

TECHNICAL REPORT

A STUDY OF WAVE PERSISTENCE FOR
SELECTED LOCATIONS IN THE
NORTH ATLANTIC OCEAN, NORTH SEA,
AND BALTIC SEA

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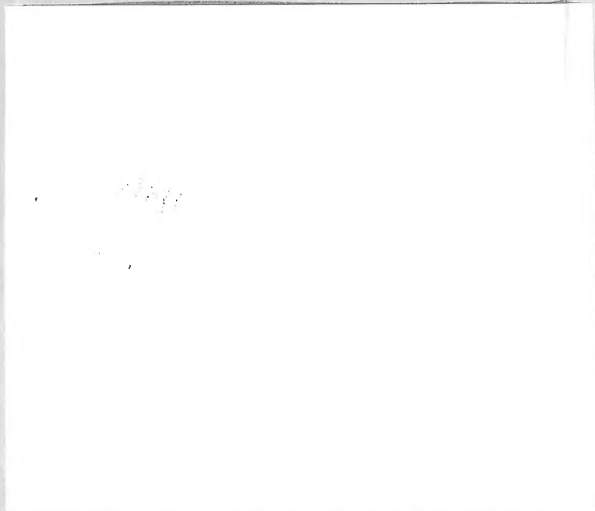
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ABSTRACT

Wave persistence graphs were constructed from wave data obtained from lightships and ocean station vessels. An explanation and examples of how to interpret the wave persistence graphics are given. A climatological summary for the selected regions is supplied as a background for arriving at certain generalizations concerning wave persistence. Several applications of wave persistence data are cited.

ACKNOWLEDGMENT


The authors wish to express their indebtedness to Mr. Marvin D. Burkhart, whose helpful suggestions and continued interest made this publication possible.



FOREWORD

The duration of favorable and unfavorable wave conditions is of prime importance to shipping concerns for economic purposes, to coastal installations for protective purposes, and to the Navy for military expediency. When used simultaneously with other available information, wave persistence data are especially beneficial to forecasting personnel and shipmasters in ship routing and to design engineers in coastal construction.

This is one of a series of reports published by the U. S. Naval Oceanographic Office in its continuous endeavor to improve the ship routing program and its deep concern for the safety of ships at sea.


DENIS M. KNOLL
Rear Admiral, U. S. Navy
Commander
U. S. Naval Oceanographic Office



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A STUDY OF WAVE PERSISTENCE IN THE NORTH ATLANTIC OCEAN, NORTH SEA, AND BALTIC SEA

INTRODUCTION

Little information has been published on the persistence (duration) of storm waves or time length of continuous spells* of low waves. It is often advantageous to know the expected duration of adverse wave conditions, since many marine operations become ineffective or restricted when waves reach or exceed a certain height. Conversely, for specific marine activities it may be important also to know the duration of waves lower than a particular height category. To serve these needs, two sets of curves have been prepared for selected lightships and ocean station vessels for each of the four seasons. The selected stations are grouped regionally for reasons of climatology and textual presentation. Seasonal frequency of occurrence of selected wave height categories is furnished in bar graph form to provide additional information on the wave climatology at each of the selected locations.

EXPLANATION OF THE GRAPHICS

Only observations made over an unbroken period of time from stationary ships can be used to provide information on wave persistence. The informational data gathered for this report were obtained from continuous records taken at the lightships and ocean station vessels. The longer the period of continuous record, the more reliable is the graphical mean. In this study, a minimum of three years of continuous record was considered adequate.

In Figure 3 the set of curves labeled "Persistence of Favorable Waves" indicates the number of times during a season that waves decrease to less than specific height categories. These curves also show how long waves are expected to remain below the specified heights. The other set of curves labeled "Persistence of Unfavorable Waves" indicates the number of times during a season that waves increase to specific height categories or exceed them; they also show how long waves can be expected to exceed the specified heights.

In each set of curves the number of occurrences of waves of each height category is expressed as the average number of occasions during the season that waves decreased in height below or rose to equal or exceed a specific height. Since percentages are based on the average number of occasions that waves of the lowest height category were observed during a season, it is possible for the number of occasions for the higher height categories during the same season to exceed 100 percent. As an example, in the curves for Frying-pan Shoals Lightship (Figure 3J) for autumn the number of occasions of 6 ft. height category waves exceeds

*Spells are based upon an analysis of 2-, 3-, 4-, or 6-hourly observations.

those of 3 ft. height category waves by about 25 percent. However, the combined durations of the occasions when waves are ≥ 6 feet never can exceed the combined durations of waves ≤ 3 feet. These facts are readily seen in the smoothed wave profile shown in Figure 1.

The various interpretations of the persistence curves can be made by consulting the legend. As an example, suppose one is interested in knowing how many times during the summer at Portland Lightship waves will be less than 6 feet high continuously for at least 5 days (120 hours). Reference to the appropriate set of curves in Figure 3A shows this to be about 10 percent of 48 (Point A), or about 5 times during the season. Similarly, suppose one wants to know how many times during the winter at Portland Lightship waves will exceed 6 feet for at least 24 hours. Again, reference to the appropriate set of curves in Figure 3A shows this to be about 13 percent of 43 (Point B), or 5.6 times, i.e., between 5 or 6 times during the season.

Reference to the examples on the legend will suggest other ways in which the curves can be used. Certain generalizations as to the seasonal variability of waves at the lightships and ocean station vessels also are evident from comparative studies. To illustrate, the durations of favorable waves generally are longer than those of unfavorable waves, particularly in summer.

The bar graphs associated with each persistence graph give the total relative frequencies of occurrence seasonally for each wave height category.

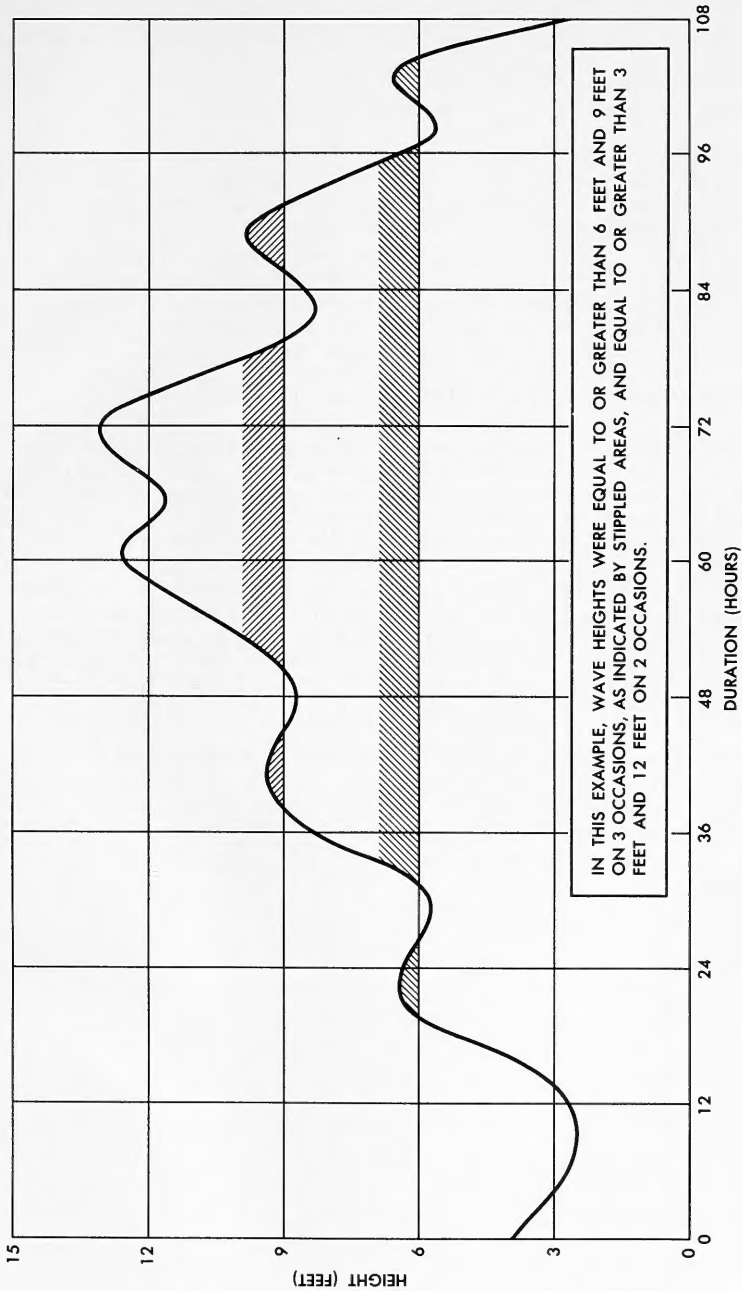


FIGURE 1 WAVE HEIGHT PROFILE

LIGHTSHIPS ALONG THE EAST COAST OF THE UNITED STATES

A major storm track (along which there has been a maximum concentration of individual storm paths) prevails along the east coast of the United States during the late autumn, winter, and early spring. The winds of the individual storms largely determine wave conditions. Hence, maximum frequencies of waves ≥ 5 feet occur approximately along the axis of the major storm track from the Carolinas to Newfoundland. However, because migratory storms generally move through this region at moderate rates of speed, the persistence graphs in Figures 3 through 5 show that durations of unfavorable waves are shorter than those of favorable waves. In addition, the influence of prevailing westerly component winds (offshore winds) on unfavorable wave generation is minimized by the sheltering effect of the continent; i.e., the fetch distances are short between the shoreline and the lightships.

An exception occurs at Fryng-pan Shoals Lightship, where unfavorable waves persist through spells in excess of 300 hours. This is due mainly to the location of this lightship in a region of storm generation, where the lightship is subjected to lengthy periods of adverse waves before the newly generated storm moves out of the region.

The east coast of the United States is so oriented that high swell waves from distant storms generally do not radiate toward it. On rare occasions, however, a meteorological situation arises whereby the forward progress of a deepening storm is temporarily blocked, and the low pressure cell may be forced into an east-to-west elongation pattern. The pressure gradient and subsequent strong winds over long fetch distances on the north side of such a stagnated storm produces high waves and directs an onslaught of successive high swell waves into the shore. A recent notable example was the destructive storm of 5-9 March 1962 along the east coast of the United States during which many places recorded a runup of waves 20 to 30 feet high for the period of surge accompanying this storm.

In general, the east coast lightships (except Frying-pan Shoals Lightship) experience longer durations of favorable wave conditions than unfavorable wave conditions throughout the year, which reach a maximum during the summer season when the Azores high is at its westernmost extension and peak of influence.

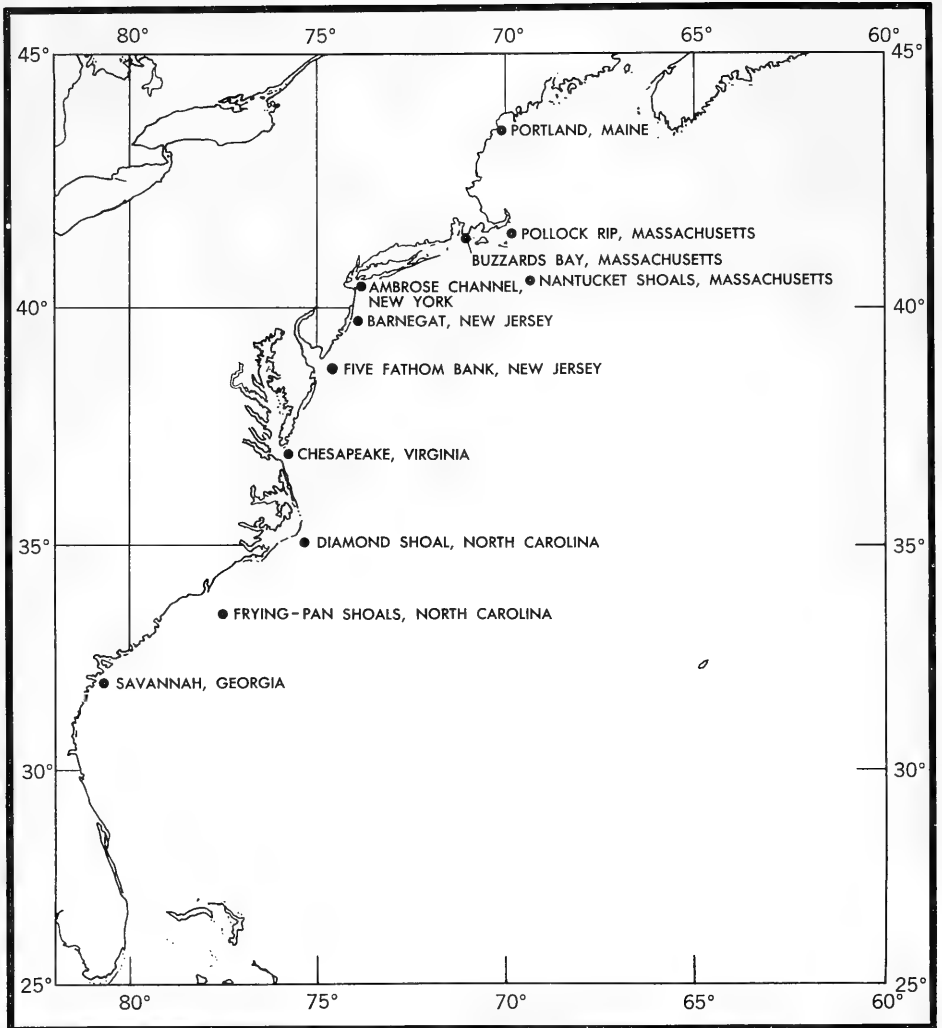
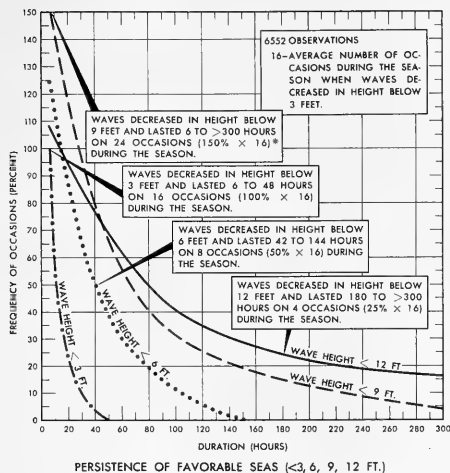
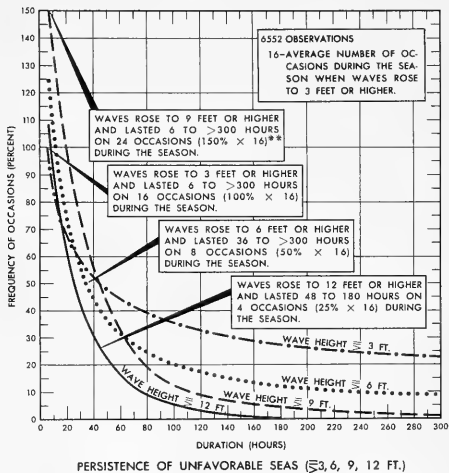


FIGURE 2 LOCATION CHART OF EAST COAST LIGHTSHIPS

LEGEND AND EXAMPLES



* IN THIS EXAMPLE, FOR EACH TWO OCCURRENCES OF WAVES BELOW 3 FEET THERE ARE THREE CHANCES WAVES WILL BE LESS THAN 9 FEET.



** IN THIS EXAMPLE, FOR EACH TWO OCCURRENCES OF WAVES 3 FEET OR HIGHER THERE ARE THREE CHANCES WAVES WILL EQUAL OR EXCEED 9 FEET.

LEGEND

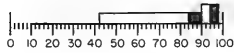
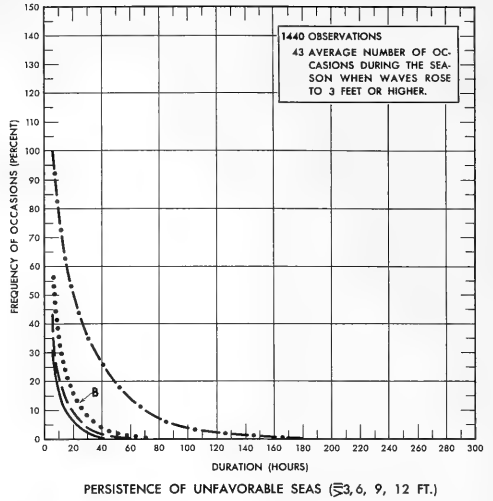
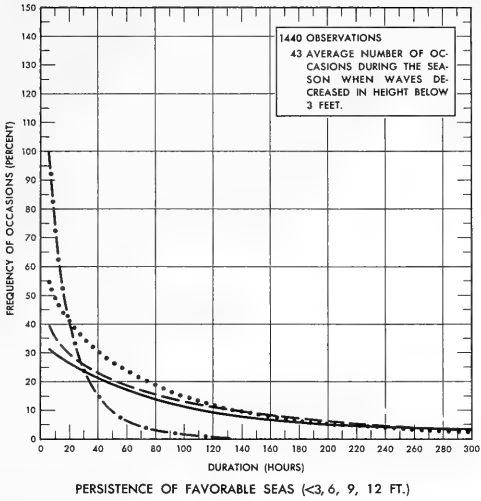
WAVE HEIGHT

CAUM
1-3 FT.
3-6 FT.
6-9 FT.
9-12 FT.
≥ 12 FT.
INDETERMINATE



FIGURE 3 WAVE PERSISTENCE CURVES AND WAVE HEIGHT BAR GRAPHS FOR EAST COAST (U.S.) LIGHTSHIPS

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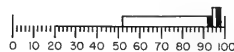
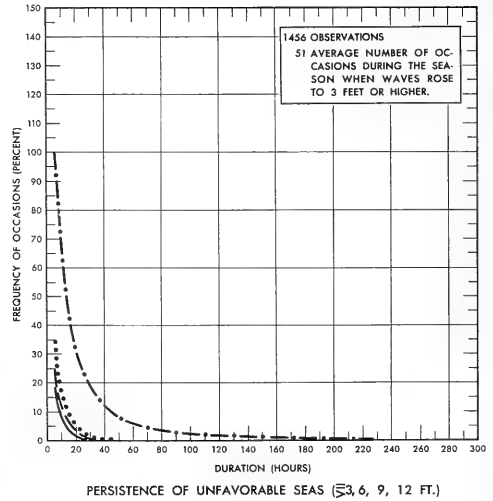
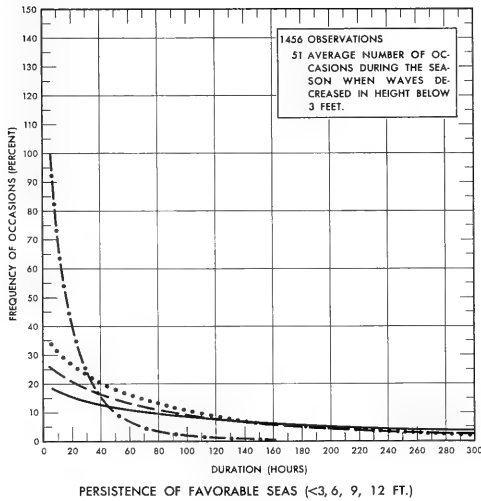
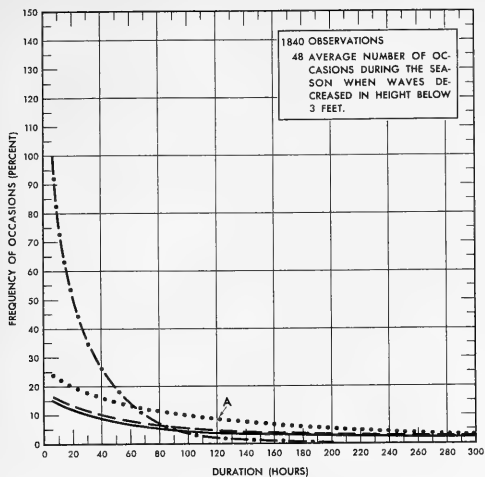
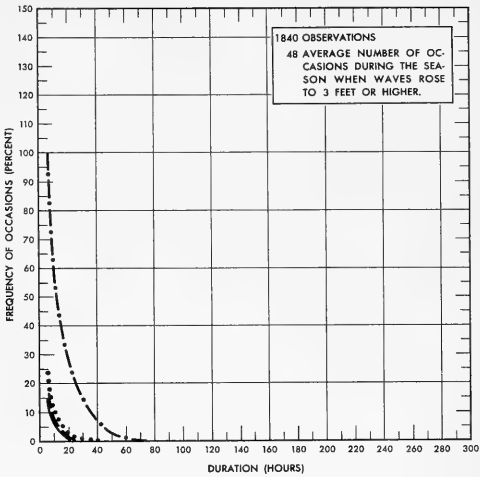


FIGURE 3A PORTLAND, MAINE 43°48.4'N., 70°5.5'W.

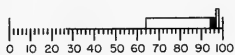
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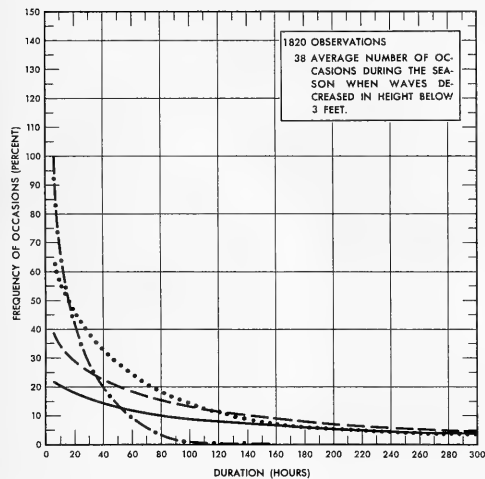
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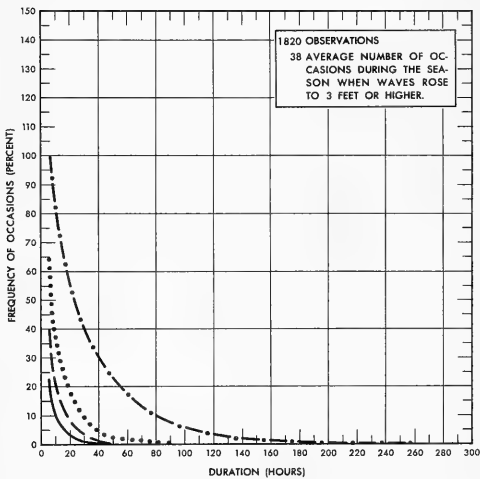
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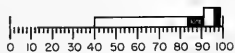
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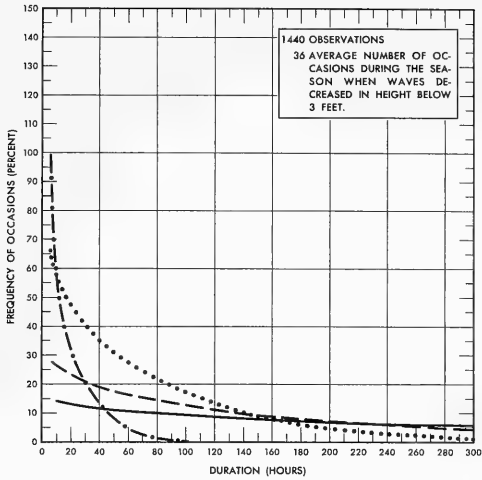
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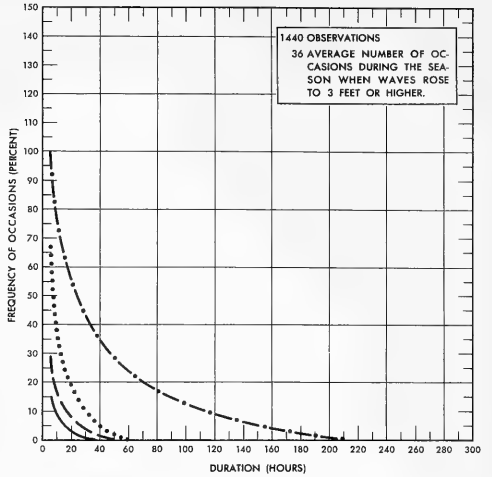
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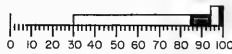
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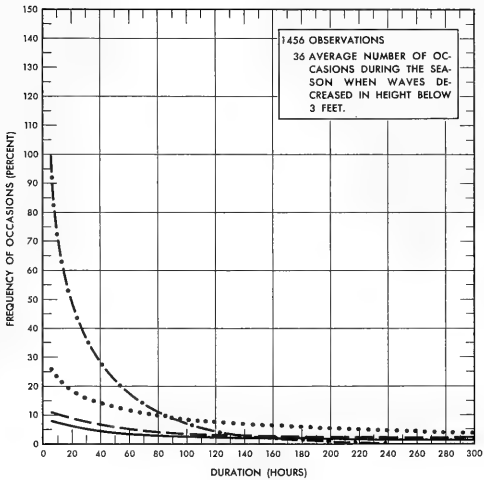
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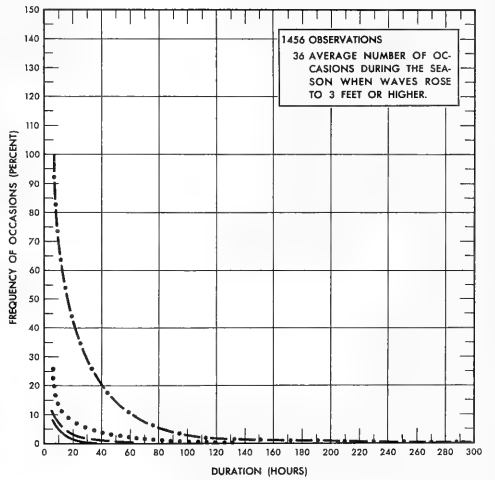
PERSISTENCE OF UNFAVORABLE SEAS ($\geq 3, 6, 9, 12\text{ FT.}$)



APRIL, MAY, JUNE



PERSISTENCE OF FAVORABLE SEAS ($\leq 3, 6, 9, 12\text{ FT.}$)



PERSISTENCE OF UNFAVORABLE SEAS ($\geq 3, 6, 9, 12\text{ FT.}$)

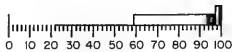
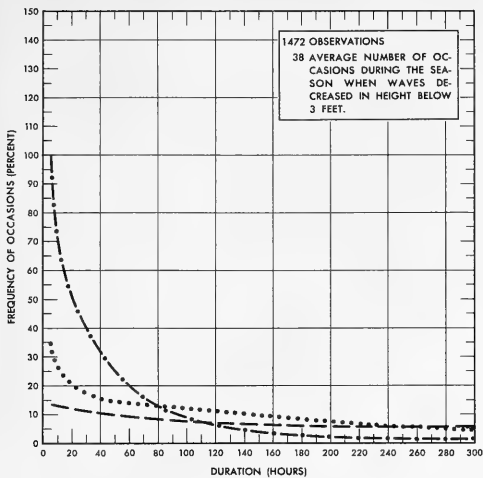
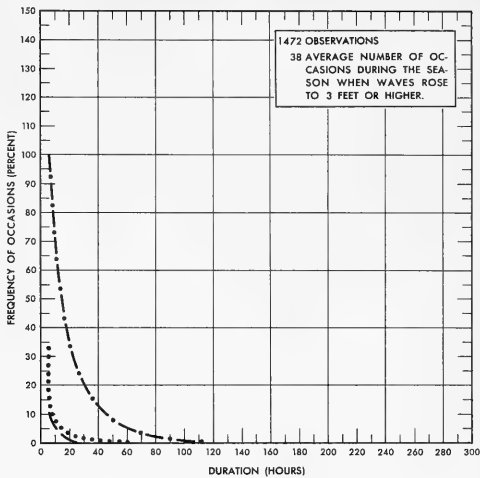


FIGURE 3B POLLOCK RIP, MASS. $41^{\circ}36.1'N$, $69^{\circ}51.1'W$.

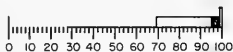
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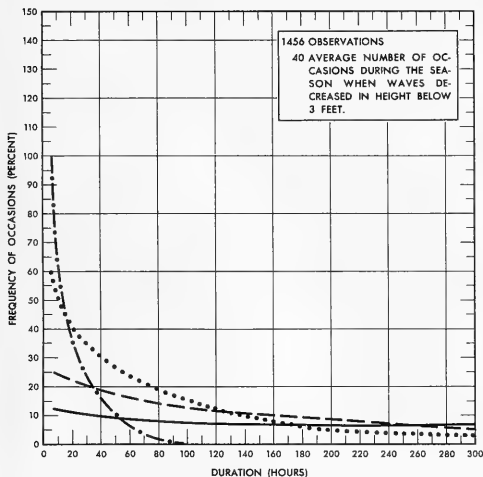
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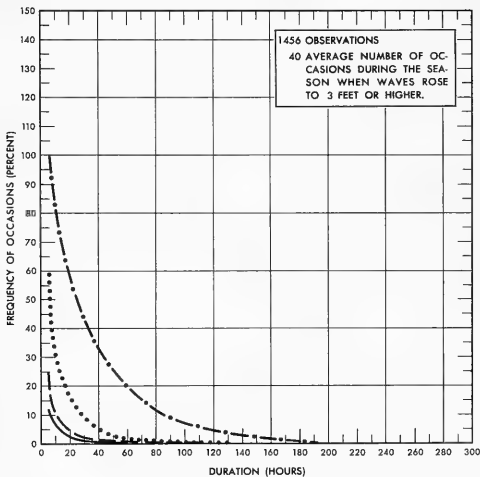
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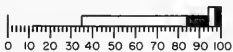
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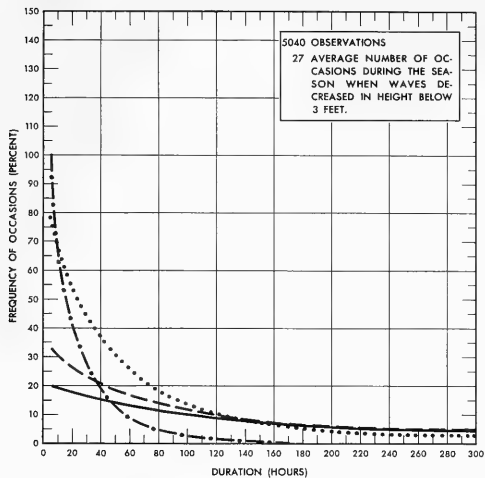
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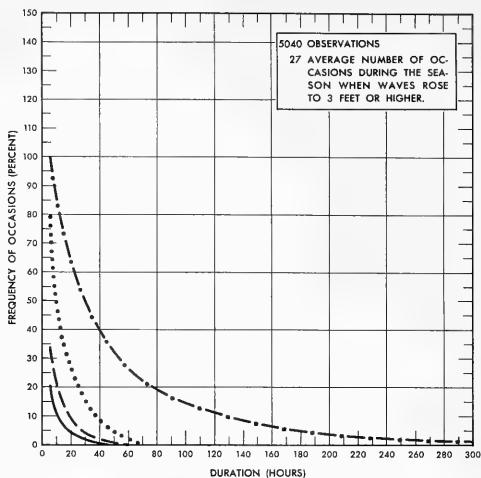
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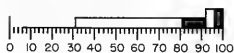
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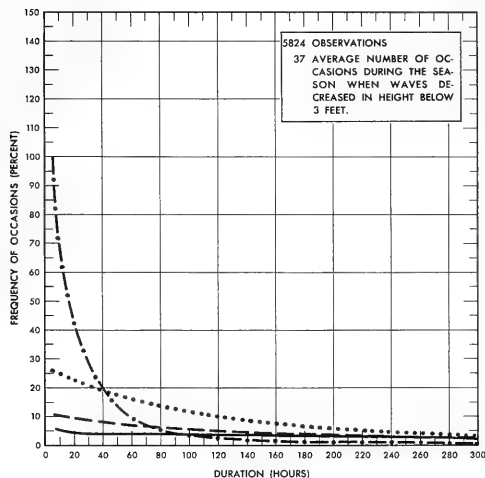
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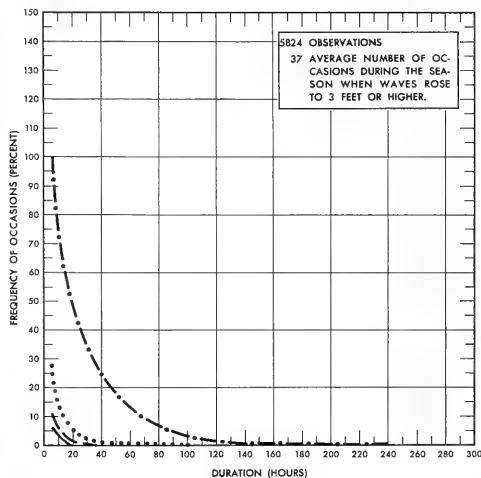
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PERSISTENCE OF FAVORABLE WAVES (<3, 6, 9, 12 FT.)

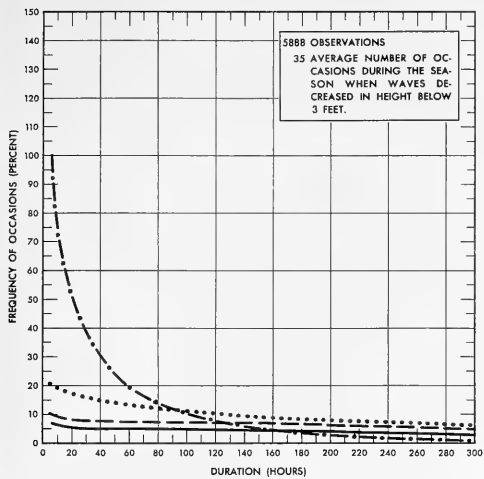


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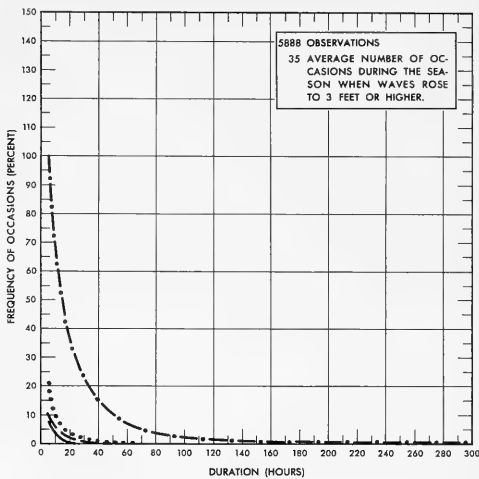


FIGURE 3C NANTUCKET SHOALS, MASS. 40°37.0'N., 69°18.5'W.

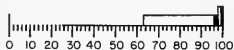
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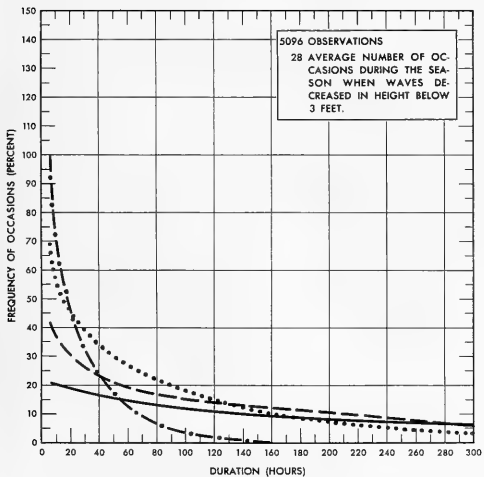
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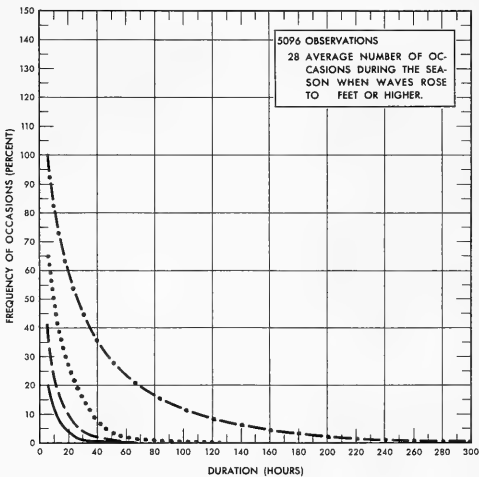
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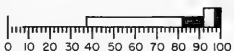
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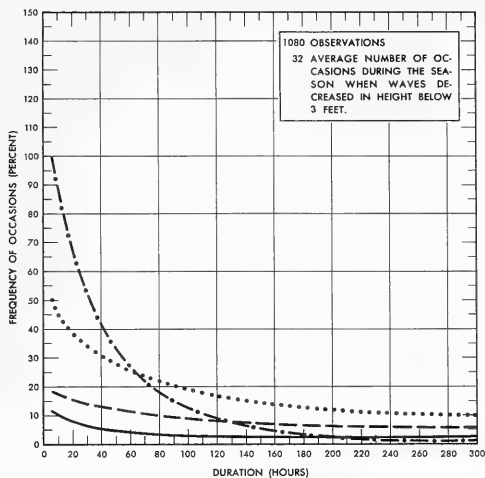
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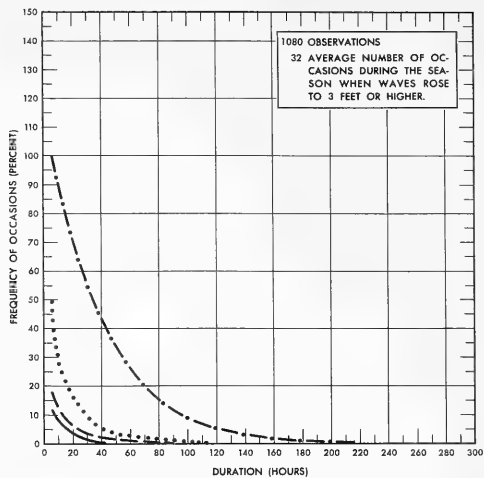
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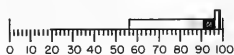
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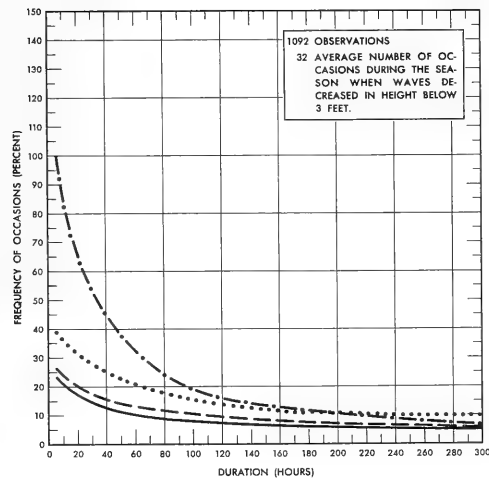
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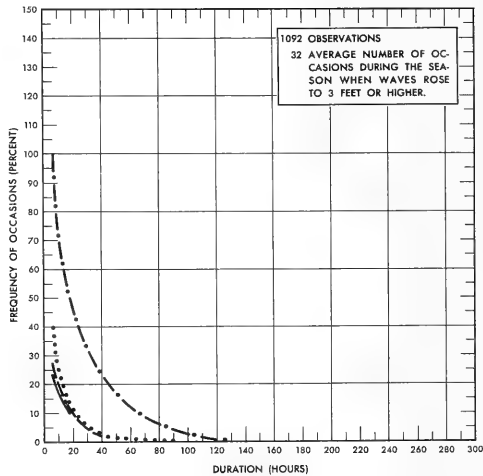
PERSISTENCE OF UNFAVORABLE WAVES ($\geq 3, 6, 9, 12$ FT.)



APRIL, MAY, JUNE



PERSISTENCE OF FAVORABLE WAVES ($\leq 3, 6, 9, 12$ FT.)



PERSISTENCE OF UNFAVORABLE WAVES ($\geq 3, 6, 9, 12$ FT.)

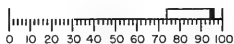
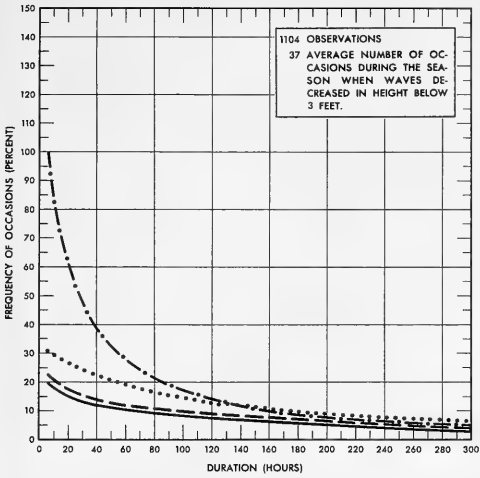
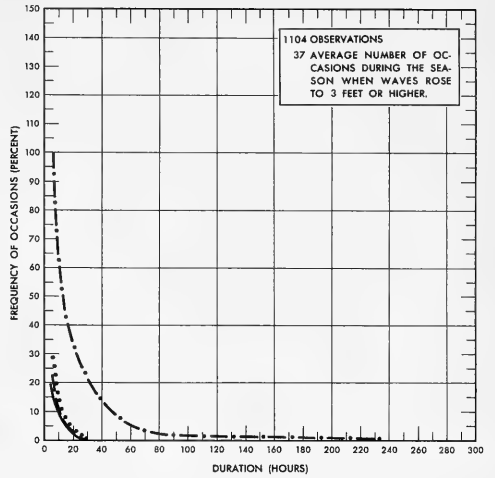


FIGURE 3D BUZZARDS BAY, MASS. $41^{\circ}24.0'N.$, $71^{\circ}3.0'W.$

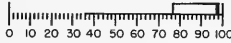
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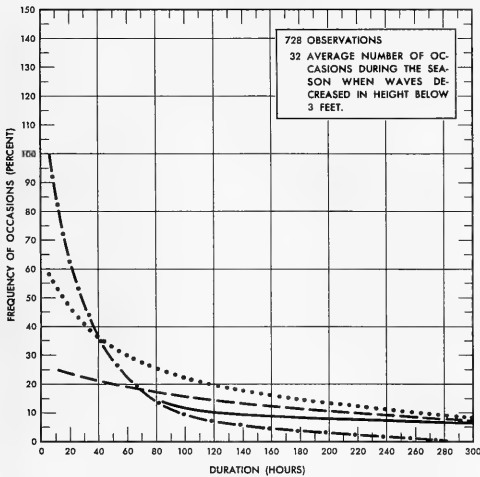
PERSISTENCE OF FAVORABLE WAVES ($\leq 3, 6, 9, 12$ FT.)



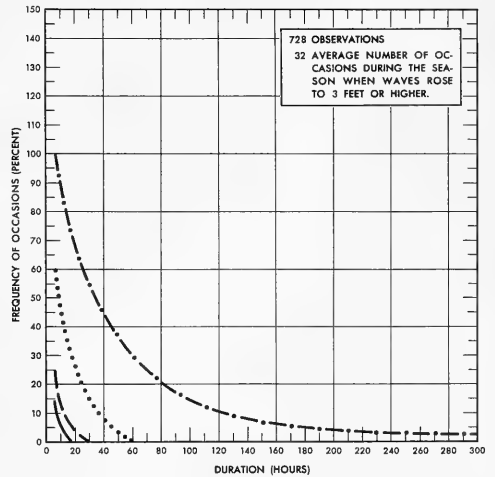
PERSISTENCE OF UNFAVORABLE WAVES ($\geq 3, 6, 9, 12$ FT.)



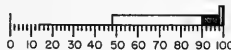
OCTOBER, NOVEMBER, DECEMBER



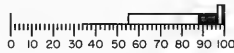
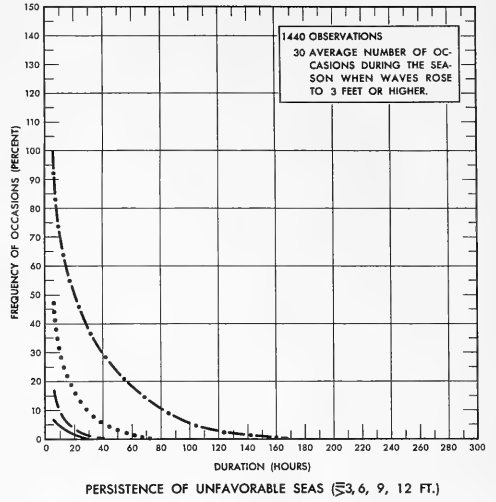
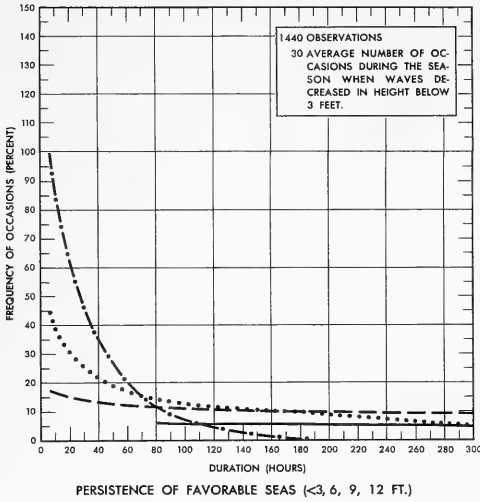
PERSISTENCE OF FAVORABLE WAVES ($\leq 3, 6, 9, 12$ FT.)



PERSISTENCE OF UNFAVORABLE WAVES ($\geq 3, 6, 9, 12$ FT.)



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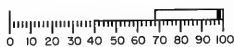
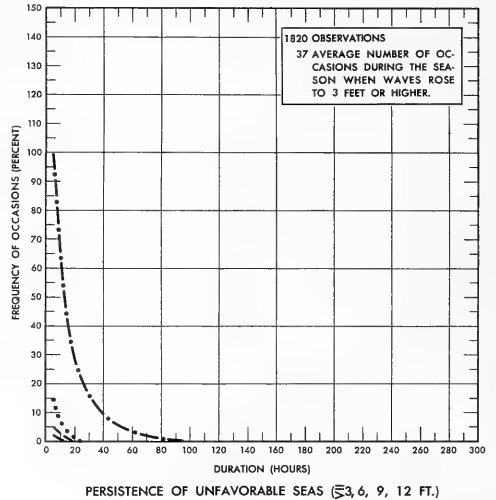
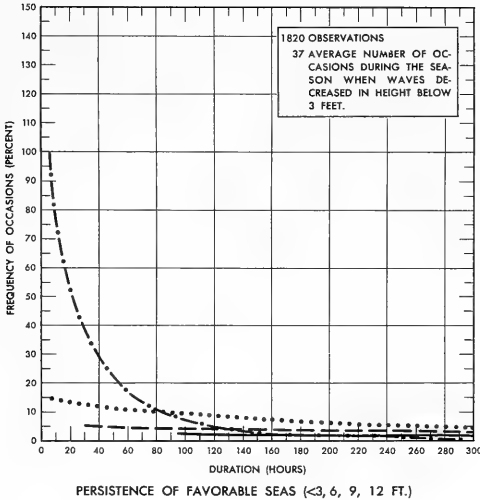
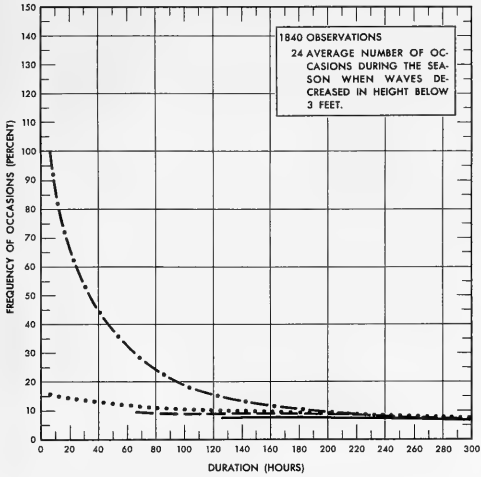
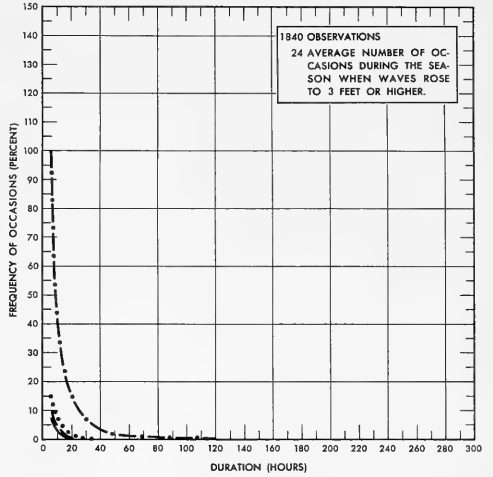


FIGURE 3E AMBROSE CHANNEL, N. Y. $40^{\circ}27.1'N.$, $73^{\circ}49.4'W.$

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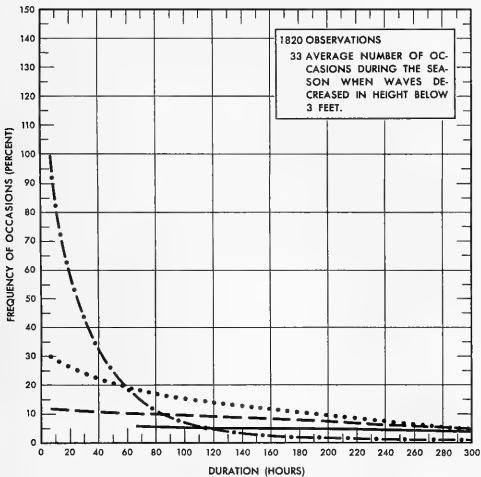
PERSISTENCE OF FAVORABLE SEAS (<3, 6, 9, 12 FT.)



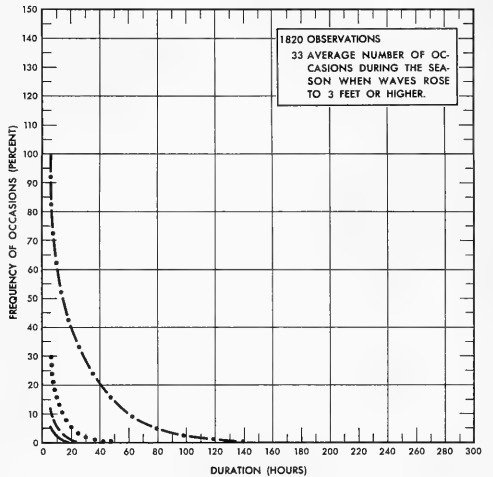
PERSISTENCE OF UNFAVORABLE SEAS (≥3, 6, 9, 12 FT.)



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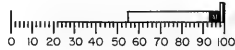
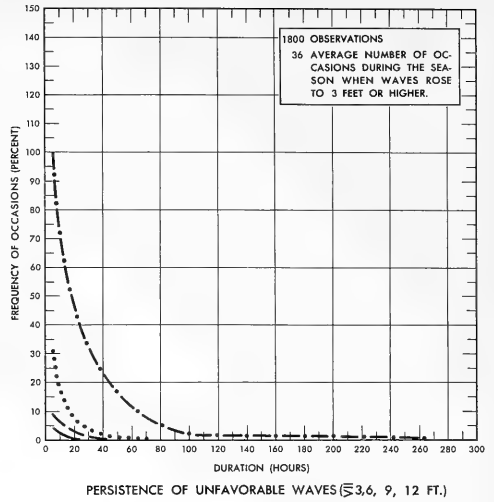
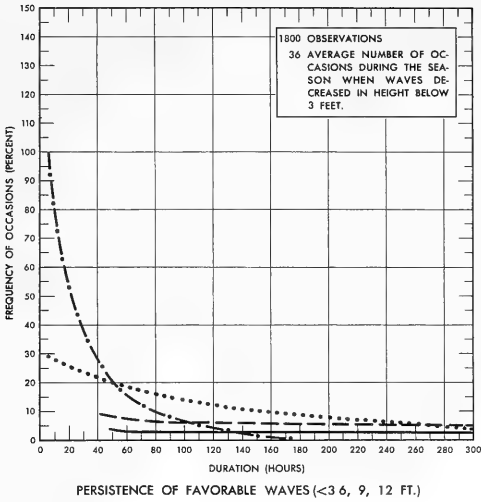
PERSISTENCE OF FAVORABLE SEAS (<3, 6, 9, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (≥3, 6, 9, 12 FT.)



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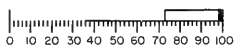
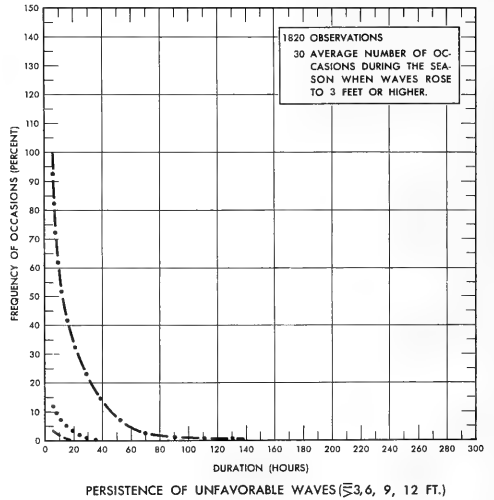
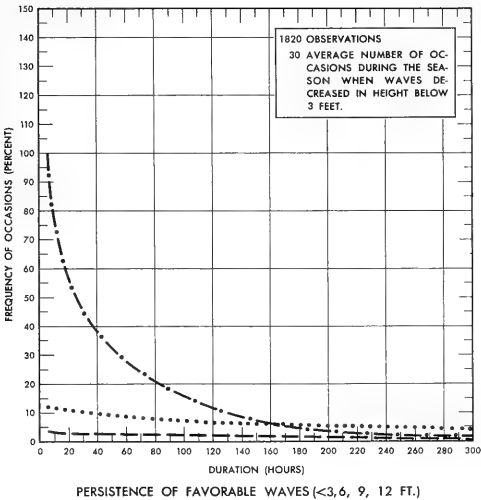
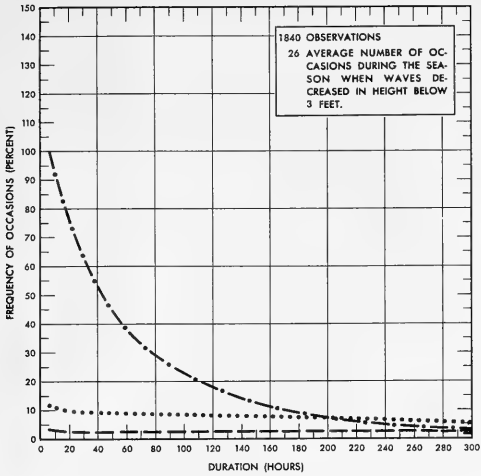
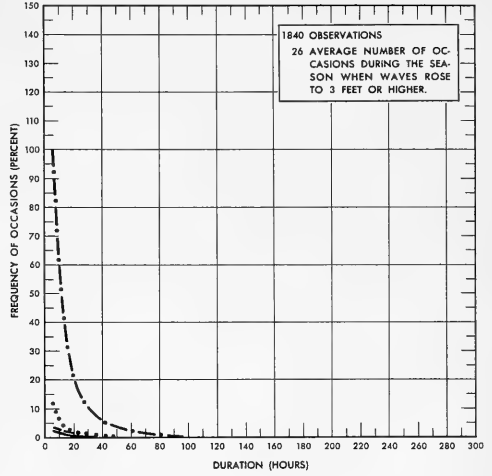


FIGURE 3F BARNEGAT, N. J. 39°45.8'N., 73°56.0'W.

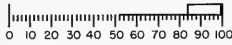
JULY, AUGUST, SEPTEMBER



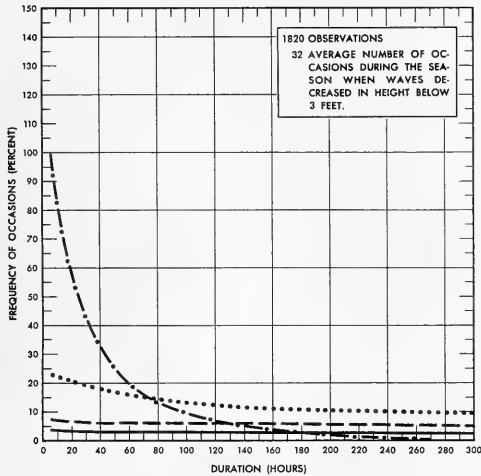
PERSISTENCE OF FAVORABLE WAVES ($\leq 3, 6, 9, 12$ FT.)



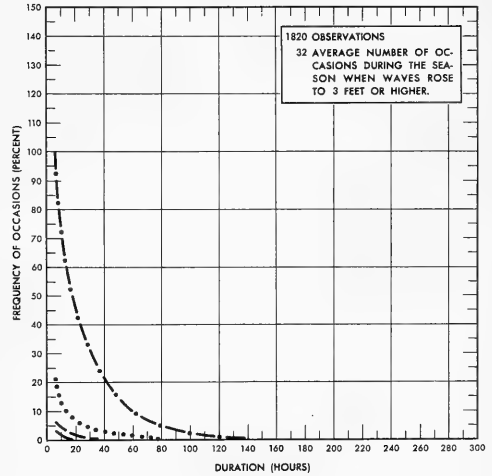
PERSISTENCE OF UNFAVORABLE WAVES ($\geq 3, 6, 9, 12$ FT.)



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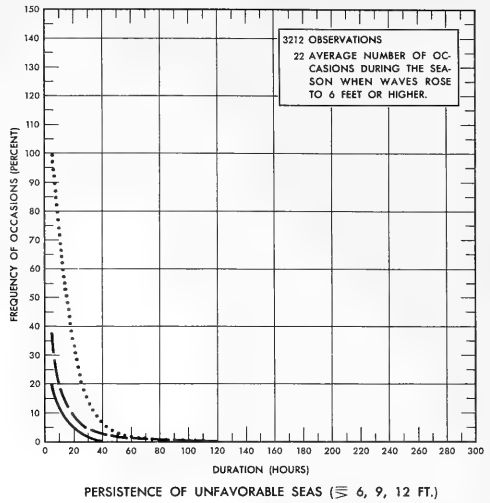
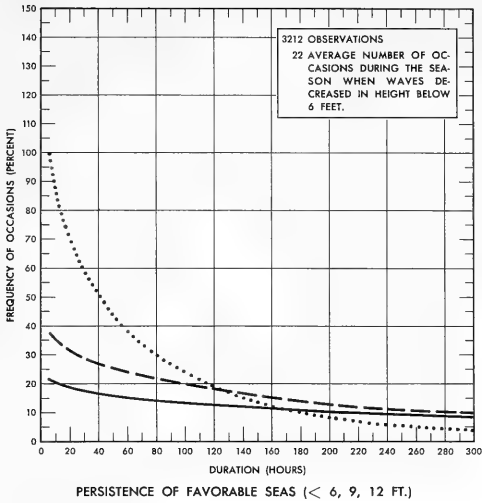
PERSISTENCE OF FAVORABLE WAVES ($\leq 3, 6, 9, 12$ FT.)



PERSISTENCE OF UNFAVORABLE WAVES ($\geq 3, 6, 9, 12$ FT.)



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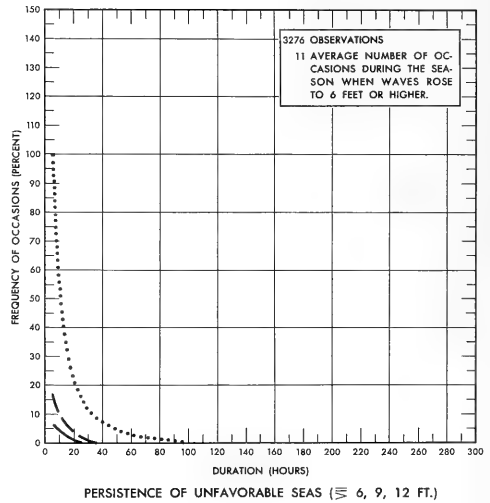
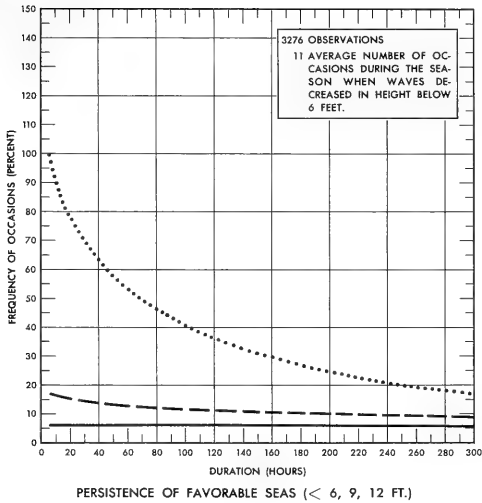
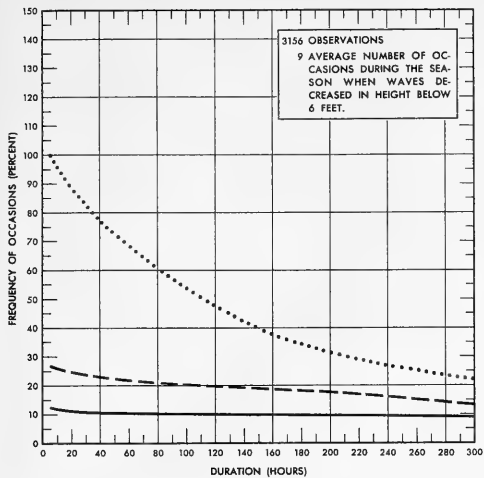
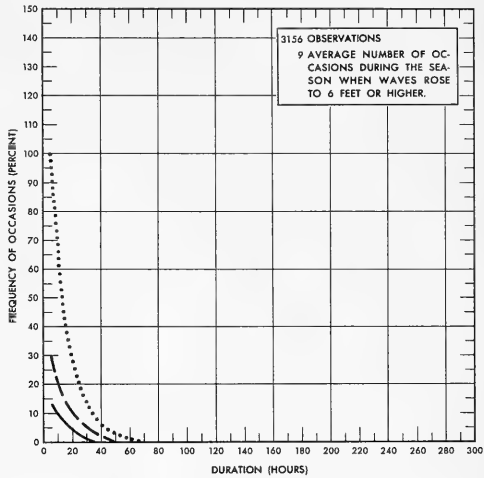


FIGURE 3G FIVE FATHOMS BANK, N. J. 38°47.3'N., 74°34.6'W.

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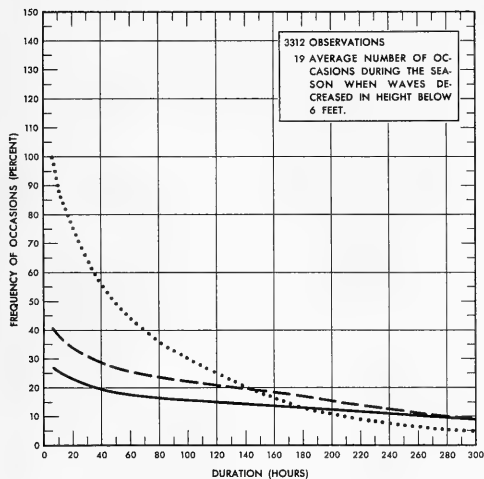


PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)

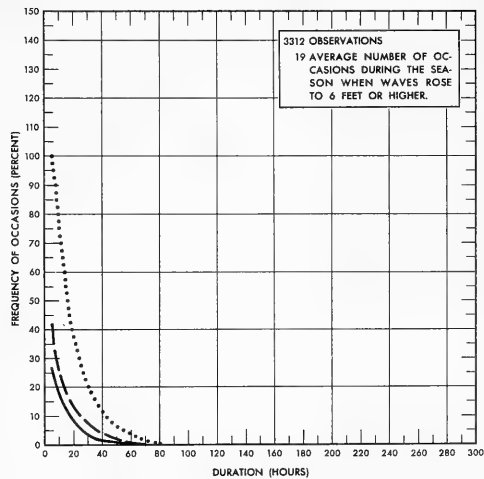


PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)

OCTOBER, NOVEMBER, DECEMBER

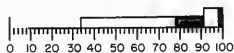
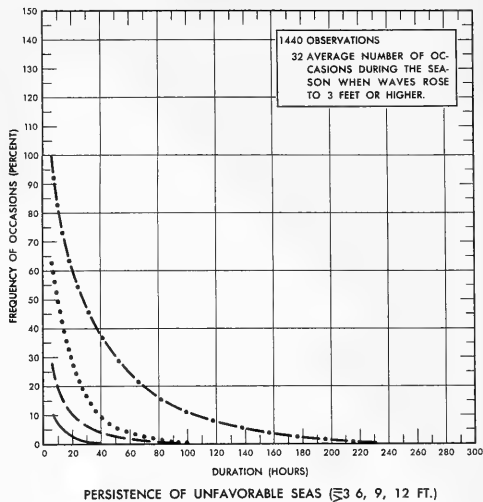
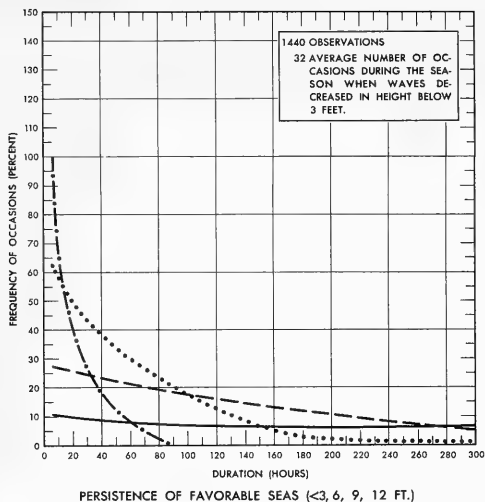


PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)

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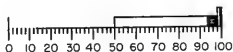
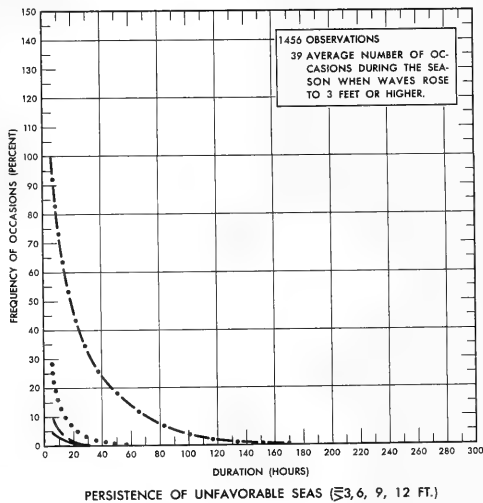
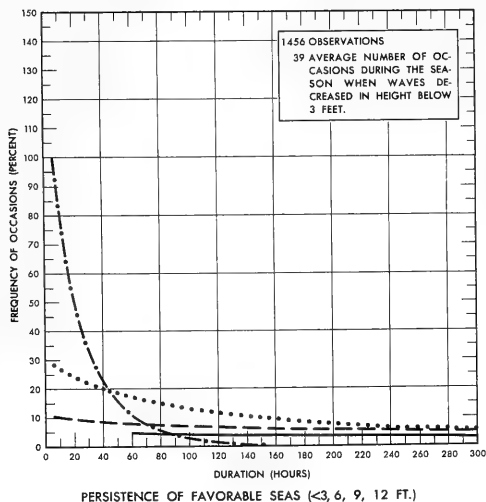
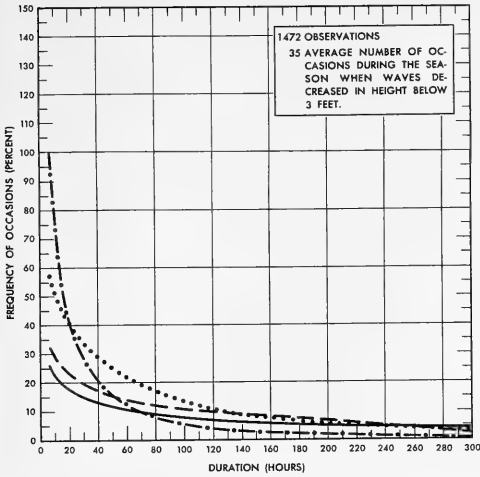
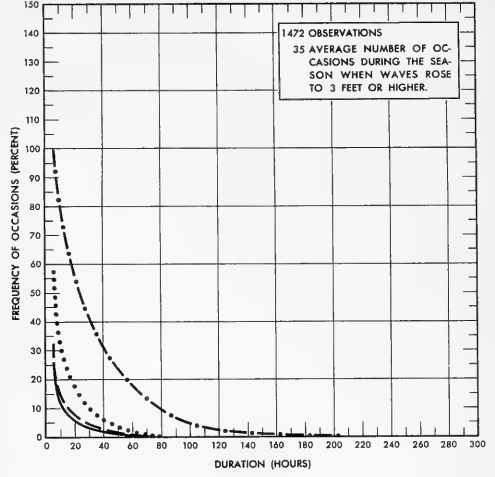


FIGURE 3H CHESAPEAKE, VA. $36^{\circ}58.7'N$, $75^{\circ}42.2'W$.

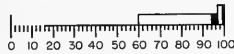
JULY, AUGUST, SEPTEMBER



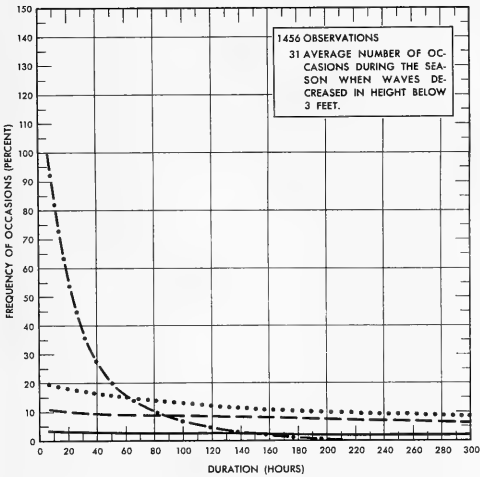
PERSISTENCE OF FAVORABLE SEAS (<3, 6, 9, 12 FT.)



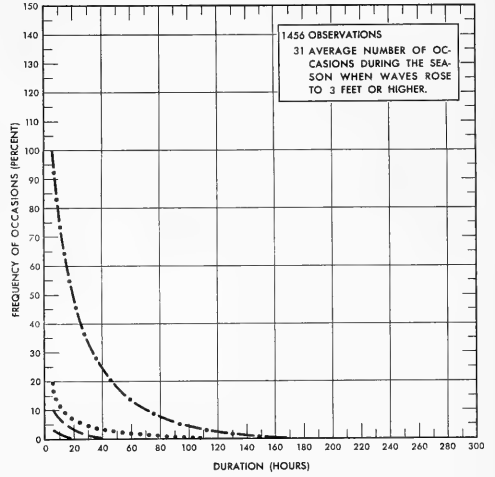
PERSISTENCE OF UNFAVORABLE SEAS (\geq 3, 6, 9, 12 FT.)



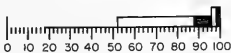
OCTOBER, NOVEMBER, DECEMBER



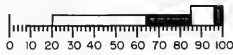
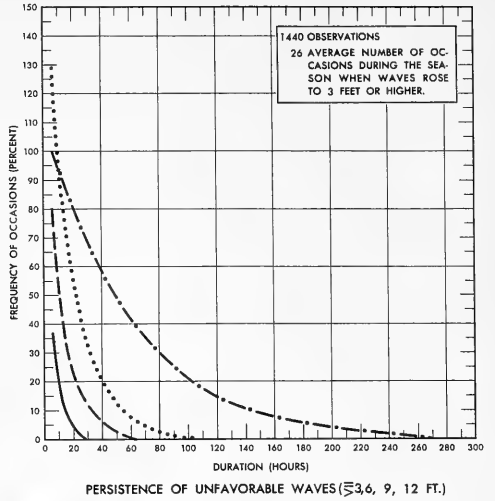
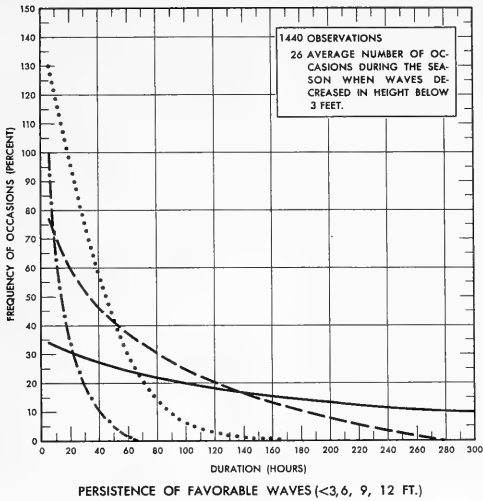
PERSISTENCE OF FAVORABLE SEAS (<3, 6, 9, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (\geq 3, 6, 9, 12 FT.)



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APRIL, MAY, JUNE

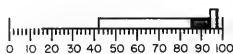
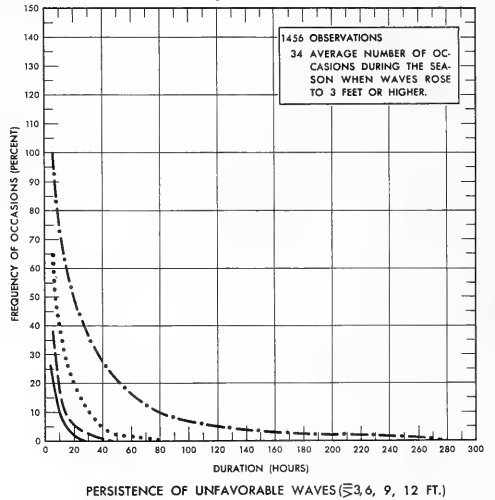
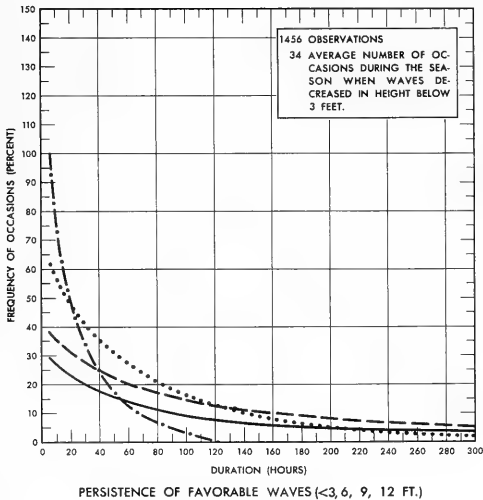
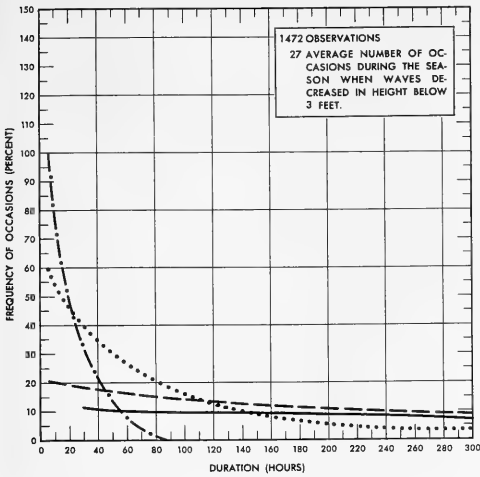
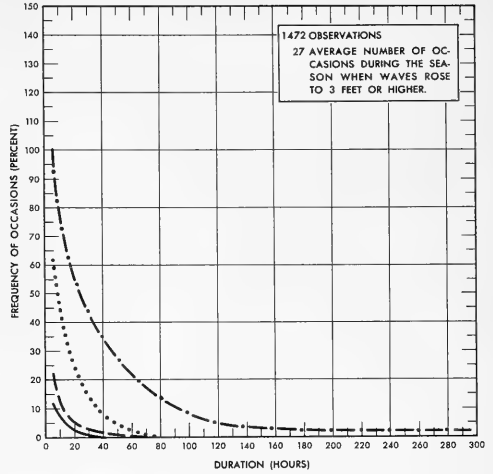


FIGURE 31 DIAMOND SHOALS, N. C. $35^{\circ}05.3'N$, $75^{\circ}19.7'W$.

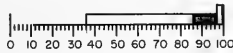
JULY, AUGUST, SEPTEMBER



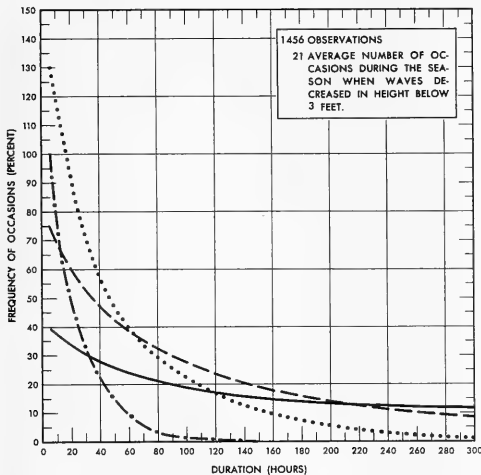
PERSISTENCE OF FAVORABLE WAVES (<3, 6, 9, 12 FT.)



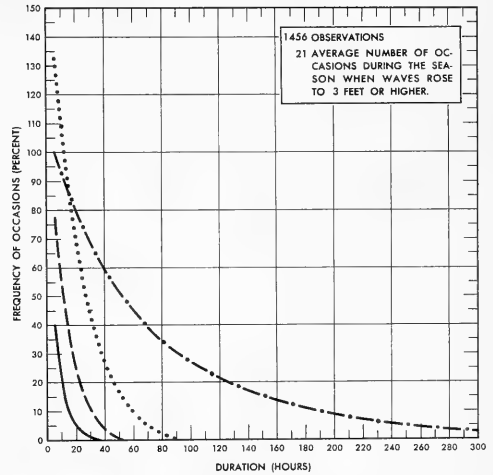
PERSISTENCE OF UNFAVORABLE WAVES (\geq 3, 6, 9, 12 FT.)



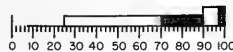
OCTOBER, NOVEMBER, DECEMBER



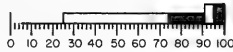
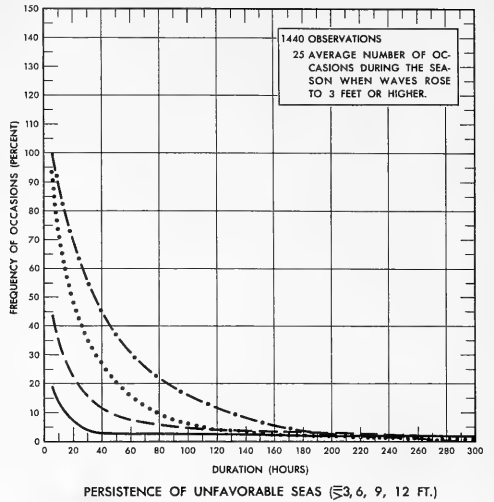
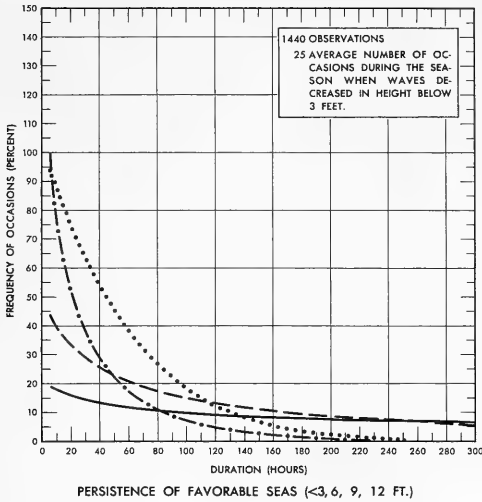
PERSISTENCE OF FAVORABLE WAVES (<3, 6, 9, 12 FT.)



PERSISTENCE OF UNFAVORABLE WAVES (\geq 3, 6, 9, 12 FT.)



JANUARY, FEBRUARY, MARCH



APRIL, MAY, JUNE

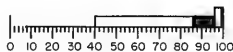
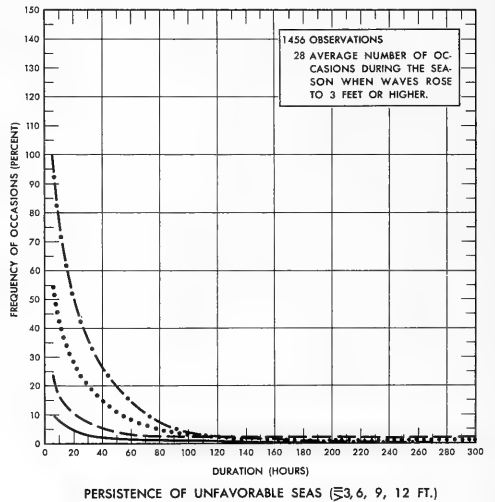
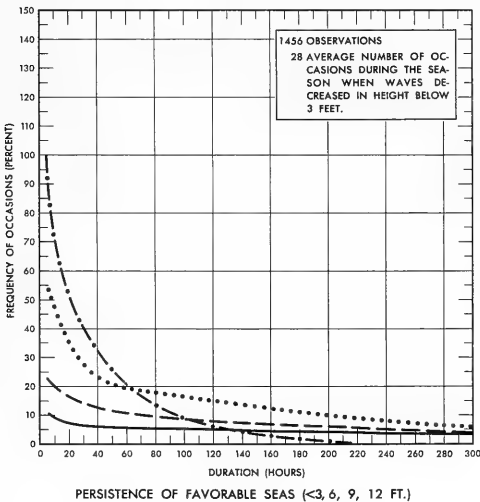
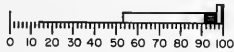
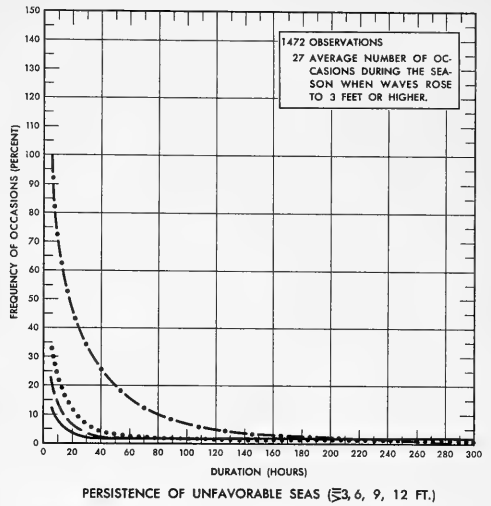
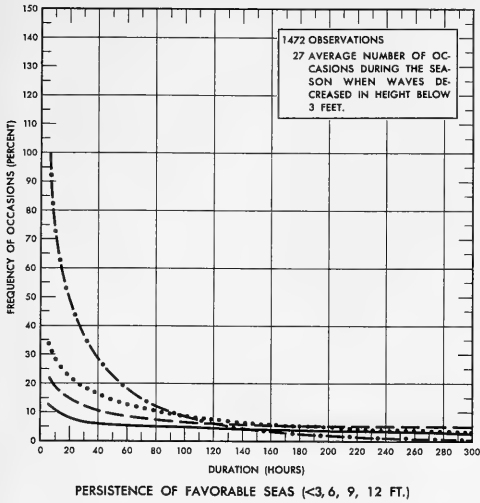
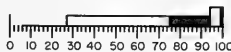
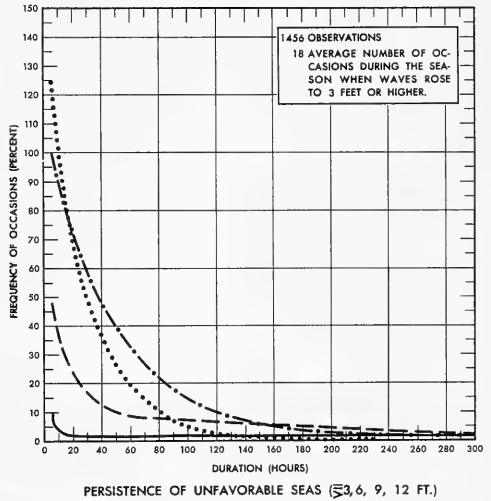
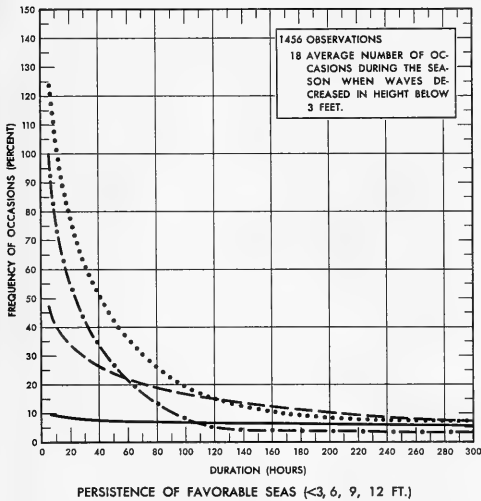


FIGURE 3J FRYING-PAN SHOAL 33°28.0'N., 77°33.8'W.

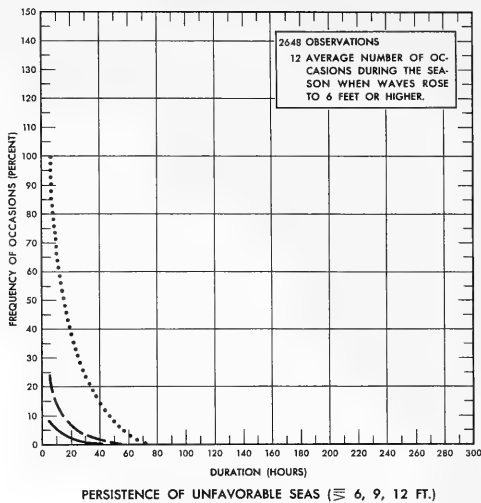
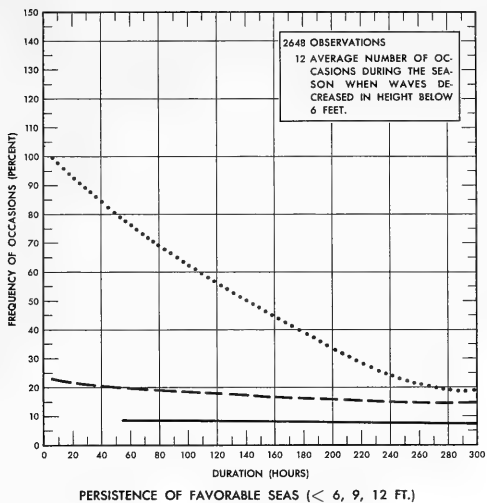
JULY, AUGUST, SEPTEMBER



OCTOBER, NOVEMBER, DECEMBER



JANUARY, FEBRUARY, MARCH



APRIL, MAY, JUNE

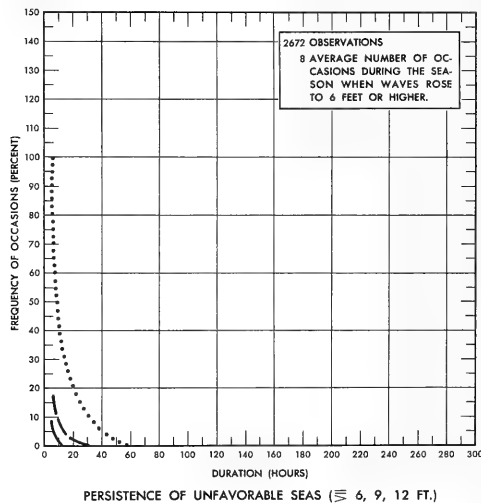
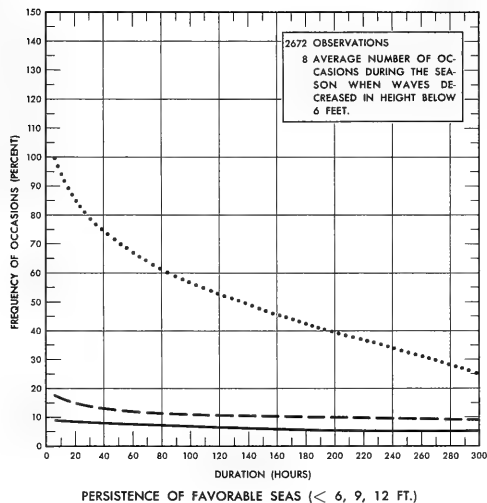
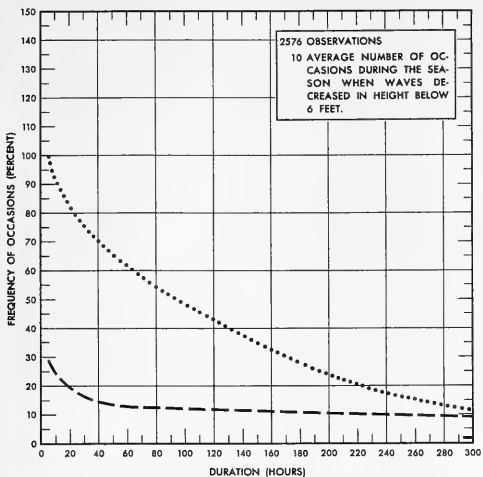
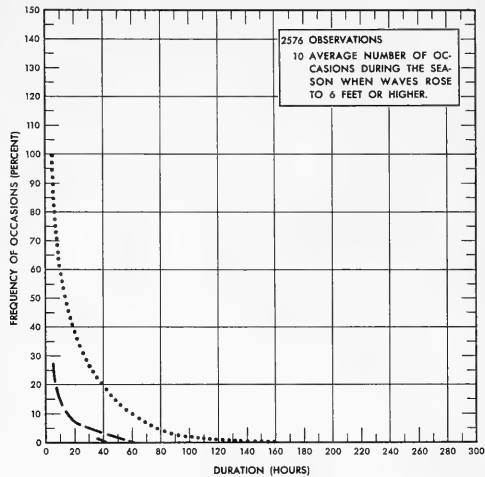


FIGURE 3K SAVANNAH, GEORGIA 31°56.6'N., 80°39.8'W.

JULY, AUGUST, SEPTEMBER

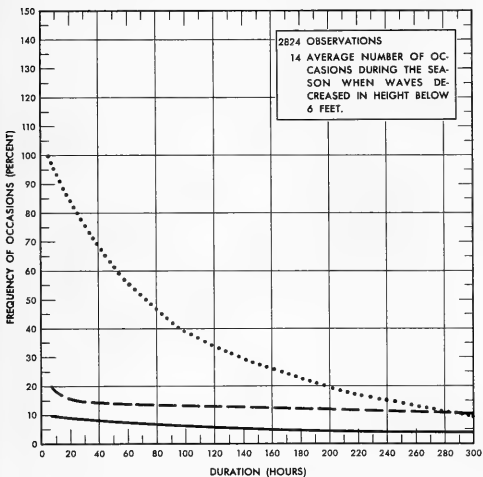


PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)

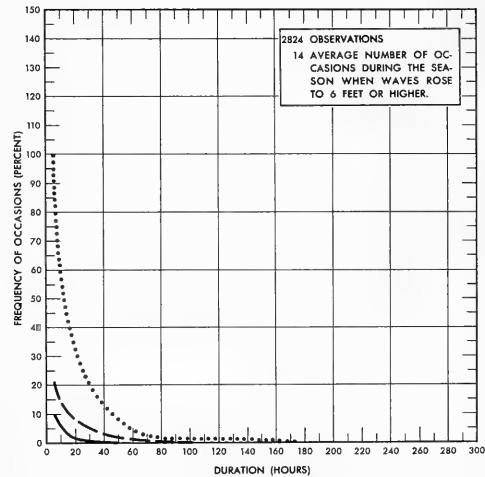


PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)

OCTOBER, NOVEMBER, DECEMBER



PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)

OCEAN STATION VESSELS OF THE NORTH ATLANTIC

The deep, open expanse of the ocean generally affords maximum uninterrupted fetch distances for wave development during migratory storms, the wave heights being limited only by the duration of wind action. The major storm track along the east coast of the United States continues northward and northeastward toward Greenland and Iceland, where storms for a short period often stagnate before moving on again. A blocking situation in the upper air circulation may be such that a storm will stall at one location perhaps for days at a time. During stagnation, the storms often retain or increase their intensity of circulation. Since the ocean station vessels mentioned here are in close proximity to major and secondary storm tracks, the circumstances outlined above induce persistence of unfavorable waves of longer durations at ocean station locations than at locations near sheltering influences.

The progression of storms through this region affects the northern tier of ocean station vessels (north of 50°N . latitude) during all seasons. Examination of the persistence curves in Figures 5A through 5I reveals, as should be expected, that long durations of unfavorable waves of all height categories are experienced by the northern tier of ocean station vessels throughout the year.

On the other hand, the southern tier of ocean station vessels (south of 50°N . latitude) experiences long durations of unfavorable waves in autumn and winter only, whereas favorable wave conditions persist for long periods during the spring and summer. The reason is that the storm tracks are well to the north of the southern tier of ocean station vessels during the spring and summer seasons, when the dominant climatic control is the Azores high pressure system.

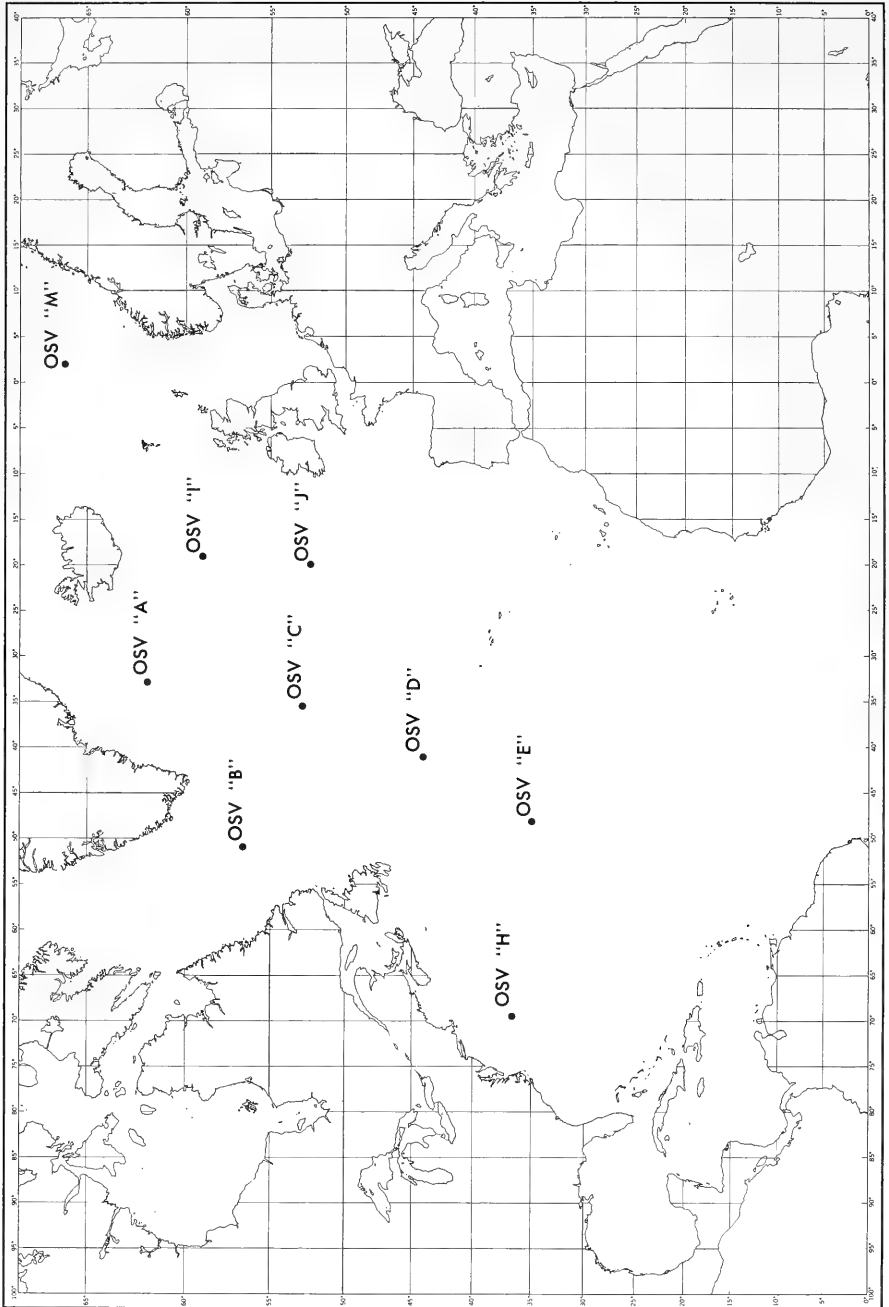
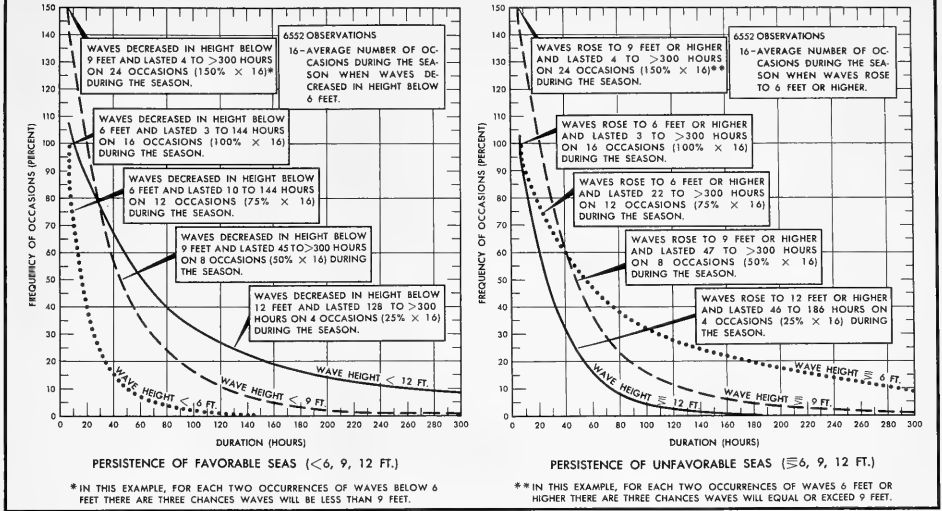


FIGURE 4 LOCATION CHART OF OCEAN STATION VESSELS

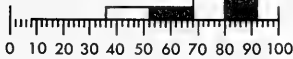
LEGEND AND EXAMPLES



LEGEND

WAVE HEIGHT

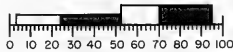
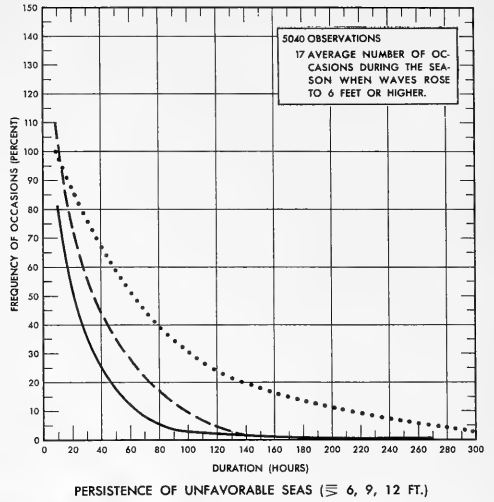
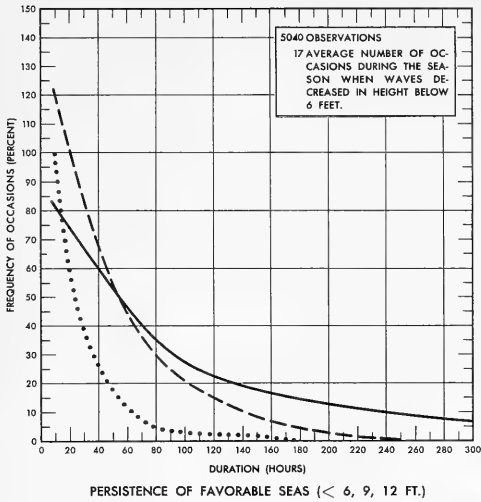
CALM
1-3 FT.
3-6 FT.
6-9 FT.
9-12 FT.
≥12 FT.
INDETERMINATE



SUMMARY SCALE
(ALL DIRECTIONS)

FIGURE 5 WAVE PERSISTENCE CURVES AND WAVE HEIGHT BAR GRAPHS FOR OCEAN STATION VESSELS OF THE NORTH ATLANTIC

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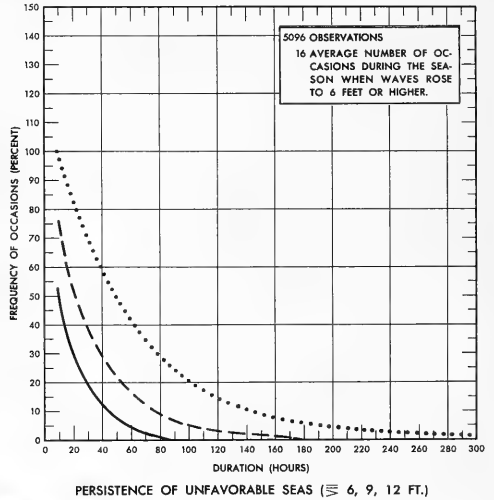
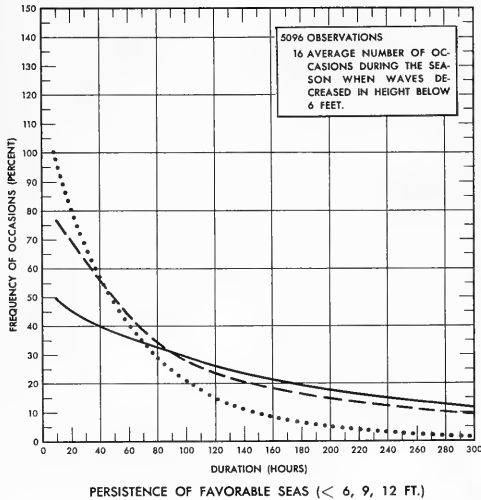
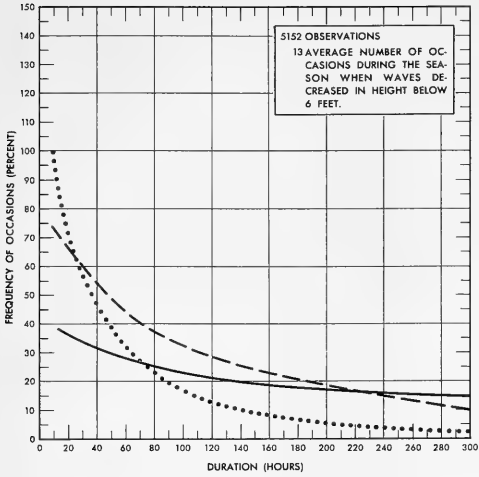
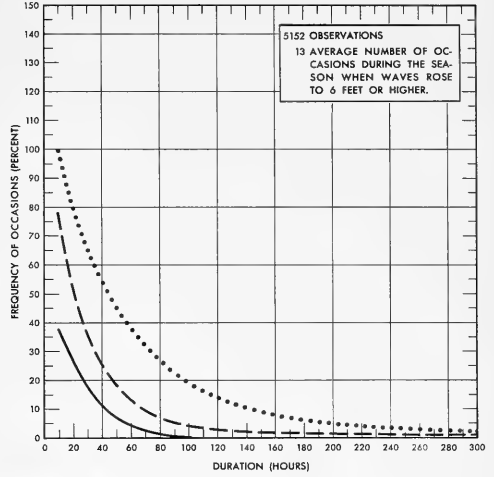


FIGURE 5A OSV "A" 62.0°N., 33.0°W.

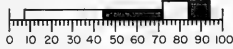
JULY, AUGUST, SEPTEMBER



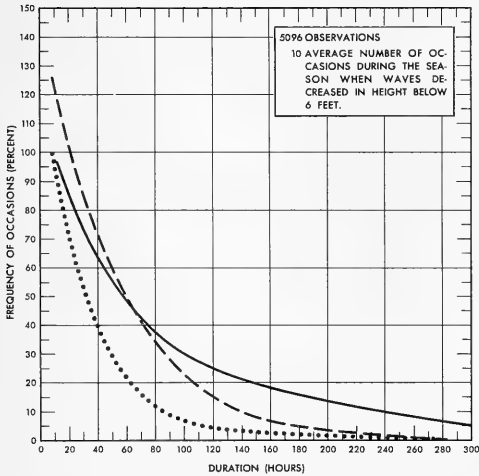
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



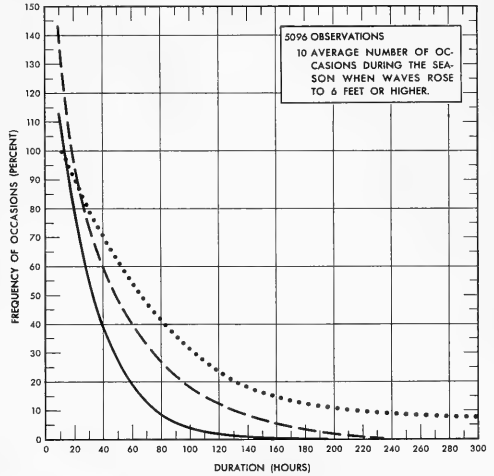
PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)



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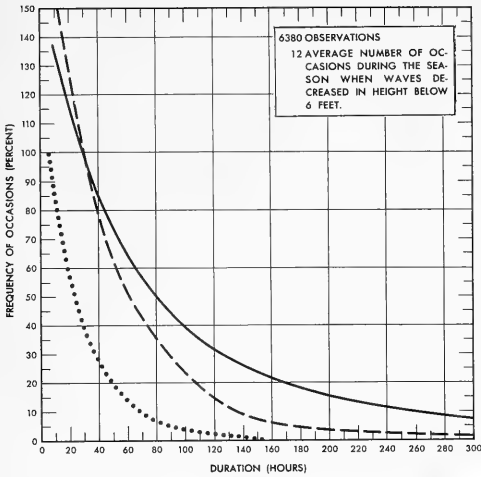
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



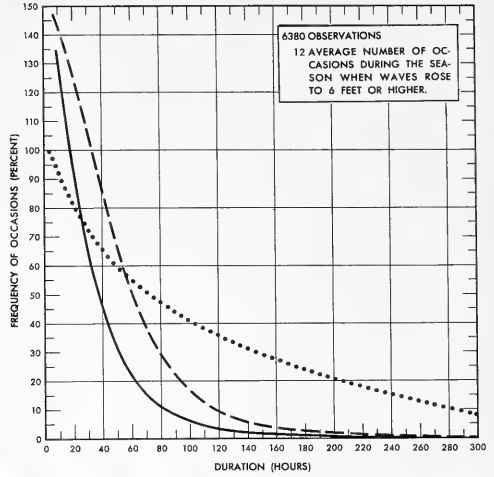
PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)



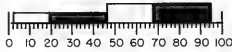
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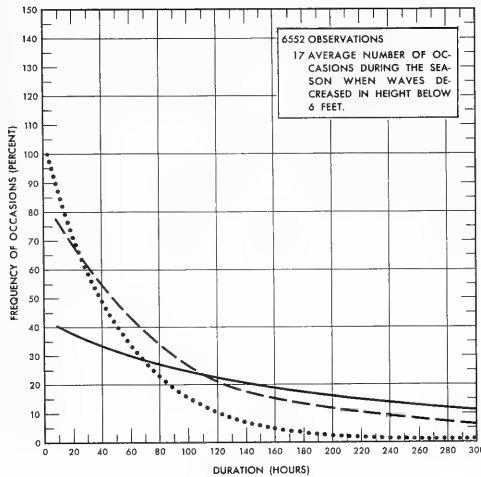
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



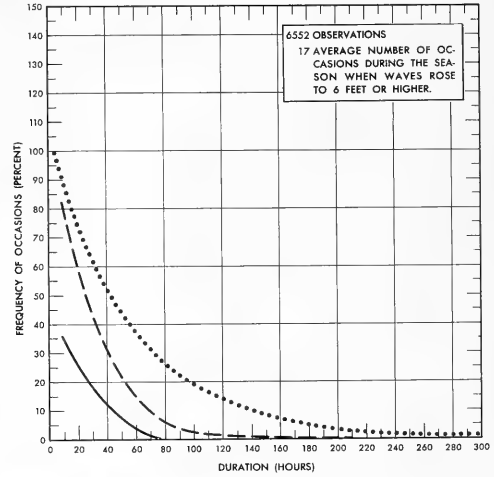
PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)



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PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)

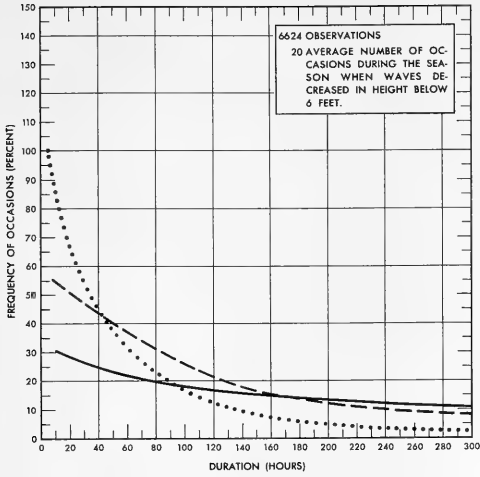


PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)

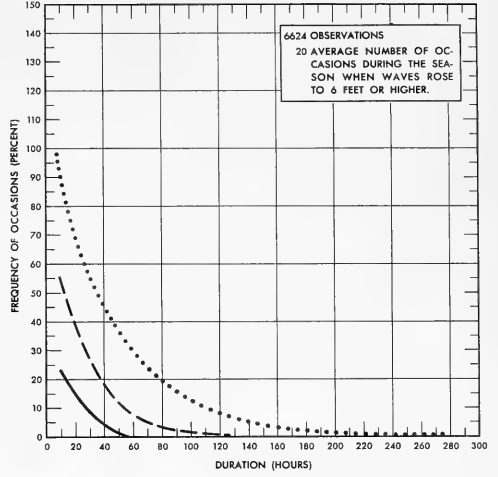


FIGURE 5B OSV "B" 56.5°N., 51.0°W.

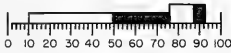
JULY, AUGUST, SEPTEMBER



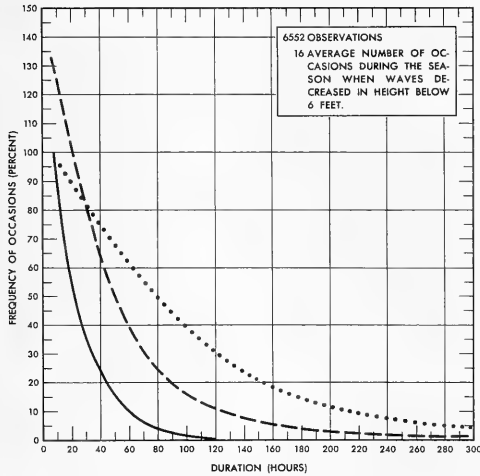
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



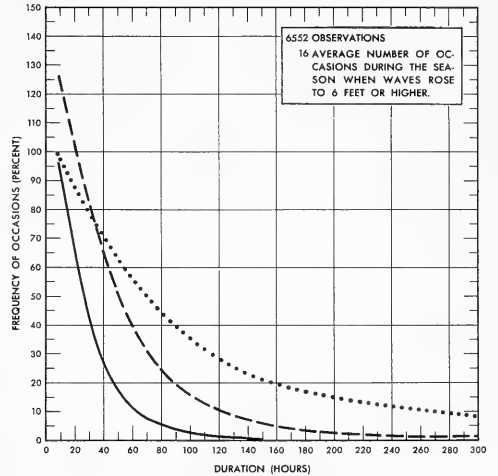
PERSISTENCE OF UNFAVORABLE SEAS (\geq 6, 9, 12 FT.)



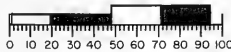
OCTOBER, NOVEMBER, DECEMBER



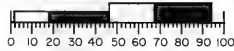
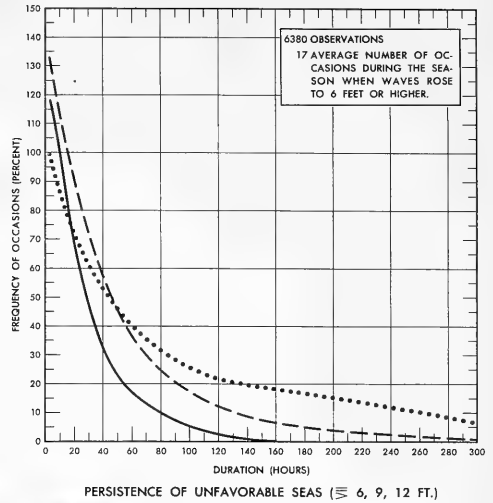
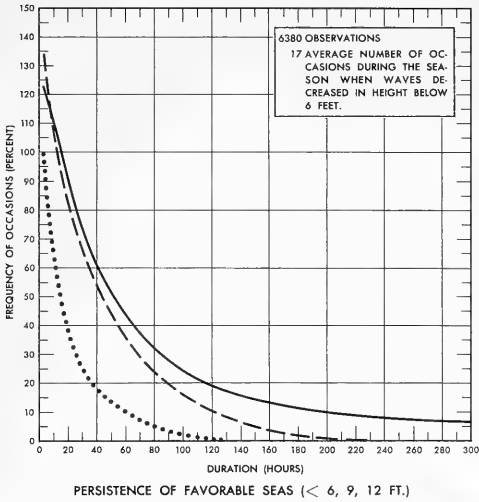
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (\geq 6, 9, 12 FT.)



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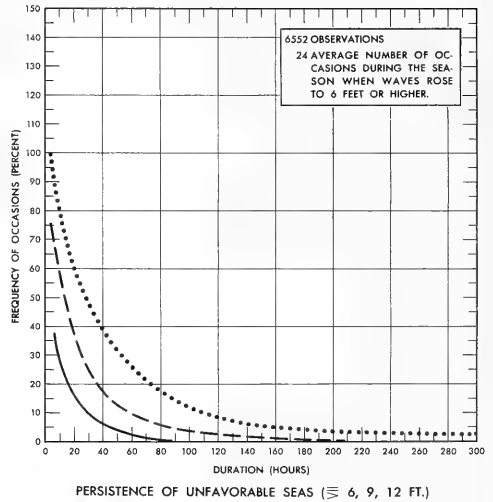
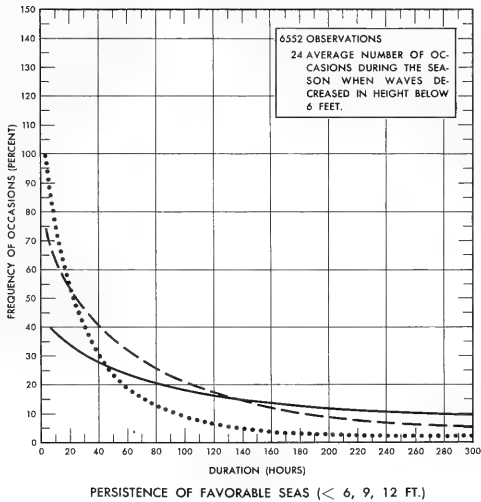
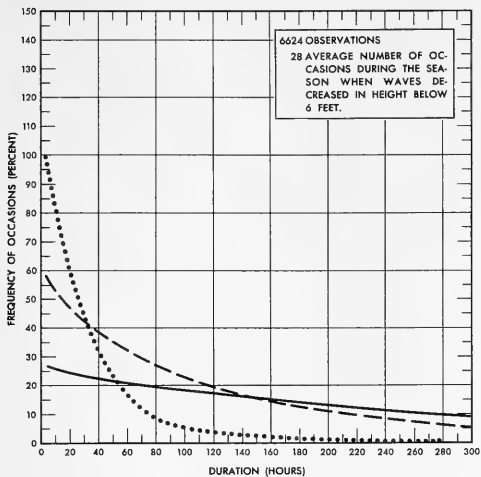
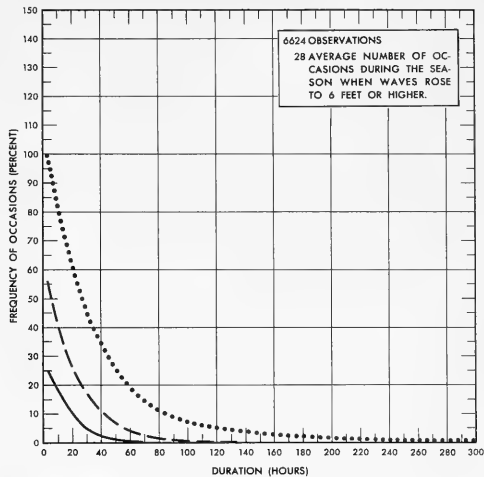


FIGURE 5C OSV "C" 52.8°N., 35.5°W.

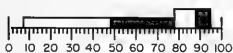
JULY, AUGUST, SEPTEMBER



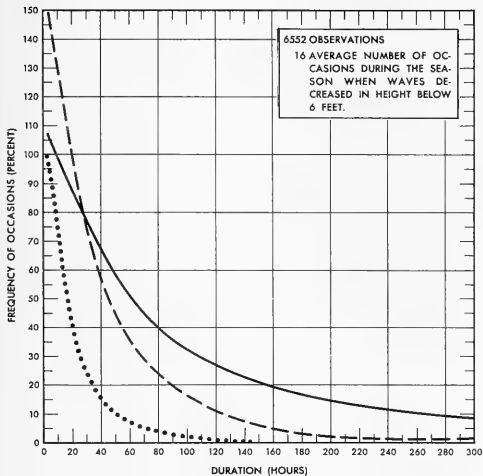
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



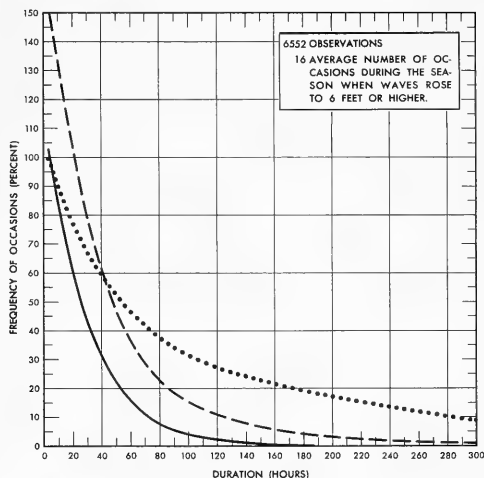
PERSISTENCE OF UNFAVORABLE SEAS (\geq 6, 9, 12 FT.)



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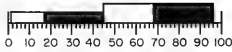
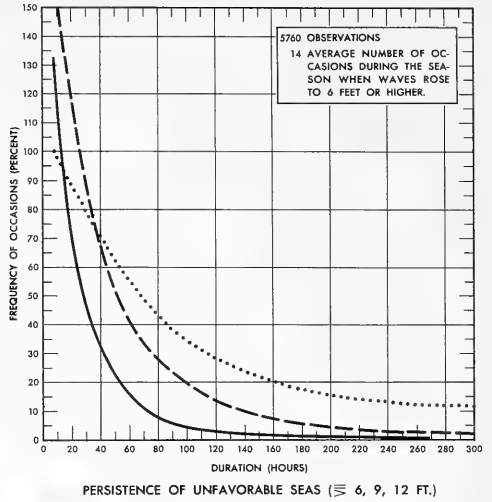
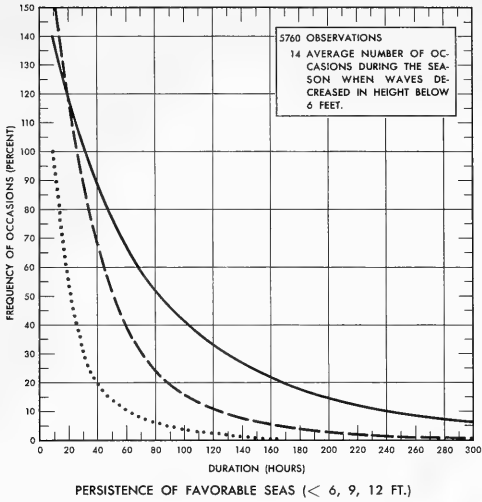
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (\geq 6, 9, 12 FT.)



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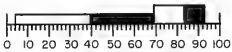
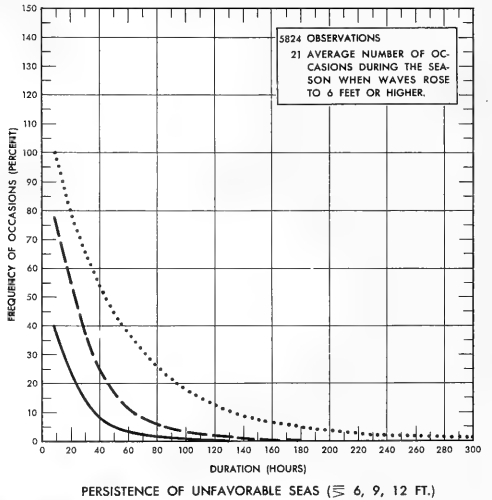
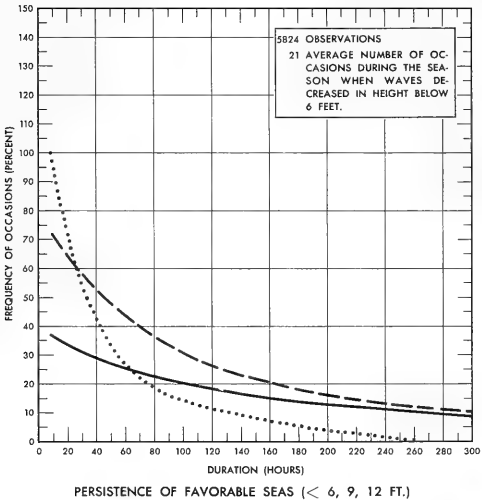
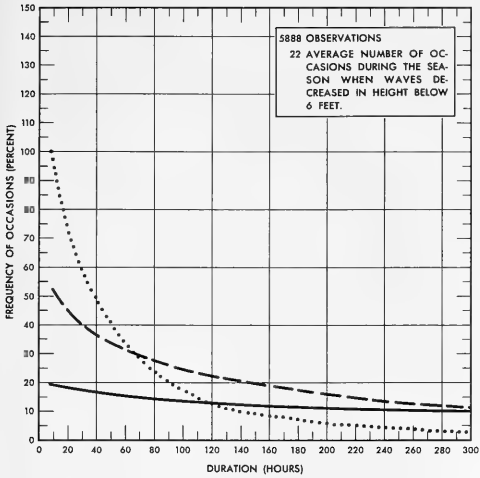
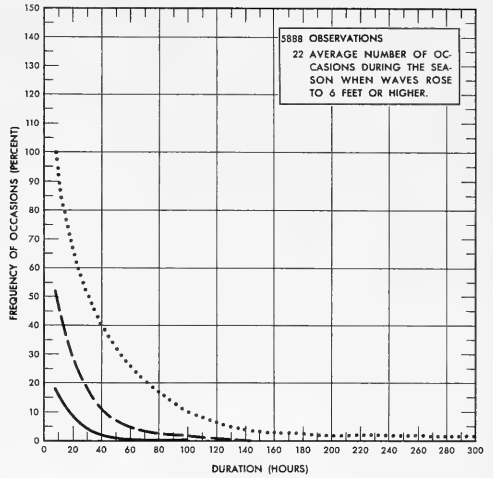


FIGURE 5D OSV "D" 44.0°N, 41.0°W.

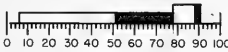
JULY, AUGUST, SEPTEMBER



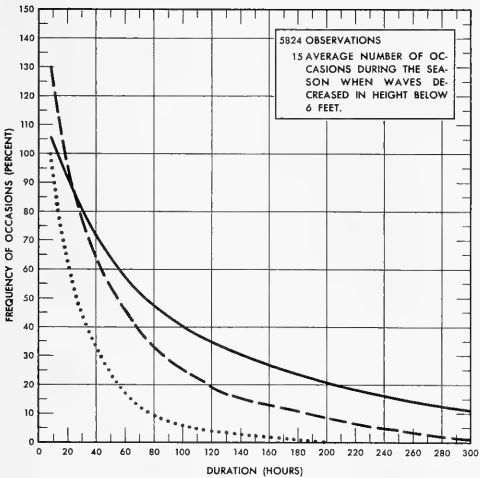
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



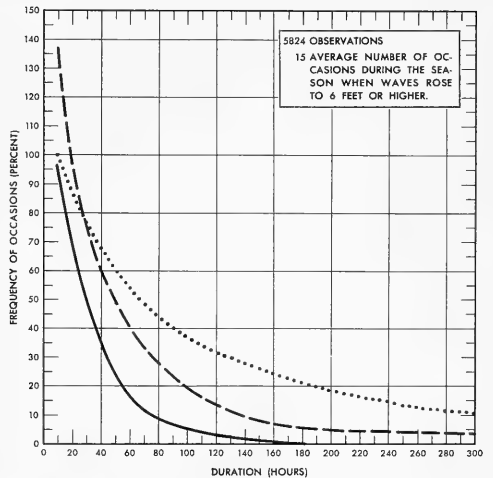
PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)



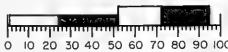
OCTOBER, NOVEMBER, DECEMBER



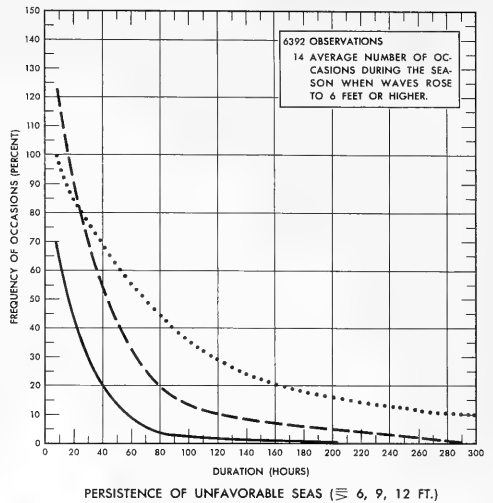
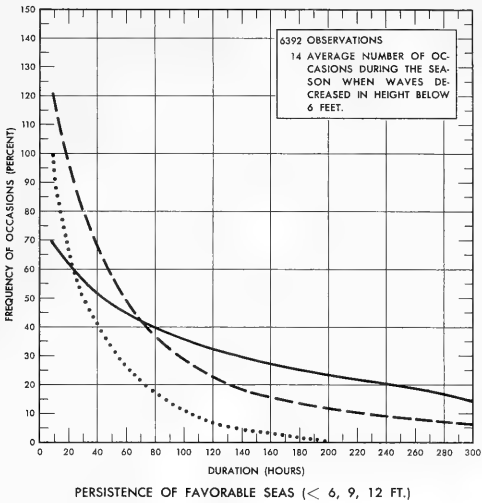
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)



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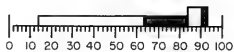
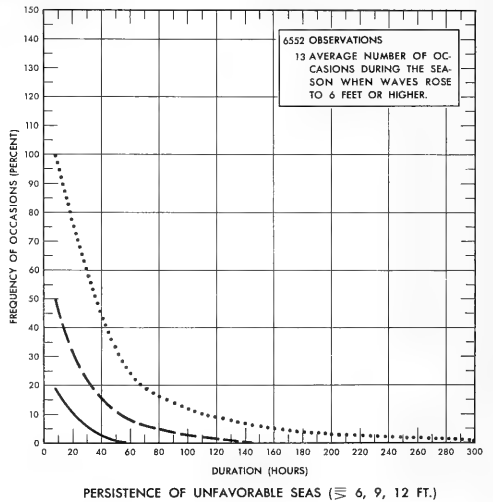
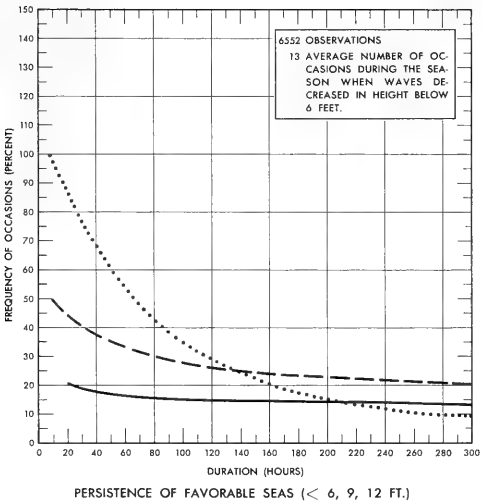
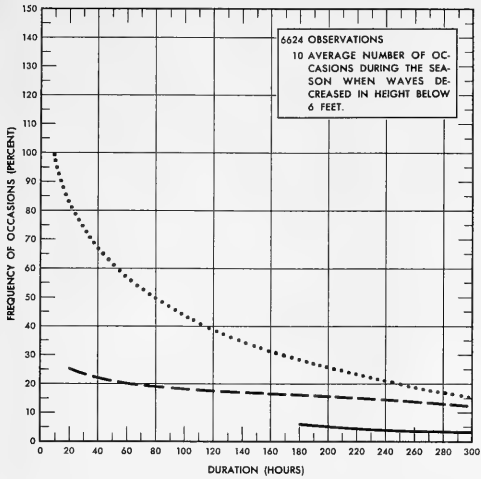
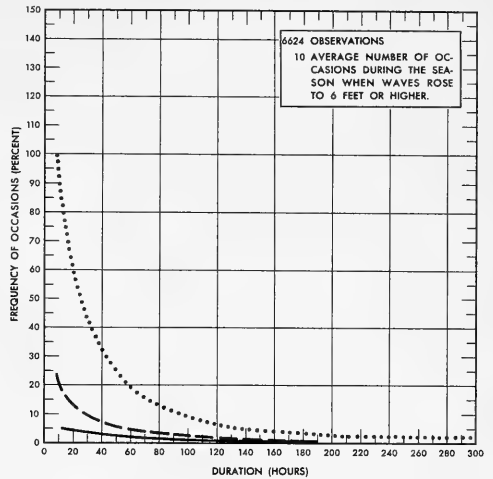


FIGURE 5E OSV "E" 35.0°N., 48.0°W.

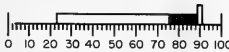
JULY, AUGUST, SEPTEMBER



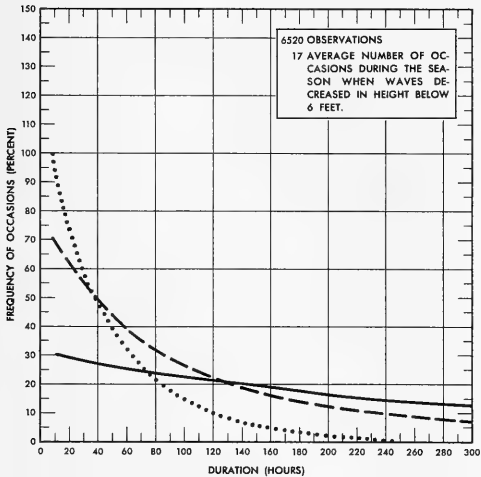
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



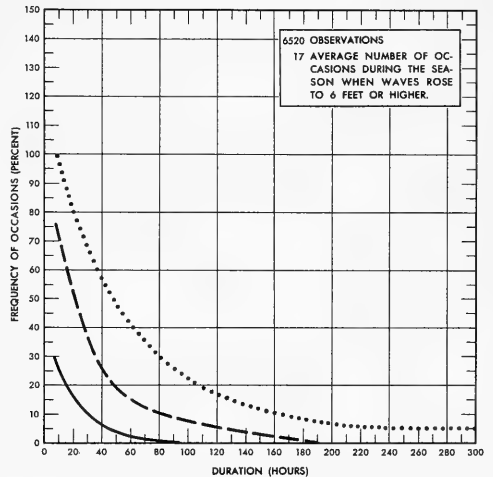
PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)



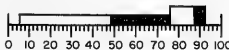
OCTOBER, NOVEMBER, DECEMBER



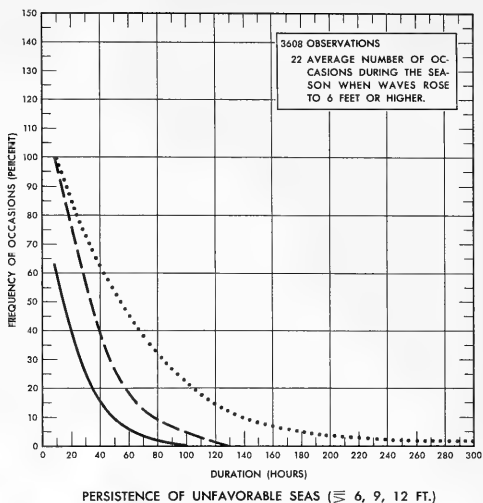
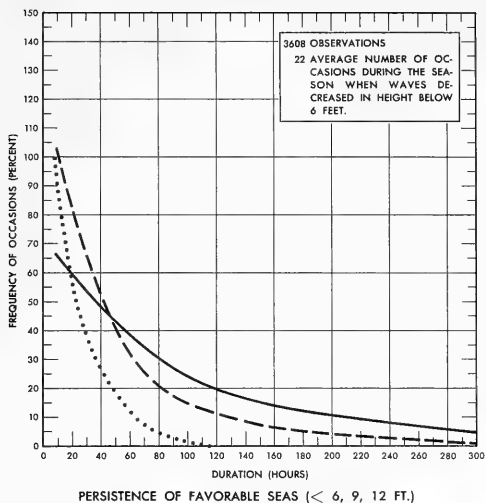
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)



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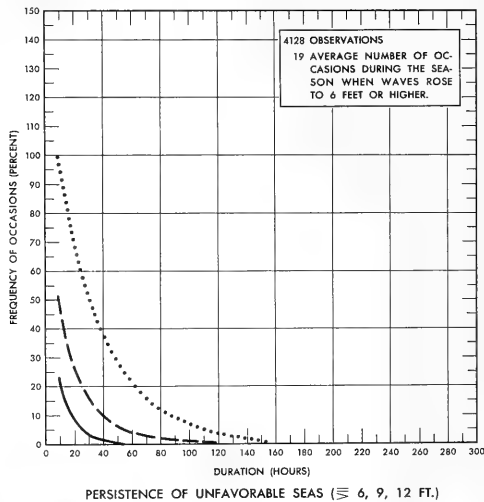
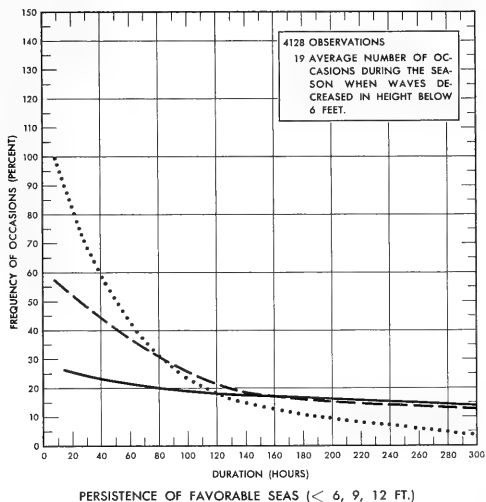
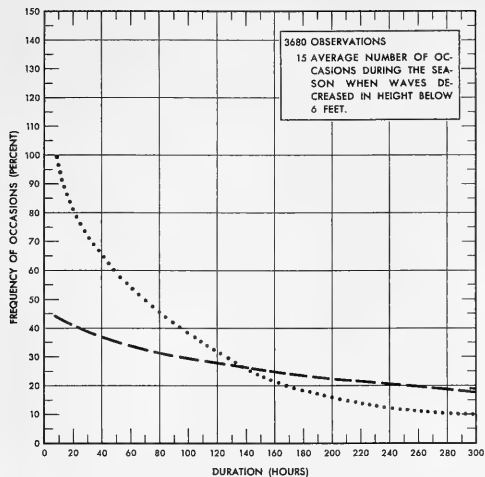
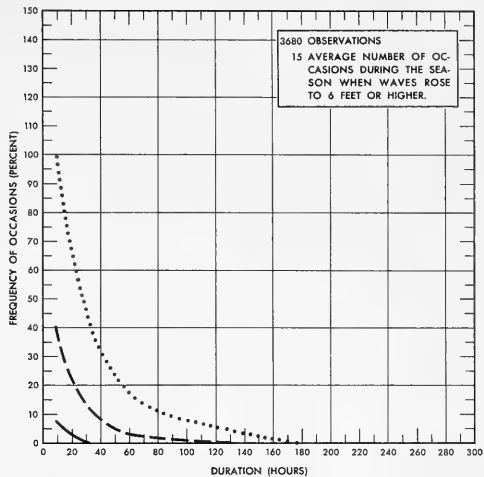


FIGURE 5F OSV "H" 36.7°N., 69.6°W.

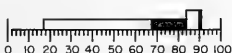
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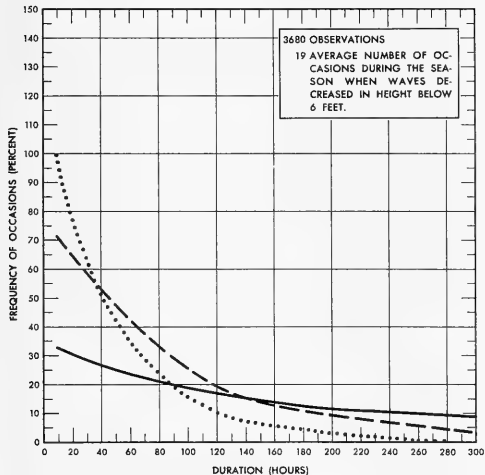
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



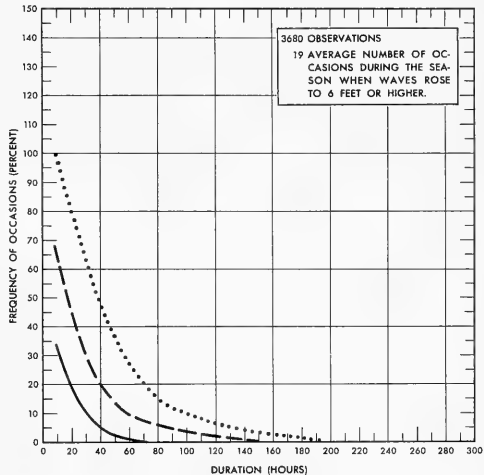
PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)



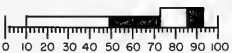
OCTOBER, NOVEMBER, DECEMBER



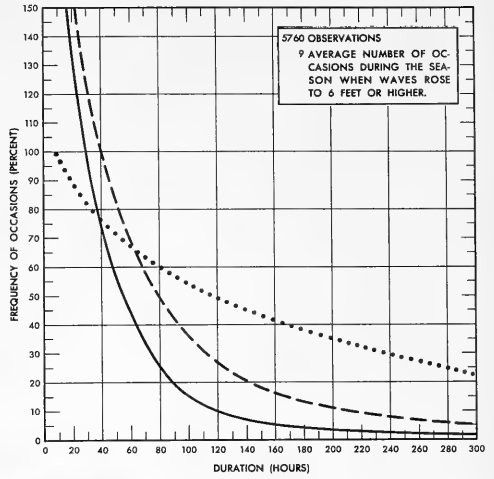
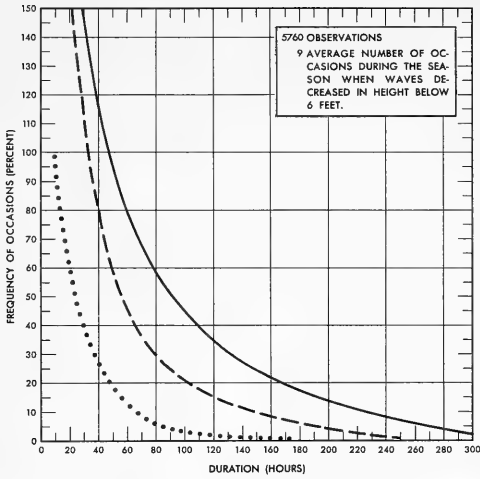
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)



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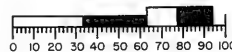
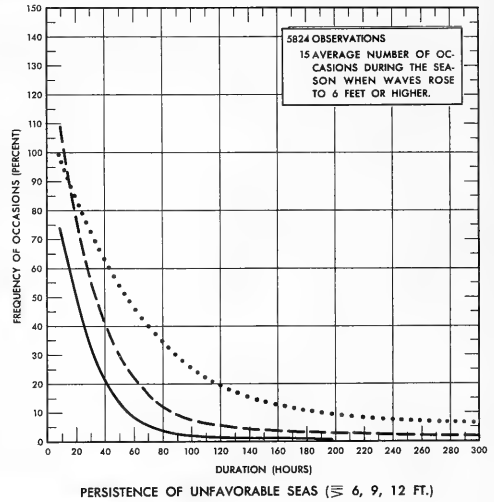
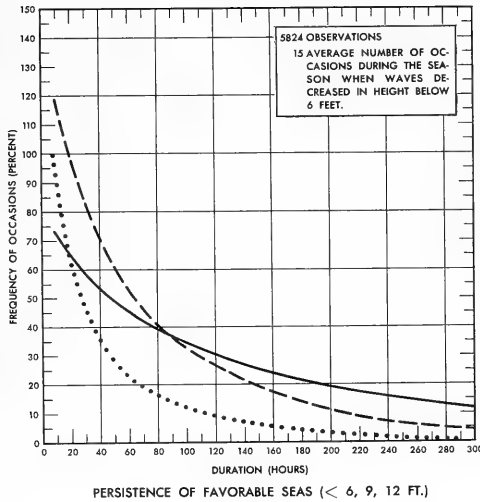
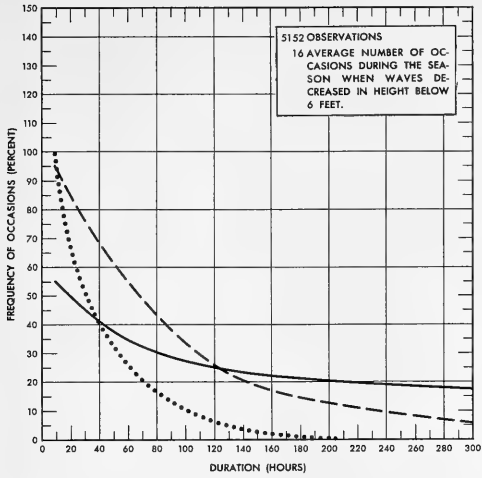
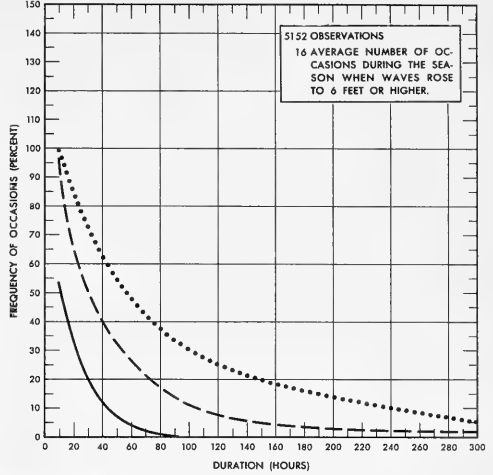


FIGURE 5G OSV "I" 59.0°N., 19.0°W.

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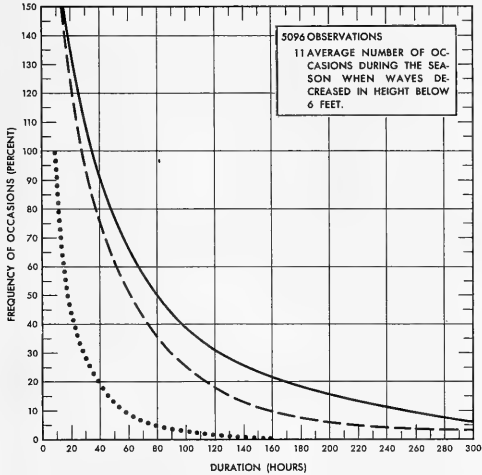
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



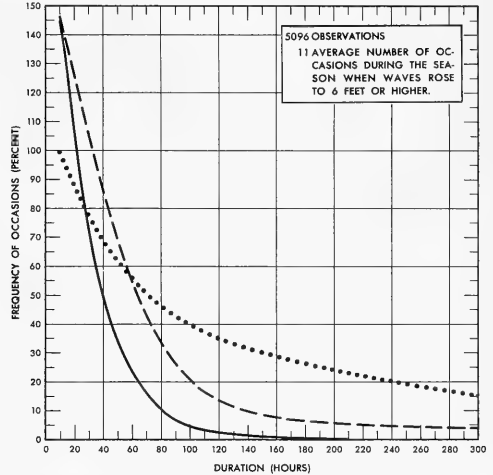
PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)



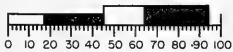
OCTOBER, NOVEMBER, DECEMBER



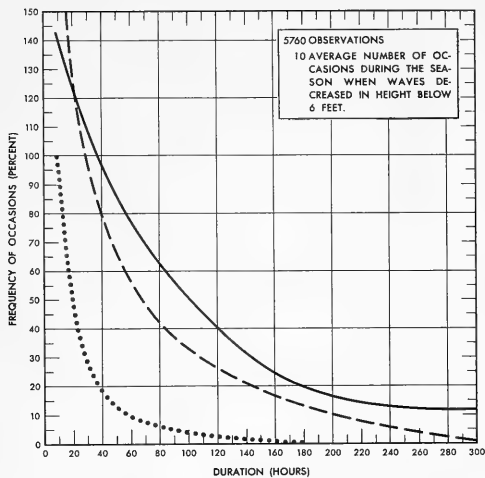
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



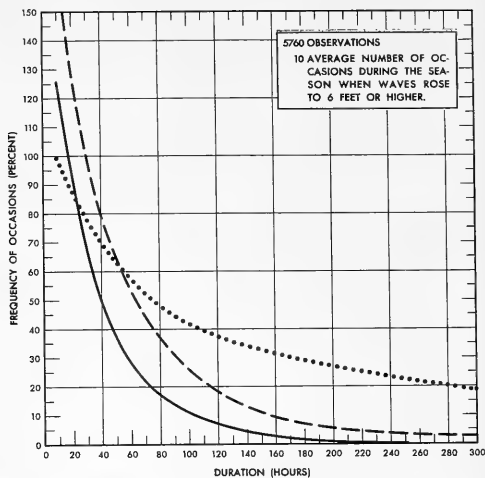
PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)



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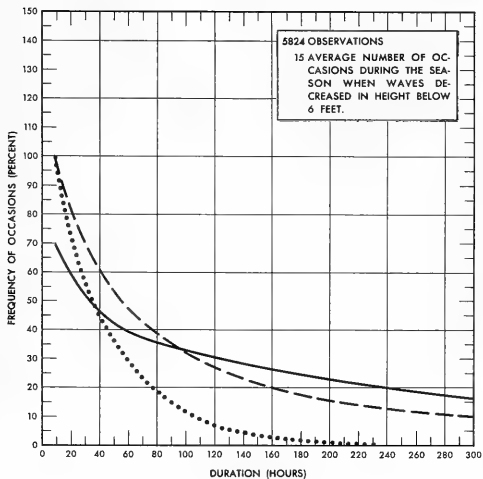
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



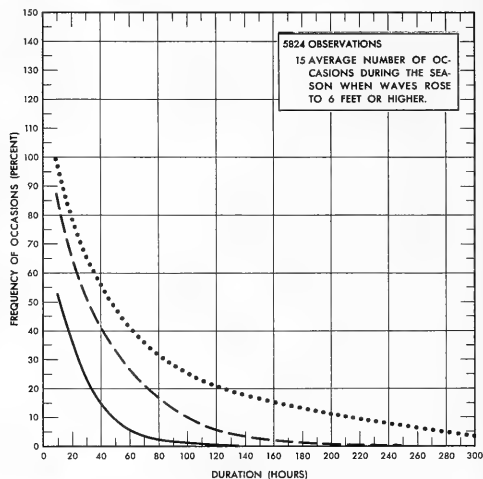
PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)



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PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)

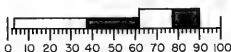
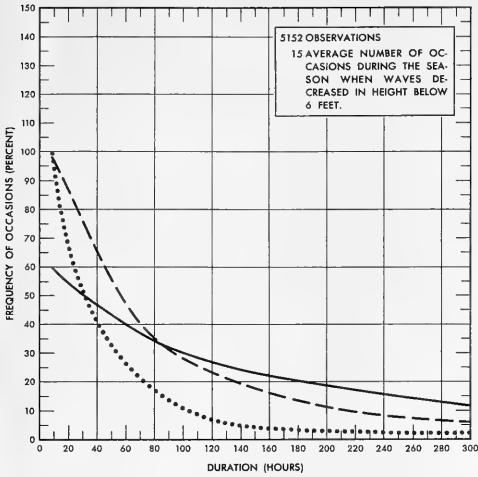
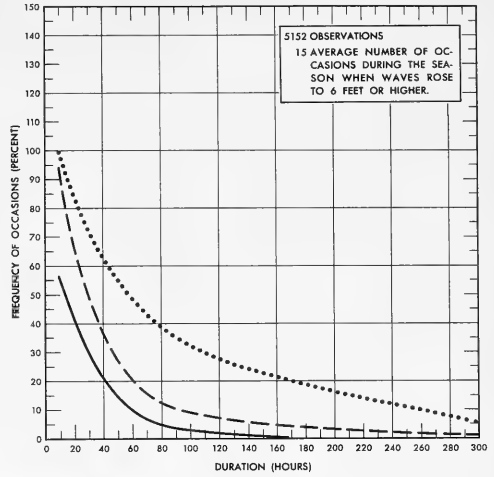


FIGURE 5H OSV "J" 52.5°N., 20.0°W.

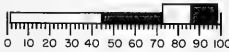
JULY, AUGUST, SEPTEMBER



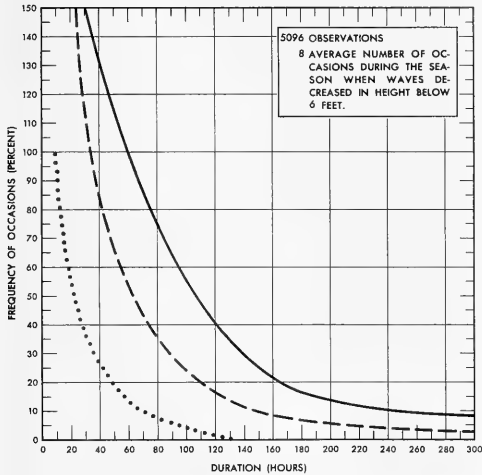
PERSISTENCE OF FAVORABLE SEAS (< 6, 9, 12 FT.)



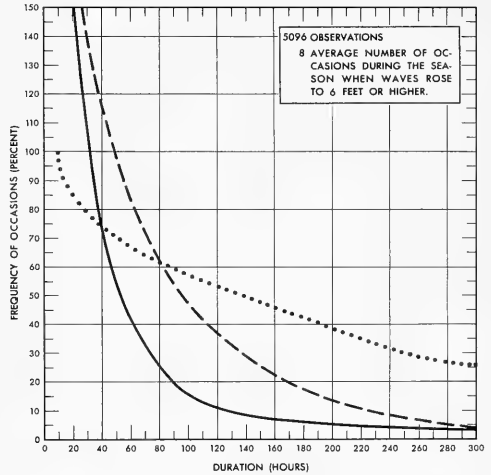
PERSISTENCE OF UNFAVORABLE SEAS (≥ 6, 9, 12 FT.)



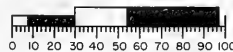
OCTOBER, NOVEMBER, DECEMBER



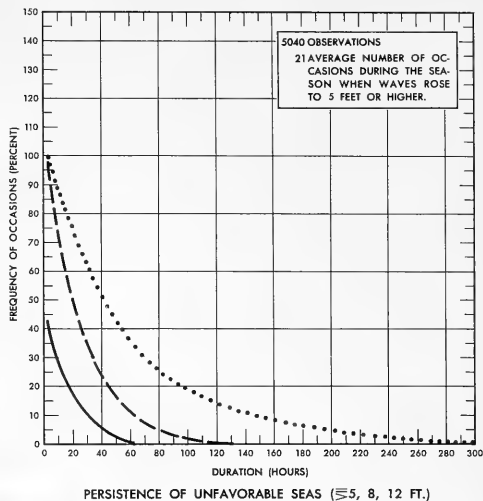
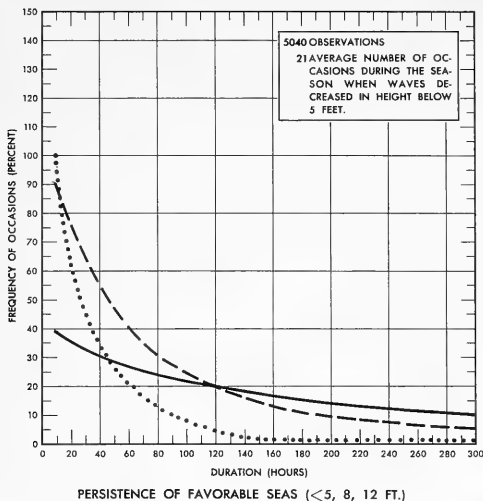
PERSISTENCE OF FAVORABLE WAVES (< 6, 9, 12 FT.)



PERSISTENCE OF UNFAVORABLE WAVES (≥ 6, 9, 12 FT.)



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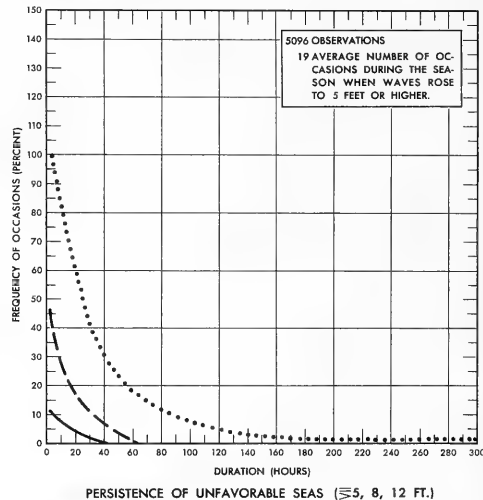
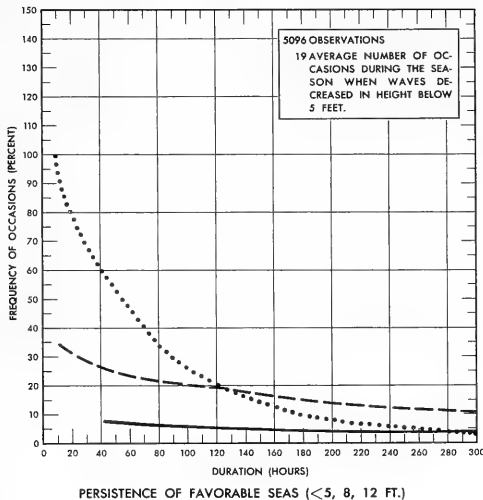
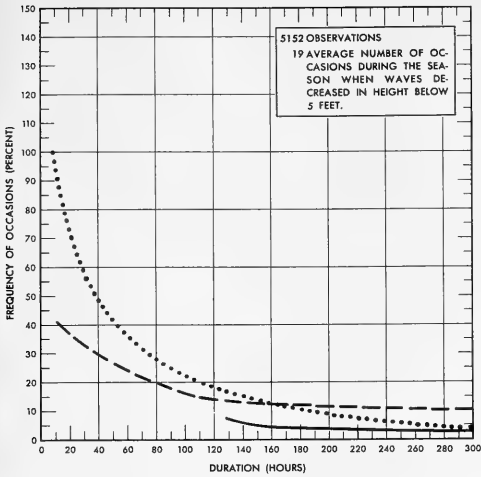
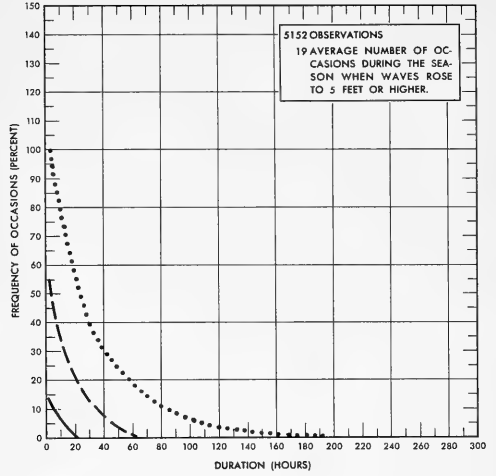


FIGURE 51 OSV "M" 66.0°N., 2.0°E.

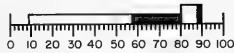
JULY, AUGUST, SEPTEMBER



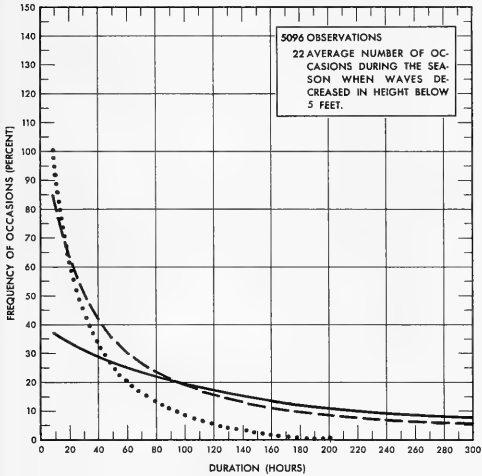
PERSISTENCE OF FAVORABLE SEAS (<5, 8, 12 FT.)



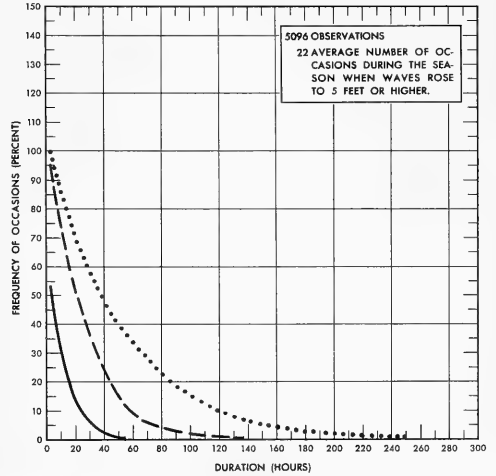
PERSISTENCE OF UNFAVORABLE SEAS (≥5, 8, 12 FT.)



OCTOBER, NOVEMBER, DECEMBER



PERSISTENCE OF FAVORABLE SEAS (<5, 8, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (≥5, 8, 12 FT.)



LIGHTSHIPS OF THE NORTH SEA AND BALTIC SEA

Because of the higher latitude locations of the North and Baltic Seas, the North Atlantic storm tracks influence these sea regions throughout the year. Storm activity here is more frequent and more intense during the autumn and winter seasons. Therefore, a higher number of occasions above and below certain threshold heights are experienced at the North and Baltic Sea lightships in autumn and winter. The spring and summer seasons are controlled largely by the Azores high pressure circulation, which produces long periods of favorable wave conditions. These points are reflected in the persistence curves for the North and Baltic Sea lightships in Figures 7A through 7F

Although the autumn and winter storms are of severe intensity, the buildup of waves to higher height categories and unfavorable wave conditions is hindered both by the shallow waters of the North and Baltic Seas and by the limitations of their semienclosed and closed basins to fetch distances. The shallow waters retard wave growth (both in height and length) within the basins, and wave shoaling (the alteration of a wave proceeding from deep water into shallow water) reduces much of the energy content of waves through bottom friction and thus shortens wavelengths and steepens wave crests often to the point of breaking far offshore. Shallowest depths are present at Elbe I Lightship in the North Sea. However, the sheltering effect of land on oceanic wave trains headed toward these sea regions and the rapid migration of storms through these regions probably are more responsible for the short durations of unfavorable waves at the selected lightships. Maximum sheltering occurs at the Baltic Sea lightships (Figures 7E and 7F).

On occasion, however, when winds of gale force are blowing steadily onshore, water regions of shoaling bottom are plagued by the development of steep crested seas on the far end of fetch areas. The occurrence of this phenomenon on the Danish side of the North Sea during a western gale is notoriously dangerous to small ships, as well as the western part of the English Channel when storm waves are directed from the open Atlantic.

Persistence of strong onshore winds over a period of time piles up the water at the far end of the fetch area along the shoreface. When a basin lacks an outlet for sufficient drainage, the result is a storm surge or seiche. Storm surges raise the normal level of the water and permit waves to run farther up the shoreface before breaking. When a strong surge from a meteorological influence occurs in coincidence with the period of high tide, both reaching their peak at the same time, the result is a flooding of the adjacent lowlands and possible damage to breakwaters and seawalls by the tremendous force of pounding breakers. It was this type of situation which brought about the disastrous North Sea storm of February 1953 which inundated over 1,400 square miles in Holland and England, claimed 1,611 lives, left 100,000 people homeless, and caused untold millions of dollars of damage to property and livestock.

In general, however, the persistence curves of the North Sea and Baltic Sea lightships (Figures 7A through 7F) indicate long durations of favorable waves and relatively short durations of unfavorable wave conditions throughout the year.

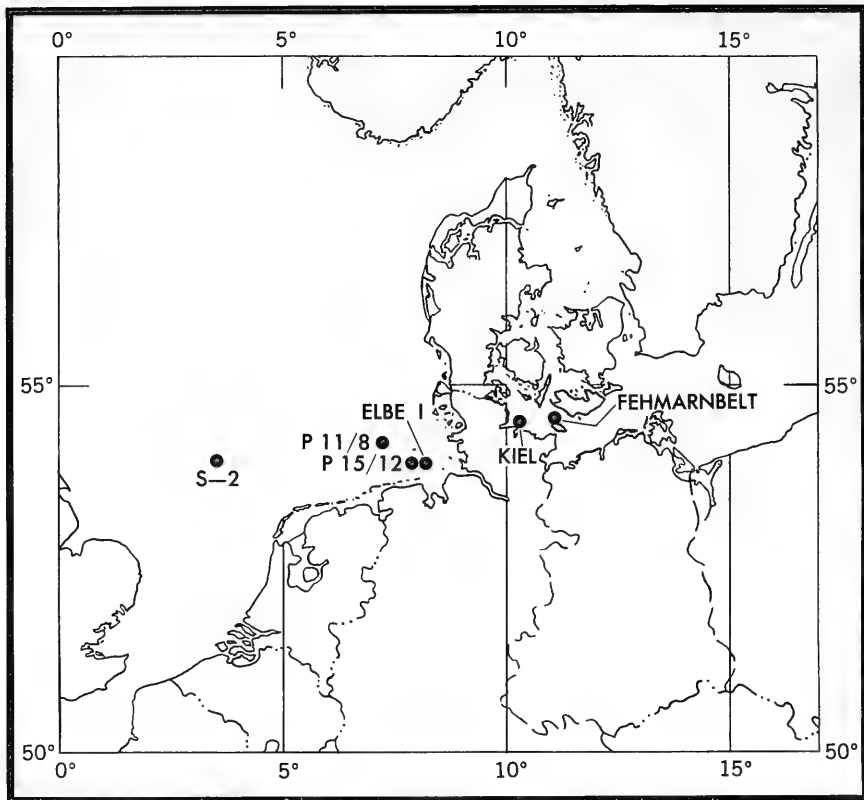


FIGURE 6 LOCATION CHART OF NORTH SEA AND BALTIC LIGHTSHIPS

LEGEND AND EXAMPLES

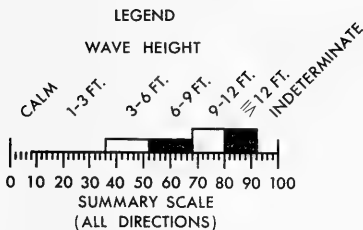
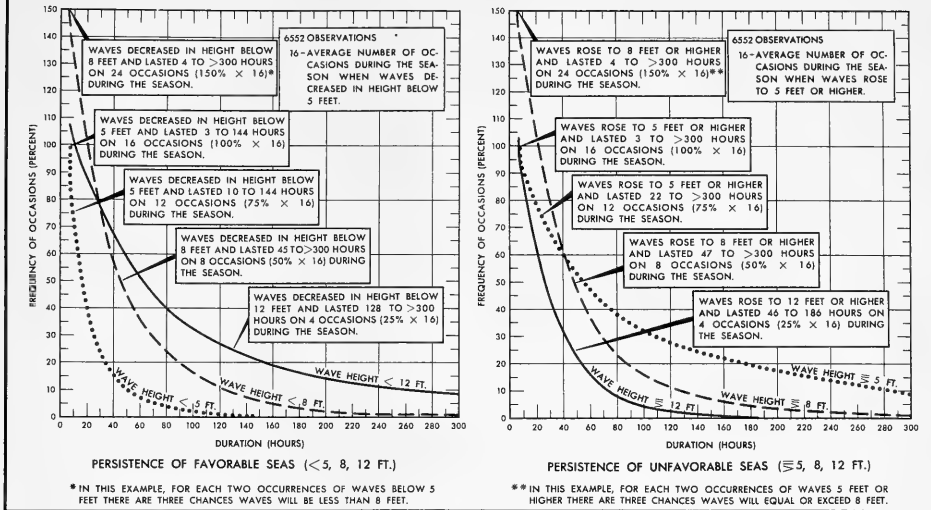
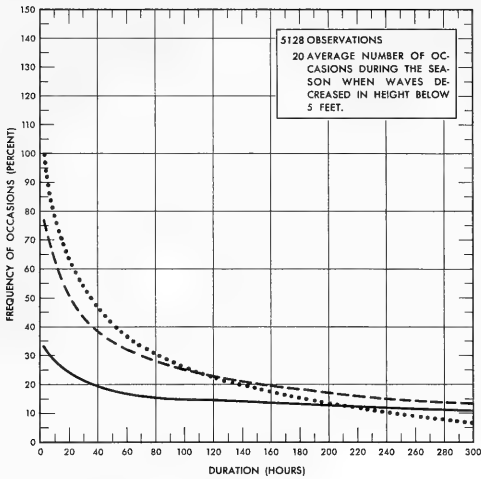
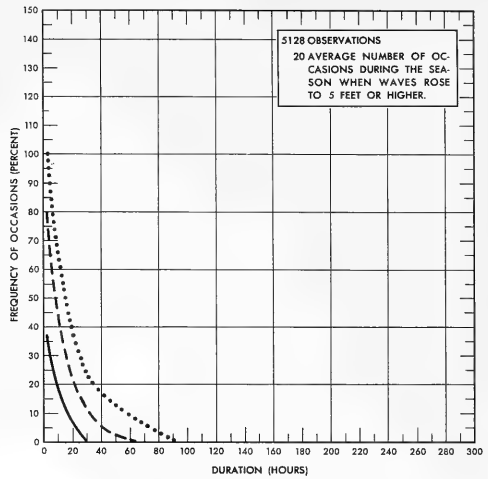


FIGURE 7 WAVE PERSISTENCE CURVES AND WAVE HEIGHT BAR GRAPHS FOR NORTH SEA AND BALTIC SEA LIGHTSHIPS

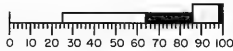
JANUARY, FEBRUARY, MARCH



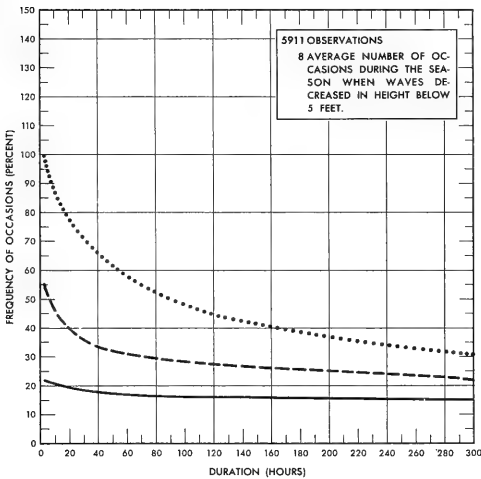
PERSISTENCE OF FAVORABLE SEAS (<5, 8, 12 FT.)



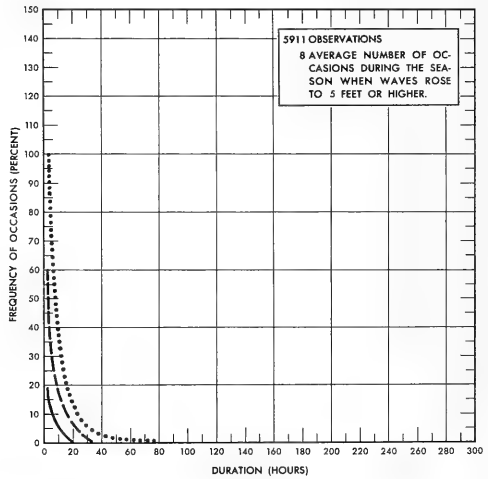
PERSISTENCE OF UNFAVORABLE SEAS (≥5, 8, 12 FT.)



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PERSISTENCE OF FAVORABLE SEAS (<5, 8, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (≥5, 8, 12 FT.)

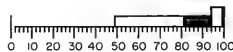
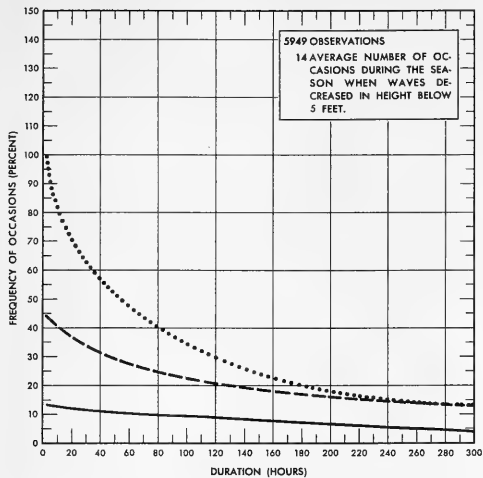
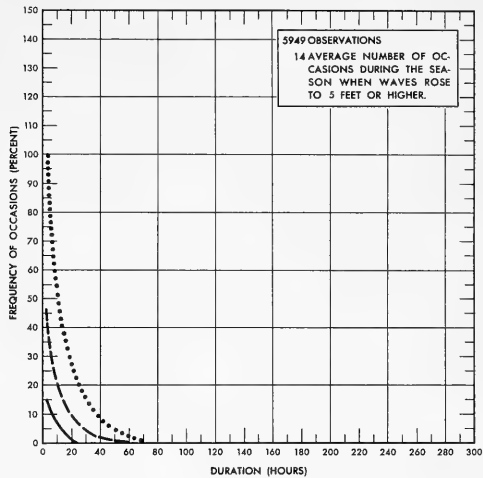


FIGURE 7A S-2 54°0.5'N., 3°32.0'E.

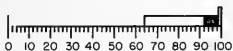
JULY, AUGUST, SEPTEMBER



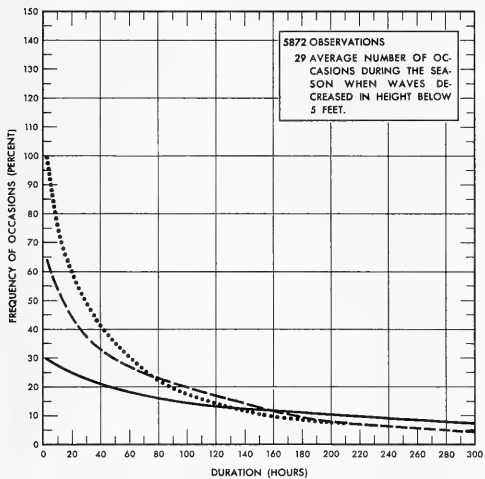
PERSISTENCE OF FAVORABLE SEAS (< 5, 8, 12 FT.)



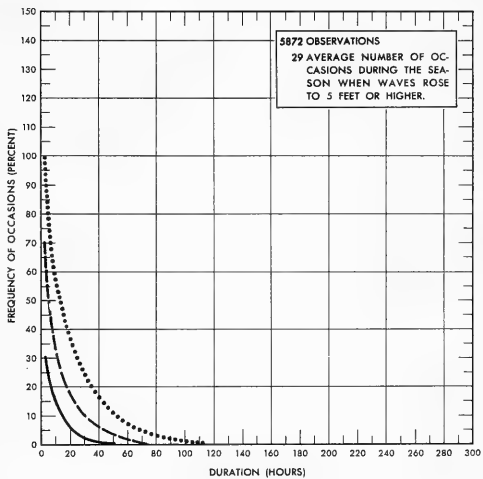
PERSISTENCE OF UNFAVORABLE SEAS (≥ 5, 8, 12 FT.)



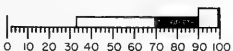
OCTOBER, NOVEMBER, DECEMBER



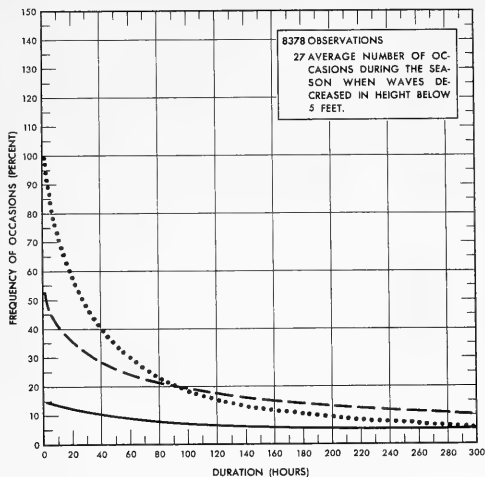
PERSISTENCE OF FAVORABLE SEAS (< 5, 8, 12 FT.)



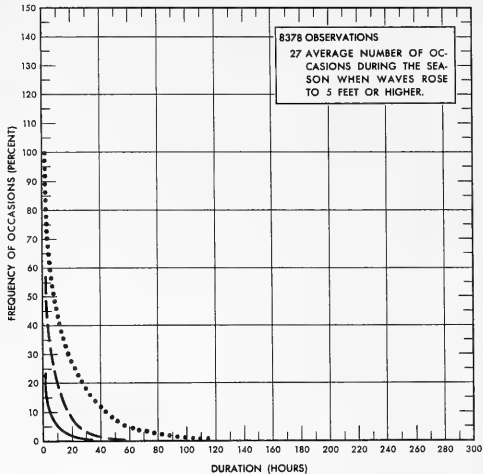
PERSISTENCE OF UNFAVORABLE SEAS (≥ 5, 8, 12 FT.)



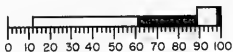
JANUARY, FEBRUARY, MARCH



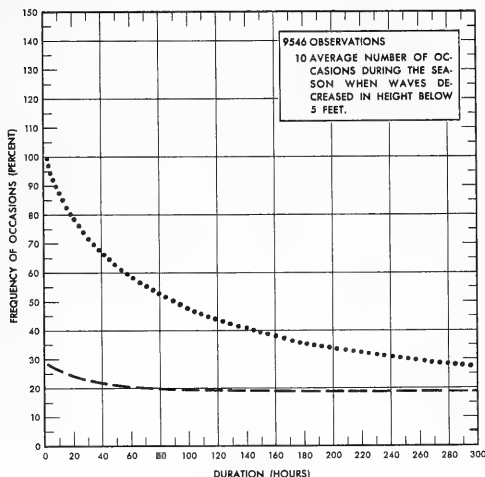
PERSISTENCE OF FAVORABLE SEAS ($< 5, 8, 12 \text{ FT.}$)



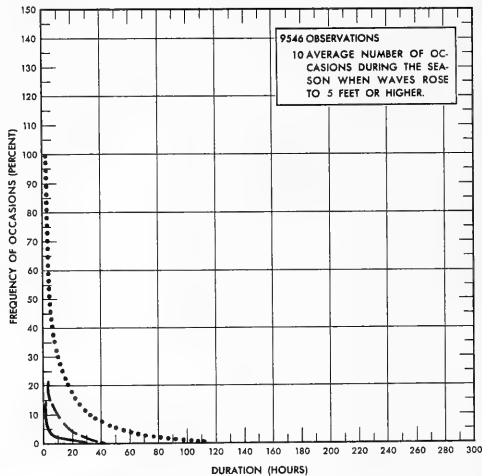
PERSISTENCE OF UNFAVORABLE SEAS ($\ge 5, 8, 12 \text{ FT.}$)



APRIL, MAY, JUNE



PERSISTENCE OF FAVORABLE SEAS ($< 5, 8, 12 \text{ FT.}$)



PERSISTENCE OF UNFAVORABLE SEAS ($\ge 5, 8, 12 \text{ FT.}$)

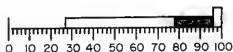
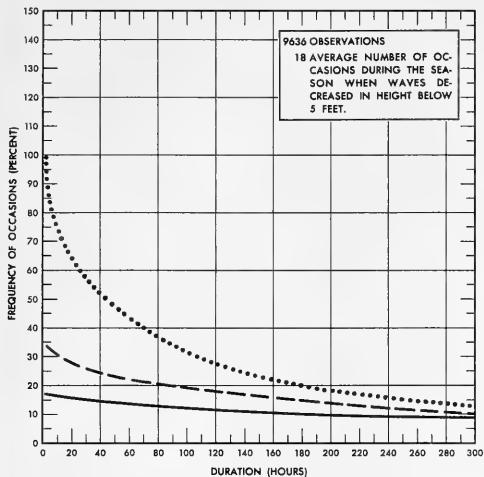
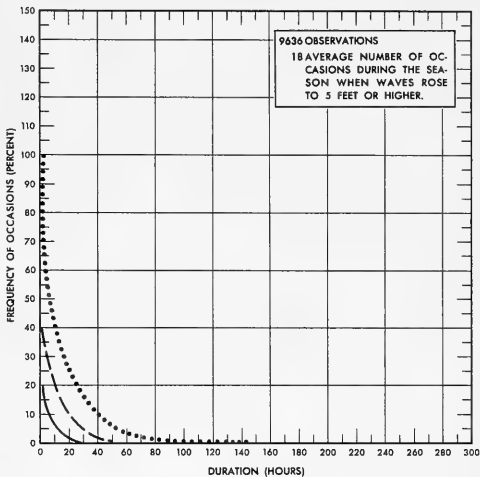


FIGURE 7B P-15/12 $54^{\circ}0.0'N., 7^{\circ}51.0'E.$

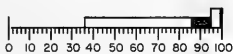
JULY, AUGUST, SEPTEMBER



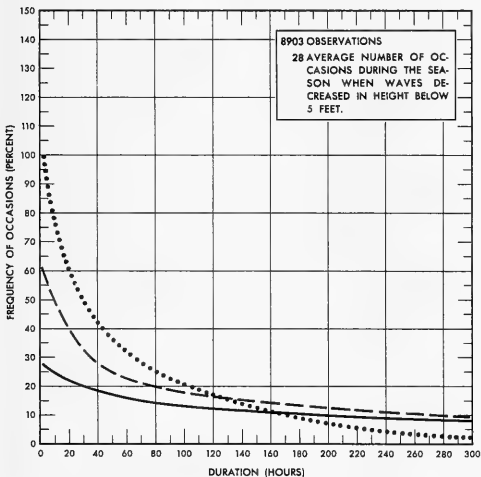
PERSISTENCE OF FAVORABLE SEAS (<5, 8, 12 FT.)



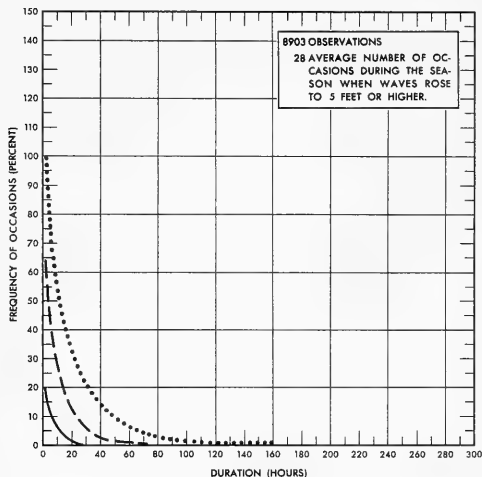
PERSISTENCE OF UNFAVORABLE SEAS (≥5, 8, 12 FT.)



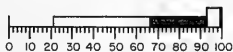
OCTOBER, NOVEMBER, DECEMBER



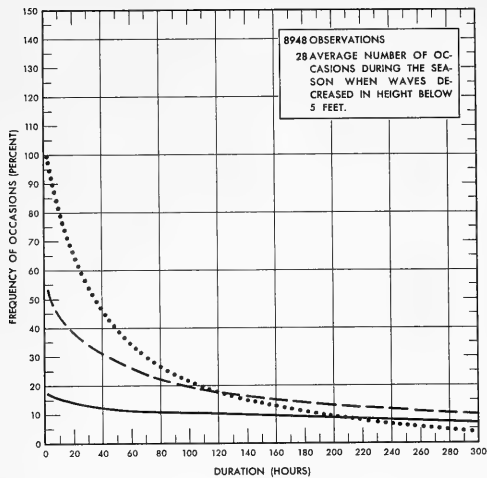
PERSISTENCE OF FAVORABLE SEAS (<5, 8, 12 FT.)



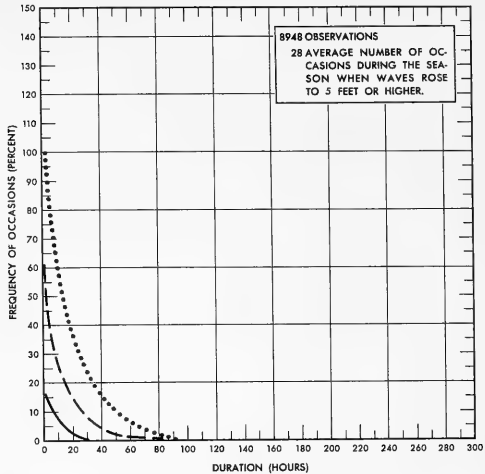
PERSISTENCE OF UNFAVORABLE SEAS (≥5, 8, 12 FT.)



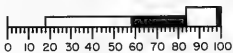
JANUARY, FEBRUARY, MARCH



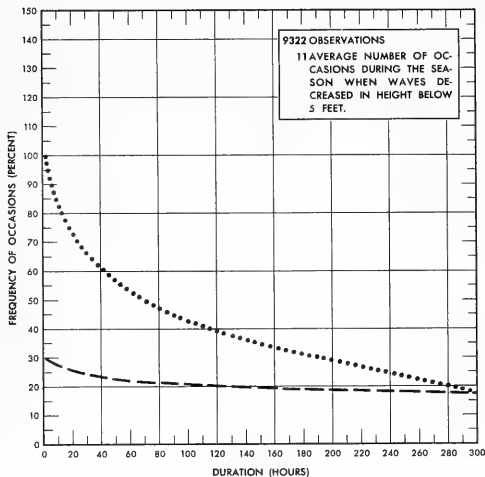
PERSISTENCE OF FAVORABLE SEAS (<5, 8, 12 FT.)



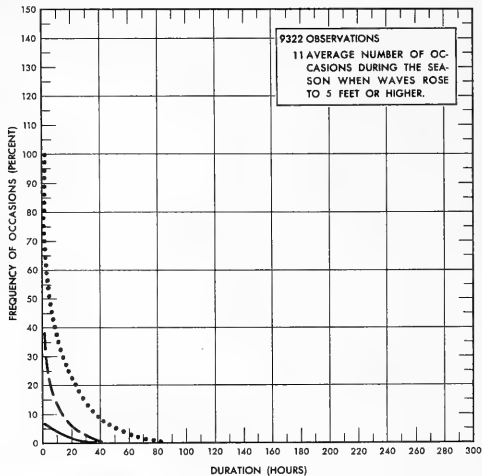
PERSISTENCE OF UNFAVORABLE SEAS (≥5, 8, 12 FT.)



APRIL, MAY, JUNE



PERSISTENCE OF FAVORABLE SEAS (<5, 8, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (≥5, 8, 12 FT.)

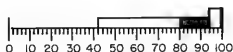
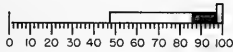
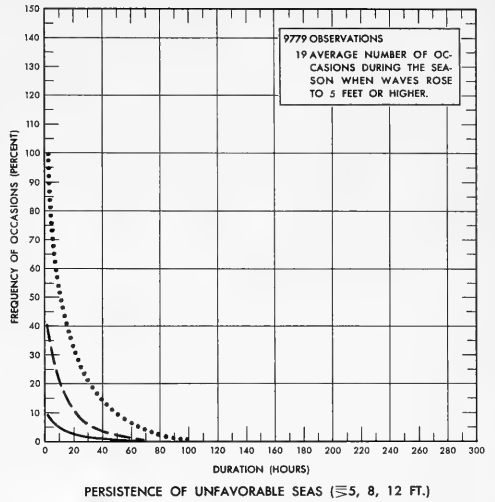
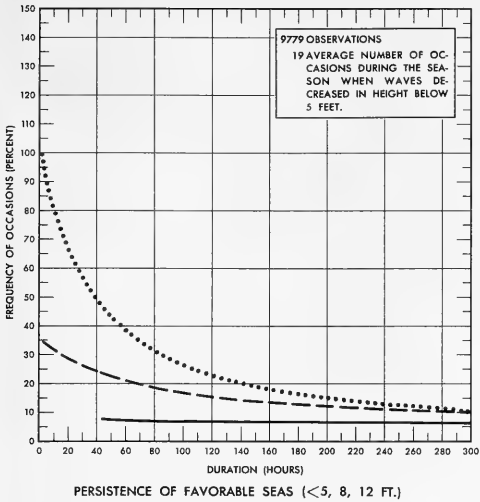
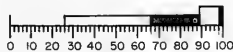
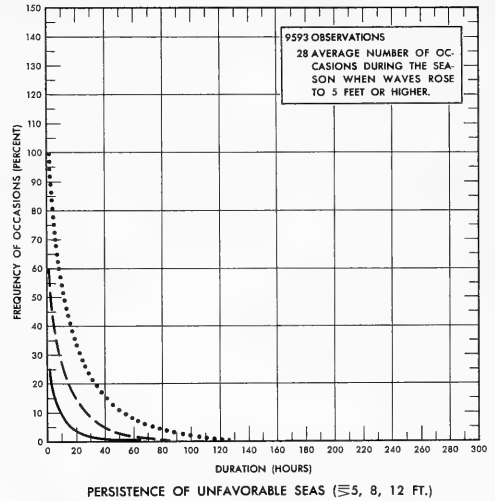
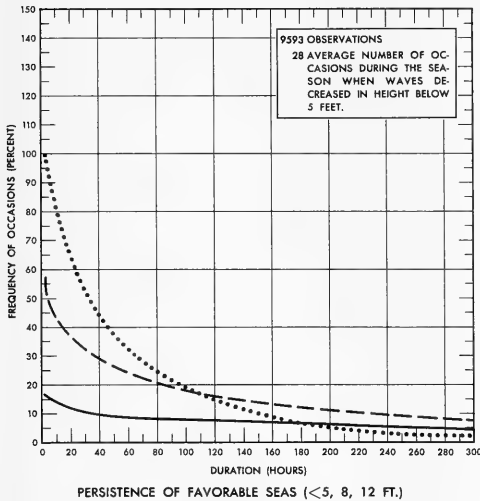


FIGURE 7C P-11/8 54°16.0'N, 7°11.5'E.

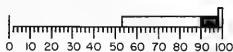
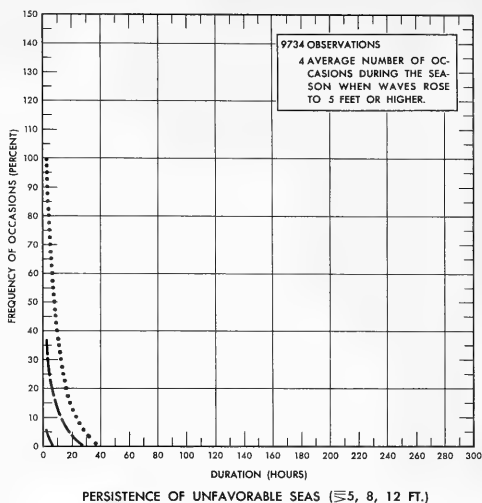
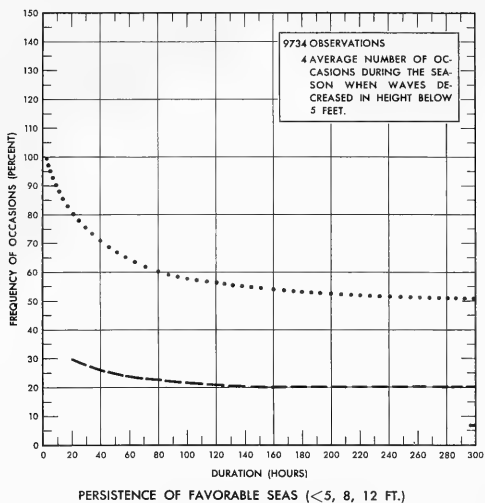
JULY, AUGUST, SEPTEMBER



OCTOBER, NOVEMBER, DECEMBER



JANUARY, FEBRUARY, MARCH



APRIL, MAY, JUNE

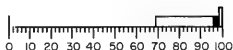
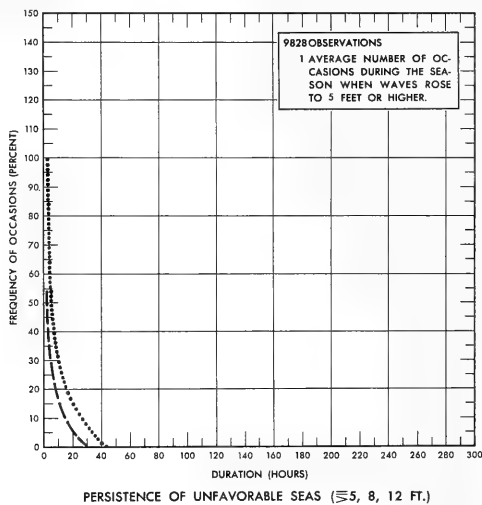
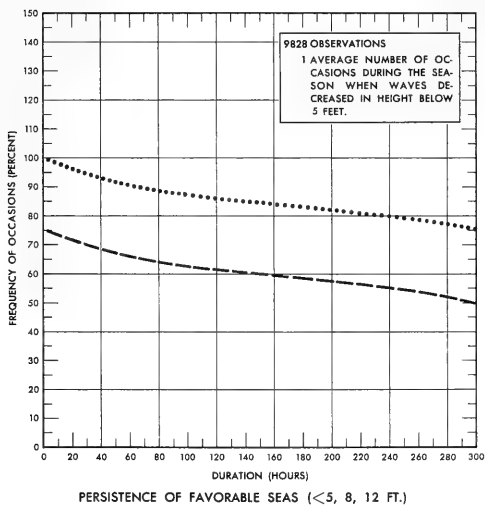
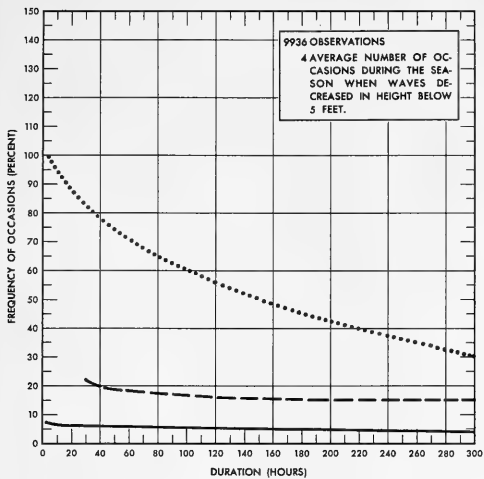
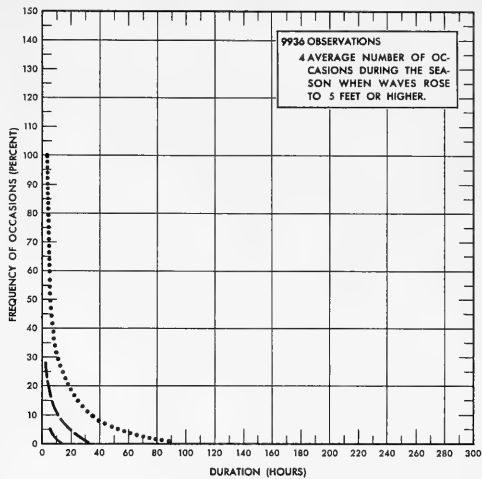


FIGURE 7D ELBE I 54°0.0'N., 8°10.7'E.

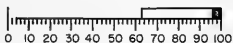
JULY, AUGUST, SEPTEMBER



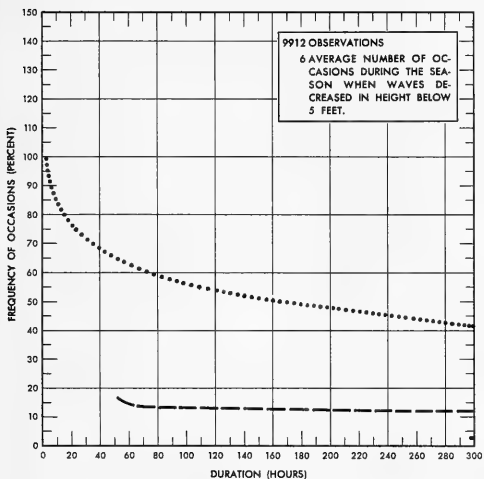
PERSISTENCE OF FAVORABLE SEAS ($\le 5, 8, 12\text{ FT.}$)



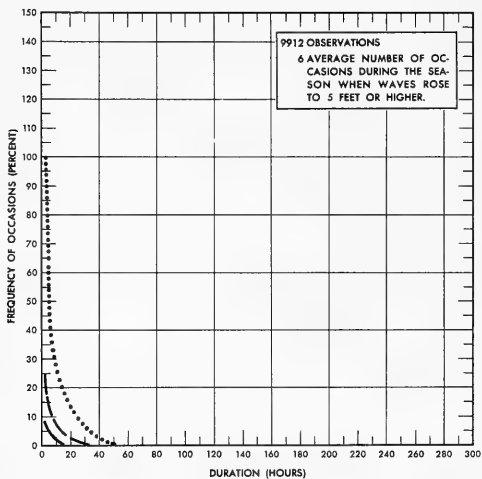
PERSISTENCE OF UNFAVORABLE SEAS ($\ge 5, 8, 12\text{ FT.}$)



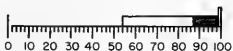
OCTOBER, NOVEMBER, DECEMBER



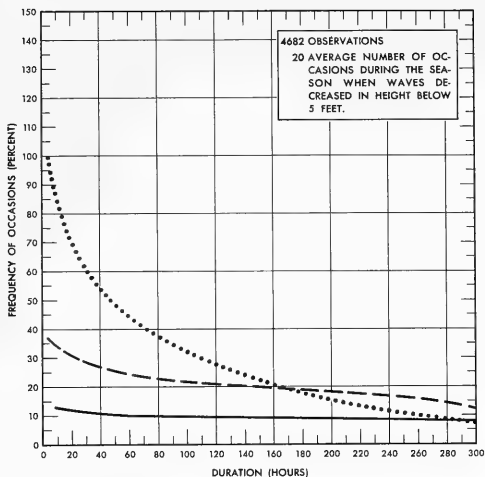
PERSISTENCE OF FAVORABLE SEAS ($\le 5, 8, 12\text{ FT.}$)



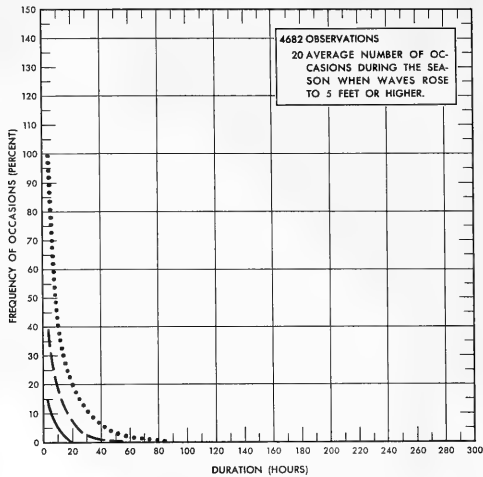
PERSISTENCE OF UNFAVORABLE SEAS ($\ge 5, 8, 12\text{ FT.}$)



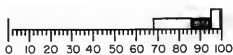
JANUARY, FEBRUARY, MARCH



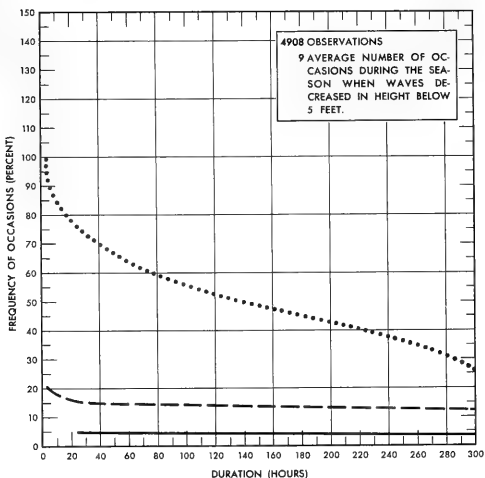
PERSISTENCE OF FAVORABLE SEAS (<5, 8, 12 FT.)



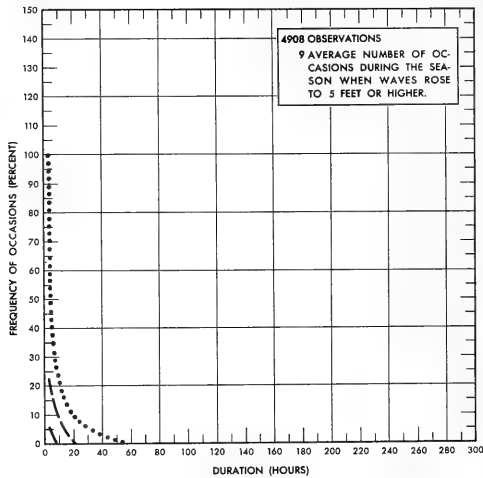
PERSISTENCE OF UNFAVORABLE SEAS (≧5, 8, 12 FT.)



APRIL, MAY, JUNE



PERSISTENCE OF FAVORABLE SEAS (<5, 8, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (≧5, 8, 12 FT.)

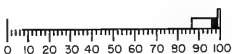
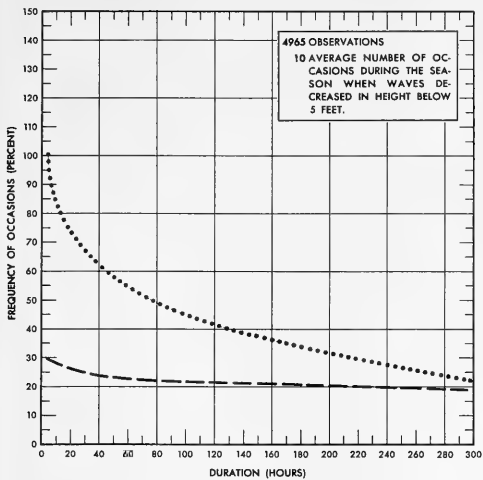
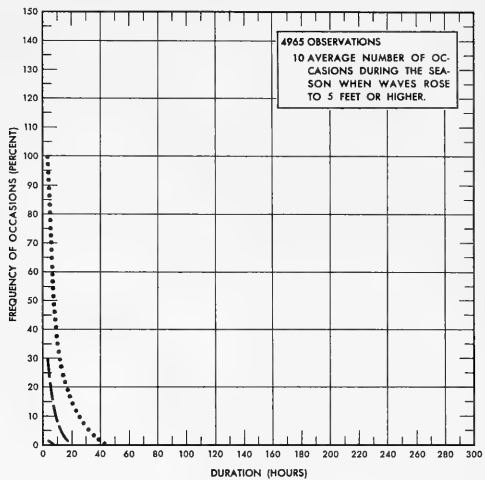


FIGURE 7E KIEL 54°29.9'N, 10°18.0'E.

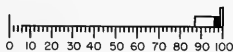
JULY, AUGUST, SEPTEMBER



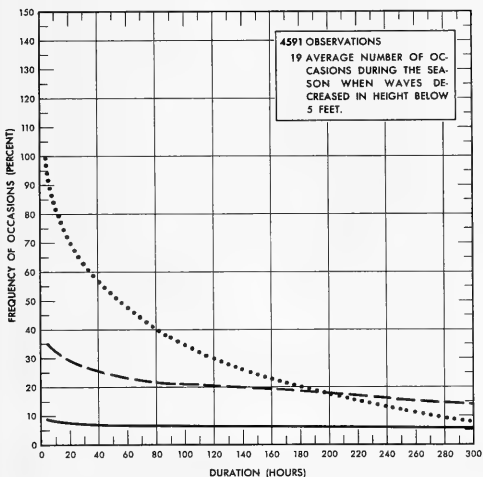
PERSISTENCE OF FAVORABLE SEAS (<5, 8, 12 FT.)



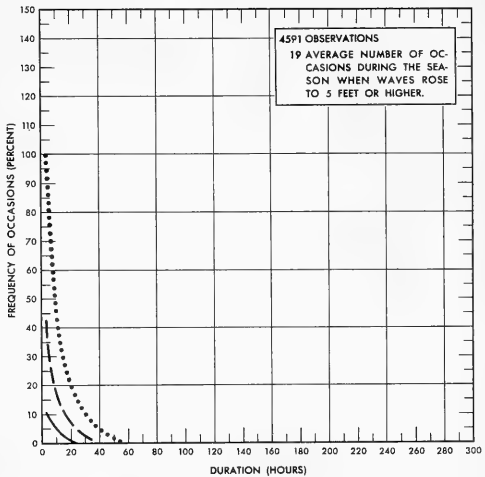
PERSISTENCE OF UNFAVORABLE SEAS (≥5, 8, 12 FT.)



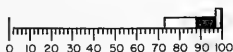
OCTOBER, NOVEMBER, DECEMBER



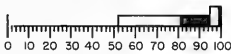
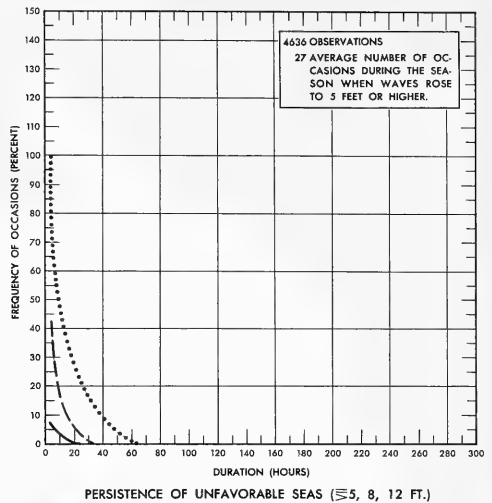
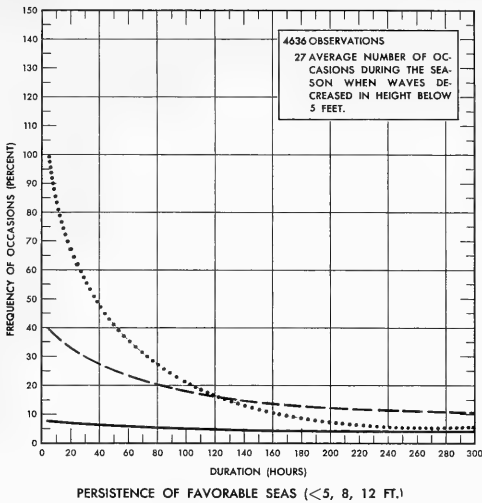
PERSISTENCE OF FAVORABLE SEAS (<5, 8, 12 FT.)



PERSISTENCE OF UNFAVORABLE SEAS (≥5, 8, 12 FT.)



JANUARY, FEBRUARY, MARCH



APRIL, MAY, JUNE

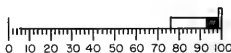
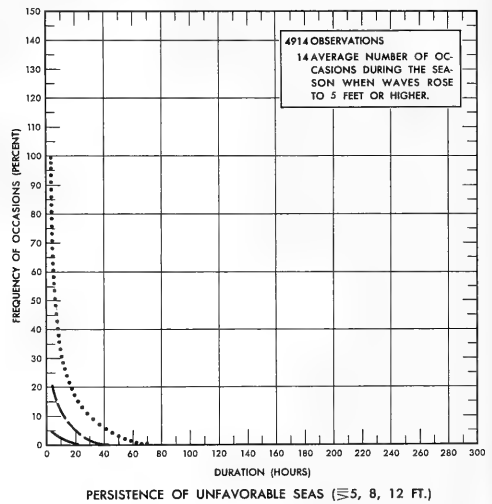
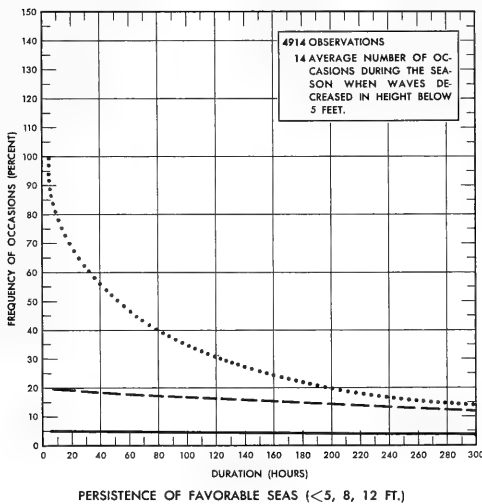
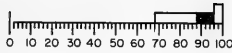
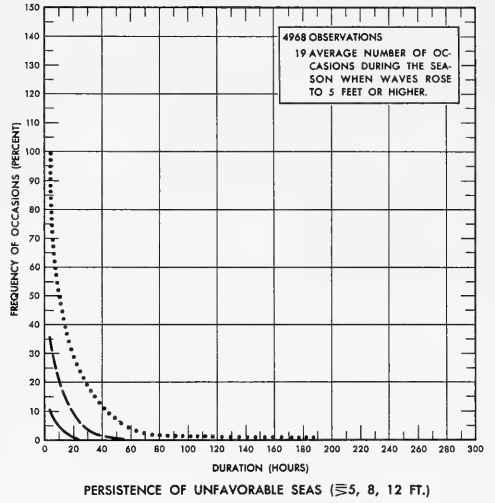
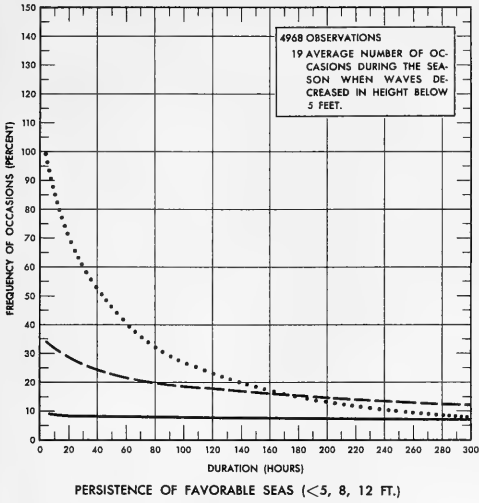
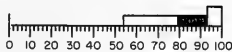
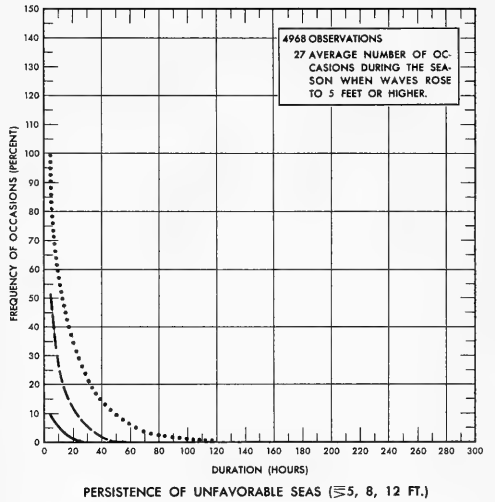
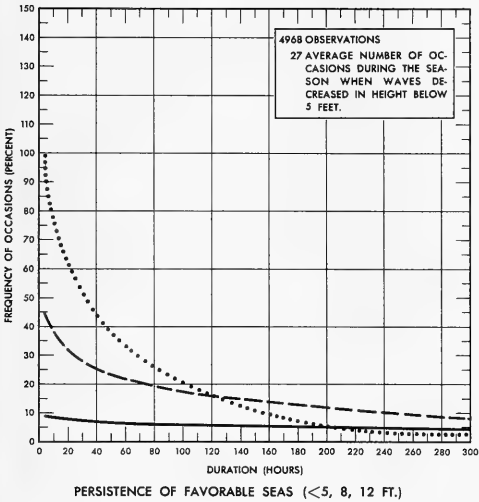


FIGURE 7F FEHMARNBELT 54°36.0'N., 11°9.0'E.

JULY, AUGUST, SEPTEMBER



OCTOBER, NOVEMBER, DECEMBER



APPLICATION OF WAVE PERSISTENCE GRAPHICS

The wave persistence graphics presented in this report contain a wealth of information when applied to specific problems involving duration of particular wave heights. The graphs are intended for application to any particular operation or problem, where the limits of the operation or problem determine whether the waves are favorable or unfavorable. Several examples of the application of wave persistence are:

1. forecasting durations of storm waves, which can result in economic savings to maritime concerns when known regions of adverse waves of long durations are avoided in ship routing;
2. estimating durations of particular wave height categories which are hazardous to refueling operations or cargo transfer;
3. estimating durations of regional adverse wave conditions which would hinder or restrict survey operations or salvage operations;
4. estimating durations of particular wave heights pertinent to construction of offshore platforms for oil drilling or communications;
5. gaining nearshore information on duration of adverse waves and breakers pertinent to the construction of piers, breakwaters, dikes, and other structures along coastlines or harbors;
6. predicting high water levels and durations from storm surges affecting unprotected coastal installations;
7. predicting extent of beach erosion and shoreline processes by relating sustained wave action with beach profile characteristics.

Many more applications of wave persistence are possible, depending on the special requirements of the user. Whatever the interest, it is hoped that this initial investigation of wave persistence will encourage further research on a subject of great concern to all engaged in maritime operations and to all affected by wave activity.

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U. S. Naval Oceanographic Office
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