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Summary of the Oceanography and Surface Wind Structure of the Pacific Subarctic Region in Relation to Waste Releases at Sea

CLEAN WATER

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NORTHWEST REGION

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SUMMARY OF THE OCEANOGRAPHY AND SURFACE WIND STRUCTURE OF THE PACIFIC SUBARCTIC REGION IN RELATION TO WASTE RELEASES AT SEA

by

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National Coastal Pollution Research Program

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Corvallis, Oregon 97330

September 1970

DEPARTMENT OF THE INTERIOR

In its assigned function as the Nation's principal natural resource agency, the Department of the Interior bears a special obligation to assure that our expendable resources are conserved, that renewable resources are managed to produce optimum yields, and that all resources contribute their full measure to the progress, prosperity, and security of America, now and in the future.

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INTRODUCTION

The purpose of this report is to briefly outline the physical oceanography and surface wind structure of the Gulf of Alaska and waters adjacent to the Pacific Coast of Alaska. The information to be gained from this summary is then used to evaluate the efficacy of the rather arbitrary 50-mile International Agreement Zone inside which vessels are prohibited from discharging oily ballast waters and slop oil with a concentration greater than 100 ppm.

The narrative portion of this report is intended as a resumé of the many accompanying figures. Since the conclusions reached were based largely on these figures and the reports from which they were taken, they are presented here as the background material.

No attempt is made to calculate the dispersion of crude oil wastes since these are not generally miscible with seawater. It is known (Kinney et al., 1969) that the lower fraction hydrocarbons, gasoline and kerosene will evaporate rather rapidly (less than a day in Cook Inlet studies). The live crude oils of Cook Inlet origin are considerably less likely to remain clumped (at sea) than those originating from Sumatra or other regions. Oils recovered from tank cleaning are altered considerably, however. Weathering turns Cook Inlet crude oils into a viscous, tar-like material (Ray Morris, FWQA, personal communication). The bulk of this report, then, is concerned with those wastes discharged in rather large volume which are likely to maintain their identity in such a fashion that they will be aesthetic nuisances if washed ashore or will intefere with bird and animal life at sea or ashore.

Geographic Regions

The North Pacific has been the subject of intense study by oceanographers from Japan, Russia, Canada, and the United States for many years, particularly in connection with its extensive salmon and other fisheries. As a result, the geography of the so-called Subarctic Pacific (SP) has been well-defined.

Figures 1 and 2 exhibit the principal features of the SP. Of particular interest are the American and Alaskan Coastal Regions and the Western Gyral Region south of the Aleutian chain. These regions are defined mainly on the basis of their surface and subsurface currents and temperature-salinity relationships. In other words, waters of a particular region are sufficiently unlike those of others and also so similar over a broad area that they can be so classified. The circulation in a given region will be unique; for instance, waters in the Alaskan Gyral may recirculate within the Gyral for several orbits before entering the coastal water regions. Waters once in the coastal regions, however, are more likely to move westward within the coastal region, leaving the system by entering the Western Gyral or Subarctic Region.

Bathymetry

The seaward extent of the continental shelf area is sometimes given by the 200-meter depth contour. The bathymetric charts (Figures 3 and 4) show as the first contour the 1000-meter isobath; since the 200-meter isobath lies quite close, the former contour can be taken as the limit of the continental shelf in the Alaska region. It can be seen that this is near the Aleutian Island chain, about 60-120 miles off the south and southeast coast of Alaska, and shows the broad extent of the shelf area in the Bristol Bay region.

Although the shelf is relatively far offshore (as opposed to the West Coast of the United States) it will be pointed out that onshore currents still exist in this region.

Figure 5 shows the complex inland sea area of southeast Alaska.

Currents Deduced from Drift Bottle Releases

Because drift bottles are partly exposed directly to the wind, their use as indicators of surface currents is often viewed with suspicion by oceanographers. However, drift bottle release results are good indicators of the path likely to be followed by solids, such as impacted oil sludges, and other surface debris.

According to Dodimead et al. (1963), the drift bottle data shown in Figures 6 to 11 exhibit the following surface flow phenomena:

1. northward drift between Attu and Komandorski Islands;
2. from as far south as latitude 46°N between 140°W and 145°W into the Gulf of Alaska;
3. around the Gulf of Alaska (Alaskan Gyre);
4. along the southern side of the Aleutian Islands, into the Bering Sea, and eastward along the northern side of the islands;
5. circulating within the Subarctic Region;
6. from the Subarctic Region into the California Current system, toward the Hawaiian Islands, and then westward to the Philippine and Japanese Islands;
7. around the western Subarctic Gyre.

From the viewpoint of solid wastes drifting with the surface currents one reaches the unhappy, but not surprising, conclusion that there is really no safe place to dump refuse, even in the middle of the North Pacific Ocean, since the waste will eventually end up on a beach. In transit, of course, the waste may disintegrate and fall to the bottom or become indistinguishable, depending on the time of transit, the sea state during its passage, and the nature of the waste.

Computed Surface Currents

Figure 12 shows a schematic diagram of the surface circulation deduced from direct and indirect observations. Some of the features given in Figures 1 and 2 are also present here. In Figure 13 the currents at a depth of about 200 meters are shown; it can be seen that the surface features maintain themselves at this depth for the most part with additional structure coming into the picture as exemplified by the California Undercurrent.

Figures 14 to 23 show the so-called geostrophic surface currents from 1955 to 1962. These currents are computed from a knowledge of the vertical distribution of density obtained at widely separated locations in the ocean. Density, in turn, is calculated from the temperature and salinity of water samples obtained at different depths in a given column of water.

The charts of 'geopotential topography' show contours on which current direction is indicated by arrows. Current speed is inversely proportional to the separation of the contours, hence closely spaced contours indicate swift currents. Insets on the charts can be used to pick off current speeds.

In general there are rather swiftly moving currents in the coastal regions moving out along the Aleutian chain. Currents move northward along the Canadian-Alaskan coast and eastward from the Subarctic current and the West Wind drift (Figure 12).

The broad area of seemingly sluggish currents (as revealed by widely separated contours) corresponds to the Alaskan Gyre.

Because of the method of calculation, the currents shown are seaward of the 1000-meter isobath with the exception of Figure 20, which is based on a 300-meter computation. The latter figure exhibits a component of current toward Kodiak Island from the east, as well as the onshore currents along the Aleutians. In the Aleutian chain currents are shown as moving north into Bristol Bay (this feature is also shown in the other figures).

Figure 23 shows in more detail the currents in the Gulf and the relative position of the Alaskan Gyre.

In all figures the velocities in sea miles per day (SMD) at selected positions are indicated. In the last figure, for instance, a current of 1 SMD is shown south of the Alaskan Gyre, but in Figure 15 a 12 SMD current is shown southwest of Kodiak.

The current charts, then, exhibit great extremes in speed and direction, both in time and space. It should be borne in mind that the currents shown in these charts do not show short duration wind effects; hence, wind drift at the surface would be superimposed on these currents. The resultant drift of surface material could then be parallel to the contours or could cross the contours at right angles. This is an extremely important fact to consider when attempting to show probable drift of any ocean waste discharge, especially one which will be constrained to remain in the very few upper inches of water and which is discharged nearshore.

The indications of this section are that there is an onshore component of current in the coastal regions; in conjunction with the drift bottle data it can be seen that material discharged within several hundred miles of the coast will move alongshore at speeds of 1-15 miles per day (independent of wind drift). The prevailing wind drift will determine in the mean whether a waste discharged, say, in the northeast part of the Alaskan Gyral will move into Cook Inlet, out along the Aleutian chain, or remain within the Gyral.

Inferred Currents

Temperature and salinity determine density - the distribution of which can be used to compute current velocity. The individual distribution of properties can also be used to infer current directions.

Figures 24 to 27 show these properties; comparison with the SP zones (Figure 24) reveals the presence of the Alaskan Gyre, the northward bending of the 10°-15°C temperature contours shows that the temperature of the water masses is fairly well retained in transit and shows a shoreward component. The salinity distribution (Figures 25 and 26) reveals relatively fresh water along the coast due to runoff. The density distribution (as Sigma-t) also reveals a marked coastal region extending several hundred miles offshore. As a rule of thumb it can be postulated that a waste released inside the 23.8 contour west of Juneau and the 24.6 contour south of Kodiak will quite likely reach shore within a few days, depending on the set of the wind.

Winds

During the winter, the Subarctic is under the influence of the Aleutian Low which is located in the Bering Sea near the Aleutians. In conjunction with the Siberian and North American Arctic High pressure cells, the winter winds are predominantly westerly. They blow from the northwest in the western part of the region through southwest on the eastern side. In the northern gulf, easterly winds prevail.

In the summer the North Pacific High predominates over the Aleutian Low, and the prevailing westerlies of the winter are replaced by south or southwest winds. Near the Canadian and Alaskan coasts prevailing summer winds are generally light and variable.

Figures 28 to 51 show average monthly surface wind data, sea level pressures, and storm tracks in the region of interest.

Each monthly wind rose shows the speed and direction frequency of surface winds at various locations. For instance, Figure 28, for January, has onshore winds about 26 percent of the time at the Seward station. At the station off Queen Charlotte Island there is an onshore component about 50 percent of the time. Additional information is also given at each wind rose.

The surface pressure charts can be used to infer wind direction by noting that circulation is counterclockwise around a low and clockwise around a high. Wind direction does not parallel the isobars, but has a slight component inward toward a low and out from a high. The memory aid is that with one's back to the wind the low pressure cell will be on one's left-hand side. The monthly frequency at the Seward station is given in Table 1 where an 'onshore component' is defined as coming from the south, southwest and west bars of the wind rose.

TABLE 1

Onshore Winds, Seward Wind Rose
(from U.S. Navy, 1956)

Month	J	F	M	A	M	J	J	A	S	O	N	D
%	26	20	25	22	32	43	34	46	32	34	20	24

The implications of this section on wind are rather obvious: there will be an onshore wind component sometime during any month of the year. Surface material will drift at 2-5 percent of the imposed wind speed, and this drift will be superimposed on the net density related currents shown in the previous section.

NORPAC Data

During the summer of 1955 a multi-ship, multi-nation oceanographic expedition of the North Pacific (NORPAC) took place. The station spacing in the Gulf of Alaska was good and sections of some of the figures from the NORPAC Atlas are reproduced.

Figure 52 shows the surface currents during the cruise; the Alaskan Gyre is outlined by the 0.70 contour and the currents are similar to those shown previously.

In Figure 53 the quantity of zooplankton was estimated from data collected at varying depths and with different nets. Some features are worthy of comment: note that south of about latitude 30°N there is a relative absence of zooplankton, while there is an increase northward and particularly along the coast. The large amount in the coastal areas supports the idea that this is a zone of nutrient abundance and is a very important enrichment and biotic area.

The number of fish larvae, Figure 54, was standardized to the amount in a volume of water 10 square meters in area at the surface and 140 meters thick. It is difficult to generalize on the data presented in the chart, other than to suggest that there are no obvious barren or fertile zones that probably could not be explained on the basis of sampling methods or gear. Larvae are, however, present throughout the North Pacific.

Seal and porpoise sightings during NORPAC are shown in Figure 55. Since no special effort was made to maintain a sea-life watch aboard all vessels, the result should not be taken as to indicate more than the fact that these mammals can and do live hundreds of miles from land.

Figure 56 shows whale sightings. As in Figure 54, the most sightings occur between latitudes 40°N and 50°N, and longitudes 150° to 180°.

Conclusions to be reached in this section are that the North Pacific and especially the coastal zones are highly productive in terms of zooplankton and fish larvae and many marine mammals can be found far offshore. The Aleutian Islands are well-known breeding grounds for different species of seagoing mammals which depend on the nearshore fishery for food while raising their young. The Gulf of Alaska and the Bering Sea--Bristol Bay area contains relatively high concentrations of nutrients making the lower stages of the food chain highly productive and available to grazing zooplankton. As has been shown, this is reflected in the large gradients of zooplankton toward the coast.

SUMMARY

It has been shown that the circulation in the Gulf of Alaska and the Pacific side of the Alaska coast is somewhat closed. A counter-clockwise circulation exists at all times of the year. Currents near the coast are fairly fast with a jet-like stream passing south of Kodiak, out along the Aleutian chain and into the Bering Sea.

Wind systems in the Gulf will drive surface material inshore a few days of each month at a rate of 3-5 percent of the wind speed.

The naturally high nutrient level in the Pacific Subarctic supports an extensive and unique biota both inshore and at sea. The Gulf itself is traversed periodically by Asian and North American salmon stocks.

CONCLUSIONS AND RECOMMENDATIONS

Nonsoluble or sparingly soluble liquids such as those normally discharged at sea from freighters and tankers discharging oily ballast or slops from tank-cleaning operations will eventually end up on Alaskan or other beaches no matter where they are discharged in the Pacific north of about 45°N latitude. If the amount of discharge at any one time is slight, if dispersion is great, or if part of the material falls to the bottom during its sea drift period, then the identifiable amount on shore could be minuscule.

The closer to shore the discharge, the better the chance for its ending up on shore, of course. The dispersant action of the sea will not apply to these wastes since they are not miscible in the usual sense. The velocity shear associated with circulation around the Alaskan Gyral will tend to move a waste material into the coastal region where the prevailing onshore wind system will exert itself.

Material once inside the southeast Alaskan inland waters will be effectively trapped. Wastes discharged at depth in the vicinity of Cook Inlet will probably move into the estuary with bottom water which replaces waters moving out at the surface. This mechanism has not been established for Cook Inlet but has for the Columbia River and Chesapeake Bay estuaries, among others.

Releases near the 50-mile zone along the Aleutians will most likely either end up on the Islands or enter the Bering Sea, assuming a relatively long half-life. The 50-mile zone is a rather ineffective arbitrary limit; in fact, there is no limit that could be set that would ensure that sea discharges would not affect remote areas, much less the immediate region of the discharge. The NORPAC biological observations (Figures 52 to 56) point out that there is no desert in the sea where wastes can be discharged and put out of mind.

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U. S. Navy. 1956. Marine Climatic Atlas of the World. Volume II. North Pacific Ocean. NAVAER 50-1C-529. xviii plus 275 charts. [28-51]

*Numbers in brackets refer to figure numbers in this report taken from the indicated references.

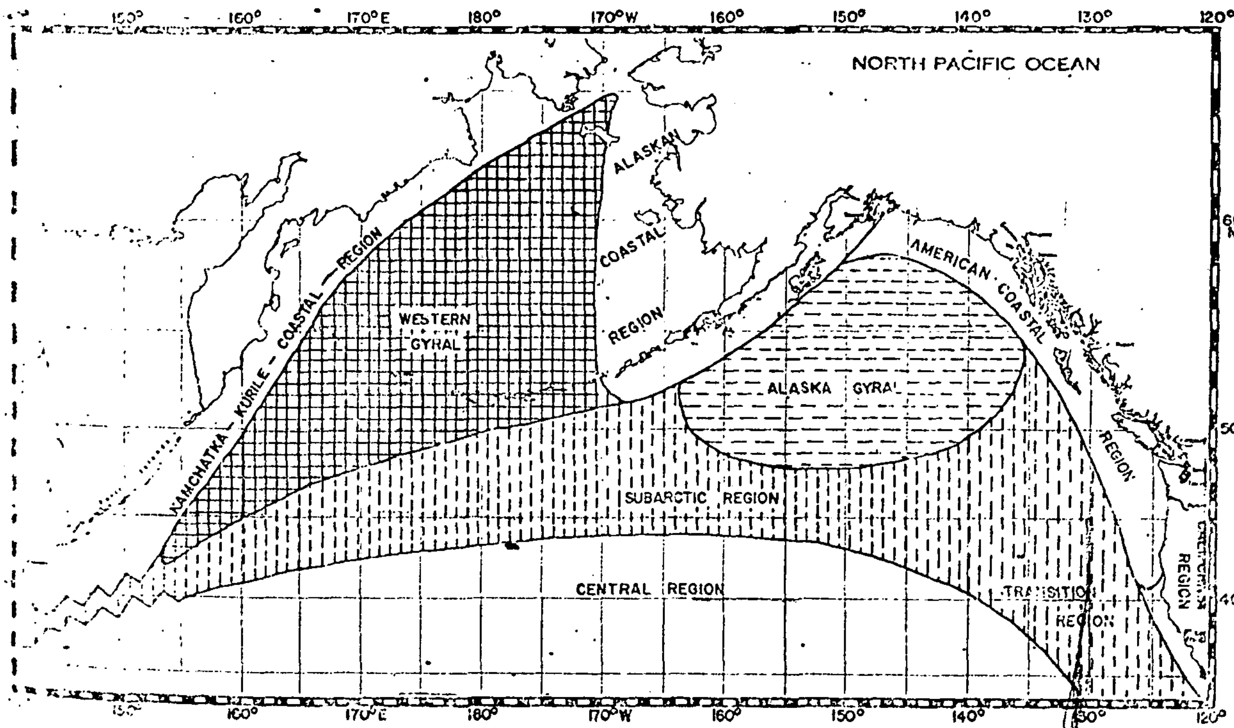


FIGURE 1. Regions and zones in the northern Pacific (adapted from Fleming, 1955).

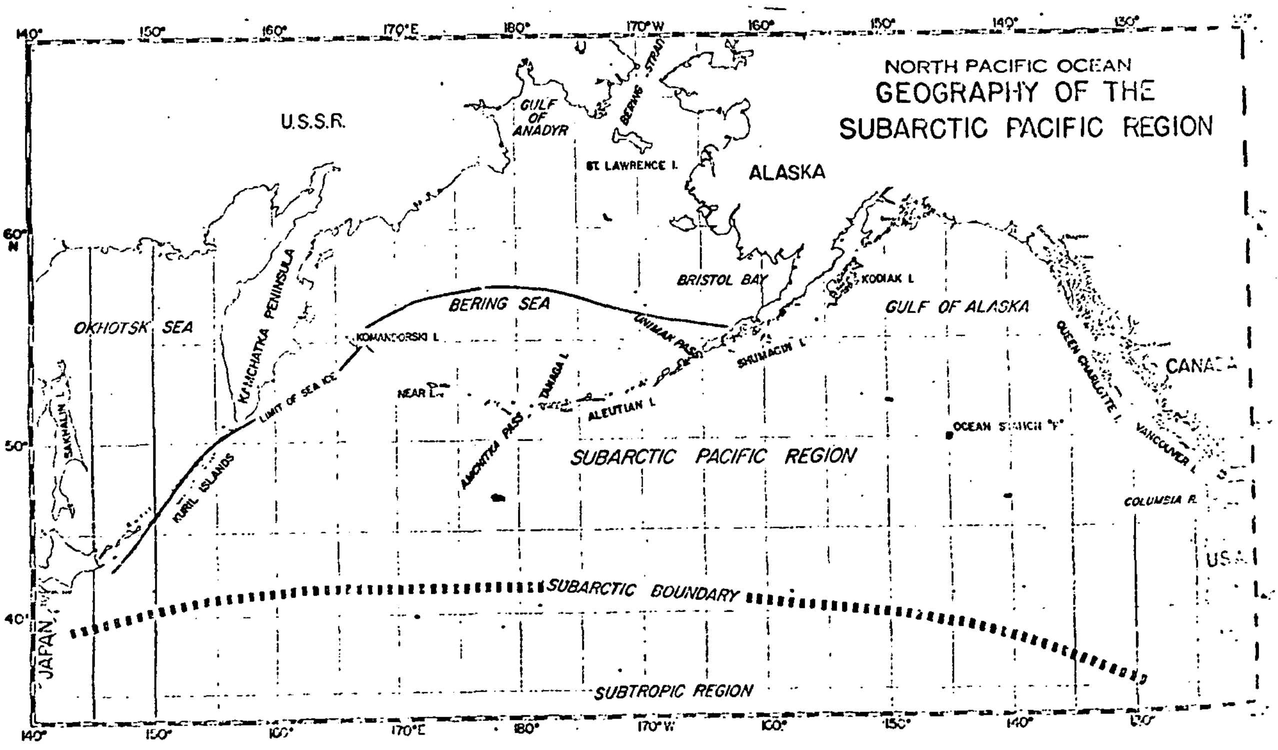


FIGURE 2. Geography of Subarctic Pacific Region.

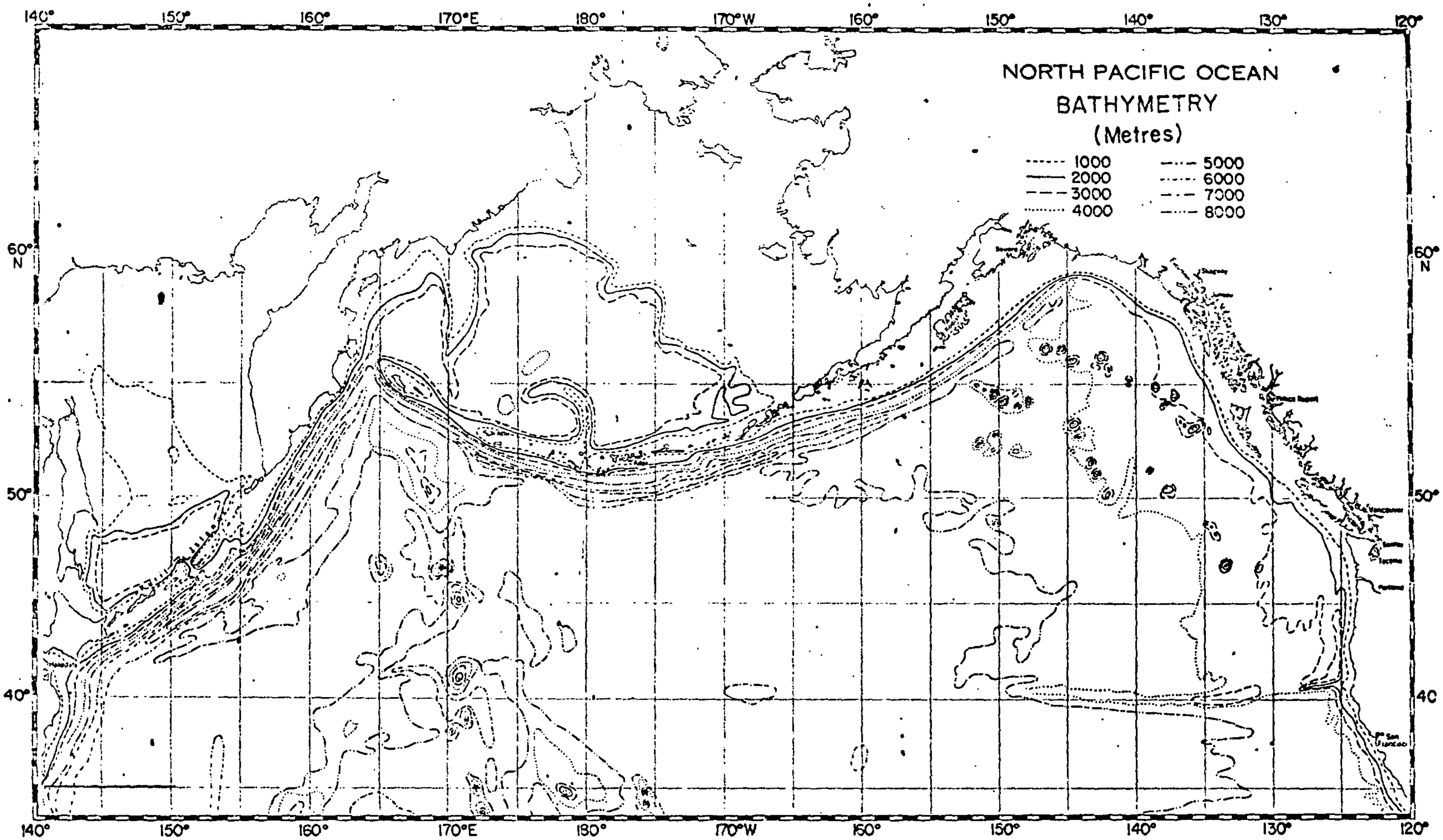


FIGURE 3. Bathymetry (metres).

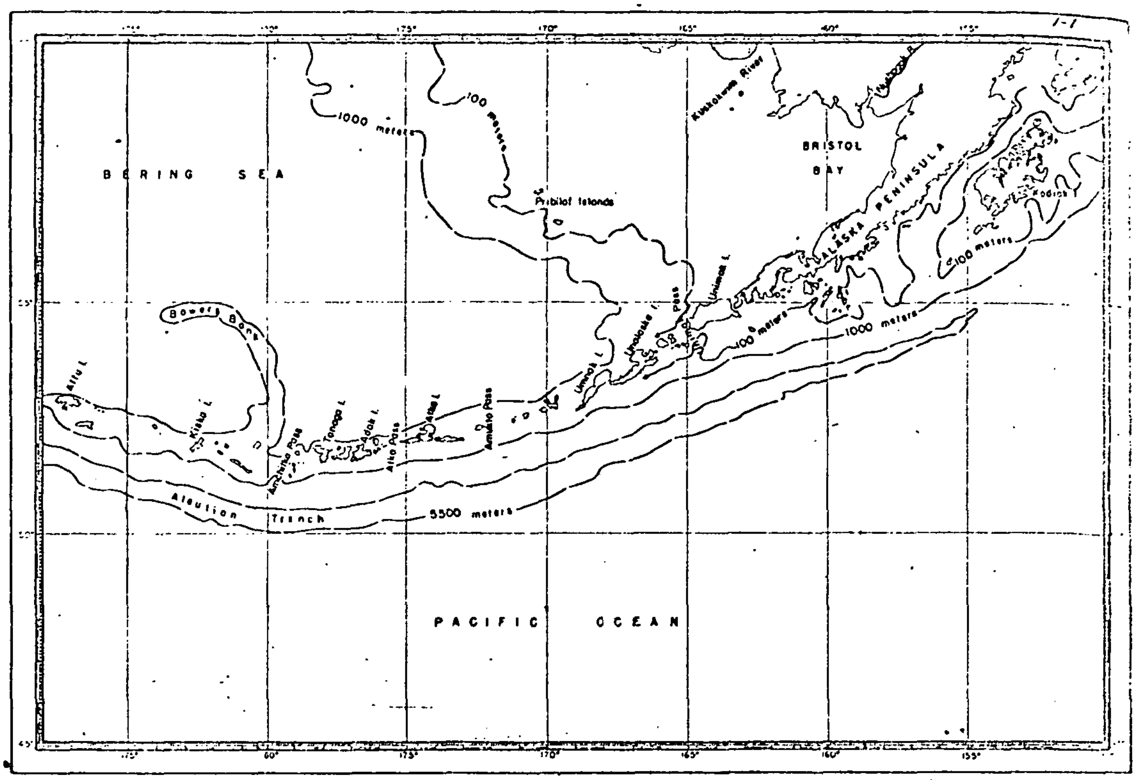


FIGURE 4. Chart of the Aleutian Island area.

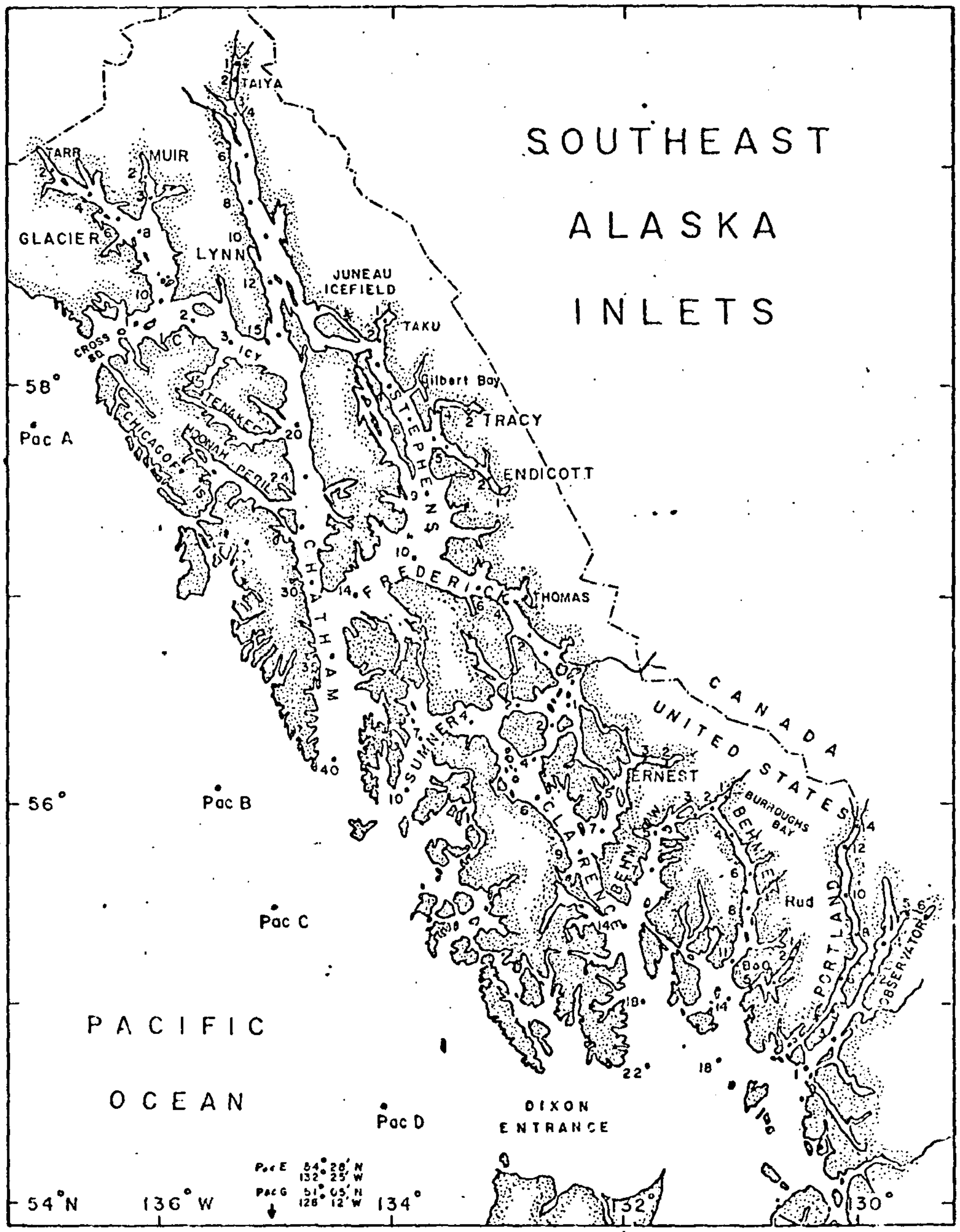


FIG. 5. Coast of southeast Alaska showing inlets described in this study.

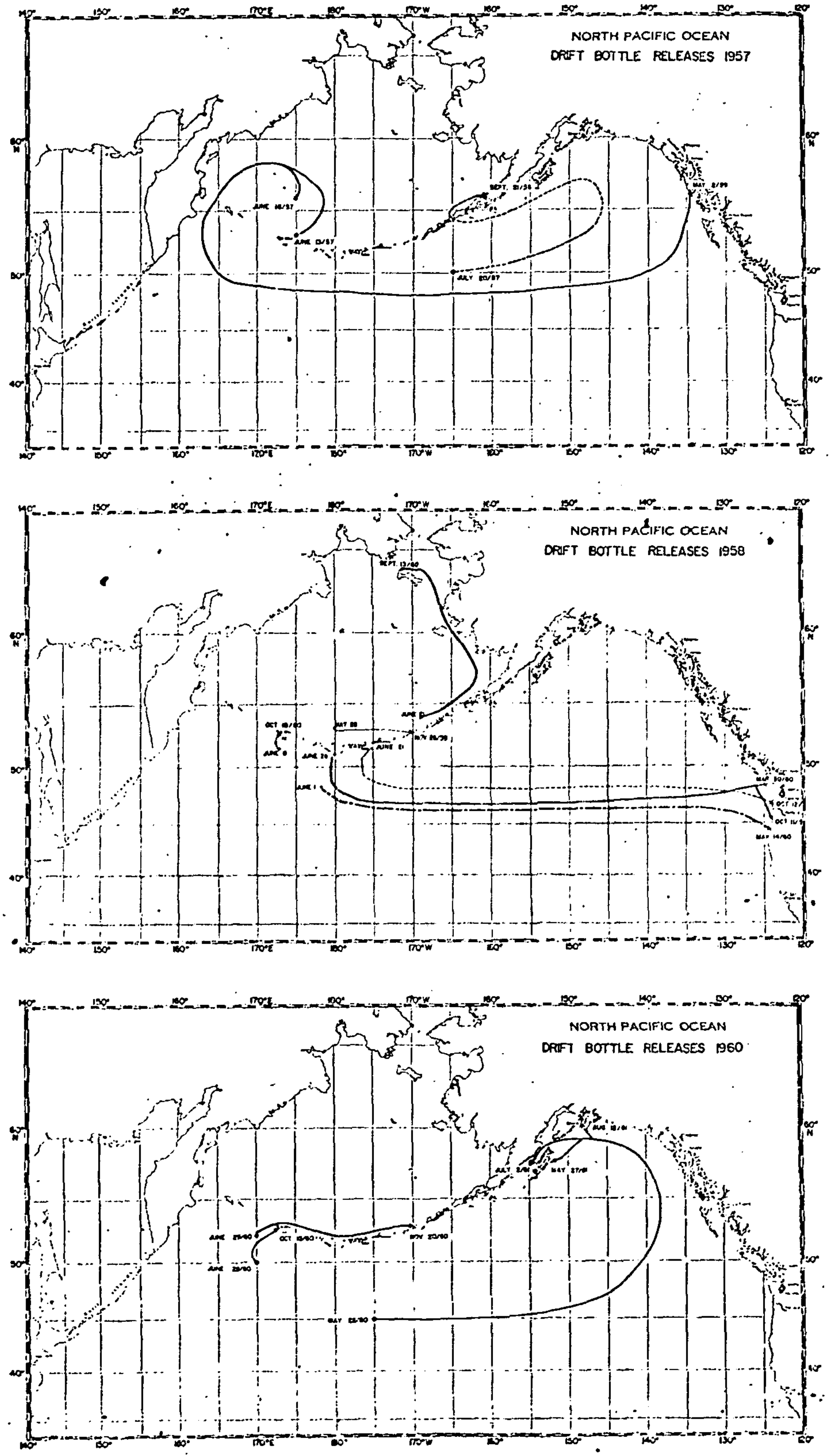


FIGURE 6. Drift bottle releases in central Subarctic.

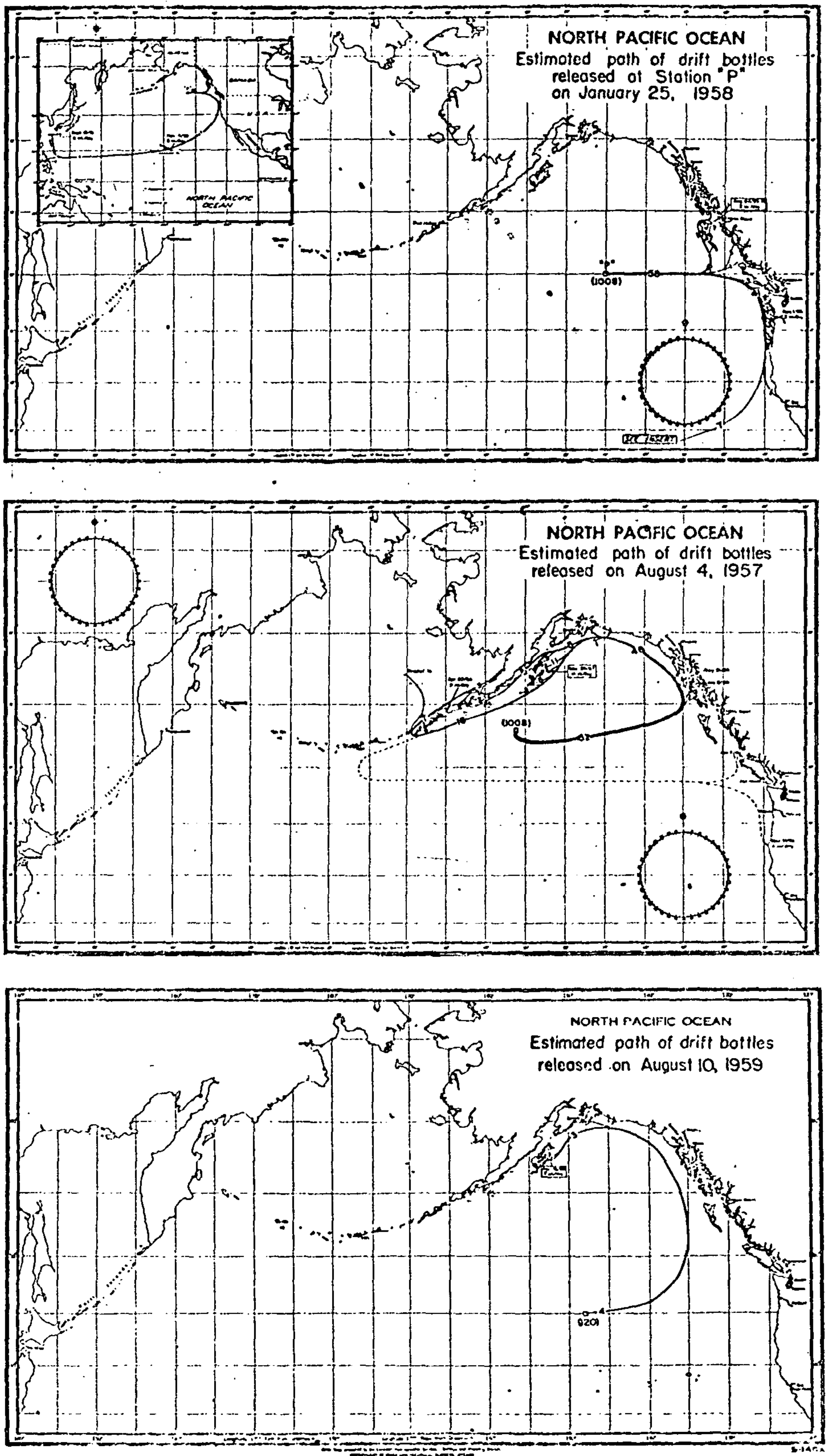
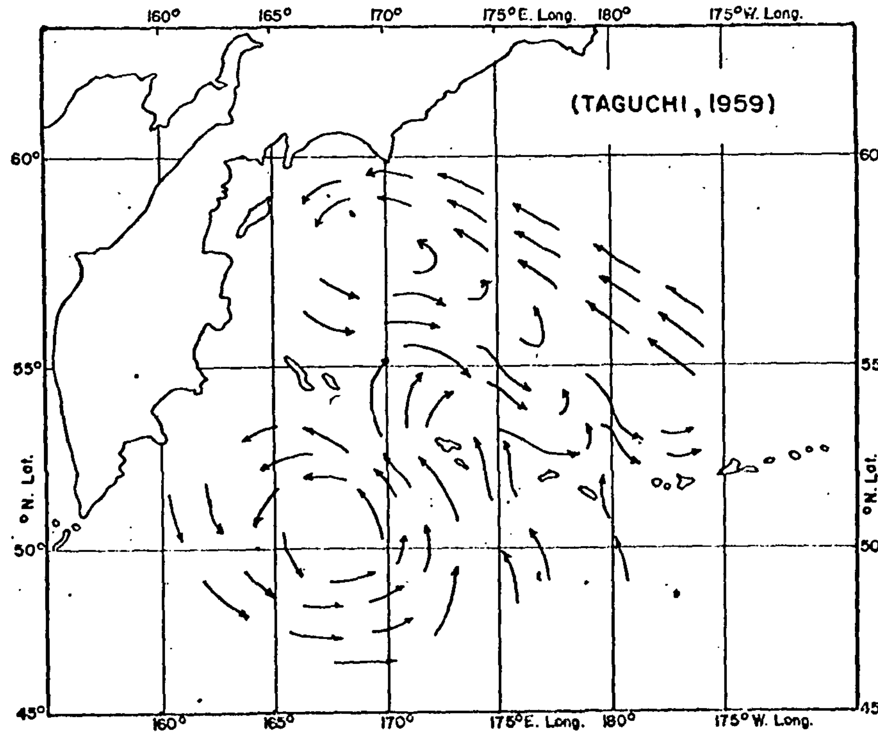


FIGURE 7: Drift bottle releases in eastern Subarctic.



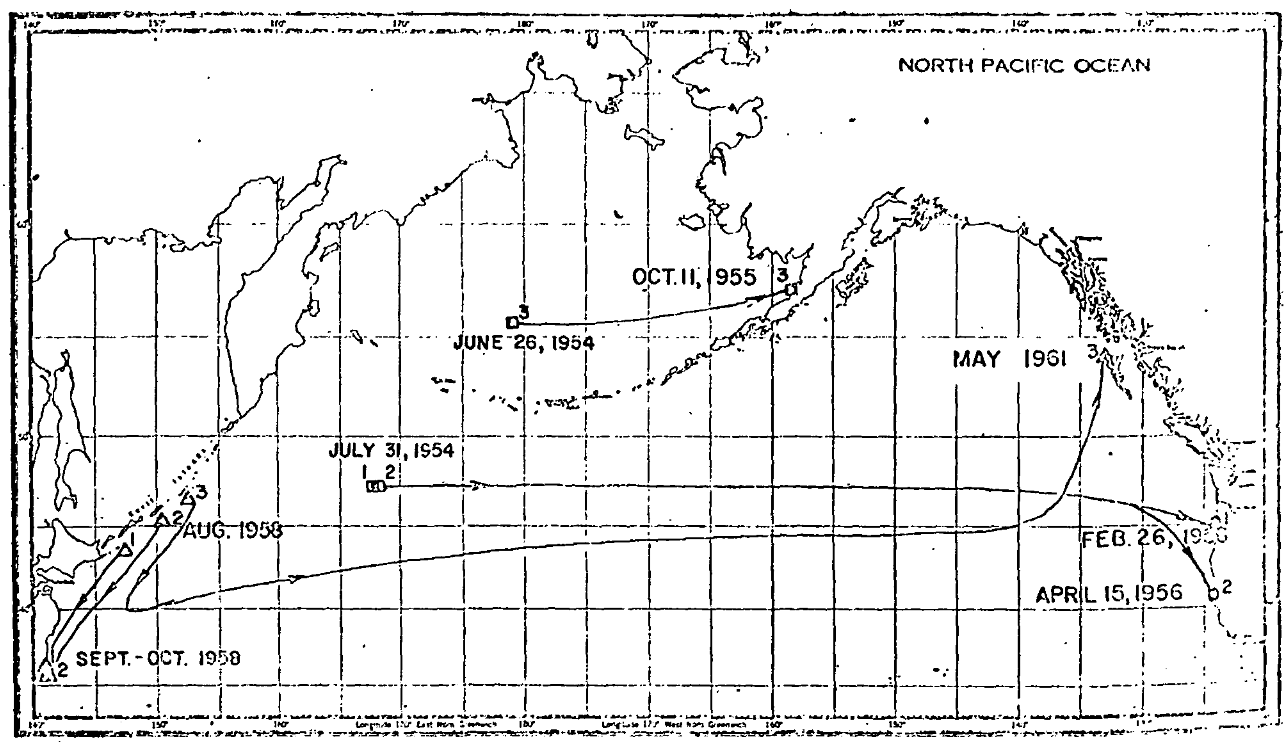


FIGURE 8. Drift bottle releases in western Subarctic.

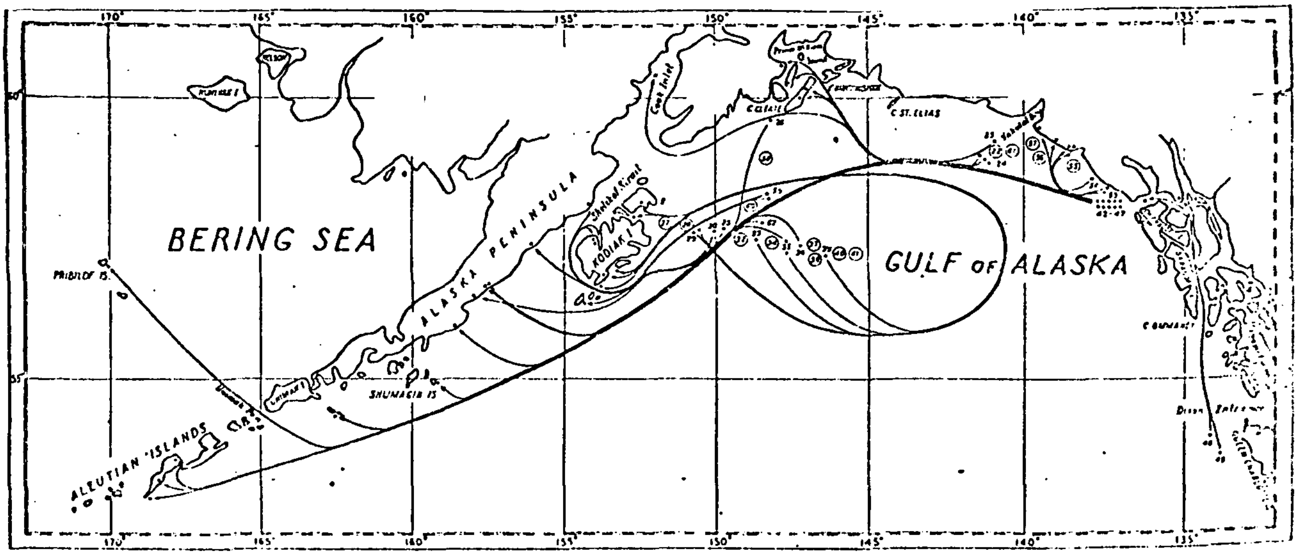


FIGURE 9. Returns from drift bottles released between January 3 and March 7, 1933, and January 9 and February 25, 1934 (Thomposn and Van Cleve, 1936).

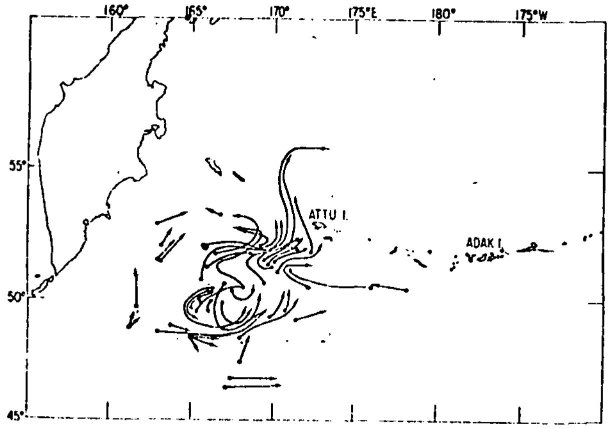


FIGURE 10. Release and recovery points of selected drift floats, May to July 1959 (adapted from Taguchi, 1959).

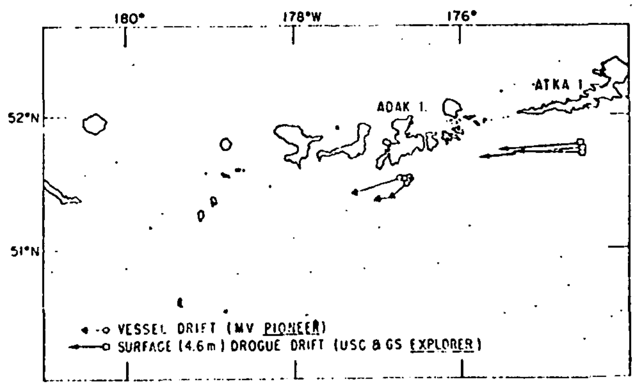


FIGURE 11. Drift of MV *Pioneer* during three consecutive nights (July 26-29, 1959) and drift of parachute drogues (4.6 m depth) released and tracked by USC & GS vessel *Explorer* (June 1959).

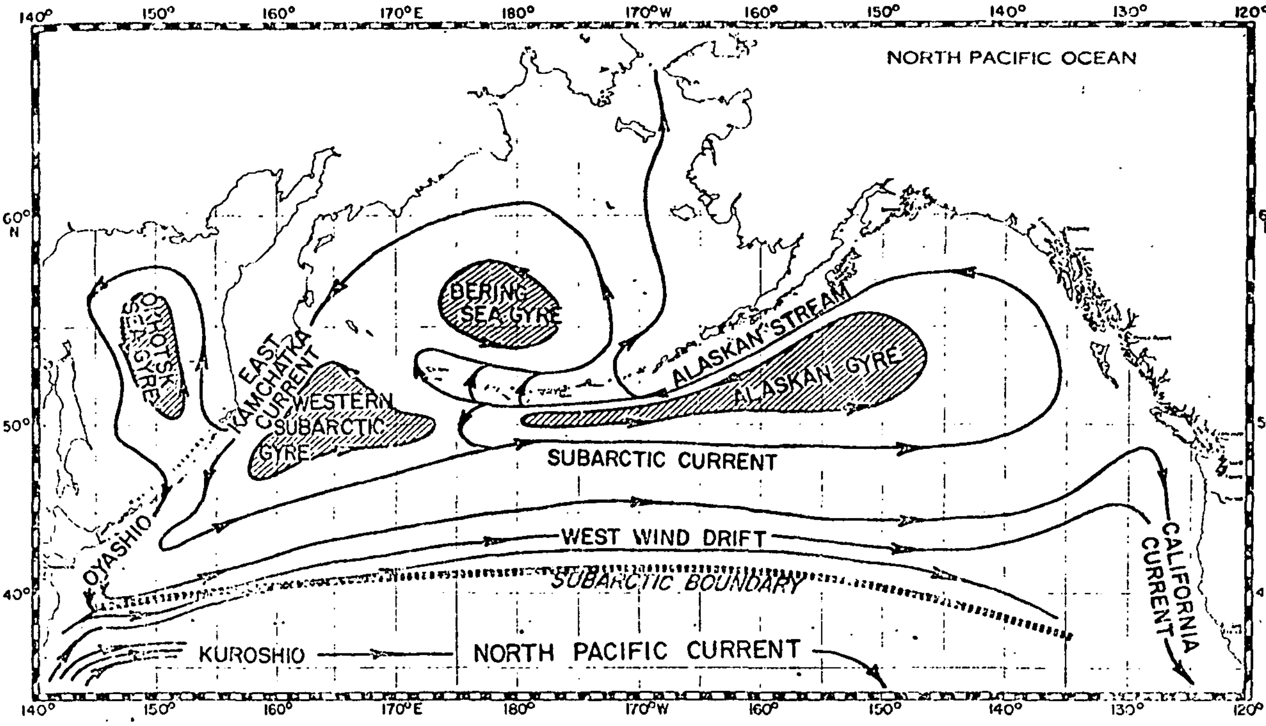


FIGURE 12. Schematic diagram of surface circulation relative to 1000 decibars.

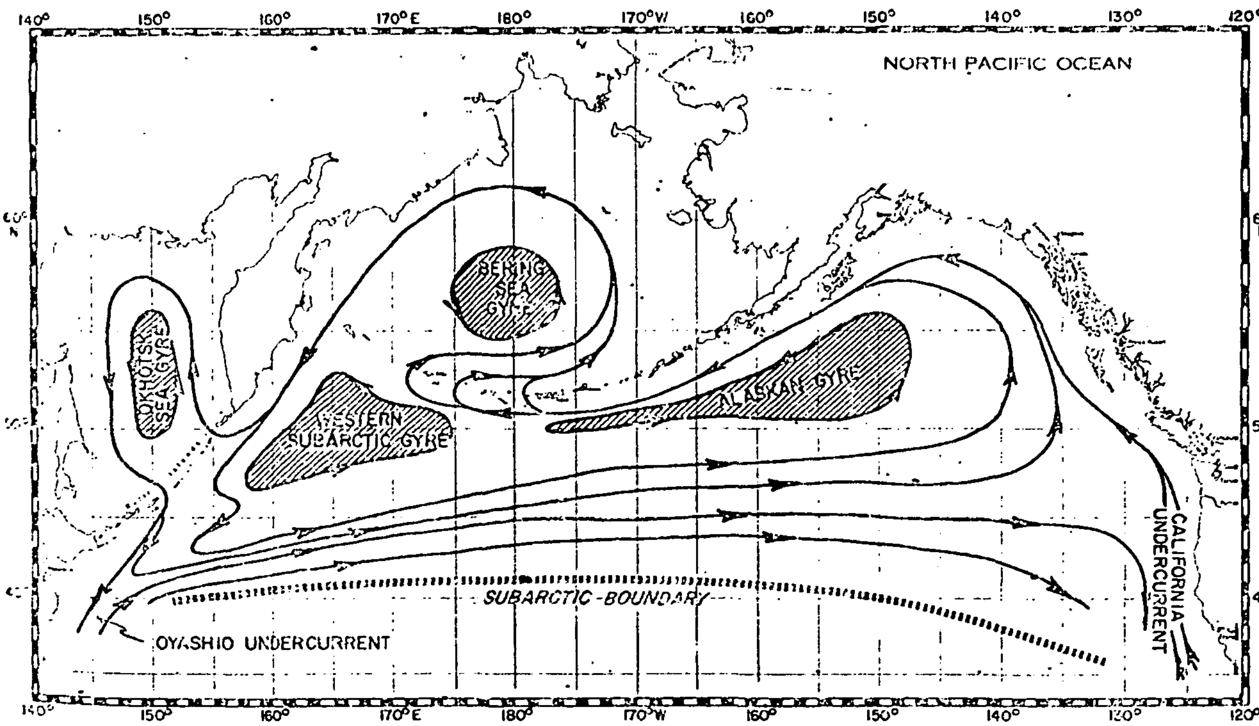


FIGURE 13. Schematic diagram of circulation at 200 decibars relative to 1000 decibars.

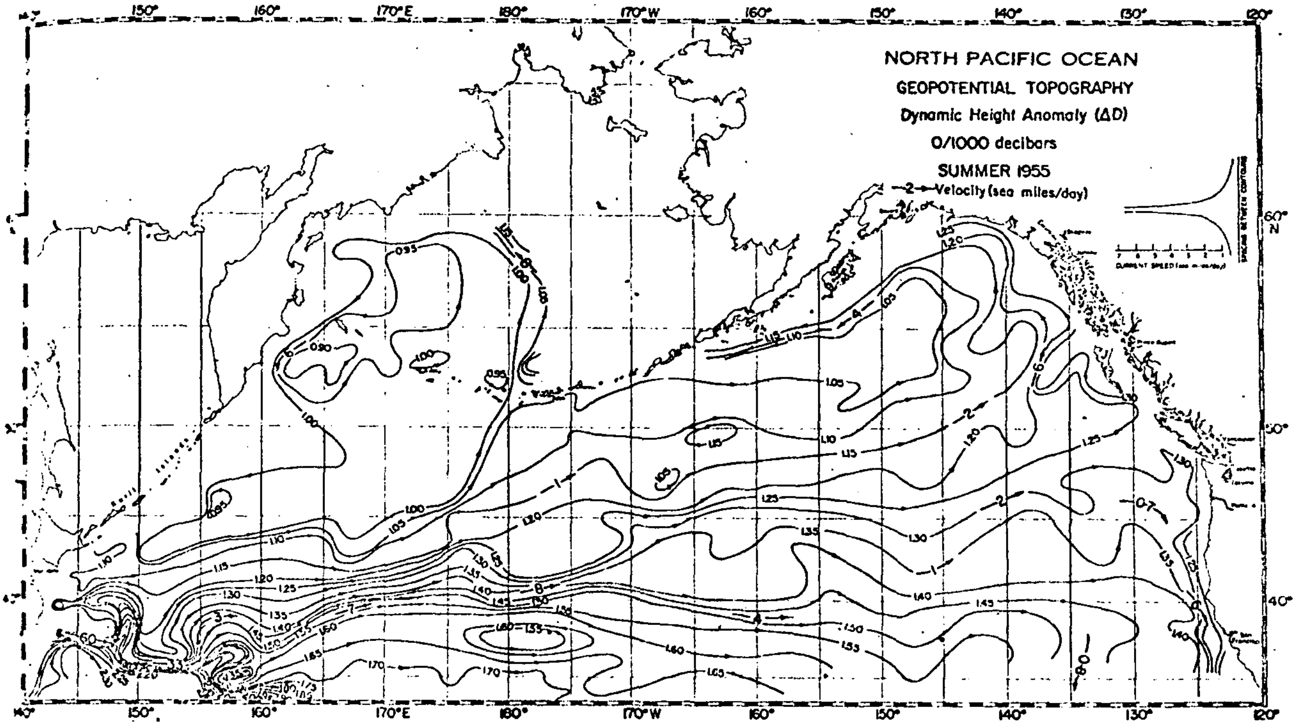


FIGURE 14. Geopotential topography, 0/1000 decibars, summer 1955.

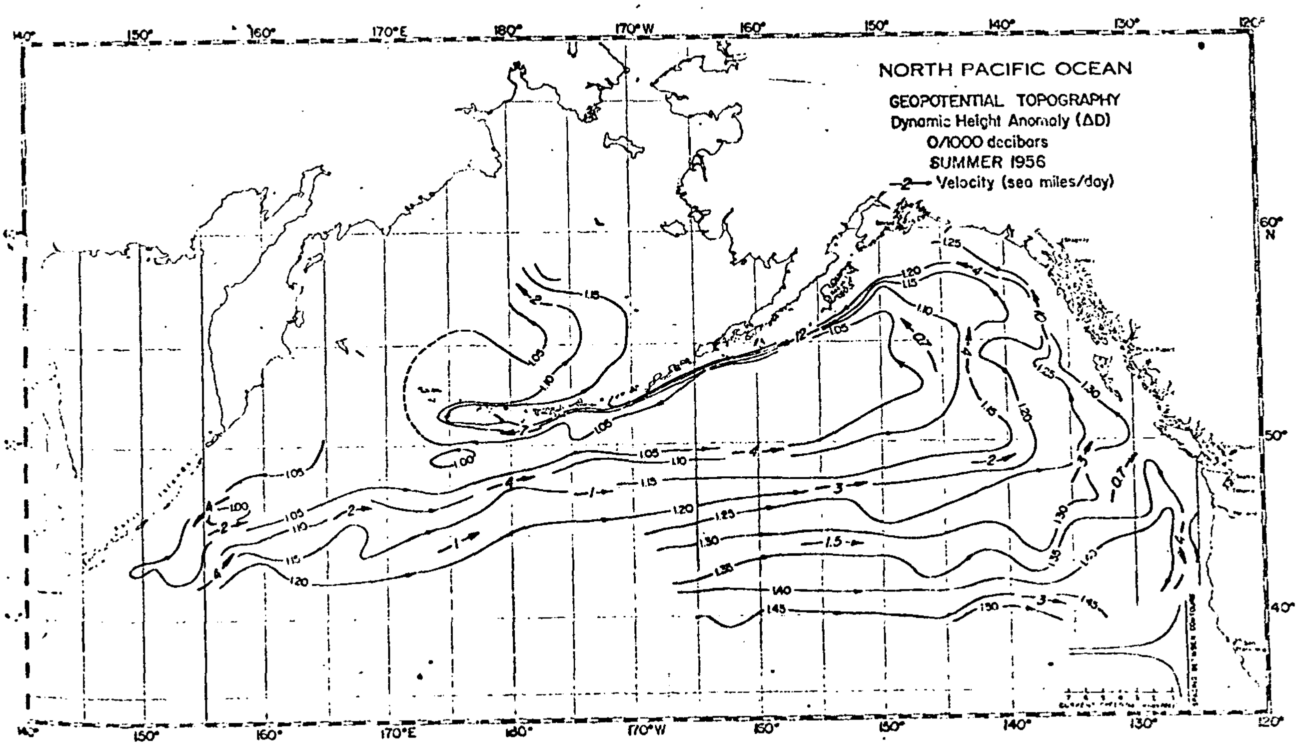


FIGURE 15. Geopotential topography, 0/1000 decibars, summer 1956.

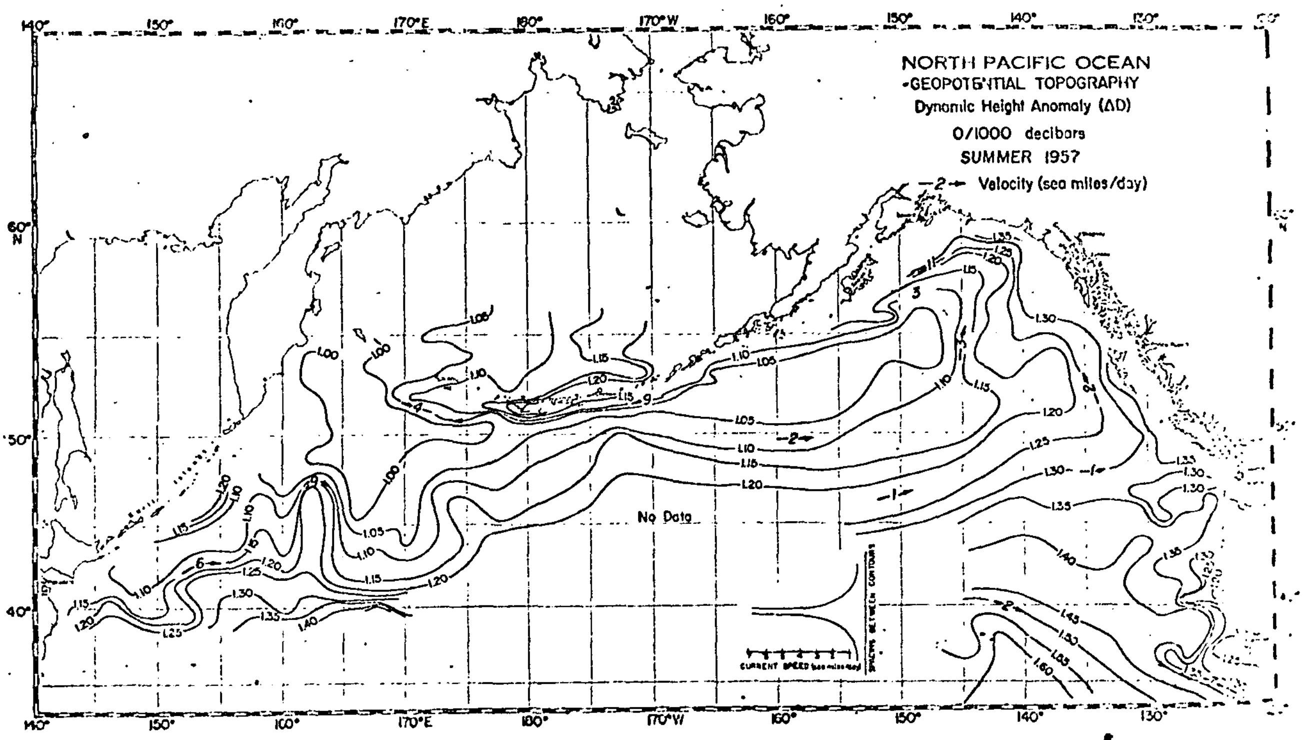


FIGURE 16. Geopotential topography, 0/1000 decibars, summer 1957.

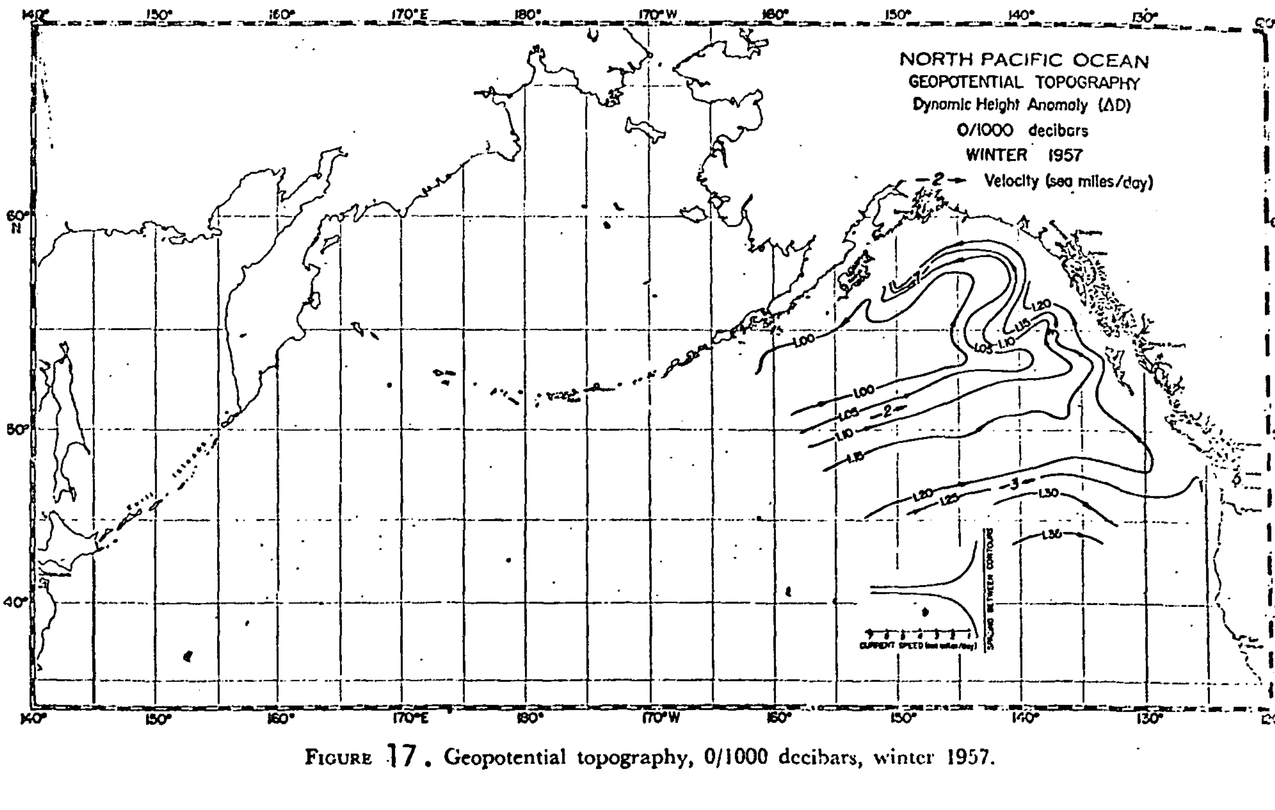


FIGURE 17. Geopotential topography, 0/1000 decibars, winter 1957.

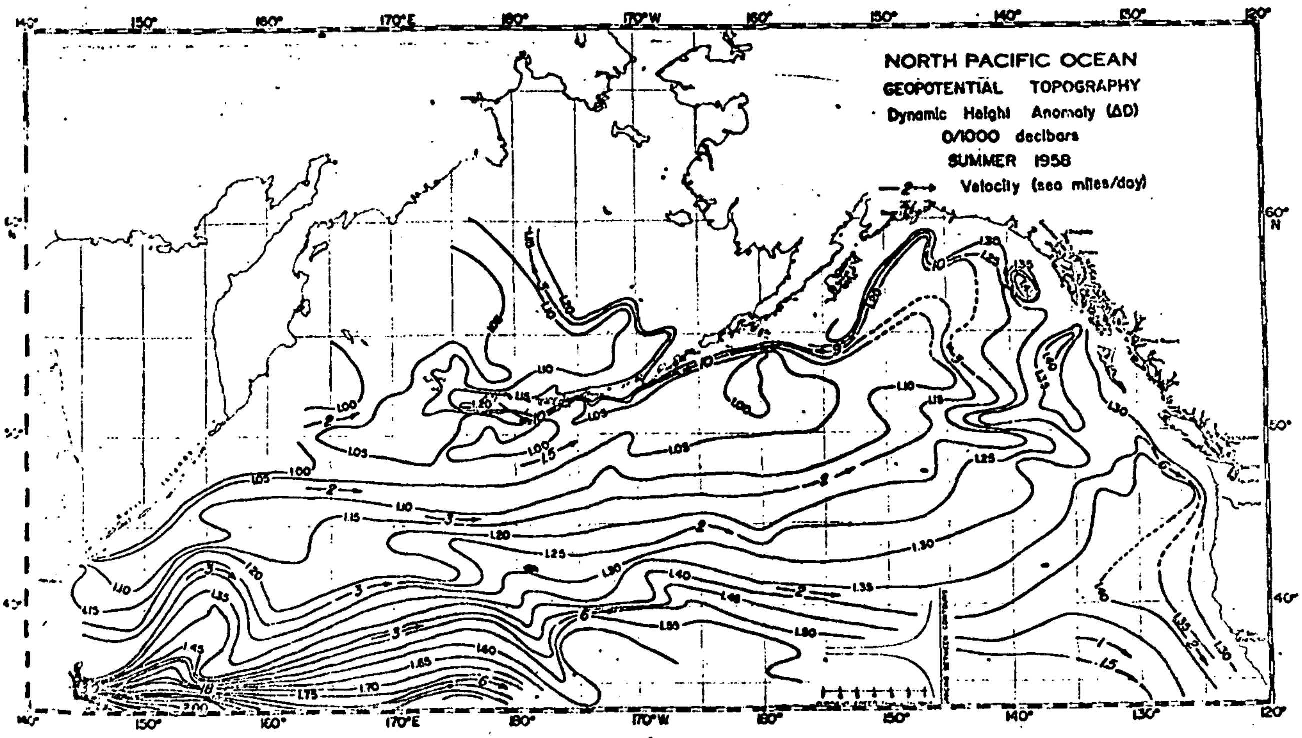


FIGURE 18. Geopotential topography, 0/1000 decibars, summer 1958.

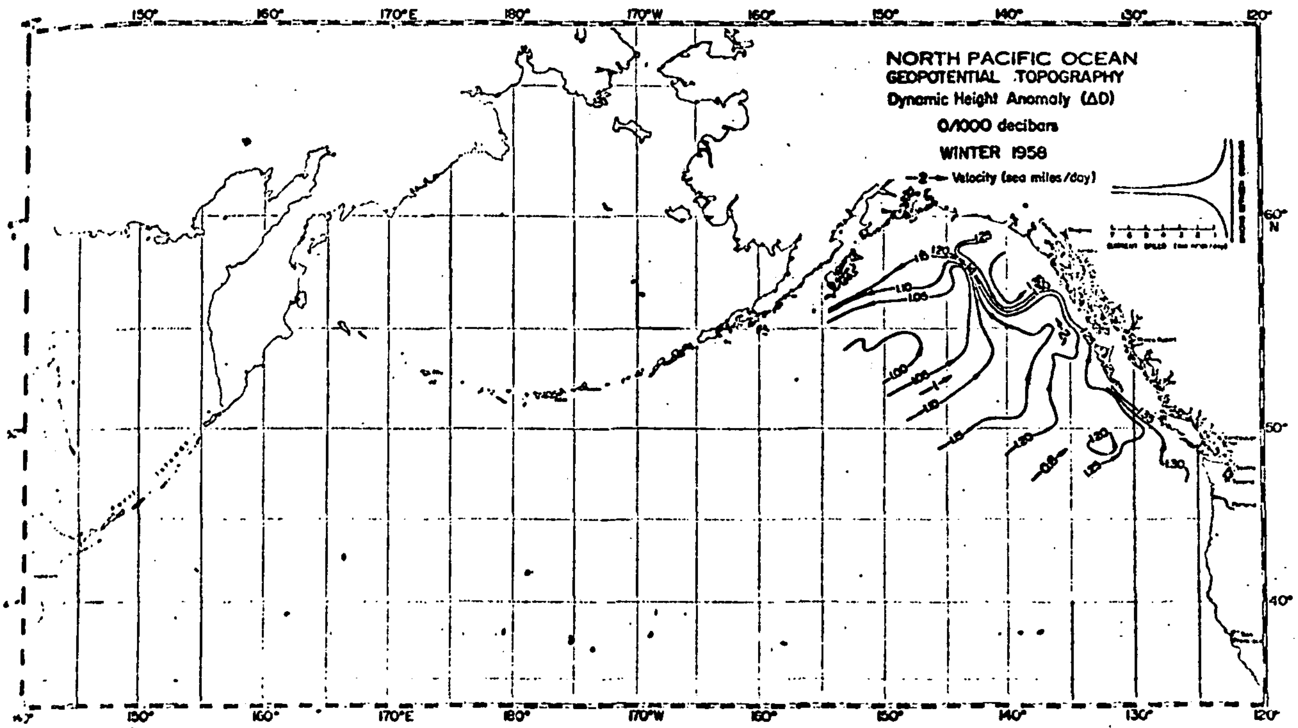


FIGURE 19. Geopotential topography, 0/1000 decibars, winter 1958.

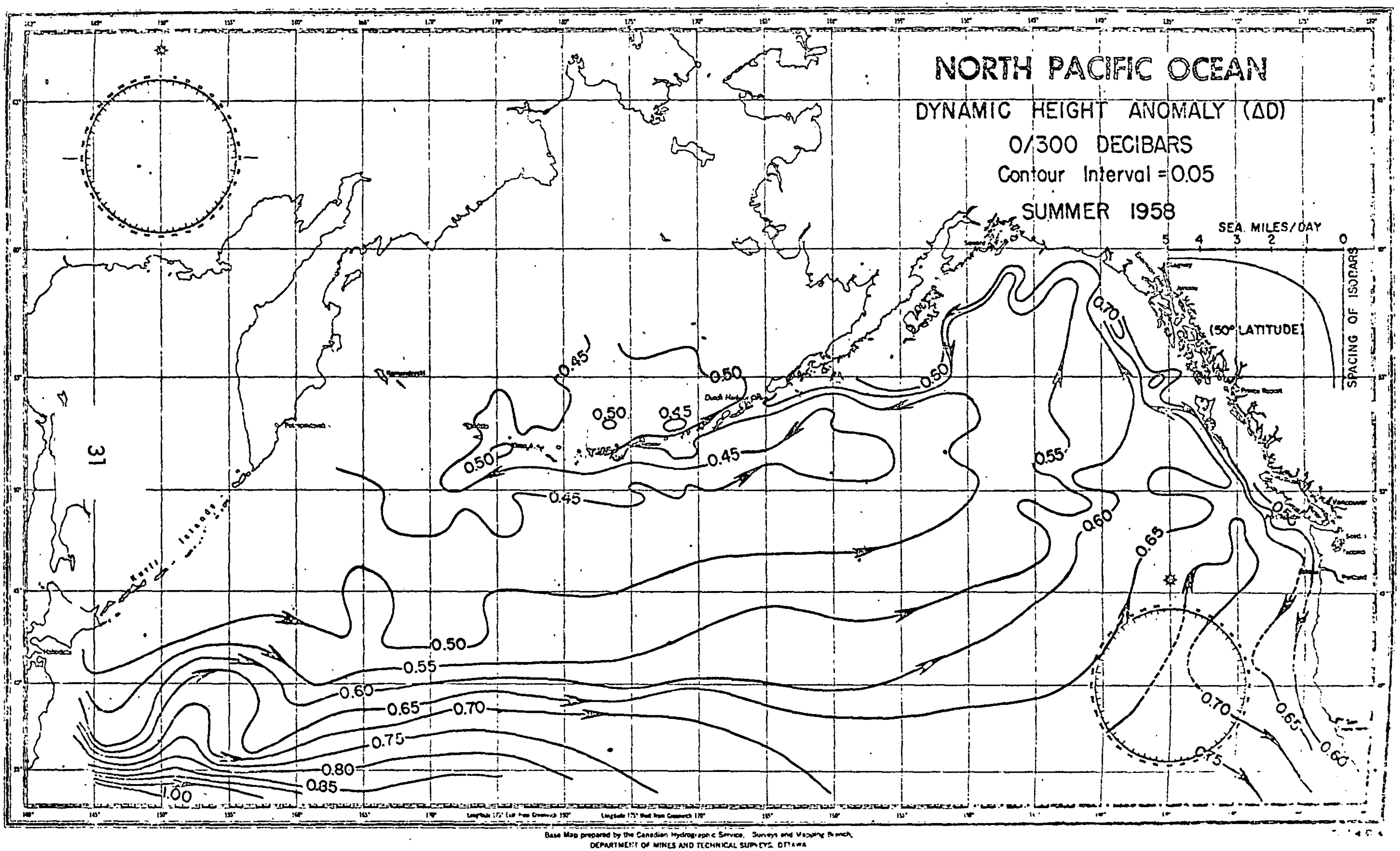

NORTH PACIFIC OCEAN
DYNAMIC HEIGHT ANOMALY (ΔD)
0/300 DECIBARS
Contour Interval = 0.05
SUMMER 1958
SEA. MILES/DAY
5 4 3 2 1 0
SPACING OF ISOBARS
(50° LATITUDE)
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
1.00
Base Map prepared by the Canadian Hydrographic Service, Surveys and Mapping Branch,
DEPARTMENT OF MINES AND TECHNICAL SURVEYS, OTTAWA

Figure 20.

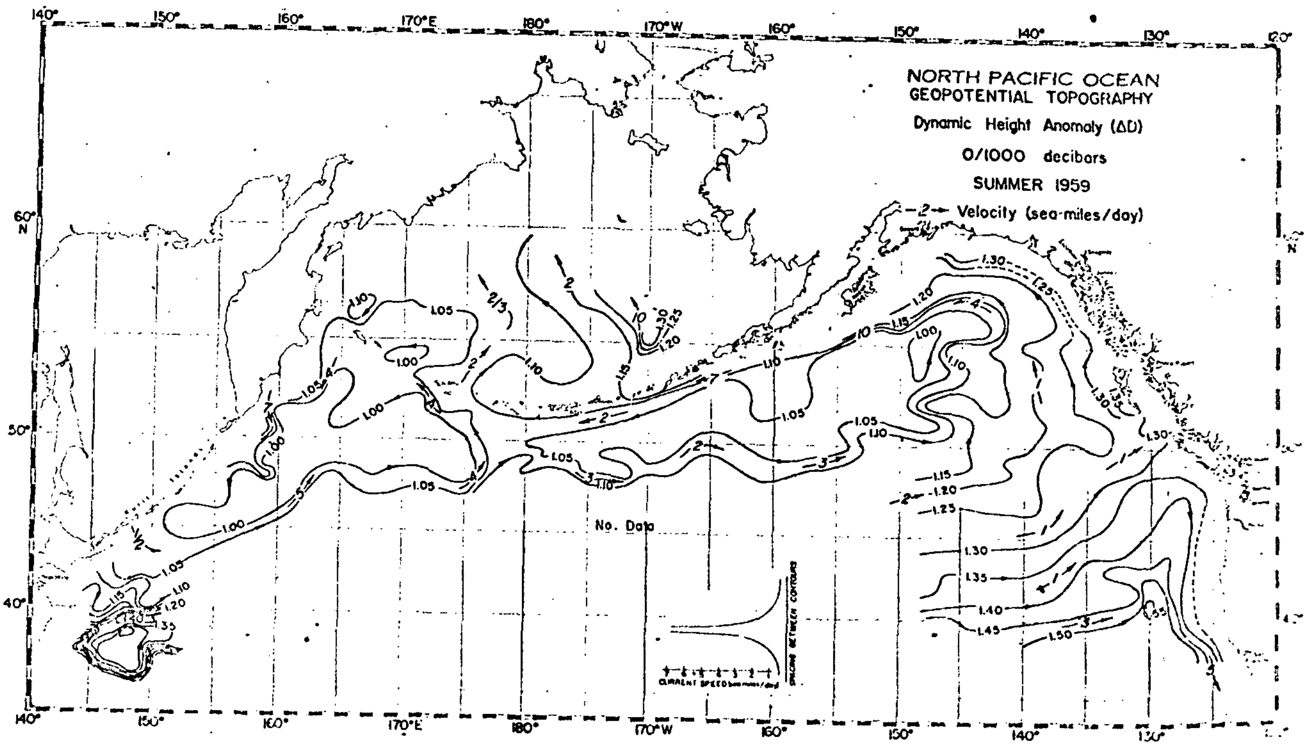


FIGURE 21. Geopotential topography, 0/1000 decibars, summer 1959.

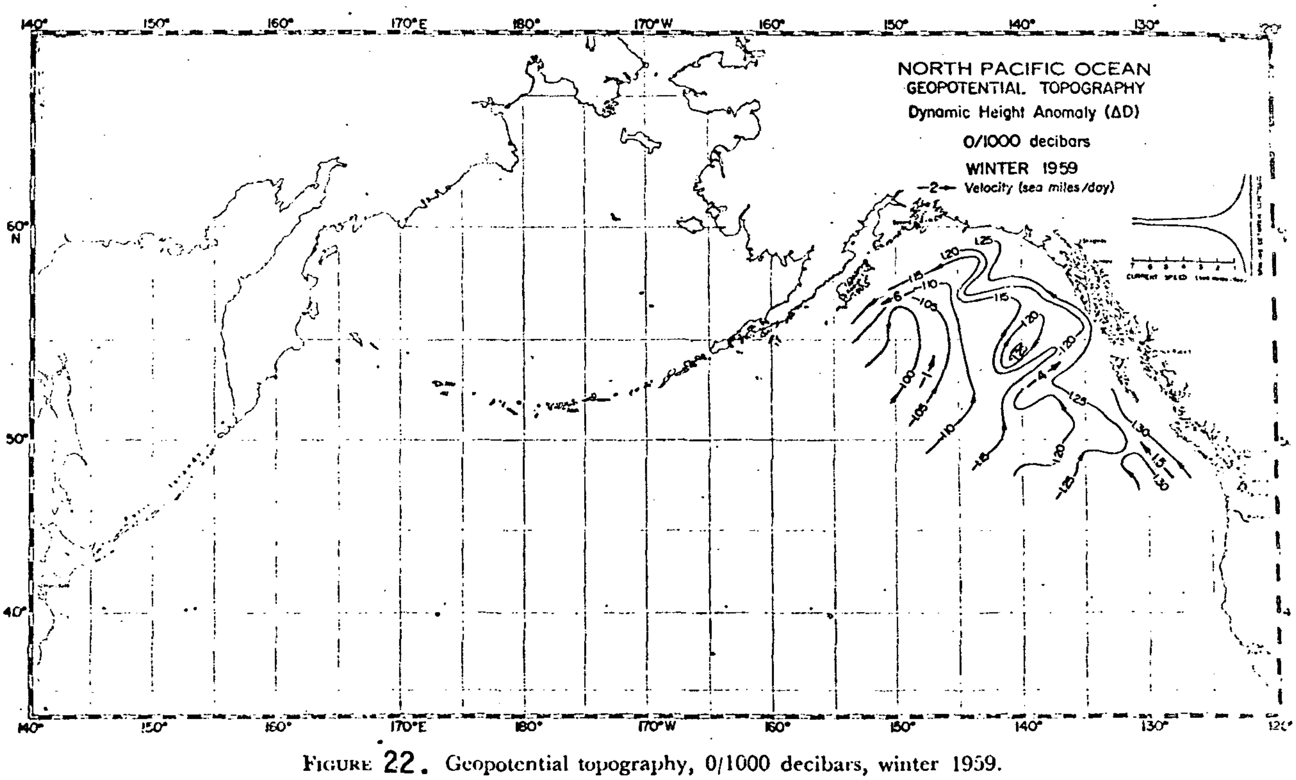


FIGURE 22. Geopotential topography, 0/1000 decibars, winter 1959.

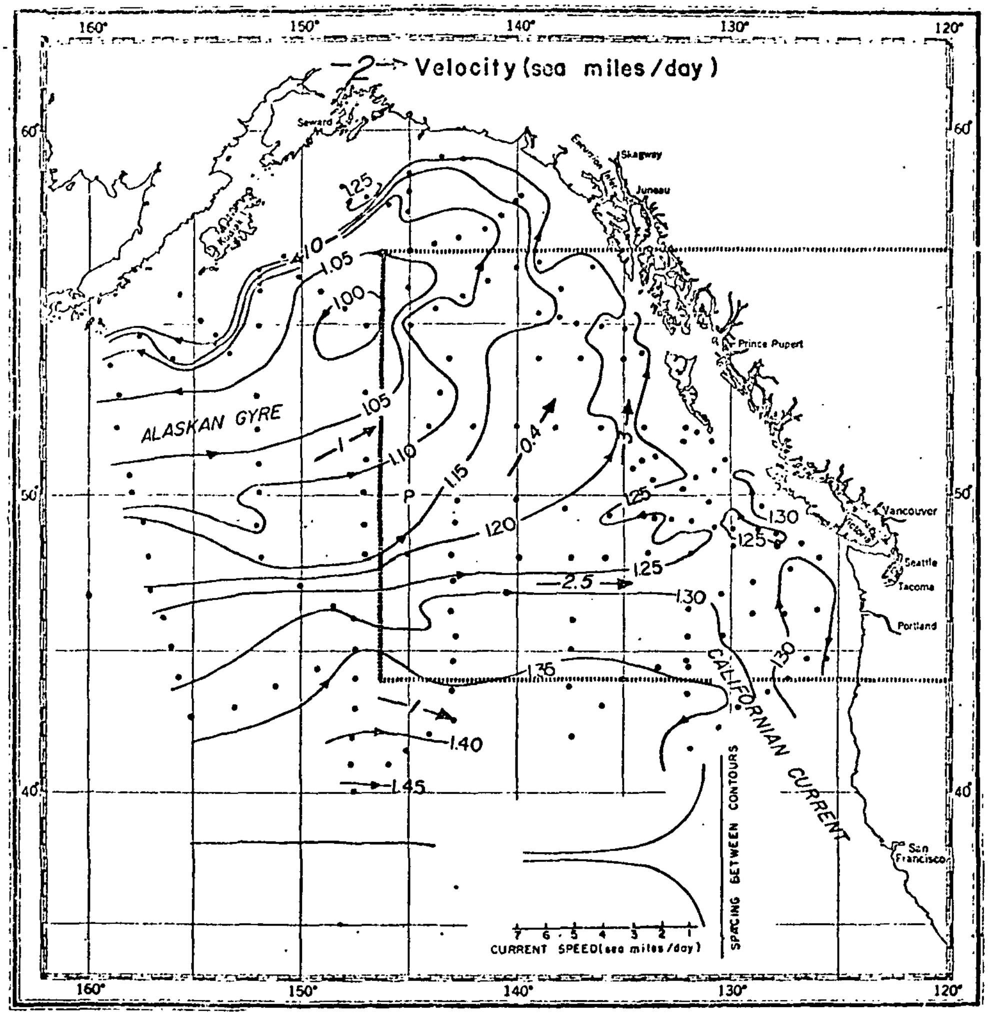


FIG. 23. Geopotential topography, 0/1000 decibars, eastern Subarctic Pacific, June 1962 (broken line encompasses area shown in subsequent figures).

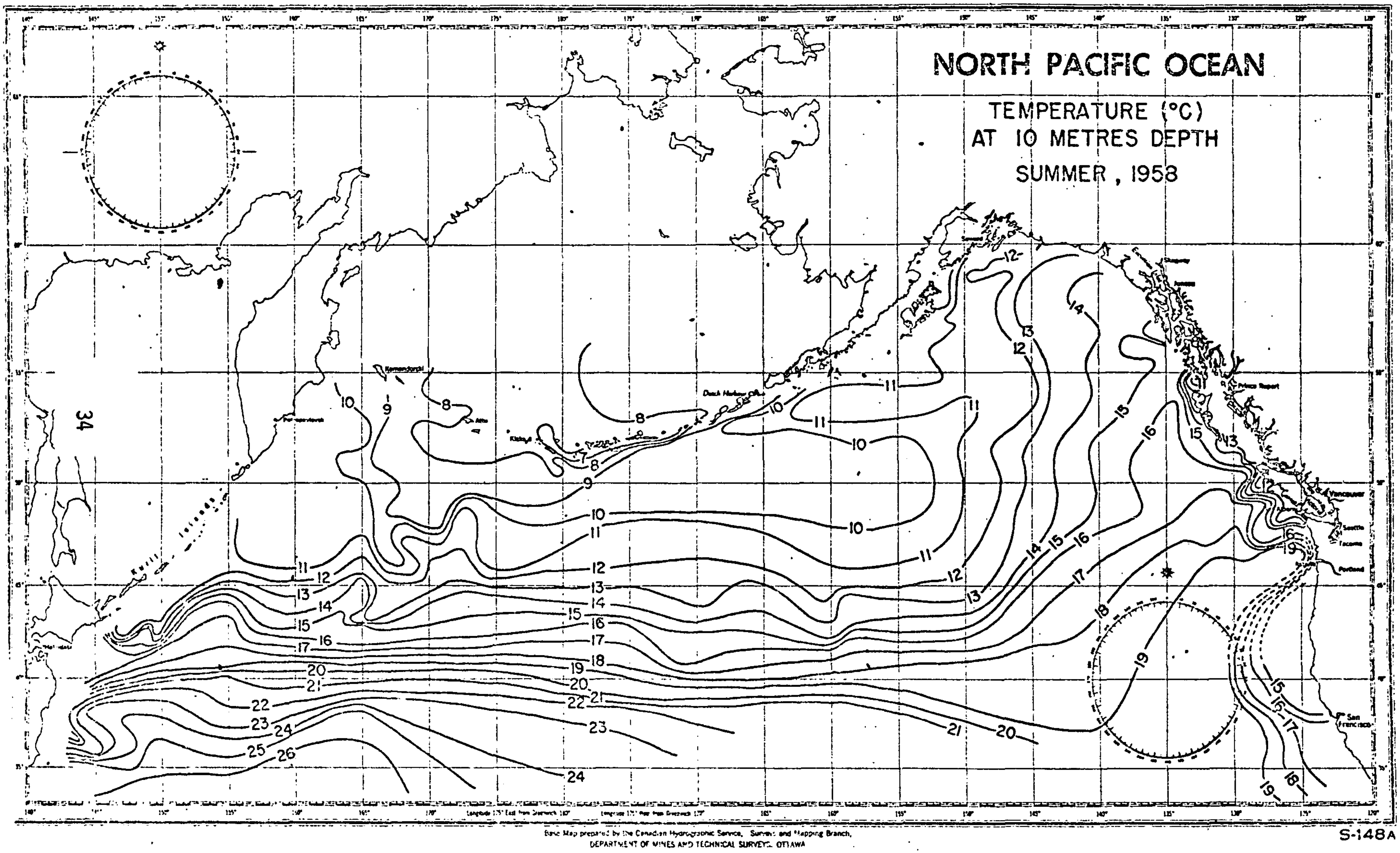

NORTH PACIFIC OCEAN
TEMPERATURE (°C)
AT 10 METRES DEPTH
SUMMER, 1958
34
Vancouver
Seattle
Tacoma
Portland
San Francisco
Prince Rupert
Dutch Harbour
Kiska
Attu
Komandorski
Petropavlovsk
Kurile Islands
Base Map prepared by the Canadian Hydrographic Service, Surveys and Mapping Branch,
DEPARTMENT OF MINES AND TECHNICAL SURVEYS, OTTAWA
S-148A

Figure 24.

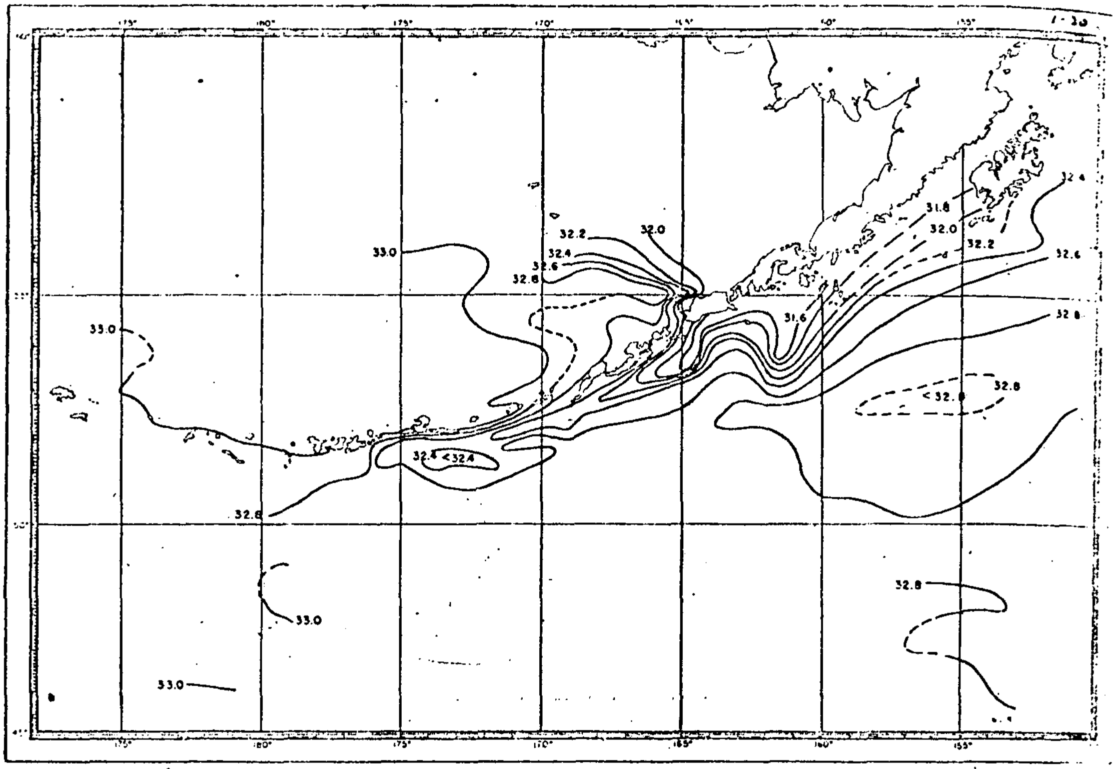


FIGURE 25. Surface salinity (‰), July—August, 1957.

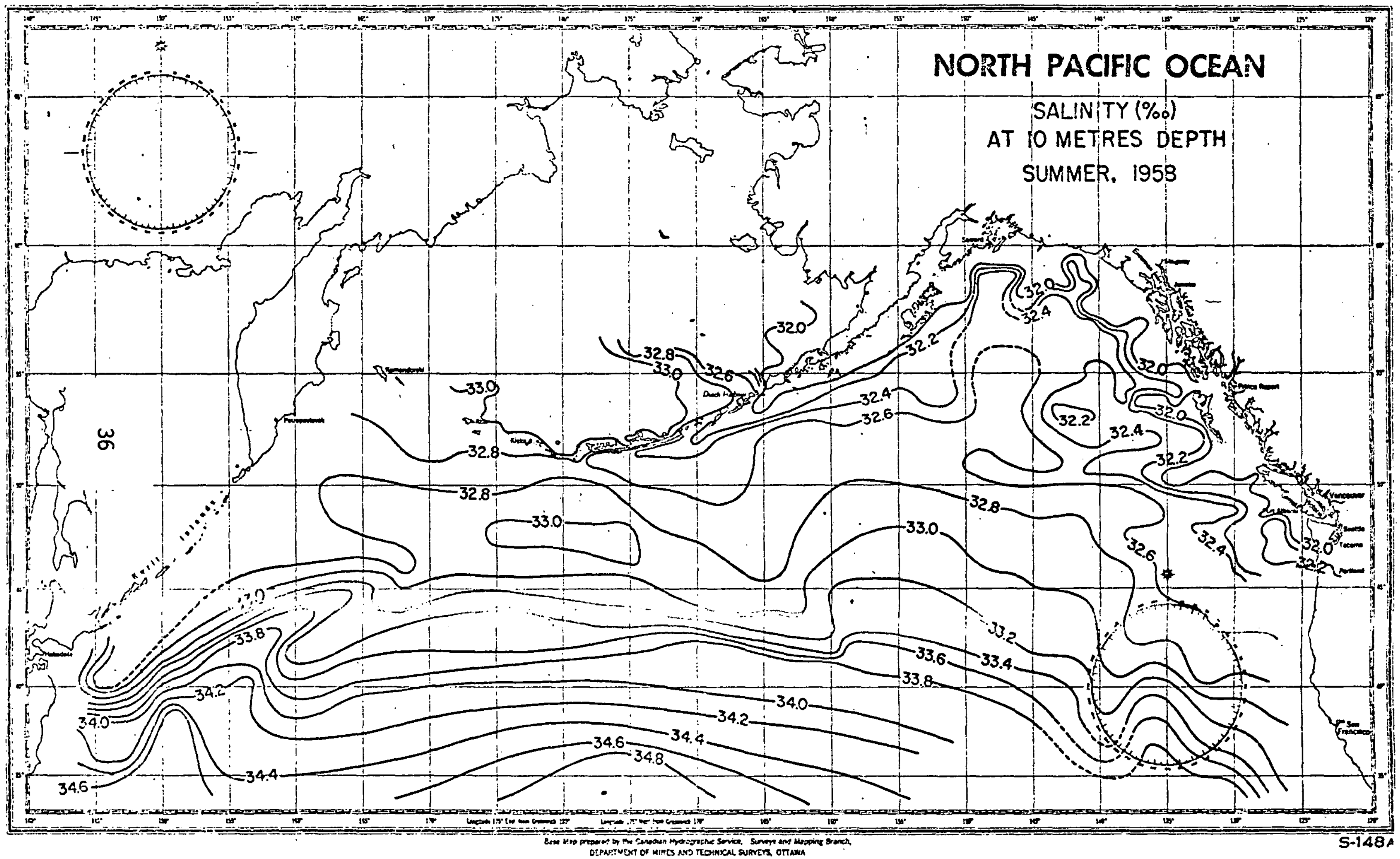

NORTH PACIFIC OCEAN
SALINITY (‰)
AT 10 METRES DEPTH
SUMMER, 1958
32.0
32.2
32.4
32.6
32.8
33.0
33.2
33.4
33.6
33.8
34.0
34.2
34.4
34.6
34.8
Base Map prepared by the Canadian Hydrographic Service, Surveys and Mapping Branch,
DEPARTMENT OF MINES AND TECHNICAL SURVEYS, OTTAWA
S-148A

Figure 26.

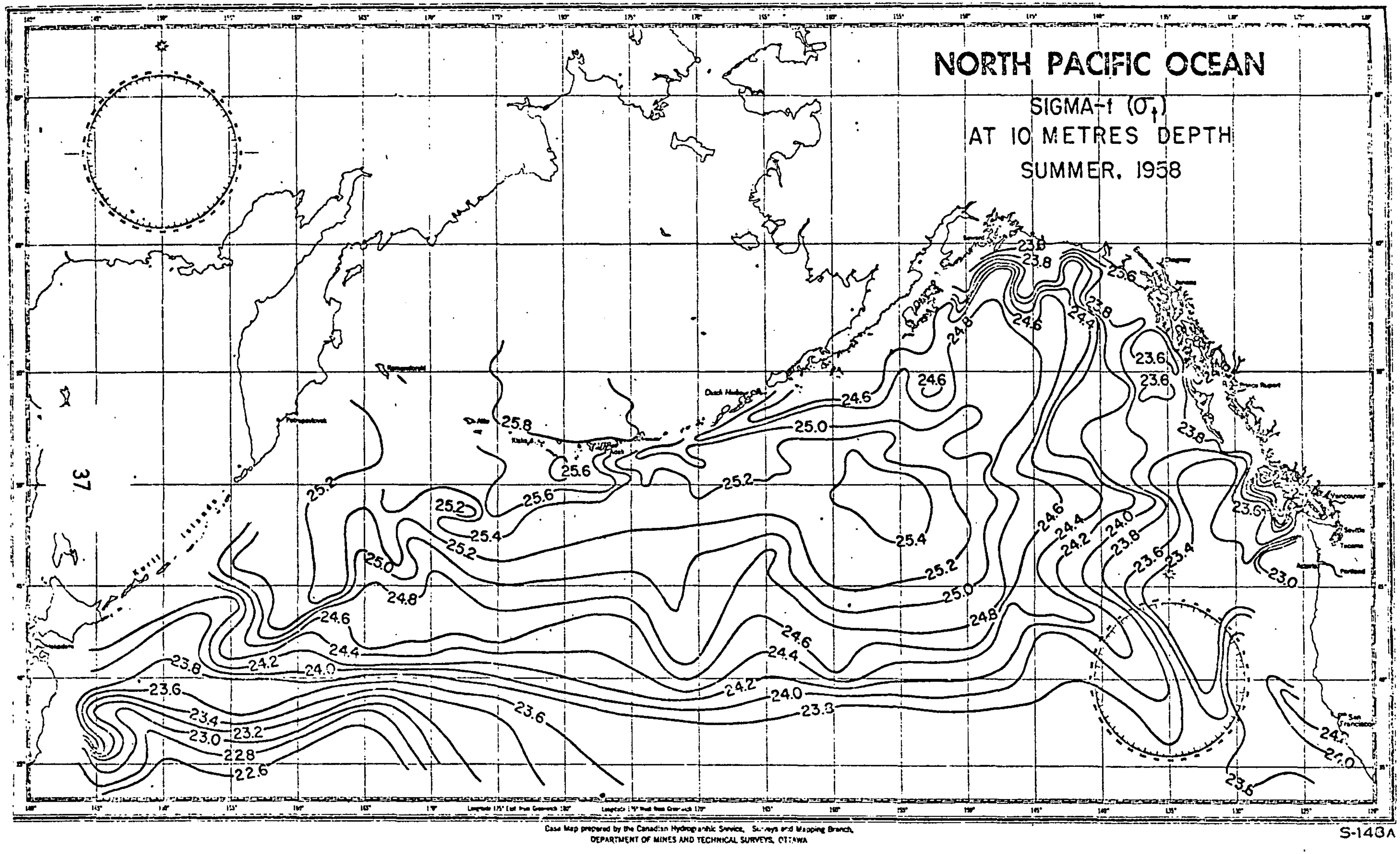

NORTH PACIFIC OCEAN
SIGMA-t (σt)
AT 10 METRES DEPTH
SUMMER, 1958
Petropavlovsk
Dutch Harbor
Kiska
Adak
Attu
Seward
Skagway
Juneau
Prince Rupert
Vancouver
Seattle
Tacoma
Astoria
Portland
San Francisco
25.8
25.6
25.4
25.2
25.0
24.8
24.6
24.4
24.2
24.0
23.8
23.6
23.4
23.3
23.2
23.0
22.8
22.6
Case Map prepared by the Canadian Hydrographic Service, Surveys and Mapping Branch,
DEPARTMENT OF MINES AND TECHNICAL SURVEYS, OTTAWA
S-143A

Figure 27.

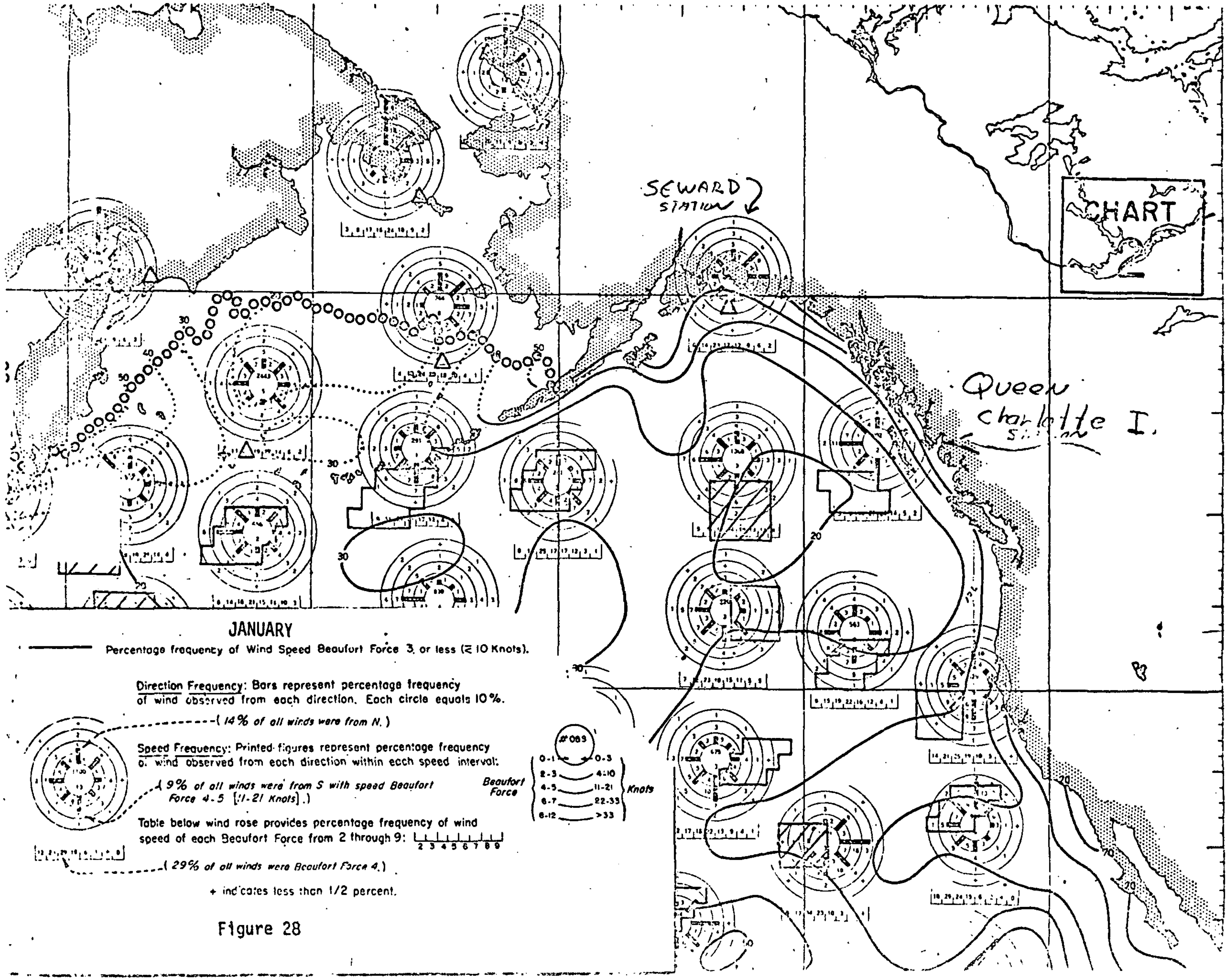

SEWARD STATION
CHART
Queen Charlotte I.
JANUARY
Percentage frequency of Wind Speed Beaufort Force 3, or less (≦ 10 Knots).
Direction Frequency: Bars represent percentage frequency of wind observed from each direction. Each circle equals 10%.
(14% of all winds were from N.)
Speed Frequency: Printed figures represent percentage frequency of wind observed from each direction within each speed interval:
(9% of all winds were from S with speed Beaufort Force 4-5 [11-21 Knots].)
Table below wind rose provides percentage frequency of wind speed of each Beaufort Force from 2 through 9:
(29% of all winds were Beaufort Force 4.)
+ indicates less than 1/2 percent.
Beaufort Force
Knots
0-1 0-3
2-3 4-10
4-5 11-21
6-7 22-33
8-12 >33

Figure 28

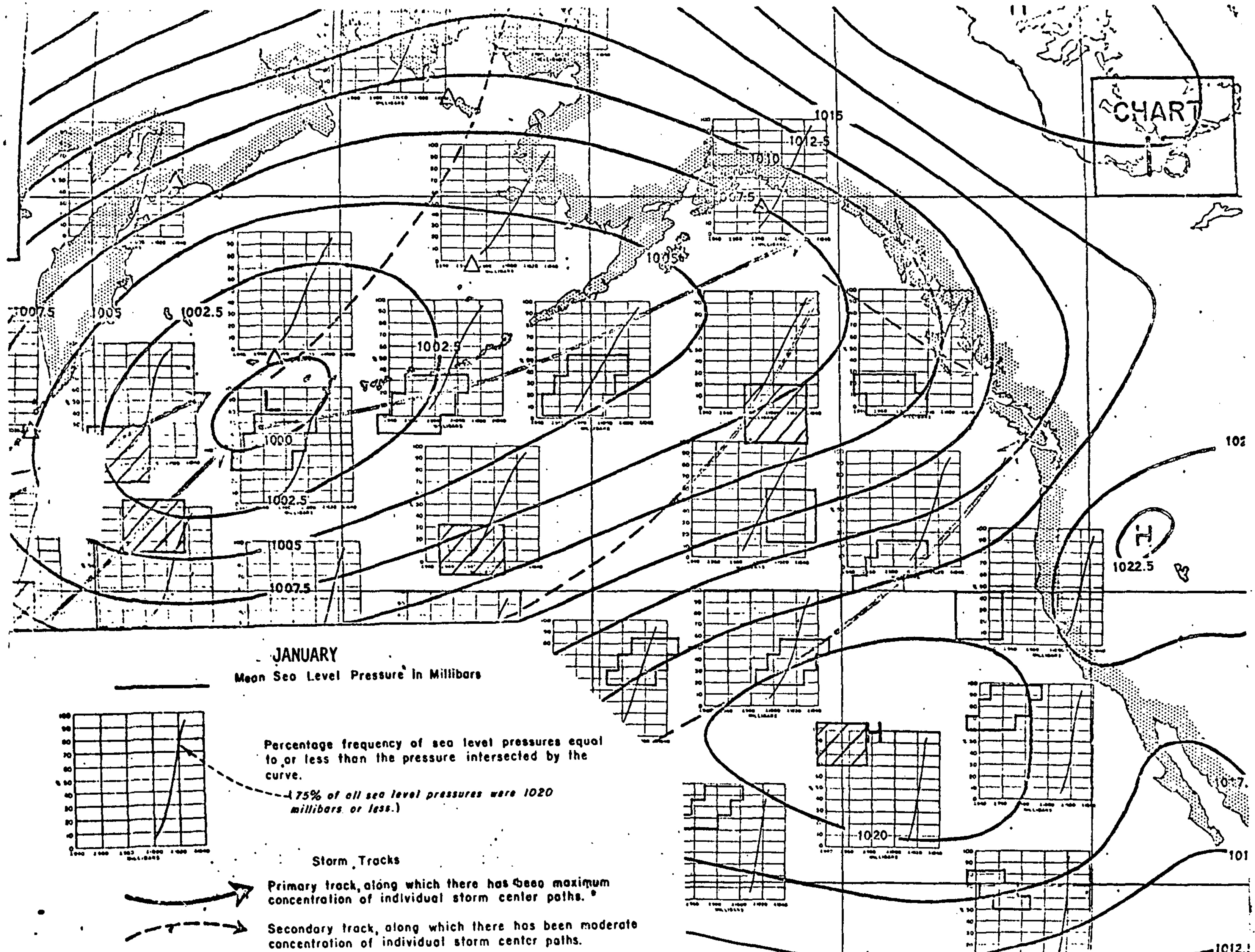


CHART
1015
1012.5
1010
1007.5
1005
1002.5
1000
1022.5
H
L
1020
JANUARY
Mean Sea Level Pressure in Millibars
Percentage frequency of sea level pressures equal to or less than the pressure intersected by the curve.
(75% of all sea level pressures were 1020 millibars or less.)
Storm Tracks
Primary track, along which there has been maximum concentration of individual storm center paths.
Secondary track, along which there has been moderate concentration of individual storm center paths.

Figure 29

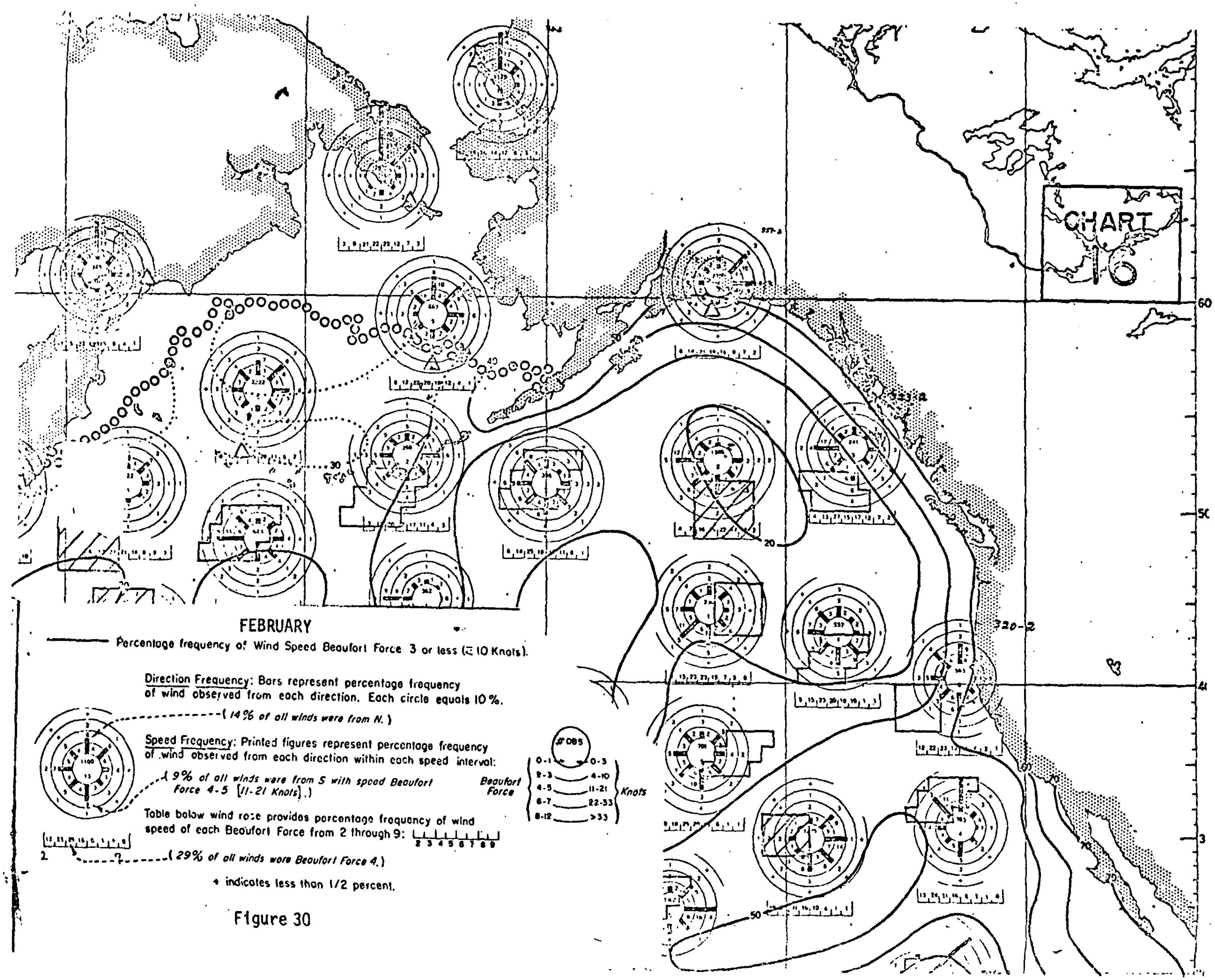


CHART 16
FEBRUARY
Percentage frequency of Wind Speed Beaufort Force 3 or less (≦10 Knots).
Direction Frequency: Bars represent percentage frequency of wind observed from each direction. Each circle equals 10%.
(14% of all winds were from N.)
Speed Frequency: Printed figures represent percentage frequency of wind observed from each direction within each speed interval:
(9% of all winds were from S with speed Beaufort Force 4-5 [11-21 Knots].)
Table below wind rose provides percentage frequency of wind speed of each Beaufort Force from 2 through 9:
(29% of all winds were Beaufort Force 4.)
+ indicates less than 1/2 percent.
# OBS
Beaufort Force
Knots
0-1 0-3
2-3 4-10
4-5 11-21
6-7 22-33
8-12 >33
60
50
40
30
20

Figure 30

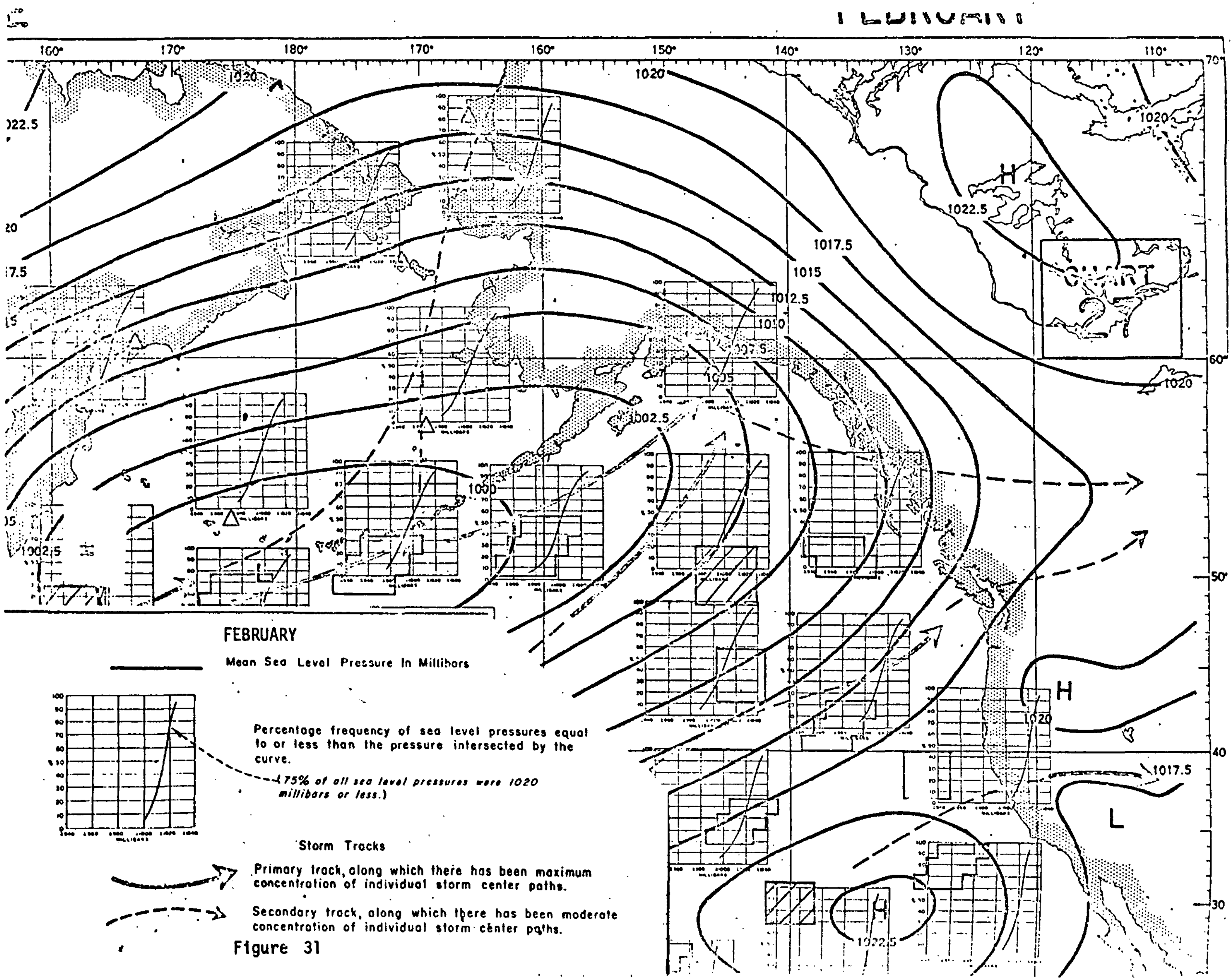

FEBRUARY
160° 170° 180° 170° 160° 150° 140° 130° 120° 110°
70° 60° 50° 40° 30°
1020
1017.5
1015
1012.5
1010
1007.5
1005
1002.5
1000
1022.5
H
L
CHART 2
FEBRUARY
Mean Sea Level Pressure In Millibars
Percentage frequency of sea level pressures equal to or less than the pressure intersected by the curve.
(75% of all sea level pressures were 1020 millibars or less.)
Storm Tracks
Primary track, along which there has been maximum concentration of individual storm center paths.
Secondary track, along which there has been moderate concentration of individual storm center paths.

Figure 31

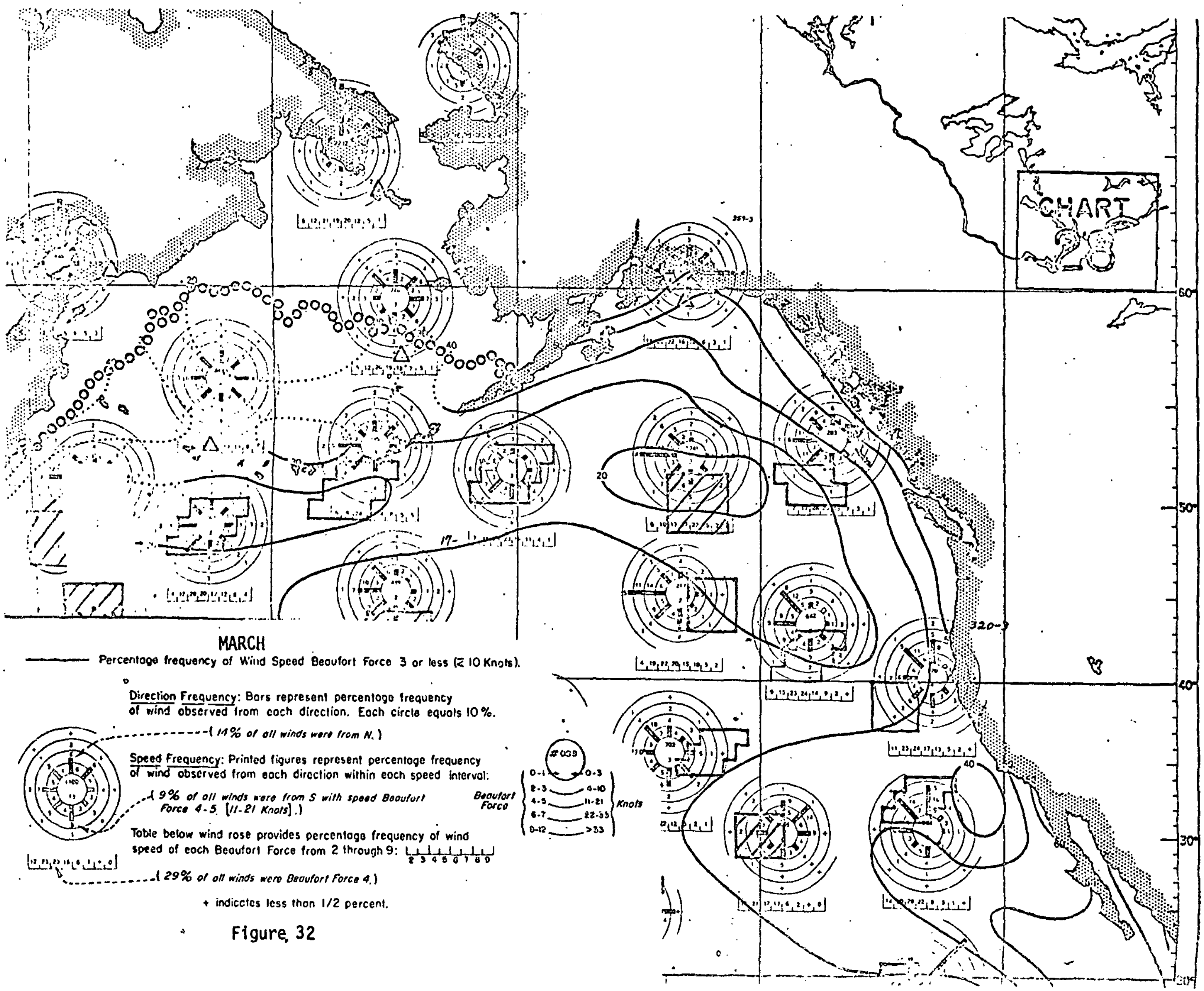


CHART 28
60°
50°
40°
30°
20°
MARCH
Percentage frequency of Wind Speed Beaufort Force 3 or less (≤ 10 Knots).
Direction Frequency: Bars represent percentage frequency of wind observed from each direction. Each circle equals 10 %.
(14% of all winds were from N.)
Speed Frequency: Printed figures represent percentage frequency of wind observed from each direction within each speed interval:
(9% of all winds were from S with speed Beaufort Force 4-5 [11-21 Knots].)
Table below wind rose provides percentage frequency of wind speed of each Beaufort Force from 2 through 9:
(29% of all winds were Beaufort Force 4.)
+ indicates less than 1/2 percent.
Beaufort Force
Knots
0-1 0-3
2-3 4-10
4-5 11-21
6-7 22-33
8-12 >33

Figure 32

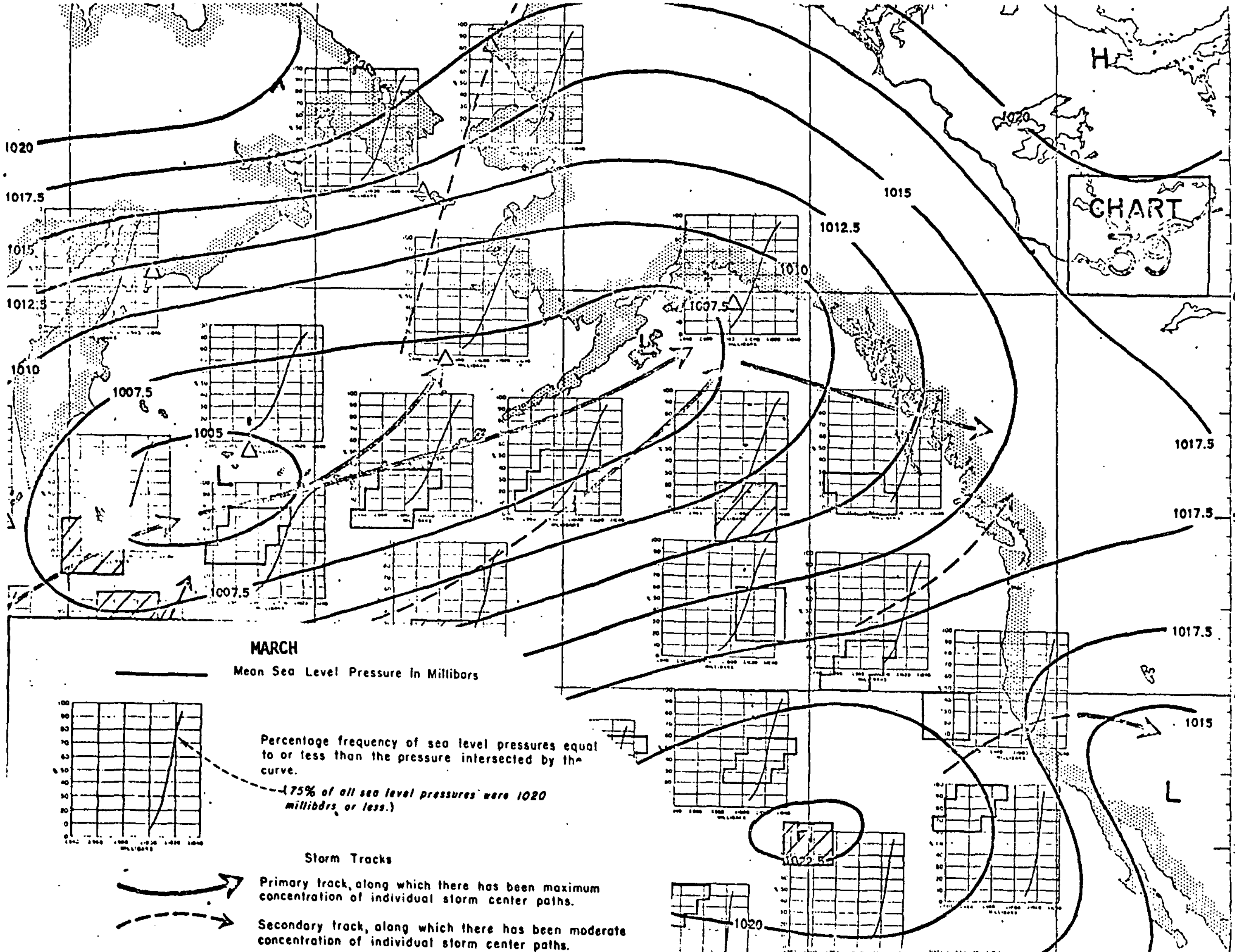


CHART 33
H
L
1020
1017.5
1015
1012.5
1010
1007.5
1005
1022.5
MARCH
Mean Sea Level Pressure in Millibars
Percentage frequency of sea level pressures equal to or less than the pressure intersected by the curve.
(75% of all sea level pressures were 1020 millibars or less.)
Storm Tracks
Primary track, along which there has been maximum concentration of individual storm center paths.
Secondary track, along which there has been moderate concentration of individual storm center paths.

Figure 33

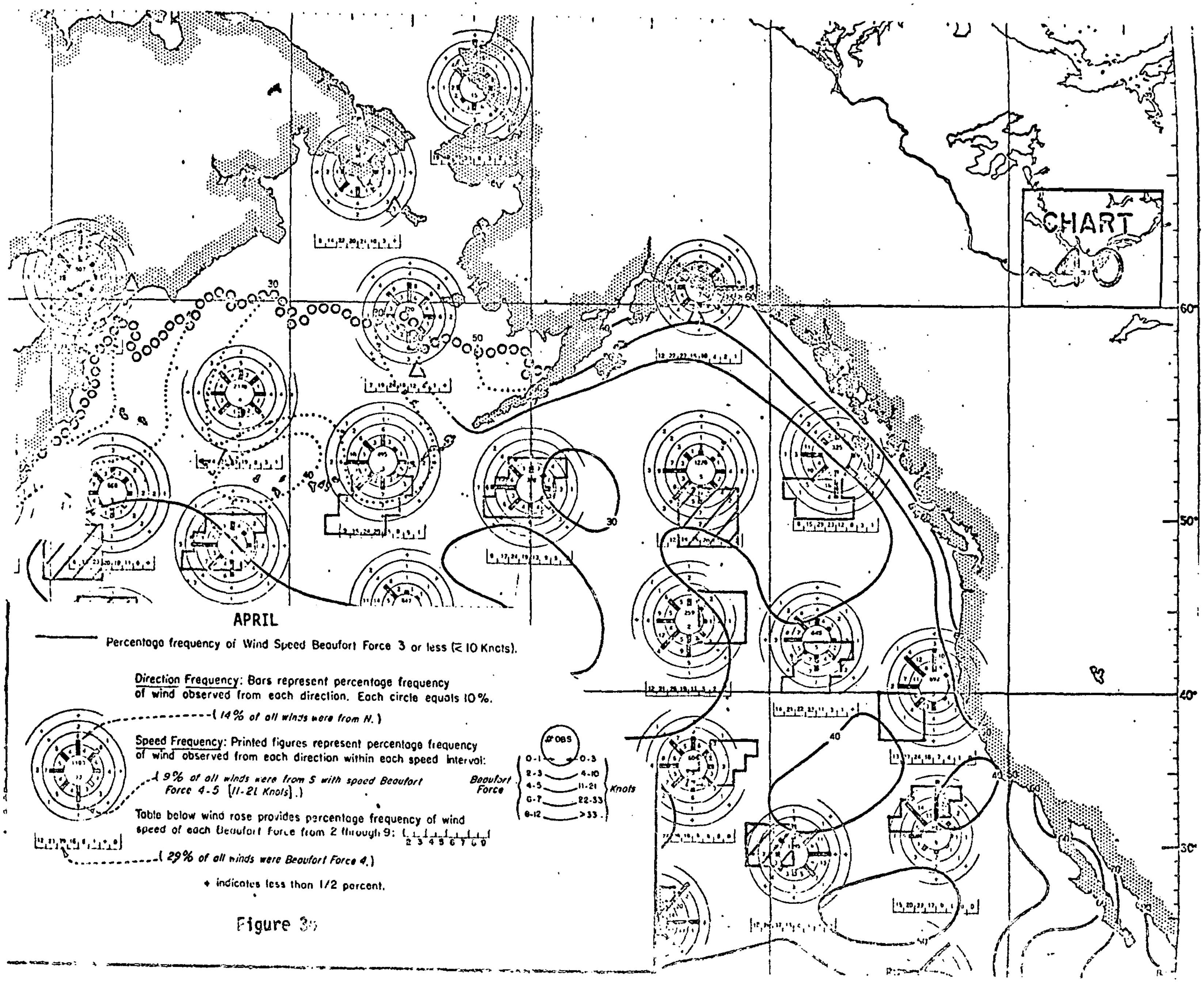


CHART
60°
50°
40°
30°
APRIL
Percentage frequency of Wind Speed Beaufort Force 3 or less (≲ 10 Knots).
Direction Frequency: Bars represent percentage frequency of wind observed from each direction. Each circle equals 10%.
(14% of all winds were from N.)
Speed Frequency: Printed figures represent percentage frequency of wind observed from each direction within each speed interval:
(9% of all winds were from S with speed Beaufort Force 4-5 (11-21 Knots).)
Table below wind rose provides percentage frequency of wind speed of each Beaufort Force from 2 through 9:
2 3 4 5 6 7 8 9
(29% of all winds were Beaufort Force 4.)
◆ indicates less than 1/2 percent.
#OBS
Beaufort Force
0-1
2-3
4-5
6-7
8-12
0-3
4-10
11-21
22-33
>33
Knots

Figure 35

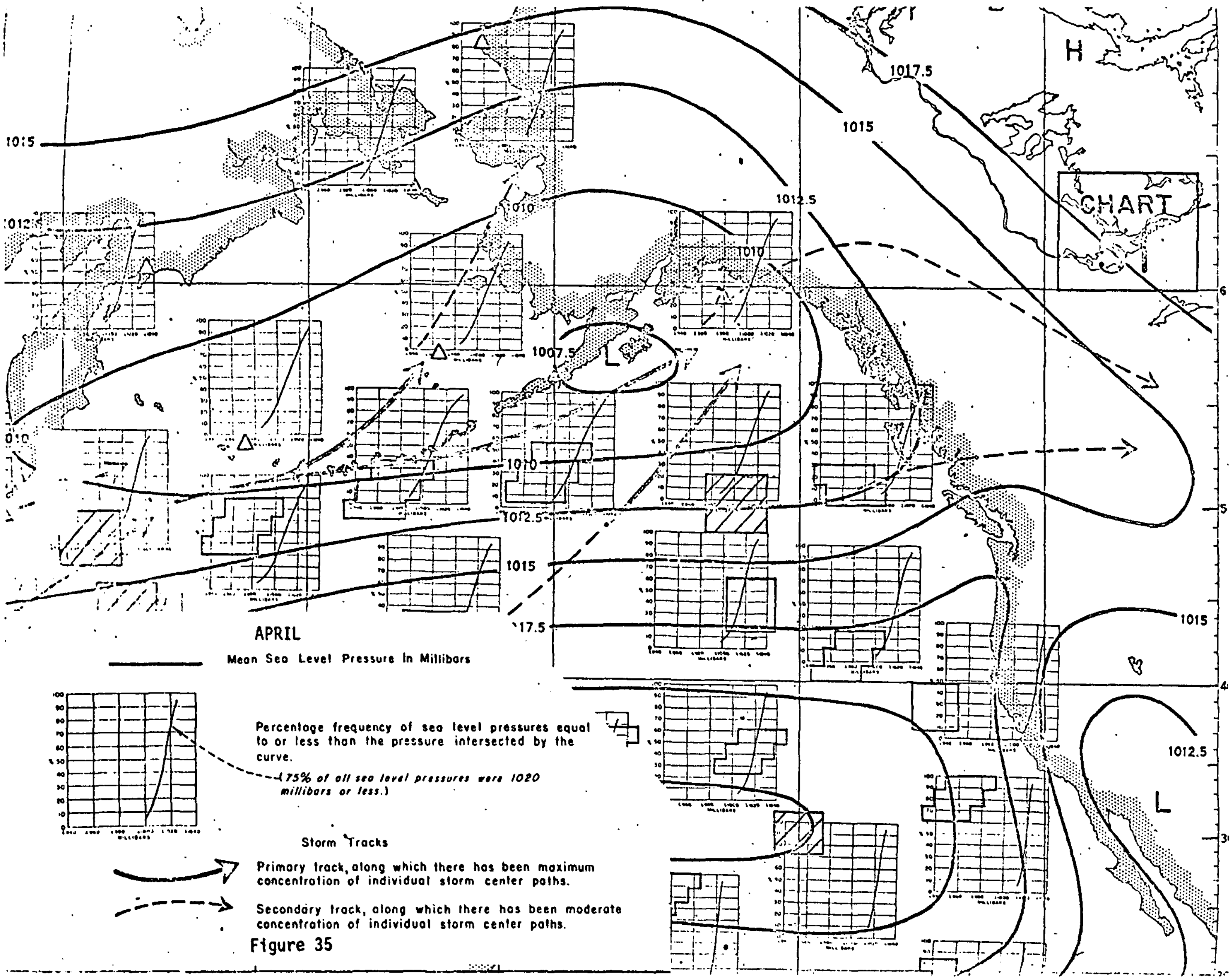

APRIL
Mean Sea Level Pressure In Millibars
Percentage frequency of sea level pressures equal to or less than the pressure intersected by the curve.
(75% of all sea level pressures were 1020 millibars or less.)
Storm Tracks
Primary track, along which there has been maximum concentration of individual storm center paths.
Secondary track, along which there has been moderate concentration of individual storm center paths.
H
CHART
L
1017.5
1015
1012.5
1010
1007.5

Figure 35

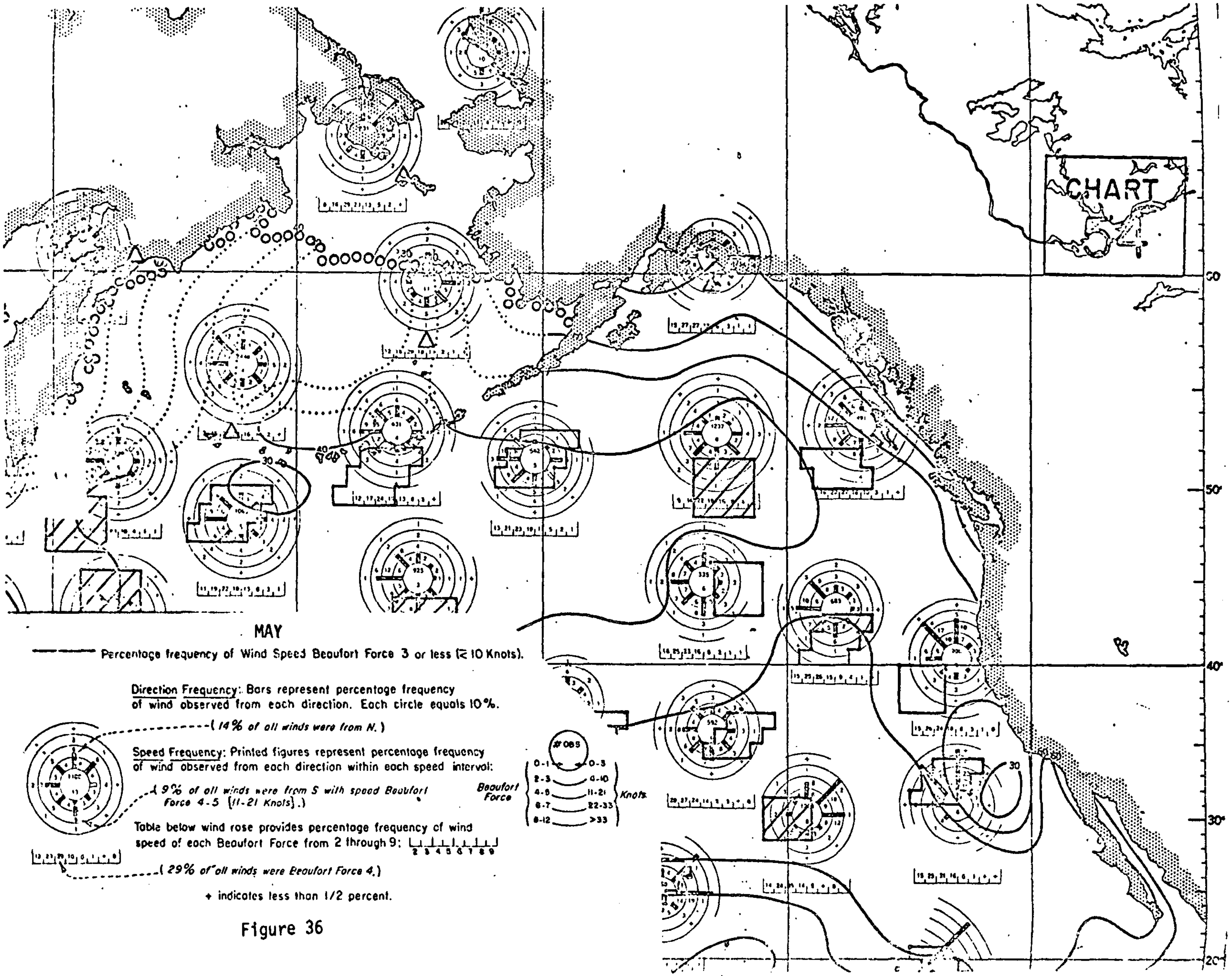


CHART
60
50'
40'
30'
20
MAY
Percentage frequency of Wind Speed Beaufort Force 3 or less (≤ 10 Knots).
Direction Frequency: Bars represent percentage frequency of wind observed from each direction. Each circle equals 10%.
(14% of all winds were from N.)
Speed Frequency: Printed figures represent percentage frequency of wind observed from each direction within each speed interval:
(9% of all winds were from S with speed Beaufort Force 4-5 (11-21 Knots).)
Table below wind rose provides percentage frequency of wind speed of each Beaufort Force from 2 through 9:
(29% of all winds were Beaufort Force 4.)
+ indicates less than 1/2 percent.
# OBS
0-1 0-3
2-3 4-10
4-5 11-21
6-7 22-33
8-12 >33
Beaufort Force
Knots

Figure 36

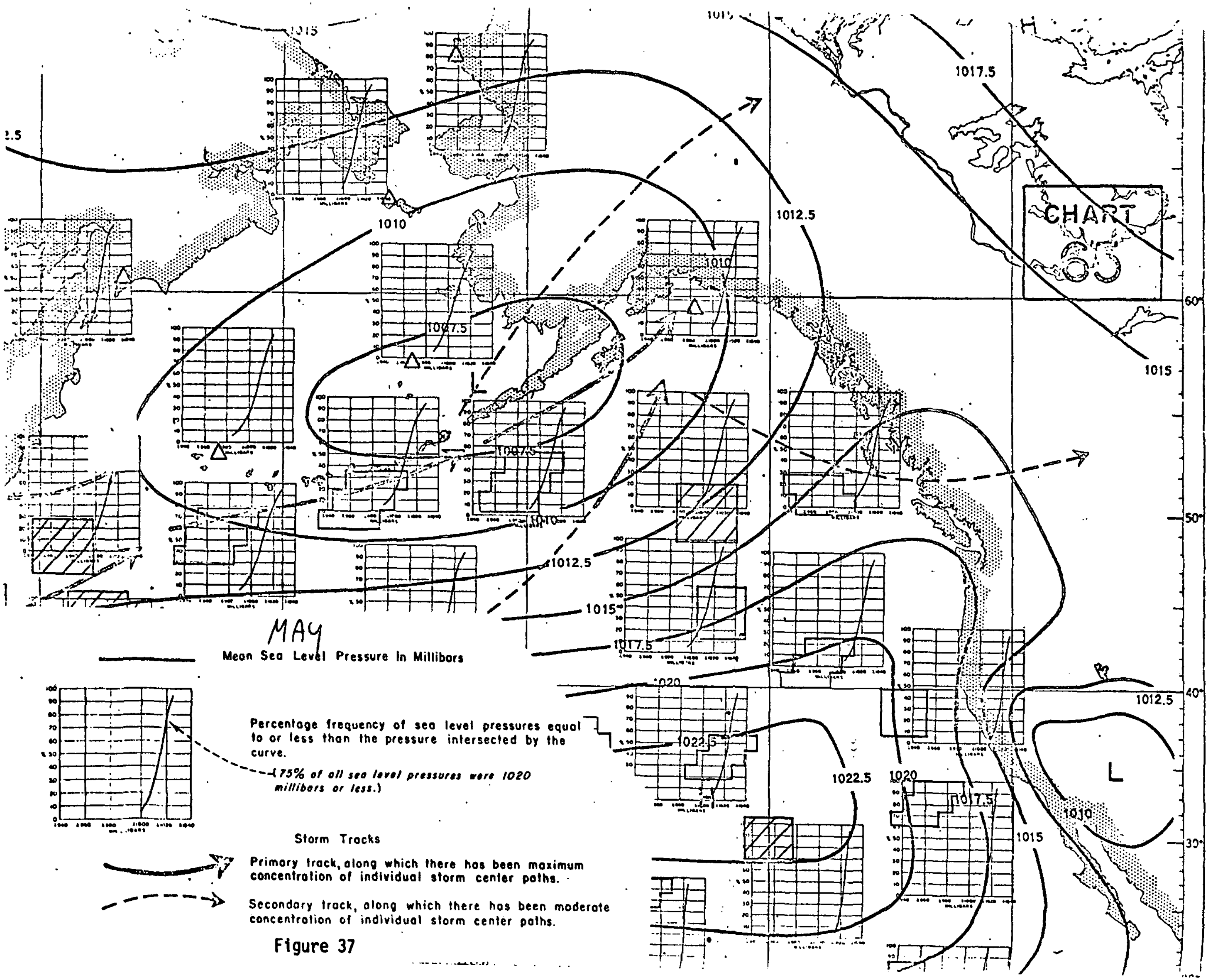


CHART 65
MAY
Mean Sea Level Pressure In Millibars
Percentage frequency of sea level pressures equal to or less than the pressure intersected by the curve.
(75% of all sea level pressures were 1020 millibars or less.)
Storm Tracks
Primary track, along which there has been maximum concentration of individual storm center paths.
Secondary track, along which there has been moderate concentration of individual storm center paths.
1007.5
1010
1012.5
1015
1017.5
1020
1022.5
L
H
60°
50°
40°
30°

Figure 37

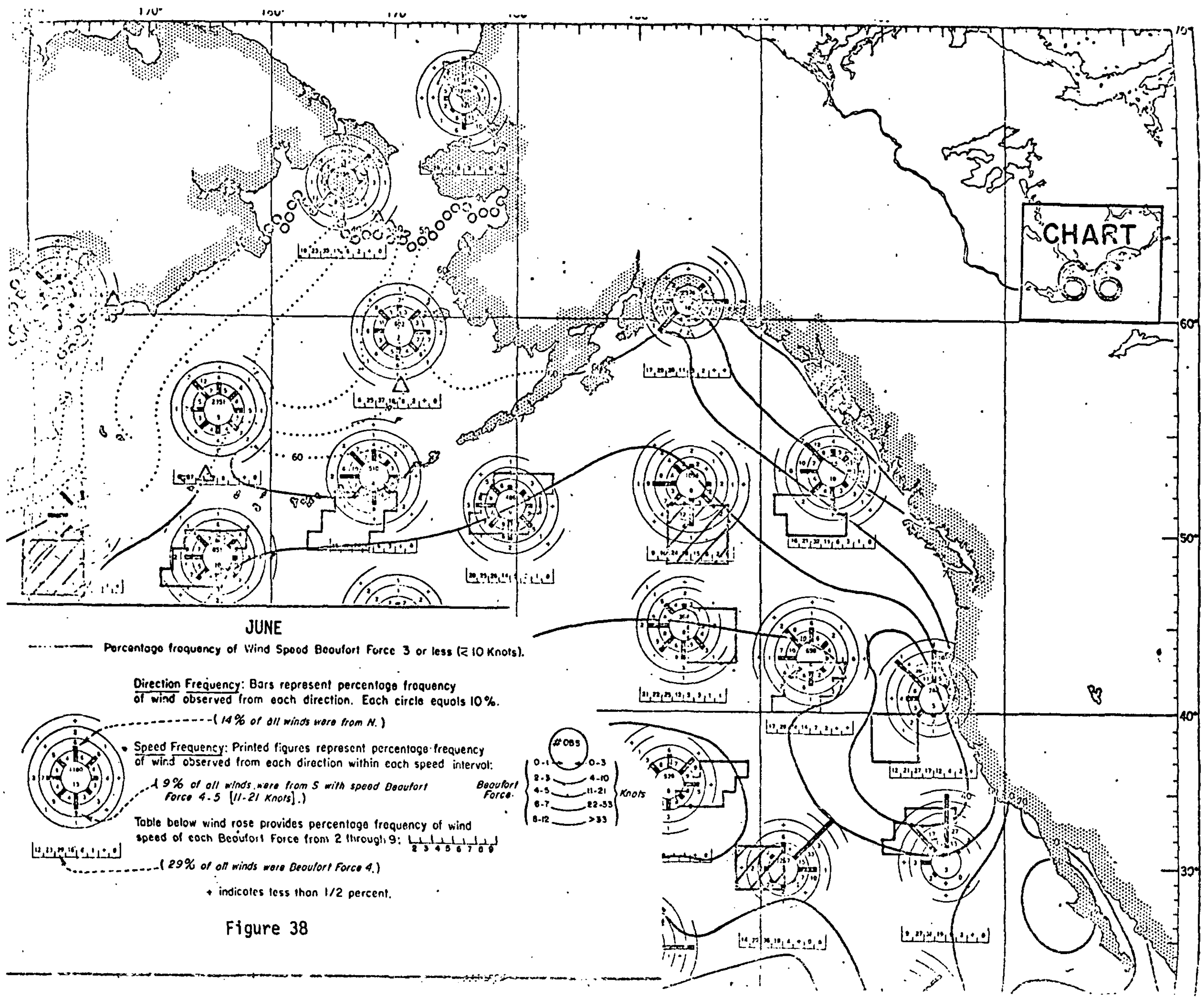


CHART 66
70°
60°
50°
40°
30°
60
JUNE
Percentage frequency of Wind Speed Beaufort Force 3 or less (≤ 10 Knots).
Direction Frequency: Bars represent percentage frequency of wind observed from each direction. Each circle equals 10%.
(14% of all winds were from N.)
Speed Frequency: Printed figures represent percentage frequency of wind observed from each direction within each speed interval:
(9% of all winds were from S with speed Beaufort Force 4-5 [11-21 Knots].)
Table below wind rose provides percentage frequency of wind speed of each Beaufort Force from 2 through 9:
(29% of all winds were Beaufort Force 4.)
+ indicates less than 1/2 percent.
#OBS
Beaufort Force
0-1
2-3
4-5
6-7
8-12
Knots
0-3
4-10
11-21
22-33
>33

Figure 38

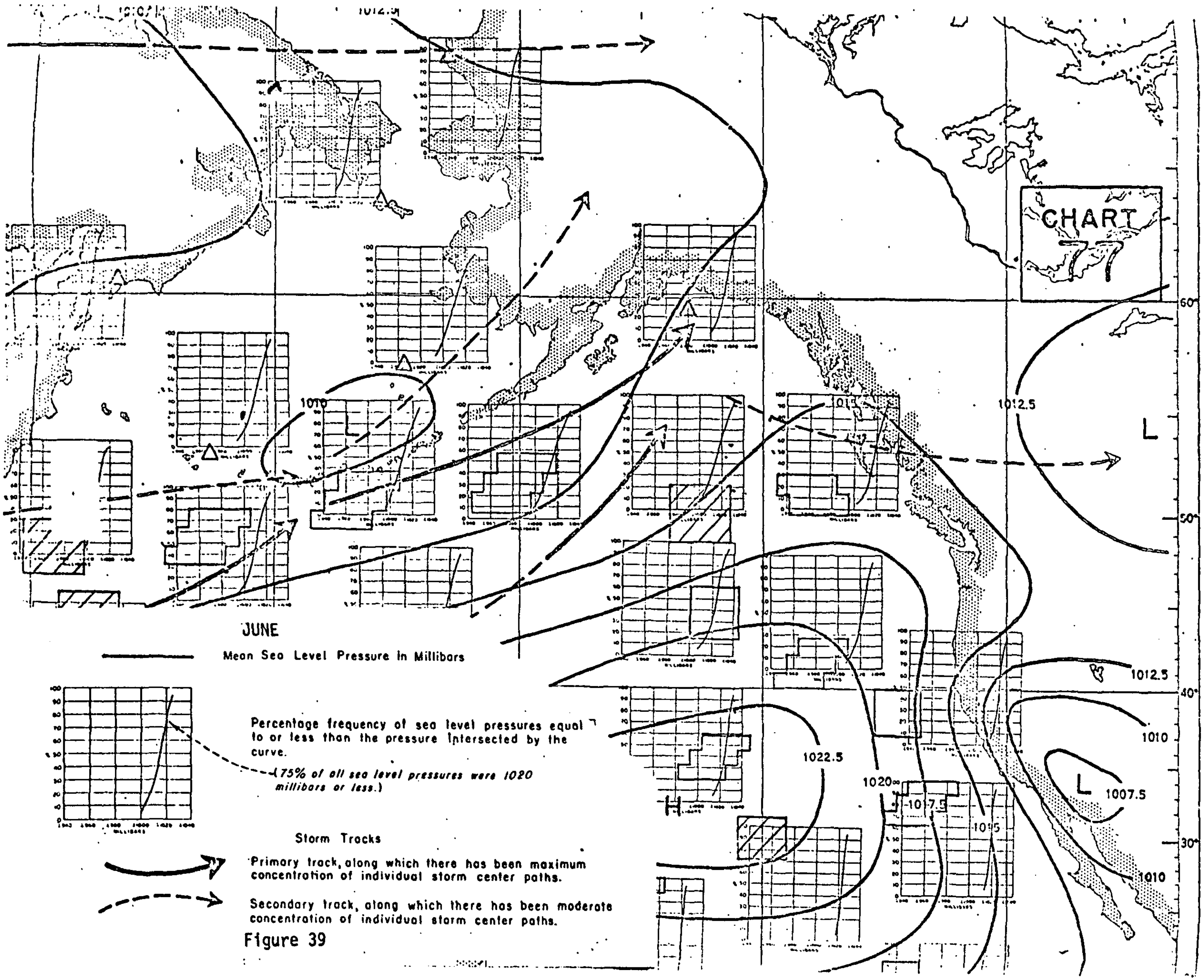


CHART 77
JUNE
Mean Sea Level Pressure in Millibars
Percentage frequency of sea level pressures equal to or less than the pressure intersected by the curve.
(75% of all sea level pressures were 1020 millibars or less.)
Storm Tracks
Primary track, along which there has been maximum concentration of individual storm center paths.
Secondary track, along which there has been moderate concentration of individual storm center paths.
1010
1012.5
1015
1022.5
1020
1017.5
1007.5
L
H
60°
50°
40°
30°

Figure 39

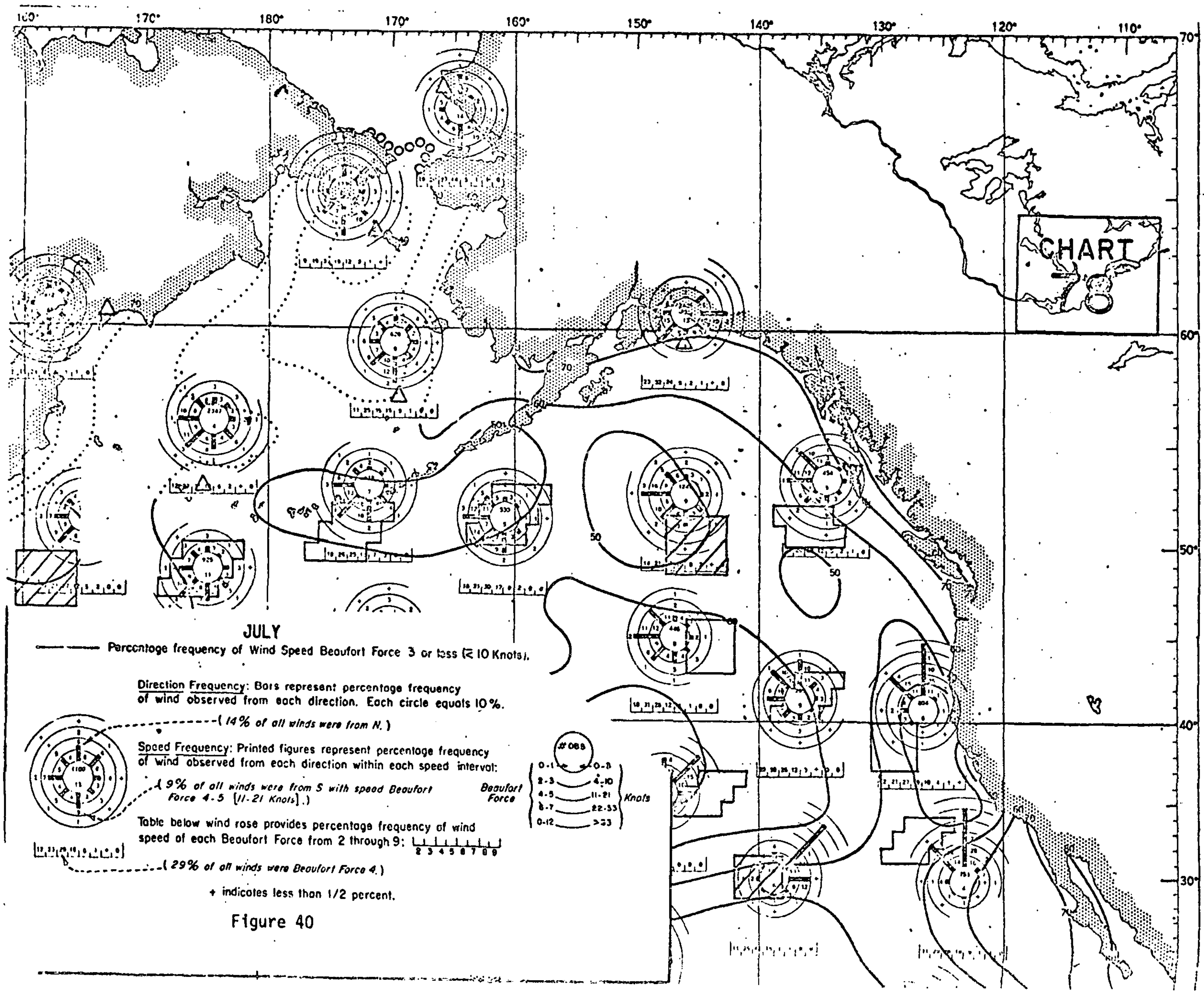


CHART 8
JULY
Percentage frequency of Wind Speed Beaufort Force 3 or less (≤ 10 Knots).
Direction Frequency: Bars represent percentage frequency of wind observed from each direction. Each circle equals 10 %.
(14% of all winds were from N.)
Speed Frequency: Printed figures represent percentage frequency of wind observed from each direction within each speed interval:
(9% of all winds were from S with speed Beaufort Force 4-5 (11-21 Knots).)
Table below wind rose provides percentage frequency of wind speed of each Beaufort Force from 2 through 9:
2 3 4 5 6 7 8 9
(29% of all winds were Beaufort Force 4.)
+ indicates less than 1/2 percent.
# OBS
Beaufort Force
0-1
2-3
4-5
6-7
8-12
Knots
0-3
4-10
11-21
22-33
>33
170°
180°
170°
160°
150°
140°
130°
120°
110°
70°
60°
50°
40°
30°
50
70

Figure 40

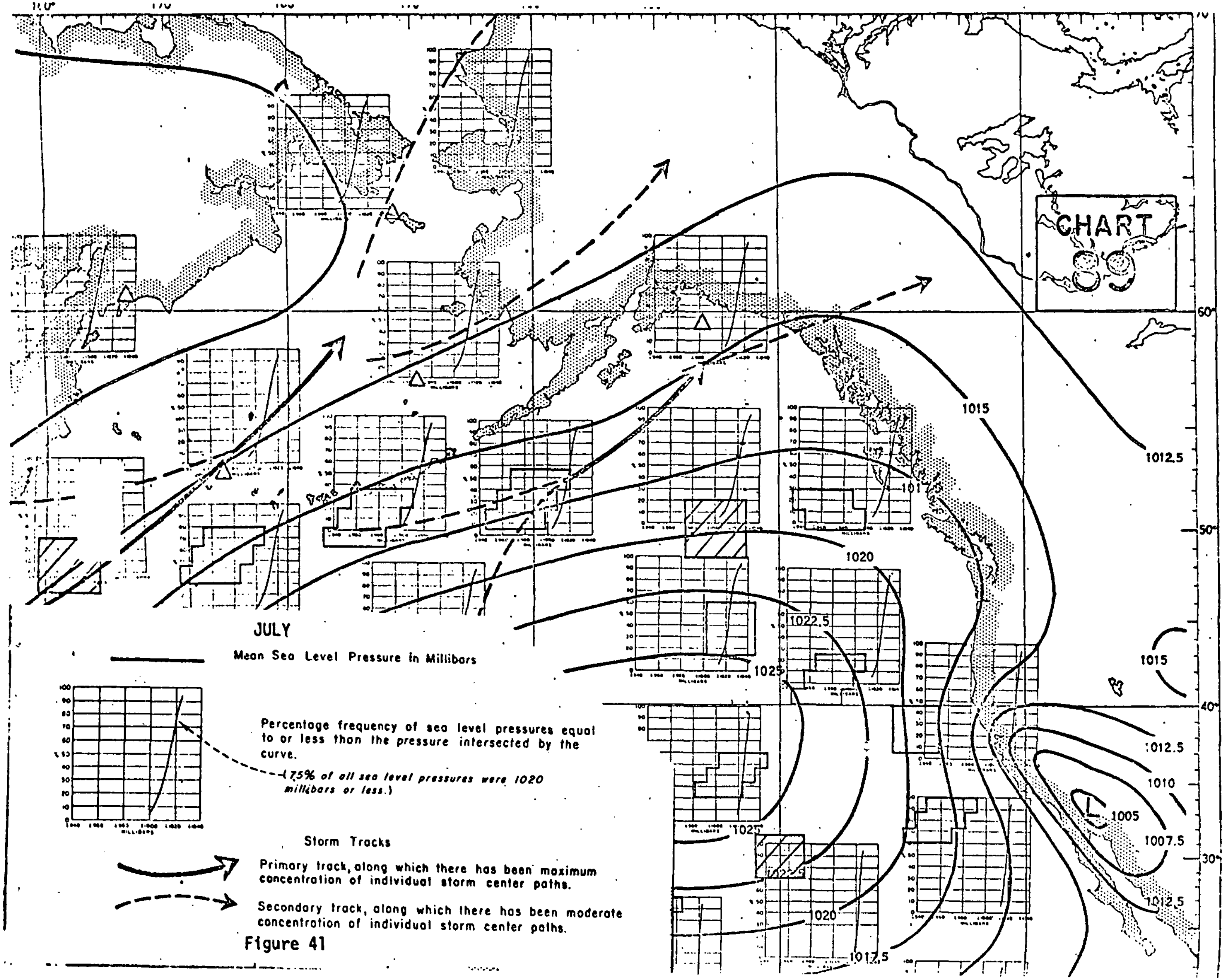


CHART 89
JULY
Mean Sea Level Pressure in Millibars
Percentage frequency of sea level pressures equal to or less than the pressure intersected by the curve.
(75% of all sea level pressures were 1020 millibars or less.)
Storm Tracks
Primary track, along which there has been maximum concentration of individual storm center paths.
Secondary track, along which there has been moderate concentration of individual storm center paths.
1015
1012.5
1020
1022.5
1025
1010
1005
1007.5
60°
50°
40°
30°
L

Figure 41

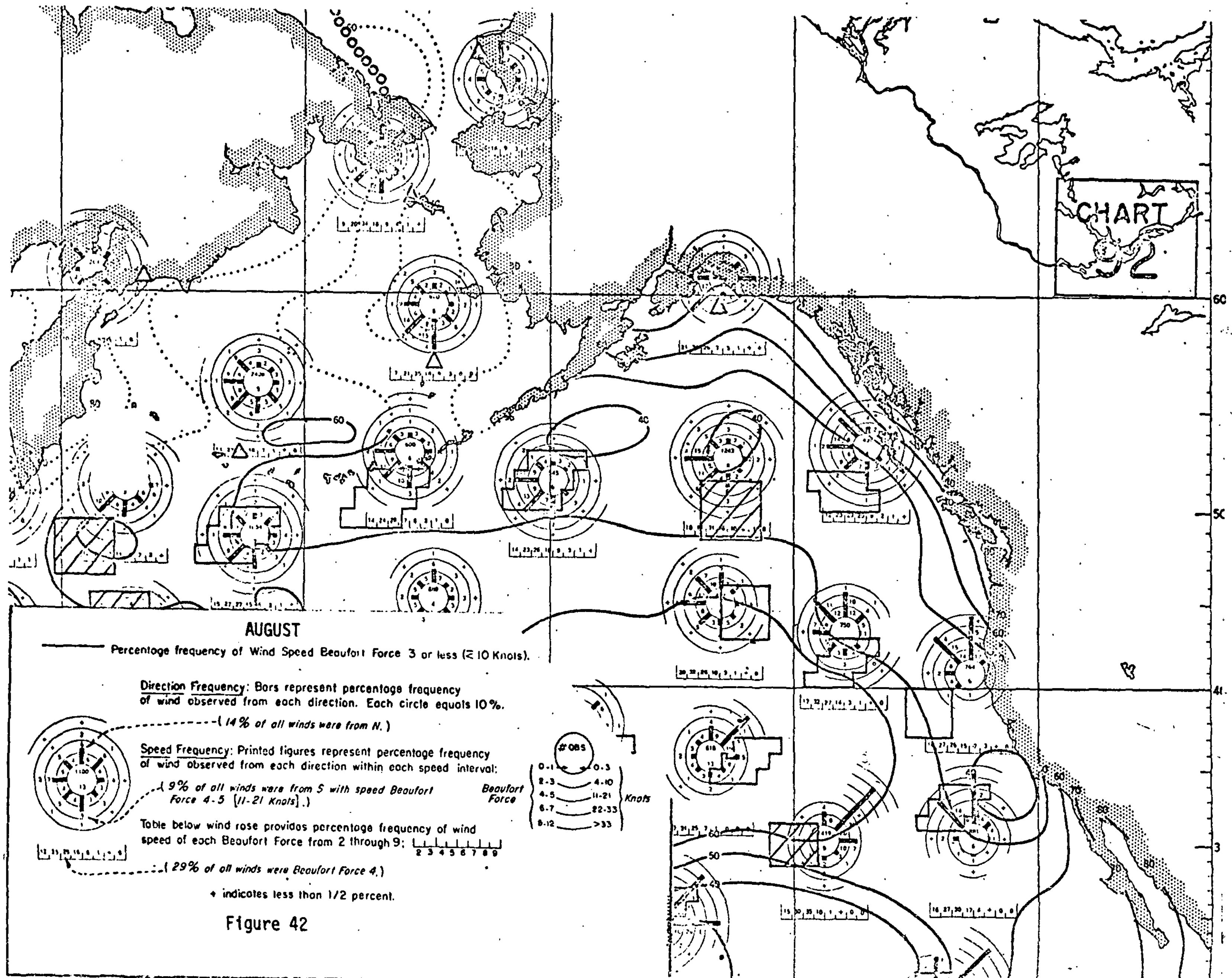


CHART 2
AUGUST
Percentage frequency of Wind Speed Beaufort Force 3 or less (≦ 10 Knots).
Direction Frequency: Bars represent percentage frequency of wind observed from each direction. Each circle equals 10%.
(14% of all winds were from N.)
Speed Frequency: Printed figures represent percentage frequency of wind observed from each direction within each speed interval:
(9% of all winds were from S with speed Beaufort Force 4-5 (11-21 Knots).)
Beaufort Force
Knots
OBS
0-1 0-3
2-3 4-10
4-5 11-21
6-7 22-33
8-12 >33
Table below wind rose provides percentage frequency of wind speed of each Beaufort Force from 2 through 9:
2 3 4 5 6 7 8 9
(29% of all winds were Beaufort Force 4.)
+ indicates less than 1/2 percent.
60
50
40
30

Figure 42

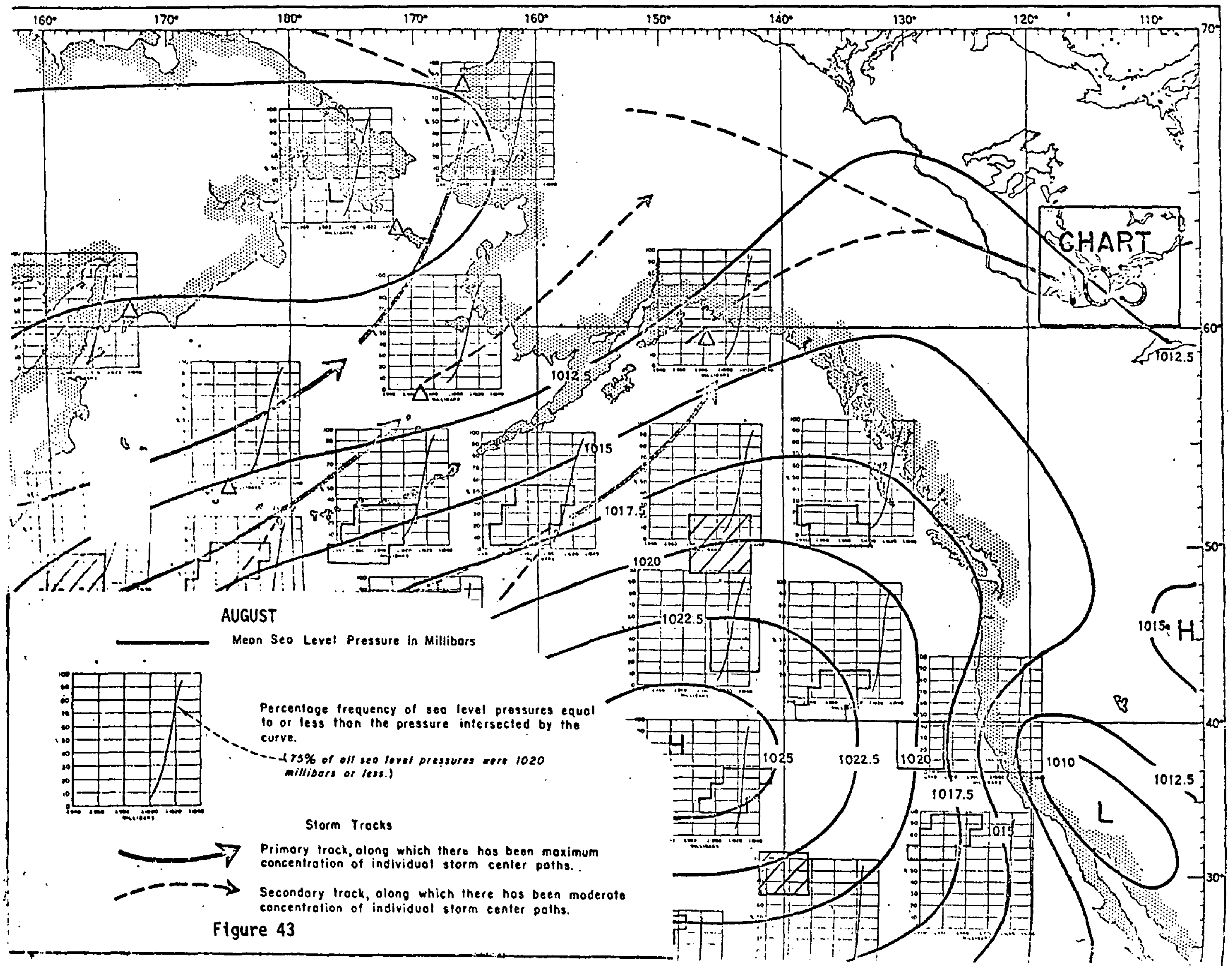
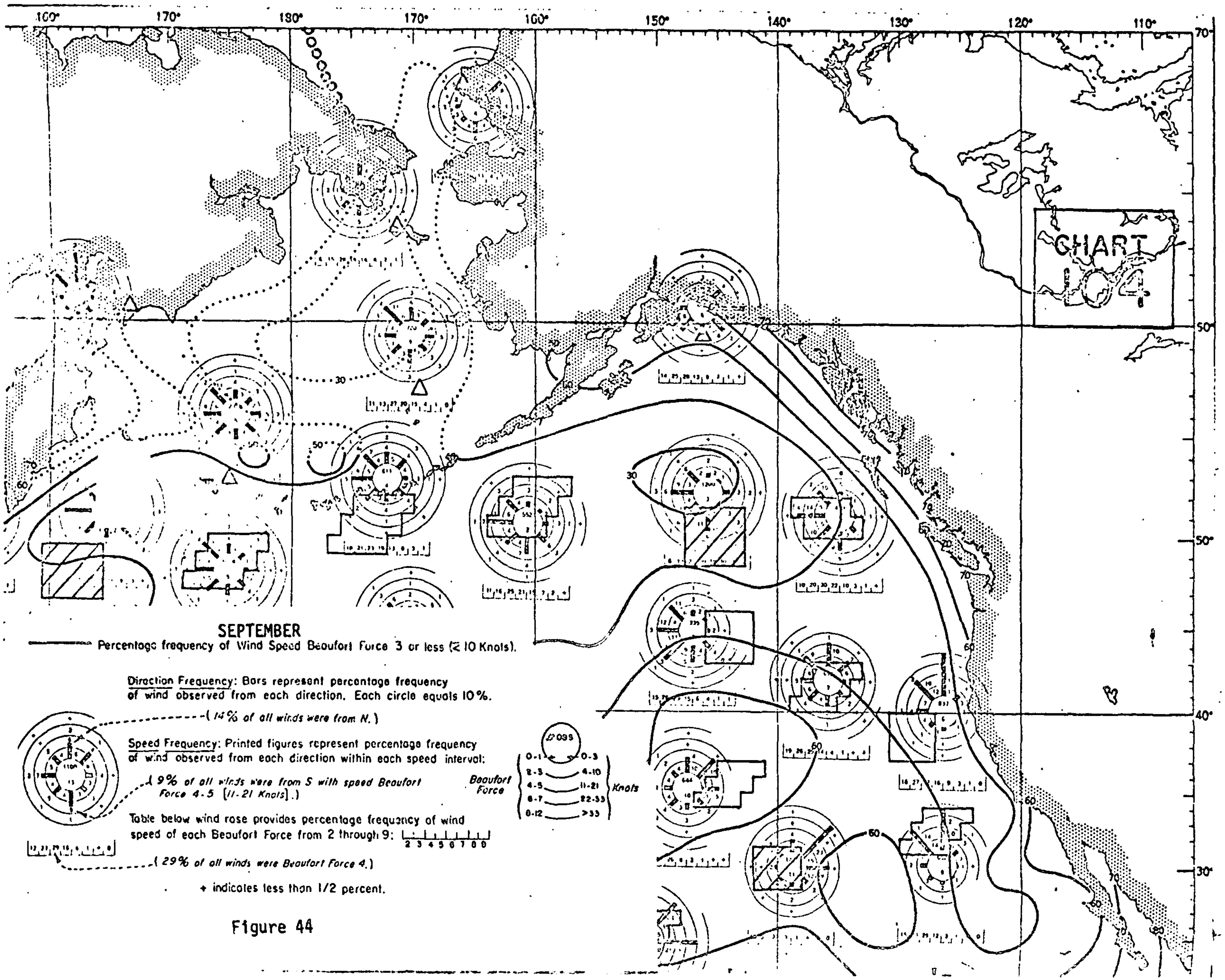

160°
170°
180°
170°
160°
150°
140°
130°
120°
110°
70°
60°
50°
40°
30°
CHART
1012.5
1015
1017.5
1020
1022.5
1025
1022.5
1020
1017.5
1015
1010
1012.5
1015
H
L
H
L
AUGUST
Mean Sea Level Pressure in Millibars
Percentage frequency of sea level pressures equal to or less than the pressure intersected by the curve.
(75% of all sea level pressures were 1020 millibars or less.)
Storm Tracks
Primary track, along which there has been maximum concentration of individual storm center paths.
Secondary track, along which there has been moderate concentration of individual storm center paths.

Figure 43



160°
170°
180°
170°
160°
150°
140°
130°
120°
110°
70°
50°
40°
30°
CHART L04
SEPTEMBER
Percentage frequency of Wind Speed Beaufort Force 3 or less (≦ 10 Knots).
Direction Frequency: Bars represent percentage frequency of wind observed from each direction. Each circle equals 10%.
(14% of all winds were from N.)
Speed Frequency: Printed figures represent percentage frequency of wind observed from each direction within each speed interval:
(9% of all winds were from S with speed Beaufort Force 4-5 [11-21 Knots].)
Beaufort Force
Knots
0-1
2-3
4-5
6-7
8-12
0-3
4-10
11-21
22-33
>33
Table below wind rose provides percentage frequency of wind speed of each Beaufort Force from 2 through 9:
2 3 4 5 6 7 8 9
(29% of all winds were Beaufort Force 4.)
+ indicates less than 1/2 percent.

Figure 44

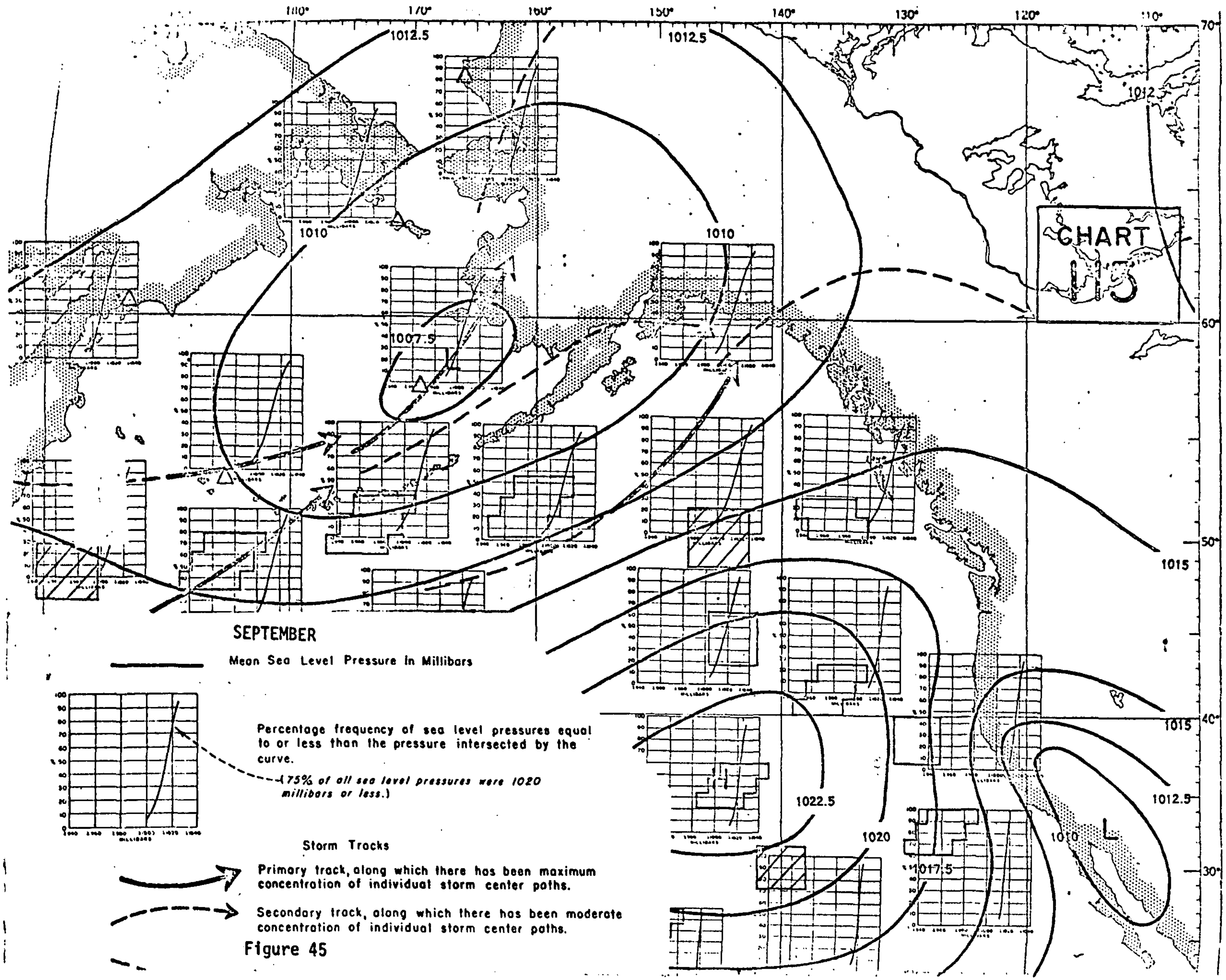

180°
170°
160°
150°
140°
130°
120°
110°
70°
60°
50°
40°
30°
1012.5
1012.5
1012
1010
1010
1007.5
1015
1015
1012.5
1022.5
1020
1017.5
1010
L
CHART
SEPTEMBER
Mean Sea Level Pressure in Millibars
Percentage frequency of sea level pressures equal to or less than the pressure intersected by the curve.
(75% of all sea level pressures were 1020 millibars or less.)
Storm Tracks
Primary track, along which there has been maximum concentration of individual storm center paths.
Secondary track, along which there has been moderate concentration of individual storm center paths.

Figure 45

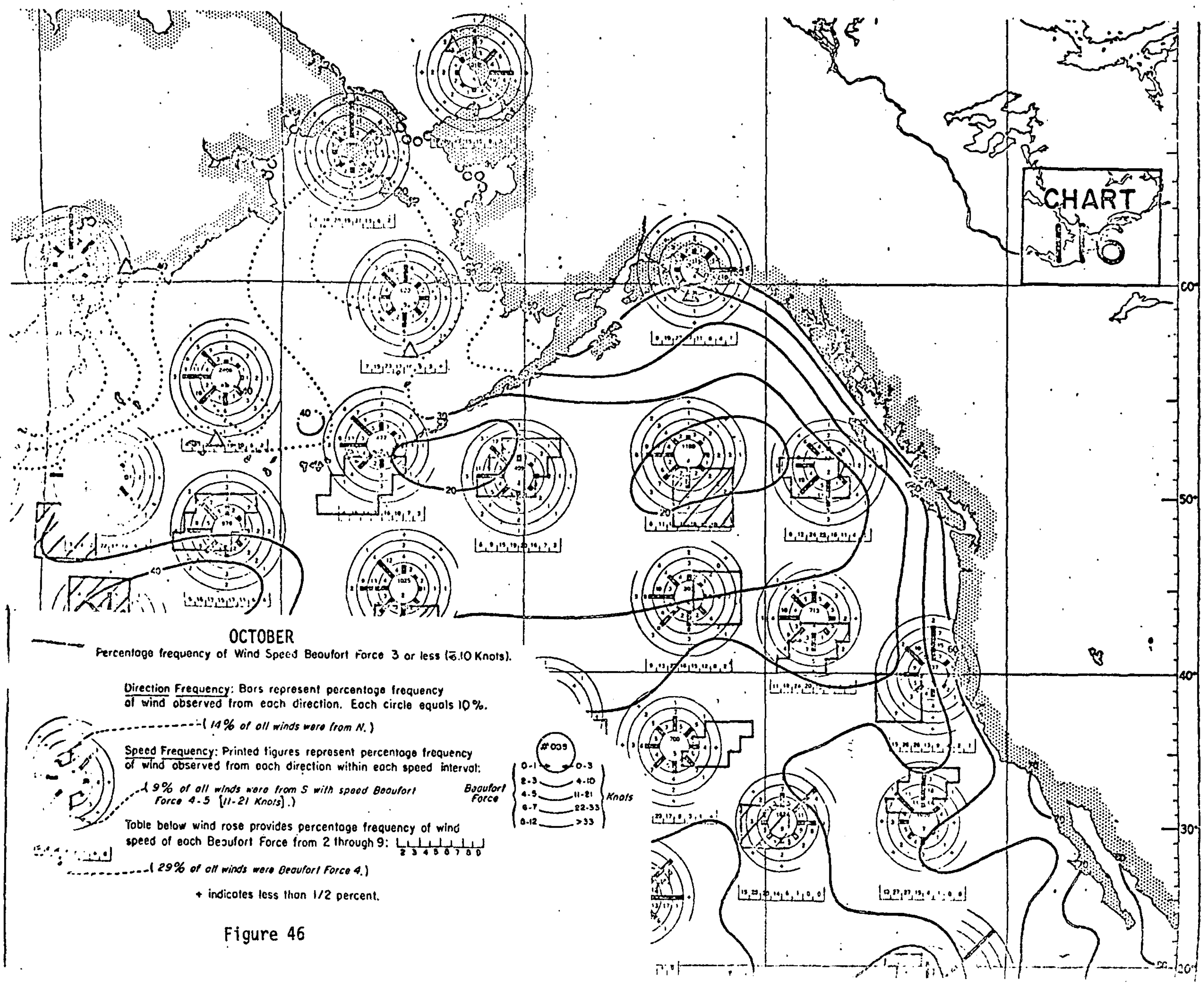


CHART 16
OCTOBER
Percentage frequency of Wind Speed Beaufort Force 3 or less (≤10 Knots).
Direction Frequency: Bars represent percentage frequency of wind observed from each direction. Each circle equals 10%.
(14% of all winds were from N.)
Speed Frequency: Printed figures represent percentage frequency of wind observed from each direction within each speed interval:
(9% of all winds were from S with speed Beaufort Force 4-5 (11-21 Knots).)
Table below wind rose provides percentage frequency of wind speed of each Beaufort Force from 2 through 9:
(29% of all winds were Beaufort Force 4.)
+ indicates less than 1/2 percent.
Beaufort Force
Knots
0-1
2-3
4-5
6-7
8-12
0-3
4-10
11-21
22-33
>33
60°
50°
40°
30°
20°

Figure 46

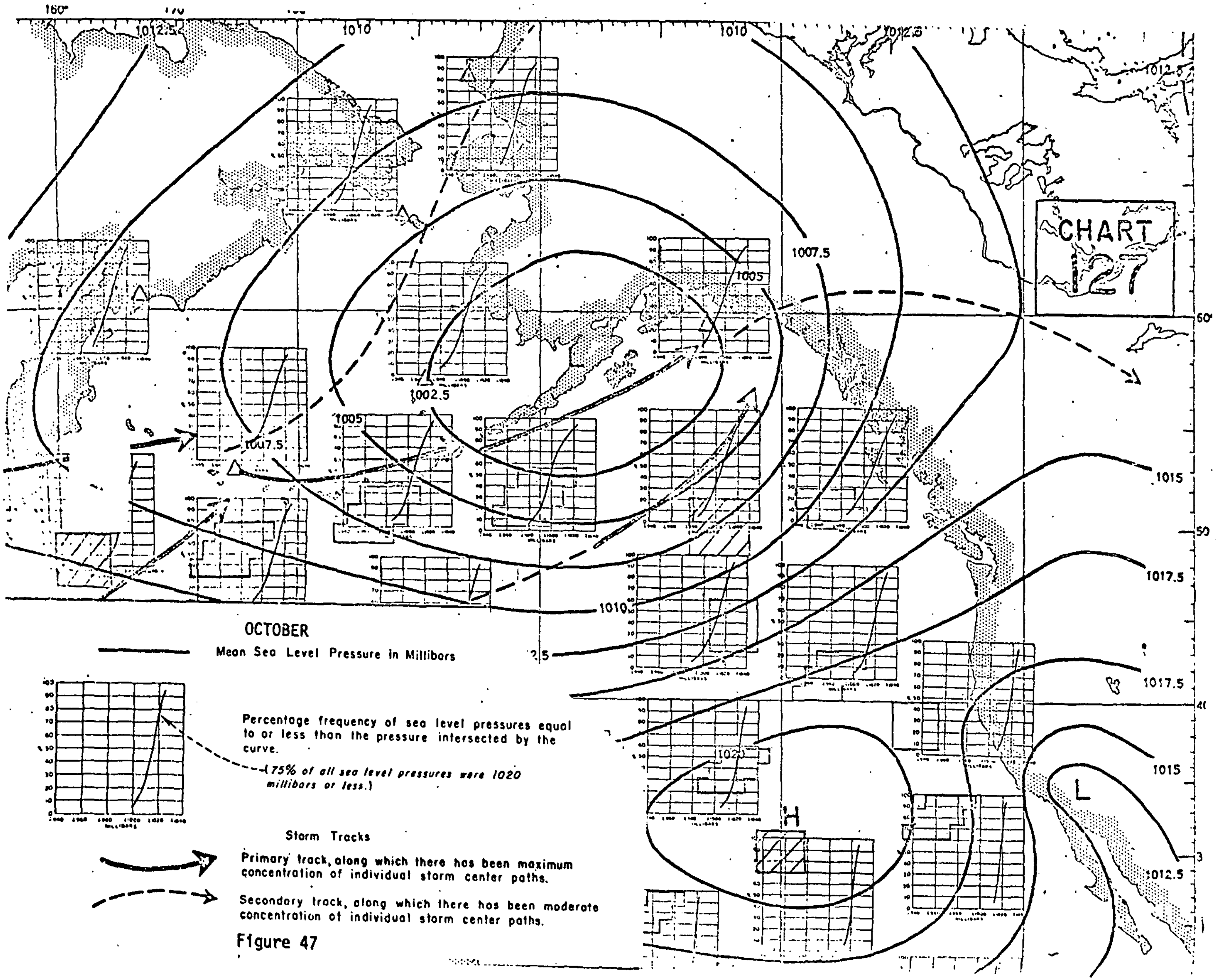

160°
1012.5
1010
1010
1012.5
1012.5
CHART
127
1007.5
1005
1002.5
1005
1007.5
60°
1015
50
1017.5
1010
2.5
1017.5
1020
1015
H
L
1012.5
OCTOBER
Mean Sea Level Pressure in Millibars
Percentage frequency of sea level pressures equal to or less than the pressure intersected by the curve.
(75% of all sea level pressures were 1020 millibars or less.)
Storm Tracks
Primary track, along which there has been maximum concentration of individual storm center paths.
Secondary track, along which there has been moderate concentration of individual storm center paths.

Figure 47

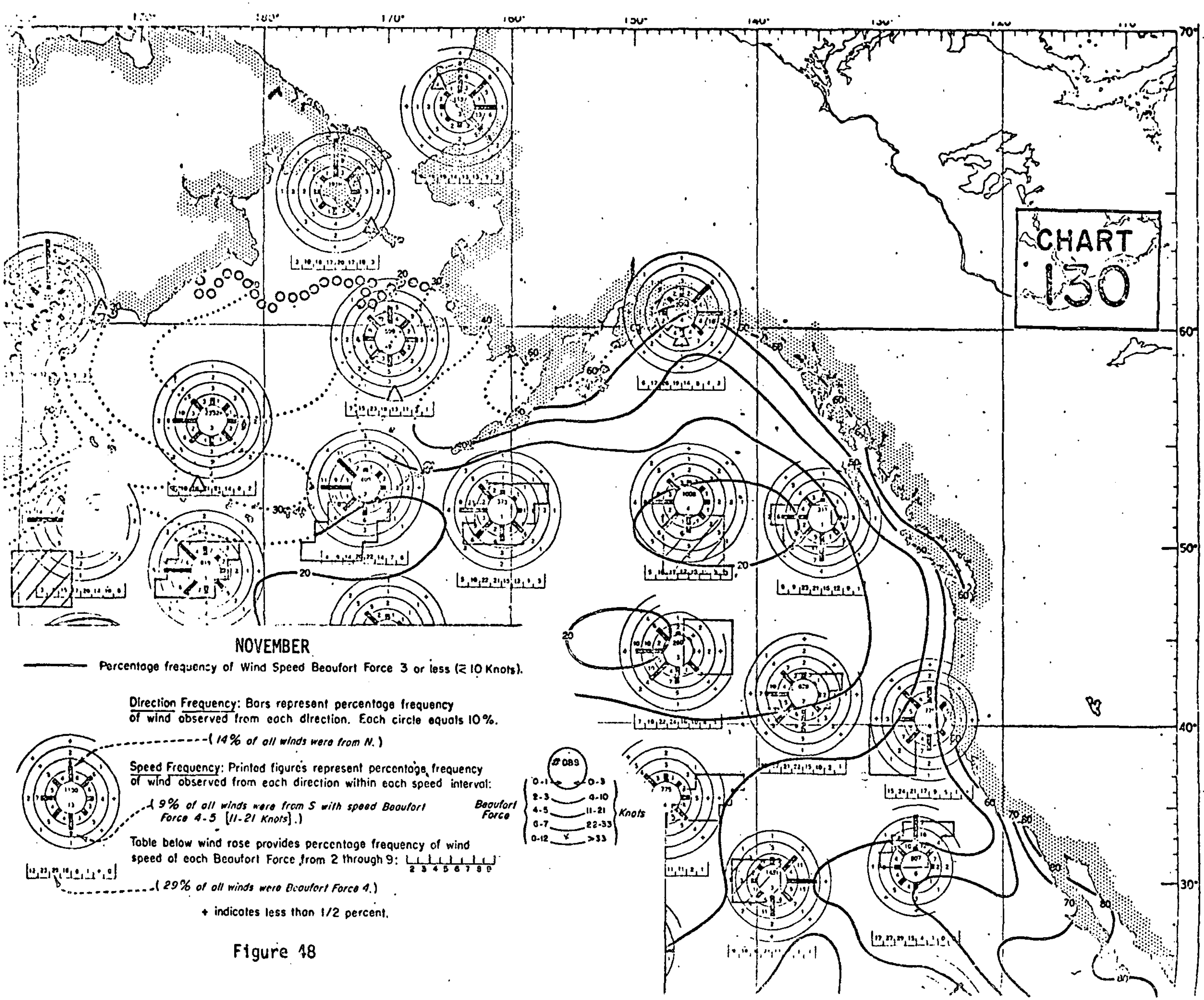


CHART 130
NOVEMBER
Percentage frequency of Wind Speed Beaufort Force 3 or less (≤ 10 Knots).
Direction Frequency: Bars represent percentage frequency of wind observed from each direction. Each circle equals 10%.
(14% of all winds were from N.)
Speed Frequency: Printed figures represent percentage frequency of wind observed from each direction within each speed interval:
(9% of all winds were from S with speed Beaufort Force 4-5 [11-21 Knots].)
Table below wind rose provides percentage frequency of wind speed of each Beaufort Force from 2 through 9:
(29% of all winds were Beaufort Force 4.)
+ indicates less than 1/2 percent.
# OBS
Beaufort Force
0-1 0-3
2-3 4-10
4-5 11-21
6-7 22-33
8-12 >33
Knots

Figure 48

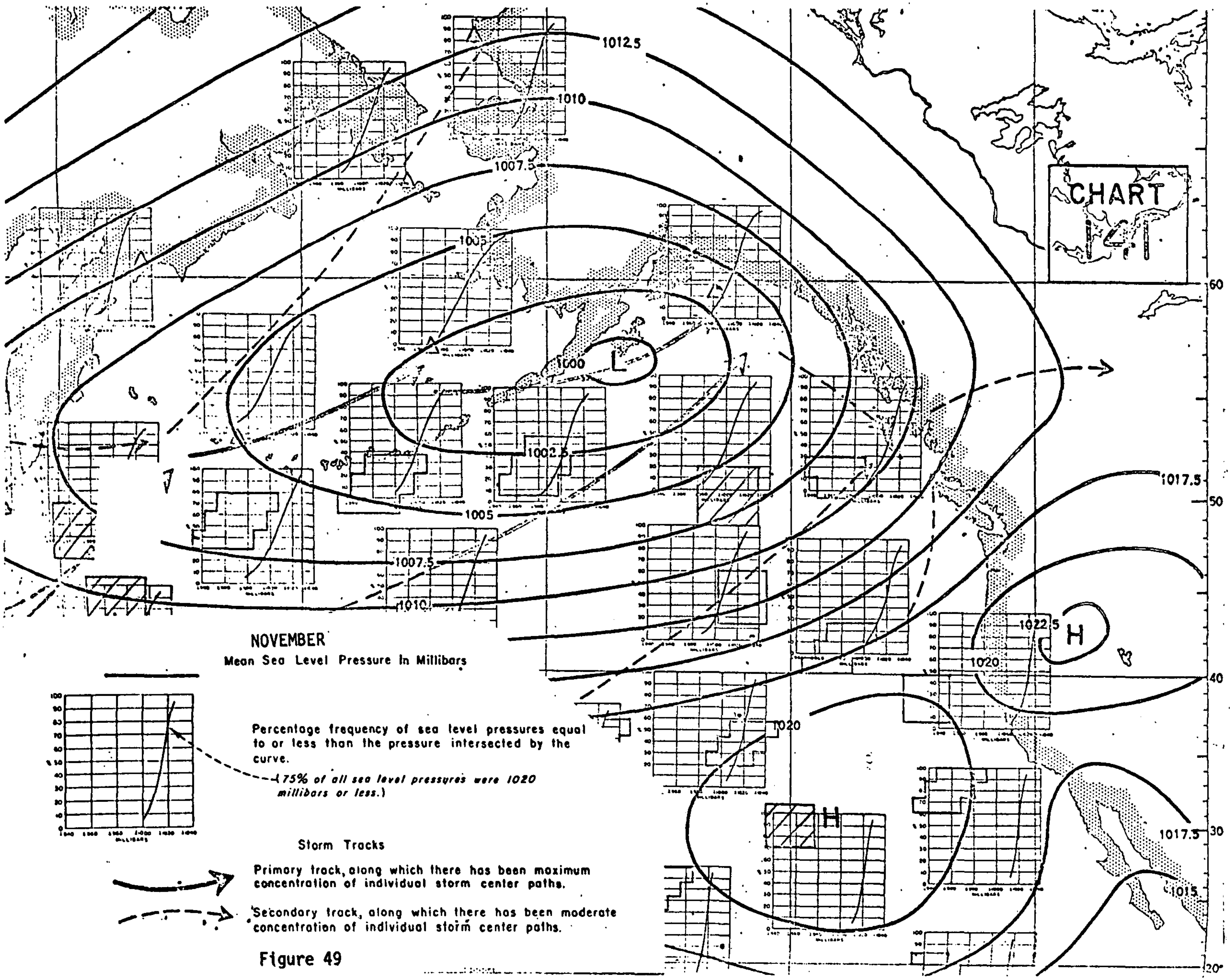


CHART 141
1012.5
1010
1007.5
1005
1000
L
1002.5
1005
1007.5
1010
1017.5
1022.5
H
1020
1020
H
1017.5
1015
60
50
40
30
20°
NOVEMBER
Mean Sea Level Pressure In Millibars
Percentage frequency of sea level pressures equal to or less than the pressure intersected by the curve.
(75% of all sea level pressures were 1020 millibars or less.)
Storm Tracks
Primary track, along which there has been maximum concentration of individual storm center paths.
Secondary track, along which there has been moderate concentration of individual storm center paths.

Figure 49

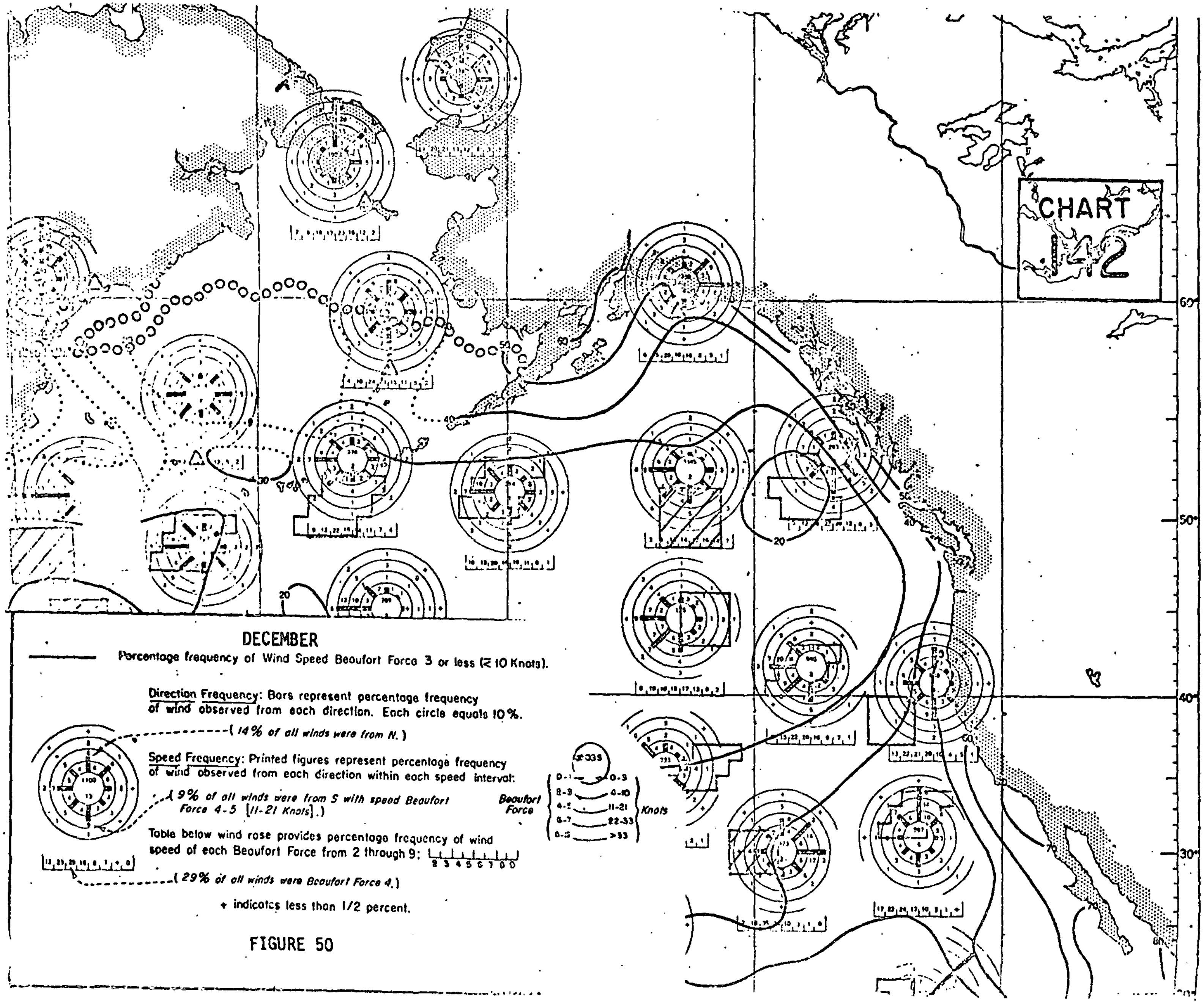
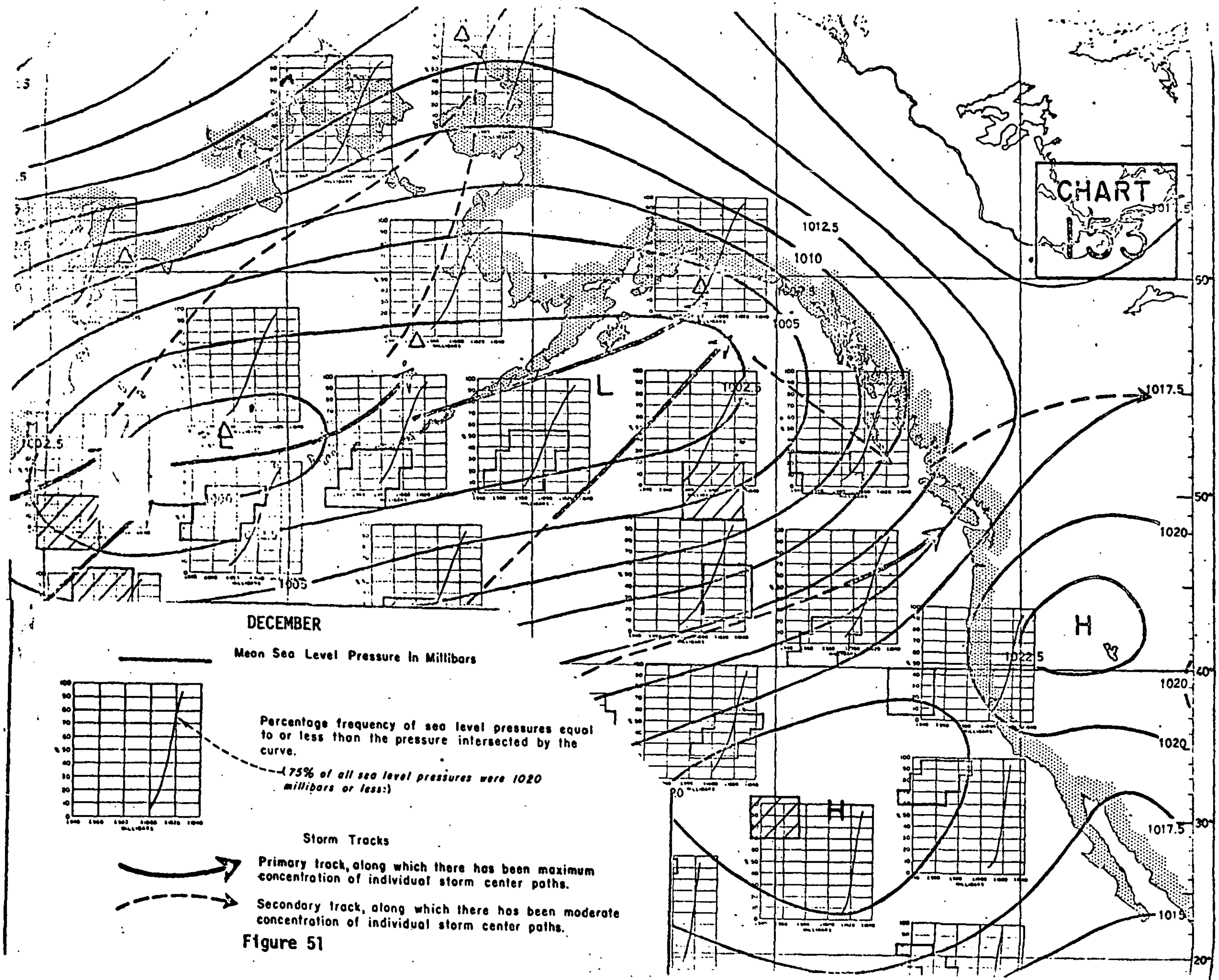


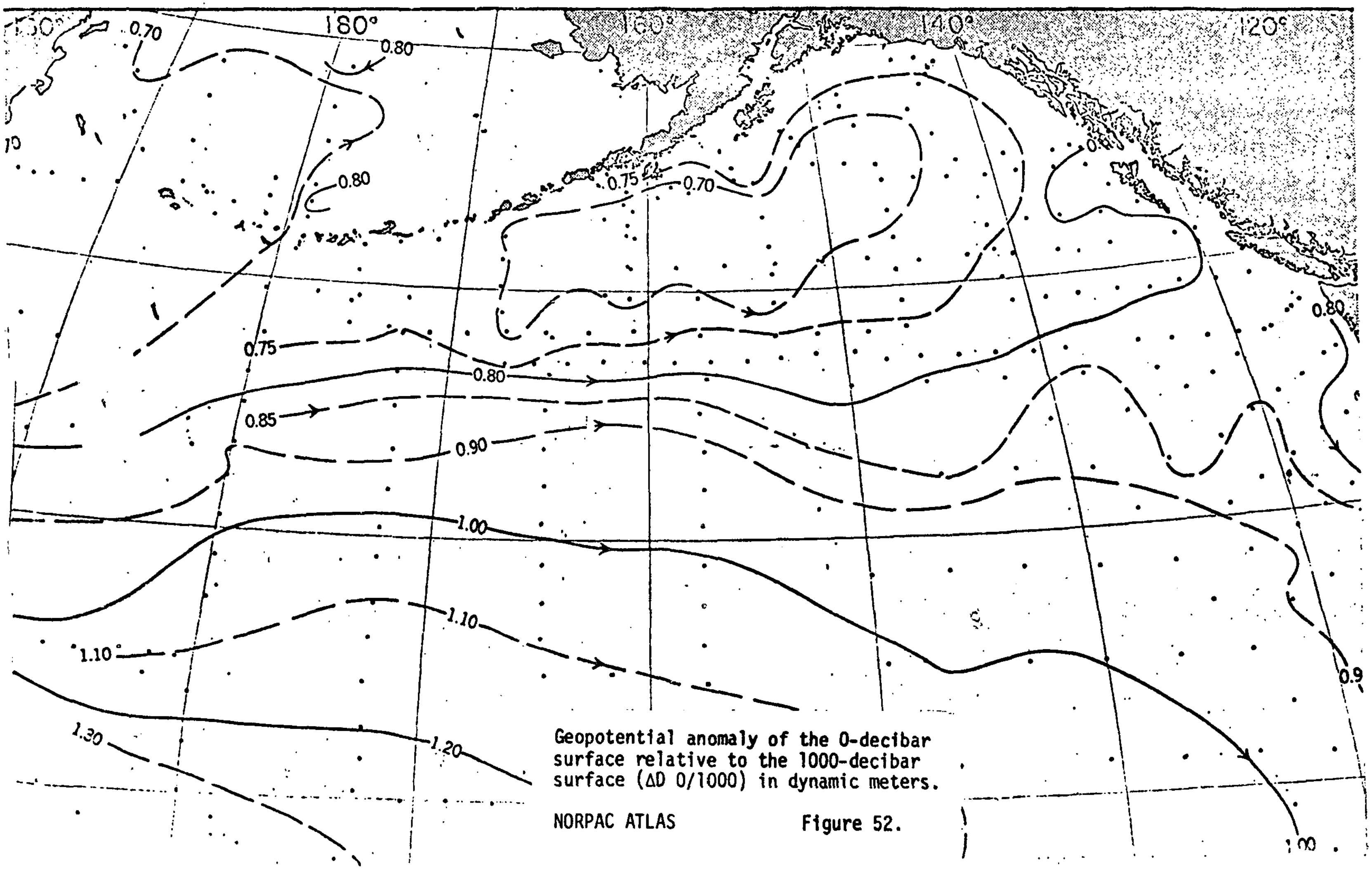
CHART J42
DECEMBER
Percentage frequency of Wind Speed Beaufort Force 3 or less (≲ 10 Knots).
Direction Frequency: Bars represent percentage frequency of wind observed from each direction. Each circle equals 10%.
(14% of all winds were from N.)
Speed Frequency: Printed figures represent percentage frequency of wind observed from each direction within each speed interval:
(9% of all winds were from S with speed Beaufort Force 4-5 [11-21 Knots].)
Table below wind rose provides percentage frequency of wind speed of each Beaufort Force from 2 through 9:
(29% of all winds were Beaufort Force 4.)
+ indicates less than 1/2 percent.
Beaufort Force
Knots
60°
50°
40°
30°

FIGURE 50



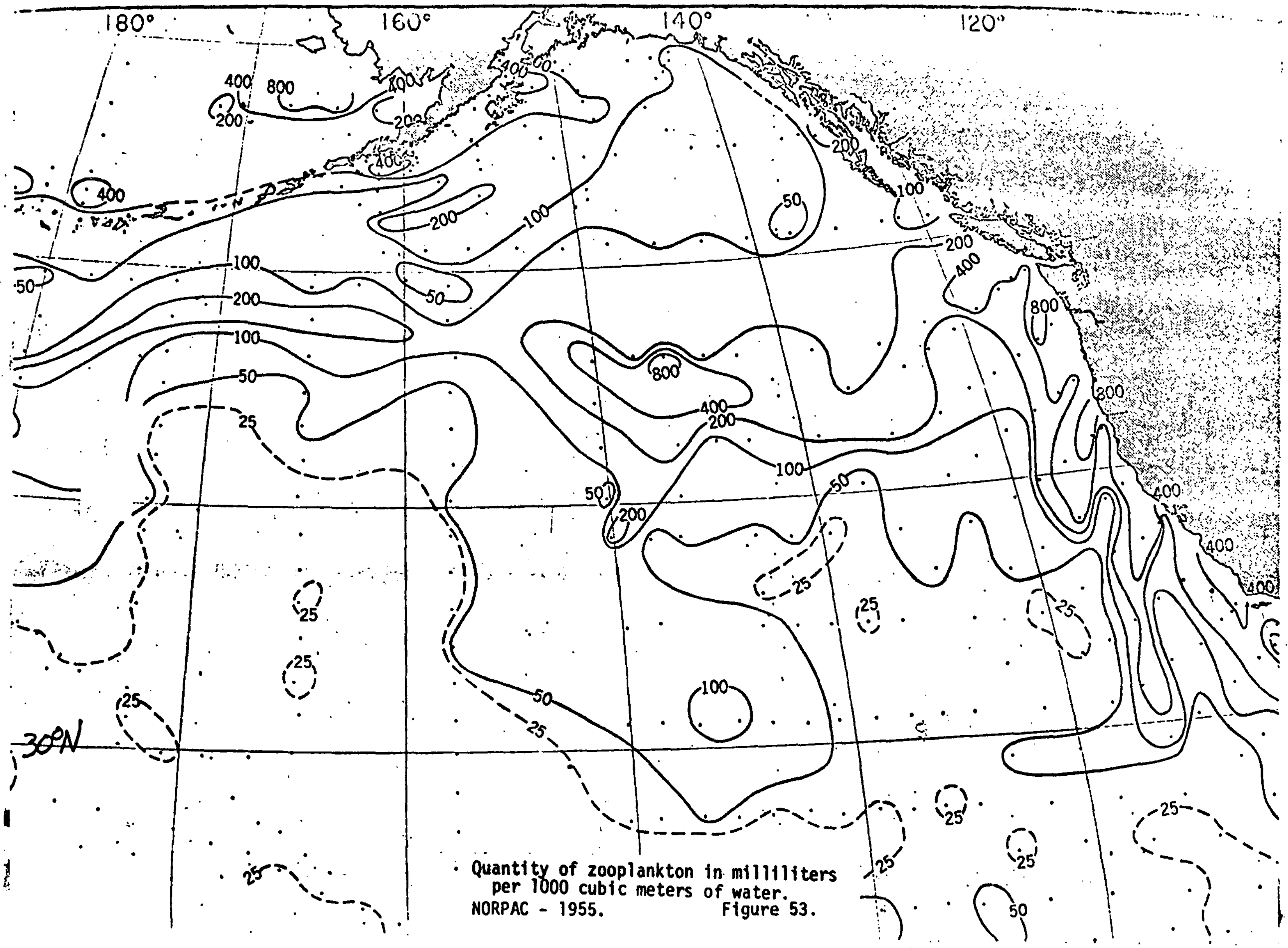
DECEMBER
Mean Sea Level Pressure In Millibars
Percentage frequency of sea level pressures equal to or less than the pressure intersected by the curve.
(75% of all sea level pressures were 1020 millibars or less.)
Storm Tracks
Primary track, along which there has been maximum concentration of individual storm center paths.
Secondary track, along which there has been moderate concentration of individual storm center paths.
CHART 153
L
H
H
1002.5
1005
1010
1012.5
1015
1017.5
1020
1022.5

Figure 51

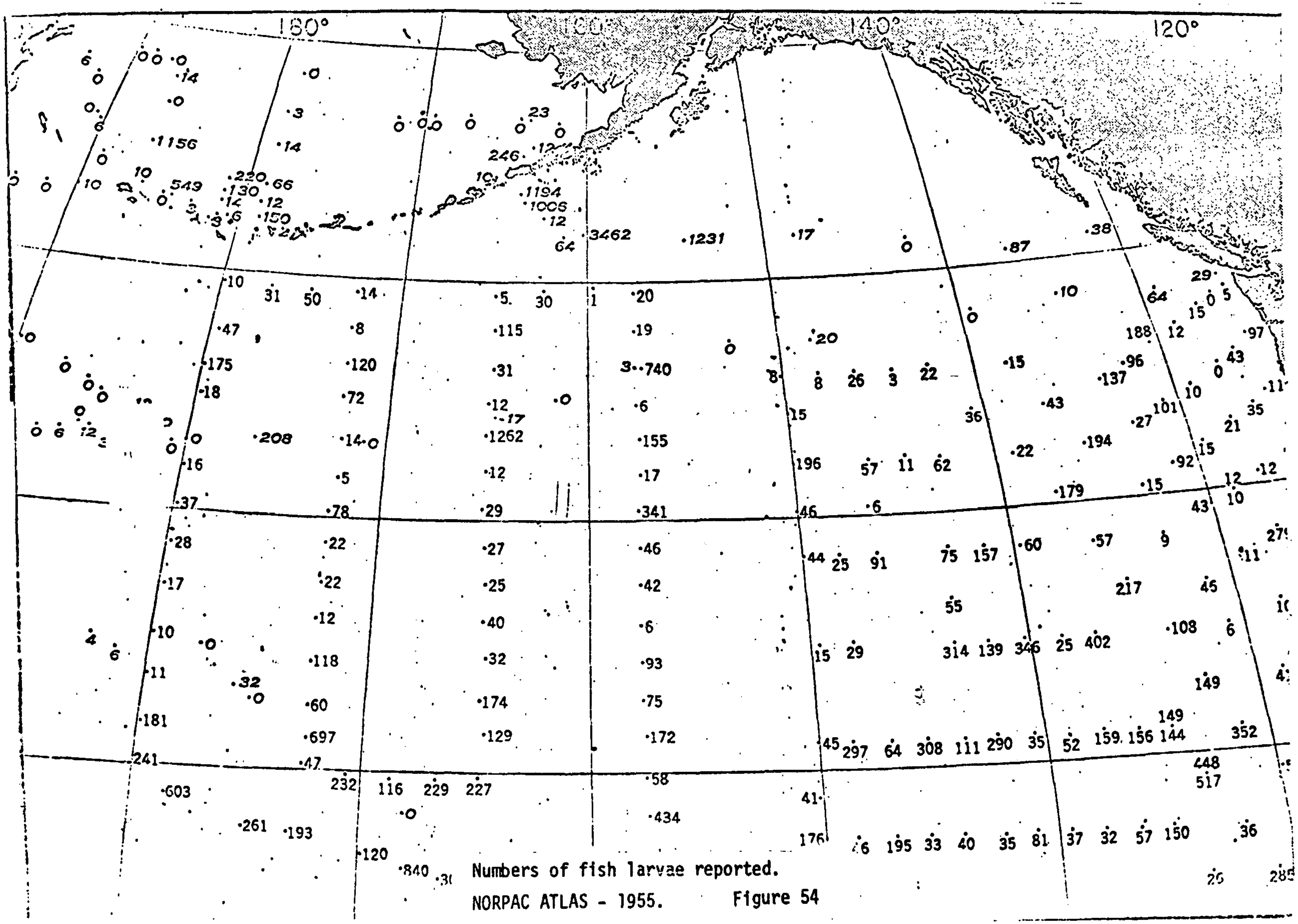


Geopotential anomaly of the 0-decibar surface relative to the 1000-decibar surface (ΔD 0/1000) in dynamic meters.

NORPAC ATLAS Figure 52.

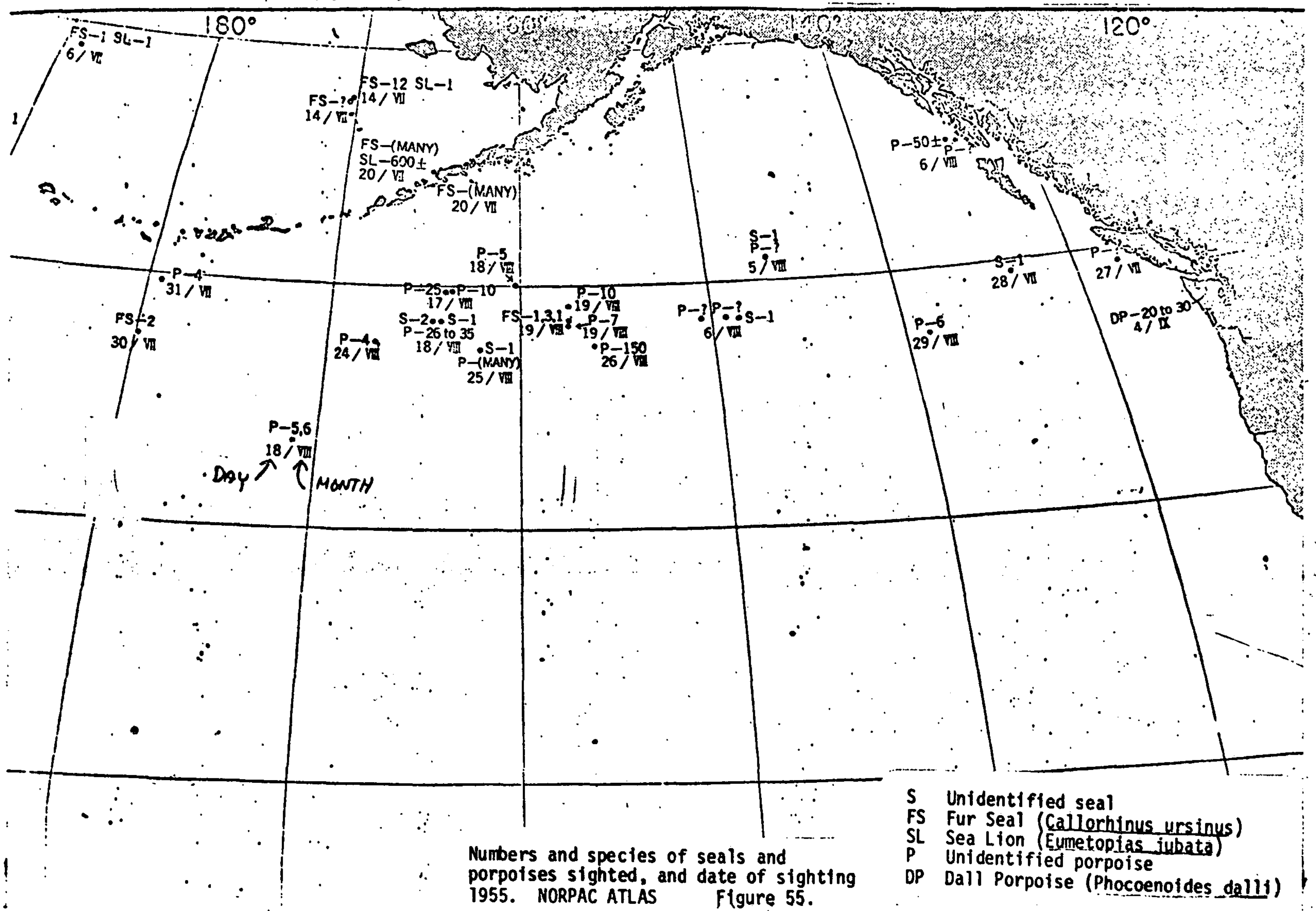


Quantity of zooplankton in milliliters per 1000 cubic meters of water. NORPAC - 1955. Figure 53.



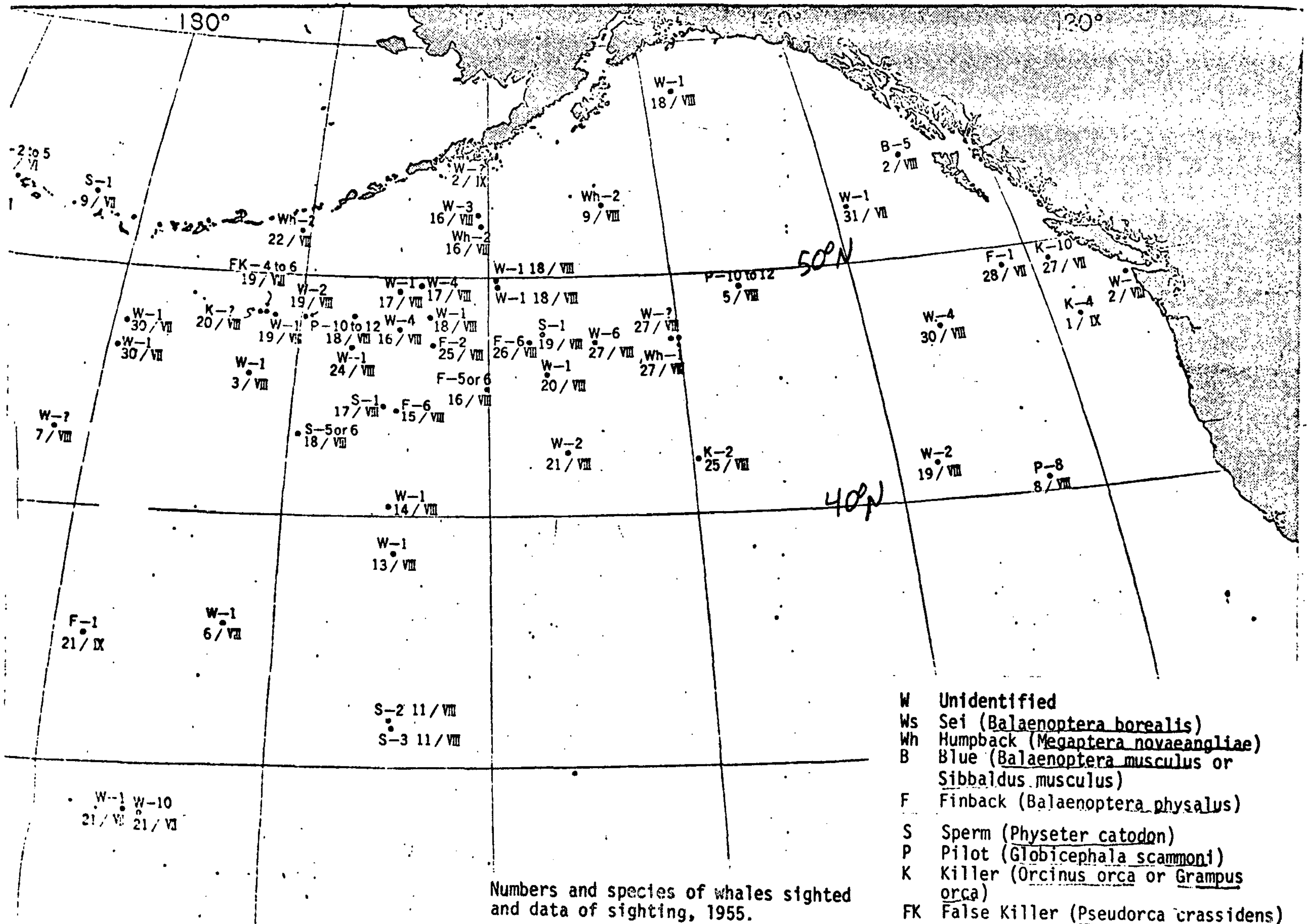
Numbers of fish larvae reported.

NORPAC ATLAS - 1955.   Figure 54



Numbers and species of seals and porpoises sighted, and date of sighting 1955. NORPAC ATLAS Figure 55.

S	Unidentified seal
FS	Fur Seal (*Callorhinus ursinus*)
SL	Sea Lion (*Eumetopias jubata*)
P	Unidentified porpoise
DP	Dall Porpoise (*Phocoenoides dalli*)



W	Unidentified	
Ws	Sei (*Balaenoptera borealis*)	
Wh	Humpback (*Megaptera novaeangliae*)	
B	Blue (*Balaenoptera musculus* or *Sibbaldus musculus*)	
F	Finback (*Balaenoptera physalus*)	
S	Sperm (*Physeter catodon*)	
P	Pilot (*Globicephala scammoni*)	
K	Killer (*Orcinus orca* or *Grampus orca*)	
FK	False Killer (*Pseudorca crassidens*)	

Numbers and species of whales sighted and data of sighting, 1955.

NORPAC ATLAS Figure 56.