FIRE WEATHER

EXTREME FIRE WEATHER UNDER PREFRONTAL—POST-SANTA ANA CONDITIONS

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ABSTRACT

In December 1977, a fire burned more than 10,000 acres at Vandenberg Air Force Base (VAFB) in southern California. A study of the worst fire weather conditions during the 3-day fire showed that a specific synoptic weather pattern was associated with it. This prefrontal -- post-Santa Ana pattern was marked by a short distance between a retreating ridge responsible for Santa Ana conditions and an advancing upstream trough with associated frontal system. Under these conditions, dry easterly winds persisted at low levels while moist winds from the southwest persisted aloft. An analysis of 15 years of weather data for the VAFB area showed only eight patterns that were similar to the one identified in the 1977 fire. The results suggest that the prefrontal -- post-Santa Ana pattern should be recognized as having potential for dangerous fire weather conditions in the VAFB area.

1. INTRODUCION

Extreme fire weather and a fire that burned more than 10,000 acres at Vandenberg Air Force Base (VAFB) in southern California, December 20-22, 1977, has stimulated interest in the synoptic weather pattern associated with it. The wind characteristics of that pattern need to be identified and frequencies of the pattern determined.

The worst fire weather conditions during the 3-day period -- simultaneous strong, erratic winds and low relative humidities -- were observed on December 20. On that day, a VAFB recording station near 2000-ft elevation indicated southeast winds at speeds up to 43 knots with gusts almost twice that. Relative humidities ranged from 14 to 24 percent. The fire, which began at 0709 PST on December 20, trapped and burned several persons who were near 600-ft elevation shortly before 1000 PST. Wind reports from near that location, to the southeast and at an elevation of 1530 ft, show that the wind shifted dramatically sometime between 0930 and 0935 PST.

Prevailing wind directions at VAFB are northwest through north-northwest, but southeasterly winds are not rare (Figure 1). East through south wind directions exist in 18.3 percent of all observations, and southeast winds (the primary direction recorded on the 20th) were present in 4.8 percent of the observations. Southeast winds with mean speed of 22 knots or greater, however, were recorded in only 0.1 percent of the hourly observations, and no observations showed southeasterly winds over 27 knots. Yet, on the 20th, at the same location, winds of 28 and 30 knots were recorded from the southeast for 2 hours.

Synoptic weather patterns, which produce critical fire weather in southern California, have been classified, by frequency, into four principal types: the subtropical high aloft, meridional ridge -- southeast flow, Pacific high -- postfrontal, and Santa Ana (3). The synoptic weather pattern of December 20-21, 1977, should also be recognized when defining extreme fire weather in parts of southern California.

2. DATA SOURCES

Except as mentioned in the text, data were taken from (a) microfilmed surface and upper-air maps originally obtained from the National Oceanic and Atmospheric Administration (NOAA), National Records Center; (b) copies of Air Weather Service Form 10, MF1-10A, or MF1-10 (Federal Meteorological Form for Surface Weather Observations) from NOAA, National Climatic Center; (c) computer output wind data from automatic weather stations located on VAFB obtained directly from VAFB; and (d) precipitation data, "California Climatological Data," from NOAA, National Climatic Center.

3. SYNOPTIC PATTERNS BEFORE AND DURING DECEMBER 20-22, 1977

Late on December 17, 1977, synoptic weather patterns signaled possible Santa Ana conditions. A cold front oriented northeast-southwest over the Vandenberg area was moving south at approximately 17 knots. Vandenberg received more than 0.5

inch of rain from the storm (4). The surface low associated with the cold front had moved eastward and was located over northeastern Oklahoma on the morning of the 19th. In the meantime, surface pressure was increasing rapidly over the Great Basin, while it was falling over coastal California. By 0400 PST on December 20 (Figure 2) the surface pressure difference between Los Angeles and Tonopah, Nevada, was -13.1 mb, much greater than the offshore surface-pressure gradient typically producing a Santa Ana (3).

At upper levels, a northerly wind component at 500 mb is usually present to support Santa Ana conditions. Such conditions were present at 1600 PST, December 19, 1977, when slight ridging along the coast produced a west-northwest flow at 500 mb over southern California. But, by 0400 PST on the 20th, the VAFB area lost all upper-level wind support for a Santa Ana, and 500 mb winds became southwesterly. Farther south in the San Diego area, however, the northerly wind support at 500 mb continued.

On the 20th, the surface weather pattern and the 500 mb pattern became atypical -- "out-of-phase" -- for a Santa Ana. A trough at the 500 mb level, located off the coast was moving eastward gradually. This resulted in the southwesterly winds aloft at the same time the Great Basin High at the surface was still building. Farther eastward, progession of the Great Basin High appeared to be stalled when the downstream trough intensified over the East-Central United States. Coupled with the next upstream low-pressure system moving in from the west, a strong offshore surface pressure gradient was maintained. The area was experiencing a critical fire weather situation that could be described best as prefrontal -- post-Santa Ana.

The prefrontal -- post-Santa Ana synoptic pattern is easily recognized, especially by those already familiar with the typical Santa Ana pattern (Figure 3). The surface map is similar to a Santa Ana with the intense surface high over the Great Basin. It differs in that the upstream surface front is already close to the southern California coast. The front is associated with a low pressure system off the coast, and is generally oriented north-south for this pattern to occur. At 500 mb, winds are southwesterly, in opposition to the typical Santa Ana.

During most Santa Anas, isobars are oriented either east-west or northwest-southeast. At Norton Air Force Base, San Bernardino (190 miles east-southeast of VAFB), for strong northerly winds under a Santa Ana, isobars are oriented "essentially east-west" (5). But on December 20-21 the isobars over the VAFB area were positioned nearly north-south (Figures 2 and 4). Generally, a Santa Ana condition will dissipate under prefrontal conditions, and successive fronts usually approach the area from the north or northwest. The lower pressure associated with such fronts is typically north or northeast of the area while, correspondingly, pressure is reduced over the Great Basin, resulting in the decay of the Santa Ana. But in the December 20-21 pattern, and others that we identified, southwesterly flow aloft and an associated surface cold front (oriented nearly north-south) to the west of the VAFB area, along with an intense Great Basin high pressure system at the surface, were the main synoptic features.

Cold fronts moving into the area during the winter months aligned north-south are not rare. What is unique in the December 20-21 pattern is the simultaneous occurrence of the north-south front and an exceptionally strong offshore surface pressure gradient. The front moved through the VAFB area on December 21 at approximately 9 knots. This is slow if compared with the average movement of a front through the area in December, which is 20 knots (6). Timing of the frontal passage at VAFB on the 21st was not recorded, but light rain showers began at 0503 PST. Relative humidities rose gradually, reaching 64 percent by noon on the 21st. With the approach of the front on the 20th, winds at many California coastal locations had shifted to southeast and continued strong southeasterly through the 22nd.

4. WEATHER AT VAFB AND SURROUNDING AREA DECEMBER 20-22, 1977

After the strong southeasterly flow pattern began, fire weather conditions in the VAFB area can be described best as Santa Ana type: "A foehn wind . . . produces some of the most critical fire weather conditions known. Humidities are frequently less than 5 percent . . . windspeeds may be 50 to 60 mph, with gusts to 100 mph" (3). On the 20th, relative humidities in the VAFB area were as low as 7 percent, and VAFB had 1-second wind gusts as high as 78 knots -- certainly an example of extreme fire weather.

The onset of strong dry winds in the general area is shown best at Bakersfield, where at 2200 PST on December 19, winds were northwest at 10 knots and relative humidity was 96 percent. Within 3 hours, however, by 0100 PST on the 20th, conditions had changed drastically. Winds had become southeast, relative humidity was now 19 percent and peak wind gusts had already been recorded at 26 knots. By 0400 PST, temperature at Bakersfield reached

64°F and relative humidity was 13 percent (Figure 2). This contrasts with the 37°F temperature and 100 percent relative humidity at Fresno.

Meanwhile, on the coastal side of the mountains at Santa Maria (238-ft elevation and 14 miles north-northeast of VAFB), the transition from a northwesterly wind condition to a strong southeasterly condition took longer than it did at Bakersfield. Winds from several directions were observed hourly on the morning of the 20th, but none were over 10 knots until 1400 PST (Figure 5).

Data from VAFB's automatic wind recording stations (Figures 5 and 6) indicated that the strong southeasterly wind condition had become the dominant pattern at VAFB by 0400 PST on the 20th. On the basis of 30-minute averages and 1-second gusts, station 055 at 1530-ft elevation recorded wind averages of 25 knots with a gust at 44 knots (25 + 44 knots); station 054 at 445-ft elevation had southeast winds of 15 + 27 knots; and station 103, near sea level, had 21 + 26 knots at 0400 PST.

Winds were plotted for 0730 PST (Figure 7). The fire at VAFB began at 0709 PST when relative humidities were near 20 percent and still dropping. Winds continued to increase in speed (Figure 5) and windspeeds and directions were plotted at VAFB for 0930 PST (Figure 8). Shortly before 1000 PST, the fire started burning northwest of station 055, where it resulted in several fatalities. A special wind sample from station 055, at 0955 PST, showed a 5-minute average windspeed of 34 knots from the west-northwest and a 1-second gust of unknown direction at 71 knots whereas the main weather station at 0955 PST, had southeast winds at 21 knots, gusting to 26. The strongest gust for the day at the main station, at 0912 PST, was 41 knots from the southeast.

The power failed between 1000 and 1100 PST and, therefore, no wind records from the automatic stations were available until 1100. At that time, station 055 was still recording erratic wind directions -- west-northwest at 33 knots with gusts to 78. At 1130 PST, station 055 (Figure 5) again had a 5-minute average wind direction from the southeast at 34 knots with gusts to 70. These erratic winds continued at station 055 through 1300 PST when a 4-knot wind from the northwest was recorded with a 1-second gust of 63 knots from an unknown direction. This erratic wind behavior, recorded at station 055, cannot be explained with the data available. An examination of wind data from 055 from different times with winds at other stations under different synoptic conditions, however, indicated that wind directions at station 055 were fairly consistent with wind directions at station 019 under strong (over 12 knots) wind conditions. But under weak wind conditions, station 055 often had winds more consistent with those of some of the lower-elevation stations.

Winds continued to be strong in the VAFB area through the night, and they remained southeasterly with similar strong speeds on the 21st. Even though rain showers began early on the 21st, relative humidities did not increase abruptly, and smoke from the fire was still being reported at 2040 PST.

Winds in the Santa Barbara area were compared for the 20th (Figure 5). At Santa Barbara Airport (near sea level and 45 miles east-southeast of VAFB), the apparent change to a steady southeasterly wind direction began between 0800 and 0900 PST. Winds at La Cumbre Peak (7) (4000-ft elevation just north of Santa Barbara), gradually changed from east-northeast at 10 knots at 0800 PST to southeast at 17 knots at noon (hourly averages). The 1200-ft elevation recording station at Santa Barbara had only 2 hours with southeasterly winds, 1100-1200 PST (5). Relative humidities in the Santa Barbara area were also extremely low, especially at the 1200-ft elevation station.

A special report was prepared by a meteorological research corporation (8) for a local utility company because several transmission towers were blown down during this windstorm. The towers were located southeast of Bakersfield near Grapevine and Wheeler Ridge along the north slope of the San Emigdio Mountains at 2625- and 2000-ft elevations. They were blown down at 1115 PST and 1514 PST on December 20. The report was based on a detailed study of the wind, specifically in the area of the towers. Results showed 5-minute average windspeeds ranging from 90 to 110 mph (78 to 96 knots) and 2-second gusts ranging from 125 to 150 mph (109 to 130 knots), with the extreme winds occurring where canyons funneled the winds. Wind directions varied per location from southeast to south-southeast, but the report contains no evidence of any extreme windshifts like those of station 055 at VAFB.

The report states that damage from the windstorm extended from the coastal areas of northern Mexico to Oregon. It shows San Nicolas Island to have had southeast winds at 25 knots on a morning and afternoon sounding at 1000 mb on the 20th. Pt. Mugu (90 miles east-southeast of VAFB), however, had winds at the 1000 mb level (approximately 200 ft above the station) from the northeast at 35 and 30 knots, the typical direction observed for Santa Anas. Farther inland, at San Bernardino (Norton

AFB), winds were calm most of the day, reaching a peak of 14 knots from the northwest at 1500 PST. Lowest relative humidity was 37 percent at San Bernardino.

Coastal temperatures in southern California, as typical for a Santa Ana, were much higher than those inland. Riverside, for example, had a maximum temperature of 64°F, on the 20th, whereas Los Angeles and nearby coastal cities had 71°F. San Diego had the highest temperature of all stations -- 76°F -- exceeding the Palm Springs high by 11°F.

5. IDENTIFYING PATTERNS SIMILAR TO PREFRONTAL -- POST-SANTA ANA

The outstanding synoptic features causing the extreme fire weather at VAFB have been described as (a) an intense high pressure system over the Great Basin with offshore surface pressure gradient similar to that usually required for a Santa Ana (at least -7.0 mb between Los Angeles and Tonopah), (b) isobars oriented over the area in nearly a north-south direction, requiring Los Angeles and Bakersfield to have nearly equal sea-level pressures, and (c) a surface cold front to the west of the area, oriented nearly north-south, and associated with (d) southwesterly flow over the area at the 500 mb level. Surface and 500 mb maps were examined for a 15-year period -- 1963-1964 and September 1968-June 1981. A total of nine occurrences of similar patterns were identified, including that of 1977 (Table 1). In all nine instances, based on Schroeder's criteria for a Santa Ana (9), a Santa Ana of varying time periods had just occurred and the high pressure system over the Great Basin was still intact.

Criteria for the strong offshore pressure gradient were met on many maps. But whether or not the coastal areas near VAFB had the strong and dry southeasterly winds, when the "Los Angeles to Tonopah" criteria were met, was a matter very sensitive to the orientation of the isobars. It was found that, if Los Angeles and Bakersfield differed by more than about 2 mb in surface pressure for very long, either the strong winds or the very dry conditions did not occur simultaneously, if at all. Relative humidities were increasing on December 21, for example, when the 0400 PST surface map (Figure 4) showed that difference to be 3.1 mb.

In all nine patterns, winds at the 500 mb level were southwesterly. This was the criterion that distinguished the pattern from being classified as a "pure" Santa Ana type.

Length of time of prefrontal -- post-Santa Ana conditions had no relationship to intensity (Table 1). The October 28-30, 1970 situation was only intermittent, unlike that in 1977, when once the strong southeasterly flow began, it persisted in the VAFB area for the full period.

In selecting the patterns, only the 0400 PST map was examined for a possible occurrence. If some of the criteria were met on the 0400 PST map, maps for every 3 or 6 hours were examined. Usually, when a pattern was identified, the 0400 PST hour did not represent the strongest segment of the period, and the data listed (Table 1) do not represent any specific hour during the pattern.

6. TYPICAL WEATHER UNDER THE PREFRONTAL -- POST-SANTA ANA PATTERN

Surface data for days of all patterns are not shown. Lower-elevation stations on VAFB, however, had maximum windspeeds at 13 to 15 knots with gusts near 20 to 25 knots from the southeast, and low relative humidities near 20 percent. At higher elevation stations, maximum windspeeds ranged from 20 to 25 knots with gusts to 30 or 40 knots.

During the February 21-23, 1976 pattern, winds at VAFB were southeast through south-southeast, depending on the station. Station 055 had a direction of 158°, slightly more southerly than that of the 1977 pattern. Winds tended to be weakest near midnight and strongest near 1000 PST and 1500 PST. Strongest average windspeed at station 055 was 22 knots and strongest 1-second gust was 33 knots. At the low elevations, a typical strong speed was 14 knots with gusts to 21 knots at station 103. (During this period Bakersfield had a low relative humidity of 13 percent, and Santa Maria had a low of 10 percent.)

The pattern on February 4-5, 1978, was rather short-lived in terms of low relative humidities. Lowest relative humidities at VAFB were 30 percent by the morning of the 4th, becoming 24 percent at 1130 PST when station 055 had southeast winds at 21 knots with gusts to 34 knots. Strongest windspeed recorded at station 055 was 30 knots with gusts to 55 knots from the southeast at 2200 PST on the 4th. Station 103 had average speeds of 24 knots with gusts at 32 knots for a maximum at 0400 PST on the 5th.

Maps for February 4-5, 1978 show the similarities of the 1977 pattern. The 1978 pattern, however, differs in that the front did not extend as far south as in the 1977 pattern, and pressure gradients between Los Angeles and Tonopah were not as strong offshore as in the 1977 pattern. Strong winds and low humidities did not occur simultaneously for very long, and rain was falling early on the 5th. On

the 3rd, when San Diego had zonal flow aloft, before shifting to strong southwesterly, the surface pressure gradient between Los Angeles and Tonopah was great enough to produce a brief, moderate Santa Ana condition.

To determine how surface weather differed under our prefrontal -- post-Santa Ana conditions from those of a typical Santa Ana, we examined weather at VAFB on 64 days when the broad-scale classification of a Santa Ana (10) occurred. Average minimum relative humidity at VAFB on those days ways 32 percent and the average maximum windspeed recorded was 8 knots -- less sever than the conditions we have described.

7. SUMMARY

The prefrontal -- post-Santa Ana pattern described is marked by a short distance between a retreating ridge responsible for Santa Ana conditions and an advancing upstream trough with associated frontal system. With these conditions, dry easterly winds persist at low levels while moist winds from the southwest persist aloft. Rain may even fall through the dry air and reach the surface.

In the 15 years of data examined, only 8 weather patterns were identified as similar to the pattern of December 20-22, 1977. In the eight instances, wind behavior was not as erratic as that recorded on December 20, 1977, for station 055. We did not discount the data; further investigation is necessary to either explain or substantiate it. We have included the data because the instrumentation appeared to be functioning properly both before and after the erratic behavior, and because data from station 055 is generally consistent with data from station 019 or the lower elevation stations and does not appear to have a miniwind climatology of its own.

In the 15-year period examined, the "case-pattern" occurred at least once every 3 years. In 1970 and 1973 the pattern occurred twice each year; in 1973; the two occurrences were within 4 days of each other. All nine instances of prefrontal -- post-Santa Ana conditions occurred in October through February. On the basis of the average number of true Santa Anas from October through February, we can expect that 5 percent of the Santa Anas would later become the type of pattern described. We suggest that this information be used to supplement the "Synoptic Weather Types Associated with Critical Fire Weather" (3) for those people involved with weather-related management activities in the area of VAFB. The synoptic weather pattern that we have referred to as prefrontal -- post-Santa Ana should be recognized as a pattern resulting in potentially dangerous conditions in the VAFB area should a fire occur.

Table 1. Dates of patterns identified as prefrontal -- post-Santa Ana in which winds in the Vandenberg Air Force Base area were strong southeasterly and relative humidities were very low. The table also lists pertinent pressure gradients and 500 mb windflow.

Dates of Occurrence*	Large-Scale Surface Pressure Differences (mb) Los Angeles - Tonopah	Los Angeles - Bakersfield	500-mb Wind (knots) at VAFB***
October 28-30, 1970	-12.0	-2.0	SW/5
November 14-15, 1970	-13.0	+1.0	SW/25
February 4, 1972 (weak)	- 8.0	0.0	SW/25
January 28-29, 1973	-10.0	0.0	SW/65
February 2-3, 1973	- 8.0	0.0	SW/40
February 21-23, 1976	- 9.7	-0.7	SW/15 and 45
December 20-21, 1977**	-13.1	+0.4	SW/30
February 4-5, 1978	- 7.1	+0.9	SW/45
January 2, 1979	-11.7	-1.0	SW/15

* Data provided do not represent any specific hour of the period.

** This occurrence resulted in extreme fire conditions that prompted the study of prefrontal -- post-Santa Ana conditons and their frequency.

*** In all nine occurrences, winds at the 500 mb level were southwesterly. This fact distinguished the pattern from the Santa Ana type.

SURFACE WINDS

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED
(FROM HOURLY OBSERVATIONS)

93214 (STATION) VANDENBERG AFB CALIFORNIA (STATION NAME) 51-53,58-70 (YEARS) ALL (MONTH)

ALL WEATHER (CLASS) ALL (HOUR (L.S.T.))

34°43',120°34', 381' (LOCATION)

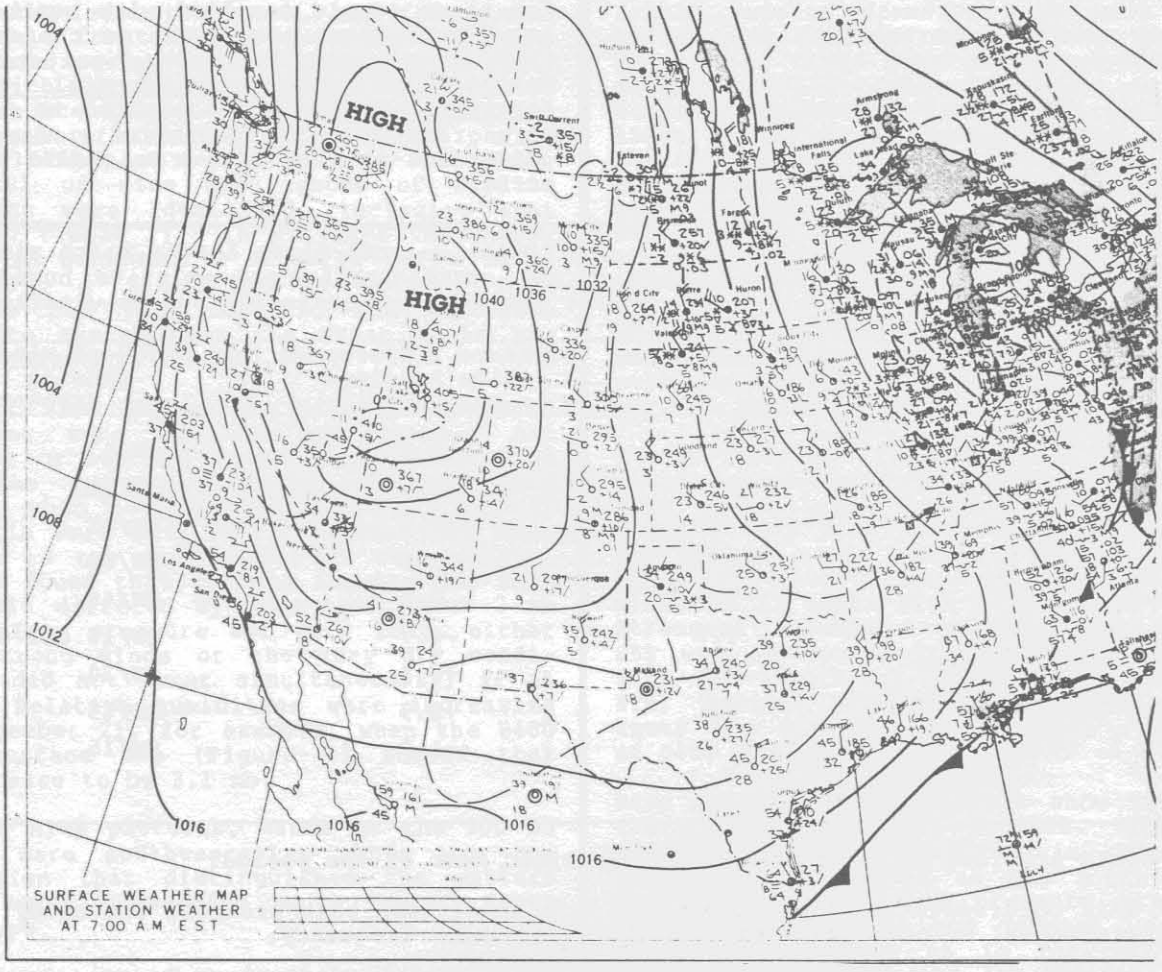
13' (HEIGHT ABOVE GROUND)

SPEED (KNTS) DIR.	1 - 3	4 - 6	7 - 10	11 - 16	17 - 21	22 - 27	28 - 33	34 - 40	41 - 47	48 - 55	≥56	%	MEAN WIND SPEED
N	1.7	2.6	1.7	.8	.1	.0	.0					7.0	6.4
NNE	.8	.9	.5	.3	.0	.0	.0					2.5	5.6
NE	.7	.6	.2	.1	.0	.0						1.6	4.7
ENE	.5	.3	.1	.0	.0		.0					.9	3.7
E	1.5	2.1	.6	.1	.0							4.4	4.7
ESE	1.7	3.3	1.3	.3	.0	.0	.0	.0				6.7	5.3
SE	1.2	1.8	.9	.7	.2	.1	.0					4.8	7.1
SSE	.3	.3	.3	.2	.1	.0	.0					1.2	7.4
S	.3	.3	.3	.2	.0	.0						1.2	7.5
SSW	.2	.2	.2	.1	.0	.0	.0					.7	6.8
SW	.3	.5	.4	.2	.0	.0						1.4	6.8
WSW	.3	.6	.7	.1	.0							1.7	6.4
W	.8	2.5	2.4	.3	.0	.0						6.1	6.4
WNW	.9	2.6	3.1	1.0	.1	.0	.0	.0				7.6	7.8
NW	1.9	5.5	8.2	4.9	1.1	.4	.0	.0				22.1	9.0
NNW	1.5	3.8	4.4	2.7	.6	.1	.0	.0				13.2	8.4
CALM												16.9	
16.9	14.7	27.9	25.3	12.0	2.4	.7	.1	.0				100.0	6.1

DATA FROM NATIONAL CLIMATIC CENTER
FEDERAL BUILDING - ASHEVILLE, N.C., 28801

TOTAL NUMBER OF OBSERVATIONS 115324

Figure 1. Frequency table of windspeeds and directions for Vandenberg Air Force Base, California (from Bulletin No. 185, Wind in California, State of California, Department of Water Resources, 1978).



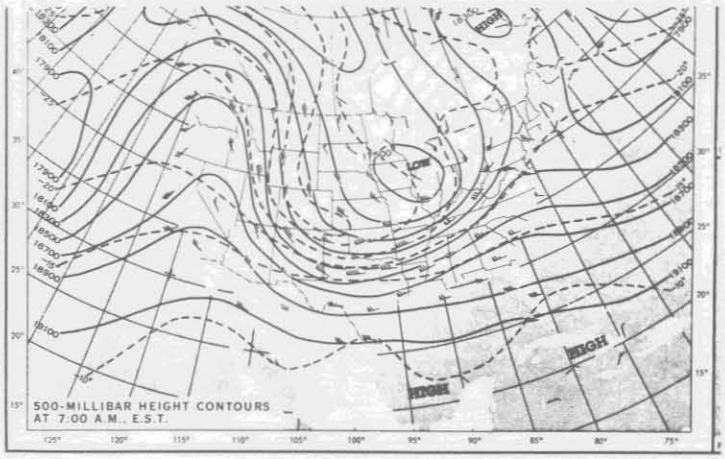
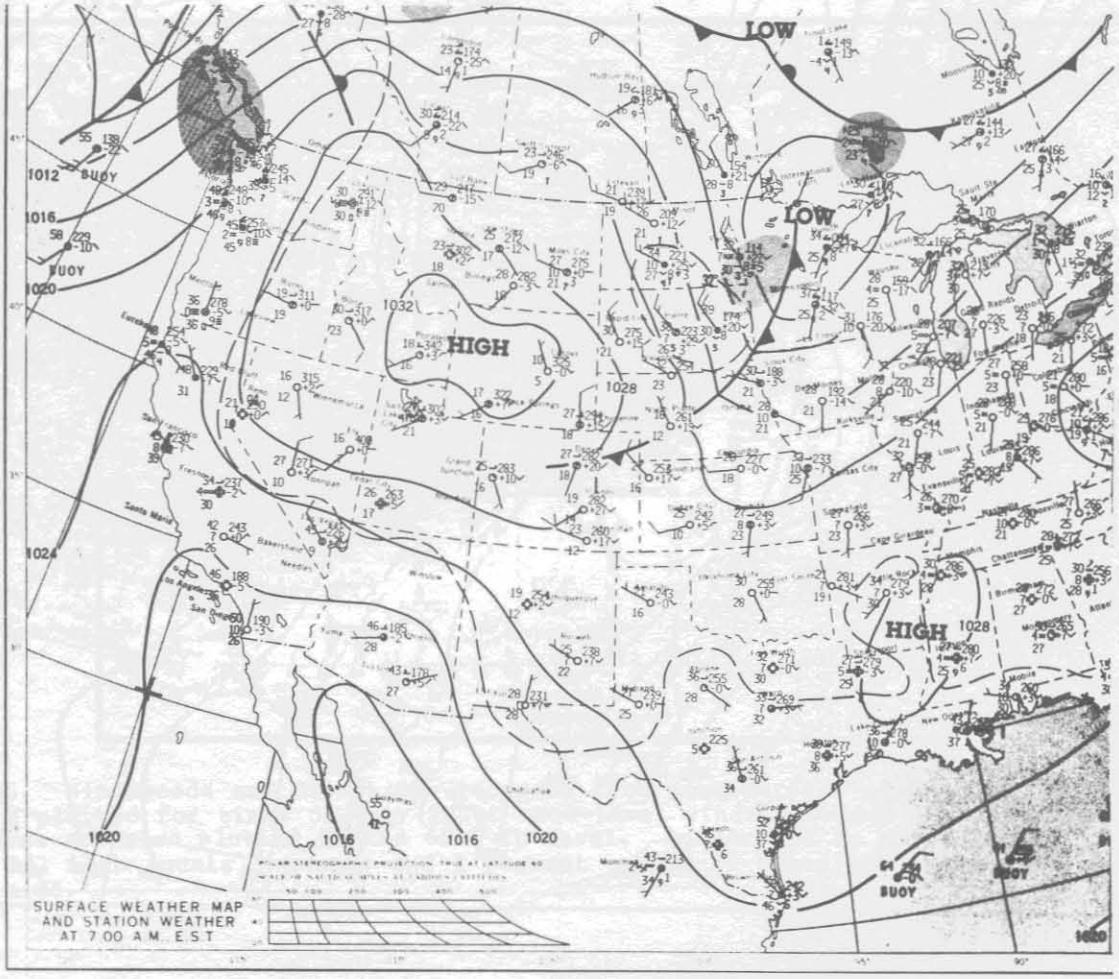


Figure 2. Surface and 500 mb maps for 0400 PST December 20, 1977. The small area shaded is part of the Vandenberg Air Force Base Test Range where, at that time, a 1530-ft elevation weather station recorded winds from 131° with a 5-minute average of 25 knots and a 1-second gust at 44 knots.



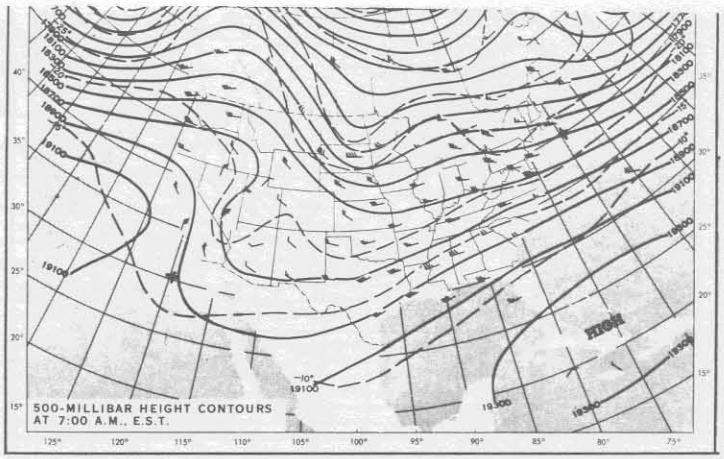
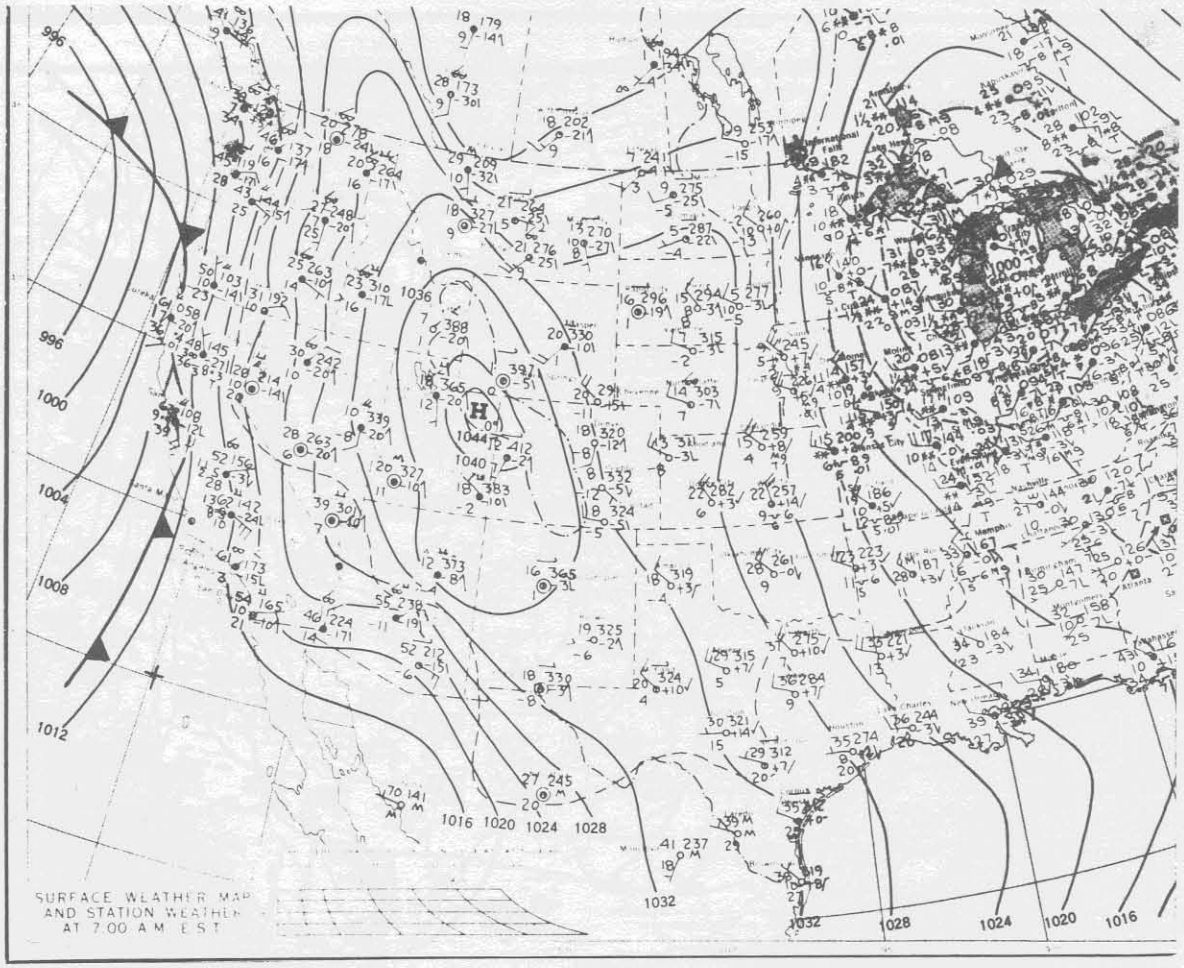


Figure 3. Surface and 500 mb maps for 0400 PST November 20, 1980, showing the patterns typical for Santa Ana conditions in southern California.



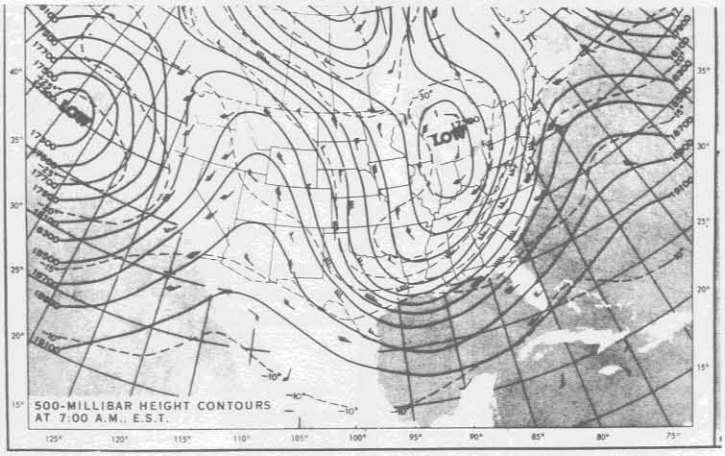


Figure 4. Surface and 500 mb maps for 0400 PST, December 21, 1977. The shaded insert shows the location of part of the Vandenberg Air Force Base Test Range. At 0400 PST, the official 368-ft elevation station at the Base reported southeast winds at 12 knots, 14 percent relative humidity, and an overcast cloud condition with cloud bases estimated at 8000 ft. By 0503 PST, light rain showers began.

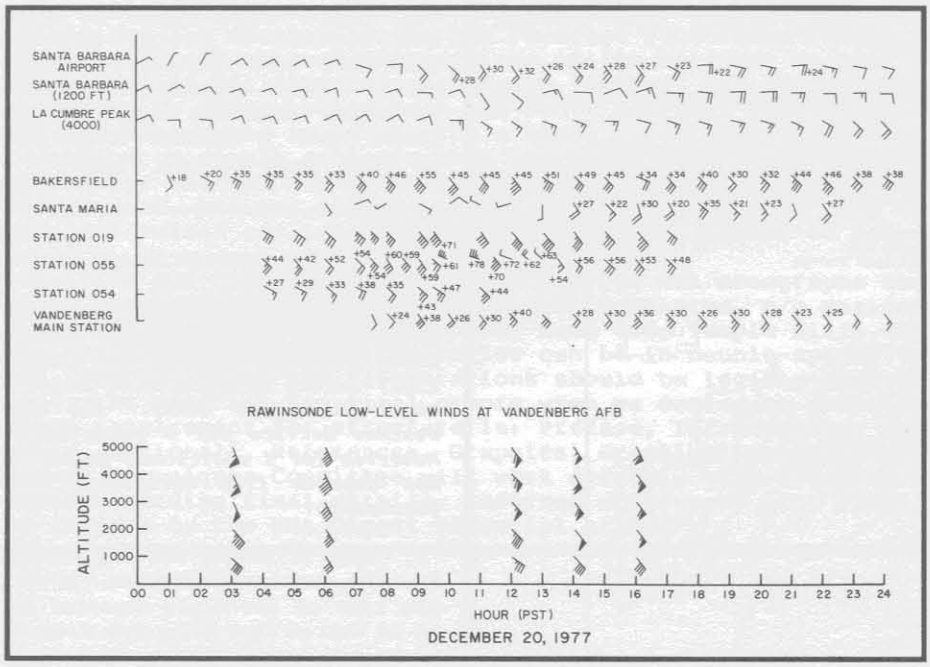


Figure 5. Windspeeds and directions recorded from nine surface stations on December 20, 1977 are plotted for times of day (PST). Low-level winds recorded by the Vandenberg Air Force Base are also plotted to the 5000-ft level. Speeds are in knots (1 barb equals 10 knots, 1/2 barb equals 5 knots, and 1 pennant equals 50 knots) and peak gusts are shown at the side.

Figure 6. Locator map for the main weather station at Vandenberg Air Force Base and some of the automatic wind recording stations. Elevations (feet) are listed below the stations.

Figure 7. Windspeeds (knots) and directions recorded at Vandenberg Air Force Base at 0730 PST, December 20, 1977. Each full barb represents 10 knots, each half barb equals 5 knots, and gusts that were recorded are placed at the end of the barb. Main windspeeds are 30-minute averages and peak gusts are 1-second averages. (Direction of peak gust is not known.)

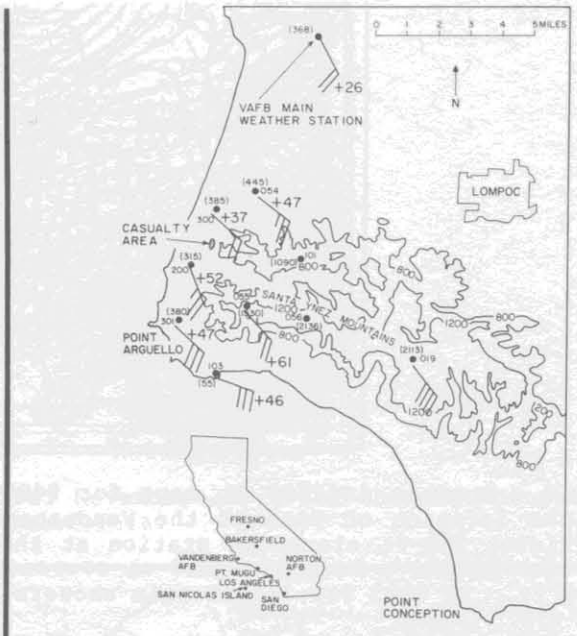


Figure 8. Windspeeds (knots) and directions recorded at Vandenberg Air Force Base at 0930 PST, December 20, 1977. Each full barb represents 10 knots, each half barb equals 5 knots, and gusts that were recorded are placed at the end of the barb. Main windspeeds are from 5-minute averages (timing was changed) and peak gusts are 1-second averages. (Direction of peak gust is not known.)

REFERENCES AND FOOTNOTES

1. Bernadine A. Taylor, until her retirement in 1982, was a meteorological technician at the Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Riverside, Calif. She served in the Air Weather Service for 3 years (1953-56) and in the Reserves for 3 additional years. She holds BA and MBA degrees from California State College, San Bernardino.

2. Lola M. Thomas was a statistical clerk at the Pacific Southwest Station, Riverside, Calif. at the time of the study reported herein. She holds an AA degree from Riverside City College.

3. Schroeder, M.J., M. Glovinsky, V.F. Herndricks, F.C. Hood, M.K. Hull, H.L. Jacobson, R. Kirkpatrick, D.W. Krueger, L.P. Mallory, A.G. Oertel, R.H. Reese, L.A. Sergius, C.E. Syverson, 1964. Synoptic weather types associated with critical fire weather. Pacific Southwest Forest and Range Experiment Station, Berkely, CA. 492 pp.

4. A statistical forecasting aid for Santa Anas at Point Mugu is that 25 percent of wet fronts are followed by a Santa Ana within 4 days. See Rosenthal's (1972) Point Mugu forecasters handbook, PMR-TP-721, Pacific Missile Range, Point Mugu, CA. 425 pp.

5. Rasmussen, Milton M., 1971. Northerly winds at Norton AFB. Military Airlift Command, Air Weather Service, Det. 14, 7th Weather Wing, Norton AFB, CA. 26 pp. (Unpublished report).

6. Taylor, B.A., 1974. Frontal movement through southern California. Pacific Southwest Forest and Range Experiment Station, Berkeley, CA. 5 pp. (Unpublished report).

7. Data were recorded by Forest Service personnel. Winds were from MRI mechanical recording stations, and relative humidities from hygrothermograph.

8. Gouze, S.C., M.C. Richmond, 1978. The meteorological study of the December, 1977 windstorm along the number 1 and 2 midway-Vincent 500 kv transmission line route on the north slope of the San Emigdio mountains. Meteorology Research Corporation, Altadena, CA. 22 pp.

9. This publication states that a Santa Ana has rarely been observed to occur with zonal flow aloft, but it makes no mention of Santa Anas occurring with an opposing southwesterly flow aloft.

10. Schroeder (1964) has suggested that subclassifications of his major "critical fire weather types" could be made to achieve more refinement for individual geographical areas within his categorized regions.

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