CRH SSD
JANUARY 1993

CENTRAL REGION TECHNICAL ATTACHMENT 93-01

THE FRONT RANGE/PALMER DIVIDE BLIZZARD OF 7 JANUARY 1992

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1. Introduction

A moderate intensity blizzard struck the eastern edge of the Colorado Front Range and northeast Palmer Divide on 7 January 1992. The storm produced up to 22 inches of snow with three to six foot drifts (including 14 inches of snow in twenty-four hours at the Weather Service Forecast Office in Denver (WSFO DEN), a record for January). This was a result of a rapidly intensifying eastward moving cyclone. Blizzard conditions were most pronounced in a 30 to 40 mile wide band, mainly east of Interstate 25 from the Wyoming border south to the Palmer Divide (Figure 1).

This storm also caused heavy snow in the Four Corners area on the 6th, and the Colorado mountains on the 6th and 7th. Widespread heavy snow on the 6th amounted to between three and eight inches in the Four Corners. Two day snowfall totals for the mountains ranged from 12 to 18 inches in the Southwest Mountains and between 8 and 25 inches in the Northern and Central Mountains.

This storm provided an excellent opportunity for forecasters at WSFO Denver to use the Denver AWIPS Risk Reduction and Requirements Evaluation (DARE) workstation to its fullest diagnostic and forecasting capacities. The DARE workstation is the functional prototype AWIPS workstation. Forecasters at Denver have been using this system exclusively in the routine preparation of forecasts and warnings for nearly three years.

Interestingly, with the new ease of higher resolution diagnosis, there has also begun a revival, of sorts, of the science of meteorology. For example, no longer is 500 mb height and vorticity acceptable to determine atmospheric vertical motion. Rather, a more complete application of quasi-geostrophic theory has taken its place. In the same way, mean relative humidity fields are being used less now than fields such as specific humidity and condensation pressure deficit at specific isobaric and isentropic levels. Stability indices are no longer as revered as are detailed analyses and forecasts of lapse rates.

The addition of a tremendous number of varied and complex forecast and analysis products has also brought a search for simplicity. Foremost, the forecasters at Denver have come to focus on the question, "Will there be upward vertical motion?". This then leads to a search for the intensity, location and timing of the lift, and furthermore a determination of the moisture and thermal structure of the atmosphere. With the help of the DARE system, we will analyze the 7 January 1992 blizzard as pertains to these elements.

2. Meteorology

A. Circulation and Stability

A closed circulation center, and associated cold pool south of the center, moved into northwest California on Sunday evening 5 January 1992. The circulation remained nearly closed as it moved across the Great Basin on the 6th. Heavy mountain snows over the Sierras and parts of the Great Basin spread into western Colorado by late afternoon on the 6th associated with strong negative Q-vector divergence (or Q-vector convergence). This upward forcing was a result of geostrophic frontogenesis. The Grand Junction, CO (GJT) sounding from 12 UTC 6 January 1992 indicated a 700-500 mb lapse rate near 8 degrees C/km (approximately psuedo adiabatic) and a 700-500 mb temperature difference around 20 degrees C (Fig. 2).

As specific humidity increased, a number of thundersnowstorms occurred that afternoon and evening in the Four Corners area and adjacent Southwest Mountains. The 12 UTC 6 January 1992 DEN sounding indicated stability similar to GJT with a 700-500 mb lapse rate near 8 degrees C/km. This moist adiabatic air over northeast Colorado remained in place through the night of the 6th even as specific humidity rapidly increased with the help of a 40 to 50 kt southerly jet apparent from the Granada, CO (GDA) profiler.

B. Pressure Falls

As the cyclone center crossed into central Colorado on the 7th, surface pressure falls on the order of 8 to 10 mb were measured at both Pueblo, CO (PUB) and DEN in a 12 to 15 hour period. The cyclone center rapidly intensified over east-central Colorado and became vertically stacked by 19 UTC on the 7th with the surface low of 993.5 mb centered between Limon, CO (LIC) and Goodland, KS (GLD). The development of deep north to northeast winds over northeastern Colorado resulted in strong isentropic upglide by 12 UTC as well. This upglide, as forecast by the Mesoscale Analysis and Prediction System (MAPS) (Benjamin et al. 1991), was to last the entire day.

C. Confluence and Convergence

The MAPS 00 UTC model run on the 7th indicated moderate 700 mb deformation (implying confluence) over west-central and southwest Colorado associated with the main dynamic forcing. This area shifted steadily to the Front Range and strengthened significantly by 15 UTC of the 7th (Fig. 3). This deformation field was frontogenetic. A MAPS analysis valid at 15 UTC of the 7th showed massive 700 mb convergence of 7 to $10x10^{-5}$ s^{-1} centered over the northern Front Range. Thus, both confluence and convergence occurred simultaneously in this instance. Meanwhile, a 70 kt plus jet core at 400-500 mb rotated out of New Mexico and across the Texas panhandle placing northeast Colorado in the cyclonic exit region aloft, which indeed corresponded with a divergence lobe at 400 mb, according to MAPS. In addition, NGM Q-vector divergence fields implied an area of deep synoptic-scale forcing for upward vertical motion over northeast Colorado.

D. Front Range Heavy Snow Band

The question arose in our minds whether the 30 to 40 mile wide heavy snow band was a result of cold air damming and, consequently, a barrier jet along the Front Range. After later analyses, we think more likely the focused heavy snow was due to strong convergence in a baroclinic zone caused by the storm systems tilt with height early on the 7th and resulting frontogenetically forced ageostrophic circulation. By late on the 7th, the system became vertically stacked, easing the convergence, and hence the heavy snow.

Development of the strong surface low, in east-central Colorado early on the 7th, caused strong north to northwest (apparent downslope) winds to develop. Most of the area immediately adjacent to the foothills, with the exception of the Fort Collins, Colorado (FCL) area, did not receive heavy snowfall because of this flow. The system's tilt to the south southwest with height was such that easterly winds increased above the low level flow, or from about 550 mb to 250 mb (Fig. 4). This appeared to cause strong deep convergence mostly from 20 to 50 miles east of the Front Range as well as a strong 40 kt plus low level jet oriented north-northwest to south-southeast through the heavy snow band. The verticality of the system after 19 UTC is implied by the deep northerly winds, reaching the surface at 30 to 45 kts as the lower level pressure gradient increased.

Blizzard conditions became most pronounced after this time, even though the heaviest snow had ended. The blizzard ended by

04 UTC 8 January as the cyclone moved far enough into Nebraska to lessen gradient winds over eastern Colorado.

The Platteville profiler seemed to suggest a barrier jet, but the strong easterly flow was never indicated below 550 mb. The Front Range peaks are near 600 mb. This is not to say a bubble of cold air did not dam aloft (mesonet data never showed surface damming) and add convergence to some extent. The low level jet considerations may also help explain the lack of snow to the west (right exit region divergence) and abundance to the east (left exit region convergence). But if so, we were not able to diagnose either feature from the MAPS 60 km gridded data.

E. Models

The 120-hour MRF valid 00 UTC Tuesday 7 January 1992 indicated a closed surface low over eastern Colorado. Successive runs thereafter, however, including the early short range model runs, trended away from this scenario with a weaker, more open wave passing mainly north of Colorado. The location of leeside cyclogenesis is critical for forecasts of eastern Colorado weather. Typically, upslope precipitation occurs to the north of the low while westerly winds to the south and west of the low are downslope, occasionally at speeds requiring high wind warnings, and usually precipitation-free. Thus, the dilemma faced by the forecasters was to choose between dry downslope winds or heavy snow in the northeast. The 30-hour NGM forecast valid 18 UTC on the 7th started to show a reversal of the "open wave to the north" scenario but still indicated an open 700 mb trough with the center west of North Platte, NE (LBF).

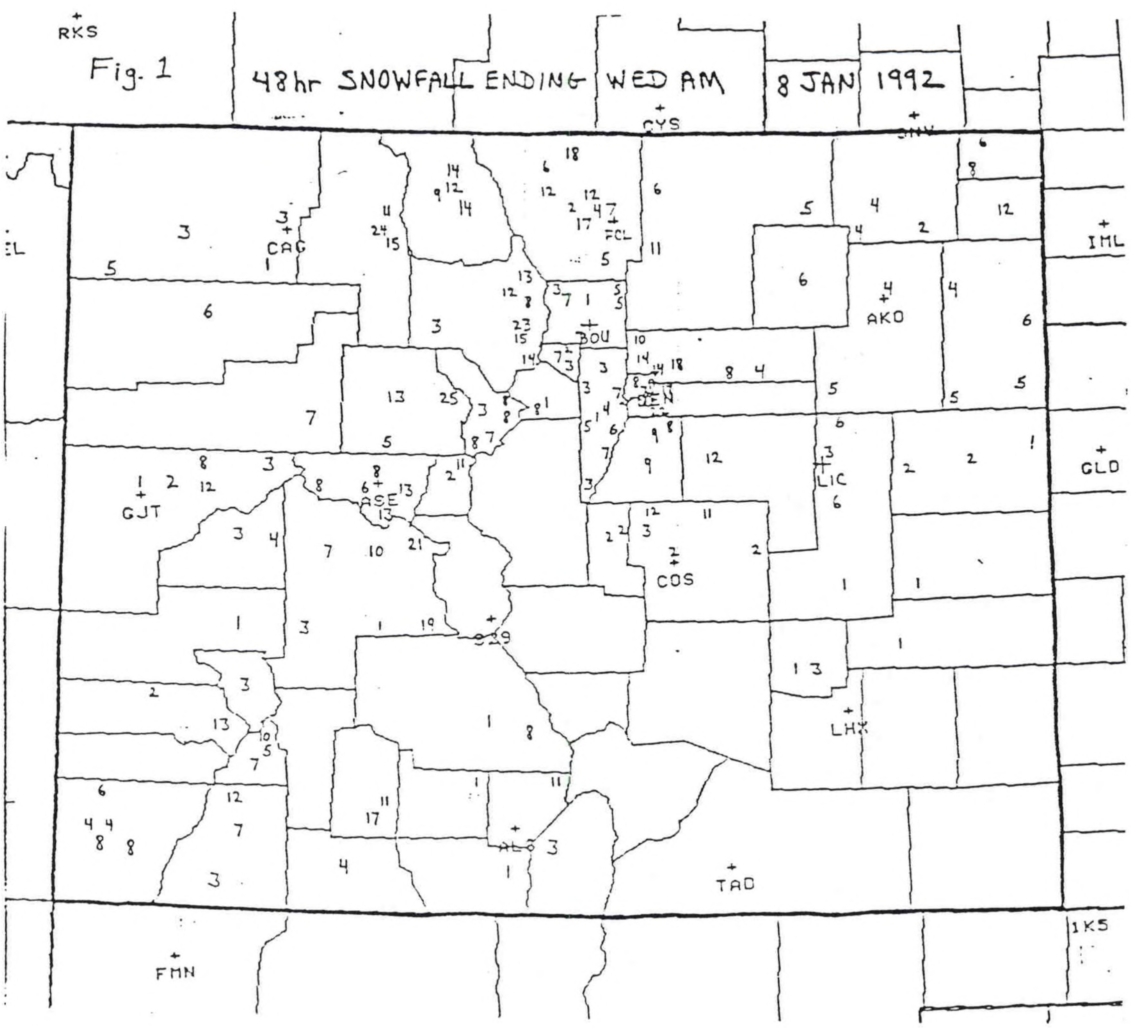
As it turned out, the actual 700 mb low was 50 to 60 meters lower and 175 miles to the south-southwest within a LIC-GLD-LHX triangle. Interestingly, the NGM 500-300 mb layer Q-vector divergence forecast valid from 12 UTC Tuesday to 06 UTC Wednesday indicated massive Q-vector convergence (implying forcing for upward vertical motion) across northeast Colorado (in spite of the height forecast problems) with strongest values centered at 18 UTC Tuesday (Figure 6). The point here is, that despite the new fields used in diagnosing and forecasting an event, the models still retain their flaws and biases, and these need to be evaluated as in the past.

3. Conclusion

Even though significant improvements to specifics of the forecast were made using various elements of the DARE system, especially the gridded fields of the NGM and MAPS, this complex storm illustrates the tremendous difficulty in trying to think in the four dimensions (three spatial plus time). We are learning a great deal from evaluations, such as this, which have led to better application of the science of meteorology. We expect, with time and experience, to see more dramatic improvements in forecasts.

4. REFERENCE

Benjamin, S.G., K.A. Brewster, R. Brummer, B.F. Jewett, T.W.Schlatter, T.L. Smith, and P.A. Stamus, 1989: "An Isentropic Three-Hourly Data Assimilation System Using ACARS Aircraft Observations", *Mon. Wea. Rev.* 119, 888-906.



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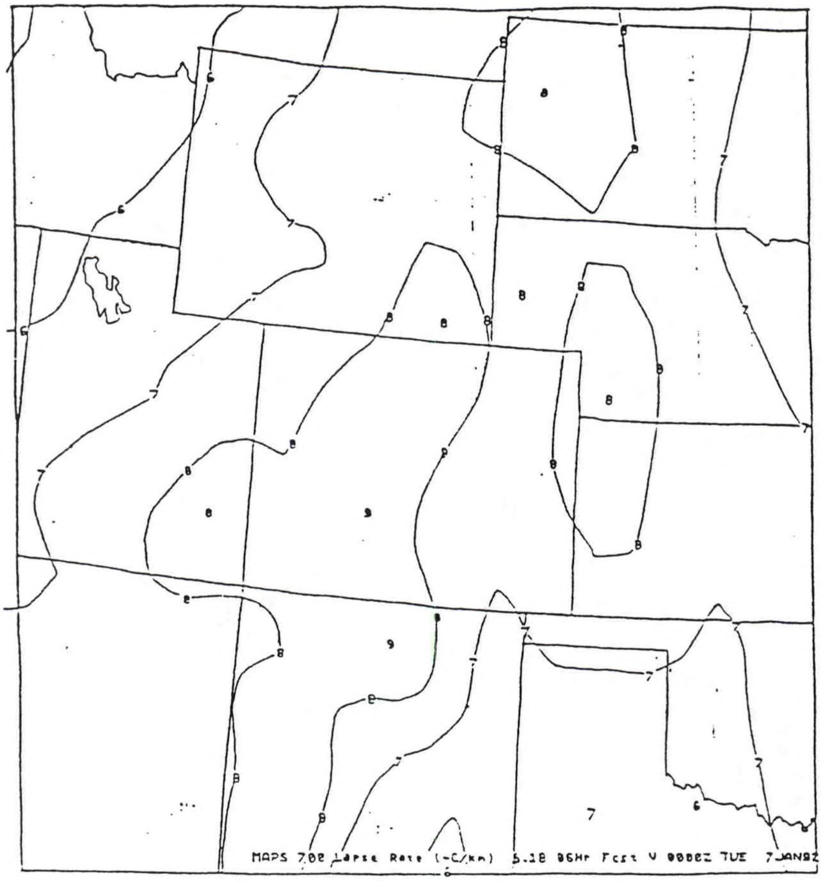

Figure 2. MAPS 700 mb lapse rates,
06 hr forecast valid 00 UTC 7 Jan 1992.

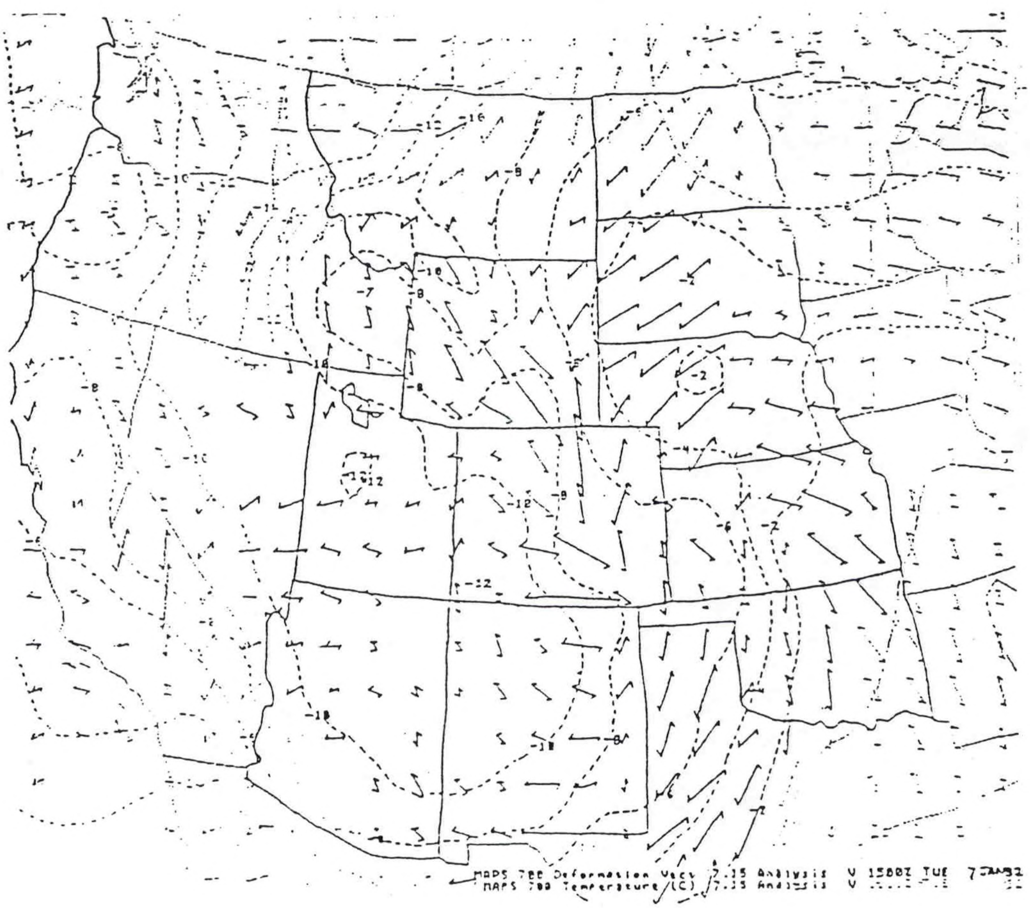

Figure 3. MAPS 700 mb deformation vectors and temperature,
analysis 15 UTC 7 Jan 1992.

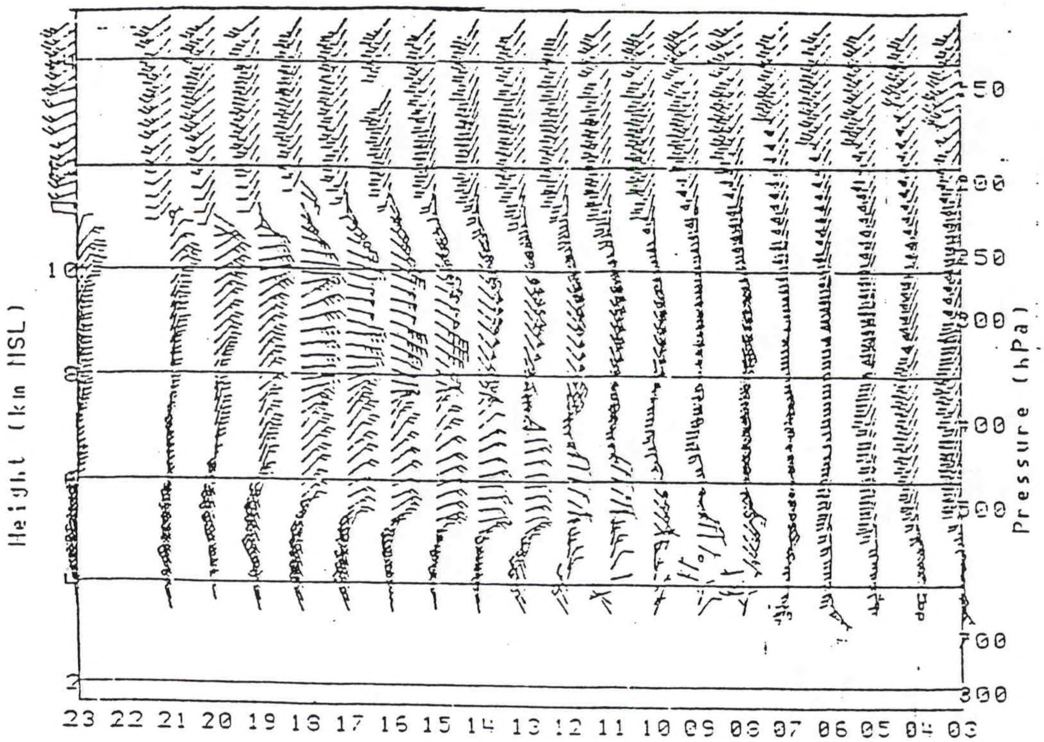

Figure 4. Platteville, CO profiler, 03 UTC to 23 UTC 7 Jan 1992.

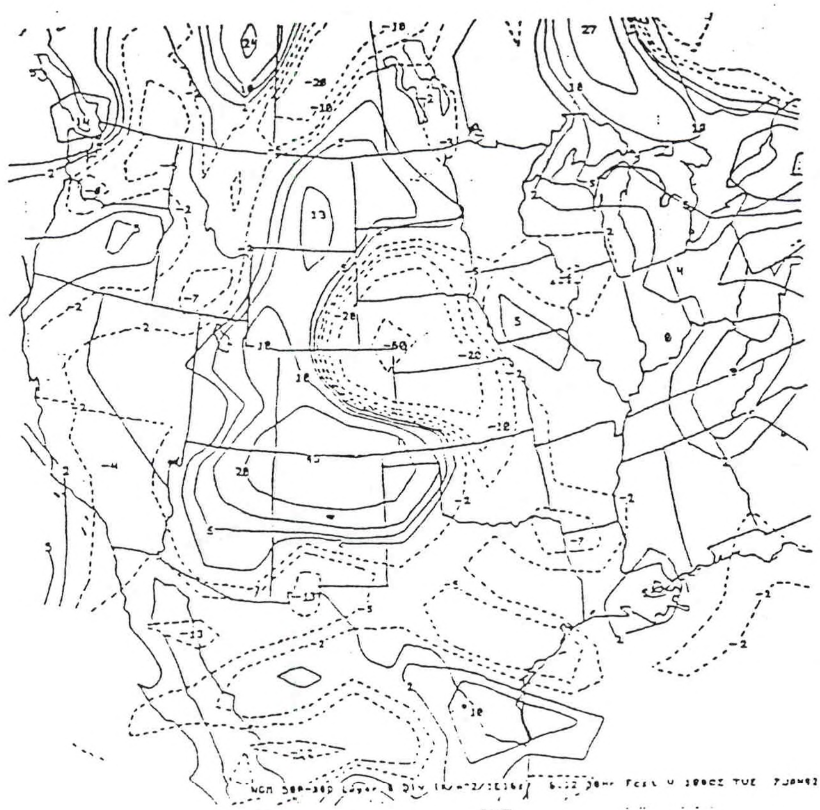

Figure 5. NGM 500-300 mb layer Q-vector divergence, 30 hr forecast valid 18 UTC 7 Jan 1992.