P2.9 THE OPERATIONAL IMPLICATIONS OF FORECASTING A HEAVY SNOW EVENT OVER THE CENTRAL ROCKIES IN AN ATYPICAL FLOW REGIME

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1. INTRODUCTION

A devastating snowstorm affected much of the central Rockies and adjacent plains during the period 16-20 March 2003 (Poulos et al. 2003; Shaw et al. 2003; Wesley et al. 2003). The greatest impact was over the Front Range of Colorado and southern Wyoming where heavy snow accumulations crippled travel for several days. Significant snowfall also occurred over the Grand Junction National Weather Forecast Office (GJT) county warning area (CWA) which includes western Colorado and eastern Utah. Surprisingly, a great deal of the precipitation which fell over the northern half of the GJT CWA occurred in fairly deep easterly flow. Easterly flow is typically not conducive for widespread heavy snowfall since it results in downslope conditions for a majority of this region. Total snow accumulations up to several feet fell over the area.

This study will examine the primary forcing mechanisms which focused heavy snowfall across the northern portion of the GJT CWA. It also will detail the benefits of augmenting the NCEP model suite with a local mesoscale model especially in complex terrain.

2. STORM OVERVIEW

A prolonged storm system affected much of the Rocky mountain region and High Plains during the period 16-20 March 2003. This slow moving system produced several feet of heavy wet snowfall along the urban corridor from Cheyenne Wyoming to Pueblo Colorado, with up to 200 cm of snowfall in some of the adjacent foothill locations. NCEP models did quite well with this event. These models were able to capture the large scale features of this storm, which enabled forecasters to give ample warning on the strength and duration of the event. Over western Colorado and eastern Utah,

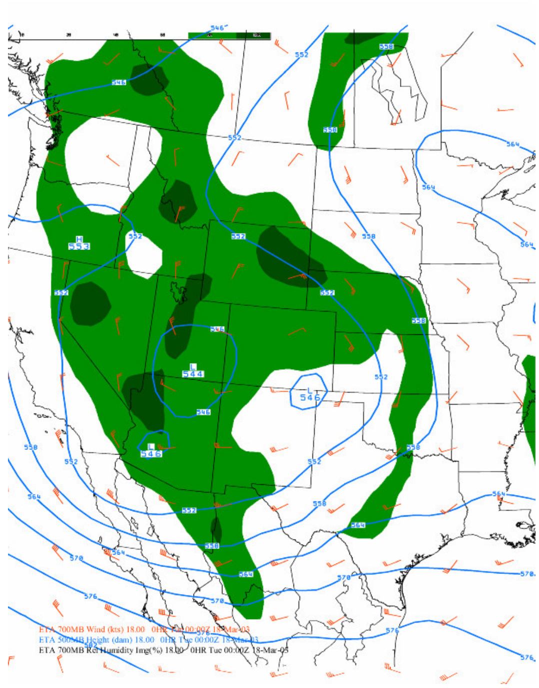

Figure 1. Eta analysis at 0000 UTC 18 March 2003. 500 hPa heights are indicated by solid lines. 700 hPa wind barbs (knots) and relative humidity (shaded >70%, and dark shade > 90%) is also shown.

a closer analysis of the storm showed that widespread precipitation did occur over much of the northern half of the CWA. However, the bulk of the snowfall occurred, primarily, between 0000 UTC 18 and 1200 UTC 18 March. Figure 1 shows a closed low over the Four Corners region by 0000 UTC 18 March, with another closed circulation developing over southeastern Colorado. A moist airmass existed across the Intermountain West, with nearly saturated conditions up to 300 hPa. The Grand Junction Colorado sounding also indicated an unstable environment with a Lifted Index of -2 at 0000 UTC 18 March. The environment was dominated by a deep easterly flow, which extended from 700 hPa through the 300 hPa level as indicated

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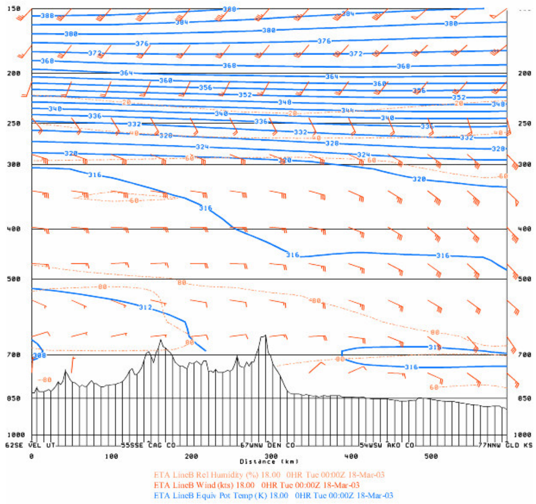

Figure 2. Eta east-west cross section at 0000 UTC 18 March across 39.3°N latitude. Equivalent Potential Temperature is indicated by solid blue lines (K). Relative humidity (%) is indicated by dotted orange lines. Wind barbs (knots) are also shown.

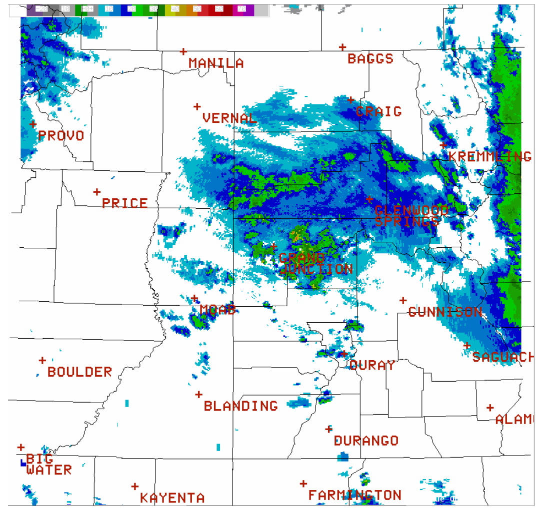

Figure 3. WSR-88D radar mosiac of the composite reflectivity at 0000 UTC 18 March 2003.

by the east-west cross section from the Eta analysis at 0000 UTC 18 March across central Colorado (Figure 2). Uplift generated by weak short waves moving east to west in the flow were evident in the Eta 12-h forecasts (not shown) valid at 0000 UTC. These forecasts also indicated low-level north winds moving in from Wyoming by the early morning hours of the 18th. This cold air would eventually play a major role in the snowfall distribution across the region. Heavy snowfall of 30 to 90 cm fell on the western slope of the Continental Divide of Colorado and as far west as the eastern Uinta mountains of northeastern Utah during this event. By 1200 UTC 18 March, the closed low deepened over northeast New Mexico. Snow intensity decreased across western Colorado and eastern Utah by the morning of the 18th, except in locations in close proximity to the Continental Divide.

3. FORECAST CHALLENGES

NCEP model guidance did quite well with the storm evolution and strength but did not handle the fine scale detail of the precipitation fields over this complex topographic region. Another complication for the GJT forecast staff was the fact that an easterly flow pattern is not usually conducive for heavy snow across this region. In typical situations, a westerly flow results in upslope flow for many of the mountain locations in the GJT CWA. To complicate the forecast process, precipitation detection by the WSR-88D was limited in many locations. The shallow nature of the wintertime precipitation resulted in overshooting the reflectivity cores along the periphery of the CWA. Beam blockage by mountains also made precipitation detection and strength quite difficult to ascertain over many locations. Figure 3 shows a mosaic of the Composite Reflectivity at 0000 UTC 18 March. The broad area of reflectivity is shown on the eastern boundary of the figure which is being detected by the radars on the Front Range. Another area of higher reflectivity is evident over western Colorado stretching from Ouray Colorado northwest to Vernal Utah. During this time, heavy snow was observed in the mountains south of Ouray, north of Vernal, and east of Glenwood Springs Colorado. However, the radar was not able to detect much of this precipitation.

3.1 Mesoscale Forecasts

To help resolve fine scale features across the region, the GJT forecasters had a "local mesoscale model" available for operational use, the Regional Atmospheric Modeling System (RAMS) (Cotton et al., 2003). Utilization of RAMS was part of a research effort between the NWS and Colorado State University (CSU) through the Cooperative Program for Operational Meteorology, Education and Training (COMET). RAMS has been run in a prototype forecasting mode over Colorado for winter seasons since 1991, and its current nested grid configuration (version 4.30) was run by CSU similar to that described by Meyers *et al.* (2001). The model for the present simulations

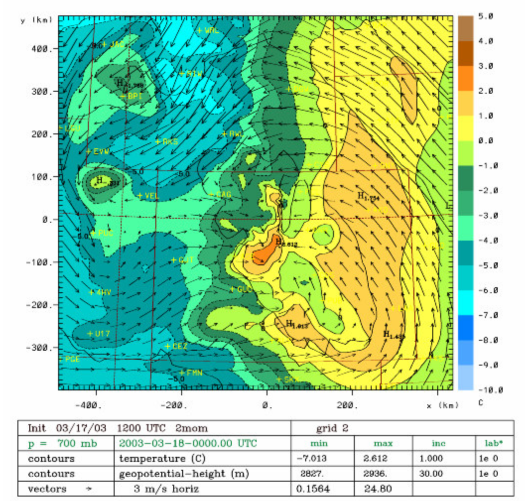

Figure 4 RAMS 12 hour forecast from 1200 UTC 17 March initialization, valid at 0000 UTC 18 March. 700 hPa temperatures are shown with dashed lines and shading. 700 hPa wind vectors are also indicated.

contained an outer domain at 48 km resolution, and two inner domains at 12 and 3 km horizontal grid resolution, respectively. The terrain-following sigma-z vertical coordinate system had 36 levels, with grid spacing stretching from <150 m near the surface to approximately 1000m at and above 9 km. The model used the two-moment, mixed-phased microphysical scheme described by Walko *et al.* (1995) and Meyers et al. (1997), with prognostic fields for cloud droplets, rain, pristine ice crystals, snow, aggregates, graupel and hail. Hydrometeor sizes were distributed according to a gamma function.

The RAMS forecast of winds and temperature is shown in Figure 4. With the increased spatial resolution in RAMS, the northerly surge of cold air across the western portion of GJT CWA is depicted more realistically than in the coarser NCEP models. With abundant moisture and adequate mid-level dynamical support, this cold surge was the necessary ingredient to precondition the lower troposphere for heavy snow. As cold air spread and deepened across western Colorado and eastern Utah, the easterly flow was lifted isentropically producing the heavy snow. The RAMS 24-h precipitation forecast is shown in Figure 5. RAMS did a fairly good job detailing the spatial and temporal distribution of precipitation, however, it tended to over-predict precipitation amounts, especially near the Continental Divide. The precipitation forecasts showed a broad area of 1.0-2.0 cm across northwestern Colorado and northeastern Utah. Peak values of 5-6 cm were also found in the

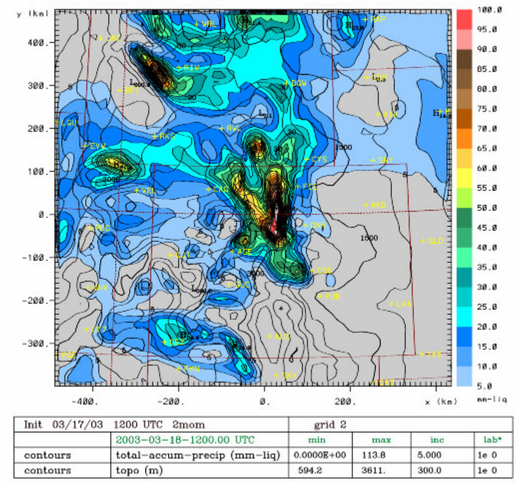

Figure 5 RAMS 24-h precipitation forecast from 1200 UTC 17 March initialization, valid at 1200 UTC 18 March. Accumulated precipitation is shaded. Topography (m) is also indicated by solid lines.

eastern Uinta mountains of Utah and along the Continental Divide.

3.2 Operational Forecasts

In spite of some of the forecast challenges for this storm, the GJT staff was able to give adequate warning for most locations in western Colorado and eastern Utah. "Winter storm warnings" (25 to 50 cm of snowfall) were issued for many mountain locations with many valley locations upgraded to a "winter weather advisory" (13 to 25 cm) by the afternoon forecast on the 17^{th} of March. Most of these forecasts verified quite well, however, some isolated outliers had over 60 cm of snowfall. The biggest problem area for this event occurred over the central mountains of Colorado near the towns of Aspen and Vail, which is east of Grand Junction, Colorado. In these locations, the forecasters expected less accumulation due to downslope conditions in the easterly flow, and less cold air to make it into the higher valleys. It should be noted that the RAMS forecasted 3-5 cm in this region. By 03 UTC 18 March, with heavy snow falling across the region, forecasters decided to upgrade to a winter storm warning (25 to 50 cm) for the central mountains of Colorado.

4. SUMMARY

A major snowstorm affected western Colorado and eastern Utah in predominately deep easterly flow on 17-18 March 2003. This direction of flow is usually not conducive for heavy snow over this region. A combination of factors: 1) a very moist unstable airmass, 2) a low level northerly flow which allowed colder air to move south across the area, and 3) mid-level uplift generated by embedded short waves in the easterly flow, were the key ingredients for heavy snow across the area. NCEP models did an excellent job with the large scale forcing, and an operational version of the mesocale model RAMS provided more detailed forecasts of the cold surge and the resultant precipitation distribution for the storm.

5. ACKNOWLEDGEMENTS

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