SOME INTERESTING CHARACTERISTICS OF THE SOUTHERN CALIFORNIA WILDFIRES AND THE RESULTING WATERMAN CANYON FLASH FLOOD/MUDSLIDE EVENT OF DECEMBER 25, 2003

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INTRODUCTION

Strong, but weakening upper level high pressure over the west combined with weakening onshore flow results in what can be referred to as our "peak firestorm season" during the fall and early winter in southern California (Fig 1 and Fig 2). As a result of these firestorms there is a significant flash flood/mudslide threat during the strong Pacific storms of mid winter, the "cut off low" seasons of spring and fall, and the summer monsoon season of the following year, with lesser threats in subsequent years. Flood guidance falls to about 1/3 - 1/2 of typical "non burn" values in burn areas. The Santa Ana Winds, fires, and floods/mudslides of winter 2003-2004 are prime examples of this cycle. The goal of this TA-Lite is to overview this event.

OVERVIEW OF THE FIRE CONDITIONS

The hot, dry fire conditions were driven by an almost unheard of 603 decameter 500 mb high moving over the west coast with strong subsidence, as seen in the 1800 UTC 26 October 2003 500 mb heights and 850 mb heights (Fig. 3). An "east-west ridge axis to the north" pattern, noted for long heat waves, developed over southern California with easterly flow south of the ridge axis. The strong flow generated a mesoscale response in the form of a mountain wave which can be seen via the wave - induced darkening/drying near the mountains in the 1200 UTC 26 October 2003 250 mb data and water vapor imagery (Fig. 4). Mesoscale subsidence along with some fringe synoptic scale subsidence from the jet was sufficient for gusts between 60 and 70 mph. A northeast through southwest oriented jet (common for strong Santa Ana Wind Events) of 120-140 knots generated synoptic scale subsidence in the water vapor imagery. Interestingly, the most pronounced synoptic scale darkening/strong subsidence drying was well to the east, near the Arizona/New Mexico border. The San Diego sounding (KNKX) (Fig 5) shows 30 knots near 850 mb, which when doubled is 60 knots (69 mph), a good estimate for peak gusts in the "favored areas". This closely approximates the 57 knot (66 mph) wind gust in the mountains at Campo (KCZZ), a favored area for east/west surface pressure gradients and associated flow. Also interesting, as seen in this case, KCZZ winds usually begin with gradients that appear to still be onshore (about +2.0 mb KSAN-KIPL), and can be tricky to forecast. Although Fremont Canyon (FMC) in the Santa Ana Mountains to the north is usually the windiest location, however and because the strongest synoptic and mesoscale "support" was in the south, the winds at KCZZ exceeded those found at Fremont Canyon.

As for the heat, pressure gradient values in the "weak to neutral" category (at or slightly more offshore than about +3.0, +2.0, +2.0, and 0.0 for KLAX-KLAS, KLAX-KTRM, KSAN-KIPL, and KLAX-KDAG respectively) are common for such hot days. These values open the door for heat waves when a ridge axis or upper high is over (or even better, just north) of the area, usually with at least weak offshore winds below canyons and passes. The gradients were far more offshore than these values, and adiabatic flow pushed the marine layer out of the coastal areas. Other parameters supporting heat were dewpoint depressions near the surface that were well in excess of 10 degrees C (no cool marine layer to slow the heating), a 950 mb "boundary layer" temperature of about 27 degrees C, a surface based inversion with a top below 950 mb, and inversion top temperature approaching 30 C (fig. 5). Such a low inversion brought the hot air aloft very close to the ground, resulting in a rapid morning temperature rise before the sea breeze could slow the heating. The adiabatic flow from about 850 mb can be seen surfacing near the coast in figure 6. The period of maximum turbulent mixing and highest heating rate during the late morning coincides with the gusty, surfacing mountain wave, and oftentimes the strongest wind. This is followed by the well mixed, less gusty, and usually weaker winds of the mid to late afternoon period. Since northeast wind gusts were far above 10 mph in the canyons adjacent to the valleys (coast), simply adding 26 to 30 F to the 850 mb temperature approximates maximum temperatures in the warmer valley (warmer coastal) areas. Adding about 26 degrees F to the 850 mb temperature (64 + 26 = 90 F) accurately approximates Fullerton (KFUL) and Anaheim on the inland portion of the coastal plain, since the profile is essentially adiabatic (and temperatures are more related to elevation rather than the usual "distance from the ocean"). With the upper high or ridge axis to the north or overhead, or strong northeast 850 mb winds, beaches may even reach adiabatic values (which occurred in this case). Coastal areas are usually cooled by the sea breeze on day 2 for many events, while inland areas remain warm, but in this case, coastal areas warmed further on day 2, typical of prolonged events with slow moving highs. The event occurred near the end of a record period (181 days) with no measurable rain at San Diego Lindbergh Field (KSAN) thus the stage was set for a major fire disaster. Worse, during the latter part of hot offshore flow events such as this, the sea breeze is stronger than normal, and helps fan the flames in the opposite direction. Gradient wind gusts in the favored mountain/desert areas, as a rough estimate, are about 5 times the gradient from the coast to the northern deserts (KLAX-KDAG) when the flow turns strongly onshore. After the fires the hills were denude of vegetation, and flash flood guidance values were reduced to about 1/3 to 1/2 of the "usual" values. Hence, the stage was set for flooding.

THE FLOODS AND MUDSLIDES OF DECEMBER 2003

On Christmas Day, less than 2 months after the fires, a strong (130 knot) 250 mb jet, a common flood pattern element (Fig. 7) developed with southern California in the left front quadrant. There was 850 mb flow of 30 - 40 knots (Fig. 8), and a moist layer exceeding 10,000 feet deep saturating the 1000-500 mb layer to over 80 percent relative humidity. About 3 inches of low topped pre-frontal moderate-heavy rain fell by about noon (2000 UTC) on the 25th (Fig. 9) in the Lytle Creek/Waterman Canyon area along a terrain forced convergence zone. This was followed by a fierce strengthening of a convergence zone just ahead of and with the front, packing rainfall rates of over 5 inches in 6 hours. The convergence zone resulted in a wall of water and mud in the Lytle Creek/Waterman Canyon burn area (near the Cajon Pass). The observations and radar data show the convergence zone (Fig. 10 and Fig. 11). This is a reflection of the flow being channeled east along the San Gabriel Mountains colliding with flow moving north along the San Bernardino Mountains. This terrain forced horizontal moisture convergence was supplemented by the orographic lift. The 2114 UTC 25 December 2003 1 hour precipitation (fig. 11) best shows this convergence zone extending northeast into the Waterman Canyon area near San Bernardino (KSBD). The 2114 and 2200 UTC 25 December 2003 KSOX composite reflectivity shows a very strong precipitation band along the convergence zone (Fig. 12 and Fig. 13), which is the location of the mudslide area. For the remainder of the afternoon, transverse bands, perpendicular to, but moving along the front enhanced the precipitation, resulting in up to 0.75 inches per hour in most areas. Although there was steady heavy rain of around 0.75 inches per hour after 1900 UTC at Lytle Creek, the Waterman Canyon storm was quasi-stationary along the convergence zone, very intense, and aligned along the canyon for maximum effect. This likely produced much heavier rain in the Waterman Canyon area. Finally, the cold front reaches the edge of the Lytle Creek area north of Ontario (Fig. 14). It slowly moves through, so some echo training occurs. It dumps about 1.4 inches in 1 hour during a "frontal burst" of precipitation, approximately twice the previous rates. With enough moisture (especially surface based moisture) and 500 mb temperatures down to around -20 C, some thunderstorms almost always occur. However, in this case, although there was initially surface based moisture, no thunderstorms were reported. This was partly due to the 500 mb temperature remaining above about -20 C until after the moisture became rather shallow.

Although the models, in general, predicted some heavy rain, the actual magnitude of the dynamics and mechanics was much stronger. Because the event was a very efficient low topped warm rain event enhanced by upslope and convergent flow through at least 2000 UTC on the 25th, radar estimates were lower than what actually fell, and less than what can be expected with cooler, more convective storms. (The 850 mb dewpoints were around 5 C and specific humidity was around 6, which supports a warm rain scenario). This may have even lowered early Flash Flood Monitoring and Prediction System (FFMP) radar rainfall estimates. The storm total precipitation from 1304 UTC 25 December 25 to 0158 UTC 26 December showed a maximum of 3.8 inches, less than 1/2 of what actually fell (Fig. 15). However radar estimates improved after the cold air and deep explosive convection arrived near and after frontal passage. This is a more typical setup for good radar estimates in southern California, with likely improvements in FFMP estimates. When 850 mb winds in excess of 30 knots are observed, surface gusts to around 70 mph (or 2 times as high as the 850 mb winds) can be expected. Usually winds peak with the front, and correspondingly, gusts at Granite Mountain (GAM), a mountain peak near the northern end of the CWFA, reached 68 mph with the front.

COMBINATION STRATIFORM/CONVECTIVE EVENTS

In this case we are dealing with 2 rainfall types; the dreaded combination of a long period of moderate to heavy stratiform rain followed by a burst of very heavy convection and higher rainfall rates. Negative tilt diffluent troughs, or convergence zones that set up late in an event are notorious for this. Some combination of moisture depth, duration, and flux must be used to formulate guidance. Since cool season flood events are frequently based on moisture rooted in the boundary layer, boundary layer moisture depth is a good start. Duration of the deep moisture is also critical. Flow speed can help diagnose moisture convergence away from the mountains and upslope enhancement in the mountains. The preliminary results of a local study using this reasoning shows that if the 1000-500 mb relative humidity (about 10,000 feet of nearly saturated air) reaches 80 % with over 25 knots of 850 mb flow, urban and small stream flooding along with flash flooding in the most vulnerable areas is likely, with a chance of flooding in the somewhat less vulnerable areas. The recently burned areas and areas known for "low water crossings" can be considered as the "most vulnerable areas". The moisture in the Lytle Creek/Waterman Canyon event easily reached 80 %, with 35 knot winds.

Late in the Lytle Creek/Waterman Canyon event the airmass began drying aloft, leaving a profile with limited moisture aloft and a rather wet airmass at the lower levels. Snow still fell in the mountains, but Mount Laguna (near 6000 feet just north of KCZZ) only received 2 inches of snow. Although the thickness of the "over 80 % relative humidity mid level layer" resident in the 850 to 700 mb region was sufficient for precipitation, the cold pool was so far behind the deep moisture that there was little time for snow to fall before the moisture moved east. If the cold pool had come in faster and the snow level dropped lower, there would have been more snow and less rain in the burn areas, reducing the flood threat. As it was, the lowering snow level indicated a transition from warm rain to a colder, more convective rain in the burn areas with higher rates, but little if any snow fell, further amplifying the problem.

SUMMARY AND CONCLUSION

Weak to neutral offshore pressure gradients (generally 0.0 to +2.0 mb range) and winds below canyons and passes can generate afternoon high temperatures that are 26 degrees F above the 850 mb temperature and produce high fire potential and record breaking heat just about any time of year - with a boost of another 2-4 degrees F in the warmest areas. Another problem associated with the firestorms was the easterly flow with low inversions trapped dense fog, smoke, low clouds, and afternoon haze in the populated coastal areas with very poor visibilities and limited afternoon improvement, (even with the sea breeze). The major improvements during the 2003 firestorms were delayed until the large scale flow switched to onshore and lifted the inversion for more mixing/convection beneath the inversion. Eventually the cold advection aloft eliminated the inversion and the fog/smoke cleared. This dramatically improved visibilities at the coast, but the onshore flow lowered visibilities in the deserts, before finally rain moved in to help douse the fire. This has significant effects on aviation traffic as well. To add insult to injury, southern California was left with denude hillsides and a serious flash flood problem. With heavy early winter rains there was virtually no time for re-growth. Burn areas and other vulnerable locations in the CWFA must be closely watched. Rates resulting in mud and/or water over roads are about 1/3-1/2 of that in less "flood - prone" areas (about 0.40-0.50 in an hour or less in burn areas and vulnerable flood areas, about 1.00 to 1.25 inches in one hour or less for the less vulnerable areas, and just about anywhere for amounts over 1.25 inches in one hour or less). This creates variable guidance that is a "moving target" spatially and temporally. The problems resurface again with a vengeance during the summer monsoon period, where an inch in 1/2 hour can be rather typical, making rainfall rates and amounts that are generally insignificant in most parts of the country into flash flood/mudslide threats in southern California. This case illustrates the fact that the potential for extreme events are often set up on the synoptic scale, and executed on the mesoscale, so forecasters must be diligent throughout the event for mesoscale forcing, especially late in an event. During the warm season, the burn areas need to be closely monitored when the monsoon thunderstorms return to the southland, with rainfall rates that can far exceed those of the cool season. This is especially true when convergence zones come into play. Further evaluation of these types of events will continue.

Figure 1

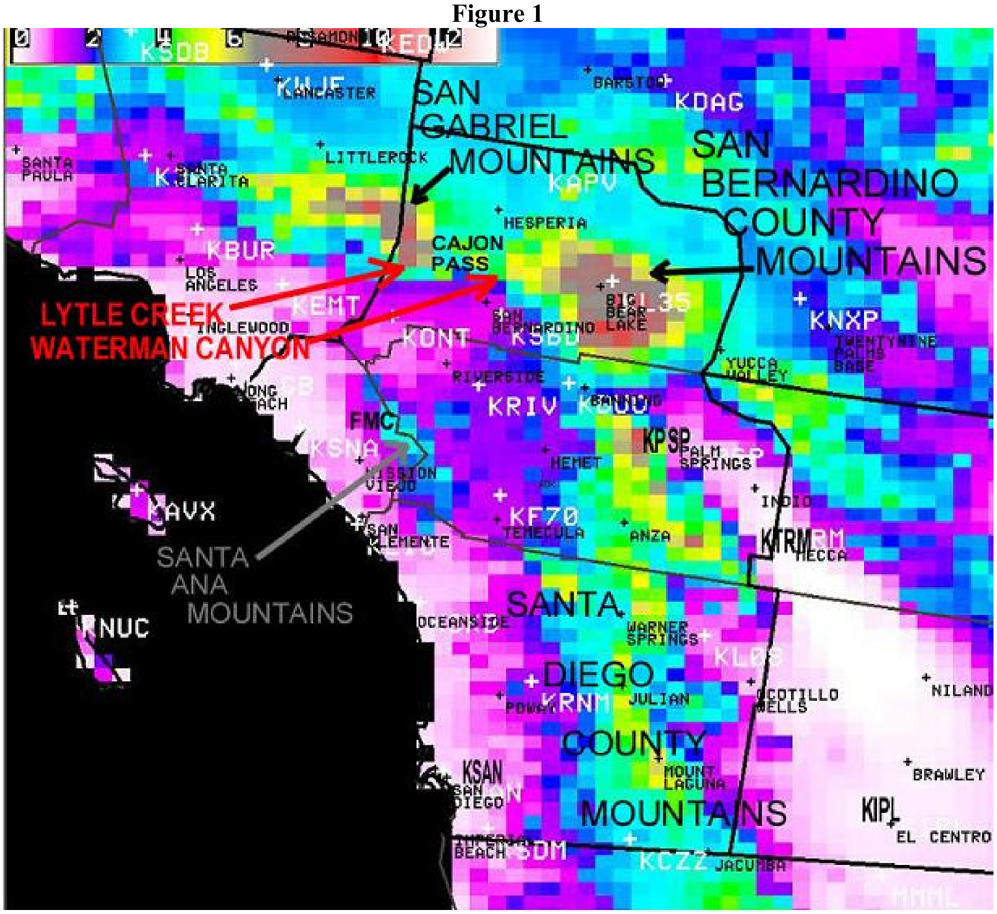

Fig. 1. Map of southern California locations and terrain.

Figure 2

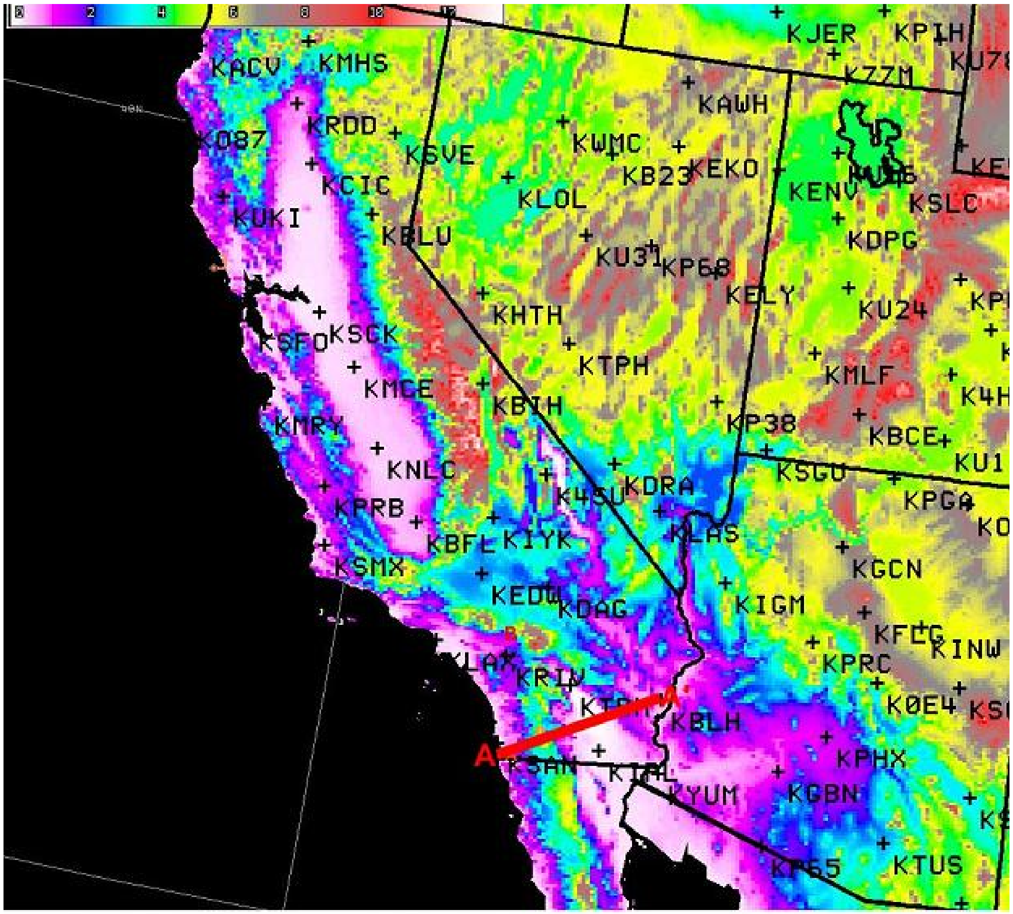

Fig. 2. Map of southern California terrain and cross section locations.

Figure 3

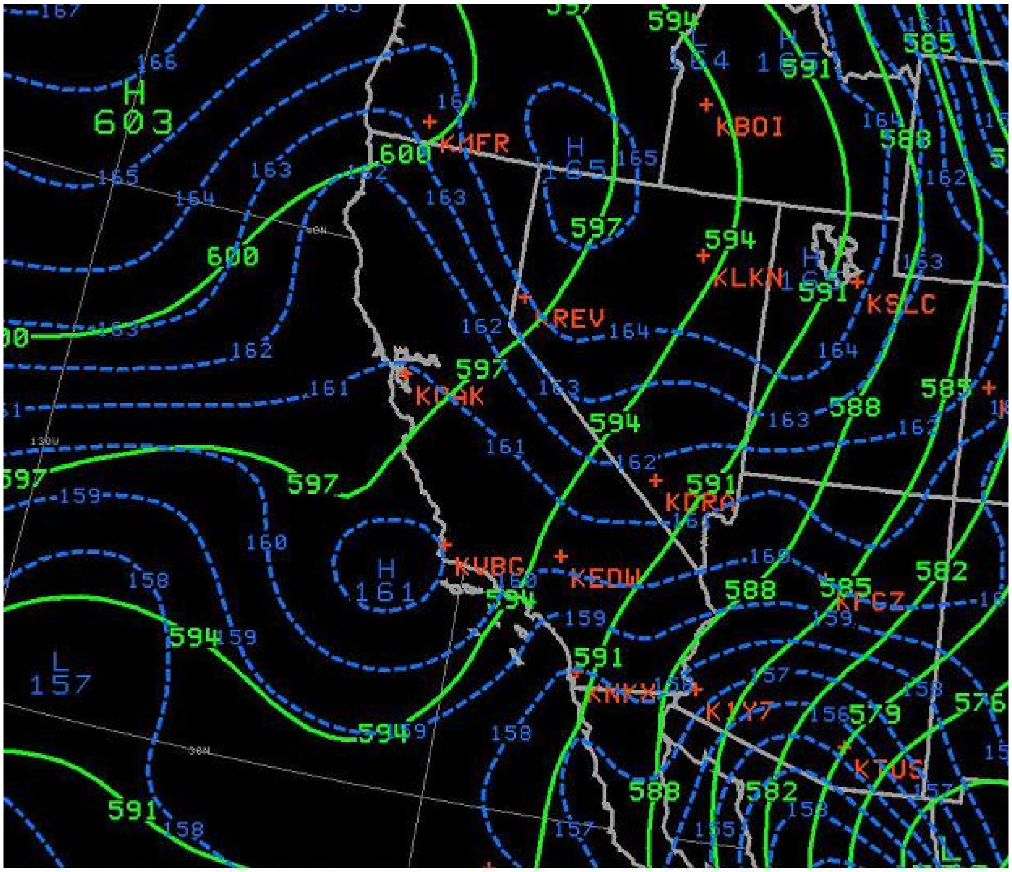

Fig. 3. 500 mb heights in 3 dekameter intervals (solid green lines) and the 850 mb heights in 1 dekameter intervals (dashed blue lines) at 1800 UTC 26 October 2003.

Figure 4

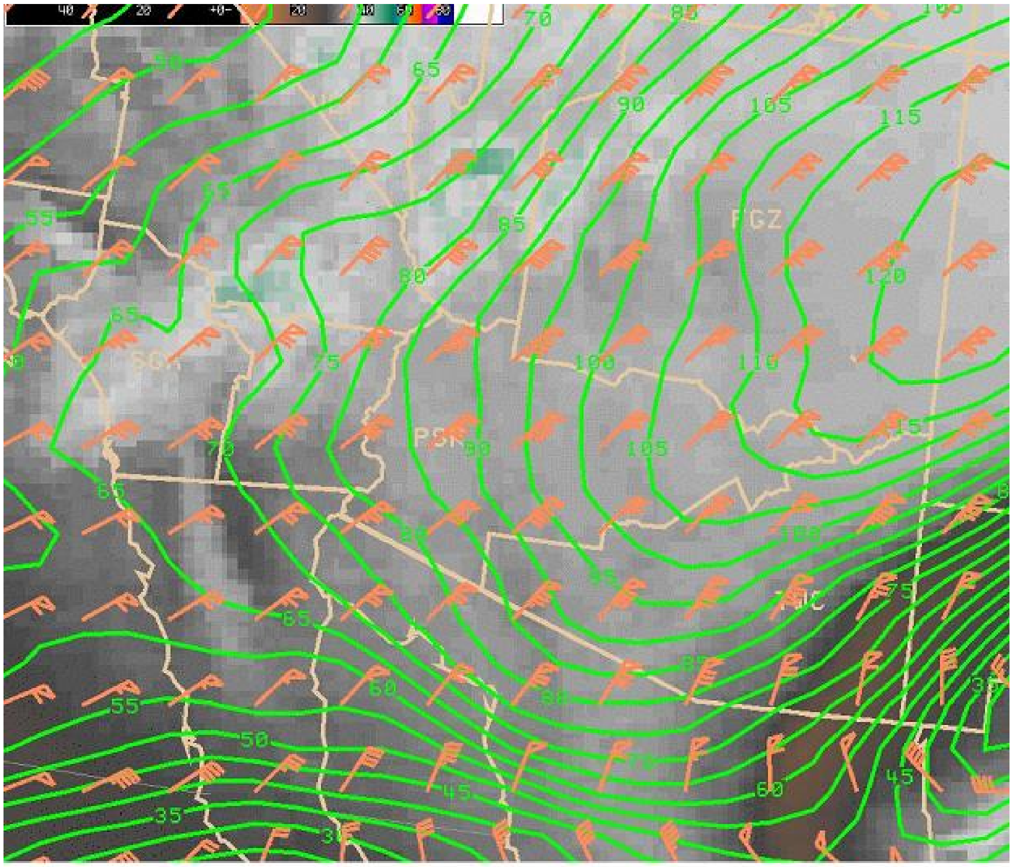

Fig. 4. 250 mb isotachs (in 5 knot intervals), winds (knots) and water vapor imagery at 1200 UTC 26 October 2003.

Figure 5

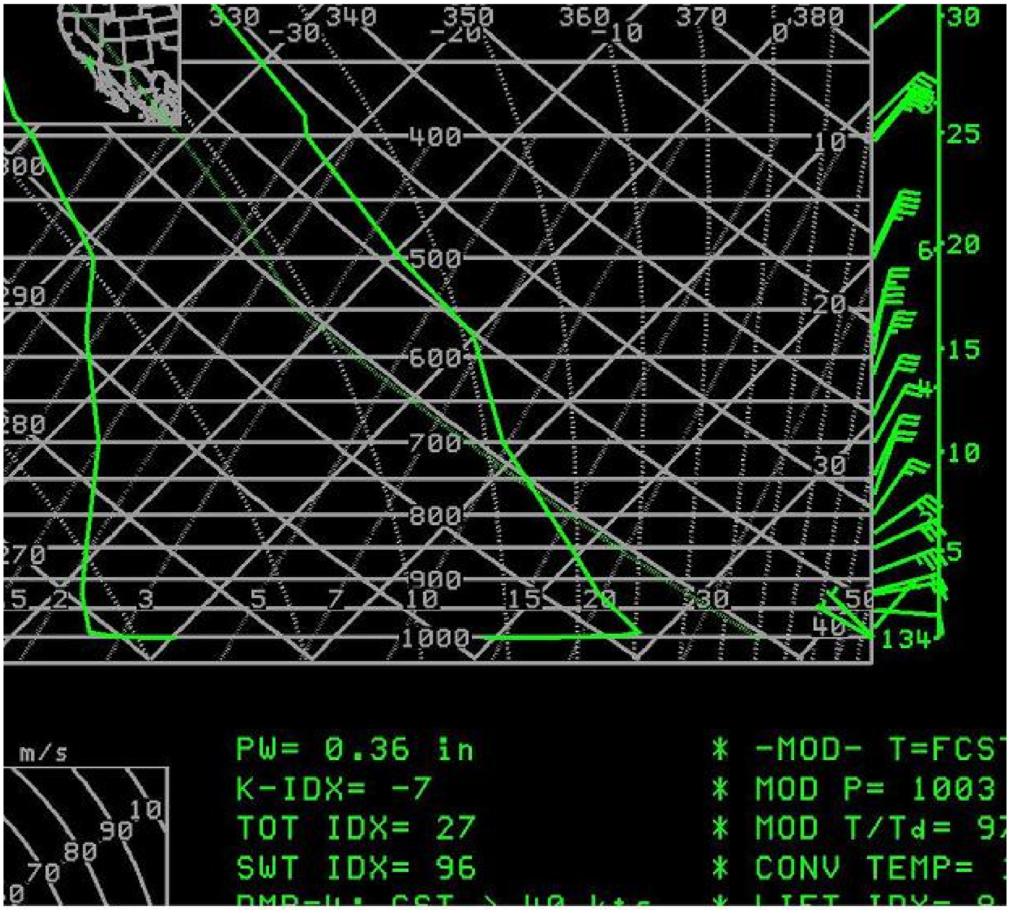

Fig. 5. 1200 UTC 26 October 2003 KNKX sounding.

Figure 6

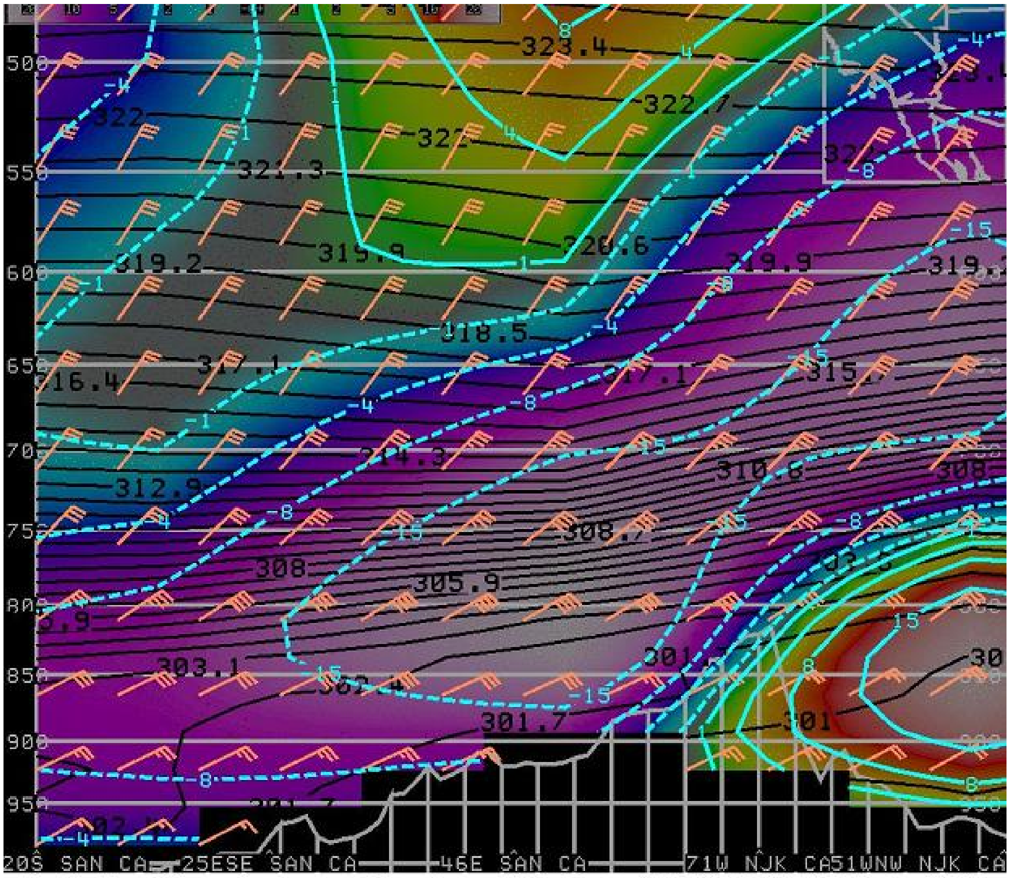

Fig. 6. MesoEta vertical crossection along AA' in Figure 2 at 1800 UTC 26 October 2003. Vertical velocity in microbars per second (dashed blue lines) and shading, wind in knots, and potential temperature in intervals of 0.7 degrees K (solid black contours).

Figure 7

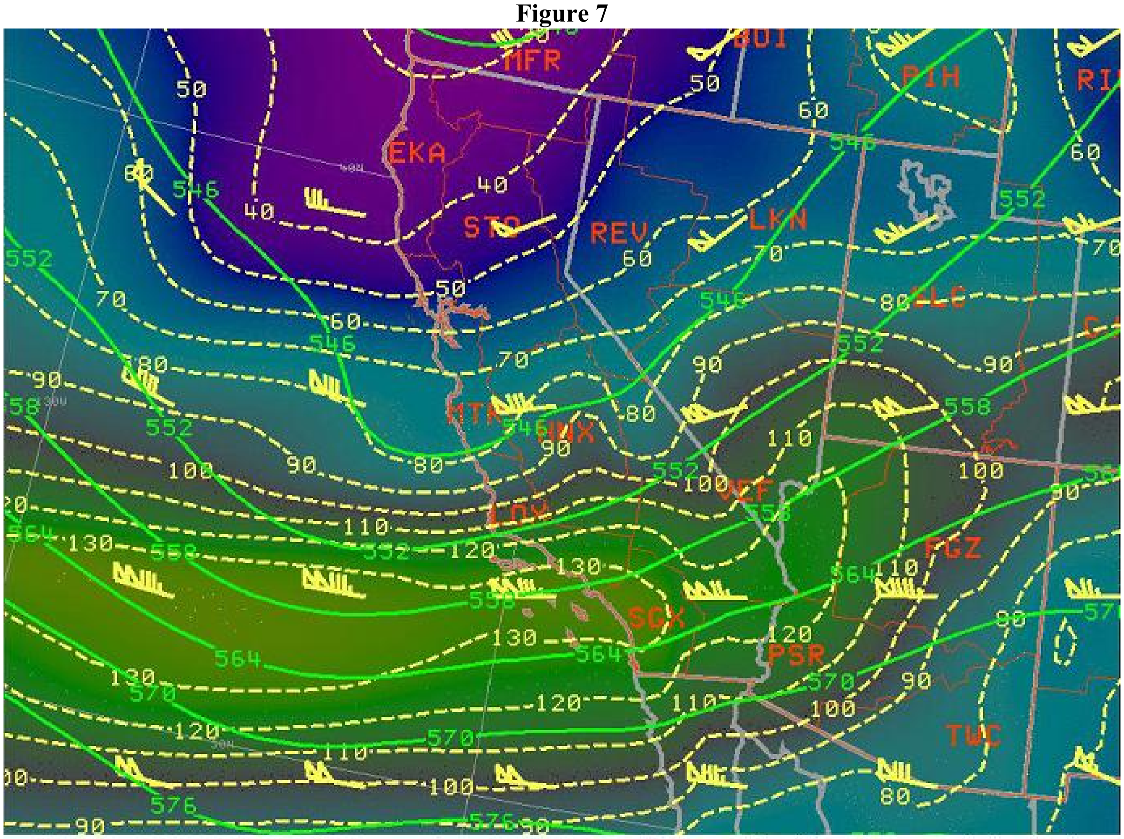

Fig. 7. 0000 UTC 26 December 2003 250 mb isotachs (shading, and dashed yellow contours in intervals of 10 knots), 250 mb winds (knots), and 500 mb heights (green contours in intervals of 60 meters).

Figure 8

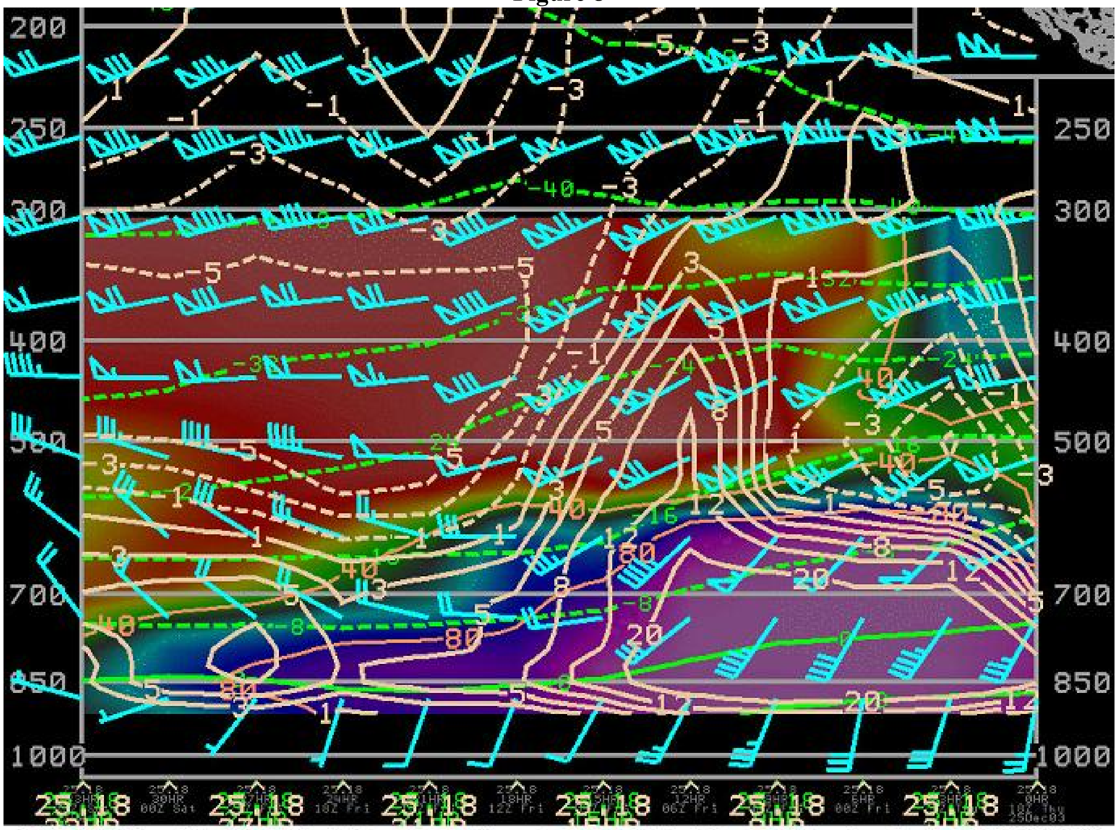

Fig. 8. MesoEta time/height crossection at point B in Figure 2 beginning at 1800 UTC 25 December 2003. Relative humidity in intervals of 40 percent (orange contours). Vertical velocity in microbars per second (solid beige contours) and shading, wind (knots), and temperature in intervals of 8 degrees C (dashed green contours).

Figure 9

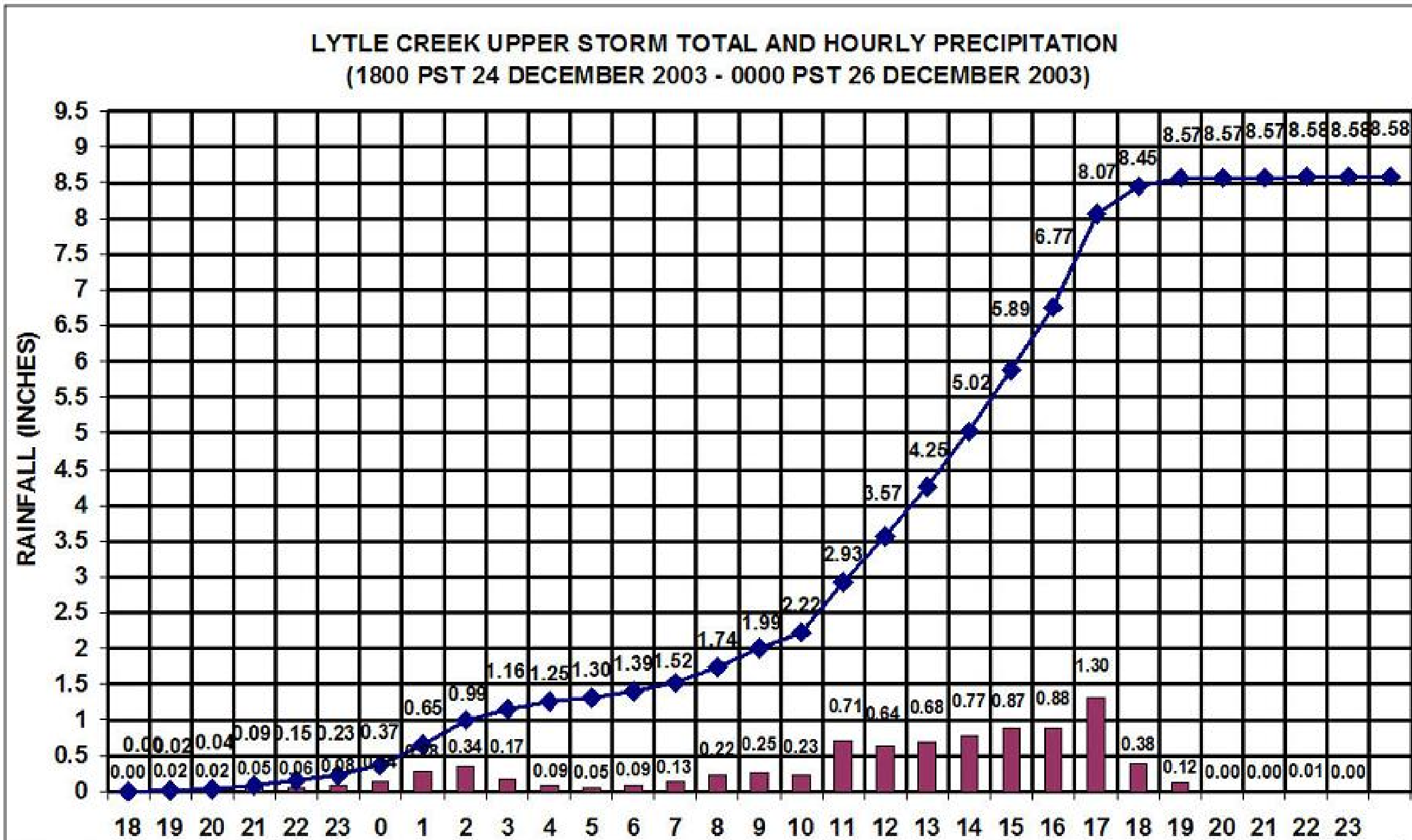

Fig. 9. Lytle Creek Upper Storm Total Precipitation (curve) and Hourly Precipitation (bars).

Figure 10

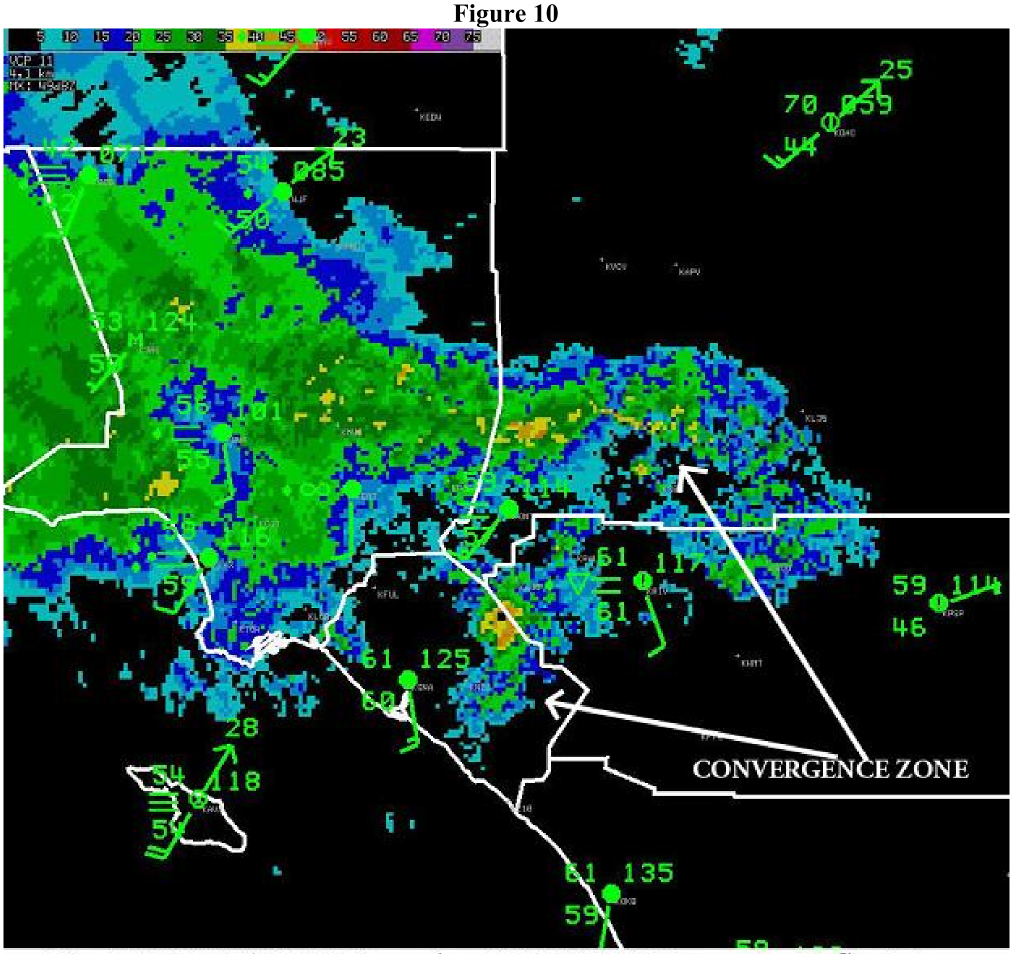

Fig. 10. 2000 UTC 25 December 2003 KSOX Composite Reflectivity.

Figure 11

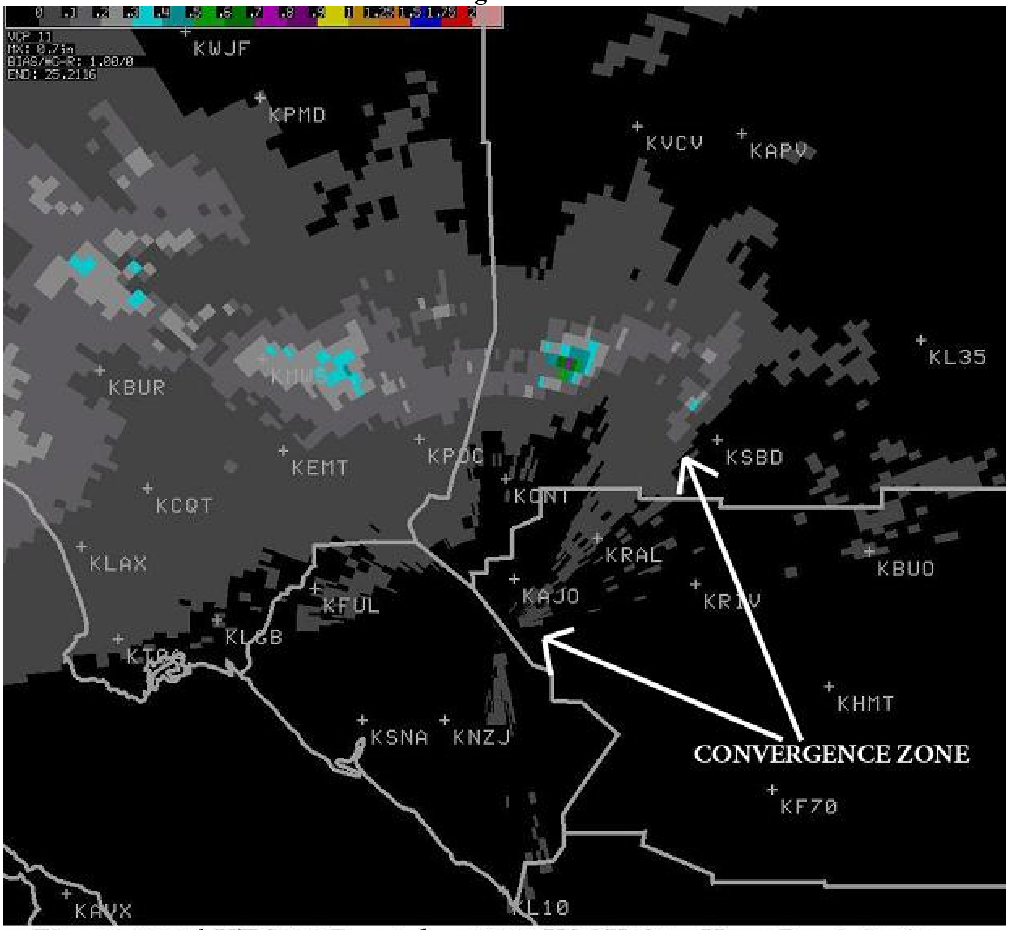

Fig. 11. 2114 UTC 25 December 2003 KSOX One Hour Precipitation.

Figure 12

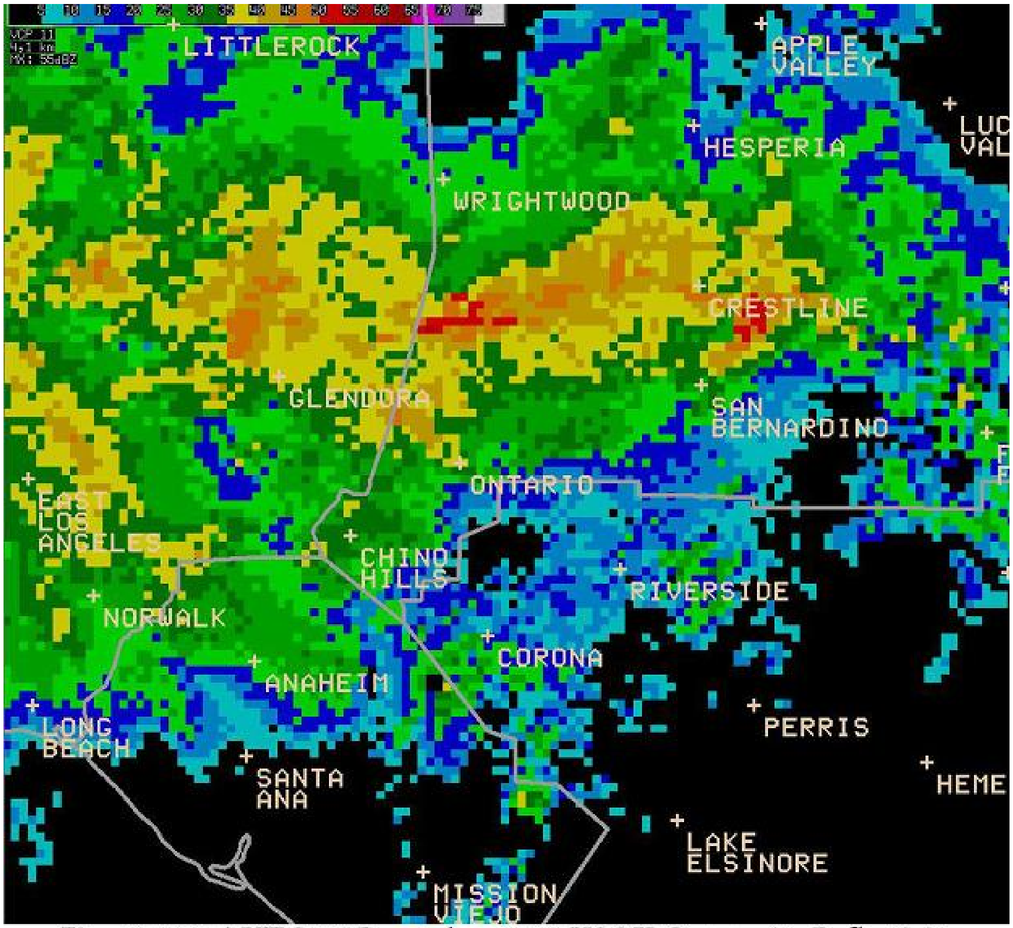

Fig. 12. 2114 UTC 25 December 2003 KSOX Composite Reflectivity.

Figure 13

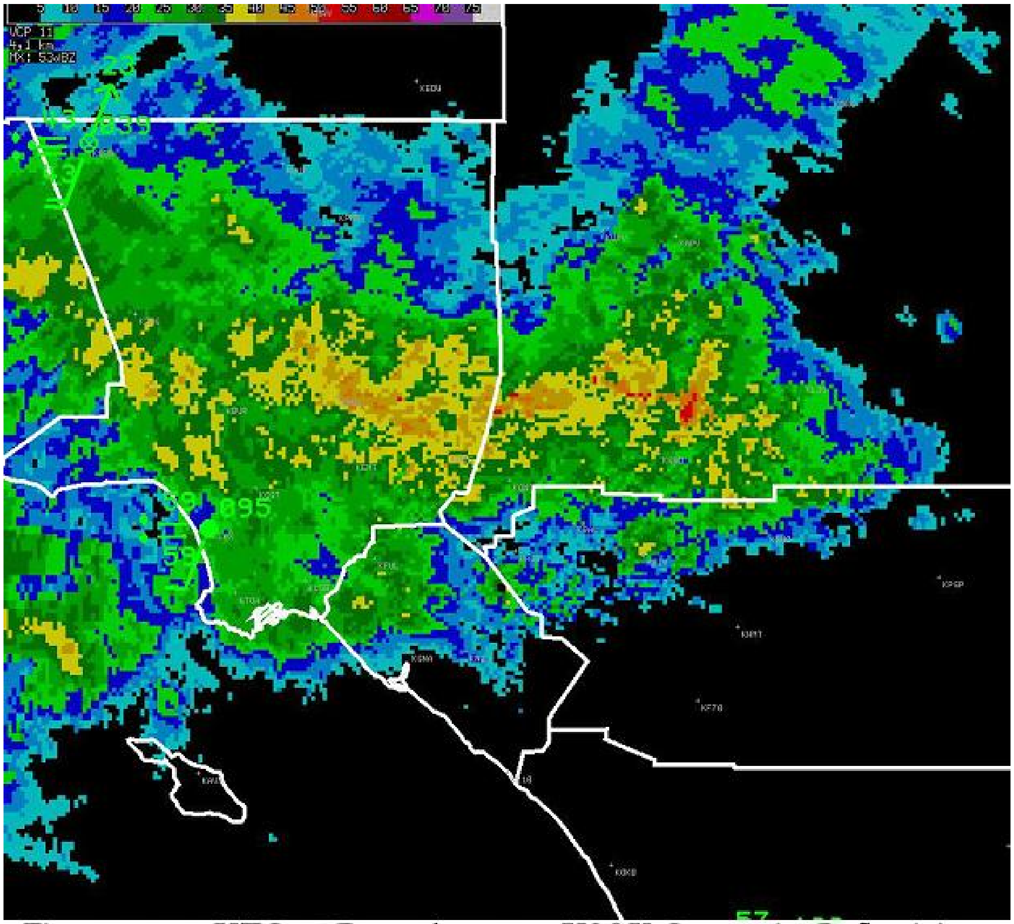

Fig. 13. 2200 UTC 25 December 2003 KSOX Composite Reflectivity.

Figure 14

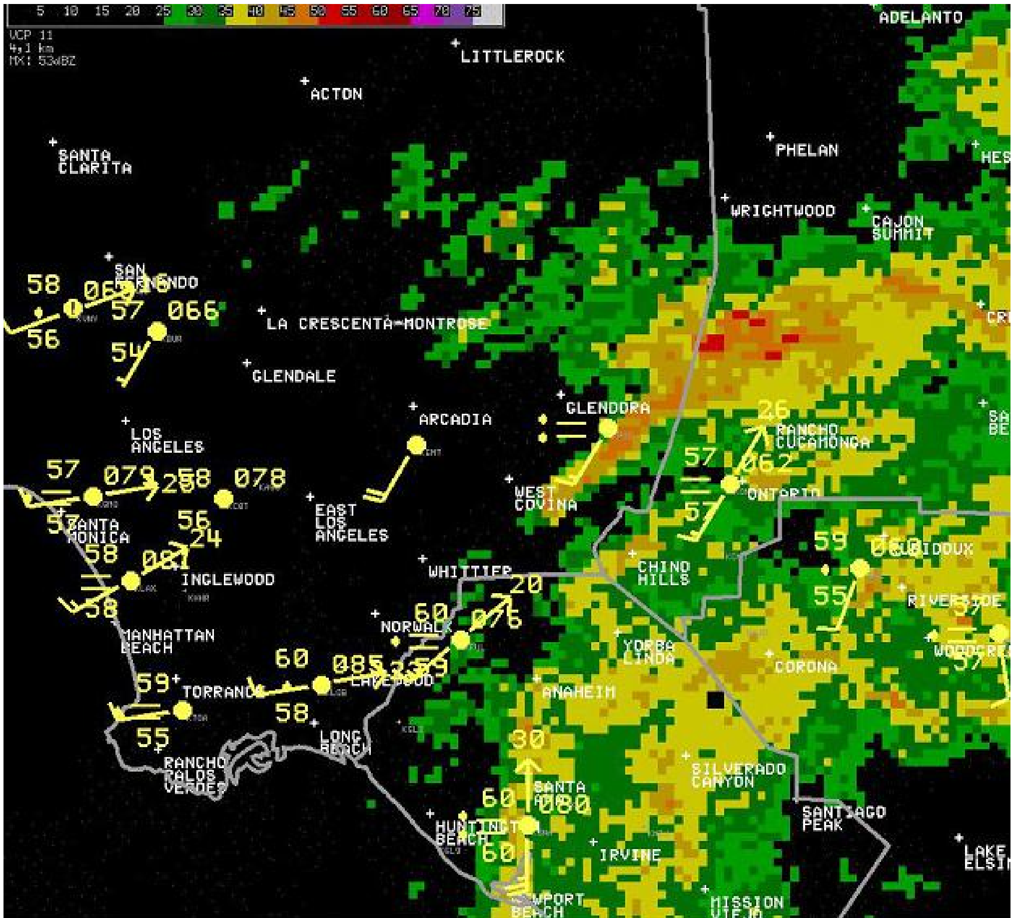

Fig. 14. 0100 UTC 26 December 2003 KSOX Composite Reflectivity.

Figure 15

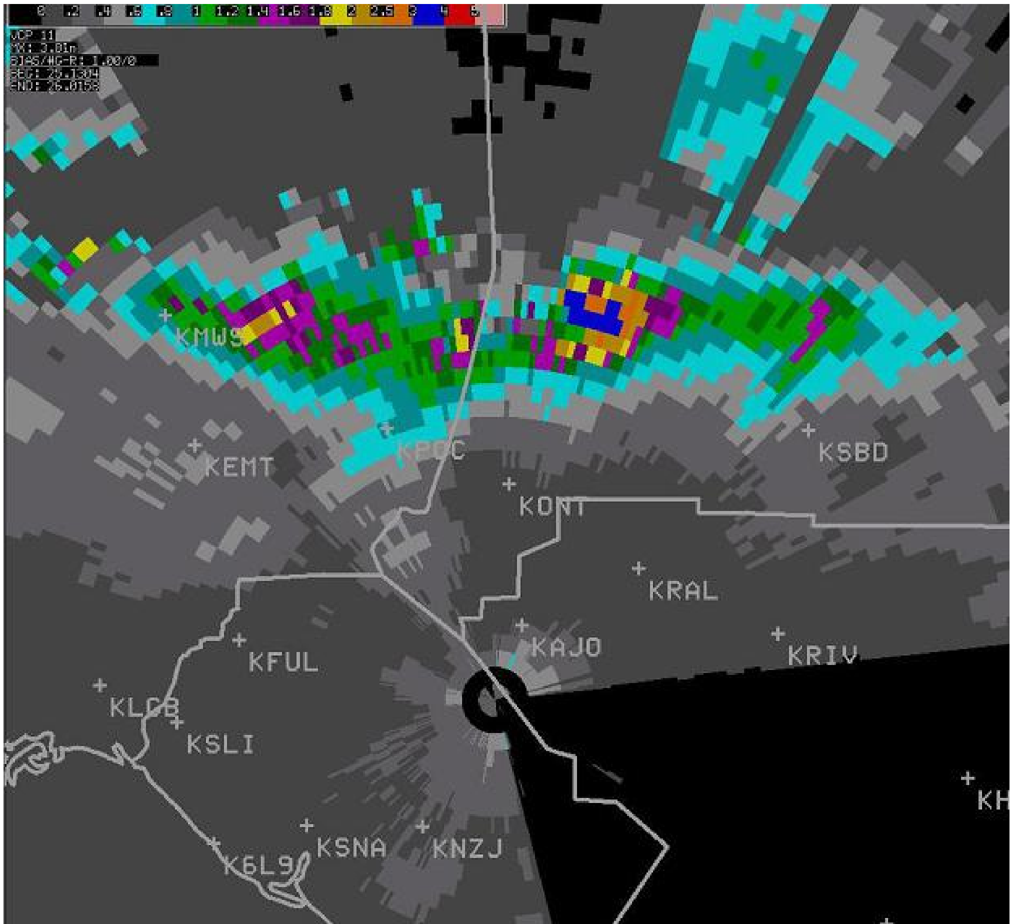

Fig. 15. 0100 UTC 26 December 2003 KSOX Storm Total Precipitation