Western Nevada “Inside Slider”: 3 December 2013

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1. Introduction

A band of heavy snow developed during the morning commute on 3 December 2013 in the Reno-Sparks metropolitan area of western Nevada (see Fig. 1 for location) that resulted in dozens of motor-vehicle accidents and the cancellation of twelve flights at Reno-Tahoe International Airport. The National Weather Service (NWS) office in north Reno was inaccessible by vehicle for almost 3 hours in the late morning as local law enforcement restricted access to Desert Research Institute/Truckee Meadows Community College campus due to numerous accidents in the area. Four to eight inches of snow was observed near Reno, Sparks and Carson City with the highest totals observed in Spanish Springs and the North Valleys of Reno (Fig. 1).

The forcing for the heavy snow event was provided by an “inside slider” (Wallmann 2006a; Wallmann 2006b), a shortwave trough with origins in the Pacific Northwest that tracks south along the eastern flank of the Cascade and Sierra Nevada Mountains. Inside sliders frequently produce a band of heavy precipitation as they cross the western Nevada Sierra Front near Reno (see Fig. 1 for location). Unlike typical west coast precipitation events, inside sliders often produce two to three times more precipitation across western Nevada than over the higher terrain of the Sierra (Wallmann 2006a). Numerical weather prediction models typically underestimate quantitative precipitation forecast (QPF) amounts for western Nevada from these types of events (Wallmann 2006b).

This paper will focus on the key ingredients that combined to produce the slow moving band of heavy snow across the western Nevada Sierra Front on 3 December 2013. Several weather elements are examined including moisture and frontogenesis. In addition, evidence of a stratospheric intrusion that may have enhanced the heavy snow across western Nevada is presented.

2. Synoptic analysis

Leading up to the event, global models consistently advertised the potential for an “inside slider” to drop south across the Reno forecast area during the morning hours on 3 December 2013. To analyze the event, a 4-panel 6-h forecast from the 1200 UTC 3 December 2013 Global Forecast System (GFS) model valid at 1800 UTC December 2013 is shown in Figure 2. At 700 mb, a strong cold front (circled in Fig. 2d) was forecast to move south across the Sierra and western Nevada with an associated band of precipitation stretching from Lassen County across central Nevada (Fig. 2c). Behind the front, 700 mb temperatures were forecast to fall into the -14 to -16 ^{o}C range, cold enough for snow in all populated areas of Reno and Carson City. With such a rapid drop in temperatures, NWS Reno forecasters were confident that the change over from rain to snow would occur quickly and result in accumulations on valley floors early in the event. In addition, the precipitation band was forecast to intensify as the front moved across the Interstate 80 corridor between 1500 and 1800 UTC, in the midst of the morning commute.

Upper level lift associated with the right entrance region of an upper-level jet would likely enhance the precipitation band and intensify snowfall rates in the lee of the Sierra (circled in Fig. 2b). The GFS forecast also showed the formation of a 700 mb low across northern California by 1800 UTC (Fig. 2d), which in many cases places a mid-level deformation zone just to the northeast of the low over the Sierra Front. The formation of this low and its associated deformation zone may have acted to slow the southward progression of the frontal band and its precipitation, leaving the Reno and Carson City metropolitan areas in a band of enhanced precipitation for a longer period of time. The east to west orientation of the upper level jet would also increase the likelihood of the frontal boundary stalling across the Interstate 80 corridor. The 1800 UTC run of the GFS (not shown) depicted an even stronger 700 mb low on the west side of the Sierra Crest with a broad deformation zone developing across the Interstate 80 corridor near Reno.

3. Mesoscale analysis

To examine the forcing mechanisms behind the heavy snow band, GFS and NAM model forecast cross sections across the frontal boundary (line E-F in Fig. 2d) are presented in Figs. 3-6. At 1200 UTC, isentropic analysis from the GFS initialization indicated lower level instability ahead of the front across Reno and the Interstate 80 corridor (circled in Fig. 3a). This lower level instability lined up well with substantial moisture and strong frontogenesis (circled in Figs. 3c-d). Similarly, cross sections from the 1200 UTC 3 December NAM valid at 1500 UTC depicted cohesive frontogenesis through 500 mb, an upper level jet aloft, and substantial moisture and lift in the dendritic growth zone (circled in Fig. 4). Cold air behind the front along with strong frontogenesis, moisture in the dendritic growth zone, mid to upper level divergence associated with the right entrance region of the jet, and pre-existing lower level instability increased forecaster confidence for a heavy snow event to impact the western Nevada Sierra Front.

By 1800 UTC, there is evidence in both the GFS (circled in Fig. 5a) and NAM (circled in Fig. 6a) forecast potential vorticity cross sections of tropopause folding. Both models show this signature dipping as low as 700mb, co-located with an area of very dry air (circled in Figs. 5c and 6c). Uccellini et al. (1985) wrote that stratospheric air contains values of potential vorticity greater than 1 potential vorticity unit (PVU). Utilizing Uccellini et al.'s definition, the GFS and NAM forecasts depict this stratospheric air wrapping underneath the entrance region of the jet streak. The model cross sections of potential temperature and potential vorticity show the stratospheric intrusion then sweeps southward just behind the cold front. The stratospheric intrusion feature shown by the GFS and the NAM would increase the vertical extent of the moisture and lift, creating a stronger, narrow, intense band of precipitation (Figs. 5c and 6c), and enhancing snowfall intensity and snow amounts (Uccellini et al. 1985).

4. High resolution model guidance

Output from the High Resolution Rapid Refresh (HRRR; http://ruc.noaa.gov/hrrr/) was used by NWS Reno forecasters leading up to the event to forecast the onset and progression of snowfall. Several HRRR runs 4-6 hours before the event showed the potential for a precipitation band to develop and intensify across the Interstate 80 corridor. For example, Fig. 7a depicts a 5-h HRRR composite reflectivity forecast valid at 1700 UTC 3 December 2013 (during the peak of the event). The near real-time HRRR model forecast data increased forecaster confidence on the timing and the location of the precipitation band. This information increased forecaster confidence that heavy snow would fall during the morning commute period and gave more weight to the existing Winter Storm Warning that was in effect for the Sierra Front.

5. Observations

Surface winds at KRNO (Reno-Tahoe International Airport) shifted to the north around 1400 UTC, several hours before the onset of the heavy snow band (Table 1). As is often the case with inside slider events, the band of heavy snow formed several hours after surface frontal passage just to the north of the Interstate 80 corridor. Conditions at KRNO rapidly deteriorated between 1500 and 1600 UTC (Table 1). Moderate snow was reported from 1620-1740 UTC with snow accumulating at the airport. By 1800 UTC, a band of heavy snow was evident on radar (Fig. 7b) and NWS Reno received numerous reports of rapid snow accumulations along and just north of Interstate 80. The heavy snow band moved slowly southward and gradually weakened by late afternoon. Overall, 4 to 8 inches of snow was reported across Reno, the north valleys, and near Carson City (Fig. 1). There were several impacts to ground transportation (Fig. 8) including chain controls, road closures, vehicle accidents, as well as an early release for the Washoe County School District, which encompasses Reno and Sparks.

6. Conclusion

Multiple factors combined to produce a localized area of heavy snow across the Interstate 80 corridor near Reno and Carson City on 3 December 2013. Strong frontogenesis, moisture and lift in the dendritic growth zone, mid to upper level divergence associated with the right entrance region of an upper level jet, and pre-existing lower level instability contributed to the enhancement of the heavy snow band. There is also evidence that a tropopause fold may have provided additional forcing. Additional case studies are needed to quantify the role of stratospheric intrusions in enhancing snow bands associated with inside slider events across western Nevada.

7. References

Uccellini, L. W., D. Keyser, K. F. Brill, and C. H. Wash, 1985: The Presidents' Day Cyclone of 18–19 February 1979: Influence of Upstream Trough Amplification and Associated Tropopause Folding on Rapid Cyclogenesis. *Mon. Wea. Rev.*, **113**, 962–988.

Wallmann, J. 2006a: Inside Sliders. Part I: Their Features, and Their Effects on the Sierra Front of Western Nevada. WR Technical Attachment No. 06-02.

Wallmann, J. 2006b: Inside Sliders. Part II: Model Forecasts for Inside Sliders and Their Biases. WR Technical Attachment No. 06-03.

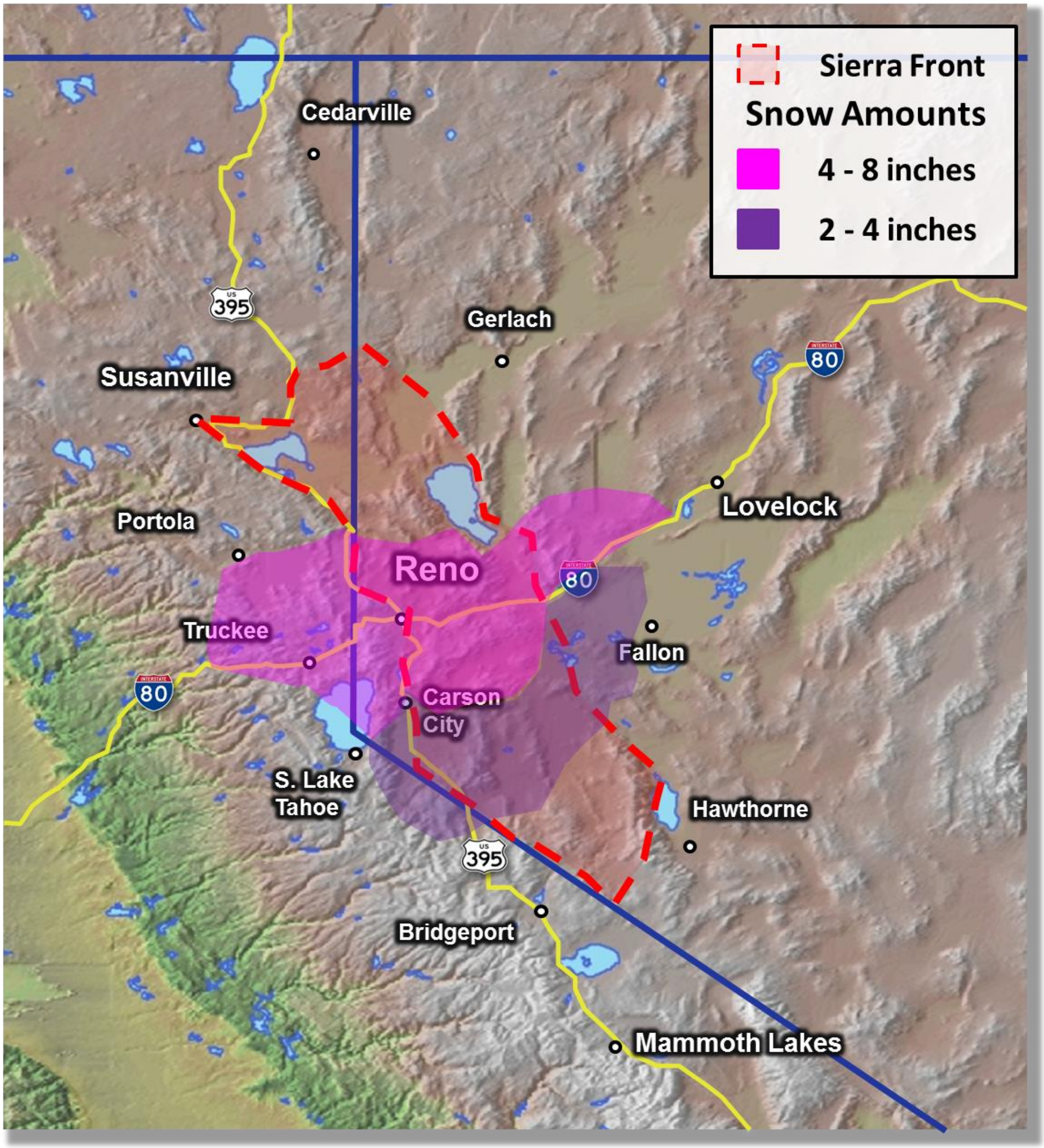

Figure 1: Map of the western Nevada Sierra Front region (dashed red). Observed snow amounts shown with 4 to 6 inches (shaded pink) and 2 to 4 inches (shaded purple).

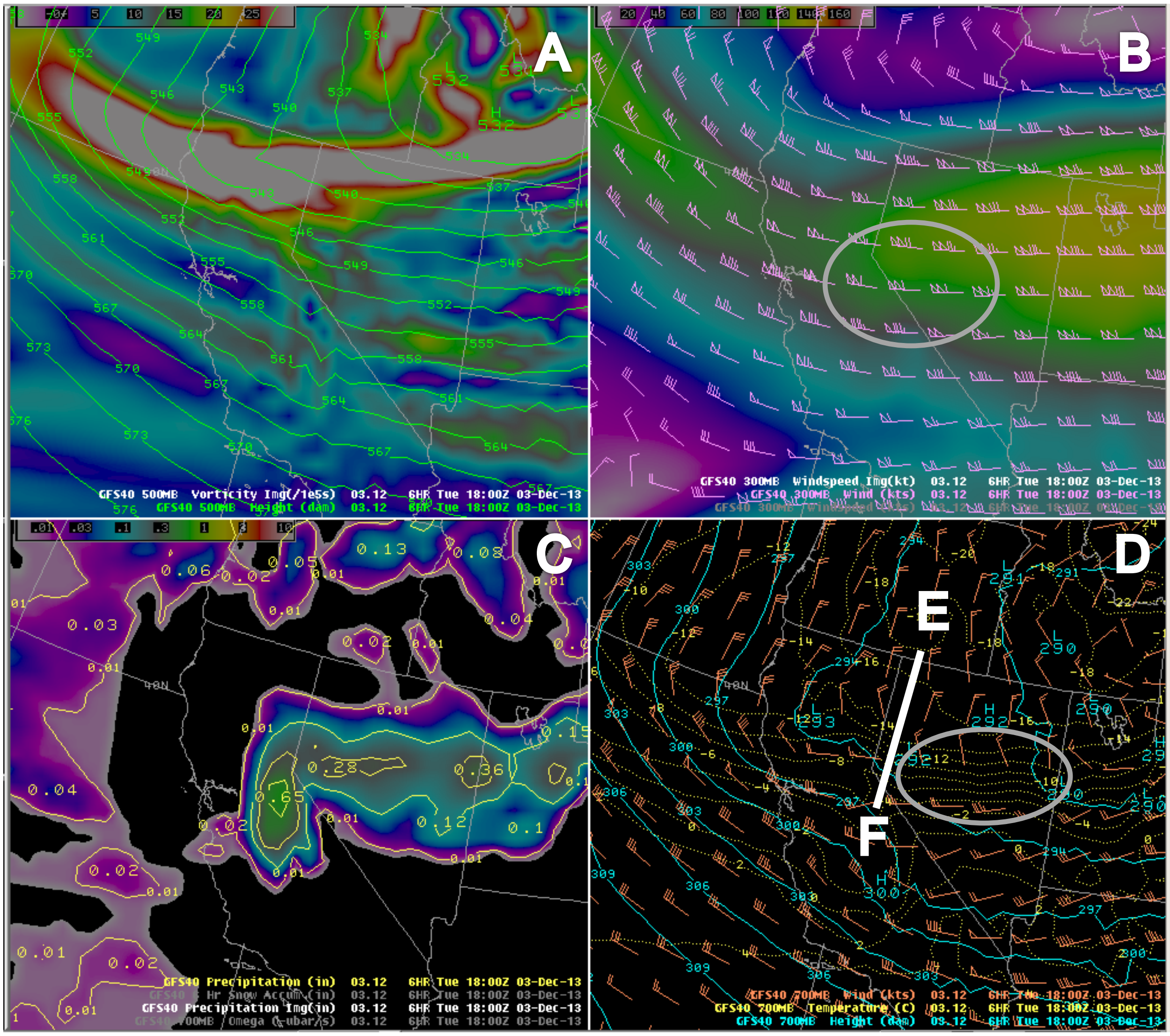

Figure 2: 1200 UTC 3 December 2013 GFS forecast valid at 1800 UTC 3 December 2013. (a) 500-hPa height (dam; green contours) and absolute vorticity (10^{-5} s^{-1}; shaded), (b) 300-hPa wind (kt; barbs) and wind speed (kt; shaded), (c) 6-hour precipitation (shaded) valid 1200-1800 UTC, and (d) 700-hPa height (blue contours), temperature (yellow contours) and wind (kt; barbs). The white line E-F in (d) denotes the location of the cross section shown in Figs. 4-7.

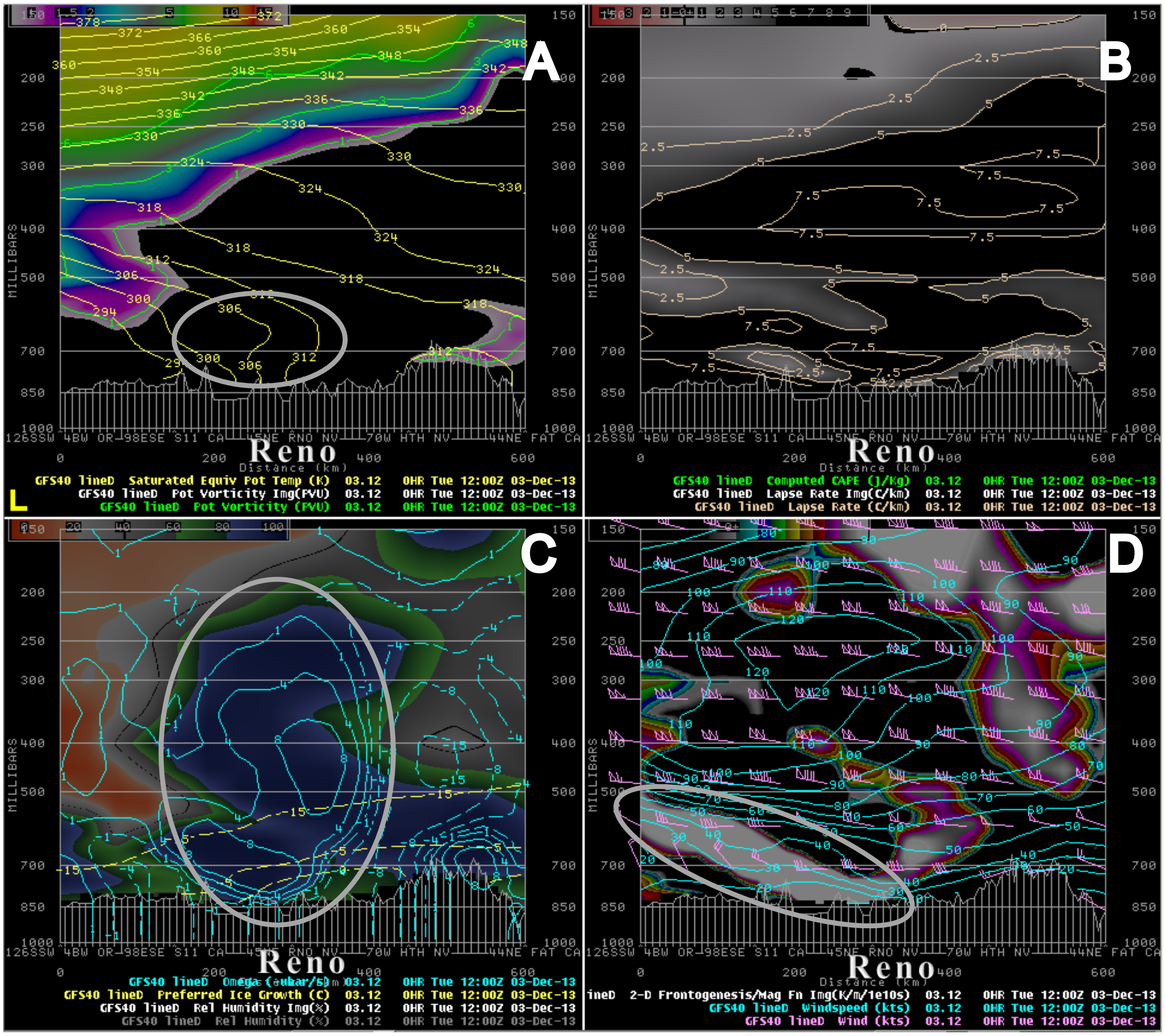

Figure 3: 1200 UTC 3 December 2013 GFS initialization cross section. The location of the cross section is denoted by the white line E-F in Fig. 3d. (a) saturated equivalent potential temperature (K; yellow contours) and potential vorticity (PVU, shaded), (b) lapse rate ($^oC\ km^{-1}$; shaded), (c) omega (-ubar s^{-1}; blue contours), preferred ice growth zone (^oC; yellow contours) and relative humidity (%; shaded), and (d) wind (kt; blue barbs) and 2-D frontogenesis ($K\ m^{-1}\ 10^{-10}\ s^{-1}$; shaded).

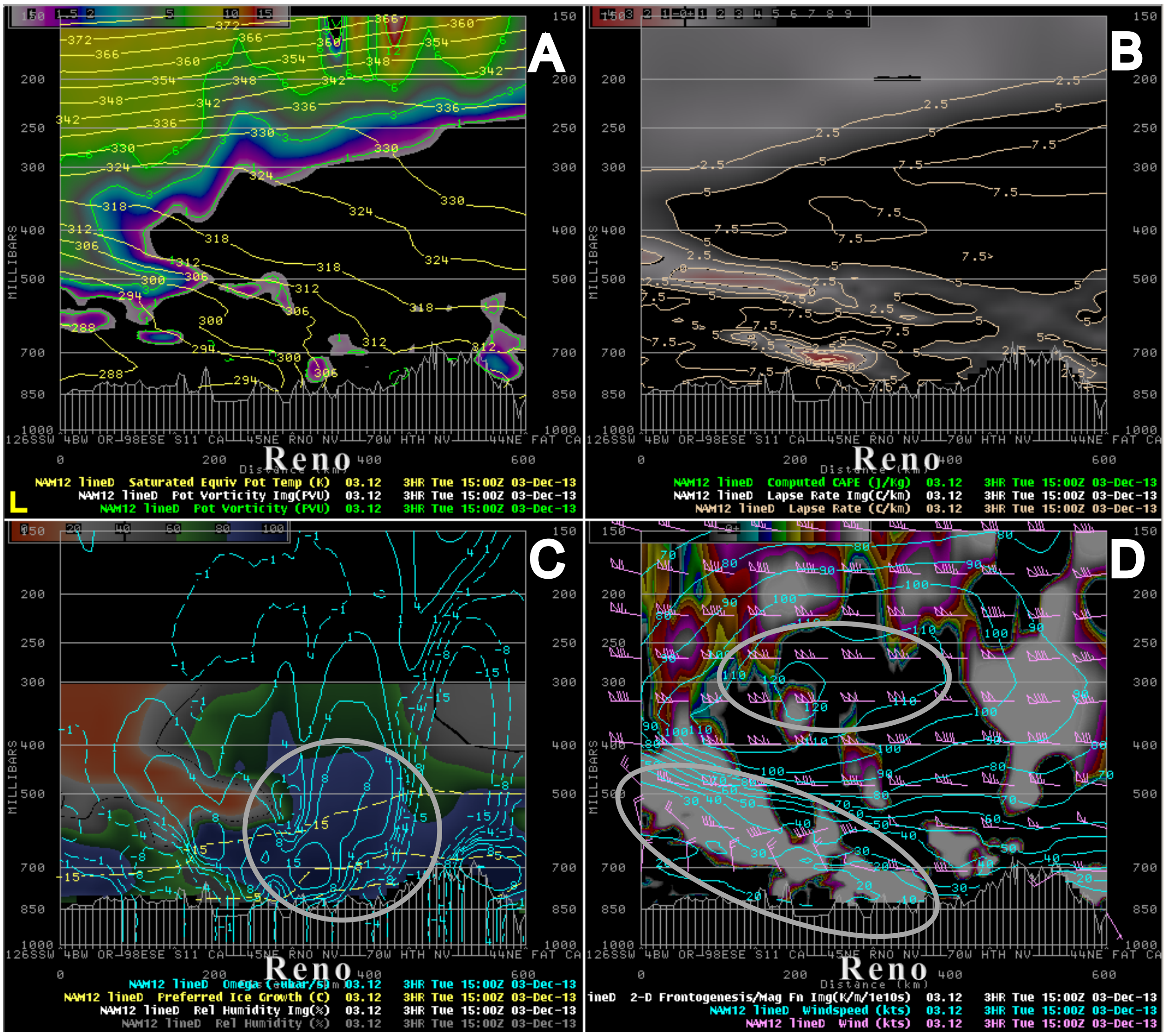

Figure 4: 1200 UTC 3 December 2013 NAM forecast cross section valid at 1500 UTC 3 December 2013. The location of the cross section is denoted by the white line E-F in Fig. 3d. (a) saturated equivalent potential temperature (K; yellow contours) and potential vorticity (PVU, shaded), (b) lapse rate (^{o}C km^{-1}; shaded), (c) omega (-ubar s^{-1}; blue contours), preferred ice growth zone (^{o}C; yellow contours) and relative humidity (%; shaded), and (d) wind (kt; blue barbs) and 2-D frontogenesis (K m^{-1} 10^{-10} s^{-1}; shaded).

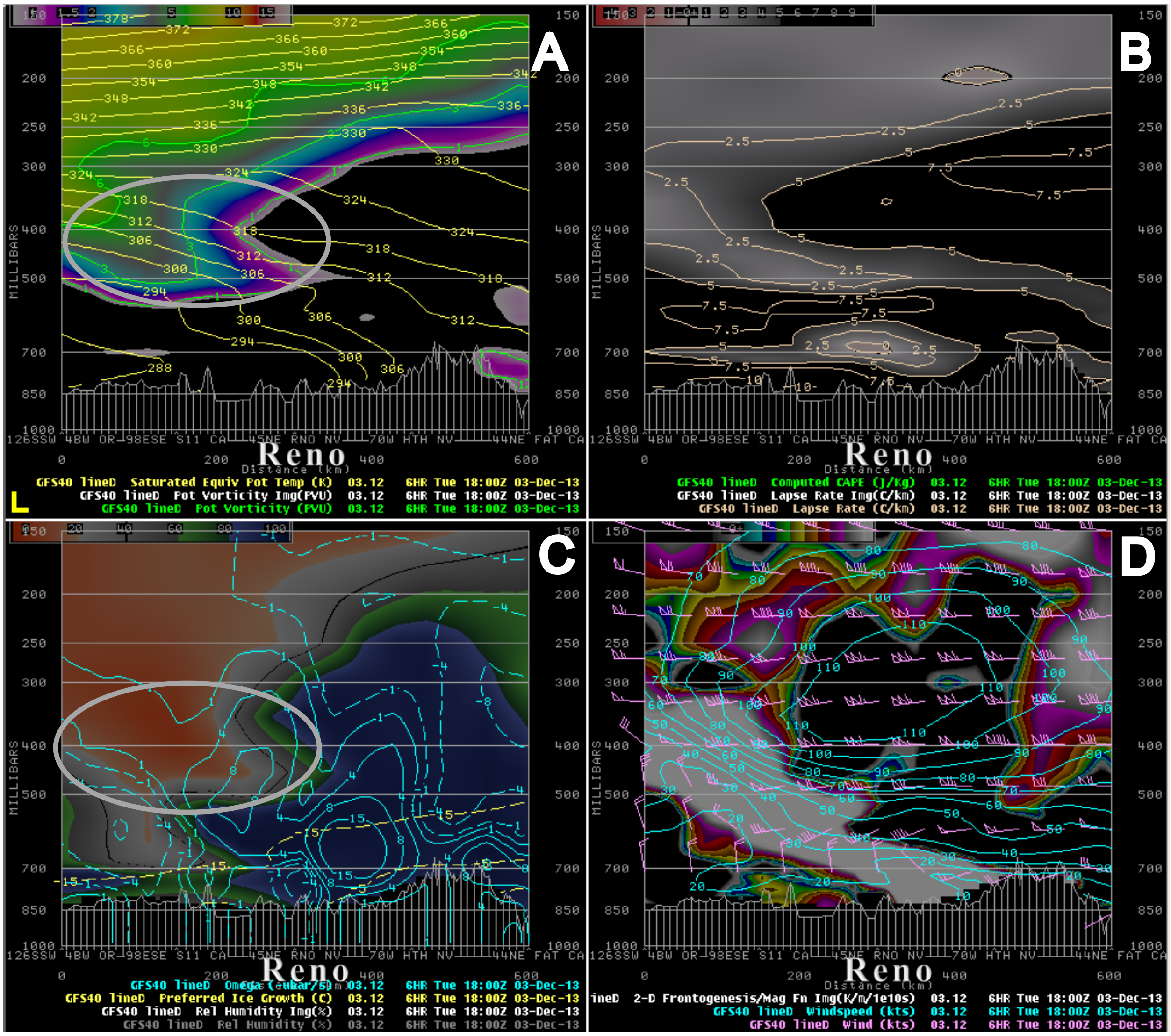

Figure 5: As in Fig. 3, except 1200 UTC 3 December 2013 GFS forecast cross section valid at 1800 UTC 3 December 2013.

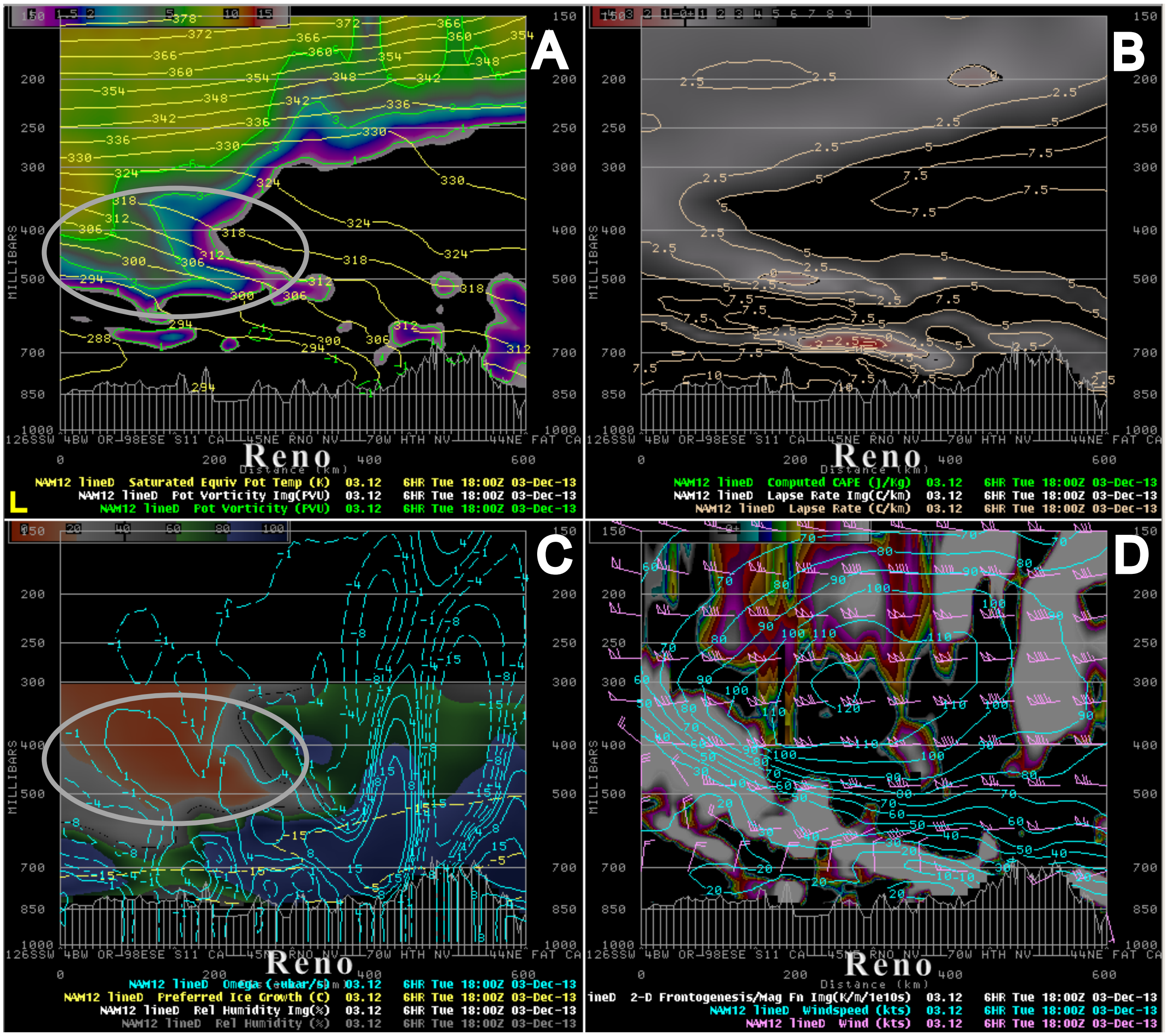

Figure 6: As in Fig. 4, except valid at 1800 UTC 3 December 2013.

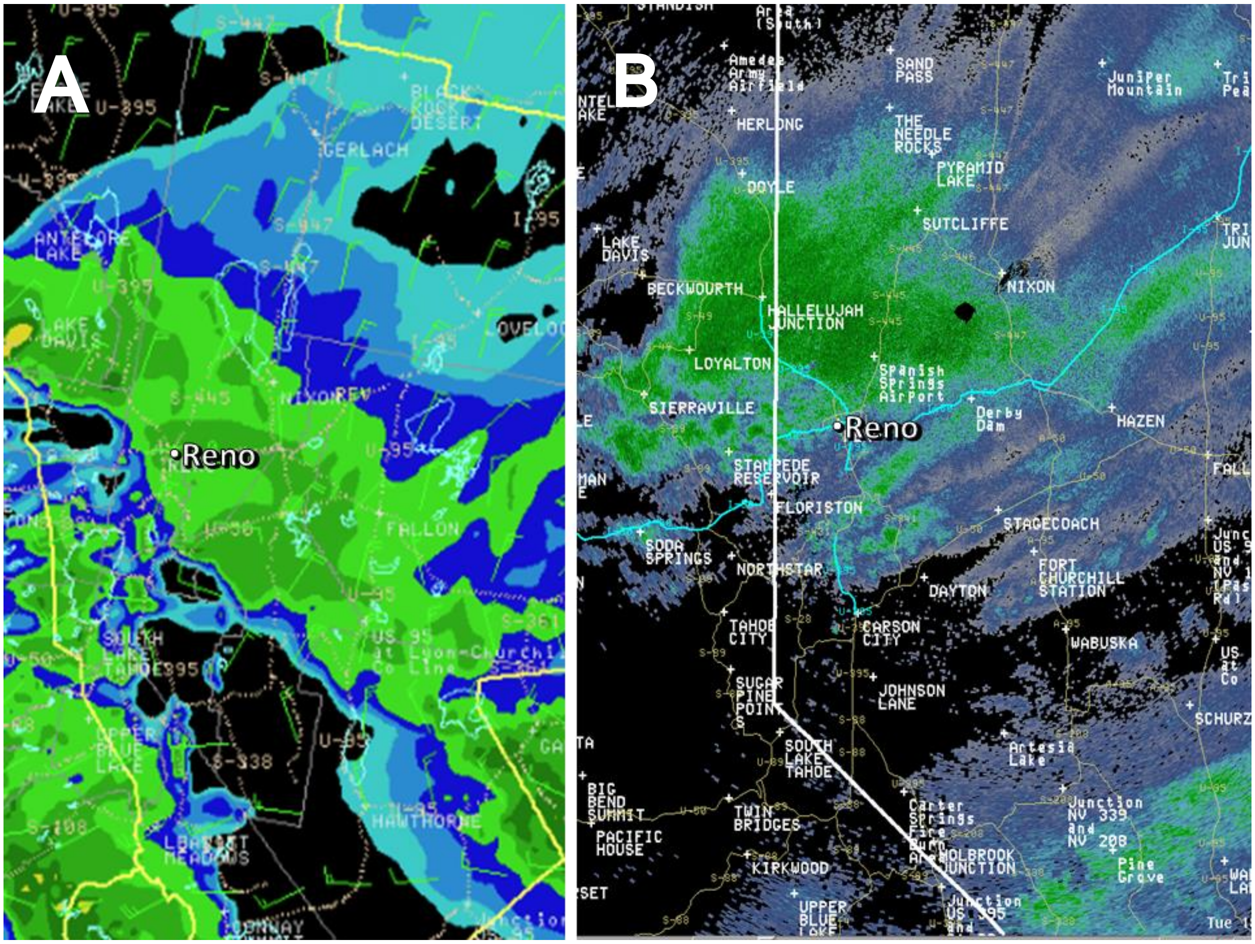

Figure 7: (a) 1200 UTC 3 December 2013 HRRR composite reflectivity (shaded) and surface wind (kts) forecast valid at 1700 UTC 3 December 2013. (b) WSR-88d RGX composite reflectivity observed at 1804 UTC 3 December 2013.

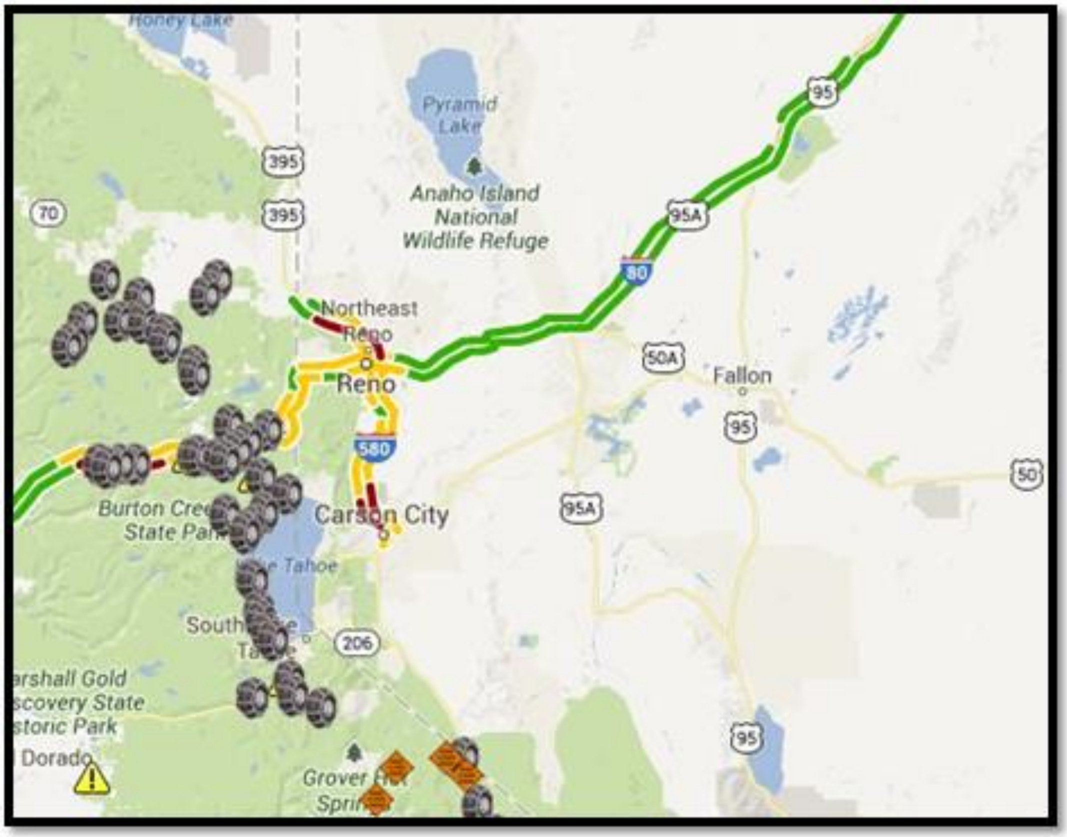

Figure 8: Map of road conditions from the morning of 3 December 2013. Courtesy of www.nvroads.com. Chain controls (shown with tire icons) and areas of heavy, medium, and low traffic (red, yellow, and green respectively) are shown.

UTC	T	Td	RH	WS	WG	WD	Weather	Vis	Precip	Cig
8:55	48.9	34	56	15		W	mostly cloudy	10		10000
9:55	48.9	33.1	54	8		W	mostly cloudy	10		10000
10:55	50	32	50	13	23	WNW	mostly cloudy	10		11000
11:55	48	28	46	21	30	W	overcast	10		11000
12:55	48	28.9	47	18		NW	mostly cloudy	10		11000
13:55	46	30	53	15	20	WNW	overcast	10		10000
14:42	39.9	30	67	23	28	NE	overcast	10		6000
14:55	37.9	28.9	70	22	30	NNE	overcast	10		6000
15:34	35.1	28.9	78	21	30	N	lt snow	3	T	3400
15:41	34	28.9	82	21		NNE	lt snow	2.5	T	2800
15:55	32	28.9	88	21	29	N	lt snow	0.5	T	1500
16:20	30	28	92	18		N	mod snow	0.25	0.04	
16:52	28.4	26.6	93	12		N	mod snow, ice fog	0.25	0.1	
16:55	28	27	96	13		N	mod snow, ice fog	0.25	0.12	
17:39	27	25	92	17		N	mod snow, ice fog	0.5	0.07	
17:46	27	25	92	13		NNE	lt snow, fog	0.75	0.08	600
17:55	27	25	92	13		N	lt snow, fog	0.75	0.09	600
18:04	27	24.1	89	15		NNE	lt snow, fog	1	0.01	1500
18:24	26.1	24.1	92	16		NNE	lt snow, fog	0.5	0.02	1500
18:49	26.6	24.8	93	10		NNE	lt snow, fog	0.5	0.05	1200
18:55	26.1	23	88	12		NNE	lt snow, fog	0.5	0.05	1200
19:36	25	21.9	88	15		NNE	lt snow, fog	0.75	0.02	1500
19:55	26.1	21.9	84	9		NNE	lt snow, fog	0.75	0.02	1500
20:27	26.1	21	81	10		N	lt snow, fog	1.75	0.01	1500
20:40	26.1	21	81	10		N	lt snow, fog	3	0.01	1800
20:55	26.1	21.9	84	9		N	lt snow, fog	3	0.01	1800
21:07	27	21.9	81	8		N	overcast	7	T	3000
21:55	27	19	72	6		NNE	overcast	10	T	3500
22:51	26.6	17.6	68	8		N	lt snow	3	T	3500

Table 1: KRNO surface observations valid 0855 – 2251 UTC 3 December 2013. Columns from left to right are: time (UTC), temperature (T; °F), dewpoint (Td °F), relative humidity (RH; %), wind speed (WS; mph), wind gust (WG; mph), wind direction (WD), present weather, visibility (Vis; mi), 1-h precip (Precip; in) and ceiling height (Cig; ft).