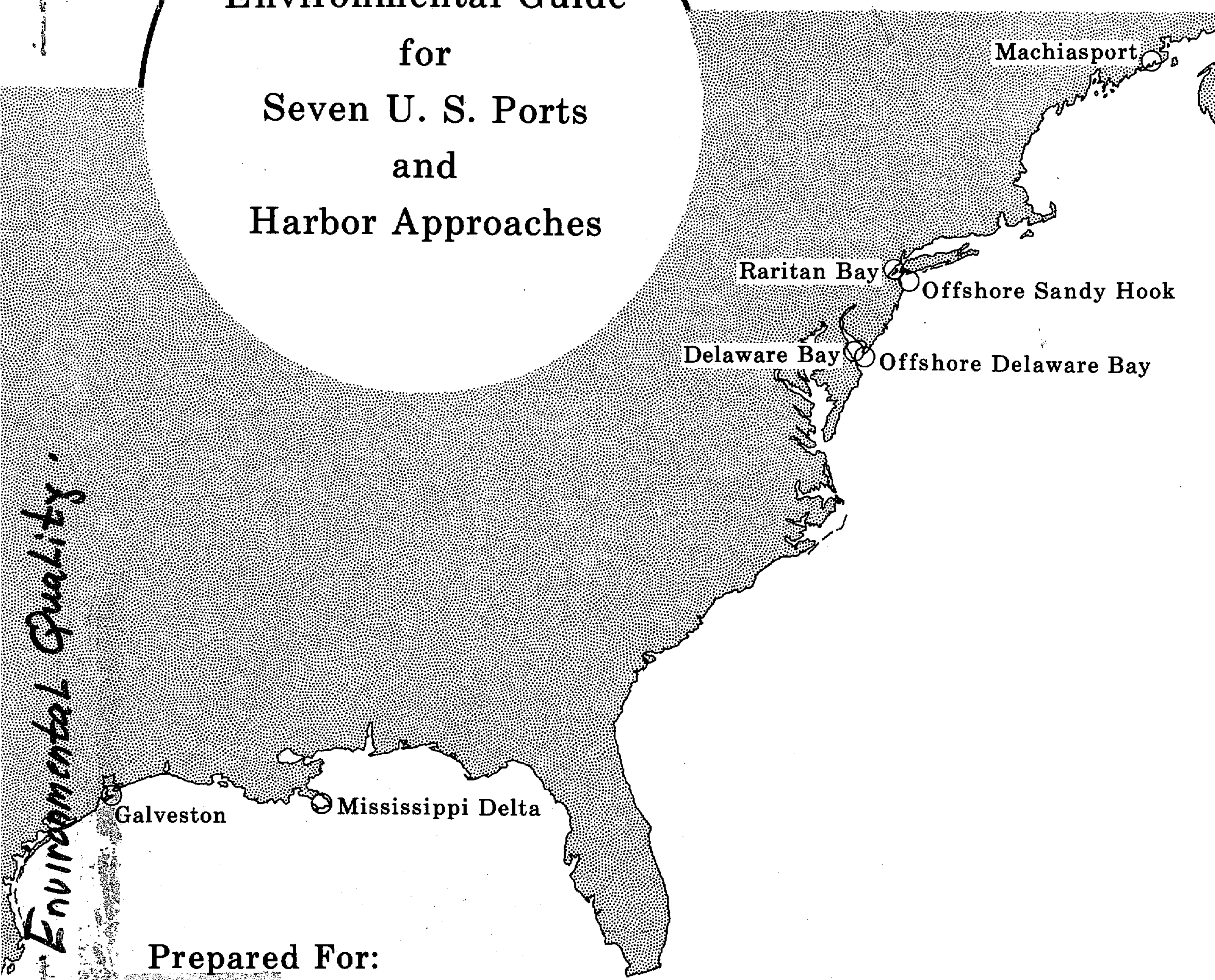
Environmental Guide for Seven U. S. Ports and Harbor Approaches



Prepared For:
The President's Council on Environmental Quality

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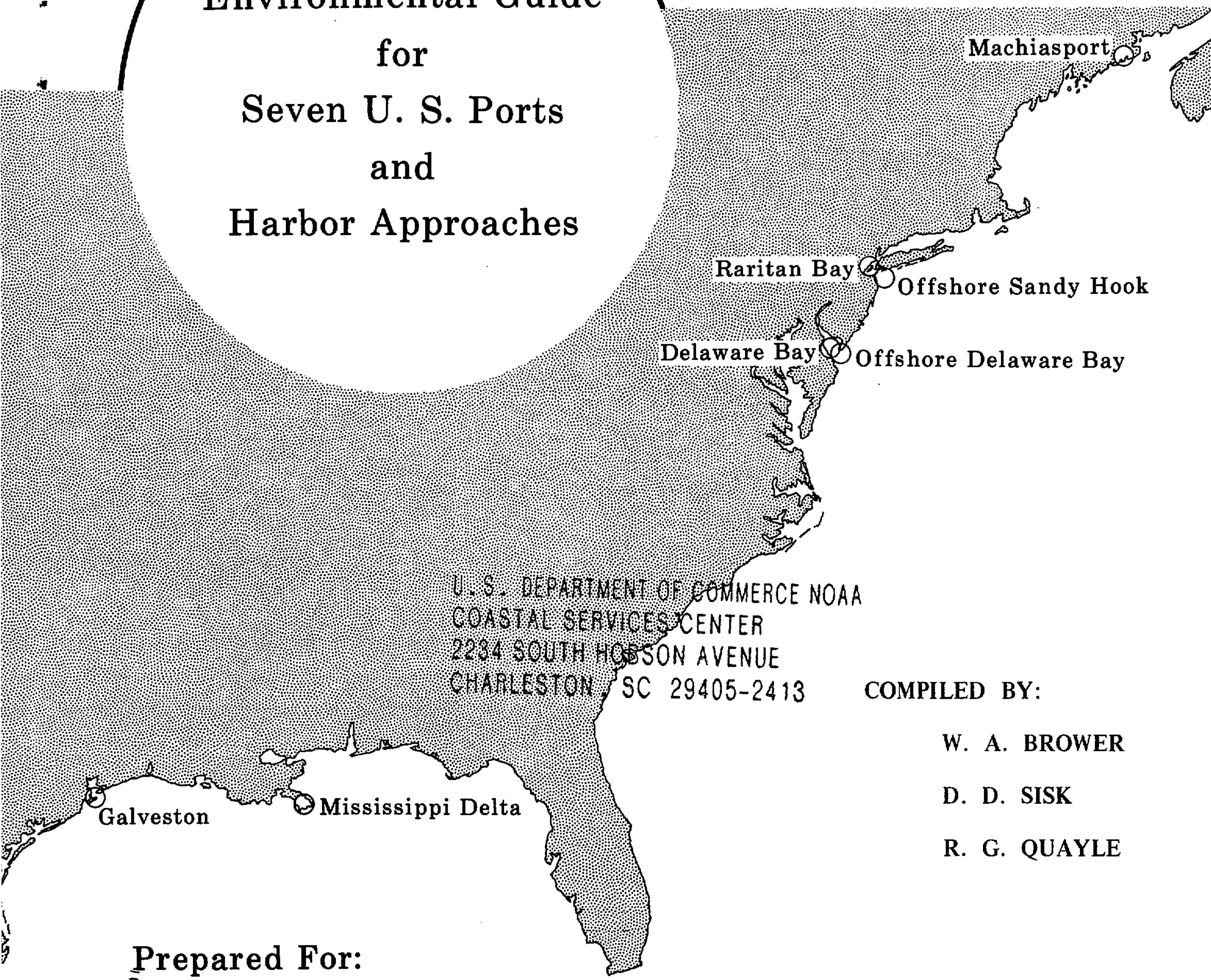

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FEBRUARY 1972

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Abstract

This report was compiled to aid in selecting suitable supertanker terminal sites for the United States. It presents climatological criteria necessary to assess the environmental effects on supertankers at selected Gulf and East Coast ports.

A general description of the major environmental controls governing the study area is followed by detailed analytical summaries for each port.

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Acknowledgement

Several members of the NCC staff assisted in producing this report. Without their help such a report would not have been possible.

The National Ocean Survey provided a great deal of information on tides and currents.

The Naval Weather Service provided most of the support for the computer programming effort which made speedy summarization of large volumes of data possible.

D. Lee Harris of the U.S. Army Coastal Engineering Research Center furnished information on coastal waves.

Introduction

For the purposes of this study, tank ships of 100,000 deadweight tons and more are considered to be "supertankers." The term was originally coined around 1950 to describe tankers of over about 28,000 deadweight tons. Deadweight tonnage is the weight (in long tons: 2240 lbs.) of cargo and fuel which a vessel is designed to carry safely.

Currently the largest tankers are rated at about 326,000 deadweight tons which translates to about 90 million gallons of oil. Because of their size (over 1000 feet in length, nearly 200 feet in width) and draft (50-70 feet) U.S. ports cannot be economically dredged to accommodate the supertankers. It will be necessary, therefore, to construct new berthing facilities if such tankers are to call on U.S. ports.

This report is designed to serve as a data base describing the existing environment of seven coastal areas. It may be used for planning, site selection and assessment of potential environmental impact. Section one describes the large scale features of the climate of the U.S. Gulf and East Coast. Section two provides the detailed statistics compiled for each study area separately.

Some repetition may occur from one study area to another. This is done so that any single area summary may be understood when read independently.

Data Sources and Definitions

The bibliography contains an alphabetical list of the primary data sources. It must be remembered that marine observations are taken by ships in passage. Since such ships tend to avoid bad weather whenever possible, a "good weather" bias may be introduced into the summaries. This problem has been partially overcome by relying on land and light station data as well as synoptic weather maps for inferences regarding extreme conditions.

Wind and waves are of paramount interest to most mariners.

Several types of wind measurements are taken regularly. Among the most significant variables to consider are:

1) the height above the surface of the earth at which the measurements were taken,

2) the duration at or above a given wind speed. Sustained winds are those averaged over a period of about a minute. Peak gusts are relatively high wind speeds having a duration of less than a minute. In general a sustained wind may be multiplied by a factor of about 1.4 to estimate the peak gust during gusty weather. Unless otherwise specified, sustained winds are described in this report. An average height of 10 m above the surface is assumed. Most marine wind observations are estimated based on sea conditions, spray, etc.

Waves are observed in two categories:

Wind waves or seas are waves generated by the local winds in the area of the observation.

Swell waves are those which have moved beyond this area of origin. The higher of sea or swell was used in the summary. Observers note the significant waves on their observational forms. This is the approximate height of the highest one-third of all waves present. Higher waves may also exist. These are called extreme waves and they may be estimated by multiplying the significant wave height by 1.8. Unless otherwise specified, this report deals with significant waves. It must be kept in mind that water depth is a limiting factor for wave heights. Since point source data are rarely available in the marine environment data must be summarized for fairly large areas. Extreme wave heights may have to be adjusted depending on the actual water depth at the point of interest. Maximum wave heights will be somewhat less than this depth (except in the case of tsunami waves or storm surges).

Tropical cyclones are cyclonic storms of tropical origin. There are two major types considered in this report: tropical storms which have wind speeds of 34 to 64 knots and hurricanes which have wind speeds equal to or greater than 64 knots. Two presentations are given. One deals with coastal strike zones (lines along the coast over which storms may pass), the other with penetration areas (areas within which a storm may occur). Detailed tropical cyclone statistics appear in Appendix A.

Charts of extratropical cyclone tracks appear in Appendix B.

Section One

General Description

Description of General Climate of the Northeastern U. S. Coast

This region of interest covers the east coast of the U. S. extending from the Delaware Bay area north to Eastport, Maine.

This region, with its low elevation, lies within the zone of the "prevailing westerlies." The climate and weather of this region is generally affected by masses of air originating in higher or lower latitudes and interacting to produce storm systems. The majority of air masses affecting this region belong to three types: (1) cold dry continental polar air that pours down from Canada, (2) warm moist air flowing northward over land from the Gulf of Mexico and from subtropical waters eastward in the Atlantic, and (3) cool damp air moving down from the North Atlantic. Thus, the basic climate results from an integrated effect of the various air mass systems. The Atlantic Ocean constitutes an important modifying influence, particularly on the immediate coast, but does not dominate the climate. Rapid and marked weather changes are characteristic of this section of the U. S.

In the winter the cold dry northwest continental polar air moving down from Canada follows in the rear of cyclonic storms resulting in extremely cold temperatures. After the passage of one of these systems the weather is usually clear east of the Appalachian, Adirondak and New England mountain barriers since the dry air sinks and warms. This northwest continental dry polar air also brings cooling spells in the summer.

The warmest weather in winter or summer is usually brought by southerly and southwesterly winds which bring warm moist air from the lower and warmer latitudes of the Gulf of Mexico. At times easterly winds from the waters of the Atlantic bring warm moist air to the eastern coastal region. The warmest weather in the summer is influenced by the mean positioning of the semi-permanent subtropical Atlantic (Bermuda) high with its clockwise circulation between latitudes 32° to 35° N. and longitudes 40° to 45° W. As the Bermuda high intensifies and extends westward, it tends to dominate the flow over the eastern section of the U. S. bringing warm moist tropical air inland. The resulting weather consists of scattered thundershowers, considerable daytime cloudiness and, at times, hot sultry conditions. Persistence of this high over the eastern U. S. frequently results in drought conditions as the dry subsiding air prevents the formation of precipitation. This high also exerts blocking actions on lows forcing them to travel across more northerly latitudes.

Occasionally, in the summer, cool maritime polar air flowing on shore from the North Atlantic will tend to suppress Atlantic coastal thunderstorm activity and bring a relief from the warm temperatures. In late summer and fall this coastal area is subjected to tropical storms or hurricanes moving north from the Caribbean Sea and southwestern Atlantic.

The damage by high tides is often severe whether the storm passes offshore or inland. Flooding caused by heavy rains is also associated with storms of a tropical origin.

In winter and spring the northeast cyclonic winds along the North Atlantic coast are damp and chilly. Increased wintry precipitation and strong winds and tides result from coastal storms or "Northeasters." Easterly winds associated with cyclonic storms along the east coast advect air from the mild waters tending to raise coastal winter temperatures and lowering coastal summer temperatures compared to inland stations. Persistent dense fog along this coastal region is present as warm air over the water is advected inland over the cold land surface. The higher relative humidities along the coast causes summer heat to be muggy and winter cold to be more raw and penetrating than inland. In the New England portion of the areas, summers are much cooler than in the more southerly areas.

Description of General Climate of the Central U. S. Gulf Coast

This region of interest consists of the Gulf Coastal area extending just east of the Mississippi Delta westward to Galveston, Texas.

The climate of this region is broadly determined by the huge land mass lying to the north, its subtropic latitude, the Atlantic (Bermuda) High, and its proximity to the Gulf of Mexico. The Gulf principally influences the predominant year-round maritime tropical climate for this region.

In winter, the area is subjected alternately to maritime tropical and polar continental air masses in periods of varying length. This region is usually south of the average track of winter cyclones but occasionally one will move this far south. Westerly systems make their influence felt as cold fronts from the northwest which at times push southward into the Gulf of Mexico. The cold air behind these fronts, though modified by the southern journey, brings sudden and occasionally large drops in the temperature. The Gulf of Mexico, with its relatively warm waters, introduces a retarding effect upon cold fronts. As the invading cold air mass pushes out over the Gulf it moves against a strong flow of maritime tropical air in the opposite direction causing the front to become quasi-stationary. At these times the Northern Gulf area becomes a favored region for cyclogenesis. A wave usually develops on the front in association with an eastward-moving upper air trough. The principal track of the associated low center parallels the Gulf Coast or moves inland producing persistent low stratus ceilings and rain in the Northern Gulf area. These conditions usually persist ahead of the low centers. The colder air masses in winter tend to gradually cool the sea surface temperatures offshore. This plays an important role in the formation of advection-radiation fogs in coastal areas from November-March and the formation of dense sea fog over the cold water surface. The low level direction of warm air above the surface near the coast determines where the fog will form. Snow seldom reaches this far south in winter. As spring arrives, these types of weather become less frequent.

By May the semi-permanent subtropic Atlantic (Bermuda) high becomes well developed. Westerly storm systems are too weak to penetrate the strong ridge of high pressure extending westward across the Gulf of Mexico. The season is also too early for easterly systems to influence the Gulf coastal weather. Occasionally tropical disturbances and easterly waves will appear in the Gulf of Mexico by early summer.

In summer the Bermuda high becomes very strong extending its anticyclonic influence over the Gulf. The prevailing southerly winds from the Gulf provide a rich source of moist tropical air which results in almost daily shower activity along the coast and nearshore waters of the northern Gulf. Air mass thundershower activity increases during the day with the greatest activity in the afternoon. Summer rainfall is generally associated with southerly winds. When westerly to northerly winds occur in summer, periods of hotter and drier weather interrupt the moist semi-tropical climate of this coastal region.

By August, easterly waves and tropical storms increase in the Gulf of Mexico and reach a peak in September. They begin to affect the weather in the Gulf with the principal paths of tropical storms into the Gulf coming from the straits of Florida and the Yucatan Channel. Over half of these tropical storms become hurricanes which bring their dèstructive force to both property and life along the coastal region.

By mid fall the semi-permanent subtropic Atlantic (Bermuda) high begins its migratory movement eastward in the Atlantic. By November westerly systems begin their influence upon the weather in the Gulf and adjacent coastal regions. Advection and frontal fog make their appearance. The maritime tropical climate along this coastal region affords mild winters, cool springs, pleasant summers and warm autumns.

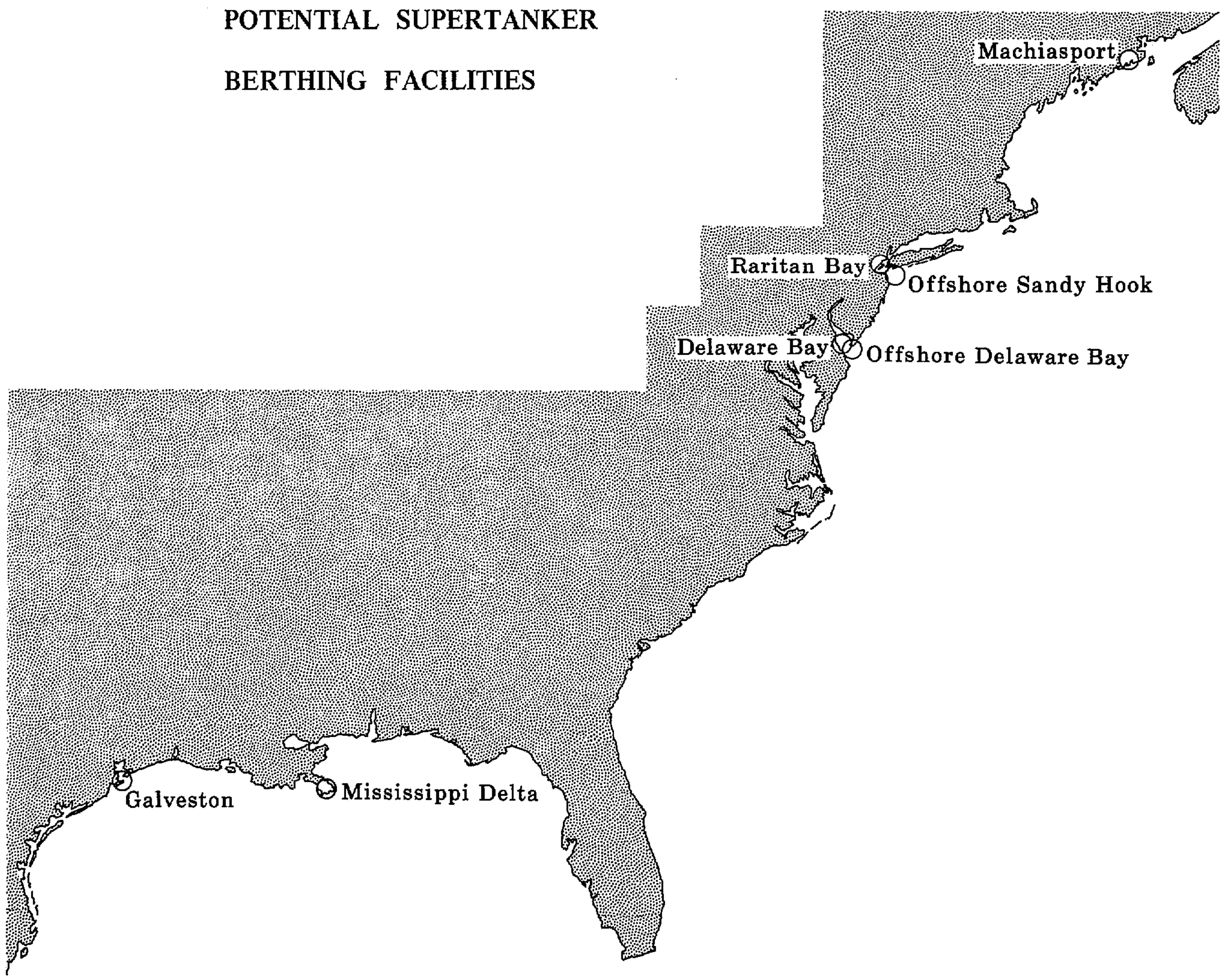


Fig. 1 Key map for supertanker port study areas.

Section Two

Area Summaries

MACHIASPORT, MAINE AREA

General Description

The coastline of the Machiasport area (see Fig. 2) is irregular, rocky, and bold with numerous islands, bays, rivers, and coves. The larger bays afford excellent harbors and anchorage in adverse weather. The many boulders, rocks, and ledges along and off the coast, in many cases rising abruptly from deep water, make navigation somewhat difficult. Wrecks have occurred on practically all of the offlying islands and rocks between Portland and Machias Bay, most of them during bad weather. Spring tides (tides of increased range which occur about every two weeks when the moon is new or full) range from 11 to 21 feet along the coast.

Numerous lights, both on the mainland and offshore islands, aid in navigation. Most of the principal light stations are equipped with radiobeacons and fog signals which are synchronized for distance finding. Many coastal and harbor buoys are equipped with radar reflectors which greatly increase the range at which the buoys may be detected on the radarscope. Radar is an important navigation aid in the area due to the extended periods of low visibility.

Machias Bay is the approach to Machias River and the towns of Machiasport and Machias. The bay is about six miles long and one to three miles wide, is easily entered day or night, and affords well-sheltered anchorage for large vessels. Libby Islands, lying in the middle of the two-mile-wide entrance, has a light tower 91

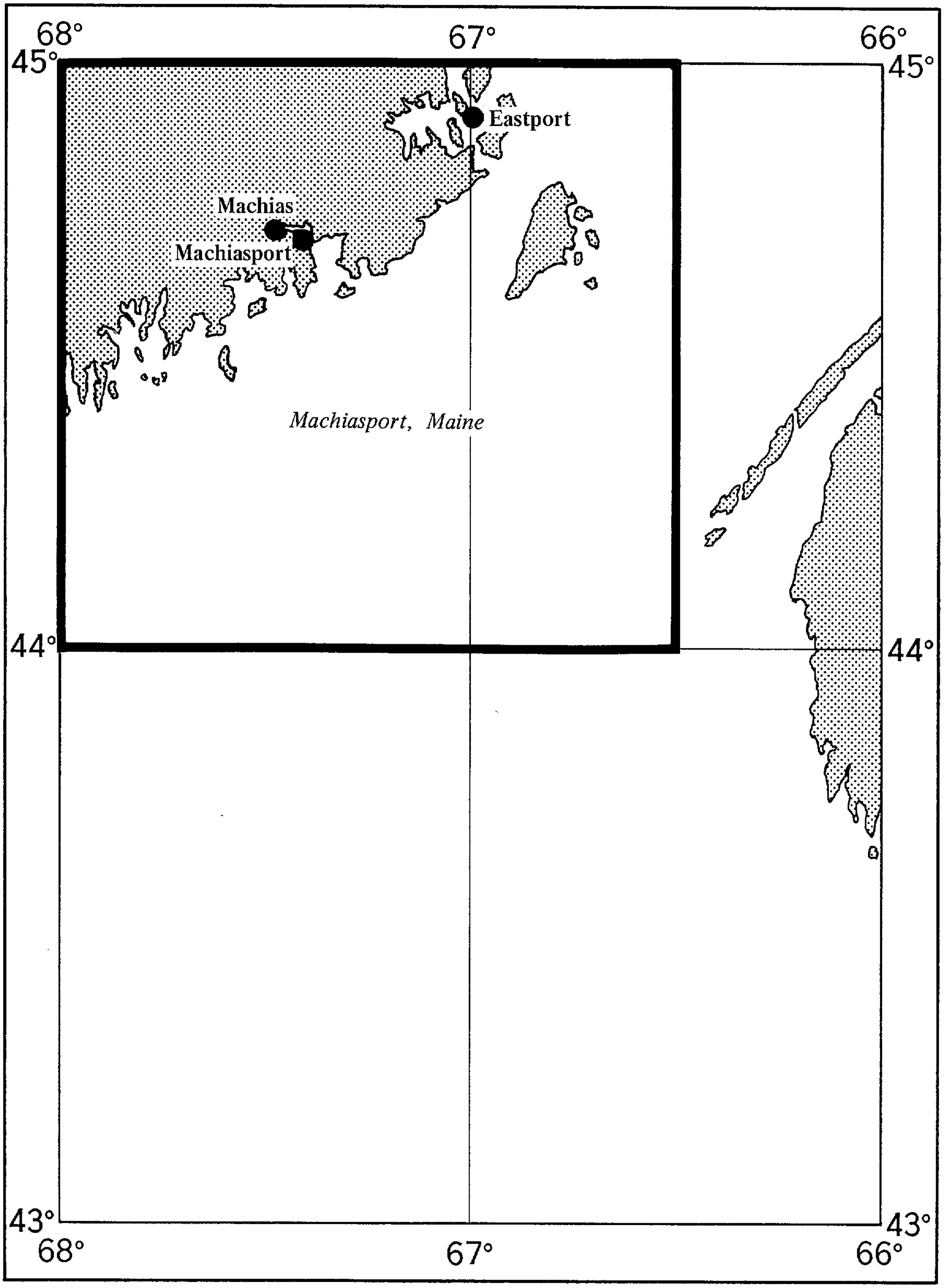


Fig. 2 Machiasport, Maine area map.

feet above the water and is the principal guide to the entrance of Machias Bay.

The extent to which the harbors of the area are closed to navigation by ice varies greatly in different years. During some winters most of the harbors are open while in others the only harbors available for anchorages are Quoddy Narrows, Eastport, Little River, and Machias Bay. Portland Harbor generally has an open channel in all winters.

THE ENVIRONMENT

The Machiasport area lies in the region of most frequent movement of cyclonic storms. The region is in the general zone of west to east motion on which are superimposed northward and southward movements of large air masses from tropical and polar regions. The Labrador Current flows southward along the Nova Scotia coast. Branching to bring cold water in to the Gulf of Maine, it exerts a moderating influence on the immediate coastal and near offshore regions. The following sections describe the climatology of the Machiasport area. They are intended to give the overall climatological picture of the entire area.

Pressure

In the winter, the area lies between the Icelandic low-pressure area and the moderate North American continental high-pressure area, resulting in prevailing west-to-north winds in the coastal regions. In spring and early summer, as the two pressure systems weaken, the Azores-Bermuda high intensifies and expands over most of the Atlantic Ocean. This extensive high pressure system shifts northward during the summer, with the center reaching 35° to 40° latitude near mid-ocean in August and September, causing southwesterly prevailing winds in the Machiasport area.

There are, however, great day-to-day variations in pressure, wind, and weather produced by migratory low- and high-pressure systems which tend to be more intense and to move faster in winter than in summer. Since the area includes some of the paths most frequently traveled by these pressure systems, deviations from the mean pressure may be large, with consequent changes in wind and weather.

The mean monthly atmospheric pressures, however, show small variation during the year, the normal level ranging from 1012 millibars in the late winter to 1017 millibars in the early fall season.

Extratropical Cyclones

As the Machiasport area lies along the paths most frequently followed by extratropical cyclones, the area experiences frequent wind shifts and rapid weather changes in the cooler seasons. These depressions generally enter the area from the west or from the southwest, the latter (Nor'easters) normally being of greater severity due to a considerable passage over water. Heavy rain or snow before the passage of the storm center may be extensive, and winds of hurricane force sometimes accompany then. After the storm center passes, the northwesterly winds, coming directly from the interior, are often bitterly cold.

The classical "Nor'easter" (Northeastern or Northeast storm) is so called because winds over the coastal area are from the northeast. They may occur at any time but are most frequent and violent between September and April. They usually develop in the area 30-40°N within about 100 miles of the coast and move north to northeastward, attaining maximum intensity near New England and the Maritime Provinces. They nearly always bring precipitation and frequently bring gale force winds to the coastal area.

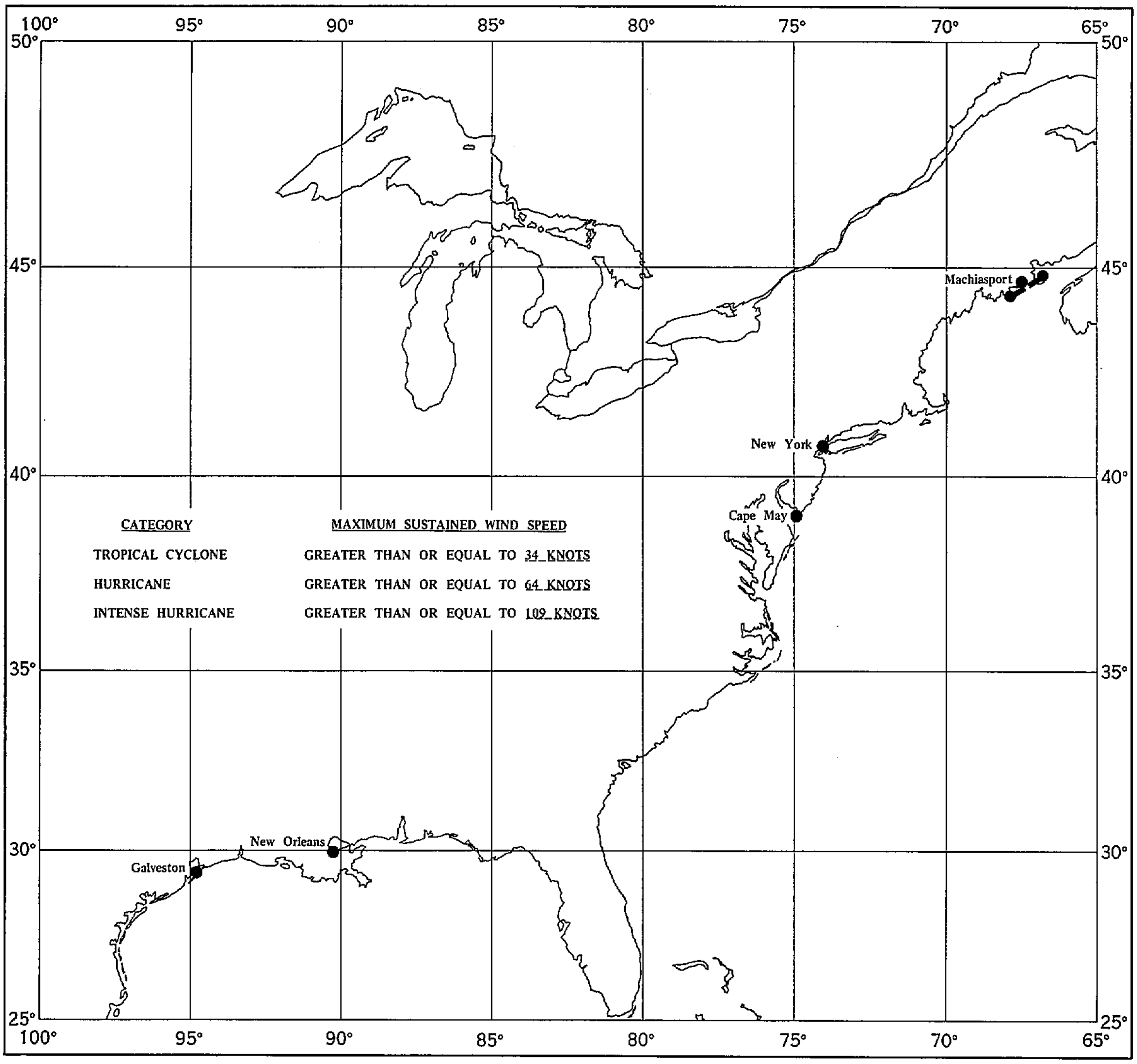
Table 2a compares "Nor'easters" to storms of the tropical variety. Appendix B contains mean tracks and movement roses of extratropical cyclones.

Tropical Cyclones

Tropical cyclones, although much rarer than the extratropical variety, occasionally move northward in late summer and autumn. Fig. 3 gives the rather low strike probabilities for the Machiasport Coastal Zone. The storm centers generally move through the region in a north-eastward direction and, as a rule, are much more violent than the extratropical storms of the same season. Tropical cyclones tend to take on some characteristics of extratropical cyclones before reaching the area, and are less intense than in more southerly latitudes. The table below reflects the frequency of tropical cyclones and hurricanes in the Machiasport study area

Table 2a Comparison of hurricanes and northeasters in northern New England.

Characteristics	Hurricanes	Northeasters
Climatology		
Origin	Tropics, always over water	Mostly Gulf of Mexico or South Atlantic regions, usually near coast
Season	August-October	October-April
Development	Reach greatest intensity south of New England and then diminish	Reach greatest intensity as they pass New England
Frequency	Average of 1 per 6 yr.	1-2 per yr. with surge $\geq$ 2.0 ft.
Track		
Direction	N to NE	N to E
Speed	Avg. 36 kt.; range 29-48	Avg. 22 kt.; range 6-43
Pressures		
Central pressure	Avg. 958 mb.; lowest 943 mb.	Avg. 983 mb.; lowest 957 mb.
Pressure pattern	Usually symmetrical	Usually asymmetrical
Average storm diameter	Small (400-600 n. mi.)	Large (600-1500 n. mi.)
Winds		
Maximum speeds	80-100 kt. not uncommon	70 kt. is rare
Radius of maximum winds	22-66 n. mi., well-defined	90-340 n. mi., not well-defined, sometimes more than one
Fetch lengths	Short	Long, 300-1400 n. mi.
Surge		
Surge heights	3.7 ft. highest observed	Up to 5.1 ft. observed
Duration of high surge and strong wind	6-12 hr.	12 hr. to 3 days
Inverted barometer effect	May give important contribution to surge	Relatively unimportant contribution to surge
Topographical considerations	Cape Cod protects northern New England to some extent	Little protection afforded by Cape Cod



AREA Machiasport

	PROBABILITY (%) OF OCCURRENCE IN ANY ONE YEAR	AVERAGE NUMBER OF YEARS BETWEEN OCCURRENCES	TOTAL NUMBER OF OCCURRENCES 1886-1970
TROPICAL CYCLONE	13%	7	11
HURRICANE	5%	21	4
INTENSE HURRICANE	<1%	–	–

Fig. 3 Tropical cyclone strike zone and probabilities for the Machiasport area.

(as distinguished from the coastal zone analysis present in Fig. 3).

	Total Number 1886 - 1971	Average Number of Years between Occurrences
Tropical Cyclones	9	10
Hurricanes	4	21

Of the total number of tropical cyclones (9) for the total period of record, there were 4 which reached hurricane intensity.

Appendix A contains detailed information on tropical cyclones.

Winds

The prevailing westerly winds have a northerly component from November to March, with a southerly component from April to October. Along the coast the general features of wind direction are similar to those over the water area except when modified by local topography. The windiest period coincides with the time prevailing winds have a northerly component. The highest frequency of gales (winds greater than or equal to 34 knots) also occurs during this time. Wind speeds over the open ocean areas approaching Machiasport are nearly always greater than the winds in harbor. Consequently, there may be twice the number of gales at sea. Hot summer afternoons are frequently relieved by a refreshing wind blowing onshore from the cooler water. The effect of this sea breeze, however, seldom penetrates more than a few miles inland.

Extreme Winds

As sufficient wind observations are unavailable for the region, both in time and space, the return values of maximum sustained winds given in the table below are based primarily on statistical methods by Thom (30).

Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Maximum Sustained Wind	67 kt	74 kt	85 kt	96 kt

For example, on the average, there will be a maximum sustained wind speed of 85 knots in the Machiasport area once in every 25 years.

Waves

The distribution of high waves is roughly the same as that for the windiest period, as expected. Late Fall to early Spring are the seasons of maximum occurrence. There is a marked decrease in the average wave heights from April to September.

The area has frequencies of high waves (greater than or equal to 12 ft) of over eight percent in March and November. There are some occurrences of waves greater than 20 feet for the same months. As with the winds, because there are insufficient observations for a climatological conclusion of significant wave heights, the table below primarily reflects the statistical method.

Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Max. Significant Wave Ht.	29 ft	35 ft	40 ft	44 ft
Extreme Wave Height	52 ft	63 ft	72 ft	80 ft

Visibility

Poor visibility may be produced by fog, haze, rain, and snow. Advection sea fog is the type most common along the coastal area. It occurs when warm humid air is cooled in passing over the cold ocean, usually during warmer months when the winds are from the south or southwest. This may, however, happen in any season. These fogs often set in almost without warning, and have been known to persist for three weeks with little interruption.

The areas along the coast, at the heads of bays and within the rivers, are often comparatively clear while fog is very thick outside. Most land fog occurs in winter, and most sea fog occurs in summer. Steam fog (sea smoke), sometimes encountered in winter, forms in very cold weather when the air temperature is much lower than that of the water. Fog is more likely to form with light to moderate winds, as confirmed when comparing the percent frequency of fog with the mean winds in Table 3. The maximum number of days with fog occurs in July, the month having the lowest mean wind speed. The percentage frequency of reduced visibility also reaches a maximum during the summer months. With the onset of the stronger northwesterly winds, visibility improves.

Temperature

Summer temperatures in the Machiasport area are generally comfortably cool, with afternoon maxima occasionally in the low 70's. Days with readings of 90°F or more are rare. The June through August summer mean temperature average is about 55°F.

Winters average about 33°F in the Bay area. Days with 0°F or lower have varied from four to 33 in a winter. Minima of 0°F or lower seldom persist for more than a few days.

In all seasons, changes in wind direction can cause large temperature fluctuations. In winter, southerly and southwesterly winds may bring mild weather, while northwesterly winds may be bitterly cold. In summer, warm weather occurs with southwesterly and westerly winds, and northeast winds may be cool and sometimes chilly.

Temperatures at sea average about 4 to 8°F warmer in January, and 2 to 8°F cooler in July than along the coast.

Precipitation

Precipitation is relatively abundant and dependable throughout the year. Summer totals are somewhat less than in winter. Much summertime rain is from brief showers and thunderstorms, the latter being somewhat infrequent and occurring on the average of less than 20 per year, mainly during the summer season. Over the sea their frequency and severity decrease.

Seasonal snowfall is subject to wide variations from the average, with 27 inches in 1952-3 to 132 inches in 1955-6 in Machias. Generally, the season for frozen precipitation runs from October through May, with the maximum occurring in February.

Cloudiness

Overcast conditions of 0.8 to 1.0 sky cover at the coastal stations range from about 55 to 60 percent in winter and from 30 to 40 percent in summer. Total cloud amounts measured at the coastal stations are fairly consistent with the sky cover at sea. In winter the amount will tend to become progressively greater downwind with winds between west and north.

Summer brings a decrease in cloudiness while sky obscuration increases considerably. This occurs as the result of the combination of weaker winds and greater number of days with fog. This is also reflected in the percentage frequency increase in reduced visibility.

Relative Humidity

Relative humidity is high throughout the year, and seasonal variations are small. Humidity is generally lower with winds from the continent and higher with southerly and easterly winds from the ocean. Therefore, maximum humidities are observed during the summer months.

Tides and Currents

At Machiasport, Maine the spring tidal range is 14.4 feet; the mean range is 12.6 feet. The mean tide level is 6.3 feet.

Currents are rather swift in the area and are summarized as follows:

LOCATION	MAXIMUM CURRENTS			
	FLOOD		EBB	
	Dir. (deg)	Speed (kts)	Dir. (deg)	Speed (kts)
Bay of Fundy Entrance 44°45'N 66°56;W	030	2.3	210	2.4

LOCATION	MAXIMUM CURRENTS FLOOD Dir. (deg)	Speed (kts)	EBB Dir. (deg)	Speed (kts)
5 miles W of Brier Island 44°13'N 66°30'W	005	2.7	185	2.5
5 miles SE of Gannet Rock 44°29'N 66°41'W	040	2.6	230	3.9
7.6 miles SSE of Pond Point 44°20'N 67°30'W	015	0.5	215	1.2
Moosabec Reach (East) 44°32'N 67°34'W	110	1.0	260	1.0

The greatest storm surges in the Machiasport area result from the offshore passage of extratropical cyclones. Surges over five feet above mean high water have been experienced.

STATION: MACHIAS, MAINE
POSITION: 44.7N 67.5W
ELEVATION: 40 FEET

MEANS AND EXTREMES FOR PERIOD 1940-1970

Month	Temperature (°F) Means: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	** Mean degree days	Precipitation Totals (Inches): Mean	Greatest daily	Year	Snow, Sleet: Mean	Maximum monthly	Year	Greatest daily	Year	Mean number of days: Precip. .10 inch or more	Temperatures Max.: 90° and above	32° and below	Min.: 32° and below	0° and below	Month
(a)	19	19	19	19		19		19	30	30		19	19		19		30	19	19	19	19	
JAN.	31.0	10.8	20.9	51	1953	-26	1961+	1360	4.21	2.49	1958	20.9	44.7	1952	15.5	1956	8	0	15	30	7	JAN.
FEB.	32.3	11.1	21.7	50	1966+	-26	1961	1226	4.19	3.73	1951	19.6	40.0	1967	13.5	1955	7	0	13	27	7	FEB.
MAR.	39.1	21.2	30.3	64	1953	-12	1956	1068	3.68	2.26	1941	13.4	42.4	1956	8.0	1967+	7	0	5	28	1	MAR.
APR.	50.3	30.9	40.6	80	1957	7	1969	725	3.81	2.77	1954	2.2	9.7	1958	6.7	1957	8	0	*	18	0	APR.
MAY	61.3	39.5	50.4	88	1959	23	1966	446	4.08	3.40	1961	.2	2.4	1963	2.4	1963	8	0	0	5	0	MAY
JUNE	69.3	48.4	58.9	89	1963+	32	1953	185	3.36	5.02	1942	0	0		0		6	0	0	*	0	JUNE
JULY	73.9	54.1	64.0	93	1968+	37	1965+	60	3.33	4.14	1948	0	0		0		6	*	0	0	0	JULY
AUG.	72.8	53.1	63.0	87	1961	34	1965	92	3.13	3.06	1951	0	0		0		6	0	0	0	0	AUG.
SEP.	65.6	46.4	56.0	89	1969	25	1965	270	4.01	4.02	1940	0	0		0		6	0	0	2	0	SEP.
OCT.	57.2	38.1	47.7	83	1963	18	1966	535	4.08	2.98	1952	.3	2.0	1969+	2.0	1965	7	0	0	9	0	OCT.
NOV.	46.3	29.6	38.0	70	1956	5	1951	803	6.06	2.68	1958	2.2	11.3	1962	6.0	1962	9	0	1	20	0	NOV.
DEC.	34.6	16.6	25.6	57	1962	-24	1951	1214	4.91	4.15	1950	16.6	43.5	1964	15.0	1964	8	0	13	28	3	DEC.
Year	52.8	33.3	43.1	93	July 1968+	-26	Feb. 1961+	7984	48.85	5.02	June 1942	75.4	44.7	Jan. 1952	15.5	Jan. 1956	86	*	47	167	18	Year

(a) Average length of record, years.

T Trace, an amount too small to measure.

** Base 65°F

\+ Also on earlier dates, months, or years.

* Less than one half.

Table 1 Land station climatological data summary for MACHIAS, MAINE.

STATION: EASTPORT, MAINE
POSITION: 44.9N 67.0W
ELEVATION: 80 FEET

MEANS AND EXTREMES FOR PERIOD OF RECORD 1931-1960**

Month	Temperature (°F) Means: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Record lowest	Mean degree days	Precipitation Totals (Inches): Mean	Greatest daily	Snow, Sleet, Hail: Mean	Maximum monthly	Greatest daily	Mean number of days: Precipitation .10 inch or more	Temperatures Max.: 90° and above	32° and below	Min.: 32° and below	0° and below	Sunrise to Sunset: Clear	Partly Cloudy	Cloudy	Thunderstorms	Heavy Fog	Relative Humidity: 7:30 AM EST	1:30 PM EST	7:30 PM EST	Pct. of poss. sunshine	Avg. Sky Cover (tenths) Sunrise to Sunset	Month
(a)	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	71	71	71	30	67	65	34	65	59	63	
Jan	30.6	15.1	22.9	58	-16	1303	4.11	2.47	18.0	53.7	16.8	8	0	16	29	3	8	8	15	*	2	74	72	71	45	5.6	Jan
Feb	31.0	15.9	23.5	54	-22	1172	3.44	1.91	18.0	41.8	17.7	7	0	15	27	2	8	7	13	*	2	74	70	71	50	6.2	Feb
Mar	37.4	24.2	30.8	76	-10	1057	3.68	1.93	12.7	25.7	10.7	7	0	8	26	*	8	9	14	*	3	75	69	73	52	6.3	Mar
Apr	47.0	33.2	40.1	81	10	742	3.50	2.21	4.4	27.9	18.5	7	0	*	13	0	7	9	14	1	4	77	71	77	51	6.5	Apr
May	56.8	40.6	48.7	90	24	503	3.09	2.94	T	0.4	0.4	7	*	0	1	0	7	11	13	1	6	79	71	78	52	6.6	May
Jun	64.4	47.2	55.8	92	36	279	3.55	2.65	0	0	0	7	*	0	0	0	6	12	12	3	8	82	75	81	54	6.6	Jun
Jul	70.5	52.4	61.5	89	44	123	3.07	2.63	0	0	0	6	0	0	0	0	7	13	11	4	12	85	77	83	56	6.2	Jul
Aug	70.4	53.4	61.9	93	42	112	2.86	4.20	0	0	0	5	*	0	0	0	9	11	11	3	10	85	76	83	57	6.0	Aug
Sep	64.0	49.3	56.7	92	33	253	3.53	3.66	0	0	0	6	*	0	0	0	9	9	12	1	6	84	75	81	55	6.0	Sep
Oct	55.2	42.0	48.6	80	22	508	3.62	2.89	0.1	1.6	1.5	6	0	0	3	0	8	9	14	1	4	81	72	79	50	6.2	Oct
Nov	45.2	32.8	39.0	71	4	776	4.48	3.69	3.0	14.8	9.0	8	0	2	14	0	5	8	17	*	2	80	75	76	38	7.2	Nov
Dec	34.0	19.5	26.8	60	-23	1182	3.74	3.15	10.7	35.2	12.0	8	0	12	27	2	7	8	16	*	1	77	73	75	40	6.9	Dec
Year	50.5	35.5	43.0	93 Aug. 1949	-23 Dec. 1933	8010	42.67	4.20 Aug. 1943	66.9	53.7 Jan. 1952	18.5 Apr. 1946	82	*	53	140	7	89	114	162	14	60	79	73	77	51	6.4	Year

(a) Average length of record, years.

T Trace, an amount too small to measure.

\+ Also on later dates, months or years.

* Less than one half.

** See Station History

Table 2 Land station climatological data summary for EASTPORT, MAINE.

ENVIRONMENTAL DATA SUMMARY (PART 1)

AREA: Machiasport, Maine

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WIND SPEED (KNOTS)													
01% ≤	3	4	3	3	2	1	2	3	2	3	4	3	3
Mean	21.3	19.9	17.9	14.7	13.5	11.3	9.8	10.8	11.7	15.0	18.4	21.9	15.5
99% ≤	46	47	45	40	34	30	29	31	32	39	47	47	40
Maximum observed (1871 - 1971)	Extreme winds of over 100 knots are known to have occurred during Northeasters.												
≥ 34 Knots (% freq.)	12.4	10.0	8.9	3.6	2.2	0.3	0.4	0.3	0.6	3.9	8.6	15.3	5.5
≥ 41 Knots (% freq.)	2.8	2.7	1.3	1.0	0.3	0.0	0.0	0.0	0.0	0.1	1.1	2.4	1.0
Prevailing direction	NW	NW	NW	SW	SW	SW	SW	SW	SW	SW	NW	NW	SW
WAVES (FEET)													
01% ≤	1	0	1	0	0	0	0	0	0	0	0	0	<¼
Mean	5	5	4	3	3	2	2	2	2	3	4	5	3
99% ≤	17	18	13	10	10	9	8	8	10	10	14	18	12
≥ 12 Feet (% freq.)	4.0	1.4	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1	2.1	2.2
≥ 20 Feet (% freq.)	+	+	+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+	+	+
VISIBILITY (% FREQ.)													
Visibility <½ N. mile	2.9	2.3	5.9	6.5	9.4	14.4	27.8	22.2	10.4	7.3	4.1	6.4	10.0
Visibility <1 N. mile	4.2	3.6	8.7	7.7	10.2	17.5	32.3	25.9	12.6	8.7	5.3	8.6	12.2
Visibility <2 N. miles	6.9	7.5	12.7	11.2	13.2	22.8	38.3	31.7	15.7	13.4	7.9	14.0	16.4
Visibility <5 N. miles	18.6	18.5	19.1	17.4	21.6	33.9	49.4	44.1	23.3	19.7	15.8	25.4	25.7
Visibility <10 N. miles	44.4	39.1	39.6	41.6	39.7	56.0	67.7	60.7	40.6	45.9	41.0	51.8	47.5

+ = less than 0.05%

Table. 3 Environmental data summary; Machiasport, Maine area.

ENVIRONMENTAL DATA SUMMARY (PART 2)

AREA: Machiasport, Maine

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
FOG													
Occurrence of fog (% freq.)	3.5	0.8	5.8	9.3	13.8	25.2	38.7	34.7	14.9	10.4	6.3	4.7	14.0
Mean number of hours operation of fog signals *	105	84	87	91	135	196	290	271	140	94	72	85	1650
Maximum number of hours operation of fog signals for any year (annual only)*													2364
WEATHER & CLOUDS (% FREQ.)													
Precipitation	13.6	16.2	14.2	10.6	11.3	8.4	5.8	6.8	8.7	9.4	13.9	22.4	11.8
Freezing precipitation	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1
Frozen precipitation	10.1	13.4	8.8	3.4	0.2	0.0	0.0	0.0	0.0	0.3	3.0	14.3	4.4
Thunder & lightning	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.2	0.2	0.0	0.0	0.0	0.1
Sky ≤2/8	24.3	24.5	30.1	33.9	30.4	28.2	34.7	38.4	42.7	30.8	13.8	18.3	29.2
Sky overcast (8/8)	34.0	29.8	26.8	20.0	17.3	14.7	12.5	13.4	14.0	18.9	31.2	35.0	22.3
Sky obscured	2.8	3.4	5.8	7.5	9.5	11.2	17.9	17.4	8.5	5.8	4.3	5.6	8.3
Low cloud overcast	23.3	22.2	19.4	16.5	13.7	12.5	10.2	10.2	12.1	15.9	22.6	26.9	17.1
Mean cloud cover (eighths)	5.4	5.1	4.9	4.6	4.7	4.7	4.3	4.1	4.0	4.6	5.8	5.8	4.8
AIR TEMPERATURE (°F)													
Minimum	-5	-2	14	21	33	42	46	47	44	32	12	0	-5
01% ≤	5	2	16	26	36	43	48	50	46	34	25	8	28
Mean	28.2	27.4	33.7	39.0	45.4	51.7	56.6	58.0	55.2	49.7	41.9	31.8	43.7
99% ≤	44	44	46	50	57	63	68	72	66	60	55	50	56
Maximum	59	47	57	63	64	73	78	84	70	84	60	55	84
≤ 32 °F (% freq.)	64.6	50.3	38.0	7.1	0.0	0.0	0.0	0.0	0.0	0.0	9.1	56.3	18.8
≥ 85 °F (% freq.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* Libby Islands fog signal

Table 3 Continued.

ENVIRONMENTAL DATA SUMMARY (PART 3)

AREA: Machiasport, Maine

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
RELATIVE HUMIDITY (%)													
Mean	79	78	78	80	84	87	89	89	83	79	77	79	82
SEA TEMPERATURE (°F)													
Minimum	27	27	27	31	32	37	39	44	42	34	36	32	27
01% ≤	30	29	31	32	35	39	43	45	46	44	41	35	38
Mean	39.8	37.0	36.2	37.6	42.1	46.5	50.5	53.1	52.0	50.2	47.7	43.3	44.6
99% ≤	50	50	48	52	57	66	71	74	70	65	58	54	60
Maximum	56	54	52	56	62	76	76	84	76	76	64	60	84
SALINITY (‰)													
Minimum	28.9	28.9	29.1	28.9	29.1	29.0	30.6	31.1	31.1	31.4	30.6	29.4	28.9
Mean	32.1	32.0	31.9	31.5	31.4	31.6	32.0	32.3	32.5	32.5	32.4	32.1	32.0
Maximum	33.5	33.5	33.2	32.7	33.1	32.9	33.6	33.7	34.4	34.0	34.1	33.7	34.4
DENSITY (ρ)													
Mean (σ_t)*	23.8	23.7	23.7	23.3	23.2	23.5	23.8	24.0	24.1	24.2	24.0	23.8	23.8
SEA-LEVEL PRESSURE (mb)													
Minimum	975	976	967	980	992	995	994	996	988	973	976	978	967
01% ≤	980	981	984	988	996	1000	1001	1000	997	989	985	985	991
Mean	1013	1012	1013	1015	1015	1014	1015	1014	1017	1017	1015	1014	1014
99% ≤	1038	1042	1036	1035	1032	1028	1026	1027	1031	1033	1037	1033	1033
Maximum	1041	1044	1045	1040	1043	1031	1028	1034	1035	1038	1039	1041	1045

* $\sigma_t = (\rho - 1) \times 10^3$; ρ = gm cm^{-3}

Table 3 Continued

General Description

The coastal regions of the New York area (see Fig. 4) are generally flat and sandy, having very low elevation above mean sea level. The area presents problems of unusual difficulty to the mariner due to the offlying shoals, strong and variable currents, large amounts of fog, and turbulence of wind and sea in the great storms that so frequently sweep it. A great volume of waterborne commerce also moves through the area to and from the Port of New York.

The approach to New York and Raritan Bays from sea is generally along the south coast of Long Island or the east coast of New Jersey. Ambrose Channel Light, equipped with a fog signal and a radio beacon, marks the entrance to Ambrose Channel, the principal deep water passage extending from the sea to the deep water of Lower New York Bay.

Sandy Hook Light, the oldest light in continuous use in the United States (established in 1764), marks a secondary, southerly route from the sea to Lower Bay and to Raritan Bay. Raritan Bay, with depths of seven to 18 feet, is full of shoals and has a mean tidal range of about 5 feet. Sandy Hook Bay, the southern part of Lower Bay, affords excellent anchorage as the shoaling is gradual, the bottom is good holding ground, and the depths of water range from 15 to 30 feet. The mean tidal range is 4.6 feet.

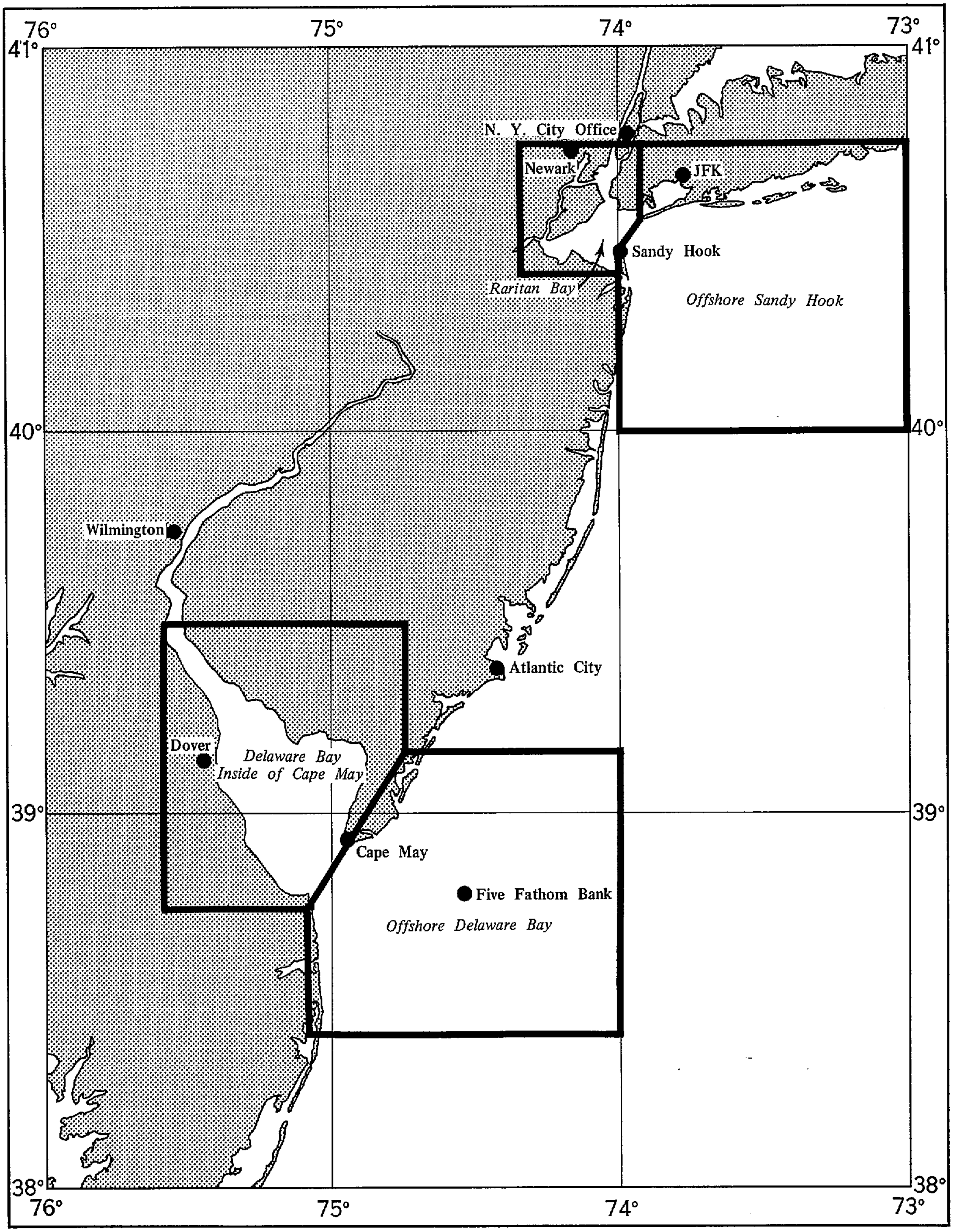


Fig. 4 New York and Delaware Bay area map.

Only during extremely severe winters will the main channels be restricted by ice, and then only for short periods of time.

Near the outer extremities of Sandy Hook, at the western end of the Ambrose Channel entrance, the flood current attains a velocity of about 2 knots. The ebb tide in Lower Bay is generally stronger than the flood by 10% or more. At the seaward end of Ambrose Channel the velocity of the flood current is 1.7 knots and the ebb current is 2.3 knots.

The important currents affecting navigation in the approach to the New York and Raritan Bays are those due to winds. The largest current velocity likely to occur under storm conditions is 1.5 knots. A sudden reversal in the direction of the wind produces a corresponding change in the current, either diminishing or augmenting the velocity.

Offshore and away from the influence of the tidal flow into and out of the larger bays, the tidal current maintains an approximately uniform velocity, generally less than 0.3 knots. Shifting its direction continuously to the right, it sets all directions of the compass during each tidal cycle of 12.4 hours.

THE ENVIRONMENT

The New York area lies in the "prevailing westerly belt" of the middle latitudes on the east coast or leeward side of the continent. The daily weather, which makes up the climatic pattern, moves generally from west to east; consequently, the region is influenced more by land mass to the west than by the ocean to the east. The proximity of the ocean, nevertheless, influences the winds, temperature, and precipitation enough to modify the typical continental regime. Therefore, the climate on all but the outlying islands can best be described as modified continental.

Superimposed on the general westerly circulation are the frequent wind shifts and changes in weather associated with extratropical cyclones. In the winter, the area lies within the heart of the belt traversed by these storms. As a result, changes of wind, temperature, and clouds are frequently abrupt and conditions are generally variable. In summer and fall tropical cyclones can bring stormy weather, although most of these storms assume extratropical characteristics by the time they reach the northern latitudes.

A principal area of storm formation is off the Middle Atlantic coast. Extratropical storms spawned in this area during the cooler months generally move northward or northeastward toward New England and New York. These coastal storms may, on occasion, produce strong winds and heavy precipitation.

The cold Labrador Current which flows parallel to the coastline, and the warm Gulf stream farther eastward, exert considerable influence on the climate. The cooling of warm moist air brought northward by the prevailing southwesterlies during the warm months causes fog which reaches the approaches to New York.

From November through April prevailing winds are from the NW; for the remainder of the year, SW. Gales with wind velocities of

34 knots or more are predominately from the NW. There are also many from the NE.

Pressure

During the winter, the New York area is sandwiched between the Icelandic Low and the North American Continental High, which results in a pressure pattern producing the prevailing northwesterly winds in the colder months. As the two pressure systems weaken in the spring, the Bermuda High intensifies; and by summer, it covers the Northeastern States, producing the prevailing southwest winds of the warmer months. There is little seasonal variation in the mean pressure, which ranges from a high of about 1019 millibars in late fall and early winter to a low of about 1014 millibars in late spring. There are, however, great day-to-day variations in these means, primarily due to the numerous cyclones and anticyclones that traverse the area. Daily variations are much greater in winter than in summer. Occasionally, large variations are experienced when a tropical cyclone passes through in late summer or fall.

Extratropical Cyclones

In winter, the center of the mean tracks followed by extratropical cyclones traverses the New York area. Consequently, there are frequent shifts from the prevailing westerlies and rapid changes in weather. Usually the cyclones enter the area from the west, passing through the northeastern states, or they move from the southwest with the center offshore.

The coastal storms which move northeastward (Nor'easters) are likely to be of greater severity from having passed over considerable water. Before the storm center passes, it may bring heavy rain or snow. Strong winds, sometimes of hurricane force, accompany it. The northwesterly winds in the western half of the storm, having come directly from the interior of the cold continent, will often be bitterly cold.

The Machiasport narrative contains a detailed description of "Nor'easters." Appendix B contains extratropical cyclone tracks and movement roses.

Tropical Cyclones

Tropical cyclones occasionally move northward into the area in late summer or autumn. The storm centers generally move through the region on northeastward courses toward Nova Scotia or over the adjacent ocean. Some severe hurricanes have moved northward across Long Island, with reported wind speeds of 70 to 80 knots. As a rule, these tropical storms are much more violent than the extratropical storms of the same season. Many of them take on some extratropical characteristics prior to reaching the area and are less intense than in more southerly latitudes.

The table below reflects the frequency of tropical cyclones and hurricanes for the New York area.

	Total Number 1886 - 1971	Average Number of Years between Occurrences
Tropical Cyclones	11	8
Hurricanes	4	21

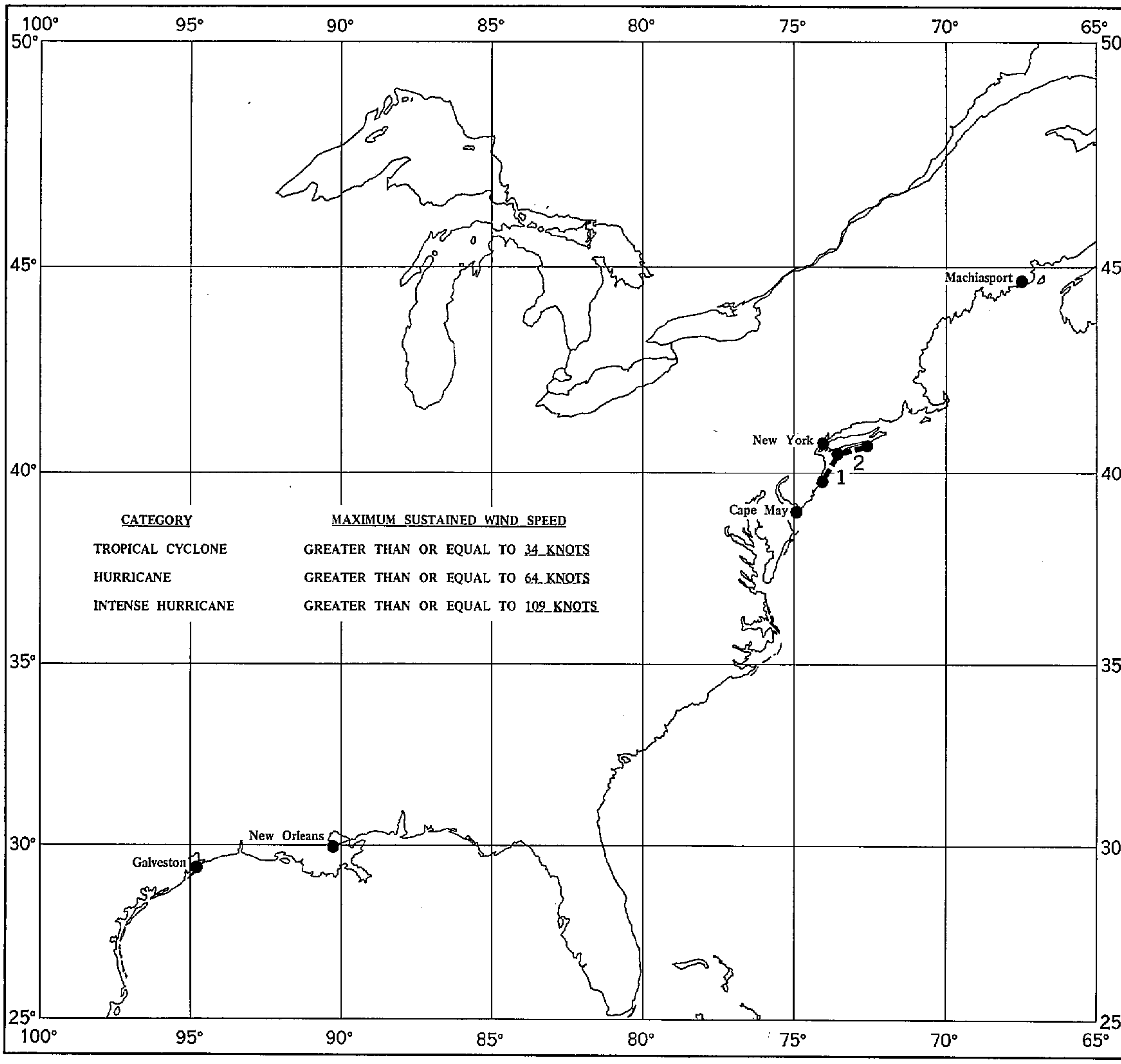
Of the total number of tropical cyclones (11) for the total period of record, there were 4 which were of hurricane intensity. Appendix A contains detailed information of tropical cyclones for the study area. A summary of tropical cyclones for the two New York strike zones is presented in Figure 5.

Winds

From October to March, the prevailing winds over the New York area are between west and north. After March until the summer regime is established, the wind is variable. From June through September the prevailing winds are southerly. Winds are stronger from November through March; and in the warmer months, May through August, the winds are the weakest. However, the summertime prevailing southerlies are more persistent than the wintertime northwesterlies, because of the lack of extratropical cyclone acitivity during the warmer months. The summer period, at times, is disturbed by tropical cyclones and severe thunderstorms.

In general, the wind regime in the Raritan Bay area is similar to that east of Sandy Hook. The average wind speeds in Raritan Bay are generally less, owing to the increased friction caused by the surrounding land mass.

At the coastal stations, the hot summer afternoons often are relieved by a refreshing sea breeze blowing onshore from the cooler waters adjacent to the coast. This breeze seldom penetrates more than 10 miles inland.



AREA New York Zone 1

	PROBABILITY (%) OF OCCURRENCE IN ANY ONE YEAR	AVERAGE NUMBER OF YEARS BETWEEN OCCURRENCES	TOTAL NUMBER OF OCCURRENCES 1886-1970
TROPICAL CYCLONE	1%	85	1
HURRICANE	1%	85	1
INTENSE HURRICANE	<1%	–	–

AREA New York Zone 2

	PROBABILITY (%) OF OCCURRENCE IN ANY ONE YEAR	AVERAGE NUMBER OF YEARS BETWEEN OCCURRENCES	TOTAL NUMBER OF OCCURRENCES 1886-1970
TROPICAL CYCLONE	11%	9	9
HURRICANE	6%	17	5
INTENSE HURRICANE	<1%	–	–

Fig. 5 Tropical cyclone strike zones and probabilities for the New York area.

Gales (greater than or equal to 34 knots) are encountered in about 2 to 4 percent of the observations during winter. They are more frequent with westerly or northwesterly winds. Gales are rare in summer, but may be encountered in tropical cyclones or in thunderstorms.

Extreme Winds

As there are insufficient wind observations for the area, both in time and space, the return values of maximum sustained winds, given in the table below, are estimated with the aid of statistical methods.

OFF SANDY HOOK

Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Maximum Sustained Wind	74 kts	81 kts	90 kts	99 kts

RARITAN BAY

Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Maximum Sustained Wind	69 kts	76 kts	85 kts	92 kts

For example, on the average, there will be a maximum sustained wind speed of 81 knots east of Sandy Hook once in every 10 years.

Waves

Distribution of high waves is roughly the same as that for the windiest period. September to March are the months of maximum occurrence. The maximum frequency of waves equal to or greater than 12 feet also occurs during these months. However, Raritan Bay, sandwiched between New Jersey and New York, has significantly fewer waves of such height. Heights greater than 20 feet are rarely observed in the Bay, while occurrences are more common off the coast of Sandy Hook.

As with the winds, because there are insufficient observations for a climatological conclusion of a significant wave height, the tables below primarily reflect a statistical estimate.

OFF SANDY HOOK

Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Max. Significant Wave Ht.	37 ft	41 ft	47 ft	53 ft
Extreme Wave Height	67 ft	74 ft	85 ft	96 ft

RARITAN BAY

Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Max Significant Wave Ht.	11 ft	14 ft	17 ft	19 ft
Extreme Wave Height	20 ft	25 ft	30 ft	35 ft

Visibility

Although fog, haze, rain, and snow are all causes of poor visibility, in the New York area, visibility at sea and in the Bay area is most commonly restricted by advection fog. This type of fog occurs most frequently in late spring and early summer when the winds are from south to southwest and the warm humid air is cooled to its dewpoint by the cold Labrador Current. During the summer months there is an increase in observations reporting restricted visibility. This frequency increases on approaching the Bay area. A partial explanation is the decrease in winds as the Bay area is approached and the resulting enhancement of conditions conducive to the development of fog.

Steam fog occasionally forms during very cold weather when the air temperature is much lower than that of the water. However, it is usually quite shallow.

Temperature

The maritime influence affects temperatures. In spring and summer the sea breeze tends to reduce temperatures, but in winter, when the water temperatures are warmer than those of land, the opposite occurs. In any season, a change in wind direction can cause a large fluctuation in temperature. In winter, southerly and southwesterly winds may bring in mild weather, while northwesterly winds bring in extreme cold. In summertime, southwesterly and westerly winds will be warming, but northeast winds may be cooling and sometimes chilly.

Readings in the coastal area rarely exceed 100°F and the 90°F level is reached on only 1/3 to 1/2 of the days during the summer. Air temperatures off Sandy Hook are warmer than over Raritan Bay during the winter months because of warmer sea temperatures and less continental effect.

Precipitation

Precipitation over the coastal sections is moderately heavy. Normal monthly totals vary from minima of 2.5 to 3.0 inches in February or October to maxima of 4.5 to 6.0 inches in August. Annual totals range from 41 to 45 inches.

Showers and thunderstorms, which provide most of the rainfall from May through September, are localized and tend to be "spotty." Thunderstorms come most frequently in the late afternoon and evening and usually are brief. However, rainfall from thunderstorms can be very intense and may seriously restrict visibility at sea. Thunderstorms occur in the New York area on an average of 30 days per year, mostly during June, July, and August. Their frequency and severity decrease over the ocean, as does the annual percent frequency of total precipitation.

Cloudiness

At sea in winter, overcast skies and clear skies (cloud amount less than or equal to 2/8) are each recorded on about 35 percent of the observations. The summer conditions are a little better, with about 26 percent of the observations showing overcast and 37 percent clear skies. Over Raritan Bay, overcast conditions range from about 36 to 44 percent in winter and about 30 percent in summer.

Relative Humidity

In the New York area throughout the year, relative humidity is rather high with annual early morning averages from 70 to 80 percent, and evening averages from 60 to 80 percent. There is some seasonal variation, with highest readings during the summer months. Humidity variations, like temperature fluctuations, are dependent on the wind patterns. Humidities in the Raritan Bay area are higher with onshore winds, but usually a few percent lower than humidities seaward off Sandy Hook.

Tides and Currents - Offshore Sandy Hook

The spring tide range at Sandy Hook is 5.6 feet with a mean range of 4.6 feet. The mean tide level is 2.3 feet.

The currents may be summarized as follows:

LOCATION	MAXIMUM CURRENTS FLOOD Dir. (deg)	Speed (kts)	EBB Dir. (deg)	Speed (kts)
1.7 miles ENE of the N. Tip of Sandy Hook 40°30'N 73°59'W	295	1.5	100	1.7
0.4 mile W of the N. Tip of Sandy Hook Channel 40°29'N 74°01'W	235	2.0	50	1.6

Rotary tidal currents are experienced on a semi-diurnal basis. The following data are from about .2 mile west of Sandy Hook Approach Lighted Horn Buoy 2A, 40°27'N 73°55'W:

Hours after max. flood at the Narrows, New York Harbor	TIDAL CURRENTS Dir. (deg)	Speed (kts)
0	313	0.4
1	325	0.3
2	356	0.2
3	055	0.2
4	094	0.3
5	118	0.4
6	136	0.6
7	147	0.5
8	177	0.2
9	256	0.2
10	290	0.3
11	298	0.4

Storm surges in the New York area can result from either tropical or extratropical cyclones. The highest observed storm surges have been about 10 feet above mean high water. The highest surges are associated with hurricanes.

Tides and Currents - Raritan Bay

At all stations in Raritan Bay, spring tidal ranges are less than six feet and currents less than one knot. At Atlantic Highlands (40°25'N, 74°02'W) the spring tidal range is 5.7 feet; mean tidal range is 4.7 feet and mean tide level is 2.3 feet.

LOCATION	MAXIMUM CURRENTS FLOOD Dir. (deg)	FLOOD Speed (kts)	EBB Dir. (deg)	EBB Speed (kts)
2 miles W of Sandy Hook Point 40°29'N 74°04'W	265	0.6	085	0.6

Storm surges often enter Raritan Bay as the result of tropical or extratropical cyclone passages, the highest being the result of hurricanes. Surges of nearly ten feet above mean high water have been recorded.

STATION: J. F. KENNEDY INT'L. AIRPORT, NEW YORK
POSITION: 40.7N 73.8W
ELEVATION: 13 FEET

NORMALS, MEANS, AND EXTREMES

Month	Temperature – Normal – Daily maximum	Temperature – Normal – Daily minimum	Temperature – Normal – Monthly	Temperature – Extremes Ø – Record highest	Year	Temperature – Extremes Ø – Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation – Normal total	Precipitation – Maximum monthly	Year	Precipitation – Minimum monthly	Year	Precipitation – Maximum in 24 hrs. #	Year
(a)	(b)	(b)	(b)	10		10		(b)	(b)	23		23		23	
J	38.0	25.6	31.8	64	1967	0	1968	1029	3.23	5.77	1949	0.21	1956	1.60	1958
F	38.5	24.7	31.6	62	1965	-2	1963	935	2.93	5.48	1960	1.73	1968	2.87	1958
M	45.9	31.4	38.7	72	1963	7	1967	815	4.15	7.93	1953	1.35	1966	2.27	1962
A	57.5	40.4	49.0	82	1964+	26	1969+	480	3.48	6.60	1964	1.12	1963	1.79	1969
M	69.5	50.9	60.2	99	1969	34	1966	167	3.67	6.14	1951	0.38	1955	2.88	1968
J	79.3	60.9	70.1	99	1964	45	1967	12	3.35	4.27	1962+	T	1949	1.81	1968
J	84.7	67.1	75.9	104	1966	55	1963	0	4.04	8.48	1969	0.46	1954	3.21	1969
A	82.9	66.0	74.5	97	1969	46	1965	0	4.97	17.41	1955	0.87	1964	6.59	1955
S	76.2	59.3	67.8	94	1961	40	1963	36	4.16	9.60	1960	0.70	1951	5.83	1960
O	65.9	49.3	57.6	84	1967	25	1961	248	3.21	6.41	1958	0.09	1963	3.21	1966
N	53.2	39.1	46.2	73	1968+	20	1967	564	3.51	7.89	1963	1.30	1949	2.93	1963
D	41.3	28.4	34.9	68	1962	5	1962	933	3.23	6.16	1969	1.72	1958	2.05	1968
YR	61.1	45.3	53.2	104	JUL. 1966	-2	FEB. 1963	5219	43.93	17.41	AUG. 1955	T	JUN. 1949	6.59	AUG. 1955

Month	Snow, Ice pellets – Mean total	Snow, Ice pellets – Maximum monthly	Year	Snow, Ice pellets – Maximum in 24 hrs. $	Year	Relative humidity – Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Wind & – Mean speed	Wind – Prevailing direction	Fastest mile – Speed	Fastest mile – Direction	Fastest mile – Year
(a)	12	12		12		9	9	9	9	12		7	7	
J	7.1	17.4	1965	13.0	1964	68	70	59	64	13.2		52	26	1966
F	9.3	25.3	1961	19.9	1969	67	69	58	62	13.9		46	25	1967
M	5.2	21.1	1960	8.1	1967	70	71	57	64	13.6		41	30	1966
A	0.1	1.4	1965	1.4	1965	71	71	56	66	12.8		44	26	1970
M	T	T	1967	T	1967	76	70	55	67	11.7		35	24	1969+
J	0.0	0.0		0.0		79	73	59	71	10.9		32	30	1967
J	0.0	0.0		0.0		78	74	57	71	10.6		37	34	1969
A	0.0	0.0		0.0		78	76	57	71	10.4		46	30	1965
S	0.0	0.0		0.0		79	78	56	70	10.7		40	30	1970
O	T	0.5	1962	0.5	1962	75	77	53	68	11.2		39	26	1967
N	0.2	2.1	1967	2.1	1967	73	75	58	68	12.3		44	05	1968
D	6.0	16.4	1960	8.2	1960	71	73	61	66	12.8		46	06	1969+
YR	27.9	25.3	FEB. 1961	19.9	FEB. 1969	74	73	57	67	12.0		52	26	JAN. 1966

Month	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days – Sunrise to sunset – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures – Max. – 90° and above ‡	Max. – 32° and below	Min. – 32° and below	Min. – 0° and below	Average daily solar radiation - langleys
(a)		12	12	12	12	12	12	12	12	9	9	9	9	
J		6.0	9	8	14	10	2	*	2	0	9	25	*	
F		6.3	7	8	13	10	2	*	3	0	6	24	*	
M		6.0	8	10	13	12	2	1	3	0	1	15	0	
A		6.2	7	10	13	11	*	2	3	0	0	2	0	
M		6.0	7	13	11	11	0	3	3	1	0	0	0	
J		6.0	7	11	12	9	0	4	4	3	0	0	0	
J		6.2	6	12	13	9	0	5	3	4	0	0	0	
A		5.9	7	13	11	9	0	5	2	2	0	0	0	
S		5.2	11	9	10	8	0	2	1	1	0	0	0	
O		5.1	12	9	10	7	0	1	3	0	0	1	0	
N		6.4	8	8	14	11	*	1	2	0	0	6	0	
D		6.1	8	9	14	11	2	*	3	0	5	21	0	
YR		6.0	97	120	148	118	8	23	32	10	21	93	*	

Ø For the period June 1961 through the current year.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

$ Greatest calendar day through March 1969.
# Greatest calendar day August 1966 through March 1969.

Table 4 Land station climatological data summary for J. F. KENNEDY INTERNATIONAL AIRPORT, NEW YORK

STATION: NEWARK, NEW JERSEY
POSITION: 40.7N 74.2W
ELEVATION: 7 FEET

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Daily minimum	Monthly	Extremes ∅: Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	5		5		(b)	(b)	17		17		17	
J	39.5	25.0	32.3	68	1967	1	1968	1014	3.33	5.12	1964	0.81	1955	1.78	1962
F	40.7	24.7	32.7	59	1967	4	1967	904	2.80	4.47	1956	1.22	1968	2.45	1961
M	48.8	32.1	40.5	79	1968	8	1967	760	4.09	6.29	1954	1.12	1966	2.58	1969
A	60.9	41.7	51.3	88	1969	28	1969	411	3.51	6.41	1958	0.90	1963	2.01	1958
M	72.1	51.9	62.0	96	1969	35	1966	127	3.65	6.28	1968	0.52	1964	4.11	1968
J	81.3	61.2	71.3	101	1966	49	1967	9	3.44	4.37	1968	0.49	1966	1.75	1968+
J	86.1	66.5	76.3	105	1966	59	1969+	0	3.67	7.95	1961	0.89	1966	3.15	1961
A	83.8	64.9	74.4	95	1968+	50	1965	0	4.43	11.84	1955	0.50	1964	4.17	1959
S	77.0	57.6	67.3	94	1970+	42	1965	39	3.76	7.86	1966	1.30	1964	4.71	1966
O	66.2	47.0	56.6	87	1967	28	1969	276	3.11	6.70	1955	0.21	1963	2.65	1966
N	53.5	37.3	45.4	76	1968	20	1967	588	3.37	5.68	1963	1.48	1965	2.09	1963
D	42.0	27.4	34.7	68	1966	8	1968	939	3.22	5.74	1957	0.27	1955	1.90	1968
YR	62.7	44.8	53.7	105	JUL. 1966	1	JAN. 1968	5067	42.38	11.84	AUG. 1955	0.21	OCT. 1963	4.71	SEP. 1966

Month	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity: Hour 01	Hour 07	Hour 13	Hour 19 (Local time)	Wind &: Mean speed	Prevailing direction	Fastest mile: Speed	Direction	Year
(a)	29	29		29		5	5	5	5	27	22	22	22	
J	7.1	22.2	1961	13.7	1961	69	71	57	62	11.3	NE	45	25	1951
F	8.1	25.4	1967	20.0	1961	66	69	55	59	11.7	NW	46	23	1965
M	5.6	26.0	1956	17.6	1956	67	69	51	57	12.1	NW	43	27	1950
A	0.5	4.1	1957	4.1	1957	65	66	47	53	11.3	WNW	50	27	1951
M	T	T	1956	T	1956	69	66	50	56	10.2	SW	50	32	1963
J	0.0	0.0		0.0		74	72	53	59	9.4	SW	55	07	1952
J	0.0	0.0		0.0		73	72	53	61	8.8	SW	45	18	1950
A	0.0	0.0		0.0		75	75	52	60	8.7	SW	46	09	1955
S	0.0	0.0		0.0		75	76	52	62	9.1	SW	51	05	1960
O	T	0.3	1952	0.3	1952	75	77	53	64	9.4	SW	48	11	1954
N	0.5	3.1	1967	3.1	1967	74	78	59	67	10.2	SW	82	09	1950
D	7.9	29.1	1947	26.0	1947	73	75	61	67	10.9	SW	55	32	1962
YR	29.7	29.1	DEC. 1947	26.0	DEC. 1947	71	72	54	61	10.3	SW	82	09	NOV. 1950

Month	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max.: 90° and above ‡	Max.: 32° and below	Min.: 32° and below	Min.: 0° and below	Average daily solar radiation - langleys
(a)		25	29	29	29	29	29	29	29	5	5	5	5	
J		6.3	8	8	15	11	2	*	3	0	10	24	0	
F		6.3	7	8	13	10	2	*	2	0	5	23	0	
M		6.1	8	9	14	11	1	1	2	0	1	15	0	
A		6.4	7	9	14	11	*	1	1	0	0	1	0	
M		6.4	7	11	13	12	0	4	2	1	0	0	0	
J		6.0	7	11	12	10	0	5	1	5	0	0	0	
J		6.2	7	12	12	10	0	6	1	7	0	0	0	
A		5.9	8	12	11	9	0	4	1	6	0	0	0	
S		5.4	11	8	11	8	0	2	1	2	0	0	0	
O		5.2	12	8	11	8	0	1	2	0	0	1	0	
N		6.2	8	8	14	10	*	*	2	0	0	6	0	
D		6.2	9	8	14	11	2	*	2	0	4	22	0	
YR		6.1	99	112	154	122	8	25	21	20	20	93	0	

∅ For period June 1965 through current year.
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Lowest temperature -14 in February 1934; maximum monthly precipitation 22.48 in August 1943; minimum monthly precipitation 0.07 in June 1949.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

Table 5 Land station climatological data summary for NEWARK, NEW JERSEY.

STATION: NEW YORK CITY OFFICE
POSITION: 40.8N 74.0W
ELEVATION: 132 FEET

NORMALS, MEANS, AND EXTREMES

Month	Temperature – Normal – Daily maximum	Temperature – Normal – Daily minimum	Temperature – Normal – Monthly	Temperature – Extremes – Record highest	Year	Temperature – Extremes – Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation – Normal total	Precipitation – Maximum monthly	Year	Precipitation – Minimum monthly	Year	Precipitation – Maximum in 24 hrs.	Year	Snow, Ice pellets – Mean total	Snow, Ice pellets – Maximum monthly	Year	Snow, Ice pellets – Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	101		101		(b)	(b)	101		101		58		101	101		101	
J	39.5	26.9	33.2	72	1950	-6	1882	986	3.31	7.94	1915	0.77	1955	3.33	1915	7.6	27.4	1925	13.0	1935
F	40.3	26.4	33.4	75	1930	-15	1934	885	2.84	6.87	1869	0.46	1895	2.96	1941	8.7	27.9	1934	17.4	1961
M	47.8	33.2	40.5	86	1945	3	1872	760	4.01	8.79	1876	0.90	1885	4.25	1876	5.4	30.5	1896	18.1	1941
A	59.6	43.1	51.4	92	1915	12	1923	408	3.43	8.77	1874	0.95	1881	2.67	1886	1.0	13.5	1875	10.2	1915
M	71.4	53.4	62.4	99	1962	32	1891	118	3.67	8.51	1908	0.30	1903	4.88	1968	T	T	1946	T	1946
J	80.2	62.5	71.4	101	1966+	44	1945	9	3.31	9.78	1903	0.02	1949	4.74	1884	0.0	0.0		0.0	
J	85.3	68.2	76.8	106	1936	52	1943	0	3.70	11.89	1889	0.49	1910	3.56	1960	0.0	0.0		0.0	
A	83.3	66.8	75.1	104	1918	50	1965+	0	4.44	10.86	1955	0.24	1964	4.80	1909	0.0	0.0		0.0	
S	76.8	60.1	68.5	102	1953	39	1912	30	3.87	16.85	1882	0.21	1884	8.30	1882	0.0	0.0		0.0	
O	66.3	50.3	58.3	94	1941	28	1936	233	3.14	13.31	1903	0.14	1963	11.17	1903	T	0.8	1925	0.8	1925
N	53.7	40.3	47.0	84	1950	5	1875	540	3.39	9.97	1889	0.60	1931	3.81	1963	1.0	19.0	1898	10.0	1898
D	42.1	29.7	35.9	70	1946	-13	1917	902	3.26	7.53	1936	0.25	1955	3.21	1909	6.2	29.6	1947	26.4	1947
YR	62.2	46.7	54.5	106	JUL. 1936	-15	FEB. 1934	4871	42.37	16.85	SEP. 1882	0.02	JUN. 1949	11.17	OCT. 1903	29.9	30.5	MAR. 1896	26.4	DEC. 1947

Month	Relative humidity – Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Wind & – Mean speed	Wind – Prevailing direction #	Fastest mile – Speed	Fastest mile – Direction #	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days – Sunrise to sunset – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures – Max. – 90° and above ‡	Max. – 32° and below	Min. – 32° and below	Min. – 0° and below	Average daily solar radiation - langleys
(a)	38	50	50	50	50	45	23	23		93	42	42	42	42	101	99	9		56	56	56	56	42
J	65	68	60	61	10.9	NW	47	NW	1959	50	6.0	8	9	14	11	2	*		0	8	22	*	135
F	65	68	58	60	11.0	NW	47	NE	1961+	55	5.8	8	9	11	10	2	*		0	6	21	*	204
M	64	67	55	58	11.2	NW	60	NW	1950	57	5.7	9	10	12	12	2	1		0	1	13	0	294
A	65	68	52	57	10.6	NW	45	NE	1961	59	6.0	8	10	12	11	*	1		*	0	1	0	373
M	70	71	53	60	9.0	SW	38	NE	1967+	62	5.7	8	12	11	11	0	2		1	0	*	0	441
J	73	73	55	61	8.2	SW	49	SW	1952	65	5.6	8	12	10	10	0	4		3	0	0	0	477
J	75	75	56	63	7.7	SW	43	NW	1949	65	5.5	8	13	10	11	0	4		6	0	0	0	463
A	78	78	58	66	7.8	SW	36	NE	1954	64	5.5	9	12	10	10	0	4		4	0	0	0	398
S	77	79	57	67	8.2	SW	44	NE	1960	63	5.2	11	10	9	8	0	1		1	0	0	0	335
O	71	76	55	62	9.1	SW	40	NE	1955+	62	4.9	12	10	9	8	0	1		*	0	*	0	247
N	69	73	59	63	10.1	NW	70	NE	1950	53	5.8	9	9	12	9	*	*		0	*	5	0	149
D	67	69	60	62	10.5	NW	43	NW	1962+	50	5.9	9	9	13	10	2	*		0	5	19	*	117
YR	70	72	56	62	9.5	NW	70	NE	NOV. 1950	59	5.6	107	125	133	121	8	18		16	20	82	1	303

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Maximum monthly snowfall 37.9 inches in February 1894; fastest mile of wind 113 from the SE in October 1954.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1964.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

To 8 compass points only.

Table 6 Land station climatological data summary for NEW YORK CITY OFFICE, NEW YORK

ENVIRONMENTAL DATA SUMMARY (PART 1)

AREA: Raritan Bay

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WIND SPEED (KNOTS)													
01% ≤	2	2	2	3	2	1	1	2	2	2	2	3	2
Mean	11.4	11.5	12.2	11.4	10.0	9.7	9.2	8.8	9.4	9.7	10.5	10.9	10.4
99% ≤	35	32	32	36	32	28	31	29	28	34	31	31	32
Maximum observed (1871 - 1971)	Winds near 100 knots have probably occurred during the passage of Tropical Cyclones.												
≥ 34 Knots (% freq.)	1.2	0.1	0.1	1.3	+	+	+	+	0.1	1.3	0.1	+	0.4
≥ 41 Knots (% freq.)	+	+	+	+	+	+	0.0	0.0	+	+	0.1	+	+
Prevailing direction	WNW	NW	NW	S	S	S	S	S	S	SW	WSW	WSW	S
WAVES (FEET)													
01% ≤	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean	3	3	3	2	2	2	2	2	3	2	2	2	2
99% ≤	9	8	8	8	8	5	6	8	7	6	8	6	7
≥ 12 Feet (% freq.)	+	+	+	+	+	0.0	0.0	0.0	+	+	+	0.0	+
≥ 20 Feet (% freq.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+	0.0	+
VISIBILITY (% FREQ.)													
Visibility <½ N. mile	2.5	2.2	1.4	1.8	1.7	1.4	0.7	0.5	0.4	0.9	1.2	1.7	1.4
Visibility <1 N. mile	4.4	3.7	3.2	3.0	2.9	2.4	1.3	1.1	1.0	1.7	2.2	3.4	2.5
Visibility <2 N. miles	7.4	7.1	5.3	4.8	5.3	4.9	3.5	3.0	2.7	3.3	4.4	6.4	4.9
Visibility <5 N. miles	22.1	20.6	15.0	14.8	17.4	18.9	19.3	19.5	14.3	16.6	17.9	21.1	18.1
Visibility <10 N. miles	51.4	46.5	39.1	40.5	42.4	49.0	53.9	51.8	42.8	44.6	45.8	53.5	46.8

+ = less than 0.05%

Table. 7 Environmental data summary; Raritan Bay area.

ENVIRONMENTAL DATA SUMMARY (PART 2)

AREA: Raritan Bay

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
FOG													
Occurrence of fog (% freq.)	11.5	11.3	10.7	11.2	11.2	10.0	7.0	7.8	6.5	7.0	9.0	11.2	9.5
Mean number of hours operation of fog signals *	40	34	29	40	45	43	29	18	17	22	29	34	380
Maximum number of hours operation of fog signals for any year (annual only)*													578
WEATHER & CLOUDS (% FREQ.)													
Precipitation	15.0	15.1	16.4	14.9	11.3	7.9	6.9	7.5	7.9	8.7	11.2	14.5	11.4
Freezing precipitation	0.6	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1
Frozen precipitation	4.8	5.5	4.8	0.6	+	+	0.0	0.0	0.0	0.1	0.7	3.8	1.7
Thunder & lightning	0.0	0.0	0.1	0.2	0.6	0.6	1.1	0.7	0.3	0.1	0.0	0.0	0.3
Sky ≤2/8	35.9	36.9	38.2	33.7	33.2	37.0	36.0	38.4	43.7	47.2	40.4	38.9	38.3
Sky overcast (8/8)	44.1	42.0	40.6	40.3	37.0	30.7	28.9	29.7	28.7	29.6	36.3	40.1	35.6
Sky obscured	9.9	15.4	11.2	13.8	20.9	15.8	11.0	8.9	4.0	4.4	3.0	4.8	10.0
Low cloud overcast	24.2	22.0	22.8	19.2	16.0	14.5	15.3	13.6	14.8	14.9	20.4	22.3	18.4
Mean cloud cover (eighths)	4.8	4.7	4.6	4.9	4.8	4.5	4.6	4.4	4.1	3.8	4.4	4.6	4.5
AIR TEMPERATURE (°F)													
Minimum	-6	-15	3	12	31	44	52	46	39	25	5	-13	-15
01% ≤	12	11	21	30	45	55	61	61	53	39	27	16	36
Mean	33.6	33.5	40.0	49.8	59.9	69.4	75.1	73.9	67.5	57.8	47.3	36.5	54.0
99% ≤	49	47	61	69	79	83	88	87	83	73	62	51	70
Maximum	72	75	86	92	99	101	106	104	102	94	84	70	106
≤ 32 °F (% freq.)	62.7	67.1	42.6	5.8	0.1	0.0	0.0	0.0	0.0	0.3	14.0	52.6	20.4
≥ 85 °F (% freq.)	0.0	0.0	+	+	0.5	0.9	6.8	3.7	0.3	+	0.0	0.0	1.0

* West Bank fog Signal

\+ = less than 0.05%

Table 7 Continued.

ENVIRONMENTAL DATA SUMMARY (PART 3)

AREA: Raritan Bay

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
RELATIVE HUMIDITY (%)													
Mean	69	67	67	68	70	71	72	73	72	70	69	69	70
SEA TEMPERATURE (°F)													
Minimum	28	27	27	35	46	51	63	65	56	41	32	28	27
01% ≤	29	29	33	38	49	54	64	67	59	51	42	32	45
Mean	38.5	37.0	39.6	46.3	55.3	65.2	71.8	72.9	69.3	60.7	51.8	43.1	54.3
99% ≤	50	52	54	59	72	78	80	82	81	72	61	53	66
Maximum	54	56	59	64	81	83	85	87	86	78	67	63	87
SALINITY (‰)													
Minimum	5.6	10.1	4.2	1.7	2.0	3.9	11.4	11.6	5.9	7.5	9.9	5.6	1.7
Mean	22.0	22.5	20.2	19.1	20.8	22.7	24.5	24.8	25.0	24.8	23.7	22.8	22.7
Maximum	28.6	29.3	28.4	28.1	28.0	29.3	30.7	30.2	31.2	32.9	29.1	31.1	32.9
DENSITY (ρ)													
Mean (σ_t)*	16.3	16.5	14.8	14.0	15.2	16.6	17.9	18.3	18.4	18.3	17.4	16.8	16.7
SEA-LEVEL PRESSURE (mb)													
Minimum	978	971	983	985	995	992	994	977	992	995	989	983	971
01% ≤	992	983	990	991	1000	1002	1001	1002	1001	999	992	993	996
Mean	1016	1016	1015	1015	1014	1014	1015	1015	1018	1018	1018	1019	1016
99% ≤	1039	1040	1035	1034	1030	1031	1031	1029	1034	1036	1039	1040	1035
Maximum	1042	1042	1041	1035	1032	1035	1032	1032	1037	1040	1041	1041	1042

* $\sigma_t = (\rho - 1) \times 10^3$; ρ = gm cm^{-3}

Table 7 Continued.

ENVIRONMENTAL DATA SUMMARY (PART 1)

AREA: Offshore Sandy Hook

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WIND SPEED (KNOTS)													
01% ≤	3	3	2	3	2	1	1	2	2	2	3	4	2
Mean	14.4	14.3	13.6	12.7	10.6	9.9	9.2	9.2	10.6	11.9	14.3	14.9	12.1
99% ≤	46	43	46	39	32	28	31	30	32	39	40	40	37
Maximum observed (1871 - 1971)	Winds in excess of 100 knots have been recorded in Hurricanes and Northeasters.												
≥ 34 Knots (% freq.)	3.3	2.5	3.2	1.5	0.3	0.1	0.1	0.3	0.4	1.2	2.4	3.9	1.6
≥ 41 Knots (% freq.)	1.2	1.1	1.2	0.3	0.1	0.0	0.0	0.1	0.1	0.5	1.0	1.0	0.6
Prevailing direction	NW	NW	NW	NW	SW	S	S	SW	S	NW	NW	NW	NW
WAVES (FEET)													
01% ≤	0	0	0	0	0	0	0	0	0	0	0	1	< $\frac{1}{4}$
Mean	3	3	3	3	2	3	2	2	3	3	3	4	3
99% ≤	16	15	12	10	10	8	9	10	12	12	15	13	12
≥ 12 Feet (% freq.)	1.2	2.4	2.9	0.5	0.2	0.0	0.2	0.0	1.6	1.2	1.4	2.2	1.2
≥ 20 Feet (% freq.)	+	+	0.8	0.0	0.0	0.0	0.2	0.0	0.3	0.0	0.3	+	0.1
VISIBILITY (% FREQ.)													
Visibility < $\frac{1}{2}$ N. mile	5.0	4.4	2.7	6.9	9.3	5.8	5.6	2.3	2.3	1.8	1.5	0.7	4.0
Visibility <1 N. mile	8.7	7.0	6.2	8.6	11.9	8.3	6.3	4.6	3.7	3.6	2.4	2.1	6.1
Visibility <2 N. miles	11.8	12.9	8.1	11.1	14.5	13.1	9.5	6.6	4.6	5.1	5.4	3.7	8.9
Visibility <5 N. miles	17.6	22.8	15.0	18.8	22.8	26.6	20.6	19.3	9.8	10.3	8.7	8.1	16.7
Visibility <10 N. miles	44.7	48.6	39.6	39.9	55.6	58.9	58.5	49.9	42.7	43.6	44.2	41.2	47.2

+ = less than 0.05%

Table. 8 Environmental data summary; Offshore Sandy Hook area.

ENVIRONMENTAL DATA SUMMARY (PART 2)

AREA: Offshore Sandy Hook

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
FOG													
Occurrence of fog (% freq.)	8.4	8.0	9.4	11.9	20.3	20.1	15.0	10.8	8.9	9.0	3.9	5.3	10.9
Mean number of hours operation of fog signals *	75	72	75	74	91	81	73	59	51	42	44	57	794
Maximum number of hours operation of fog signals for any year (annual only)*													1169
WEATHER & CLOUDS (% FREQ.)													
Precipitation	10.9	12.2	11.1	12.2	6.7	5.6	6.9	5.3	8.9	9.1	11.9	10.5	9.3
Freezing precipitation	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1
Frozen precipitation	5.6	5.0	2.7	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.3
Thunder & lightning	0.0	0.0	0.1	0.2	0.5	0.8	1.3	1.5	0.9	0.2	0.5	0.0	0.5
Sky ≤2/8	34.0	36.7	38.8	34.5	35.0	39.0	35.1	37.7	43.1	44.6	34.3	33.2	37.2
Sky overcast (8/8)	34.5	33.4	31.6	31.3	25.8	22.5	27.9	27.2	26.3	24.6	33.1	32.3	29.3
Sky obscured	8.3	12.8	7.4	8.3	12.5	11.8	8.0	7.3	2.4	2.9	1.4	2.2	7.1
Low cloud overcast	21.6	18.5	19.6	16.2	19.2	14.0	16.0	12.0	12.7	14.7	20.8	25.0	17.4
Mean cloud cover (eighths)	4.5	4.3	4.4	4.6	4.7	4.4	4.5	4.0	4.0	4.3	4.7	4.7	4.4
AIR TEMPERATURE (°F)													
Minimum	5	-1	17	27	36	48	54	53	50	39	16	7	-1
01% ≤	11	14	23	35	43	54	61	63	53	42	29	18	37
Mean	34.7	35.3	39.6	47.2	56.0	65.6	72.3	72.9	67.7	59.2	49.9	39.7	53.2
99% ≤	54	53	55	63	72	80	84	84	80	73	64	58	68
Maximum	64	61	72	75	85	88	90	90	89	88	70	68	90
≤ 32 °F (% freq.)	45.7	31.0	10.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.3	20.8	9.2
≥ 85 °F (% freq.)	0.0	0.0	0.0	0.0	0.1	0.2	1.0	0.7	+	+	0.0	0.0	0.2

* Ambrose fog signal

\+ = less than 0.05%

Table 8 Continued.

ENVIRONMENTAL DATA SUMMARY (PART 3)

AREA: Offshore Sandy Hook

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
RELATIVE HUMIDITY (%)													
Mean	85	84	80	79	82	84	83	82	80	79	79	80	81
SEA TEMPERATURE (°F)													
Minimum	30	27	27	35	40	45	51	56	52	46	42	30	27
01% ≤	31	29	31	37	41	49	59	62	58	51	44	36	44
Mean	39.9	38.2	39.7	44.3	52.2	62.4	69.7	71.6	68.1	60.9	53.6	47.0	53.9
99% ≤	56	56	55	57	68	74	78	80	79	72	64	59	67
Maximum	60	60	60	62	76	84	84	82	84	78	70	70	84
SALINITY (‰)													
Minimum	13.2	10.5	12.8	11.4	10.3	13.6	17.9	17.7	18.6	12.8	14.4	14.6	10.3
Mean	22.6	22.9	21.4	20.3	21.8	23.8	25.5	25.6	25.8	25.6	24.7	23.7	23.6
Maximum	28.6	29.3	28.4	28.1	28.0	29.3	30.7	30.2	31.2	32.9	29.1	31.1	32.9
DENSITY (ρ)													
Mean (σ_t)*	16.4	17.1	15.3	15.0	15.9	16.9	18.3	18.5	18.6	18.6	17.9	17.5	17.2
SEA-LEVEL PRESSURE (mb)													
Minimum	975	980	977	981	996	998	952	977	987	993	989	983	952
01% ≤	991	987	990	993	999	1002	1002	1003	1001	998	992	992	996
Mean	1016	1017	1015	1014	1015	1015	1016	1016	1018	1019	1016	1017	1016
99% ≤	1035	1038	1035	1032	1031	1021	1027	1028	1032	1035	1033	1034	1032
Maximum	1040	1041	1053	1041	1038	1035	1032	1032	1037	1038	1039	1041	1053

* $\sigma_t = (\rho - 1) \times 10^3$; $\rho = \text{gm cm}^{-3}$

Table 8 Continued.

DELAWARE AREA

General Description

The area covered in this section is generally low and flat. Long stretches of sandy beaches and tidewater marshes characterize the New Jersey and Delaware ocean coasts, while the shores of Delaware Bay are mostly low with few conspicuous marks other than lights.

The principal dangers along the Atlantic coastal region are the outlying sand shoals, the fogs, and the doubtful direction and velocity of the currents after heavy gales. Gales from the northeast to southeast cause heavy breakers along the coast and outlying shoals. Such dangers have produced many wrecks. Traffic is heavy along this coast and a sharp lookout must be kept to avoid collision.

Deep-draft vessels should stay outside of Barnegat Lighted Horn Buoy B and Five Fathom Bank Lightship between New York Harbor and Delaware Bay. Depths as little as seven fathoms are found as far as 13 miles from the Atlantic shore. Depths inside the 20-fathom curve, about 25 miles off Delaware Bay, are irregular, and in thick weather a deep-draft vessel should not approach the coast until sure of its position. Tides range from 3.5 to 4.5 feet along this section of the Atlantic coast.

Five Fathom Bank Lightship, located about 20 miles seaward of the Delaware Bay entrance, is the only remaining lightship along this section of the coast. The ship is equipped with fog signal and a radiobeacon, and its light is 63 feet above the water. Tidal currents in its vicinity average 0.2 knots.

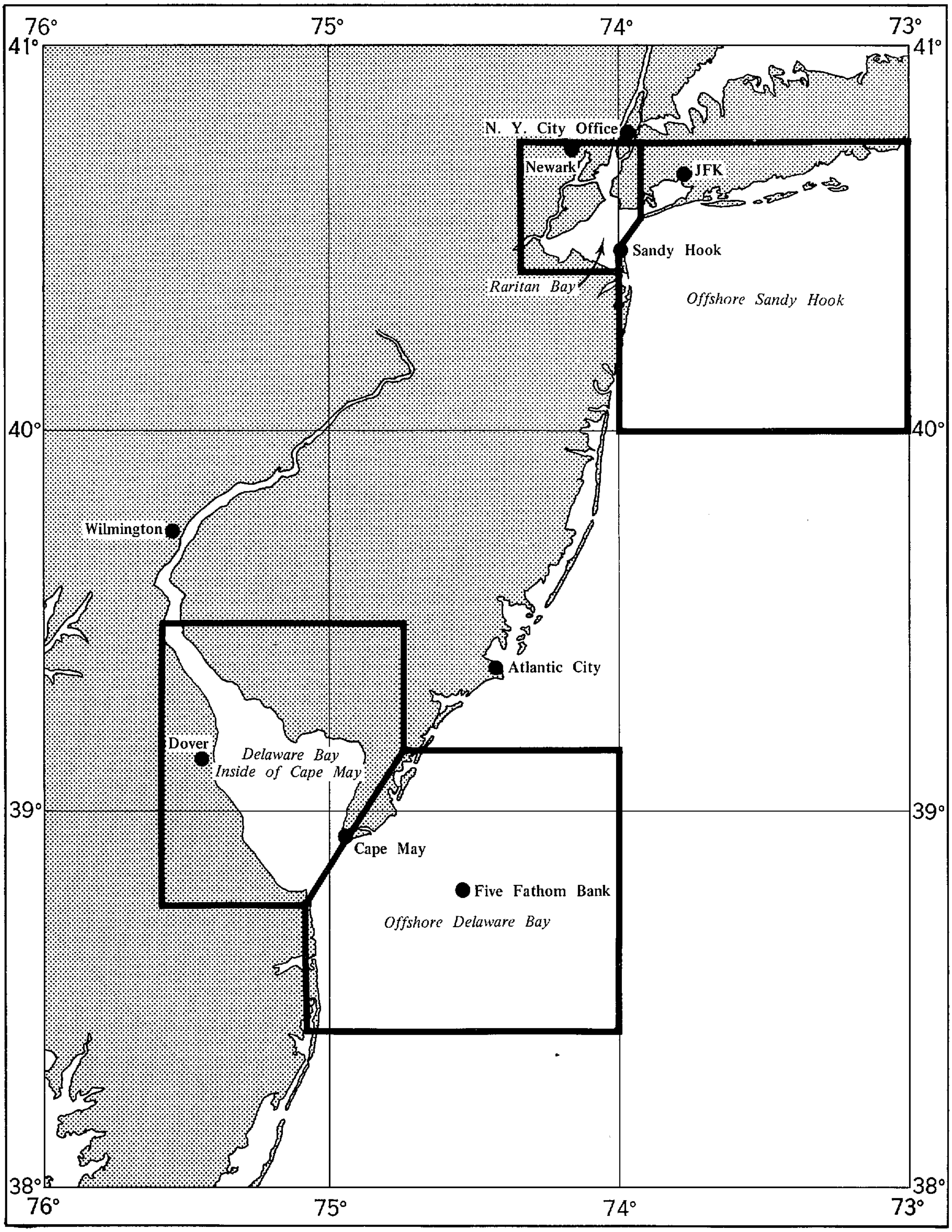


Fig. 6 New York and Delaware Bay area map.

Deep-draft vessels use established traffic lanes at the Atlantic entrance to Delaware Bay. The entrance is about 10 miles wide between Cape May on the northeast and Cape Henlopen on the southwest. The channel into Delaware Bay is broad and deep, and has an average current velocity of 1.8 knots.

Delaware Bay is an expansion of the lower part of Delaware River. The Bay affords the only protected anchorage for deep-draft vessels between New York Bay and Chesapeake Bay. Delaware Bay is shallow along its northeast and southwest sides and there are extensive shoal areas close to the main channel. The Bay has natural depths of 50 feet or more for a distance of five miles above the Capes; thence federal project depths of 40 feet to the upper end of Newbold Island, 110 miles above the Capes.

In ordinary winters there is usually sufficient ice in Delaware Bay to be of some concern to navigation. The tidal currents keep the ice in motion.

THE ENVIRONMENT

The Appalachian Mountains, although some distance from the ocean, exert an important influence on the winter climatic pattern in the coastal area. They partly block the cold continental air from the interior, and this combines with the moderating effect of the ocean to produce a more equable climate than is found in continental locations in the same latitude elsewhere.

The general surface wind pattern along the Atlantic coast is controlled largely by the position and intensity of the Bermuda high-pressure system. The characteristics and location of this extensive high vary considerably during the year. In the winter, it usually is centered far to the southeast. The major low-pressure storm systems, which develop over the interior, the Gulf of Mexico, and off the southeastern coast may sweep through the Middle Atlantic States. These extratropical cyclones usually travel between north and east-northeastward. Many are intense and accompanied by strong gusty winds and rain or snow.

Highs from the interior usually follow the passage of these Lows, producing a pattern of rapidly changing air masses and variable winter weather conditions. There are marked temperature fluctuations and an alternation of brief stormy periods with clear crisp days and relatively mild weather.

In the spring the Bermuda High, although still centered far to the southeast, begins to affect the southeastern states. The Middle Atlantic area usually is located outside the high-pressure circulation, however, and is still subject to the passage of extratropical cyclones, frontal activity and changing air masses. Warm spells, sometimes with abundant rain, alternate with cool, dry weather.

In the summer, the Bermuda High reaches its most northerly and westerly position, embracing the entire eastern seaboard within its circulation. The strength of this circulation is moderate but persistent, sufficiently so to hold back the eastward movement of the continental low-pressure system. As a consequence, the daily weather along the coast may not change much for several weeks at a time; it is controlled by the southerly and southwesterly winds bringing moist, warm air from the Gulf. This weather is characterized by frequent instability showers and thunderstorms, uniform warm temperatures and high humidity, and relatively low wind speeds. However, the summer months also include the beginning of the hurricane season.

In autumn, the Bermuda High again shifts southward and eastward, leaving the Atlantic coast in a weak continental high-pressure area. This gradually gives way to the winter weather pattern, bringing increased frontal activity and more frequent passage of cyclones and anticyclones.

Pressure

The pressure pattern over the Delaware area changes considerably from summer to winter. However, the differences of mean annual pressure between the Delaware Bay area and offshore Delaware Bay area are negligible. Large short-term variations of pressure are occasionally experienced during tropical cyclones in the late summer and autumn, and during the movement of extratropical cyclones and anticyclones in the winter and spring. The day-to-day changes of pressure in summer are less marked.

Extratropical Cyclones

The frequent winter extratropical cyclones traversing the Delaware area produce frequent shifts from the prevailing westerlies and produce rapid changes in the weather. The cyclones may be of continental or marine character, with the latter (Nor'easters) usually being of greater severity from having passed over water. Strong winds, sometimes of hurricane force, accompany the storms. The northwesterly winds in the western half of the storm, having come directly from the interior of the cold continent, will often be very cold.

Appendix B contains extratropical cyclone tracks and movement roses. The Machiasport narrative contains a detailed description of "Nor'easters."

Tropical Cyclones

Tropical cyclones occur almost entirely in six rather distinct regions of the world; one of these, the North Atlantic Region, includes the Delaware area. Tropical cyclones are infrequent in comparison with the extratropical cyclones, but they have a record of destruction far exceeding that of any other type of storm. The tropical storms are most frequently oceanic and, therefore, of greater fury.

As a tropical cyclone moves out of the tropics to the Delaware latitudes, it normally loses energy slowly, expanding in area until it gradually dissipates or acquires the characteristics of extratropical cyclones. At any stage, a tropical cyclone loses energy at a much faster rate if it moves over land. As a general rule, tropical cyclones move with the prevailing winds of the area.

The frequency of occurrences of tropical cyclones for the Delaware areas (as they appear on the map in Fig. 6) are noted in the table below:

	Total Number 1886 - 1971	Average Number of Years between Occurrences
Tropical Cyclones	11	8
Hurricanes	3	30

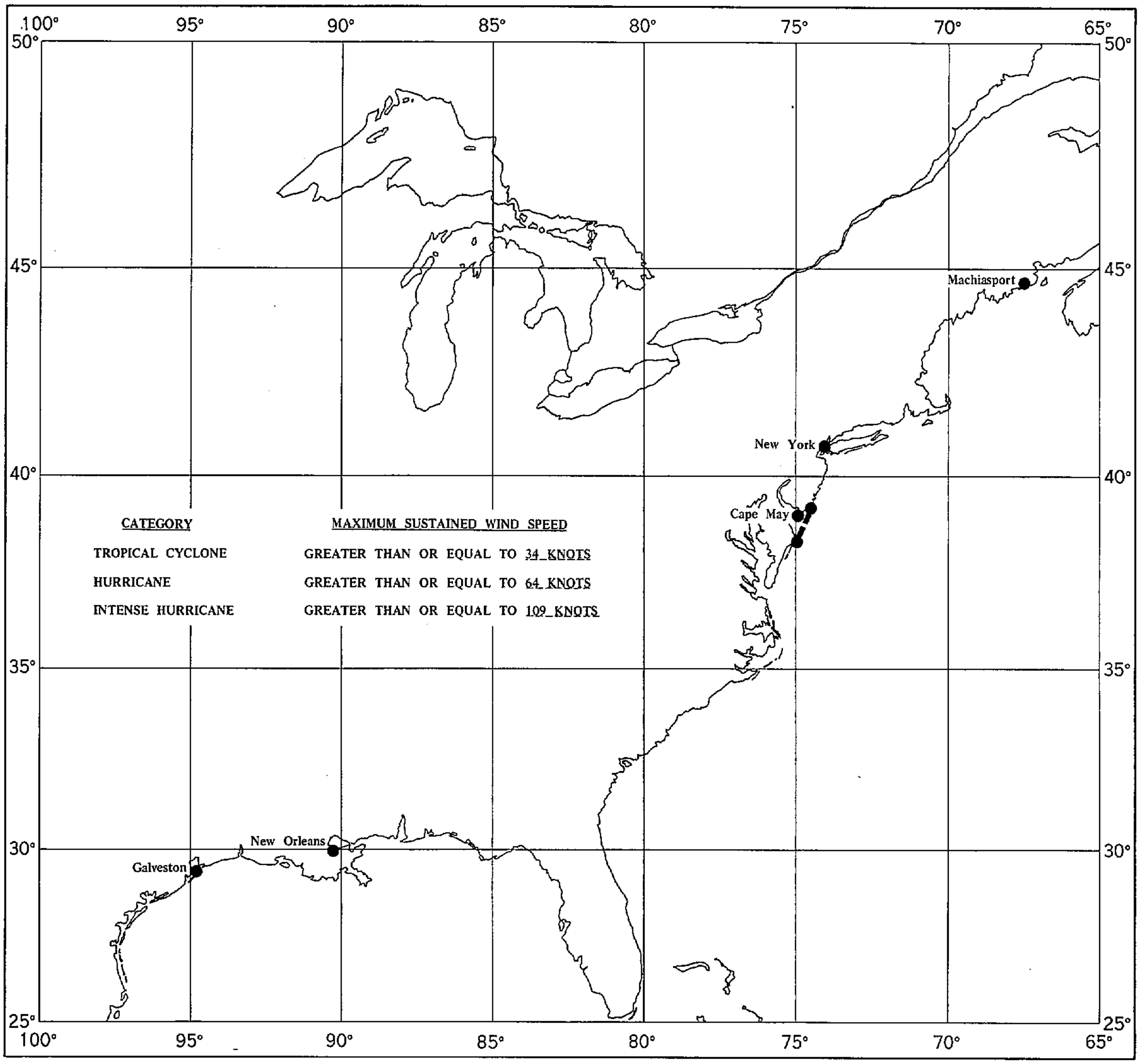
Of the 11 tropical cyclones, three were hurricanes while in the vicinity of the Delaware area. Appendix A contains detailed information of the study area for tropical cyclones.

A summary of tropical cyclones for the Delaware Bay area strike zone is presented in Figure 7.

Winds

Prevailing winds over both the Delaware Bay area and offshore Delaware Bay area are from northwest during the cooler months, November through March, and from a southerly direction May through September. April and October are the transition months of the seasonal wind systems and are quite variable. The average wind speeds during the warmer months are generally lower than during the cold seasons because of the absence of extratropical cyclones. The winds over the ocean area are stronger throughout the year than winds over the Bay area. However, the differences are smaller during the summer period.

In the warmer season, a daily shift in wind direction occurs when the regions are not under the influence of cyclonic storms.



AREA Delaware Bay

	PROBABILITY (%) OF OCCURRENCE IN ANY ONE YEAR	AVERAGE NUMBER OF YEARS BETWEEN OCCURRENCES	TOTAL NUMBER OF OCCURRENCES 1886-1970
TROPICAL CYCLONE	1%	85	1
HURRICANE	1%	85	1
INTENSE HURRICANE	<1%	–	–

Fig. 7 Tropical cyclone strike zone and probabilities for the Delaware Bay area.

During the warmer part of the day winds blow onshore, and during the cooler part, offshore. This land-sea breeze seldom penetrates more than a few miles inland.

Gales (greater than or equal to 34 knots) are reported in about five percent of the observations over the ocean area during winter, and about half that number over the Bay area. Summer gales are rare, but may be encountered during tropical cyclones or local thunderstorms. Again, the frequency of occurrence decreases from ocean to Bay area.

Extreme Winds

As sufficient wind observations are unavailable for the Delaware area, both in time and space, the return values of maximum sustained winds, for the Bay area and the Offshore area, given in the table below, are based primarily on statistical estimates.

DELAWARE BAY AREA

Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Maximum Sustained Wind	63 kts	70 kts	80 kts	92 kts

OFFSHORE DELAWARE BAY AREA

Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Maximum Sustained Wind	71 kts	80 kts	92 kts	100 kts

For example, on the average, there will be a maximum sustained wind speed of 63 knots in the Delaware Bay area once in every five years.

Waves

The distribution of high waves is roughly the same as that for the windiest period for the Delaware area. Maxima for the Delaware Bay area are significantly less because of the combined effects of weaker winds and insufficient fetch.

As with the winds, because there are insufficient observations for a climatological conclusion of significant wave heights, the table below primarily reflects statistical estimates.

DELAWARE BAY AREA

Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Max. Significant Wave Ht.	11 ft	14 ft	17 ft	22 ft
Extreme Wave Height	20 ft	25 ft	30 ft	35 ft

OFFSHORE DELAWARE BAY AREA

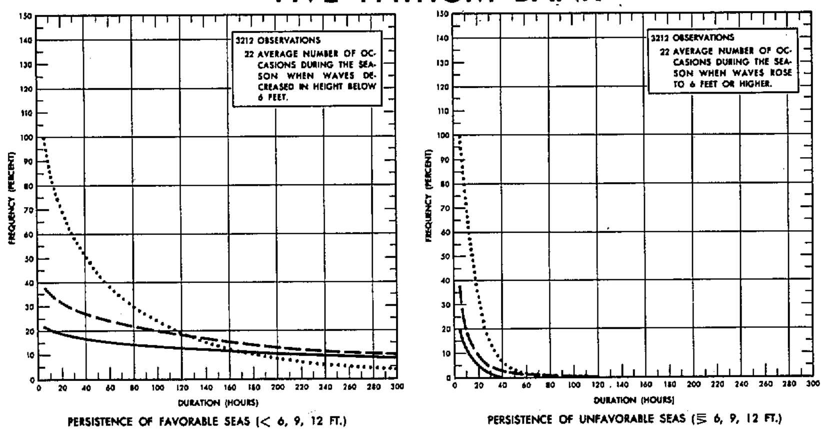
Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Max. Significant Wave Ht.	37 ft	41 ft	47 ft	53 ft
Extreme Wave Height	60 ft	70 ft	85 ft	95 ft

Visibility

Although generally good over the Delaware area, visibility at any time can be hampered by smoke, haze, fog, and precipitation. The frequency of occurrences for visibility less than five miles is greater throughout the year for the Bay area, while the annual range is quite small when compared to the Ocean area.

Advection sea fog occasionally drifts onshore in the warmer months, burning off from the surface and usually lifting by afternoon. This process is reversed over the water area where fog usually dissipates from the top downward. Very shallow steam fog

FIVE FATHOM BANK



WINTER (JANUARY, FEBRUARY, MARCH)

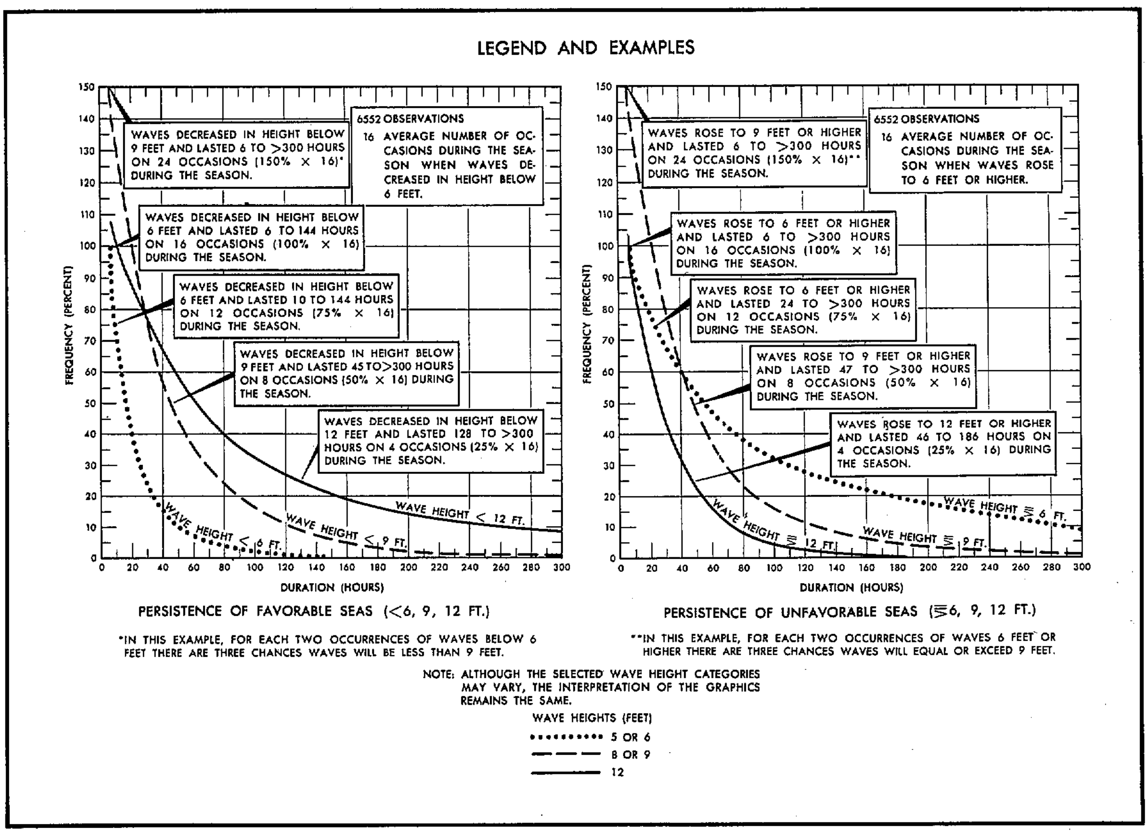
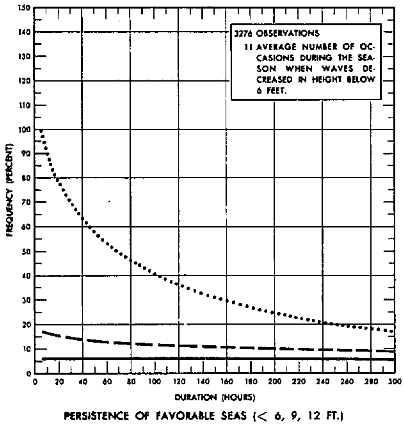
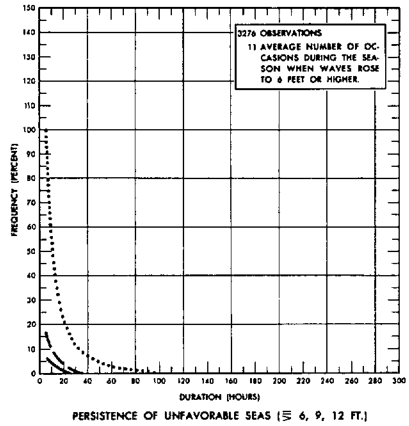


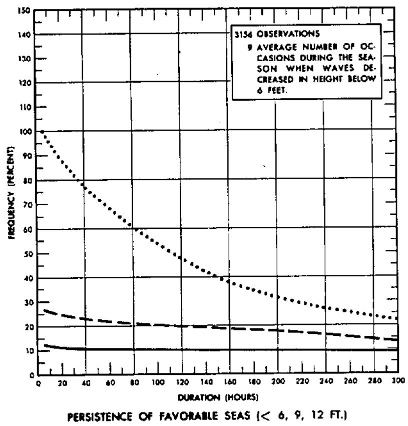
Fig. 8 Persistence of waves of specified heights at Five Fathom Bank.

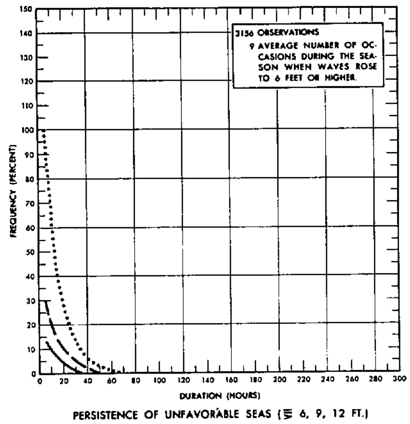
FIVE FATHOM BANK



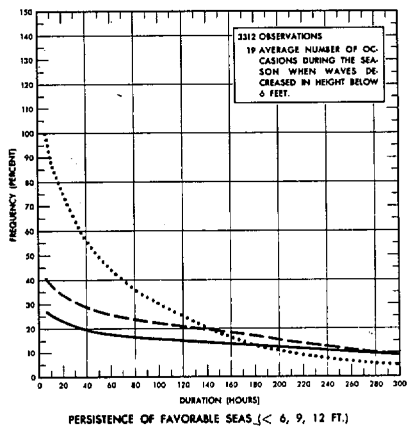


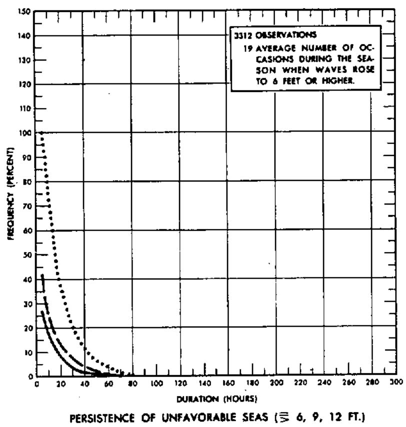
SPRING (APRIL, MAY, JUNE)





SUMMER (JULY, AUGUST, SEPTEMBER)





AUTUMN (OCTOBER, NOVEMBER, DECEMBER)

Fig. 8 (Cont.) Presistence of waves of specified heights at Five Fathom Bank.

is sometimes experienced in the winter. This fog type, which occurs only in very cold weather when the air is much colder than the water, may hide the hull of a ship while leaving the masts and upper rigging plainly visible.

Fog is more likely to form with light to moderate winds. The greatest frequency of fog occurrence coincides with the period of weakest winds. Fogs usually come in with easterly winds and are cleared away by westerly and northerly winds. In the late fall, dense fogs are liable to occur and may last through the forenoons for two or three days in succession. Autumn fogs nearly always clear away before noon. Fog rarely forms or persists with gale force winds. The number of observations reporting fog over the Delaware Bay area is approximately twice that reported over the Ocean area.

Temperature

Temperatures are generally moderate along the Middle Atlantic coast. The Ocean area east of the Delaware Bay area has air temperatures with a slightly higher annual mean, a slightly smaller annual range of the monthly mean, and a significantly smaller annual range of the extreme air temperatures than the Bay area itself. Such differences occur because of the decrease in land effect seaward and because the sea temperatures are typically warmer than air temperatures during the cooler months and cooler than air temperatures during the warmer months. Over a land surface, the air warms and cools readily, but over water it does so more slowly. Land surfaces absorb heat in only a thin surface layer and give it up freely, while water absorbs heat to substantial depths and retains it longer.

The lowest and the highest mean monthly air temperatures for the Bay area occur in January and July, respectively. There is a month delay over the Ocean area; again, because of the oceanic effect.

The daily air temperature range near shore averages from 10° to 20°F throughout the year, and is generally much less over the water, decreasing with distance from shore. Readings rarely exceed 100°F and the 90°F level is reached on only one-third to one-half of the days during summer. Freezing temperatures are probable on one-half or more of the days from November through March. Below-zero readings have been recorded during December, January, and February at most of the nearby coastal stations.

Precipitation

Precipitation over the Delaware area is moderately heavy and well distributed, but having a general decrease seaward throughout the year. The maxima occur in winter, while the minima occur in summer. Summer thunderstorms are more frequent in the coastal area in the afternoon; at night they are more frequent over open water. Thunderstorm rainfall is less intense over the ocean, but can severely restrict visibility. July is the month having the greatest frequency of thunderstorms for the general area.

Snow may be expected from November through March, maximum fall being in January and February. On rare occasions, freezing rain, or glaze, is encountered; if prolonged, it can cause damage to rigging. Snow at sea can be a severe restriction to visibility.

Cloudiness

At sea in winter, overcast conditions are recorded in about 30 percent of the observations, while clear conditions (2/8 or less) are recorded in about 36 percent. In summer, some 20 percent of observations show overcast and about 40 percent clear skies. Over the Bay area, overcast conditions occur with greater frequency throughout the year, while clear skies occur with slightly less frequency.

The least cloudiness for the general area occurs when the air is dominated by the Bermuda High in late summer and early autumn, and the greatest cloudiness during the frequent winter cyclones. The annual mean cloud cover over the sea is about 4/8, with the Bay area being slightly higher.

Relative Humidity

Throughout the year the relative humidity is high, with the annual mean for the Ocean area being greater than the Delaware Bay area. The summer months will average higher for both areas because of the more persistent southerly, weaker winds. Humidities for the coastal area usually increase with onshore winds and decrease with offshore winds.

Tides and Currents - Offshore Delaware Bay

On the outer coast of Delaware, the spring range at Rehoboth Beach is 4.7 feet. Maximum flood and ebb at the Delaware Bay entrance are 1.8 and 1.9 knots, respectively. More detailed information is presented in the following summaries:

Location	Mean Tidal Range (feet)	Spring Tidal Range (feet)	Mean Tide Level (feet)
Five Fathom Bank 38°51'N 74°38'W	4.1	4.9	2.0
Cape May Mun. Pier 38°56'N 74°55'W	4.3	5.2	2.1
Rehoboth Beach 38°43'N 75°05'W	3.9	4.7	1.9

LOCATION	MAXIMUM CURRENTS FLOOD Dir. (deg)	FLOOD Speed (kts)	EBB Dir. (deg)	EBB Speed (kts)
Delaware Bay Entrance 38°48'N 75°01'W	305	1.8	140	1.9
2 miles NE of Cape Henlopen 38°49'N 75°03'W	315	2.0	145	2.3

The highest storm surges off Delaware Bay are probably the result of hurricane passages, though little data are available for confirmation. Extratropical cyclones can also cause considerable surges. The highest surge to be expected in the offshore Delaware Bay area is estimated to be about six feet above mean high water.

Tides and Currents - Delaware Bay

Inside Delaware Bay, spring tidal ranges are about five feet and maximum current speeds about 2.5 knots. Detailed data appear below.

Location	Mean Tidal Range (feet)	Spring Tidal Range (feet)	Mean Tide Level (feet)
Cape Henlopen 38°48'N 75°05'W	4.1	4.9	2.0
Breakwater Harbor 38°47'N 75°05'W	4.1	4.9	2.1

Location	MAXIMUM CURRENTS FLOOD Dir. (deg)	FLOOD Speed (kts)	EBB Dir. (deg)	EBB Speed (kts)
Delaware Bay Entrance 38°48'N 75°01'W	305	1.8	140	1.9
0.3 mile N. of Cape Henlopen 38°48'N 75°05'W	300	2.0	125	2.3

Though the offshore islands serve to protect Delaware Bay from the ranges of extremely large surges, levels of four feet above mean high water have been achieved by the passage of extratropical cyclones. Tropical cyclones can also be expected to produce significant surges.

Strong easterly and southeasterly winds sometimes cause high tide in the Delaware Bay and the Delaware River, resulting in the flooding of lowlands and damage to bay front and river front properties.

STATION: DOVER, DELAWARE
POSITION: 39.2N 75.5W
ELEVATION: 25 FEET

MEANS AND EXTREMES FOR PERIOD Means: 1931-1960; Extremes: Oct 1891-Dec 1896, Jan-Dec 1898, Jun 1906-May 1916, Aug 1919-Dec 1965

Month	Temperature (°F) Means Daily maximum	Daily minimum	Monthly	Extremes Record highest	Year	Record lowest	Year	Mean degree days **	Precipitation Totals (Inches) Mean	Greatest daily	Year	Snow, Sleet Mean	Maximum monthly	Year	Greatest daily	Year	Mean number of days Precip. .10 inch or more	Temperatures Max. 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	Month
(a)	30	30	30	61		61		30	30	61		30	61		61		30	30	30	30	30	
Jan.	44.8	27.8	36.4	76	1950	-7	1935	887	3.70	2.68	1936	4.3	20.5	1940	15.0	1928	7	0	3	22	*	Jan.
Feb.	46.0	27.5	36.8	80	1930	-11	1934	790	3.03	2.30	1936	4.7	22.0	1934	10.0	1936	6	0	3	20	*	Feb.
Mar.	53.6	33.8	43.7	88	1921	7	1934+	660	4.12	3.00	1912	2.8	23.0	1914	8.5	1960+	8	0	1	15	0	Mar.
Apr.	65.1	43.1	54.1	95	1896	14	1923	327	3.42	3.35	1928	T	15.0	1915	15.0	1915	7	*	0	2	0	Apr.
May	75.6	53.3	64.4	98	1914	32	1947	84	4.15	5.40	1948	0	0	0	0	0	8	1	0	0	0	May
June	83.7	62.3	72.9	101	1914	41	1938	6	3.46	3.96	1943	0	0	0	0	0	6	7	0	0	0	June
July	87.4	66.9	77.1	104	1936+	45	1963	0	4.67	4.52	1938	0	0	0	0	0	6	11	0	0	0	July
Aug.	85.4	65.4	75.4	100	1953+	47	1925	0	5.73	7.42	1919	0	0	0	0	0	7	8	0	0	0	Aug.
Sept.	79.8	58.9	69.4	99	1953	33	1947	27	3.81	6.33	1960	0	0	0	0	0	5	3	0	0	0	Sept.
Oct.	69.3	48.1	58.7	95	1941	25	1909	220	3.27	3.30	1910	T	3.0	1940+	3.0	1940+	5	*	0	1	0	Oct.
Nov.	57.9	37.9	47.9	85	1950	11	1938	513	3.67	3.35	1950	0.7	10.0	1953	7.0	1953	6	0	*	10	0	Nov.
Dec.	46.7	29.1	37.9	74	1964	-3	1942	840	3.11	2.40	1909	3.0	25.0	1909	24.0	1909	6	0	3	20	*	Dec.
Year	66.3	46.2	56.2	104	1936+	-11	1934	4354	46.14	7.42	1919	15.5	25.0	1909	24.0	1909	77	31	10	90	*	Year

(a) Average length of record, years.

T Trace, an amount too small to measure.

** Base 65°F

+ Also on earlier dates, months, or years.

* Less than one half.

Table 9 Land station climatological data summary for DOVER, DELAWARE.

STATION: WILMINGTON, DELAWARE
POSITION: 39.7N 75.6W
ELEVATION: 74 FEET

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	23		23		(b)	(b)	23		23		23	
J	41.3	25.5	33.4	75	1950	-4	1957	980	3.40	5.55	1949	0.59	1955	1.61	1968
F	42.4	25.2	33.8	74	1954+	-4	1961	874	2.95	4.90	1966	1.52	1968	2.29	1966
M	50.5	32.0	41.3	86	1948	9	1960	735	4.02	5.72	1953	0.81	1966	2.75	1958
A	62.5	41.6	52.1	89	1960	22	1965	387	3.33	5.97	1964	1.12	1963	2.56	1961
M	73.4	52.0	62.7	95	1962	32	1966	112	3.53	7.35	1948	0.22	1964	2.35	1968
J	81.8	61.0	71.4	99	1952	44	1966+	6	4.07	6.34	1955	0.44	1954	2.67	1955
J	86.2	65.8	76.0	102	1966+	50	1952	0	4.25	7.51	1958	0.16	1955	6.24	1952
A	84.2	64.3	74.3	101	1955+	46	1965	0	5.59	12.09	1955	1.17	1968	4.00	1955
S	77.9	57.3	67.6	100	1953	37	1963+	51	3.95	9.53	1960	0.82	1970	5.62	1960
O	67.3	45.9	56.6	91	1951	24	1969	270	2.91	5.17	1966	0.21	1963	3.88	1966
N	55.1	35.7	45.4	85	1950	14	1955	588	3.53	7.32	1951	0.94	1965	3.83	1956
D	43.5	26.7	35.1	72	1966	3	1962	927	3.03	7.90	1969	0.19	1955	2.22	1969
YR	63.8	44.4	54.1	102	JUL. 1966+	-4	FEB. 1961+	4930	44.56	12.09	AUG. 1955	0.16	JUL. 1955	6.24	JUL. 1952

Month	Precipitation: Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity: Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Wind &: Mean speed	Prevailing direction	Fastest mile: Speed	Direction	Year
(a)	23	23		23		23	23	23	23	22	16	22	22	
J	6.0	17.2	1966	11.2	1966	74	75	61	69	9.8	WNW	46	29	1957
F	6.0	18.7	1967	9.9	1967	73	75	59	67	10.5	NW	46	29	1956
M	4.3	20.3	1958	15.6	1958	73	75	54	64	11.1	WNW	43	16	1952
A	0.1	1.1	1959	1.1	1959	75	74	51	62	10.4	WNW	45	29	1963+
M	T	T	1963	T	1963	79	76	53	64	8.9	S	45	27	1957
J	0.0	0.0		0.0		83	78	53	66	8.3	S	40	23	1960
J	0.0	0.0		0.0		84	81	54	67	7.6	NW	48	27	1963
A	0.0	0.0		0.0		86	84	56	71	7.3	S	40	02	1960+
S	0.0	0.0		0.0		85	85	54	72	7.9	S	40	07	1956
O	T	0.3	1962	0.3	1962	83	84	53	71	8.1	NW	58	20	1954
N	1.3	11.9	1953	11.9	1953	79	81	56	70	9.1	NW	46	16	1950
D	4.7	21.5	1966	12.4	1966	76	77	60	70	9.3	WNW	44	29	1962
YR	22.4	21.5	DEC. 1966	15.6	MAR. 1958	79	79	55	68	9.0	NW	58	20	OCT. 1954

Month	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures Max.: 90° and above ‡	Max.: 32° and below	Min.: 32° and below	Min.: 0° and below	Average daily solar radiation - langleys
(a)		23	23	23	23	23	23	23	23	23	23	23	23	
J		6.5	8	7	16	11	2	*	4	0	7	26	*	
F		6.4	7	7	14	9	2	*	4	0	4	23	*	
M		6.3	8	8	15	12	1	1	3	0	1	17	0	
A		6.5	7	8	15	11	*	2	3	0	0	3	0	
M		6.5	6	11	14	11	0	4	3	1	0	*	0	
J		5.9	8	11	11	9	0	6	2	4	0	0	0	
J		6.1	7	12	12	9	0	6	2	8	0	0	0	
A		5.8	9	10	12	9	0	6	3	5	0	0	0	
S		5.5	10	9	11	7	0	2	3	2	0	0	0	
O		5.3	12	7	12	7	0	1	4	*	0	2	0	
N		6.2	8	9	13	9	*	1	4	0	*	11	0	
D		6.3	8	8	15	10	1	*	4	0	5	23	0	
YR		6.1	98	107	160	115	6	31	40	19	16	104	*	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 107 in August 1918; lowest temperature -15 in February 1934; maximum monthly precipitation 14.91 in August 1911; minimum monthly precipitation 0.06 in October 1924; maximum precipitation in 24 hours 6.53 in August 1945; maximum monthly snowfall 27.0 in January 1935; maximum snowfall in 24 hours 22.0 in December 1909.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≦ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

Table 10 Land station climatological data summary for WILMINGTON, DELAWARE.

STATION: ATLANTIC CITY, NEW JRESEY
POSITION: 39.5N 74.6W
ELEVATION: 64 FEET

NORMALS, MEANS, AND EXTREMES

Month	Temperature – Normal – Daily maximum	Temperature – Normal – Daily minimum	Temperature – Normal – Monthly	Temperature – Extremes Ø – Record highest	Year	Temperature – Extremes Ø – Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation % – Normal total	Precipitation – Maximum monthly $	Year	Precipitation – Minimum monthly $	Year	Precipitation – Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	6		6		(b)	(b)	27		27		27	
J	42.9	26.6	34.8	78	1967	-8	1965	936	3.56	7.71	1948	0.26	1955	2.86	1944
F	43.3	26.1	34.7	69	1965	-7	1967	848	3.13	5.98	1958	1.46	1946	2.59	1966
M	49.7	32.4	41.1	81	1968	7	1967	741	3.91	6.80	1953	0.62	1945	2.27	1968
A	60.3	41.7	51.0	94	1969	12	1969	420	3.41	7.95	1952	1.24	1945	3.37	1952
M	71.0	51.5	61.3	99	1969	25	1966	133	3.51	11.51	1948	0.40	1957	4.15	1959
J	79.2	60.7	70.0	106	1969	37	1967	15	2.83	6.36	1970	0.10	1954	2.91	1952
J	83.8	66.3	75.1	104	1966	46	1965	0	3.72	13.09	1959	1.30	1957	6.46	1959
A	82.2	65.1	73.7	97	1968	40	1965	0	4.90	11.98	1967	0.34	1943	6.40	1966
S	76.0	58.4	67.2	93	1970+	32	1969+	39	3.31	6.27	1966	0.41	1970	3.98	1954
O	66.5	47.8	57.2	87	1967	23	1969	251	3.20	7.50	1943	0.15	1963	2.95	1958
N	55.5	37.9	46.7	76	1965	11	1964	549	3.66	8.60	1944	0.72	1946	3.93	1953
D	45.1	28.1	36.6	72	1966	0	1968	880	3.22	7.33	1969	0.62	1955	2.75	1951
YR	63.0	45.2	54.1	106	JUN. 1969	-8	JAN. 1965	4812	42.36	13.09	JUL. 1959	0.10	JUN. 1954	6.46	JUL. 1959

Month	Snow, Ice pellets – Mean total	Snow, Ice pellets – Maximum monthly	Year	Snow, Ice pellets – Maximum in 24 hrs.	Year	Relative humidity – Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Wind & – Mean speed	Wind – Prevailing direction	Wind – Fastest mile – Speed	Fastest mile – Direction	Fastest mile – Year
(a)	26	26		26		6	6	6	6	12	5	11	11	
J	5.2	15.9	1961	14.4	1964	75	77	58	70	12.3	WNW	37	29	1963
F	5.3	35.2	1967	13.1	1967	73	76	56	66	12.4	W	43	27	1960
M	3.6	17.6	1969	11.5	1969	76	78	54	66	12.4	WNW	44	30	1964+
A	0.3	3.2	1965	3.2	1965	78	76	51	66	12.1	S	46	07	1961
M	0.0	0.0		0.0		81	75	52	66	10.8	S	32	22	1966
J	0.0	0.0		0.0		88	83	56	72	9.8	S	37	29	1964+
J	0.0	0.0		0.0		89	86	59	74	9.2	S	37	26	1970+
A	0.0	0.0		0.0		90	86	56	75	9.0	S	32	32	1963
S	0.0	0.0		0.0		89	86	54	77	9.7	ENE	60	32	1960
O	T	T	1962+	T	1962+	86	86	54	76	10.1	W	41	29	1961
N	0.5	7.8	1967	7.8	1967	81	84	57	75	11.5	W	40	27	1960
D	2.8	8.6	1960	7.5	1960	76	79	59	72	11.6	WNW	55	36	1960
YR	17.7	35.2	FEB. 1967	14.4	JAN. 1964	82	81	55	71	10.9	S	60	32	SEP. 1960

Month	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days – Sunrise to sunset – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures – Max. – 90° and above ‡	Temperatures – Max. – 32° and below	Temperatures – Min. – 32° and below	Temperatures – Min. – 0° and below	Average daily solar radiation - langleys
(a)	10	12	12	12	12	27	26	12	12	6	6	6	6	
J	54	5.9	10	7	14	11	1	*	3	0	9	26	1	
F	50	6.4	7	6	15	10	2	*	4	0	6	23	1	
M	53	6.0	9	8	14	11	1	1	4	0	1	20	0	
A	51	6.4	7	9	14	11	*	2	4	*	0	7	0	
M	56	6.2	7	12	12	10	0	4	4	1	0	1	0	
J	61	5.9	8	11	11	9	0	5	4	5	0	0	0	
J	57	6.4	7	9	15	9	0	6	5	5	0	0	0	
A	62	6.0	8	10	13	9	0	5	3	5	0	0	0	
S	61	5.4	11	8	11	7	0	1	3	2	0	*	0	
O	60	5.1	12	8	11	7	0	1	5	0	0	4	0	
N	51	6.1	8	9	13	9	*	1	3	0	*	14	0	
D	46	6.2	9	8	14	9	1	*	4	0	3	24	*	
YR	55	6.0	103	105	157	112	5	26	46	19	19	118	2	

Ø For period November 1964 through the current year.
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Lowest temperature -9 in February 1934; maximum monthly precipitation 14.87 in August 1882; minimum monthly precipitation .01 in September 1941; maximum precipitation in 24 hours 9.21 in October 1903; maximum snowfall in 24 hours 18.0 in February 1902.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

% Based on U.S. Naval Air Station and Weather Bureau Airport Station records.

$ Beginning with August 1943.

Table 11 Land station climatological data summary for ATLANTIC CITY, NEW JERSEY.

ENVIRONMENTAL DATA SUMMARY (PART 1)

AREA: Delaware Bay

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WIND SPEED (KNOTS)													
01% ≤	2	2	2	2	2	2	1	1	1	2	2	3	2
Mean	11.1	11.2	11.3	10.4	9.0	8.3	7.9	7.8	8.5	9.2	10.2	10.3	9.6
99% ≤	37	35	37	32	25	24	22	22	24	33	36	36	30
Maximum observed (1871 - 1971)	Winds near 90 knots have probably occurred over Delaware Bay												
≥ 34 Knots (% freq.)	2.7	2.5	1.8	0.8	0.2	0.1	0.2	0.3	0.5	1.0	1.4	1.8	1.1
≥ 41 Knots (% freq.)	0.7	0.7	0.5	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.5	0.3
Prevailing direction	NW	NW	NW	NW	SW	SW	SW	SW	S	N	NW	W	W
WAVES (FEET)													
01% ≤	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean	3	3	3	2	2	2	1	1	2	3	3	3	2
99% ≤	11	10	10	9	9	8	7	6	8	9	10	10	9
≥ 12 Feet (% freq.)	1.0	+	+	+	+	0.0	0.0	+	+	+	+	+	0.1
≥ 20 Feet (% freq.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+	0.0	0.0	0.0	+
VISIBILITY (% FREQ.)													
Visibility <½ N. mile	2.0	2.1	1.9	2.6	3.0	2.7	1.0	0.7	0.8	1.2	1.5	1.9	1.8
Visibility <1 N. mile	3.8	3.9	3.3	3.7	4.1	3.6	1.6	1.4	1.5	2.3	2.4	3.2	2.9
Visibility <2 N. miles	6.7	6.8	5.9	5.9	5.9	5.5	3.1	3.3	3.6	4.2	4.5	6.0	5.6
Visibility <5 N. miles	17.3	18.0	16.1	15.2	14.9	17.7	14.5	16.9	15.5	14.4	14.8	17.4	16.1
Visibility <10 N. miles	48.3	49.2	46.4	49.7	48.8	56.8	55.4	57.1	50.4	44.1	45.3	47.5	50.0

\+ = less than 0.05%

Table. 12 Environmental data summary; Delaware Bay area.

ENVIRONMENTAL DATA SUMMARY (PART 2)

AREA: Delaware Bay

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
FOG													
Occurrence of fog (% freq.)	7.4	11.2	11.1	12.4	13.0	13.1	9.7	10.3	10.8	10.3	9.2	10.6	11.1
Mean number of hours operation of fog signals *	57	69	53	35	32	25	17	18	16	22	31	53	428
Maximum number of hours operation of fog signals for any year (annual only)*													840
WEATHER & CLOUDS (% FREQ.)													
Precipitation	11.3	11.1	11.0	9.1	7.3	5.6	4.8	5.3	6.3	6.4	8.5	10.0	8.1
Freezing precipitation	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Frozen precipitation	3.4	2.8	1.9	0.3	0.0	+	0.0	0.0	0.0	0.0	0.4	2.0	0.9
Thunder & lightning	0.2	0.1	0.2	0.5	1.2	1.3	1.8	1.6	0.7	0.2	0.3	0.1	0.7
Sky ≤2/8	34.4	35.2	39.2	36.8	36.2	37.9	37.1	38.0	43.2	46.1	38.5	34.5	38.2
Sky overcast (8/8)	38.7	37.6	34.1	33.4	30.8	25.1	23.2	23.8	25.1	25.3	30.1	35.3	30.1
Sky obscured	5.1	6.6	8.2	9.6	12.4	11.4	4.7	3.1	2.5	2.2	2.1	2.7	6.0
Low cloud overcast	26.0	23.9	19.7	17.5	16.1	12.5	10.5	11.9	13.3	13.7	17.3	21.3	17.0
Mean cloud cover (eighths)	4.9	5.0	4.8	4.8	4.8	4.5	4.6	4.5	4.2	3.9	4.7	4.9	4.6
AIR TEMPERATURE (°F)													
Minimum	-8	-7	7	12	25	37	46	40	32	23	11	0	-8
01% ≤	16	17	25	30	46	55	65	63	53	41	30	19	39
Mean	36.0	36.4	51.4	51.6	61.1	70.0	75.5	74.2	68.2	58.3	48.2	38.2	56.1
99% ≤	53	54	73	75	78	87	90	88	87	72	61	53	73
Maximum	78	76	87	89	99	106	104	101	100	91	85	75	106
≤ 32 °F (% freq.)	60.5	68.9	30.6	8.4	+	0.0	0.0	0.0	0.1	0.2	21.9	57.0	20.6
≥ 85 °F (% freq.)	0.0	0.0	0.2	0.3	0.7	19.8	28.0	20.3	10.0	0.3	+	0.0	6.6

*Mean of Miah Maull, Ship John and Delaware Bay Shoals fog signals   + = less than 0.05%

Table 12 Continued.

ENVIRONMENTAL DATA SUMMARY (PART 3)

AREA: Delaware Bay

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
RELATIVE HUMIDITY (%)													
Mean	72	71	71	71	73	76	77	77	77	76	74	73	74
SEA TEMPERATURE (°F)													
Minimum	28	28	27	33	40	41	54	57	56	46	38	28	27
01% ≤	28	29	33	39	42	53	63	65	58	51	44	34	45
Mean	41.2	39.8	42.5	48.6	56.7	65.8	72.0	73.4	71.0	62.9	54.2	45.5	56.1
99% ≤	57	57	60	70	72	78	82	82	80	74	65	58	70
Maximum	80	78	76	80	84	88	90	88	90	84	82	80	90
SALINITY (‰)													
Minimum	20.6	21.6	21.6	20.6	20.8	20.0	25.5	22.2	25.4	23.0	22.6	22.4	20.0
Mean	29.7	29.8	29.5	29.2	29.6	30.0	30.8	30.8	30.7	30.7	30.5	30.0	30.1
Maximum	34.5	34.1	33.6	34.2	34.6	35.0	34.6	34.1	34.1	34.0	34.1	33.6	35.0
DENSITY (ρ)													
Mean (σ_t)*	22.0	22.1	21.9	21.7	22.1	22.4	22.9	22.8	22.7	22.8	22.7	22.3	22.4
SEA-LEVEL PRESSURE (mb)													
Minimum	977	972	971	981	991	992	977	976	985	993	979	979	971
01% ≤	993	988	992	994	1000	1001	1002	1002	1001	998	994	995	997
Mean	1019	1018	1016	1015	1016	1015	1016	1016	1019	1018	1018	1019	1017
99% ≤	1042	1041	1038	1035	1034	1032	1029	1030	1036	1034	1039	1039	1036
Maximum	1045	1044	1042	1040	1037	1038	1031	1041	1043	1040	1040	1043	1045

* $\sigma_t = (\rho - 1) \times 10^3$; ρ = gm cm^{-3}

Table 12 Continued.

ENVIRONMENTAL DATA SUMMARY (PART 1)

AREA: Offshore Delaware Bay

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WIND SPEED (KNOTS)													
01% ≤	3	3	3	3	2	2	2	3	2	3	3	4	3
Mean	15.7	14.6	14.0	12.1	10.6	10.0	9.9	10.3	11.6	13.5	14.6	15.0	12.6
99% ≤	45	44	40	38	31	30	30	31	32	38	43	44	37
Maximum observed (1871 - 1971)	Winds in excess of 100 knots have been recorded in Hurricanes and Northeasters.												
≥ 34 Knots (% freq.)	4.6	3.0	3.2	1.3	0.5	0.2	0.4	0.6	0.6	2.2	2.3	2.9	1.8
≥ 41 Knots (% freq.)	1.1	1.1	1.0	0.1	0.1	0.1	0.2	0.3	0.1	0.8	1.1	1.2	0.6
Prevailing direction	NW	NW	NW	S	S	S	S	S	NE	N	NW	NW	SW
WAVES (FEET)													
01% ≤	0	0	0	1	0	0	0	0	0	0	1	0	< ¼
Mean	4	4	4	3	3	3	3	3	3	4	4	4	4
99% ≤	18	18	15	14	11	10	9	12	17	14	16	15	14
≥ 12 Feet (% freq.)	3.7	4.9	3.9	2.0	1.0	0.8	0.2	1.1	1.7	4.0	2.7	3.4	2.5
≥ 20 Feet (% freq.)	0.2	0.6	0.5	0.2	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2
VISIBILITY (% FREQ.)													
Visibility <½ N. mile	1.9	2.4	3.1	6.1	6.2	4.6	1.1	0.5	0.6	0.9	0.5	1.2	2.4
Visibility <1 N. mile	2.8	3.6	4.1	6.9	7.8	5.3	1.7	0.7	0.9	1.5	0.6	1.6	3.1
Visibility <2 N. miles	3.5	4.7	4.7	8.4	9.9	6.9	2.5	1.4	1.3	2.2	1.1	2.2	4.1
Visibility <5 N. miles	8.2	9.1	11.4	14.9	16.6	15.8	10.3	8.6	4.8	6.2	4.1	5.9	9.7
Visibility <10 N. miles	32.9	32.8	37.1	39.5	48.4	48.0	44.8	43.0	28.9	27.1	24.7	26.2	36.2

+ = less than 0.05%

Table. 13 Environmental data summary; Offshore Delaware Bay area.

ENVIRONMENTAL DATA SUMMARY (PART 2)

AREA: Offshore Delaware Bay

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
FOG													
Occurrence of fog (% freq.)	3.7	4.9	5.6	12.0	13.4	11.2	5.8	2.9	3.4	3.3	2.1	2.9	5.9
Mean number of hours operation of fog signals *	41	61	59	55	41	45	32	22	29	28	21	41	475
Maximum number of hours operation of fog signals for any year (annual only)*													1059
WEATHER & CLOUDS (% FREQ.)													
Precipitation	6.9	7.9	7.8	5.1	6.0	3.6	4.0	4.2	3.5	5.6	6.3	7.3	5.7
Freezing precipitation	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+
Frozen precipitation	1.6	1.5	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.5
Thunder & lightning	0.2	0.2	0.2	0.4	1.0	1.5	1.9	1.2	0.7	0.1	0.3	0.0	0.6
Sky ≤2/8	37.2	38.3	43.5	44.3	45.3	42.3	36.4	40.2	42.9	43.4	39.0	35.4	40.7
Sky overcast (8/8)	31.6	29.1	24.9	23.8	21.5	19.2	21.4	18.8	19.2	25.7	24.6	27.9	24.0
Sky obscured	2.3	3.5	4.5	5.2	7.0	5.7	2.6	1.4	1.0	1.0	0.8	1.1	3.0
Low cloud overcast	23.8	21.2	20.4	16.8	15.4	12.0	11.6	11.2	12.0	18.1	16.3	19.6	16.5
Mean cloud cover (eighths)	4.4	4.2	3.9	3.9	3.8	3.9	4.2	3.9	3.7	3.8	4.1	4.4	4.0
AIR TEMPERATURE (°F)													
Minimum	3	12	20	32	36	35	61	61	40	39	27	16	3
01% ≤	18	16	27	36	45	55	64	66	56	45	33	22	40
Mean	39.9	39.8	43.1	49.2	57.3	67.8	74.8	75.4	70.6	61.9	53.6	44.2	56.3
99% ≤	60	58	60	64	72	80	86	85	83	76	68	62	71
Maximum	75	77	77	80	96	88	93	92	93	99	80	74	99
≤ 32 °F (% freq.)	23.0	16.3	4.5	+	0.0	0.0	0.0	0.0	0.0	0.0	0.6	10.0	4.5
≥ 85 °F (% freq.)	0.0	0.0	0.0	0.0	0.2	0.3	2.5	1.0	0.8	+	0.0	0.0	0.4

* Brandywine and Delaware Shoals fog signals + = less than 0.05%

Table 13 Continued

ENVIRONMENTAL DATA SUMMARY (PART 3)

AREA: Offshore Delaware Bay

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
RELATIVE HUMIDITY (%)													
Mean	80	80	81	84	86	85	85	84	81	80	78	78	82
SEA TEMPERATURE (°F)													
Minimum	30	28	27	33	40	41	59	60	56	50	42	34	27
01% ≤	33	33	35	39	42	53	64	66	59	53	48	40	47
Mean	45.1	43.4	43.0	46.6	54.1	64.7	73.0	75.1	71.3	64.2	57.7	51.1	57.4
99% ≤	66	65	64	70	72	78	84	84	81	76	71	68	73
Maximum	80	78	76	80	84	88	90	88	90	84	82	80	90
SALINITY (‰)													
Minimum	27.1	27.5	27.5	27.3	27.1	26.8	28.6	28.5	27.8	27.7	28.0	28.0	26.8
Mean	31.4	31.4	31.2	31.1	31.4	31.6	31.9	31.6	31.6	31.6	31.5	31.4	31.5
Maximum	34.5	34.1	33.6	34.2	34.6	35.0	34.6	34.1	34.1	34.0	34.1	33.6	35.0
DENSITY (ρ)													
Mean (σ_t)*	23.1	23.2	23.1	23.0	23.2	23.5	23.6	23.5	23.4	23.4	23.4	23.2	23.3
SEA-LEVEL PRESSURE (mb)													
Minimum	977	980	981	985	995	997	981	976	990	957	981	988	957
01% ≤	994	990	992	994	1001	1001	1002	1003	1002	998	995	997	997
Mean	1018	1017	1016	1016	1017	1016	1017	1016	1018	1018	1018	1019	1017
99% ≤	1037	1038	1035	1033	1033	1029	1027	1026	1031	1033	1034	1037	1033
Maximum	1044	1044	1045	1039	1040	1030	1034	1032	1041	1040	1040	1043	1045

* $\sigma_t = (\rho - 1) \times 10^3$; ρ = gm cm^{-3}

Table 13 Continued.

General Description

The Mississippi Delta area is primarily marsh delta land with numerous bayous, canals, and drainage ditches. The natural elevations vary from a few feet below to a few feet above mean sea level. The Mississippi River flows in a winding but general southeast direction, emptying into the north central part of the Gulf of Mexico through a number of mouths or passes which, when taken together, form the delta of the river.

The shape of the delta is somewhat like the foot of a bird (see Fig. 9), with its four toelike extensions protruding into the Gulf. The passes consist of narrow-banked deposits of sand and clay brought down by the river current which continuously adds them to the seaward margins of the delta. In this manner the delta is being built seaward at an estimated average rate of 300 feet a year.

The discolored water discharge from the Mississippi River usually provides mariners with their first indication that they are approaching land. During high-river stages and with northerly winds the discolored water will be encountered in some directions 60 miles or more from land.

Numerous oil-well structures and appurtenances are located offshore between the Mississippi River Delta and Galveston Bay, extending as far as the 35-fathom curve, and as far as 70 miles offshore.

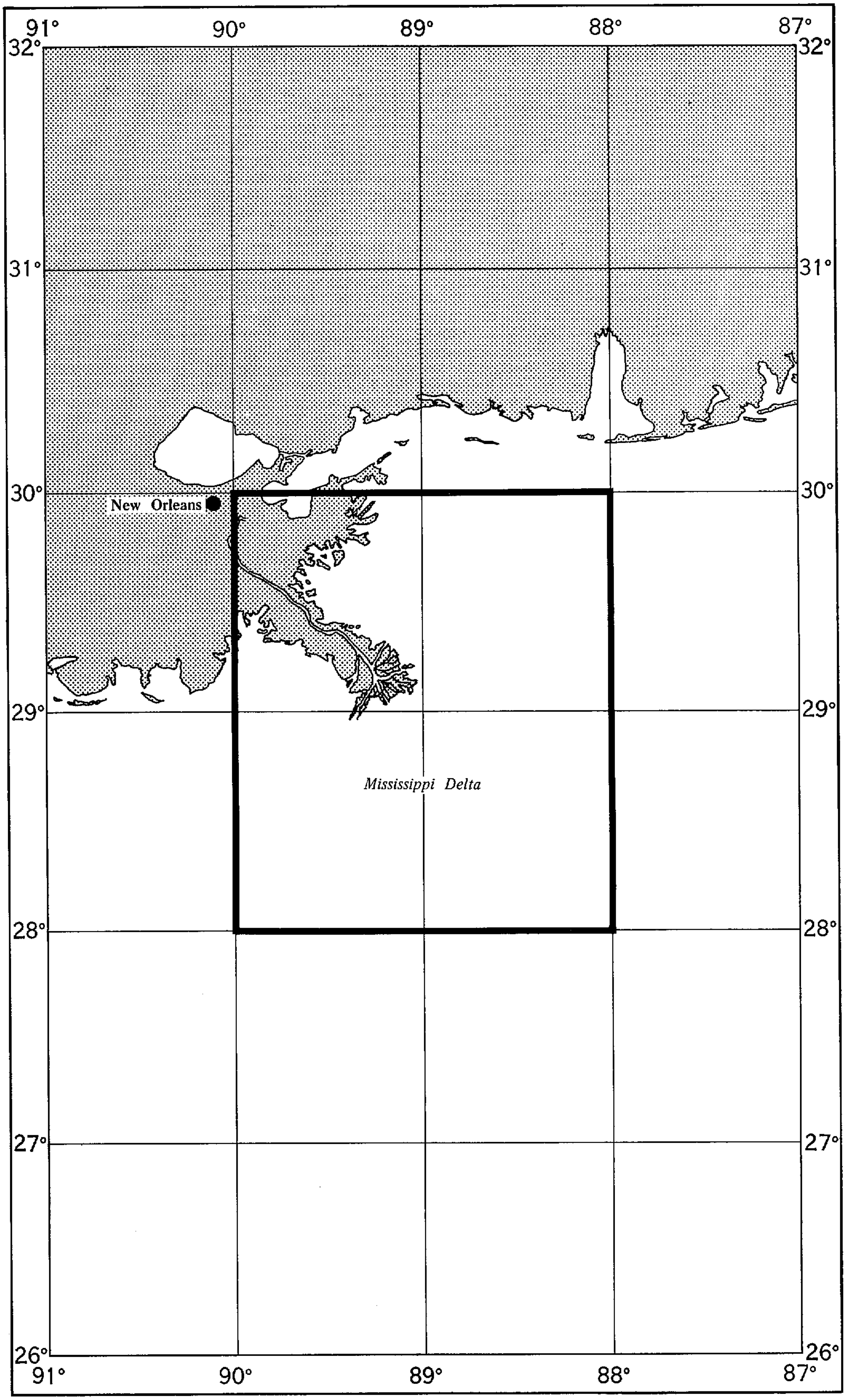


Fig. 9 Mississippi Delta area map.

Periodic tides in the Gulf area usually are small and may, therefore, be greatly modified and sometimes obliterated by fluctuations in the water surface due to winds or other meteorological conditions. Along the northern shore of the Gulf from St. George Sound to the Rio Grande the tide is generally diurnal and the mean range is less than two feet,. However, wind generated fluctuations of 3.5 feet below to four feet above the plane of reference are not uncommon.

Tidal currents are generally weak in the open Gulf, but at times they are strong near shore, in the vicinities of shoals, and in the entrances to harbors.

Wind-driven currents are very complex. Their speeds and directions depend upon a number of factors such as the speed, direction, and duration of the wind, the proximity of the coast and the orientation of the coastline.

THE ENVIRONMENT

The climate of the Delta area is influenced by the many water surfaces provided by the numerous lakes, streams, and canals, and by the proximity to the Gulf of Mexico. Throughout the year, these water areas modify the humidity and temperature conditions, decreasing the range between extremes; when southerly winds prevail, these effects are increased, imparting the characteristics of a marine climate.

From June to September, the prevailing southeast to southwesterly winds carry warm, moist air inland. This is favorable for sporadic, often quite localized, development of thunderstorms.

From November to March, the area is subjected alternately to tropical air and cold continental air in periods of varying length.

From December to May or June, the Mississippi River waters are colder than the air temperature, favoring the formation of river fogs, particularly with weak, southerly winds. With such winds, fog may be encountered anywhere from 60 miles off the Delta passes to the city of New Orleans.

Pressure

The general circulation of air over the Mississippi Delta area follows the sweep of the western extension of the Bermuda High during the spring and summer months. High pressure systems over the North American continent modify the pattern for the remaining months until spring, when the western extension of the Bermuda High again emerges as the dominant control over the Delta area. The monthly mean pressures range from a maximum of 1020 millibars in December and January to a minimum of 1015 in September.

The Bermuda High has greater constancy that the continental high pressure systems so that in late spring and summer it maintains a rather steady flow of warm moist air which, to a large degree, controls the climate over the Delta area during these seasons. Accordingly, spells of good weather tend to be longer during these seasons than during the late fall, winter, and early spring.

There is an obvious diurnal pressure variation, with early morning (4 a.m.) and late afternoon (4 p.m.) minima and late morning (10 a.m.) and night (10 p.m.) maxima. This regular pattern is masked at times by the larger pressure changes associated with storms of continental origin and tropical cyclones that reach the area. However, during the more settled weather of the summer and early fall, and during periods of steady weather conditions at other times of the year, the occurrence of a diurnal pressure change is so characteristic that an interruption of the pattern is generally considered to be an indication of a change in the weather and possibly the approach of a tropical cyclone.

Extratropical Cyclones

Some 30 to 40 polar air masses penetrate the Gulf of Mexico from the North American continent each winter. During the year some 15 to 20 of these bring strong northerly winds to the Gulf area and are called "Northers." Winds from 25 to 50 knots or more may occur in severe northers of the Gulf. Northers ordinarily occur from November to March. Severe northers usually occur from December to February, but occasionally later. They generally last about a day and a half, but severe storms may endure for three or four days.

Tropical Cyclones

Of the large number of tropical cyclones originating in the North Atlantic and Caribbean Sea that enter the Gulf of Mexico, combined with those which are born in the Gulf area, many strike some part of the northern Gulf coast. Some of these storms find their way into or near the Mississippi Delta area, causing wind and water damage.

Since 1900 the centers of three great hurricanes have passed over the New Orleans area. Numerous other hurricanes have affected the Delta area. In 1965, Hurricane Betsy brought destructive winds to that area and caused over 50 deaths from drowning. Extreme winds of Betsy were estimated at 108 knots. Camille, which struck the area in 1969, was the greatest hurricane ever recorded in North America.

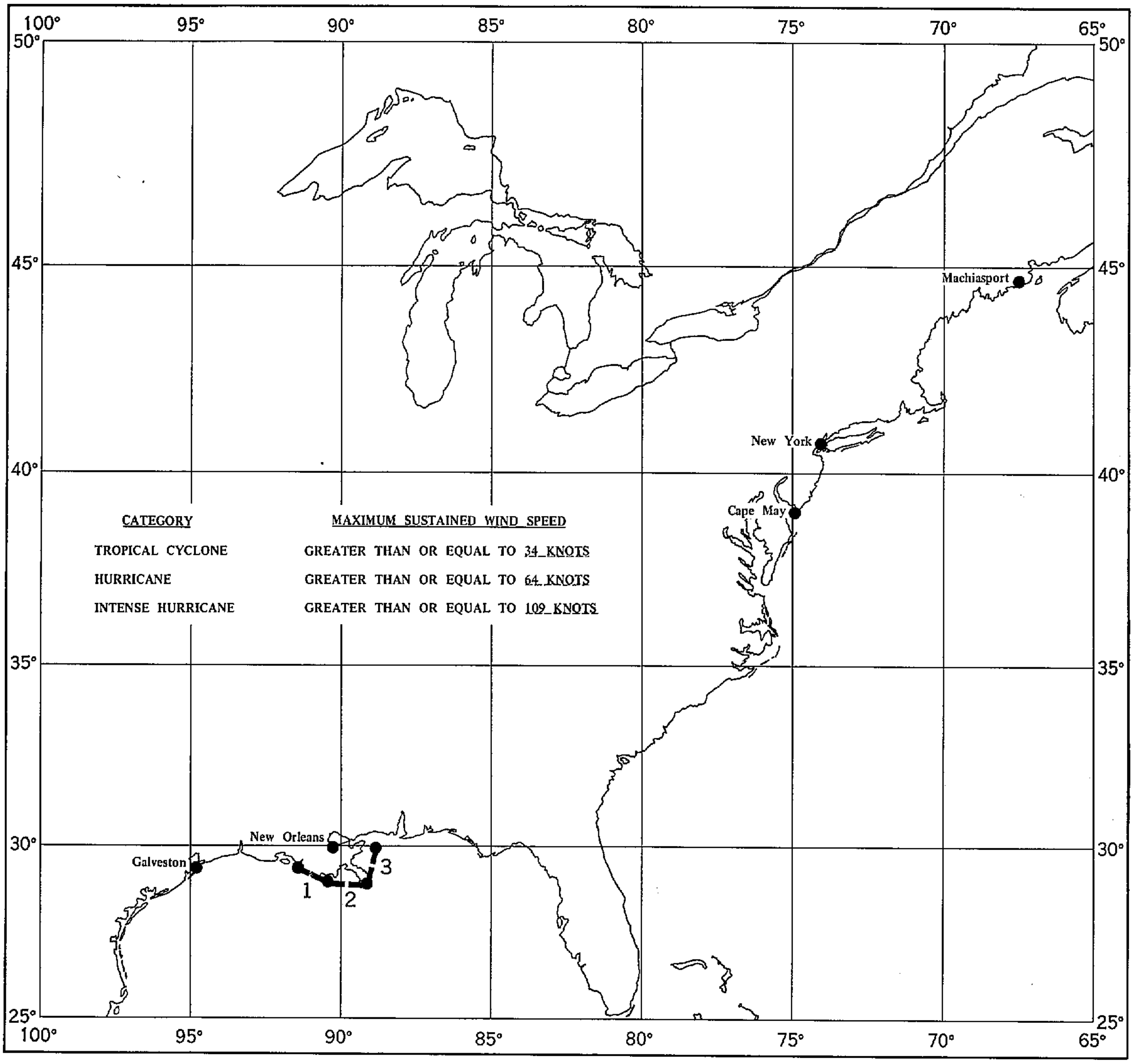
Figure 10 shows the tropical cyclone strike zones and probabilities for the Mississippi Delta area. The table below shows the frequency of tropical cyclones and hurricanes in the study area outlined on the map in Fig. 9.

	Total Number 1886 - 1971	Average Number of Years between Occurrences
Tropical Cyclones	43	2
Hurricanes	20	4
Great Hurricanes	3	28

Between 1886 and 1971 there were a total of 43 tropical cyclones in the Delta area. Of these, 20 were of hurricane force and three were defined as great hurricanes.

Winds

Winds near the Gulf Coast are more variable than over the open waters of the Gulf since the coastal winds fall more directly under the influence of the moving cyclonic storms that are charac-



CATEGORY	MAXIMUM SUSTAINED WIND SPEED
TROPICAL CYCLONE	GREATER THAN OR EQUAL TO 34 KNOTS
HURRICANE	GREATER THAN OR EQUAL TO 64 KNOTS
INTENSE HURRICANE	GREATER THAN OR EQUAL TO 109 KNOTS

AREA Mississippi Delta Zone 1

	PROBABILITY (%) OF OCCURRENCE IN ANY ONE YEAR	AVERAGE NUMBER OF YEARS BETWEEN OCCURRENCES	TOTAL NUMBER OF OCCURRENCES 1886-1970
TROPICAL CYCLONE	18%	5	15
HURRICANE	9%	10	8
INTENSE HURRICANE	<1%	-	-

AREA Mississippi Delta Zone 2

	PROBABILITY (%) OF OCCURRENCE IN ANY ONE YEAR	AVERAGE NUMBER OF YEARS BETWEEN OCCURRENCES	TOTAL NUMBER OF OCCURRENCES 1886-1970
TROPICAL CYCLONE	21%	4	18
HURRICANE	13%	7	11
INTENSE HURRICANE	2%	42	2

AREA Mississippi Delta Zone 3

	PROBABILITY (%) OF OCCURRENCE IN ANY ONE YEAR	AVERAGE NUMBER OF YEARS BETWEEN OCCURRENCES	TOTAL NUMBER OF OCCURRENCES 1886-1970
TROPICAL CYCLONE	15%	6	13
HURRICANE	9%	10	8
INTENSE HURRICANE	4%	28	3

Fig. 10 Tropical cyclone strike zones and probabilities for the Mississippi Delta area.

teristic of the continent, especially during the winter season. Along the coast, land and sea breezes prevail, although over the open waters little difference between daytime and nighttime winds is noticed.

The higher mean monthly winds in the winter season are a product of the frequent winter storms that usually follow an easterly path north of the Delta. Occasionally one moves into the area, producing the winter gales.

The easterly winds of the Bermuda High, although more consistent, are weaker, with a minimum monthly mean occurring in July. However, the strongest winds observed are more likely to occur during the hurricane season.

Extreme Winds

As sufficient wind observations are unavailable for the Mississippi Delta area, both in time and space, the return values of maximum sustained winds, given in the table below, are primarily statistical estimates.

Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Maximum Sustained Wind	90 kts	100 kts	115 kts	125 kts

For example, on the average, there will be a maximum sustained wind speed of 100 knots in the Mississippi Delta area once in every 10 years.

Waves

The distribution of wave heights is roughly the same as that for the winds, the maxima occurring during the time of strongest mean monthly winds, from October through March. The minimum heights occur in summer.

The Delta area has frequencies of waves greater than or equal to 12 feet ranging from 0.1 percent in late summer to 3.2 percent in February. There are some occurrences of waves greater than 20 feet for the majority of months, with a maximum of one-half percent in December.

As with the winds, because of insufficient data for a climatological conclusion of significant wave heights, the table below primarily reflects a statistical approach.

Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Max. Significant Wave Ht.	31 ft	34 ft	39 ft	43 ft

Visibility

Warm, moist Gulf air blowing gently over the Delta area often brings about the formation of fog. With such winds, fog may be encountered some distance off the Delta area. Fog is most common from December to April with little heavy fog in summer. The mean number of hours of fog signal operation at Head of Passes West Jetty points out that the greatest frequency of fog occurrences are during winter over the Delta area.

Visibility is reduced during the winter primarily because of fog. Visibility may also be lowered when northerly winds bring the industrial pollution from plants in the New Orleans area, or when marshlands are burning.

Temperature

Cold temperatures in winter depend largely on the frequency and intensity of northers. The mean annual temperature for the Delta area is about 75°F, with the monthly mean minimum and maximum occurring in January and the July-August months, respectively.

Throughout the year the mean monthly temperatures of the Delta area generally follow the temperatures of the surrounding water areas. Because of this, the area has a subtropical marine climate. There are exceptions, as the range of extreme temperatures is about 90°F. The extremes occur with the warm and cold fronts that pass through the area; and with them, comes the departure from a marine environment.

There are few observations in which the temperatures are below freezing. However, temperatures usually reach 85°F or greater at sometime during every month of the year, the maximum frequency of occurrence taking place during the July-August period.

Precipitation

A fairly definite rainy period occurs during the late autumn, winter, and early spring months, and is generally associated with extratropical cyclones. In summer and early autumn scattered shower and thunderstorm activity is high. The gentle coastal slopes do not, however, give rise to persistent areas of concentrated thunderstorm activity day after day. In general, the greatest rainfall occurs in summer and early autumn with some of the heaviest falls associated with tropical cyclones during the months of August, September, and October.

While thunder usually accompanies summer showers, thunderstorms with damaging winds are relatively infrequent. The most damaging thunderstorms are those associated with cold fronts and line squalls. Hail of a damaging nature seldom occurs, and tornadoes or waterspouts are extremely rare.

Measurable precipitation occurs on about one-third of the days in winter. Much of this falls to the north of warm or cold fronts which have stalled over the northern Gulf of Mexico. Rain is as apt to fall in one hour as another, generally slow, steady, and relatively continous. At times, winter rainy periods extend over several days. Snowfall amounts are generally small, with the snow usually melting as it falls.

The pattern of spring rains is similar to that of winter, while fall rains are distributed in much the same manner as summer rains.

Cloudiness

Over the Mississippi Delta area cloudiness averages between about 3/8 in May to about 5/8 in December with relatively small seasonal variation. The nature of the cloudiness varies with the season. In winter the area has occasional gray, overcast days but in summer these are rare. Much of the summer cloudiness consists of convective cumulus clouds or high, relatively transparent clouds.

There is a considerable variation in frequency of overcast days for the year, with the minimum occurring during the summer and the maximum in winter. Low cloud overcasts and total sky obscurations also increase in frequency during the winter months.

The greatest frequency of observations having clear skies (equal to or less than 2/8) occurs during the spring period.

Relative Humidity

The monthly mean relative humidities are high throughout the year, with negligible seasonal variation because of the close proximity of the Delta area to the Gulf waters. Maximum values of the monthly means occur during spring, the time of greatest constancy of southeasterly winds.

Tides and Currents

Tides in the Mississippi Delta area are chiefly diurnal. There is very little tidal variability, with ranges under two feet in all areas.

Location	Diurnal Tide Range (feet)	Mean Tide Level (feet)
Pass at Loutre Entrance 29°12'N 89°02'W	1.2	0.6
Southeast Pass 29°07'N 89°03'W	1.2	0.6
Southwest Pass 28°56'N 89°26'W	1.3	0.6

Currents to the north of the Delta are generally more swift and steady than those to the south. North of the Delta directions vary from westerly to southerly with average speeds of 1.0 to 1.5 knots. South of the Delta, currents are more steady, flowing toward the northwest at an average speed of about one knot. Currents are somewhat weaker and more variable in the spring and summer.

Significant storm surges in the Delta region are most often associated with hurricanes. A surge of over 15 feet above mean high water was recorded with the passage of Hurricane Camille. This was highest ever reached in the United States.

Surges of nearly equal intensity have been recorded in the past during other great hurricanes.

STATION: NEW ORLEANS, LOUISIANA
POSITION: 30.0N 90.3W
ELEVATION: 4 FEET

NORMALS, MEANS, AND EXTREMES

Temperature and heating degree days

Month	Temperature: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)
(a)	(b)	(b)	(b)	24		24		(b)
J	64.4	44.8	54.6	83	1957	14	1963+	363
F	66.7	47.5	57.1	84	1948	19	1970+	258
M	71.2	51.6	61.4	87	1963+	26	1968	192
A	77.7	58.1	67.9	91	1948	38	1962	39
M	84.4	64.4	74.4	96	1953+	41	1960	0
J	89.6	70.5	80.1	100	1954	55	1966	0
J	90.6	72.6	81.6	99	1951	60	1967	0
A	90.7	73.0	81.9	100	1951	60	1968	0
S	87.2	69.3	78.3	97	1954+	42	1967	0
O	80.3	60.5	70.4	92	1962+	35	1968	19
N	70.3	49.6	60.0	86	1951	24	1970	192
D	65.3	45.5	55.4	83	1970+	17	1962	322
YR	78.2	59.0	68.6	100	JUN. 1954+	14	JAN. 1963+	1385

Precipitation

Month	Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	24		24		24		24	24		24	
J	3.84	12.62	1966	0.54	1968	4.77	1955	T	T	1969+	T	1969+
F	3.99	10.56	1959	1.02	1962	5.60	1961	0.1	2.0	1958	2.0	1958
M	5.34	19.09	1948	0.24	1955	7.87	1948	T	T	1959	T	1959
A	4.55	8.78	1949	0.33	1965	4.35	1953	0.0	0.0		0.0	
M	4.38	14.33	1959	0.99	1949	9.86	1959	0.0	0.0		0.0	
J	4.43	8.87	1962	1.12	1952	4.19	1953	0.0	0.0		0.0	
J	6.72	11.46	1954	3.45	1951	4.30	1966	0.0	0.0		0.0	
A	5.34	11.77	1955	2.00	1952	3.06	1969	0.0	0.0		0.0	
S	5.03	13.53	1948	0.24	1953	5.46	1957	0.0	0.0		0.0	
O	2.84	6.45	1959	0.00	1952	2.58	1960	0.0	0.0		0.0	
N	3.34	14.58	1947	0.21	1949	6.38	1953	T	T	1950	T	1950
D	4.10	10.77	1967	1.46	1958	3.94	1952	0.1	2.7	1963	2.7	1963
YR	53.90	19.09	MAR. 1948	0.00	OCT. 1952	9.86	MAY 1959	0.2	2.7	DEC. 1963	2.7	DEC. 1963

Relative humidity, wind, sunshine and sky cover

Month	Relative humidity: Hour 00 (Local time)	Hour 06	Hour 12	Hour 18	Wind &: Mean speed	Prevailing direction	Fastest mile: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover, sunrise to sunset
(a)	22	22	22	22	22		11	11			22
J	84	86	67	73	9.6		33	28	1966		6.7
F	82	85	63	68	10.2		43	26	1970		6.3
M	83	84	60	65	10.2		37	18	1969		6.1
A	85	88	60	66	9.7		35	07	1960		5.7
M	86	89	60	65	8.3		31	23	1962		5.1
J	87	90	62	67	7.0		38	27	1962		4.9
J	89	91	66	73	6.4		32	07	1969		6.1
A	89	92	66	73	6.2		42	33	1969		5.5
S	87	89	65	74	7.5		69	09	1965		5.2
O	84	87	59	72	7.8		40	17	1964		4.1
N	83	86	59	73	8.9		30	31	1969		4.9
D	83	86	66	75	9.2		32	17	1969		6.1
YR	85	88	63	70	8.4		69	09	SEP. 1965		5.6

Mean number of days

Month	Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max. 90° and above ‡	Max. 32° and below	Min. 32° and below	Min. 0° and below	Average daily solar radiation - langleys
(a)	22	22	22	22	22	22	22	24	24	24	24	
J	7	8	16	10	0	2	7	0	*	5	0	
F	8	6	14	10	*	2	5	0	0	3	0	
M	8	9	14	9	0	3	5	0	0	1	0	
A	8	11	11	7	0	4	2	*	0	0	0	
M	11	11	9	8	0	6	1	4	0	0	0	
J	10	13	7	10	0	9	*	17	0	0	0	
J	5	16	10	15	0	16	*	20	0	0	0	
A	9	13	9	13	0	13	*	19	0	0	0	
S	11	10	9	9	0	7	*	9	0	0	0	
O	16	7	8	6	0	2	2	1	0	0	0	
N	12	8	10	6	0	1	4	0	0	1	0	
D	8	8	15	10	*	2	5	0	*	3	0	
YR	113	120	132	112	*	68	32	69	*	13	0	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 102 in June 1954 and earlier (City Office); lowest temperature 7 in February 1899; maximum monthly precipitation 25.11 in October 1937; maximum precipitation in 24 hours 14.01 in April 1927; maximum monthly snowfall 8.2 in February 1895; maximum snowfall in 24 hours 8.2 in February 1895.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

Table 14 Land station climatological data summary for NEW ORLEANS, LOUISIANA.

ENVIRONMENTAL DATA SUMMARY (PART 1)

AREA: Mississippi Delta

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WIND SPEED (KNOTS)													
01% ≤	3	3	3	4	2	1	2	2	2	3	3	4	3
Mean	14.1	14.2	13.6	12.4	10.5	9.2	8.2	8.5	11.9	12.7	13.5	13.7	11.9
99% ≤	38	39	32	32	28	28	22	28	32	32	33	33	31
Maximum observed (1871 - 1971)	Winds of 175 knots are estimated to have occurred south of the Delta during Hurricane Camille.												
≥ 34 Knots (% freq.)	1.2	1.2	0.7	0.4	0.1	0.1	0.1	0.1	0.5	0.7	1.0	1.0	0.6
≥ 41 Knots (% freq.)	0.2	0.1	0.1	0.1	+	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1
Prevailing direction	E	SE	SE	SE	SE	SE	SE	E	E	E	E	E	E
WAVES (FEET)													
01% ≤	0	1	1	0	0	0	0	0	0	1	0	0	¼
Mean	4	4	4	3	3	2	2	2	3	4	3	4	3
99% ≤	17	16	12	10	9	8	7	7	12	14	12	14	12
≥ 12 Feet (% freq.)	2.2	3.2	2.0	0.4	0.5	0.2	0.1	0.1	1.6	2.6	1.2	1.8	1.3
≥ 20 Feet (% freq.)	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.1	0.2	+	0.5	0.1
VISIBILITY (% FREQ.)													
Visibility <½ N. mile	0.5	0.3	0.6	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.2
Visibility <1 N. mile	0.7	0.4	0.7	0.4	0.1	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.3
Visibility <2 N. miles	0.9	0.7	1.1	0.7	0.3	0.3	0.4	0.3	0.5	0.4	0.4	0.5	0.5
Visibility <5 N. miles	2.0	2.4	3.0	2.1	0.8	1.0	0.9	0.8	1.7	1.0	1.2	1.5	1.5
Visibility <10 N. miles	12.9	17.4	20.8	17.9	10.4	7.9	5.9	7.0	12.6	9.0	10.3	12.4	12.0

+ = less than 0.05%

Table. 15 Environmental data summary; Mississippi Delta area.

ENVIRONMENTAL DATA SUMMARY (PART 2)

AREA: Mississippi Delta

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
FOG													
Occurrence of fog (% freq.)	1.2	1.2	2.1	1.1	0.2	+	+	+	0.1	0.1	0.2	0.5	0.6
Mean number of hours operation of fog signals *	156	148	171	103	13	4	5	4	9	9	38	100	760
Maximum number of hours operation of fog signals for any year (annual only)*													1452
WEATHER & CLOUDS (% FREQ.)													
Precipitation	3.2	4.3	2.7	1.9	1.7	1.9	2.8	3.2	4.1	2.9	2.9	3.6	2.9
Freezing precipitation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Frozen precipitation	0.0	+	+	+	+	0.0	0.0	+	+	0.0	+	+	+
Thunder & lightning	0.6	0.8	1.0	0.9	1.0	1.7	2.8	2.3	1.6	0.8	0.6	0.5	1.2
Sky ≤2/8	29.1	30.4	33.9	39.9	45.3	39.8	31.5	31.6	27.3	38.2	34.6	27.8	34.1
Sky overcast (8/8)	25.1	25.3	20.8	15.6	9.8	8.4	9.2	9.4	14.8	11.4	17.0	22.6	15.8
Sky obscured	0.7	0.8	0.7	0.5	0.2	0.2	0.2	0.2	0.3	0.2	0.4	0.7	0.4
Low cloud overcast	16.0	15.6	11.8	7.4	4.2	2.6	2.8	2.7	5.9	5.3	9.3	12.9	8.1
Mean cloud cover (eighths)	4.8	4.6	4.3	3.8	3.3	3.5	3.9	3.9	4.3	3.7	4.1	4.7	4.1
AIR TEMPERATURE (°F)													
Minimum	15	10	25	36	45	56	62	67	50	38	26	18	10
01% ≤	43	45	49	58	66	73	75	75	71	60	51	46	59
Mean	65.4	66.1	68.1	72.5	77.7	82.3	83.9	83.9	82.1	77.3	71.5	67.4	74.9
99% ≤	79	81	81	83	89	91	92	93	91	87	82	81	86
Maximum	88	88	88	92	95	97	100	100	100	96	91	86	100
≤ 32 °F (% freq.)	+	+	+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+	+	+
≥ 85 °F (% freq.)	+	0.2	0.2	0.9	4.7	17.9	36.9	36.2	18.5	4.1	0.6	0.1	10.0

* Head of Passes West Jetty fog signal + = less than 0.05%

Table 15 Continued

ENVIRONMENTAL DATA SUMMARY (PART 3)

AREA: Mississippi Delta

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
RELATIVE HUMIDITY (%)													
Mean	76	77	78	79	79	78	76	77	78	74	75	76	77
SEA TEMPERATURE (°F)													
Minimum	45	39	45	53	62	67	67	72	70	68	58	52	39
01% ≤	57	56	58	65	70	76	80	80	78	73	65	62	68
Mean	71.4	70.4	70.9	73.2	77.9	82.4	85.0	85.4	84.2	81.1	76.8	73.5	77.7
99% ≤	81	80	79	81	83	87	90	91	88	86	83	81	84
Maximum	86	86	88	88	92	94	94	94	94	90	90	86	94
SALINITY (‰)													
Minimum	11.6	0.0	2.6	14.0	4.3	5.4	3.8	12.7	19.6	18.7	21.4	16.9	0.0
Mean	30.2	27.3	26.9	25.0	22.5	23.8	26.8	28.0	28.2	30.1	32.7	31.9	27.8
Maximum	37.9	36.3	36.3	35.0	34.5	38.1	37.1	38.8	34.2	35.8	36.7	36.3	38.8
DENSITY (ρ)													
Mean (σ_t)*	21.1	26.8	26.2	24.2	21.4	21.5	23.3	24.1	24.8	19.2	22.1	22.1	21.1
SEA-LEVEL PRESSURE (mb)													
Minimum	997	995	998	980	990	978	999	999	981	998	992	976	976
01% ≤	1007	1003	1004	1004	1006	1007	1009	1009	1004	1005	1007	1008	1006
Mean	1020	1018	1017	1017	1016	1016	1017	1016	1015	1017	1019	1020	1017
99% ≤	1033	1032	1032	1029	1025	1022	1025	1025	1024	1027	1030	1034	1028
Maximum	1037	1041	1033	1032	1029	1031	1030	1031	1029	1035	1035	1037	1041

* $\sigma_t = (\rho - 1) \times 10^3$; $\rho =$ gm cm^{-3}

Table 15 Continued

GALVESTON, TEXAS AREA

General Description

The Galveston, Texas area (see Fig. 11) is located in the flat Coastal Plains on the northwestern shores of the Gulf of Mexico. The city is located on one of the many barrier islands found along the Gulf coast. Galveston is protected on the Gulf side by a concrete seawall 17 feet high. Northeast of the island is the channel entrance to Galveston Bay, the approach to the cities of Galveston, Texas City, and Houston.

Galveston Bay is a large irregularly shaped shallow body of water and, except for the Federal Project Channels which range in depth from 36 to 40 feet, has general depths of seven to nine feet. Galveston Jetty Light, 91 feet above the water and equipped with a fog signal and radiobeacon, marks the entrance to the Bay. A considerable number of unmarked dangerous wrecks exist in the Gulf Approach to the Bay.

Deep water extends fairly close inshore along this section of Gulf shore. The 30 foot isobath ranges from about one and one-half to four nautical miles seaward.

A system of shipping safety fairways exists along the Gulf Coast to provide safe lanes for shipping that are free of oil well structures.

The effect of the wind on the water level in this part of the Gulf and adjoining bays may be considerable. A level two to four

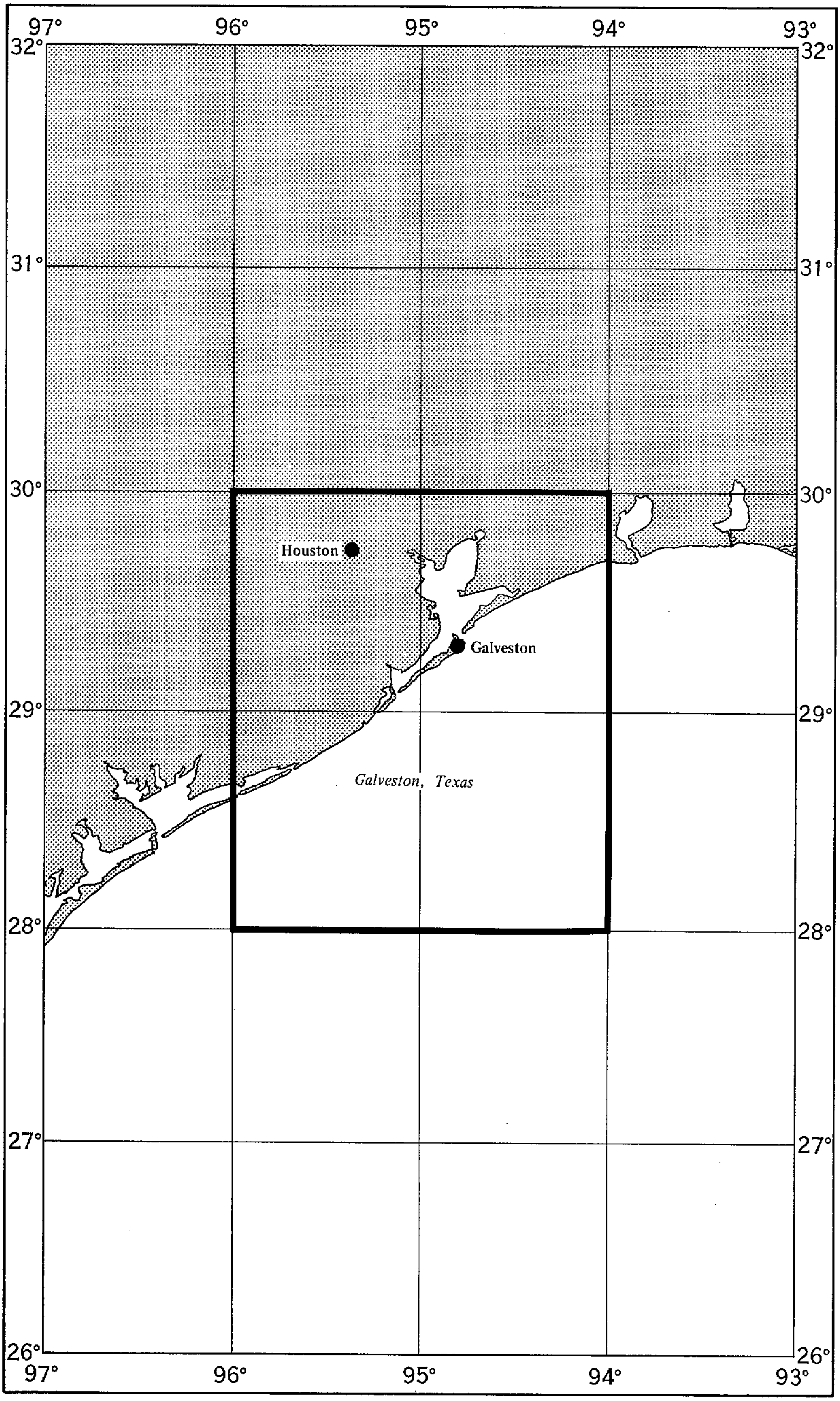


Fig. 11 Galveston, Texas area map.

feet above mean low tide may result from a strong wind blowing continuously for several days from the east and southeast. A strong wind blowing steadily from the north for several days may lower the water to a level two or three feet below mean low tide. The diurnal range of tide at Galveston Bay entrance at the south jetty is 2.0 feet.

The currents are also modified frequently by the winds. Easterly or southeasterly winds may cause a continuous flood current between the jetties at the entrance for a period of a day or more, and westerly or northwesterly winds sometimes set up continuous outgoing currents for a similar period. The average velocity of the current between the jetties (at strength) is 1.7 knots on the flood and 2.3 knots on the ebb.

The current outside the jetties frequently has a velocity exceeding one knot. The set may be in any direction under the combined influence of the entrance currents and currents setting along the coast.

THE ENVIRONMENT

The climate of the Galveston area is predominantly marine, with periods of modified continental influence during the colder months when cold fronts from the northwest sometimes reach the coast.

Because of its coastal location and relatively low latitude, cold fronts which do reach the area are very seldom severe and temperatures below 32°F are recorded on an average of only four times a year at Galveston.

Throughout the year, the Gulf waters modify the humidity and temperature conditions, decreasing the range between extremes. From November to March, the area is subject alternately to tropical and cold continental air in periods of varying length. From June to September, the prevailing southeast to southwesterly winds carry warm, moist air inland. This is favorable for the development of thunderstorms.

Pressure

During the spring and summer months the western extension of the Bermuda High dominates the general circulation of air over the Galveston area. The North American continental high pressure systems modify the pressure pattern for the remaining months. Winds of the Bermuda High have a greater constancy and, therefore, greatly influence the climate of the area with its steady flow of warm, moist air. Such influences have a tendency to produce longer periods of good weather.

The monthly mean pressures vary from a low of 1015 millibars in late spring to a high of 1020 millibars in winter.

Extratropical Cyclones

Of the 30 to 40 polar air masses penetrating the Gulf of Mexico each winter, some 15 to 20 bring strong northerly winds. These "northers" occur from November to March. The winds, although occasionally blowing with a speed of over 35 knots, are not dangerous to vessels anywhere close to the coast, as they blow offshore and the sea is not heavy. Charts of mean extratropical cyclone tracks appear in Appendix B.

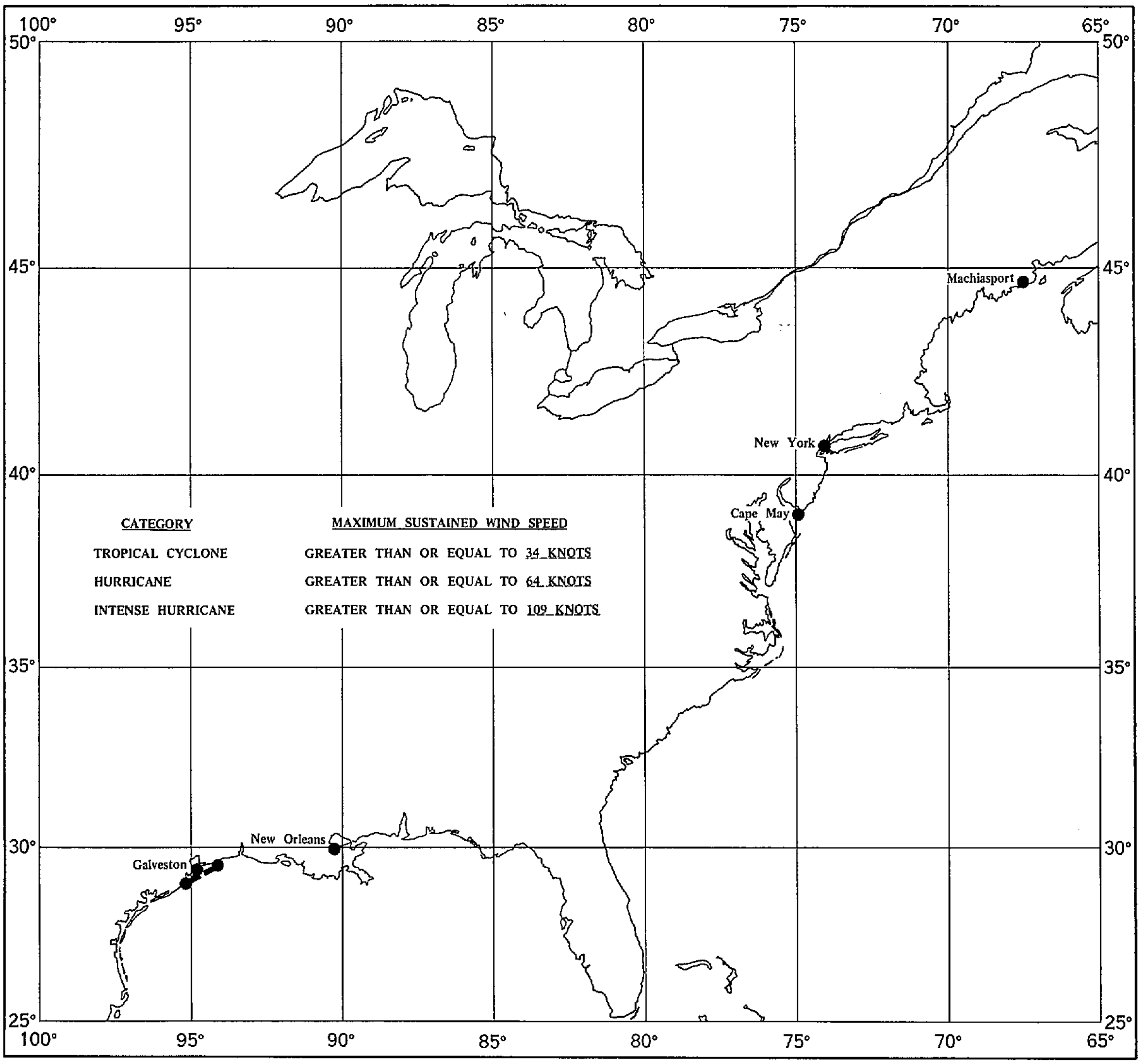
Tropical Cyclones

Of the many tropical cyclones observed in the Gulf of Mexico a few find their way to the Galveston area. The area has been subjected to major tropical storms of hurricane force at infrequent intervals. The 1900 hurricane completely destroyed the city of Galveston, but the building of a 17 foot seawall on the Gulf side of the island afterwards reduced the danger of direct wave and swell action associated with this type of storm. These storms are dangerous to shipping near the coast because the wind is onshore.

Fig. 12 displays the tropical cyclone strike zones and probabilities for the Galveston area. The table below shows the frequency of tropical cyclones and hurricanes in the general study area outlined on the map in Figure 11 (see Appendix A for coordinates).

	Total Number 1886 - 1971	Average Number of Years between Occurrences
Tropical Cyclones	29	3
Hurricanes	15	5-6
Great Hurricanes	3	28

The table shows that between 1866 and 1971 there were a total of 29 tropical cyclones in the Galveston area. Of these, 15 were of hurricane force and three were considered to be great hurricanes.



AREA Galveston

	PROBABILITY (%) OF OCCURRENCE IN ANY ONE YEAR	AVERAGE NUMBER OF YEARS BETWEEN OCCURRENCES	TOTAL NUMBER OF OCCURRENCES 1886-1970
TROPICAL CYCLONE	20%	5	17
HURRICANE	12%	8	10
INTENSE HURRICANE	4%	28	3

Fig. 12 Tropical cyclone strike zone and probabilities for the Galveston area.

Winds

The prevailing winds are northerly from November through January, throughout which time "northers" occur frequently. Although winds greater than 34 knots are observed for each month of the year, the greatest frequency is during the winter months.

Land and sea breezes prevail along the coast, while little difference between daytime and nighttime winds are noticed over the open waters.

The lowest monthly mean winds occur during the summer months, with the prevailing easterly winds of the Bermuda High. Extreme winds for the year, however, are likely to occur during the late summer-early fall, which includes the hurricane season. Damaging winds are relatively infrequent in summer thunderstorms, but are sometimes associated with winter cold fronts and squall lines.

Extreme Winds

As sufficient wind observations are unavailable for the Galveston area, the return values of maximum sustained winds, given in the table below, are primarily statistical estimates.

Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Maximum Sustained Wind	75 kts	85 kts	95 kts	105 kts

For example, on the average there will be a maximum sustained wind speed of 85 knots in the Galveston area once in every 10 years.

Waves

The distribution of wave heights follows the winds for the Galveston area, as expected. Waves of heights greater than 12 feet are observed for all months of the year but August. Some have probably occurred during August but were not observed. The greatest frequency of high waves occurs from September through February. There are observations with wave heights greater than 20 feet only during the October, November, and January months.

As there are insufficient data for a climatological conclusion of significant wave heights, the table below shows a statistical estimate of high wave occurrences.

Mean Recurrence Interval	5 yr	10 yr	25 yr	50 yr
Max. Significant Wave Ht.	29 ft	32 ft	37 ft	41 ft

From the table it can be expected that there will be one occurrence having, on the average, a significant wave height of 32 feet every 10 years.

Visibility

There are occurrences of fog throughout the year, the greatest frequencies taking place from December through April. Fog is the primary cause of reduced visibility, as these same months also reflect the highest percent frequencies in which visibility is less than five miles. The monthly mean number of hours in which fog signals operated at Galveston Channel Light reflects this long season of relatively foggy days.

The close proximity of the Gulf waters and the Bay of Galveston enhances fog occurrences there. An average of 16 days a year have heavy fog in the city.

Temperature

Temperatures are moderated by the influence of winds from the Gulf, which results in mild winters and relatively cool summer nights for the Galveston area. However, polar air penetrates the area frequently enough to provide stimulating variability in the weather. A record low temperature of 8°F occurred in February 1899 in the city of Galveston.

The annual mean air temperature of the marine area of Galveston is about 74°F. There is an annual mean range of about 21°F with the mean low occurring in January and the mean high occurring in July and August. The extremes out over the water range from 10 to 100°F for the period of record.

There are few occurrences of freezing temperatures, and these are confined to the months of November through March. On the other hand, all months but December and January had temperatures greater than 85°F.

Precipitation

Mean monthly rainfall is rather evenly distributed throughout the year. The greatest frequency of precipitation occurs during the winter months, coming mainly from frontal activity and low stratus clouds, the latter producing slow, steady rains. Precipitation may occur at any hour, and may continue intermittently for several days.

Amounts of rainfall during the summer months may vary greatly over the Galveston area, as most of the rain in this season is from local thunderstorm activity. Hail is infrequent because the necessary strong vertical lifting is usually absent. Tornadoes and waterspouts are rare.

Cloudiness

Cloudiness over the Galveston area averages between about 3/8 in June to about 5/8 in December and January. The nature of the cloudiness varies with the season, with winter having occasional gray, overcast days and summer consisting mainly of convective cumulus clouds. It follows that the percent frequency of overcast skies is greatest in winter and smallest in summer. The degree of obscured skies also follows this annual cycle.

The greatest frequency of observations having clear skies occurs during the late spring period.

Relative Humidity

High humidities prevail throughout the year, with little seasonal variation. This is because of a rather evenly distributed annual precipitation pattern and the availability of water vapor from the Gulf surface. Maximum values of the monthly means occur during spring, the time of greatest constancy of southeasterly winds, which bring moisture from the Gulf.

Tides and Currents

Tides in the Galveston area are predominantly diurnal with ranges of two feet at the South Jetty (29°20'N 94°42'W) and 1.4

feet at the ship channel (29°19'N 94°48'W). Mean tide levels are 1.0 and 0.7 feet, respectively.

Currents off Galveston are generally light and variable, averaging about one knot in winter, somewhat less in summer.

Diurnal tidal currents at the Galveston Bay entrance (29°21'N 94°42'W) are 1.7 knots toward the WNW at flood and 2.3 knots toward the ESE at ebb.

Significant storm surges are most often related to the passage of hurricanes. Surges of nearly 14 feet above mean high water have occurred with the passage of great hurricanes. Ten foot surges have been recorded during the offshore passage of intense hurricanes.

STATION: GALVESTON, TEXAS
POSITION: 29.3N 94.8W
ELEVATION: 7 FEET

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Daily minimum	Monthly	Temperature: Extremes: Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
				100		100				100		100		100	
(a)	(b)	(b)	(b)					(b)	(b)						
J	60.5	49.3	54.9	77	1969	11	1886	350	3.46	10.39	1899	0.02	1909	5.38	1923
F	62.4	51.2	56.8	83	1932	8	1899	258	2.88	8.29	1881	0.09	1954	6.55	1952
M	66.6	56.2	61.4	85	1879	27	1943	189	2.86	9.39	1926	0.06	1953	4.58	1944
A	73.0	64.0	68.5	92	1953	38	1938	30	2.59	11.04	1904	0.01	1887	9.23	1904
M	80.1	71.5	75.8	93	1911	52	1954+	0	2.79	10.50	1929	T	1889	6.13	1916
J	85.6	77.7	81.7	99	1918	57	1903	0	2.65	15.49	1919	T	1907	12.56	1961
J	87.3	78.9	83.1	101	1932	66	1910	0	4.79	18.74	1900	T	1962+	14.35	1900
A	87.5	79.0	83.3	100	1924	67	1966+	0	4.39	19.08	1915	0.00	1902	9.05	1915
S	84.6	75.5	80.1	96	1927	52	1942	0	5.09	26.01	1885	0.04	1924	11.65	1961
O	78.5	68.4	73.5	94	1952+	41	1925+	0	2.86	17.78	1871	T	1952+	14.10	1901
N	68.6	57.4	63.0	85	1886	26	1911	138	3.56	16.18	1940	0.03	1903	9.01	1940
D	62.7	51.6	57.2	80	1918	18	1880	270	3.89	10.28	1887	0.23	1889	5.43	1964
YR	74.8	65.1	69.9	101	JUL. 1932	8	FEB. 1899	1235	41.81	26.01	SEP. 1885	0.00	AUG. 1902	14.35	JUL. 1900

Month	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity: Hour 00 (Local time)	Hour 06	Hour 12	Hour 18	Wind &: Mean speed %	Prevailing direction	Fastest mile: Speed	Direction #	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max.: 90° and above ‡	Max.: 32° and below	Min.: 32° and below	Min.: 0° and below	Average daily solar radiation - langleys
(a)	100	100		100		31	83	53	83	93		99	99		80					99	99			85	100	100	100	
J	T	0.9	1940	0.9	1940	84	85	77	80	11.6		53	S	1915	49					10	0			0	*	2	0	
F	0.2	15.4	1895	15.4	1895	83	84	74	77	11.8		60	N	1927	50					9	*			0	*	1	0	
M	T	T	1932	T	1932	84	85	74	79	11.9		50	SE	1952	56					8	0			0	0	*	0	
A	0.0	0.0		0.0		86	86	75	80	12.1		57	NW	1961	61					6	0			*	0	0	0	
M	0.0	0.0		0.0		83	84	73	77	11.5		66	W	1959	68					6	0			*	0	0	0	
J	0.0	0.0		0.0		80	81	70	73	10.7		62	SE	1921	76					6	0			1	0	0	0	
J	0.0	0.0		0.0		80	81	70	73	9.8		68	NW	1943	72					9	0			4	0	0	0	
A	0.0	0.0		0.0		79	81	69	73	9.4		91	E	1915	71					9	0			5	0	0	0	
S	0.0	0.0		0.0		78	81	68	75	10.1		100	NE	1900	69					9	0			1	0	0	0	
O	0.0	0.0		0.0		76	80	65	71	10.3		66	SE	1949	72					6	0			*	0	0	0	
N	0.0	0.0		0.0		82	84	72	77	11.2		54	N	1950	61					8	0			0	0	*	0	
D	T	0.2	1924	0.2	1924	83	86	77	80	11.3		50	NW	1954	49					10	0			0	*	1	0	
YR	0.2	15.4	FEB. 1895	15.4	FEB. 1895	81	83	72	76	11.0		Ø 100	NE	SEP. 1900	64					96	*			12	*	4	0	

Ø 100 m.p.h. recorded at 6:15 p.m. Sept. 8 just before anemometer blew away. Maximum velocity estimated 120 from NE between 7:30 and 8:30 p.m.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

% Through 1964.

\# To 8 compass points only.

Table 16 Land station climatological data summary for GALVESTON, TEXAS.

STATION: HOUSTON, TEXAS
POSITION: 30.0N 95.4W
ELEVATION: 96 FEET

NORMALS, MEANS, AND EXTREMES[¢]

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes Ø: Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)
				9		9		
(a)	(b)	(b)	(b)					(b)
J	63.6	43.6	53.6	83	1967+	17	1963+	384
F	65.5	46.0	55.8	87	1962	25	1963	288
M	71.7	50.8	61.3	88	1967	28	1965	192
A	78.0	59.0	68.5	93	1963	38	1962	36
M	85.7	66.2	76.0	94	1967	52	1967	0
J	91.1	72.0	81.6	100	1963	59	1964	0
J	92.1	73.8	83.0	101	1964	64	1967	0
A	92.8	73.6	83.2	106	1962	64	1967	0
S	89.1	69.3	79.2	98	1963	50	1967	0
O	82.3	60.4	71.4	96	1962	38	1964	6
N	71.1	50.5	60.8	88	1963	32	1968	183
D	65.4	45.9	55.7	82	1964	19	1963	307
YR	79.0	59.3	69.2	106	AUG. 1962	17	JAN. 1963+	1396

Month	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
		36		36		36		36	36		36	
(a)	(b)											
J	3.78	10.51	1944	0.86	1952	3.66	1944	0.2	3.1	1949	3.1	1949
F	3.44	11.33	1959	0.09	1954	5.03	1966	0.2	4.4	1960	4.4	1960
M	2.67	11.42	1957	0.07	1953	5.00	1957	T	1.0	1968	1.0	1968
A	3.24	8.07	1957	0.36	1937	5.18	1966	0.0	0.0		0.0	
M	4.32	13.24	1968	T	1937	6.35	1968	0.0	0.0		0.0	
J	3.69	14.66	1960	0.08	1934	8.51	1960	0.0	0.0		0.0	
J	4.29	12.38	1942	0.07	1962	6.34	1943	0.0	0.0		0.0	
A	4.27	18.51	1945	0.38	1956+	15.65	1945	0.0	0.0		0.0	
S	4.26	15.40	1958	0.14	1953	5.62	1944	0.0	0.0		0.0	
O	3.77	22.31	1949	T	1952	10.25	1949	0.0	0.0		0.0	
N	3.86	14.36	1946	0.18	1949	7.89	1943	0.0	0.0		0.0	
D	4.36	9.80	1949	0.78	1958	4.39	1964	T	T	1961+	T	1961+
YR	45.95	22.31	OCT. 1949	T	OCT. 1952+	15.65	AUG. 1945	0.4	4.4	FEB. 1960	4.4	FEB. 1960

Month	Relative humidity: Hour 00 (Local time)	Hour 06	Hour 12	Hour 18	Wind&: Mean speed	Prevailing direction	Fastest mile: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max. 90° and above ‡	Max. 32° and below	Min. 32° and below	Min. 0° and below	Average daily solar radiation - langleys
	8	8	8	8	20	15	6	6		7	20	20	20	20	36	36	30	23	8	8	8	8	
J	81	84	64	67	11.9	NNW	32	33	1964	47	7.0	7	4	20	11	*	2	7	0	*	6	0	
F	81	84	60	63	12.1	SSE	40	36	1963	56	6.7	7	5	16	10	*	3	6	0	0	3	0	
M	82	86	59	62	12.7	SSE	35	30	1968+	57	6.8	6	13	12	8	*	2	6	0	0	1	0	
A	86	89	63	68	13.0	SSE	38	16	1966+	54	7.0	5	7	18	8	0	4	4	1	0	0	0	
M	87	90	61	66	11.7	SSE	41	17	1968	62	6.4	5	13	13	8	0	7	2	6	0	0	0	
J	88	91	61	65	10.2	SSE	44	17	1965	72	5.6	6	17	7	8	0	7	1	19	0	0	0	
J	88	91	59	64	8.8	S	40	36	1964	74	5.9	5	17	9	9	0	10	*	26	0	0	0	
A	87	91	59	64	8.4	SSE	54	34	1963	70	5.7	8	15	8	9	0	9	*	26	0	0	0	
S	85	88	60	65	9.1	SSE	31	36	1963	66	5.4	9	12	9	9	0	7	1	15	0	0	0	
O	83	86	52	63	9.8	ESE	35	31	1967	73	4.7	12	10	9	7	0	3	4	3	0	0	0	
N	82	85	60	68	11.2	SSE	30	14	1963	60	5.8	9	8	13	8	0	2	5	0	0	*	0	
D	81	84	64	69	11.3	SSE	35	31	1968+	50	6.7	8	5	18	10	0	2	6	0	0	4	0	
YR	84	87	60	66	10.8	SSE	54	34	AUG. 1963	62	6.2	87	126	152	103	*	59	42	95	*	13	0	

Ø For record August 1960 through 1968.
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Highest temperature 108 in August 1909; lowest temperature 5 in January 1940 and earlier; fastest mile of wind 84 from Northwest in March 1926.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ⋝ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

¢ Data from William P. Hobby Airport through 1968. Summary for the Intercontinental Airport will be published when sufficient data have been accumulated. See next page for normals applicable to the observation site at the Intercontinental Airport.

Table 17 Land station climatological data summary for HOUSTON, TEXAS.

ENVIRONMENTAL DATA SUMMARY (PART 1)

AREA: Galveston, Texas

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WIND SPEED (KNOTS)													
01% ≤	3	3	3	3	2	2	2	2	2	2	3	3	3
Mean	13.7	13.6	12.9	12.6	11.5	10.4	9.2	8.9	11.7	12.3	13.8	13.8	12.0
99% ≤	39	39	32	31	29	28	28	28	32	32	33	35	32
Maximum observed (1871 - 1971)	Winds in excess of 100 knots are estimated to have occurred during great Hurricanes.												
≥ 34 Knots (% freq.)	1.2	1.2	0.7	0.3	0.2	0.2	0.1	0.1	0.8	0.5	1.0	1.2	0.6
≥ 41 Knots (% freq.)	0.2	0.3	0.1	+	+	0.1	+	0.0	0.5	0.1	0.1	0.2	0.1
Prevailing direction	N	SE	SE	SE	SE	SE	S	S	E	E	N	N	SE
WAVES (FEET)													
01% ≤	0	0	1	1	0	0	0	0	0	0	0	1	¼
Mean	4	4	3	3	3	2	2	2	3	3	3	3	3
99% ≤	13	12	10	10	9	8	7	8	12	12	13	12	11
≥ 12 Feet (% freq.)	2.2	2.2	0.7	0.3	0.4	0.1	0.1	0.0	1.6	2.0	1.4	1.4	1.0
≥ 20 Feet (% freq.)	0.1	+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	+	0.1
VISIBILITY (% FREQ.)													
Visibility <½ N. mile	1.6	1.2	1.7	0.8	0.2	0.2	0.2	0.2	0.3	0.1	0.3	0.7	0.6
Visibility <1 N. mile	1.8	1.5	2.0	1.0	0.3	0.4	0.2	0.2	0.4	0.1	0.5	0.9	0.8
Visibility <2 N. miles	2.5	2.5	2.7	1.6	0.6	0.6	0.3	0.3	0.5	0.2	0.6	1.6	1.1
Visibility <5 N. miles	5.2	5.2	6.6	4.8	1.8	1.9	0.8	0.6	1.3	0.8	2.0	4.1	2.9
Visibility <10 N. miles	23.2	25.0	30.1	29.1	16.5	7.9	6.0	6.3	10.4	10.7	16.3	22.3	17.0

+ = less than 0.05%

Table. 18 Environmental data summary; Galveston, Texas area.

ENVIRONMENTAL DATA SUMMARY (PART 2)

AREA: Galveston, Texas

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
FOG													
Occurrence of fog (% freq.)	3.8	3.5	4.6	3.3	0.8	0.1	+	+	0.1	0.1	0.9	2.0	1.6
Mean number of hours operation of fog signals *	105	72	86	37	3	3	2	4	4	8	27	78	429
Maximum number of hours operation of fog signals for any year (annual only)*													697
WEATHER & CLOUDS (% FREQ.)													
Precipitation	3.6	3.9	1.9	1.6	1.4	1.8	1.9	2.6	3.1	2.1	2.8	4.5	2.6
Freezing precipitation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Frozen precipitation	0.0	0.0	0.0	0.0	+	0.0	0.0	0.0	0.0	+	0.0	0.0	+
Thunder & lightning	0.4	0.7	0.4	0.5	0.9	1.2	1.3	1.5	1.7	0.8	1.1	0.7	0.9
Sky ≤2/8	29.6	33.1	31.1	33.6	39.4	40.1	33.7	33.6	33.5	42.2	34.5	29.0	34.5
Sky overcast (8/8)	26.9	28.8	23.9	21.8	11.8	6.5	7.9	8.9	12.7	12.7	21.2	29.4	17.7
Sky obscured	2.1	2.3	2.4	1.4	0.2	0.3	0.1	0.1	0.6	0.2	0.7	1.6	1.0
Low cloud overcast	20.8	19.1	16.5	11.5	4.9	2.3	2.4	2.9	4.9	5.9	12.0	17.8	10.1
Mean cloud cover (eighths)	4.9	4.6	4.7	4.3	3.7	3.4	3.7	3.8	3.9	3.5	4.2	4.9	4.1
AIR TEMPERATURE (°F)													
Minimum	15	10	26	36	45	56	61	66	48	37	26	18	10
01% ≤	41	42	47	56	65	73	75	74	70	59	49	44	58
Mean	62.9	63.7	66.3	71.4	77.1	82.1	84.0	84.0	82.3	76.8	70.3	66.0	73.9
99% ≤	77	76	78	83	87	90	92	93	92	89	83	78	85
Maximum	84	86	86	90	94	95	100	100	100	93	91	84	100
≤ 32 °F (% freq.)	+	+	+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+	+	+
≥ 85 °F (% freq.)	0.0	+	0.1	0.4	2.7	18.5	36.0	40.0	21.1	4.5	0.3	0.0	10.3

* Galveston Channel fog signal + = less than 0.05%

Table 18 Continued

ENVIRONMENTAL DATA SUMMARY (PART 3)

AREA: Galveston, Texas

ENVIRONMENTAL FACTORS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
RELATIVE HUMIDITY (%)													
Mean	79	80	81	82	82	80	79	78	77	74	77	78	79
SEA TEMPERATURE (°F)													
Minimum	48	47	49	53	66	69	73	76	74	66	56	50	47
01% ≤	52	52	55	62	69	76	80	80	77	70	62	57	66
Mean	66.8	66.0	67.3	71.0	77.0	82.4	84.9	85.4	84.1	80.4	74.6	70.1	75.8
99% ≤	78	78	76	80	83	88	90	92	89	85	82	78	83
Maximum	84	86	80	86	92	92	92	94	94	90	86	86	94
SALINITY (‰)													
Minimum	20.3	21.7	22.0	15.6	13.1	16.9	3.9	20.5	18.4	21.0	19.7	23.8	3.9
Mean	28.5	28.5	26.8	26.9	25.2	27.4	30.3	32.0	27.5	27.9	28.2	29.2	28.2
Maximum	33.8	34.4	31.9	31.5	33.1	34.0	37.9	38.2	34.1	32.3	33.8	33.2	38.2
DENSITY (ρ)													
Mean (σ_t)*	15.8	15.2	15.2	15.2	14.3	14.8	18.4	22.0	20.0	18.5	18.1	17.0	17.0
SEA-LEVEL PRESSURE (mb)													
Minimum	996	994	996	993	1000	985	999	996	981	1000	998	1000	981
01% ≤	1005	1003	1002	1003	1005	1006	1009	1009	1004	1006	1005	1005	1005
Mean	1020	1018	1017	1016	1015	1015	1017	1016	1015	1017	1019	1020	1017
99% ≤	1034	1033	1032	1029	1026	1025	1025	1022	1024	1029	1034	1033	1028
Maximum	1040	1041	1038	1031	1031	1029	1027	1028	1025	1037	1040	1040	1041

* $\sigma_t = (\rho - 1) \times 10^3$; $\rho =$ gm cm^{-3}

Table 18 Continued

Appendix A

Tropical Cyclone Data

Summaries

APPENDIX A

TROPICAL CYCLONES PENETRATING THE SUB-SQUARE (SS) REGIONS OF MACHIASPORT, RARITAN BAY AND OFFSHORE SANDY HOOK, DELAWARE BAY AND OFFSHORE DELAWARE BAY, MISSISSIPPI DELTA, AND GALVESTON BAY

This study considers the actual occurrence of tropical cyclones that "penetrated" a sub-square (SS) boundary for five coastal areas of the United States. If a tropical cyclone penetrated any of the sub-squares (SS) in any respect (passing through or skimming a corner of the sub-square), it was considered a "penetration." This differs from the terminology of a "strike zone" in the main text which refers to a tropical cyclone moving onshore only in any of several designated coastal zones which are about 50 miles in length.

Maximum tropical cyclone activity for these five sub-squares (SS) occurs in the months of August and September with the latter being the peak month. The favored season of tropical cyclone activity for the Atlantic coast is July through September. This area is not nearly as prone to intense tropical cyclone activity in June or October.

Tropical cyclone activity is more intense and has a longer season along the Gulf coast. The hurricane genesis regions are the Western Caribbean and the Gulf of Mexico. The period from

June to early November favors tropical cyclone activity for this area. Referring to Technical Paper No. 55 (Cry), no tropical cyclone activity existed in the Gulf of Mexico for the following years: 1876, 1883, 1884, 1890, 1927, 1952, and 1962.

The chronological listing for each sub-square (SS) was obtained from several references. Each is preceded by a letter designating its code in the "Reference Found" column of each listing. These references are brief since their entirety may be found in the bibliography. They are:

D = Dunn and Miller, Atlantic Hurricanes

L = Ludlum, Early American Hurricanes 1492-1870

N = USAF, USMC, USN Annual Hurricane or Reports, 1950-1970

R = Cry, Technical Paper No. 55, Tropical Cyclones of the North Atlantic 1871-1963

T = Tannehill, Hurricanes, Chapter XV

W = Mariners Weather Log, Vol. 16, No. 1, January 1972.

For the period before 1871, the references relied heavily on Dunn, Ludlum and occasionally Tannehill. Technical Paper No. 55 (Cry) presented a reliable and continuous source of tropical cyclone data (1871 to 1963) including tropical cyclone intensities (1886 to 1963).

Prior to 1886 no accurate assessment of tropical cyclone intensity (wind) was available. The intensity column before 1886 remains blank for this reason. The intensity classification incorporated into this Appendix commencing with tropical cyclones in 1886 is: TS = Tropical Storm (sustained winds 34 to 63 knots) and H = Hurricane (sustained winds greater than 63 knots). In addition, a table is included listing the tropical cyclone intensity by month and period.

Charts 1-12 at the end of this Appendix show tropical cyclone movement roses based on the period 1886-1957.

MACHIASPORT REGION

This "penetration" study considered a sub-square (SS) bounded by 45°N68°W to 45°N66.5°W on the north to 44°N68°W to 44°N66.5°W on the south. "Penetration" has to be inside the SS. After referring to Technical Paper #55 (Cry) containing the general path of tropical cyclones through the study area, it was felt that any tropical cyclones prior to 1871 should have some indication of passing east of Cape Cod from the south or over Massachusetts Bay or Boston from the south or southwest in order to reach the SS. This generally appears to be the most favored cyclone track. Only the months July through September were considered. Cyclone movements in the vicinity of Nova Scotia were considered. The following tropical cyclones presented the above characteristics and probably penetrated the SS.

YEAR	DATE	INTENSITY	REF. FOUND
1635	Mid Aug.		D,L
1638	23-25 Sept.		D,L
1675	Late Aug.		L
1727	Sept.		L
1806	Late Aug.		L
1830	Mid Aug.		L
1839	30-31 Aug.		L
1850	9-10 Sept.		L
1858	Mid Sept.		L
1867	3 Aug.		L
1885	23 Sept.		R
Total:	11 Tropical Cyclones		
1888	22 Aug.	TS	R
1888	12 Sept.	TS	R

YEAR	DATE	INTENSITY	REF. FOUND
1888	22 Sept.	TS	R
1889	25 Sept.	H	R
1940	2 Sept.	TS	R
1953	7 Sept.	H	N,R
1954	11 Sept.	H Edna	N,R
1969	10 Sept.	H Gerda	N
1971	14 Sept.	TS Heida	W

Total: 9 Tropical Cyclones for the period 1886 - 1971 consisting of 5 Tropical Storms (TS) and 4 Hurricanes (H)

Period 1635 to 1971: 20 recorded Tropical Cyclones

Period	Aug.	Sept.	Total
Before 1871	6	4	10 Tropical Cyclones
1871 - 1971	1	9	10 Tropical Cyclones
1886 - 1971	(1)(0)	(4)(4)	(5 Tropical Storms) (4 Hurricanes)

RARITAN BAY AND OFF SANDY HOOK REGION

This "penetration" study considered a sub-square (SS) bounded by 41°N74.5°W to 41°N73°W on the north to 40°N74.5°W to 40°73°W on the south. "Penetration" has to be inside the SS. Any tropical cyclones prior to 1871 were included in the listing below if the reference material indicated a passage along the middle to northern New Jersey coast or western Long Island. Only the months July through September were considered. Most tropical cyclones penetrating this SS originate in the Southern North Atlantic moving in a path generally westward then northerly from 25°N along the Atlantic Coast.

YEAR	DATE	INTENSITY	REF. FOUND
1769	Early Sept.		L
1788	19-20 Aug.		D,L
1806	21-23 Aug.		L
1815	22-23 Sept.		D,L
1821	3 Sept.		D,L
1874	29 Sept.		R
1882	23 Sept.		R

Total: 7 Tropical Cyclones

YEAR	DATE	INTENSITY	REF. FOUND
1888	11 Sept.	TS	R
1893	23-24 Aug.	H	D,R
1897	24 Sept.	TS	R
1904	14 Sept.	TS	D,R
1944	14 Sept.	H	D,R
1954	31 Aug.	H Carol	D,R
1955	18 Aug.	TS Diane	D,N,R
1960	30 July	TS Brenda	N,R
1960	12 Sept.	H Donna	N,R
1961	14 Sept.	TS	R
1971	27-28 Aug.	TS Doria	W

Total: 11 Tropical Cyclones for the period 1886 - 1971 consisting of 7 Tropical Storms (TS) and 4 Hurricanes (H)

Period 1769 to 1971: 18 recorded Tropical Cyclones

Period	July	Aug.	Sept.	Total
Before 1871	0	2	3	5 Tropical Cyclones
1871 - 1971	1	4	8	13 Tropical Cyclones
1886 - 1971	(1)(0)	(2)(2)	(4)(2)	(7 Tropical Storms) (4 Hurricanes)

DELAWARE BAY AND OFFSHORE DELAWARE BAY

This "penetration" study considered a sub-square (SS) bounded by 39.3°N75.5°W to 39.3°N74°W on the north to 38.3°N75.5°W to 38.3° N74°W on the south. "Penetration" has to be inside the SS. Any tropical cyclones prior to 1871 were included in the listing below if the reference material indicated a passage along the Delaware Bay Region or the southern New Jersey coastline. Only the months July through September were considered. Tropical cyclones penetrating this SS usually originate in the Southern North Atlantic and move in a path westward and then northward along the Atlantic coast. Some cross inland over the Carolinas and exit into this SS.

YEAR	DATE	INTENSITY	REF. FOUND
1769	Early Sept.		L
1788	19-20 Aug.		D,L
1806	21-23 Aug.		L
1821	3 Sept.		D,L
1867	Early Aug.		L
1874	29 Sept.		R
1881	10 Sept.		R
1882	11 Sept.		R
1882	23 Sept.		R
Total:	9 Tropical Cyclones		
1888	11 Sept.	TS	R
1897	23 Sept.	TS	R
1903	16 Sept.	H	D,R
1904	14 Sept.	TS	D,R
1943	30 Sept.	TS	D,R
1944	2 Aug.	TS	R
1944	14 Sept.	H	D,R
1960	30 July	TS Brenda	N,R

YEAR	DATE	INTENSITY	REF. FOUND
1960	12 Sept.	H Donna	N,R
1961	14 Sept.	TS	R
1971	27-28 Aug.	TS Doria	W

Total: 11 Tropical Cyclones for the period 1886 - 1971 consisting of 8 Tropical Storms (TS) and 3 Hurricanes (H)

Period 1769 to 1971: 20 recorded Tropical Cyclones

Period	July	Aug.	Sept.	Total
Before 1871	0	3	2	5 Tropical Cyclones
1871 - 1971	1	2	12	15 Tropical Cyclones
1886 - 1971	(1)(0)	(2)(0)	(5)(3)	(8 Tropical Storms) (3 Hurricanes)

This "penetration" study considered a sub-square (SS) bounded by 30°N90°W and 30°N88°W on the north to 28°N90°W and 28°N88°W on the south. "Penetration" has to be inside this SS. Tropical cyclones penetrating this SS originate in the Gulf of Mexico moving north, the Southern North Atlantic moving west (generally through the Caribbean and Yucatan Channel) or in the Caribbean moving north or northwest through the Yucatan Channel.

YEAR	DATE	INTENSITY	REF. FOUND
1711	11-13 Sept.		D,T
1722	12-13 Sept.		D,L,T
1740	12 Sept.		D,L
1772	Sept.		D,L
1778	7-10 Oct.		D,L
1779	18 Aug.		D,L
1780	24 Aug.		D,L,T
1781	23 Aug.		T
1793	Aug.		D,L
1794	Late Aug.		D,L
1812	19 Aug.		D,L
1819	27-28 July		D,L
1821	Mid Sept.		D,L
1822	7-8 July		D,L
1831	16-17 Aug.		D,L
1837	6-7 Oct.		D,L
1855	15 Sept.		L
1856	10-11 Aug.		D,L
1860	11 Aug.		D,L
1860	15 Sept.		D,L
1860	Oct.		L
1871	4 Oct.		R
1872	10-11 July		R
1875	26 Sept.		R
1877	18-19 Sept.		D,R
1877	25-26 Oct.		R
1878	10 Oct.		R
1879	6 Oct.		D,R

YEAR	DATE	INTENSITY	REF. FOUND
1882	9 Sept.		R
1885	29-30 Aug.		R
1885	20 Sept.		R
1885	25-26 Sept.		D,R
Total:	32 Tropical Cyclones		
1887	18-19 Oct.	H	D,R
1889	22-23 Sept.	H	D,R
1892	12 Sept.	TS	D,R
1893	1-2 Oct.	H	D,R
1895	15-16 Aug.	TS	D,R
1897	12 Sept.	H	D,R
1900	12-13 Sept.	TS	D,R
1901	14-15 Aug.	H	D,R
1901	17 Sept.	TS	R
1902	10 Oct.	TS	D,R
1904	2 Nov.	TS	D,R
1906	26-27 Sept.	H	D,R
1907	21 Sept.	TS	D,R
1909	20-21 Sept.	H	D,R
1912	13-14 Sept.	H	D,R
1915	29 Sept.	H	D,R
1916	5 July	H	D,R
1916	18 Oct.	H	D,R
1917	27-28 Sept.	H	D,R
1923	17 Oct.	TS	D,R
1934	23-24 July	TS	R
1934	5 Oct.	TS	R
1936	27 July	TS	D,R
1937	19 Sept.	TS	D,R
1939	15-16 June	TS	D,R
1940	5 Aug.	TS	D,R
1941	12 Sept.	TS	R
1943	26 July	H	R
1944	10 Sept.	TS	D,R
1946	14-15 June	TS	R
1947	18-19 Sept.	H	D,R
1948	8 July	TS	D,R
1948	4 Sept.	H	D,R
1950	30-31 Aug.	H Baker	D,N,R
1953	19 Sept.	TS	R
1955	1 Aug.	TS Brenda	D,N,R
1955	26-27 Aug.	TS	D,R
1956	24 Sept.	H Flossy	D,N,R
1959	7-8 Oct.	TS Irene	N,R
1960	15 Sept.	H Ethel	N,R

YEAR	DATE	INTENSITY	REF. FOUND
1965	9-10 Sept.	H Betsy	N
1965	28 Sept.	TS Debbie	N
1969	17-18 Aug.	H Camille	N

Total: 43 Tropical Cyclones for the period 1886 - 1971 consisting of 23 Tropical Storms (TS) and 20 Hurricanes (H)

Period 1711 to 1971: 75 recorded Tropical Cyclones

Period	June	July	Aug.	Sept.
Before 1871	-	2	9	7
1871 - 1971	2	6	8	26
1886 - 1971	(1)(0)	(3)(2)	(3)(4)	(10)(11)

Period	Oct.	Nov.	Total
Before 1871	3	-	21 Tropical Cyclones
1871 - 1971	11	1	54 Tropical Cyclones
1886 - 1971	(5)(3)	(1)(0)	(23 Tropical Storms) (20 Hurricanes)

GALVESTON BAY REGION

This "penetration" study considered a sub-square (SS) bounded on the SW by 28.5°N96°W, on the SE by 28.5°N94°W and on the north by the Texas Coast. "Penetration" has to be inside this SS. Most tropical cyclones penetrating this SS originate in the Gulf or in the Caribbean moving westward through the Yucatan Channel. During the time period 1767-1817 and 1819-1836 this Region remained uninhabited except for Indians and Pirates.

YEAR	DATE	INTENSITY	REF. FOUND
1766	4 Sept.		D,L,T
1818	12-14 Sept.		D,L
1837	3-6 Oct.		D,L
1839	5 Nov.		D
1842	17-18 Sept.		D
1854	17-18 Sept.		D,L
1867	3 Oct.		D,L
1871	4 June		D,R
1871	9 June		D,R
1877	17 Sept.		D,R
1879	22-23 Aug.		D,R
1880	24 June		R
Total:	12 Tropical Cyclones		
1886	14 June	TS	D,R
1886	12 Oct.	H	D,R
1888	16-17 June	H	D,R
1888	5 July	TS	D,R
1891	4-5 July	H	D,R
1895	6 Oct.	TS	D,R
1898	27-28 Sept.	TS	D,R
1900	8 Sept.	H	D,L,R
1909	21 July	H	D,R
1915	16-17 Aug.	H	D,L,R
1932	13 Aug.	H	D,R
1933	22-23 July	TS	D,R
1934	27 Aug.	TS	D,R

YEAR	DATE	INTENSITY	REF. FOUND
1938	17 Oct.	TS	D,R
1940	23 Sept.	TS	D,R
1941	14 Sept.	TS	D,R
1941	23 Sept.	TS	D,R
1942	20-21 Aug.	H	D,R
1942	29-30 Aug.	H	D,R
1943	27 July	H	D,R
1945	20-21 July	TS	R
1947	24 Aug.	H	D,R
1949	3-4 Oct.	H	D,R
1957	27 June	H Audrey	D,N,R
1959	24-25 July	H Debra	N,R
1963	16-17 Sept.	TS Cindy	N,R
1964	7-8 Aug.	TS Abby	N
1970	16 Sept.	TS Felice	N
1971	10 Sept.	H Fern	W

Total: 29 Tropical Cyclones for the period 1886 - 1971 consisting of 14 Tropical Storms (TS) and 15 Hurricanes (H)

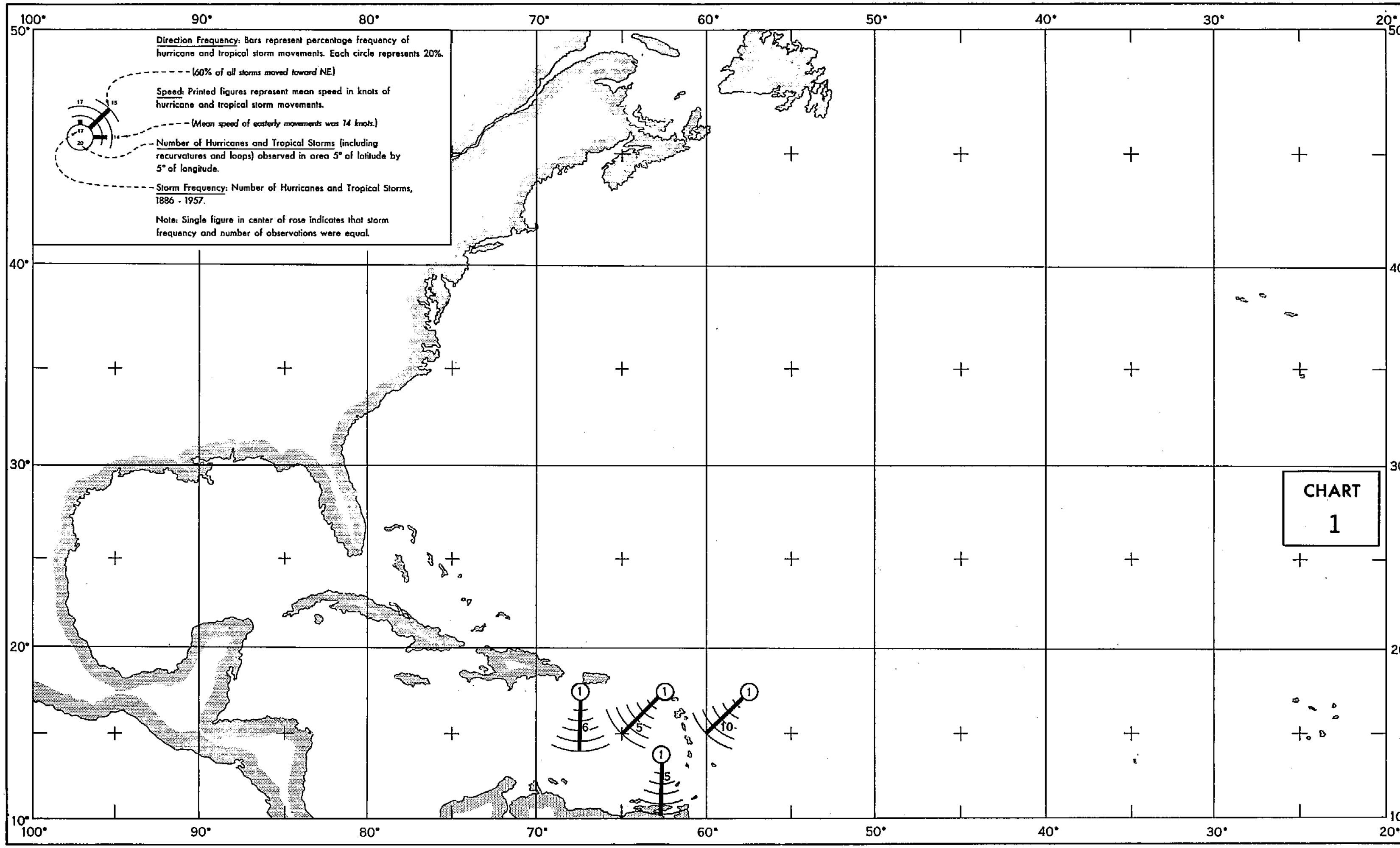
Period 1766 to 1971: 41 recorded Tropical Cyclones

Period	June	July	Aug.	Sept.
Before 1871	-	-	-	4
1871 - 1971	6	7	8	9
1886 - 1971	(1)(2)	(3)(4)	(2)(5)	(5)(3)

Period	Oct.	Nov.	Total
Before 1871	2	1	7 Tropical Cyclones
1871 - 1971	4	-	34 Tropical Cyclones
1886 - 1971	(2)(2)	-	(13 Tropical Storms) (16 Hurricanes)

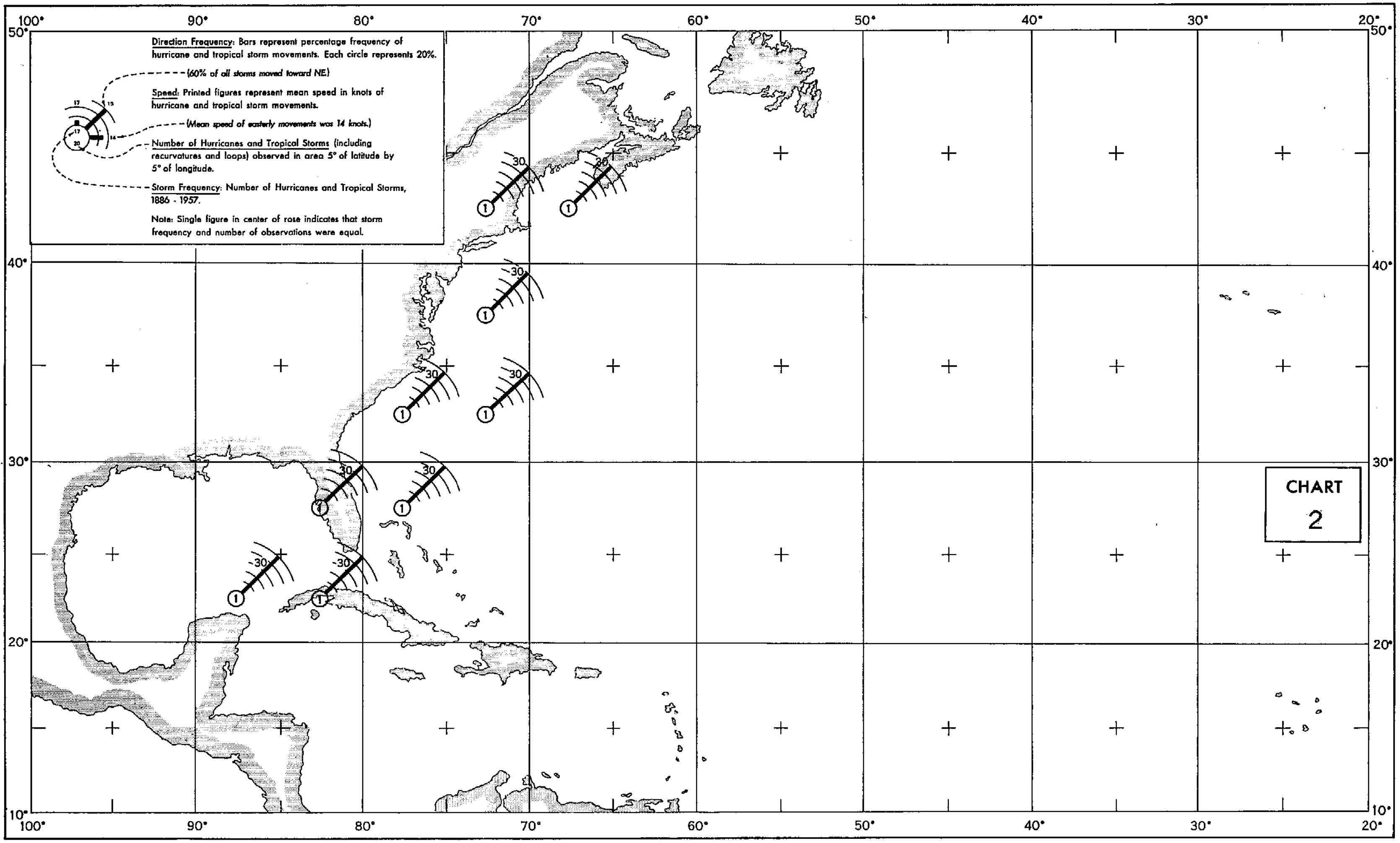
TROPICAL STORMS & HURRICANES

JANUARY



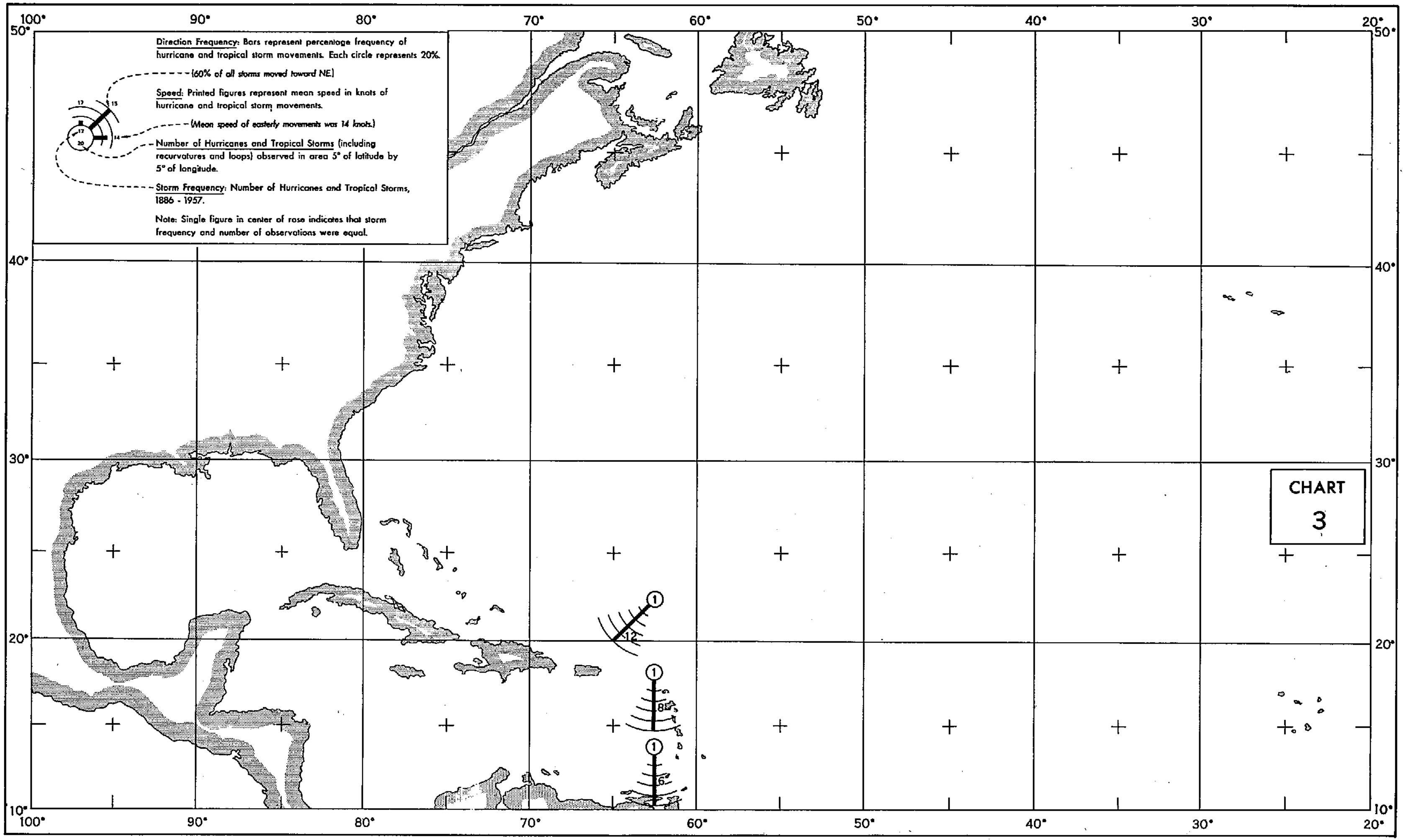
TROPICAL STORMS & HURRICANES

FEBRUARY



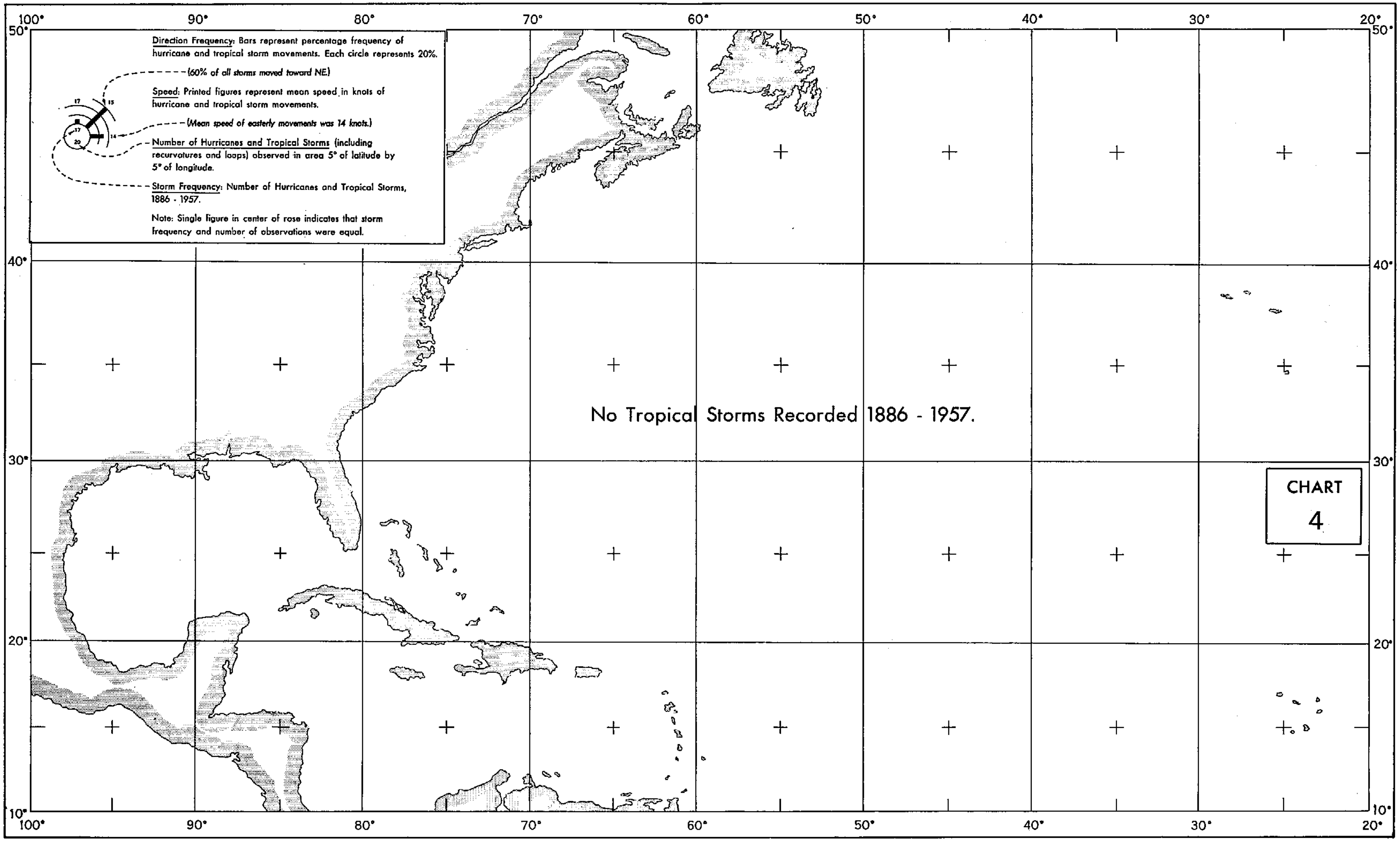
TROPICAL STORMS & HURRICANES

MARCH



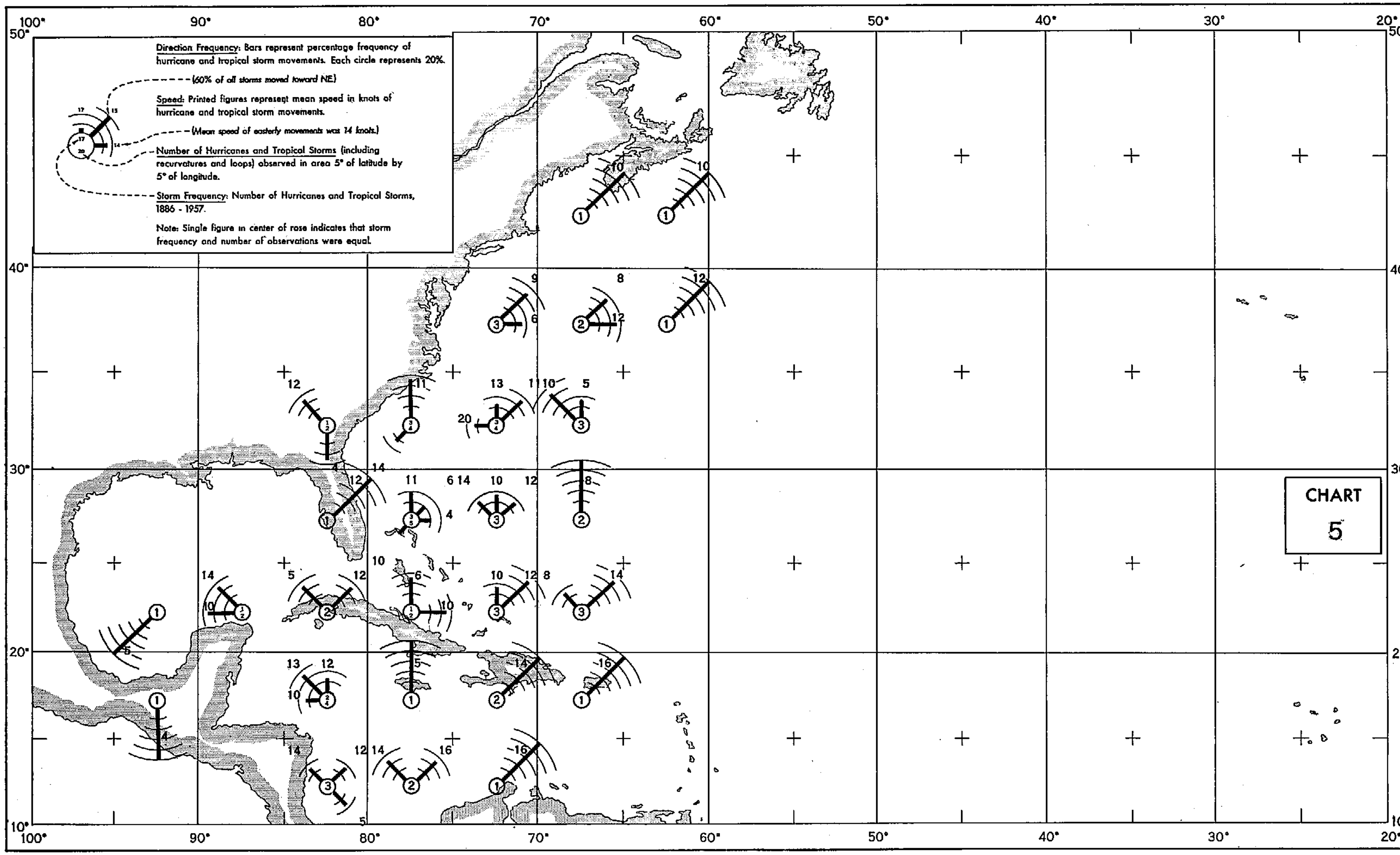
TROPICAL STORMS & HURRICANES

APRIL

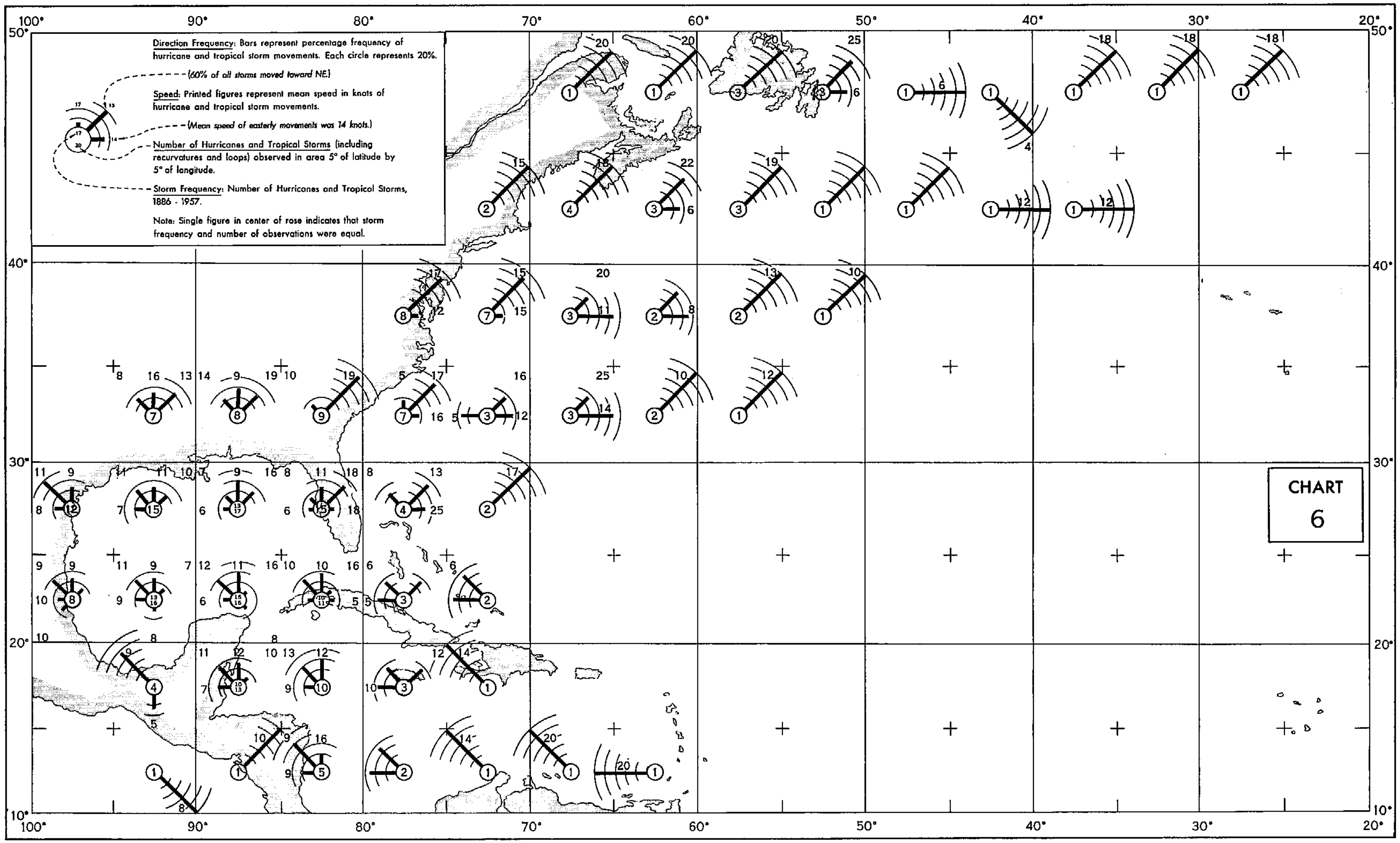


TROPICAL STORMS & HURRICANES

MAY

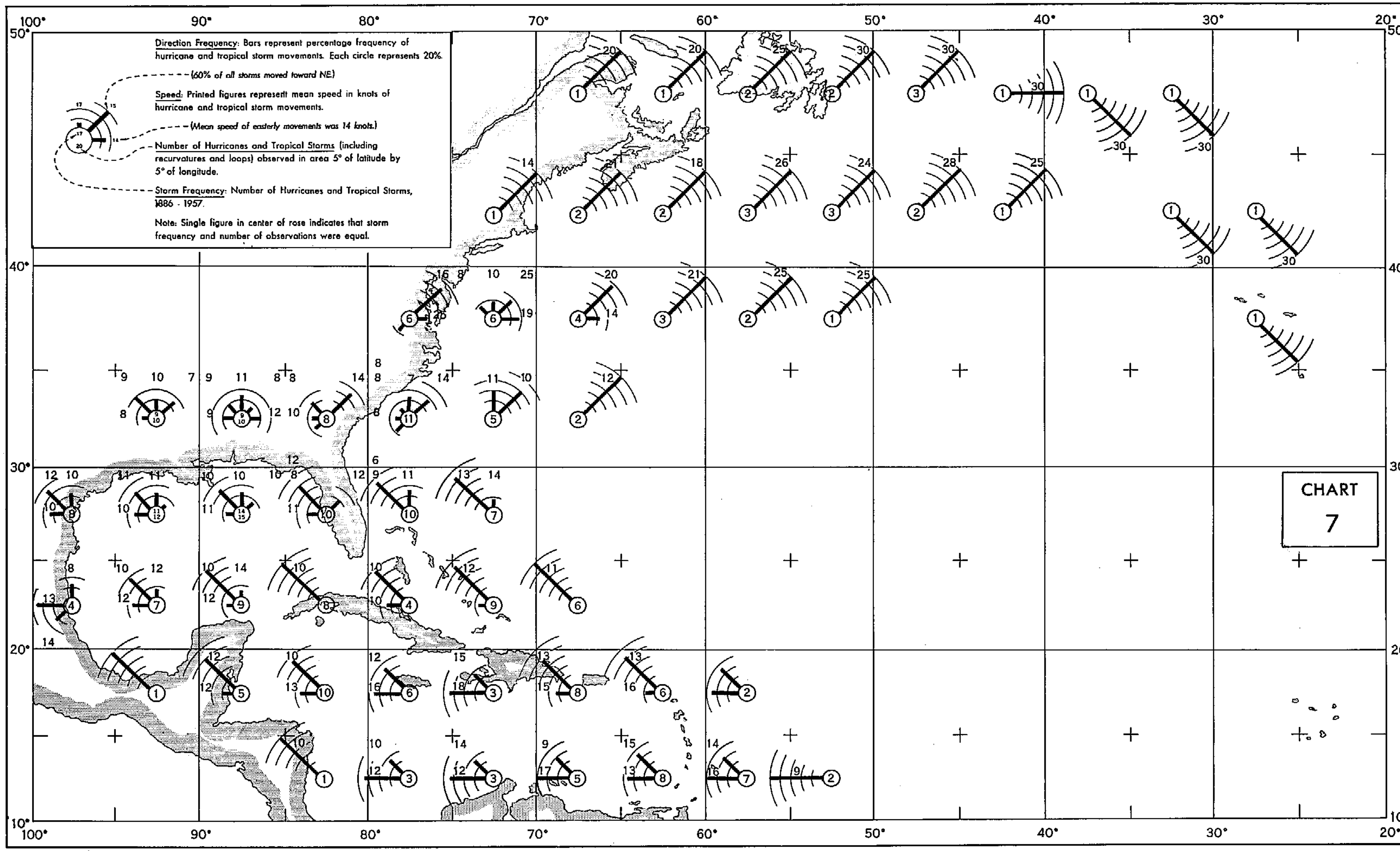


TROPICAL STORMS & HURRICANES JUNE



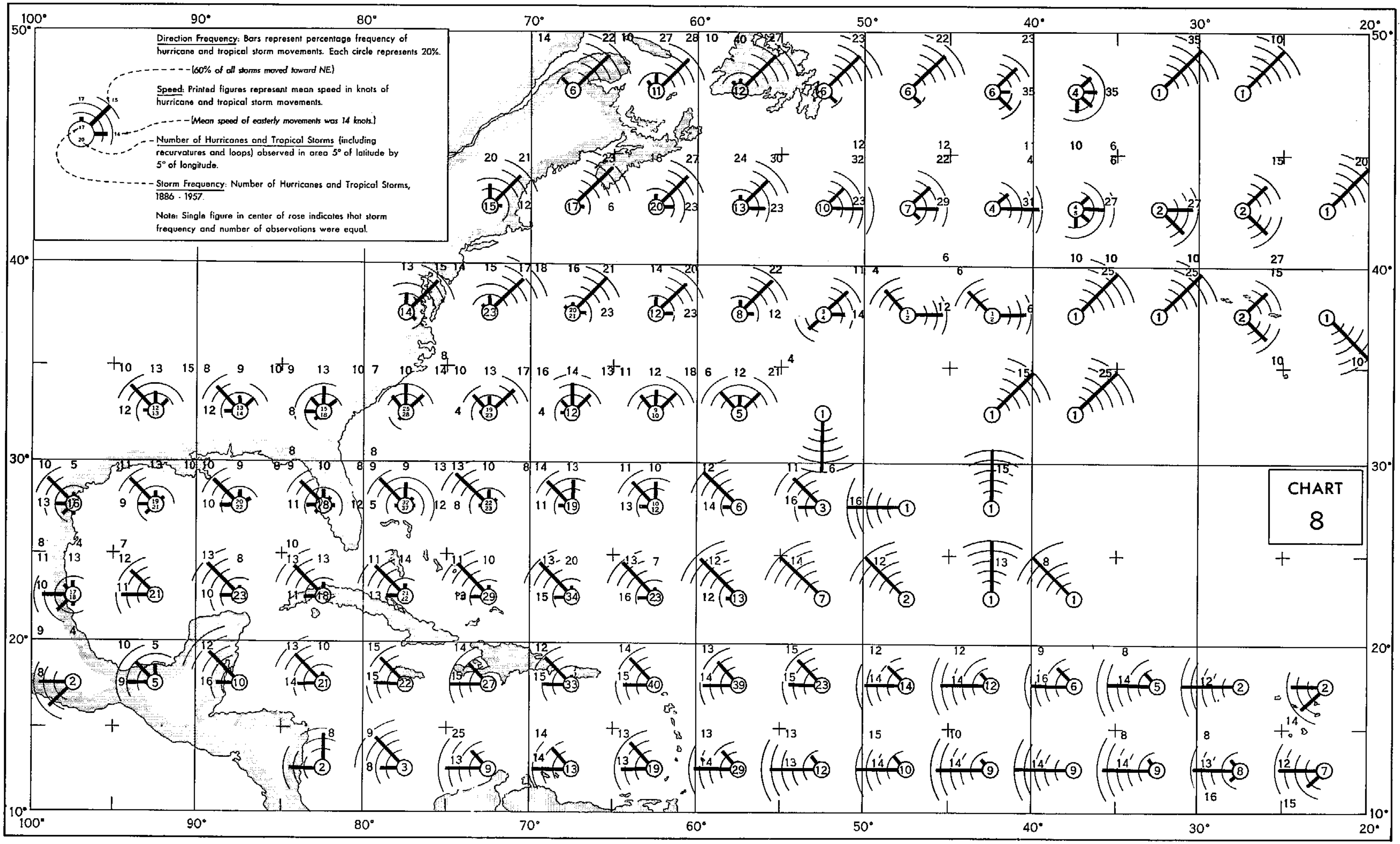
TROPICAL STORMS & HURRICANES

JULY



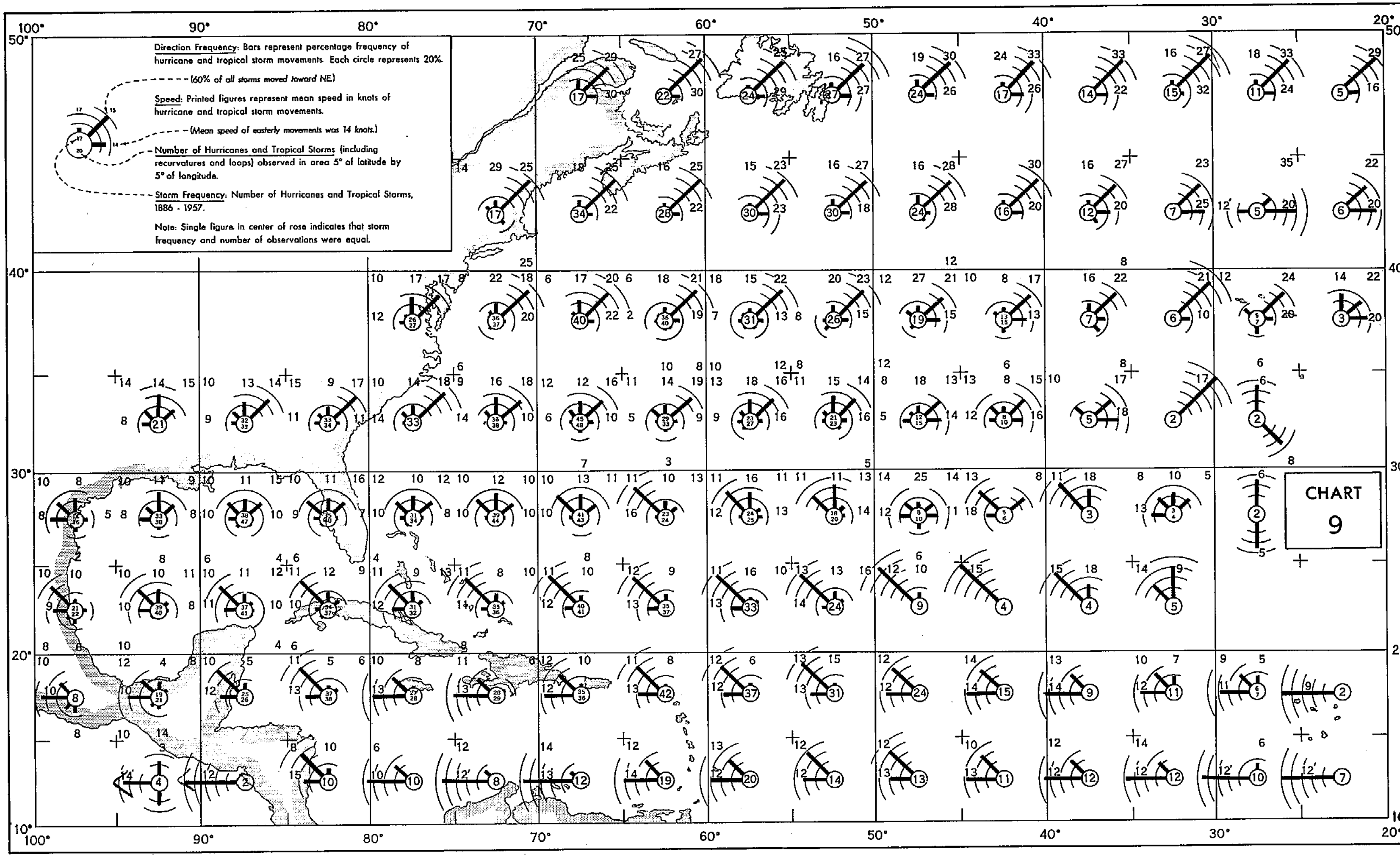
TROPICAL STORMS & HURRICANES

AUGUST

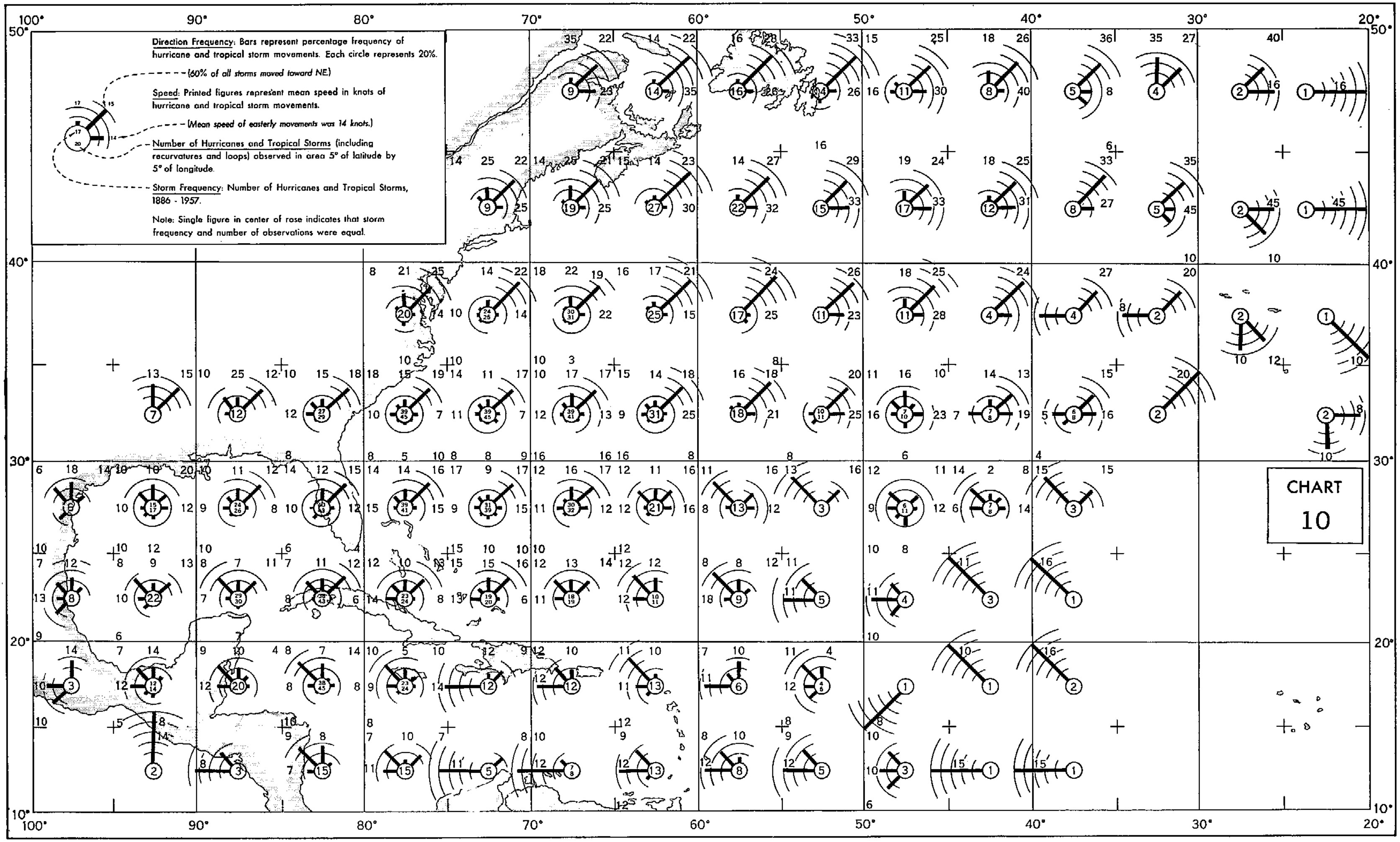


TROPICAL STORMS & HURRICANES

SEPTEMBER

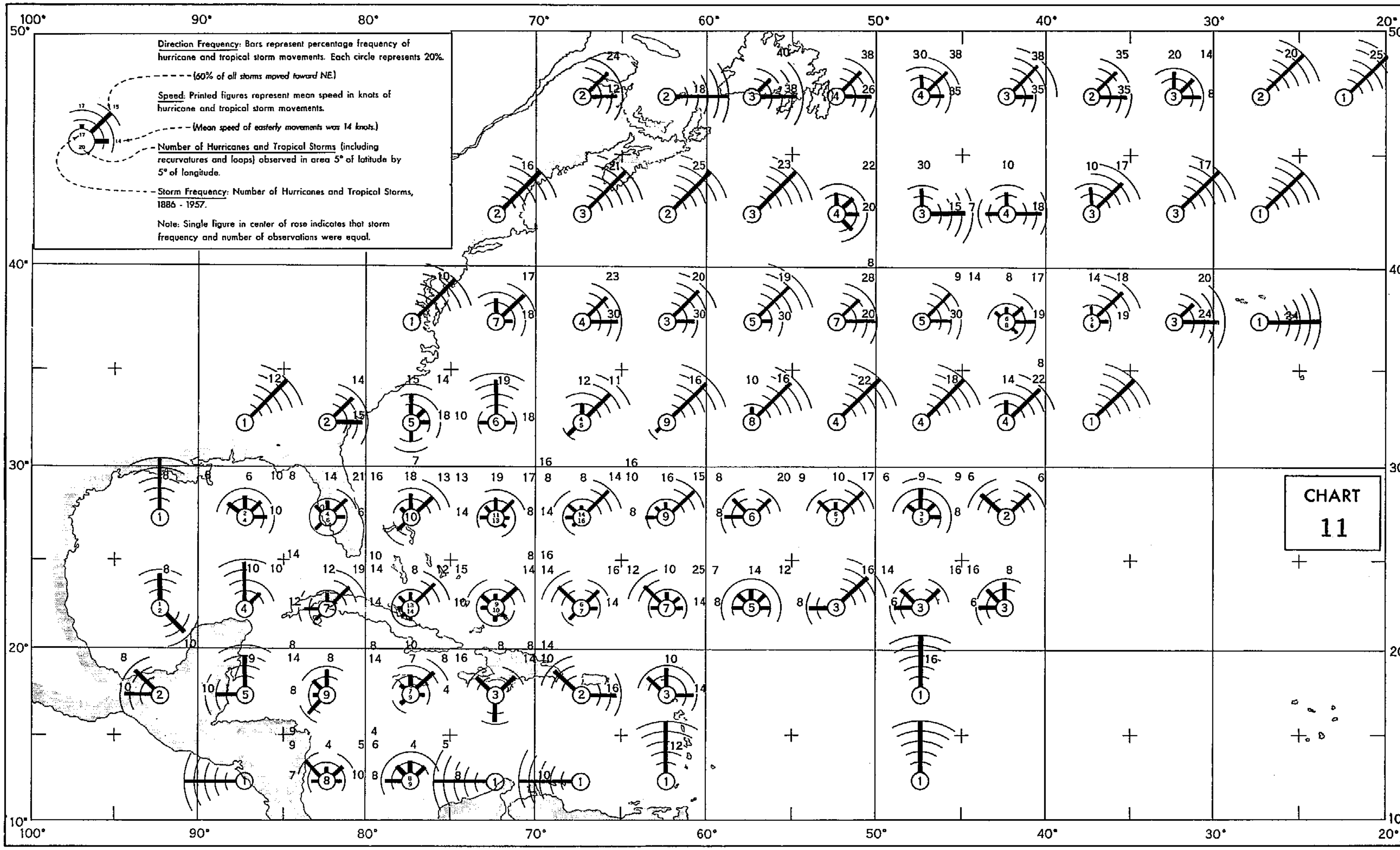


TROPICAL STORMS & HURRICANES OCTOBER



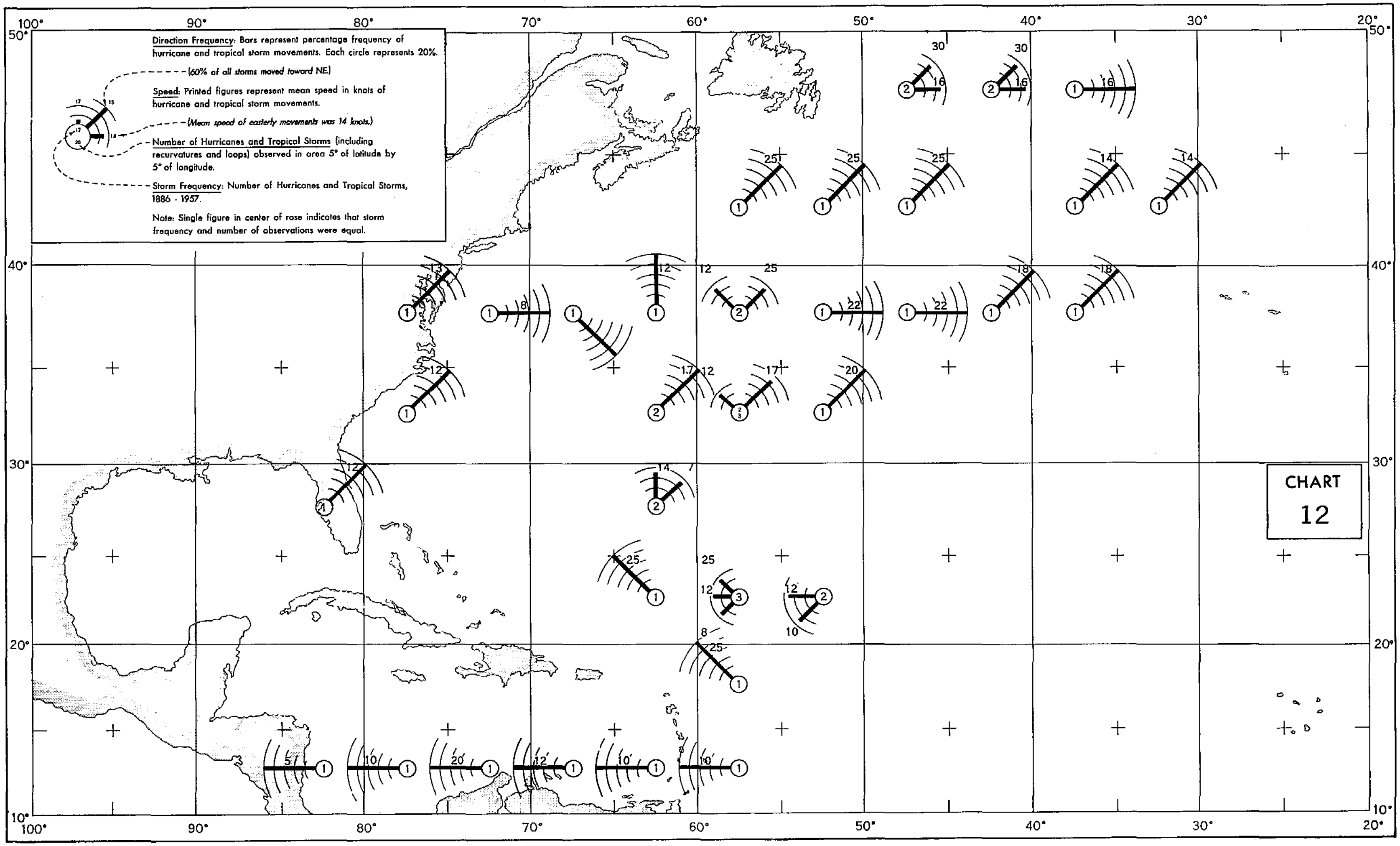
TROPICAL STORMS & HURRICANES

NOVEMBER



TROPICAL STORMS & HURRICANES

DECEMBER

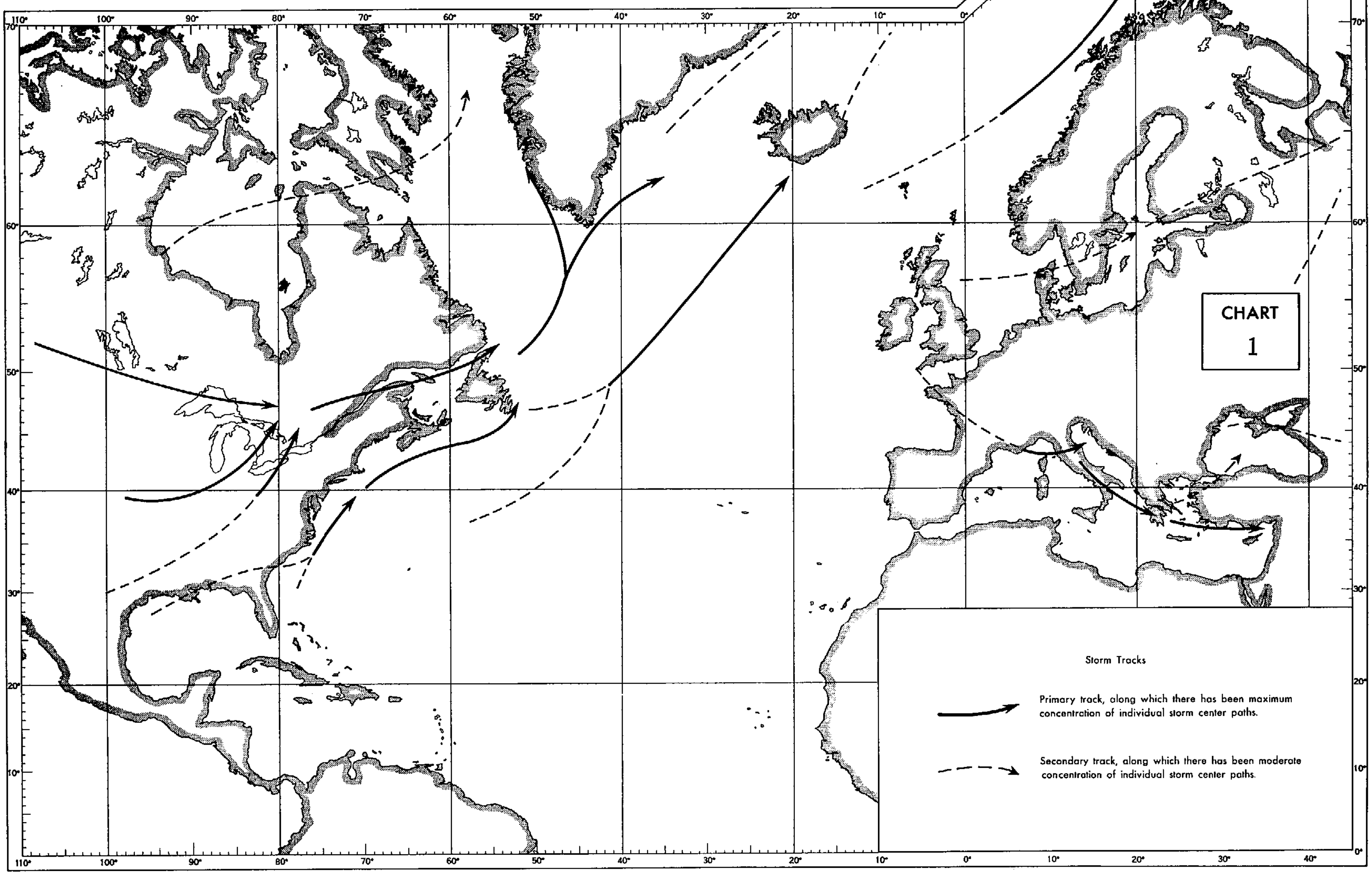


Appendix B

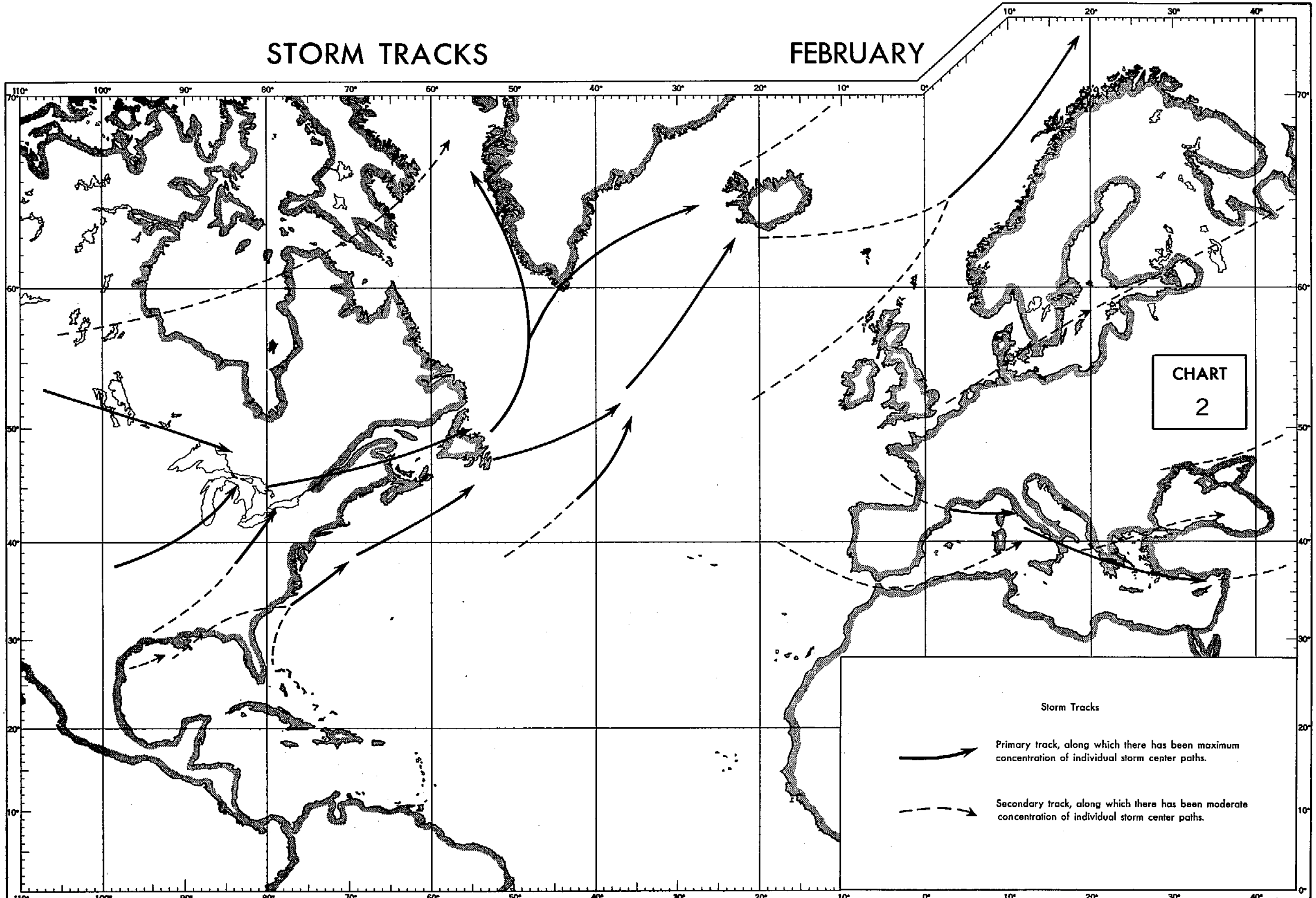
Cyclone Track Charts

These charts show generalized tracks of moving cyclonic storms, both tropical and extratropical.

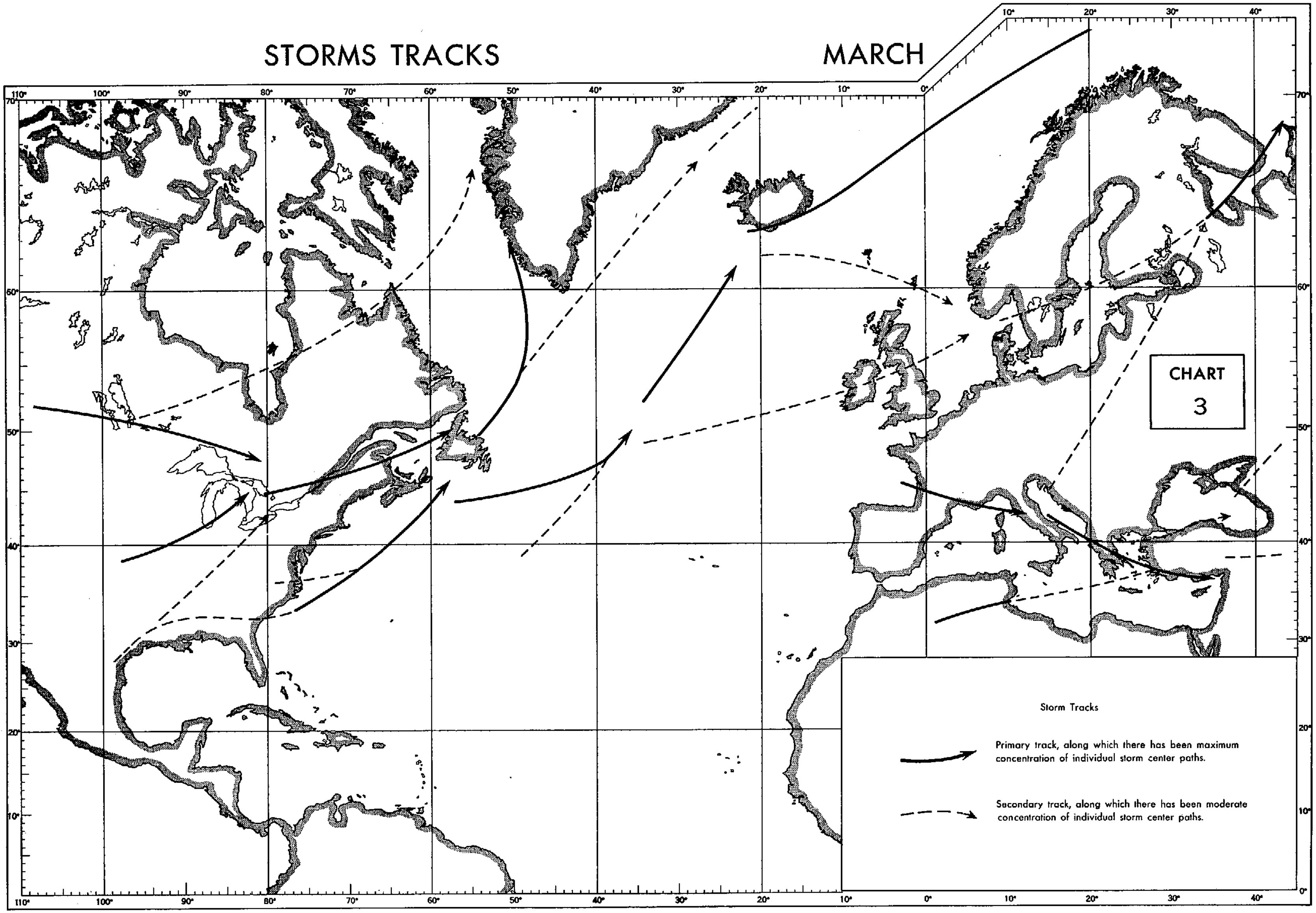
STORM TRACKS JANUARY



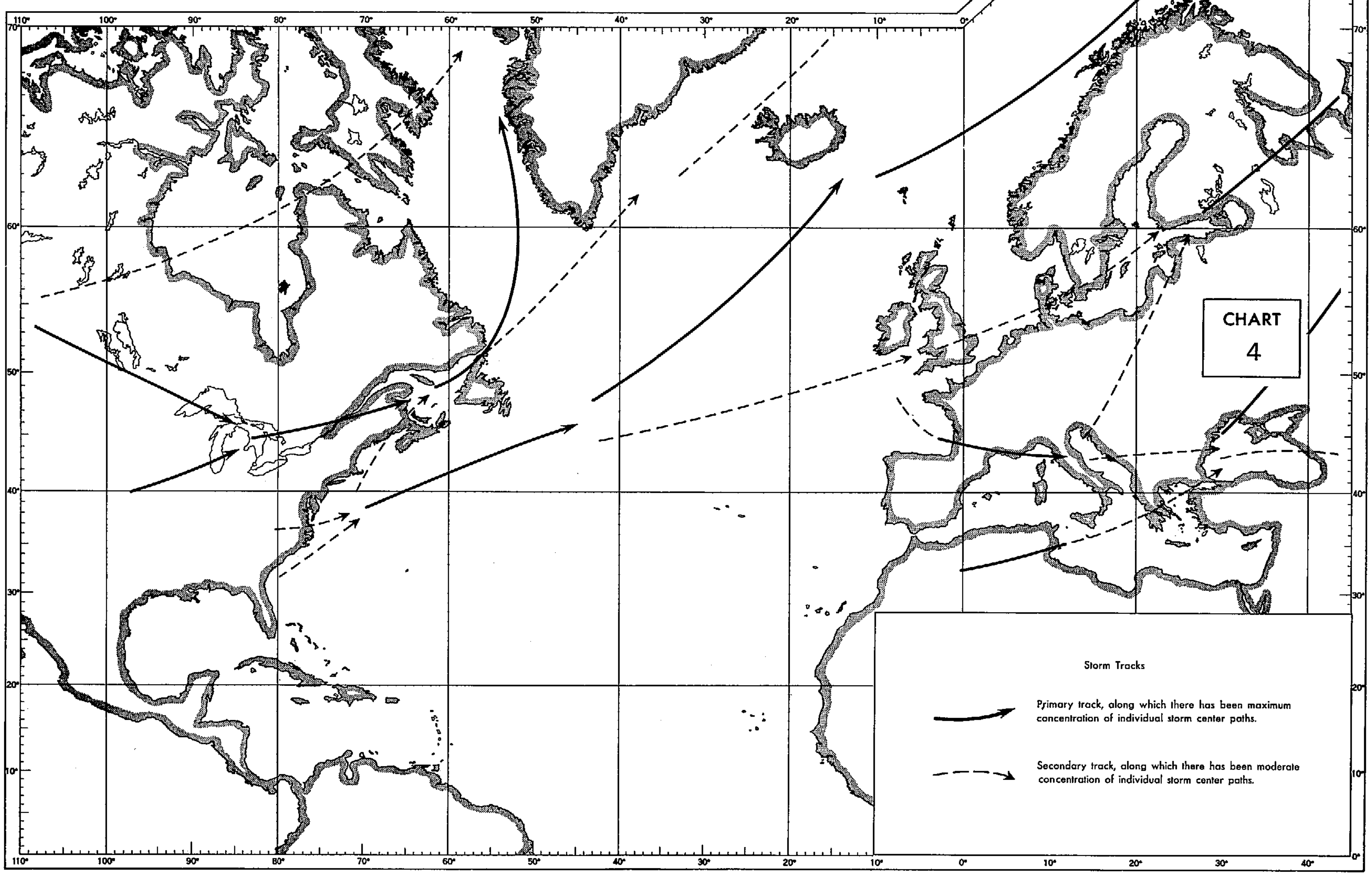
STORM TRACKS FEBRUARY



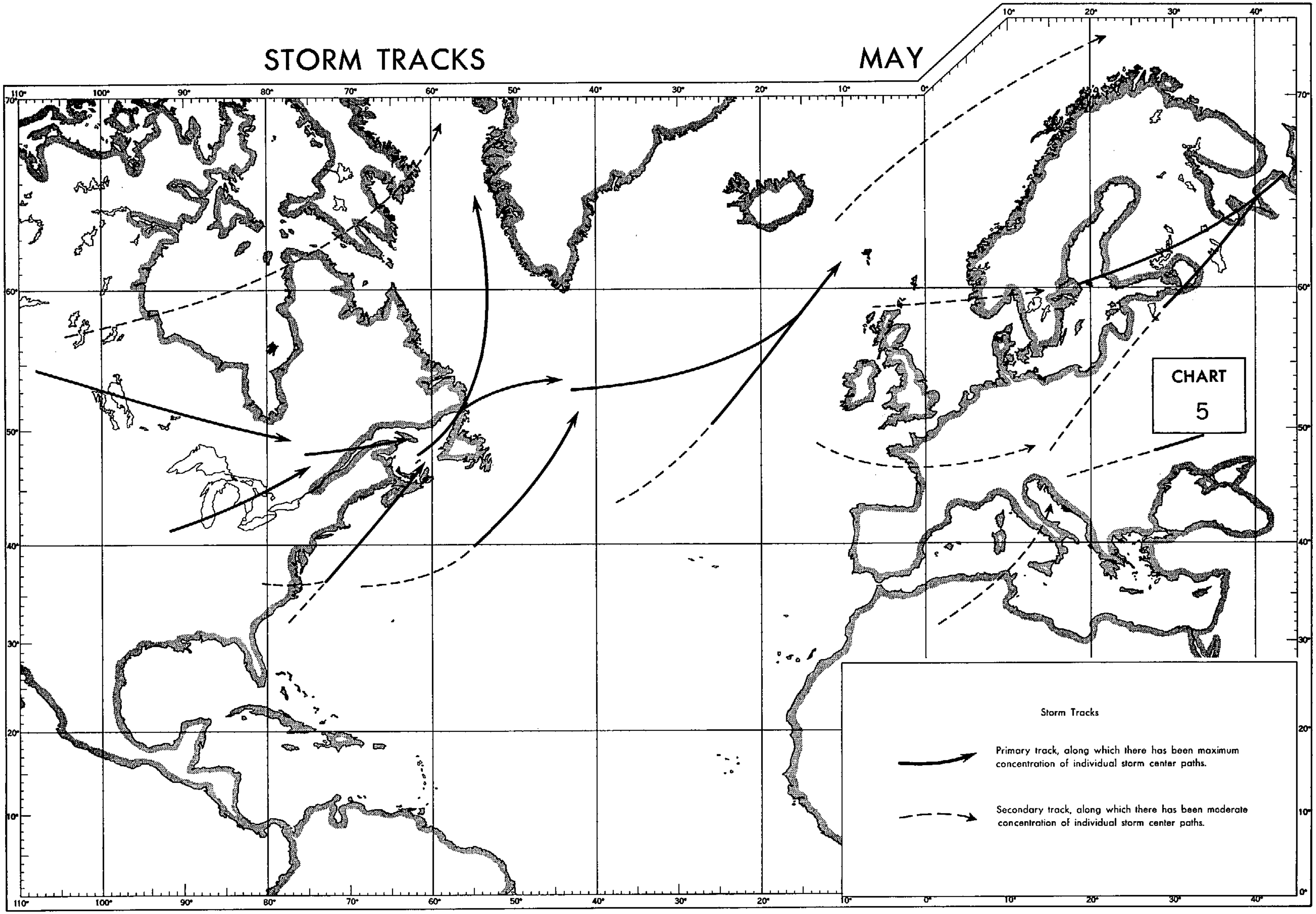
STORMS TRACKS MARCH



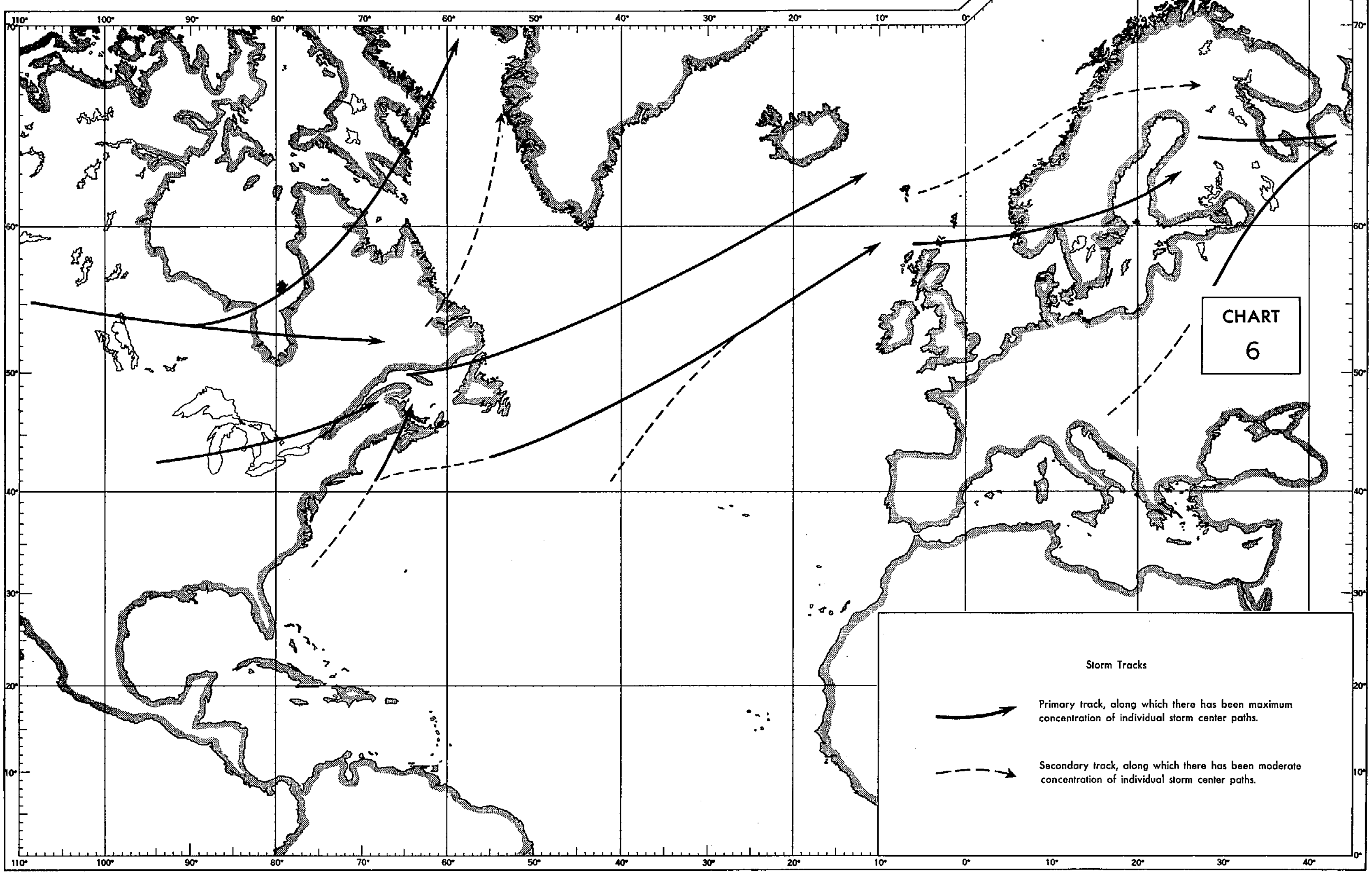
STORM TRACKS — APRIL

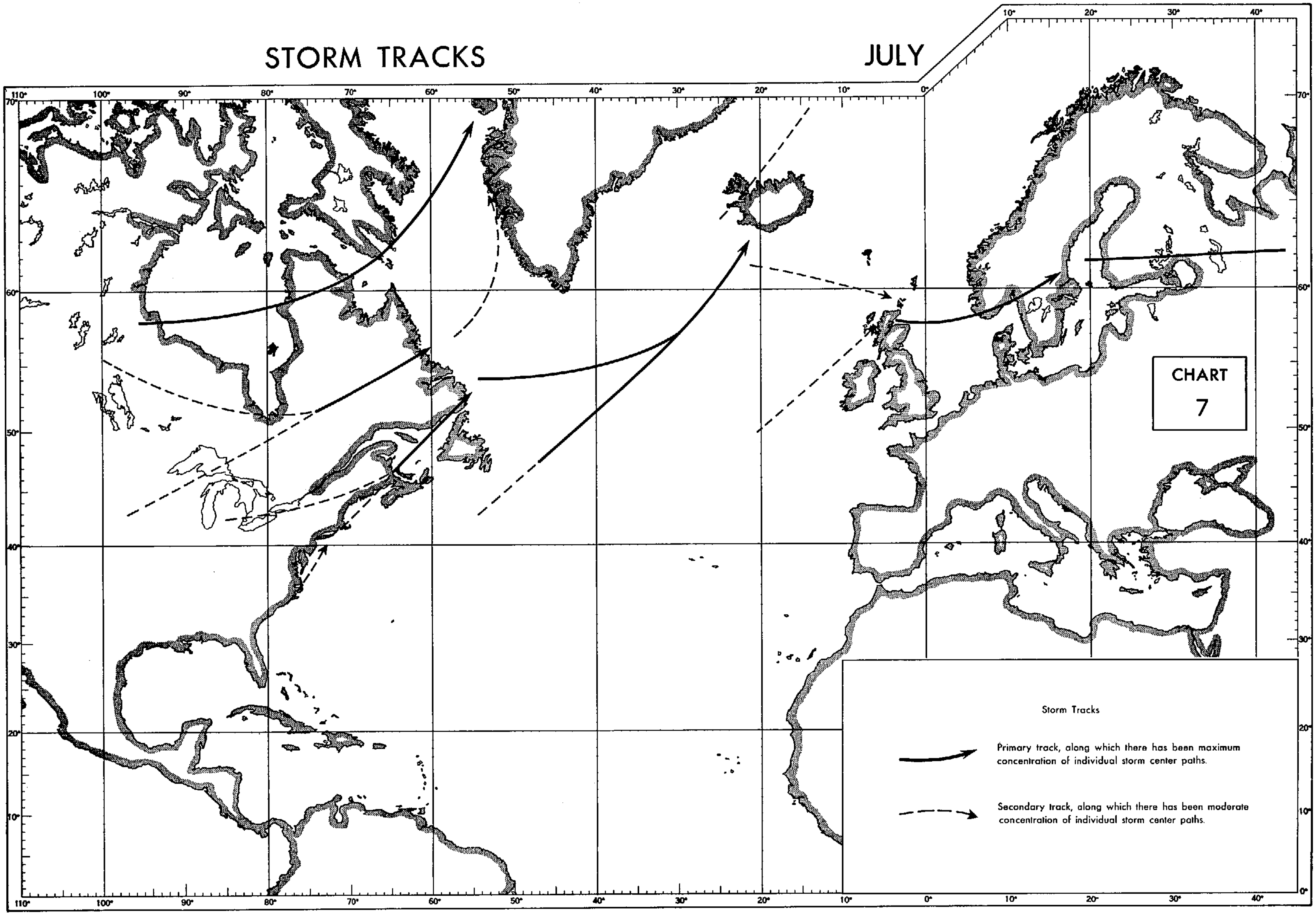


STORM TRACKS MAY

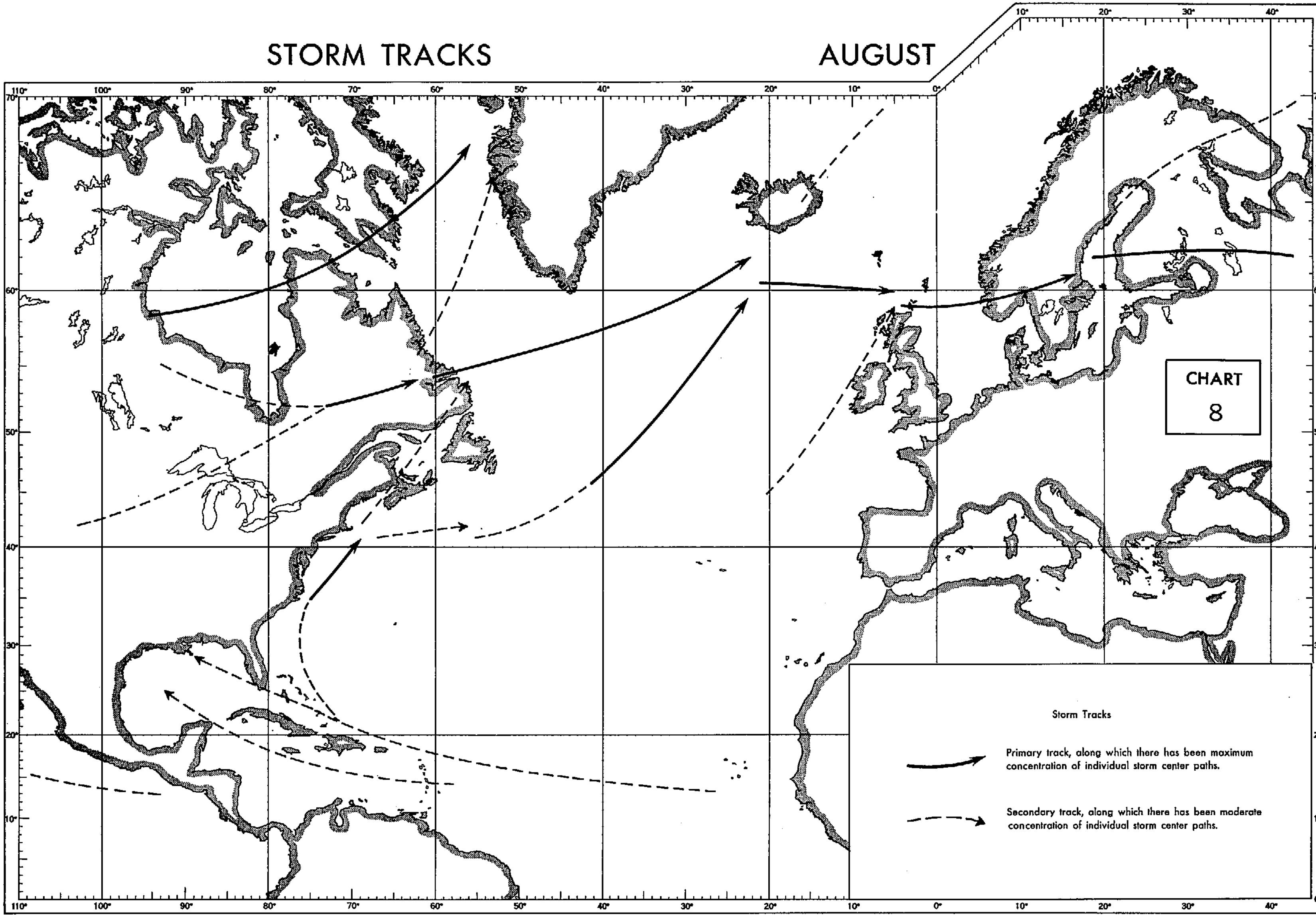


STORM TRACKS JUNE

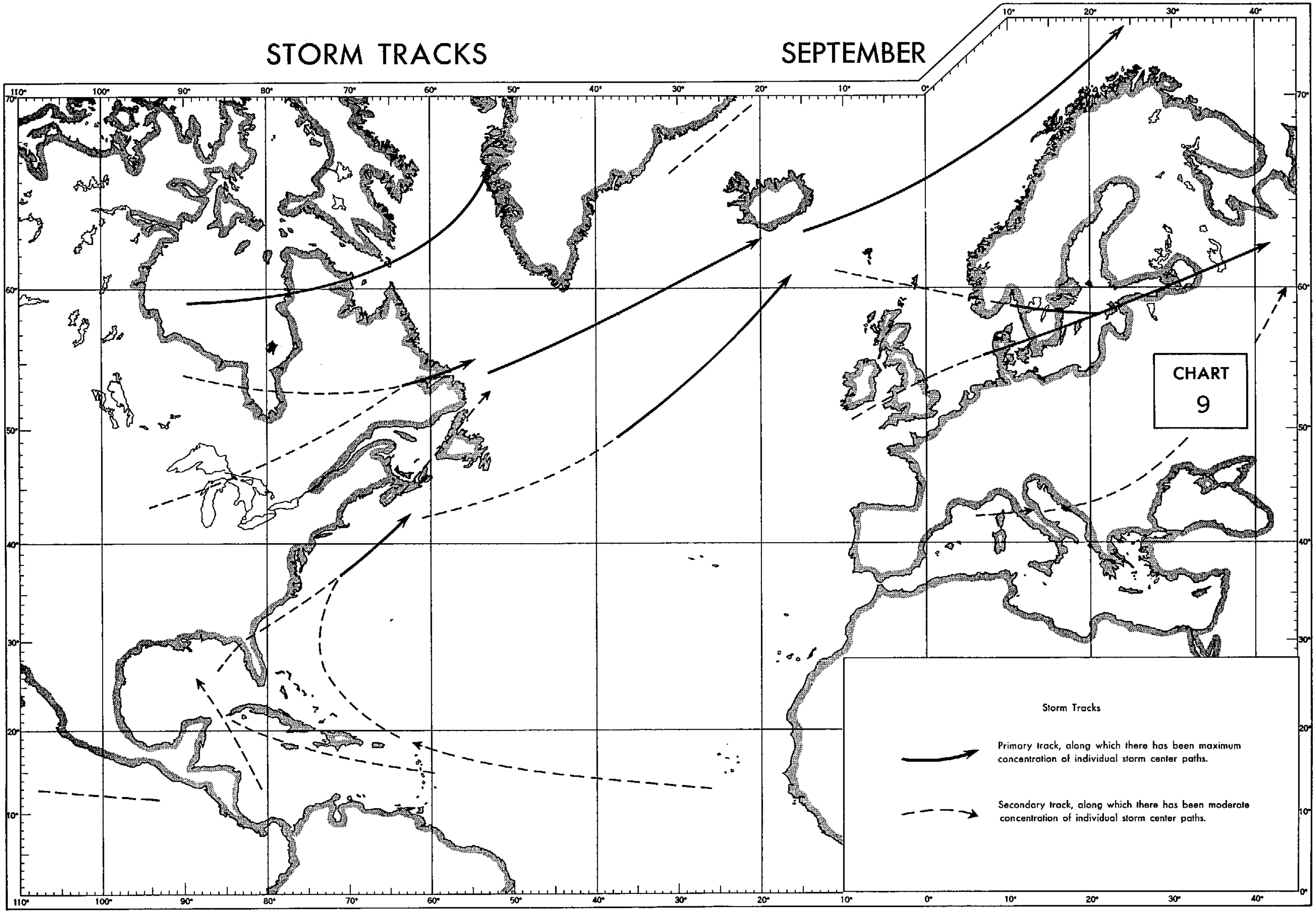



STORM TRACKS
JULY
CHART
7
Storm Tracks
Primary track, along which there has been maximum concentration of individual storm center paths.
Secondary track, along which there has been moderate concentration of individual storm center paths.

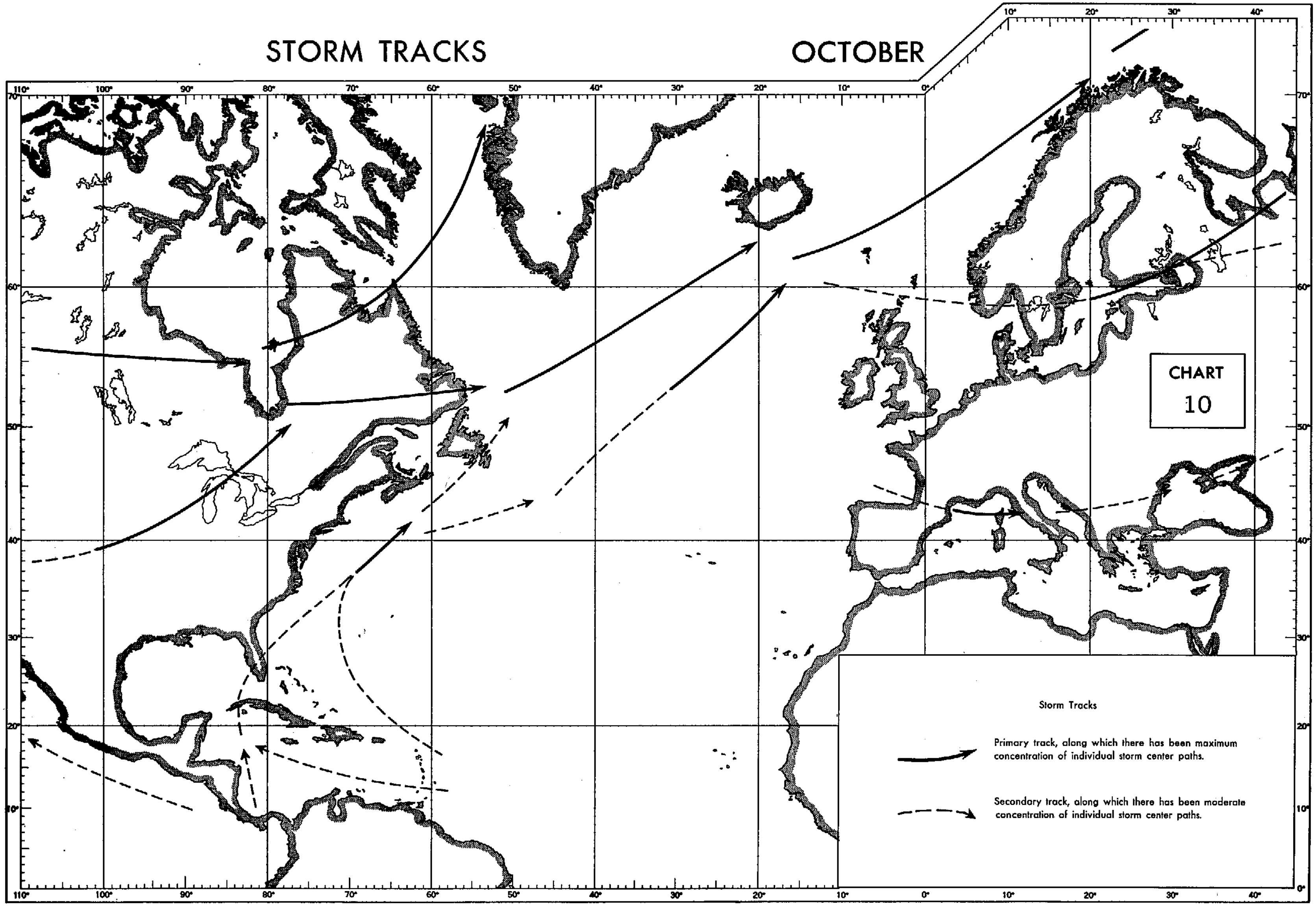
STORM TRACKS AUGUST



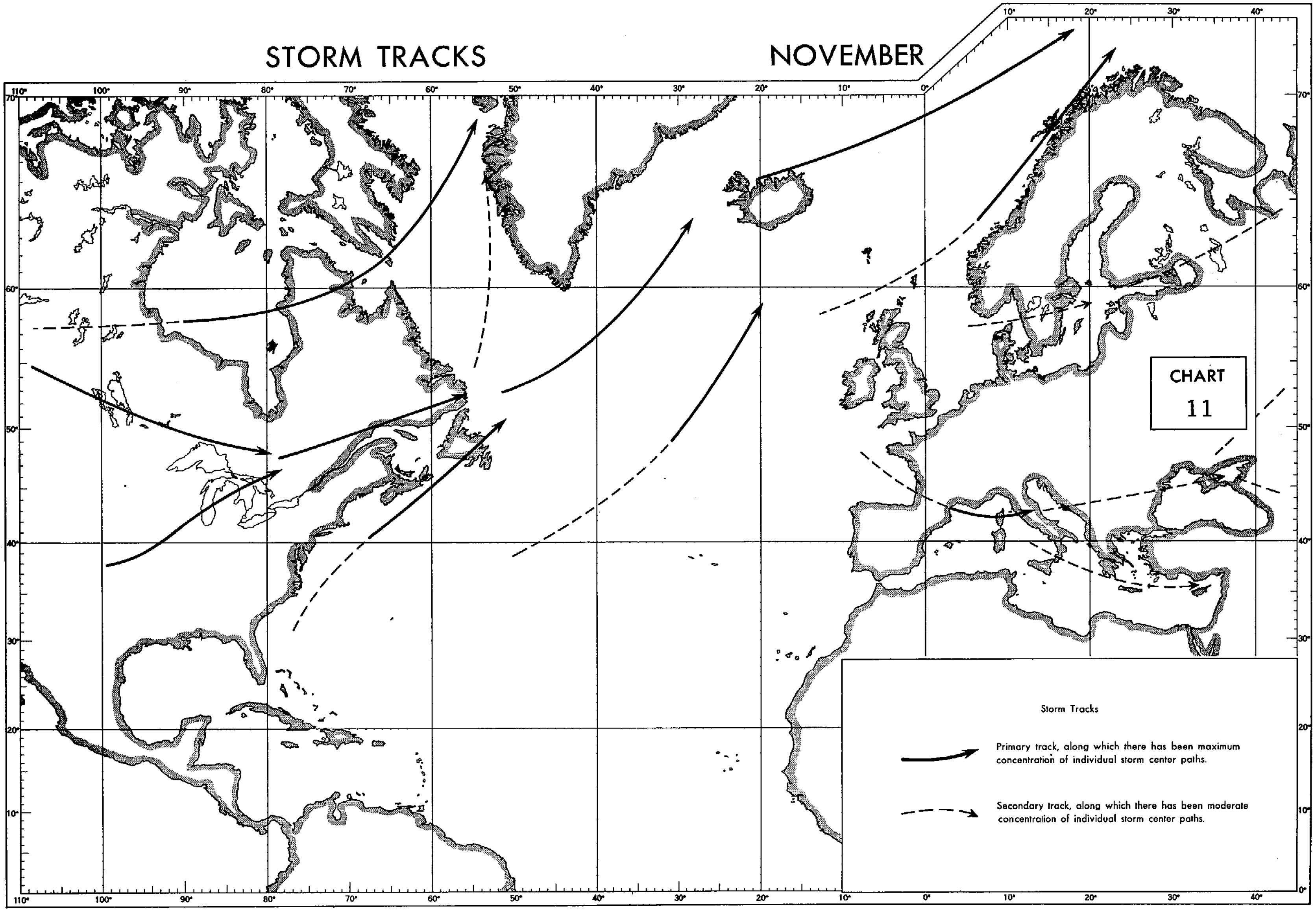
STORM TRACKS SEPTEMBER



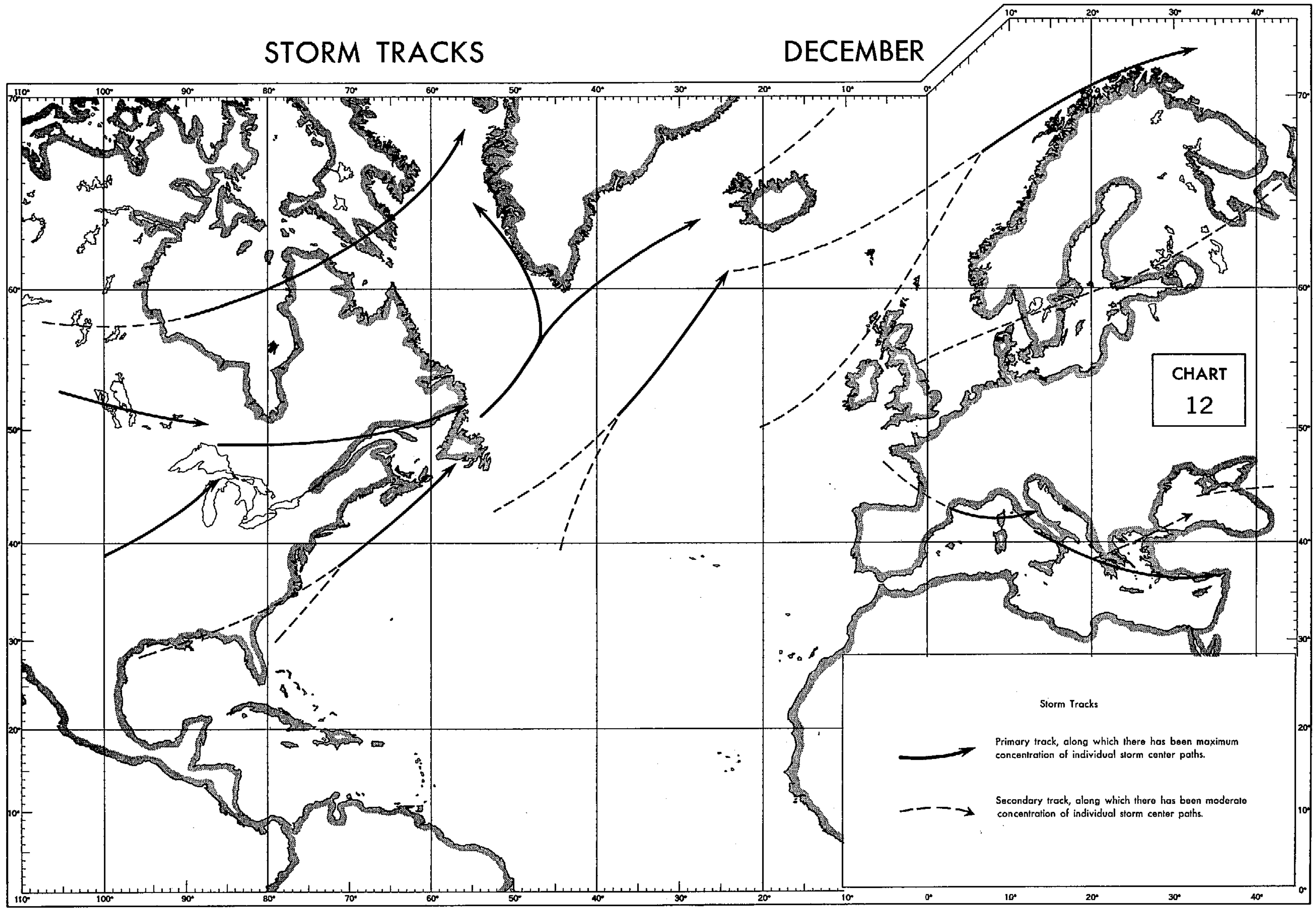
STORM TRACKS OCTOBER

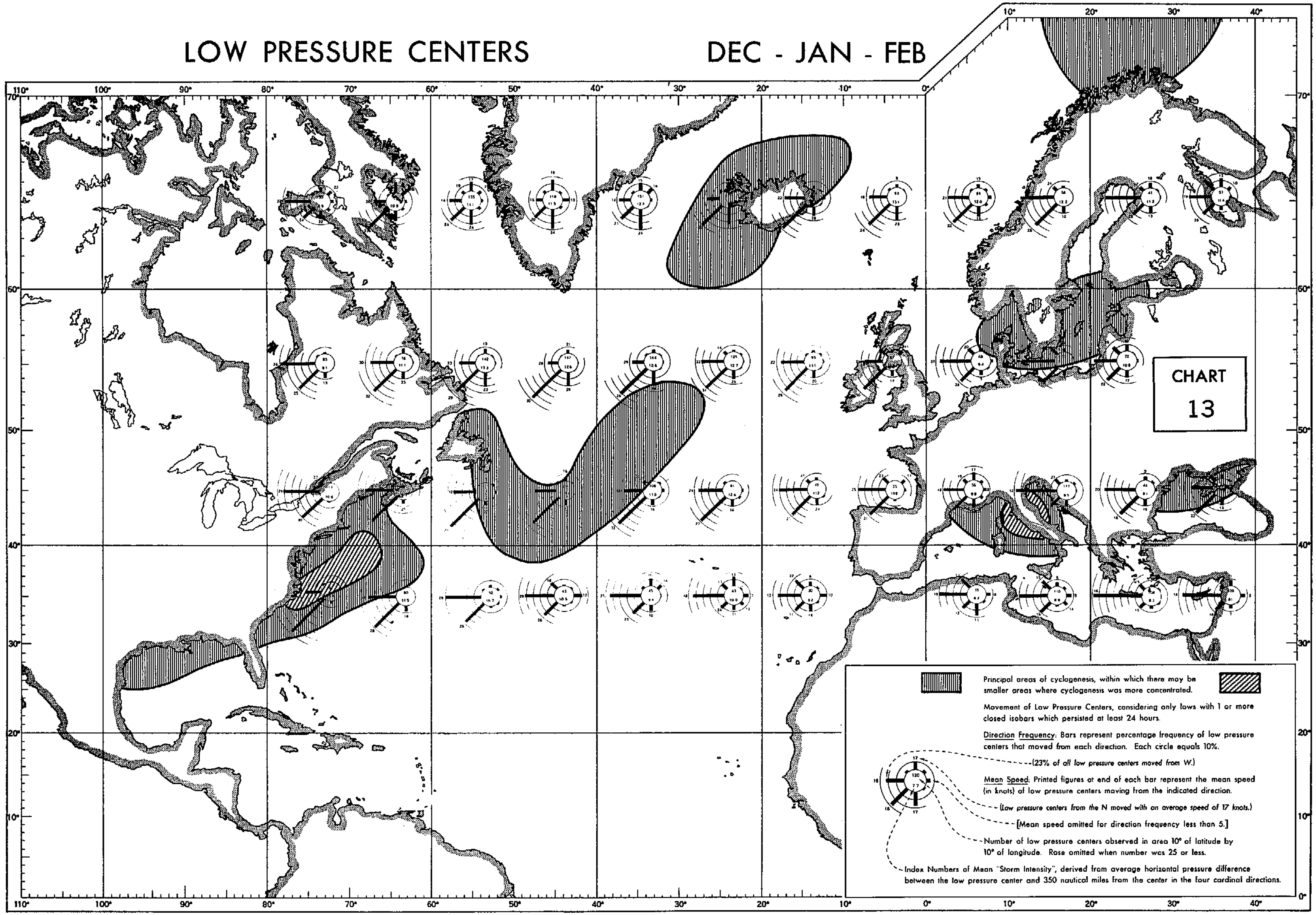


STORM TRACKS NOVEMBER

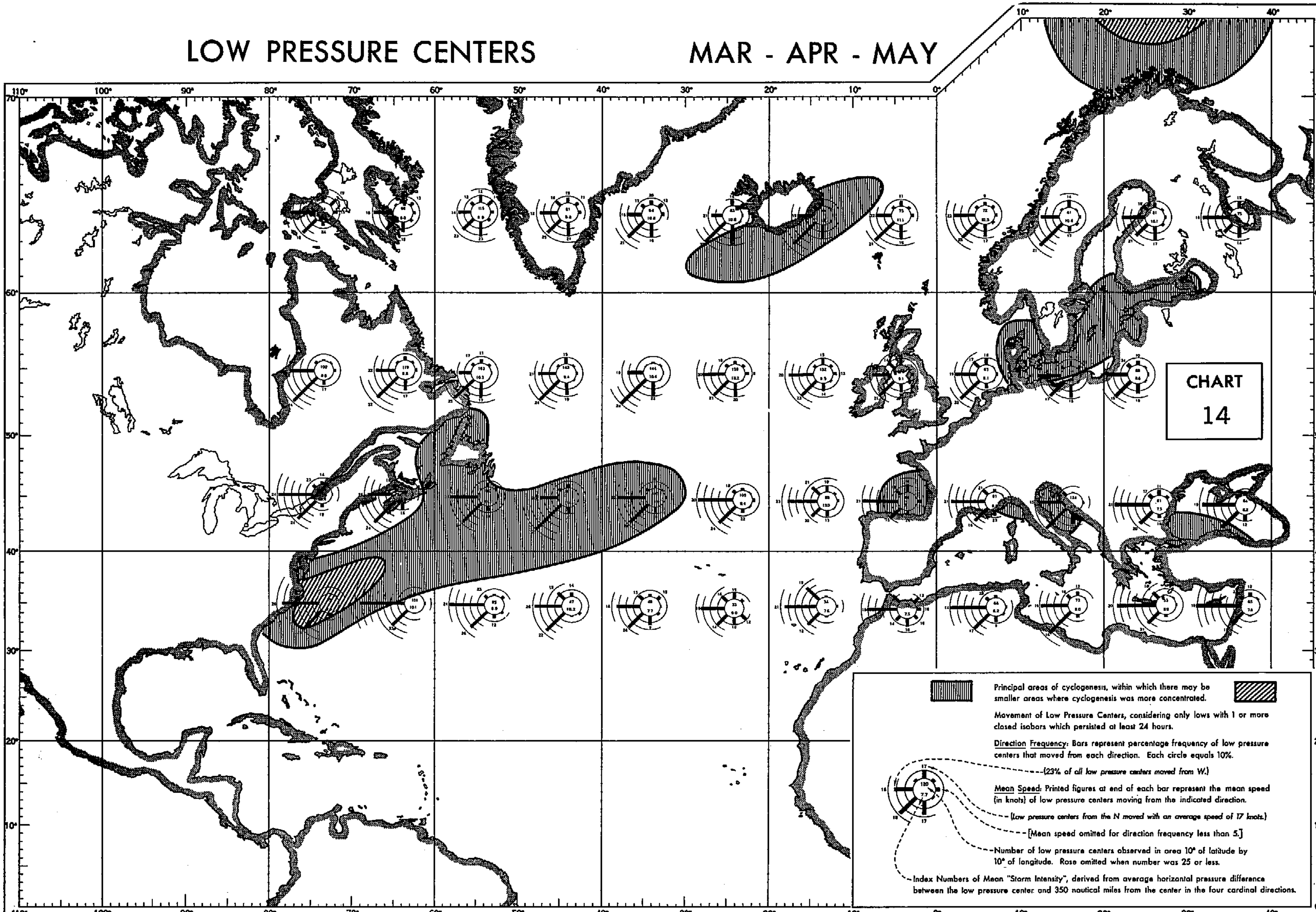


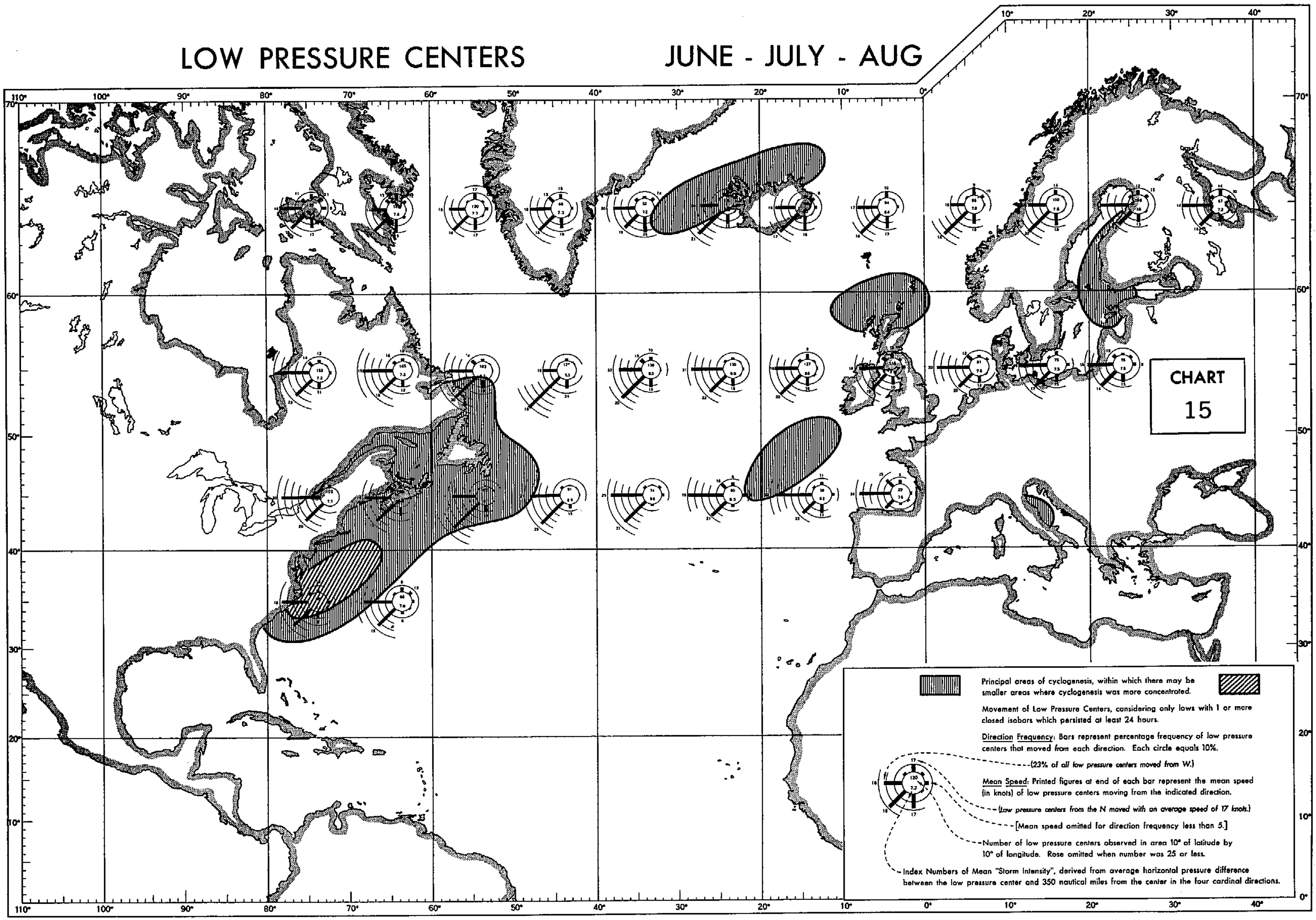
STORM TRACKS DECEMBER



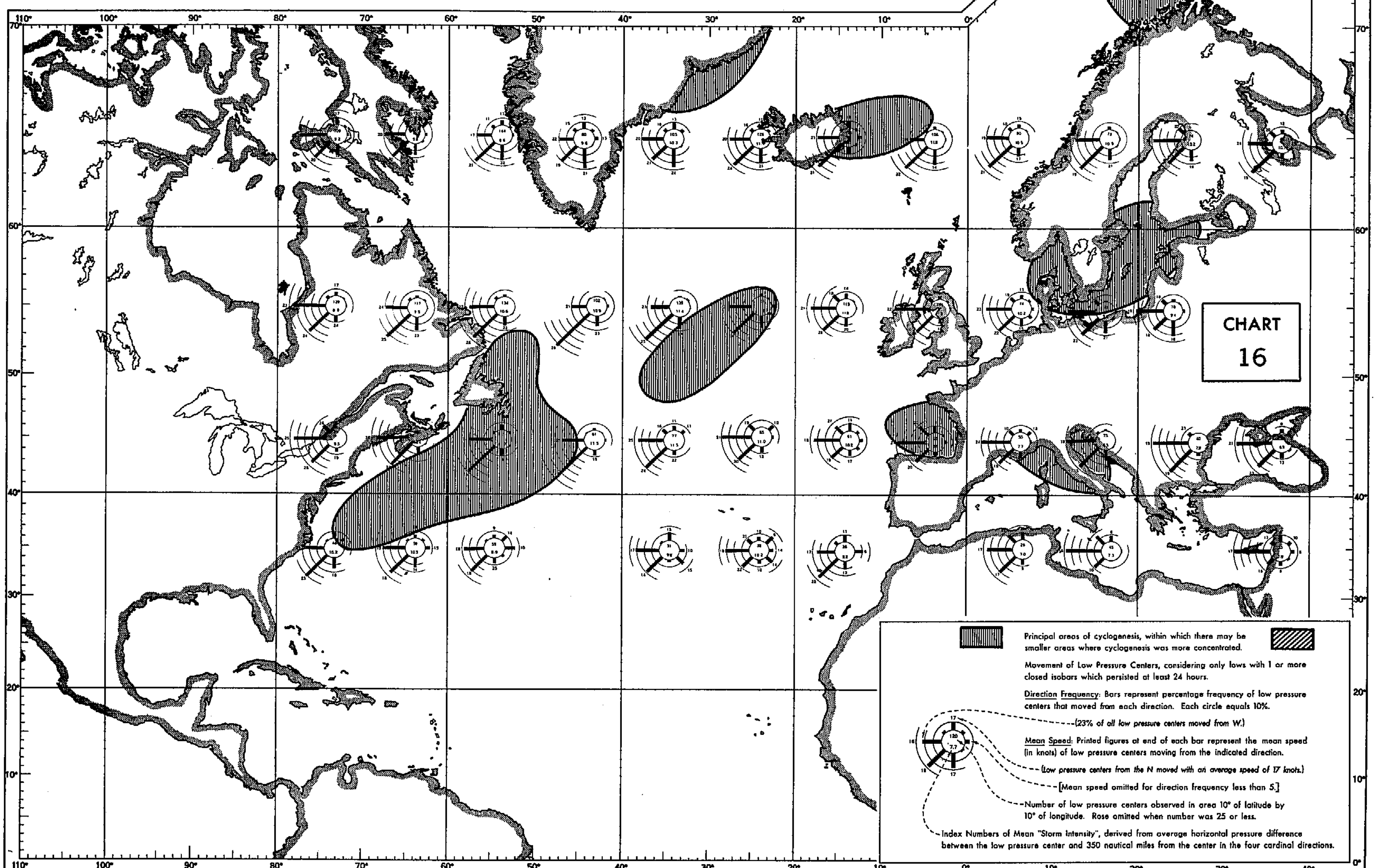

LOW PRESSURE CENTERS
DEC - JAN - FEB
CHART 13
Principal areas of cyclogenesis, within which there may be smaller areas where cyclogenesis was more concentrated.
Movement of Low Pressure Centers, considering only lows with 1 or more closed isobars which persisted at least 24 hours.
Direction Frequency: Bars represent percentage frequency of low pressure centers that moved from each direction. Each circle equals 10%.
(23% of all low pressure centers moved from W.)
Mean Speed: Printed figures at end of each bar represent the mean speed (in knots) of low pressure centers moving from the indicated direction.
(Low pressure centers from the N moved with an average speed of 17 knots.)
[Mean speed omitted for direction frequency less than 5.]
Number of low pressure centers observed in area 10° of latitude by 10° of longitude. Rose omitted when number was 25 or less.
Index Numbers of Mean "Storm Intensity", derived from average horizontal pressure difference between the low pressure center and 350 nautical miles from the center in the four cardinal directions.

LOW PRESSURE CENTERS MAR - APR - MAY




LOW PRESSURE CENTERS
JUNE - JULY - AUG
CHART
15
Principal areas of cyclogenesis, within which there may be smaller areas where cyclogenesis was more concentrated.
Movement of Low Pressure Centers, considering only lows with 1 or more closed isobars which persisted at least 24 hours.
Direction Frequency: Bars represent percentage frequency of low pressure centers that moved from each direction. Each circle equals 10%.
(23% of all low pressure centers moved from W.)
Mean Speed: Printed figures at end of each bar represent the mean speed (in knots) of low pressure centers moving from the indicated direction.
(Low pressure centers from the N moved with an average speed of 17 knots.)
[Mean speed omitted for direction frequency less than 5.]
Number of low pressure centers observed in area 10° of latitude by 10° of longitude. Rose omitted when number was 25 or less.
Index Numbers of Mean "Storm Intensity", derived from average horizontal pressure difference between the low pressure center and 350 nautical miles from the center in the four cardinal directions.

LOW PRESSURE CENTERS SEPT - OCT - NOV



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