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ANALYSIS OF A HEAVY SNOW EVENT OVER EAST CENTRAL NEVADA USING THE WEATHER EVENT SIMULATOR (WES) OCTOBER 1, 2002

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Introduction

On October 1, 2002 an early season heavy snow event occurred across East Central Nevada with record snowfall amounts of 9 to 15 inches reported in less than 24 hours. Early season snow events are not uncommon across the elevated terrain of East Central Nevada with a mean elevation of 6000 ft msl in the valleys to over 13000 ft msl in the mountains. This event was rare because it produced sustained heavy snow for over five hours in two separate snow bands. The Weather Event Simulator (WES) was used in a case study format to help identify complementary processes to frontogenetic forcing in heavy snow events. The goal of the WES training exercise was to increase the situational awareness of the forecast staff and provide improved forecast methodologies for future events.

Synoptic and Mesoscale Overview

At 1400 UTC October 1, 2002, IR satellite and RUC40 500 mb Heights analysis showed a closed upper low near the Central Oregon/Idaho border dropping into Nevada with a baroclinic boundary in East Central Nevada and shortwave south of Reno, NV (Fig. 1). The digging shortwave coupled with a 110kt jet max slowed the progression of the baroclinic boundary and drove the upper low due south into Northern Nevada. At this time, IR satellite imagery began to show rapid cloud top enhancement to -42 deg C in White Pine County, NV.

By 1500 UTC, the baroclinic boundary had shifted to just south of Ely, Nevada as indicated by the RUC40 700 mb temperature analysis overlaid on the Visible satellite image (Fig. 2). The Ely Airport ASOS observation indicated 1/4SM +SN with snow beginning at 1524 UTC and a northeast wind shift. The WSR-88D 0.5 deg reflectivity mosaic image (Fig 2) showed a 30 mile wide band of precipitation extending northeast along the boundary into

Utah. Embedded reflectivity echoes of 35 to 45 dBZ were commonly observed in this band, but no lightning strike activity was recorded. One noticeable and unfortunate aspect of Ely's location is the fact that much of White Pine County is on the edge of the 124 nm range of the WFO Elko WSR-88D (KLRX). The KLRX radar was scanning over 25000 ft msl across the baroclinic boundary and picked up very few echoes throughout the entire event.

Forcing Mechanisms

The evidence of a strong baroclinic boundary was readily apparent in many of the simulation's 2-D AWIPS graphics such as 700mb wind convergence, temperature gradient magnitude, and moisture convergence. To shift the focus to a three dimensional case study approach, cross sections were generated to examine the vertical structure across the heaviest snow bands. Using the1500 UTC RUC40 analysis, a cross section was generated perpendicular to the baroclinic boundary across White Pine County and through the city of Ely, NV (Fig. 3). Winds and a 2-D Petterson frontogenesis image were plotted together to show strong frontogenetic forcing and 700 mb wind convergence from Ely to the south along the main precipitation band.

Equivalent Potential Vorticity

Significant frontogenetic forcing was evident along the boundary, so an instability analysis was performed to support enhancement of the heavy snow bands beginning at 1500 UTC. The RUC40 analysis was used, and a cross section image of Equivalent Potential Vorticity (EPV) was generated along with Equivalent Potential Temperature (Theta-e) contours (Fig. 4). EPV combines upright potential stability and inertial stability concepts in a saturated environment as mainly a function of vertical and horizontal temperature gradients. This allows EPV to be a valuable tool for diagnosing both vertical or slantwise convection (McCann 1995). Negative EPV (EPV < 0) is favorable for diagnosing upright convection due to gravitational instability and slantwise convection due to symmetric instability (Moore and Lambert 1993).

The vertical cross section generated across the baroclinic boundary at 1500 UTC showed a broad negative EPV area (EPV < 0.5) near 700 mb, the level of the strongest horizontal temperature gradient. Within the negative EPV area, the Theta-e analysis revealed a "folding" or decrease with height of the Theta-e contours south of Ely in the warm sector (Fig. 4). The combination of negative EPV and decreasing Theta-e with height indicated that Convective Instability was present and the dominate factor for vertical convection.

Conditional Symmetric Instability

Two hours into the event at 1700 UTC, the heavy snow band was still evident across White Pine County (Fig. 5). The Ely Airport ASOS observation continued to show 1/4SM +SN and snowfall amounts of 3 inches in about 2 hours were commonly reported by weather spotters near Ely. With the baroclinic boundary displaced slightly farther south, the simulation was directed toward finding Conditional Symmetric Instability (CSI) to contribute to possible slantwise convection. To evaluate CSI properly, a RUC40 cross section analysis image of Relative Humidity (RH), wind and EPV < 0 was generated along the same perpendicular axis as in Figure 4 across the baroclinic boundary (Fig. 6). A large area of 80-90% RH was present from 550-650 mb with 90-100% RH from 650 mb to the surface. A veering wind profile also continued above 700 mb with speed shear from 10-40kts up to 500 mb and -0.25 EPV. These indicators were present within the frontogenetic band and necessary factors to evaluate CSI potential (Snook 1992).

A second RUC40 vertical cross section analysis along the same perpendicular axis was generated at 1700 UTC using Theta-e surfaces overlaid with geostrophic momentum (m_g) surfaces (Fig. 7). Saturated Theta-e (Theta-es) was not available with the AWIPS localization used in the simulation. Instead, the atmosphere along the baroclinic boundary was assumed to be saturated as shown with the RH vertical cross section. Use of Theta-e surfaces has been shown to be a more common indicator of Potential Symmetric Instability (PSI) with Theta-es surfaces used for diagnosis of CSI (Schultz and Schumacher 1999).

To properly assess whether Conditional Symmetric Instability is present, the Theta-e surfaces (Theta-es) must slope more steeply than the geostrophic momentum surfaces (Snook 1992). The vertical cross section indicated three distinct areas of steeper sloped Theta-e surfaces from 310K to 312K near 650 mb. The steeper sloped Theta-e surfaces extended from Ely, NV in the cold sector across the baroclinic boundary toward southern sections White Pine County (Fig. 7). The combination of CSI to be released in the frontogenetic area and EPV appeared to be key factors in potential for slantwise convection as the dominant factor at 1700 UTC.

Event Verification and Impact

By 2000 UTC, heavy snow along the baroclinic boundary had shifted farther south into White Pine County, NV near Great Basin National Park. The 0.5 deg reflectivity radar mosaic and RUC40 700 mb wind analysis indicated a slow southeast progression of the boundary while the visible satellite image showed a more diffuse appearance as convection in the warm sector increased (Fig 8). Observational data and spotter reports indicated that moderate snow (1/2SM SN) continued from Ely east and south in a 50 mile wide band through 2300 UTC. By 0000 UTC, the strong shortwave and 110 kt jet max had rounded the base of the upper low and ejected into southern Nevada. This caused the baroclinic boundary to pivot into a north-south orientation and focused the snow band along the extreme eastern White Pine County border into Utah. Light snow finally ended in

Ely at 0214 UTC 02 Oct 2002 with only sections of Great Basin National Park continuing to report snow after 0600 UTC.

Local agencies and storm spotters reported record 24 hour snowfall totals of 9 inches at the Ely Airport and Great Basin National Park (park headquarters) with 12 inches in the city limits of Ely. Snowfall reports of 12 inches were also received from the towns Ruth and McGill, NV. The highest snowfall report was 15 inches at the Goshute Indian reservation in Northeast White Pine County. Several spotters reported amounts of 20 inches or more just 700 feet above the mean valley elevations at 7000 ft msl. A winter storm damage assessment was conducted immediately after the storm and a snowfall map was constructed showing two major valley snow bands (Fig 9).

The true impact of the heavy snow event was felt in the damage reported in White Pine County. Since this was an early season event, most of the deciduous trees still had their leaves. The heavy wet snow accumulations caused massive tree damage, and nearly 1400 truckloads of tree limbs were reported by the Ely landfill. Power outages were reported across White Pine County for several days, and livestock herds were stranded without food.

Discussion and Conclusion

The Weather Event Simulator proved to be a valuable tool for focusing the forecast staff toward an ingredients based winter storm methodology. By using the WES in a case study simulation approach, several key ingredients were identified to show potential mesoscale heavy snow bands within a larger frontogenetically forced band. Forecasters learned to look at the three dimensional impacts of moisture, lift and instability along a baroclinic boundary instead of relying on standard two dimensional analysis. The possibility of coexisting vertical convection due to convective instability and slantwise convection due to CSI were aspects new to some of the staff who had just arrived at WFO Elko. The simulation was also an important situational awareness tool for forecasters. It helped the forecast staff realize that heavy snow events in complex terrain can be more than a standard meteorological diagnosis. The WES provided valuable "pattern recognition" experience for diagnosis of future events, and it also showed that an accurate understanding of all meteorological factors is necessary to provide proper protection of life and property.

Acknowledgments

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References

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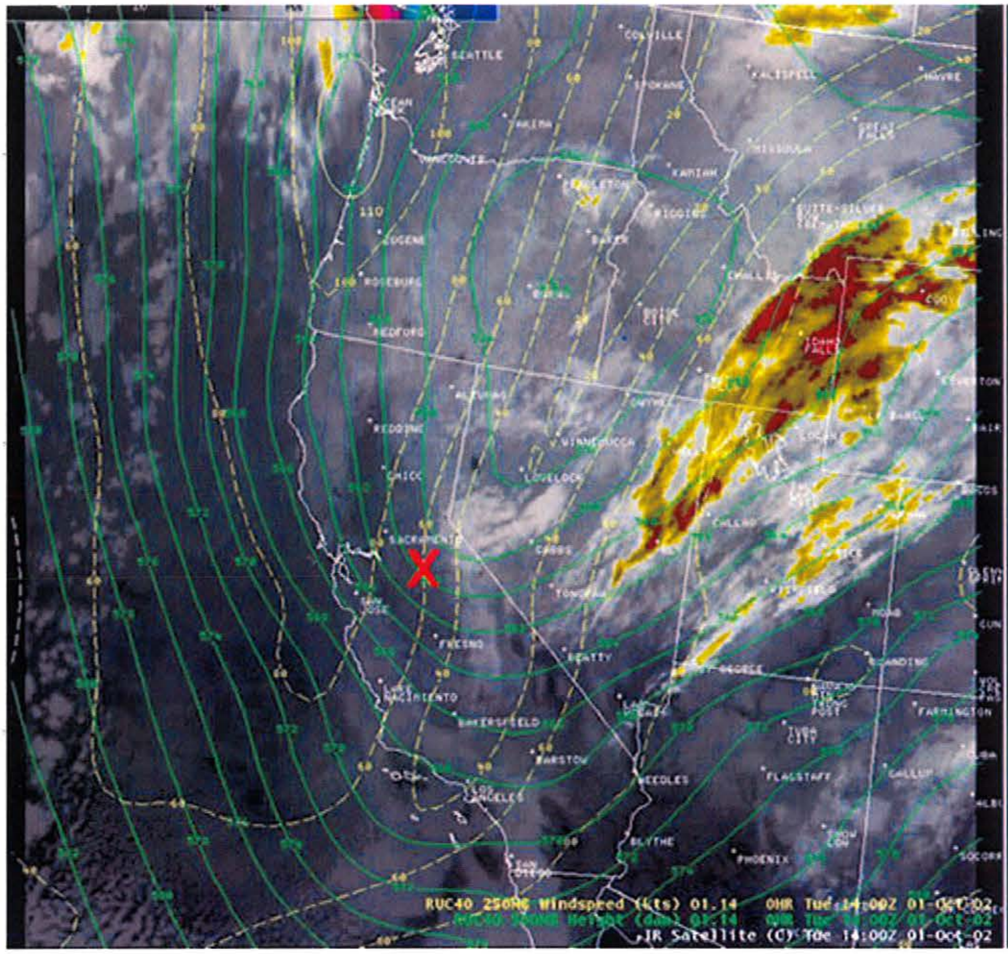
Moore, J. T., and T. E. Lambert, 1993: The use of equivalent potential vorticity to diagnose regions of conditional symmetric instability. Wea. Forecasting, 8, 301-308.

Schultz, D. M., and P. N. Schumacher, 1999: The use and misuse of conditional symmetric instability. Mon. Wea. Rev., 127, 2709-2732.

Snook, J. S., 1992: Current techniques for real-time evaluation of conditional symmetric instability. Wea. Forecasting, 7, 430-439.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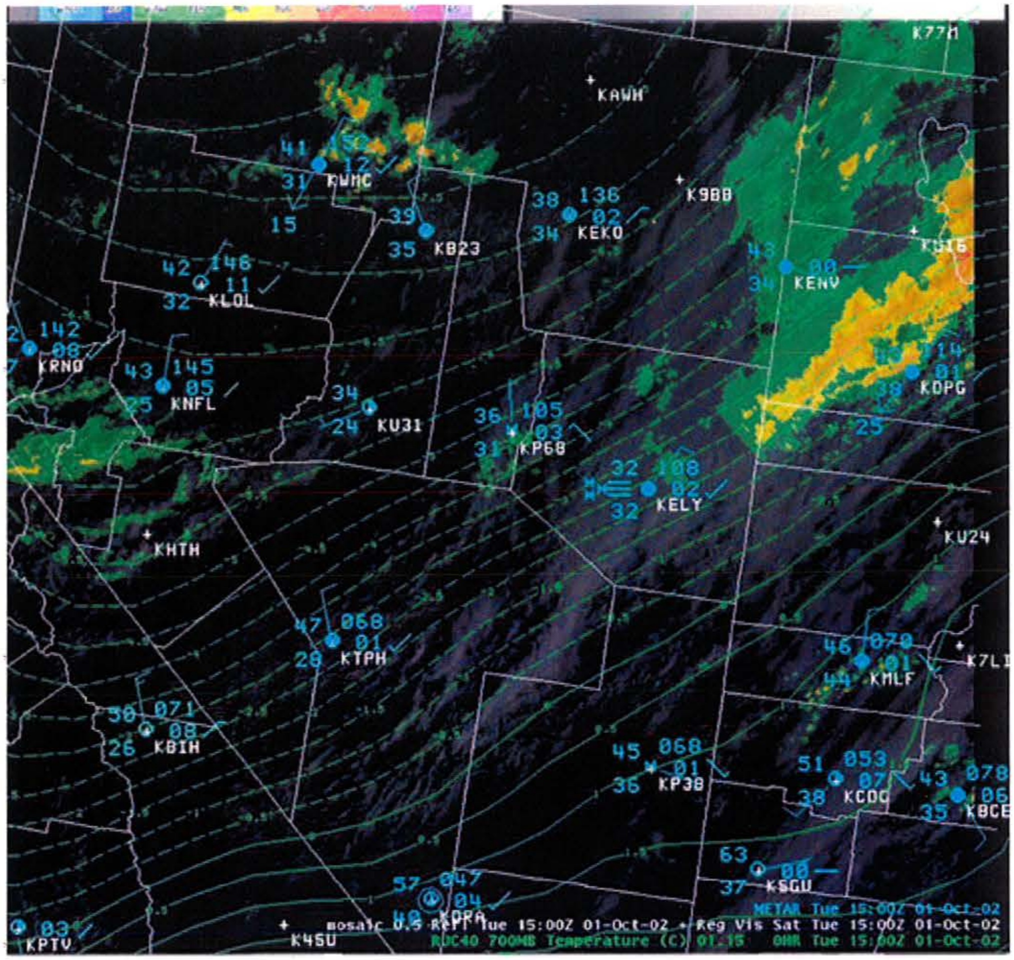
IR Satellite (C) Tue 14:00Z 01-Oct-02



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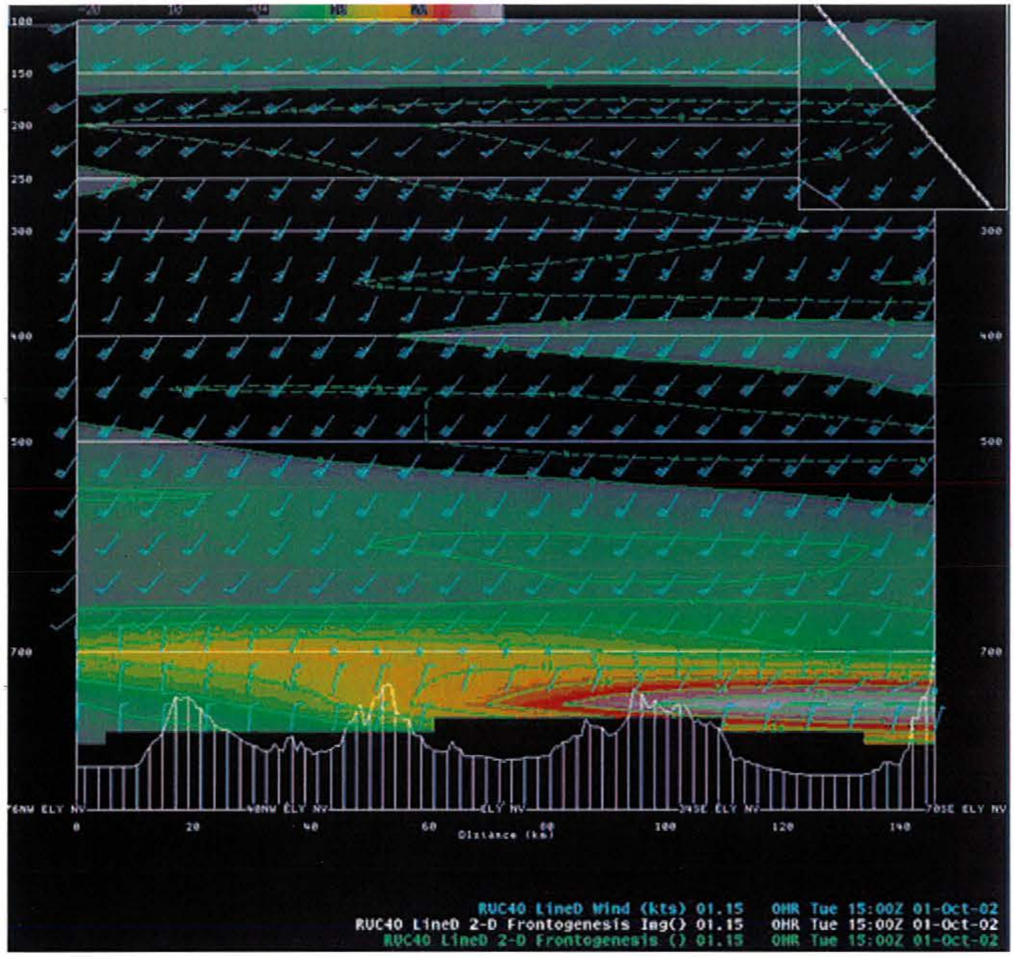
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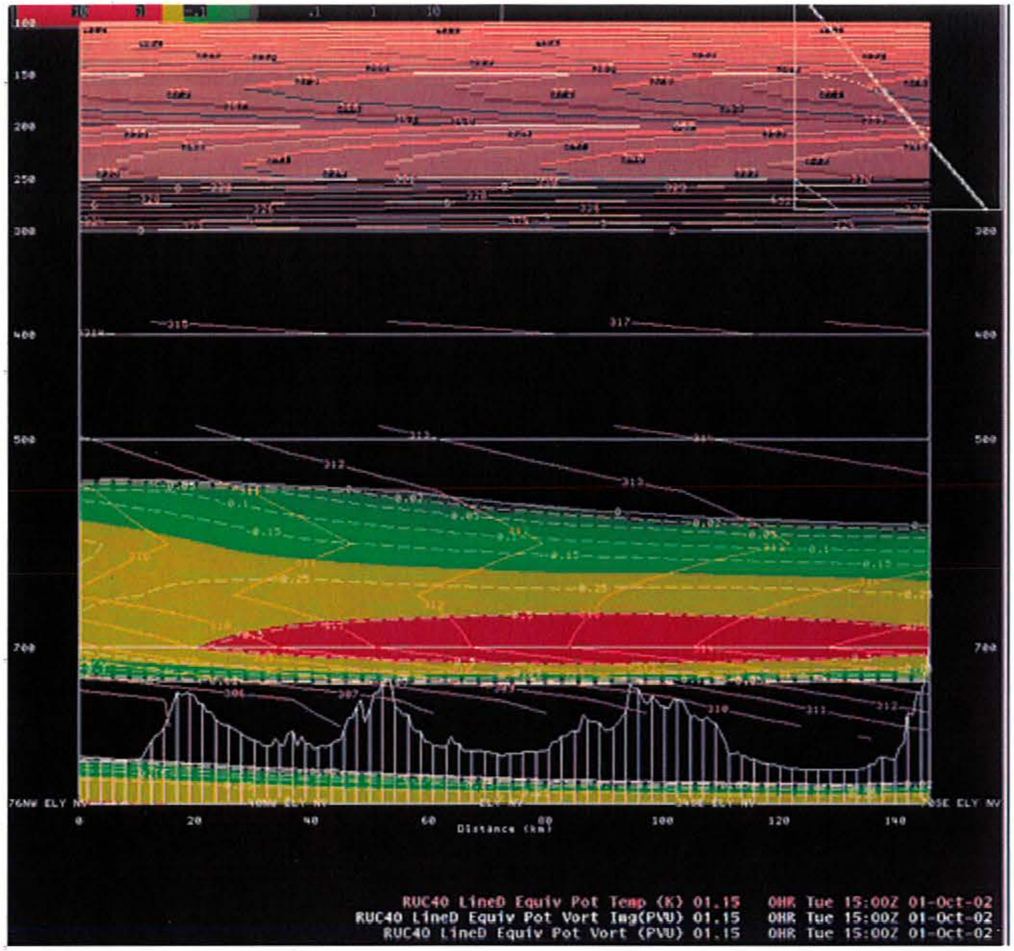
Distance (km)
RUC40 LineD Wind (kts) 01.15 0HR Tue 15:00Z 01-Oct-02
RUC40 LineD 2-D Frontogenesis Img() 01.15 0HR Tue 15:00Z 01-Oct-02
RUC40 LineD 2-D Frontogenesis () 01.15 0HR Tue 15:00Z 01-Oct-02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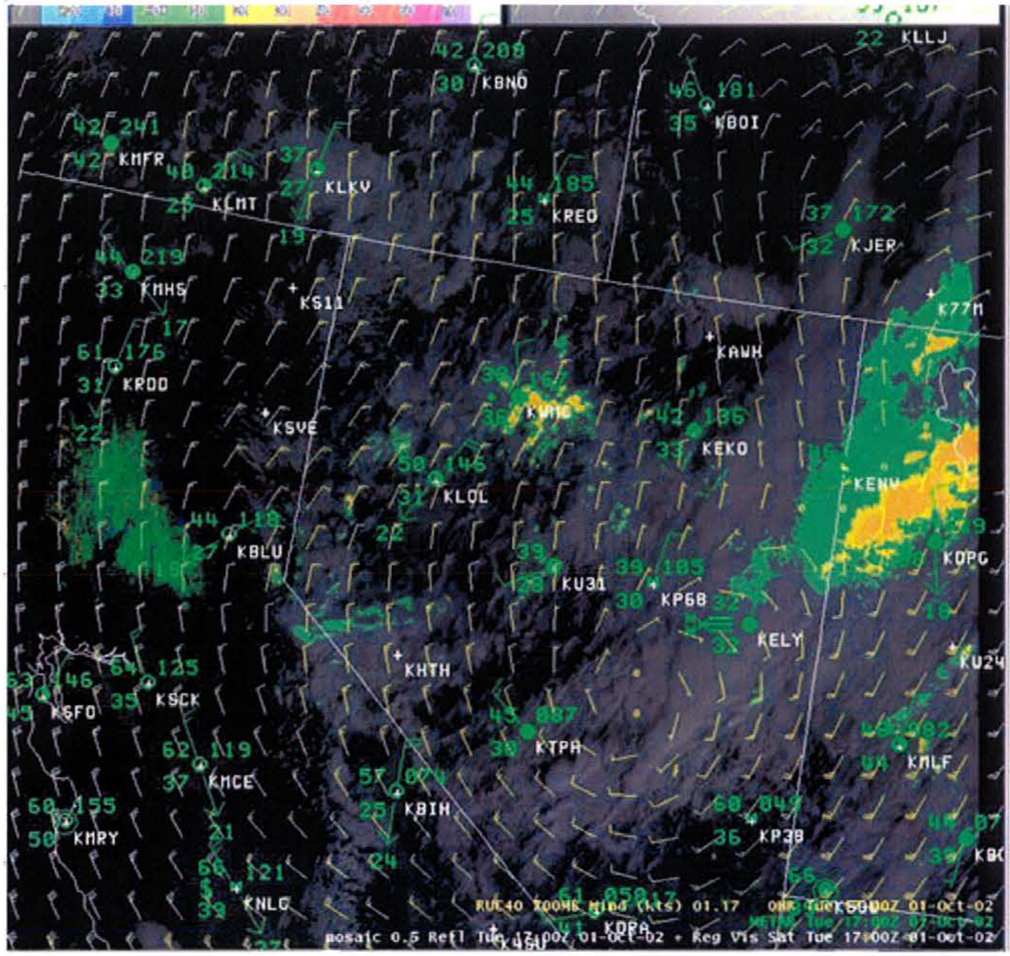
Distance (km)
RUC40 LineD Equiv Pot Temp (K) 01.15 0HR Tue 15:00Z 01-Oct-02
RUC40 LineD Equiv Pot Vort Img(PVU) 01.15 0HR Tue 15:00Z 01-Oct-02
RUC40 LineD Equiv Pot Vort (PVU) 01.15 0HR Tue 15:00Z 01-Oct-02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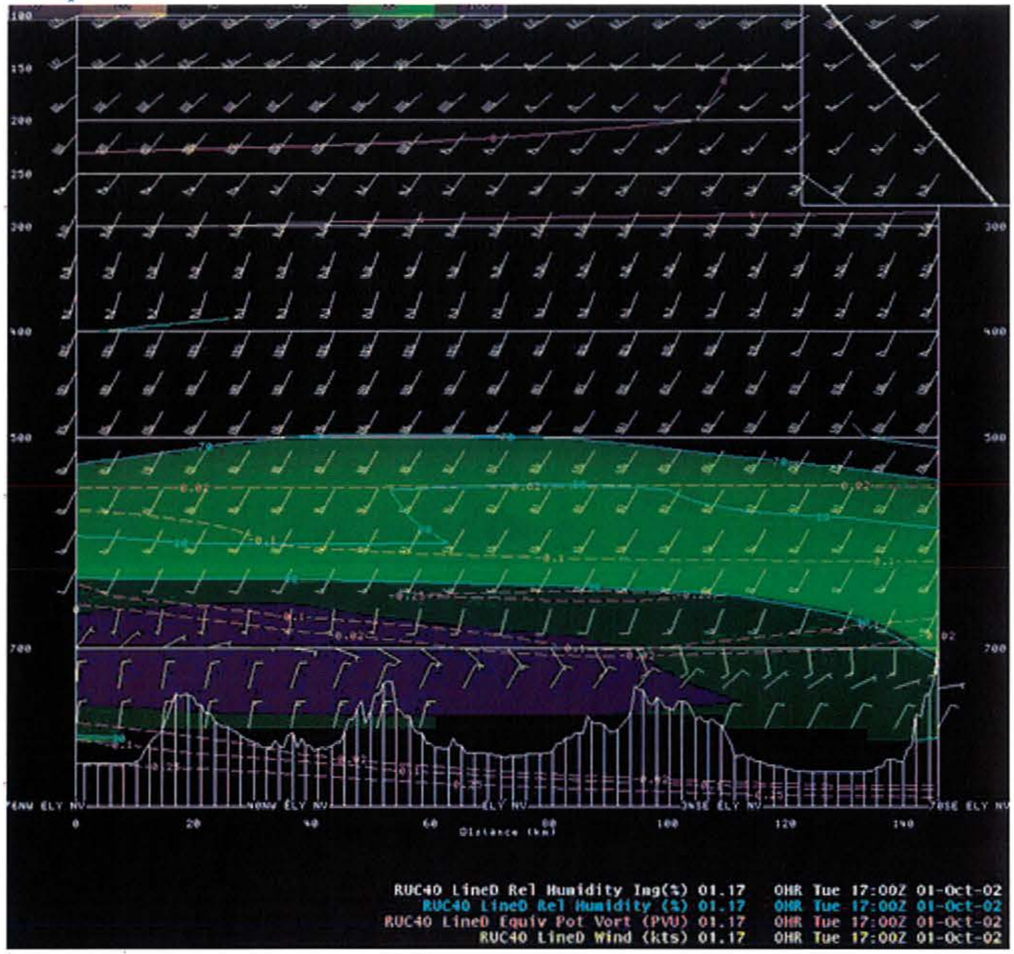
mosaic 0.5 Refl Tue 17:00Z 01-Oct-02 + Reg Vis Sat Tue 17:00Z 01-Oct-02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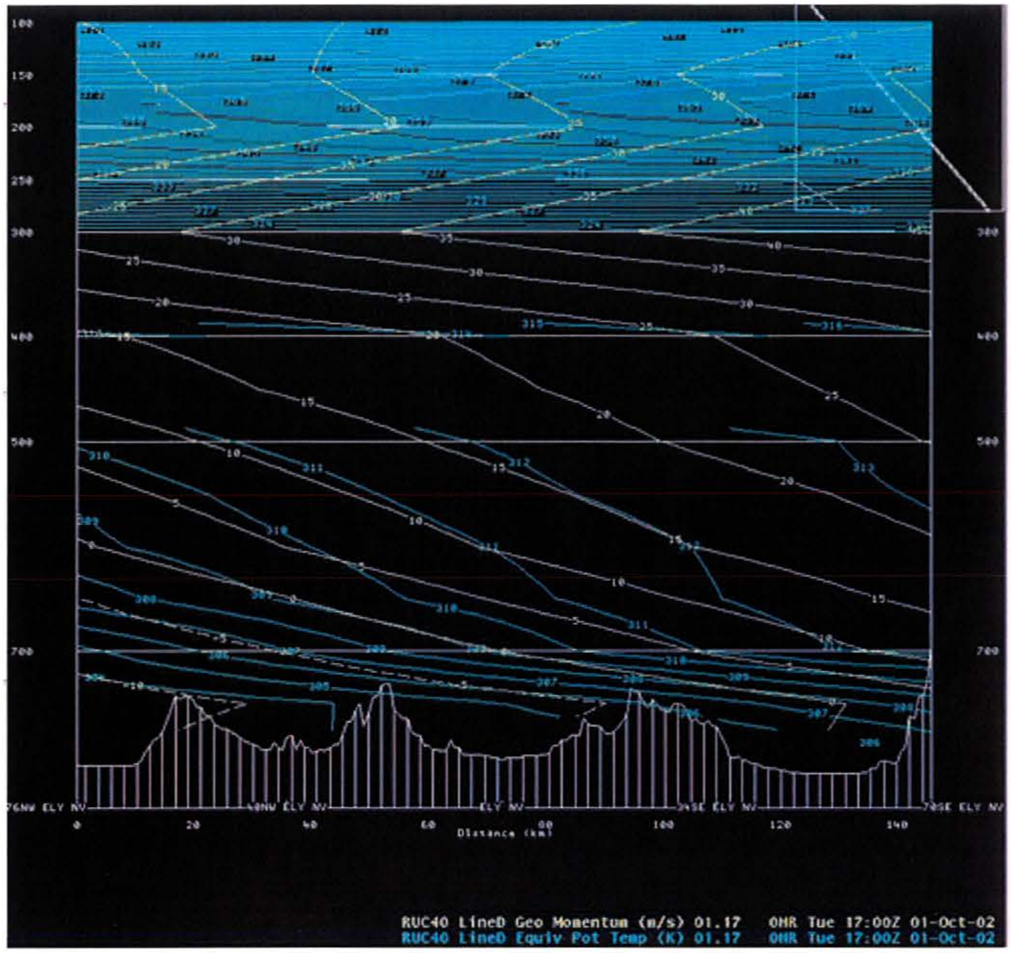
RUC40 LineD Rel Humidity (%) 01.17 OHR Tue 17:00Z 01-Oct-02
RUC40 LineD Equiv Pot Vort (PVU) 01.17 OHR Tue 17:00Z 01-Oct-02
RUC40 LineD Wind (kts) 01.17 OHR Tue 17:00Z 01-Oct-02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Distance (km)
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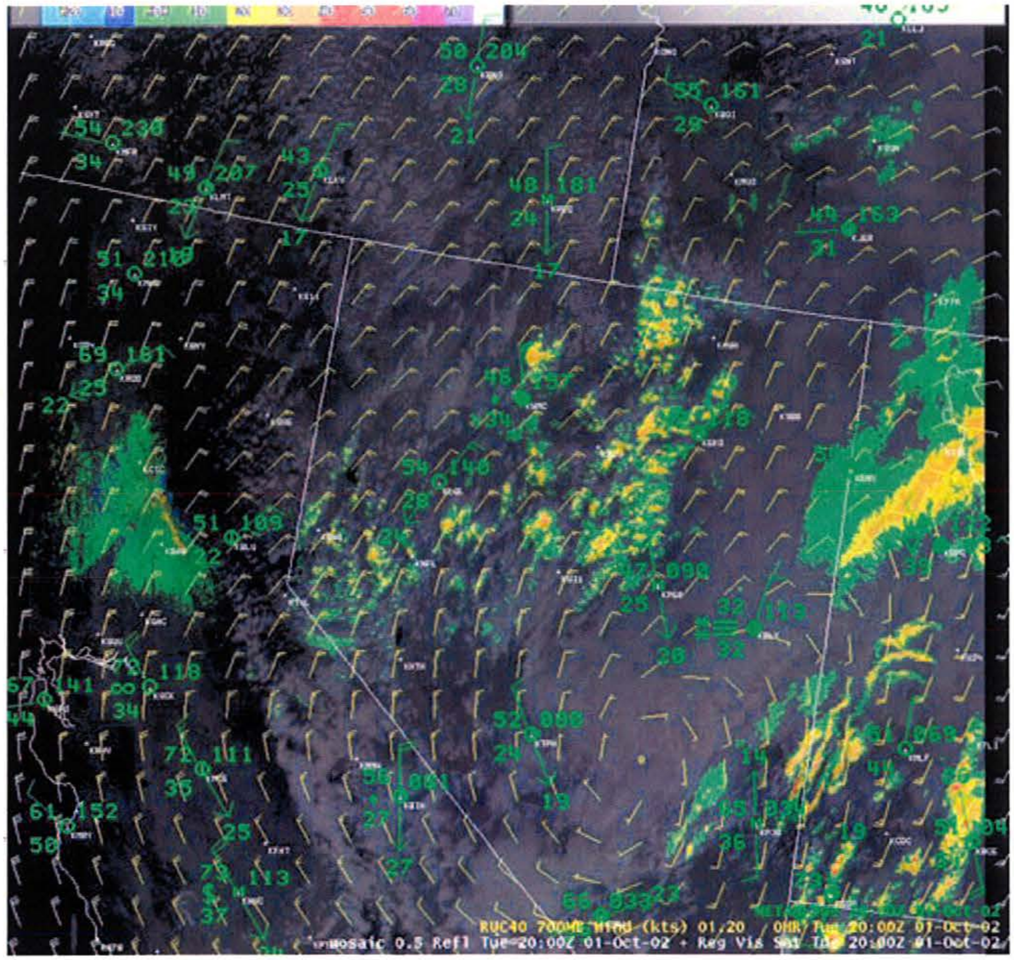
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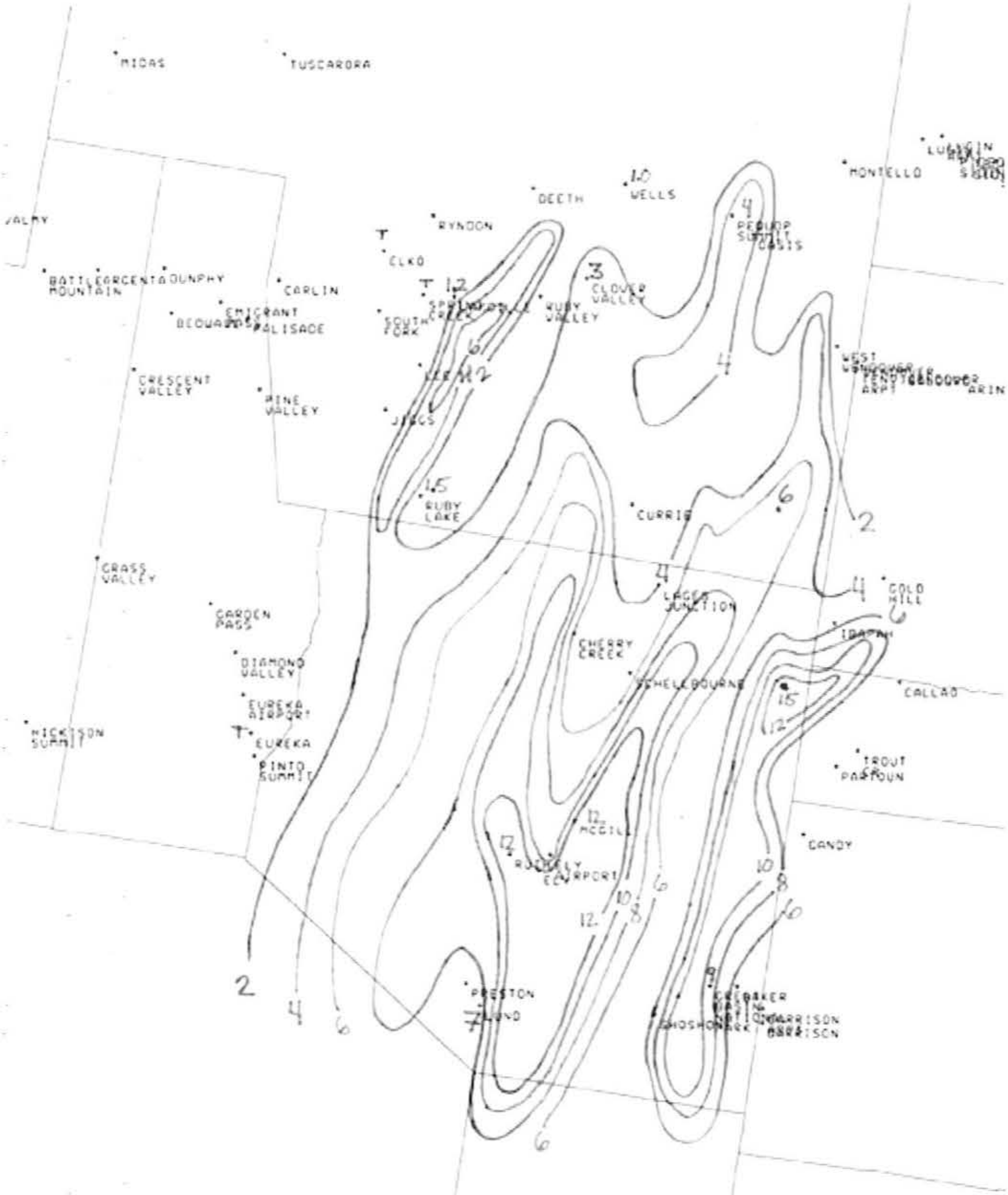
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