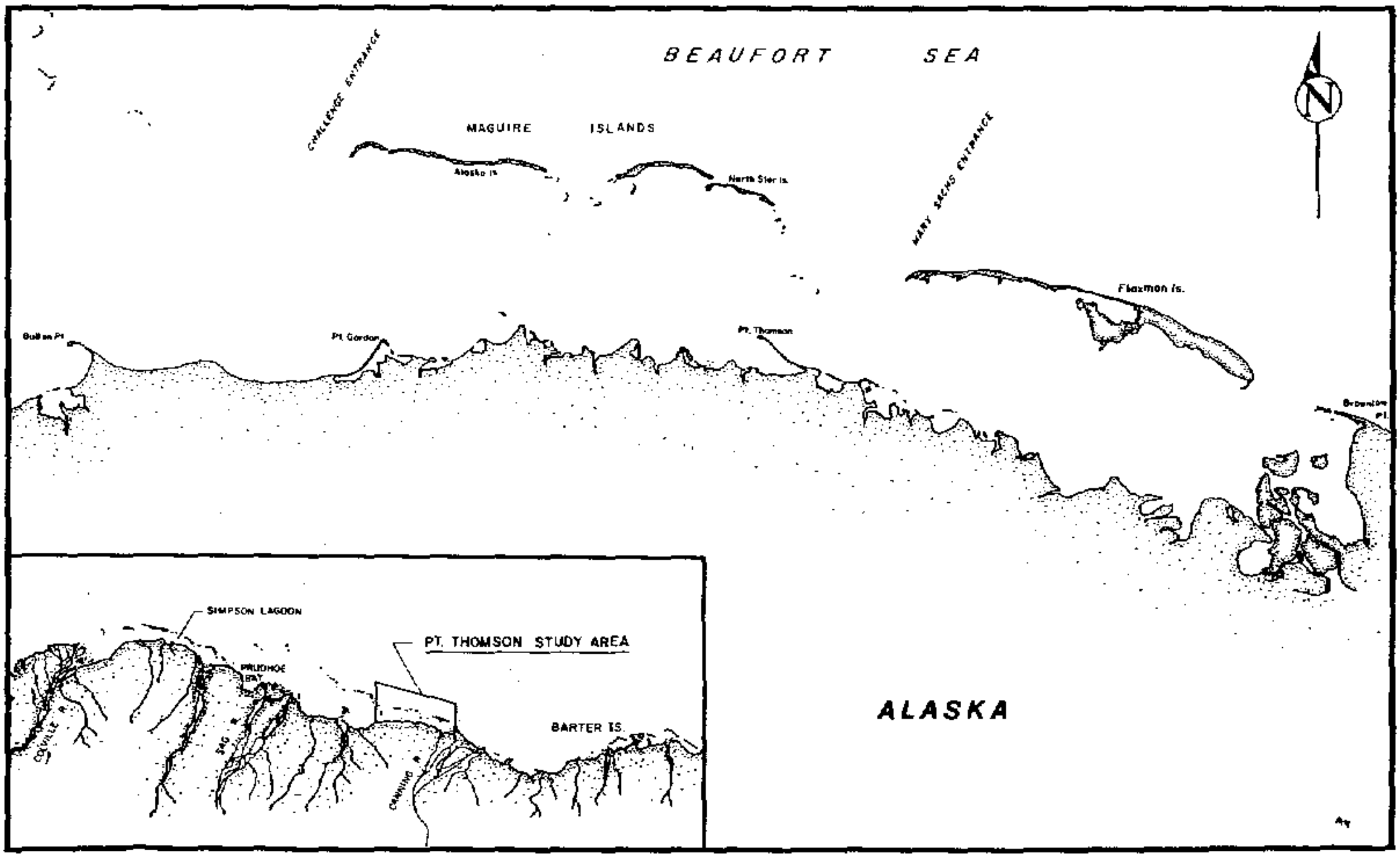
OCEANOGRAPHIC ENGINEERING SERVICES
POINT THOMSON DEVELOPMENT PROJECT
Agreement Number PTD-8204



VOLUME 1

Prepared for:
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Los Angeles, California

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Final Report

OCEANOGRAPHIC ENGINEERING SERVICES

POINT THOMSON DEVELOPMENT PROJECT

Agreement Number PTD-8204

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Los Angeles, California
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1 February 1983
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SUMMARY

1. Meteorological and oceanographic instrumentation was emplaced in the Point Thomson region extending from Bullen Point to Brownlow Point, and outside the barrier islands to the 50 foot depth contour. Instrumentation included a meteorological station on Challenge Island, two wave and water level gauges outside the barrier islands, two water level recorders within the lagoon system, and current meters both inside and outside the lagoon, including entrances. Instruments were emplaced at the end of July 1982 and recovered at the beginning of September 1982. Selected instruments were remoored for later recovery through the ice after freeze-up. The meteorological station was left in place. A wave gauge and current meter was placed outside the islands, another set emplaced inside the lagoon south of Flaxman Island, and a water level recorder and current meter emplaced in Mary Sachs Entrance. The instruments were emplaced in early September 1982. The station inside the lagoon and the meteorological station were recovered in early November 1982; the mooring outside the island and the one in the entrance were lost to ice.

2. Meteorological data recorded at Challenge Island between 28 July and 30 October 1982 correlated very well with simultaneous data taken by the National Weather Service at Barter Island. For example, correlation coefficients of 0.89 and 0.91 were obtained between Challenge Island and Barter Island data, with no significant time lags, for the fall and summer periods respectively. These results indicate that the long data base available at Barter Island should be a good representation of Point Thomson meteorological conditions for hindcasting and planning purposes. However, the extreme winds measured at Barter Island were higher than similar winds measured at the same time at Challenge Island (45 to 35 knots, respectively).

3. Wave conditions measured offshore the barrier islands during the summer of 1982 were very low, reflecting the general lack of strong winds and the rather persistent presence of moving ice observed during the summer.

   Maximum waves were usually less than two to three feet, with significant wave heights, H (s), of just over one foot and significant periods of about 2.5 seconds. One storm event (August 21-24) with winds about 20-plus knots, produced waves of maximum height of about five feet, with significant wave heights of about 2.75 feet and periods of about 3.2 to 3.5 seconds. An intense

storm during the fall (22 September) produced winds of 45 knots at Challenge Island and 50 knots at Barter Island. However, ice apparently moved over the lagoon wave gauge by 21 September, and no significant waves were recorded during this intense fall storm at the site within the lagoon.

4. Water depth records were returned from the two stations outside the barrier islands and from two stations inside the lagoon for the summer period. As expected, tidal signals extracted form these records were small relative to water level surge effects.

   The surge data clearly show the negative surge associated with easterly winds and the positive surge associated with westerlies. For the meteorological events of the summer record, which were of the order of 20 knot maximum winds, surge variations were of the order of ± one foot. Similar plots for the fall period show a surge of two feet plus associated with high winds during the ice covered period of 19-20 October, when winds reached 35 knots at Challenge Island and 45 knots at Barter Island. Driftwood elevations observed by Reimnitz and Mauer (1977) in the Point Thomson region indicate historical storm surges as high as 2.0 to 2.7 meters (6.6 to 8.9 feet), felt to be a 50- or 100-year event.

5. Coastal currents, both inside and outside the barrier islands were found to be wind driven, with tidal influences significant only in the lagoon entrance. A simple pattern of easterly and westerly water flow through the study region was found for both west wind and east wind conditions. For east wind conditions, flow outside the barrier islands was to the west, relatively slow (<25 cm/sec) at 50 foot depth and faster (to 75 cm/sec) at 25 foot depth. Flow under easterly wind condtions is into the lagoon at Mary Sachs Entrance and inshore at Challenge Entrance. Flow inside the lagoon is to the west, exiting the area near Bullen Point. This flow pattern simply reverses under westerly winds, except that flow is still into the lagoon through Challenge Entrance. Correlation coefficients for wind and currents were found to be 0.80 for the case of the deep (50 foot) offshore station with a lag of about 21 hours. A coefficient of 0.82 was found for a shallow station in the lagoon at the west end, with no significant lag.

6. Hydrographic profiles of salinity, temperature, dissolved oxygen, pH, temperature, and depth were accomplished at multiple stations covering the study area three times during the open water season. In addition, long term records of temperature and salinity were collected on six current meters in the area. Temperature recores were also collected from three of the four water pressure measuring gauges.

The water mass of the study area is typical of the nearshore Beaufort Sea, as described by other investigators. The warmer, less saline surface water is probably of river origin and overlies the colder, more saline oceanic shelf waters in the deeper offshore area. A slow increase in salinity with time indicated a limited exchange of oceanic waters with the nearshore lagoon waters. Major exchanges of water masses was driven by storm surges and local winds.

INTRODUCTION

Objectives

The purpose of this study was to provide oceanographic information for use in the engineering design associated with the Point Thomson Development Project. Specific objectives of the present study were the following:

1. Obtain measurements of nearshore and lagoonal currents, water levels, and waves by moored instrumentation in the Point Thomson development area from Bullen Point to Brownlow Point.

2. Obtain meteorological field measurements from a site located on one of the barrier islands in the Point Thomson area.

3. Collect temperature, salinity, depth, oxygen, pH, and transmissivity at hydrographic stations at least three times over the summer field season.

4. Synthesize existing literature data with the new field information.

5. Produce a summary document presenting the total data on these physical oceanographic and meteorological topics for the Point Thomson and offshore areas in a form convenient for use in engineering design. The topic of ice is not included in this present study.

Present Study

The present study was designed to meet some of the engineering needs and establish an initial data base for the development of the Point Thomson Area. Anticipated development may include offshore structures and gravel islands for exploration and production, causeways for cargo landing or pipeline protection, and increased vessel traffic in the area. Associated with this development will be erosion/sedimentation problems, ice protection, and concerns over nearshore temperature/salinity changes due to alterations in circulation as a result of construction of causeways or other structures.

The meteorological and oceanographic data needs for the Point Thomson area were thus planned against these applied problems involving erosion/sedimentation, coastal currents, and ice movements. Both local and coastwise meteorological parameters were viewed as oceanographic forcing functions of the waves, storm surges, and coastal currents. The work described herein was carried out to address the above needs during the open water/floating ice regime of the Beaufort Sea summer season of 1982. In addition, three station consisting of current meters, water level gauges, and wave gauges were emplaced both outside the barrier islands and inside the lagoon during the fall freeze-up period to be retrieved through the ice after freeze-up. The results of these fall mooring efforts are included in this report.

LITERATURE REVIEW

Due to the sparse amount of oceanographic data and information available for the Point Thomson area, a comprehensive literature review was made for the entire Beaufort Sea nearshore region. The oceanography of the Beaufort coast seems to be governed by the same forces throughout, combined with similar onshore and offshore topography. As a first approximation, data taken along this coast at distances far from the study area may still be used as a guide to conditions to be expected in the Point Thomson area.

Study Area

The study area is on the northern coast of Alaska to the east of Prudhoe Bay and the Sagavanirktok River and to the west of the Canning River (Figure 1). The specific area consists of the nearshore regions of this Beaufort Sea coastline bounded by Bullen Point on the west and Brownlow Point on the east, and extending outside the barrier islands to about the 60-foot depth contour (Figure 2).

The shoreline consists of tundra characteristic of the Arctic Coastal plain. Vertical relief is low, generally of the order of three to ten feet. Coastal erosion of the tundra thus exposes beach cliffs of only a few feet in height, consisting of peat soil with permafrost and associated ice lenses. A system of barrier islands exists offshore at a distance of approximately three nautical miles, separated by shallow lagoons with characteristic depths of three to twelve feet. These lagoons are more or less continuous along the Point Thomson region of the coast, with openings to the Beaufort Sea existing between the individual barrier islands or at the ends of specific lagoon complexes. The beaches within the lagoons which are protected from offshore wave action are of relatively fine materials or mud. Mainland beaches, exposed due to breaks in the offshore barrier island chain, graduate up to hard gravel beaches with spits being a common feature. The offshore barrier islands are also sand and gravel features, with remnants of tundra remaining on some islands. Offshore the barrier islands, water depths drop off to reach about 60-foot depths at distances of three miles. Ice break-up within the lagoons occurs in early July, with small boat navigation possible by mid-July. Floating ice floes is characteristic of the offshore area in summer, with density and movement dependent on winds which bring the pack ice either onshore or move it offshore. Freeze-up of the lagoons occurs in late September, preventing small boat navigation. Offshore, shorefast ice forms, out to about the 60-foot contour, protected from the moving ice floes of the Beaufort Sea by grounded ice ridges.

Very little physical oceanographic or meteorological data have been done in the Point Thomson region. Most of this work has been in regions to the west of the current study area. Early work was often centered around Point Barrow because of logistic constraints and the availability of the Naval Arctic Research Laboratory and associated logistics. Later work using these logistics included multiyear studies of the Colville River and delta (Louisiana State University) and in the Simpson Lagoon-Harrison Bay area (University of Alaska). Later, the Outer Continental Shelf Environmental Assessment Program concentrated efforts in the Simpson Lagoon to Prudhoe region, with later efforts in Harrison Bay. Industry sponsored work has been associated with development of oil related facilities, and has been concentrated in the Prudhoe Bay region, particularly in the area of the causeway. Recently, more work has been done offshore in conjunction with leasing and development of offshore tracts. The multi-year proprietary oceanographic measurement program funded by industry (Oceanographic Services Inc.) represents a body of such information for the central Beaufort coast to the west of the present study area, extending into Harrison Bay.

The applicability of data from elsewhere along the Beaufort coast to the Point Thomson region can only be by analogy, but possible because of similar topographic and meteorological conditions which exist along this region. The entire coastal area is backed by the flat arctic coastal plain, with the Brooks Range of mountains approaching the coast only at the far eastern end of the Alaskan Beaufort coast. Similarly, offshore shallow water with occasional barrier islands and lagoon systems persist along the coast. As a first approximation then, the Point Thomson area will exhibit low tides, with water levels controlled by wind and barometric pressure effects. From limited data elsewhere along the Beaufort nearshore areas, currents would be expected to be primarily wind driven, with tidal forcing effects low, except in restricted lagoon entrances. As with elsewhere along the coast wave climates would be expected to be highly controlled by ice. Storms that occur when the pack-ice is far offshore would result in significant wave activity, while those that occur when inshore ice cover is high would result in a markedly reduced wave climate.

Meteorology

Barrow (71°18'N, 156°47'W) and Barter Island (70°08'N, 143°38'W) are the only first-order weather stations on the Beaufort Sea coast. Besides these two stations, atmospheric data is collected at the DEW Line site (Oliktok) four times daily and at the Deadhorse Airport. The most complete compilation of weather statistics of all atmospheric parameters measured is presented in Browers Marine and Coastal Climatic Atlas (1977). This data is presented by month for Barrow, Barter Island, Lonely and Oliktok with an overall predicted mean condition for the entire Beaufort Sea coast.

To understand the winds that affect the Beaufort Sea coast, one must look at regional scale atmospheric pressure patterns. The most frequently occurring pressure pattern includes a high pressure system in the Beaufort Sea area with a low pressure system south of central Alaska (Moritz, 1979). This persistant weather pattern is what causes the prevailing easterly geostrophic winds in the Alaskan Arctic. During the summer and fall (July - December), cyclonic storm systems begin to penetrate into Alaska and the Arctic which cause intense west winds at times along the Beaufort Sea coastline (Billello, 1973; Moritz, 1979).

Winds are much more variable due to local dynamic forcing than was described in the general regional circulation patterns. Two types of local synoptic scale forcing are important along the Alaskan arctic coast: mountain barrier baroclinicity and sea breeze forcing.

Mountain barrier baroclinicity is caused by the piling up of cold air against the mountain range which creates a tilted cold air/warm air interface. This, in turn, produces a local pressure gradient independent of the regional scale gradients with the net result of a thermal wind (Schwerdtfeger, 1974). Schwerdtfeger has suggested that this explains why west winds are more common at Barter Island than at Point Barrow due to Barter Island's proximity to the Brooks Range. This phenomenon is most common during the winter, but could be important in the summer. Billello (1973) shows a bimodal wind distribution for Barter Island with east or northeast winds 45 percent of the time and west or southwest winds 34 percent of the time, whereas Barrow has just one peak for easterly winds, and is evenly distributed for the remainder of the compass directions.

Sea breeze effect is caused by differences in air temperatures over land and water. These winds have a large along-shore component due to continuous solar heat in the Arctic during the summer, the large horizontal extent of the coastline, and relatively large Coriolis acceleration at high latitudes (Moritz, 1977). Moritz first noticed the sea breeze effect in Barrow's wind records, where surface geostrophic winds were predicted to be 40 percent higher in January than in July but, on examining the records, the winds were found to be roughly the same speed. It was concluded by Moritz that an additional pressure gradient exists that is not recorded by the synoptic observation network, which acts to increase the winds in the easterly direction. Carsey's (1977) data from the summer of 1976 indicates the sea breeze to be occurring approximately one-third of the time. Further existence of sea breeze circulation is presented in Leavitt (1978), Kozo and Brown (1979), and Kozo (1979) for the Beaufort Sea Coast. Kozo and Brown (1979) also present a model for sea breeze circulation in the Arctic, and have shown sea breeze effects up to 30 km from the coast.

Carsey (1977) has shown the increased accuracy that can be obtained for predicting winds by adding surface pressure data from OCS buoys and a number of inland stations to the NWS observation network. In some instances, geostrophic wind directions differed as much as 60° between preditions using Carsey's and NWS surface charts. In Dygas (1975), wind data from Oliktok for the summer of 1972 is compared to long-term wind data for Barter Island showing a strong correlation. Data also indicates an increase in northwesterly winds between July and September with a corresponding increase in energy; this is believed to be due to the higher frequency of storm activity late in the summer. Kozo and Brown (1979) have shown a strong correlation between surface winds measurements at separation of up to 200 km along the Beaufort Sea Coast from Lonely to Barter Island, both from their data and Leavitt's (1978). Moritz (1979) presents a summary of climatic statistics for Barrow and Barter Island. Annual maximum sustained winds for selected return periods are calculated for Barrow and Barter Island (Brower, 1977). The 100-year return period wind speed is predicted to be 87.8 mph for Barrow and 124.5 mph for Barter Island. The higher wind speeds at Barter Island are believed to be an orographic effect due to the close proximity of the Brooks Range (Moritz, 1979).

Nearshore Currents

The nearshore currents are primarily wind-driven, with tides, river discharge and density gradients having a lesser influence on circulation patterns. Kinney et al (1972) measured currents in Simpson Lagoon with drifters and drogue floats and found the currents to be highly correlated with wind speed and direction. Other studies of currents in the Beaufort Sea employing surface drifters and drogues have had similar results with wind drift current calculated to be approximately 3 percent of the wind speed (Wiseman, 1973, 1975; Mungall et al, 1981). Using spectral analysis techniques, Dygas (1975) determined that currents are mainly wind-driven with approximately 80 percent of their spectral energy at periods of four days or higher, and correlations of 0.73 between wind and current speed and -0.52 between wind and current direction. Kinney et al (1972) made continuous measurements of currents near Oliktok Point and found speeds ranging from 0 to 30 cm/sec with an average speed of 17.5 cm/sec and high correlations between wind and current velocity. Other current meter records taken during the open water season nearshore confirm the theory that the currents are mainly wind-driven and follow the bathymetric contours (Barnes et al, 1976; Matthews, 1978; Chin et al, 1979; Mangarella et al, 1982).

Since tides range from six to twelve inches over most of the Beaufort Sea Coast, there are very little currents associated with them except in lagoon entrances. Some tidal response can be seen in most of the current meter records but, in Mangarella et al (1982), current meter record taken between West Dock and Stump Island show the tidal currents are as strong as 30 cm/sec.

In areas of large river outflow, such as the Mackenzie River, it has been shown (Giovando and Herlinveaux, 1981; MacNeil and Garrett, 1975) that the river affects the nearshore circulation in two ways. First, by its direct influence of the current pattern associated with the outflow itself and secondly, by its indirect influence on the density structure creating a frontal zone in its vicinity.

During an east wind in the Beaufort Sea, the net transport is away from the coast, resulting in an upwelling of deeper water from the shelf, according to Ekman's wind drift theory. This phenomenon has been observed by Hufford (1974) in waters 20 to 100 meters deep off the continental shelf from hydrographic records.

All evidence so far indicates that the nearshore and inner shelf region out to the 50m isobath is mainly wind driven, with currents responding rapidly to change in wind speed and direction.

Waves

Almost no work has been done on waves in the Beaufort Sea that has been published in the open literature, although some studies have been performed that are proprietary. Wiseman et al (1973, 1974) conducted a wave study on the seaward side of Pingok Island during the summer of 1972. Wiseman (1973) found that the most common wave conditions had an energy peak at two to three seconds with a significant wave of 20 to 30 cm. A storm did pass somewhere east of Wiseman's measurement location, at which time swell was recorded with heights of 1.5 to 2.5 meters and periods of nine to ten seconds. Wave measurements were also made of low frequency (30 seconds to 10 minutes) waves which showed a peak believed to be caused by a surf beat and also a die-off of energy with frequency at a rate of $f^{-3.3}$. This is very similar to what Hunkin (1962) found when he measured waves through the ice off of Barrow. Grider et al (1978) and Chin et al (1979) measured waves near Prudhoe Bay by photographing waves with a motion picture camera and stadia rod, but the stadia rod was held in only a few feet of water so the results are questionable. Dygas (1975) measured waves inside of Simpson Lagoon off of Oliktok Point and found the mean breaker height to be 17.7 cm, a significant wave height of 27.3 cm and a mean wave period of 2.2 seconds. Besides an energy peak near two seconds in the wave spectrum, lower energy peaks with periods ranging from 7.5 to 15.0 seconds were present which are believed to be swell from the Beaufort Sea. Dygas also observed that increasing the duration of the wind increases the peak energy but not the significant wave height unless the wind speed is increased. Mangarella et al (1982) had a wave gauge in approximately ten meters of water northeast of Prudhoe Bay. Mangarella found three specific features in the spectra which are of interest: 1) the overall wave energy is small, 2) energy is concentrated at the high frequency end of the spectrum, and 3) no obvious differences exist between spectra associated with either east or west winds. From the data available (Mangarella et al, 1982; Wiseman et al, 1973; Dygas, 1975), it seems that waves are mainly fetch limited due to the close proximity of the pack ice during the open water season. The only time the winds are not fetch limited is when the winds are blowing parallel to the coast. Though it has not been shown in the data, large waves have been visually observed in the Beaufort Sea as high as six meters (Hume and Schalk, 1967).

Tides and Storm Surge

Very little work has been done to date on tides along the Beaufort Sea coast. The tides seem to be mainly semidiurnal, approaching the continental shelf from the north with little phase change along the entire Beaufort coastline (Hugget et al, 1975; Aagaard, 1978). Matthews (1970, 1971) and Wiseman et al (1973) measured the tides at Point Barrow and Oliktok Point and found the principal component (M_2) of the lunar tide to be 4.7 cm. for Point Barrow with tides at Oliktok Point ranging slightly higher. Sea level variations at Narwhal Island were found to range about 10 cm due to tides and over ten times larger due to surges in the winter months (Matthews, 1980). The diurnal range which is defined as the average difference in height between mean higher high water and mean lower low water on a single day is predicted to be 13 cm at Point Barrow and 36 cm at Flaxman Island (Brower, 1977). A tide station has been operated by NOS for a number of years during open water at Prudhoe Bay, but so far a tidal datum has not been established. To establish a tidal datum, water levels have to be observed over a specific 19-year Metonic cycle (the National Tidal Datum Epoch) to obtain a primary control tide station (NOAA/NOS Tide Tables, 1982). Once this has been established, then stations with shorter time series can be compared to the primary control tide station to obtain the equivalent of a 19-year value, for example, for the Mean Lower Low Water.

Storm surges, or atmospheric tides as they are often referred to, is the process where water levels either rise or fall due to direct wind stress, atmospheric pressure changes, transport of water by waves and swell, rainfall, Coriolis effect and the specific configuration of the coastline and bathymetry. Storm surges are very important along the Beaufort Sea coast since they cause much larger variations in sea level than do astronomical tides. This can be seen in tidal records (Matthews, 1970, 1980; Wiseman et al, 1973) and data available from the National Oceanic Survey's tide station located at West Dock in Prudhoe Bay. The largest recorded storm surge occurred 3-5 October 1963 at Barrow with wind speeds up to 65 knots, ten-foot waves, and ten-foot storm surge (Hume, 1964). This storm surge caused extensive damage, with some low lying areas flooded up to a mile inland,and some beaches receded up to 60 feet. Longshore transport occurred which added approximately 200,000 cubic meters of sediment to the west and southwest equivalent to 20 years of normal net transport (Hume, 1964; Matthews, 1970; Brower, 1977). In 1970, another large storm of gale-force westerly winds left driftwood up to 3.4 meters above normal water level, and flooded some low lying areas and deltas as far as 5000 meters inland (Reimnitz and Maurer, 1978, 1979). They measured the height of the surge by measuring the distance above the normal water that lines of driftwood were found. A recurrence interval for a surge of that magnitude was estimated from historical evidence to be 100 years. Grider (1978) shows a high correlation between wind velocity measured at Deadhorse and water level measurements taken by NOAA at Prudhoe Bay. Henry and Heaps (1976) reviewed storm surge records in the Canadian Beaufort, showing positive storm surges of up to two meters and negative surges of one meter.

Hydrographic and Water Quality

Water temperature and salinity have large temporal and spatial variations during open water season in the Beaufort Sea. The nearshore region can be characterized by three distinct water masses: river flow, sea-ice melt water and oceanic shelf water (Hufford and Bowman, 1974; Barnes et al, 1977). River water has relatively low salinities (0 to 10 ppt) and warm temperatures (1 to 11°C) with large suspended sediment concentrations, whereas sea-ice melt can be distinguished by low salinity (5 to 15 ppt), cold temperatures (0 to 2°C) and has little suspended materials. Shelf waters have high salinities (27 to 30 ppt) and low temperatures (-1 to 3°C). Early during the open water season the river water is very evident, as in Chin et al (1979) where the Sagavanirktok is shown flowing through Prudhoe Bay over toward West Dock and Stump Island. As open water season progresses, river discharge slows down and wind mixes the nearshore zone, weakening vertical stratification (Chin, 1980; Mangarella et al, 1982).

In the surveys conducted by Mungall et al (1979), it was found that water on the mainland side of the lagoon is warmer and less saline than on the barrier island side. Salinity has been observed to change more than five percent in a five-minute period in the Stump Island Channel (Matthews, 1978). Also, large changes in salinity from one side of the causeway to the other have been observed by Chin (1979, 1980) and Mangarella et al (1982). These differences seem to be highly dependant on wind direction, with water density being mainly salinity dominated.

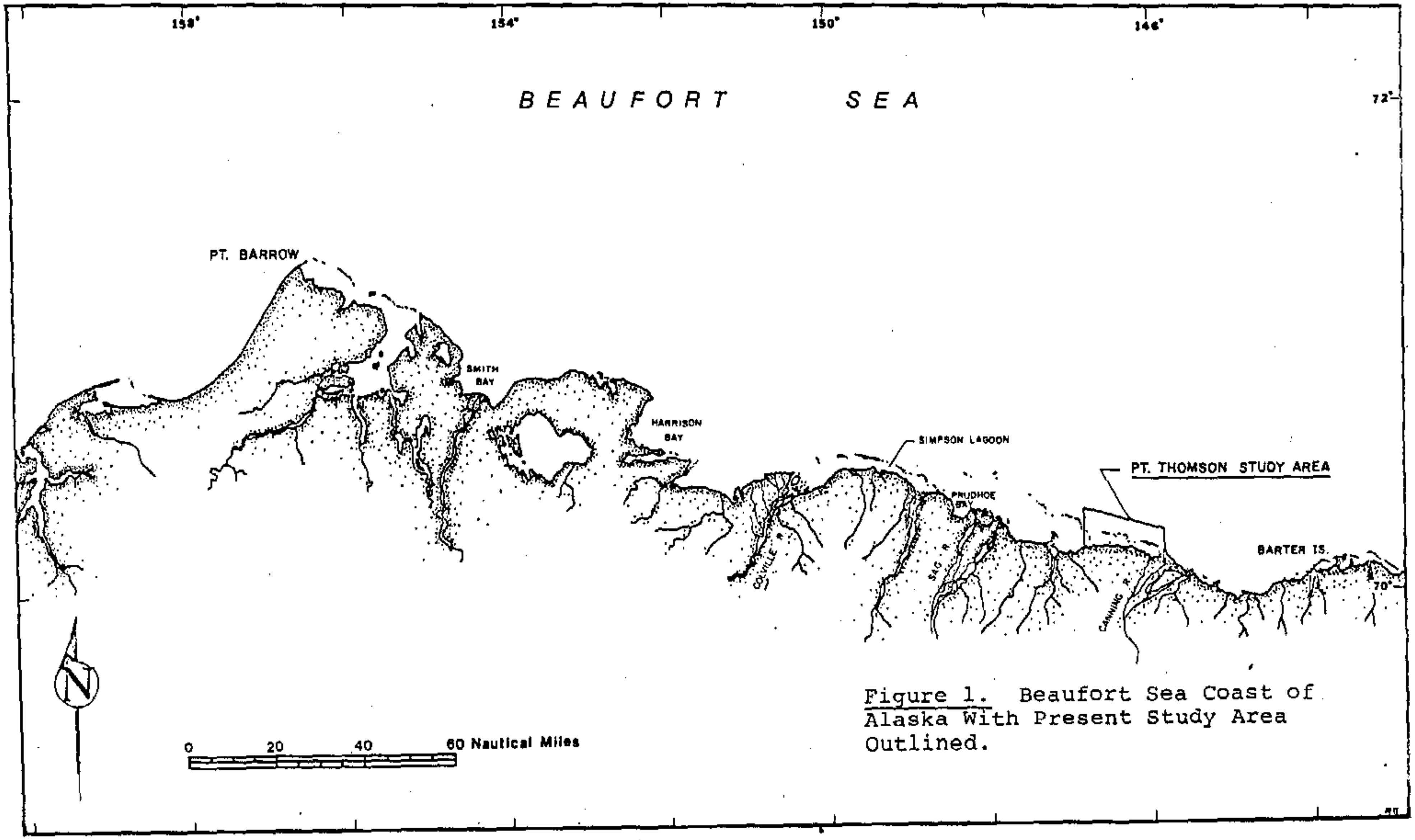


Figure 1. Beaufort Sea Coast of Alaska With Present Study Area Outlined.

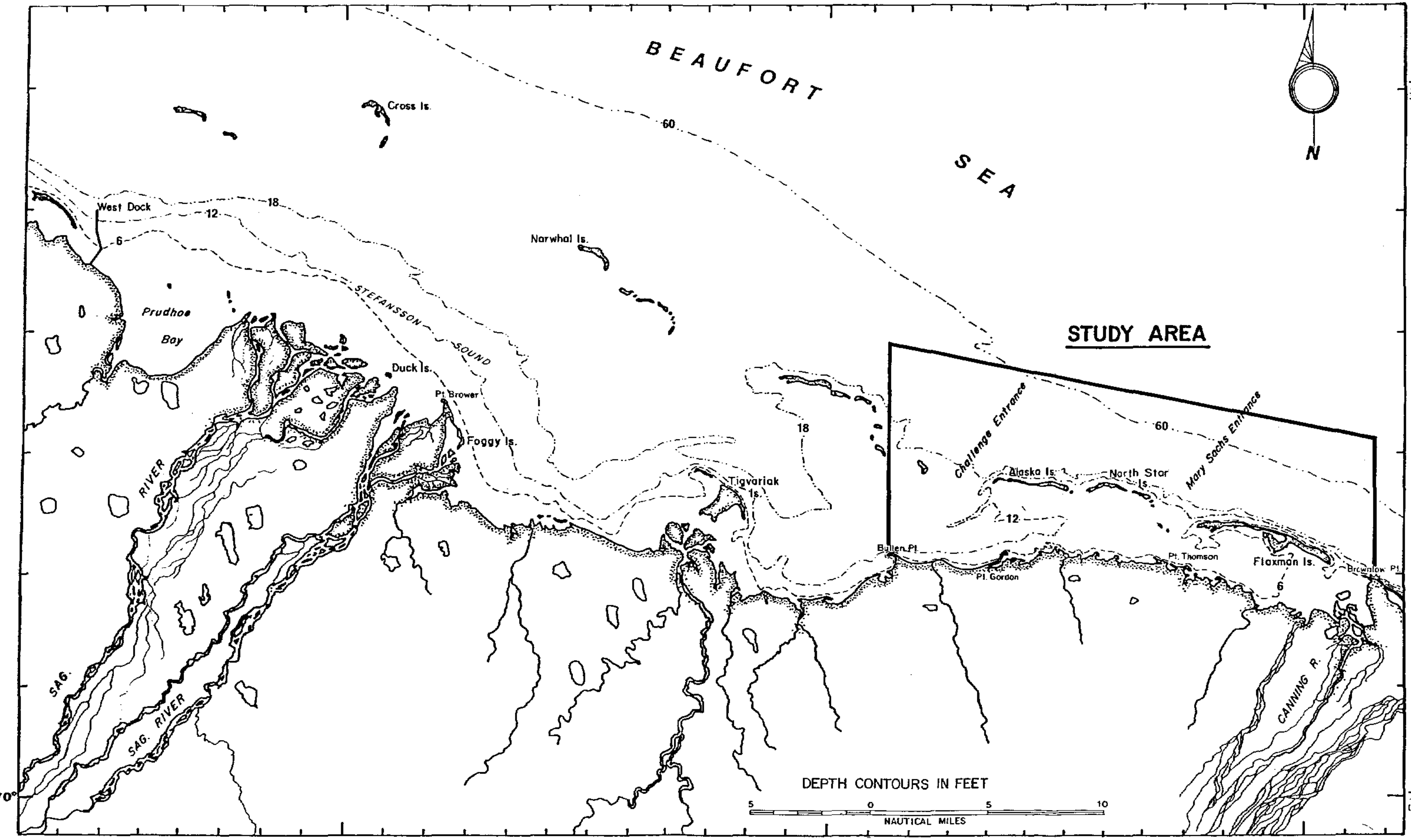


Figure 2. Location of Present Study Area in Point Thomson Region, Alaskan Beaufort Sea Coast.

MATERIALS AND METHODS

Design of Field Measurement Program

The meteorological and oceanographic data needs were planned against the applied problems involving erosion/sedimentation, coastal currents, and ice movements in the Point Thomson area. A wave measurement program was recommended for the Point Thomson area to expand the total data base for hindcast analyses and for input into the erosion/sedimentation problem. Currents, tides and storm surges were also measured along with meteorological parameters which are viewed as oceanographic forcing functions.

Summer Program. The specific physical oceanographic and meteorological program which was carried out during the open water period (ice break-up about 15 July to early September) is as follows with reference to Figure 3 and Table 1. Latitude and longitude of stations given in Table 1 were determined by plotting locations on a USC&GS navigational chart using field MiniRanger range/range data and picking latitude/ longitude data from the chart.

1. Emplaced an automatic, digitally recording meteorological station (with backup) on Challenge Island: included wind speed and direction, temperature, and pressure. This station was to supply local meteorological data to compare with Barter Island data. It was also to provide data to cross-correlate with local oceanographic measurements.

2. Emplaced a digitally recording wave (directional), tide gauge outside Mary Sachs Entrance, station Q, in about 50 feet of water. This installation included an electromagnetic current sensor. Also at this station and another closer to shore, station P were current meters (bottom at Q and mid-water at P) with temperature and salinity sensors, which were tethered Endeco Type 174 meters. The top meter was set on a separate mooring. These records are to supplement the electromagnetic current meter profiling in the upper offshore layers as described below. This installation gave incident wave climate. Open coastal currents were also measured at this location and, because of the bathymetry, should be representative of the offshore currents in the study area.

3. Emplaced a wave/tide gauge off of Challenge Entrance, station Y, chiefly as a backup wave climate recorder in case the outside instrument was lost to ice. Emplaced a current meter to monitor currents at the Challenge Entrance, station D.

4. Emplaced three current meters on a transect between Alaska Island and the mainland, and three more on a transect between Flaxman Island and the mainland, in order to monitor lagoon currents versus wind and water level forcing events. Used one meter with temperature and conductivity sensors at the central station south of Alaska Island, (station E). Two such meters (top and bottom) were emplaced at the lagoon station south of Flaxman, (station S) to detect if vertical stratification (temperature and salinity) and current shear were present.

5. Emplaced a current meter at each of the two remaining major entrances, Mary Sachs Entrance (station O), and the one to the right of Flaxman (station V), the former with temperature and conductivity. These allowed monitoring of the flushing of the lagoon system.

6. Occupied hydrographic stations throughout the study area three times over the season, stations A-W. Measured temperature, salinity, depth, oxygen, pH, and transmissivity with calibrated STD system. On the Flaxman and Alaska Island transects within the lagoon, two-point anchored the boat and measured current profiles with depth using electromagnetic current meter and a burst-sampling, digital recorder. This data will detect any shear effect present at locations away from the prime lagoon current meter site.

7. Emplaced two water level gauges within the lagoon, stations Z & AA, near each end to yield data on storm surge observations behind the local barrier islands. The wave/tide gauges offshore Mary Sachs Entrance and at Challenge Entrance were to provide data outside.

8. Moored an electromagnetic current meter with burst sample and vector averaging capacity at the surface in the lagoon at the center station south of Flaxman Island, station S. This was to provide direct comparison with any wave bias in the other top current meter (Endeco) as well as provide excellent surface current records. Top and bottom temperature and conductivity records were obtained by the Endeco meters.

9. Surface and bottom drifters were released at the center of the lagoon at two different periods and two different wind regimes. Recoveries were to be by project personnel on local beaches (Task 2.4) and by helicopter flights to and from Prudhoe during the course of the study.

10. Made ice observations during the season's work in the Point Thomson area, with emphasis in the area outside the barrier islands.

The following major equipment was used:

1. Survey vessel D.W.HOOD.

2. Six Endeco Type 174 current meters with temperature and conductivity sensors.

3. One Seadata 635-12 wave and direction electromagnetic current meter, tide gauge with digital recorder.

4. One Seadata 635-11 wave/tide gauge with digital recorder.

5. Six General Oceanics 2010 film recording current meters.

6. Two Seadata TDR, 2A tide recorders.

7. One Marsh-McBirney electromagnetic current sensor, compass interfaced with InterOcean 680 digital recorder.

8. Three Innerspace 431 acoustic releases with one 430 deck unit.

9. One Helle acoustic pinger locator and 13 acoustic pingers.

10. One InterOcean Model 513 STD system with conductivity, temperature, depth, pH, oxygen, and transmissivity probes, and electomagnetic current probes.

11. One Motorola MiniRanger III system, with four shore stations.

12. One Meteorology Research, Inc. Model 5000 digital weather station with wind speed and direction, temperature, and barometric pressure.

13. One Climet analog weather station with wind speed and direction, temperature, and barometric pressure.

The above program, although not symetrical, optimizes data return and cost effectiveness. In some cases, the best instruments available were used, while in other cases less expensive equipment was employed based on cost and data return.

The best remote meteorological station (Meteorological Research, Inc.) was selected based on its 90 percent data return on other Alaskan projects and the importance of the meteorological data to the oceanographic studies. An optimum location was picked on the low-lying Challenge Island which would be representative of the local winds forcing the lagoon and surrounding waters. In addition, a backup analog meteorological station was used which measured wind speed and direction, temperature and barometric pressure.

SeaData wave and tide gauges were selected because of their capabilities (microprocessor controlled), reliability and the fact that they yield comparable data with the other industry measurements to the west. Another advantage of the SeaData equipment is that it is mounted on the bottom, versus other wave measuring equipment that is surface moored and in constant danger of floating ice which is ever present. Also, the SeaData wave gauges measure tides and temperature along with waves.

The types of current meters were picked on cost and on their performance and reliability in a shallow water environment. The Endeco meters were decided upon because of their design, which makes them suited for shallow water operation. The design features a ducted flow reversible propellor and a tether to filter out the effects of mooring motion and orbital motions in the water column. Another type of meter that has attempted to decouple the mooring line motion from the meter by inertial damping is the General Oceanics (Niskin) tiltmeter. We and the USGS (R. Cheng, USGS at Menlo Park) have tested both meters, together with AMF and Marsh-McBirney meters in shallow water. In open coast (west coast) swell environments, errors are of the order of 20 percent of the drift current; in faster shallow tidal waters of San Francisco Bay, the errors are much less than five percent. The cost of these meters are 40 and 10 percent of the cost of the fast sensor/vector averaging meters.

Our approach to the present study was to specify the electromagnetic sensor with appropriate digital recording for two prime stations, offshore and in the lagoon. These are to be supplemented by Endeco 174 meters on these stations and elsewhere to provide good spatial coverage of the lagoon system. General Oceanics 2010 film meters were also used because of their cost and because they were found to be better mechanically than the tape recording versions.

Features considered of importance to the design of the program were determining whether two-layer stratification and flow was important, the securing of long-term data with maximum chance of storm events of most importance, the inclusion of good measurements of all basic oceanographic data, emphasis on the meteorological forcing transfer functions, and the effects of tides on currents, lagoonal flushing, and water level changes. The most important features were the placement of stations, the selection of reliable instrumentation, and the provision of a well-equipped survey vessel and experienced crew to ensure proper deployment and retrieval of equipment.

Fall Program During Freeze-Up. To obtain needed oceanographic data for the freeze-up period, selected instruments were redeployed. The specific physical oceanographic and meteorological program which was carried out from early September to mid-November is as follows, with reference to Figure 4.

1. An automatic, digitally-recording meteorological station was placed on Challenge Island, including wind speed and direction, temperature and barometric pressure. This station supplied local meteorological data to compare with Barter Island data, and also to cross-correlate with local oceanographic measurements.

2. Emplaced digitally-recording wave/tide/temperature gauges outside Mary Sachs Entrance in about 50 feet of water. Included was a current meter to measure current speed and direction near the bottom.

3. Emplaced a tide/temperature gauge in Mary Sachs Entrance to yield water level information on tides and storm surges. Also included at this staiton was a curent meter with temperature and conductivity sensors moored at mid-depth.

4. Emplaced digitally recording wave/tide/temperature gauge south of the center of Flaxman Island in the lagoon in eight feet of water. Also included was a current meter to measure current speed and direction.

The following major equipment was used:

1. Two SeaData 635-11 wave/tide/temperature gauges with digital recorders.

2. One SeaData TDR-2A tide/temperature gauge with a digital recorder.

3. One Endeco 174 current meter with temperature and conductivity sensors.

4. One Endeco 105 film recording current meter.

5. One General Oceanics 2010 film recording current meter.

6. One Meteorology Research, Inc. Model 5000 digital weather station with wind speed and direction, temperature, and barometric pressure with back-up temperature and barometric pressure instrumentation.

Our approach to the fall study was to design a program for measuring the late season storms. Features of primary interest were the securing of good wave data during a large storm along with the meteorological forcing functions. Because of the high probability of ice grounding, thus destroying the primary station in the shear zone off of Mary Sachs Entrance, a secondary station was placed in back of Flaxman Island in the relatively safe fast-ice zone. Also of importance, in addition to waves during the storms, is the associated storm surges. For this purpose, a water level recorder and current meter were placed in Mary Sachs Entrance along with the tides measured by the wave gauges. Another feature that was addressed in the design was picking instrumentation that could record data for 60 or more days without being serviced. Because of this criteria, the MRI meteorological station had to be reprogrammed in the field (switching the sampling rate from 15 to 30 minutes) in order to accomplish this.

Mooring Designs. The mooring configuration for the SeaData 635-11 wave/tide/temperature gauge is shown in Figure 5. It was mounted horizontally on a large, heavy (100 lb) square metal frame that provided a stable platform and also acted as an anchor. An acoustic pinger was attached to the frame for a back-up relocation method. Attached to the frame's lifting bridle was a 600-foot, 3/8-inch nylon groundline used as a target for a grapling hook, if necessary, as a secondary recovery technique. The primary recovery method consisted of an acoustic release and subsurface float attached to the terminal end of the groundline and the 50 to 75-pound secondary anchor.

The SeaData TDR-2A tide/temperature gauges were mounted horizontally on a scaled-down version of the weighted frame version used on the 635-11 wave/tide/temperature gauge (Figure 5). The only difference between the two versions is that the terminal end of the groundline on the TDR-2A's were run to shore and attached to an earth anchor instead of a secondary anchor. The SeaData 635-12 was moored in a vertical position utilizing a heavy 200-pound metal quadrapod (Figure 6). Vertical mounting was necessary because the electromagnetic current sensor at the top of the meter must be vertical to function properly. The bottom crosspiece that the meter stood upon was made of wood so as not to interfere with the compass located in the bottom of the meter. Two recovery techniques were incorporated into the mooring design as with the 635-11: a 600-foot, 3/8-inch nylon groundline stretched between the quadrapod and a secondary anchor and an acoustic release attached to the groundline and secondary anchor. Mounted above the acoustic release on the secondary anchor was an Endeco 174 tape-recording current meter and subsurface float. As with all the moorings, acoustic pingers were secured to each piece of equipment (27 KHz on one end and 37 KHz on the other) to provide relocation back-up should the primary relocation method (MiniRanger) fail or the moorings move after deployment.

The Endeco 174 eight-track tape recording current/temperature/conductivity meters and the Endeco film recording current meter were moored as in Figures 6 and 7. The Endecos were mounted on taut-line moorings of 1/4-inch stainless steel cable with heavy anchors (200 lb) and large subsurface floats (75-80 lb buoyancy). The Endecos were attached to the taut-line at the desired depth by a four-foot nylon line in order to decouple the meters from mooring line motion. The mooring was completed by an acoustic pinger attached to the taut-line and 600 feet of 3/8-inch nylon groundline connecting the meter mooring and a smaller secondary anchor.

The remaining General Oceanics model 2010 film recording current meters were moored as in Figure 8. Since the G.O meters are positively buoyant and measure current speed as degrees of inclination, they were simply tethered to 60-pound anchors with lengths of nylon rope. An acoustic pinger was attached at the primary anchor and 600 feet of groundline stretched to the secondary anchor, completing the mooring.

Instrumentation Checkouts

All equipment placed in the field was tested by standard set-up and checkout procedures at the base camp prior to deployment. Typically, upon receipt of the equipment from the carrier, the physical condition was first inspected for damage during shipment and, if no problems were found, the instruments were tested in the field sampling mode. Specific tests for the various instrumentation are described below.

SeaData. Three types of SeaData equpment were used: Model TDR-2A tide/temperature gauges, Model 635-11 wave/tide/temperature gauges, and a Model 635-12 directional wave/tide/current/temperature gauge. Each of these instruments contains appropriate cirsuitry to monitor its own basic measurements and recording functions. In addition to these checks, the actual values of the parameters recorded onto tape were inspected using a SeaData Visual Display Module (VDM). Each instrument was placed in test mode under several sampling rates, the battery voltages were measured under load, the correct measurement/record sequence noted by the flashing lights, and the actual data records checked on the VDM plugged into the instrument. The data format, sampling sequence, and measured values were monitored against standard formats and known values. The VDM display for the TDR-2A gauges was in decimal, whereas the 635-11 and 635-12 were in hexidecimal form and had to be converted manually to decimal for comparison to known values. The current meter zero of the 635-12 was checked by immersing the electromagnetic sensor ball into a bucket of water and noting that the current reading from the VDM display was zero. The sampling intervals to be utilized were then programmed into the instrument. These intervals were based upon battery life and/or tape capacity calculations from values given in the manuals specific to each type of instrument. For this study, settings were based upon utilizing a complete data tape in 60 days. After progamming and initialization, the pressure case and seals were inspected and serviced, the electronics replaced within the pressure case, and the system purged with freon gas (all except the TDR-2A's). Details of the sampling intervals, VDM readout values and initialization times were recorded in appropriate set-up data sheets.

Sampling intervals and records per burst varied between types of SeaData equipment. Both TDR-2A tide gauges were set at 128 records per sample (averaged) and a sampling interval of 7.5 minutes. Both the 635-11 wave/tide gauge and the 635-12 directional wave/tide gauge were set up to record the maximum amount of data for the time of implacement. The wave function of the 635-11's were set at 2048 records per burst at 0.5 second intervals and a burst interval of four hours. Tides and temperatures were recorded eight times per hour. The wave function of the 635-12 was set at 1024 records per burst at 0.5 second intervals and a burst interval of four hours. Each wave record per burst included a measurement of pressure and the two current velocity components, V_x and V_y, for wave direction. Tidal pressures were measured 16 times per hour and current velocity and temperature were measured twice per hour.

Endeco. Two types of Endeco current meters were used: Model 174 eight-track tape recording meters with auxiliary temperature and conductivity sensors and a Model 105 film-recording meter. Both types of meters utilize ducted impellers and a short rope tether to the mooring to decouple the meter response from wave or mooring line motion. The condition of the pressure housing and seals and the mechanical components of the meter were inspected and repaired or replaced as necessary. In order to achieve a full 60 days of recording capability, the sampling interval of the Model 174 meters was changed from the standard one sample every two minutes to one sample every five minutes. To accomplish this task, each meter was completely disassembled and a jumper wire resoldered on a multipoled switch assembly located on one of the printed circuit boards. This operation was unnecessary with the Model 105 since the standard 30-minute sampling rate gives a maximum operating endurance of 75 days.

The meters were then individually tested for functionality by inserting a set of fresh batteries, closing the battery compartment (also the on-off switch), pressing the reset switch, and noting the associated movement of the internal trim weight. Since deployment of the meters must follow within 24 hours of this point, set-up was not completed at the base camp. Instead of allowing the meters to continue to run, they were deactivated by inserting a cardboard strip between the battery contacts, inserting a labeled blank tape and dessicant packs, and resealing the pressure cases. Later, in the field, the meters were brought to neutral buoyancy and trimmed to level at the ambient surface water density by the addition of small increments of lead weights. Just prior to deployment, the meters were opened again, the cardboard strips removed, and the reset swtich pressed twice to activate the meters. These reset times were accurately noted and recorded. The internal trim weight was recentered, the dessicant bags replaced, and the pressure case resealed to ready the meters for deployment.

General Oceanics. G.O. Model 2010 film-recording inclinometer current meters were used for this study. Prior to shipment to Alaska, the meters were fitted with fresh batteries (both camera and watch) and functionality fully tested utilizing several meter positions. Predeployment check out was repeated at the base camp. Each meter was opened, pressure housing seals inspected and serviced, the watches set to local time and date, and the basic camera functionality tested. This was done by setting the sampling rate to 256 times per hour and noting the correct film advance, exposure light flash, and timing sequence. A fresh labeled film was then manually advanced several turns to assure free movement and inserted into the camera. The sampling rate was set to the desired rate (twice per hour) and the timing sequence noted for at least two samples. The cameras were then deactivated using the external on/off switch and resealed in the pressure housing to ready them for transport to the deployment sites.

Innerspace. After inspection, the Innerspace Model 431 acoustic release modules were opened, the seals inspected and serviced, and fresh batteries inserted. The functionality of the release was monitored by connecting the sacrificial link to the Model 430 code generator through a system test unit, a modified voltmeter. The proper operation of the system was shown by noting the proper sequence of three voltages when the appropriate release code was generated. The release link was then reconnected within the unit and the electonics resealed in the pressure case to ready the unit for deployment.

Acoustic Relocation Pingers. Two makes of pingers were used: EFCOM UB series 2700 and 3700 and Helle Engineering Model 2215 and 2220. Different frequencies (27 and 37 KHz) were used to prevent interference with each other since the deployment sites were often located within the one mile range rating of each other. The EFCOM units were prepared by screwing them apart, selecting the desired deployment time limits (3-6 months), inserting batteries, inspecting and servicing the seals, and resealing. The Helle units were factory sealed and did not need any preparation prior to deployment. The pingers were tested at the time of deployment following immersion by listening at the proper frequency transmission with a Helle Engneering Model 6120 relocation unit coupled with the omnidirectional antenna.

Meteorological Research, Inc. The MRI Weather Wizard 5000 series equipment was assembled, properly programmed and activated at the base camp to verify functioning before deployment. Values of barometric pressure, temperature, wind speed and direction obtained were compared with known values. Upon deployment in the field, the unit was assembled, and the Julian date and Alaska Standard Time entered and checked. A labeled blank data tape was inserted after the wind speed and directional sensors were zeroed and test values were observed by a digital readout. Additionally, the unit was checked periodically on a two-to-three week basis when tapes were replaced and real values examined.

Back-up Meteorological Instrumentation. In the event the main meteorological instrumentation failed, redundant information was simultaneously collected. Three instruments were utilized to collect this information: a Climet Model CI-26 wind speed and direction recorder, a Belfort Instruments Model 335 BP microbarograph, and a Ryan Peabody Model J thermograph. The Climet equipment was set up at the base camp and the speed and direction translator functions checked by noting the correct recorder response. In the field, these tests were repeated, the sensor units mounted on the ten-meter tower, the speed recording pen set to zero with the anemometer held at rest, the direction recording pen set to 270°(M) with the vane pointing due west (relative to a hand-bearing compass), and appropriate time marks placed upon the recording chart paper. Time marks were placed each time the meteorological station was visited and the battery changed.

The microbarograph was set up at the base camp by inserting a chart paper, filling the pen with ink, inserting the battery (on/off switch), setting the pen to the correct time mark on the chart, and adjusting the pen position to the correct local barometric pressure. The time and pressure tracking accuracy was monitored by placing appropriate time and pressure marks on the chart. It was later transported to the field while still running.

The thermograph was treated in exactly the same manner as the microbarograph except that no ink was necessary for the pen; pressure-sensitive paper was utilized in the recorder.

Field Methodology

Positioning Equipment. Placement and prelocation of moored instruments was accomplished using a MiniRanger III range-range positioning system. This system is a line-of-sight microwave unit which gives range data between the receiver (on the boat) and transponders (on shore). The system is operated by placing two or more transponders at known locations on shore and then simultaneously receiving two ranges on the deck unit which gives a digital readout in meters. The MiniRanger III has an accuracy of ±3 meters so that relocation of the moorings was accurate and straight-forward.

Moored Instruments. All open water instrumentation deployments and retrievals were performed from the research vessel D.W. HOOD during the period spanning 22 July to 8 September 1982.

Since all mooring assemblies were much the same, deployment procedures were similar for each. Satisfactory range data was acquired from the MiniRanger positioning equipment on board the HOOD, initiating deployment procedures at each station. Accurate depth recordings and radar fixes also were recorded on-site. The primary anchor and accompanying equipment were lowered over the side with the ship's boom and hydraulics system. Once on the bottom, a MiniRanger fix was recorded with the exact local time. The groundline was played out with the direction of prevailing wind drift to minimize possible targets for drifting ice keels and the secondary anchor was dropped with another MiniRanger fix. After deployment, the acoustic pinger signals were verified and any subsurface floats were checked for leaks (rising bubbles) and proximity to the surface.

Relocation was accomplished by returning to the initial MiniRanger coordinates, marking the fix with a float and weighted line, and confirming the location of equipment with the acoustic pinger system. When the mooring system had been moved by passing ice, the new location was established using the directional pinger location system, which is a long procedure when the displacement distance is great. Once the location of the equipment was pinpointed and marked, retrieval procedures were carried out.

Methods of retrieval varied with types of mooring assemblies. Moorings attached to a terrestrial anchor were recovered by unearthing the hidden tagline and manually hauling the payload aboard. Assemblies consisting of a groundline only were retrieved by hooking the line with a grapnel hook, and hauling the system aboard utilizing the ship's boom and hydraulics. Assemblies equipped with acoustic releases were retrieved by activating the release with a signal generator and winching the system aboard with the ship's boom and hydraulics. If the release failed, the groundline was snagged with a grapnel hook and the assembly was winched aboard.

Both SeaData TDR-2A waterlevel recorders were surveyed in position from nearby U.S.G.S. vertical control benchmarks during the final retrieval procedures. The survey operation was conducted with a level and stadia rod during calm conditions and provided water level measurement assurance of ± 0.1 inches.

<u>Meteorological Instruments.</u> Deployment of the meteorological tower at Challenge Island was accomplished with a helicopter and the D.W. HOOD. The helicopter dropped a crew and supplies to pour a cement pad for the tower while the HOOD ferried the equipment and instrumentation to the site a few days later. Once the tower was erected and the equipment was installed, all systems were activated and checked for operation.

Routine servicing of the meterological tower took place on a "ship of opportunity" basis or about once every two to three weeks. Servicing included changing data tapes, recording local time on chart papers, replacing batteries and repairing equipment as necessary.

Recovery of meterological equipment and instrumentation occured in two stages. The Climate secondary system, used as a back-up to the MRI primary system, was removed at the end of the open water season by helicopter. The primary system was removed by helicopter at the end of the field season in November.

<u>Water Column Profiling.</u> Current profiling was accomplished with an InterOcean 195R current meter and 680 recording instruments during the initial study period and with a Martec current meter and deck readout during the final open water recovery period.

The sampling procedure included establishing the station location, securing the vessel on-station and acquiring data on tape or by direct readout. The location was recorded from a MiniRanger fix, a radar setting and a depth recording. Location of stations formed two transects traversing either end of the lagoon (Figure 3). During the operation, the HOOD was anchored fore and aft to prevent swinging from a single point during data acquisition. The current meter was lowered at half-meter intervals and data was continuously recorded for a 20-second period at each level.

Water quality profiles were recovered from data acquired with an InterOcean 513D C/STD system. Data was recorded from a deck readout and later analyzed for content.

Sampling procedure was similar to that of a current profiling, with the exception that the vessel was not anchored on station. Instead, the HOOD was allowed to drift with the wind, preventing collision with the floe ice which is ever-present in the offshore areas. Depth intervals were every half-meter within the confines of the lagoon and every meter in the offshore areas. Location of stations formed transects across the lagoon and offshore areas (Figure 3). Values were recorded for the parameters of temperature, conductivity, depth, transparency, pH and dissolved oxygen. Water samples were taken for salinity during each of the three sampling periods in all of the major water mass bodies. Care was exercised not to sample zones of mixing between two bodies of water which might later lead to confusion with calibration of the data.

Drifter Experiments. Two drifter experiments were performed in the study area. Drifters utilized were the small plastic Woodhead or "Sea Daisy" type, the surface ones being fitted with a cork and the bottom ones fitted with just sufficient weight to sink them. The first experiment was initiated with the release of 400 bottom drifters and 250 surface drifters south of Mary Sachs Entrance on 26 July 1982. The second experiment was initiated on 4 September 1982 in the same area with 200 bottom drifters and 250 surface drifters.

Results were recorded from helicopter observations reported by Kinnetic Laboratories and Tekmarine personnel incidental to primary objectives carried out within the study area. Aerial surveys by KLI covered the offshore barrier islands and the mainland from Brownlow Point to the East Dock facility at Prudhoe Bay. Other observations were kindly transmitted from personnel of other companies working on the West Dock facilities in Prudhoe Bay.

Redeployment and Through -Ice Recovery. Redeployment of stations O, Q, and S (redesignated stations OP, QP, and SP) was executed in early September with special deference to an ice recovery anticipated for early November. Each of the three stations was moored in a low profile mode to avoid freezing in of the equipment by thickening surface ice, and each was weighted to avoid movement during fall storms. Each station position was triangulated from right angle fixes from the MiniRanger positioning system and two acoustic pingers were attached to ensure accurate relocation during recovery. At one station, OP at Mary Sachs Entrance, 1/4-inch stainless steel cable replaced the usual nylon ground line in the anticipation of a helicopter lift through the ice. Additionally, both Mary Sachs Entrance (OP) and the offshore station (QP) were equipped with acoustic releases in the off-chance that extensive leads made an open water, rather than through the ice, recovery.

Through-ice recovery operations proceeded in early November when weather and light conditions still permitted safe flying and working conditions. The actual ice work took place over a four-day period from 14 to 17 November 1982 when surface winds dropped below 15 knots, air temperatures stabilized at −10° F, daylight was three to five hours in length, and sea-ice thickness varied between 27 and 32 inches.

The following is a chronological account of the through-ice recovery operation.

On 14 November, the Point Thomson Camp MiniRanger transponder was established during high winds with low wind chill factors. On 15 November, the MiniRanger relocation team established two transponder stations on Flaxman Island, and located and marked the three station locations OP, QP, and SP before rendezvousing with the diving team at the lagoon station. At station SP the two teams pinpointed the location of the equipment with the pinger relocation system, opened and cleared a four by five foot dive hole over eight feet of water and recovered the equipment by diver and a tripod lifting system. The entire operation from touchdown to take-off took three hours. On 16 November, the same relocation and set-up procedure was followed at the Mary Sachs Entrance and the offshore station. However, no pinger signals were detected at either station. Diving operations then took place at the offshore site to fully establish if the equipment was actually there or not and whether the pingers had malfunctioned.

After the dive hole was cleared, a weighted guide line was established between the ice hole and the sea bottom, providing a direct line of communication from the working divers to the surface standby diver. Though both working divers were attached, one remained at the line, communicated with the surface tender, and tended the diver swimming a circular search pattern on the end of a 100-foot tether. Visability of 100 feet facilitated operations, and approximately three acres of bottom area were covered in less than 20 minutes at the original site of redeployment without positive results. Recovery of the MiniRanger transponder station and the meteorological equipment and data was carried out en route to the Exxon Camp at Prudhoe Bay.

On 17 November, a final helicopter search was conducted over the entire study area in an effort to locate pinger signals from the missing equipment. In total, 17 sites were visited, holes drilled through the ice, and the pinger relocation transponder lowered through the hole to listen for signals. No positive results were realized in covering an area of several square miles along the barrier islands and the Mary Sachs Entrance, however.

Data Processing Methods

Meteorological Parameters. Data cassettes were first dumped onto 9-track tape, then read and copied into computer disk files. Data on strip charts were digitized and entered into disk files. All data files were then edited for any spurious points that might cause errors in analysis.

The meteorological data from the field aspect of this study was correlated with the simultaneously-measured coastal data base, using Barter Island station as the prime location of comparison. These correlations allow the long historical data base available at these stations to be used to extrapolate frequencies of occurrence of various meteorological conditions to the Point Thomson area.

Time history plots of wind (vector stick plot and components), barometric pressure, and air temperature are presented. Wind roses are presented which graphically show wind speed versus direction frequency distribution. For each wind event greater than 20 knots for at least three hours, three-hour averages, highest one-hour, highest ten-minute, and highest gust are tabulated. Cumulative probability plots for wind speed are also given.

Meteorological data are also presented in tabular form for wind speed versus direction frequency distribution and air temperature frequency distribution. In addition, persistence tables are calculated for wind speed and air temperature. Persistence tables were calculated as a percent conditional probability that the given parameter was at or above a given level for X amount of hours after it had reached that level for any observation.

Correlations of the meteorological data with the other oceanographic time series data were done as described in the following sections under the appropriate oceanographic parameter.

Wave Data. Subsurface pressure data was recorded using SeaData pressure recorders. The SeaData 635-11 recorded 2048 ($=2^{10}$) pressure values at an 0.5 second sampling interval every four hours. The SeaData 635-12 recorded 1024 ($=2^9$) values every 0.5 seconds every four hours. The following review of the complex process used to convert the subsurface data has been abbreviated for the purposes of this report.

The subsurface pressures were converted to equivalent water depths by

$$1.0 \text{ psi} = 2.2508 \text{ feet of seawater.}$$

Subsurface pressure induced by surface waves is attenuated with depth as a function of wave length. The subsurface pressure time series was converted to surface wave spectral density by frequency analysis. This process is accomplished by a Fourier transform.

For a continuous function, x(t) for the t on [0, T], the Fourier transform, F(f) is defined as

$$F(f) = \frac{1}{T}\int_{o}^{T} e^{-i2\pi ft} x(t)dt$$

where the f is the frequency defined on $[0,\infty]$. Each subsurface pressure time series is a discrete series of N points, recorded at time t, t = 0,1/2, 1, ..., (N-1)/2. This necessitates using a discrete Fourier transform (DFT),

$$F(f_k) = \frac{1}{T}\sum_{t=o,1/2,1,...}^{(N-1)/2} e^{[-i2\pi(f_k)t]} x(t)\Delta t$$

$$= \frac{1}{N}\sum_{t=o,1/2,1,...}^{(N-1)/2} e^{(-i\frac{4\pi k}{N} t)} x(t)$$

where $f_k = k/(N\Delta t) = 2k/N\ sec^{-1}$; $k = 0, 1, ..., N/2$; $(i = \sqrt{-1})$ (note that $\Delta t = 1/2 = T/N$). Discrete Fourier transforms are discrete complex functions, defined at $N_f = N/2 + 1$ frequencies. With a discrete time series of sampling interval Δ, the maximum detectable frequency with the series, called the Nyquist frequency, is the one whose period is two samples, or 2Δ. Thus, the Nyquist frequency for the wave profiles is $1/(2\Delta) = 1/(2x.5) = 1\ sec^{-1}$. This is the frequency $f_{N/2} = 2(N/2)/N = 1$.

The conversion of the subsurface time series to surface spectral density took place as follows:

1. The DFT of the subsurface pressures, $F_b(f_i)$, was calculated.

2. $F_b(f_i)$ was converted to the surface DFT, $F_s(f_i)$, by the following transformation from linear wave theory:

$$F_s(f_i) = F_b(f_i) \frac{\cosh(k_i d)}{\cosh(k_i[d-l])}$$

where d = water depth in feet
l = meter depth in feet
$k_i = 2\pi/\lambda_i$, the wave number of frequency f_i, derived from

$$f_i = \frac{1}{2\pi}\sqrt{gk_i \tanh(k_i d)}$$

$$(g = 32.2\ ft/sec^2)$$

The Sea Data tide gauges used in the Point Thomson experiment were moored on the bottom in a variety of depths. For these meters, l was approximately equal to d, so the denominator in the fraction above was near cosh(0) = 1. Thus, the "attenuation factor" cosh(kd)/cosh[k(d-l)] was approximately cosh(kd) for sufficiently large k (high frequencies). This function is essentially exponential (e^k) in behavior.

Thus, conversion from subsurface to surface DFT's at high frequencies involved multiplication by a large number (on the order of 10,000 and more) for the deeper meters. The effect of this is to amplify noise due to turbulence, meter electronics, etc. into the calculation, sometimes to the point that surface wave information is lost.

To alleviate this problem, we chose to halt the transformation calculation at a cutoff frequency, f_c. Experimentation showed that most wave periods at the time of the experiment were 2.5 seconds or more (frequencies of .4 sec^{-1} or less). Based on this, we chose f_c = .5 sec^{-1} (i.e., we zeroed out the upper half of the available frequency range).

3. The surface wave power spectrum, $S_s(f_i)$, was determined by

$$S_s(f_i) = \|F_s(f_i)\|^2$$

where $\|z\| = \|x + iy\| = \sqrt{x^2+y^2}$

This spectrum represents the contribution to the energy of the surface wave train at each frequency, f_i.

The spectral energy at each frequency, f_i, was assumed not to exceed the wave breaking spectrum (saturation spectrum) (Phillips, 1976):

$$\|F_s(f_i)\|^2 = S_s(f_i) \leq \frac{\beta g^2 \Delta f_i}{(2\pi)^4 (f_i)^5}$$

where Δf_i = frequency band width.

If any value of S_s was calculated to be larger than this quantity, it and the corresponding components of the wave DFT, $F_s(f_i)$, were limited such that the energy at frequency, f_i, equaled the saturation limit. Note that for $f_i > f_c$, $S_s(f_i) = 0$.

The quantity β (the "Phillips constant") is a dimensionless constant which has been determined empirically in a variety of sea experiments (Phillips, 1976) and found to range over from .005 to near .1, with a mean of .0123. In summarizing results from many of the same experiments, Hasselman and others in the JONSWAP experiment (Hasselman et al, 1973), found the β depended on fetch and wind speed:

$$\beta = 0.076 \left(\frac{U_{10}^2}{xg}\right)^{.22}$$

where U_{10} = wind velocity measured at 10 meters (ft/sec)
x = fetch distance (in feet)
g = 32.2 ft/sec^2

This relation shows that β decreases with increasing fetch (at a fixed wind speed).

Choice of a value of β was important in the Point Thomson experiment. Most of the energy in the wave spectra was in the high frequency ($\sim$.4 sec) range, where the wave breaking spectrum limitation has its greatest effect.

Table 2 shows typical values of fetch in miles for various combinations of β and wind speed. Fetch in the North Slope region varies greatly and depends heavily on the location of offshore ice and wind direction. We felt the fetch values for β = .01 were most representative of the Point Thomson experiment when measured wind speeds stayed at 30 knots or less.

4. Because of variance induced by the DFT, the surface spectrum was smoothed to give more reliable results. The smoothed spectral density spectrum, $P(f_j)$, was produced by employing a modified Daniall frequency window (Yuen, 1979). The Daniall window that was used simply involved a weighted sum of a group of nine spectral values from S_s divided by the frequency bandwidth to produce a single value of $P(f_i)$:

$$\overline{P}(f_j) = \sum_{i=j-4}^{j+4} \frac{a_i S_s(f_i)}{\Delta f_j}, \quad a_i = \begin{cases} 1/4 & i = j-4,\ j+4 \\ 1/2 & \text{otherwise} \end{cases}$$

where j = 4, 6, 12, ..., N_f-4; and

$$\overline{P}(f_{N_f}) = \frac{S_s(f_{N_f})}{4\Delta f_{N_f}} + \frac{1}{2}\left[\frac{S_s(f_{N_f}-1)+S_s(f_{N_f}-2)+S_s(f_{N_f}-3)+S_s(f_{N_f}-4)}{f_{N_f}}\right]$$

where Δf_i = frequency bandwidth (defined below).

Note that $\overline{P}(f_j)$ has $N' = (N_f-1)/4 = N/8$ frequencies.

Spectral Wave Statistics

Significant wave statistics from the smoothed spectral density, $P(f_j)$, were derived by calculating zeroth and first moments:

$$M_o = \sum_{i=1}^{N'} \overline{P}(f_i)\Delta f_i$$

$$M_1 = \sum_{i=1}^{N'} \overline{P}(f_i)\ f_i\ \Delta f_i$$

where $f_i = {}^{i}/_{N'} \cdot f_{N'}$, $f_{N'}$ = Nyquist frequency

Δf_i = frequency bandwidth

$= {}^{f_{N'}}/_{N'}$ for $2 \leq i \leq (N'-1)$ and

${}^{f_{N'}}/_{2N'}$ for $i = 1$ or $i = N'$

The spectral significant wave heights and periods were calculated as

$$H_s = 4\sqrt{M_o}$$

$$T_s = {}^{M_o}/_{M_1}$$

Wave Profile Analysis

The sea surface profile was generated by using an inverse discrete Fourier Transform on the sea surface DFT, $F_s(f_i)$. One assumption in the process is that there is no phase difference between the subsurface DFT, $F_b(f_i)$, and $F_s(f_i)$. Put another way, any pressure change at the surface induced by a surface wave is measurable instantaneously at the depth of the meter. This assumption is incorrect for high frequency (generally small height) waves, and tends to introduce spikes in the transformed sea surface profile. In order to determine valid wave statistics from the profile, it is necessary to distinguish between these spikes and "real" waves.

Waves in the surface profile are detected by the zero down-crossing method. Points where the sea surface passes through mean sea level from above the mean to below it are zero down crossing points and sea level values between two successive down-crossing points belong to individual "waves". Wave height is measured as the maximum trough-to-crest distance in each wave, and wave period as the elapsed time between successive down-crossing points. Note that both spikes and actual waves had associated heights and periods in this stage of the calculation.

A critical level for the maximum wave height, H_{max}, was determined by one of two methods:

Method 1: From work by G.Z. Forristall (Forristal, 1978), the set of wave heights from a profile of N_w waves formed an empirical cumulative distribution which was fit via a least-squares method to a Weibull distribution.

$$P(H > H_O) = \text{Probability of occurrence of a wave with height greater than } H_O$$

$$= e^{-\left(H_O/\sqrt{M_O}\right)^{\alpha}/\theta}$$

where M_O = zero moment from spectrum (variance of the sea surface).

α, θ = constants derived from fit and the fit is done only for waves whose height is greater than $2\sqrt{M_O}$ and less than the height of the ten largest "waves" in the profile (the largest ten were assumed to be potential spikes).

The critical level (ie, expected maximum wave height) is calculated from α and θ as:

$$H_{crit} = \sqrt{M_O}\left[\theta \operatorname{Ln}(N_W)\right]^{1/\alpha}\left[1 + 0.5772/(\alpha \operatorname{Ln}(N_W))\right]$$

If the result of this fit was that $\alpha < 1$, one or more spikes (waves with heights "too large" when compared to the average) entered the calculation, and the resulting H_{crit} was invalid. In that case, the following was used:

Method 2: From classical theory (Longuet-Higgins, 1952 and WMO, 1976), the maximum expected wave in a profile of N_w waves is:

$$\sqrt{\frac{M_O \operatorname{Ln}(N_W)}{8}}$$

All waves with heights above H_{crit} were excluded from further analysis.

The largest wave with height $\leq H_{crit}$ was considered to be the maximal wave unless it failed to meet the Stoke's criterion (Stokes, 1880).

$$\frac{H}{\lambda} \leq \frac{1}{7}$$

where λ = wavelength determined from relationship:

$$T = \frac{1}{2\pi} \sqrt{\frac{2\pi g}{\lambda} \tanh \frac{2\pi d}{\lambda}}$$

where T = wave period
d = water depth.

If this wave failed this test, the test was successively applied to the next largest wave until an acceptable maximum wave was found. The height of this wave and its period were recorded as H_{max} and T_{max}.

The significant wave height, H(s), and wave period, T(s) were determined as means of those values from the largest 1/3 waves and the profile with heights $\leq H_{max}$.

Tide and Storm Surge. Data cassettes were first dumped onto 9-track, then read, edited and copied into computer disk files. The pressure measured by the water level gauges is the hydrostatic pressure of the water column fluctuations with the tide and storm surges, and the pressure due to the atmospheric barometric pressure. Using the barometric pressure measured at Challenge Island, the atmospheric pressure was subtracted from the gauge pressure before converting to water elevations. The water level elevation (in meters) is given by

$$H = 0.70369 \frac{Pg - Pa}{\rho}$$

where 0.70369 = Constant to convert water pressure to depth in meters
P_g = gauge pressure in PSI.
P_a = atmospheric pressure in PSI.
ρ = water density in g/cc.

Corrections due to variations in water density were neglected, since they are very minor.

Using a first order low pass recursive filter with a cut-off frequency of 0.5 cycles/hour, the water level data was processed, decimating the data to hourly intervals. A Doodson filter, a low pass filter designed to pass only tidal frequencies, was then passed over the decimated time series and finally the mean was removed. The resulting time series contains variations in water level due only to tidal components.

Seven tidal constituents (O_1, K_1, N_2, M_2, S_2, M_4, M_6) were fitted to the tidal height time series using a least squares harmonic analysis program developed by NOS/NOAA with further developments added by U.S.G.S., Menlo Park, California. A table is given of the seven tidal constituents and their periods plus the resulting amplitude and phase for each water level gauge location. Note that the phasing used here is relative to 0000 hours, ADST, 1 January 1900 and lunar transit at the local meridian.

The surge time series was obtained by taking the water level time series (data after initial decimation of series) and subtracting its mean and the tidal height time series. The surge is then the change in water level due to storm surge, relative to Mean Water Level (MWL) for that time series. Time history plots of the water level, tide elevation and storm surge are presented for the different water level gauges.

Coastal Currents. Film cartridges were developed and digitized, then entered into appropriate computer disk files and subsequently edited for any spurious points. Current meter cassettes were read and dumped onto 9-track tape, then read, edited and copied into computer disk files.

Time history plots (vector stick plots and components) and current speed persistence tables are presented for all current meters, plus time history plots of salinity and temperature for any current meters with probes. Current speed versus direction frequency distribution tables, cumulative probability plots of current speed, current roses, and progressive vector current plots are given for selected meters. Scatter plots of wind speed versus current speed for selected meters are also presented.

The current meter time series components at selected locations were analyzed for tidal currents by the same techniques that were used for the water level measurements. The data was first decimated to get hourly intervals, then passed through a low pass Doodson filter and the mean removed. Seven tidal constituents (O_1, K_1, N_2, M_2, S_2, M_4, M_6) were fitted to the tidal current time series using a least squares harmonic analysis computer program. A table is given of the seven constituents and their periods plus the resulting amplitude and phase for the U and V components for the selected locations.

Hydrographic and Water Quality. Tables of water temperature, salinity, pH, and transmissivity versus depth are presented for all hydrographic stations that were occupied during deployment, mid-season and retrieval of moorings. Data are also presented as vertical cross-sections of the above parameters with contours drawn where appropriate.

Data Products. A list and description of all data products is presented in Table 3.

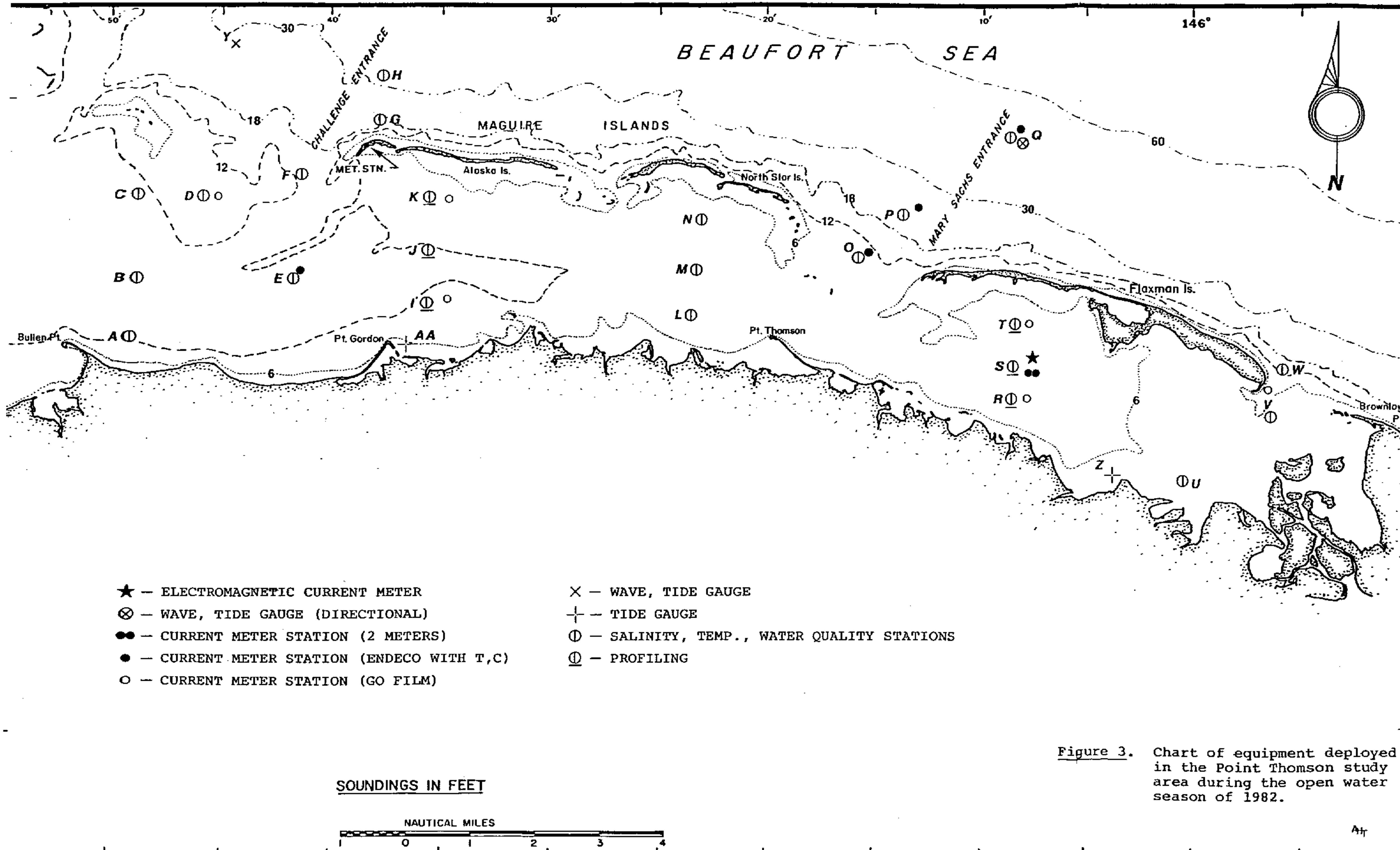


Figure 3. Chart of equipment deployed in the Point Thomson study area during the open water season of 1982.

Table 1 . Station Locations.

		Location	
Station	Data Taken	N. Latitude	W. Longitude
A	Hydrographic sections	70°11'23"	146°49'24"
B	Hydrographic sections	70°12'36"	146°49'18"
C	Hydrographic sections	70°14'04"	146°49'11"
D	Hydrographic sections & moored current metering	70°14'13"	146°45'28"
E	Hydrographic sections, moored current, conductivity & temperature measurements	70°12'20"	146°40'30"
F	Hydrographic sections	70°13'45"	146°40'55"
G	Hydrographic sections	70°14'29"	146°37'42"
H	Hydrographic sections	70°15'18"	146°37'48"
I	Hydrographic sections & moored current metering	70°12'10"	146°34'00"
J	Hydrographic sections	70°12'28"	146°34'14"
K	Hydrographic sections & moored current metering	70°13'28"	146°35'00"
L	Hydrographic sections	70°11'22"	146°22'14"
M	Hydrographic sections	70°12'17"	146°22'14"
N	Hydrographic sections	70°13'09"	146°22'18"
O	Hydrographic sections & moored current, conductivity & temperature measurements	70°12'36"	146°16'17"
P	Hydrographic sections & moored current, conductivity & temperature measurements	70°13'18"	146°13'00"
Q	Hydrographic sections & moored current, conductivity, temperature, wave & tide measurements	70°14'02"	146°06'44"

Table 1. (Continued)

Station	Data Taken	Location N. Latitude	Location W. Longitude
R	Hydrographic sections & moored current metering	70°10'03"	146°06'34"
S	Hydrographic sections & moored current, conductivity & temperature measurements	70°10'45"	146°06'30"
T	Hydrographic sections & moored current metering	70°11'40"	146°06'11"
U	Hydrographic sections	70°08'55"	146°00'32"
V	Hydrographic sections & moored current metering	70°10'39"	145°57'14"
W	Hydrographic sections	70°10'47"	145°50'38"
Y	Moored wave, tide & temperature measurements	70°16'46"	146°48'20"
Z	Moored tide & temperature measurements	70°11'47"	146°31'04"
AA	Moored tide & temperature measurements	70°09'04"	146°03'34"

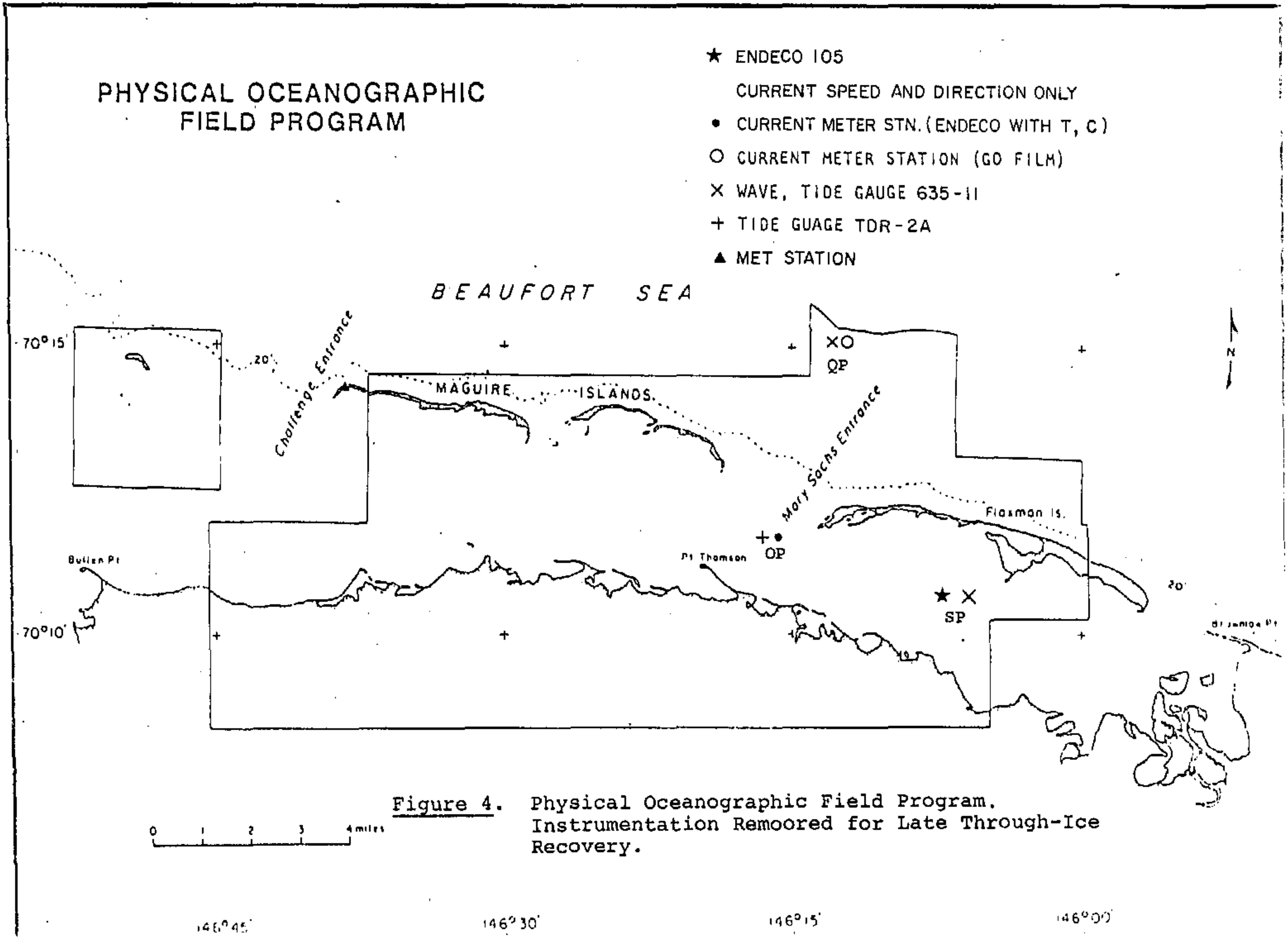


Figure 4. Physical Oceanographic Field Program. Instrumentation Remoored for Late Through-Ice Recovery.

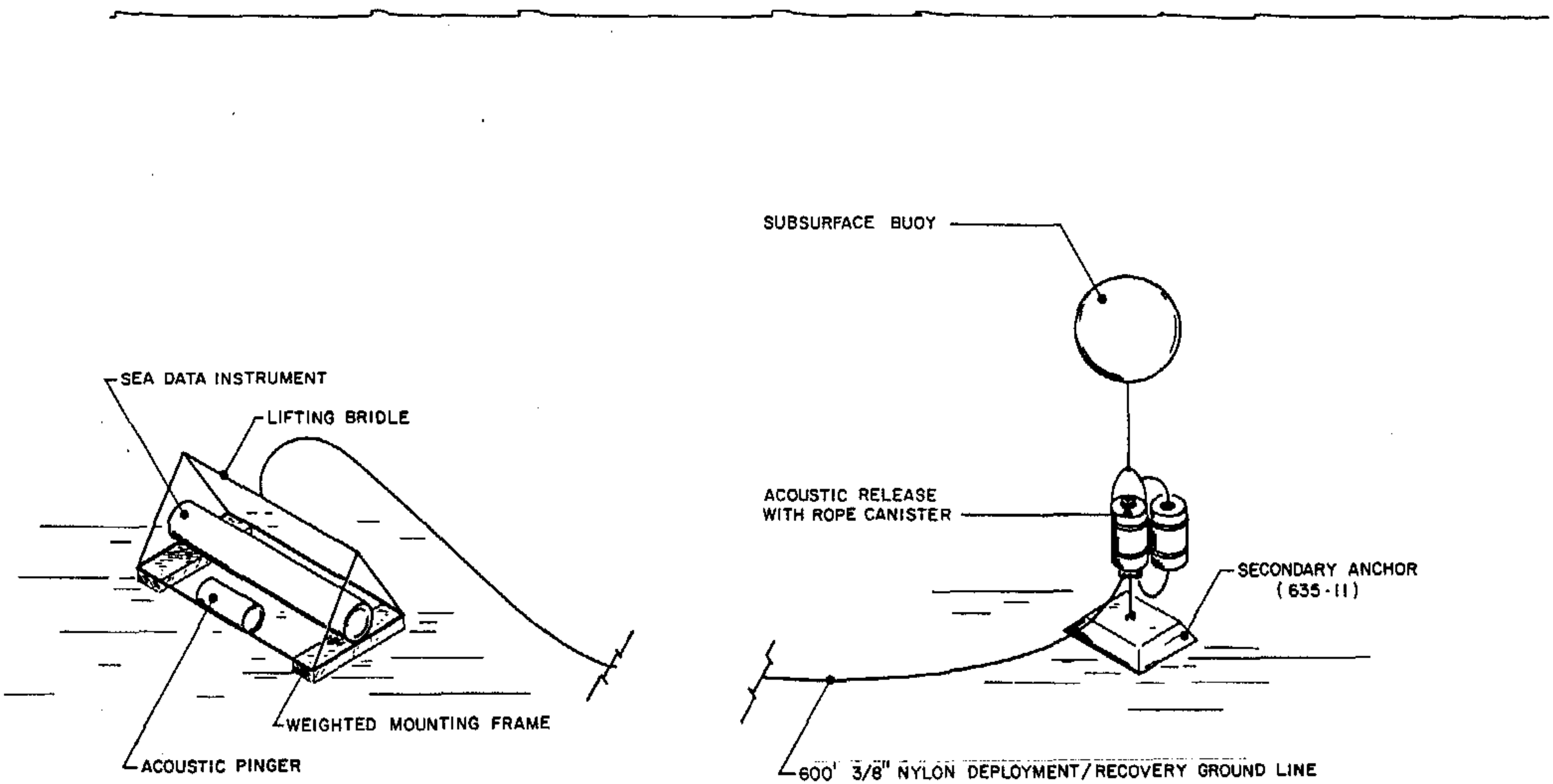


Figure 5. Mooring Configuration - Bottom Mounted Pressure Sensor Equipment.

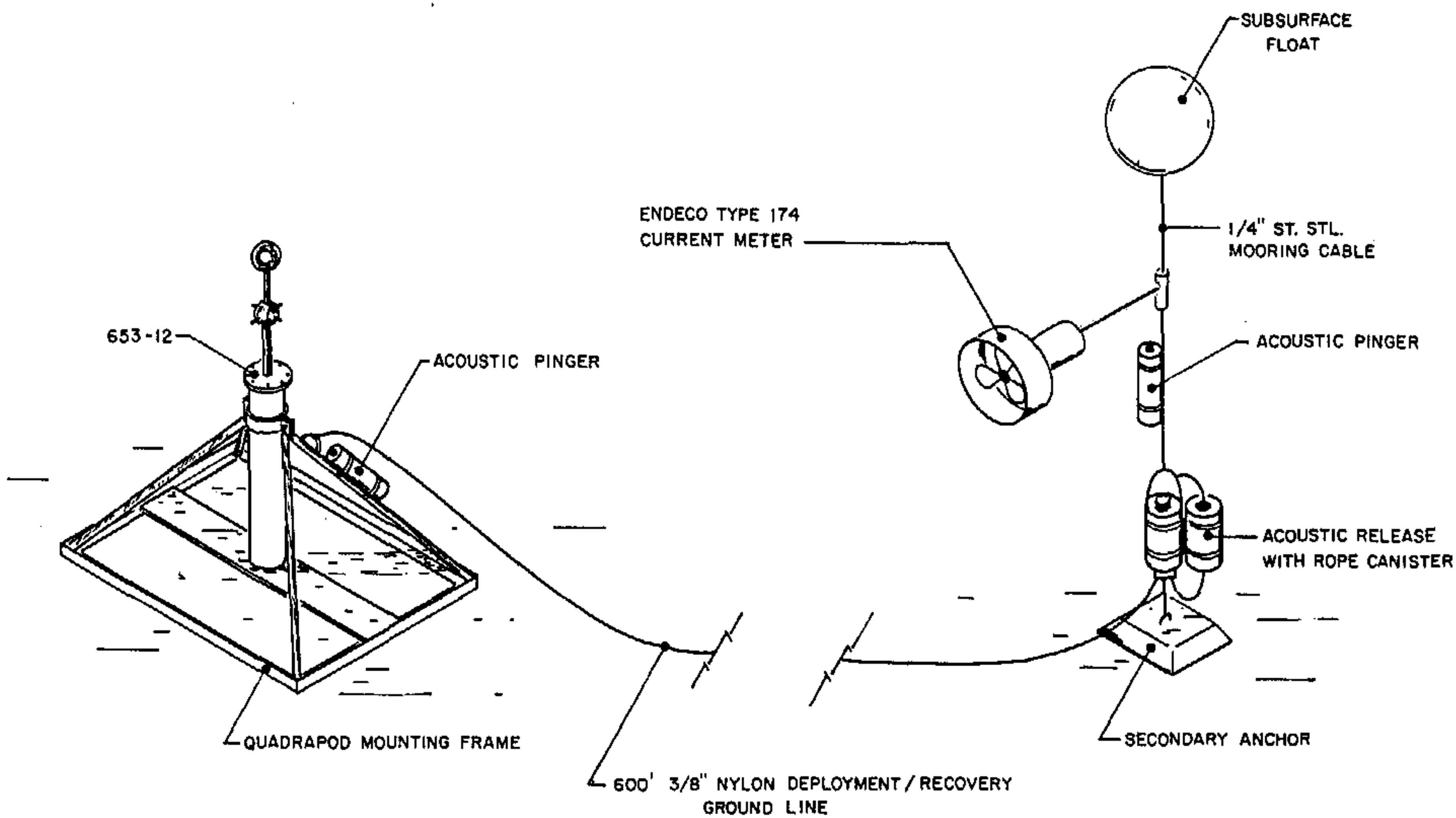


Figure 6. Mooring Configuration; Sea Data 635-12.

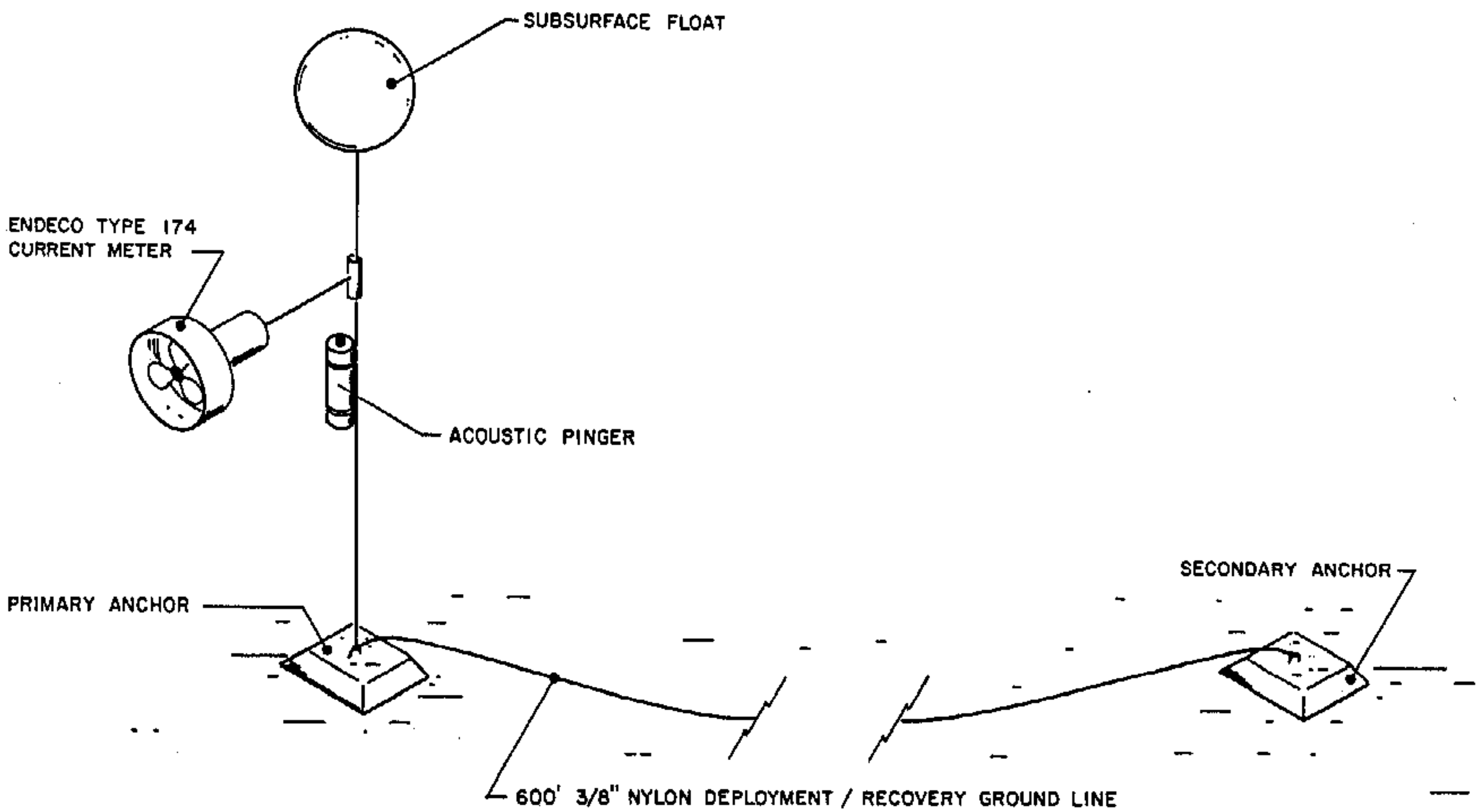


Figure 7. Mooring Configuration - Endeco Current Meters.

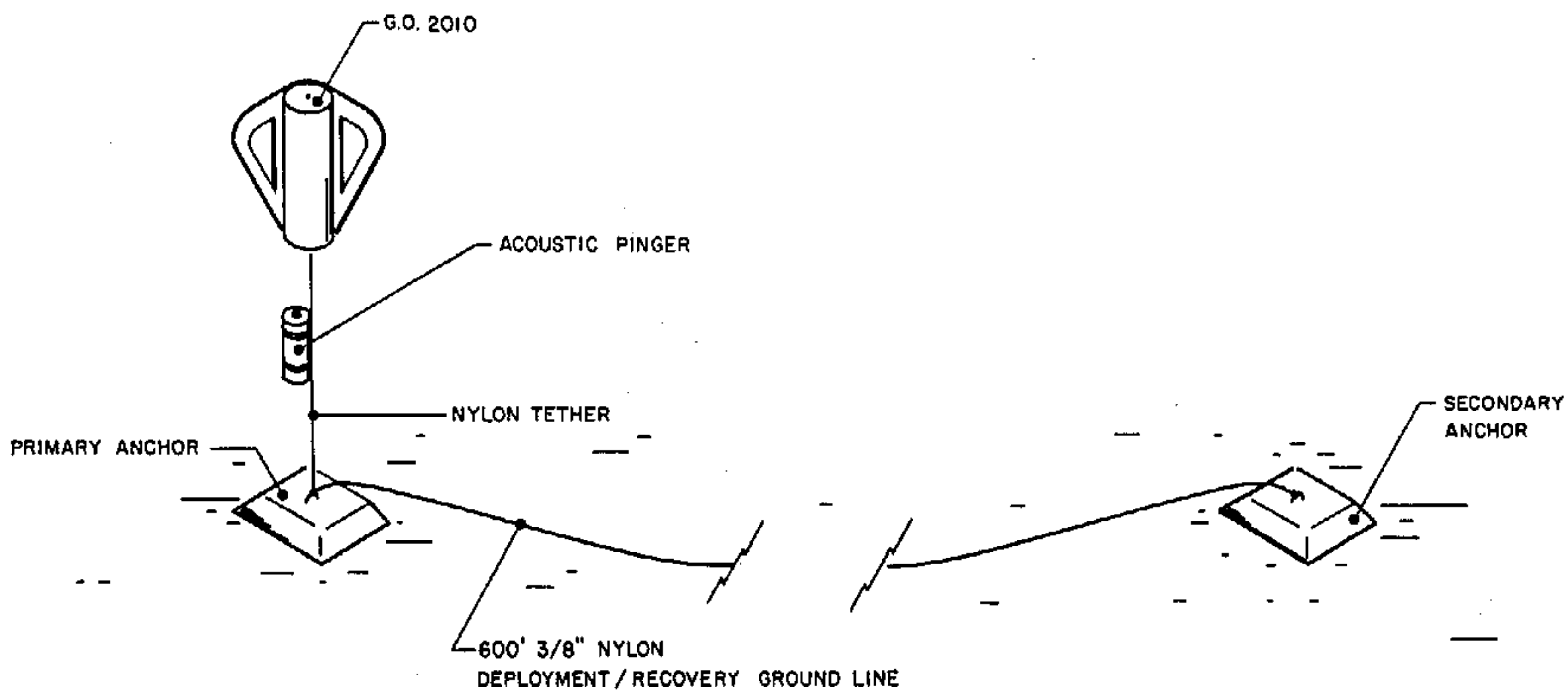


Figure 8. Mooring Configuration: General Oceanics Current Meters.

Table 2. Values of Fetch (miles) for Specific Values of Wind Speed and β, Phillips Constant.

β	Wind Speed (knots) (U_{10}) 5	10	20
.008	11	44	176
.01	4	17	68
.12	2	7	26

Note: Based on $\beta = 0.076 \left(\frac{U_{10}{}^2}{xg}\right)^{.22}$

Table 3. List of Data Products.

A. Time History Plots for Each Location

1. Significant wave height and zero-crossing period (based on profile).
2. Significant wave height and significant period (based on spectra).
3. Maximum wave height and associated period.
4. Water level.
5. Tide elevation.
6. Storm surge.
7. Total current (vector stick plot and components).
8. Wind (vector stick plot and components).
9. Barometric pressure.
10. Air temperature.
11. Water temperature.
12. Water salinity.

B. Frequency Distribution and Persistency Tables for Each Location*

1. Significant wave height vs. zero-crossing period (based on profile) frequency distribution table.
2. Significant wave height (based on profile) persistence table.
3. Significant wave height vs. significant period (based on spectra) frequency distribution table.
4. Significant wave height (based on spectra) persistence table.
5. Maximum wave height vs. associated period frequency distribution table.
6. Current speed vs. direction frequency distribution table.**
7. Current speed persistence table.
8. Wind speed vs. direction frequency distribution table.
9. Wind speed persistence table.
10. Air temperature frequency distribution table.
11. Air temperature persistence table.

C. Cumulative Probability Plots for Each Location

1. Wave height (maximum and significant).
2. Wave period (zero-crossing and significant wave period).
3. Current speed.**
4. Wind speed.

Table 3. (Continued)

D. Scatter Plots of Maximum Wave Height vs. Significant Wave Height

E. Amplitude, Phase, and Period of Harmonic Constants for Water Levels and Tidal Currents
for Endeco meters only

F. Progressive Current Vector Plots
for Endeco meters only

G. Surface Wave Spectra (Plots and Printouts), vs. Frequency When Significant Wave Height Is Greater Than 3 Feet at Each Location

H. Wind Speed vs. Significant Wave Height (Either Frequency Distribution Table or Scatter Plot)

I. Wind Speed vs. Current Speed (Either Frequency Distribution Table or Scatter Plot)
for Endeco meters only

J. Wind Roses

K. Current Roses
for Endeco meters only.

L. Coherence and Phase Plots Between Barter Island and Point Thomson Wind

M. Wind Gust Tabulations
(as mentiond in proposed work plan)

Table 3. (Continued)

N. Tables of Water Quality and Temperature/Salinity Data

O. Plots of Velocity Profiles

P. Polar Plot and Principal Axis Analysis of Currents***

Q. Cross-Spectral Analysis of Wind/Current***

* Tables should be for entire duration of measurements, except for meters to stay in for through-ice recovery. For those measurements, tables should be for July-early September (when tapes are changed) and for September-end of record. Persistency tables should present both favorable and unfavorable conditions.

** Current tables for Endeco meters only.

*** Low priority items, to be furnished if time and funds allow.

RESULTS

The meteorological, wave, tide and storm surge, current, and hydrographical data recoveries are summarized briefly below. Table 4 summarizes the deployment and recovery of moored instrumentation for the Point Thomson summer study. Table 5 summarizes the same information for the fall mooring period. Tables 6 and 7 show, for summer and fall periods respectively, the sampling rate of each instrument and the amount of data actually recovered from each.

Presentations of all required data products are complete in the appendices, organized by major topics such as meteorological data, current data, etc. In addition, all digital data have been recorded on nine-track tape with an index and tape specifications furnished in Appendix F.

Meteorological Results

Wind speed and direction data were obtained from the MRI-5000 digital weather station emplaced on Challenge Island for the period 28 July to 3 September 1982. The temperature and barometric pressure sensors failed to record on the digital tape of this instrument. However, temperature and barometric pressure data were digitized from the analog back-up instrumentation emplaced at the same weather station on Challenge Island. Thus, meteorological data for all parameters was recovered for the full period of emplacement.

The meteorological station was left in operation after September, through the fall freeze-up period, during the time that moored instrumentation was also emplaced. This station was then removed on 28 October. Though not serviced during this period, wind, pressure, and temperature data were also recovered for this full time period.

Similar meteorological data were obtained in the form of digital tape, from the National Weather Service for the Barter Island and Barrow stations.

All meteorological data are presented in Appendix A, and discussed in the summary section below.

Wave Results

Two wave recording instruments were deployed on the outside of the barrier islands and both moorings were recovered. One Sea Data 635-11 digital wave gauge was bottom mounted in approximately 32 feet of water outside Challenge

Entrance. This instrument was recovered undamaged at its original position and returned a full tape of wave data for the period 27 July to 3 September 1982. The second instrument was the SeaData 635-12 wave gauge equipped with a Marsh-McBirney electromagnetic current sensors and capable of obtaining directional wave data. This instrument was recovered, but in a damaged condition, as was the Endeco 174 current meter attached to the same mooring. The rod of the 635-12 which held the electromagnetic sensor was bent. However, a full tape of data was recovered from the SeaData 635-12 instrument, and only the directional aspects of the wave data from this instrument have been lost. The deployed Endeco adjacent to the 635-12 returned data, except for the last seven days of deployment. However, this latter event did not perturb the 635-12, which was moored at the end of the tag line, thus attached to the same mooring.

During the fall deployment, two SeaData 635-11 gauges were deployed, one in the lagoon south of Flaxman Island in eight feet of water and one outside Mary Sachs Entrance in 48 feet of water. The lagoon station was recovered undamaged and in its original location and returned a full tape of data for the period 5 September to 30 October 1982. The offshore station was not recovered, presumably having been carried away by drifting ice.

Results of the wave measurements are discussed in the summary section and presented in Appendix B.

Tide and Storm Surge Results

Tide or storm surge sea level measurements were obtained by two SeaData TDR-2A water level recorders, bottom mounted within the lagoon at stations Z and AA. Station Z returned data for the entire period, whereas station AA stopped for some unexplained reason halfway through. In addition, the two SeaData 635 wave gauges, which were moored at offshore stations Q and Y, also returned full digital tapes. All records extended from late July to early September, with specific dates tabulated in Table 4.

During the fall deployment, one SeaData TDR-2A gauge was bottom-mounted in Mary Sachs Entrance in 12 feet of water. This meter was not recovered, however, presumably lost to drifting ice.

Results are discussed in the summary section and presented in Appendix C.

Coastal Currents

Of the 13 current meters deployed for the period late July to early September 1982 in the Point Thomson study area, twelve instruments were recovered. Although a fair number of these instruments were moved or damaged by ice, long data records were recovered on a total of eight instruments. Details of deployment and recovery are shown in Table 4 for each station.

Drift cards of two types were released for each of two summer experiments. One type of drift card was designed to float on the surface of the water, the other type to move along the bottom. Cards were released on 26 July and again on 4 September. Results are given in Table 8.

During the fall deployment, current meters were deployed at all three stations: in the lagoon south of Flaxman Island in eight feet of water (station SP), in Mary Sachs Entrance in twelve feet of water (station OP), and outside Mary Sachs Entrance in 48 feet of water (station QP). The lagoon meter, an Endeco Type 105 film-recording meter, was recovered and returned a full data tape for the time period 5 September to 15 November 1982. The entrance meter, an Endeco Type 174, and the offshore meter, a General Oceanics model 2010, were both not recovered, presumably having been lost to drifting ice.

An analysis of the coastal current results is discussed in the Point Thomson summary section below. A complete set of the required data products for the current data is presented in Appendix D.

Of the six General Oceanics Model 2010 film-recording current meters deployed, only two returned any data. The meter deployed in the Brownlow Entrance returned about three days of data before failure. During that time, however, the data recovered showed that the meter was in a horizontal position. Since the meter was recovered grounded on the beach, it is assumed that the meter was caught under drift ice and dragged into shallow water. The failure in the meter was the illumination bulb used to expose the film during sampling. It is assumed that repeated bumping by the moving ice significantly added to that failure.

The remaining three meters all showed the same type of failure: overexposed film. The overexposure is caused by a failure to advance the film one complete frame during sampling, so that each frame receives multiple exposures. After extensive testing, the most probable cause for this failure appears to be sticky film cassettes. The cameras were all thoroughly checked out both prior to and after deployment. No problems were detected even with the meters which produced blank films. Of course, it is impossible to tell whether the film is advancing once the cassette is inserted.

These instruments have been used successfully on numerous other deployments, including similar environments in the Artic. Exhaustive testing, including at 0°C, has been carried out, as well as actual field deployments under a wide variety of conditions, and only one failure has been recorded. One test cassette was sticking, yet the external functionality of the camera (exposure light flashing and film advance motor noise) were normal. After manually freeing the cassette, normal film advance was noted.

Since each film was manually advanced prior to insertion into the camera, it is assumed that partial slippage occurred in the film cartridge of the cassettes. Examination of the cameras by a professional camera repair facility indicated no slippage was possible inside the camera itself, since the mechanism is 100 percent gear driven. Therefore, the conclusion is that an unusual batch of film cassettes with sticking characteristics had been supplied by Kodak.

Hydrography and Water Quality

Hydrographic and water quality profiles were taken during the summer on the required station patterns within the lagoon and outside Mary Sachs Entrance (Figure 3). These results are also discussed in the summary section below. The full set of data products is displayed in Appendix E.

Velocity profile data are not presented since the data tapes containing profile data gave spurious data upon translation. The recorder was lost to drift ice, so final determination of "why" cannot be given. Subsequent discussions with the equipment manufactorer lead us to believe that one channel of the four channel tape-writing head had malfunctioned. This leads to random numbers appearing on the tape and also matches the physical evidence (unusual noise in recorder) noted at the time data was taken. Data recorded manually in the field indicated a very low current speed at each station measured and no evidence of stratified conditions or shear currents.

Table 4. Equipment Deployment and Recovery Log; Exxon - Point Thomson, Summer 1982.

Station	Instrument	Date: Deployment	Date: Recovery	Location: Latitude (North)	Location: Longitude (West)	Meter Depth (m)	Water Depth (m)	Comments
D	General Oceanics 2010 - S.N. "P"	27 Jul	3 Sep	70°14'13"	146°45'28"	1.8 (6')	3.6 (12')	Mooring dragged by ice over 300 meters.
E	Endeco Type 174 S.N. 232	29 Jul	3 Sep	70°12'20"	146°40'30"	2.0 (6.5')	3.9 (13')	Mooring dragged by ice and recovered at 70°13'20"N,, 146°49'40"W.
I	General Oceanics 2010 - S.N. "H"	28 Jul	3 Sep	70°12'10"	146°34'00"	1.5 (5')	3.0 (10')	Mooring dragged by ice nearly 300 meters; meter failed.
K	General Oceanics 2010 - S.N. "X"	27 Jul	3 Sep	70°13'28"	146°35'00"	1.4 (4.5')	2.7 (9')	Meter failed.
O	Endeco Type 174 S.N. A049	28 Jul	4 Sep	70°12'36"	146°16'17"	1.8 (6')	3.6 (12')	Okay
P	Endeco Type 174 S.N. A048	29 Jul	4 Sep	70°13'18"	146°13'00"	3.6 (12')	7.9 (26')	Okay
Q	Sea Data 635-12	1 Aug	4 Sep	70°14'02"	146°06'44"	13.3 (44')	14.5 (48')	Meter damaged and dragged by ice ice about 200 m; data recovered.
Q'	Endeco Type 174 S.N. A047	1 Aug	4 Sep	70°14'02"	146°06'44"	12.7 (42')	14.5 (48')	Meter damaged by ice; data recovered.
R	General Oceanics 2010 - S.N. "A"	28 Jul	5 Sep	70°10'03"	146°06'34"	1.1 (3.75')	2.3 (7.5')	Meter failed.

Table 4. (Continued)

Station	Instrument	Date		Location		Meter Depth (m)	Water Depth (m)	Comments
		Deployment	Recovery	Latitude	Longitude			
S	InterOcean 195R with Marsh-McBirney EM sensor	28 Jul	--	70°10'44"	146°06'30"	1.5 (5')	2.4 (8')	Meter/mooring lost to drifting ice.
S'	Endeco Type 174 S.N. A052	28 Jul	5 Sep	70°10'45"	146°06'30"	1.6 (5.5')	2.4 (8')	Okay
S''	Endeco Type 174 S.N. A175	28 Jul	5 Sep	70°10'45"	146°06'30"	0.6 (2')	2.4 (8')	Okay
T	General Oceanics 2010 - S.N. "C"	28 Jul	5 Sep	70°11'40"	146°06'11"	1.1 (3.5')	2.1 (7')	Okay
V	General Oceanics 2010 - S.N. "Z"	28 Jul	5 Sep	70°10'39"	145°57'14"	2.1 (7')	4.2 (14')	Meter damaged and dragged by ice 100 meters on to shore; data lost.
Y	Sea Data 635-11 S.N. 14417	27 Jul	3 Sep	70°16'46"	146°48'20"	9.7 (32')	9.7 (32')	Okay
Z	Sea Data TDR-2A S.N. 146	24 Jul 11 Aug	11 Aug 5 Sep	70°11'47"	146°31'04"	1.5 (5')	1.5 (5')	Okay
AA	Sea Data TDR-2A S.N. 109	24 Jul	2 Sep	70°09'04"	146°03'34"	1.8 (6')	1.8 (6')	Okay
--	Digital Weather Station, MRI-5000	28 Jul	3 Sep	70°14'15"	146°38'15"	onshore, Challenge Island		Retrieved, station maintained.
--	Backup Meterological Equipment (Climet, Ryan-Peabody, and Belfort Instruments	28 Jul	3 Sep	70°14'15"	146°38'15"	onshore, Challenge Island		Retrieved, station maintained

Table 5 . Equipment Deployment and Recovery Log; Exxon - Point Thomson, Fall 1982.

Station	Instrument	Date: Deployment	Date: Recovery	Location: Latitude (North)	Location: Longitude (West)	Meter Depth (m)	Water Depth (m)	Comments
SP	Sea Data 635-11 S.N. 3385	5 Sep	15 Nov	70°10'46"	146°07'12"	2.4 (8')	2.4 (8')	Okay
SP	Endeco Type 105	5 Sep	15 Nov	70°10'46"	146°07'12"	1.6 (5.5')	2.4 (8')	Okay
OP	Sea Data TDR-2A S.N. 146	4 Sep	-	70°12'21"	146°14'18"	4.5 (15')	4.0 (15')	Mooring lost to drifting ice
OP	Endeco Type 174	4 Sep	-	70°12'21"	146°14'18"	2.3 (7.5')	4.5 (15')	Mooring lost to drifting ice
QP	Sea Data 635-11 S.N. 14417	8 Sep	-	70°14'07"	146°7'26"	14.5 (48')	14.5 (48')	Mooring lost to drifting ice
QP	General Oceanics S.N. 2010 "H"	8 Sep	-	70°14'07"	146°7'26"	13.6 (45')	14.5 (48')	Mooring lost to drifting ice
--	Digital Weather Station, MRI-5000	2 Sep	15 Nov	70°14'15"	146°38'15"	onshore Challenge Island		Okay
--	Backup meteorological Equipment (Ryan-Peabody, and Belfort Instruments	2 Sep	15 Nov	70°14'15"	146°38'15"	onshore Challenge Island		Okay

Table 6. Equipment Sampling Rate and Data Recovered; Exxon - Point Thomson, Summer 1982

Station	Instrument	Sampling Rate		Data Recovered
D	General Oceanics 2010 - S.N. "P"	Current speed and direction: one reading every 30 minutes		39 days (full record)
E	Endeco Type 174 S.N. 232	Current speed and direction, temperature, and conductivity: one reading every 5 minutes.		37 days (full record)
I	General Oceanics 2010 - S.N. "H"	Current speed and direction: one reading every 30 minutes		-0- (meter failed)
K	General Oceanics 2010 - S.N. "X"	Current speed and direction: one reading every 30 minutes		-0- (meter failed)
Q	Endeco Type 174 S.N. A049	Current speed and direction, temperature, and conductivity: one reading every 5 minutes		39 days (full record)
P	Endeco Type 174 S.N. A048	Current speed and direction, temperature, and conductivity: one reading every 5 minutes		38 days (full record)
Q	Sea Data 635-12	Waves:	4 hour sampling interval 1024 readings 0.5 sec. apart/sample	35 days (full record)
		Tides:	one reading every 3.75 min.	35 days (full record)
		Temp:	one reading every 30 min.	35 days (full record)
		Currents:	one reading of speed with each wave measuremeant and each 30 min (mean speed and direction)	-0- (sensor failed)

Table 6. (Continued)

Station	Instrument	Sampling Rate	Data Recovered
Q '	Endeco Type 174 S.N. A047	Current speed and direction, temperature, and conductivity: one reading every 5 minutes	30 days (meter damaged 5 days before recovery)
R	General Oceanics 2010 - S.N. "A"	Current speed and direction: one reading every 30 minutes.	-0- (meter failed)
S	InterOcean 195R with Marsh-McBirney Em sensor	Current speed and direction: 32 readings, one sec apart every 30 minutes	-0- (mooring lost)
S'	Endeco Type 174 S.N. A052	Current speed and direction, temperature, and conductivity: one reading every 5 minutes	40 days (full record)
S'	Endeco Type 174 S.N. A175	Current speed and direction, temperature, and conductivity: one reading every 5 minutes	40 days (full record)
T	General Oceanics 2010 - S.N. "C"	Current speed and direction: one reading every 30 minutes	40 days (full record)
V	General Oceanics 2010 - S.N. "Z"	Current speed and direction: one reading every 30 minutes	-0- (meter failed)

Table 6. (Continued)

Station	Instrument	Sampling Rate	Data Recovered
Y	Sea Data 635-11 S.N. 14417	Waves: 4-hour sampling interval; 2048 readings 0.5 sec. apart/sample	39 days (full record)
		temp/tides: one sample every 7.5 minutes	39 days (full record)
Z	Sea Data TDR-2A S.N. 146	temp/tides: 7.5 min sampling rate; 128 readings one sec. apart/sample	44 days (full record; however, temp. sensor failed)
AA	Sea Data TDR-2A S.N. 109	temp/tides: 7.5 min. sampling rate; 128 readings one sec. apart/sample	21 1/2 days (tape or battery limitation [?])
--	Digital Weather Station, MRI-5000	Wind speed and direction, air temp., and barometric pressure: one sample every 15 minutes	38 days (full record; however, temp. and barometric pressure sensors failed)
	Backup meteorological equipment (Climet, Ryan-Peabody, and Belfort Instruments)	Wind speed and direction, air temp., and barometric pressure: continuous record on strip chart	38 days (full record)

Table 7. Equipment Sampling Rate and Data Recovered; Exxon - Point Thomson, Fall 1982

Station	Instrument	Sampling Rate	Data Recovered
SP	Sea Data 635-11 S.N. 3385	Waves: 4 hour sampling interval 2048 readings 0.5 sec. apart/sample	56 days (full record)
		Temp/tides: one sample every 7.5 min.	56 days (full record)
SP	Endeco Type 105	Current speed and direction: one reading every 30 min.	71 days (full record)
OP	Sea Data TDR-2A S.N. 146	Temp/tides: 7.5 min sampling interval; 128 readings one sec. apart/sample	-0- (mooring lost)
OP	Endeco Type 174	Current speed and direction, temperature, and conductivity: one reading every 5 min.	-0- (mooring lost)
QP	Sea Data 635-11 S.N. 14417	Waves: 4 hour sampling interval 2048 reading 0.5 sec. apart/ sample Temp/tides: one sample every 7.5 min.	-0- (mooring lost)
QP	General Oceanics 2010 - S.N. "H"	Current speed and direction: one reading per hour	-0- (mooring lost)
--	Digital Weather Station, MRI-5000	Wind speed and direction: one reading every 30 min.	55 days (tape limitation)
--	Backup Meteorological Equipment (Belfort Instruments)	Barometric pressure: continuous record on strip chart	60 days (full record)

Table 8 . Drifter Results, Pt. Thomson, Summer 1982.

Drifter Type	Number Released	Release Location	Release Date	Number Found	Location of Find	Date of Find
Surface	200	Central lagoon, inside Mary Sachs Entrance	26 Jul	0*	---	---
Bottom	400	(as above)	26 Jul	160-190**	North shore of Flaxman Island, plus one on mainland at Pt. Thomson	2-11 Sep
Surface	250	(as above)	4 Sep	47	8: East side of Tigvariak Is. 6: Between Tigvariak Is. and Sag. River Delta 7: on Foggy Island 26: Westdock at Prudhoe Bay	8-11 Sep
Bottom	200	(as above)	4 Sep	93	82: Between Pt. Gordon and Bullen Pt. 11: Between Bullen Pt. and Tigvariak Is.	8 Sep

* No searches conducted east of Brownlow Point or west of Westdock at Prudhoe Bay.

** Two separate counts, combining air and ground search techniques.

SUMMARY CONDITIONS, POINT THOMSON AREA

The results of the summer and fall meteorological and oceanographic measuring program are summarized and discussed briefly in this section, including specific data displays for illustrative purposes. However, all data products and displays are reproduced completely in the Appendices to this report, organized as to type of data.

Meteorology

Meteorological data was measured from the ten-meter tower erected on Challenge Island for the period 28 July to 30 October 1982. Similar data was obtained from the National Weather Service stations at Barter Island and Point Barrow for the same time period.

Time series plots for the summer period of wind speed and direction are shown in Figure 9 for both Challenge Island and for Barter Island. Similar plots are shown in Figure 10 for the fall time period. Note that the meteorological convention for winds is used throughout this report: wind directions quoted are for winds from that direction. The barometric pressure and temperature time series plots are shown in Figures 11 and 12.

Wind speeds at Challenge Island were moderate throughout the summer period. The maximum wind speed was about 24 knots, with the median speed for the summer period being about nine knots. During the fall period, a maximum wind of 38 knots was recorded, with a median wind speed for the fall time period of about 12 knots.

Polar plots of speed and direction data are shown in Figures 13 and 14, for the summer and fall time periods of the Challenge Island records. The principal axis of these wind records are along the direction northeast or southwest (64-71° true bearing). These results agree with historical data summaries given in Brower et al (1977) for Barter Island wind data summaries.

Rose plots of these Challenge Island data (Figures 15 and 16) show this directionality and distribution of the data. The cumulative probability plot of Figure 17 shows that 95 percent of the wind values were below 20 knots for the summer period, whereas only 75 percent of the values were below 20 knots for the fall period (Figure 18). Figures 19-22 show similar rose plots and cumulative speed plots for the Barter Island data.

With reference to the time series wind speed and direction plots of Figures 9 and 10, significant meteorological events of higher winds occur at the following times:

July 29 - 30	September 6 - 7
August 2 - 3	September 18 - 22
August 20 - 22	October 3 - 6
August 22 - 25	October 16 - 17
	October 19 - 21

The above meteorological events can be used to look for simultaneous response by oceanographic variables such as waves, currents, water level or surge, and salinity and temperature.

Referring back to the time series plots of Figures 9 and 10, the Challenge Island winds and those of Barter Island are strikingly comparable. Events, speeds, and directions all compare well. Barter Island's extreme winds are somewhat higher in the fall period; for example, 46 knot winds at Barter versus 35 knots at Challenge Island. However, cross correlations of these Barter Island and Challenge Island records show high cross correlation coefficients of 0.91 and 0.89 for the summer and fall time periods, respectively (Figures 23 and 24). Coherence and phase relationships are shown in Figures 25-28 for these respective cross correlations. No significant time lag is indicated between these wind records at Barter and Challenge Islands.

The records of barometric pressure and temperature for Challenge Island and Barter Island (Figures 11 and 12) show the same similarities. For example, the barometric pressure records for Challenge Island and Barter Island can be superimposed almost perfectly, with no lag noted. Challenge Island temperature plots are not included for the fall period, as the temperature sensor at the Challenge Island station recorded spurious data for this unattended period.

The above similarities and high correlation coefficients indicate that the long data base available at Barter Island should be a good representation of Point Thomson meteorological conditions, for hindcasting and planning purposes. Therefore, the historical records available for Barter Island at the National Climatic Center (Asheville, North Carolina) should be useful for Point Thomson area planning purposes, as should published analyses of these records, as in Brower et al (1977). Our only indication of differences were the somewhat higher extreme winds in the fall Barter Island records.

Wave Climate

Wave conditions were measured during the summer time period at two stations offshore the barrier island system of the Point Thomson area. These stations were station Q, to the east and north of Mary Sachs Entrance, and station Y, north of Challenge Entrance. During the fall time period, one wave measuring station, station QP, was placed out near the location of the summer station Q. A second station,

station SP, was placed inside the lagoon south of Flaxman Island at the location of the summer current metering station S. All wave instruments were recovered with data, except for the fall mooring outside the barrier islands, station QP, which was lost to ice. The current sensor on the SeaData 635-12 instrument at station Q was also damaged, so that wave directionality data could not be obtained for the summer period.

Waves measured during both the summer and fall time periods were low, compared to maximum values reported for other years at other locations along the Alaskan Beaufort coast. These low waves were due to a combination of two factors; generally low winds or the presence of ice.

Measured maximum wave heights, significant wave heights, and significant wave periods are plotted versus time in Figures 29 and 30 for stations Q and Y respectively, using the summer data.

Shown also is the Challenge Island wind speed and direction data. Waves are shown to be low for most of the summer period, with maximum values of two-three feet, significant wave heights of just over one foot, and significant wave periods of about 2.5 seconds. Only one event stands out from this back-ground, the period of 20 knot plus westerly winds of 20-22 August followed by 20 knot easterly winds of 22-23 August.

During this event in August, maximum wave heights of about five feet were reached at about a 3.5 second period, with a significant wave height (profile) of 2.75 feet at 3.15 second period.

Cumulative probability plots of H(max) and H(s) are shown in Figures 31 and 32 for staton Q which illustrate the predominant low waves present during most of the 1982 summer season outside the barrier islands of the Point Thomson region. The cumulative probability plot of the corresponding significant wave periods (Figure 33) illustrates the high frequency nature of this wind chop. Corresponding probability plots for station Y to the west (Figures 34 through 36) indicate even lower wave conditions at this location.

Waves were low during the summer time period of 1982. First of all, there was a lack of strong storm events, with even the event of 20-26 August only exhibiting winds of about 20 knots. Secondly, ice was persistent for much of this season just outside the barrier islands of the Point Thomson region and to the east. Also, other periods of 20 knot winds during the summer did not produce notable waves, presumably because of ice effects.

The nature of the summer waves measured and their relationship to wind speed can be illustrated by a few data products reproduced in Figures 37 through 44.

For the entire summer record, wind speed does not correlate strongly with significant wave heights, particularly at lower wind speeds (Figure 37). A better correlation is obtained for the restricted time period of 20-26 August, when other conditions such as ice may be more constant (Figure 38). Also, higher wind and wave conditions occurred during this latter period and thus instrument noise is less of a factor in the data. Scatter plots of H(s) verses H(max), T(s) versus H(s), and spectral T(s) verses Spectral H(s) show good correlations as expected (Figures 39 through 41).

Surface wave specta shown in Figures 42 through 44 are typical spectra obtained during the 20-26 August event of higher waves. Only a limited number of records indicated waves of greater than two-foot significant heights, all occurring during this 20-26 August event.

For the fall mooring period, the measured maximum wave heights, significant wave heights, and significant wave periods are plotted versus time in Figure 45 for station SP located south of Flaxman Island in the lagoon.

Winds of 20 knots or higher early in September caused maximum wave heights of one to two feet. Later in the month and during 35-45 knot winds, little wave response is indicated, undoubtedly due to ice within the lagoon. Cummulative probability plots of these wave parameters for the fall data are given in Figures 46 through 48.

Tide and Storm Surge

During the summer time period, two water level gauges were placed within the lagoon: one at station AA near Point Gordon and one at station Z near the mainland coast south of Flaxman Island. The SeaData gauge at station AA malfunctioned on 19 August, yielding a short record for this station. Water level records were also obtained by the wave gauges placed offshore the barrier islands at stations Q and Y. During the winter time period, a record was obtained from the instrument recovered from station SP within the lagoon south of Flaxman Island.

For the summer time period, the data are plotted in Figures 49 through 52 for stations AA, Z, Q, and Y, respectively. Wind speed and direction plots are also included in these figures. From Figure 49 through 52, it can be seen that water depth variations were similar at all stations. Tidal signals were extracted and plotted relative to the benchmark found 11.2 feet above mean sea level, as determined from the collected data, on Flaxman Island and yielded virtually identical tidal records for all summer stations. These tidal amplitudes were, as expected, a small part of the total water depth variation. Of most interest is the surge water depths, which account for most of the total water depth variation. These surge water depth records also closely resemble each other, with minor differences noted between station Q and Y records when superimposed.

These surge water depths respond to the meteorological forcing functions very closely. Comparison of the wind and surge records of Figures 49 through 52 show clearly the negative surge associated with easterly winds and the positive surge associated with westerly winds. For the approximate 20 knot events in the summer record, the variations in water level were only about ±1 foot. Similar plots for the fall period (Figure 53) show a surge of +2 feet, associated with the high winds during the ice covered period of 19-20 October when winds reached 35 knots at Challenge Island and 45 knots at Barter Island. In contrast, however, Reimnitz and Maurer (1979) estimated, from driftwood elevations left after the 1970 storm, surge levels in the Point Thomson region of +2.0-2.7 meters (6.6-8.9 feet). This was felt to be a 50- or 100-year event.

Coastal Currents

Coastal currents were measured within the lagoon, in entrances, and outside the barrier islands. A brief summary of the current results from selected stations is given in Figure 54 in the form of stick plots, along with the Challenge Island wind results. Station Q was offshore, north of Flaxman Island in about 50 feet of water. Station P was outside Mary Sachs Entrance and station O was in the entrance. Station S was inside the lagoon on the eastern side, south of Flaxman Island, and station E was at the far western end of the lagoon.

Currents were strongest at station O, Mary Sachs Entrance. Visually, the correlation of the currents at station O and the Challenge Island winds is apparent, with easterly winds resulting in flow into Mary Sachs Entrance and out at the western end at station E. Flows at station S are weaker than those at the entrances, flowing easterly when flow is easterly at station E. At the same time, flows are outward at Mary Sachs Entrance. Flows at station D, in Challenge Entrance, are predominantly inward (Figure 55) bearing to the southwest under easterly wind conditions and to the southeast under westerly winds. The simple pattern shown in Figure 55 seems to be the basic flow regime of the lagoon system. As noted in the previous section, however, surge effects will be positive under westerly winds and negative under easterly winds.

Examining these current data somewhat more closely, it is apparent that the direction of the measured currents is parallel to the local bathymetry, an indication of valid data in shallow water. Polar plots are shown in Figures 56 through 60, giving the principal axis of flow for data from stations Q, O, S(top), S(bottom), and E. A comparison of these principal axis directions with the locations and bathymetry of the individual stations, as mapped in Figure 61, show this agreement with the local bathymetry.

Speed and direction data can also be examined more closely in the time series plots for the individual stations. Currents at station Q (Figure 62) are generally low, often below 10 cm/sec and reaching median values of 25 cm/sec (0.5 knot) only during the windy period of 19-25 August, also noted as affecting the wave and surge results.

Current speeds measured at station O (Figure 63), at Mary Sachs Entrance, are much higher. They measured 65 cm/sec outward on 30 July, and regularly exceeded 25 cm/sec (0.5 knot). Tidal influence is apparent in this record.

Current speeds measured at station P, offshore but shallower (26-foot depth) show values often exceeding 50 cm/sec and reaching 75 cm/sec (1.5 knots). Comparing the time series of this station with that of the Challenge Island wind data (Figure 64) leads to the conclusion that this current is driven by the local wind. A cross-correlation of the deeper station Q currents with the Challenge Island winds was also carried out. The results shown in Figures 65 through 67 give a high correlation coefficient of 0.80, with a lag time of about 21 hours for this deep station. A corresponding correlation coefficient of 0.85 and a lag of 0 hours was obtained for the station E data. These results indicate that, though the deeper (44 foot depth) bottom currents offshore are essentially wind driven, some 20 hours are required for momentum to be effectively transferred to this deeper layer. The existence of density stratification found at these outside stations, and discussed in the Hydrography and Water Quality section below, may act to retard such momentum transfer.

Low currents are indicated (Figure 68) for station S within the lagoon south of Flaxman Island. Moderate currents are indicated at station E (Figure 69) at the western entrances to the lagoon.

Of interest, the small tidal component of station S is plotted in Figure 70, significantly contrasting with the tidal component of the current at Mary Sachs Entrace (Figure 71), as the latter reaches about 15 cm/sec.

Currents measured within the lagoon at station SP during the fall period were also low (Figure 72). The record indicates currents were measured through 23 September. Following that date, little to no currents were recorded, even though the meter was apparently still functioning (a full film cassette was recovered). This is felt to be explained most probably by a meter malfunction beginning 24 September (the meter was recovered in a slightly damaged condition) or by a lack of water movement in the lagoon after freezeup. Unfortunately, no other data was collected to support or deny the latter explanation.

Drifters, both surface and bottom, were released south of Mary Sachs Entrance on two occasions: 26 July and 4 September 1982. On both days, the drifters were dropped during relatively calm wind and wave conditions. Also on both occasions, however, the drop was followed by periods of fairly intense winds.

Within eight hours of the release of 200 surface and 400 bottom drifters on 29 July 1982, the wind began to blow from the northeast at 15-20 knots and contined for about 24 hours. Table 8 and Figure 73 show that only bottom drifters were found from this release, but nearly 50 percent were recovered. All were found on the offshore side of Flaxman Island. A thorough search of the lagoon and barrier island shorelines revealed no additional drifters. Since over a month had elapsed between release and recoverey, the mechanism of net transport to outside the lagoon cannot be completely described. The current meter station in Mary Sachs Entrance indicates a net flow outward during westerly winds. Several periods of westerly wind regimes (net offshore movement through Mary Sachs Entrance) occurred which could easily have carried the drifters out through the entrance.

The release of 4 September 1982 resulted in a clearer understanding of the transport mechanism. As listed in Table 8, 47 of the 250 surface drifters and 93 of the 200 bottom drifters were recovered within a week of release. The wind regime at this time (Figure 10) was of sustained easterly winds of 10-20 knots for over a week. The drifters, both surface and bottom, closely followed the wind (Figure 73), as has also been shown for the nearshore currents. The surface drifters more closely followed depth contours exhibiting faster net transport rates over greater distances than the bottom drifters which beached much closer to the release point. Since over half of the surface drifters were recovered from Westdock at Prudhoe Bay, it seems likely that some, maybe most, also passed seaward of that causeway.

The drifter results corroborate the results of the current metering in the Pt. Thomson area: the nearshore waters, especially at the surface, are very responsive to and clearly follow the local winds. Overall net transport in times of low winds is less defined, but is probably sluggish.

In summary, the coastal currents are wind driven, with tidal influences significant only in the entrances. A simple pattern (Figure 61) of easterly and westerly flow under west and east wind conditions, respectively, seems to prevail in the Point Thomson region.

Hydrography and Water Quality

Hydrographic sections were carried out in the Pt. Thomson study area during three separate phases of the open water season: early (July), midseason (August), and late (September).

Figure 74 shows typical plots for temperature, salinity, and density for both lagoon and offshore stations for the three time periods. Stations M and S are stations with typical conditions inside the lagoon. Station Q is outside the islands, north of Flaxman Island, and at 50 feet depth. Additional profiles are plotted in Appendix E, showing areal extent of water properties throughout the Point Thomson area.

During the early season, the lagoon area inside the Maguire Islands complex was characterized by relatively warm (6-9°C), low salinity (8-10 ppt) water. Although the salinity was slightly lower and the temperature slightly higher nearer the mainland, the lagoon was basically well-mixed and quite uniform throughout. Outside the barrier islands, a sharp thermocline/halocline was found at 4-7 meters. The surface layer was very similar to that inside the lagoon, whereas the bottom layer was much colder (0-1.5°C) and much more saline (28-29 ppt). As might be expected, the shallower waters of the lagoon were more turbid than the region outside the barrier islands.

During the midseason, in general, the water temperature dropped and the salinity increased slightly in the lagoon and surface layer offshore the islands, relative to the early season. The lagoon from Alaska Island eastward was well-mixed and unstratified with slightly more saline water at the entrances. At the more open west end, however, a thermocline was noted at a depth of 2-3 meters. Also at the west end, salinity generally increased slightly with increasing distance from the mainland. Offshore the barrier islands, a sharp halocline was found at 4-5 meters, very similar to the earlier results. Again, the surface layer was very similar to that found in the lagoon. Little difference was noted in water quality parameters in the bottom layer from season to season.

In the late season, only the east end (stations O - W) of the lagoon were sampled because of weather difficulties. No stratification was noted in any stations sampled. The salinity of all water sampled was very similar and of the level of the deeper layer found throughout the summer (28-29 ppt).

Long-term measurements of salinities and temperatures were also measured by several instruments at a number of locations throughout the study area. Figure 75 compares continuous temperature and salinity records taken at station S within the lagoon near the top of the water column and at the bottom. The curves are virtually identical, thus showing that no stratified conditions existed in the eastern side of the lagoon south of Flaxman Island during the summer time period.

Continuous temperature and salinity plots are shown in Figure 76 for station Q (outside the lagoon and 50 feet deep), for station P (just outside Mary Sachs Entrance), and for station S (inside the lagoon). Also shown in Figure 76 is the surge water level recorded at station Z, within the lagoon near station S.

In examining the data presented in these figures, it can be seen that the lagoon water is of low salinity (10-12 ppt) and relatively high temperature (3-8°C) during most of the study. There are numerous "events" of fine structure, especially near the entrance where pulsing might be expected to be most pronounced, but little change is noted except a gradual increase in salinity until the third week of August. As was noted from the STD profiles, the bottom layer outside at 50 feet depth (station Q) is very uniform throughout the time period except for the event from 19-22 August. The surface layer offshore at station P is seen to be of the same water mass as found inside the lagoon, as noted earlier.

Of particular interest is the major event noted in all records during the third week of August. Starting on 19 August, a drop of 8-10 ppt in salinity and a slight increase in temperature were noted in the bottom layer offshore. Several days later, between 22 and 23 August, a return to normal conditions occurred. Starting on 23 August, each inshore meter recorded a dramatic increase in salinity and a drop in temperature that remained through the end of the record. STD profiles also corroborate finding more oceanic waters at all the stations visited during the late phase of the study. These events are explained by examining the wind/surge correlations presented earlier and shown in Figure 76. Starting on 19 August, a strong wind blew out of the west thus producing a positive surge (water level rise) and a period of strong mixing (maximum wave heights). This was evidently of sufficient strength to mix warmer, less saline surface waters into the bottom layer. After blowing hard from the west, the wind then immediately reversed directions and blew hard from the east. This resulted in a negative surge and another period of stronger mixing. The subsequent refilling of the lagoon evidently allowed the colder, more saline bottom layer to flow into the lagoon.

In summary, the water mass of the study area is quite typical of the Beaufort Sea nearshore region, as described earlier in the literature survey. The warmer, less saline surface water is probably of river origin (Hufford and Bowman, 1974; Barnes et al, 1977) and overlies the colder, more saline oceanic shelf waters in the deeper, offshore areas. A slow increase in salinity indicates a limited exchange of oceanic waters with the nearshore region. Major exchange of water masses is driven by storm surges and local winds.

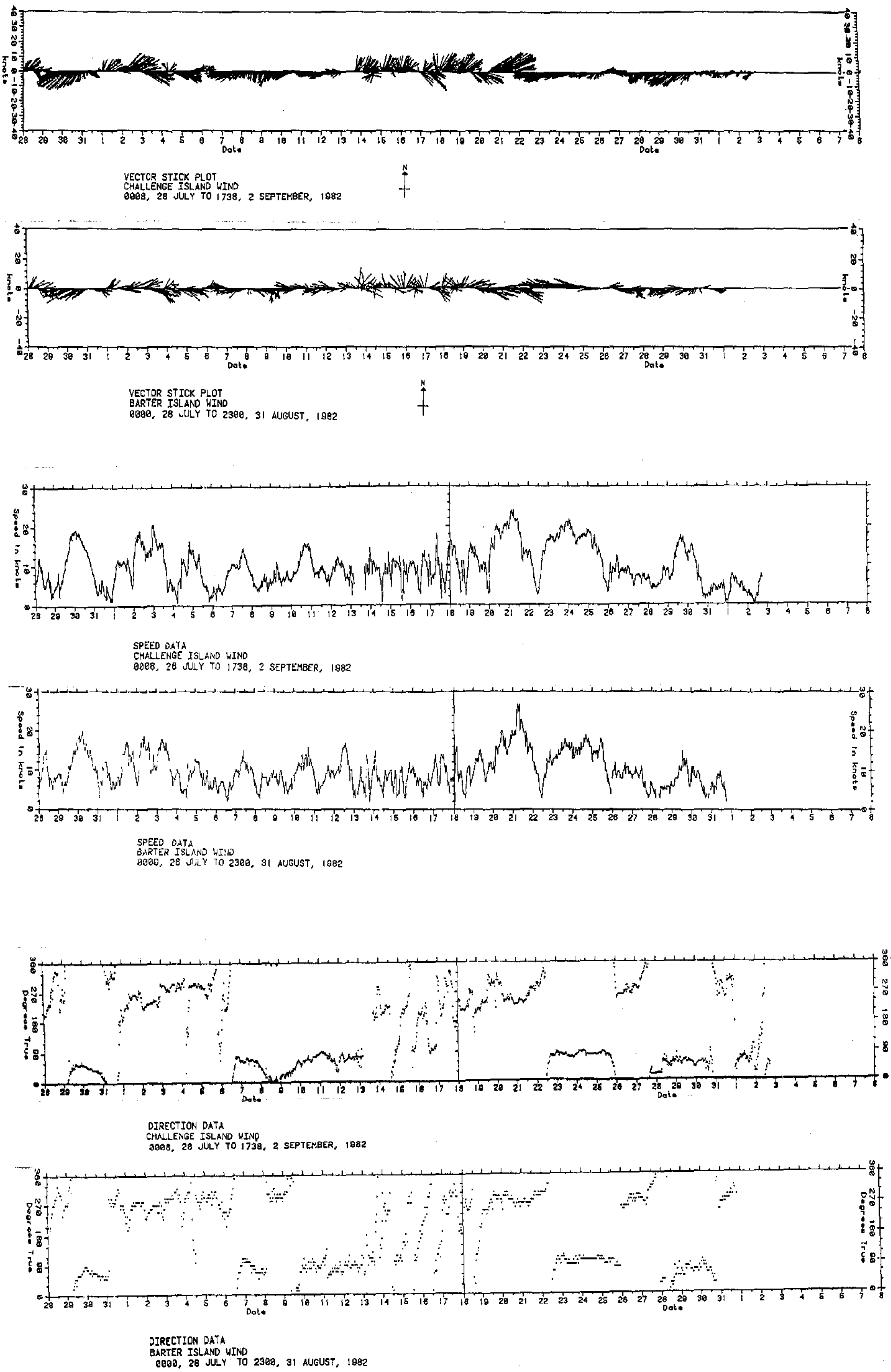
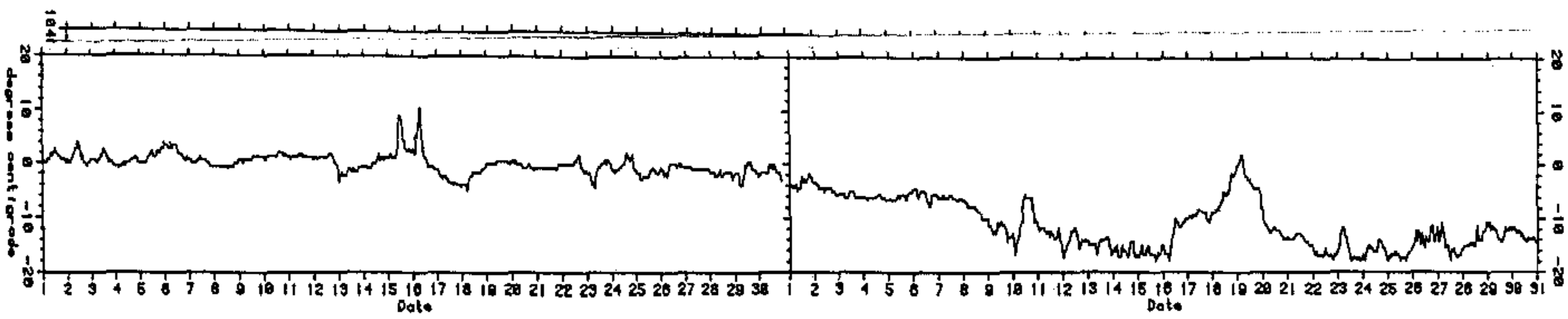
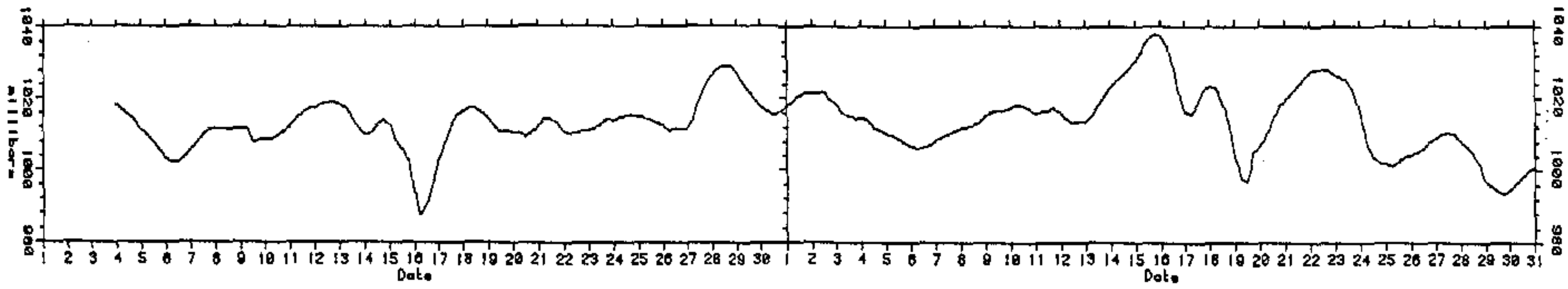


Figure 9. Time Series Plots of Wind Speed and Direction, Challenge Island and Barter Island, Summer 1982.

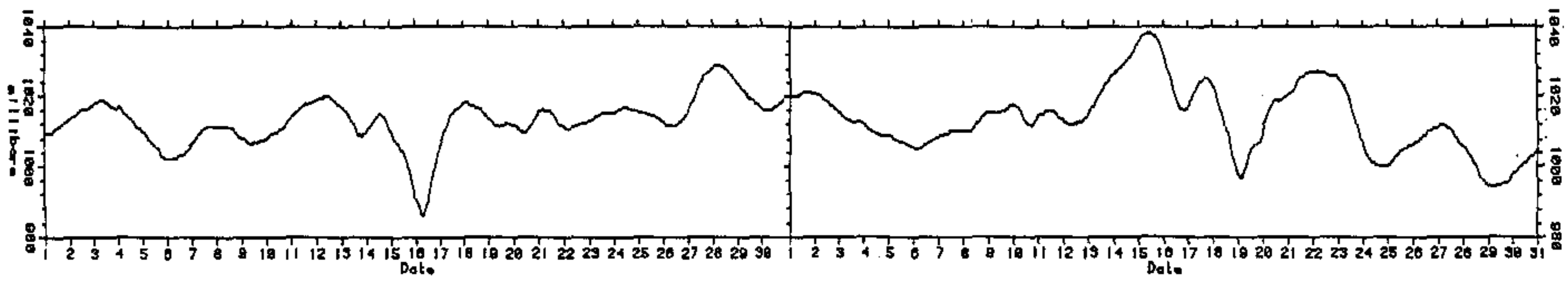


AIR TEMPERATURE
BARTER ISLAND
0000, 1 SEPTEMBER TO 2300, 30 OCTOBER, 1982

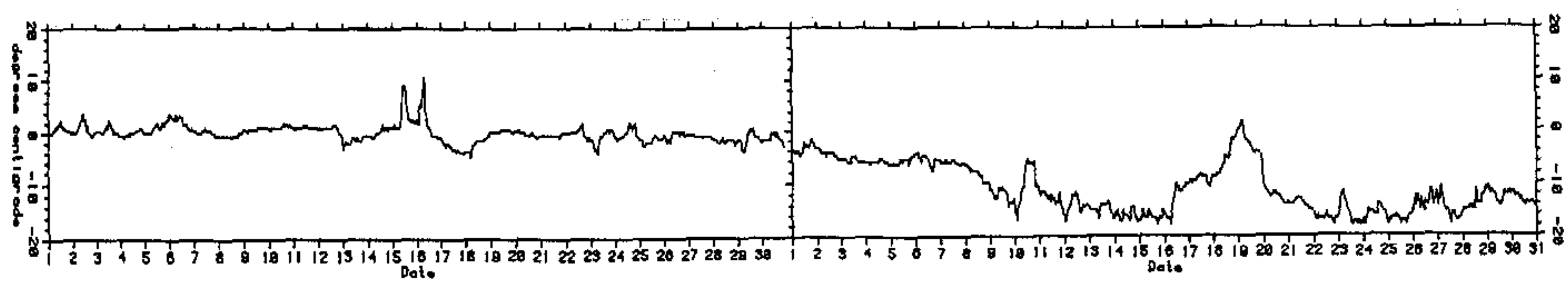
Figure 12. Time Series Plots of Barometric Pressure and Temperature Challenge Island and Barter Island, Fall 1982.



BAROMETRIC PRESSURE
CHALLENGE ISLAND WEATHER STATION
0000, 4 SEPTEMBER TO 2300, 30 OCTOBER, 1982



BAROMETRIC PRESSURE
BARTER ISLAND
0000, 1 SEPTEMBER TO 2300, 30 OCTOBER, 1982



AIR TEMPERATURE
BARTER ISLAND
0000, 1 SEPTEMBER TO 2300, 30 OCTOBER, 1982

Figure 12. Time Series Plots of Barometric Pressure and Temperature Challenge Island and Barter Island, Fall 1982.

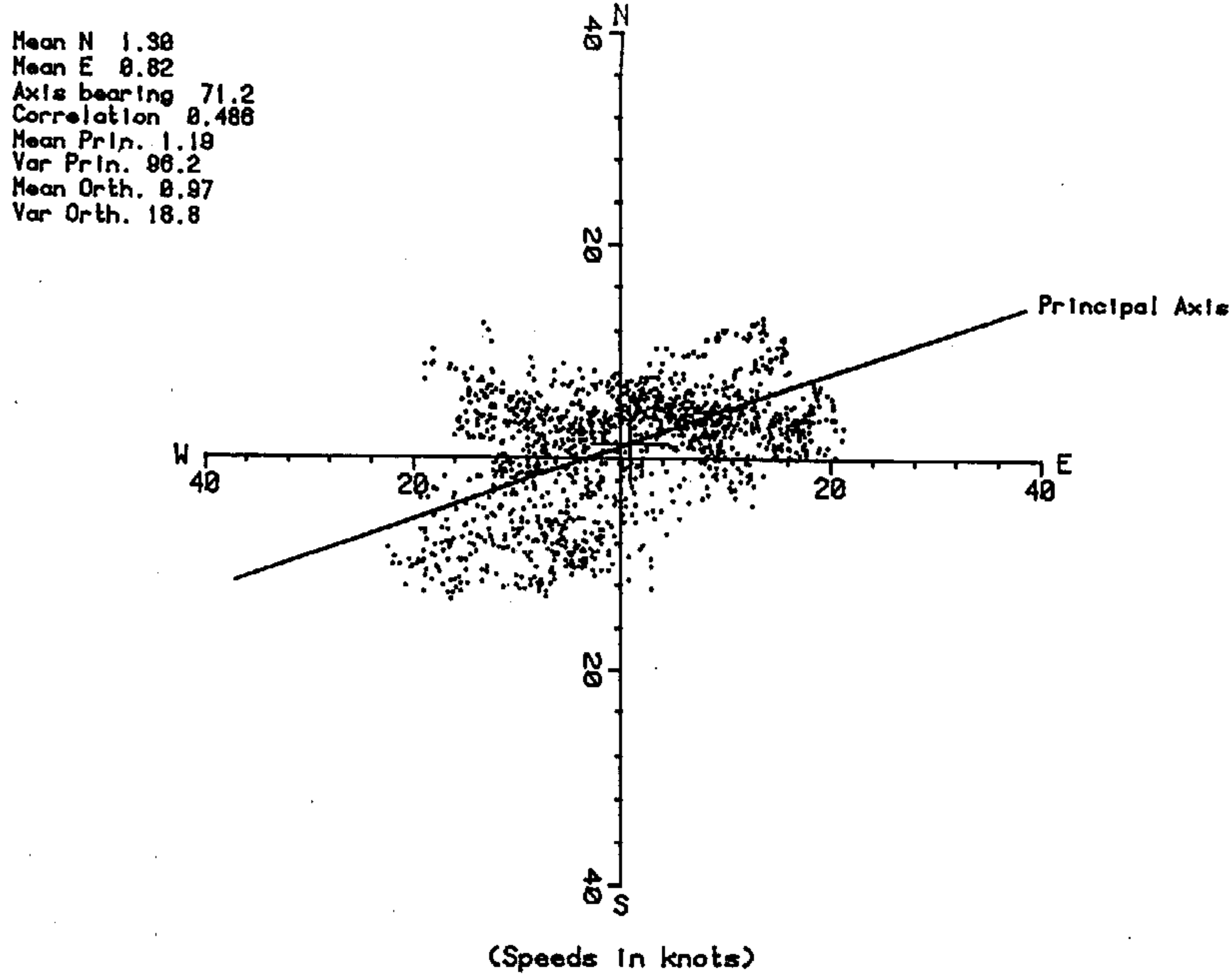


FIGURE 13. POLAR PLOT - SPEED AND DIRECTION DATA
CHALLENGE ISLAND WIND
0008, 28 JULY TO 1738, 3 SEPTEMBER, 1982

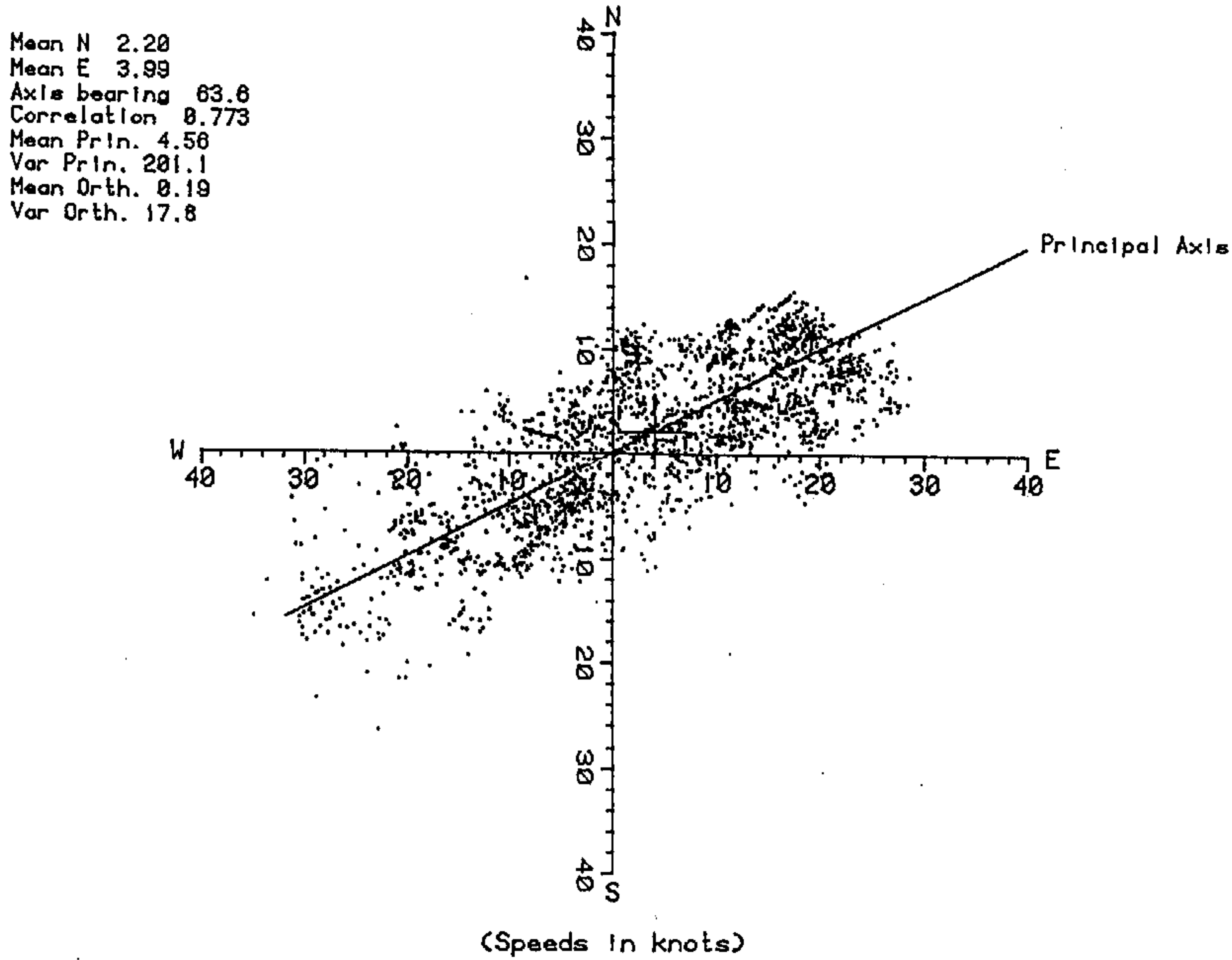


FIGURE 14. POLAR PLOT - SPEED AND DIRECTION DATA
CHALLENGE ISLAND WIND
1400, 4 SEPTEMBER TO 0700, 28 OCTOBER, 1982

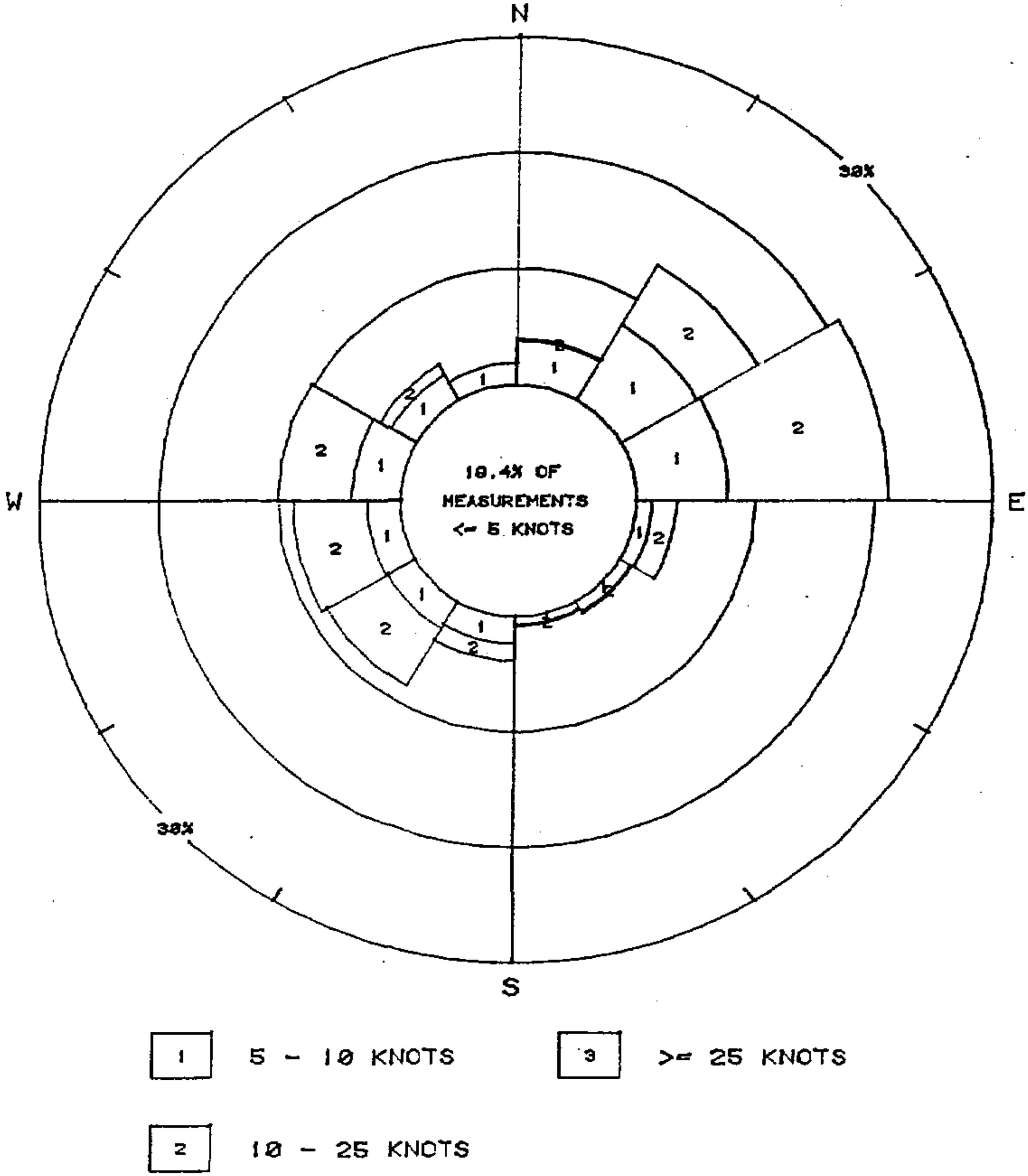
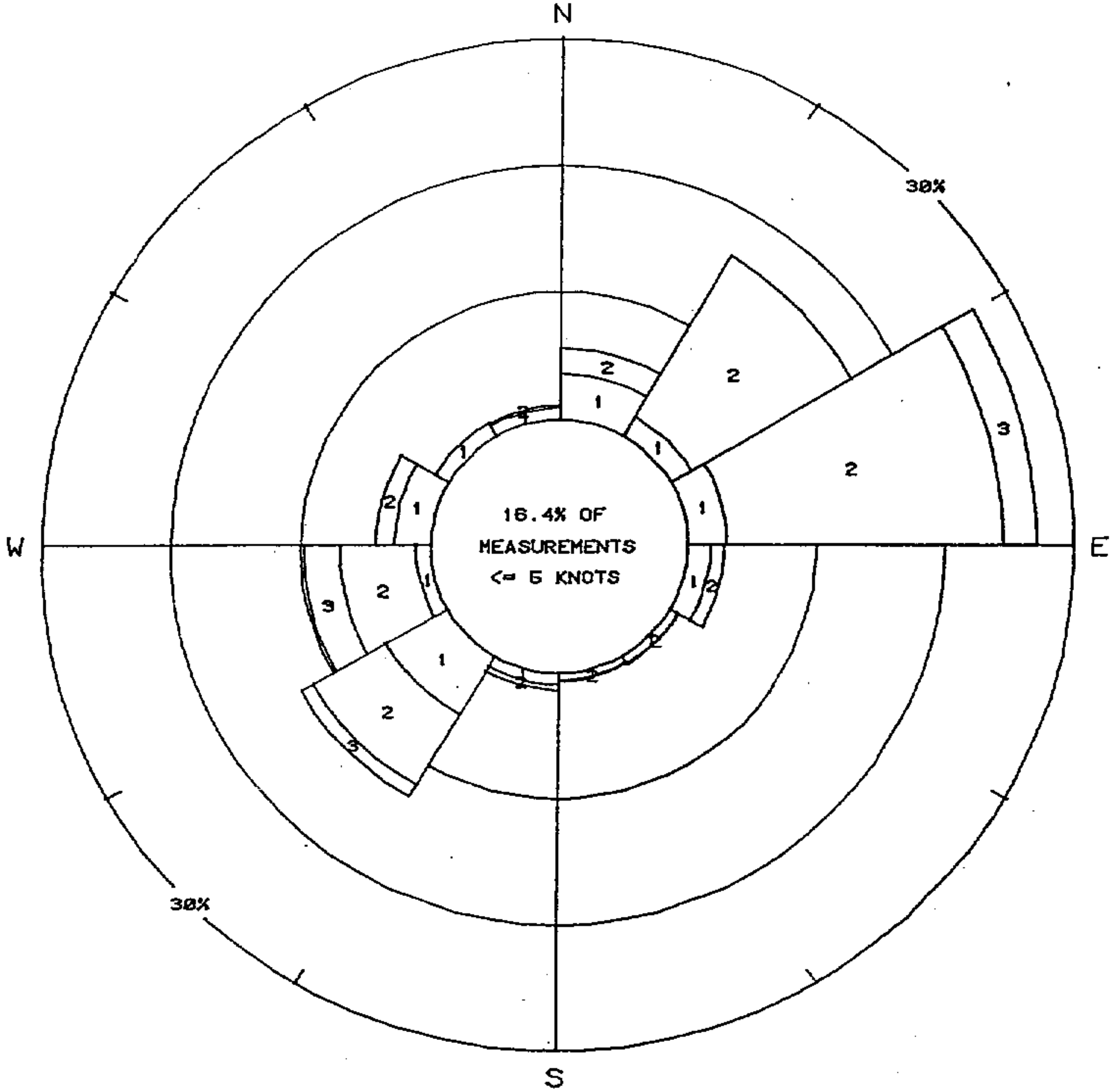


FIGURE 15. ROSE DIAGRAM
1/2 HR. AVERAGE WIND
CHALLENGE ISLAND
0008, 28 JULY TO 1738, 3 SEPTEMBER, 198



1 5 - 10 KNOTS

3 >= 25 KNOTS

2 10 - 25 KNOTS

FIGURE 16. ROSE DIAGRAM
WIND
CHALLENGE ISLAND WEATHER STATION
1400, 4 SEPTEMBER TO 0700, 28 OCTOBER,

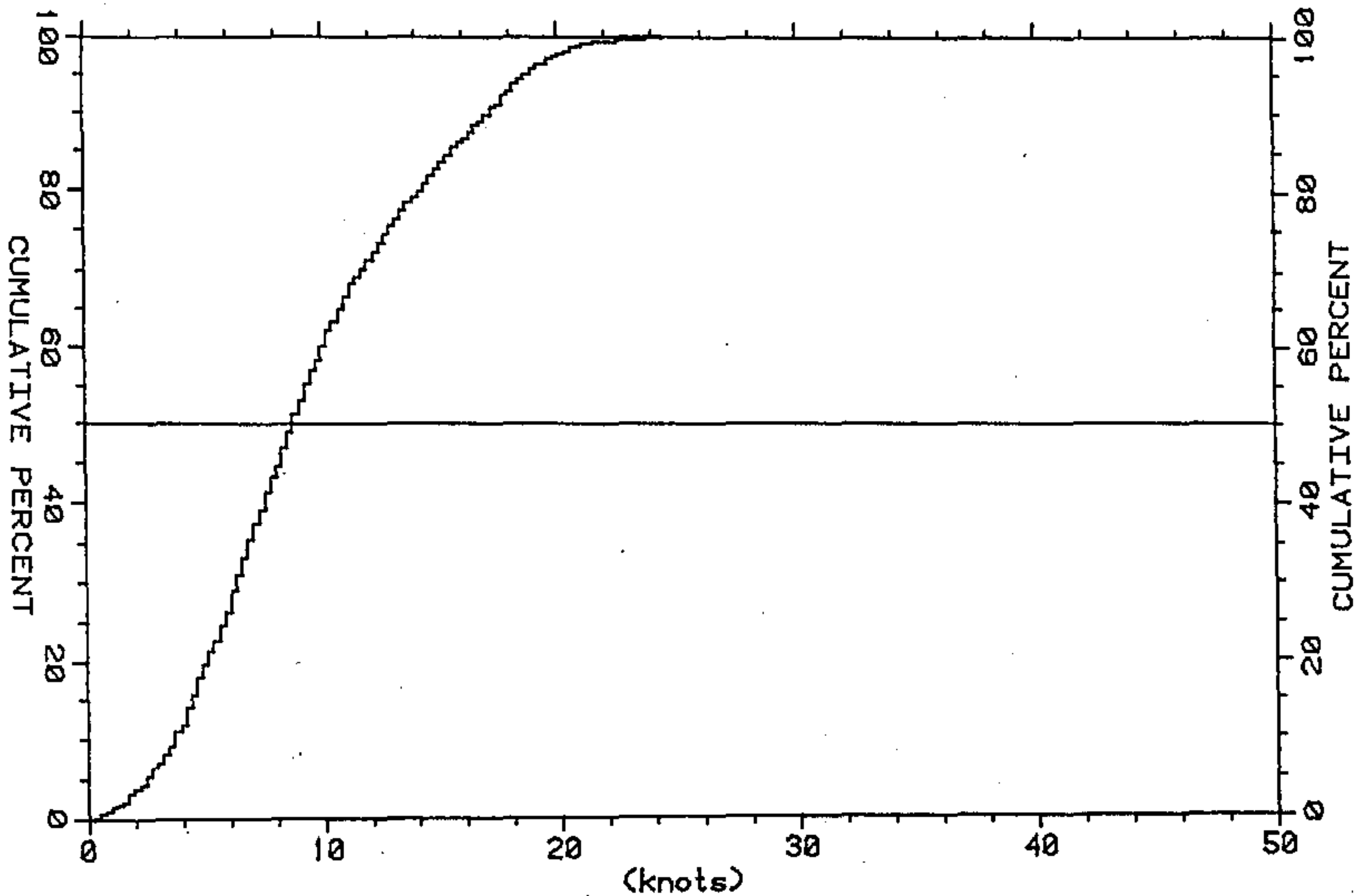


FIGURE 17. CUMULATIVE PROBABILITY PLOT
1/2 HR AVERAGE WIND
CHALLENGE ISLAND WEATHER STATION
0208, 24 JULY TO 1738, 2 SEPTEMBER, 1982
1967 DATA POINTS

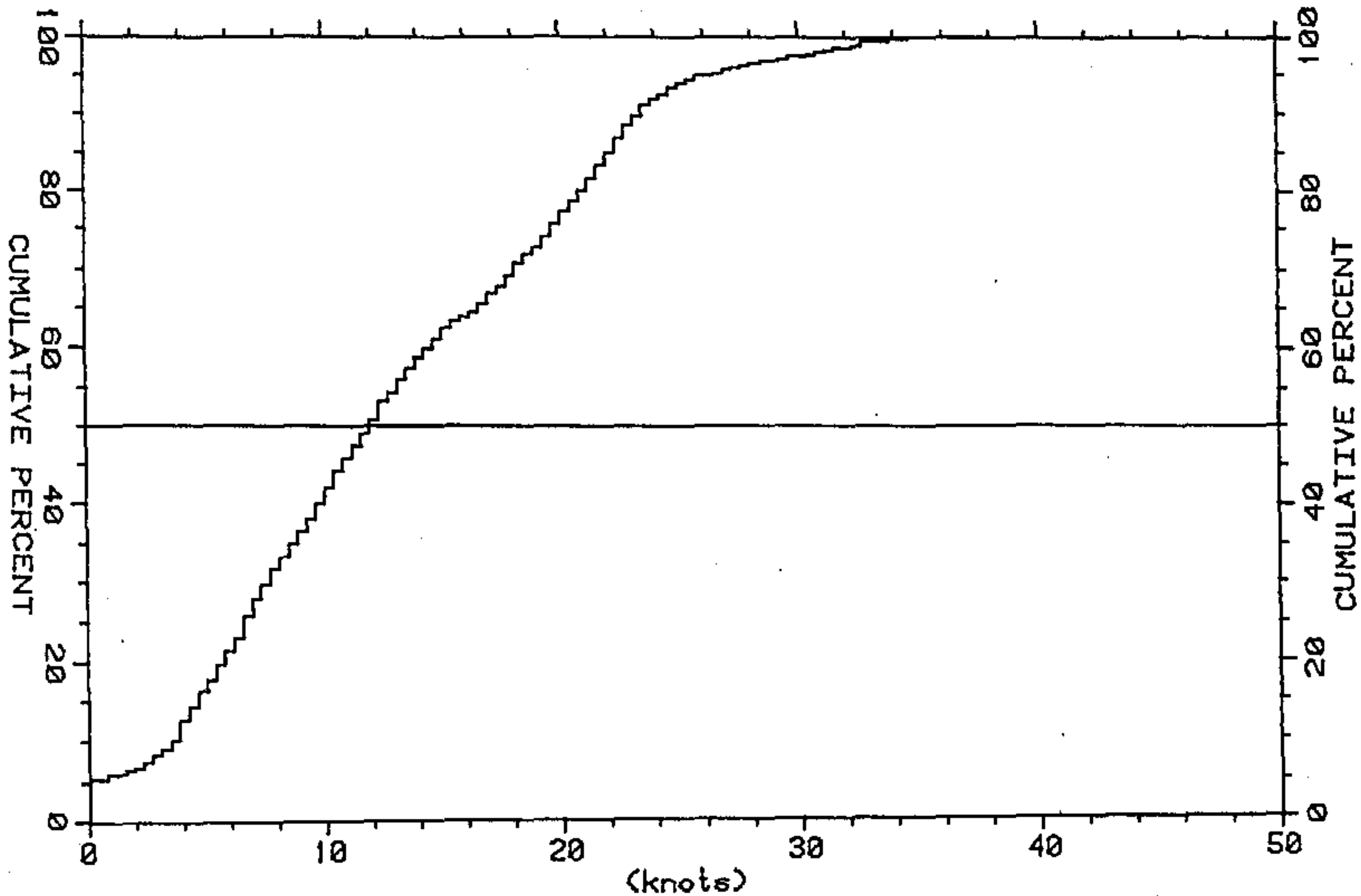


FIGURE 18. CUMULATIVE PROBABILITY PLOT
WIND
CHALLENGE ISLAND WEATHER STATION
1400, 4 SEPTEMBER TO 0700, 28 OCTOBER, 1982
2423 DATA POINTS

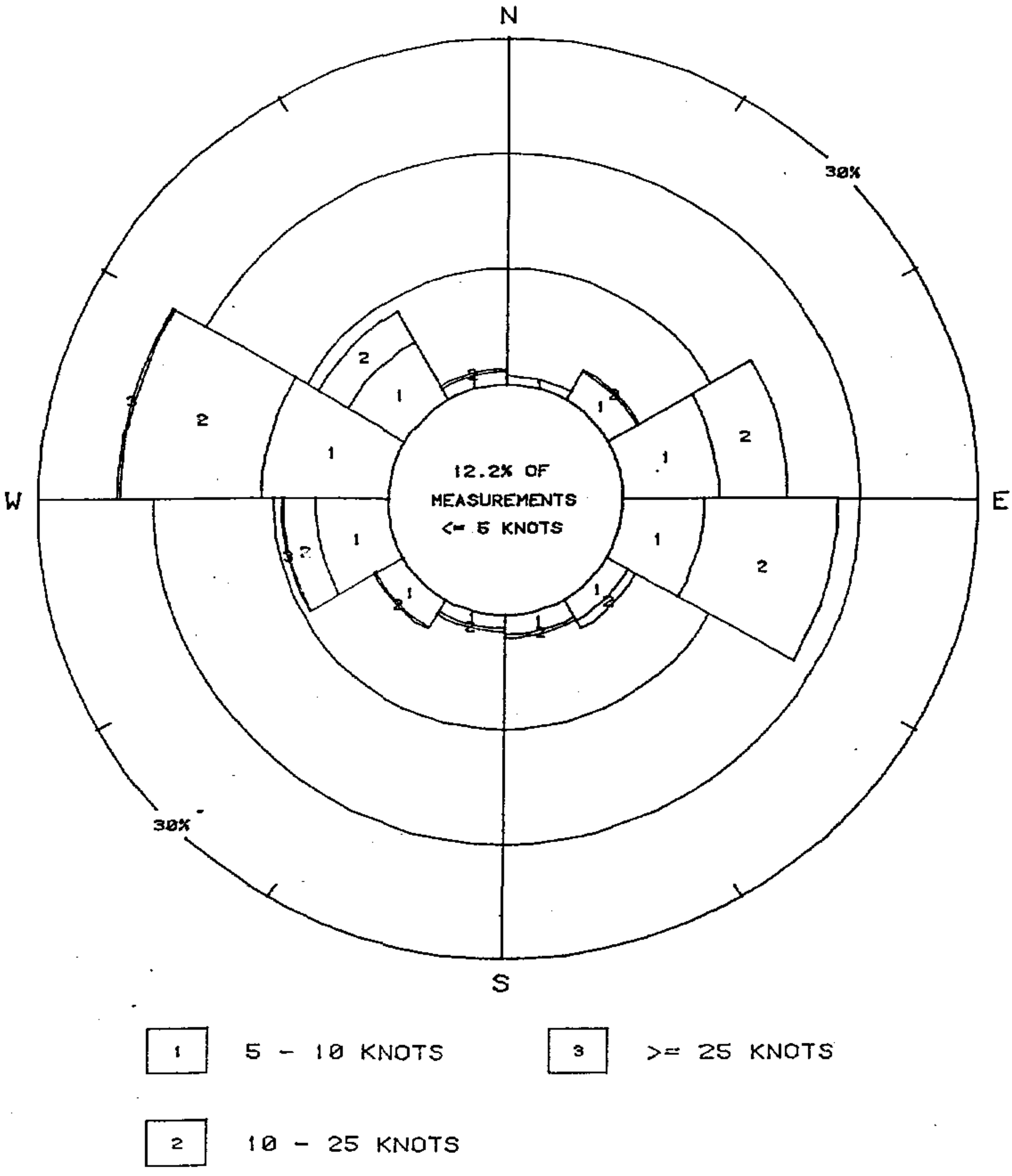
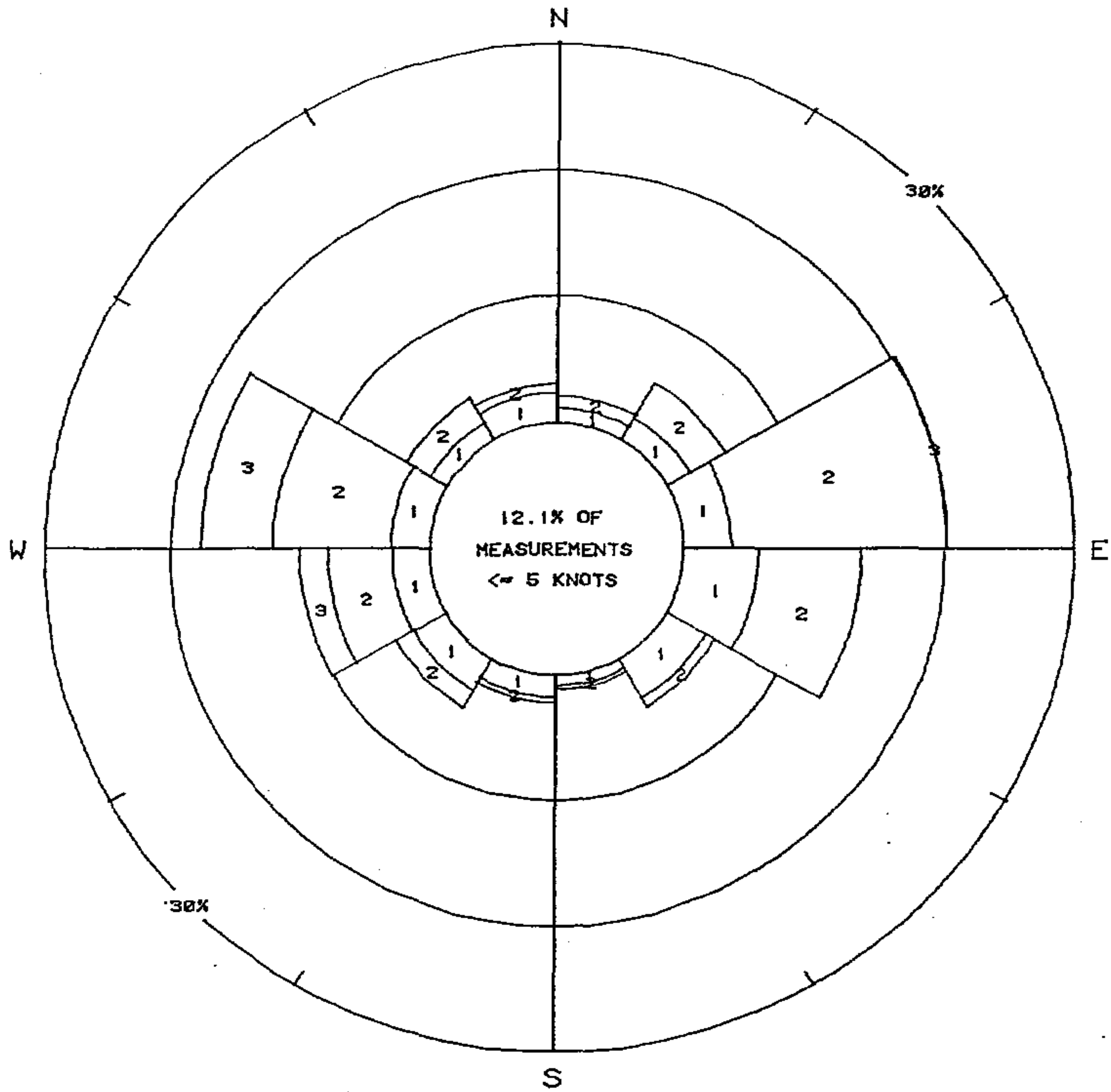


FIGURE 19. ROSE DIAGRAM
WIND
BARTER ISLAND
0000, 25 JULY TO 2300, 31 AUGUST, 1982



1	5 - 10 KNOTS
2	10 - 25 KNOTS
3	>= 25 KNOTS

FIGURE 20. ROSE DIAGRAM
WIND
BARTER ISLAND
0000, 1 SEPTEMBER TO 2300, 31 OCTOBER

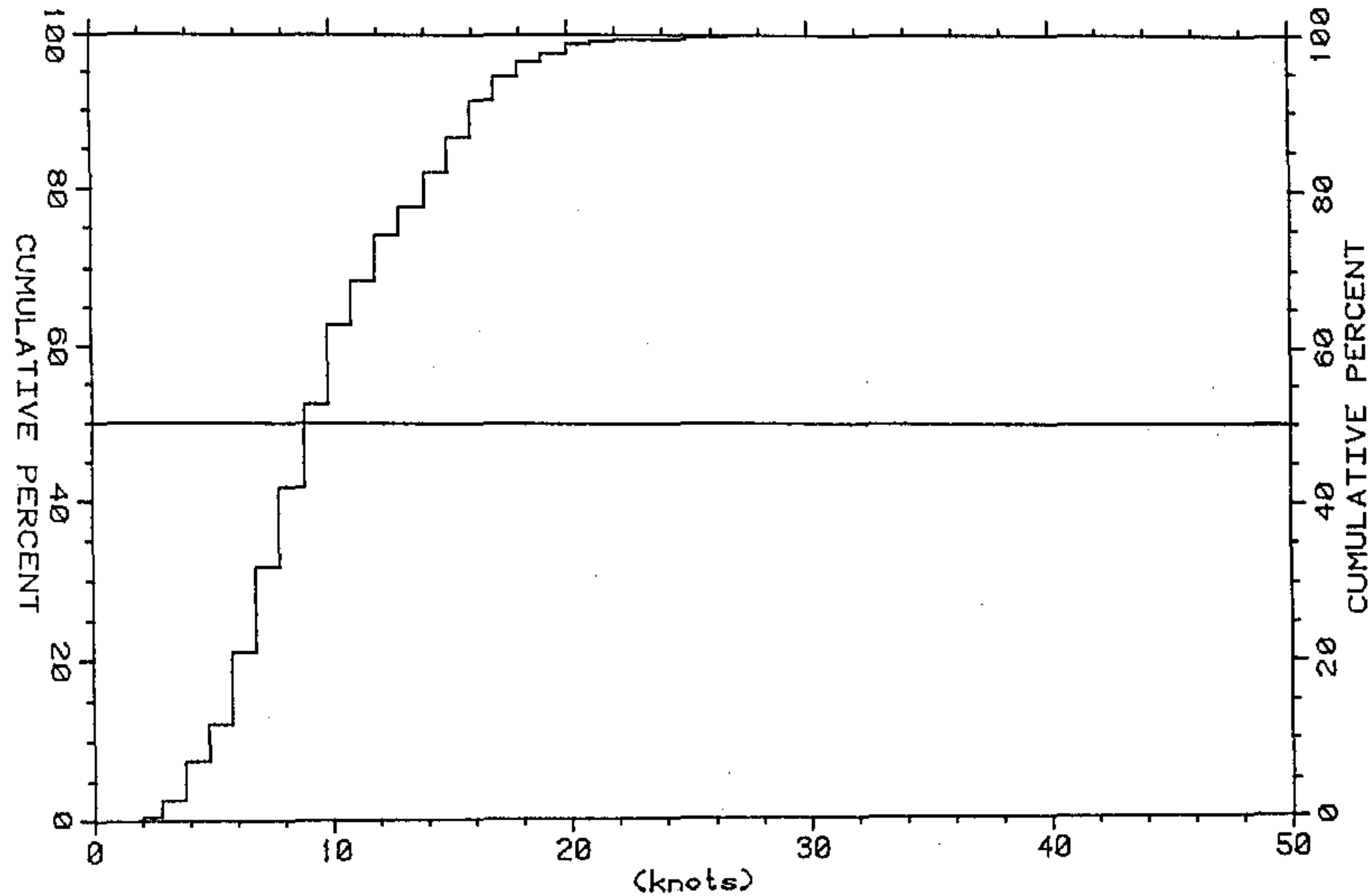


FIGURE 21. CUMULATIVE PROBABILITY PLOT
WIND SPEED
BARTER ISLAND
0000, 25 JULY TO 2300, 31 AUGUST, 1982
898 DATA POINTS

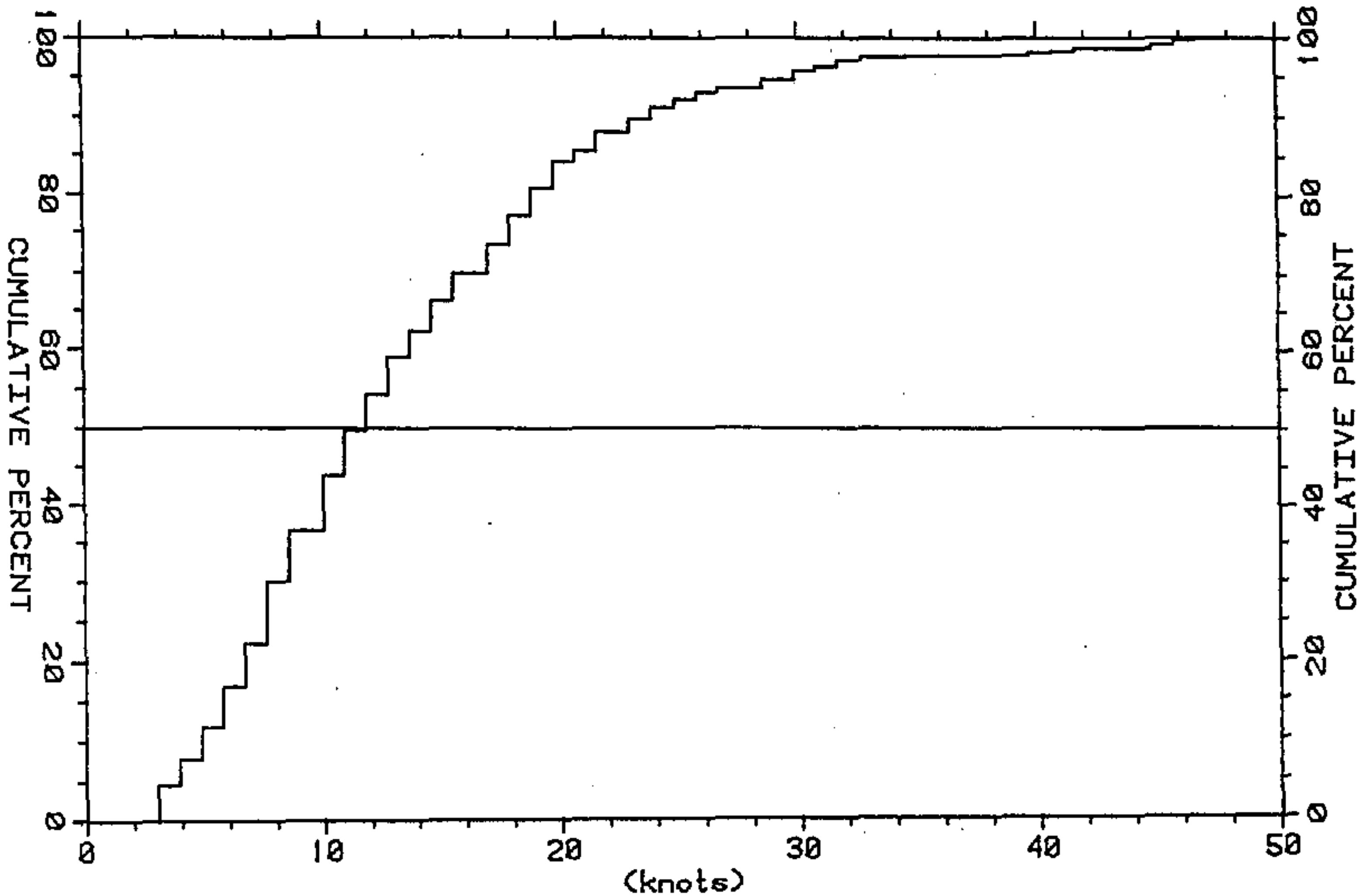


FIGURE 22. CUMULATIVE PROBABILITY PLOT
WIND
BARTER ISLAND
0000, 1 SEPTEMBER TO 2300, 31 OCTOBER, 1982
1430 DATA POINTS

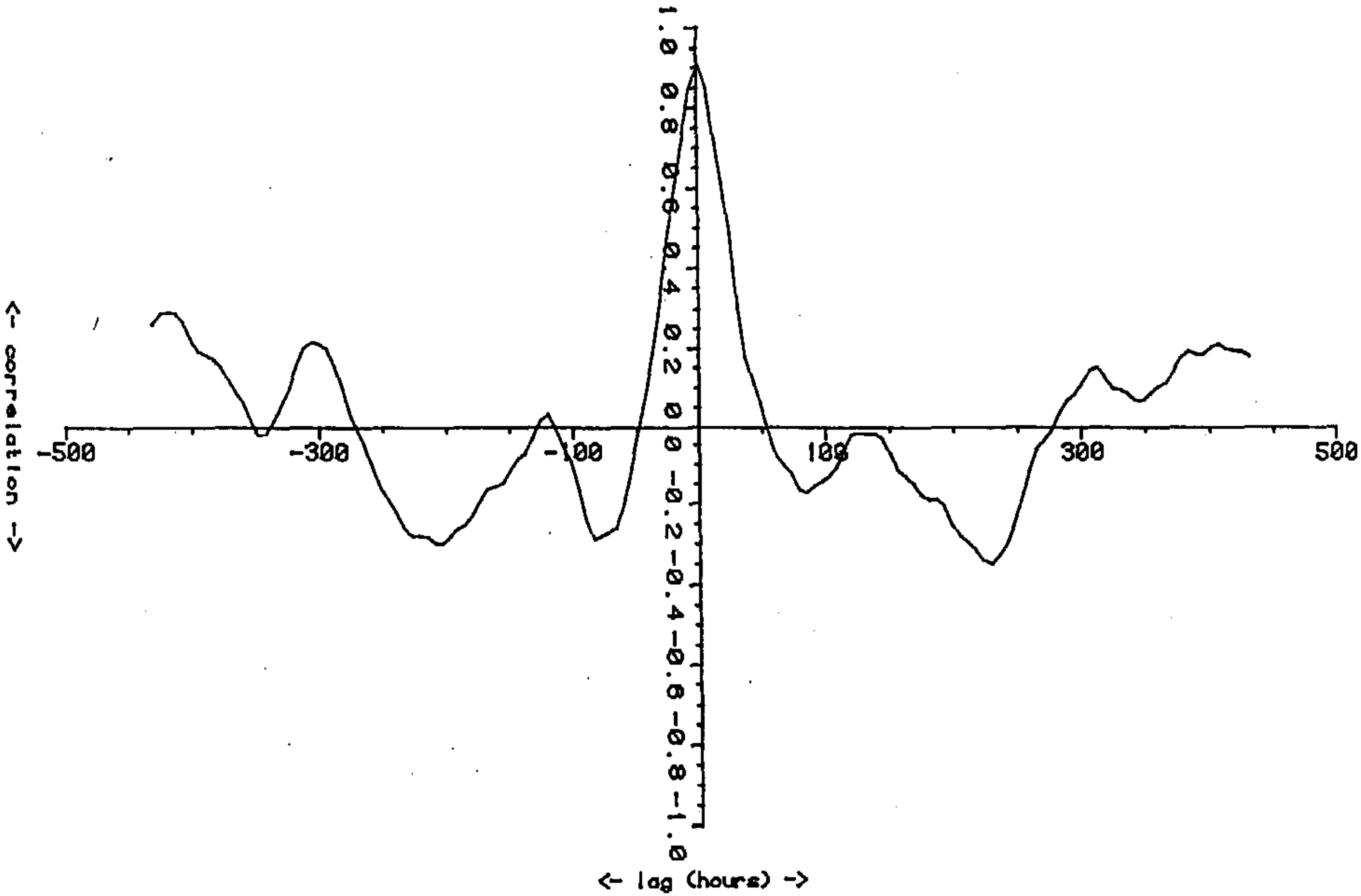


FIGURE 23. CROSS CORRELATIONS
BARTER ISLAND WIND (72 DEG. COMP.) VS. LAGGED CHALLENGE
ISLAND WIND (72 DEG. COMP.) (ΔT=6 HR) (FILTERED DATA)
0004 25 JULY TO 1804 31 AUGUST 1982

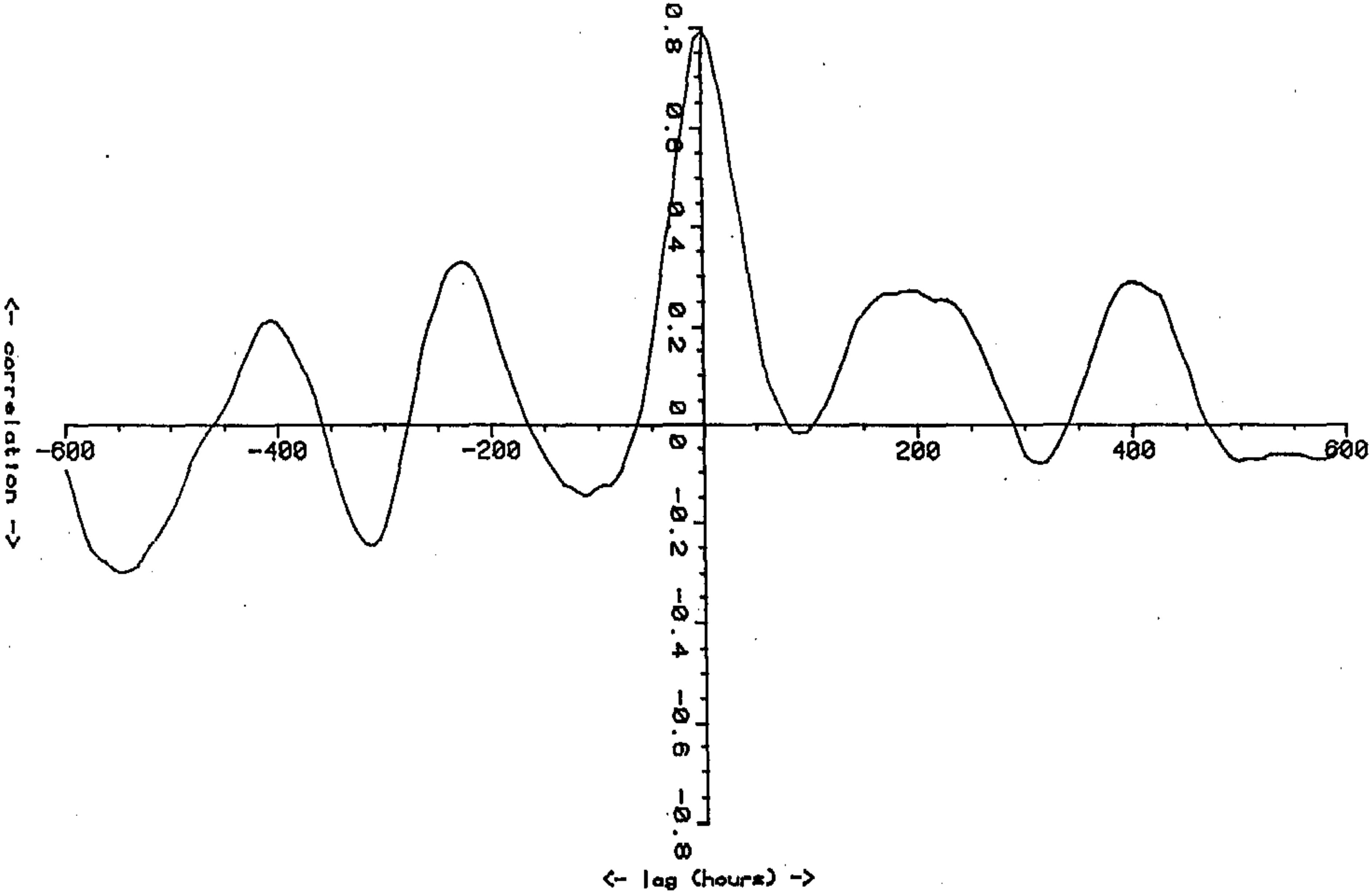


FIGURE 24. CROSS CORRELATIONS
BARTER ISLAND WIND (64 DEG. COMP.) VS. LAGGED CHALLENGE ISLAND WIND (64 DEG. COMP.) (ΔT=6 HR) (FILTERED DATA)
1400 4 SEPTEMBER TO 0200 28 OCTOBER 1982

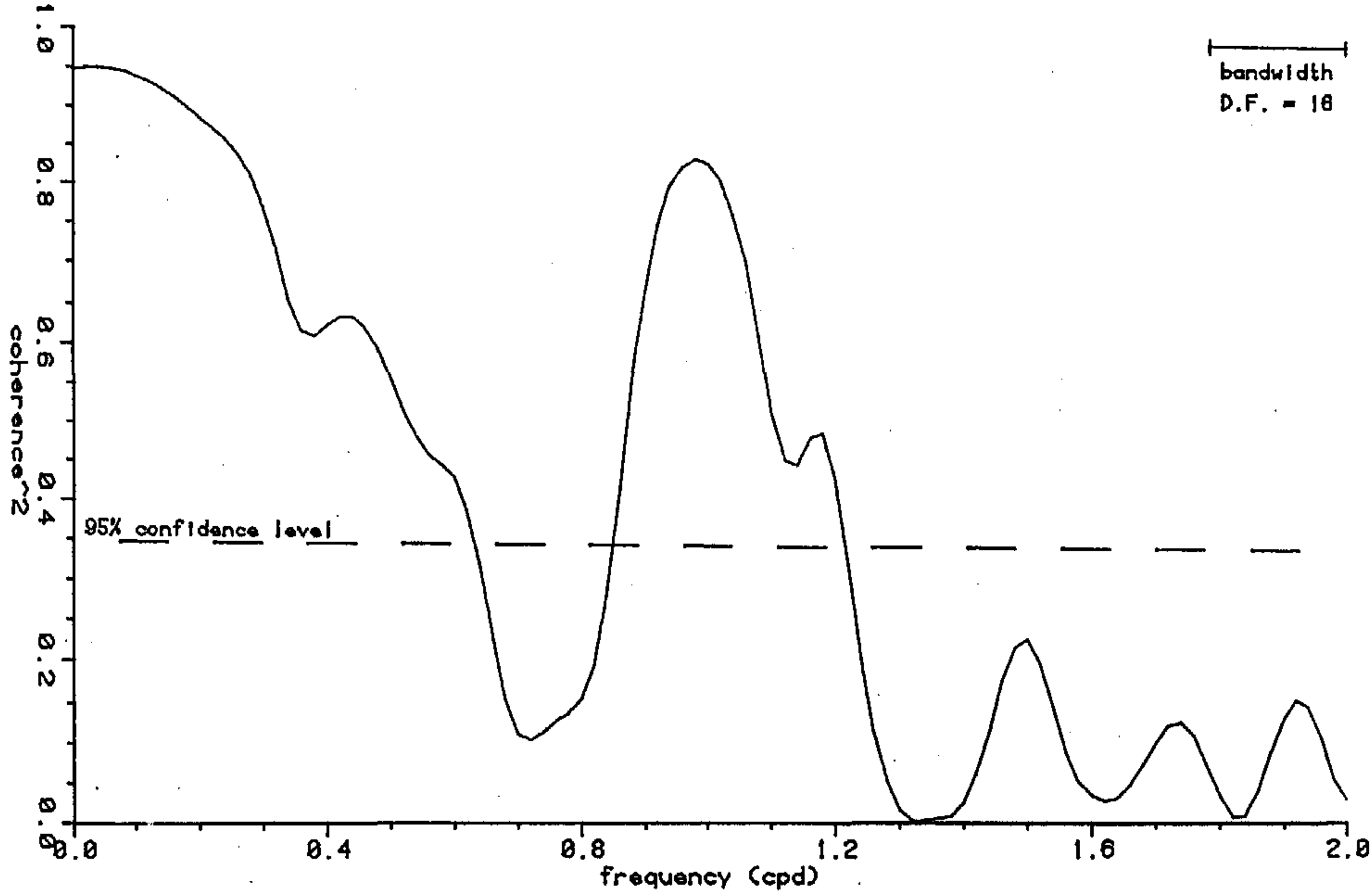
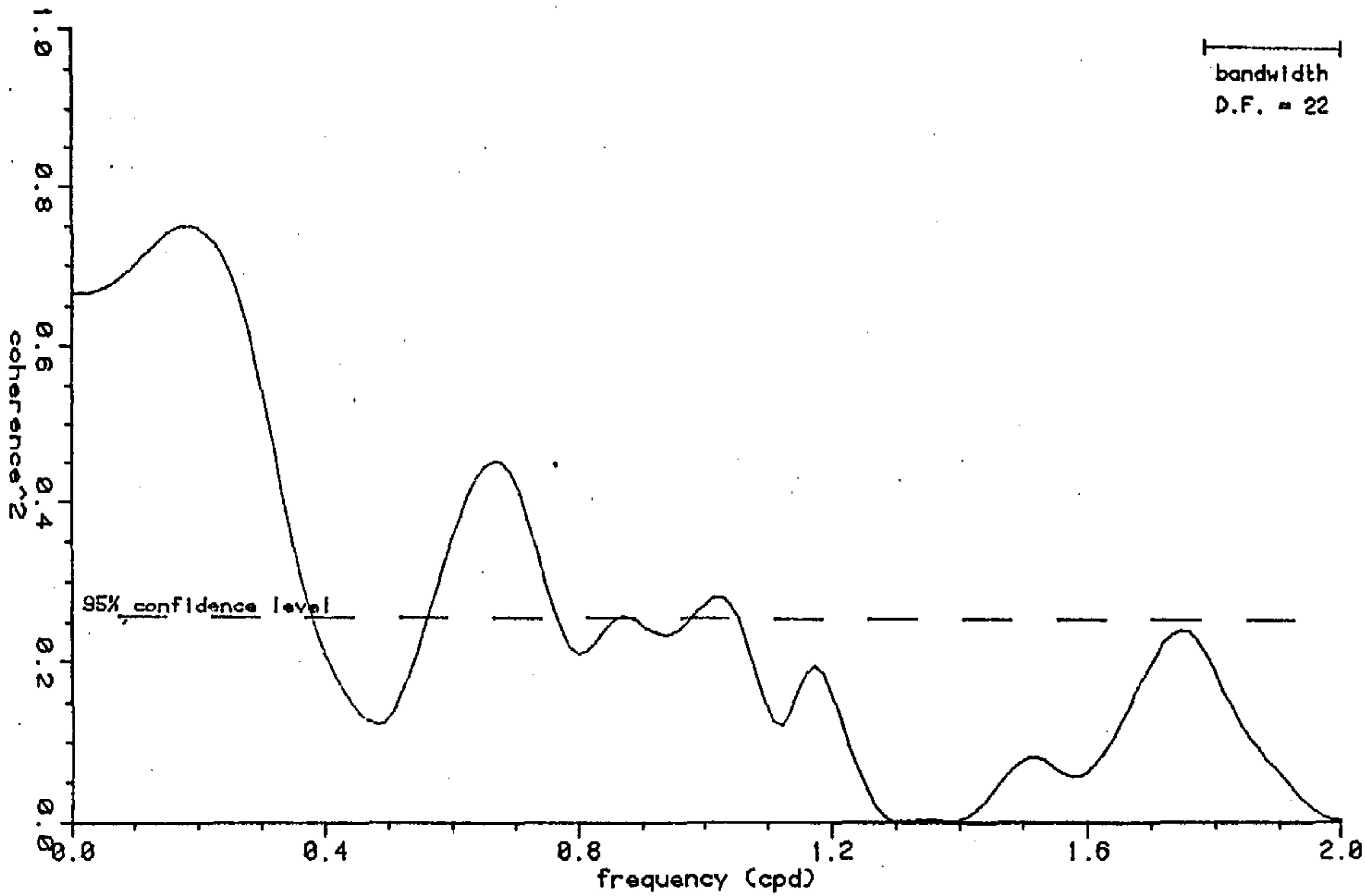


FIGURE 25. SQUARED COHERENCE SPECTRUM
BARTER ISLAND WIND (72 DEG. COMP.) VS. LAGGED CHALLENGE
ISLAND WIND (72 DEG. COMP.) (ΔT=6 HR) (FILTERED DATA)
0004 25 JULY TO 1804 31 AUGUST 1982



87

FIGURE 26. SQUARED COHERENCE SPECTRUM
BARTER ISLAND WIND (64 DEG. COMP.) VS. LAGGED CHALLENGE ISLAND WIND (64 DEG. COMP.) (ΔT=6 HR) (FILTERED DATA)
1400, 4 SEPTEMBER TO 0200, 28 OCTOBER, 1982

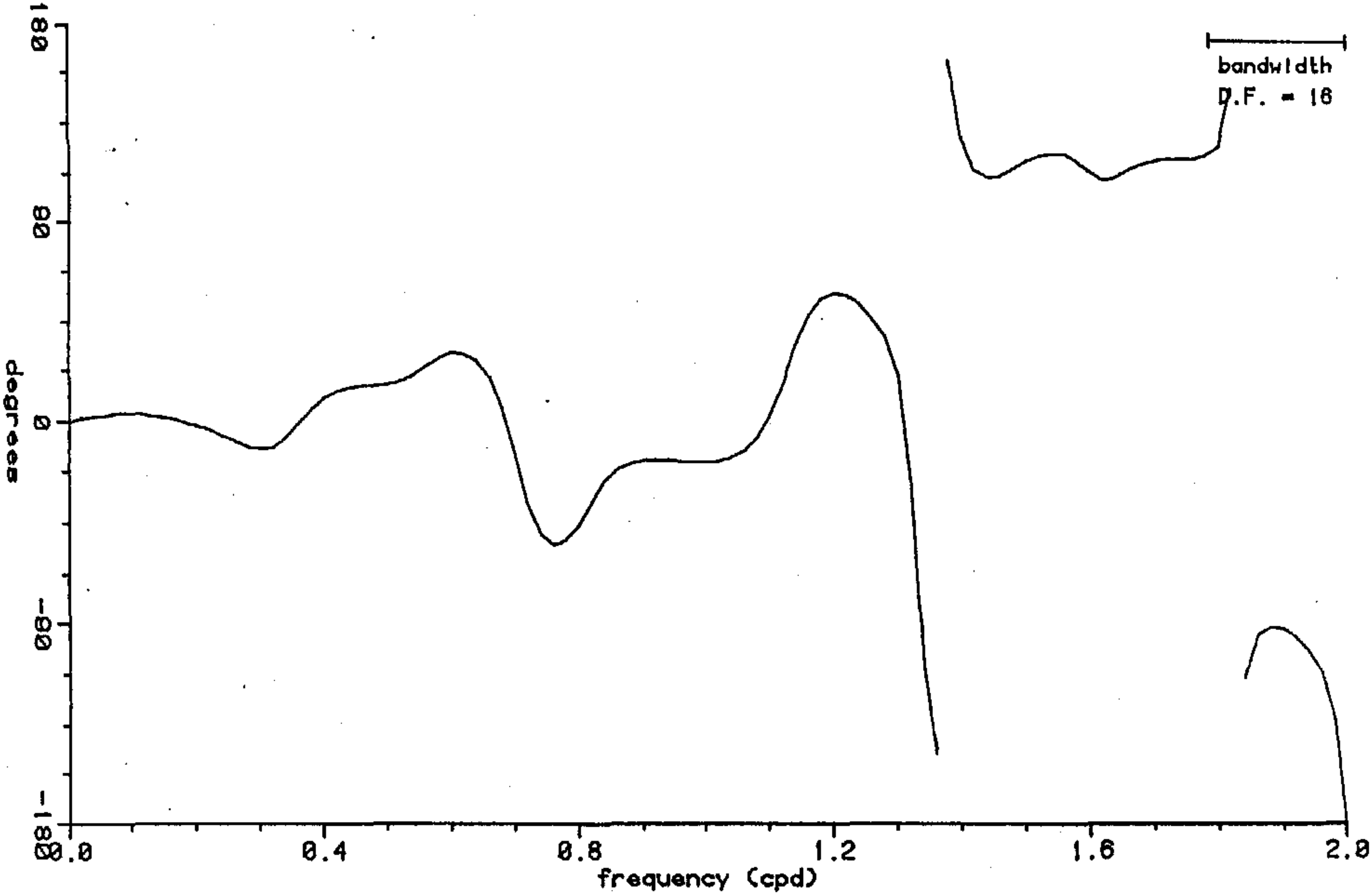


FIGURE 27 PHASE SPECTRUM
BARTER ISLAND WIND (72 DEG. COMP.) VS LAGGED CHALLENGE
ISLAND WIND (72 DEG. COMP.) (ΔT=6 HR) (FILTERED DATA)
0004 25 JULY TO 1804 31 AUGUST 1982

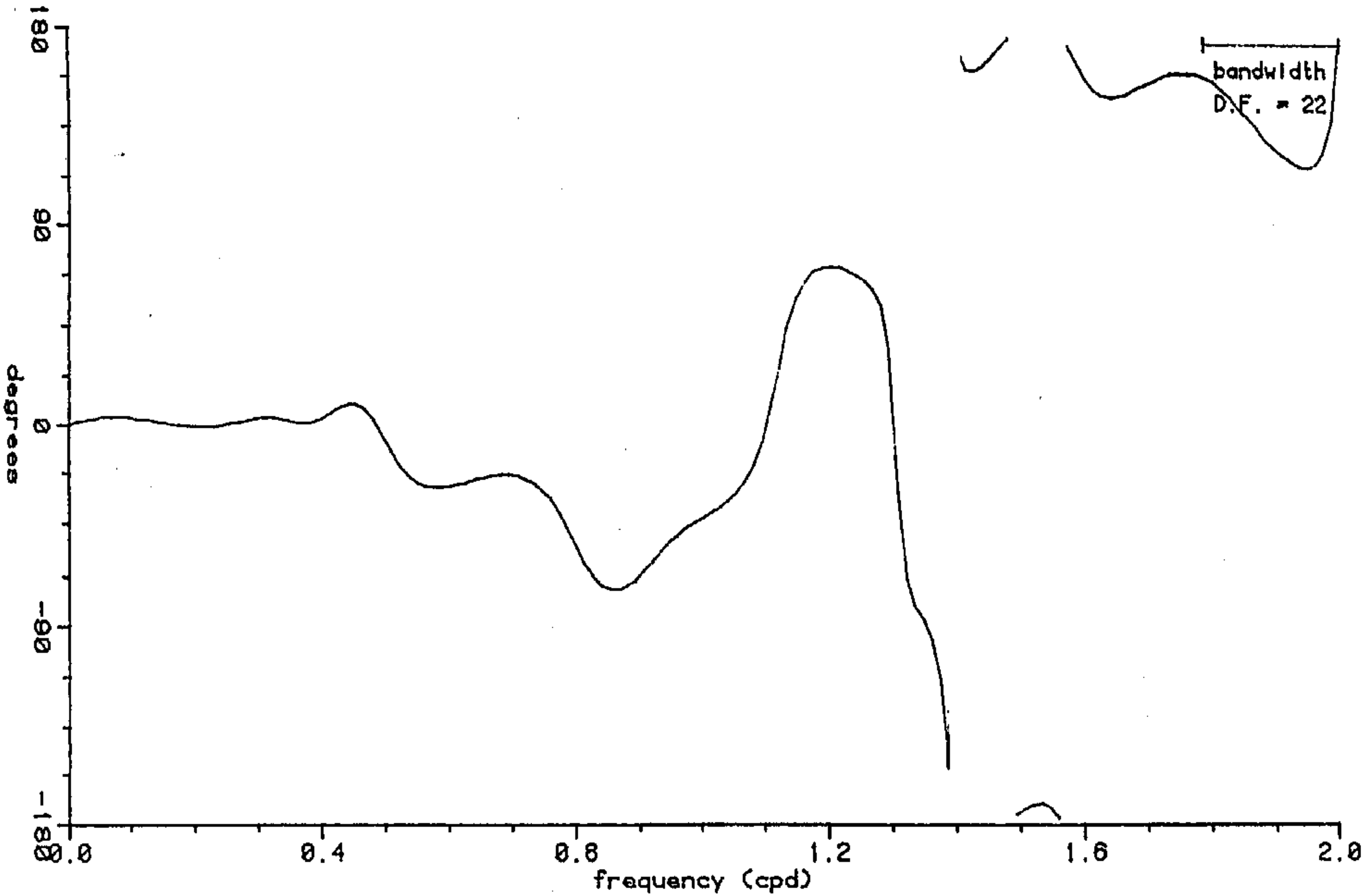
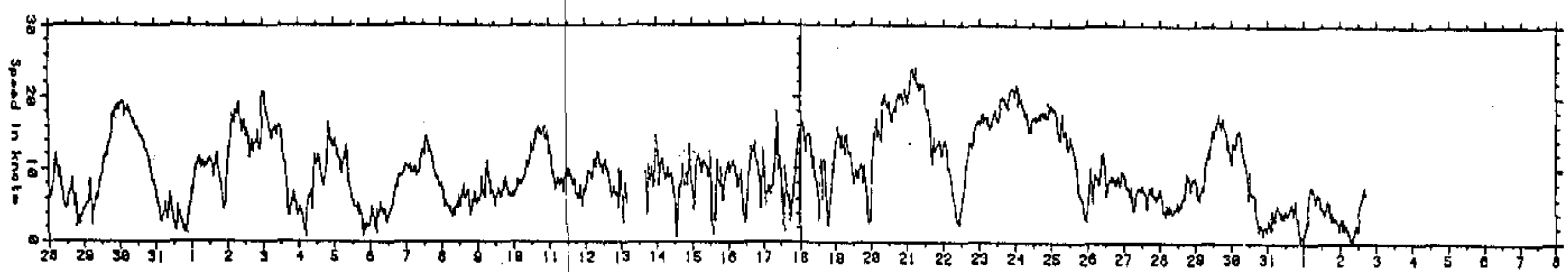
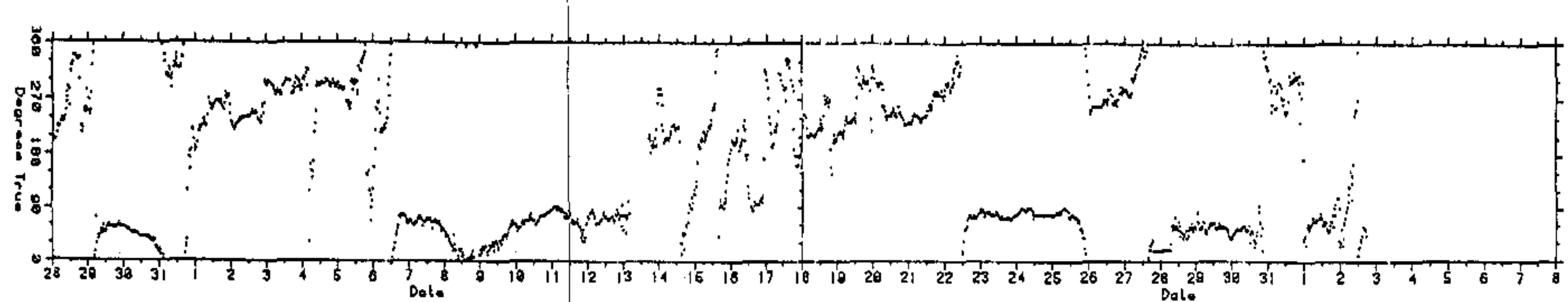


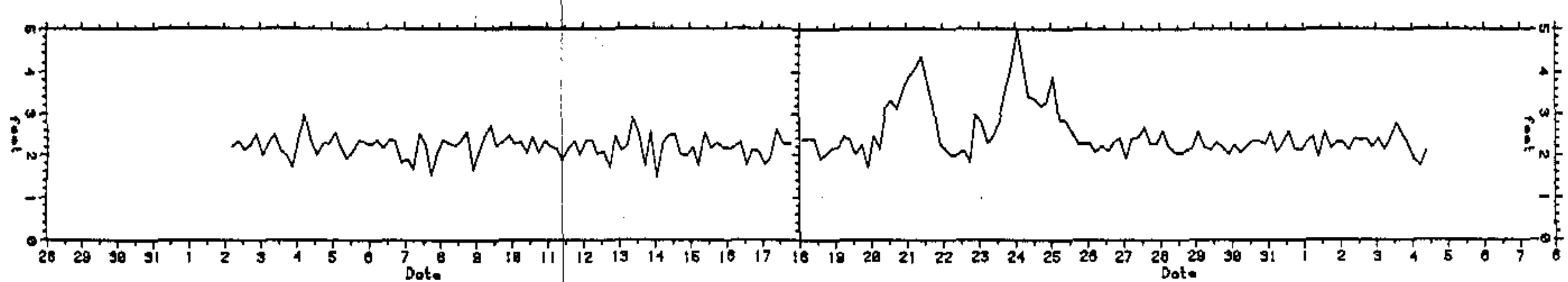
FIGURE 28. PHASE SPECTRUM
BARTER ISLAND WIND (64 DEG. COMP.) VS. LAGGED CHALLENGE ISLAND WIND (64 DEG. COMP.) (T=6 HR) (FILTERED DATA)
1400 4 SEPTEMBER TO 0200. 28 OCTOBER. 1982



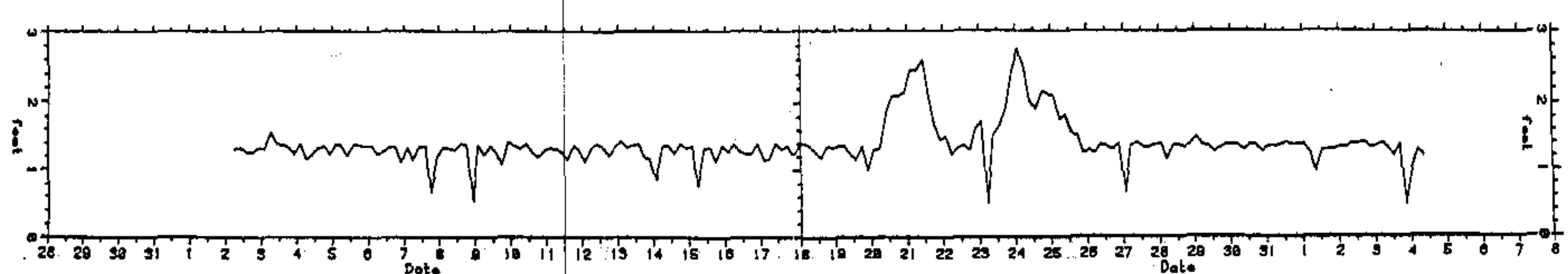
SPEED DATA
CHALLENGE ISLAND WIND
0000, 28 JULY TO 1730, 2 SEPTEMBER, 1982



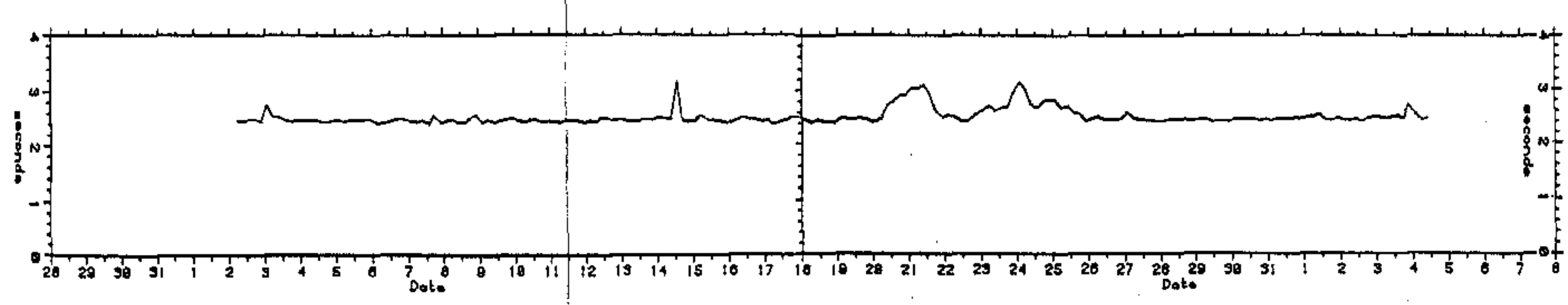
DIRECTION DATA
CHALLENGE ISLAND WIND
0000, 28 JULY TO 1730, 2 SEPTEMBER, 1982



MAXIMUM WAVE HEIGHT
POINT THOMSON STATION Q
0550, 2 AUGUST TO 0950, 4 SEPTEMBER, 1982

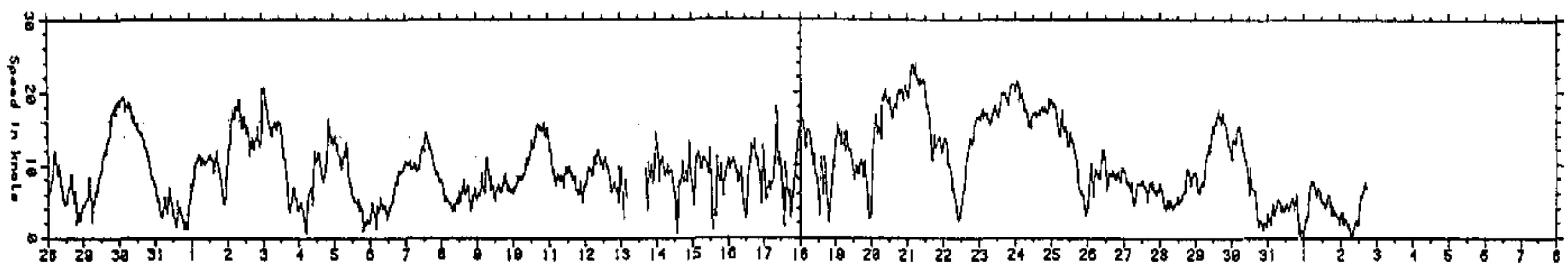


SIGNIFICANT WAVE HEIGHT
POINT THOMSON STATION Q
0550, 2 AUGUST TO 0950, 4 SEPTEMBER, 1982

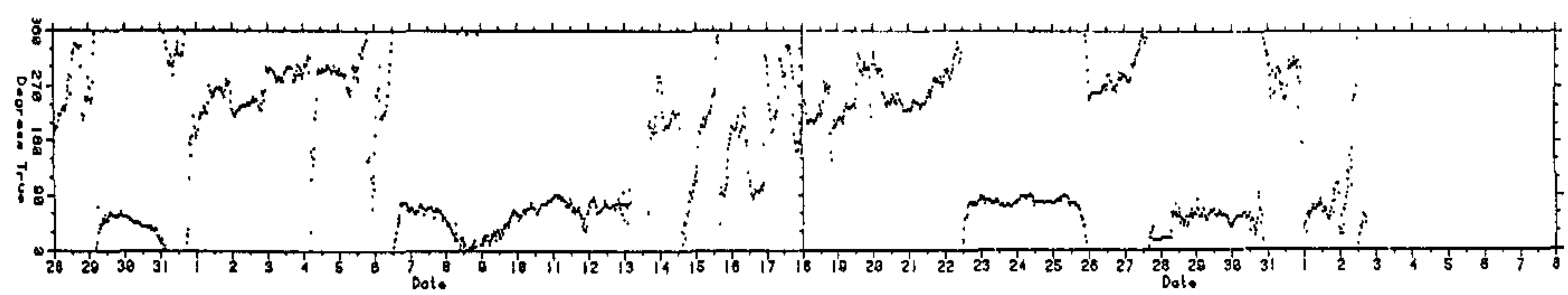


SIGNIFICANT WAVE PERIOD
POINT THOMSON STATION Q
0550, 2 AUGUST TO 0950, 4 SEPTEMBER, 1982

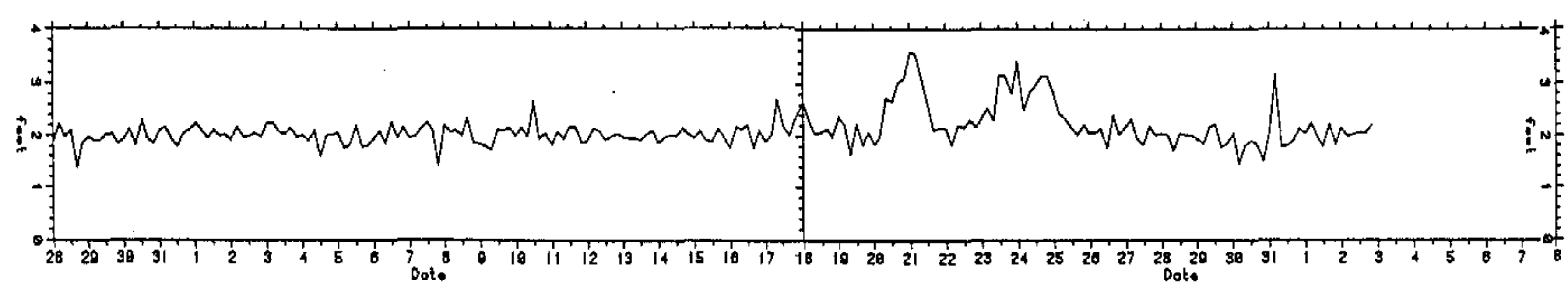
FIGURE 29. WAVE PARAMETERS VS. TIME FOR STATION Q, SUMMER 1982.



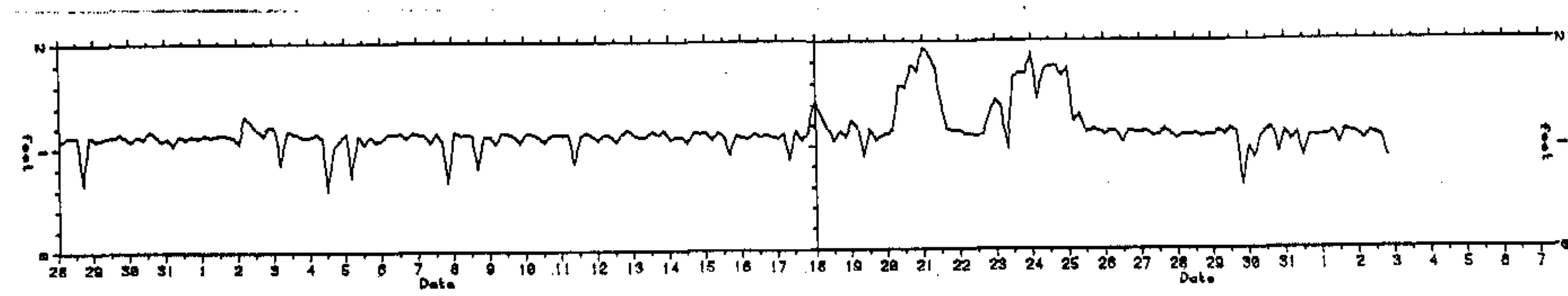
SPEED DATA
CHALLENGE ISLAND WIND
0000, 28 JULY TO 1730, 2 SEPTEMBER, 1982



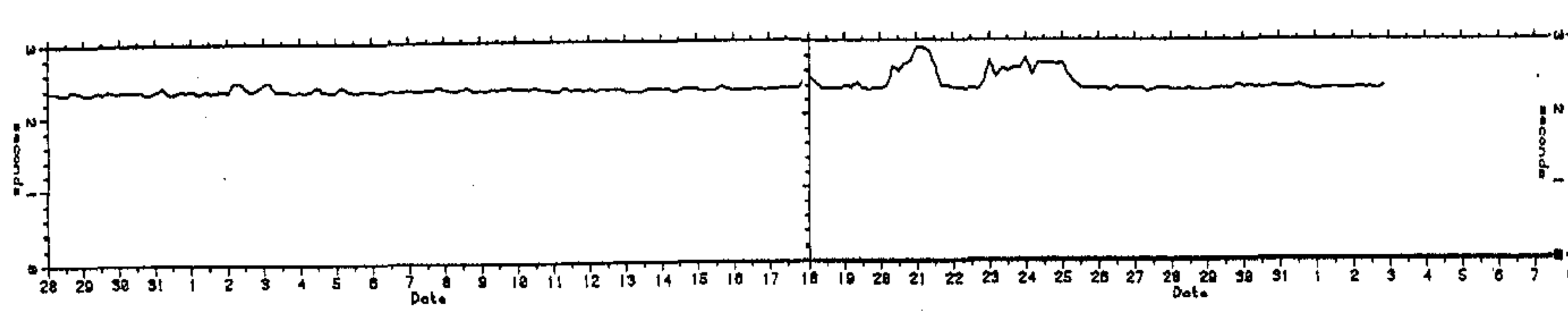
DIRECTION DATA
CHALLENGE ISLAND WIND
0000, 28 JULY TO 1730, 2 SEPTEMBER, 1982



MAXIMUM WAVE HEIGHT
POINT THOMSON STATION Y
0015, 28 JULY TO 2015, 2 SEPTEMBER, 1982



SIGNIFICANT WAVE HEIGHT
POINT THOMSON STATION Y
0015, 28 JULY TO 2015, 2 SEPTEMBER, 1982



SIGNIFICANT WAVE PERIOD
POINT THOMSON STATION Y
0015, 28 JULY TO 2015, 2 SEPTEMBER, 1982

FIGURE 30. WAVE PARAMETERS VS. TIME FOR STATION Y, SUMMER 1982.

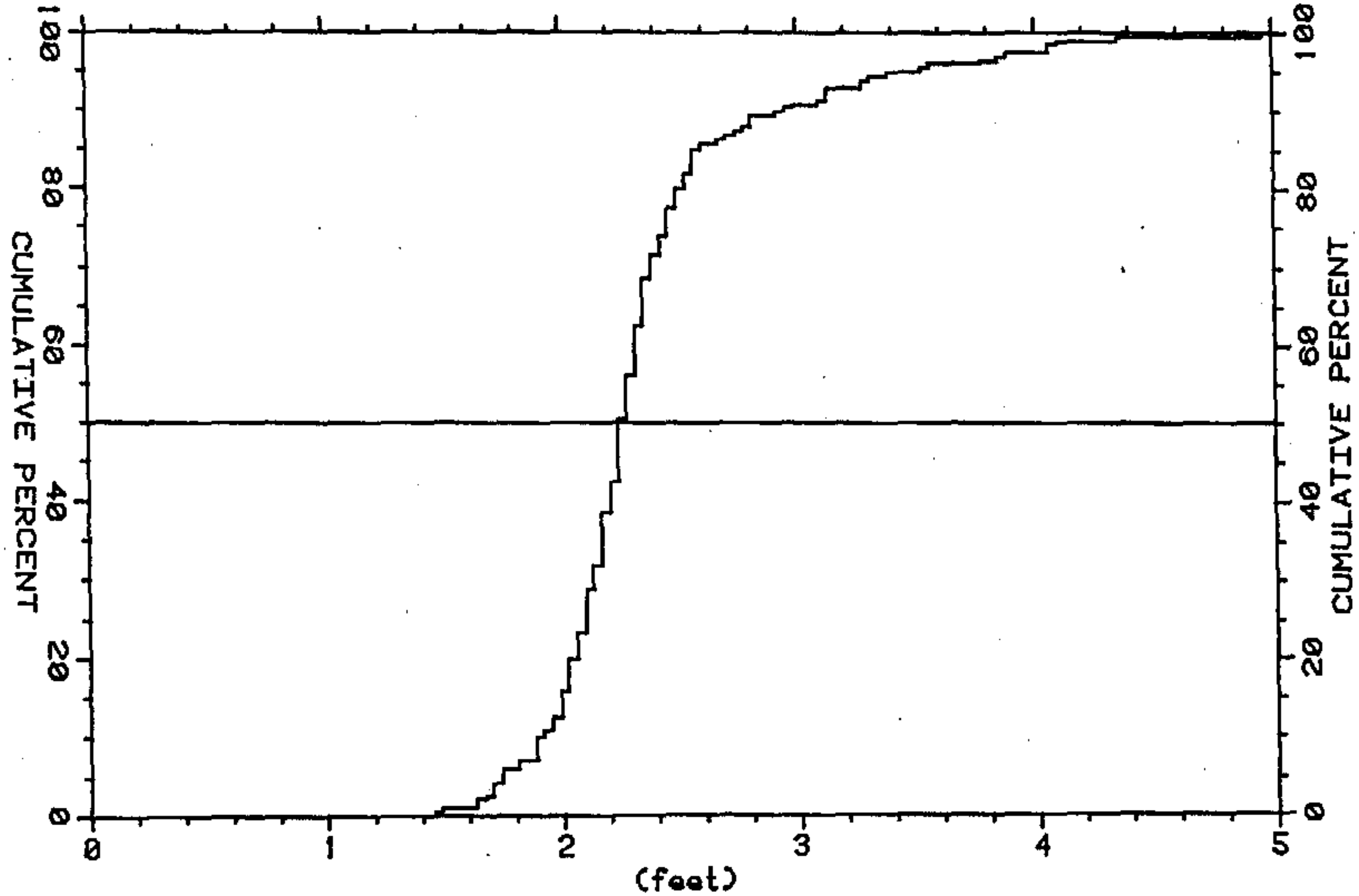


FIGURE 31. CUMULATIVE PROBABILITY PLOT
H(MAX)
PT. THOMSON STATION Q
0550, 2 AUGUST TO 0950, 4 SEPTEMBER, 1982
200 DATA POINTS

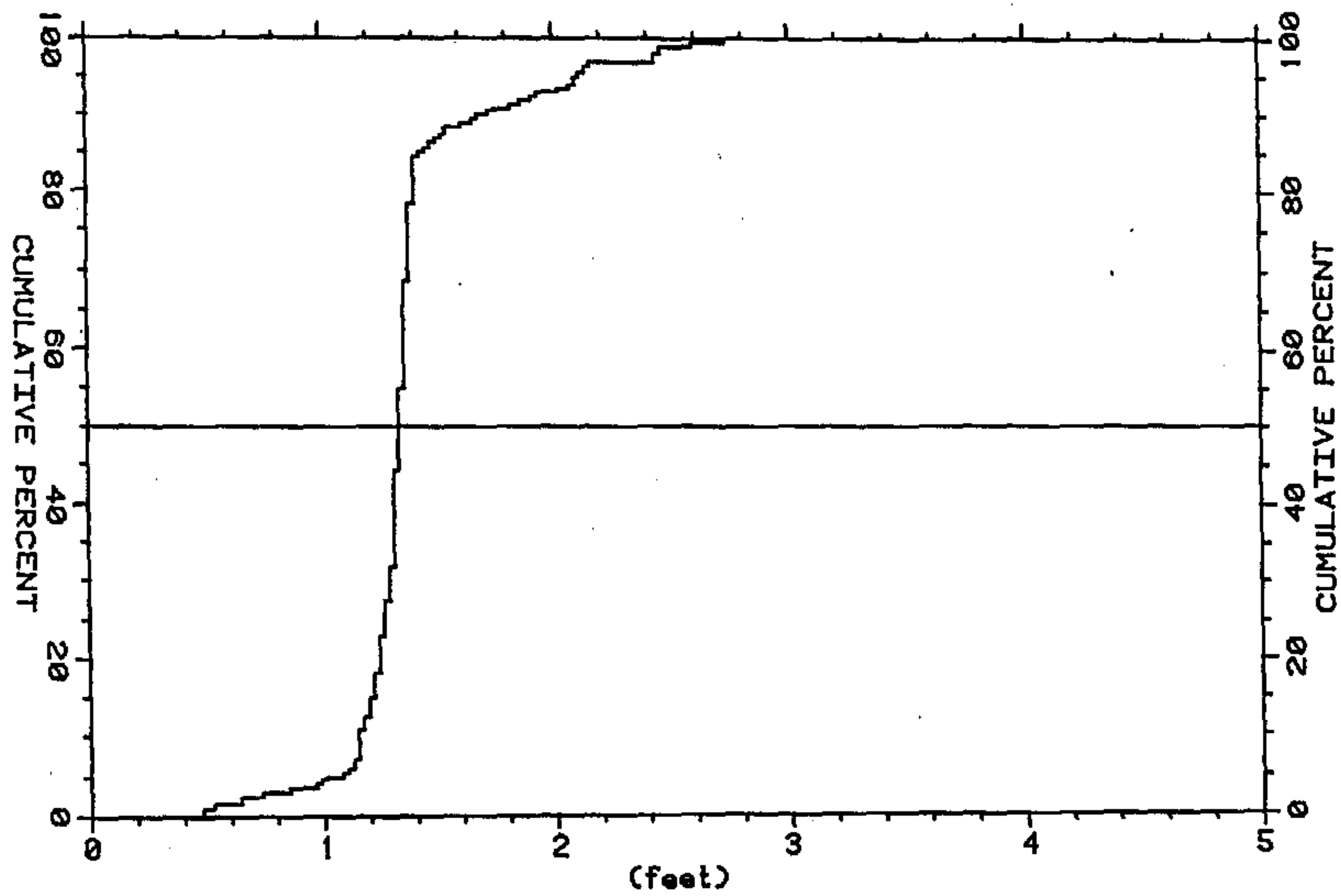


FIGURE 32. CUMULATIVE PROBABILITY PLOT
SIGNIFICANT WAVE HEIGHT
POINT THOMSON STATION Q
0550, 2 AUGUST TO 0950, 4 SEPTEMBER, 1982
200 DATA POINTS

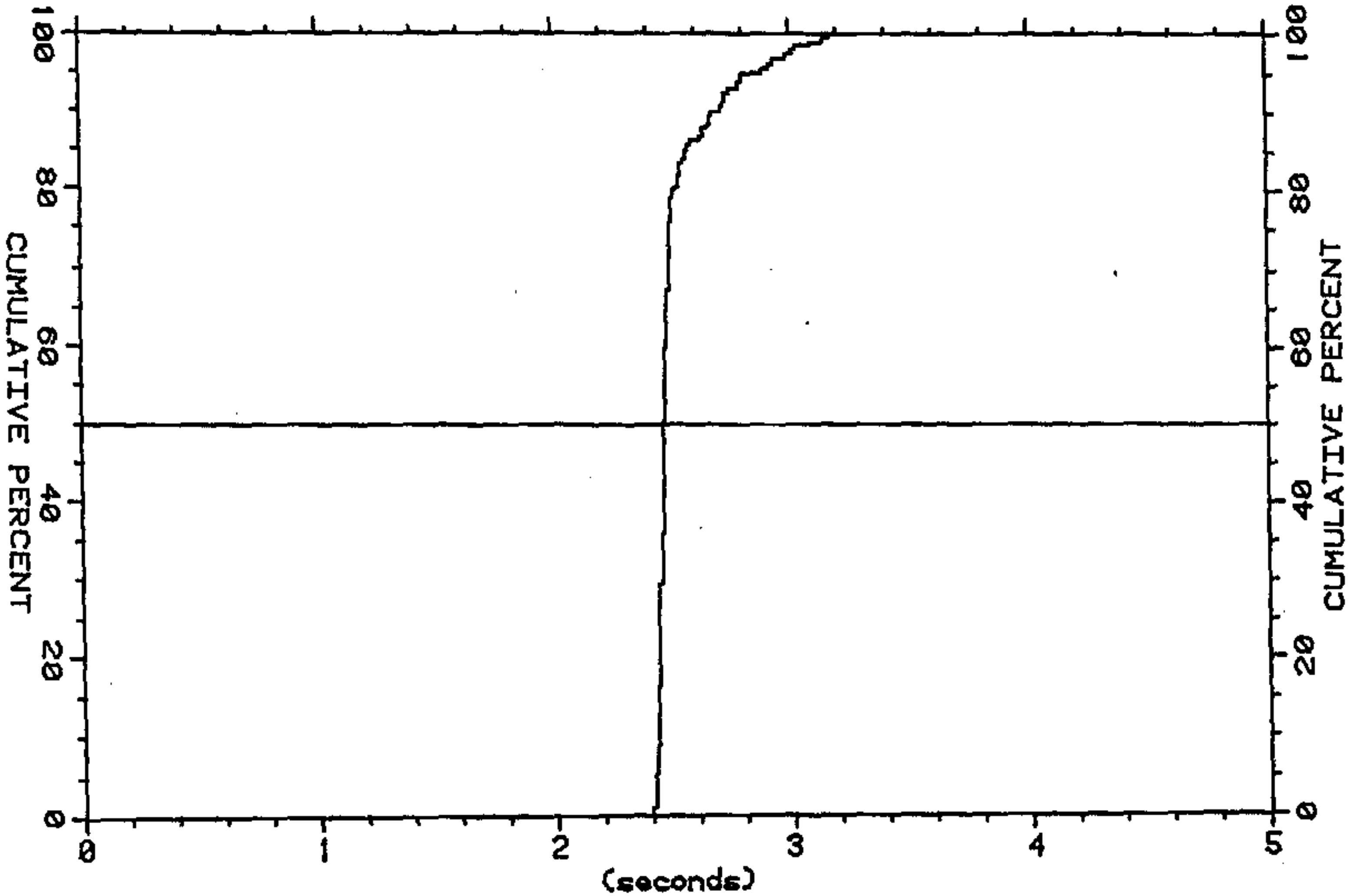


FIGURE 33. CUMULATIVE PROBABILITY PLOT
SIGNIFICANT WAVE PERIOD
POINT THOMSON STATION Q
0550, 2 AUGUST TO 0950, 4 SEPTEMBER, 1982
200 DATA POINTS

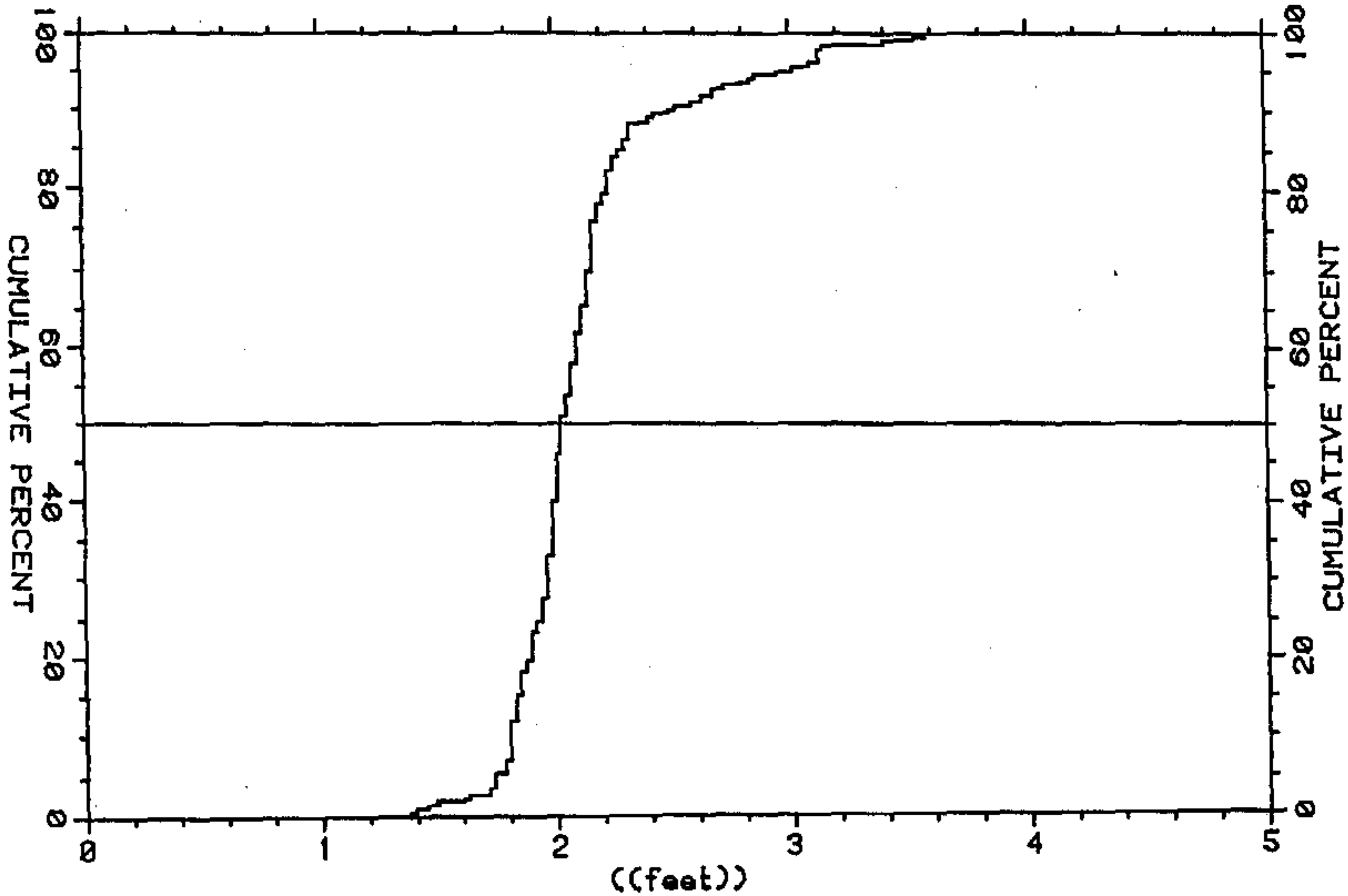


FIGURE 34. CUMULATIVE PROBABILITY PLOT
MAXIMUM WAVE HEIGHT
POINT THOMSON STATION Y
2015, 27 JULY TO 2015, 2 SEPTEMBER, 1982
223 DATA POINTS

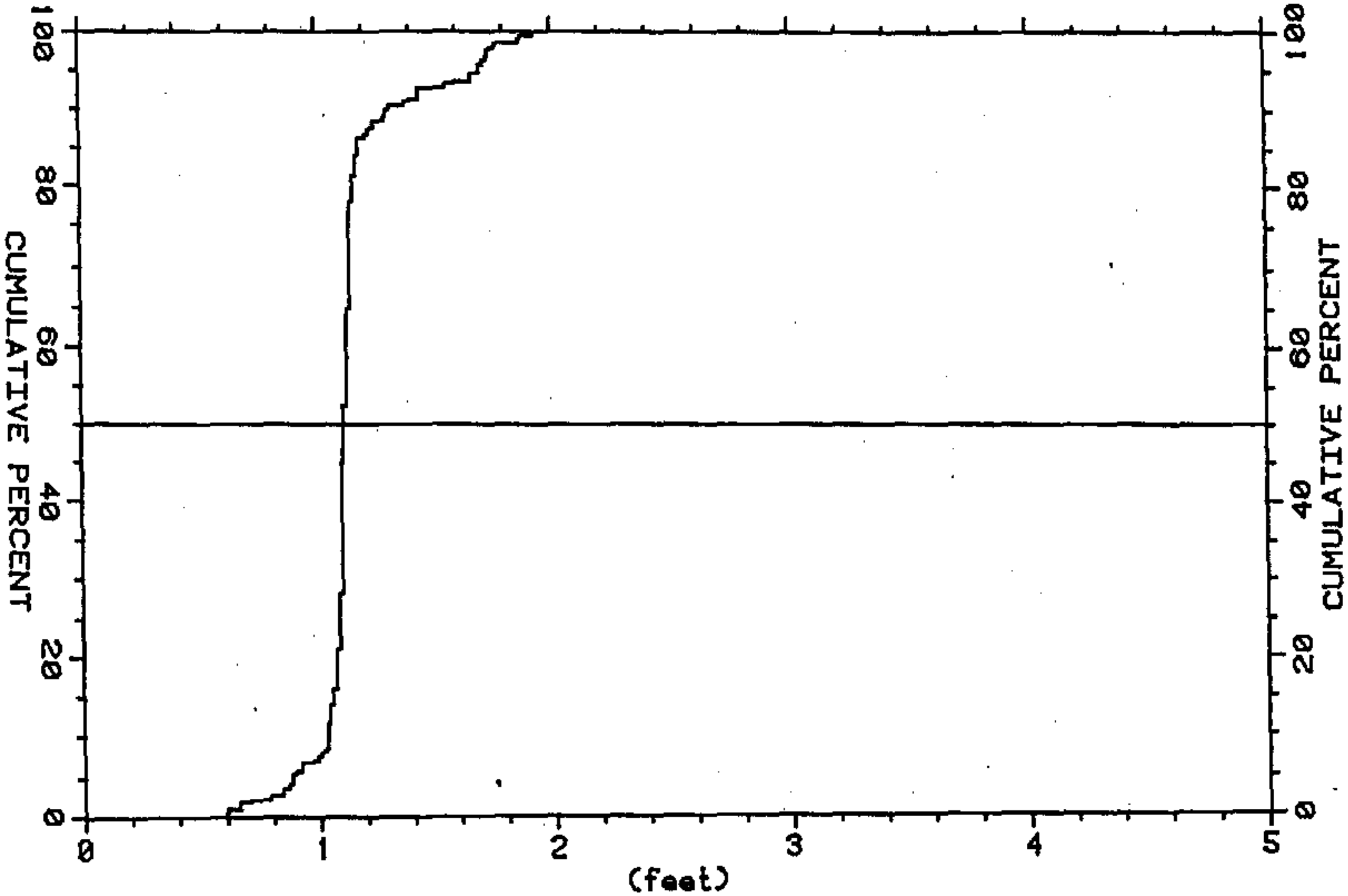


FIGURE 35. CUMULATIVE PROBABILITY PLOT
SIGNIFICANT WAVE HEIGHT
POINT THOMSON STATION Y
2015, 27 JULY TO 2015, 2 SEPTEMBER, 1982
223 DATA POINTS

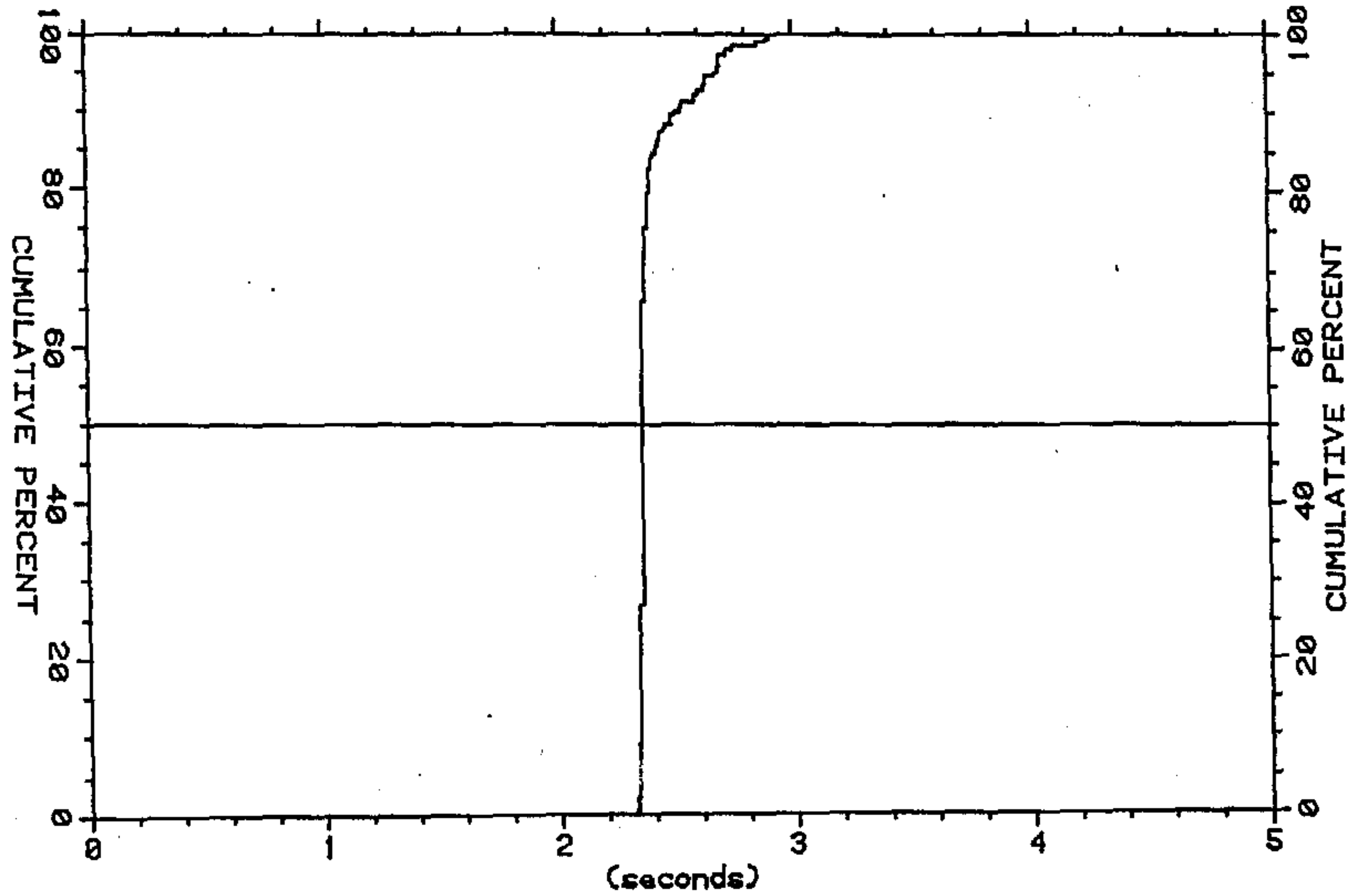
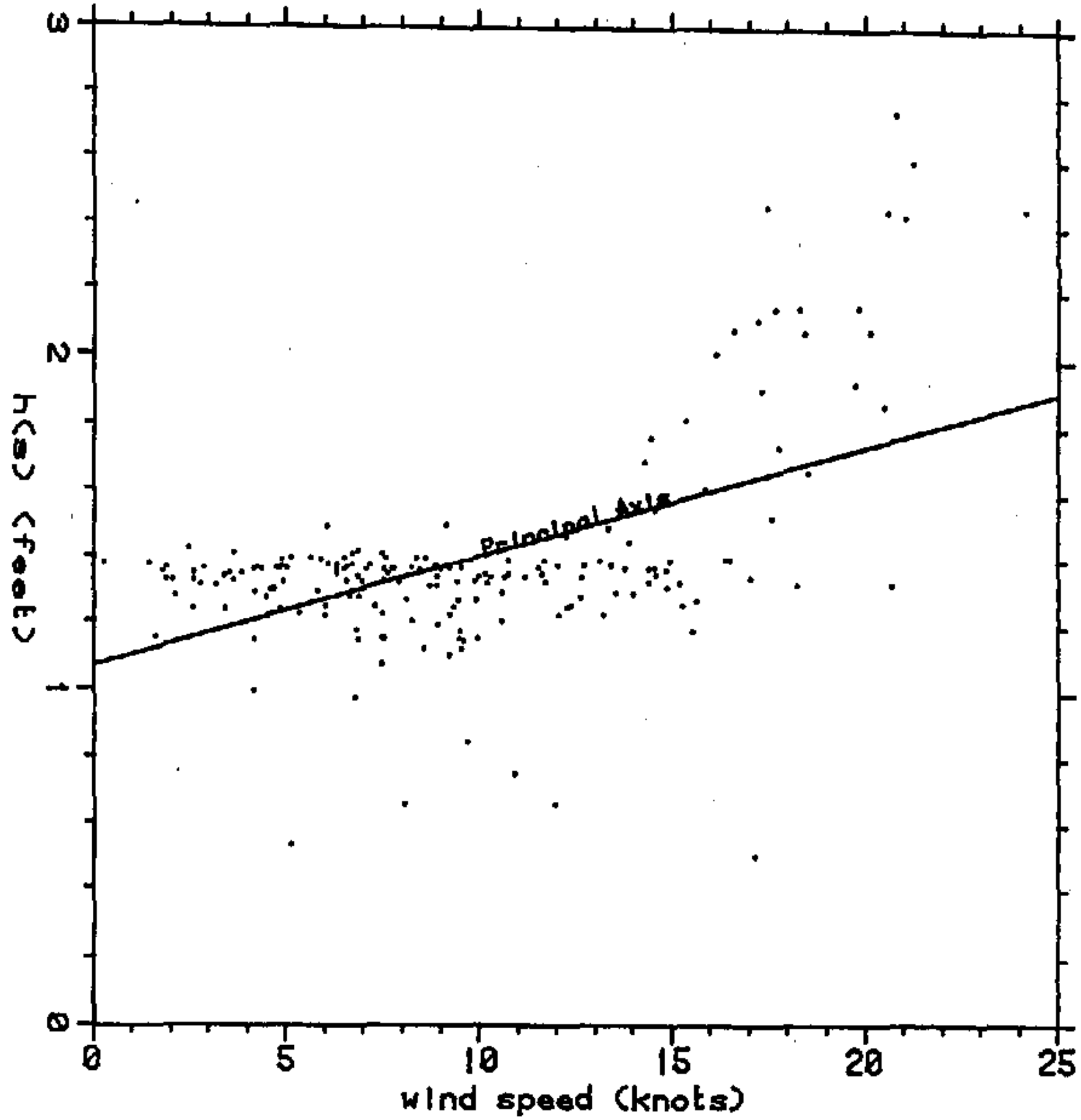
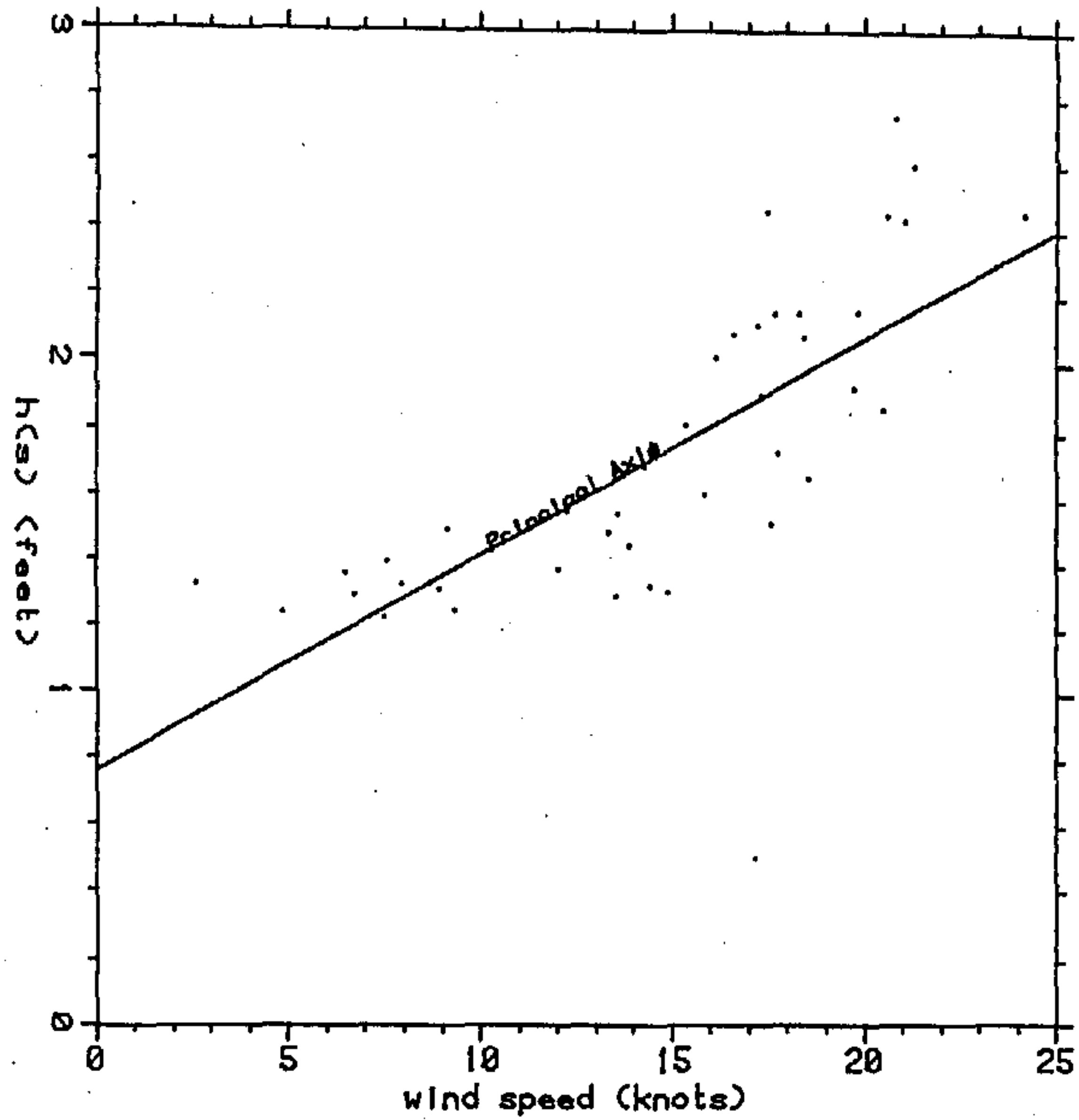


FIGURE 36. CUMULATIVE PROBABILITY PLOT
SIGNIFICANT WAVE PERIOD
POINT THOMSON STATION Y
2015, 27 JULY TO 2015, 2 SEPTEMBER, 1982
223 DATA POINTS



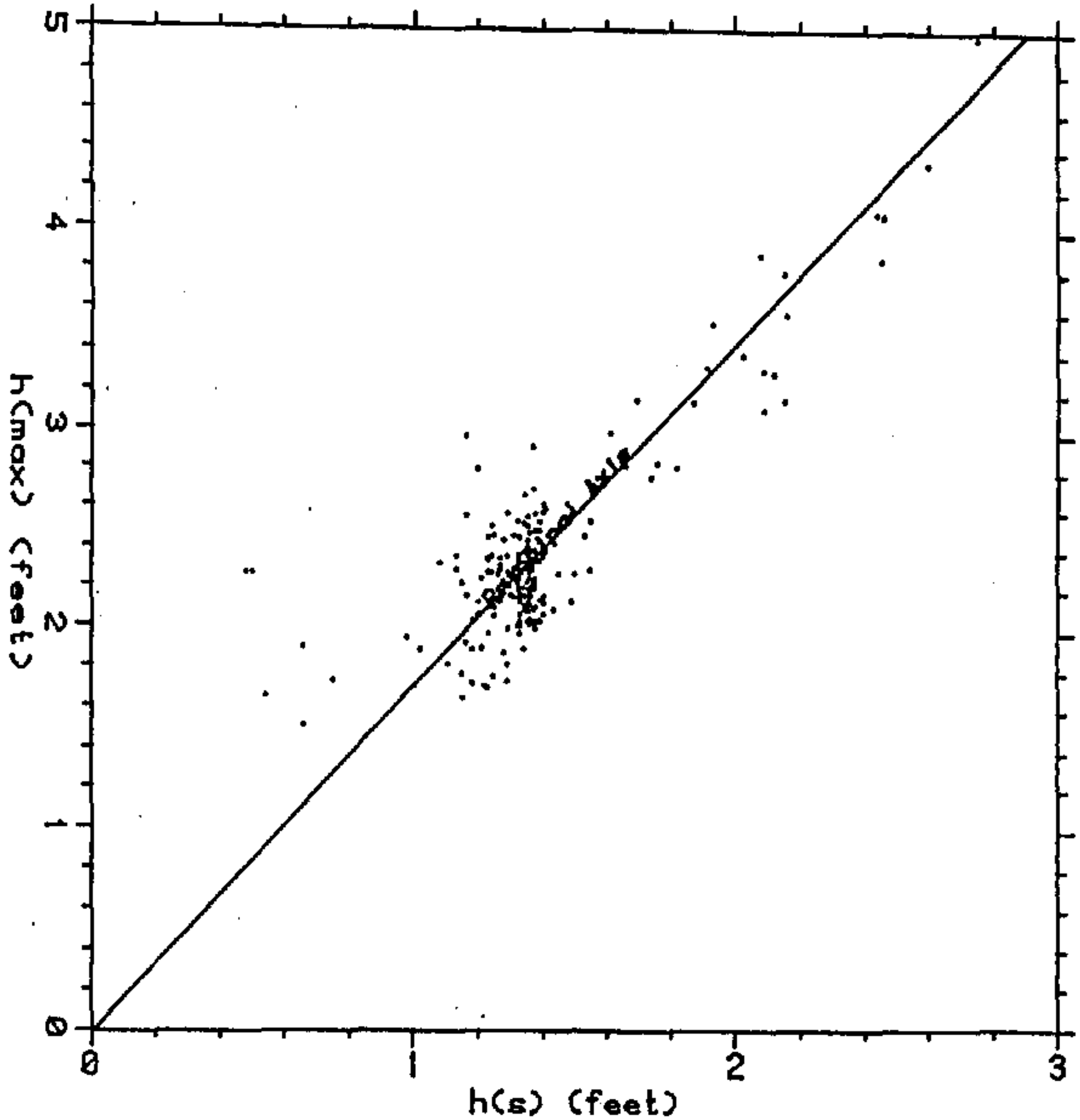
Statistics:
190 data points
time interval = 4.000 hours
Wind speed:
Mean = 9.58
Std. Dev. = 5.20
H(s):
Mean = 1.39
Std. Dev. = 0.32
Covariance = 0.90
Correlation = 0.546
Principal axis:
Slope = 0.033
Intercept = 1.073

FIGURE 37. SCATTER PLOT
WIND SPEED VS. H(S)
CHALLENGE ISLAND WEATHER STATION VS. PT. THOMSON STATION (
0544, 2 AUGUST TO 1744, 2 SEPTEMBER, 1982



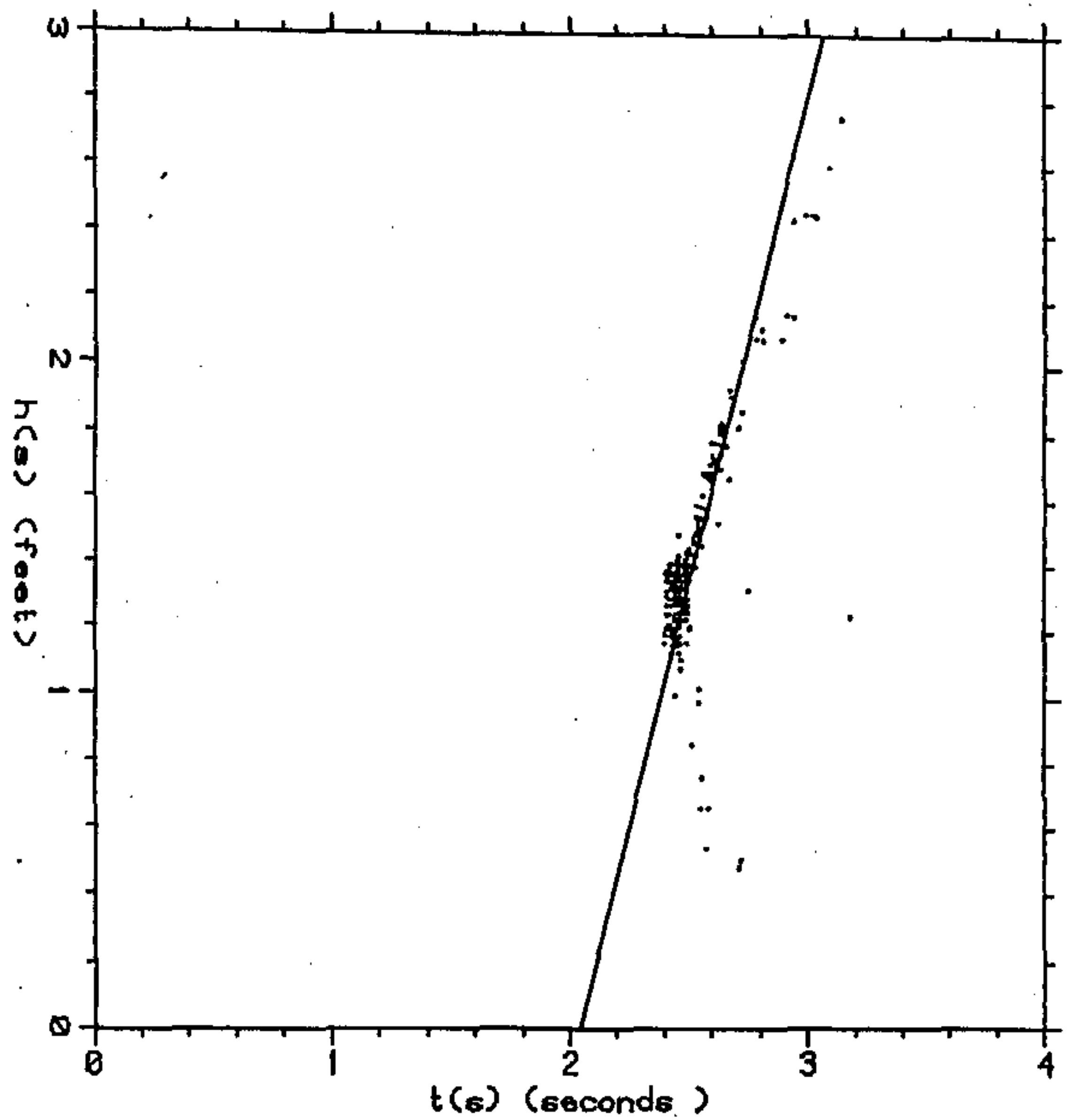
Statistics:
42 data points
time interval = 4.000 hours
Wind speed:
Mean = 14.87
Std. Dev. = 5.15
H(s):
Mean = 1.74
Std. Dev. = 0.47
Covariance = 1.74
Correlation = 0.713
Principal axis:
Slope = 0.066
Intercept = 0.759

FIGURE 38. SCATTER PLOT
WIND SPEED VS. H(S)
CHALLENGE ISLAND WEATHER STATION VS. PT. THOMSON STATION
0144, 20 AUGUST TO 2144, 26 AUGUST, 1982



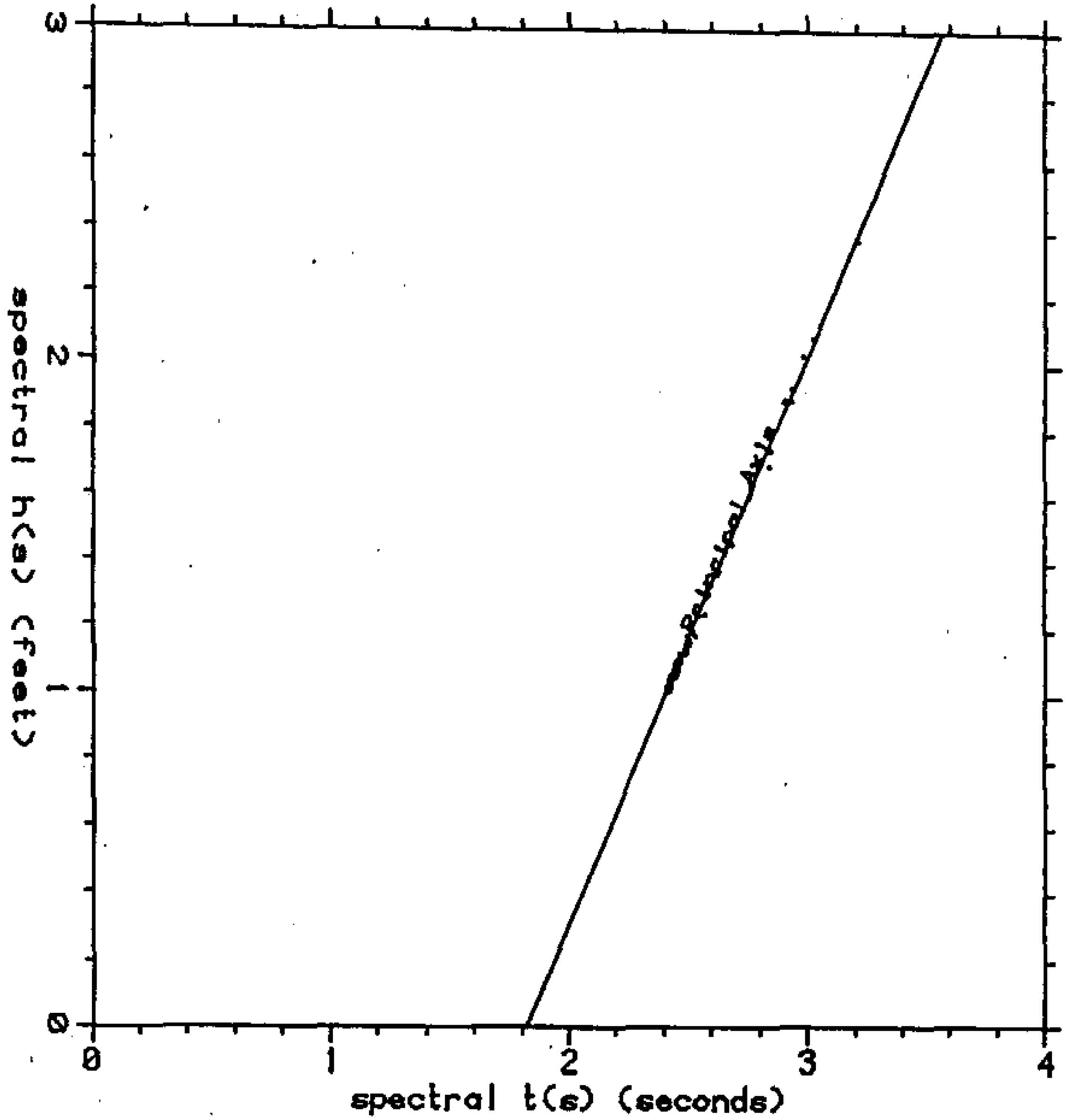
Statistics:
200 data points
time interval = 4.000 hours
H(s):
Mean = 1.38
Std. Dev. = 0.32
H(max):
Mean = 2.37
Std. Dev. = 0.51
Covariance = 0.14
Correlation = 0.853
Principal axis:
Slope = 1.726
Intercept = -0.015

FIGURE 39. SCATTER PLOT
H(S) VS. H(MAX)
POINT THOMSON STATION Q
0550, 2 AUGUST TO 0950, 4 SEPTEMBER, 1982



Statistics:
200 data points
time interval = 4.000 hours
T(s):
Mean = 2.51
Std. Dev. = 0.14
H(s):
Mean = 1.38
Std. Dev. = 0.32
Covariance = 0.03
Correlation = 0.684
Principal axis:
Slope = 2.937
Intercept = -5.997

FIGURE 40. SCATTER PLOT
T(S) VS. H(S)
POINT THOMSON STATION Q
0550, 2 AUGUST TO 0950, 4 SEPTEMBER, 1982



Statistics:
200 data points
time interval = 4.000 hours
Spectral t(s):
Mean = 2.49
Std. Dev. = 0.13
Spectral h(s):
Mean = 1.16
Std. Dev. = 0.22
Covariance = 0.03
Correlation = 0.998
Principal axis:
Slope = 1.727
Intercept = -3.149

FIGURE 41. SCATTER PLOT
SPECTRAL T(S) VS. SPECTRAL H(S)
POINT THOMSON STATION Q
0550, 2 AUGUST TO 0950, 4 SEPTEMBER, 1982

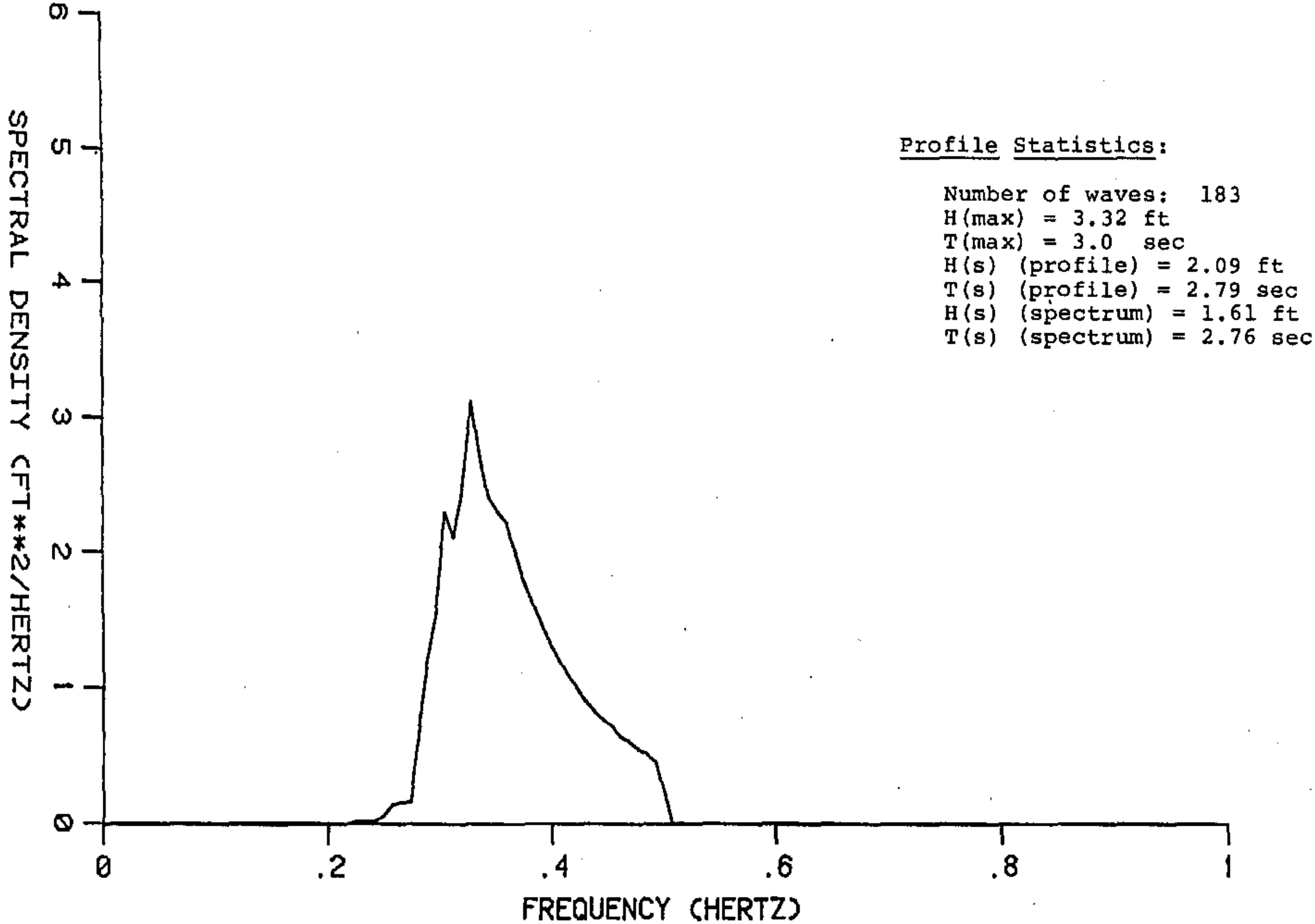


FIGURE 42. SURFACE WAVE SPECTRUM
PT. THOMSON STATION Q
1350, 20 AUGUST, 1982

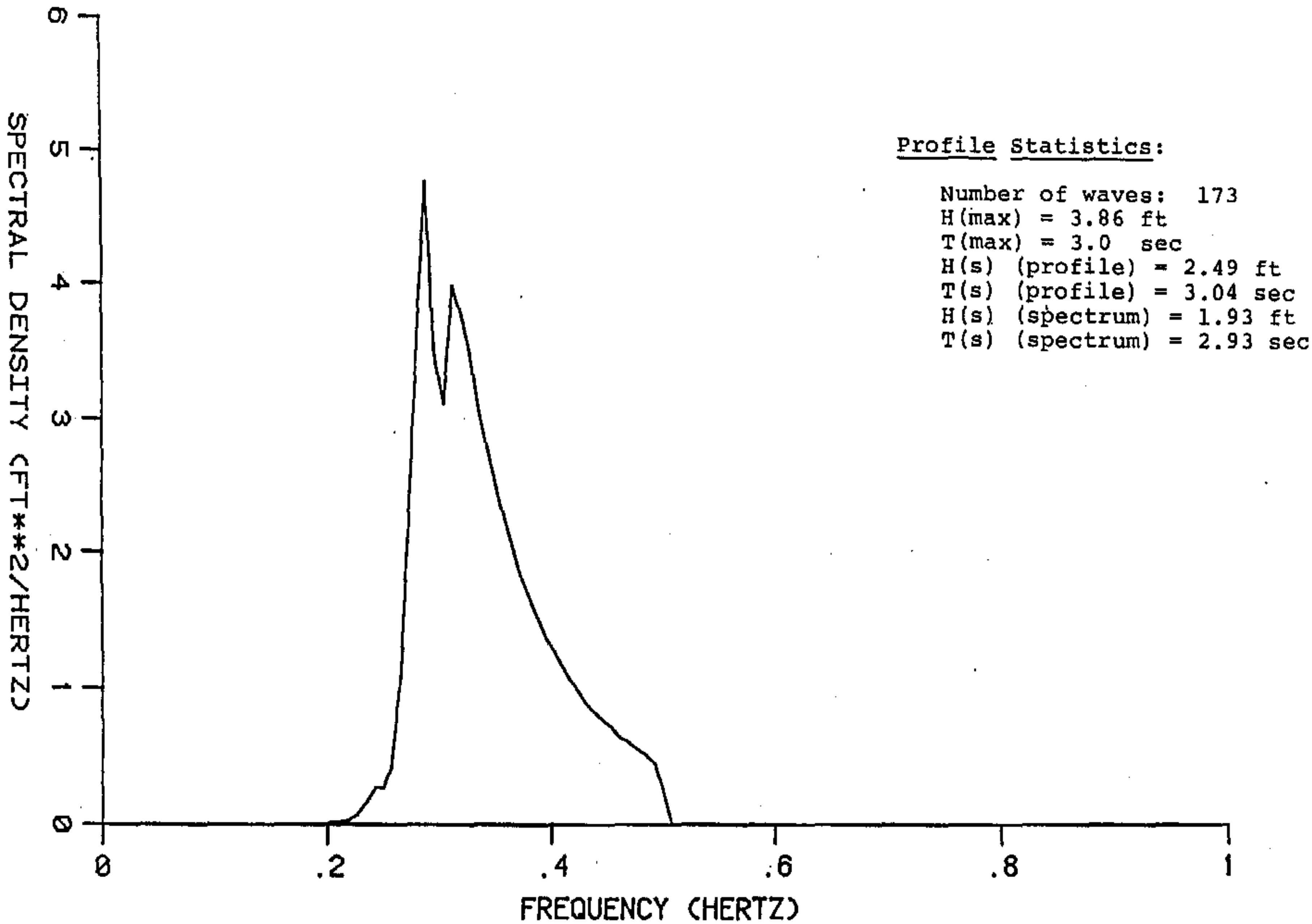


FIGURE 43. SURFACE WAVE SPECTRUM
PT. THOMSON STATION Q
0150, 21 AUGUST, 1982

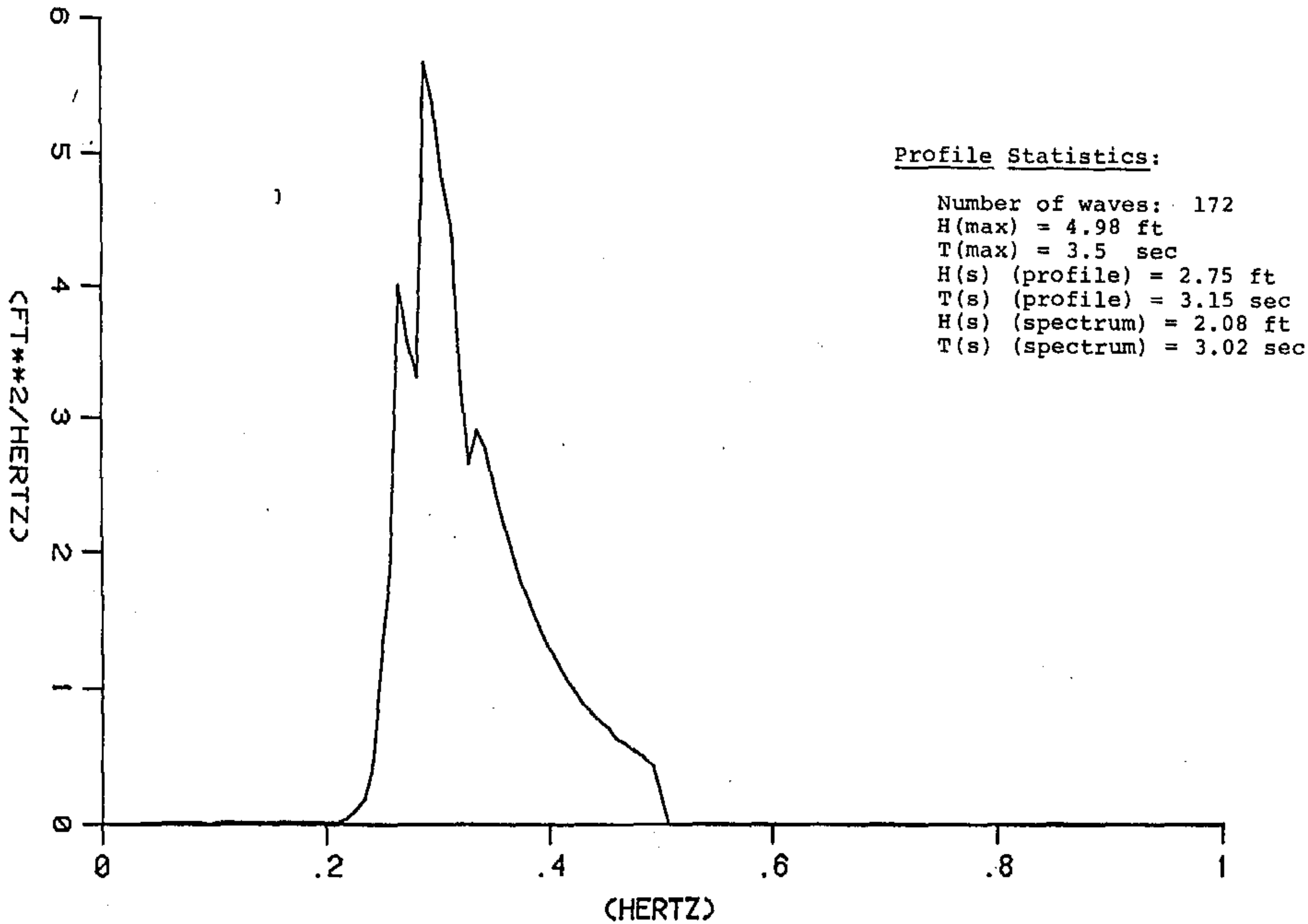


FIGURE 44. SURFACE WAVE SPECTRUM
PT. THOMSON STATION Q

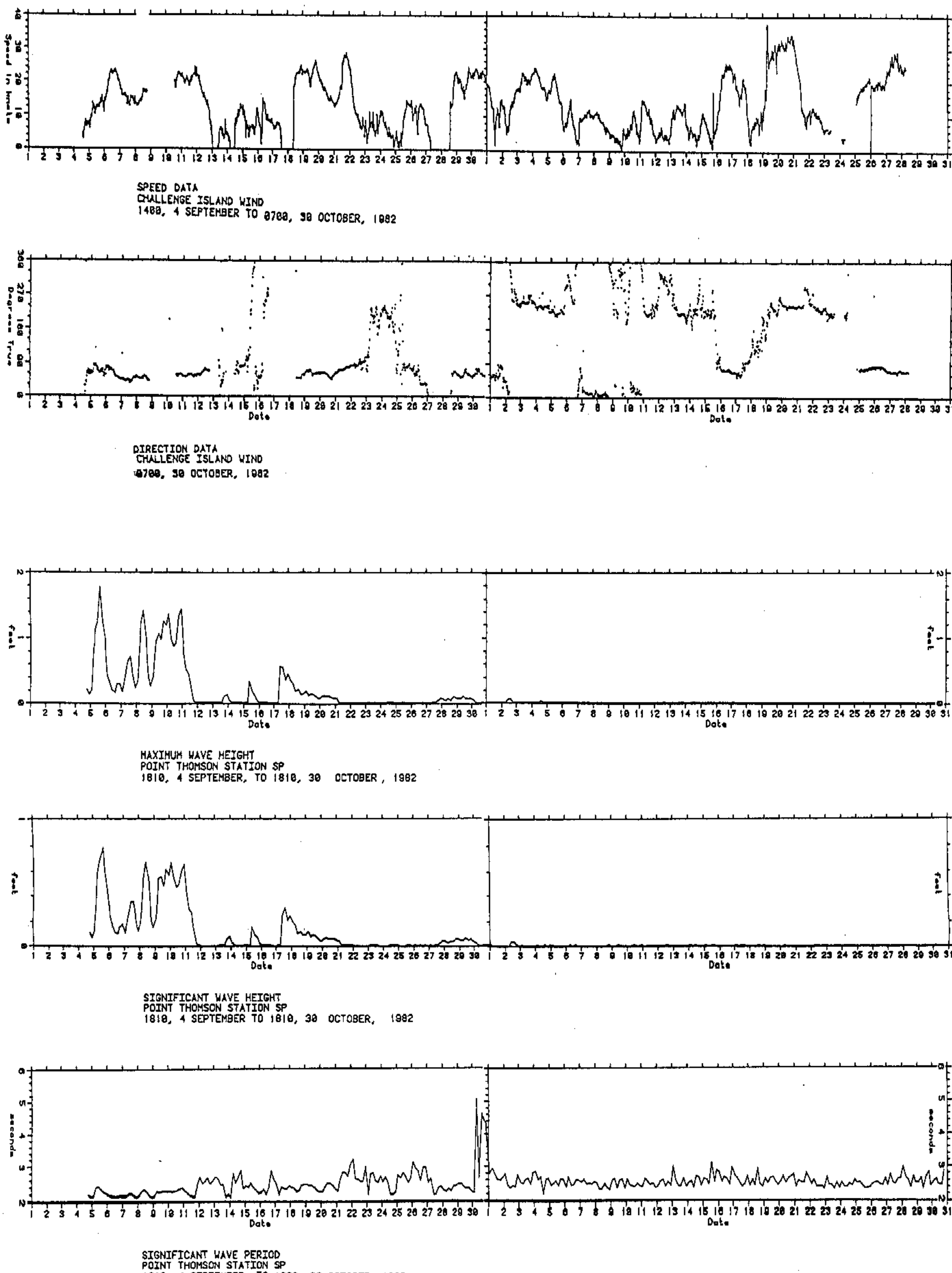


FIGURE 45. WAVE PARAMETERS VS. TIME FOR STATION SP, FALL 1982.

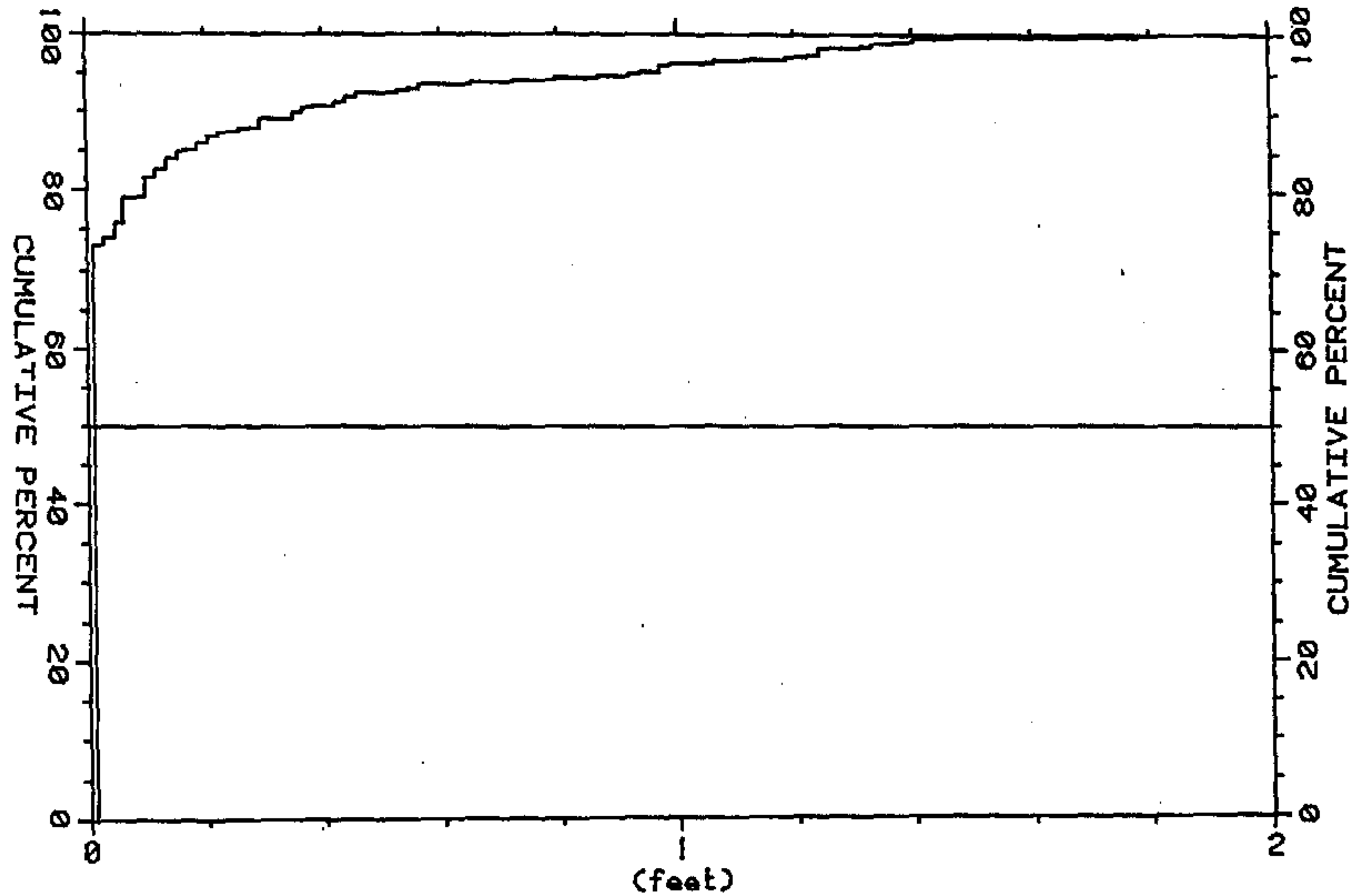


FIGURE 46. CUMULATIVE PROBABILITY PLOT
MAXIMUM WAVE HEIGHT
POINT THOMSON STATION SP
1810, 4 SEPTEMBER TO 0210, 31 OCTOBER, 1982
339 DATA POINTS

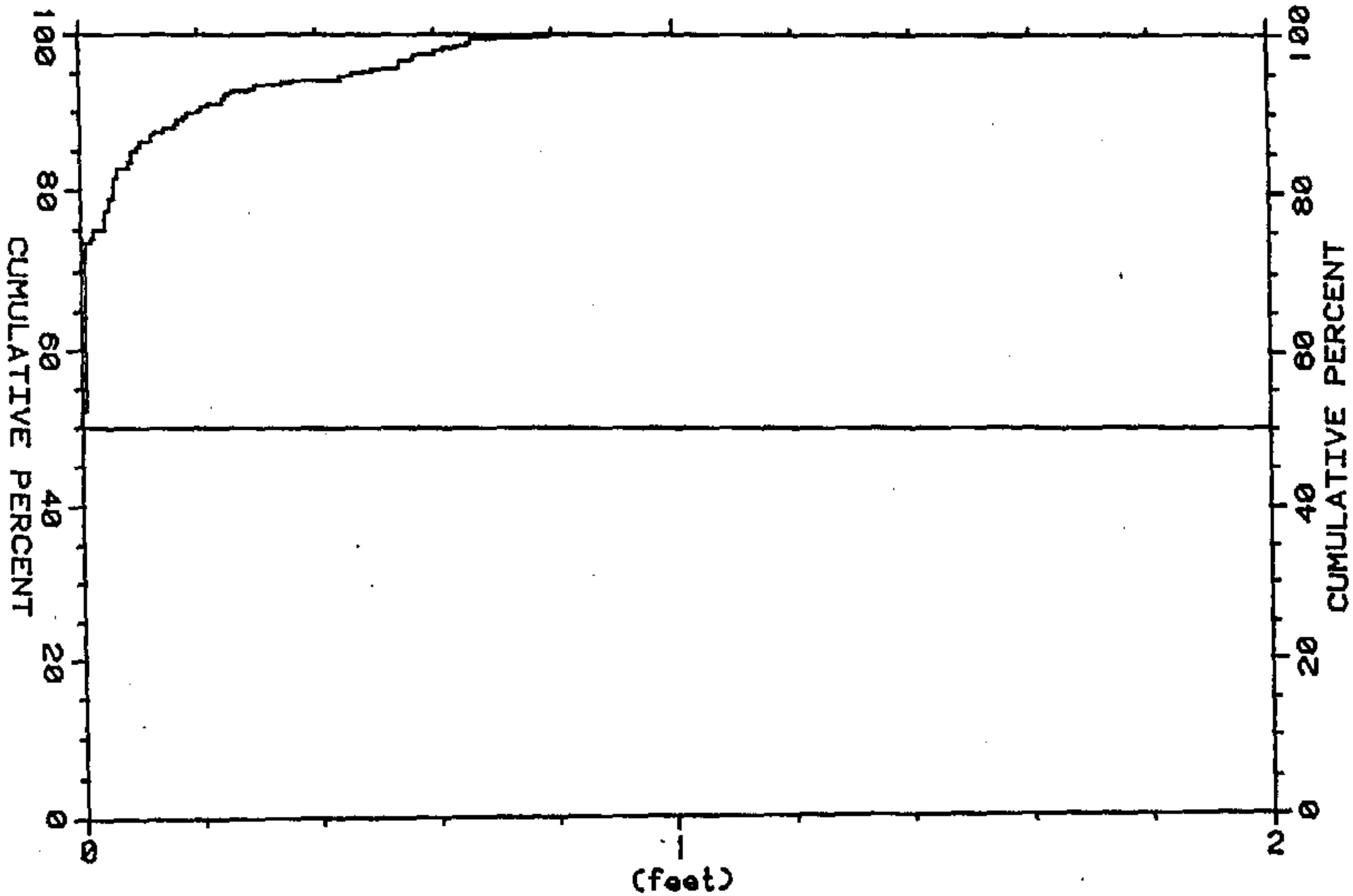


FIGURE 47. CUMULATIVE PROBABILITY PLOT
SIGNIFICANT WAVE HEIGHT
POINT THOMSON STATION SP
1810, 4 SEPTEMBER TO 0210, 31 OCTOBER, 1982
339 DATA POINTS

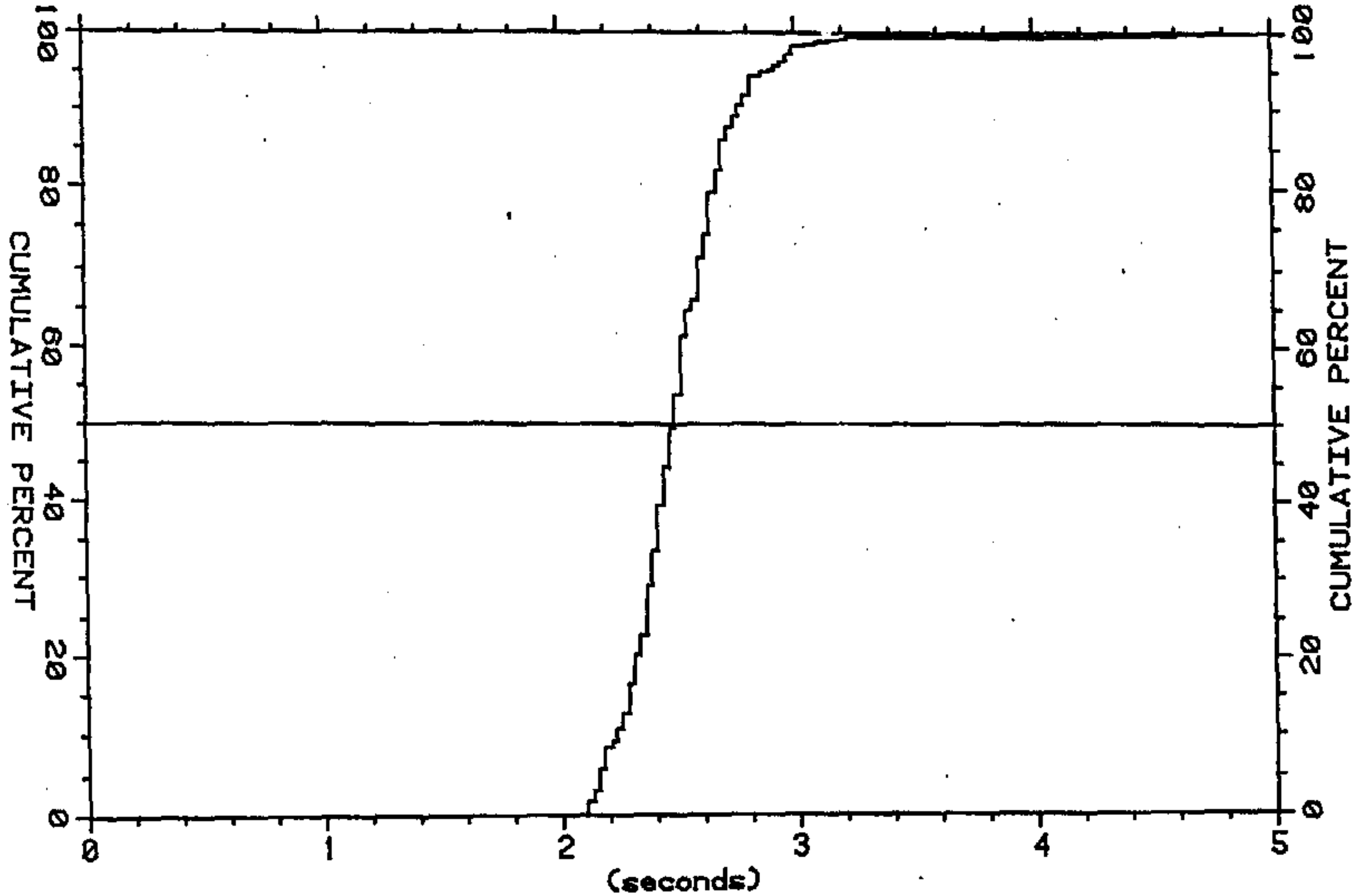


FIGURE 48. CUMULATIVE PROBABILITY PLOT
SIGNIFICANT WAVE PERIOD
POINT THOMSON STATION SP
1810, 4 SEPTEMBER TO 0210, 31 OCTOBER, 1982
338 DATA POINTS

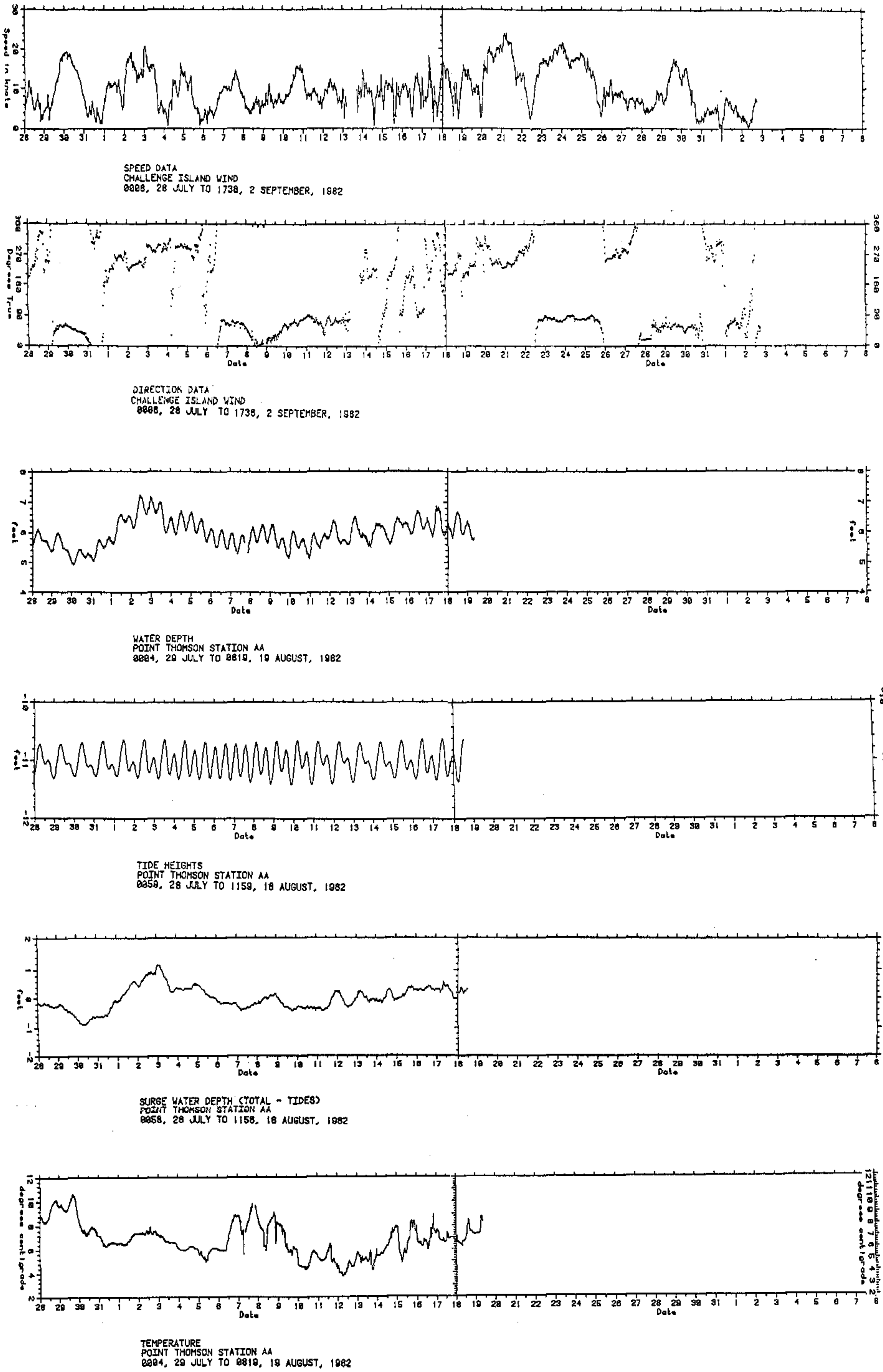


Figure 49. Water Level, Tide, and Surge Data; Station AA, Summer 1982.

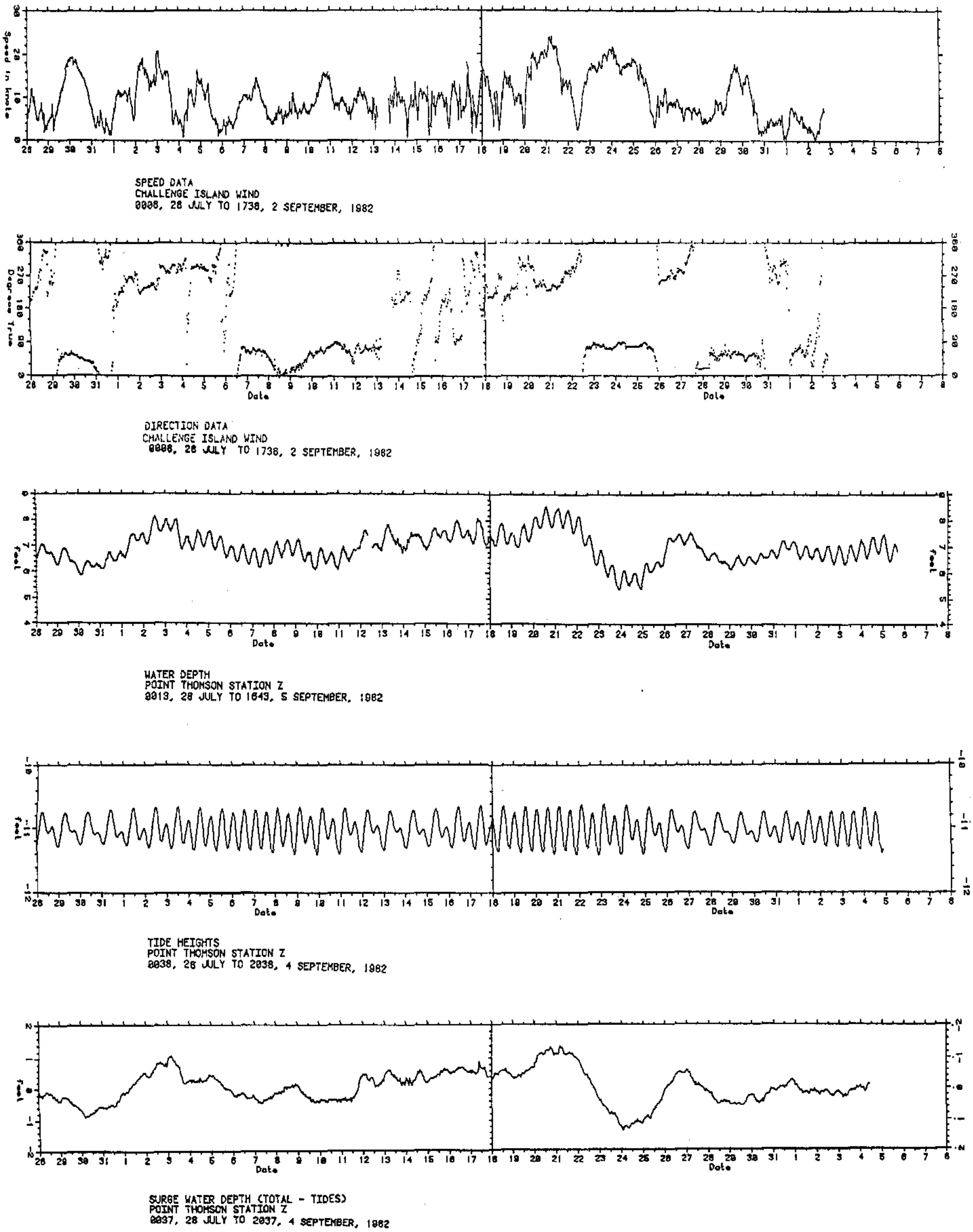


Figure 50. Water Level, Tide, and Surge Data; Station Z, Summer 1982.

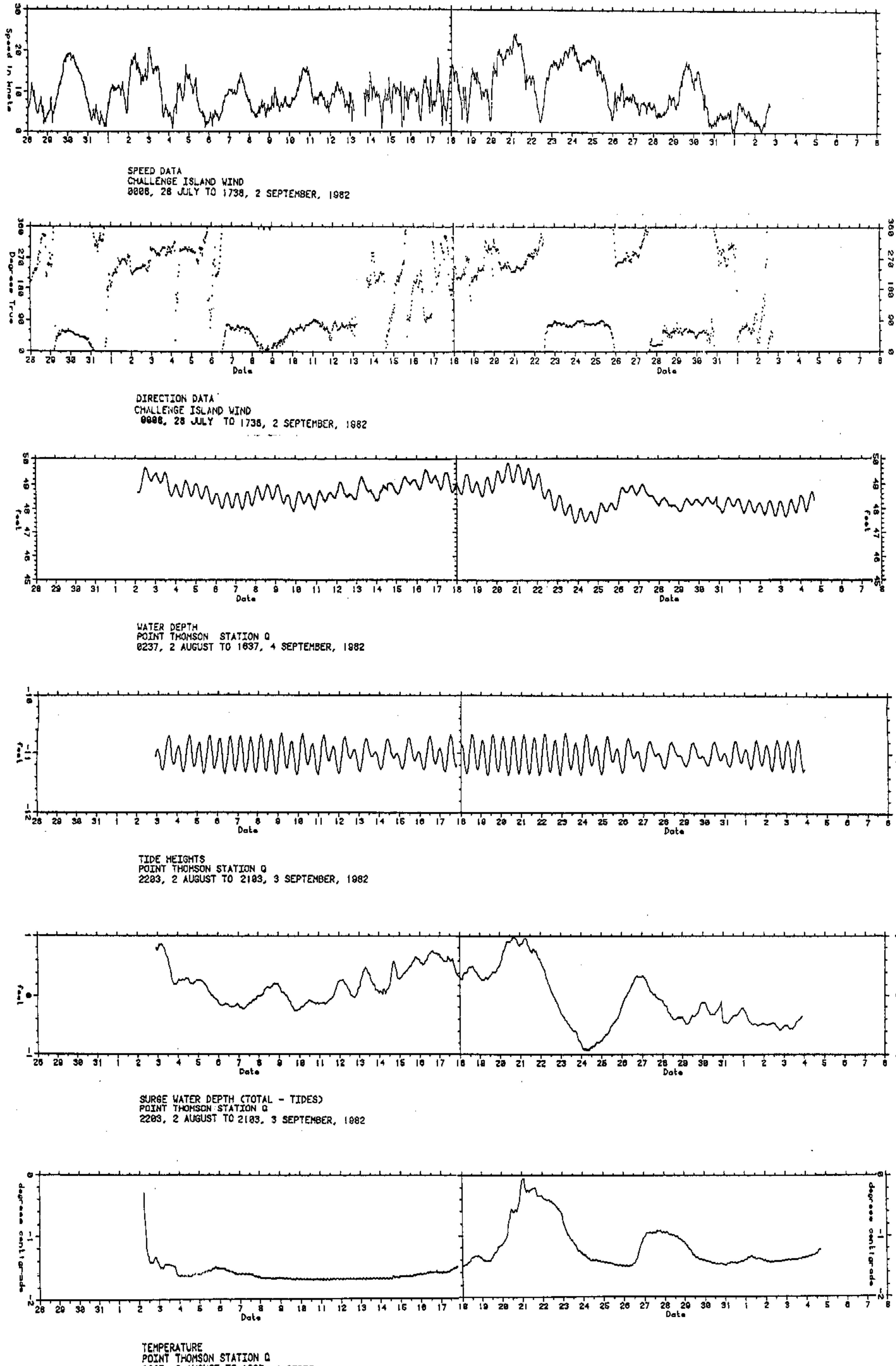
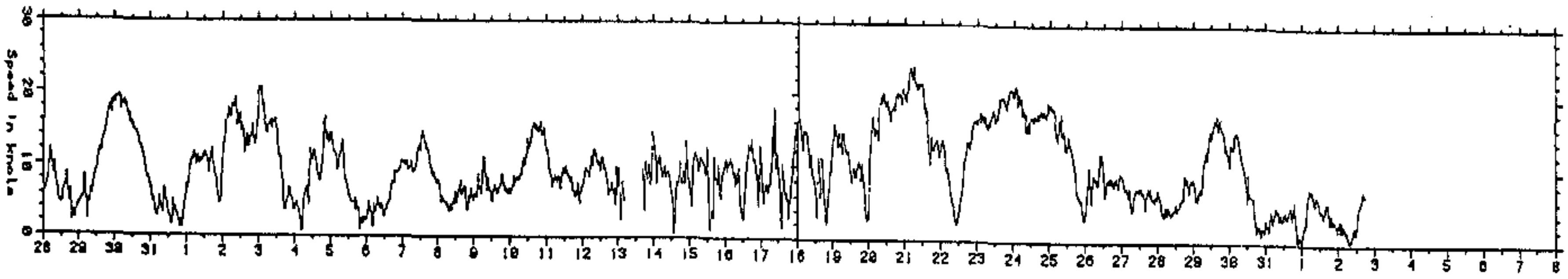
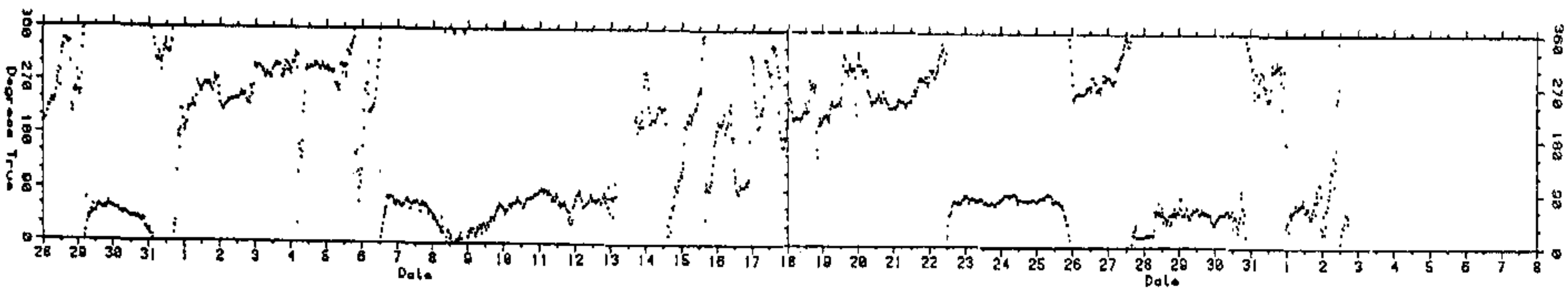


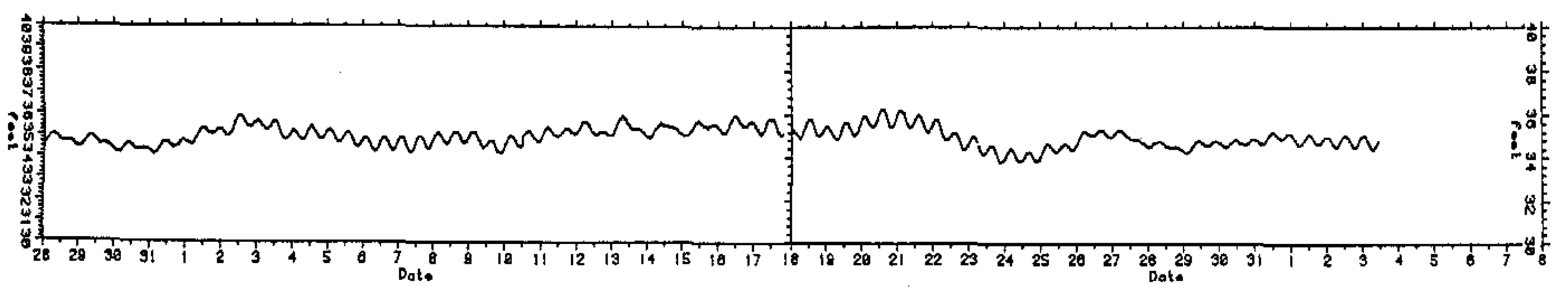
Figure 51. Water Level, Tide, and Surge Data; Station Q, Summer 1982.



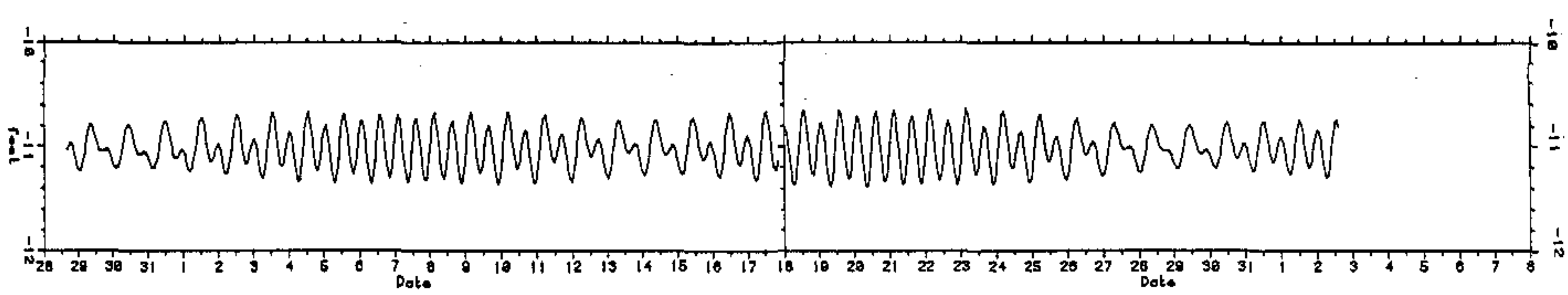
SPEED DATA
CHALLENGE ISLAND WIND
0000, 28 JULY TO 1730, 2 SEPTEMBER, 1982



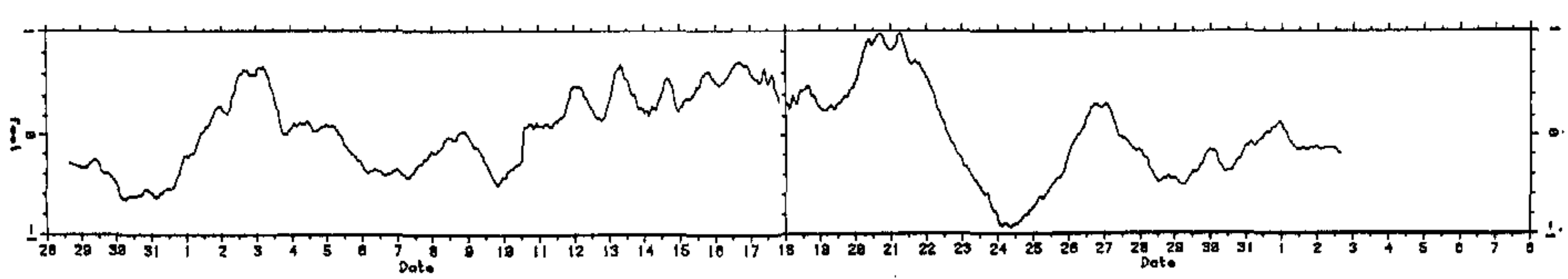
DIRECTION DATA
CHALLENGE ISLAND WIND
0000, 28 JULY TO 1730, 2 SEPTEMBER, 1982



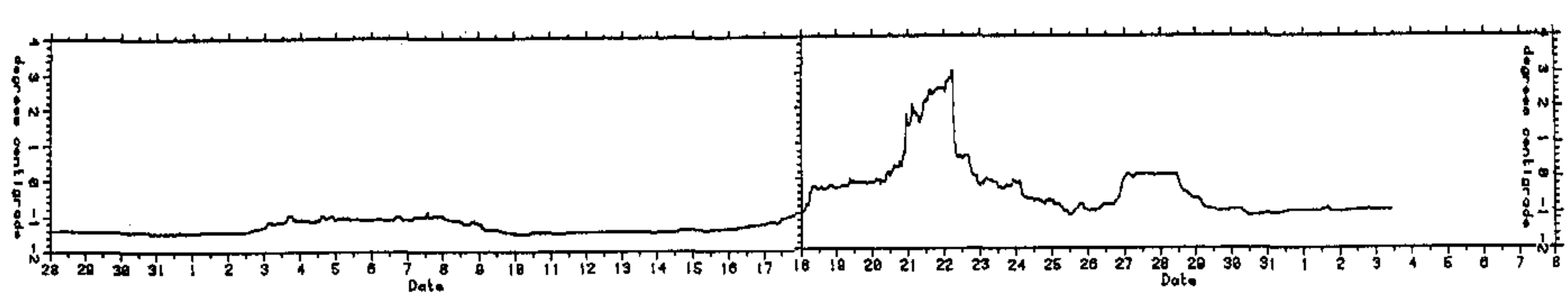
WATER DEPTH
POINT THOMSON STATION Y
0000, 28 JULY TO 1023, 3 SEPTEMBER, 1982



TIDE HEIGHTS
PT. THOMSON STATION Y
1540, 28 JULY TO 1440, 2 SEPTEMBER, 1982



SURGE WATER DEPTH (TOTAL - TIDES)
POINT THOMSON STATION Y
1540, 28 JULY TO 1440, 2 SEPTEMBER, 1982



TEMPERATURE
POINT THOMSON STATION Y
0000, 28 JULY TO 1023, 3 SEPTEMBER, 1982

Figure 52. Water Level, Tide, and Surge Data; Station Y, Summer 1982.

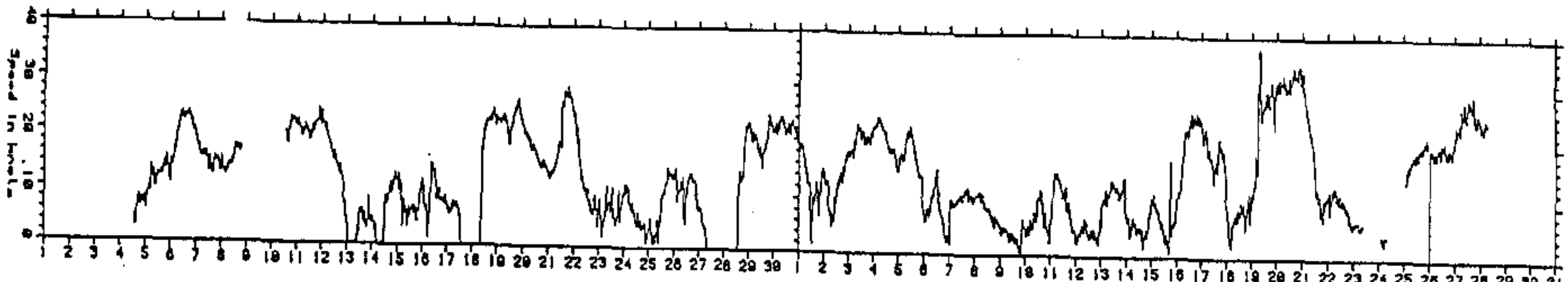


FIGURE ____ SPEED DATA
CHALLENGE ISLAND WIND
1400, 4 SEPTEMBER TO 0700, 30 OCTOBER, 1982

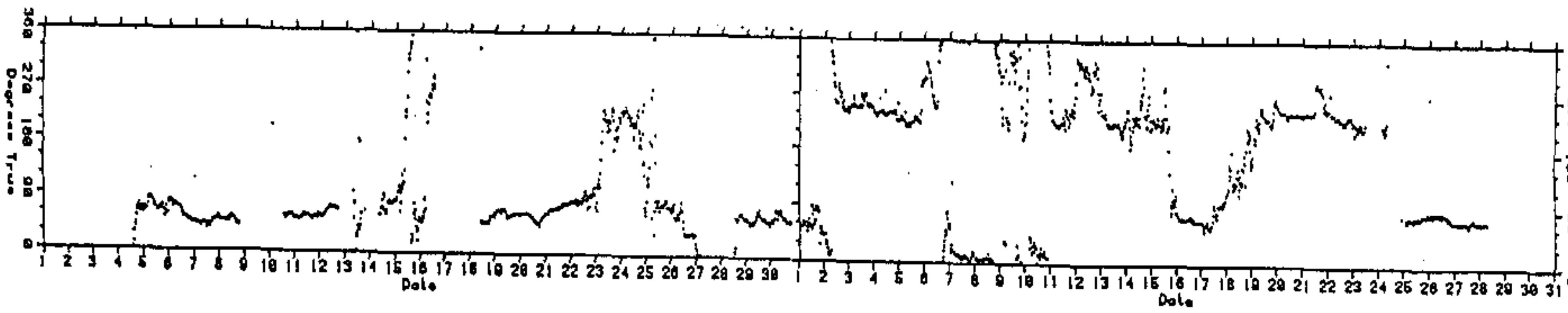
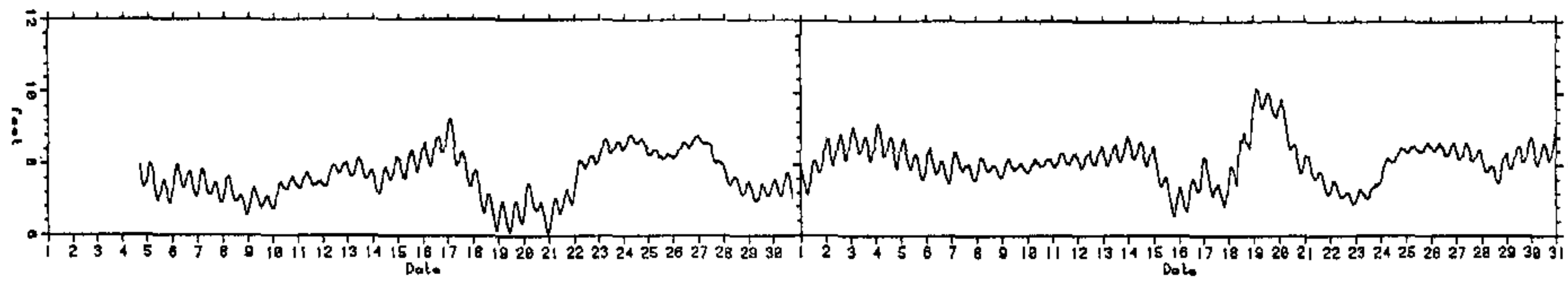
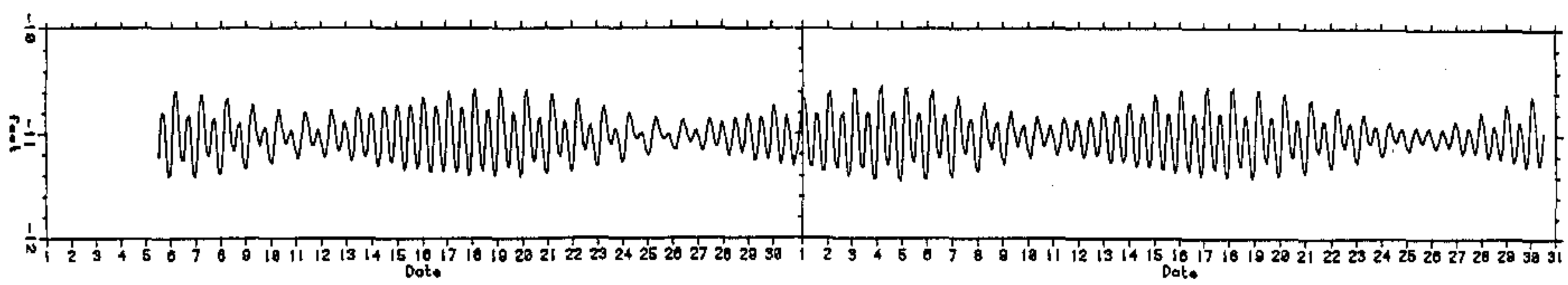


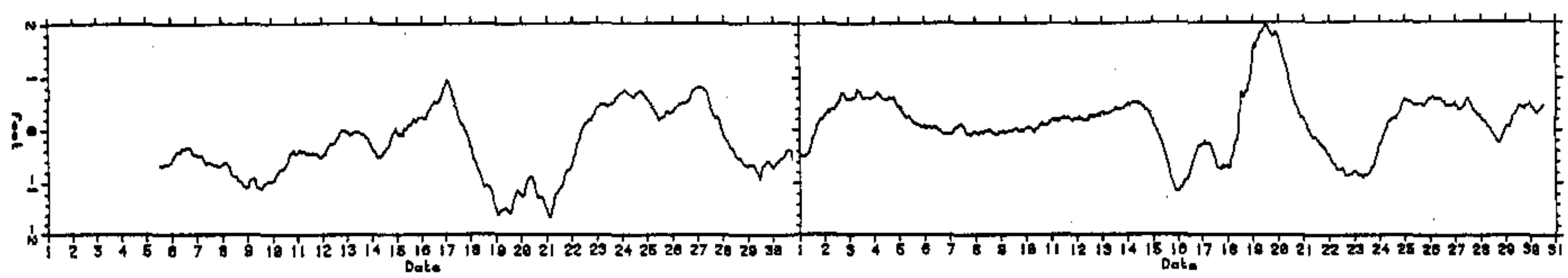
FIGURE ____ DIRECTION DATA
CHALLENGE ISLAND WIND
0000, 1 OCTOBER TO 0700, 30 OCTOBER, 1982



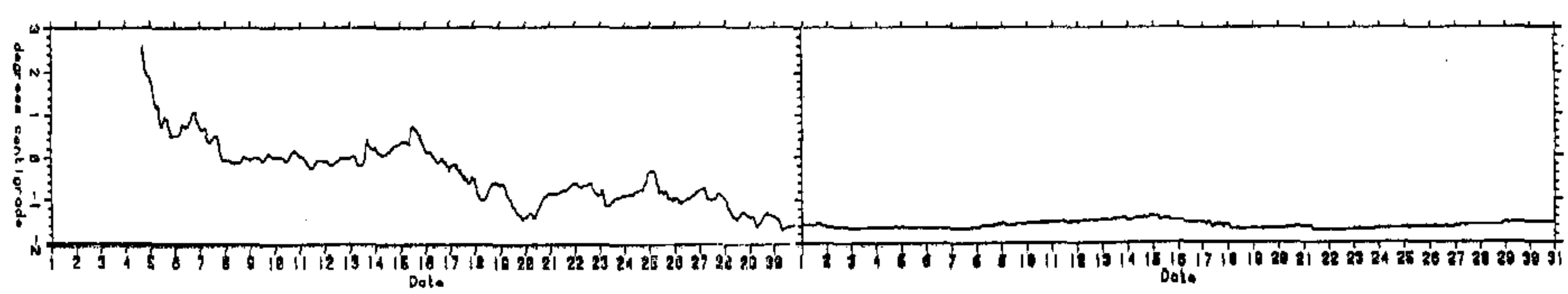
WATER DEPTH
POINT THOMSON STATION SP
1610, 4 SEPTEMBER TO 2355, 30 OCTOBER, 1982



TIDE HEIGHTS
POINT THOMSON STATION SP
1130, 5 SEPTEMBER TO 1130, 30 OCTOBER, 1982

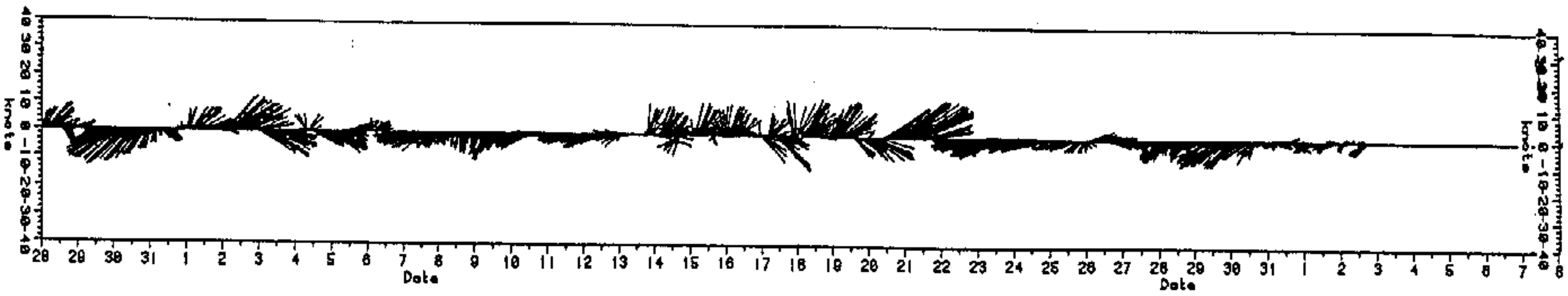


SURGE WATER DEPTH (TOTAL - TIDES)
POINT THOMSON STATION SP
1130, 5 SEPTEMBER TO 1130, 30 OCTOBER, 1982

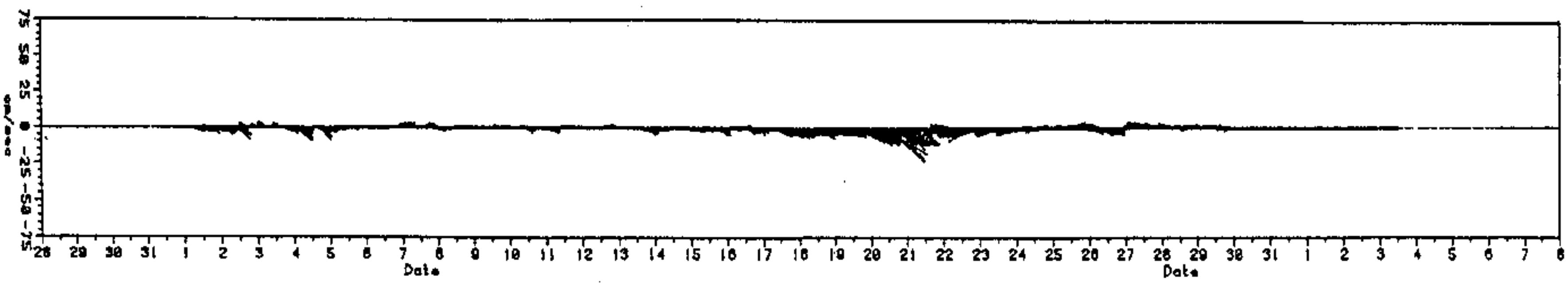


TEMPERATURE
POINT THOMSON STATION SP
1610, 1 SEPTEMBER TO 2355, 30 OCTOBER, 1982

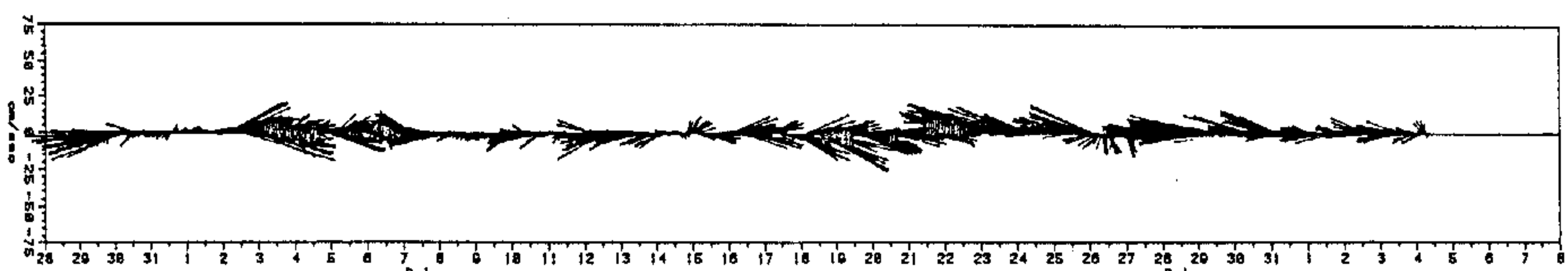
Figure 53. Water Level, Tide, and Surge Data; Station SP, Fall 1982.



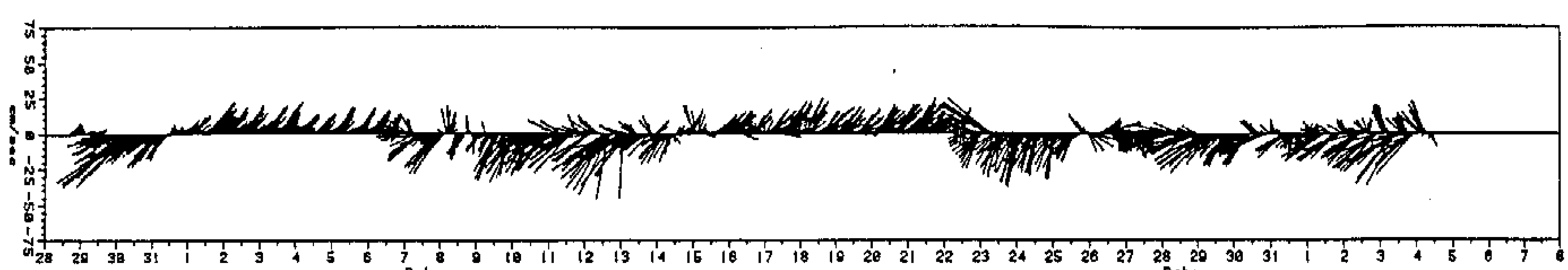
VECTOR STICK PLOT
CHALLENGE ISLAND WIND
0008, 28 JULY TO 1738, 2 SEPTEMBER, 1982



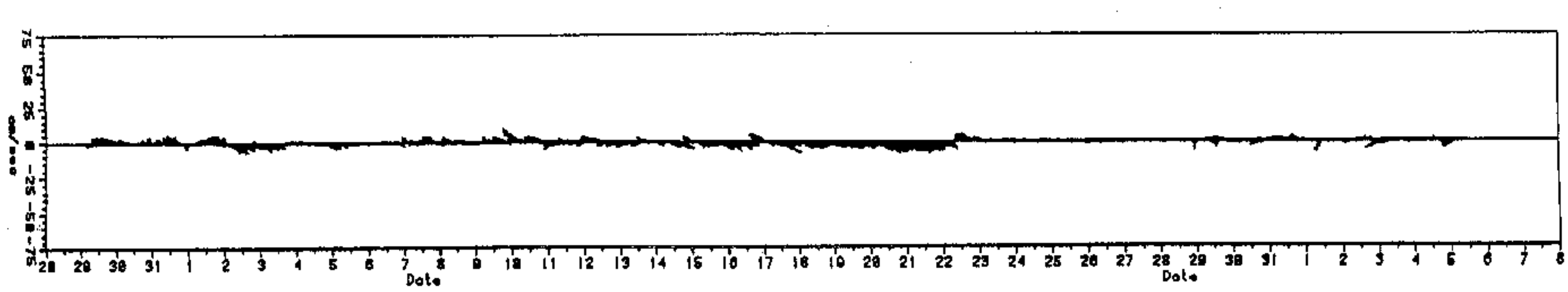
Vector Stick Plot, Station Q;
1/2 Hr. Average Current, Endeco
#047, 0228, 1 August to 1228,
3 September 1982.



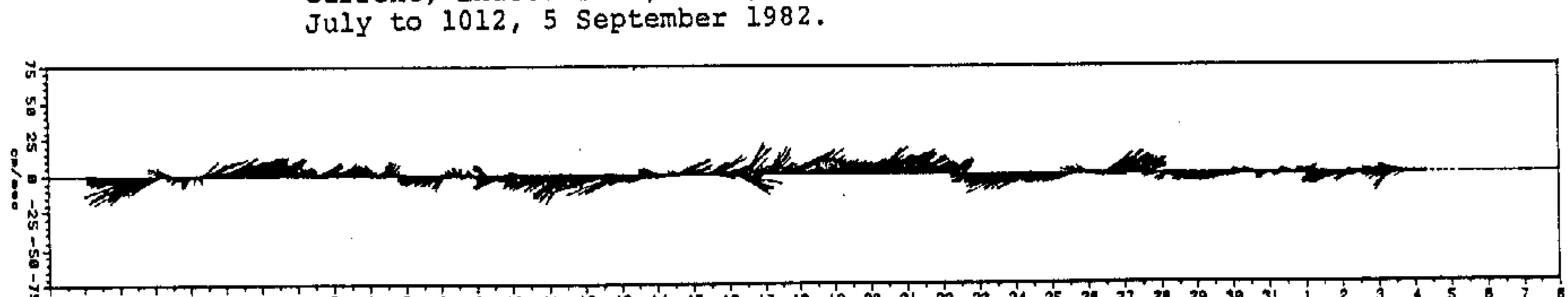
Vector Stick Plot, Station P;
1/2 Hour Average Current,
Endeco #048; 1545, 29 July to
0845, 4 September 1982.



Vector Stick Plot, Station O;
1/2 Hour Average Current,
Endeco #049; 1538, 28 July
to 1008, 4 September 1982.



Vector Stick Plot, Station S
(bottom) - 1/2 Hr. Average
Current, Endeco #052, 2242, 28
July to 1012, 5 September 1982.



Vector Stick Plot, Station E;
1/2 Hour Average Current,
Endeco #232; 2122, 29 July
to 0722, 4 September 1982.

Figure 54. Summary of Current Results for Selected Stations, Summer 1982.

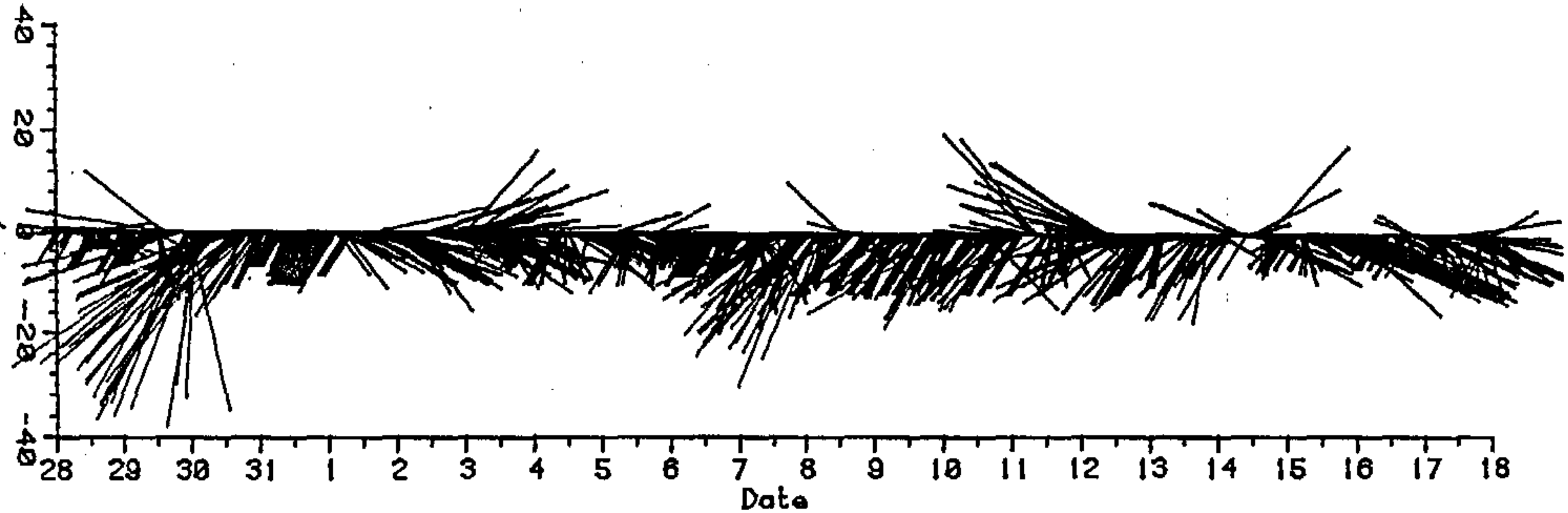


FIGURE 55. VECTOR STICK PLOT
POINT THOMSON STATION D CURRENT
0010, 28 JULY TO 2340, 17 AUGUST, 1982

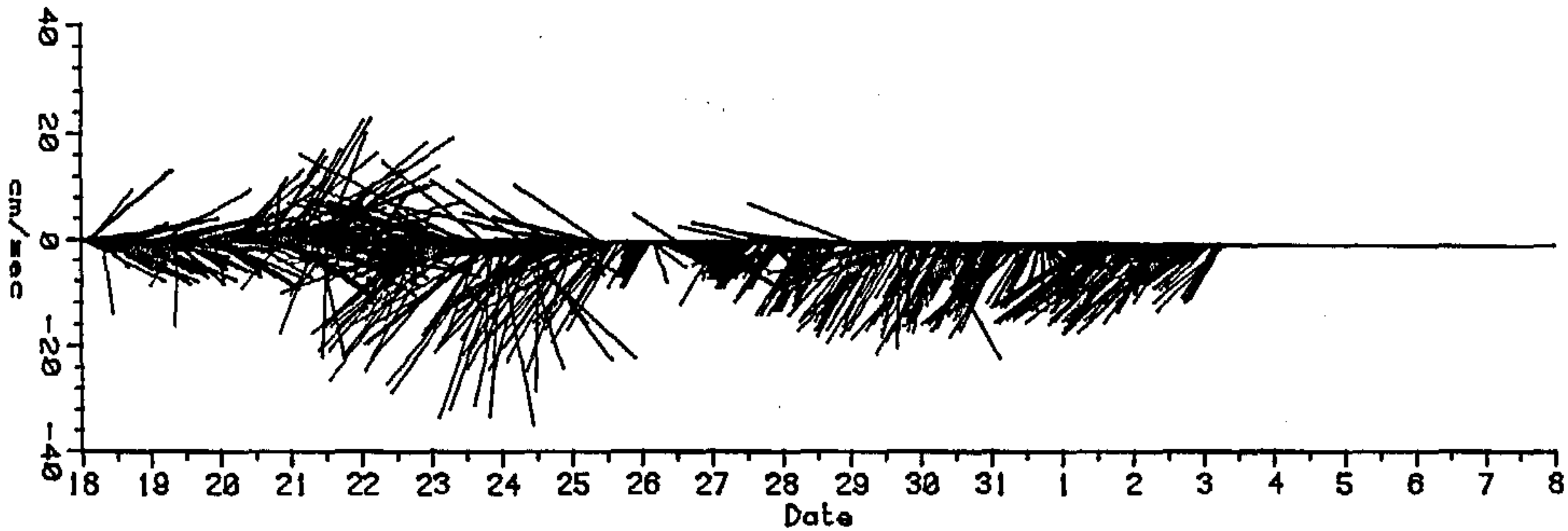


FIGURE 55 CONT. VECTOR STICK PLOT
POINT THOMSON STATION D CURRENT
0010, 18 AUGUST TO 0940, 3 SEPTEMBER, 1982

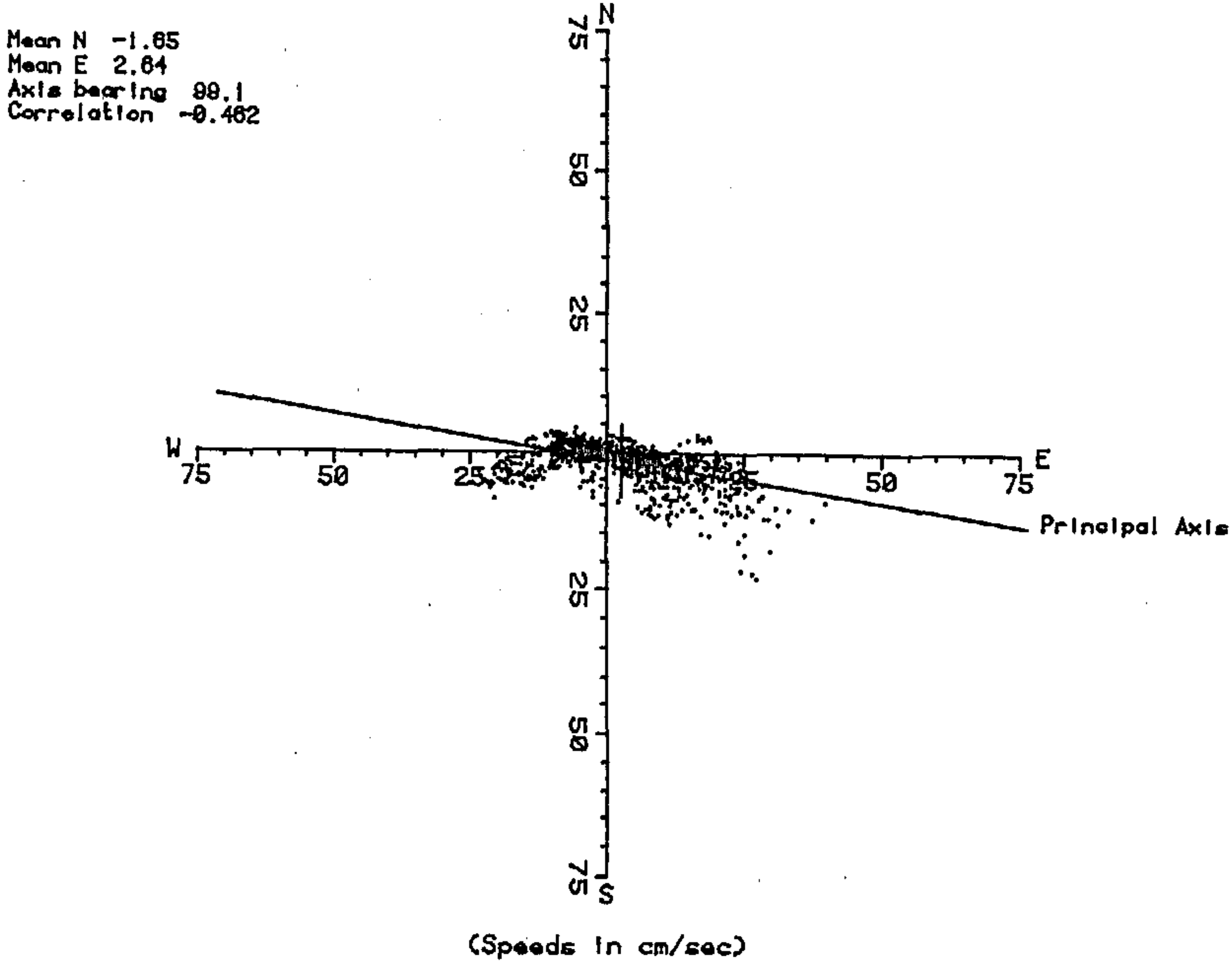


FIGURE 56. POLAR PLOT - SPEED AND DIRECTION DATA
STATION Q - 1/2 AVERAGE CURRENT - ENDECO #047
0228, 1 AUGUST TO 1228, 3 SEPTEMBER, 1982

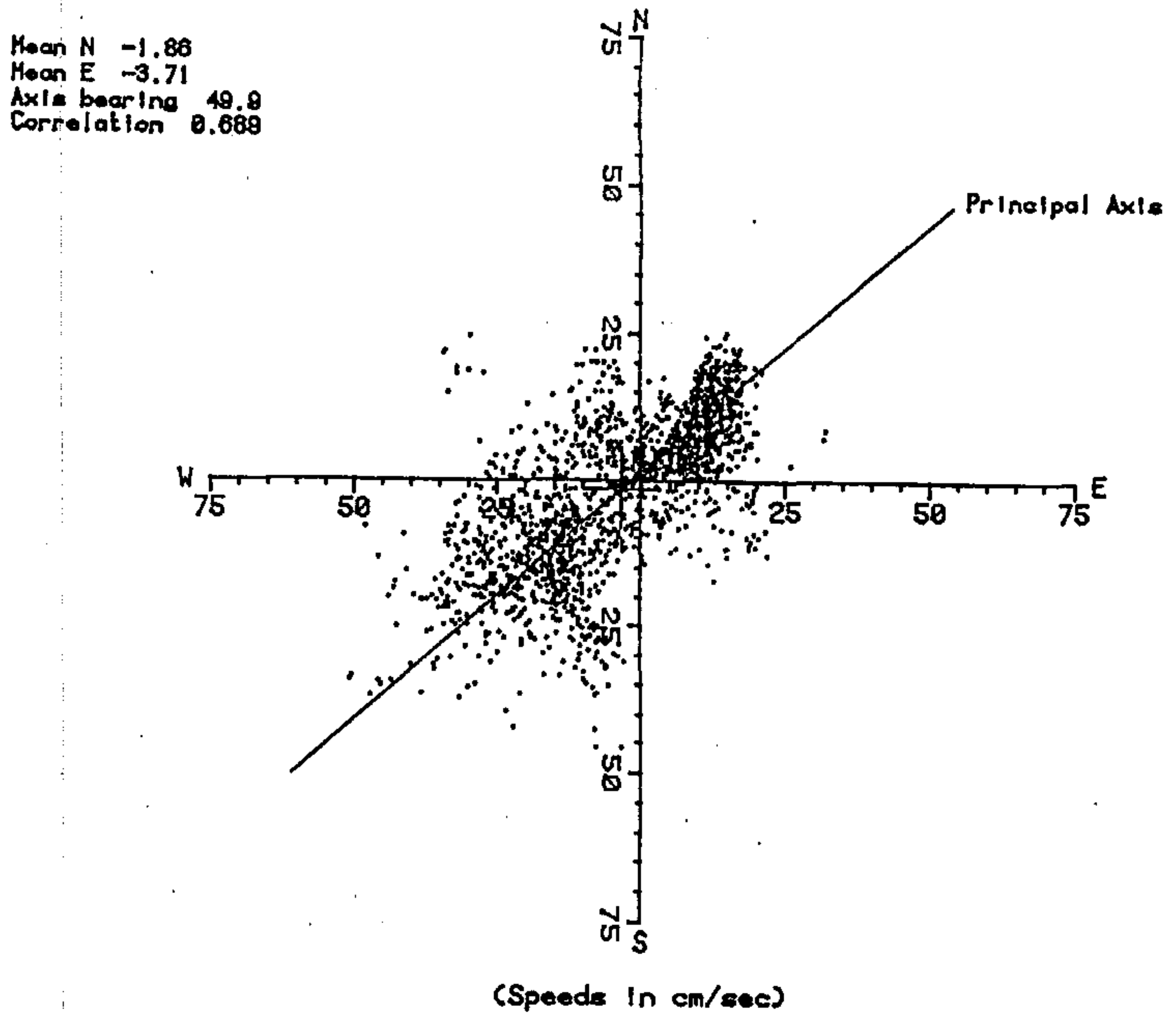


FIGURE 57. POLAR PLOT - SPEED AND DIRECTION DATA
STATION O - 1/2 HR. AVERAGE CURRENT - ENDECO #049
1538, 28 JULY TO 1008, 4 SEPTEMBER, 1982

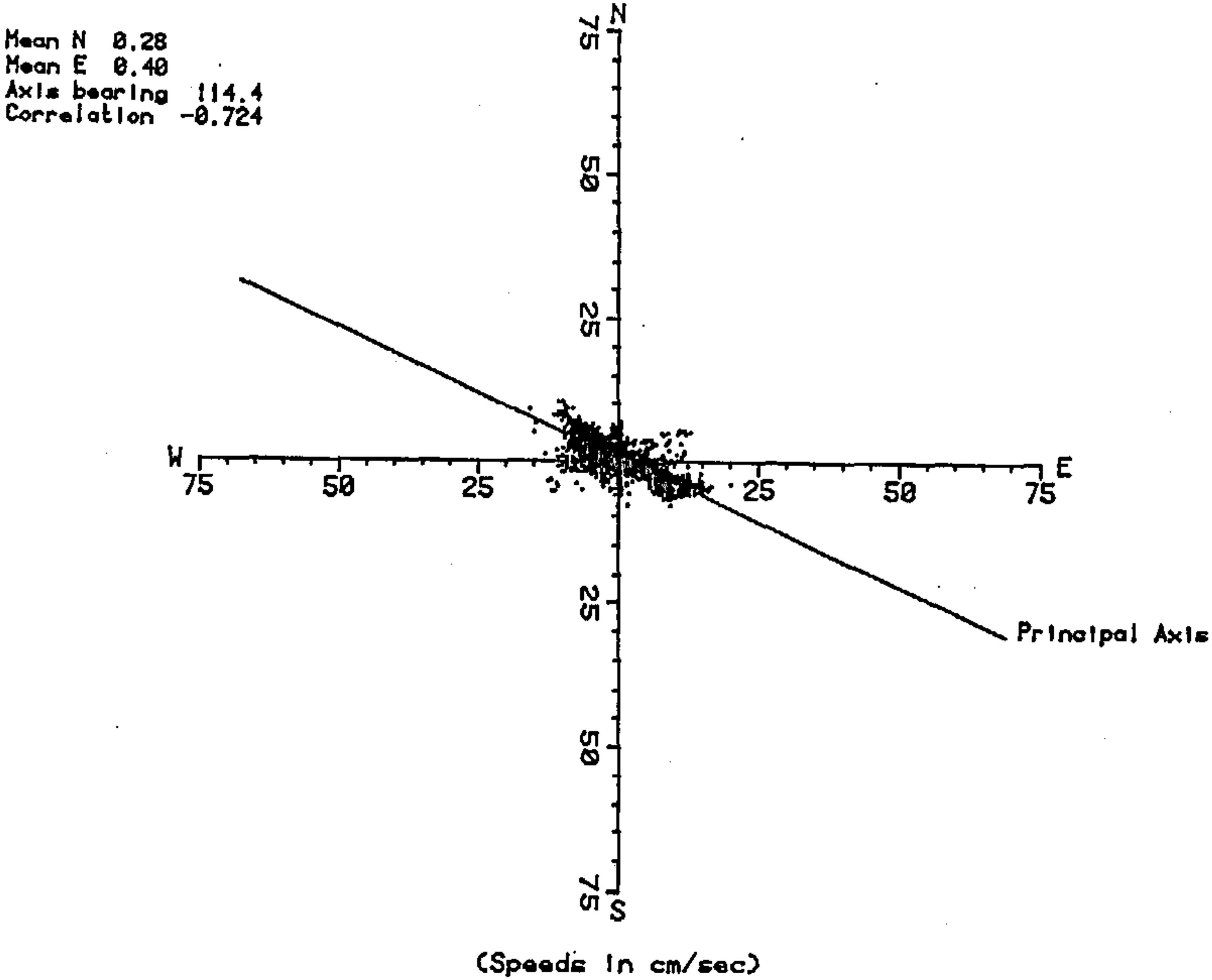


FIGURE 58. POLAR PLOT - SPEED AND DIRECTION DATA
STATION S (TOP) - 1/2 HR. AVERAGE CURRENT - ENDECO #175
2252, 28 JULY TO 1022, 5 SEPTEMBER, 1982

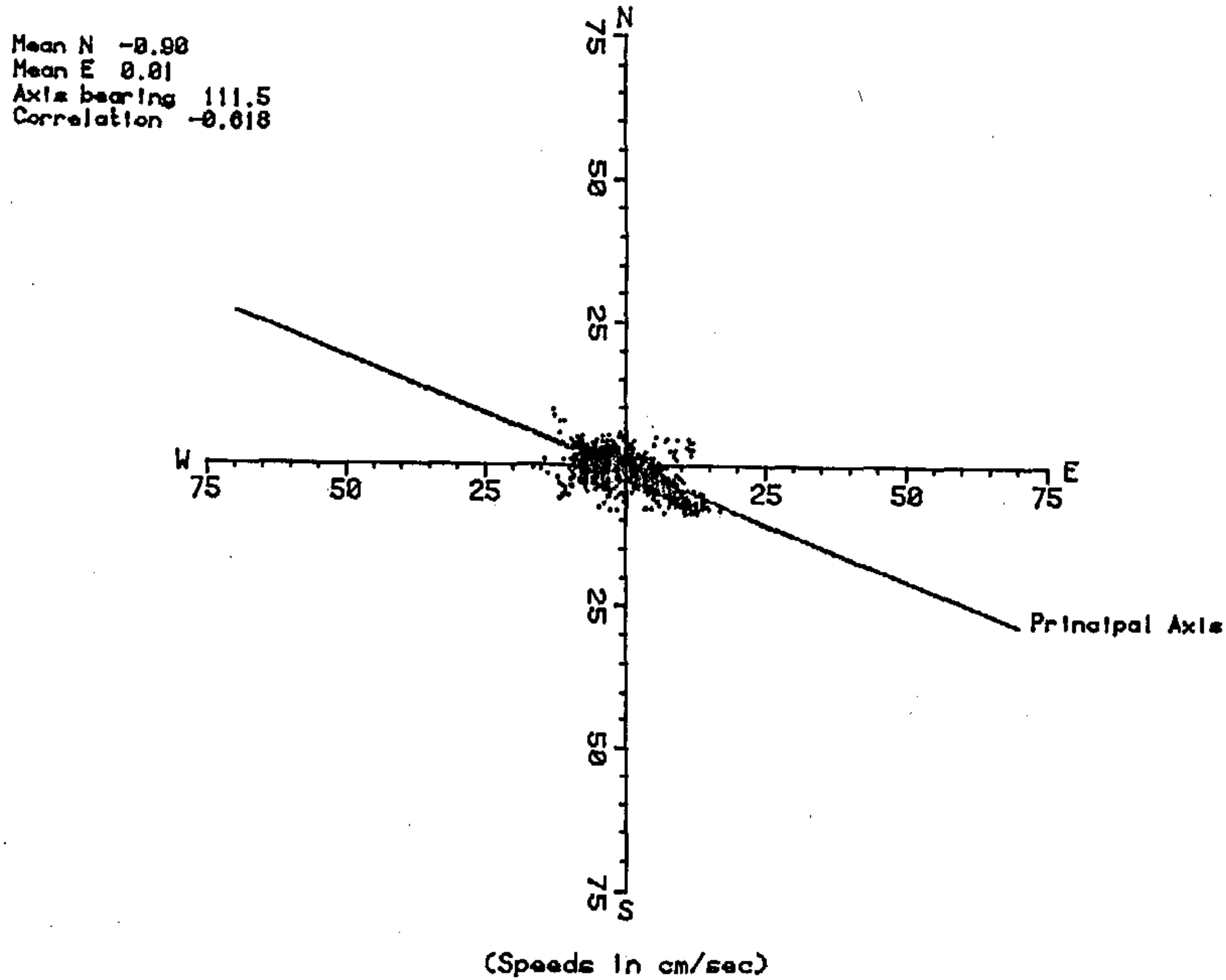


FIGURE 59. POLAR PLOT - SPEED AND DIRECTION DATA
STATION S (BOTTOM) - 1/2 HR. AVERAGE CURRENT - ENDECO #052
2242, 28 JULY TO 1012, 5 SEPTEMBER, 1982

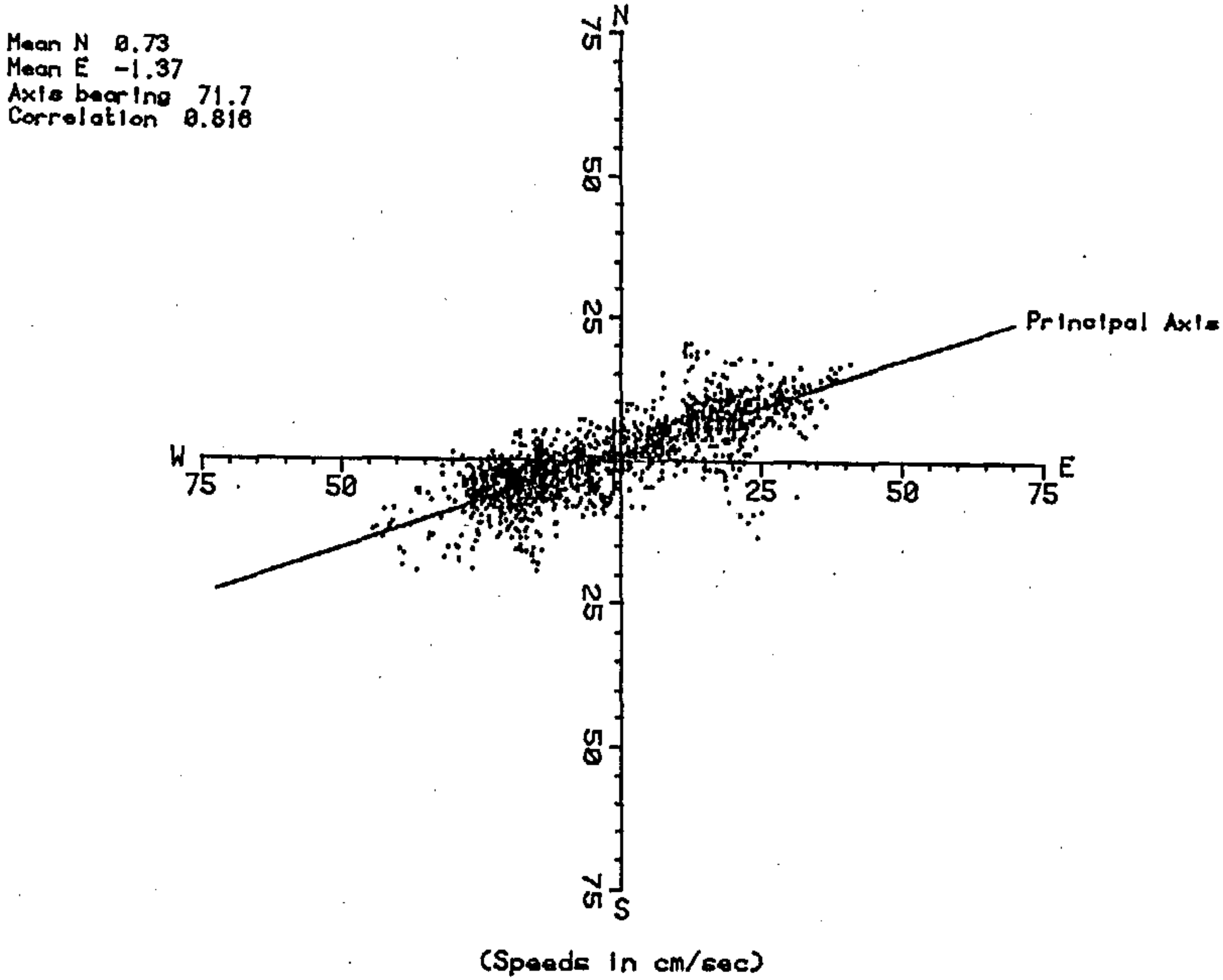


FIGURE 60. POLAR PLOT - SPEED AND DIRECTION DATA
STATION E - 1/2 HR. AVERAGE CURRENT - ENDECO #232
2122, 29 JULY TO 0722, 4 SEPTEMBER, 1982

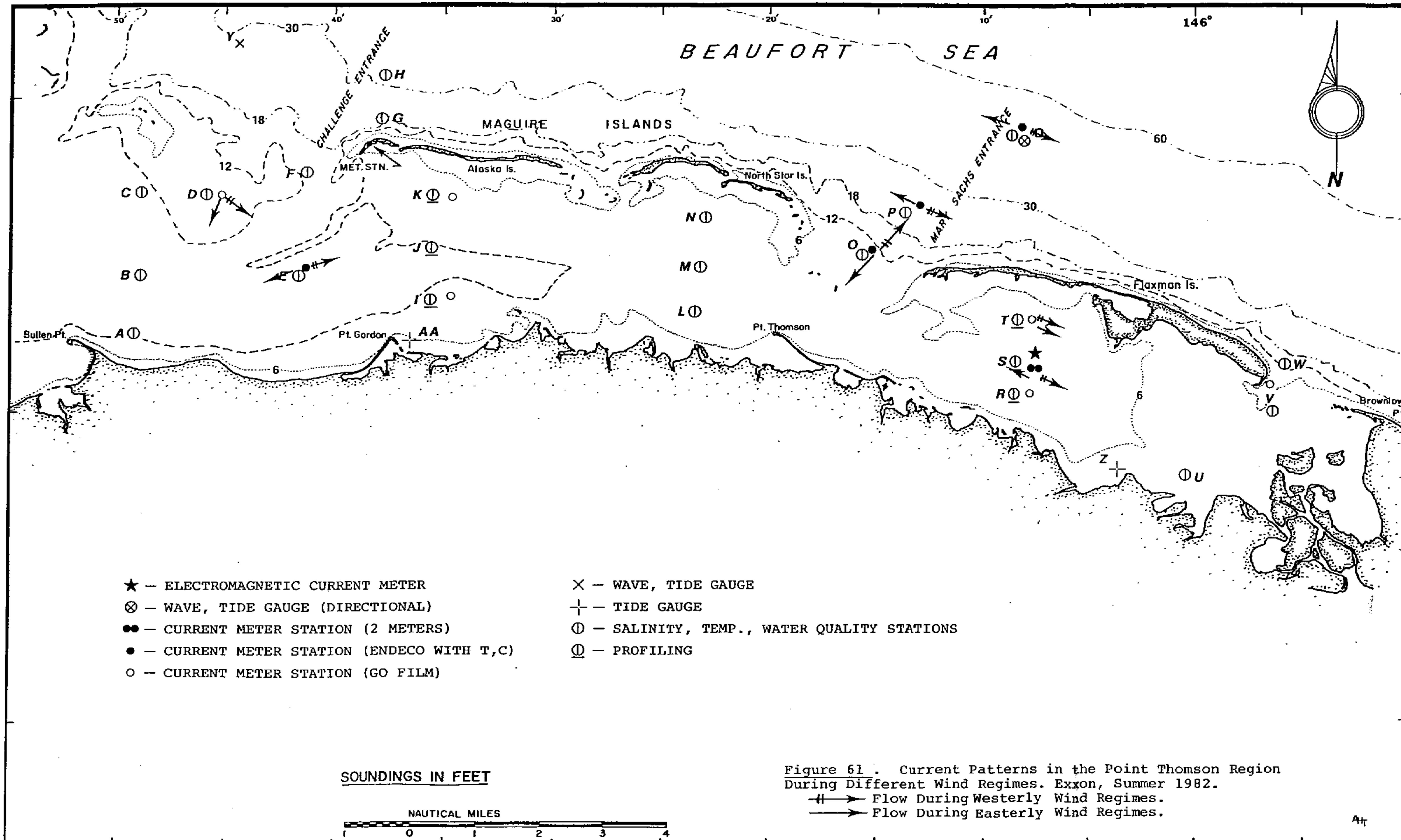


Figure 61 . Current Patterns in the Point Thomson Region During Different Wind Regimes. Exxon, Summer 1982.
—+→ Flow During Westerly Wind Regimes.
——→ Flow During Easterly Wind Regimes.

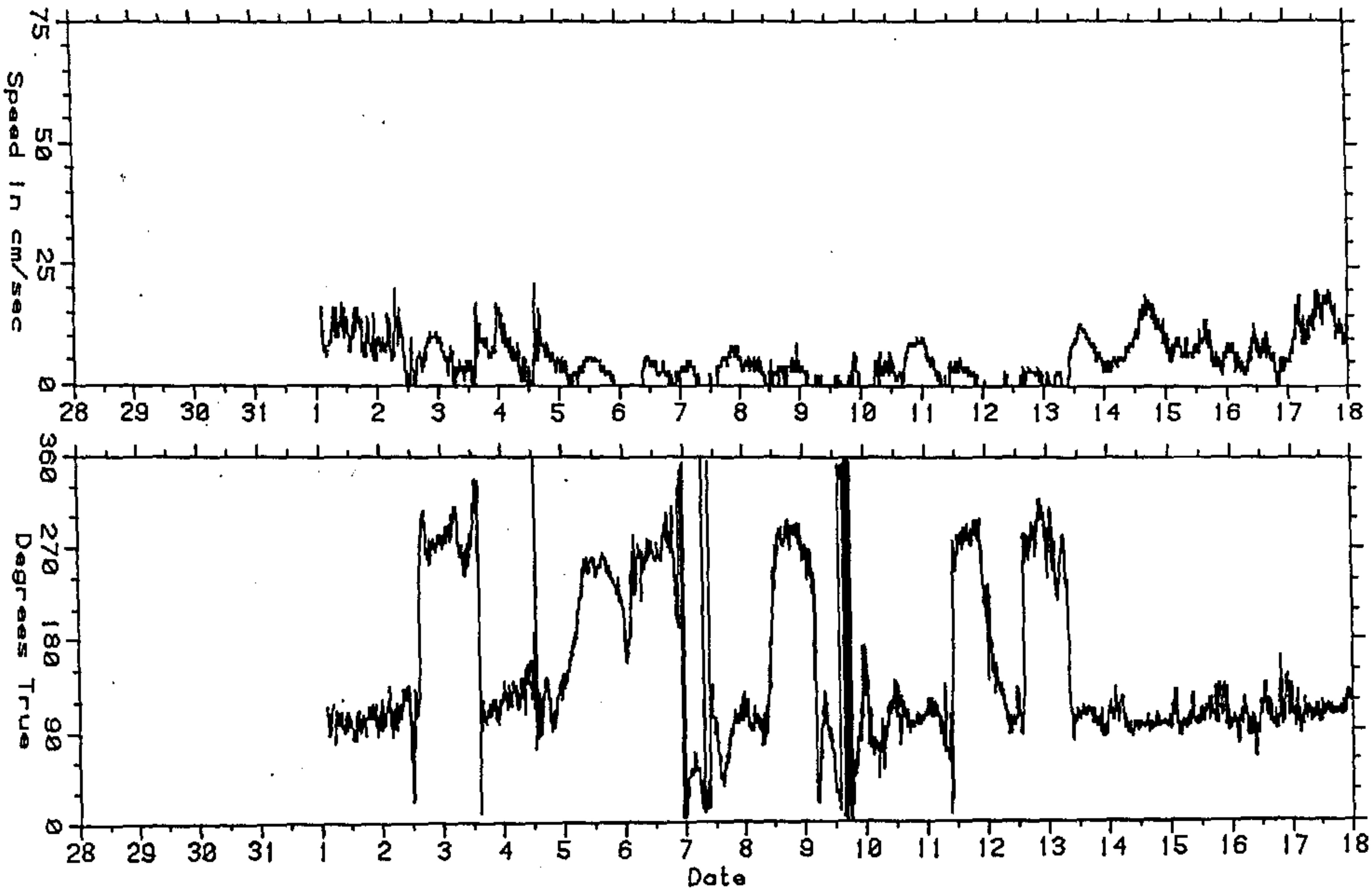


FIGURE 62. SPEED AND DIRECTION DATA
STATION Q - NORTH OF FLAXMAN ISLAND - ENDECO #047
0215, 1 AUGUST TO 0000, 18 AUGUST, 1982

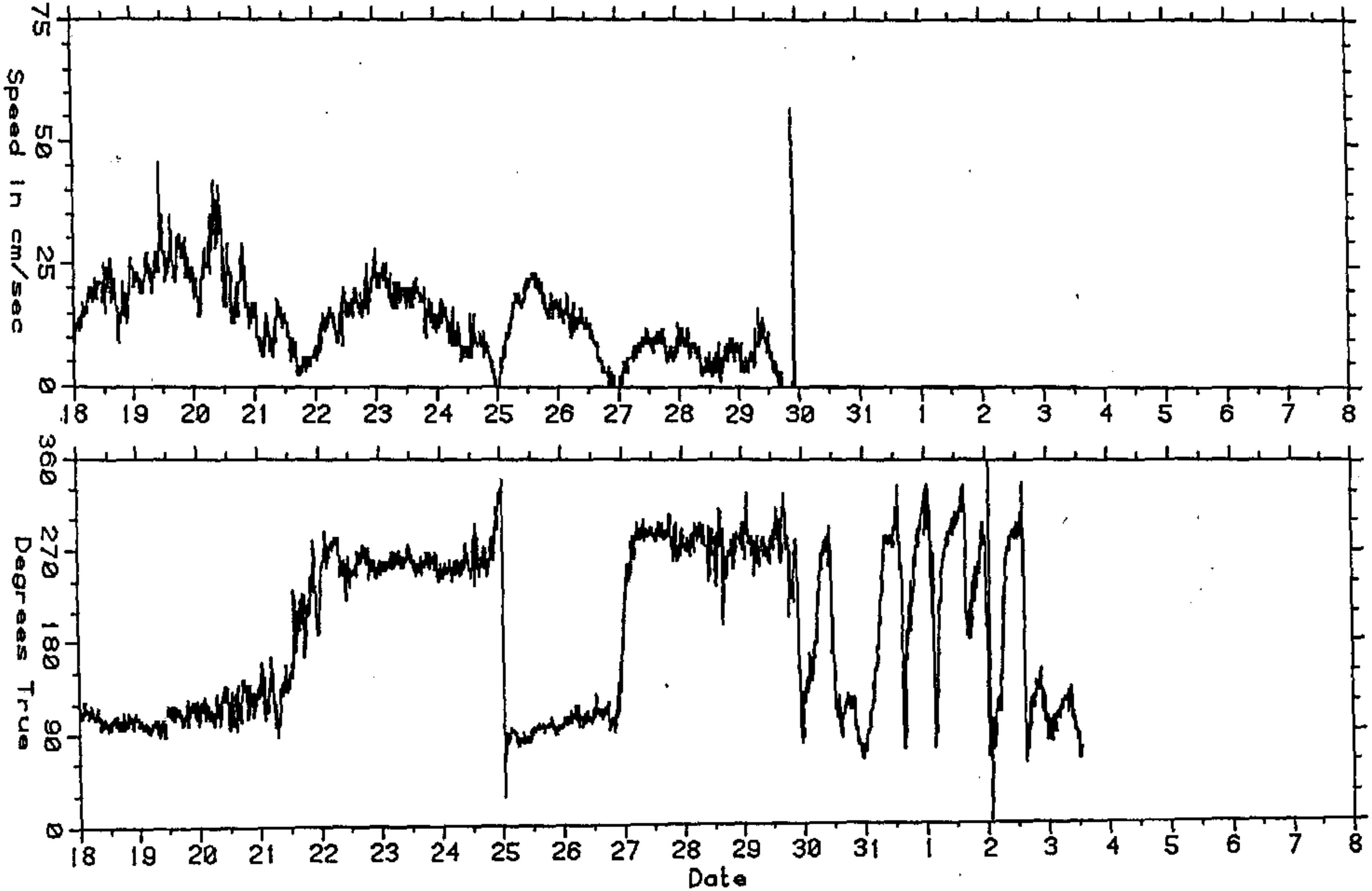


FIGURE 62 CONT. SPEED AND DIRECTION DATA
STATION Q - NORTH OF FLAXMAN ISLAND - ENDECO #047
0000, 18 AUGUST TO 1300, 3 SEPTEMBER, 1982

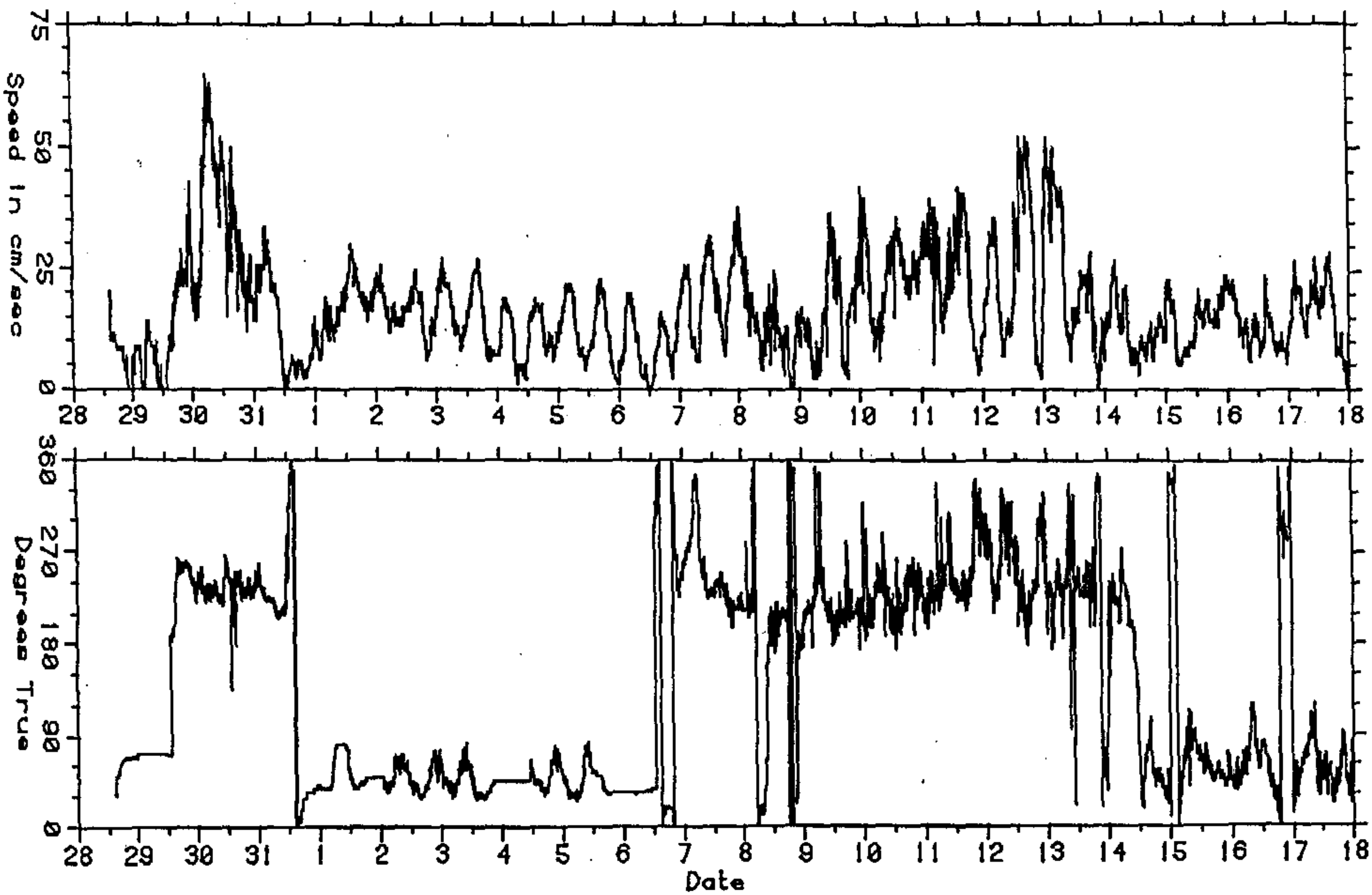


FIGURE 63. SPEED AND DIRECTION DATA
STATION O - MARY SACHS ENTRANCE - ENDECO #049
1525, 28 JULY TO 0000, 18 AUGUST, 1982

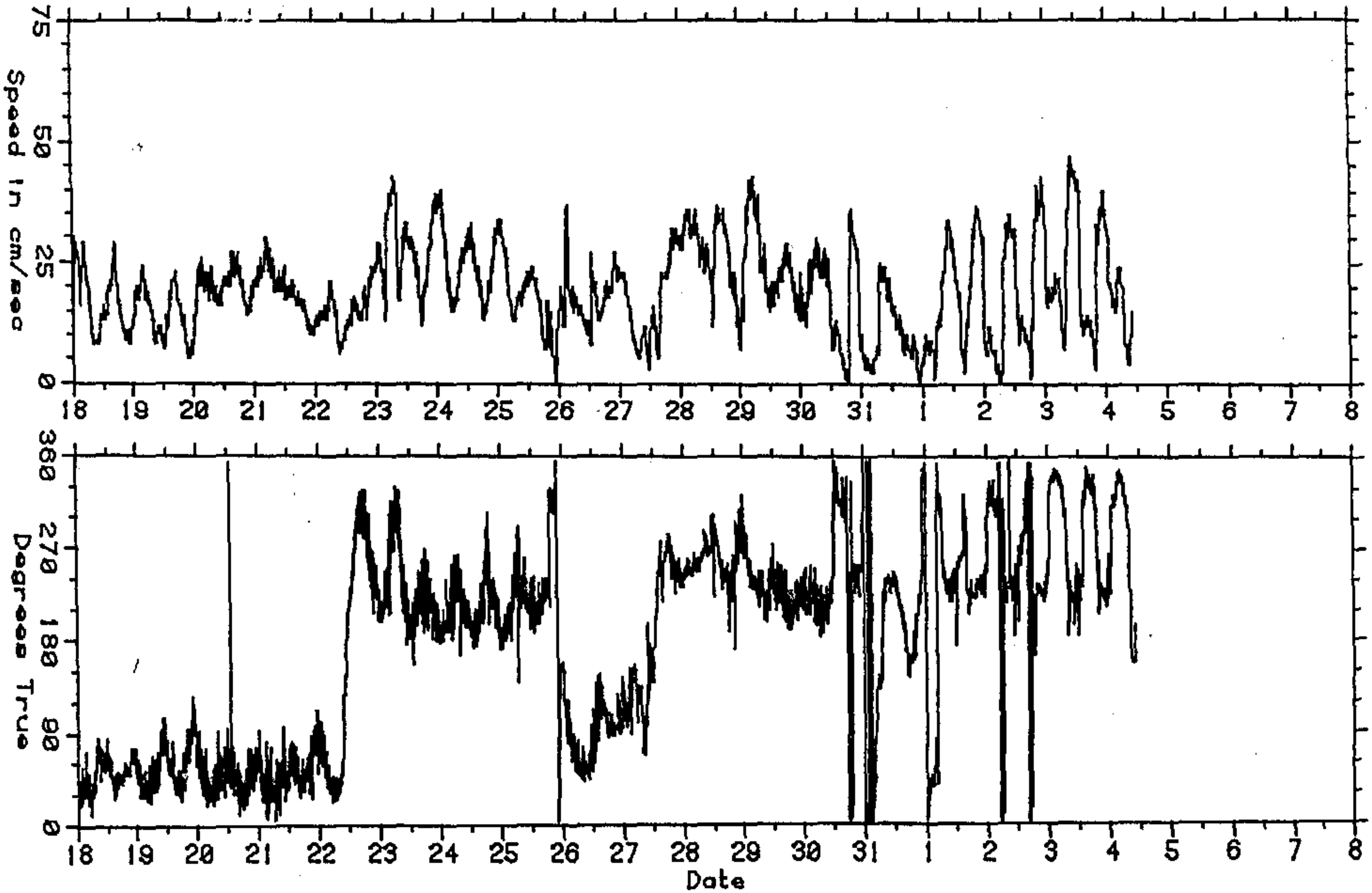
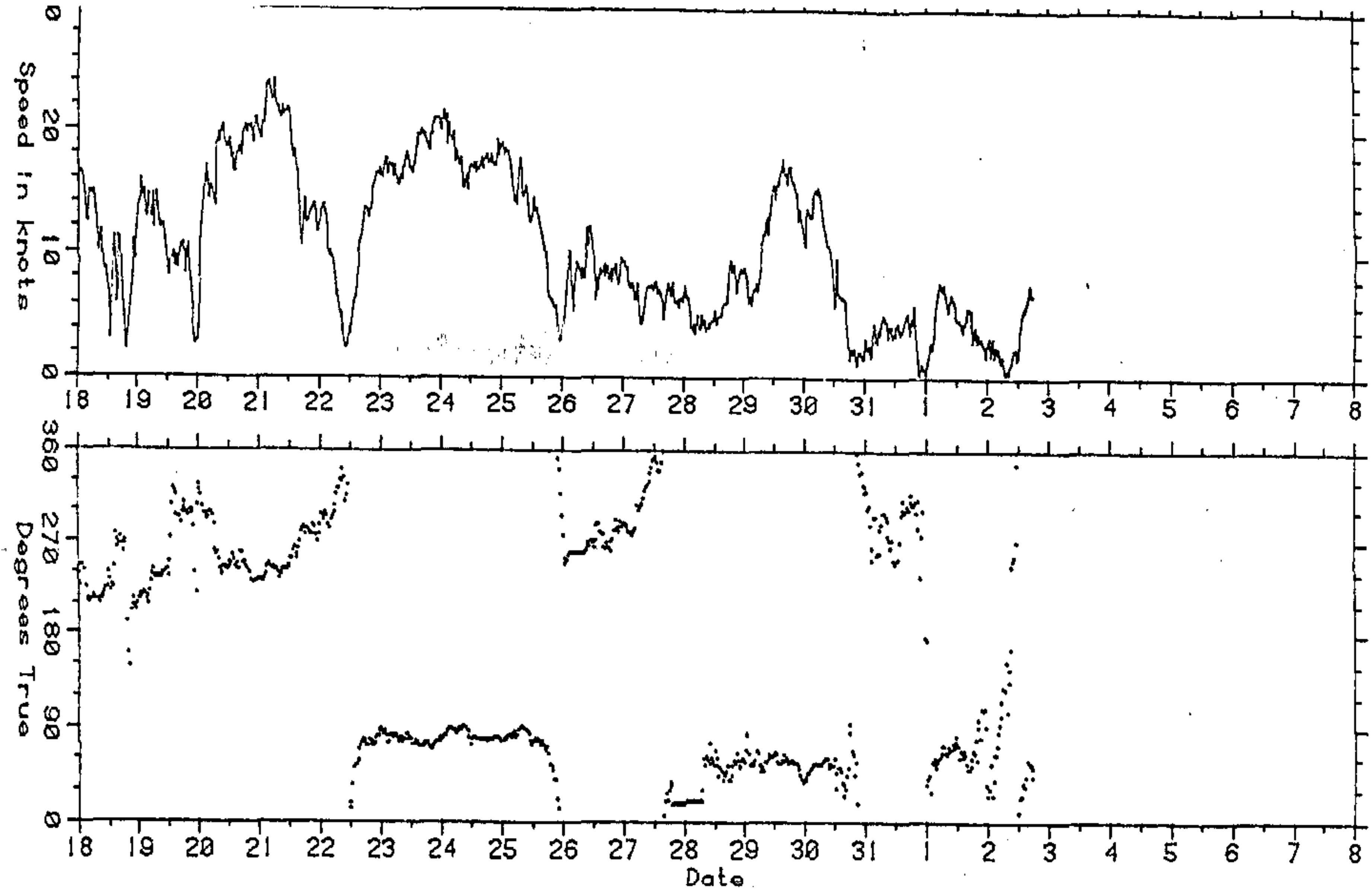
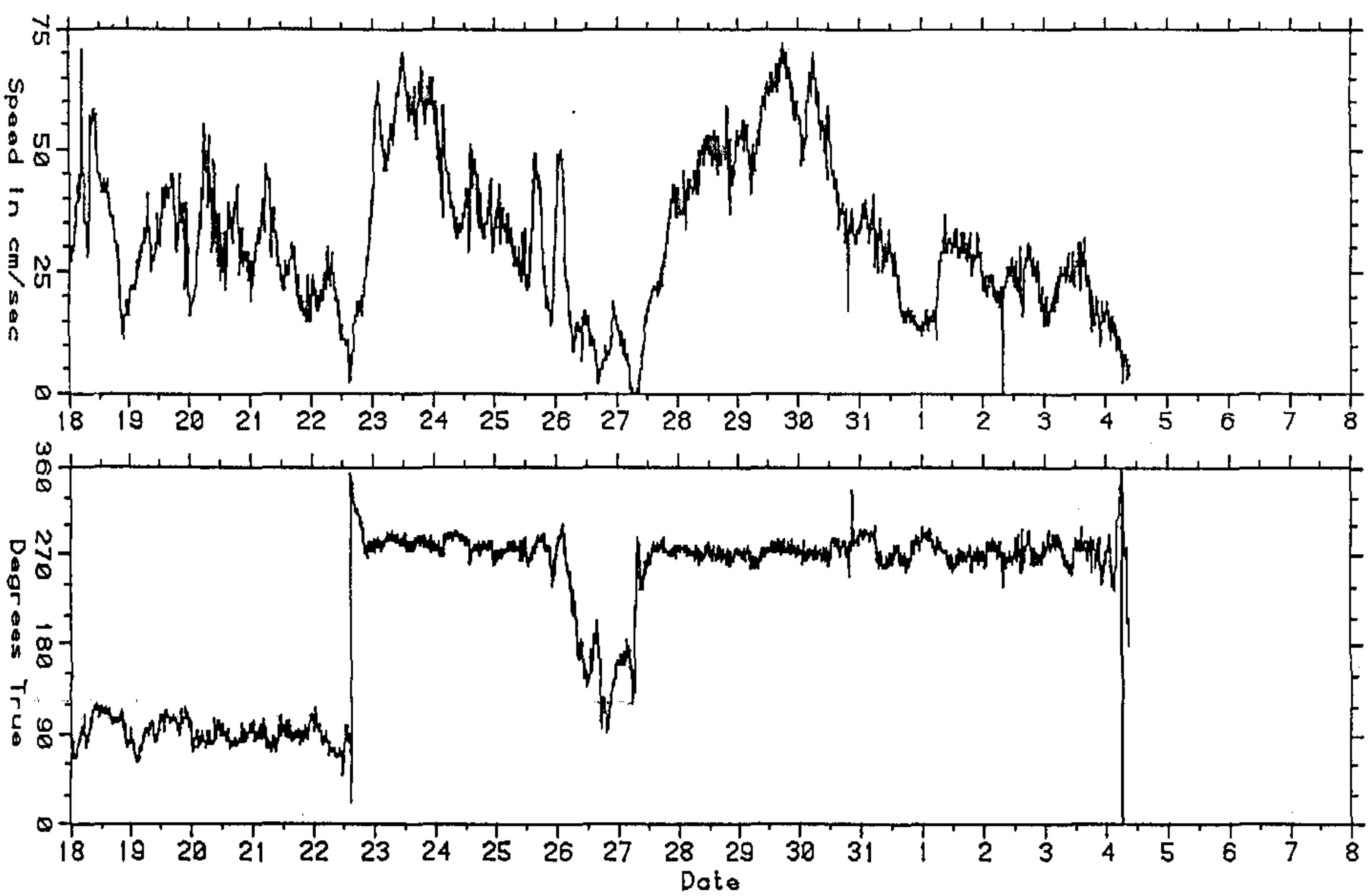


FIGURE 63 CONT. SPEED AND DIRECTION DATA
STATION O - MARY SACHS ENTRANCE - ENDECO #049
0000, 18 AUGUST TO 1035, 4 SEPTEMBER, 1982

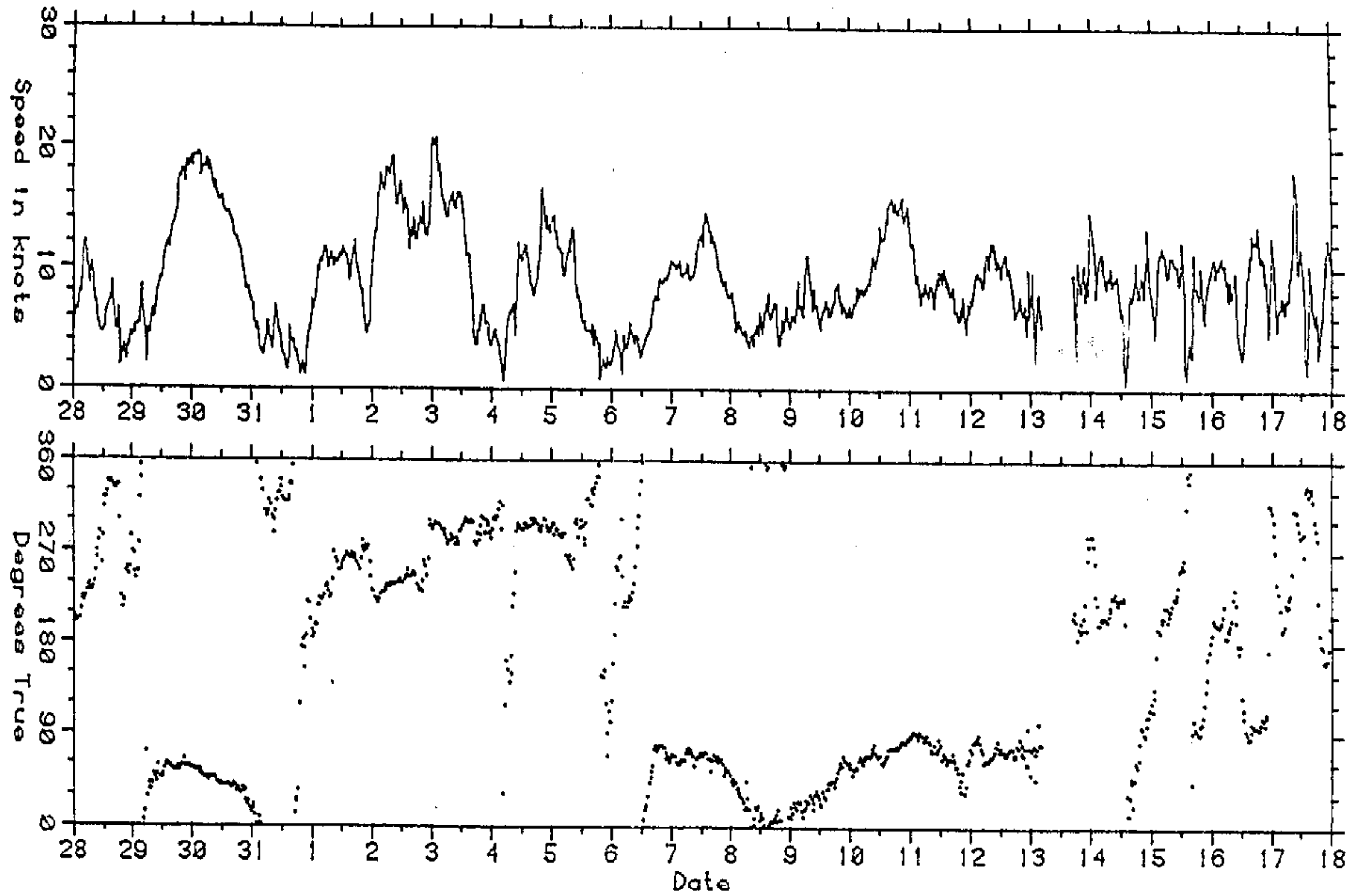


SPEED AND DIRECTION DATA
CHALLENGE ISLAND WIND
0008, 18 AUGUST TO 1738, 2 SEPTEMBER, 1982

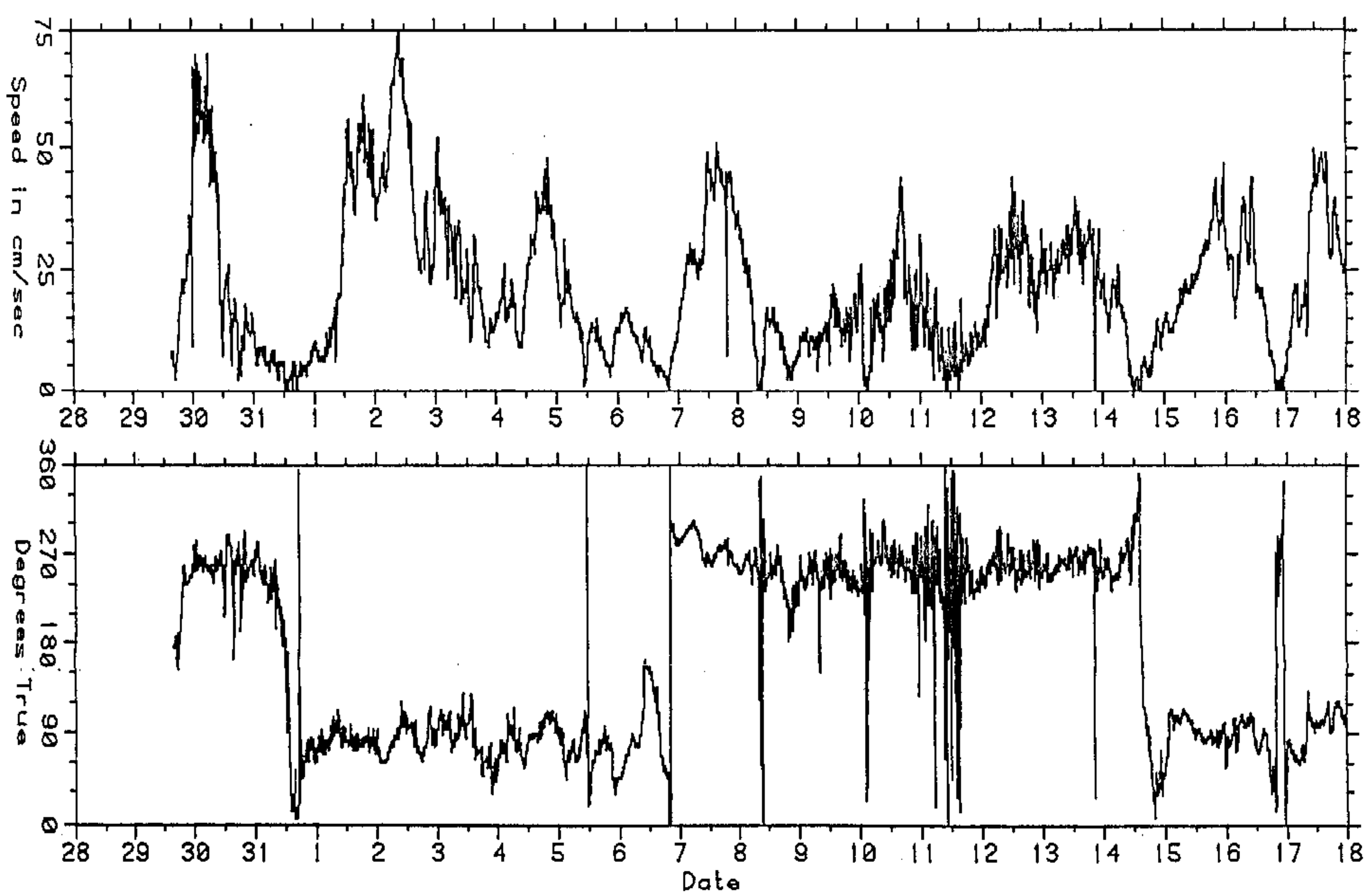


SPEED AND DIRECTION DATA
STATION P - MARY SACHS ENTRANCE - ENDECO #048
0002, 18 AUGUST TO 0922, 4 SEPTEMBER, 1982

FIGURE 64. COMPARISON OF CURRENTS AT STATION P AND CHALLENGE ISLAND WINDS.



SPEED AND DIRECTION DATA
CHALLENGE ISLAND WIND
0008, 28 JULY TO 2338, 17 AUGUST, 1982



SPEED AND DIRECTION DATA
STATION P - MARY SACHS ENTRANCE - ENDECO #048
1532, 29 JULY TO 2357, 17 AUGUST, 1982

FIGURE 64 CONT. COMPARISON OF CURRENTS AT STATION P AND CHALLENGE ISLAND WINDS.

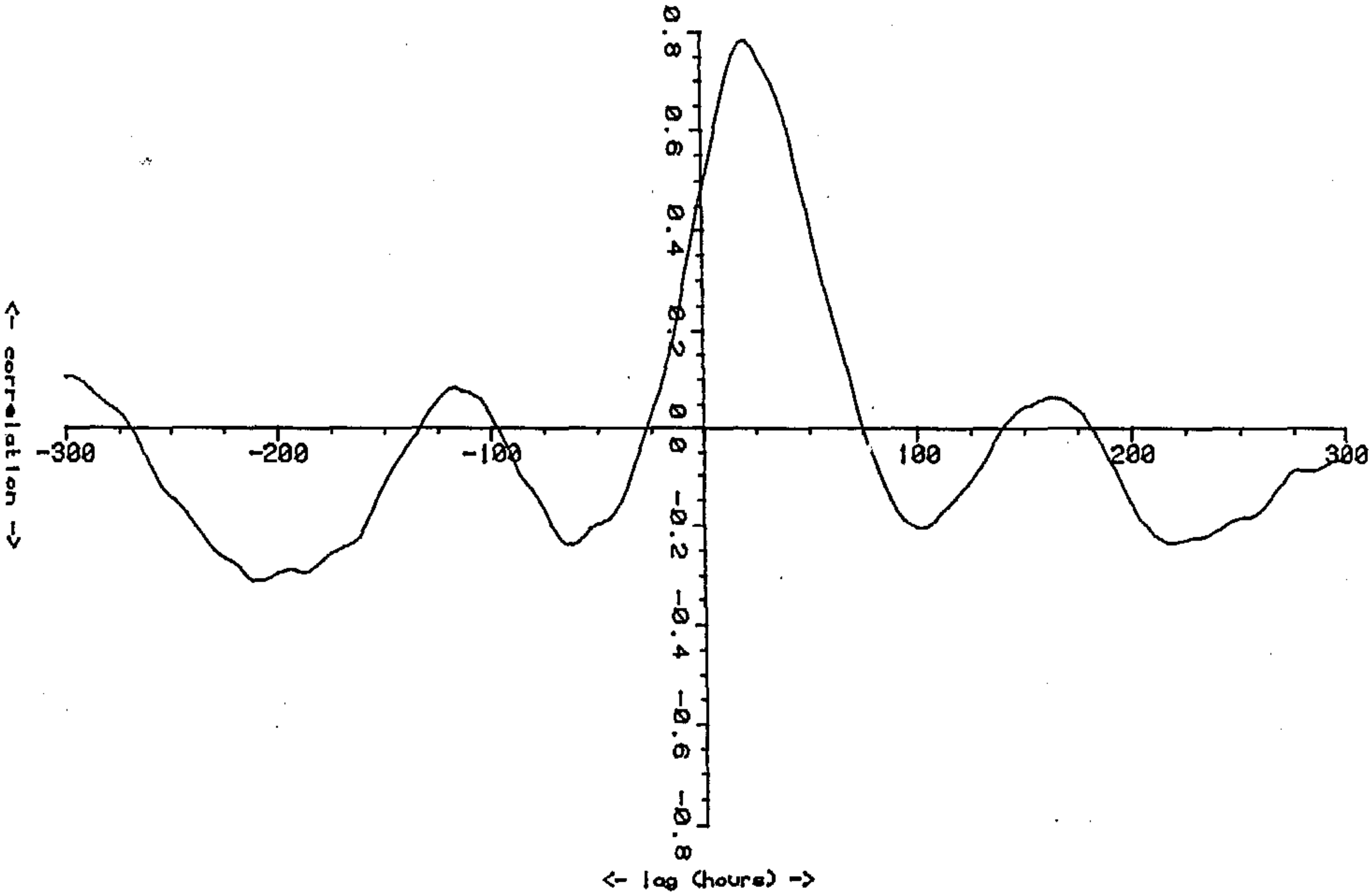


FIGURE 65. CROSS CORRELATIONS
CHALLENGE ISLAND WIND (71 DEG. COMP.) VS. LAGGED PT. THOMSON
STATION Q CURRENT (99 DEG. COMP.) (T=3 HR)
0233 1 AUGUST TO 1733 2 SEPTEMBER 1982

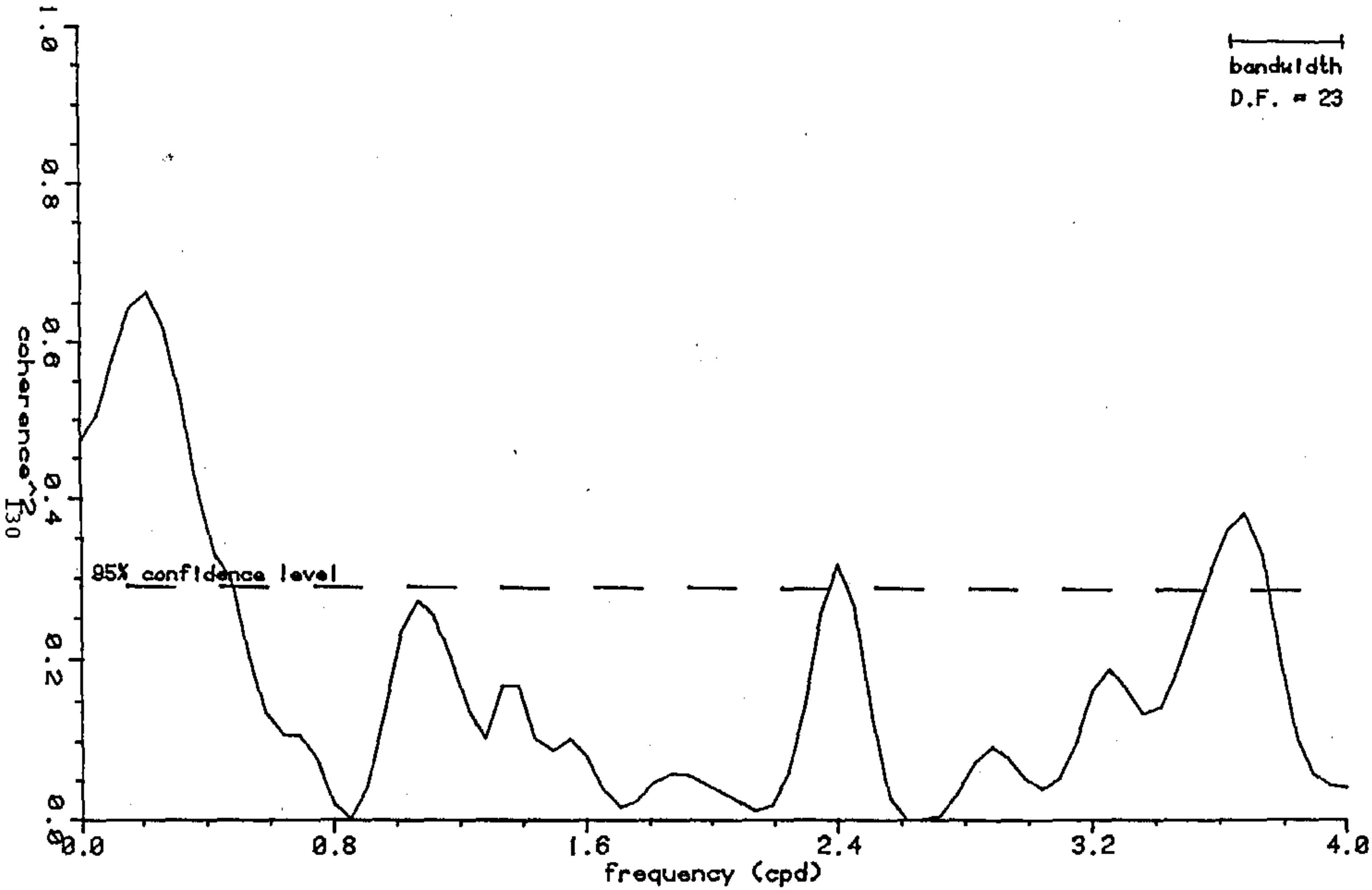


FIGURE 66. SQUARED COHERENCE SPECTRUM
CHALLENGE ISLAND WIND (71 DEG. COMP.) VS. LAGGED PT. THOMSON
STATION Q CURRENT (99 DEG. COMP.) (T=3 HR)

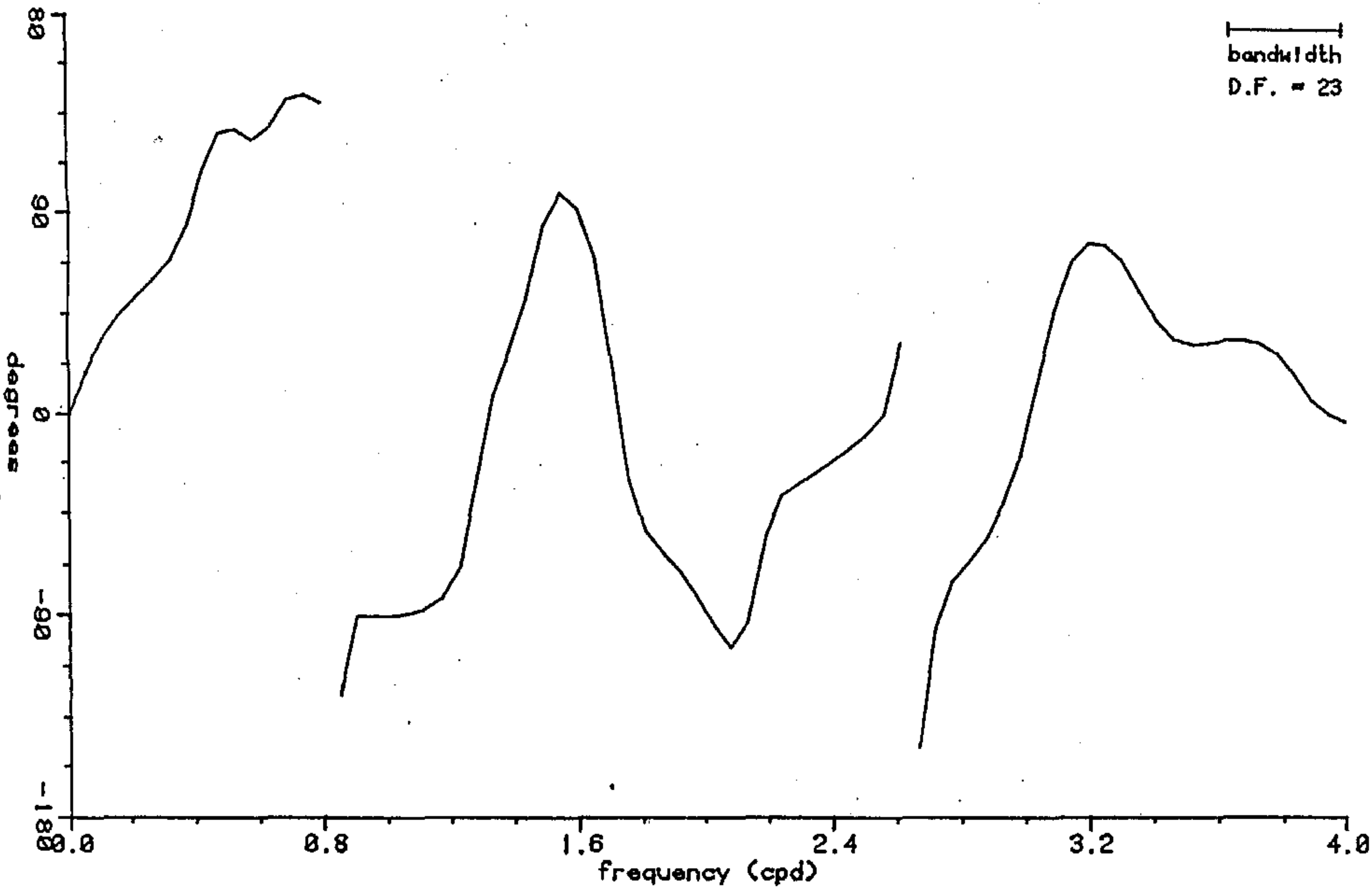


FIGURE 67. PHASE SPECTRUM
CHALLENGE ISLAND WIND (71 DEG. COMP.) VS. LAGGED PT. THOMSON STATION Q CURRENT (99 DEG. COMP.) (T=3 HR)

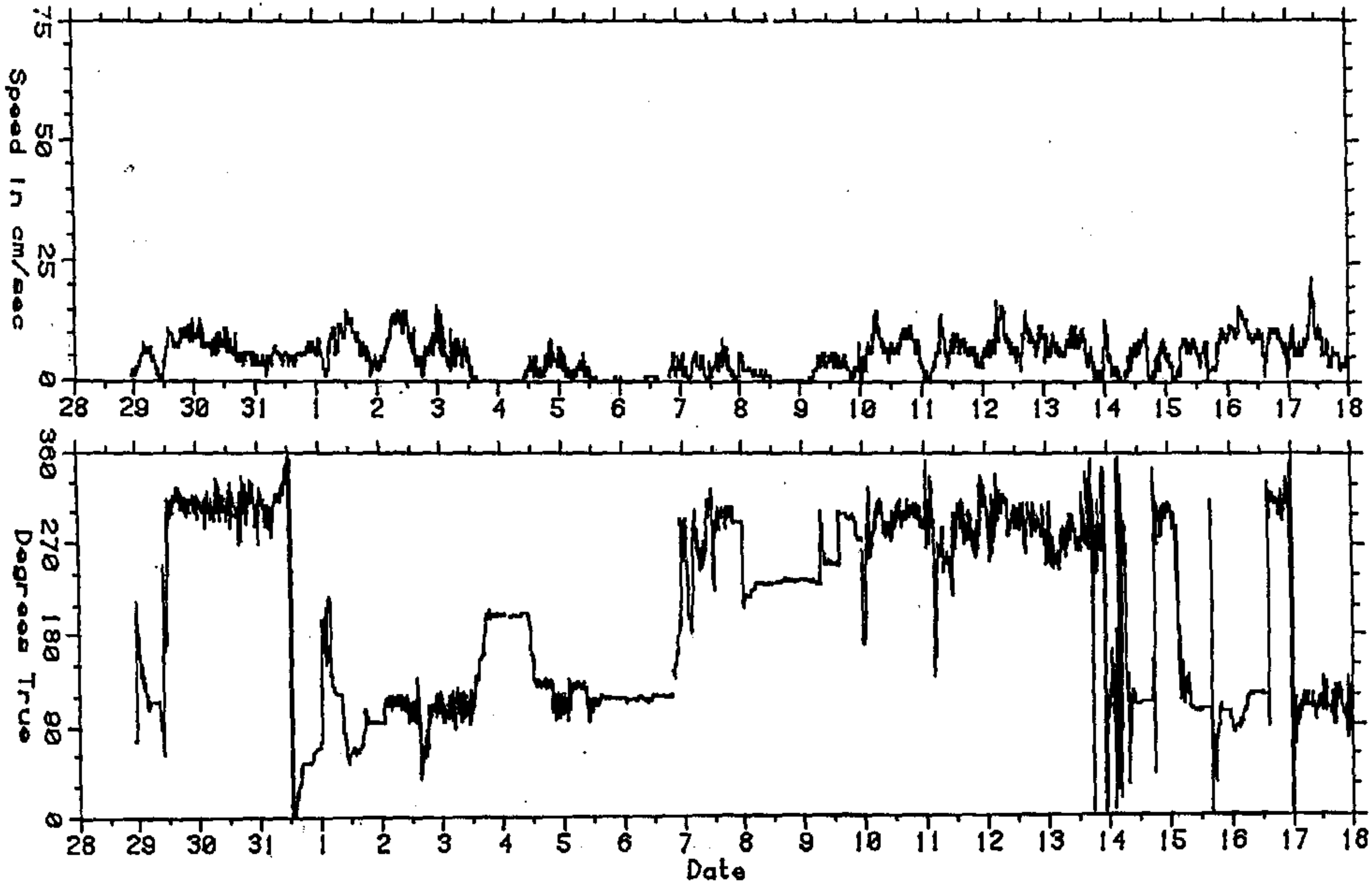


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FIGURE 68. Speed and Direction Data
Station S (Top), South of Flaxman Island, Endeco #175
2239, 28 July to 2359, 17 August, 1982.

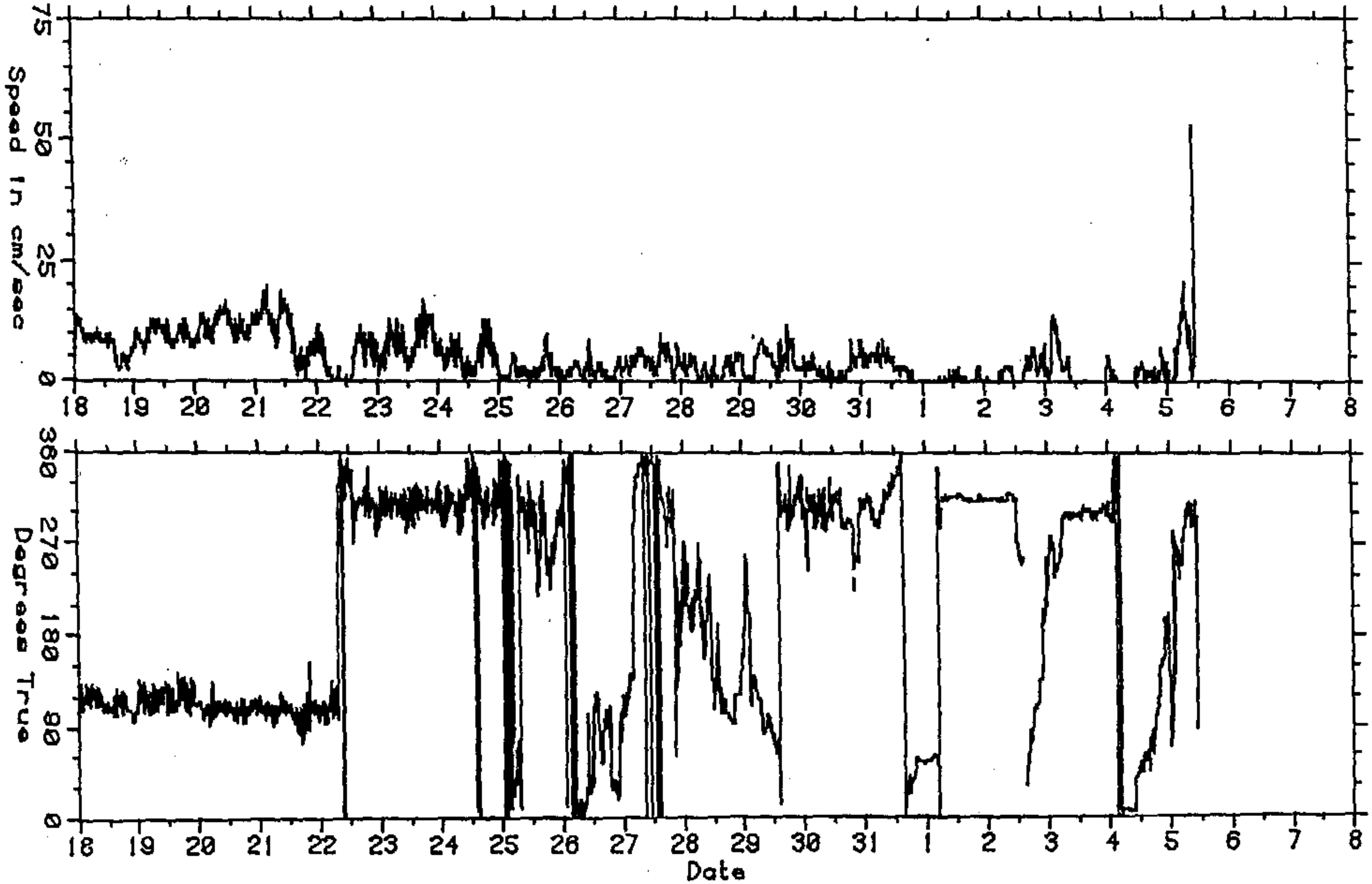


FIGURE 68 CONT. SPEED AND DIRECTION DATA
STATION S (TOP) - SOUTH OF FLAXMAN ISLAND - ENDECO #175
0004, 18 JULY TO 1044, 5 SEPTEMBER, 1982

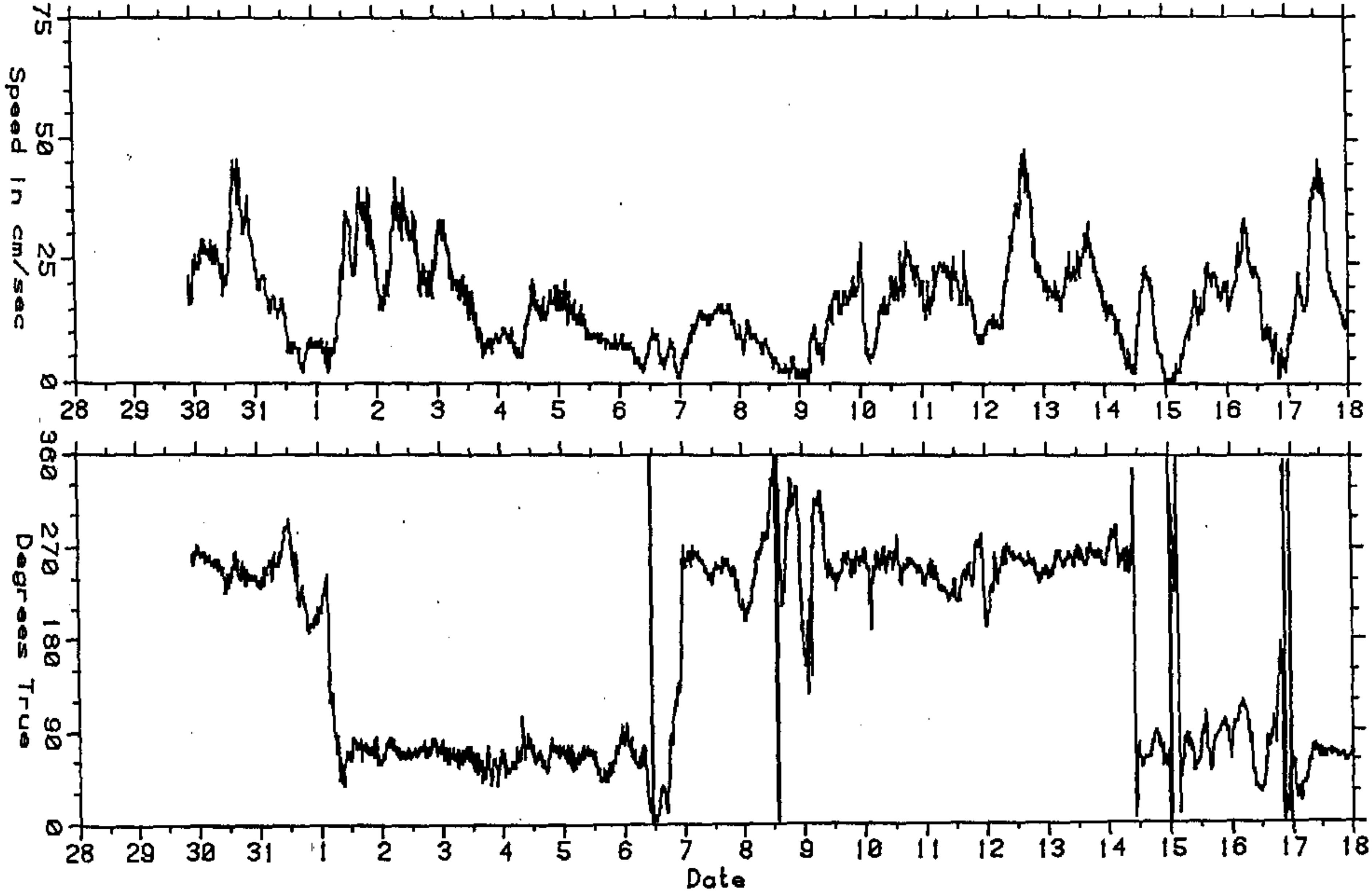


FIGURE 69. Speed and Direction Data
Station E; South of Alaska Island, Endeco #232
2109, 29 July to 2359, 17 August, 1982

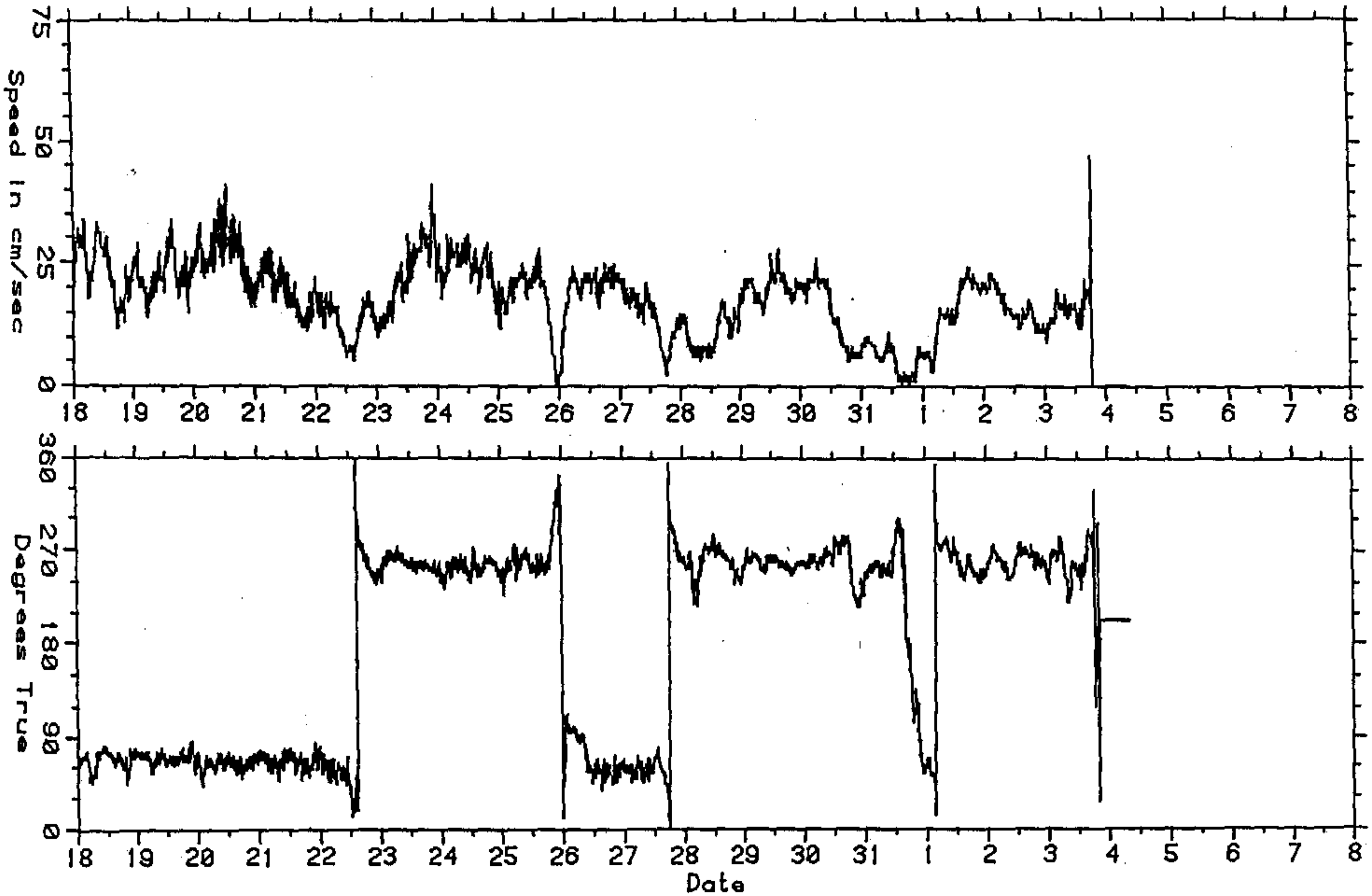
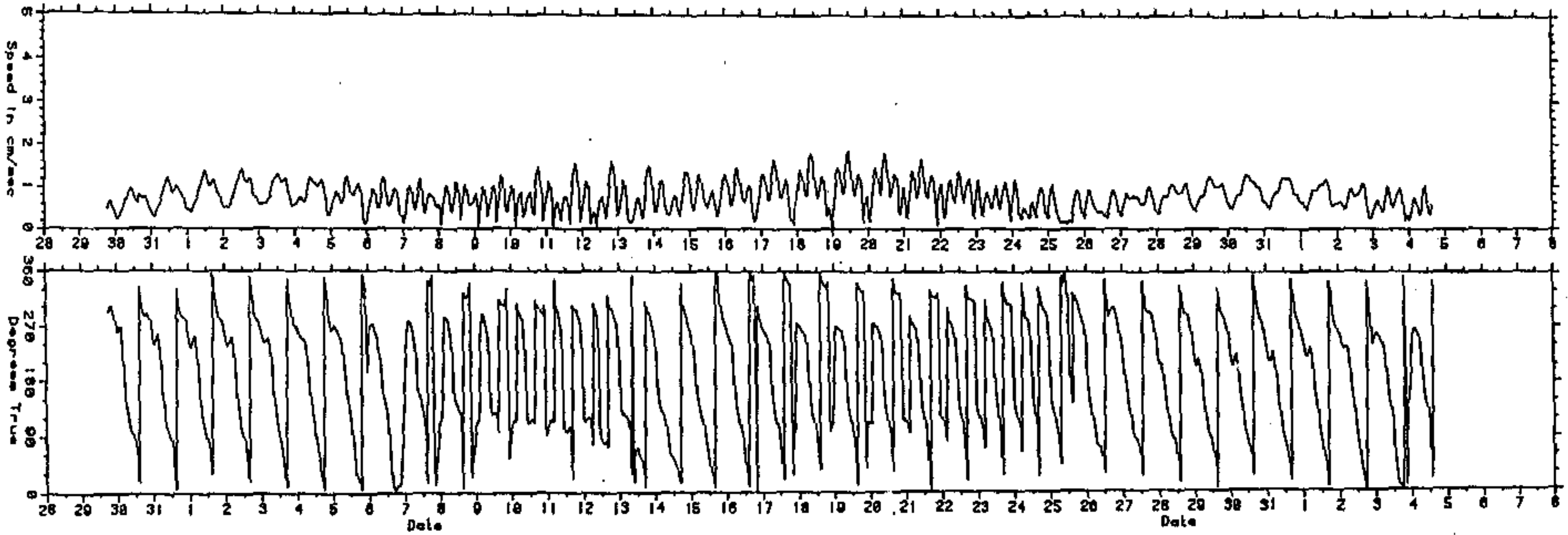


FIGURE 69 CONT. Speed and Direction Data
Station E, South of Alaska Island, Endeco #232
0004, 18 August to 0754, 4 September, 1982.



<u>Figure 70.</u> Speed and Direction Data Station S (Bottom); Least Squares Tidal Currents, 1757, 29 July to 1457, 4 September 1982.

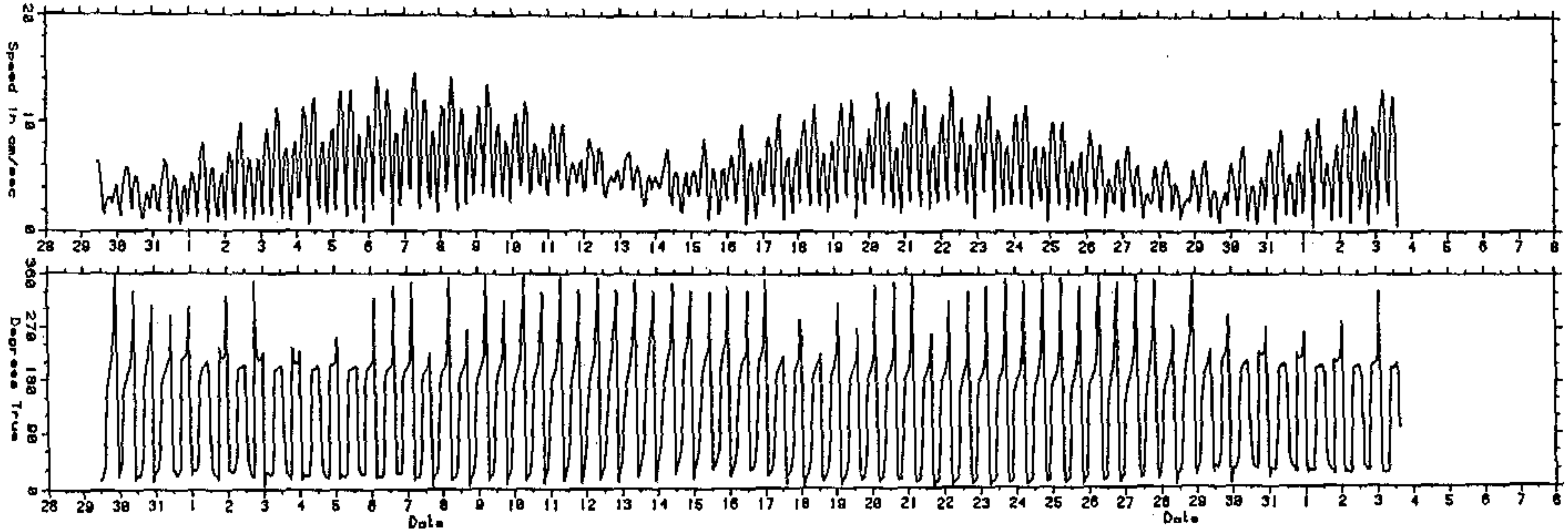


Figure 71. Speed and Direction Data Station 0, Least-Squares Tidal Current, Endeco #049, 1053, 29 July to 1453, 3 September 1982.

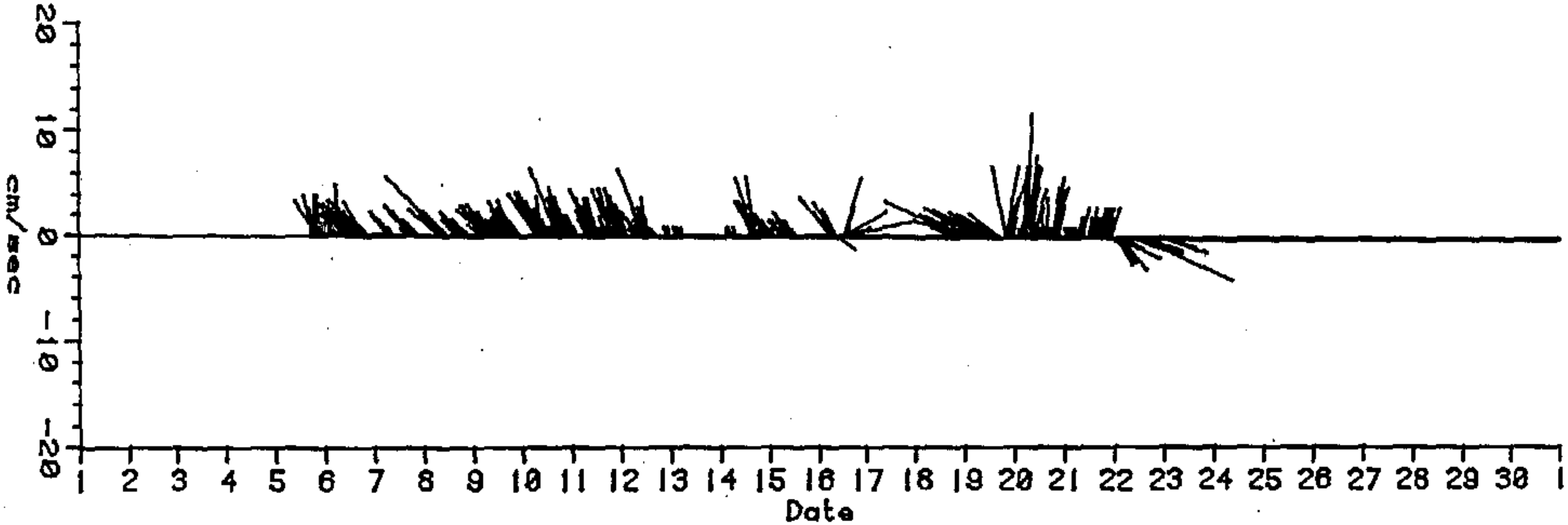


FIGURE 72. VECTOR STICK PLOT
POINT THOMSON STATION SP CURRENT
1600, 5 SEPTEMBER TO 2300, 30 SEPTEMBER, 1982

N

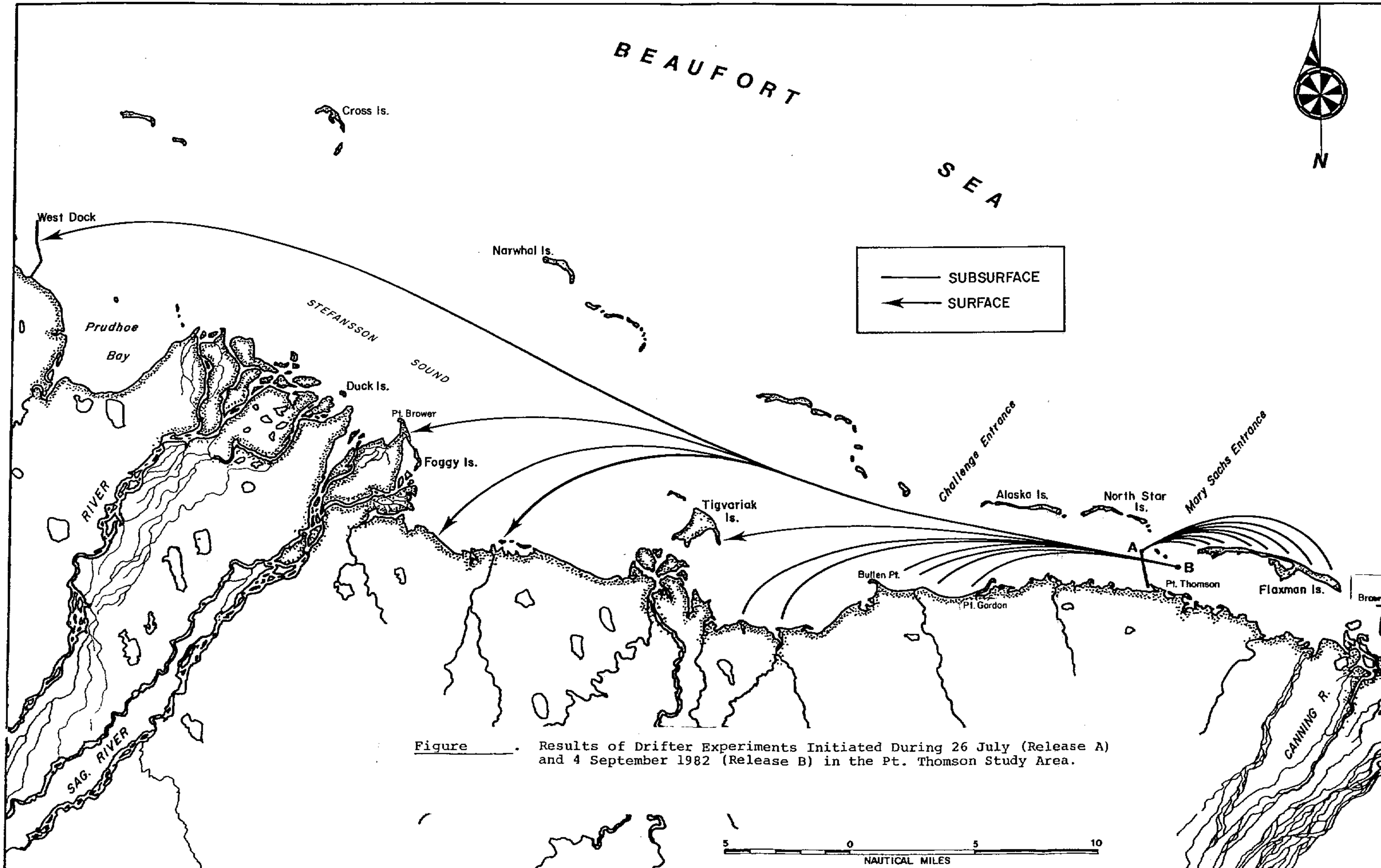


Figure . Results of Drifter Experiments Initiated During 26 July (Release A) and 4 September 1982 (Release B) in the Pt. Thomson Study Area.

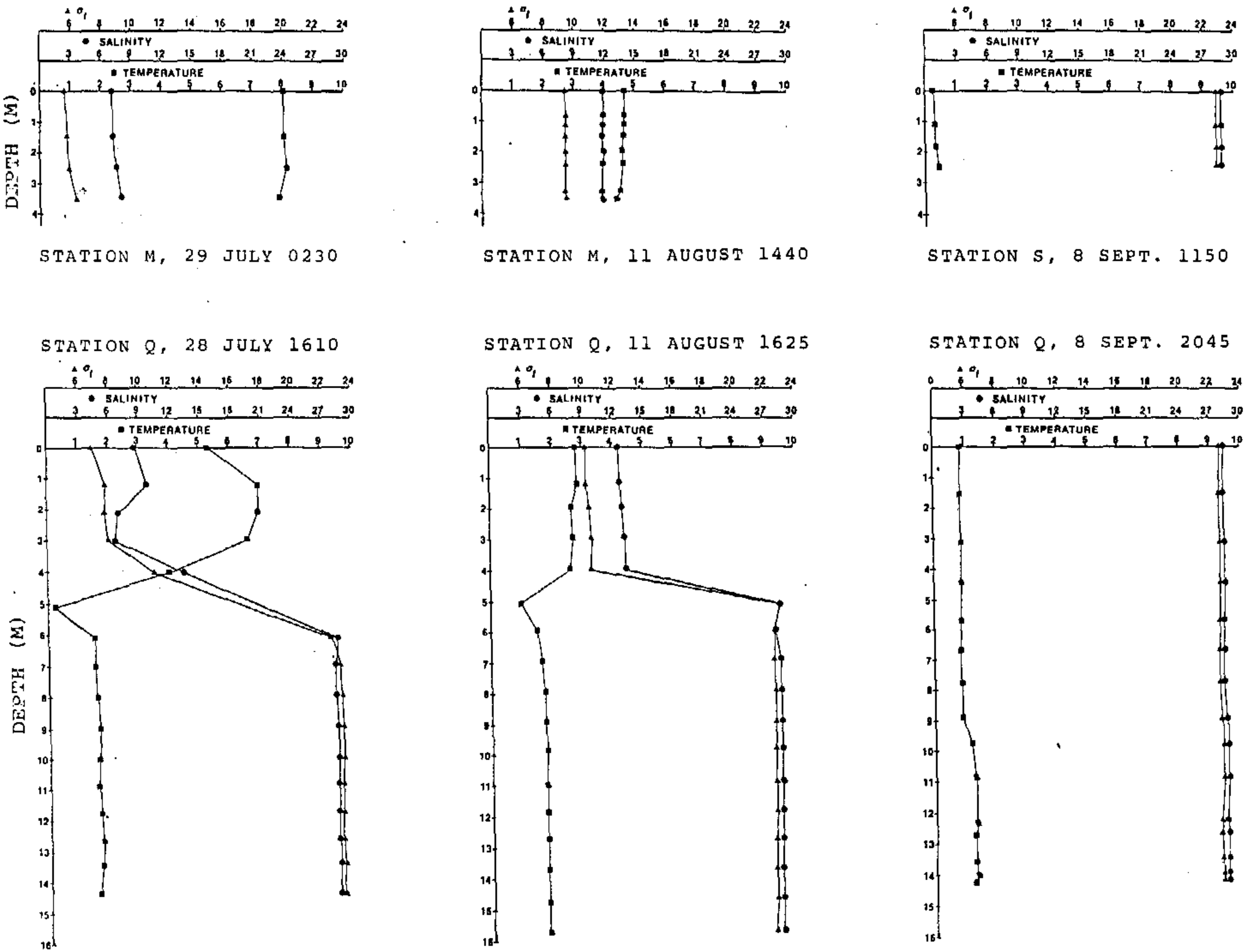
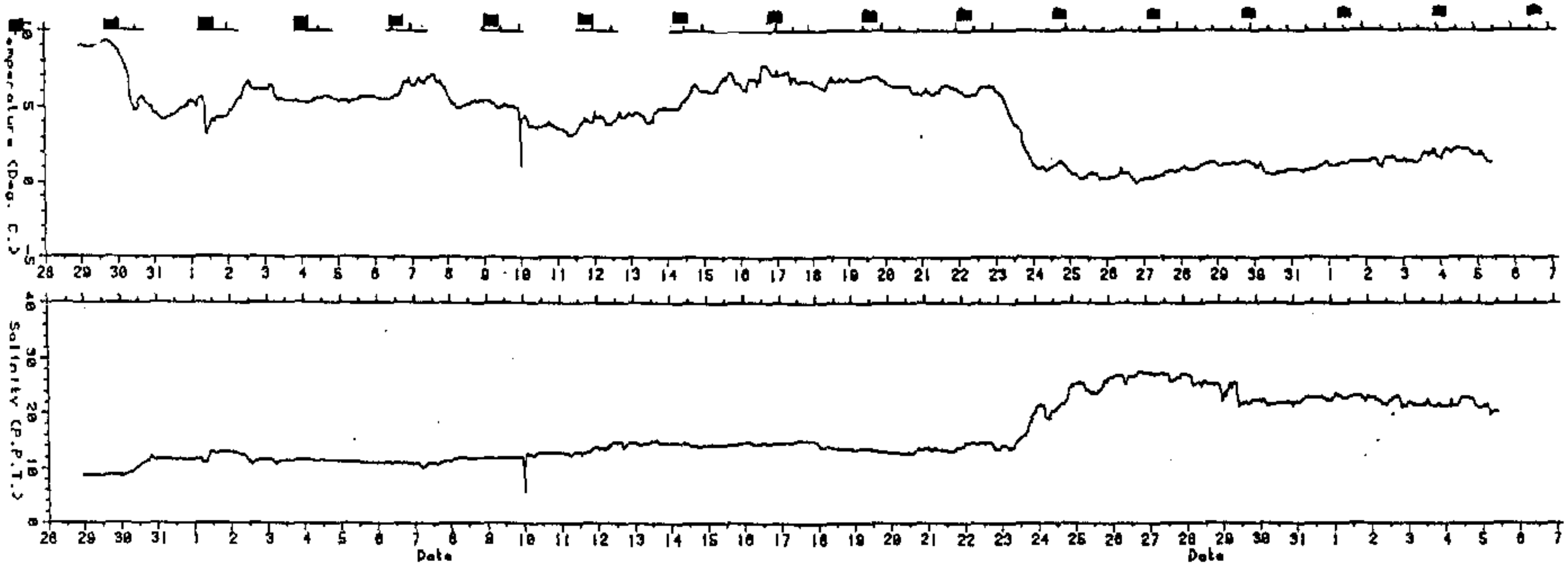


Figure 74. Salinity, Temperature, and Density Profiles vs Depth. Typical Lagoon and Offshore Stations, Pt. Thomson Region. Summer 198[illegible]



Temperature and Salinity Data
Station S (Top); 1/2 Hr.
Averages, Endeco #175, 2252,
28 July to 1022, 5 September 1982.

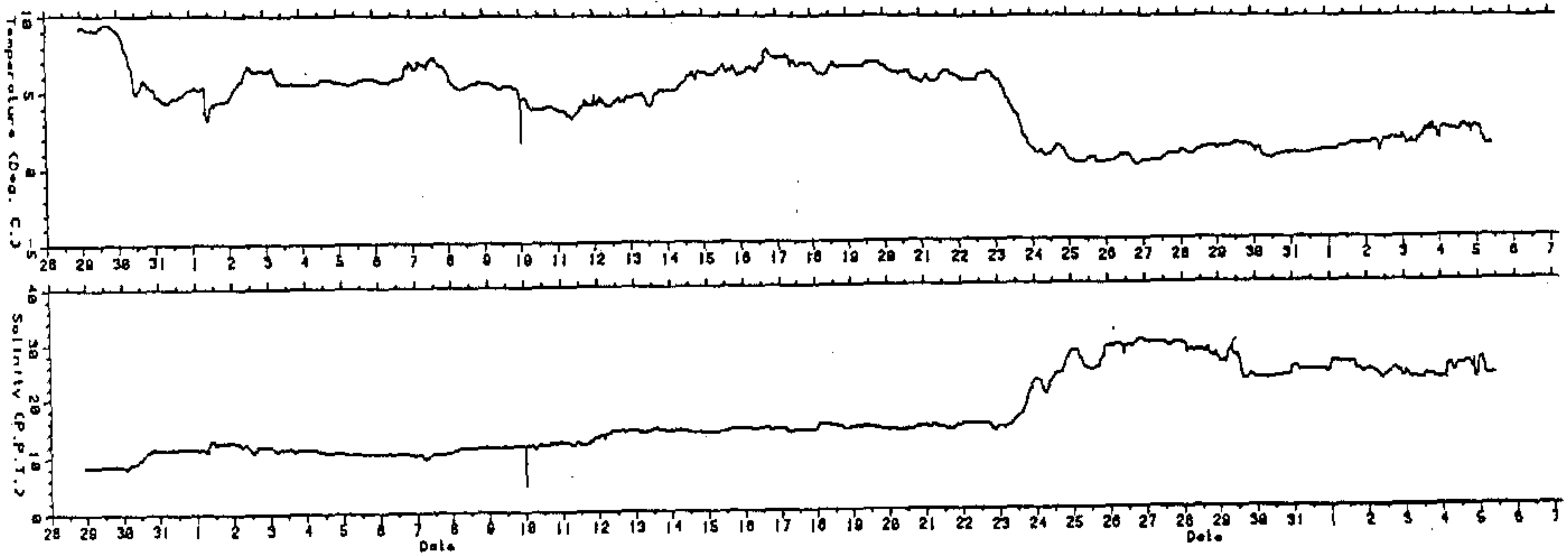
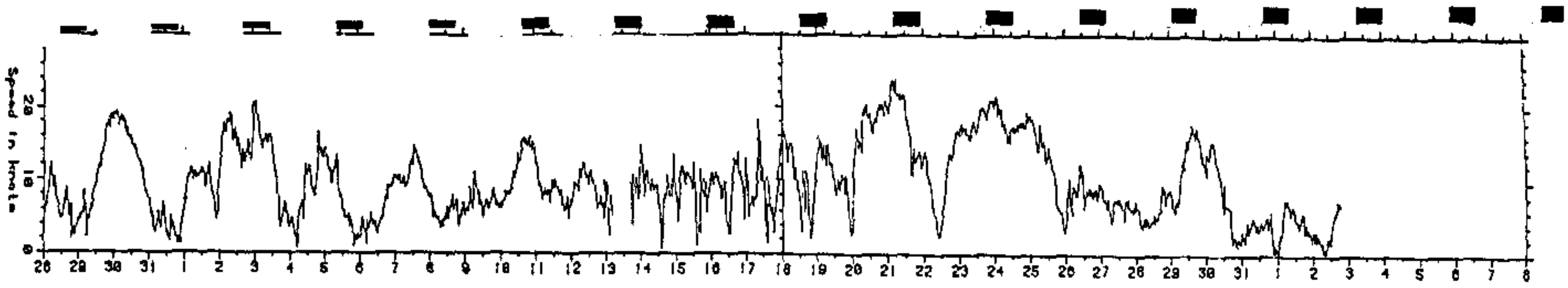
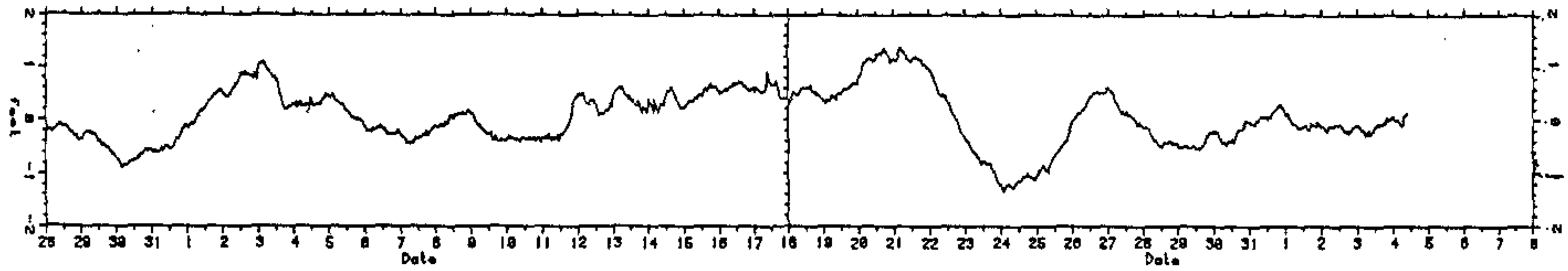


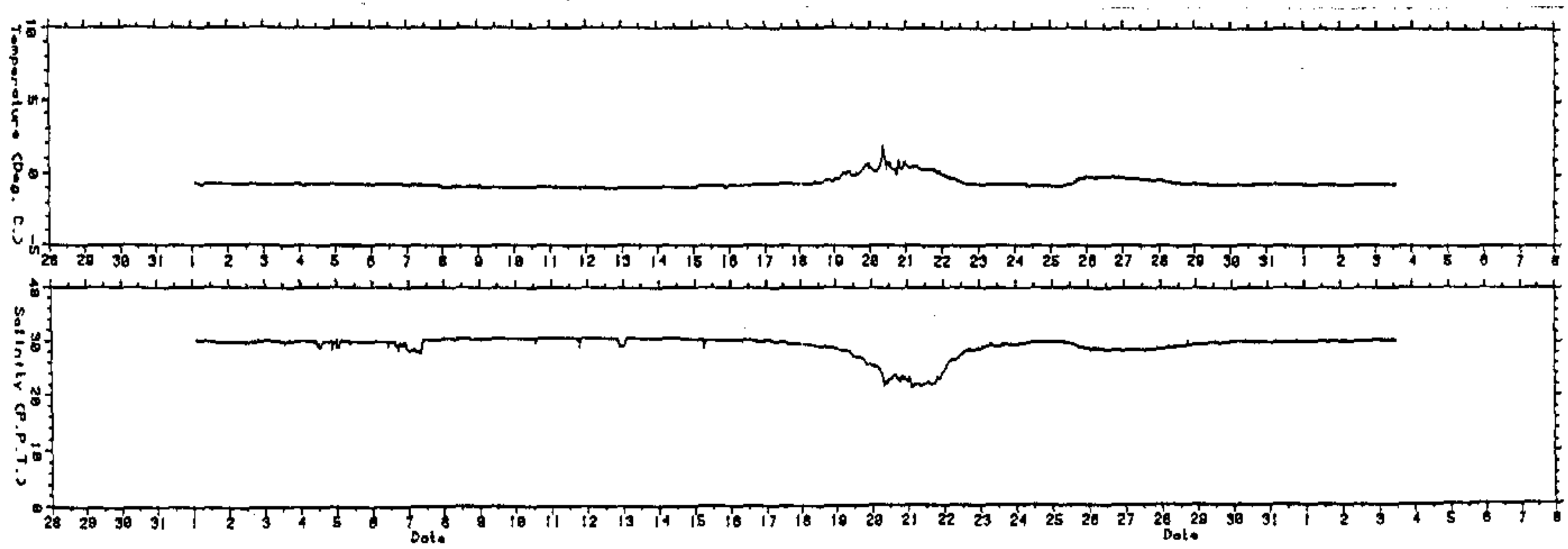
Figure 75. Temperature and Salinity Data
Station S (Bottom); 1/2 Hr.
Averages, Endeco #052, 2242,
28 July to 1012, 5 September 1982.



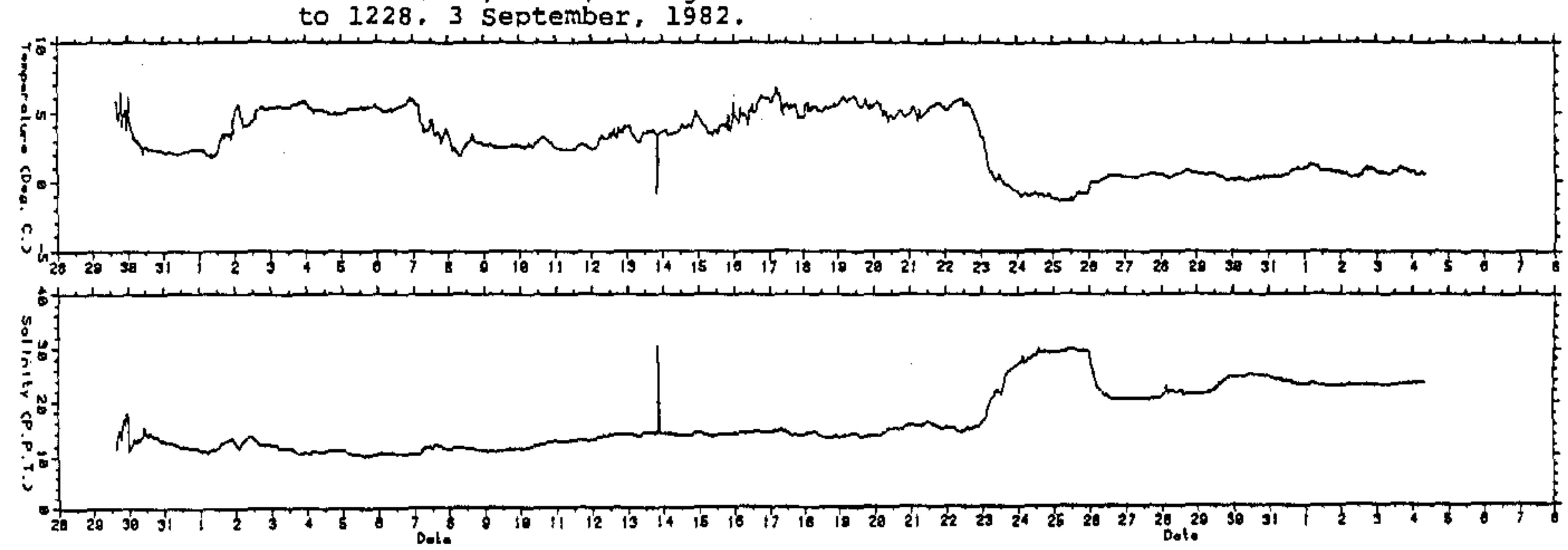
SPEED DATA
CHALLENGE ISLAND WIND
0000, 28 JULY TO 1730, 2 SEPTEMBER, 1982



SURGE WATER DEPTH (TOTAL - TIDES)
POINT THOMSON STATION Z
0037, 28 JULY TO 2037, 4 SEPTEMBER, 1982



Temperature and Salinity Data
Station Q; 1/2 Hr. Averages,
Endeco #047, 0228, 1 August
to 1228, 3 September, 1982.



Temperature and Salinity Data
Station P; 1/2 Hr. Averages,
Endeco #048, 1545, 29 July to
0845, 4 September 1982.

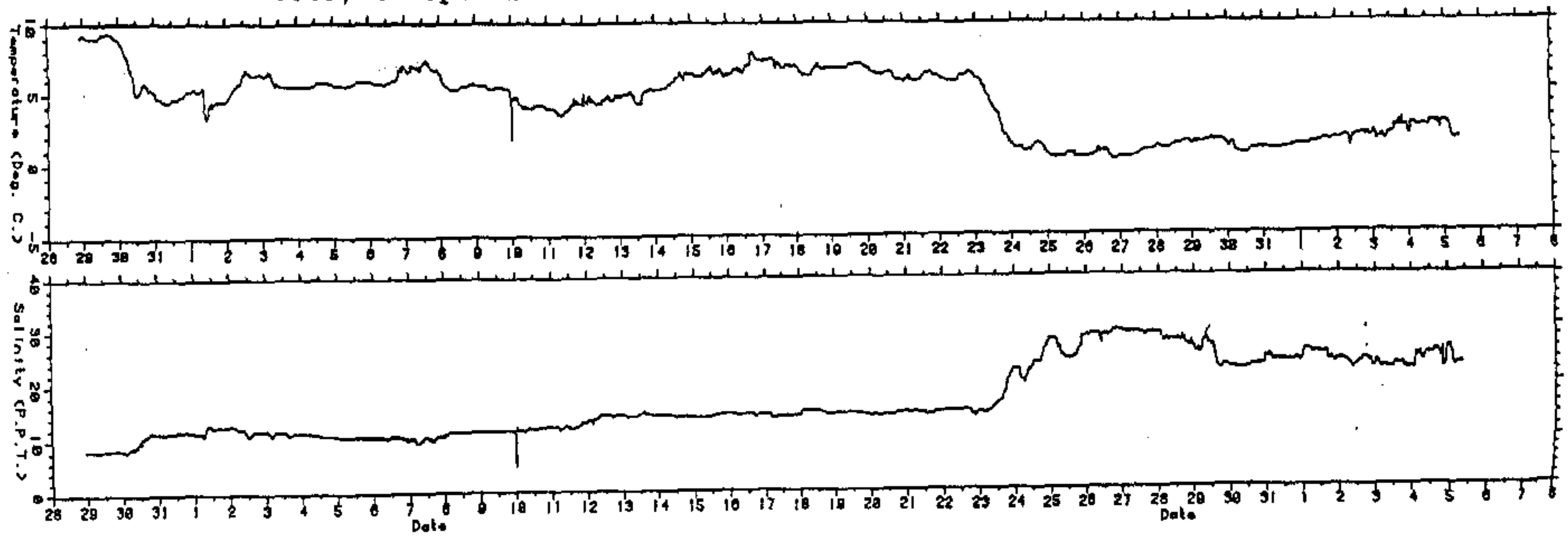


Figure 76. Temperature and Salinity Data
Station S (Bottom); 1/2 Hr.
Averages, Endeco #052, 2242,
28 July to 1012, 5 September
1982.

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The following Kinnetic Laboratories Inc. personnel were responsible for conducting the Oceanographic Study of the Point Thomson region:

Donald Wilson, PhD	Project Manager
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