A PACIFIC STORM AS SEEN VIA THE WEATHER EVENT SIMULATOR (WES) : FOCUS ON A GAP WIND ENHANCED CONVERGENCE ZONE AND ASSOCIATED FLOODING

Ivory J. Small and Daniel V. Atkin
Weather Forecast Office, San Diego, CA

INTRODUCTION

On 12 November 2003 a cold upper level low pressure system moved through the southern California Bight Region (coastal waters and immediate coastal areas of southern California shown in figure 1). Although the central heights at 500 mb were not exceptionally low (about 558 decameters), conditions generally associated with a strong Pacific storm developed. Thunderstorms with very heavy rain, small hail, and some flooding developed in the region, with the heaviest rainfall rates along a gap wind enhanced convergence zone in the afternoon. With 500 mb temperatures dipping to near -25 degrees C a funnel cloud was reported. The mountains and local deserts were under a slow moving baroclinic zone ahead of a slow moving (less than about 20 knots) upper level low during the morning. There was a significant variation of not only precipitation duration, but also precipitation intensity (convective versus non-convective). On the eastern slopes of the mountains there was southeast to south (upslope) flow just above the desert floor. About 1 inch of rain (1/4 of the normal annual rainfall) fell in the deserts, with between 2 and 3 inches of rain in the mountains. [This is in stark contrast with the 7-9 November 2002 rainfall event a year earlier, where low level winds from the westerly direction resulted in no measurable rain at KPSP and KTRM even though over 10 inches of rain fell on the western slopes (Small and Dandrea, 2003)]. At the higher elevations (above about 6000 feet), up to about 8 inches of snow fell in this 12 November 2003 case. By afternoon low level post frontal flow generated an unusually strong convergence zone over the coastal plain. The convergence zone developed between offshore (easterly) flow funneled into the coastal areas below the favored mountain passes and canyons, and the post-frontal westerly onshore flow (modified by the sea breeze) moving inland from the Pacific. Along this convergence zone Chino Hills (near KONT) reported over 1 inch of rain in 45 minutes, with a total of 1.60 inches between 0015 UTC 13 November 2003 and 0300 UTC 13 November 2003. This case is especially interesting because such well developed terrain forced arcs of convection along convergence zones between easterly gap flow and westerly onshore flow are usually more of a warm season phenomena between the sea breeze and monsoonal flow (Small et al., 2000). In this cool season case, the convergence zone developed in a near-classic fashion during the afternoon and evening and assumed an "arc" shape below major canyons and passes. There was even thunderstorm propagation along the convergence zone, similar to what has been seen in the past during the warm season. As is common with cool season upper level lows, no thunderstorms developed in the local deserts, even though showers and thunderstorms with small hail developed from the coastal waters inland to the western slopes of the mountains (and the thunderstorms that did form during this event developed in the cold air behind the front). The goal of this WES TA-Lite is to examine the synoptic and mesoscale pattern associated with this event.

SYNOPTIC AND MESOSCALE PATTERN

The 0000 UTC 13 November 2003 500 mb heights and 250 mb winds (Fig. 2) showed heights that were around 558 decameters, which was not too impressive as upper lows go, however, the jet stream flow was quite impressive. Southern California was north of a 130 knot 250 mb jet (in the left-front quadrant), which has a tendency to supply excellent dynamics, high rainfall rates and produce flooding. The 0000 UTC 13 November 2003 500 mb heights and vorticity (Fig. 3) showed a vorticity center moving directly over the basin, which is the optimal pattern for accumulating hail, especially along convergence zones. There was weak mid level flow near the low center, significant dynamic forcing, and a freezing level near 7500 feet, creating an environment for slow-moving cells with accumulating small hail. There was also the potential for large hail and flooding under slow moving cells whether or not a convergence zone is involved. Although numerous hail reports were received, no significant accumulating hail or large hail was reported in the WFO SGX CWFA (but the flooding did occur).

The 0000 UTC 13 November 2003 500 mb heights and MSL pressure (Fig. 4) shows weak high pressure over the interior and a surface low over the coastal areas for weak offshore flow at the surface. The 0000 UTC 13 November 2003 surface CAPE (Fig. 5) shows about 700 joules over the coastal strip, which diminishes rapidly from the coastal areas to the deserts. The 0000 UTC 13 November 2003 850, 750 and 500 mb surface lifted indices (Fig. 6) were between about -2 and -4 over the coastal plain, with the impressive -2 from the surface to 850 mb showing strong boundary layer instability. The 1200 UTC 12 November 2003 KNKX sounding (Fig. 7) shows a very moist and unstable airmass at the low levels. (It should be mentioned that based on the surface temperature of about 18 C, the sounding shows a surface to 500 mb lifted index of +1, but far more unstable values of -1 and -4 from the surface to 850 mb and 700 mb are noted). The strong destablization aloft shows up on the 0000 UTC 13 November 2003 sounding (Fig. 8) with the surface to 500 mb lifted index falling to about -3. The extremely large (in excess of 300 joules) boundary layer CAPE easily showed a high potential for flooding at a whopping 594 joules. (This is well above the 300 to 400 joule values seen with some of the most damaging floods during the 1997-1998 El Nino). Other notable cool season values on the 0000 UTC 13 November 2003 sounding were the Precipitable Water (nearly an inch, at 0.80 inches) and the negative energy below the level of free convection was zero.

At 1600 UTC 12 November 2003 the visible satellite imagery and surface observations (Fig. 9) showed weak offshore flow over the entire area. There was even northwest surface flow into Palm Springs (KPSP) in the Coachella Valley, consistent with a weak offshore flow pattern (even though the flow above the desert floor was southeasterly). The low level airmass showed the potential for convergence zones with heavy rain early, as a low level convergence zone can be seen pushing out over the coastal waters in easterly offshore low level flow (similar to a land breeze front) at 1800 UTC 12 November 2003 (Fig. 10). At 2000 UTC 12 November 2003 (Fig. 11) and 2200 UTC 12 November 2003 (Fig. 12) the developing sea breeze, with dew points in the mid 50s, was flowing inland over the coastal plain. However, northeast flow was pouring in from the upper deserts, accelerating through the mountain passes, past Ontario International Airport (KONT) and Riverside Municipal Airport (KRAL), and locally into the coastal plain. This results in terrain-generated arcs of convection (best seen in Fig 12) where it attempts to flow out into the coastal plain. Northeast winds enhanced by gap flow can be seen at KRAL behind one such arc. (KRAL is usually the first METAR site to receive the gap flow from the Cajon Pass, and in this case, the flow shows up best there). Although the dew points along the coast are generally in the mid 50s, the drier dew points (in the 30s and 40s in the upper deserts to the north and east) showed up at KONT and KRAL as dew points in the mid 40s. Figure 13, an overlay of the 2300 UTC 12 November 2003 observations and the 2315 UTC 12 November 2003 visible satellite imagery, shows the flow emerging below the passes and canyons, resulting in an enhancement of the sea breeze front. This is not a "normal" sea breeze convergence zone, since there is an opposing gusty, northeast flow to enhance the convergence, similar to the convective arcs seen during summer monsoonal flow. The scenario was set for an afternoon of heavy showers and thunderstorms.

With cool season upper lows (and especially in westerly flow), thunderstorms seem to only develop in and west of the mountains, with no thunderstorms in the local deserts. This may be because the moisture and instability for thunderstorms is mainly low level marine moisture, which is blocked from the deserts by the mountains. Thus thunderstorms seem to be rooted in the marine layer moisture. Also, low level convergence zones are more likely to develop in the marine moisture west of the mountains. For desert thunderstorms, usually the moisture and instability is elevated, which is generally a warm season scenario characterized by monsoonal flows and/or "warmer" upper lows. (For example, a forecast of snow below about 8000 feet usually means no desert thunderstorms). The cooler events allow the meteorologist to focus more attention on areas over and west of the mountains, where the highest rainfall rates are more likely to occur during these patterns.

CONVECTION ON THE TERRAIN FORCED CONVERGENCE ZONE

Figure 14 shows the KNKX WSR-88D Three Hour Precipitation (THP) at 2311 UTC 12 November 2003, 0008 UTC 13 November 2003, 0110 UTC 13 November 2003, and 0212 UTC 13 November 2003 respectively. Strong thunderstorms initially developed near the northwest end of an "L - shaped" convergence zone just northwest of Los Alamitos (KSLI). The thunderstorms resulted in an outflow boundary, which propagated east along the convergence zone toward Ontario (KONT). The associated very heavy rain with flooding continued to travel along the convergence zone to near Chino (KCNO). At 0209 UTC 13 November 2003 1.02 inches fell in 45 minutes near KCNO. Between 0209 UTC and 0300 UTC more significant flooding occurred, with a total of 1.60 inches falling between 0100 UTC and 0300 UTC. Northeast surface flow at KRAL continued to reinforce the convergence zone, before finally becoming calm at 0400 UTC 13 November 2003, thus allowing the convergence zone to dissipate. The generation of a thunderstorm triggered by the outflow boundary as it tracked along the convergence zone can be seen moving away from the main convective cell and moving down the convergence zone (figure 15 a-d) in the infrared satellite imagery and surface observations. Aloft, the cold cloud tops drifted off to the northeast as the cells dissipated at 0300 UTC 13 November 2003.

DISCUSSION AND CONCLUSION

In this case an upper level low with a rather cold, unstable low level airmass brought thunderstorms, small hail, mountain snows, and even a funnel cloud to the area. As is common with these cold upper level lows, the heaviest continuous rainfall was with the baroclinic zone, but the highest rates occurred in the cold unstable airmass behind the front. A rainfall total of about 1 inch in 45 minutes resulted in flooding. (This converts to a rate of 1.33 inches per hour, which is on pace to satisfy the 1.25 inch one hour rainfall total threshold common for flooding in extreme southwest California). The rainfall total was 1.60 inches for a 2 hour period. An outflow boundary tracking along a convergence zone created the flooding. The convergence zone was created by northeasterly offshore flow converging with post-frontal onshore flow enhanced by a sea breeze circulation. The sea breeze can be seen in the coastal areas via the slight reduction in the boundary layer convection as the sea breeze moved inland and stablized the immediate coastal strip. The 850, 700 and 500 mb surface lifted indices were between about -2 and -4 over the coastal plain. The CAPE showed a high flood potential (in excess of 300 joules) indicating tremendous boundary layer instability for a southern California storm during the cool season. Severe weather was also a problem (a funnel cloud was reported) with this 300+

CAPE.

As usual, thunderstorms were confined to areas west of the ridge line of the higher mountain ranges, (even though there was good southeast flow into the deserts). Since the flow had an easterly component, generous rains occurred in the mountains and deserts, but rates were much less than those west of the ridge line. Highest widespread rainfall rates were in the regions of nearly perpendicular, orographic flow in the higher mountains as the system pushed through, with a peak in that region associated with the baroclinic zone. Highest isolated rainfall rates were post-frontal, and in the vicinity of terrain forced convergence zones (the strongest of which was near the border of the coastal and valley areas during the afternoon near KONT).

There were 2 obvious arcs of convection bowing out over the coastal areas due to flow through gaps in the mountains, that showed up best on figure 12 at 2200 UTC 12 November 2003. The apex of the northern convective arc was near KSNA, and is the flow through the gap between the San Gabriel Mountains and the Santa Ana Mountains (convective arc). The apex of the southern bow is near Carlsbad (KCRQ). It is due to the flow between the Santa Ana Mountains and the mountains of northern San Diego County exiting the Temecula Valley south of KRAL. The funnel cloud formed near the southern end of the arc near the Temecula Valley. This case shows that while a Pacific storm may not be exceptionally deep, it may still produce funnel clouds and flooding in the lowlands, and exceed 6 inches of snow at the higher elevations.

REFERENCES

Small, I., T. Mackechnie, and B. Bower., 2000: Mesoscale Interactions Triggering Severe Thunderstorms and Flash Flooding in Southwest California - July 1999. Western Region Technical Attachment 00-01.
http://www.wrh.noaa.gov/wrh/00TAs/0001/index.html

Small, I., and J. Dandrea, 2003: A Low Level Blocking Ridge Along With Downward Motion Aloft in the Right Front Quadrant of the Upper Level Jet - A Recipe for Minor Flooding and High Winds. Western Region Technical Attachment 03-04.
http://www.wrh.noaa.gov/wrh/03TAs/0305/index.html

Figure 1

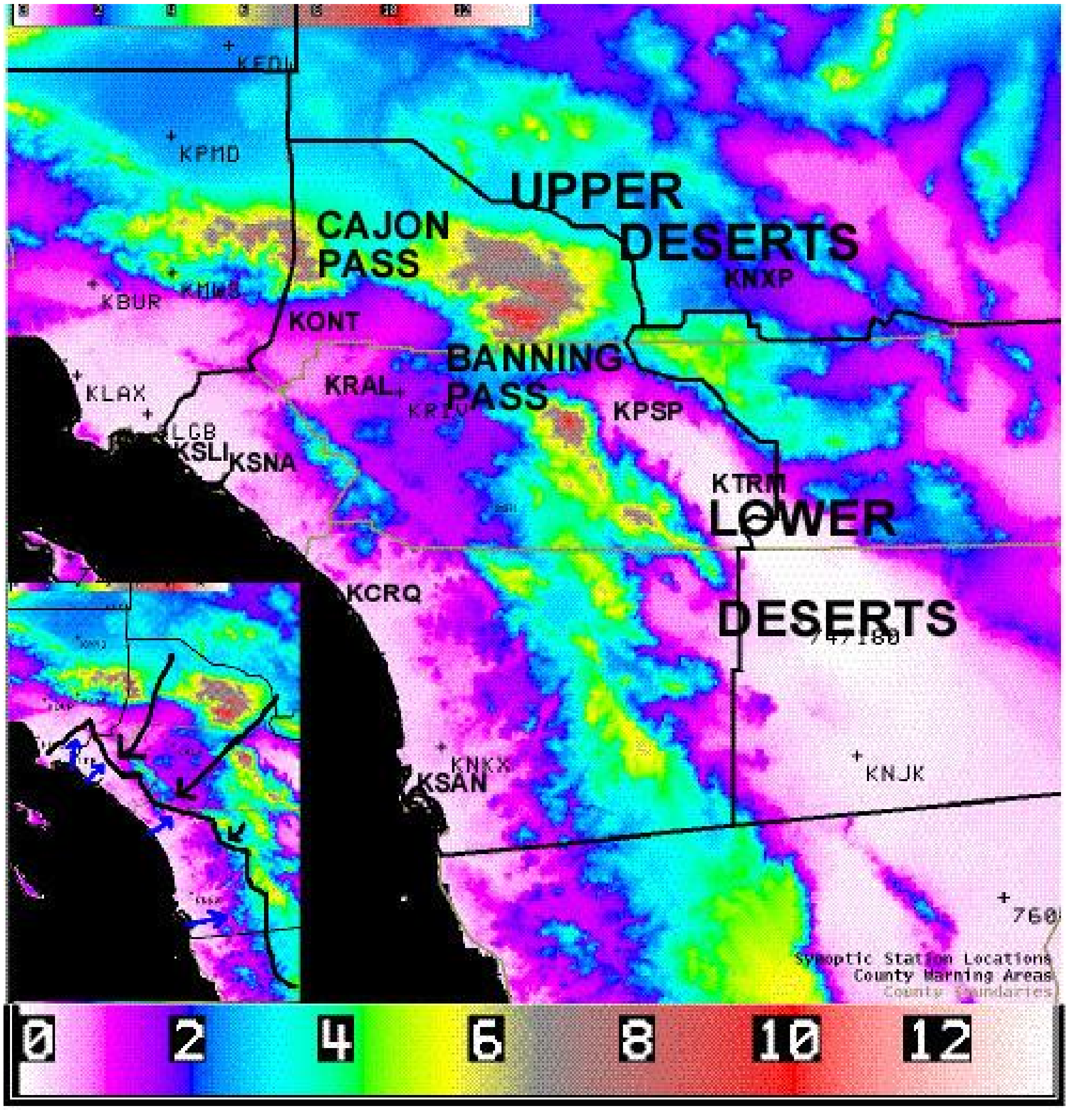


Figure 1. Terrain map of WFO SGX CWFA. Inset shows the location of the convergence zone (the thick black line) at 2200 UTC 12 November 2003. The black arrows indicate the offshore flow, and the blue arrows indicate the onshore flow. The legend is in thousands of feet msl.

Figure 2

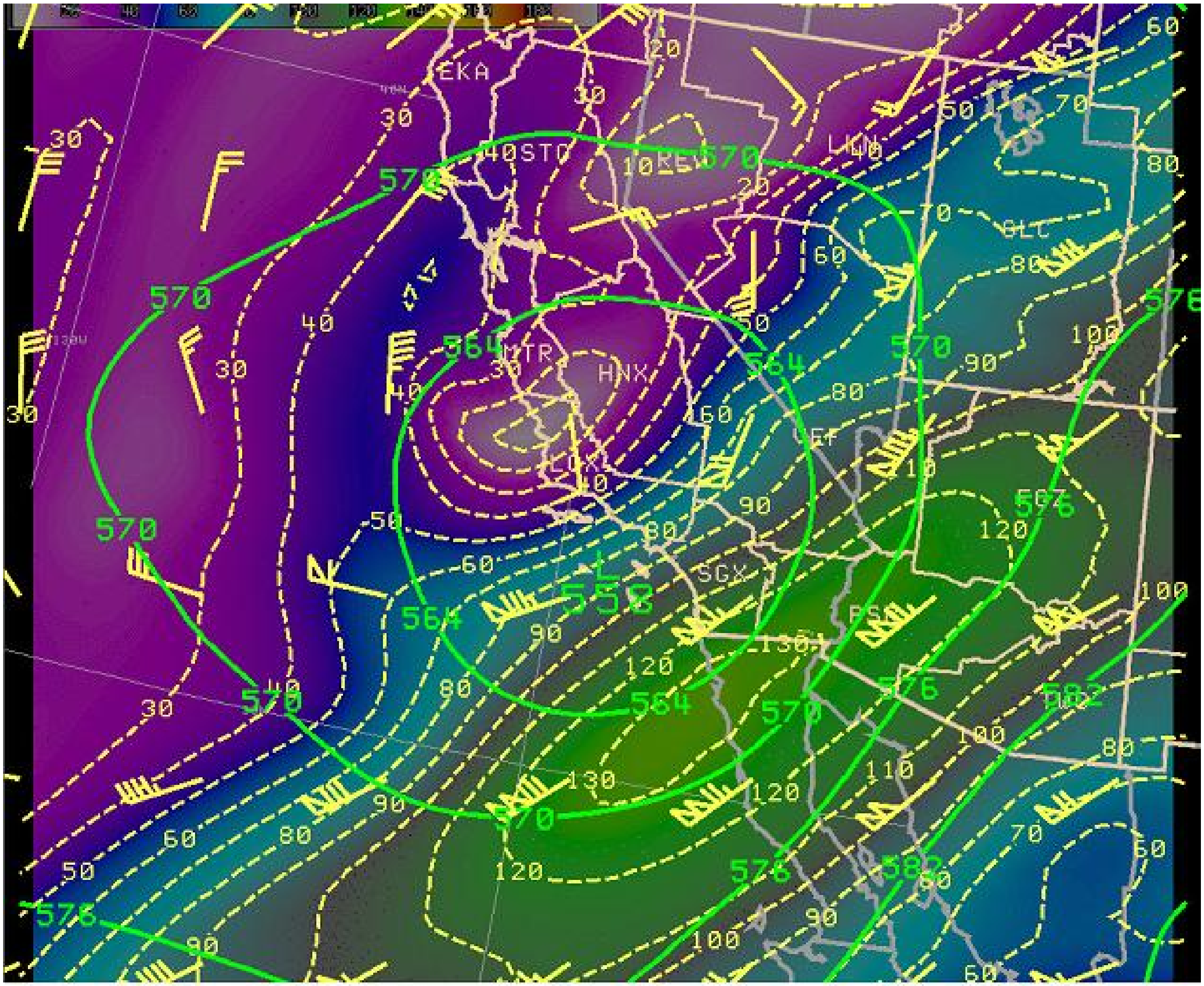


Figure 2. The 0000 UTC 13 November 2003 MesoETA 500 mb heights in decameters (green) overlayed with the 250 mb wind barbs (yellow, in knots) and isotachs (shaded, and yellow dashed contours, in knots).

Figure 3

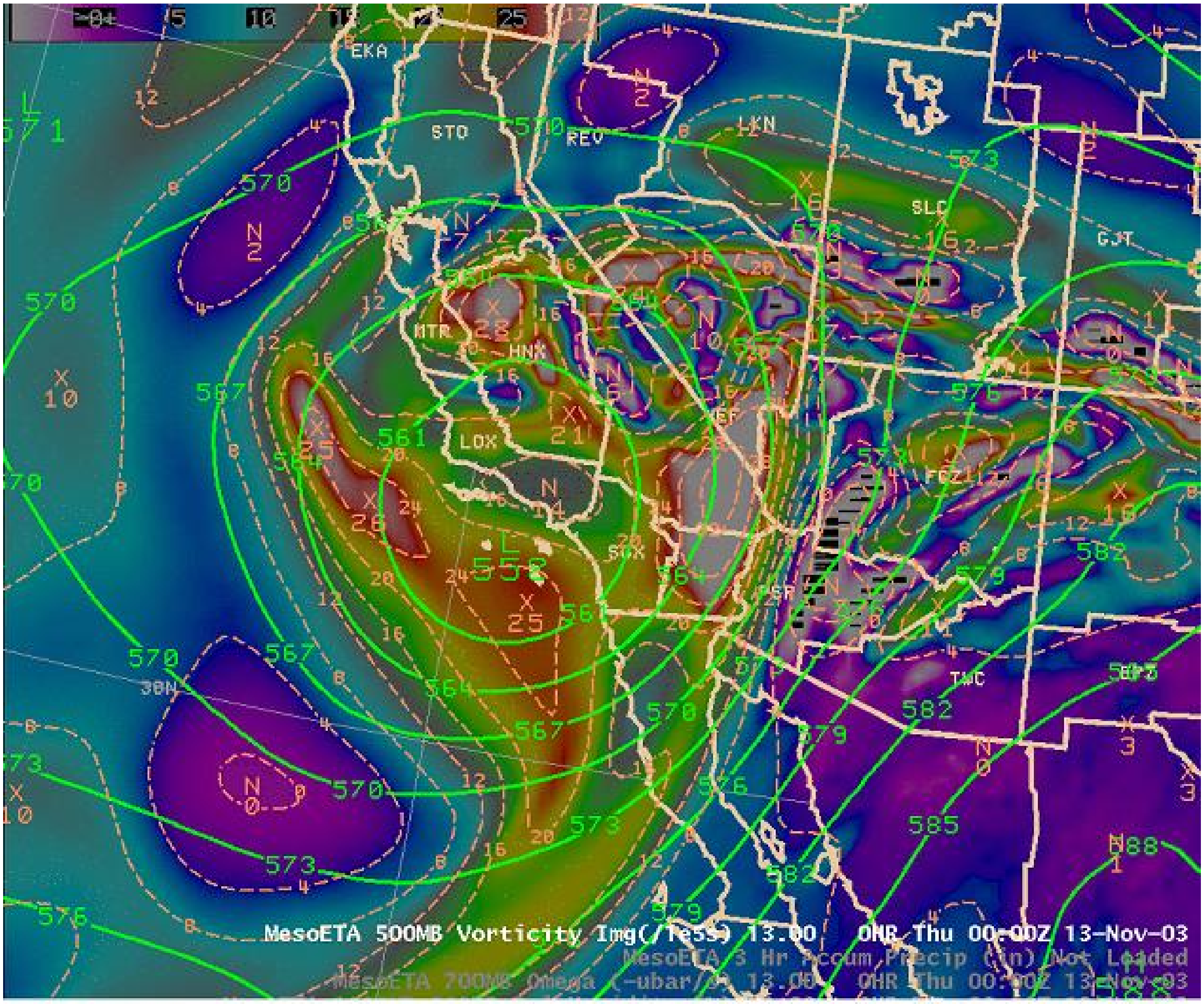


Figure 3. The 0000 UTC 13 November 2003 MesoETA 500 mb heights in decameters (solid green contours), and vorticity (shaded, and dashed orange contours).

Figure 4

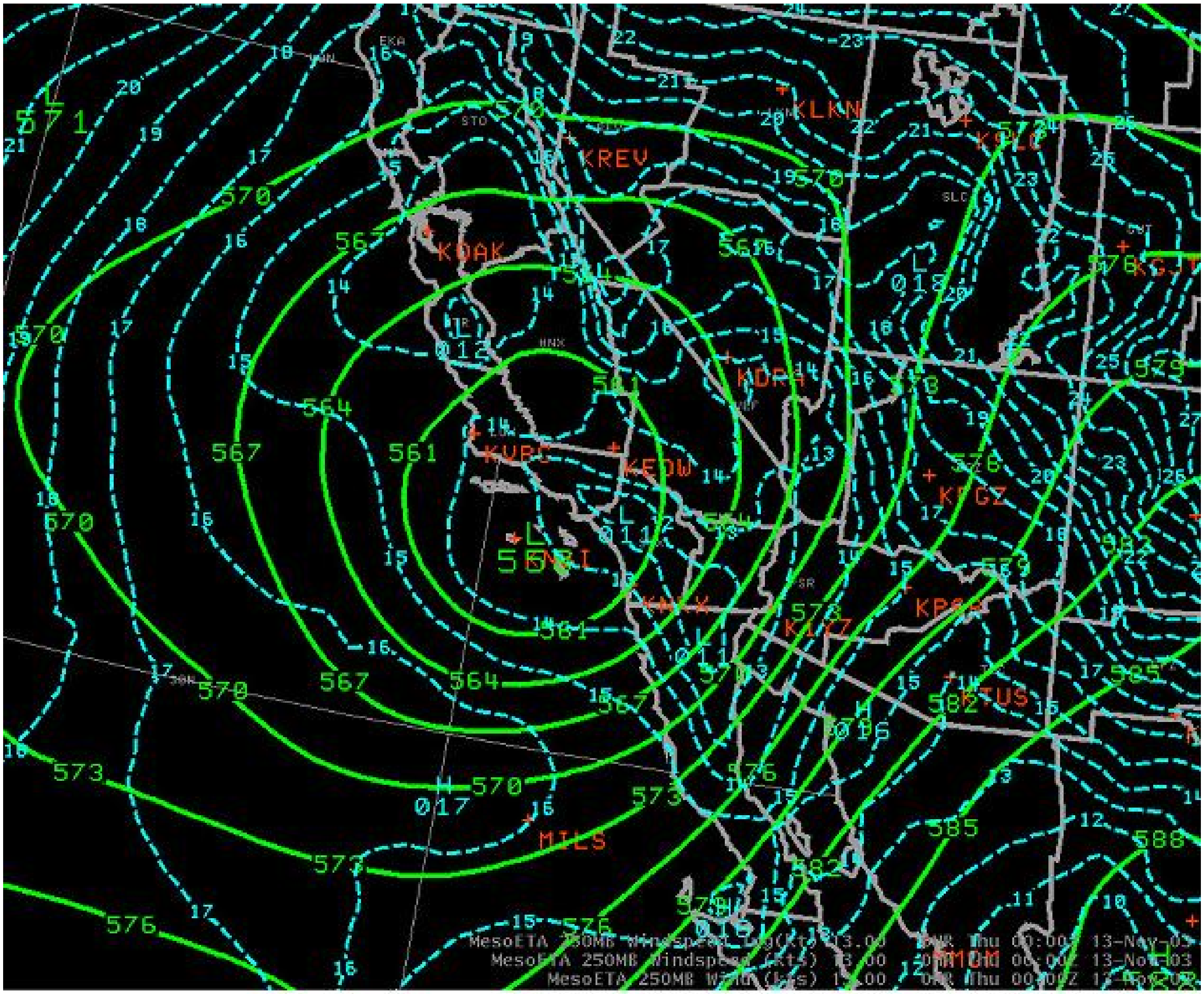


Figure 4. The 0000 UTC 13 November 2003 MesoEta 500 mb heights in decameters (solid green contours), and mean sea level pressure (dashed blue contours).

Figure 5

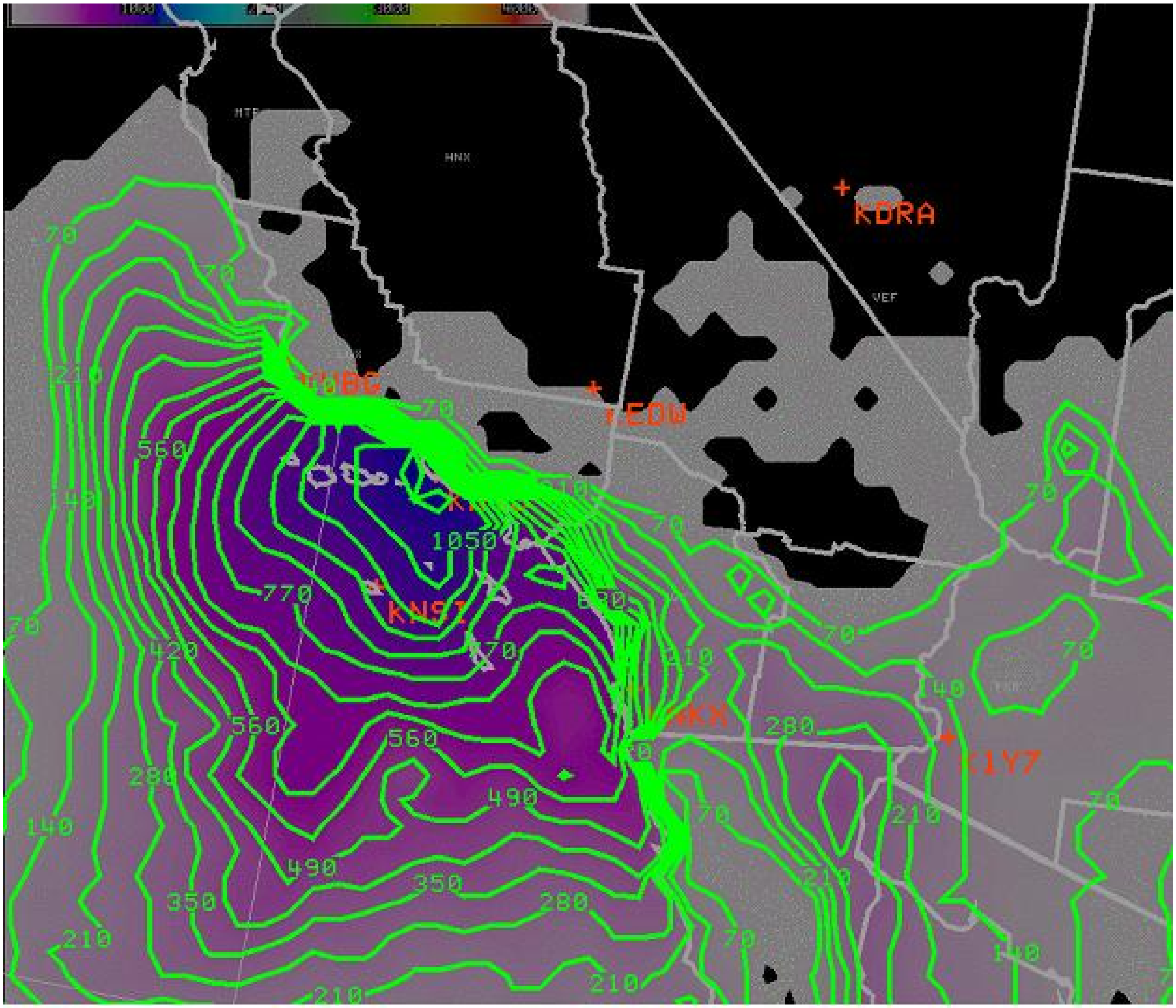


Figure 5. The 0000 UTC 13 November 2003 MesoETA surface CAPE (joules).

Figure 6

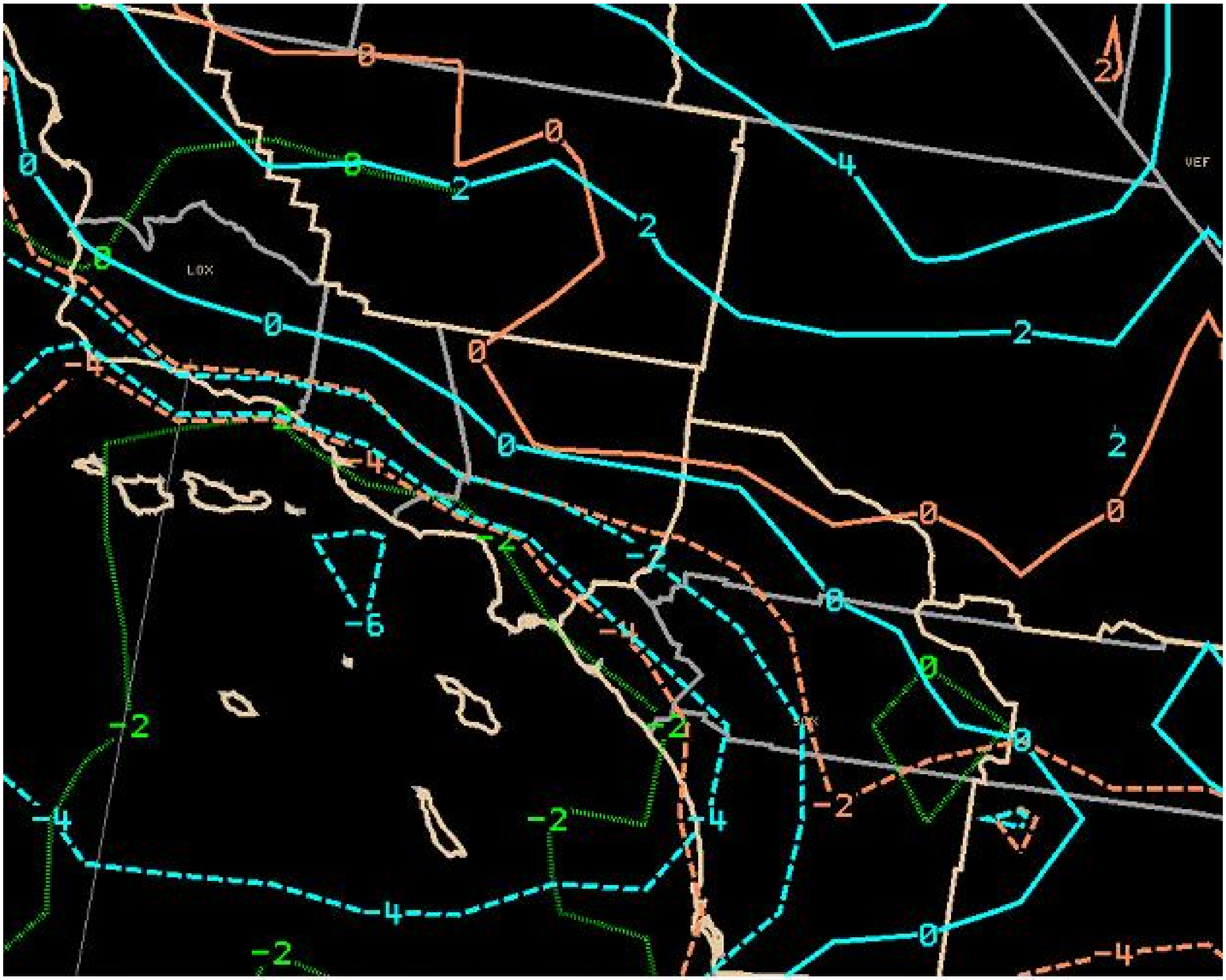


Figure 6. The 0000 UTC 13 November 2003 MesoEta surface based lifted index evaluated at 500 mb (blue contours), 700 mb (orange contours) and 850 mb (green contours). Negative values are dashed contours.

Figure 7

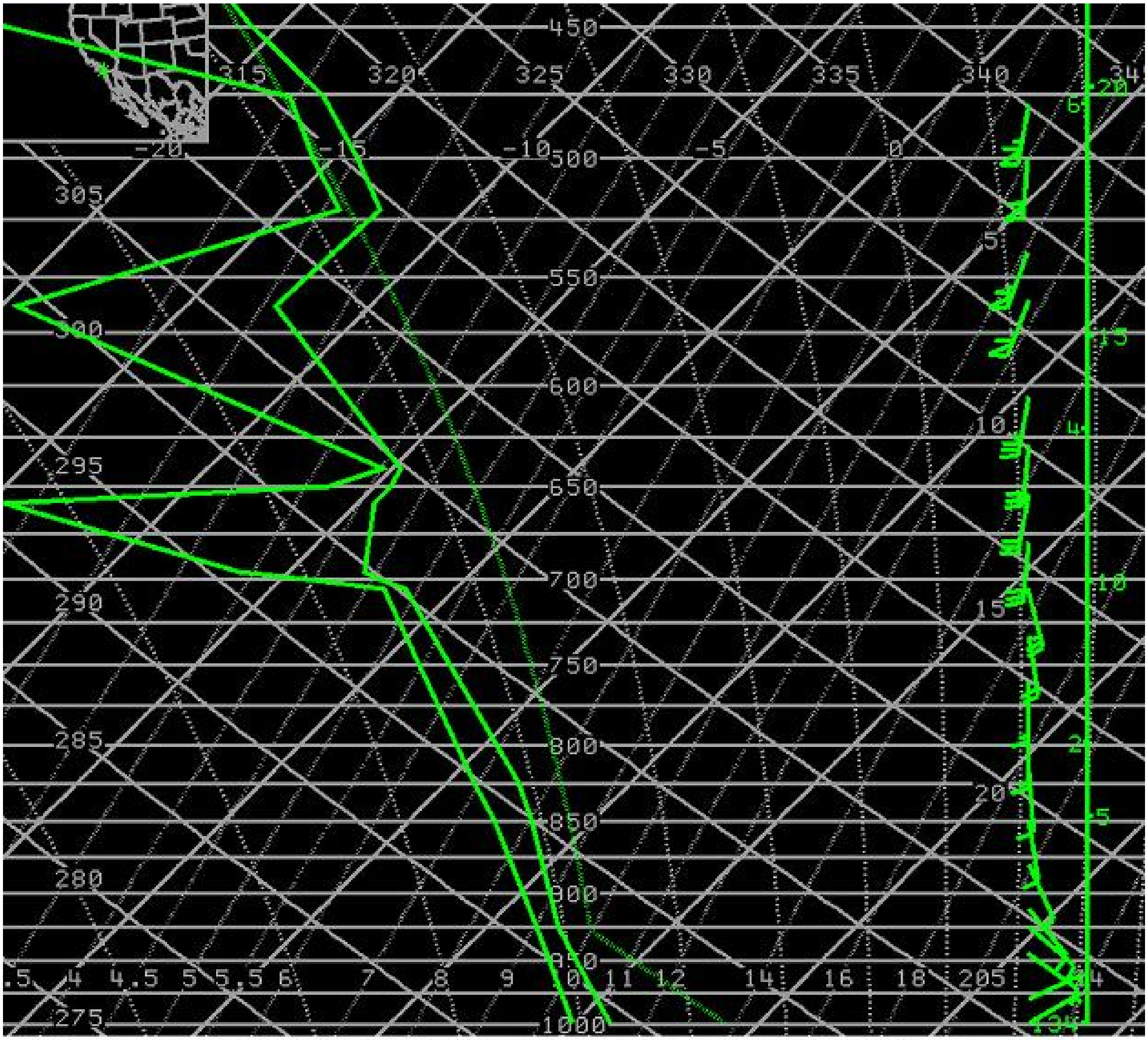


Figure 7. The 1200 UTC 12 November 2003 KNKX sounding.

Figure 8

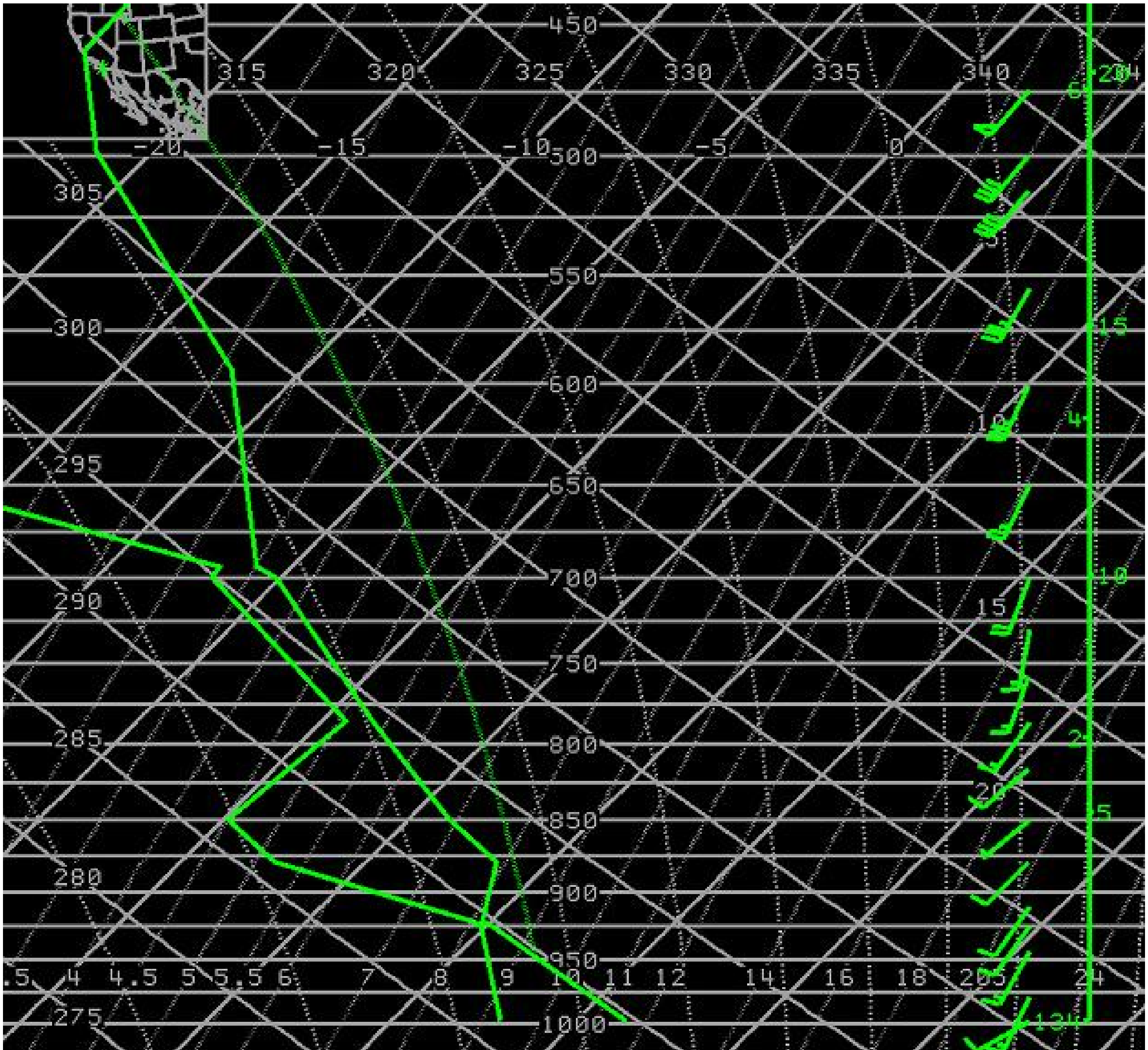


Figure 8. The 0000 UTC 13 November 2003 KNKX sounding.

Figure 9

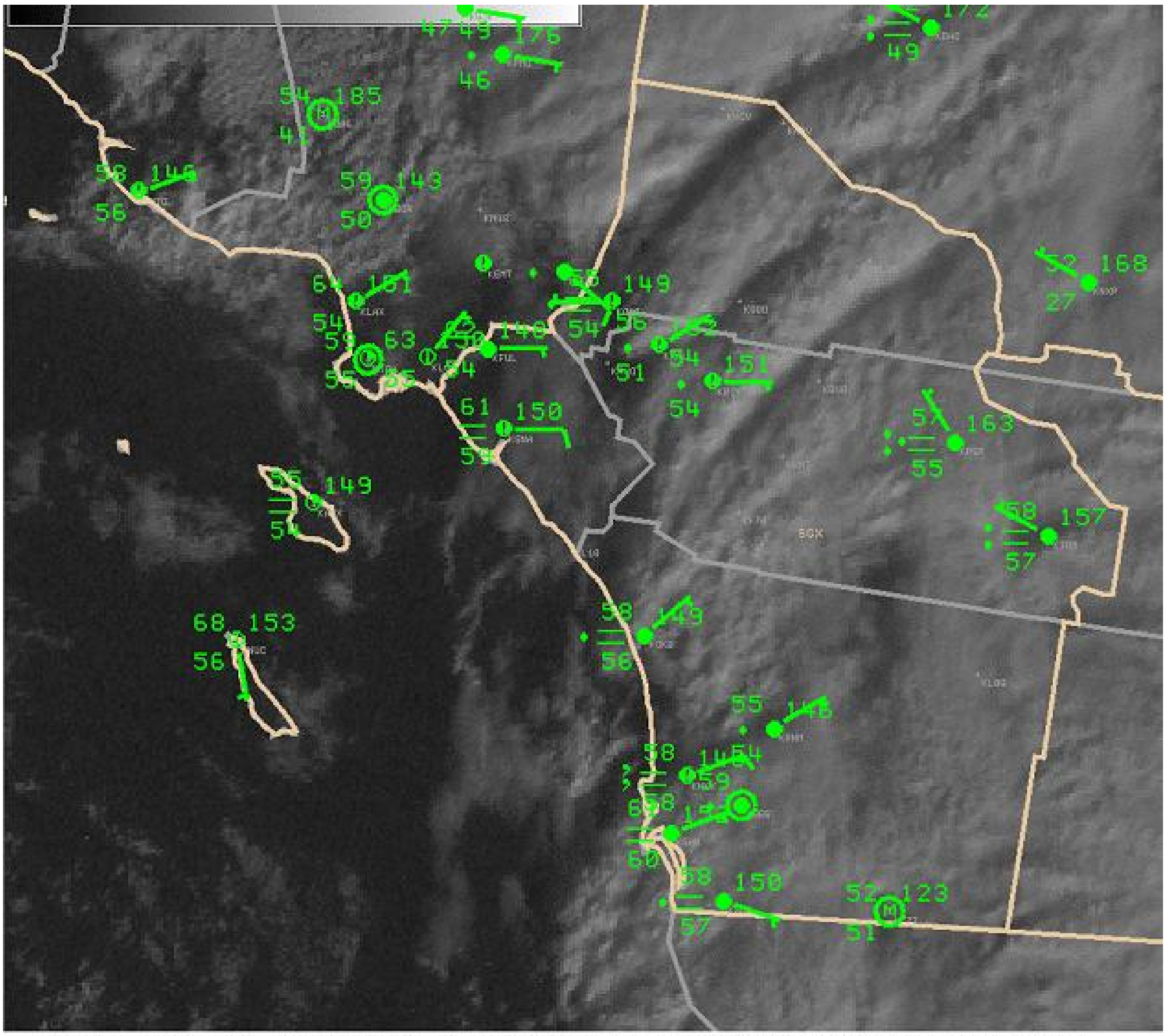


Figure 9. The 1600 UTC 12 November 2003 visible satellite imagery and surface observations.

Figure 9

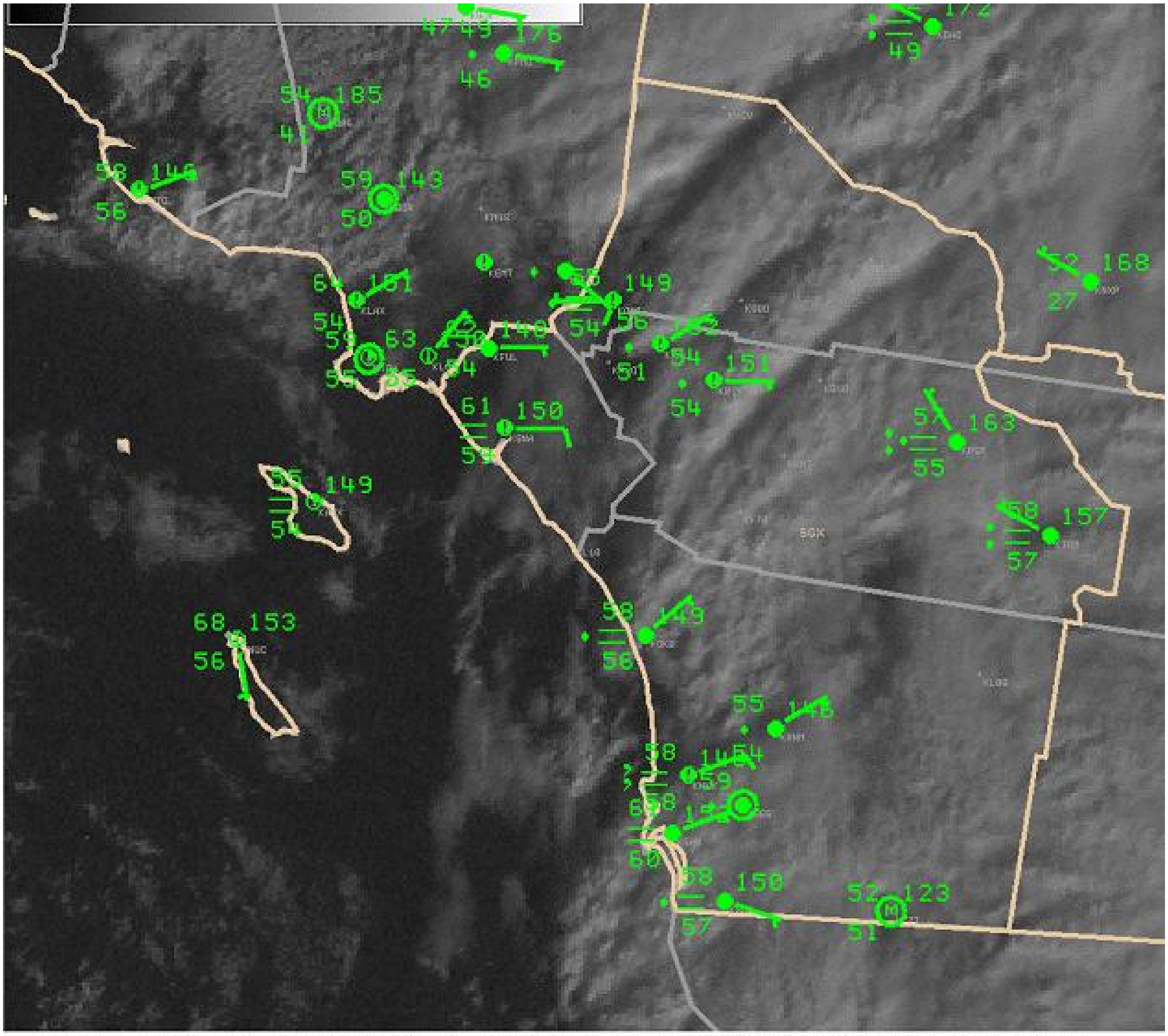


Figure 9. The 1600 UTC 12 November 2003 visible satellite imagery and surface observations.

Figure 10

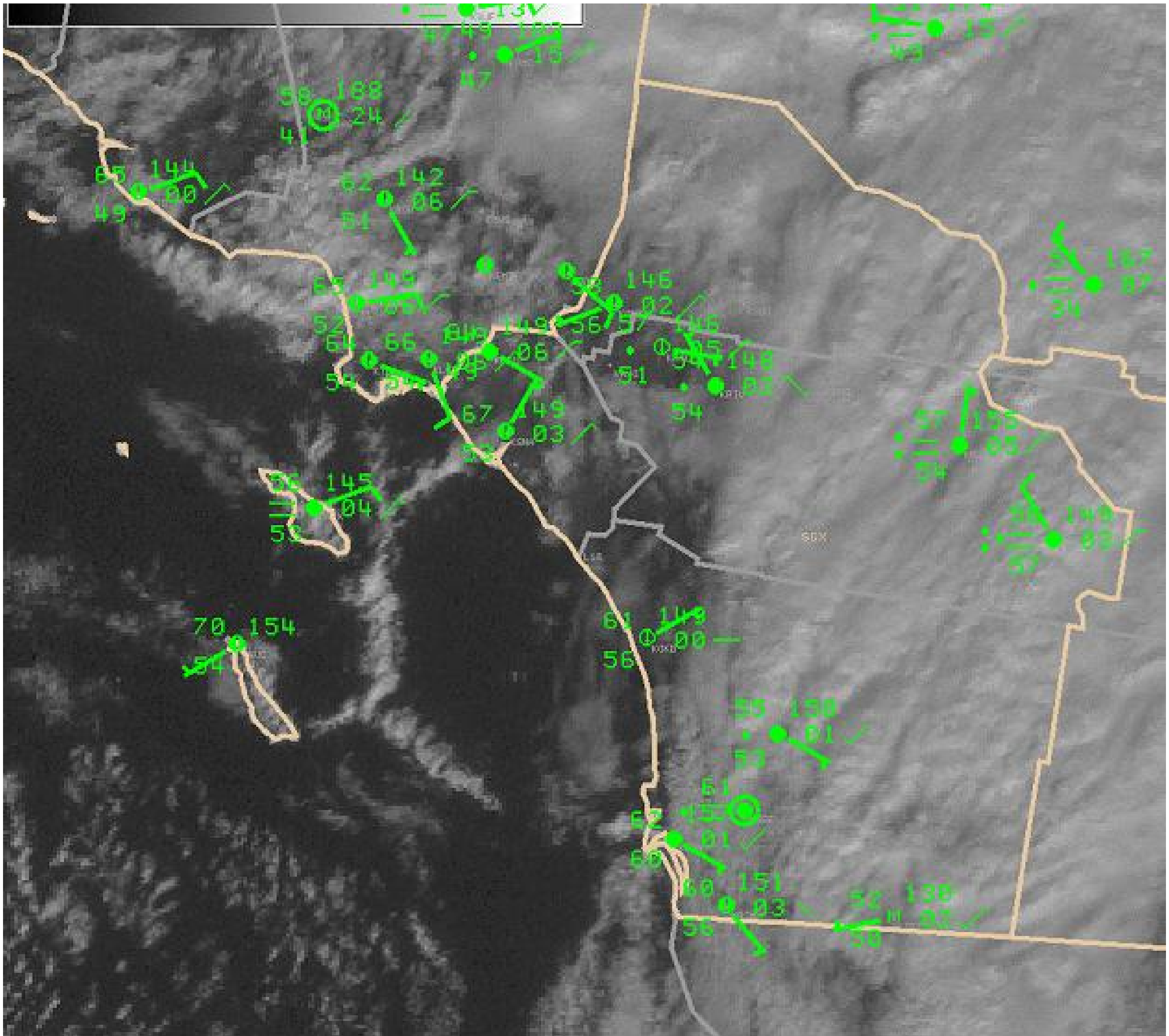


Figure 10. The 1800 UTC 12 November 2003 visible satellite imagery and surface observations.

Figure 11

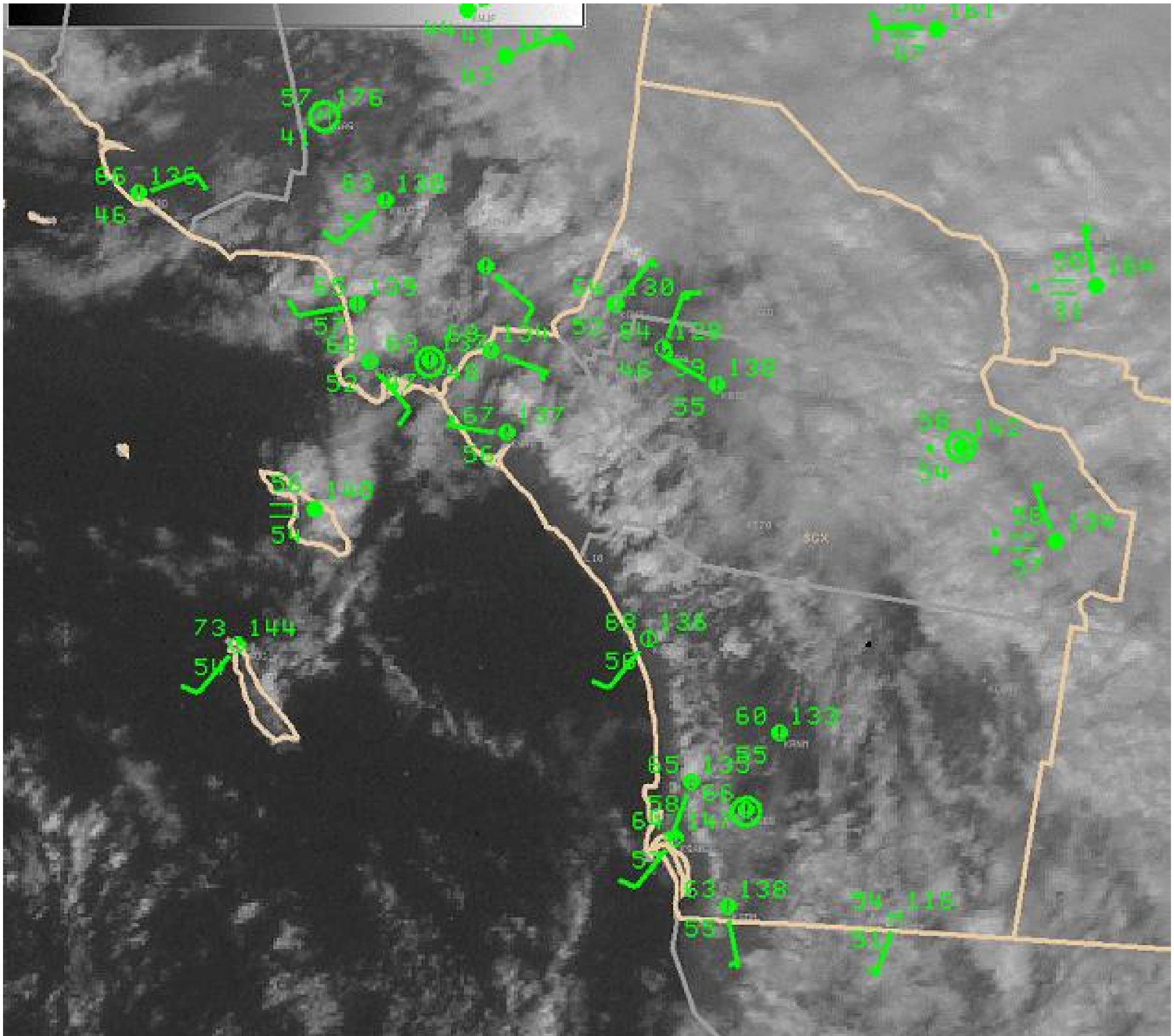
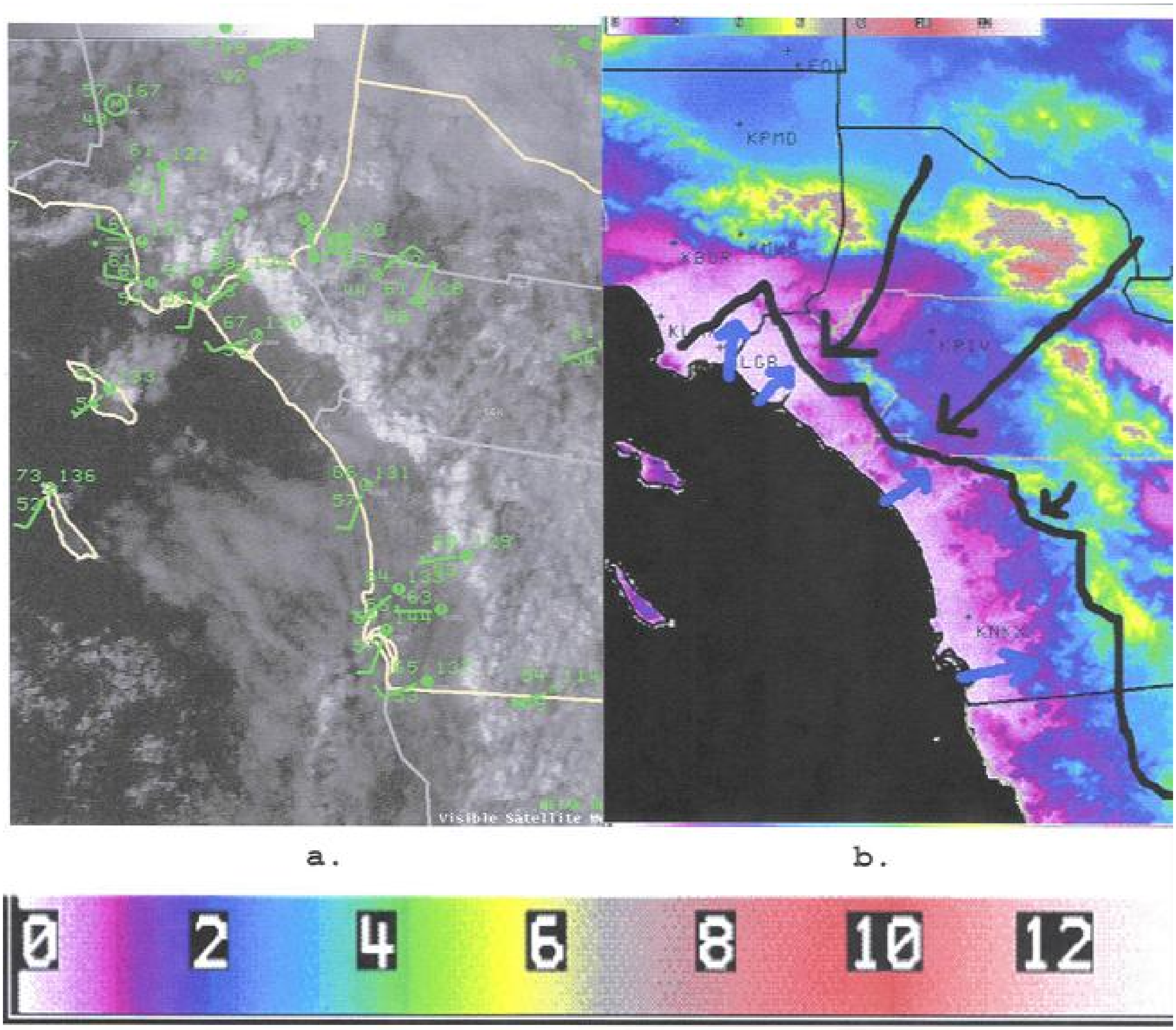


Figure 11. The 2000 UTC 12 November 2003 visible satellite imagery and surface observations.

Figure 12



c.

Figure 12. (a) The 2200 UTC 12 November 2003 visible satellite imagery and surface observations. Arcs of convection generated by northeasterly gap flow colliding with onshore/sea breeze flow are apparent. (b) The approximate location of the convergence zone at 2200 UTC 12 November 2003 on a high resolution terrain map. (c) Elevation scale for the high resolution terrain map (height in thousands of feet msl).

Figure 13

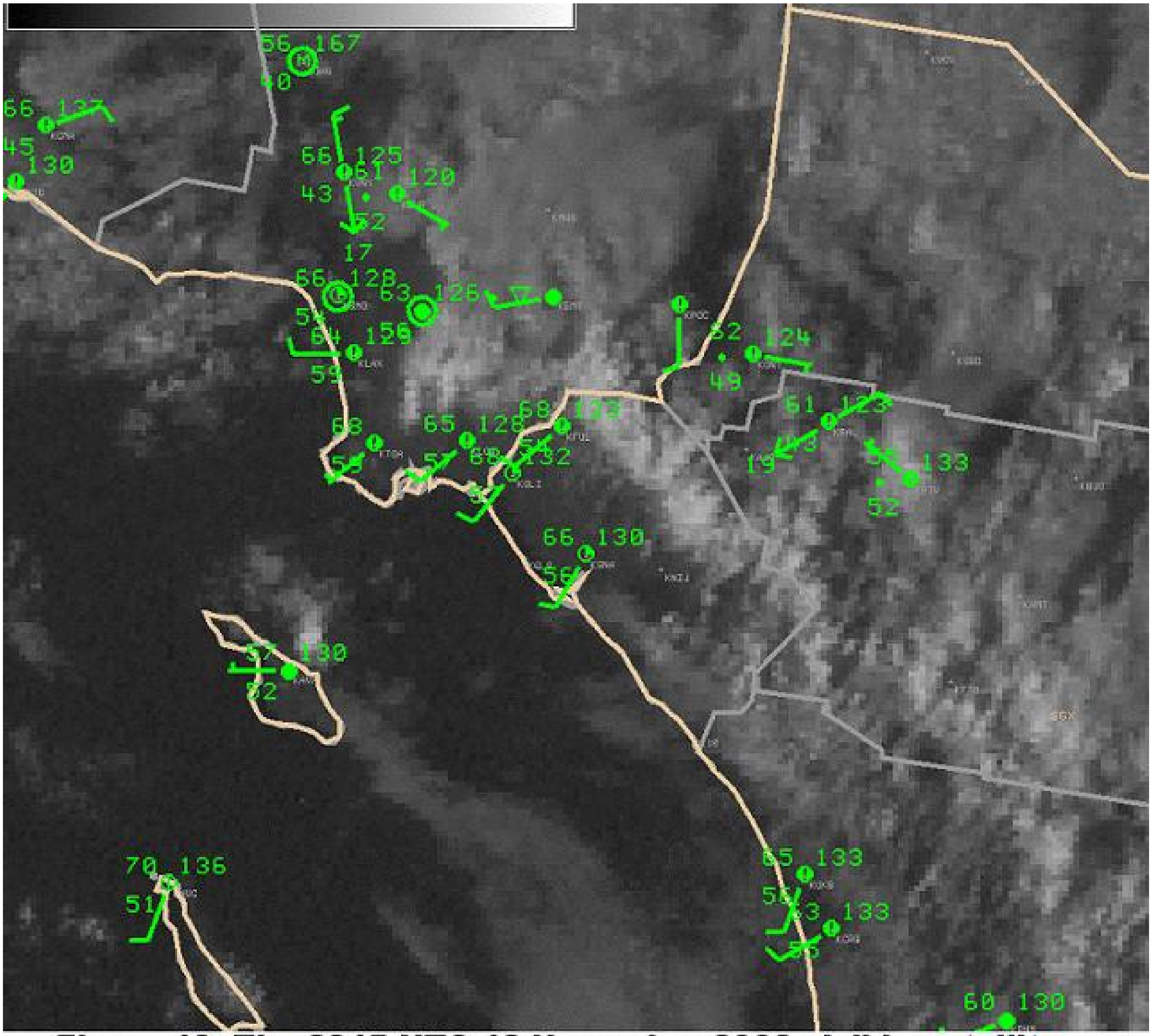
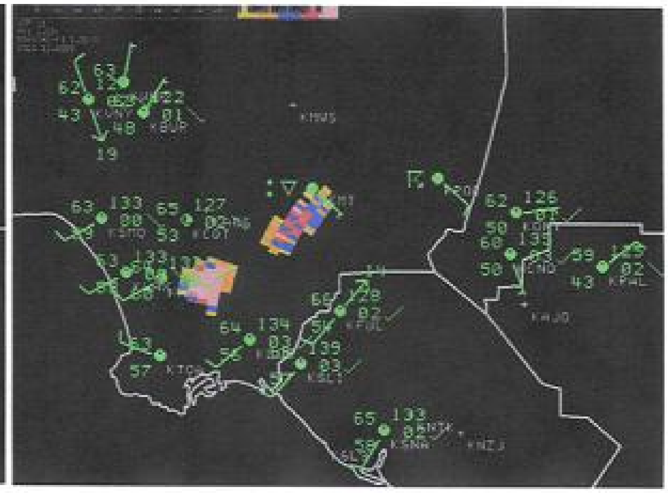


Figure 13. The 2315 UTC 12 November 2003 visible satellite imagery and 2300 UTC surface observations.

Figure 14

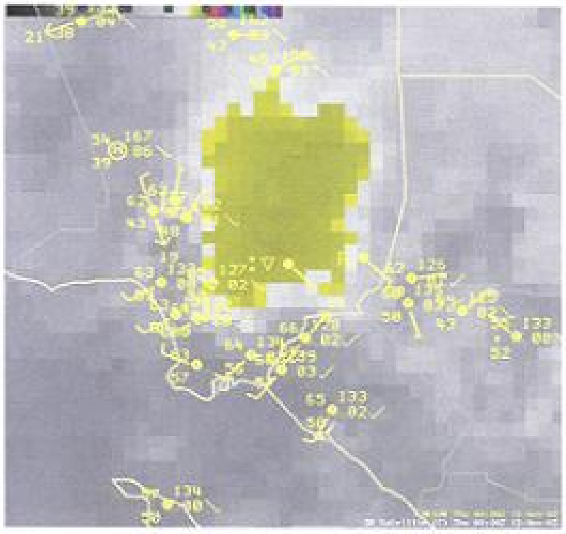


a. b.

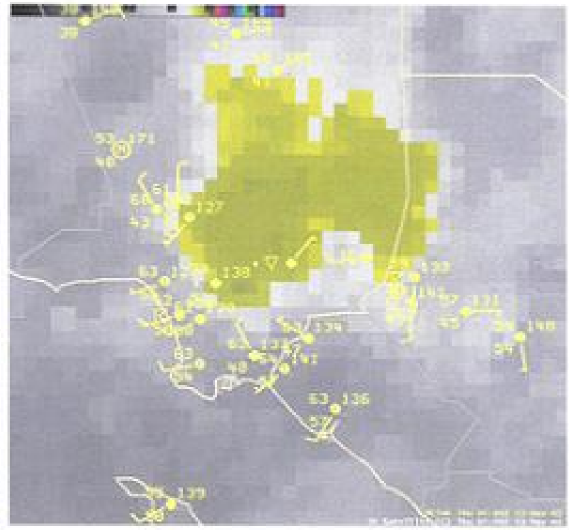
c. d.

Figure 14. KNKX WSR-88D Three Hour Precipitation (THP) and surface observations at 2311 UTC 12 November 2003, 0008 UTC 13 November 2003, 0110 UTC 13 November 2003, and 0212 UTC 13 November 2003 showing heavy precipitation spreading east along the convergence zone. (The pink region represents a radar rainfall estimate of greater than 2 inches).

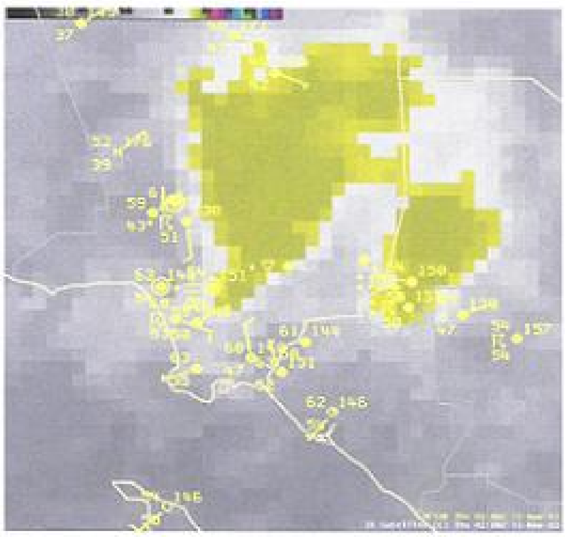
Figure 15



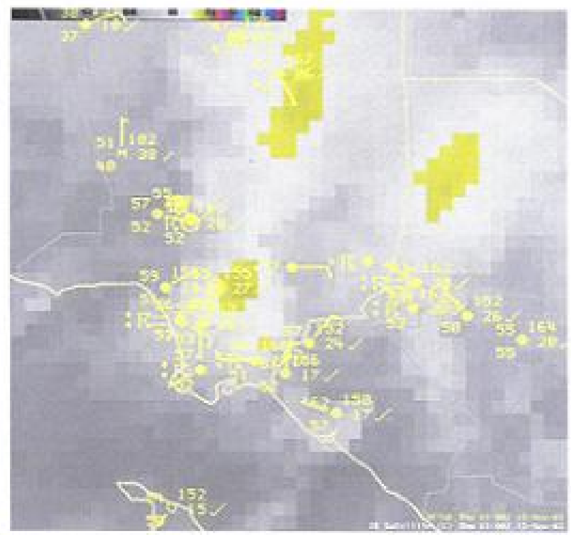
a.



b.



c.



d.

Fig. 15. Infrared satellite imagery and surface observations at (a) 0000 UTC 13 November 2003, (b) 0100 UTC 13 November 2003, (c) 0200 UTC 13 November 2003 and (d) 0300 UTC 13 November 2003. The first thunderstorm generates an outflow boundary. As the outflow boundary moves east, it creates another thunderstorm, which can be seen moving away from the first thunderstorm and east along the convergence zone. The storms have begun to dissipate by 0300 UTC 13 November 2003.