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MESOSCALE PERTURBATIONS IN THE MOISTURE FIELD OVER NORTHERN CALIFORNIA

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On 28-29 March 1994, a significant drop in dewpoint temperatures occurred over portions of the California Central Valley. Dewpoint temperatures throughout the day had been in the low and middle 50s°F due to an intrusion of marine air into the valley ahead of a weak upper-level system. Towards late afternoon, after this weak system had moved to the east, numerous mesoscale areas of low dewpoint temperatures in the lower to middle 30s°F developed over the ocean and propagated inland. These dry "bubbles" propagated from southwest to northeast causing dewpoint temperatures to drop between 10 - 30°F over the course of 30 minutes. However, a windshift or pressure rise did not accompany this phenomena. Climatologically speaking, when dry air moves into the Central Valley after frontal passage aloft, it is almost always accompanied by a windshift to a northerly direction, rising pressures, and the dry air covering the entire area. The phenomena on 28 March did not follow the typical manner of dry air intrusions into the Central Valley, and thus became the focus of this paper.

Synoptic Situation

At 0000 UTC 29 March 1994, a ridge of high pressure covered much of the western United States. At 500 mb, a large-scale ridge could be seen over California with the 564 dam height line well north of the state (Fig. 1). A weak vorticity maximum was rotating around a low situated over the Gulf of Alaska. This weak vorticity maximum extended over California at 0000 UTC causing cloudiness but no rainfall.

The Oakland sounding (OAK) at this time indicated three distinct dry layers with a near saturated layer around 915 mb (Fig. 2). This was likely the level of the scattered low clouds over the state at this time. A weak frontal inversion could also be seen at this level indicating the front aloft. Winds over OAK were from the west in the low levels, backing to southerly in the mid-levels before becoming westerly again in the upper levels, indicative of cold air advection within the lower levels of the atmosphere.

Mesoscale Analyses

The weak upper-level system was denoted by satellite imagery at 2301 UTC (Fig. 3) as a line of cloudiness extending from northwest California to Reno, NV and southward towards Palm Springs. A mesoscale analysis at 2300 UTC 28 March 1994 (Fig. 5a) indicated an initial "bubble" of dry air was located from Guenoc Valley (GNO) through Fairfield (SUU) to

Livermore (LIV) with dewpoint temperatures around 40°F (see Fig. 4 for locations). Low-level flow across this region was generally from the southwest, which typically brings in marine air from the Pacific Ocean. The dewpoint temperatures over the Sacramento area were around 50°F.

By 0000 UTC 29 March, the initial "bubble" had apparently split into two areas with one located near GNO and the other to the northeast of SUU (Fig. 5b), both of which dried further with dewpoint temperatures now in the low to mid-30s°F. General southerly to southwesterly flow continued over the Central Valley and near San Francisco.

By 0100 UTC, the initial "bubble" had moved into the Sacramento area (Fig. 6a). Dewpoint temperatures with this feature were now in the upper 20s°F near GNO to the low 30s°F near Sacramento. Over the course of 30 minutes, dewpoint temperatures dropped from the low 50s°F to the low 30s°F with 33°F being reported at the Weather Service Office downtown (DTS) and at Sacramento Executive Airport (SAC). A strong gradient of dewpoint temperatures existed across the metro area as could be seen in the isodrosotherm analysis. McClellan Air Base (MCC), which is 7 miles from DTS, had a dewpoint temperature of 47°F, or 14°F higher than downtown. Winds had not switched direction during the dewpoint temperature fall, staying southerly or southwesterly. Another area of low dewpoint temperatures could be seen propagating onshore near San Francisco (SFO) at this time as evident by the dewpoint temperature fall of 9°F over the past hour. A surge of moist air could be seen from Santa Rosa (STS) to SUU with dewpoint temperatures near 50°F.

The 0200 UTC analysis indicated that the initial "bubble" was now over the northeastern part of Sacramento, with a 13°F fall in dewpoint temperature at MCC, and a 10°F rise at SAC (Fig. 6a). More moist air was punching into the dry "bubble" over Sacramento with a tight gradient in isodrosotherms across the southwestern portion of the city. The dry "bubble" that was over SFO at 0100 UTC was now located near LIV. Another dry surge was located over San Francisco with dewpoint temperatures in the mid-30s°F. Again, surface flow was from the southwest directly off the ocean. A fourth dry surge was beginning to occur near GNO.

By 0300 UTC, the initial "bubble" was beginning to decelerate and moisten (Fig. 7). Dewpoint temperatures were near 39°F at MCC while DTS was reporting 51°F. Two "bubbles" could be seen from northwest of Stockton (SCK) southwestward to near Concord (CCR) and LIV. The "bubble" near GNO was rapidly drying as evident by the 21°F dewpoint temperature reported. This was a valid observation since Knoxville (KNO) reported a dewpoint temperature of 28°F during the next hour.

After 0400 UTC, the "bubbles" continued to decelerate as they moved towards the northeast. They slowly moistened through the night as well. By early morning, generally uniform dewpoint temperatures were located over the region.

Discussion

Synoptic conditions over California on 28-29 March 1994 were similar to those found behind most weak weather systems. However, numerous mesoscale perturbations in the moisture field were seen to propagate across the Central Valley under "climatologically" moist southwest flow. No windshifts or pressure rises accompanied these perturbations, as is typically seen with dry surges. Dewpoint temperature changes of nearly 20°F in 30 minutes were experienced at many locations. This phenomena could have potential ramifications in both agricultural and fire weather forecast areas.

Agricultural areas could be affected by this phenomena if an area of dry air moved over an orchard after nightfall and became stationary. Since many orchards in northern California are located at lower elevations, minimum temperatures are usually lower than in metropolitan areas. If a dry "bubble" would move over the orchard, significantly colder temperatures could result due to the rapid cooling of drier air, with possible frost forming if temperatures fall close to 32°F. Unfortunately, no minimum temperature observations were available in any areas affected by the dry "bubbles" on 28-29 March 1994 for verification. However, once the sun sets, rates of temperature falls in the dry air were twice that in the more moist air.

Ramifications also exist in areas with forest fire potential. Due to the rapid drying of the airmass, areas that originally were thought to be marginally unsafe for fire potential could have even higher potential if one of these "bubbles" moves over the region. In areas where fires are already burning, this phenomena could cause the fire to increase in strength.

So what causes these dry "bubbles" to develop and move over the region? Due to the fact that these "bubbles" appear to propagate onshore from over the ocean, a mechanism needs to be found that allows for the continual replenishing of dry air. If the dry air is not replenished, the "bubble" would rapidly moisten over the ocean before it moved onshore. Since dry air is not commonly found near the ocean surface, the likely source would be aloft. Thus, continued vertical mixing must have become established, replenishing the dry air as it was modified by the ocean. Over land, this replenishment could be seen as the "bubbles" continued to dry out, since the modification was less than over the ocean.

The airmass over California that day was marginally unstable. Thus, the atmosphere was likely very close to the point at which mixing could occur. It is likely that mixing could only occur in small areas where the static stability was the lowest. So, rather than the typical manner of dry intrusions into the Central Valley, smaller areas of mixing occurred showing up as "bubbles" of dry air at the surface.

One concern about this hypothesis, however, is the lack of westerly momentum showing up at the surface. If mixing was occurring, the westerly winds noted in the OAK sounding should have also been mixed down with the drier air. But, since winds never changed much from a constant southerly to southwesterly direction, this momentum transfer seems to have not taken place. The flat pressure field across California that day suggested that any westerly momentum should have appeared as a veering of the winds or a windshift at the surface. No windshift was noted. Terrain can sometimes have a significant impact on wind regimes at certain stations in the Western Region. However, southwesterly winds are climatologically the most prevalent winds near Sacramento, thus any westerly momentum being transferred to the surface should have easily been seen in a veering of the wind from southerly to southwesterly or even west-southwesterly in the Sacramento area. This was not observed.

The setting of the sun and the development of a nocturnal radiational inversion seemed to play an important role in this phenomena as well. Once the inversion began to develop, the "bubbles" began to decelerate and moisten as vertical mixing was cut off. This has ramifications for the agricultural community. After sunset, as these "bubbles" decelerated and eventually became quasi-stationary, temperatures fell rapidly. At Concord, a temperature fall of 8°F in two hours took place, which was about twice as great a fall as locations not under the dry "bubbles". Thus, a rapid rate of temperature decrease can occur under these dry "bubbles" allowing for much lower minimum temperatures and possibly even frost under the right circumstances. This type of phenomena may help to explain the large variability in some morning low temperatures across the agricultural district.

Conclusion

On 28-29 March 1994, a series of "bubbles" of dry air moved onshore and propagated to the northeast over parts of the San Francisco Bay area and the lower Sacramento Valley. These "bubbles" had dewpoint temperatures from 10 - 30 °F lower than the synoptic airmass. No windshift or pressure rise was associated with these "bubbles", thus breaking from the traditional way that dry air intrusions occur in the Central Valley. It appears that mesoscale areas of vertical mixing developed over the ocean that day and moved onshore through the late afternoon. This mixing continued to replenish the dry air in these "bubbles" until nightfall, when a nocturnal inversion developed, cutting off the circulation. This supports the hypothesis that these mesoscale circulations developed in areas in which the static stability was near a critical level that allowed for the development of vertical mixing. As the inversion developed and deepened, this vertical mixing was cut off, allowing the dry "bubbles" to decelerate and modify. The location of these "bubbles" have ramifications in both agricultural and fire weather due to rapid temperature falls in the dry air at night and an increase in fire danger.

Acknowledgements

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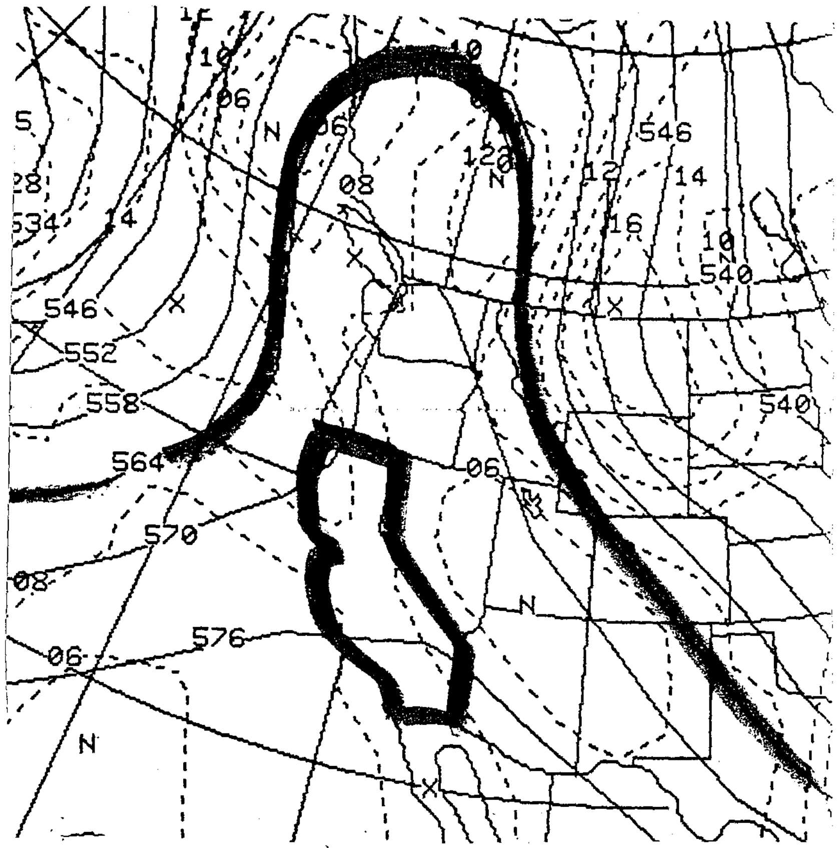

Fig. 1 500 mb height (contoured every 6 dam) and vorticity (contoured every $2x10^{-5}$ s^{-1}) analysis at 0000 UTC 29 March 1994.

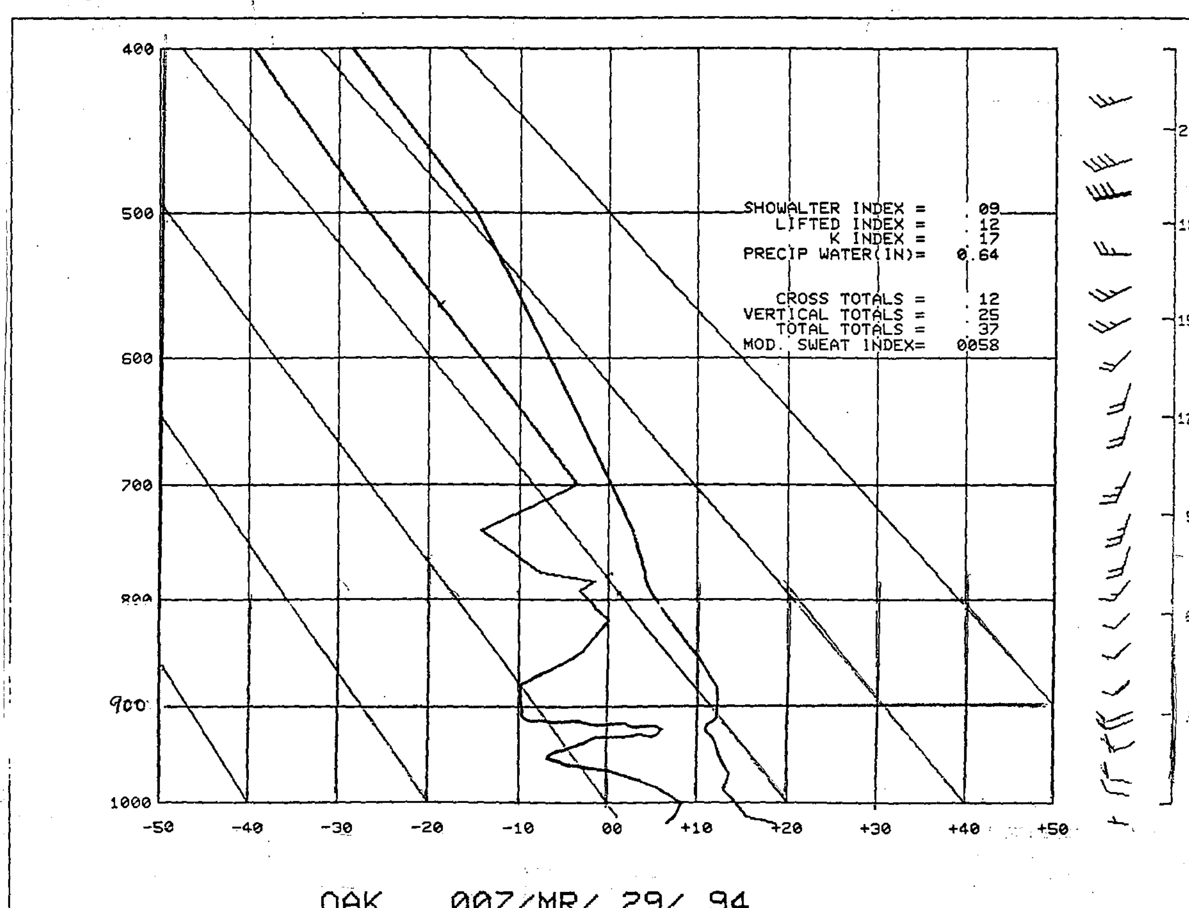

Fig. 2 0000 UTC 29 March 1994 Oakland, California sounding.

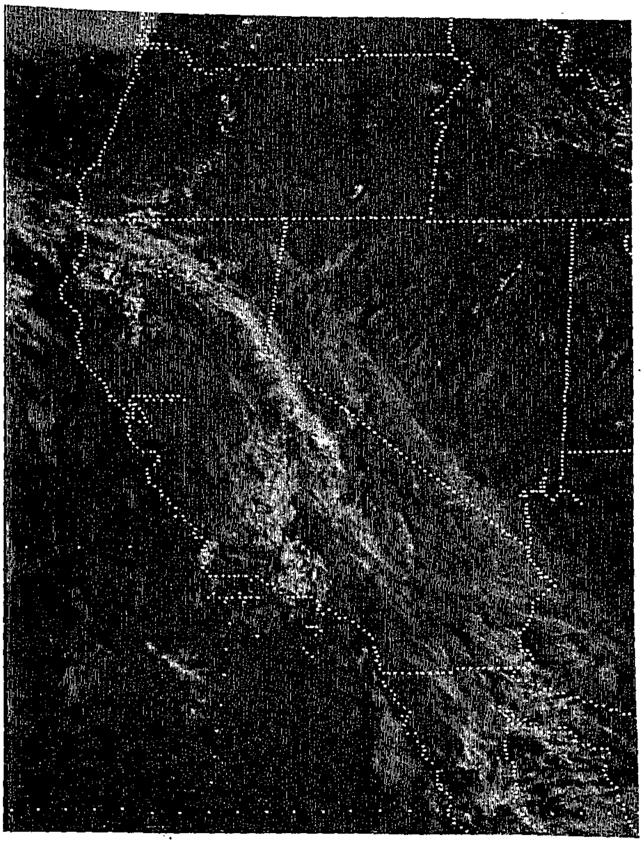

Fig. 3 2301 UTC 28 March 1994 visible satellite image.

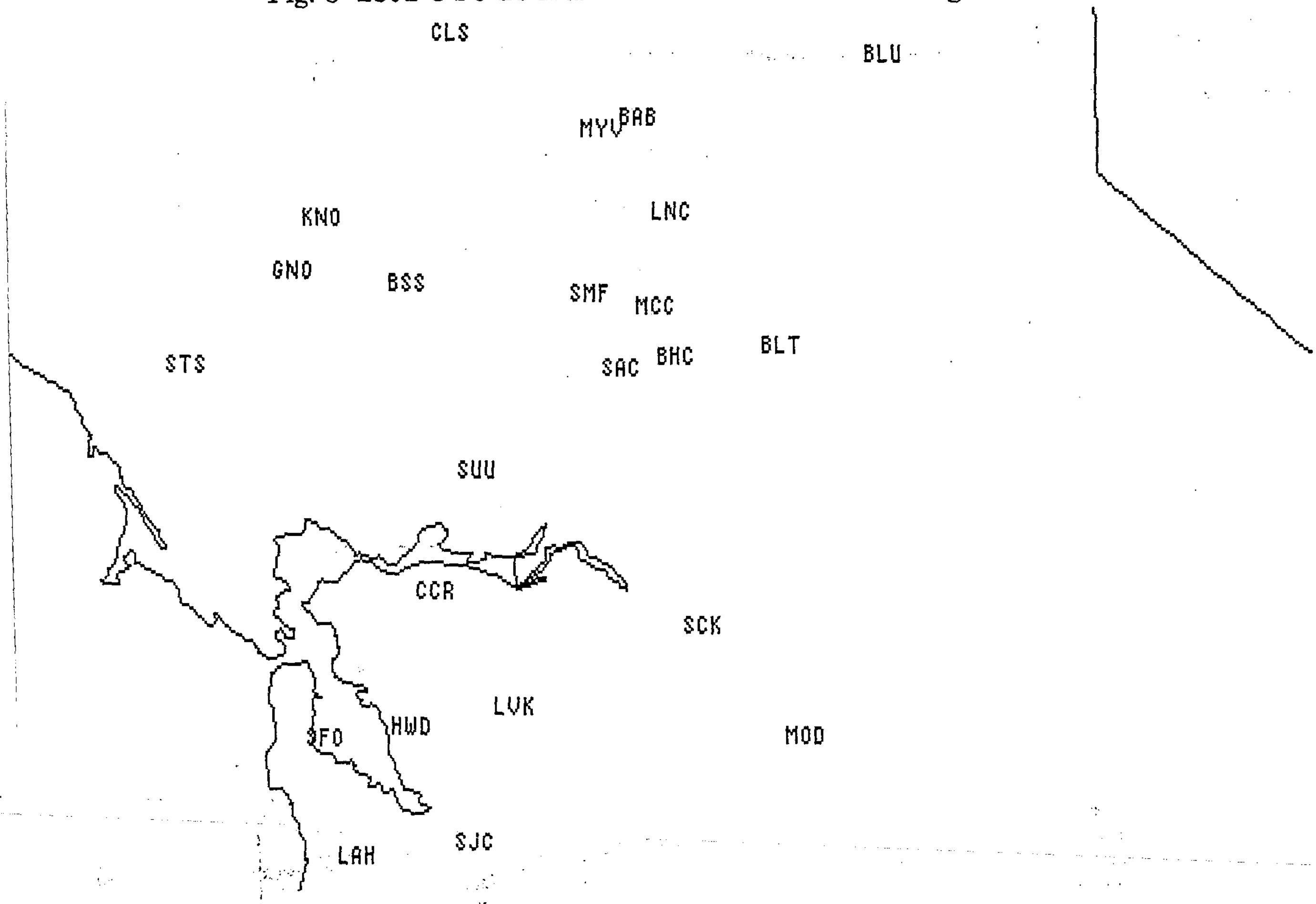

Fig. 4 Site locations and identifiers.

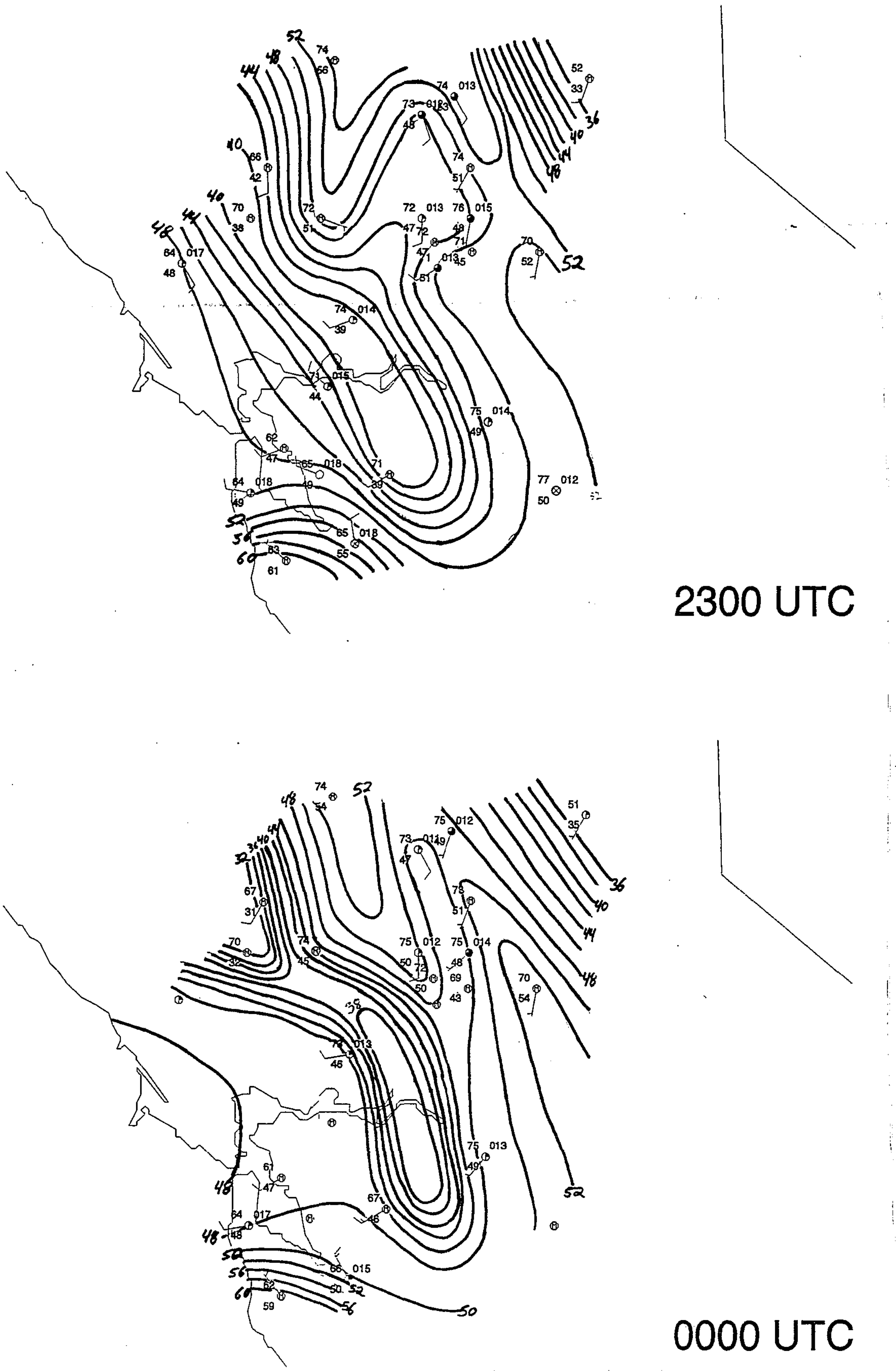

Fig. 5 Surface map and dewpoint temperature analysis (contoured every 2° F) at a) 2300 UTC 28 March 1994 and b) 0000 UTC 29 March 1994.

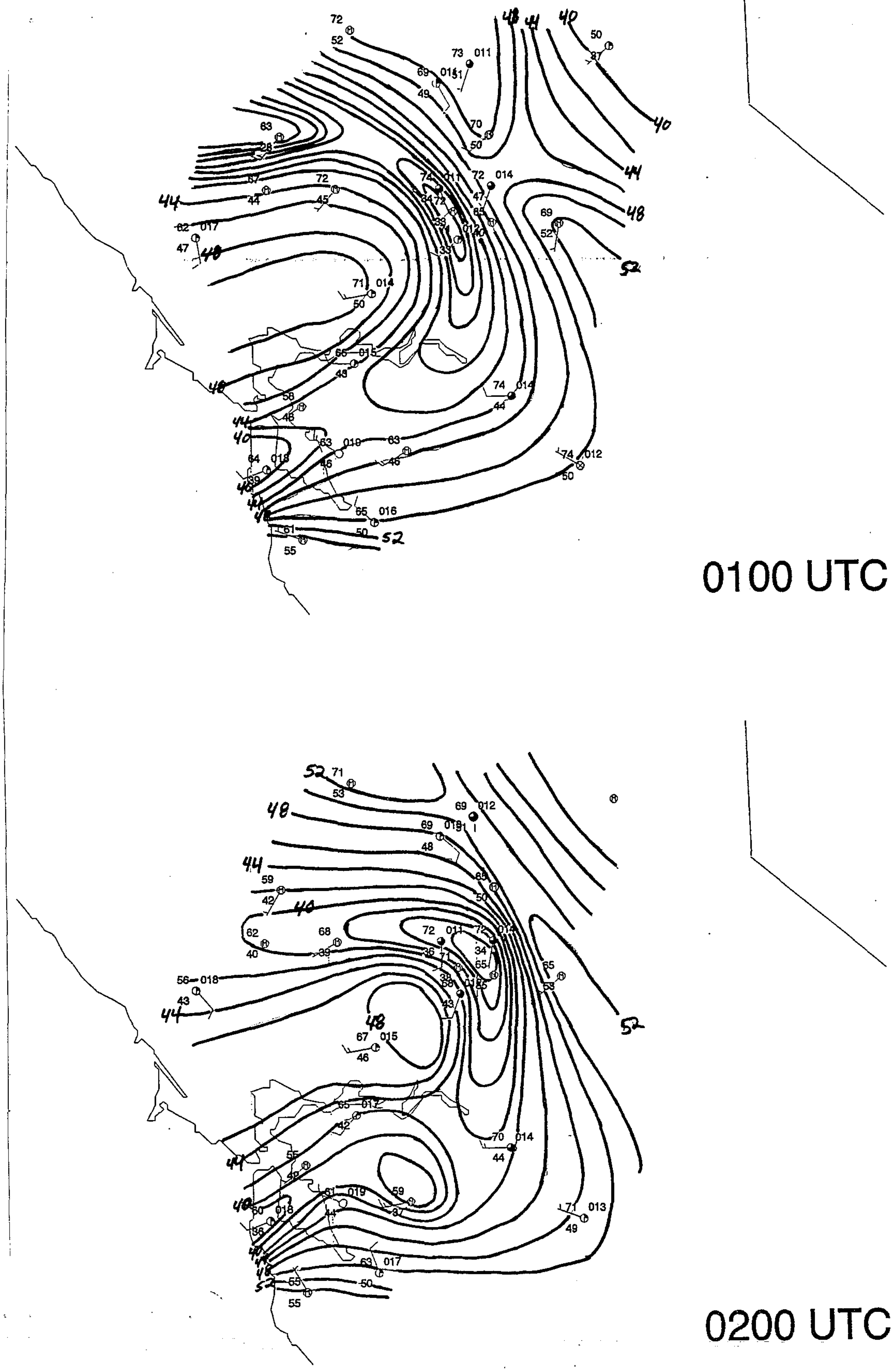

Fig. 6 Surface map and dewpoint temperature analysis (contoured every 2°F) at a) 0100 UTC and b) 0200 UTC 29 March 1994.

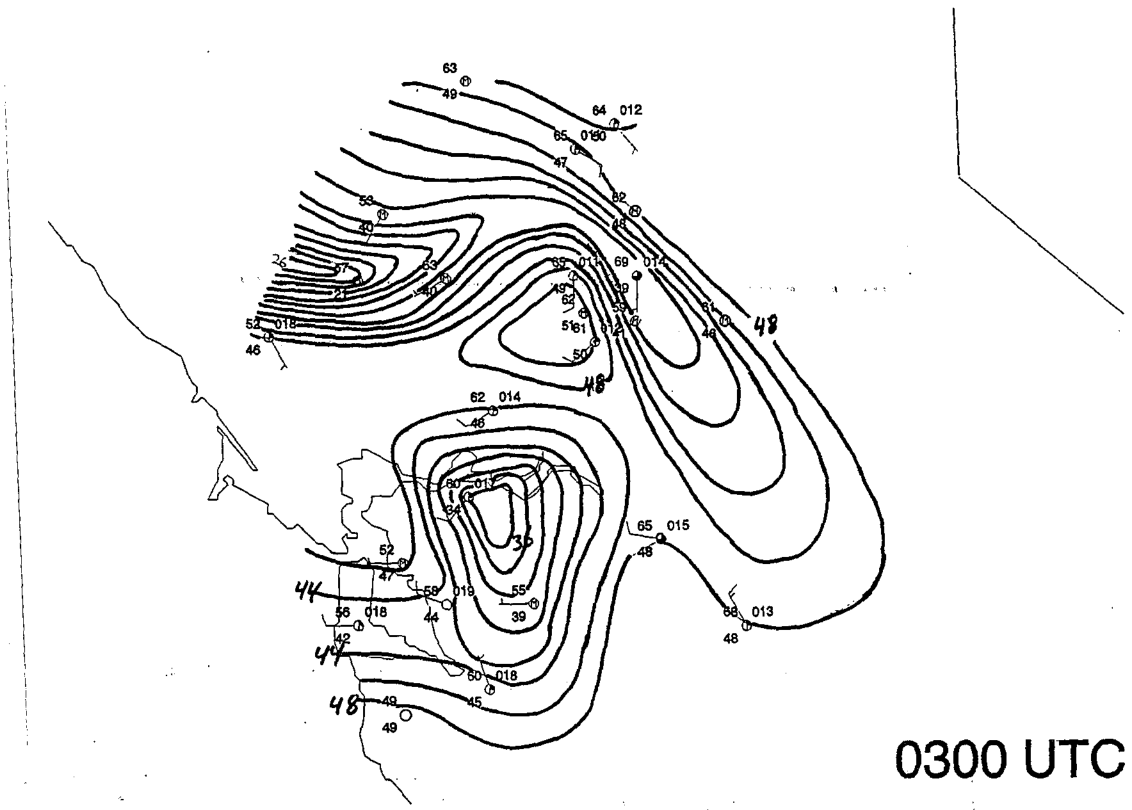

Fig. 7 Surface map and dewpoint temperature analysis (contoured every 2°F) at a) 0300 UTC 29 March 1994.