U.S. NAVY
MARINE CLIMATIC ATLAS OF THE WORLD
(Version 1.1 August 1995)

SOUTH PACIFIC OCEAN

The first section provides a seasonal summary overview of the weather across the entire South 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.

GENERAL CLIMATOLOGY

As the climate of land depends upon its proximity to the ocean, so is the ocean's climate regulated by land distribution. Since the Southern Hemisphere lacks the large masses of the Northern Hemisphere, there are many differences in the climate of their oceans.

In the South Pacific the result of fewer large land masses is less variability in climate both season and latitudinally, than its North Pacific counter-part. Although the South Pacific has no land protection from colder high-latitude seas this is more than offset by the oceans moderating effect and the lack of more than one source of cold air. The South Pacific is generally, warmer and less subject to wide variability in temperature. The lack of land also allows low pressure systems to travel a nearly circumpolar route S of 40 degrees S. Lows forming to the N also move southeastward toward this belt. This is an area of year-round clouds, precipitation and strong winds. In the Southern Hemisphere lows have a clockwise circulation while high pressure systems have a counterclockwise circulation. To the N of the "roaring 40's" lies a large semipermanent high which varies only slightly from winter to summer. It is centered closest to the equator (30 degrees S) in summer.

This high pressure belt influences weather from the Equator to about 40 degrees S, from South America to Australia. Strong subsidence over the eastern South Pacific results in frequent good weather except along the South American coast where its flow over the Peru or Humboldt Current creates low stratus and fog. In the W, weather is more unstable due to convection. Convective showers are also frequent in the tropics particularly where the two trade wind systems converge to form the Intertropical Convergence Zone (ITCZ). The ITCZ follows the sun but does not cross the equator in the E. This is one explanation for the lack of tropical cyclone activity in the eastern South Pacific. The Australia-western South Pacific region is responsible for about 16 tropical cyclones (tropical storms and hurricanes) in an average season; these too generate a clockwise circulation.

The seasons in the Southern Hemisphere are the reverse of those to the N. Since most of the area in this book lies S of the equator, seasonal terms will always apply to the Southern Hemisphere seasons.

MELBOURNE, HAWAII AND SAN FRANCISCO (to 10 degrees N)

Good weather is encountered most of the time. Weather problems include the threat of tropical cyclones from November through April and showers and thunderstorms in the Intertropical Convergence Zone (ITCZ). Sailing conditions are considered excellent (visibilities => 5 miles and windspeeds <= 22 knots) 70 to 90 percent of the time along both routes.

Tropical cyclones can occur in any month, but are most likely from November through April from the Tasman Sea to the Phoenix Islands. From Lord Howe Island to the Fijis is a 60-to 70-percent chance of either a tropical storm or hurricane passage sometime during the season; the portion of the routes between New Caledonia and Fiji are the most vulnerable, particularly from mid-January through mid-February. Tropical cyclones in the South Pacific have generated winds up to 130 knots and dumped more than 30 inches of rain in a 2-day period.

North of 30 degrees S excellent sailing conditions are encountered 85 percent or more of the time. Gales are rare and winds are generally less than 10 knots, particularly near the Equator. South of the fluctuating ITCZ, easterlies and southeasterlies prevail, while northeasterlies are common to the N. In this region the ITCZ usually lies N of the Equator, dipping to the S in autumn. It is responsible for a band of showers and thunderstorms, which occur about 15 to 25 percent of the time; they are most frequent N of the Equator during the southern summer and autumn. Visibilities are excellent, except when reduced by

rain. Air temperatures near the Equator run in the low eighties (degrees F) year-round with extremes ranging up to near 90 degrees F. To the S there is a slight variation with averages in the upper sixties and low seventies in summer and fall and about 10 degrees cooler the rest of the year. North of the Loyalty Islands, warm temperatures and high humidities combine to create conditions uncomfortable for most people 80 to 90 percent of the time year-round.

Tasman Sea sailing conditions are considered excellent about 80 percent of the time throughout the year. Strong winds and poor visibilities are more of a problem than farther N as the area is brushed by wayward storms from the "roaring forties." Gales, while infrequent, blow up to 4 percent of the time in fall and winter, compared to 2 to 3 percent at other times. Winds of 10 knots or less are encountered about one-half of the time. Visibilities are at their worst in spring and summer, when they fall below 2 miles as much as 8 percent of the time. Precipitation varies with storm activity, which reaches a peak during winter (June-August). Rainfall is encountered up to 15 percent of the time in fall and winter, compared to 5 to 10 percent at other times. Temperatures along this portion of these routes range from the mid-fifties (degrees F) to low sixties in winter to the mid-sixty-degree to low-seventy-degree range in summer. Temperatures do not usually fall below the mid-forties (degrees F).

SOUTHERN AUSTRALIA and PANAMA CANAL ROUTES

Extratropical cyclones S of 30 degrees S and the Intertropical Convergence Zone (ITCZ) near the Equator create most of the weather hazards along these routes. In general, fewer problems are encountered over the northernmost routes. Excellent sailing conditions (visibilities => 5 miles and winds <= 22 knots) are encountered from about 70 to more than 90 percent of the time. Tropical cyclones or their extratropical remnants infrequently roam the Great Australian Bight or Tasman Sea.

Along the portion of these routes between Albany, Adelaide, and New Zealand winter, fall, and spring are the roughest times. Excellent sailing conditions occur 65 to 80 percent of the time; lowest frequencies occur on the passage around the Southwest Cape to the Foveaux Strait. It is here where gales and visibilities below 2 miles are encountered up to 13 percent of the time. Also, precipitation occurs 20 to 30 percent of the time. This falls as rain, since temperatures range from the mid-forties (degrees F) to around 50 degrees F with extremes falling to the upper thirties (degrees F). The passage through the Bass Strait to Cook Strait encounters gales and poor visibilities about 5 percent of the time except for a 10-percent chance of gales near the Cook Strait in spring. Precipitation occurs 10 to 20 percent of the time, while temperatures are about 10 degrees F warmer.

During summer, excellent sailing conditions are encountered about 80 to 90 percent of the time along all routes. Gales occur 5 percent or less of the time as do visibilities less than 2 miles; gales and poor visibilities may be encountered up to 10 percent of the time through the Bass Strait and near the Foveaux Strait. Precipitation occurs less than 5 percent of the time in the northwestern Great Australian Bight, increasing to 10 to 20 percent in the Tasman Sea and to near 25 percent in spring near the Traps. Summer temperatures range from the mid sixties (degrees F) in the N to the mid fifties (degrees F) in the S; extremes range from the mid seventies along the S Australian coast and near Cook Strait down to lows in the mid forties (degrees F) off the Traps.

Between New Zealand and the Panama Canal weather is worst S of Pitcairn Island on the run to the Cook Strait and S of Easter Island between Foveaux Strait and the Canal. Windspeeds are the problem. From autumn through early spring W of about 140 degrees W gales occur 10 to 20 percent of the time on the more southerly route and 5 to 10 percent of the time on the Cook Strait run. The increase in strong winds is responsible for a decrease in excellent sailing conditions (visibilities => 5 miles and winds <= 22 knots) which drop off to 60 to 75 percent over these southern stretches. By late spring they are back up to the 80 to 95 percent range. Winds are quite variable due to the progression of winter storms; S through NW winds are common along the southern portions. East of 140 degrees W variable winds give way to the trades N of Easter and Pitcairn Islands; these are out of the E through S year-round. In the Panama Basin N through NE winds prevail in summer and fall (December - May), while southwesterlies and westerlies are common during the remainder of the year. North of Pitcairn and Easter Island excellent sailing conditions are the rule.

Visibilities drop below 2 miles 5 to 10 percent of the time year-round S of Easter Island. Otherwise on both routes these conditions occur less than 5 percent of the time everywhere and in all seasons, except for a 5-percent chance near the Cook Strait in winter and spring. In the Tropics poor visibilities may briefly occur in occasional heavy showers. Precipitation along these routes is most likely at the beginnings and ends of the runs. In the Panama Basin the ITCZ is responsible for numerous showers and thunderstorms. These are most frequent during winter and spring when frequencies between the Galapagos Islands and the Panama Canal range from 20 to 30 percent. They are less numerous in other seasons. Between the Galapagos and Pitcairn and Easter Islands frequencies range from less than 5 percent in summer to near 15 percent in winter. To the S of Easter Island, rain can be expected 15 to 30 percent of the time with a winter peak. South of Pitcairn precipitation is encountered 15 to 20 percent of the time, except 10 to 15 percent in summer. Most of this rainfall is generated by extratropical systems, but on a rare occasion, a torrential downpour may occur in a tropical cyclone.

Tropical cyclones, although rare, may occur from spring through fall W of about 130 degrees W, and N of about 40 degrees N. This makes them most likely on the more northern route, S of Pitcairn Island. They have occurred most often in summer and fall near Cook Strait.

There is a wide range of temperatures encountered along these routes, which pass from the midaltitudes to the Equator. During winter temperatures range from the mid 40's (degrees F) to 50 degrees F along the New Zealand coast to the mid 60's at Easter Island and mid 70's at Pitcairn Island to near 80 degrees F at the Panama Canal. Extremes range from the mid 30's near Foveaux Strait in winter to 90 degrees F in the Panama Basin in fall. Summer temperatures range from the mid 50's to low 60's off New Zealand to the mid 70's near Easter and Pitcairn to still around 80 degrees F near Panama. High temperature and humidity combine to create uncomfortable conditions in the Panama Basin. These uncomfortable conditions are mainly confined to N of the Galapagos, where they occur 40 to 90 percent of the time.

SOUTHERN AUSTRALIA, SOUTH AMERICA (CALLAO, VALPARAISO, MAGELLAN STRAIT)

The portion of these routes W of New Zealand is covered in the preceding section. These routes all have seasonal options due to the rough winter season along the Great Circle routes. The length of the winter season, or at least the rough conditions, varies. Near New Zealand it runs from about April through November, lengthening eastward to near the Magellan Strait, where it lasts three-fourths of the year with a break from December through February. Excellent sailing conditions (winds <= 22 knots and visibilities => 5 miles) are encountered only 50 to 60 percent of the time in contrast to near Callao, where they occur 95 to near 100 percent.

Along the southernmost route between the Foveaux and Magellan Straits, with branches to Callao and Valparaiso, conditions are worst from about April through September. Excellent sailing conditions are encountered 60 to 80 percent of the time W of about 120 degrees W; to the E this range falls by about 10 percent. Along the Callao and Valparaiso branches conditions improve dramatically N of about 40 degrees S. They climb to the 80-percent range and better throughout the year, reflecting better visibilities and lighter winds. Winds along the southern route, influenced by a near endless progression of storms, blow mainly out of the SW through NW, and are constantly shifting, year-round. Near the Strait of Magellan they reach gale force 20 to 25 percent of the time from April through November. To the W gales are less frequent and the season is shorter. On the Callao and Valparaiso branches gale frequencies don't drop below 20 percent in winter (10 percent at other times) until N of 40 degrees N. While the alternate routes to the N aren't gale-free in winter frequencies usually stay below 20 percent. Even on the alternate Cook Strait-Magellan Strait run, wind conditions are good W of about 110 degrees W, where the route begins to dip down into the "roaring forties."

During the relatively short summer season along this shortest, southernmost route gales occur about 5 to 10 percent of the time, except rising to near 20 percent near the Magellan Strait. On the branches they fall below 5 percent N of about 45 degrees S.

Fog, rain and snow all restrict visibilities along the southernmost route, where visibilities fall below 2 miles 10 to 20 percent of the time year-round. This drops to 10 percent or less on the Callao and Valparaiso branches N of 40 degrees N; less than 5 percent in summer. The northern alternatives offer less than 10-percent frequencies all year and less than 5 percent in summer N of about 35 degrees S.

Temperatures, in general, remain constant from E to W and increase northward. This pattern is interrupted along the South American coast N of about 40 degrees N where the Peru Current causes cooler air temperatures close to the coast. Temperatures are coldest in winter along the Cape Foveaux-Magellan Strait run, where they average in the low 40's (degrees F); extremes have dipped into the low 20's (degrees F) near the Magellan Strait. The alternate routes are generally 10 degrees to 20 degrees F warmer. Near Callao, winter temperatures have climbed to the mid 70's (degrees F) on rare occasions. Spring and autumn temperatures are about 5 degrees to 10 degrees F warmer than those of winter. Fall is the warmer of the two. In fact near the South American coast autumn temperatures often exceed those of summer; extremes have reached the upper 80's (degrees F) near Callao and about 80 degrees F near Valparaiso, both slightly higher than the summer extremes. During summer, temperatures along the southern route range from the upper 50's (degrees F) off New Zealand to the upper 40's near the Magellan Strait, where they have dropped into the upper 30's on occasion. To the N temperatures climb into the mid 70's off Callao and the low 60's near Valparaiso.

Along the southern route precipitation usually rain, falls about 30 to 35 percent of the time near the Magellan Strait in winter and spring and only slightly less during the other seasons. In winter it does occur as snow 5 to 10 percent of the time. Farther W frequencies fall to 20 percent, even 15 percent near Cape Foveaux in summer. Along the northern routes rain is most frequent in winter S of about 20 degrees S, where it occurs 15 to 25 percent of the time, and 5 to 10 percent less in other seasons. Near Callao rain occurs less than 5 percent of the time year-round, while off Valparaiso it falls less than 5 percent from September through April and 5 to 10 percent of the time in late fall and winter.

Tropical cyclones are rare along these routes. Usually they have turned extratropical by the time they reach 40 degrees S. From spring through fall there is a slight chance of an encounter near the Cook Strait to about 150 degrees W and even a remote possibility between the Foveaux Strait and 170 degrees W.

ROUNDING CAPE HORN

South of 50 degrees S you begin the "rounding of the horn." For more than two centuries mariners have battled Cape Horn. In the days of "square riggers" a westward passage in winter was an unforgettable experience for those that survived. Ships known as Cape Horners were especially built for the journey, and many captains who sailed the route regularly belonged to the "Amicale Internationale des Capitaines au Long-Cours Cape Horners" (The International Society of Captains who have sailed around Cape Horn).

An experienced Cape Horn captain summed up the ordeal: "You've noted the way cyclonic movements race across the Southern Ocean-Indian or Pacific, it's much the same. You've learned the signs for shifts of wind-the slight clearing in the SW sky, a movement in rising cloud, then the swift sudden shift. It's the same off the Horn, except the wind is madder there, the shifts faster, nights longer, seas higher, ice nearer …you get no sleep. You'll get so wet so long your skin will come off with your socks, if you get the time to take them off. But with luck you'll get past Cape Horn and, by the grace of God, you won't kill anybody."

With todays bigger, powered vessels, better navigation equipment and superior weather knowledge, Cape Horn is less feared than it was at the turn of the century and before. However, the weather has not improved. Raging storms are no less frequent. In winter, gales and precipitation occur up to 30 percent of the time, while seas of 12 feet or more are even more frequent. Sometimes all these elements combine to drop visibilities to less than 1/2 mile. While the Drake passage is a year-round storm route, these storms are usually less intense and less frequent during the summer, particularly December, January, and February.

During the summer, temperatures reach the upper 40's (degrees F), skies clear 10 to 15 percent of the time, gales fall off to less than 5 percent, and 12-foot plus seas to less than 15 percent. Precipitation is less frequent, while poor visibilities are uncommon.

An alternative to the Horn are the channels and fjords known as the Straits of Magellan. Here the gales of Cape Horn are seldom encountered, except in the widest entrances and passages. They blow on less than 30 days a year at the sea level observing stations, but occur in every month. The most dangerous winds are the violent, unpredictable squalls known as "williwaws." They depend on the existence of strong winds at sea or aloft; at higher elevations gales blow on up to 130 days annually. When these strong winds strike the rugged mountains of the archipelagos they set up eddies of varying size and intensity. In sheltered inlets, speed and direction vary constantly. Strong winds can blow from one direction and then because of the channeling effect, reverse themselves 180 degrees. While these squalls may last only a few minutes, accompanying rain or snow can reduce visibilities to near zero. These winds have exceeded 100 knots on occasion.

Except for these infrequent williwaws, weather in the Straits is usually navigable. At the eastern entrance Punta Dungeness has average windspeeds of 14 to 17 knots at Punta Arenas; gales are similarly less frequent. Afternoon temperatures that were in the upper 30's (degrees F) in winter climb to near 60 degrees F in midsummer, while minimums range from the low 30's to mid 40's. Precipitation averages 1 to 2 inches on 4 to 8 days per month. Fog creeps in on less than 10 days per year.

SPECIAL WEATHER-RELATED PHENOMENON-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 sea 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 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 southern 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.

Superstructure icing at its worst can sink a small vessel. It elevates the center of gravity, decreasing the metacentric height. Icing increases the sail area and the heeling moment due to wind action. Its nonuniform distribution changes the trim; it can

hamper steerability and lower ship speed. Icing can also cause hazardous deck conditions. These conditions are found in the extreme southern limits of the area covered by this Planning Guide.

SPECIAL WEATHER-RELATED PHENOMENON -- 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. Maximum and minimum dew point by season can be found in the Appendix Atlas.

SPECIAL WEATHER-RELATED PHENOMENON -- 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 warm 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 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.

SPECIAL WEATHER-RELATED PHENOMENON -- OPTICAL PHENOMENON

Much of this area, particularly the southern portion, in the subantarctic, is favorable for the formation of optical phenomenon. Numerous observations of mirages and abnormal refractions have been reported, but frequency of occurrence is unavailable owing to the sparsity of data.

The two basic types of optical phenomena are those associated with electromagnetic displays, and those associated with the refraction or diffraction of light. The aurora and Saint Elmo's fire are electromagnetic displays. Halos, coronas, parhelia, sun pillars, and related effects are optical phenomena associated with the refraction and diffraction of light through suspended cloud particles; mirages, looming, and twilight phenomena such as the "green flash" are optical phenomena associated with the refraction of light through air of varying density. Occasionally, sunlight is refracted simultaneously by cloud suspensions and by dense layers of air producing complex symmetric patterns of light around the Sun.

Superior mirages form most often when a warm layer of air overlies a cooler water mass. A superior mirage characteristically appears in the form of an inverted image over an object, and when atmospheric conditions are ideal an erect second image is visible. If the object and the inverted image are below the horizon, the erect second image may be the only portion of the mirage visible. The stable conditions necessary for the formation of superior mirages are also conducive to the formation of sea fogs, hence they may be found in close association.

An inferior mirage may appear as whitish streaks which apparently separate coastlines from the sea, or in the form of sinking, which causes apparent depression of objects ordinarily visible. Captain Cook, while on his south polar voyage, reported the disappearance of icebergs attributed to sinking, after the passage of a sharp cold front. The presence of an inferior mirage is an indication that the sea is warmer than the air.

A combination of superior and inferior mirages, termed the Fata Morgana, may occur in the extreme. It is most likely to form in conjunction with the Antarctic icepack. The surface roughness of the pack appears as high pinnacles, and there is much repetition of images.

Abnormal refraction phenomena are common. Similar to superior mirages, they tend to form when the air is warmer than the sea. Looming, the most common form of abnormal refraction at sea, may cause apparent elevation of the horizon and considerable vertical elongation of objects. Extreme elongation of objects will give the effect of towering. The observations of

distant lights and other objects that are ordinarily below the horizon are caused by looming. Stooping, the opposite of looming, causes vertical contraction of objects. This flattening may be so slight that it is not noticeable, yet it will seriously affect the determination of distances by optical methods. Another form of abnormal refraction will cause an erect image to be visible directly above objects.

It should be stressed that the degree of illusion often depends upon the position of the observer's eye. Movement upward or downward may cause the disappearance of the phenomena. In addition, certain objects may be under the influence of mirage or abnormal refraction, while other objects in the immediate vicinity are unaffected. This is caused mainly by local differences in temperatures.

Bright but short-lived green light that emanates from the setting Sun on clear evenings is referred to as the green flash. This refraction of the green band from the Sun's spectrum may be repeated at sunrise.

The multicolored rainbow and the whitish fog bow stand out among the phenomena caused by refraction through droplets. Solar and, to a lesser extent, lunar halos of 22 degrees and 46 degrees are induced by refraction through the high-level ice particles usually associated with cirriform cloudiness. A colored halo may be differentiated from coronas and other diffractional phenomena by the red tinge in the inner rings rather than in the outer ones. Refraction through ice may assume such other forms as various-sized arcs and mock suns. The shapes and positions of the ice crystals create these unusual geometrical patterns.

Solar and lunar coronas and iridescent clouds with a ring-color sequence the reverse of that of refraction are classified as diffraction phenomena. The size of the intervening particles determines whether diffraction or refraction is likely to prevail.

Sun pillars and parbelic circles which may surround the thinly veiled Sun are among the reflection phenomena that may be witnessed with increased frequency toward colder latitudes.

Electrical phenomena include the aurora australis and St. Elmo's fire. The latter, which follows the unusual electrification of the air in blizzards and on very cold days, manifests itself as a series of faint bluish flickers usually around sharp-tipped objects. Such sudden outbreaks of static electricity may interfere with radio communications.

The aurora australis with its center of activity in nearby Antarctica, often glows in the southern sky S of 55 degrees S but rarely extends N of 45 degrees S. Auroras sometimes assume a sharp ray structure (streams, draperies, coronas, etc.) or lapse into indistinct forms (glows, nebulas); other times, they may acquire various sizes, shapes, and intensities (pulsating arc, pulsating surface). Moreover, the aurora australis may remain uniformly red, green or purple, or rapidly switch one color to another. Macquarie Island (54 degrees 37'S, 158 degrees 54'E) lying SW of New Zealand has an average of 206 nights each year with auroral displays.

NORTHEASTERN AUSTRALIA (NORTH OF 22 degrees N)

Weather in the Australian tropics is influenced by a belt of low pressure and a semipermanent, subtropical anticyclone; the Intertropical Convergence Zone (ITCZ) also plays a seasonal role. Sometime in March or April the subtropical high begins to push northward, spreading steady, dry SE trades across the region. By midwinter (July) this anticyclone, which represents a series of eastward-moving high-pressure systems, is dominant with its axis near 25 degrees S. The tropical belt of low pressure lies to the N. Good weather prevails into October. Sometime during the spring transitional period the high is shoved southward as the low-pressure belt advances. The Northwest Monsoon sets in, accompanied by intermittent at first then more frequent squalls. The rainy season, which can vary from year to year, usually stretches from December to April. In midsummer (January) the high is S of 35 degrees S, while the belt of low pressure lies along the 20th parallel, and the ITCZ moves southward to near 10 degrees S. The ITCZ is a discontinuous band of showers and thunderstorms. It is also the birthplace of many tropical cyclones.

Tropical Cyclones.- These clockwise-revolving storms are infrequent, but loom as the greatest navigational weather hazard in tropical Australia. About 16 tropical cyclones (tropical storms and hurricanes) form each year across the Australia-South Pacific region (100 degrees E-140 degrees W). On the average six or seven of these tropical cyclones reach hurricane intensity.

Australians use the term cyclone to denote tropical storm strength or greater (winds => 34 knots). In the N and NW they are known as "Willy-Willies." There are tropical cyclone centers at Darwin, Brisbane, and Perth. Each has its own area of forecast responsibility and its own list of tropical cyclone names.

The dangers from tropical cyclones include strong winds, torrential rains, and tumultuous seas. On the coast flooding from rains and high tides is often the major cause of damage. Winds can climb to 130 knots or more. Along the E coast a 109-knot gust was recorded at Willis Island, while one of 101 knots blew at Bowen. Hurricanes can also generate seas of 30 feet or more and tides of 10 feet or more above normal. In the Gulf of Carpentaria there is a 50 to 60 percent chance of at least one storm at most locations. This percentage is slightly lower along the E Queensland coast (45 to 55 percent) and off the coast of the Northern Territory (30 to 40 percent). While tropical cyclones can develop in any month they are most likely from November through April. The heart of the season is January, February, and March. November activity is unusual but most likely off the NE Queensland coast. During December there is a chance of a storm in the Gulf of Carpentaria and along the E coast. Activity increases in January, when storms develop from the Timor Sea through the Arafura Sea, sometimes as far N as 5 degrees S. Many of these tropical cyclones move southwestward, on a track parallel to Western Australia, to the North West Cape. The cyclones that form in the Arafura Sea or Gulf of Carpentaria tend to move southeastward across the Cape York Peninsula and along the E coast. February development is concentrated in the Timor Sea. These systems often move southwestward to about 20 degrees S and recurve overland near the North West Cape-Shark Bay area or turn west-southwestward out to sea. In the N activity is slight. Most storms tend to form E of Cape Melville and, moving well off the coast head east-southeastward; late in the month they may recurve toward Australia, near New South Wales. March brings an abundance of coastal storms forming from the Gulf of Carpentaria westward. Early in the month Coral Sea activity is similar to that of late February. Later, storms are more confined to the Coral Sea. April tropical cyclones are infrequent, with a slight chance of one in the Gulf of Carpentaria or eastern Coral Sea. Tropical activity and cyclone tracks are based on climatological patterns and trends. Actual storms can be very unpredictable.

Winds.- The winds over open water are predominantly southeasterly from the end of April to the beginning of November and northwesterly for nearly the remainder of the year. These general directions as well as windspeeds are greatly influenced by local topography and the land-sea breeze effect.

While gales (winds => 34 knots) are uncommon in these tropical waters, windspeeds of 20 to 30 knots are not. These speeds can be attained by the strengthening SE trades of winter as well as the westerly monsoon in summer. Along the E coast from Rockhampton northward gales are most likely from January through March, particularly S of Cairns; they are most likely off Rockhampton, where they blow up to 2 percent of the time in March. Highest average windspeeds occur in the afternoon and run about 8 to 12 knots from April through October; on Thursday Island these speeds climb to 15 to 17 knots. Gales generated by tropical cyclones are most likely from January through March. The cause of strong winds in the Torres Strait is usually either a tropical cyclone or local squalls associated with the westerly monsoon.

Along the coast from Rockhampton to Thursday Island winds are usually out of the E through S from March or April through September or October. From about November through March there is usually a noticeable diurnal variation in both direction and speed. It is most evident at Rockhampton, Townsville, and Thursday Island where calms occur up to 60 percent of the time in the morning. Light westerlies, southeasterlies, and southerlies are also common along the coast during the morning hours. Afternoon winds, frequently sea breezes, often blow out of the NE through SE; at Thursday Island W and NW winds blow from the sea as well as being part of the westerly monsoon that affects the N coast.

Climate.- The climate of Australia's tropical coasts is monsoonal; along the E coast the SE trades prevail. Most of the bad weather comes in the summer (December through April) as a result of the westerly monsoon, tropical belt of low pressure. Along the E coast January through March are the worst weather months. Under skies that are cloudy on about 15 to 25 days per month rain falls on about 8 to 12 of these days. At exposed locations like Thursday Island and Cairns, rain may occur on

up to 20 days per month and total 10 to 17 inches; between Cairns and Innisfail heavy rainfall is a result of the moist SE trades being forced over the mountains. Tropical cyclones are mainly responsible for 24-hour amounts of 8 to 15 inches. Thunderstorms occur on about 2 to 7 days per month in summer. Heavy showers and thunderstorms can reduce visibilities briefly, but overall visibilities fall below 2 miles on only 1 to 5 mornings per month. Temperatures are consistent with maximums in the upper 80's (degrees F) to 90 degrees F; they climb above 90 degrees F on 5 to 15 days per month-even less on the islands. Nighttime temperatures range from the low to upper 70's (degrees F). These minimums result in early morning relative humidities near 90 percent. During the day they fall into the 60-percent range. Extreme high temperatures for the year usually occur during this period and have reached 105 degrees F to 110 degrees F, except on the islands where they remain in the 90's (degrees F). These extremes often occur in December, which is usually less cloudy than the January through March period; however, temperatures will climb above 100 degrees F when breaks occur. The northward movement of the ITCZ and tropical low-pressure area and the establishment of the semi-permanent high brings good weather in the winter season (May through November). Skies are clear on 10 to 20 days per month and cloudy on just one-half of that amount. August and September are the driest months. Rain falls on 3 to 10 days per month and average amounts fall to less than 3 inches throughout the season except at Cairns. Thunderstorms are infrequent. Temperatures cool off but are mostly dependent upon exposure to the sea. At the more protected locations, they range from the mid 70's (degrees F) during the day to around 50 degrees F at night, while on the islands and at the exposed coastal locations a range from the upper 70's and low 80's down to the low to mid 70's is more common. June and July are the coolest months. Again there is a wide range of extreme low temperatures, from near freezing at Rockhampton to 64 degrees F at Willets Islets and Thursday Island. Temperatures do not reach the 90's (degrees F) from May through August. Where there are wide temperature fluctuations relative humidities also vary. Morning readings from the 80 to 90 percent range fall to the 50 percent range by afternoon. On the islands this minimum remains in the 70 percent range. For the most part visibilities are good. There is some early morning radiation fog in sheltered locations. For example, at Rockhampton visibilities fall to less than 2 miles on about 5 to 10 mornings per month from April through September and below 1/2 mile on up to 8 mornings. Conditions improve considerably by noon.

SOUTHEASTERN AUSTRALIA

The weather along this coast is largely controlled by an eastward progression of anticyclones, which makes up a semi-permanent belt of high pressure. In between these migratory highs are troughs and low-pressure areas that bring the weather. The axis of the climatological anticyclone lies across southern Australia in winter, drifts southward over the Great Australian Bight during spring, and lies S of 35 degrees S in summer. Gales are most likely in winter, when storms from the "roaring 40's" or "whistling 50's" are able to penetrate northward. Troughs can penetrate N to about 25 degrees S. Winds along these coasts are variable and usually moderate. Winters are often mild with little frost. Summer temperatures are hot and can climb to 100 degrees F or more on occasion, but low humidities reduce the discomfort. Rainfall is plentiful along the SW and SE coasts. Tropical cyclones are an infrequent but dangerous problem.

Tropical Cyclones.- Usually developing between 5 degrees and 18 degrees S, tropical cyclones often follow a parabolic track paralleling the coastline and eventually moving inland or off to the SE. South of 40 degrees S these systems often turn extratropical. Sometimes they combine with an already existing extratropical system and find new life as a vigorous low pressure system. East coast storms rarely reach the Great Australian Bight but have been sighted off Cape Howe. Early in the season they tend to move southeastward across Queensland from the Gulf of Carpentaria. By late January there is some coastal activity S to Clarence; in January there is about a 25 percent chance of at least one tropical cyclone off Brisbane. In February there is a 20 percent chance near Sydney as some tropical cyclones recurve southwestward across New South Wales. Late in the month and through March much of the activity is confined to the eastern Coral Sea and even coastal storms tend to move toward the SE or S. Tropical cyclones of hurricane strength (windspeed of 64 knot or greater) are more likely to be encountered along the E coast, particularly S of 25 degrees S. They are most likely in February and March. Along the W coast chances are greatest in January and March W of the Exmouth Gulf.

Southerly Buster (or Burster).- This is the name given to the sudden burst of cold air that may accompany a summertime cold front passage along the E coast. Prior to its arrival northerly winds and high temperatures prevail for several days. Just before the onset of the "buster," ball-shaped cumulus clouds, and then heavy cumulo-nimbus clouds gather in the SW. Many times during the hour or so before the onset, a heavy cumulus roll, which may be 30 miles or more in length, appears low on the southern horizon. As it approaches, the wind dies, then begins to whip up from a southerly direction, often reaching gale force in minutes. Temperatures may fall 15 degrees F or more. Often the buster is accompanied by rain and sometimes by thunder and lightning. If it has been very dry, the sky may be cloudless during this change. Initial gusts generally range from 17 to 35 knots but higher speeds have been recorded at Outer North Head. These "Southerly Busters" are most likely S of Port Macquarie, where they occur about 30 times annually, and on an average 27 of these blow in between October and March.

Winds.- Because of a progression of weather systems winds are continually changing, particularly in winter. From November to April these changes are fairly regular, corresponding to the procession of anticyclones. North of its track winds are S to SE as the high approaches backing to E or NE as the center passes; sometimes there is a sudden shift back to S as a new system approaches. South of the track S to SW winds in advance of the center veer to the W and finally NW or N as the center passes. The area which lies S of the track spreads northward between January and July. By July most of the area, S

of Brisbane is under the influence of a southwesterly through northwesterly flow. Later in the year the area of prevailing westerly winds recedes southward and winds from the NE through S become dominant by January.

Gales are most likely during June and July, when they are encountered 5 to 12 percent of the time in the waters off these coasts; off Carnarvon they blow less than 2 percent of the time year-round. Gales are most likely off the Indian Oceans coasts of Tasmania; they blow 8 to 12 percent of the time in June and July. Gales are least frequent in summer (January and February). They are encountered less than 5 percent of the time and in many areas less than 1 percent. Spring is a quiet time off Brisbane.

Coastal winds are complicated by local topography and the land-sea breeze effect. In general there is a tendency toward southerlies and easterlies in summer with northerlies and northwesterlies becoming frequent in winter. Early morning summer winds are often light and variable; sometimes they blow off the land. Windspeeds average 4 to 8 knots; about 6 knots higher on the exposed capes.

Along the E coast NE through SE winds at 10 to 12 knots are common. Gales at coastal locations are infrequent in summer and would most likely result from a rare tropical cyclone, or a southerly buster S of Port Macquarie along the E coast.

As winter approaches winds get stronger and their diurnal change becomes less noticeable. They are influenced by southern extratropical storms as well as passing anticyclones. Along the E and S coasts winds blow mostly out of the S through NW with occasional northeasterlies. Windspeeds average 8 to 10 knots along the E coast and 8 to 16 knots in the S.

Climate.- In addition to the progression of high-pressure systems across Australia, this region is affected by storms of both tropical and extratropical origin. Cyclone activity is greatest in winter, when extratropical storms pass close to the S coast with their fronts and associated troughs spreading poor weather as far N as 25 degrees S. Tropical cyclones, though less frequent, can create problems from late spring through early fall.

Along the E coast average annual amounts range from 35 to 45 inches with a summer peak N of Coffs Harbor and a slight autumn peak to the S. Nearly 50 inches falls on the W coast of Tasmania. The more uniform distribution along this coast results from the intensification of the SE trades. Rain falls on 8 to 15 days per month. While not frequent, snow falls as far N as 31 degrees S in a winter. It usually melts on contact except in the mountains. Thunderstorms are likely along the E coast. At Sydney and Brisbane they occur on 30 to 40 days annually with a peak in late spring and summer. Elsewhere they pop up on about 5 to 16 days annually. Cloud cover varies like rainfall. Along the E coast cloudy skies occur on the average of 18 to 20 days per month from December through March, while clear days are observed on 15 to 20 days per month in winter. Along the S coast summer skies are clear on 15 to 20 days at most locations; Melbourne and Tasmania have about 5 fewer clear days each month. From fall through spring skies are cloudy along the S coast on 10 to 20 days per month; Tasmania records these frequencies throughout the year with slight peaks in spring and fall.

Temperatures vary with latitude, season, and exposure. During the summer from Brisbane northward, on the E coast, and at sheltered locations along the S coast, daytime highs climb into the mid to upper 80's (degrees F) with nighttime lows ranging from the low to 60's to low 70's (degrees F). Along the E and S coasts temperatures reach or exceed 90 degrees F on about 20 to 30 days each season at sheltered locations. At spots exposed to cooling sea breezes 90 degrees F temperatures occur on less than 15 days each season; on Tasmania, this figure drops to 1 to 2 days. However, in most places extremes have topped the 100 degrees F mark. The winter season brings daytime highs in the upper 50's to upper 60's (degrees F), except for the low 50's on Tasmania. At night temperatures drop into the upper 30's to low 50's; coolest temperatures are recorded in the SE. Temperatures drop to freezing or below on 5 to 15 days each season along the Victoria coast and the E coast of Tasmania; elsewhere they are infrequent. Extremes range from the upper 20's (degrees F) along the S coast to the mid 30's in the more northern latitudes.

Visibilities are generally good to excellent. Sometimes rain drops visibilities below 2 miles, but rarely below 1/2 mile. Radiation fog may develop towards dawn in a few coastal locations, but this clears before noon. From Sydney to Cape Northumberland fog occurs from March through October. By far the worst area is near Sale where visibilities in the early morning drop below 1/2 mile on 55 days annually; this includes about 10 to 16 mornings per month in winter. In the S northerly summer winds bring a reddish dust haze to coastal regions. With sufficiently strong offshore winds, particularly following a prolonged drought, a thick dust storm can affect visibility for a considerable distance out to sea.

NEW ZEALAND

The climate of New Zealand is determined mainly by its location. With Australia some 900 mi to the N and Antarctica even farther to the S, the expanse of surrounding sea ensures a mild winter and cool summer. Large, deep extratropical storms travel relentlessly eastward on a track just S of about 50 degrees S with frequent troughs extending northward across New Zealand. Secondary centers often develop along associated fronts and generate strong winds, rough seas, and heavy rain. Occasionally tropical cyclones move into the New Zealand area. An extensive mountain barrier along almost the whole length of the interior produces differences in wind and weather between the W and E coasts. While rainfall is plentiful the topography produces an uneven distribution.

Cyclones and Cold Fronts.- Day-to-day weather is controlled by the migratory anticyclones and the low-pressure troughs which lie between them. These troughs nearly always contain a cold front, separating warm, moist subtropical air to the E and cold maritime air to the W. Weather associated with the front is characteristic-heavy rainshowers, possibly thunderstorms, strong surface winds, and rapid temperature changes. These fronts are usually oriented NW-SE and move northeastward. The southernmost portion of the front is often connected to a circumpolar low.

The storms, often secondary centers, that pass over or close to New Zealand, from along these fronts. The more intense storms, called cyclones in New Zealand, generates gale-force winds, rough seas, and heavy rains. The tracks of these cyclones are usually eastward, or southeastward. Cyclones traveling eastward often pass S of Stewart Island and are most severe from Foveaux Strait to Cook Strait, but their effects can be felt throughout New Zealand. Cyclones moving southeastward often cross the northern portion of South Island, or, less frequently pass eastward of North Cape and along the coast of North Island to East Cape. Occasionally these storms pass directly over North Island.

Tropical Cyclones.- Occasionally a tropical cyclone may affect New Zealand. They are most likely to cross North Island; however, South Island is not invulnerable. Sometimes these systems have acquired extratropical characteristics by the time they reach these latitudes, but they can still generate strong winds, rough seas, and torrential rains. Most tropical cyclones are headed southward, southeastward, or eastward. Probabilities range from 15 to 30 percent of at least one tropical cyclone affecting some part of New Zealand in a given year; that's an average of about one every 3 to 6 years. They can occur in any month, but are most likely in New Zealand waters from mid-January through mid-February and again in March.

Winds.- Weather is greatly influenced by prevailing wind. Frequently the weather is referred to as "northwesterly day" or "southeasterly weather." During the winter in advance of a cold front moist northwesterlies bring overcast skies along the W coast of South Island but few clouds to the sheltered E coast. Over the less mountainous North Island, clouds penetrate most regions except the coast from Hawke Bay to the southern part of the Bay of Plenty. When westerlies follow a cold front, prefrontal showers are generated along the W coast of South Island and on the E coast as far N as Dunedin. Steady rains fall along North Island's W coast N of Levin, while on the E coast between Dunedin and East Cape the frontal passage is often marked only by a local wind shift and pressure change. Northwesterlies behind the primary cold front can spread considerable precipitation from Stewart Island across Foveaux Strait and northward along the W coast of South Island. The E coast is usually unaffected, N of Dunedin. North Island weather consists of scattered heavy showers as far N as New Plymouth with decreasing activity to the N. Fair skies usually prevail to the E.

Southerlies usually refer to SE, S and SW winds. Any of these winds may bring cold, rainy weather, replacing warm, fair weather. This change is usually marked by a dark line of clouds, and sharply increasing winds. Temperatures fall rapidly and heavy rain or sometimes thunderstorms with hail are present. Although less apparent in some sections, the change generally engulfs all of New Zealand. Gales blow up to 13 percent of the time in coastal waters and 20 to 30 days annually at the more exposed coastal locations. March through October is usually the worst time. In the waters around Stewart Island, including the Foveaux Strait, winds reach gale force 10 to 13 percent of the time. At Invercargill winds climb to 28 knots or more on 2 to 3 days per month year-round, except 4 days in October on the average. In other coastal waters gale frequencies average 5 to 10 percent from autumn through spring with a peak usually during winter. However, through the Cook Strait this peak usually occurs in spring. Gales in the open waters of Cook Strait are encountered about 10 percent of the time from September through December. At Wellington winds of 28 knots or more are reported on up to 3 days in October on the average. At coastal locations that are sheltered, such as Nelson in Tasman Bay and Napier in Hawke Bay, gales blow on less than 10 days each year. This compares to exposed Campell Island to the S, where winds reach 28 knots or more on an average of 68 days annually.

While New Zealand lies in a belt of prevailing westerlies, this is often marked at coastal locations by local influences. Most noticeable is topography. Sheltered by mountains some areas experience weak winds with frequent calms. Through the Cook and Foveaux Straits there is a funneling effect resulting in strong winds and a preponderance of northwesterlies and southeasterlies. From Jacksons Bay southward there is a tendency for winds to be deflected around Puysegur Point, where they join with frequent westerly and southwesterly winds common to southern sections of South Island. Farther N they may appear as southerly or even southeasterly winds, conforming to the land. Land and sea breezes are fairly extensive, especially when pressure gradients are slack. The sea breeze sets in about midmorning and is relatively strong until sunset. At night the land breeze is usually weaker, but can be a problem along steep coasts where a drainage effect is produced. During periods of strong westerly winds aloft, foehn winds often develop along the lee slopes of the Southern Alps during the afternoon; less frequently this occurs on the North Island also. These winds frequently exceed gale force and continue well into the night.

Strong winds, in fact most winds, in Cook Strait blow out of the NW or SE. Gales are frequent and violent, often accompanied by dark clouds and lightening. Mean speeds of 15 to 16 knots are common with speeds exceeding 22 knots 20 to 30 percent of the time. Gales blow up to 10 percent of the time and are most likely during winter and spring. These winds are local and the harbors that indent the shores are usually well protected. The head of Tasman Bay is remarkably free of strong winds and frequently enjoys fine, calm weather, while a gale is blowing in Cook Strait.

Foveaux Strait is also vulnerable to strong winds. Gales blow 5 to 15 percent of the time, while winds exceed 22 knots 25 to 35 percent of the time. Summer is usually the best season. Southwest through NW winds are most frequent.

Climate.- The maritime climate of New Zealand is modified somewhat by the height and length of the mountain ranges. In all seasons New Zealand lies in the zone of strong prevailing westerly winds between the semipermanent high pressure belt of the subtropics and the low pressure belt near the Antarctic Circle. Within this region fluctuations of weather are produced by the recurring series of anticyclones and depressions which traverse the area from W to E.

Rainfall amounts are plentiful, but uneven due to the mountains. The western coast of South Island records 100 to 200 inches annually, while the E coast from Christchurch to Dunedin is usually the driest with 20 to 40 inches. While precipitation varies little with season, there is a slight winter and spring maximum at some locations. Along the W coast of South Island precipitation falls on 100 to 200 days annually with a range of about 10 to 20 days per month. North of Dunedin about 100 to 175 rainy days are recorded each year. The North Island has a more uniform distribution with a winter maximum and summer minimum; seasonal variations over South Island are more erratic. Precipitation amounts along the North Island coasts range from 35 to 65 inches with the highest amounts in the N. Days with precipitation range from about 140 to 200 days annually.

Snow is infrequent at low elevations throughout New Zealand and generally melts soon after it falls, except on the eastern side of South Island, where a snow cover sometimes persists for a few days. Thunderstorms are infrequent. They are increasingly less common from N to S and from E to W. An average of about 20 thunderstorms in the extreme N decreases to about 2 to 5 each year along the E coast of South Island. Winter and spring are the more favored times of year in the N; elsewhere there is little seasonal preference. Although tornadoes are rare, they do occur. Defined by New Zealanders tornadoes include waterspouts, funnel clouds, and localized storms with damaging winds-a definition much braoder than that used in the United States. Tornadoes are most likely in regions of severe thunderstorm activity and during the afternoon. Most are associated with cold fronts particularly those with a strong southwesterly flow. The most severe occur from May through October with the greatest frequencies near the western coasts.

Temperatures are also influenced by topography. Seasonal and diurnal variations are small along the coasts. Mean daily maximums are generally highest on North Island ranging from the 70's (degrees F) during the summer to the 50's (degrees F) in winter. Minimums remain above freezing in winter. Mean daily maximums along the South Island coasts range from the mid 60's to low 70's (degrees F) in summer to the upper 40's to low 30's (degrees F) in winter. Minimums range from the upper 20's to low 30's (degrees F) with up to 70 days annually of below-freezing temperatures at some locations.

Relative humidities are usually high throughout New Zealand. Along the coasts there are only small diurnal variations. Average values range from about 80 to 90 percent during the early morning dropping to 65 to 80 percent during the afternoon.

Cloudiness is related to the topography, with the windward slopes experiencing the greatest amount of cloudiness. With the airflow mainly from the W, it is usually cloudiest along the western coasts with a minimum along the eastern coasts. Convectivetype clouds are predominant so maximum cloudiness generally occurs in the afternoon with a nighttime minimum. Good clear periods along the coasts and adjacent waters occur with the anticyclones, while widespread thick clouds will prevail during frontal passages. There is often a marked difference, however, between the W and E coasts as descending air on the lee side tends to disperse clouds. Averaged cloud amounts increase S of about 45 degrees S, where the moist westerlies become more persistent. Visibilities are usually good. Low clouds may obscure the coastline at times and visibility is often reduced below fog limits in heavy rain for short periods. Radiation fog occasionally forms over estuaries around dawn, on calm, clear nights, and may drift a mile or so out to sea. This usually clears soon after sunrise. Sea fog is unusual since the sea is usually warmer than the air above.

TROPICAL PACIFIC ISLANDS

Because of the vast ocean area and the small land surface the most noteworthy characteristic of this region is the monotonous uniformity of the weather throughout the year and throughout much of the area as well. The influence of strong insulation and isolation from any cold source is reflected by sea surface temperatures that exceed 70 degrees F year-round - 75 degrees F N of 10 degrees S. This moderating effect is evident in the air temperatures as well. Only S of 15 degrees S and N of 10 degrees N are there noticeable seasonal changes.

The climate is dominated by two great airstreams, which originate in the semipermanent high pressure belts of the North and South Pacific Ocean and converge toward the equatorial low pressure trough. They meet along the Intertropical Convergency Zone (ITCZ), which migrates N and S with the sun. Long overwater trajectories of this air results in climates of high temperatures and humidities, abundant cumulus clouds and frequent, sometimes heavy, rain showers. An important feature of the climate are the tropical cyclones that roam the waters S of the equator eastward to about 140 degrees W and N of the equator everywhere.

Intertropical Convergence Zone (ITCZ).- This discontinuous band of clouds, showers and thunderstorms is formed by the convergence of northern hemisphere northeasterlies with southern hemisphere southeasterlies. Lying roughly E-W the ITCZ can vary from 50 to 200 miles in width. Its intensity can vary from scattered clouds to torrential downpours. Its position can fluctuate daily but in general it follows the movement of the sun. West of 150 degrees W the ITCZ moves back and forth across the equator while to the E it ranges between 12 degrees N during the southern winter and the equator in summer. Many tropical cyclones, both N and S of the equator, are spawned in the ITCZ.

During the southern hemisphere winter (June through October) the ITCZ is N of the equator everywhere. It reaches its northern most position during July through September and the entire region N of the equator is active. Towering cumulus and cumulonimbus clouds, moderate to heavy showers and thunderstorms, and maximum tropical cyclone development are the characteristics. The ITCZ retreats southward from October on. During the most active period, generally from July through October, periodic wavelike deformations, known as easterly waves, are generated in the NE trades of the E central Pacific. As they move westward and slowly intensify they bring clouds and rain to the entire area. Sometimes they form cyclonic vorticies and develop into tropical cyclones.

During summer (December through March) the ITCZ moves into the southern hemisphere E to about 150 degrees W where it crosses the equator and remains to the N. The ITCZ usually makes its deepest penetration by February in the W and March in the E. Intermittent but often heavy showers occur throughout the zone. Thunderstorms are more frequent than they were in winter, except near the equator, and precipitation is greater except where topography exerts a strong influence. The ITCZ also serves as a spawning ground for tropical cyclones in the southern hemisphere.

Tropical Cyclones.- North of the equator tropical cyclones (winds => 34 knots) have been encountered from the Philippine Sea to the eastern limits of the area. To the S tropical cyclones are rare E of about 150 degrees W.

The Western North Pacific has spawned tropical cyclones in every month. They are most likely from July through October, least likely from December through April. About 27 tropical cyclones develop each year, on the average, and some 17 of these attain typhoon strength (winds => 64 knots). Several of these reach the supertyphoon state (winds => 130 knots). A mature typhoon may grow to 600 miles in diameter, generate winds of 150 knots or more, seas of 40 feet and torrential rains. They can wreak havoc from Wake Island to the western Caroline Islands. Tropical cyclones can also generate a storm surge that may result in tides 10 to 15 feet above normal.

From January through April tropical cyclone activity is mostly confined E of the Philippines between 5 degrees and 20 degrees N. From May onward this activity spreads northward and westward; by August its center stretches from Luzon to Honshu. In the fall (southern hemisphere spring) the area of activity begins to shrink, until by November its concentrated just E of the Philippines. Supertyphoons are usually limited to the northwestern edge of the area and the Marianas are occasionally raked by these storms. In general the Marianas and western Carolines are more vulnerable to tropical cyclones than the eastern Carolines and Marshalls. On the average between July and October at least one typhoon will pass through or near the Marianas and two through the western Carolines. The Marshalls and northern Gilbert Islands lie on the fringe of the tropical cyclone activity. Storms are often in their formative stages in these areas. The Gilberts are too far S and the Marshalls are most likely to be affected from September through December; a tropical cyclone will affect these islands about once every three years on the average.

Eastern North Pacific tropical cyclones, referred to as Central North Pacific storms when they form between 160 degrees W and 160 degrees E, are unlikely S of 10 degrees N; E of 160 degrees W they are unusual S of 15 degrees N. However, there is always the possibility of an errant storm affecting the northern part of this area. This would be most likely in August or September when they make their farthest westward penetration.

South of the equator tropical cyclones roam from the Territory of New Guinea past the Society Islands; however they are rare E of 150 degrees W. In March 1975, cyclone Alison blew over New Caledonia where sustained winds of 103 knots with gusts to 119 knots were reported at Baie Ugue. Farther east Bebe, an out of season October hurricane, devastated the British Gilbert, Ellice and Fiji Islands. Winds exceeding 150 knots were reported. The South Pacific tropical cyclone season generally runs from December through April, although they can form in any month. January, February and March are the most active months. From E of about 100 degrees E an average of 16 tropical cyclones come to life each year; six of these become hurricanes. They usually form between 5 degrees and 15 degrees S between New Guinea and 180 degrees . Initially they tend to move toward the S or SW then recurve toward the SE or E. Early season activity is concentrated between the Solomon and Fiji Islands. During January and February these storms usually originate in the northern Coral Sea, near the Fiji Islands or New Hebrides. Moving east-southeastward or southeastward they are most likely to be encountered between the New Hebrides and New Caledonia. Except for some activity around Samoa, March storms tend to remain in the Coral Sea. April tropical cyclones often move from the Coral Sea to between New Caledonia and the New Hebrides southward through the western south Pacific.

Tropical cyclones are most likely in the New Hebrides-New Caledonia region which is affected by 2 to 3 storms each year on the average. The Fijis and southern Solomon's can expect 1 to 2 storms in an average season. About 1 storm each year affects the Samoa Islands while the Cook Islands are hit about once every 2 years or so. To the E frequencies fall

progressively lower although they have on occasion affected the Society Islands, the Iles Tubuai and the Tuamotu Archipelago.

Winds.- The general air flow throughout this region can be traced to the trade wind regime. During the southern hemisphere winter (June through October) the SE trades emanating from the South Pacific high, gradually veer to a more southerly flow upon crossing the equator and invade the Carolines, Marshalls and Gilbert Islands. By the time it reaches these islands the winds are often out of the SW to W. To the S of the equator the SE trades remain remarkably steady. The islands poleward of about 20 degrees S are occasionally invaded by the westerlies that prevail to the S. In summer (December-March) northeasterlies originate in the North Pacific high, and in the western regions in the Siberian High, and encroach S of the equator. Northeasterlies prevail over most of the area except over and W of New Ireland where they are northerly or northwesterly and E of about 150 degrees W where they remain easterly and southeasterly. This trade wind system is steady with average speeds of 8 to 12 knots. In some areas the trades will strengthen at times to near gale force.

Gales throughout this tropical region are rare. They are usually generated by tropical cyclones or occasionally by thunderstorms. The periodic strengthening of the trades increase speeds to near gale force but rarely above it.

Local winds are created by an interruption of the general flow. North of the equator, because of the small size and height of many of the islands, land and sea breezes are almost completely absent. Only a few islands are mountainous enough to disrupt the prevailing trades. North of the equator the NE trades are by far the steadiest and strongest with wind constancies from 70 to 90 percent and average speeds of 5 to 15 knots. The southeasterlies and their components are less steady and weaker. Calms or light and variable winds are prominent at most locations when the ITCZ passes through-once known as the doldrums.

The islands S of the equator have a more complex topography and, coupled with a light to moderate windflow, this produces an endless variety of directions and speeds. While over water winds are relatively constant and average 8 to 12 knots, land and sea breezes effect changes on many islands. Strong katabatic (downslope) winds are also reported where mountains border the coast. Sea breezes are most prevalent in the lee of larger islands such as at Nandi in the Fiji Islands. Many of the islands to the E are low and flat and exert little local influence.

Over New Guinea and the Solomon Islands winds blow out of the W through N 40 to 60 percent of the time from December through February while easterly and southeasterly winds prevail from May through October. Winds are variable with frequent calms, during the transitional periods when the ITCZ passes through. Sheltered coastal locations are susceptible to land and sea breezes and a few places where mountain valleys reach the coast strong local winds are often observed. Best known is the "guba" at Port Moresby, which may occur, up to 5 or 6 times each year, during any season. It is an early morning wind, usually lasting 20 to 30 minutes and reaching speeds of 50 to 60 knots (Port Moresby is just outside the region).

East and SE winds prevail year-round over the New Herbrides, Santa Cruz Islands, New Caledonia and Loyalty Islands. Speeds average 10 to 12 knots from May through November and 5 to 10 knots at other times. In February and March the ITCZ reaches the New Hebrides-Santa Cruz Island area. Light winds and calms are occasionally interrupted by 15 to 20 knots squalls. Gales are infrequent but most likely with tropical cyclones.

In the islands E of about 170 degrees E the SE trades are dominant through most of the year. Between 170 degrees E and about 150 degrees W the ITCZ moves S of the equator; behind it northeasterly winds blow on the islands closest to the equator in summer. Easterlies remain the prevailing winds throughout the islands. Northeasteries penetrate to about 12 to 15 degrees S during this season. To the W of 180 degrees a belt of variable westerly winds has been reported at times between the two converging trade wind systems.

On the larger and more mountainous islands local effects are well pronounced. For example at Nandi, on the W coast of Vitu Levu, Fiji winds are mainly calm or southeasterly in the early morning but afternoon westerly sea breezes predominate throughout the year. However, at Suva on the SE side easterlies and southeasterlies prevail with little diurnal variation. At Christman Atoll easterlies blow 70 percent of the time year - round. Similar frequencies can be found for Fanning, Baker Island, Phoenix Island and Tokelau Islands. On the larger Samoan Islands of Upolu and Savai'i diurnal changes are evident leeward of the track winds, usually on the W coasts. The rugged terrain of the Marguesas Islands also obstruct the trades and land and sea breezes are prevalent on the sheltered sides of the islands. The Society Islands lie in the path of SE trades but because of terrain effects winds are quite variable on the northern and western coasts. At Bora-Bora and Papeete winds average about 5 knots with a high percentage of calms; 20 to 30 percent with summer frequencies highest. Southeast trades do not usually extend to Rapa and Pitcairn Island. Winds are more variable at the southerly locations, with NW to N winds common from fall through spring and NE winds predominant in summer. Calms are a lot less frequent than farther N and gales occur up to 5 percent of the time at Palmerston, Rurutu, Rikitea and Pitcairn Island; gales are most likely from June through August.

CLIMATE

Mariana Islands.- Within these islands, which lie just N of the maximum rainfall belt, annual rainfall amounts decrease erratically from S to N. In the S amounts range from 85 to 120 inches annually compared to near 70 inches in the N. The principal rain and cloud producers are the Intertropical Convergency Zone (ITCZ), easterly waves and tropical cyclones. Maximum 24-hour amounts of near 9 inches have been recorded. July through October is the rainest, cloudiest period. Showers and cloudy skies are reported on 20 to 27 days per month. December through June is the driest period but clear skies are still infrequent except at night. Temperatures are usually highest in June before the onset of the cloudy season. With an annual range of only 3 degrees to 7 degrees F daytime highs reach the 80's(degrees F) with nighttime lows in the 70's (degrees F). Coolest temperatures occur in January and February during the height of the NE monsoon. Extremes range from near 100 degrees F to just below 60 degrees F. Relative humidities are high year -round averaging 85 to 90 percent in the early morning and 60 to upper 70 percent by afternoon; lowest values occur from March through May. Visibilities are usually good; they drop below 6 miles less than 10 percent of the time. They are poorest in showers or thunderstorms; thunderstorms only occur on about 5 to 20 days annually and are most likely from July through October.

Caroline Islands.- Most locations, except far out Tobi Island, record annual rainfall amounts in excess of 100 inches, and many in excess of 140 inches. Wet and dry periods are apparent in and W of the Truk Islands, where January through April reflect the intrusion of dry northeasterlies. Precipitation is generally heaviest during the evening hours. Maximum 24-hour amounts range from 6 to 22 inches and can occur in any month, although the heaviest amounts are more likely during the typhoon season. The eastern Carolines receive the heaviest and most evenly distributed rainfall because of their position outside the monsoonal flow and the small latitudinal sweep of the ITCZ in this region. Mean annual totals can range up to 250 inches in this area. Rain falls on 150 to more than 300 days each year. Throughout the island group extreme fluctuations in rainfall occur from year to year. The Caroline Islands experience the most uniform temperatures of all the island groups because of their E- W orientation, their nearness to the Equator, and the high frequency of cloud cover year-round. Cloud cover in excess of 70 percent is common most of the year. Mean daily maximum temperatures climb into the upper 80's (degrees F) with mean daily minimums in the mid to upper 70's (degrees F); both vary no more than 3 degrees F between warmer and cooler months. Throughout the Carolines extremes in the 90's and high 60's or low 70's have been observed. Relative humidities are high year "round with readings in the 80 to 90 percent range in the early morning and 70 to 80 percent range during the early afternoon. Visibilities are good to excellent at most locations. They drop below 2 miles 1 percent or less of the time. This is most likely in torrential downpours. However, at Falalop visibilities fall below 6 miles 20 to 50 percent of the time during the night remaining below that level 5 to 15 percent of the time during the day. Thunderstorms are more likely in the western islands than in the eastern part. They occur on up to 22 days annually at Koror and on about 10 days annually at Ponape; they are most likely from May or June through December.

Marshall Islands.- Precipitation is abundant and fairly evenly distributed throughout the year. Since the islands and atolls are less mountainous than the eastern Carolines there are fewer local differences. Mean annual amounts range from 55 to 160 inches increasing from N to S. The southern Marshalls are influenced more by the ITCZ in summer while the northern sections are influenced more by the drier NE monsoon in winter; the northern Marshalls receive 60 to 85 percent of their rainfall from about July through November. Rain falls on about 200 to 300 days annually. Even though the Marshall chains are N-S oriented there are little regional temperature differences. Very cloudy conditions in the S restrict the annual range of mean maximums and minimums to less than about a couple of degrees. In the N where partly cloudy skies prevail, an annual range of 4 to 5 degrees F is common. However, most locations record mean daily maximums in the mid to upper 80's and mean daily minimums in the upper 70's. Extreme highs have exceeded 100 degrees F only at Jaluit Atoll and lows have dipped to 66 degrees F on Kwajalein Atoll. Cloudy conditions occur on about 20 to 25 days per month in the S and 10 to 20 days per month in the northern Marshalls. However, completely overcast skies are uncommon and usually short lived. Relative humidities, while high, are lower than they are elsewhere. Early morning readings in the upper 70 to mid 80 percent range are common while afternoon readings usually fall into the low to mid 70's. The visibility is generally excellent, falling below 6 miles less than 10 percent of the time. Thunderstorms, which can lower visibilities to a few hundred yards for a short period of time, are likely on about 16 days or less annually, with a peak from about July through October.

Wake and Johnston Islands- On these isolated islands rainfall is drastically reduced; 36 inches on Wake and 27 inches on Johnston in an average year. Both, situated in the heart of the NE trades, undergo a wet and dry season. When the trades are best developed, generally January through March, is Wake's dry season; the wet season runs from July through October. However, on Johnston Island occasional weak polar fronts make their way S to bring some January rainfall; June and July receive the lowest amounts. Skies are cloudiest from July through October at Wake and in April and May at Johnston. Temperatures at Wake and Johnston are similar to those in the Marianas; they are also subjected to infrequent invasions by weak polar fronts, when temperatures fall about 3 to 5 degrees F from normal. Mean daily maximums range in the low to upper 80's (degrees F) with the warmest period from July through October, while minimums fall into the mid to upper 70's. Relative humidities are low compared to the other islands. Early morning readings range from the mid to upper 70's while afternoon readings are in the mid 60 to low 70 percent range. (Visibilities below 6 miles occur less than 5 percent of the time.) Thunderstorms are infrequent; at Wake, where they are more likely, they occur on about 5 days annually.

New Guinea and Solomon Islands (including the Santa Cruz Islands).- Rainfall is heavy and frequent with annual amounts ranging from 75 to more than 250 inches annually. Maximum 24-hour amounts have exceeded 20 inches in several locations. Topography is important in determining rainfall amount and rainy seasons. For example Talasea on the N side of

New Britain is exposed to the NW summer flow while Lindenhafen Plantation on the S side is exposed to the SE flow of winter. Talasea averages 20 to 32 inches per month from December through April while Lindenhafen records 6 to 11 inches. In contrast Lindenhafen Plantation averages 20 to 42 inches per month from May through October while Talasea records 4 to 8 inches. Tropical cyclones and thunderstorms add to the torrential nature of the rains. Thunderstorms occur on about 50 to 90 days annually. They are most likely during winter and spring except where exposure is to northeasterly winds. Rain can be expected on 130 to near 300 days annually. Skies are usually cloudiest during the passages of the ITCZ and, on the larger islands, during the season of the onshore monsoon. This is primarily convective cloudiness and is most likely during the late morning and early afternoon. Temperatures and relative humidities are consistently high throughout the year. Mean daily maximum temperatures range from the mid 80's (degrees F) to low 90's with a slight peak in spring (October-December) while mean daily minimums run in the low to mid 70's. Extremes of 100 degrees F and the mid 60's are common. Relative humidities range from the low 70's to low 80's during the morning to the upper 60 to low 80 per cent range during the afternoon. The diurnal variation is usually less than 10 percent. Visibilities are good except in showers, when heavy rain may reduce them to a few hundred yards. In dry weather haze occasionally reduces visibility to between 3 and 6 miles.

New Hebrides, New Caledonia and Loyalty Islands.- While rainfall amounts vary widely the rainy season generally runs from December or January through April, when up to 20 inches per month is common at some locations. July through November is usually the dry season. Rain can be expected on 70 to more than 200 days annually. The rainy season is also the cloudiest time of year and, as in many tropical Pacific Island groups, clear conditions are uncommon throughout the year. However, clouds are least likely late at night. Thunderstorms are not frequent, particularly over the low lying islands. Temperatures and relative humidities are constantly high but show more of a seasonal variation than those islands closer to the equator. December through March is the warmest season when mean daily maximums climb to the mid 80's (degrees F) during the day and mean daily minimums range from the low to mid 70's; extremes reach the low to upper 90's. During the winter (June through September) mean daily maximums range from the mid 70's (degrees F) to low 80's with a definite northward increase. Nighttime lows average in the low 60's in the S to low 70's in the N. Noumea once recorded a 52 degrees F reading in July. Relative humidities also show both diurnal and seasonal variations. During the summer they reach to 80 to 90 percent range at night and fall to the 70 percent range during the day. In winter readings fall off by about 10 percent at night and about 5 percent during the day. Visibilities are usually good, although haze may reduce it to 4 to 6 miles during a dry spell. Heavy showers cause short periods of low visibilities.

Fiji and Tonga Island.- Rainfall amounts vary from about 60 inches to 150 inches annually along the coasts of these islands. This falls on an average of 125 to 250 days each year. The wide range is due mainly to topography and exposure. In general the rainy season runs from June through September. Heaviest rains occur in tropical cyclones. In winter a local convergence zone generally about 600 miles northeast of the Fiji Islands may occasionally move down over the area bringing clouds and rain. Thunderstorms are most likely from November through April. Cloud cover corresponds with the rainy and dry seasons and is also dependent upon exposure. Cloudiness is more likely during the afternoon. Temperatures are pleasant year-round. In general mean daily maximums are in the 80's (degrees F), mid to upper in summer and low to mid in winter. Mean daily minimums range from the mid 70's in summer to the mid to upper 60's in winter. Extreme maximums stay below 100 degrees F while extreme minimums remain above 50 degrees F. Relative humidities are also higher in the summer. Nighttime readings in the 85 to 90 percent range are common compared to low to mid 80's in winter. During the day readings fall into the 70 percent range in summer and 60 to low 70 percent range in winter. Visibilities are 12 miles or more about 80 percent of the time. The most serious reductions are caused by showers, thunderstorms and tropical cyclones. Haze is common from July through September but rarely reduces visibilities to below 3 miles.

Gilbert and Ellice Island (including nearby islands).- December through March is the most likely time for frequent and heavy rains; these are associated with the ITCZ. Annual rainfall amounts vary from 50 to 75 inches on 125 to 160 days in the Gilberts and about 80 to 160 inches on 200 to 250 days in the Ellice Islands. Thunderstorms are recorded on up to 20 days annually. While they are most likely during the rainy season they also occur in winter. Clouds are most abundant during the rainy season with a minimum from about August through November. During the rainy season cloudy skies are observed on about 15 to 20 days each month; they are less frequent at night. Temperatures vary only a few degrees throughout the year. Average daytime highs range from the upper 80's to low 90's (degrees F) while nighttime lows dip into the mid to upper 70's. Extremes range from near 100 degrees F to 60 degrees F. Relative humidities remain fairly high year-round although it is somewhat drier in from August through November. Nightime readings climb into the mid to upper 80 percent range, low 80's in spring. During the day relative humidities fall into the 70 percent range, dropping to the mid to upper 60's, particularly in the Gilbert Islands, in spring. Fog is uncommon and visibilities are usually good. Heavy rains occasionally reduce visibilities to less than 1 mile, for a brief period.

Howland Island, Baker Island and the Phoenix Islands.- These islands lie in what is known as the dry zone. Canton, for example, records 23 inches of rainfall in an average year and it is reported that Howland and Baker Islands are dry. This dry zone extends across the entire region of the eastern Pacific from about 3 degrees N to 5 degrees S and most stations record less than 25 inches annually. The boundary of this zone can fluctuate from year to year so that Canton has recorded as much as 63 inches in a single year and as little as 8 inches. Rain falls on about 100 days annually with April through August being the rainest period. Thunderstorms are infrequent, but are most likely during the rainy season; Canton records about five annually. December through February is slightly more cloudy than the rest of the year although cloudy skies are infrequent, occurring less than 15 percent of the time. Clear skies are observed from 20 to 50 percent of the time, with a peak in September and October. Temperatures are fairly constant throughout the year. Mean daily maximum temperatures

range from the mid 80's (degrees F) to about 90 degrees F with nighttime lows dipping into the upper 70's to low 80's. Extremes range from about 101 degrees F down to 70 degrees F. Relative humidities are in the 80 percent range at night, except in spring when the frequently dip into the upper 70's, and fall into the 60 to 70 percent range during the afternoon; in spring these readings are at their lowest also. Visibilities are good. They fall below 2 miles less than 1 percent of the time at sea and fog is also rare over the islands. Visibilities are restricted mainly in heavy showers.

Tokelau Islands Samoa Islands and Niue Island.- Rainfall is variable throughout the islands depending upon exposure and topography. Annual amounts range from 80 inches to more than 190 inches. October through April is usually considered the rainy season although even in other months rainfall is substantial. Rain can be expected on 15 to 20 days per month during the wet season. Record amounts in 24 hours have totaled up to 20 inches. These are most likely in rare tropical cyclones or in the ITCZ. Skies are cloudiest from November through February. Cloudy conditions at sea are encountered 20 to 30 percent of the time. From June through August when cloudiness is at a minimum skies are clear from 20 to 30 percent of the time. Temperatures show little seasonal variation but a 7 degrees to 15 degrees F duirnal variation. Daytime highs range from the low to mid 80's, on the average, while nightime lows dip into the mid 60's to mid 70's (degrees F). Extremes range from just below 100 degrees F down to the mid 60's, except on Niue Island where extreme lows have reached the mid 50's. Relative humidities also show little seasonal variation and much more variability from day to night. During the night they climb to the 80 to low 90 percent range falling during the morning till they reach the 70 precent range by early afternoon. Spring is slightly drier than the rest of the year. Visibilities are good and fog is seldom observed. Poor visibility is mainly associated with showers. At sea visibilities fall below 2 miles less than 1 percent of the time. Thunderstorms are observed on about 20 to 40 days annually and are more frequent here than in most of the other island chains. They are well distributed throughout the year with a slight peak during the spring and summer.

Cook Islands and Iles Tubuai.- Precipitation over these islands is plentiful with October through March the wettest period. Annual amounts range from about 75 to 120 inches on about 150 to 200 days. Thunderstorms usually occur on about 15 to 30 days annually and are most likely in summer. Skies are, on the average, cloudier S of about 15 degrees S. Cloudy skies coincide with the rainy season and are present about 20 to 30 percent of the time while clear skies are observed at the same frequency from about April through November. Temperatures in the northern Cook Islands show little seasonal variation while those in the S and in the Iles Tubuai show a variation of about 5 degrees to 8 degrees F. In the N mean daily maximums range in the mid to upper 80's (degrees F) with minimums in the mid to upper 70's. In the S daytime highs range from the low to mid 80's in summer to the mid to upper 70's in winter, while nightime lows dip into the low 70's in summer and mid 60's in winter. Extreme high temperatures remain below 100 degrees F everywhere while extreme minimums drop to around 70 degrees F in the N down to the upper 40's to mid 50's S of 15 degrees S. Relative humidities are less prone to seasonal and latitudinal variations and more susceptible to diurnal changes. Nightime readings are in the mid to upper 80 percent range. They fall during the morning hours, reaching a low in the early afternoon in the low to mid 70 percent range. Visibilities are usually good at sea dropping below 2 miles 1 percent or less of the time. On the Iles Tubuai haze is observed occasionally but is unlikely in winter. Sometime local fog exists when the weather is clear a few miles to sea.

Line Islands and Marquesas Islands.- Annual precipitation amounts range from 20 to 150 inches on the average. The larger values are found N of Christmas Island and S of Malden. The relatively dry zone usually ranges from just N of the equator to about 5 degrees F. There seems to be no definite rainy period although Fanning, Christmas, and Malden Island usually have an April peak. Rain falls on about 90 to more than 250 days annually. Thunderstorms are infrequent. There is little difference in cloud amounts N and S of the equator. At sea cloudy conditions are observed 10 percent or less of the time while clear skies occur 30 to 60 percent of the time, with a slight winter and spring peak in the north. Temperatures vary only a few degrees seasonally or latitudinally. Daytime highs average in the mid 80's to around 90 degrees F while lows drop into the low to mid 70's. Extremes range from about 100 degrees F to 60 degrees F. Relative humidities vary from the 80 percent range at night to the 60 percent range during the day. September through November is often the driest period. Visibility is good throughout the area with showers accounting for most of the restrictions.

Society Islands, Tuamotu Archipelago, Iles Gambier, Pitcairn, Ducie and Henderson Islands.- In an average year rainfall amounts range 60 inches to more than 100 inches in this region. At sea precipitation is observed 7 to 12 percent of the time near Pitcairn Island and 2 to 7 percent of the time elsewhere. Thunderstorms are infrequent being recorded on 8 to 20 days annually; they are most likely from January through July. The rainy season runs from about November through May N of 20 degrees S and spread out through most of the year to the S. Except in the SE portion where there is little seasonal variation clouds are more likely during the rainy season (November-May). At sea cloudy conditions are observed about 10 to 18 percent of the time during this season. Near Pitcairn a peak of 20 to 23 percent of the time occurs in spring. Clear skies are encountered 20 to 35 percent of the time in the N and 15 to 30 percent of the time near Pitcairn. Temperatures vary little N of Iles Gambier. Mean daily maximums range from the mid 80's to around 90 degrees F with minimums in the upper 60's to low 70's. To the S warmest readings occur from December through March when daytime highs usually reach the low to upper 80's (degrees F) and nighttime lows dip into the low to mid 70's. During July and August mean daily maximums reach the low to upper 70's with minimums in the mid 60's. Extremes range from the mid to upper 90's (degrees F) to the mid 50's in the S and around 60 degrees F N of 20 degrees S. Relative humidities are fairly constant throughout the year with more of a diurnal variation. During the night readings climb into the 80 percent range. During the morning hours they begin to fall reaching a minimum in the upper 60 to mid 70 percent range by early afternoon. The main restrictions to visibilities are showers. At sea visibilities drop below 2 miles about 2 to 3 percent of the time in summer around the Tuamotu Archipelago but less than 1 percent elsewhere year-round.

Galapogos Islands.- This region, some 600 miles W of Ecuador, is subjected all year to the stabilizing influences of the South Pacific trades and the cold Peru Current. Skies are usually partly cloudy, with stratus more common than cumulus. Low ceilings and moderate rainfall occur only on the windward slopes. Rain is spotty on the flat sections and leeward slopes, causing semiarid conditions. The high relative humidity is alleviated by the steady winds and moderated temperatures. Thunderstorms are rare but fog and haze are common.

WEST COAST OF SOUTH AMERICA

Climates along the W coast of South America range from the hot, humid, tropical rainforest of the Panama Gulf region through the cool, tropical desert region of Peru, and northern Chile and the transitional, moderate climate of central Chile, to the damp, cool climate of the S. The boundaries are not sharp but ones where one climatic zone gradually merge into that of another.

The controlling climatic features are the South Pacific subtropical high flanked on the N by the Intertropical Convergency Zone (ITCZ) and on S by migratory, circumpolar low pressure systems. The coastal climate is also influenced by two markedly different ocean currents-the warm Equatorial Current and the cold Peru or Humboldt Current.

The equatorial low and ITCZ range between 12 degrees to 14 degrees N in winter (August) and 0 to 2 degrees N in summer (February). Rainfall along the Panama-Colombia coast reflects this movement as peaks occur when the ITCZ is near. Rainfall rather than temperatures, which are high year-round, determine the seasons.

From Ecuador to northern Chile the coast is blanketed by a subsiding, southerly flow of cool dry air emanating from the South Pacific high. Originally warm and dry, the air is exposed to the cool Peru or Humboldt current and becomes even more stable, with an almost total lack of precipiation. This results in the barren wastes that make up the Atacoma Desert, which is similar to BAja California and NW Mexico.

Along the northern coast of Ecuador the Equatorial Current brings some relief from the dryness during the summer (December-April). Trades blowing across this current bring warm humid air, rainfall and clouds. The southward invasion of this warm water is known locally as El Nino (The Child) because of its advent near Christmas. In some years the current spreads a thin layer of warm surface water farther southward along the coast of Peru. This usually dissipates quickly, but in abnormal years the cold water of the Peru Current is replaced by a rather deep layer of warm water, with surface temperatures near 80 degrees F. The air above becomes warm and moist, giving rise to banks of towering cumulus and torrential rains along the coast as far S as 14 degrees S. Sometimes more than ten times as much rain will fall in a few days as would normally fall all year or in several years. An exceptionally strong El Nino has an average return period of 20 to 25 years near Lima compared to 6 or 7 years on the N coast of Peru. The duration of El Nino ranges from 1 week or more in the S to 2 months or more in the N.

To the S of the South Pacific high, air moves eastward over a large expanse of ocean becoming cool and moist. This becomes the mainstream of the midlatitude westerlies which, along with the migratory low pressure systems, completely dominate the southern one-third of Chile. This coast has a climate characteristic of the NW United States and British Colombia. The central coast of Chile is a battleground between the dry weather to the N and the wet weather of the S. During winter when the subtropical high is farthest N (about 25 degrees S) westerlies prevail while summer (January) brings the dry subsiding southerly flow. The weather conditions are "Mediterranean", and similar to California with warm, dry summers and wet, mild winters.

Intertropical Convergence Zone.- This area of frequently disturbed weather moves N and S with the sun. It reaches its northernmost position, about 12 degrees to 14 degrees N, in February and lies between the equator and 2 degrees N in August. In oscillates from day to day from its mean position and can vary a couple of hundred miles in a few days. The ITCZ, an important source of rainfall, is discontinuous as well as variable. Disturbed weather areas may vary in width from less than 50 miles to several hundred miles. Rain is usually showery in nature and thunderstorms can occur. During less vigorous periods the ITCZ may degenerate into an area of broken cumulus clouds and scattered showers; sometimes it becomes so weak that little or no cloudiness can be found.

Camanchaca.- The air flowing over the upwelled waters of the Peru Current is humidified and cooled until it reaches its dewpoint. Fog and low stratus clouds form. Known as "camanchaca" this fog and low stratus is often several thousand feet thick and frequently persists over water during all hours of the day. Onshore winds, generally the sea breeze, carries this fog to the coast over northern and central Chile. The camanchaca may occour in all seasons, but it is most frequent from May through October. It may last for weeks at a time during the latter half of this period. Dense fog or drizzle from the low stratus supply most of the meager amounts of moisture to the northern coast.

Roaring Forties.- Temperature differences between the subtropical oceans and the antarctic continent cause a strong pressure gradient between about 35 degrees and 60 degrees S, which induces a belt of strong prevailing westerlies known to mariners as the "roaring forties" and "whistling fifties". Southern South America juts into this stream creating the only

major interruption to its flow around the Southern Hemisphere. Mean wind speeds are near 20 knots year 'round. Gales are frequent and 80 knot winds have been recorded at a few island locations. Large migratory low pressure systems often ride these westerlies and their associated fronts trail northward often bringing poor weather to the central and S coasts of Chile. Some rain may even extend to the southern fringes of the Atacama Desert.

Winds.- Offshore, S of 40 degrees S in summer and 35 degrees S in winter, lie the variable westerlies of the midlatitudes. Moderate and frequently strong SW through NW winds prevail. Gales (wind 34 knots or more) are encountered 15 to 25 percent of the time S of 50 degrees S with a peak from fall through spring. Some of the island locations report winds of 28 knots or more on more than 100 days annually. Mean speeds 15 to 20 knots are common S of 40 degrees S. North of this region to just S of the equator winds tend to follow the coastline, which results in a preponderance of SE, S and SW winds. Gales become increasing less likely; N of 20 degrees S they blow less than 1 percent of the time year-round. Windspeeds average 5 to 10 knots. In the Panama Gulf winds vary with the season and the shifting of the ITCZ.

There is a seasonal battle between the trade winds from the two hemispheres. From about December through April northerlies, along with northeasterlies, are in control. Windspeeds average 8 to 12 knots and gales are rare. After a short transition period southwesterlies and westerlies gain control in June and persist until November. Windspeeds average 7 to 10 knots and, again, gales are rare.

Coastal winds are subject to the land-sea breeze effect, topography and other local influences. This is particularly true in the tropics where pressure gradients are often weak. From May through September N of the equator and January through April to the S early morning winds are often light or calm. By late morning a sea breeze picks up, increasing in intensity until reaching full strength by early afternoon. These breezes commonly reach 10 to 20 knots and occasionally, when they reinforce the prevailing flow, speeds, may approach gale force. The sea breezes are frequently out of the S through NW depending upon location. Shortly after sunset the wind abates. During the night winds are often calm or a light land breeze may develop. This effect extends along the entire coast when pressure gradients are weak. It is most noticeable from central Chile northward in summer. These sea breezes and the prevailing flow combine to bring a preponderance of S through NW winds year 'round to the coasts of Colombia, Ecuador and Peru. The Panama coast reports the sea winds from about May through November. For the rest of the year NW through N winds are common. Strong winds along these equatorial coasts are most often associated with thunderstorm gusts. Occasionally they approach hurricane force (64-knots or more); Buenaventura, Colombia has recorded a 45-knot sustained wind.

Land and sea breezes affect the northern and central coast of Chile. Sea breezes are a factor year 'round while land breezes are prominent in winter, usually between midnight and sunrise; they seldom reach more than a moderate speed. To the S the coast is exposed to strong westerlies, which are interrupted by migratory cyclones with their associated fronts. Winds become variable with frequent frontal approaches and passages. Winds shift from a northerly to southerly then to a westerly component. Windspeeds increase. Winds greater than 20-knots are common while gales occasionally blow, particularly at the more exposed locations. In the southernmost sections there is little seasonal difference in the frequency of high winds while a winter maximum can be expected near central Chile. Along this coast winds out of the SW through N are common.

Climate.- Rainfall near the Panama Canal averages about 70 inches annually on about 150 to 170 days. May through November is generally the rainy period. Thunderstorms occur on 40 to 80 days annually, mostly during the rainy period, particularly June through October. The driest period is February and March when monthly amounts usually average less than 1 inch. Along the coast of Colombia and northern Ecuador annual rainfall amounts range from about 100 to nearly 300 inches falling on 200 to 300 days. Precipitation shows some seasonal variation, with a slight lull during February and March in the N and August through November in the S. Thunderstorms become increasingly less frequent towards the S; Buenaventura records 27 thunderstorm days annually while Esmeraldas records 1 day. Maximum 24-hour amounts along the section of the coast from the Panama Canal to northern Ecuador range from 5 to 10 inches. Rainfall on this coast is mainly dependent upon the ITCZ.

Near the Gulf of Guayaquil annual amounts fall to 10 inches or less and this drops to less than 5 inches along the coast of Peru and northern Chile; many locations record less than 2 inches annually, some less than 1 inch. (There are some places on the Atacama Desert that have received a total of less than 1 inch in 50 years.) This sparse rain falls on 10 to 20 days each year. This is due to in part the stabilizing effect of the Peru Current. From Lima S, the summer half of the year receives the least precipitation. During the winter persistent low stratus is sometimes accompanied by a very light drizzle known locally as "garua". This is the principal form of precipitation along the coast. In areas where 10 to 20 inches is normal, an abnormal year can produce 40 to 60 inches; like when the El Nino becomes established. Heavy amounts are most likely during February, March and April. This variation is usually confined to Ecuador and northern Peru. Thunderstorms are unusual.

Along the central coast of Chile rainfall amounts begin to increase uniformly from about 10 inches to 100 inches. Along the S coast of Chile precipitation amounts vary with exposure between 100 inches and 300 inches and rain falls on over 300 days in some sections. There is in general a lack of seasonality in the S while in the central region, from Valparaiso to Puerto Montt summer is the driest period, when monthly amounts are often less than 2 inches, which falls on less than 5 days. May through August are the wettest months. Averages vary from less than 5 inches to more than 15 inches on 8 to 20 days per month. In the southernmost part of Chile snow falls on about 2 to 10 days per month from May through October, but is

temporary at lower elevations. Maximum 24-hour precipitation amounts range from less than one-half inch along the northern coast of Chile to near 13 inches in the S. Thunderstorms occur on less than 10 days annually, with a slight winter maximum.

In general cloudiness has seasonal patterns similar to rainfall. In the tropics a diurnal variation is often noticeable as well. Clouds increase during the afternoon and early evening, due to convective activity, and decrease late at night. Near the Panama Canal skies are cloudy on 20 to 30 days per month from May through November, while clear skies are observed on 8 to 16 days per month during January, February and March. Colombia and northern Ecuador are a lot cloudier with little seasonal fluctuation. Cloudy days occur, on the average, 20 to 27 days per month year-round with only 20 to 30 clear days all year. Around the Gulf of Guayaquil during the dry period, May through September, a dense cover of low stratus often drifts ashore and maintains an overcast day and night. This flow across the Peru Current results in a winter and spring maximum along the central and S coasts of Peru; the central coast experiences a minimum in autumn. Cloudy skies occur on 100 to 200 days annually. Chile experiences a wide variety of sky conditions from the nearly cloudless skies of the northern desert to the almost endless cloudiness of the southern tip. Along the northern coast early morning clouds are observed mostly from July through October; cloudy skies occur on about 120 to 150 days annually. Clear skies are most likely in summer when they are likely on 10 to 15 days per month. Along the central coast May through October are the cloudiest months accounting for much of the 120 to 190 days of cloudy skies each year, on the average. Clear skies are common from October through March. However, S of Valdivia (40 degrees S) clear days are few. Skies are cloudy on about 200 to 300 days annually. Near 40 degrees S midsummer is about the least cloudy time.

In the tropics temperatures change more between day and night than they do seasonally or even latitudinally. Cloud cover is a moderating factor under the hot tropic sun. Lowest afternoon temperatures often occur during the rainy season while coolest nightime lows are most likely during the clear, dry season. From the equator northward temperatures at coastal locations reach the low 80's to around 90 degrees F during the day with nighttime lows in the 70's. March and April are usually the warmest months, when about 15 to 25 days per month see the temperature climb to 90 degrees F or above. However, extremes never reach 100 degrees F at exposed locations. Extreme lows are usually in the low to mid 60's (degrees F) and are just as likely in the southern summer season as at any other time.