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CLIMATOLOGICAL AND OCEANOGRAPHIC ATLAS FOR MARINERS

VOLUME II
NORTH PACIFIC OCEAN

Prepared by
OFFICE OF CLIMATOLOGY
and
OCEANOGRAPHIC ANALYSIS DIVISION

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PREFACE

The increasing use of environmental information in maritime operations and the vast accumulation of this type of data over the past two decades have created a need for an up-to-date comprehensive atlas of both the atmosphere and hydrosphere. This atlas, the second of a series to be published by the U.S. Weather Bureau in cooperation with the U. S. Navy Hydrographic Office, is intended to fill the specific needs of the mariner.

The majority of the climatic charts in this atlas have been adapted from the U. S. Navy Marine Climatic Atlas of the World, Volume II; the oceanographic charts are primarily original compilations based on the most recent data and reference sources. Development of each of the chart series began with the original objective of presenting analyzed environmental information in the manner considered to be most usable in the various maritime operations. For a number of years, similar presentations of the marine environment have found use by the Navy in almost every conceivable type of operation; now such information is considered a standard requirement and serves as a valuable tool from the very first planning stages. It is hoped that this volume will serve both the professional and amateur mariner in an equal manner.

The size of the atlas was designed for handy reference. It can be placed in the book rack with other navigation publications located in the chart room and is readily adaptable to desk-top stowage.

Comments on this atlas by mariners are desired. They will be applied to future volumes. Remarks on climatology should be addressed to Chief, U. S. Weather Bureau, Washington 25, D. C., and on oceanography to The Hydrographer, U. S. Navy Hydrographic Office, Washington 25, D. C.

ACKNOWLEDGMENTS

Most of the climatological charts in this atlas have been adapted from the U.S. Navy Marine Climatic Atlas of the World, Volume II. The U.S. Weather Bureau gratefully acknowledges the cooperation of the U.S. Naval Weather Service for permitting this adaptation. Within the U.S. Weather Bureau, Dr. Helmut E. Landsberg, Director, Office of Climatology and William H. Haggard were instrumental in initiating the project and provided guidance during preparation of the material; Arthur I. Cooperman coordinated the various aspects of the project. Most of the material was prepared at the National Weather Records Center, Asheville, N. C.; the full cooperation of Dr. Gerald L. Barger, Director, and his staff is gratefully acknowledged. Chart analysis is by Norman L. Canfield, William T. Hodge, and Arthur C. Wagner, Assisted by John S. Arnett, Oliver M. Davis and Clarence L. Mitchell.

The Hydrographic Office contribution was produced in the Oceanographic Analysis Division, A. R. Gordon, Jr., Director. Since the oceanographic section represents the cooperative effort of many individuals, it is virtually impossible to list all who have assisted in the data compilation, the analyses, and the illustration of the finished presentation. However, a few persons who have devoted much time and effort to the preparation of the oceanographic sections are especially deserving of recognition. All work was accomplished under the guidance of Robert D. Geisenderfer, who served as technical supervisor of this project. Miss Don Trussell was chief illustrator, and Miss Mary Jane Snellings prepared the final copy. Subject specialists were William E. Boisvert, Tides and Currents; Marvin D. Burkhart, Sea Waves; Robert V. Ochinero, Physical Properties; Theodore Frontenac, Ice; and Kenneth W. Kaye, Immersion Hypothermia.

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INTRODUCTION

MARINE CLIMATOLOGY

The climatological section of this atlas, largely an adaptation of the U.S. Navy Marine Climatic Atlas of the World, Volume II, is designed to serve merchant mariners and others concerned with various aspects of maritime commerce, particularly operational planning. Two new chart series, considered to be of particular operational import to the merchant marine have been added to this publication. Others generally have been condensed or reproduced from the Navy Atlas.

The climatic data are presented by graphs and isopleths. The basic elements used from surface weather observations are precipitation, wind, pressure, visibility, cloudiness, and temperature. In addition, seasonal charts of the 500-millibar pressure level are included.

Emphasis in the treatment of wind, pressure, and temperature observations is placed on the graphical presentation of percentage frequency distributions. This gives information about the range of values observed, supplementing more traditional single percentage frequencies or averages.

The descriptive explanations which follow give some details concerning the processing of the weather observations, the development of the charts, a few of the many applications of the various charts, and limitations imposed by the character of available data. Such background material is presented to aid those called upon to provide interpretations of the charts to meet operational planning problems. For those who simply require up-to-date, factual, and quantitative knowledge of the climate of the North Pacific Ocean, the charts are designed to stand by themselves.

THE OBSERVATIONS AND THEIR PROCESSING

In addition to ships of the U.S. Navy and Merchant Marine, the surface weather observations on which this atlas is based have been made aboard ships of many nations, notably Dutch, British, German, and Japanese. The North Pacific Ocean Stations have been manned by ships from the United States, Canada, and Japan. The coastal and island stations, for which graphs of surface weather elements are included, are operated by the meteorological services of the United States, Japan, and the U.S.S.R. Two land stations and two ocean stations operated by Japan and one ocean station operated by Canada provided data to supplement the far-flung network of upper-air observing stations operated by the U.S. Navy, Weather Bureau, and Air Force. In other words this atlas is made possible by the cooperation of mariners and weather services of many nations.

Variations in definitions, codes, and units of measure used by maritime nations during the past century for recording and punching merchant ships' weather observations resulted in 10 separate and unique forms (or "decks") of punched cards available for combined use in preparing tabulations for the climatological charts of this atlas.

Exclusive of the observations from the "fixed" ocean stations, the punched card files at the National Weather Records Center now contain more than 2,500,000 ships' weather observations for the ocean and seas shown on the charts. Most of these were available in summarized form for the drawing of the surface isopleths. For the selected ocean areas shown on the base surface charts, 200,000 observations were available. Actually, some additional areas were tabulated to insure the best practicable selection of areas. Those areas for which graphs are shown on the surface charts represent the final selection of areas deemed appropriate for inclusion in this atlas.

The graphs on each surface chart series represent, on the average, about 3,000,000 card passes through the data processing machines.

THE SURFACE OBSERVATIONS

The "point statistics" of land climatology are made possible by the maintenance of weather records at fixed or nearly fixed locations for a long period of years. However desirable, statistics for a "fixed point" at sea are not yet possible to a comparable extent. The establishment of ocean station networks through the cooperation of several maritime nations, nevertheless, is a real step toward that goal. This is true even though studies of climate are handicapped by frequent changes of assigned positions of ocean stations as dictated by operational requirements.

Ocean Stations.--The detailed weather observations from those ocean stations assigned to a nearly stationary location for a period of years have been processed and used in this atlas. When their assigned positions remain unchanged, there are several obvious advantages to marine climatology of observations from the ocean stations:

(1) A continuous or nearly continuous weather record is obtained.

(2) The ships are especially equipped for weather observing.

(3) Trained observers record the weather; conformity with all established observing practices may reasonably be expected.

(4) Observations are made at least every 3 hours, thereby permitting tabulation of duration frequencies not otherwise feasible.

(5) All observable elements of the weather are regularly observed.

(6) A higher degree of instrumental accuracy may be expected.

(7) Most station positions are away from heavily traveled shipping lanes.

(8) Ships are not usually underway under full power when weather observations are made.

Beyond the coverage afforded by these 9 ocean station vessel locations in the North Pacific, there remain vast areas for which transient ships' logs of surface weather observations are the only source of detailed knowledge of ocean climates.

Selected Ocean Areas.--Today weather observations made on moving merchant and naval vessels are reduced to punched cards to facilitate processing by electronic data machines. Where the number of such observations from moving ships is sufficient, as it now is along many trade routes, it becomes possible to select areas small enough to permit at least an approach to the advantages of the "point" climatological data long published for weather stations ashore.

For centuries mariners have known and classified the major wind belts of the world's ocean areas: the doldrum belt, the southeast trades, the northeast trades, the horse latitudes, the prevailing westerlies, and the prevailing easterlies of the polar regions. In more recent decades the concept of continentality has been employed by climatologists to help describe variations in climate between different parts of the earth. Both of these methods of classification were employed in order to determine, from existing compilations of ships' weather observations, small areas representative of a relatively homogeneous climatic region. To obtain observations numerous enough for the construction of frequency distributions, the areas necessarily had to be selected largely along established trade routes. The areas, though as small as practicable, actually range from near 28,000 to about 38,000 square miles in size.

Although the incidence and distribution of heat received at the earth's surface is the primary control of the climate, it was deemed appropriate to use the resulting distributions of surface wind as the primary quantity for the delineation of the various oceanic climatic regions. The use of recent compilations of many ships' wind observations together with the concept of continentality served: (1) to permit rational selection of ocean areas that would supplement the coverage afforded by the North Pacific Ocean Station network; (2) to reaffirm the location of oceanic climatic regions as known by observant mariners of past centuries; and (3) to refine, somewhat, the delineation of these climatic regions.

Thus, ocean areas representative of the climate of surrounding regions of several hundred thousand square miles were selected. These areas, along with the continental outlines and ice boundaries, are shown on several of the surface chart series. On each monthly surface chart that includes graphs or tables, each area for which sufficient data were available is directly overprinted or is touched by the appropriate graph or table.

Coastal Stations.--To further supplement the ocean stations and ocean areas, 13 coastal stations were selected to make areal coverage more nearly complete. The selection was confined to regions where ships' observations are relatively scarce.

The Surface Graphs.--For the ocean stations, selected ocean areas, and coastal stations, wind data are presented by circular contingency tables in combination with the traditional "rose" type of graph. Otherwise, the bar graph is the graphic form chiefly used.

The single bar graphs of air temperature and sea level pressure show at a glance the range of values recorded in 9 out of every 10 observations. Specific information is shown also. For example, the top of the thicker part of a bar may indicate the air temperature to be equal to or less than 62°F. in 75 percent of the observations. This would also mean that the air temperature has been reported to be greater than 62°F. in 25 percent of the observations.

In general, each station-month (or area-month) graph printed is based on at least 300 observations, but occasionally graphs based on a total of as few as 150 are included. The actual number of observations is not shown on all graphs, but the number of wind observations is given for each surface wind rose. A survey of past ship reports in representative ocean areas shows that all observations invariably contain wind direction and force; in addition the following percentages of other basic weather elements were recorded:

Element	Percent
Air Temperature	99
Total Cloud Amount	92
Present Weather	90
Visibility	84
Sea-Level Pressure	70

Hence, the number of observations for a corresponding graph of another element may be estimated by use of the appropriate percentage listed above.

The Surface Isopleths.--Isopleths (lines connecting points of equal magnitude) are shown on most of the chart series. The isopleths of surface elements are based on all pertinent ships' observations summarized for up to 100 years of record and readily available in tabular form, as well as upon the observations from stations and areas for which graphs are shown.

Isopleth intervals vary between chart series, but a standard interval suggested by the data was selected and maintained for all months within each individual chart series. Supplementary or intervening isopleths necessary to show the pattern are shown by broken, rather than solid, lines.

The values of surface isopleths within about 1° of latitude or longitude of coastlines and the ice limits must be interpreted with particular caution. The discontinuity of the underlying surface and the resulting intense gradients of averages or frequencies of weather elements along these boundaries require special and detailed climatological studies beyond the scope of this atlas. Also, at present, the number of ships' observations from points within 1° of the coasts and ice limits is inadequate except where commonly used trade routes approach or closely parallel coastlines.

Away from the coasts, confidence in the various sets of isopleths is a function of the number of observations. Therefore, confidence not only varies between elements, but also varies between regions on a single chart.

Occasional differences will be noted between isopleth values and those for graphs in the same area. Most discrepancies are the result of two factors. The periods of record for the ocean stations are much shorter than for the transient ships which provided the ocean-wide data, the foundation of the isopleth analyses. Ocean areas were several times the size of the units for which ocean-wide data were summarized, thereby admitting data gradient influence into the ocean area summaries.

THE UPPER AIR OBSERVATIONS

Both series of upper air charts are based on balloon soundings taken generally twice a day for periods of up to 6 years of record. The height data are from radiosonde instruments attached to balloons. The wind data result from ground- or ship-based electronic tracking of a reflector attached to the balloon, or visual sighting of the balloon with the aid of a theodolite.

The isopleths of height are based on data summarized from about 65 radiosonde stations. Wind roses for the 500-millibar level are shown for 36 stations and are based on 5 years of daily observations. Where winds-aloft observations were missing during the 5-year period, they were filled in by converting the orientation and spacing of charted daily height isopleths into inferred values of wind direction and speed.

A table listing the upper wind stations follows:

Station	Latitude*	Longitude*	Operated by
OSV N	32.5°N.	135.0°W.	U.S.A.
OSV P	50.0°N.	145.0°W.	Canada
OSV Q	43.0°N.	167.0°W.	U.S.A.
OSV S	48.0°N.	162.0°E.	U.S.A.
OSV U	27.7°N.	145.0°W.	U.S.A.
OSV V	31.0°N.	164.0°E.	U.S.A.
OSV X	39.0°N.	153.0°E.	Japan
Adak, Alaska	51°53'N.	176°40'W.	U.S.A.
Anchorage, Alaska	61°13'N.	149°50'W.	U.S.A.
Annette, Alaska	55°04'N.	131°33'W.	U.S.A.
Barrow, Alaska	71°20'N.	156°24'W.	U.S.A.
Dutch Harbor, Alaska	53°53'N.	166°32'W.	U.S.A.
Fukuoka, Japan	33°35'N.	130°23'E.	U.S.A.
Furumaki, Japan	40°41'N.	141°22'E.	U.S.A.
Guam, Marianas Is.	13°31'N.	144°49'E.	U.S.A.
Honolulu, Hawaii	21°20'N.	157°55'W.	U.S.A.
Iwo Jima, Volcano Is.	24°47'N.	141°20'E.	U.S.A.
Johnston Island	16°44'N.	169°32'W.	U.S.A.
Kodiak, Alaska	57°45'N.	152°31'W.	U.S.A.
Koror, Palau Is.	7°20'N.	134°29'E.	U.S.A.
Kwajalein, Marshall Is.	8°44'N.	167°43'E.	U.S.A.
Luzon, P.I. (Clark Field)	15°11'N.	120°33'E.	U.S.A.
Marcus Island	24°17'N.	153°58'E.	Japan
Midway Island	28°13'N.	177°23'W.	U.S.A.
Nome, Alaska	64°31'N.	165°26'W.	U.S.A.
Oakland, California	37°44'N.	122°12'W.	U.S.A.
Okinawa, Ryukyu Is.	26°12'N.	127°39'E.	U.S.A.
San Diego, California	32°44'N.	117°10'W.	U.S.A.
Seoul, Korea	37°34'N.	126°58'E.	U.S.A.
Shemya, Alaska	52°43'N.	174°06'E.	U.S.A.
Tatoosh I., Washington	48°23'N.	124°44'W.	U.S.A.
Tokyo, Japan	35°41'N.	139°46'E.	U.S.A.
Wake Island	19°17'N.	166°39'E.	U.S.A.
Yakutat, Alaska	59°31'N.	139°40'W.	U.S.A.
Selected Point	40°00'N.	150°00'W.	--
Selected Point	40°00'N.	175°00'E.	--

*Shows central position for ship stations.

THE SURFACE CHARTS

The legend of each chart is designed to explain chart content; the graphs, isopleths, or both. Detailed instructions telling how to read the graphs are given, and explanatory notes are included as far as practicable. The following paragraphs contain additional remarks likely to be of interest to those called upon to interpret the charts and provide answers to specific climatic questions raised by operational problems.

PRECIPITATION

On a single chart, percentage frequency of occurrence of liquid and frozen precipitation for all twelve months of the year is shown for the various areas and stations. Thus, the annual "march" of the incidence of rain and snow can be quickly pictured. The graphs show the wide variation from frequent precipitation in the Gulf of Alaska to its rare occurrence near the Tropic of Cancer.

Such generalizations are valid. However, literal interpretation or precise comparison of the percentages shown on this chart particularly are to be avoided. This is primarily due to processing difficulties caused by varying, and in some cases, unfathomable practices of transforming older "present weather" observations into codes for punching into cards.

SURFACE WIND

Surface wind is the element most commonly observed and punched into the cards available for the preparation of this atlas. It was the element considered basic in the selection of ocean areas for construction of complete frequency distributions. This selection, described above, was such as to point up significant differences between various regions within an entire ocean basin. Therefore, significant differences between adjacent graphs on the charts are frequent. Subject to the limitations imposed by the shorter period of record from the ocean stations, these differences are generally reliable due to the relatively large number of wind observations. Within the innermost circle of each surface wind rose is printed the actual number of observations on which the rose is based.

Wind distributions are presented by means of a combination of two graphic forms--the traditional wind rose and the circular contingency table. The circles serve in two separate and distinct ways: (1) as a scale marked at increments of 10 percent, facilitating immediate reading of wind direction frequency as represented by the length of each bar; (2) as lines separating the selected class intervals of Beaufort Force within which the percentage frequency for each direction and class interval of wind force is actually printed.

If percentage frequency of one of the class intervals of wind force, with all directions combined, is desired, it may be obtained by merely adding the numbers around but within the appropriate circle. However, appropriate critical or threshold values of wind force, irrespective of direction, tend to vary with different applications or problems. To meet this need, a one-line table which gives the percentage frequency of occurrence of each individual Beaufort Force, all directions combined, from Force 2 through Force 9 is printed below each rose.

A condensed table of Beaufort equivalents follows:

Beaufort Force	Speed (Knots)	Beaufort Force	Speed (Knots)
0	0	7	28-33
1	1-3	8	34-40
2	4-6	9	41-47
3	7-10	10	48-55
4	11-16	11	56-63
5	17-21	12	64 and above
6	22-27		

STORM TRACKS

Except for the inset charts of eastern North Pacific tropical cyclones, the storm tracks are adapted from Weather Bureau Research Paper No. 40 (source 2) which is based on all available data for sea level systems from 1866 to 1954. The prevailing direction of motion of storm systems is indicated by the arrows. Heavy solid lines denote primary tracks--those which are most frequent and clearly defined; thin dashed lines denote secondary, less frequent, and less well defined tracks. In areas of maximum frequency the arrow heads end, and the tracks may cross, branch, or merge.

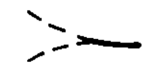
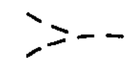
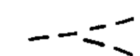
A detailed legend for storm tracks of the western and northern parts of the North Pacific Ocean follows:

Symbol (all motion from left to right)

An area of frequent genesis is indicated where one of the following occurs:

1. A secondary track begins................
2. A primary track begins..................
3. A single secondary track changes to a single primary track..................
4. Two secondary tracks merge to form a primary track, with a break between dashed and solid lines.................. 

Genesis is not indicated where:

1. Two secondary tracks merge to form a primary track, without a break between dashed and solid lines........... 
2. A secondary track merges with a primary track, without a break between dashed and solid lines........... 
3. Two secondary tracks merge to form another secondary track.................. 
4. Two primary tracks merge................. 
5. A primary track decreases in frequency to a secondary track..................... 
6. A secondary track branches off from a primary track........................... 
7. A primary track splits into two primary branches................................ 
8. A secondary track splits into two secondary branches...................... 

The inset maps showing eastern North Pacific tropical cyclone tracks for July through October are based primarily on those storms whose movements are most accurately known for the 50-year period, 1910 through 1959. Arrow width is roughly proportional to storm frequency, i.e., the widest arrows show the most frequently traveled paths. Onshore tropical cyclone tracks are most frequent in September and October; these are shown by unshaded arrows.

TROPICAL STORMS AND TYPHOONS

The tropical cyclone charts are based on 15 years of closely tracked storms - 1945 through 1959. On the tropical cyclone "roses" the number of tropical storm and typhoon centers passing through each area during each month and the total of their directions of movement are shown in the innermost circle. When the latter figure exceeds the storm frequency, sharp recurvatures, loops, or other erratic movements of the storm center occurred. The percentage frequency of storm movement in each of the octants centered at N, NE, E, etc., is indicated by the bars, and the mean speed in knots in each direction is shown by the figures at the end of the bars. Where no speed is shown, storm positions were not available, either at the beginning or end of a storm track, and speeds, therefore, could not be computed.

VISIBILITY

Visibility is practically always an estimated, not a measured, element in the marine weather observation. Precise estimation is made difficult by the typical absence of objects at known distances and is nearly impossible at sea during hours of darkness. The presentation of a climatological visibility chart is further hindered by the fact that marine visibility observations are relatively new, and thus less numerous, having become routine only since the 1920's. Interpretation of the series of visibility charts should proceed with these factors in mind.

The isopleths showing percentage frequency of all visibility observations in which the visibility was reported to be less than 5 nautical miles represent, in effect, the relative frequency of occurrence of any "obstruction to vision" as defined by aviation weather codes in the United States and Canada.

TOTAL CLOUDS

The two sets of isopleths of total cloud amount provide a measure of the incidence of clear and cloudy conditions. From these one can infer general expectancy of conditions suitable and unsuitable for celestial navigation.

The isopleths are defined in terms of tenths of cloud cover. A majority of the available observations are so defined, as coding in terms of eighths of sky covered is a change introduced only 12 years ago.

AIR TEMPERATURE

Despite the variations in temperature between the equator and the polar regions, four temperature scales are sufficient for the graphs for all ocean stations and areas in all months. These four scales are used as necessary. As they shift between adjacent areas, and from one month to the next for the same area, it is important to note the scale each time a value is read from a graph. This rule of caution is always appropriate, of course, but this is the only series of climatological charts in this volume where the scale changes from one area to another on a single chart. At the northern coastal stations individual scales suggested by the data are used on the graphs. They show the marked extremes of temperature induced by the proximity of each station to a major land mass.

DEW POINT

This element, obtained from simultaneous readings of dry bulb and wet bulb thermometers, is vital to undamaged delivery of ships' cargo vulnerable to condensation (sweat) damage. Knowledge of the day's atmospheric dew point, together with cargo temperature and moisture content, permits intelligent hold ventilation practices during a voyage. Dew point is also an important element in daily weather forecasting; for example, the relationship between atmospheric dew point and sea water temperature is an indicator of the potential of fog formation. For such reasons, isopleths of monthly mean dew point temperature are presented for familiarization and guidance of the user.

These new charts are included despite the fact that the number of presently available dew point observations is small. Like visibility, psychrometric data are relatively new items in marine weather observations, wet bulb and/or dew point temperature having gradually become more or less routine since the 1930's.

Their importance to both shipping and science dictates that ships' dew point observations be frequently and carefully made in the future. Refinement of climatological averages and valid determination and presentation of ranges of observed dew point values may then follow.

SEA LEVEL PRESSURE

The graphs of sea level pressure are shown for as many ocean areas and months as practicable and are presented in a form similar to the graphs of air temperature.

The mean sea level isobars are adapted from Weather Bureau Technical Paper No. 21 (source 3). Unlike other elements (such as temperature and visibility), pressure is an element that does not show marked discontinuities in mean data at coastlines and limits of ice.

Lines of equal pressure are the principal isopleths drawn on daily surface weather maps. From day to day, the motions of centers of high and low pressure can be traced. This movement is real and continuing and should always be kept in mind when studying the static picture presented by monthly mean isobars. The graphs help in this, as they show the monthly distribution of air pressure observed at numerous locations.

LOW PRESSURE CENTERS

The seasonal charts, showing "storm roses", summarize extratropical low pressure areas within 10-degree "squares" of latitude and longitude, and are based on daily historical weather maps for the 15-year period, 1924 through 1938. This is the best continuous period of sufficient length with adequate coverage of ships' observations. Tropical storms are excluded except at a point in their history when they assumed the appearance of extratropical cyclones. The principal areas of cyclogenesis (initial formation of a low pressure center) are for the 20-year period, 1909 through 1914 and 1924 through 1937. This very generalized picture of cyclogenesis was drawn from data tabulated for Weather Bureau Research Paper No.40 (source 2).

The lower of the two figures in the center of each storm rose is an index number derived from the average difference between the estimated sea level pressure at the center of each low pressure area and the estimated sea level pressure at points 350 nautical miles from the center in the directions north, east, south, and west. The use of such a measure of storm intensity is suggested in Air Force Geophysical Research Paper No. 23 (source 1).

In the reading of the maps, only low pressure areas with at least one closed isobar were used, and shallow lows that maintained their identity for less than two consecutive 1200 GMT charts were not considered. Occasionally two low centers were charted close together and the highest pressure at the "edge" of one low in one direction was well within a radius of 350 miles of the other. In such cases, the pressure difference was derived through the use of the highest pressure within the assigned radius in that particular direction.

Comparison of the printed index numbers in different "squares" or in different seasons provides a guide as to the severity of storms that have generally been encountered by ships in the past. Judgement concerning the frequency of difficult or hazardous navigational or operating conditions may be deduced from knowledge of the frequency of rough or high seas or from the frequency of gales. Nevertheless, the natural choice of ships' masters to avoid severe storm conditions, where possible, unquestionably affects the reliability of such frequencies even though the degree of such influence is unknown. To supplement sea or wave height and gale data, this measure of pressure gradient, closely related to wind, is introduced as a further guide. It has the advantage of being an average, based on daily analyses of all charted low pressure centers of significance.

The areas of cyclogenesis are based on the first appearance of lows within individual "unit" areas averaging 300 miles north-south by 180 miles east-west. Within any "unit" area in the light shaded regions there was an average of 5 to 9 cases of cyclogenesis in 10 years; within any "unit" area in the heavier shaded portions, the average number of cases of cyclogenesis in 10 years was 10 or more. Multiplying average frequency by the number of "unit" areas included in each shaded area provides a rough estimate of the total average frequency of cyclogenesis per 10 years. The areas, however, are primarily shown to indicate in a qualitative sense where extra alertness to the possibility of new low pressure center formation is in order.

AIR-SEA TEMPERATURE DIFFERENCE

Similar to the charts of Low Pressure Centers, these seasonal charts appear in the established sequence of surface charts at the mid-month of each season - January, April, July, and October. Sea temperature observations available are generally inferior to those of air temperature in both quality and quantity. Despite this limitation, the charts provide a generalized picture of the average stability or instability of the lower layers of the atmosphere immediately above the sea surface. They also contain generalized implications concerning optical and radiowave refraction, particularly the frequency of existence of the "oceanic duct", a refraction phenomenon affecting the performance of shipboard radars.

THE UPPER AIR CHARTS

Mariners are becoming ever more aware of the importance of upper atmosphere measurements and their utility in anticipating tomorrow's weather. Daily weather charts for constant pressure surfaces aloft are becoming available for the use of marine interests. To present a brief picture of the climatology of one pressure surface, two series of 500-millibar charts are included: isopleths of mean height of the pressure surface and wind roses. The latter are in a graphic form similar to those for surface wind distributions.

Very roughly speaking, in terms of presently measurable air density, the 500-millibar surface is about halfway through the relatively thin layer of atmosphere that surrounds our earth. Charts of this imaginary "surface" thus provide a good first approximation in determining the characteristics of the air above us. Other pressure surfaces as well as graphed "profiles" of the atmosphere over individual stations (pseudoadiabatic charts) are used daily in weather forecast offices. The 500-millibar surface is particularly noted and referred to by many meteorologists.

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2. W. H. Klein, "Principal Tracks and Mean Frequencies of Cyclones and Anticyclones in the Northern Hemisphere," U.S. Weather Bureau Research Paper No. 40, 1957, 60 pp.

3. U.S. Weather Bureau, "Normal Weather Charts for the Northern Hemisphere," Technical Paper No. 21, Oct. 1952, 74 pp.

For additional climatological charts in similar form (of primarily aeronautical application) and for a list of atlases frequently consulted in the preparation of these charts, the reader is referred to this publication's "parent" book - U.S. Navy Marine Climatic Atlas of the World, Volume II, North Pacific Ocean. This atlas, NAVAER 50-1C-529, was published by direction of the Chief of Naval Operations on July 1, 1956 (an Errata Sheet was published in July 1958) and is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D. C.

OCEANOGRAPHY

Many atlases and charts prepared by different government and private institutions have shown either the climatological or oceanographic aspects of the North Pacific. However, seldom were both aspects brought together under one cover, nor were the charts necessarily designed with the merchant mariner specifically in mind. Here for the first time, an atlas has been created to satisfy both these needs. As the marine scientist must consider the characteristics of both water and the atmosphere in order to arrive at sound conclusions concerning matters of the sea, so does the mariner evaluate the total marine environment to plan for a safer and more expeditious passage. The charts of this atlas endeavor to provide the mariner with the necessary tools for advance planning and to give him information on conditions to be expected in the North Pacific, so that he can profit by whatever advantages the marine environment offers and may counter intelligently unfavorable conditions. The atlas is intended to provide a comprehensive picture of the marine environment, encompassing the atmosphere and hydrosphere -- the total operating area of the mariner. This atlas therefore represents a summary of modern man's knowledge of marine environment.

Considerable effort has been expanded to develop the various presentations into the most appropriate form, and at the same time retain the standards of clarity and accuracy required of scientific data. The threshold values shown on the various charts were not selected specifically, nor are they intended to apply to any special maritime operation or to a particular type or class of vessel. Rather, the thresholds used are generally the conditions which tend to facilitate or curtail a wide variety of marine activities. Likewise, the information contained herein is not exclusively for masters in the merchant marine but is intended to serve persons in all areas of marine industry. Of course it is realized that it has been impossible to cover every item of interest to each industry or to individual mariners; but some treatment is presented on all topics considered to be of use to those who operate, live, or work on the sea.

This atlas, as is typical of most atlases, attempts to provide a general "climatic" summary of ocean conditions based upon past recorded observations. A great majority of these observations have been taken by the transient mariners from the merchant fleets of many countries; these are supplemented by observations from Navy ships, Coast Guard cutters and lightships, and from natural and manmade islands. These observations are also finding use in daily operational forecasts for the mariner which are tailored to meet the specific needs of his particular operation. Already Optimum Sea Route Forecasts are routine precedure for a number of Navy supply operations. Private consultants providing similar services have also reported that these forecasts have reduced cost and danger to operations of their contractors and increased "cruise comfort" to crew and passengers. Similarly, ice forecasts are also now standard for northern sea areas; substantial savings in time, money, and ship damage have resulted from their use. It is expected that ocean forecasts will in the future become more and more a standard requirement for mariners. They will provide on a day-to-day (or hour-to-hour) basis the same type of information that this atlas is intended to provide for the seasons of the year.

THE SURFACE CHARTS

A brief evaluating treatment of source material by topics follows, accompanied by pertinent references which can supply supplementary material.

TIDES

The cotidal and corange charts are based on information obtained from the tide tables and tidal harmonic constants. The spacing of observation stations and the length of the observation periods along the shores of the North Pacific are adequate for general analytical purposes only. The cotidal lines are for the principal lunar semidiurnal tidal constituent and are accurate for those regions of the North Pacific where the tides are of the semidiurnal type.

Since tides are not considered of practical importance in open ocean areas, little work on their measurement in "deep water" has been done. The values shown in open ocean areas are only interpretations of Hydrographic Office analysts and are primarily of academic interest. The only places where corange lines in the open ocean have practical significance are near islands or banks and shallow areas.

CURRENTS

The ocean current charts are compiled principally from ship drift reports forwarded to the U.S. Navy Hydrographic Office. U.S. Navy Hydrographic Office publications provided additional information. As expected, the observation density is greatest, and the reliability of the presentation is best, along the major shipping lanes. The mean speeds and directions of the prevailing currents are derived from these drift observations compiled per one-degree quadrangle. Considerable variation from the directions and speeds of the prevailing currents shown can be expected, especially in areas where the currents are weak. In areas where ship drift observations are few, references are used, where available, to supplement the basic current data.

SEA WAVES

One of the most difficult surface observations for either the mariner or professional observer to make is that of sea waves. The reason is primarily that sea waves are irregular. From the interlaced pattern of waves on the sea surface an observer must determine a height value which represents the significant wave. (The significant wave height is defined as the average height of the one-third highest waves in a given observation).

The analysis in this atlas is based primarily on observations recorded and contained in Deck 110, 115, 192, 193, 194, 195, H1-9, and 281 of source 24. In addition the 8 Ocean Station Vessels provide a network of regular observation records, which serve as a core for the analysis.

The climatic sea data are presented in the form of isolines which emphasize the geographical distribution of specific wave heights. The direction of the waves can be inferred from the wind roses.

ICE

The ice limits shown on all charts are based on observations recorded over many decades and enclose areas whose average ice concentration equals or exceeds five-tenths. However, this boundary may vary widely from day to day and year to year under the influence of changing climatic and oceanographic conditions.

The concentration of sea ice and the approximate maximum extent of sea ice of one-tenth or greater concentration are shown for each month. The only icebergs, bergy bits, and growlers observed in the North Pacific region are confined to the shore of the Gulf of Alaska. In addition, the ice conditions at key locations along the periphery of this ocean are summarized in tabular form. All dates are approximate unless followed by the number of years of record. Whenever data were not abailable, the dates are omitted.

The bulk of the ice information contained in this publication was derived from sources 25 through 32. Various Japanese references, and in particular source 26, were consulted to determine the extent of ice in the western North Pacific. Similarly, several general references in addition to sources 30 through 32, were used to establish the ice conditions near Alaska.

PHYSICAL PROPERTIES

Temperature.--The mean sea surface temperatures are based primarily on temperature observations reported by the merchant marine. Temperature observations also are concentrated along major shipping lanes; in other areas data are significantly sparser. In general, the observations are considered accurate for most purposes; the data compilations and analyses have been carried to the accuracy that data concentration and reported observations permit. In areas where appreciable horizontal gradients appear, particular care was exercised in the analysis.

The basic data used are essentially the same as those used for H.O. Pub. No. 225 (source 33); several other sources which are recognized as authoritative were used for supplemental information.

Density.--Normally density charts are computed from paired sea temperature-salinity observations; however, surface density values for the various seasons can be determined, to a fair degree of accuracy, from mean monthly sea surface temperature and salinity charts. Sources 34 through 52 were utilized in preparing these charts. Surface water density was computed from mean temperature and salinity values for a unit area rather than from paired temperature-salinity values. This method is considered to provide information sufficiently reliable for most maritime applications. The density of sea water is normally computed at atmospheric pressure and the temperature at which collected, and is defined as the ratio of the mass per unit volume of sea water to distilled water.

IMMERSION HYPOTHERMIA

The approximate survival time of human beings in the sea is directly related and charted according to sea surface temperature. However, the survival time given can be considered only a first order approximation since data records do not incorporate many uncontrollable physiological variables. For example, neither quantitative appraisal nor records have been made of such intangible factors as the physical condition of the individual or his will to survive.

Among the numerous studies on physiological effects of immersion hypothermia, those which have been most useful in the determination of actual or theoretical survival times have been published by Glaser (source 53), Molnar (source 54), and the U.S. Bureau of Naval Personnel (source 55). Treatment of survivors is discussed in source 56.

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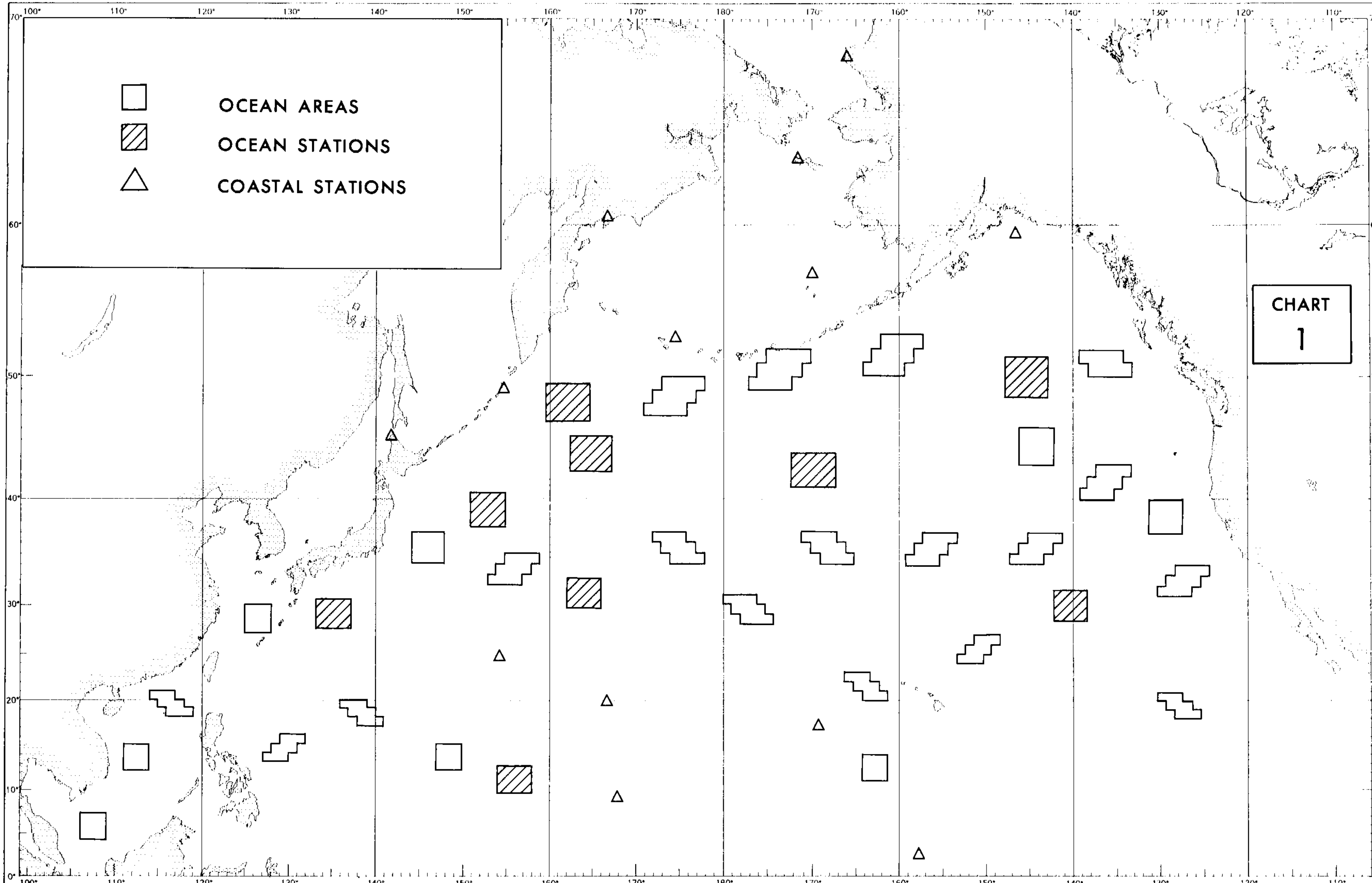
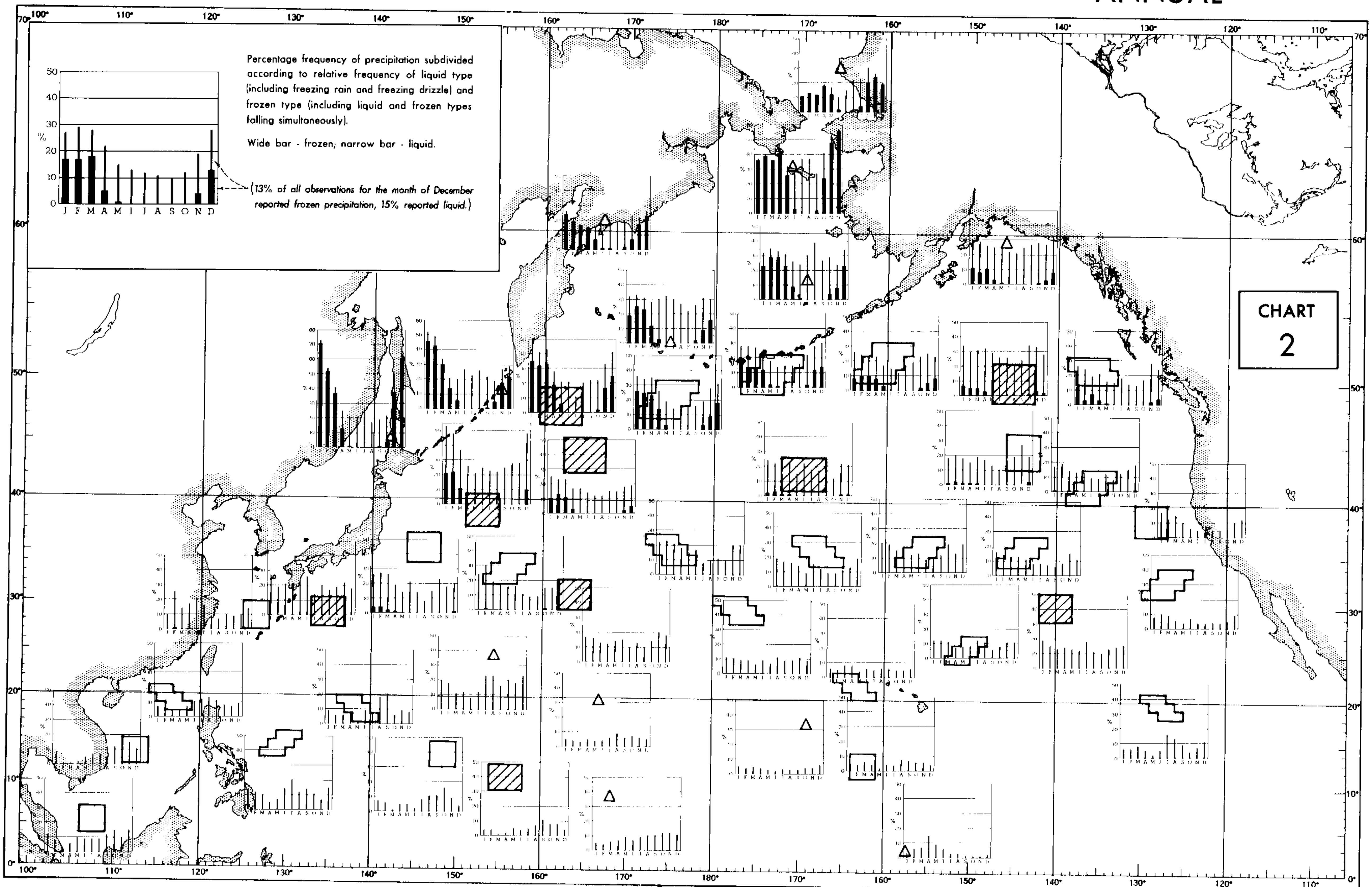
MARINE CLIMATIC CHARTS

SURFACE CLIMATIC CHART AREAS & STATIONS



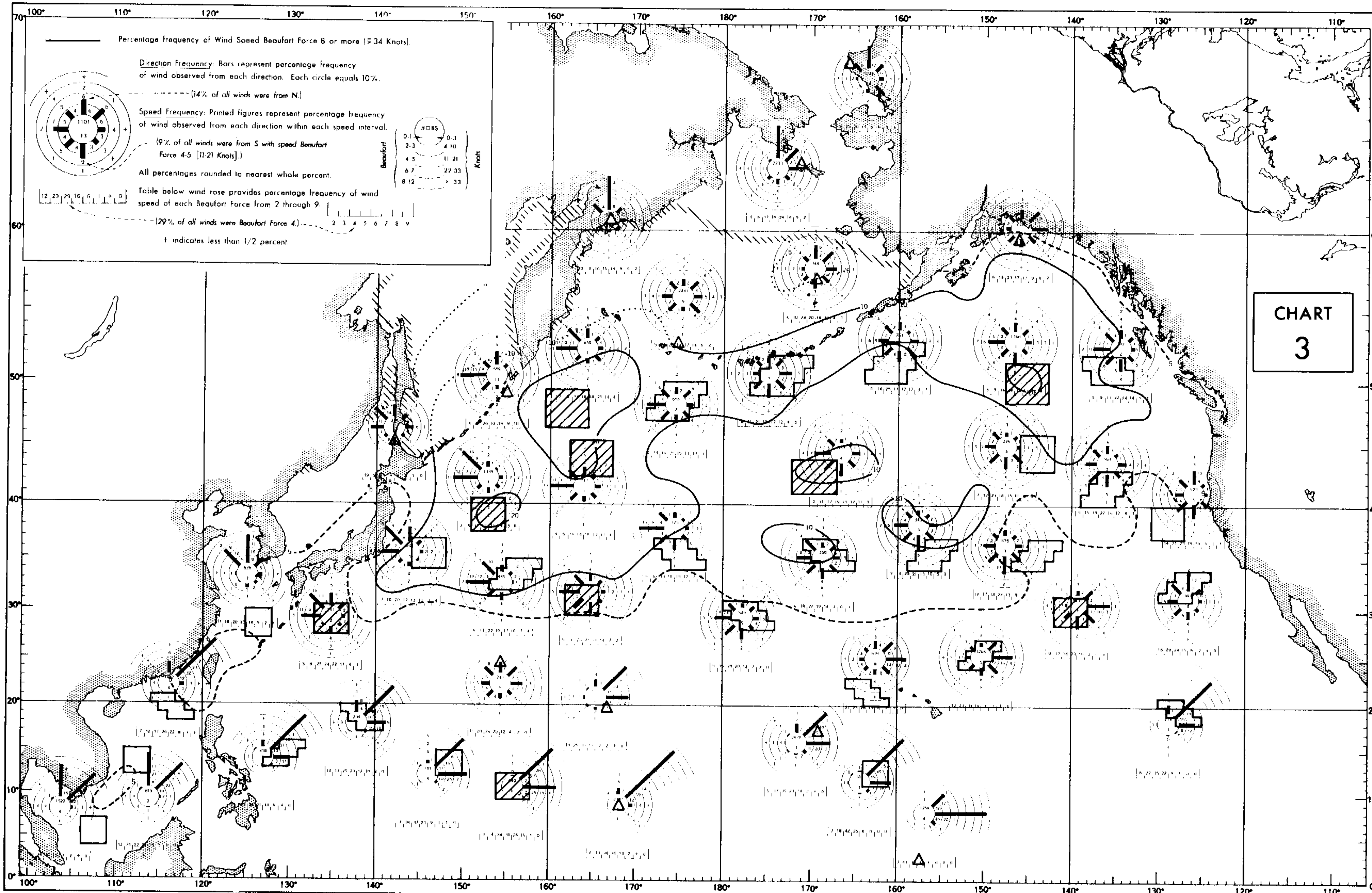
PRECIPITATION

ANNUAL

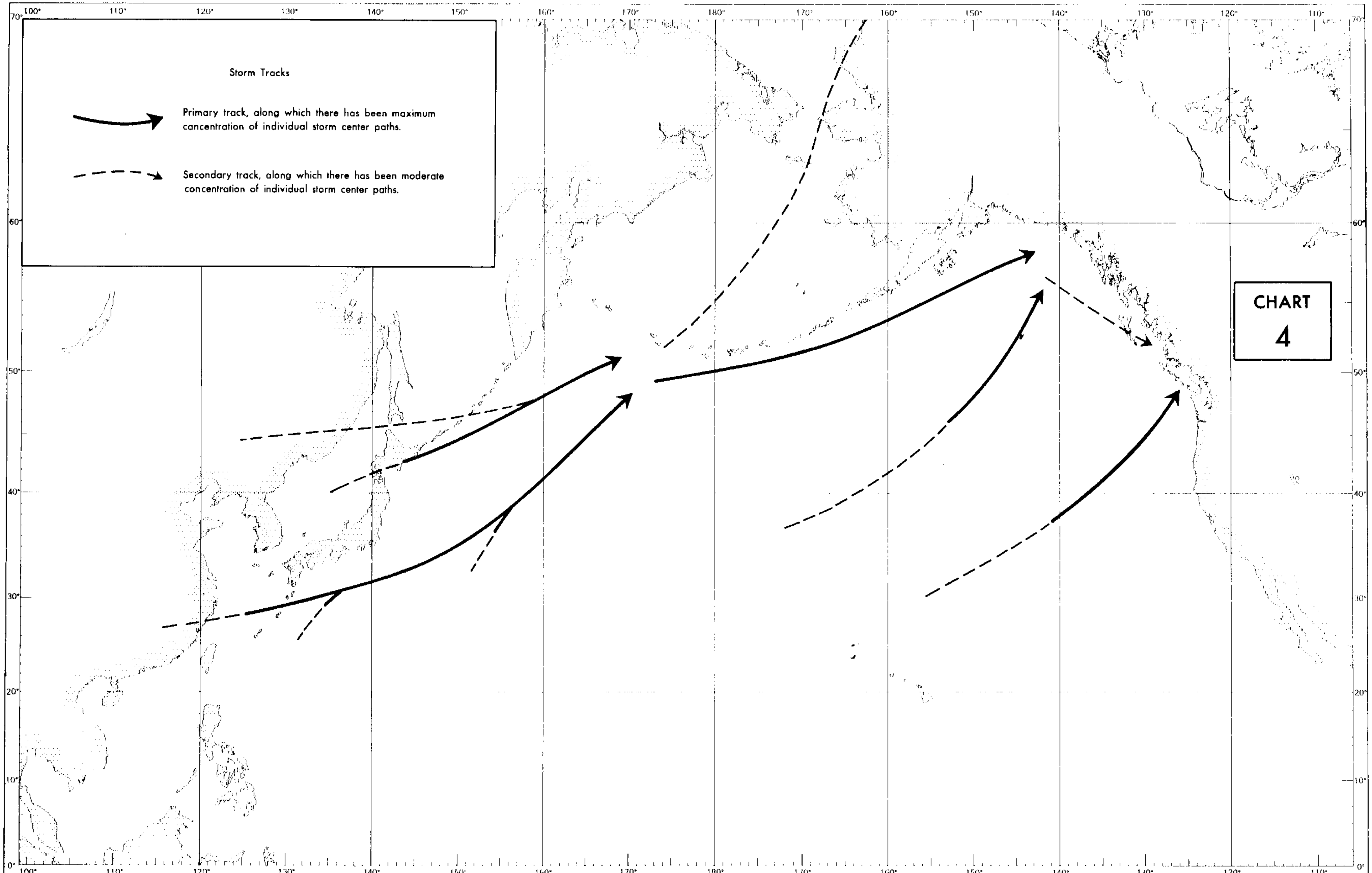


SURFACE WINDS

JANUARY

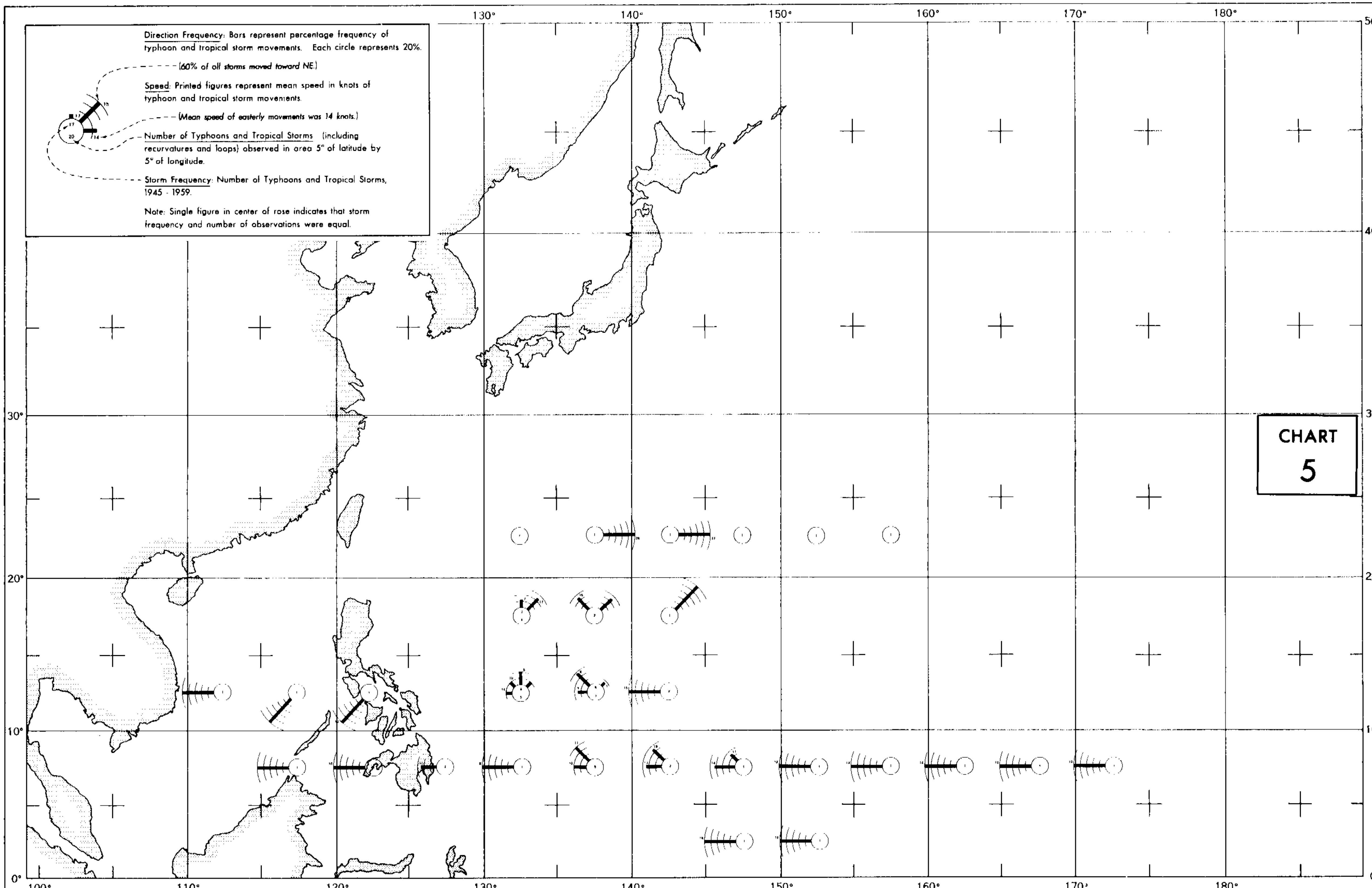


STORM TRACKS JANUARY



TROPICAL STORMS & TYPHOONS

JANUARY



VISIBILITY

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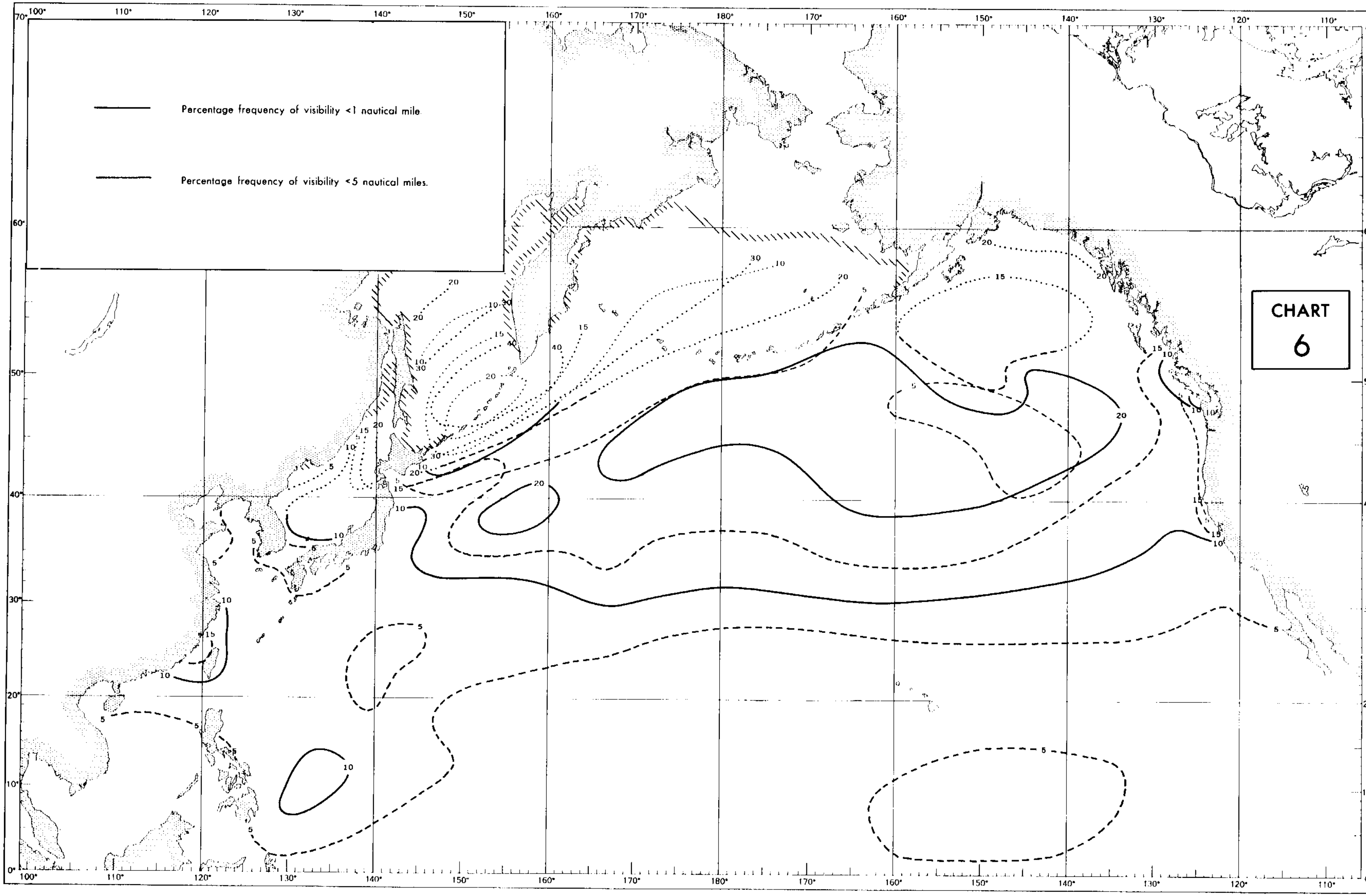
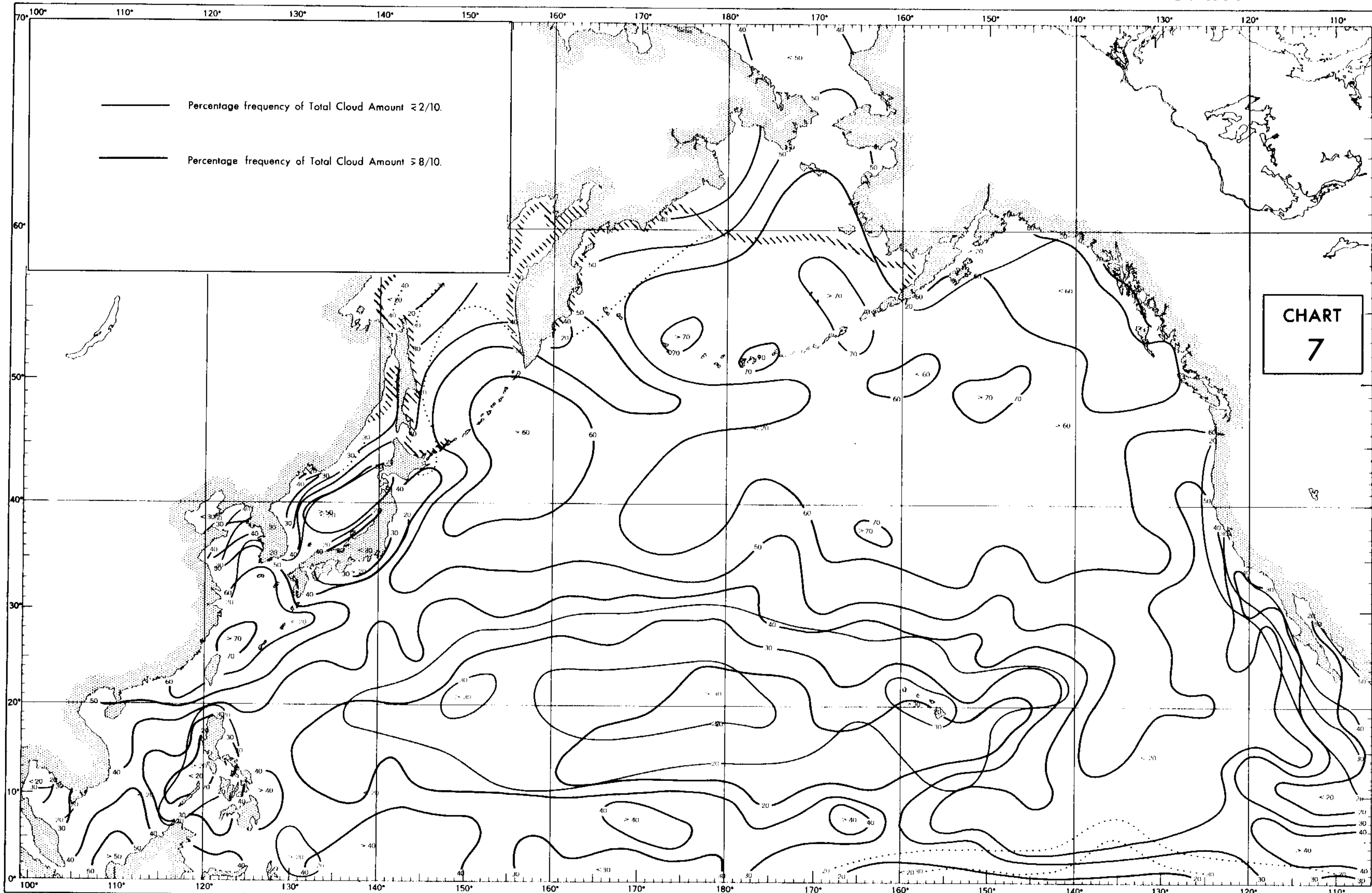


TOTAL CLOUD AMOUNT

JANUARY



AIR TEMPERATURE

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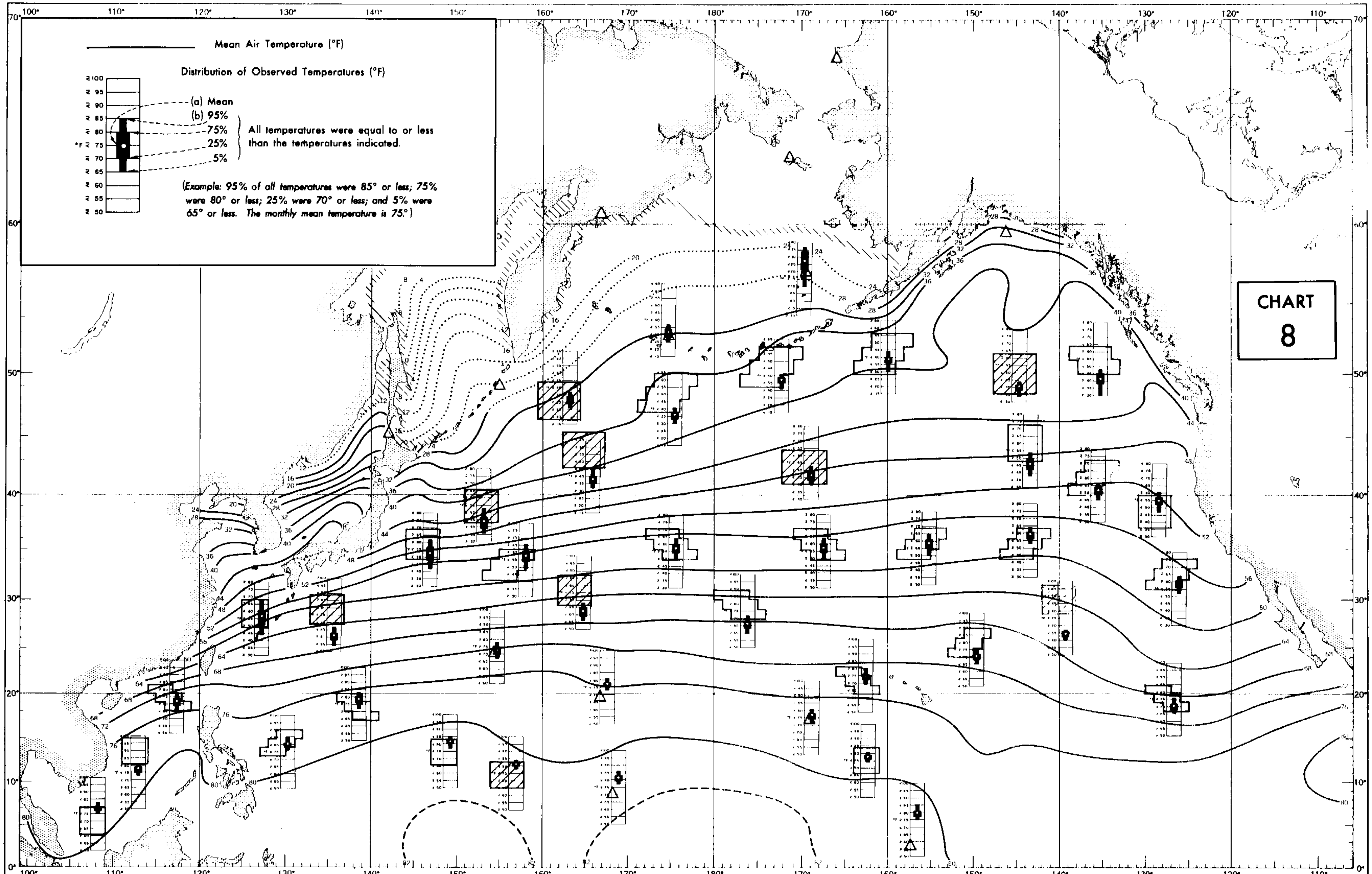

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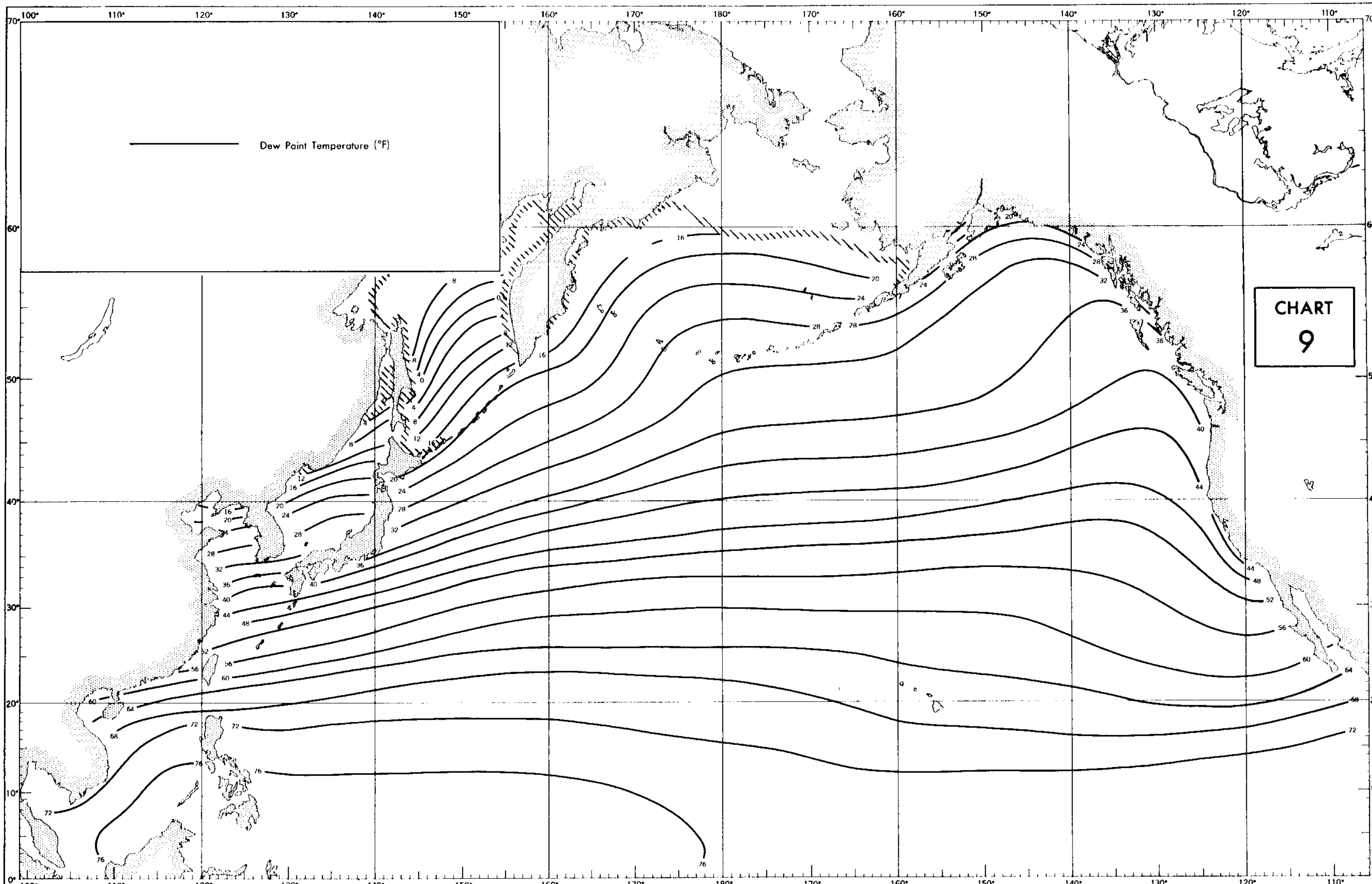

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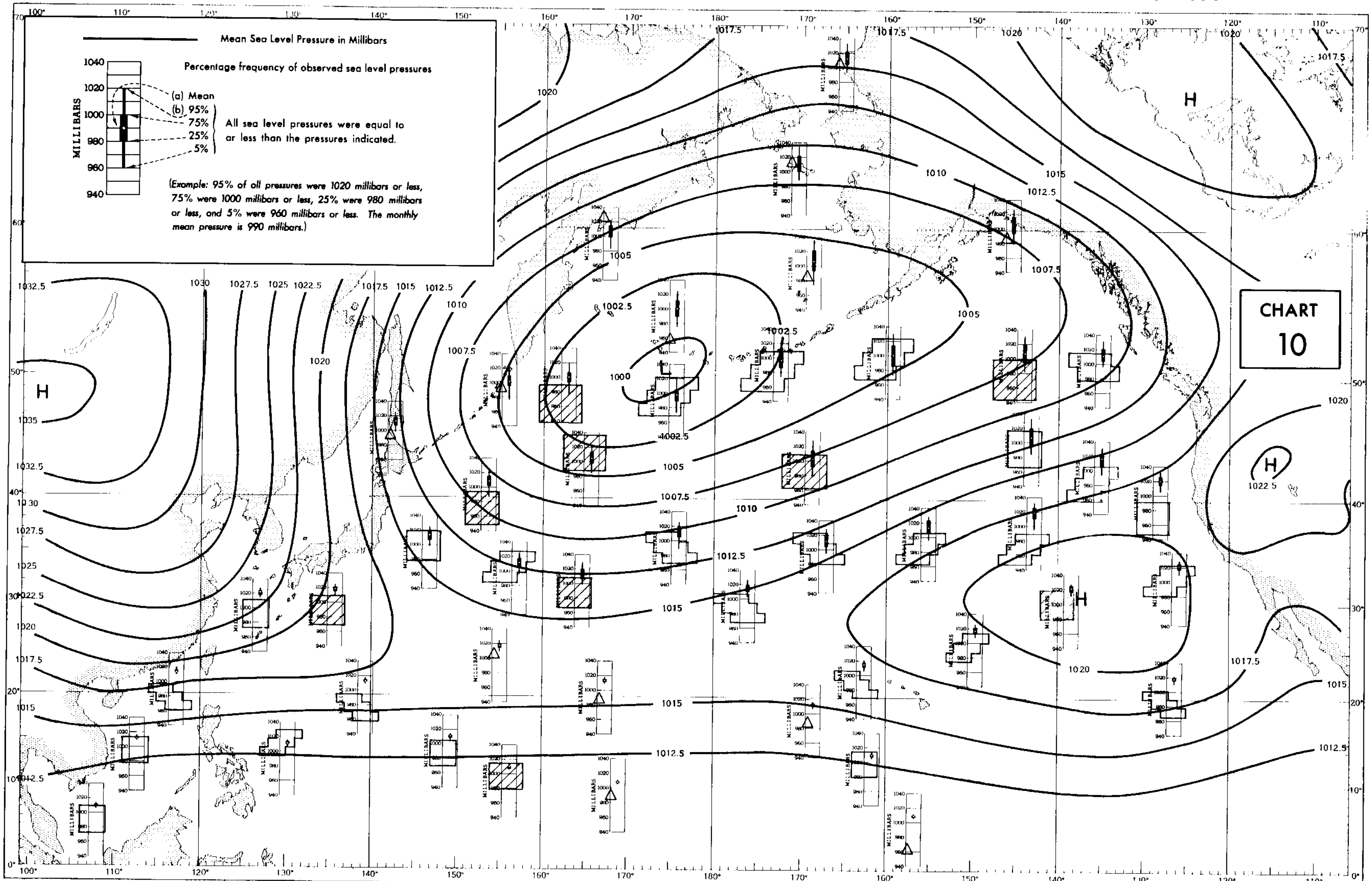
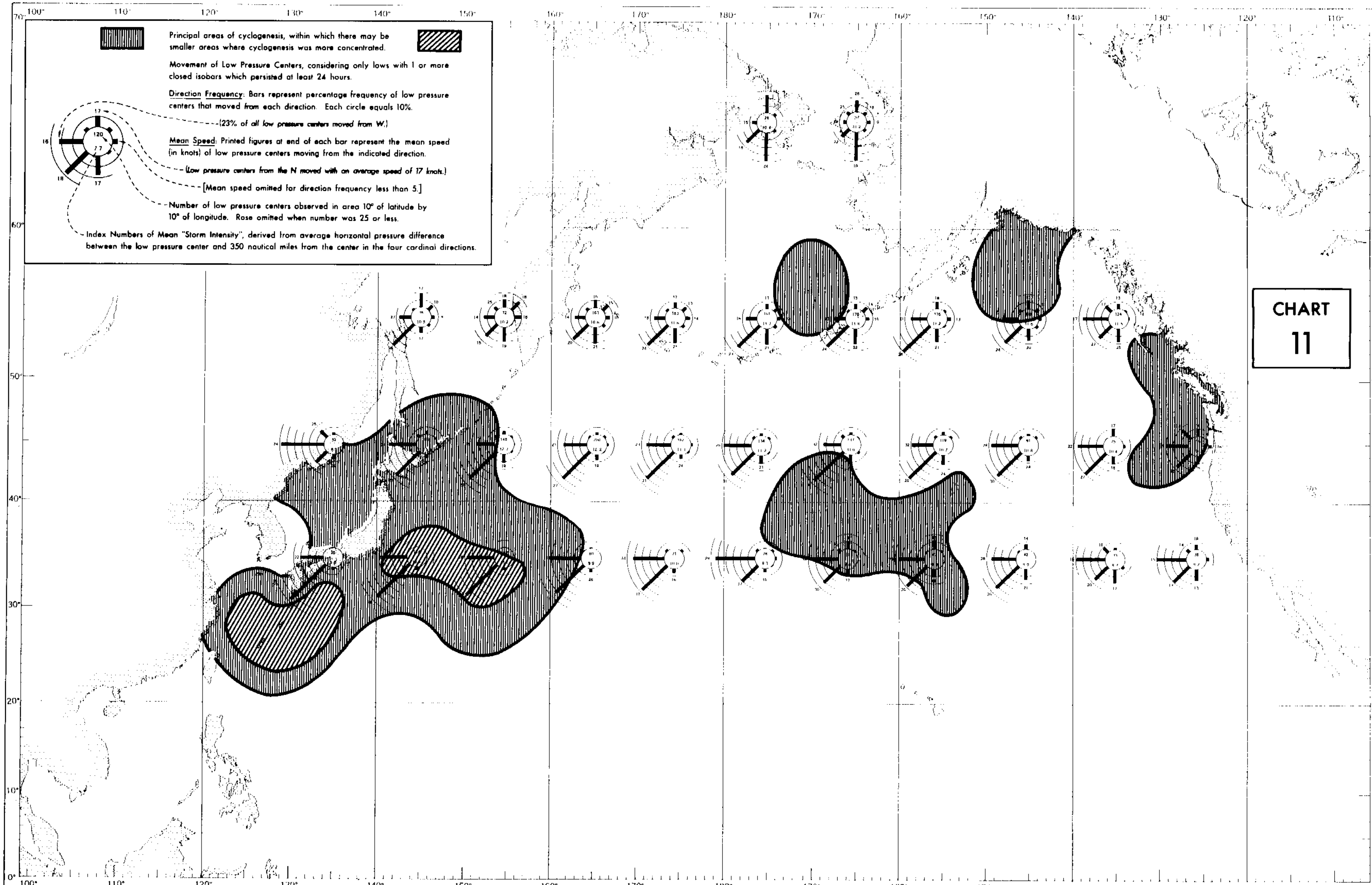


LOW PRESSURE CENTERS

DEC - JAN - FEB



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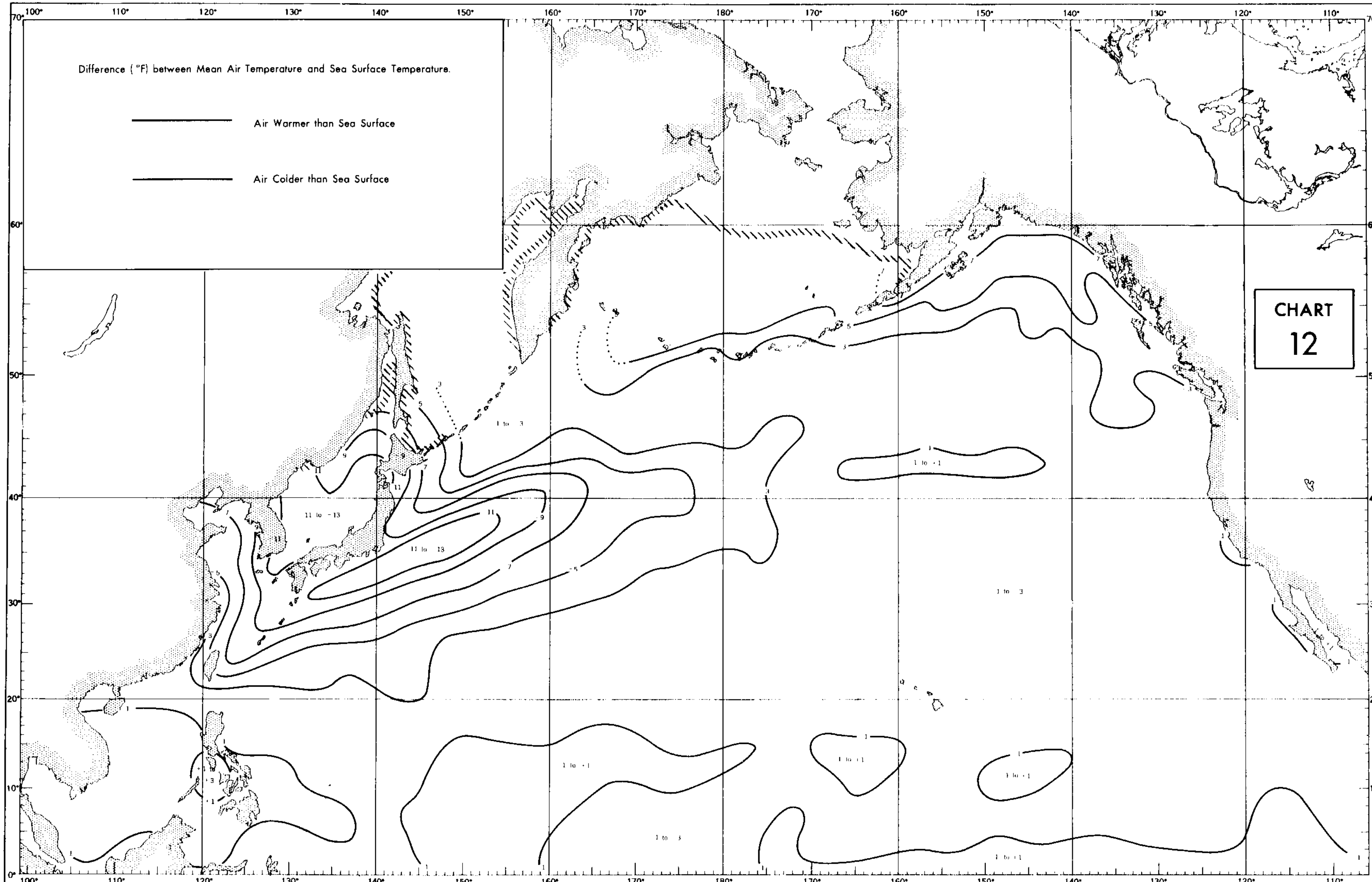

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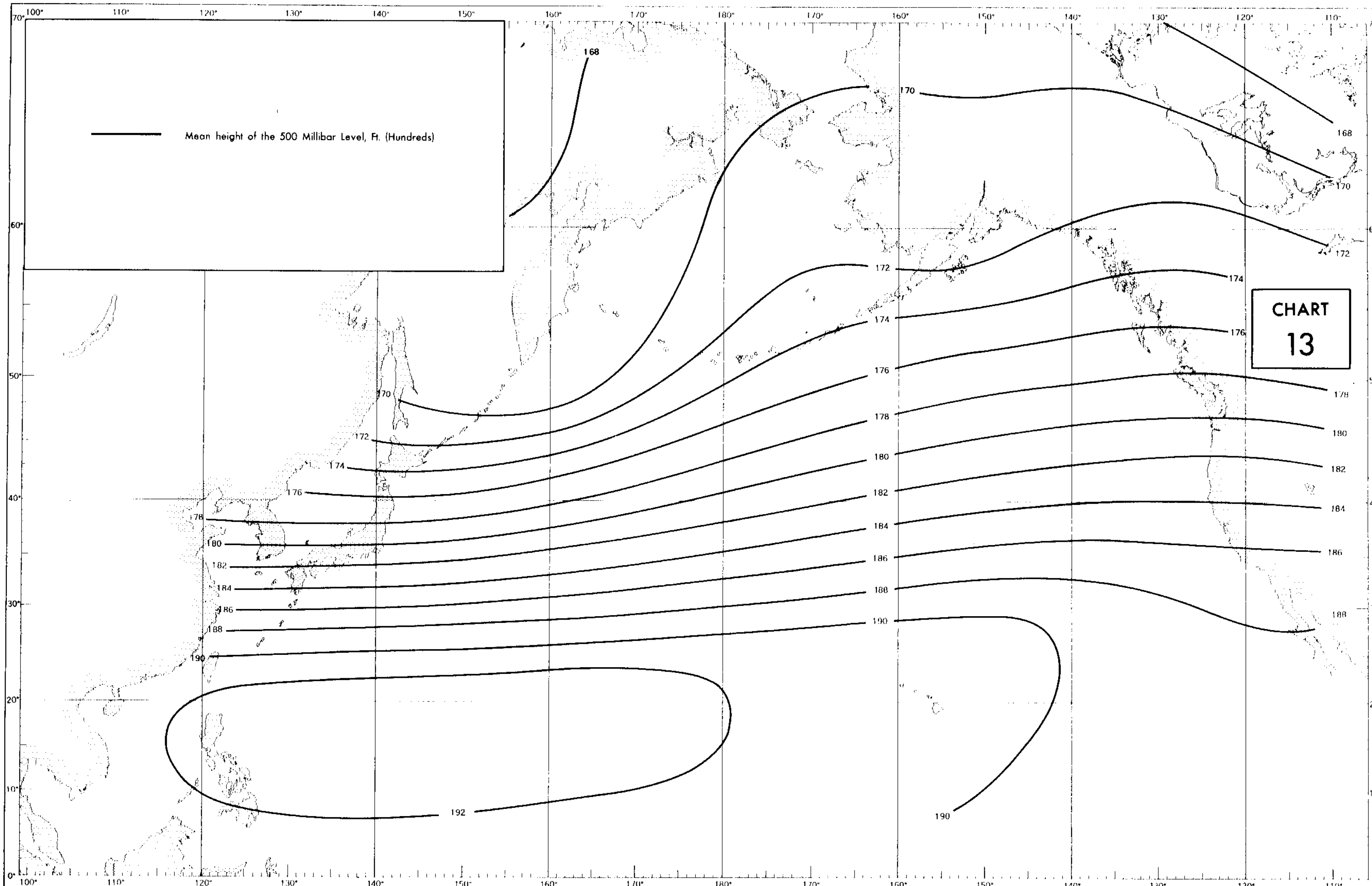

500 mb WIND ROSES

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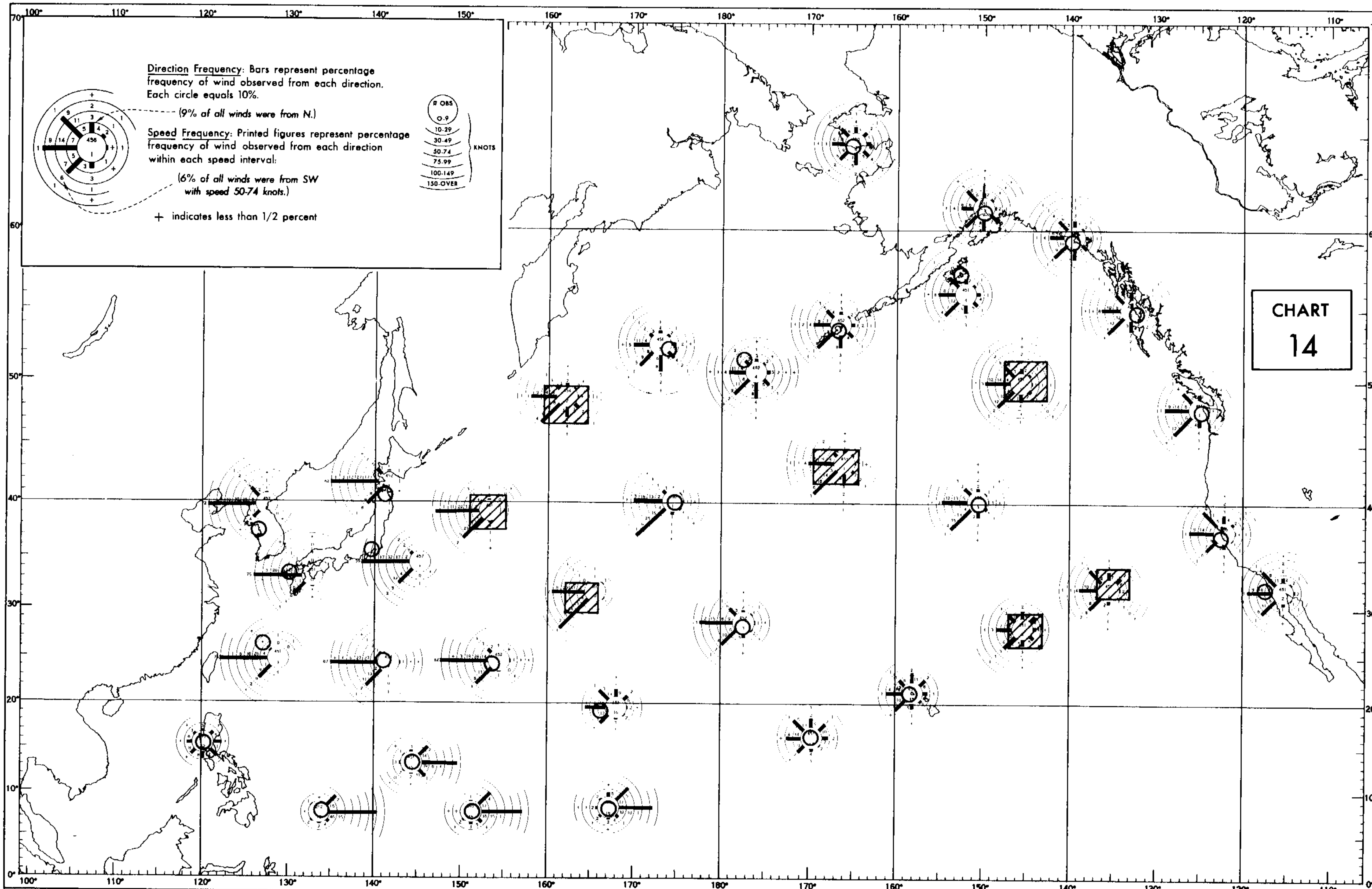
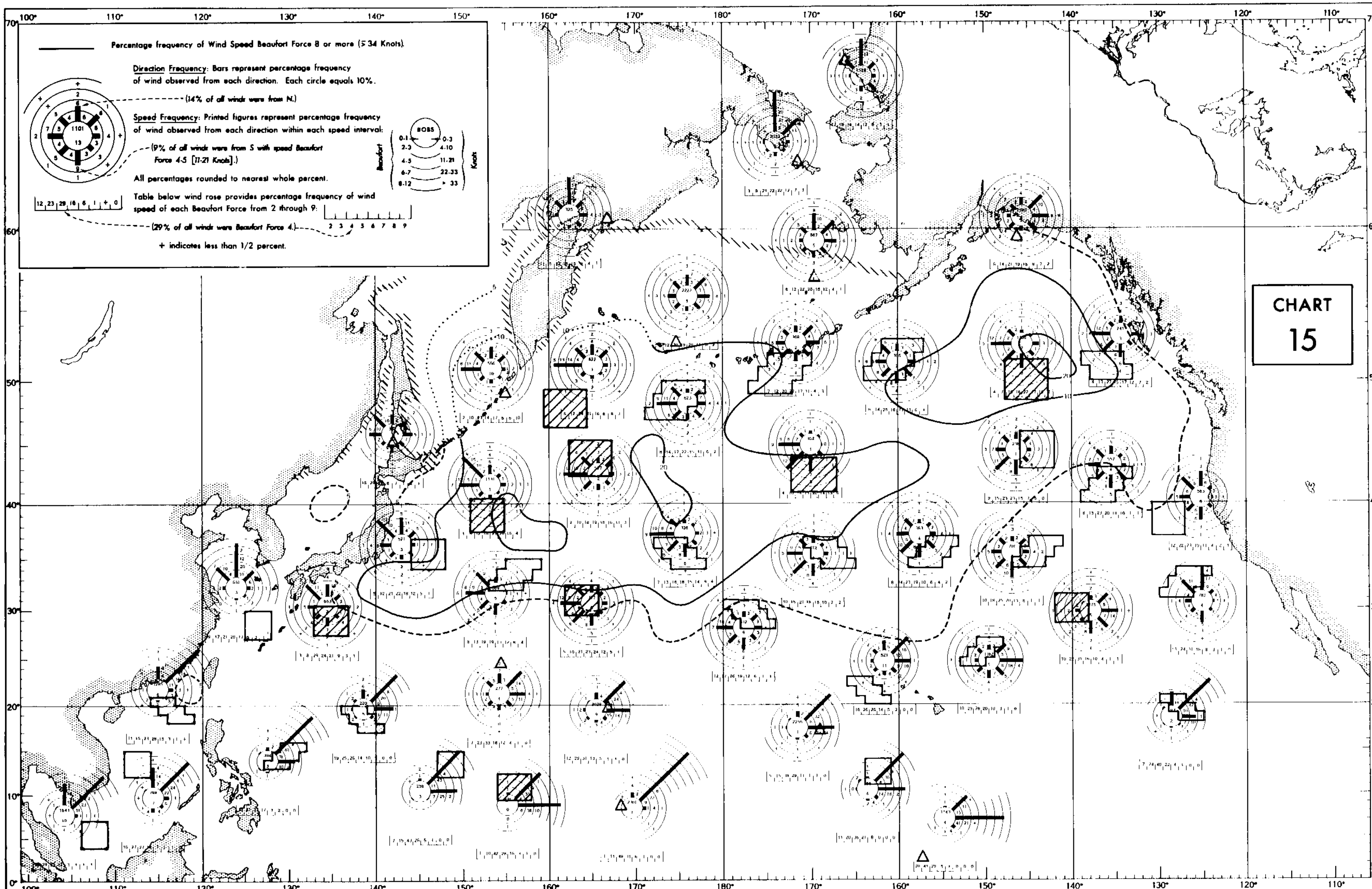


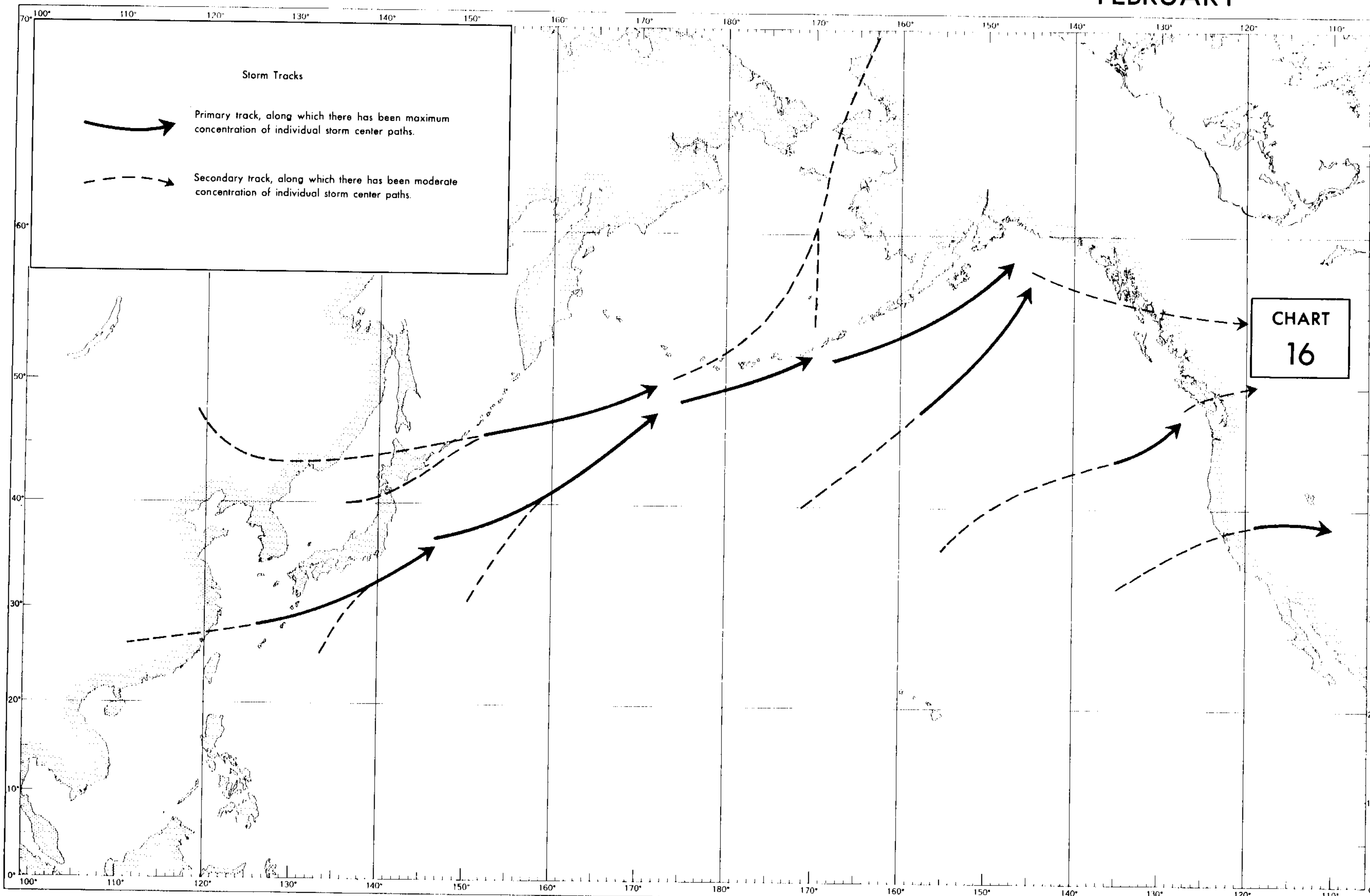
SURFACE WINDS

FEBRUARY

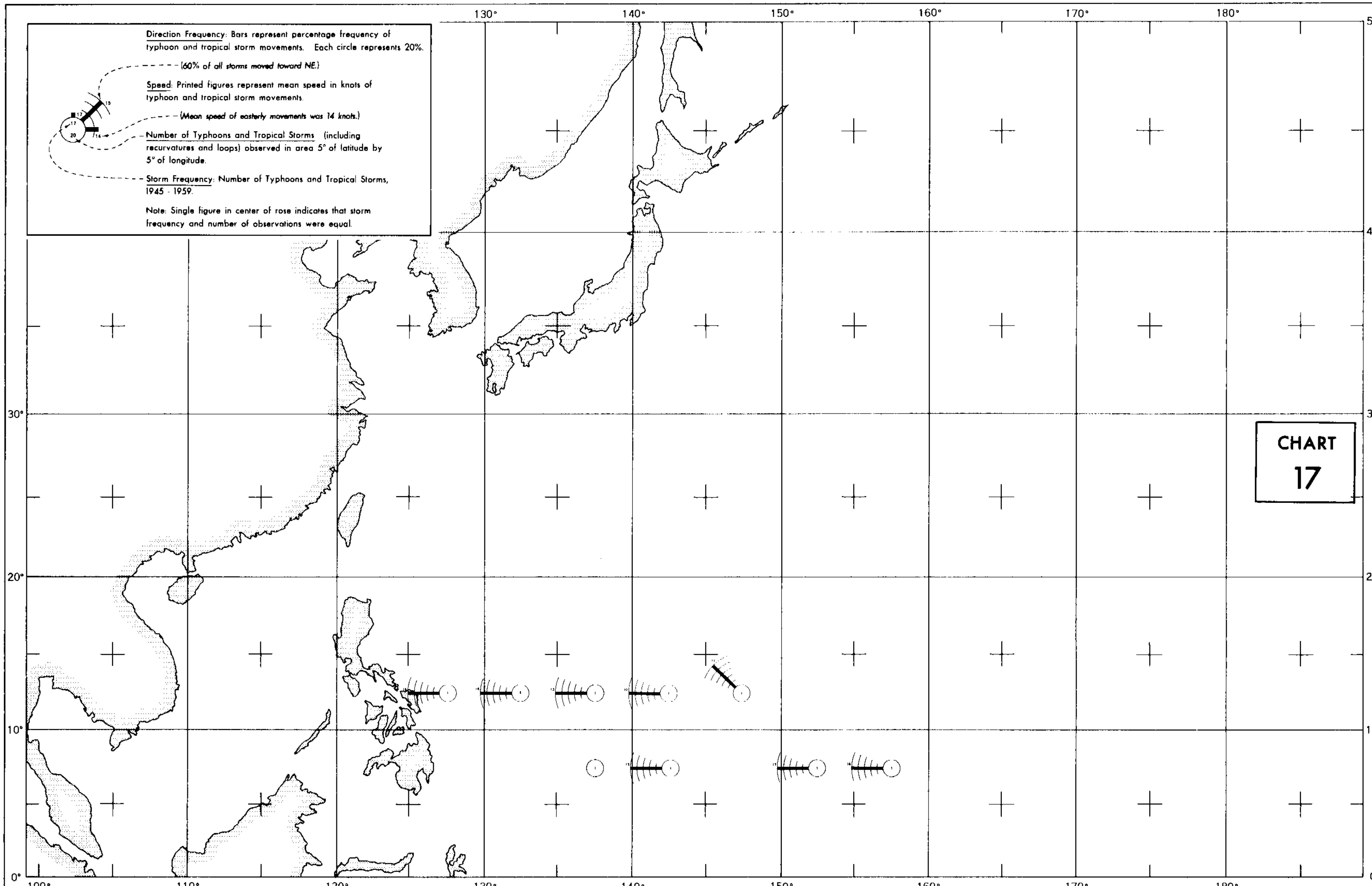


STORM TRACKS

FEBRUARY

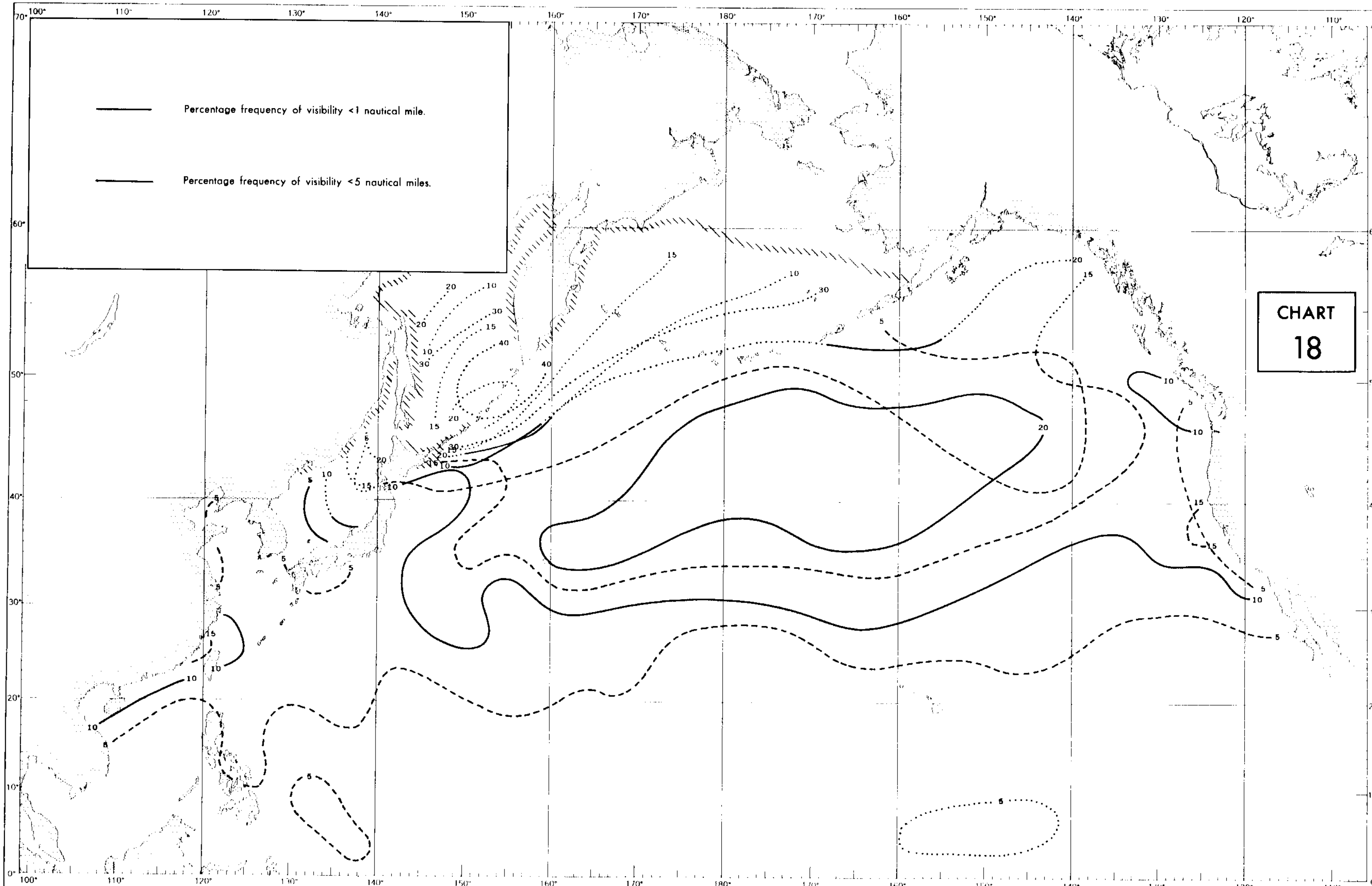


TROPICAL STORMS & TYPHOONS FEBRUARY



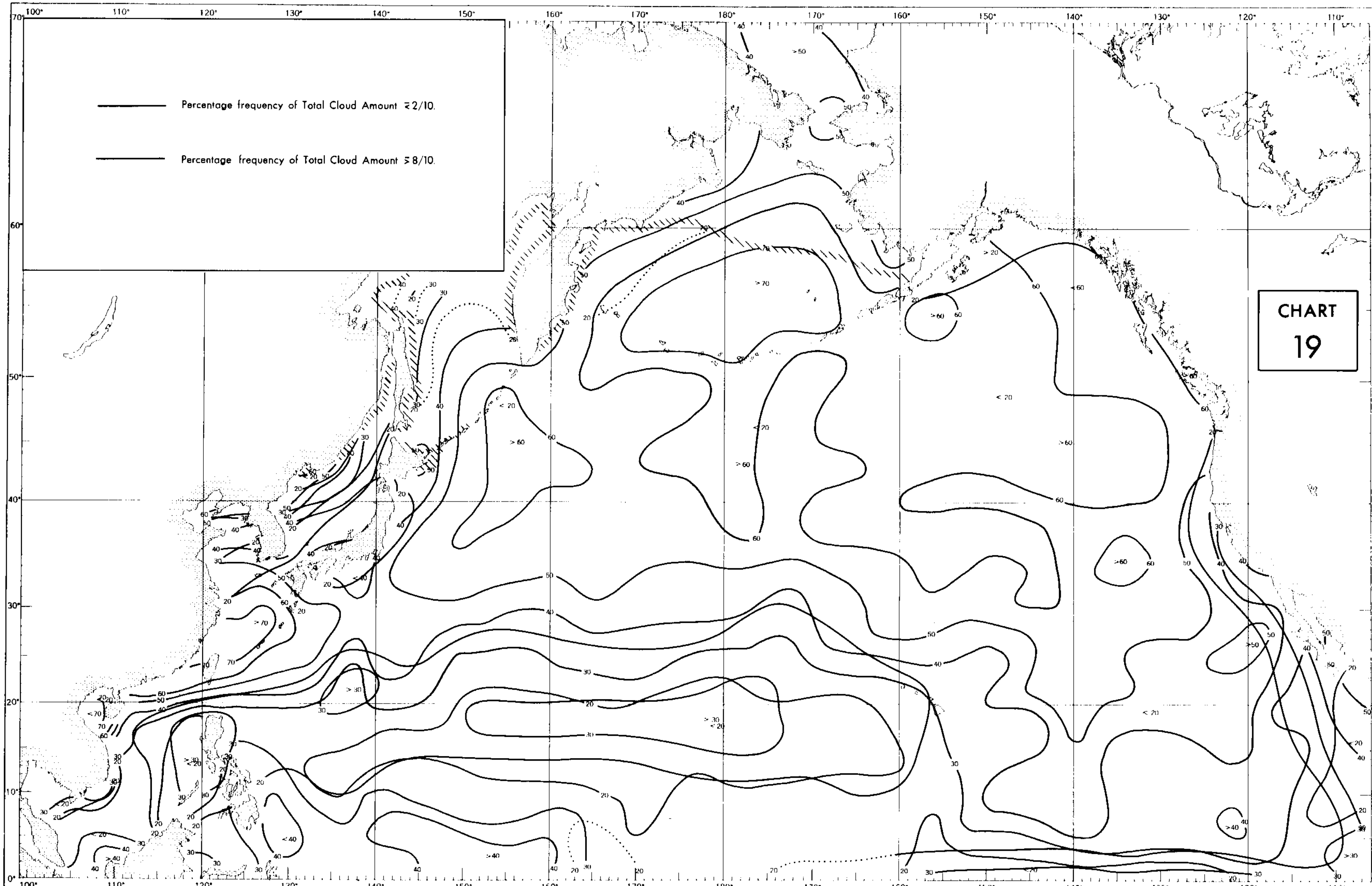
VISIBILITY

FEBRUARY



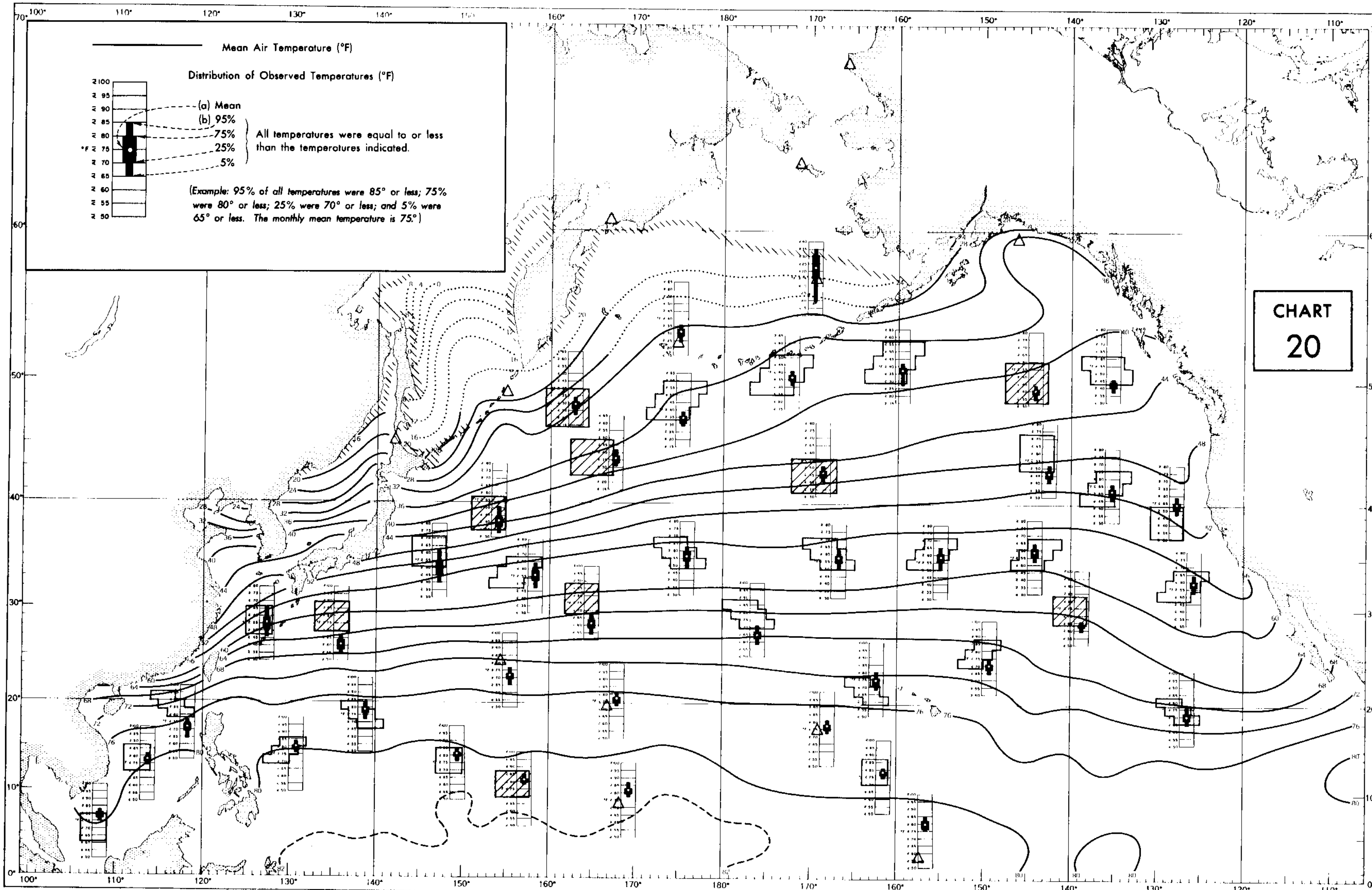
TOTAL CLOUD AMOUNT

FEBRUARY

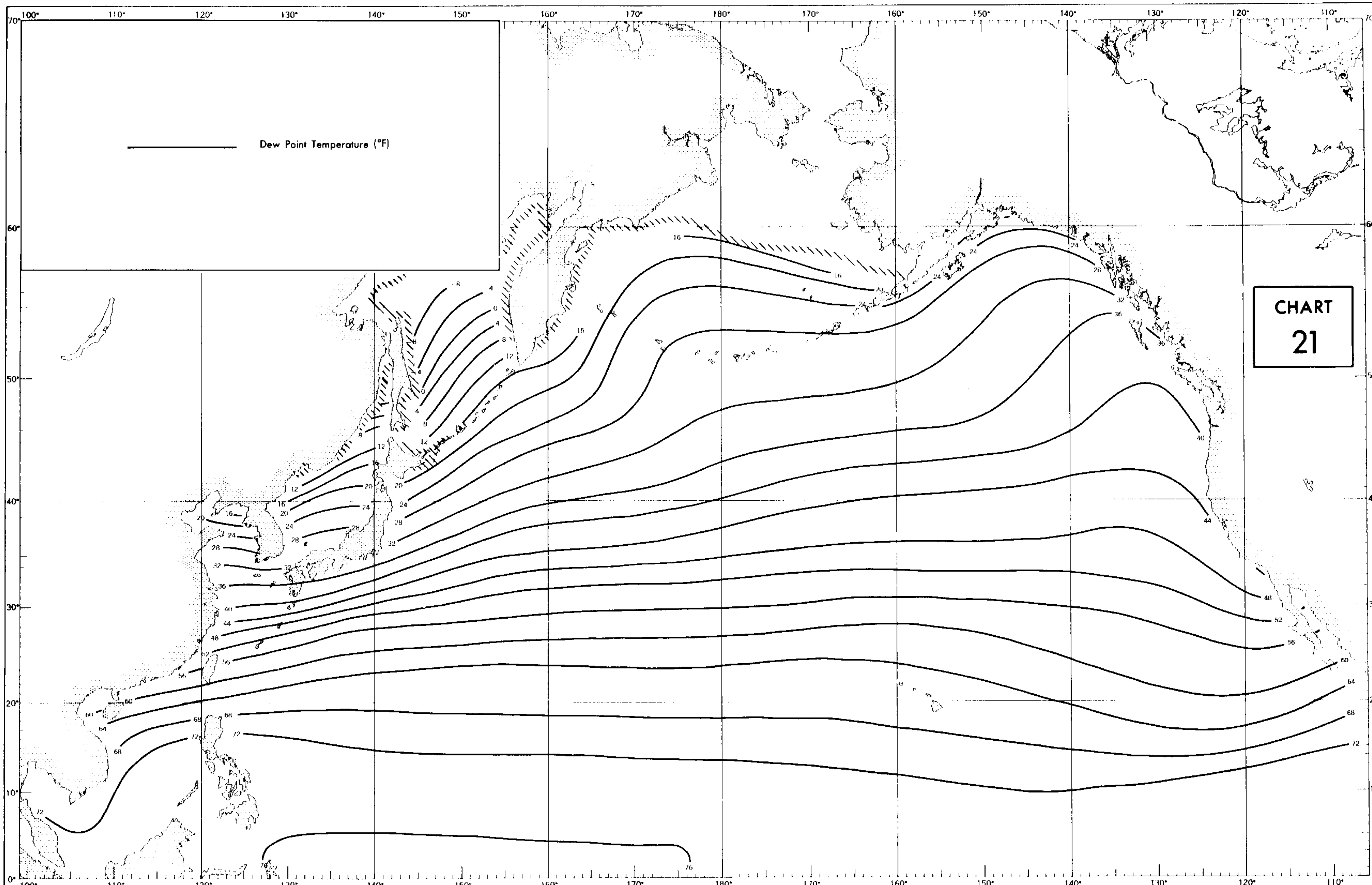


AIR TEMPERATURE

FEBRUARY

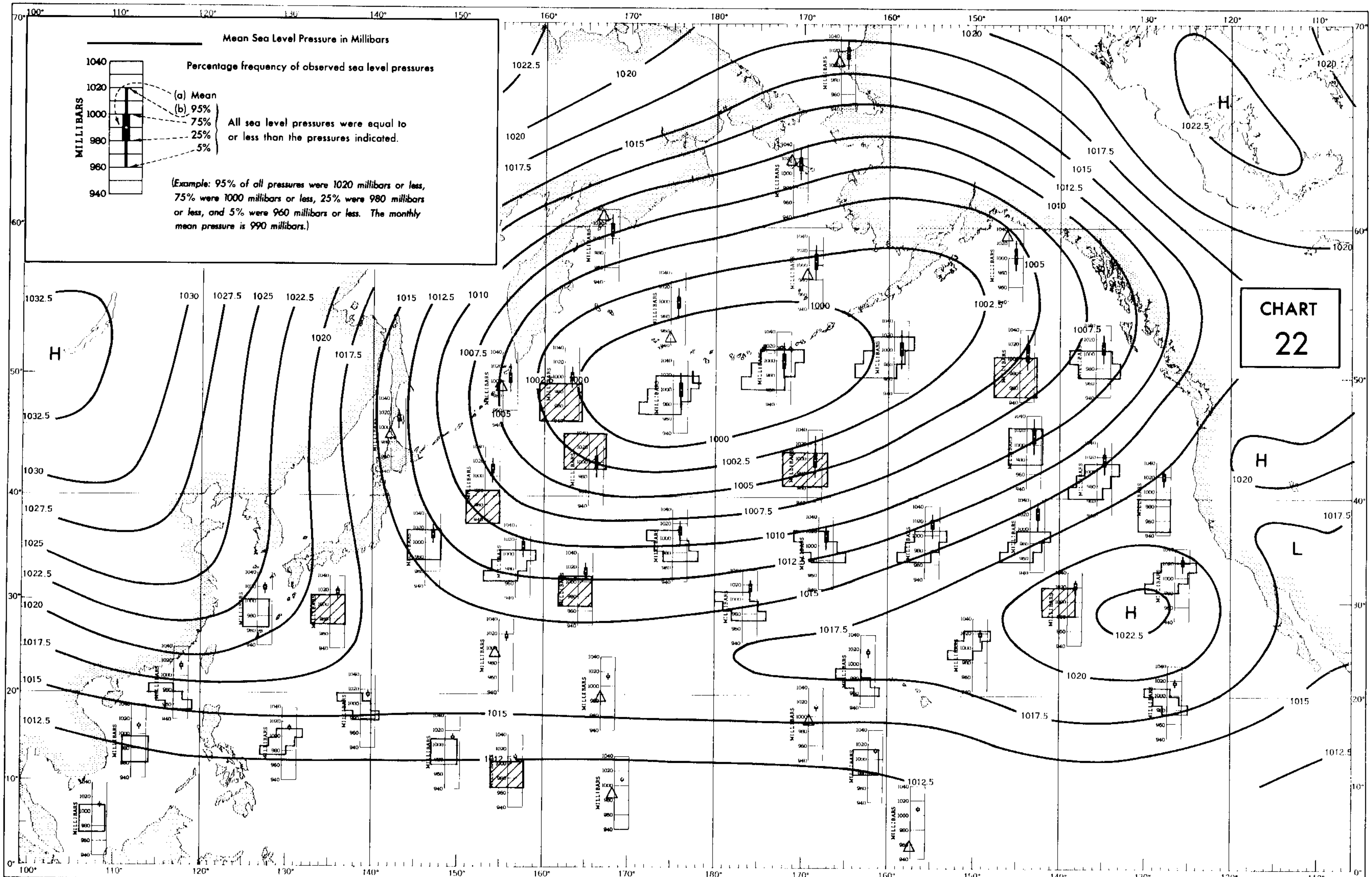


DEW POINT FEBRUARY



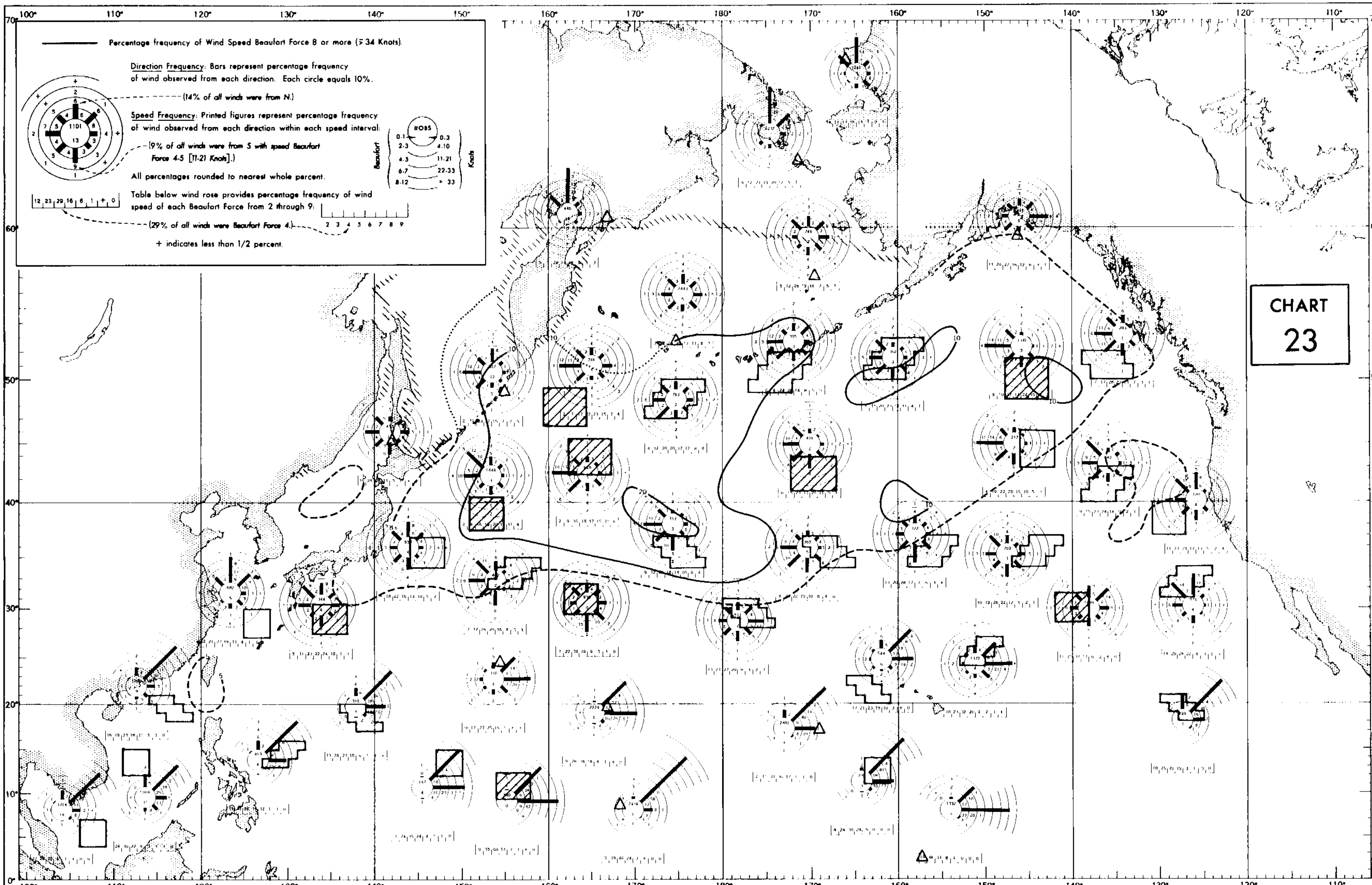
SEA LEVEL PRESSURE

FEBRUARY



SURFACE WINDS

MARCH



STORM TRACKS MARCH

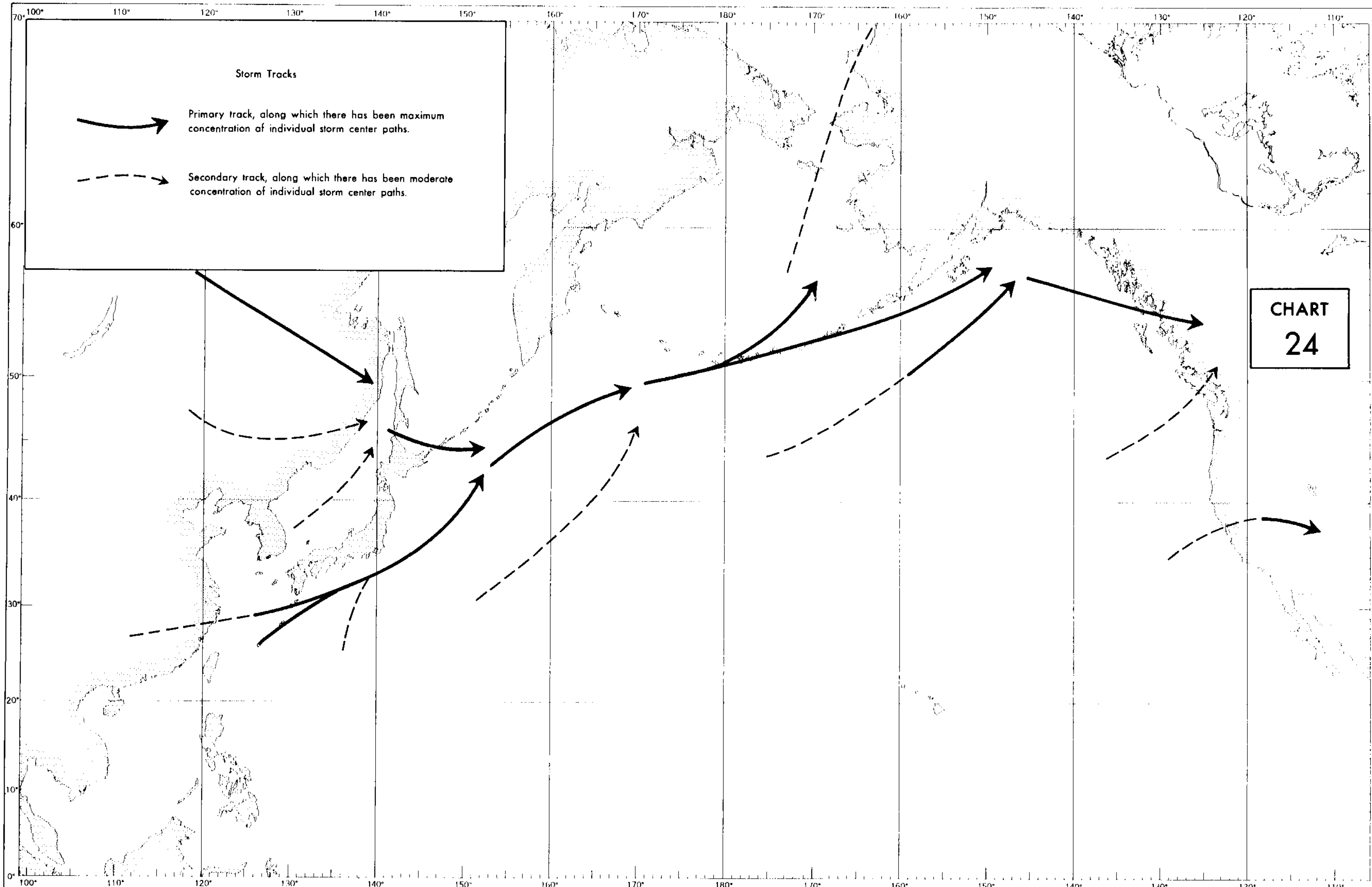


CHART 24

TROPICAL STORMS & TYPHOONS

MARCH