An Examination of the 25-26 February 2003 Snow Event - A Weather Event Simulation

Mike Staudenmaier, Jr.
WFO Flagstaff
December 10, 2003

Introduction

Forecasting snowfall amounts over northern Arizona is particularly challenging due to widely varied terrain across the CWA (see map). A significant winter storm affected portions of northern Arizona on 25-26 February 2003. Two to six inches of snow fell at many locations across northern Arizona above 4500 feet with an area along the immediate edge of the Mogollon Rim and White Mountains receiving 10 to 20 inches. Rainfall amounts of over an inch were widespread south of the Mogollon Rim with less than a tenth of an inch in the Little Colorado River Valley north of the Mogollon Rim. This event demonstrated how synoptic and mesoscale forcing mechanisms were modified by stability to generate heavy snowfall along the immediate Mogollon Rim locations with much less snowfall further onto the higher terrain. This event also demonstrated the importance of stability in modulating the precipitation distribution during the event.

For this simulation, forecasters were first placed in the simulation at 0600 UTC 25 February 2003 with data on the Weather Event Simulator (WES) available up to that point. Forecasters were asked to assess the current situation and discuss the synoptic and mesoscale ingredients that were both present and predicted to define what headlines would be needed for the approaching storm, and also to determine the extent of the snowfall/rainfall potential. An interesting aspect at this time included model data that suggested very different potentials for precipitation amounts - a common predicament during the winter season in Arizona.

The clock on the WES was advanced to 1200 UTC to then reassess the new observations and model data and examine the evolution of features up to that point. Changes in the model runs were discussed along with a discussion of some subtle features present in the observations. Modifications to the forecast were discussed and then the clock was advanced to 0600 UTC 26 February to examine the main portion of the storm evolution. A discussion of the verification concluded the simulation.

Synoptic and Mesoscale Features

Satellite imagery at 0600 UTC 25 February 2003 (Fig. 1) indicated the general synoptic situation. A 546 dm low was located off the California coast with a large shield of clouds located in the diffluent region ahead of the low. Over southern California, a frontal band could be seen with more active cloud elements and associated precipitation. This frontal band could also be seen faintly in the low clouds off the California coast.

Models indicated this low would move across northern Arizona during the late afternoon and evening hours. However, there were differences in position and strength of the system as it moved across the region. A comparison of 500 mb heights forecasted by the latest AVN/Eta models for 0600 UTC 26 February (Fig. 2) showed these differences with the AVN stronger and further south with the trough, while the Eta solution was weaker and further north. A comparison of time height cross sections for Flagstaff from both models illustrated further the differences in model solutions with a much weaker omega field predicted by the Eta model (Fig. 3). Significant differences in the potential vorticity (PV) field and stability stratification could also be seen between the model solutions with the AVN showing two distinct waves with the system along with much more instability as the stronger potential vorticity maxima passed over the region (Fig. 4). Needless to say, there were also significant differences between the model precipitation expected for the event, with the AVN model indicating well over an inch over the southern portion of the CWA, with the Eta model indicated much less precipitation (Fig. 5).

Forecasters had a tough decision to make at this point, since a forecast of the expected ramifications with this storm were required. At this time, there were very few clues as to which model would verify best, however a few issues were discussed. A strong jet core was entering the western boundary of the Eta domain at this time, and would play a significant role in the ejection of the system into Arizona. A very moist plume of moisture (5 g/km in the 850-700 mb layer) was shown in the analysis and was expected to move over the state with the system, which is a high amount of moisture for winter storms in Arizona. The Eta model weakened the potential vorticity core over the first twelve hours of the model integration whereas the AVN model kept the core much more conserved and compact. Because of the impacts of the jet streak entering the Eta western domain boundary and the subsequent weakening of the potential vorticity core, along with the heavier QPF generated in the AVN model, many forecasters went toward a compromise solution leaning toward the AVN solution, which seemed appropriate at this time.

Examination of important snowfall ingredients for this event were then examined using the AVN model. Moderate to strong orographic enhancement was predicted with this event due to the 30-40 kt of flow which would be perpendicular to much of the higher terrain of northern Arizona (previously shown in Fig. 4). As the second, and stronger, PV center approached the state, strong omega was forecast by the model to develop around 0000 UTC 26 February. Stability was forecast to decrease, especially later in the afternoon as this PV anomaly approached. The time height cross section indicated deep moisture available for the system. Examination of other parameters (Fig. 6) indicated that much of the omega field was supported by strong PV advection aloft along with WAA aloft due to the PV anomaly. The Div-Q field showed the combination of these fields well with a maximum moving over Flagstaff around 0000 UTC 26 February. The strong omega field existed well above the -15C isotherm, which combined with the deep moisture, made for excellent cloud microphysics potential. Jet dynamics were moderate for this event, but the more significant jet core would remain in Mexico which made it a secondary player (not shown). Thus, model diagnosis using an ingredients-based snowfall methodology indicated that the environment over northern Arizona would be improving for heavy snowfall during the afternoon as the strong forcing approached. Significant vertical motion forcing in an increasingly unstable environment, combined with a temperature structure conducive for snow above 5000 feet, adequate moisture, and an excellent snow microphysics environment were all expected to develop over the forecast area through the afternoon, peak at around 0000 UTC near the Flagstaff area, and decrease during the evening hours.

Satellite imagery at 1200 UTC 25 Feb 2003 indicated that the low was moving over extreme southwest California and the first cloud shield was moving across the CWA (Fig. 7). The dynamic frontal band and associated clouds were developing rapidly at this time over southern California, strongly forced by PV advection and WAA aloft. Radar indicated that the first cloud shield was bringing only light to moderate amounts of snowfall at this time, enhanced strongly by the stable atmosphere (Fig. 8). The Little Colorado River Valley was devoid of radar echoes with additional radar echoes reforming northeast of this area as the terrain once again started to rise. This is a typical scenario that occurs in Arizona during the winter season when the atmosphere is more stable, with upsloping and downsloping winds significantly modifying the precipitation pattern over the CWA.

Examination of the 1200 UTC 500 mb raob data along with model first guess fields of 500 mb temperature show another deficiency in model solutions at this time (Fig. 9). Temperatures at Vandenberg AFB, San Diego, Oakland, Desert Rock, and Reno all indicated a colder air mass than what the models were initialized with. San Diego reported a 500 mb temperature of -25C, while the models were initialized with -23C. With the cold core still off the coast, and not in the observation network, it appeared that the models were too warm with the cold air associated with this system, especially the Eta model which predicted a cold core temperature of -25C, which was probably 3-4 degrees too warm based on these observations. Thus, predictions for snow levels from the models were likely to be too high.

The 1200 UTC model solutions continued with some disagreement, although the Eta solution trended more strongly toward the AVN solution, which continued with strong run-to-run consistency (not shown). This, along with a slightly better initial analysis in the AVN, suggested that the AVN model had the best handle on the situation. Forecasters issued Winter Storm Warnings and Snow Advisories over the CWA, expecting the heaviest amounts from south of Flagstaff to the White Mountains.

By 1800 UTC, radar and satellite imagery continued to show light to moderate snow showers along the higher terrain of the forecast area, with strong downsloping still occurring downwind of the Mogollon Rim (Fig. 10). IR imagery looked very innocuous, with no enhancements showing in the imagery and even clearing in the downslope region of the Little Colorado River Valley. However, a color enhancement scheme that begins shading of cloud top temperatures at the -15C level (important for cloud microphysics) brings out much more detail in the IR imagery and indicates where the active weather actually was (Fig. 11).

By 0000 UTC 26 February, radar imagery showed a large band of precipitation moving into the southwest CWA and approaching Flagstaff (Fig. 12). This band of precipitation moved across the forecast area and by 0300 UTC precipitation was widespread over the region (Fig. 13). The stability was still strong enough to continue the strong downsloping into the Little Colorado River Valley, but some showers were beginning to move over the valley, especially after this time period as the instability increased more (not shown).

By the end of the event, most locations along the Mogollon Rim and White Mountains had received 2-6 inches of snowfall, except for along the immediate upstream portion of the higher terrain where a belt of 10-20 inches of snowfall occurred (Fig. 14). This gradient in snowfall on the higher terrain was due largely to the stability of the event, which strongly modulated the precipitation. Snow levels were as low as 4000 feet in the western portion of the CWA, likely due in part to the colder than forecasted airmass of the system. Rainfall amounts were impressive upstream of the higher terrain with a large area of over an inch of precipitation over the southern portion of the CWA. In the Little Colorado River Valley, Winslow reported only 0.04" of precipitation, again showing the strong modulation in precipitation over this region due to persistent downsloping winds in a stable atmosphere.

Summary

A significant winter storm affected portions of northern Arizona on 25-26 February 2003. 2-6 inches of snow fell at many locations across northern Arizona above 4500 feet with an area along the Mogollon Rim receiving 10 to 20 inches. It was shown that this range in snowfall amounts was primarily driven by orographic forcing in a moderately stable environment. This caused the most significant omega at the edge of and upstream of the higher terrain, with diminishing omega fields further downstream from the terrain. Rainfall amounts of over an inch were widespread south of the Mogollon Rim with less than a tenth of an inch in the Little Colorado River Valley north of the Mogollon Rim, again demonstrating the significant role of stability in modulating precipitation patterns during the event.

See Map

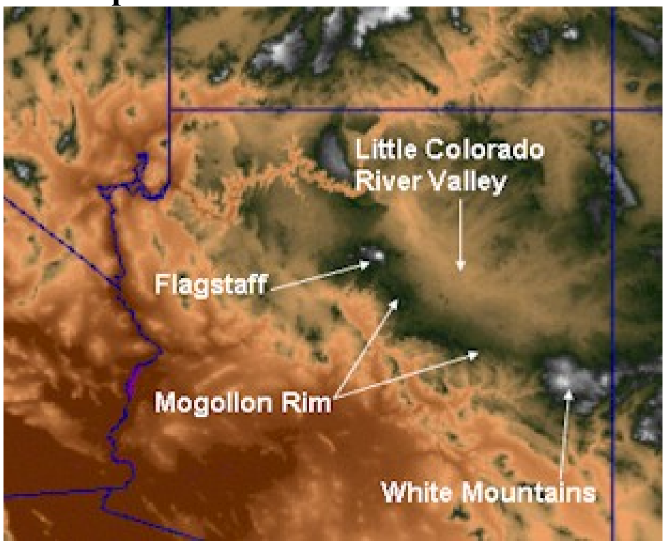
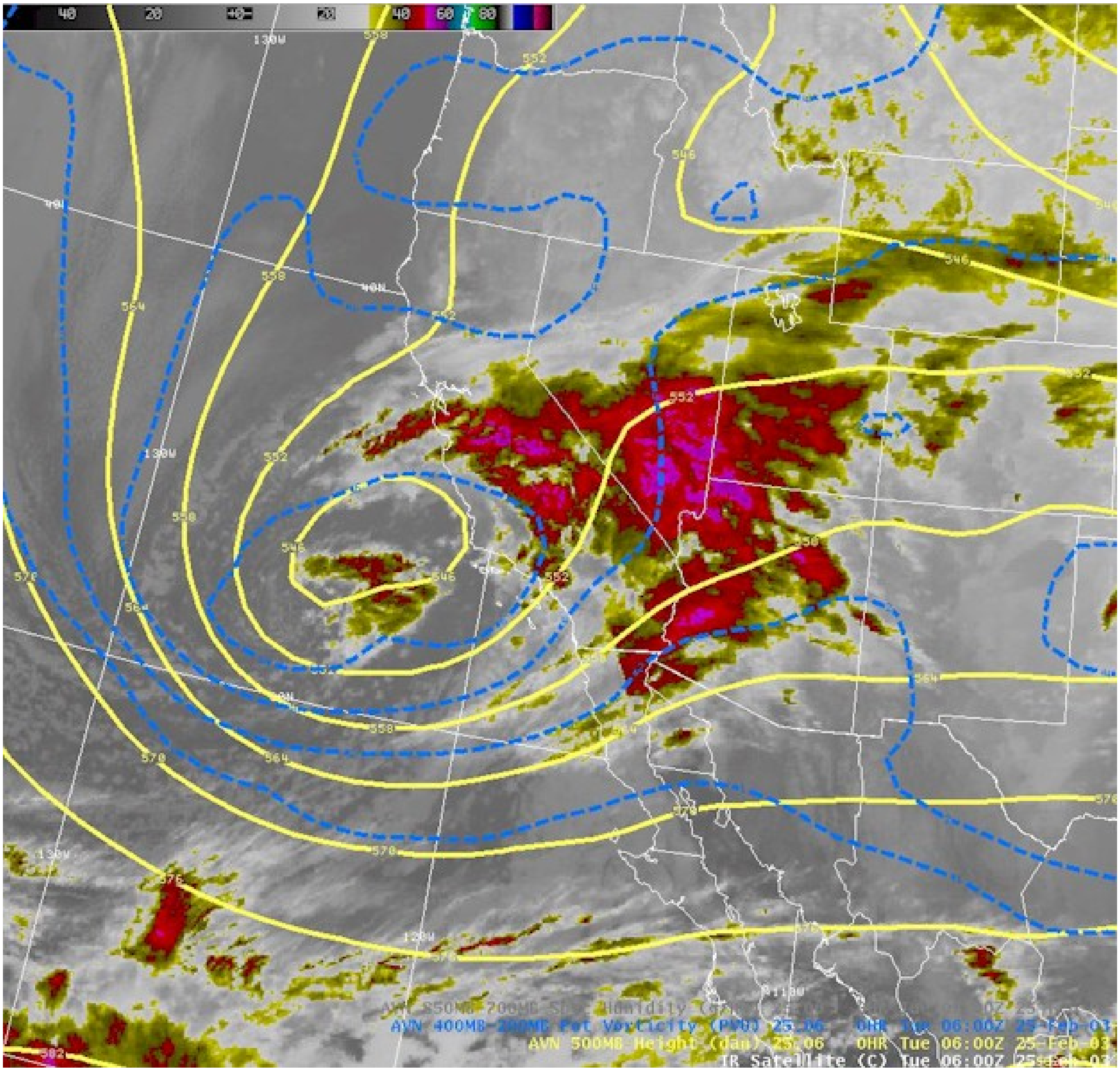


Figure 1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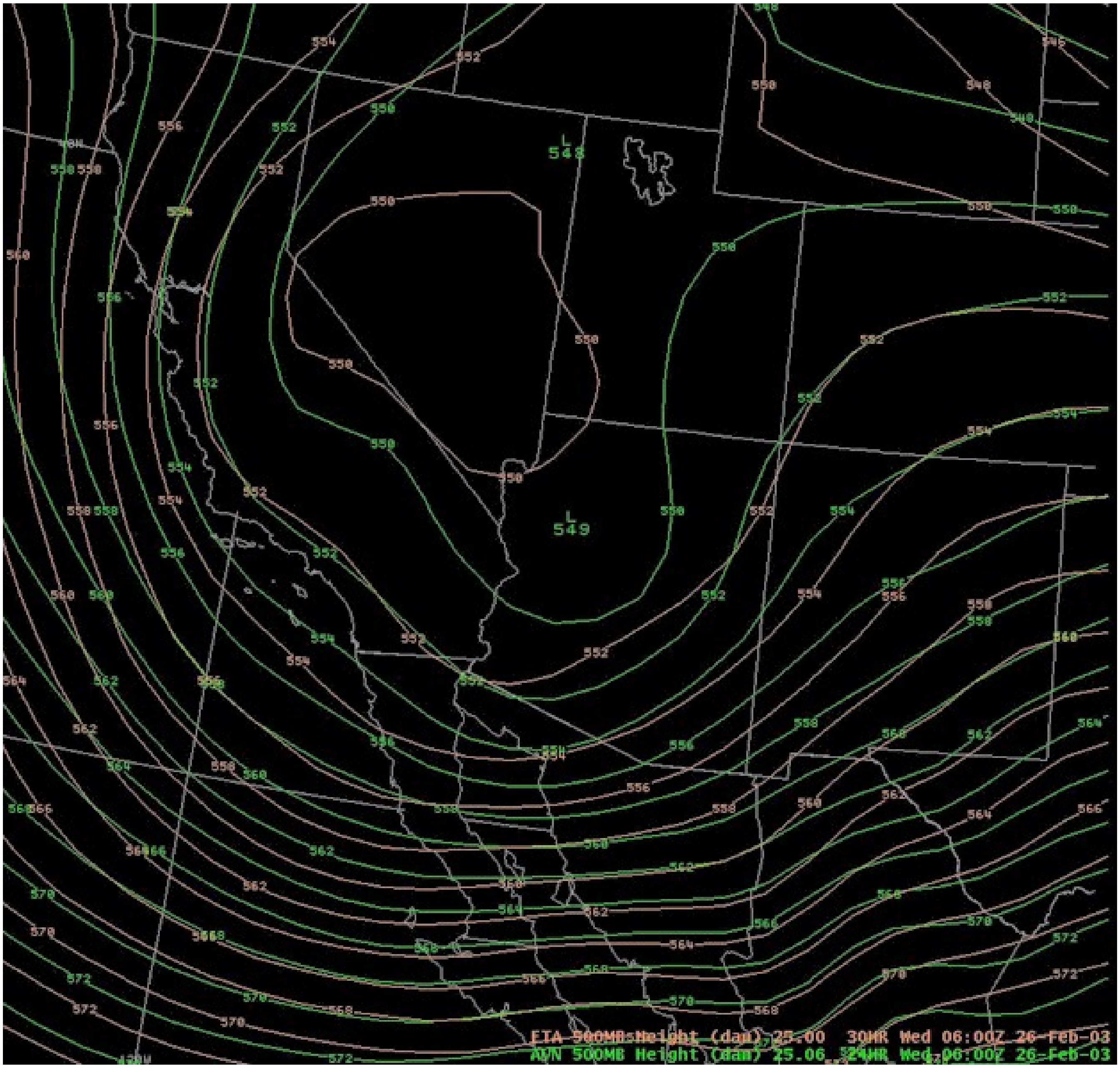
AVN 500MB Height (dam) 25.06 0HR Tue 06:00Z 25-Feb-03
IR Satellite (C) Tue 06:00Z

Figure 2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AVN 500MB Height (dam) 25.06 24HR Wed 06:00Z 26-Feb-03

Figure 3

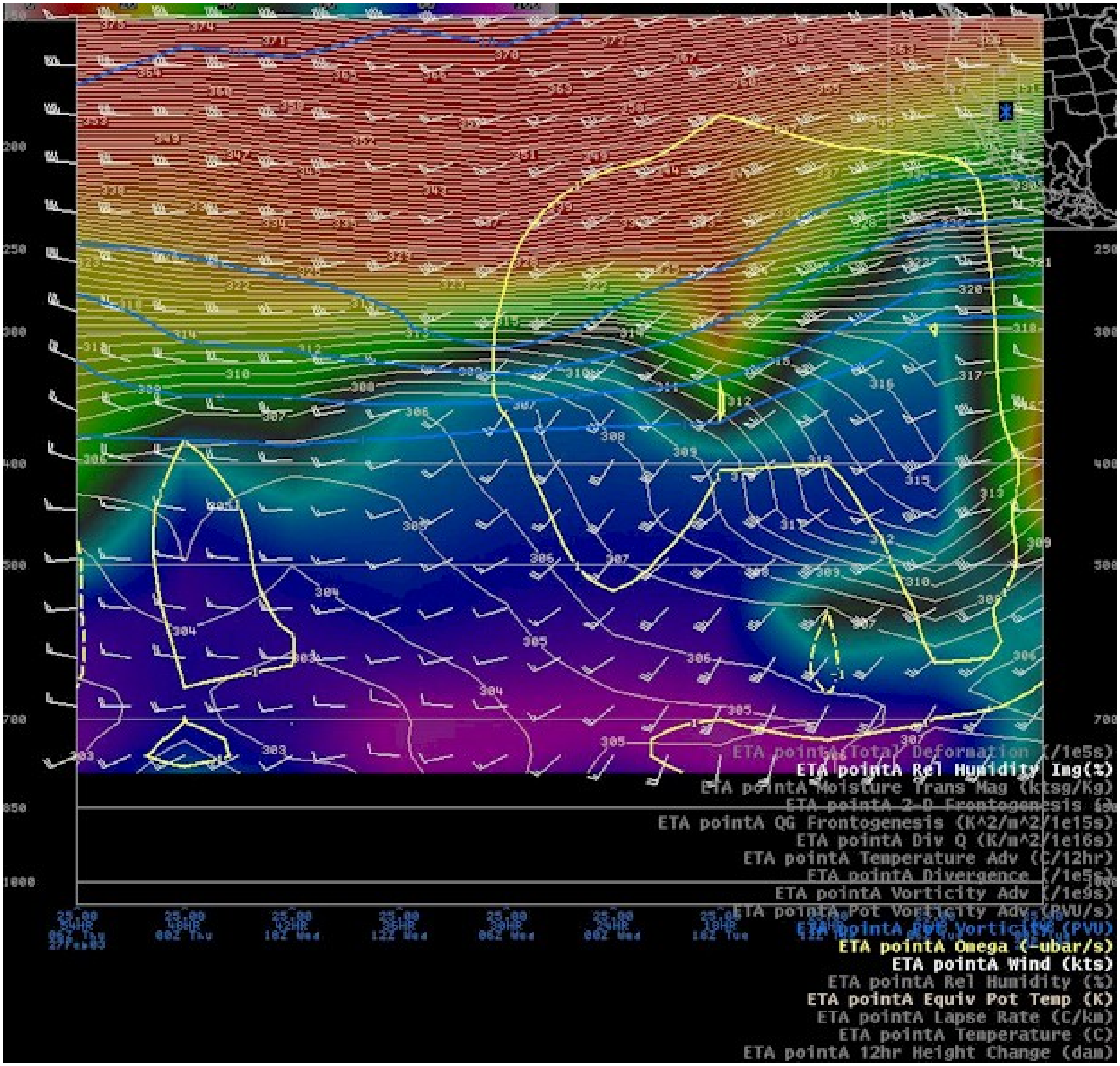
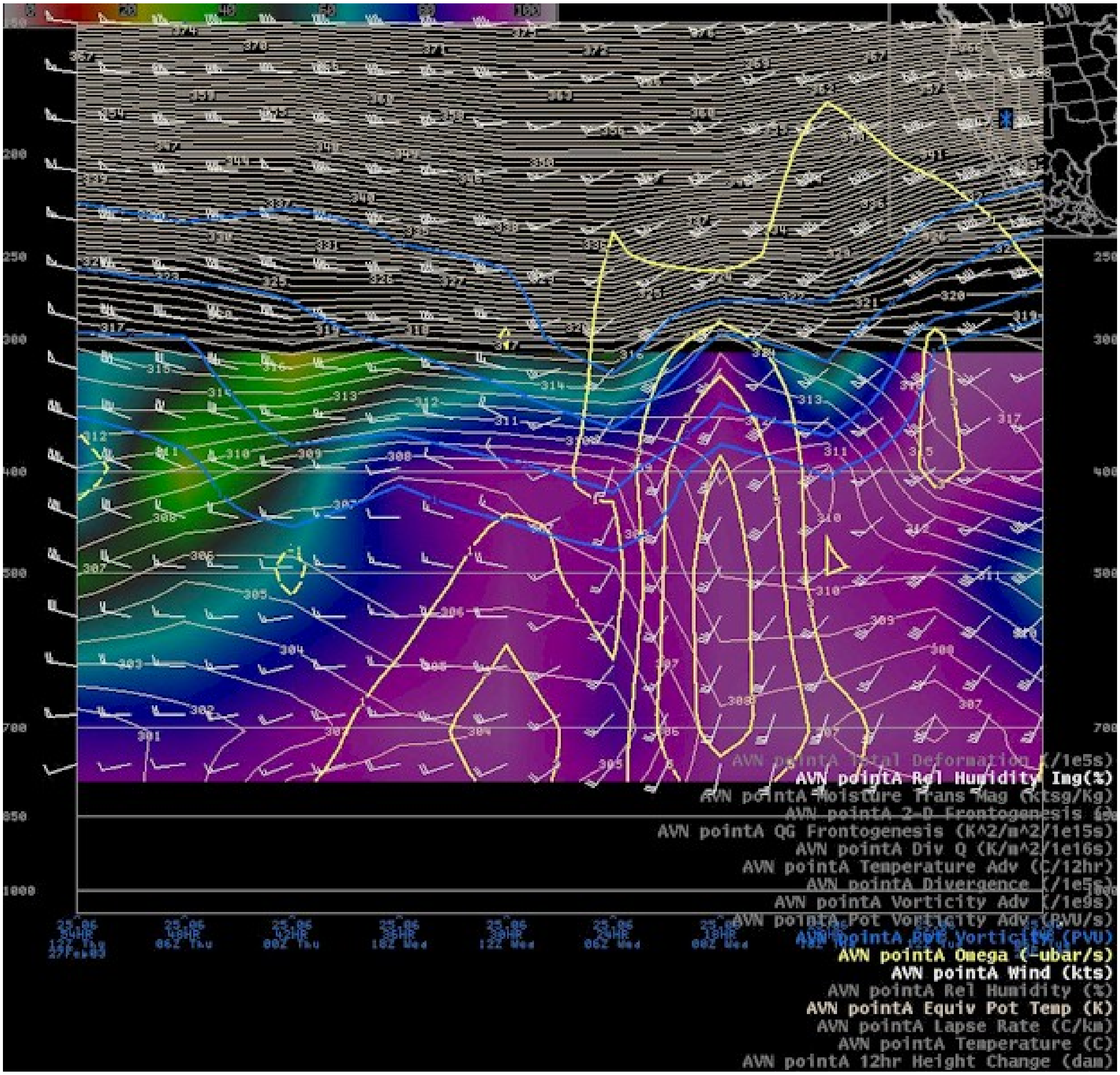

200
250
300
400
500
700
850
1000
ETA pointA Total Deformation (/1e5s)
ETA pointA Rel Humidity Img(%)
ETA pointA Moisture Trans Mag (ktsg/Kg)
ETA pointA QG Frontogenesis (K^2/m^2/1e15s)
ETA pointA Div Q (K/m^2/1e16s)
ETA pointA Temperature Adv (C/12hr)
ETA pointA Divergence (/1e5s)
ETA pointA Vorticity Adv (/1e9s)
ETA pointA Pot Vorticity Adv (PVU/s)
ETA pointA Pot Vorticity (PVU)
ETA pointA Omega (-ubar/s)
ETA pointA Wind (kts)
ETA pointA Rel Humidity (%)
ETA pointA Equiv Pot Temp (K)
ETA pointA Lapse Rate (C/km)
ETA pointA Temperature (C)
ETA pointA 12hr Height Change (dam)

Figure 4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AVN pointA QG Frontogenesis (K^2/m^2/1e15s)
AVN pointA Div Q (K/m^2/1e16s)
AVN pointA Temperature Adv (C/12hr)
AVN pointA Divergence (/1e5s)
AVN pointA Vorticity Adv (/1e9s)
AVN pointA Pot Vorticity Adv (PVU/s)
AVN pointA Pot Vorticity (PVU)
AVN pointA Omega (-ubar/s)
AVN pointA Wind (kts)
AVN pointA Rel Humidity (%)
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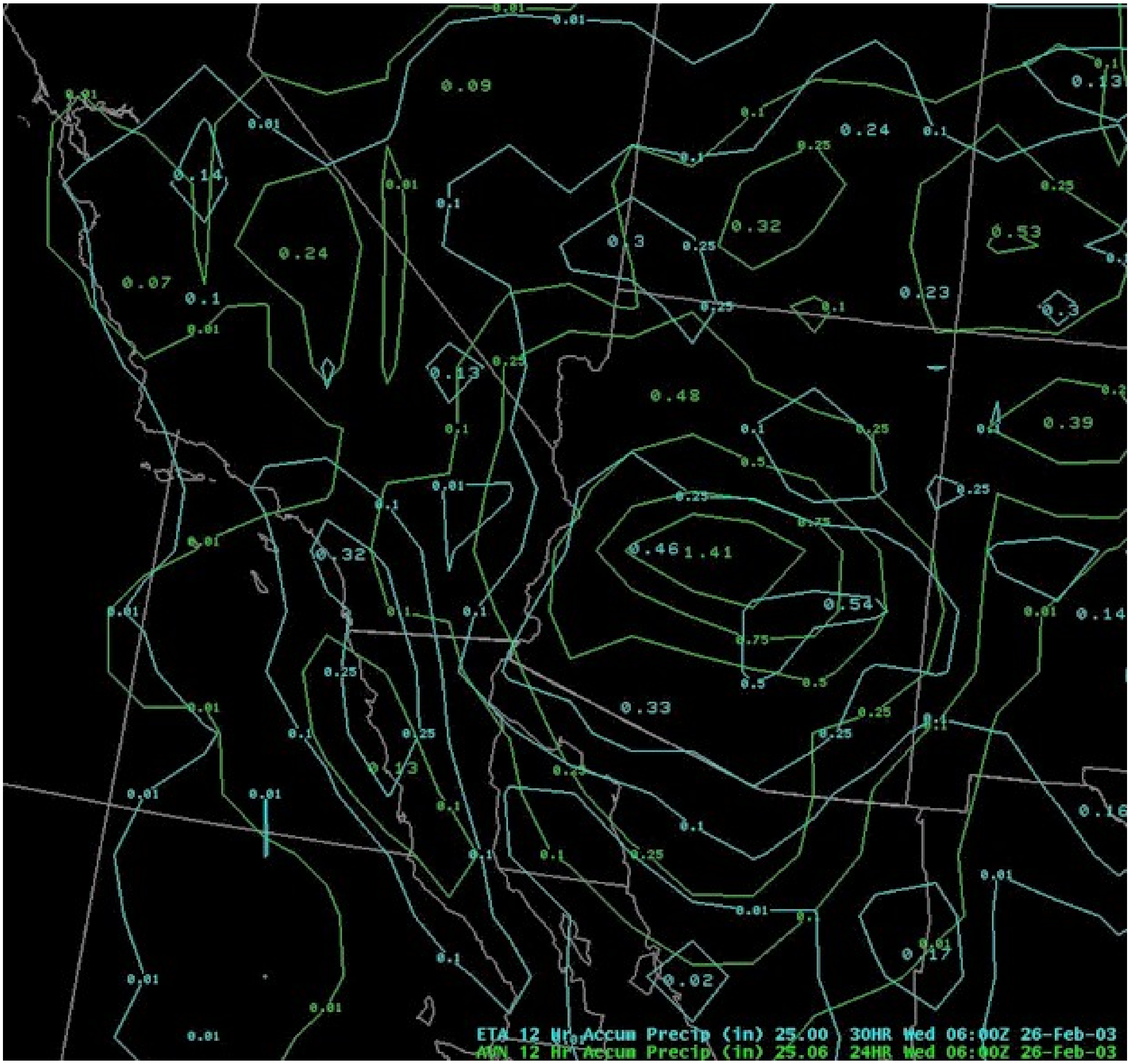
AVN pointA Lapse Rate (C/km)
AVN pointA Temperature (C)
AVN pointA 12hr Height Change (dam)

Figure 5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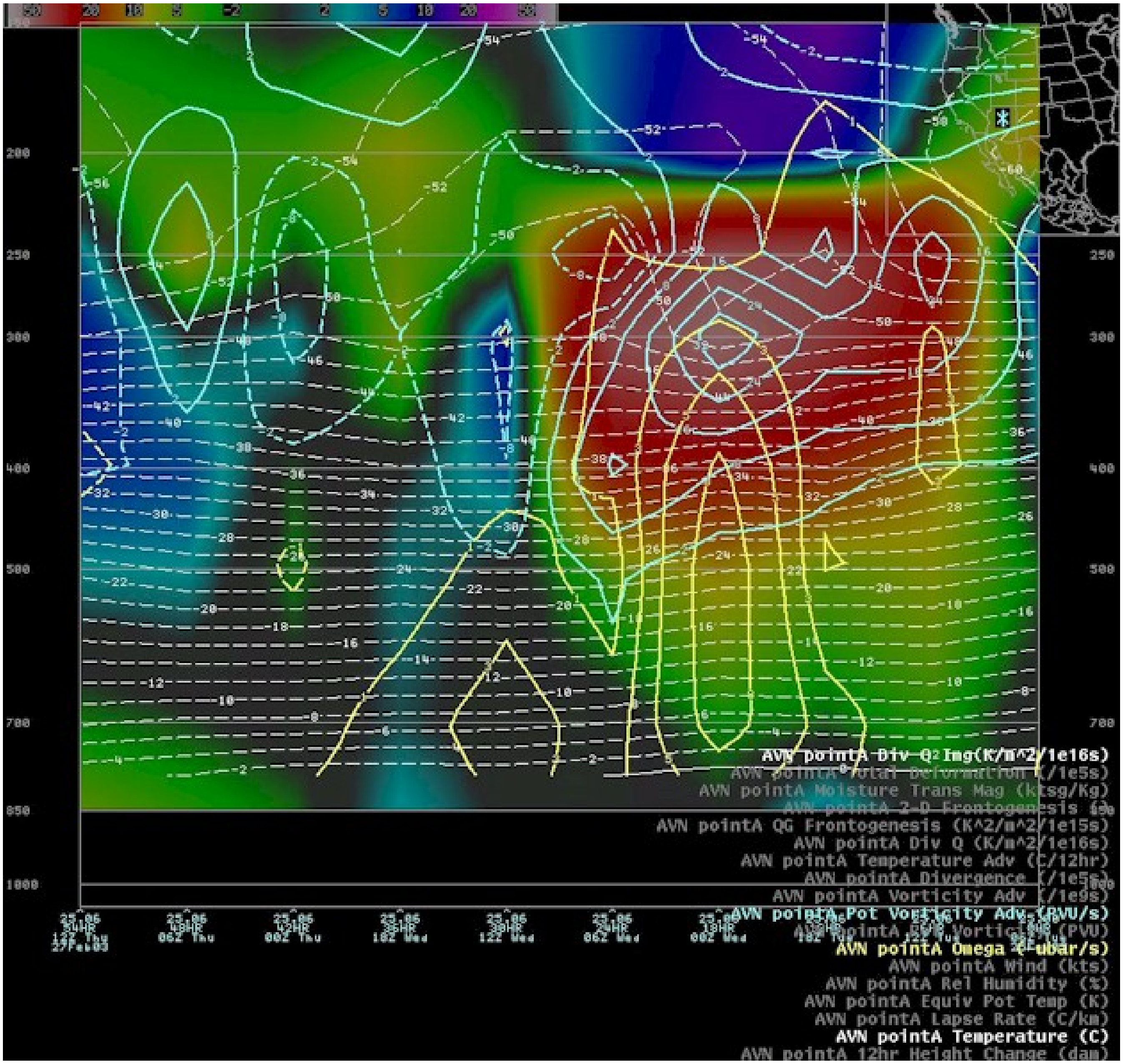
AVN 12 Hr Accum Precip (in) 25.06 24HR Wed 06:00Z 26-Feb-03

Figure 6


AVN pointA Div Q Img(K/m^2/1e16s)
AVN pointA Moisture Trans Mag (ktsg/Kg)
AVN pointA QG Frontogenesis (K^2/m^2/1e15s)
AVN pointA Div Q (K/m^2/1e16s)
AVN pointA Temperature Adv (C/12hr)
AVN pointA Divergence (/1e5s)
AVN pointA Vorticity Adv (/1e9s)
AVN pointA Pot Vorticity Adv (PVU/s)
AVN pointA Omega (ubar/s)
AVN pointA Wind (kts)
AVN pointA Rel Humidity (%)
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AVN pointA Lapse Rate (C/km)
AVN pointA Temperature (C)
AVN pointA 12hr Height Change (dam)

Figure 7

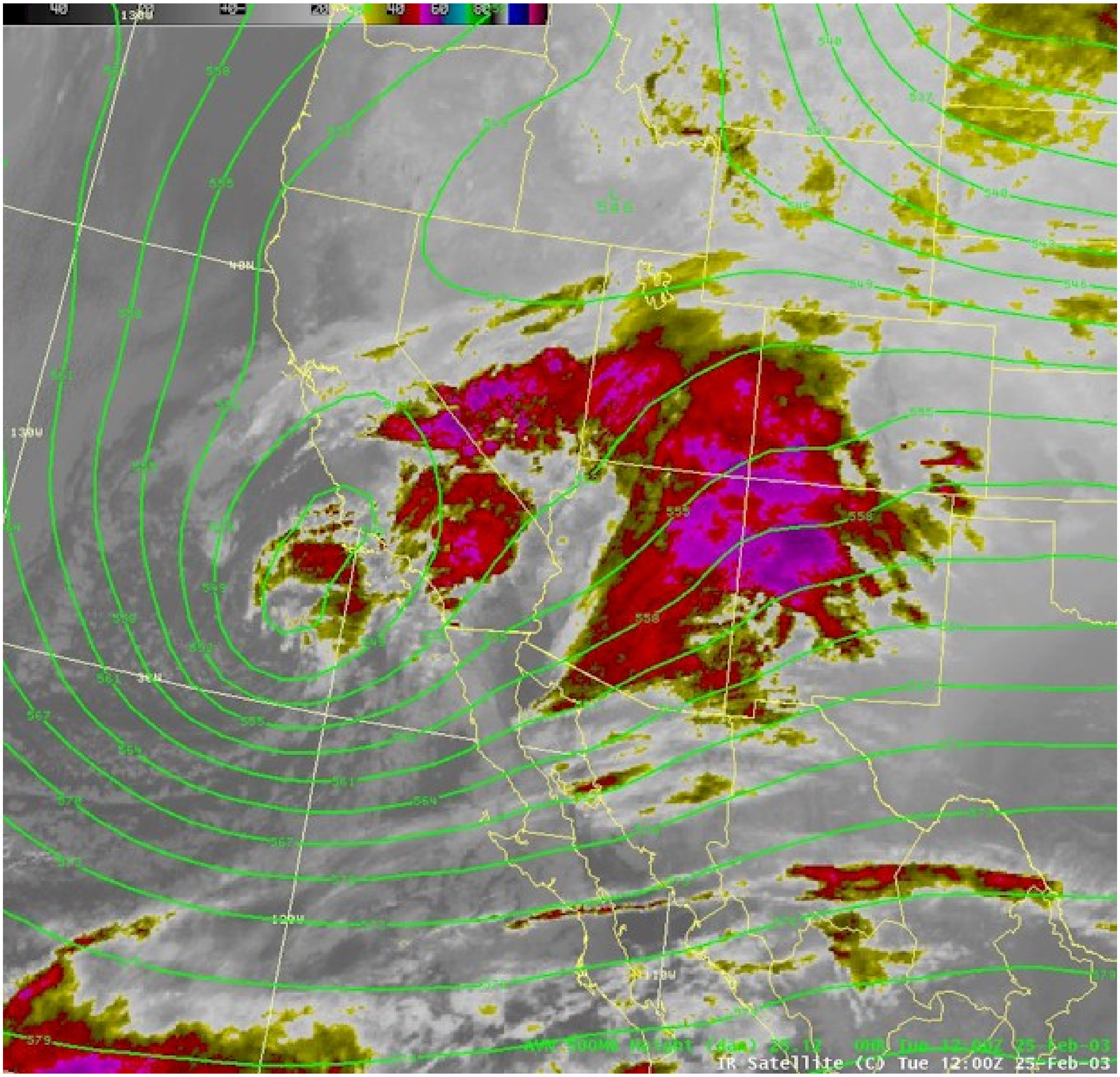
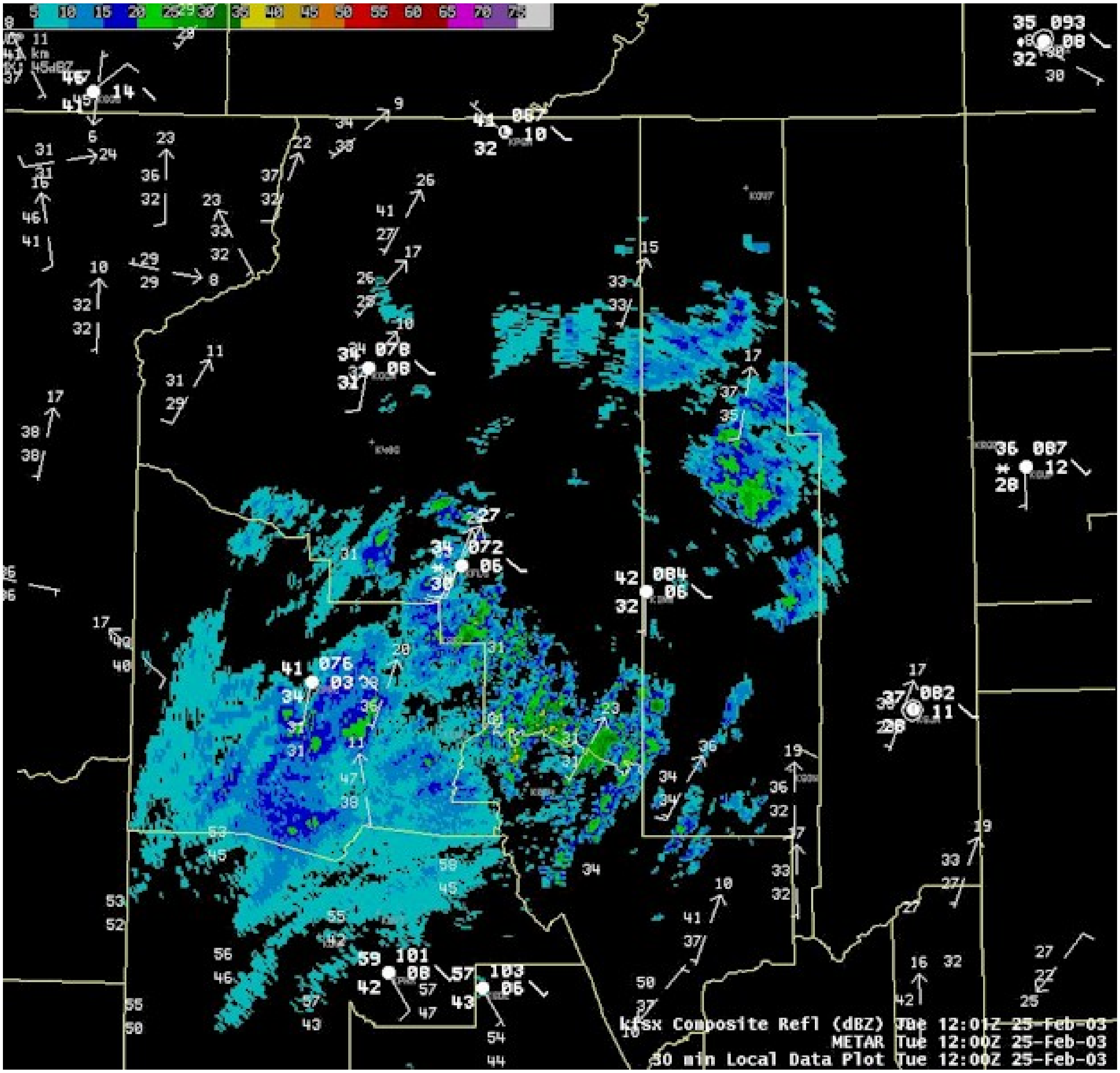


Figure 8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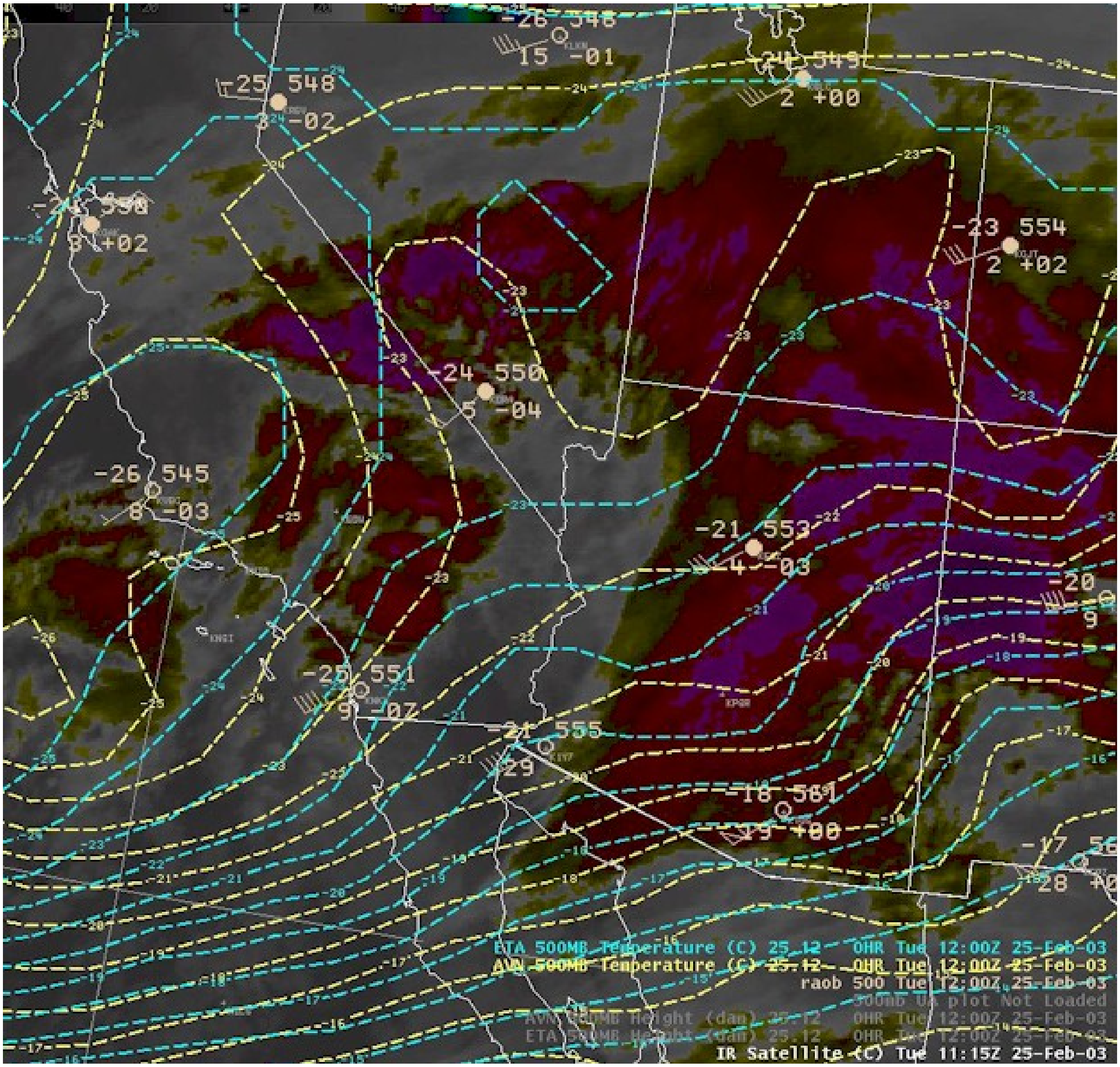
METAR Tue 12:00Z 25-Feb-03
30 min Local Data Plot Tue 12:00Z 25-Feb-03

Figure 9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AVN 500MB Temperature (C) 25.12 0HR Tue 12:00Z 25-Feb-03
raob 500 Tue 12:00Z 25-Feb-03
500mb UA plot Not Loaded
AVN 500MB Height (dam) 25.12 0HR Tue 12:00Z 25-Feb-03
ETA 500MB Height (dam) 25.12 0HR Tue 12:00Z 25-Feb-03
IR Satellite (C) Tue 11:15Z 25-Feb-03

Figure 10

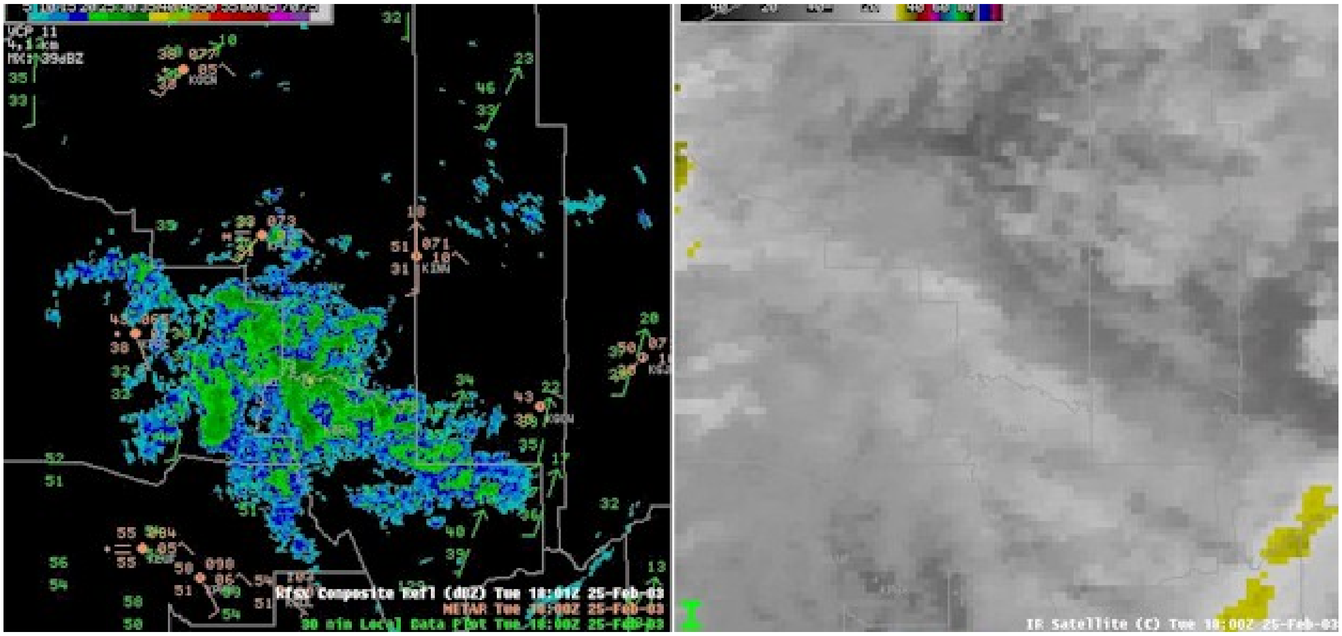

Figure 11

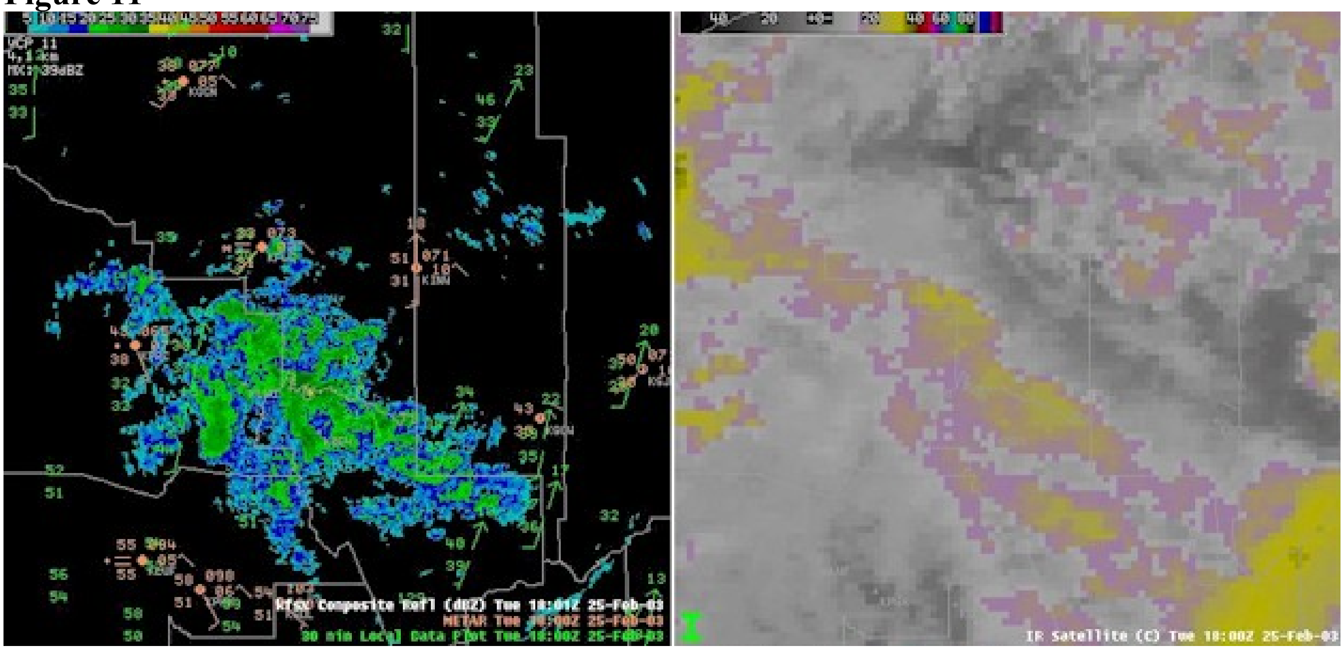

Figure 12

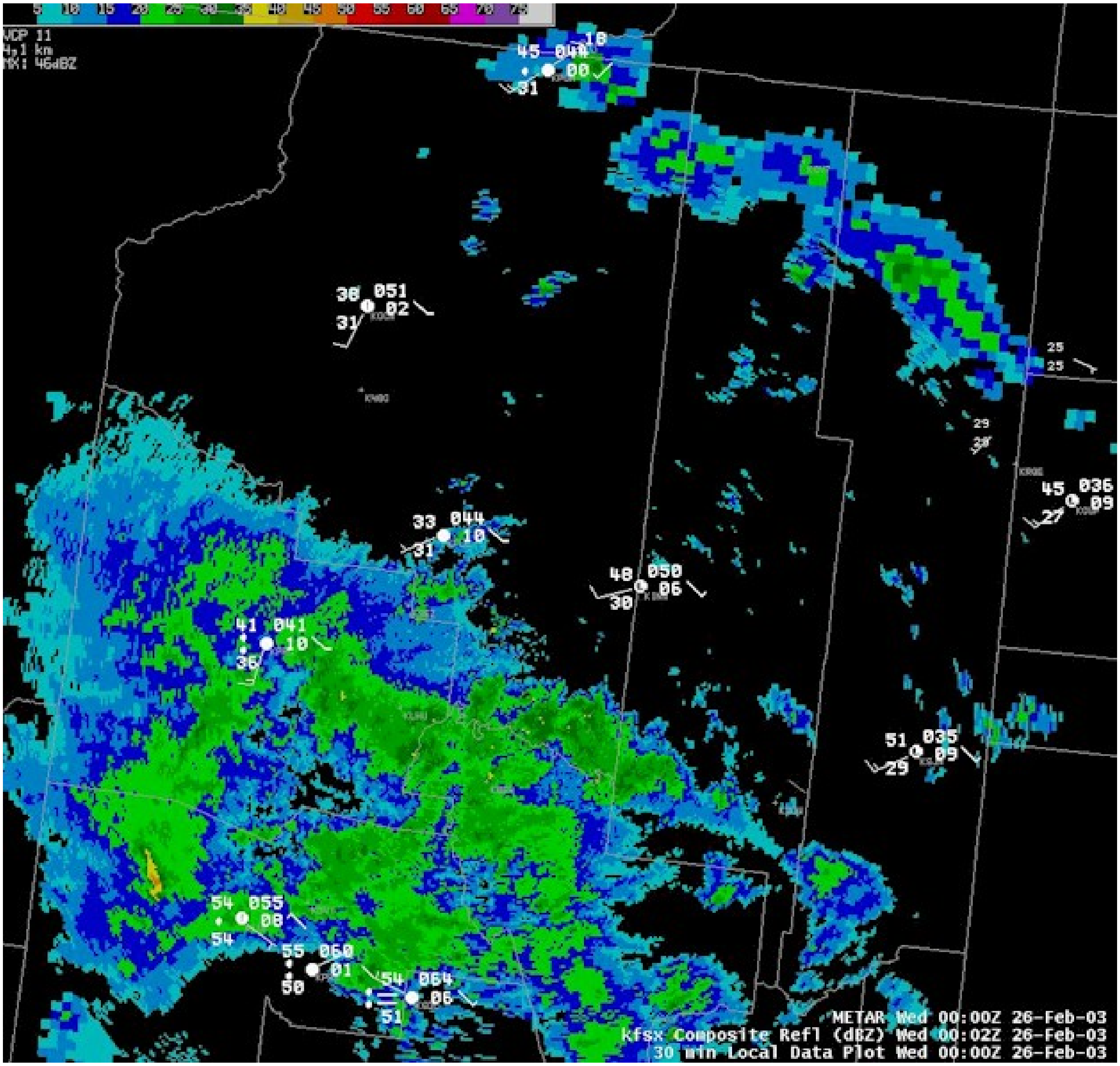
VCP 11
4.1 km
MX: 46dBZ
METAR Wed 00:00Z 26-Feb-03
Kfsx Composite Refl (dBZ) Wed 00:02Z 26-Feb-03
30 min Local Data Plot Wed 00:00Z 26-Feb-03

Figure 13

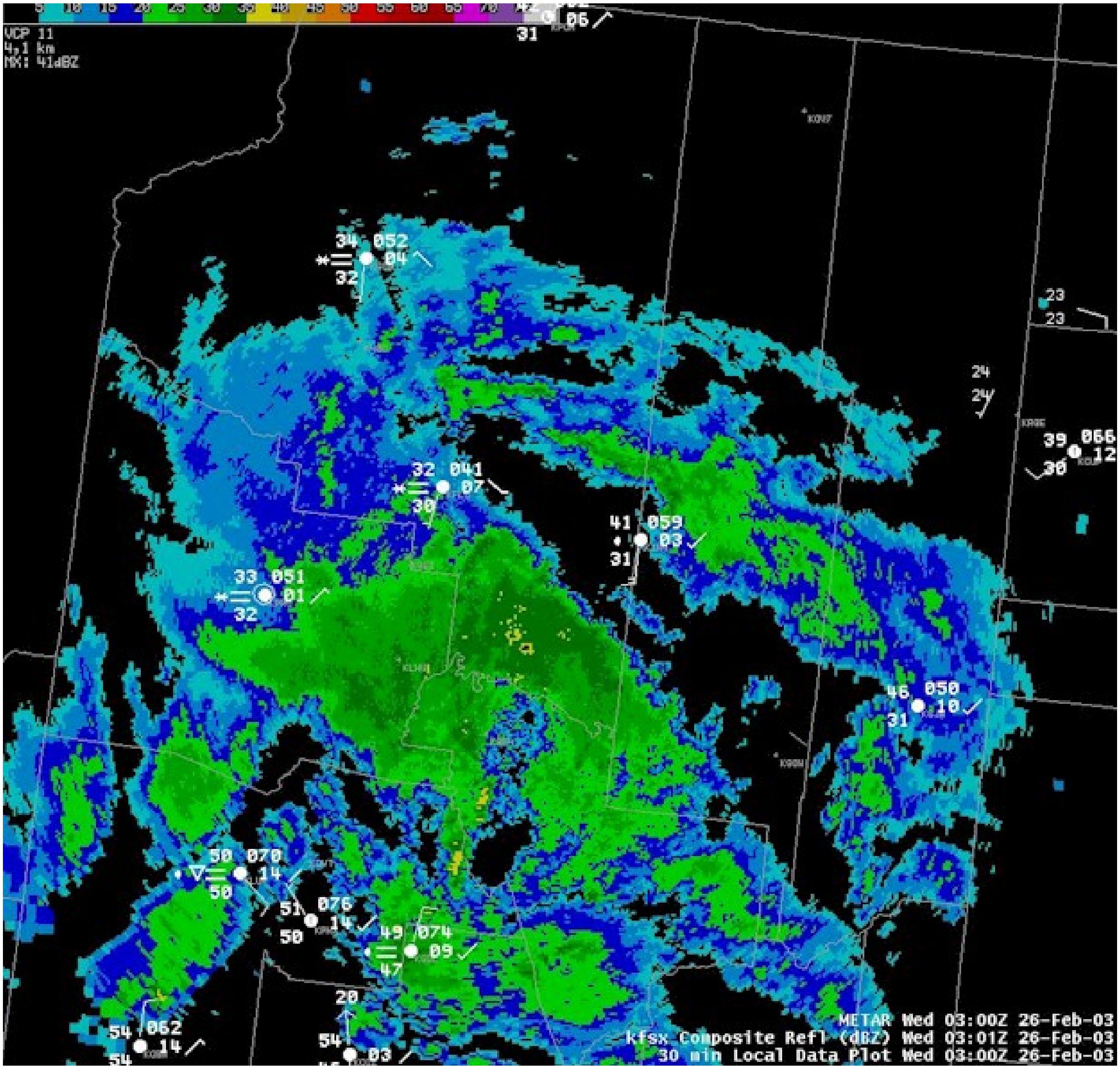
VCP 11
4.1 km
MX: 41dBZ
METAR Wed 03:00Z 26-Feb-03
kfsx Composite Refl (dBZ) Wed 03:01Z 26-Feb-03
30 min Local Data Plot Wed 03:00Z 26-Feb-03

Figure 14