An Examination of the 12-14 March 2002 Utah Winter Storm Using the Weather Event Simulator (WES)

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Introduction

Winter storms are by far the most challenging forecast issue in Utah. A strong winter storm moved through Utah over the period of 12-14 March 2002. Snowfall reports from around Utah over this period ranged from as high as nearly 5 feet in the mountains to less than an inch in valley locations, and affected areas from the Wasatch Mountains in the north to areas as far south as St. George in southwest Utah, where damaging winds also occurred. This system exhibited several common attributes of a Utah winter storm, while also displaying more complicated and difficult to forecast characteristics. A key ingredient to winter storms in Utah is Upward Vertical Velocity (UVV), either attributed to dynamic forcing, orographic forcing, or a combination of both. Instability is also an important factor, while moisture, as it turns out, is not a limiting factor. The more important contributors to heavy snow at lower elevations of the Urban Wasatch Front (north-south from Ogden to Salt Lake City to Provo) are the presence of strong dynamic forcing (UVV through a deep portion of the troposphere), instability through a deep layer of the atmosphere behind a wind-shift/front, and a well-defined frontal passage at some time during the event. The primary determining factor of snowfall amount is simply the storm's duration. Besides the ever present challenge of understanding the effects of orographics, the accurate prediction of snowfall downwind from the Great Salt Lake is maybe the biggest challenge facing forecasters in Utah. This is why local meteorologists have coined the phrase "The Dreaded Lake Effect", or DLE!.

For this simulation, forecasters were first placed in the forecast situation at 1100 UTC 13 March 2002 (11Z/13) with data on the AWIPS Weather Event Simulator (WES) available up to that point. Copies of the official Zone Forecast Product (ZFP) issued at 23Z/12 March by the Salt Lake City WFO were available, as well as copies of the current advisories in effect and valid over their forecast period. Forecasters were also provided additional model data from the University of Utah's MM5, as well as point-and-click maps displaying MesoWest data archived at the University of Utah. After answering a set of questions on the storm, forecasters moved ahead 6 hours to determine if changes were needed to their original answers based on new data, both in AWIPS and through the web. This creates a unique situation where a forecaster can forecast the possible onset of the event, then immediately watch the event unfold as it happens. Finally, forecasters were able to view what actually happened during this storm by viewing AWIPS data out through 14 March.

Synoptic and Mesoscale Overview

A cold and fairly progressive upper wave was forecast to move out of the Pacific Northwest and through the Rockies over the simulation period. The significant characteristic of this storm was the very cold air aloft, with a 500 mb temperature core in the -30's C (Fig. 1), and preceded by a strong surface cold front. Heavy snow was reported across some areas of the Wasatch through the night of 12-13 March and ahead of the main trough. This was likely a result of a strong southwesterly jet aloft and deep instability. Rain showers also occurred overnight in the valley areas due to relatively warm surface temperatures (Fig.2). Models were all relatively consistent with the timing and intensity of the trough and surface front as it would move through the area. As is common with the stronger Utah winter storms, the surface front was forecast to move through ahead of the upper trough, allowing for a favorable period of unstable orographic flow enhanced by upper level dynamics. The 06Z/13 March 2002 AVN time-height for Salt Lake City, Utah (SLC, Fig. 3) showed the favorable system tilt to the northwest as it moved through, along with a moderate period of UVV during the afternoon of 13 March, and convective instability as depicted with theta-e. A question remained, though, as to whether enough dynamic forcing would be present to produce significant snowfall during the post-frontal orographic stage of the storm along the Wasatch Front in northern Utah. Very nearly as forecasted by the models, the surface front moved through northern Utah and the Wasatch Front early in the afternoon of 13 March, beginning an active period of mountain snowfall that would eventually spread south through Utah's higher terrain. After a slow change from rain to snow in valley areas, there was little if any accumulation across these areas (e.g. in the Salt Lake City area) due to relatively low surface relative humidity. The 00Z/14 sounding from SLC (Fig. 4) shows some of this low level dry air. Visibility at SLC during the period of light snow over the afternoon of 13 March remained above 5 sm, and at times as high as 10 sm. Mountain snows continued to spread south during the day and early evening. Once the mid level trough moved through the northern Utah around 06Z/14 and the surface low moved into central Colorado, most valley precipitation diminished to weak shower activity. Mountain snowfall, though weakening, continued into the afternoon of 14 March as cold air aloft and an unstable environment produced afternoon snow showers.

Lake effect snows off the Great Salt Lake (GSL), which is analogous to lake effect snows off the Great Lakes, is always a concern for forecasters when considering snowfall amounts in the Salt Lake/Tooele Valley and Wasatch Front in post frontal northwest flow. Steenburgh et al (Monthly Weather Review March 2000) determined that the primary contributors to GSL effect snow include 1) a 700 Mb-lake temperature difference of at least 16C, 2) an absence of capping inversions or stable layers below 700 Mb, 3) limited (< 60 deg) steering-layer (800-600 Mb) directional shear (except in weak flow), and 4) the existence of low-level convergence over the GSL. Supportive upper-level dynamics can also enhance lake effect events. The low-level convergence is typically brought about by lake-land temperature differences that are enhanced by snow-covered ground around the lake. The temperature contrast results in land breezes and subsequent low-level convergence bands over the lake, forming precipitation areas that are advected downwind of the lake. The onset of these events is more common after sunset when the land-lake temperature differences are greatest, and can last on average 13-24 hours.

Lake effect was a concern with this particular storm given most factors were in place. The most significant lake effect band formed over night, anchored near Centerville, UT (just north of SLC) at around 05Z/14 March 2002, and extended southeast across the east Salt Lake City area and into Big and Little Cottonwood Canyons (Fig. 5). This band was responsible for moderate snowfall across the east Salt Lake City benches and was a major contributor to very heavy snowfall in the Alta area (21" in 12 h, ending 11Z/14) at the top of Little Cottonwood Canyon southeast of SLC (Alta's location is labeled by "Home" in Fig. 5). Timing-wise, this band formed in a favorable period of the night, in cold low-shear northwest flow. There appears to be more to this band, however, than what typically characterizes a lake effect band. Further investigation reveals that it was enhanced by a low-level vorticity center that moved south out of Idaho and across the GSL. The GOES IR loop from 0330Z/14 to 1115Z/14 (Fig. 6a) verifies this idea. Fig 6b is a single IR image from 0915Z/14 showing the band radiating southeast out of the GSL. The IR loop shows a weak mid-level rotation moving south across northern Utah as this band forms on its eastern edge. This feature was also responsible for a period of light to moderate snowfall in the SLC area late in the evening (1.1" officially measured at the SLC). At the surface, a University of Utah MesoWest image from 0845Z/14 (Fig. 7) shows northwest surface winds over the GSL which back to westerly at stations south of the lake, thus depicting cyclonic effects at the surface and increased convergence and orographics in the East Salt Lake City area. It's likely something of this time and space scale would not be modeled by numerical guidance, emphasizing the importance of using satellite and WSR-88D data in this case. This band and its source feature will be examined further in a local study, including evaluating model performance and the application of the AWIPS D3D on the WES. After this precipitation area crossed the GSL and diminished around 12Z/14, a second lake band (though weak) formed in the early morning hours, and extended out of the south end of the GSL (Fig. 8). This trajectory was due to the increasing low-level northerly flow focusing the band south of the lake. Forecasting lake effect or lake enhancement bands such as these are extremely difficult and represent a common challenge to forecasters at the SLC WFO - that is understanding when and where lake bands will form, and how long they will exist. The effects of orographics also complicates the situation as it did in this case. In many cases, it's generally a matter of anticipating the possibility of such event, then quickly adjusting if necessary as it unfolds. Forecasters today *are* better able to identify the ingredients that are needed to produce lake effect events off the GSL, although forecasting their location, timing, intensity and duration is still very difficult.

Other areas of Utah, most notably from the Southern Wasatch Front just south of the Salt Lake Valley and southward into the central and southern mountains and nearby valleys, also received significant snow with this system. The mountains of central and southwest Utah are generally oriented northeast-southwest (Fig. 9), creating favorable orographics in low-level northwest flow situations. In addition, the track of the main vorticity center, which was along the Utah-Arizona border, provided favorable dynamics for these areas. Finally, strong winds just ahead of and just behind the front produced over 60 mph winds at Wahweap in southeast Utah, and 66 mph at St. George in southwest Utah. Damage was reported in the St. George area as a result of these winds.

Conclusion

The WES allowed forecasters access to a full suite of AWIPS and supplemental web data during the drill and for case review. A simulation such as this duplicates a real-time event in a controlled training environment. In addition, allowing forecasters access to their own AWIPS procedures enables them to use familiar routines to refine their pattern recognition techniques. The drills concluded with constructive discussion using the WES as a backdrop, thus overall creating a dynamic learning experience.

Figure 1

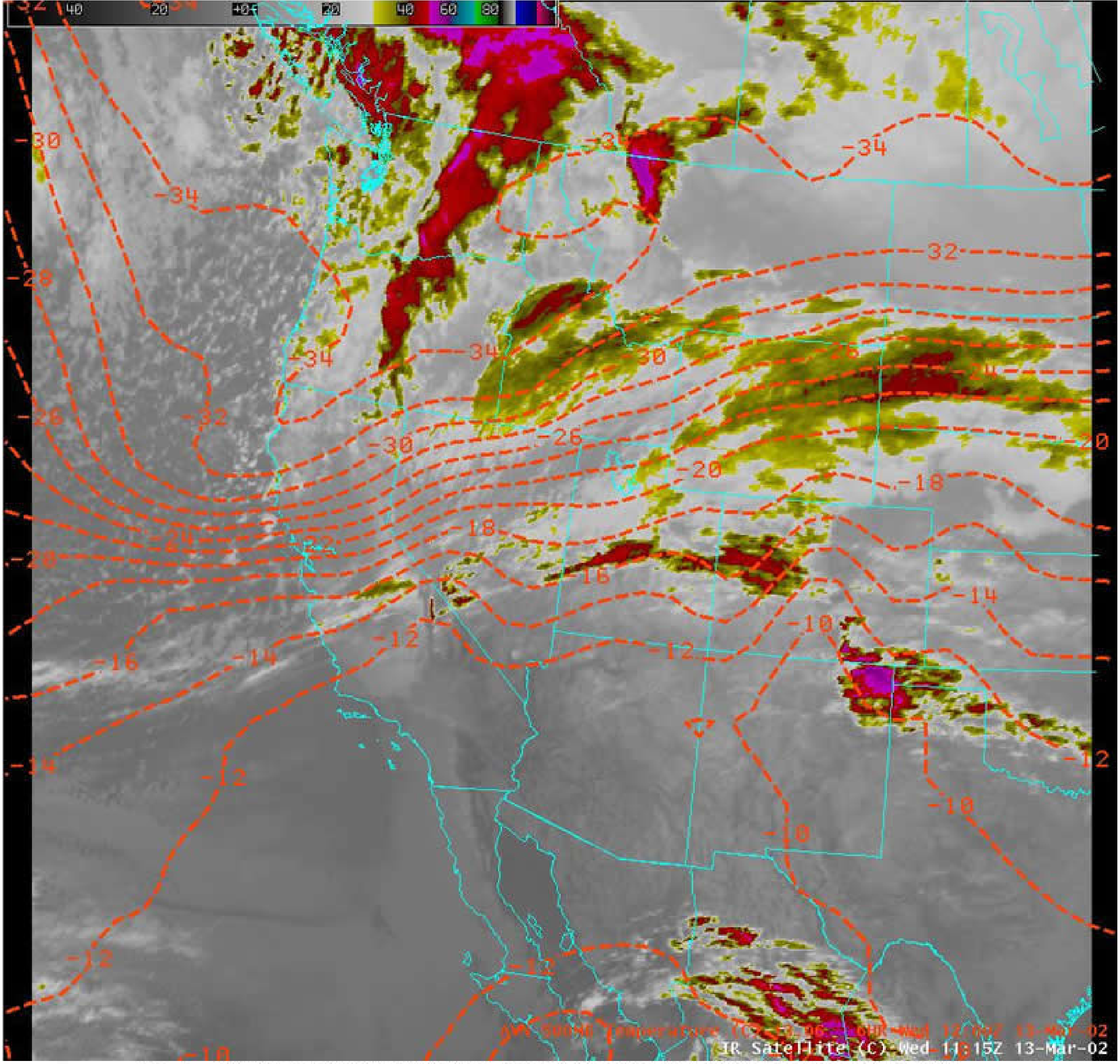


Fig. 1 - GOES IR at 1115 UTC 13 March 2002 with AVN 500 mb temperature (C), 6-h forecast valid 1200 UTC 13 March 2002

Figure 2

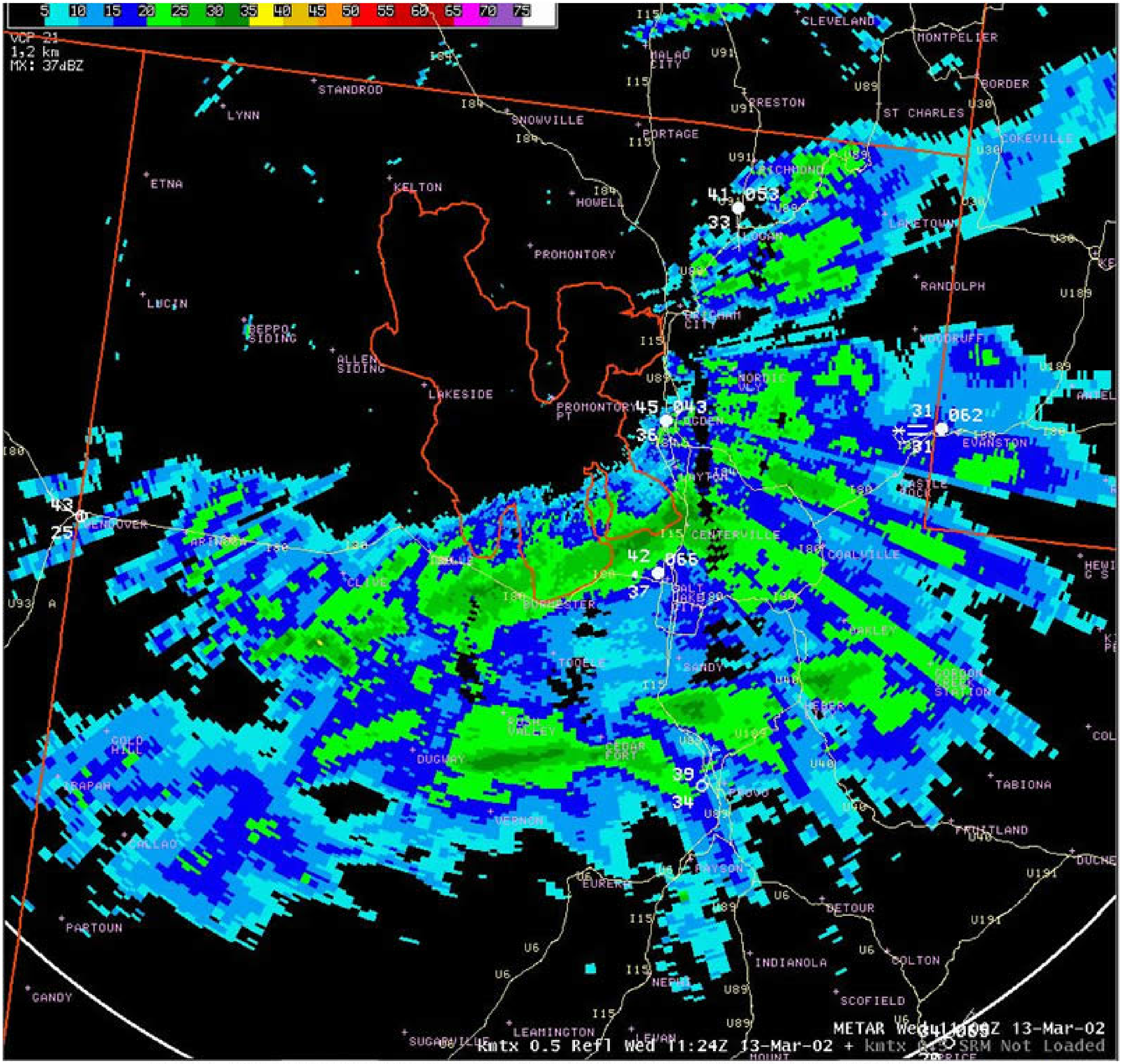


Fig. 2 - KMTX Composite Reflectivity (dBZ) at 1124 UTC 13 March 2002 with 1100 UTC 13 March 2002 METAR reports.

Figure 3

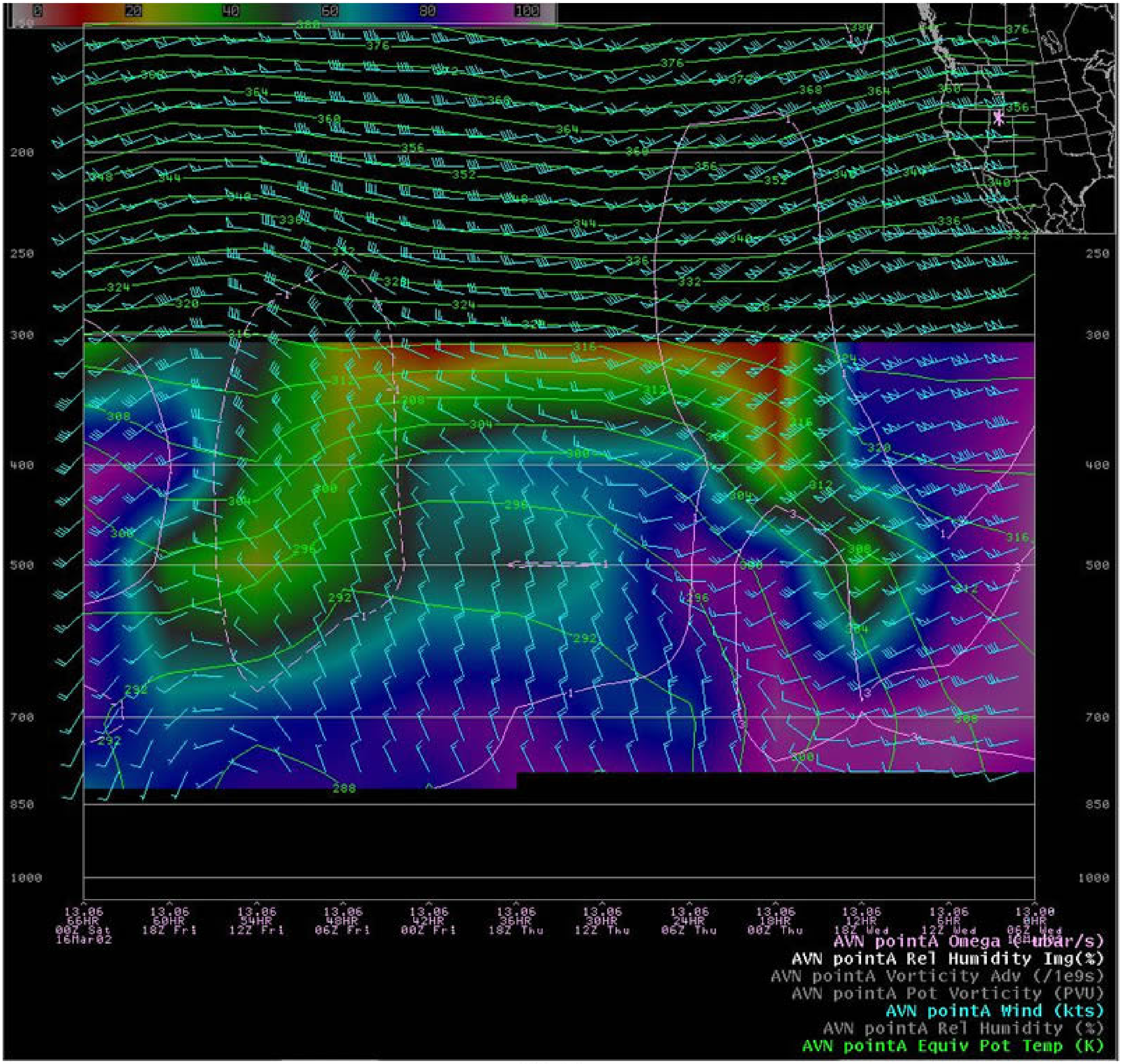
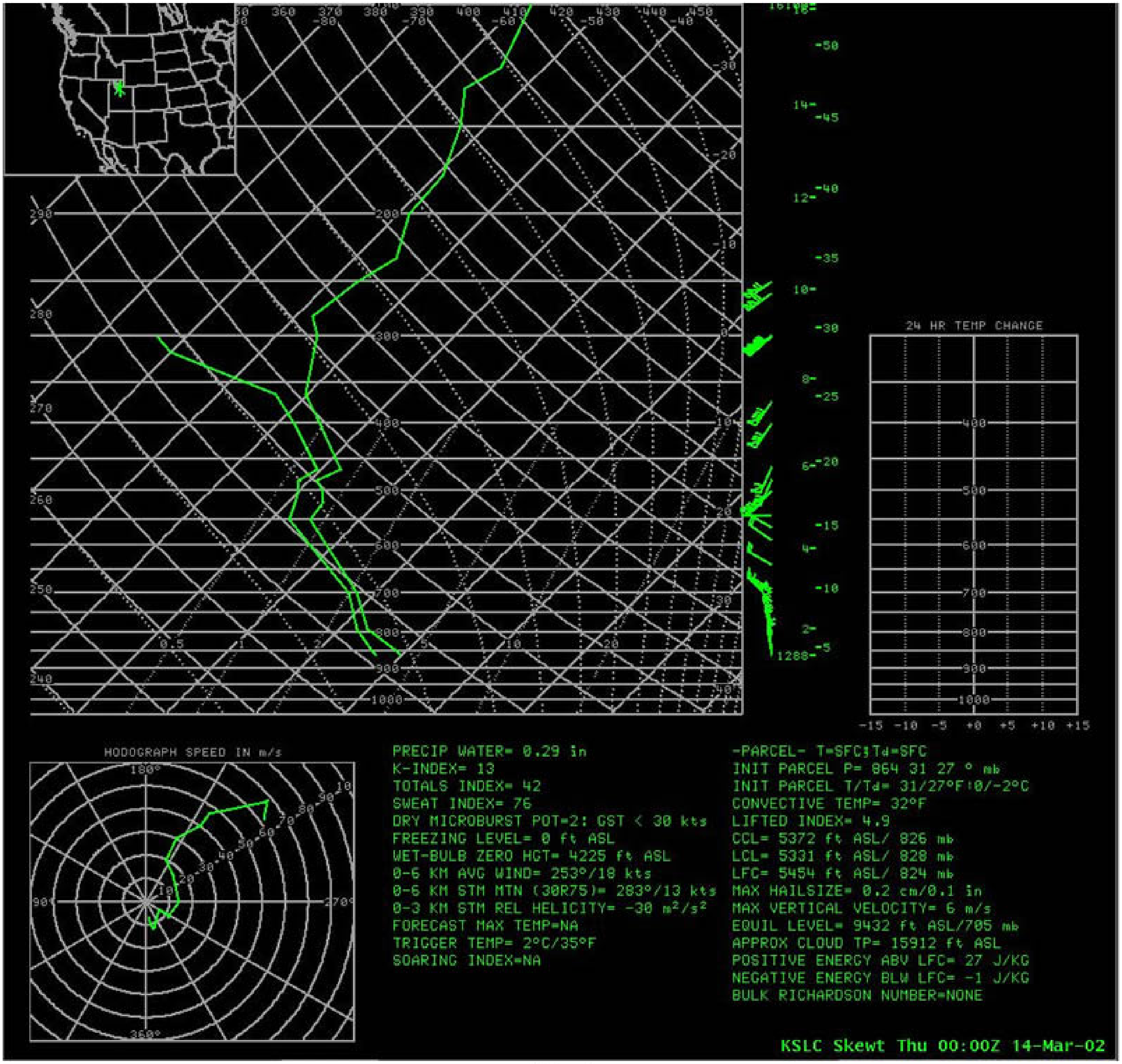


Fig. 3

Figure 4



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PRECIP WATER= 0.29 in                    -PARCEL- T=SFC;Td=SFC
K-INDEX= 13                              INIT PARCEL P= 864 31 27 ° mb
TOTALS INDEX= 42                         INIT PARCEL T/Td= 31/27°F:0/-2°C
SWEAT INDEX= 76                          CONVECTIVE TEMP= 32°F
DRY MICROBURST POT=2: GST < 30 kts       LIFTED INDEX= 4.9
FREEZING LEVEL= 0 ft ASL                 CCL= 5372 ft ASL/ 826 mb
WET-BULB ZERO HGT= 4225 ft ASL           LCL= 5331 ft ASL/ 828 mb
0-6 KM AVG WIND= 253°/18 kts             LFC= 5454 ft ASL/ 824 mb
0-6 KM STM MTN (30R75)= 283°/13 kts      MAX HAILSIZE= 0.2 cm/0.1 in
0-3 KM STM REL HELICITY= -30 m²/s²       MAX VERTICAL VELOCITY= 6 m/s
FORECAST MAX TEMP=NA                     EQUIL LEVEL= 9432 ft ASL/705 mb
TRIGGER TEMP= 2°C/35°F                   APPROX CLOUD TP= 15912 ft ASL
SOARING INDEX=NA                         POSITIVE ENERGY ABV LFC= 27 J/KG
                                         NEGATIVE ENERGY BLW LFC= -1 J/KG
                                         BULK RICHARDSON NUMBER=NONE
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Fig. 4

Figure 5

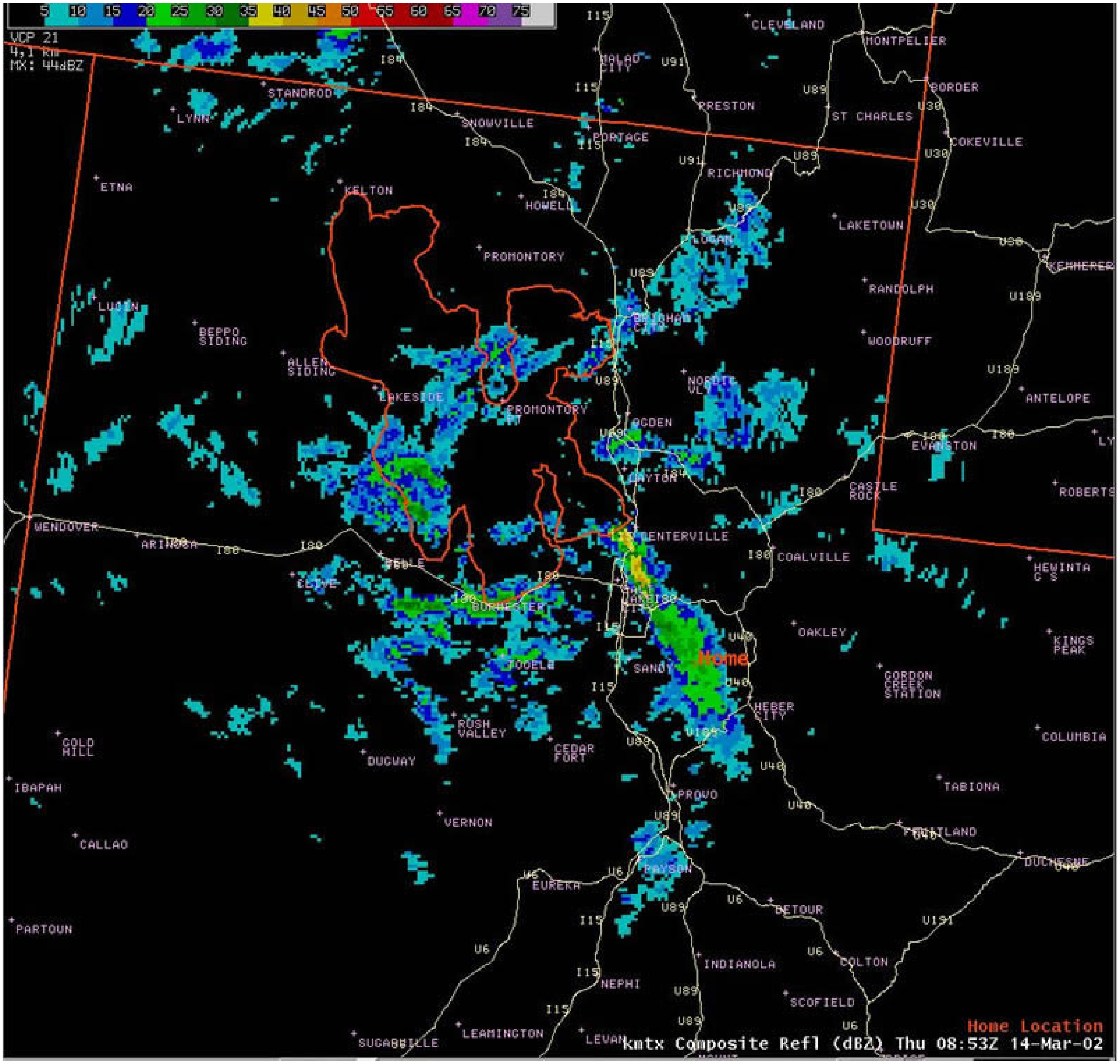

Fig. 5 - "Home" denotes location of Alta, UT

Figure 6a

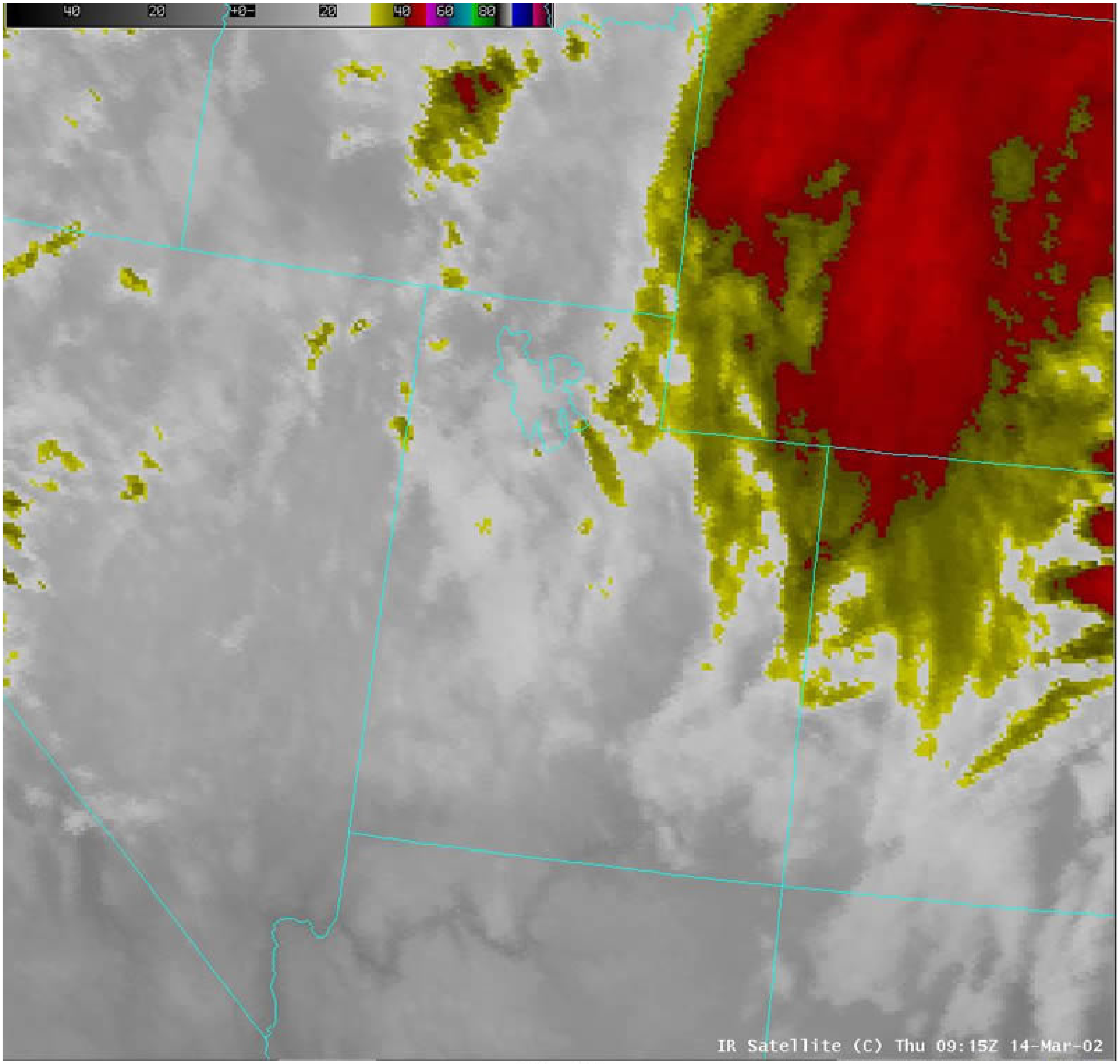

Fig. 6b

Figure 6b

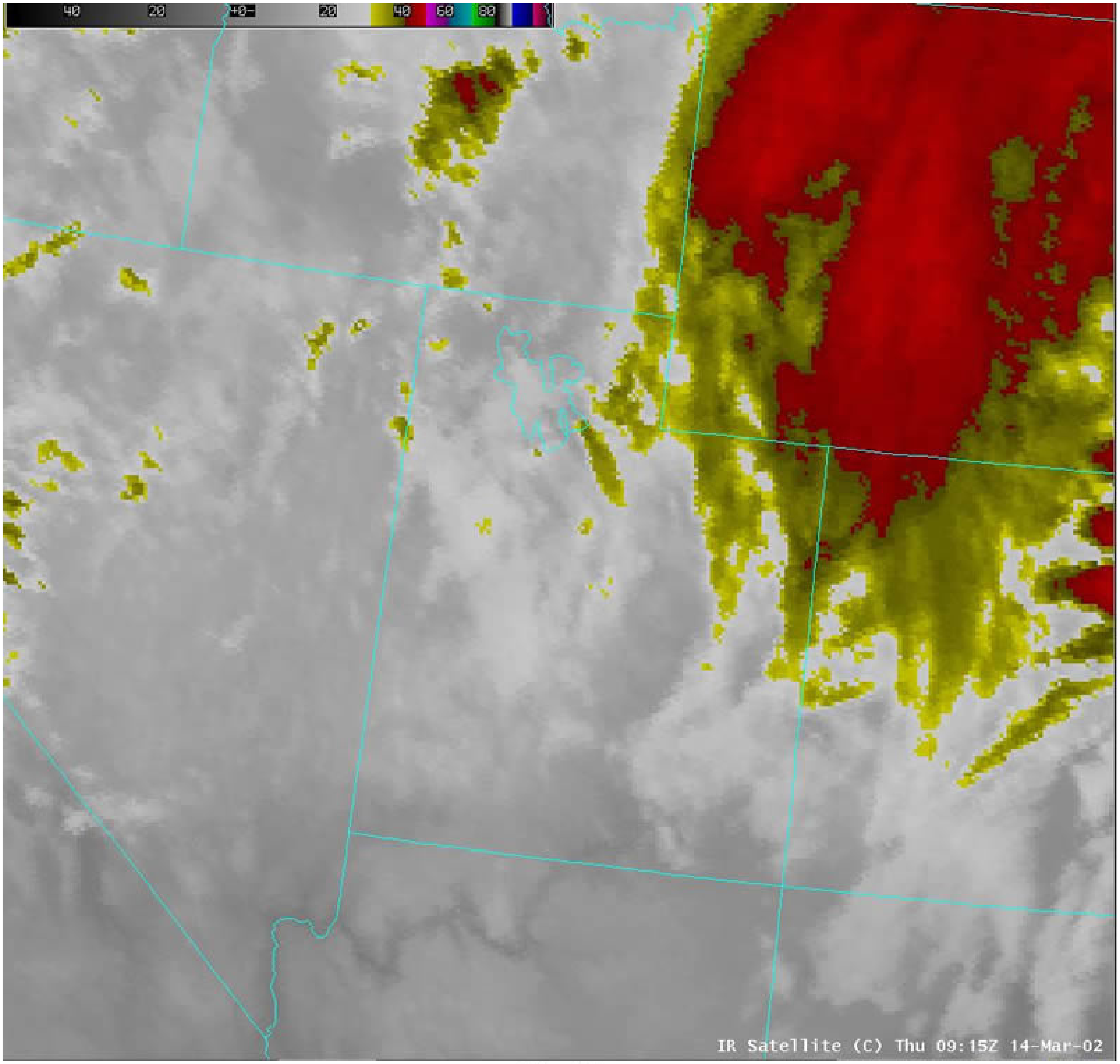

Fig. 6b

Figure 7

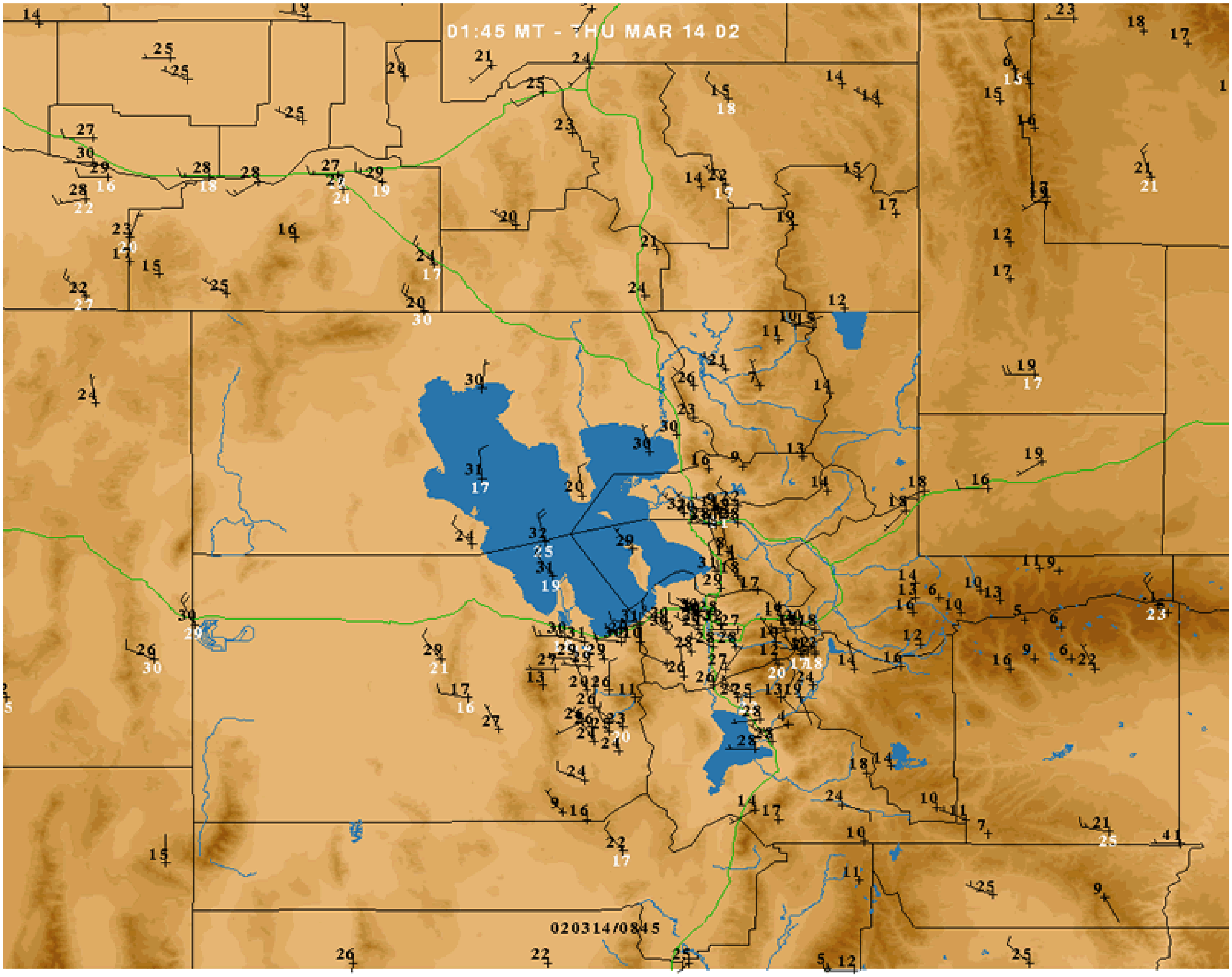

Fig. 7

Figure 8

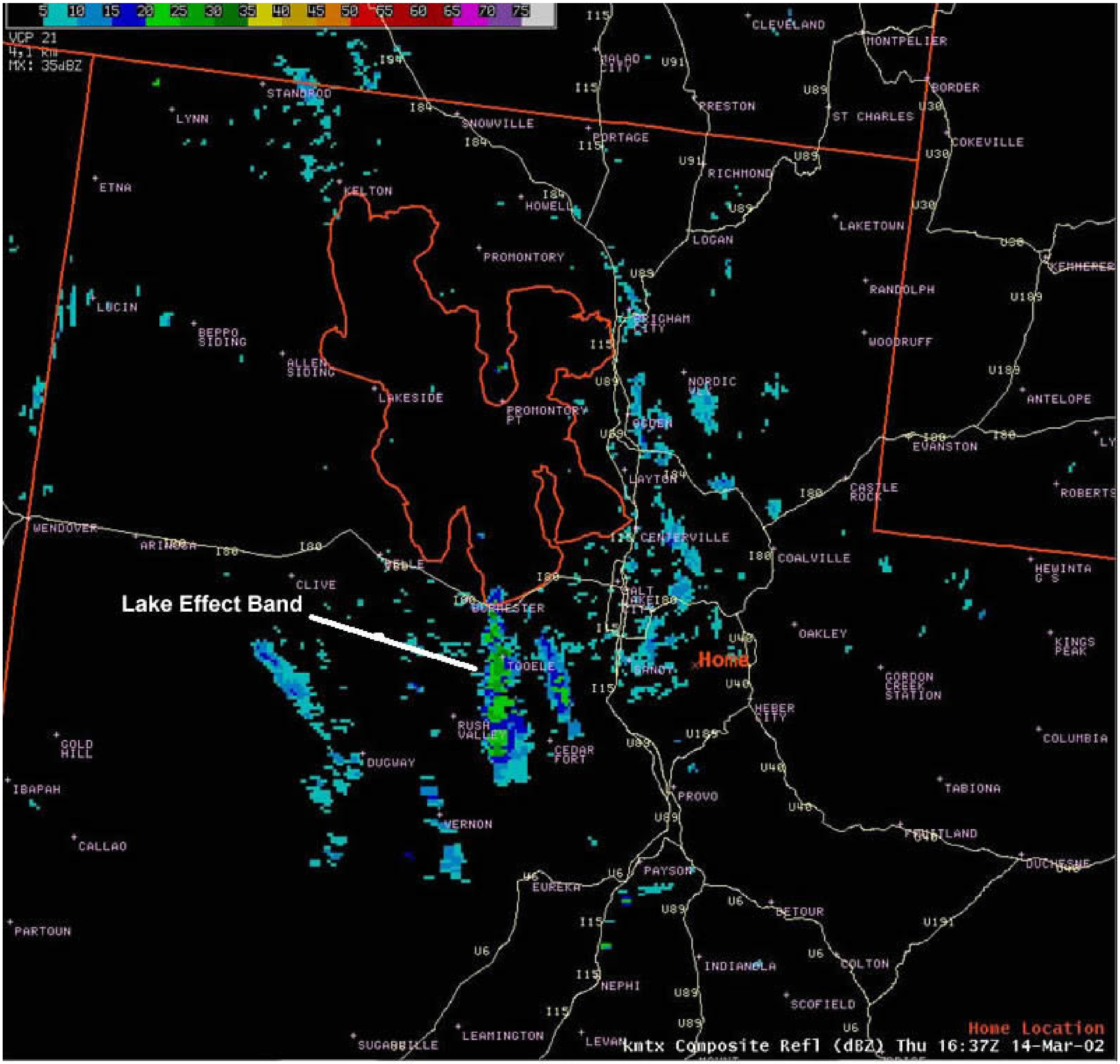

Fig. 8

Figure 9

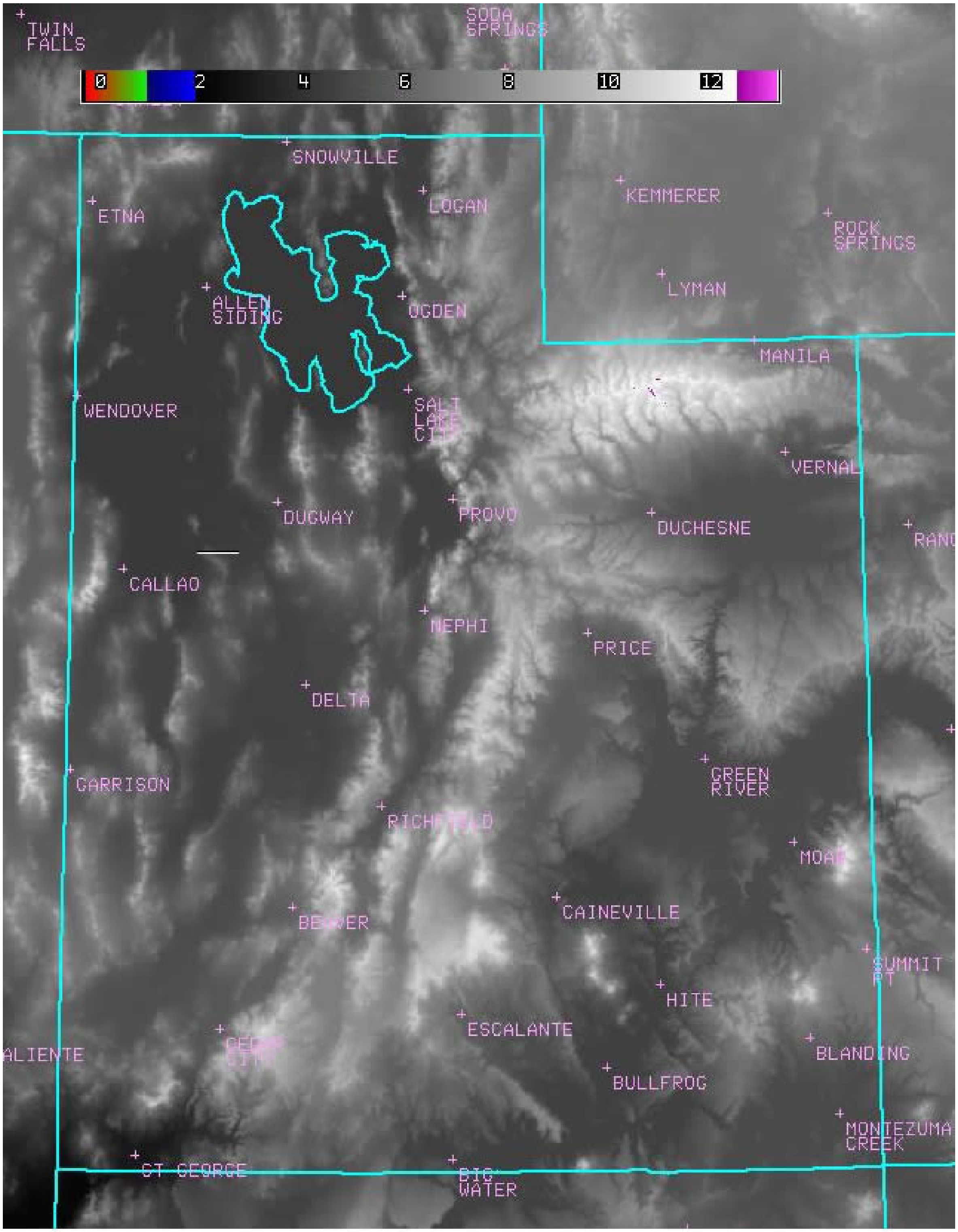

Fig. 9 - Elevation (kft)