

Post-Christmas 2003 Heavy Snow Event for central Montana

John Blank, WFO Great Falls, MT

In the midst of a long-term drought a late December storm in 2003 dumped several feet of snow over central Montana. This storm tied the maximum 24-hour snowfall total for Montana as 48 inches fell southeast of Millegan on 27 December. Two-day snowfall totals in excess of 16 inches covered a large area of central Montana and extended from northern Meagher county northeast to Phillips county (figure 1). Storm snowfall totals of 53 inches were reported near Milligan and Shonkin. Blizzard conditions were reported over much of central Montana as winds gusted to as high as 50 mph.

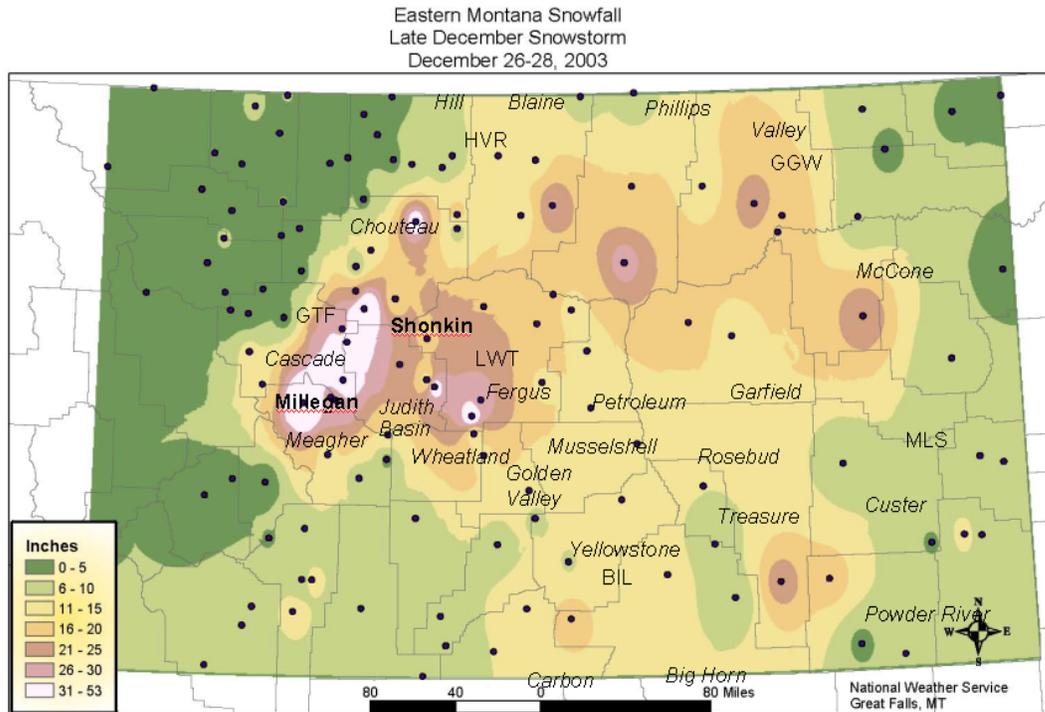


Figure 1. Observed snowfall December 26-28, 2003. County names in italics.

DISCUSSION

This storm was very challenging for forecasters as models were not consistent with the strength and track of the storm. Not only were there inconsistencies amongst the various models, there were run-to-run inconsistencies with individual models. Inconsistencies not only plagued extended forecasts but even short-term forecasts. As an example figure 2 shows 60hr 700mb forecasts from the 1200Z 25 December GFS (orange) and ETA (green) model runs.

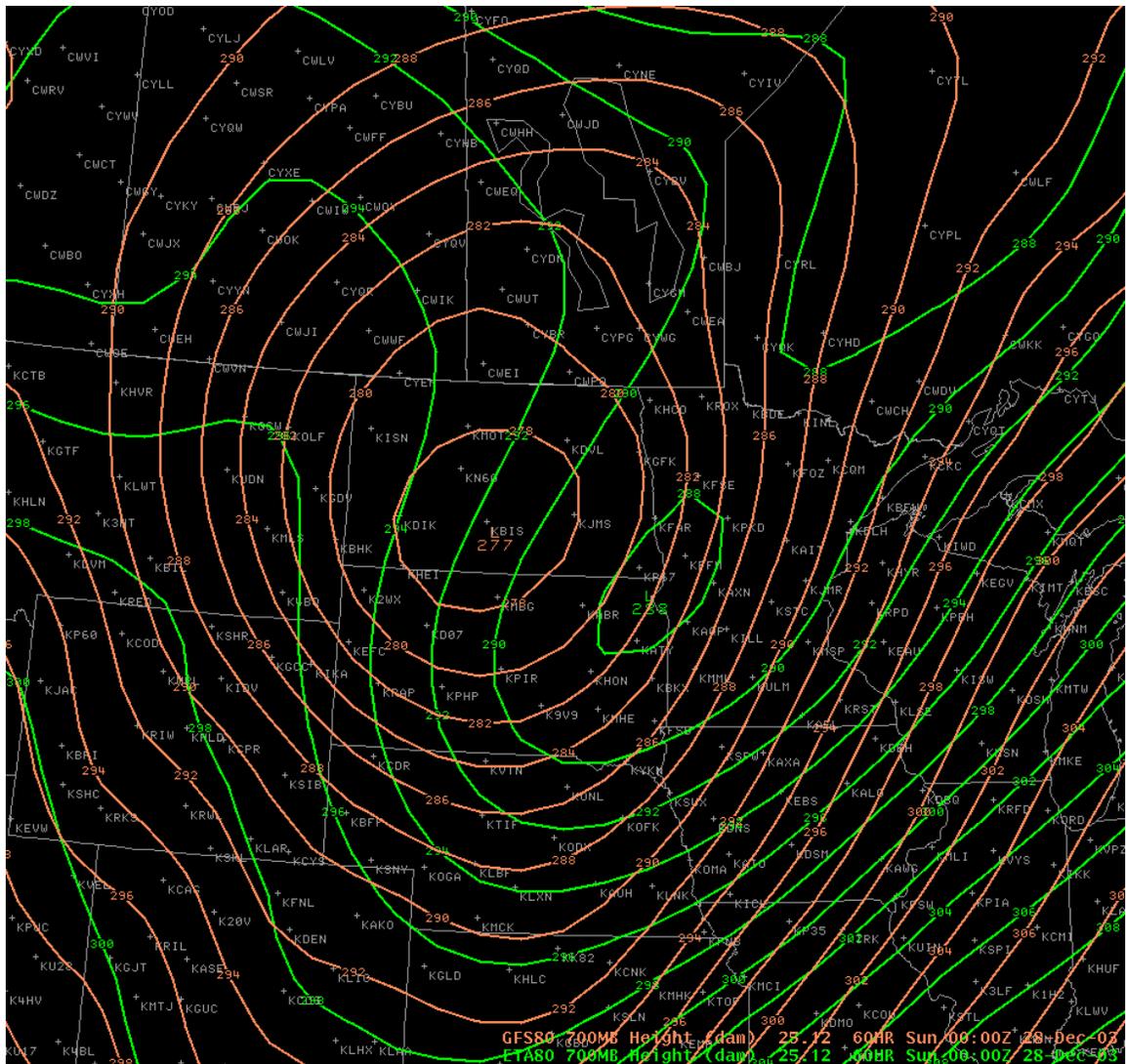


Figure 2. 60hr ETA/GFS 700 mb forecasts valid at 0000Z 28 December 2003. Orange lines are GFS 700 mb height forecasts. Green lines are ETA 700 mb height forecasts.

The ETA forecast had an open trough extending from Minnesota to eastern South Dakota while the GFS forecast a strong closed low over south central North Dakota. With mean sea level (MSL) pressure forecasts from the same model run (Figure 3),

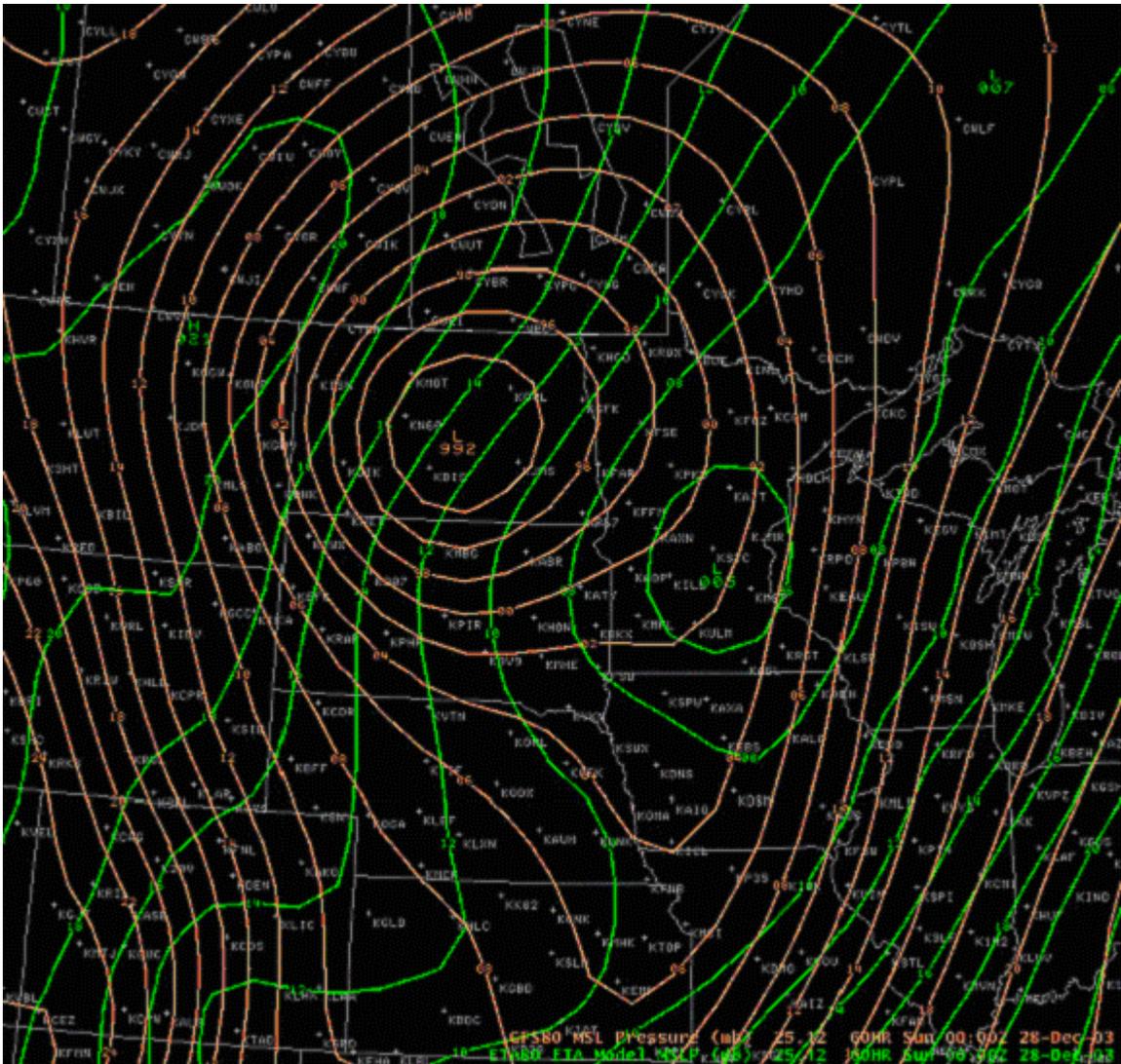


Figure 3. 60hr ETA/GFS mean sea level forecasts valid at 0000Z 28 December 2003. Green lines are GFS mean sea level (MSL) forecasts. Magenta lines are ETA MSL forecasts.

the ETA forecasted a relatively weak 1005mb low in Minnesota while the GFS projected a strong, 992mb low over central South Dakota. Although both models forecast significant precipitation amounts (Figure 4) - due in part to the very different forecast positions of the surface and 700mb lows – the geographic distribution of the precipitation forecasts markedly differed.

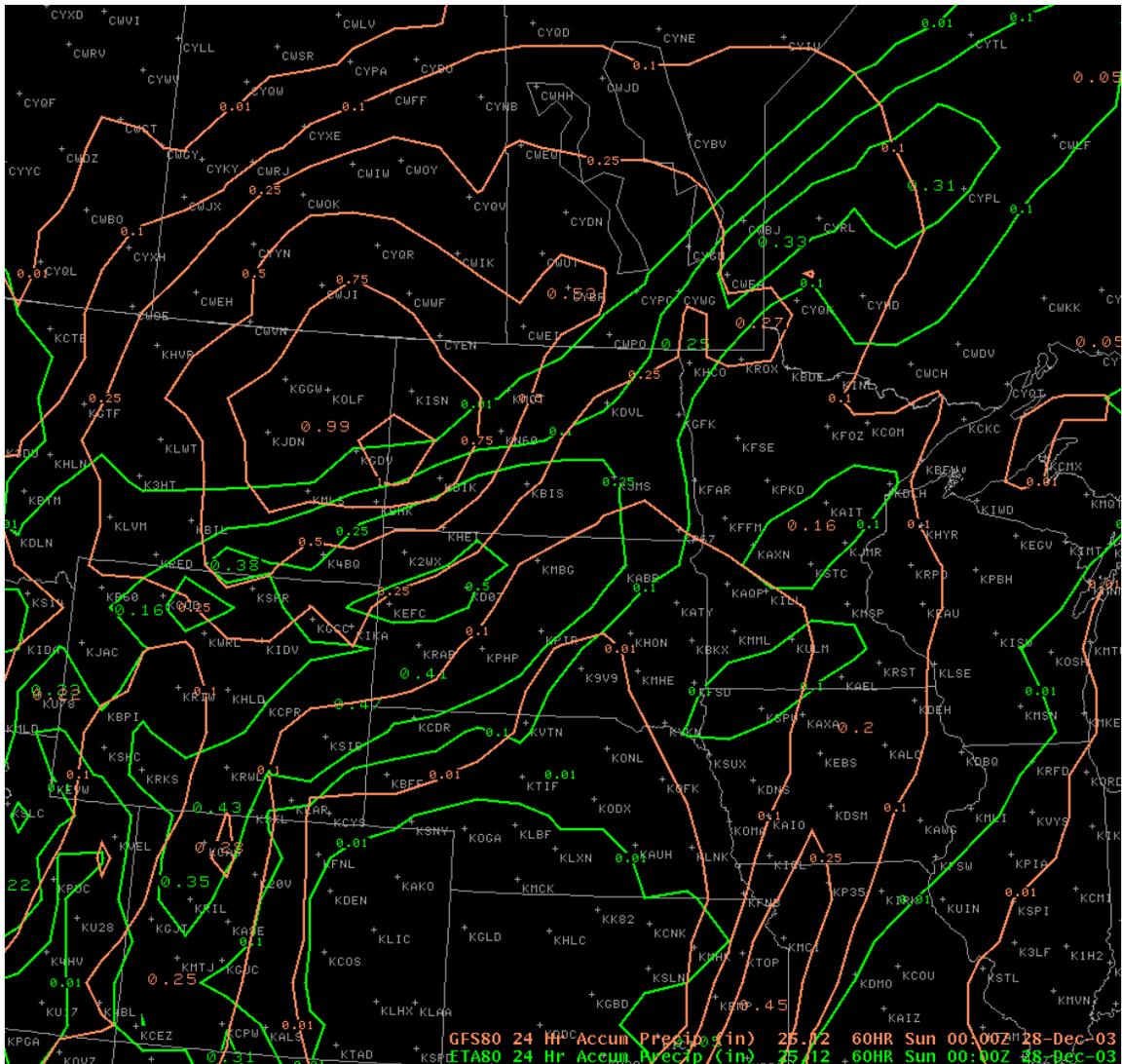


Figure 4. 60hr ETA/GFS 24hr QPF valid 0000Z 28 December 2003. Orange lines are GFS 24hr precipitation accumulation forecasts. Green lines are ETA 24hr precipitation accumulation forecasts.

The ETA forecast most of central and eastern Montana to be dry. On the other hand, the GFS forecast central and eastern Montana to receive a half-inch or more of moisture, with maximum amounts around an inch near the eastern border of Montana.

ETA and GFS model runs from 0000Z 26 December were in better agreement with regard to the track and intensity of the surface through 500mb lows, and leaned more towards forecasts from the 1200Z 25 December GFS. The 0000Z model runs were hampered by data ingest problems. It was not until the 1200Z 26 December model runs that the ETA and GFS agreed with their forecasts of this system. Unfortunately, by this time the storm had already started. Thus, after several inconsistent model runs, the models came into agreement after the storm was underway.

With the 1800Z 26 December model runs both the ETA and GFS forecast a vertically-stacked strong closed low over South Dakota at 0000Z 28 December. Both

models were forecasting MSL pressures near 995mb. Both model runs were forecasting widespread northwest near-surface winds of 20-40kts over central and eastern Montana, with isolated 50kt values with the ETA. Also both models forecast much of central and eastern Montana to receive over a foot of new snow over the following two days. Of note, the ETA forecast a small portion of southeast Blaine County to receive over 50 inches of snow accumulation. Although this area was displaced from where maximum snowfall actually fell, it was close to the maximum amount observed.

When there is the potential for heavy snow it is a good idea to check for areas of potential snow growth. The 1800Z 26 December ETA40 run indicated strong lift and a moist air mass in the layer between -12°C and -18°C (figure 5).

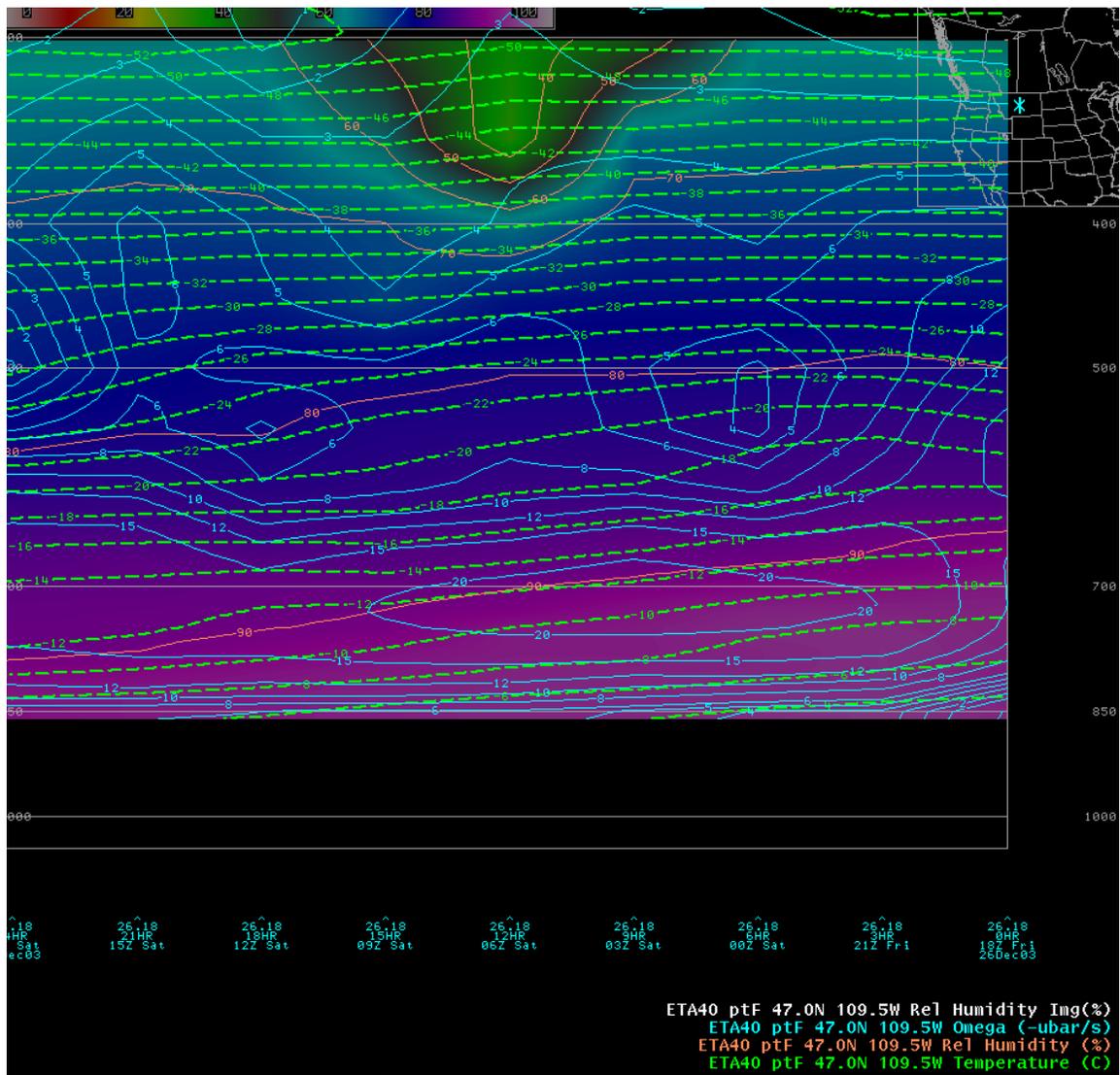


Figure 5. Lewistown ETA 24hr time/height cross-section forecast from 1800z 26 December 2003. Relative humidity shaded. Vertical velocity (solid cyan lines), temperature (dashed green lines).

One of the problems with the GFS (and also with the ETA once it came into better agreement with the GFS on the 26th) was that the heaviest snowfall was forecast to be over eastern Montana whereas it occurred over central Montana. This was the case not only before the storm began but also once the storm had started. Prior to 1800Z December 26, the GFS forecast the strongest 700mb warm air advection and upward lift to be over the eastern plains of Montana. Although the 1800Z 26 December GFS forecast the best 700mb thermal advection and upward lift closer to central Montana, it was still too far east with its forecast of the heaviest snow. From this run, the 6-hr GFS forecast at 700mb was for southeast winds at 30kts at GGW and less than 20kt north winds at GTF (figure 6).

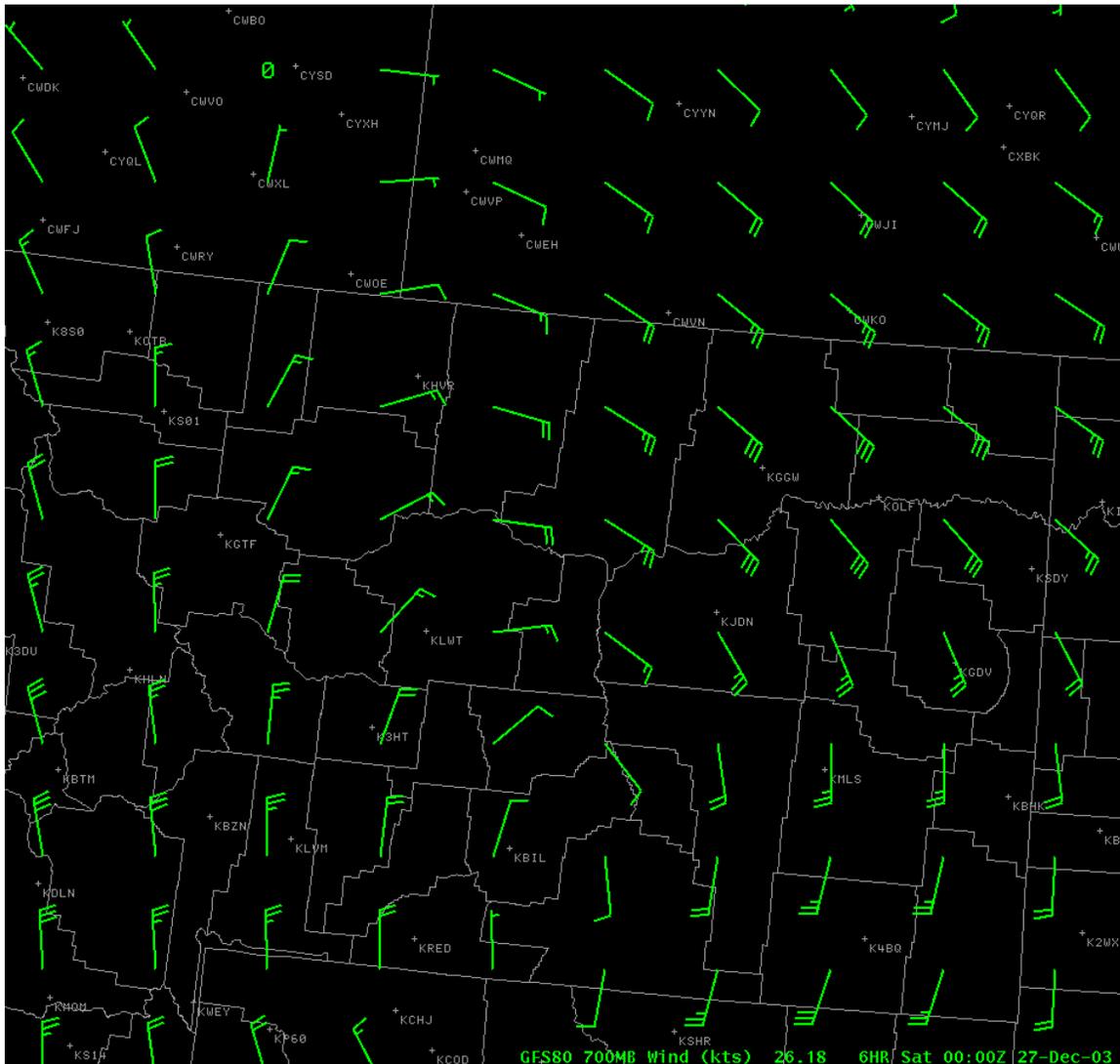


Figure 6. 6hr GFS 700 mb wind forecast valid 0000Z 27 December 2003.

The observed 700mb chart for 0000Z 27 December (Figure 7) indicated 45kt southeast winds at GGW and 25kt north winds at GTF.

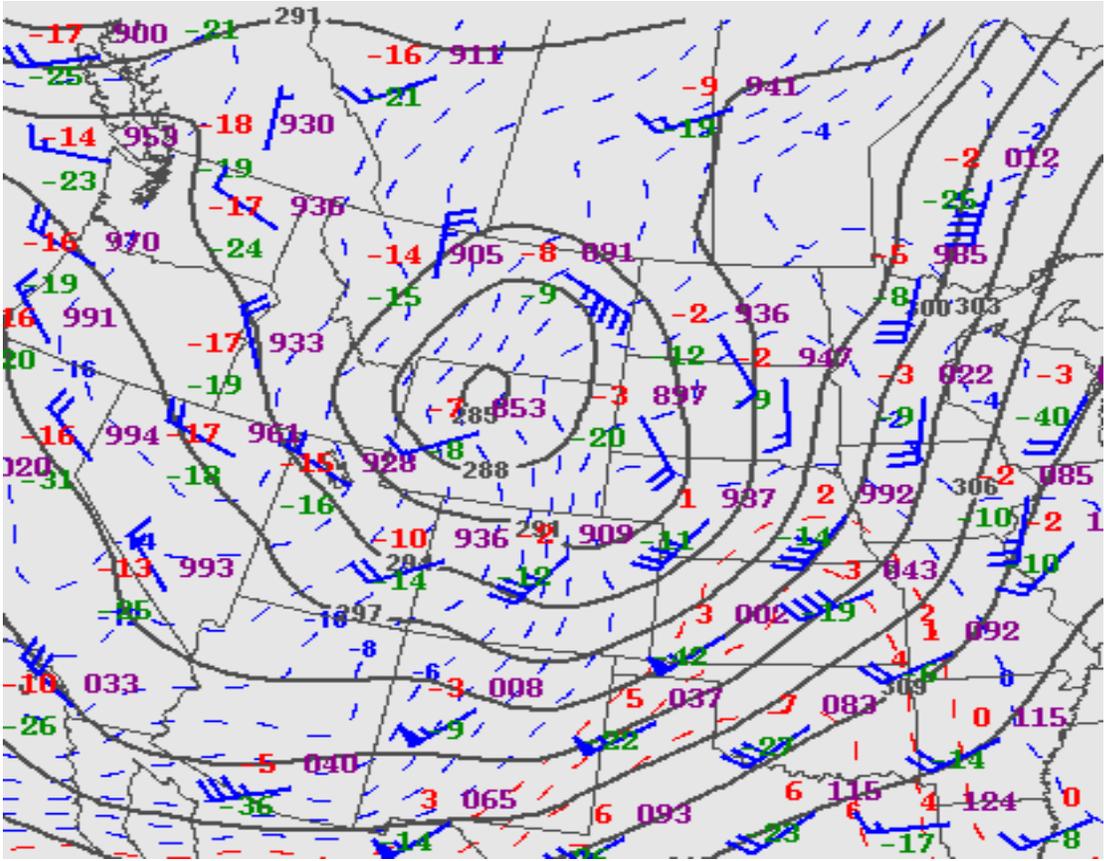


Figure 7. 700 mb analysis at 0000Z 27 December 2003.
Solid gray – heights (dam); dashed blue – isotherms (degrees C).

The observed data implied better lift over central Montana than what the model forecast. The data also implied stronger upslope flow for the north-facing slopes of the central Montana mountain ranges (observed 25 kt vs. 15-20kt forecast). Also, the GFS model terrain heights for the central Montana mountains are a little over 5000 feet while the ETA40 has heights to around 6500 feet. Actual heights range from 6000 feet to near 9000 feet. With actual terrain heights varying more than what the models have, this could also lead to the models not forecasting as much snow as what was observed in that area.

As it turned out the GFS was more accurate than the ETA with its forecast of this storm. A surface low over the Great Basin at 1200Z December 26 moved to the east slopes of Wyoming and Colorado by 0000Z December 27 and then intensified as it moved to eastern North Dakota by 0000Z 28 December (figure 8).

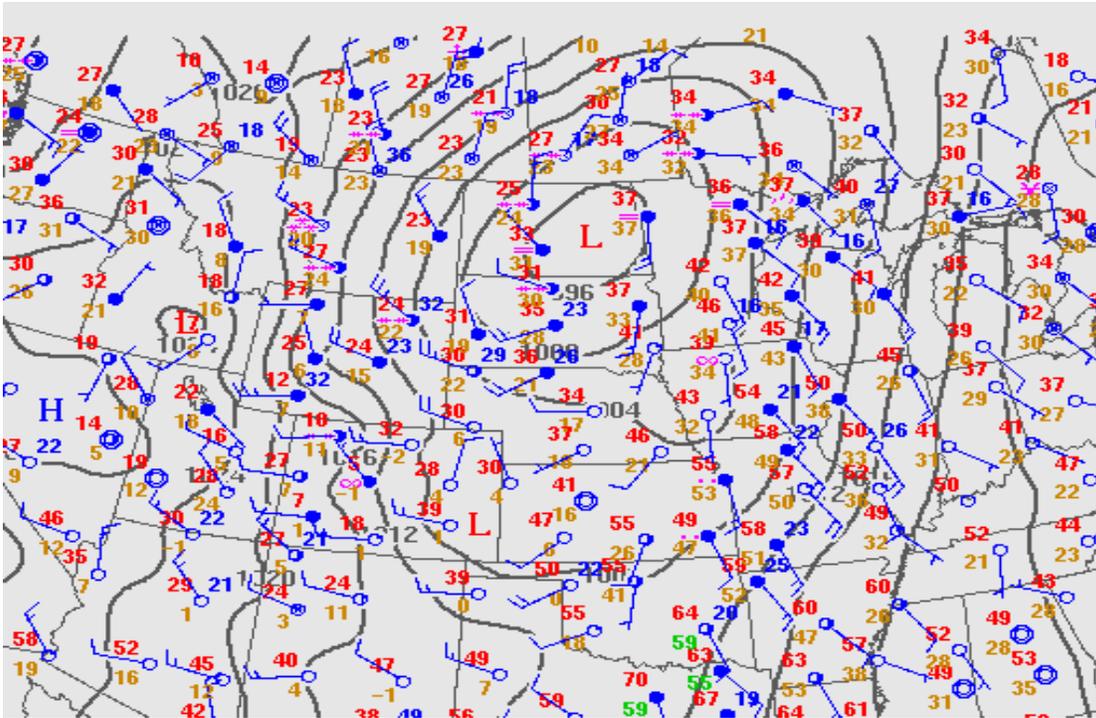


Figure 8. Surface analysis 0000Z 28 December 2003. Solid gray – pressure (mb).

Even the 60hr GFS forecast valid at 0000Z 28 December was reasonably accurate with the position and strength of the surface low (Figure 8; compare with Figure 3). Even though the heaviest snow fell west of where the GFS forecast it to fall, it did indicate the possibility of heavy snow for eastern Montana well before the ETA did.

Even before the 0000Z 26 December model runs there was a small clue as to whether the ETA or GFS model might serve better as a basis for the forecast. Refer to Figure 9 for 0000Z 25 December ETA and GFS model runs. shows ETA (orange) and GFS (blue) 00 hr forecasts of 400mb RH from the 0000Z 25 December ETA and GFS model runs.

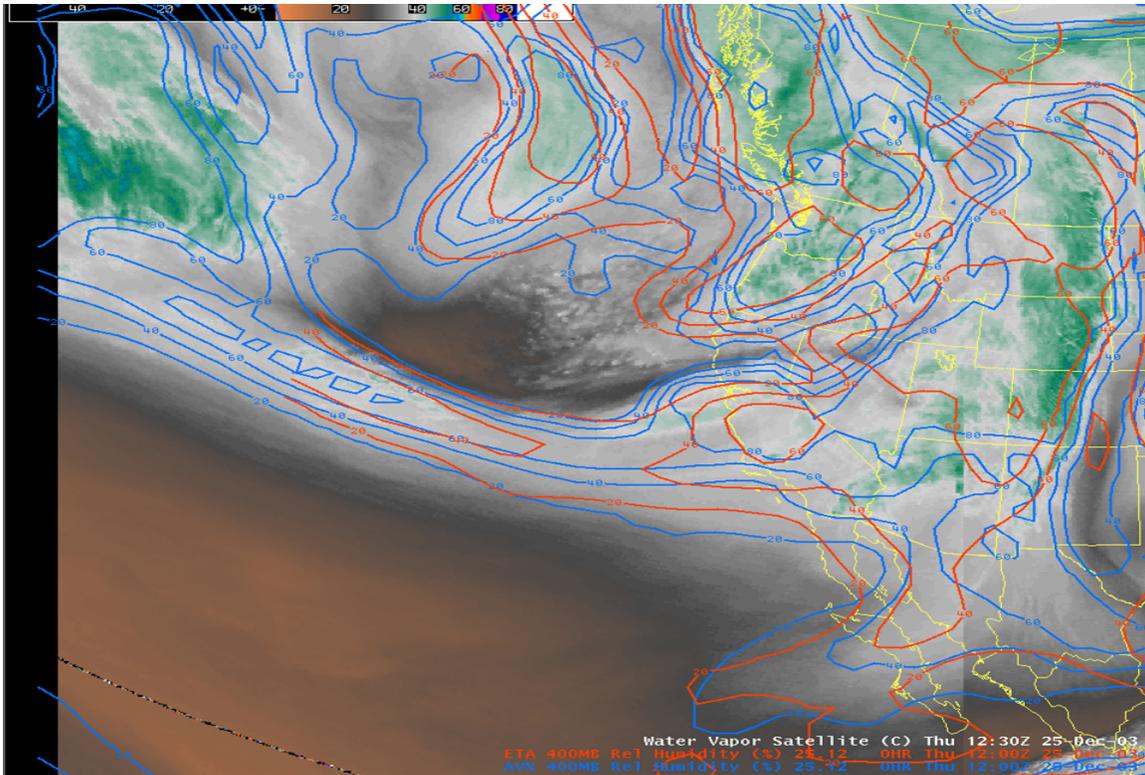


Figure 9. 00hr ETA/GFS 400 mb Relative Humidity forecasts overlaid on water vapor satellite imagery valid 1200Z 25 December 2003. ETA RH (orange) and GFS RH (blue).

Note how the GFS captures the moisture associated with the baroclinic leaf near the California coast better than the ETA. This system would eventually blossom into the winter storm that affected central and eastern Montana.

CONCLUSIONS

This case was especially challenging to the forecaster as model inconsistencies persisted up to the time of the storm. In cases of model inconsistency forecasters might want to examine short-range ensemble forecasts (SREF) to aide in determining which model to use for their forecast. Observed soundings, initial analyses, and satellite data, as well as other diagnostics tools can, at times, be useful in indicating where model forecasts might be leading the forecaster astray. Finally forecasters should be aware of the differences between model terrain and actual terrain in their forecast area and how this can affect model forecasts of QPF.