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Inside Sliders. Part I: Their Features, and Their Effects on the Sierra Front of Western Nevada

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I - Introduction

Heavy snowfall along the Sierra Nevada Front (hereafter "Sierra Front") of Western Nevada (the Reno, Carson City, and Minden areas) is rare, mainly due to down slope winds in the lee of the Sierra Nevada, which tend to favor high winds in the region (Milne 2003). While these same events can bring heavy snow to the Sierra Front, such as the December 28-30, 1992 and December 30-31, 2004 snowstorms, there is another subset of smaller storms, or "inside sliders," that can bring localized heavy snow to western Nevada. Two recent examples of these types of storms include January 20, 2004 and March 1, 2004 where localized heavy snow was reported in and around the Sierra Front of Western Nevada (Fig. 1). Despite their small scale these storms can bring significant weather to the Sierra Front. This paper will define the 'inside slider' system and will discuss common synoptic and mesoscale features associated with inside sliders, and the typical evolution of the precipitation band. A second companion paper (Wallmann, 2006) will take a look at typical model forecasts of inside sliders, and common adjustments often needed to model forecasts.

II - Defining Inside Sliders

An inside slider, for the purpose of this paper, is a southward moving short wave trough inside the West Coast of North America. A schematic at the 500 mb level is presented in Figure 2, and shows the typical, over land trajectory of the system. These short waves are often embedded in a neutral to positively tilted long wave trough, with the axis of the long wave trough oriented northeast to southwest lying east of the Sierra Nevada and Cascade mountain ranges (Fig. 2.) These systems will often deepen as they progress southward into California, and to avoid confusion with a more moisture laden deepening trough, the deepening should take place east of the California coastal mountain ranges. This latter part of the definition is arbitrary, and systems that track close to this 'boundary' tend to be hybrids of moist over water Pacific systems, and drier inside sliders.

Five cases of inside sliders were investigated, ranging from a 'hybrid' system that dropped through the Sacramento Valley on March 1, 2004 (Brong 2006), to a true inside slider that moved south through Western Nevada on January 19-20, 2004. Two other cases used in the investigation were May 11, 2004 and September 20, 2004 which were also true inside sliders. The final case, Aug. 28, 2004, was a dry inside slider where no precipitation was observed.

III - Synoptic and Meso-α Scale Features of Inside Sliders over the Eastern Sierra and Western Nevada

This section will investigate the larger meso-α scale features associated with inside sliders, generally those between 200 km and 3000 km in size (Atkinson 1981). As mentioned in the earlier section, inside sliders are southward moving short waves embedded in a positive tilt long wave trough (Fig. 3a and 3c). The main synoptic feature will be a strong north to south jet streak on the upstream side of the long wave trough (Fig. 3). In inside slider cases, the jet streak will move from British Columbia south to southeast into southern California while precipitation is occurring along the Sierra Front. When the heaviest precipitation is falling, the jet streak is typically located from southwest Oregon into northern California. With the jet streak in this location, the Sierra Front is typically located in the thermally indirect circulation of the left front quadrant of the jet streak, and therefore in a region of weak upward vertical motion.

A second feature of interest is the location of the 500 mb cold pool (Fig. 4). While this feature is really a meso-α scale feature, its track is important, as the cold pool dictates the location of the greatest atmospheric instability, assuming similar thermodynamic conditions in the low levels (below 700 mb) of the atmosphere. With greater instability, there is a faster and stronger response to any upward forcing, which can result in snow bursts over the Sierra Front. In the strongest snowfall cases, such as March 1, 2004, snowfall rates up to 3 inches per hour were observed.

In addition to tracking the cold pool at 500 mb, some indices may be used to help assess the instability. However, caution should be used with these indices as they are sensitive to the low level moisture, which may provide values that are too stable if the model forecast is too dry at low levels. The first is the Lifted Index (LI – Figs. 4 and 5). Values less than +2 C are often associated with inside sliders that produce moderate to heavy precipitation while larger values are associated with cases that produce little if any precipitation.

The second index is the High Level Total Totals (HLTT – Milne 2004) shown here:

1) 850T – 850Td + (500T x 2) = HLTT

While this index was developed to help predict thunderstorms over the Great Basin, Milne noted that the index was highly sensitive to cold 500 mb temperatures. Milne showed that very cold temperatures aloft produced high values of HLTT with little convection during the spring. However, this oversensitivity to cold 500 mb temperatures provides a useful tool to track the 500 mb cold pool for inside sliders. HLTT values greater than 34 C were noted to occur with weak convective cells during an inside slider system (not shown). HLTT values greater than 38 C were associated with the heaviest precipitation, one example being 0900 UTC on 20 Jan 2004 (Table 1.) However, neither of these indices should replace a thorough analysis of any local upper air observations (Fig. 6).

IV - Meso-β Scale Features and Microphysics

Meso-β scale features are those that are between 20 km and 200 km in size. Here, there are two features to be concerned with. The first is generally not terrain dependent, the deformation that forms in the northeast quadrant of the short wave (Fig. 7), which is at the larger end of the scale. While the majority of cases do not have as pronounced low-level deformation axis as in the 1 Mar 2004 case shown in Fig. 8, all have at least a weak deformation axis present although model forecasts may not depict it due to the small scale. The deformation axis is typically where the main band of precipitation forms, and can be verified in radar imagery (Fig. 8)

A second feature has to do with the shape of the terrain along the Sierra Front. As the short waves pass by to the west, the prevailing flow is generally north to northeast. At low levels, it is parallel to the terrain (Fig. 9), across northwest Nevada north of Pyramid Lake, well east of the Cascade Crest, and north of the Sierra Nevada. Along the Sierra Front, the Sierra Nevada Crest is just to the west, and the orientation of the Sierra Nevada is northwest to southeast. As a result, there is more of an upslope component to the low level wind field for precipitation in the foothills of the Sierra Front. The upslope component can also be rather strong in the Reno area as air in northeast flow may be forced upward up to 6,000 feet over a distance of only 10-15 miles. The Reno Airport sits at 4450 feet, while the highest peak to the southwest of Reno is Mount Rose at 10,776 feet, only 15 miles to the southwest. Several other mountain peaks are over 9,000 feet including Slide Mountain at 9,694 feet, 17 miles to the south-southwest.

In addition, it is possible that even in the weakly stable environment, that some of the north to northeast low-level flow gets diverted by the east slopes of the Sierra Nevada to a more northwesterly direction. In this case, there would also be convergence in the valleys, including the Reno area, immediately upstream of the Sierra Nevada Crest. This is analogous to observations in the northern Wasatch Mountains of Utah in southwest flow (Steenburgh et al. 2003) where precipitation does not occur near the Wasatch Crest, but upstream of the Wasatch, on the benches and foothills. While the northwest winds of this type were not observed, in almost every case examined, precipitation maxima occurred on the east slopes of the Sierra (Fig. 10), with lighter amounts on top of Mount Rose, 15 miles southwest of the Reno Airport, and further to the west around Lake Tahoe. Table 1 shows the precipitation totals used to create the analysis seen in Fig. 10.

Microphysics

Microphysical processes are important in any storm regardless of season. Inside sliders are no exception as snow level and snowfall rate are dependent on the microphysical processes within the clouds. An excellent discussion of the microphysical processes that affected the 1 Mar 2004 inside slider may be found in Brong, 2006. The discussion used for the 1 Mar 2004 case can also be used for any other inside slider, but it should be noted that the March case is an extreme.

V - Typical Evolution

The typical evolution of the precipitation band during an inside slider event as it progresses through northwest Nevada is shown in Figure 11. Before entering Nevada, there is often scattered convection upstream over Oregon, which was observed in the hours preceding the first KRGX image in Fig. 11. By 04Z in Fig. 11a, convection associated with the short wave had progressed into northwest Nevada and northeast California. While most of the convection at the time was disorganized and scattered, a weakly organized band of convection was forming in northeast California, just west of the Nevada border, and northwest of Reno, NV (KRNO).

Location	Direction and Distance from the Reno Airport	Precipitation Amount
Reno Airport	0	0.57”
Reno- North Hills	5 mi N	0.24”
Stead, NV	11 mi NW	0.15”
Sparks, NV	4 mi NE	0.34”
SE Sparks, NV	1 mi NE	0.56”
Virginia City, NV	16 mi SE	0.32”
Spanish Springs, NV	9 mi NE	0.38”
Carson City, NV	21 mi S	0.40”
Minden, NV	40 mi S	0.34”
Dagget Pass, NV	39 mi S	0.30”
Glenbrook, NV	30 mi S	0.16”
Fallon NAS, NV	58 mi E	Trace
Gerlach, NV	82 mi N	0.06”
Fernley, NV	31 mi E	0.05”
Markleeville, CA	57 mi S	0.36”
Yerington, NV	49 mi SE	0.04”
Hawthorne, NV	91 mi SE	0.10”
Truckee, CA	22 mi SW	0.20”
Portola, CA	39 mi NW	0.07”
South Lake Tahoe AP, CA	43 mi SSW	0.04”
6 N Smith, NV	47 mi SE	0.66”
Lovelock, NV	77 mi NE	0.03”
4N Topaz Lake, NV	55 mi S	0.15”

Table 1. *Selected locations used in the subjective analysis of Figure 11. Distance from the Reno airport, elevation, and liquid equivalent precipitation amount for 20 Jan 2004.*

By 06Z (Fig. 11b), the convective band that was over California became better organized and stretched from 20 miles northwest of Reno to 20 miles northeast of Reno. At this point the band began to affect Interstate 80 just west of Fernley, NV. Elsewhere, scattered convection continued more than 25 miles to the northeast of Reno, near the town of Lovelock, Nevada (KLOL in Fig. 11).

At 09Z (Fig. 11c), the band of precipitation progressed into Reno with heavy rain reported at the airport. The band continued to broaden as it moved through Reno while convection over 25 miles east of Reno continued to be scattered. After 12Z (Fig. 11d), broadening continued within the band as it reached the southern end of the Sierra Front near Minden as the influence of the Carson Range was better felt under the northerly flow. Further behind the main band where the flow had begun to turn to the northeast, upslope snow continued over southwest Reno as the flow continued up toward Mount Rose, approximately 15 miles southwest of Reno.

Exceptions

While the aforementioned progression of an inside slider system represents a ‘typical’ event, there are a few exceptions. Therefore, a forecaster should not focus on the typical events shown in this paper, but a broader spectrum of inside slider cases. Two such exceptions to the generalized idea are presented below.

The most notable occurred with the March 1, 2004 event described in Brong, 2006. In this event, the deformation axis and microphysics were extremely important in the heavy snowfall, and the deformation band remained stationary instead of progressing south and expanding.

A second exception included the May 11, 2004 case where the precipitation band progressed from the northwest instead of the north (Fig. 12). However, when the scattered convection over northern California approached the Nevada border, an organized cluster of convection formed and continued to broaden as it moved through the Sierra Front. After it passed the Sierra Front, the band slowly weakened as it moved into central Nevada. The forcing for this event was a bit different, as the main forcing mechanisms where the leading cold front coupled with the cold pool aloft.

VI - Summary

Inside sliders, as presented, are southward moving short wave troughs east of the West Coast of the United States which are embedded in the backside of a positive tilt long wave trough. The significant meteorological features, both synoptic and mesoscale, of inside sliders were presented. While the overland track of an inside slider often implies drier conditions, the meteorological features combined with the unique topography of the Sierra Front create a precipitation maximum often near Reno and Carson City, Nevada.

References

Atkinson, B. W., 1981: **Meso-scale Atmospheric Circulations**. *Academic Press.* 495 pp.

Brong, Brian, 2005: **Microphysical Processes and the Reno Snow Storm on March 1st, 2004.** *Western Region Technical Attachment No. 06-01.* January 24, 2006.

Milne, Rhett, 2003: **Using the Weather Event Simulator (WES) as a Training Tool for Predicting High Winds in the Lee of the Sierra Nevada**. *Western Region Technical Attachment Lite No. 03-10.* February 15, 2003.

_____, 2004: **A Modified Total Totals Index for Thunderstorm Potential Over the Intermountain West**. *Western Region Technical Attachment No. 04-04.* June 15, 2004.

Steenburgh, W. James, 2003: **One Hundred Inches in One Hundred Hours: Evolution of a Wasatch Mountain Winter Storm Cycle.** *Weather and Forecasting*: Vol. 18, No. 6, pp. 1018–1036.

Wallmann, James, 2005: **Inside Sliders. Part II: Model Forecasts for Inside Sliders and Their Biases.** *Western Region Technical Attachment No. 05-??.*

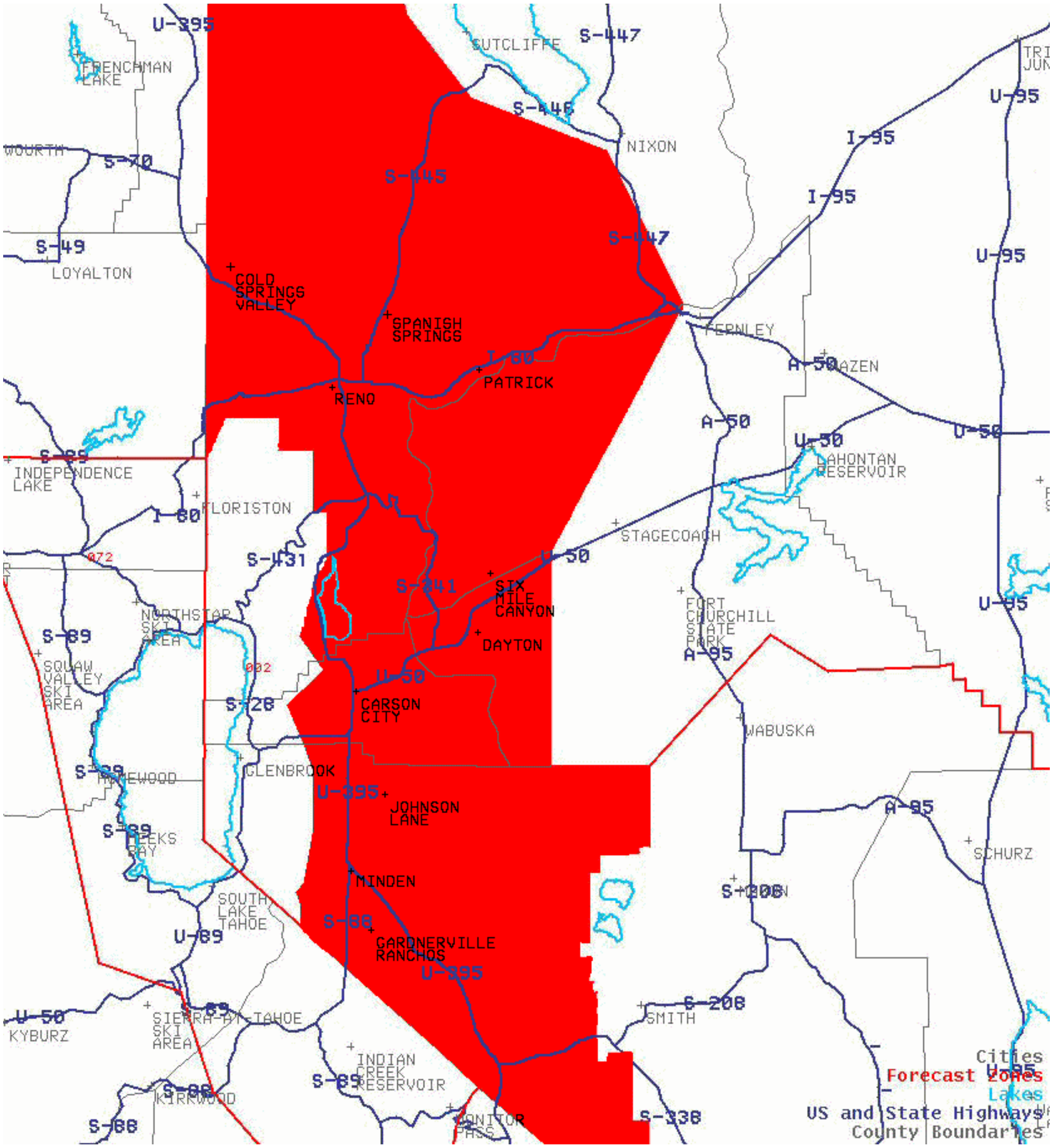

Figure 1. A map detailing the Sierra Front of western Nevada. The Sierra Front is highlighted in red.

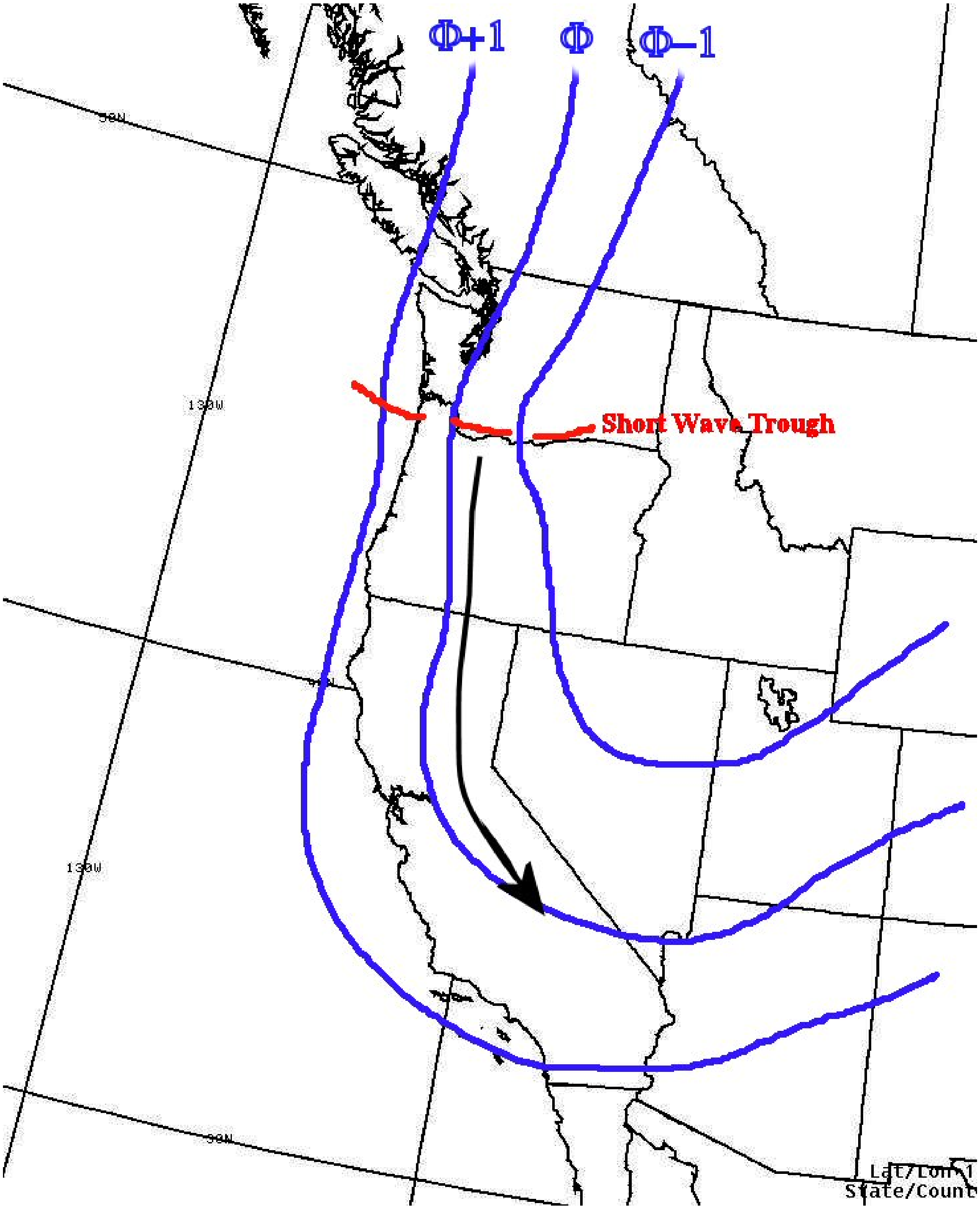

Figure 2. A 500 mb level schematic of the overall long wave trough across the Western United States, and the embedded short wave trough in the north-northwest flow on the upstream side of the long wave trough.

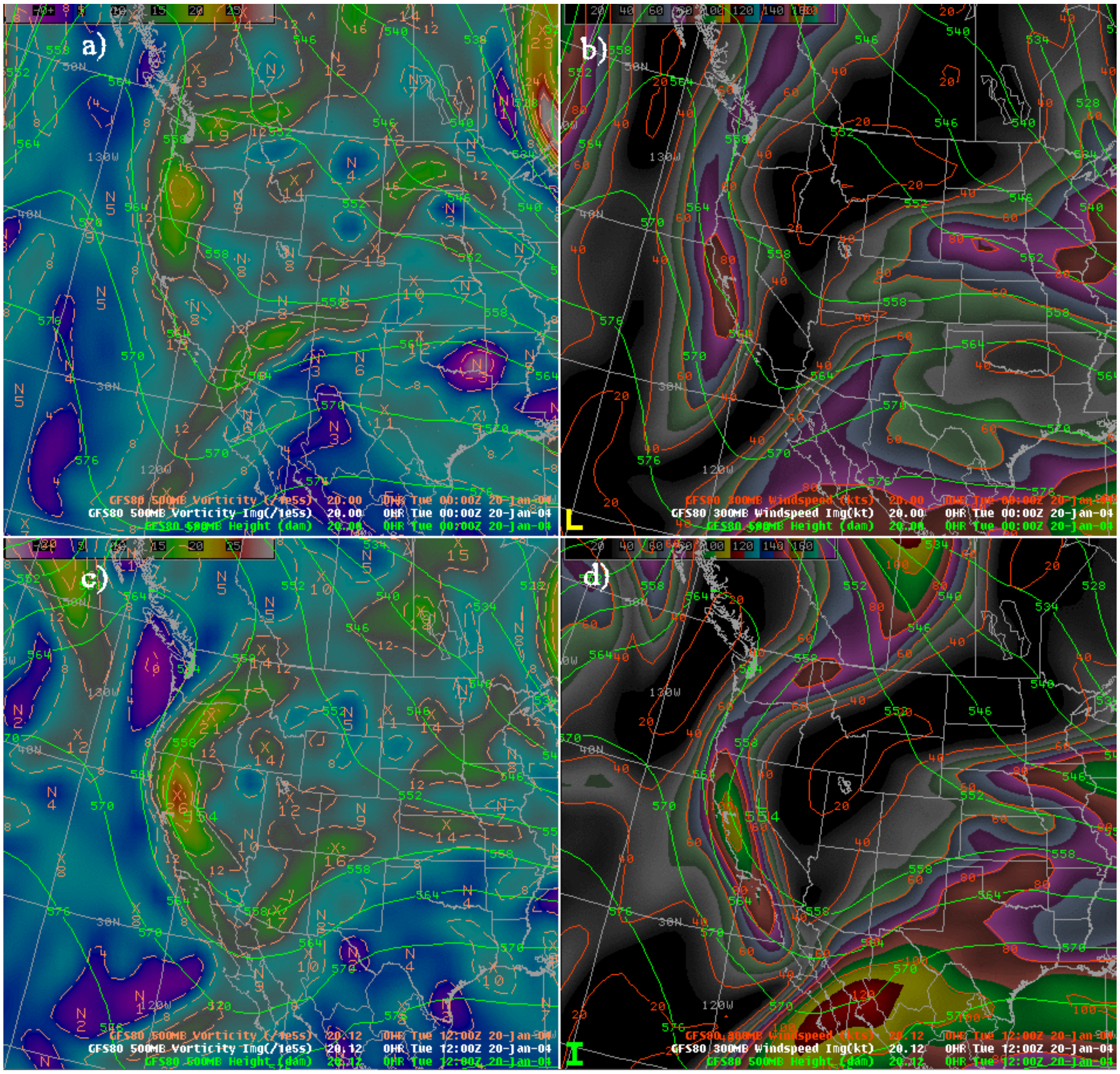

Figure 3. Four panel GFS analyses from January 20, 2004 depicting the general location and motion of the 500 mb short wave and the 300 mb jet streak. In a) 500 mb heights and vorticity from 00Z Jan 20, b) 500 mb heights and 300 mb wind speed from 00Z Jan 20, c) 500 mb heights and vorticity from 12Z Jan 20, and d) 500 mb heights and 300 mb wind speed from 12Z Jan 20.

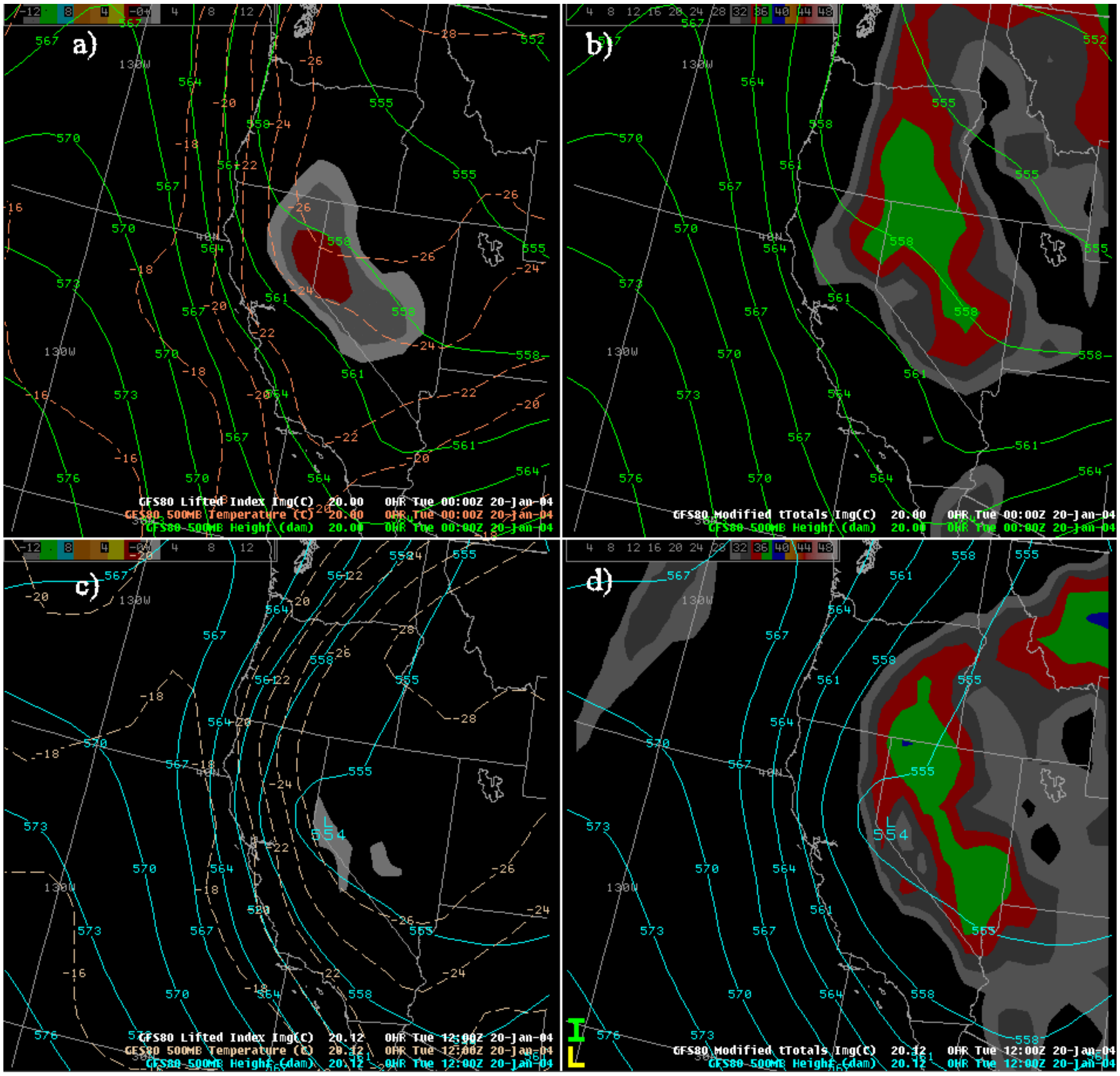

Figure 4. GFS analyses of 500 mb heights, temperatures, LI, and HLTT. a) 500 mb heights, temperatures and LI at 00Z Jan 20, b) 500 mb heights and HLTT at 00Z Jan 20, c) 500 mb heights, temperatures and LI at 12Z Jan 20, and d) 500 mb heights and HLTT at 12Z Jan 20.

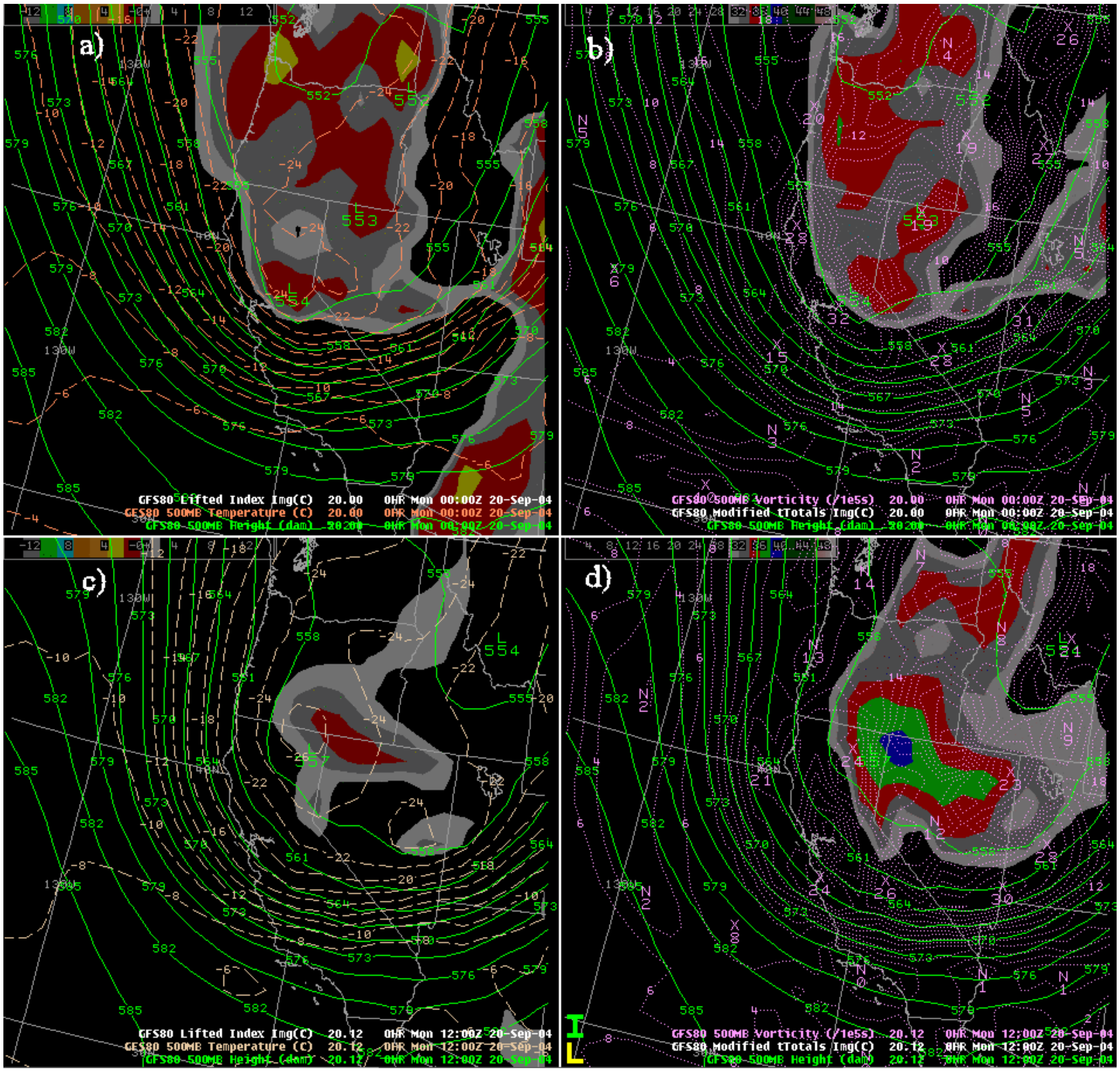

Figure 5. GFS analyses of 500 mb heights, LI, and HLTT. a) 500 mb heights, temperatures and LI at 00Z Sep 20, b) 500 mb heights and HLTT at 00Z Sep 20, c) 500 mb heights, temperatures and LI at 12Z Sep 20, and d) 500 mb heights and HLTT at 12Z Sep 20.

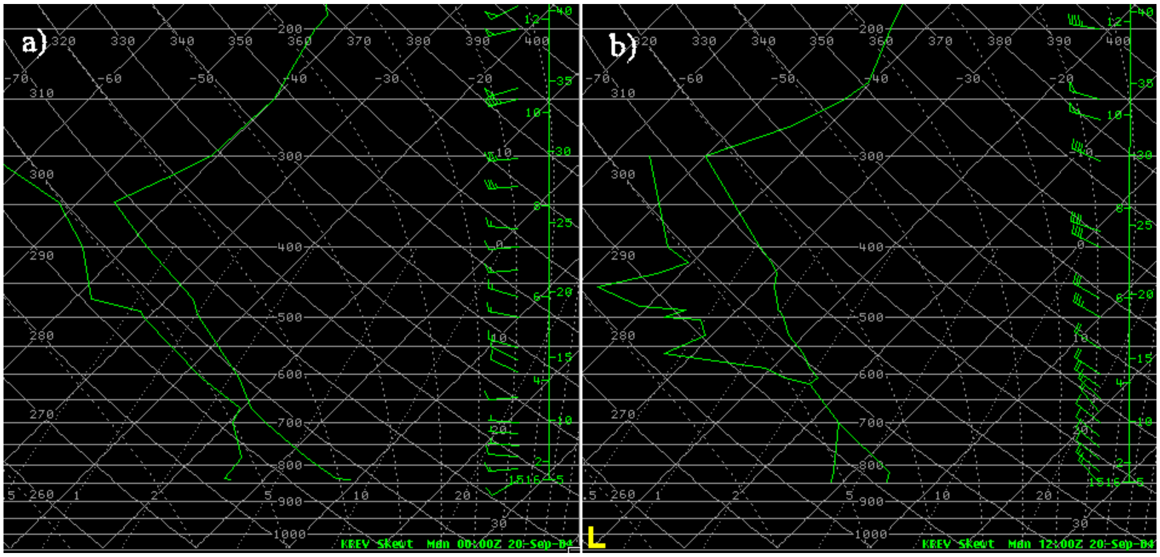

Figure 6. KREV soundings from 00Z 20 Sep 2004 (a) and 12Z 20 Sep 2004 (b).

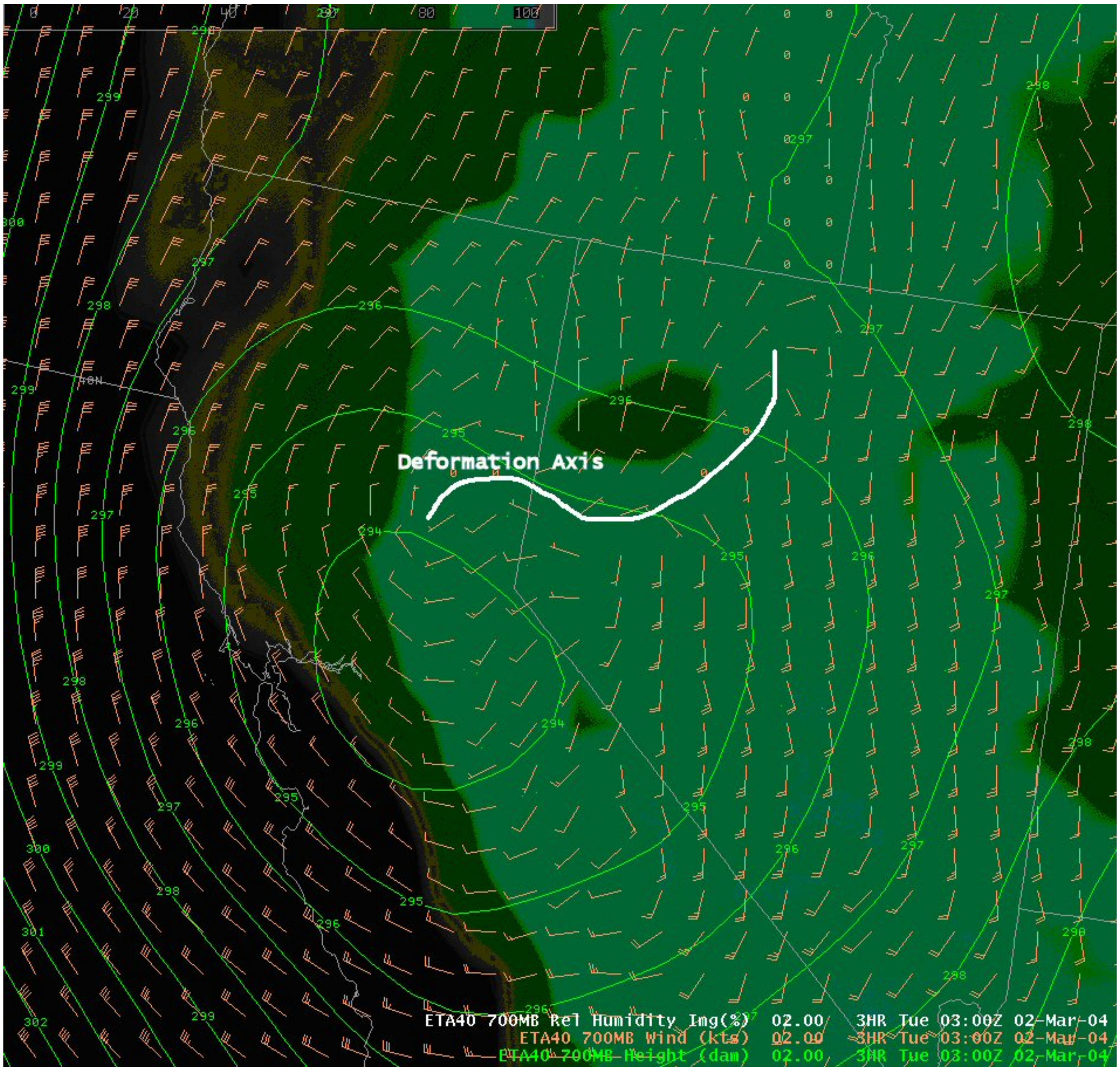

Figure 7. 700 mb height, winds and RH. The white line shows the 700 mb deformation axis.

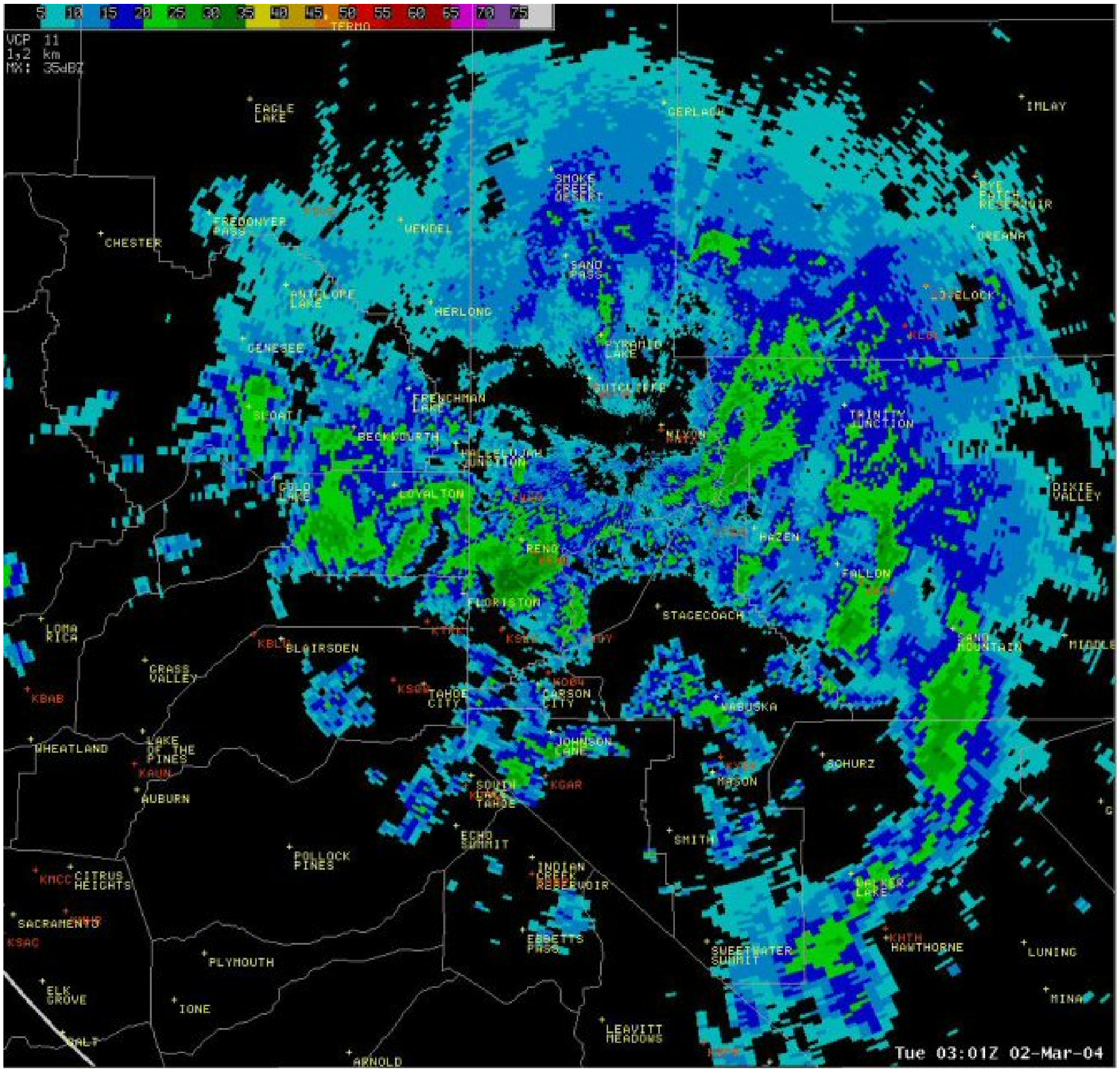

Figure 8. KRGX 0.5 degree elevation reflectivity at 0300 UTC 2 Mar 2004.

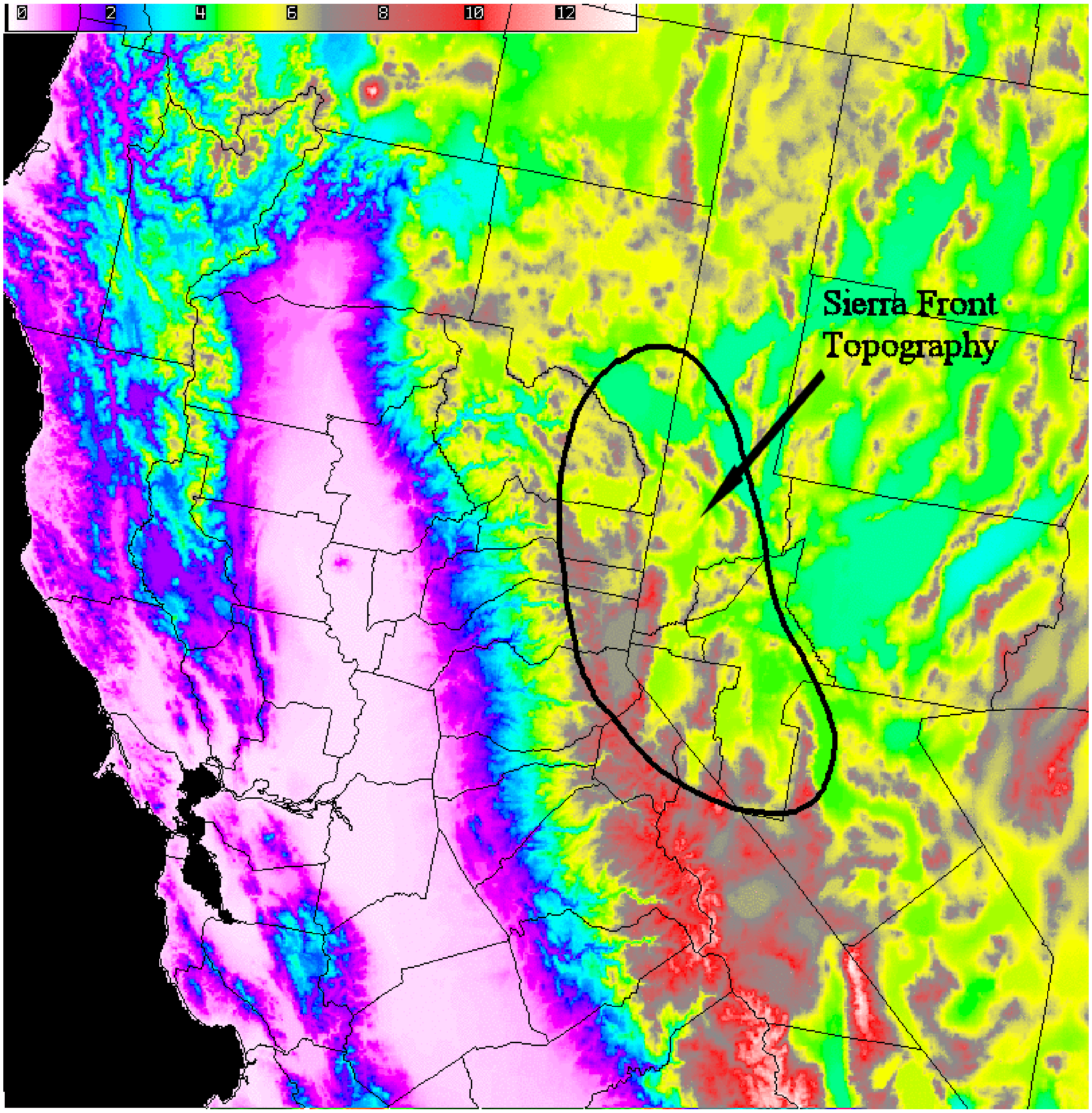

Figure 9. Map showing the topography of western Nevada and eastern California, and area of focus for the Sierra Front.

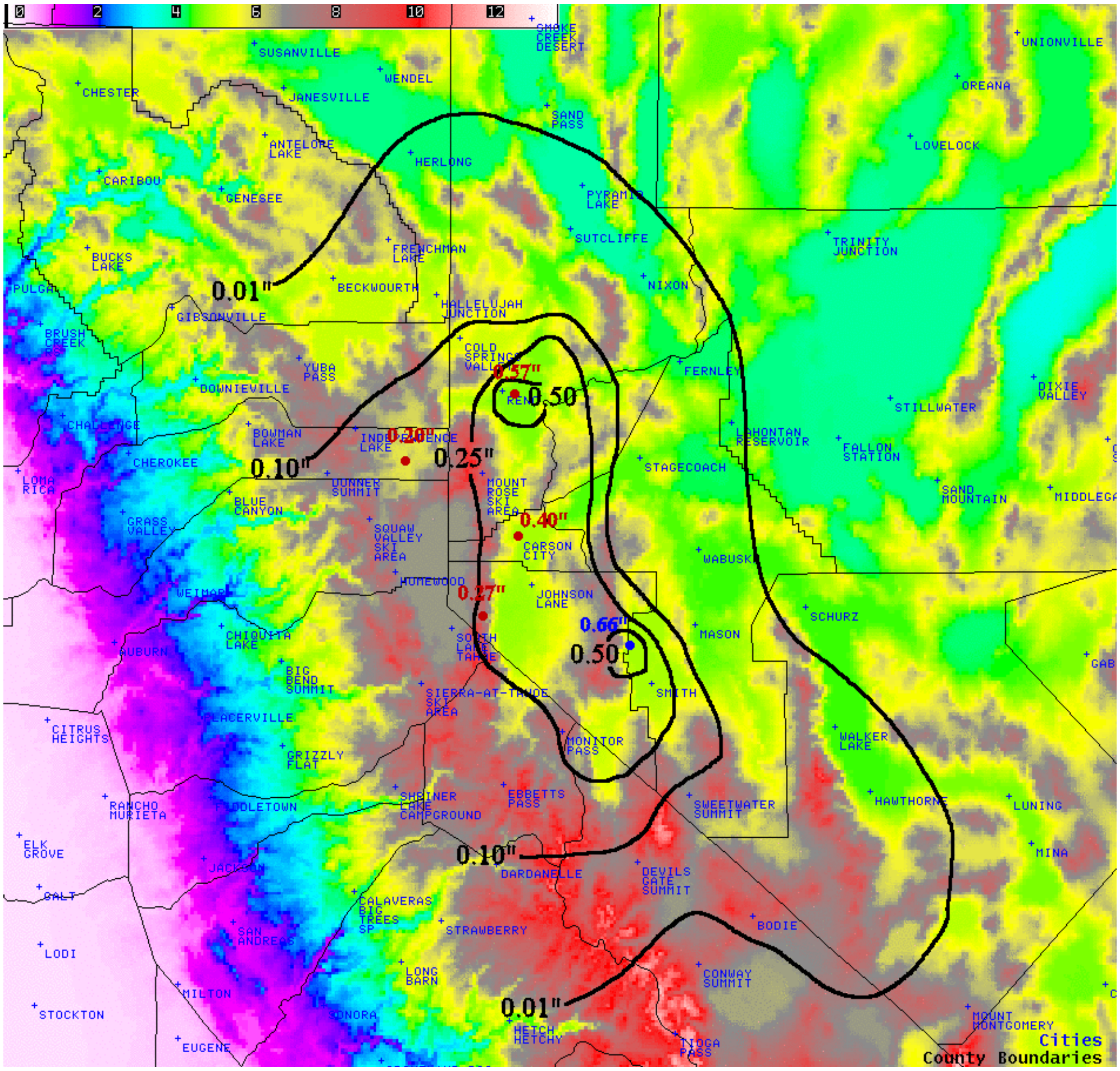

Figure 10. Subjective analysis of precipitation amounts (liquid equivalent) ending 18Z Jan 20. Amounts used are also summarized in Table 1. Locations of the select amounts are shown by the maroon dots along with the amounts. The greatest liquid equivalent amount is shown by the blue dot north of Smith, NV.

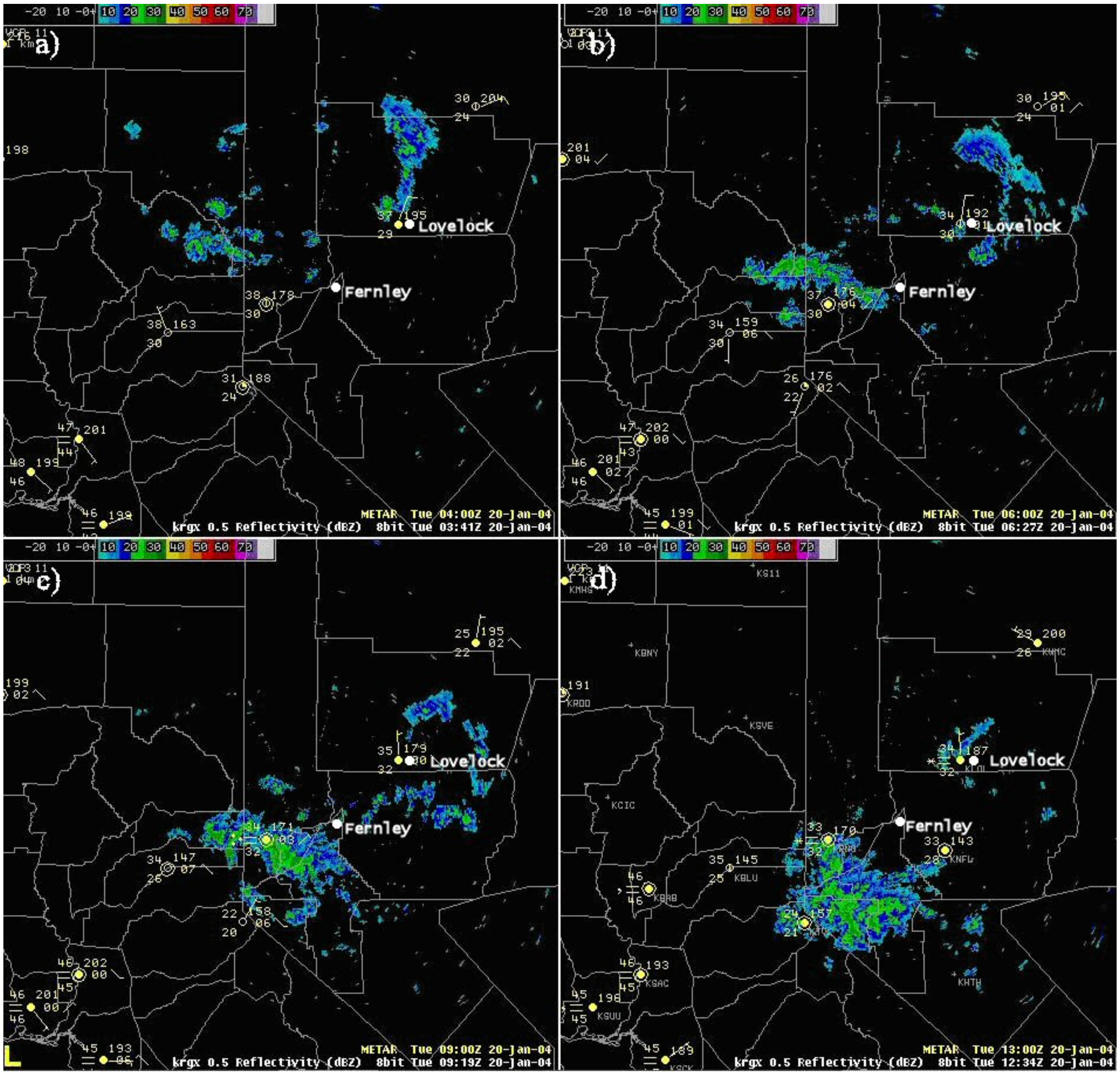

Figure 11. Four panel 0.5 degree elevation reflectivity image from KRGX. a) 0341 UTC 20 Jan, b) 0627 UTC 20 Jan, c) 0919 UTC 20 Jan, d) 1234 UTC 20 Jan.

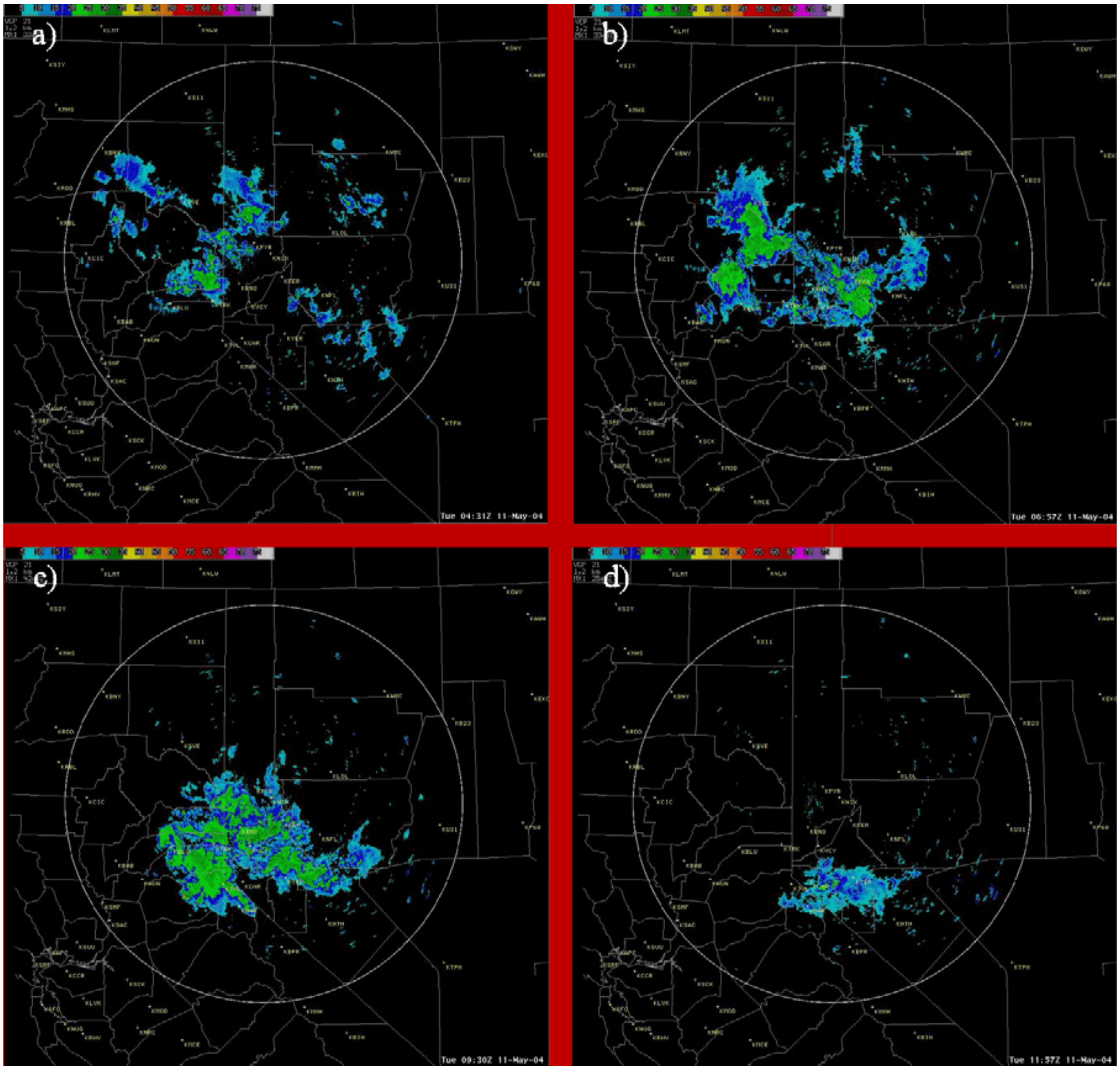

Figure 12. Four panel 0.5 degree elevation reflectivity image from KRGX. a) 0431 UTC 11 May 2004, b) 0657 UTC 11 May, c) 0932 UTC 11 May, and d) 1157 UTC 11 May.