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STRONG SANTA ANA WIND AND TURBULENCE EVENT DIAGNOSED WITH SATELLITE AND UPPER AIR DATA

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On the morning of February 17, 1988, unusually strong Santa Ana winds struck southern California. Wind gusts in excess of 60 mph were observed beginning early in the morning, resulting in some property damage in the Los Angeles Basin. A study of the upper air data and satellite imagery for this case reveals some interesting features which may be helpful in diagnosing such events in the future.

The 500mb analysis at 1200 UTC that morning (Figure 1) showed that a digging shortwave trough had dropped southward, forming a closed low near the Grand Canyon. To the north, an upper ridge had become oriented nearly west to east and was strengthening as indicated by very large height rises over the Great Basin area. A wind speed maximum of 80 kt was observed at Desert Rock, NV. The surface analysis at 1200 UTC (Figure 2) revealed a moderately strong north to south pressure gradient over southern California which would support geostrophic winds of approximately 40 kt.

To understand why the high winds occurred, it may be helpful to look at the structure of the upper atmosphere. A potential temperature (Theta) cross section was produced by an AFOS program called CRS. The cross section extended from Glasgow, MT southwestward to San Diego, CA along the path shown in Figure 3. The cross section (Figure 4) is oriented approximately parallel to the upper level flow which is from left to right. Although a detailed analysis is difficult because of the large separation of the upper air stations at Desert Rock, NV (2387) and San Diego (2290), it is apparent that the Theta surfaces slope steeply from left to right (NE to SW). Since Theta is conservative in unsaturated conditions, the air parcels should follow these Theta surfaces. This implies that air near the surface over southern California had descended, perhaps from as high as 6-8 kft MSL. The vertical wind profile upstream at Desert Rock (Figure 5) shows that winds at those levels were about 40 kt sustained. Combined with channeling effects by canyons and thermal mixing after sunrise, this could easily account for the observed wind gusts in the Los Angeles Basin. A previous study of LFM forecast variables related to Santa Ana conditions (Sommers, 1978) shows that subsidence, in addition to strong east or northeast winds aloft are important factors.

The 6.7 micron water vapor imagery is sometimes useful in Santa Ana situations (See WR Tech. Attach. 83-11), since strong subsidence through a deep layer is often reflected by a steady darkening with time in successive images. The 0016 UTC image (Figure 6) was already dark along the southern California coast due to the deep, dry atmosphere present. At 300 mb (Figure 7), there was pronounced confluence between the northerly Polar jet stream and the westerly Subtropical jet which was located over northern Baja California, further evidence of subsidence over this region. Over southern Nevada, a separate but subtle dark grey zone could be seen near the upper trough axis (arrow). This feature moved south and southwest during the night and by 1216 UTC, it had enlarged and reinforced the dark zone over southern California. Animation of this imagery would have revealed this process much more clearly. Examination of imagery from other recent Santa Ana events (January 22, 1988 and January 9, 1987) reveal a similar pattern evolution.

Concurrent with the strong surface winds, moderate to severe clear air turbulence (CAT) was reported over southern California, southern Nevada and southwest Arizona by numerous large jets from 27 to 35 thousand feet (Figure 8). This situation had many of the synoptic scale signatures conducive to CAT such as: a sharp, positively tilted upper trough, confluent jet streams, and cold advection aloft (Reiter and Nania, 1964; Rammer, 1973). The author has found that many significant outbreaks of CAT are accompanied by darkening in the water vapor imagery (Ellrod, 1986). The cross section (Figure 4) suggests the presence of one or more sloping, stable layers above 500 mb. Studies of mesoscale conditions associated with turbulence (i.e., Endlich, 1964) show that CAT often occurs near sloping upper level frontal zones where vertical wind shears are often large. Unfortunately, missing wind data precluded an analysis of the upper wind structure on this morning. Due to the strong low level winds, there were many reports of turbulence at lower altitudes also.

In summary, the strong Santa Ana winds on February 17, 1988 were most likely due to strong downward transport of momentum from 6-8 kft MSL at the base of a positively tilted, intensifying trough-ridge couplet. Evidence for this subsidence was provided by a cross section and, partially, by water vapor imagery. One or more upper level, sloping stable layers appeared to show that conditions conducive to CAT were present.

References:

Ellrod, G. P., 1985: Detection of high level turbulence using satellite imagery and upper air data. NOAA Tech. Memo. NESDIS 10, Satellite Applications Laboratory, Washington, DC, 30 pp.

Endlich, R. M., 1964: The mesoscale structure of some regions of clear-air turbulence. J. Appl. Meteor., 3, 261-276.

Reiter, E. R. and A. Nania, 1964: Jet stream structure and clear air turbulence (CAT). J. Appl. Meteor., 3, 247-260.

Rammer, W. A., 1973: Model relationships of CAT to upper flow patterns. Aviation Weather Branch Tech. Note, National Meteorological Center, Washington, DC, 13 pp.

Sommers, W. T., 1978: LFM forecast variables related to Santa Ana wind occurrences. Mon. Wea. Rev., 106, 1307-1316.

Western Region Tech. Attach. 83-11, Looking at the Santa Ana with water vapor imagery, May 3, 1983, NWS Western Region HQ, Salt Lake City, UT.

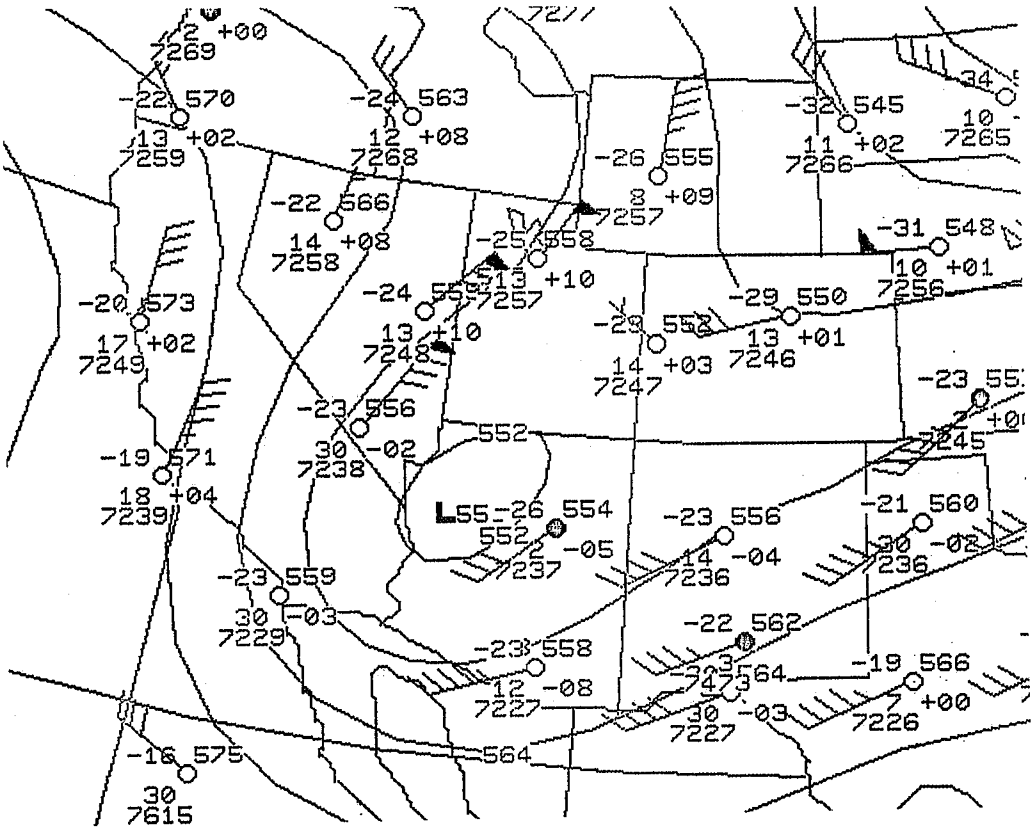

Figure 1. 500mb analysis at 1200 UTC, February 17, 1988.

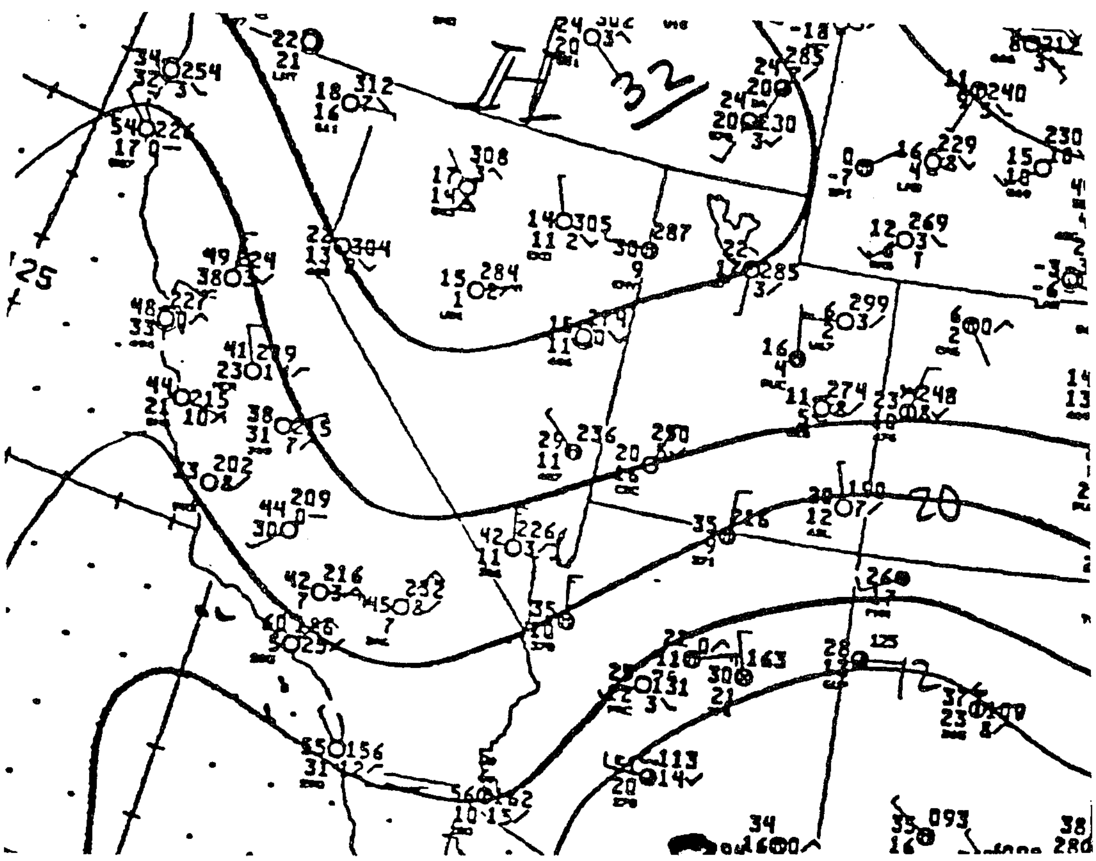

Figure 2. Surface analysis at 1200 UTC, February 17, 1988.

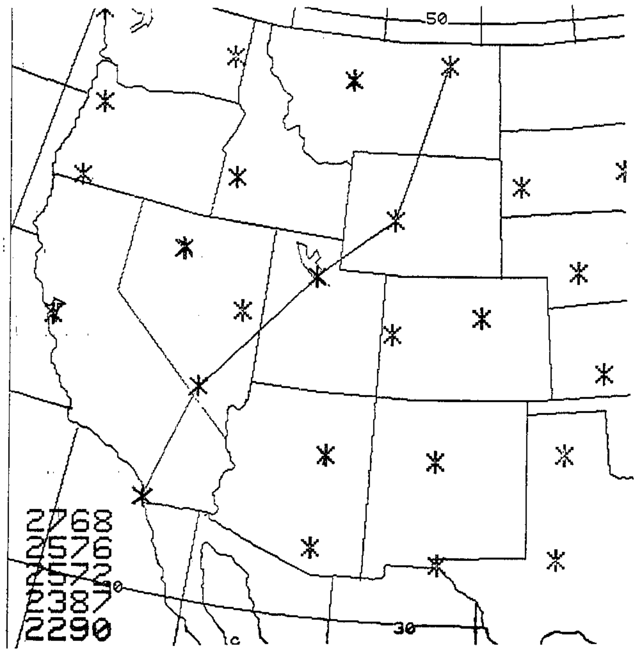

Figure 3. Orientation of cross section in Figure 4.

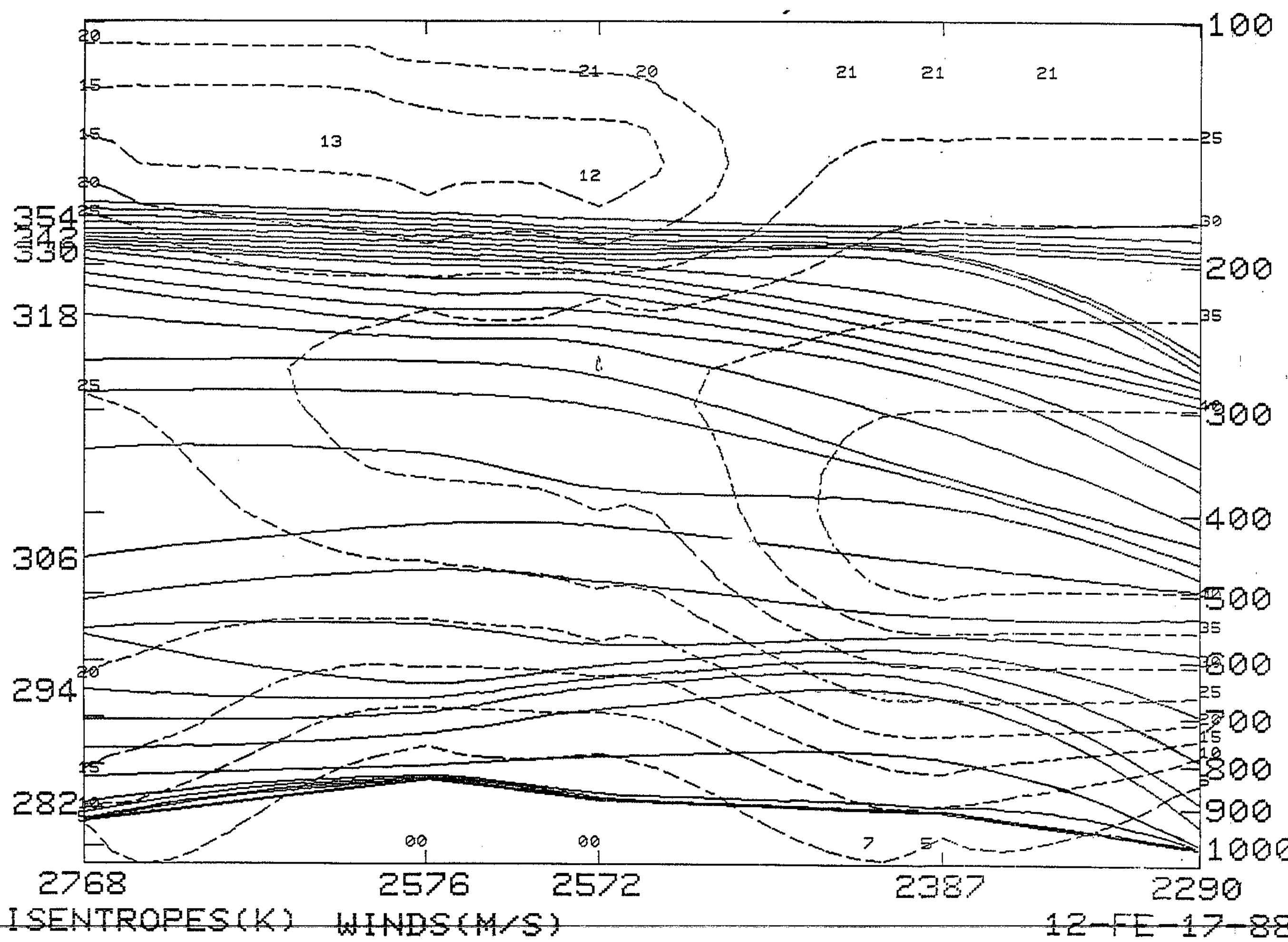

Figure 4. Isentropic cross section from Glasgow, MT to San Diego, CA at 1200 UTC, February 17, 1988. Solid lines are potential temperature (degrees K), dashed lines are wind speeds (m/sec). The wind analysis on the right side of cross section is unreliable because of missing winds.

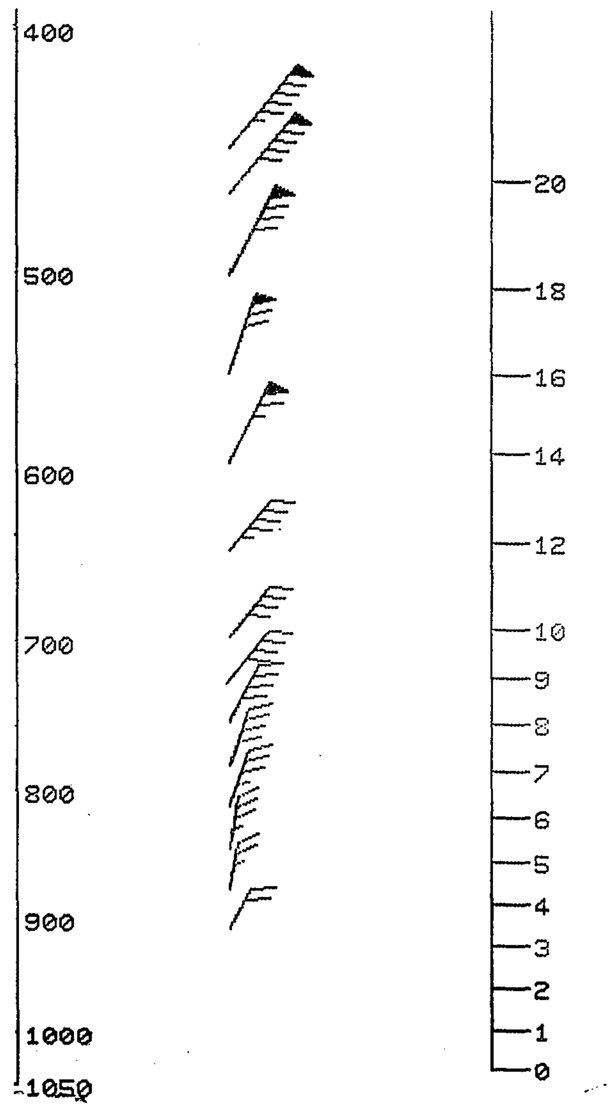

Figure 5. Vertical wind profile at Desert Rock, NV at 1200 UTC, February 17, 1988.

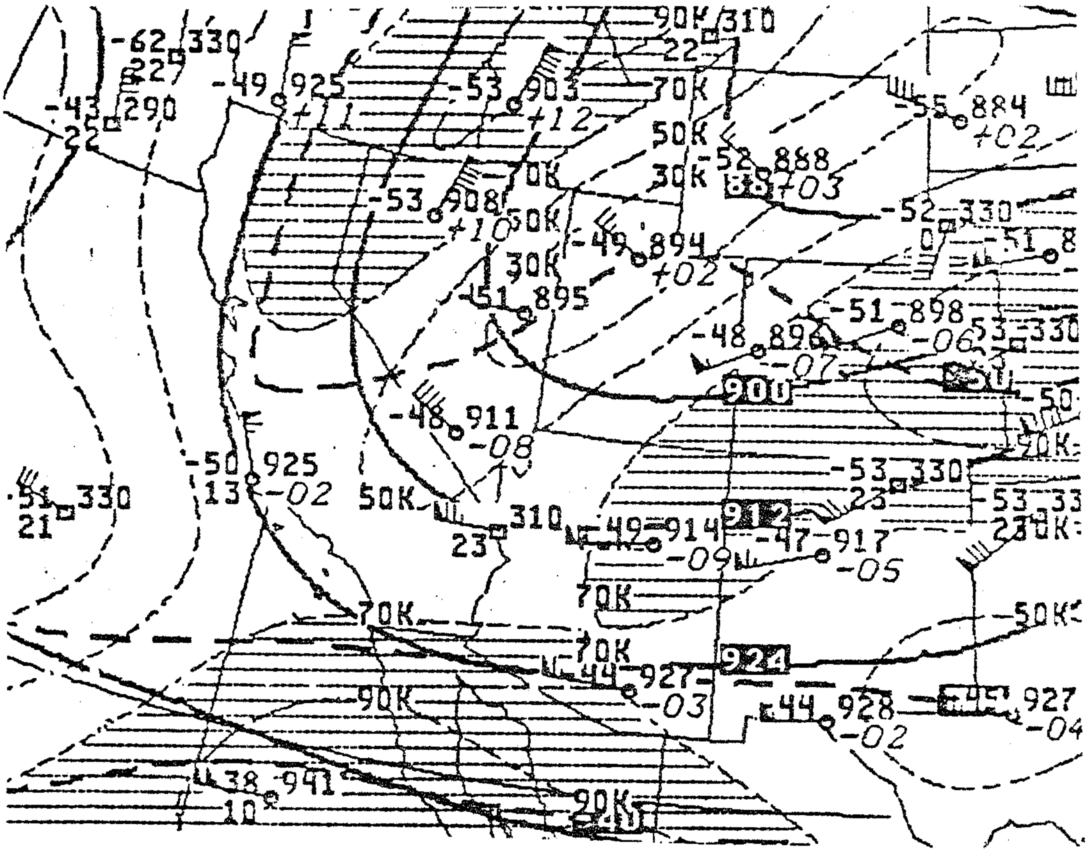

Figure 7. 300mb analysis at 0000 UTC, February 17, 1988.

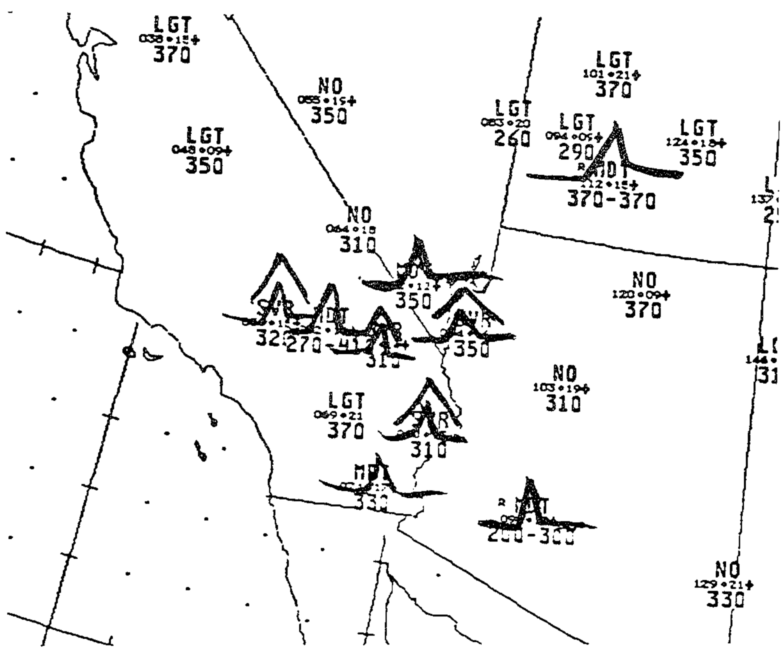

Figure 8. High altitude turbulence reports from 0915 to 2155 UTC on February 17, 1988. ⁀╱╲⁀ is moderate turbulence, ⁀╱╲╱╲⁀ is severe.

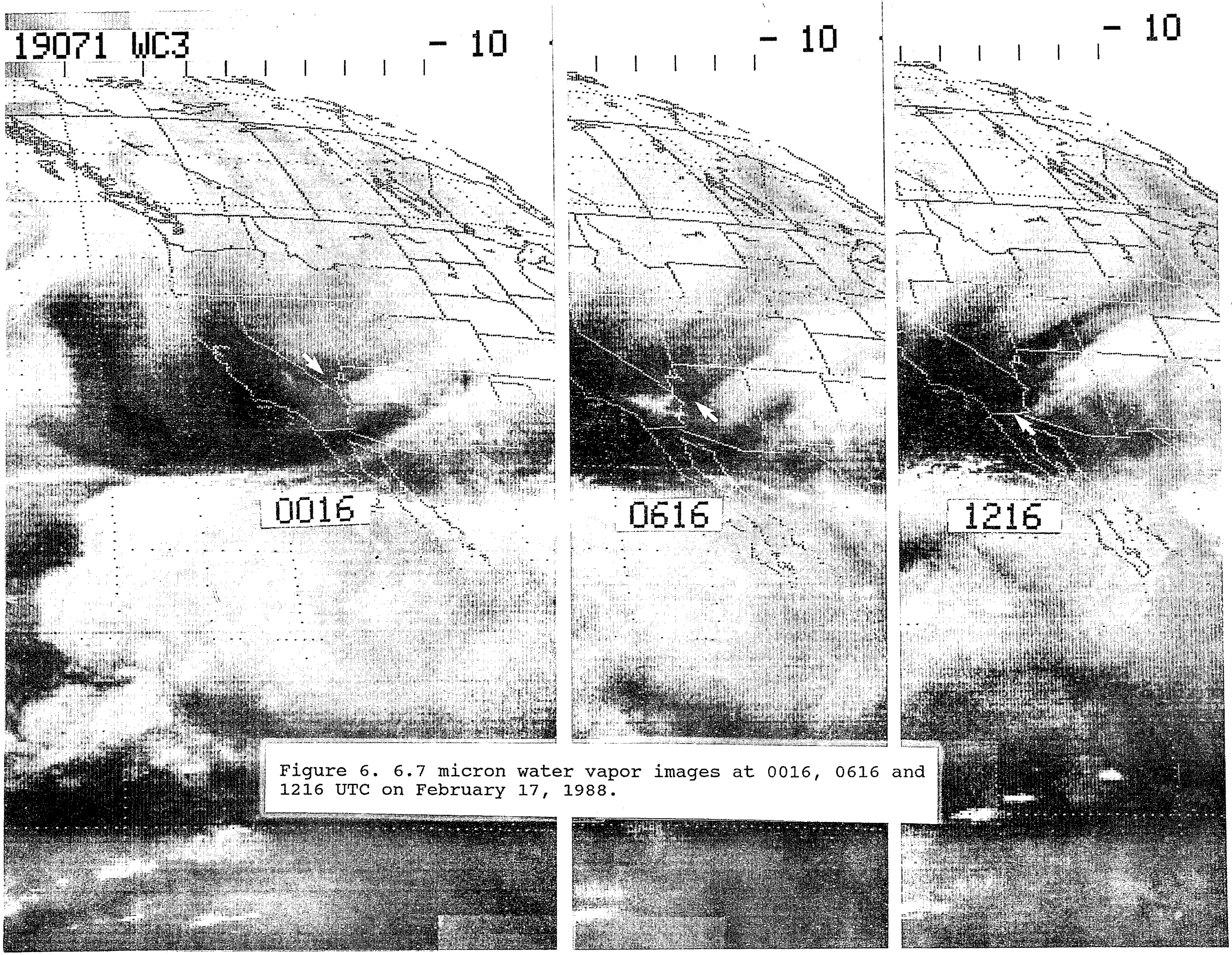

Figure 6. 6.7 micron water vapor images at 0016, 0616 and 1216 UTC on February 17, 1988.