12.1 A PRELIMINARY SURVEY OF COSTLY PAST WEATHER EVENTS IN SOUTHERN CALIFORNIA AND A LOOK AT POTENTIALLY COSTLY WEATHER EVENTS

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1. INTRODUCTION

Standardized anomalies (Hart and Grumm 2000; Grumm and Hart 2001), have recently begun to gain wider usage. This is partly due to the fact that standardized anomaly methods are an attempt to not only determine how large a parameter is, but also determine how much of a "departure from normal" a parameter is. In this paper, examples will be used to illustrate the utility of standardized anomalies for looking at data such as gradient fields and indices. Short term climatological approximations (datasets of less than 10 years of data) will be used to estimate the means and standardized anomalies.

Storm Data (1948-2005) was interrogated to find entries during which 1 million dollars or more in damages were logged. If a million dollar event was found, all of the entries for that event were added up (neglecting entries below 1 million dollars) for the 4 county area to get a damage approximation for the entire event. Only one episode in excess of 1 million dollars per event type will be analyzed (for example, there are many multi-million dollar firestorms, but only 1 of this particular event type will be analyzed in this study).

The event types that resulted in the most damage were the October 2003 Wildfires (2.13 billion), the January 2005 Floods (203.4 million), the January 2003 Windstorm (21.3 million), the 16 March 1986 Tornado (2.5 million), the January 2002 Freeze (1.8 million) and the Dense Fog Event of April 2004 (1.5 million). These approximated dollar amounts are not adjusted for inflation.

2. THE FIRESTORMS OF OCTOBER 2003

Wildfires are by far the most expensive weather related events in Southern California (Figure 1). Individual fires can burn hundreds of thousands of acres). Such large fires typically occur during the fall "Firestorm Season", during which strong northwest to east winds can gust to triple digit values. The surface pressure gradient is a good indicator of whether the wind gusts [typically 2 times the 850 mb wind speed (winds around 5000 feet MSL)] can dip low enough to reach the favored canyon and pass areas and spread out below them.

Figure 2 shows the synoptic scale pattern associated with the October 2003 event. During the October 2003 event the surface pressure gradient from the coast to the lower deserts to the east (from Las Flores to Rice Valley) was a rather strong -1.8 mb (Figure 3). This converts to a huge standardized anomaly of -3.0. This allowed surface wind gusts of over 60 mph. It is during such times that the stage is set for wildfires. The winds can bring down power lines, which can spark wildfires. Arson is also a common cause of wildfires. Such a catalyst is needed to change a pattern from simply producing wind damage to one of wildfires. If no fire is started, then there is no wildfire, and the event is simply one of "wildfire potential". We have many wind events with high "wildfire potential" each year but only a few of them result in 100,000 acre fires. Another problem is there can be many fires at the same time. Numerous fires were started during this episode.

3. THE FLASH FLOODS OF JANUARY 2005

Flash floods visit southern California on a rather regular basis, and are second on the damage list. The 3 to 5 year El Nino cycle is one forcing mechanism that can easily produce 1 foot rainfall events, and occasionally 2 or more feet of rain. Sometimes 2 foot rainfall events occur outside of El Nino episodes. The January 2005 episode produced well over 2 feet of rainfall. To make matters worse, the 3-4 January 2005 event

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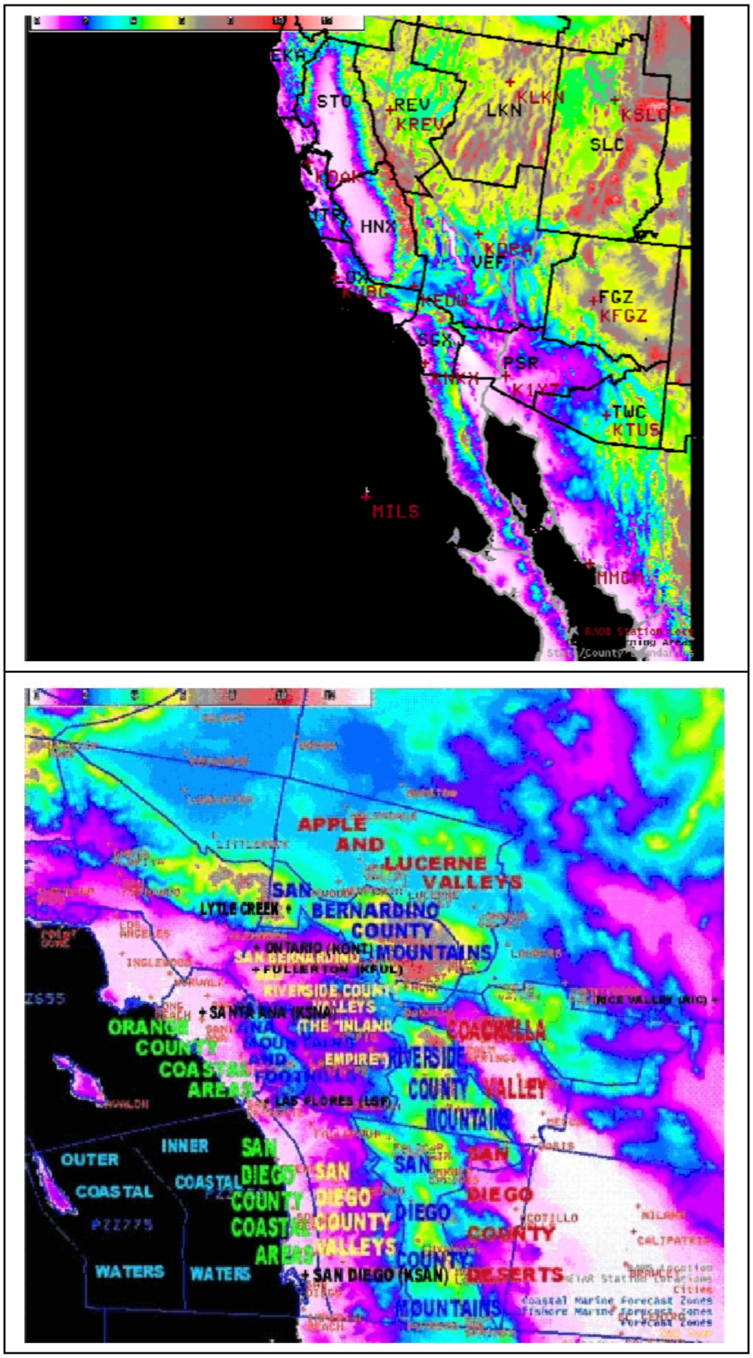


Fig. 1. Terrain map of the WFO SGX CWFA. Color coding in the legend is in thousands of feet MSL. The sounding sites are indicated in red on the upper panel.

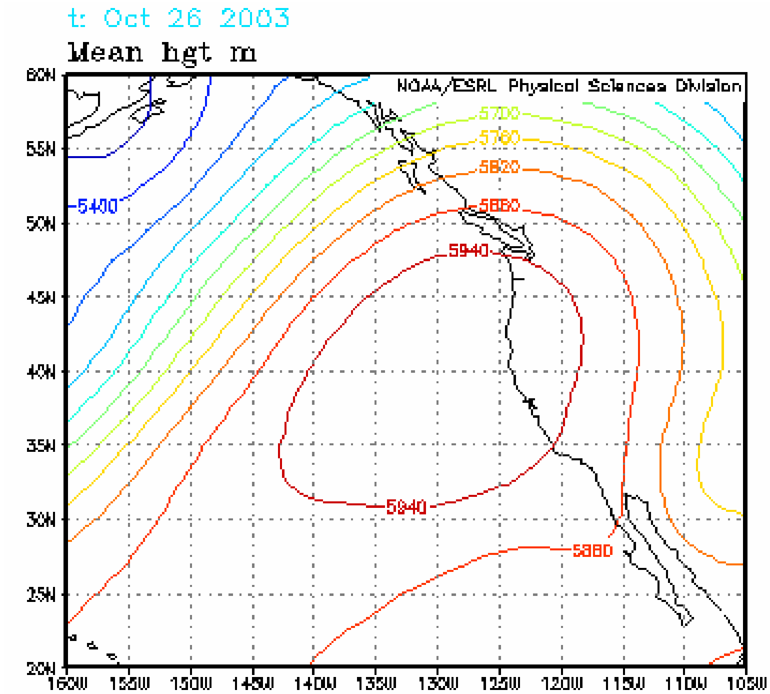


Fig. 2. 500 mb heights in meters on 26 October 2003.

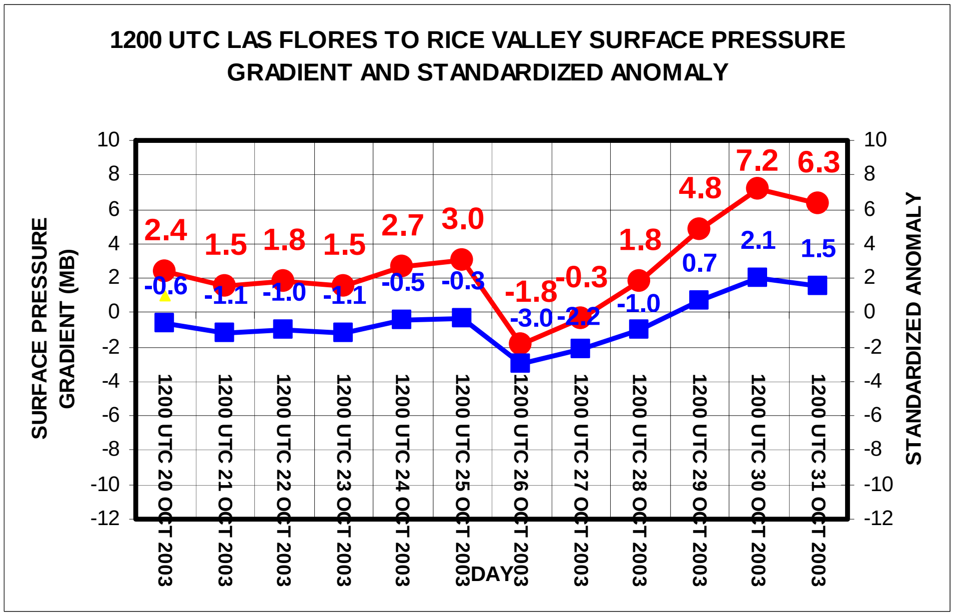


Fig.3. The graphic is the comparison between the 1200 UTC surface pressure gradient (in mb) between Las Flores (LSF) and Rice Valley (RIC) between 1200 UTC 20 October 2003 and 31 October 2003 and the standardized anomaly. The pressure gradient is the red curve with the circles. The standardized anomaly is the blue curve with the squares. At the time of the minimum in the surface pressure gradient (-1.8 mb) there was also a rather large minimum in the standardized anomaly (-3.0) in this case. The pressure gradient trend for the 24 hour time period ending at 1200 UTC 26 October 2003 was -4.8 mb.

dumped very heavy snow in the mountains. The 7-12 January event was a warmer storm ("rain on snow"), and with mountain drainage systems choked with snow, widespread flooding ensued.

Figure 4 shows the synoptic pattern associated with the event. The upper panel of Figure 5 shows the relationship between the 700-500 mb relative humidity, the 1000-500 mb relative humidity, the 850 mb wind speed and the 12 hour precipitation totals at Lytle Creek. The lower panel shows standardized anomalies and precipitation. What is very apparent is the difference in rainfall rates and amounts between the rainfall event on 3-4 January and the event on 7-12 January. At the time that the winds peak for the first event, the peak wind speed of 22 knots and relative humidity values near 90 percent produces a 12 hour maximum of about an inch. For similar relative humidity values during the second storm, but with twice the wind speed the maximum 12 hour rainfall was much higher at nearly 6 inches. (Unfortunately, there is some missing data during the 2^{nd} event, but the graphic still clearly shows a dramatic increase in rainfall rate and accumulation strongly correlated with wind speed. (Storm dynamics may also have played a part, but that topic is not explicitly addressed in this paper). Orographic enhancement is key at Lytle Creek since it sits in the foothills of the San Bernardino County Mountains just under the 3000 foot level.

4. THE DAMAGING OFFSHORE WIND EVENT OF JANUARY 2003

On 7 January 2003 a strong windstorm swept into the region (Figure 6). Temperatures in the coastal areas soared into the 80s, even though the 60s are average January high temperatures for the coastal areas. These northeasterly winds produced 3.3 million dollars of property damage, but 18 million dollars in crop damage since some crops were literally blown from their trees. It is interesting to note that this damage was not fire related (although they do occur, firestorms are less likely in January since there is usually enough rainfall in early winter to keep the "fuels" fairly moist). Figure 7 shows the pressure gradient and the standardized anomaly of the pressure gradient for the January 2003 windstorm. It shows that with or without a wildfire, considerable damage can still be done. It should be noted that the surface pressure gradients for this event are actually stronger than those of the October 2003 firestorm event. The difference is that with wildfires, the damage was multiplied by 2 orders of magnitude.

5. THE TORNADO EVENT OF 16 MARCH 1986

A tornado moving through the northern coastal portion of the forecast area resulted in 2.5 million dollars in damage on 16 March 1986. The synoptic makeup of this event (Figure 8) fit the characteristics of a pattern that could produce a tornado as seen in Hales (1985) and Small et al. (2002). On the mesoscale, the critical parameters (total totals index at or above 50, the surface to 850 mb lifted index at or less than -2, and the low level jet at or above 25 knots) are good indicators of the possibility of at least producing a "damaging winds and/or a tornado event. (The values were in excess of those expected for such events as seen in figure 9. The actual peak values were 52.8, -2.87 and 29 knots respectively). The standardized anomalies peaked at 2.0, -1.7, and 3.2 respectively.

6. THE FREEZE EVENT OF JANUARY 2002

On 28-31 January 2002 a freeze event occurred. Figure 10 shows cold northerly flow developing behind a cold system, a common synoptic pattern for freeze events. Figure 11 shows the 850 mb heights (red, diamonds) and the 1000-850 mb thickness (blue, squares). The 850 mb height and a rather low 1000-850 mb thickness value bottomed out at 1447 meters and 1310 meters respectively. Temperatures reached the upper 20s at the coast and the lower 20s inland valleys. The higher mountain resorts fell into the single digits.

7. THE DENSE FOG EVENT ON 1 APRIL 2004

On 1 April 2004 a dense fog event resulted in numerous traffic pile-ups in the mountain areas of southern California, resulting in 1.5 million dollars in property damage. These pile-ups seem to happen once every 3-5 years lately. There are common meteorological

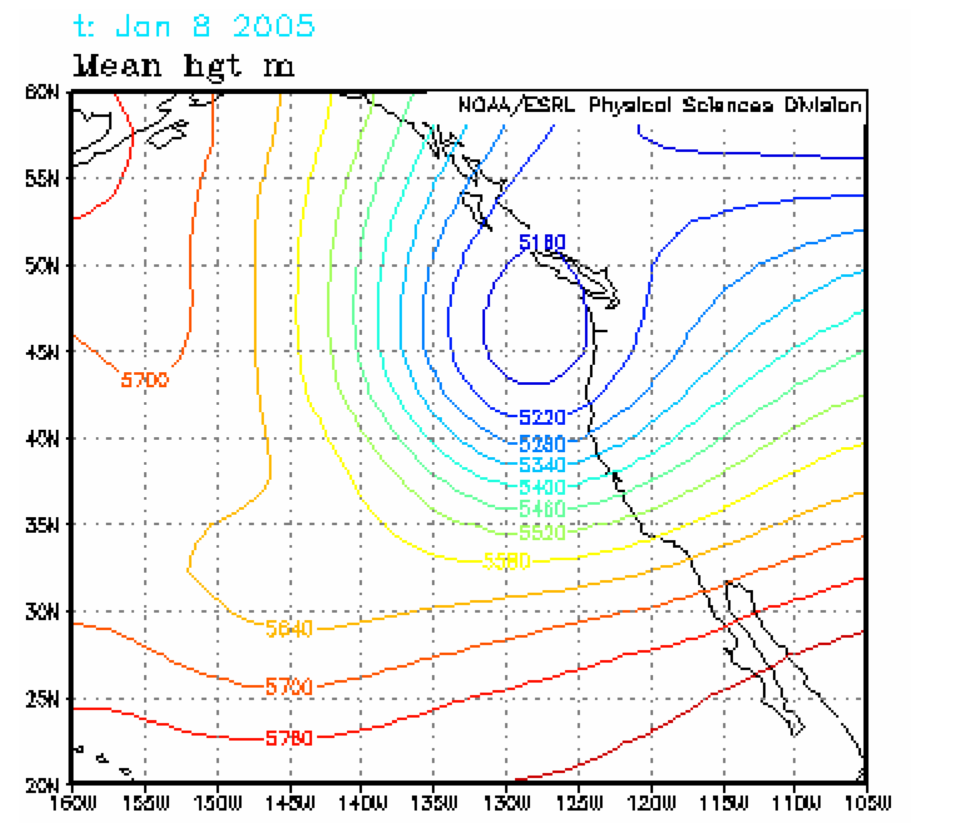
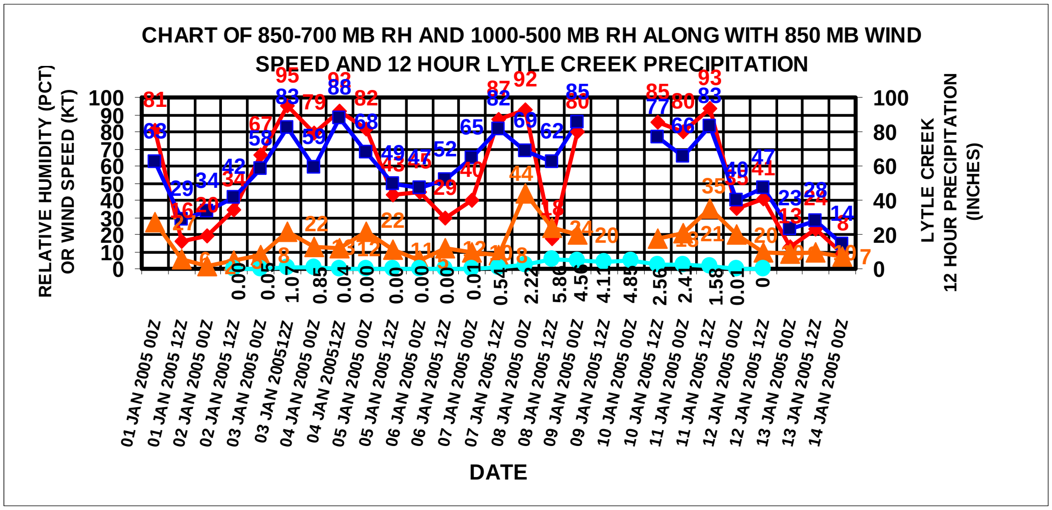


Fig 4. 500 mb heights in meters for 8 January 2005. Lytle Creek received nearly 6 inches of rainfall in a 12 hour period. Notice the cold air and waves from the northwest rotating around the low into a strong, moist southwesterly flow from near Hawaii.



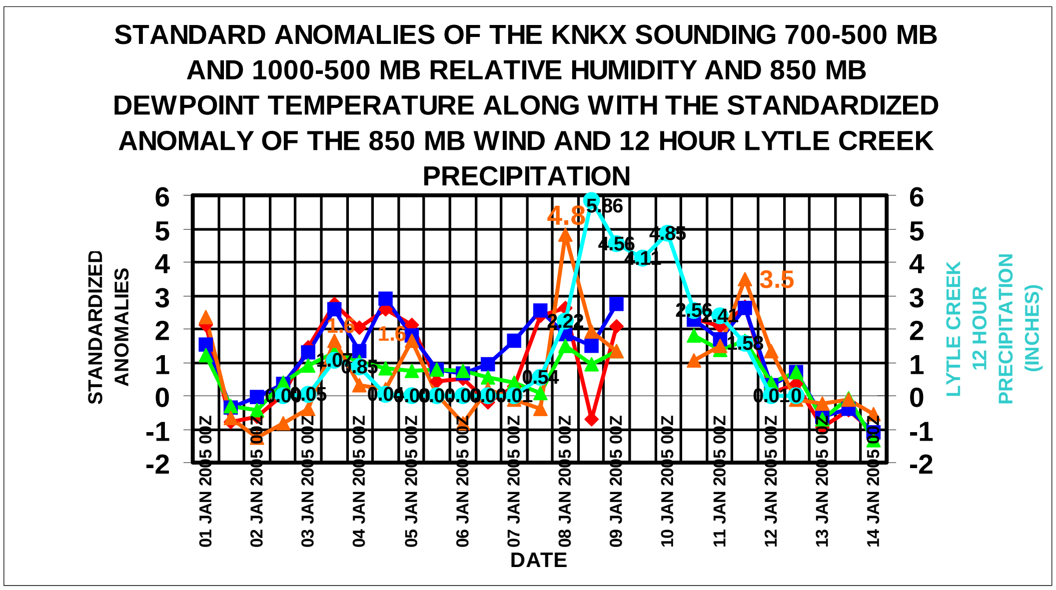


Fig. 5. The figure represents KNKX sounding wind and moisture parameters for the period 0000 UTC 1 January 2005 through 0000 UTC 14 January 2005 and the Lytle Creek 12 hour rainfall totals. The rainfall totals are for a 12 hour period centered at the indicated time. The first storm was around 3-4 January 2005 and the second storm was around 7-12 January 2005. On the upper panel is the 850-700 mb relative humidity (red curve, diamonds), the 1000-500 mb relative humidity (blue curve, squares), the 850 mb wind speed (orange curve, triangles), and the 12 hour Lytle Creek precipitation totals (cyan curve, circles). The lower panel is the standardized anomaly of the 850 mb wind speed (orange, triangles), the standardized anomaly of the 850-700 mb relative humidity (red, diamonds), the standardized anomaly of the 1000-500 mb relative humidity (blue, squares), the standardized anomaly of the 850 mb dewpoint (green, dashes), and the 12 hour Lytle Creek precipitation totals (cyan curve, circles). A key feature is the very high relative humidity values (in the 90s for the 700-500 mb layer and in the 80s for the 1000-500 mb layer) resulting in standardized anomaly values approaching 3. When the standardized anomalies of the 850 mb wind speed reached the very high value of 4.8 (850 mb wind speed of 44 knots) the peak 12 hour rainfall rate skyrocketed to 5.86 inches. Even the rates near the standardized anomaly of 3.5 (35 knots) results in a much higher rainfall rate than those of the first storm, which had rainfall rates of around an inch or less and standardized anomalies of only 1.6 (22 knots).

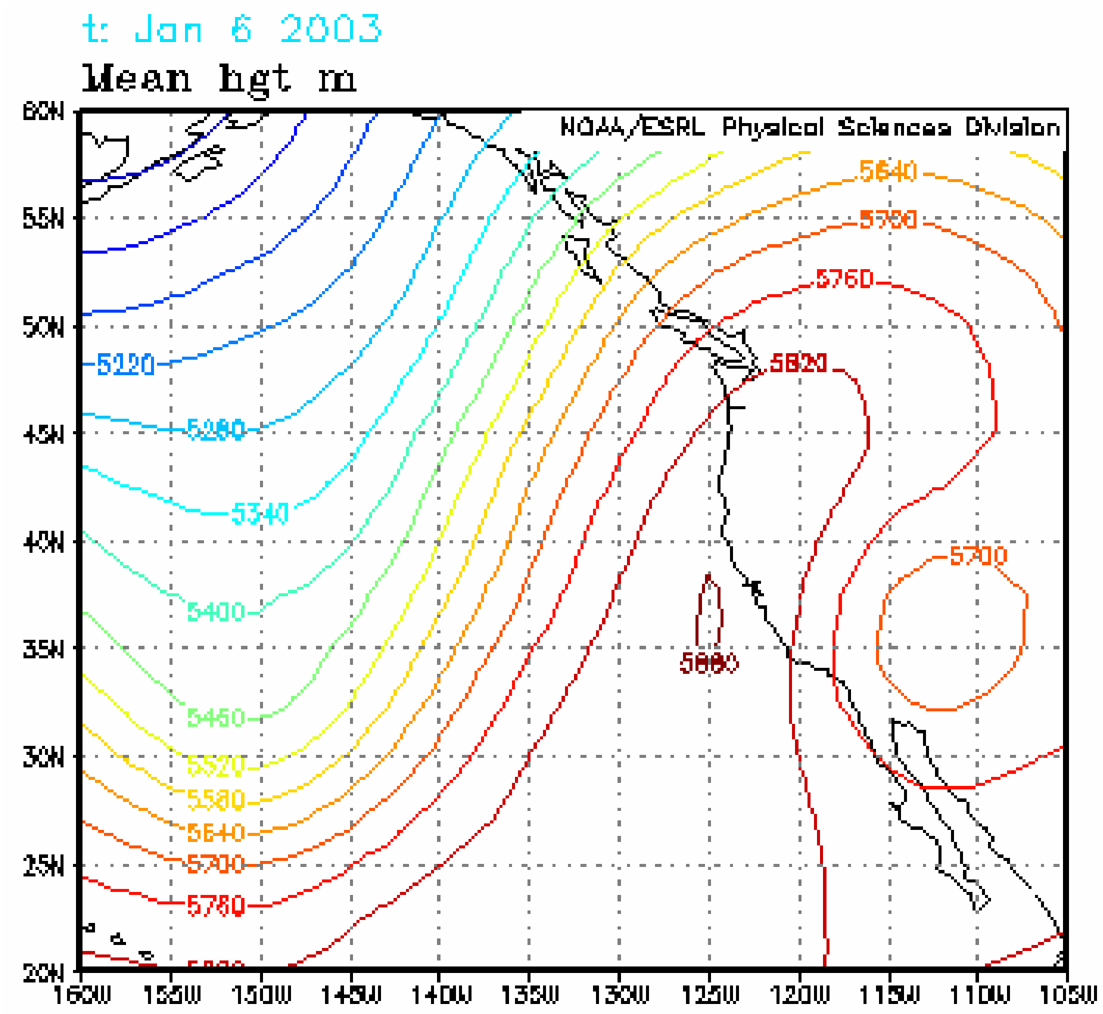


Fig. 6. 500 mb heights in meters for 6 January 2003. The upper support for this event was stronger than that of 26-27 October 2003 (easily seen in the tight height gradient on the western side of the low). This factor helped to produce stronger winds than those of the 26-27 October 2003 event.

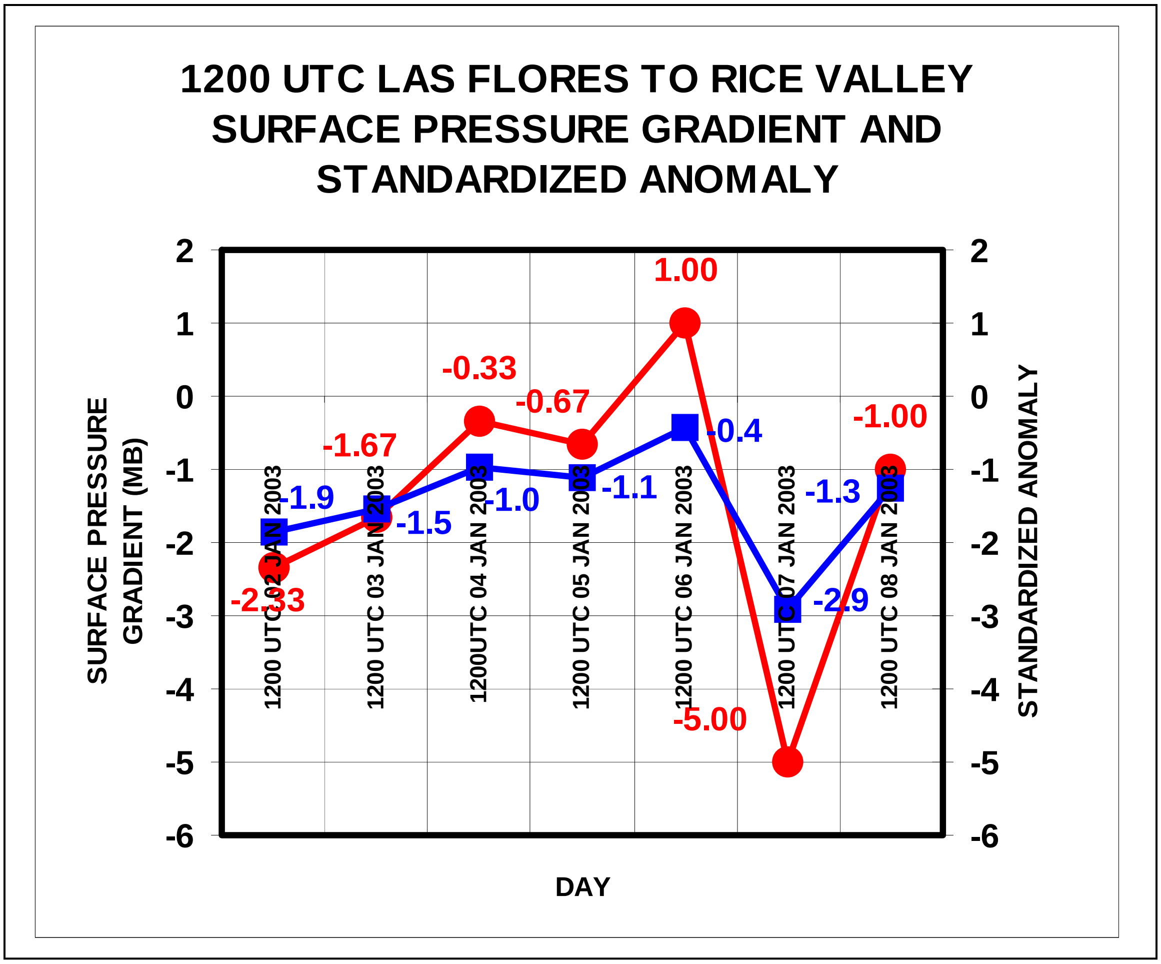


Fig 7. The above graphic is the comparison between the 1200 UTC surface pressure gradient (in mb) between Las Flores (LSF) and Rice Valley (RIC) between 2 January 2003 and 8 January 2003 and the standardized anomaly. The pressure gradient is the red curve with the circles. The standardized anomaly is the blue curve with the squares. At the time of the minimum in the surface pressure gradient (-5.0 mb) there was also a rather respectable minimum in the standardized anomaly (-2.9) in this case. The 24 hour pressure gradient trend for the time period ending at 1200 UTC 7 January 2003 was a huge -6.0 mb.

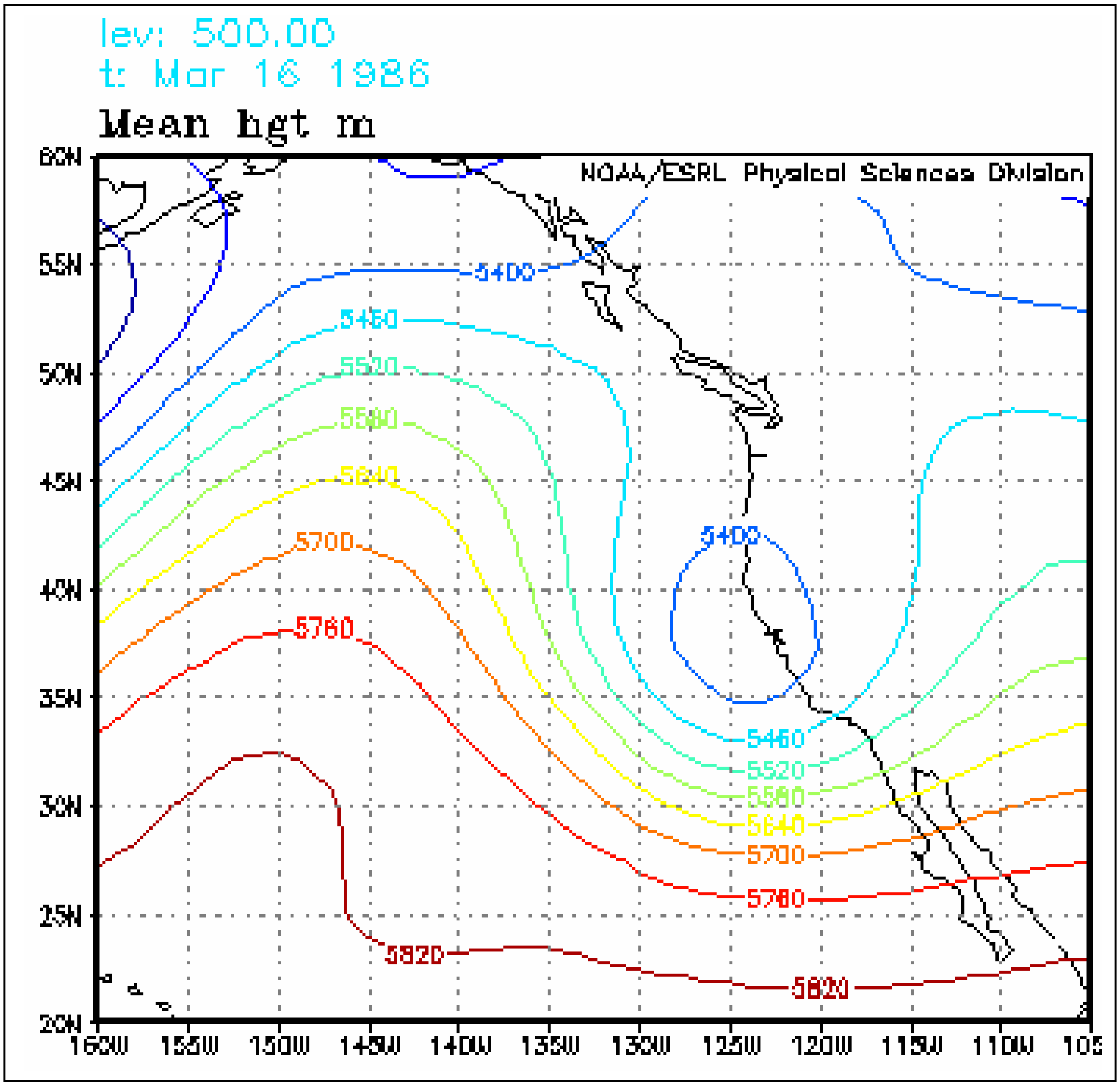


Fig. 8. 500 mb heights in meters for 16 March 1986.

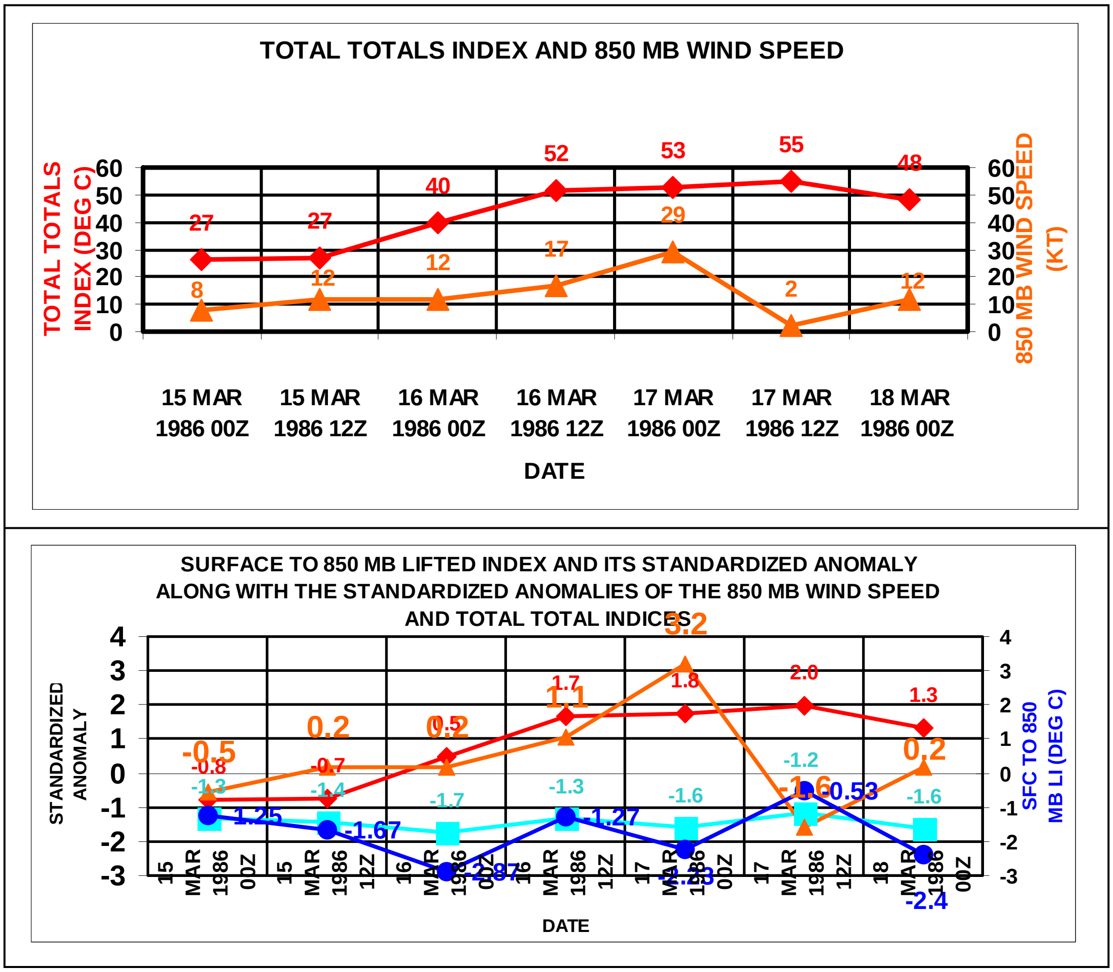


Fig. 9. The upper panel is the total totals index (the highest curve, red, diamonds) along with the 850 mb wind speed (lower curve, orange triangles). The lower panel is the standardized anomaly of the 850 mb wind speed (orange, triangles) the standardized anomaly of the total totals index (red, diamonds), the surface to 850 mb lifted index (dark blue, circles), and the standardized anomaly of the surface to 850 mb lifted index (cyan, squares).

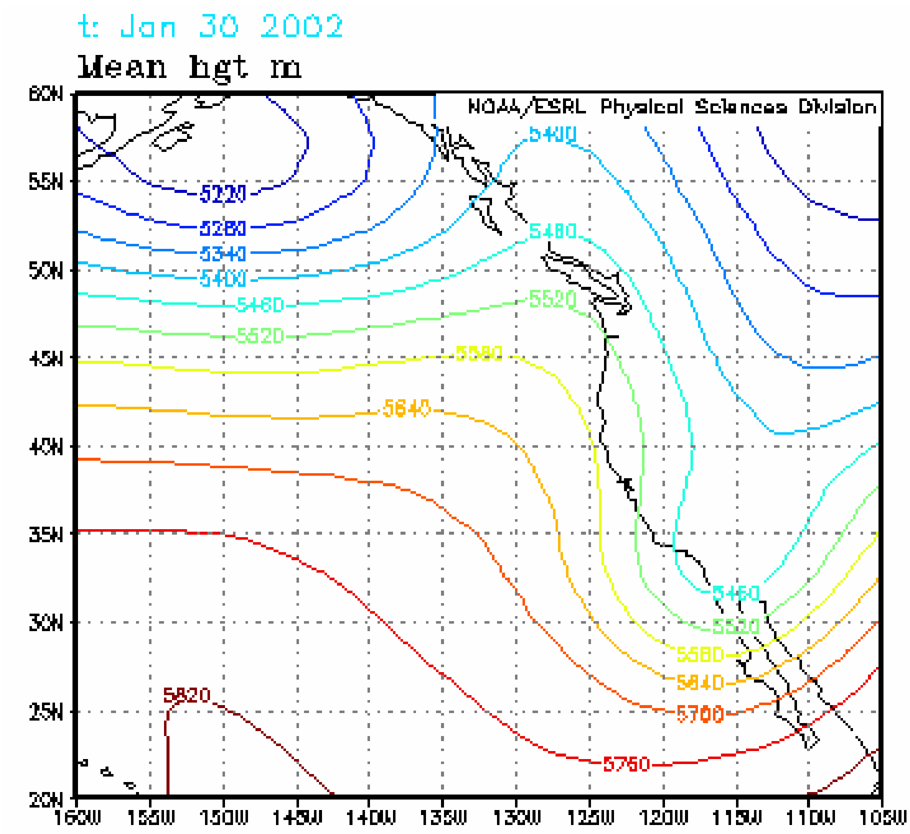
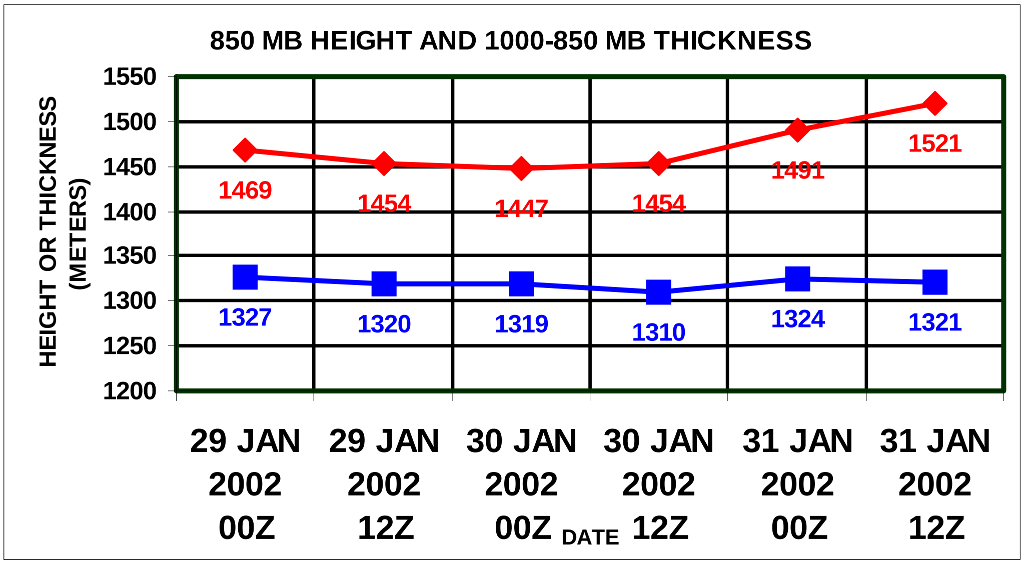


Fig.10. 500 mb heights in meters for 30 January 2002



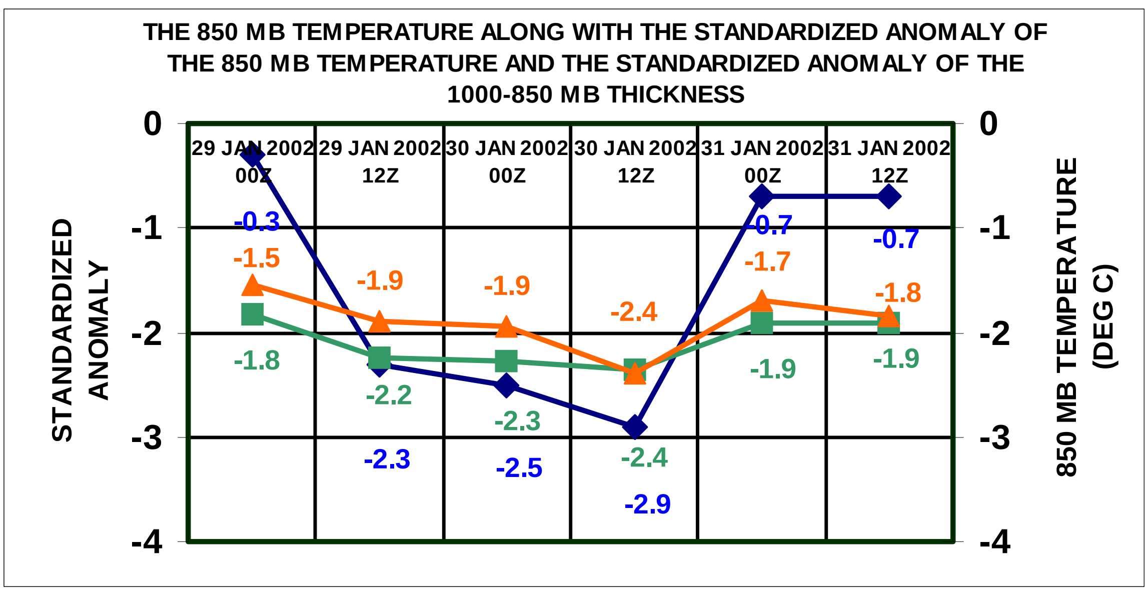


Fig. 11. The upper panel shows the KNKX sounding 850 mb heights in meters (red, diamonds) and 1000-850 mb thickness in meters (blue, squares). The lower panel shows the 850 mb temperature (blue, diamonds). Also shown is the standardized anomaly of the 850 mb temperature (orange, triangles). The green curve with the squares is the standardized anomaly of the 1000-850 mb thickness. The 850 mb temperature fell to a rather low -2.9 degrees C. The standardized anomaly seen for the 1000-850 mb thickness was quite low at -2.4 (1310 meters) indicating a large deviation from normal.

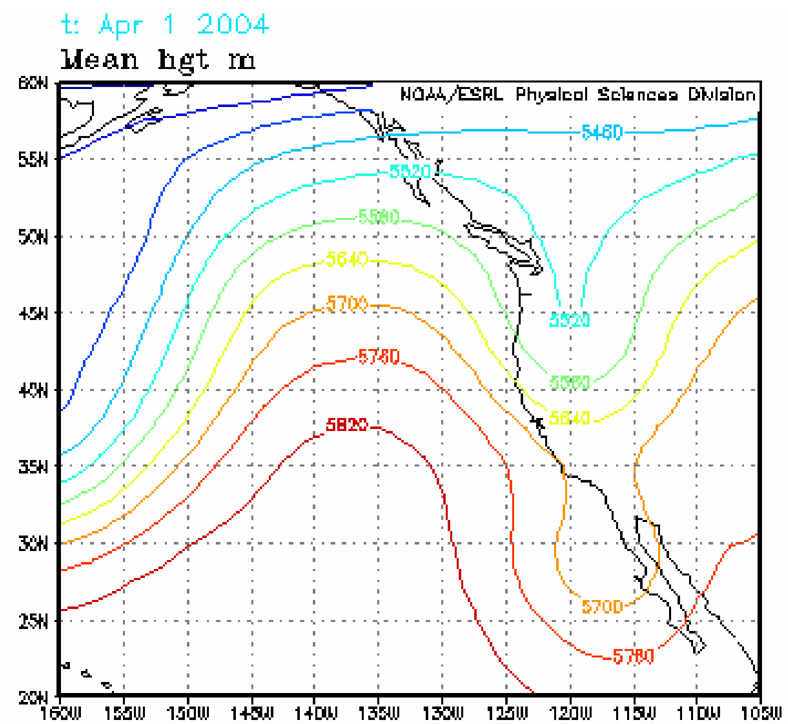


Figure 12. The above figure is the 500 heights in meters for 1 April 2004, the day of the chain-reaction accident in the San Bernardino County Mountains. It shows a fairly unimpressive trough moving through California.

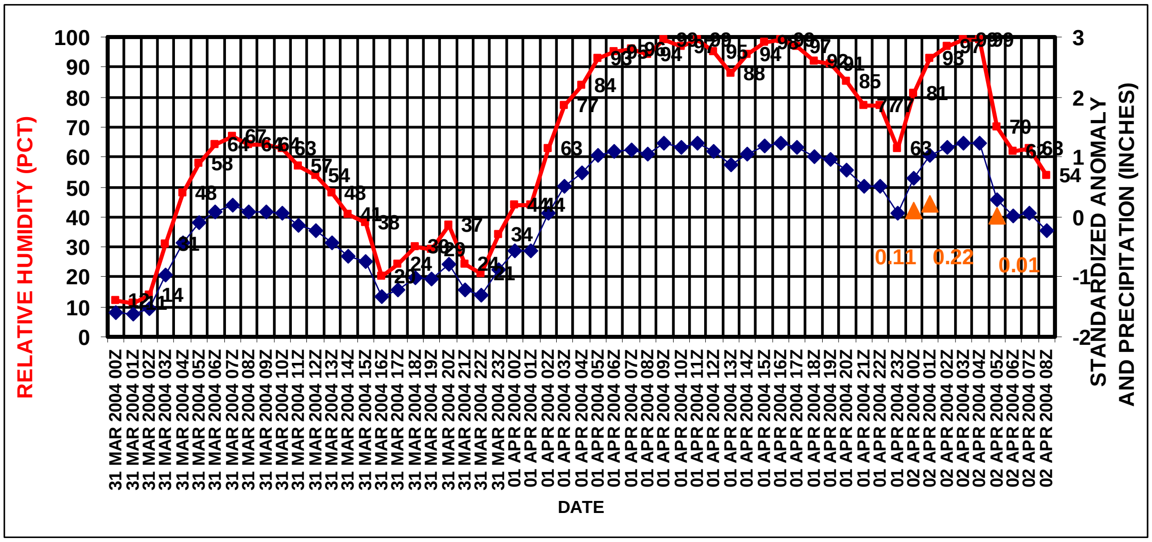


Fig. 13. The above plots are the Lytle Creek surface relative humidity (red curve with the squares), the standardized anomaly of the relative humidity (blue curve with the diamonds) and the 1 hour precipitation amounts (orange, triangles) in inches. Only the measurable precipitation amounts are shown.

features that have accompanied these events. The synoptic pattern, typically a trough moving into and through the region, is shown in figure 12. Figure 13 shows a plot of the surface relative humidity, the standardized anomaly of the relative humidity, and also a plot of the measurable precipitation at Lytle Creek.

Dense fog events typically involve a rapidly deepening marine layer and associated cloud deck that pushes into the coastal slopes of the mountains as dense fog. Marine layers that deepen to at least 3 thousand feet deep, which is the lower end of the mountain zones, often produce dense fog, reducing the visibility, and bring drizzle to make the roads slick. The red curve in the figure shows the deepening trend of the marine layer and the diurnal cycle in the relative humidity. The standardized anomaly of the relative humidity maxes out near 1.25 as seen in the lower blue curve with diamonds. This shows that the peak in the relative humidity, and possibly the "densest" fog is in the late night through mid morning hours. (This also corresponds to the morning rush hour through the mountains). The situation that often results in such deepening is surface pressure falling to the north and in the interior in response to an upper level low pressure system or trough that moves by to the north. The precipitation finally becomes measurable at Lytle Creek at 0000 UTC 2 April 2004, but there was a strong likelihood of drizzle and wet roads before then.

8. CONCLUSION AND DISCUSSION

It has been shown that the phrase "in southern California it blows, glows, flows, and snows" fits the scenario well. (The Santa Ana wind blows, the resulting fire glows, early season rain and mud in the burned areas flows, and by mid winter, it snows). The winter of 2007-2008 is no exception. Shortly before this paper was completed, southern California was hit by another round of October wildfires. It was followed in January by a storm that not only produced double digit rainfall, it produced around 1 ½ feet of snow at the resort levels in the mountains near 6000 feet MSL. There were reports of 3 to 6 feet of snow at the higher elevations. (The highest point in the forecast area is 11,102 feet MSL). Another interesting point is the Wildfires of 1993, 2003, and 2006 all peaked in the second half of October (and the peak winds of the 1993 and the 2003 windstorms were both on 26-27 October). As for rainfall and floods, fires are a major factor in lowering flash flood guidance, but sometimes storms are big enough to cause floods regardless of burn scars.

Although somewhat speculative, the population boom could result in events (for example, large hail, coastal snow, or a hurricane) with as much or more damage than those mentioned earlier. Even adjusted for inflation, the dollar value of weather events of the same meteorological magnitude may still rise in southern California.

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