DTNSRDC/SPD-0795-02

DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

DEVELOPMENT OF CONSISTENT NATURAL ENVIRONMENT PARAMETER SETS FOR COMBATANT CAPABILITY ASSESSMENT (CCA)

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SHIP PERFORMANCE DEPARTMENT

MARCH 1980

DTNSRDC/SPD-0795-02

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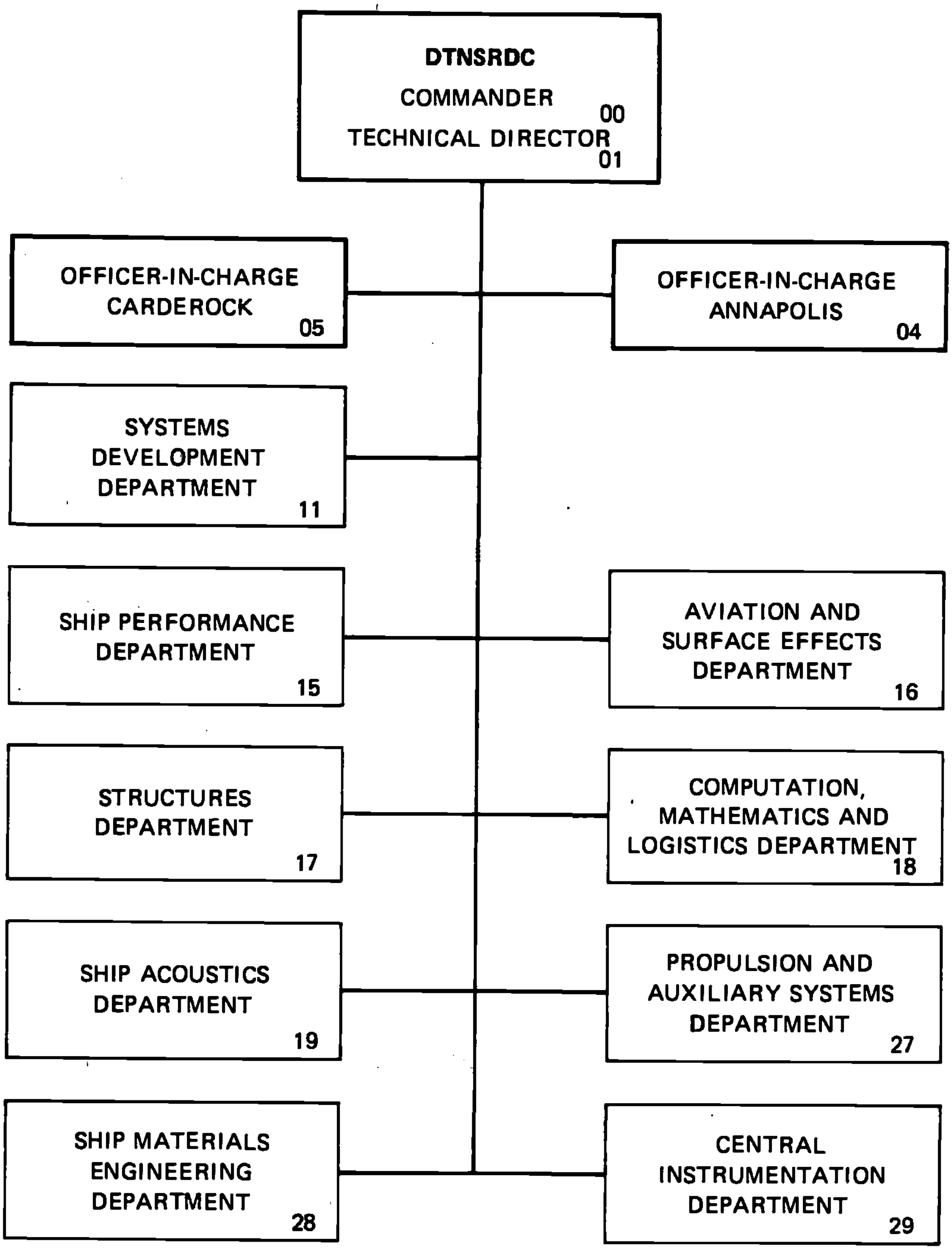

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER DTNSRDC/SPD-0795-02	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DEVELOPMENT OF CONSISTENT NATURAL ENVIRONMENT PARAMETER SETS FOR COMBATANT CAPABILITY ASSESSMENT (CCA)		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Wah T. Lee and Susan L. Bales		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Ship Performance Department David W. Taylor Naval Ship R&D Center Bethesda, Maryland 20084		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Work Unit Nos. 1568-817 and 1568-830
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Sea Systems Command Washington, D.C. 20362		12. REPORT DATE March 1980
		13. NUMBER OF PAGES 41
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This report is the second in a series describing efforts to improve natural environment specification in naval ship design practice for purposes of Combatant Capability Assessment (CCA).

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Combatant Capability Assessment (CCA)
Ship Performance
Seakeeping
Natural Environment
Statistics
Regression Analysis
Meteorology

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In order to design and model some combat systems, it may be necessary to consider joint distributions of two or more natural environment parameters. This can be accomplished by simultaneous sampling of various natural environment parameters. A major part of the investigation reported herein is the development of wind generated significant wave height as a function of latitude for the Northern Hemisphere, however, a joint sampling of other surface and atmospheric parameters is also included.

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S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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ABSTRACT

In order to design and model some combat systems, it may be necessary to consider joint distribution of two or more natural environment parameters. This can be accomplished by simultaneous sampling of various natural environment parameters. A major part of the investigation reported herein is the development of wind generated significant wave height as a function of latitude for the Northern Hemisphere, however, a joint sampling of other surface and atmospheric parameters is also included.

ADMINISTRATIVE INFORMATION

The work reported herein was carried out at the request of the Naval Sea Systems Command (NAVSEA) 61433 and authorized by Work Request Numbers WR 92590 and WR OG091. It is identified by Work Unit Numbers 1568-817 and 1568-830 at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC). The data presented herein was developed as long ago as 1976, and in keeping with the sponsor's wishes at the time that the work was initiated, metric units have not been used in this report.

INTRODUCTION

The procedures used for modeling the effects of the natural environment on naval ship performance are outlined in another report* and Reference 1.** The "Sea Environment Manual for Ship Design" is a source document on seaway models where wind and wave statistics are developed for seakeeping analyses typical of concept and preliminary ship design investigations. Reference 1 is an extraction from the so-called Ship Designer's Atlas*** which provides a mesh of both threat and natural environments derived for a number of global "hot spots." It provides an overall climatology, with the emphasis on the worst season (month) for each hot spot, and is primarily aimed at the combat systems (weapons, sensors, etc.) designer.

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*Bales, S.L. and J.M. Voelker, "Sea Environment Manual for Ship Design," Report DTNSRDC/SPD-0720-01 (to be published in 1980).

**A complete listing of references is given on page 11.

***The Ship Designer's Atlas is being developed under the cognizance of the Naval Sea Systems Command (NAVSEA) for purposes of Combatant Capability Assessment (CCA).

A fundamental deficiency in existing ship design methodology is the lack of integration of realistic measures of ship performance into the decision making process. While the Ship Designer's Atlas is an attempt at overcoming this deficiency, it has several weaknesses which have not been satisfactorily addressed. The most important ones are:

1. Threat and natural environment parameters are not integrated into consistent data sets
2. Simultaneous sampling of natural environment parameters from each medium (atmosphere, surface, subsurface) is not addressed

In order to address the first weakness, it is necessary to overcome the second, and it is this which is addressed in the current report.

Specifically, this report outlines the statistical results derived by simultaneous sampling of various natural environment parameter distributions taken from Reference 1 and from an expanded version which is in preparation. The physics of the marine environment as well as meteorological and oceanographic dynamics have been considered in the procedures developed. Global locations considered are sixteen in number, and are designated Points A through P which are identified in Table 1 and Figure 1.

ENVIRONMENTAL PARAMETERS

Eight environment parameters have been considered for each location. They are winds, waves, fog, thunderstorms, icing (superstructure), pressure centers, refractivity, and air masses. Before discussing the results of this investigation, some comments regarding the quality of the data are in order. The data examined are for the worst month* at each location as presented in Reference 1 and its revision (now in preparation). Unfortunately, some parameters may not be well represented, especially at the extremes, due to the fact that data is developed from shipboard observations, and ships generally try to avoid areas of severe weather.

A description of the phenomena associated with the parameters analyzed (except winds and waves) is now given. Winds and waves are discussed in detail in a subsequent section of the report.

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*Worst month is defined to be that in which the wind speeds and wave heights are statistically most severe.

METEOROLOGICAL DAY

As indicated in Figure 2, from Reference 2, a meteorological day is divided into three periods:

1. Night - from 2 hours after sunset until 2 hours after sunrise
2. Afternoon - from 5 hours after sunrise until 1 hour before sunset
3. Transition - the two 3-hour periods between the night and afternoon period; also, if the sky is covered by opaque clouds at any time of the day, the period should be treated as a transition period

FOG

Fog is rare when the difference between air and sea temperature is more than 5°F. A high relative humidity is the major contributor to the formation of fog, since no condensation will occur unless the relative humidity is more than 90 percent, see References 3 and 4. A light wind causes a gentle mixing action which is generally favorable for a deeper and thicker layer of fog, and a very light wind usually generates a shallow layer only about 6 feet deep. In general, one would expect benign to moderate wave conditions under a layer of fog. Most fogs evaporate after sunrise.

THUNDERSTORMS

Thunderstorms over the ocean are most common during the night and early morning. They frequently occur offshore in low pressure centers when the land and sea breezes are blowing toward the water, as indicated in Reference 3. The rapid change in wind direction and speed are the major characteristics prior to storm passage over the sea. Also, the wind speeds at the leading edge of the storm are far greater than those at the trailing edge. A particular sequence of pressure variations usually accompanies thunderstorms:

1. Pressure falls as the storm approaches
2. Pressure rises rapidly as the storm brings rain showers overhead
3. Rain ceases and pressure gradually returns to normal after the storm

Generally, thunderstorms provide high winds, severe wave conditions, and visibility is normally poor.

ICING (SUPERSTRUCTURE)

The worst icing conditions are met with the combination of very low temperatures and strong winds. They frequently occur to the rear of a low pressure system on its poleward side. As indicated in Reference 1, a potential for moderate icing exists when the air temperature is 28°F (-2.2°C) or less and the wind speeds are 13 knots or greater. Moderate icing potential implies a buildup of less than one-tenth of an inch an hour. Severe icing of the ship is likely when the air temperature drops to 16°F (-8.9°C) or less and the wind speed is 30 knots or greater. Severe icing implies a buildup of one-tenth of an inch or more per hour.

LOW PRESSURE CENTERS

The wind flow around a low pressure system is counterclockwise in the Northern Hemisphere. Low pressure systems are usually associated with severe storm characteristics such as hurricanes, tropical storms, and tornadoes. Other unfavorable conditions in low pressure systems are low clouds, poor visibility caused by precipitation and fog, severe wave conditions, and closely spaced isobars with strong and gusty winds, see References 3 and 5. Standard atmospheric pressure is about 1013 mb in the near surface ocean environment and, in general, is also taken as the boundary contour that separates high from low pressure system.

HIGH PRESSURE CENTERS

The wind flow around a high pressure system is clockwise in the Northern Hemisphere. High pressure systems occur predominately over cold surfaces and are accompanied by few clouds. Other favorable conditions associated with high pressure centers are good daytime visibility, benign to moderate wind and wave conditions, and widely spaced isobars with light and calm winds.

SUPER-REFRACTION OR DUCTING

As indicated in References 6 and 7, if the refractive index decreases with height at more than 0.000013 per 1000 feet, radar waves will be bent closer to the earth's surface and the distance to the radar horizon will increase. This phenomenon is referred to as super-refraction or ducting. Ducts frequently occur offshore with high pressure systems during the transition from morning to afternoon and generally indicate a decrease of relative humidity with height. Ducts are also associated with warm sea or land breezes over a cold surface. Ducts are sometimes accompanied by strong winds and severe wave conditions.

SUB-REFRACTION

If the refractive index decreases with height at less than 0.000013 per 1000 feet, radar waves will tend to lift further above the earth's surface and the radar horizon will be limited to a shorter range. This phenomenon is known as sub-refraction. Sub-refractions frequently occur simultaneously with sea or land breezes during the evening transition period. In general, sub-refraction is associated with an increase of relative humidity with height and with the occurrence of cold air over a warm surface.

COLD FRONT

As indicated in References 3 and 4, a cold front is the leading edge of an advancing mass of cold air, and clouds are predominately cumuliform with good to excellent visibility. Cumuliform clouds are clouds with vertical development and generally have their bases below 6500 feet and their tops sometimes above 65,000 feet. Cold fronts frequently occur together with low pressure systems and hence with strong winds, high waves, and a line of thunderstorms developing along the surface front and may extend for hundreds of miles.

WARM FRONT

A warm front is the trailing edge of a retreating mass of cold air with stratiform clouds. Warm fronts may be accompanied by fog and poor to fair visibility. Stratiform clouds are low clouds occurring from near the surface to about 6500 feet. Warm fronts also occur simultaneously in low pressure systems with light to calm winds.

JOINT PARAMETER DATA

The surface natural environment data of the worst months for the 16 locations are presented in Tables 2 through 7. The alphabetic designation of locations within each table corresponds to that given in Reference 1. All wind and wave data (except for locations C, D, E, F, H and I) are derived from the Twenty Year Hindcast Wind and Wave Climatology described in Reference 1. In some cases, a particular phenomenon or parameter was not available for a given location. These cases are noted by a dashed line as they occur.

The first approach to simultaneous sampling of natural environment parameters is by selecting the most probable values of the weather features associated with each phenomenon. For example, Table 2 presents numerical values of the most probable weather features associated with fog. Values for air-sea temperature difference, air temperature, relative humidity, sun, meteorological period, wind direction, wind speed, significant wave height, and modal wave period for each of the 16 locations are provided. Thus, if the effects of fog are to be considered in a combat system design, Table 2 can be used to provide probable values of other environmental parameters. Similarly, Tables 3, 4, 5, 6, and 7 provide probable values for thunderstorms, icing, low and high pressure centers, refractivity, and cold and warm air masses, respectively.

GEOGRAPHIC VARIATIONS OF WINDS AND WAVES

Ocean waves are generated by four major factors:

1. Wind blowing over the water surface
2. Surface pressure variations
3. Earthquakes
4. Sun and moon tidal attraction

Wind waves are probably the most important and fundamental phenomenon in the open sea. The second approach to simultaneous sampling of natural environment parameters is by using wind speed as a fixed parameter. The most probable values of wind generated wave height can be calculated as a function of latitude for each of the 16 ocean locations by using wind speed as the independent variable in linear regression. The results are shown in Figure 3, which permits the determination of significant wave height for given values of wind speed and latitude in the Northern Hemisphere. The three sets of curves plotted on Figure 3 correspond to the open ocean area, the coastal area, and the boundary area between them. Coastal area is defined to be within 200 miles of the continent or 75 miles from an island; all other ocean areas are classified as open ocean. The boundary area is taken as a 50-mile wide zone between open ocean and coastal areas. A few aids useful in applying Figure 3 are now given. In general, it is assumed that a wind speed and direction is known.

The equation to find the great circle distance between two points on the earth's surface as indicated in Reference 8 is

$$D = 60 \cos^{-1}[\sin L_1 \sin L_2 + \cos L_1 \cos L_2 \cos(\lambda_2 - \lambda_1)]$$

where D is the distance in nautical miles, L_i and λ_i are longitude and latitude in degrees, respectively.

Wind speed should be considered the average value for at least one hour. When the change of wind direction is no greater than 15 degrees, it should be treated as a constant. If wind persists for more than 5 hours from the same general direction, Table 8 should be used to determine correction factors for significant wave heights produced by different wind speeds blowing for various lengths of time. If wind speed is less than 3 knots, wind generated wave height is negligible (e.g., $\leq$ 2 feet).

Landlocked ocean areas (e.g., the Gulf of Mexico and the Mediterranean Sea) should be classified as boundary areas even though some regions are located more than 200 miles from the continent.

The highest wave heights are generated between about 58 and 62° N; beyond that point, wind generated waves start declining with respect to latitude. This probably is due to the limited fetch and great possibility of land mass interference near the North Pole.

A sample application of Figure 3 is now given.

A 20-knot wind has been blowing for the last 10 hours from the same general direction at a region located near 50° N and 30° W. What is the estimated significant wave height?

Since this region is located at more than 250 miles from the continent, it is classified as an open ocean area. By reading across the intersection at 50° N in Figure 3, the wind speed coefficient is 0.68 and the constant is 1.5. Then

$$(\tilde{\zeta}_w)_{1/3} = \text{wind speed (in knots)} \times \text{Coefficient} + \text{Constant}$$

$$(\tilde{\zeta}_w)_{1/3} = 20 \times (0.68) + 1.5$$

$$= 15.1 \text{ ft}$$

As the wind has been blowing for 10 hours in the same general direction, a correction factor of 1.25 is taken from Table 8 adopted from Reference 5. Finally, the estimated significant wave height is

$$(\tilde{\zeta}_w)_{1/3} = 15.1 \times 1.25$$

$$= 18.9 \text{ ft}$$

In general, modal wave period is a function of wind speed and fetch. Attempts to correlate it with latitude have not been successful in this investigation. However, significant wave height and modal wave period by wind speed is presented in Table 9 for all 16 ocean locations. Table 10 provides a comparison of wind speed and significant wave height by wind direction. The primary objective of these tables is in ship design and engineering applications. However, in ship operations applications, Tables 9 and 10 could produce misleading results. For example, surface pressure variations and swells from distant storms are important factors in wave height forecasts that are excluded in this investigation due to lack of available data.

CONCLUDING REMARKS

In summary, this report outlines the results of simultaneous sampling of various natural environment parameters in the Ship Designer's Atlas, see Reference 1. Eight environmental phenomena have been considered for each of 16 locations. They are winds, waves, fog, thunderstorms, icing (superstructure), pressure centers, refractivity, and air masses. The first approach applied to the development of consistent natural environment parameter sets is that of selecting the most probable values for the weather features associated with each phenomenon as presented. These results are given in Tables 2 through 7. The second approach to simultaneous sampling of natural environment parameters is the development of wind generated wave height as a function of latitude and proximity to the coast for the Northern Hemisphere and is given in Figure 3.

It is considered that each approach provides additional guidance to the combat systems engineer. As the Navy further refines the emerging ship performance design practice, this guidance will become useful in systems integration analyses.

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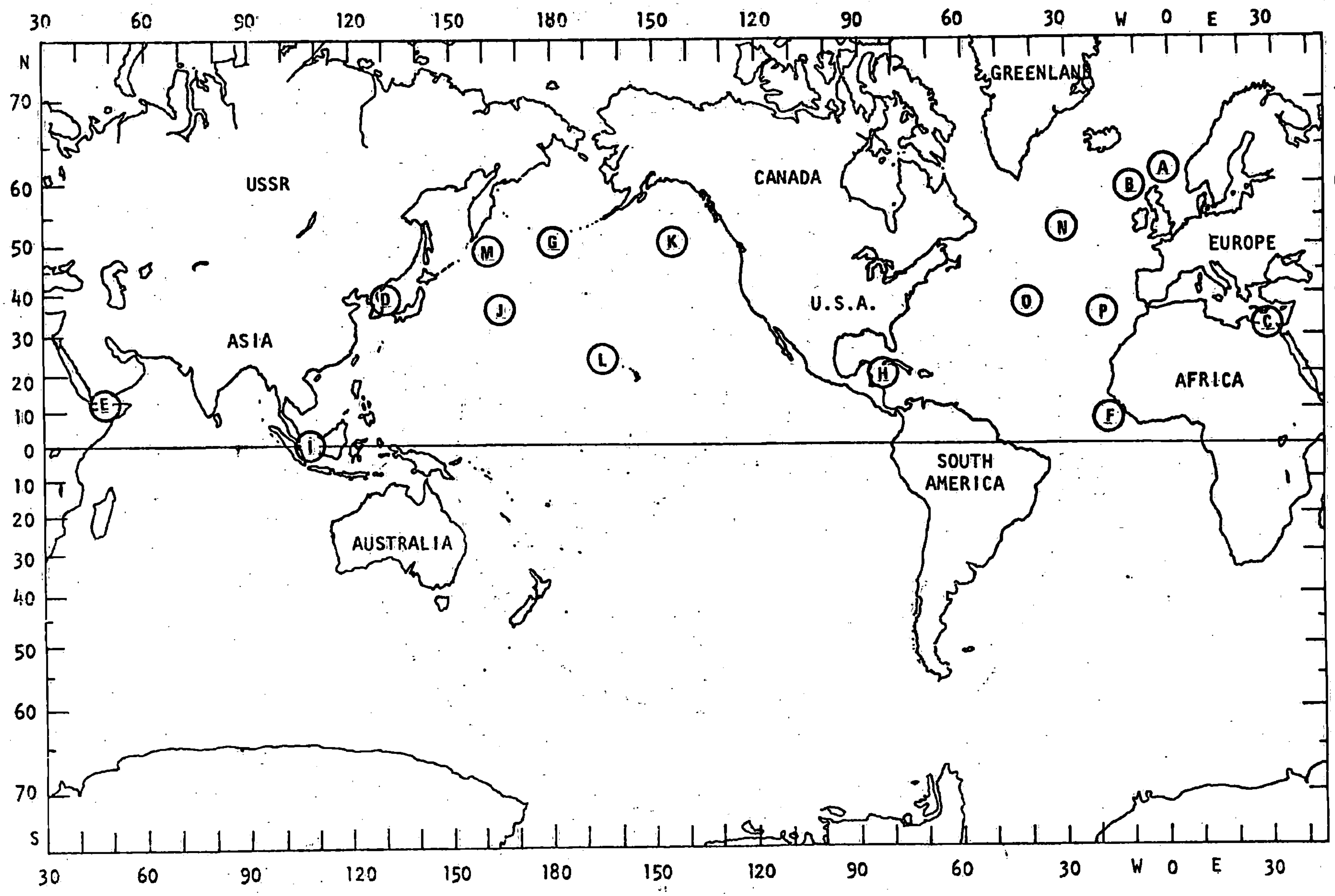

Figure 1 - Sixteen Potential Naval Operational Areas

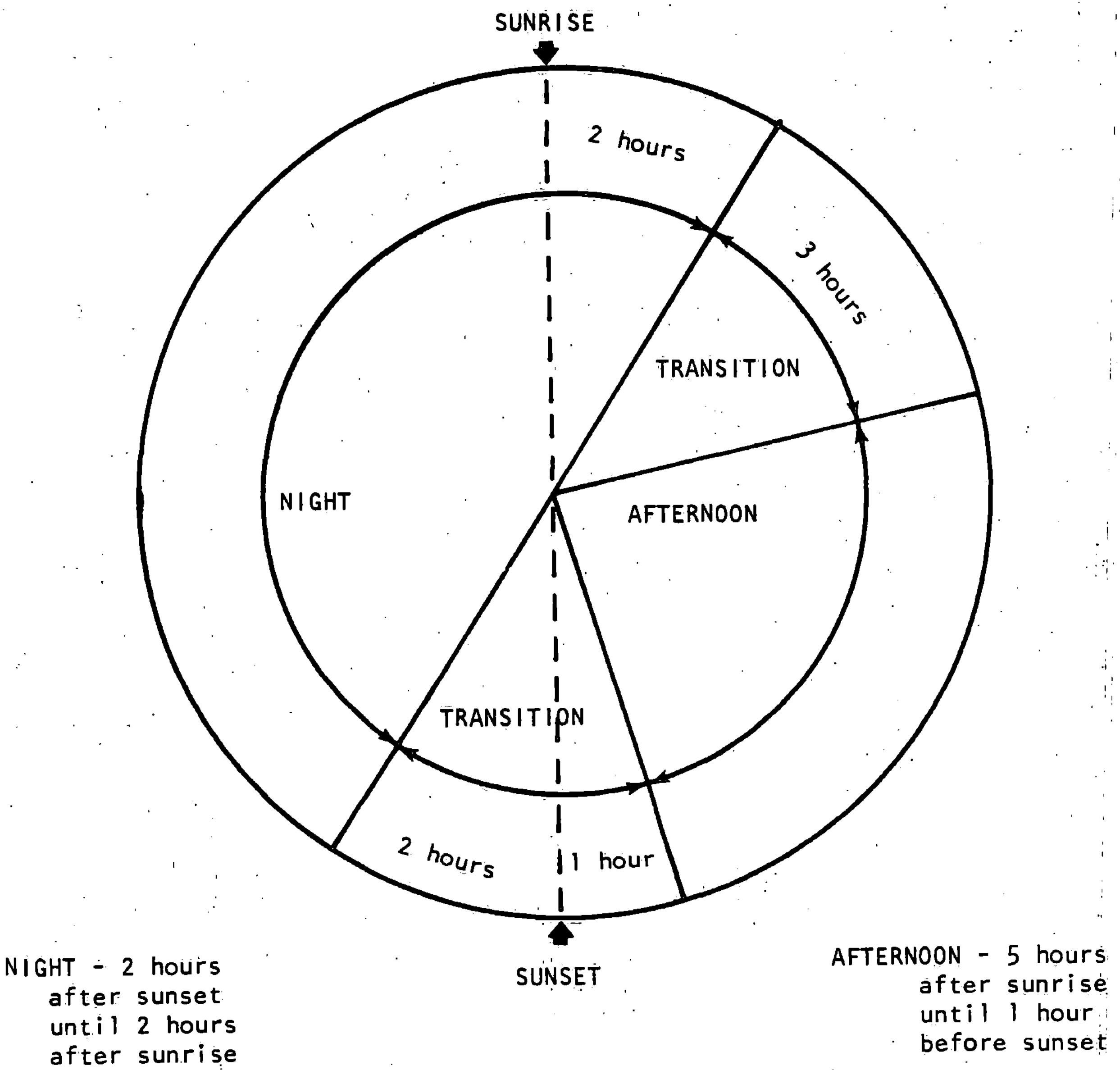

Figure 2 - Meteorological Day (from Reference 3)

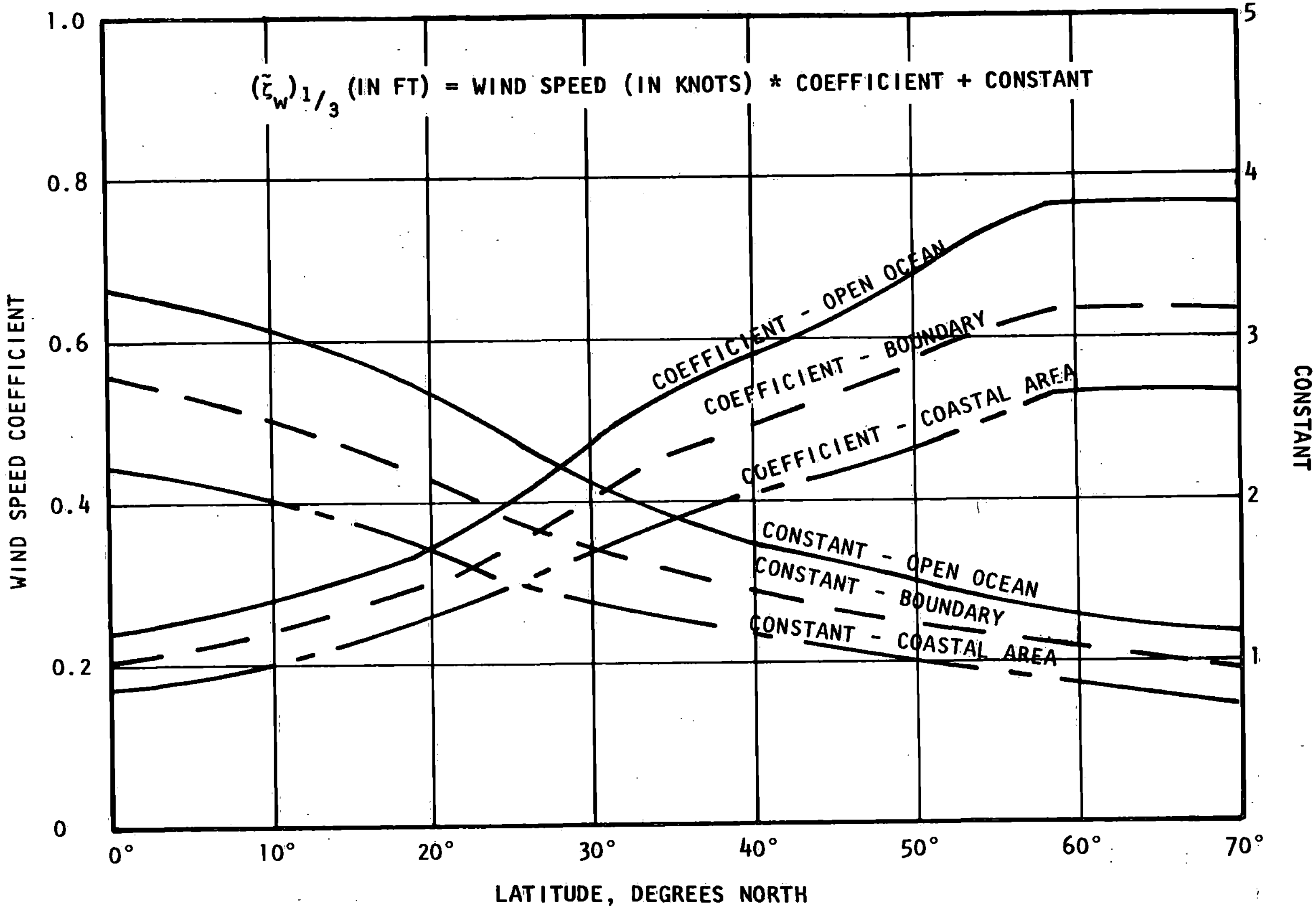

Figure 3 - Significant Wave Height by Wind Speed

TABLE 1 - OPERATIONAL AREA IDENTIFICATION

Location ID	Latitude, Longitude	Description	Area
A	63°N, 2°W	Northern Northeast Atlantic (off Norway)	Boundary
B	58°N, 12°W	Northern North Atlantic (off Scotland)	Boundary
C	33°30' - 35°0'N, 29°30' - 30°30'E	Eastern Mediterranean (off Cyprus)	Coastal
D	39°N, 129°E	Japan Sea (off Korea)	Coastal
E	12°N, 46°30'E	Gulf of Aden (off Saudi Arabia)	Coastal
F	9°30'N, 16°0'W	Southeastern North Atlantic (off Guinea)	Coastal
G	50°N, 180°W	North Pacific (off the Aleutians)	Open Ocean
H	20°45' - 21°50'N, 80° - 86°W	Caribbean (off Cuba)	Coastal
I	0°N, 106°E	Strait of Malacca (off Singapore)	Coastal
J	34°12'N, 163°48'E	Western North Pacific (North of Wake Island)	Open Ocean
K	50°54'N, 145°36'W	Northeastern North Pacific (South of Gulf of Alaska)	Open Ocean
L	24°48'N, 162°3'W	Mid-North Pacific (Northwest of Hawaiian Islands)	Open Ocean
M	51°18'N, 162°3'E	Northern Northwest Pacific (Off Kamchatka Peninsula)	Open Ocean
N	52°48'N, 33°48'W	Mid-Northern North Atlantic	Open Ocean
O	34°6'N, 52°54'W	Mid-North Atlantic	Open Ocean
P	39°54'N, 21°48'W	Mid-Eastern North Atlantic (East of Azores)	Open Ocean

TABLE 2 - MOST PROBABLE WEATHER FEATURES OF FOG

LOCATION	FOG	AIR-SEA TEMPERATURE DIFFERENCE	AIR TEMPERATURE	RELATIVE HUMIDITY	SUN	METEOROLOGICAL PERIOD	WIND DIRECTION	WIND SPEED	WAVE HEIGHT $(\bar{\zeta}_w)1/3$	MODAL WAVE PERIOD
A	DEEP LAYER	$\leq 5^0F$	$\leq 40^0F$	$\geq 90\%$ HIGH	NC SUNSHINE	TRANSITION	SOUTH OR SOUTHWEST	≤ 8 KTS	≤ 6 ft	≤ 10 SEC
	SHALLOW LAYER							≤ 5 KTS	≤ 5 ft	≤ 9 SEC
B	DEEP LAYER	$\leq 6^0F$	$\leq 45^0F$	$\geq 90\%$ HIGH	NO SUNSHINE	TRANSITION	EAST OR SOUTH	≤ 8 KTS	≤ 7 ft	≤ 10 SEC
	SHALLOW LAYER							≤ 5 KTS	≤ 6 ft	≤ 9 SEC
C	DEEP LAYER	$\leq 4^0F$	$\leq 58^0F$	$\geq 90\%$ HIGH	NO SUNSHINE	TRANSITION	SOUTH	≤ 5 KTS	≤ 5 ft	≤ 6 SEC
	SHALLOW LAYER							≤ 3 KTS	≤ 4 ft	≤ 5 SEC
D	DEEP LAYER	$\leq 4^0F$	$\leq 38^0F$	$\geq 90\%$ HIGH	NO SUNSHINE	TRANSITION	— **	≤ 5 KTS	≤ 4 ft	≤ 6 SEC
	SHALLOW LAYER							≤ 3 KTS	≤ 3 ft	≤ 5 SEC
E	DEEP LAYER	$\leq 6^0F$	$\leq 85^0F$	$\geq 90\%$ HIGH	NO SUNSHINE	TRANSITION	NORTHEAST OR SOUTHEAST	≤ 5 KTS	≤ 4 ft	≤ 6 SEC
	SHALLOW LAYER							≤ 3 KTS	≤ 3 ft	≤ 5 SEC
F	DEEP LAYER	$\leq 2^0F$	$\leq 78^0F$	$\geq 90\%$ HIGH	NO SUNSHINE	TRANSITION	SOUTHWEST OR NORTHWEST	≤ 4 KTS	≤ 4 ft	≤ 6 SEC
	SHALLOW LAYER							≤ 2 KTS	≤ 3 ft	≤ 5 SEC
G	DEEP LAYER	$\leq 4^0F$	$\leq 35^0F$	$\geq 90\%$ HIGH	NO SUNSHINE	TRANSITION	—	≤ 8 KTS	≤ 9 ft	≤ 12 SEC
	SHALLOW LAYER							≤ 5 KTS	≤ 8 ft	≤ 11 SEC
H	DEEP LAYER	$\leq 4^0F$	$\leq 75^0F$	$\geq 90\%$ HIGH	NO SUNSHINE	TRANSITION	—	≤ 6 KTS	≤ 4 ft	≤ 6 SEC
	SHALLOW LAYER							≤ 3 KTS	≤ 3 ft	≤ 5 SEC

** DASH-NOT AVAILABLE

TABLE 2 (Continued)

LOCATION	FOG	AIR-SEA TEMPERATURE DIFFERNECE	AIR TEMPERATURE	RELATIVE HUMIDITY	SUN	METEOROLOGICAL PERIOD	WIND DIRECTION	WIND SPEED	WAVE HEIGHT $(\bar{\zeta}_w)_{1/3}$	MODAL WAVE PERIOD
I	DEEP LAYER	≤ 2°F	≤ 80°F	≥ 90% HIGH	NO SUNSHINE	TRANSITION	NORTH	≤ 5 KTS	≤ 4 ft	≤ 6 SEC
	SHALLOW LAYER							≤ 3 KTS	≤ 3 ft	≤ 5 SEC
J	DEEP LAYER	≤ 4°F	≤ 55°F	≥ 90% HIGH	NO SUNSHINE	TRANSITION	—	≤ 8 KTS	≤ 9 ft	≤ 13 SEC
	SHALLOW LAYER							≤ 5 KTS	≤ 8 ft	≤ 12 SEC
K	DEEP LAYER	≤ 4°F	≤ 42°F	≥ 90% HIGH	NO SUNSHINE	TRANSITION	—	≤ 8 KTS	≤ 9 ft	≤ 12 SEC
	SHALLOW LAYER							≤ 5 KTS	≤ 8 ft	≤ 11 SEC
L	DEEP LAYER	≤ 4°F	≤ 70°F	≥ 90% HIGH	NO SUNSHINE	TRANSITION	—	≤ 6 KTS	≤ 6 ft	≤ 12 SEC
	SHALLOW LAYER							≤ 3 KTS	≤ 5 ft	≤ 11 SEC
M	DEEP LAYER	≤ 4°F	≤ 23°F	≥ 90% HIGH	NO SUNSHINE	TRANSITION	—	≤ 8 KTS	≤ 9 ft	≤ 13 SEC
	SHALLOW LAYER							≤ 5 KTS	≤ 8 ft	≤ 12 SEC
N	DEEP LAYER	≤ 4°F	≤ 40°F	≥ 90% HIGH	NO SUNSHINE	TRANSITION	—	≤ 8 KTS	≤ 11 ft	≤ 12 SEC
	SHALLOW LAYER							≤ 5 KTS	≤ 10 ft	≤ 11 SEC
O	DEEP LAYER	≤ 4°F	≤ 63°F	≥ 90% HIGH	NO SUNSHINE	TRANSITION	—	≤ 6 KTS	≤ 6 ft	≤ 12 SEC
	SHALLOW LAYER							≤ 3 KTS	≤ 5 ft	≤ 11 SEC
P	DEEP LAYER	≤ 4°F	≤ 57°F	≥ 90% HIGH	NO SUNSHINE	TRANSITION	—	≤ 6 KTS	≤ 6 ft	≤ 12 SEC
	SHALLOW LAYER							≤ 3 KTS	≤ 5 ft	≤ 11 SEC

TABLE 3 - MOST PROBABLE WEATHER FEATURES OF THUNDERSTORMS

LOCATION	METEOROLOGICAL PERIOO	PRECIPITATION		PRESSURE CENTER	LIGHTNING ANO THUNDER	CEILING ANO VISIBILITY	PRESSURE VARIATIONS IN THE STORM			WINO OIRECTIONS IN THE STORM		WINO SPEEO LEADING EDGE * TRAILING EDGE	WAVE HEIGHT $(\tilde{\zeta}_w)_{1/3}$	MOOAL WAVE PERIOO
		LIQUIO	STATIC				BEFORE	OURING	AFTER	BEFORE	OURING			
A	NIGHT ANO EARLY MORNING	+ LIKELY	* CHANCE	LOW	LIKELY	POOR OVERCAST ≤ 2 N.M.	FALLING	RISING	GRAOUAL RETURN TO NORMAL	FROM LANO BLOWING TOWARO THE SEA	VARY UP TO 180°	≥ 27 KTS	≥ 14 ft	≥ 12 SEC
B	NIGHT ANO EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST ≤ 2 N.M.	FALLING	RISING	GRAOUAL RETURN TO NORMAL	FROM LANO BLOWING TOWARO THE SEA	VARY UP TO 180°	≥ 30 KTS	≥ 14 ft	≥ 12 SEC
C	NIGHT ANO EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST ≤ 2 N.M.	FALLING	RISING	GRAOUAL RETURN TO NORMAL	FROM LANO BLOWING TOWARO THE SEA	VARY UP TO 180°	≥ 25 KTS	≥ 10 ft	≥ 7 SEC
D	NIGHT ANO EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST ≤ 2 N.M	FALLING	RISING	GRAOUAL RETURN TO NORMAL	FROM LANO BLOWING TOWARO THE SEA	VARY UP TO 180°	≥ 25 KTS	≥ 10 ft	≥ 7 SEC
E	NIGHT ANO EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST ≤ 2 N.M.	FALLING	RISING	GRAOUAL RETURE TO NORMAL	FROM LANO BLOWING TOWARO THE SEA	VARY UP TO 180°	≥ 20 KTS	≥ 7 ft	≥ 6 SEC
F	NIGHT ANO EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST ≤ 2 N.M.	FALLING	RISING	GRAOUAL RETURN TO NORMAL	FROM LANO BLOWING TOWARO THE SEA	VARY UP TO 180°	≥ 15 KTS	≥ 6 ft	≥ 6 SEC
G	NIGHT ANO EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST ≤ 2 N.M.	FALLING	RISING	GRAOUAL RETURN TO NORMAL	FROM LANO BLOWING TOWARO THE SEA	VARY UP TO 180°	≥ 30 KTS	≥ 17 ft	≥ 14 SEC
H	NIGHT ANO EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST ≤ 2 N.M.	FALLING	RISING	GRAOUAL RETURN TO NORMAL	FROM LANO BLOWING TOWARO THE SEA	VARY UP TO 180°	≥ 20 KTS	≥ 7 ft	≥ 6 SEC

+ LIKELY - ≥ 40% OF OCCURRENCES

* CHANCE - 20%-40% OF OCCURRENCES

TABLE 3 (Continued)

LOCATION	METEOROLOGICAL PERIOD	PRECIPITATION		PRESSURE CENTER	LIGHTNING AND THUNDER	CEILING AND VISIBILITY	PRESSURE VARIATIONS IN THE STORM			WIND DIRECTIONS IN THE STORM		WIND SPEED (LEADING EDGE > TRAILING EDGE)	WAVE HEIGHT $(\zeta_w)^1/_3$	MODAL WAVE PERIOD
		LIQUID	STATIC				BEFORE	DURING	AFTER	BEFORE	DURING			
I	NIGHT AND EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST $\leq$ 2 N.M.	FALLING	RISING	GRADUAL RETURN TO NORMAL	FROM LAND BLOWING TOWARD THE SEA	VARY UP TO 180°	$\geq$ 20 KTS	$\geq$ 5 ft	$\geq$ 5 SEC
J	NIGHT AND EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST $\leq$ 2 N.M.	FALLING	RISING	GRADUAL RETURN TO NORMAL	FROM LAND BLOWING TOWARD THE SEA	VARY UP TO 180°	$\geq$ 27 KTS	$\geq$ 13 ft	$\geq$ 13 SEC
K	NIGHT AND EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST $\leq$ 2 N.M.	FALLING	RISING	GRADUAL RETURN TO NORMAL	FROM LAND BLOWING TOWARD THE SEA	VARY UP TO 180°	$\geq$ 30 KTS	$\geq$ 15 ft	$\geq$ 13 SEC
L	NIGHT AND EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST $\leq$ 2 N.M.	FALLING	RISING	GRADUAL RETURN TO NORMAL	FROM LAND BLOWING TOWARD THE SEA	VARY UP TO 180°	$\geq$ 20 KTS	$\geq$ 7 ft	$\geq$ 11 SEC
M	NIGHT AND EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST $\leq$ 2 N.M.	FALLING	RISING	GRADUAL RETURN TO NORMAL	FROM LAND BLOWING TOWARD THE SEA	VARY UP TO 180°	$\geq$ 30 KTS	$\geq$ 16 ft	$\geq$ 13 SEC
N	NIGHT AND EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST $\leq$ 2 N.M.	FALLING	RISING	GRADUAL RETURN TO NORMAL	FROM LAND BLOWING TOWARD THE SEA	VARY UP TO 180°	$\geq$ 30 KTS	$\geq$ 16 ft	$\geq$ 13 SEC
O	NIGHT AND EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST $\leq$ 2 N.M.	FALLING	RISING	GRADUAL RETURN TO NORMAL	FROM LAND BLOWING TOWARD THE SEA	VARY UP TO 180°	$\geq$ 25 KTS	$\geq$ 12 ft	$\geq$ 12 SEC
P	NIGHT AND EARLY MORNING	LIKELY	CHANCE	LOW	LIKELY	POOR OVERCAST $\leq$ 2 N.M.	FALLING	RISING	GRADUAL RETURN TO NORMAL	FROM LAND BLOWING TOWARD THE SEA	VARY UP TO 180°	$\geq$ 25 KTS	$\geq$ 13 ft	$\geq$ 12 SEC

TABLE 4 - MOST PROBABLE WEATHER FEATURES OF ICING

LOCATION	AIR TEMPERATURE	SEA TEMPERATURE	WIND SPEED	PRESSURE
A	≤ 30°F	≤ 37°F	≥ 25 KTS	REAR OF A LOW PRESSURE SYSTEM ON ITS POLEWARD SIDE
B	≤ 32°F	≤ 40°F	≥ 27 KTS	REAR OF A LOW PRESSURE SYSTEM ON ITS POLEWARD SIDE
D	≤ 28°F	≤ 40°F	≥ 20 KTS	REAR OF A LOW PRESSURE SYSTEM ON ITS POLEWARD SIDE
G	≤ 28°F	≤ 37°F	≥ 27 KTS	REAR OF A LOW PRESSURE SYSTEM ON ITS POLEWARD SIDE
J	≤ 32°F	≤ 40°F	≥ 25 KTS	REAR OF A LOW PRESSURE SYSTEM ON ITS POLEWARD SIDE
K	≤ 32°F	≤ 40°F	≥ 27 KTS	REAR OF A LOW PRESSURE SYSTEM ON ITS POLEWARD SIDE
M	≤ 28°F	≤ 35°F	≥ 28 KTS	REAR OF A LOW PRESSURE SYSTEM ON ITS POLEWARD SIDE
N	≤ 28°F	≤ 40°F	≥ 30 KTS	REAR OF A LOW PRESSURE SYSTEM ON ITS POLEWARD SIDE
O	≤ 32°F	≤ 40°F	≥ 22 KTS	REAR OF A LOW PRESSURE SYSTEM ON ITS POLEWARD SIDE

TABLE 5 - MOST PROBABLE WEATHER FEATURES OF PRESSURE CENTERS

LOCATION	PRESSURE CENTER	SEA LEVEL PRESSURE	ISOBARS	STORM	CLOUD COVER	TEMPERATURE	FOG	PRECIPITATION	VISIBILITY	WIND DIRECTION	WIND SPEED	WAVE HEIGHT $(\bar{\zeta}_w)_{1/3}$	MODAL WAVE PERIOD
A	LOW	≤ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 40°F	CHANCE	CHANCE	< 4 N.M.	COUNTER CLOCKWISE	≥ 25 KTS	≥ 15 ft	≥ 13 SEC
A	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	≥ 40°F	CHANCE	RARE *	≥ 4 N.M.	CLOCKWISE	≤ 15 KTS	≤ 10 ft	≤ 11 SEC
						< 40°F	RARE						
B	LOW	≤ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 45 F	CHANCE	CHANCE	< 5 N.M.	COUNTER CLOCKWISE	≥ 27 KTS	≥ 15 ft	≥ 13 SEC
B	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	≥ 45°F	CHANCE	RARE	≥ 5 N.M.	CLOCKWISE	≤ 17 KTS	≤ 10 ft	≤ 11 SEC
						< 45°F	RARE						
C	LOW	≤ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 60°F	CHANCE	CHANCE	< 6 N.M.	COUNTER CLOCKWISE	≥ 15 KTS	≥ 8 ft	≥ 6 SEC
C	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	≥ 60°F	CHANCE	RARE	≥ 6 N.M.	CLOCKWISE	≤ 10 KTS	≤ 6 ft	≤ 5 SEC
						< 60°F	RARE						
D	LOW	≤ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 50°F	CHANCE	CHANCE	< 6 N.M.	COUNTER CLOCKWISE	≥ 20 KTS	≥ 9 ft	≥ 7 SEC
D	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	≥ 50°F	CHANCE	RARE	≥ 6 N.M.	CLOCKWISE	≤ 12 KTS	≤ 6 ft	≤ 5 SEC
						< 50°F	RARE						

* RARE - ≤ 10% OF OCCURENCES

TABLE 5 (Continued)

LOCATION	PRESSURE CENTER	SEA LEVEL PRESSURE	ISOBARS	STORM	CLOUD COVER	TEMPERATURE	FOG	PRECIPITATION	VISIBILITY	WIND DIRECTION	WIND SPEED	WAVE HEIGHT $(\bar{\zeta}_w)_{1/3}$	MODAL WAVE PERIOD
E	LOW	≤ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 85°F	CHANCE	CHANCE	< 5 N.M.	COUNTER CLOCKWISE	≥ 17 KTS	≥ 6 ft	≥ 5 SEC
	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	≥ 85°F	CHANCE	RARE	≥ 5 N.M.	CLOCKWISE	≤ 8 KTS	≤ 4 ft	≤ 5 SEC
						< 85°F	RARE						
F	LOW	≤ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 78°F	CHANCE	CHANCE	< 5 N.M.	COUNTER CLOCKWISE	≥ 10 KTS	≥ 5 ft	≥ 5 SEC
	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	≥ 78°F	CHANCE	RARE	≥ 5 N.M.	CLOCKWISE	≤ 3 KTS	< 2 ft	< 5 SEC
						< 78°F	RARE						
G	LOW	≤ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 36°F	CHANCE	CHANCE	< 4 N.M.	COUNTER CLOCKWISE	≥ 27 KTS	≥ 16 ft	≥ 14 SEC
	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	≥ 36°F	CHANCE	RARE	≥ 4 N.M.	CLOCKWISE	≤ 17 KTS	≤ 14 ft	≤ 13 SEC
						< 36°F	RARE						
H	LOW	≤ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 77°F	CHANCE	CHANCE	< 5 N.M.	COUNTER CLOCKWISE	≥ 18 KTS	≥ 7 ft	≥ 6 SEC
	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	≥ 77°F	CHANCE	RARE	≥ 5 N.M.	CLOCKWISE	≤ 8 KTS	≤ 4 ft	≤ 5 SEC
						< 77°F	RARE						

TABLE 5 (Continued)

LOCATION	PRESSURE CENTER	SEA LEVEL PRESSURE	ISOBARS	STORM	CLOUD COVER	TEMPERATURE	FOG	PRECIPITATION	VISIBILITY	WIND DIRECTION	WIND SPEED	WAVE HEIGHT $(\zeta_w)_{1/3}$	MODAL WAVE PERIOD
I	LOW	$\leq$ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 80°F	CHANCE	CHANCE	< 5 N.M.	COUNTER CLOCKWISE	$\geq$ 15 KTS	$\geq$ 4 ft	$\geq$ 5 SEC
	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	$\geq$ 80°F	CHANCE	RARE	$\geq$ 5 N.M.	CLOCKWISE	$\leq$ 6 KTS	$\leq$ 2 ft	$\leq$ 4 SEC
						< 80°F	RARE						
J	LOW	$\leq$ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 57°F	CHANCE	CHANCE	< 6 N.M.	COUNTER CLOCKWISE	$\geq$ 25 KTS	$\geq$ 15 ft	$\geq$ 14 SEC
	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	$\geq$ 57°F	CHANCE	RARE	$\geq$ 6 N.M.	CLOCKWISE	$\leq$ 15 KTS	$\leq$ 12 ft	$\leq$ 13 SEC
						< 57°F	RARE						
K	LOW	$\leq$ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 42°F	CHANCE	CHANCE	< 5 N.M.	COUNTER CLOCKWISE	$\geq$ 27 KTS	$\geq$ 15 ft	$\geq$ 13 SEC
	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	$\geq$ 42°F	CHANCE	RARE	$\geq$ 5 N.M.	CLOCKWISE	$\leq$ 17 KTS	$\leq$ 12 ft	$\leq$ 12 SEC
						< 42°F	RARE						
L	LOW	$\leq$ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 72°F	CHANCE	CHANCE	< 6 N.M.	COUNTER CLOCKWISE	$\geq$ 17 KTS	$\geq$ 7 ft	$\geq$ 12 SEC
	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	$\geq$ 72°F	CHANCE	RARE	$\geq$ 6 N.M.	CLOCKWISE	$\leq$ 8 KTS	$\leq$ 6 ft	$\leq$ 12 SEC
						< 72°F	RARE						

TABLE 5 (Continued)

LOCATION	PRESSURE CENTER	SEA LEVEL PRESSURE	ISOBARS	STORM	CLOUD COVER	TEMPERATURE	FOG	PRECIPITATION	VISIBILITY	WIND DIRECTION	WIND SPEED	WAVE HEIGHT $(\zeta_w)_{1/3}$	MODAL WAVE PERIOD
M	LOW	$\leq$ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 25°F	CHANCE	CHANCE	< 2 N.M.	COUNTER CLOCKWISE	$\geq$ 28 KTS	$\geq$ 16 ft	$\geq$ 14 SEC
	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	$\geq$ 25°F	CHANCE	RARE	$\geq$ 2 N.M.	CLOCKWISE	$\leq$ 18 KTS	$\leq$ 13 ft	$\leq$ 13 SEC
						< 25°F	RARE						
N	LOW	$\leq$ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 40°F	CHANCE	CHANCE	< 6 N.M.	COUNTER CLOCKWISE	$\geq$ 30 KTS	$\geq$ 17 ft	$\geq$ 13 SEC
	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	$\geq$ 40°F	CHANCE	RARE	$\geq$ 6 N.M.	CLOCKWISE	$\leq$ 20 KTS	$\leq$ 13 ft	< 13 SEC
						< 40°F	RARE						
O	LOW	$\leq$ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 64°F	CHANCE	CHANCE	< 7 N.M.	COUNTER CLOCKWISE	$\geq$ 22 KTS	$\geq$ 12 ft	$\geq$ 12 SEC
	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	$\geq$ 64°F	CHANCE	RARE	$\geq$ 7 N.M.	CLOCKWISE	$\leq$ 12 KTS	$\leq$ 10 ft	< 12 SEC
						< 64°F	RARE						
P	LOW	$\leq$ 1013mb	CLOSELY SPACED	CHANCE	.6 - .9 BROKEN	< 58°F	CHANCE	CHANCE	< 9 N.M.	COUNTER CLOCKWISE	$\geq$ 22 KTS	$\geq$ 8 ft	$\geq$ 12 SEC
	HIGH	> 1013mb	WIDELY SPACED	RARE	.1 - .5 SCATTERED	$\geq$ 58°F	CHANCE	RARE	$\geq$ 9 N.M.	CLOCKWISE	$\leq$ 12 KTS	$\leq$ 7 ft	< 12 SEC
						< 58°F	RARE						

TABLE 6 - MOST PROBABLE WEATHER FEATURES OF REFRACTIVITY

LOCATION	REFRACTIVITY	METEOROLOGICAL PERIOD	RELATIVE HUMIDITY	PRESSURE CENTER	TEMPERATURE VARIATION	FOG	AREA	WIND DIRECTION	WIND SPEED	WAVE HEIGHT $(\tilde{\zeta}_w)_{1/3}$	MODAL WAVE PERIOD
ALL	SUB REFRACTION	EVENING TRANSITION	INCREASING WITH HEIGHT	—	COLD AIR OVER WARM SURFACE	RARE	—	SEA OR LAND BREEZE	—	—	—
A	SUPER REFRACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 25 KTS	≥ 13 ft	≥ 11 SEC
B	SUPER REFRACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 27 KTS	≥ 13 ft	≥ 11 SEC
C	SUPER REFRACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 15 KTS	≥ 8 ft	≥ 6 SEC
D	SUPER REFRACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 20 KTS	≥ 9 ft	≥ 6 SEC
E	SUPER REFRACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 17 KTS	≥ 6 ft	≥ 5 SEC
F	SUPER REFRACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 12 KTS	≥ 6 ft	≥ 6 SEC
G	SUPER REFRACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 27 KTS	≥ 16 ft	≥ 14 SEC
H	SUPER REFRACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 18 KTS	≥ 7 ft	≥ 6 SEC

TABLE 6 (Continued)

LOCATION	REFRACTIVITY	METEOROLOGICAL PERIOD	RELATIVE HUMIDITY	PRESSURE CENTER	TEMPERATURE VARIATION	FOG	AREA	WIND DIRECTION	WIND SPEED	WAVE HEIGHT $(\bar{\zeta}_w)^{1/3}$	MODAL WAVE PERIOD
ALL	SUB REFRACTION	EVENING TRANSITION	INCREASING WITH HEIGHT	—	COLD AIR OVER WARM SURFACE	RARE	—	SEA OR LAND BREEZE	—	—	—
I	SUPER REFACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 15 KTS	≥ 4 ft	≥ 5 SEC
J	SUPER REFACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 25 KTS	≥ 12 ft	≥ 12 SEC
K	SUPER REFACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 27 KTS	≥ 14 ft	≥ 12 SEC
L	SUPER REFACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 17 KTS	≥ 6 ft	≥ 10 SEC
M	SUPER REFACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 27 KTS	≥ 15 ft	≥ 12 SEC
N	SUPER REFACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 27 KTS	≥ 15 ft	≥ 12 SEC
O	SUPER REFACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 22 KTS	≥ 11 ft	≥ 12 SEC
P	SUPER REFACTION OR DUCT	MORNING TRANSITION TO AFTERNOON	DECREASING WITH HEIGHT	HIGH	WARM AIR OVER COLD SURFACE	RARE	COASTAL AREAS	SEA OR LAND BREEZE	≥ 22 KTS	≥ 12 ft	≥ 12 SEC

TABLE 7 - MOST PROBABLE WEATHER FEATURES OF AIR MASSES

LOCATION	FRONT	THUNDERSTORM	RELATIVE HUMIDITY	VISIBILITY	PRESSURE CENTER	FOG	WIND SPEED	WAVE HEIGHT $(\zeta_w)_{1/3}$	MODAL WAVE PERIOD
A	COLD	CHANCE	$\leq$ 83%	> 6 N.M.	LOW	RARE	$\geq$ 25 KTS	$\geq$ 15 ft	$\geq$ 13 SEC
	WARM	RARE	$\geq$ 88%	$\leq$ 6 N.M.	LOW	CHANCE	$\leq$ 15 KTS	$\leq$ 10 ft	$\leq$ 11 SEC
B	COLD	CHANCE	$\leq$ 75%	> 6 N.M.	LOW	RARE	$\geq$ 27 KTS	$\geq$ 15 ft	$\geq$ 13 SEC
	WARM	RARE	$\geq$ 82%	$\leq$ 6 N.M.	LOW	CHANCE	$\leq$ 17 KTS	$\leq$ 10 ft	$\leq$ 11 SEC
C	COLD	CHANCE	$\leq$ 70%	> 7 N.M.	LOW	RARE	$\geq$ 15 KTS	$\geq$ 7 ft	$\geq$ 6 SEC
	WARM	RARE	$\geq$ 75%	$\leq$ 7 N.M.	LOW	CHANCE	$\leq$ 10 KTS	$\leq$ 5 ft	$\leq$ 5 SEC
D	COLD	CHANCE	$\leq$ 65%	> 6 N.M.	LOW	RARE	$\geq$ 20 KTS	$\geq$ 9 ft	$\geq$ 7 SEC
	WARM	RARE	$\geq$ 72%	$\leq$ 6 N.M.	LOW	CHANCE	$\leq$ 12 KTS	$\leq$ 6 ft	$\leq$ 5 SEC

TABLE 7 (Continued)

LOCATION	FRONT	THUNDERSTORM	RELATIVE HUMIDITY	VISIBILITY	PRESSURE CENTER	FOG	WIND SPEED	WAVE HEIGHT $(\tilde{\zeta}_w)_{1/3}$	MODAL WAVE PERIOD
E	COLD	CHANCE	≤ 75%	> 6 N.M.	LOW	RARE	≥ 17 KTS	≥ 6 ft	≥ 5 SEC
	WARM	RARE	≥ 80%	≤ 6 N.M.	LOW	CHANCE	≤ 8 KTS	≤ 4 ft	< 5 SEC
F	COLD	CHANCE	≤ 83%	> 6 N.M	LOW	RARE	≥ 10 KTS	≥ 5 ft	≥ 5 SEC
	WARM	RARE	≥ 88%	≤ 6 N.M.	LOW	CHANCE	≤ 3 KTS	< 3 ft	< 5 SEC
G	COLD	CHANCE	≤ 82%	> 5 N.M.	LOW	RARE	≥ 27 KTS	≥ 16 ft	≥ 14 SEC
	WARM	RARE	≥ 88%	≤ 5 N.M.	LOW	CHANCE	≤ 17 KTS	≤ 14 ft	≤ 13 SEC
H	COLD	CHANCE	≤ 73%	> 5 N.M.	LOW	RARE	≥ 18 KTS	≥ 7 ft	≥ 6 SEC
	WARM	RARE	≥ 78%	≤ 5 N.M.	LOW	CHANCE	≤ 8 KTS	≤ 4 ft	≤ 5 SEC

TABLE 7 (Continued)

LOCATION	FRONT	THUNDERSTORM	RELATIVE HUMIDITY	VISIBILITY	PRESSURE CENTER	FOG	WIND SPEED	WAVE HEIGHT $(\bar{\zeta}_w)_{1/3}$	MODAL WAVE PERIOD
I	COLD	CHANCE	≤ 78%	> 5 N.M.	LOW	RARE	≥ 15 KTS	≥ 4 ft	≥ 5 SEC
	WARM	RARE	≥ 82%	≤ 5 N.M.	LOW	CHANCE	≤ 6 KTS	≤ 2 ft	≤ 4 SEC
J	COLD	CHANCE	≤ 68%	> 7 N.M.	LOW	RARE	≥ 25 KTS	≥ 15 ft	≥ 14 SEC
	WARM	RARE	≥ 74%	≤ 7 N.M.	LOW	CHANCE	≤ 15 KTS	≤ 12 ft	≤ 13 SEC
K	COLD	CHANCE	≤ 80%	> 6 N.M.	LOW	RARE	≥ 27 KTS	≥ 15 ft	≥ 13 SEC
	WARM	RARE	≥ 88%	≤ 6 N.M.	LOW	CHANCE	≤ 17 KTS	≤ 12 ft	≤ 12 SEC
L	COLD	CHANCE	≤ 70%	> 9 N.M.	LOW	RARE	≥ 17 KTS	≥ 7 ft	≥ 12 SEC
	WARM	RARE	≥ 76%	≤ 9 N.M.	LOW	CHANCE	≤ 8 KTS	≤ 6 ft	< 12 SEC

TABLE 7 (Continued)

LOCATION	FRONT	THUNDERSTORM	RELATIVE HUMIDITY	VISIBILITY	PRESSURE CENTER	FOG	WIND SPEED	WAVE HEIGHT $(\bar{\zeta}_w)^{1/3}$	MODAL WAVE PERIOD
M	COLD	CHANCE	≤ 75 %	> 4 N.M.	LOW	RARE	≥ 28 KTS	≥ 16 ft	≥ 14 SEC
	WARM	RARE	≥ 85%	≤ 4 N.M.	LOW	CHANCE	≤ 18 KTS	≤ 13 ft	≤ 13 SEC
N	COLD	CHANCE	≤ 77%	> 6 N.M.	LOW	RARE	≥ 30 KTS	≥ 17 ft	≥ 13 SEC
	WARM	RARE	≥ 82%	≤ 6 N.M.	LOW	CHANCE	≤ 20 KTS	≤ 13 ft	< 13 SEC
O	COLD	CHANCE	≤ 70%	> 6 N.M.	LOW	RARE	≥ 22 KTS	≥ 12 ft	≥ 12 SEC
	WARM	RARE	≥ 75%	≤ 6 N.M.	LOW	CHANCE	≤ 12 KTS	≤ 10 ft	< 12 SEC
P	COLD	CHANCE	≤ 78%	> 8 N.M.	LOW	RARE	≥ 22 KTS	≥ 8 ft	≥ 12 SEC
	WARM	RARE	≥ 83%	≤ 8 N.M.	LOW	CHANCE	≤ 12 KTS	≤ 7 ft	< 12 SEC

TABLE 8 - CORRECTION FACTORS FOR SIGNIFICANT WAVE HEIGHTS PRODUCED BY DIFFERENT WIND SPEEDS BLOWING FOR VARIOUS LENGTHS OF TIME

WIND SPEED (knots)	DURATION (HOURS)						
	5	10	15	20	30	40	50
10	1	1	1	1	1	1	1
15	1	1	1.2	1.2	1.2	1.2	1.2
20	1	1.25	1.4	1.4	1.5	1.5	1.5
30	1	1.3	1.4	1.5	1.6	1.6	1.6
40	1	1.3	1.4	1.6	1.7	1.7	1.7
50	1	1.3	1.5	1.6	1.7	1.8	1.8
60	1	1.4	1.5	1.7	1.8	1.8	2

TABLE 9 - MOST PROBABLE SIGNIFICANT WAVE HEIGHT AND MODAL PERIOD BY WIND SPEED

LOCATION		A		B		C		D		E		F		G		H	
WIND SPEED (KTS)	MAX WAVE HEIGHT (ft)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)
8	12	6	10	7	11	5	5.5	4	5	4	4.5	4	5	9	12	4	5
12	13	8	11.5	9	12	6	6	6	5.5	5	5	5	6	11	14	5	5.5
16	14	10	12.5	10	12.5	9	6.5	8	6.5	6	5.5	6	7	13	14.5	6	6
19	15	12	13	11	12.5	10	7	9	7	8	5.5	6.5	8	15	15	8	6.5
27	20	17	14	16	13.5	11	8	12	8.5	9	6	7	8.5	19	15.5	10	7.5
31	25	19	14	18	14	13	8.5	14	9	9	6	8	9	21	16	11	8
35	30	22	14	20	14	15	8.5	15	9.5	10	7	—	—	23	16.5	—	—
39	36	24	14.5	23	14	16	9	—	—	—	—	—	—	26	17	—	—
43	39	28	15	28	15	17	9.5	—	—	—	—	—	—	29	17	—	—
47	45	32	15.5	34	16	—	—	—	—	—	—	—	—	33	17.5	—	—
51	51	36	16	39	16.5	—	—	—	—	—	—	—	—	36	18	—	—

TABLE 9 - (Continued)

LOCATION		I		J		K		L		M		N		O		P	
WIND SPEED (KTS)	MAX WAVE HEIGHT (ft)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)	$(\tilde{\zeta}_w)_{1/3}$ (ft)	MODAL PERIOD (SEC)
8	12	2	4.5	9	13	9	12.5	5	11.5	9	13	11	13	6	12	6	12
12	13	3	5	11	14	11	13	7	11.5	11	13.5	12	13.5	7	12	7	12
16	14	5	5.5	13	14.5	12	13.5	8	12	13	14	12	13.5	8	12.5	8	12.5
19	15	6	6	14	14.5	13	13.5	9	12	14	14	14	14	10	13	10	13
27	20	8	6.5	16	15	16	14.5	13	12.5	17	14.5	18	14.5	14	14	15	14
31	25	—	—	18	15	19	15	14	13	20	14.5	21	15	17	14	18	15
35	30	—	—	20	15.5	22	15	16	13	22	15	23	15.5	19	14	21	15.5
39	36	—	—	22	16	26	15.5	17	13	25	15.5	26	15.5	22	14.5	24	15.5
43	39	—	—	25	16.5	31	16.5	18	13.5	29	16	31	16.5	28	15	29	16
47	45	—	—	29	17	37	17	—	—	33	17	38	17	33	16	—	—
51	51	—	—	33	17.5	42	17.5	—	—	36	17.5	43	17.5	38	17	—	—

TABLE 10 - MOST PROBABLE WIND SPEED AND SIGNIFICANT WAVE HEIGHT BY WIND DIRECTION

LOCATION	WIND DIRECTION	NORTH	NORTHEAST	EAST	SOUTHEAST	SOUTH	SOUTHWEST	WEST	NORTHWEST
A	WIND SPEED (KTS)	16	13	20	23	21	18	20	19
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	10	8	13	15	13	11	13	12
B	WIND SPEED (KTS)	19	20	24	26	24	19	27	14
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	11	12	14	15	14	11	16	9
C	WIND SPEED (KTS)	14	10	11	11	12	16	14	15
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	8	6	6	6	6	9	8	8
D	WIND SPEED (KTS)	15	16	12	10	12	12	18	19
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	8	8	6	5	6	6	9	9

TABLE 10 - (Continued)

LOCATION	WIND DIRECTION	NORTH	NORTHEAST	EAST	SOUTHEAST	SOUTH	SOUTHWEST	WEST	NORTHWEST
E	WIND SPEED (KTS)	10	8	7	8	12	14	13	12
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	4	4	4	4	5	6	5	5
F	WIND SPEED (KTS)	2	4	6	6	3	5	7	6
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	2	3	4	4	2	3	4	4
G	WIND SPEED (KTS)	20	21	17	28	27	25	21	19
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	15	16	14	19	19	18	16	15
H	WIND SPEED (KTS)	15	14	13	11	10	12	14	16
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	6	6	5	5	4	5	6	6

TABLE 10 - (Continued)

LOCATION	WIND DIRECTION	NORTH	NORTHEAST	EAST	SOUTHEAST	SOUTH	SOUTHWEST	WEST	NORTHWEST
I	WIND SPEED (KTS)	11	10	6	4	6	8	8	10
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	3	3	2	2	2	2	2	3
J	WIND SPEED (KTS)	14	12	14	15	19	22	19	22
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	13	12	13	13	14	15	13	15
K	WIND SPEED (KTS)	20	26	20	19	25	23	22	28
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	14	16	14	13	16	15	14	17
L	WIND SPEED (KTS)	13	11	13	13	14	13	9	12
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	7	7	7	7	7	7	6	7

TABLE 10 - (Continued)

LOCATION	WIND DIRECTION	NORTH	NORTHEAST	EAST	SOUTHEAST	SOUTH	SOUTHWEST	WEST	NORTHWEST
M	WIND SPEED (KTS)	22	26	17	27	23	25	23	23
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	15	17	13	17	16	17	16	16
N	WIND SPEED (KTS)	12	18	26	26	22	25	30	30
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	12	14	18	18	16	17	20	20
O	WIND SPEED (KTS)	9	10	10	10	12	19	22	16
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	6	6	6	6	7	10	11	8
P	WIND SPEED (KTS)	12	12	12	20	19	20	23	20
	$(\tilde{\zeta}_w)_{1/3}$ (ft)	7	7	7	11	10	11	13	11

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