5.9 SIMULATION OF INTERACTION OF THE ATMOSPHERIC MARINE LAYER WITH POINT CONCEPION

Clive E. Dorman*
Scripps Institution of Oceanography, San Diego, California
San Diego State University, San Diego, California

Darko Koračin
Desert Research Institute, Reno, Nevada

1. INTRODUCTION

In an atmospheric numerical model investigation of the summer coastal winds, wind stress and wind stress curl along California and Baja California, Koračin et al. (2004) found great inhomogenanity associated with topographic features. A fast, low supercritical or transcritical, atmospheric marine flow reacting to land structures generates hydraulic features. Upwind of a cape is a compression bulge with slower speeds and a deeper marine layer. On the lee side is an expansion fan with faster speeds and a shallower marine layer. These features extend more than 100 km offshore of the larger capes. The wind stress structure is closely related to the wind as the stress is proportional to the wind speed squared. The effect is alternating zones of wind stress minima and maxima dominating the coastal zone from Southern Oregon to Central Baja California. These zones are consistent with satellite sensed sea surface temperatures at all capes, atmospheric numerical modeling of the large, regional, and mesoscale wind patterns (Koracin and Dorman 2001, Koračin et al. 2004) and confirmed by surface measurements (Dorman and Winant, 1995, 2000; Dorman et al. 2000) and by direct over-water aircraft measurements at most of the major capes (Beardsley et al. 1987, Rogers et al. 1998, Dorman et al. 1999, 2000). Several theoretical and numerical works have expanded on different aspects of atmospheric marine layer hydraulic features (Burk et al. 1999, Cui et al. 1988, Edwards 2000, Edwards et al. 2001, Haack 2001, Rogerson 1998, Samelson 1992, Tjernstrom and Grisogono 2000, Winant et al. 1988, Koracin and Dorman 2001).

Direct oceanographic and meteorological measurements have been made around Point Conception in a series of programs since the early-1980's. Brink et al. (1984) and Caldwell (1986) were one of the first to discuss the upwelling and the wind variations in the spring. Münchow reanalyzed earlier aircraft data to estimate the wind stress and curl in the western mouth of the Santa Barbara Channel. Local aspects of the surface winds, marine layer supercritical flow and marine layer depth are investigated in Dorman and Winant (2000), Edwards (2000) and Skyllingstad (2002).

The coastal area affected by the greatest bend in the California coastline which is at Point Conception, warrants a closer examination. This area is characterized by frequent inhomogeneous wind structure of considerable variation. To understand this complex structure, the 3-D nature of the upwind compression bulge and the lee expansion fan is investigated using the MM5 simulations for the entire month of June 1999 with 1-km grid point separations.

2. COMPARISON WITH SURFACE MEASUREMENTS

There are more than 25 surface meteorological stations with hourly observations in the modeled area to compare with the model. Of these, 17 buoys, platforms and coastal stations representing over water and coastal areas relative to Pt Conception are shown in Fig. 1. The main statistics of the comparison reveal that the stations fall into three geographical groups. The over-water stations on buoys or the edge of islands have high correlations with model simulations (0.68 - 0.87, median 0.81) and faster winds (5.1 - 9.7 m/s). The North Coastal stations (ARGO, PURI, PSAL) have generally more moderate correlations with the simulations (0.56 - 0.77) and moderate wind speeds. The East Coastal stations (GAVW to EMMA) and platforms (HOND and GAIL) stand out as much more poorly correlated with the model simulations (-9 - 0.65) and have the weakest winds (2.3 – 5.0 m/s). The median correlation coefficient for all stations is 0.73.

* *Corresponding author address*: Clive Dorman, IOD, Scripps Institution of Oceanography, La Jolla, CA 92093-0209; e-mail: cdorman@ucsd.edu

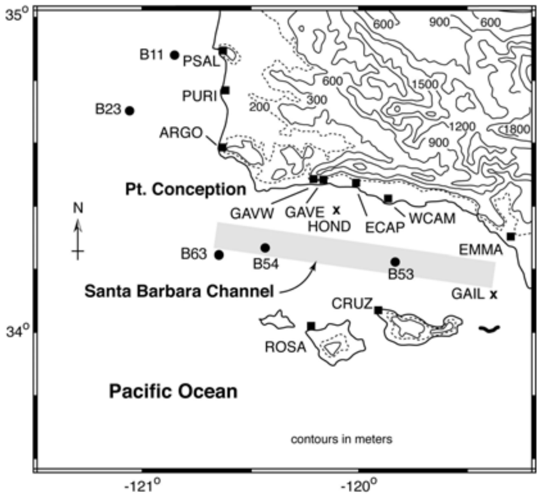

Fig. 1. Map of the MM5 domain and topography with indicated surface meteorological stations and geographical points.

3. MEAN SEA LEVEL AND SURFACE WINDS FOR JUNE 1999

The surface wind field expresses the dynamical relationships of the marine layer interacting with Pt Conception. The inbound winds approach the greater Pt Conception area from the NW, being guided by the Central California coast with this orientation. Flow passing just to the SW of Pt Conception turns to east into the Santa Barbara Channel. An expansion fan extends from the Pt Conception complex to over the western mouth of the Santa Barbara Channel, forming a wind maximum. Flow continuing east in the Santa Barbara Channel decelerates into a weak wind zone in the east end of the Santa Barbara Channel. Winds approaching the upwind side of islands decelerate (compression bulges) and increase on the sides. Weak wind zone banners extend down wind of the center of the islands.

A special area of note is in the compression bulge on upwind portion of the coast that runs nearly north-south between Point Arguello and Point Sal. The slowing of the wind speed is confirmed by the three offshore stations and two coastal (Fig. 1). The mean measured winds linearly decrease from 33 km to the coast at PURI and PSAL. The measured and the simulated winds have similar values and trends.

A second weak wind zone along the Santa Barbara coastal area stretching to the east is confirmed by stations (GAVE, HOND, ECAP, WCAM). At the very eastern end of this of the Santa Barbara Channel, there are very weak winds in the last few kilometers as the marine air slows just before crossing the coast is also confirmed by direct measurements (GAIL, EMMA, ERIO, see Dorman and Winant, 2000).

The apex of the high speed winds in the expansion fan starts at Pt Arguello and increases to the south and east across buoys and reaching the stations on the western tips of Santa Rosa and Santa Cruz Islands. In the high speed zone over water at the western mouth of the Santa Barbara Channel, the measured winds at B11, B23, B63 and B54 the maximum in the area, from 7.1 – 9.8 m s^{-1}, which is also closely captured by the model winds speeds ranging from 7.1 – 9.2 m s^{-1}.

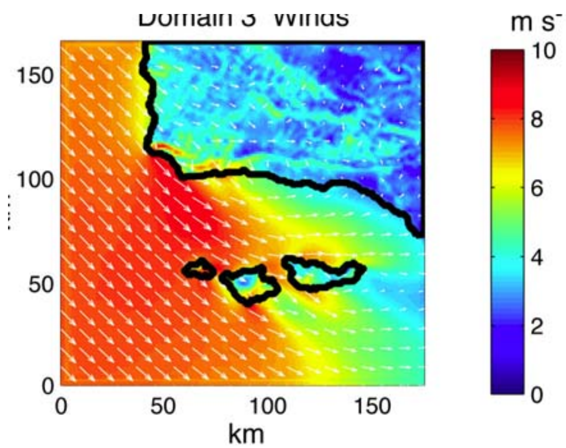

Fig. 2. June 1999 mean MM5 simulated 7-m winds (m s^{-1}).

4. DIRURNAL VARIATION OF WINDS FOR JUNE 1999.

The near surface winds at 1200 UTC (0400 LST) and 0000 UTC (1600 LST) capture the appreciable range of diurnal variation. The over-water winds increase to a maximum in the afternoon (Fig. 3a). The high speed expansion fan winds extend from Pt Arguello to near the eastern end of the Santa Barbara Channel with the maximum in western mouth. High speed expansion fans extend SW from the lee of the larger islands. A narrow low speed lee extends to the ESE of Santa Rosa Island while a wider, lower speed weak wind zone extends downwind of Santa Cruz Island. Another weak wind zone extends along the coast from Santa Barbara eastward to the east end of the Santa Barbara Channel. A narrow, low speed zone extends along the coast, north of Point Arguello.

Around sunrise, the over water winds are slowest and the high speed winds cover the smallest area (Fig. 3b). The eastern edge of the expansion fan high speed winds ends sharply along a line extending from the Pt Arguello/Pt Conception along a bearing of 140 ^{o}T, that appears to be a characteristic, where the marine layer increases in depth and decreases speed. To the east, most of wind speeds in the Santa Barbara channel and island lees are weak.

The strongest diurnal wind speed range is in the center of the mid-portion of the Santa Barbara Channel. This is covered by the higher speed winds in the afternoon as the high speed winds in the western mouth of the channel extend farther East, and is covered by weaker Eastern Santa Barbara Channel winds that extend farther to the west late night and early morning.

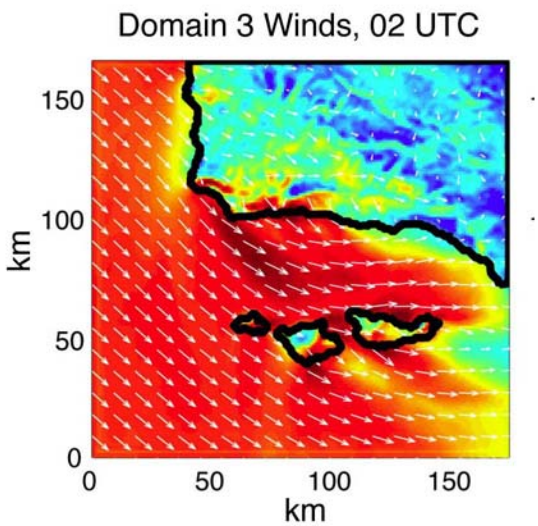

Fig. 3a. June 1999 simulated domain (1-km resolution) winds at 7 m at 0200 UTC (near sunset).

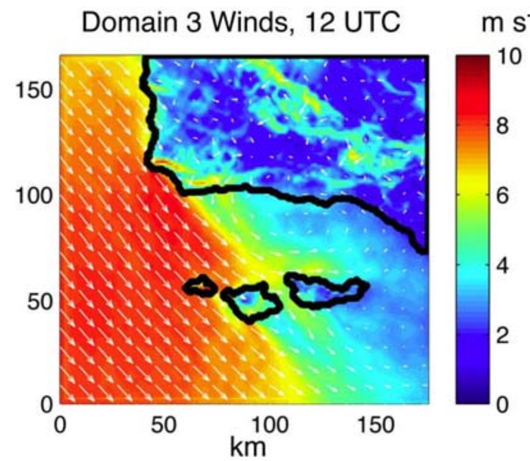

Fig. 3b. As for Fig. 3a, but for 1200 UTC (near sunrise).

5. STRONG WIND EVENT

A strong event occurred on 10 June. At 00 Z, high speed winds (> 8 m s^{-1}) extended along almost the complete length of the Santa Barbara Channel with the maximum center extending from Pt Conception to the SW (Fig. 4). In addition, the winds speeds are strong to the west of Pt Conception. Twelve hours later, near sunrise, the fast winds are restricted to the western third of the Santa Barbara Channel, and to west of Pt Conception. Winds are weak in the eastern half of the Santa Barbara Channel and the Southern California Bight. There is some faint, slightly curved, narrow weak and strong wind speed bands that extend to the south of Point Arguello, and the Channel Islands. These are believed to be marine layer hydraulic flow characteristics that are occasionally visualized in satellite cloud images when the conditions are just right.

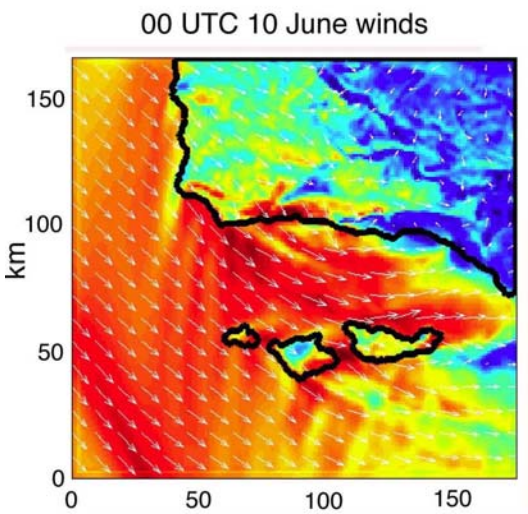

Fig. 4a. Strong wind case on 10 June 1999 at 0000 UTC.

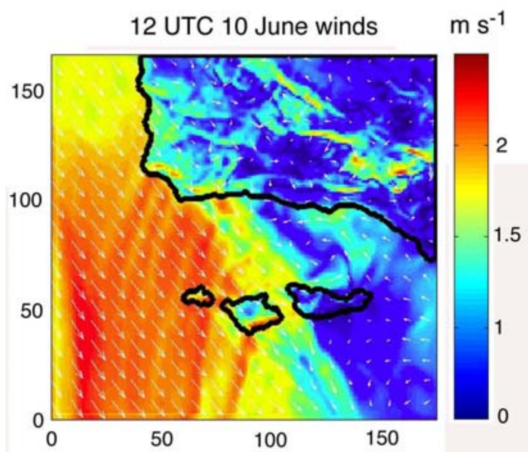

Fig. 4b. As for Fig. 4a but for 1200 UTC.

6. MODERATE WIND EVENT

A moderate case (7 m s^{-1}) occurred on 19 June. At 00 UTC, a moderate wind speed maximum covered a smaller, isolated area, which is centered in the western 1/3 of the Santa Barbara Channel and touches Pt Conception (Fig. 5). Weaker wind speeds extend from over the remainder of the Channel. The larger islands have shock lines of high speed winds extending from down wind from the islands sides. In the center of the island lees, a very light wind speed zone extends downwind in the form of a wake “v”. At 12 UTC, there is a small area, moderate wind speed maximum that shifted to the lee of Pt Arguello. Very weak winds cover the remainder of the Santa Barbara Channel and the island lees.

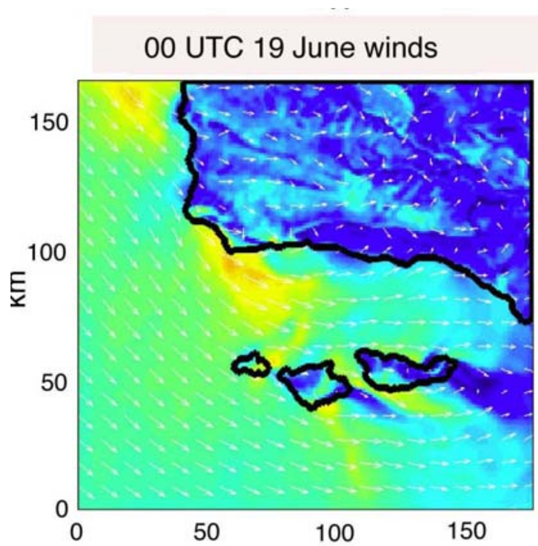

Fig. 5a. Moderate wind case on 19 June 1999 at 0000 UTC.

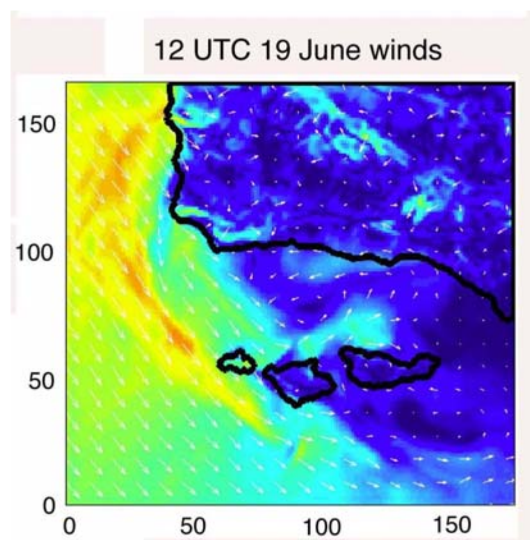

Fig. 5b. As for Fig. 5a but for 1200 UTC.

7. WEAK WIND EVENT

A weak wind case (< 4 m s^{-1}) occurred on 23 June. At 0000 UTC, the sea surface winds area almost uniformly weak with no clear maximum in the western mouth of the SBCH or near Pt Conception/Arguello (Fig. 6). Flow is from the W in the Santa Barbara Channel and from the SW in the eastern portion of the regime. By 1200 UTC, most of the wind is from a southerly direction over water and weak. The reversal of the flow from the S or SE has shifted the fastest winds speeds to the small expansion fan extending to the NNW from Pt Arguello. With flow to the NW, the position and the time of the diurnal wind speed maximum shifts to the early morning.

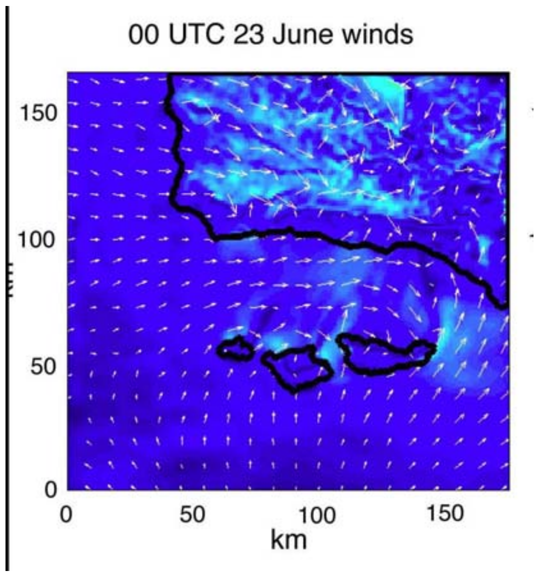

Fig. 6a. Weak wind case on 23 June 1999 at 0000 UTC.

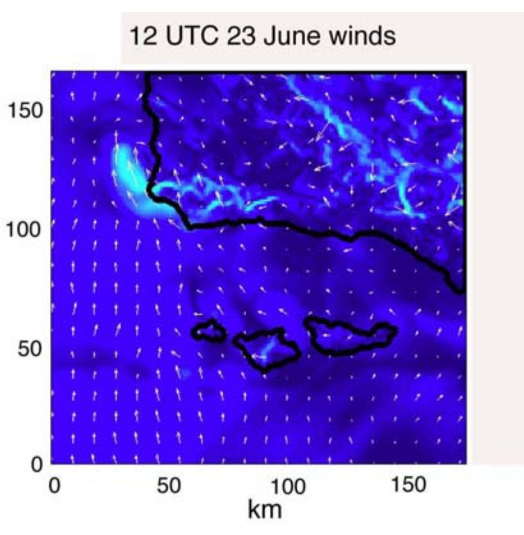

Fig. 6b. As for Fig. 6a but for 1200 UTC.

8. SUMMARY OF FEATURES

An approaching deep, inbound marine layer is aligned by the Central California Coast bearing $300^{o}/120^{o}$ T. This is on a collision course with the western edge of the Point Conception monolith that is oriented 180^{o} T on the upwind coast. As the marine layer approaches the western edge in the last 30 km, a compression bulge is formed, with the marine layer slowing and deepening. A portion of the marine layer continues to the south and a portion is diverted around the Pt Arguello-Pt Conception complex cape. The diverted portion turns more eastward, thins, accelerates and metamorphoses into a transcritical flow expansion fan (Rogerson 1998) that reaches its greatest expression in the western mouth of the Santa Barbara Channel. This transcritical flow, heading due east, slows and thickens. The eastbound marine layer metamorphoses back to subcritial in the eastern half of the Santa Barbara channel. Surface winds speeds are very slow in the eastern end of the Santa Barbara Channel, with the flow either moving over the Ventura river valley coast or diverting to the SE, remaining over water.

There are smaller important features of note. One is that there is a narrow coastal zone covering the Santa Barbara coastal plain and extending a few kilometers over water, reaching from Santa Barbara to past Ventura. This zone usually has weak surface winds, running parallel to the coastline. Sometimes, localized cross coast flow will occur at the foot of Goleta Canyon, and less at other locations. Strong, cross coast flow is a-typical of this zone. The weakest coastal wind zone include the Oxnard plain, but the winds are cross coast in the afternoon in response to a weak onshore, up-valley, thermal circulation.

The Channel Islands form a “picket fence” barrier on the south side of the Santa Barbara Channel. The larger islands, projecting above the marine layer, guide most of the marine layer to the east. A southeasterly oriented pressure gradient pulls marine air away from the southern side of the Islands. This Island southern side air is replaced by from the west, passing through the gaps between islands, or, subsiding island lee flow. South bound flow accelerates through the island gaps, and into narrow, island lee side expansion fans and lee transcritical expansion fans.

References

Beardsley, R.C., C.E. Dorman, C.A. Friehe, L.K. Rosenfeld, and C.D. Winant, 1987: Local Atmospheric Forcing During the Coastal Ocean Dynamics Experiment. I. A Description of the Marine Boundary Layer and Atmospheric Conditions Over a Northern California Upwelling Region. *J. Geophys. Res.*, **92**, 1467-1488.

Brink, K.H. D.W. Stuart, and J.C. Van Leer, 1984: Observations of the coastal upwelling region near 34° 30'N off California: Spring 1981. *J. Phys. Ocean*, **14**, 378-391.

Burk, S. D., T. Haack, and R. M. Samelson, 1999: Mesoscale simulation of supercritical, subcritical, and transcritical flow along coastal topography. *J. Atmos. Sci.*, **56**, 2780-2795.

Caldwell, P. C., D. W. Stuart, and K. H. Brink, 1986: Mesoscale wind variability near Point Conception, California, during spring 1983. *J. Climate Appl. Meteor*., **25**, 1241-1254.

Cui, Z, M. Tjernstrom, and B. Grisogono, 1998: Idealized simulations of atmospheric coastal flow along the central coast of California. *J. Appl. Meteor*., **37**, 1332-1363.

Dorman, C.E., D. P. Rogers, W. Nuss and W. T. Thompson, 1999: Adjustment of the Summer Marine Boundary Layer Around Pt. Sur, California. *Mon. Wea. Rev.*, **127**, 2143-2159**.**

Dorman ,C. E., T. Holt, D. P. Rogers and K. Edwards, 2000: Large-Scale Structure of the June-July 1996 Marine Boundary Layer Along California and Oregon. *Mon. Wea. Rev.*, **128**, 1632-1652.

Dorman, C. E. and C. D. Winant, 1995: Buoy observations of the atmosphere along the west coast of the United States, 1981- 1990. *J. Geophys. Res.*, **100**, 16029-16044.

Dorman, C. E. and C. D. Winant, 2000: The Marine Layer in and Around the Santa Barbara Channel. *Mon. Wea. Rev.*, **128**, 261-282.

Edwards, K. A., 2000: The marine atmospheric boundary layer during Coastal Waves 96. Ph.D. thesis, University of California, San Diego.

Koračin, D. and C.E. Dorman, 2001: Marine atmospheric boundary layer divergence and clouds along California in June 1996. *Mon. Wea. Rev.*, **129**, 2040-2056.

Koračin, D and C. E. Dorman and E. P. Dever, 2004: Coastal Perturbations of Marine Layer Winds, Wind Stress, and Wind Stress Curl Along the California and Baja California in June 1999. *J. Phys. Ocean.*, **34**, 1152-1173.

Münchow, A., 2000: Wind Stress Curl Forcing of the Coastal Ocean near Point Conception, California. *J. Phys. Ocean.,* **30**, 1265-1280.

Rogers, D., C. Dorman, K. Edwards, I. Brooks, K. Melville, S. Burk, W. Thompson, T. Holt, L. Strom, M. Tjernstrom, B. Grisogono, J. Bane, W. Nuss, B. Morley, A. Schanot, 1998: Highlights of Coastal Waves, 1996. *Bull. Amer. Meteorol. Soc.*, **7**, 1307-1326.

Rogerson, A.M., 1998: Transcritical Flows in the Coastal Marine Atmospheric Boundary Layer. *J. Atmos. Sci.*, **56**, 2761-2779

Skyllingstad, Eric, Philip Barbour, and Clive E. Dorman, 2002: The Dynamics of Northwest Summer Winds over the Santa Barbara Channel. *Mon. Wea. Rev*, **129**, 1042-1061.

Winant, C. D., C. E. Dorman, C. A. Friehe, and R. C. Beardsley, 1988: The marine layer off northern California: An example of supercritical channel flow. *J. Atmos. Sci.*, 45, 3588-3605.