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An Example of Nighttime Drying in the Santa Ana Mountains

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ABSTRACT: Humidity patterns near the 500- to 1,000-meter level on California's coastal mountains often show an anomolous decrease in the moisture content at night and early morning. A study in the Santa Ana mountains suggests that nighttime downslope winds provide the most satisfactory explanation for the decrease in moisture because of their effect on the marine layer.

The moisture content of air is one of the most important determinants of forest fire behavior. It often shows an unusual pattern at mid-elevation in the coastal mountains of the western United States. Instead of rising as night approaches, it may sometimes drop sharply to a point even lower than at mid-afternoon. The firefighter not aware of this phenomenon may find himself relaxing as relative humidities and moisture content begin to rise--only to find a sharp reversal in the weather trend. Suddenly he faces a situation more dangerous than that during the day.

This nighttime drying has been previously reported by Schroeder[1] and by Lowry[2]. Lowry's study in the Valsetz Basin of Oregon[3] showed evidence of the phenomenon at all elevations. He advanced the hypothesis[2, 4] that the drop in moisture content and the decreased depth of the marine layer were caused by a gravity wave on the marine inversion. The shallow portion of the wave was over the mountains during the day and over the valleys at night.

Schroeder[1] also attributed the decrease in relative humidity and absolute moisture content to the lowering of the marine inversion, but his explanation was the movement of the more moist air

[1]Schroeder, Mark J. Humidity patterns at middle elevations in the coastal mountains of southern California. U.S. Forest Serv. Pacific SW. Forest & Range Expt. Sta. Res. Note 165, 6 pp., illus. 1960.

[2]Lowry, William P. The sea breeze of northwest Oregon and its influence on forestry operations. 1962. (Unpublished doctor's thesis on file at Oregon State Univ., Corvallis.)

[3]Lowry, William P. Observation of atmospheric structure during summer in a coastal mountain basin in northwest Oregon. Jour. Applied Meteor. 2:713-721, illus. 1963.

[4]Lowry, William P. Periods of nocturnal drying during summer in the coastal mountains of Oregon. (Paper presented at Western Fire Weather Meteorologists Meeting, Portland, Ore., March 5, 1963.)

by downslope winds during the night. Similarly the daytime upslope winds caused the marine inversion to rise.

Both Edinger[5] and Lowry[2] found the moisture content within the marine layer to be nearly constant. They found a sharp transition to the dry subsiding air aloft above the marine layer. Thus all elevations remaining within the marine layer experienced only normal diurnal changes in relative humidity even though the depth of the marine layer varied. If the transition to the dry air aloft dropped below the ridge tops, however, dry air bathed the upper portions of the coastal mountains. Thus the anomolous humidity patterns were related to the depth of the marine layer.

A 3-day survey in southern California supported Schroeder's hypothesis by showing that the depth of the marine layer varied diurnally to produce lower nighttime and higher daytime humidities at higher elevations in the coastal mountains.

ELSINORE-DANA POINT SURVEY

The survey was conducted in the Santa Ana mountains of southern California along a line from Lake Elsinore to Dana Point on August 6-8, 1963. We placed six recording weather stations along the survey line (fig. 1). Each station recorded wind direction and speed every 6 minutes and wet- and dry-bulb temperatures every half hour.

Upper-air winds to 3,000 meters were observed by double theodolite pibals at stations 2, 4, and 6 every 2 hours. Temperature and humidity soundings were obtained by radiosonde at station 4 each 4 hours, and by LARP (Low Altitude Retriever Probe) at station 6 each 2 hours during the daytime. Temperature and humidity data for the coast were obtained by merging the San Diego and Santa Monica radiosonde observations so as to preserve the marine layer characteristics rather than use a straight averaging that would destroy the significant features.

All the upper-air temperature and humidity data for analysis were obtained from time cross-sections. The cross-sections are time-height diagrams on which the desired variable is plotted. The data are read from the scalar analysis at the desired times.

HUMIDITY AND WIND PROFILES

Data collected during this 3-day study were not as typical of summer conditions as they might be because of the unusual synoptic scale influences. Normally precipitation in this area during August is not expected. During this study period, however, the flow pattern aloft was such that Gulf of Mexico moisture could be transported to southern California August 6, 7, and 8.

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[5] Edinger, James G. Modification of the marine layer over coastal southern California. Jour. Applied Meteor. 2: 706-712, illus. 1963

On August 7 a weak disturbance aloft in the form of an easterly wave passed through southern California and brought scattered showers to the area. At climatological stations surrounding the study area, amounts of precipitation varied from a trace to about one-fourth inch. The only measurement of precipitation in the study area was 0.02 inches on August 7 at station 2 (fig. 1) on the ocean side of the Santa Ana mountains. A ridge-top station southeast of the study area measured 0.15 inches that day. The marine layer, although less distinct than normal, could still be identified because the disturbance was primarily aloft. The data were less than ideal, but the phenomenon of nighttime drying could still be identified.

This note reports a synopsis of the wind and moisture analysis of one 24-hour period of the survey. The moisture is reported in terms of absolute moisture content (mixing ratio); the units are grams of water vapor per kilogram of dry air.

At 1000 P.s.t. August 6, 1963 (fig. 1), the low-level moisture pattern showed a stratification at the coast which is typical of the marine layer. The moisture increase above 1,500 meters can be attributed to the synoptic effects. In the vicinity of the ridge, the moisture pattern also was stratified, though the isopleths sloped up to the ridge. Local upslope winds were well developed; a convergence zone was just west of the ridge. Schroeder[6] has described this convergent zone and its relation to local winds.

The divergent wind pattern near 1,500 meters between stations 2 and 4 was slightly misleading. The northeast winds over station 2 were a combination of the anti-valley wind and the synoptic scale influences. Wind speeds were low.

The free-air moisture pattern at 1600 P.s.t. (fig. 2) August 6, 1963, resembled the mid-morning pattern. A marine layer still existed at the coast in low levels. The low-level moisture pattern in the vicinity of the ridge had a pronounced distortion. The isopleths followed the terrain contour up the windward side and down the leeward side because of a lee wave.

Westerly flow was dominant in the low levels at all stations. Normal upslope winds were found on the west side of the ridge; on the east side, a lee wave produced downcanyon westerly winds. The convergence zone previously on the west side of the ridge had moved east of station 6. By 2200 P.s.t. August 6, 1963 (fig. 3), the moisture on the ridge top had begun to decrease, although it was slightly greater than at 1000 P.s.t. The minimum values were on the east slope. On both sides of the ridge, a moisture maximum existed in the low levels. The upper-level moisture pattern still remained essentially unchanged.

Wind flow had become quite complex in the vicinity of the ridge top. Nighttime downslope flow existed near the ground on both sides

[6]Schroeder, Mark J. Down-canyon afternoon winds. Bul. Amer. Met. Soc. 42: 527-542, illus. 1961.

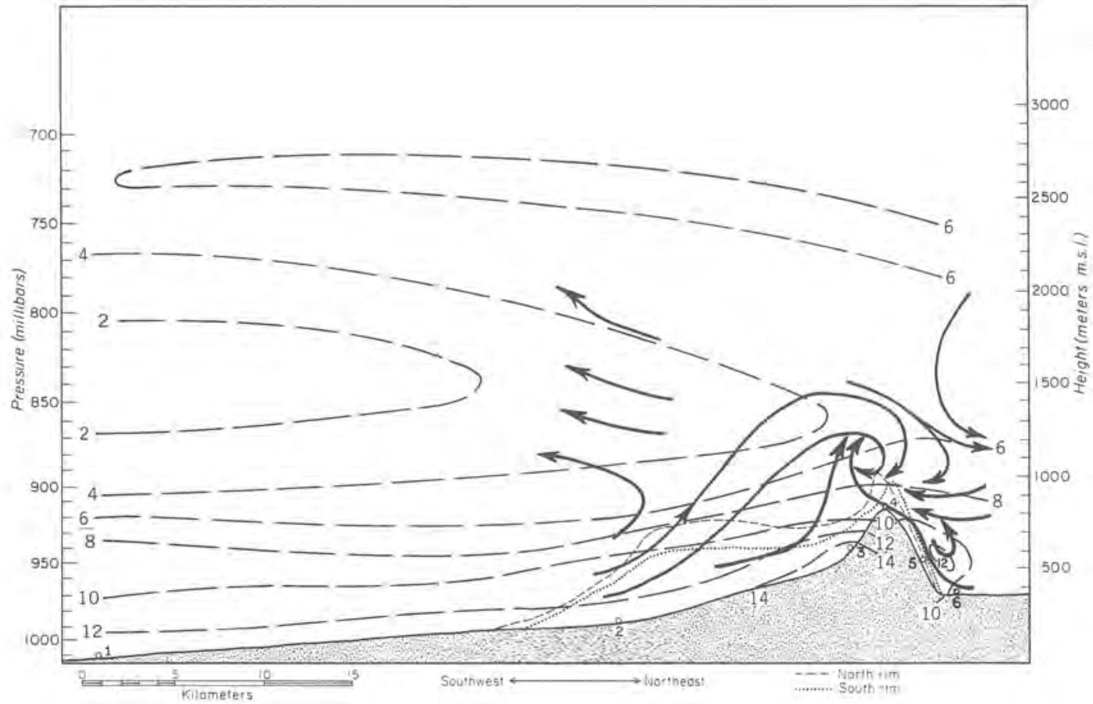

Figure 1.--1000 P.s.t., August 6, 1963: Cross section showing wind flow and moisture distribution shortly after beginning of upslope moisture transport along ridge. The heavier lines are streamlines and the dashed lines are isopleths of mixing ratio (labeled in grams per kilogram).

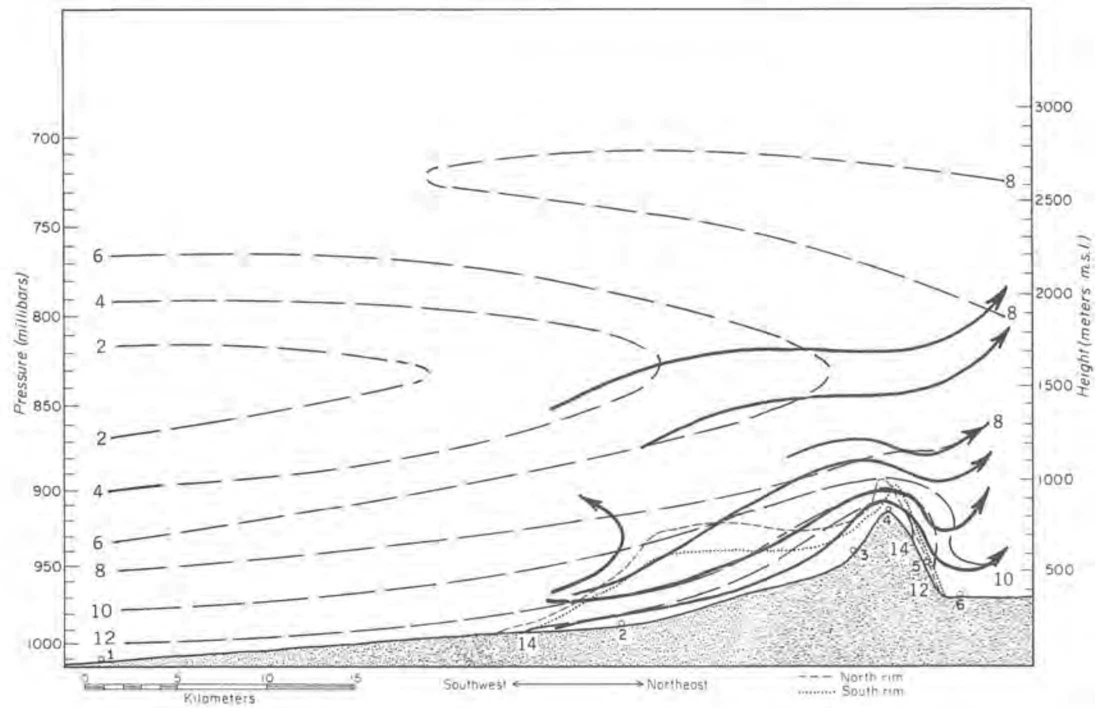

Figure 2.--1600 P.s.t., August 6, 1963: Cross section showing wind flow and moisture distribution at time of near maximum moisture at ridge top.

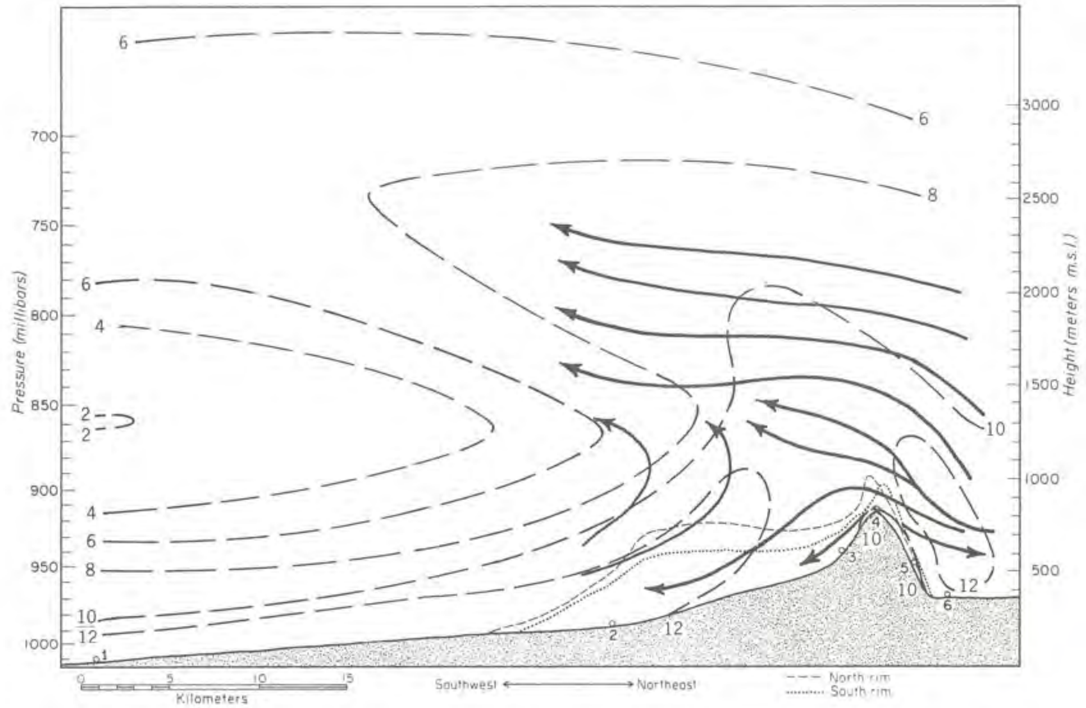

Figure 3.--2200 P.s.t., August 6, 1963: Cross section showing wind flow and moisture distribution slightly after beginning of downslope moisture transport along ridge.

Figure 4.--0400 P.s.t., August 7, 1963: Cross section showing wind flow and moisture distribution at time of minimum moisture at the ridge top.

of the ridge. Above the ridge, and on the east side, easterly winds reflected the synoptic-scale influence. At this time the flow and the moisture pattern were in agreement--indicating a steady-state condition.

At 0400 P.s.t. (fig. 4) August 7, 1963, the moisture at the ridge reached the minimum surface value. The marine layer was now much shallower. On the east side of the ridge, a tongue of moist air had intersected the slope. Aloft, the moisture pattern still showed little change.

Next to the ground, the winds were nearly calm. A few hundred meters aloft the synoptic scale flow was predominantly easterly.

DISCUSSION

Were these conditions similar to normal summertime weather? Several factors should be considered. First, a marine layer existed at the coast with a dry layer above it. Second, local circulations with daytime upslope winds and nighttime downslope winds were present. The lee wave, also a phenomenon of the normal pattern, developed during the afternoon. Unfortunately precipitation occurred in the area; it generally raised the moisture content of the air and prevented the relative humidity from falling at night. But the synoptic conditions offered one piece of valuable information. The fact that nighttime dryness occurred in spite of the abnormal conditions indicated that it was a local condition and that the synoptic pattern was not the primary control.

Mixing ratio is a conservative property, and so it is carried unchanged by the wind. Only when moisture is added or removed, or when mixing with adjacent parcels of air takes place, will the mixing ratio change.

Both of these processes occurred. Advection must have been the primary mechanism for moisture change because the synoptic influence was secondary and turbulent mixing was of little importance owing to the uniform moisture distribution in the marine layer.

Valley winds during the morning transported the moisture up the slope. This process increased the ridge-top moisture. In the afternoon, the upslope winds on the west side continued to transport marine air up the slope, while the lee wave on the east side was carrying it back down. At night and early morning, the moist air that had been carried aloft to the ridge-top was carried back down by the mountain winds. On the west side the marine layer subsided. This movement completed the thermal processes.

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