CHANNEL ISLANDS AND SANTA BARBARA CHANNEL METEOROLOGY

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ABSTRACT

The lower atmosphere in this area has great structure in the vertical and horizontal. In the summer, a dense, cool marine air 300 m deep is capped by hot, dry air above. Strong and persistent westerly winds extend across the western mouth of the Santa Barbara Channel, decreasing to the east. High speed winds push between the islands. Air temperature tracks the sea surface temperature with the coldest in the western portions. The marine layer and wind structure is consistent with a transcritical flow regime responding to the local topography. In the winter, the vertical structure weakens. Extended weak wind periods are followed by strong southeast winds that reverse to strong northwest winds. Temperature changes are modest with the warmest temperatures in the central, southern portion of the bight.

Keywords: Meteorology, Santa Barbara Channel, Santa Maria Basin.

INTRODUCTION

The Center for Coastal Studies at Scripps Institution of Oceanography has been running a long-term field project to understand the ocean and atmosphere around the Channel Islands and the Santa Barbara Channel. An extensive and unusually dense surface meteorological station network was developed (Figure 1). These included shore stations supervised by the Santa Barbara and Ventura air pollution control districts, the U.S. Navy at Point Mugu, and meteorological buoys operated by the National Data Buoy Center. The Center for Coastal Studies maintained stations on three oil platforms and the western tips of Santa Cruz and Santa Rosa Islands. Although only one summer and one winter are presented here, the results are typical.

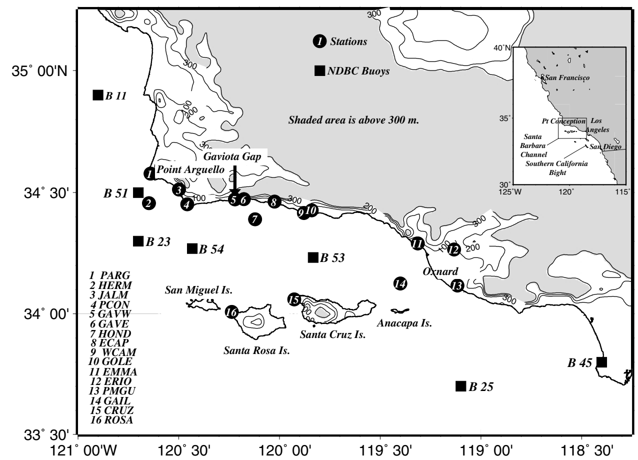

Figure 1. Station locations and topography.

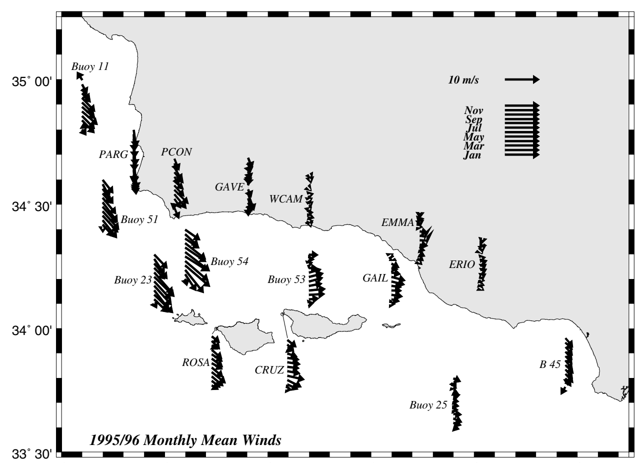

Figure 2. Wind vector mean monthly annual trend. Monthly mean winds for January (lowermost arrow) through December 1996 (uppermost arrow). Speeds are greatest in the western channel mouth in the summer.

RESULTS

Annual Trend

A distinct annual trend is seen in the monthly mean wind vectors along California (Dorman and Winant 1995) and at the western end of the Santa Barbara Channel and the islands (Figure 2). The strongest speeds are in the summer (maximum is April and May 1996) and weakest in the winter (minimum is February 1996) but always from a northwesterly direction. The annual trend has similar annual phase but much weaker magnitude in the eastern end of the channel. Stations on the north channel coast and east of Point Conception, with the exception of Ventura (designated as station EMMA), have weak means with no significant annual speed trend that is typified by Gaviota east station (GAVE) and the Santa Barbara west campus station (WCAM).

The weather in the area is typified by two seasons: the summer and the winter. The remainder of this paper is organized around examining the two representative seasons. The summer structure and variations are presented first. This is followed by a shorter winter structure and variations as the winter has less complicated structure and provides a contrast with the summer season.

Summer

In the mean (Figure 3, upper), the sea-level winds approach the channel from the northwest, accelerate and turn cyclonically around Point Arguello, reaching a maximum in the middle of the western channel. Once past this point, the near-surface air slows as it continues down the center of the channel, exiting to the east into the Ventura Valley or continuing over water to the southeast toward the greater Los Angeles Valley. Compared to the center channel, winds are weaker at the islands on the south edge. Standard deviations are less than the means for the over-water stations in the western mouth.

Correlations for the summer season were computed among the stations for the wind along the principal axis (PA)

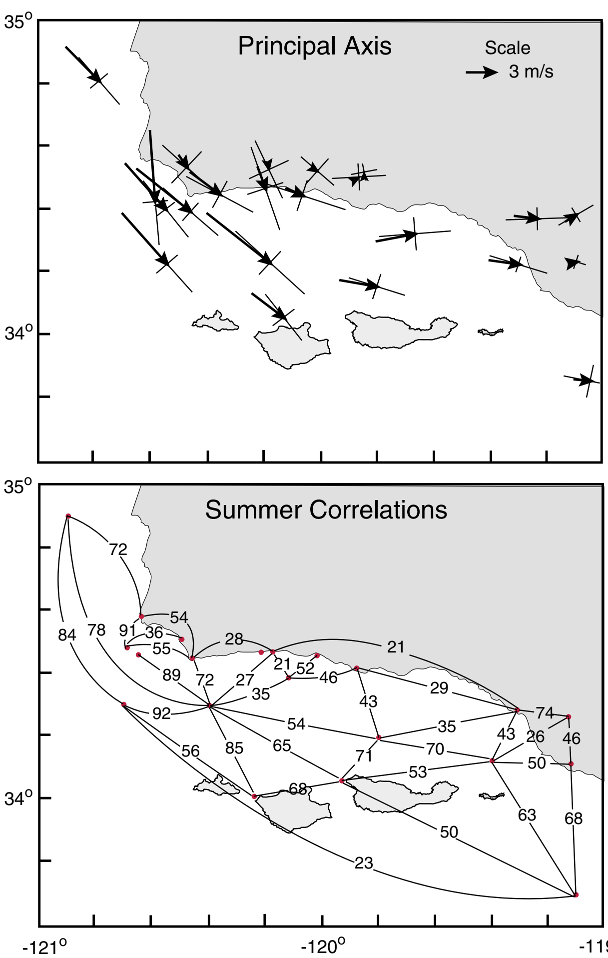

Figure 3. Summer mean surface wind speed and principal axes (PA) (upper frame). Mean is the arrow that flies with the wind. The cross at the end of the wind vector is the wind standard deviation with the long side the maximum magnitude and orientation and the short side the minimum. Wind correlations along station PA's (lower frame).

or the direction of the maximum variance which is close to mean wind direction (Figure 3, lower). The best correlations (0.7 to 0.9) are between the stations in the western mouth of the channel (B54 with others). Weak correlations (0.5 to 0.6) are between the western mouth (as represented by B54) and the eastern central stations as B53 and CRUZ. Poor correlations exists between the center line channel stations (B54, B53) and the land coastal stations Gaviota West (GODW) to EMMA and Platform Hondo (HOND). Even though it is over water, HOND is poorly related to B54 and also the coastal stations. In contrast, the two stations on exposed Point Arguello (PARG and Point Conception (PCON) are at least moderately correlated with the near, over-water stations Buoy 54 (B54), and Platform Hermosa (HERM).

The most frequently occurring summer event is high speed, sustained winds from the north followed by a short period of weak winds. Fastest winds are at the western mouth of the Santa Barbara Channel and are associated with strengthened along-coast sea-level pressure gradient and weak cyclonic circulation in the mid-level of the atmosphere. A typical case is examined for the period 2 to 11 July 1996. The main sea level synoptic features are the North Pacific anticyclone to the northwest with a heat low in the southwest U.S. north of Point Conception, the along-coast pressure gradient strengthens from the 3 to 5 July then decreases again on 9 July as the heat low expands (not shown). Sea-level pressure gradients over water are consistently weak southeast of Point Conception for the entire period despite of the variation in sea-level speeds at the western mouth. At 700 hPa an approaching trough on 3 July weakens as it moves over the California coast on 7 July and to eastern California on 9 July.

The sea-level winds along the main channel are sensitive to the above-noted synoptic variations. Examples of selected stations are shown in Figure 4 for which the wind direction has been rotated to the station's PA so as to make viewing easier. After a brief period of weak winds, strong inbound northerly winds persisted at Buoy 51 (B51) for seven days with stronger winds at B54. Once past B54, wind speeds decrease to Buoy 53 (B53), then to Platform GAIL (GAIL) (not shown), to reach a minimum speed at El Rio (ERIO) in the eastern end. Indeed, it would be hard to determine the state of the winds at the western mouth of the Santa Barbara Channel if only the El Rio observations were available. Not shown are winds at the Channel Islands of Santa Rosa (SROS) and Santa Cruz (SCRZ) which are somewhat weaker but coincident with the buoy winds at B54 and B51. The winds over the land stations were generally west-east with only an occasional clear, cross-coast, northerly velocity such as occurred at GAVE (and GAVW and HOND) for four hours early on 5 July. Finishing up this synoptic sequence, weak winds and reversals occurred on 9 July and 10 July which are the second most frequently occurring event over the open channel.

The explicit diurnal trends for cross channel stations are not shown. However, all stations wind speeds are a minimum around sunrise and increase in the afternoon. The

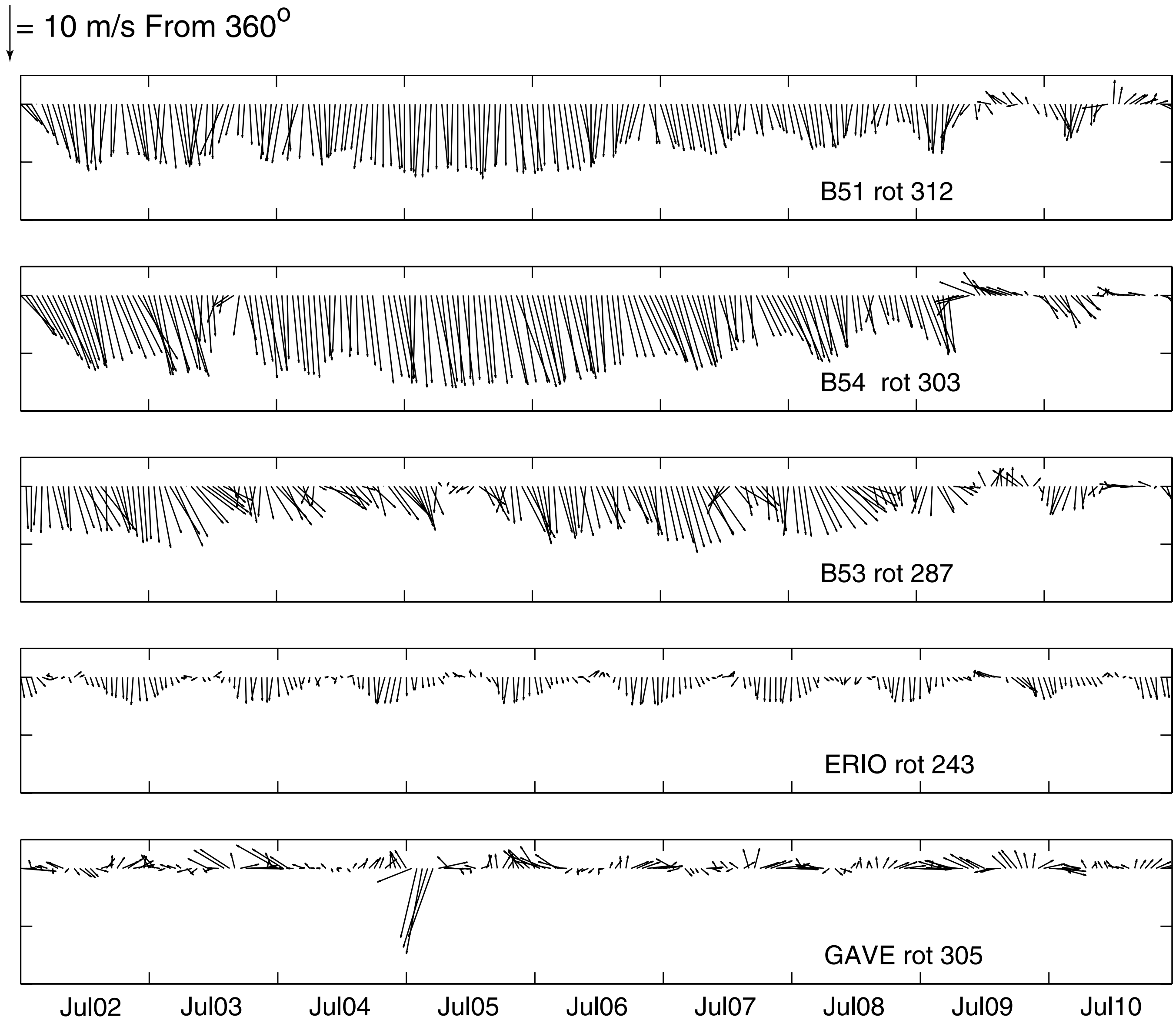

Figure 4. Surface wind vector time series rotated to the PA for 2 to 11 July 1996 for selected stations.

stations on Santa Rosa and Santa Cruz islands have a small diurnal change while Buoy 54 in the center of the channel has the largest in the area.

Temperatures for the summer are shown in Figure 5. In the summer morning, the land is warmer than the sea in the Santa Barbara Channel, with a weak gradient to the east. In the afternoon, all stations are warmer, with the weakest increases over the western mouth and the greatest over the land at the eastern end. Added to the 0600 PST chart are the seasonal averaged sea-surface temperature contours from satellite infrared images as thin dashed lines. Wind-driven upwelling, associated with the fastest winds, causes the sea-surface temperature minimum in the western mouth. The air-temperature field follows the sea-surface temperature field on account of the low heat capacity of the air and the restricted exchange of the marine air with other sources.

A synopsis of the results of the Navy Variability of Coastal Atmospheric Refractivity (VOCAR) sounding program is presented that maintained eight upper-air stations in the Southern California Bight in August and September 1993. In the morning at 0400 PST, the inversion base was lowest in the Santa Barbara Channel and highest in the southern half of the bight (Figure 6). The strength of the inversion is greater offshore. In the afternoon, at 1600 PST, all base heights are typically about 100 m lower but still is the lowest is in the Santa Barbara Channel. The strongest horizontal gradient in the inversion base height is at the western mouth of the Santa Barbara Channel. The greatest inversion strength is to the southwestern portion of the bight while it is weakest in the Santa Barbara Channel.

VOCAR winds over the Southern California Bight are relatively strong only on the western side (not shown). The winds are greatly accelerated in the afternoon, sweeping directly across the Bight with little curvature.

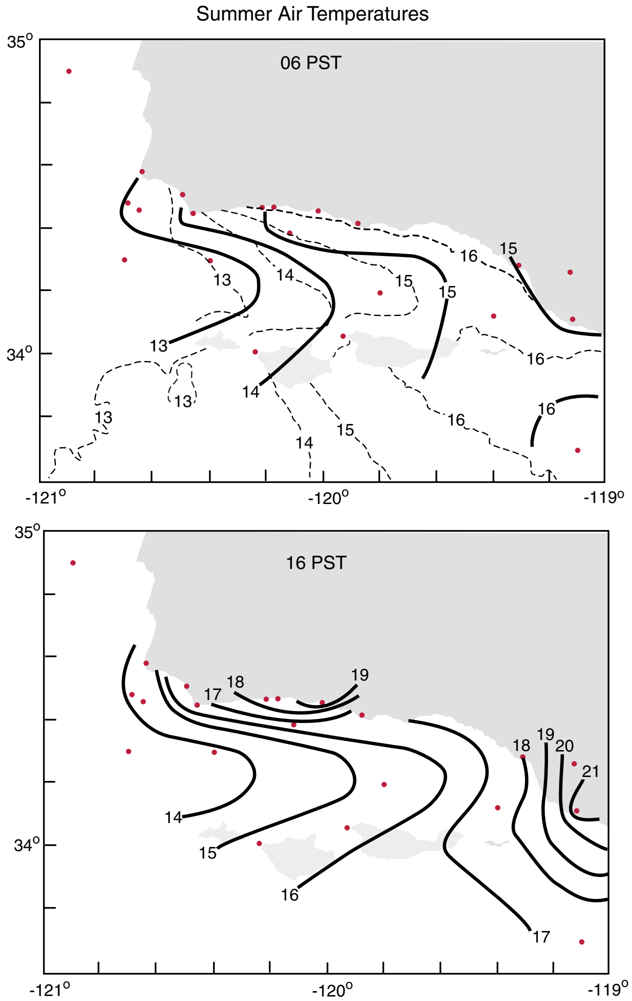

Figure 5. Summer mean air temperatures at 0600 PST (upper frame) and 1400 PST (lower frame). It is coolest in the western mouth. The summer sea surface temperature estimated from satellite infrared images are superimposed on the upper chart as thin dashed lines.

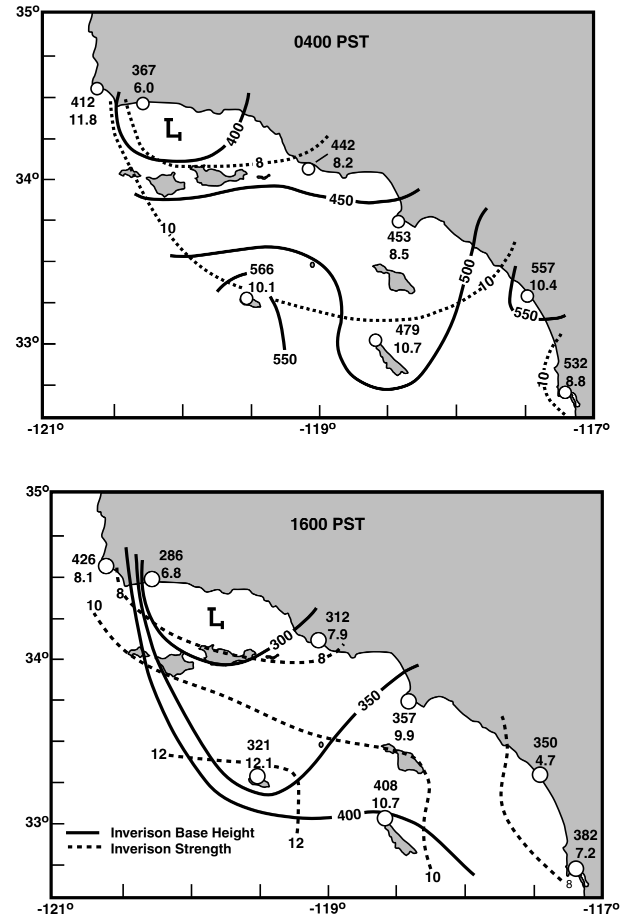

Figure 6. 0400 PST (upper frame) inversion base height (solid) and strength (dashed). Stations locations are at circles, where the upper plotted number is the air temperature inversion base height in meters and the lower number is the inversion strength in °C. 1600 PST (lower frame) inversion base height and strength. The lowest inversion base height is over the Santa Barbara Channel at both times.

Winter

Mean winter winds are for the December 1995 to February 1996 period for all stations except B11 and JALM. The December 1994 to February 1995 observations are used to compute the mean for B11 and JALM as these stations were not available for the 1995/1996 season. The winter wind mean and PA for the surface stations are from the northwest at the western mouth and turn to the east in the Santa Barbara Channel (Figure 7, upper) as during the summer. However, drainage flows down the Ventura river valley caused by colder night temperature over the elevated topography causes offshore wind at ERIO, EMMA, and GAIL. There is a mean offshore flow over the north coast stations in contrast to summer. Winter standard deviations are larger than the mean winds and also greater than the summer standard deviations.

Correlations of the over-water wind component along the PA (Figure 7, lower) are greater than in the summer, which is evidence of a larger synoptic scale. Most of the over water stations have correlations of 0.7 to 0.8 or better with neighboring stations. The lowest correlation between a central channel stations (B54) and a near coast station (GAVE) dips to only 0.69. Even the stations away from the Santa Barbara Channel (B11, B25) are correlated with those in it. The poorest correlations are between the land stations at the eastern end of the Santa Barbara Channel.

A late-December 1995 case is typical of strong southerly sea-level winds followed by a reversal to strong northerly winds. The synoptic situation for strong southerly winds is an approaching front off California and a deep low extending from sea level to above 500 hPa (not shown). Sea level and mid-level winds are from the south along central California and the western portion of the Southern California Bight. Later, by 28 December a ridge oriented northwest-southwest developed across central California from sea level to above 500 hPa and a trough to the east of California. The result were strong winds from the northwest from sea level to the upper atmosphere over the Santa Barbara Channel.

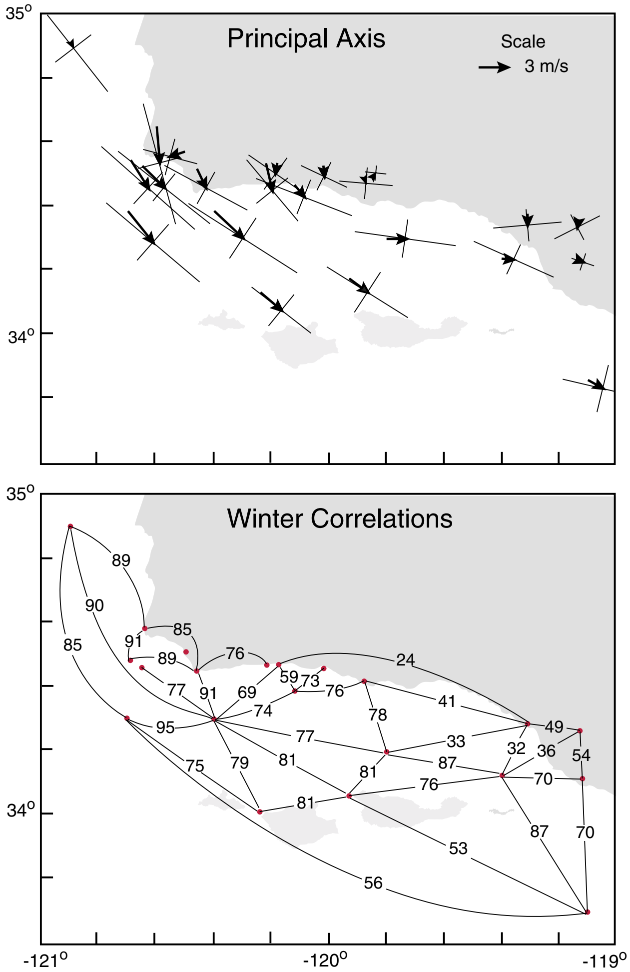

Figure 7. Winter mean surface wind speed and principle axis (PA) (upper frame). See Figure 3 for explanation. Wind correlations along station PA's (lower frame).

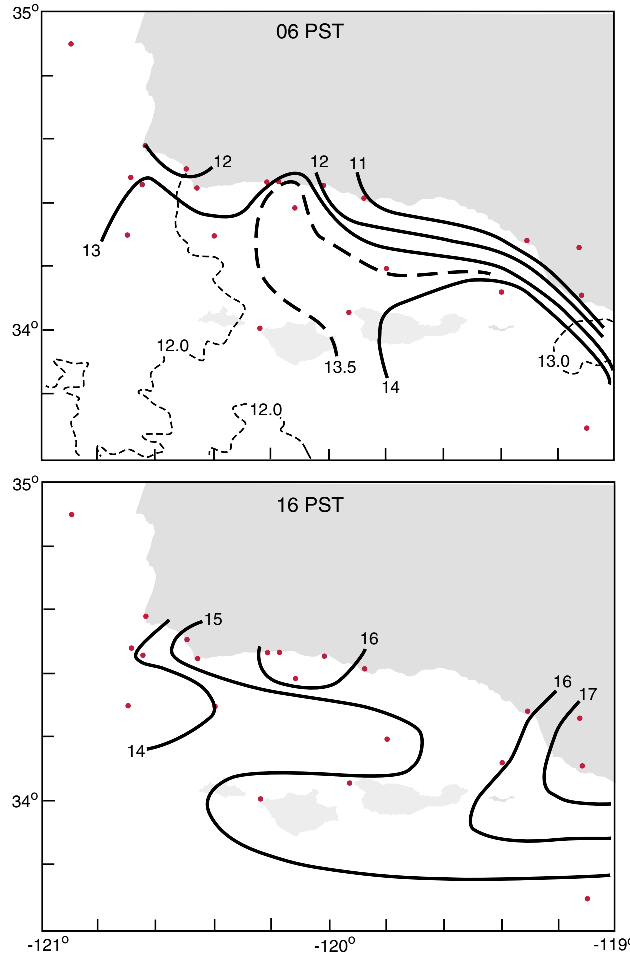

Figure 9. Winter mean air temperatures at 0600 PST (upper) and 1400 PST (lower). The winter sea surface temperature estimated from satellite infrared images are superimposed on the upper chart as thin dashed lines.

Strong southerly winds at the western Santa Barbara Channel surface stations extended from 22 to 26 December with the winds increasing in strength from the Islands to B51 (Figure 8). Winds were slower and from the east in the eastern portion of the channel. North coastal stations varied between periods of southerly and along-shore winds.

The winds reversed abruptly around midnight on 26 to 27 December to be strong from the north-northwest of the western channel until 1 January. Winds increased from B51 to maximum at B54 then mildly decreased at the islands. The north coast stations as GAVE experienced persistent offshore winds but at speeds less than at the islands. Finally, winds were weak and variable in direction at the eastern coastal station ERIO.

Winter air temperatures shown in Figure 9. In the winter morning, there is a weak air temperature maximum over the center of the channel while the strongest minimum is over the Oxnard Plain on the eastern end. By the afternoon, stronger diurnal warming has reversed the situation so that the warmest temperatures are over land. Somewhat similar to the summer, there are along- and cross-channel gradients with the coldest air at the western mouth of the channel. However, satellite-derived sea-surface temperatures (thin dashed lines in Figure 9) are nearly uniform over the Santa Barbara Channel.

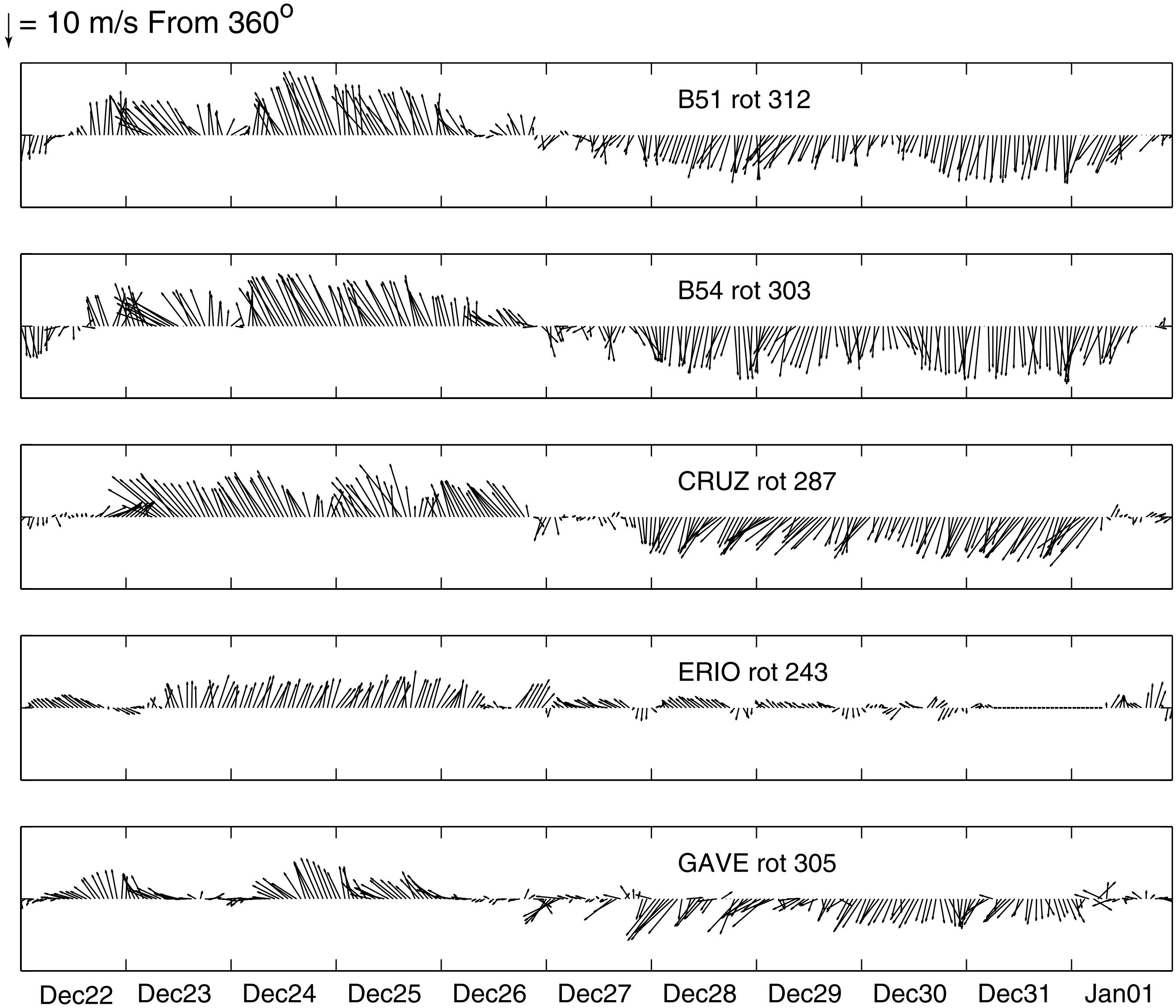

Figure 8. Surface station wind vector series rotated to the PA for 22 December 1995 to 2 January 1996.

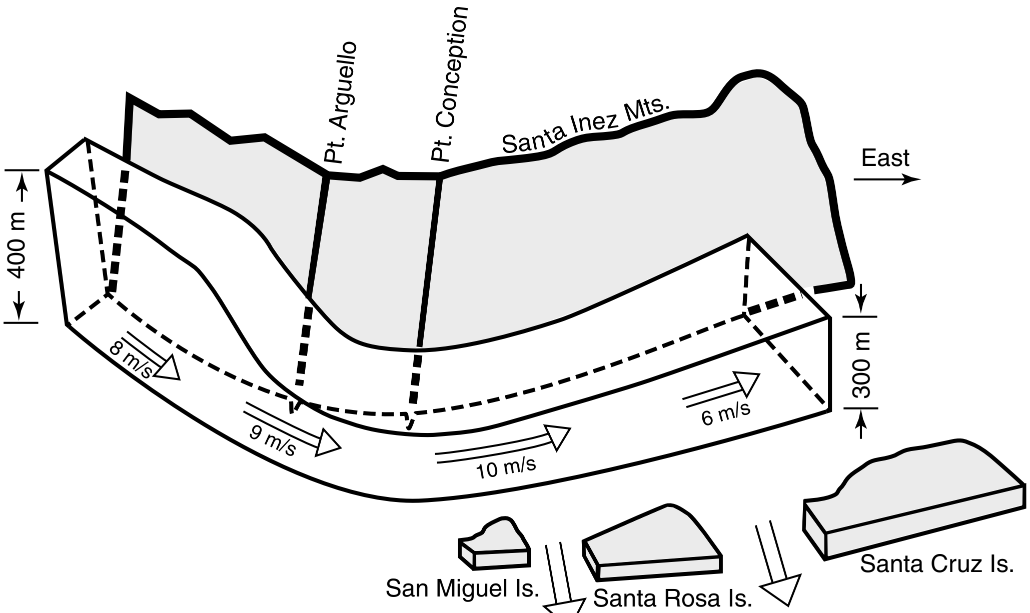

Figure 10. Schematic model of the marine layer structure turning into the Santa Barbara Channel. The marine air thins, expands, and accelerates as it turns the corner into the Santa Barbara Channel, causing the fastest winds to be at the western mouth.

Model

We propose that the dynamical explanation for the high speed winds in the western mouth of the Santa Barbara Channel is a transcritical expansion fan. Supercritical marine layer conditions were found around Point Arena (Winant et al. 1988). Subcritical upstream flow with Froude numbers between 0.5 and 1.0 will result in limited areas of supercritical or transcritical flow in the lee of a point (Rogerson 1998) which is what is found here.

The conditions in the western mouth are very much like a supercritical or transcritical expansion fan in the lee of a corner. A schematic model in Figure 10 summarizes the details. Under strong, supercritical flow to the south or southeast, the near sea level air accelerates from around Point Arguello/Point Conception to the speed maximum around B54. At the same time the atmospheric marine layer expands and thins to a minimum height and the sea-level pressure decreases. The inversion also tilts downward to the north across the channel, making the lowest inversion base along the north coast. As marine air continues eastward toward B53, it slows and the vertical dimension increases. Some of the air mass entering the western mouth exits at supercritical speeds via the gaps between the Channel Islands.

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