U.S. NAVY
MARINE CLIMATIC ATLAS OF THE WORLD
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NORTH PACIFIC OCEAN

The first section provides a seasonal summary overview of the weather across the entire North Pacific Ocean. The second section deals with important weather-related features. The remaining sections provide a detailed climatological breakdown by region, stressing those features which are of particular concern to the mariner.

NORTH PACIFIC OCEAN CLIMATE - SUMMER

Summer over the North Pacific is relatively calm, interrupted occasionally by the violence of tropical cyclones. A large semi-permanent, quasi-stationary High dominates almost the entire North Pacific on the mean pressure charts. Some 1200 miles north of Hawaii its average central pressure builds to more than 1025mb. Extratropical storms, so abundant in other seasons, decrease in number and intensity. They are confined to mainly north of 40 degrees N. Their mean tracks are similar to those of other seasons. They run from the China mainland, and from waters around Japan, northeastward to the Aleutians where they either move into the Bering Sea or Gulf of Alaska. Some start in the central North Pacific and extend northeastward into the Gulf of Alaska. North of 40 degrees N overcast conditions (sky cover greater than or equal to 8/10) prevail about 60-80 percent of the time as warm moist air is cooled by the sea surface. Clear skies are uncommon. These same phenomena are responsible for the prevalent foggy conditions over the northern great circle routes at this time of the year. Visibilities less than 1 mile are observed 10-40 percent of the time in general, and up to 60 percent of the time near the Kuril Islands. Precipitation frequencies drop off slightly over these northern latitudes. Precipitation is observed about 10-20 percent of the time north of 30 degrees N. South of this latitude frequencies fall below 10 percent.

Summer winds are light and variable north of a line from the Philippines to Vancouver Island. They blow most often from the southern semicircle, and in the western North Pacific are labeled the southwest monsoon. The northeast trades prevail south of this line where winds are generally northeast through east. Summer gales are infrequent but can be experienced in the Intertropical Convergence Zone (ITCZ) and within the circulation of a tropical cyclone.

The ITCZ is a broad, discontinuous, fluctuating, band of clouds, showers and thunderstorms. It is responsible for most of the weather in the tropics and is often the birthplace of tropical cyclones. Winds are generally northeasterly on the north side of the ITCZ and southwesterly on the south side. Its position fluctuates seasonally to a large degree and daily to a lesser degree. Its seasonal path follows the sun.

The ITCZ reaches its northernmost position in early summer. It extends discontinuously from the Philippines to Panama, fluctuating between the equator and 10 degrees N, except over parts of the eastern North Pacific where it bulges northward to about 15 degrees N. The ITCZ is responsible for overcast conditions that prevail 20-40 percent of the time in the tropics. Clear days are observed from 10-20 percent of the time reflecting the discontinuity of the ITCZ.

Coincident with the northward push of the ITCZ, is the start of the tropical cyclone season in both the western and eastern North Pacific by May or June. The western North Pacific season runs through December while the eastern season usually terminates in October. Although these tropical cyclones fall into similar categories, their characteristics are dissimilar.

The western North Pacific has an annual average of 30 tropical cyclones (tropical storms and typhoons) of which approximately 20 reach typhoon strength. North Pacific typhoons are the largest tropical cyclones in the world. Diameters of 500 miles are common. Maximum wind speeds often reach 130 knots or more; about 15 percent of all tropical cyclones achieve this supertyphoon category.

The eastern North Pacific spawns an annual average of about 15 tropical cyclones (tropical storms and hurricanes) of which about 5 become hurricanes. These storms are small and tightly organized and diameters less than 100 miles are common. Maximum sustained winds speeds rarely reach 130 knots. This may be due in part to lack of observations near the center of such small storms.

In both regions tropical cyclones form between 5 degrees and 20 degrees N, move initially in a westerly direction, then either continue on this path or curve to the northwest through northeast. Eastern North Pacific tropical cyclones are in general much shorter lived than western North Pacific storms. Occasionally a North Pacific tropical cyclone will cross the dateline

from either side, so the delineation between regions is not always clear cut. The rare tropical cyclones that affect the Hawaiian Islands form in the eastern North Pacific.

Tropical cyclones upon reaching northern latitudes often become extratropical and continue across the ocean in this manner. These former tropical cyclones can be dangerous.

During the summer, western North Pacific tropical cyclones develop between the Marshall Islands and the Philippines. This area expands latitudinally until, by August, a substantial percentage of storms form north of 20 degrees N and on rare occasions close to 30 degrees N. The heart of this broad area of formation is just west of Saipan in the Marianas. Tropical storms most often reach typhoon stage between the Marianas and northern Philippines, but this can occur anywhere from Wake Island to the South Vietnam coast and from 5 degrees to 35 degrees N.

In the eastern North Pacific the area of tropical cyclone formation spreads out longitudinally during the summer. In June these storms are usually first detected between 90 degrees W and 110 degrees W and by August the western boundary is the Hawaiian Islands. These tropical cyclones usually form between 10 and 25 degrees N during the summer. Hurricanes most often recurve east of 120 degrees W in June. As the summer progresses they gradually move farther westward before recurring. By September the westward limit of recurvature is about 170 degrees W.

NORTH PACIFIC OCEAN CLIMATE - AUTUMN

The transitional nature of this season is apparent in the monthly sea level pressure charts. From September through November, The Aleutian Low gradually strengthens and expands while the north Pacific High weakens and shrinks. North of 30 degrees N extratropical storms become more frequent and more intense. In the tropics, eastern North Pacific typhoons are still frequent and can affect shipping as far north as 45 degrees N. Eastern North Pacific hurricanes continue to plague the waters west of the Mexican coast but their frequency drops sharply by November.

Western North Pacific tropical cyclones form below 20 degrees N in September and then below 15 degrees N by November. The average latitude of recurvature, which was 28 degrees N in August, drops to 20 degrees N by November. Tropical storms often reach typhoon intensity between the Marianas and northern Philippines. In the eastern North Pacific the area of formation shrinks from its August spread and seems to be restricted to east of 125 degrees W and between 10 degrees and 20 degrees N. By the end of September these storms tend to hug the Mexican coastline and a large percentage move inland.

The ITCZ is around 10 degrees N across the entire Pacific in October. By November, it has slipped a few more degrees southward, east of and below the equator west of 180 degrees.

Clear skies, good visibilities, and light winds are the rule between 20 degrees N and 35 degrees N. South of 20 degrees N overcast conditions are observed 20-40 percent of the time; precipitation remains light and visibility good.

Extratropical storms from over the Asian Continent and in the waters around Japan, often from the remnants of tropical cyclones. These storms move toward the Aleutian Islands and into the Bering Sea or Gulf of Alaska. Storms also develop in the central North Pacific and move into the Gulf of Alaska. During most of the cool season (late fall, winter and early spring) the Gulf of Alaska has the highest frequency of extratropical cyclones in the Northern Hemisphere.

The increase in number and intensity of extratropical storms is reflected in the gale frequencies over the northern great circle routes; there is an increase from the summer lull to 10-20 percent north of 40 degrees N. Wind directions in this region are variable but show a slight preference for the western semicircle, northwest quadrant south of the Aleutians and southwest quadrant in the Gulf of Alaska. Overcast conditions (sky cover greater than or equal to 8/10) prevail 60 to greater than 70 percent of the time north of 40 degrees N while clear days (sky cover less than or equal to 2/10) are observed less than 20 percent of the time. Visibilities in these northern latitudes improve dramatically from summer. Visibilities less than or equal to 1 mile occur 5-10 percent of the time while visibilities less than or equal to 5 miles occur 10 to greater than 20 percent of the time.

South of 30 degrees N northeasterly winds continue to prevail. These are known as the northeast trades over most of the Pacific, and as the northeast monsoon, west of about 150 degrees E. These winds persist from 70-90 percent of the time.

NORTH PACIFIC OCEAN CLIMATE - WINTER

In winter the Aleutian Low looms over the North Pacific as a climatic warning to mariners navigating the northern great circle routes. The extent, position and central pressure of this semi-permanent climatic system reflects many features of the every day weather patterns. This Low, centered in Bristol Bay, during the fall, progresses southwestward centering itself near the Rat Islands by December. Its mean central pressure remains below 1000 mb from December through February, the season of storms for the northern North Pacific. Its broad expanse covers the Pacific Basin from the Arctic Ocean to 30 degrees N

and from the North American coast to Japan. The southeastern North Pacific, between the Hawaiian Islands and Baja California, is covered by a remnant of the Summer-dominant Pacific High while the Sea of Japan and the East China Sea are under the influence of a seaward bulge of the Siberian Anticyclone.

Winter storms from the China mainland and the waters around Japan move northeastward toward the center of the Aleutian Low then into the Bering Sea or Gulf of Alaska. Storms from the central North Pacific also tend to move into the Gulf of Alaska, making these waters the most active in the Northern Hemisphere. And with this activity comes the rain, sleet and snow, the howling gales, and the poor visibilities which characterize the weather along the northern great circle routes during this season. Gales can be expected 20 to 30 percent of the time north of a line from southern Japan to Vancouver Island. They frequently ride winds from the northwest quadrant, west of the dateline and winds from the southeast quadrant, east of the dateline. The more potent Pacific storms carry gales in both and sometimes all quadrants. Any ship sailing a route north of 40 degrees N is likely to encounter gales in winter.

In addition to the wind along these northerly tracks, overcast conditions (sky cover greater than or equal to 8/10) prevail 50 to 70 percent of the time, precipitation occurs 25 to 45 percent of the time (50 to 95 percent of this occurs in a frozen form), and visibilities less than or equal to 5 miles are encountered up to 20 percent of the time. In isolated areas along the Kuril Islands, in the Sea of Okhotsk, and in the Bering Sea these poor visibility frequencies are as high as 40 percent. Visibilities less than 1 mile are found 5 to 15 percent of the time along the North American coast between Vancouver Island and southern California, and in the Gulf of Alaska, and 10 to 20 percent of the time in the Bering Sea and Sea of Okhotsk.

Over the western North Pacific, the northwest (winter) monsoon is the controlling feature. This monsoon originates in the intense Siberian High. It is a remarkably persistent flow west of 160 degrees E; it strengthens and fades in a series of surges and lulls covering periods that last from 10-12 days. Over open waters, north to northwest winds average 17-22 knots during the winter. January is the heart of the winter monsoon season, and south of 50 degrees N winds from the northwest quadrant prevail 70-75 percent of the time.

South of 35 degrees N over most of the Pacific and south of 30 degrees N in the waters around Japan, the transition zone from the northern latitudes of storms to the northeast trade wind regime begins. This moderating zone extends southward to about 25 degrees N. It is characterized by light and variable winds, partly cloudy skies, good visibilities, mild temperatures and little precipitation. These mild conditions are occasionally interrupted by an errant extratropical storm caught in a westerly flow or in the eastern North Pacific by the occasional northward displacement of the ITCZ.

During the winter the ITCZ lies between the equator and 10 degrees N to the east of the dateline, and moves into the southern hemisphere to the west of the dateline. The ITCZ is responsible for showers and thunderstorms, and for the overcast conditions which occur up to 40 percent of the time over the eastern North Pacific tropics in winter. Winds are generally northeasterly on the north side of the ITCZ and southwesterly on the south side. Gales that infrequently occur are the result of squalls within this band.

In the tropics west of the dateline, clear skies, warm temperatures and northeast to east winds are the rule. Visibilities are good and precipitation is spotty. The serenity of this area is occasionally interrupted by the infrequent appearance of a winter tropical cyclone. These off-season storms are more likely in December than in any other winter month. They are usually confined to the tropics and are most frequent in and around the Philippines. They can be just as potent as their summer counterparts. They reach typhoon strength about 60 percent of the time. On the average, two tropical cyclones can be expected each winter in the western North Pacific.

NORTH PACIFIC OCEAN CLIMATE - SPRING

The monthly sea level pressure chart for spring looks like a battle for control of the Pacific Basin between the advancing summer High and the retreating Aleutian Low. The High covers the North Pacific, south of about 42 degrees N (latitude of northern Honshu) while the Aleutian Low covers the remainder. Storms still move off the Asian mainland, and from the waters around Japan, toward the western Aleutians, and then either into the Bering Sea or Gulf of Alaska. Central North Pacific storms still tend to move northeastward into the Gulf of Alaska. However, there is a noticeable difference from the violent winter storms that plyed these same waters. While the number of storms decreases only slightly, there is a significant reduction in the storms' intensity. This can be seen in the higher central pressure of the Aleutian Low (1002.5 mb) and also in the frequency of gales over the northern great circle routes. In areas where winter gales were occurring up to 20 percent of the time, they are not occurring about 10 percent of the time. South of a line from Taiwan to Vancouver Island, gales are rare. Gales occur most often in the northwest and southwest quadrant of extratropical storms.

A general decline in wind speed and an increase in variability sets in over the Pacific in March as the winter monsoon and the winter pressure systems begin to weaken. This change accelerates during April and May. By May, over the Sea of Japan and Yellow Sea, southerly winds have replaced the prevailing winter flow. Elsewhere, north of 30 degrees N southerly winds have become more pronounced. South of 30 degrees N and east of 160 degrees E, the northeast trades prevail. West of 160 degrees E these trades are more easterly.

Spring brings even more cloudiness than winter. In the northern North Pacific, the large number of lows and the warm springtime air blowing over still cold waters, cause overcast conditions (sky cover greater than or equal to 8/10) 60-80 percent of the time. Locally around the Aleutians, these bleak conditions occur greater than 80 percent of the time. Visibilities, on the average, are the same as they are in winter. Visibilities less than 5 miles occur up to 20 percent of the time and visibilities less than 1 mile occur up to 5 percent of the time, over the northern great circle routes; the latter increases to greater than 10 percent on both sides of the Kuril Islands. Precipitation frequencies, in general, decrease during the spring, over the northern routes, with 25 to 40 percent frequencies dropping to 20 percent by spring's end. By May, frozen precipitation occurs less than 5 percent of the time in the waters north of 35 degrees N.

Cloudiness in the tropics does not differ much from winter conditions. The ITCZ now fluctuates between the equator and 12 degrees N, from Colombia, South America to about the longitude of the Hawaiian Islands (160 degrees W), and then between the equator and 10 degrees S over to the longitude of eastern New Guinea (145 degrees E) where it re-crosses the equator and extends northwest-ward into the South China Sea. The influence of this discontinuous zone is reflected in the cloud cover of the tropics. Overcast conditions and clear skies are encountered 20-30 percent of the time. Rainfall which does not vary much over tropical ocean areas is generally encountered less than 10 percent of the time in the spring. Most of these rainfall encounters are with showers in the ITCZ, within the circulation of an occasional tropical cyclone in the western North Pacific, or a rare one in the eastern North Pacific. Any rare gales in the tropics are also associated with tropical cyclones and the ITCZ.

Two to three tropical cyclones can be expected in any given spring in the western North Pacific; either one or two should reach typhoon strength. These storms would most likely be encountered between 10 and 20 degrees N. They usually form somewhere east of the Philippines, move eastward either through the Philippines into the South China Sea or recurve toward the northeast, and dissipate or become extratropical over the colder waters at higher latitudes. May is the most likely spring month for a typhoon, just as it is for an eastern North Pacific hurricane. Spring tropical cyclones have only been observed in eastern waters during May, but could form earlier. These rare May storms form close to the Mexican coast and usually exist for just 3-4 days. However, they can reach hurricane strength very rapidly.

SPECIAL WEATHER PHENOMENA

Dew Point.- The temperature at which condensation to water droplets occurs is called the dew point. If this dew point is above freezing, condensation will be to water; if it is below freezing, then ice crystals will be deposited on cold surfaces. Knowledge of the dew point along with cargo temperature and moisture content is vital for hold ventilation decisions. It is also a parameter used in forecasting fog formation.

Cargo Care.- The relatively high humidity values and temperatures encountered in the tropical areas make protection of cargoes from sweat an important consideration. Critical conditions are most likely to develop when cargoes are loaded under conditions of high temperatures, such as prevail in the equatorial regions. When free air has a dew point temperature higher than the temperature of the surface with which it comes in contact, the air is often cooled sufficiently below its dew point to release moisture. When this happens aboard ship, condensation will take place on relatively cool cargo or on the ship's structure within the hold where it later drips onto the cargo. Thus, if cargo is stowed in a cool climate and the vessel sails into warmer waters, ventilation of the hold with outside air will likely lead to sweat damage in any cargo sensitive to moisture. Under such conditions external ventilation, should as a rule, be closed off entirely, unless the cargo generates internal heat, that hazard being greater than sweat damage. In the opposite case, when a vessel is loaded during a warm period, and moves into cooler weather, vulnerable cargo should be ventilated.

A safe rule for ventilation directed toward moisture control may be stated as follows: Whenever accurate measurements show the outside air has a dew point below the dew point of the air surrounding the cargo to be protected, such outside air is capable of removing moisture from the hold and the ventilation process can be safely started. Whenever the reverse is true, and the outside dew point is higher than the dew point temperature around the cargo, then ventilation will increase the moisture content of the hold and may readily result in sweating within the ship. The above does not take into account, possible fumes or gases in the compartment. In such cases discretion must be used.

Optical Phenomena.- Optical phenomena, unusual in most parts of the world are common in the northern North Pacific. The Aurora Borealis, the very colorful solar and lunar coronas, and the halos are just a few of the many optical phenomena that occur with unusual brilliance. However, this discussion is confined to those optical phenomena which are associated with the weather or weather parameters.

Superior and inferior mirages are quite common and cause weather observers to underestimate and overestimate, respectively, the distance to objects seen near the horizon. Superior mirages are the result of a strong surface temperature inversion over the ice-covered northern seas. This inversion is deepest and most intense in winter. The differential in speed of light rays traveling quasi-horizontally through a layer which shows a denser stratification of the lower atmosphere rapidly decreasing with height causes the light rays to be bent toward the earth's surface. Occasionally the rate of bending almost parallels the earth's curvature for some distance. What the observer then sees is a superior mirage of the distant objects, which may actually be below or partially below the horizon. This phenomenon is known as looming.

Inferior mirages occur when a very unstable lapse rate develops within the first few yards above the surface, and light is bent upward and away from the surface; this occurs because the rays travel faster through the warm, less dense air at the surface than through the more dense air above. This has the effect of causing nearby objects to appear to sink below, or partially below, the horizon. This phenomenon is probable over the Bering Sea in winter when extremely cold continental air flows offshore and is heated over the relatively warm water. An inferior mirage may cause an observer to overestimate the distance to nearby objects. The phenomenon is frequently accompanied by an optical haze and the blurring of the outline and appearance of objects seen in the distance.

The presence is vertically adjacent layers of density gradients that would give an inferior mirage and a superior mirage will produce a complex mirage characterized by a multiple and fanciful distortion of images. This phenomenon is known as Fata Morgana.

Superstructure Icing.- In certain weather conditions ice accumulating on hulls and superstructures can be a serious danger to ships. Ice accumulation may occur from three causes:

(a) Fog with freezing conditions.
(b) Freezing rain or drizzle.
(c) Sea spray or seawater breaking over the ship when the air temperature is below the freezing point of seawater (about 28.6 degrees F).

Ice accumulation from the first two causes, if appreciable, could induce enough damage to the rigging to cause it to fall. This is minor however, in comparison with the weight of the ice accumulated in rough weather and low temperatures, when large amounts of spray and often heavy seas break over a vessel. When the air temperature is below the freezing point of sea water and the ship is in heavy seas, considerable amounts of water will freeze to the superstructure and those parts of the hull which are sufficiently above the waterline to escape being frequently washed by the sea. The amounts so frozen to surfaces exposed to the air will rapidly increase with falling air and sea temperatures, and might in extreme cases lead to capsizing of the vessel. The dangerous conditions are those in which gale force winds last for several days in association with air temperatures of 28 degrees F or lower. These conditions will normally occur when the wind comes from the northern quadrants. Indications of when these conditions are likely to occur can often be obtained by observing the rate of fall of the barometer, at the onset of strengthening winds from a cold quarter, together with observations of air and sea temperatures.

NORTHEASTERN NORTH PACIFIC
(INCLUDING THE GULF OF ALASKA AND BRITISH COLUMBIA)

Extratropical Cyclones.- In winter all of the many extratropical cyclones that reach the Gulf of Alaska and the British Columbia coast generally originate in the western or central Pacific. These storms are the principal source of bad weather and a single storm may affect this area for days before dissipating or moving inland. Often they come in a series of interconnected families of four or five and may affect weather conditions for two weeks or longer. These storms generally move at a rate of 20 to 25 knots in an easterly or northeasterly direction.

In general two groups of storms are easily recognized. Those in the southern group develop rapidly into closed circulations and move northeastward towards British Columbia. Off the coast some slow down and fill, others alter course and follow the coast northwestward, while some continue eastward passing over British Columbia. The northern group is comprised of those storms which form far to the west near Kamchatka or Japan. Some of these cyclones move northeastward through the Bering Sea into the Arctic, and some travel eastward through the Gulf of Alaska. On approaching the mainland, some become stationary and die out, while others swing southeastward along the British Columbia coast.

In the summer cyclonic activity is very much reduced although some activity continues in the northern Gulf of Alaska. Cyclones approaching the British Columbia coast during these months are not able to penetrate the anticyclone and usually remain west of 170 degrees W. Summer conditions usually last until the middle of September and change abruptly near the end of that month to the winter type.

Winds.- North of 40 degrees N, late fall and winter winds are westerly to southwesterly in the central Gulf, changing to southerly near British Columbia and easterly off the Alaska coast. In spring, southwesterly to westerly winds over the open ocean become southeasterly to southwesterly in the Gulf of Alaska. Over the Gulf in summer, southwesterly winds change to northwesterly in the south. In early fall areas north of 45 degrees N experience westerly to southwesterly winds that become southeasterly near the coast. South of 45 degrees N winds are westerly to northwesterly.

Average winds speeds are highest in late fall and early winter. North of 45 degrees N in the open Gulf of Alaska average wind speeds range from 20-25 knots while closer to the British Columbia coast averages drop to 15-20 knots, decreasing southward. In the spring, mean winds speeds range from 13-17 knots near the coast to about 20 knots over open waters. Summer winds are weakest with averages of 10-15 knots over the entire area. In the fall, winds begin to increase again and over the open Gulf, they range from 18 knots in the north to 22 knots in the south and 10-15 knots along the British Columbia coast.

Gales.- Gales (winds greater than or equal to 34 knots) may be encountered in the Gulf of Alaska year round, although they are rare during the summer months. Locations most frequently affected by strong winds are those along the exposed coast or islands but funneling effects may intensify winds at more protected stations. As a general rule, intense Gulf lows tend to create strong southerly or southeasterly winds over the southern Gulf and along the British Columbia coast; gust of 60 knots or greater occur almost monthly during the winter season.

From a minimum of about 1 percent or less in summer, the frequency of gales increases rapidly in the fall. By October, gales are experienced about 8-10 percent of the time in the northern Gulf of Alaska and up to 18 percent of the time in the south. Closer to the British Columbia coast, these frequencies are just 3-5 percent. Gale frequencies remain high through March. They reach a peak in December, when frequencies over open waters range from 17 to 26 percent north to south. This range is 5-10 percent off the British Columbia coast. By April, gale frequencies along the coast have dropped to below 5 percent and to below 12 percent over the open waters of the Gulf.

Local Winds.- The inland waters of British Columbia are a labyrinth of deep inlets bordered by high cliffs and steep mountainous slopes. The direction and strength of the wind is influenced by this type of topography. Winds are funneled through these inlets and they tend to blow along the axis of the strait.

Squamishes.- This wind is named after a settlement at the head of Howe Sound. It occurs during the winter months when the continental anticyclone is well established. Squamishes are strong, often violent winds which bluster down the fiords bringing cold polar air from the continent to the coast. They lose their strength when free of the confining fiords and are not noticeable 15 to 20 miles offshore. Offshore winds tend to be frequent in winter on coasts in middle and high latitudes, especially if highlands back the coast. Squamishes are merely local topographical intensifications of these winds. Their strength makes them a source of damage on land and a danger to navigation at sea. Squamishes are well known in many of the fiords of British Columbia. They occur in those fiords oriented in a northeast-southwest or east-west direction, where the cold polar air can be funneled westward. They are notable in Jervis, Toba, and Bute inlets, and in Dean Channel and Portland Canal. One Squamish blew at Green Island Lighthouse, 8 miles southwest of Portland Canal entrance, from December 27 until January 3 and was less than a fresh gale on only one day.

Williwaw.- The Williwaw is a violent squall with strong gusty winds that is encountered in the northern inlets of British Columbia and in particular off the west coast of Queen Charlotte Islands. Williwaws unlike the Squamish are usually of short duration. They are encountered during the winter and are caused by the drainage of cold air which sweeps down the

mountain slopes with great force in these narrow inlets. When piloting close to the coast in stormy weather, Williwaws may be encountered near the mouth of these inlets. Vessels at anchor should be cautious. Williwaws come up suddenly and the successive strong gusts of wind from varying directions may cause the vessel to yaw badly with the possibility of dragging anchor.

Land and Sea Breezes.- Land and sea breezes are prominent in the fine settled weather of the summer. The sea breeze sets in on the coast about 1000, strengthens until the afternoon and dies away before sunset. At its strongest it usually reaches a gentle to moderate breeze. The land breeze is much lighter, from a light to gentle breeze. Under favorable situations both can be much stronger. The sea breeze may occasionally rise to a strong breeze and persist far into the evening.

Coastal winds.- Along the coast winds from the southeast, except for the warmer months, predominate. In winter, the southeasterlies far exceed all other directions in frequency. However, in summer, winds between north and west increase and in some locations are encountered more frequently than the southeasterlies. Some of the coastal stations at protected locations report a high frequency of calms.

At Prince Rupert between October and April southeasterly winds are encountered about 40 percent of the time. In the warmer months this frequency drops to about 25 percent. This change in frequency is reflected by an increase of calms to about 30 percent in the early morning hours and an increase of the northwesterlies to about 25 percent in the afternoon. Between October and March, the average number of days with gales is 2 or 3. Gales are rarely encountered during the warmer months.

At Masset, southeasterly winds also predominate from October to April, but they are not as persistent as those at Prince Rupert, occurring on only about 30 percent of the observations. North and northeast winds are fairly common during this period. From May to September, winds from the west and northwest are reported about 50 percent of the time with southeasterlies now averaging about 25 percent. The mean number of days per month with gales averages about one, from October to March. Gales are rarely encountered in the summer months. Calms are very infrequent at Masset compared to their high frequency at Prince Rupert.

In the Strait of Juan de Fuca, the winds often blow in our out, following coastal contours; blowing in with the prevailing southwesterly to northwesterly winds but blowing seaward during the southeasterly gales of winter. When the seas raised by these outflowing winds from the strait meet the southwesterly swell at the entrance, heavy cross seas are the result.

The prevailing wind in the Strait of Georgia is from the northwest in the summer. From May to September, it blows with considerable strength and steadiness as far as Point Roberts, commencing about 0900 and dying down toward sunset. During the cooler months, strong northwesterly winds often follow the passage of an intense cold front. These winds may obtain gale force, particularly in the southern part of the Strait of Georgia where they are funneled between mountain ranges rising steeply to several thousand feet on both sides. Often they are intensified by offshore winds blowing down the inlets of the mainland. These strong winds have caused considerable damage ashore and to small craft.

In the San Juan Archipelago, the winds become variable. The westerly winds in the Strait of Juan de Fuca are deflected to the southwest in the main channels of Rosario and Haro Straits. Upon entering the Strait of Georgia they often shift to the northwest.

Climate.- Navigation is mainly affected by winds, seas, and fog in these waters. In winter all factors come into play while in fall, winds and seas are important. Taking all factors into consideration, spring and summer are the best seasons for navigating these waters. Summer would stand alone except for the fog that shrouds the area at this time. Over open seas, precipitation occurs most frequently during the winter months. Off the British Columbia coast, precipitation frequency reaches a maximum of about 35 percent in January. During this month snow occurs on about 5 percent of the observations. During the summer months the percentage frequency of observations reporting precipitation is at a minimum and varies between 15 and 20 percent. Along the coast, precipitation varies considerably due to the topography. On the windward or western side of Vancouver Island and the Queen Charlotte Islands, the average annual falls exceed 100 inches. On the lee coasts, rainfall amounts are much smaller, averaging less than 50 inches. On the mainland, precipitation again increases, reaching over 100 inches at some of the higher locations.

At most of the stations the rainy season extends from October to April, with November and December being the wettest months. Although the summer months are relatively dry, exposed locations receive over 4 inches during July, one of the driest months.

Estevan Point, representing the more exposed stations on the western side of Vancouver Island, has an average annual rainfall of about 110 inches. It ranges from a low monthly average of about 3 inches in August to about 16.5 inches in December. The mean number of days reporting precipitation is 205 for the year. The monthly average is over 20 days between October and April. Langara on the northwestern side of Graham Island, has an average annual rainfall of about 65 inches. It ranges from a low monthly average of about 3 inches in July to more than 9 inches in October. The mean number of days reporting precipitation is 254 for the year, with a maximum of 26 days in October.

The southeastern shore of Vancouver Island, on the lee side of the mountains, is the driest region of this coast. Victoria, on the southeastern tip of Vancouver Island, has an average annual fall of only 27 inches, ranging from a low monthly average of about 0.4 inches in July to a high of 4.67 inches in December. Although the totals are not too great, the mean number of days reporting precipitation is still high, averaging 147 days per year. During the winter months, an average of about 19 days per month report precipitation.

Those stations exposed to the full effect of the sea, record the fewest number of snowy days. Estevan Point has an annual average of about 5 days with snow. At Victoria, it increases to 9 and at Vancouver to 13, 5 of which occur in January. Masset has an annual average of about 9 days with snow. At Prince Rupert, it increases to 22, 17 of which occur from December through March. On the mainland, snow occasionally falls until May and may start as early as October. At the more exposed locations, it hardly ever falls outside the months of December through March.

Thunderstorms are very rare, occurring on the average, only once or twice a year.

Cloudiness is high throughout the area with relatively little seasonal or diurnal variation. The amount of cloudiness varies very little throughout the year and the monthly averages usually range between 7/10 and 9/10. The minimum monthly average amount reported is 6/10. Masset has an annual average coverage of 8/10 with none of the individual months falling below 7/10. In June and July, 81 percent of the time the sky is overcast and about 10 percent of the time, clear. March has the highest percentage of clear days, 22 percent, however, 63 percent of the observations during this month still report overcast skies. The sky is almost always overcast or practically clear. During the winter, overcast weather clears rapidly after the passage of a cold front and there may be several days of cloudless skies associated with the high pressure system that follows the front. Visibilities are poor in both winter and summer in the Gulf of Alaska. The winter maximum is a result of the heavy precipitation (including snows) which is experienced in the colder months. Surface visibility in the summer months is hindered mainly by fog. Over the southern Gulf of Alaska and along the coast of British Columbia in winter months, visibilities less than 2 miles occur between 6 and 8 percent of the time. In the spring, the frequency falls to 3-5 percent. Peak summer months show visibility less than 2 miles occurring between 6 and 12 percent, and in fall the frequency drops to 2-6 percent. In the Gulf, visibilities less than 1/2 nautical mile reach a peak of 5.3 percent in July, decreasing to less than 1 percent in April. Winter frequencies are about 2 percent.

Conditions are most favorable for the formation of advection fog during the summer months. The relatively cool water temperatures off the British Columbia coast and the generally light anticyclonic winds associated with the stable North Pacific High are conducive to both the formation and maintenance of fog. The seaward extent of fog varies greatly. The area of dense and most frequent fog occurs over the narrow stream of cold water just off the coast and is frequently limited to a band of 50 miles or less. At other times fog covers large areas and may extend hundreds of miles to sea. Fog may be spotty, reflecting the differences in sea temperature. When warm southerly winds bring in moist air, fog banks will appear where this air moves over stretches of cold water. This also occurs when prolonged strong northwesterly winds produce upwelling off the coast. A change to southerly winds will then form extensive fog banks to seaward. Fog banks are sometimes seen at the entrances to sounds or inlets in the early morning, but burn off rapidly as the temperature rises on clear days. At those stations fully exposed to the sea, advection or sea fog is most common between July and September. It reaches a maximum in August. At Langara, fog banks may frequently be seen offshore when there is no fog in the vicinity of the station.

Offshore near the Strait of Juan de Fuca, thick fog banks sometimes rear themselves almost perpendicularly, facing clear weather inshore, thus allowing vessels to arrive at their destination without difficulty. At other times, the bank will move slowly into the strait, enveloping both shores for some distance, then perhaps leave the Vancouver shore to the northward and cling to the Washington shore. As a rule the fog is more likely to follow into the strait along the southern shore, reaching as far as Port Townsend. These fogs may remain over the entrance of the strait for days. Usually they are accompanied by calms or very light winds from the northwest. During spring, fogs are also frequent in the strait; with a westerly wind, they often extend as far as the headland between Crescent and Freshwater Bay while farther eastward the weather is clear.

In the northern part of Queen Charlotte Strait, fog sweeping in from seaward, usually breaks up after passing the islands at the mouth of the strait. This forms a line of fog between the Gordon and Millar groups and leaves the area to the southeast comparatively clear. In the interior straits and sounds, fog is generally encountered in the fall with October having the highest number of occurrences. The type of fog encountered during these months is generally radiation fog. During the late summer and fall, there are a great number of nights with clear skies and very little movement of air. During the night, as heat is lost from the earth by radiation, the air cools to its dew point, and fog results. In late summer, the nights are shorter and the opportunity for radiation cooling is not quite so great, therefore the fog is not so thick and dissipates rather early in the morning. As the nights lengthen during autumn, the fog will form earlier and to a greater depth and will not dissipate so early in the morning. In fact, under very stagnant conditions in October, it is not uncommon to have fog for several days. This condition may persist until a storm approaches the coast with sufficient wind to blow out the fog.

Smoke from forest fires may considerably reduce the visibility. The great expanse over which the smoke may spread and its persistence make it a real factor to be considered when navigating. These fires generally occur during the hot, dry summers and reach a maximum in August and September.

In the vicinity of Vancouver, industrial smoke may seriously restrict visibility. After any night with calm or light winds, a dense pall of smoke can be seen over the city. It often moves away in the light land breeze down Durrard Inlet to the Strait of Georgia and at times across the strait to Vancouver Island. With an increase of the wind, the setting in of the sea breeze, or the approach of a storm with less stable air, the atmosphere clears, but haze frequently persists even in the afternoon. This condition is found most frequently in the summer with calm clear nights and in the winter with high humidity.

The winter temperatures are caused by a combination of the prevailing oceanic westerlies and warm Pacific current that fronts the coastline. The summers are hardly ever uncomfortable, because of the prevailing northwesterlies and the cool sea breezes. The coastal region is sheltered from the very cold polar outbreaks which originate in the interior by the coastal range which backs the coast. The few that do reach the coast have been considerably modified and their temperatures are much higher than those experienced east of the coastal range.

Triangle Island, represents those localities fully exposed to the maritime climate. The small range in annual temperatures at such locations is readily seen. Triangle Island has an annual average temperature of 45 degrees F, ranging from 36 degrees F in January to 54 degrees F in August. In those months, the average daily maximum ranges from 39 degrees to 58 degrees F and the minimum from 34 degrees to 51 degrees F. The extreme temperatures recorded at Triangle island were 78 degrees F in May and 0 degrees F in January.

Temperatures are more variable at those ports not fully exposed to the sea. Vancouver, located in the lee of Vancouver Island, has a wider range of temperatures. The mean annual temperature at Vancouver is 49 degrees F, ranging from 64 degrees F in July to 36 degrees F in January. For those months the average daily maximum ranges from 74 degrees to 41 degrees F and the minimum from 54 degrees to 32 degrees F. The extreme temperatures recorded at Vancouver were 92 degrees F in August and 0 degrees F in January. Extreme temperatures have a wider range at the mainland ports with Ocean Falls recording a maximum of 103 degrees F and a minimum of -6 degrees F. An extreme maximum temperature recorded was 100 degrees F at Bull Harbor in June and an extreme minimum temperature recorded was -2 degrees F in January at Victoria and Masset. Over the ocean area fronting the British Columbia coast, air temperature maxima are experienced in August and September and minima in January and February. In August, the median air temperature at sea is about 57 degrees F and in February about 42 degrees F.

Average air temperatures over the open waters of the Northeastern Pacific and the Gulf of Alaska range from about 42 degrees F in the south to 28 degrees F along the Alaska coast in winter.

In the summer, coldest air temperatures, on the average, are found westward toward the Aleutians where the average is 48 degrees F and less, and warmest temperatures are around 56 degrees F off of Vancouver Island.

SOUTHEASTERN NORTH PACIFIC
(INCLUDING WEST COAST OF MEXICO AND CENTRAL AMERICA)

The North Pacific subtropical High is a primary climatic feature of the entire area. Its center roams an area bounded by 30 degrees and 38 degrees N and 132 degrees and 160 degrees W. The High expands and intensifies as it moves poleward and westward from winter to summer. Its counterpart in the South Pacific, off the coast of South America, also effects the climate of this area. Between these Pacific subtropical Highs lies the Intertropical Convergence Zone (ITCZ)- the area's most important climate feature. Like the subtropical High, the ITCZ moves north and south with the sun. To understand the ITCZ is to know the wind, cloud, and rainfall regimes in this area. During the winter season (December-April) most of the ITCZ lies just south of the area; consequently the area is under the influence of the northeast trades. During April and May the ITCZ begins its northward progression. Most of the area remains under the influence of the northeast trades; the southeast trades are just beginning to reach the southern portions of the area. By August, the ITCZ is spread out between 5 degrees and 18 degrees N. The southeast trades achieve their maximum northward penetration - close to 8 degrees N, in some areas. During the transition months of October and November, the ITCZ retreats southward. Once again the northeast trades dominate the area.

Tropical Cyclones.- Tropical cyclones are encountered in the waters between 10 degrees and 30 degrees N from the Central American-Mexican coast, westward. Although tropical cyclones can form in any month, they are most prevalent from late May through early November. August is the most active month; however, early and late season storms are often more intense. In recent years - the satellite era - an average of 16 storms have formed in these waters each year. About 7 of these storms have been classified as hurricanes; this figure may be low, since a lack of observations close to the center makes it difficult to tell if the storm has reached hurricane intensity.

August is the heart of the eastern North Pacific tropical cyclone season. During this month an average of 4.3 tropical cyclones (tropical storms and hurricanes) develop with 2.2 reaching hurricane strength. In June an average of 1.5 tropical cyclones are observed and by October, the average falls to 2.2. The frequencies for the year can be found in the first section.

Early and late season tropical cyclones usually form close to the coast, parallel to the coastline, and recurve onto the mainland anywhere from the Golfo de Tehuantepec to northern Baja California. About 3 each season cross a coastline. Once inland they dissipate rapidly. Midseason storms, which form in a wide band from the Mexican coast to the Hawaiian Islands, either parallel the coast or move in a more westerly direction.

Forward speeds of tropical cyclones are variable in all areas of the world; in this area, since most storms remain below 30 degrees N, the variation of speed is less. Average speeds range from 7-12 knots while extremes range from stationary to 25 knots. Average forward speeds are highest in August (10-12 knots) and lowest during June (7-8) knots.) Tropical cyclones rarely move faster than 15 knots below 15 degrees N, and slowest speeds are observed when the storm is recurving or making a tight turn.

The main features of hurricanes in this region are their size, ability to intensify quickly, and seasonal preferences. The radius of hurricane-force winds seldom exceeds 50 miles and often extends no farther than 30 miles; winds may increase from 40 knots, 50 miles from the center to 140 knots within 10 miles of the center. These storms often intensify rapidly; it is not unusual for winds near the center to increase from 40 to 100 knots in less than 12 hours. This is particularly true in October storms.

Winds.- The northeast trades that blow over this area are steady winds that have their origins in the clockwise flow around the North Pacific High. Near the Mexican coast, they are diverted to the north through west-northwest by the coastline and other local effects. For most of the year these trades extend southward to about 10 degrees N, but in the winter season they dominate almost the entire area. These steady winds blow at a mean speed of nearly 15 knots.

The southeast trades migrate northward, with the ITCZ, during the spring. They make their greatest penetration during August. Their name is misleading, in this region, since these trades, moving on clockwise-curving paths, actually reach the area as weak south or southwest winds.

Within the ITCZ the northeast and southeast trades converge to form a zone of light and variable winds. Winds of less than 10 knots are characteristic in this zone; during November, winds are less than 10 knots, 80 percent of the time. During August, when the ITCZ expands to its greatest coverage, winds are less than 10 knots about 50-80 percent of the time.

Local and Coastal Winds.- Except for tropical cyclones, most gales are the result of local effects. The Tehuantepecer, a local wind in the Golfo de Tehuantepec, is caused by intense continental highs that move southward from the U.S. over the Gulf of Mexico. The air flows into the narrow Tehuantepec Pass and then rushes violently down to the Gulf, frequently spreading over the entire area and is felt out to 100 miles at sea. Although there may be a preliminary squall, skies are most often cloudless. Wind direction is northeast thru northwest, and the duration of the gale depends on extent, strength and permanence of the controlling high; gales may last for a few hours or continue for several days. Salina Cruz, at the head of the Gulf, has 140 days of gale force winds each year. These winds are most frequent in the winter; they are recorded more than one percent of the time in the Gulf, and Salina Cruz averages about 20 days per month with gale force winds from November through January.

When this same phenomena occurs farther south; along the west coast of Central America, the wind is called Papagayos; this name was taken from the Golfo de Papagayo on the upper Costa Rican coast. These northerly through northeasterly gales are observed from just east of the Gulf of Tehuantepec to lower Costa Rica and are encountered mainly in harbors and inlets such as the Golfo de Fonseca, the harbor of Corinto, and other Central American ports. Usually the Papagayos is weaker than the Tehuantepecer, although it can reach gale force. These winds are most frequent in January and February. They often last 3 or 4 days without interruption except for a weakening between 0700 and 1000 local time.

During the rainy season, local gale-force winds, associated with violent thunderstorms, are common along the entire coast. These squalls are known as Chubascos. They are prevalent in May and October, sometimes occurring day after day. They occur in the late afternoon. As the storm breaks, southwesterly winds suddenly veer to the eastnortheast and often reach gale-force.

Sometimes in the summer, a southwesterly or westerly flow will briefly intensify to gale force and cause heavy seas. These winds are called Temporales and are occasionally observed along the Central American coast during July and August.

Land and sea breezes attain their greatest development along the coasts in summer when the strength of the general circulation is at the minimum. These breezes, blowing onshore during the day and offshore at night, may extend out to 10 miles at sea in the vicinity of bays and inlets. In the Gulf of California, the land-sea breeze regime prevails through the year. It is weakest along the coast of lower Baja California.

Climate.- There are few weather problems when navigating these waters. Local winds, tropical cyclones and the Intertropical Convergence Zone (ITCZ) are the main ones. Winter and Spring are usually the best seasons, as the ITCZ is far south and tropical cyclones are rare.

The ITCZ is one of the principal precipitation areas in the world. Pronounced convergence, high temperatures, and strong convective activity combine to produce heavy year-round rainfall in this zone. The wet and dry seasons along the Central American and Mexican coasts can be traced to the movement of the ITCZ, and the dryness of Baja California reflects the limits of its northward movement. Other than the ITCZ, rainfall in this area comes from tropical cyclones and local showers.

Tropical cyclone activity is rare south of 10 degrees N, so this region is dependent on the ITCZ and local air mass showers for its rainfall. Annual totals along the Panama and the lower Costa Rica coasts average between 50 to 150 inches. These amounts depend on exposure; for example Palmar Sur, Costa Rica and Balboa Heights, Panama are at exactly the same latitude, but Balboa Heights (in the sheltered Canal Zone) records 70 inches annually, while the more exposed Palmar Sur is doused by 146 inches. Characteristic of rainfall in this area is a relatively dry winter, followed by a secondary maximum in spring, a lull in summer, and a peak in fall (usually October). At Palmar Sur a 2-inch average in February gives way to a 17-inch average in May, which drops to 15 inches in August, and peaks near 33 inches in October.

Along the coast from upper Costa Rica to Guatemala, annual averages range from 50 to 80 inches. While few tropical cyclones cross this stretch of coast, many form in offshore waters and spread rain along the coast. Maximum totals are recorded in October or September, a secondary is observed in June, and a minimum occurs in February. Tropical cyclone activity is reflected in the high June average rainfall and the maximum 24-hour amounts which are highest in June; San Salvador, El Salvador recorded 7.6 inches, one June day.

Along the Mexican coast from the Golfo de Tehuantepec to Mazatlan, annual average rainfall ranges from 30 to 60 inches. This reflects the northward influence of the ITCZ plus vigorous tropical cyclone seasons. In years with exceptional tropical cyclone activity, yearly rainfall totals can reach 60-90 inches. Heaviest rainfall occurs in either June, August, or September, while smallest amounts are usually observed in March. The variation in rainfall between May and June is often dramatic; Acapulco records an average of 1.42 inches in May, and this jumps to 12.80 inches during June. A potent tropical cyclone can cause enough rain in 24 hours to nearly match the monthly average at many ports. In the dry season an average of less than 1 inch falls from about November through April.

Along Baja California and the northern Mexican coast, rainfall is scanty, averaging about 6-12 inches annually. This area depends on tropical cyclones for significant rainfall, and maximum amounts occur in September and October; extreme northern Baja California, under the influence of extratropical weather, has a winter maximum. An active tropical cyclone season in this region can increase amounts significantly; La Paz, which has an annual average rainfall of 7 inches, once recorded more than 24 inches in one year. Abnormal extratropical activity, usually associated with a breakdown of the North Pacific High, can cause monthly totals up to 8 inches as far south as the southern tip of Baja California. On the other hand, there have been below normal years when annual totals of 2 and 3 inches were common. In areas of light rainfall, totals are often more variable than in the wetter regions.

Over northern sections subsidence and divergence from the subtropical high produces a widespread inversion, resulting in a stable atmosphere and thunderstorms on 10 days or less each year. Conversely, convergence and convection near and within the ITCZ causes unstable conditions over southern sections, resulting in a high frequency of thunderstorms. Average days with thunderstorms range from less than 20 over open water to more than 100 along the coast each year. Thunderstorms occur throughout the year in the ITCZ, but concentrations over open water are most evident from June through October, and are often associated with tropical cyclones traveling westward along the ITCZ. Along the southern Mexican and Central American coasts, the ITCZ is only partially responsible for the high frequency of thunderstorms. Daily heating, nocturnal cooling aloft, and local squall lines contribute to frequent and often violent thunderstorms. Activity is most frequent along the southern Mexican coast from July through September and along the Central American coast from May through October. The arid coastal regions of northern Mexico, including Baja California, experience isolated thunderstorms mostly in July and August, and these are caused by intense coastal heating.

Cool northeast trades blowing over warm water, warm air moving over the cool California current, and convergence in the ITCZ are responsible for the cloudiness in this area. The range of mean cloud cover varies from 20 to 80 percent, while more common averages are in the 40-70 percent range. Divergent winds from the North Pacific High and a northerly overland flow are responsible for minimum cloudiness along the southern Mexican and Central American coasts. The cloudiest region lies in the area of minimum precipitation; over the seas in the northwest section, average sky cover is around 7/10. This is the area of fair weather cumulus that form as the northeast trades pass warm water.

From November through April there is an area of minimum cloudiness cloudiness along the Mexican coast. This results from a flow of cool, dry air, including the northers that originate in the Gulf of Mexico. At Salina Cruz, in the Golfo de Tehuantepec, clear conditions are found on 20 days or more each month from November through April; in December and January an average of 25 days each month are clear (less than or equal to 2/10 sky cover). Clear skies are also common along the Central American coast from December through March.

Summer is the cloudy season-the ITCZ is farthest north and the trades are more active. Cloud cover in the ITCZ ranges from 5/10 to 7/10 and is greatest during the summer and fall season. From May through September there is an average of 7/10 cloud cover along the Central American coast.

Visibility in this region is usually excellent. The main restriction is heavy rain in the ITCZ, which often reduces visibility below 5 miles but seldom below 1 mile. Fog is rare and is only found, with any degree of consistency, north of 26 degrees N.

South of about 15 degrees N, during the summer and fall, visibilities are reduced below 5 miles 5 to 10 percent of the time offshore, and reduced below 1/2 mile more than one percent of the time off the western Panama coast in the fall. At other times, visibility rarely drops below 5 miles, and south of 20 degrees N fog is almost unknown at sea. At night, fog may occasionally develop in narrow gulfs or estuaries, if there is little or no wind; it disperses shortly after sunrise. There is no season for such fog. Another restriction to visibility is a light dust haze that forms during the dry season and reduces visibility below 5 miles for as much as several days a month.

In the Golfo de Tehuantepec, visibilities are less than 5 miles from 0 to 5 percent of the time; the peak month is September which is the heart of the rainy season. In the winter season, visibility may be reduced to below 5 miles up to 3 percent of the time by dust haze from the offshore northers. Salina Cruz records genuine fog on about 1 day in June and 5 days annually. Fog frequency increases northward along the coast; at Mazatlan, fog is most frequent from March through May when it occurs on 1-3 days a month. A northwesterly flow over the relatively cool California Current is responsible for this increase.

At La Paz, fog forms when cool air moves over warmer waters. From December through May, fog at this port occurs, on the average, 2-4 days a month and 18 days annually. Along the west coast of Baja California, fog is most frequent from June through November when warm air is cooled by upwelling of the California Current. Visibility less than 1 mile is observed less in August and September than in other months during this period because of the high surface temperatures.

During this same period, visibility restrictions less than 5 miles occur from time to time over the northern Gulf of California. Just south of the Baja Peninsula there are 23 days annually, with visibility less than 5 miles and 8 of these days occur during May and June.

There are two temperature cycles in these waters. South of about 15 degrees N., temperatures are greatly influenced by the position of the ITCZ. The warmest season is February through April when the ITCZ is farthest south, resulting in clear skies and efficient radiational heating. From Balboa Heights, Panama to Acajutla, El Salvador, daytime readings are in the low 90's (degrees F), while nighttime lows drop into the low 70's. As the ITCZ moves northward, temperatures begin to fall and the rainy season becomes the cool season. Rainfall and cloud cover cut down on the radiation and the cool southeast trades also help to drop temperatures. October is usually the coolest month. Maximum temperatures range from the mid to upper 80's while minimums are in the low 70's.

North of 15 degrees N temperatures are more variable. Cooling is underway in November as air temperatures closely resemble the underlying sea surface temperatures. Temperatures increase southward; average daytime maximums increase from 71 degrees F at Ensenada to 88 degrees F at Acapulco. The greatest temperature increase is along the Baja California coast; the difference in the average November temperature is 12 degrees F between Ensenada and La Paz and only 9 degrees F between La Paz and Acapulco, a much greater distance. The cooling trend continues and by January, the advection of cool air is felt to 10 degrees N. Average daily minimums range from 65 degrees F in northern Baja California to the mid 80's along the southern Mexican coast. Nighttime lows range from the mid 40's to the low 70's. By May, the warming trend is in progress. Average daily maximum temperatures range from the upper 60's in the north to near 90*8DF along the southern Mexican coast. Nighttime lows range from the mid 50's to the low 70's. The warming trend in the north reaches a peak about August. The thermal equator reaches its maximum northward position and daytime highs range from the mid 70's in the north to near 90 degrees F along the southern Mexican coast; temperatures over the southern position are held down to near May levels by cloud cover and rain from the ITCZ. The temperature cycle is completed during September and October with the onset of cooling in the north.

Temperatures over the area rarely go above 110 degrees F or below 40 degrees F; one February night, La Paz recorded a 31 degrees F, while one hot August day, the temperature at Guaymas reached 117 degrees F. Temperatures are most variable along the Mexican coastline, La Paz, for example, has recorded a 108 degrees F reading, while Guaymas has recorded a 41 degrees F. The section between Manzanillo and the Guatemalan border is often the hottest. Temperatures along the Central American coast reach 100 degrees F or more, but cloud cover and rain keep this from being a common occurrence.

NORTHWESTERN NORTH PACIFIC (INCLUDING SEA OF OKHOTSK AND BERING SEA)

Day to day weather is largely determined by the almost constant progression of extratropical cyclones with their frequent gales and abundant precipitation. The result is cold, snowy winters with frequent blizzards and cool, rainy summers with persistent fog.

Extratropical Cyclones.- An almost continuous stream of extratropical cyclones move into and across the area. Many form in the waters around Japan and move northeastward into the Bering Sea or east-northeastward into the Gulf of Alaska. Occasionally storms will move off the Siberian continent across the Sea of Okhotsk and either Sakhalin or the Kuril Islands. Storms may also move north along the eastern or western shores of the Bering Sea and into the Bering Strait where they are

usually blocked by an arctic high pressure cell. Bering Sea storms are often in a mature stage and tend to stall and fill along the western or southern coasts of Alaska. Extratropical lows are most intense in fall and early winter, but most numerous in spring. Activity reaches a minimum during July and August, September is a short transition season and by October storms are numerous and intense.

Tropical Cyclones.- Hokkaido is on the northern border of the usual tropical cyclone paths. Most of these warm season storms start recurring farther south, hence are well east of Hokkaido by the time they reach 40 degrees N. Tropical cyclones that enter the Sea of Japan have the best chance of affecting the area, either in a tropical or extratropical state. Some typhoons turn extratropical as cold air intrudes into their circulation at temperate latitudes. These extratropical storms can grow to almost double the size of the typhoon while remaining almost as potent. The chances for a tropical cyclone, or tropical cyclone turned extratropical, to affect this area are best from July through September. The highest frequency is in September.

Winds.- Over the Sea of Okhotsk and the Bering Sea, winds may be characterized as variable. This variability is induced by the steady procession of extratropical cylones with their attendant frontal systems. Any monsoonal influence in this area weakens northward. In October there is a radical increase in wind speeds and gale frequencies. By November average wind speeds have reached a 20-knot annual maximum in the Bering Sea and are approaching the 22-knot winter maximum in the open Pacific waters. During the winter months, gale frequencies over 20 percent occur in the waters southeast of Kamchatka. Autumn and early winter winds are also very strong in the Sea of Okhotsk. South of 50 degrees N. winter winds show some evidence of the northerly monsoonal flow and can be expected up to 30 percent of the time in this area (42 degrees N.-50 degrees N.) North of 50 degrees N. prevailing wind directions shift counterclockwise around the Aleutian Low and clockwise around the Siberian High. Late winter average wind speeds drop to 17 to 19 knots in the Bering Sea as storms are in their decaying stages when they reach this area. Spring starts an overall decline in wind speeds as extratropical cyclonic intensity wanes. Average speeds drop to less than 15 knots by May. Low wind speeds are the outstanding summer weather characteristic. Averages are near 12 knots and gales are encountered less than 5 percent of the time throughout the area. Summer winds take on a southerly component.

Local Winds.- Modifications of the prevailing winds are almost always present in the vicinity of coastlines. The generally complex configuration and rugged terrain of this area's coasts and islands can greatly alter wind speed and direction. Local topography may cause increases in wind speeds through straits and passes and around capes or points. This can result in gusts or persistent winds of gale force. At the same time, sheltered leeward bays may experience only light and variable winds. Coastal winds tend to parallel the coastline. Along mountainous coasts air from the higher altitudes may strengthen coastal flow enough to cause gale force winds. This is most likely in autumn or early winter after temperatures have been abnormally low inland for several days. In the southern part of the area, the weak southerly monsoon permits development of land and sea breezes in summer. These winds may be felt out to 15 miles at sea.

Along the western shores of the Bering Sea the ravine or valley wind blows down to the coast, sometimes reaching 100 knots or more. Valley winds are most common in winter, spring, and fall. In summer, very strong winds occasionally blow into estuaries and may continue up river for 100 miles or more.

Coastal Winds-Hokkaido and the Kuril Islands. - Along most of the west coast of Hokkaido, westerly to northwesterly winds are common in winter and southeasterly through southwesterly winds in summer. Along the other coasts, winter winds are more variable while summer winds are commonly from the east through south. At Otaru southwesterly to westerly winds are most common and northwesterly to westerly winds are often strong enough to impede cargo handling. Extreme wind speeds have reached 54 knots in September. At Wakkanai westerly to northwesterly winds prevail from November through January; in February and March winds are variable, and from April through October, southwesterlies are common. Average wind speeds are highest in December (11 knots) and lowest in July and August (8 knots). Wind speeds less than or equal to 19 knots occur on an average of 13 days in January and 4 days in August. At Hakodate, westerly through northwesterly winds prevail from November through March while southeasterly through easterly winds are common in summer. Winds greater than or equal to 19 knots occur on about 12 days per month in winter and 3 days per month in summer. At Muroran, northwesterly winds which raise a sea occur from mid-September until the end of March. In Nemuro Kaikyo gales accompanied by rain or snow are common from November through March while southeasterly winds may be accompanied by squalls in May and June. At the port of Nemuro, winds greater than or equal to 19 knots occur on about 12 days per month in winter, but only 2 days per month in summer.

Wind speeds in La Perouse Strait average 16 knots during winter. Gales are most frequent in December and January with squalls common in November and December. Summer winds are usually light, averaging 6-8 knots from May through August. Strong local southwesterly winds are often encountered off the northwestern tip of Hokkaido in summer, and frequent northeasterly blizzards occur along southern Sakhalin during January and February.

Due to the close passage of extratropical lows, winds are variable in the Kuril Islands. The coasts of Ostrov Kunashir are the scenes of many northwesterly blizzards in winter. At Reyd Tyatinskiy, northwesterlies often bring good weather in winter. In the spring easterlies and southeasterlies are frequent and bring fog. Near Ostrov Iturup, strong northwesterlies raise heavy seas from November through April. At Zaliv Kasatka, occasional southeasterly gales raise heavy seas during February and March. In Zaliv Shelikhova, easterly gales often blow off the mountains.

Southeast Coast of Soviet Union, Sakhalin and Tatar Strait.- In this area, winter winds are northerly in the south and change to northwesterly farther north. Summer winds are more variable and lighter with prevailing directions opposite those of winter. At Vladivostok, winter wind speeds usually increase from 8 knots in the morning to 10 knots by afternoon. Summer winds also have a diurnal range of 2 knots as average speeds increase from 5 knots to 7 knots. Winds of 28 knots or more occur on 3-5 days per month from September through May and on only 1 day per month in July. At Nikolaevsk, gales are common on about 2 days per month in November and December.

Along the west and east coasts of Sakhalin, winter winds are usually from the northwest; in summer southeasterly winds at night usually veer to southerly or southwesterly in the middle part of the day. At Kholmsk average wind speeds vary seasonally but not diurnally. They range from 5-7 knots in June and July to 10-13 knots from October to February. Gales are rare and, even in the winter months, are observed on just one day per month. At Aleksandrovsk winter winds are frequently out of the east and southeast but the northwesterly winds are stronger. Here the average number of days with gales ranges from 7 in October to 2 in June and July.

Sea of Okhotsk, Kamchatka, and in Bering Sea.- Along these coasts, summer and winter prevailing winds are often directly opposite. In general, winds are offshore in winter and onshore in summer. Much of this coastal region is mountainous; this results in very local winds flow. On the southern shores of the Shantarskoye More, the winter monsoon is predominantly westerly and changes with the lie of the coastline; it becomes northwesterly and then northerly between Udskaya Guba and Okhotsk. Between Okhotsk and Penzhinskaya Guba, the prevailing winter direction is northeasterly while summer winds are much more variable. Gales are frequent on some parts of this coast. For example, at Pestraya Dresva, winds of 28 knots or greater occur on an average of 2 days out of every 3 from November through February. At more protected locations like Okhotsk, this frequency drops to about 1-2 days per month. Along the west coast of Kamchatka, winds of 28 knots or more occur on 10-11 days per month during March and April and 1 day or less per month from July to September. At Ozernaya these wind speeds occur on 4-8 days per month from November through April and are rare from July to September.

Along the southeast Kamchatka coast, mean wind speeds show a large seasonal variation. At Petropavlovsk, summer wind speeds average 7-8 knots while winter speeds average 15-18 knots. The average frequency of winds with speeds of 28 knots or more ranges from 5-7 days per month from October through April to 1 day per month in June and July.

Coastal winds north of Petropavlovsk show a marked reversal of direction in June and a remarkably high percentage of calms. For example, calms are more prevalent than any wind direction at Ostrov Beringa from September through November. At Anadyr, calms are frequent in April and May while at Uelen they are frequent in winter and summer. Wind directions are influenced by the shape of the coastline; this results in prevailing winds from the north through northeast from about October through May. Summer winds are mainly from the south of southeast. For example, at Ust Kamchatsk winds are out of the south more than 45 percent of the time during July. Mean wind speeds show little diurnal variation but a definite seasonal change. Average winter winds range from 12-20 knots from the Kamchatka Peninsula to the Bering Strait. During the summer, these speeds drop off to 6-8 knots south of St. Lawrence Island and to 6-12 knots in the Bering Strait. Gales occur on 5-8 days per month in winter and on less than 1 to 2 days per month in summer. At Uelen, however, the change from a due north wind to a July south wind, brings an increase of from 1 day with gales to 6 days with gales.

Climate-Hokkaido, Sakhalin, and the Sea of Okhotsk.- This is an area where many factors influence navigation. In winter, ice, winds and seas severely restrict navigation in these waters. During spring and summer, fog is an important navigational hazard and by autumn, seas and winds are again a factor. However, take all these parameters into consideration and fall becomes the best time of the year and winter the worst, for navigating these seas. For it is autumn that ice is uncommon, winds and seas are still well below their winter peaks, and fog frequency has slackened from its summer maximum.

Coastal precipitation decreases northward in general. Average annual amounts range from 47 inches on the Hokkaido coast to 15-17 inches along the shores of the Sea of Okhotsk. About one-half to one-third of these annual amounts accumulate from July through September; however, some locations record a maximum monthly amount in October or November. Winter rains are sparse and light with most monthly averages less than 1 inch. Snow can be expected in September over the northern Sea of Okhotsk and by October along the entire coast. The snow season extends till May in the south and June in the north. There is a wide variation in the number of days that it snows. Along the leeward Russian coast, on the Sea of Japan, snow occurs about 15-20 days annually, and 2-3 days in December and January. A short distance across the sea, Otaru, Japan, on a windward coast, has snow about 124 days annually and on about 30 days every January. Sakhalin shores receive snow on about 70-90 days annually while 40 to 60 days of snow are observed around the shores of the Sea of Okhotsk. Aside from Hokkaido, snow days range from 3-19 per month during winter. Blizzards occur frequently in winter, especially on coasts exposed to north and west winds.

Thunderstorms are least frequent in late winter and early spring and most frequent in summer and fall. For example, at Hakodate, thunderstorms are rare from January to March but occur on 1-3 days per month from June to November. In the Kurils thunderstorms are infrequent but occasionally occur on as many as 3 days in one summer or fall month. Along the Sea of Okhotsk, a rare thunderstorm is observed during the summer.

Monthly and annual rainfall averages can be misleading in this part of the world. For example, Okhotsk which has an average annual fall of about 15 inches has recorded more than 26 inches in a single year and less than 5 inches in another year. Their July average is 2.56 inches but this includes an 11.10-inch total and a 0.39-inch total.

Year around, the Sea of Okhotsk-Tatar Strait-Northwest Pacific Ocean area is one of the cloudiest regions in the Pacific. Extratropical cyclones are responsible for this cloudiness; they are aided in summer by the fog and low stratus clouds, that form as warm, moist air from the south flows northward over the progressively colder seas. The cloudiest region is over the waters east of the Kuril Islands.

Early summer brings almost endless cloudiness to this region. Average cloud cover over the Sea of Okhotsk is about 8/10 while along its shores cloud cover ranges from 6/10 to 9/10. In July, overcast conditions can be expected on 25-27 days on this coast. East of the Kurils, average cloud cover in July is 9/10. On the southeast Kamchatka coast and in the Kurils, summer cloud cover is around 6/10. Cloud cover decreases in August, particularly over the Sea of Okhotsk, as prevailing southerly winds start to change to northerly. Cloud cover averages drop off to around 6/10 in the northwest section of the Sea but remain around 8/10 southwest of Kamchatka. September and October are usually the clearest months of the year since cyclonic activity is still weak in this area; fog disappears with the more northerly flow. Cloud cover drops to 5/10 in the northwest part of the Sea of Okhotsk and is generally less than 70 percent elsewhere, except near the west coast of Kamchatka. Along the Hokkaido coast, average cloud cover is least in October when it ranges between 5/10 and 6/10. There are 12-15 days with clear skies during this month. By November, water in the northern Sea of Okhotsk has started to freeze near the coast, so it loses potential as a moisture source. The result is an average cloud cover of 5/10 in these waters and 7/10 over the eastern seas. Winter brings increased cloudiness to areas lying near storm paths and areas exposed to a northerly flow. For example, at Kuri'sk and Otaru, January is the cloudiest month of the year. However, where northerly winds blow off the frozen sea surface or the continent, cloud cover is likely to reach a minimum in winter. For example, along the Russian coast at places like Vladivostok, Grossevichi, Aleksandrovsk and Okhotsk, average cloud cover is less than 4/10 and there are 15-20 days per month with clear skies.

By April, cloudiness over the northwestern Sea of Okhotsk has increased to about 6/10 while an overcast area appears off the southwestern Kamchatka coast. Coastal areas of Hokkaido are relatively clear during this period, but on many other shores cloudiness is increasing toward its early summer maximum. There are usually 15-20 cloudy days along these coasts in April. May cloudiness is rather uniform over the area and is continuing to increase in the Sea of Okhotsk and Tatar Strait.

The waters along the east coast of Kamchatka and around the Kurils are the foggiest in the world during the summer. Visibili- ties less than 1 mile occur up to 60-70 percent of the time in these waters. In general, fog frequently reduces visibilities below 1 mile in summer, while winter precipitation often reduces it below 5 miles.

Summer advection fog occurs as warm, moist air creeps in over the cold, muddy-green Oyashio current and the Sea of Okhotsk. As a result, fog frequency increases from late May until it reaches a peak in late July. During this peak period, visibilities less than 1 mile attain a frequency of 60 percent or more over the central Kurils and along the east coast of Kamchatka. Visibilities less then 5 miles can be expected up to 80 percent of the time. Fog can be expected on up to 26 days per month along the west Tatar Strait coast and from 4-18 days elsewhere. The most fog-free areas are around Hokkaido, along the western shores of the Sea of Okhotsk, and on the west Sakhalin coast.

Visibilities continue to be poor in the Sea of Okhotsk until late August when winds begin to blow off the Asian continent once again. During September conditions improve slightly over most of the area. However, visibilities less than 1 mile still occur up to 35 percent of the time over the central Kurils. In October, visibilities less than 5 miles are becoming the main problem; they reach a maximum frequency of 40 percent around the Kuril Islands. By November, winter has begun to settle in, and reduced visibility frequencies are patterned after the precipitation frequency distribution. Visibilities less than 5 miles occur less than 25 percent of the time, except around northern Hokkaido and southern Sakhalin where visibilities are often reduced by weak snow squalls. Occurrence of visibilities of less than 1 mile are less than 5 percent in November. Poor visibility frequencies increase from December through February with the increase in intensity and number of extratropical cyclones. Visibilities less than 5 miles are encountered 35 percent of the time in the waters east of the Kurils and up to 40 percent of the time to the east of Hokkaido. Visibilities of less than 1 mile are mainly encountered in the southeastern Sea of Okhotsk and east of the Kuril Islands, where they occur a little more than 5 percent of the time. During the winter radiation fog is apt to occur on calm, clear nights at some of the more protected ports. For example, at Vladivostok, fog can be expected on 2-3 days per winter month. Even so, fog is at a minimum along nearly all coasts in this season. During March and April, visibility restrictions increase everywhere except along the Hokkaido coast where they remain at a minimum. During this period the center of maximum restrictions begins to spread northward from the southern Kurils until, by May, visibilities less than 1 mile occur 35 percent or more of the time along the central Kurils.

The cold Oyashio current, winter ice, and monsoonal flow combine to make this region continental in terms of temperature. This means a large diurnal and seasonal variation and a large difference in extremes. Temperatures over water are warmest in August when average temperature range from 50 degrees F in the northern Sea of Okhotsk to near 70 degrees F west of Hokkaido. The effect of the Oyashio current is evident in the seas east of Hokkaido, where air temperatures are about 6 degrees F cooler than they are over the waters to the west. Also average temperatures reach a secondary minimum in the low 50's, around the Kurils, under the influence of this cold current. Summer daytime coastal temperatures range from the

upper 70's around Hokkaido to the low 60's along the north Sea of Okhotsk coast. Nighttime lows range from the mid 60's in the south to the lows range from the mid 60's in the south to the upper 40's in the north. Extreme maximum temperatures are observed during the summer and most ports have records of 90 degrees F or greater. For example, Okhotsk, one of the northern ports, has recorded a 97 degrees F temperature.

An abrupt change in average temperature takes place in November. South of Sakhalin, October daytime temperatures in the 50's and 60's drop into the 40's and 30's and even mid 20's while nighttime lows fall into the 20's and 30's. For example, at Khabarovsk, a 50 degrees F daily maximum in October drops to 24 degrees F in November. Along the Sea of Okhotsk coast, daytime highs are in the 20's and nighttime lows drop to the teens and below. Over water, air temperatures decrease rapidly, both northward and eastward. The average freezing line extends from about the middle of the Tatar Strait, east-northeastward to the southern tip of the Kamchatka Peninsula.

During the winter, over water, the average air temperature freezing line extends from northern North Korea east-northeastward to southern Hokkaido and then northeastward to the mid Aleutians. Lowest coastal temperatures are most likely in January. Along the frozen coasts of the Sea of Okhotsk, temperatures climb to a little above zero during the day and fall into the minus teens at night. Warmest winter temperatures are found on Hokkaido where daytime highs average near freezing and nighttime minimums are in the upper teens to low 20's. The influence of the continent and slight modifying effects of the water can be seen by comparing temperatures at Vladivostok with those at Otaru. The mean daily maximum is 29 degrees F at Otaru and 13 degrees F at Vladivostok, while the mean daily minimum is 19 degrees F at Otaru and a cool 0 degrees F at Vladivostok. Both ports are at approximately the same latitude. The continental influence is even more apparent when both these ports are compared with La Coruna, Spain, at about the same latitude, which has an average daily maximum of 55 degrees F, an average daily minimum of 44 degrees F, and an extreme low of 34 degrees F. Extreme minimum temperatures in our region drop to 0 degrees F at Otaru, to a -50 degrees F at Okhotsk and to a -22 degrees F at Vladivostok.

There is a more gradual temperature change in spring than there was in fall, except along the north coast of the Sea of Okhotsk where average temperatures jump 15 degrees to 20 degrees F from March to April. Daytime highs in the teens and 20's in March climb into the 30's in April. Farther south, temperatures gradually increase from February on. By May, daytime highs are in the 50's and low 60's, while nighttime lows drop to the mid 30's to mid 40's. Over open water, average air temperatures are also rising and the freezing isotherm has retreated into the far northern reaches of the Sea of Okhotsk. Average air temperatures are around 50 degrees F off southern Hokkaido.

Bering Sea and East Coast of Kamchatka- Many factors influence navigation in the Bering Sea. Winds and ice in winter, fog in spring and summer, and winds and seas in autumn. Taking all parameters into consideration, winter is by far the worst season and spring is best. Spring is just a little better than summer, which is a little better than fall. In spring, winds have died down from their winter maxima, fog has not reached its peak, ice is beginning to thaw and seas are as calm as they are during any season. The frequency, intensity and amount of precipitation are related to the available water vapor in the air which, in the northern Bering Sea, in winter is restricted by cold temperatures and lack of moisture sources. The large number of extratropical cyclones account for the substantial precipitation over the southern Bering Sea. For example, Uelen, in the north, has an average annual total of 11.8 inches compared to a 65-inch average at Adak in the Aleutians.

In autumn, precipitation occurs 25 percent or more of the time in a band from the Aleutians northward to about 58 degrees N. At St. Paul Island, for example, precipitation occurs on 20-22 days per month from September through November. Over the northern Bering Sea, frequencies range from 15-25 percent and by October most of the precipitation is snow. In the south, snow is rare before November. Winter is the rainy season across the southern Bering Sea where precipitation occurs from 15 percent to greater than 30 percent. In the north, these frequencies run 10 to 15 percent, almost all of which is snow. In the south, snow and sleet occur 15-20 percent of the time that there is precipitation. Along the east Siberian coast, average monthly winter amounts range from 2- 3 inches along the east coast of Kamchatka to a scanty 0.3 inches at Anadyr. In spring, precipitation frequencies drop off to 10-15 percent with snow seen only 5-10 percent of the time when precipitation occurs in May. Many coastal locations have minimum monthly amounts from March through June. Summer precipitation reaches a maximum in the north and is on the increase in the south. Coastal monthly averages in summer range from 3.5 inches at Ust Kamchatsk to 2.1 inches at Uelen. Thunderstorms are rare even in summer, when at most, an average of one occurs along the Alaskan coast and in the Aleutians.

Cloudiness in the Bering Sea is produced by extratropical cyclones aided in the summer by warm air advection. In the fall average cloud amounts range from 7/10 along the Siberian and Alaskan coasts to more than 8/10 in the Bering Strait and over the southern Bering Sea. Along the east coast of Kamchatka and Siberia, skies are cloudy (sky cover greater than or equal to 8/10) about 10-18 days per month while near the Strait, at Gambell, cloudy skies are observed an average of 25-27 days per month. Cloudiness diminishes to less than 6/10 in the winter over the northern Bering Sea. Along the Siberian coast offshore winter winds are often associated with clear skies. For example, at Anadyr in January an average of 10 days have clear skies (sky cover less than or equal to 2/10). At Uelen, there are about 10 cloudy days in January, compared to 22 cloudy days at St. Paul Island in the south. Average cloud cover is around 7/10 or more over the southern Bering Sea.

Spring and summer are the cloudiest seasons in general. A significant change occurs from April to May when mean cloud amounts increase, particularly in the north where seas are thawing. Mean cloud amounts are about 8/10. Along the

Kamchatka and Siberian coasts, cloudy skies are observed on 15-25 days per month; the highest frequency is in the south. Frontal activity and warm air advection bring a greater than 9/10 mean cloud cover to the Aleutian Island region in June and to almost the entire Bering Sea by August. Coastal areas observe overcast conditions on 25 days per month or more. Fog and stratus are a major factor aided by a maximum in extratropical activity north of 60 degrees N. Toward the end of August and in September, a decrease in cloudiness becomes apparent.

Visibility is affected by rain, snow, fog, arctic haze, inferior and superior mirages, and extended periods of twilight. Rain, arctic haze, mirages and twilight cause frequent restrictions of less than 5 miles but, except for rain, rarely produce restrictions less than 1/2 mile. As fall progresses daylight hours decline; this lack of illumination noticeably reduces the distance at which objects may be identified. During the fall, snow and blowing snow gradually replace rain and fog as restrictions to visibility over the northern Bering Sea and rain replaces fog in the south. In autumn, visibilities less than 5 miles are more common than visibilities less than 1 mile and they occur 15-20 percent of the time over most of the sea; they reach 25 percent in the Gulf of Anadyr. Most coastal locations observe fog on 1-2 days per month. In winter north of 60 degrees N, snow and blowing snow reduce visibilities to less than 5 miles 15-20 percent of the time; visibilities less than 1/2 mile are observed 5-10 percent of the time. Farther south, snow and rain cause visibilities less than 5 miles 15-20 percent of the time while visibilities less than 1/2 mile are rare. Ice and steam fog occur locally in winter. Ice fog occurs when moisture is introduced into very cold air (usually with a temperature of -20 degrees F or colder). This fog is shallow but may cover a ship when moisture is produced by engine exhausts and steam outlets. Steam fog occurs above frozen seas when strong tides or other phenomena crack or break the ice and expose lanes of water to the extremely cold air above. Steam fog, called arctic smoke, covers small areas and normally dissipates rapidly. It can often be used to identify open water in winter.

By spring, the frequency of poor visibilities is on the rise with an increase of fog and rain. In and around Bristol Bay, visibilities less than or equal to 1/2 mile occur 5-15 percent of the time and elsewhere 5-10 percent of the time. By May, fog is observed up to 9 days per month along the Kamchatka Peninsula and Siberian coast. June, July and August bring the worst visibilities. Fog is particularly intense south of 60 degrees N, over the north- western Bering Sea and in the Anadyriskiy Zaliv. Visibilities equal to or less than 1/2 mile occur greater than 40 percent of the time off Mys Olyutorskiy and 15 percent or more of the time west of 175 W. They occur between 5 and 15 percent elsewhere. Visibilities less than 5 miles occur up to 65 percent of the time north of the western and eastern Aleutians. They occur from 30-50 percent of the time over the northwestern Bering Sea and 10-25 percent of the time from Norton Sound to St. Lawrence Island. Fog occurs on 10-20 days per month along the western Bering Sea coast. As summer comes to an end, a general improvement in visi- bility sets in over the entire area.

Air temperatures are colder than those at comparable latitudes in the Atlantic due to lack of a major warm ocean current, the proximity of permanent polar ice and the strong continental influence. In general, the cold Oyashio current brings coldest air temperatures to the western Bering Sea. The annual range of average monthly temperatures is up to 50 degrees F in the north and around 20 degrees F in the south. Average winter temperatures over the open sea range from around 36 degrees F in the eastern Aleutians to 0 degrees F in the Bering Strait, and a -4 degrees F in the northern part of Anadyriskiy Zaliv.

Along the east coast of Kamchatka, average daily maxima range from 15 degrees to 20 degrees F while minima range from 2 degrees to 10 degrees F. Farther north, temperatures drop rapidly and at Anadyr in January, the average daily maximum is -9 degrees F and the minimum is -18 degrees F. Extremes range from a -51 degrees F reading at Anadyr to 10 degrees -12 degrees F readings in the Aleutians.

By May, incoming solar radiation is approaching a maximum and pronounced warming is apparent. In the north, average temperatures have risen 25 degrees to 30 degrees F since February. For example, at Anadyr, the average daily maximum rises from a -5 degrees F in February to 30 degrees F by May. Average air temperatures over open water in May range from the low 40's in the Aleutians to about 25 degrees F in the Bering Strait, and the freezing isotherm is north of 60 degrees N. Along the east Kamchatka coast, average daytime highs are near 40 degrees F and lows are near freezing. Maximum temperatures usually occur in August. Average temperatures range from the low 50's along the Aleutians to about 45 degrees F over the Bering Strait. Even along the coast the range of temperatures is small. At Petropavlovsk, the average daytime maximum is 59 degrees F compared to a 52 degrees reading at Anadyr. These two ports have a 30 degrees F spread in January. Nighttime August lows are usually in the 40's. Extreme maximums reflect the continental influence; they range from 84 degrees F at Petropavlovsk to 75 degrees F at Anadyr. This can also be seen when comparing the 75 degrees F extreme at Ust-Kamchatsk with a 63 degrees F at the nearby island location of Ostrov Beringa.

In September temperatures gradually begin to fall, and by October ice is forming along the northern Bering Sea coast. Average air temperatures in November range from the low 40's in the Aleutians to around 8 degrees F in the northern Gulf of Anadyr. The freezing isotherm is between 56 degrees and 57 degrees N. Along the coast, temperatures take their biggest fall from October to November. This drop averages about 15-20 degrees F. At Anadyr, the average daily maximum drops from 25 degrees F in October to 6 degrees F in November. At Gambell, a more maritime location, the average daily maximum drops from 35 degrees F in October to 27 degrees F in November.

SOUTHWESTERN NORTH PACIFIC
(INCLUDING EAST CHINA SEA, YELLOW SEA AND SEA OF JAPAN)

Extratropical Cyclones - These storms often follow two paths. In the north lows originating over mainland China or eastern Siberia move southeastward toward northern Japan and then swing east-northeastward. A second tract begins either in the South China Sea or near the Ryukyu Islands and parallels the east coast of Japan. These storms begin as weak systems but intensify rapidly over water. In winter they are intense and bring cloudiness, strong winds, and snow or heavy rain. Korea is less affected than most coastal areas; however, occasionally an intense storm in the waters adjacent to Korea will cause strong winds and snow, particularly along the southern coast.

Extratropical cyclonic activity frequency reaches a peak in May and June in the seas off the mainland, then declines rapidly to a minimum by July. After September there is an increase in storm activity along the northern tracks, and by December lows are common along both paths. Throughout the year the waters east and south of Japan are the breeding grounds and areas of intensification for extratropical cyclones, particularly during the winter and spring. Spring and summer storms are often weak systems bringing just cloudiness and rain.

Tropical Cyclones - Most of this region's 30 annual tropical cyclones are observed from July through September. An average of 20 of these tropical cyclones reach typhoon strength (winds greater than or equal to 64 knots). The seas east of Taiwan are the hotbed of activity with an average of 4-5 tropical cyclones (tropical storms and typhoons) each season. An average of 3 tropical cyclones pass just south of southeastern Honshu. Korea's south coast can expect one tropical cyclone each season while the Yellow Sea hosts one every 2 years.

The waters around Taiwan and the Ryukyu's are often the site for any pre-May tropical cyclones. By May, a storm will occasionally reach the southeast coast of Honshu or the East China Sea. August and September are the most likely months for encountering a tropical cyclone. They are most likely in the waters off southeastern Honshu in August and off Taiwan in September. A full-fledged typhoon is always more likely in the southern portions of the region. Tropical cyclones cross the China coast between Hong Kong and Tsingtao several times each year. The most active area lies between Hong Kong and Fu-chou during September. Typhoons passing east of Honshu do not usually affect northern Honshu or Hokkaido. However, the storms that enter the Sea of Japan usually remain intense either as tropical or extratropical storms and move eastward across northern Honshu or Hokkaido. Most of the tropical cyclones that strike Korea have been weakened by the cold water and mountainous terrain. Rainfall from these weak storms can be destructive, particularly on Cheju do and along the southern and western coasts of the Peninsula. Land areas of the southwest Pacific are susceptible to severe flooding and land- slides. These conditions are caused by the torrential rains over mountainous terrain and are as likely with a tropical depression as with a typhoon.

The supertyphoon is the name given to the violent tropical cyclones of this region that generate maximum sustained winds greater than or equal to 130 knots. An average of 6 typhoons each year reach this supertyphoon category. Most occur from June through December with September the most likely month. The Philippine Sea is the area where a typhoon is most likely to first achieve the super category; the most likely areas of encounter in the region under consideration are east of Taiwan and the Ryukyu Islands. Tropical storm and typhoon roses, by 5 degrees squares, giving frequency, speed and direction of movement of these vicious storms, can be found in the atlas appearing in the appendix.

Winds - Two monsoonal systems are responsible for the general wind circulation in this region. Winds generally have a southerly component in summer and a northwesterly component in winter. The winter monsoon is stronger. Topography and migratory lows exert a strong influence on these general wind patterns. Ports protected by mountains often experience light and variable winds while those less protected have stronger, less variable winds. Lows moving along the southeast coast of Japan cause variation in wind directions over those waters. Strongest winds in the region occur along the west coast of northern Honshu and in the cyclonically active region along the southern coasts of the Japanese mainland and northern Ryukyu Islands.

During the fall, the northwest (winter) monsoon advances southeastward from the Asian continent. It gradually increases in strength and steadiness so by November's end, winter winds have pervaded the entire region. Average wind speeds range from 12-20 knots over open waters. The first signs of slackening usually come in March with diminishing cyclone intensity and a weakening of the Siberian High and Aleutian Low. Gradually a reversal of flow known as the southerly monsoon takes charge as a low replaces the winter High in eastern Asia, and the North Pacific High moves into our ocean area. During the summer, wind strength continues to decline and reaches an annual minimum. Wind directions are most variable in the transition seasons (May, September) between monsoons.

Gales occur infrequently in the seas off the mainland. They are most likely during the winter monsoon and are often associated with extratropical or tropical cyclones. During the winter months gale frequencies of over 10 percent occur in the waters east of Japan. Extreme winds in the area are associated with typhoons. Highest wind speeds have occurred along the south Taiwan mainland and in the Ryukyu Islands where gusts in excess of 150 knots have been reported.

Local Winds - Wind directions and speeds are affected by local topography and land-sea interaction. Land and sea breezes are well-marked along most of this region's coast. This regime is strongest in spring and summer. These breezes are caused

by the unequal heating of land and water. When the land is well heated in the forenoon, the sea breeze beings flowing in. It dies down in the evening and during the night is replaced by an offshore breeze. The influence of these breezes in confined to within 20 miles of the coast. During the winter season, particularly along the Sea of Japan coastline, the regime is overcome by the strength of the monsoon. Some sections of Naikai coastal areas have the land and sea regime throughout the year, although it is most pronounced during the summer.

The Foehn wind is a dry, warm, gusty wind which occurs when an airstream is forced over a mountain range and descends the lee slopes. The air becomes relatively warmer and drier before reaching the shore. Foehn winds occur frequently along the east coast of Korea from Wonsan to Unggi, when a high moves over the peninsula behind a cold front that spawns a cyclonic disturbance over the Sea of Japan. Pressure gradients then cause strong westerly winds to move down mountain slopes. These winds also occur along the east coast of Japan.

The fall wind occurs when very cold air spills down the mountains and, even though warmed in its descent, remains colder than surrounding air after it has reached the coast. A local wind known as Hiroto Kaze occurs just east of Tsuyama, Honshu. It is a strong north wind with speeds from 35 to more than 60 knots. This wind usually occurs between late evening and noon in later summer and fall. Generally it occurs when a typhoon is south of Shikoku but may also occur with the passage of a strong cold front. In the Tsugaru Kaikyo, southeasterly winds are called Yamase. Such winds occur in advance of lows moving eastward or northeastward over the Sea of Japan. They are often moderate to strong in the strait and can be accompanied by rain or snow. They arise suddenly. In summer, Yamase are usually light but may persist for a week at a time.

Coastal Winds - Taiwan - The topography of Taiwan, featuring a ridge of north-south running mountains extending the entire length of the island, causes deviations in the air flow. One of the outstanding winter characteristics is the high frequency of strong winds and gales. For example, at Hengchun there are, on the average, 22 days in December with winds equal to or greater than 19 knots; on 13 of these days winds exceeded 28 knots. At Taipei the mean number of days with winds of 19 knots or more range between 10 and 14 from October through April, and 58 from June through September. However, the most likely time for wind speeds greater than 56 knots is August, September and October. In general, gales (winds greater than or equal to 34 knots) occur 5-7 percent of the time along the coasts from October through December and 2-3 percent of the time from January through March. Gales are most prevalent along the northwest coast of Taiwan, on the Peng-hu Lieh-tao (Pescadores Islands) and on other islands in the Formosa Strait. Strong winds are most likely during the afternoon hours along the northwest coast, but over the islands, they are apt to occur at any hour. May is consistently the most gale-free month. Coastal winds are mainly monsoonal with the northeast monsoon well established from October through March when north through northeast winds average about 12 knots. The monsoon reaches a peak in December and January when over 85 percent of the coastal winds are from the north or northeast at an average speed of 16 knots. April and May are transitional months and by June, the southwest monsoon has set in. During June, July, and August, winds are south or southwest about 50 percent of the time at an average speed of about 7 knots. The southwest monsoon is often subordinate to land and sea breezes.

Japan - The land-sea breeze regime is well-marked and most noticeable in late spring and summer. In winter, under the influence of the northerly monsoon, wind directions vary only slightly from day to night. In summer, during lulls in the southerly monsoon, there may be no winds other than land and sea breezes.

Naikai (Inland Sea) - Winds in these waters are greatly modified by the land, time of day, and season. For example, at Shimonoseki, winds channeled by the neighboring strait, are easterly in the morning and westerly by late afternoon during the period from February to May. Average wind speeds run 2-5 knots in the morning and 6-10 knots during the afternoon. Winds near prominent capes differ widely from those at sea. For example, when a strong northerly wind is blowing in Kii Suido, there may be a light, easterly or westerly wind at Shiono Misaki. Osaka offers an excellent example of the harboring effect of topography. In its sheltered position at the eastern end of the Naikai, gales are unheard of except in the rare case of a close typhoon passage. Prevalent winds are from the west, year round, illustrating the deflective force of topography. In winter these westerly winds may blow strongly for a week or more, bringing in a sea which may make cargo handling difficult. Northwesterly winter winds, crossing Osaka Wan, often split into two streams as they reach the southeastern shore. One blows up the Yodo Gawa, while the other blows southwestward along the coast toward Kii Suido.

Gales are infrequent in the Naikai. From December through April most gales are due to passing extratropical lows. Usually, the approach of a storm causes a weakening or reversal of the monsoonal gradient. With the passage of the cold front, the northerly flow returns and is often intensified. Summer gale frequencies are much less, but winds may reach extremes due to typhoons. Hiroshima, for example, has reported a 60-knot wind with gusts to 95 knots in October while Shimonoseki has recorded an easterly wind of 66 knots with gusts to 86 knots in August. In Murotsu Wan, at the southwestern approach to Kii Suido, winds are relatively strong throughout the year. In Bungo Suido and Kii Suido, strong northerly winds often reach gale force during the day, in winter. Locally, these winds will follow the coastline rather than the direction of the mid-channel wind.

Southern Japan Coasts. - Along the southern coasts of Honshu and Shikoku, the land-sea breeze regime prevails, particularly in summer. Most of the Shikoku coast is relatively sheltered in winter and winds tend to be light. On Kyushu, the northern and western coasts are exposed to the winter monsoon, but the east coast is sheltered. In Ise, Suruga, and Tokyo Bays, the winter monsoon is northerly rather than northwesterly, owing to the general north-south trend of the coastline;

gales occur mostly in the afternoon. Tokyo and Nagoya are well sheltered and gales are rare. Extreme wind speeds were 72 knots during a September typhoon at Nagoya and 60 knots during a September typhoon at Tokyo. Between the southern Honshu coast and Hachijo Shima, winter gales are frequent since a large number of storms pass through this area.

At well-protected Kochi, Shikoku, average wind speeds range from 4 knots in winter to 2 knots during the summer. Extreme winds have reached 50 knots with gusts to 78 knots. At more exposed points on Shikoku, like Muroto Zaki, wind speeds are much higher.

On Kyushu, there is a strong diurnal variation in wind, which, while strongest in summer, is noticeable at many locations even in the winter months. For example at Nagasaki, diurnal variation is most noticeable in the winter when average morning wind speeds of 6-7 knots increase to 10-11 knots by afternoon. The port of Sasebo is well sheltered from the onslaught of typhoons; its extreme wind is 42 knots. Nagasaki has an extreme wind of 86 knots, while Kagoshima's extreme is 96 knots.

Chichi Shima is representative of the Ogasawara Gunto (Bonis Islands); winds from the west and north prevail from December through February. March and April winds are variable, May and June winds are from the southwest quadrant, and from July through October easterly winds prevail. Wind speeds show slight diurnal variation; they average 3-6 knots during the morning and 5-7 knots during the afternoon. Gales in these islands are infrequent since most storms pass well to the north. However, the region is vulnerable to typhoons.

In the Ryukyu Islands the winter monsoon blows mainly from the north and northeast. Winds are often strong, bringing rough seas and are accompanied by cloudy, showery weather, particularly on the island's northern coasts. Winter gales are most common with cold front passages and almost always come from a northerly direction. At Naha, Okinawa, wind speeds of 28 knots or more occur about once a month from August to January. The area's worst weather, occurs in the Osumi Kaikyo. Lows often pass close to this strait resulting in sudden large changes in wind direction and speed.

East Coast of Honshu and the Tsugaru Kaikyo - From Tokyo, northward, prevailing winds blow offshore and are less strong than those over open waters. At Mikayo, winter winds blow between west and southwest throughout the day. The same winds prevail during the spring, summer, and fall mornings and evenings. However, in the middle part of the day, spring and fall winds are variable, while summer winds are mostly from the north. Average wind speeds range from 6 knots in April to 3 knots in July. While winds equal to or above 19 knots occur on about 9 days in March and just 1 day in July. At Hachinobe, southwesterly to westerly winds are most frequent throughout the day from November through April. From May through October, southwesterlies continue to be most frequent during the night and early morning while easterly winds prevail during the day. Winds 19 knots or greater occur on 10-11 days per month from December through April, but only on 1 day per month in July and August, on the average.

In Tsugaru Kaikyo, the previously mentioned wind known as the Yamase is a hazard to navigation. It is a southeasterly wind often reaching gale force. In the summer it is lighter but can persist for a week at a time bringing clouds, rain, and fog. In the Tairadate Kaikyo, at the entrance to Mutsu Wan, the worst winds are squalls from the east, and northwesterly winds, which raise heavy seas. In Mutsu Bay apart from occasional easterlies, May through August are often calm. Periods of sustained high winds are most frequent in November, December and January. At the port of Aomori, southwesterlies prevail from October through April. Morning winds are variable from May through August with northerly winds prevailing during the afternoon. Winds of 19 knots and above occur on 11 days per month in January and just 1 day per month in August, on the average.

Sea of Japan Coast - At the port of Akita, average wind speeds range from about 12 knots in January to 7 knots in July. The average number of days with winds of 19 knots or greater, ranges from 11 in January to 1 in July. Average wind speeds at Sakata, range from 17 knots in January to 7 knots in July while the average number of days with winds greater than or equal to 19 knots ranges from 26 in January to 3 in August. From Tappi Saki to Niigata, northwesterly winds and rough seas are a feature from October to March, while summer brings light winds and slight seas. At Niigata northwesterly winds prevail from December through March, while in April winds are from the west through the south. Summer brings the land-sea breeze regime. January wind speeds average 12 knots while the July average drops to 6 knots. Winds greater than or equal to 19 knots occur on an average of 23 days in January and on 2 days in July. May, June and July are the calmest months. In Fushiki-Toyama Harbor southwesterly winds prevail from November to March with northeasterly winds just as prevalent during April and May. The land-sea breeze regime prevails during the summer. Wind speeds average 5-6 knots in all seasons. At Tsuruga, in Wakasa Wan, winds are usually either southerly or northerly. For most of the year southerlies prevail, but from about January to March, the north wind takes over and sometimes reaches gale force. Wind speeds reach 19 knots or greater on the average of 6-8 days per month from December to March and on just 1 day per month from June to August. In Miho Wan northwest winds are frequently strong in winter but diminish in April. During the summer light southerly winds prevail while easterlies are prevalent during the fall. The worst conditions when trying to reach Sakai in Miho Bay are generally encountered from October to April.

China-South China Coast - During the winter monsoon, from November through March, prevailing winds from the Gulf of Tonkin to Hong Kong blow from the northeast through east. From Hong Kong to Fu-chou, winds are northeasterly and from Fu-chou to Shanghai, they are from the north through northwest. Average wind speeds during the winter, range from 8-10 knots except along the western side of the Formosa Strait, where the average is 15-20 knots. Gales along this exposed

coast of the Formosa Strait, occur up to 15 percent of the time, while elsewhere along the coast they occur less than 2 percent of the time, winter or summer.

During the summer monsoon, which generally runs from June through August, prevailing winds south of Hong Kong are southerly to southeasterly. From Hong Kong to Fu-chou, winds are generally southerly to southwesterly, while north of Fu-Chou, southerly to southeasterly winds prevail. These summer winds are often strengthened, weakened, or deflected by the land-sea breeze regime. Wind speeds average about 6-8 knots except in the vicinity of the Formosa Strait where 10- to 15-knot averages are common. Here gales occur up to 5 percent of the time in summer. Gales along the south China Coast are usually a result of a strengthening of the winter monsoon, the summer monsoon in the Formosa Strait, the passage of winter cold fronts, and summer tropical cyclones.

At Hong Kong, the prevailing wind in the harbor is east-northeast from October to December, and it becomes more easterly from January to March. During the summer monsoon, winds are variable, but in the harbor, easterlies still tend to be slightly more frequent than southerly or southwesterly winds. On the south side of the island, however, southerly and southwesterly winds prevail, but even as far out as Wen-wei chou (Gap Rock), easterly winds are common during the southwest monsoon. Wind speeds increase from dawn to midday then slacken toward evening. At 0800 the average wind speed at the Royal Observatory is between 6 and 9 knots and by 1400, it is between 8 and 10 knots. Gales are very rare from December through February, and infrequent at other times. The chance of encountering gales is greatest in July.

At Shanghai, northwesterly and northerly winds prevail during the winter monsoon from November through March. March and April are transitional months, and then winds out of the southeast prevail from May through August. September and October are the transitional months. Afternoon winds average 10-12 knots while morning winds average 7-8 knots throughout the year. Gales are infrequent.

North China Coast - North through northwest winds averaging about 8 knots prevail in winter, while southerly winds of 4-6 knots prevail in summer. Both directions occur frequently during the spring and autumn transitional periods and wind speeds average about 10 knots in spring and about 7 knots during the fall. Winds of 28 knots or more can occur during any month but are most frequent in winter, when they are observed on 10 days or more per month at exposed coastal locations and over open seas. For example, at Yen-Tai gales are expected on 10-13 days per month from November through April. Extreme wind speeds are most likely in winter and spring along the north China coast, since this area is somewhat sheltered from strong typhoons. Most of the coastal extremes have been about 35-45 knots except at high elevations, where winter winds have been clocked at over 100 knots.

Land and sea breezes are noticeable in summer, particularly in enclosed gulfs like the Po Hai (Gulf of Chihli) and along the coasts of Korea Bay. During the afternoon in Korea Bay, the general southerly flow is strengthened by the onshore sea breeze. At night, the air tends to stagnate with light offshore breezes from the north and frequent calms. Similar conditions are present along the Liaotung Wan, although here the pressure gradient causes the night winds to blow from the south-southeast or parallel to the coast, and afternoon winds to blow directly onshore.

Korea - In the Yellow Sea and along the west coast of North and South Korea, the winter monsoon results in a steady northwesterly flow from September through March. During December and January, winds are almost always from the north and northwest and long-lasting gales from these directions can be expected. Over the eastern Yellow Sea, gales are infrequent and occur mostly in fall and winter. The winter monsoon at Inchon is in full swing from October through March when winds average 7-10 knots. Days with winds of 28 knots or more average 1 day in March and less than 1 day per month for the rest of the year. However, at a more exposed location like Paengnyong-do, winds greater than 28 knots can be expected on 5-8 days per month during the winter monsoon. The extreme wind speed recorded at a protected port like Haeju is 47 knots in April and October. Paengnyong-do had extreme winds greater than 47 knots in 9 months with a high of 63 knots one June. During the summer months, the southwest monsoon prevails with winds from the south through west and wind speeds averaging 6-8 knots.

Along the south coast of South Korea and at Cheju do, the winter monsoon brings a preponderance of northerly and northwesterly winds from October through March. From April through September, winds are variable and mostly under the influence of the land-sea breeze regime. For example, at the well-sheltered port of Busan April and May winds are variable, but then in June and July, southerly through southwesterly winds are common; from August to October, winds are northeasterly or northerly a great deal of the time. At land stations, wind speeds vary little throughout the year, and average 6-9 knots in the afternoon. In coastal waters, average speeds range from 7 knots in the spring up to 13 knots in mid winter. Wind speeds equal to or greater than 28 knots are most often encountered in January and February with about 7 days per month, and least frequent in September and October when the average drops to 1 day or less per month. Gales in coastal waters are most frequent in winter when they occur about 1 percent of the time.

Along the east coasts of North and South Korea, the winter monsoon brings prevailing winds from the west through north from October through March while local winds prevail the rest of the year. Wind speeds greater than or equal to 28 knots have been observed from October to April, but the average frequency is less than 1 percent, even in these months. In northern coastal waters gales can be encountered up to 2 percent of the time in January. This, however, does not include some local conditions caused by topography. In January, for example, at Changgi-Ap, in Changgi Gap, winds are channeled

by the mountains from the west across Yongil Man and reach 28 knots or greater on an average of 11 days that month. Farther north at Kangnung, southerly through southwesterly winds prevail year round. At Wonsan, early morning winds are southwesterly, year round. Afternoon winds swing to the west from November through March and to the east or northeast from April through September. Average wind speeds are 4-6 knots in the morning and 7-9 knots during the afternoon. Gales are infrequent but most likely to occur in either August or December.

From Wonsan to Unggi, foehn winds are common in spring and early summer when air is warmed and dried as it spills down the mountains to the west. At Songjin, in addition to the foehn winds, strong, southerly or south-southeasterly winds known as Songjin sand winds are common during April and May. These Winds spring up at about 1100 and last to around 1500. However, gales are infrequent and most likely in winter. At Unggi winds are predominantly from the north in winter and from the south in summer. These northerly winds from Unggi Mountain and often strong, but it is the southerly winds that create a heavy sea in Unggi Harbor.

Climate-Taiwan - The winter monsoon brings cool, moist air from the northeast over Taiwan from October through March. The southwest monsoon, prevailing during June, July and August, is composed of warm, humid air with a long trajectory over tropical seas. Transitional season weather is a mixture of these two systems. Typhoons are a threat to Taiwan from May through October. However, May through July is the most favorable period for sailing the Formosa Strait. Seas are calmest, gales are at a minimum, fog is least frequent, and it's early in the typhoon season. The late summer and fall are handicapped by increased typhoon activity and the winter is least favorable because of high gale frequencies, dense fog along the coasts, and high sea and swell conditions. However, the south coast of Taiwan is sheltered by mountains from the strong northeast monsoon and hence from high seas. Conditions on the south coast are least favorable from July through October when frequent typhoons to the south generate high sea and swell conditions.

The greatest amount of precipitation falls during the southwest monsoon except along Taiwan's northeast coast, which receives most of its rain during the winter monsoon. The Taiwan coastal regions observe more than 70 inches annually while the Pescadores and offshore islands receive about 35-45 inches. Torrential downpour in tropical cyclones have totaled 20 inches in 24 hours at some coastal locations, while 10 inches in 24 hours has occurred on all coasts. Snow is not seen along the coasts.

Thunderstorms are rare during the northeast monsoon. During the southwest monsoon they occur on 3-5 days per month from May to September and maximum activity occurs from June through August.

Mountains and monsoons control cloudiness over Taiwan. On the north and east coasts in winter cloud cover averages more than 8/10, while the sheltered south coast has an average 5-6/10 cover and basks in the sun (sky cover less than or equal to 2/10 on 4-9 days each month). When the southwest monsoon sets in, cloudiness on the east coast diminishes to an average 6/10 and July is the sunniest month. At the same time, cloud cover on the south and west coasts have increased to an average 6/10-8/10 with only 2 clear days (sky over less than or equal to 2/10) a month. The offshore islands have an average 7/10-8/10 cloud cover from January through May and 6/10 from July through October. There is usually less cloudiness on the lee sides of the islands. The Peng-hu Lieh-tao (Pescadores) average more than 7/10 cloud cover during the northeast monsoon and about 6/10 during the southwest monsoon.

Rain, fog and haze are the main restrictions to visibility. Northern Taiwan experiences dense fog (visibility less than or equal to 5/8 mile) about 5 percent of the time from January through April; it is even more frequent at daybreak. Otherwise, Taiwan and the Peng-hu Lieh-tao are mostly fog free. However, the offshore islands experience dense fog frequently during the northeast monsoon and spring seasons. From March to May dense fog is observed on as many as 15 days per month, particularly at daybreak. Visibilities less than 2 miles occur about 2 percent of the time during the southwest monsoon, increasing to 5 percent around Taiwan and the Peng-hu Lieh-tao and to 8 percent near the offshore islands.

Temperature averages range from about 65 degrees F in February to 82 degrees F in July on the Taiwan coasts. On the Peng-hu Lieh-tao and offshore islands, comparable figures are 51 degrees F and 82 degrees F. Freezing temperatures are an extreme as well as temperatures of 100 degrees F.

Japan - Since the winter monsoon brings cold air off the Asian continent and the summer monsoon brings warm tropical air from the south, the climate of Japan is more extreme or continental than its island position suggests. This means summers are warm, winters are cold and snow is common. Spring is the best season for sailing the waters around Japan. Early in the typhoon season, rainfall hasn't reached its early summer or fall peak, gales are rare and fog, which is uncommon at any time, has not reached its slight summer maximum; at insulated ports like Tokyo and Osaka, fog is more prevalent in late fall and early winter.

Rainfall is plentiful and often excessive. There are two rainy seasons; the rainiest is in an early summer and a secondary rainy season occurs about September. Annual averages range from 40 inches at protected ports around the Inland Sea to around 160 inches at some island locations, like Isso, or exposed spots along the southeast coasts of Shikoku and Honshu, between Muroto Zaki and Irako. More typical, however, are rainfall averages between 40 and 90 inches. Seasonal variations depend largely on exposure to monsoon winds. Where there is shelter from the winter monsoon, like at Tokyo and on southern Honshu, a well-marked dry season exists. However, on the exposed west coast of Honshu, winter is as wet as any

season. Some of the September rain which makes up the secondary rainy season is contributed by tropical cyclones in the form of torrential downpours. These downpours, which usually occur from July through October, are responsible for maximum 24-hour amounts of generally 12-25 inches and, in exceptional cases, up to 42 inches at some small island locations. Thunderstorms occur on about 10-15 days per year with a late summer and fall maximum at most locations. Snow is more common than might be expected. It usually begins in early November in northern Honshu, in mid December along the western-most part of the west coast of Honshu and exposed coasts of Kyushu, in late December at Tokyo, and in mid January on southern Kyushu. Snow has been observed as far south as Isso from January through March. The last snow is generally around mid March in the south and mid April in the north.

Cloud cover is influenced by exposure to monsoon winds. It is greatest in winter along the west coast of Honshu and the Ryukyu Islands while summer is most cloudy along the east coast of Honshu, Shikoku and Kyushu. The Inland Sea area has an early summer maximum. From Niigata northward, the west coast of Honshu has average winter cloud amounts exceeding 8/10; south of Niigata, including the Ryukyus, the winter average is 7/10-8/10. During this same season skies are at their best along the east coast of Honshu and around the Naikai. Along these coasts, cloud cover is usually below 5/10. During the summer the situation is largely reversed. The east coast of Honshu-Naikai area has cloud cover of 7/10 or more on the average while at the same time average cloud cover is 6/10 or less along the west coast of Honshu and the Ryukyus.

Visibilities around Japan are usually good. From August to April, fog occurs less than 2 percent of the time over open waters and at exposed locations. At sheltered ports, particularly industrial locations, fog occurs in the winter. This is usually a radiation fog aided by pollutants, and forms on calm, clear winter nights. It usually dissipates in late morning; where pollution is great it may persist into the afternoon. At these ports, such as Tokyo, Osaka, and Kobe, fog can be expected on 2-5 days per month during the winter. At the more exposed locations, fog is observed on 1-3 days per month from April to July. Visibilities may also be restricted by rain and snow.

The monsoons are responsible for a large seasonal temperature range along the coasts of Japan. August if the warmest month and daily maximum temperatures range from 85-90 degrees F, except north of 38 degrees N. where averages dip to 80-85 degrees F. Nighttime readings in August range from 70-75 degrees F except over the Ryukyu Islands where they are a few degrees warmer. Extreme high temperatures are just over 100 degrees F at the more sheltered ports and in the 90's at exposed coastal sites and on the southern Islands. The coldest months are January and February. Average nighttime lows drop into the mid 20's north of Sakata and Sendai, gradually rise to near freezing around Tokyo and Kanazawa, climb into the upper 40's in the northern Ryukyu's, and reach the 60's in the southern portion of the Ryukyu's and other islands south of 25 degrees N. Extreme lows have dropped to -10 degrees to -12 degrees F at northern ports, around plug 15 degrees F in the central regions, and only into the low to mid 40's in the south.

China - May and June are the most desirable months for navigating waters along the south China coast while early autumn is to be favored north of Shanghai. Typhoons are a hazard to the south China coast in summer and fall, while winter gales and rough seas are a handicap during the northeast monsoon along the entire coast of China. From January through April, periods of light rain or drizzle, low overcast skies and poor visibilities are a hazard and may persist for several days, along the southern coast; these conditions are known as crachin. Late spring is unfavorable along the north coast because of strong winds and poor visibilities, while summer offers high temperatures and relative humidities, heavy rains, frequent dense fog, and low visibilities.

Annual precipitation averages range from about 100 inches in the south, to 45 inches near Shanghai, to around 20 inches in the extreme north. Summer is the wet season when more than one-half of the annual totals are recorded. Summer precipitation is generally in the form of showers and thunderstorms; continuous rain is observed only when a tropical cyclone is in the vicinity. Extreme 24-hour amounts exceeding 10 inches have been observed along the south coast. Winter is the dry season with monthly amounts of less than 1 inch north of Shanghai and less than 2 inches to the south. Snow is rare south of Fu-Chou but its frequency increases northward. In the northeast, most winter precipitation falls as snow, and maximum accumulated depths range between about 5 and 15 inches. The first snow usually falls in late October or early November and the last around the end of March or early April. Thunderstorms are common from April through September; the most activity occurs in July and August. At this time, the number of days with thunderstorms range from 1-2 days per month at some offshore islands, to 15-20 at some locations along the southern coast.

South of the Shantung Pan-tao, cloud cover is extensive all year round. The average ranges from 5/10-8/10 with a slight maximum from January through May and a slight minimum from October through December. North of the Shantung Peninsula summer tends to be the cloudier season, when averages range from 5/10- 8/10. In winter, these averages drop to 3/10-5/10 and clear days become commonplace.

Fog, dust, and rain restrict visibilities along the China coast. Fog is a summer phenomena in the Liaotung Wan, Korea Bay and along the shores of the Yellow Sea. In these regions, visibilities less than 1 mile occur from 5-12 percent of the time in summer. Summer visibilities are excellent elsewhere, except for brief deterioration in showers. South of Shanghai, dense fog is prevalent in late winter and spring. Dense fog (visibilities less than or equal to 5/8 mile) is observed overall less than 5 percent of the time, but from 5-15 percent of the time around sunrise. In some spots along the East China Sea coast, dense fog obscures the sunrise about 50 percent of the time. Along the Po Hai (Gulf of Chihli) coast, visibilities of less than 1 mile occur about 5 percent of the time in late winter and spring, and less than 1 percent of the time during the rest of the year. In

the northeast visibilities drop below 1 mile up to 4 percent of the time during spring and fall, and up to 3 percent of the time in winter. Winter visibilities elsewhere are usually good except for dust. North of 35 degrees N. northwesterly winds carry dust from the deserts of Mongolia and North China. The resultant haze is often very thick over coastal waters.
January is the coldest month along the entire coast. Mean daily minimum temperatures range from 5 degrees F to 10 degrees F in the northeast, to a warm 60 degrees F on the island of Hainan. Extreme minimums have ranged from about -25 degrees F in the northeast to a chilly 45 degrees F on Hainan. July and August are the warmest months and mean daily maximums show less of a spread. They range from the low 80's in the northeast to the low 90's in the south. Extreme maximum temperatures have come close to or exceeded 100 degrees F along most of the coast.

Korea - During the winter monsoon (November-March), cold dry air flows down from the Asian continent to the Pacific Ocean, resulting in cool temperatures and nearly cloudless skies over Korea. The summer monsoon (June-August) brings warm moist air from the sea resulting in hot, humid, rainy conditions. Variations in these conditions are caused by topography, exposure, and effects of adjacent warm and cold ocean currents.

While weather hazards to navigation are present in all seasons, early spring is the least hazardous. Seas are becoming calmer as they near their summer lull, typhoons are rare, gales are infrequent, and fog and rain have not reached their summer peak. Most tropical cyclones that strike Korea are losing strength due to the cool waters and mountainous terrain of surrounding lands.

Summer brings the plum rains to Korea as weak lows and fronts move through the area bringing widespread cloudiness, heavy rains, and thunderstorm activity. Tropical cyclones also contribute to this summer peak. Annual rainfall averages range from 30-60 inches along the entire coast, and on Cheju-do. Variations are more dependent on exposure than latitude. More than one-half of the annual amount falls during July, August, and September. Since rain often falls as heavy showers, the number of rainy summer days is less than normally expected and averages 4-6 days per month. The greatest 24 hour rainfall amounts occur in July, August, or September and are usually associated with a tropical cyclone. These amounts range from 7-14 inches. Thunderstorms can be expected on 1-3 days per month from May through October, with July and August the most likely months. Snow falls from mid December through early March on Cheju-do. In January, snow is observed on up to 9 days per month, even in the south, and maximum snow depths range from 3-12 inches. Both of these criteria depend on exposure. In northern coastal waters, snow is observed up to 15 percent of the time in winter. Precipitation frequencies over coastal waters are highest in winter, particularly in the south, where precipitation is observed up to 50 percent of the time. In summer, frequencies drop to 15 percent along the northeast coast and 25 percent in southern waters.

The summer monsoon brings cloudy skies to the entire coast with an average July cloud cover of more than 7/10. This average is generally greater than 6/10 from about May to October. Winter skies are clearest and cloud cover averages drop to around 3/10- 4/10 during this season. Along the southern and eastern coastal areas, this minimum may occur during late fall and early winter. In general, overcast conditions (sky cover greater than or equal to 6/8) are observed on 100-150 days a year, with many in the summer, while clear days (sky cover less than or equal to 2/8) are seen on about 90-100 days annually with a winter maximum.

Visibilities along the Korean coasts are generally good. Poor visibilities are most likely in early summer when rain and fog are prevalent. Sea fog forms over parts of the Sea of Japan and Yellow Sea from late March through August, and most often in June and July. If surface winds are onshore this fog may move inland. Visibilities are lowest around sunrise and best in the afternoon. Early morning summer fog occurs 30-50 percent of the time along the west coast of Korea and 10-20 percent of the time along the southern and eastern coasts. By mid-afternoon the fog has usually dissipated along the coasts, except at an exposed location like Paengnyong-do. Smoke and haze reduce winter visibilities when a cold stagnant air mass lies over a large industrial area. Snow and rain also help to reduce wintertime visibilities. However, visibilities are best in fall and early winter.

August is the hottest month and mean daily maximum temperatures range from 80-85 degrees F while extremes of 100 degrees F are common. Mid-summer minimums are usually in the mid 70's. Spring and fall daytime temperatures average in the 60's with nighttime lows in the upper 30's and low 40's. January is the coldest month with nighttime lows averaging near 25 degrees F over most of the coast; this dips to 20 degrees F in northern sections and jumps to around 35 degrees F on Cheju-do. Extreme minimums have dropped below 0 degrees F at all but southern locations. Average air temperatures over coastal waters range from 76 degrees -78 degrees F in August to 37 degrees -40 degrees F in January.