The 23 January 2003 Snow Event in the Lee of the Appalachians

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I. Introduction

Heavy snow developed over the foothills and piedmont of North Carolina during the early morning hours of 23 January 2003. This area of heavy snow featured several northeast to southwest oriented snow bands, a tendency to “stand” in the lee of the mountains, and a slow southward drift as the night wore on. Thunder snow was reported in the areas of heaviest accumulation, across the North Carolina foothills and piedmont. In the experience of the forecasters at WFO GSP, this event was in many ways without precedent.

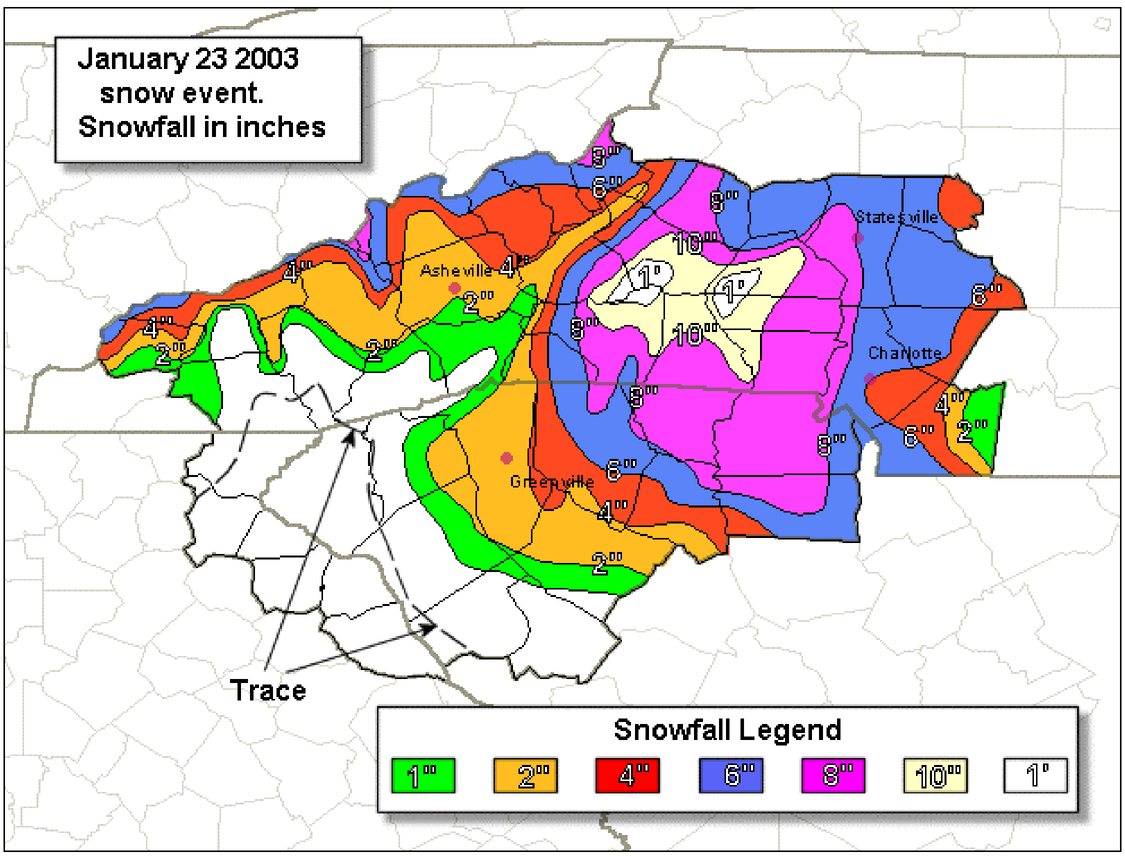

Figure 1: Snowfall map from the 23 January 2003 event.

As the short wave energy responsible for the heavy snow over western North Carolina moved east, rapid cyclogenesis occurred along the North Carolina coast. Due to the exceptionally cold nature of the airmass over the region, heavy snow also fell across coastal North Carolina. Up to a foot of snow blanketed the outer banks, the worst storm to hit that area since 1989. The North Carolina State Climatologist observed that this was one of a very few systems to bring measurable snowfall to every county in the state.

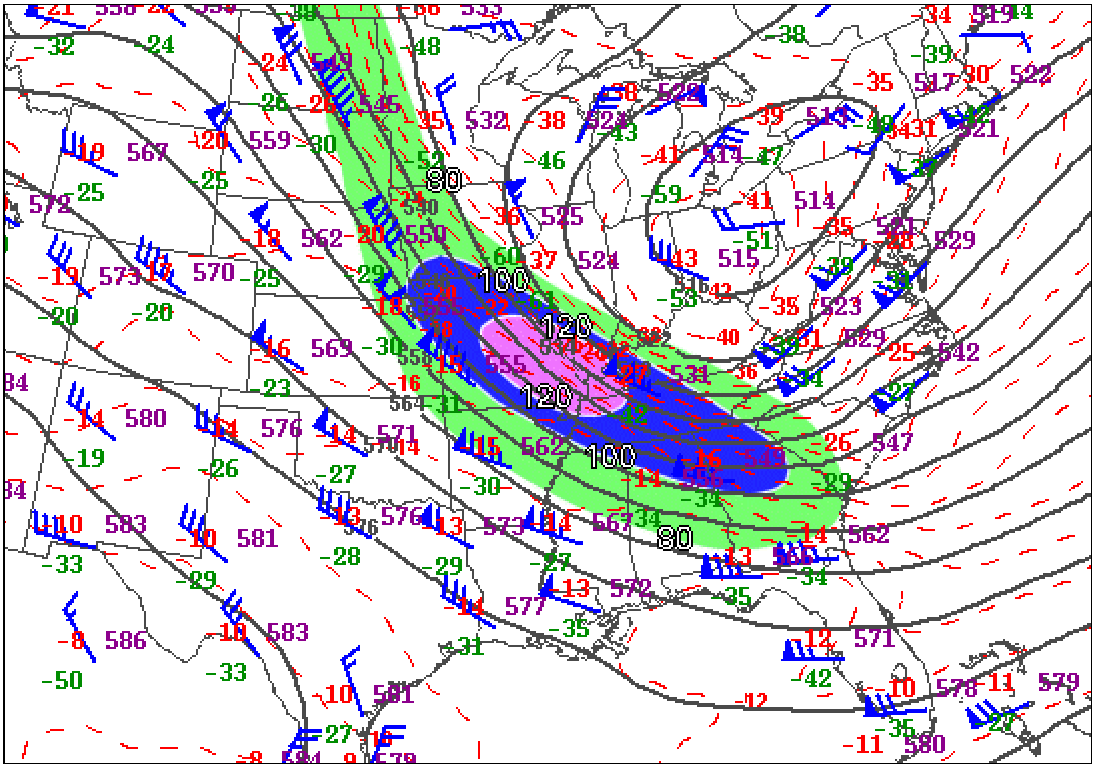

Figure 2: 1200 UTC 23 January 2003 500 mb Raob plot. Isotachs color filled beginning at 80 knots.

2. Evolution of the event

Figure 1 shows storm total snowfall. As much as a foot of snow fell in the North Carolina foothills and the western piedmont. Of a great deal of interest was a distinct “snow shadow” in the immediate lee of the mountains. In fact, amounts were probably lower than what is indicated on the map. To the east, amounts quickly tapered off outside of the GSP CWA. Father north, similar banded snowfall occurred in the Blacksburg CWA, though maximum amounts there were on the order of 7 inches. Amounts in the western North Carolina Mountains were partially the result of northwest flow snow later in the day, and partially the result of similar “standing” snow bands from the morning hours. The snow in the foothills and Piedmont will be the primary focus of this analysis.

While in some ways this appeared to be a “northwest flow” event, typified by a short wave crossing the region from the northwest, and a limited supply of surface moisture, there were several aspects of the 23 January storm that did not fit the northwest flow conceptual model.

Aloft, a strong jet streak, and associated 500 mb vorticity center, was translating through the southwest side of the long wave trough over the Eastern states. The left exit region of this jet streak was the dominant upper level, synoptic scale forcing mechanism for the event. This was an exceptionally fast moving and strong upper through, and between 0000 and 1200 UTC on 23 January, tremendous upper divergence spread across the region. Figure 2, the 1200 UTC 23 January 500 mb RAOB plot, shows this feature at 1200 UTC on the 23rd, about the time the event was winding down. Isotachs of 80 knots and greater are color-filled. At 300 mb, the jet was oriented in a similar manner, with maximum wind speeds of almost 180 knots. This synoptic scale feature affected a large area from the upper mid-west, through the Mid-Atlantic States. However, until the surface low began to deepen, few areas received amounts as high as those in the lee of the Appalachians

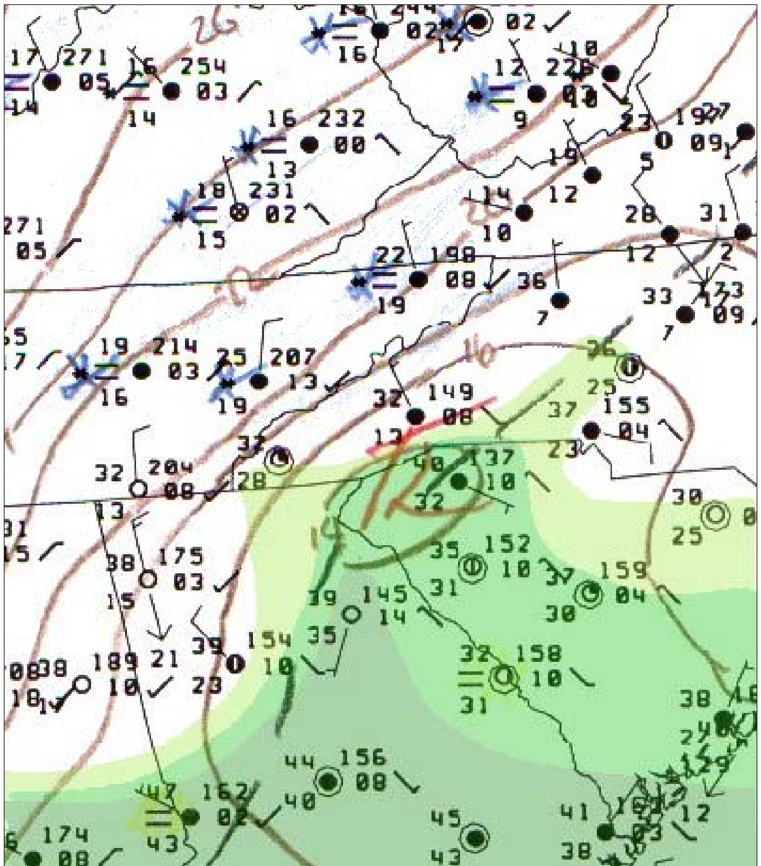

Figure 3: 0300 UTC 23 January 2003 surface pressure, dewpoints (color-filled) and surface observations.

Table 1: Hickory Regional Airport ASOS Observations					
Time	Temperature	Dew Point	Pressure	Wind (MPH)	Weather
4 UTC	36 (2.2)	23 (-5.0)	29.95	NE 10	
5 UTC	28 (-2)	26 (-3)	29.96	NE 10	-SN
6 UTC	26 (-3)	24 (-4)	29.96	ENE 8	SN
7 UTC	24 (-4)	24 (-4)	29.95	E 10	SN
8 UTC	24 (-4)	24 (-4)	29.93	ENE 13	+SN
9 UTC	21 (-6)	21 (-6)	29.93	ENE 8	-SN
10 UTC	21 (-6)	19 (-7)	29.94	NE 13	-SN
11 UTC	19 (-7)	17 (-7)	29.97	N 13	-SN
12 UTC	19 (-7)	14 (-10)	30.00	N5	-SN

At the surface (Fig 3), a dewpoint maximum extended from the Savannah River valley, across the Upstate and into the North Carolina Foothills. This moisture axis is a fairly typical feature that forms down shear of the higher elevations of the Appalachians as surface fronts have a difficult time making over the higher elevations of the southern Appalachians (ref paper). In fact, there has been at least one other "surprise" heavy snow event in recent years where this moisture axis played a part (ref Morristown paper).

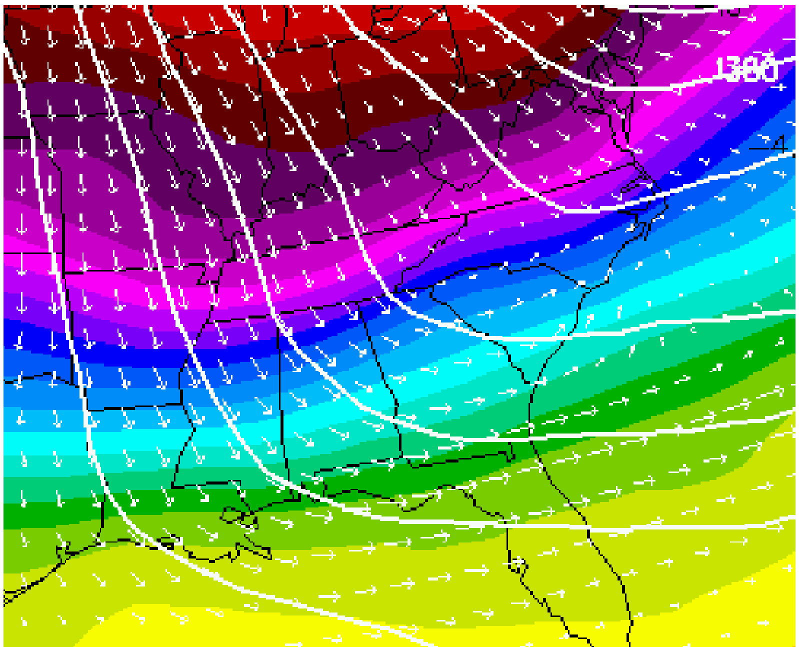

Figure 4: 0600 UTC 23 January 2003 Canadian GEM 850 mb winds, heights and temperature (color-filled).

As surface pressures fell ahead of the advancing area of upper divergence, low pressure developed in the lee. In fact, through about the lowest 5kft of the atmosphere in the lee, winds backed in advance of the upper low. This can be see in Figure 4, an 850 mb plot of winds and temperatures, taken from the Canadian model, valid at 0600 UTC, 23 January. This resulted in an area of tight temperature packing in the lee along the developing dilatation axis.

Table 1 shows conditions reported at the Hickory Regional airport during the early morning hours of the 23rd. Snow began in the northern part of the CWA around 10 pm. As the night progressed, the area of moderate to heavy snow (the data in table 1 does not do justice to the several hours of heavy snow reported at many locations) gradually developed to the south southwest, along the surface trough. Notice that the surface winds are northeast for almost the entire duration of the snow event. Toward the end, the flow turns more northerly as the cold air finally enters the region. However, farther south, this took even longer to occur.

III. Numerical Model and GSP Forecast Performance

There was little expectation by the forecasters at GSP of heavy snow in the lee in the days leading up to the event. Nor was the event well anticipated by NCEP, surrounding offices or local television meteorologists. However, by the day before the event, forecasters at GSP, as well as those involved in various chat sessions and conference calls recognized that some snow would fall in the lee. HPC, in the WWE conference call that morning, painted a bulls-eye of heavy snow across the northern part of the upstate and the southern and central North Carolina Mountains.

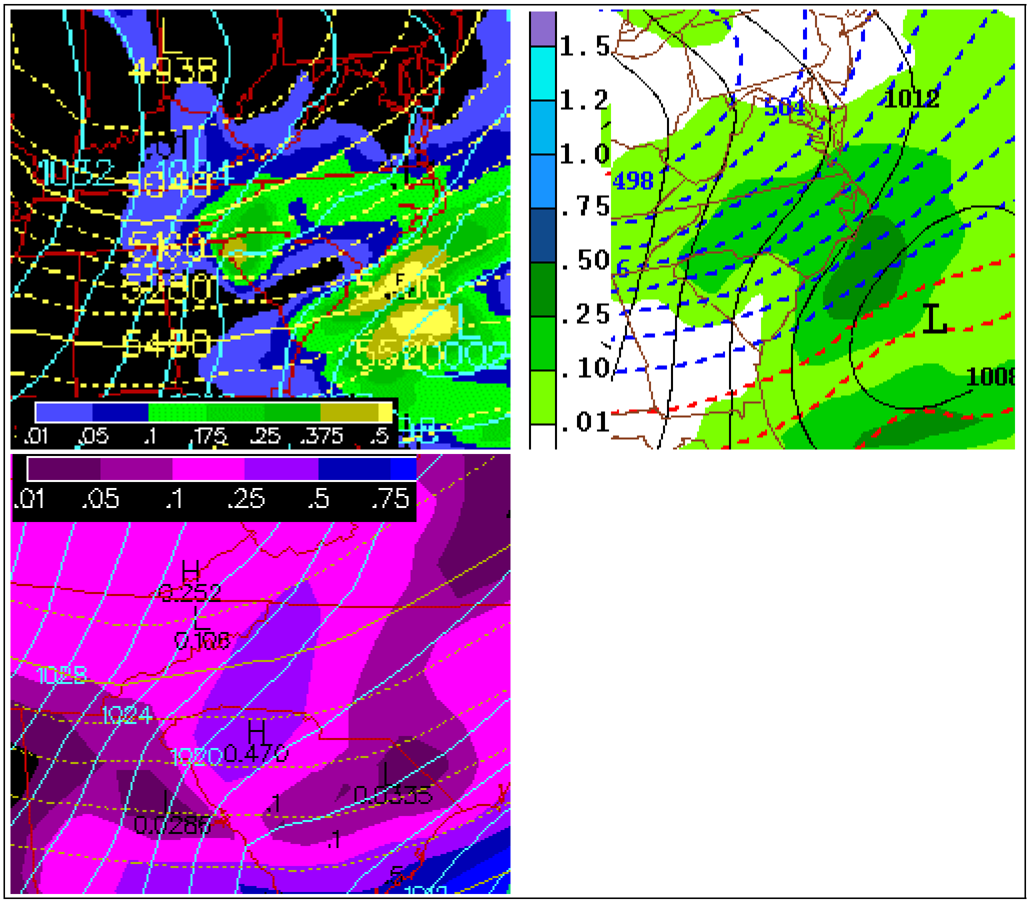

Figure 5: 12 hour QPF from the Eta, AVN and GEM models, ending at 1200 UTC 23 January 2002.

Unfortunately, as of this writing, it has not yet been possible to access high-resolution data saved from this event. Thus, many of these observations are taken from memory and what images we were able to save and retrieve from Internet based archives.

The HPC and locally collaborated forecast matched up well with the Eta's UVV and QPF bulls-eye as seen in Figure 5. Unfortunately, this area actually experienced a precipitation minimum. For example, Anderson, SC, near the center of the Eta's heavy precipitation bulls-eye, where 0.50 inches of liquid was forecast (nearly all in the form of snow), had only 0.07 inches of precipitation, most of it falling as rain. The Asheville airport, an area nearly at the center of HPC's snow max, had only .06" liquid, with around an inch of snow.

For several runs before the event, the Eta generated this rather heavy QPF bull's-eye in the lee. Run to run, these bull's-eyes of predominately convective precipitation would shift position and were generally in an area that received relatively little snow. Figure 5 shows the Eta, GFS and Regional GEM model QPF's from the 12 UTC runs on the 22nd, valid at 12 UTC on the 23rd.

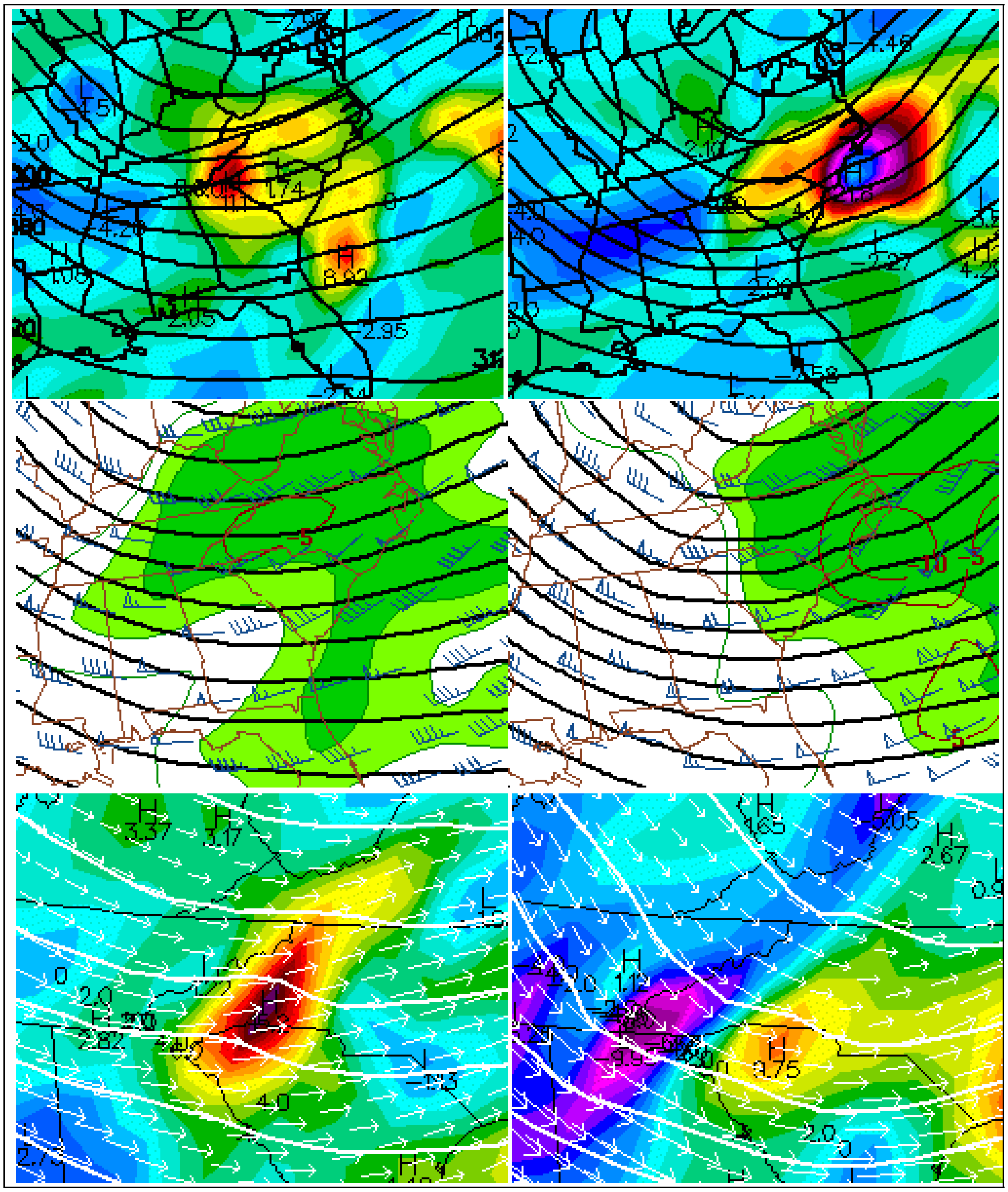

Figure 6: 700 mb heights, winds and UVV (color-filled) from the Eta, GFS and Canadian GEM valid at 0600 UTC (left) and 1200 UTC (right) 23 January 2003.

In short, the Eta had the right idea, it was just too far to the southwest, and likely was generating precipitation in a purely convective manner, not resolving the hybrid nature of the event. The GFS did not produce this area of convective precipitation. Instead, it produced widespread, lighter QPF across much of western North Carolina and Virginia. Interestingly, the model that seemed to handle the event best was the Canadian model. We have noticed several times in recent years the Canadian regional model has been one of the most consistent and accurate models when it comes to wintry weather in the western Carolinas and northeast Georgia.

4. Discussion

It is strongly suspected that the backed surface to 850 mb winds in the lee that morning resulted in an area of increased frontogenetical forcing. The 12 km Eta 850 mb winds were even more strongly backed than those in Fig 4. However, archive data from this event has not yet been reviewed. Figure 6, a composite of the Eta, GFS and Canadian models 700 mb UVV's at 0600 and 1200 UTC further supports this idea. Notice the strong UVV's on the Eta and in particular the Canadian oriented along the low level front. In the GFS, this forcing was essentially absent, and the QPF was much lighter. Essentially, the GFS QPF reflected precipitation amounts one would expect in the exit region of a strong jet without any mesoscale enhancement.

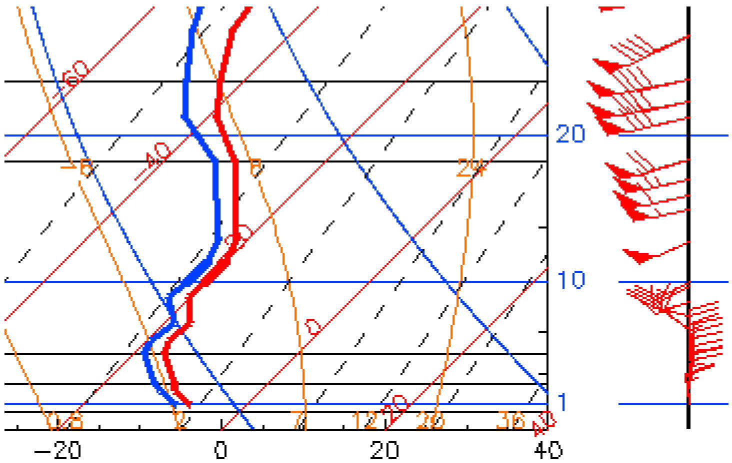

Figure 7: lower levels of the 1200 23 January 2003 GSO sounding

Protected to an extent from the advancing arctic air, temperatures and dewpoints stayed fairly high in the lee. Aloft, however, a significant cold front aloft crossed the region. The 0000 UTC 700 mb temperature at GSO was –7 deg C, while the 1200 UTC temperature fell to –20 deg C. Figure 7 shows the 1200 UTC GSO sounding. Note the nearly isothermal –20 deg C layer between 5 and 14 kft. During much of the period of heavy snow, Bufkit soundings (not shown) had temperatures in this layer close to –14 deg C, the optimal temperature for snow crystal growth. While this layer from 5 to 15 kft had shallow lapse rates, the lower levels had very steep lapse rates, the product of the CFA. Exactly what contribution these steep lapse rates made to the event are not known. However, as the event wound down, at least one snow band, with reflectivities in excess of 30 dBz, persisted as the other activity diminished. This band, responsible for several inches of snow in the northern part of the Upstate, looked very much like a lake effect snow band.

Another possible forcing mechanism for this event was upglide as the backed flow overran the northeasterly jet, which itself was an ageostrophic adjustment into the deepening surface low over the upstate. This would explain the snow shadow in the immediate lee of the mountains. Such a forcing mechanism is fairly common in the lee of the Rockies, but seldom has been observed here.

This was another case where the Canadian model was both consistent and accurate in its forecasts. Over the past several winters, the regional and global runs of the GEM have played an import part in many of our successful winter precipitation forecasts.