**1.2 SANTA YNEZ MOUNTAIN LEE-SIDE EFFECTS OVER THE SANTA BARBARA CHANNEL**

Clive E. Dorman*
Scripps Institution of Oceanography, La Jolla, California

## 1. INTRODUCTION

It has been suggested that the east-west extending Santa Ynez/San Rafael mountains just north of Santa Barbara (Fig. 1) have significant lee-side effects on the Santa Barbara Channel and a mesoscale event contained in the Southern California Bight known as a Catalina Eddy ( initially Bosart 1983; and others). Schematic models (i.e. Mass and Albright 1989) and numerical modeling studies (Thompson, et. al. 1997; Ulrickson, et. al. 1995; Ueyoshi and Roads, 1993: Davis, et. al. 2000) have strong northerly winds above the Santa Ynez/San Rafael crests forcing lee-side effects down wind. Many of these models show strong, cross-shore, northerly surface winds sweeping across the lee of the Santa Ynez mountains and the Santa Barbara coast. Further, a number of studies cite a sea-level low pressure at Santa Barbara as supporting evidence of lee-side effects.
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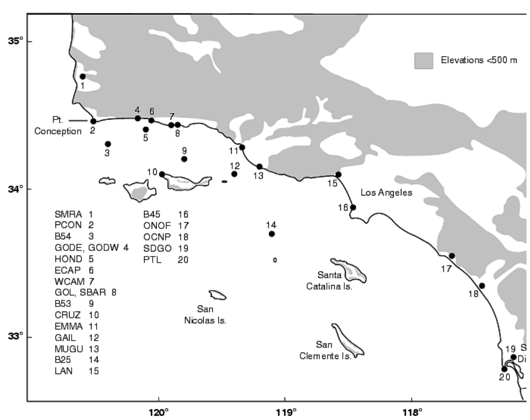


**Figure 1. Topography and stations.**

*Clive E. Dorman, Scripps Institution of Oceanography, La Jolla, CA 92093-0209; e-mail; cdorman@ucsd.edu

The readers are reminded that radar profiler measured winds above Santa Barbara are generally not northerly (Dorman and Winant 1999). Instead, the winds are mostly along coast and weak at the surface stations along the Santa Barbara Coast (Dorman and Winant 1999) and the low pressure in the Santa Barbara Channel is a semi-permanent feature (Dorman and Winant 1999) with a dynamical explanation provided by Robinson (1997). Since the mean wind field below 2 km is weak and **not** northerly, cross-shore flow cannot be cited as the cause of the semi-permanent Santa Barbara Channel low pressure. It should be pointed out that the published mean Vandenberg AFB sounding winds (Mass and Albright 1989) are considerably different, and not representative of those above Santa Barbara (Dorman and Winant 1999).

The observational network around the Santa Barbara Channel and the Southern California Bight has changed substantially in the mid-1990's. An extensive series of surface stations now exist in the Southern California Bight and especially in the Santa Barbara Channel and the lee-side of the Santa Ynez mountains. Some of those close to the coast are shown in Fig. 1. Automated hourly winds and pressure were taken at five National Data Buoy Center buoys and a coastal station. The Minerals Management Service funded the Scripps Institution of Oceanography as part of a Santa Barbara Channel/Santa Maria Basin oceanographic study to make minute-averaged wind, pressure, and air temperature measurements at five islands and oil platforms. Air pollution agencies (Santa Barbara County Air Pollution Control District and Ventura County Air Pollution Control District) operated seven, hourly-averaging, automated surface stations along the Santa Barbara Channel coast. The San Diego County Air Pollution Control District and nuclear power plants (Southern California Edison's San Onofre; Pacific Gas and Electric's Diablo Canyon) recorded winds and temperatures, but not pressure. Also available are National Weather Service, FAA, and military airport weather observations, some of which included clouds although many did not take 24-hour observations.

An improved mix of upper air stations within the Bight has also been available since the mid-1990's. Three of these are hourly-averaged, radar profilers with RASS, one of which was at the Santa Barbara airport (Golita) in the immediate lee of the Santa Ynez Mountains. Others are at San Diego and next to the Los Angeles airport (LAX). Twice daily, balloon-borne RAOB stations are at San Diego and Vandenberg AFB, although only the latter truly samples the marine layer in the bight and both suffer from incomplete resolution of scales less than about two days. Two additional upper-air balloon stations at San Nicolas Island and Pt. Mugu are only marginally useful as their soundings are taken at irregular intervals making it nearly impossible to separate out synoptic induced trends and diurnal variations with mesoscale responses on the order of hours.

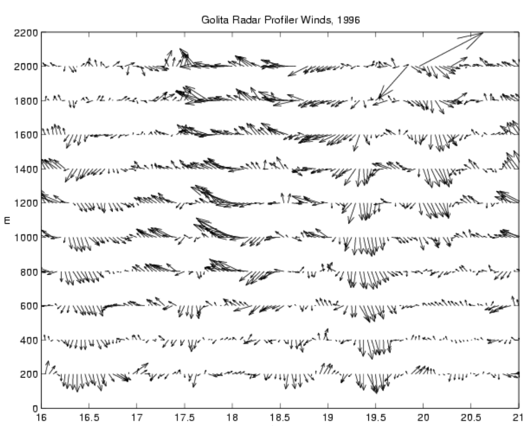


**Figure 2. Golita (Santa Barbara airport) radar profiler winds for June 1996.**

## 2. UPPER AIR OBSERVATIONS

First, we examine the Goleta radar profiler-measured flow above Santa Barbara, in the immediate lee of the Santa Ynez mountains, and directly downwind of the San Rafael mountain center. The hourly-averaged, winds at ~50 m intervals are further averaged here in 200 m intervals (Fig. 2). No evidence of significant, persistent, northerly cross-ridge flow above 800 m, nor responding northerly along-slope flow below 800 m, in duration or strength, is apparent on 16 - 18 June proceeding a Catalina eddy formed on the 18$^{th}$ – 19th. In fact, for the 16$^{th}$ – 18$^{th}$, above 800 m, flow is characterized as weak, with the dominant direction from the east (especially on the 17$^{th}$ and 18$^{th}$). Below 800 m, a modest northerly flow repeats on most non-eddy days near sunrise as a result of local thermal circulations, rather than any significant, cross-ridge, synoptic-scale forcing flow from above. Similar flow patterns are associated with most other 1996 Catalina Eddy events, which directly challenges the hypothesis that mountain lee-side effects are important for Catalina Eddy formation.

Convention requires the presentation of the unsuitable Vandenberg AFB RAOB data (Fig. 3). The most striking aspect is how poorly this station represents the flow over Santa Barbara, both above and below the Santa Ynez mountain Crest. For example, at 00 UTC on 18 June, flow at 800 – 2200 m at Santa Barbara (Goleta) is from the east, whereas at Vandenberg it is from a north or northwesterly direction.

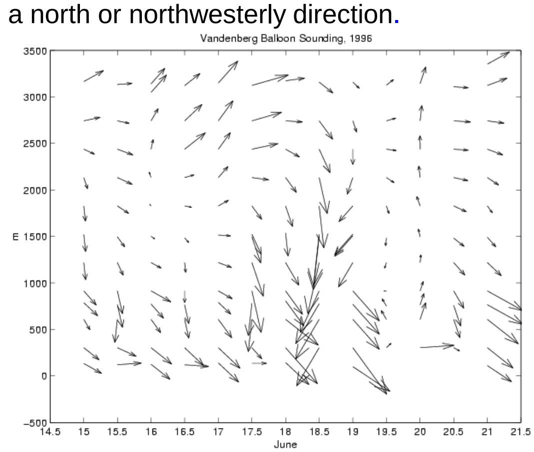


**Figure 3. Vandenberg RAOB sounding winds for June 1996.**

At the same time, below 800 m~~,~~ the winds are weak and easterly over Santa Barbara, and strong from the NW over Vandenberg. Considering that the Vandenberg station is located off the extreme western edge of the east-west Santa Ynez mountains, and thus directly exposed to the Central California along-coast marine layer flow, this disassociation between sounding locations is not surprising. As the sounding balloon ascends to above 2 km, it is carried mostly to the south and out of the lee of the higher Santa Ynez and San Rafael mountains (located respectively 20-50 km and 40- 80 km to the east). On the other hand, the Santa Barbara profiler lies dead in the lee for northerly flow formed by ~~of~~ the highest Santa Ynez and San Rafael mountains. In addition to the location problem, the Vandenberg RAOB badly aliases diurnal changes and trends over the scale of hours.

## 3. SURFACE STATIONS

To show the nature of the typical weak and along-coast winds, data from selected stations along the Santa Barbara coast ~~line~~ are presented, from the easternmost ~~third~~ (EMMA) to the westernmost (PCON) stations (Fig. 4). The winds are oriented with "up" being true north, posted in the upper left of each frame. Vectors point downwind. GODE to EMMA oscillate between weak offshore winds in the late morning, to on-shore winds in the afternoon. These stations switch irregularly to easterly winds, without any east-to-west order. Further, the easterly winds at these stations on the nights of the 18th – 19th June, in addition to being representative of the four preceding days, are typical of the summer (Dorman and Winant 2000). The only strong offshore wind is for two hours at the start of 18 June at GODE, located ~~that is~~ at the mouth of the Gaviota canyon/gap.

The lack of cross-ridge lee effects are confirmed by data from all available surface wind stations above 30 m elevation on the southern slope of the Santa Ynez mountains (Fig. 5). The highest station is NOJO, which at 305 m elevation is well above the average marine layer top. FLOR, located in a canyon at 189 m, is near the marine layer top, which is blown away by offshore lee flow of any consequence. Finally, GOLE is on the upper, north end of the Santa Barbara Coastal plane.

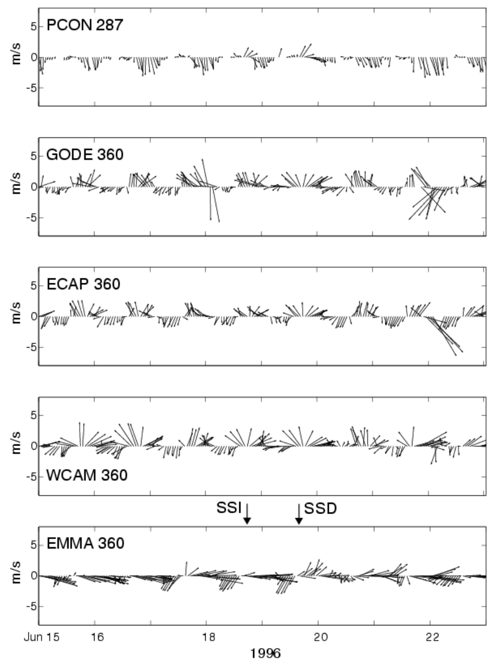


**Figure 4. Winds at stations along the Santa Barbara coast. The stations are oriented with "up" in the compass direction listed in the upper left of the frame. SSI and SSD are explained in the text.**

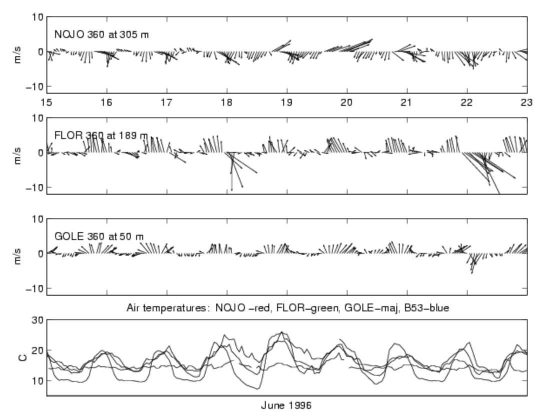


**Figure 5. Winds and air temperatures for elevated stations on the western slope of the Santa Ynez mountains. The elevation is posted in the left portion of the frame.**

Typical of summer conditions, all stations basically record weak diurnally reversing winds in the five days preceding the formation of a Catalina Eddy. The brief spike of down-canyon flow shown at FLOR is too short and not coincident with other stations to indicate a broad, down-slope flow. The increase in afternoon peak temperatures on the 17th - 19th is not correlated with increasing offshore winds, but rather is more consistent with weak, broad subsidence over Southern California.

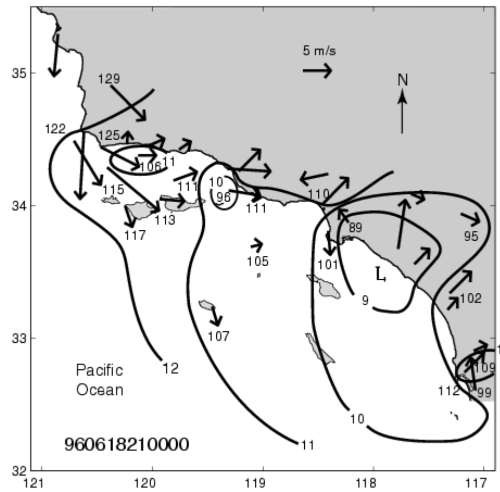


**Figure 6. Sea-level pressure analysis for 2100 UTC 18 June 1996. The deepest and largest low pressure is centered south of Los Angeles, well separated from the semi-permanent, weak low in the Santa Barbara Channel.**

## 4. SEA-LEVEL PRESSURE AND CLOUDS

Sea-level pressure analysis challenges the hypothesis that a lee-side low forms in the Santa Barbara Channel and moves to the south to become the center of the mature Catalina Eddy. Rather, it reveals a new feature, a large pressure minimum in the central and southern portion of the bight that is in place well before any stratus spreading and easterly wind surge occurs along the Santa Barbara Channel. At 2100 on18 June, an isolated low southeast of Los Angeles is coincident with the start of the extended period of southerly winds at San Diego (not shown). This east-side low is isolated from the Santa Barbara Channel semi-permanent low and cannot be associated with Santa Ynez/ San Rafael mountain lee effects.

Three hours later at 0000 UTC on 19 June (not shown), the low centered in the southeastern portion of the bight remains while a separate, isolated pressure low is in the Santa Barbara Channel. This former low covers a greater area and is separated from the Santa Barbara Channel low by a weak high pressure ridge supported by observations from Pt. Mugu, Gail platform, and the Channel Island stations. By 1500 UTC on 19 June (not shown), the east-side low expands westward to the west side of Buoy 25 (B25) to form the center of a mature Catalina Eddy.

There are two important components to this pressure and wind analysis. First, the increased observations around the Santa Barbara Channel clearly show no indication of the semi-permanent Santa Barbara Channel pressure minimum hypothesized to migrate to the central portion of the bight near B25 to form the core of the mature Catalina Eddy. Second, the new feature, an east-side Santa Ana low that forms and expands westward to eventually become the mature eddy center, was not observed in all earlier studies.

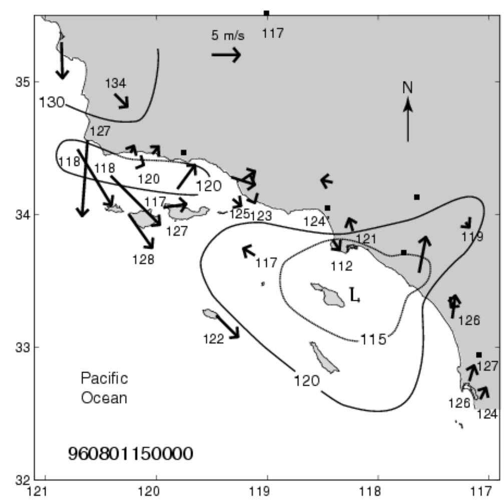


**Figure 7. Sea-level pressure analysis for 1500 UTC 1 August 1996. The deepest low is south of Los Angeles, well isolated from the Santa Barbara Channel.**

The appearance of the sea-level pressure low south of Los Angeles and the stationary aspect of the Santa Barbara Channel low prior to formation of a Catalina Eddy are repeatable. Another case is shown in Fig. 7 for a Catalina Eddy beginning about the same time. The stationary visual satellite image for this same event but about an hour later is shown in Fig. 8. This Eddy differs from the eddy beginning on 18/19 June in that the latter is entirely restricted to the Bight south of the Channel Islands, and does not have any easterly winds nor a west-bound surge in the Santa Barbara Channel.

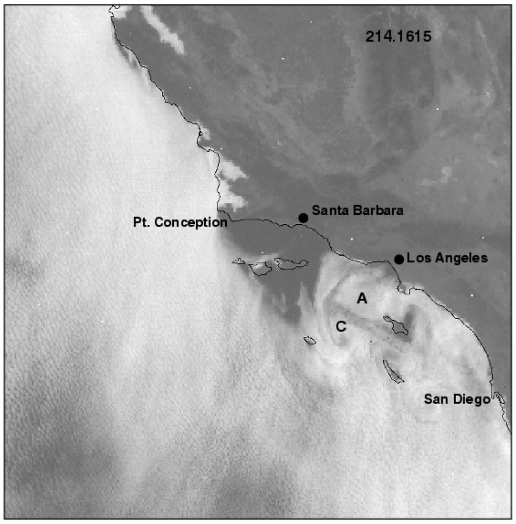


**Figure 8. Visual satellite image for 1615 UTC 1 August 1996. An eddy forms that is well removed from the Santa Barbara Channel.**

## 5. CONCLUSIONS

The greatly expanded surface data and radar profiler data available in the mid-1990's provide an opportunity to re-examine lee-side effects of the Santa Ynez/San Rafael mountains on the northern end of the Southern California Bight. Hourly-averaged radar profiler data at Santa Barbara in the center of the immediate Santa Ynez/San Rafael mountain lee fail to show anything that could be characterized as significant northerly, cross-ridge flow before or during a Catalina Eddy or on most other summer days. Rather, this radar profiler data show weak winds from other directions, which indicates that results from Vandenberg AFB RAOB are completely unrepresentative this site. This conclusion directly conflicts with earlier analysis and numerical models that attribute formation of a Catalina Eddy to a prolonged, northerly flow over the Santa Ynez mountain crest.

An expanded set of hourly automated surface stations on the lee Santa Ynez mountain slope, the Santa Barbara Coast, weather buoys, and the Channel Islands also show that significant northerly, down-slope, cross-coast flow is rare. Moreover, no such flow occurred before or during any of the Catalina Eddies identified in 1996.

This contradicts previous publications that did not take advantage of this data set.

The expanded surface network in the greater Santa Barbara Channel area with others in the Southern California Bight confirm the existence of a semi-permanent, low pressure area in the Channel. The collective stations in the Southern California Bight reveal a previously undisclosed low forming on the east side of the Bight, south of Los Angeles, during the initiation of Catalina Eddies. This low expands westward to become the center of the mature Eddy. No evidence is found to support the former theory that a special, leeward low forms in the Santa Barbara Channel, then moves south to become the center of a Catalina Eddy.

## 6. REFERENCES

Bosart, L.F., 1983: Analysis of a California Catalina eddy event. *Mon. Wea. Rev.*, **111**, 1619-1633.

Davis, C., S. Low-Nam, and C. Mass, 2000: Dynamics of a Catalina Eddy Revealed by Numerical Simulation. *Mon. Wea. Rev.*, **128**, 2885-2904.

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

Mass, C.F. and M.D. Albright, 1989: Origin of the Catalina Eddy, *Mon. Wea. Rev*., **117**, 2406-2436.

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

Thompson, W. T., S. D. Burk, and J. Rosenthal, 1997: An Investigation of the Catalina Eddy. *Mon. Wea. Rev.*, **125**, 1135-1146.

Ueyoshi, K. and J.O. Roads, 1993: Simulation and Prediction of the Catalina Eddy. *Mon. Wea. Rev.*, **123**, 2975-3000.

Ulrickson, B. L., J.S. Hoffmaster, J. Robinson and D. Vimont, 1995: A Numerical Modeling Study of the Catalina Eddy. *Mon. Wea. Rev.*, **123**, 1364-1373.