National Weather Service

SOUTHERN CALIFORNIA WEATHER FOR BOATERS

Emil S. Kurtz (Retired) - March 1977

Revised - January 2002
San Diego Weather Forecast Office
Richard Stitt
Don Whitlow
Debra Tarczy

Revised - November 2006
San Diego Weather Forecast Office
Don Whitlow

Table of Contents

List of Figures

List of Figures and Table **Page**

SOUTHERN CALIFORNIA WEATHER FOR BOATERS

I. INTRODUCTION

The great upsurge in boating activity in southern California is due in part to the usually reliable weather that permits year-round participation. Even so, the weather cannot always be taken for granted, for on occasions, weather-related problems arise where fore-warning would help. Prudent skippers should acquire some knowledge of particular weather situations that complicate boating operations and an awareness of the best sources of forecasts and warning information.

The Weather Forecast Office (WFO) in San Diego (Rancho Bernardo) issues forecasts for the coastal waters off San Diego County, from San Mateo Point to the Mexico Border and out 60 nautical miles. These forecasts primarily indicate wind direction and speed, occurrence of fog, rain or thunderstorms, swell height and direction, wind waves and any other variables of particular significance through 5 days.

For the coastal area extending from Point Conception to the Mexico border, there are many local variations in wind and weather patterns, which are due in part to the irregular coastline and land forms and the Southern California Bight. Obviously not all small-scale variations in the wind pattern can be described in the forecasts. These variations are only partially indicated by the selected list of coastal observations included in the Weather Service or Coast Guard radio broadcasts. It is unlikely that forecasts will ever be detailed enough to cover all these small-scale irregularities even though their importance to individual yachtsmen is recognized.

Since forecasts stress general features of significant coastal weather, and warn of weather hazards that appear imminent, the yachtsman is left with the problem of deciding what the weather will be in the local area during the time involved in his boating plans. It will be easier to do this if he has some knowledge of larger scale weather patterns and processes that cause local variations in his area of interest.

There are a number of excellent books available on general meteorology and some of these discuss certain aspects of southern California weather. The intent here is to outline sources of coastal forecasts and weather warnings for Southern California and to relate forecast wording to the category or type of weather situation involved. Also, the intent is to set down a few helpful forecasting rules. A little armchair meteorology will be worked in, but no more than necessary.

II. WEATHER FORECASTS AND WARNINGS

The following list contains the principal sources of weather information available to the small boat skipper. Although the Weather Service issues the basic information, there are many methods of distribution of forecasts to users.

1. VHF: A continuous broadcast of public and marine weather observations, forecasts, and warnings is available along the West Coast of the United States (see Figure 1). Southern California waters are served from Los Angeles on 162.550 MHz, Santa Ana Mountains on 162.450 MHz, San Diego (Mt. Woodson) on 162.400 MHz and also from Mount Soledad on 162.425 MHz which is Marine Information Only. Reception is usually good within 40 miles of the coast, except it can be unreliable in the lee of coastal hills and offshore islands.

2. Coast Guard Weather Broadcasts: NMQ 2670 KHz. KOU 2566 KHz. Broad area coverage.

3. Commercial Radio Stations: Frequent spot forecasts. Pick your favorite.

4. TV Weathercasters: Weather Channel and local weather forecasts. Most TV stations have capabilities to scroll warnings, advisories and updates for significant weather events.

5. Newspapers: Most Major city newspapers include excellent graphics maps and forecasts.

6. Web Pages: San Diego WFO www.weather.gov/sandiego
   NWS Marine www.nws.noaa.gov/om/marine/home.htm
   National Data Buoy Center www.ndbc.noaa.gov/index.shtml

Each of these sources contributes in its own way and at times more than one may be needed to get the whole picture. The VHF broadcast is adequate for most small-boaters and is easily acquired with inexpensive receivers. Coast Guard weather broadcasts have greater range than VHF broadcasts, but are available only at scheduled times. Weather Service

aviation forecasts, broadcast by FAA radio, deal especially with flying weather but can be adapted for use on waterways, lakes and rivers. Newspaper forecast weather maps are helpful in that they show locations and movements of weather fronts and areas of high and low pressure. TV weathercasters usually discuss effects of weather fronts or low-pressure systems on local weather.

A suggested step-by-step approach to getting the most out of available weather information is as follows:

1. For the month in question, consider weather types most likely to occur, such as a weather front, Santa Ana, coastal fog, or Catalina Eddy.

2. Become acquainted with aspects of each weather type so that when they are highlighted in the forecasts, you can recognize the type.

3. Examine the text or wording of forecasts or warnings in order to identify the principal weather type involved.

4. Follow-up to keep informed on visual weather clues or later forecasts.

III. BOATERS ALMANAC OF WEATHER FOR SOUTHERN CALIFORNIA COASTAL WATERS

The following outline of typical weather events is given to assist in evaluating chances of certain problem conditions developing. Obviously, it should not be used like a forecast since it would be too general. Use it as a first approximation.

<u>January, February, March:</u>

New Year's Day has a record showing favoritism for fair weather, nevertheless, the rainy season is in progress. Weather fronts are active and vigorous. Four to six rainy periods per month are associated with these fronts. These periods are usually of one-to-two days' duration. Occasionally, a close sequence of fronts may give four to seven successive rainy days before final clearing. A few days may have coastal fog but usually not of long duration. Fog may form, then lift to a stratus cloud layer with the approach of frontal weather.

Winds are usually less than 15 knots, but with weather fronts, the frontal wind sequence comes into the picture: increasing southeast winds at first, shifting to west or northwest upon arrival of the front with gusts possibly exceeding 30 knots. Post-frontal squalls and occasionally frontal or post-frontal thunderstorms may occur with gusts over 35 knots. Santa Ana winds may develop once or twice per month as a surface high pressure center moves into the Great Basin. The winds are usually from the north to northeast and briefly cause wind speeds of 30 to 40 knots over coastal waters. Small craft advisory are usually issued for frontal winds and occasionally gale warnings are required. On the average, wind advisories or warnings may be up 3 to 5 days during these months.

Long period swells, predominantly from the west to northwest and may range up to four to six feet with high surf at times. These swells are generated by intense storms quite a distance away as in the Gulf of Alaska or in the Western Pacific Ocean. Occasionally significant wind swells will develop off Point Conception or farther north and move into the Southern California Bight.

Afternoon beach temperature 62/67. Water temperature 54/60.

<u>April-May Weather:</u>

Weather fronts are becoming less frequent and not so active. Usually not more than one or two weather fronts bring rains that may involve a day's duration, possibly two. Winds usually not over 20 knots but some frontal storms have required small craft advisories for wind speeds 25 to 30 knots. Southeast winds picking up then shifting to west or northwest with frontal systems make up the usual pattern. Santa Ana winds rarely affect coastal waters. Coastal fog and low clouds are more frequent night and mornings and often persist around offshore islands. High wind may continue for up to 2 to 3 days.

Long period swells from south to southwest and west to northwest may occur a few days and reach 3 to 5 feet with more swells beginning to come from the southern hemisphere. High surf will come from storms well out in the Pacific.

Afternoon beach temperature 63/67. Water temperature 57/61.

<u>June Weather:</u>

Normally no fronts move through the area in June. Night and morning coastal low clouds and fog occur as the coastal inversion becomes stronger, and may produce drizzle at times. Cloud or fog pockets often develop around islands. Diurnal winds become more pronounced with afternoon sea breezes 15 and occasionally 20 knots a usual occurrence, but rarely requiring small-craft warnings. No Santa Ana winds. Wind advisories or warnings rarely more than one or two days in the month.

Swells arrive more frequently from the Southern Hemisphere with long period swells 2 to 4 feet from the south to southwest with west to northwest swells becoming quite small. Once or twice during the month there may be large south swells causing swells 3 to 6 feet from early season tropical storms moving off the west coast of Mexico. These swells usually occur for two to three days.

Afternoon beach temperature 67/70. Water temperature 61/64.

<u>July, August, and September Weather:</u>

No fronts move through the area. The coastal marine layer and inversion are more prominent with frequent night and morning coastal fog or low clouds along the coast, usually clearing in the afternoons. There usually are a few days each month with tropical air moving up from the south to southeast, accompanied by middle and high clouds, desert and mountain thunderstorms, and with less persistent coastal low clouds and fog. These thunderstorms seldom affect coastal waters. Occasionally there will be 4 to 6 days of very high temperatures. Winds along the coast seldom exceed 10 knots, but over the outer channel waters and around the islands and up to Point Conception, northwest winds may reach 30 knots on several days in association with a Catalina Eddy. Small craft advisories are virtually non-existent.

On a few days, south swells may reach 4 to 6 feet generated by tropical storms off the Mexican west coast. Long period swells caused by storms in the Southern Hemisphere occur, but due to the long period of 18 to 20 seconds, these do not seriously affect boating. The Beaches mainly in Orange County and Northern San Diego County receive the large surf, while Southern San Diego County may get very small surf as the swell does not refract into the coast. It can affect the Points and outer rock reef breaks in Southern San Diego County. Boating operations over coastal waters are not much affected due to the long period of the swells.

Afternoon beach temperature 73/76. Water temperature 66/71.

<u>October and November Weather:</u>

One or two active weather fronts in October (3-4 in November) may be expected to bring short periods of rain with durations of one or two days. One or two days may involve Santa Ana Northeast winds in October (3-4 in November) with speeds occasionally reaching 30 to 40 knots along the coast below coastal canyons. Otherwise, winds are usually less than 20 knots except for short periods during frontal activity. Then they may reach 20 to 30 knots and may require small craft advisories, but usually not more than one to three days during the month. Coastal low clouds or fog may develop on a few mornings, but variable inversions tend to shorten the duration of low clouds and fog. Delayed "Indian Summer" heat spells are not uncommon with warm weather to the coast.

Swells are more frequently from the west to northwest with a mix of Northern Hemisphere and Southern Hemisphere swells and the Southern Hemisphere swells decreasing. Swells from either direction are generally long period.

Afternoon beach temperature 70/73. Water temperature 64/68.

<u>December Weather:</u>

Weather fronts become more active and more frequent with 3 or 4 fronts involving periods of rain with durations of one to two days. Usually about six or seven days with rain occur during the month, but many Decembers have dry spells lasting 2 to 3 weeks. Dense night and morning fog over the coast may occur on 6 to 8 days. Santa Ana winds can occur up to 4 to 6 days. Northeast winds may extend out over coastal waters and reach 30 to 40 knots in areas exposed to coastal canyons. Otherwise, winds over coastal waters do not exceed 20 knots except with frontal situations, then the usual southeast winds shifting to west-to-northwest reaching 25 to 35 knots with the front, and requiring small craft advisories. Occasional post-frontal squalls have winds over 30 knots. Wind Advisories or Warnings may be required for strong northeast winds during Santa Ana wind events. Wind advisories or warnings are issued 3 or 4 days on the average.

Long period swells are virtually all from the west to northwest and may reach 5 to 8 feet on a few occasions. Southern Hemisphere swells are almost nonexistent.

Afternoon beach temperature 67/70. Water temperature 62/64.

IV. THE COASTAL MARINE LAYER

Before going into the various weather categories of southern California, one typical feature of the coastal climate should be discussed. The presence of a high pressure area off the California coast and a low pressure area over the southwestern interior (southern Nevada and southern California deserts) creates a pressure difference which maintains a flow of air from the Pacific in over coastal waters and across the coast.

A cold current (California Current) that flows along the coast from the northwest keeps the coastal waters cool. The relatively cool coastal waters cool the air passing over toward the coast, developing a layer of relatively cool air, referred to as the "Marine Layer", to distinguish it from the warmer and drier air above. Mixing within this cool marine layer takes place to varying degrees, distributing fairly uniform cooling throughout the layer and forming a sharp transition layer between it and the warmer air above. This transition layer - cool below and sharply warmer above - is called an "Inversion Layer", or simply an "Inversion" (Figure 2). This shows a plot of temperature versus height. The strength of the inversion varies, depending on the difference in temperature between the cool air beneath it and the warm air above. The height of the inversion may vary from near the surface up to several thousand feet. Variations in strength and height are influenced by pressure differences that affect the balance of the onshore-offshore movements of air along the coast. Lower pressure to the north, northeast, or east tends to lift and weaken the inversion. Any tendency of warm air aloft to subside or sink to lower elevations over the coastal area adds to the warmth of the air above the inversion, thus strengthening the inversion, while cooling aloft above the inversion weakens the inversion. The inversion layer acts to suppress vertical air movements and thus tends to place a "lid" over the marine layer; and the stronger the inversion, the stronger the resistance to vertical movements through the inversion. This is so because any parcel of cool air that might be forced upward through the inversion into the warmer air above would be more dense than its new surroundings, and would then sink back to lower levels beneath the inversion.

Moisture is added to this lower layer of air as it passes over the cool coastal waters and fog or coastal stratus clouds may form beneath the inversion. Fog or low clouds vary in height or thickness with variations in the depth of the marine layer. Haze and atmospheric pollutants tend to accumulate beneath the inversion since dispersion through the inversion layer is strongly suppressed.

The inversion is most pronounced at night, therefore coastal fog and low clouds have their greatest frequency in those hours. Although the inversion may persist over coastal waters throughout the day and night, daytime warming of air near the surface over land may gradually cause the temperature of this lower air layer to become as warm as the air above the inversion. The inversion will then be eliminated and might not re-form until nighttime cooling over the land allows the coastal inversion to once again extend in over land. Eliminating the inversion through surface heating also tends to dissipate any clouds or fog beneath it, and the reappearance of low level clouds or fog will be delayed until the inversion begins to reform.

<u>The Land Breeze/Sea Breeze Influence:</u>

Among weather patterns discussed, several will involve large scale movements of air in response to differences in pressure between high and low pressure systems. Locations of these pressure centers with respect to each other and to southern California are a determining factor on southern California winds and weather.

At times when highs or lows are weak or at a considerable distance, pressure differences are not very great over southern California and have only a minor effect on winds along the coast. Then changes in wind or cloudiness are more affected by the diurnal change from a land breeze to a sea breeze and back to a land breeze; coastal fog or low clouds form during the night and early morning, and burn off during the afternoon.

The influence of this land breeze and sea breeze cycle acts as a modifying factor, even when other stronger pressure forces are at work. First consider the land breeze that moves out from the shore over coastal waters at night. As the land cools after sundown, the air begins to cool in the lower layers, becomes denser and will tend to sink toward lower levels. Slopes that face toward the north will begin to cool earlier than those facing south, so this "drainage wind" will first start moving down these northern slopes; but as nighttime cooling goes on, the drainage winds start moving down southern slopes as well. The drainage wind gathers force as the air progresses toward the lowest levels and on to the coast (Figure 3). Since nighttime cooling is more pronounced under clear skies and will be more developed during long winter nights than during shorter summer nights, the land breeze develops best during clear, cold winter nights and will be less developed during cloudy nights or in summer.

The drainage wind will depend on the slope of the land over which it moves; thus when it reaches the shoreline and moves out over the water, its direction will conform pretty much to the direction as it moved down slope to the coastline. Once it reaches the shore, however, it loses its driving force and its speed decreases. Under the most favorable conditions, it may have enough momentum to carry several miles out to sea, but seldom more than five or ten miles. If the down slope influence is weak, the land breeze may only move out a few hundred yards beyond the coastline. When a down slope or drainage wind moves across a coastline and out over coastal waters, it is called a land breeze - also referred to as an "offshore breeze".

Ordinarily, the land breeze will be most developed around sunrise; then, as warming commences and progresses over land, the drainage wind rapidly weakens and the land breeze ends.

The sea breeze, in a sense, develops under a reverse process. As land areas, especially slopes, begin to warm during the day, air is warmed from contact with the land. Continued warming leads to a movement of air up slope and ascending columns of air over other land areas.

By contrast, the air over coastal waters remains cooler than that over the warming land areas, and begins to exert a push toward the land to replace some of the warm air that is moving up slope. In southern California, the interior valleys and desert areas warm rapidly during summer, which leads to relatively low surface pressures in those places, and as a result of this, a movement of air sets in toward this lower pressure. This adds much to the force of the movement of air that takes place from coastal waters inland over the coast and on to passes that lead out to the deserts.

The direction of the sea breeze will be toward the shoreline and usually perpendicular to it, but since there are usually certain preferred escape routes for the air after it has moved onshore, the direction of the sea breeze as it nears the shore will be modified toward the path of easiest flow inland. Any hill near the shore will act as a barrier, tending to force the sea breeze around it, resulting in an acceleration of air around its sides and also an area of eddying or variable wind along the windward shore below the hill.

Effects of the sea breeze will ordinarily be most pronounced within a few miles of the shore, usually not over ten miles. However, the sea breeze sweeping in toward the shoreline will have a modifying effect on wind flow farther off the coast, turning the flow slightly in toward the direction of the sea breeze itself. Thus, if large scale pressure gradients remain the same, the sea breeze/land breeze cycle can provide some diurnal modification to the wind flow even twenty or thirty miles off the coast.

Along the southern California coast, the land breeze is best developed from late November to March, with the sea breeze least pronounced. Generally, the sea breeze reaches its most regular and strongest period from June through September, with the land breeze least noticeable out beyond the shoreline. During spring and fall, land and sea breezes are of nearly equal strength.

When the forecaster believes the land breeze/sea breeze influence will be the primary influence on wind, he may issue a forecast worded like this: "Light and variable winds in the night and morning hours becoming west 10 to 15 knots in the afternoon..."

V. FOG AND LOW CLOUDS

Fog and low clouds along the southern California coast are important to the offshore sailor because during much of the year these are the principal weather features. During the season when fog or coastal low clouds make up the most frequent weather event - usually from May to August - the weather portion of the forecast may go something like this: "Low clouds over coastal waters moving in over the coastline in the late night and early morning hours, clearing in the afternoon...". Low clouds of the stratus (layered) type present no real hazard provided that the base of the layers remains well above the water or land surface. Of course, when the layer is resting near the surface as fog, the visibility becomes seriously reduced. Dense fogs are most likely to occur in otherwise fair weather situations in late fall or early winter, and usually will be associated with persistent daytime haze or smog in coastal areas. Summertime fogs over the coastal waters are usually less dense and more often occur in association with low stratus clouds in a marine layer from 800 to 1200 feet deep.

Forecasts do not always indicate the extent of fog and at times may only indicate "fog or low clouds". This may be due to uncertainty as to which may first appear, at times it may suggest a transition from one to the other, at still other times, it may indicate that both will be present; and, you may encounter one of these or both depending on where you are located. The height of the "inversion" which caps the marine layer will strongly influence the elevation of fog or cloud layers beneath it, and determine whether there is fog on the surface, or a low stratus cloud layer with the base, some hundreds of feet above the surface.

Some judgment of the height of the inversion can be made by observing whether a heavy accumulation of haze persists near the coast during the day (low inversion), or whether clouds already forming along the coast appear to rest well up on the hills (high inversion). Estimating the height of the inversion is an indirect way of determining the chances of fog versus low clouds but when you have to rely on your own resources, it may be worth a try.

Fog or stratus that has covered the coast during the night and gradually cleared with midday warming will begin to reform up near the base of the inversion when evening or nighttime cooling sets in. As further cooling takes place, the layer of clouds thickens downward. If clouds appear to be forming lower than about 800 feet above sea level (Figure 4), the chance of fog instead of low clouds is more than a 50/50 chance, and if the layer of clouds appears to be lower than 600 feet, the chances of fog over stratus are much greater. If clouds seem to be first forming higher than about 800 feet (Figure 5), the risk of dense fog is reduced.

Although, fog sometimes sweeps in along the coast in mid afternoon or earlier and catches offshore sailors by surprise, in most cases, the fog had been lying over the coastal waters during the day and is brought in over the coastline by the sea breeze. Sometimes the fog will rapidly develop near the coast and move inland due to dynamical processes such as an eddy developing. Some warning of the presence of fog may be provided by observations from offshore islands included in VHF continuous weather broadcasts. San Nicolas Island or San Clemente Island may provide some clue if fog is already surrounding them; on the other hand, if they are reporting cloudy weather rather than fog, the risk of fog along the coast is reduced, with indications of a higher inversion.

Weather forecasters have come up with a rule with regard to an early burst of fog over the coastline. Although weather rules, like many other rules, don't work every time, there is some basis for this one. It goes like this: "If fog comes in fast, then it surely won't last". The interpretation is; the sea breeze that brought in the early afternoon fog will begin to lose its force before long and the fog will then tend to break up or back off from the coast. This might be true if the sea breeze was induced by rapid warming just a few miles inland. This warming will be cut off upon arrival of the cooler sea breeze, thus in turn, diminishing the sea breeze.

In this type of fog situation, with the sudden arrival of a fog bank, apparently eliminating possibility of an afternoon cruise, the best course may be to wait awhile and see what the fog does. Meanwhile, if you are already out, keep your fog horn blowing to let other boats know your location. If you are near the shore or in shallow water, the best procedure may be to drop anchor. This would be preferable than to risk collision with other boats or ending up on the rocks by making a hasty run for harbor. Either would be much worse than waiting an hour or two to see if the fog lifted or dissipated, as it often does.

One situation favorable for fog formation will be discussed in connection with the Santa Ana wind. With the "warm type" Santa Ana, the inversion is depressed to quite a low elevation, but the marine layer persists along many parts of the coast. Haze may persist near the coast because of the drift of air from inland areas toward the coast, the haze being trapped beneath the inversion. This day-long haze condition is often a clue that pockets of fog can easily form along and off the coast. These fog pockets often develop near the end of a two or three day Santa Ana condition.

In addition to dense fog or "pea soup", where visibilities may be a hundred feet or less, there are often very extensive light fog conditions that affect nearly all coastal waters off southern California, including offshore islands. As a rule, these include combinations of fog and low clouds with enough variation in the depth of the marine surface in many locations, with visibilities of a hundred yards or more. Whether there is pea soup fog or fog with visibility of a hundred yards may not seem to be very important, but it will make quite a difference in what you are able to do. While there can be no substitute for keeping accurate determinations of position and course, at least the dangers of collision or running aground are much reduced when you can see a few hundred feet. Some practice in obtaining bearings from radio beacons along the coast should be part of every skipper's bag of tricks and are particularly helpful in unexpected fog situations.

It would be fine if someone would come up with an instrument that could give a warning that fog will form within a predicted time. A hygrometer that measures humidity will probably come the closest to such an instrument. Humidity will be well over ninety percent before fog forms. The difficulty with this type of prediction is that fog usually develops rapidly as the wind moves over the cool ocean surface and can be considered to be blown or swept in over an area rather than just forming there and the high humidity and fog arrives at nearly the same time.

When forecasts mention "night and morning fog or low clouds..." or "increasing coastal fog night and morning hours", such mention of the possibility of fog should be taken seriously, and attention should be given to later forecasts and coastal observations as provided in VHF weather broadcasts.

VI. THE CATALINA EDDY

The Catalina Eddy is a name for a particular wind pattern that frequently develops along the southern California coast. Local skippers show much interest in the Catalina Eddy, although there is considerable uncertainty as to just what is involved. The confusion is not theirs alone, for while meteorologists have discussed it, written reports on it [1], and generally accept it as a fact of life, they do not all agree on how it forms or exactly what factors distinguish it from certain other wind patterns.

Identifying the features of a Catalina Eddy will help for early recognition of its development or disappearance which will be described along with factors that influence changes in strength and some ways that it may affect sailing plans. If everyone agreed on terminology, forecasts to cover the Eddy could simply state, "Strong Catalina Eddy today and tomorrow", or "Weak Catalina Eddy...", etc.

The most persistent synoptic feature off the California coast is the Pacific High. The pressure gradient between this high and the characteristically lower pressure over southwestern United States maintains the northwest current of air over California coastal waters. This air current is most persistent during the summer. The northwest air flow sweeps along nearly parallel to the northern California coast, pushing inland through broad openings in the coast range (Figure 6). Notice that the southern California coast makes a sharp bend around Point Conception toward the east. When a fast wind current (25 to 35 knots) moves along the California coast and reaches Point Conception, it begins to broaden out as it sweeps toward San Nicolas Island. Some of this fast current turns in toward the left to follow along the coast, and this turning increases as the current continues south of Point Conception. This swirl of air turning counter-clockwise toward the coast is the Catalina Eddy. The eddy usually forms a circular, counterclockwise as in a low pressure system, wind pattern over the coastal waters, especially at night, but at other times it may describe only a sweeping arc toward the coastline.

During a Catalina Eddy, winds at Point Conception will be north or north-northwest 20 to 30 knots, and at San Nicolas Island northwest 15 to 30 knots. Winds from San Diego to Long Beach and Los Angeles will be southerly; southeasterly during night and early morning hours and south to southwest in afternoons. Winds over the channel will maintain more of a southerly component than when no eddy is working, and the afternoon sea breeze will usually hold south to west. This departure from the normal wind pattern may be of little interest to the power cruiser but has to be taken into account by sailboat skippers. If the wind holds due south in the afternoon, then it is probably a strong eddy. If the wind veers to the southwest to west afternoon, then it is more likely to be a weak eddy.

Meteorologists who have weather charts can confirm that a Catalina Eddy has formed by observing the pattern of pressure, wind, and clouds along the southern California coast. The small-boat skipper obviously does not have enough information to fill in the complete picture from what he can see. However, he can learn to recognize from the wording of forecasts when a Catalina Eddy may be shaping up. Since the wind pattern is complex to describe, the forecast may read like this: "Northwest winds 20 to 30 knots over outer channel waters today through tomorrow, but near the coast southeast winds 5 to 10 knots in night and morning hours becoming southwest 10 to 15 knots in afternoons. Coastal low clouds night and morning becoming mostly sunny or partly cloudy in the afternoon."

With the eddy, pressures will be higher at San Francisco than along the southern California coast, and pressures will be lower in the deserts from Yuma to Daggett and Las Vegas than at Los Angeles. The surface pressure will usually be lower at Santa Barbara and Los Angeles than at Point Conception and slightly lower at Los Angeles than at San Nicolas Island and San Diego with differences on the order of 1 or 2 millibars. This is an indirect way of saying that the Catalina Eddy circulates around a small low-pressure area centered near Catalina. The center of eddies in the Southern California Bight do not always form off the south end of Catalina and they usually form elsewhere in the Bight and they usually change position.

Effects related to pressure differences will not be very meaningful unless the shipboard meteorologist has some means of determining what the pressure is at selected locations. There are a number of sites that have pressure readings in millibars given every hour. Altimeter settings are given for these sites. The units are in inches of mercury. These can be converted to millibars using Table 1.

Development of an eddy brings an increase and deepening of existing fog or low clouds. If no fog is present, there will be a tendency toward fog formation. If fog has already formed, the change will be toward increasing fog that tends to lift to form a low cloud layer. If a general low cloud layer has formed, there will be a tendency toward lifting the bases to higher elevations with improving visibilities beneath.

Variations in the eddy pattern are created by some of the following influences:

1. Strength of the pressure gradient between the Pacific High and the southwest U.S. low pressure area. A stronger pressure gradient increases the northwest current off Point Conception, and also the wind that projects down the coast toward the outer islands, such as San Nicolas and San Clemente.

2. Location of lowest pressure in the desert and interior: If the lowest pressure is near Las Vegas, there is a strong tendency for the wind current to turn in toward the coast (Figure 6a). If the lowest pressure is farther south, near Yuma, the wind current does not turn in quite so sharply toward the coast (Figure 6b).

3. Land/Sea Breeze Influence: Nighttime cooling over land surfaces reduces the tendency for air to flow in across the coastline. The current of air turning in toward the coast, meeting the opposition of the land or drainage breeze, is then forced to drift northward along the coast, making up a southerly or even a southeasterly wind flow (Figure 6c). The flow is then roughly circular and dramatically illustrates the Catalina Eddy. Satellite pictures also show the eddy very well (Figure 7). Daytime warming over the land increases the sea breeze over the shoreline and begins to turn the southeast wind around so it comes in from a more southwesterly direction over the coastline (Figure 6a). This diurnal modification of the Catalina Eddy

should be kept in mind.

4. Location of Center of the Eddy: When the Pacific High is strong and its eastern perimeter is close to the Northern California coast, the northwest wind reaches its maximum off Point Arguello and extends south toward San Nicolas Island. Then the eddy is centered approximately over Catalina. When the Pacific High drifts farther away from the coast, or pressure begins to fall along the coast of Northern California, a broader eddy may be evident over the waters off southern California; but the center then shifts away from the coast, perhaps even west of San Nicolas Island. As a general rule, when the wind at San Nicolas Island drops below 10 knots from the northwest, or blows from another direction, there is no eddy present.

5. The Catalina Eddy is most likely to be present during spring, summer, or fall when the Pacific High is well formed west of the California coast in a fair weather situation, although it may develop to a degree in winter. Winter cases are frequently associated with the approach of a low pressure center, and while these may give some appearance of an eddy, they usually do not meet all the specifications.

6. Changes in strength of the eddy are associated with changes in the depth of the marine layer and height of the coastal inversion, as with a strong well formed eddy, the inversion rises with a deepening of the marine layer. Under the influences of an eddy, the marine layer along the coast usually becomes so deep that stratus clouds with high bases will be over the coastal waters and over land to the coastal slopes.

VII. WINTER STORMS AND WEATHER FRONTS

There is a nearly endless procession of low pressure centers and weather fronts moving eastward across the Pacific throughout the year. During summer, the persistent Pacific High west of the California coast prevents any significant frontal weather from reaching southern California because it is situated farther north and forces systems to move north of the state. Pacific lows and weather fronts begin to show increasing intensity from about November on through the winter months, and clouds and rain associated with them progressively work farther south along the California coast. Since boating activities flourish throughout the year in southern California, some allowance has to be made for interruptions in plans that these winter storms bring about.

Forecasts provide advance information of the effects on weather, of the approach of Pacific lows and weather fronts for periods up to about 72 hours and outlooks from 4 to 7 days, but some knowledge of the various types of winter storms and their behavior can assist the yachtsman in judging how much and for how long his plans may be affected. Television weather forecasts have for several years been discussed low pressure systems and cold fronts that bring 24 to 48 hours of rainy weather to southern California from 10 to 15 times a year. Southern California yachtsmen have gained some familiarity with the effects of low pressure systems and cold fronts in this way.

Weather statements often make reference to the location of a center of low pressure. The movements of these storms eastward progress across the Pacific are tracked from one weather map to the next. Circulation of air around lows is such that a flow of cool air from northern latitudes is moving southward around the western periphery of the low, and a warmer current of air is moving northward around the eastern side of the low. The leading edge of the cold current displaces warm air that is in its path, and the warmer current spreading northward gradually replaces cooler air ahead of it. The leading edge marking the boundary between contrasting air masses is called a "front", cold front if it marks the advance of colder air, and warm front if it is the leading edge of a warm air mass. Figure 8 shows how warm and cold fronts are represented on weather maps. Figure 9 shows a cross section view of cold and warm fronts.

Turbulent mixing, vertical motions and dynamical processes occurring in the frontal zone result in development of clouds and rain along the front. Cloud areas are more extensive along and to the east of the weather front, while the cold air west of the cold front is more unstable, and rising vertical currents tend to develop cumulus clouds. Pictures from weather satellites (Figure 10) help to determine patterns of clouds around lows and weather fronts. Figure 11 shows a schematic representation of a typical low just off the west coast and indicates wind and weather patterns associated with it. A decision can be made of conditions that would be encountered by a ship traveling through the storm.

If the rate and direction of movement of the storm are known, some estimate can be made of the sequence of changes in wind and weather that would occur at various points in the path of the storm. It is evident that, as a low-pressure center moves toward the West Coast, not all points along the coast will experience the same sequence of changes. For example, as the low center moves inland, it causes changes in wind directions for coastal points north of the center that are different from changes at points south of the center.

Since most centers of low pressure usually move inland well to the north of

Southern California, with only the trailing portion of the weather front moving through Southern California, the sequence of changes indicated in the forecasts might be like this: "Increasing south to southeast winds tonight reaching 15 to 25 knots tonight and tomorrow morning and southwest to west winds 20 to 30 knots tomorrow afternoon with west to northwest winds 20 to 30 knots tomorrow evening. The weather will be Cloudy with rain spreading southward along the coast tonight and tomorrow and showery weather tomorrow night gradually clearing the next day."

During the winter rainy season, forecasts of southeast winds increasing to 15 to 25 knots would most likely occur in anticipation of a weather front. The mention of rain helps to identify the situation as involving a front and low pressure system. The change in wind direction from southerly to a more westerly direction occurs as the frontal zone arrives and passes on toward the east. The reference to showery weather indicates the instability of the cold air moving in behind the front.

As a winter low pressure system and weather front approaches, small craft advisories are posted for winds 25 to 30 knots and quite infrequently gale warnings might be required for winds 35 to 45 knots in the frontal zone.

Low pressure systems that move across the Pacific approach the west coast from a number of directions ranging from southwest through west to northwest. The path followed by each storm is determined to a degree by broad currents in the upper air, but movements of surface low pressure areas are also influenced by the locations, shape, and strength of the semipermanent Pacific high pressure areas. These highs may steer or deflect the lows, or in some cases, act as obstructions in their paths. Where the highs have an elongated shape, the major axis often conforms roughly to the direction of movement of the lows; thus, consideration of the highs can help in predicting future positions of the lows.

The direction of approach of the lows has a bearing on variations in weather that each brings to Southern California. This helps to classify the lows into types for early recognition of certain aspects of their behavior.

The Southwest Type (Figure 12), because of its passage over warmer water at lower latitudes on its way to the coast, arrives with a good supply of moist air. Southwest Types produce some of the heaviest rains in southern California coastal and mountain areas. These rains may continue for 36 to 48 hours. Extensive cloud layers moving from the southwest ahead of the low pressure center and front usually give advance notice of the approach of rain. Surface winds along the coast are from a southeasterly direction from 10 to about 20 knots before the rains begin, and gradually veer around to southwest 15 to 25 knots as the low pressure center approaches the northern California coast. But winds usually do not veer beyond the west. Since weather fronts with these lows are not sharply defined, winds shift gradually rather than abruptly. Clouds and rain gradually decrease after the front has moved inland in Southern California, but since the entire system has moved in from warmer latitudes, there is little or no cooling with the clearing weather. Pressure values remain relatively high in Southern California with this type, although some fall in pressure occurs as the storm moves to the coast. However, pressure is lower to the north and northwest. Pressure observations at San Francisco are usually from 2 to 5 millibars lower than at Los Angeles before rain begins in Southern California.

The Northwest Type Low (Figure 13) moves southeastward from the Gulf of Alaska toward the California coast with a supply of cold air that becomes unstable as it moves over progressively warmer waters. Though lacking the heavy charge of moisture of the Southwest Type, it can still bring a period of heavy rain, strong, gusty winds, and squalls, and usually a few thunderstorms.

Northwest Type Lows characteristically move inland through Washington or Oregon, and the weather front extends out from the low center toward the southwest. The front advances southeastward along the California coast. Frontal cloud bands may extend only a short distance ahead of the area of rain and a rather abrupt change to cumulus clouds appears after the shift in wind marks passage of the front. Showers may occur along with gusty west to northwest winds for several hours after the front has passed, but frequently the rain ends promptly with rapidly clearing skies behind the front. Occasionally, lines of showers with the potential for thunderstorms moving off the islands continue for several hours after the front has moved east.

The Northwest Type produces good wind shifts as the cold front moves south along the coast, and shifts to west or northwest at places like San Francisco or Monterey will indicate the frontal passage. Winds along the Southern California coast will be from a south or southeast direction ahead of the front and then swing around to the west after the front has passed. Small-craft warnings will usually be displayed as wind speeds increase to 15 to 25 knots. Gustiness with the front and in squalls after the front may be accompanied by speeds to 35 knots.

Weather maps that show curvature of isobars along the front help in making an estimate of the duration of the showery period after the front has passed. Generally, if isobars make a sharp "V" in crossing the front with anticyclonic curvature west of the front (Figure 14), clearing is rapid and usually post frontal rains are of short duration. A broad cyclonic curvature of isobars across the frontal zone (Figure 13) favors a more gradual clearing with a longer period of showers.

The Westerly Type (Figure 15) moves eastward at middle latitudes to approach the California coast from the west. It draws in a moderate supply of moisture from lower latitudes as it passes across the Pacific, and pulls down behind it moderately cold air from northern latitudes for a combination that makes it a decidedly rainy type. This type is frequently associated with a broad area of low pressure over the eastern Pacific at mid latitudes which directs a series of low centers toward the Northern California coast to bring rainy periods to southern California for several days.

Since centers of low pressure usually head toward Northern California, pressure readings along the coast fall rapidly as the lows approach, and pressure at San Francisco may become 4 to 6 millibars lower than Los Angeles before rain reaches Southern California. Barometric pressure observations may drop to less than 1014 millibars along the Southern California coast.

Winds pick up from the southeast along the Southern California coast as the low nears the north coast, and only gradual shifts to southwest and west are characteristic. Wind speeds usually range up to near 30 knots, requiring small craft advisories. If a pronounced frontal passage does not occur, it may be a clue that the front extends westward to another low pressure center farther off the coast that will bring in another rainy period after a temporary clearing.

In each of these types, low pressure centers move to the coast north of Southern California before rains reach the latter area. A usually reliable indicator of rain at Los Angeles is that the pressure at San Francisco should be more than 2 millibars lower than the pressure at Los Angeles. Rain is all the more likely if winds aloft over southern California are strong from the southwest. This information may be obtained from VHF NOAA Weather Radio Stations (Fig. 1).

In summary, skippers should keep a sharp lookout for the following items with regard to winter cold fronts:

1. 24 to 36 hours ahead of the onset of frontal weather, there will frequently be a deepening of the coastal marine layer to form extensive low clouds.

2. Southeast winds seldom exceed 20 knots until shortly before arrival

of the front and rain.

3. 20 to 30 knot winds, clouds and rain are most likely from about 6 hours before to 6 hours after the cold front passage.

4. Squalls, rain and shifting winds accompany the front.

5. With west to northwest winds of 20 to 35 knots, rain squalls in unstable air following the cold front are quite likely.

6. A choppy sea and high swells are most likely to arrive with passage of the cold front and may continue for another day or two.

VIII. POST-FRONTAL SQUALLS

One after affect of vigorous fronts is a period of gusty winds often associated with rain squalls. If the cold air mass arriving with a front extends to a considerable depth, say 15 to 20 thousand feet, it will usually be quite unstable with turbulent mixing to a large vertical extent. This favors continuation of showers and rain squalls for several hours after the front has moved inland.

Winds at a few hundred feet above the surface flow more freely than winds at the surface. Surface winds are slowed by friction, which causes them to be slightly toward the left as in Figure 16A. When the air is unstable, as it usually is following a cold front, turbulent mixing occurs from the surface upward and gusty winds develop because momentum is transported downward to the surface from the faster upper level winds. This tends to increase surface wind speeds, with frequent gusts 25 to 35 knots. Also, the surface wind will veer slightly as in Figure 16 from time to time. If a rhythm between gusts and slack periods can be detected, and gusts last as long as slack periods, some sailing skippers try to be on starboard tack during gusts as this permits pointing a little higher when beating to a mark.

An alert watch should be kept during periods of squalls in order to avoid them if possible. Also be ready with corrective action if you are unable to keep away from them. The direction of movement of these squalls is often indicated by the "lean" or "tilt" of the clouds, for they drift along with the wind near cloud top level (Figure 17). If there is a curtain of rain, it can be used to help single out the more violent squalls. All rules are off at night, of course, for then it is rarely possible to tell much about the shapes or distances of clouds and squalls. Unfortunately, squalls can be just as violent at night as during the daytime. Lightning in the area is a sure sign of violent squalls.

One special type of weather phenomenon that may accompany squalls that deserves mention is the waterspout. While these are comparatively rare, they may number half a dozen or so during the rainy season along the coast of Southern California. First reports of these are most often made by airplane pilots, perhaps because the usually good visibility aloft enables pilots to spot them at a distance more readily than could a surface observer. Also, because pilots can promptly radio the report to a control tower and pass it on to the Weather Service. Conditions most favorable for waterspouts to develop require the passage of a sharp, active cold front and marked instability in the air following the front.

It is not known whether any small craft have been involved directly with any of these Southern California waterspouts. No measurements or close estimates of wind speeds around them are available. A reasonable guess would be that winds might reach 50 to 60 knots or higher around the perimeter of these waterspouts and that the entire column moves at speeds of 10 to 20 knots. The visible rotating column contains spray or small water drops, sometimes so thin they can be seen through. Textbook descriptions cite ranges in vertical extent of waterspouts as from less than 20 feet to several hundred feet, but usually less than one hundred feet in diameter.

Waterspouts will also develop with a deep cold upper level low that moves directly over the area. These situations have a cold pool of air aloft that makes the air mass very unstable with the potential for waterspouts and weak tornadoes over the land.

IX. THE SANTA ANA WIND OF SOUTHERN CALIFORNIA

If you are a Southern California boating enthusiast, it can be reasonably assumed that you have some familiarity with the dry northeast wind referred to as “The Santa Ana”. Its name implies an association with the Santa Ana River Valley which serves as one of the favorite routes for the northeast winds on their way from the mountains to the coast. Usage has become less precise in that the Santa Ana label has served to identify the more general northeast wind condition that in its various stages may affect most Southern California mountain and coastal areas.

Forecasts issued to cover the Santa Ana wind condition may read as follows: “Local northeast winds 25 to 35 knots in and near coastal canyons but elsewhere variable winds 8 to 18 knots in the afternoon today and tomorrow with clear skies”. This forecast would mainly be for coastal waters off Orange County and to the north while areas south of this may have a forecast as follows: “Local northeast winds 10 to 20 knots in and near coastal canyons with northwest winds 5 to 10 knots afternoon”. A strong Santa Ana wind condition would have stronger northeast winds in the south part and preclude northwest winds in the afternoon.

The northeast wind, with or without reference to its being localized, and the clear skies, tends to identify the culprit as a Santa Ana. With winds of this strength, small craft advisories may be posted and on rare occasions gale warnings may be required. This would mostly happen for areas in the north part of the Southern California Bight.

Strong winds begin to sweep down into Southern California from the north or northeast when surface pressures become substantially higher over Nevada and Utah than over southern California. This situation occurs after a weather front has moved inland through northern California and Nevada and is followed by a portion of the Pacific High that builds in over the Pacific Northwest and then into the Great Basin. The weather front may have brought rains into southern California, although in many cases it moves through the area with little or no precipitation. In some cases, strong northwest winds precede the Santa Ana and gradually veer around to the north and northeast as the ridge of high pressure builds into Nevada and Utah.

The difference in pressure between the Great Basin High and the area of lower pressure along the southern California coast will determine the strength of the Santa Ana and may be as much as twenty millibars or higher in extreme situations. During the Santa Ana, pressure may run from 3 to 6 millibars higher over the Mojave Desert than at Los Angeles, and surface pressures in southern Nevada will often run from 8 to 15 millibars higher than at Los Angeles and San Diego.

Air moving into southern California from the north or northeast must ascend to cross the mountains before descending to reach the coastal plain. As the air descends from mountains to coast, it warms at about 5.5 degrees Fahrenheit per thousand feet by compression. If the air is initially very cold, it will tend to flow through passes rather than to ascend over ridges, but pressure forces are usually great enough for it to make a broad sweep over ridges and passes and continue toward the coast. If an air mass after its descent to the coast is colder than the air overlying the coastal plain, it will push the coastal marine air out to sea. If the air descending from the mountains has warmed enough to reach the coastal plain at a higher temperature than the marine air, it will tend to ride over the marine layer and its effects will be more localized and mainly in the canyon areas. Meteorologists try to consider these temperature contrasts in making a distinction between the “cold type” Santa Ana which is more general and destructive and the “warm type” which is quite localized and usually less intense.

Figure 18 shows typical location of the Great Basin High for a Santa Ana. Maps printed in newspapers are of some help in anticipating the development of the Great Basin High. Figure 19 shows the favorite courses of these high speed northeast winds down to the coast and indicates areas most likely to be affected, both as to frequency and intensity of Santa Ana winds. These mark the locations of the strongest winds as they extend out over coastal waters to offshore islands. Coves or harbors open to the northeast are subjected to strong winds. A heavy surge or swell will make anchorages difficult and often unsafe.

With the "cold type" Santa Ana and its general gusty wind pattern that usually affects the entire coastal area, small craft advisories will usually be needed. When the Santa Ana is of the "warm type" and only areas exposed to canyons are subjected to strong winds, the need for advisories or warnings is not as frequent. Some sections of the coast are unaffected by the northeast winds and may even develop a sea breeze as a part of the return flow around the flanks of eddies set up by strong localized winds through canyons. Northeast winds are usually very light in the far south part of the Southern California coast and a weak afternoon sea breeze is typical. But due to the northeast direction, strong northeast winds coming off the coast from Orange County will spread into the outer waters in the far Southern California Bight.

The favored season for Santa Ana wind events is from October through March with the main peak of events in November with a secondary peak in March. Conditions similar to the Santa Ana may occur at other times of the year with dry northeast winds of lesser intensity and abnormally warm temperatures along the coast. The Great Basin High that initiates these winds usually persists from four to six days, and in some Novembers and Decembers, it may reform repeatedly with only temporary interruptions as weak weather fronts move in over the Pacific Northwest. Normally, winds are no longer a problem over coastal waters after the first day or two of a Santa Ana. As the Great Basin High finally begins to weaken or move to the east, the marine layer reforms along the coast and fog moves in over the coast and coastal waters.

The following checklist is included to help in anticipating the Santa Ana, identifying its presence and evaluating its effects:

1. Dry weather fronts (without rain) or rapid clearing after frontal rainy weather offer a hint that higher pressure is moving inland over the Pacific Northwest. The Santa Ana may be next on the program.

2. Forecast weather maps in newspapers that indicate a "High" pressure

area over Nevada and Utah are indicating a Santa Ana will occur.

3. Check pressure differences between Daggett or Palmdale and Los Angeles. During Santa Ana wind events, the Mojave Desert will have pressures 4 to 6 millibars higher than at Los Angeles. Check Imperial and San Diego for the south coast. Imperial being higher than San Diego by 2 to 5 millibars means east winds along the south coast. VHF NOAA Weather Radio broadcasts surface pressure for a number of locations. The altimeter setting in inches of mercury can be converted to millibars, a difference of 0.1 inch equals 3 millibars).

4. Mention of dry northeast winds of any strength over mountains and canyons in forecasts indicates effects of the Great Basin High. If mentioned in coastal forecasts, even as a localized condition, boaters should be alert for small craft advisories or other warnings, mainly in the north part of the Southern California Bight.

5. Strong Santa Ana's are associated with a very strong jet of north winds aloft over Northern California and Nevada.

6. A strong northeast wind over coastal waters can quickly stir up very choppy seas with strong surges in coves and anchorages on the east or northeast coast of offshore islands.

7. The first day or two of a Santa Ana are usually the worst for offshore winds, although the weaker Santa Ana winds may persist for another four to six days.

8. The final breakdown of the Santa Ana is when winds are weakening and advisories or warnings are dropped. This sets up conditions favorable for coastal fog, so keep this possibility in mind. This is more likely if desert temperatures are forecast to be notably higher than coastal temperatures.

X. RIP CURRENTS

Rip currents occur all over the world at any beaches, generally where this is surf. Erroneously called undertows or rip tides, these currents can last from a few minutes to a few hours, while other, more permanent ones, associated with groins or jetties, may last days. Rip currents can be killers. If you are caught in one, how you respond could make the difference between life and death.

Rip currents form when water is piled up against the shore and begins to return to deeper water. In some areas, strong winds and waves push water over a sandbar allowing excess water to collect. Eventually, the buildup of water starts to return seaward through low areas in the sandbar, "ripping" an opening.

Near the beach, rip currents are narrow (30-60 feet wide) with increasing width as they extend up to 1000 feet offshore. The velocity of the water intensifies during low tide and can be as high as 5 mph.

Rip currents can be observed from the shore. If the current has recently formed, you will see murky water (as compared to the surrounding water) due to sediment mixing as a channel is opened in the sandbar. However, if the rip current has lasted a long time, the color of the water will appear darker (compared to the surrounding water color) due to the channel carved by the flowing water.

You can also spot a rip current by looking for objects or foam moving steadily seaward. Wave heights are also lower and choppier in rip currents. Wearing polarized sunglasses can aid in locating rip currents by cutting the glare. Finally, they can be easily seen by the local lifeguards from their elevated towers. Watch for posted flags or signs warning you of the danger and take heed of a lifeguards warnings.

Rip currents can be strong seaward moving currents and will generally not pull you underwater but will take you out to sea. The most common mistake drowning victims make is to panic and try to swim directly toward the shore. Even the best Olympic swimmers are not able to successfully swim toward shore in the strongest rip currents.

Anyone going into any water, whether it is a pool or the ocean, should know how to swim. Swimming at guarded beaches is especially good for inexperienced swimmers. Always heed the lifeguards or beach patrol.
If caught in a rip current, remember it will not pull you under and you should remain calm.

Swim out of the current by swimming parallel to the coast. Since the currents are relatively narrow, you can escape the flow by swimming parallel to the shore until you break free, then swim toward the shore. Float if you cannot swim out of the current and signal the lifeguards for help by waving your hands. Use a flotation device if you attempt to rescue someone.

XI. SEA AND SWELLS

Sea and swell conditions in Southern California coastal waters often become disturbed to such an extent that they have an effect on boating safety. More often they may have an effect on security of anchoring, and most often on boating enjoyment or comfort. (A comprehensive study of sea and swell conditions has been written by Shields and Burdwell.) [2]

To distinguish between the terms "sea" and "swell" conditions, consider that "sea" refers to the combination of wind waves and swell, producing a roughness or disturbance of the water surface generated by wind and sometimes strong and gusty winds in the immediate area. Waves that are generated by the wind are considered to be wind waves. A train of wind waves will move along a direction closely conforming to the direction of winds causing them. In actual practice, the sea state will involve all the various disturbances, whether from an immediate (short period wind swell or wind waves) or a more distant origin (long period swell).

After several hours of wind over a water surface as the ocean or a lake, waves move out in a direction fanning out downwind from the generating area. This traveling train of waves will continue until it spends its energy as waves breaking on a coast. Swells traveling a long distance will decay and lose energy to friction. The wave train will gradually become more organized, with a direction, period and height that can serve as a means of identification and is called "swell". The direction of the swell will continue along a line (great circle route) downwind from its generating area and is reported as the direction in degrees from which it is traveling. The height is reported in feet (or meters) as the vertical difference between wave troughs and crests (Figure 20) and is assigned a "significant height" for the wave train, since there will be differences between individual waves within the train. The "period" is the time in seconds required for successive wave crests or troughs to move past the observation point.

Large intense storms or low pressure systems that move across the Pacific may subject a great expanse of ocean surface to strong or gale force winds for several hours, long enough to develop "maximum" waves for the given condition of wind speed. Around the southern and western portions of the storm, winds will be blowing from the southwest, west or northwest, so in these quadrants waves will be generated that can form swells that move toward the west coast. A Pacific weather map of this type of storm is shown for illustration (Figure 21).

After the swell has been generated and advances form the generating area beyond the influence of the wind that developed it, a gradual decay begins and continues until the swell nears a coastline and expends its energy upon the shore as surf. As this travel distance or "decay distance" increases, swell height decreases and the time and distance between successive waves making up the swell increase. Put another way, the periods become longer and heights become smaller.

Up until now, the distance a wave train or swell travels has been described as being along its original direction, with the only modification in its height and period over the decay distance. This is true as long as the swell travels as a deep water wave train. Upon nearing a coastline, other modifications can take place. For example, if the depth of water rapidly decreases, the height of the swell increases. A swell nearing an irregular coastline will be refracted or bent toward a pattern to more nearly conform to the shape of the coastline. Islands or headlands will bend the line of advancing swells as though to drape them around the land forms. Swells reaching an island will be dissipated as surf along the shores but will form bent or refracted lines around flanks of the island with a shadow of very low swell behind the island.

Islands off the southern California coast will tend to intercept or refract swells approaching the coast. Islands may in this way prevent swells from reaching certain portions of the coast, and for most parts of the southern California coast, there are certain directions from which swells are rarely, if ever, observed. As you sail through coastal waters, you may have noticed the absence of swells in some locations, while a few miles farther along you begin to feel and see the swell that had threaded its way through these interisland "windows".

One of the most important points for boaters, when considering sea and swell conditions, is to keep in mind the great risk that rapidly increasing winds in the local area can create. A 30 to 35 knot wind can generate 5 to 6 foot wind waves within an hour or two over an initially smooth surface. If the sea is already disturbed by large swells, a 30 to 35 knot wind can generate high waves which, when imposed upon swells, will create very large waves at random intervals. Due to decreased maneuverability in heavy and confused seas, these large waves may suddenly present some very complicated and dangerous situations.

XII. SWELLS FROM TROPICAL STORMS

Tropical storms are well known generators of large seas and swells. Because hurricanes characteristically move rather slowly, heavy swell can move out ahead of the generating area. Since strong winds surround the storm, there can be a pattern of swells radiating out in all directions from the storm. However, as the storm is relatively small in diameter, there is a shift in wind direction as the storm approaches and moves past a generating area. This allows the sea surface around most quadrants of the storm only a limited time to develop large waves before the change in wind direction.

However, if the storm path is extended forward to show future positions of the center, it will be seen that swells moving out from the quadrant to the right of its path will move along a line parallel to the future path of the storm (Figure 22). These swells will become important over the open sea, and especially as they move into a shoreline.

Tropical storms that move in a northwest direction from the Mexican west coast, keeping west of Baja California, develop the largest swells that may affect the southern California coastline. From storms of this type, huge swells are directed toward the Southern California Coast in a way that results in 6 to 8 foot breakers or larger along portions of our coastline facing toward the south to southwest. West facing beaches such as the southern part of San Diego County may have little or none of the swell arriving at the coast.

XII. REFERENCES

[1] Eichelberger, A. L., "Forecasting the Catalina Eddy", National Weather Service Western Region Technical Memorandum, No. 62, February 1971

[2] Shields, G. C. and Burdwell, G. B., "Western Region Sea State and Surf Forecaster's Manual", National Weather Service Western Region Technical Memorandum, No. 51, July 1970

National Weather Service Weather Radio Frequencies

Main Weather Service Site http://www.nws.noaa.gov
Weather Radio Site http://www.nws.noaa.gov/nwr
Weather Radio Station Listing and Coverage http://www.nws.noaa.gov/nwr/listcov.htm
Weather Radio Frequencies Listed by State http://www.nws.noaa.gov/nwr/nwrbro.htm

Selection	Frequency	Areas Covered
1.	162.550 MHz	Oxnard/Los Angeles - Point Arena (Eureka) - Monterey - San Luis Obispo
2.	162.400 MHz	San Diego - Santa Barbara - Coachella Valley - Eureka - San Francisco
3.	162.475 MHz	Santa Barbara Marine Only
4.	162.425 MHz	San Diego Mount Soledad Marine Only
5.	162.450 MHz	Santa Ana/Orange County - Monterey Marine Only
6.	162.500 MHz	
7.	162.525 MHz	Avalon - Coachella Valley (Spanish) - San Simeon
8.	161.650 MHz	
9.	161.775 MHz	
10.	163.275 MHz	

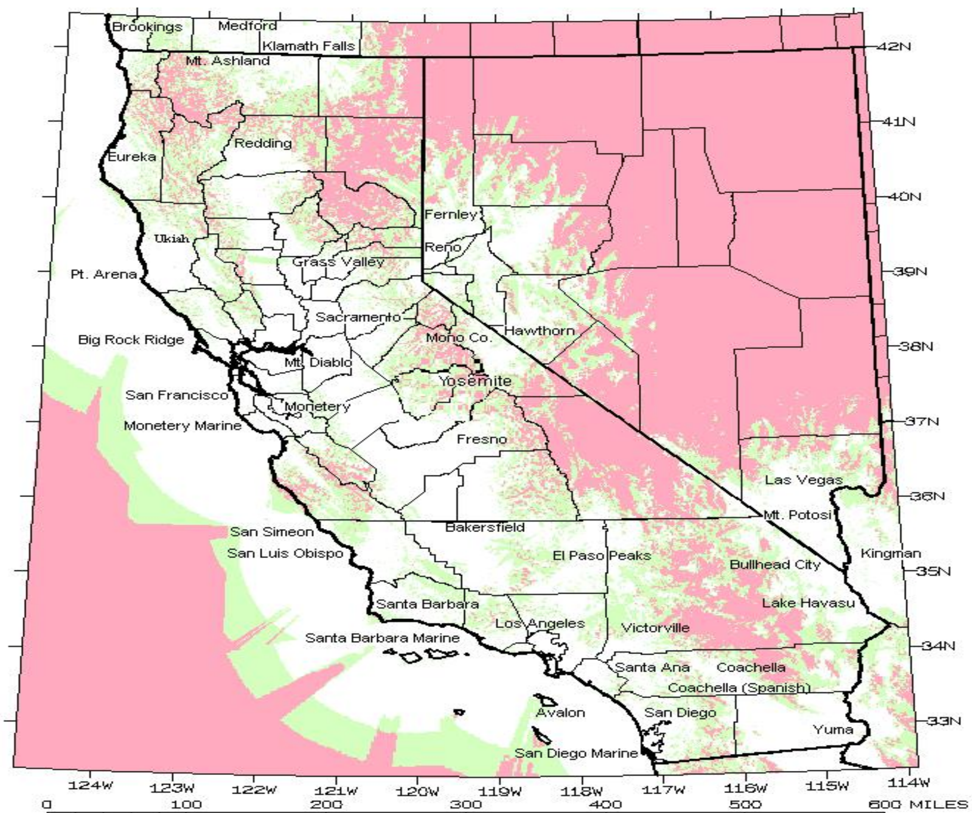


Figure 1 – National Weather Service Weather Radio Coverage

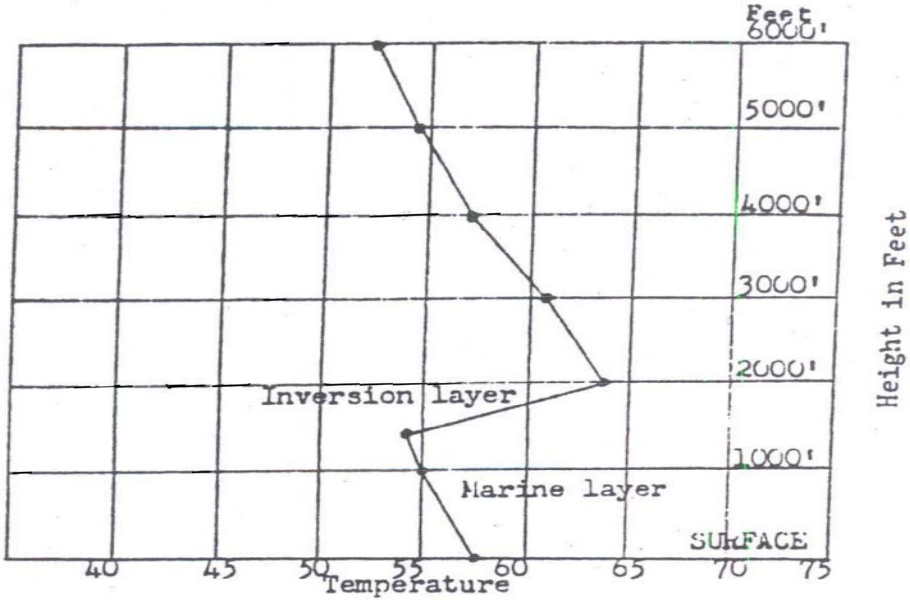


Figure 2 – Graph of Temperature vs Height to Show Inversion Layer

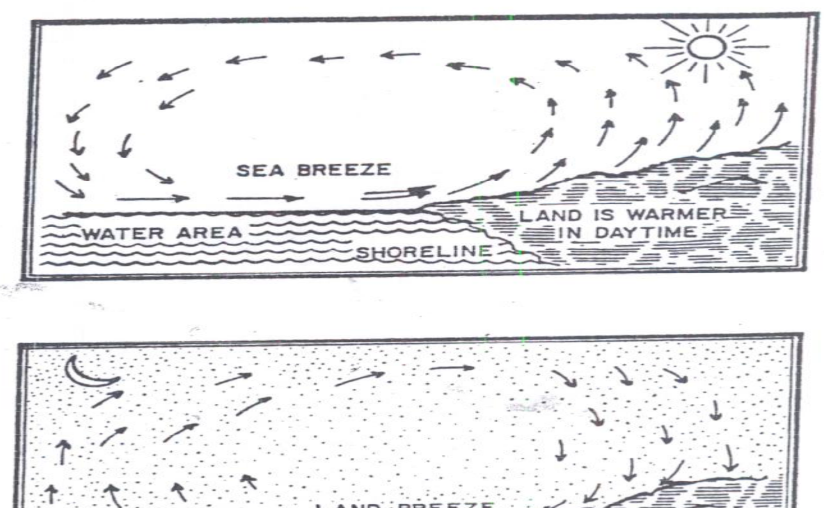


Figure 3 – Circulation of Air during Sea Breeze and Land Breeze

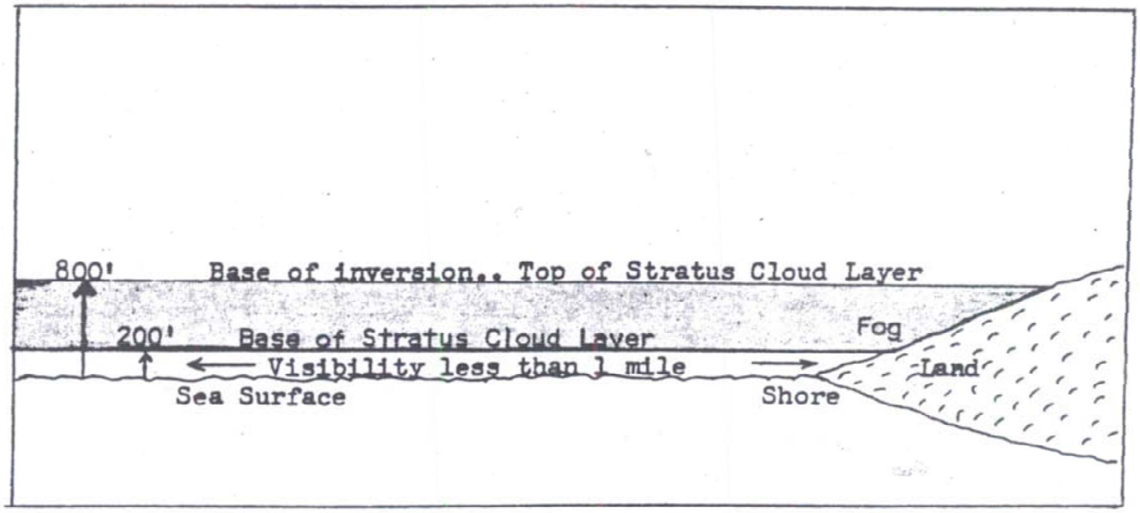


FIGURE 4. WHEN THE INVERSION IS AT AN ELEVATION OF 800 FEET OR LOWER, THE CHANCE OF HEAVY FOG OVER THE COASTAL WATERS INCREASES.

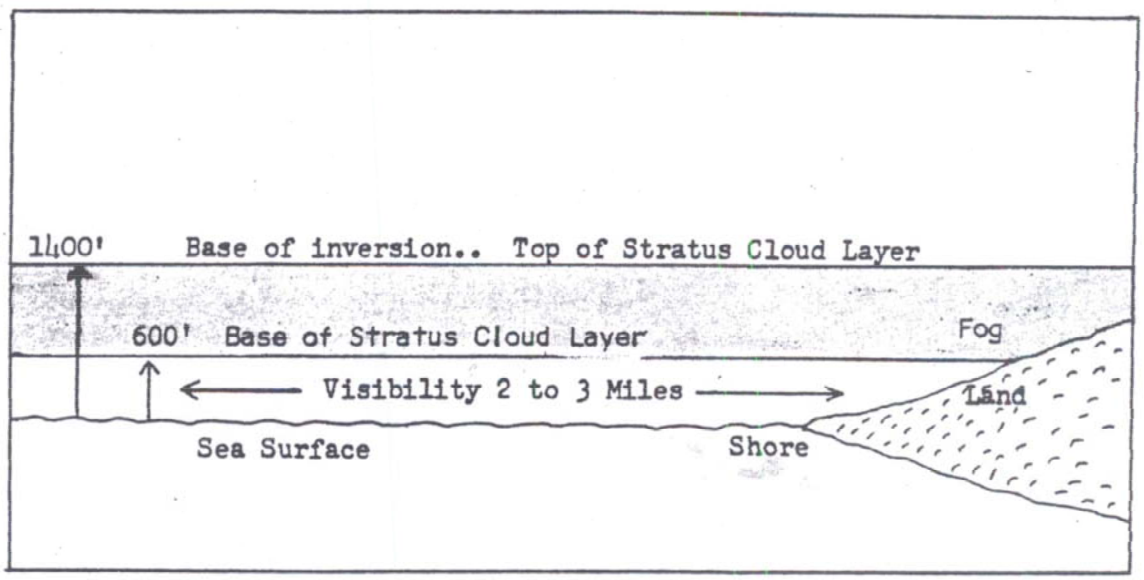


FIGURE 5. WHEN THE COASTAL INVERSION IS UP AROUND 1400 FEET, LOW CLOUDS RATHER THAN FOG AFFECT THE COASTAL WATERS.

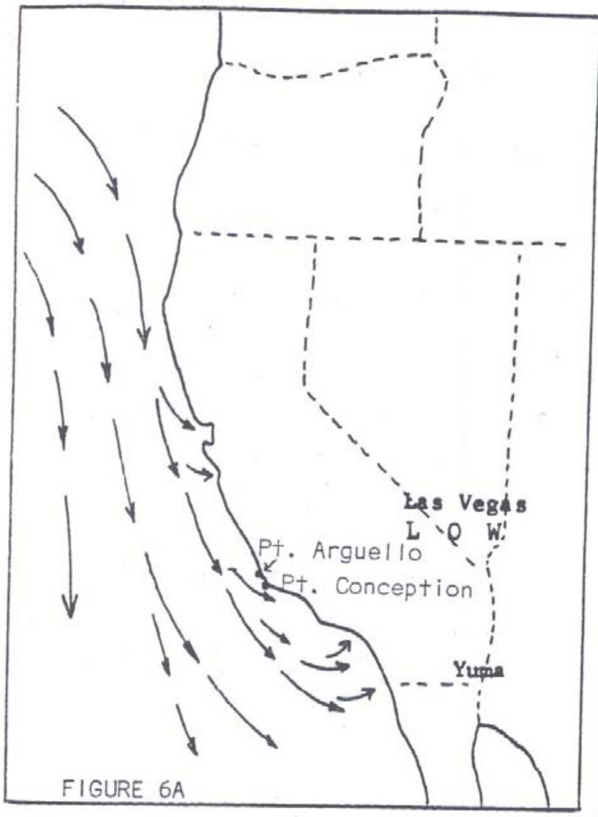


FIGURE 6A

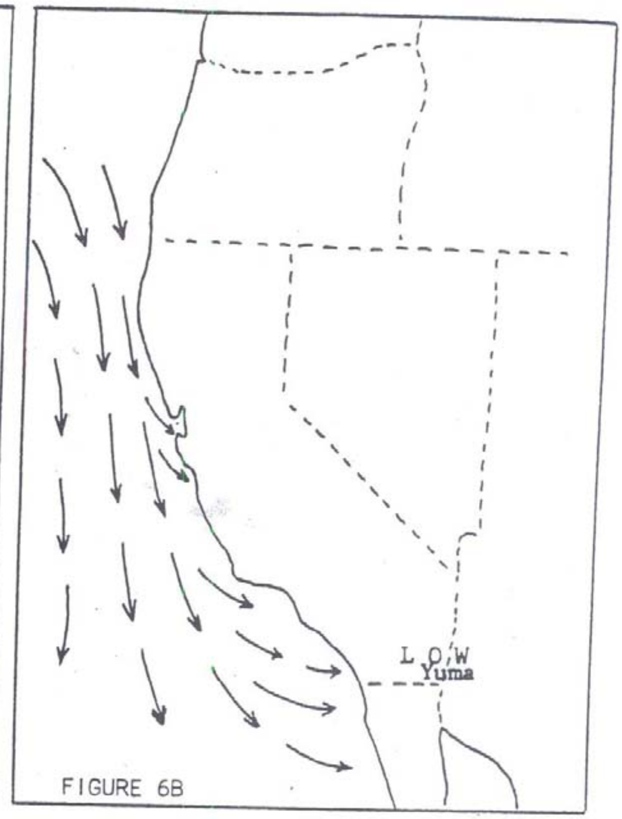


FIGURE 6B

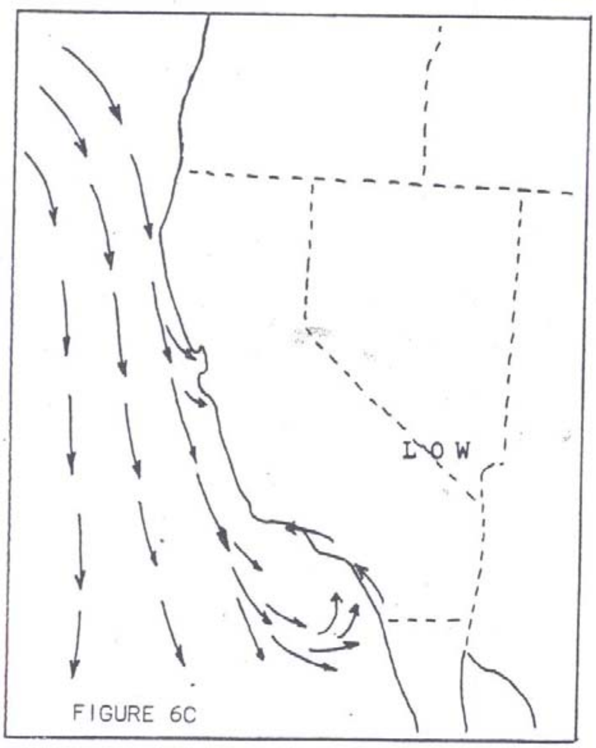


FIGURE 6C

6A. North-northwest wind current moving down California coast turns toward southern California coast after it has passed Point Conception.

6B. Current does not turn in quite as sharply toward the coast if lowest pressure shifts south to near Yuma.

6C. A nearly closed "eddy" circulation may form during the nighttime when effects of a land breeze may obstruct the flow of air toward the coast and deflect it toward the north or northwest.

FIGURE 6. Circulation Around the Catalina Eddy

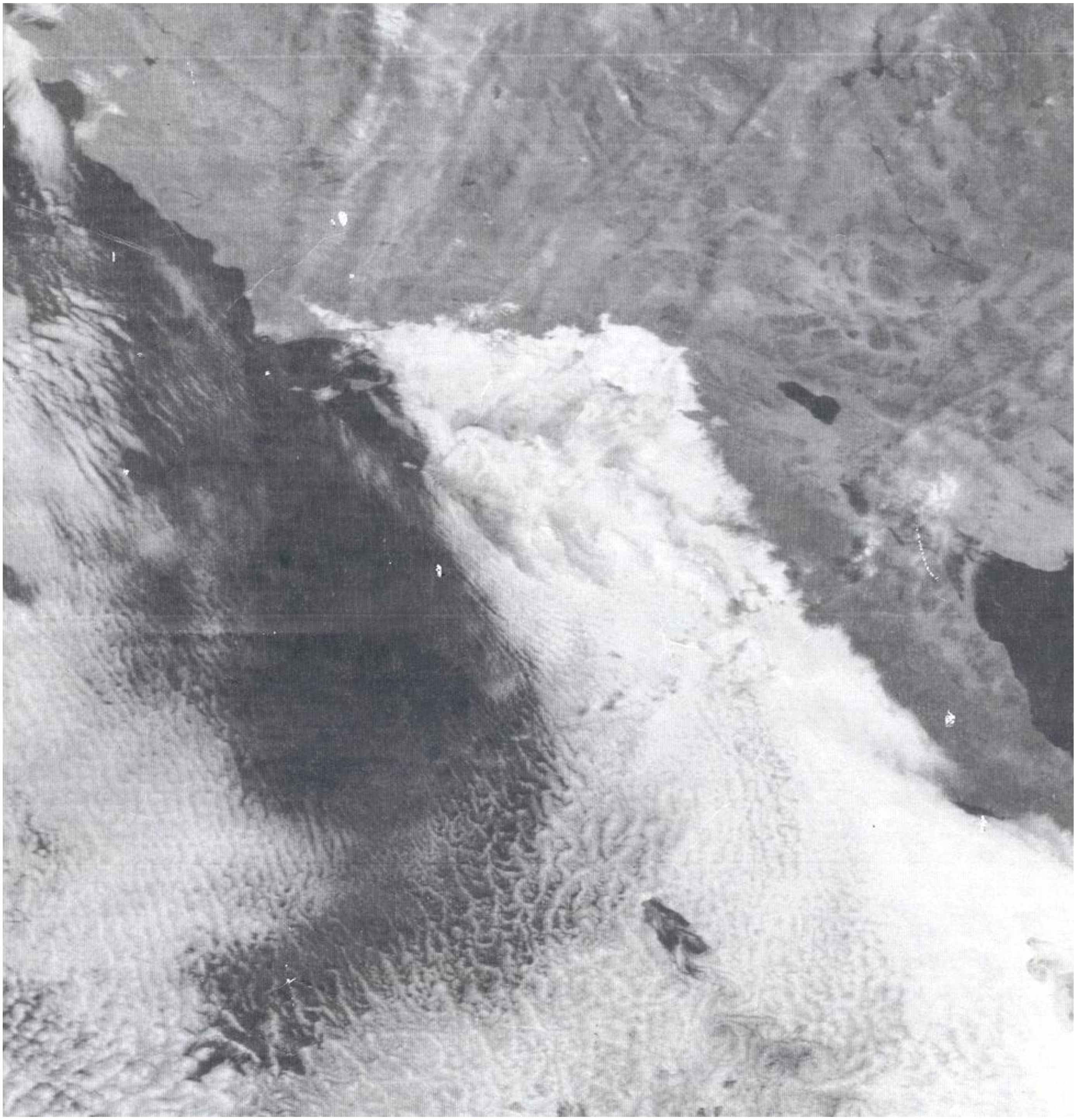


Figure 7 – Polar Orbit Satellite Image of Catalina Eddy. Note Cyclonic Spiral of Stratus in the Bight

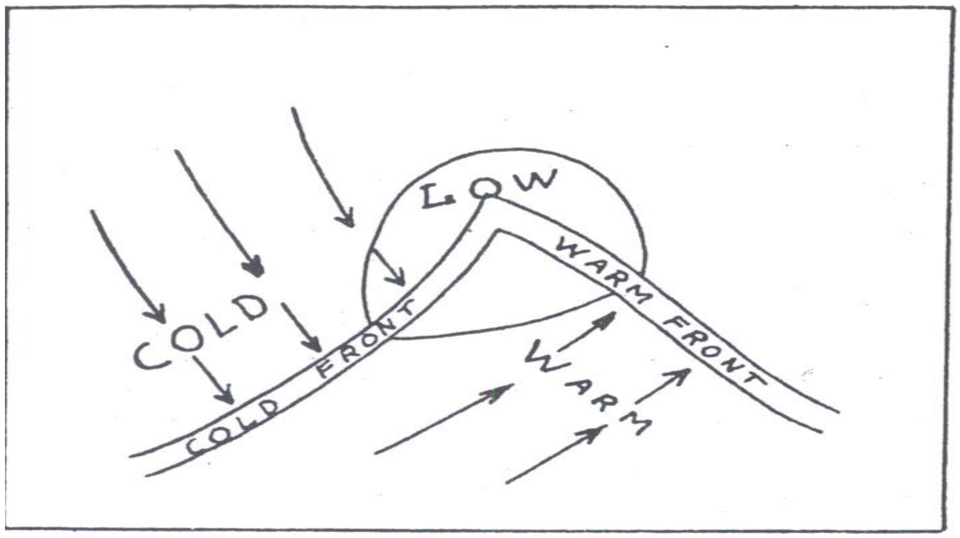
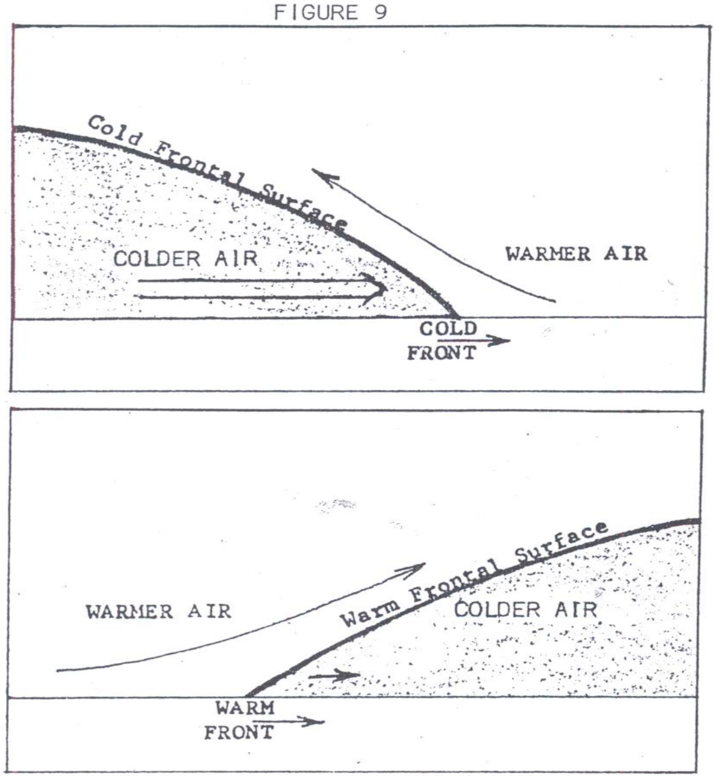


Figure 8 – Pattern of Fronts and a Developing Wave

FIGURE 9



The Cold Front marks the leading edge of a cold air mass as it advances toward a warm air mass, driving in under the warm air and lifting it up along the frontal surface.

The Warm Front marks the leading edge of a warm air mass where it encounters the cold air mass. The warm air, being less dense than the cold air, moves up along the frontal surface. The surface position of the warm front moves forward as the cold air mass gradually retreats.

Figure 9 – Cold and Warm Fronts

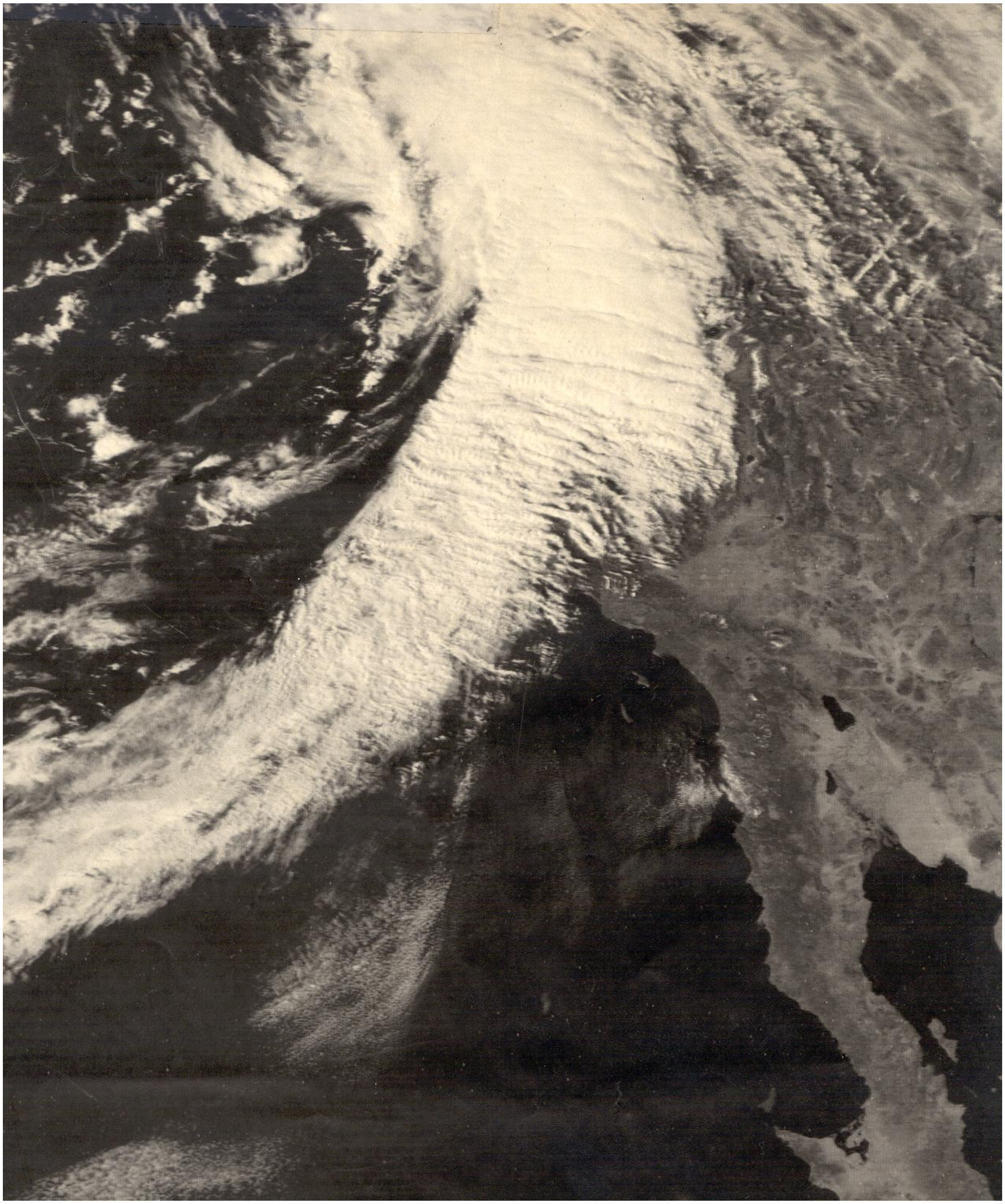


Figure 10 – Polar Orbit Satellite Image of a Cold Front moving into California. The Southern part of the Front is over Santa Barbara County and moving into Ventura County.

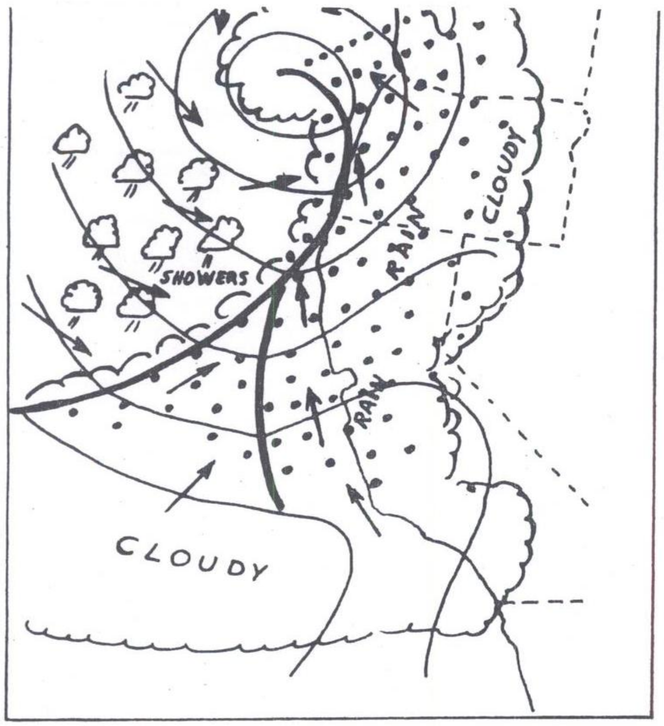


Figure 11. Sketch showing typical distribution of clouds, wind, and weather around a low-pressure area and frontal system.

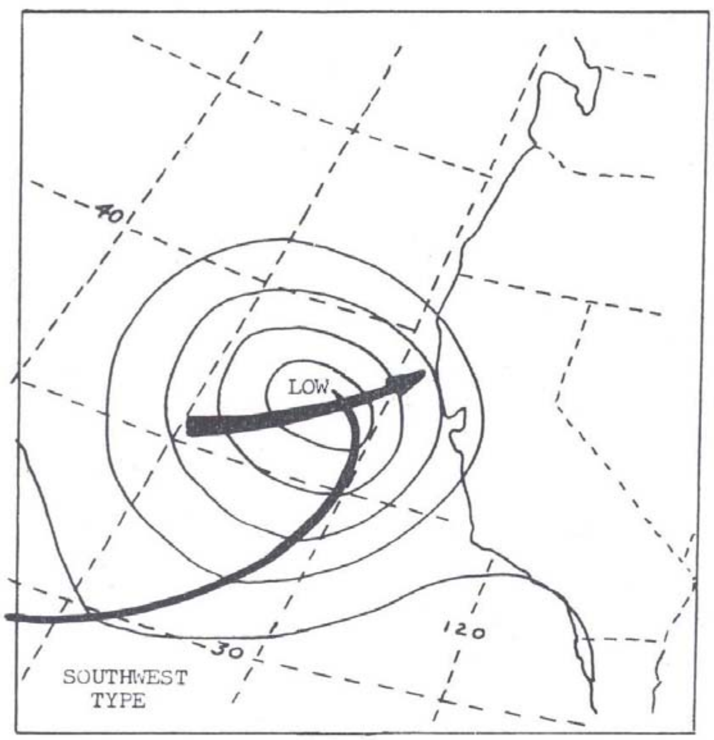


Figure 12. Pressure pattern and weather front in a low approaching the coast from the southwest (Southwest Type).

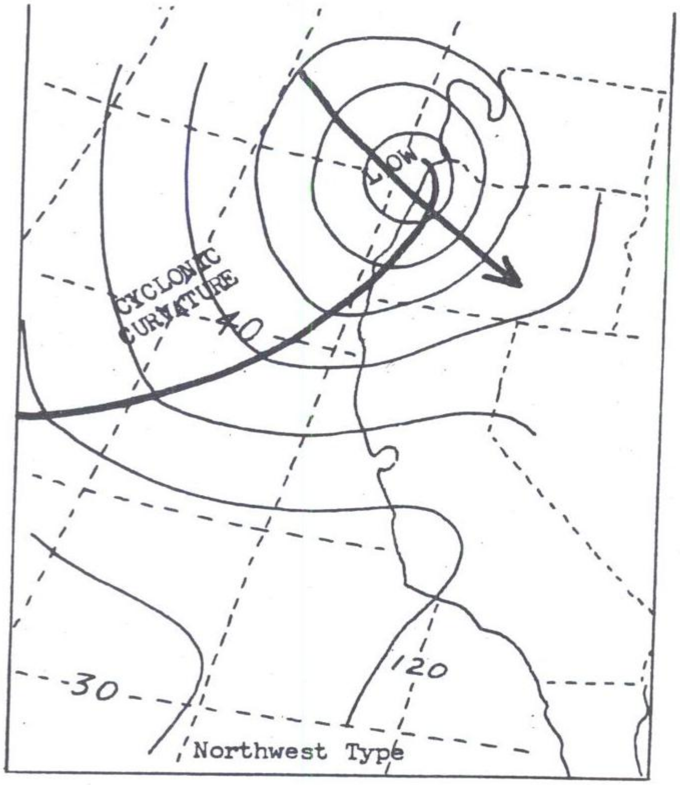


Figure 13. Pressure pattern and weather front in a low approaching the coast from the northwest (Northwest Type). Note cyclonically curved isobars behind front.

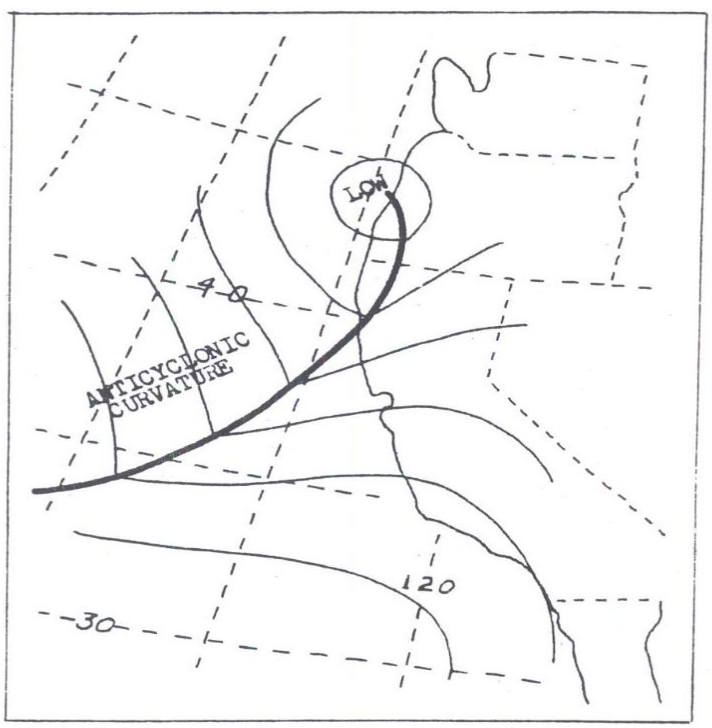


Figure 14. Sketch shows strong anticyclonic curvature immediately behin the front. This usually indicates rapid ending o rains after passage of the front.

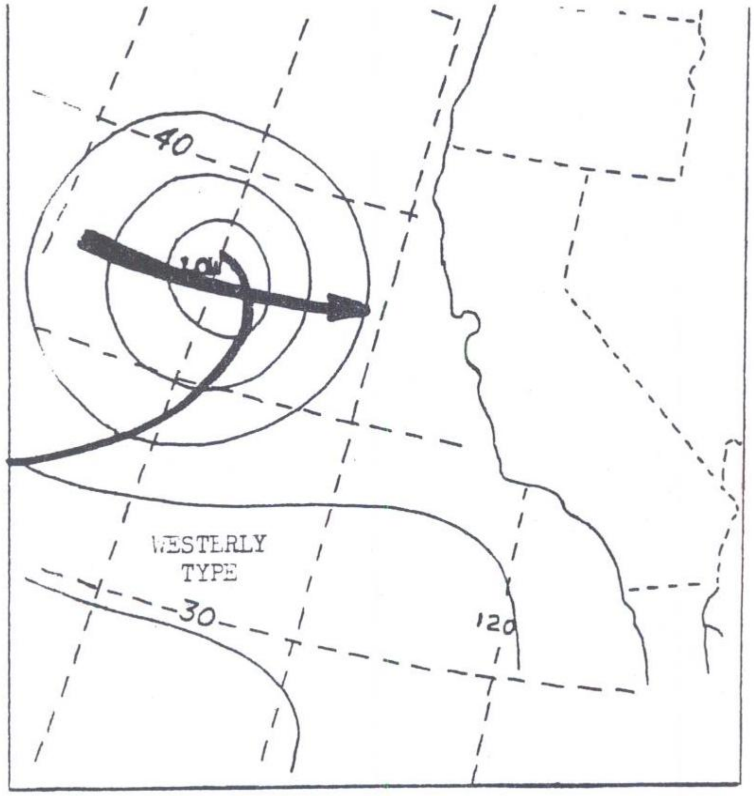


Figure 15. Showing pressure pattern and weather front in low approaching the coast from west (Westerly Type).

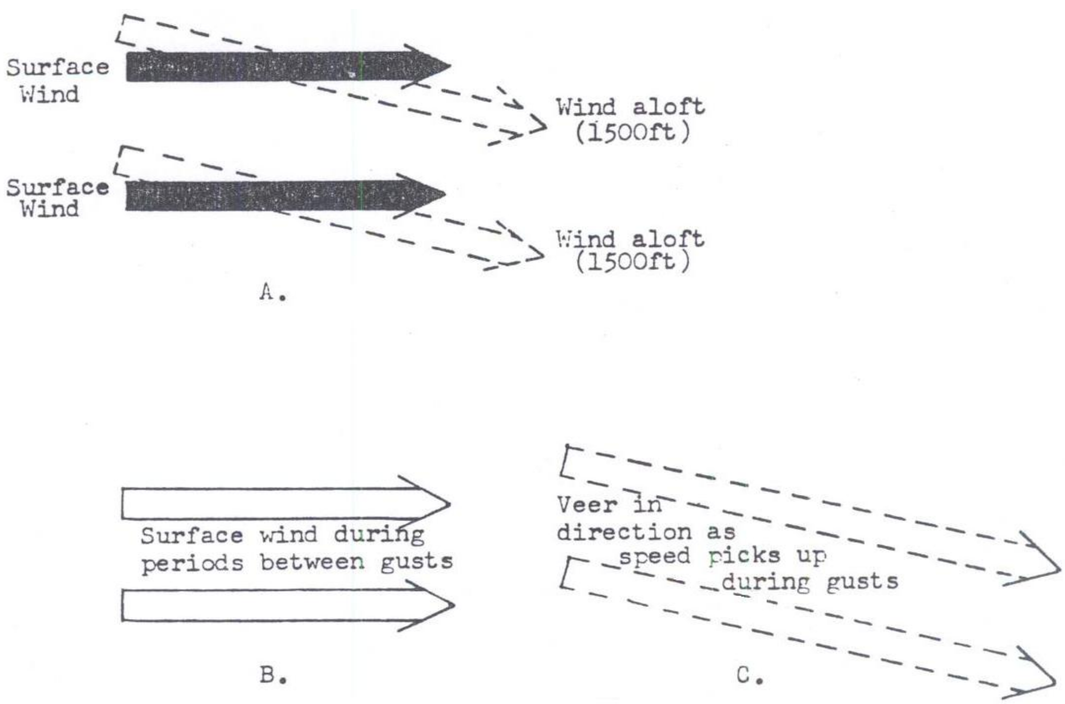


Figure 16. Effects of gusts on wind direction.

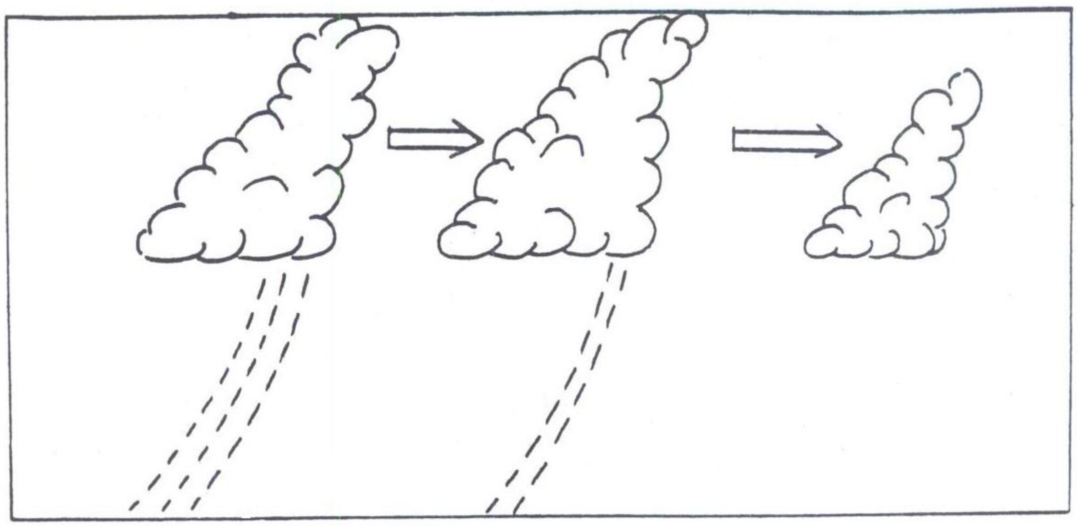


Figure 17. Cumulus clouds carried along with the wind often lean or tilt in their direction of movement. Some indication of the direction of movement can be observed if a curtain of rain is evident below cloud bases.

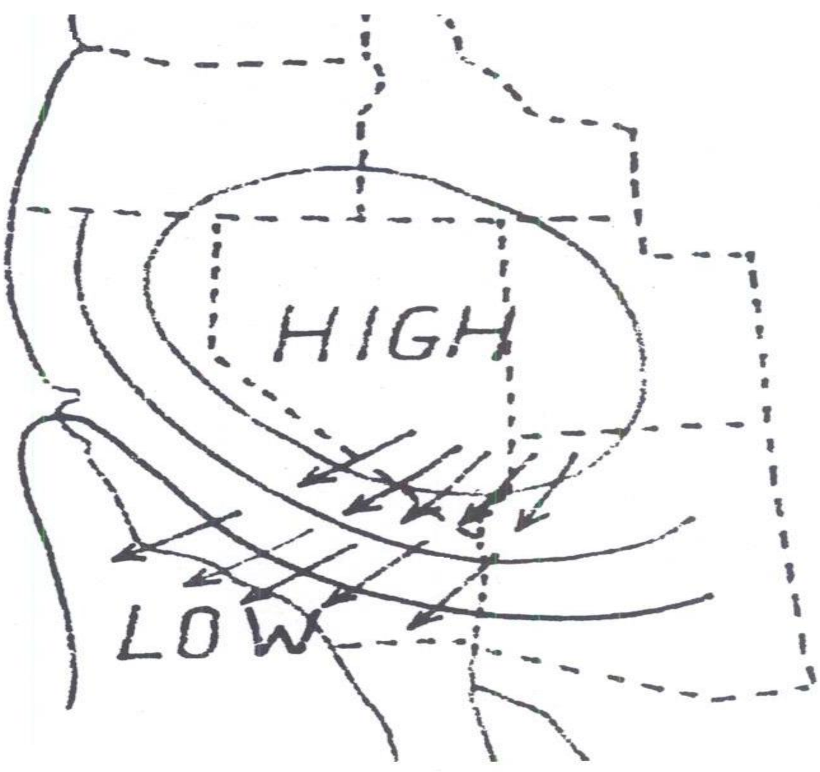


Figure 18. Pressure pattern associated with Santa Anas.

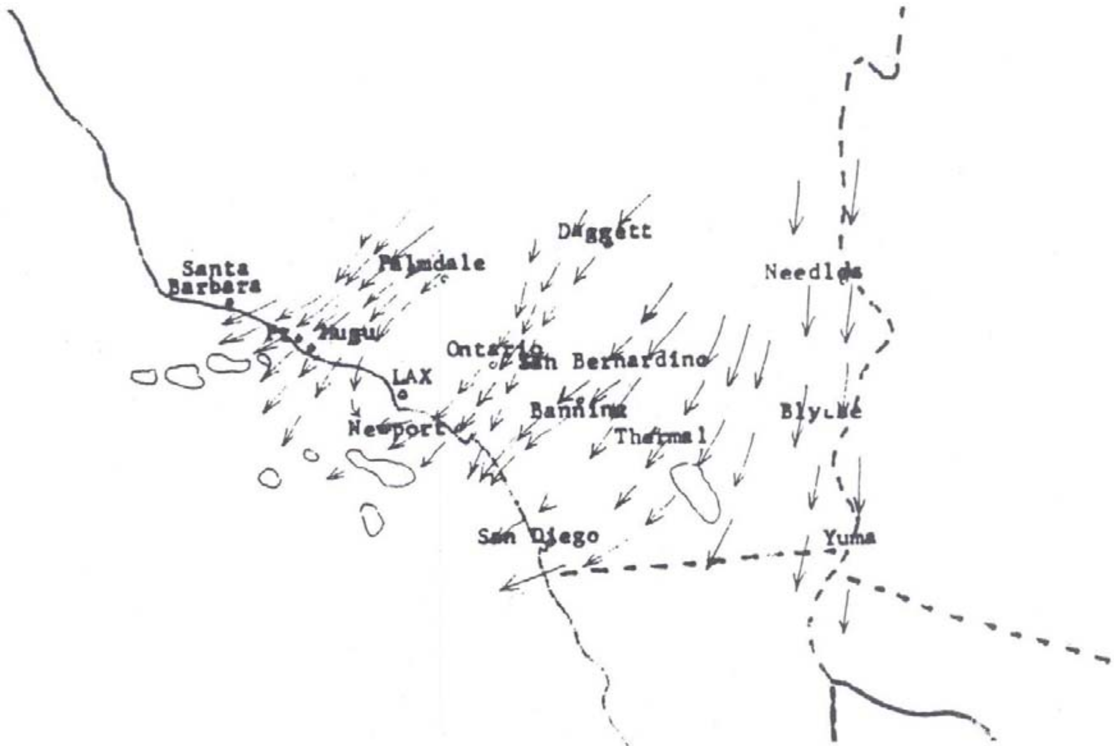


Figure 19. Favored courses of Santa Ana winds.

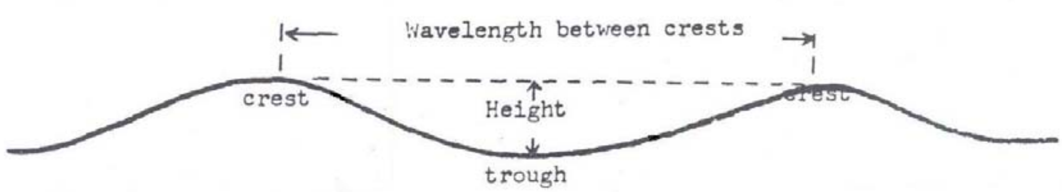


Figure 20 – Sketch of Height and Wavelength of Swells. Period is the time in seconds for Crests or Troughs to travel a distance equal to the wavelength.

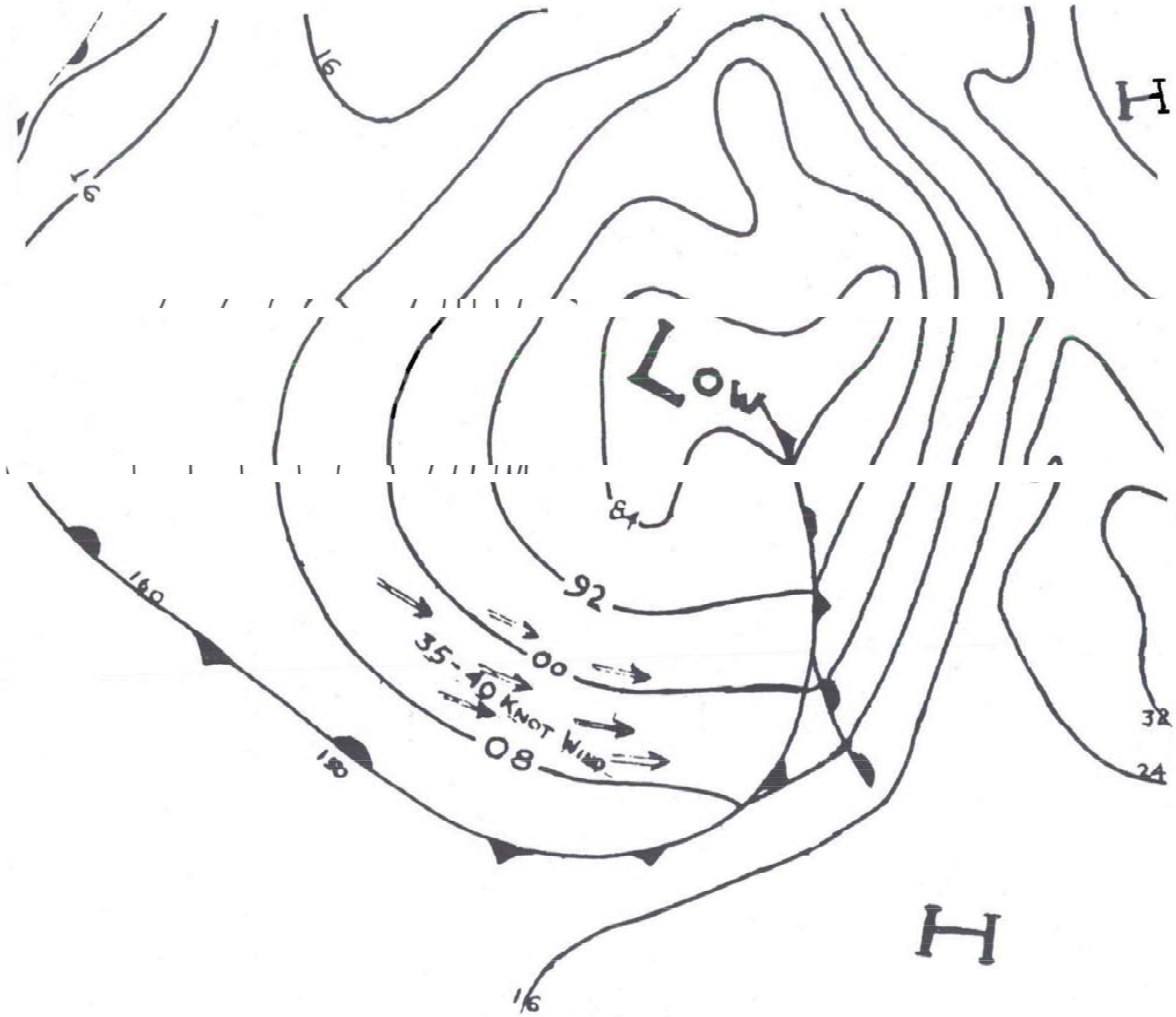


Figure 21 – Weather Chart showing strong wind field south of a Pacific Low. Winds in this area will generate swells that will move to the Southern California coast from the west.

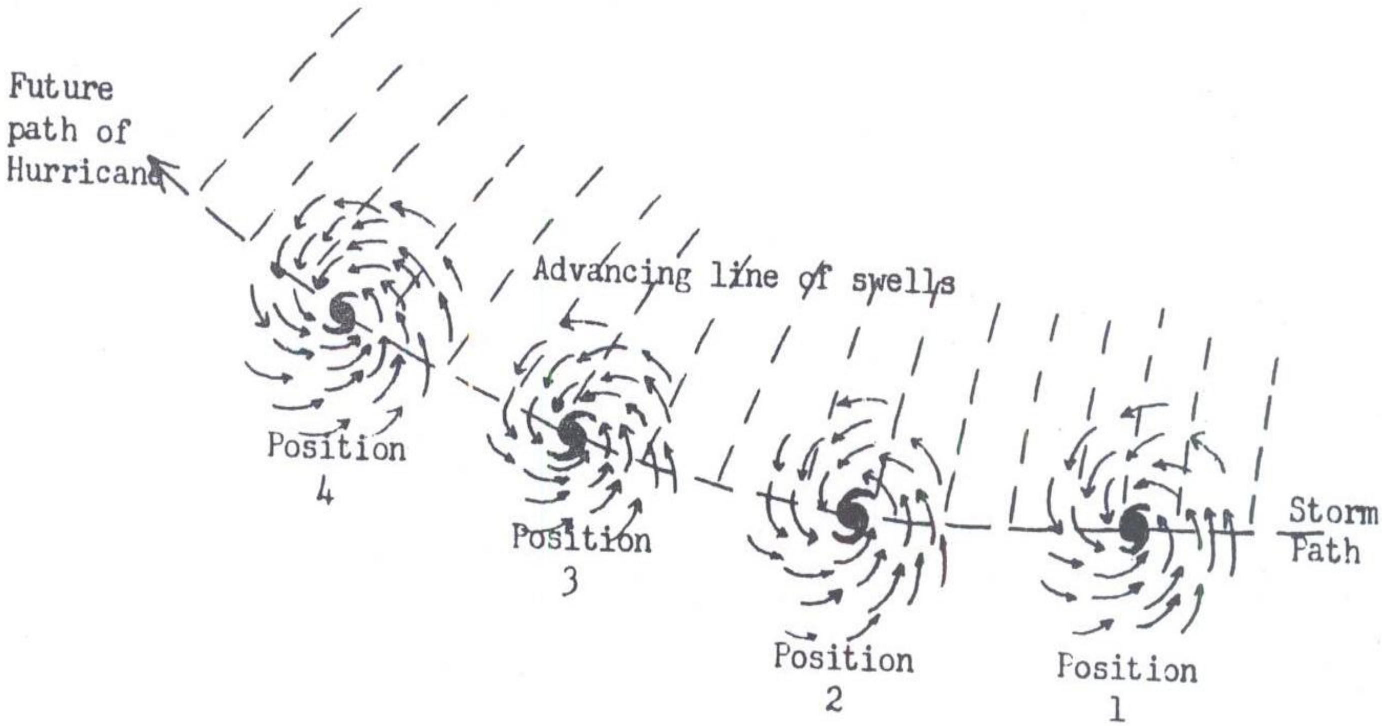


Figure 22 – Representation of the area along the path of a Tropical Storm or Hurricane generating and propagating large swells.

Distance

To Go From	To	Calculate This
kilometers (km)	miles (mi)	1 km = 0.62 mi
kilometers	nautical miles (n mi)	1 km = 0.54 n mi
miles	kilometers	1 mi =1.61 km
miles	nautical miles	1 mi = 0.86 n mi
nautical miles	miles	1 n mi = 1.15 mi
nautical miles	kilometers	1 n mi = 1.85 km
meters (m)	feet (ft)	1 m = 3.3 ft
feet	meters	1 ft = 0.3 m

Speed

To Go From	To	Calculate This
kilometers/hour (kph)	miles/hour (mph)	1 kph = 0.62 mph
kilometers/hour	knots (kts)	1 kph = 0.54 kts
miles/hour	kilometers/hour	1 mph = 1.61 kph
miles/hour	knots	1 mph = 0.86 kts
knots	miles/hour	1 kt = 1.15 mph
knots	kilometers/hour	1 kt = 1.85 kph

Temperature

To Go From	To	Calculate This
Celsius	Fahrenheit	°C = .555 x (°F-32)
Fahrenheit	Celsius	°F = (1.8 x °C)+32

Pressure

To Go From	To	Calculate This
millibars (mb)	inches of mercury (in. Hg.)	1 mb = 0.0295 in. Hg.
inches of mercury	millibars	1 in. Hg. = 33.86 mb

Table 1 - Conversions for Various Units