8.2 ANALYSIS OF THE TEXAS NORTHER: CASE STUDY

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1. INTRODUCTION

The Texas Norther, according to the Glossary of Meteorology (2001), is "... a cold air outbreak associated with the southward movement of a cold anticyclone ... [which comes as] ... a rushing blast and brings a sudden drop of temperature of as much as 25 °F in one hour..." During the Spring of 2003, there were several Texas Northers in the U.S. One of these cases is detailed here using observations and mesoscale model output from both the Penn State/NCAR Mesoscale Model, version 5 (MM5) and the National Centers for Environmental Prediction (NCEP) Eta model.

On March 5, 2003, Wichita Falls, TX, recorded a temperature change of 11 °C in one hour, and a 24 °C over a time span of 6 hours, as the winds changed from southerly at 10 knots to northerly at 20 knots. The NCEP Eta model 24 hour temperature forecasts for the area near Wichita Falls, TX were in error by more than 10 °C.

2. MODEL CONFIGURATION

The MM5 was run for 36 hours of simulated time beginning at 12 UTC, March 4, 2003, using Eta Model, 90-km gridded output for boundary and initial conditions. The model was set up with 2 grids, as shown in Figs. 1 and 2. The outer grid had a 27 km grid size, and two-way interaction was used for the nested 9 km grid. Simple ice physics (Dudhia, 1989) was employed, the MRF boundary layer parameterization (Hong and Pan, 1996) produced the boundary layer fluxes, and the Grell convective scheme (Grell, 1993) was applied in both grids. The model was run with 34 sigma levels in the vertical, twelve of which were below 1.5 km to allow the model to resolve the shallow cold air associated with the norther.

The model output was produced at three hour intervals, and processed into GrADS format using a Unix script, (Grid Analysis and Display System – see http://grads.iges.org/grads for more details) .

3. OBSERVATIONAL OVERVIEW

3.1 *Synoptic-Scale Analyses*

At 15 UTC on the 4th, the leading edge of the cold air comprising the Norther (norther-front) stretched across Kansas towards the northwestern corner of the Texas Panhandle (see Fig. 3). A v-shaped area of low pressure was centered over the Texas Panhandle, forced largely by weak cyclonic vorticity advection from a vorticity maximum located over New Mexico (see Fig. 4). The location of the surface low, west of the region of greatest vorticity advection, suggests that the low may also be responding to lee cyclogenesis, especially given the zonal flow aloft.

By 00 UTC on the 5th, the surface low weakened, as the area of cyclonic vorticity advection moved to the northeast (see Figs. 5 and 6). The norther-front moved south into the central Texas Panhandle, as the cold air and high pressure built in behind it. Twelve hours later, by 12 UTC, March 5, the norther-front was in south-central Texas, and the temperatures had fallen 40 °F from their highs the evening before (see Fig. 7). The upper-level forcing from the vorticity maximum was now focused in the Midwest, and the associated surface low pressure region was in Ohio.

One way to judge the shallowness of the cold air behind the norther-front is to note that while the 850 hPa analysis at 00 UTC on the 5th (Fig. 8) shows a weak area of high pressure in western Nebraska, the 700 hPa map in Fig. 9 shows only pressure troughs in the area.

3.2 Surface Observations and MOS Forecasts

The hourly METAR surface temperatures and dewpoints from Wichita, KS and Wichita Falls, TX are shown in Figs. 10 and 11, along with the Model Output Statistics forecasts from the 00 UTC run of the Eta model. From the plots, it is easy to see how sharp the norther-front actually was. At Wichita, KS, the temperature fell over 10 °C in an hour, and over 15 °C in 3 hours at Wichita Falls, TX.

The MOS forecasts indicate that the forecasts were predicting the passage of a boundary. The wind shift (not shown) was well forecast, but the intensity of the cold air was seriously under-predicted. At Wichita, KS, the error at 00 UTC on the 5th (a 24-hour forecast) was 7 °C, while at Wichita Falls, TX, the error at 6 UTC on the 5th (a 30-hour forecast) was 10 °C.

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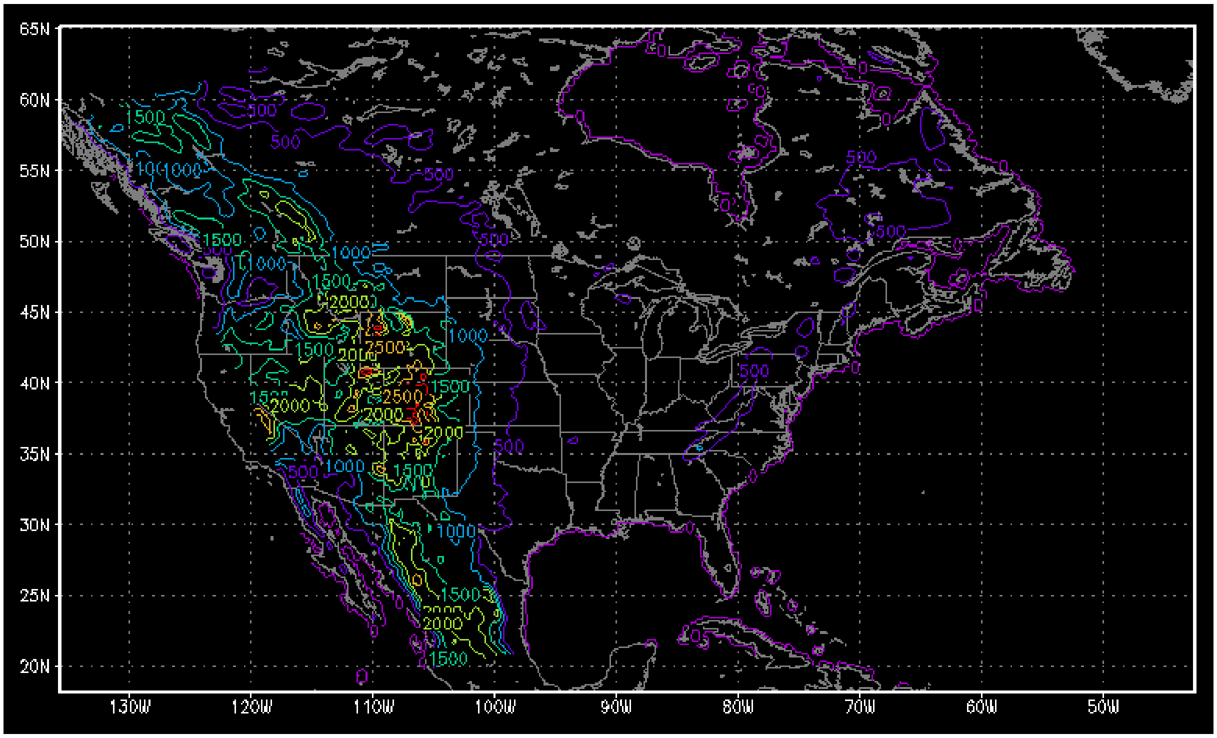

Figure 1. Map showing extent and location of the 27-km grid mentioned in the text.

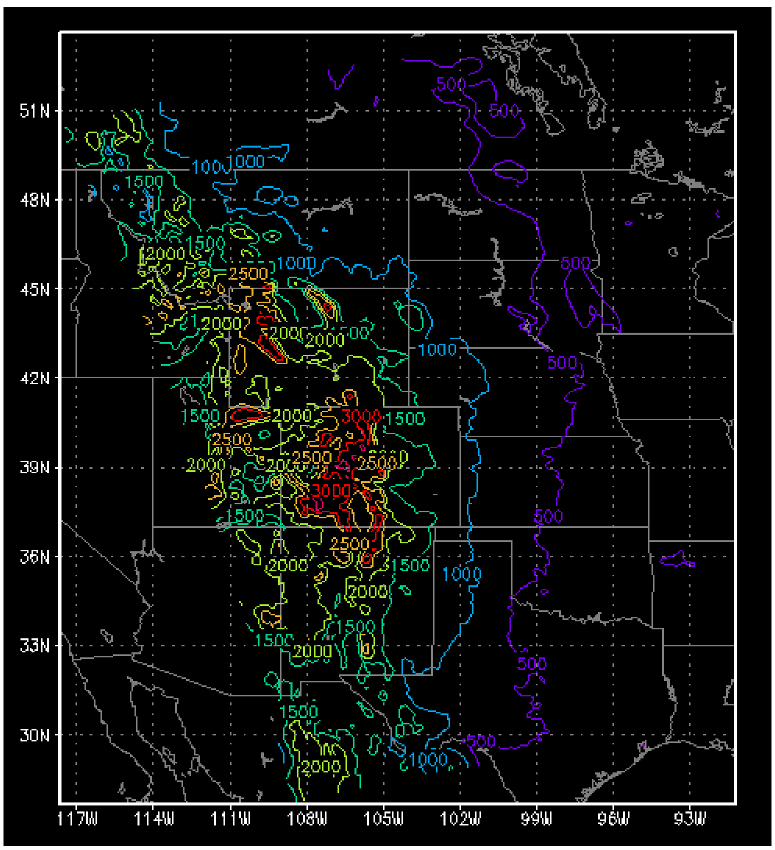

Figure 2. Map showing extent and location of the 9-km grid mentioned in the text.

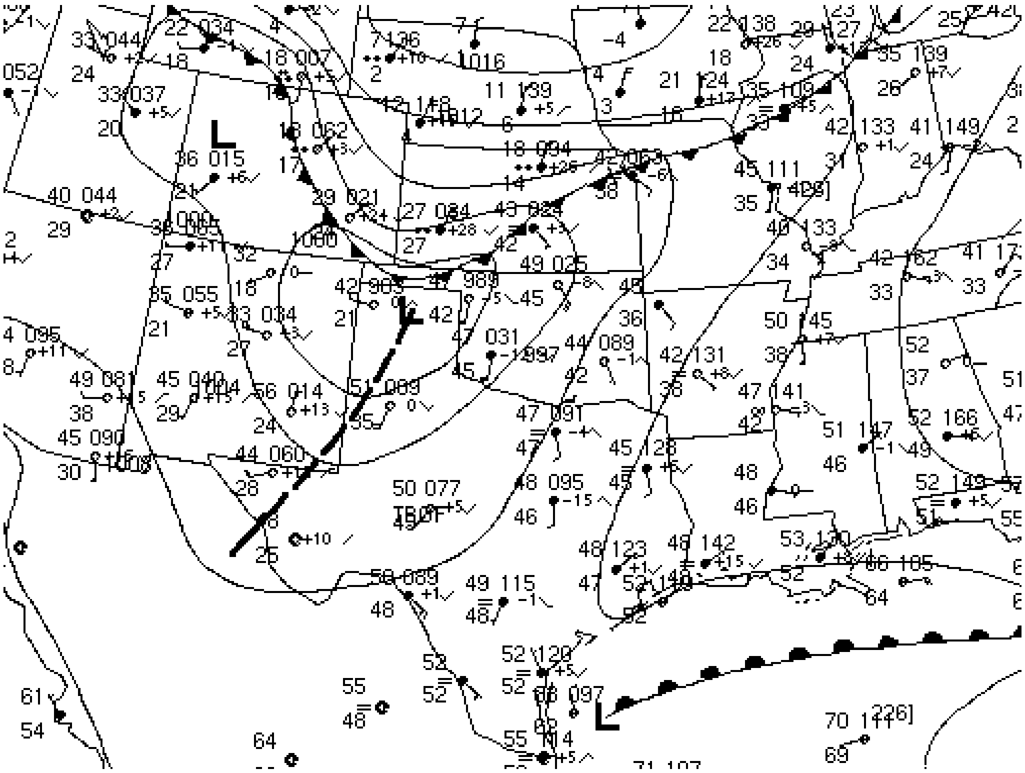

Figure 3. National Weather Service surface analysis for 15 UTC, 04 March 2003.

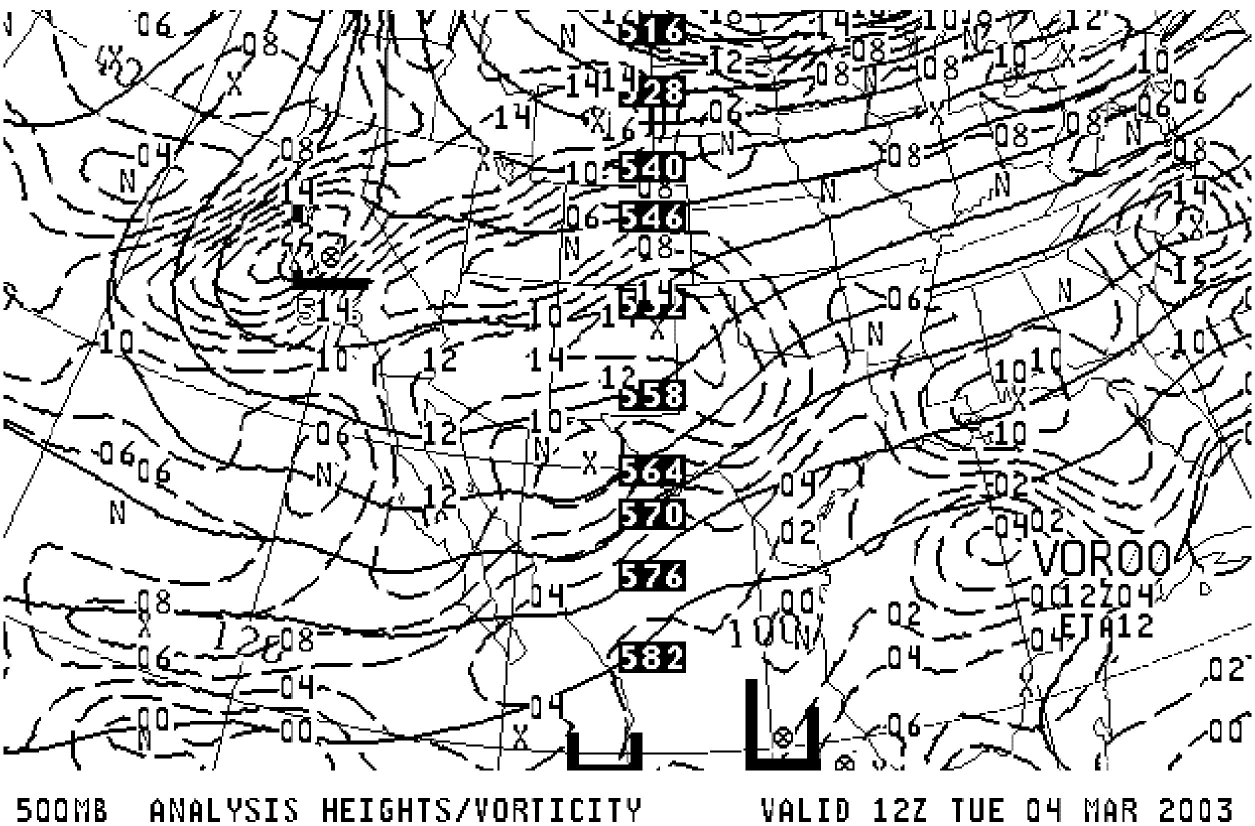

Figure 4. 500 hPa heights and absolute vorticity from initial analysis for Eta model run, valid 12 UTC, 04 March 2003.

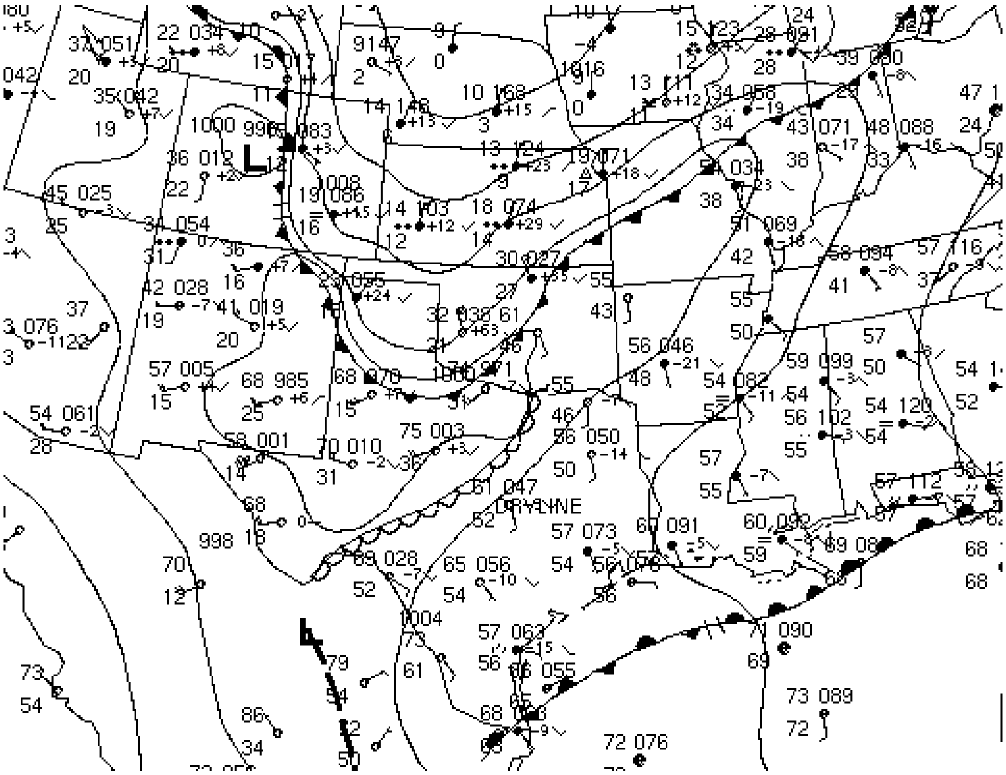

Figure 5. As in Fig. 3, except for 00 UTC, 05 March 2003.

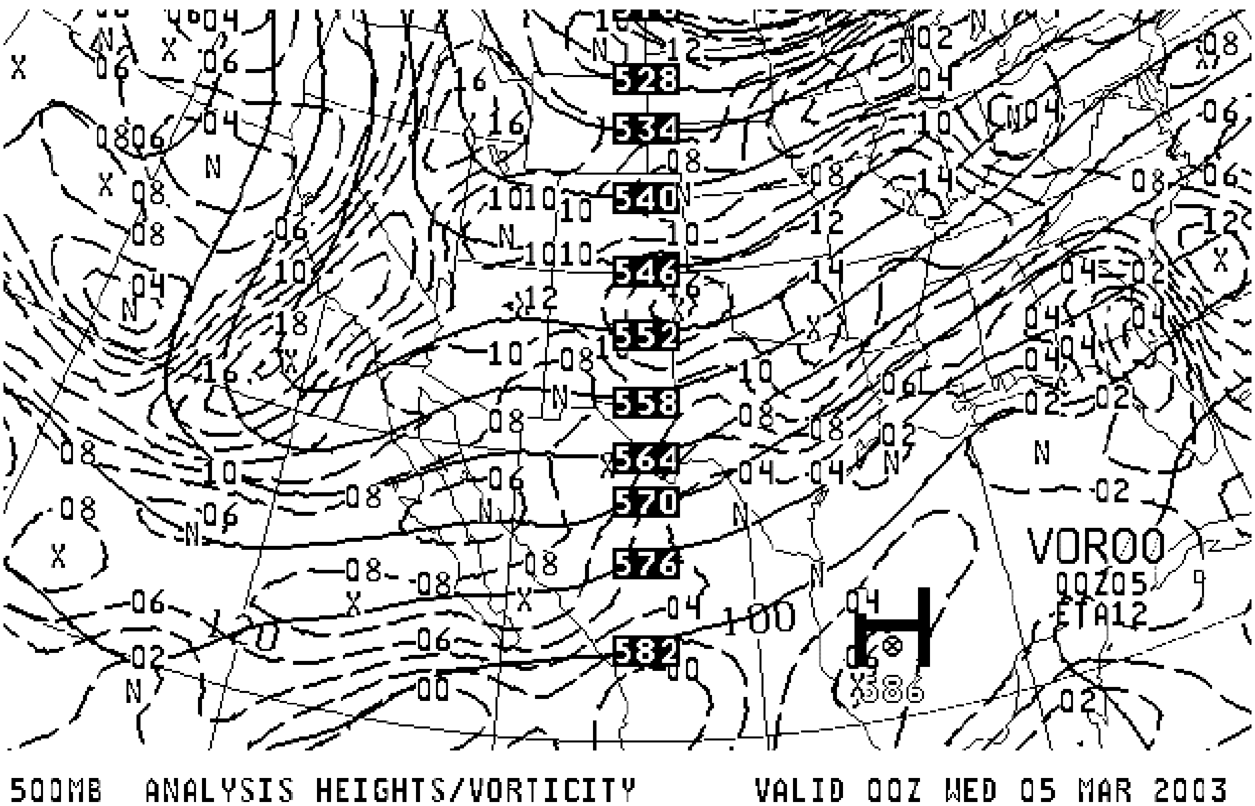

Figure 6. As in Fig. 4, except for 00 UTC, 05 March 2003.

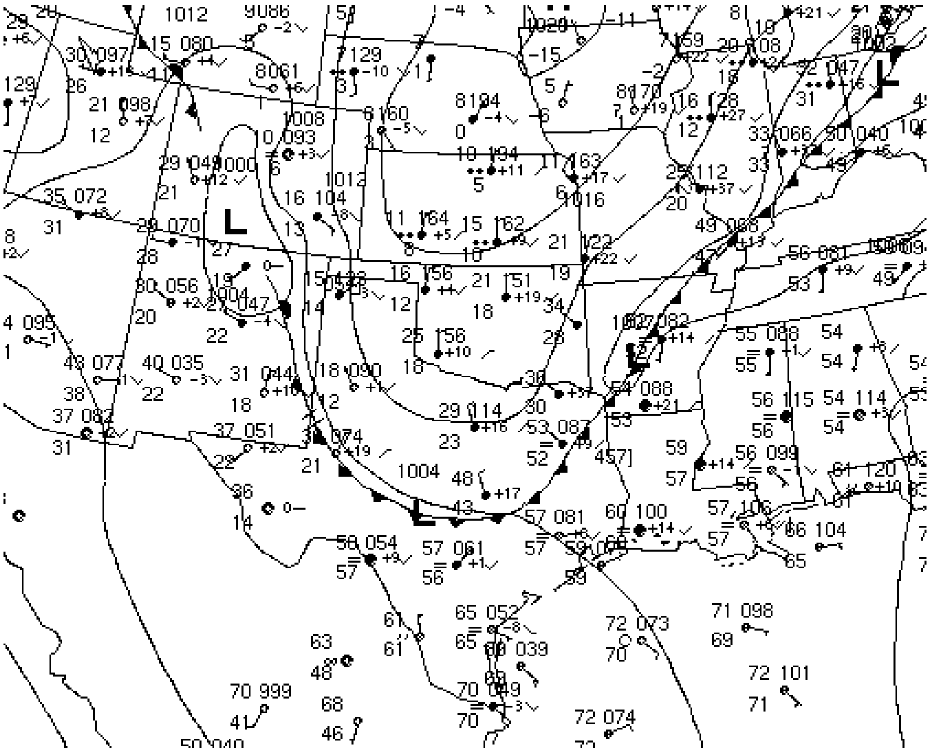

Figure 7. As in Fig. 3, except for 12 UTC, 05 March 2003.

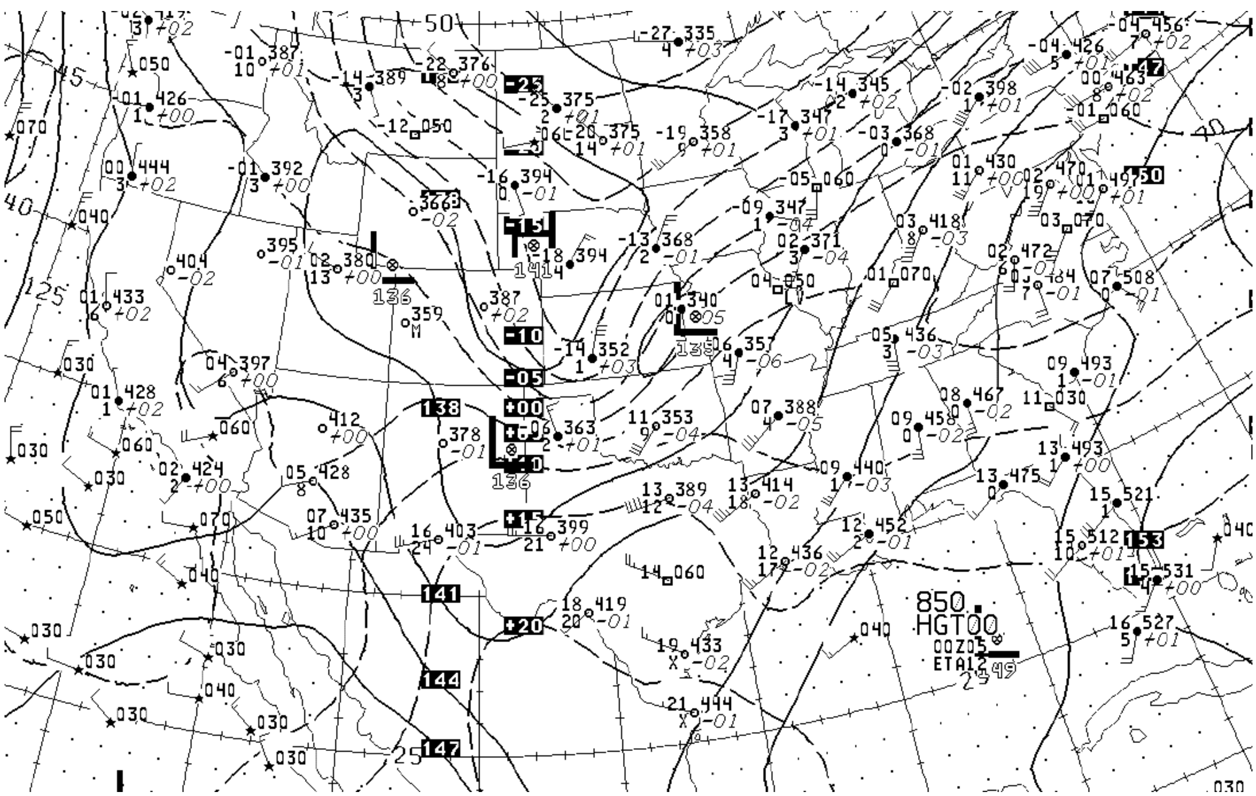

Figure 8. National Weather Service analysis at 850 hPa for 00 UTC, 05 March 2003.

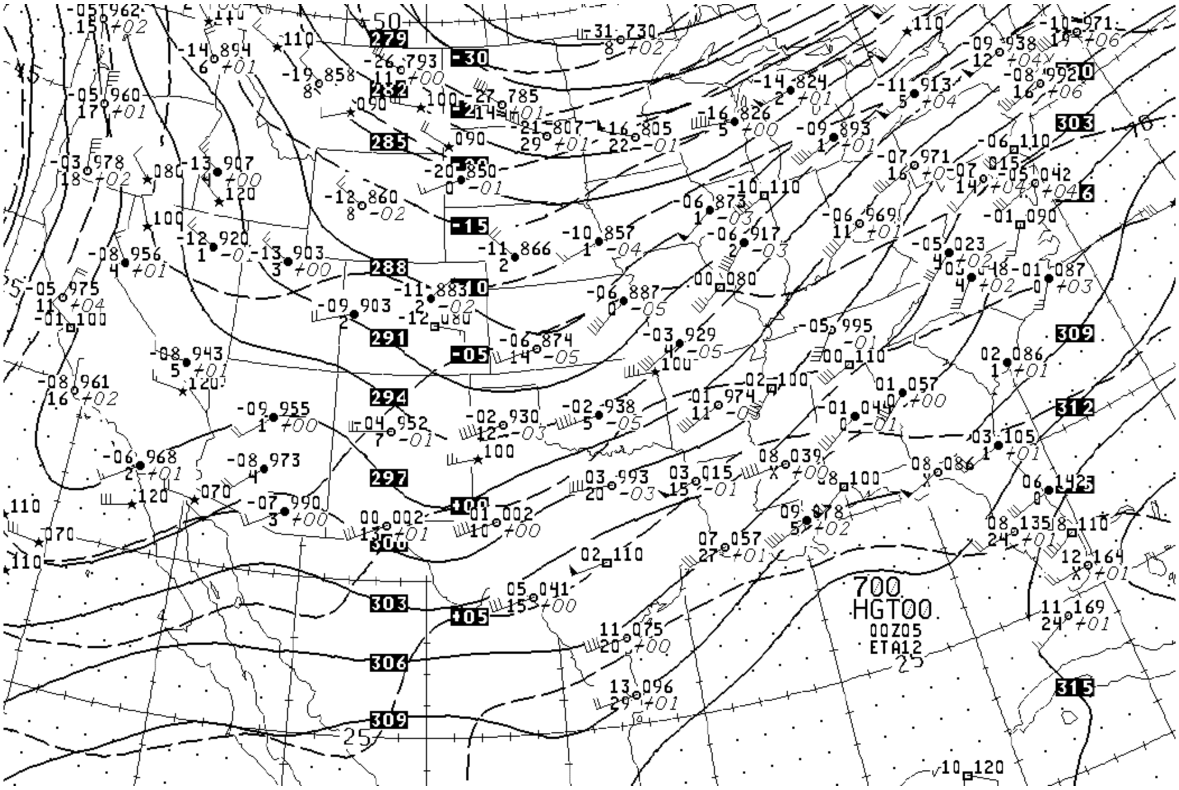

Figure 9. National Weather Service analysis at 700 hPa for 00 UTC, 05 March 2003.

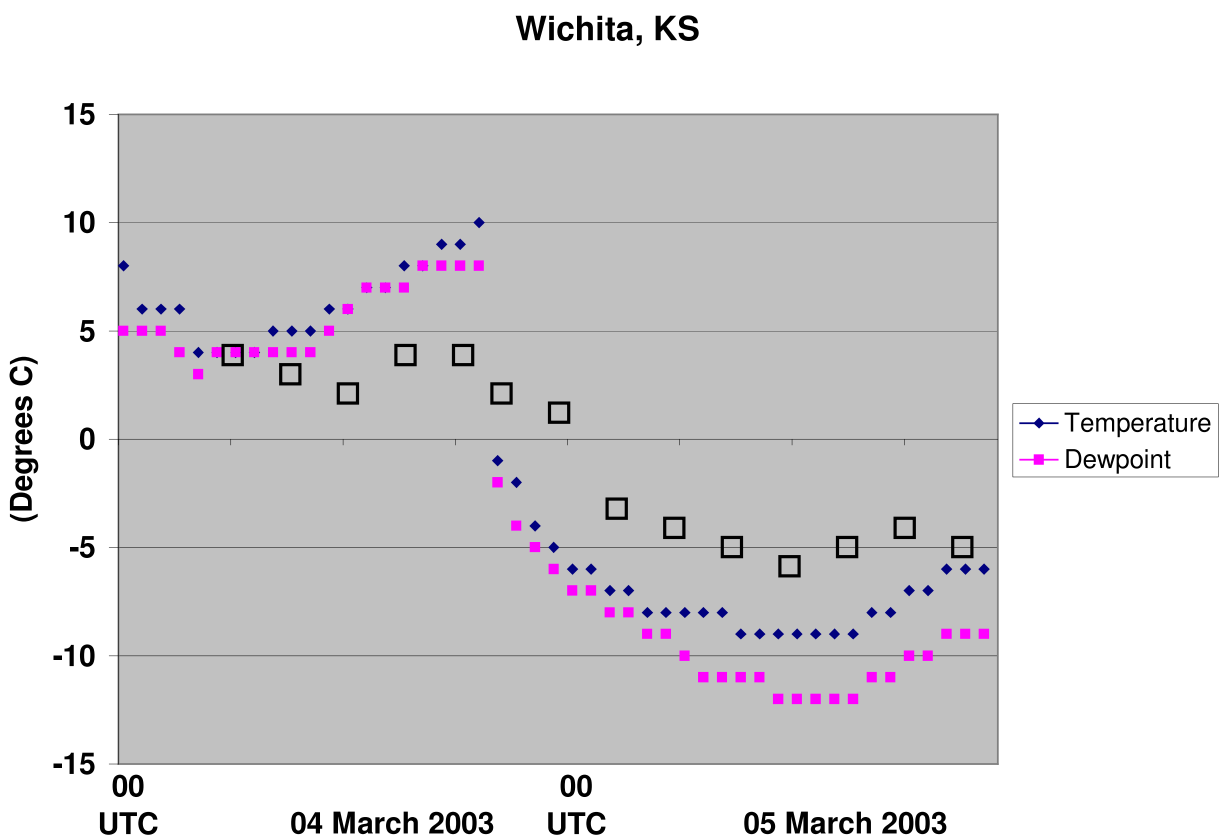

Figure 10. Graph of surface temperature and dewpoint for 45 hours beginning 00 UTC, 04 March 2003 at Wichita, KS. Tick marks along axis at 6 hour intervals. Squares show 00 UTC Eta MOS forecast.

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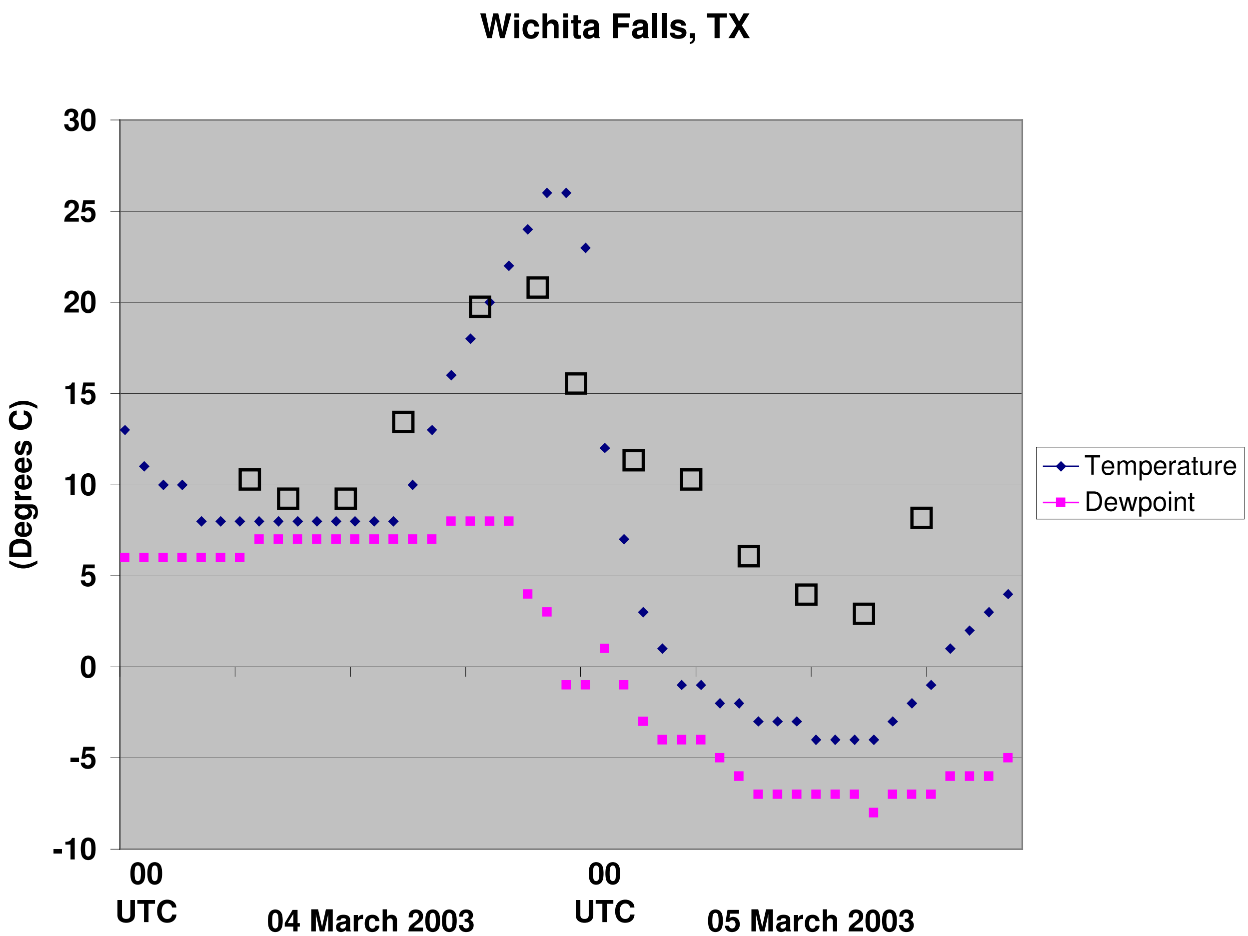

Figure 11. Graph of surface temperature and dewpoint for 45 hours beginning 00 UTC, 04 March 2003 at Wichita Falls, TX. Tick marks along axis at 6 hour intervals. Squares show 00 UTC Eta MOS forecast.

4. Model Simulations

The Eta model output for this case demonstrates the inability of a coarse-grid model to properly simulate the norther-front. Figure 12 shows the 18-hour Eta forecast for 18 UTC, 04 March 2003. The norther-front is clearly there, but much less intense than in reality. This output is on a 90 km grid, which limits the intensity of gradients. The structure of the wind field is essentially correct, however, with the winds blowing straight down the pressure gradient.

The output from the 27-km MM5 simulation appears in Fig. 13 for the same time. Notice how tight the temperature and pressure gradients are in this figure. Cross-sections taken across the norther-front for this time appear in Figs. 14 and 15 from the two models with the MM5 output taken from the 9-km grid. Again, the structure of the frontal boundary is washed out in the operational output from the Eta model. The same differences appear later on in the simulations. Figures 16 and 17 show the plan views six hours later.

The 9-km cross-sections from the MM5 simulations also show hints of wave-like undulations in the isentropes, as well as illustrating the boundary layer structure. The daytime mixed layer shows up very clearly in these cross-sections during the daylight hours, despite the much colder temperatures in this air mass. The presence of the waves along the top of the cold air are intriguing and merit further study.

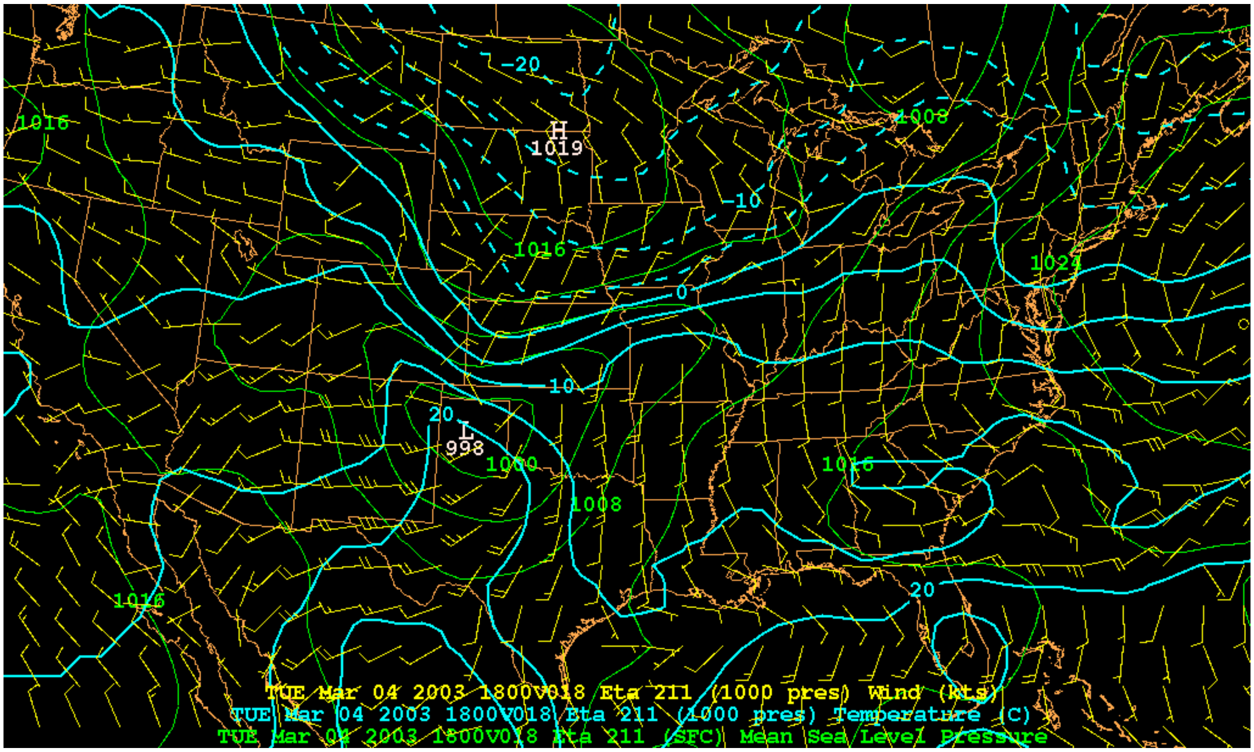

Figure 12. 18-hour Eta model forecast showing sea-level pressure, and 1000 hPa temperatures and winds.

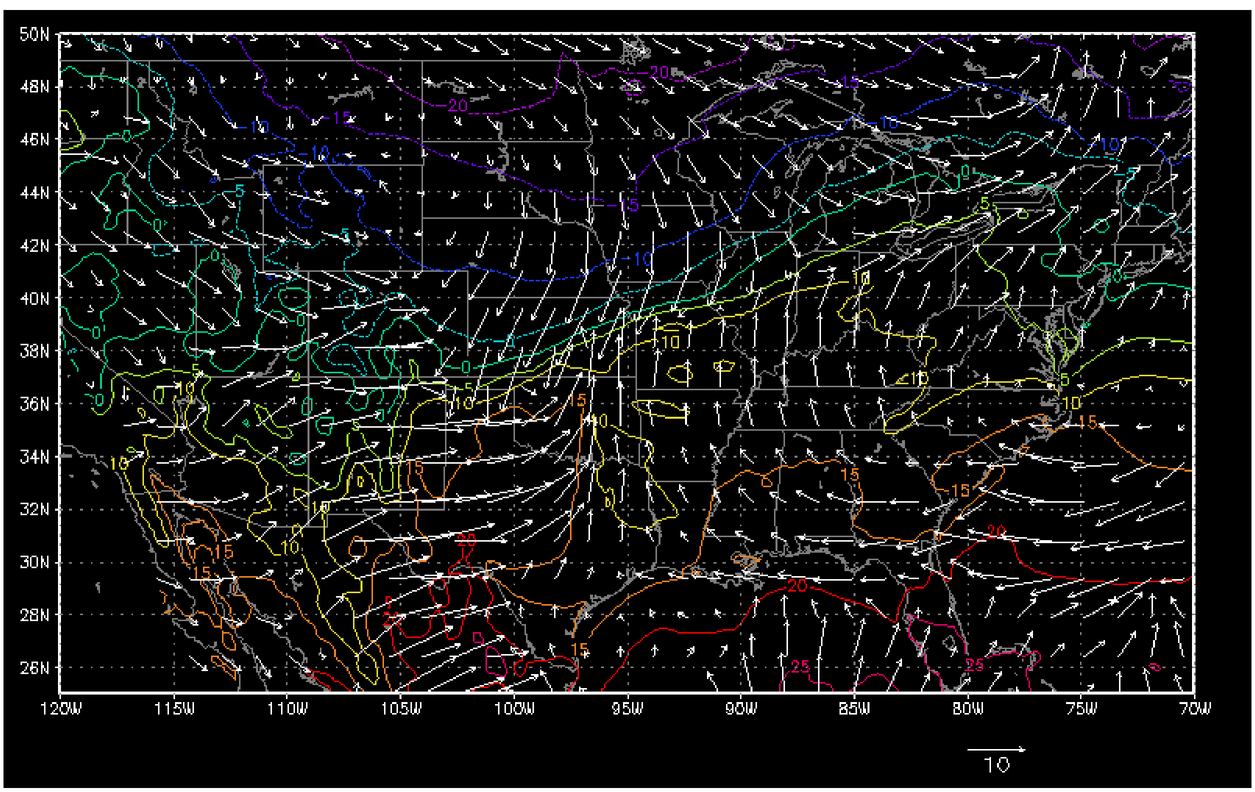

Figure 13. Output from MM5 model run for same time as Fig. 14, 18 UTC, 04 March 2003. 50 m temperatures and winds are shown, with wind speeds in m/s and scaled as shown in arrow below map.

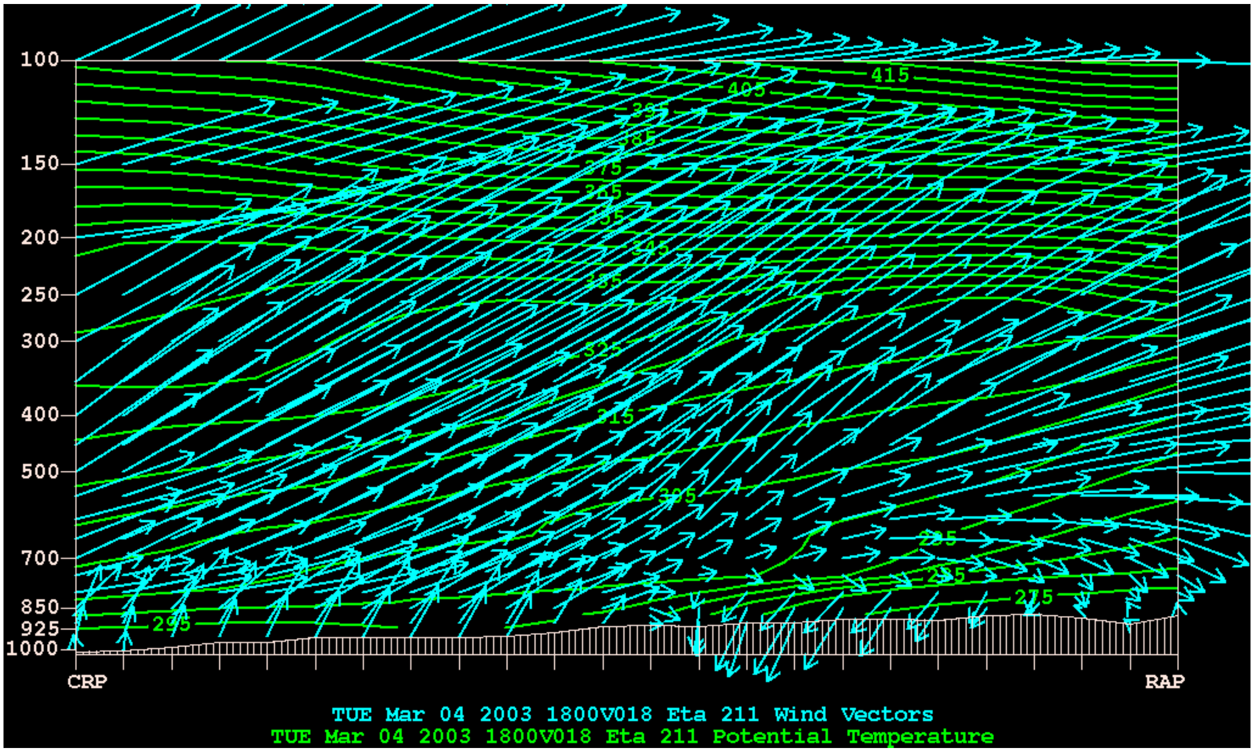

Figure 14. Cross-section from Eta model output, valid at 18 UTC, 04 March 2003.

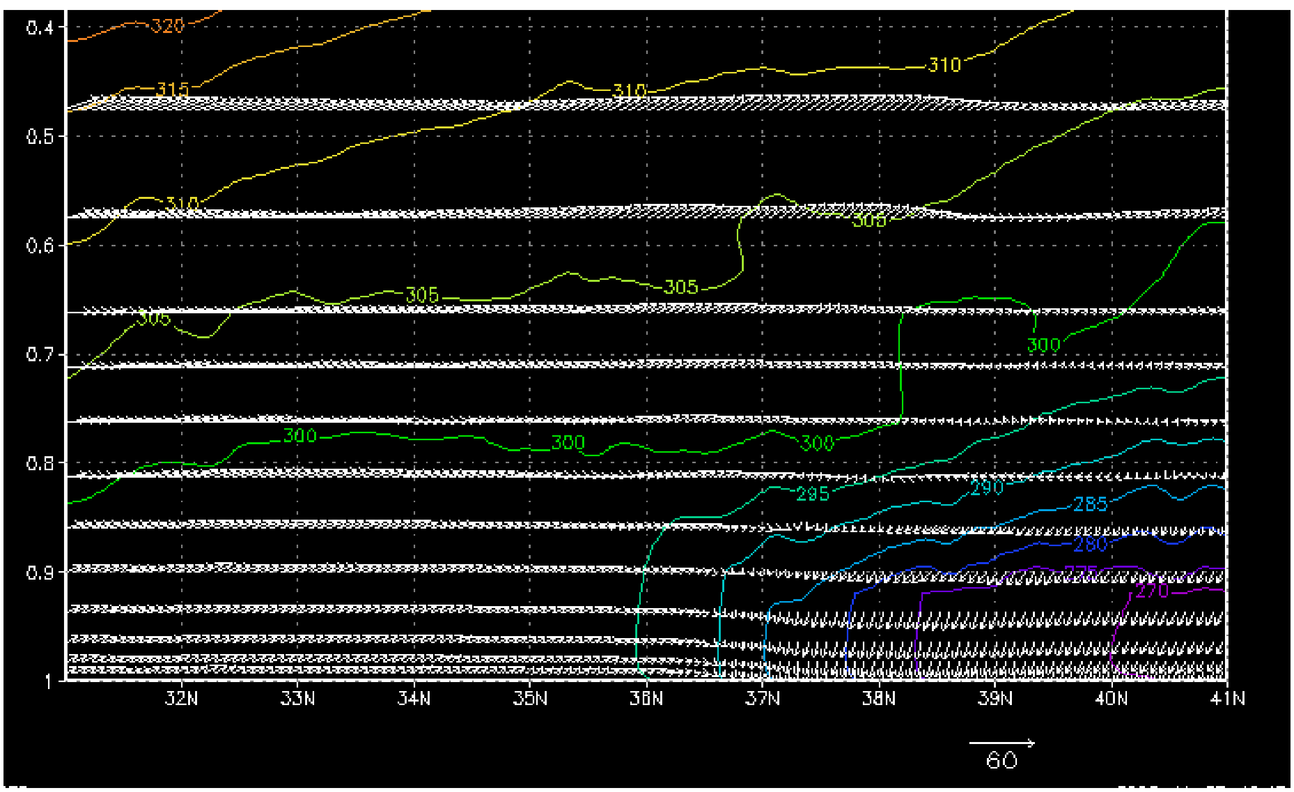

Figure 15. North-south cross-section from 9-km grid output from MM5 simulation, valid 18 UTC, 04 March 2003. Vertical axis is sigma (=p/surface p). Contours are potential temperature.

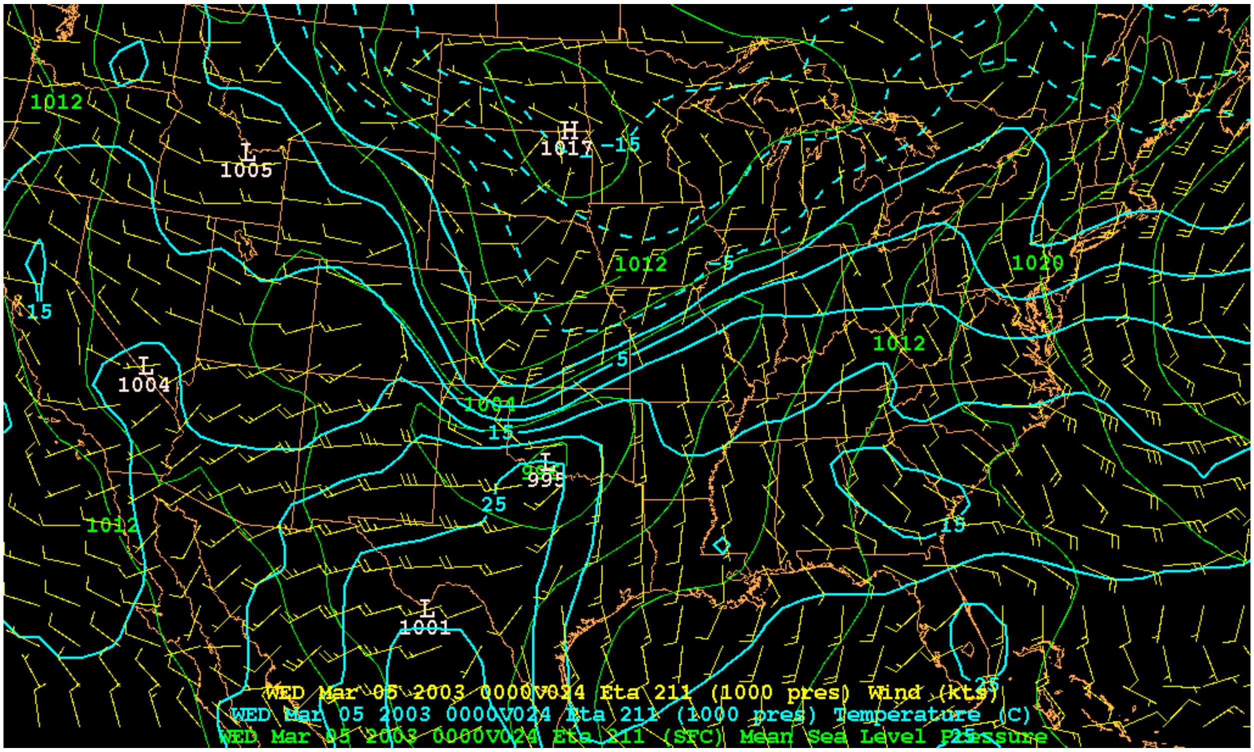

Figure 16. As in Fig. 12 except for 24-hour forecast, valid 00 UTC, 05 March 2003.

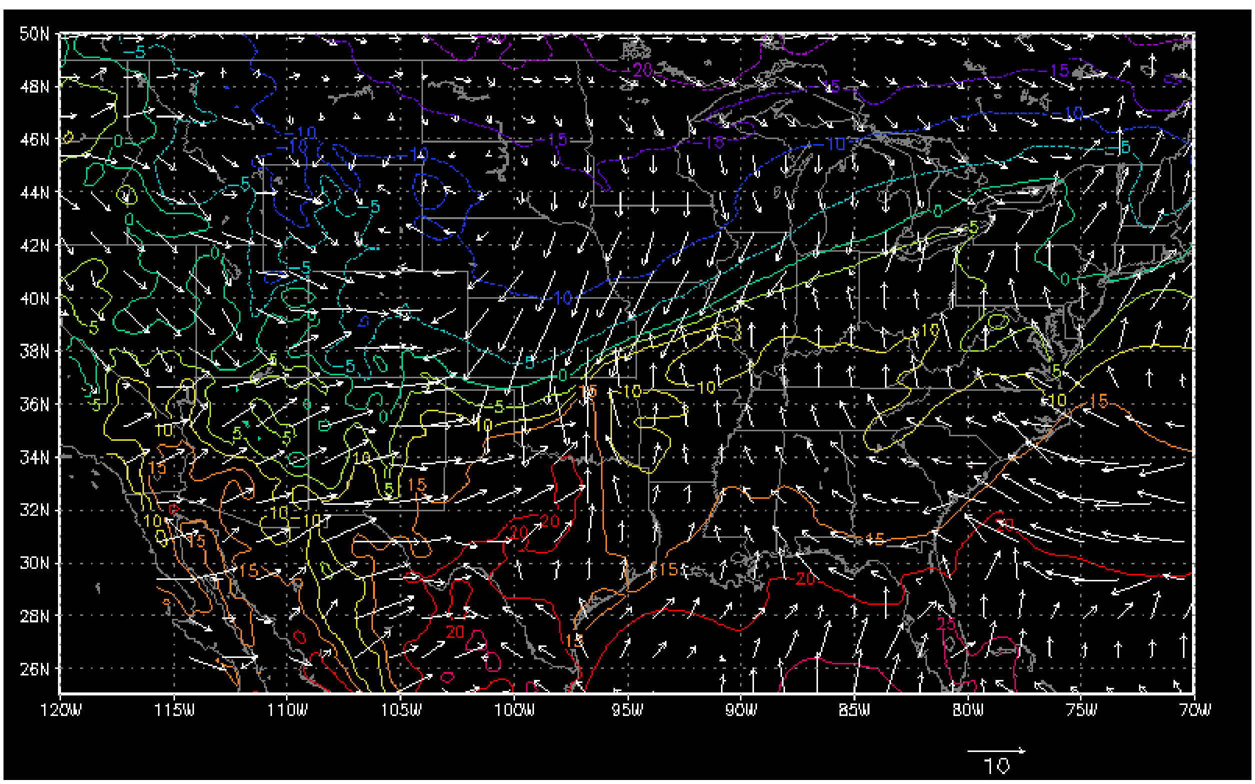

Figure 16. As in Fig. 13 except for 00 UTC, 05 March 2003.

5. Conclusions

The Texas Norther of 04-06 March 2003 has been described here, and model output from the National Centers for Environmental Prediction Eta model has been compared with 27-km and 9-km output from an MM5 simulation. The high-resolution model output is much more successful in resolving the temperature gradient across the norther-front, as expected. Operational MOS forecasts were also unable to capture the intense nature of the norther-front, as illustrated at Wichita, KS and Wichita Falls, TX.

Much more work remains to be done on this case. The cross-sections from the MM5 show wave-like undulations in the isentropes, and the speed at which the norther-front moved needs to be compared with that expected of waves and gust fronts. Schultz, et al., 1997, noted in an extraordinary case they examined from 1993, that the "… cold surge had characteristics reminiscent of a Kelvin wave, a tipped-forward cold front, a pressure-jump line, a bore, and a gravity current, but none of these conceptual/dynamical models was fully applicable. " The MM5 cross-sections suggest that the wind shift and temperature drop are coincident, which is characteristic of a gust-front structure, rather than a wave, but this conclusion must be regarded as tentative at this point.

6. References

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Shultz, D.M., W. E. Bracken, L. F. Bosart, G. J. Hakim, M. A. Bedrick, M. J. Dickinson, K. R. Tyle, 1997: The 1993 superstorm cold surge: frontal structure, gap flow, and tropical impact. *Mon. Wea. Rev.,* **125,** 5-38.