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A Case Study of the Santa Ana Winds in the San Gabriel Mountains

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ABSTRACT: Santa Ana wind structure varies between the high main ridges, the foothills, and the canyon bottoms. In each of these regions, a typical pattern characterizes the Santa Ana. Strong steady winds at the high levels are determined almost completely by the large scale weather patterns. Intermediate canyons and ridges are affected by Santa Ana winds only when the foehn is well developed. The low lee side foothills are affected only on the most intense days.

The north and east Santa Ana winds of southern California bring about extremely high fire danger because they are accompanied by low humidities and often by high temperatures. Fires during Santa Ana periods, for example--the 1961 Bel Air Fire, are difficult or nearly impossible to control and can endanger lives and property. To have a better chance of controlling such fires, we need to understand how the Santa Ana winds begin, develop, and die.

Campbell (1906) suggested that the Santa Ana may be a foehn wind, and Krick (1933) established the foehn origin of the air. Much research has been done on foehn winds in the Alps. In three-dimensional studies, Von Ficker (1905) described the wave motion associated with the foehn at Innsbruck, Austria.

More detailed studies of these wave motions have been provided by Kanitschieder (1931). Various mechanisms have been described to account for the descent of the foehn (Gutman and Tebuev 1961; Streiff-Becker 1931; Von Ficker 1931). Lee waves are now considered the primary descent mechanism. Lee waves within the mountains are highly complex and detailed studies of the flow patterns are necessary to their understanding.

THE MT. BALDY SURVEY

To investigate the life history of a Santa Ana, data[1] were collected at 16 fireclimate stations in the Mount Baldy District of the Angeles National Forest, north of Glendora, California (fig. 1).

[1] Data for this study were collected by Mark J. Schroeder and Clive M. Countryman, both of the Pacific Southwest Station.

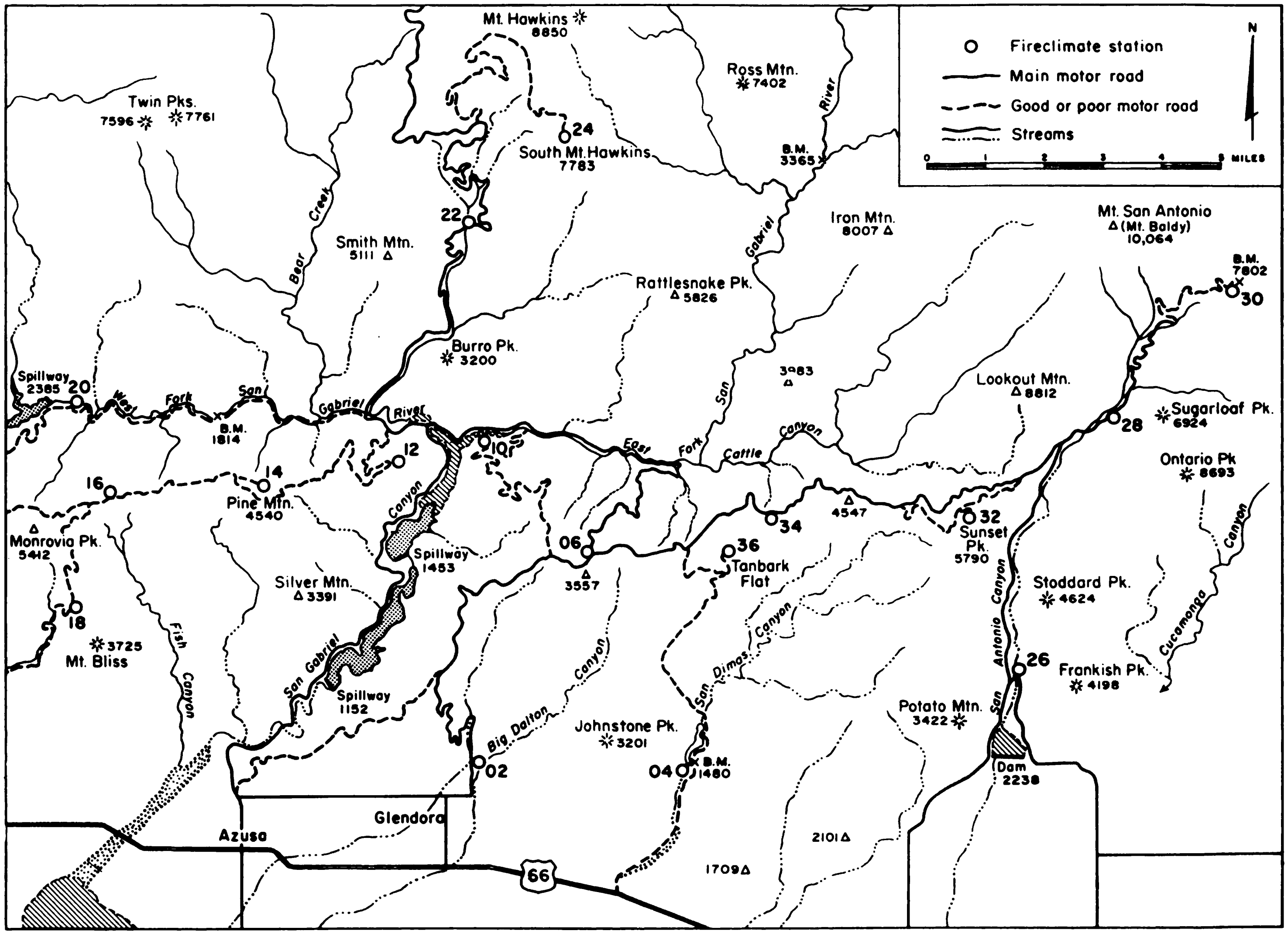

Figure 1.--Network of weather stations for Mount Baldy fireclimate survey.

Data consisted of wind, temperature, and humidity measurements from October 26 through November 7, 1958. Figure 2 gives wind speeds at selected stations at noon for each day of this survey. The general picture shows that this Santa Ana was a moderately warm one.

The high level stations (Nos. 24, 30), the intermediate canyons (Nos. 10, 12, 22, 28), the canyon mouth (No. 26), and the sheltered lee slope station (No. 36) each show a different aspect of the life history of this Santa Ana. Station 30, near the ski lift on Mt. Baldy, showed strong, steady winds during the entire period. At South Mt. Hawkins (Station 24) the Santa Ana showed an eddy so that winds were light and wind direction was quite variable.

The sheltered lee slope station (No. 36) experienced Santa Ana winds only on the strongest days. Tanbark Flat is protected by the up-wind ridge.

The intermediate canyon stations (Nos. 22, 28), like the lee slope stations, showed a variable wind regime. At times, up-and downcanyon winds predominated, but during more intense periods of the Santa Ana, lee slope stations also experienced strong downslope winds.

Intermediate level stations 10 and 12, on the other hand, reacted somewhat differently to Santa Anas than intermediate canyon stations 22 and 28. Daytime upcanyon flow diverged and followed both forks of the San Gabriel River. At night, the shallow down-slope winds met at the fork, merged, and flowed out through San Gabriel Canyon. When the Santa Ana penetrated into the canyon, the convergent flow contained many eddies; the wind direction and speed were both extremely variable.

Areal variations in the Santa Ana are illustrated in Figures 3, 4, and 5, for a 20-hour period when the Santa Ana affected only the high levels at the beginning, and at the end began to scour out the canyon.

At 2000 P.s.t., 27 October 1958 (fig. 3), only high level station 30 had Santa Ana winds, although high level station 24 may have been under slight Santa Ana influence. All the other stations exhibited normal nighttime downcanyon winds. The two flows can easily be separated because of the significant difference in speed. Wind speeds in the canyon bottom were 1 to 6 miles per hour; during the Santa Ana, winds were 8 to 12 miles per hour.

In the San Gabriel Canyon, the Santa Ana had not reached down to the surface at 1200 P.s.t, 28 October 1958 (fig. 4). This was demonstrated by the upcanyon winds at intermediate level stations 10 and 12. In the San Antonio Canyon and the north fork of the San Gabriel River, the Santa Ana had begun to scour out the canyons.

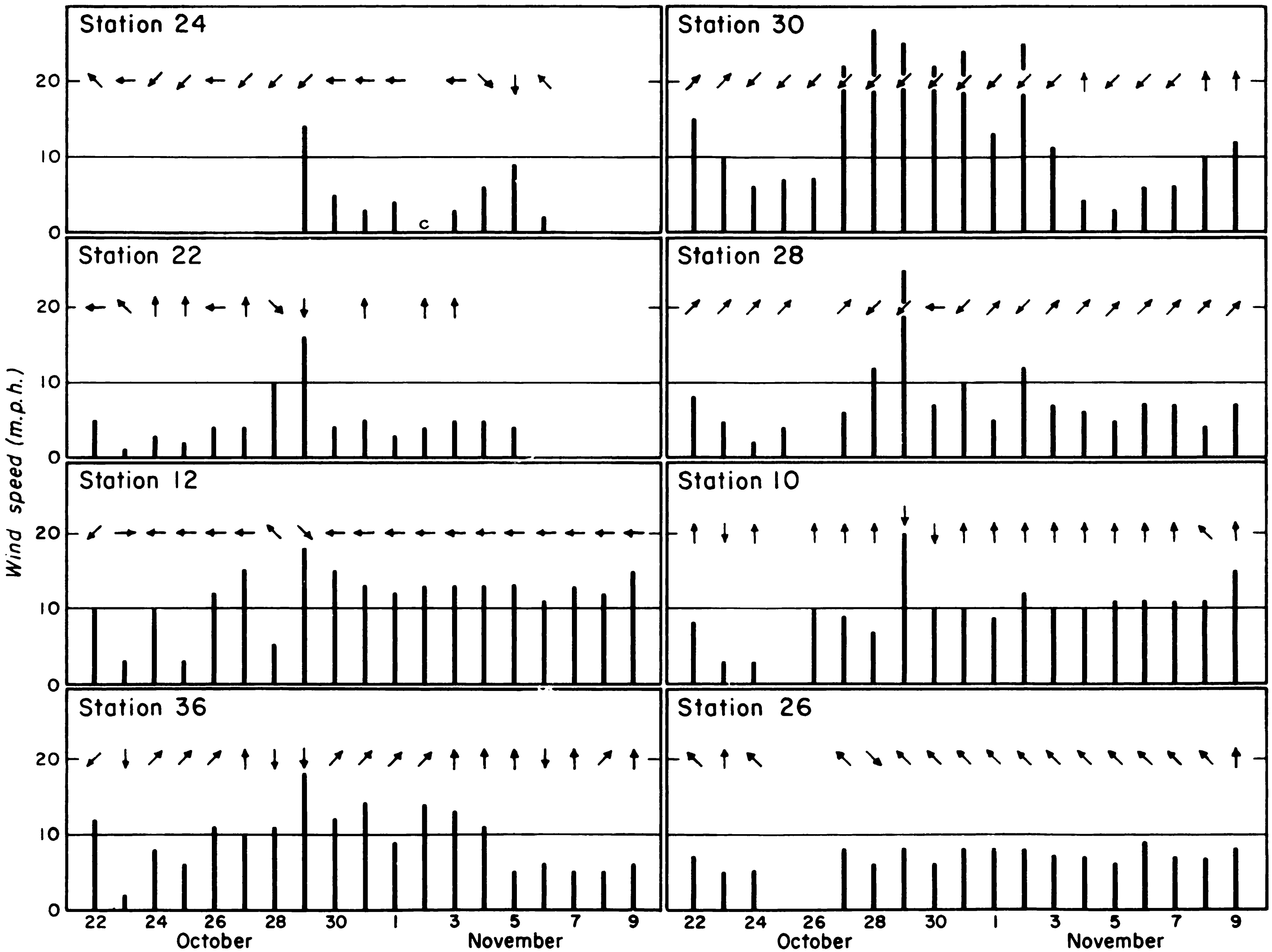

Figure 2.--Wind data for selected stations. Length of bar shows wind speed, and arrow head shows wind direction. Where bars and arrows are not shown, data were not available.

Table 1.--*Speed and direction of Santa Ana winds measured at station 30 at 4-hour intervals, October 22-November 9, 1958*

Time (hours)	Normal conditions October--		Period of change October--		Santa Ana days									Period of change November--				Normal conditions November--	
					October--						November--								
	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9
	M.p.h. and direction																		
0400	11 S	14 SW	8 N	8 S	3 NE	20 NE	22 NE	36 NE	28 N	20 NE	14 NE	31 NE	13 NE	3 NE	6 S	10 N	9 S	8 S	10 S
0800	15 SW	12 S	12 N	5 SW	4 NE	25 NE	28 NE	38 NE	24 N	20 NE	8 NE	31 NE	12 NE	9 S	4 E	9 NE	2 S	11 S	14 S
1200	15 SW	10 SW	6 NE	7 NE	7 NE	22 NE	27 NE	25 NE	22 NE	24 NE	13 NE	25 NE	11 NE	4 N	3 NE	6 NE	6 NE	10 S	12 S
1600	11 SW	11 S	6 SW	9 NE	11 NE	25 NE	33 NE	28 NE	13 NE	9 NE	16 NE	8 NE	6 NE	6 NE	- -	5 S	5 NE	8 S	13 S
2000	12 SW	12 S	6 S	2 N	12 NE	19 NE	28 NE	24 NE	7 NE	4 NE	17 NE	15 NE	2 NE	14 N	11 N	8 S	5 NE	10 SW	14 S
2400	15 SW	6 S	9 S	2 N	13 NE	20 NE	37 NE	35 NE	12 N	17 N	26 NE	19 NE	2 SW	4 NE	10 NE	- -	5 N	11 SW	14 S

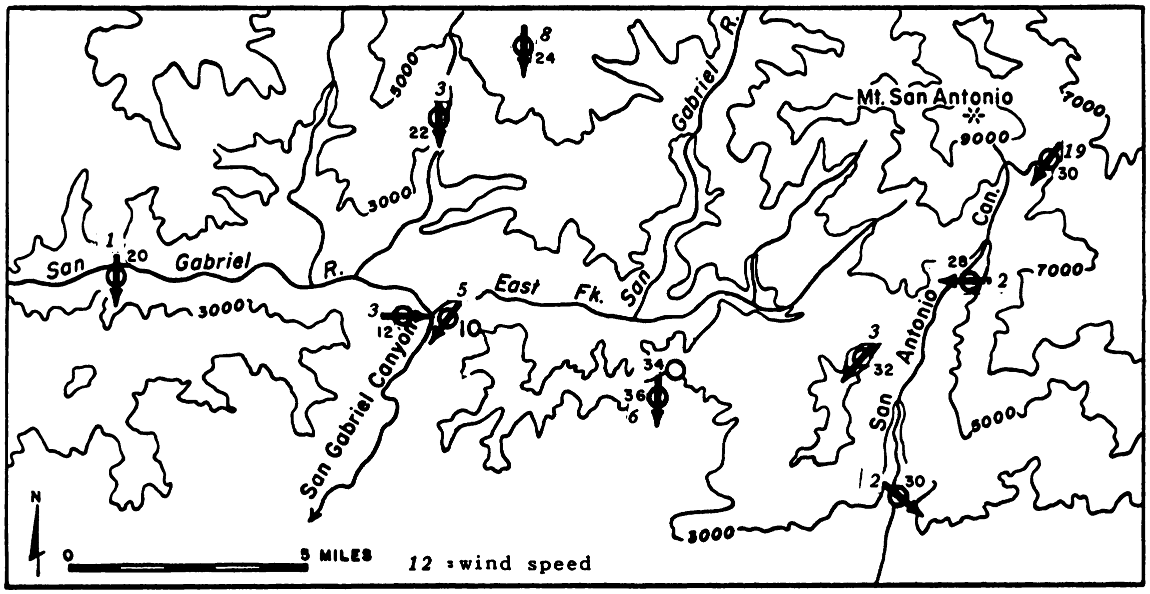

Figure 3.--Surface weather map 2000 P.s.t., 27 October 1958. Only main ridge stations were affected by the Santa Ana.

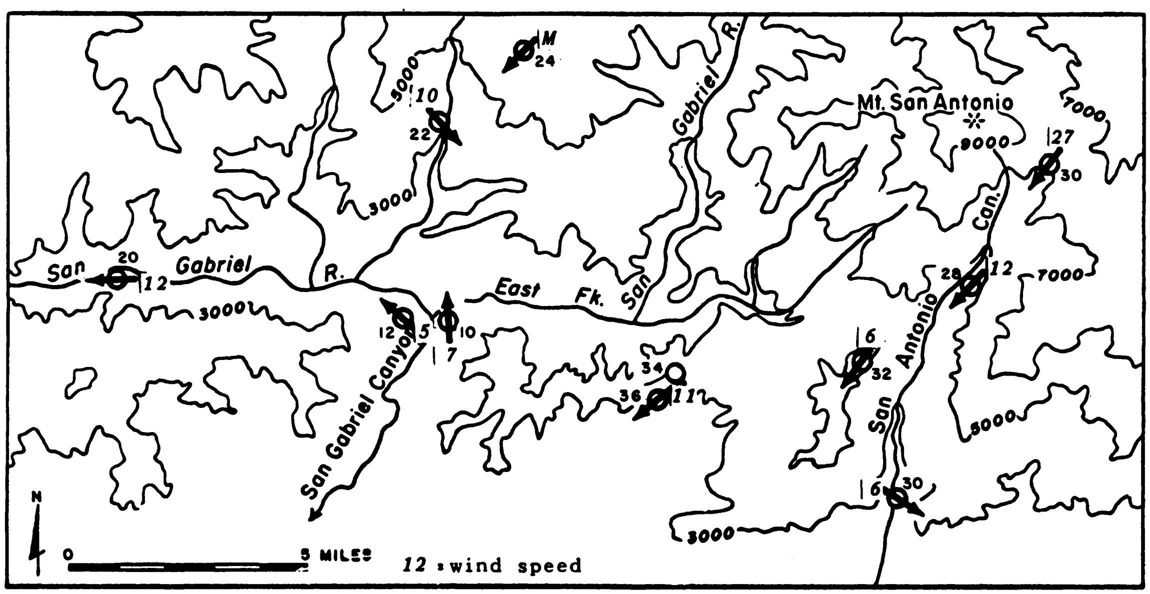

Figure 4.--Surface weather map, 1200 P.s.t., 28 October 1958. The Santa Ana had reached down into some of the intermediate level canyons.

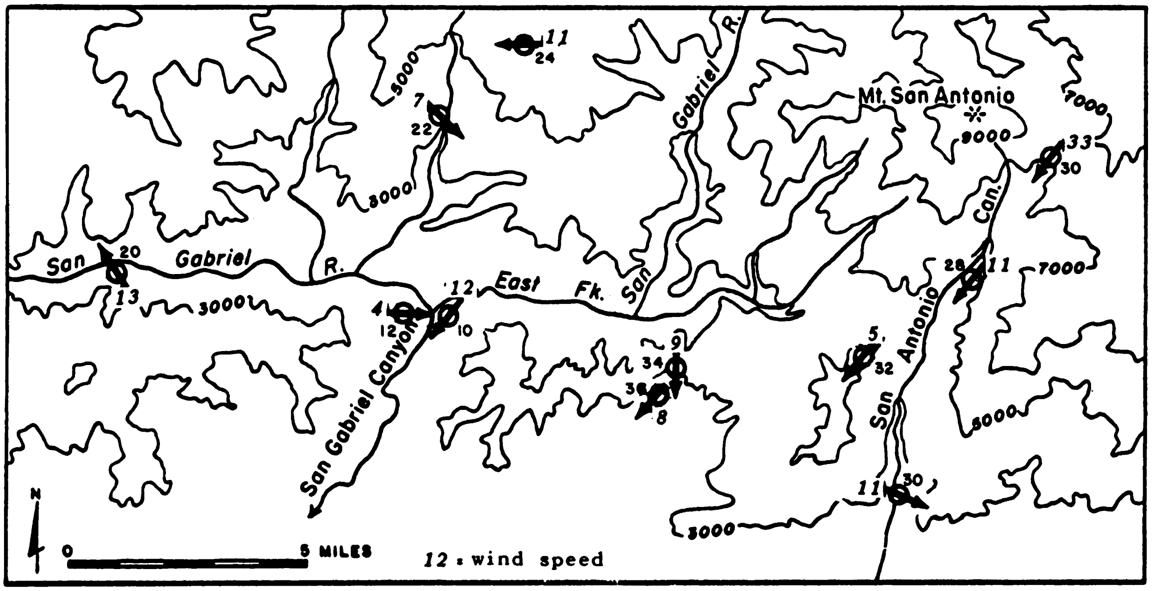

Figure 5.--Surface weather map, 1600 P.s.t., 28 October 1958. Fully developed Santa Ana affected all weather stations.

The trough line at 700 and 500 mb passed east of the area at this time so that the synoptic flow pattern was now normal to the mountains. The fully developed surface Santa Ana (fig. 5) followed the canyon to lower levels. All stations had strong descending winds when compared to normal drainage flow.

The life cycle of this Santa Ana lasted about 15 days from the time the variable pattern became apparent until the normal pattern returned (table 1). Santa Ana winds can complete their life cycle much more quickly. They can be as short as one or two days; mean life is about three days.

Wind patterns at the lower elevation stations were quite different than at high level station 30. At low level station 28 (fig. 1), the Santa Ana did not appear until October 28--four days after the variable winds began at station 30. When the wind speed dropped at station 30, the winds at station 28 returned to normal. At canyon mouth station 26, the wind direction was unaffected by the Santa Ana except on October 28, the day of the highest wind speeds at station 30. Winds at high level station 24 were erratic. Apparently there was an eddy in the vicinity, although there were not enough data to detect or describe it.

CONCLUSIONS

Although this case was an extraordinarily long Santa Ana, it illustrates the life history of foehn winds quite well. And other than the length of time involved, it may be considered typical of the development and decay of a Santa Ana. Three distinct regions stood out in this analysis: the high country, which was affected by strong northeasterlies; the intermediate canyons, in which Santa Ana winds blow only when the foehn is well developed; and the canyon mouths which were affected only during the most intense Santa Ana days. When the foehn is not intense, the canyon mouths and the intermediate canyons experience the more normal mountain and valley winds.

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