Weather, San Francisco Bay

The following weather overview focuses primarily on weather conditions of the San Francisco Bay and the coastal waters outside the Golden Gate. To a lesser extent, this overview also includes information on the Delta region as well as the southern Sacramento Valley and northern San Joaquin Valley.

The climate of the San Francisco Bay Area is broadly classified as a Mediterranean Climate, which generally means that summers are dry, sunny, and warm and winters are mild, wet and occasionally stormy. However, the Mediterranean Climate classification is somewhat of a simplification for the region. In reality the Bay Area has several climate regimes, sometimes referred to as microclimates. Significant differences in temperature, winds, and fog patterns over relatively short distances are due to variations in airmass between land and sea and to the complex terrain of the coastal mountain ranges. Gaps in the coastal mountain ranges further modify weather conditions on a local scale.

Climate is an average of weather conditions over a period of time. Most people are more concerned with day-to-day weather and how it will affect them personally. Few people are affected more directly by weather than the mariner. An unexpected change in winds, seas, or visibility can reduce the efficiency of marine operations and threaten the safety of a vessel and its crew. Because of the many microclimates of the San Francisco Bay Area, mariners who navigate the waters from outside the Golden Gate, through the San Francisco Bay and Delta and into the Central Valley must be aware of how weather conditions can change significantly over short distances and over short periods of time. Mariners must also be aware of the unique weather conditions and weather hazards that are most prevalent during each season.

<u>Spring</u>:

Storms that periodically affect the region during the winter months often continue with regularity into March, but by April the storm track begins to shift north and storms rolling inland off the pacific become less frequent. The rainy season is typically over by mid-April. The variation in wind direction that occurs with passing storms occurs less frequently during April and mostly ends by May. During spring an area of high pressure over the Pacific gradually strengthens and moves north. Meanwhile, longer days and a more direct sun angle result in increased warming over land, particularly in the interior valleys. Warming at the surface causes air to expand and air pressure near the surface to fall. The resulting difference between higher pressure over the ocean and lower pressure over land brings about increasingly persistent west to northwest winds during the spring months. And these onshore winds can be quite strong. In fact, spring is generally the windiest time of the year in the Bay Area. However, springtime weather is highly variable and onshore breezes do not blow as consistently then as they do in the summer months. The region can experience several days of generally light winds before the next round of brisk west to northwest winds develops. Wind speeds with the stronger springtime wind events sometimes reach gale force over the coastal waters outside the Golden Gate, and approach Gale Force locally in northern San Francisco Bay. West to

northwest winds during the spring months decrease farther inland and are generally lighter in the Central Valley compared to the Bay and Delta.

Strong springtime winds over the coastal waters produce rough and choppy seas with a short period swell. The large long-period swells that are common during the winter months still roll through the coastal waters quite often during the early spring, but taper off considerably by late spring as the storm track across the Pacific becomes less active.

Persistent northwest winds along the California coast during the spring months enhance the current of surface water flowing south and parallel to the coast known as the California Current. In the Northern Hemisphere, oceanic currents are deflected to the right by the Coriolis force. This deflection caries surface water offshore and causes cold nutrient-rich water from the bottom of the ocean to surge up along the coast. As moist air blowing across the Pacific comes into contact with the cold upwelled coastal waters, condensation occurs and a layer of low clouds and/or fog develops. The low clouds that form in this situation are called stratus clouds. Stratus clouds are gray with generally uniform bases. They usually do not produce precipitation, although drizzle can sometime occur if the stratus layer is sufficiently thick.

Fog and low clouds typically form first over the coastal waters and are then swept inland with onshore breezes through the Golden Gate and other gaps in the coastal mountain ranges. When stratus and fog are present along the coast, meteorologists often use the term “marine layer.” The marine layer is a moist and cool layer near the surface that is capped by an inversion (a very stable atmospheric condition where warm air lies above cold air). The marine layer ranges in depth from just a few hundred feet to as much as 4000 feet or more. The depth of the marine layer depends on the height of the inversion above the surface, and the inversion height is regulated by various atmospheric conditions as well as land-sea interaction. The marine layer can exist without low clouds and fog, but typically clouds and/or fog are present when there is a marine layer. As spring progresses, the marine layer is present along the coast with greater frequency, and thus coastal low clouds and fog become more common late in the season as summer approaches.

People often mistakenly refer to stratus clouds as fog or “high fog.” By definition, fog is composed of tiny water droplets that are in contact with the surface, essentially a cloud in contact with the ground. The distinction between stratus clouds and fog is important because fog reduces visibility and makes marine navigation more difficult or even dangerous. Stratus clouds, on the other hand, do not by themselves reduce the visibility at the water’s surface.

Dense fog is defined by the National Weather Service as fog that reduces visibility to one-half mile or less on the San Francisco Bay or to one mile or less over the coastal waters. Spring and summer fog is not usually dense over the bays and into the Delta and Central Valley. However, fog can often be dense over the coastal waters when the marine layer is shallow (typically less than 1000 feet deep). During shallow marine layer scenarios, the coastal mountains act as a barrier blocking fog and low clouds from

moving inland. However, even with a shallow marine layer, fog can still advect into the Bay through the Golden Gate. In this situation, dense fog is almost always limited to local sections of the San Francisco Bay, primarily from the Golden Gate to Berkeley.

Because the atmosphere in early spring is more unstable than in the late spring and summer months, fog and low clouds are then less frequent. Also, when a marine layer does develop in the spring, it typically is not as shallow as the summer season marine layer, and so dense fog episodes occur more rarely. Dense fog is most common in San Francisco Bay, and especially in the Delta and Central Valley, during the winter months.

Summer:

During the months of June, July and August the eastern Pacific high is well established offshore while a trough of low pressure is a nearly a constant feature over California's interior. The inland low pressure is often referred to as a "thermal trough" because its formation and strength are primarily driven by robust daytime surface heating that persists throughout the great Central Valley during the dry and sunny summer months. The pressure difference between the eastern Pacific high and the thermal trough over the interior maintains both northwesterly winds over the coastal waters and onshore winds through the coastal gaps and across the Bay. Persistent northwest winds over the coastal waters in turn continue the cold upwelling near the coast. Meanwhile, subsidence under the strengthening eastern Pacific high produces additional warming aloft which strengthens the low level inversion, effectively placing a "cap" on the marine layer. Because these meteorological conditions tend to prevail throughout in the summer, the marine layer is a semi-permanent fixture along the California coast from June through August. Fog and low clouds can remain entrenched along the coast for days, sometimes weeks, at a time.

During the late afternoon or early evening hours of a typical summer day, low clouds and fog over the ocean begin to spread into San Francisco Bay through the Golden Gate, and inland through gaps in the coastal mountains. Low clouds and fog that enter the Bay through the Golden Gate typically travel east toward the Berkeley Hills where they are deflected north towards San Pablo Bay and south towards the San Mateo Bridge and South Bay. During the course of the night stratus coverage will sometimes expand to encompass the entire Bay and adjoining land areas. Fog and stratus are most widespread around the Bay from late at night until a few hours after sunrise. By mid-morning, the strong summer sun provides enough heating to begin dissipating the fog and stratus. Clearing typically occurs in the Bay by midday, but stratus often persists over the coastal waters throughout the day.

How far inland the stratus and fog penetrate overnight depends primarily on the depth of the marine layer, but also on the strength of the onshore flow. If the marine layer is shallow (i.e., less than about 1000 feet), low clouds will spread only locally inland around San Francisco Bay, but seldom reach as far inland as the Delta, and never to the Central Valley. A shallow marine layer typically results in more fog and reduced visibilities, especially over the coastal waters and locally over San Francisco Bay near the Golden

Gate. Overall, the foggiest waters in summer are the ocean approaches to the Golden Gate, and locally inside the Gate to about Alcatraz.

A deeper marine layer and stronger onshore flow can allow stratus to surge well inland through the Delta overnight, sometimes reaching as far as Sacramento and Stockton by sunrise. Inland marine surges such as these typically are characterized by low overcast conditions and lack of fog. Daytime clearing is gradual, and low clouds often persist near the Golden Gate and locally around the Bay well into the afternoon.

Summer winds across the Bay and Delta nearly always flow from high pressure offshore toward the lower pressure of the inland thermal trough. This type of wind flow is referred to as onshore flow or a seabreeze. The magnitude of the onshore flow is regulated by the daily cycle of differential heating between land and sea. Because ocean temperatures remain nearly constant from day to night, the most important factor in driving the daily wind cycle is inland heating. Daytime heating over land causes surface air pressure to diminish during the afternoon hours, increasing onshore pressure gradients. Onshore winds begin to increase by early afternoon and reach a peak by late afternoon into the early evening hours. Winds then gradually subside during the evening as surface heating over land decreases. Wind speeds reach their lowest point late at night and remain relatively light through mid-morning before the cycle starts over again.

Wind direction is generally west-to-east, although there is a great deal of variation on a local scale due to the complex topography. The most prominent gap in the coastal ranges is the Golden Gate and it is here the onshore winds funnel inland with the least amount of resistance. Once the airflow moves through the Golden Gate, it fans out across San Francisco Bay, to the southeast toward the southern part of the Bay and the warm Santa Clara Valley, to the northeast toward the Carquinez Strait, Delta and the heat of the Central Valley beyond, and to the north into the Petaluma and Napa Valleys of the North Bay. The strongest afternoon and evening summer seabreezes usually occur along a path from the Golden Gate to the Central Valley that goes past Alcatraz and the southern end of Angel Island (Point Blunt), east to Berkeley, north past Pinole Point, northeast to the Carquinez Strait and finally east into the Delta and Central Valley. By the time the airflow reaches the Central Valley, it spreads out and diminishes. During the summer months, afternoon and evening wind speeds frequently reach 20 to 25 knots (meeting small craft advisory criteria) in the northern San Francisco Bay from mid-afternoon through mid-evening. In fact, small craft advisory conditions occur nearly every day in summer through the central and northern San Francisco Bay and eastward through the Carquinez Strait. Wind speeds sometimes locally reach 30 knots in these areas. Gales are rare in summer, but can occur during an unusually intense onshore push. Marine air also spills inland through other gaps in the coastal ranges, including the San Bruno gap just to the west-northwest of San Francisco Airport (SFO). In fact, some of the strongest summer seabreezes occur on the west side of the Bay from Hunters Point south through the area around SFO, and small craft conditions are common here as well. Elsewhere in the Bay, summer seabreezes generally do not exceed 20 knots. Wind speeds throughout the Bay Area gradually taper off after sunset and reach a low point from the late-night hours through late morning. On many days, winds can be variable at less than 10 knots

during this time period. But once surface heating increases in the interior around midday, the daily cycle begins again and onshore winds start to increase.

Over the coastal waters outside of the Golden Gate, in the Gulf of the Farallones, summer winds are predominantly from the northwest, parallel to the coast and the coastal mountain ranges. Maximum wind speeds here occur from mid afternoon to mid evening, similar to the time of maximum seabreeze winds in the San Francisco Bay. Wind speeds generally range from 5 to 15 knots during the night and morning hours, increasing to 10 to 20 knots or even 15 to 25 knots in the afternoon and early evening hours. Strongest northwest winds over the coastal waters in summer typically occur to the south of points and capes. For example, a climatological wind maxima occurs to the south of Point Arena offshore of Bodega Bay, as well as along the Big Sur coast south of Point Lobos.

During the summer months, seas in the coastal waters are mostly generated from local winds and therefore have a short period and tend to be choppy. Large, long-period swells from the open ocean contribute much less to the overall wave height than during the late fall to early spring time frame. Wave direction is predominantly from the northwest, but a mixed swell with a component from the south and southwest become more frequent later in summer. These southerly swells are generated from tropical storms far to the south, over the tropical Pacific. Because these swells originate a long distance from our coast, they typically have long periods, generally 15 seconds or more, and generally have heights of three feet or less.

Occasionally during the summer, the typical wind pattern is disrupted. This disruption occurs when high pressure builds inland over the Pacific Northwest and Great Basin while the trough of low pressure that usually resides over the interior of California migrates to the west and becomes established over the coastal waters. Under this scenario, the usual pattern of high pressure over the ocean and low pressure over land is reversed and winds then blow from land to sea. This is called offshore flow. Because these winds originate over land, they are typically hot and dry. Also, the airmass undergoes further warming as it descends mountain ranges on its journey from inland areas to the sea. Strongest winds during offshore wind events usually occur in the hills of the northern and eastern San Francisco Bay Area during the late night and morning hours. But offshore winds can also develop near and over the water, and sometimes reach 20 knots or more through the Carquinez Strait to the Golden Gate. Even during offshore winds events though, a weak late afternoon and early evening seabreeze often develops. The start of an offshore wind event is often characterized by strong and gusty northerly winds down the Sacramento Valley and across the Delta. Winds over the coastal waters usually remain light, except locally moderate just outside the Golden Gate.

Offshore flow events usually last no more than two or three days before the inland high pressure breaks down and onshore flow returns. Not uncommonly, offshore wind events are followed by a phenomenon known as a “southerly surge.” A southerly surge occurs when surface air pressure falls over the coastal waters on the lee side of the coastal ranges. When the pressure along the northern California coast falls below air pressure along the southern California coast, a southerly wind develops. Southerly wind onset over

the coastal waters is usually accompanied by rapidly falling visibilities as the leading edge of a fog bank surges up along the coast accompanied by a very shallow marine layer. During southerly surge events, weather conditions over the coastal waters can change rapidly from light winds with clear skies, to southerly winds of 15-to-20 knots and thick fog reducing visibilities to less than a half mile. As the leading edge of the southerly surge reaches the Golden Gate, the much colder fog-laden airmass surges through the Gate and inland across the northern San Francisco Bay towards the Carquinez Strait. Here too, conditions can change rapidly from light winds to southwest winds reaching 25 knots or greater. After several hours, the shallow marine layer deepens, onshore breezes spread out across a more widespread area, and the locally strong winds gradually subside.

Although rare, summer thunderstorms can sometimes develop in the Bay Area. Summer thunderstorms are most likely late in the season when mid and upper-level moisture from either the southwestern U.S. monsoon or Pacific tropical storms makes its way into the region. Thunderstorms in summer can produce brief heavy rain and local gusty winds. But one of the biggest safety concerns for mariners during these rare summer thunderstorms are lightning strikes.

Autumn:

Weather in and around the San Francisco Bay is most tranquil during the months of September, October and November. The Pacific high gradually loses strength while heating over the interior subsides. Pressure gradients relax and wind speeds ease over the ocean and bays. The trend toward lighter winds starts in late summer and continues through the fall. Gales are almost non-existent from late August through October.

Offshore wind events discussed in the summer section are most common and strongest during the fall months. Locally strong and gusty easterly winds can occur through the Carquinez Strait and into northern San Francisco Bay. Moderate to strong offshore winds can also occur over the coastal waters below coastal ridges and canyons. On some clear autumn mornings when winds are light easterly across most of the region, strong winds can occur locally along the San Mateo and Marin county coasts.

Because of weaker seabreezes and more frequent offshore wind events, the marine layer and associated low clouds and fog are less prevalent in fall than in summer.

Wind wave heights are also at a minimum during the autumn months. But long period swells arriving along the northern and central California coasts begin to increase in height and frequency by late October or early November, when storms over the northern Pacific become stronger and more frequent.

Winter:

The storm track across the Pacific becomes increasingly active by November and also migrates to the south. By the second half of the month, Pacific weather systems begin to

move through the San Francisco Bay Area. Most yearly rainfall in the Bay Area occurs between mid-November and early April, with the stormiest months being December, January and February (though late November and even much of March can also have active stormy periods). Some storms during the winter months can produce powerful winds and seas, conditions that can be very hazardous to the mariner.

As winter storm systems approach the coast, typically from the west or northwest, winds increase from the south to southeast. Typically, strongest winter winds occur in the hours just prior to the cold frontal passage. Depending on the strength of the storm, southerly winds ahead of the cold front commonly reach 20 to 25 knots across the region, and sometimes even gale force. Although rare, storm force winds of 48 knots or greater can occur with the strongest of these winter storms. A few notable storm force wind events over the greater San Francisco Bay region waters occurred on December 12, 1995 and January 4, 2008. Strong south winds occur on a large scale and thus have much less local variation than the summer seabreeze. Gale force winds can occur anywhere from the coastal waters east across the Bay and into the Central Valley.

After frontal passage winds veer to the southwest and eventually to the west and northwest. Wind speeds then generally decrease significantly, but can remain quite strong and gusty for the next several hours. On occasion, winds will veer from the southeast to the southwest after the frontal passage, only to shift back to the south or southeast a few hours later as a secondary post-frontal low pressure trough approaches.

Thunderstorms are relatively rare in the San Francisco Bay Area, but can sometimes develop within the frontal rain bands of intense winter storms. Thunderstorms can also occur in the cold and unstable airmass behind a cold front. Climatologically, thunderstorm chances peak during the late winter and are more common over the Central Valley and Delta compared to the San Francisco Bay. Thunderstorm activity often exacerbates hazardous weather conditions during winter storms by increasing wind speeds on a local scale and by producing dangerous lightning.

Winter is the season with the most significant seas, both in terms of locally driven wind waves as well as open ocean swells that are generated by long fetches of strong winds over the eastern Pacific. Seas can be confused ahead of a front with wind waves moving from south-to-north on top of long-period swells coming in from the west or northwest. Seas are sometimes large enough to produce breakers across the San Francisco bar, several miles west of the Golden Gate. These breaking waves in the open ocean present a significant danger to mariners, especially those unfamiliar with the area. Breakers across the bar are most common with a long period westerly swell around the time of maximum ebb current through the Golden Gate.

Although the strongest wind events occur during the winter months, there are often long periods of tranquil weather in the winter when the storm track shifts to the north, sometimes for weeks at a time. During these periods, high pressure dominates the area and the low levels of the atmosphere become very stable. When this occurs, an inversion develops over the inland valleys. Widespread radiation fog will then develop if the

surface is sufficiently moist (e.g., after soaking rains). This type of radiation fog is most common in the Central Valley and is often referred to as "tule fog." Tule fog is notoriously thick and dense. Visibilities often fall to near zero in the Delta, southern Sacramento Valley, and northern San Joaquin Valley, making marine navigation in these areas difficult. Lowest visibilities occur late during the night through mid-morning hours. Visibilities improve by late morning and often the fog layer lifts into a low overcast during the afternoon. Sometimes if there is a light offshore flow during a tule fog event, dense fog can drift seaward through the Carquinez Strait and move across the bay to San Francisco and Marin, as well as south to SFO and even as far as the southern end of the bay. Radiation fog events are most likely in December and January and can persist for a week or longer in the Central Valley and around the Delta, but for no more than a few days at a time around San Francisco Bay.

Offshore winds during the winter months are generally light. However, locally strong and gusty easterly winds can occur through the Carquinez Strait and into northern San Francisco Bay. Also, strong easterly winds can occur during the late night and morning hours locally below coastal ridges and canyons along the Marin and San Mateo county coasts. These localized offshore winds over the coastal waters also occur in autumn, but tend to be strongest during the winter months.

Winter weather is often highly variable. Long periods of dry weather with light winds can be followed by weeks of stormy weather with only short breaks in between individual storms. Years of studies have concluded that large-scale sea surface temperature anomalies in the equatorial Pacific can have an impact on the overall amount of precipitation and storminess across California during the winter months. When El Nino conditions exist, sea surface temperatures in the eastern tropical Pacific are warmer than normal. Strong or moderately strong El Nino winters tend to be characterized by higher than normal precipitation across central and southern California. However, this does not mean that individual storms with the heaviest rain and strongest winds occur during El Nino winters. In fact, two of the most powerful winter storms to pummel the region in the past 20 years occurred during non-El Nino winters. The upshot is that mariners need to be prepared for the possibility of dangerous storms in any winter, and not assume that navigating the ocean and bays will be less hazardous during non-El Nino winters.

Marine Weather Services

The National Weather Service (NWS), a part of the National Oceanic and Atmospheric Administration (NOAA), provides marine weather warnings and forecasts to serve all mariners who use the waters for livelihood or recreation. The warning and forecast program is the core of the NWS's responsibility to mariners. Warnings and forecasts help the mariner plan and make decisions protecting life and property. The NWS also provides information through weather statements and outlooks that supplements basic warnings and forecasts. The following are the basic marine warning products the NWS offers:

Small Craft Advisory: Forecast winds of 22 to 33 knots and/or hazardous sea conditions (usually seas greater than 10 feet).
Gale Warning: Forecast winds of 34 to 47 knots.
Storm Warning: Forecast winds of 48 knots or higher.
Dense Fog Advisory: Visibility reduced to one-half mile or less in the bay. Visibility reduced to one mile or less in the coastal waters.
Special Marine Warning: Potentially hazardous over-water events of short duration (two hours or less) such as thunderstorms with strong gusty winds.

Advisories and warnings listed above are headlined in the Coastal Waters Forecast (CWF). The CWF is a routine product issued by the NWS four times daily (3 AM, 9 AM, 3 PM, 9 PM) or more frequently under rapidly changing weather conditions. The National Weather Service Forecast office for the San Francisco Bay Area (located in Monterey) is responsible for issuing forecasts and warnings for the coastal waters outside the Golden Gate (out to 60 nautical miles offshore), and also for San Francisco Bay, San Pablo Bay, Suisun Bay and the west Delta. Besides headlining hazardous weather conditions, the CWF includes forecast information on wind speed and direction, waves, swell, and significant weather (including fog, rain or showers, and thunderstorms). Public forecasts and warnings are issued by NWS San Francisco Bay Area for all land areas bordering the ocean and bays. Although there are no forecasts issued specifically for marine navigation areas to the east of the delta, public forecasts and warnings are issued for the southern Sacramento Valley, northern San Joaquin Valley, and Delta by the NWS Forecast office in Sacramento.

Beginning in March 2006, NWS San Francisco Bay Area began issuing a specific forecast for the San Francisco Bar as part of the Coastal Waters Forecast (CWF) product. The bar forecast includes expected sea state conditions for the next two periods (e.g., tonight and tomorrow), times of maximum ebb current through the Golden Gate and across the bar, and expected hazards such as a small craft advisory for hazardous bar conditions and/or breaking waves on the bar. The bar forecast is updated four times a day along with the rest of the CWF.

Marine Warning and Forecast Dissemination

Marine weather observations, forecasts, and warnings are disseminated through a wide variety of methods, including those listed below.

NOAA Weather Radio (NWR): The NWR network provides voice broadcasts of coastal marine forecasts on a continuous cycle. Broadcast coverage extends across the bays and typically offshore about 25 nautical miles. When severe weather threatens, an alarm tone is sent to automatically turn on compatible NWR receivers in the transmitter's coverage area. Transmitters that broadcast in the San Francisco Bay Area include:

Frequency	Call Sign	Location
162.400 MHz	KHB-49	San Francisco (Mt. Pise)
162.500	KDX-54	San Francisco North Bay Marine (Big Rock Ridge)

162.550	KEC-49	San Jose/Monterey (Mt. Umunhum)
162.450	WWF-64	San Jose/Monterey Marine (Mt. Umunhum)
162.425	KZZ-75	East Bay/Delta (Mt. Diablo)

The Internet:

- National Weather Service San Francisco Bay Area: weather.gov/sanfrancisco
- NWS San Francisco Bay Area marine forecast web page: www.wrh.noaa.gov/mtr/marine.php
- Point and Click Marine Forecast: The NWS now offers the opportunity to get a site-specific forecast instead of relying on a zone forecast: www.wrh.noaa.gov/firewx/fwpfm/fwpfm.php?wfo=mtr&interface=marine By selecting any spot on the interactive map, the web page user will receive a forecast table that will include specific information on winds, waves, swells and other parameters for the next seven days.
- Buoy and Coastal Observation Information: Wind and wave data from offshore buoys, as well as other coastal weather observations, can be found at: http://www.wrh.noaa.gov/mtr/buoy.php

Buoys data can also be obtained over the phone using the National Data Buoy Center's "dial-a-buoy" service: 1-888-701-8992

Use the buoy number below when prompted to access the latest buoy observations.

Buoy #	Lat/Long	Location
46013	38.2N/123.3W	Bodega Bay
46026	37.8N/122.8W	San Francisco
46012	37.4N/122.9W	Half Moon Bay
46042	36.8N/122.4W	Monterey