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DOWNSLOPE WINDS OF SANTA BARBARA, CALIFORNIA

Gary Ryan
NEXRAD Weather Service Forecast Office
Oxnard, California

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ESSA Technical Memoranda, Weather Bureau Technical Memoranda (WBTM)

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125 Statistical Guidance on the Prediction of Eastern North Pacific Tropical Cyclone Motion - Part II. Preston W. Leftwich and Charles J. Neumann, August 1977. (PB 273 155/AS)
126 Climate of San Francisco. E. Jan Null, February 1978. Revised by George T. Pericht, April 1988. (PB88 208624/AS)
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DOWNSLOPE WINDS OF SANTA BARBARA, CALIFORNIA

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ABSTRACT

Warming, downslope winds from the Santa Ynez Mountains in Southern California can translate to gusty surface winds in the vicinity of Santa Barbara. These winds, called "sundowners," have many of the same characteristics common to downslope winds found elsewhere in the world. Sundowners can be strong enough to cause considerable damage and are sometimes accompanied by very high temperatures. This study provides historical information from several severe sundowner events which affected the Santa Barbara area--including accounts of the incidents of 1859, 1917, and 1990--and addresses public safety concerns relative to these episodes. The paper also discusses the dynamics of downslope winds, establishes a categorical rating for sundowner episodes, and offers empirical rules for identifying and forecasting the sundowner regime.

I. INTRODUCTION

Approximately 150 kilometers northwest of Los Angeles, along the Pacific coast and beneath the ridges and canyons of the Santa Ynez Mountains, lies the city of Santa Barbara (1993 population 87,500). Due to the proximity of the mountains, this area occasionally experiences warm, downslope winds--known locally as "sundowners."

Sundowners, while similar in some respects, are independent of Santa Ana winds and much smaller in scale. Sundowners receive their name from the wind's predominant time of occurrence--the late afternoon and evening hours. The exact origin of the term "sundowner" is unknown; but the name dates from about the middle of the 20th century. Bosart (1983) and Clark and Dembek (1991), in their studies of the Catalina Eddy, noted afternoon downslope winds along the southern slopes of the Santa Ynez Mountains accompanied by extremely hot temperatures at Santa Barbara (>104°F).

Sundowners, like most downslope winds, vary in duration and intensity. Light sundowners cause irregular rises in temperature and accompanying gentle offshore breezes at Santa Barbara. Strong sundowners, occurring two or three times a year, coincide with sharp rises in temperature and local gale force winds which can cause damage to structures or vehicles. On rare occasions, about once every five or ten years, a severe sundowner develops producing hot, damaging winds along the south side of the Santa Ynez Mountains and the adjacent littoral.

Urban wildfires, fanned by the high winds, pose the most significant hazard associated with strong to severe sundowner windstorms. In the past two decades, four major wildfires have occurred during such sundowner episodes. The most recent and damaging of these events, the Painted Cave Fire, occurred on June 27, 1990, burning 4900 acres and destroying over 500 structures. The fire raced along the western periphery of the city of Santa Barbara, spread by winds gusting to over 60 mph (27 m/s).

This paper discusses the sundowner wind phenomenon, establishes a categorical rating, and offers empirical rules for identifying and forecasting sundowner wind events. While this study is limited to downslope winds in the vicinity of Santa Barbara, it may have applications elsewhere along the south-facing coast of Santa Barbara County.

II. SECTION ONE

A. SANTA BARBARA SUNDOWNERS, A HISTORICAL PERSPECTIVE

Historically, severe sundowner windstorms have occurred only occasionally in the Santa Barbara area. A survey of these events is important for understanding their threat to public safety.

The following is a chronological listing of the most notable severe sundowner events which have occurred since 1850, the year Santa Barbara came under United States authority. The apparent increased frequency of these events in the late twentieth century is likely due to improved observing and reporting techniques, rather than to any climatological change. The criteria for a "severe" event is discussed elsewhere in this paper:

1. June 17, 1859
2. September 21-24 1885 (wildfire at Mission Creek)
3. July 27, 1889
4. July 2-3, 1907
5. June 15-17, 1917 (numerous wildfires)
6. July 12-13, 1925 (wildfire near city)
7. July 29, 1930
8. June 30-July 1, 1937
9. September 22, 1964 (Coyote Fire)
10. July 25-26, 1977 (Sycamore Fire)
11. July 15, 1978
12. September 18, 1979 (Eagle Canyon Fire)
13. August 30, 1984
14. July 2, 1985 (Wheeler Fire)
15. June 25-27, 1990 (Painted Cave Fire)

June 17, 1859

Historical texts describe a phenomenal sundowner which struck the city of Santa Barbara on Friday, June 17, 1859. Contemporary accounts termed the downslope windstorm a "simoom" or "simoon"-- from the Arabic "samum" which means a "hot and violent dust-laden desert wind." During this event, very hot north to northwest winds caused a hellish duststorm that frightened the inhabitants of the city. There are two accounts of this windstorm. George Davidson, an assistant in the U.S. Coast Survey in California, wrote an account of the sundowner which was published in the Coast Pilot in 1869:

THE SIMOOM

The only instance of the simoom on this coast, mentioned either in its history or traditions, was that occurring at Santa Barbara, on Friday, the 17th of June, 1859. The temperature during the morning was between 75° and 80°, and gradually and regularly increased until about one o'clock p.m., when a blast of hot air from the northwest swept suddenly over the town and struck the inhabitants with terror. It was quickly followed by others. At two o'clock the thermometer exposed to the air rose to 133°, and continued at or near that point for nearly three hours, whilst the burning wind raised dense clouds of impalpable dust. No human being could withstand the heat. All betook themselves to their dwellings and carefully closed every door and window. The thick adobe walls would have required days to have become warmed, and were consequently an admirable protection. Calves, rabbits, birds, &c., were killed; trees were blighted; fruit was blasted and fell to the ground, burned only on one side; and gardens were ruined. At five o'clock the thermometer fell to 122°, and at seven it stood at 77°. A fisherman, in the channel in an open boat, came back with his arms badly blistered.

Davidson's secondary account of the 1859 simoom was embellished by a local historian, Walker A. Tompkins, in his book Goleta, the Good Land (1962). It was Tompkins who placed a U.S. Coast Survey ship in Santa Barbara Channel to document what he claimed was a record high temperature for the United States. His other liberties with the Davidson account cast doubt on this claimed record.

Fortunately, another account of the 1859 windstorm was preserved by the Santa Barbara Morning Press, in 1907, when it quoted an 1876 volume on The History and Resources of Santa Barbara:

On the 17th day of June, 1859, a hot wind, like a sirocco, visited the city of Santa Barbara. The wind was from the northwest and blew furiously, with a dense cloud of dust. The temperature rose to 136 Fahrenheit's scale. It commenced blowing about noon and continued until about half past three in the afternoon. Birds, rabbits, and tender lambs were killed; the leaves on the side toward the wind were scorched and died, and some fruit was blasted.

Although there is little doubt that a severe downslope wind and dust storm occurred in Santa Barbara on June 17, 1859, the reported temperature reading of 136°F (57.8°C) is highly suspect. If true, that reading would tie the record high temperature for the Earth set in Libya in 1922.

While the two accounts are fairly consistent, and ambient surface temperatures in the 130s are theoretically possible within the sundowner regime, another explanation for the reported record-setting temperature is more likely. At the time of these accounts, thermometers were not always shaded from the sun. Significantly, in the Davidson account, the phrase "thermometer exposed to the air" could refer to a thermometer hanging in direct sunlight. Then again, wind-blown dust--mentioned in all accounts--may have obscured the sky during that afternoon. Thus, an "exposed" thermometer might not have been exposed to full direct sunlight.

Weather observation techniques were not standardized by the United States government until about 1870, and official temperature records were not taken at Santa Barbara until 1883. Since then, the official maximum recorded temperature at Santa Barbara has been 115°F. The reported temperatures of 136°F and 133°F, contained in the 1859 accounts, are well above the records within the official Santa Barbara climatological record. Therefore, the alleged 1859 maximum temperatures are very likely inaccurate and should not be considered official.

September 21-24 1885

Three days of hot downslope winds culminated on September 24th when the temperature peaked at 108° at 4 pm. By 8 pm, it was still 102°. A fire which had started on the north side of the Santa Ynez Mountain ridge line was carried rapidly from the ridge crest into the Mission Creek district of Santa Barbara. The Santa Barbara Morning Press reported that

No Fourth of July celebration could compare with this. The fire came down the mountainside with the speed of a horse; and soon the mountain seemed a vast furnace painting the heavens with its lurid crimson hues... The awful roar of the voracious element, plainly heard a distance of five miles, the sheet of flames sweeping along the mountainside and leaping high into the air, the immense volumes of black smoke rolling skyward, rendered the scene grand and appalling.

July 2-3, 1907

The Santa Barbara Morning Press reported that the city temperature was 88° at midnight. It noted that the sundowner wind within the city "came in hot puffs and gusts from all directions." It added:

The only time Santa Barbara has suffered any such visitation is when the Santa Ynez Mountains are aflame with forest fires. Colonel Slosson reported last night that the ranges were free from fire, so other causes must be responsible for the excessive heat wave.

New weather observer George W. Russell recorded a high temperature of 108° on July 3rd, which still stands as the all-time record high temperature for the month of July for the city of Santa Barbara.

June 15-17, 1917

The most severe downslope wind episode to occur thus far in the twentieth century struck Santa Barbara on Saturday night and Sunday, June 16-17, 1917. Fires burned throughout the district, whipped by the strong winds. The situation was especially critical at nearby Carpinteria, where residents carried their belongings to the beaches to avoid an advancing canyon fire. In Santa Barbara, strong winds created a duststorm "such as had never been known in this city before." (Fig. 2) The winds blew at gale force from 6 pm Saturday until 2 am on Sunday, and later on Sunday from 2 pm to 10 pm. On Sunday afternoon, June 17th, the official temperature at Santa Barbara reached its all-time modern record (since 1883) of 115°, as the four-day heat wave peaked. Cooperative weather observer George W. Russell entered the following remarks on the official record (Fig. 3):

The hottest day ever recorded on the 17th. A hot wind during night 16th with velocity of 35 to 45 miles per hour, *damaged fruit and other trees. Nuts are damaged, beans seem to have escaped.*

July 12-14, 1925
At 10:45 pm on July 12th, gale force winds swept down from Mission Ridge into the city of Santa Barbara. A fire started and spread quickly toward the city. The fire was suppressed by a company of Marines, on duty at Santa Barbara after an earthquake which had occurred a few days earlier. Reliable estimates placed wind speeds at 40 to 60 mph, and accompanying temperatures were measured in excess of 100°. According to the Santa Barbara Morning Press:

It was the first time in many years, old residents said, that a wind had blown from that direction. It was what old residents call "a Santa Ana" and blew hot off the desert beyond the mountains almost all day... The heavy windstorm damaged many trees in the city, tearing down a few eucalyptus...and splitting limbs off in all sections of the city.

July 29, 1930
Official cooperative weather observer Ella M. Russell logged high temperatures of 100° on July 29th and 30th in the Oak Park section of Santa Barbara. She wrote that there had been a "very strong north wind on the 29th from 3 a.m. until midnight."

June 30-July 1, 1937
The high temperature on June 30 reached 101° between 4:00 and 4:30 pm. On July 1 the maximum temperature reached 108° at 2 pm and was accompanied by a "firey [sic] northeast wind."

July 26, 1977
Downslope winds began about 7:30 pm and reached storm force (55 mph) by 8:20 pm. Reported winds of 60 to 70 mph were accompanied by temperatures in excess of 100°. In the event, a young man was flying a four-foot kite in a canyon above Santa Barbara when the kite got tangled in power lines, causing a shower of sparks. This initiated a fierce wind-driven fire which raced down Sycamore Canyon into Santa Barbara and Montecito, destroying 195 homes within eight hours.

July 15, 1978
Temperatures at Santa Barbara and Montecito reached 106 degrees with a relative humidity of 24 percent. In the foothills, upper Mission Canyon reported 100° and San Roque Canyon 102°. Santa Barbara Harbor noted offshore winds gusting to 30 knots between 4:00 and 6:00 pm. The California Highway Patrol reported that a large cabover camper overturned on Highway 101 at Gaviota.

September 18, 1979
Downslope canyon winds of 40 mph, accompanied by temperatures of more than 100°, pushed a major brush fire from Eagle Canyon southward across the 101 Freeway almost to the ocean. Eagle Canyon is located just west of Santa Barbara.

August 30, 1984
The FAA reported a maximum temperature of 101° (a record for that date) at Santa Barbara Airport. The following notation was made in a log of recent sundowner activity. The log was kept by Santa Barbara meteorologist Chris Crabtree:

Late am NW-N/25+ in Goleta. Temperatures above 100° at Santa Barbara. Point Conception NW 60. Due to passing short wave kicked out of cutoff low offshore. SMX-SBA 6 mb!, 5 mb at 2000.

This pressure gradient entry is significant in the context of sundowner research conducted since 1950 and noted within this paper.

June 27, 1990

A three-day heat wave at Santa Barbara culminated on Wednesday, June 27th, with an epic sundowner windstorm. Meteorological parameters from that day have been well-documented relative to previous severe sundowner events.

Temperatures at Santa Barbara reached the 90s by mid-morning, and peaked at 109° at Santa Barbara Airport at 1:30 pm PDT. Maximum reported temperatures along the Santa Barbara coastal strip ranged from 103° at the El Estero Water Treatment Plant near lower State Street in Santa Barbara to 116° at El Capitan Beach 11 miles west of Santa Barbara Airport. Ambient temperatures near the fire along Old San Marcos Road were estimated to have been nearly 150°F (Ford, 1991 and Lebonville, personal communication, 1994).

Winds at 5,000 feet over Santa Barbara were from the north-northwest at about 23 mph. At normally windy Point Conception, surface winds were northwest up to 53 mph and temperatures were in the upper 50s. At the summit of San Marcos Pass, where temperatures remained in the 80s throughout the sundowner event, winds were also from the northwest at 10 to 20 mph. However, on the south side of San Marcos Pass, downslope winds were strong and erratic. At La Cumbre and State Streets in Santa Barbara, winds gusted to 60 mph; while at Santa Barbara Airport, the winds peaked at only 30 mph at 3:48 pm PDT. The strongest winds were reported near Tucker's Grove, at the base of Old San Marcos Road, where wind speeds reached 80 mph.

A description of the Painted Cave Fire and associated meteorological conditions is contained in the following section.

B. PUBLIC SAFETY, WILDFIRES, AND PAINTED CAVE.

Downslope windstorms in the Santa Barbara area pose a serious hazard to public safety on at least two fronts: increased fire danger and a potential threat to ground and air transportation. Since 1950, five of seven severe downslope windstorms have fanned wildfires in the immediate vicinity of the city of Santa Barbara. These sometimes tragic and invariably expensive fires resulted in significant disruption to normal activity and commerce in the area. Other areas of concern, including public health, agriculture, and marine, are significant but beyond the scope of this study.

The fire danger associated with downslope wind events is well documented. While all wildfires in the vicinity of Santa Barbara are not driven by sundowner winds---for example, the Refugio Fire of 1955---most major fires affecting the Santa Barbara area appear to be spread by downslope wind conditions.

Historical evidence indicates that fires have periodically burned over the Santa Barbara district for a very long time. Layers of graded silt in the channel near Santa Barbara contain charcoal from wildfires that occurred two million years ago (Gomes, 1993). Core samples taken from the channel indicate that large wildfires, presumably lightning-caused, occurred in the district on an average of once every 66 years (Ford, 1991). With the coming of man, fire became an even more frequent intruder. Wildland burning was a frequent practice of the Chumash Indians, whose pre-European settlement of Syukhtun stretched from Goleta to Carpinteria. Ford quotes an early Spanish governor at Santa Barbara, Jose Joaquin de Arrillaga, who forbade the practice of setting wildland fires in 1793:

With attention to the widespread damage which results to the public from the burning of fields, customary up to now along both Christian and Gentile Indians in this country, whose childishness has been unduly tolerated, and as a consequence of various complaints that I have had of such abuse, I see myself required to have the foresight to prohibit for the future...all kinds of burning, not only in the vicinity of towns but even at the most remote distances...

Fire suppression efforts have intensified during the past 200 years, coincident with large increases in urban and suburban populations. Ford points out that...

After almost two hundred years of efforts to the contrary, the policy of excluding fire from the hills has done the opposite of what has been desired; there are far fewer small fires, but those which do occur burn even larger, and are more destructive than those which once occurred in prehistoric times.

Fires associated with downslope wind episodes pose a unique danger for fire fighters. According to Fritz Cahill, former U.S. Forest Service Fuels Officer for the Los Padres National Forest, the problem with sundowner-generated fires is that they run downhill, not uphill like normal fires. Therefore, they can catch even a veteran fire fighter off guard.

The June 27, 1990 fire, called "Painted Cave" after a prehistoric Native American landmark near the fire's origin, was the worst of all the sundowner blazes. This arson-caused disaster was the focus of considerable national media attention. The Forest Service had issued a "Red Flag Alert" for extreme fire danger on June 27th, which was the third day of downslope wind conditions in Santa Barbara. Fire protection crews, patrolling the entire district, spotted the first smoke early after ignition, at 6:02 pm PDT. The origin of the fire was at the intersection of Old San Marcos Road and Highway 154. The ambient temperature at the fire's point of origin was 96°, with relative humidity at 10% and winds from the northwest at 12 to 20 mph (Gomes).

The fire gathered momentum quickly in the steeply sloped (40-60%) terrain. The foliage, consisting mostly of dense, oily chaparral, had not burned since the 1890s. The flame front climbed 40 to 70 feet high and temperatures in the vicinity of the front were estimated to have reached 3000°F. By 6:45 pm, the fire front had already advanced two miles from the point of origin. Downslope winds increased to about 60 mph, pushing the wall of flame downhill more rapidly. Due to severe turbulence over the fire caused by the high winds and thermals, air tanker support for fire suppression was not available until after 7:00 pm.

Before the fire was extinguished, it had taken one life and consumed over 4900 acres. It stretched over five miles from San Marcos Pass across State Street at the edge of Santa Barbara and across the 101 Freeway, a 340 foot wide man-made firebreak. In doing so, it completely cut off transportation through the district. Property losses were extensive with over 500 structures destroyed, valued at $290 million. Videotape from the fire showed ash falling on Old San Marcos Road like some bizarre June snowfall.

As bad as the Painted Cave fire was in terms of destructiveness, it came very close to being a lot worse. Stan Dumas, Assistant Fire Chief for the City of Santa Barbara, recalled that the fire raced to State Street and burned to within yards of a commercial chlorine supply tank containing up to 5000 gallons of the chemical. Fourteen heroic fire fighters kept the tank from exploding. Dumas said that the chlorine... "would have gone through [the] Hope Ranch [district]. It would have been a real killer."

Santa Barbara area resident Jay Lebonville, a National Weather Service storm spotter, described (personal communication, 1994) the winds during the Painted Cave Fire in his report of the event:

You could see the smoke was coming down the hill and it was actually dropping in elevation before heading out to sea and rising as it left the coast. The winds were gusty and would go in different directions, but they predominantly traveled southeast, which is downhill, and once they got down to the [coastal strip] they tended to fan out a little bit, but generally they continued to travel in a south-easterly direction. The smoke was an excellent indicator of airflow around the fire.

The winds are one of the major problems during a fire as they blow whole burning branches and large flaming embers around and the fire spreads very rapidly. The fire burns so intense and so hot that it sucks the oxygen away and pulls more air towards it... [the] heat tends to dry everything out in front of the fire so things literally explode; buildings, trees, cars, anything can explode into flames...

At one point during the firestorm, Jay Lebonville climbed up onto his friend's roof with a garden hose, in an unsuccessful attempt to save the house:

At times gusts in excess of fifty miles per hour would push us over [when we were] on the roof, our footing became hard to keep. I continued to spray the roof, ourselves and a nearby hedge with water while my friend's family tried to get as much as they could out of the house...[Fig. 4]

Even without a fire, strong downslope winds associated with sundowners can greatly impact local transportation due to the high velocities attained. Trucks, vans, and other high profile vehicles may be affected by high winds along Highway 154 south of San Marcos Pass and on some sections of the 101 Freeway near Santa Barbara. The California Highway Patrol frequently issues a "high wind warning" for the areas affected, based on an officer's subjective report of an occurrence already in progress.

Downslope winds are of great concern to aviation interests in Santa Barbara. The Santa Barbara FAA Flight Service Station documented three aircraft mishaps at or near the Santa Barbara Airport during sundowner activity occurring between 1985 and 1991. Pilots flying into the area during episodes of downslope winds must be aware of the low-level wind shear hazard and strong downdrafts which can occur on the lee side of the Santa Ynez Mountains.

One veteran Santa Maria pilot, who has flown the Santa Maria to Santa Barbara route during several sundowner events, described the flights as being "scary." Flying over the Santa Ynez Mountain ridge line and descending to around 5000 feet, the aircraft can be forced downward within the downslope wind regime. The aircraft is virtually out of control until stabilization can be attained, generally about 500 feet over the Santa Barbara runway complex.

During sundowner wind occurrences, low-level wind shear poses a significant hazard; runway winds vary rapidly in both speed and direction. During one recent episode, the FAA at Santa Barbara Airport issued several "urgent" pilot reports when local air traffic reported severe updrafts and downdrafts.

III. SECTION TWO - DOWNSLOPE WIND MECHANISMS

This section reviews some basic theories regarding the mechanics of downslope winds in general, and warming (foehn) winds in particular. The reader may find this review to be helpful before considering specific analyses of occurrences of Santa Barbara's sundowner winds.

There has been a considerable amount of scientific research into downslope wind phenomena, dating back to at least 1885. Modern theories advanced since World War II have been amplified by atmospheric modeling and complex computer techniques. A few standard sources are listed in the "references" section of this report, and an excellent overview was presented by Keith Meier (1994) in a National Weather Service publication.

To a considerable extent, investigations into fluid dynamics have been vigorously adapted by meteorologists to explain downslope wind mechanics. Jakob Bernoulli's equation relating fluid pressures and velocities has been used in discussions of wind channeling through topographic gaps and canyons. But the "Bernoulli effect" is not a predictor: the equation can't be used to model flow through a hydraulic jump.

Hydraulic flow models used in fluid dynamics to describe open channel flow over a barrier were adapted by Long (1953) in a mainly successful application to atmospheric criteria. Horel (1992) states that recent investigation indicates that much of observed downslope wind phenomena can be explained by utilizing the "hydraulic jump" concept. This conclusion is supported by Jim Goodridge, an engineer and former California state climatologist, who has intensively studied downslope wind events (personal communication, 1994).

Long's hydraulic flow model described the movement of a fluid streaming over the top of a barrier, regarding velocities, layer thicknesses (in a two-layer model), and the formation of a breaking wave or "jump" on the lee side of the barrier. The efficacy of Long's work was in its hardware modeling and in its linear equation work, which factored out small perturbations within the flow.

Hydraulic jump representations employed the use of the Froude number (Fr), named for British naval architect William Froude. Fr expresses the ratio between gravitational and inertial forces, and serves as a flow indicator. Specifically, Fr describes the nature of the flow (subcritical or supercritical), thus indicating whether wave propagation can progress upstream, and marking the location of the breaking regime (at Fr=1). Channel or terrain slope is an important consideration here, since gravity may accelerate the flow to supercritical values. "Hydraulic jump" may be satisfactory for modeling the majority of parameters in downslope wind events; however, the atmosphere cannot be approximated in a free-surface or rigid form where no energy can be transported vertically through the upper boundary of the model. Contrary to hydraulic jump theory, in the atmosphere waves can propagate vertically as well as horizontally. In severe downslope wind episodes, vertical wave propagation might be a critical element.

Although different theoretically, two classic studies have underlined the importance of vertical wave propagation in downslope wind occurrences. The analyses of Klemp and Lilly (1975) and Clark and Peltier (1977) agree that the entire troposphere can become involved in wave and energy transport. These authors did not discard hydraulic jump theory; however, they believed that hydraulic jump models were incomplete and that the results may be misleading.

Klemp and Lilly argued the importance of strong static stability layers to reflect energy. They concluded that when a low-level, stable layer and the less stable layer above have optimum thicknesses, reflectivity in the lower atmosphere can produce mountain wave regimes to heights of several kilometers. The authors devised a scheme to estimate maximum perturbation surface velocities, based upon the height of the inversion layer.

Clark and Peltier described upward propagating gravity waves, which "break" and create what they termed a "wave-induced critical level." This level, characterized by wind reversal and significant mixing, reflects large amplitude waves back toward the surface.

Investigations are ongoing with respect to the vertically propagating mountain wave. Wurtele (personal communication, 1993) underlined the uncertainty inherent in current understanding of mountain wave processes:

Studies of the critical layer have for the most part been limited to the impact of a single monochromatic wave, and when the disturbance is forced over a continuous spectrum, the question is still pretty much open. Clark, Peltier, and Co. have speculated on the result when the wind reversal is in the stratosphere, that is, when the disturbance is forced upward through a troposphere with increasing wind. They suggest some sort of *resonance, but their results are not at all complete or conclusive.*

Due to changing system dynamics and complex terrain, downslope wind episodes simultaneously combine the characteristics of Bernoulli effect, hydraulic jump, and vertically propagating mountain waves. Hence, the difficulty in creating one satisfactory model of a downslope wind occurrence. The accurate forecast of downslope wind parameters, such as timing, period, intensity, and focus, is not presently possible. Projecting wave celerity within a vertically propagating regime is especially difficult. It is no wonder that downslope wind profiles and associated mesoscale patterns are largely inscrutable, especially given the rapidity with which the dynamics can change.

While the precise forecasting of downslope wind parameters remains elusive, there are specific features that can be used successfully to predict the development of mesoscale downslope wind events. Durran (1986) lists three conditions set by Queney in 1960 in which strong lee waves are likely to occur:

(1) The mountain barrier in question has a steep lee slope.
(2) The wind is directed across the mountain (roughly within 30° of perpendicular to the ridge line)...and [the wind] should increase with height.
(3) The upstream temperature profile exhibits an inversion or a layer of strong stability near mountain top height, with weaker stability at higher levels.

Horel, Wurtele and others have suggested that a reversal of zonal flow above the ridge line crest can be a primary factor, both theoretically and practically, in the initialization of strong downslope windstorms.

Yet another, perhaps more obvious, condition for downslope wind generation is noted by Durran. He states that the synoptic-scale pressure gradient is important in that

...mountain waves generate a mesoscale pressure distribution with high pressure upstream of the crest and low pressure in the lee. Strong downslope winds are more likely to develop when the synoptic-scale pressure gradient is in phase with the wave-induced pressure gradient.

A basic understanding of some principles of flow dynamics and a consideration of atmospheric factors as outlined above, provide a good backdrop for an analysis of Santa Barbara's sundowner winds.

IV. SECTION THREE - INVESTIGATION OF SANTA BARBARA DOWNSLOPE WINDS

A. PHYSICAL GEOGRAPHY

Santa Barbara County is located on the south central coast of California, approximately 35°N 120°W. To the north of the county lies the broad, flat and (in the summertime) hot San Joaquin Basin, including the city of Bakersfield. Within Santa Barbara County, which extends 43 miles north from the city of Santa Barbara, the terrain is rugged and mountainous (Figs. 5 and 6). Much of the county is under the administration of the

U.S. Forest Service's Los Padres National Forest.

The Santa Ynez Mountain ridge, with elevations from about 2000 feet to 4298 feet, is oriented east to west along the south-facing coast of Santa Barbara County. The 40-mile long ridge line is notched with four significant openings: Nojoqui (pronounced nah-HO-wee) Pass at 925 feet; Refugio Pass at 2254 feet; San Marcos Pass at 2224 feet, and Romero Saddle at 3025 feet. The ridge line extends to within six miles of the city of Santa Barbara, with canyons and foothills stretching to within the city limits.

Directly to the north of the Santa Ynez Mountains lies the Santa Ynez River Valley. The intermittent Santa Ynez River drains the valley from above Gibraltar Reservoir (1326 feet) to Bradbury Dam at Lake Cachuma (751 feet) to the ocean via Lompoc and Vandenberg AFB.

The city of Santa Barbara is built on a narrow, one-to-five mile wide coastal plain which rises precipitously to the ridge crest of the Santa Ynez Mountains. From the city, the Santa Ynez Range appears as a sharp and looming escarpment with restricted access. The most visible and significant indentation in the mountain ridge line as viewed from the Santa Barbara area is San Marcos Pass, six miles northwest of the city. A heavily traveled scenic highway, California Route 154, snakes from the 101 Freeway near Santa Barbara across the ridge line at San Marcos Pass. Directly below San Marcos Pass, and opening toward the west side of Santa Barbara, is a steep-walled chasm, Maria Ygnacia Canyon, which focuses and channels downslope winds onto the coastal strip (Figs. 7, 7a). Other canyons which can be significant channelers of downslope winds into the proximity of Santa Barbara include Winchester, Glen Annie, Barger, Mission, Rattlesnake, and Sycamore.

B. STUDY METHOD, DATA ANALYSIS AND REDUCTION.

The results obtained in this study are based on an examination of 31 significant warming events (SWE) at Santa Barbara in the years 1985 to 1991, inclusive. SWEs are not defined by a specific temperature, but rather by a significant anomalous departure from seasonal norms. For example, 81 degrees would be classified as anomalous or significant warming in February, but not in July. Therefore, SWEs can occur in all seasons. More importantly, some SWEs were "sundowner" events and some were not.

Climatological data from several stations were utilized in this analysis. In the Santa Barbara area, hourly and special observations from the Santa Barbara Airport (SBA) FAA/Flight Service Station (No. 04-7905) were compiled for the 70 month period between April 1985 and January 1991. Coincident records were obtained from the Santa Barbara Cooperative Weather Station (No. 04-7902) at El Estero Waste Treatment Plant. Official weather observations at the Santa Barbara Harbormaster office and at City Fire Station No. 5 were also reviewed.

Three-hourly surface observations from SBA were employed in surface pressure gradient analysis. Sea level pressure gradients were computed from Santa Maria Airport (SMX) to SBA, and from

Bakersfield (BFL) to SBA. BFL data were not available for 2200 PST, therefore 2100 PST data were substituted. All SLP data are listed in tenths of millibars with the decimal point omitted. SLP data are normally temperature compensated, but may not be so adjusted in all cases. This should not significantly impact the integrity of the database.

Rawinsonde data were selected from 1200 GMT (0400 PST) soundings (unless otherwise noted) taken at Vandenberg AFB (VBG) and from the Naval Station at Point Mugu (NTD). The city of Santa Barbara lies almost exactly halfway between these upper air sounding points. Temperature and wind data were compared for the 850 and 700 mb levels and winds were profiled from 1000 feet to the 500mb level.

Other temperature and weather records were reviewed: From Santa Ynez Airport (IZA), from El Capitan State Park, the Harvest Oil Platform at Point Conception and from the dam tender's weather log at Bradbury Dam (Lake Cachuma). Forest Service observation records were obtained from Los Prietos Ranger Station in the upper Santa Ynez Valley. In addition, as noted in the acknowledgment section, several private citizen weather observers made their weather records and notes available to the author.

Data for each SWE were analyzed and classified based on criteria developed by the author and specified in Table I. Of the 31 SWEs, ten events showed no sign of downslope wind activity (Category 0), five events manifested weak downslope regimes (Category 1), fourteen were coincident with moderate or strong downslope winds (Category 2) and two were classified as severe downslope windstorms (Category 3).

Mean statistical data are presented in tabular form for each of the four SWE categories in Tables II through V. Standard deviations (S) were computed for the SLP gradient field. Figures for combined means of all SWE categories are given in Table VI.

C. DISCUSSION

1. Non-Sundowner Warming.

Ten of the subject SWEs showed no evidence of downslope wind and were used as a control group within the study. For these Category 0 events, diurnal temperature curves were normal with temperature maxima at approximately 1300 PST. In most cases, this strong warming could be ascribed to a large ridge dominating the area. The warm air is sometimes connected to Santa Ana conditions developing over Ventura and Los Angeles counties. This situation typically manifests itself in light easterly or variable winds up to 18000 feet at both VBG and NTD. Surface winds at Santa Barbara are light from the south to southwest and absolute SLP values are notably higher than during downslope wind episodes.

Temperatures at Santa Barbara can exceed 104°F in Category 0 events. The boundary between the relatively hot air over the littoral and the marine air over Santa Barbara Channel can be sharp and active. Associated low-level wind shears and air density changes are hazardous to aviation, sometimes contributing to air traffic control problems at Santa Barbara Airport--located immediately adjacent to the ocean at Goleta.

2. Sundowner Wind Circulation.

Downslope and offshore wind mechanisms that cause warming at Santa Barbara are very similar to those that cause the larger scale Santa Ana winds near Los Angeles, and the smaller scale warming winds at Avila Beach, near San Luis Obispo. Sundowner winds seem to be a combination of hydraulic jump and mountain wave regime, with an observable Bernoulli effect. Light to moderate sundowners appear to have characteristics of a relatively simple low-level gradient wind, while strong or severe sundowners combine the full force of vertically propagating mountain waves.

All categories of Santa Barbara sundowner winds are generated in similar fashion. A positive north to south sea level pressure (SLP) gradient is a prerequisite for their development. These gradients are typically established by cool air advection into the district from the north. The influx of cool air may be signaled by a synoptic scale cold front or short wave passage, or it may be seen in the subtle ridging between the surface and 700 mb levels within a relatively warm air mass. In either case, a stable layer with a strong, surface-based inversion is established to the north of the Santa Ynez ridge line. Heights of this inversion layer typically extend to between 2000 and 4000 feet MSL.

The north to south pressure gradient flow over the Santa Ynez ridge line initiates a downslope wind regime. If the gradient flow is weak, downslope winds through the passes and gaps in the ridge line are blocked by the relatively cool, stable marine layer which frequents Santa Barbara. The average depth of this marine layer inversion is about 2000 feet during the summer and fall seasons. Within this marine layer, along the entire Santa Barbara littoral, winds are normally light southerly or southeasterly.

A strengthening of the north-south pressure SLP gradient across the county usually signals the initialization of downslope wind conditions at Santa Barbara. When minimum observed thresholds for sundowner conditions are realized (p. 36), downslope winds begin to extrude through gaps in the Santa Ynez Range. The adiabatic warming of low-level air descending from the ridge line results in hydrostatic lowering of pressures along the coastal strip, further increasing the north-south SLP gradient.

Topographical considerations (i.e., the relatively low elevation and physical structure) make Nojoqui Pass the most favored place for early development of a sundowner flow. Sundowner winds frequently begin here, channeling downward toward Gaviota Beach, often meeting the marine layer head-on, then deflecting to the left (eastward) along the beaches toward Santa Barbara, where the modified sundowner is observed as a 250° to 280° surface wind at, roughly, 10 to 25 knots. This sundowner airstream is marked by sharp external boundaries; it does not mix with the marine layer and causes strong low-level turbulence along the beaches and at the airport. Temperature changes of 15-30°F have been noted within a few hundred yards near the beaches (Greg White, personal communication, 1991).

Sometimes, when downslope winds do not occur through the higher passes, the Nojoqui flow will be the only significant sundowner stream into the Santa Barbara area. Frequently, however, the other major passes and canyons along the Santa Ynez ridge line also direct downslope wind streams toward Santa Barbara.

The main sundowner channel opening to Santa Barbara and Goleta is San Marcos Pass. Sundowner winds are generally measured at their greatest intensity directly below San Marcos Pass, from two miles south of the Pass to the vicinity of Windy Gap along Highway 154 and westward along the Maria Ygnacio Creek and San Antonio Creek drainages. Downslope flow from San Marcos Pass is usually experienced as a northwest wind within the city of Santa Barbara and at Santa Barbara Harbor, and as a north to northeast wind at Santa Barbara Airport.

North to northeast sundowner winds are sometimes directed into Santa Barbara through less prominent canyons to the north of the city. These include Barger, Mission and Rattlesnake Canyons, as well as the Sycamore Creek drainage. An 850mb flow to the east of true north tends to de-activate the San Marcos Pass sundowner flow, while significantly increasing wave energy toward the east, notably in the Montecito and Carpinteria districts.

The downslope regime tends to be somewhat capricious and erratic with regard to boundary layer flow. For example, wind sensors may report calm conditions at Santa Barbara Harbor and downtown, while a low-level jet intersects KEYT's TV Hill (elevation 450 feet MSL) with a resultant northwest gale. Forty knot gusts may occur on Twinridge Road while a few blocks away on Old San Marcos Road the wind is not felt, but may be heard in the distance. At a given observation point within the downslope flow, wind observations manifest strong surging gusts of wind with occasional quiet periods and occasional abrupt changes in direction (Fig. 8).

While sundowners are channeled through gaps and canyons on the lee side of the Santa Ynez Mountains, sundowner winds are sometimes wrongly described as simply "canyon" winds. The strongest and most persistent winds are not observed through the gaps, as in Bernoulli flows, but are instead measured at various specific locations along the south facing slopes and at some sites on the coastal plain.

3. Severe or Category 3 Sundowners.

Category 3 (severe) sundowner episodes are characterized by temperatures of 104°F or more with winds of more than 20 knots at the ocean and more than 50 knots on leeward slopes of the Santa Ynez Range. Historical data suggest that windstorms of this magnitude have occurred at least 15 times since 1850.

Category 3 windstorms seem to follow a somewhat narrow developmental course. Synoptic scale analyses show a strong (roughly 5900m) ridge at 500mb centered over the Four Corners area within a few weeks on either side of the summer solstice (Fig. 8). A surface "thermal" low pressure regime is centered near California's Imperial Valley. Low pressure off the Pacific Northwest coast supplies the mechanism for cool air advection into northern and central California, while maintaining a southwest wind flow at 500mb. The 500mb wind flow manifests at least 90° of backing from the northerly ridge top flow. At 925mb and 850mb, a high pressure ridge extends inland across central California from the Bay Area to the San Joaquin Valley, with accompanying increases in pressures and stability from north to south. Strong cool air advection is noted on the 850mb analysis (Fig. 9).

In Santa Barbara County, a strong inversion, as measured in the Vandenberg sounding, reaches from 2000 to 4000 feet MSL (Fig. 10). The sounding typically exhibits two other characteristics which may impact on the development of mountain waves: (1) increasing wind with altitude, expected theoretically in an application of the Scorer parameter, and (2) additional stable layers just below the tropopause, as anticipated by Clark and Peltier.

Another feature present during severe sundowner wind events is strong heating in the upper Santa Ynez Valley. With 500mb heights and thicknesses at high summertime values, intense heating occurs in the Cachuma Lake/Los Prietos areas. Maximum temperatures at these sites have been documented at 105° to 115° or more during these conditions, creating a strong surface-based super adiabatic lapse rate. It is not certain if this heating contributes in some way to the development or the strengthening of the San Marcos sundowner wave, but there is some suggestion that venting of hot air from the Santa Ynez Valley may be occurring. This could result from low-level northwest (up-valley) winds, generally 10 to 20 knots, measured at Santa Maria, Lompoc, Santa Ynez, and Bradbury Dam in Category 3 episodes.

It is interesting to note that at the summit of San Marcos Pass, winds during severe downslope events are generally light, about 10 to 20 knots, and blow from the Santa Ynez Valley (from the north or northwest). Temperatures at the pass usually hold in the 80's.

While Category 1 or 2 downslope events generally cause maximum diurnal surface temperatures to occur between 1600 and 1900 LST, Category 3 sundowners produce very rapid temperature rises which tend to peak earlier, between 1200 and 1500 LST. One possible explanation for this phenomenon is that Category 3 episodes are typically preceded by at least one day of moderate downslope activity. Thus, on Category 3 days there is little boundary layer opposition from an established Santa Barbara marine incursion. Furthermore, lee waves have already established flow positions on the south side of the Santa Ynez Range on day one, and may thereafter be in a better position for phasing with an increasing southwesterly flow aloft.

Compressional heating occurs in atmospheric layers above the lee side of the Santa Ynez Range. This heating may be enhanced by downward vertical wave propagation through the troposphere. The presence and the strength of these waves is confirmed by the effects of sundowner airflow on aircraft approaching Santa Barbara Airport from the north of the Santa Ynez ridge line (p. 14).

In severe sundowners, strong channels of super-heated air reach from the lee slopes below San Marcos Pass across the coastal strip, and can occasionally push all the way to the Channel Islands, some 25 miles to the south. Videotapes taken from the vicinity of San Marcos Pass during the 1990 Category 3 windstorm clearly show the location, marked by a huge smoke plume, of a hydraulic jump boundary directly over the city of Santa Barbara.

Modeling sundowner winds over the Santa Barbara area is difficult. With the inclusion of mountain wave factors in severe events, this difficulty is compounded. In the first place, classical hydraulic jump diagrams are not assignable to the Santa Barbara condition. The north-south flow over Santa Barbara County is not laminar; it crosses a large area of rough terrain before reaching the Santa Ynez Valley and Santa Ynez Mountains. Further, there are significant valley winds that typically approach San Marcos Pass from the northwest and a variable-strength marine layer on the lee side of the pass to consider. In addition, there are frequently gusty northwest winds across much of Santa Barbara Channel during severe sundowners. Finally, synoptic scale flow reversal above 10000 feet adds yet another dimension to the modeling problem.

Notwithstanding the difficulties mentioned above, an approximate sundowner flow diagram can be made for a severe event occurring at San Marcos Pass (Fig. 12). Assuming dry air, the wind flow follows isentropic surfaces and indicates strong atmospheric perturbations throughout the troposphere. Surface temperatures at Santa Barbara could, within this context, reach values approaching 130°F.

Downslope wind potential at Santa Barbara is somewhat enigmatic. The shape of the lee side of the Santa Ynez Range is that of a sharp, steep escarpment. Atkinson (1981) and others speak to the importance of this element; it is commonly asserted that maximum surface wind speeds are much greater with similar sharp topographic features. Atkinson quotes a study indicating that wind maxima are dependent upon the presence of an inversion near the mountaintop level on the windward side of the crest. Using data analogous to Santa Barbara terrain features, this study yielded a maximum wind of 40m/s (78 knots). This value approximates peak wind values extrapolated from the Maria Ygnacio sensor northwest of the city of Santa Barbara, and from measurements noted by ground observers (Figs. 13 and 14).

While the effects of sundowner regimes in the San Marcos Pass and Santa Barbara area can be documented and analyzed in general terms, individual events display broad variability in location of impact and in all measurable parameters.

D. FORECASTING SUNDOWNERS.

It is essential that forecasters exercise synoptic and mesoscale pattern recognition skill to anticipate downslope windstorm development. Favorable patterns, outlined in this paper, are now best viewed using gridded data. Although lacking in fine detail, standard NGM and MRF models have been used with success to forecast downslope wind conditions at Santa Barbara from one to three days in advance.

In the hours before a potential sundowner occurrence, and for the duration of any event, the computed SLP gradient field is the most important indicator of the strength of any downslope wind event. Forecasters need to continually monitor pressure gradient fields when the potential for sundowners exist or when an event is occurring. Perhaps the single best indicator of wind strength and duration is the pressure gradient between Santa Barbara and Santa Maria. Another gradient to monitor closely is the one between Santa Barbara and Bakersfield.

The importance of wind profile information in forecasting wind events is noted by many downslope wind researchers. A potential tool for forecasting these events in the Santa Barbara area is the recently installed Vandenberg (VBG) Air Force Base Doppler radar system (WSR-88D). The antenna for this radar is located about 5 miles southeast of Santa Maria Airport. In clear-air mode, Doppler radar can be used to profile wind layers through a dry atmosphere. Although it cannot detect vertical motion, it has produced some spectacular imagery of precursor wind fields above the Santa Ynez Range. National Weather Service meteorologist Mike Wofford (NWSFO Oxnard) has demonstrated considerable skill in adapting the Doppler system to evaluating Santa Barbara downslope events. This radar shows promise as a research tool for future sundowner events (Figs. 15 and 16).

E. GUIDELINES FOR FORECASTERS.

Based on supporting data compiled within the context of this study, the following rules apply for sundowner evaluation and forecasting:

1. Sundowners have not been observed to occur when the BFL-SBA SLP gradient is negative, or if the SMX-SBA gradient is less than 1.8mb.
2. Winds at 3000 feet MSL (see VBG upper air sounding, VBG profiler data, or VBG Doppler radar) must flow from between 335° and 025° for sundowner development to occur. Wind speed at 3000 feet is normally about 20 knots, but a threshold speed of only 12 knots is supported by data analysis.
3. The VBG sounding must exhibit a significant low-level inversion extending to ≈ 1500 to 3000 feet MSL.
4. Category 1 sundowners are observed when SMX-SBA SLP gradients range from 1.8 to 4.0mb.
5. Category 2 sundowners are observed when SMX-SBA SLP gradients range from 3.5 to 6.5mb.
6. Category 3 sundowners are observed when SMX-SBA SLP gradients are > 5.0mb, with the following parameters likely to be noted concurrently:
   a. A sundowner flow has been observed at Santa Barbara during at least the previous 24 hours.
   b. North-to-south SLP gradients across Santa Barbara county are stable or increasing.
   c. Strong insolation is occurring; all known severe events have occurred between June and September but are most numerous in June and July.
   d. Winds between 3000 feet and 18000 feet MSL back from approximately 360° to 250°, respectively.

Forecasting specific meteorological parameters for downslope windstorms at Santa Barbara requires an application of techniques developed during many years of observations. Einar Hovind, a Santa Barbara consulting meteorologist with many years of experience in sundowner forecasting, has observed the following (Personal communication, 1992):

Santa Maria-Santa Barbara Sea Level Pressure Gradient

SMX-SBA SLP GRADIENT	WIND RANGES
less than 2 mb	no downslope wind
2-3 mb	20-30 knots
3-4 mb	30-40 knots
4-5 mb	40-50 knots
greater than 5 mb	over 50 knots

The author's experience in comparing wind sensor reports from Maria Ygnacia Canyon versus pressure gradients demonstrates the remarkable reliability of this gradient/resultant wind guide.

Forecasting maximum temperatures for Santa Barbara during sundowner events is very difficult. This is due to the uneven nature of the downslope flow caused by complex terrain and related turbulence. In general, the maximum surface temperature at Santa Barbara during a sundowner episode will exceed the potential temperature at 850mb. As a rough estimate, the maximum temperature during Category 1 and 2 events is approximately 15°F higher than the 1300 LST temperature at La Cumbre Peak (Alert Gage #2505). Remarkably, the surface temperature at Santa Barbara will exceed the potential temperature at 700mb during Category 3 events!

When downslope windstorms are imminent or are occurring, aviation forecasters should include low-level wind shear conditions in the terminal forecast for Santa Barbara Airport. In addition, wind advisories or warnings should be considered for the affected zone forecasts, as appropriate. The following products may be applicable during sundowner conditions:

(1) Red Flag Alert (Fire Weather)

(2) High Wind Warning/Wind Advisory

(3) Heat Advisory

(4) Small Craft Advisory

In addition, special weather statements should be issued during downslope windstorms to update the situation, highlight specific effects, and address public concerns--which tend to heighten during strong episodes.

As recently as 1990, the only readily available surface observation near the city of Santa Barbara was at the Santa Barbara Airport (SBA) in Goleta. However, this is one of the last locations on the coastal strip to manifest sundowner conditions. Therefore, observations from SBA alone may fail to indicate a sundowner event in progress even though strong conditions are currently occurring elsewhere in the city. Fortunately, surface weather observation points in and near the city have increased greatly during the years since the Painted Cave Fire. Temperature and wind data can be monitored through the following collection points:

+ Santa Barbara County Flood Control Alert Gages 2505, 2515, 2568, 2500, 2510, 2537, 2542, 2563, and 3090

+ Santa Barbara County Air Pollution Control District Gages 26, 29, 31, and 32.

+ Severe Weather Spotter Network Sites in Santa Barbara 804, 805, 808, 809, 810, 811, 813, 814, 815, 820, 902, 907

+ U.S. Forest Service Automated Weather Observation Sites at San Marcos Pass and Glen Annie Canyon.

+ KEYT Television on TV Hill and an associated downtown site.

Vandenberg AFB wind profiler data and Doppler radar imagery and wind profiles are now being made available to forecasters and researchers. It is only a matter of time before guidelines are established for the use of these diagnostic tools in downslope wind analysis.

V. CONCLUSION

A significant mesoscale event, such as a sundowner, occurring over a heavily populated coastal plain clearly presents a threat to public safety. The technology, observational network, and forecast focus is now in place to do a better job of both monitoring and predicting these potentially dangerous events. Perhaps, in the future, lives, and property can be saved as a result of further research into the sundowner regime, refinements, modernization of forecast technique, and close interagency cooperation.

VI. REFERENCES

Atkinson, B. W., 1981: *Meso-Scale Atmospheric Circulations.* Academic Press, San Francisco, 495pp.

Bosart, Lance F., 1983: Analysis of a California Eddy Event. *Mon. Wea. Rev.* (AMS), **111**, pp1619-1633.

Clark, John H. E. and Dembek, Scott R., 1990: The Catalina Eddy Event of July 1987: A Coastally Trapped Mesoscale Response to Synoptic Forcing. *Mon. Wea. Rev.* (AMS), **119**, pp1714-1735.

Durran, Dale R. (Contrib. Ed.) 1986: Mesoscale Meteorology and Forecasting, Peter S. Ray, Ed. American Meteorological Society, Boston, 793pp.

Elevatorski, Edward A., 1959: *Hydraulic Energy Dissipators.* McGraw-Hill Book Co. Inc, New York.

Finke, Brian W., 1990: Sundowner Winds and the June 25-28 Santa Barbara Fire. Western Region Technical Attachment No 90-30, National Weather Service Western Region, Salt Lake City.

Ford, Raymond Jr., 1991: *Santa Barbara Wildfire: Fire on the Hills.* McNally and Loftin, Santa Barbara, 228pp.

Gomes, Daniel, et al., 1993: *Sifting Through the Ashes: Lessons Learned From the Painted Cave Fire.* University of California, Santa Barbara, 194pp.

Fox, Robert W. and McDonald, Alan T., 1985: Introduction to Fluid Mechanics. John Wiley & Sons, New York, 741pp.

Hooke, William H. (Contrib. Ed.) 1986: Mesoscale Meteorology and Forecasting, Peter S. Ray, Ed. American Meteorological Society, Boston, 793pp.

Horel, John, 1992: Mountain Waves, Videotape lecture at the University of Utah. National Weather Service Western Region Library, Salt Lake City.

Independent Insurance Agents of Santa Barbara, 1982: The Lessons of the Sycamore Fire, Santa Barbara, California. Haagen Printing, Santa Barbara, 57pp.

Jones, Douglas F., 1974: The Goleta Simoom of 1859 --- A Summary of Facts. Noticias, Vol 20 No 4, pp6-10, Santa Barbara Historical Society Museum, Santa Barbara.

Long, R. R., 1953: A Laboratory Model Resembling the "Bishop Wave" Phenomenon. *Bull. Amer. Meteor. Soc.*, **34**, 250-311.

Meier, Keith, 1994: A Southern California Wind Event: An Alternative Explanation. Western Region Technical Attachment No. 94-11, National Weather Service Western Region, Salt Lake City.

Pettre, Paul, 1982: On the Problem of Violent Valley Winds. Journal of the Atmospheric Sciences, **Vol. 39**, pp 542-554.

Ryan, Gary, 1994: Climate of Santa Barbara, California. Western Region Technical Memorandum NWS WR-225, National Weather Service Western Region, Salt Lake City.

Western Region Headquarters Staff, 1990: Downslope Windstorms and Mountain Waves. Western Region Technical Attachment No 90-31, National Weather Service Western Region, Salt Lake City.

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Morton G. Wurtele, Atmospheric Remote Sensing Laboratory, UCLA

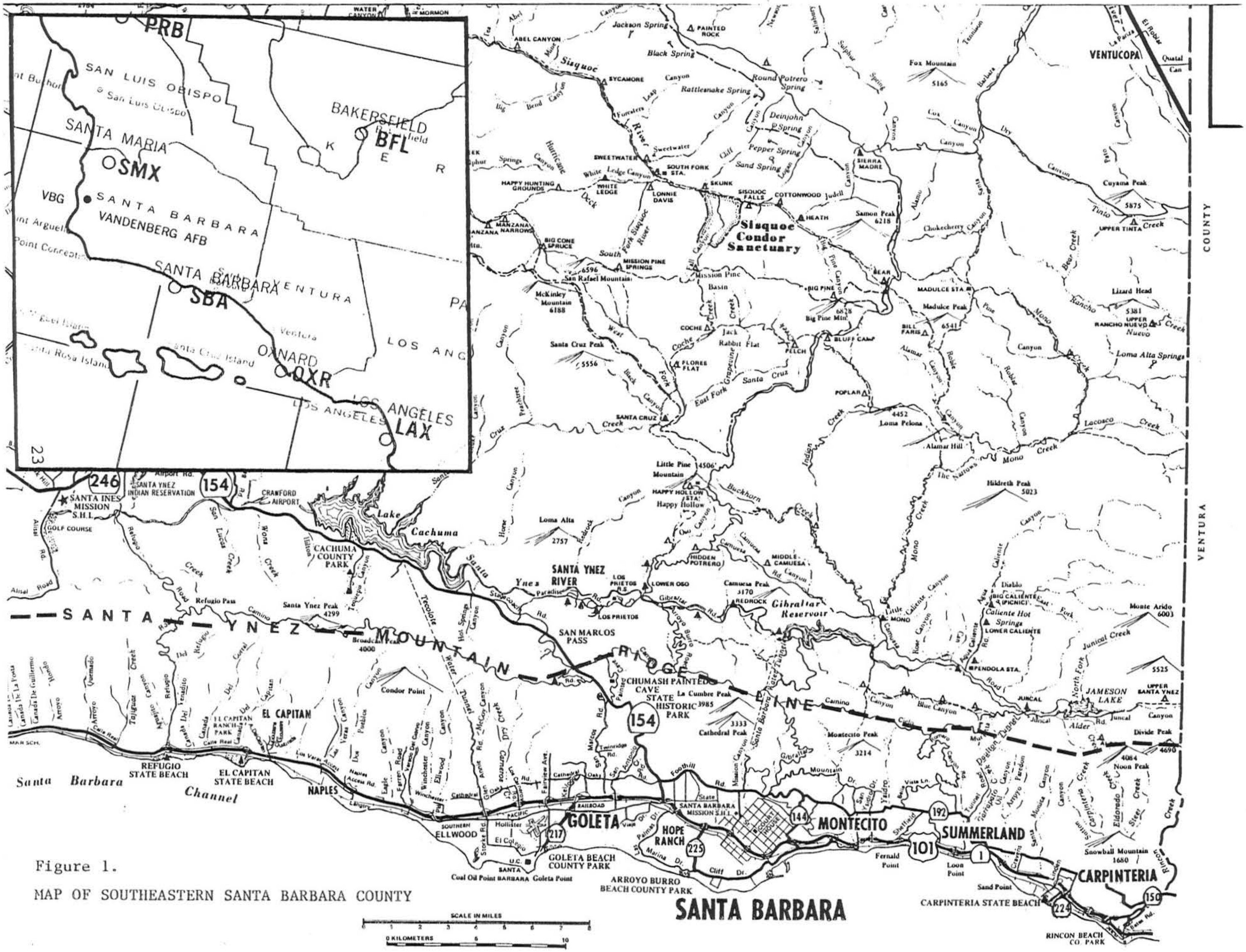


Figure 1.

MAP OF SOUTHEASTERN SANTA BARBARA COUNTY

Monday, June 18, 1917.

Weather Observer Says Relief Will Come Soon; Many Go to Beach

Never in the history of Santa Barbara has there been such heat as that prevailing since the Ojai and Carpinteria fires started. Weather Observer George W. Russell's reports show that the nearest heat record to that which yesterday set a new top notch at 115 degrees, was in September, 1914, when the mercury climbed to 108. That heat, also, was occasioned by the presence of a fire, the Hope Park district then being in the grasp of the flames.

While a part of the heat was due to desert winds, it is stated that the high record was forced through the heat from the forest fires. The severity of the winds, also, are attributed to the fires, and normal weather conditions are expected when the fires which now are raging in the Ojai and above Carpinteria, have been extinguished.

In Santa Barbara a dust storm prevailed Saturday night, such as has never been known in this city before. The winds whipped papers from bill boards, lashed numerous American flags, left flying over the stores, into shreds, and drove the finest dust into dwellings and stores, no place being too securely closed to prevent the particles from sifting through.

The heat through the evening sent thousands to the beach. Last night the number was materially diminished, as a breeze from the ocean set in just before midnight, and gave a cool night to the city.

Never before have such numbers of people sought the surf to cool off, hundreds of surf bathers spent most of the Sunday either in the water or lolling on the beach, taking an occasional plunge to keep cool. The bath house yesterday served 750 bathers, and there were many others who used their automobiles in which to don their bathing suits, it being estimated that during the day, from Graham's on the east, to far beyond Castle Rock, over 1000 people took to the water during the day.

Musical Program at High School

A musical program, to which the public has been invited, will be given

Figure 2.
SANTA BARBARA MORNING PRESS FEATURE STORY, 6/18/17. The headline reads "HEAT RECORDS SET FOR CITY BY FIRES AND WIND". The article quotes Weather Bureau Cooperative Observer George W. Russell.
(Courtesy, Mary Compton)

Form No. 1000—Met'l.

U. S. Department of Agriculture, Weather Bureau.

COOPERATIVE OBSERVERS' METEOROLOGICAL RECORD:

Month of June JUNE, 1917 *Station,* Santa Barbara; *County,* Santa Barbara

State, California; *Latitude,* 34° 25'; *Longitude,* 119° 15'; *Hour of Observation,* 6am 7 Pm; *Time used on this form,* ______

Date	Temperature: Maximum	Temperature: Minimum	Temperature: Range	Temperature: Set Max.	Precipitation: Time of Beginning	Precipitation: Time of Ending	Precipitation: Amount	Precipitation: Snowfall in Inches	Precipitation: Depth of Snow on Ground at Time of Observation	Prevailing Wind Direction	Character of Day	Miscellaneous Phenomena
1	70	48	22							W	Clear	Fog to 10
2	70	53	17							W	"	9
3	70	52	18							W	"	8
4	67	44	23							W	"	10
5	67	45	22							W	"	10
6	65	45	20							W	"	9
7	65	50	15							W	"	11
8	65	50	15							"	"	10
9	66	50	16							"	"	11
10	63	50	13							"	"	12
11	70	46	24							"	"	11
12	78	45	33							"	"	9
13	80	48	32							"	"	7.30
14	95	48	47							"	"	[illegible]
15	105	57	48								"	[illegible]
16	107	58	49							NE	"	[illegible]
17	115	62	53							NE	"	"
18	80	65	15							E	"	Fog early
19	76	60	16							W	"	[illegible] fog
20	75	60	15							W	"	"
21	73	58	15							W	"	8
22	73	59	14							W	"	9
23	75	59	16							W	"	7.30
24	76	50	26							W	"	
25	76	55	21							W	"	
26	76	58	18							"	"	
27	78	56	22							"	"	[illegible]
28	84	56	28							E	"	
29	86	54	32							E	"	
30	87	55	32							E	"	
31												
Sum	2332	1597	735						[illegible] 33	W		
									4.5 th			

George Russell, Cooperative Observer.

MONTHLY SUMMARY.

TEMPERATURE.

Mean maximum, 77.8

Mean minimum, 53 1/2

Mean, 65.5

Maximum, 115; date, 17th

Minimum, 44 ~~45~~; date, ~~2~~ 4

Greatest daily range, 53 - 17

PRECIPITATION.

Total, 0 inches.

Greatest in 24 hours, 0; date, ______

SNOW.

Total fall, 0 inches; on ground 15th, ______ inches; at end of month, ______ inches.

NUMBER OF DAYS.

With .01 inch or more precipitation, 0

Clear, 30; partly cloudy, 0; cloudy, 0

DATES OF—

Killing frost, ______

Thunderstorms, ______

Hail, ______

Sleet, ______

Auroras, ______

REMARKS.

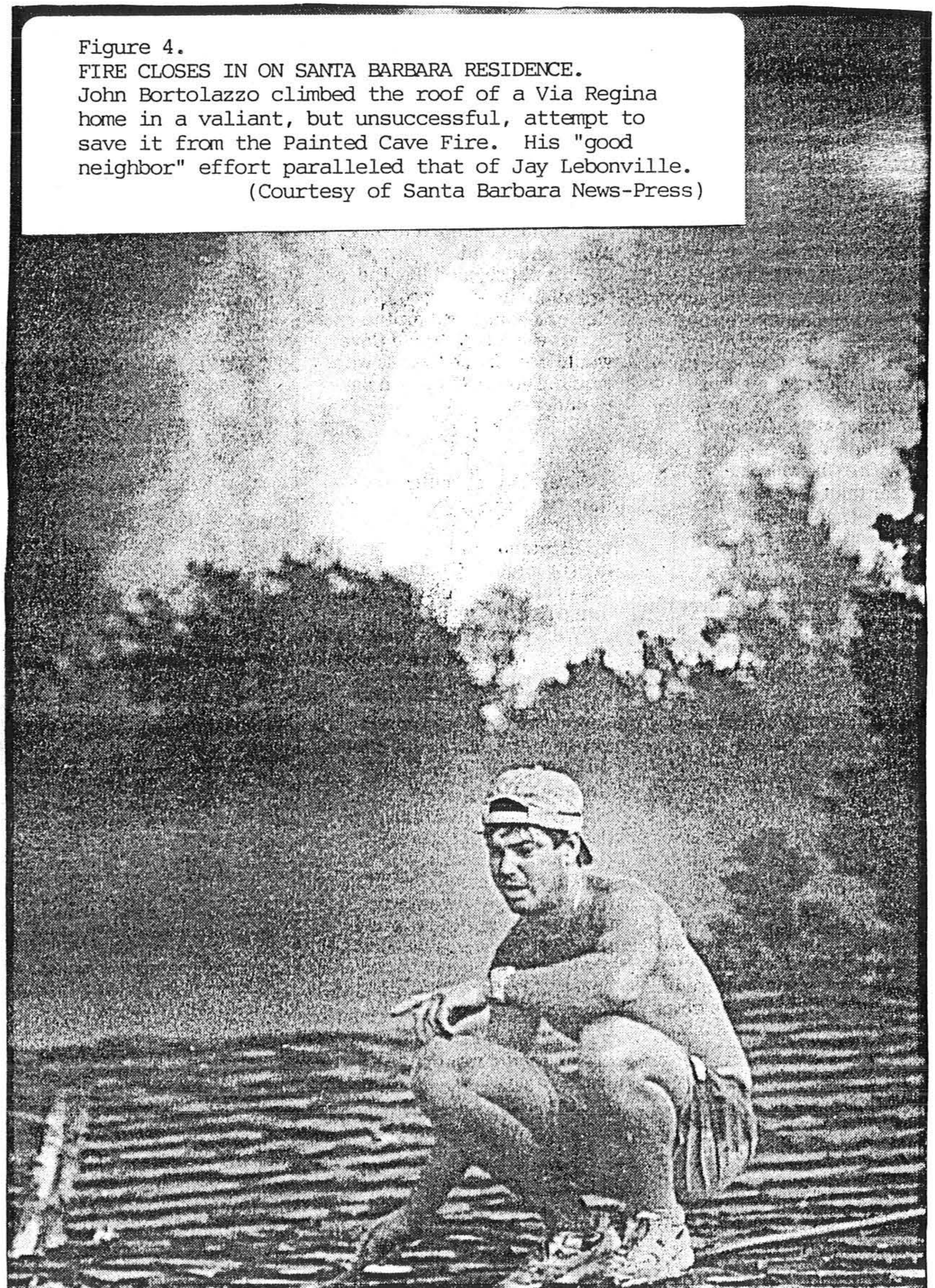
The hottest day ever recorded on the 17th. A hot wind during night 16th with velocity of 35 to 45 miles per hour, damaged fruit & other trees. Nuts were damaged, [illegible] [illegible] to have [illegible]

Figure 3.

GEORGE RUSSELL'S WEATHER LOG, JUNE 1917.

(Courtesy of Tom Ross,
National Climatic Data Center)

Figure 4.
FIRE CLOSES IN ON SANTA BARBARA RESIDENCE.
John Bortolazzo climbed the roof of a Via Regina home in a valiant, but unsuccessful, attempt to save it from the Painted Cave Fire. His "good neighbor" effort paralleled that of Jay Lebonville.
(Courtesy of Santa Barbara News-Press)



Len Wood/News-Press

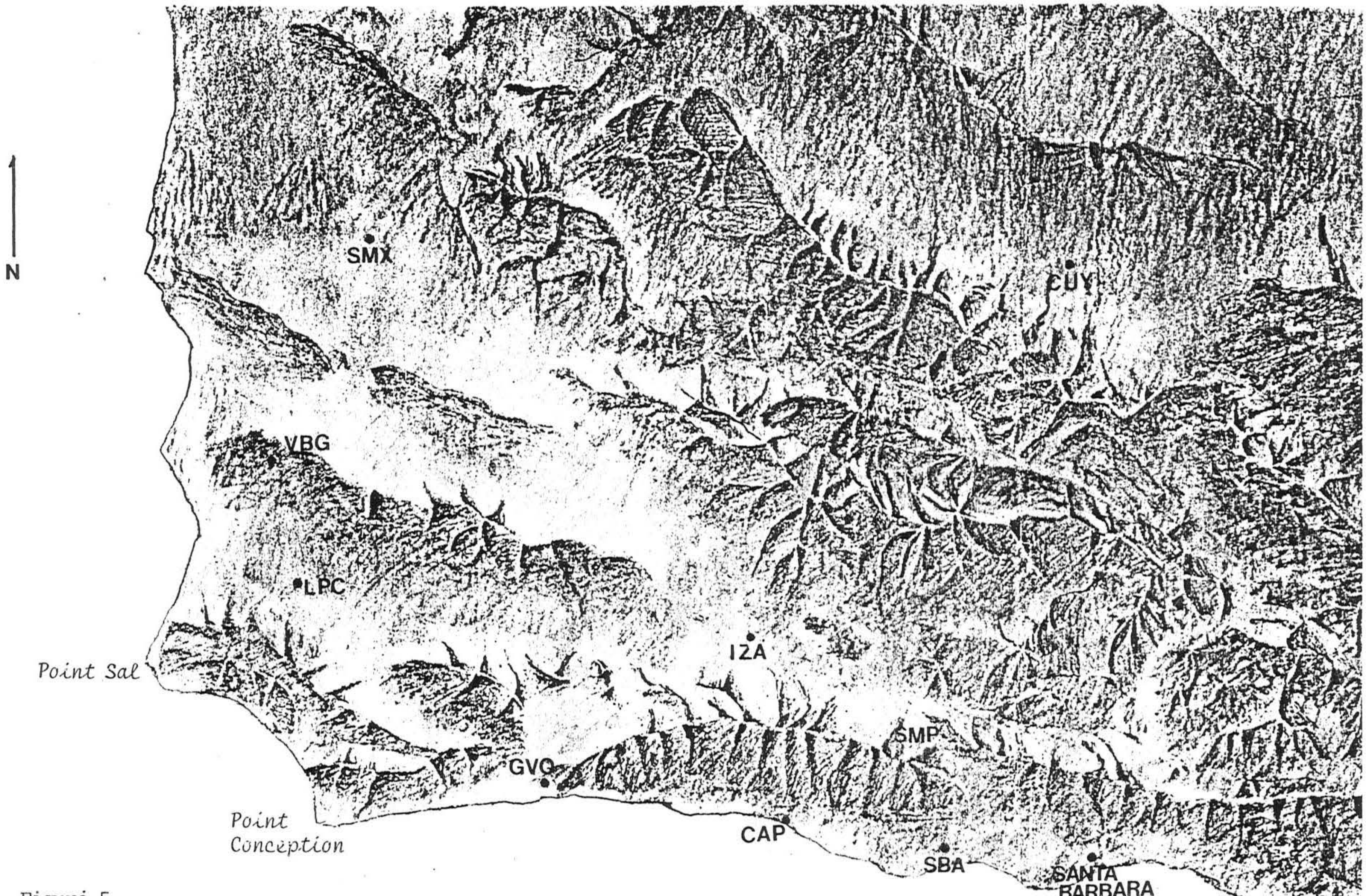


Figure 5.
RELIEF MAP OF SANTA BARBARA COUNTY, CALIFORNIA

SBA - Santa Barbara Airport
SMX - Santa Maria
VBG - Vandenberg AFB
LPC - Lompoc
GVO - Gaviota
IZA - Santa Ynez Airport
CAP - El Capitan
CUY - Cuyama
SMP - San Marcos Pass

One Inch = Approx 8 Miles

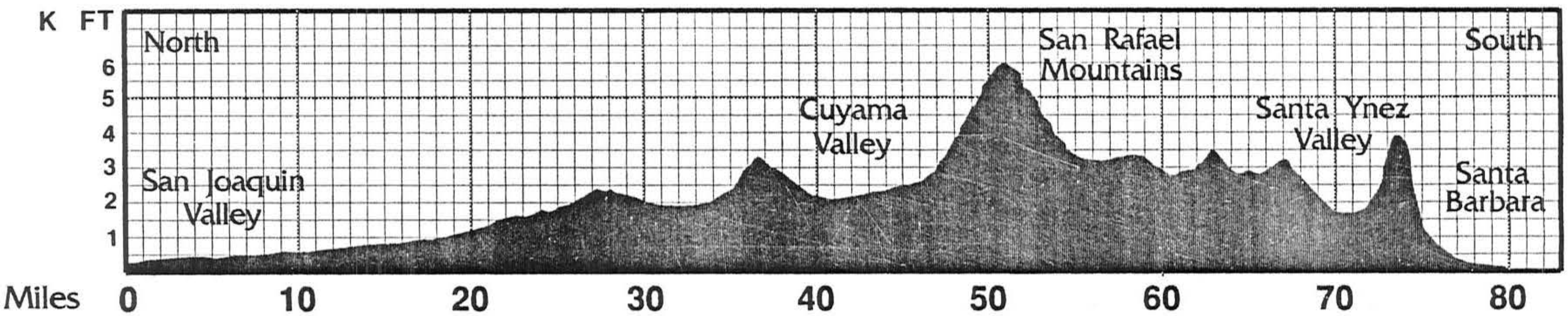


FIG. 6 Santa Barbara County Profile (vert 10x horiz)

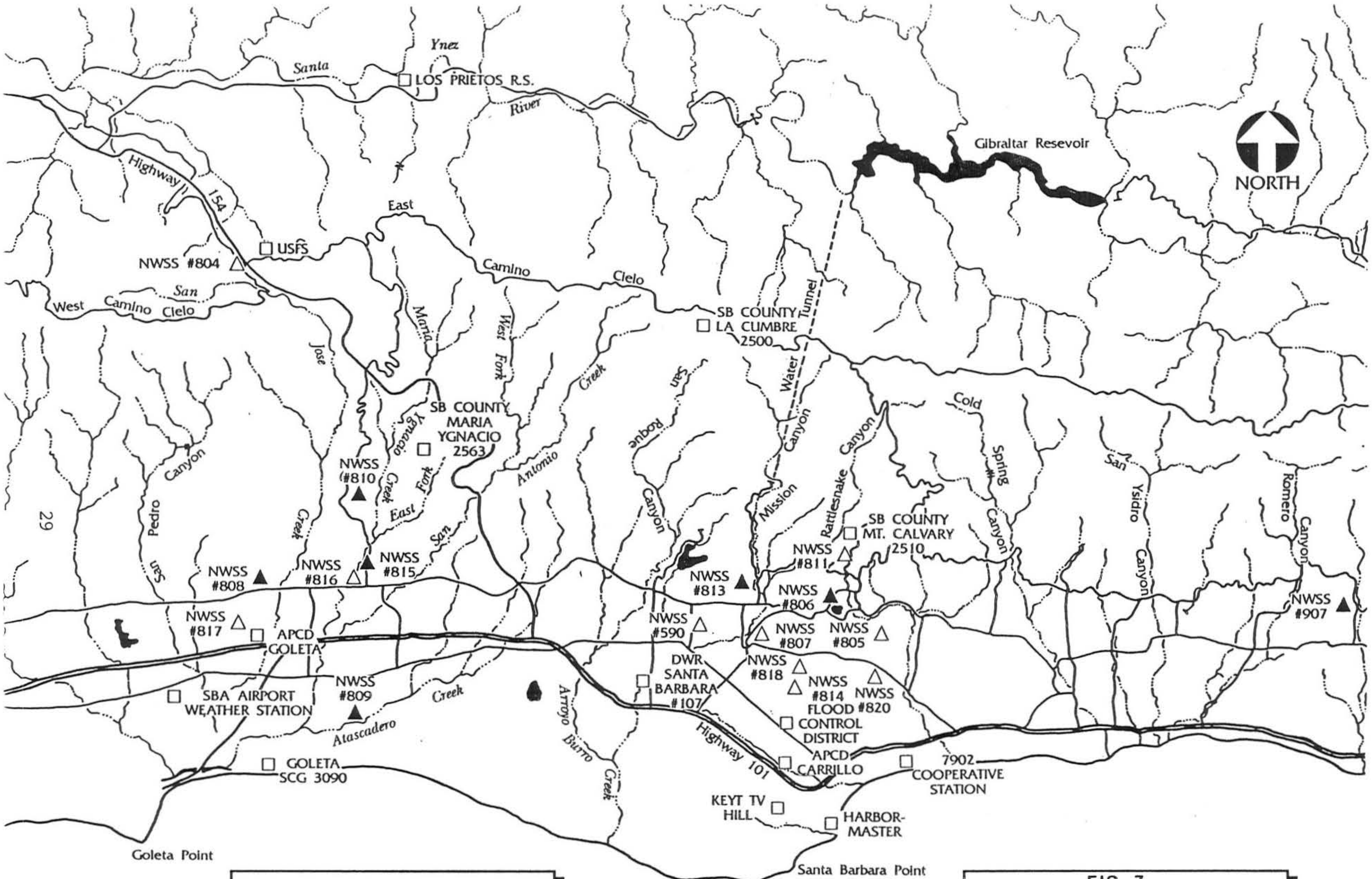


FIG. 7

Santa Barbara Area
Weather Reporting Sites
March 1995

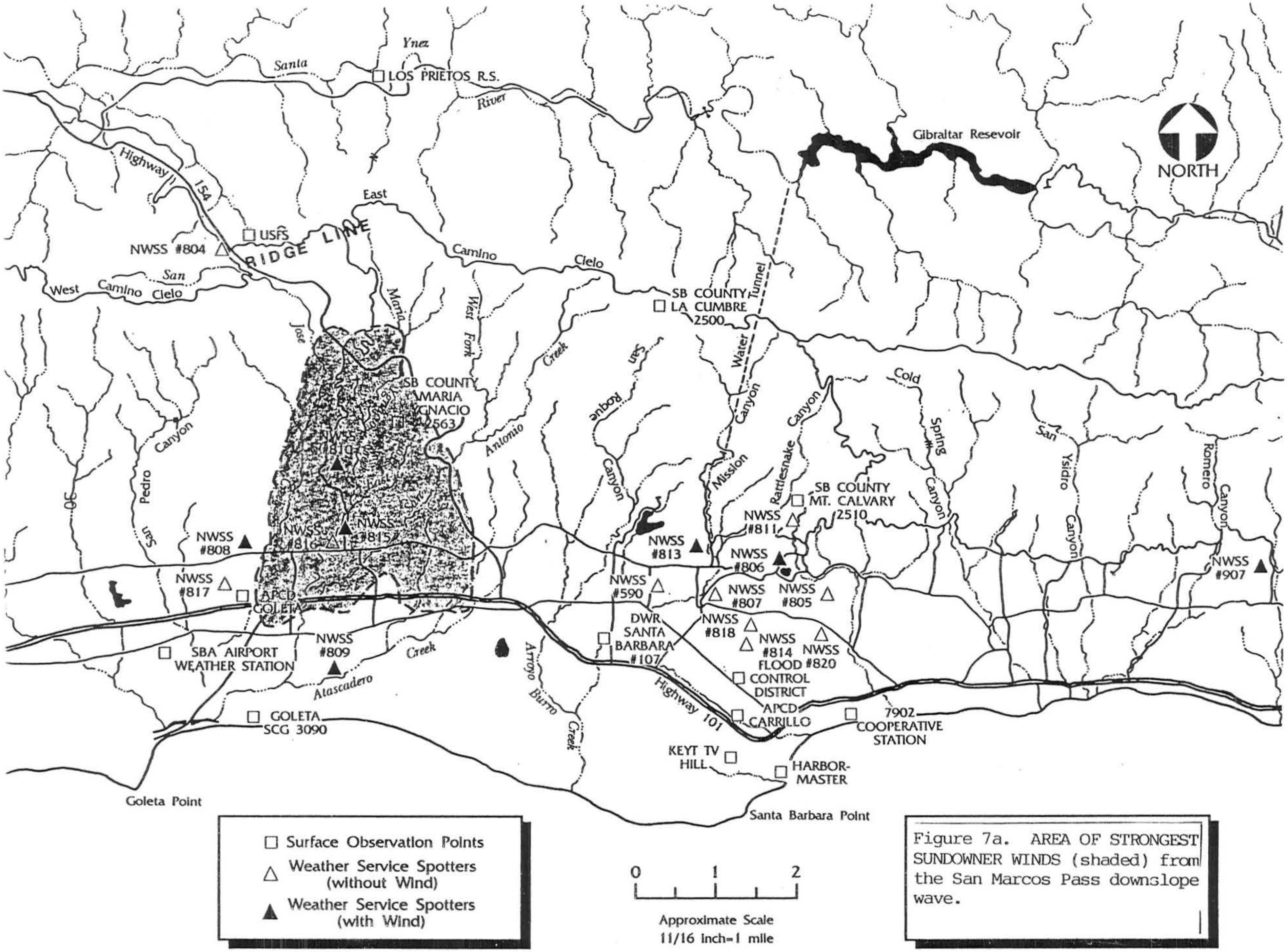


Figure 7a. AREA OF STRONGEST SUNDOWNER WINDS (shaded) from the San Marcos Pass downslope wave.

TABLE I. SIGNIFICANT WARMING EVENT (SWE) CATEGORIES	
CATEGORY	DESCRIPTION
0	WARM ANOMALY/NON-SUNDOWNER. Control data. No downslope winds. Warm advection with moderate or strong diurnal heating usually associated with mean ridging over the area. Normal diurnal temperature curve. Light winds, onshore afternoon. Sea level pressure (SLP) relatively high. Surface temperature at SBA may reach 104 deg F (40 deg C).
1	WEAK SUNDOWNER. Maximum temperature occurs out- side normal diurnal curve. Surface winds tend offshore over 15 knots (8 m/s) at the ocean. Strongest winds in passes and canyons 30 knots (15 m/s).
2	MODERATE TO STRONG SUNDOWNER. Temperature maximum occurs outside normal diurnal curve and is 15 deg F (8 deg C) or more above normal. Gusty winds, usually offshore, greater than 15 knots at coast. Strongest winds 30 to 50 knots (15 to 26 m/s) in passes and canyons.
3	SEVERE SUNDOWNER. Surface temperature exceeds 104 deg F during early or mid-afternoon. Gusty off- shore winds reach 20 knots (10 m/s) or more at the ocean. Pass and canyon winds exceed 50 knots (26 m/s). SLP relatively suppressed. Mainly occurs in June, July, or September.

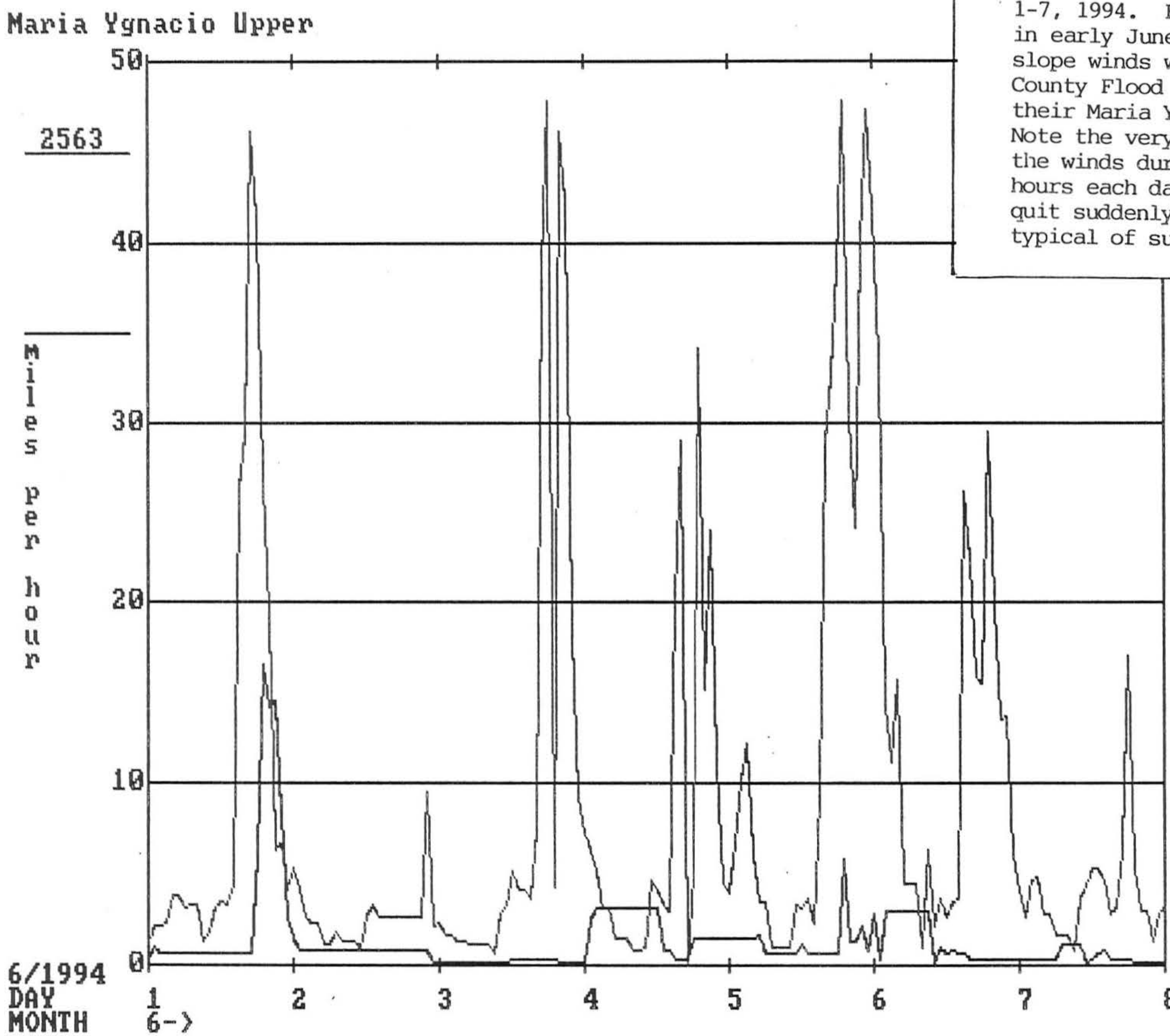


Figure 8.
DOWNSLOPE WIND PROFILE, JUNE 1-7, 1994. For several days in early June, strong downslope winds were monitored by County Flood Control through their Maria Ygnacio wind gage. Note the very sudden onset of the winds during the afternoon hours each day. The winds quit suddenly, also. This is typical of sundowner profiles.

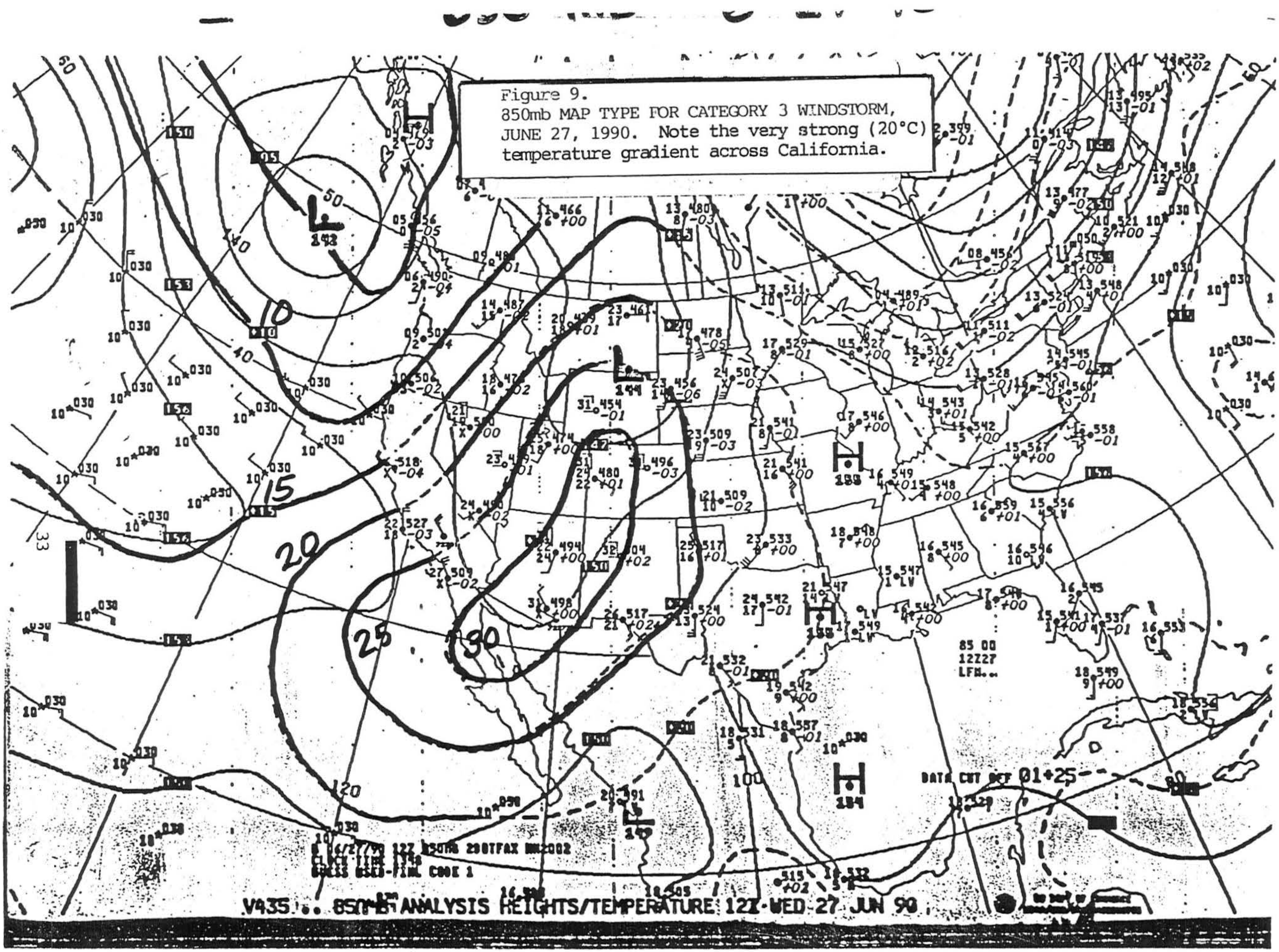


Figure 9.
850mb MAP TYPE FOR CATEGORY 3 WINDSTORM, JUNE 27, 1990. Note the very strong (20°C) temperature gradient across California.

WEDNESDAY, JUNE 27, 1990

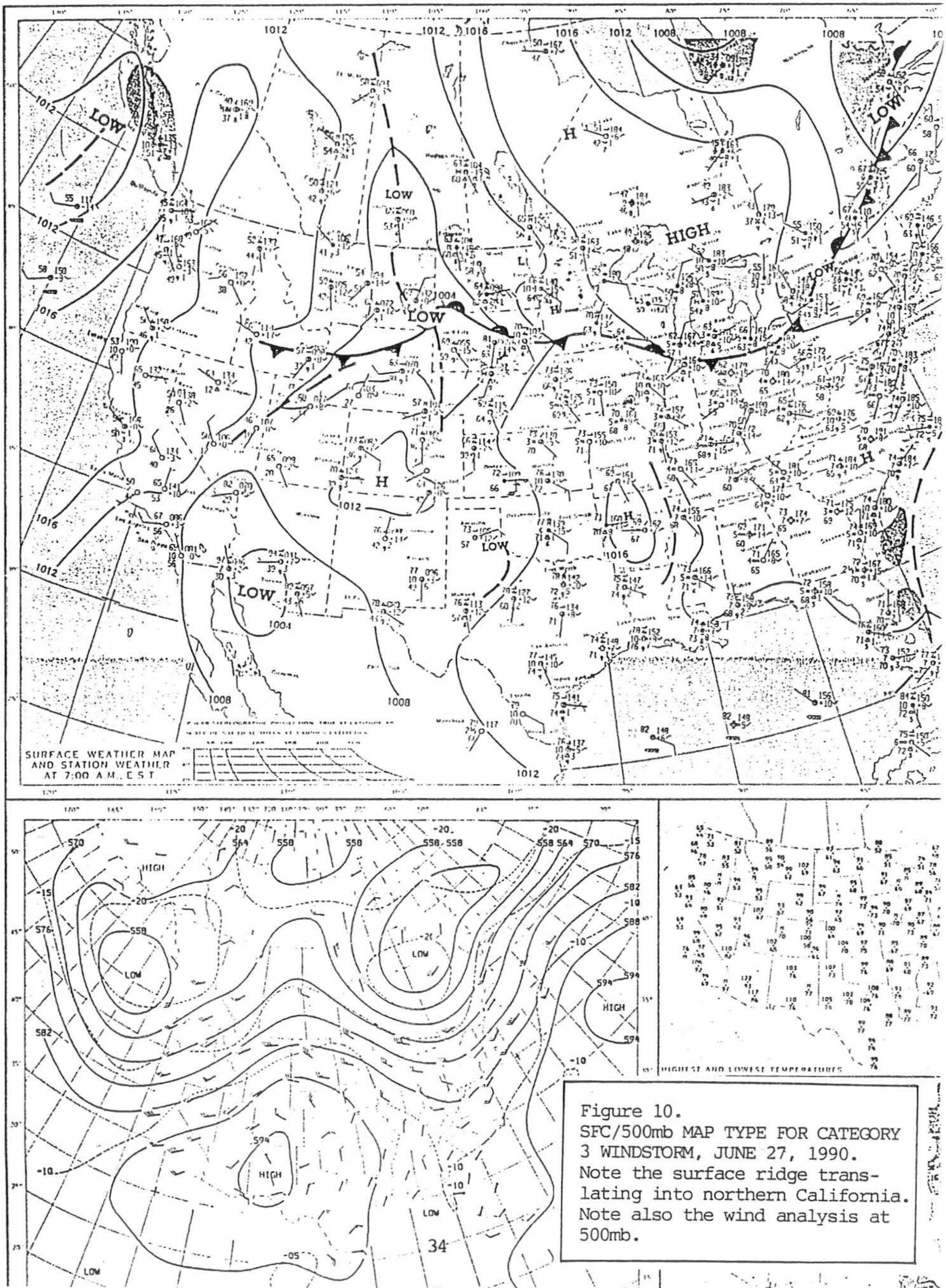


Figure 10.
SFC/500mb MAP TYPE FOR CATEGORY 3 WINDSTORM, JUNE 27, 1990. Note the surface ridge translating into northern California. Note also the wind analysis at 500mb.

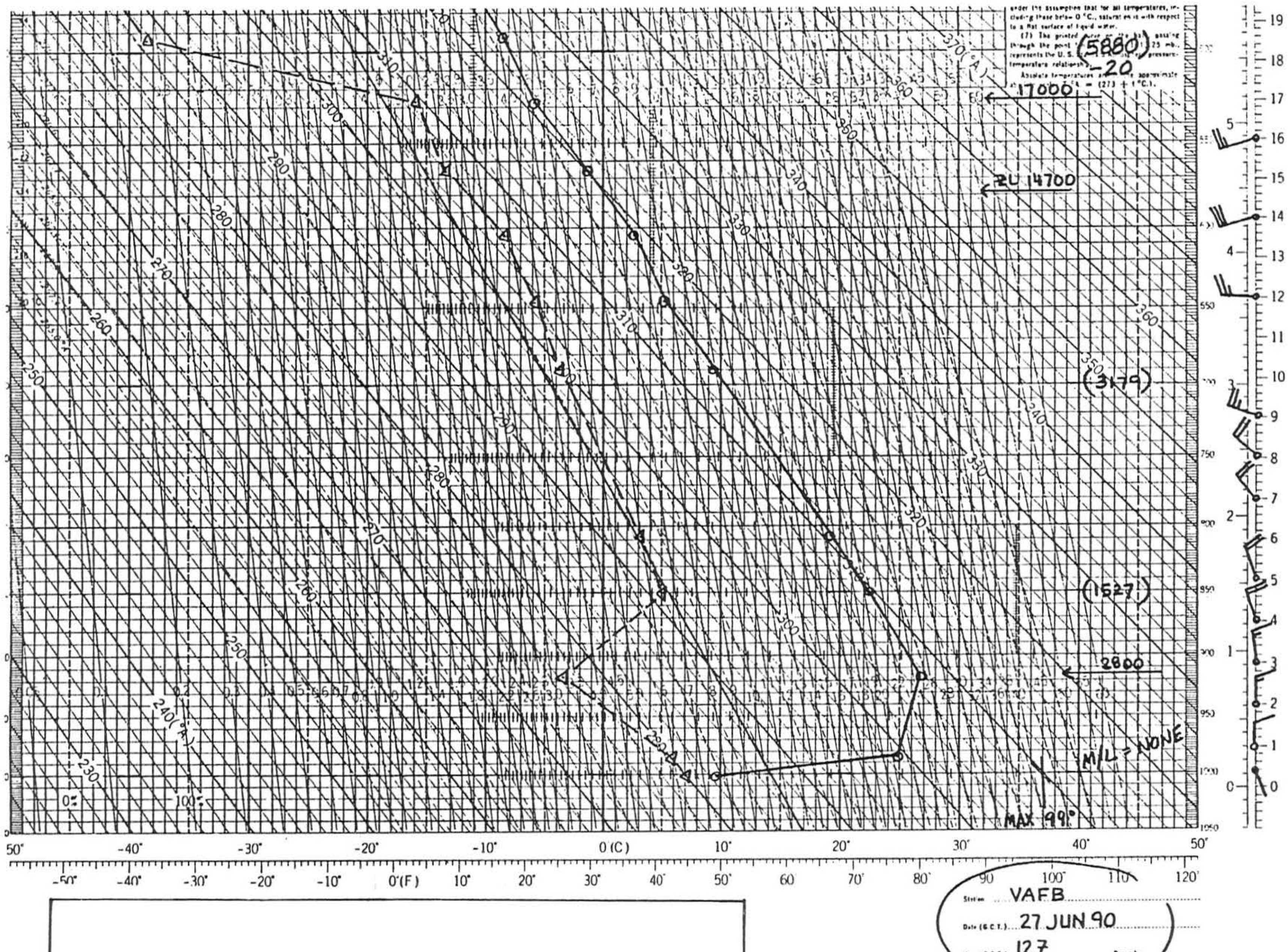


Figure 11.
VANDENBERG AFB UA SOUNDING 6/27/90 1200 UTC
The strong inversion extends to the level of the Santa Ynez Ridge.

Figure 12.
PROJECTED ISENTROPIC FLOW AT SANTA BARBARA, 6/27/90.
Two or more high amplitude waves would be expected in the immediate downstream flow. Note the blocking marine layer lower right near Highway 101.

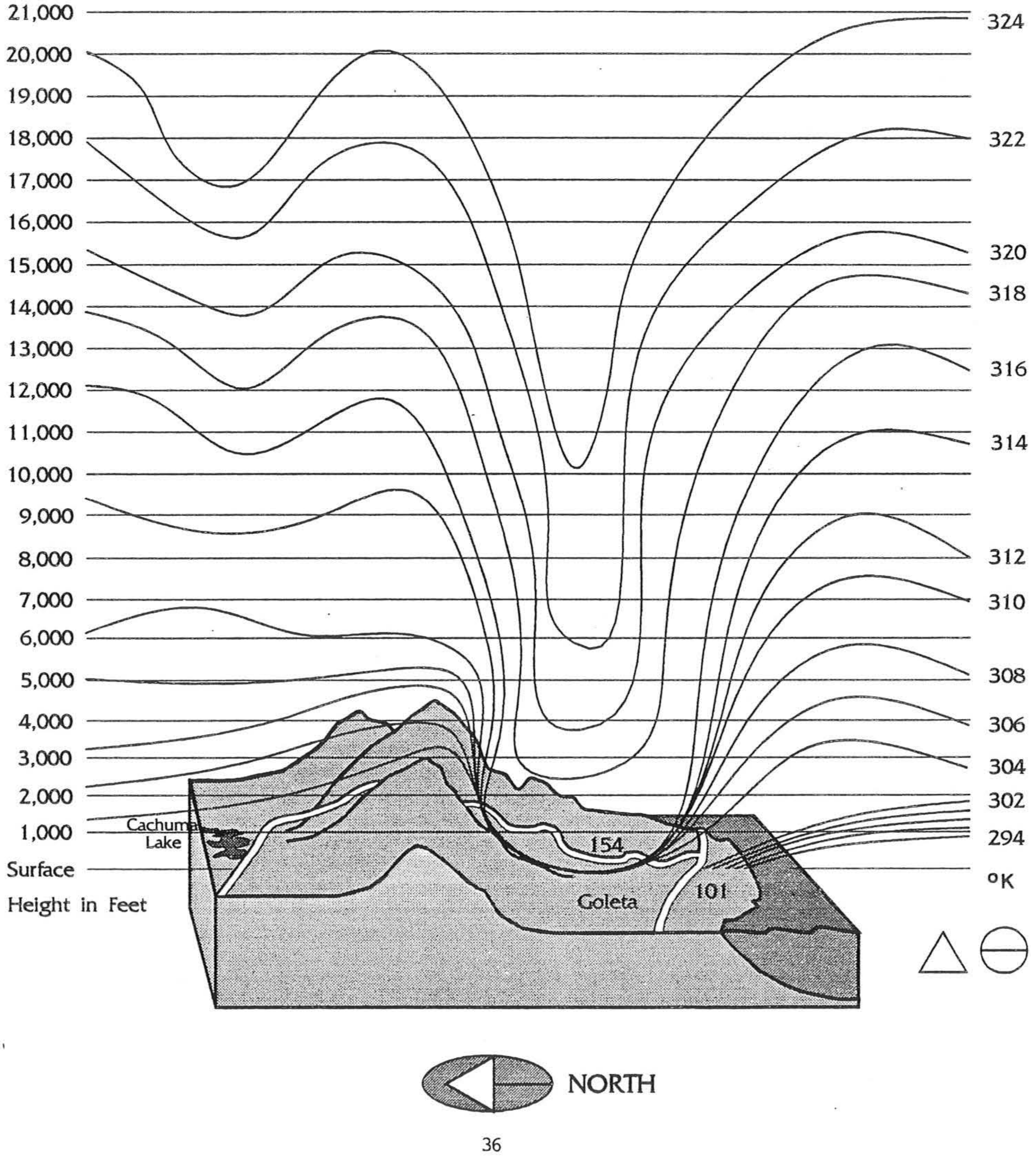
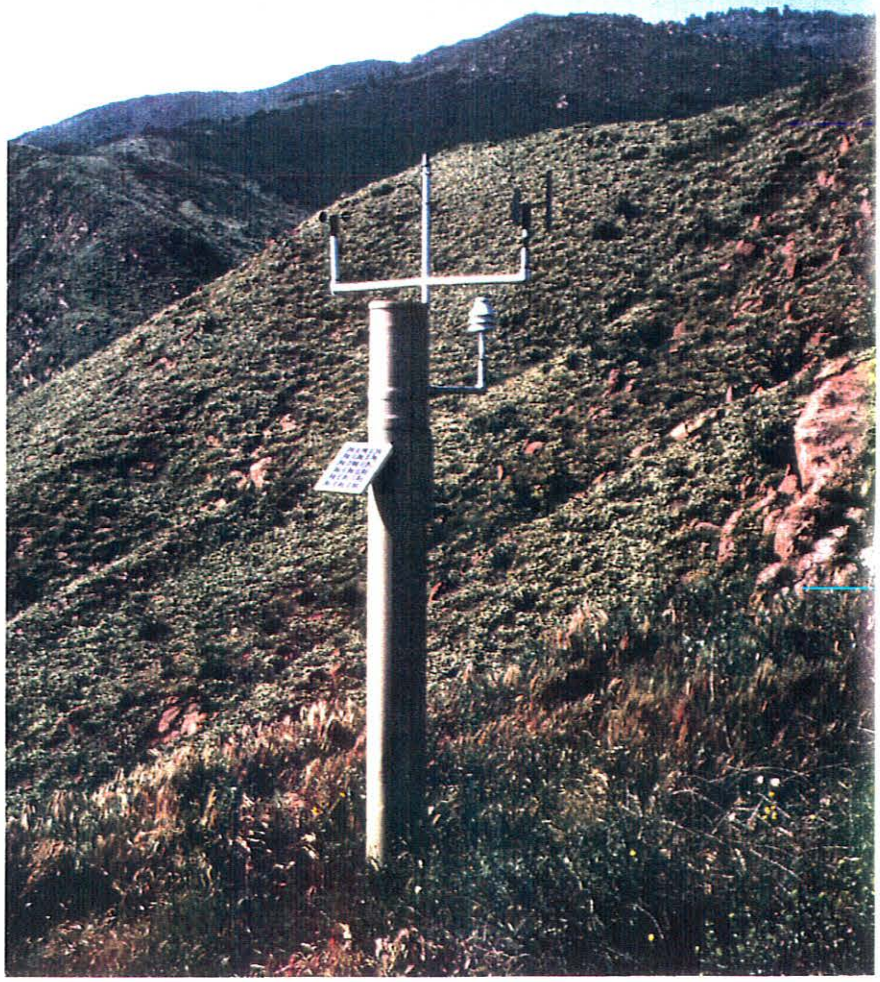


FIG
13

Figure 13.
MARIA YGNACIO RIDGE FOLLOWING PAINTED CAVE FIRE IN 1990.

Figure 14.
SANTA BARBARA COUNTY FLOOD CONTROL MET SENSOR ARRAY ON MARIA YGNACIO RIDGE.

FIG
14



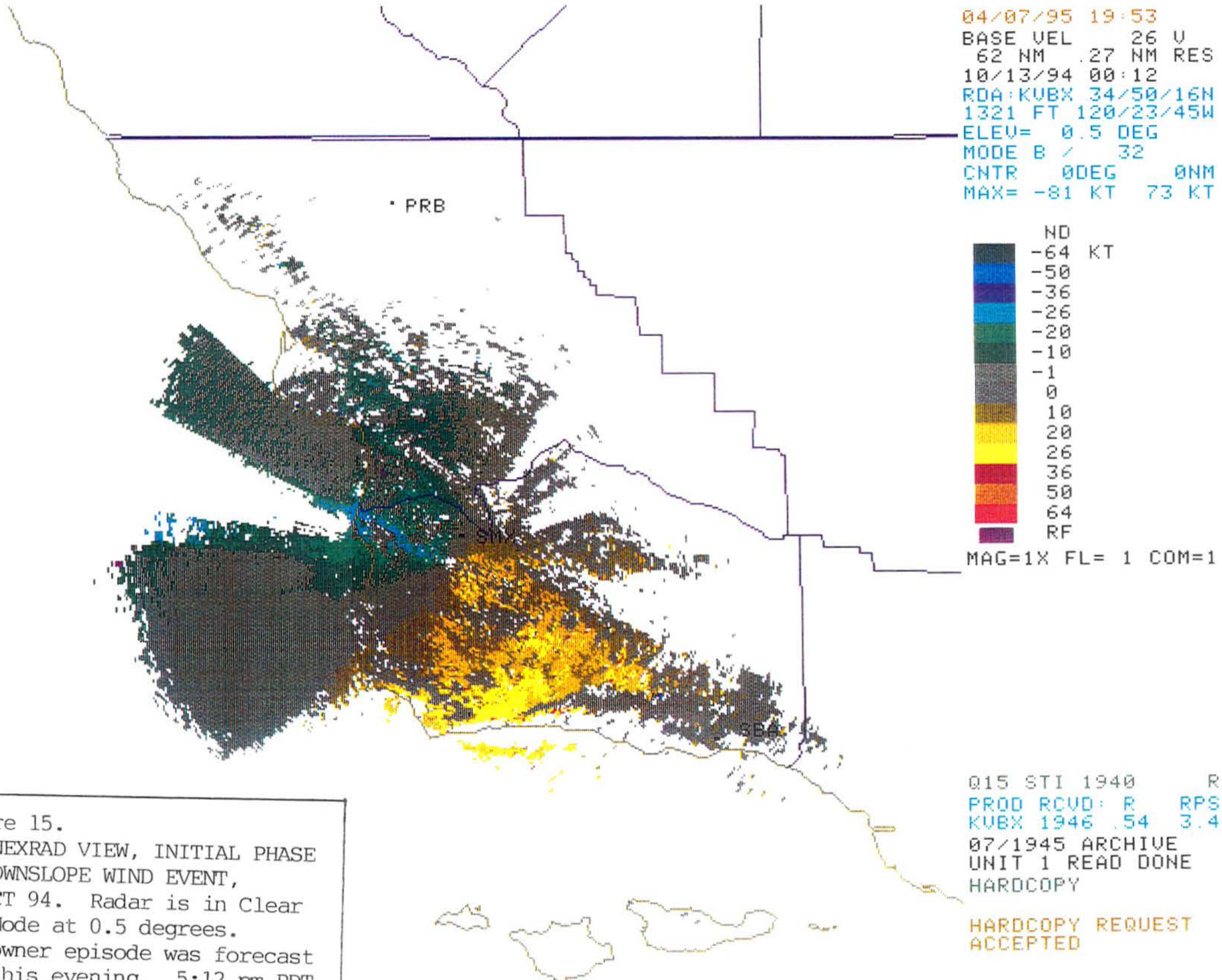


Figure 15.
VBG NEXRAD VIEW, INITIAL PHASE OF DOWNSLOPE WIND EVENT, 13 OCT 94. Radar is in Clear Air Mode at 0.5 degrees. Sundowner episode was forecast for this evening. 5:12 pm PDT.