9.7 DEVELOPMENT OF NCEP's NONHYDROSTATIC MESOSCALE MODEL WITHIN WRF: DESCRIPTION AND FORECAST GUIDANCE

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1. INTRODUCTION

Development of NCEP's Nonhydrostatic Mesoscale Model (NMM) (Janjić 2003; Janjić et al. 2001) is ongoing within the framework of the Weather and Research Forecast effort (WRF) (http://www.wrf-model.org). Forecasts with 8 km gridpoint spacing are made each day over subdomains nested within the operational 12 km Eta Model. Until a data assimilation system for the NMM is complete a version of the WRF Standard Initilialization (SI) procedure provides the initial conditions as well as the boundary conditions for the nests using Eta Model data as primary input. Three of these nests cover the western, central, and eastern parts of the CONUS, a fourth covers Alaska, and smaller ones covers Hawaii. The start times are: Alaska at 0000 UTC, the western CONUS nest at 0600 UTC, the central nest at 1200 UTC, the eastern nest at 1800 UTC, and the Hawaiian nest at 1200 UTC. The WRF post-processor generates GriB output from the raw native grid forecast output. Numerous fields from the daily NMM runs alongside those of the Eta Model and the NCEP runs of the WRF Eulerian Mass (EM) model can be viewed at http://wwwt.emc.ncep.noaa.gov/mmb/mmbpll/nestpage/ for up to a week. With their higher spatial resolution, the NMM nests are expected to augment the guidance of the Eta Model in describing smaller scale features and circulations. Examples of this enhanced detail are described below.

In addition to the 8 km nests, another nested domain with 4.5 km gridpoint spacing covering the central and part of the eastern CONUS was defined in order to provide NCEP's Storm Prediction Center (SPC) with high resolution guidance for its forecasters to evaluate during its 2004 Spring Program (Kain et al. 2003). These forecasts were produced daily to 30 hours with a start time of 0000 UTC.

Full placement of the NMM forecast model within the WRF infrastructure is being finalized although the daily runs described above have been produced using the infrastructure since the autumn of 2003. Several technical modifications will be made soon which will complete all aspects of the incorporation. NCEP's immediate plans regarding the NMM in WRF are described.

2. EXAMPLES OF NMM GUIDANCE

The synoptic guidance from the Eta Model and the NMM tend to be similar and even at finer scales some aspects of these models' forecasts may differ little. However in numerous instances the NMM demonstrates the ability to more accurately describe small scale structures and/or circulations thereby providing additional detail in its guidance to forecasters beyond that available from the Eta alone.

Figure 1 shows the observed and 42-hour forecast 10-m winds over central California valid at 0000 UTC 9 June 2004 from the NMM 8 km western nest and from the operational Eta Model. While the overall flow patterns are quite similar in the two models' forecasts, the most notable difference is seen in the San Joaquin Valley from around Merced in the north to Bakersfield in the south. The observed winds are generally blowing parallel to the valley's axis or roughly toward the south southeast as are the winds in the NMM. In the Eta forecast though the winds appear to be much less influenced by the valley and are blowing mostly toward the east or east southeast. The Eta winds are slightly better though in a small area near the southeast corner of the plot where they

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somewhat better reflect the onshore breeze as it turns toward the north after moving inland northwest of Los Angeles. Figure 2 shows an example where topography does not play any role as it clearly does in Figure 1. The observed and 36-hour forecast 10-m winds from the NMM 8 km central nest and the Eta Model over Oklahoma and northern Texas valid at 0000 UTC 29 May 2004 are depicted. Both models properly show the generally south to southeasterly flow off the Gulf of Mexico and the southeasterly flow over Oklahoma. In the Eta forecast though the southerly winds extend as far north in Texas as the Red River while in the NMM forecast the winds turn to easterly and southeasterly significantly further to the south. The many observations in and around the Dallas/Ft. Worth area show that the winds were indeed generally southeasterly as seen in the NMM forecast across a large portion of northeast Texas.

Low level winds are again the primary difference between forecasts in the cases depicted in Figure 3. The soundings show the observed temperature, dewpoint, and wind vector profiles below 500 hPa at Denver along with the forecasts from the Eta and NMM 8km western nest. The top panel shows the 42-hour forecasts valid at 0000 UTC 20 May 2004. While the thermodynamic profiles are similar as are the winds above 700 hPa, below that pressure level the observed winds are distinctly easterly as are those in the NMM while the Eta winds are southwesterly as they are throughout the entire column. The bottom panel shows observations and 42-hour forecast conditions valid for 0000 UTC 11 June 2004. Again the lower level winds turn sharply to northwesterly and northerly below about 700 hPa in both the observations and in the NMM forecast while in the Eta forecast the wind column shows a very smooth vertical profile with no indication of a sharp transition around that pressure level.

In 2004 NCEP's Storm Prediction Center (SPC) continued its Spring Program and this year the evaluation of very high resolution WRF forecast output was evaluated. The WRF NMM was one of the models used during this exercise for which it was run daily from 0000 UTC out to 30 hours over a domain covering much of the central and part of the eastern CONUS with a gridpoint spacing of about 4.5 km. No convective parameterization was utilized in these runs. By turning off parameterized convection, the model's microphysics can produce very localized heavy precipitation and SPC's evaluation was very useful in determining if such maxima generated in the forecasts might correlate well with actual severe weather events. Severe weather was frequent during the spring of 2004 and one such event occurred during the evening of 21 May. Figure 4a shows the storm reports from SPC for that day. The tornadic activity which took place between about 1900 UTC 21 May and 0300 22 May was responsible for loss of life and considerable property damage. Among the graphics produced by SPC during the spring program were 1-hour rainfall totals derived from Stage 2 radar data along with analogous precipitation plots from the various numerical models. These depictions were one way of assessing the models' ability to signal the onset and nature of systems that could potentially produce severe weather. Figure 4b shows the observed 1-hour rainfall ending at 2100 UTC 21 May while Figures 4c and 4d show the 1-hour precipitation amounts from the 4.5 km NMM and from the operational Eta. The rainfall signature of the NMM agrees quite well with the observed line that extended across northeast Iowa into southwest Wisconsin. The NMM also produced a spurious maximum in southern Iowa. For comparison the much coarser resolution Eta essentially predicted a broad maximum over northern Wisconsin. Tornadoes broke out again the following evening in eastern Nebraska and western Iowa and the NMM's forecast (not shown) again indicated considerable accuracy in predicting the observed pattern of heavy rainfall in the area of severe weather.

Another example from SPC's 2004 Spring Program is seen in Figure 5. During the evening of 28 May a small cluster of strong thunderstorm cells developed over southeastern South Dakota and propagated into northwest Iowa as part of a larger region of precipitation. The forecasts in this case were initialized at 0000 UTC 28 May. The top panels show the base radar reflectivity at 0000 UTC 29 May and 0300 UTC 29 May and indicate the motion and evolution of the storms. The middle panels show the NMM's forecasts of 1-hour rainfall amounts valid at those two times. The model did produce a group of maxima just to the west of where they actually formed in a north-south line that was somewhat longer than observed. At the second forecast time the maxima are moving into extreme northwest Iowa near the actual locations. The NMM did not produce the broader region of less intense rainfall that was indicated by radar. The bottom panels show the Eta 1-hour rainfall forecasts which predicted the general area of precipitation but of course could not generate smaller scale maxima with its much coarser resolution and with convective parameterization turned on.

3. NMM IN WRF INFRASTRUCTURE

Currently the NMM runs in the so-called Hi-Res Window forecast slots in the operational suite at NCEP. Plans call for these slots to be the first to transition to WRF in operations. Specifically an ensemble of WRF runs is planned to make up the new Hi-Res Window which is to become operational in Fall 2004. Initially there will only be one pair of runs consisting of the standard forecasts of the NMM and NCAR's EM. Following a scheduled computer upgrade in early 2005 that number will be increased while maintaining equal numbers of NMM members and EM members. Given the demands on the current NCEP computing system, the number of ensemble members will have to be reduced when the operational runs of GFDL's hurricane model are executing because the highest priority access to system resources is given to hurricane events. In the worst case there will still always be a single member each of the NMM and EM.

The NMM dynamic core and physics packages have been placed inside the WRF infrastructure. Several technical modifications remain to be made to the NMM code in order to achieve complete and proper connection to all aspects of the WRF infrastructure (for example the ability to use computational threading inside the infrastructure is being addressed). As these final tasks are completed issues such as computational efficiency will be carefully examined.

4. SUMMARY

Daily runs from NCEP's NMM continue to indicate the model's potential for providing valuable guidance in the prediction of small scale structures and circulations beyond that currently available from the 12 km Eta Model over North America. Development of the model continues in order to provide forecasters with the most useful guidance possible at all relevant scales. The NMM has been placed into the WRF infrastructure as NCEP prepares to make it part of the Hi-Res Window forecast that will be the first to transition to WRF in operations. The Hi-Res Window will consist of an ensemble of runs produced by both the NMM and NCAR's Eulerian Mass model.

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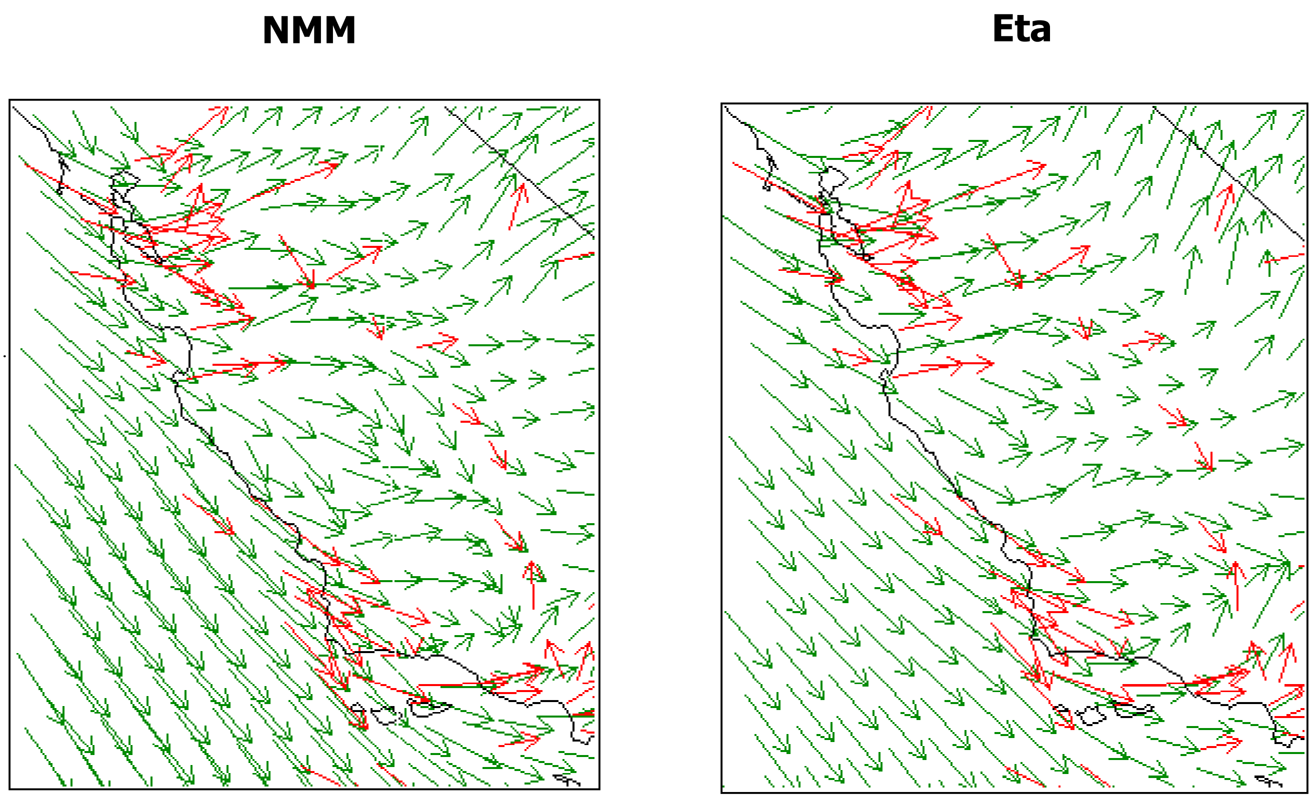

Fig. 1. Observed (red) and 42-hour forecast (green) 10-m winds valid at 0000 UTC 9 June 2004.

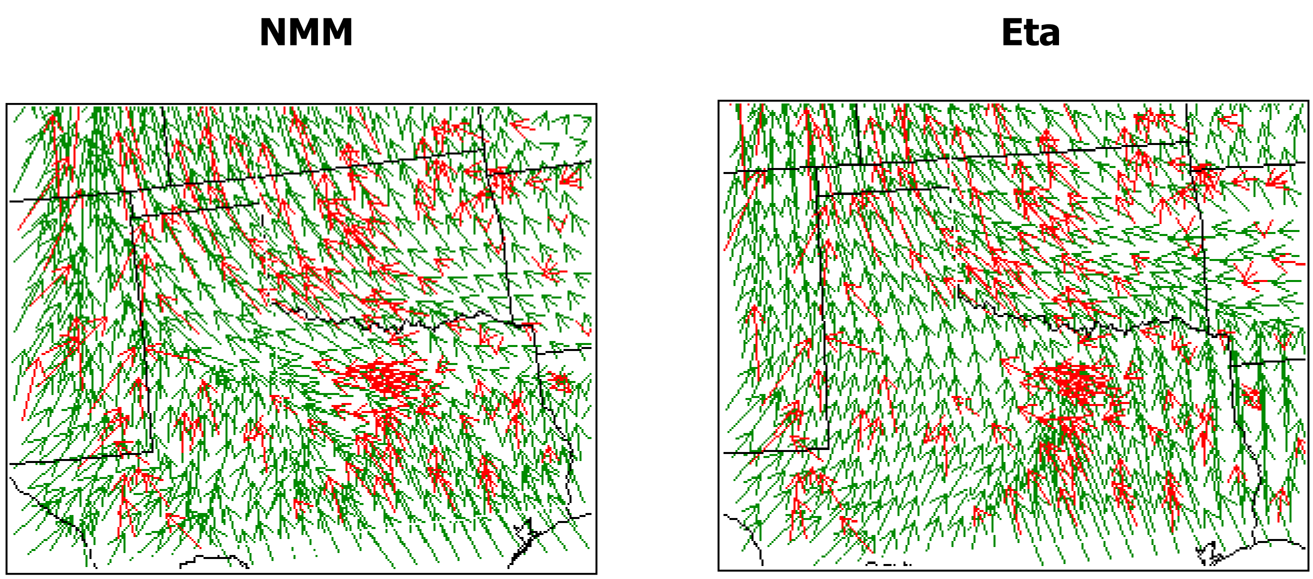

Fig. 2. Observed (red) and 36-hour forecast (green) 10-m winds valid at 0000 UTC 29 May 2004.

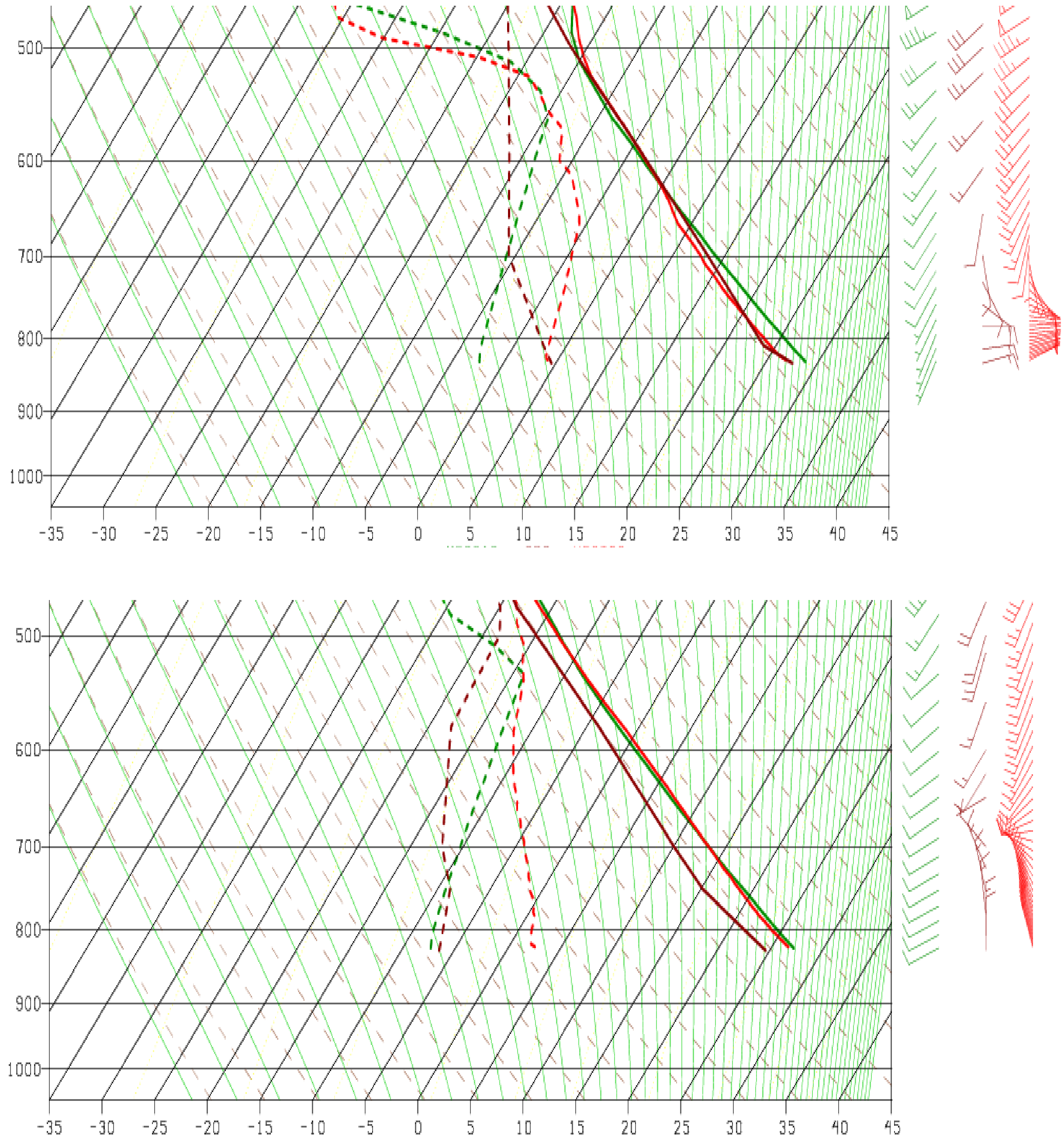

Fig. 3. Soundings at Denver International Airport valid at 0000 UTC 20 May 2004 (top) and 0000 UTC 11 June 2004 (bottom). 42-hour forecasts from NMM (red) and Eta (green) vs. observations (brick).

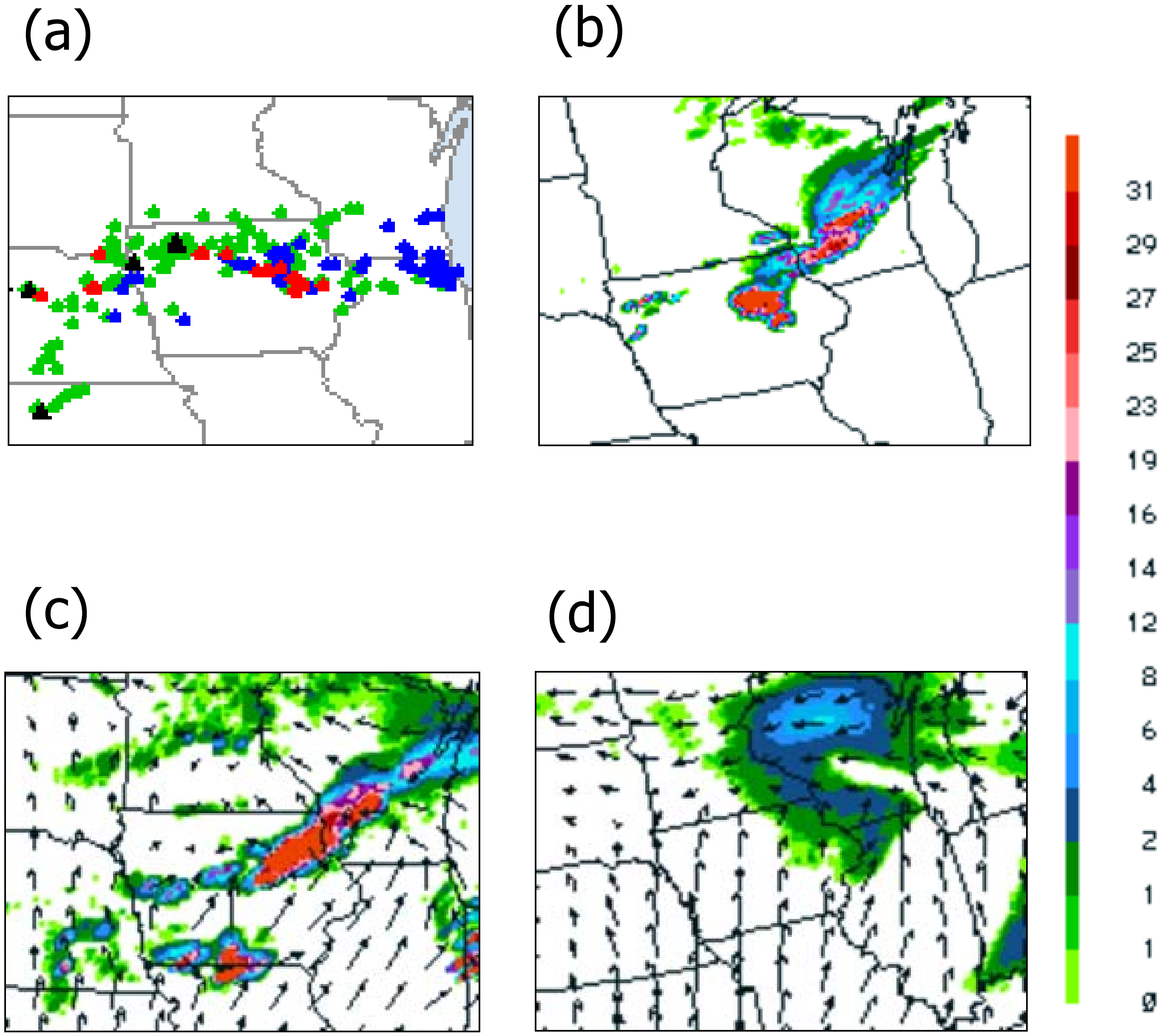

Fig. 4. Severe weather outbreak on 21 May 2004. (a) Storm reports from the Storm Prediction Center; tornadoes (red), hail (green), wind (blue). The remaining plots show 1-hour rainfall (mm) ending at 2100 UTC using color scale at right: (b) Stage 2 radar data; (c) NMM 4.5 km nest forecast; (d) Eta forecast. Model forecasts initialized at 0000 UTC 21 May. (Plots courtesy of SPC.)

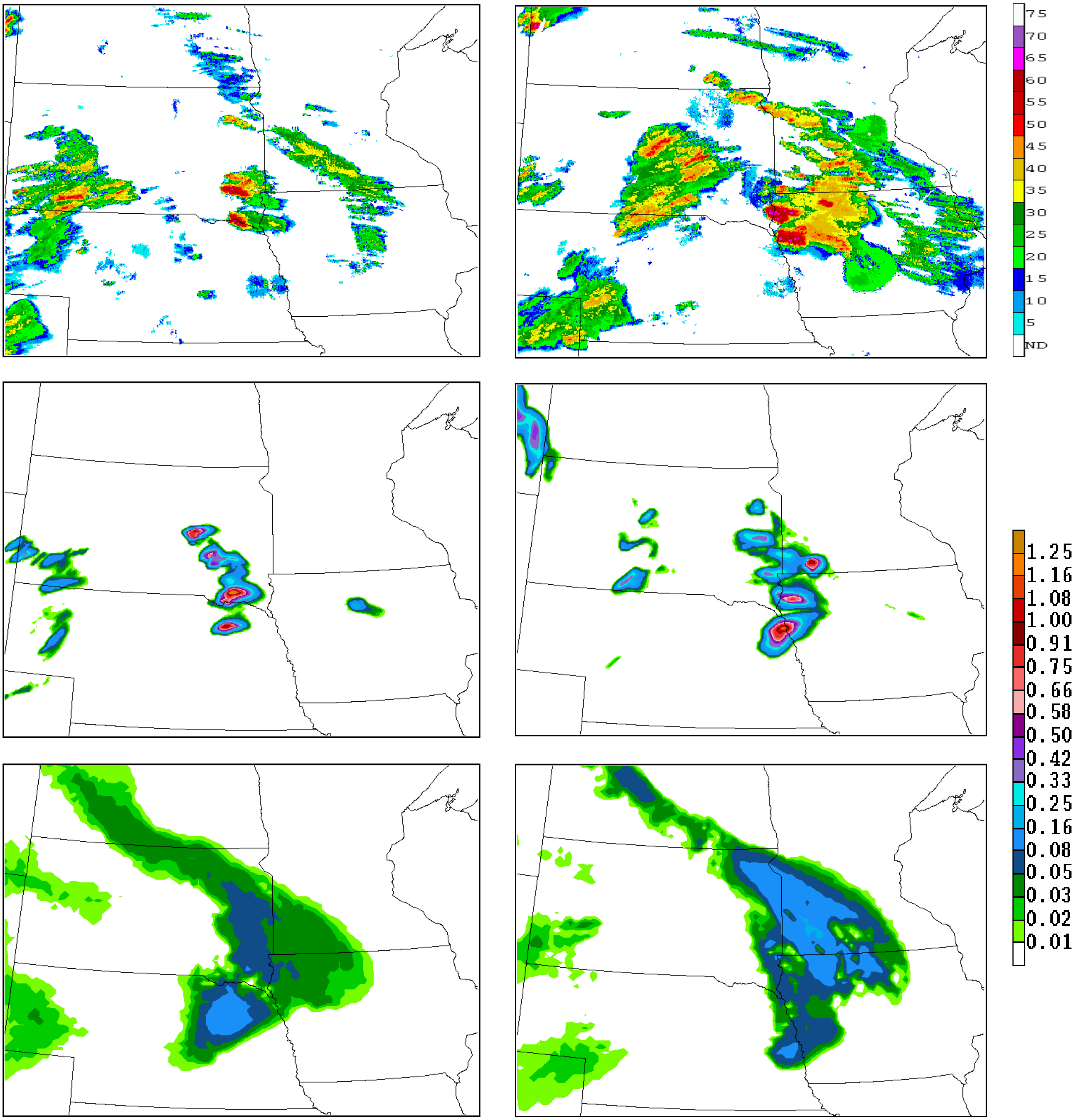

Fig. 5. (top) National 2 km base reflectivity (dBZ); (middle) NMM 4.5 km nest and (bottom) Eta 1-hour rainfall forecasts (mm). Left column valid at 0000 UTC 29 May 2004; right column valid at 0300 UTC 29 May 2004. NMM and Eta forecasts initialized at 0000 UTC 28 May. (Plots courtesy of Jack Kain, SPC)