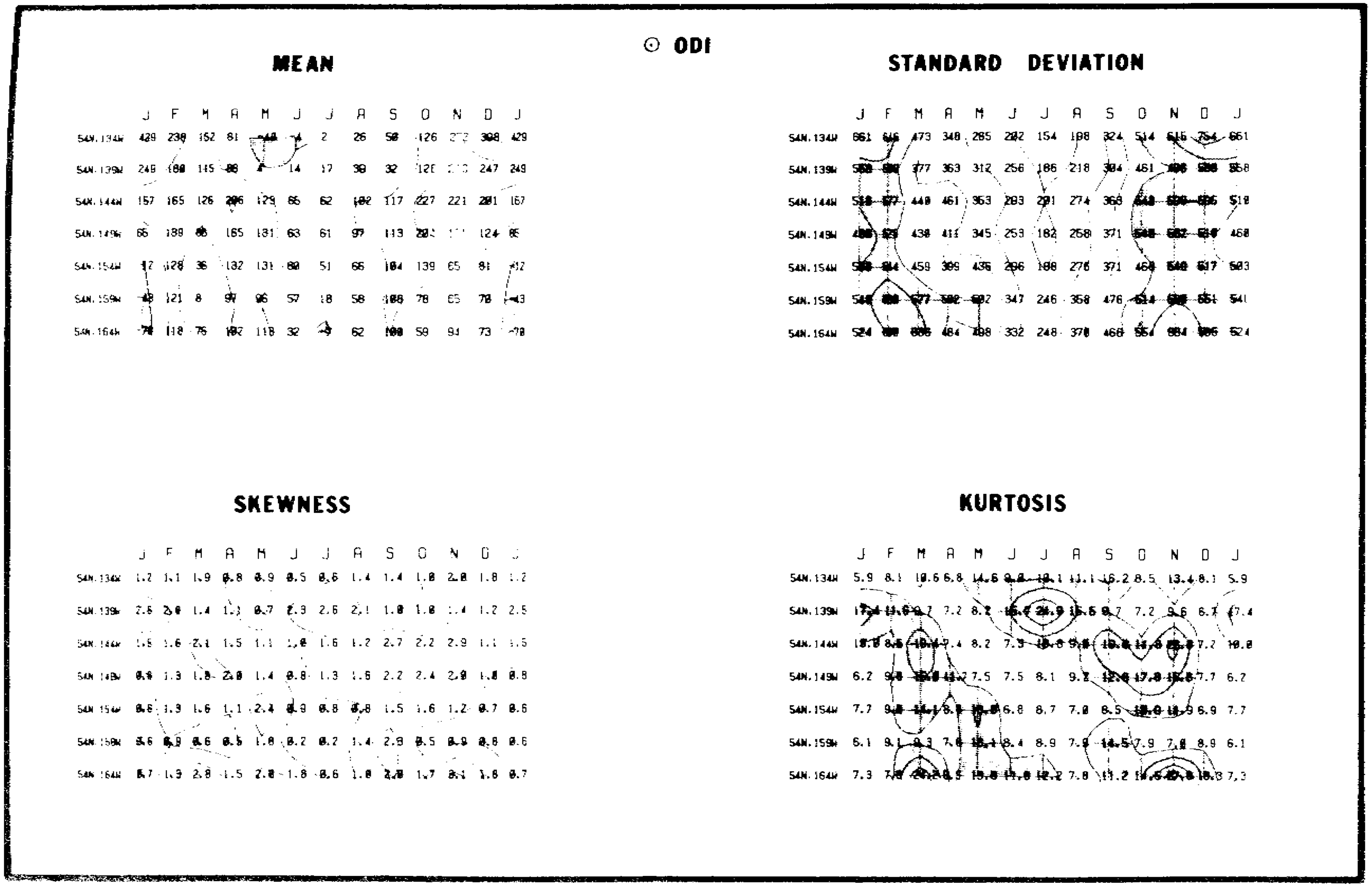

Figure 56 - Moments of the frequency distributions of offshore divergence indices (ODI) grouped by month at the locations along 54N indicated by circle synbols in Fig. 41. Mean: units are millimeters per day upward velocity through the bottom of the Ekman layer required to balance the indicated divergence; contour interval is 100. Standard deviation: units and contour interval are as for the mean. Skewness: contour interval is one normalized unit. Kurtosis: contour interval is 5 normalized units.

extremely rapid and strong pulsations. A lesser maxima in variance at 57N, 152W is apparently connected to the maxima along the coast at 59N, 151W (Fig. 46).

The skewness is negative along 54N latitude (Fig. 56) and, except for a limited period during the summer convergence season, along 57N latitude (see Fig. 55). Extreme events are usually divergent. The kurtosis as before, indicates major importance of rather infrequent, very intense events.

Power spectra for summer and winter ODI series at locations along 57N (Fig. 57) and at locations along 54N (Fig. 58) indicate that winter energy tends to be greatest to the north and east and summer energy is greatest to the south and west. The spike indicating the diurnal periodicity during summer is most prominent near the point of "maximum energy" at 57N, 140W. To the west and south the diurnal spike disappears.

Examples of cross correlations between the "maximum energy" locations at 57N, 140W and several surrounding locations (Fig. 59) indicate that correlation is highest at zero lag between 57N, 140W and the point of maximum winter "type A" coastal situation at 59N, 141W. A suggestion of higher correlation at positive lags between 57N, 140W and 57N, 137W and at negative lags between 57N, 140W and 57N, 144W illustrates the general eastward progression of the signal. Correlation with a location to the south, 54N, 139W, is considerably lower and is highest at a negative lag of one 6-hour period, even though the southern location is one degree further east. This indicates the northward progression of the signal which added to the eastward progression matches the general northeastward trend of the storm tracks. Correlation with the point at

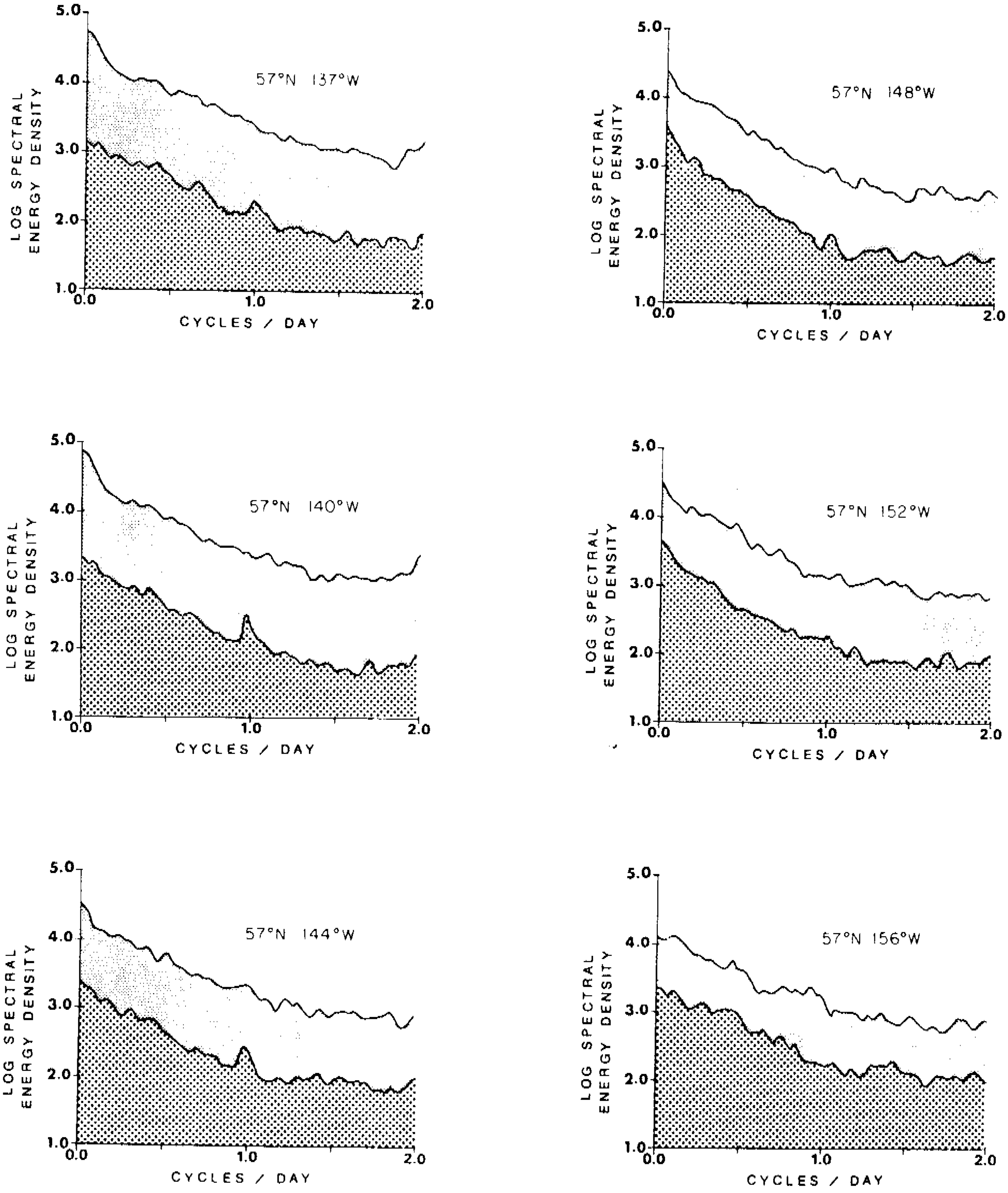

Figure 57 - Power spectra for offshore divergence indices (ODI) at locations along 57N latitude (locations indicated by squares in Fig. 41.) Winter and summer spectra at each location are superimposed. Higher energy (upper) trace plots the winter spectrum.

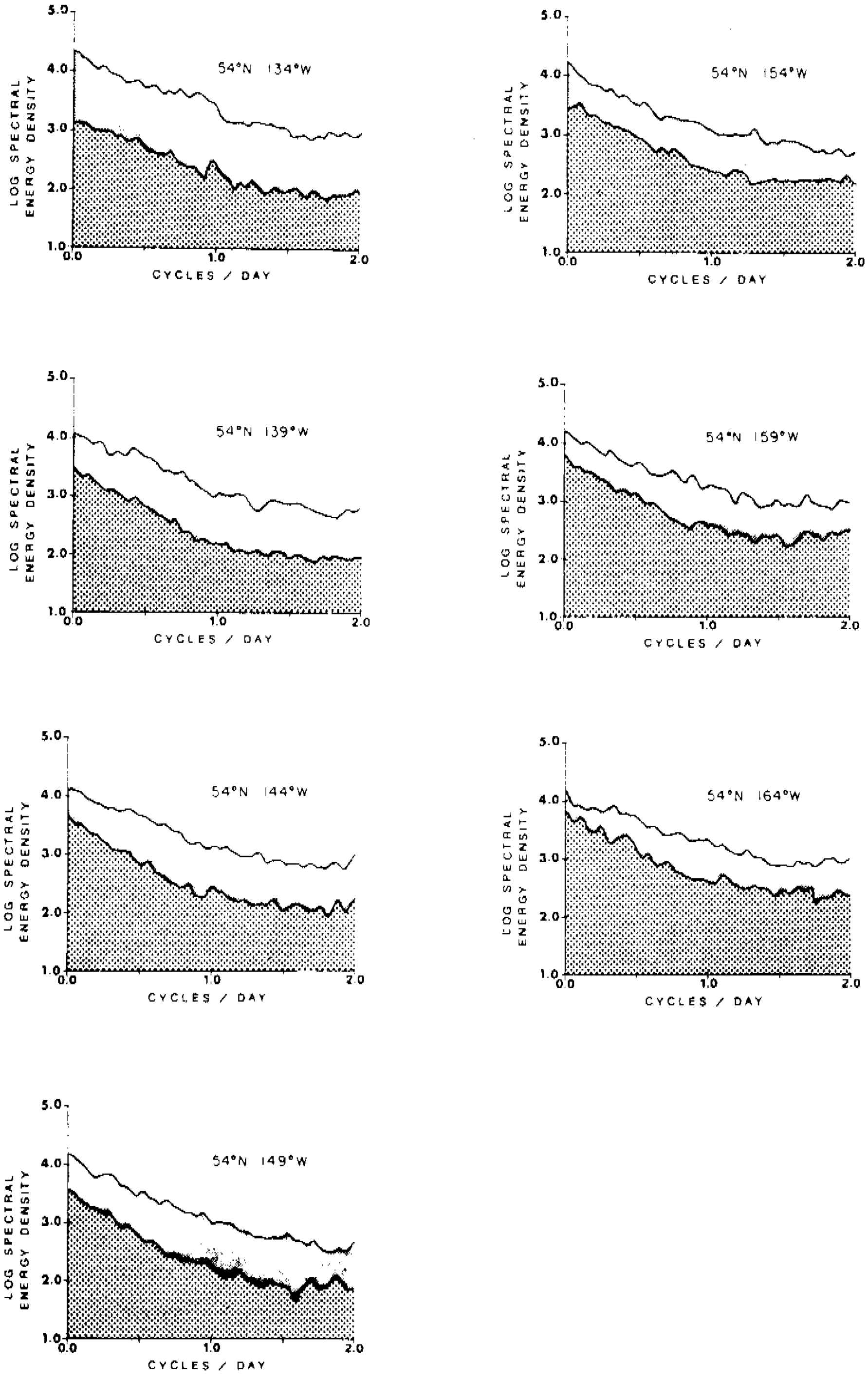

Figure 58 - Power spectra for offshore divergence indices (ODI) at locations along 54N latitude (locations indicated by circles in Fig. 41.) Winter and summer spectra at each location are superimposed. Higher energy (upper) trace plots the winter spectrum.

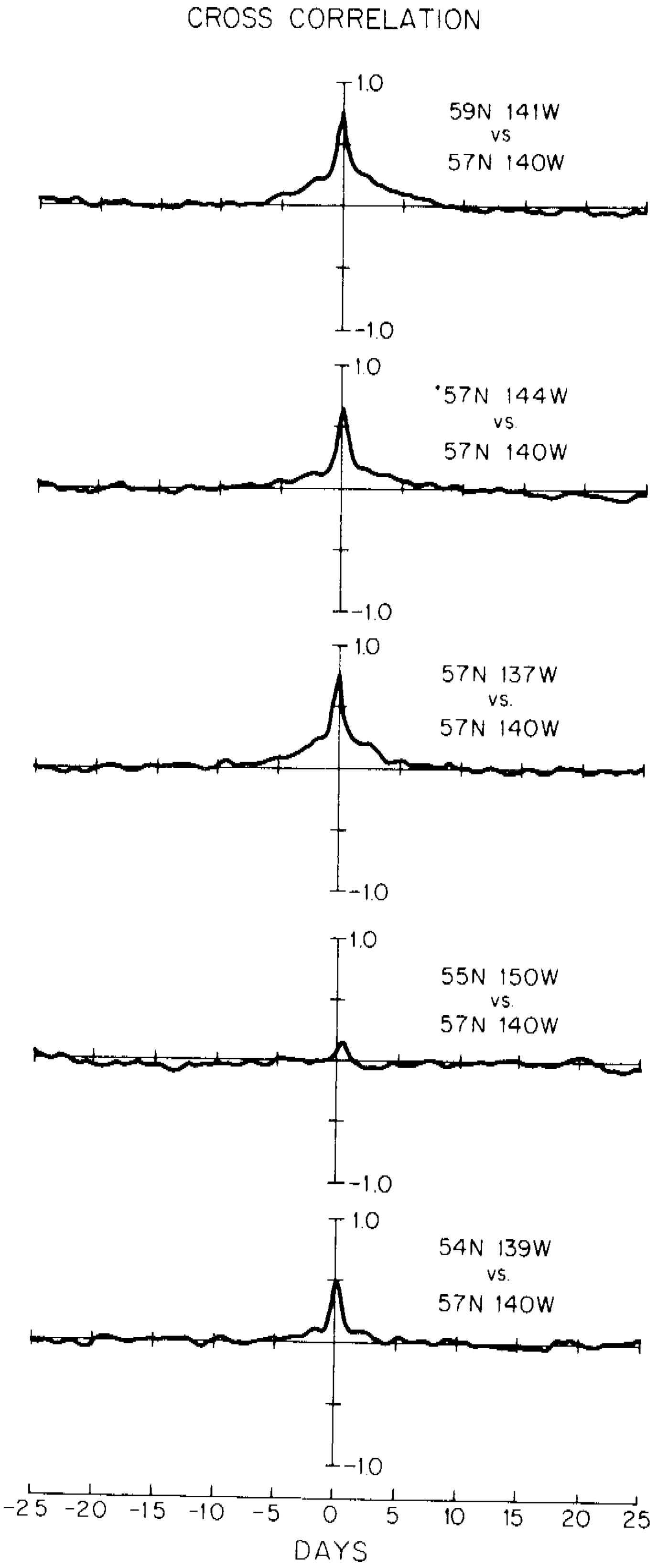

Figure 59 - Cross correlation functions for the winter ODI series at 57N, 140W v.s. winter ODI series at several surrounding locations.

55N, 150W is quite low, reaching its greatest value at negative lags of two 6-hour periods in the winter and three six hour periods in the summer; the progression is slower in the summer than in the winter.

Coherence functions corresponding to the cross-correlation functions of Fig. 59 indicate that the signal at 59N, 141W appears strongly related to that at 57N, 140W (Fig. 60). The adjacent points along 57N are likewise quite strongly related, particularly in the "event" frequency range. However, the coherence with the location to the south, 54N, 139W, is considerably less. Coherence with the signal at 55N, 150W, although on the line of general storm progression, is so low that it is not possible to prove statistically the signals are even related. This indicates considerable modification of the storm systems as they move across the gulf, consistent with its description as a region of strong atmospheric cyclogenisis.

C. Conditions - 1973, 1974 and 1975

The monthly mean CDI and ODI values at the near-coastal locations and the monthly mean ODI values at locations along 57N for the individual years 1973, 1974, and 1975 (Fig. 61) show distributions which are rather complicated in detail. However, it may be useful to delineate certain major features which may have had important effects on the ocean environment during these most recent years of increased field studies. In early 1973, maximum magnitudes of both the ODI and CDI indices appeared during January at 57N, 151W; apparently, the maximum strength of the winter "type A" couple was located in the northwestern Gulf, rather than in its "usual" position in the northeastern Gulf as indicated by the

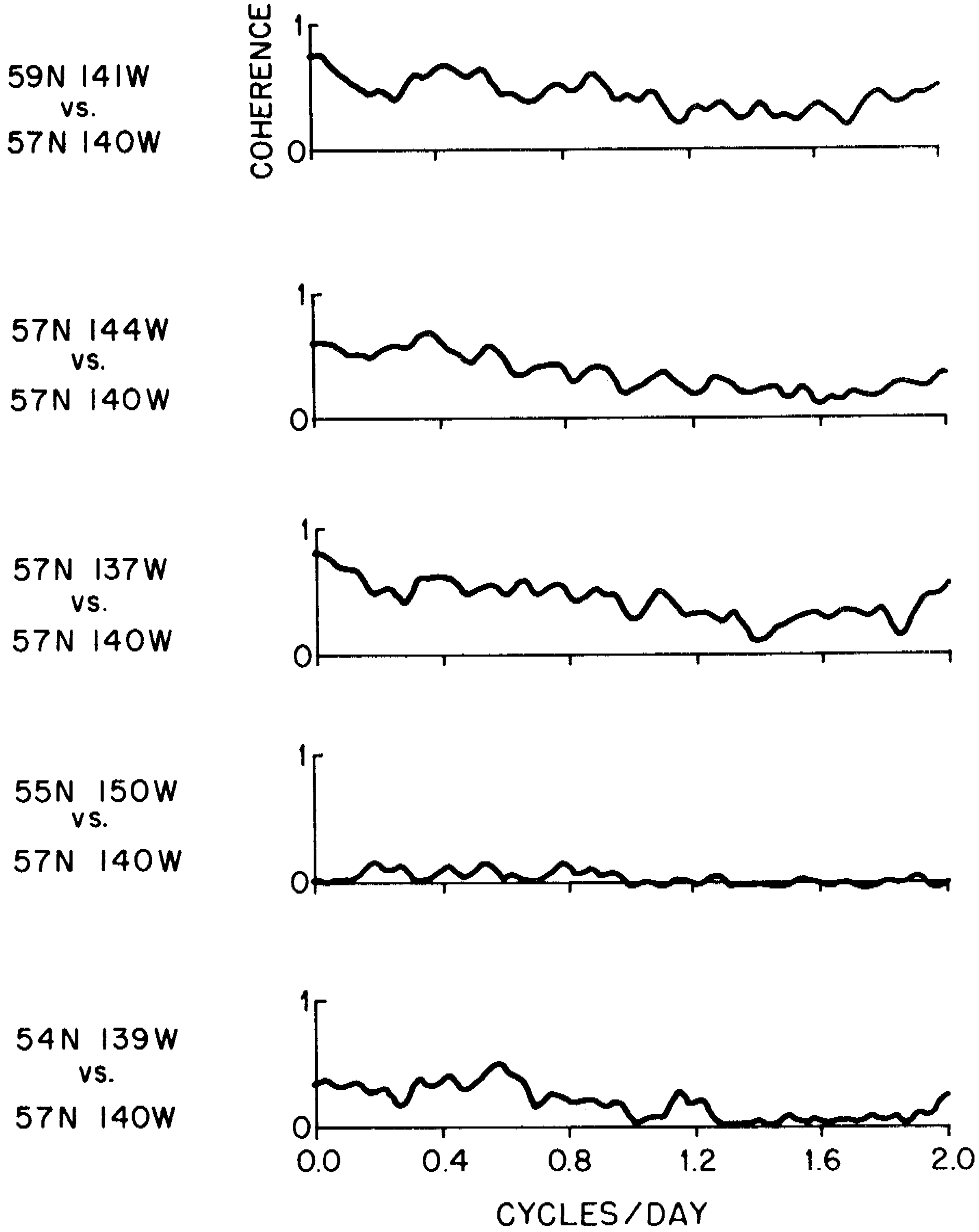

Figure 60 - Coherence functions for the winter ODI series at 57N, 140W v.s. winter ODI series at several surrounding locations.

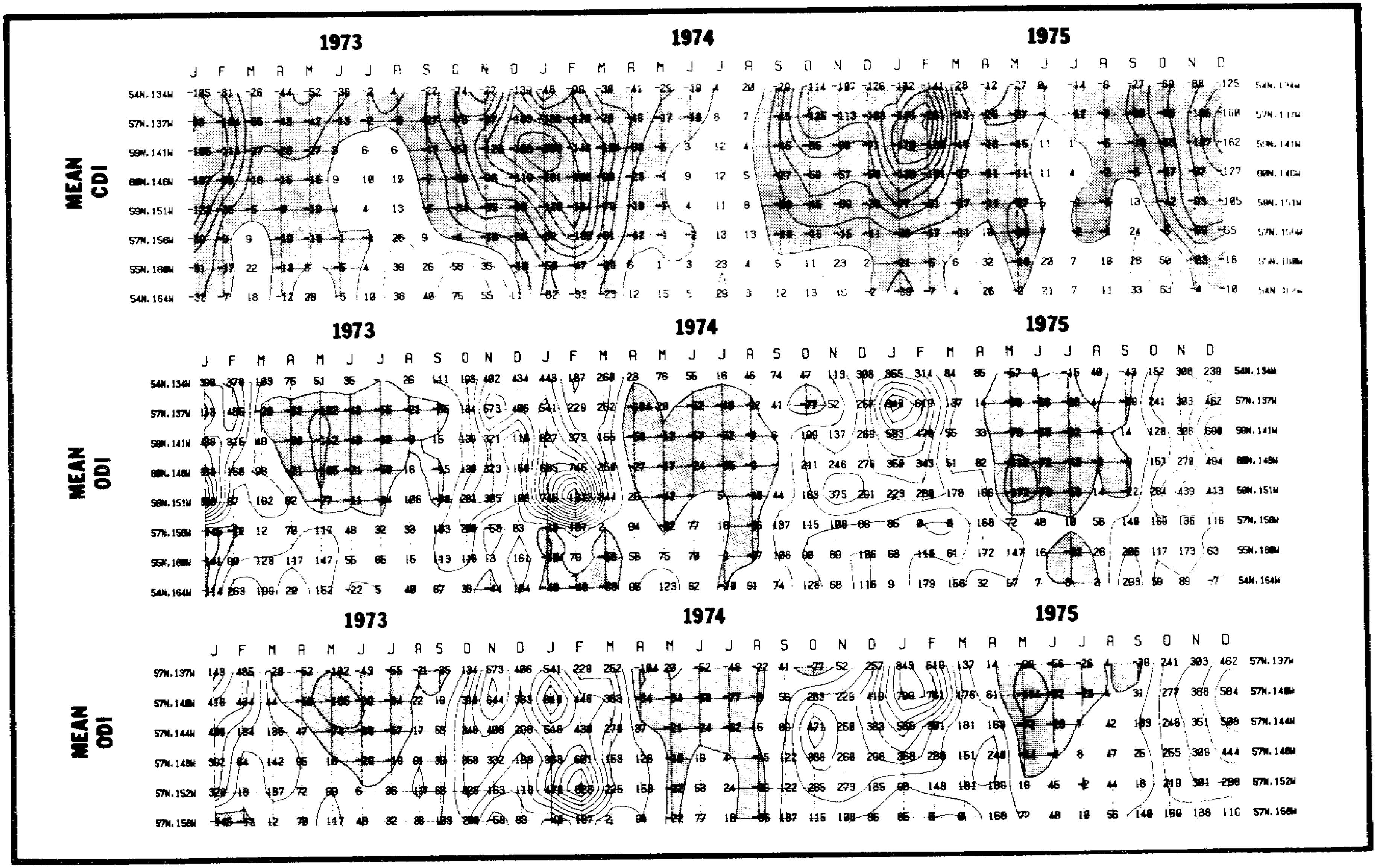

Figure 61 - Monthly means of index series for the years 1973, 1974, and 1975. Top figure: CDI series at near-coastal locations; units are cubic meters per second transported off each 100-meter width of coast. Middle figure: ODI series at near coastal locations; units are millimeters per day upward velocity through the bottom of the Ekman layer required to balance the indicated divergence. Bottom figure: ODI series at locations along 57N latitude; units, etc., are same as for middle figure.

nine-year composite mean monthly distributions (see Figs. 45 and 46). Lower than normal magnitudes of both types of indices during February and March throughout the northern Gulf point to an unusually rapid relaxation of the winter situation. For example, an early transition to a "type C" couple is indicated off the Alaskan Peninsula during March, where normally the transition occurs in April (Table 2). The trend toward less positive than normal ODI values in the northern Gulf continued through the spring to considerably stronger than normal negative values in May, representing quite energetic downward pumping in the offshore area, particularly in the northeastern Gulf. The last quarter of 1973 featured a strong predominance of coastal upwelling along the outer Alaskan Peninsula.

During the first quarter of 1974, stronger than normal convergence (negative CDI values) is indicated along the coast of the Gulf of Alaska, except in the extreme east. Maximum offshore divergence (positive ODI values) appeared, as in the previous year, in the northwestern Gulf. An extremely large mean ODI value was computed for February at 59N, 151W. Actually, anomalously large values appeared during all of the first three months of 1974 at both 59N, 151W, and 60N, 146W. The values at 59N, 141W, the normal maximum along the coast, although much smaller than those further east, were near the 9-year mean values for that location. The result is an extremely strong "type A" couple for the northern Gulf during early 1974. The implication is that dramatically increased baroclinicity in the ocean structure may have had an important effect on the dynamics of the area for some period to follow.

During the spring and summer of 1974, the indices tended to have values near the seasonal means, but by fall a situation of weaker than normal coastal convergence (smaller negative CDI values) seems to have set in. This situation generally persisted through the whole winter over much of the Gulf and was coupled with generally weaker than normal divergence offshore during December and January. An exception was the eastern Gulf where a reasonably strong "type A" couple is indicated for January and February. In total, the winter of 1974-75 appears to have been one of less energetic "type A" pumping than seems to be normal. Certainly the situation contrasts highly with the very energetic situation of the previous winter.

VII. SUMMARY AND CONCLUSIONS

Our knowledge of the physical oceanography of the Gulf of Alaska is quite inadequate to forecast flow. This stems largely from the lack of a persistent, challenging oceanographic program that permits progressive advances based on acquired knowledge. The focus of attention has been not only limited, but intermittent, however, this has not been due to a lack of interest on the part of the oceanographer, rather because of lack of funds, equipment, and adequate theory. Thus, a normal advance from the descriptive phases of presenting observed and steady-state conditions to the analytical phases of understanding processes and forecasting various time-dependent phenomena has not taken place.

There have been several periods of rather extensive research activity: in the late 19th century by the U.S. Bureau of Fisheries, the late 1920's and early 1930's by the International Fish Commission, the mid 1950's to the early 1970's by the International North Pacific Fisheries Commission, and in recent years by the Institute of Marine Science of the University of Alaska.[6/] The interval between periods of activity has gradually decreased from about 50 years to the order of 5 years or less, and hopefully the instigation of the OCSEAP studies will result in the continuing research effort required to obtain adequate knowledge concerning flow.

The dominant physical phenomena in the Gulf of Alaska is the Aleutian low pressure system whose center moves anti-cyclonically out of the northern Bering Sea in early autumn, crosses the Alaska Peninsula and attains a mean position of about 55°N, 155°W in the gulf in late fall and early winter. During winter it moves southwestward to about

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[6/] See Rosenberg (1972).

50°N, 175°E before returning northward into the western Bering Sea in late winter and early spring. The cyclogenesis and cold air advection in the gulf associated with the mean position of the low pressure center in fall and winter determines the extent and intensity of winter overturn and vertical divergence, as well as, the containment of precipitation, in the form of ice and snow along the coast and in the snowshed ringing the gulf which determines to a great extent the amount of dilution in coastal waters in spring and summer. Station data are marginally adequate in period 1955-62 to show considerable differences between the upper layer temperature distributions in 1956 and 1958, and between the surface salinity distributions in 1957 and 1958, but these are certainly not extreme conditions. Approximate ranges for temperatures in coastal waters are -1.8 - 18°C, and in the central part of the gulf, 1 - 14°C; approximate ranges of salinity in coastal waters are several parts per thousand to 32.6 $^{o}/oo$ and in the central part of the gulf, 32.2 - 33.0 $^{o}/oo$. At depth, below the effects of seasonal influences, conditions are somewhat in a steady-state condition, this makes it difficult to trace anomalous intrusions, or percentage of flow attributed to various sources without extensive data, but there is evidence in the temperature fields that significant changes can occur over periods of several years and certainly longer trends must also exist. Temperature data in the gulf are considered too fragmentary to show the rather consistent 2-3 year variations of ± 1-2°C detected in the central and western parts of the Pacific Ocean by Favorite and McLain (1973).

In regard to surface flow, drift bottle studies have shown that the source of surface flow into the gulf is not from the Kuroshio but largely from the Oyashio and its extension the Subarctic Current, and there is a well documented coastal flow northward along the west coasts of the United States and Canada that also extends into the gulf. Studies have shown that the nature of the separation of the Subarctic Current off the coast is quite variable and complex and, thus, the effect of the northern branch of this flow, which penetrates into the gulf, is equally variable and complex. There is an indisputable onshore component of surface flow around the gulf. But it is not known whether the drifting objects are transported around the gulf largely seaward of the continental shelf and only when they are carried out of the oceanic flow and over the shelf are they trapped in a coastal regime and carried directly ashore, or whether, in spite of tidal currents and increased frictional effects, there is continuity in northward flow in offshore and onshore areas that results in a gradual dispersal of floating objects on the coast as the flow sweeps around the gulf. Nevertheless, it is apparent that floating objects released over the continental shelf at the eastern part of the gulf drift into coastal embayments such as Prince William Sound and Cook Inlet, and move southwestward on either side of Kodiak Island. Further, there is evidence that floating objects in the northern part of the gulf have a potential for wide dispersal: northward into Bering Sea, westward out along the Aleutian Islands, eastward in the Subarctic Current to the coast of Southeastern Alaska, the west coasts of British Columbia, Washington, Oregon and California, and westward again to the central Pacific Islands and the Asian coast.

Geostrophic currents are somewhat of a dilemma. First, closely spaced data suggest that the broad sweep of cyclonic flow around the gulf, generally shown in atlases or summaries of widely spaced data, is actually a highly turbulent regime composed of eddies of various dimensions. There is a frequent suggestion of a large perturbation at the eastern side of the gulf whose dimensions and configuration do not suggest a shelf wave phenomenon, but rather the possibility that at times some of the northward flow funneling into the eastern side of the gulf is unable to move westward across the head of the gulf and is found to turn back on itself. Second, although geostrophic currents clearly reflect the area of divergence, the Ridge Domain, a dominant oceanographic feature in the gulf, there are no direct measurements that permit ascertaining to what extent this feature is governed by (1) Ekman transport (2) a normal internal readjustment of mass between two opposing flows, and (3) a vertical movement of northward flowing deep water, caused by the effect of the land barrier imposed by the gulf. Third, the high velocity cyclonic flow at the edge of the continental shelf is also a dominant feature and an inshore countercurrent is usually detected in geostrophic computations. At this time it is not clear whether this is an aspirative phenomenon not uncommon under such circumstances, whether it is merely an error caused by inadequacies in this method in the presence of physical boundaries, or whether it is largely the effect of eddies or shelf waves along the edge of the continental shelf. Finally, there is the large variability in transport computed from the sporadic cruise data in one instance (1960) a 50% increase in mean flow, and a 100% increase over low flows, but there is no consistent evidence of winter intensification in flow expected as a result of increased wind-stress during that period. However, increases in sea levels at coastal stations in winter suggest that there is at least a barotropic response. Thus, it would appear that winter intensification of flow does occur but the pulses of winter wind-stress are of too short a duration for the distribution of mass to adjust to the actual flow regime; however, over decades and centuries the calculated geostrophic regime appears to have adjusted to an integrated, quasi-steady state between the effects of winter intensification and summer relaxation. Thus, there may be an inherent under-estimation of actual flow in summer when using the wind-stress transport method. The long data record of sea level pressures provides a qualitative indication of transport variability. Spectral energy densities indicate a dominant annual period and a suggestion of an approximate 3-year period. The latter is evident primarily in the decade 1950-59 and does not appear to be a dependable forecasting index. Although monthly transports occasionally show totally unrealistic values, quarterly means and 12-month running means indicate a relatively ordered system (within limits) with no apparent indices to forecast anomalous events.

Of course, wind-stress estimates are merely that, estimates, and so are the outputs of model studies whose results are largely dependent on wind-stress inputs. It should also be obvious that fluctuations in conditions in the gulf are also influenced by various external and internal forces throughout the Pacific Ocean. Nevertheless, considerable advances in our knowledge of the physical oceanography of the gulf will come from short-period monitoring of actual conditions and extensive direct current measurements, not only across the shelf, but also across the slope and in the Ridge Domain. OCSEAP studies are beginning to provide such data.

Studies of surface divergence indices show the extreme variability in direction and intensity of wind-stress in time and space around the gulf, as well as insight into mechanisms that essentially pump water in contact with the shelf shoreward in summer and seaward in winter. The eastern side of the gulf has been shown to be the most energetic in regard to these processes and considerable variability is apparent. An attractive feature of the ODI and CDI computations is their basis in data fields that are routinely prepared and made available in real-time by meteorological agencies; in fact the fields are forecast over periods up to 72 hours or more. Thus, there is a potential for a very inexpensive, real-time monitoring of conditions affecting the flow field in the gulf. Hopefully the OCSEAP studies now underway will help to establish the quantitative linkages required to translate such information into a practical tool for marine environmental management.

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QUARTERLY REPORT

Contract No.:

R7120848

Research Unit No.:

367

Reporting Period:

1 April 1976 - 30 June 1976

Number of Pages:

2

NEAR-SHORE METEOROLOGY

R. Michael Reynolds

Bernard A. Walter

Pacific Marine Environmental Laboratory

15 July 1976

Task Title: NEAR-SHORE METEOROLOGY

PI: R. Michael Reynolds
Bernard A. Walter
NOAA/PMEL
3711 15th Avenue N.E.
Seattle, WA 98105

Report Period 1 April - 30 June 1976

I. Task Objectives:

1) Determine the distances off-shore that the effects of land are discernible, especially during winter conditions.
2) Document occurances of katabatic flow conditions which lead to high velocity off-shore winds.
3) Prepare a simple numerical model by adapting one of about three existing models to the specific study area (Icy Bay-Yakutat).
4) Begin a study of coastal Meteorology on the north coast in the Prudhoe Bay area. Specifically, to examine the structure of the stable boundary layer and its modification by the Alaskan land mass.

II. Field and Laboratory Activities:

A. Cruises: None.

B. Field Experiments: A field site was established at Narwahl Island on the north coast. The instruments included four levels of anemometers, an acoustic sounder and precision barometers. The site was occupied for approximately six weeks.

C. Laboratory Activities:

i) A meeting of PI's was held at Sandpoint facility on 13-14 May to coordinate plans for FY77 and to discuss this year's work. A future meeting was planned for October. In attendance were scientists from PMEL, U of A, UW and ERL.

ii) A meeting of meteorologists was held to discuss preliminary results from the Narwahl Island experiments. It was agreed that the effects of the Brooks range are significant on the stable boundary layer. Fresh water outflow over the ice acts to modify atmospheric structure on a local scale.

iii) Topography of the Icy Bay-Yakutat study area was digitized on a 5 km grid. This grid is now being prepared as an input to the Lavoie boundary layer model.

III. Results:

All radiosonde data from NEGOA are digitized and plotted. Archival formats are being prepared for these data. The boundary layer profiler data is presently being worked up (30% complete).

IV. Preliminary Interpretation of Results:

A discussion of NEGOA Meteorology was given by R. Michael Reynolds at the AMS Meetings on Air-Sea Interaction in Seattle, 30 March - 1 April 1976.

GEOLOGY

GEOLOGY

GEOLOGY

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212/ 216	Bruce F. Molnia Paul R. Carlson USGS	Faulting and Instability and Erosion and Deposition of Shelf Sediments, Eastern Gulf of Alaska	747
251	Hans Pulpan Jurgen Kienle Geophys. Inst. U. of Alaska	Seismic and Volcanic Risk Studies Western Gulf of Alaska	755
253/ 255/ 256	T. E. Osterkamp William D. Harrison Geophys. Inst. U. of Alaska	Offshore Permafrost-Drilling, Boundary Conditions, Properties, Processes and Models	757
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290/ 291/ 292	Charles M. Hoskin IMS/U. of Alaska	Benthos-Sedimentary Substrate Interactions	765
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407	R. Lewellen Arctic Research	A Study of Beaufort Sea Coastal Erosion, Northern Alaska	771

RU# 16

NO REPORT SUBMITTED

The principal investigator is in the field.

RU# 59

NO REPORT SUBMITTED

The principal investigator is in the field.

QUARTERLY REPORT

Contract 03-5-022-56
Task Order Number 6
Quarter Ending -
30 June 1976

THE ENVIRONMENTAL GEOLOGY AND GEOMORPHOLOGY OF THE GULF OF ALASKA COASTAL PLAIN

Dr. P. Jan Cannon
Assistant Professor of Geology
Department of Geology
University of Alaska
Fairbanks, Alaska 99701

June 30, 1976

QUARTERLY REPORT

I. Task Objectives

A. To produce three maps of the coastal plain section of the Gulf of Alaska.

B. To produce a report on the application of radar imagery to the environmental geologic mapping of coastal zones.

C. To construct an annotated mosaic of the area from radar imagery.

D. To indicate the effects (beneficial and adverse) that oil and gas development might have in relation to the geologic setting.

II. Activities

Field checked basic map units in Yakutat area. Updated radar imagery of the Yakutat area was obtained May 7, 1976. In June, field checked beach stability and longshore drift indicators. The search for traces of active faults was continued.

III. Results

The coastal plain sediments are thin blankets of material lying on a bedrock bench. Total longshore drift is from southeast to northwest. From Yakutat Bay toward the southeast the degree of recent tectonic uplift increases.

IV. Preliminary Interpretation of Results

The beach is relatively stable in respect to the erosional and depositional processes which are operating in the area. Major changes on the beach in the future will be mostly related to tectonic activity. Bedrock is closer to the surface at the beach, east of Dry Bay. East of Dry Bay would be the best site for a deepwater port in the Gulf of Alaska itself.

V. Problems Encountered/Recommended Changes

Winter snowfall at Yakutat totaled 407 inches. Much of the low areas were still covered with snow at the end of June. The importance of tectonic activity in the area indicates that the mapping of geologic hazards should be extended from Dry Bay southeastward to Icy Point.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: June 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 6 R.U. NUMBER: 99

PRINCIPAL INVESTIGATOR: Dr. P. Jan Cannon

No environmental data are to be taken by this task order as indicated in the Data Management Plan. A schedule of submission is therefore not applicable[1].

NOTE: [1] Data management plan was submitted to NOAA in draft form on October 9, 1975 and University of Alaska approval given on November 20, 1975. We await formal approval from NOAA.

Contract no. - 01-50-22-2313
Research Unit no. - 105
Reporting period - April - June 1976
Number of pages - 8

Quarterly Report
to

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
Arctic Projects Office
Fairbanks, Alaska

DELINEATION AND ENGINEERING CHARACTERISTICS OF PERMAFROST BENEATH THE BEAUFORT SEA

Principal Investigator:
P. V. Sellmann

Associate Investigators:
R. Berg
J. Brown
S. Blouin
E. Chamberlain
I. Iskandar
H. Ueda

CORPS OF ENGINEERS, U.S. ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

JUL 1976
REC'D
OCS/APO

I. TASK OBJECTIVES

The emphasis of the program is on quantifying the engineering characteristics of permafrost beneath the Beaufort Sea, and determining their relation to temperature, sediment type, ice content and chemical composition. These data will be used in conjunction with those from the marine and subsea permafrost projects listed below to develop a map portraying the occurrence and depth of permafrost under the Beaufort Sea. The drilling program will provide subsurface samples and control for the other programs. It is also designed to test drilling, sampling, and in-situ measurement techniques in this offshore environmental setting where material types and ice conditions make acquisition of undisturbed samples extremely difficult.

We are actively coordinating our activities with the following OCS projects:

Research Unit #204: Offshore permafrost studies, Beaufort Sea - Peter Barnes and Erk Reimnitz, U.S. Geological Survey.

Research Unit #205: Marine environmental problems in the ice-covered Beaufort Sea Shelf and coastal regions - Peter Barnes, Erk Reimnitz and David Drake, U.S. Geological Survey.

Research Units #253,255, 256: Offshore permafrost drilling, boundary conditions, properties, processes and models - T. E. Osterkamp and William D. Harrison, University of Alaska.

Research Unit #271: Beaufort seacoast permafrost studies - James C. Rogers, University of Alaska.

Research Unit #407: A study of Beaufort Sea coastal erosion, northern Alaska - Robert Lewellen, Littleton, Colorado.

II. FIELD OR LABORATORY ACTIVITIES

A. Field Trip Schedule

During this reporting period the field program was undertaken in the Prudhoe Bay area. The project personnel who conducted the drilling, sampling and probe study were in the field from 20 March to 7 May. The first ten days were spent mobilizing the equipment at the VE Construction Company camp at Prudhoe Bay. During this time all prospective drill sites were also flagged on the sea ice and positioned using an electronic ranging system. The equipment and camp were moved onto the ice and positioned for drilling by 1 April. The month of April and the first two days of May were devoted to drilling and sampling. The equipment was returned to Prudhoe Bay by 3 May and several days were then spent preparing it for storage. All of the CRREL project personnel departed Prudhoe on 6 May.

Subsequent visits were made to Prudhoe Bay in mid-May and early June by Robert Lewellen and USGS personnel to revisit the drill sites to make thermal measurements.

B. Scientific Party

The size of the field party ranged from 6-9 people, not including Dr. Jerry Brown and Dr. I. K. Iskandar who visited the camp to coordinate sampling procedures for the chemical studies. The only unanticipated change in the personnel schedule during this period was Mr. Ueda's unfortunate departure because of illness in the family.

The following personnel were in the field during the study:

Mr. Paul V. Sellmann, CRREL, 20 March to 6 May
Drilling effort and core logging

Mr. Herbert Ueda, CRREL, 20 March to 16 April
Drilling effort

Mr. Allen Delaney, CRREL, 20 March to 7 April
Mobilization and start-up of field effort

Mr. Edwin Chamberlain, CRREL, 29 March to 6 May
Engineering properties of materials, core logging and probe program

Mr. Scott Blouin, CRREL, 7 to 28 April
Engineering properties of materials, probe program

Dr. Robert Lewellen, Arctic consultant (cooperative), 31 March to 8 May
Drilling effort and thermal data

Dr. Peter Barnes, USGS (cooperative), 21 March to 7 April
Field control, position of drill sites, mobilization

Mr. David Carter, USGS (cooperative), 30 March to 15 April
Hole and core logging (geological studies); shared responsibility with D. M. Hopkins

Mr. David Hopkins, USGS (cooperative), 14 April to 3 May
Hole and core logging (geological studies)

Mr. Vaughn Marshall, USGS (cooperative), 29 March to 8 May
Thermal logging of holes, and independent thermal probe studies

C. Methods

1. Drilling and Sampling Program

The drilling equipment was described in some detail in the annual report; therefore, only drilling and sampling methods will be discussed. The wire line and conventional rotary sampling equipment, in general, were not well suited for the common material types encountered in the area. As a result, drive sampling techniques were used for most of the sampling. Material properties of both the fine- and coarse-grained parts of the section required all open holes to be cased, which also influenced sampling procedures.

The fine-grained upper portions of the sections (5 to 9 meters) were sampled on a fairly continuous basis. The sand and gravel were sampled at greater intervals which were, in part, determined by casing placement procedures. Two types of drive samples were used with considerable success. In the fine-grained material (clay, silt and sandy silt) the Washington State sampler was an ideal tool. It provided excellent core recovery. The sampler had a solid barrel, and the core was removed by using a hydraulic extractor. Maximum sample length was 0.6 m and core diameter was 50 mm.

In the coarse-grained material (sand and gravel) a Lynac drive sampler was used. This sampler has a split tube barrel and provision for using a core catcher and obtaining a 0.45-m-long, 50-mm-diameter core. After modification of the core retainer and use of a flexible sample sleeve, cores were obtained on every run with a high percentage of recovery. Obtaining disturbed material in the sampler was minimized by setting casing to the required sample depth and by careful cleaning of the hole before a sample run. In fine-grained material, a jet auger was used with great success while a carbide drag bit was used in the coarse-grained material.

When possible, wash samples were obtained between sample runs to assure adequate lithologic control as well as to try to obtain organic and paleontologic material for the geological studies.

All core was examined, photographed and described in the field. Based on this examination, the cores were split for future analyses. Subsamples were selected for engineering, chemical, and geological examination at CRREL or the USGS. These samples were then packaged and transported to the appropriate laboratories.

2. Field Facilities

The facilities available for support in the field, including the three sleds containing the workshop, drill rig, soils lab, and housing unit, have been described in detail in previous reports.

3. In-situ and Field Soil Measurements

The probe equipment used during this field program was evaluated as a potential aid for acquiring engineering data more rapidly and economically than is possible by drilling techniques. Selection of a cone penetrometer was based on the desire to obtain a system that would provide a maximum amount of data over a wide range of soil types but be mechanically simple and easy to operate under Arctic conditions.

This instrument (Figure 1) was fabricated at CRREL from commercially available components. The probe string was double walled, with the cone attached to EW drill rod which was inside NX casing. A side friction sleeve was added at the base of the casing. Point penetration and side friction could be obtained separately by successively advancing the point and the casing.

The probe was advanced by two methods: 1) pushing at a constant rate with a hydraulic ram, and 2) driving with a drop hammer. A 12,000-lb reaction force could be developed with the hydraulic system using an electrically powered hydraulic pump to operate the cam. The impact penetrometer was driven using a tripod-mounted drop hammer (64 kg) driven with a gasoline-powered cathead. Usually, observations were made at 7.5-mm intervals with the hydraulic system and 15-mm intervals with the impact system.

Temperature profiles of these holes were also recorded after the penetrometer had reached maximum depth. A thermistor was placed in the fluid-filled bore of the rod and a profile of the hole was recorded after the hole had stabilized for at least 12 hours.

4. Chemical Characteristics

Care in selecting the core and the use of drive sampling technique should provide material as chemically undisturbed as possible. Samples were usually selected from the central part of the core to eliminate the chance of sea water infiltrating into the open end of the sampler. Usually finer-grained material was also selected to minimize this problem. The drive sampling technique appeared to be most satisfactory for this purpose since it eliminated additional potential for contamination from drilling fluid during the coring operation.

No processing was done in the field and all samples were shipped to Hanover for analysis. The types of determinations as well as methods have been discussed in previous reports.

D. Sample Localities

Figure 2 shows the sites selected for drilling during the 1976 program. The first hole, PB-1, was drilled in the center of Prudhoe Bay at $70^{\circ}20.9'$N, $148^{\circ}19.3'$W. The second hole, PB-2, was drilled north of Reindeer Island, at $70^{\circ}30.7'$N, $148^{\circ}18.1'$W. The third hole, PB-3, was placed between Reindeer Island and the new ARCO dock facility at $70^{\circ}25.9'$N, $148^{\circ}26.6'$W.

Water depths at PB-1 through PB-3 were approximately 2.7 m, 11.6 m, and 5.9 m respectively. At PB-1 a second hole, PB-1A, was drilled to provide additional samples from the upper part of the section.

The hole depths from the drill collar for the three holes completed were 33.8 m at PB-1, 42.8 m at PB-2, and 51.5 m at PB-3.

E. Data Collected

Descriptive logs of the holes have been prepared and will be presented in the USGS report on the project. A total of 110 samples were obtained from the cores for index property determinations, strength and permeability tests, chemical analyses, and geological examination. Thermal logs of the holes were obtained by the USGS personnel. Each hole was logged upon its completion after installation of the PVC probe access tube, and periodically thereafter in an attempt to obtain data as the holes reached equilibrium. These thermal data, coupled with the chemistry studies, will provide control for interpreting the permafrost properties in this geological setting.

Thermal profiles from four probe sites were also obtained by CRREL personnel. Both static and impact probe data were obtained from these locations.

III. RESULTS

At this time the laboratory programs are just beginning, and reporting of data from sample analyses is premature. It is only possible to make some general comments about results of the direct observations made in the field regarding permafrost distribution and preliminary data from the probe development effort.

Thermal data from the CRREL probe studies, which should closely represent undisturbed temperatures because of limited disturbance, indicate temperatures in the bed sediments below $0^{\circ}C$. They range from a minimum immediately below the bed of $-3.7^{\circ}C$ near PB-2 to a maximum of $-1.1^{\circ}C$. Preliminary results from one of the probe profiles are shown in Figure 3. Results from the thermal logging of the main drill holes will be reported by the USGS personnel after all the records have been examined.

Even though permafrost appears to exist throughout the entire interval in all holes, there was no evidence of bonded permafrost with the possible exception of near the base of PB-2. This possibility was based on the fact that in this zone, circulation was maintained and refusal was met in attempting to advance the casing. Unfortunately, it was not possible to obtain a sample from this zone because of the large gravel in the hole bottom. Only future interpretation of the thermal and chemical data from this section will answer this question.

The preliminary data from the probe study for obtaining rapid engineering property data are very encouraging. Figure 3 illustrates some typical cone penetrometer test results obtained near PB-3. A good correlation between the two techniques discussed in the methods section can be seen, with both reflecting the lithology observed in the drill hole. Initially, both the blow count and point pressure values increased, as the sand became more coarse and decreased as finer fractions were encountered to a depth of 9 meters. Between 9 and 10.5 meters, both types of data remain unchanged and at the lowest values as the soft clayey silt was encountered. At approximately 11 meters, there was a sharp increase in both the blow count and point pressure as sand and gravel were encountered. These are generally representative of the information obtained at the other sites.

The chemical analysis of interstitual water has begun. A few samples of interstitual water have been obtained from selected cores by centrifugation, the amount of solution extracted and that remaining being recorded for interpretation of the solution chemistry data. Carbonate, bicarbonate and pH measurements were performed immediately after extraction. Electrical conductivity values varied slightly with depth (5 to 7 mhos/cm).

Efforts on the bibliography on subsea permafrost were continued. The list of Soviet literature presented in Appendix 2 of the annual report was expanded. A compilation of non-Soviet subsea literature was also initiated. CRREL Draft Translation 520, "Structure, Distribution, and Formation of Sub-marine Permafrost," was processed and distributed; additional copies are available from CRREL.

IV. PRELIMINARY INTERPRETATION OF RESULTS

General comments on results were made in the previous section. Since laboratory efforts and interpretation of the data are just starting, discussion in this section would be premature.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

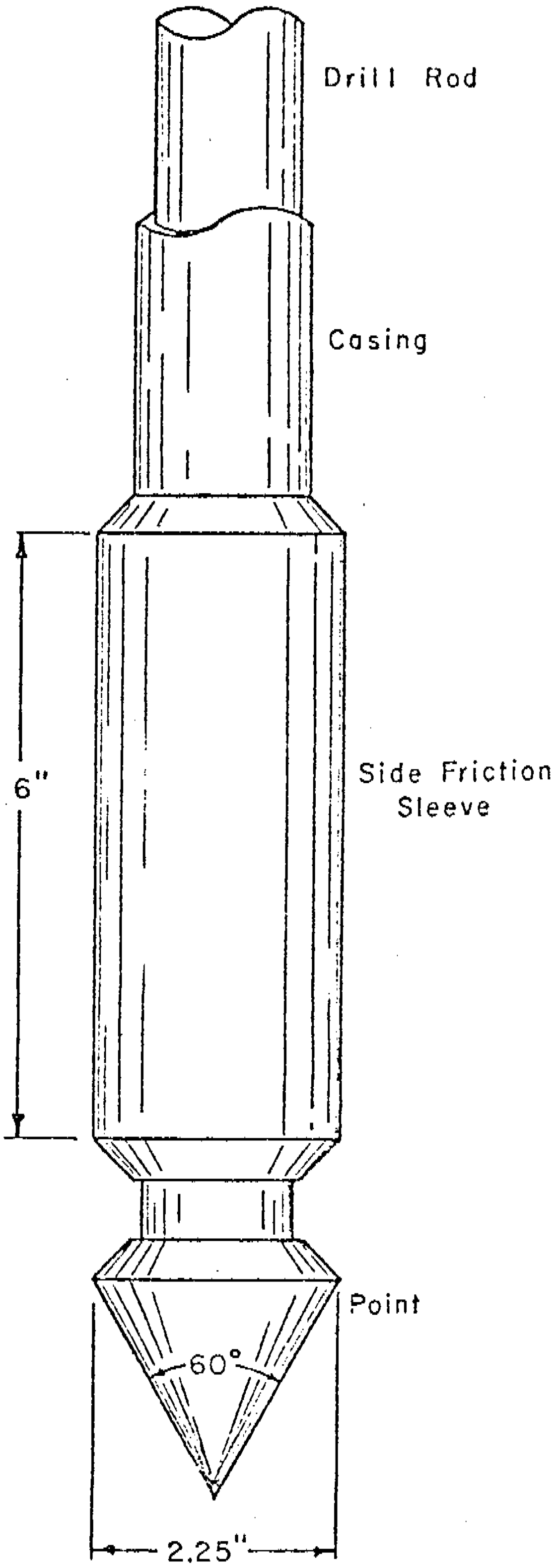
One of the major problems encountered in the program which limited the depth of the holes was the weakness of the casing string. In hole PB-3 the hole was terminated because a casing failed in the bottom section of the string, which prevented the drill rod and bit from passing. Upon removal of the casing, it was apparent that there was excessive deformation of several of the lower joints. The exact nature of the failure was not determined since it was necessary to cut the casing above the problem area to assure that when it was removed, it would not cause problems with the plastic thermal logging casing. The casing in PB-2 also, in part, limited the depth of penetration. It was not possible to transmit sufficient energy down the string because of the length of the casing in the water column.

The other significant problem initially was core recovery in the coarse-grained material. Once the hope of using rotary casing techniques was abandoned and modifications were made to the Lynac split tube drive sample, core recovery problems were, for all practical purposes, solved.

Most of the difficulties can be directly related to the coarse-grained, unconsolidated nature of the sediment; virtually no problems were encountered in the fine-grained upper part of the section.

VI. ESTIMATE OF FUNDS EXPENDED

At the end of this quarter, $200,000 of the total $320,000 had been obligated.



CRREL CONE PENETROMETER

Figure 1.

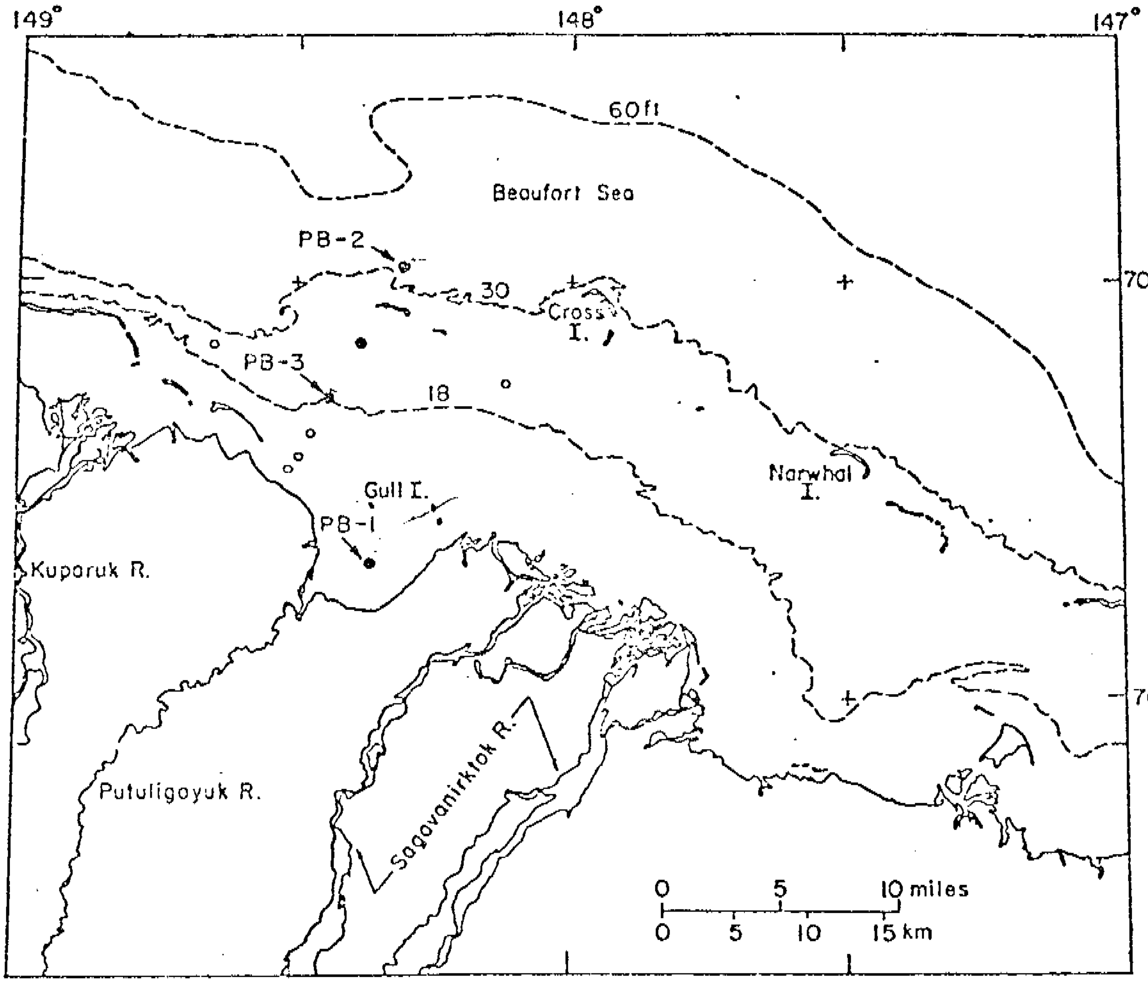


Figure 2. CRREL-USGS Subsea Drilling Location,
Prudhoe Bay Region, Spring 1976

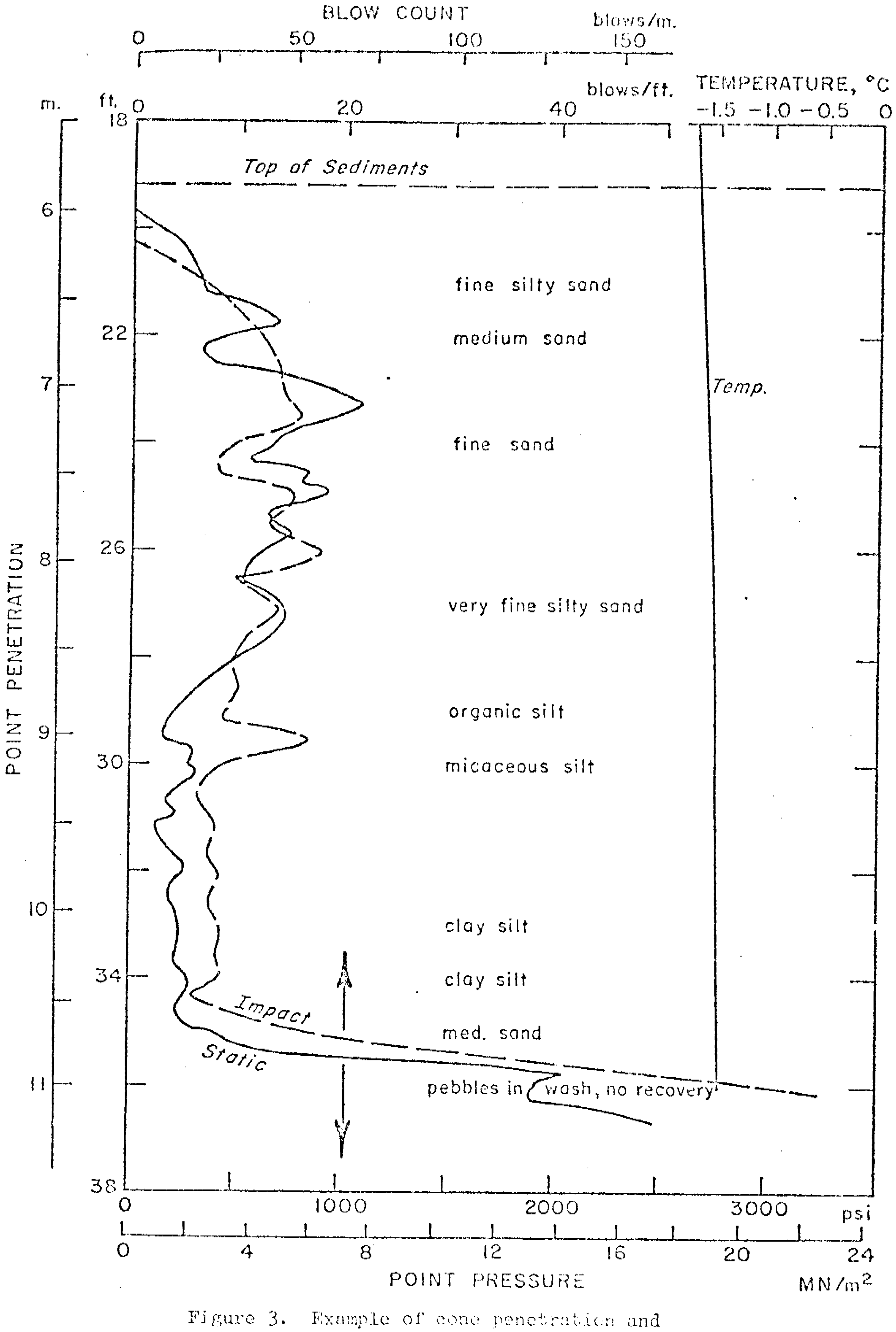


Figure 3. Example of cone penetration and temperature data (PB-1)

5TH QUARTER REPORT

Research Unit #152/154
Reporting Period 7/1/75 - 7/1/76

Distribution, Composition and Transport of Suspended Particulate Matter in the Gulf of Alaska and Southeastern Bering Shelf.

Principal Investigators: Richard A. Feely, Oceanographer
Joel D. Cline, Oceanographer

Pacific Marine Environmental Laboratory
3711 15th Ave. N.E.
Seattle, Washington 98105

I. Task Objectives

The major objective of the particulate matter program in the Gulf of Alaska and southeastern Bering Shelf is to determine the seasonal variations in the distribution, composition and transport of suspended particulate matter. Other objectives include: (1) The high frequency variability in the distribution of suspended matter, and (2) an investigation of the role of resuspension as a mechanism for redistribution of sedimentary materials.

II. Field or Laboratory Activities

A. Field Activities

1. Ship Schedule
    a. DISCOVERER Cruise (RP-4-Di-76A-I, 1-12 March 1976)
    b. DISCOVERER Cruise (RP-4-Di-76A-IV, 12-30 April 1976)
    c. DISCOVERER Cruise (RP-4 Di-76A-VI, 11-20 May 1976)
2. Participants from PMEL
    a. Mr. Gary Massoth, Chief Scientist
    b. Ms. Jane Fisher, Oceanographer
    c. Ms. Joyce Quan, Physical Science Tech.

3. Methods
    a. Particulate Matter -- Water samples were collected in 10-liter Top-drop Niskin bottles and filtered under vacuum through preweighed 0.4μm Nuclepore and Selas silver filters. The filters were removed from the filtration apparatus, placed into individually marked

petri dishes, dried in a desiccator for 24 hours and stored for shipment to the laboratory.

b. Nephelometry -- The vertical distribution of suspended matter was determined with a continuously recording integrating nephelometer. The instrument was interfaced into the Plessey CTD system using the sound velocity channel (14-16 KHZ) such that real time measurements of forward light scattering were obtained at each station. In addition, a digital recording nephelometer was placed on a current meter array (station 62G) at approximately 1.5 meters above the bottom (DISCOVERER Cruise RP-4-Di-76A-I). The nephelometer was deployed on 4 March 1976 and recovered on 16 May 1976.

4. Sample Locations

Figure 3 shows the locations of the stations where suspended matter samples were collected during cruise RP-4-Di-76-IV. Station 62/15 is the location of the bottom mounted nephelometer.

5. Data Collected

Particulate matter samples were collected from 51 stations in the northeastern Gulf of Alaska. Samples were taken from several preselected depths, depending on location. Nominally, these depths included: surface, 10m, 20m, 40m, 60m, 80m, 100m and 5 meters above the bottom. In addition, a 60 hour time series was maintained at station 62/15. Light scattering profiles were taken every two hours. Also, water samples at the surface and 5 meters above the bottom were collected and filtered for suspended matter.

B. Laboratory Activities

1. Methods

The major (Mg, Al, Si, K, Ca, Ti and Fe) and trace (Cr, Mn, Cu, Ni, Zn and Pb) element chemistry of the particulate matter is being determined by x-ray fluorescence. This technique has been successfully used for the determination of the major element composition of the particulate matter from coastal and deep water environments and the techniques are fairly well established (Baker and Piper, 1976). In our laboratory, we have developed techniques for the analysis of Cr, Mn, Cu, Ni, Zn and Pb in addition to the major elements.

Radiation from a silver x-ray tube is used to obtain a monochromatic source of x-rays from a secondary target. We are using a combination of secondary targets (Se and Zr) to analyze the particulate matter for both major and trace elements. USGS standard rocks and NBS glass standards are used for calibration of the individual elements.

Particulate carbon and nitrogen are being analyzed by the Micro-Dumas combustion method, employing a Hewlett-Packard 185B C-H-N analyzer (Sharp, 1974). Particulate matter is removed from one liter volumes by vacuum filtration and the carbon and nitrogen combusted to CO_2 and N_2. After separation by standard gas-solid chromatography (GC),

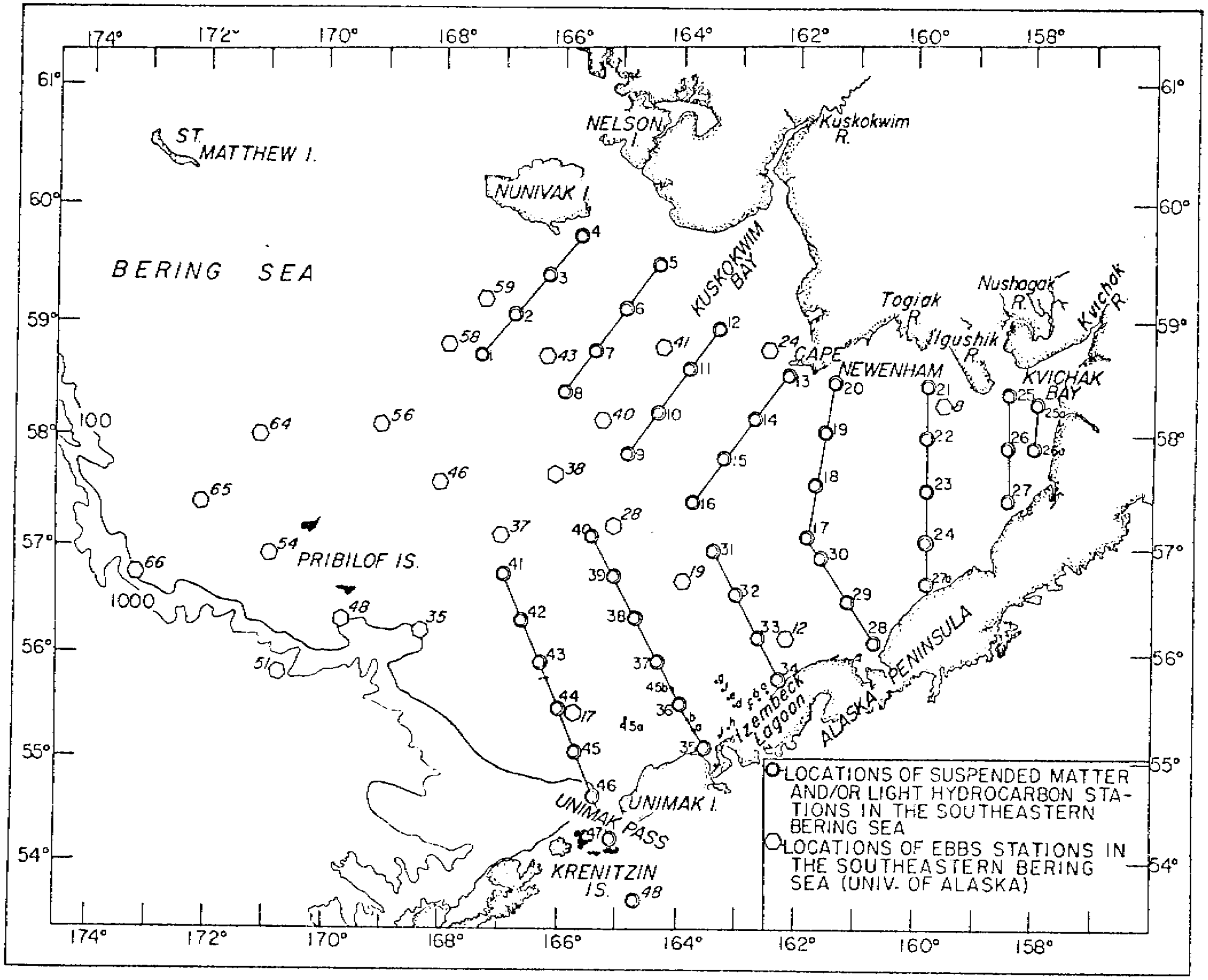


Figure 1. Locations of suspended matter stations in the southeastern Bering Shelf (Cruise RP-4-Di-75B-III, 12 Sept. - 6 Oct., 1975).

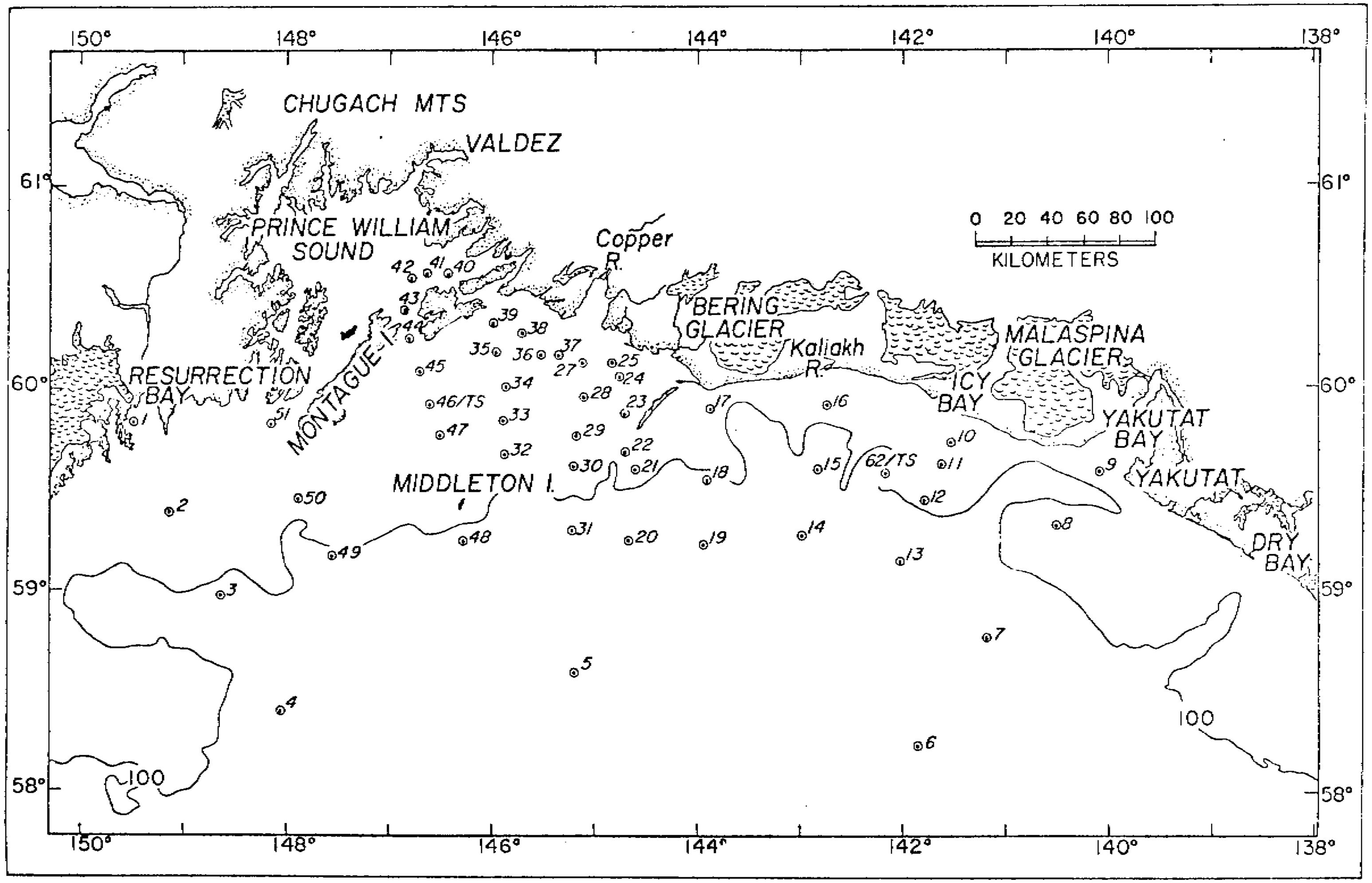


Figure 2. Locations of suspended matter stations in the northeastern Gulf of Alaska (Cruise RP-4-Di-75C-I, 21 Oct. - Nov., 1975)

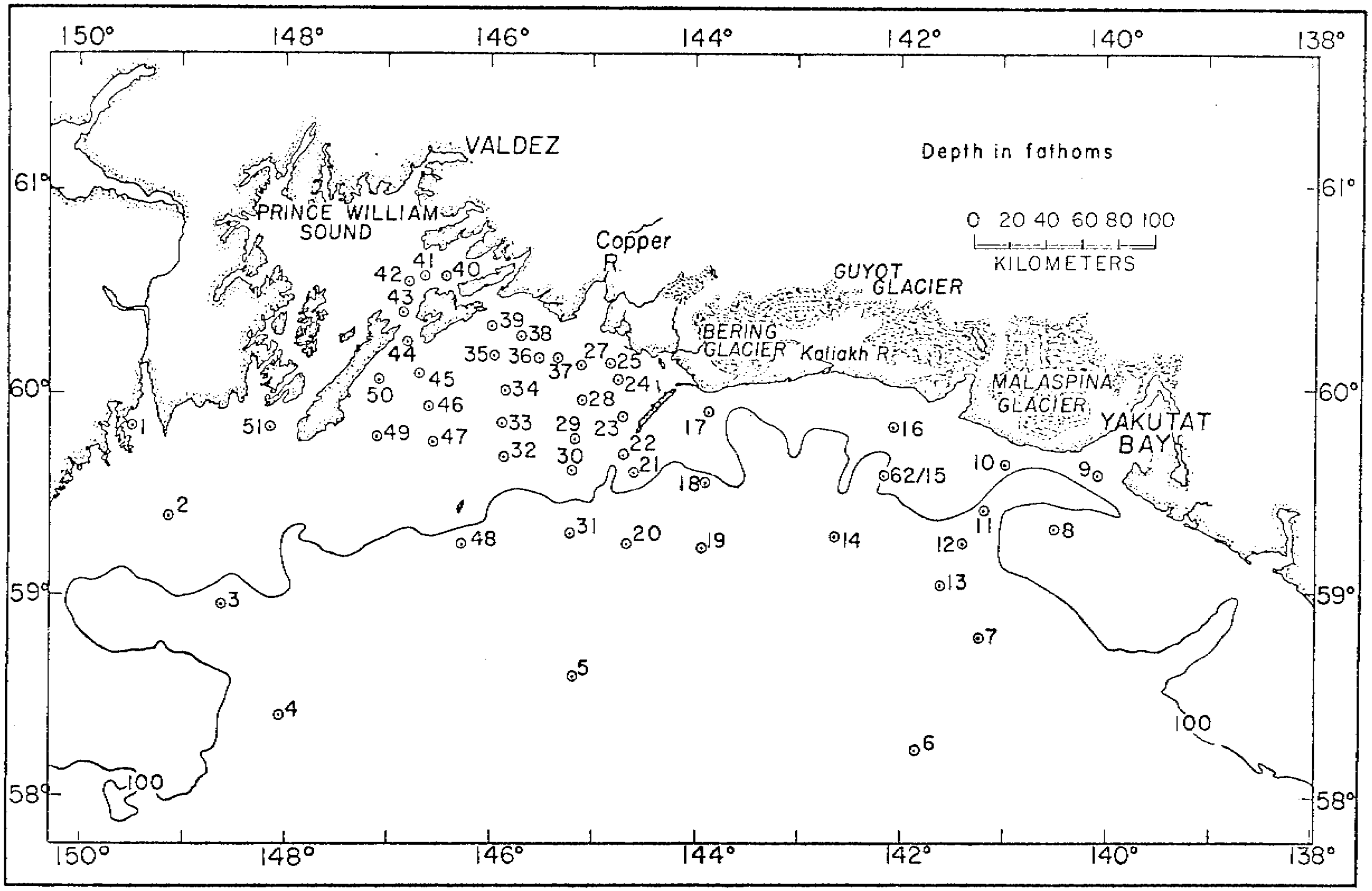


Figure 3. Locations of suspended matter stations in the northeastern Gulf o Alaska. (Cruise RP-4-Di-76-IV, 12 - 30 Apr., 1976)

the gases are quantitatively determined by thermal conductivity. Standardization is being effected with NBS acetanilide (Sharp, 1974).

2. Data Collected

To date, we have completed three of the five cruises scheduled for the present fiscal year in The Gulf of Alaska and southeastern Bering Shelf. The first cruise, RP-4-Di-75B-III of the NOAA ship DISCOVERER, was conducted in the southeastern Bering Shelf during the fall of 1975 (12 Sept.-5 Oct.). The second cruise was conducted in the northeastern Gulf of Alaska during late fall of the same year (21 Oct. - 10 Nov.). The third cruise, also in the northeastern Gulf, was conducted in early Spring of 1976 (12 Apr. - 30 Apr.). At this point, approximately 900 samples have been collected and weighed for suspended loads. In addition, approximately 300 samples have been collected for elemental analysis of the particulate material.

III. Results

A. Particulate Matter Distributions

The data on the distribution of suspended matter in the southeastern Bering Shelf and the northeastern Gulf of Alaska for the fall cruises (RP-4-Di-75B-III and RP-4-Di-75C-I) are complete and have been described in the First Annual Report, and, therefore, will not be described here. We are presently analyzing the samples from the spring cruise in the northeastern Gulf (RP-4-Di-76A-IV) and that data will be presented in a future report.

B. Elemental Chemistry of the Particulate Material

At this point, the data on the elemental composition of the particulate matter in the southeastern Bering Shelf are incomplete. We have completed all of the particulate carbon and nitrogen analyses and the results have been discussed in The First Annual Report and will not be reproduced here. Our analyses of the major and trace element composition of the particulate matter have just begun and no data will be presented at this time.

The analyses of the particulate matter samples from the fall cruise in the northeastern Gulf of Alaska are complete and the results will be described below.

1. Particulate Carbon and Nitrogen

Since the early work of Menzel and Vaccaro (1964), many investigators have used particulate carbon as a tracer of particulate organic matter in the oceans. Riley (1970) suggested a factor of 2.0 be used to estimate concentrations of particulate organic matter from particulate carbon. Recent investigators have used the carbon to nitrogen ratios in particulate matter to distinguish between terrestrial and marine sources of organic matter (Loder and Hood, 1972). The authors found that riverborne organic matter has C:N ratios which range between 15-22. In contrast, ratios for marine organic matter range between 5-15.

The distribution of particulate carbon and nitrogen at the surface and 5 meters above the bottom in the northeast Gulf are presented in Figures 4 thru 7. The surface distributions follow the same general pattern as total suspended matter. High concentrations of particulate carbon and nitrogen are found along the coast with concentration gradients decreasing slowly in a seaward direction. The highest concentrations of particulate carbon and nitrogen are located just south of the Copper River. Since primary productivity is relatively low in this region (Jerry Larrance, personal communication, 1976), the high concentrations are probably due to detrital organic matter adsorbed to inorganic particles.

The carbon to nitrogen ratios in the particulate matter at the surface indicate that the organic matter is of marine origin. Ratios range from 5.0 to 16.5 with a mean of 7.2. Although the ratios increase slightly near the coast, studies of the variability of C:N ratios of marine phytoplankton indicate that these small differences are probably not significant (Banse, 1974).

Near the bottom, particulate carbon and nitrogen distributions tend to be more localized and appear to follow the bathymetry. Figure 8 shows a vertical cross-section of particulate organic carbon for a line of stations directly south of the Copper River. The figure shows a sharp increase in particulate carbon concentrations near the bottom which appears to be associated with the bottom nepheloid layer. This is probably the result of the association of detrital organic matter with inorganic particles.

In order to evaluate the reproducibility of the measurements for total particulate carbon and nitrogen, a number of replicate experiments were conducted during the fall cruise in the Gulf. Surface samples were collected in 10-liter Niskin bottles and simultaneously filtered through 0.4 µm Selas silver filters. The results are presented in Tables 1 and 2. The average relative standard deviations for the replicate studies are 5.8% and 9.8%, respectively, for particulate carbon and nitrogen. Since the precision of our analytical technique (based on replicate studies of NBS standard) is less than 4%, most of the variability in the data appears to be due to the inhomogeneity of particulate matter in the water sample. This implies that one must be extremely careful when comparing small differences in the distribution of particulate carbon and nitrogen. For the Gulf of Alaska, only differences greater than ±16 µg C/L and ± 4 µg N/L are considered to be significant at the 95% confidence level.

In order to obtain some information about the high frequency (hourly) time variations in the distribution of particulate carbon and nitrogen, a 36 hour time series experiment was conducted at station 62. Water samples were collected every 4 hours from the surface and 5 meters above the bottom. The results of these experiments are also given in Tables 1 and 2. The relative standard deviations of the data from the time series experiment are significantly higher than the relative standard deviations from the replicate studies. This suggests that high frequency time variations, which may be due to temporal variations in primary productivity or the vertical movements of micro zooplankton, are significant and must be considered if seasonal distribution maps are to have any significance. Using mean values of 120μg C/L and 18μg N/L, respectively, for particulate carbon and nitrogen at the surface and the relative standard deviations (21.4% and 19.2%) for the time series experiments at station 62, differences greater than ±50μg C/L and ±7μg N/L are significant at the 95% confidence level for seasonal variations.

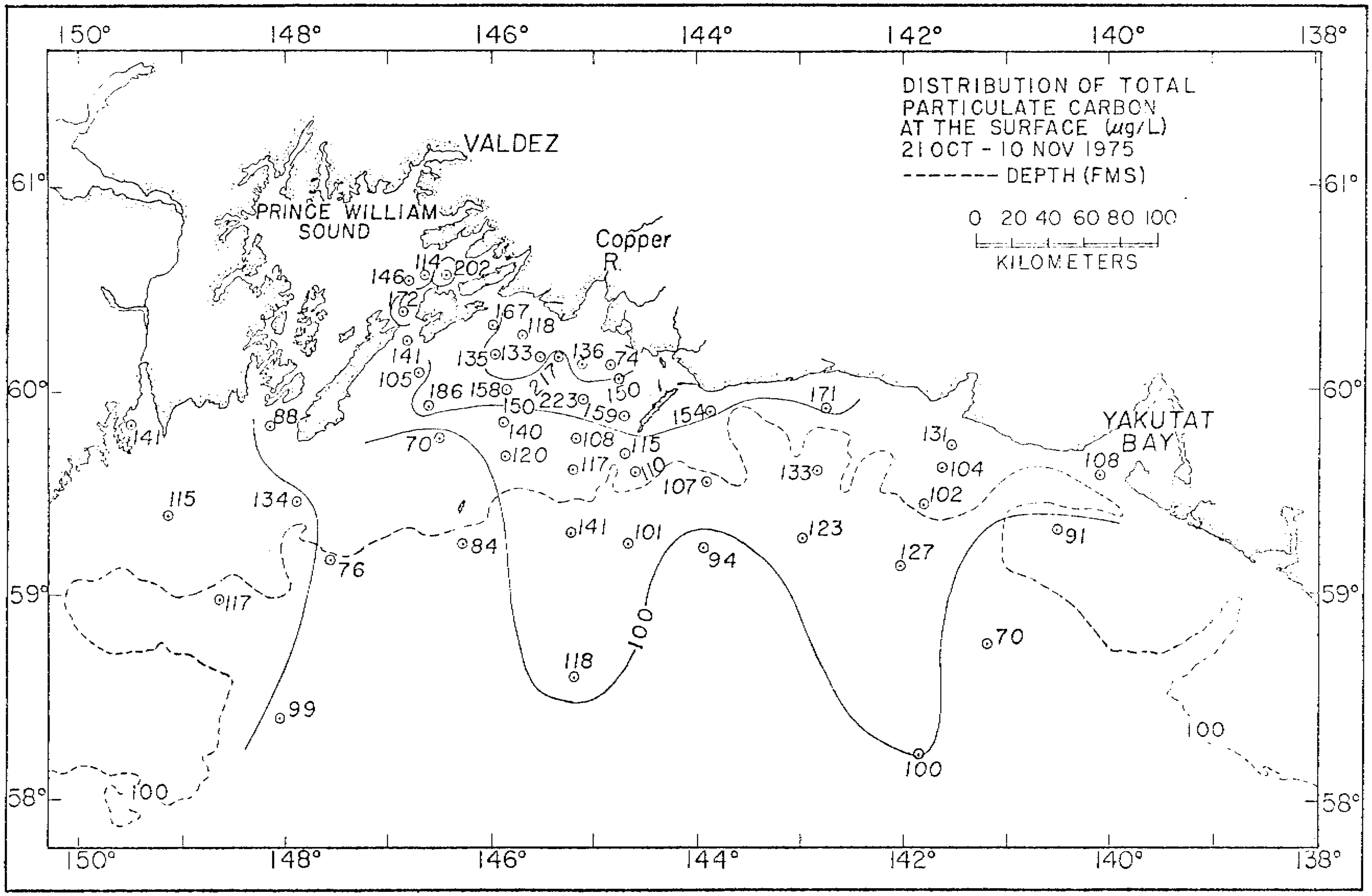


Figure 4. Distribution of total particulate carbon at the surface in the northeastern Gulf of Alaska (Cruise RP-4-Di-75C-I, 21 Oct. - Nov., 1975). The contour interval is 50µg C/L.

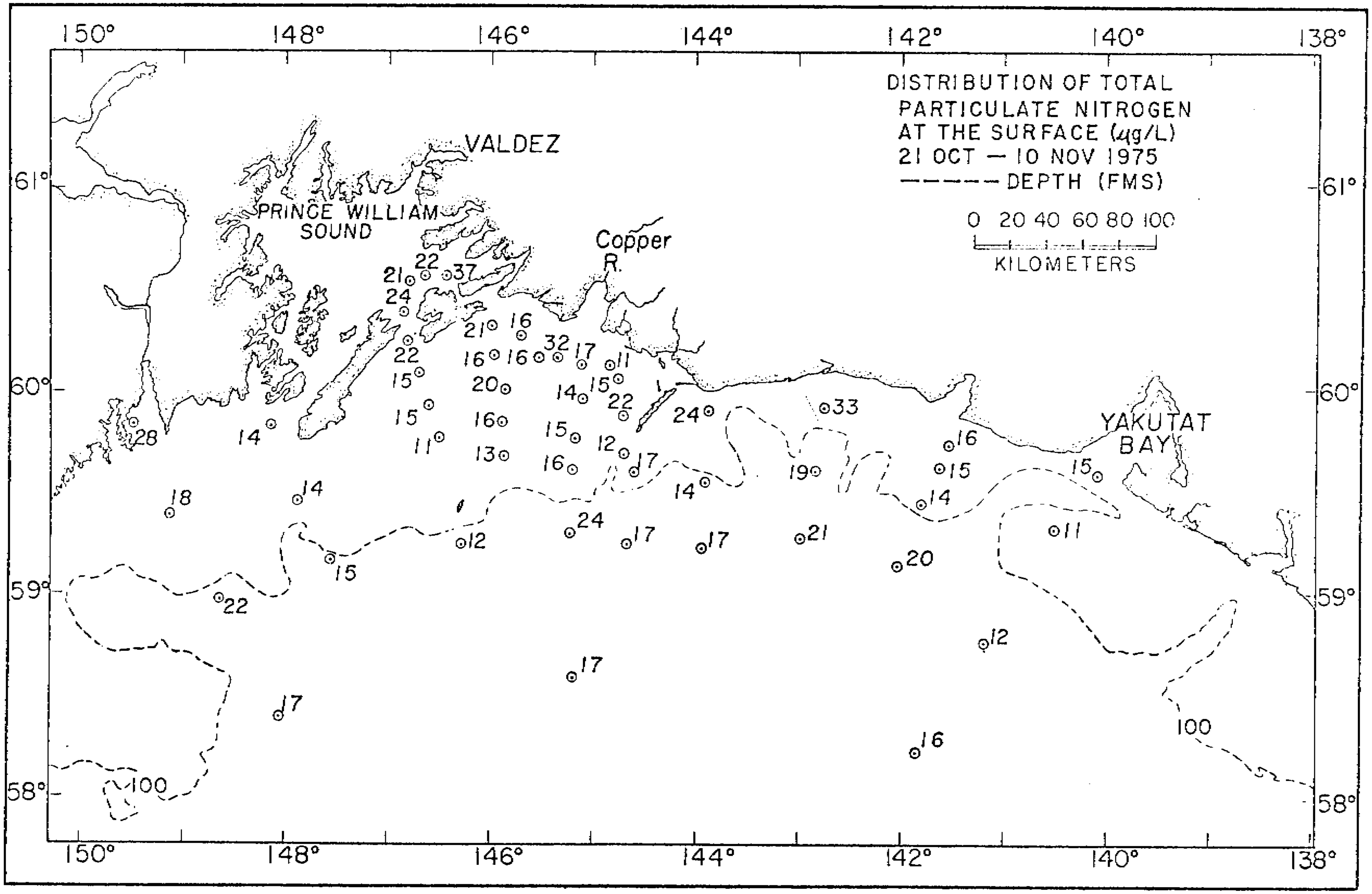


Figure 5. Distribution of total particulate nitrogen at the surface in the northeastern Gulf of Alaska (Cruise RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975).

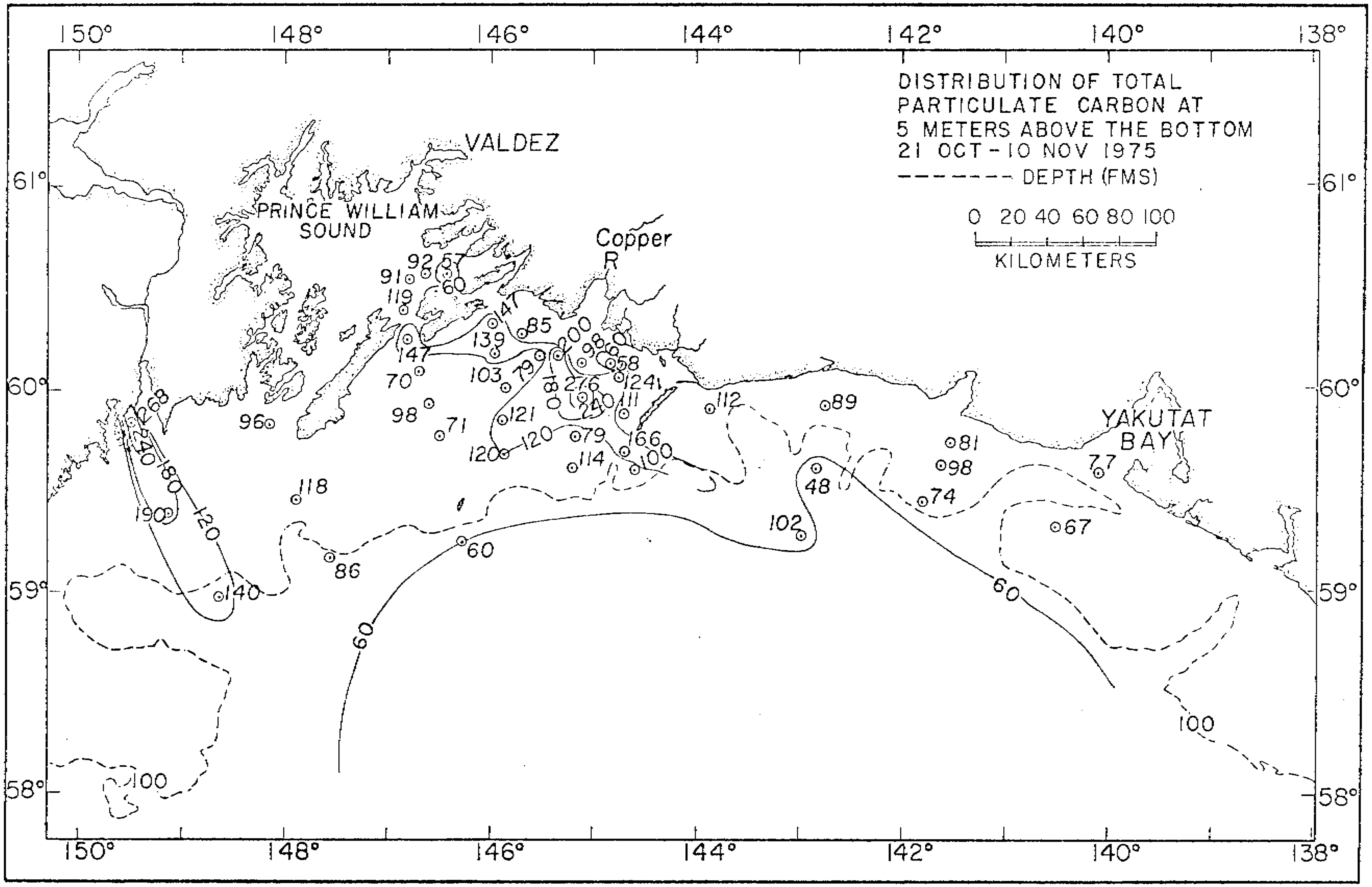


Figure 6. Distribution of total particulate carbon at 5 meters above the bottom in the northeastern Gulf of Alaska (Cruise RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975). The contour interval is 60µg C/L.

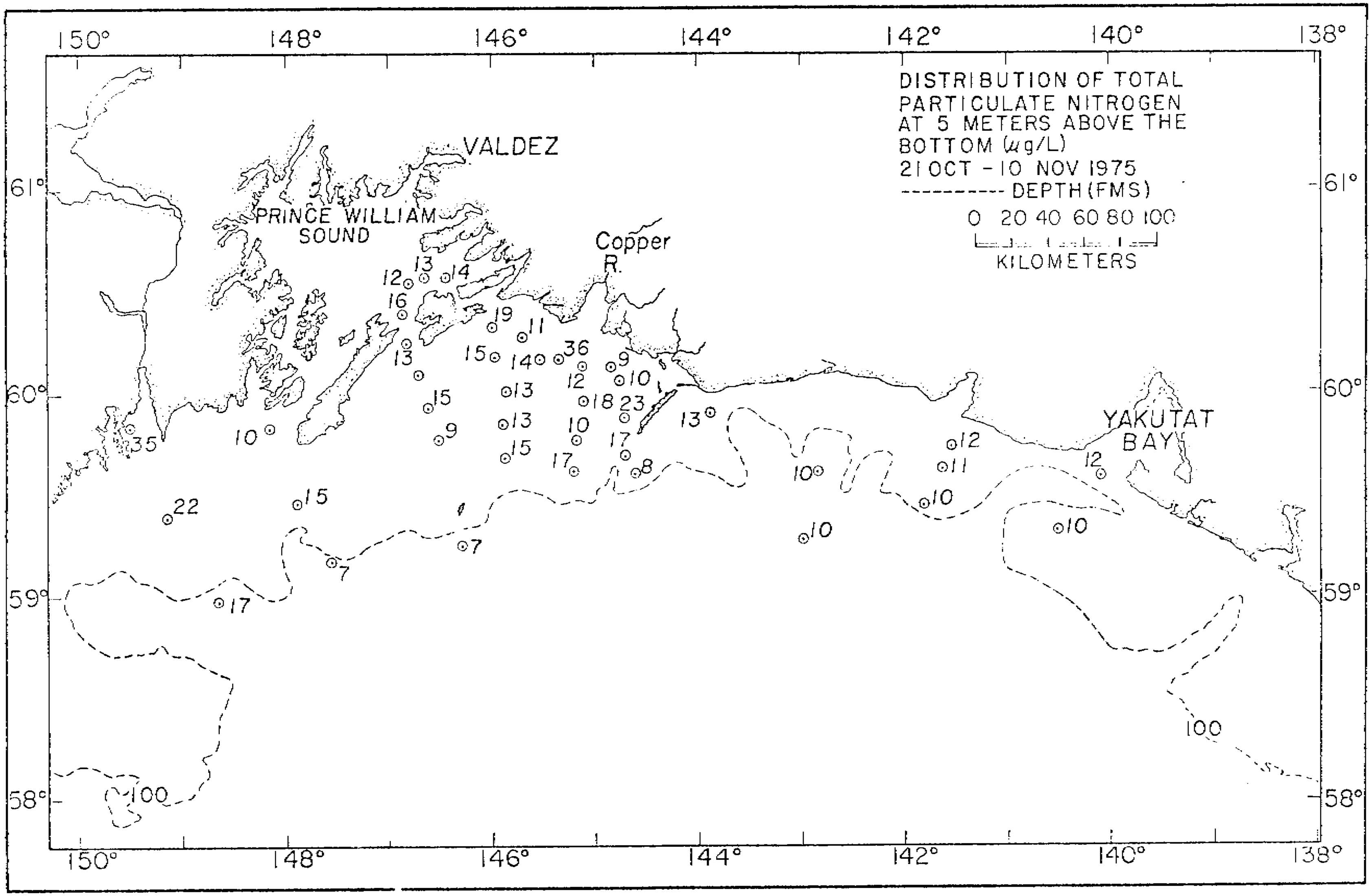


Figure 7. Distribution of total particulate nitrogen at 5 meters above the bottom in the northeastern Gulf of Alaska (Cruise RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975).

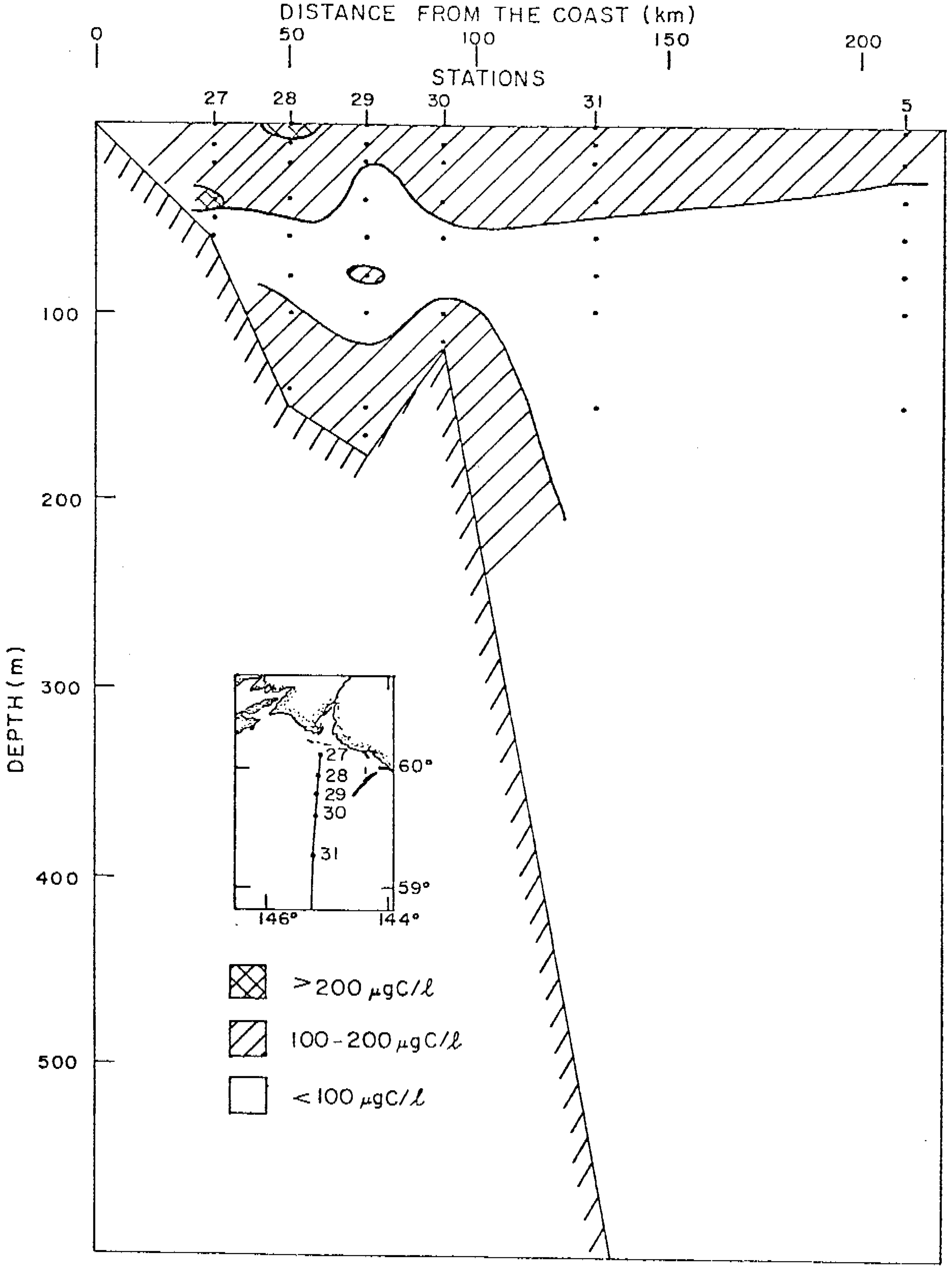


Figure 8. Vertical cross section of the distribution of particulate carbon for stations 27 thru 31 and station 5 in the northeastern Gulf of Alaska (Cruise RP-4-Di-75C-I, 21 Oct.-10 Nov., 1975).

Table 1. Replicate studies for selected stations in the northeastern Gulf of Alaska (cruise RP-4-Di-75C-I, 21 October-10 November 1975). The top five stations are replicates from a single cast, while the time series replicates were collected once every four hours during a 36-hour period.

Station	Depth	Number of Replicates	POC Mean (μg/L)	Std. Dev.	Rel. Std. Dev.
PMEL 5	sfc	4	122.5	9.828	0.080
PMEL 25	sfc	3	128.8	5.802	0.045
PMEL 29	sfc	3	128.0	13.629	0.106
PMEL 31	sfc	3	95.7	1.905	0.019
PMEL 40	sfc	5	237.8	9.388	0.039
TIME SERIES STATIONS					
PMEL 62	sfc	9	107.6	22.976	0.214
PMEL 62	∿184m	9	66.7	18.995	0.285

Table 2. Replicate studies for selected stations in the northeastern Gulf of Alaska (cruise RP-4-Di-75C-I, 21 October-10 November 1975). The top five stations are replicates from a single cast, while the time series replicates were collected once every four hours during a 36-hour period.

Station	Depth	Number of Replicates	PON Mean (μg/L)	Std. Dev.	Rel. Std. Dev.
PMEL 5	sfc	4	18.4	1.297	0.071
PMEL 25	sfc	4	16.7	2.342	0.140
PMEL 29	sfc	4	16.9	1.709	0.101
PMEL 31	sfc	4	16.3	1.801	0.110
PMEL 40	sfc	4	35.4	2.351	0.066
TIME SERIES STATIONS					
PMEL 62	sfc	9	16.4	3.148	0.192
PMEL 62	∿184m	9	9.3	3.908	0.421

2. Particulate Mg, Al, Si, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn and Pb.

As stated previously, we have completed the analyses of the surface samples from the Gulf of Alaska for major and trace elements. Table 3 summarizes the data we have obtained thus far. In order to simplify matters, the data has been arranged into two groups. Group I contains all the samples in which the sum of the major inorganic element concentrations (expressed as oxides) is greater than 60% of the total weight of material on the filter. Group II contains all the samples in which the sum is less than 60% of the total suspended load. Figure 9 shows the percentage of the total suspended matter that is due to the sum of the major inorganic elements for each surface station. The 60% isopleth divides the station into their respective groups.

As shown in Table 3, Groups I and II are quite different. The major element composition of the suspended matter from Group I appears to be dominated by suspended material from the coastal rivers and streams to the north. Several authors have suggested that since K, Mg, Al and Ti are almost exclusively associated with aluminosilicate minerals, the presence of these elements in suspended matter is indicative of terrestrial input (Spencer and Sachs, 1970; Price and Calvert, 1973; and Feely, 1975). The samples from Group I indicate that aluminosilicate minerals are the most dominant solid phase in the particulate matter. The data show that for the Group I samples, as much as 90% of the particulate matter is aluminosilicate material of terrestrial origin. In contrast, the particulate matter samples from Group II only contain about 20% aluminosilicate material.

Price and Calvert (1973) used the elemental ratios of the elements to aluminum to help identify the particular sources of the suspended matter. Table 4 shows the average Mg/Al, Si/Al, K/Al, Ca/Al, Ti/Al and Fe/Al ratios in the particulate matter from the two groups. The Si/Al, Fe/Al, Ti/Al and K/Al ratios for the Group I samples are similar to average values for shales (Krausekopf, 1967) and probably represent the elemental composition of the material discharged from the rivers. However, in Group II the Si/Al and Ca/Al ratios are considerably elevated over what would be expected for average sedimentary rocks. This is probably due to the presence of diatom frustules, fine grain quartz and coccolith tests in the suspended material.

The surface distributions of particulate Cr, Mn, Fe, Cu, Ni and Zn are presented in Figures 10 through 15 and the data are summarized in Table 3. As shown in Figures 10, 11 and 12, the distributions of particulate Cr, Mn and Fe show significant decreases in concentration in a seaward direction. The data from Table 3 corroborate these findings. The concentrations of these elements are significantly lower in the Group II samples (offshore stations) relative to the samples from Group I (nearshore stations). Apparently, the concentrations of Cr, Mn and Fe are highest in the material that is discharged from the rivers. Particles of marine origin (diatoms, coccoliths, etc.) tend to dilute the samples relative to these constituents. On the other hand, the samples from Group II show a small but significant increase in the concentrations of Cu, Ni and Zn. These elements have been shown to be biologically active and a significant uptake during primary production may be occurring (Knauer and Martin, 1973).

Only sixteen surface samples had sufficient loadings on the filters for lead to be analyzed. The sixteen samples are from Group I and the data are summarized in Table 3. Lead concentrations range between 22-60ppm with a mean of 39.6ppm. These values are slightly lower than comparable particulate matter samples from the coastal waters of the Gulf of Mexico (Trefry and Presley, 1976). However, this is not surprising since Chow and Patterson (1966) have demonstrated that particulate lead contamination of coastal waters is highest near heavily populated areas where industrial activity is high.

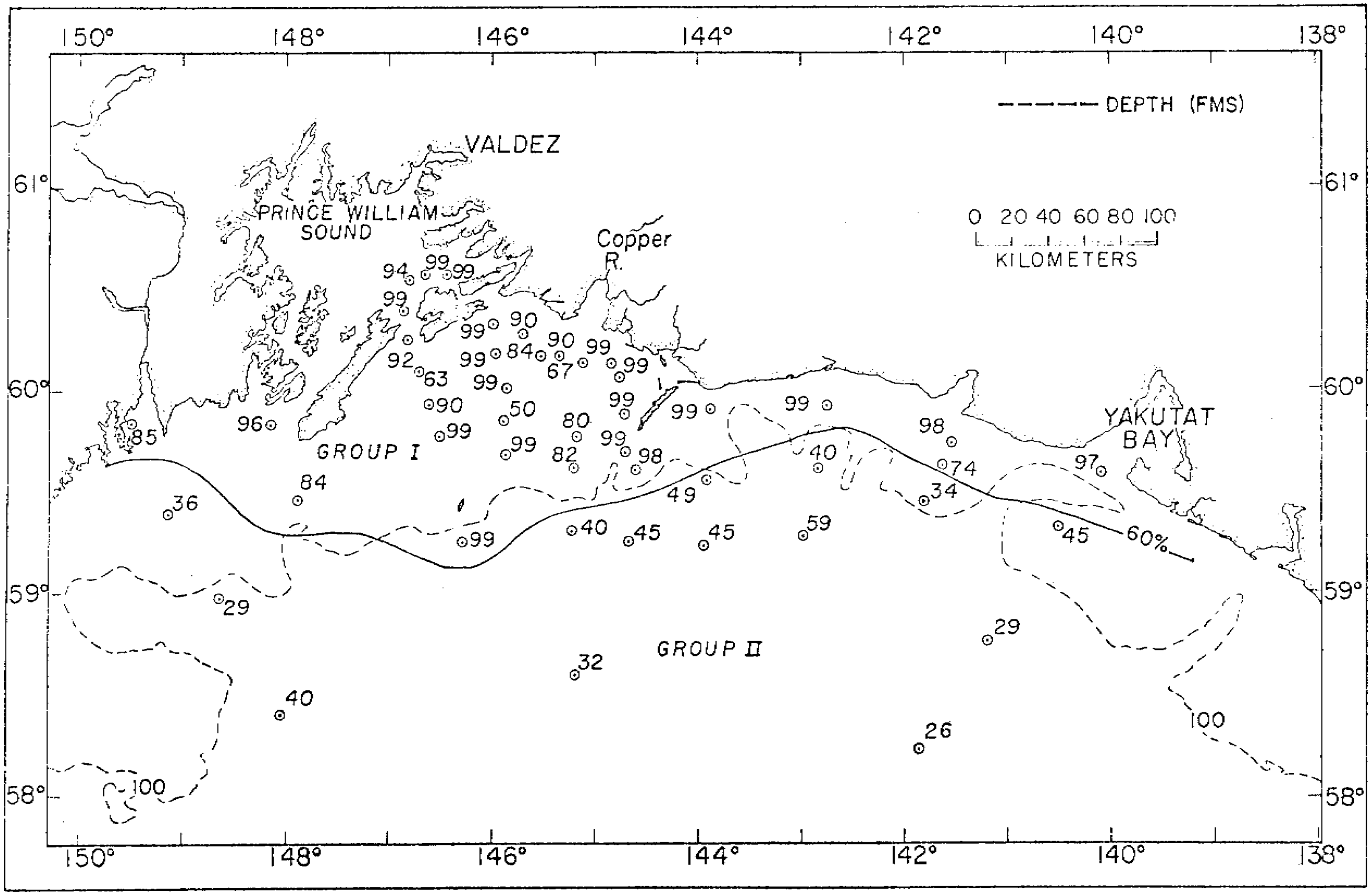


Figure 9. Map of the surface distribution of the percentage of total suspended matter that is due to the sum of the major inorganic elements expressed as oxides (Cruise RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975).

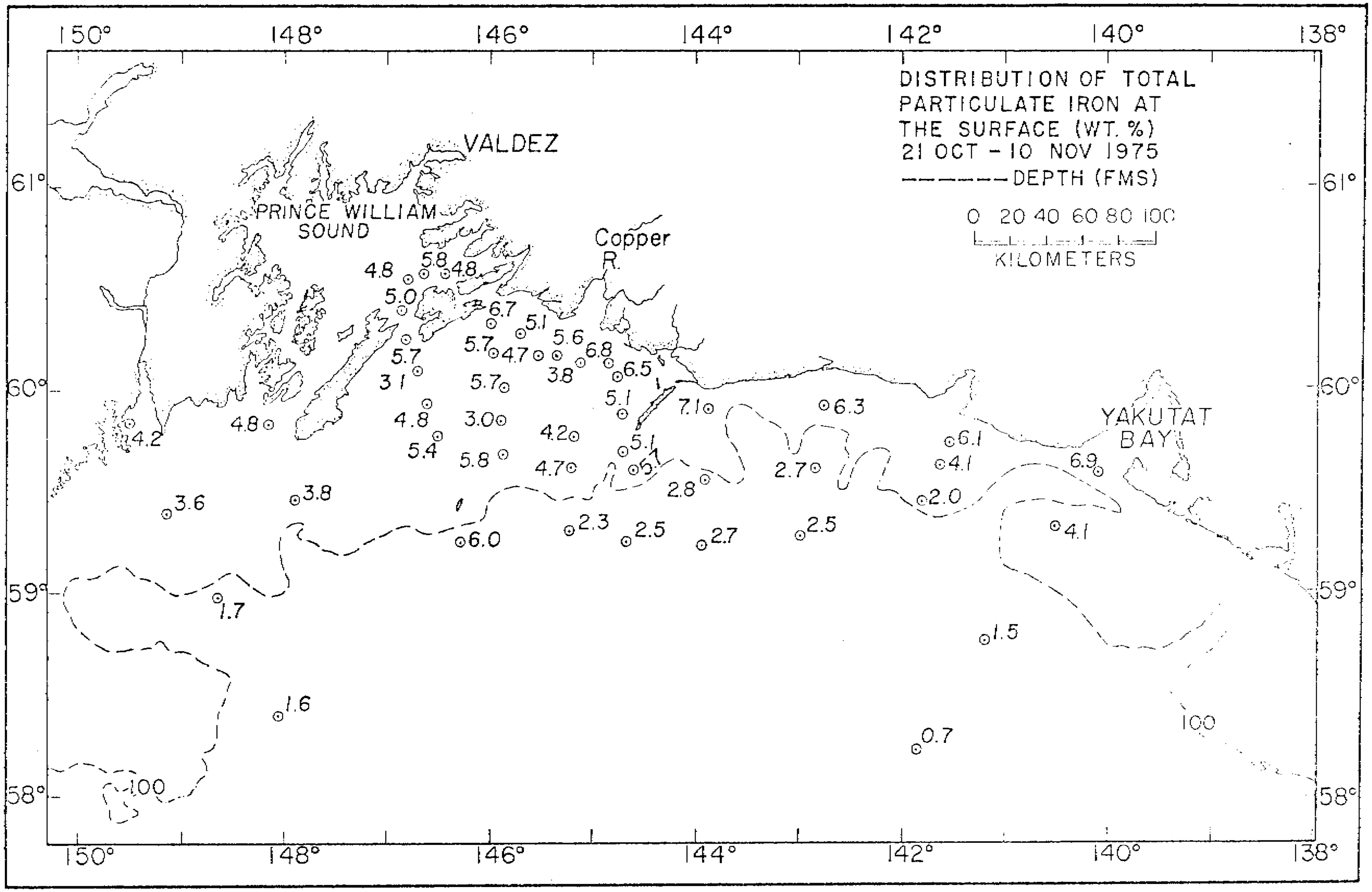


Figure 10. Distribution of total particulate iron (wt. %) in the suspended matter at the surface of the northeastern Gulf of Alaska (Cruise RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975).

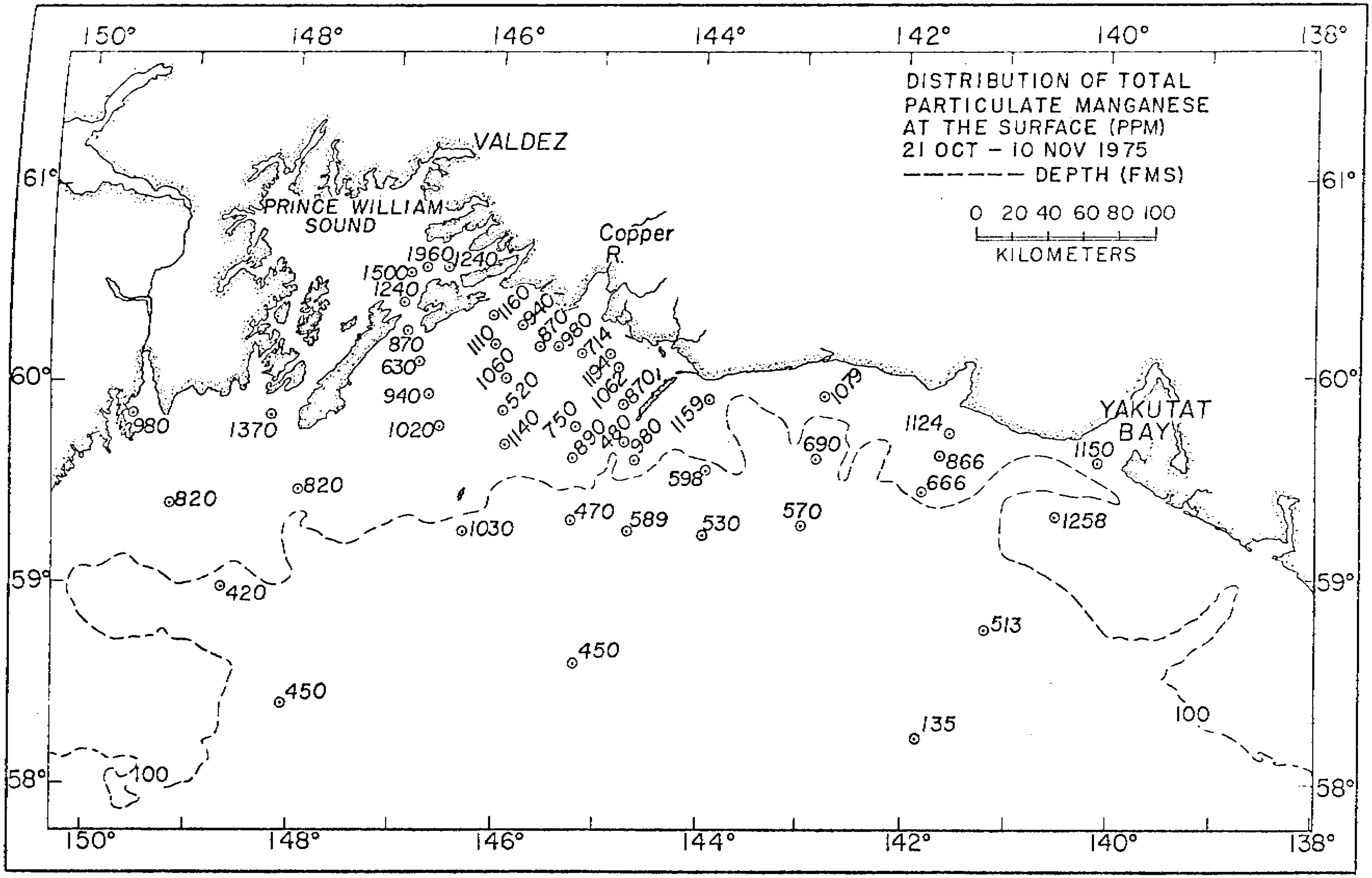


Figure 11. Distribution of total particulate manganese (ppm) in the suspended matter at the surface of the northeastern Gulf of Alaska (Cruise RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975).

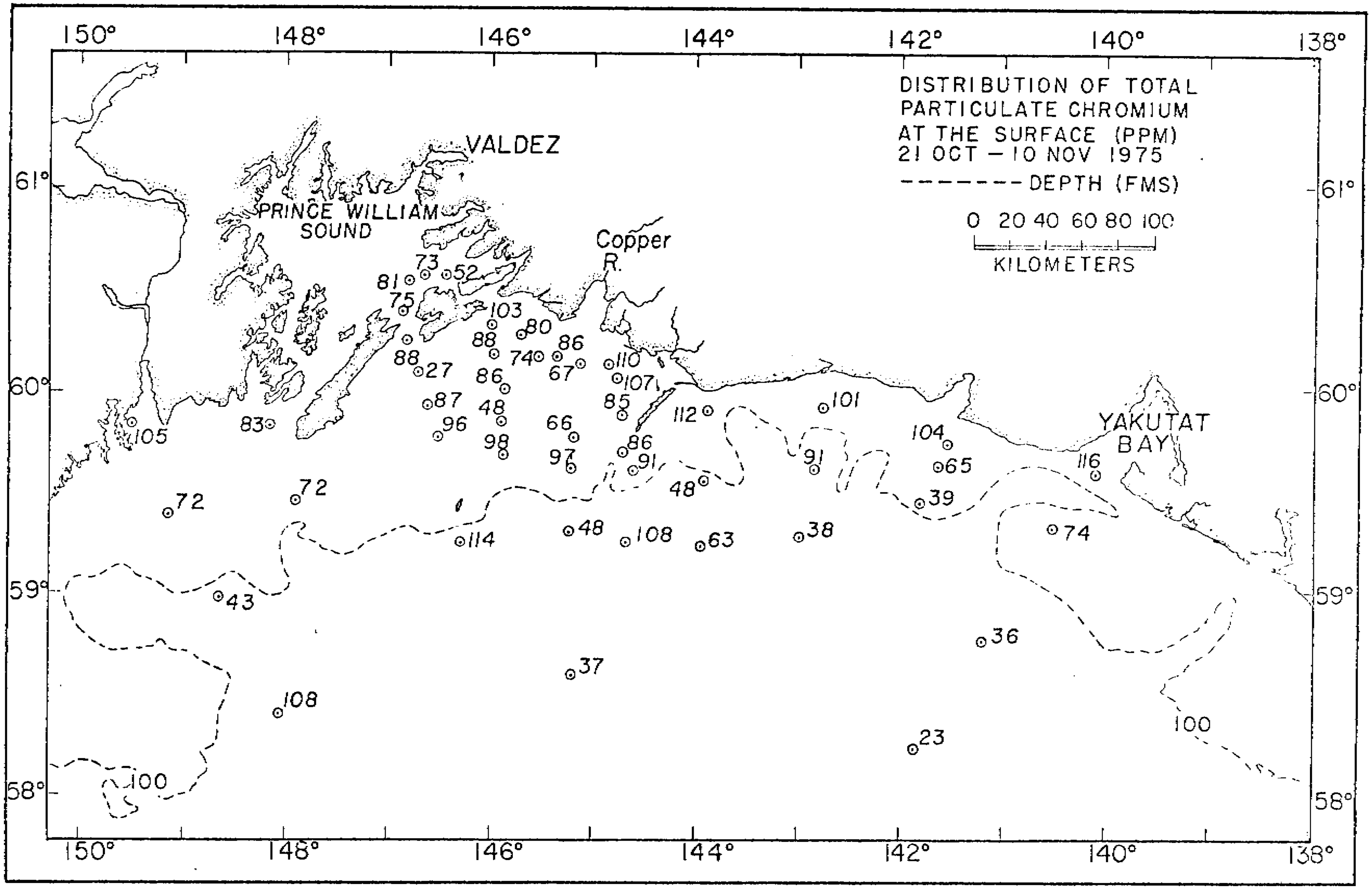


Figure 12. Distribution of total particulate chromium (ppm) in the suspended matter at the surface in the northeastern Gulf of Alaska (RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975).

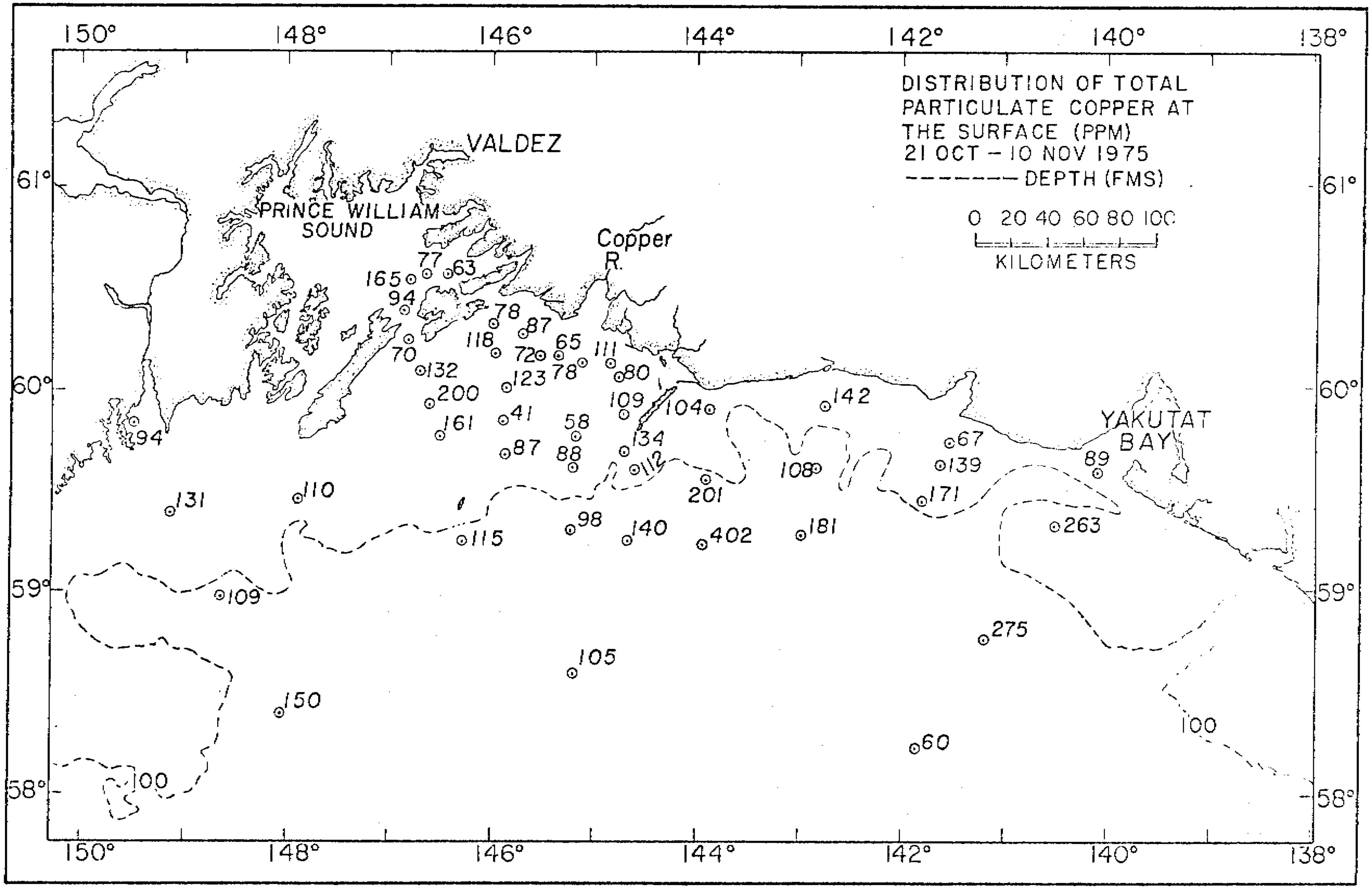


Figure 13 - Distribution of total particulate copper (ppm) in the suspended matter at the surface in the northeastern Gulf of Alaska (Cruise RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975)

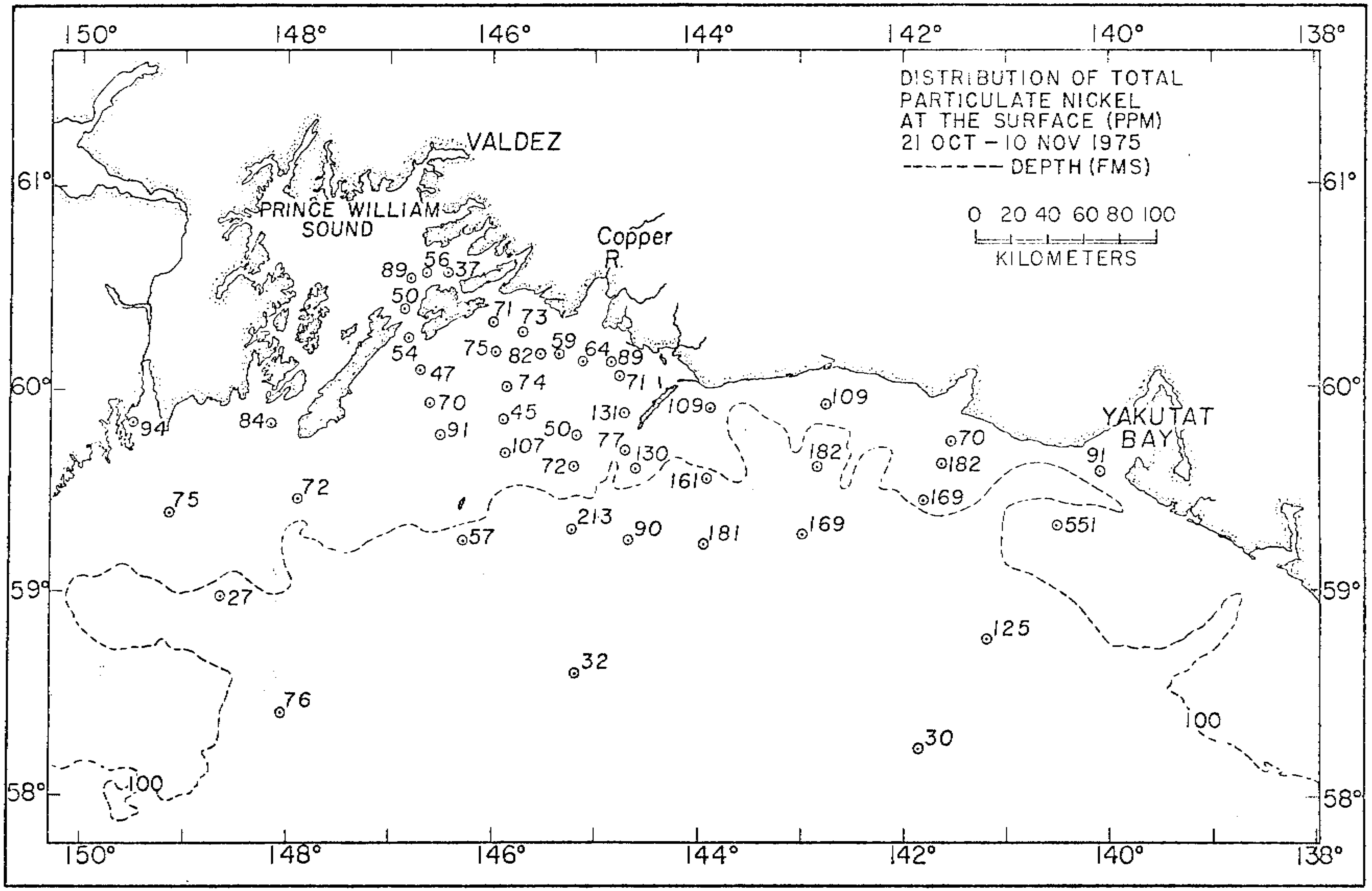


Figure 14. Distribution of total particulate nickel (ppm) in the suspended matter at the surface of the northeastern Gulf of Alaska (Cruise RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975).

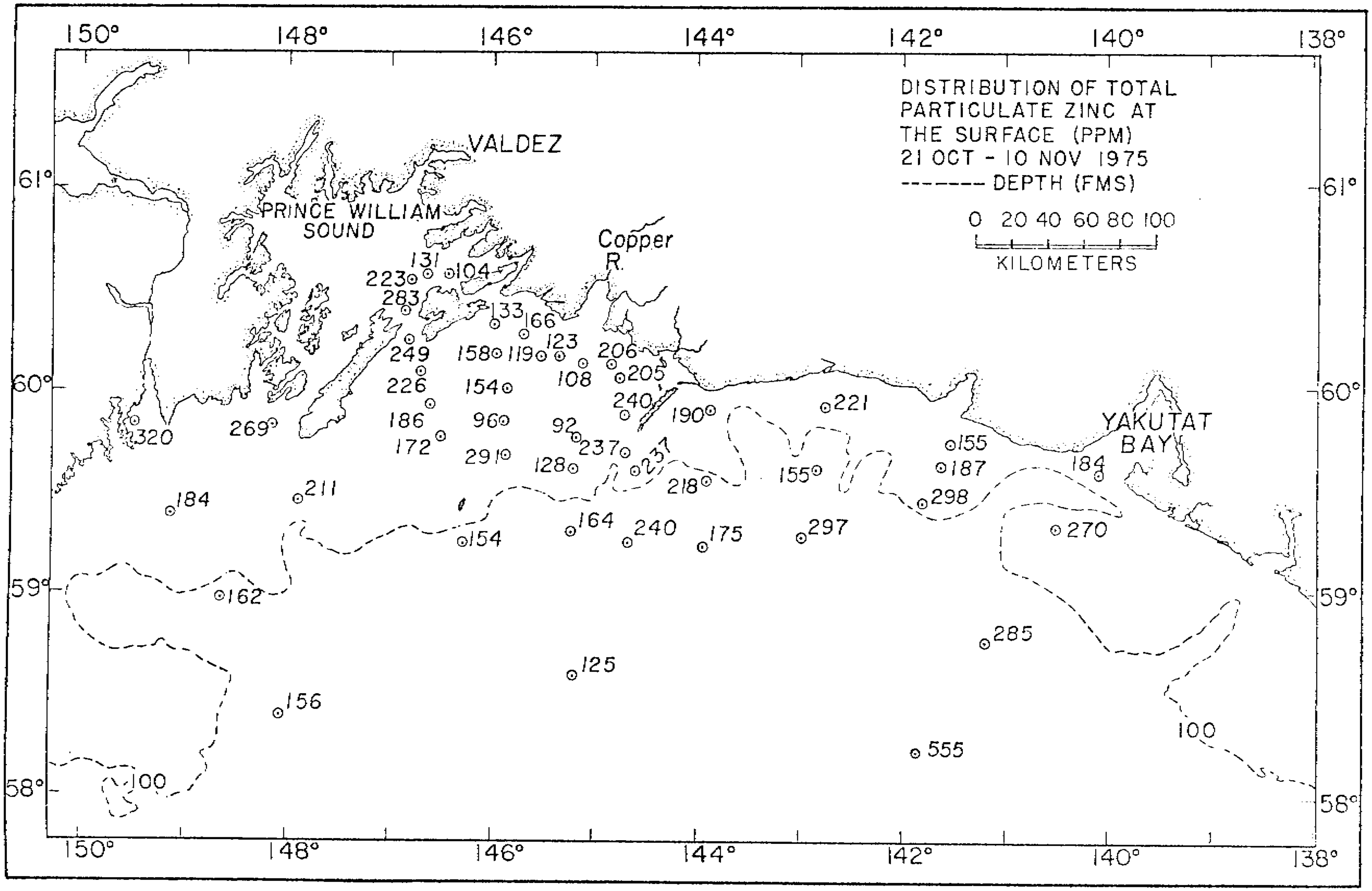


Figure 15. Distribution of total particulate zinc (ppm) in the suspended matter at the surface of the northeastern Gulf of Alaska (RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975).

IV Preliminary Interpretation of the Results

In order to develop an understanding of the processes controlling the variability of trace elements in marine particulate matter and sediments many authors have examined scatter plots of element ratios. Usually one of the elements is a structural component of one or more solid phases in the particulate matter. In this way, the concentration variability of a particular trace element can be directly related to the variability of a particular solid phase.

Figures 16 and 17 show chromium and manganese concentrations plotted as a function of the iron concentration. The strong correlation of chromium and manganese with iron suggests that these elements are associated with the structural components of the terrestrial rock debris that is discharged from the coastal rivers and/or the iron oxide/hydroxide coatings on the particles.

If it is assumed that a strong linear relationship between a particular trace element and iron is a direct function of the trace element to iron ratio in the weathered rock debris, then, it follows that a nonlinear relationship is indicative of a distinctly different source for the element in question. Figure 18 shows a scatter plot between copper and iron for all the surface samples. The plot shows little, if any, correlation between copper and iron. However, when copper is plotted against particulate carbon a fairly good correlation results (Figure 19). This suggests that the distribution of copper in the surface samples is primarily controlled by the amount of particulate organic matter that is available.

The distributions and scatter plots for nickel and zinc are similar to copper although not quite as distinct. It is possible that for nickel and zinc the two sources (terrestrial and marine) may be of nearly equal importance in controlling their concentrations in the particulate matter.

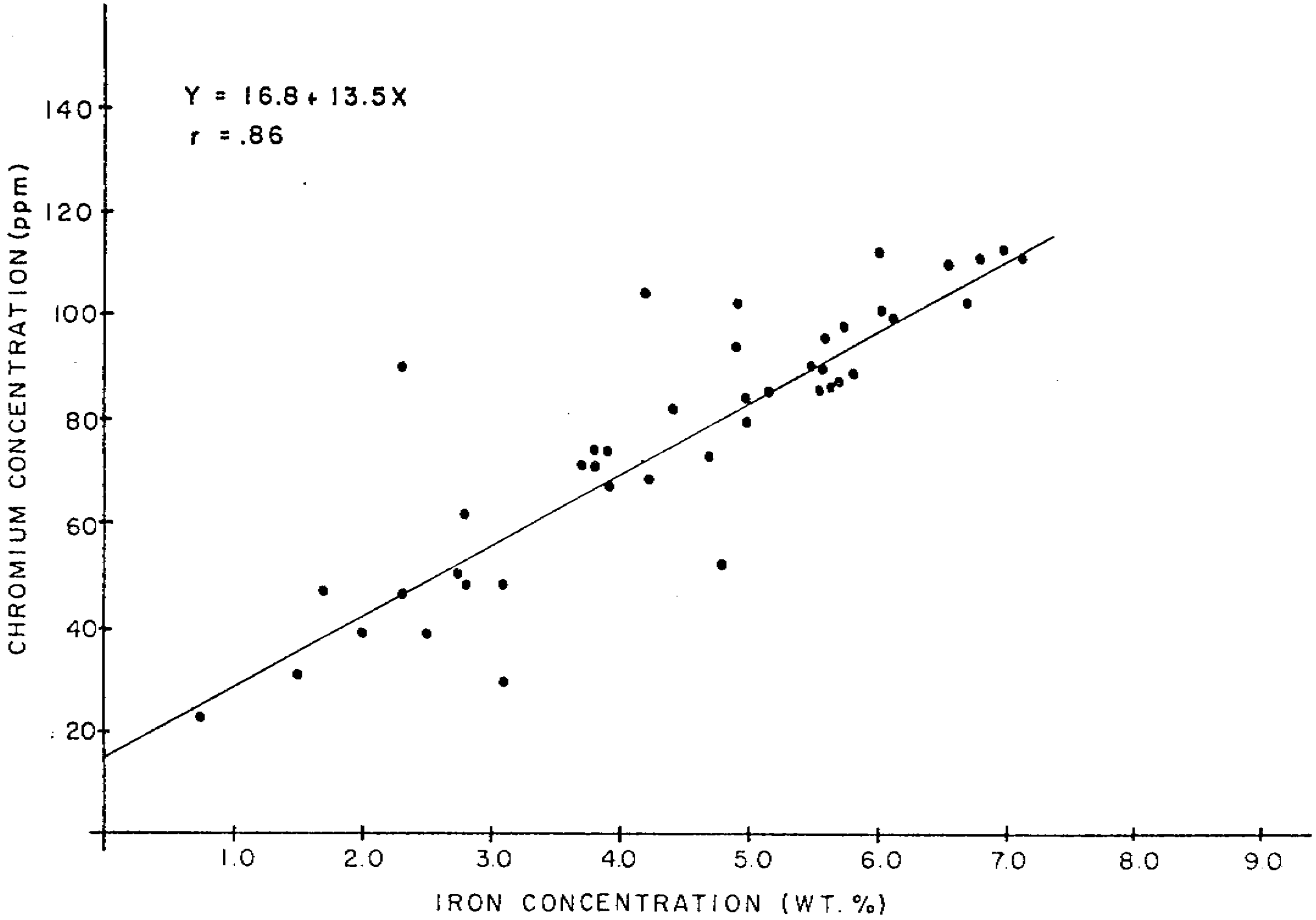


Figure 16. Scatter plot of chromium versus iron concentrations for the surface samples from the northeastern Gulf of Alaska (RP-4-Di-75C-I, 21 Oct - 10 Nov., 1975).

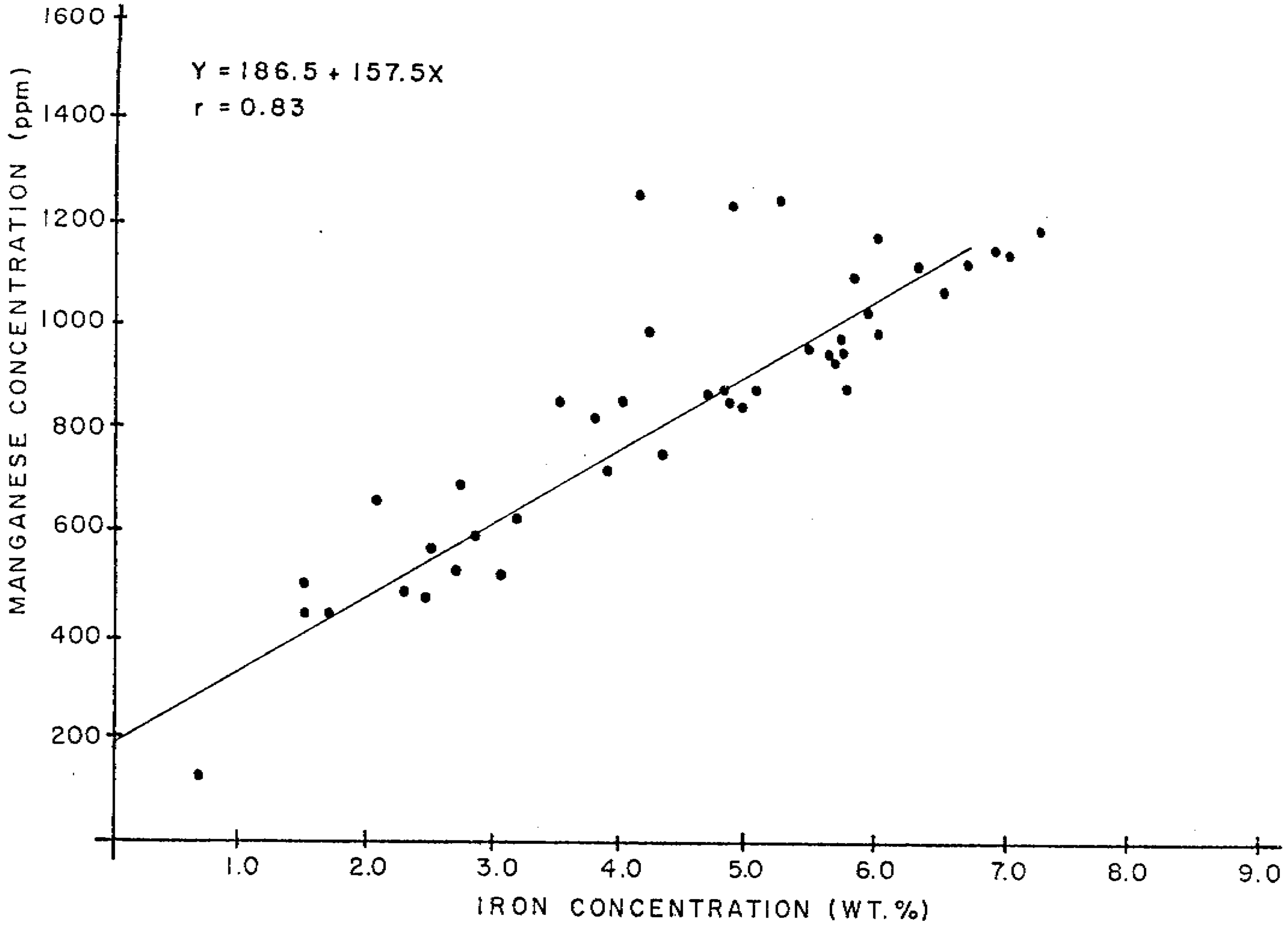


Figure 17. Scatter plot of manganese versus iron concentrations for the surface samples from the northeastern Gulf of Alaska (RP-4-Di-75C-I, 21 Oct - 10 Nov., 1975).

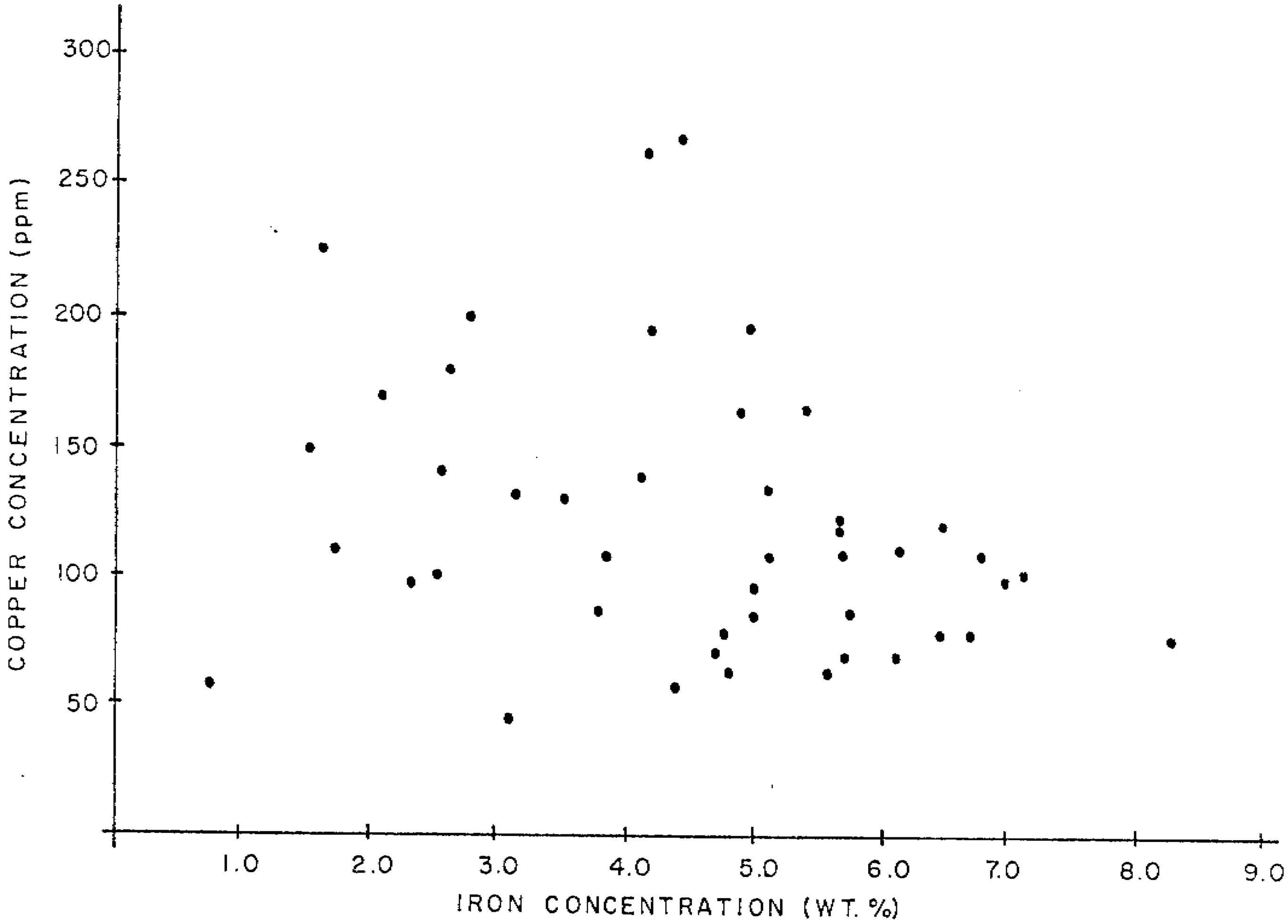


Figure 18. Scatter plot of copper versus iron concentrations for the surface samples from the northeastern Gulf of Alaska (RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975)

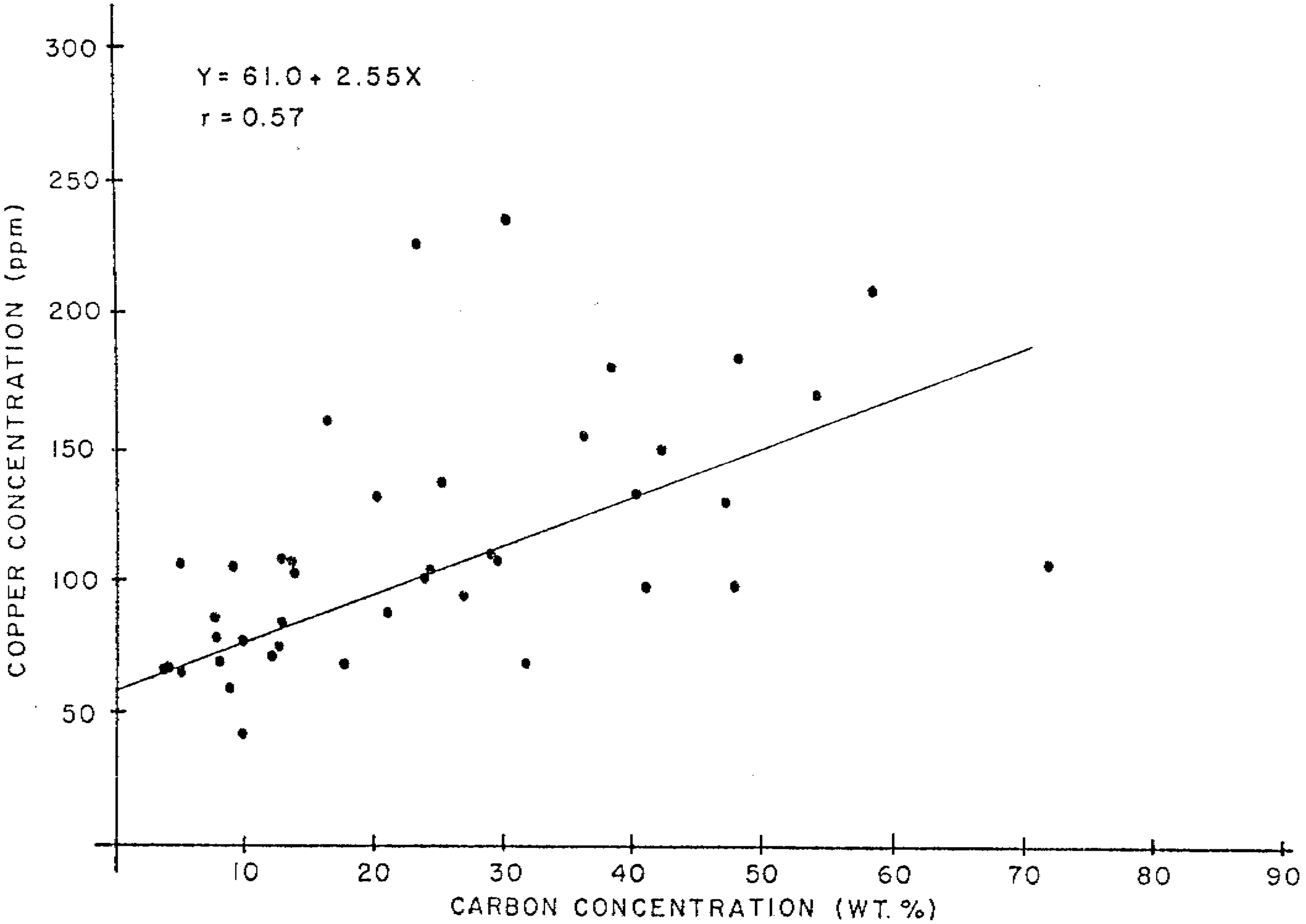


Figure 19. Scatter plot of copper versus iron concentrations for the surface samples from the northeastern Gulf of Alaska (RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975).

Table 3. Summary of the elemental composition of the surface particulate matter samples from the northeastern Gulf of Alaska (Cruise RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975)

Group	No. of Samples	Mg Wt.%	Al Wt.%	Si Wt.%	K Wt.%	Ca Wt.%	Ti Wt.%	Cr PPM	Mn PPM	Fe Wt.%	Ni PPM	Cu PPM	Zn PPM	Pb* PPM
I	35	4.81 ±1.22	9.10 ±2.21	26.51 ±5.45	1.26 ±0.45	2.69 ±0.90	0.55 ±0.13	87.1 ±18.6	1007 ±281	3.76 ±1.30	82.9 ±38.0	103.9 ±37.0	187.2 ±38.0	39.6 ±11.9
II	13	1.75 ±1.17	1.92 ±1.66	12.29 ±3.67	0.43 ±0.17	2.49 ±0.56	0.27 ±0.09	61.8 ±28.0	579 ±262	1.66 ±0.90	147 ±137	165.0 ±90.0	209.0 ±63.0	

* only 16 samples had sufficient loadings for lead to be analyzed.

Table 4. Elemental ratios to aluminum for the surface particulate matter samples from the northeastern Gulf of Alaska (Cruise RP-4-Di-75C-I, 21 Oct. - 10 Nov., 1975).

Group	Samples	Mg/Al	Si/Al	K/Al	Ca/Al	Ti/Al	Mn/Al	Fe/Al
I	35	0.528	2.910	0.138	0.295	0.060	0.001	0.413
II	13	0.911	6.400	0.223	1.920	0.142	0.003	0.864

V. Problems Encountered

We have no significant problems to report at this time.

VI. Estimate of Funds Expended.

	Allocated	Expended	Balance
Salaries and Overhead	125.6K	84.8K	40.8K
Travel and Shipping	20.0K	10.0K	10.0K
Current Meters	5.0K	2.5K	2.5K
Nephelometers	10.0K	28.3K	-18.3K
XRay Fluorescence System	70.0K	80.0K	-10.0K
Publications	6.0K	0.7K	5.3K
Computer Time	9.8K	4.6K	5.2K
Miscellaneous	14.4K	14.4K	0.0K
Banked from FY 75	10.0K	0.0K	10.0K
	270.8K	225.3K	45.5K

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QUARTERLY REPORT

Contract No.______________
Research Unit No. 204
Reporting Period: 1 April-
1 July.
Number of Pages: 20

OFFSHORE PERMAFROST STUDIES

Beaufort Sea, Alaska

D. M. Hopkins

U. S. Geological Survey

1 July 1976

I. Task Objectives.

The objectives are to compile information on offshore permafrost, its distribution, properties, and dynamics of formation. Four holes were drilled in the Prudhoe Bay, Alaska vicinity. These boreholes were sampled and geothermal observations made. Examination of core samples and cuttings revealed information on the stratigraphy, sedimentology, lithology, and geochemistry of the shelf sediments.

II. Field or Laboratory Activities.

A. Field Work.

The drilling and sampling program field work began in late March and ended in early May. Laboratory analyses began in May and are continuing.

B. Scientific Party.

The personnel involved ten individuals from four agencies and companies. The following were involved:

Vaughn Marshall	USGS
Dave Hopkins	USGS
Dave Carter	USGS
Al Dulaney	CRREL
Herb Ueda	CRREL
Paul Sellmann	CRREL
Ed Chamberlain	CRREL
Scott Blouin	CRREL
Ed Hinman	VE
Robert Lewellen	AINA-ONR

C. Methods.

Standard methods are used and will be documented in following reports. Standard rotary drilling techniques were used for drilling and soil sampling.

D. Sample Locations.

Please refer to Figure 1 of Paul Sellmann's report for Research Unit 105.

E. Data Collected and Analyzed.

Cores and cuttings were collected out of each borehole. Examinations are being made on lithology, fossils, paleomagnetism, earth temperatures, etc.

III. Results.

Selected results are attached to this report.

IV. Preliminary Interpretation of Results.

Interpretation will take considerable time, and will be deferred until the next report.

V. Problems Encountered/Recommended Changes.

Nothing to report in this category at this time.

VI. Estimate of Funds Expended.

Financial information is not available, and will be deferred to later reports.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Branch of Alaskan Geology
345 Middlefield Road
Menlo Park, California 94025

June 17, 1976

Memorandum

To: Participants in Prudhoe Bay Offshore Drilling

From: D. M. Hopkins

Subject: Progress report on stratigraphic study of Prudhoe Bay offshore boreholes

Enclosed are simplified graphic logs of our four holes drilled in Prudhoe Bay.

The marine silt-clay section was sampled in detail for paleomagnetic analysis. If any part of this section were more than 700,000 years old, it would be magnetically reversed (north pole up). Jack Hillhouse has completed analyses and the section is entirely normal (north pole down). This is no surprise, since after completion of the series of boreholes, it was evident that the upper marine section is entirely late Pleistocene and Holocene and probably less than 16,000 years old.

Field identification of the mollusk *Macoma balthica* from core 06 in hole PB-3 has been confirmed. The mollusk came from a depth of 40.9' in a borehole midway between the end of the ARCO dock and Reindeer Island, and was collected at the contact between beach gravel, below, and marine silt, above. *Macoma balthica* is more or less strictly confined to brackish water and is found only in bays, estuaries, and at river-mouths or persistent openings from bays to the open sea. As far as I know, it has never been collected alive north of Cape Lisburne, though it is a common fossil in the Gubik Formation.

We are just getting started on core radiography, washing specimens for microfossils, and accumulating material for radiocarbon dates.

My color pictures of the cores are mostly badly exposed and don't seem to show much, but I not yet looked at them carefully. I hope that the black and white photos are better.

OPTIONAL FORM NO. 10
JULY 1973 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : David M. Hopkins

DATE: June 23, 1976

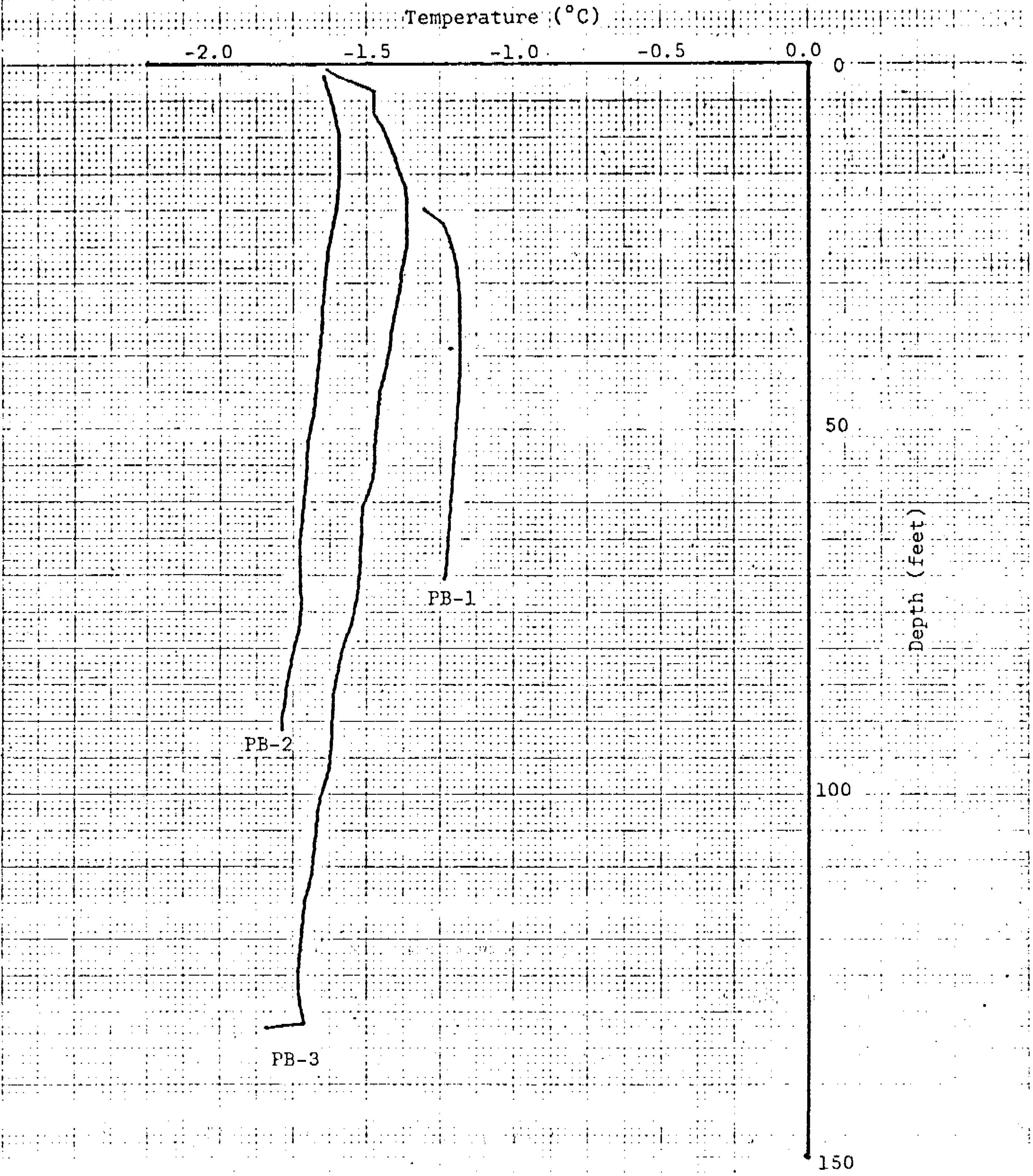
FROM : Jack Hillhouse JH

SUBJECT: Paleomagnetism of core PB-2, Prudhoe Bay Offshore Drilling Project

Twenty-six specimens from the upper third of core PB-2 were submitted for paleomagnetic analysis. After the natural remanent magnetizations (NRM) of these samples were measured, they were partially demagnetized in a 150 oersted alternating field and remeasured. This treatment removed any spurious magnetizations which the core might have acquired during drilling and storage. The magnetic signal carried by the sediment is quite strong; the NRM's averaged $1x10^{-5}$emu/cm^3 and typically the intensity decreased by a factor of 10 during the A.F. treatment. At the drill site the expected magnetic inclination is 80.0° assuming that the field is due to a geocentric dipole aligned with the geographic poles. As shown on the attached sheet, the cleaned inclinations determined from core PB2 all have normal polarity and are clustered around 80°. One sample, PB2-M8A, has a very low inclination (42.8°); however, M8B from the same horizon has a normal inclination, indicating that part of the core was disturbed during drilling. These sediments were deposited during a normal polarity epoch, most likely during the Brunhes epoch (0-0.7 m.y. ago). Variations in the inclination record are within the limits of normal secular variation exhibited by the geomagnetic field.

Attachment

Sample No.	Inclination before A.F. Cleaning	Inclination after A.F. Cleaning	Intensity(emu/cm^3) after A.F. Cleaning
PB2-M1	78.0	82.0	9.04 E-6
PB2-M2	61.5	65.8	2.90 E-6
PB2-M3A	77.9	83.4	3.37 E-6
PB2-M3B	79.8	75.6	3.72 E-6
PB2-M4A	64.6	70.1	3.74 E-6
PB2-M4B	74.9	78.3	6.25 E-6
PB2-M5A	66.6	70.9	8.18 E-6
PB2-M5B	76.3	76.8	6.36 E-6
PB2-M6A	73.8	72.3	5.06 E-6
PB2-M6B	79.6	77.1	6.21 E-6
PB2-M7A	68.6	65.6	3.29 E-6
PB2-M7B	76.8	87.2	2.26 E-6
PB2-M8A	64.3	42.8	7.56 E-6
PB2-M8B	77.1	84.1	5.18 E-6
PB2-M9	57.7	57.8	1.14 E-5
PB2-M10	87.8	87.8	8.01 E-6
PB2-M11	77.5	75.3	1.08 E-6
PB2-M12	81.0	79.1	1.50 E-6
PB2-M13	82.6	83.0	1.81 E-6
PB2-M14	79.5	80.1	1.42 E-6
PB-M15	73.8	72.7	2.52 E-6
PB2-M16	73.6	73.9	2.96 E-6
PB2-M17A	83.0	82.7	3.08 E-5
PB2-17B	85.8	82.6	2.69 E-5
PB2-M18A	78.5	78.6	1.90 E-5
PB2-M18B	79.3	80.3	1.71 E-5



Temperature profiles of three holes drilled offshore at Prudhoe Bay in April 1976. Dates of logs shown are: PB-1 and PB-2, June 8, 1976; PB-3, May 6, 1976. Depths are from sediment surface.

B. V. Marshall (USGS), 6-23-76

PB-1
June 6, 1976

Feet	Temperatùre °C
28.8	-1.301
30.8	-1.236
32.8	-1.216
34.8	-1.202
36.8	-1.193
38.8	-1.186
40.8	-1.182
42.8	-1.180
44.8	-1.180
48.8	-1.182
53.8	-1.187
58.8	-1.196
63.8	-1.205
68.8	-1.216
73.8	-1.226
78.8	-1.239
79.5	-1.243

B. V. Marshall (USGS), 6-23-76

PB-2
June 8, 1976

Feet	Temperature °C
28.7	-1.671
30.7	-1.670
32.7	-1.667
37.7	-1.664
38.7	-1.659
40.7	-1.647
42.7	-1.630
44.7	-1.615
46.7	-1.606
48.7	-1.598
50.7	-1.596
52.7	-1.596
54.7	-1.599
56.7	-1.604
58.7	-1.609
60.7	-1.617
62.7	-1.626
64.7	-1.636
66.7	-1.643
68.7	-1.648
70.7	-1.652
72.7	-1.656
74.7	-1.659
76.7	-1.663
78.7	-1.668
80.7	-1.670
82.7	-1.675
84.7	-1.681
86.7	-1.689
88.7	-1.697
90.7	-1.705
92.7	-1.711
94.7	-1.714
96.7	-1.717
98.7	-1.722
100.7	-1.726
102.7	-1.731
104.7	-1.735
106.7	-1.738
108.7	-1.738
110.7	-1.736
112.7	-1.732
114.7	-1.735
116.7	-1.741
118.7	-1.758
120.7	-1.769
122.7	-1.779
124.7	-1.789
126.7	-1.794
128.7	-1.800
130.4	-1.804

B. V. Marshall (USGS), 6-23-76

PB-3
May 6, 1976

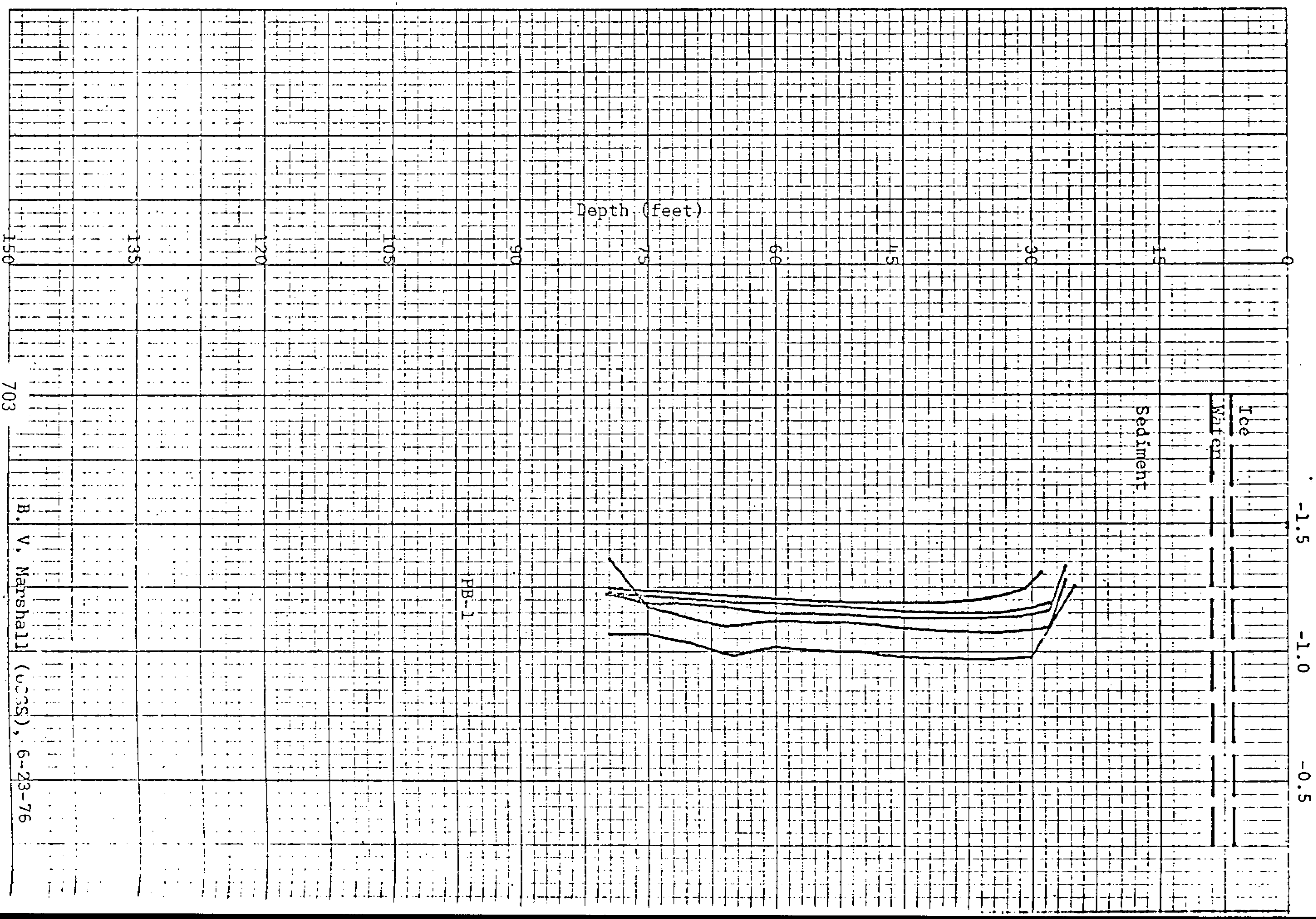
Feet	Temperature °C	Feet	Temperature °C
5	-1.695	42	-1.361
6	-1.698	44	-1.364
7	-1.700	46	-1.371
8	-1.700	48	-1.380
9	-1.701	50	-1.389
10	-1.693	52	-1.398
11	-1.697	54	-1.406
12	-1.697	56	-1.415
13	-1.697	58	-1.424
14	-1.697	60	-1.433
15	-1.695	62	-1.444
16	-1.691	64	-1.455
17	-1.687	66	-1.463
18	-1.680	68	-1.469
19	-1.669	70	-1.474
20	-1.638	72	-1.477
21	-1.598	74	-1.479
22	-1.534	76	-1.484
23	-1.474	78	-1.502
24	-1.471	80	-1.521
25	-1.472	82	-1.525
26	-1.470	84	-1.527
28	-1.443	86	-1.530
30	-1.420	88	-1.534
32	-1.404	90	-1.538
34	-1.385	92	-1.544
36	-1.366	94	-1.550
38	-1.360	96	-1.560
40	-1.360	98	-1.583

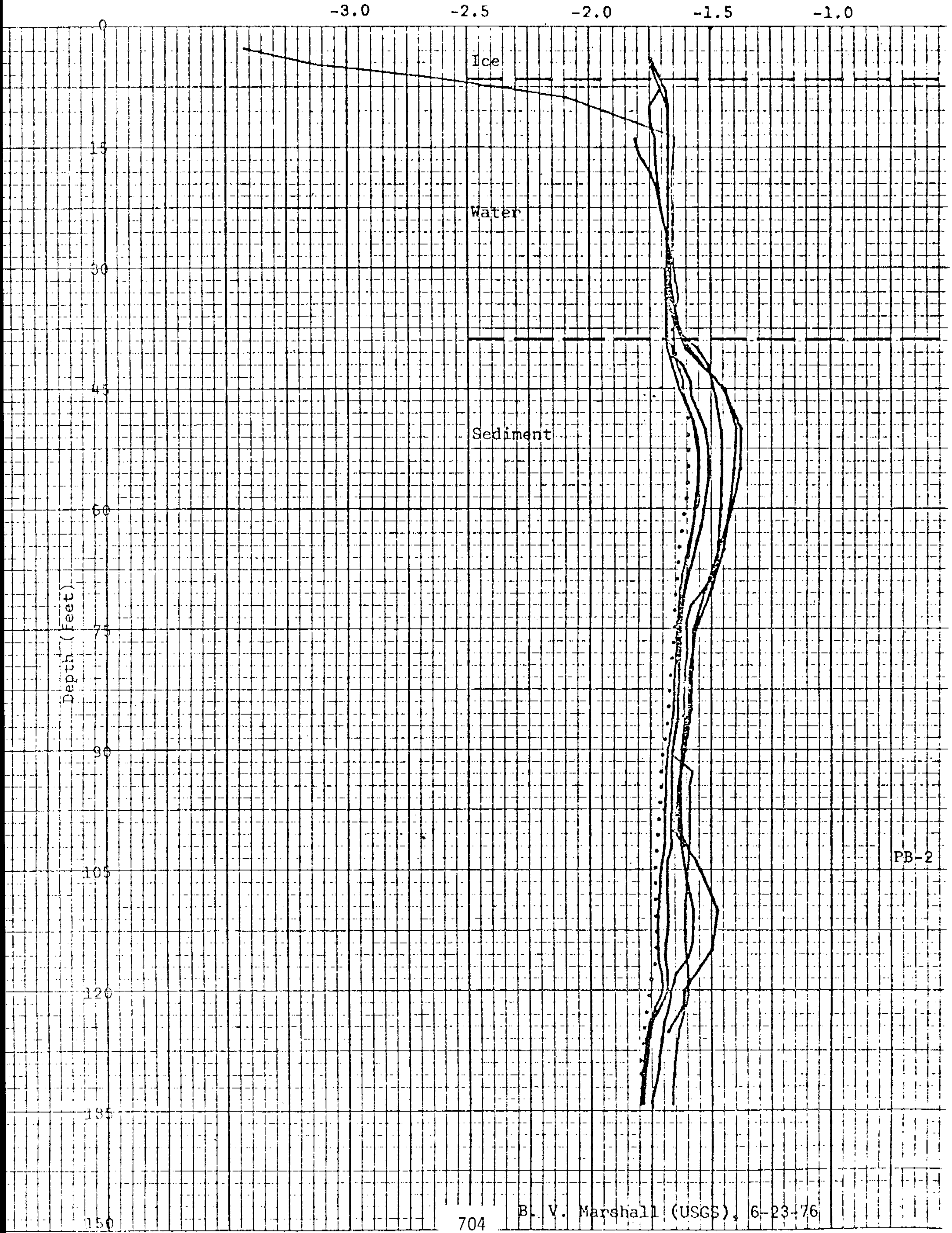
B. V. Marshall (USGS), 6-23-76

Feet	Temperature °C
100	-1.596
102	-1.608
104	-1.617
106	-1.625
108	-1.628
110	-1.631
112	-1.632
114	-1.635
116	-1.642
118	-1.657
120	-1.672
122	-1.680
124	-1.686
126	-1.690
128	-1.697
130	-1.704
132	-1.714
134	-1.726
136	-1.734
138	-1.739
140	-1.742
142	-1.746
144	-1.752
146	-1.753
148	-1.747
150	-1.739
151	-1.734
151.6	-1.862

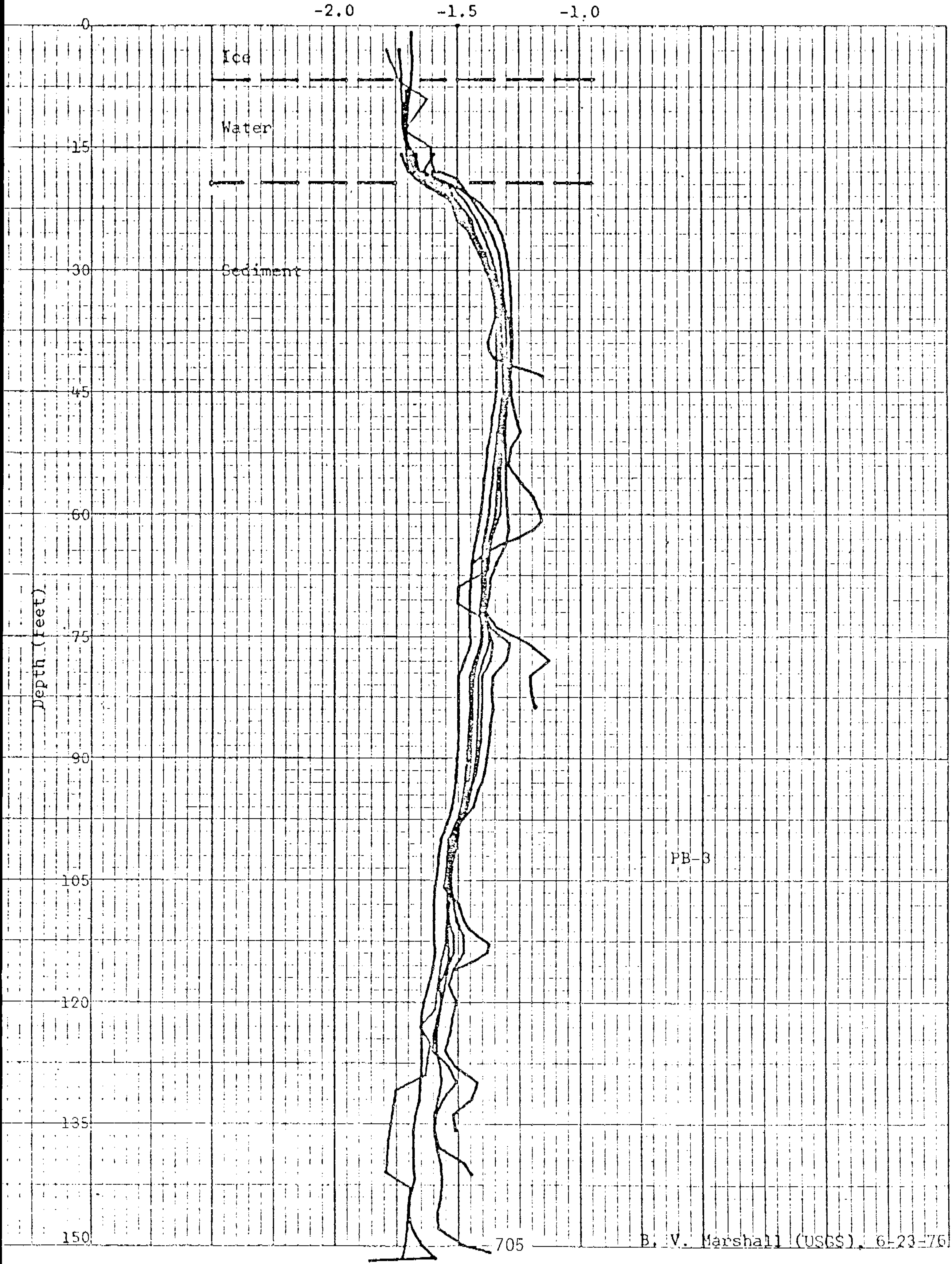
B. V. Marshall (USGS), 6-23-76

TEKTRONIX INFORMATION DISPLAY DIVISION 006-1698-00 10 x 15 in. LINEAR



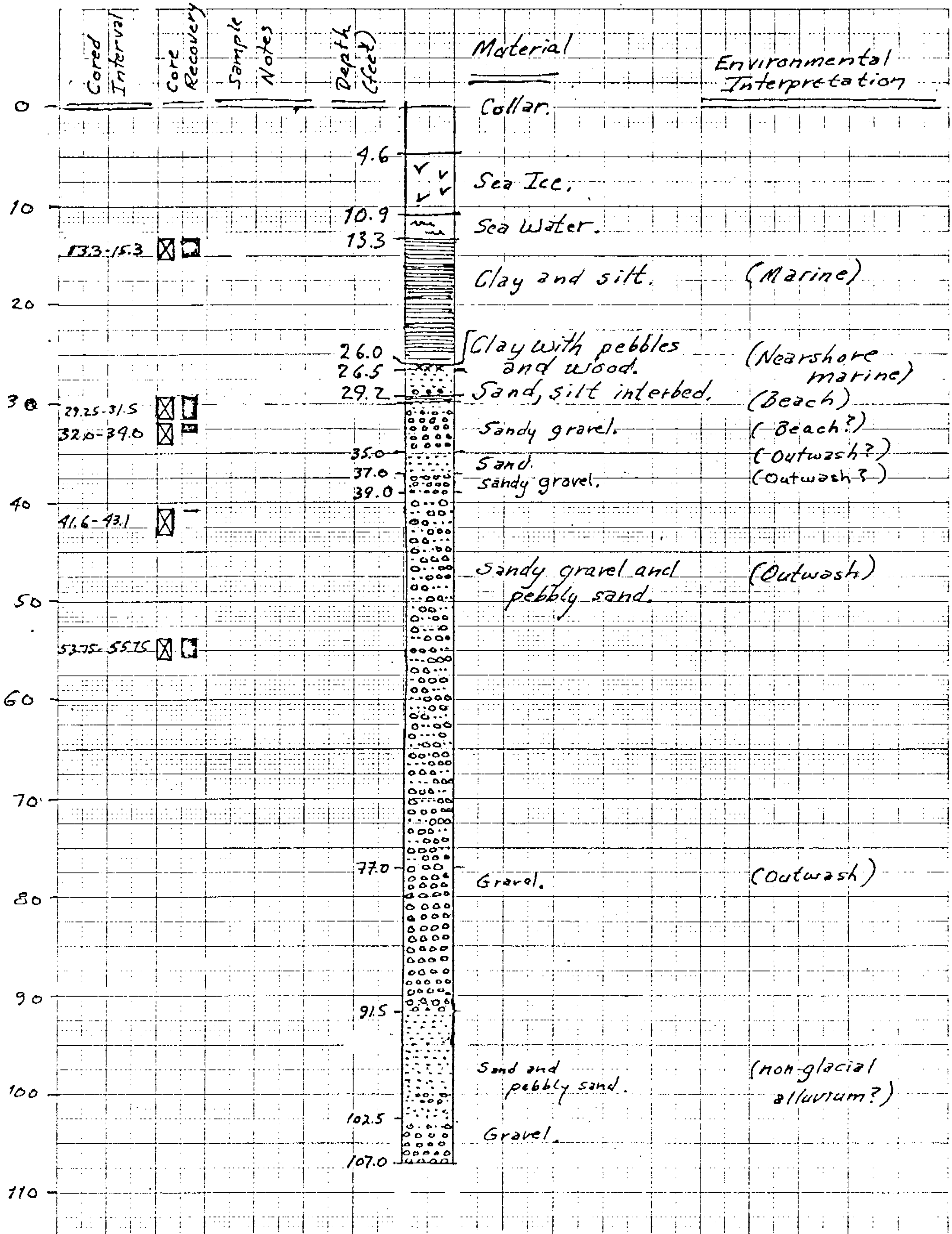


B. V. Marshall (USGS), 6-23-76



B. V. Marshall (USGS), 6-23-76

Long. 148° 19.5'W



BOREHOLE ΓD-7A

[illegible]
LONG. 148°19.3'W

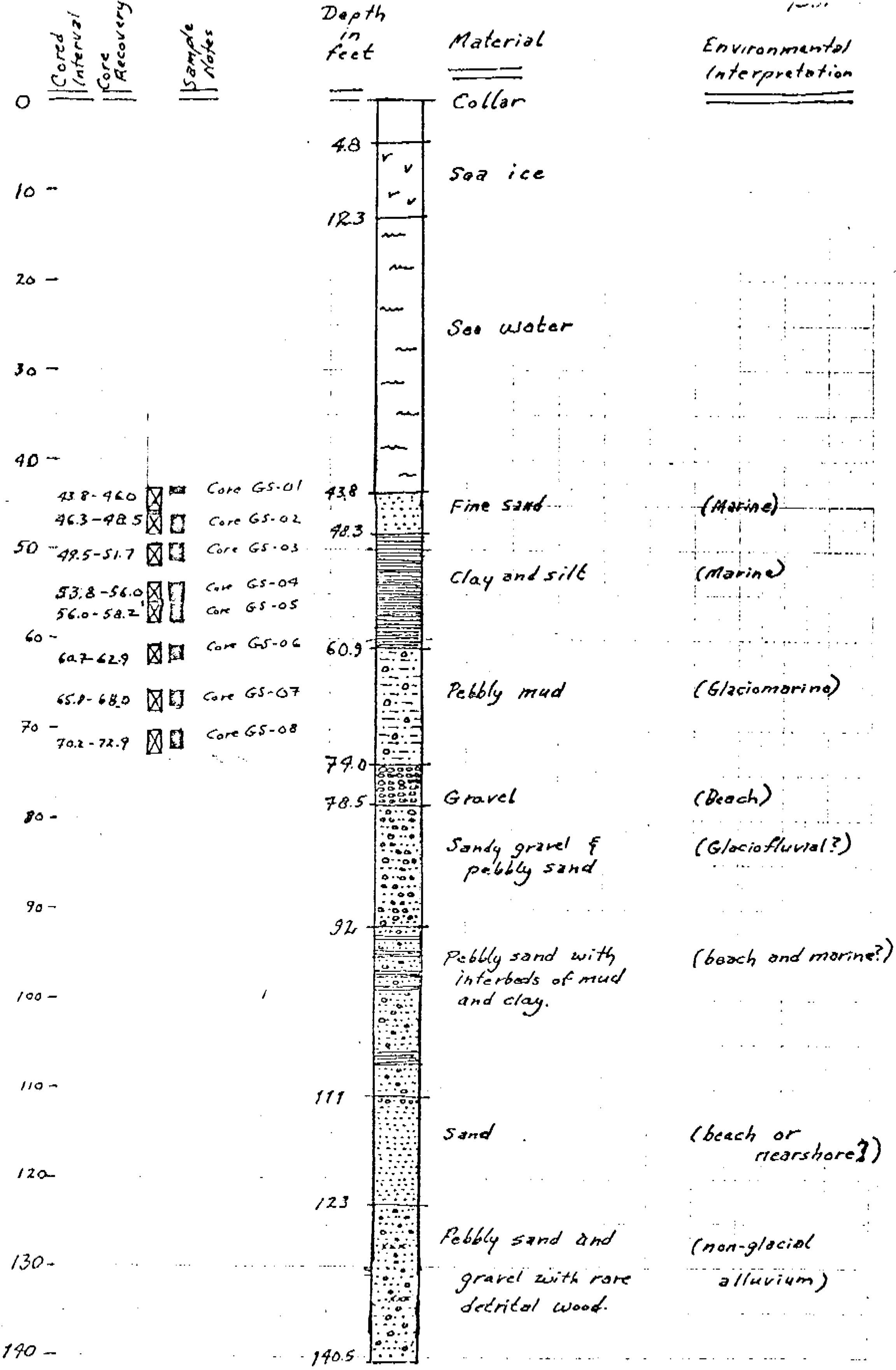
	Cored Interval	Core Recovery	Sample Notes	Depth (ft)	Material	Environmental Interpretation
0'					COLLAR	
				4.9	Ice	
10'				11.0	Sea water	
	13.2-14.6	☒ ■	01 02	13.2	Silt and clay	Marine
	17.0-19.2	☒ ■	03			
20'	20.0-22.2	☒ ■	04			
	?					
	25.6-27.8	☒ ■	05	26.6	Sand	Nearshore marine
				27.7		
30'						
40'						
50'						
60'						

P Barrow

BOREHOLE PB-2,

Lat. 70° 30.6' N.
Long. 140° 18.0' W

46151C

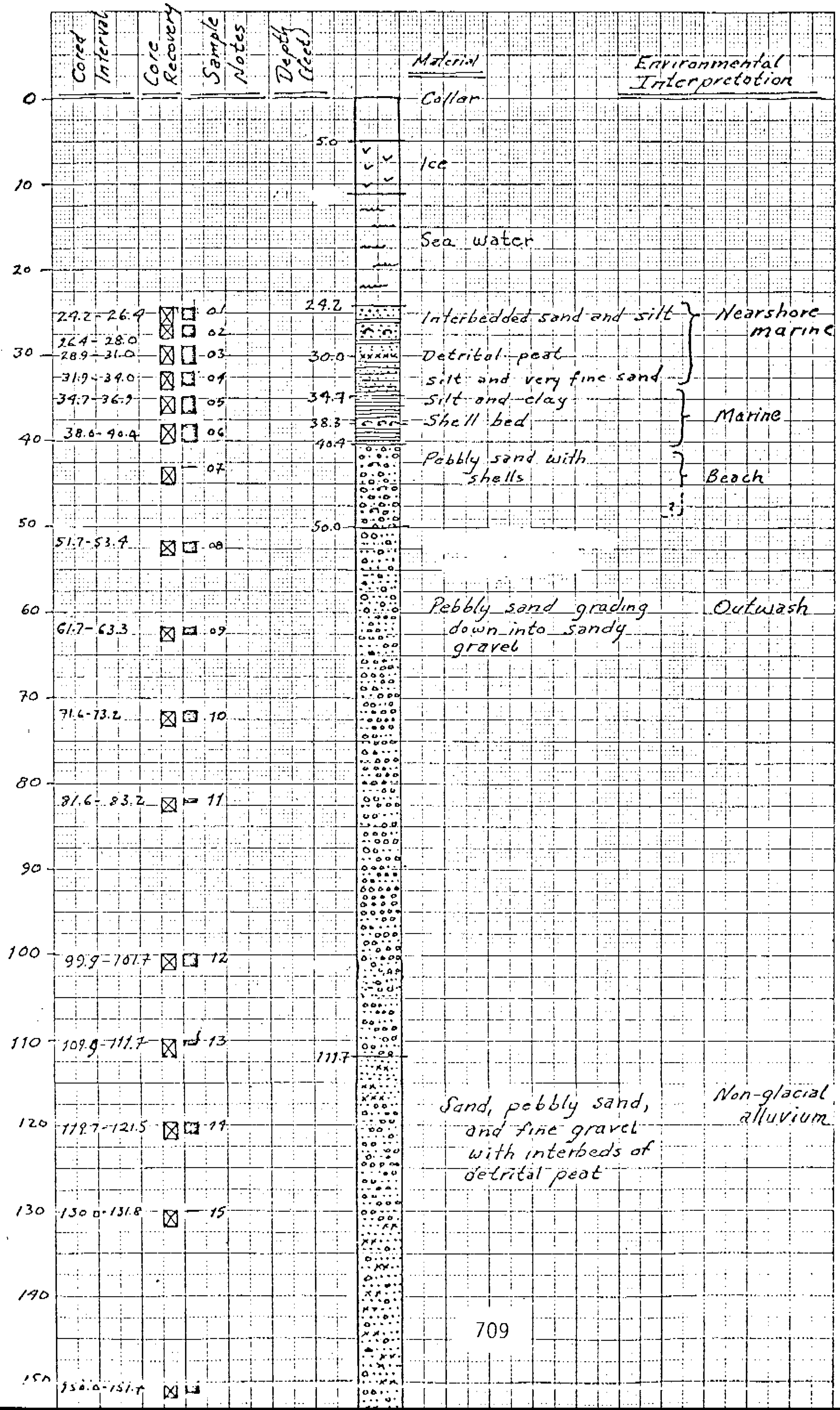


Depth in feet	Material	Environmental Interpretation
0	Collar	
4.8 – 12.3	Sea ice	
12.3 – 43.8	Sea water	
43.8 – 48.3	Fine sand	(Marine)
48.3 – 60.9	Clay and silt	(Marine)
60.9 – 74.0	Pebbly mud	(Glaciomarine)
74.0 – 78.5	Gravel	(Beach)
78.5 – 92	Sandy gravel & pebbly sand	(Glaciofluvial?)
92 – 111	Pebbly sand with interbeds of mud and clay.	(beach and marine?)
111 – 123	Sand	(beach or nearshore?)
123 – 140.5	Pebbly sand and gravel with rare detrital wood.	(non-glacial alluvium)

Cored Interval	Core Recovery	Sample Notes
43.8-46.0 ☒	■	Core GS-01
46.3-48.5 ☒	☐	Core GS-02
49.5-51.7 ☒	☐	Core GS-03
53.8-56.0 ☒	☐	Core GS-04
56.0-58.2' ☒	☐	Core GS-05
60.7-62.9 ☒	▨	Core GS-06
65.1-68.0 ☒	☐	Core GS-07
70.2-72.9 ☒	☐	Core GS-08

BOREHOLE PB-3

Lat. 70°2,58'N
Long. 148°26.6' W



Quarterly Report

Contract #RK6-6074
Research Unit #205
Reporting Period -
April 1976 - June 1976

Pages

Marine environmental problems in the ice covered Beaufort Sea shelf and coastal regions

Principal Investigators:

Peter Barnes
Erk Reimnitz
David Drake

1 July 1976

I. Task Objectives

The primary goal of this program is to study the nature, distribution and thicknesses of Holocene sediments and their relationship to sources, dispersal mechanisms and bottom processes. Emphasis is placed on dispersal processes that are unique to the arctic environment, where ice plays a dominant role. It deforms and stirs bottom sediments, permits conductive temperature transfer, inhibits free discharge of riverwaters into the ocean during the spring and transports sediments by rafting and bulldozing. Using techniques such as side-scan sonar, sounding, geophysical profiling, sampling, diving, underwater TV and photography, thermoprobes, and oceanographic sensors, we hope to achieve the following specific objectives:

1) A definition of the character, source, physical and chemical composition of bottom materials including permafrost.
2) An understanding of the present sediment transport regime, including the influence of ice, rivers, currents and the coastal wave regime.
3) An understanding of the Pleistocene and Holocene geologic record for use in interpreting the stability of the present day geologic setting of arctic Alaska.

II. Field or Laboratory Activities

A. Ship or Fieldtrip Schedule

1) March 20 - April 10, 1976

NOAA - OCS helicopter

Rolligon all-terrain vehicle (NOAA-chartered)

Scientific field party - Peter Barnes and David Drake

B. U.S.G.S. scientific laboratory party

Peter Barnes	Project Chief	Office of Marine Geology U.S.G.S.		
Erk Reimnitz	Principal Investigator	"	"	"
Dave Drake	" "	"	"	"

Larry Toimil	Co-Investigator	Office of Marine Geology U.S.G.S.
John Melchior	Assistant	" " "
Greg Smith	"	" " "

C. Methods

Collection of water transmissivity measurements and of suspended matter through sea ice

D. 12 stations of Prudhoe Bay and in Harrison Bay

E. 12 measurements of water transmissivity

12 samples of suspended sediment

(See Section III, attachment A)

III. Results

A. Preliminary field report, spring 1976

(See attachment A)

B. Evaluation of Prudhoe Bay channel restriction by fast ice

(See attachment B)

C. Bathymetric contour chart (scale 1:80,000)

(See attachment C)

D. Surface salinity, temperature, and transmissivity, summers 1972 and 1975

VI. $21,417.60 (Last quarter)

ATTACHMENT A

PRELIMINARY FIELD REPORT,SPRING 1976

PRELIMINARY FIELD REPORT: SPRING 1976

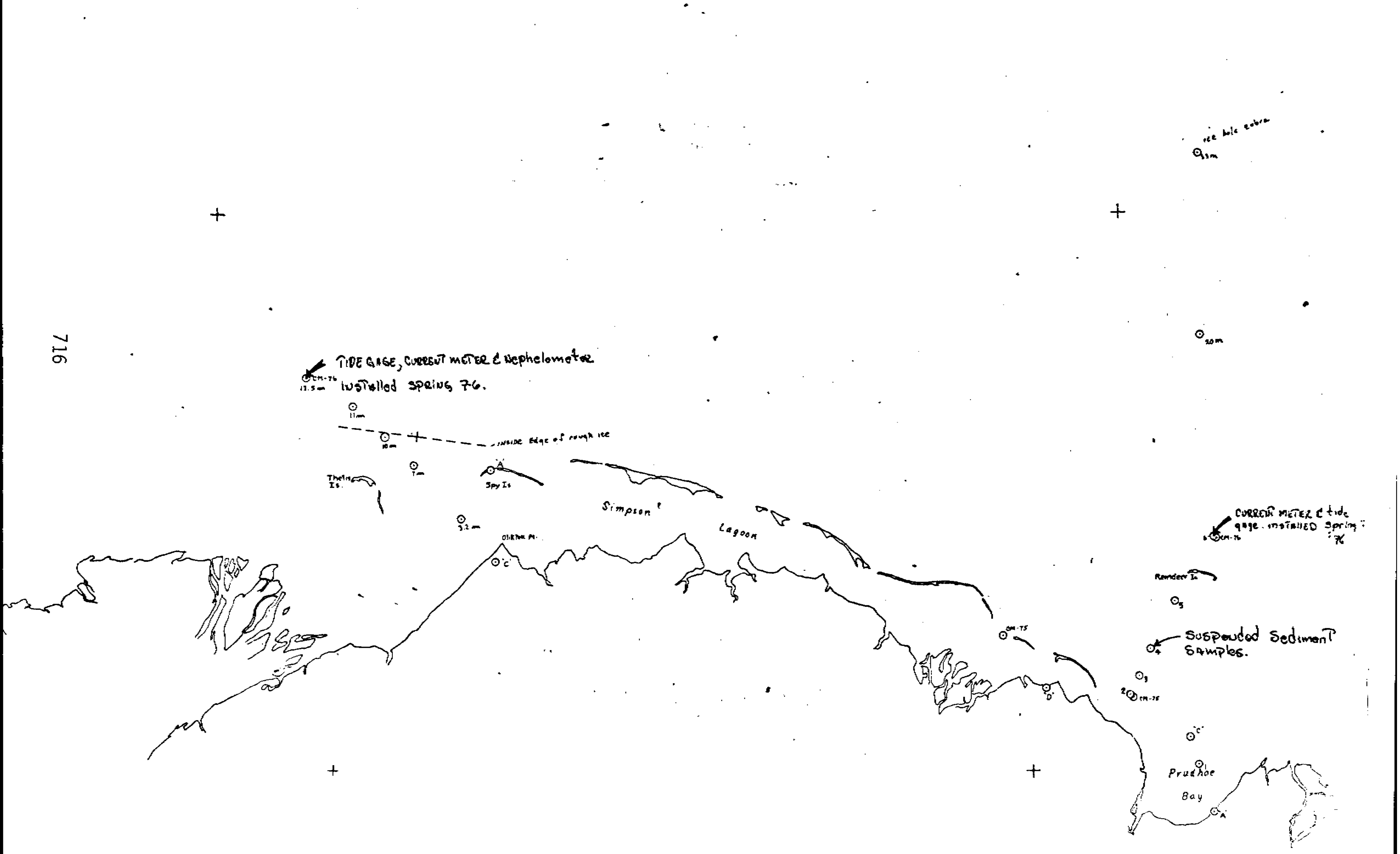
During late March and early April Peter Barnes and David Drake deployed two self-contained instrument moorings and obtained suspended sediment and light transmission samples off Prudhoe Bay and the Colville River (fig. 1). In addition; they assisted in construction of the U.S.G.S.-CRREL permafrost drill tower and located several drill sites using the Del Norte range-range navigation system. Logistic support was provided by the OCS camp at Deadhorse and transportation by the NOAA-OCS helicopter and a Rolligon all-terrain vehicle.

One instrument package installed north of Reindeer Island (fig. 1) included an Aanderaa tide gauge, and an Aanderaa current meter capable of recording temperature and salinities. Recovery aids included two acoustic beacons, a grappling line and an acoustically-activated call-up-buoy. The current meter sensors are located 1 meter above the sea bed. Northwest of Oliktok Point the instrument mooring included an Aanderaa tide gauge, a Geodyne current meter with sensors 1 meter above the bottom, a Montedero nephelometer/transmissometer, temperature sensor and data logger at 3 meters above the sea floor and 5 meters below the surface. The instruments will gather data at approximately half hour intervals until recovery in August 1976. The results of this experiment will substantially improve our understanding of the influence of ice cover on nearshore currents and sediment transport.

Light transmission measurements at 12 ice-hole stations off Prudhoe Bay and Oliktok Point show that the water within 20 km of the coast is moderately turbid (50-70% transmission) and the turbidity increases significantly within 1 to 2 metres of the sea floor. However, the concentrations of suspended matter recovered at these stations were anomalously low based on previous calibrations of the transmissometer using mineral particulate suspensions. Microscope inspection of the particulate matter shows that it is predominantly organic matter with a minor amount of clay-sized mineral grains. These findings indicate that the water turbidity was strongly influenced by low-density organics and dissolved organic matter. (This latter component would effect the water clarity but would bypass the filters.)

The composition and concentrations of surface water particulate matter samples (48 samples) recovered in nearshore areas of the Beaufort and Chukchi Seas during relatively ice-free conditions in the summer of 1975 (see Annual Report) differ markedly from our March 1976 samples. Concentrations were up to two orders of magnitude greater in 1975 and the particulate matter was predominantly terrigeuous fine silt and clay. The long-term nephelometer/transmissometer/current velocity data from our mooring off the Colville River should show whether the very low suspended matter concentrations in March are typical of the ice-covered regime.

SPRING 76 ICE STATIONS



ATTACHMENT B

EVALUATION OF PRUDHOE BAY CHANNEL RESTRICTION BY FAST ICE

Evaluation of the Prudhoe Bay channel restriction by fast ice

A knowledge of whether bay and lagoon entrances in the Arctic are blocked by fast ice during the course of the winter is of great importance in our attempts to evaluate the modern shallow water environments in the Beaufort Sea. Since the fast ice generally attains a thickness of about 2 metres (6 feet), one might assume that shallow connections between the open ocean and bays or lagoons are sealed off sometime during the winter. Our studies in Simpson Lagoon, and published reports dealing with this lagoon and others, show that salinities below the ice can be twice as high as those in the open ocean. We have also found that the temperature of the high salinity water may be on the order of -5°C. These facts would indicate that the shallow bodies of water indeed are isolated from the ocean. Before the isolation is completed, the dense water may spill from the embayment of the lagoon, and flow seaward. The implications are important for the potential dispersal of pollutants, for example.

We are not aware of winter water data for Prudhoe Bay. However, the water depth in the shallow part of the channel into Prudhoe Bay is less than 5 feet and around the 20th of July, 1972, before the breakup of the fast ice was complete, we measured salinities as low as 1% and temperatures up to 6°C in the bay. These values reflect the water contribution of the Putuligayuk River, and the warming of the shallow bay during the period of continuous daylight. The data also indicate that water exchange with the ocean at that time was still restricted by floes of rotten ice.

In order to learn more about the winter circulation between Prudhoe Bay and the ocean, we placed in late September of 1975, a recording current meter with water temperature and salinity sensors outside of the bay entrance.

Atlantic Richfield Co. kindly permitted the use of data gathered for them in May and June of 1969 on the thickness of the fast ice and the depth of the water beneath the ice, in the Prudhoe Bay channel. This data should closely represent conditions during the maximum thickness of the fast ice, although thawing was in progress.

A description of how the ARCO data was analyzed is attached. The results of this evaluation show that the fast ice covering the bay entrance is thinner than anticipated, possibly due to the effects of under-ice turbulence. Most significant is the tentative conclusion that Prudhoe Bay is not sealed off from the ocean by fast ice growth.

RESULTS

An industry reconnaissance study of the Prudhoe Bay channel made in May and June of 1969, entitled Subsurface Exploration Progress Report No. 2, contains measurements of ice thickness and bottom depth along a trackline run-out on the ice (see Fig. 1). The report gives the location of bore holes, core logs for all sites, profiles of soil conditions down to 25 feet depth, and a series of east to west trending cross-sectional views of the channel at drill sites No. 16 to 22. This data was gathered in May 1969 and used the top of the ice as the zero elevation reference. The same trackline was resurveyed on June 4th and 5th, 1969, to measure ice thickness and channel depth. At that time the Prudhoe Bay benchmark, elevation +10.69 feet, was used as the reference point.

The drill sites were located on U.S. Hydrographic Survey Smooth Sheet No. 7857, the Prudhoe Bay area, and the bathymetric contours were drawn in at 1 foot intervals (see Fig. 1). The Hydrographic survey was completed in 1950 and so the contours represent the bay's bathymetry as seen then. The 1969 drill logs show that the channel has nearly the same form now as then and in general the channel has approximately 4 feet of ice on top of 2 feet of water, with the water coming within a foot of the top of the ice canopy when stabilized in the drill hole. The May drill logs had to be corrected to take into account the irregular ice surface used as zero datum. The June data then matched with both the May drill logs and profiles and gave an accurate description of the shape of the channel and the bottom of the ice canopy. There was a difference between the depth to the bottom of the ice in May and June which could be due to thinning of the ice between surveys.

An isopach map of the thickness of the free-flowing water beneath the ice was constructed from the profiles (fig. 2). Contour intervals of 1/2 foot were projected onto the cross-sections for each drill site #16 through #22. The assumption was made that the ice bottom was flat along the trend of the cross-section, since we had no information on its shape in that direction. The isopach map shows that at its deepest the water gap is 3 feet, and at its shallowest is 1½ feet. Water should be able to flow out to the ocean even during the period of maximum ice thickness. A constant flow of water could be a factor in helping to keep the channel open, when otherwise the ice would normally freeze down to the bottom. Measurements outside the channel at drill sites #12 to #15 show ice thicknesses varying between 2½ and 4½ feet. The water gap varies between 1½ and 4 feet. There is no smooth function between thickness of the ice and distance to shore or water depth. The lower surface of the ice is much more irregular, and has greater relief, than the upper surface.

Whether the channel is ever completely closed during the winter could not be answered by this survey. The possibility exists, however, that a hydraulically maintained channel allows the mixing of waters at least close to the time of thickest ice cover, and soon after the beginning of the melt season.

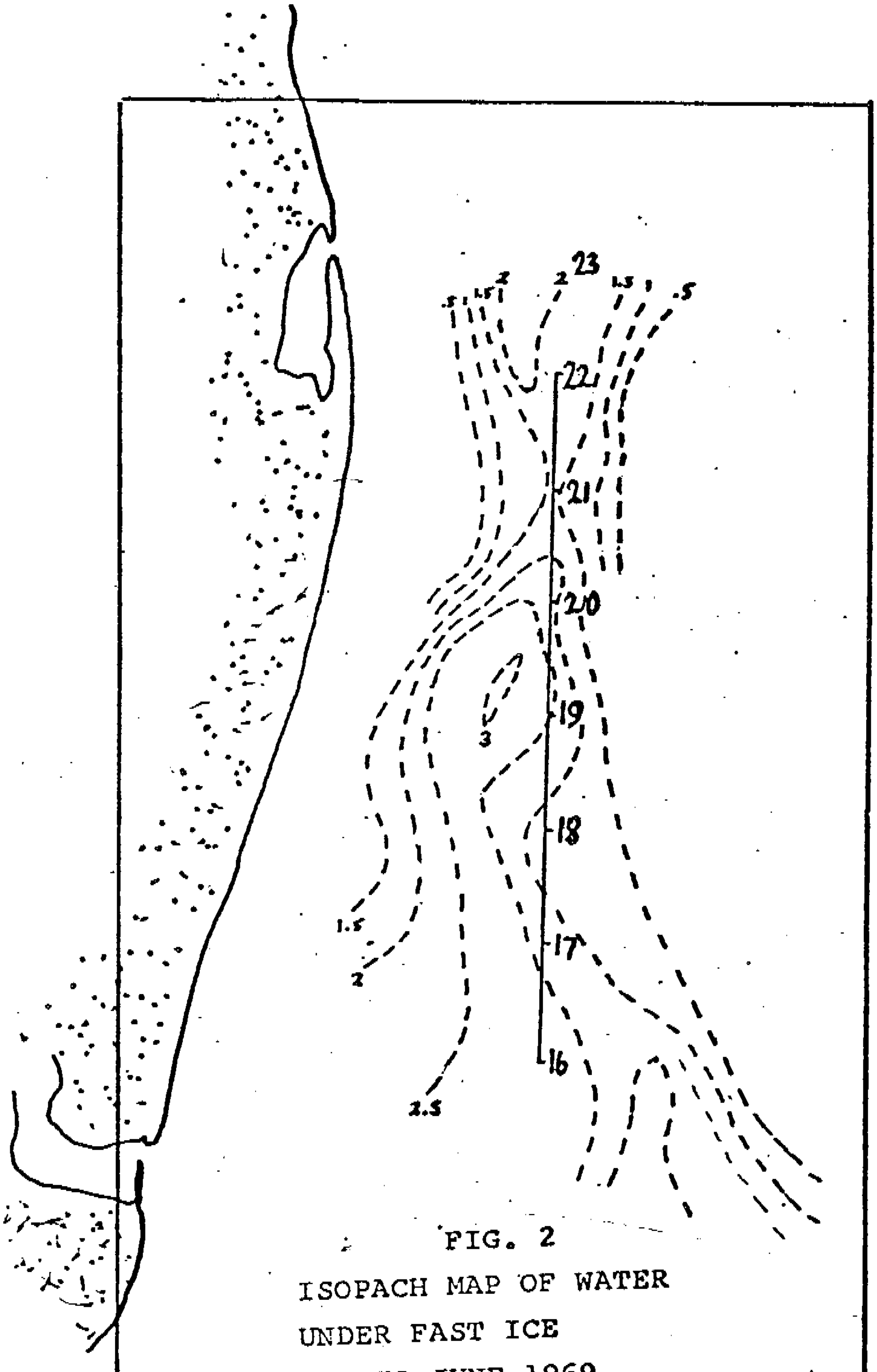
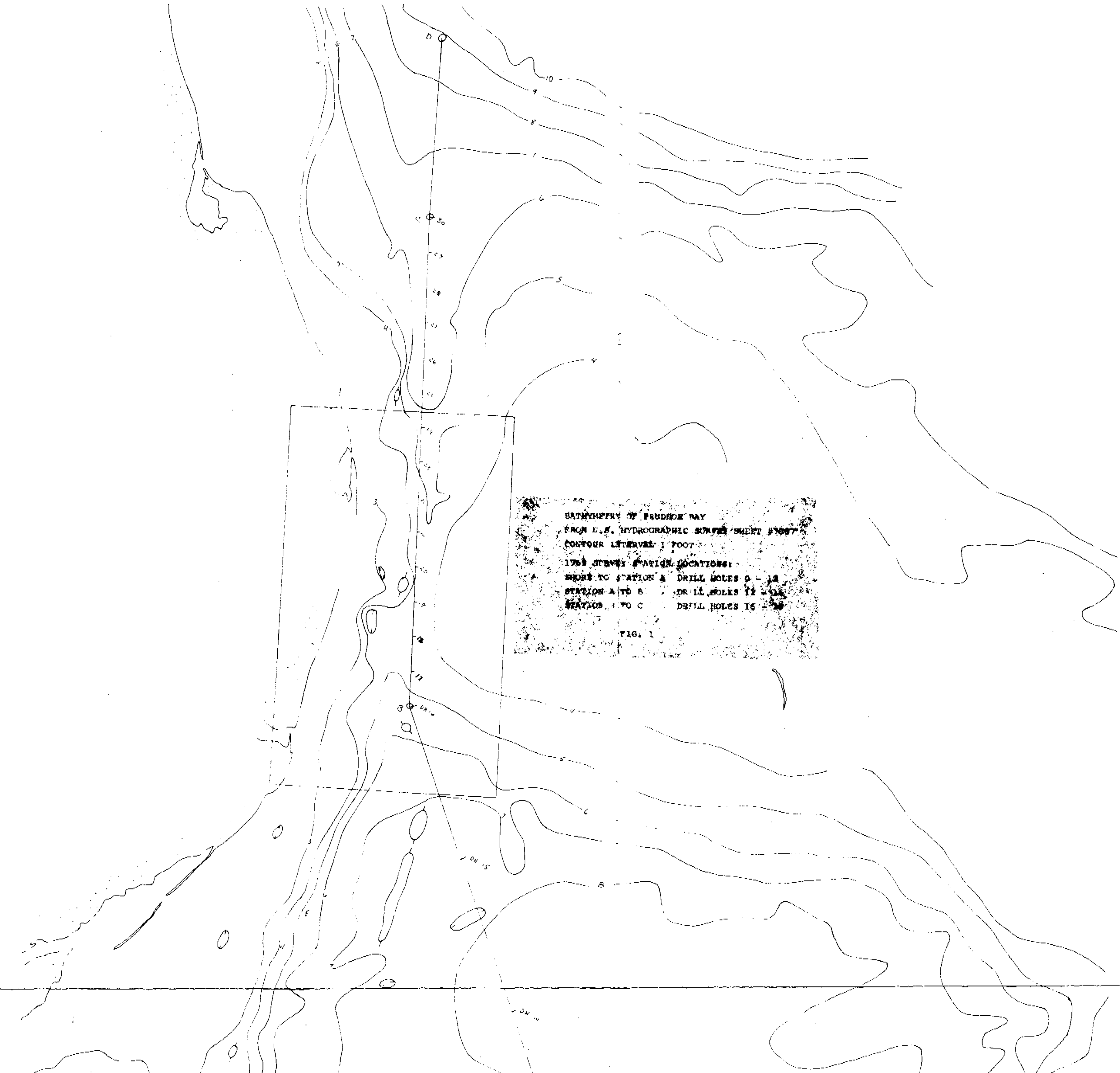
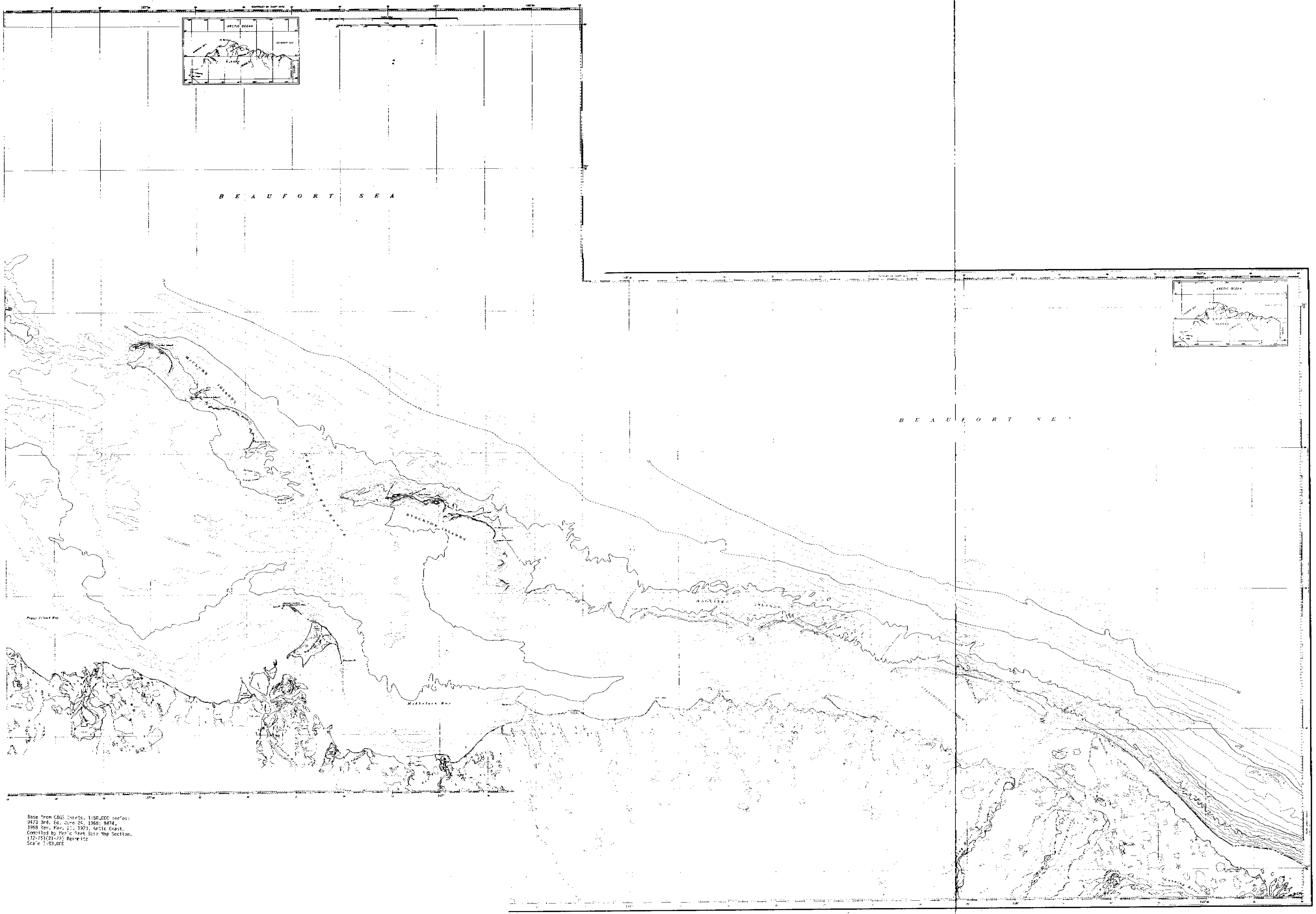


FIG. 2
ISOPACH MAP OF WATER
UNDER FAST ICE
MAY TO JUNE 1969
ISOPACHS AT ½ FT. INTERVAL



BATHYMETRY OF PRUDHOE BAY
FROM U.S. HYDROGRAPHIC SURVEY SHEET #7067
CONTOUR INTERVAL 1 FOOT
1969 SURVEY STATION LOCATIONS:
SHORE TO STATION A DRILL HOLES 0 - 12
STATION A TO B DRILL HOLES 12 - 14
STATION B TO C DRILL HOLES 15 - [illegible]

FIG. 1



Base from C&GS Charts, 1:50,000 series:
9473 3rd. Ed. June 24, 1968; 9474,
1958 Rev. Mar. 21, 1973, Artic Coast.
Compiled by Menlo Park Base Map Section.
(12-75)(21-73) Reimnitz
Scale 1:83,000

ATTACHMENT **C**

BATHYMETRIC CONTOUR CHART (Scale 1:80,000)

Bathymetric Contour Chart, (1:80,000)

U.S. Hydrographic Survey 1:50,000 scale smooth sheets No. 7756, 7757, 7758, 7851 and 7852 were incorporated into two 1970 edition 1:50,000 scale charts. The bathymetry was contoured at 1 meter intervals, and compiled at a scale of 1:80,000. The Hydrographic Survey work was done in 1950 using small boats in a dense pattern of accurately controlled tracklines. Depth was recorded with echo sounders to the nearest ½ foot in shallow water and to the nearest foot in the deeper areas offshore. The mainland shoreline mapped in connection with these surveys is in general still consistent with later chart editions, updated on the basis of new aerial surveys. Erosion of coastal bluffs at rates of up to 10 m per year (Lewellen, 1970), and occasionally much higher (Short, 1973) have been documented. At the scale of 1:80,000 such changes could not be detected. However, the crenulated nature of the coastline along the western, abandoned part of the Canning River Delta, indicates that delta front erosion is taking place. Changes of active delta fronts were not investigated in the map area. Many of the islands have migrated westward since the 1950 survey, as already reported for the Maguire Islands (Short, 1973). Where the new chart editions showed such island modifications, the isobaths were shifted accordingly, assuming that bottom slopes near the islands did not change substantially.

All slopes in the area are gentle, the steepest being 2^{o} to 2.5^{o} on the seaward side of the McClure Islands. These slopes decrease several hundred meters from shore, and approach 0.1^{o} on the shelf. Gradients in the lagoons are even less, with relief of less than 1 m over distances of thousands of meters. Randomly distributed "pits" with depths of over 1 m in some cases, were shown in the original sounding data near active river mouths. These most likely represent strudel scour depressions (Reimnitz, et al, 1974). Such features are too small to be included in the chart and their extent and number is unknown, since the trackline density was too low to delineate the small scale phenomena. The seaward slopes of the islands, and the outer parts of lagoon entrances, show gently undulating, irregular relief. This type of relief is characteristic for the entire coast westward to Harrison Bay. We suspect the presence of nearshore bars, similar to those studied by Short (1973) off Pingok Island. But their trend and configuration cannot be delineated from available sounding data in this map area. Such bars, if present, would explain the undulating relief very close to shore. In offshore areas, and expecially in the lagoon entrances, processes other than bar migration must be at work to produce this unique bottom configuration. Such relief is not found off barrier island coasts in ice-free seas, and should be further investigated.

With the completion of the attached chart, we now have bottom contour charts covering the coast from Cape Halkett to the Canning River, all contoured at 1 m interval and at a scale of 1:80,000. These charts will serve as a base for much of our data compilation and analysis.

References

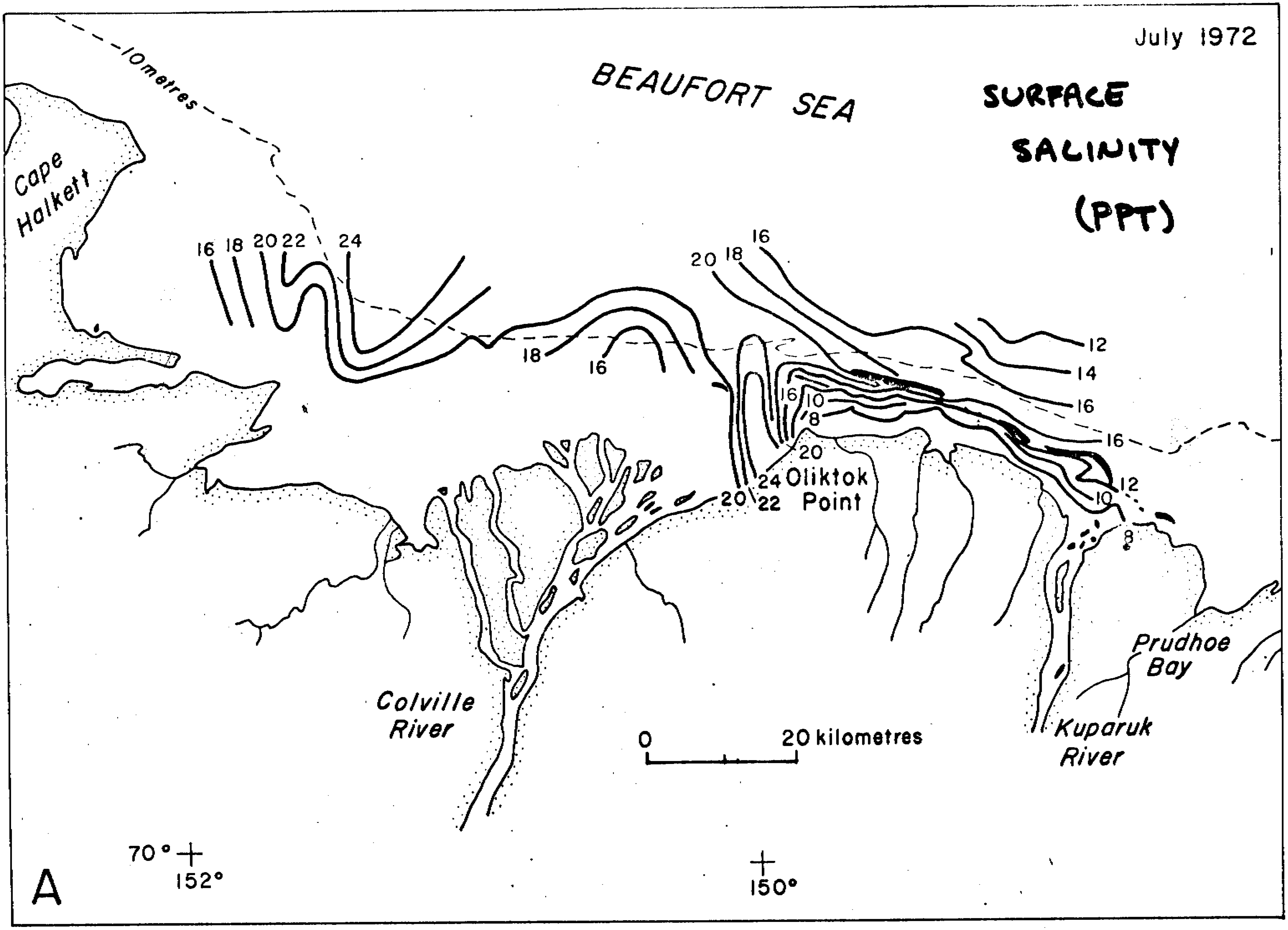
Lewellen, R.I. 1970. *Permafrost erosion along the Beaufort Sea coast.* Published by the author, Littleton, Colo., 25 pp.

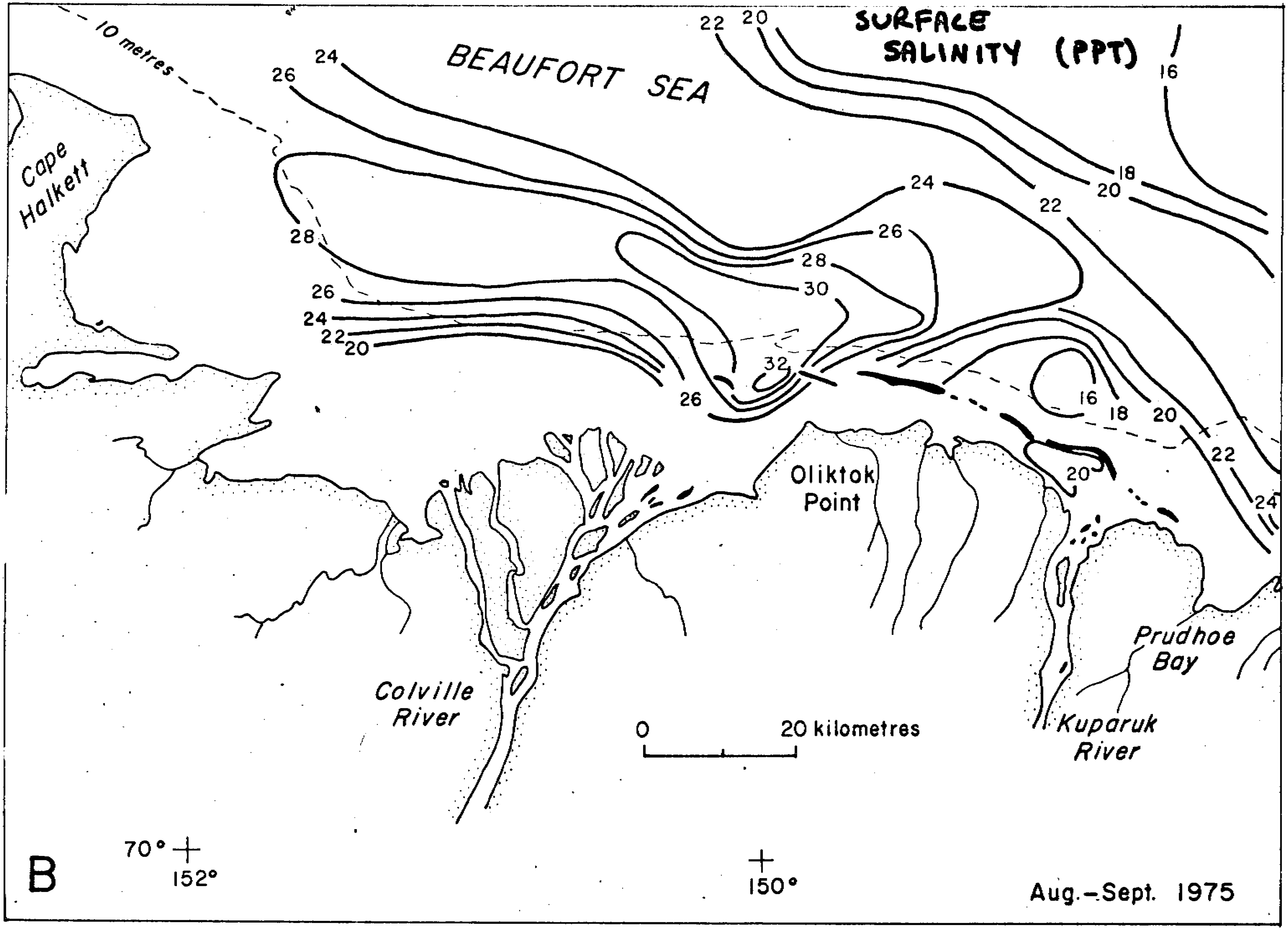
Reimnitz, E., Rodeick, C.A. and Wolf, S.C. 1974. "Strudel scours: a unique arctic marine geologic phenomena." *Journal of Sedimentary Petrology*, v. 44, n. 2, pp. 409-420.

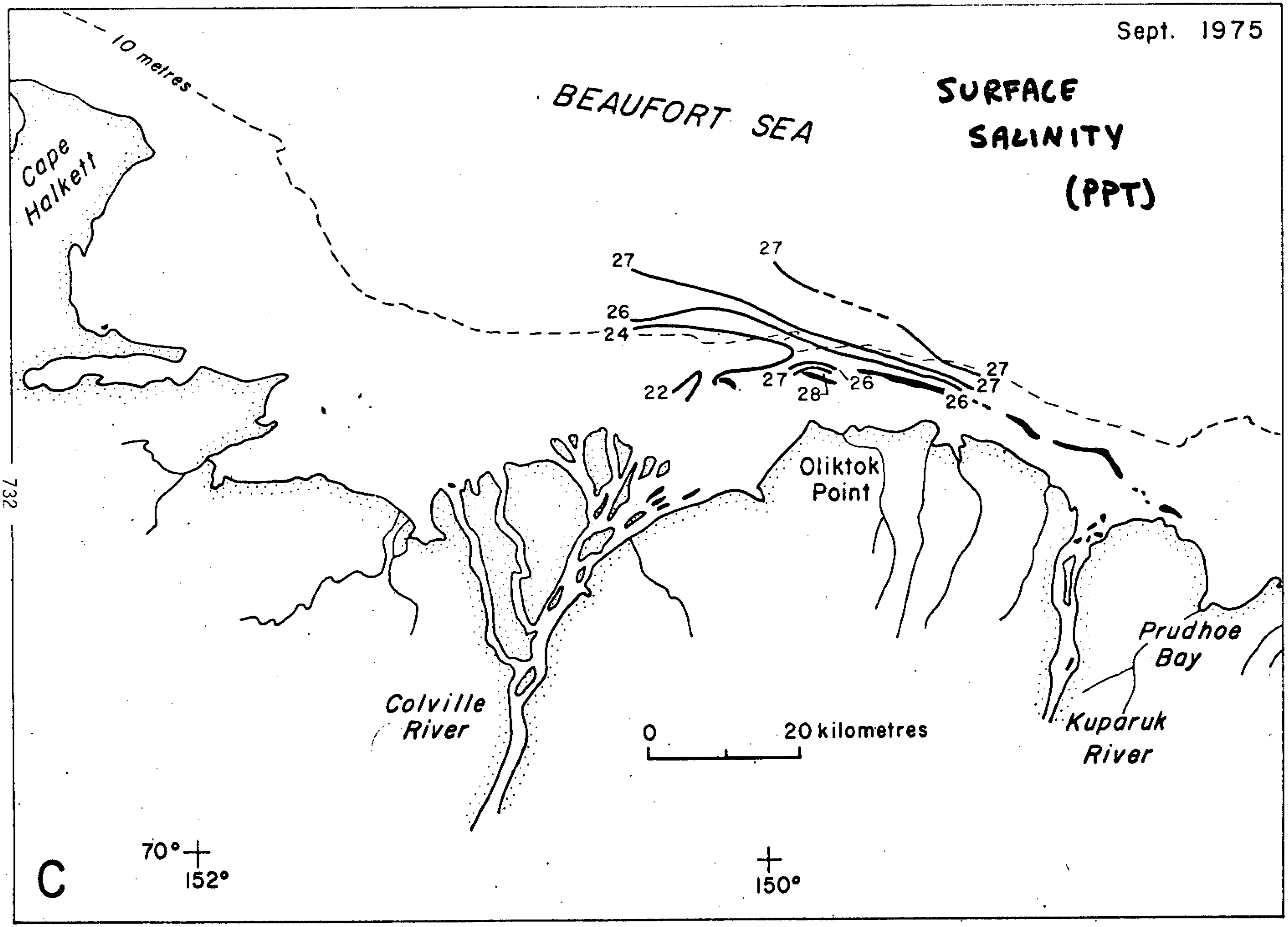
Short, A.D. 1973. *Beach dynamics and nearshore morphology of the Alaskan arctic coast.* Ph.D. dissertation, Louisiana State University, 140 pp.

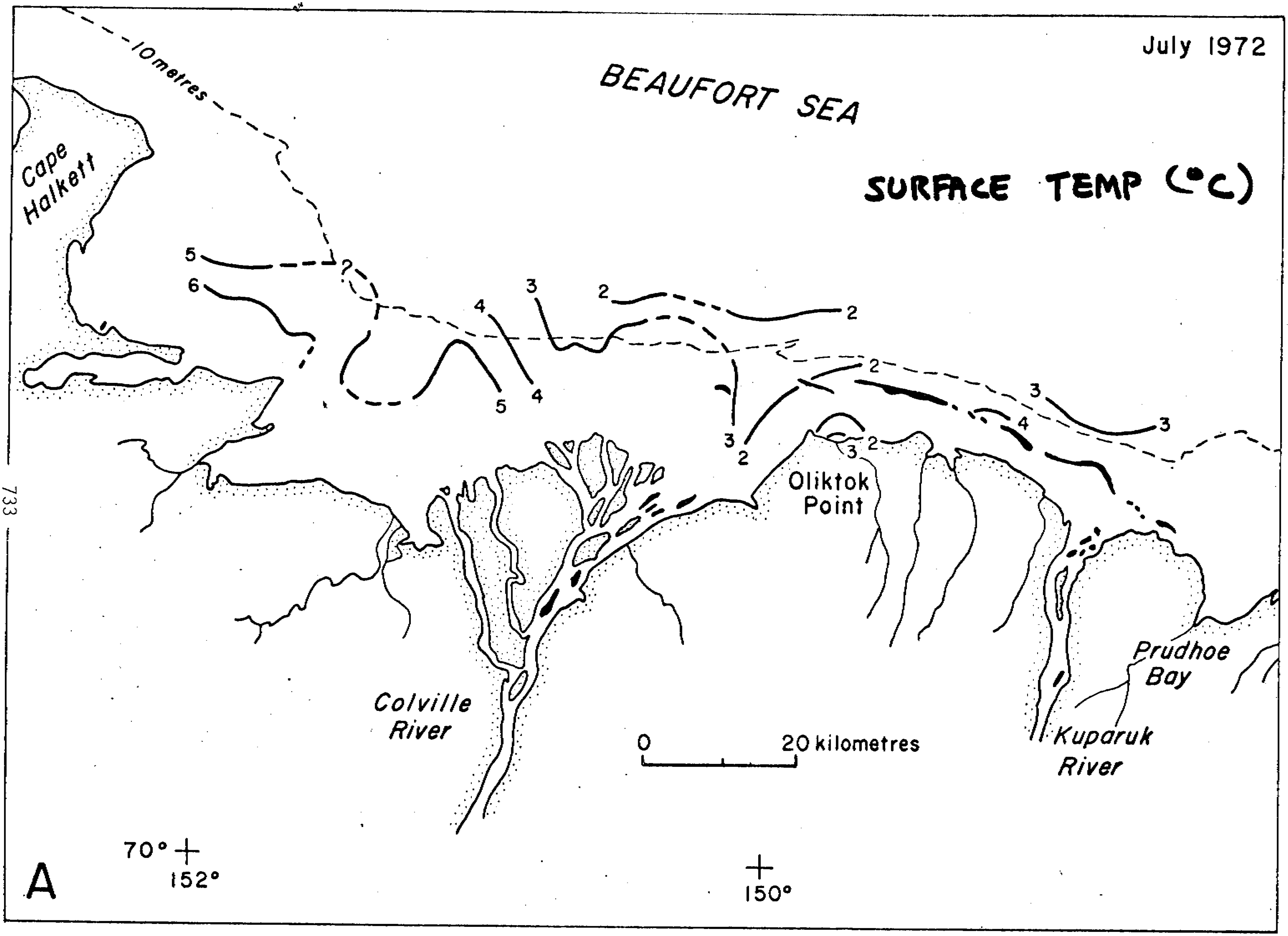
ATTACHMENT D

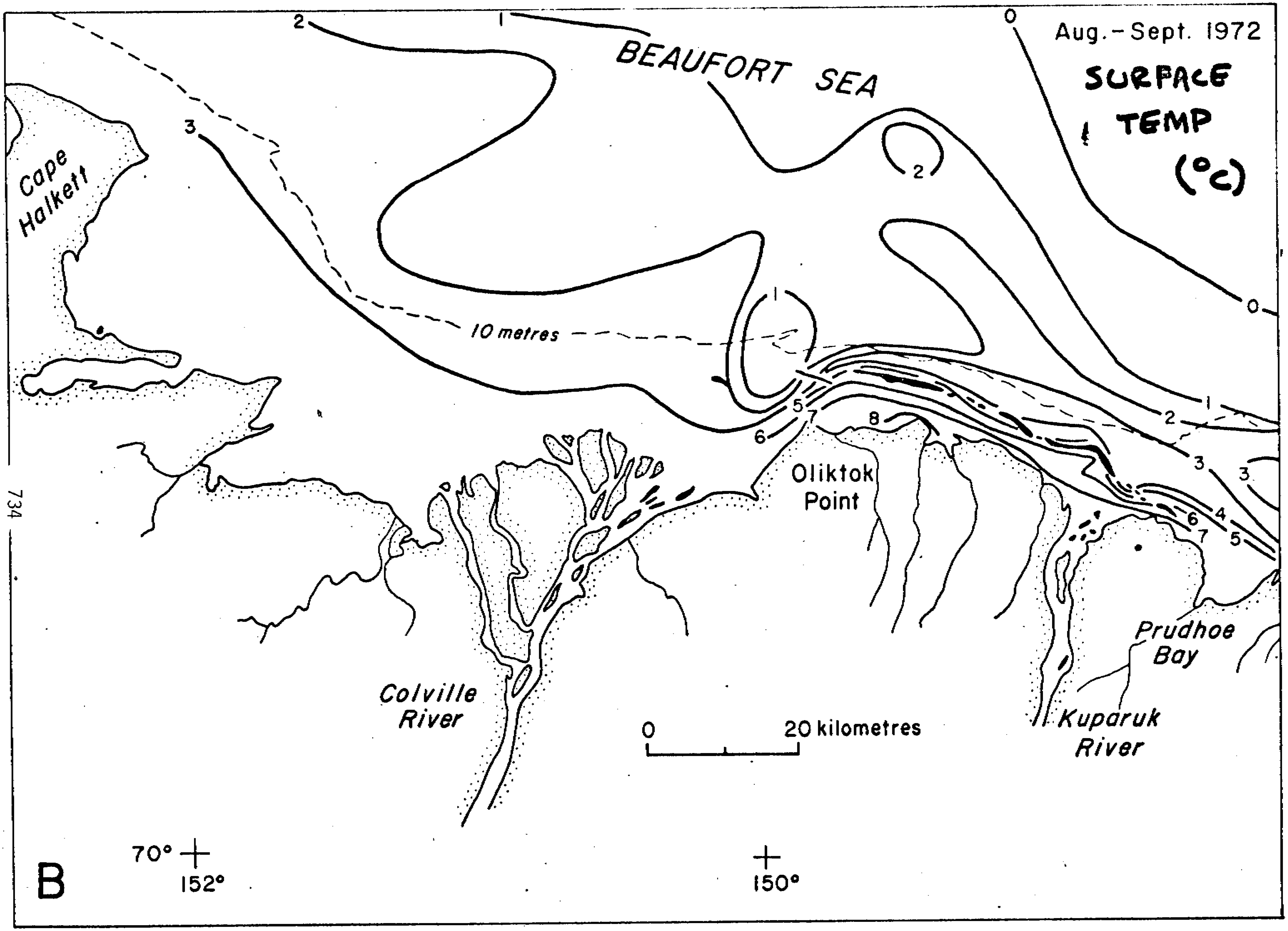
SURFACE SALINITY,TEMPERATURE,AND TRANSMISSIVITY, SUMMERS 1972 AND 1975

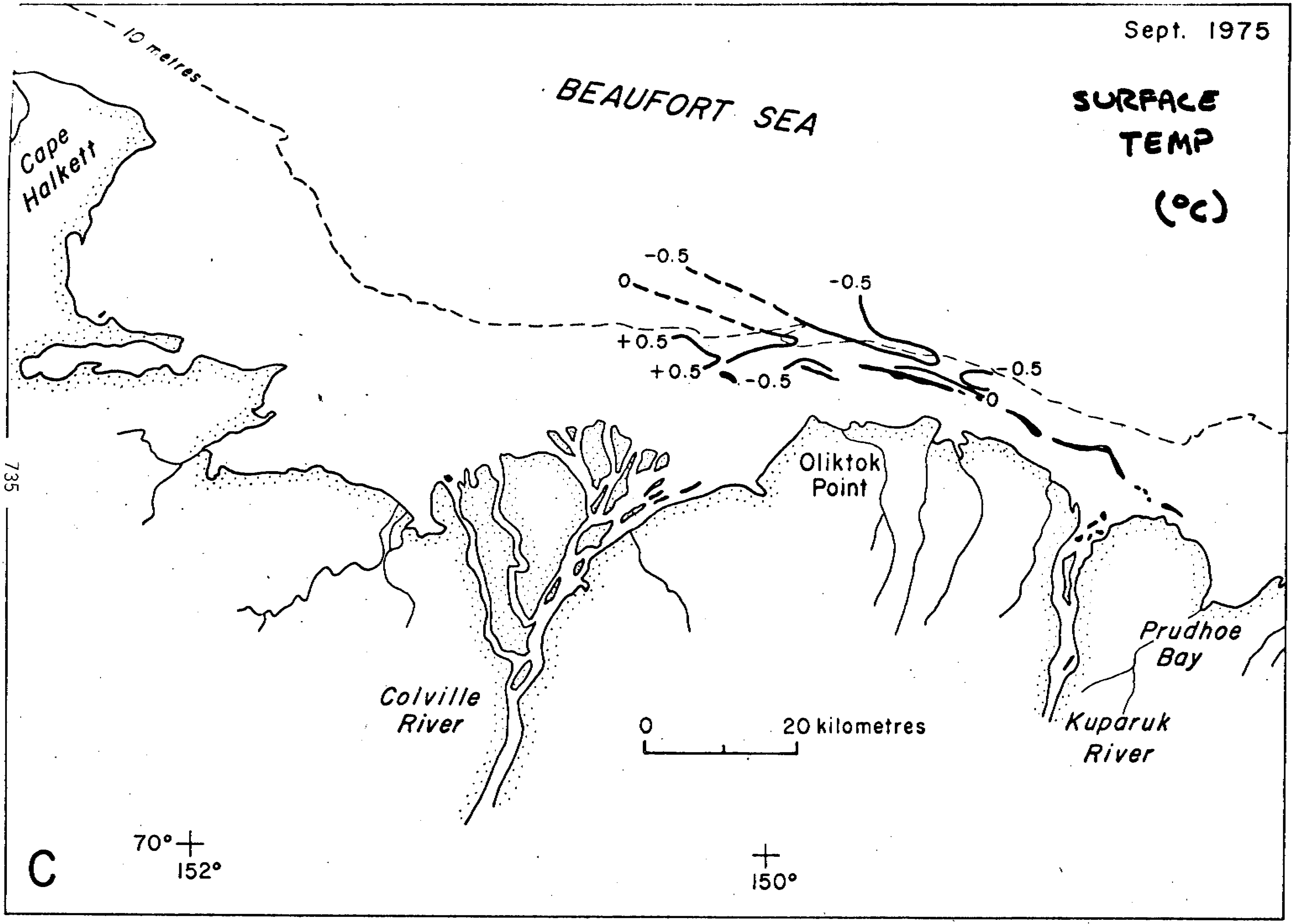

July 1972
BEAUFORT SEA
SURFACE
SALINITY
(PPT)
10 metres
Cape Halkett
16
18
20
22
24
18
16
20
18
16
12
14
16
16
16
10
8
20
24
22
20
12
10
8
Oliktok Point
Colville River
0
20 kilometres
Kuparuk River
Prudhoe Bay
70°
152°
150°
A

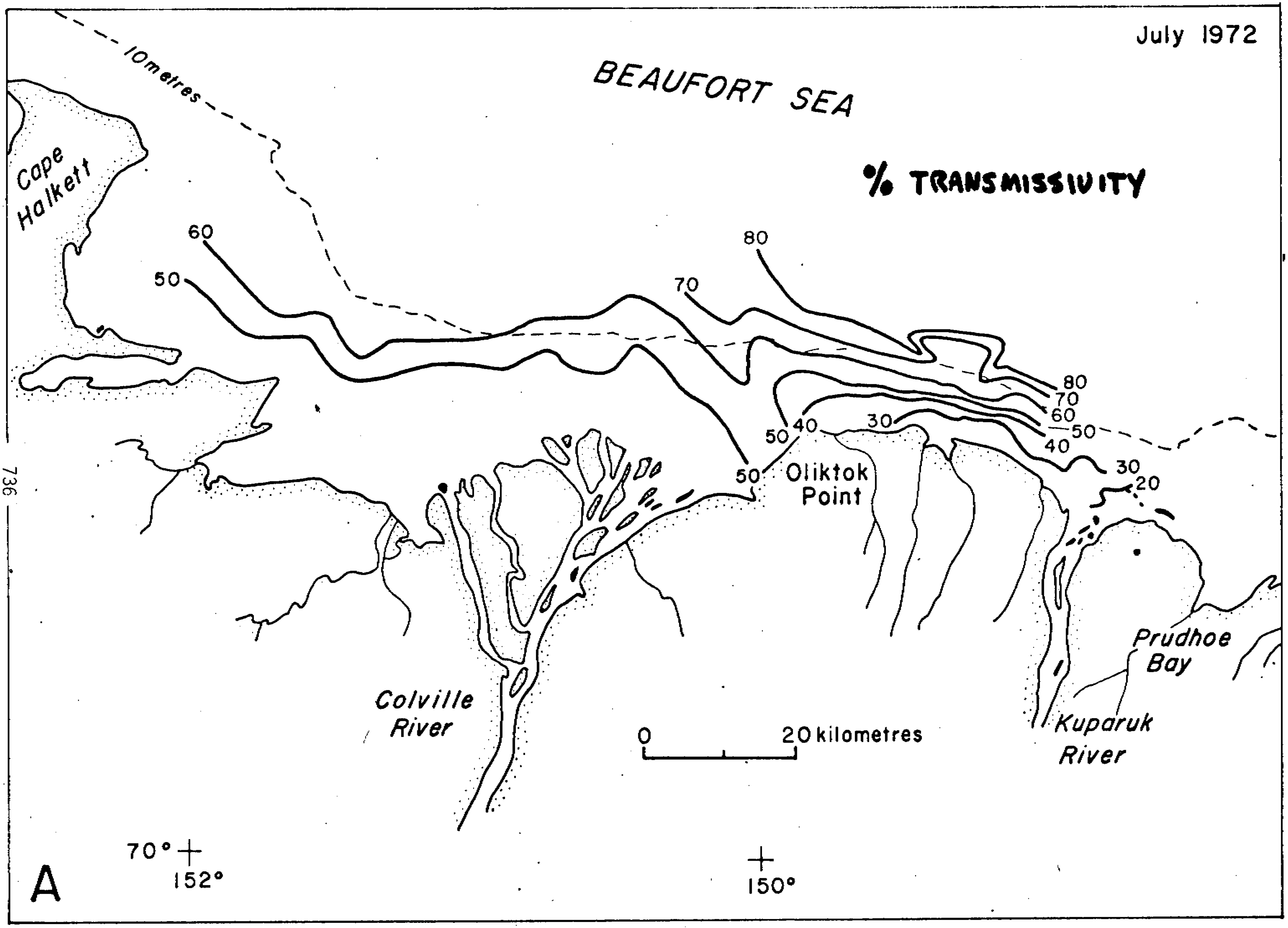

SURFACE SALINITY (PPT)
BEAUFORT SEA
10 metres
Cape Halkett
Colville River
Oliktok Point
Prudhoe Bay
Kuparuk River
0
20 kilometres
16
18
20
22
24
26
28
30
32
70°
152°
150°
B
Aug.-Sept. 1975

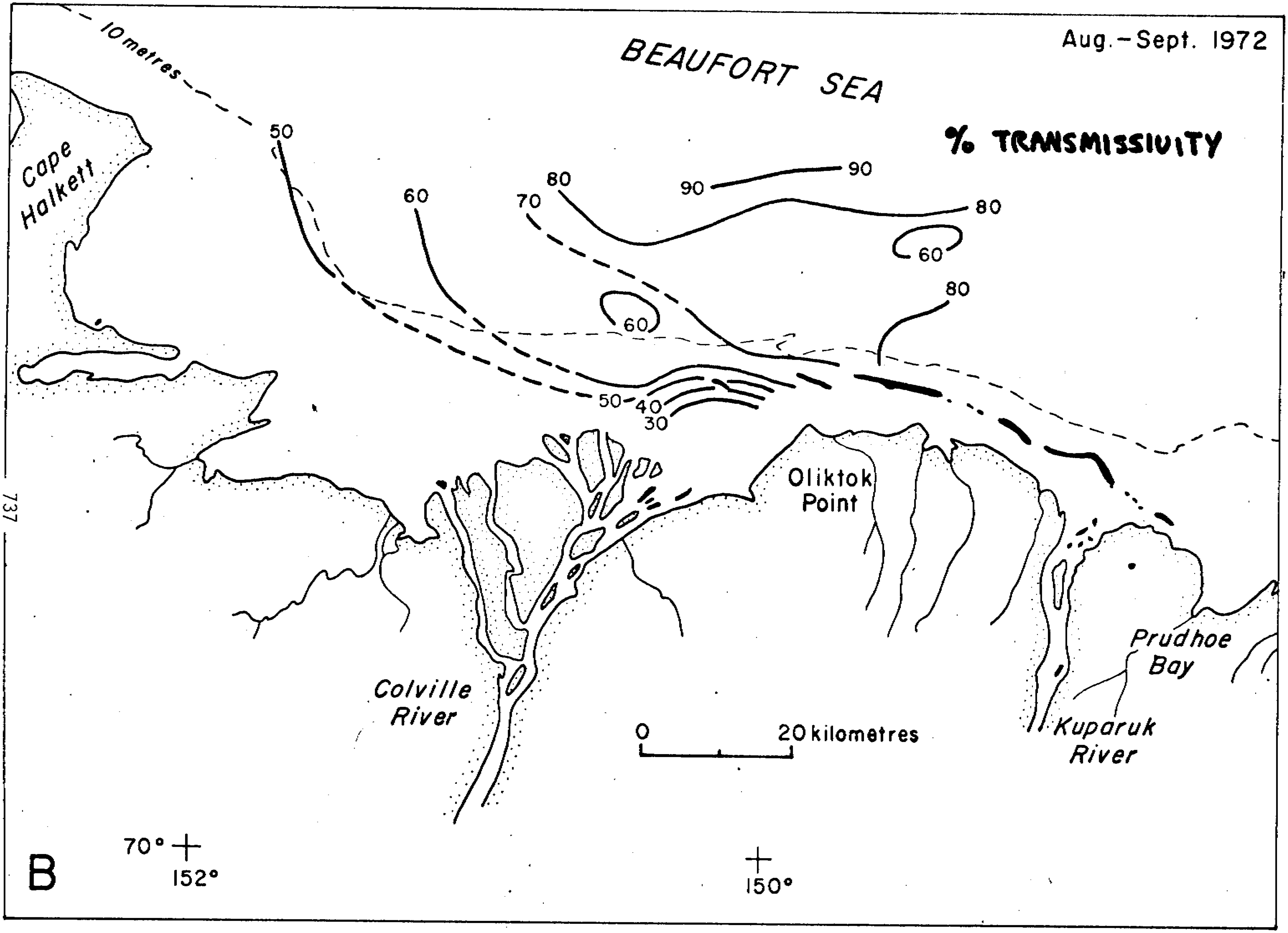

Sept. 1975
SURFACE SALINITY (PPT)
BEAUFORT SEA
10 metres
Cape Halkett
27
27
26
24
22
27
28
26
27
27
26
Oliktok Point
Colville River
Prudhoe Bay
Kuparuk River
0
20 kilometres
70°
152°
150°
C

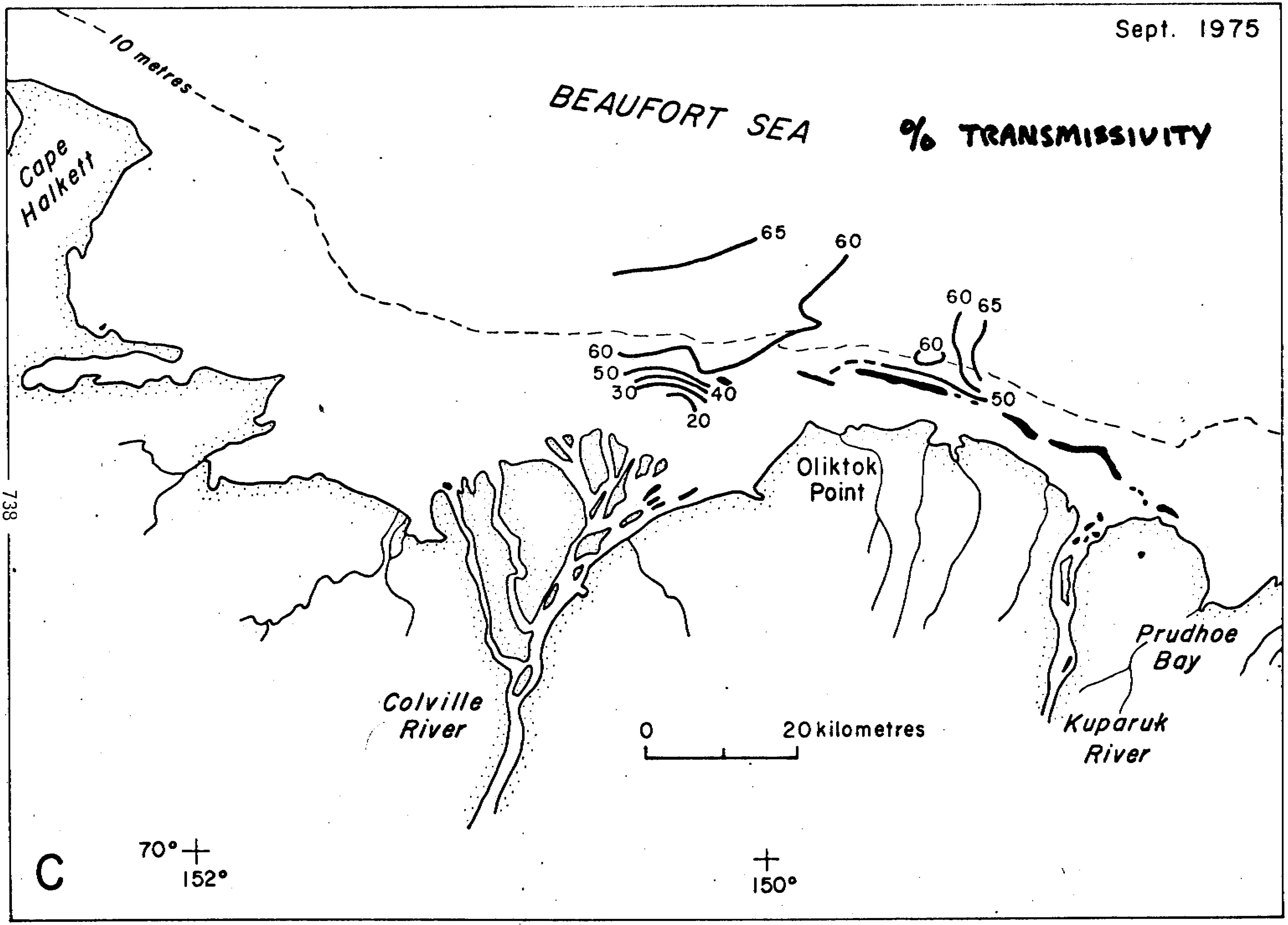

July 1972
BEAUFORT SEA
SURFACE TEMP (°C)
10 metres
Cape Halkett
5
6
?
4
3
2
2
5
4
2
3
3
2
3
2
4
3
3
2
Oliktok Point
Colville River
Kuparuk River
Prudhoe Bay
0
20 kilometres
70°
152°
150°
A


Aug.-Sept. 1972
SURFACE TEMP (°C)
BEAUFORT SEA
Cape Halkett
10 metres
Oliktok Point
Colville River
Kuparuk River
Prudhoe Bay
0
20 kilometres
0
1
2
3
4
5
6
7
8
70°
152°
150°
B


Sept. 1975
SURFACE TEMP (°C)
BEAUFORT SEA
10 metres
Cape Halkett
-0.5
0
-0.5
+0.5
+0.5
-0.5
-0.5
0
Oliktok Point
Colville River
0
20 kilometres
Prudhoe Bay
Kuparuk River
C
70°
152°
150°


July 1972
BEAUFORT SEA
10 metres
% TRANSMISSIVITY
Cape Halkett
60
50
80
70
80
70
60
50
40
30
20
50
40
30
50
Oliktok Point
Colville River
0
20 kilometres
Kuparuk River
Prudhoe Bay
70°
152°
150°
A


Aug.-Sept. 1972
BEAUFORT SEA
% TRANSMISSIVITY
10 metres
Cape Halkett
50
60
70
80
90
90
80
60
60
80
50
40
30
Oliktok Point
Colville River
Prudhoe Bay
Kuparuk River
0
20 kilometres
70°
152°
150°
B


Sept. 1975
BEAUFORT SEA
% TRANSMISSIVITY
10 metres
Cape Halkett
65
60
60
65
60
60
50
30
40
20
50
Oliktok Point
Colville River
Prudhoe Bay
Kuparuk River
0
20 kilometres
70°
152°
150°
C

RU# 206

NO REPORT SUBMITTED

The principal investigator is in the field.

RU# 208

NO REPORT SUBMITTED

The principal investigator is in the field.

Quarterly Report, April-May-June, 1976--Research Unit #209

Fault history of the Pribilof Islands and its relevance to bottom stability in the St. George Basin

1. No cruises or field trips.
2. Scientific party:

   D. M. Hopkins, principal investigator

   M. L. Silberman, geochronologist and geochemist
3. Activity this quarter consisted of geochronological studies of basaltic lava flows from the Pribilof Islands.

   Potassium analyses, rock crushing, and mineral separates were completed for about 40 specimens at the Geological Survey in Menlo Park. Silberman then took the samples to do argon-extraction and mass-spectrometry in the potassium-argon laboratory of the Hawaii Geophysical Observatory in Honolulu. The H.G.O. laboratory was selected because it features an argon-extraction line specially designed for work with very young rocks such as those from St. Paul Island. Sixteen analyses were completed at H.G.O. and then a major equipment failure closed the laboratory and forced Silberman to return to California. Barring major equipment failures here, we expect to complete the geochronological studies during the next quarter.

   The dating program on the lavas from St. George was very successful. It resulted in a refinement of our knowledge of the time span and frequency of volcanism, faulting, and sea level changes there and generally confirmed the conclusions put forth in our annual report.

The dating program on lavas from St. Paul Island produced very confusing results. Many flows appear to contain excess argon-36 for reasons that are not yet clear. Even allowing for this problem, one flow seems to have given a reasonable date; if the date is correct, then frequency of faulting and volcanism and the recurrence interval between successive episodes is much shorter than we had estimated in our annual report. More analytical work will be needed before this result can be considered to be firmly established.

4. No new sample localities.
5. Preliminary processing completed on about 40 samples for K/Ar dating.

RU# 210

NO REPORT SUBMITTED

The principal investigator is in the field.

5th QUARTER REPORT - R. U. 216/212

(April 1, 1976 - July 1, 1976)

FAULTING AND INSTABILITY AND EROSION AND DEPOSITION OF SHELF SEDIMENTS, EASTERN GULF OF ALASKA

P. I. Paul R. Carlson
Bruce F. Molnia
U. S. Geological Survey
Menlo Park, California 94025

I. Task Objectives:

B-10 - Determine the types and characteristics of bottom sediments.

D-2 - Determine the types and extent of natural seafloor stability. Compile maps indicating relative susceptibility to instability hazards.

D-6 - Determine and map the distribution, mode of faulting, age of most recent movement, and magnitude of offset for major faults.

II. Field or laboratory activities:

A. ACONA Cruise:

1. April 9-19, 1976; R/V ACONA, Univ. of Alaska

2. Scientific Party (all USGS personnel)

Paul Carlson Bruce Molnia	Cruise Leaders
Jim McQuay	Electronic Tech.
Darlene Condra	
John Cudnohufsky	
Jack Hampson	
Steve Kittelson	
Frances Wahl	

3. Equipment

Grab samplers (Shipek and VanVeen)
Gravity Corer
Underwater Camera
Minisparker

4. Sample and trackline localities

Eastern Gulf of Alaska between Kayak and Montague Islands and Prince William Sound

5. Data Collected

Grabs-------------------------------58
Cores------------------------------- 3
Bottom camera stations--------------14
Minisparker lines-------------------34; total length 1151 km

B. SEA SOUNDER Cruise

1. June 5-16, 1976; R/V SEA SOUNDER, U. S. Geological Survey

2. Scientific Party (all USGS personnel)

Paul Carlson Bruce Molnia	Cruise Leaders
Harry Hill	Electronic Tech.
George Redden	Chemist
Paula Quinterno	Micropaleontologist
Austin Post	Glaciologist
Darlene Condra Rich Garlow Glenn Schumacher	Navigation
Andrew Alden	
John Cudnohufsky	
Paul Fuller	
Jack Hampson	
Dennis Kerr	
Steve Kittelson	
Steve Wallace	
Elias Zendejas	

3. Equipment

Grab Samplers (Shipek and VanVeen)
Corers (Gravity and dart)
Underwater Camera
Underwater Television
3.5 KHz Transducer
Uniboom
90 KJ Sparker
Magnetometer
Side-scan sonar

4. Sample and Trackline Localities

Eastern Gulf of Alaska between Sitka and Seward, Cross Sound, Lituya Bay, Yakutat Bay and Icy Bay.

5. Data Collected

Grabs------------------------------------74
Cores------------------------------------12
Bottom Television Stations--------------11
Bottom Camera Stations----------------- 3
3.5 KHz---------------------------------2300 km trackline
Uniboom---------------------------------1512 km trackline
90 KJ Sparker------------------------- 857 km trackline
Magnetometer-------------------------- 800 km trackline
Side Scan Sonar----------------------- 200 km trackline

III. Results

A. Papers presented at society meetings during this past quarter:

Carlson, P. R., Molnia, B. F., and Bruns, T. R., 1976, Preliminary study of seafloor instability in the offshore Gulf of Alaska Tertiary province: Bull. of Am. Assoc. Petroleum Geologists, v. 60/4, p. 655.

Carlson, P. R., Molnia, B. F., and Reimnitz, Erk, 1976, Dispersal, distribution and thickness of Holocene sediment on the continental shelf, northern Gulf of Alaska: in, The Neogene Symposium: San Francisco, Soc. Econ. Paleont. and Sedimentol., p. 63-64.

Molnia, B. F., Carlson, P. R., and Bruns, T. R., 1976, Geologic hazards in the northern Gulf of Alaska: GSA-Cordilleran Section, Pullman, Wash., April 5-7, 1976, Abstract with Programs, Geol. Soc. Am., v. 8, no. 3, p. 396-397.

B. Open file report released during past quarter:

Carlson, Paul R., 1976, Submarine slides and faults that disrupt surficial sedimentary units, northern Gulf of Alaska: U. S. Geol. Survey Open-File Report No. 76-294, 27 p.

C. Paper submitted to Geol. Soc. of Am. for publication in Engineering Geology volume:

Molnia, Bruce F., Carlson, Paul R., and Bruns, Terry R., in press, Large submarine slide in Kayak Trough, Gulf of Alaska: Geol. Soc. of Am., Symposium Volume.

IV. Preliminary interpretation of results

High-resolution seismic profiles from the continental shelf of the northern Gulf of Alaska show a large submarine slide at the eastern edge of the Copper River prodelta. This slide which has moved down a slope of about 1^{0} to the bottom of Kayak Trough, is 17 km length, 12 km in maximum width, and has a minimum thickness of 115 m. The estimated volume of material affected is approximately 5.9×10^{11} m^{3}. In addition to very irregular surface morphology and disrupted internal reflectors, this massive slide has a fairly well preserved pull-apart scarp with a relief of about 10 m and a well-developed toe that is 20 m thick about 2 km from the distal end. The toe is partially buried, suggesting a "snowplow" type of movement as the slide moved down the gentle slope into Kayak Trough.

Sediment samples collected with a box corer from the surface of this slide consisted of structureless gray clayey silt of extremely low strength. Laboratory tests with a vane shear apparatus yielded a peak strength of 0.02 kg/cm^{2}.

Additional evidence of mass movement of Holocene sediment was seen on high-resolution profiles across the entire Copper River prodelta from Kayak Trough to Hinchinbrook Island; the evidence included disrupted bedding and irregular topographic expression. Similar structures were found on several profiles obtained from this area shortly after the 1964 Alaskan earthquake. We conclude that these structures were probably caused by the intense ground shaking that accompanied the 1964 Alaskan earthquake.

The Copper River is a major source of Holocene sediment that annually supplies 107 x 10^6 metric tons of detritus. Much of this sediment has accumulated on the prodelta, reaching a maximum thickness of 355 m southeast of the main channel and averaging about 150 m in thickness across the entire prodelta. The lag between accumulation and consolidation in regions such as deltas, which have high rates of sedimentation, gives rise to excess pore pressure.

Underconsolidated sediment is prone to sliding; such effects must be considered in the design of offshore facilities that will no doubt follow the oil and gas lease sales of Gulf of Alaska Continental shelf tracts.

Analyses of seismic and sediment information collected from the R/V THOMPSON, NOAA SHIP SURVEYOR and FRS CROMWELL indicated the presence of four major sedimentary units on the seafloor of the continental shelf in the northern Gulf of Alaska. These units, which are characterized by distinctive morphology in seismic profile, are: (1) Holocene sediments, (2) Holocene end moraines, (3) Quaternary glacial marine sediments, and (4) Tertiary and Pleistocene lithified deposits.

The ages used to describe this material are based on relative stratigraphic positions and not on isotopic dates. The term Holocene is applied to sediment accumulating today and to end moraines formed in historic time. The term Quaternary is applied to glacial marine deposits interpreted as having been deposited on the continental shelf during Pleistocene time when sea level was lowered eustatically. This unit may include Holocene ice-rafted sediment Tertiary and Pleistocene ages are applied to the stratified sedimentary rocks, which are at many places folded, faulted, and truncated. These rocks are similar in lithology and structure to onshore lithified deposits. Stratigraphically, Holocene sediment overlies Quaternary glacial marine sediment or Tertiary and Pleistocene lithified deposits. Quaternary glacial marine deposits overlie the lithified material.

Holocene sediment blankets the entire nearshore area between Hinchinbrook Island and the south end of Kayak Island, and Holocene sediment forms the surface fill in the Hinchinbrook Seavalley and covers the area south of Tarr Bank and north of Middleton Island. East of Kayak Island, Holocene sediment blankets the nearshore area except for Holocene morainal areas at Icy Bay and the Bering Glacier, and an area of Tertiary and Pleistocene bedrock that crops out southwest of Cape Yakataga between Cape Suckling and Icy Bay. Holocene sediment occurs in a series of isolated pods toward the outer edge of the continental shelf. Characteristically, Holocene sediment is well stratified with continuous reflectors extending for many kilometers. Maximum thicknesses observed are greater than 350 m.

Holocene end moraines are found at the mouth of Icy Bay and south of Bering Glacier and may lie south of the Malaspina Glacier and at the mouth of Yakutat Bay. In seismic profile, end moraines have very irregular surfaces with hummocky lobes exhibiting rapid changes in depth; they typically show discontinuous subbottom reflectors. Pockets of flat-lying sediment are frequently found ponded behind morainal lobes.

Quaternary glacial marine sediments are found in a narrow arc that borders the north and west sides of Tarr Bank and in a large arc 20 km or more offshore that parallels the shoreline between Kayak Island and Yakutat Bay. In profile glacial marine sediments show many hummocky discontinuous subbottom reflectors. In many places, glacial marine sediments have filled parts of glacially carved U-shaped bedrock valleys.

Tertiary or Pleistocene stratified sedimentary rocks, in profile commonly folded, faulted, and truncated, crop out on Tarr Bank, offshore of Montague Island, and in several localities southeast and southwest of Cape Yakataga.

V. Problems encountered/recommended changes.

We recommend reducing the number of reports. Too much time and energy are being expended for reports that are redundant because of the short time intervals between reporting periods.

VI. Estimated funds expended to date: 90% of total allotted.

RU# 251

NO REPORT SUBMITTED

The principal investigator is in the field.

TITLE: Offshore Permafrost - Drilling, Boundary Conditions, Properties, Processes and Models

PERIOD: 1 April 1975 to 30 September 1976

PRINCIPAL INVESTIGATORS: T. E. Osterkamp and W. D. Harrison

Geophysical Institute, University of Alaska,
Fairbanks, Alaska

I. TASK OBJECTIVES

(1) To carry our a nearshore drilling program during spring 1975 at Prudhoe Bay.

(2) To determine the thermal and chemical boundary conditions of offshore permafrost in shallow water areas (< 5 m depth) and to determine the properties of sea bottom sediments in these areas.

(3) To do preliminary laboratory and theoretical work necessary for an understanding of the offshore permafrost regime with an emphasis on the coupling of chemical and thermal processes.

II. FIELD AND LABORATORY WORK

Field Work: A field trip was made to Prudhoe Bay during the 1st week of May. Sea bed temperatures were measured at 18 sites in the Prudhoe Bay area. Most of these sites were located along our drilling line established during May 1975. In addition, two sites just south of Reindeer Island, one north of Cross Island and one south of Gull Island were occupied in order to extend our observations over a greater area. The hole on land was also logged for temperature for the fifth time.

Our lightweight driving rig was tested to determine its performance in the sandy gravel soils at Prudhoe Bay. We found that we could easily drive AW drill rod to a depth of 45 feet using the above apparatus. An even greater depth could have been achieved had we so desired.

A jetting technique for installing pipes in the subsea permafrost (to obtain temperature profiles) was also tested. We found that we could reach depths of 20-25 feet easily and quickly. However, it appeared that the high porosity of the subsea gravels and the resulting lack of return flow along the outside of the pipe was preventing us from achieving greater depths.

III. RESULTS

We have just begun to analyze the results of the above field work. These will be available in our next quarterly report.

IV. INTERPRETATION

The results of our drilling effort during May 1975 have been analyzed and are incorporated into a separate report. Three copies of this report are attached.

V. PROBLEMS/CHANGES

None

VI. ESTIMATED FUNDS EXPENDED

Approximately $90,000.

TITLE: (Addition) Delineation of most probable areas for sub-sea permafrost in the Chukchi Sea from existing data

PRINCIPAL INVESTIGATORS: W. D. Harrison, S.S. #554-70-4301
T. E. Osterkamp, S.S. #357-28-7107
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99701

GEOGRAPHICAL AREA AND INCLUSIVE DATES: (Addition)

Chukchi Sea
April 1, 1976 - September 30, 1976

I. TASK OBJECTIVES

To delineate the most probable areas for subsea permafrost in the Chukchi Sea from existing data.

II. FIELD AND LABORATORY WORK

None

III. RESULTS

An examination of available data relevant to the existence of subsea permafrost in the Chukchi Sea is in progress. These include water temperature and salinity, ice cover, bathemetry, and sedimentation. To date we have collected most of the available temperature data.

IV. PRELIMINARY INTERPRETATION OF RESULTS

The data have not yet been interpreted. It is hoped to complete the work by late summer.

V. PROBLEMS

None

VI. ESTIMATE OF FUNDS EXPENDED

$3,000

Quarterly Report

Contract #03-5-022-55
Research Unit #271
Report Period: 5th Quarter Ending July 1

Beaufort Sea Coast Permafrost Studies

James C. Rogers
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99701
907-272-5522, x 225

July 1, 1976

I. Task Objectives -- See previous reports.

II. Field or Laboratory Methods

A. No field work done during the last quarter ; however, plans have been made for field work during the month of July on the USGS Vessel KARLUK. Three 40" air guns will be used as well as digital ehancement techniques to increase the penetration of the seismic refraction measurements. Also, further experimentation with combined reflection and refraction measurements will be carried out.

B. J. Rogers and J. Morack participated in data analysis on data from the 1975 field season. Peter Barnes of the USGS aided in the 1976 field season planning.

C. In addition to the standard refraction analysis discussed in the last quarterly report several records have been scaled for reflection events.

D. The dashed line of Figure 1 indicates one track of the Karluk through Prudhoe Bay in 1975. It shows the location of the seismic measurements that were analyzed for refraction information in the previous quarterly report and have been recently scaled for reflection events.

E. Approximately 30 reflection points have been identified which are thought to correspond to reflection returns from the permafrost surface. These points are plotted in Figure 2 from the shore to a distance of about 15 kilometers from the shore line.

III. Results

In addition to the refraction information on the seismic records, discussed in a previous report, prominent reflection events have been observed. After scaling, these events have been plotted on Figure 2 along with the refraction and drilling information of Harrision and Osterkamp. The figure, a crossection along the vessel transect, shows the upper permafrost surface to a distance of about 15 kilometers from shore. The reflection points, as identified on the figure, are seen to fit rather well with the refraction and drilling data near shore. Data from a hole drilled to a depth of about 150m by Humble Oil on Rheindeer Island indicate frozen sediments from sea level to 20m depth and again from 90m to 125m (Reimnitz and Barnes, 1974). The vessel transect passed about two kilometers west of the island with the nearest point being over a shoal as shown on Figure 2. The depth to the reflector as determined by the reflection data is approximately 100m at the shoal, a figure thought to be in good agreement with the 90m depth of the island drilling data. Although the refraction information failed to indicate permafrost at distances several kilometers from shore it did provide a good measure of the seismic energy velocities in the non-frozen sediments. These velocities were used in calculations of depth to the reflectors which are believed to be the upper surface of the permafrost.

IV. Although all records have not been examined in detail, the preliminary interpretation of the reflection events is that they correspond to returns from the upper surface of the permafrost. The reliability of the depth estimate may be within ±15% of the depth shown on Figure 2.

V. In general the refraction equipment lacked the penetration desired. Additional air guns will be used as well as signal enhancement techniques. Also, hydrophone streamer noise will be reduced as much as possible. More time is planned for field work this year than was possible during the 1975 field season which was curtailed by bad ice conditions.

VI. Estimate of funds spent to date: $65,000.

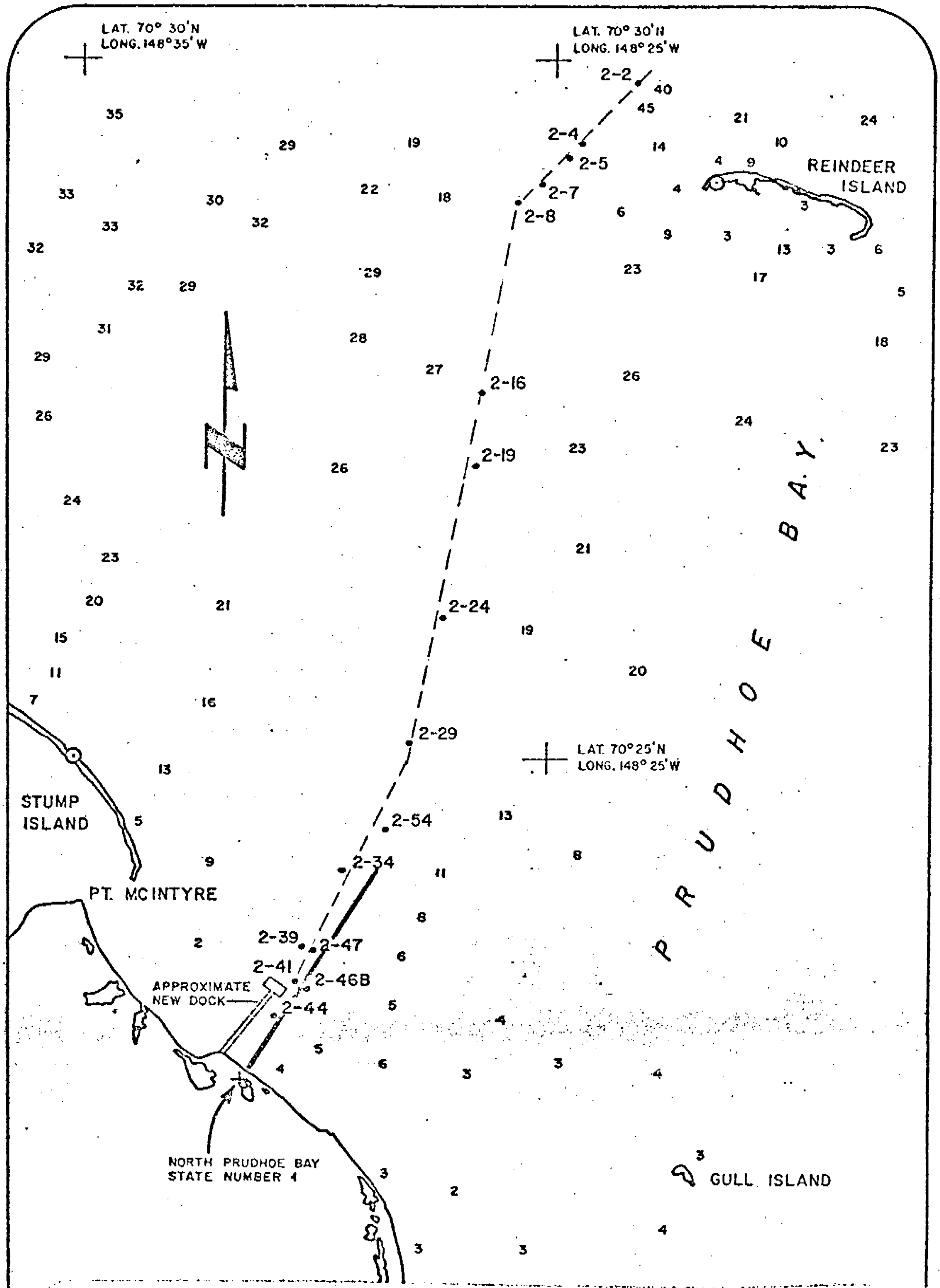


FIGURE 1. Refraction line in Prudhoe Bay shown by dashed line. Drill holes are located along the heavy line starting at North Prudhoe Bay state No. 1 and running N 32.5° E a distance of 3.4 km. Water depths are shown in feet.

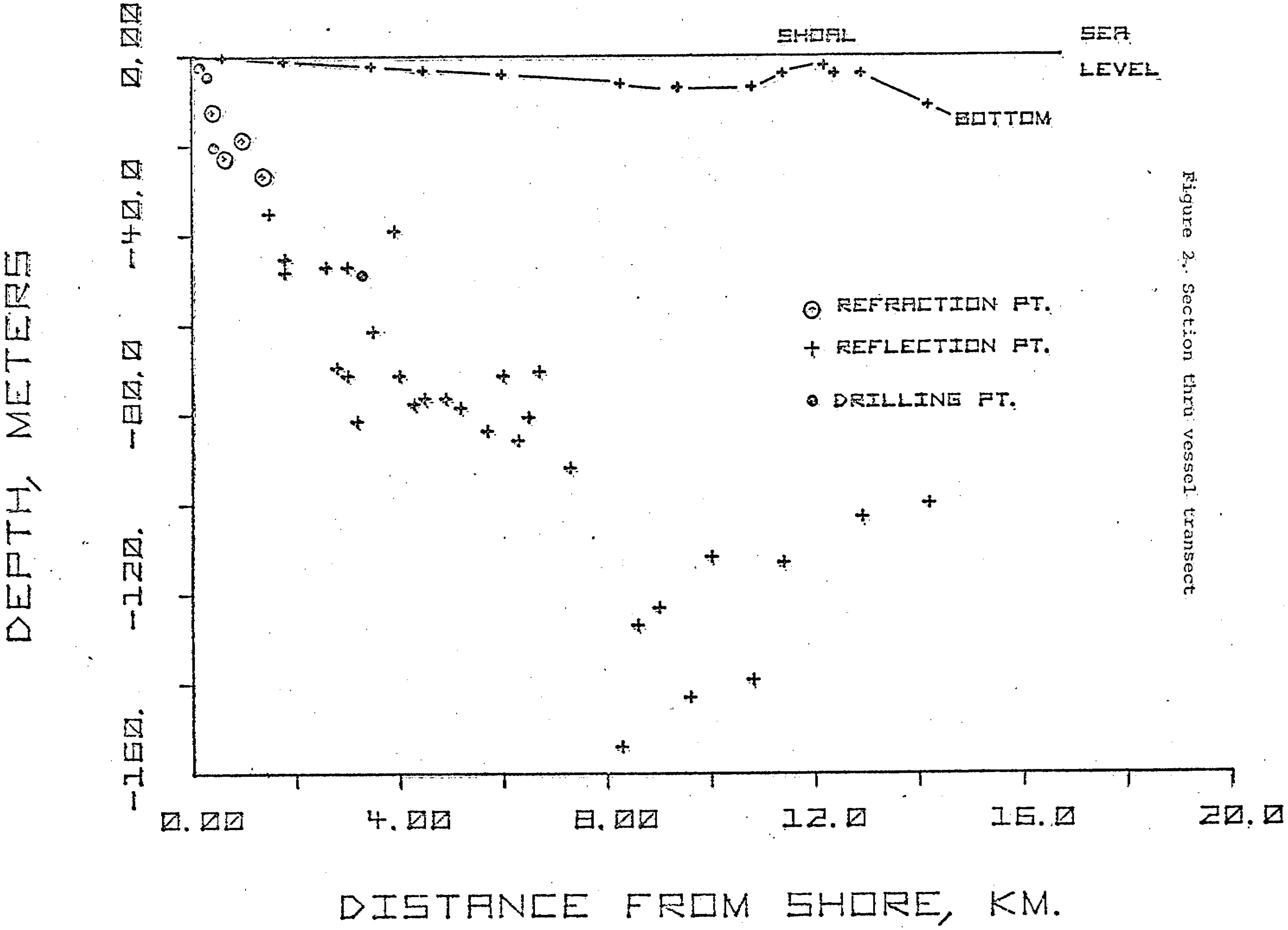


Figure 2. Section thru vessel transect

QUARTERLY REPORT

Contract 03-5-022-56
Task Order Number 3
Quarter Ending -
30 June 1976

BENTHOS-SEDIMENTARY SUBSTRATE INTERACTIONS

Dr. Charles M. Hoskin
Associate Professor of Marine Science
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

June 30, 1976

QUARTERLY REPORT

I. Task Objectives

Grain-size analyses for the 66 samples available have been completed. Previous Quarterly Reports indicated a larger total number of samples ultimately would be available but these additional samples are duplicates and do not represent new stations. A computer program for data reduction has been acquired from the University of Washington through the continued efforts of Ms. G. H. Kris Tommos. Raw grain-size data are now being key-punched, and the first computer run for data analysis is expected to occur during the week of 18 June - 2 July. With the help of Mr. Ray Hadley, the grain-size data will be formatted according to previously agreed upon standards. Size-frequency curves, depicting the variation of particle abundance through the size spectrum of 32.0 to 0.00098 mm will be begun shortly, and completed within the next quarter. Correlation between grain-size modes (peaks on the size-frequency curves) and abundance and distribution of the macrobenthos will be done next quarter with the help of Dr. Howard Feder and Mr. George Mueller.

II. Field Activities

None.

III. Results

Correlations between grain-size of bottom sediment from the Bering Sea and distribution and abundance of the macrobenthos is just starting, hence no results are available for this quarterly report.

IV. Problems Encountered

Ms. Connie Espe, who did outstanding work in performing pipet analyses of mud fractions, left the project due to uncertainties of continued funding.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: June 30, 1976

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 3 R.U. NUMBER: 291

PRINCIPAL INVESTIGATOR: Dr. C. M. Hoskin

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]		
	From	To	Batch 1		
Discoverer Leg I #808	5/15/75	5/30/75	*		
Discoverer Leg II #808	6/2/75	6/19/75	*		
Miller Freeman	8/16/75	10/20/75	*		

Note: [1] Estimated submission dates are contingent upon final approval of data management plan submitted in draft form Oct. 9, 1975 and University of Alaska approved form Nov. 10, 1975, to NOAA. Also, receipt and approval of data format is necessary.

* Data will be available for transfer to magnetic tape by 30 July. Transfer and submission will be made approximately 30 days after receipt of format and management plan approval.

5th Quarter Report

OCSEAP RU#327

Faulting and Instability of Shelf Sediments, Western Gulf of Alaska

Principal Investigators: Monty A. Hampton
Arnold H. Bouma
U.S. Geological Survey
Menlo Park, California

I. Task objectives

Assessment of the environmental geologic hazards of the western Gulf of Alaska continental shelf; in particular the identification and mapping of active surface faults and areas of sediment instability.

II. Activities

This past quarter was spent outfitting our new environmental research ship, R/V SEA SOUNDER, for the upcoming field season in Alaskan waters, and preparing for our particular cruise this summer. We will be in the lower Cook Inlet from 18 June to 1 July and on the Kodiak Shelf from 3 July to 30 July. Enclosed are our track lines for regional high-resolution seismic profiling. Approximately half of our time at sea will be spent on the profiling. The other half will be spent obtaining bottom samples and running closely spaced high-resolution profiles, side-scan sonar, and bottom photography. The locations for bottom sampling and closely spaced profiles will be determined at sea, from the regional seismic profiles, in key areas of environmental and historical-geologic concern.

QUARTERLY REPORT

Contract:
Research Unit: 352
Reporting Period: April 1, 1976-June 30, 19
Number of pages: 1

SEISMICITY OF THE BEAUFORT SEA, BERING SEA AND GULF OF ALASKA

Herbert Meyers
Solid Earth Data Services Division D62
National Geophysical and Solar-Terrestrial
Data Center
EDS/NOAA
Boulder, Colorado

June 30, 1976

I. Task Objectives. To prepare a seismic history for Alaska in a manner which will permit independent assessment of risk for any specific region of interest.

II. Field or Laboratory Activities.

A. Ship or Field trip schedule.
None

B. Scientific Party.
Work is being performed by various members of NGSDC under the direction of Herbert Meyers.

C. Methods.
Data being used are those in the files of NGSDC, supplemented by appropriate data from other sources.

D. Sample localities/ship or aircraft tracklines.
All available epicenter and felt information for Alaska and adjacent regions.

E. Data collected or analyzed.
Approximately 10,000 epicenter determinations and 4,000 felt reports will be summarized.

III. Results.

Thus far, NGSDC has printed and distributed two publications in support of the OCSEAP Alaska project. The publications are:

A Historical Summary of Earthquake Epicenters In and Near Alaska.

Catalog of Tsunamis in Alaska.

These publications will also be available on demand from any individual who has a need for these types of data. Work is continuing in the preparation of additional publications.

IV. Preliminary interpretation of results.

The data are presented in a fashion which will readily permit assessments of recurrence frequency of various types earthquakes and relative risks for areas of interest.

V. Problems encountered/recommended changes.

None

VI. Estimate of funds expended.

Approximately 80% of the $32K available for this project has been spent.

RU# 407

NO REPORT SUBMITTED

Principal investigator will submit final report next quarter

ICE

ICE

QUARTERLY REPORT

Contract # 03-5-22-67
Research Unit #87
Reporting Period: 1 April 1976 -
30 June 1976
Number of Pages: 4

THE INTERACTION OF OIL WITH SEA ICE IN THE BEAUFORT SEA

Seelye Martin
Department of Oceanography, WB-10
University of Washington
Seattle, Washington 98195

24 June 1976

I. Task Objectives: To understand the small scale interaction of petroleum and sea ice in the Beaufort Sea. Our eventual aim is to predict how an oil spill or well blow-out would interact with the mobile pack ice of the Arctic Ocean.

II. Field or Laboratory Activities

II-1. Laboratory Activities: During the past quarter, in our laboratory research on the absorption of oil by ice grown in a wave field, we have prepared for a spill of Prudhoe Bay crude oil in our laboratory wave tank. Our preparations consisted of building an oil delivery device, arranging lighting so that we can film the spill, running a few test rolls of movie and still camera film to check our exposure values, and calibrating our paddle. We plan to carry out the oil spill experiment by 15 July 1976.

II-2. Field Activities:

A. Field Trip Schedule:

1. Dates: 14 May 1976 - 1 June 1976
2. Aircraft: Bell 205 helicopter (registration 15W) chartered from ERA Helicopter

B. Scientific Party

Seelye Martin, University of Washington, chief scientist
Peter Kauffman, University of Washington, had responsibility for electronics and photographic equipment
Steven Soltar, University of Washington, helper and photographer

C. Methods: Sampled ice properties along traverses running out of Lonely, Deadhorse, and Barter Island, Alaska. We also took three cores from the ice between Prudhoe Bay and the Barrier Islands. We analyzed ice cores for their salinity, temperature, and crystal structure.

D. Sample Localities: See attached map

E. Data Collected or Analyzed:

1. Numbers and types of sample/observations: 23 ice cores plus one set of photographs of ice growing in a wind-wave field.
2. Number and types of analysis: we measured the temperature and salinity profiles of the ice cores as well as photographed their crystal structure.
3. Miles of trackline: 190 nautical miles.

III. Results: A formal data report will be submitted by 1 September 1976. Generally, the ice was very warm, with brine channels observed at almost every station. We have excellent photographs of the ice cores.

IV. Preliminary Interpretation of Results: N/A

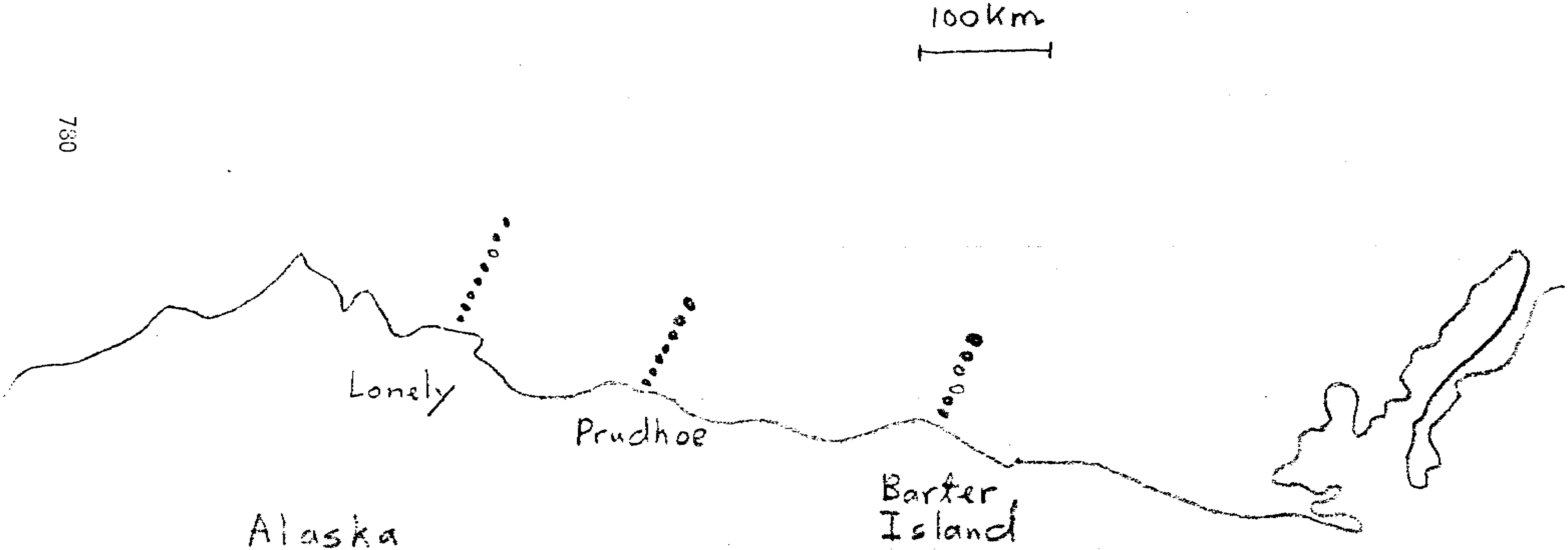
V. Problems Encountered/Recommended Changes: The warm weather on the North Slope during May created heavy fog over the ice during the latter part of the traverse, which created very dangerous flying conditions. Any repetition of helicopter flights in May should use a helicopter equipped for Instrument Flying.

VI. Estimate of Funds Expended: As of this date, we are about 97% expended.

Location of Ice Cores taken in May 1976

- ● ice core locations
- ○ site photographs only

note: core locations inside the Barrier Islands not shown



QUARTERLY REPORT

P.O.: 01-3-022-2313
Research Unit #88
Reporting Period:
April-June 1976
Number of Pages: 8

DYNAMICS OF NEAR-SHORE ICE

W. F. Weeks and A. Kovacs
Cold Regions Research and Engineering Laboratory

22 July 1976

I. Task Objectives

1. Narwhal Island

   a. Collect quantitative information on the movements (velocities, directions, accelerations, and deformation rates) of the nearshore pack ice and the fast ice along the southern coast of the Beaufort Sea.

   b. Make observations on major ice deformation features that occur near the edge of the fast/pack ice boundary.

   c. Test the operation of an air-borne radar system for measuring the thickness of sea ice.

   d. Document the nature of the internal crystal structure of the fast ice in the vicinity of Narwhal Island.

2. Bering Strait

   a. Complete arrangements leading to the installation of an ice monitoring radar system at the Bering Straits.

3. Remote Sensing

   a. Obtain further laser profiles over the near-coastal sea ice.

II. Field Activities

1. Narwhal Island

   a. Schedule. Field operations started in early March were continued through the end of May. The project's field operations were closed down by mid-June as scheduled. Support was provided by NOAA helicopter (transportation) and NARL (groceries).

   b. Scientific Party. Dr. G. D. Ashton, Dr. A. J. Gow, Dr. W. D. Hibler,

A. Kovacs, Dr. S. J. Mock, W. B. Tucker, and Dr. W. F. Weeks.

c. Methods. Laser and radar ranging systems were used to study ice motion; ice thickness variations were determined using a pulsed swept-frequency radar system; surface topography and internal structure of a large grounded multiyear shear ridge system were determined by leveling and drilling respectively; ice structure and composition were determined using standard glaciological and oceanographic techniques.

d. Sample localities. All observations were made in the general area of Narwhal and Cross Islands (NNE of Prudhoe Bay) and up to 40 km out to sea (toward the NE). Figures of the exact locations of our ice motion targets will be provided in our final report.

e. Data collected. Ranging data were obtained every 3 hours on 8 radar transponders to study the motion of the near-shore "pack" ice and daily (or twice daily) on 6 laser targets to determine the motion of the fast ice; during the time periods when the ice motion measurements were underway, atmospheric pressure, wind speed and direction, and air temperature were recorded continuously; ice thickness profiles were made both between the barrier islands and the mainland and seaward of the barrier islands (both first year and multiyear ice were included in the profiles); ice surface topography and ice salinity,ice temperature, and porosity information to a depth of 62 feet were obtained from a large grounded multiyear shear ridge located north of Cross Island; and salinity, grain size, substructure size and crystal orientation data were collected from a large 1m x 1m (horizontal area) block of undeformed 2 m thick first year sea ice quarried just north of Narwhal Island.

2. Bering Strait

   a. No field activities at present.

3. Remote Sensing

   a. Schedule. The second series of laser flights were completed in the Chukchi and Bering Seas on 29 and 30 April using the NARL C-117.

   b. Scientific Party. M. Frank.

   c. Methods. A Spectra-Physics Geodolite Laser was used for the ice profiling. A Hasselblad 2 camera set with automatic feed magazines was also used to provide aerial photography of part of the ice included in the laser profiles.

   d. Aircraft Tracklines. Six sampling lines were used: 3 in the Chukchi Sea starting from Barrow, Wainwright and Point Lay and heading out to sea on a heading of 315° true and 3 in the Beaufort Sea starting from Lonely, Cross Island and Barter Island with a heading of 025° true. Each flight line proceeded out to sea for 200 km (108 nautical miles) and back.

   e. Data collected. Roughness of the ice surface for 2400 km of total track (analog record of the output voltage). For most flights the system was operated with full scale deflecting equal to 40 feet (vertical) in order to minimize the number of phase shifts. Roughly 2000 aerial photographs were also taken (covering one quarter of the laser track).

III. Results

1. Narwhal Island

a. Data from the radar ranging stations are in the final stages of editing. Preliminary results indicate surprisingly little ice motion even seaward of the 20 m water depth where the edge of the pack ice is commonly believed to occur. The only major ice motion occurred between April 13 to 19, 1976, when two targets of the 5 target array nominally placed on the pack ice (outside of the 20 m depth contour) moved approximately 5 and 3 km respectively to the northeast and then returned to within half a kilometer of their original position. The other three outer targets moved less than 100 m during the course of the experiment. The three radar targets within the 20 m depth contour moved less than 3 m (the accuracy of the system). The 5 laser targets located closer to the island showed overall movements as large as 0.5 m with some, but not all, of this motion being a slow expansion of the ice due to the general warming trend during the time period of the study (the spring). However, several targets exhibited rather rapid shifts of 0.2 m. Preliminary attempts to correlate these discontinuous movements with the magnitude of the offshore wind have revealed no strong relationships. The major motion of the coastal ice pack mentioned earlier did, however, correlate with strong westerly winds followed by a rapid shift to easterly. Further detailed analysis of the nature of the ice movement time series is currently underway. In general it might be said that the ice was appreciably more stable than anticipated even seaward of the 20 m depth contour.

b. The ice thickness profiling tests performed by A. Kovacs used an impulse radar system in a unique configuration which allowed for the first time the continuous profiling of first-year and multiyear sea ice thickness from not only the ice surface but also from the air. The antenna arrangement allowed for the independent determination of the velocity of the electromagnetic waves in the ice, the effective in-situ dielectric constant and the thickness of the ice. Ice thickness was measured from elevations ranging between 5 to 200 m above the upper ice surface. Good correlation was found between radar determined ice thicknesses and direct drill measurements. The undulating subsurface relief of both first-year and multiyear ice was quite clearly revealed.

c. The portion of a multiyear shear ridge field that was profiled (leveling and sonar) and sampled by drilling was both quite large (sail height 13 m) and grounded in 18 m of water. The ice in the upper 19 m of the ridge was low salinity and low porosity. Although the ice was cold above the water level, its temperature was essentially -1.8° C. at locations below the water level. The ridge studied was located in a large ice fragment (in plan view 8 x 1 km) comprised of a sequence of similar ridges.

d. The crystallographic studies showed that in the lower portion of the 2 m thick piece of sea ice (horizontal dimensions = 1m x 1m) there was a pronounced crystal orientation with all c-axes horizontal and aligned in the E-W direction. Although this alignment was not sufficiently pronounced for the bottom ice to be considered a single crystal, it would be sufficient to cause major changes in the mechanical properties of the ice with changes in the direction of the stress.

2. Bering Strait

a. Arrangements have been completed to assemble the complete M-33 radar unit from within existing governmental stocks. Preliminary discussions with the Director of Operations, Alaskan Air Command have, however, indicated some major possible problems related to installing the M-33 unit of top of Cape Mountain. A trip is currently scheduled for July 1976 to visit both DO/AAC and Tin City to attempt to resolve these problems.

3. Remote Sensing

a. The analysis of the laser data has not, as yet, started. An estimate of the cost to remove the phase shifts from the profile data has been obtained. The tapes have, however, been examined to ascertain the adequate operation of the basic data acquisition system during the data flights. Analysis of the SLAR imagery obtained by the USGS is underway. The initial parameter that is being studied is the variation in the amount of ridged ice as shown by SLAR as a function of distance north of the coastline at Lonely, Alaska.

IV. Preliminary Interpretation of Results

1. The ice motions that were observed particularly within the 20 m depth contour were smaller than anticipated. Even within the pack ice there was little net motion of the ice during the period of observation (we expected to see a net drift toward the west in agreement with the direction of rotation of the Pacific Gyral). We, however, caution that one winter's data is hardly adequate to draw any confident conclusions.
2. The impulse radar system appears satisfactory to study the variations in ice thickness within both first and multiyear ice. The data that has been collected will allow the estimation of the amount of oil that can be trapped within the relief of the bottom of the ice sheet. The system will not, at present, profile deep ridges.
3. The multiyear shear ridge fields that were observed, particularly in the vicinity of Cross Island, offer formidable obstacles for off-shore operations in the Alaskan Arctic. Whether the ice in the keels of such ridge systems is always near-melting temperatures remains to be studied. Clearly more effort should be devoted to documenting the frequency with which such ridge systems form and survive the summer.
4. If it can be demonstrated that the strong c-axis alignment that we observed north of Narwhal Island extends over areas of tens of meters (as has been suggested by studies of the electrical properties of sea ice) then it will prove necessary to use the

hard-fail strength in design calculations for structures in areas of fast ice (hard-fail strengths are from 2 to 6 times the strength values as usually stated).

5. Studies of the areal percentage of the amount of deformed ice as observed by SLAR indicates large lateral variations along the coast (40%) and a gradual decrease away from the coast from 70% near the fast ice boundary to 40% at 250 km. There is no well defined entity that can be described as the shear zone from this analysis.

V. Estimate of Funds Expended (as of 30 June 1976).

	Original	Remaining	Expended
Narwhal Island	$184,198.	$ 22,720.	$161,478.
Bering Strait	$ 98,579.	$ 72,720.	$ 25,859.
Remote Sensing	$ 42,000.	$ 0.	$ 42,000.

RU# 89

NO REPORT SUBMITTED

This research unit has been terminated.

QUARTERLY REPORT

Contract: 03-5-022-67, No. 5
Research Unit: 98
Reporting Period: 1 April - 30 June 1976
Number of pages: 31

DYNAMICS OF NEAR SHORE ICE
(Data Buoys)

Norbert Untersteiner
Professor of Atmospheric Sciences and Geophysics
AIDJEX Project Director
Division of Marine Resources
University of Washington
Seattle, Washington 98195

30 June 1976

I. Task Objectives

The University of Washington, under Task Order No. 5 of NOAA Contract 03-5-022-67, as amended, agreed to deploy 20 ice buoys to gather data on ice movement and oceanographic and atmospheric conditions in the near-shore areas of the Beaufort and Chukchi Seas of the Arctic Ocean and assist with the development of six additional buoys for later deployment. The buoy developments were to be accomplished in conjunction with field work being conducted by the Arctic Ice Dynamics Joint Experiment (AIDJEX). Three types of buoys were developed and produced for the task under contracts from the NOAA Environmental Research Laboratory monitored by the NOAA Data Buoy Office (NDBO). Fourteen of the buoys are designed to be dropped by parachute from aircraft and report position through the Random Access Measuring System (RAMS) of the NIMBUS-6 satellite. Two additional buoys of this type have been modified to include a pressure sensor. All 16 of these buoys and the six future buoys are produced by Polar Research Laboratory, Inc., (PRL) of Santa Barbara, California. The other four buoys are of a more complex design and are instrumented with atmospheric pressure and temperature sensors, current meters at 3 and 30 meters under the ice, and a RAMS platform to provide position. Again, all data are transmitted through the NIMBUS-6 satellite. These buoys were developed and produced by the Applied Physics Laboratory, University of Washington. Data from the buoys are placed in the AIDJEX Data Bank after receipt from NASA.

II. Field and Laboratory Activities

A. Field trip schedule

1. The spring buoy activities began on 18 March with a flight in the Canadian Twin Otter to attempt the repair of the Met-Ocean buoy west of Banks Island. About the same time, the PRL crew began checking out the second batch of eight air-drop buoys at Barrow.

Two of these were deployed north of Point Barrow from the NARL Twin Otter on 22 March, and two more, these equipped with barometers, were deployed on 30 and 31 March from the NARL C-117. On 5 May one buoy was deployed by NOAA helicopter north of Prudhoe Bay and another was deployed northeast of the MacKenzie River delta by the Canadian Twin Otter. The final deployment was on ice island T-3 by the NARL C-117 on 17 May. The eighth buoy was returned to PRL for readjustment.

B. Scientific Party

1. In addition to the air crews, the primary people involved in the field work were: Pat Martin, AIDJEX; Wally Brown and Gary Adams, PRL. Pat Martin coordinated the activities with the logistics people, supervised checkout and testing of the buoys, evaluated the barometer results prior to deployment, and defined the time and place of deployment. The PRL crew got the buoys ready for deployment and assisted in three of the drops.

C. Methods

1. All the buoys mentioned in this report are sampled by the Random Access Measurement System on board Nimbus VI. Position is determined and barometric pressure and ocean current data are recovered several times each day.

D. Sample Localities

1. The Met-Ocean buoy mentioned in A.1., was found at 73°14'N 130°15'W. The deployment sites of the other seven buoys were as follows:

Buoy ID	Date	Location	
0137	22 March	71°30'N 154°45'W	
1761	22 March	72°10'N 155°15'W	
1015	30 March	72°28'N 150°24'W	with barometric pressure and internal temperature
0207	31 March	76°11'N 141°06'W	with barometric pressure and internal temperature
1757	05 May	71°00'N 147°00'W	
0604	05 May	71°15'N 132°30'W	
0231	17 May	82°27'N 94°16'W	Ice Island T-3

E. Data collected or analyzed

1. A total of 17 OCS buoys were tracked during the quarter, the movements of which correspond to the ice drift. Useful barometric pressure measurements were obtained from two of these buoys, and ocean mixed-layer currents were measured from two other buoys.

2. The position data are being corrected, filtered, and smoothed to produce estimates of position at uniform times. (Figs. 1a, b, c, d; Figs. 2a, b, c, d) The ocean current data are being decoded and uniform data files are being constructed. (Figs. 1e, f, Figs. 2e, f). No detailed analyses have been conducted to date.

3. The seventeen buoys had an average drift of about 100 miles to the west during the quarter (Fig. 3).

III. Results

1. The accuracy of the position fixes of the buoys as delivered by NASA varies from 1.5 to 6 kilometers. Correction of along-track orbit errors holds the errors to less than 2 kilometers. (Martin and Gillespie, 1976). Following these corrections, edited time series are being produced.

2. Barometric pressure sensors were added to the air-drop buoys. When compared with the Weather Bureau pressures after initial temperature compensation, a residual pressure error of ± 0.3 mb remains. These results were obtained only after painting the buoys to keep out the sunlight and adding insulation to the barometers and temperature sensors. Further improvements may be possible since the residual error still appears to be correlated with temperature.
3. Mixed-layer ocean current data are being recovered from buoys off the MacKenzie River delta and north of Pt. Barrow. Current speeds at the same level are clearly correlated between these two buoys with a phase lag probably representative of the storms' advection velocity. The ratio of magnitudes between 2 and 30 meters is consistent with similar ratios at the AIDJEX manned camps (Figs 1e, f and Figs 2e, f). Work is underway on the process of calculating the true current directions from the magnitude compass headings and relative current bearings.

IV. Preliminary Interpretation of Results

Very little ice movement was detected through the winter months. During the spring, the ice has become much more active following a progressive loosening of the pack from west to east. There was a significant amount of transport southwest around Pt. Barrow as far south as Cape Lisbourne, which is currently being reversed by northbound currents through the Bering Straits. This effect is noticeable throughout the eastern Chukchi Sea. It will be very interesting to see whether there was any marked change in currents in this area, if the data can be extracted from the intermittently operating buoy off Wainwright.

The process of loosening up of the pack in the Beaufort Sea left a large area of ice relatively undisturbed along the north slope from Barrow to Barter Island extending roughly 60 kilometers offshore. Large offshore movements of this ice took place during storms early in the spring, but the area has been static lately on the scale of buoy and satellite observations. One buoy is located well inside this shore-ice area just north of Prudhoe Bay, while two or three others appear to be located just seaward of the zone of movement. Comparison of the movement of these buoys with the CRREL radar tracking data should be interesting. There appears to have been a significant amount of shear between two buoys initially only about 15 kilometers apart in this area.

V. Problems Encountered/Recommended Changes

There have been continuing difficulties with the Met-Ocean buoys, the latest of which has been the silence of 1416/1420 for a couple of months, followed by a resumption of operation on 1 June. It is recommended that this buoy, or the other malfunctioning one northwest of Pt. Barrow, be recovered for examination. The small amount of ocean current data which is being received is enough to indicate that this type of measurement will be sought after in the future. Without knowledge of the nature of the failures which have occurred, it is difficult to think of improving on the present results.

Three of eight air-drop buoys deployed in December, 1975, have ceased operation after the planned six months of life. This is of some concern since the only battery data available suggested that about 50 percent more life should have been available. If another of these buoys should fail in the next few weeks, an effort should be made to recover one of the buoys still in operation for inspection and test of the remaining battery life.

The Nimbus VI spacecraft which carries the Random Access Measurement System (RAMS) through which the buoy data are transmitted is just one year old. Many of the experiments on board the spacecraft have ceased to function after achieving their design life and mission objectives. The spacecraft tape recorder capability has deteriorated significantly. The continued operation of the spacecraft is currently under review and the future of the RAMS is not clear. NOAA may want to express interest in the continued operation of the system to NASA if continuation of the buoy data is desired.

VI. Estimate of Funds Expended

As of 30 June 1976, actual expenditures under this contract totaled $62,509.89. The estimated obligations under the contract which were not yet expended were about $13,100.

Fig. 1a

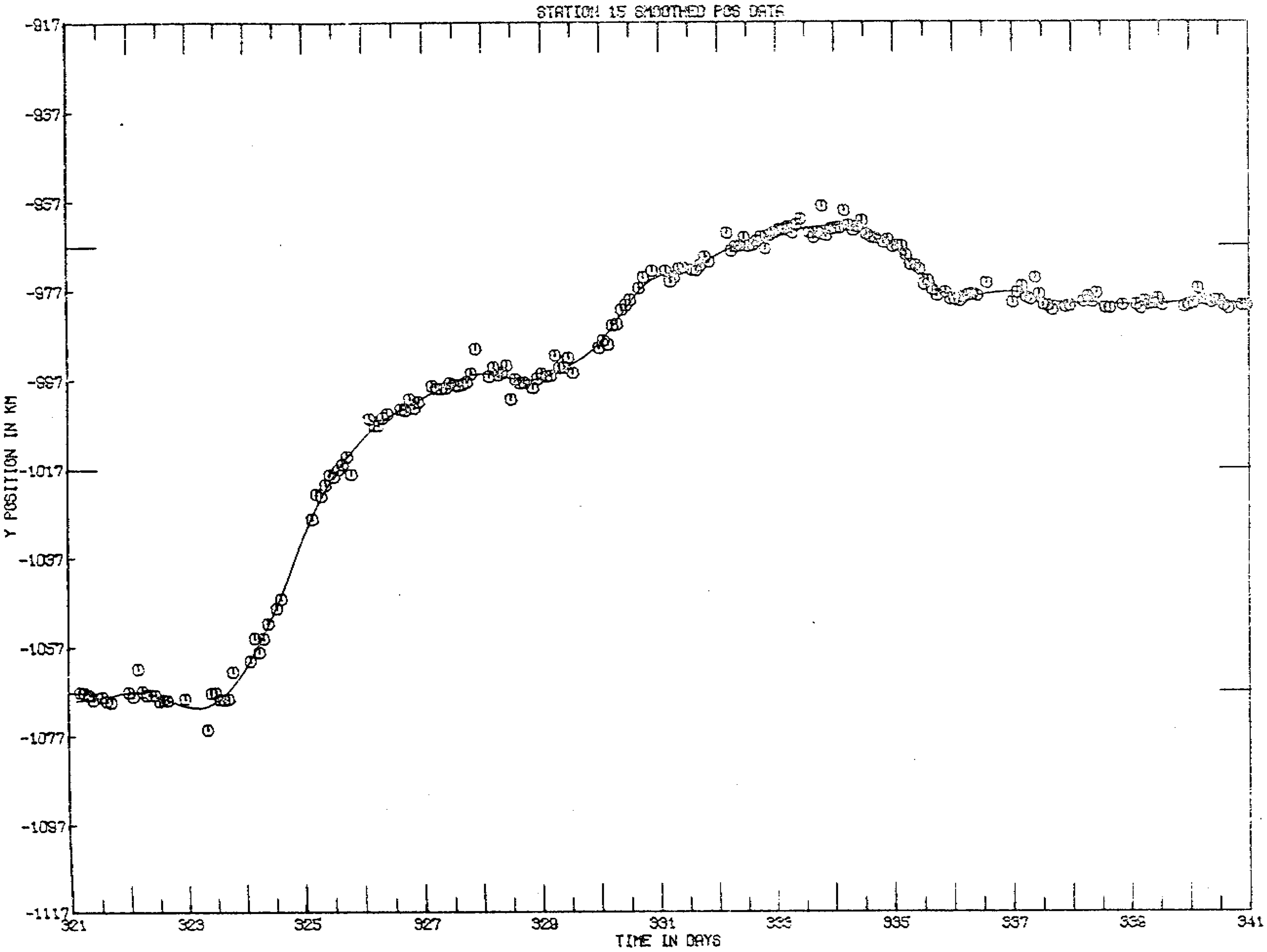


Fig. 1a One component of smoothed positions, RAMS 1420

Fig. 1b

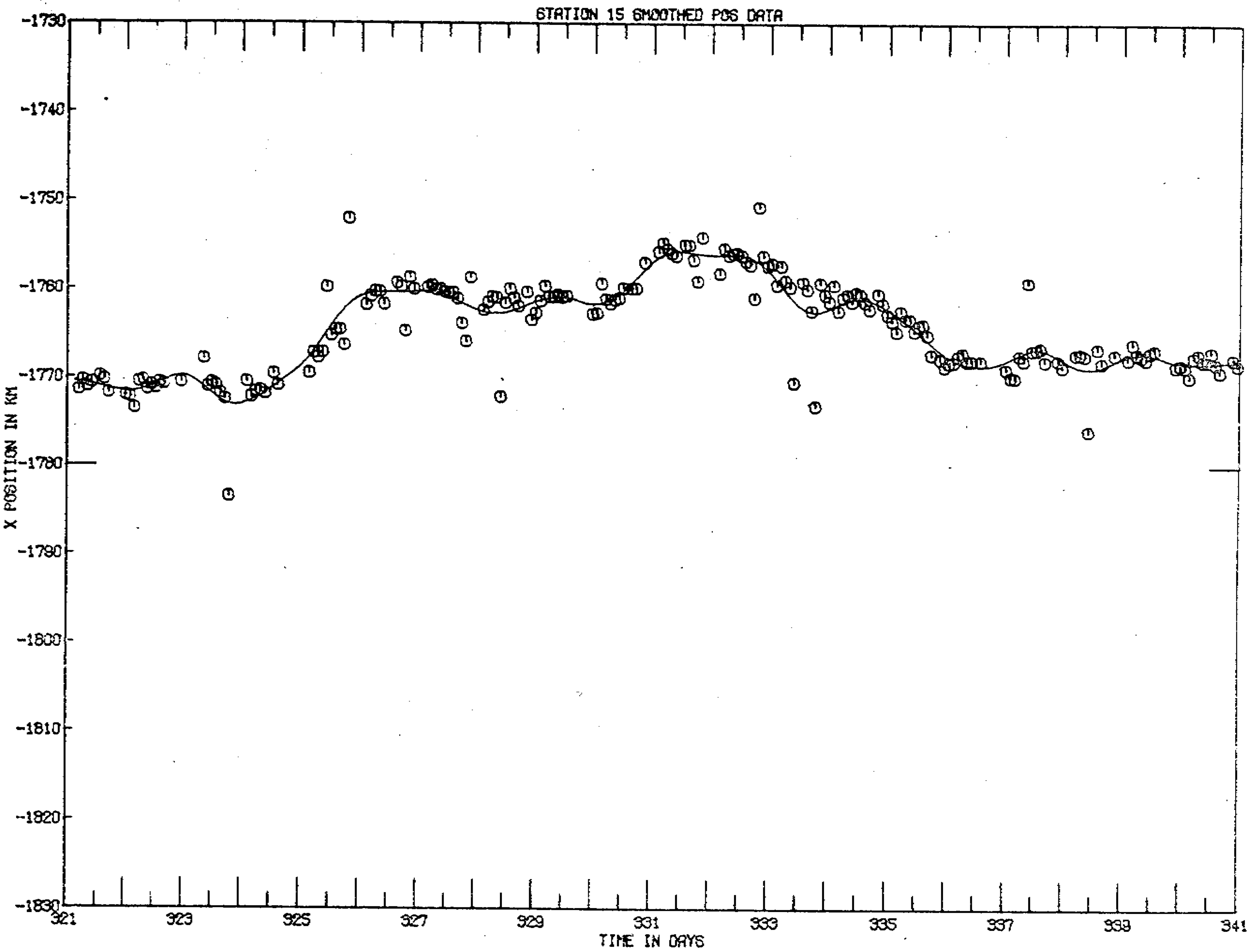


Fig. 1b The other component of smoothed positions, RAMS 1420

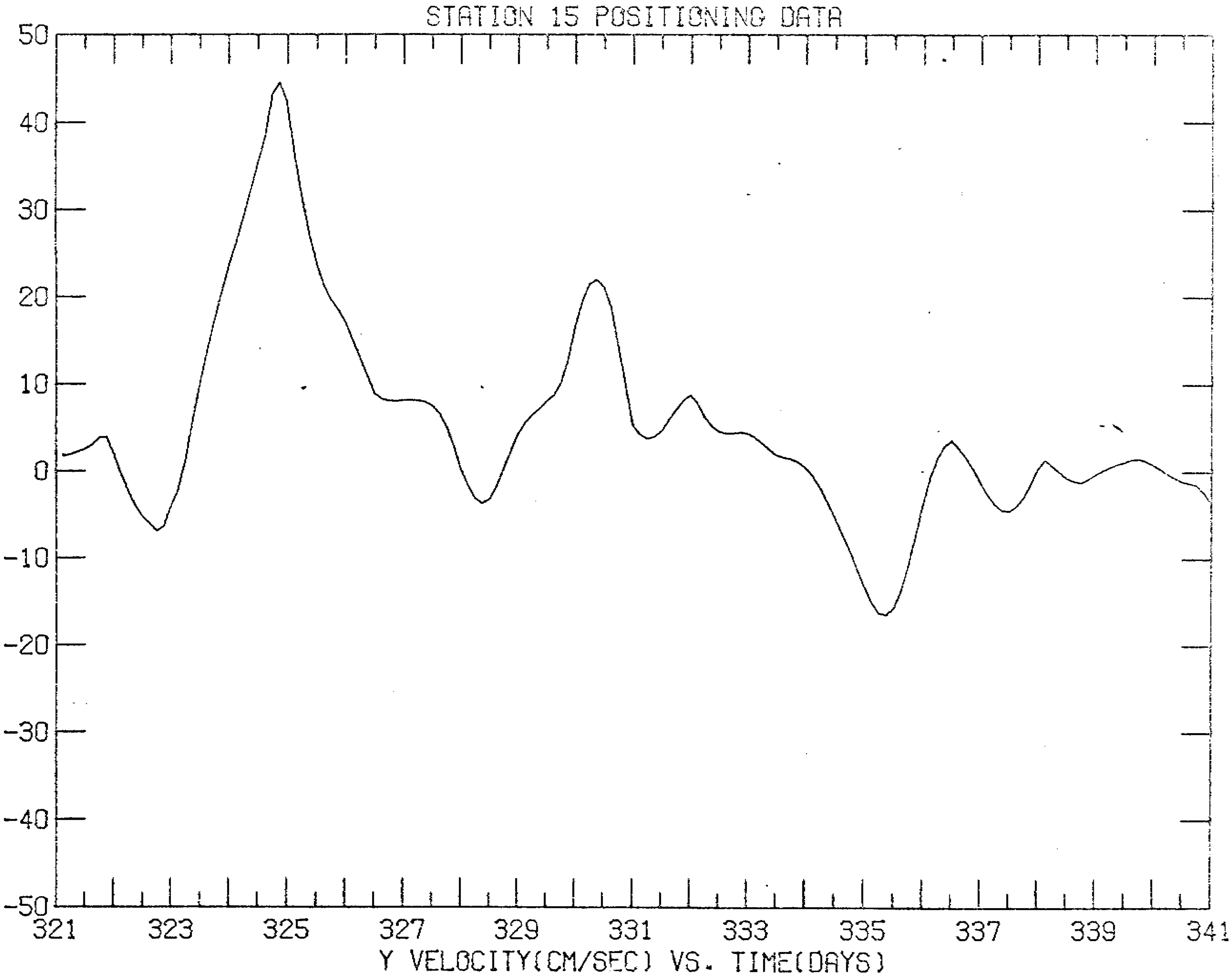


Fig. 1c. One component of velocity derived from smoothed positions, RAMS 1420.

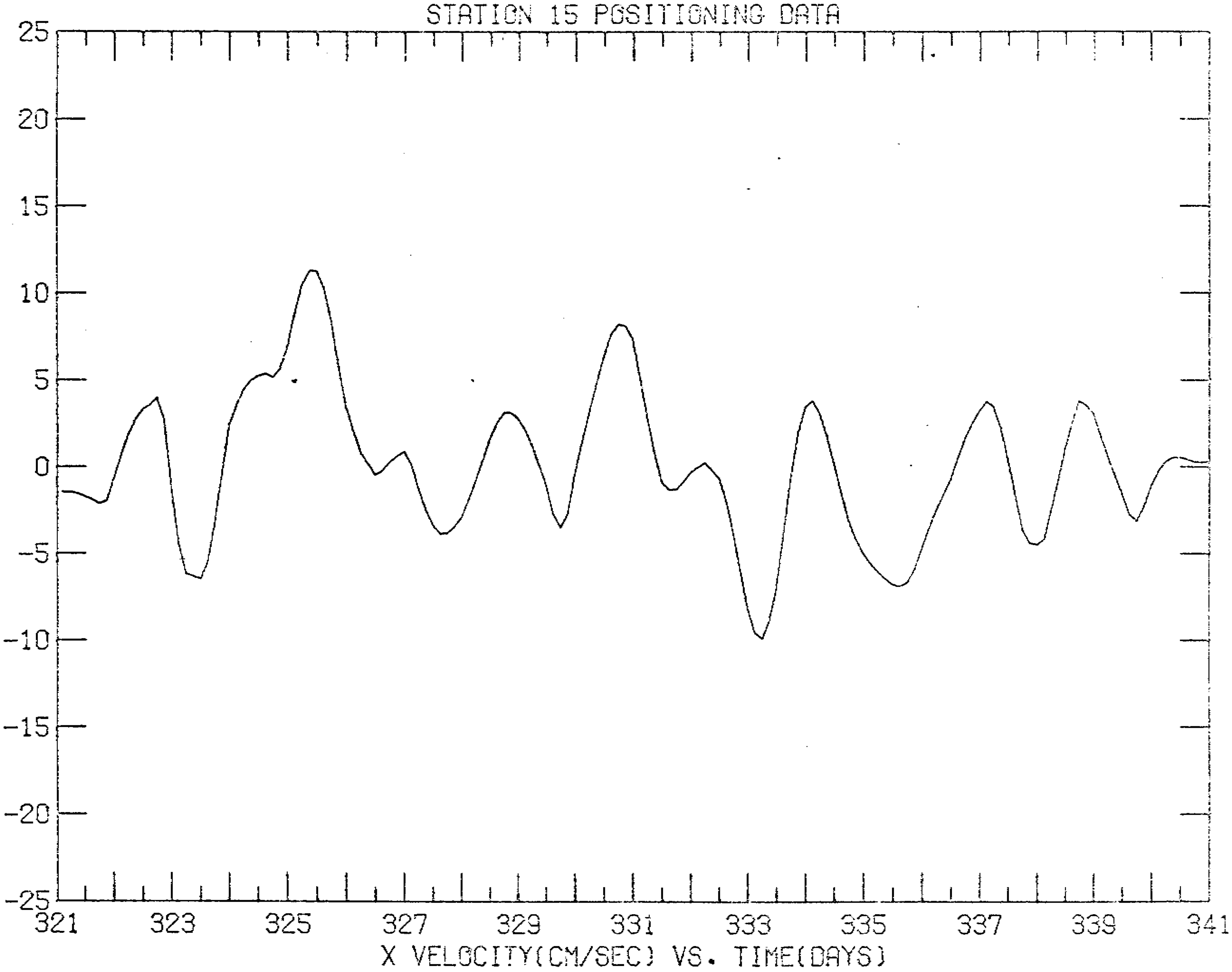


Fig. 1d The other component of velocity derived from smoothed positions, RAMS 1420

Fig. 2a

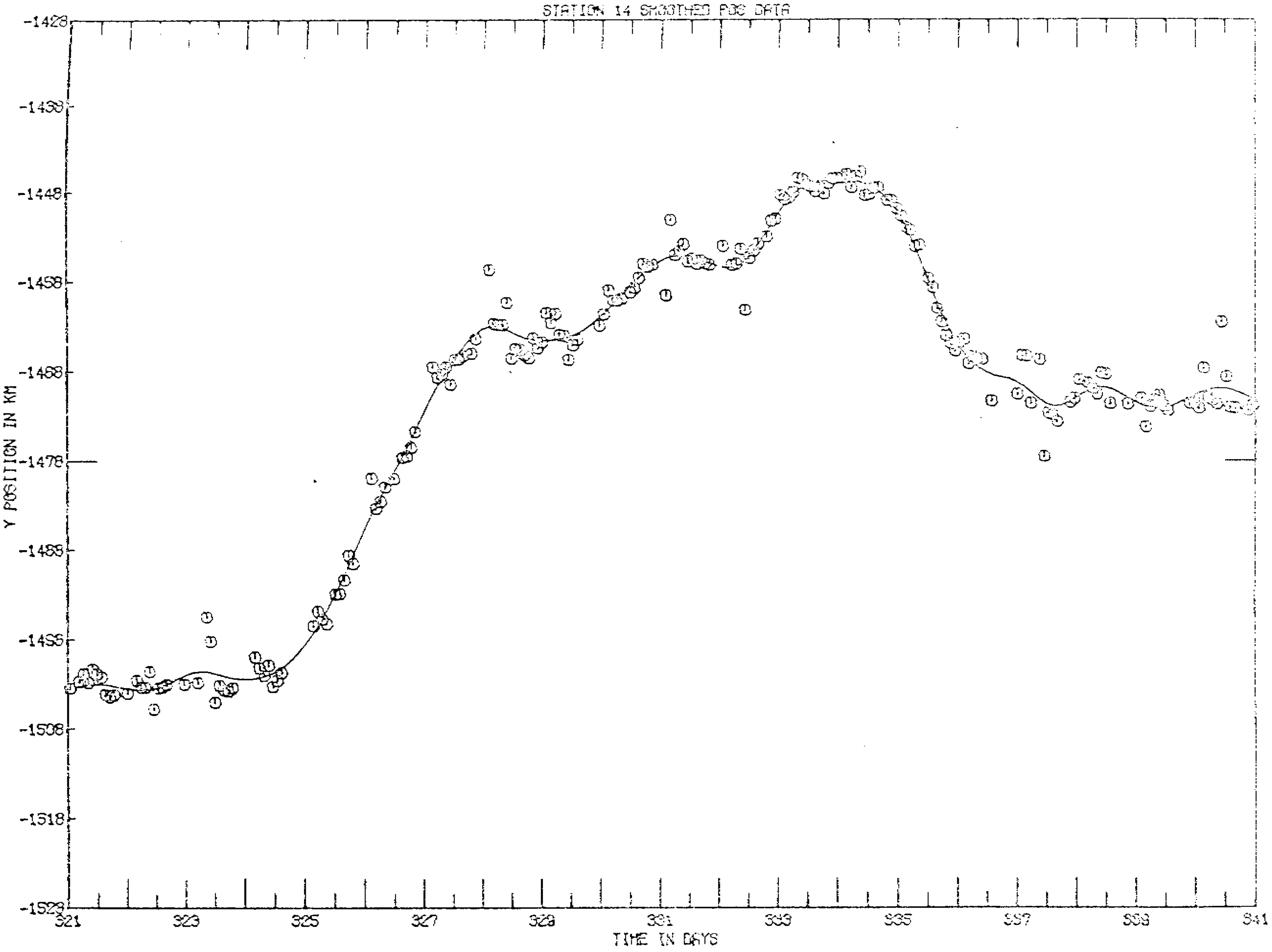


Fig. 2a One component of smoothed positions, RAMS 1273

Fig. 2b

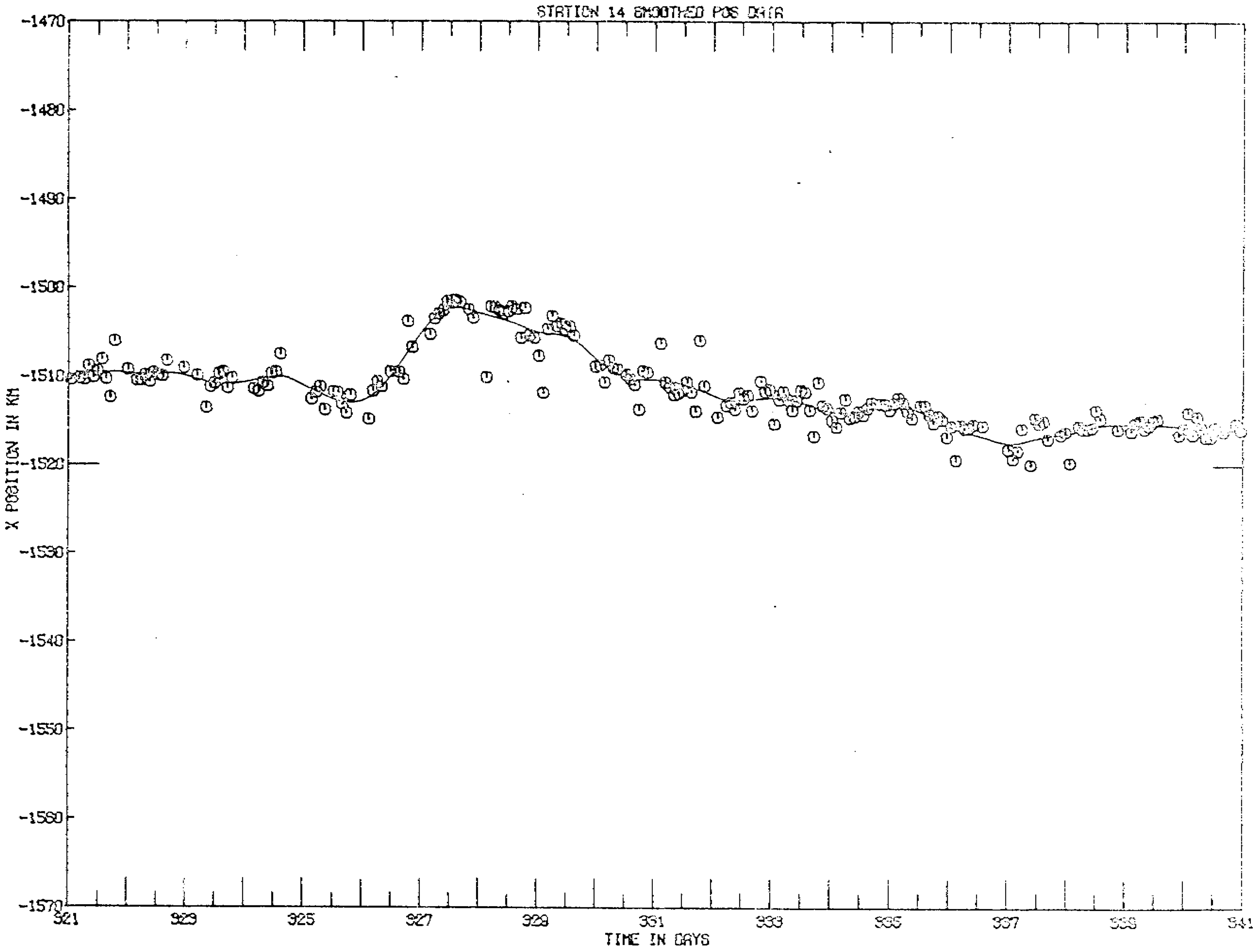


Fig. 2b The other component of smoothed positions, RAMS 1273

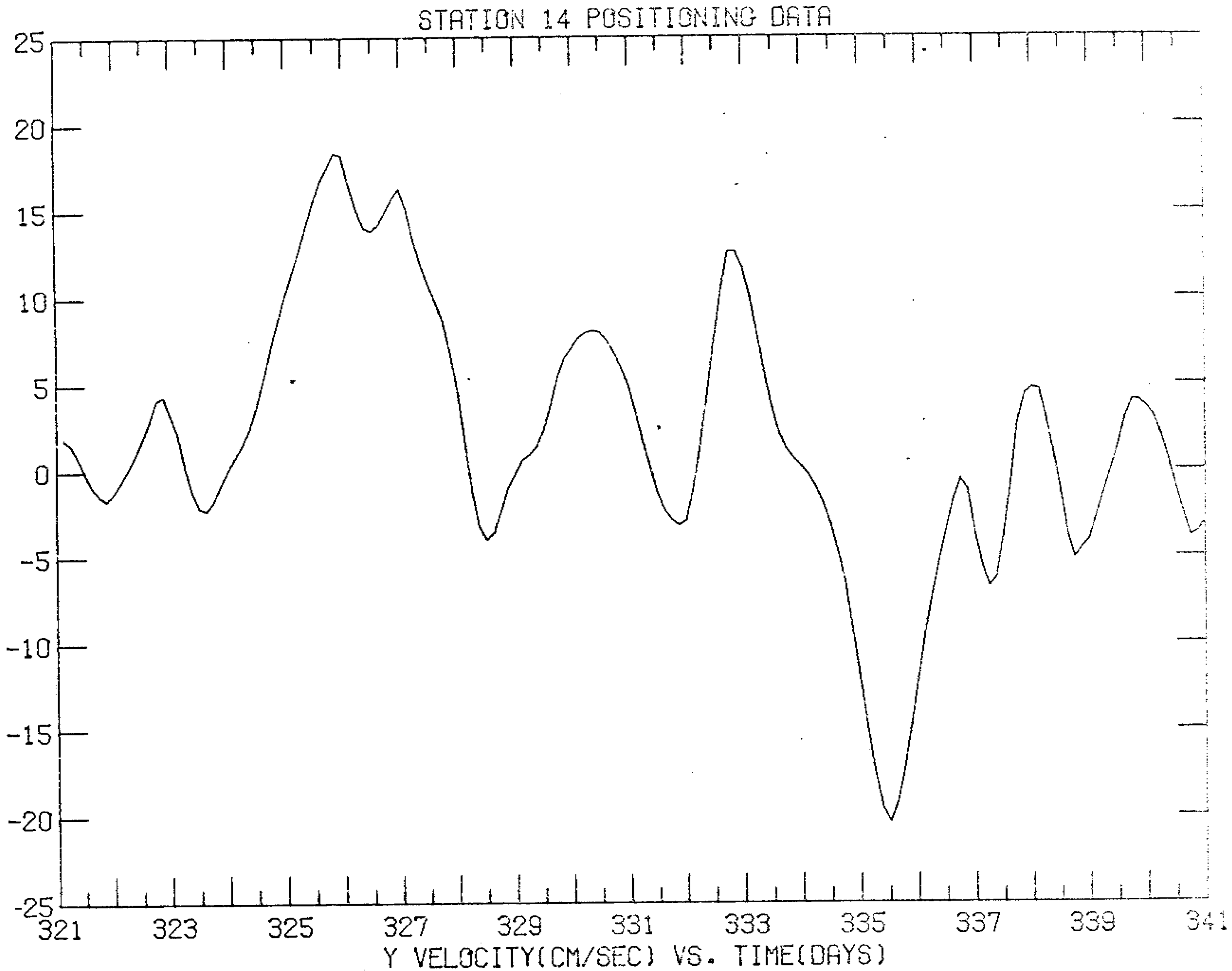


Fig. 2c One component of ice velocity derived from smoothed positions, RAMS 1273

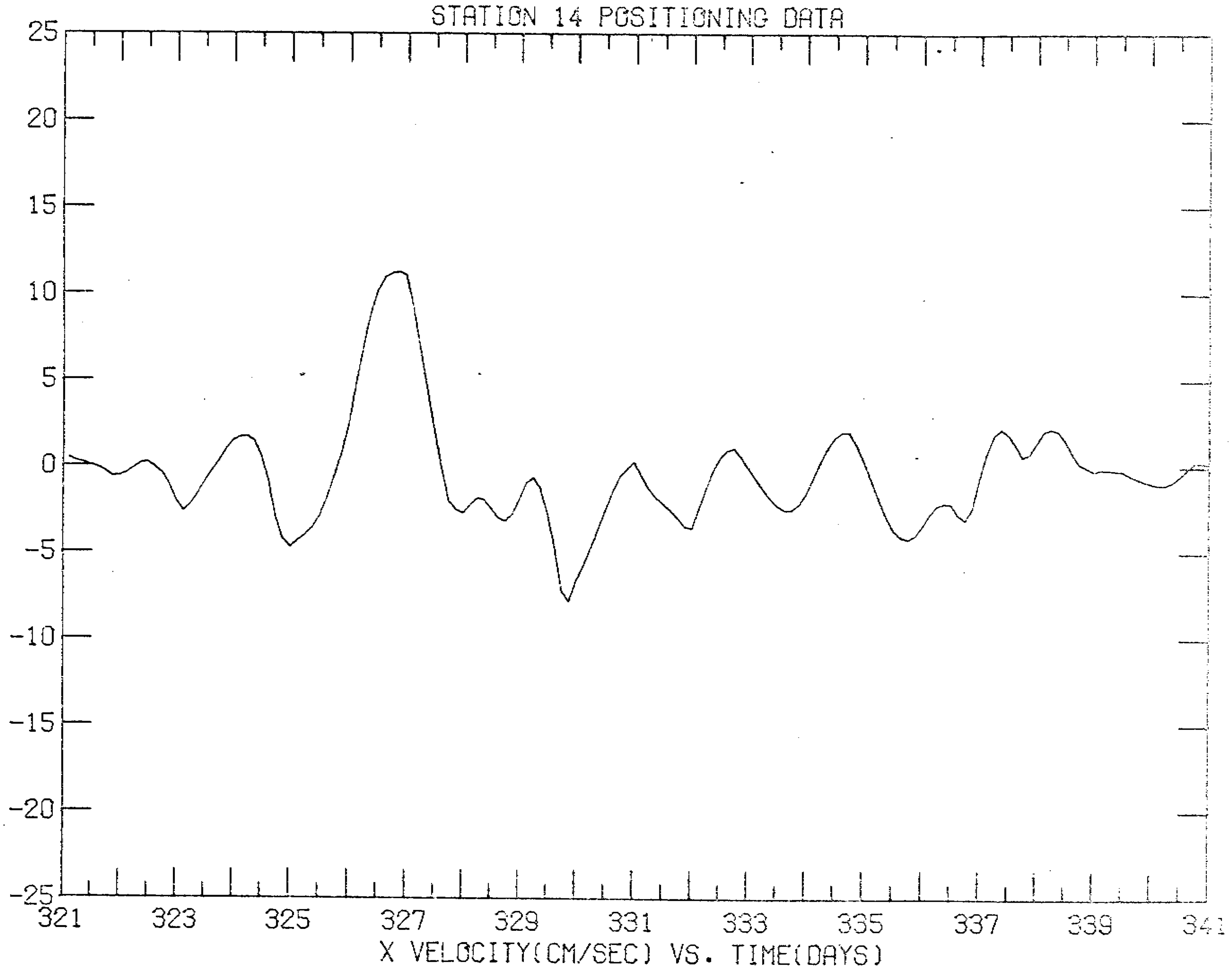


Fig. 2d The other component of ice velocity derived from smooth positions, RAMS 1273

Fig. 2e

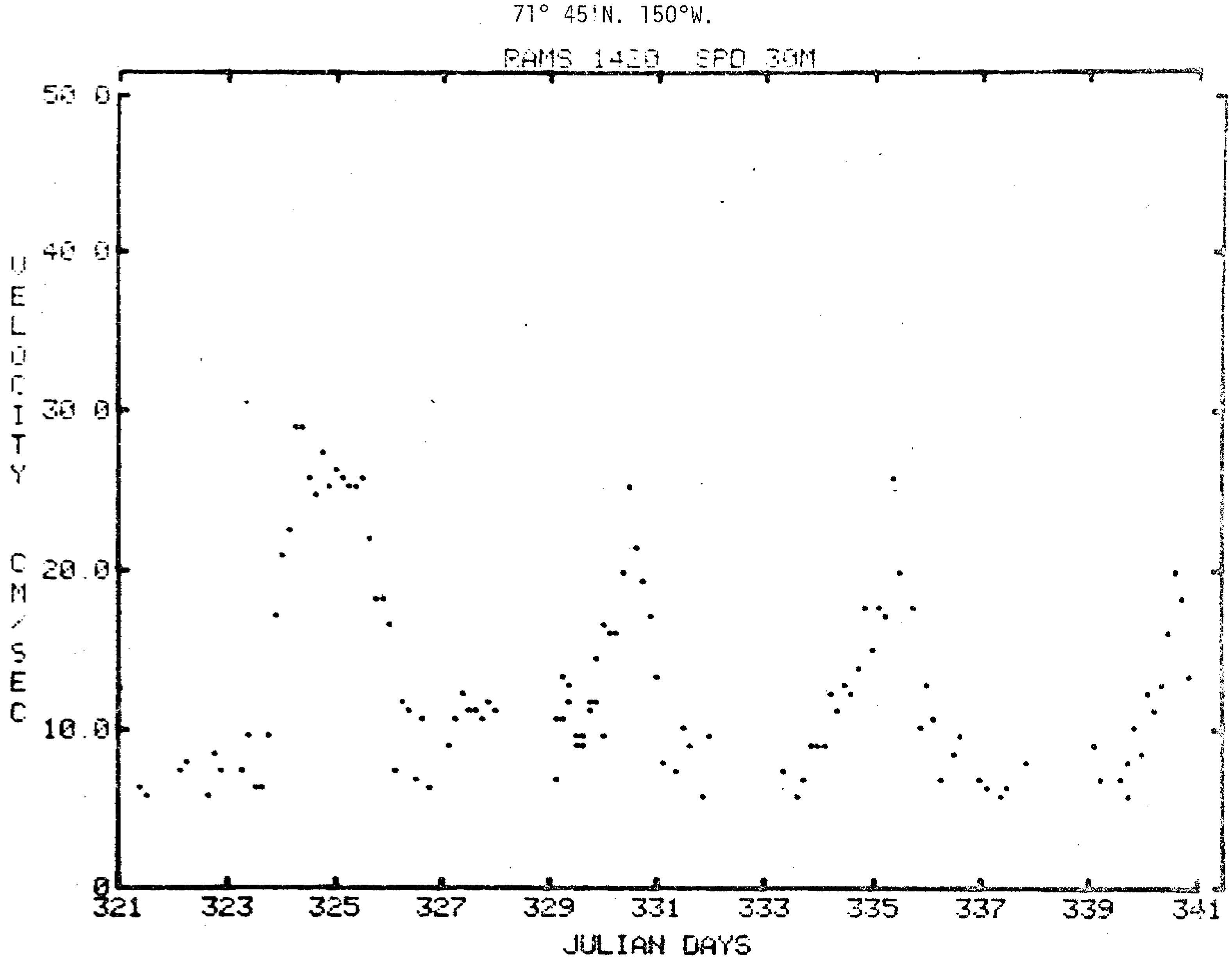


Fig. 2e Current speed at 30 meters relative to ice.

Fig. 2f

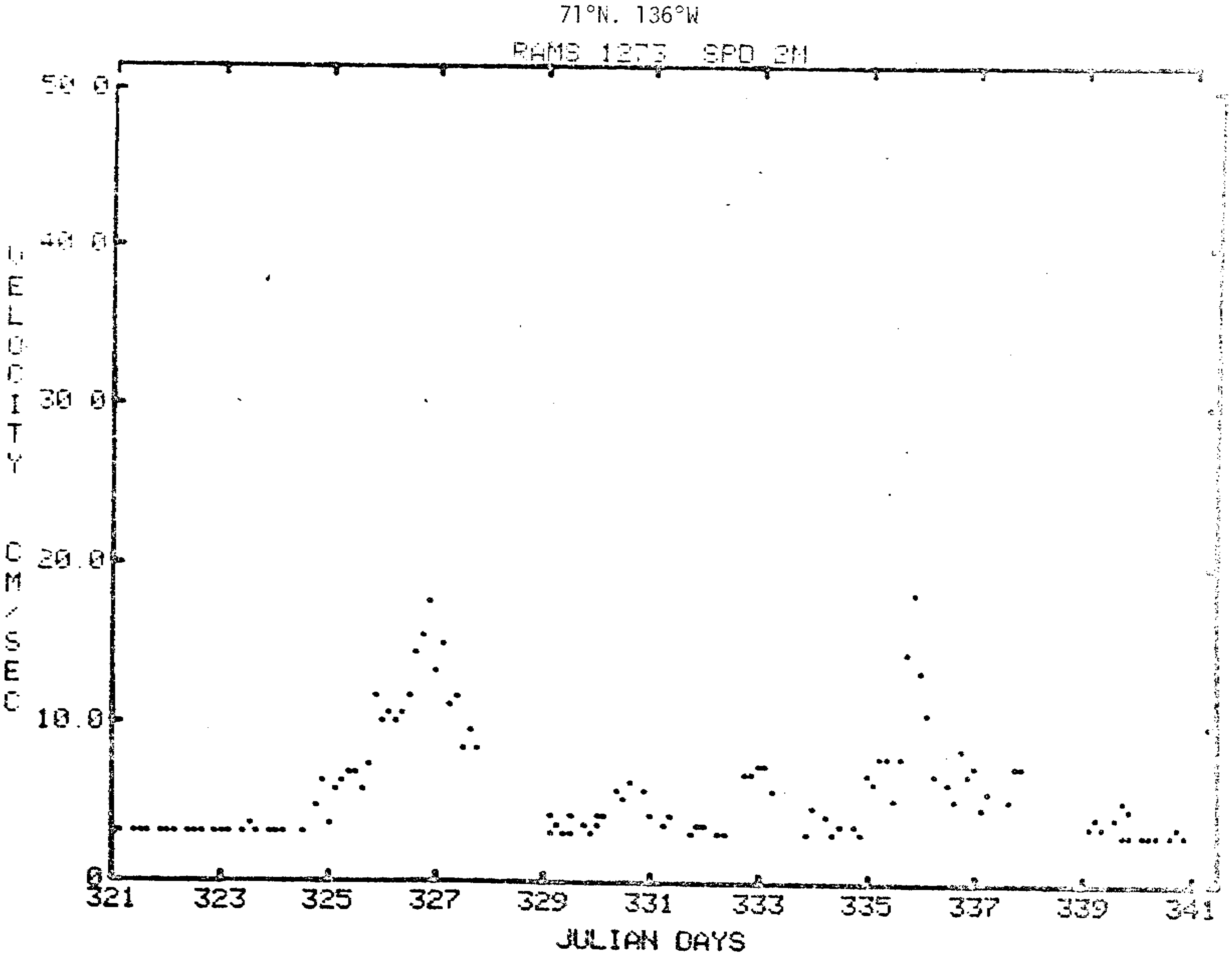


Fig. 2f Current speed at 2 meters relative to the ice.

Fig. 2e

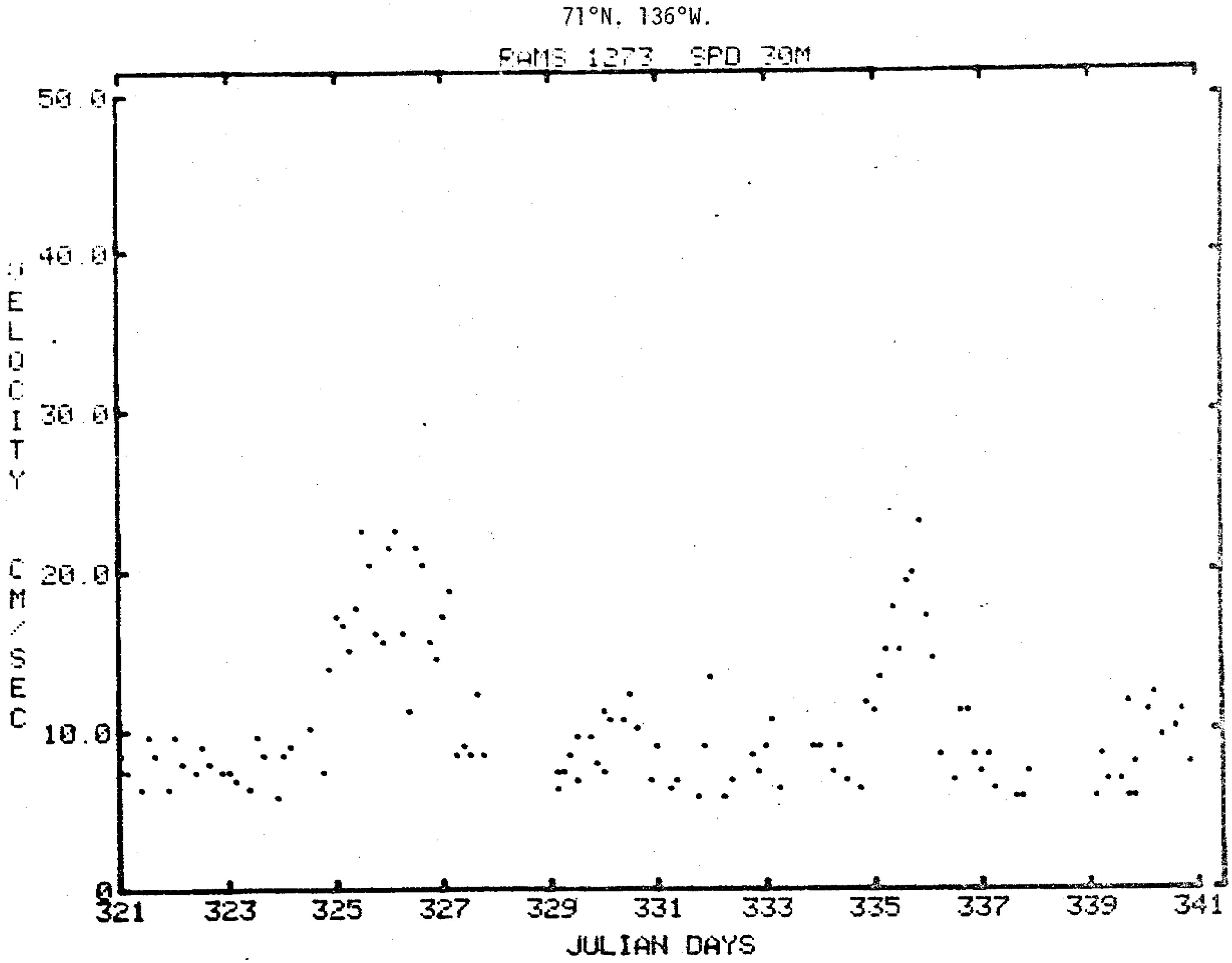


Fig. 2e Ocean current speed at 30 meters relative to ice.

Fig. 2f

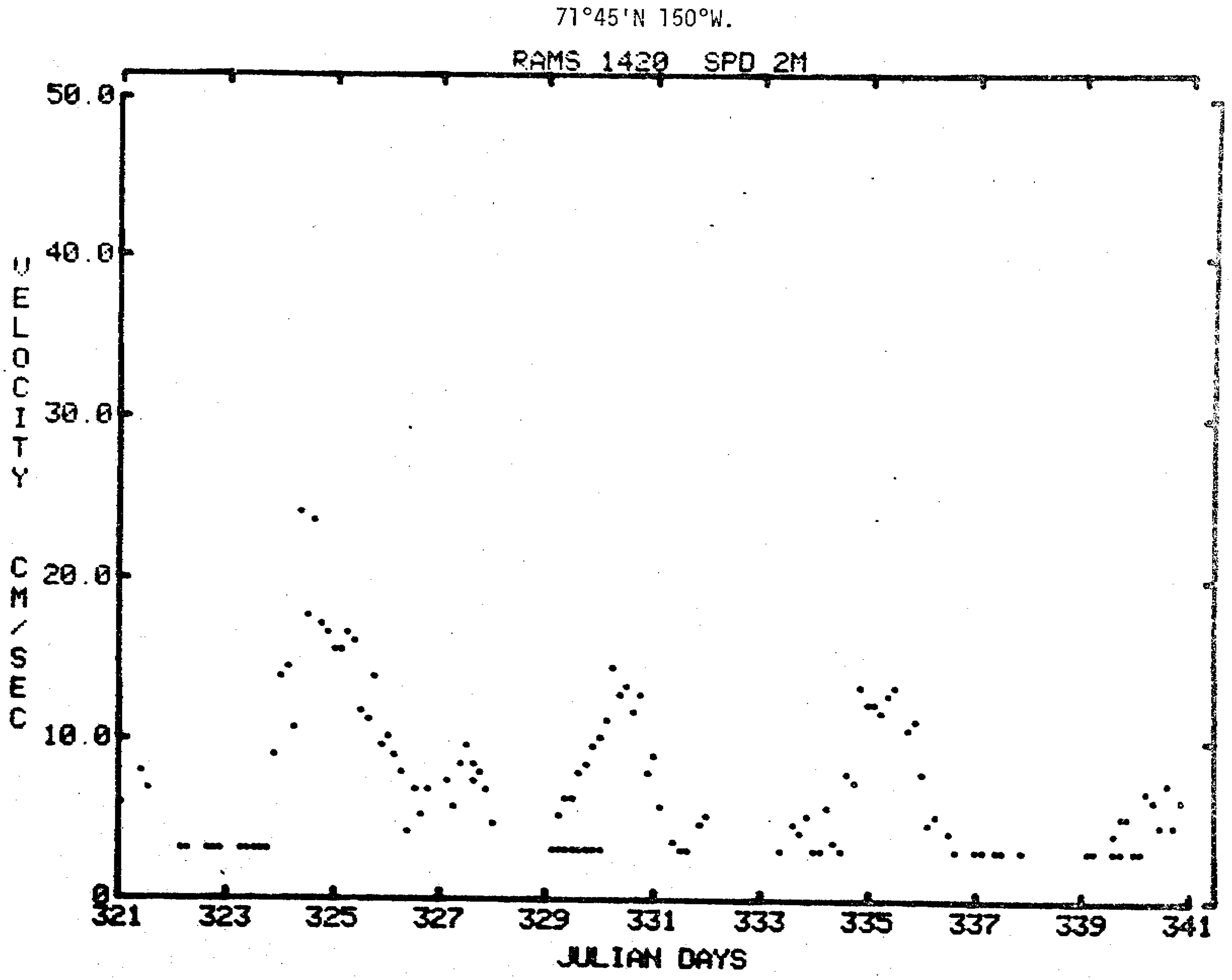


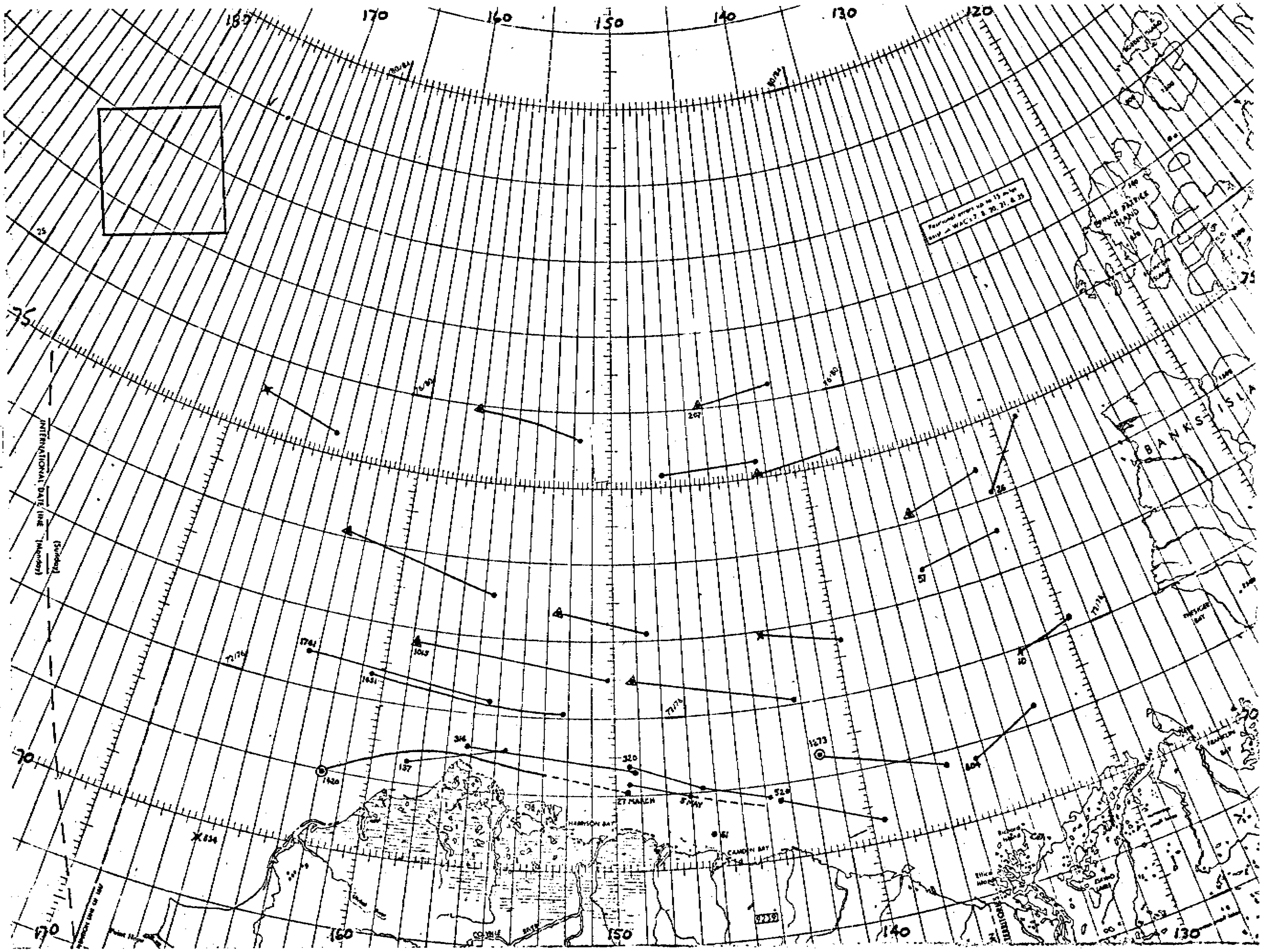
Fig. 2f Current speed at 2 meters relative to the ice.

Fig. 3

Drift from
18 April - 15 June

- ● position only buoys
- ✗ buoy currently not being received
- ◉ buoys with ocean currents
- ▲ buoys with barometric pressure

Buoy ID's given only for OCS buoys



ARCTIC ODYSSEY--FIVE YEARS OF DATA BUOYS IN AIDJEX

Pat Martin and C. R. Gillespie

AIDJEX
4059 Roosevelt Way, N.E.
Seattle, Washington

1. Introduction

The objective of the Arctic Ice Dynamics Joint Experiment (AIDJEX) is to reach a better understanding of the interaction of sea ice with the environemnt [1]. The main field experiment ended in May 1976 after one year of data collection on the Arctic Ocean. Data buoys were used to define the motion of ice on the perimeter of the area of interest and to measure the surface barometric pressure over the same area (Fig. 1).

2. Data Buoys

2.1. Data Results

A pilot experiment was conducted on the Arctic Ocean in the spring of 1972, during which data buoys made detailed measurements of barometric pressure to develop and test atmospheric boundary layer theories in preparation for the main experiment. An array of buoys which operated for a year after this experiment provided drift and surface pressure and temperature data which were also used to plan the main experiment [2].

During the 1975-1976 experiment, time series of position and pressure were obtained from a ring of 6-8 sites with accuracies adequate for numerical modeling. Two months of these position data were accurate to 100 meters.

An array of buoys with about 100-kilometer spacing along the coast of the Beaufort Sea provided position data needed to interpret shore effects on the main array. These buoys should last through 1976 and, together with the buoys further from shore which should last until 1978, will provide data valuable to ice research and forecasting along the north coast of Alaska.

2.2. Development Results

Six types of sea ice buoys have been developed over a period of five years. Each has unique features which have met data collection requirements and contributed to the evolution of new designs. The principal characteristics of each are given in Table 1. Actual field experience with these buoys and the technologies incorporated in them now totals about 30 buoy-years and is increasing at a rate which makes full evaluation of hardware performance and data very difficult (Fig. 2).

Six Arctic Data Buoys were deployed in 1972; four of these lasted about one year. The longest life was 667 days and the longest drift track was 1800 kilometers. This was the first use of a low power satellite link, the Interrogation, Recording and Location System (IRLS), for position and data retrieval. The spar configuration of this buoy was successful and has been used extensively since. Experience with this design led directly to later RAMS buoy use [3].

Four of five Short Range Arctic Measuring Stations (SHRAMS) operated 40 days in 1972 and provided a detailed record of barometric pressure which led to revised sampling on later buoys and to better field calibration procedures for barometers [4].

Eight HF-NavSat buoys were deployed in 1975 and lasted for 60 days. Four of these lasted 11 months. They raised the capabilities of sea ice buoys to a new level, with complete independence from experimental satellite systems. They featured the only operational use of full-accuracy Navy Navigation Satellite System fixes for data buoys. The high-frequency radio link was married to both the 3- and 12-day memories in the buoy to successfully overcome arctic radio propagation conditions. A fully automated command, control and data reduction facility proved its value in data collection over a full year. Data gaps in the winter emphasized the need for an alternate communications frequency, which was disabled when the antenna could not be properly tuned in the available time. Corrosive failures in the electronics point to the need for better sealing from the humid summer sea ice environment. Two different pressure sensors were used and should make it easier to isolate errors [5].

Eight of ten Synoptic RAMS (SYNRAMS) buoys deployed in 1975 before the Nimbus VI launch worked and were among the first buoys acquired when the Random Access Measurement System (RAMS) was activated. These buoys featured the first synoptic sampling and memory to work through a

INITIAL AND FINAL ARRAY OF BUOYS FOR AIDJEX MAIN EXPERIMENT 1975-76

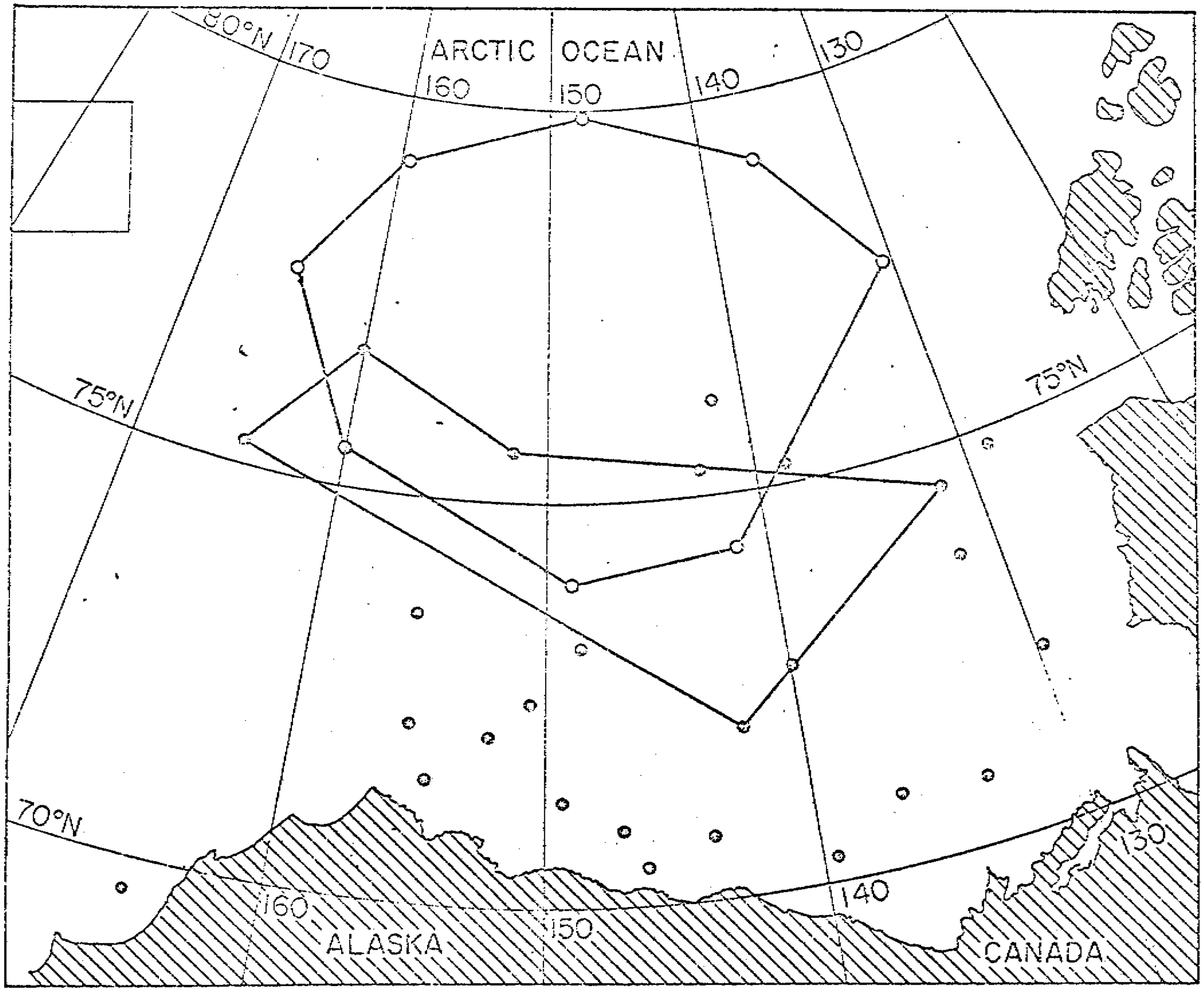
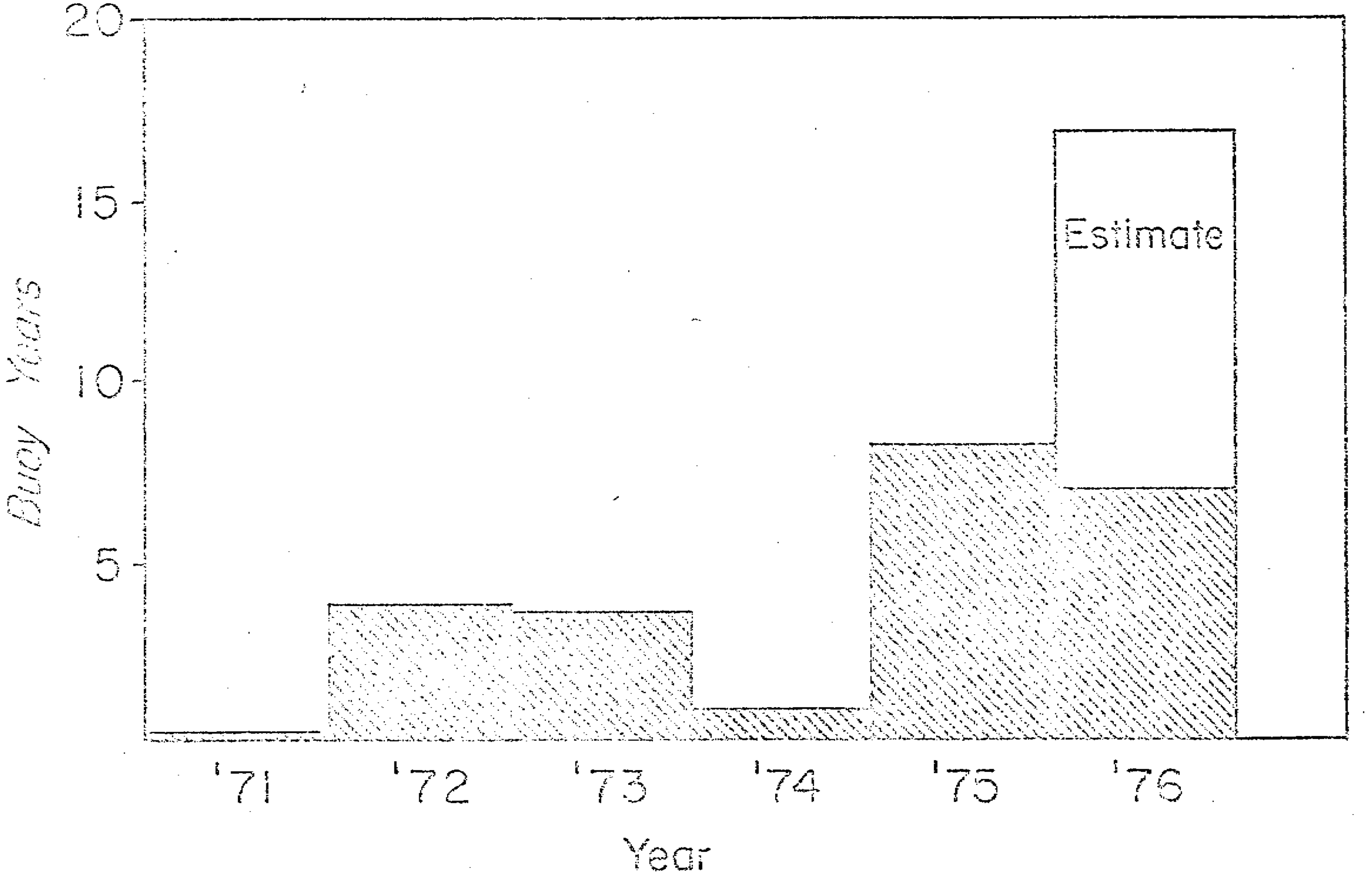


TABLE 1. DATA BUOY CHARACTERISTICS

BUOY NAME	COMMUN.	COMMANDS	FIXES	SAMPLING	NOMINAL BITS/DAY × REDUNDANCY	SENSORS	BATTERY TYPE /CAPACITY	STRUCTURE	NO. BUILT/ TOTAL COST
Arctic Data Buoy	IRLS Nimbus	Beacon turn on	2-5 km IRLS Range-range	Real time 6 orb/day	343 × 3	Pressure Temperature Voltage	Mercury 3 KWH	Polyethylene Spar buoy	7 $150.000
SHRAMS	VHF Aircraft	Transmit data	None	Hourly 24 orb/day	240 × 2	Pressure	Lead Acid 0.7 KWH	PVC tube external antenna + battery	7 $100 000
HF-NavSat	HF - 4MHz	Beacon transmit + sample clock shift	100 meters NavSat Doppler	3 Hourly 8 orb/day + Command	1632 × 8 + Command	Pressure Temperature Voltage Position	Zinc-Carbon-Air + Lead Acid 45 KWH	Polyethylene + Aluminum 4-leg spar buoy with aluminum upper structure	10 $1.000.000
SYNRAMS	RAMS Nimbus	None	1.5-5 km RAMS Doppler	3 Hourly 8 orb/day	256 × 15	Pressure Temperature Ambient noise	Zinc-Carbon-Air 1 KWH	Aluminum spar buoy	11 $140 000
Met-Ocean	RAMS Nimbus	None	1.5-5 km RAMS Doppler	3 Hourly 8 orb/day	512 × 15	Pressure Temperature Voltage Azimuth Current speed + Direction	Zinc-Carbon-Air 1 KWH	Polyethylene spar buoy	4 $104 000
DRAMS	RAMS Nimbus	None	1.5-5 km RAMS Doppler	Real time 10-12 orb /day	352 × 11	2 buoys with Pressure Temperature	Inorganic Lithium 1.5 KWH	Lexan sphere	17 $192 000



ACCUMULATION OF DATA FROM BUOYS DURING AIDJEX 1971-76 polar-orbiting satellite, which is important where uniform samples are needed and satellite coverage is poor. This pointed the way toward fuller exploitation of the RAMS data capacity [6].

Two of four Meteorological and Oceanographic (Met-Ocean) buoys operated for four months and one continues to work after seven months. A 30-second transmission interval coupled with platform address switching extends the RAMS data capability to 64 bits per minute. Current speed and direction at two levels in the mixed layer and magnetic buoy azimuth are measured.

Fifteen Air-Droppable RAMS (ADRAMS) buoys have been deployed and all continue to operate after a maximum of six months. The small electronic and battery package designed to withstand the extreme Arctic surface environment, coupled with parachute deployment, has revolutionized ice buoy deployment logistics.

3. Barometric Pressure Sensors.

Recent progress in other areas has been so rapid that the major technical challenge to remote data collection is the need for better sensors. Our experience with barometers does not contradict that conclusion. Our use of pressure sensors is perhaps unique in that we are able to revisit buoys to perform calibration checks relatively easily [4]. The preliminary results for a small sample of the pressure sensors used in the past year show that the Hamilton Standard vibrating steel cylinder transducers drifted 0.1 millibar or less during the year. There appears to have been drifts in the reported buoy pressures measured with the Paroscientific vibrating quartz beam transducers of from 1 to 4 millibars, but recalibration of the sensors in the laboratory shows drifts of from nil to 0.7 millibars. The cause of this discrepancy is not understood at this writing, but the possibility of an anomaly in the buoy electronics exists and should be a reminder that good transducers do not guarantee good measurements.

The outputs of the barometers in use vary about 10% over full scale or about 1% over 100 millibars. Thus, 0.1 millibar is one part in 10^5 of the transducer output. Clocks in buoys must be better than one part in 10^5 to avoid errors from this source. Also, synoptic sample timing requires an accuracy of one part in 10^5 to be good to 5 minutes per year. Cursors in the data or mode bits can permit calibration of the sample clock referenced to the satellite clock for synoptic systems. Where real-time sampling is used, the buoy clock can still be calibrated if the buoy transmissions are controlled by the main buoy clock, including the unmodulated carrier portion of the transmission. This method of controlling transmissions may also have benefits in enhanced positioning schemes, and has been implemented on ADRAMS.

4. RAMS Position Fix Accuracy

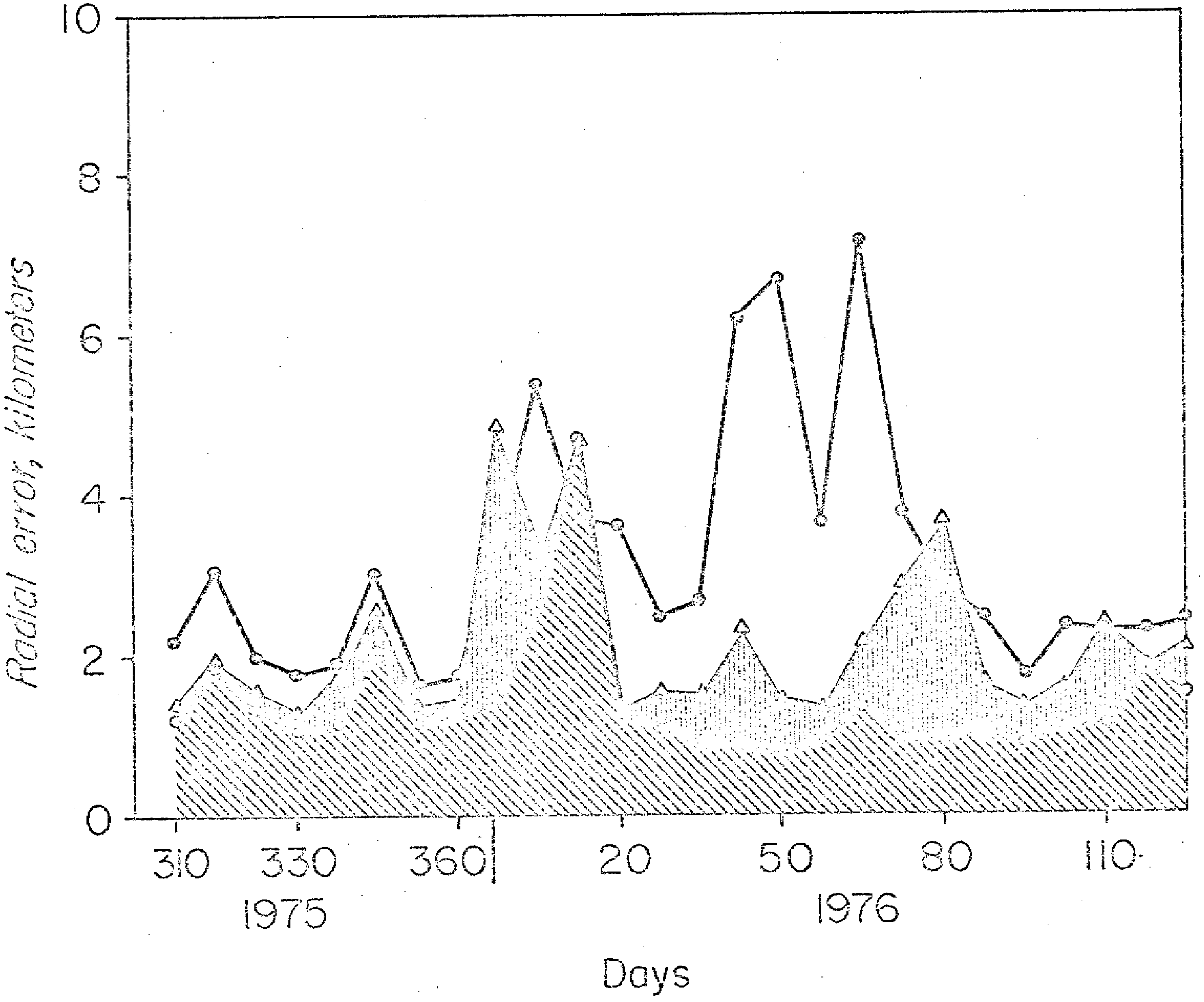
In order to provide a basis for the interpretation of the position fixes of the 25-30 drifting RAMS buoys now in use in the Arctic Ocean, a study of RAMS position errors has been made. AIDJEX receives data from NASA in the form of copies of the Nimbus archive magnetic tape with position resolution of the order centimeters and various supplementary information including satellite position data and reference platform fixes.

4.1. Along-Track Errors

Examination of the fixes of RAMS platform 1337, located on St. Lawrence Island in Alaska, shows the radial error (68th percentile of the radial distribution) varies from 2 to 6 kilometers (Fig. 3). The RAMS system specification of 5 kilometers is met or exceeded for about 85% of the weeks analyzed over a six-month period. The error pattern of a reference platform operated by NASA near Fairbanks is nearly identical to that of 1337, which suggests that the errors are from the same source; in this case, errors in the predicted satellite orbit. In fact, NASA has identified irregularities in the along-track motion of the satellite to be the major source of these correlated position errors, and the along-track error component of reference platform fixes is monitored on a daily basis to permit corrections to the orbit predictions. Since the present method of operation relies on operator analysis of error trends, detected errors only serve to improve the assumed orbit for future fix computations. The typical error growth and correction process occurs over periods of a few days, so that the weekly statistics reported here tend to average the worst events.

It is possible to use information on position errors of reference platforms directly to correct positions of moving platforms. This can be done either by adjusting the fix of a moving platform with the error in latitude and longitude for the same pass of a reference platform, or by resolving the error into along-track and cross-track components prior to the adjustment. The latter method requires information on the satellite orbit which is not normally provided to users, but it does have the advantage that it is not affected by changes in the relationship

IMPROVEMENT IN RAMS POSITION ERROR WITH REMOVAL OF ALONG-TRACK SATELLITE ERRORS



between the satellite sub-track and the latitude-longitude grid between the two platforms. Over a separation of 1000 kilometers both methods give essentially the same improvement and result in radial errors below 2 kilometers most of the time (Fig. 3).

NASA could make an improvement in the positioning accuracy of RAMS, and save the user community a lot of extra work, if the along-track errors of fixed platforms were used to correct the fixes of moving platforms. Similar arrangements should be made to improve Tiros N data, preferably by using reference platform information to enhance the orbit estimates, rather than by the direct adjustment of fixes. This was suggested for RAMS in a NASA-funded study in 1972 [8].

It is interesting that the radial position errors left after removal of along-track orbit errors show the NASA platform to be consistently better than 1337, which uses low cost bouy electronics and is exposed to large temperature fluctuations. There are significant periods of time when the NASA platform radial error is at or below 1 kilometer, which is in good agreement with theoretical studies and which probably represents the best that can be done without enhancing the actual time and frequency measurements made in the spacecraft [9]. With high quality platform hardware and implementation of software modifications the positioning accuracy of RAMS could probably be brought to about 500 meters.

4.2. RAMS Fix Editing

The accuracy figures quoted above include all fixes reported by NASA without any editing. While correction for along-track errors is more effective than any edit scheme we have tested as protection against systematic errors, there are editing schemes which do seem to be selective in eliminating bad data (Fig. 4). All editing schemes make a compromise between eliminating bad data and preserving as many fixes as possible. The quality index provided by NASA and the number of messages used in the fix computation perform better than the other edits in this regard. After either of these edits about 80% of the fixes remain and the radial error of the edited data is about 50% of the unedited errors when along-track errors are not eliminated, and about 75% when along-track errors have been removed. Edits which might also prove effective when data from two passes are used in the fix, but which we have not tested, are those which detect unrealistic velocities or large differences between the two bias frequencies.

About one-third of the fixes have larger errors than the numbers given here as the 68th percentile radial error statistic. If one has enough information about the limits of motion of the platform, then other editing schemes can be derived which eliminate the unreasonable data. In our case, since we get about 10 fixes per day for each platform, and the ice usually moves less than 10 kilometers per day, the only editing used other than along-track error correction is a running median filter. A more sophisticated Kalman filter is then used to produce the final position and velocity estimates based on the RAMS fixes [10].

5. Assessment of Polar Satellite Data Collection and Tracking

The primary advantage of data collection and tracking through a polar satellite system such as RAMS is platform simplicity. This feature makes possible high platform reliability with low cost. Those who are familiar with other more complicated satellite data collection and tracking systems can hardly mistake the message of widespread use of RAMS.

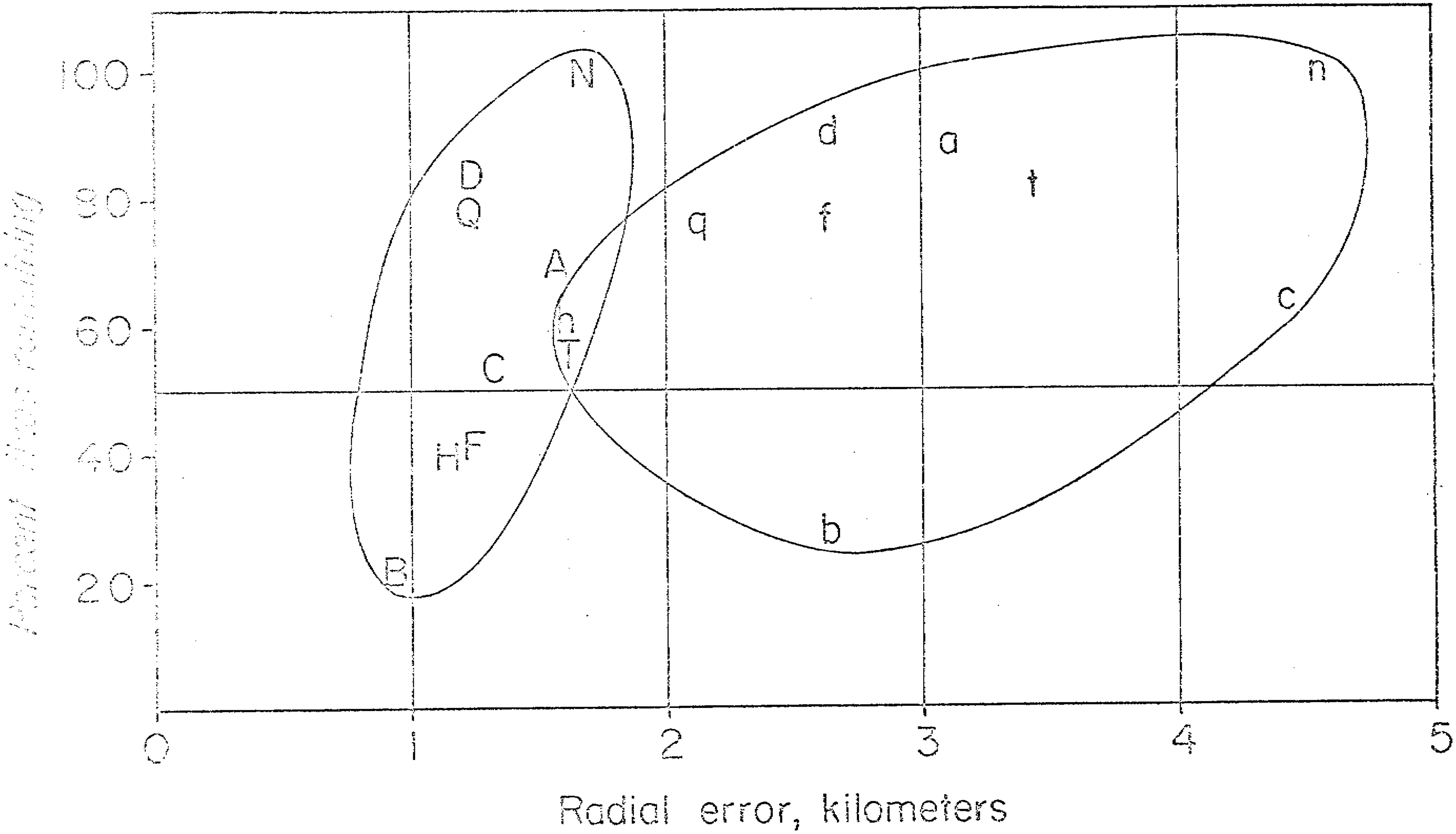
The HF-NavSat buoy array cost about $800,000 *more* than the same spatial array of RAMS buoys and was *less* reliable. *If* the HF-NavSat buoys had been as reliable as the RAMS buoys, the cost of a one-year experiment would have been about $250 per buoy-day versus $50 per buoy-day for the RAMS buoys. The HF-NavSat buoy positioning accuracy of 100 meters was valuable to AIDJEX; but the compelling reason for these buoys was that we had to have data even if Nimbus VI didn't survive. Rams buoy simplicity is made possible by *total reliance* on a satellite system which is neither simple nor cheap. Users should familiarize themselves with the total system; not just the buoys and the data package received from NASA. The active participation of an informed user community in full partnership with space organizations is essential to real progress.

As buoy costs approach $10 per buoy-day, the cost of sensors (and their simplicity and reliability) becomes an important consideration. Taken one step further, the cost of data processing becomes a major factor. These are signs of progress since no one is really after buoys or sensors, but data. Careful planning should include the cost of finished data. Data is the real curency, and the exchange rate is improving.

6. Satellite System Flexibility Concepts

The random access approach offers flexibility in data collection capacity and positioning accuracy at the user's option. A normal real-time sampling system transmits about 300 bits of data

EFFECT OF VARIOUS EDITING TECHNIQUES ON RAMS ACCURACY WITH AND WITHOUT ALONG-TRACK ERRORS



to the spacecraft during each orbit. The spacecraft memory can be used as an extended [illegible] memory to permit the integration of multiple one-minute samples into ten-minute averages. The treatment of each data reception at the spacecraft as independent allows the use of multiple addresses and higher than nominal transmit duty cycles to obtain increased data capacity with no increase in equipment costs. The availability of up to 13 satellite passes per day in polar regions means that up to 4000 bits per day can be transmitted for each address. There is a trade-off between the number of data bits and level of redundancy required, and the number of satellite passes available and number of addresses used for each platform. This trade-off is a function of latitude, and with the number of passes available in polar regions we have been extremely conservative with respect to data redundancy in our system designs. This should change as we become more confident of system performance.

Flexibility in position accuracy requires that measurements made in the satellite have sufficient accuracy potential for the most demanding users. To achieve refraction-limited position accuracy of 200 meters, a Doppler system like RAMS needs measurement accuracy of 0.1 Hz and 0.01 seconds, an order of magnitude better than RAMS. The use of multiple addresses offers the possibility of increasing the amount of data used in the position computation, as a way of improving fix accuracy. The flexibility offered to the user by random access data collection and positioning systems should be retained and enhanced in the future.

7. Real-Time Data Readout Option

The Nimbus spacecraft transmits all data in real time in addition to storing these data on magnetic tape. When the spacecraft is within view the data can be received with portable equipment and, with the proper formats, can be decoded and interpreted essentially the instant they are transmitted from the platform. The most obvious use of this capability for data buoy work is to provide for immediate verification of platform performance during checkout of electronics. This is the only practical method of authoritative confirmation of buoy performance in remote areas.

The same capability could be used to obtain data for forecasting without waiting for processing by NASA.

The primary purpose of this real-time data transmission is to provide a backup data collection mode in case of tape recorder failure in the spacecraft. The spacecraft must be in view of both the platforms and the data retrieval site for sufficient time to recover the desired data. Thus, the data retrieval site should be in the vicinity of the platforms, which is of special significance to experiments in remote areas where NASA does not maintain facilities. The use of buoys in the Southern Ocean might be one experiment which would benefit from a direct readout capability in the Antarctic in the event of a tape recorder failure.

An important addition to the real-time data transmission of the spacecraft would be the predicted orbit parameters and measured satellite clock and orbit errors needed for position fix computation. This would permit fix computation by users and would make possible dispersing the data processing function around the globe to areas where the data are being collected and used.

8. Conclusion

The data buoy program associated with AIDJEX has been large and diverse enough to gain an appreciation for the many practical difficulties involved in developing and using several kinds of data buoys. Time seems to have been the ingredient in shortest supply, and should therefore be conserved in future work. The money spent (about $2 million dollars including logistics costs), while not extravagant, must certainly be considered adequate for the objectives, which were fairly well satisfied. Personal initiative was important, and more of this ingredient would have improved the results.

We have been fortunate to try many new things with very few failures, but this should not be interpreted as an endorsement of the policy of trying something new when a proven method can be made to work. The only good pressure sensor is a used one. This is a good philosophy for buoys as well, although one probably has to settle for used designs and long checkout tests since hardware recovery is difficult.

The RAMS has 2 to 6 kilometer position accuracy and is probably capable of 500 meters. By taking full advantage of the flexibility available through random access, a data capacity of one to several thousand bits per platform per day can be acheived. There are real benefits to be achieved through real-time readout of data from the spacecraft. These proven capabilities of RAMS, plus the potential ready to be realized, make it highly desirable that a new deployment of the RAMS be scheduled so that the system can be utilized through the rest of the decade. A new orbit complementary in time to the existing one would be desirable.

Data collection and tracking from orbiting spacecraft is in its infancy. By comparison the Navy Navigation Satellite System (Transit) has been an operational system for 14 years, and currently consists of six satellites which provide users with a completely self-contained positioning capability. The insight gained in the use of this system has lead to a new satellite system which will provide continuous position information to a few meters, from a constellation of up to 24 satellites. The message is not that we need 24 data collection satellites. The current concept of data collection and tracking is elegant in its simplicity. The challenge is to raise our level of sophisitication in using the data collection and tracking concept to higher levels where even greater benefits will be realized.

9. Acknowledgments

This work was supported by the National Science Foundation, the Office of Naval Research, the National Oceanic and Atmospheric Administration, the Bureau of Land Management, the Canadian Polar Continental Shelf Project, and the National Aeronautics and Space Administration. We wish to thank the staffs of the Nimbus Operations Center, Goddard Space Flight Center; Polar Research Laboratory, Santa Barbara; the Applied Physics Laboratory, University of Washington, and our colleagues at AIDJEX.

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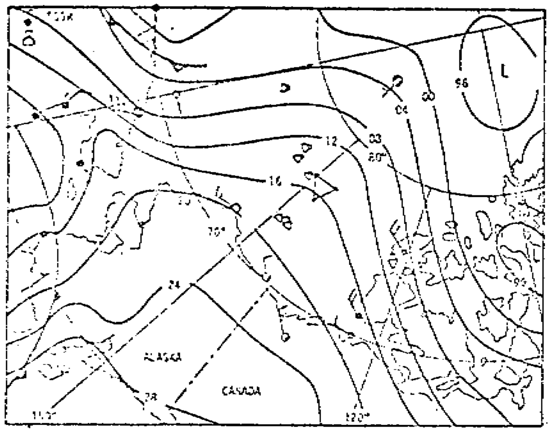
Figure 1. Initial and final array of buoys for AIDJEX main experiment 1975-76. O-O Initial array, ●-● final array, ● additional buoys.

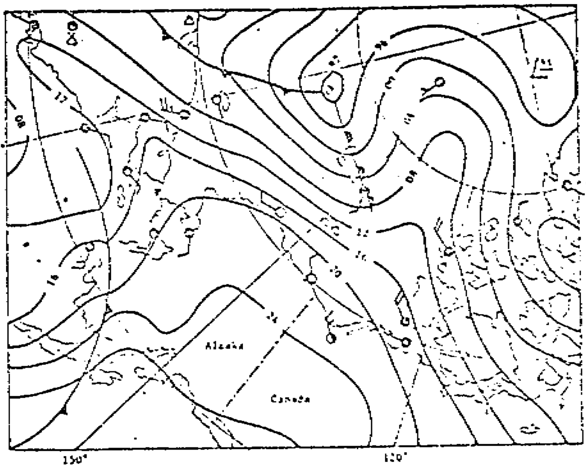
Figure 2. Accumulation of data from buoys during AIDJEX 1971-76.

Figure 3. Improvement in RAMS position error with removal of along-track satellite errors. ● platform 1337--uncorrected, Δ platform 1337--corrected, O NASA platform--corrected.

Figure 4. Effect of various editing techniques on RAMS accuracy with and without along-track errors for NASA reference platform 15-21 Feb. 1976. Lower case along-track errors are present. Upper case along-track errors are removed. Type of edit--N: None, A: Elevation Angle, B: Messages used ≥ 12, C: Messages used ≥ 10, D: Messages used ≥ 8, T: Two pass fixes only, F: A + T, Q: Quality index ≥ 47, H: A + T + Q.

COMPARISON





NWS ANALYSIS 00Z 7 JULY 1975 **AIDJEX ANALYSIS**

INCLUDES DATA FROM AIDJEX MANNED CAMPS & DATA BUOYS

QUARTERLY REPORT

Contract #03-5-022-91

Research Unit #244

Reporting Period April 1 - June 30

Number of pages

STUDY OF CLIMATIC EFFECTS ON FAST ICE EXTENT AND ITS SEASONAL DECAY IN THE BEAUFORT SEA AREA

Principal Investigator

R. G. Barry

Institute of Arctic and Alpine Research

University of Colorado

Boulder, Colorado 80309

June 30, 1976

I. TASK OBJECTIVES

The primary objective of this study is to assess the role of climatic factors in determining the extent and seasonal decay of fast ice along the Chukchi Sea coast of Alaska.

Work during this first quarter has focussed on acquiring necessary data and imagery and on field reconnaissance.

II. FIELD/OFFICE ACTIVITIES

II.1 FIELD ACTIVITIES

A. Schedule

Ice reconnaissance over the fast ice was carried out from the Cessna and Otter aircraft during 3-23 June. Liaison with other groups (Stringer, Shapiro, Ohtahke, Osterkamp, R. Brown) was also maintained.

B. Party

J. Rogers, Research Associate

R. E. Moritz, Research Associate

C. Methods

Visual observation and hand-held photography from aircraft transects.

Limited albedo measurements.

Flight logs include time, magnetic heading, indicated air speed, range and bearing, ice features, land marks for each picture number (Cessna) or latitude/longitude (Otter).

D. Localities

Barrow - Wainwright (see Fig. 1).

E. Data collected

Log of visual observations on ice surface features; hand-held photographs.

II.2. OFFICE ACTIVITIES

A. Personnel

R. G. Barry, Principal Investigator.

J. Rogers - Research Associate.

R. L. Weaver - Graduate Research Assistant.

R. E. Moritz - Graduate Research Assistant.

W. Vaughn - Workstudy student.

B. Methods

1. Remote Sensing Data

a. Maps are being prepared from Landsat imagery for 1973-75 of the continuous limits along the Beaufort Sea coast. Features being mapped are shear zone limits, occurrence of open water, 5/10, 8/10 ice and continuous ice.

b. The dates of the following events are being tabulated for three sectors (near Barrow, Prudhoe, and Barter Is.):

(1) earliest surface darkening
(2) first opening of fast ice
(3) earliest darkening of river channels
(4) flooding on ice in river mouths
(5) first movement of fast ice sheet
(6) coastline ice free
(7) new freeze-up along shore.

c. Dates of SLAR imagery during May, 1976 have been noted and selected runs have been obtained.

d. LARSYS digital map product of the unsupervised classification was prepared by LARS, Purdue University under subcontract.

2. Meteorological Data

1. Analysis of variance (ANOVA) of the daily temperature departures of the daily pressure-pattern types has now been carried out for Barter Island for every fifth day, 1 Jan. 1969 - 31 Dec. 1973.

2. Comparison of geostrophic winds and temperatures for 5-day periods between years.

III. RESULTS

1. Maps of ice extent have been prepared in draft form and will be finalized during the next quarter on the UTM base.

2. The ANOVA of daily temperature departures at Barter Island, stratified according to season and synoptic pressure type, gave the results shown in Table 1. Supplementary data on mean departures and their standard deviation according to type are given in Table 2.

3. Inter-annual comparisons are still in progress.

IV. PRELIMINARY INTERPRETATION OF RESULTS

A. Field Data

The availability of SLAR imagery for 11-13 May during the final aircraft flight on 23 June indicates that this information will greatly enhance our interpretation and mapping from LANDSAT imagery. Ice categories that are readily identifiable include smooth, flat ice (mainly first year in 1976), large ridges and ridge systems, second and multi-year ice incorporated into the fast ice sheet. It appears that most of these distinctions result from the reflectivity variations due to surface roughness. On these images for example, ridged areas composed of first-year ice have a similar radar return to ridges of multi-year ice.

The pattern of decay during the 1976 season is expected to be influenced by the relatively high percentage of inclusions of older ice in the fast ice

Table 1. F ratios for between -/within-type variance in daily temperature departures at Barter Is.

Season	Calculated F	F at .95 level	F at .99 level
Jan-Mar	4.1	1.9	2.5
Apr-June	1.5	1.7	2.2
Jul-Sep	2.3	1.7	2.2
Oct-Dec	2.3	1.8	2.3
Nov-Apr	3.8	1.8	2.2
June-Aug	1.8	1.7	2.1

Table 2. Temperature departures (^{o}F) from the daily mean value at Barter Is according to pressure pattern type.

	Pressure Type	Mean ΔT	S.D.	No. of cases
Jan-March 1969-74				
	1	- 5.24	±13.25	42
	2	+24.75	±12.09	4
	3	- 9.35	± 7.59	17
	4	+ 1.33	±13.2	9
	5	- 1.75	±11.34	8
	6	+19.00	±10.15	3
	7	- 0.27	± 8.32	11
	9	+ 0.13	±11.48	8
Apr-June 1969-74				
	1	- 0.06	± 7.32	50
	3	-10.00	± 5.55	8
	4	+ 0.83	± 8.18	6
	5	- 3.33	± 4.62	3
	6	+ 0.50	± 2.65	4
	8	- 0.43	± 3.26	7
	10	- 0.33	± 5.03	3
	11	- 2.00	± 2.16	4
	12	- 0.75	± 7.18	4
	13	+ 3.00	± 7.81	3
	17	- 2.40	± 9.42	5
Jul-Sept 1969-74				
	1	- 5.17	± 3.90	12
	2	+ 2.83	± 6.70	18
	4	+ 1.78	± 3.53	9
	5	- 1.86	± 5.83	14
	6	+ 0.73	± 5.25	11
	7	- 8.75	± 2.63	4
	8	- 4.38	± 5.47	8
	14	- 4.67	± 6.10	3
Oct-Dec 1969-73				
	1	- 2.48	± 9.4	23
	2	+13.40	±11.4	5
	3	- 5.91	±10.38	11
	4	+ 4.67	±12.41	15
	5	+12.00	± 5.00	3
	6	+ 8.00	±12.12	6
	7	- 6.00	± 9.09	4
	8	+ 3.00	± 2.65	3
	9	- 5.80	± 7.89	5
	10	+ 0.67	±22.8	3
	12	- 5.67	± 3.21	3
	13	- 6.80	± 5.63	5

sheet as a result of conditions during fall 1975.

B. Meteorological Data

The ANOVA results (Table 1) indicate that the objective pressure pattern types provide a significant discrimination of temperature departures except in the spring transition season. The problem here is caused partly by trends during the season since a different grouping of months given a statistically significant result.

C. Climate/Ice Interaction

A preliminary report on findings is being prepared for presentation at the Alaska Science Conference submitted abstract is attached as Appendix I.

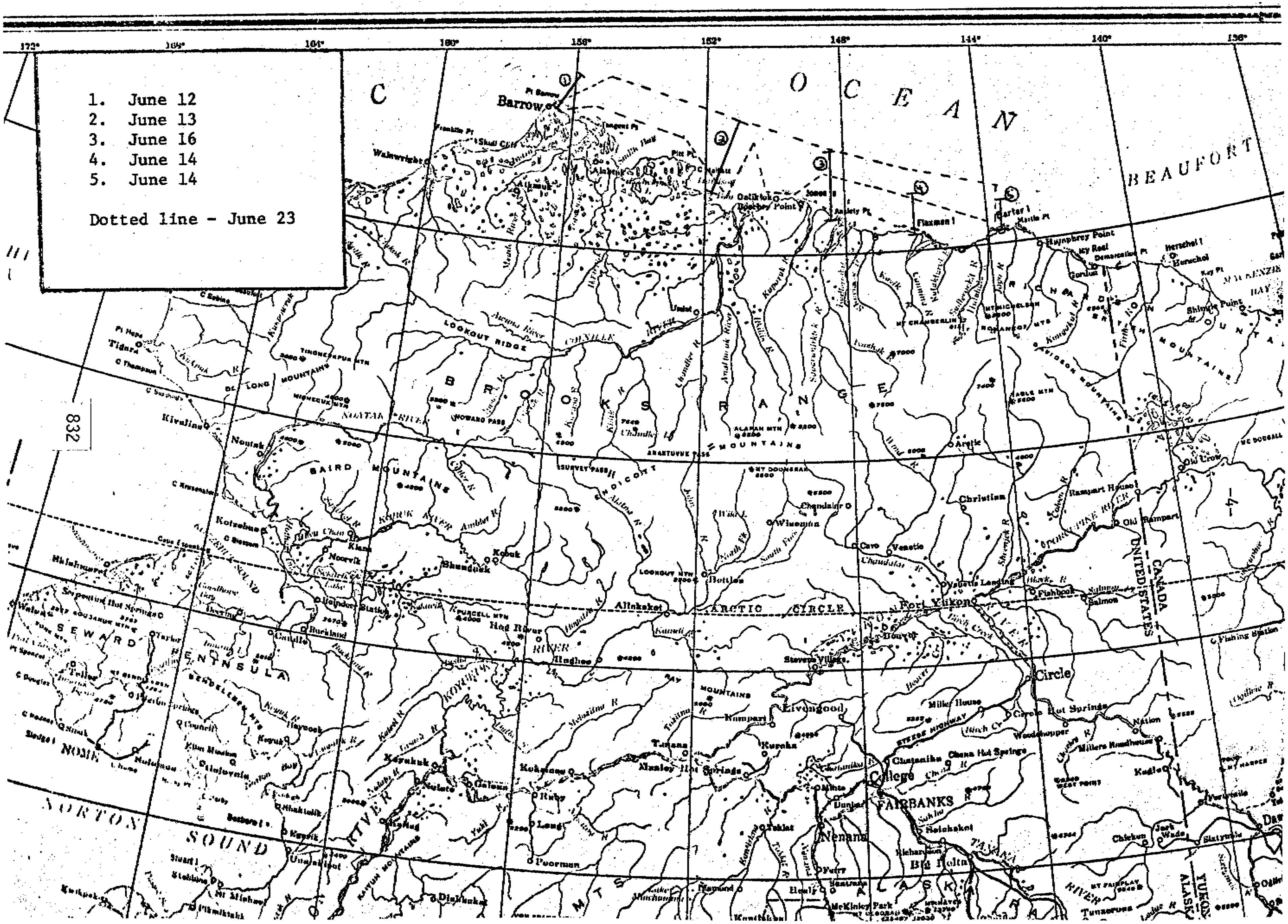
V. RECOMMENDATIONS

Inspection of the SLAR imagery indicates that coverage during October - January (once/month) for the entire coastline would aid interpretation of LANDSAT imagery and contribute greatly to understanding the nature of the spring fast ice sheet and the processes that have led to its formation.

VI. ESTIMATE OF EXPENDED FUNDS

$33,000.

Fig. 1 Flight lines



APPENDIX I

STUDIES OF CLIMATE AND FAST ICE INTERACTION DURING THE DECAY SEASON ALONG THE BEAUFORT SEA COAST

By

Roger G. Barry, Richard E. Moritz, and Jeffery C. Rogers

Institute of Arctic and Alpine Research, Univ. of Colorado, Boulder, Colo. 8030

An overview of an ongoing study of climate and fast ice during the decay season along the Beaufort Sea Coast will be made. It is the aim of the project to develop a synoptic climatology of the Alaskan north coast and to relate derived synoptic circulation types and their associated climatic characteristics to the large scale atmospheric circulation and more importantly to the fast ice regime and its variations during the decay season. Ice conditions are analyzed using ERTS/LANDSAT imagery from 1972-75 supplemented by ground truth.

The objectively derived synoptic classification scheme of 21 pressure pattern types observed along the north coast region is described and examples of ice melt features determined from the satellite imagery are presented. Case studies are discussed detailing observations of synoptic events which cause ice melt and break-up, and an example of changes in circulation pattern types which have influenced both north coast temperature conditions and the ice decay process is given. It is anticipated that the work will lead to a basis for assessing the causes of interannual and spatial variability in observed rates of ice decay along the Beaufort Sea Coast.

QUARTERLY REPORT

Contract #03-6-022-35197

Research Unit #244

Reporting Period April 1 - June 30

Number of pages

STUDY OF CLIMATIC EFFECTS ON FAST ICE EXTENT AND ITS SEASONAL DECAY IN THE CHUKCHI SEA AREA

Principal Investigator

R. G. Barry

Institute of Arctic and Alpine Research

University of Colorado

Boulder, Colorado 80309

June 30, 1976

I. TASK OBJECTIVES

The primary objective of this study is to assess the role of climatic factors in determining the extent and seasonal decay of fast ice along the Beaufort Sea coast.

Work during this quarter has focused on the preparation of ice maps, case studies of significant weather events and field collection of "ground truth" data.

II. FIELD/OFFICE ACTIVITIES

II.1. FIELD ACTIVITIES

A. Schedule

Ice reconnaissance over the fast ice was carried out from the Otter aircraft during 3 - 23 June. Liaison with other groups (Stringer, Shapiro, Ohtahke, Osterkamp, and R. Brown) was also maintained.

B. Party

J. Rogers - Research Associate.

R. E. Mortiz - Research Assistant.

C. Methods

Visual observation and hand-held photography from aircraft transects. Flight logs include latitude/longitude for each picture number.

D. Localities

Barrow - Barter Is. (see Fig. 1).

E. Data Collected

Log of visual observations on ice surface features; hand-held photographs.

II.2. OFFICE ACTIVITIES

B. Personnel

R. G. Barry, Principal Investigator

J. Rogers, Research Associate

R. Keen, Graduate Research Assistant

W. Vaughn, Work study student

C. Methods

1. Remote Sensing Data

Landsat imagery (bands 4 and 7) has been ordered for selected dates during 1973-75.

2. Meteorological Data

a) NMC grid-point MSL daily pressure data is being processed to generate:

(i) indices of local airflow (on/off-shore and westerly/southerly components) along the Chuckchi coast.

(ii) a catalog of objectively determined daily pressure pattern types for 1946-74.

III. RESULTS

Partial results on the synoptic catalog and wind indices are to hand These will be completed within the next week or so.

IV. INTERPRETATION OF RESULTS

In progress.

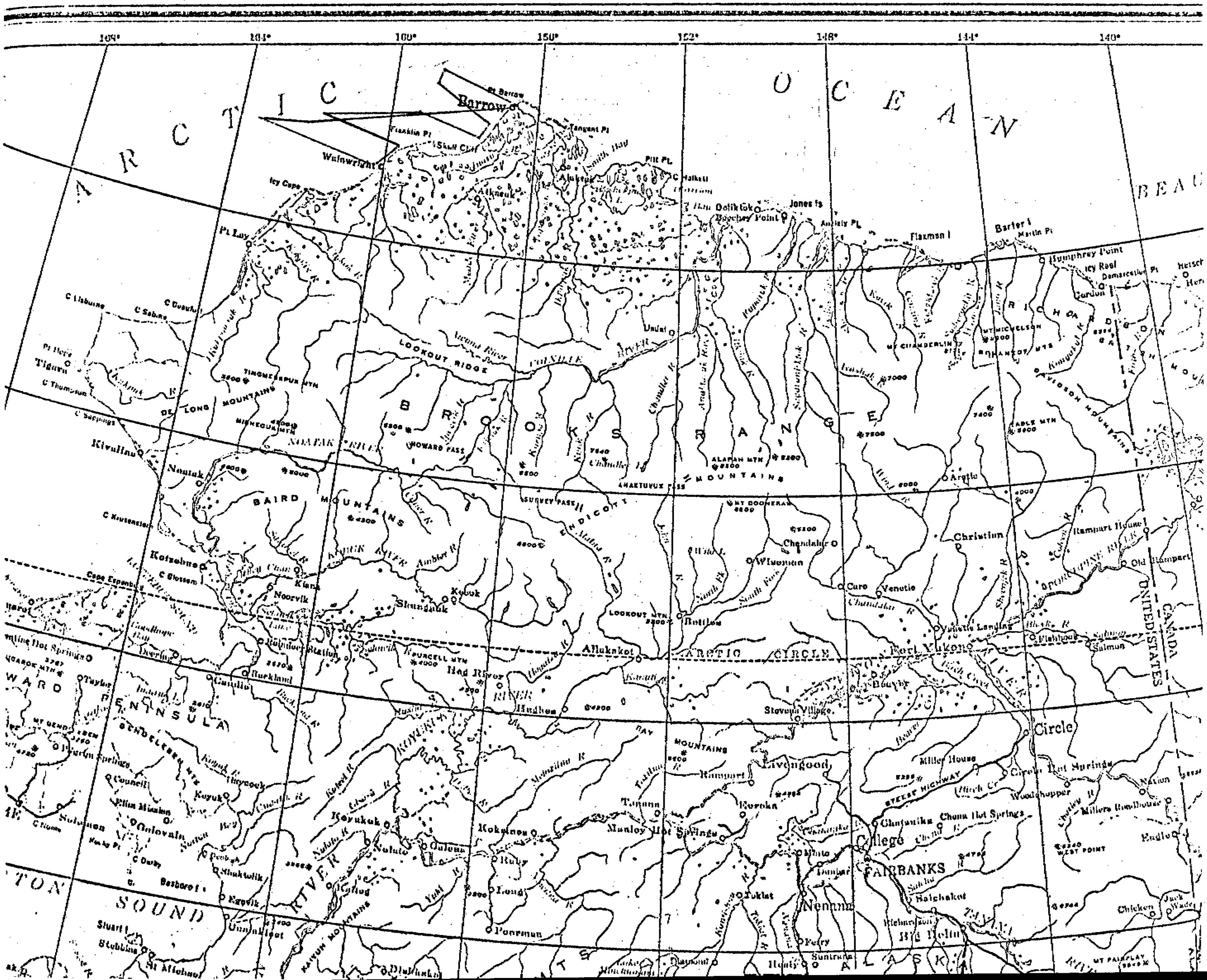
V. PROBLEMS /RECOMMENDATIONS

None.

VI. ESTIMATE OF FUNDS EXPENDED

$3,000

Fig. 1b <u>Flight lines</u> - 11 June



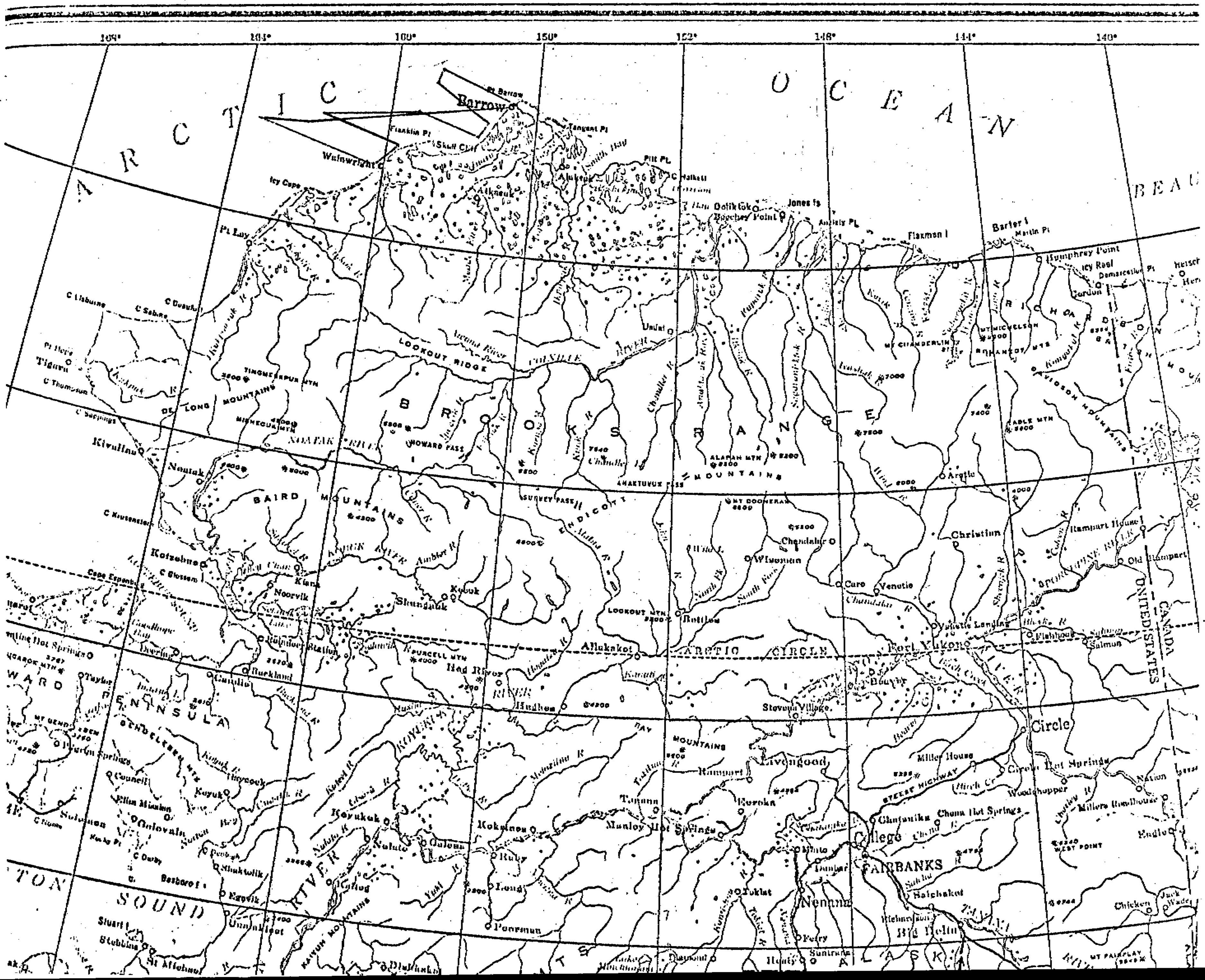


Fig. 1b Flight lines - 11 June

FIFTH QUARTERLY REPORT RU #250

TITLE: Mechanics of Origin of Pressure Ridges, Shear Ridges and Hummock Fields in Landfast Ice

PERIOD: April 1, 1976 - June 30, 1976

PRINCIPAL INVESTIGATORS: Lewis H. Shapiro and William D. Harrison
Geophysical Institute, University of Alaska

I. TASK OBJECTIVES: To determine the mechanics of origin of pressure ridges, shear ridges and hummock fields in landfast ice.

II. FIELD AND LABORATORY SCHEDULE: Field studies, continuation of preliminary theoretical work.

III. RESULTS: 1. It was anticipated that field work on ridges formed at Barrow during the winter of 1975-76 would be conducted during the past quarter. However, due to the unusual ice conditions in the area during the summer and fall of 1975, much of the landfast ice remained in place and no new ridges worth study were formed. As a result, no field work was done on this problem. However, in late June, the fast ice was pushed onto the beach at Barrow, forming a series of ridges close to shore. A total of five man-days was spent in the field examining these features. During part of this time, the ice sheet was in motion with accompanying ridge development. Observations were made of several aspects of the process, and the results are presently being analyzed.

2. Examination of simple models of the ridging process was continued during the past quarter, but no new results are available.

IV. PRELIMINARY INTERPRETATION: None.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES: None.

VI. ESTIMATED FUNDS EXPENDED: $10,000.

OCS COORDINATION OFFICE

University of Alaska

Quarterly Report for Quarter Ending June 30, 1976

Project Title:	Morphology of Beaufort Near Shore Ice Conditions by Means of Satellite and Aerial Remote Sensing
Contract Number:	03-5-022-55 RU # 057
Task Order Number:	8
Principal Investigator:	W. J. Stringer

I. Task Objectives:

The objective of this study is to develop a comprehensive morphology of near shore ice conditions in the Beaufort Sea. This morphology will include a synoptic picture of the development and decay of fast ice and related features along the Beaufort Sea coast, and in the absence of fast ice, the nature of other ice (pack ice, ice islands, hummock fields, etc.) which may occasion the near shore areas in other seasons. Special emphasis will be given to consideration of potential hazards to offshore facilities and operations created by near shore ice dynamics will be developed to aid in determining the statistical rate of occurrence of ice hazards.

II. Field and Laboratory Schedule:

This project has no established field schedule. The work to be done does not involve laboratory activities. All remote sensing aircraft data is to be provided by project management.

III. Results:

Using Landsat band 7 hard copy produced at 1:500,000 scale, preliminary Beaufort Sea near shore ice maps have been compiled for late spring, early summer 1973, 1974, and 1975. These maps have been reproduced here at half scale for reporting convenience. Particular care, described in our previous report, has been taken to locate the ice features relative to geographic coordinates and bathymetric 10-fathom contour.

It should be stressed that these maps are not final products but represent an initial stage of interpretation of each year's ice conditions. For instance, even though large ridge systems can be identified, many others are shown here as boundaries between distinctive ice categories. Analysis of later Landsat images during the melt season will determine to a greater extent the complete identification of these and other features.

III. Results: (cont'd)

Normally, half-scale reproductions of ice maps accompany these quarterly reports. However, because of the statements concerning map projections on page 4 of OCS Bulletin #10, we are witholding copies of ice maps prepared during this quarter because they were compiled by transferring ice data from Landsat imagery to the only 1:500,000 scale map base then available (a lambert conformal projection). (For details of our mapping procedures, see our second quarterly report - September 31, 1975). According to Bulletin #10 it may be necessary to convert all ice maps prepared to date - approximately 3 times as many as have appeared in these reports - to the project - provided map projection. If this is so, we certainly do not wish to proliferate the OCS literature with maps at two different projections. We plan to give this problem immediate attention.

IV. Preliminary Interpretations

An unscheduled field trip was made to the Beaufort Sea in late June to perform a reconnaissance of near shore ice from Barrow to Barter Island. This was done jointly with Dick Moritz and Jeff Rogers (RU 244) from INSTARR. The purpose of the flight was to establish "ground truth" for analysis of this year's Landsat and side-looking airborne radar data. Our preliminary conclusion is that there is an unusual amount of ice older than one year within the near shore zone this year and that except for a few ridges, the annual is unusually smooth. As would be expected, most of the radar returns come from surfaces oriented so as to give reflections back toward the aircraft. Hence, much of this year's annual ice provides little or no return signal on the SLAR imagery.

V Plans for Next Reporting Period

During this period, the preparation of ice maps will concentrate on data from summertime imagery, 1973, 1974, 1975.

VI. Problems Encountered/Recommended Changes:

The chief problem encountered recently is the change in map base mentioned above. We recommend that: I; the standard map base be 1:500,000 scale and II; a Lambert conformal conic projection be used. The reasons for these recommendations will be detailed in a letter to project management.

OCS COORDINATION OFFICE

University of Alaska

Quarterly Report for Quarter Ending June 30, 1976

Project Title: Morphology of Bering Near Shore Ice Conditions by Means of Satellite and Aerial Remote Sensing

Contract Number: 03-5-022-55 RU #265

Task Order Number: 5

Principal Investigator: W. J. Stringer

I. Task Objectives:

The objective of this study is to develop a comprehensive morphology of near shore ice conditions in the Bering Sea. This morphology will include a synoptic picture of the development and decay of fast ice and related features along the Bering Sea coast, and in the absence of fast ice, the nature of other ice (pack ice, hummock fields, etc.) which may occasion the near shore areas in other seasons. Special emphasis will be given to consideration of potential hazards to offshore facilities and operations created by near shore ice dynamics will be developed to aid in determining the statistical rate of occurrence of ice hazards.

II. Field and Laboratory Schedule:

This project has no established field schedule. The work to be done does not involve laboratory activities. All remote sensing aircraft data is to be provided by project management.

III. Results:

Using Landsat band 7 hard copy produced at 1:500,000 scale, preliminary Bering Sea near shore ice maps have been compiled for spring (May) 1973, 1974 and 1975. These maps have been reproduced here at half scale for reporting convenience. Particular care, described in our previous report, has been taken to locate the ice features relative to geographic coordinates and bathymetric 10-fathom contour.

It should be stressed that these maps are not final products but represent an initial stage of interpretation of each year's ice conditions. For instance, even though large ridge systems can be identified, many others are shown here as boundaries between distinctive ice categories. Analysis of later Landsat images during the melt season will determine to a greater extent the complete identification of these and other features.

III. Results: (cont'd)

Normally, half-scale reproductions of ice maps accompany these quarterly reports. However, because of the statements concerning map projections on page 4 of OCS Bulletin #10, we are witholding copies of ice maps prepared during this quarter because they were compiled by transferring ice data from Landsat imagery to the only 1:500,000 scale map base then available (a lambert conformal projection). (For details of our mapping procedures, see our second quarterly report - September 31, 1975). According to Bulletin #10 it may be necessary to convert all ice maps prepared to date - approximately 3 times as many as have appeared in these reports - to the project - provided map projection. If this is so, we certainly do not wish to proliferate the OCS literature with maps at two different projections. We plan to give this problem immediate attention.

IV. Preliminary Interpretations

An unscheduled field trip was made to the Beaufort Sea in late June to perform a reconnaissance of near shore ice from Barrow to Barter Island. This was done jointly with Dick Moritz and Jeff Rogers (RU 244) from INSTARR. The purpose of the flight was to establish "ground truth" for analysis of this year's Landsat and side-looking airborne radar data. Our preliminary conclusion is that there is an unusual amount of ice older than one year within the near shore zone this year and that except for a few ridges, the annual is unusually smooth. As would be expected, most of the radar returns come from surfaces oriented so as to give reflections back toward the aircraft. Hence, much of this year's annual ice provides little or no return signal on the SLAR imagery.

V. Plans for Next Reporting Period

During this period, the preparation of ice maps will concentrate on data from summertime imagery, 1973, 1974, 1975.

VI. Problems Encountered/Recommended Changes:

The chief problem encountered recently is the change in map base mentioned above. We recommend that: I; the standard map base be 1:500,000 scale and II; a Lambert conformal conic projection be used. The reasons for these recommendations will be detailed in a letter to project management.

OCS COORDINATION OFFICE

University of Alaska

Quarterly Report for Quarter Ending June 30, 1976

Project Title:	Experimental Measurements of Sea Ice Failure Stresses Near Grounded Structures
Contract Number:	03-5-022-55
Task Order Number:	7
Principal Investigator:	R. D. Nelson

I. Task Objectives:

The task objective is the in-situ measurement of stresses generated in a moving ice sheet when it interacts with a fixed obstacle. This is accomplished by means of stress transducers frozen into the ice sheet. The loads measured by these transducers are telemetered to a central data recording point. The experiments are conducted at the grounded floe island 100 miles northwest of Barrow, Alaska.

II. Schedule:

On April 20, 1976 experiments at the floe island were begun. An initial flight on April 20 indicated that the instrument hut which had been placed on the island in February was still there and that the location was stable enough to risk placing the data-gathering station there. A 15-foot UHF antenna mast was installed on the hut roof with one antenna for receiving data, and a 300-foot-long antenna was strung about 6 feet off the ground to provide a radio beacon for later navigation.

The following day the data receiver and recorders were installed and one station of three transducers was set out on the ice. The transducers were set in the middle of an ice floe on April 21 approximately 16 nautical miles on a bearing of 15° (magnetic) from the hut. These figures were obtained from the helicopter's air speed and magnetic compass heading and are therefore somewhat crude. The site was selected to be well out into the dynamic region of the ice on the windward side of the island. The ice in this region was composed of many floes separated by 10- to 20-foot-high recent pressure ridges, with short re-frozen leads in several places. The ice was generally continuous and considerably more compact than that on the sides of the island.

Because of deteriorating weather, time did not permit a thickness measurement of the floe, and only shallow salinity samples were obtained. The salinity was 0.5 p.p.t. at 5 cm. depth and 1.5 p.p.t. at 25 cm. depth. Three ice stress transducers were set out on this floe, located near its center and buried about 12 inches deep in the ice. About 8 inches of wind-packed snow covered the site.

The 15-foot-high antenna for the UHF transmitter was placed on the high point of the adjacent ridge and secured with ice pitons screwed into ice blocks. A red cloth marker was laid out over the ridge and weighted down with ice blocks to help identify the site later. The installation required two men working at top speed for two and a half hours. Once the transmitting site was in operation, it was necessary to return to the instrument hut to ascertain that data was being received and to rotate the antenna for optimal gain. With this done, the unit was left to operate on its own with enough battery power to last for two days. Further deterioration in the weather prevented us from revisiting the site for about a week. When the weather cleared enough to return, the computer, recorder, and beacon had all ceased to operate because their batteries had run down. These instruments were retrieved, but the floe with the transmitting site could not be found.

A second experiment using two transmitting sites was planned for May 21, 1976. However, the ice off shore proved to have too many areas of open water to allow safe operation of a helicopter without floats. Since no helicopter was available with floats at this time, the experiment was called off. In June a float-equipped aircraft became available, but by this time the weather was too warm to assure that the transducers would properly freeze into the ice, and no further experiments were performed.

III. Results:

Chart recordings and a tape recording of the stress data at three sites were obtained and are being analyzed.

IV. Preliminary Interpretations:

N.A.

V. Problems Encountered:

See II.

VI. Estimate of Funds Expended:

100%

QUARTERLY REPORT

Contract No. 03-5-022-55
or 261/262
Research Unit No.
Reporting Period:
April 30-Jan. 1976
Number of Pages -

BEAUFORT SEA, CHUKCHI SEA, AND BERING STRAIT
BASELINE ICE STUDY PROPOSAL

William R. Hunt

and

Claus-M. Naske

June 30, 1976

JUL 1976
REC'D
OCS/APO

QUARTERLY REPORT

I. Task Objectives:

The investigators are continuing their compilation of ship logs and other pertinent data relating to the history of ice conditions in the Beaufort and Chukchi Seas and the Bering Strait. The process of recording ice positions on base charts of the regions under study is also being carried forward.

II. Field Activities

Investigator Claus-M. Naske is currently gathering data in San Francisco (Maritime Museum), the National Archives in Washington, and in the Old Whaling Museum of New Bedford, Massachusetts. The San Francisco Maritime Museum holds the records of Liebes and Company, a pioneer whaling company which operated in the Beaufort Sea; whaling logs from the Old Whaling Museum have been examined; and further work on the U.S. Coast Guard (and its predecessor, the U.S. Revenue Marine) records has been carried on at the National Archives.

III. Results

A good deal of data has been gathered, synthesized, and recorded on blueline base maps. At the termination of the contract period an atlas will be produced in cooperation with the Arctic Environmental Information and Data Center in Anchorage.

An effort to located the logs of the Bureau of Indian Affairs cruises to the Bering Strait and the Arctic has not been successful thus far. The investigators were not able to locate these records in the Federal Record Center on a research trip to Seattle during the early part of this quarter.

FIFTH QUARTERLY REPORT

TITLE: Development of Hardware and Procedures for *In-Situ* Measurement of Creep in Sea Ice

PERIOD: April 1, 1976 - June 30, 1976

PRINCIPAL INVESTIGATORS: Lewis H. Shapiro, William M. Sackinger and Richard D. Nelson, Geophysical Institute, University of Alaska

I. TASK OBJECTIVE: To develop hardware and procedures for *in-situ* measurement of creep sea ice.

II. SCHEDULE: Field program and evaluation of results.

III. RESULTS: The field program was continued at Barrow until May 15, 1976. Tests during this quarter were primarily directed towards calibration of stress transducers and determination of the loading characteristics of flatjacks. In addition, experiments on the techniques for conducting strength tests in uniaxial compression, direct shear and indirect tension were continued with satisfactory results.

Since returning from Barrow, our efforts have been primarily directed towards data analysis, evaluation of equipment performance and modification of equipment where necessary. In addition, analysis of the creep test results presented by Peyton (1966) has continued.

IV. PRELIMINARY INTERPRETATION: None

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES: None

VI. ESTIMATED FUNDS EXPENDED: $15,000.

QUARTERLY REPORT

Contract # 03-5-022-55, task 10
Research Unit # 267
Reporting Period, April 1 to
June 30, 1976
Number of Pages - 6

OPERATION OF AN ALASKAN FACILITY FOR APPLICATIONS OF REMOTE-SENSING DATA TO OCS STUDIES

Albert E. Belon
Geophysical Institute
University of Alaska

July 1, 1976

OPERATION OF AN ALASKAN FACILITY FOR APPLICATIONS OF REMOTE-SENSING DATA TO OCS STUDIES

Principal Investigator: Albert E. Belon
Affiliation: Geophysical Institute, University of Alaska
Contract: NOAA # 03-5-022-55
Research Unit: # 267
Reporting Period: April 1 to June 30, 1976

I. TASK OBJECTIVES

The primary objective of the project is to assemble available remote-sensing data of the Alaskan outer continental shelf and to assist other OCS investigators in the analysis and interpretation of these data to provide a comprehensive assessment of the development and decay of fast ice, sediment plumes and offshore suspended sediment patterns along the Alaskan coast from Yakutat to Demarcation Bay.

II. LABORATORY ACTIVITIES

A. Operation of the Remote-Sensing Data Library

We continued to search periodically for new Landsat imagery of the Alaskan coastal zone entered in the EROS Data Center (EDC) data base. As a result 212 cloud-free Landsat scenes were selected and ordered from EDC at a cost of $1,671 and a standing order was placed with EDC for $10,000 of Landsat and aircraft data to cover purchases until the end of the contract period. These data products, which are gradually received from EDC, complete our files of Landsat data from the launch of the first satellite, July 26, 1972, with at least the following data products.

- 70 mm positive transparencies of multispectral scanner (MSS) spectral bands 4,5 and 7
- 70 mm negative transparency of MSS, spectral band 5
- 9 ½-inch print of MSS,spectral band 6

We continued to receive and catalog daily copies of NOAA satellite imagery of Alaska in both the visible and infrared spectral bands under a standing order with the NOAA/NESS Fairbanks Satellite Data Acquisition Station. 258 NOAA scenes at a total cost of $2,322.00 were acquired in 10" positive transparency format during the reporting period.

We received and catalogued 26 runs (45 ft.) of side-looking radar (SLAR) imagery acquired by a U.S. Army Mohawk aircraft on May 11, 12 and 13, 1976 under contract with NOAA/OCSEAP. The data provide complete coverage of the Beaufort and Chukchi Sea shelves during the critical pre-break-up period and are generally of very good quality. A catalog of these data was distributed to OCS investigators on June 1, 1976 through Arctic Project Bulletin No. 10 and is reproduced here as an appendix.

B. Operation and Maintenance of Data Processing Facilities

Most of the data processing equipment was kept operational, in spite of several minor break-downs, during the reporting period and was utilized by several OCS investigators.

The CDU-200 Digital Color Display System was only partially operational (one channel out of 3), owing to extraordinary delays in the delivery of the necessary parts, but this did not cause problems for the OCS investigators because they used the system primarily for intensity-slicing and reflecting profiles which require only one operating channel.

The digital image recorder, purchased with state funds, was received from the manufacturer in early May. Preliminary testing of the system indicated that the supplied software overfilled the 16 k memory of the NOVA 1620 minicomputer. The manufacturer agreed to revise the software. In the meantime mechanical and focusing tests have been made successfully, but the system is not yet operational.

The Variscan 9½" film projector, acquired from federal surplus is partially operational, but activitation of the film transport mechanism awaits the delivery of necessary electrical components.

Other data processing equipment (color-additive viewer, zoom transfer scope, multi-format stereo light table, photographic equipment) remained operational and utilized throughout the reporting period.

C. Development of Data Analysis and Interpretation Techniques

Much of the project's activity in this area during the reporting period was devoted to the conversion of existing computer programs from the IBM 360/40 University of Alaska computer which is being phased out to the recently acquired Honeywell 66/20 time-sharing computer. In particular programs for reading Landsat tapes and computing reflectivity profiles and multispectral histograms were converted and developed, respectively, at the request of Dr. Lewis Shapiro (RU # 248,249).

An "Isoclass" spectral clustering program for classification of sea-ice and land ecosystem is being acquired from NASA/Johnson Space Center and will be converted to our computing facilities during the next reporting period.

Techniques for classifying and reproducing SLAR data have been developed in cooperation with Dr. Jan Cannon (RU # 99).

D. Assistance to OCS investigators

Twenty one OCS projects requested substantial and often repeated assistance during the period, ranging from data searches and orders to operation of data processing equipment and digital analysis of Landsat data.

Data purchases by OCS investigators totalled $1,257.00 from the EROS data center and several hundred dollars in work orders to our photographic laboratory for urgent or custom reproduction of selected data, principally SLAR data. In addition many OCS investigators performed analysis of library copies of data in our facility.

The project participated in the formulation and supervision of the SLAR data acquisition program of a U.S. Army Mohawk data on May 11, 12, and 13, 1976. Twenty six data runs (several hundred flight line miles) were acquired with swath width of 25, 50 and 100 km. Most of the data is of very good quality (see appendix) and is already being used by OCS investigators.

The project also participated with John Murphy, Gunter Weller and David Kennedy (OCSEAP) in the formulation of a remote-sensing data acquisition program by the National Ocean Survey's (NOS) Buffalo aircraft. This aircraft will be based in Anchorage from June 15 to September 15 to acquire aerial photography of Shelikof Strait for NOS, and apparently may be able to acquire natural color and color-infrared photography of strategic OCS lease sale areas, on a time available basis for only the cost of the film.

Negotiations continued with the NASA/Ames Research Center for the acquisition of U-2 aerial photography of the entire Alaskan coastline during June 1976. The program was approved, but in late May problems with the aircraft and stratospheric sampling sensors, caused the postponement of the Alaskan mission to late September. This is a great disappointment because OCS field activities in the Beaufort Sea will be heavily concentrated in June and weather statistics are poor in September; but we hope that the NOS Buffalo aircraft will be an adequate substitute in June, time and weather permitting.

III. RESULTS

None to be reported at this time, except for the distribution of remote-sensing catalogs through the Arctic Project Bulletins, and the results discussed as part of the previous section.

IV. PRELIMINARY INTERPRETATION OF RESULTS

This project provides a support function to the other OCS projects. Therefore disciplinary data interpretation will be reported by the individual user projects.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

None of substance or unusual character.

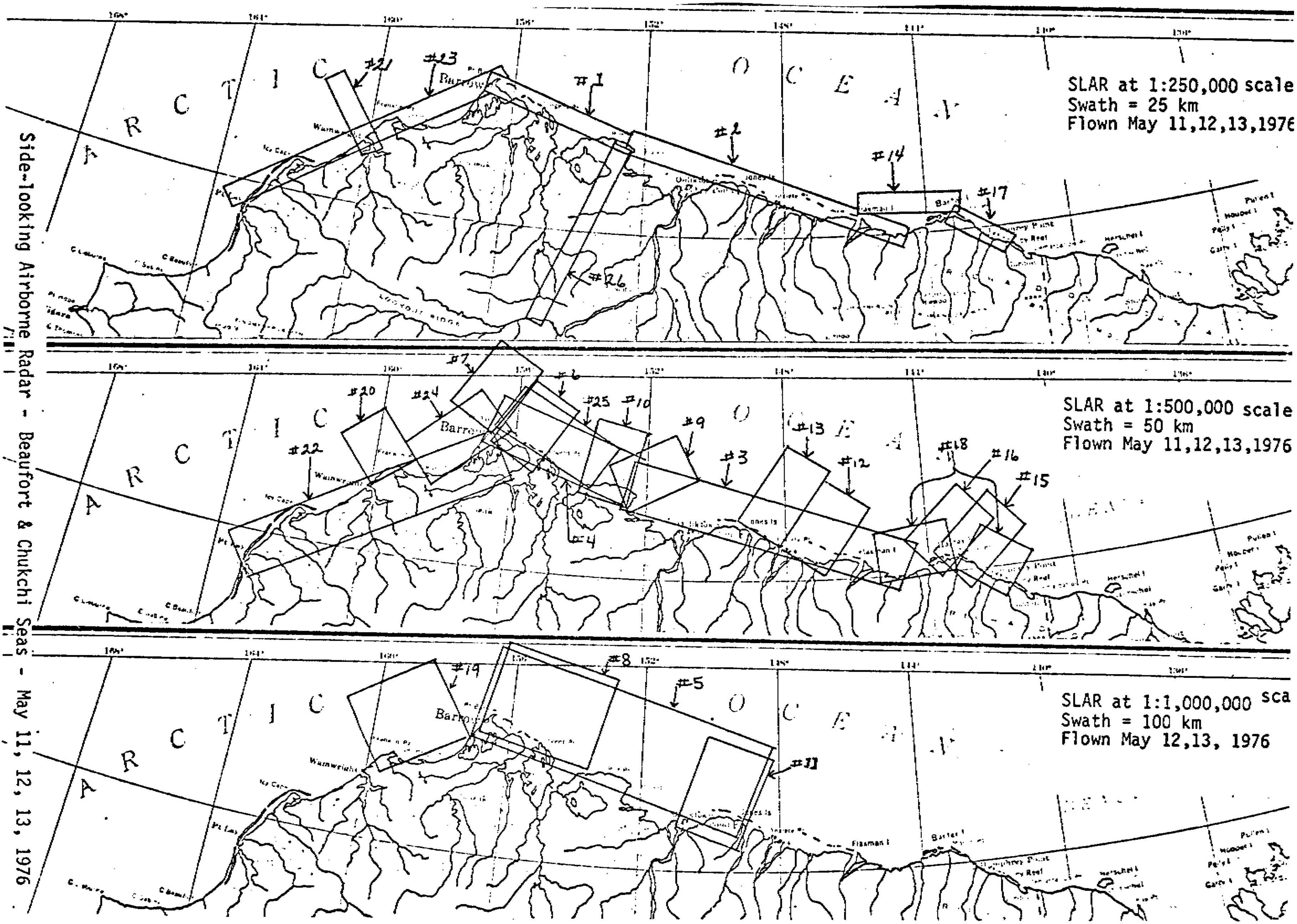
VI. ESTIMATES OF FUNDS EXPENDED

At May 30, 1976 (the last available fiscal report) the unexpended balance of the project was $57,517.48. Estimated expenses and outstanding obligations incurred in June totalled $18,000 leaving an estimated unexpended balance of $39,517 as of June 30, 1976, the end of the current reporting period.

SLAR DATA LOG

Project: Outer Continental Shelf Energy Program
Location: Beaufort and Chukchi Seas
Aircraft: Mohawk OV-1
Flight Line: Between points indicated (see map)
Instrument: Motorola Side Looking Radar
X-Band (3.5 cm) Real Aperture
Dual Antenna Mode

Date	Run	Flight Line	Range Swath	Lineal Ft of Film	Processing Quality	Film Quality
5-11-76	1	Barrow - Pitt Point	25	3'	fair	good
5-11-76	2	Cape Halkett - Flaxman	25	5'	fair	good
5-11-76	3	Flaxman - Cape Halkett	50	3'	very good	very good
5-11-76	4	Pitt Point - Barrow	50	2'	very good	very good
5-12-76	5	Barrow - Beechey Point	100	1'	very good	good
5-12-76	6	Tangent Point -	50	1'	very good	good
5-12-76	7	Barrow -	50	1'	very good	good
5-12-76	8	Barrow - Smith Bay	100	1'	very good	fair
5-12-76	9	Cape Halkett	50	1'	very good	good
5-12-76	10	Pitt Point	50	1'	fair	fair
5-12-76	11	Oliktok -	100	1'	very good	fair
5-12-76	12	Anxiety Point	50	1'	good	good
5-12-76	13	Anxiety Point	50	1'	very good	good
5-12-76	14	Flaxman - Barter Island	25	2'	very good	good
5-12-76	15	Martin Point	50	1'	very good	very good
5-12-76	16	Barter Island	50	1'	very good	good
5-12-76	17	Humphrey Point	25	1'	good	good
5-12-76	18	Barter Island - Flaxman	50	1'	very good	good
5-13-76	19	Franklin Point	100	1'	fair	fair
5-13-76	20	Franklin Point	50	1'	good	good
5-13-76	21	Wainwright - Chukchi	25	2'	very good	good
5-13-76	22	Barrow - Point Lay	50	3'	very good	good
5-13-76	23	Point Lay - Barrow	25	5'	good	good
5-13-76	24	Barrow - Franklin Point	50	1'	very good	good
5-14-76	25	Barrow - Smith Bay	50	1'	very good	very good
5-14-76	26	Cape Halkett - Colville River	25	3'	very good	very good



SLAR at 1:250,000 scale
Swath = 25 km
Flown May 11,12,13,1976

SLAR at 1:500,000 scale
Swath = 50 km
Flown May 11,12,13,1976

SLAR at 1:1,000,000 sca
Swath = 100 km
Flown May 12,13, 1976

Side-looking Airborne Radar - Beaufort & Chukchi Seas - May 11, 12, 13, 1976

DATA MANAGEMENT

DATA MANAGEMENT

Research Unit	Proposer	Title	Page
361/ 362/ 363	Edgar F. Law NODC/EDS James R. Stear ESIC/EDS	The Alaskan MEA Program	859

ANNUAL REPORT

Research Units: 361, 362, 363
Reporting Period: April 1, 1975 -
March 31, 1976
Number of Pages: 35

This report was inadvertently omitted from the Annual Reports.

R.U. 361 - Data File Index for the Alaskan MEA Program
R.U. 362 - Establish and Service a Project Marine Baseline Data Base for the Alaska MEA Program
R.U. 363 - Bibliographic Support to Alaskan Outer Continental Shelf Energy Program (OCSEP) Principal Investigators

Principal Investigators

R.U. 361, 362

Edgar F. Law
Director, Special Projects Division
NODC/EDS
Washington, DC 20235

R.U. 363

James R. Stear
ESIC/EDS
Washington, DC 20235

April 1, 1976

CONTENTS - PART I

LIST OF FIGURES AND TABLES

INTRODUCTION

The Alaskan Outer Continental Shelf Environmental Assessment Program (OCSEAP) involves approximately 150 principal investigators and 135 specific tasks. Baseline data for OCSEAP include marine birds and mammals, fishes, plankton, benthos, chemistry, geology, geophysics, intertidal studies, sea ice, physical oceanography, meteorology, effects of contaminants and the data management task for handling these data.

Within the Environmental Data Service, the National Oceanographic Data Center acts as the lead center for data archiving and data base management, involving a number of activities:

- development and distribution of formats for OCSEAP data
- accession and archival of OCSEAP data
- coordination with individual principal investigators regarding data formats, documentation, processing and products
- compilation of inventories of data to be submitted, project data received, and archival data holdings
- development of a digital data base (OCSEAP data bank) to include both historical and project data. The OCSEAP data bank is considered to be that portion of the data base consisting of digital data received from OCSEAP investigators or obtained from historical data sources.
- response to requests from the Project Office, principal investigators and other investigators for environmental data and data products using the OCSEAP data bank and other environmental data bases.
- response to requests for descriptions of other available data bases within the OCSEAP area
- response to requests for literature searches and other information within the OCSEAP area.

ACHIEVEMENTS

ADMINISTRATIVE:

In April 1975, the National Oceanographic Data Center (NODC) was designated to coordinate Environmental Data Service (EDS) activities concerning the development of Marine Environmental Assessment studies and surveys in Alaskan waters. By October 1975, orientation was completed for Michael Crane and James Audet to act as Alaskan and Washington, D. C., OCSEAP Data Coordinators. Preprocessing and data processing contracts were established in the field (Anchorage, Alaska) in March 1976, to support OCSEAP data processing requirements. The remaining three positions for OCSEAP were allocated to NODC's Data Preparation and Data Services Divisions and the National Climatic Center's Applied Climatology Branch.

A number of meetings and trips were conducted over the past year, primarily concerned with data format development and data management. The more important meetings and trips are listed in Appendices 1 and 2.

The inability to anticipate data requests for both NODC and other NOAA products and to identify proper channels and funds to provide OCSEAP investigators with these products has caused some difficulty in providing information in a reasonable length of time. Supplementary funds have been requested for FY '76 to accommodate future requests and an account has been established with the National Climatic Center for OCSEAP meteorological requests received through NODC.

A Comprehensive Data Management Plan for OCSEAP is in the final stages of completion and should be available within the next month or so.

DATA PROCESSING:

A Data Base Processing Summary for the 1975-76 OCSEAP was completed in August 1975. This summary described the work to be done, the media and distribution of the data, and the data bank status for the various data sets collected under each research unit. A revision and update of this summary was completed in March 1976, which included more detailed information available from the Program Work Statements and a limited number of data management plans, data submission schedules, cruise schedules, and information from NODC liaison officers and OCSEAP principal investigators.

Fifteen NOAA Form 24-23 -- Report of Observational/Samples Collected by Oceanographic Programs (ROSCOPs) have been received to date for NEGOA and OCSEAP (Appendix 3). A total of 14 data sets for NEGOA and OCSEAP have been received at NODC and NGSDC and are listed in Table 1. The more relevant NEGOA/OCSEAP reports received this past year are listed separately in Table 2.

Table 1 - NEGOA/OCSEAP Data Received through March 1976

Rec'd	
4/18/75	NEGOA current meter data on magnetic tape from PMEL (data available for archival but not in OCSEAP format - waiting for conversion to OCSEAP format made available to principal investigator)
4/22/75	NEGOA STD data on magnetic tape from PMEL (not in OCSEAP format)
4/25/75	Non-NEGOA Cook Inlet current meter data from NOS on nine magnetic tapes - (returned to NOS on January 1976 for reformatting in OCSEAP format)
6/3/75	NEGOA current meter data on magnetic tape from PMEL (not in OCSEAP format - same status as NEGOA current meter data listed above)
8/15/75	NEGOA CTD data on magnetic tape from PMEL (not in OCSEAP format - same status as NEGOA STD data listed above)
12/5/75	OCSEAP BT data from Reed (PMEL) for MILLER FREEMAN BTs processed by NODC
1/5/76	NEGOA Intertidal data on magnetic tape from NMFS - Auke Bay (interim OCSEAP Intertidal Format)
2/1/76*	NEGOA Thompson cruise (9-10/74) - Seismic Profiles on microfilm (see Fig. 1 for trackline coverage).
2/9/76	OCSEAP Hydrocarbon data on punched cards from PMEL (interim OCSEAP Hydrocarbon Format)
2/11/76	OCSEAP Lagrangian current data on punched cards from AOML (interim Lagrangian Current Format)
3/10/76	OCSEAP STD data on magnetic tape from IMS (in OCSEAP STD Format of 10/15/75)

*Received by NGSDC

3/12/76	OCSEAP Intertidal data on magnetic tape from Dr. Broad (W. Wash. St.) (Data in P.I.s format - will be converted to OCSEAP Intertidal Format when available)
3/25/76	OCSEAP current meter data from data buoys on magnetic tapes - U. of Washington (PMEL) (In OCSEAP current meter format)
3/25/76	OCSEAP pressure gauge data from data buoys on magnetic tape - U. of Washington (PMEL), (In OCSEAP pressure gauge format)

Table 2 - NEGOA/OCSEAP Reports Received through March 1976

Published Program Work Statements - 9 volumes, NOAA/BLM, 1975

The Western Gulf of Alaska - A Summary of Available Knowledge, Arctic Environmental Information and Data Center, April 1974

Preliminary Taxon List and Code for ADP Processing, George Mueller, University of Alaska, October, 1975

Environmental Assessment of Northeast Gulf of Alaska, ERL, 1975 (Draft)

NEGOA First Year Reports - reports of thirteen investigators with nine reports containing data suitable for NODC data accession

September, 1975 Trace Metal/Hydrocarbon Seminar Recommendations, Aerospace report for BLM

Computer Codes for Birds of North America, U.S. Fish and Wildlife Service,1975

Environmental Atlas of Chukchi Sea and Bering Strait, Arctic Environmental Information and Data Center, 1975

*USGS Open File Report 75-644 for THOMPSON cruise of Sept-Oct. 1974 (NEGOA)

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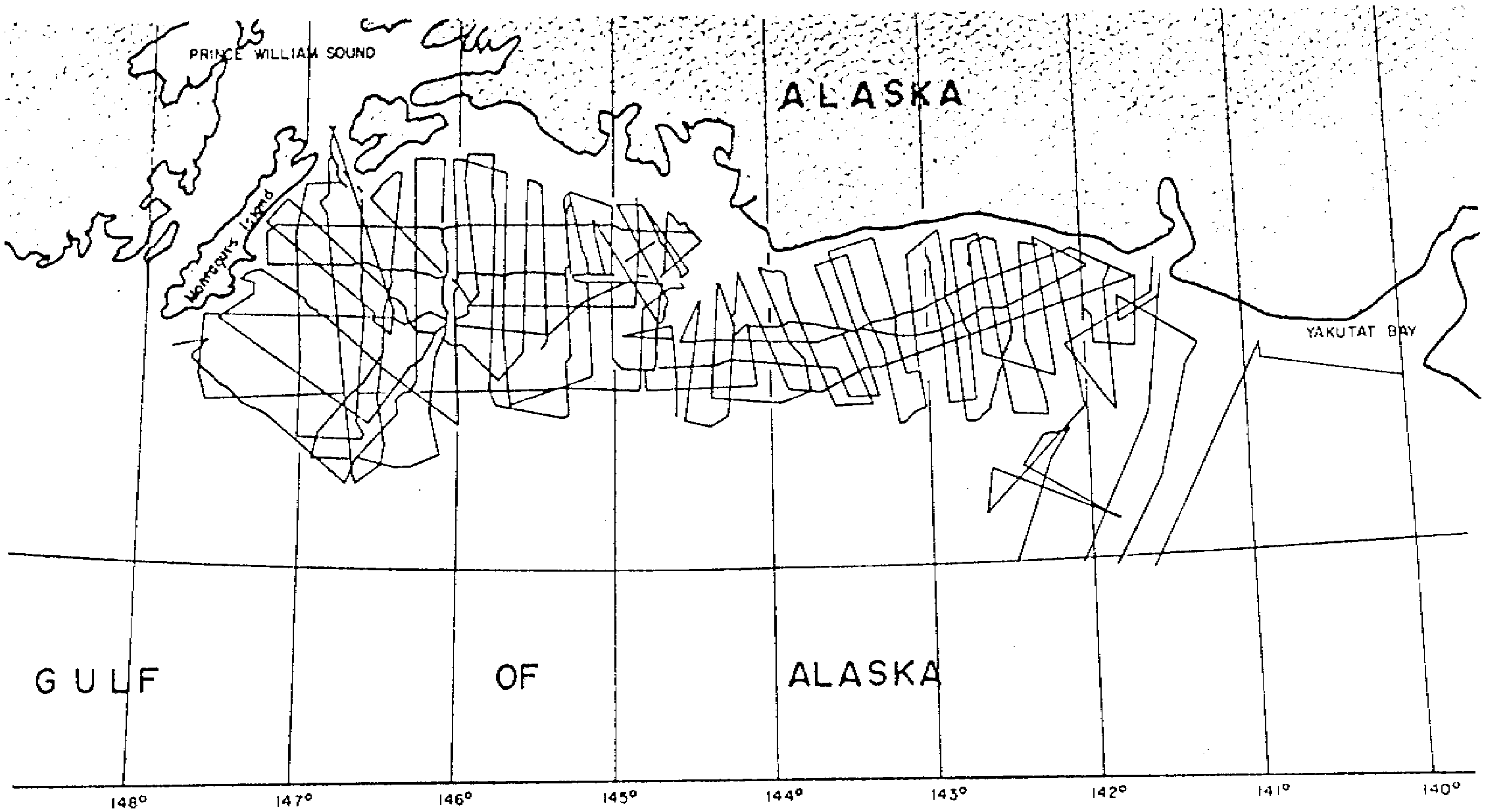
*Received at NGSDC



USGS NEGOA PROGRAM

SEISMIC REFLECTION DATA AVAILABLE FROM
ENVIRONMENTAL DATA SERVICE

TRACKLINE MAP OF THE R/V THOMAS G. THOMPSON CRUISE
(SEPTEMBER-OCTOBER, 1974)

A backlog of non-project Nansen casts (2600 stations) and XBTs (450 observations) collected within the OCSEAP area have been processed at NODC. Non-project data processing, which includes Nansen casts, STDs and BT data, is continuing on a first-priority basis.

Data requests for this past year concerning OCSEAP have been involved almost soley with historical data summaries and products (Appendix 4). Requests for products from the National Climatic Center and National Ocean Survey also have been coordinated through NODC.

Several OCSEAP data sets received at NODC presently are in the final data processing stages. Incomplete Data Documentation Forms (DDF) and improperly formatted data severely impacts on both the time required to process the data for the OCSEAP data bank and on the time needed to develop new data formats.

DATA FORMAT DEVELOPMENT:

Minimum data format requirements were distributed to BLM/OCS project managers at the OCS Data Managers Workshop in October 1975. A more complete description of minimum data format requirements was distributed in February 1976, to principal investigators through the Juneau Project Office. (This information consisted of a portion of the recently completed Data Management Plan for the Puget Sound Energy-Related Research Project and the MESA Puget Sound Project).

Approximately 20 different data formats have been developed to date for various OCSEAP investigations. Formats for currents, pressure, and STDs were distributed in September 1975. Nine additional data formats were completed and distributed to the Project Office and to a number of principal investigators during February 1976. The distribution of formats by research unit and principal investigator is shown in Appendix 5. Appendix 6 provides one example of this distribution. The remaining formats listed in Table 3 are planned for distribution by the end of March 1976.

Comparing this list with the list of potential formats to be developed (Table 4), it is estimated that format development (for the present OCSEAP investigators and tasks) is approximately 50 percent completed. A flow chart describing the principal elements in developing each format is included as Appendix 7.

The impact to date on NODC's data base management has been primarily on data format development. It is obvious that as data are submitted utilizing formats recently distributed, data processing requirements at NODC will increase rapidly while the need for additional format development still continues, as indicated in Table 4. Recent discussions with

Table 3 - Data Formats Completed and Underway

File Type	
001	Trace Metals in Organisms, Sediment and Water Column (abbreviated version)
017	Pressure Gauge
021	Trace Metals
022	STD Data
023	Fish Resource Assessment
024	Zooplankton II
025	Mammal Specimen
027	Mammal Sighting I
028	Phytoplankton Species
029	Primary Productivity
030	Intertidal Data
032	Benthic Organisms
033	Bird Sighting I - Ship/Aircraft
034	Bird Sighting II - Land Census
035	Bird Colony
036	Ship Follower (Bird)
038	Migratory Bird Sea Watch
043	Hydrocarbon I
056	Lagrangian Current Measurements

Table 4 - Potential* Data Format Development

Surficial Sediment Characteristics (undergoing revision for MESA/OCSEAP)

Feeding Flock (Marine Bird)

Intertidal/Subtidal

Benthic MicroFauna

Food/Stomach Contents

Habitat Classification (General Habitats)

Ice Characteristics

Fish Spawning (Herring)

Marine Mammal (Lab Specimen)

Marine Bird (Lab Specimen)

Fish Population

Fish Pathology

Permafrost Properties

Beach Profiles

Suspended Sediments

Hypocenter/Earthquake Data

Hydrocarbon II

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* Data management plans or other information indicate a possible need to supply one or more investigators with a data format which has not yet been developed.

personnel from the National Geophysical and Solar Terrestrial Data Center (NGSDC) has resulted in obtaining their assistance and cooperation in developing formats for geological and geophysical data collected for the OCSEAP data bank. Expected schedules for development and distribution of data formats have slipped several months because of continuing modifications and additions requested by OCSEAP investigators as well as identification of new format requirements by the Project Office and individual investigators.

DATA BASE MANAGEMENT:

An automated punched card deck listing 1975-76 OCSEAP investigators was completed in November 1975. This deck permitted sorting by research unit, principal investigator, study area, or organization. Copies were distributed to the Project Offices and NODC liaison officers. An updated version of this list was completed in March 1976. A parameter inventory technique for OCSEAP and other new data formats was initiated in November 1975. When completed, this task will provide a vocabulary format or thesaurus for environmental data and will serve as the standard for terms for acquisition and retrieval of data in the Environmental Data Base Directory (EDBD) of NODC.

In December 1975, a subset of 15,000 ocean stations and 36,000 BT observations comprising the OCSEAP area were compiled from NODC's historic data base and placed on separate magnetic tapes. Updates of these tapes will be completed as additional data are processed for the OCSEAP area. A summary of current drift information was also completed in December 1975, for the Gulf of Alaska and Bering Sea. The summary was presented for 5° areas and individual months.

An Environmental Data Base Directory (EDBD) listing of available environmental data bases in the OCSEAP area was completed in January 1976. The computer listing describes the data parameters available in each data base, the sources and availability of the data and contacts for obtaining information from the data bases. An updated version including a large number of recently described Washington and Alaska data bases was completed in March 1976 and a copy of the listing is being distributed as a separate report.

A study to develop an investigator information file was initiated in February 1976. This file is intended to provide a cross-reference and interface with ROSCOP information, data tracking inventories and file types being utilized by each OCSEAP investigator.

The poor record for submission of NEGOA and OCSEAP ROSCOPs should improve in the near future with NOS ships now being instructed to submit ROSCOPs as part of their Project Instructions. Furthermore, through personal contacts and correspondence, most OCSEAP investigators are now aware of NODC's requirements for ROSCOPs and have been instructed on how to complete the form. The lack of both ROSCOPs and specific cruise information in the past has made it extremely difficult to establish a data tracking system for OCSEAP similar to that being developed for other projects.

TAXONOMIC CODE

The complex nature of the OCSEAP program and the need for centralized archiving necessitate a single, unified list of taxonomic names with appropriate higher groups for the management of biological data. For automated storage and processing of the terms, for the correlation with associated numerical environmental data, and for the retrieval of groups of organisms, without the need for extremely large amounts of core in the computer, a hierarchical numeric code is necessary. Heretofore, different codes have been generated in an uncoordinated fashion for individual project areas. In late December 1975, through the Office of Sea Grant, NODC supported a proposal from the Institute of Marine Science (IMS), University of Alaska at Fairbanks, for a numeric code to species and higher taxa based on earlier VIMS work.

When completed in October 1976, the numeric code will be applicable on a world-wide basis to higher taxa (to family level) and genera and species can then be fitted easily into it. The code is contained in 10 digits, i.e., 5 double bytes, and is hierarchical from phylum to species or class to species, depending on the group under study. Provision is also being made for subspecies of birds and mammals to be added as digits 11 and 12.

ENVIRONMENTAL DATA INDEX (ENDEX)

The Environmental Data Base Directory (EDBD), the principal ENDEX file, contains descriptions of historical data bases. This inventory is intended to direct scientists, managers and decision-makers to sources of environmental data. During the past year this file has grown from 3500 descriptions to 5400. Of this total, 630 data bases have been described for states bordering the Pacific. A cross-indexed computer listing of all files containing data in the OCSEAP area has been prepared and is being distributed to the OCSEAP Office, the Juneau Project Office and Mike Crane's office in Anchorage.

At present, there are active efforts toward describing additional files in Alaska, British Columbia, Washington, and Oregon. These efforts will undoubtedly uncover more files pertinent to the OCS Alaskan program.

During the past year, NODC has answered thirty requests for data inventories in the OCSEAP area, as follows:

Environmental Data Base Directory - 21 requests
(EDBD)

Current Meter Inventory - 6 requests

Report of Observations/Samples Collected by - 2 requests
Oceanographic Programs (ROSCOP)

Bottom Photograph Inventory - 1 request

ENVIRONMENTAL SCIENCE INFORMATION CENTER (ESIC)

Over the past year, the Oceanic and Atmospheric Scientific Information System (OASIS) has been utilized to provide literature searches for forty-two principal investigators for OCSEAP. A total of 170 searches have been completed for these investigators. It is projected that approximately 250 searches will be completed through September, 1976.

Information concerning OASIS services has been widely distributed to OCSEAP investigators through the ESIC office and through the OCSEAP Data Coordinators in Washington, D.C. and Anchorage. The demand for this type of support has far exceeded the initial projections at the outset of the project. A submission for continued funding of this service is being submitted for FY 1977.

GOALS

(next quarter)

The following items are brief descriptions of the goals determined for the next quarter:

- Complete and distribute additional data formats.
- Conversion of selected NEGOA data presently in report form to existing or proposed data formats for inclusion in the OCSEAP data bank.
- Complete processing of XBT backlog for OCSEAP area.
- Identify specific data sets to be keypunched by Alaskan preprocessor.
- Begin Crane's role for processing data sets submitted to Juneau Project Office.
- Determine most efficient methods of transferring keypunched and processed data from Anchorage to NODC.
- Establish the investigator information file for interacting with the data tracking system and data parameter and file type information.
- Work with NGSDC/Project Office to determine required formats and data parameters for geology/geophysics work in OCSEAP.
- Complete scheduled trip by NGSDC personnel to Seattle, Juneau, Anchorage, and Fairbanks to contact investigators and Project Managers concerning geological/geophysical data format requirements.
- Continue coordination of investigator inputs to Dr. Mueller's/ NODC taxonomic code efforts.
- Continue to describe additional data files in OCSEAP area and distribute inventories to the Project Office, NODC liaison officers and principal investigators.

Appendix 1 - Major Meetings and Workshops

Place	Dates	Purpose	EDS Attendees
Wash., D.C.	10/23/75	OCS Res. Mgm't Adv. Board	Ridlon, Audet, Berger
Wash., D.C.	10/29/75	OCS Data Mgr's Workshop	NODC
Boulder, CO	11/13/75	Project-EDS Relationships and Pre-Processing by EDS	Law
Anchorage, AK	11/18/75	Marine Mammal Data Parameters	Crane
Santa Cruz, CA	12/3/75	Marine Mammal Formats	Crane
Asilomar, CA	12/10-12/12/75	Marine Bird Formats (Pacific Seabird Group)	Stein/Audet
Menlo Park, CA	12/15/75	Marine Geology Formats (USGS)	Stein/Audet/Grim
Anchorage, AK	3/1/76	Alaska Dept. of Fish and Game-Herring Studies/ Formats	Crane
Boulder, CO	3/16/76	Geological/Geophysical Data Formats with Pelto and Fischer	Hittleman/Combellick

MARINE MAMMALS MEETING, ALASKA DEPARTMENT OF FISH AND GAME

Anchorage, AK - 18 November 1975

Michael Crane	EDS Anchorage	279-4523
Robert Meyer	NOAA Juneau	586-7438
George Divoky	ADF&G Fairbanks	452-1531
Paul Arneson	ADF&G Anchorage	344-0541
Ken Pitcher	ADF&G Anchorage	344-0541
Dave Norton	U. of A-NOAA Fairbanks	479-7371
John J. Burns	ADF&G Fairbanks	452-1531
Karl Schneider	ADF&G Anchorage	344-0541
Don Calkins	ADF&G Anchorage	344-0541
Lloyd Lowry	ADF&G Fairbanks	452-1531
Tom Eley	ADF&G Fairbanks	452-1531
Mauri Pelto	Project Officer, Juneau	586-7438

Marine Mammal Meeting

Santa Cruz, CA

3 December 1975

Michael Crane	EDS Anchorage	907-279-4523
Calvin J. Lensink	FWS Anchorage	265-5401
Donald Calkins	ADF&G Anchorage	344-0541
Kenneth Pitcher	ADF&G Anchorage	344-0541
Kent Wohl	Alaska OCS Office, Anchorage	276-5131
John Hall	FWS Anchorage	265-5401
Bob Dieterich	U. of A, Fairbanks	479-7166
Howard Braham	NMFS, Seattle (MMD)	206-442-4734
Mauri J. Pelto	Data Manager, Juneau OCSEP	907-586-7438
Donald S. Day	Oceanographer, Juneau OCSEP	907-586-7435

Attendees at OCSEAP Program Review and Data Format Workshop -

Asilomar, California - Dec. 10-13, 1975

Jay Quast - Juneau Project Office

Bob Meyer - Juneau Project Office

Dave Norton - Fairbanks Project Office

Kent Wohl - Alaska OCS Office - BLM

Bob Stein - EDS - NODC

Jim Audet - EDS - NODC

Dennis Heinemann - Oregon State Univ.

Wayne Hoffman - Oregon State Univ.

Doug Causey - Univ. of California - Irvine

George and Molly Hunt - Univ. of California - Irvine

Peter Conners - Univ. of California - Bodega Bay

William Drury - Massachusetts and National Audubon Societies

Douglas and Diane Schamel - Univ. of Alaska - Fairbanks

Pete Michelson - Univ. of Alaska - Fairbanks

Stan Senner - Univ. of Alaska - Fairbanks

Sam and Rene Patten - Johns Hopkins Univ.

David Manuwal - Univ. of Washington

Juan Guzman - Univ of Calgary

James Bartonek - USFWS - Anchorage

Dave Cline - USFWS - Anchorage

Gerald Sanger - USFWS - Anchorage

Paul Arneson - Alaska Dept. F&G - Anchorage

George Divoky - Alaska Dept. F&G - Anchorage

Attendees - Menlo Park Meeting - December 15, 1975

Mauri Pelto - Juneau Project Office - OCSEAP

Paul Grim - NGSDC, Boulder

Jim Audet - NODC (D781)

Bob Stein - NODC (D752)

U.S. Geological Survey

- Paul Carlson
- Alan Cooper
- David Drake
- James Gardner
- Monty Hampton
- David Hopkins
- John Lahr
- Graig Mellendrie
- Bruce Molnia
- Hans Nelson
- Erk Reimnitz
- Dave School
- Tracey Vallier

Additional USGS personnel attended portions of the meeting but their names are not available.

Appendix 2 - OCSEAP Travel*

Place	Date	Purpose	Travelers
Seattle, WA	7/75	Formats	Stein, Ridlon
Fairbanks, AK Juneau, AK Anchorage, AK	10/6-10/17/75	Formats and OCSEAP Admin.	Crane, Stein
Seattle, WA	10/75	Data Formats	Stein, Ridlon
Juneau, AK Seattle, WA	12/8-12/12/75	Data Formats	Crane
Fairbanks, AK	1/7-1/13/76	U. Alaska & Alaska Dept. Fish & Game Formats	Crane
Fairbanks, AK	2/8-2/11/76	U. Alaska & Alaska Dept. Fish & Game Formats	Crane
Seattle, WA Anchorage, AK Juneau, AK	2/22-2/28/76	Formats/OCSEAP Admin. w/Dale, Crane, Fischer, Pelto	Audet, Picciolo
Kodiak, AK	3/2-3/5/76	Alaska Dept. Fish & Game and Northwest Fisheries Center Data Formats	Crane
Fairbanks, AK	3/15-3/17/76	U. Alaska and Alaska Dept. Fish and Game Data Processing	Crane
Juneau, AK	3/26/76	OCSEAP	Crane

*Excludes travel to meetings indicated on previous page

Appendix 3 - NEGOA/OCSEAP ROSCOPs Received through March 1976

Date Rec'd	
July/75	R/V ACONA - Cr. 193 - NEGOA 7/1-7/11/74 U. Alaska (IMS) - Phy/Chem Oceanography, Geology, Biology, Meteorology
November/75	DISCOVERER - Cr. 808 - Leg. I - NEGOA 5/15-5/30/75 U. Alaska (IMS) & USFWS - Phy/Chem Oceanography, Geology, Biology
November/75	DISCOVERER - Cr. 808 - Leg II - NEGOA 6/2-6/9/75 U. Alaska (IMS) - Phy/Chem. Oceanography, Geology, Biology, Pollution Information
November/75	USNS SILAS BENT - Cr. 811 - Leg I - OCSEAP 8/31-9/14/75, U. Alaska (IMS) & USFWS - Phy/Chem Oceanography, Pollution, Geology, Biology, Meteorology
December/75	USNS SILAS BENT - Cr. 811 - Leg II - OCSEAP 9/17-9/28/75, U. Alaska (IMS) & USFWS - Phy/Chem. Oceanography, Biology, Meteorology
December/75	DISCOVERER - Cr. 812 - Leg IV - OCSEAP 10/8-10/16/75, U. Alaska (IMS), USFWS, U. Louisville - Phy/Chem Oceanography, Pollution, Biology, Geology
December/75	MILLER FREEMAN - RP-4-MF-75B-Leg II - 11/10/75-11/30/75, U. Alaska (IMS), USFWS, PMEL - Phy/Chem Oceanography, Biology
December/75	SURVEYOR - Cr. 814 - OCSEAP 10/28/75 U. Alaska (IMS) & USFWS, Phy Oceanography, Biology
January/76	DISCOVERER - Cr. 810, Leg I - OCSEAP 8/9-8/28/75 U. Alaska(IMS) & USFWS, Phy/Chem Oceanography, Biology
January/76	DISCOVERER - RP-4-DI-75-Leg III - OCSEAP 11/23-12/2/75, U. Alaska (IMS) & USFWS Phy/Chem Oceanography, Biology, Geology

January/76	R/V MONTAGUE - Cr. 1 - NEGOA 9/12/74-10/16/74 National Marine Fisheries Service (Auke Bay), Geology, Biology
January/76	PAT SAN MARIE - PSM-75-1-OCSEAP 7/25-10/12/75 National Marine Fisheries Service (NWFC), - Phy. Oceanography, Biology
January/76	NORTH PACIFIC - NP-75-1-NEGOA/OCSEAP 5/3-8/7/75 National Marine Fisheries Center (NWFC), Biology
January/76	MILLER FREEMAN - MF-75-1-OCSEAP 8/11-10/26/75 National Marine Fisheries Service (NWFC) Phy. Oceanography, Biology
March/76	CROMWELL/SURVEYOR - EGAL-75-KC 4/1-6/7/75, USGS, Geology

Missing ROSCOPs have been indicated to the Project Office (Juneau visit 2/27/76) for the following NEGOA and OSCEAP cruise periods:

RAINIER	May, 1975
DISCOVERER	September-October, 1975
SURVEYOR	April-June, 1975
"	July-August, 1975
"	September, 1975
"	November-December, 1975
OCEANOGRAPHER	January-February, 1975
"	February-March 1975
MILLER FREEMAN	August-October, 1975
McARTHUR	August 1974-April 1975
ACONA	July, 1974 October, 1974, November, 1974, March, 1975, June, 1975, September, 1975
THOMPSON	September-October, 1974

Appendix 4 - Requests for NODC Historical Data and Other Information for OCSEAP Investigations

Name of Requestor	Description	Data Rec'd	Date Out
Auke Bay Lab (NMFS)	Test Data-NE Gulf AK	June, 1975	July, 1975
Pelto (OCSEAP)	Nansen/Zooplankton Test	May, 1975	August, 1975
Pelto (OCSEAP)	Auke Bay Zooplankton	May, 1975	August, 1975
Ridlon	STD data in OCSEAP area	August, 1975	August, 1975
Ridlon	PIDS Plots-2° areas - annual XBT/MBT/station data	Sept., 1975	Sept., 1975
Molnia/Bruns (NGSDC)	Cruise data-Gulf of Alaska and other geological/geophysical data	Sept., 1975	Sept., 1975
Audet	NAPIS-OCSEAP ship data	Nov., 1975	Nov., 1975
Audet	NMFS/ADF&G cruises in OCSEAP area	Nov., 1975	Nov., 1975
Audet/Pelto	ACONA/Univ. Alaska cruises in OCSEAP area	Nov., 1975	Nov., 1975
Searby (AEIDC)	Surface current drift summaries 50°-60°N, 130°-180°W	Nov., 1975	Nov., 1975
BLM/OCS (Anchorage)	Bottom photographs for selected OCSEAP areas	Dec., 1975	Dec., 1975
Audet/Crane	PIDS plots-5° areas/monthly ocean station distribution w/cruise numbers	Dec., 1975	Dec., 1975
Royer (IMS)	Inventory of 1974-75 Coast Guard STD data in OCSEAP area	Dec., 1975	Dec., 1975

Royer (IMS)	Selected Coast Guard STD data on magnetic tapes w/listings	Jan., 1976	Jan., 1976
Royer (IMS)	Arrange w/NCC to provide Dr. Royer with Middleton Island and EB-03 surface observations on magnetic tape-to be forwarded monthly through 9/76	Feb., 1976	March, 1976
Dr. Alverson (NMFC) *	Descriptive Geology and grain size analysis data for Bering Sea	Feb., 1976	Feb., 1976
Pelto (OCSEAP)	Lower Cook Inlet Nansen STD data for July	Feb., 1976	Feb., 1976
Laevastu (EPRF)	Cook Inlet current meter listings plots ordered through NOS	Feb., 1976	March, 1976
Pelto (OCSEAP)	Surface Pressure Charts-Northern Hemisphere ordered through NCC	Feb., 1976	March, 1976
Dr. Koeneman (ADF&G)	NEGOA STD/CTD station and NODC product information	Feb., 1976	March, 1976
Combellick (NGSDC)	USGS NEGOA Report/Geological Data Formats	March, 1976	March, 1976
Pelto (OCSEAP)	IMS/PMEL Physical Oceanography Report for NEGOA	March, 1976	March, 1976
Nelson (USGS) *	Sedimentary/Geochemistry Data Format Information	March, 1976	March, 1976

*Request to NGSDC

Appendix 5

DISTRIBUTION OF DATA FORMATS

RU	P.I. NAME	ADDRESS	STUDY AREA	FILE I.D*
3	ARNESON, P.D.	ADFG	BIRDS	033,034,035,036,038
3	DIVOKY, G.J.	ADFG	BIRDS	033,034,035,036,038
4	ARNESON, P.D.	ADFG	BIRDS	033,034,035,036,038
4	DIVOKY, G. J.	ADFG	BIRDS	033,034,035,036,038
5	FEDER, H. M.	IMS/ALASKA	FISH/PLANK	028,029,032
6	CAREY, A.G.	OREGON ST.	FISH/PLANK	028,029,032
7	CAREY, A.G.	OREGON ST.	FISH/PLANK	028,029,032
13	ESTES, J.A.	USFWS	MAMMALS	025,027
14	ESTES, J.A.	USFWS	MAMMALS	025,027
16	DAVIES, J.	LAMONT	GEOLOGY	- - -
19	REGNART, R.	ADFG	FISH/PLANK	032
23	JACKSON, P.	ADFG	FISH/PLANK	023,032
23	MCCRARY, J.	ADFG	FISH/PLANK	028,029,032
24	KAISER, R.	ADFG	FISH/PLANK	028,029,032
27	FLAGG, L.B.	ADFG	FISH/PLANK	028,029,030,032
27	ROSENTHAL, R.J.	DAMES/MOOR	FISH/PLANK	030
29	ATLAS, R.M.	LOUISVILLE	CHEMISTRY	- - -
30	ATLAS, R.M.	LOUISVILLE	CHEMISTRY	- - -
31	GALT, J.A.	NOAA/PMEL	PHY. OCEAN.	015,017,022
31	PREISENDORFER, R.	NOAA/JTRE	PHY. OCEAN.	- - -
34	RAY, G. C.	J. HOPKINS	MAMMALS	025,027
34	WARTZOK, D.	J. HOPKINS	MAMMALS	025,027
38	HICKEY, J.J.	WICONSIN	BIRDS	033,034,035,036,038
43	CHESLER, S.N.	NAT. BU. ST.	CHEMISTRY	021,043
43	GUMP, B.H.	NAT. BU. ST.	CHEMISTRY	021,043
43	HERTZ, H.S.	NAT. BU. ST.	CHEMISTRY	021,043
43	MAY, WILLIE E.	NAT. BU. ST.	CHEMISTRY	021,043
44	CHESLER, S. N.	NAT. BU. ST.	CHEMISTRY	021,043
44	GUMP, B. H.	NAT. BU. ST.	CHEMISTRY	021,043
44	HERTZ, H. S.	NAT. BU. ST.	CHEMISTRY	021,043
44	MAY, WILLIE E.	NAT. BU. ST.	CHEMISTRY	021,043
45	CHESLER, S. N.	NAT. BU. ST.	CHEMISTRY	021,043
45	GUMP, B. H.	NAT. BU. ST.	CHEMISTRY	021,043
45	HERTZ, H.S.	NAT. BU. ST.	CHEMISTRY	021,043
45	MAY, WILLIE E.	NAT. BU. ST.	CHEMISTRY	021,043
47	BARNES, I.L.	NAT. BU. ST.	CHEMISTRY	021,043
47	BECKER D.A.	NAT. BU. ST.	CHEMISTRY	021,043
47	CHESLER, S. N.	NAT. BU. ST.	CHEMISTRY	021,043
47	HERTZ, H.S.	NAT. BU. ST.	CHEMISTRY	021,043
47	LAFLEUR, P. D.	NAT. BU. ST.	CHEMISTRY	021,043
48	BARRICK, D. F.	NOAA/WPL	PHY. OCEAN.	056
58	ANDERSON, G. C.	WASHINGTON	FISH/PLANK	028,029
58	LAM, R.K.	WASHINGTON	FISH/PLANK	028,029
59	BOOTHROYD, J.C.	U/S CAR	GEOLOGY	- - -
59	HAYES, M.O.	U/S CAR	GEOLOGY	- - -
62	DEVRIES, A.L.	SCRIPPS	EFFECT/CON	023
64	NELSON, M.O.	NMFS/NWFC	FISH/PLANK	023,028,029,032

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* Data Format (See Table 3)

RU	P.I. NAME	ADDRESS	STUDY AREA	FILE I.D.*
64	PEREYRA, W. T.	NMFS/NWFC	FISH/PLANK	023,028,029,032
67	FISCUS, C. H.	NMFS/NWFC	MAMMALS	025,027
67	ROPPEL, A. Y.	NMFS/NWFC	MAMMALS	025,027
68	FISCUS, C.H.	NMFS/NWFC	MAMMALS	025,027
68	HARRY, G. Y.	NMFS/NWFC	MAMMALS	025,027
69	FISCUS, C. H.	NMFS/NWFC	MAMMALS	025,027
69	MCALISTER, W. B.	NMFS/NWFC	MAMMALS	025,027
70	HARRY, G. Y.	NMFS/NWFC	MAMMALS	025,027
70	MARQUETTE, W. M.	NMFS/NWFC	MAMMALS	025,027
71	GENTRY, R. L.	NMFS/NWFC	EFFECT/CON	- - -
71	MCALISTER, N. B.	NMFS/NWFC	EFFECT/CON	- - -
72	KARIWEN, J. F.	NMFS/AUKE	EFFECT/CON	- - -
72	RICE, S. D.	NMFS/AUKE	EFFECT/CON	- - -
73	HODGINS, H. O.	NMFS/NWFC	EFFECT/CON	001
73	MALINS, D. C.	NMFS/NWFC	EFFECT/CON	001
73	WEBER, D. D.	NMFS/NWFC	EFFECT/CON	001
74	MALINS, D. C.	NMFS/NWFC	EFFECT/CON	001
74	REICHERT, W. L.	NMFS/NWFC	EFFECT/CON	001
74	ROUBAL, W. T.	NMFS/NWFC	EFFECT/CON	001
75	MALINS, D. C.	NMFS/NWFC	EFFECT/CON	001
77	TILLMAN, M. F.	NMFS/NWFC	BIRDS	- - -
78	MERRELL, T. R.	NMFS/AUKE	FISH/PLANK	030
78	ZIMMERMAN, S. T.	NMFS/AUKE	FISH/PLANK	030
79	MERRELL, T. R.	NMFS/AUKE	FISH/PLANK	030
79	ZIMMERMAN, S. T.	NMFS/AUKE	FISH/PLANK	030
81	HUFFORD, G. L.	USCG	PHY. OCEAN.	056
83	HUNT, G. L. JR.	CALIF/IRV.	BIRDS	033,034,035,036,038
87	MARTIN, S.	WASHINGTON	SEA ICE	- - -
88	KOVACS, A.	CRREL	SEA ICE	- - -
88	WEEKS, W. F.	CRREL	SEA ICE	- - -
89	CAMPBELL, W. J.	USGS/PUGET	SEA ICE	- - -
89	WEEKS, W. F.	CRREL	SEA ICE	- - -
91	AAGAARD, K.	WASHINGTON	PHY. OCEAN	015
91	HAUGEN, D. P.	WASHINGTON	PHY. OCEAN.	015
96	PATTEN, S. M. JR.	J. HOPKINS	BIRDS	033,034,035,036,038
98	UNTERSTEINER, N.	WASHINGTON	SEA ICE	056
99	CANNON, P. J.	U/ALASKA	GEOLOGY	- - -
105	BERG, R.	CRREL	GEOLOGY	- - -
105	BLOUIN, S.	CRREL	GEOLOGY	- - -
105	CHAMBERLAIN, E.	CRREL	GEOLOGY	- - -
105	KOVACS, A.	CRREL	GEOLOGY	- - -
105	SELLMANN, P.	CRREL	GEOLOGY	- - -
108	WIENS, J. A.	OREGON ST.	BIRDS	033,034,035,036,038
111	CARLSON, R. F.	IWR/ALASKA	PHY. OCEAN.	N/A
123	SMITH, R. L.	U/ALASKA	EFFECT/CON	- - -
138	HAYES, S. P.	NOAA/PMEL	PHY. OCEAN.	015,017,022
138	SCHUMACHER, J. D.	NOAA/PMEL	PHY. OCEAN.	015,017,022
139	HAYES, S. P.	NOAA/PMEL	PHY. OCEAN.	015,017,022

RU	P.I. NAME	ADDRESS	STUDY AREA	FILE I.D.*
139	SCHUMACHER, J. D.	NOAA/PMEL	PHY. OCEAN.	015,017,022
140	GALT, J. A.	NOAA/PMEL	PHY. OCEAN.	015,017,022
140	PREISENDORFER, R.	NOAA/JTRE	PHY. OCEAN.	015,017,022
141	COACHMAN, L.K.	WASHINGTON	PHY. OCEAN.	015,017,022
141	SCHUMACHER, J. D.	NOAA/PMEL	PHY. OCEAN.	015,017,022
145	COACHMAN, L.K.	WASHINGTON	PHY. OCEAN.	015,017,022
145	SCHUMACHER, J. D.	NOAA/PMEL	PHY. OCEAN.	015,017,022
146	GALT, J. A.	NOAA/PMEL	PHY. OCEAN.	015,017,022
146	PREISENDORFER, R.	NOAA/JTRE	PHY. OCEAN.	015,017,022
147	HAYES, S. P.	NOAA/PMEL	PHY. OCEAN.	015,017,022
147	SCHUMACHER, J. D.	NOAA/PMEL	PHY. OCEAN.	015,017,022
148	COACHMAN, L. K.	WASHINGTON	PHY. OCEAN.	015,017,022
148	SCHUMACHER, J. D.	NOAA/PMEL	PHY. OCEAN.	015,017,022
149	GALT, J. A.	NOAA/PMEL	PHY. OCEAN.	015,017,022
149	PREISENDORFER, R.	NOAA/JTRE	PHY. OCEAN.	- - -
151	AAGAARD, K.	WASHINGTON	PHY. OCEAN.	- - -
152	CLINE, J. D.	NOAA/PMEL	GEOLOGY	043
152	FEELY, R. A.	NOAA/PMEL	GEOLOGY	043
153	CLINE, J. D.	NOAA/PMEL	CHEMISTRY	043
153	FEELY, R. A.	NOAA/PMEL	CHEMISTRY	043
154	CLINE, J. D.	NOAA/PMEL	GEOLOGY	043
154	FEELY, R. A.	NOAA/PMEL	GEOLOGY	043
155	CLINE, J. D.	NOAA/PMEL	CHEMISTRY	043
155	FEELY, R. A.	NOAA/PMEL	CHEMISTRY	043
156A	ENGLISH, T. S.	WASHINGTON	FISH/PLANK	024,028,029,032
156B	DAMKAER, D. M.	NOAA/PMEL	FISH/PLANK	024,028,029,032
156C	LARRANCE, J. D.	NOAA/PMEL	FISH/PLANK	028,029,032
156D	COONEY, R. T.	IMS/ALASKA	FISH/PLANK	024,028,029,032
156E	ALEXANDER, V.	IMS/ALASKA	FISH/PLANK	024,028,029,032
162	BURRELL, D. C.	IMS/ALASKA	CHEMISTRY	001,021
163	BURRELL, D. C.	IMS/ALASKA	CHEMISTRY	001,021
164A	ENGLISH, T. S.	WASHINGTON	FISH/PLANK	024,028,029,032
164B	DAMAKER, D. M.	NOAA/PMEL	FISH/PLANK	024,028,029,032
164C	LARRANCE, J. D.	NOAA/PMEL	FISH/PLANK	028,029,032
164D	COONEY, R. T.	IMS/ALASKA	FISH/PLANK	024,028,029,032
164E	ALEXANDER, V.	IMS/ALASKA	FISH/PLANK	024,028,029,032
172	CONNERS, P. G.	CALIF/BOD.	BIRDS	033,034,035,036,038
172	RISENBROUGH, R. W.	CALIF/BOD	BIRDS	033,034,035,036,038
174	HUGHES, S. E.	NMFS/NWFC	FISH/PLANK	023,028,029,032
174	PEREYRA, W. T.	NMFS/NWFC	FISH/PLANK	023,028,029,032
174	RONHOLT, L. T.	NMFS/NWFC	FISH/PLANK	023,028,029,032
175	BAKKALA, R. G.	NMFS/NWFC	FISH/PLANK	023,028,029,032
175	PEREYRA, W. T.	NMFS/NWFC	FISH/PLANK	023,028,029,032
175	REEVES, J. E.	NMFS/NWFC	FISH/PLANK	023,028,029,032
183	CALDWELL, R. S.	OREGON ST.	EFFECT/CON	N/A
190	GRIFFITHS, R. P.	OREGON ST.	CHEMISTRY	N/A
190	MORITA, R. Y.	OREGON ST.	CHEMISTRY	N/A
194	FAY, F. H.	IMS/ALASKA	MAMMALS	025/027
196	DIVOKY, G. J.	ADFG	BIRDS	033,034,035,036,038
204	BARNES, P.	USGS	GEOLOGY	- - -
204	REIMNITZ, E.	USGS	GEOLOGY	- - -
205	BARNES, P.	USGS	GEOLOGY	- - -

RU	P.I. NAME	ADDRESS	STUDY AREA	FILE I.D.*
205	DRAKE, D.	USGS	GEOLOGY	- - -
205	REIMNITZ, E.	USGS	GEOLOGY	- - -
206	VALLIER, T. L.	USGS	GEOLOGY	- - -
206	GARDNER, J.	USGS	GEOLOGY	- - -
208	DEPRE, W. R.	USGS	GEOLOGY	- - -
208	HOPKINS, D. M.	USGS	GEOLOGY	- - -
209	HOPKINS, D. M.	USGS	GEOLOGY	- - -
210	LAHR, J. C.	USGS	GEOLOGY	- - -
210	PAGE, R. A.	USGS	GEOLOGY	- - -
212	CARLSON, P. R.	USGS	GEOLOGY	021
212	MOLNIA, B. F.	USGS	GEOLOGY	021
215	MUELLER, G.	IMS/ALASKA	BIRDS	N/A
215	SCHAMEL, D.	IMS/ALASKA	BIRDS	N/A
216	CARLSON, P. R.	USGS	GEOLOGY	021
216	MOLNIA, B. F.	USGS	GEOLOGY	021
217	HANSEN, D. V.	NOAA/AOML	PHY. OCEAN.	056
229	PITCHER, K. W.	ADFG	MAMMALS	025,027
230	BURNS, J. J.	ADFG	MAMMALS	025,027
230	FLEY, T. J.	ADFG	MAMMALS	025,027
230	LOWRY, L.	ADFG	MAMMALS	025,027
231	BURNS, J. J.	ADFG	MAMMALS	025,027
231	HARBO, S. J.	ADFG	MAMMALS	025,027
232	BURNS, J. J.	ADFG	MAMMALS	025,027
232	FLEY, T. J.	ADFG	MAMMALS	025,027
232	LOWRY, L.	ADFG	MAMMALS	025,027
233	BENDOCK, T.	ADFG	FISH/PLANK	028,029,030,032
233	ROGUSKI, E. A.	ADFG	FISH/PLANK	028,029,030,032
235	LAEVASTU, T.	EPRF/NAVAL	PHY.OCEAN.	N/A
237	DRURY, W. H.	MASS. AUD.	BIRDS	033,034,035,036,038
238	DRURY, W. H.	MASS. AUD.	BIRDS	033,034,035,036,038
239	GUZMAN, J.	U. CALGARY	BIRDS	033,034,035,036
239	MYRES, M. T.	U. CALGARY	BIRDS	033,034,035,036
240	SCHNEIDER, K.	ADFG	MAMMALS	025,027
241	SCHNEIDER, K.	ADFG	MAMMALS	025,027
243	CALKINS, D.	ADFG	MAMMALS	025,027
243	PITCHER, K. W.	ADFG	MAMMALS	025,027
243	SCHNEIDER, K.	ADFG	MAMMALS	025,027
244	BARRY, R. G.	INSTAAR	SEA ICE	- - -
248	BURNS, J. J.	ADFG	MAMMALS	025,027
248	FAY, F. H.	IMS/ALASKA	MAMMALS	025,027
248	SHAPIRO, L.H.	GI/ALASKA	MAMMALS	- - -
249	BURNS, J. J.	ADFG	MAMMALS	025,027
249	FAY, F. H.	IMS/ALASKA	MAMMALS	025,027
249	SHAPIRO, L. H.	GI/ALASKA	MAMMALS	- - -
250	HARRISON, W. D.	GI/ALASKA	SEA ICE	N/A
250	SHAPIRO, L. H.	GI/ALASKA	SEA ICE	N/A
251	KIENLE, J.	GI/ALASKA	GEOLOGY	- - -
251	PILPAN, H.	GI/ALASKA	GEOLOGY	- - -
253	HARRISON, W. D.	GI/ALASKA	GEOLOGY	- - -

RU	P.I. NAME	ADDRESS	STUDY AREA	FILE I.D.*
253	OSTERKAMP, T. E.	GI/ALASKA	GEOLOGY	- - -
255	HARRISON, W. D.	GI/ALASKA	GEOLOGY	- - -
255	OSTERKAMP, T. E.	GI/ALASKA	GEOLOGY	- - -
256	HARRISON, W. D.	GI/ALASKA	GEOLOGY	- - -
256	OSTERKAMP, T. E.	GI/ALASKA	GEOLOGY	- - -
257	STRINGER, W. J.	GI/ALASKA	SEA ICE	- - -
258	STRINGER, W. J.	GI/ALASKA	SEA ICE	- - -
259	NELSON, R. D.	GI/ALASKA	SEA ICE	- - -
259	SACKINGER, W. M.	GI/ALASKA	SEA ICE	- - -
261	HUNT, W. R.	GI/ALASKA	SEA ICE	- - -
261	NASKE, C. M.	GI/ALASKA	SEA ICE	- - -
262	HUNT, W. R.	GI/ALASKA	SEA ICE	- - -
262	NASKE, C. M.	GI/ALASKA	SEA ICE	- - -
265	NELSON, R. D.	GI/ALASKA	SEA ICE	- - -
265	SACKINGER, W. M.	GI/ALASKA	SEA ICE	- - -
265	SHAPIRO, L. H.	GI/ALASKA	SEA ICE	- - -
267	BELON, A. E.	GI/ALASKA	SEA ICE	N/A
271	ROGERS, J. C.	GI/ALASKA	GEOLOGY	- - -
273	BURRELL, D. C.	IMS/ALASKA	CHEMISTRY	001,021
275	SHAW, D. G.	IMS/ALASKA	CHEMISTRY	043
276	SHAW, D. G.	IMS/ALASKA	CHEMISTRY	043
278	BARSDATE, R. J.	IMS/ALASKA	CHEMISTRY	021
281	FEDER, H. M.	IMS/ALASKA	FISH/PLANK	028,029,032
282	FEDER, H. M.	IMS/ALASKA	FISH/PLANK	028,029,032
284	SMITH, R. L.	U/ALASKA	FISH/PLANK	028,029,032
285	MORROW, J. E.	U/ALASKA	FISH/PLANK	N/A
288	BURRELL, D. C.	IMS/ALASKA	CHEMISTRY	001,021
289	ROYER, T. C.	IMS/ALASKA	PHY. OCEAN	015,017,022
290	HOSKIN, C. M.	IMS/ALASKA	GEOLOGY	- - -
291	HOSKIN, C. M.	IMS/ALASKA	GEOLOGY	- - -
292	HOSKIN, C. M.	IMS/ALASKA	GEOLOGY	- - -
293	BURRELL, D. C.	IMS/ALASKA	CHEMISTRY	001,021
294	SHAW, D. G.	IMS/ALASKA	CHEMISTRY	043
301	FEDER, H. M.	IMS/ALASKA	FISH/PLANK	028,029,032
303	FEDER, H. M.	IMS/ALASKA	FISH/PLANK	028,029,032
305	PEARSON, J. G.	IMS/ALASKA	EFFECT/CON	N/A
307	MUENCH, R. D.	IMS/ALASKA	PHY. OCEAN.	015,017,022
309	BURRELL, D. C.	IMS/ALASKA	CHEMISTRY	001,021
310	BURRELL, D. C.	IMS/ALASKA	CHEMISTRY	001,021
312	BURRELL, D. C.	IMS/ALASKA	CHEMISTRY	001,021
318	MORROW, J. E.	U/ALASKA	FISH/PLANK	N/A
327	HAMPTON, M.	USGS	GEOLOGY	- - -
330	DIVOKY, G. J.	ADFG	BIRDS	033,034,035,036,038
331	KARIWEN, J. F.	NMFS/AUKE	EFFECT/CON	- - -
331	RICE, S. D.	NMFS/AUKE	EFFECT/CON	- - -
332	MCCAIN, B. B.	NMFS/NWFC	CHEMISTRY	023
332	WELLINGS, S. R.	CALIFORNIA	CHEMISTRY	023

RU	P.I. NAME	ADDRESS	STUDY AREA	FILE I.D.*
334	KARIWEN, J.R.	NMFS/AUKE	EFFECT/CON	- - -
334	RICE, S. D.	NMFS/AUKE	EFFECT/CON	- - -
335	CALLAWAY, R. J.	PNERL/EPA	PHY. OCEAN.	- - -
337	BARTONEK, J.	USFWS	BIRDS	033,034,035,036,038
337	LENSINK, C. J.	USFWS	BIRDS	033,034,035,036,038
338	BARTONEK, J.	USFWS	BIRDS	033,034,035,036,038
338	LENSINK, C. J.	USFWS	BIRDS	033,034,035,036,038
339	BARTONEK, J.	USFWS	BIRDS	033,034,035,036,038
339	LENSINK, C. J.	USFWS	BIRDS	033,034,035,036,038
340	BARTONEK, J.	USFWS	BIRDS	033,034,035,036,038
340	LENSINK, C. J.	USFWS	BIRDS	033,034,035,036,038
341	BARTONEK, J.	USFWS	BIRDS	033,034,035,036,038
341	LENSINK C. J.	USFWS	BIRDS	033,034,035,036,038
342	BARTONEK, J.	USFWS	BIRDS	033,034,035,036,038
342	LENSINK, C. J.	USFWS	BIRDS	033,034,035,036,038
343	BARTONEK, J.	USFWS	BIRDS	033,034,035,036,038
343	LENSINK, C. J.	USFWS	BIRDS	033,034,035,036,038
347	BROWER, W. A.	NOAA/NCC	PHY. OCEAN.	N/A
347	SEARBY, H.W.	AEIDC/ALA	PHY. OCEAN.	N/A
348	MORROW, J. F.	U/ALASKA	FISH/PLANK	N/A
349	ENGLISH, T. S.	WASHINGTON	FISH/PLANK	N/A
350	ROSENBERG, D. H.	SG/ALASKA	DATA/MGMT	- - -
351	DIETER, D.	IMS/ALASKA	DATA/MGMT	- - -
352	MEYERS, H.	NOAA/NGSDC	GEOLOGY	021,043
354	MACY, P. T.	NMFS/NWFC	FISH/PLANK	023,028,029,032
354	PEREYRA, W. T.	NMFS/NWFC	FISH/PLANK	023,028,029,032
356	BROAD, A. C.	W.WASH.ST.	FISH/PLANK	- - -
357	FAVORITE, F.	NMFS/NWFC	PHY. OCEAN.	N/A
357	JOHNSON, J. H.	NMFS/PEG	PHY. OCEAN.	N/A
359	ENGLISH, T. S.	WASHINGTON	FISH/PLANK	024,028,029,032
359	HORNER, R.	WASHINGTON	FISH/PLANK	024,028,029,032
360	WILSON, W. J.	AEIDC	DATA/MGMT	- - -
361	LAW, E. F.	NOAA/NODC	DATA/MGMT	- - -
362	LAW, E. F.	NOAA/NODC	DATA/MGMT	- - -
363	STEAR, J.R.	NOAA/ESIC	DATA/MGMT	- - -
367	REYNOLDS, M.	NOAA/PMEL	PHY. OCEAN.	- - -
367	WALTER, B.	NOAA/PMEL	PHY. OCEAN.	- - -
407	LEWELLEN, R.	ARCTIC RES.	GEOLOGY	- - -
999	HICKOK, D.	AEIDC	DATA MGMT	- - -

NOTE: Because of unexpected delays, file types 023, 024, 025, 027, and 030 are now planned for distribution in early April 1976. All other file types have been distributed, as above.

In cases of multiple research units and investigators only one set of formats have been distributed for a given task; other individuals, such as data processors not on the above list have also received the appropriate formats.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
ENVIRONMENTAL DATA SERVICE
NATIONAL OCEANOGRAPHIC DATA CENTER
Washington, D.C. 20235

March 22, 1976 D781/JJA

TO : Distribution

FROM : Code D781, NODC

SUBJECT: OCSEAP Formats

We have developed the enclosed formats to be suitable for reporting specific OCSEAP data to NODC. Any formats that are not applicable to your particular data as defined in your Data Management Plan may be considered for your information only. The Juneau Project Office will be contacting you after reviewing these enclosures to indicate which of the formats are applicable to your tasks and to be incorporated in your data management plan.

It is requested that the dates indicated on both the formats and the codes be noted on the DDF for each of your data sets. It is emphasized that nothing be added or changed on the formats or codes without contacting NODC or the Juneau Project Office.

If there are any questions pertaining to this material, please contact Jim Audet (202-634-7441) or Bob Stein (202-634-7505) at the National Oceanographic Data Center.

cc: W. Fischer w/encl.
D. Norton "
M. Pelto "
M. Crane "
D. Dale "
R. Stein

Appendix 6 - Distribution of Data Format (Example)

March 22, 1976

Distribution - Migratory Bird Sea Watch Format

George Divoky

Paul Arneson

George Hunt, Jr.

Peter Conners

William Drury

James Bartonek

Calvin Lensink

Samuel Patten

Joseph Hickey

Wayne Hoffman