P9.3 AN OPERATIONAL APPROACH FOR INTEGRATING MULTIPLE HIGH RESOLUTION MODEL SOLUTIONS DURING A HIGH IMPACT EVENT: THE 22 MAY 2010 EF4 BOWDLE TORNADO

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1. INTRODUCTION

Accurate prediction of severe local storms continues to pose a major challenge to operational forecasters. Therefore, any tools or techniques that aid a forecaster's situational awareness with respect to convective scale organization and evolution are highly sought after. The advancement in computer resources over the last decade has enabled numerical weather prediction (NWP) models to run at progressively higher resolutions over increasingly large domains with the goal of explicitly representing convective scale processes. Several high resolution modeling studies (e.g. Fowle and Roebber 2003; Done et al. 2004; Weisman et al. 2008; Kain et al. 2008a; Schwartz et al. 2008) have shown skill in predicting the initiation and organizational mode of convective systems. With the recent success of these convection-allowing model forecasts, several deterministic, high resolution convection-allowing models are now run on a routine basis. Many of the models are run on a daily or twice daily basis at the United States National Centers for Environmental Prediction (NCEP) Environmental Modeling Center, the National Center for Atmospheric Research (NCAR), the National Severe Storms Laboratory (NSSL), and various universities. While the benefit of these high resolution deterministic forecasts has been discussed in many studies, these models are unable to provide uncertainty information, which is extremely useful to operational forecasters during high impact convective weather situations.

To address these uncertainty issues, a real-time storm-scale ensemble forecasting system (SSEF) was developed as part of the NOAA Hazardous Weather Testbed (HWT) Spring Experiment beginning in 2007 and continuing through 2010. (Xue et al. 2007, 2008, 2009; Kong et al. 2007, 2008, 2009).

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Preliminary results from previous HWT Spring Experiments have indicated that the high resolution ensemble guidance can provide meaningful uncertainty information unavailable from a single deterministic model. Improvements in skill have been shown using traditional quantitative metrics (e.g. equitable threat score, bias, etc) and has also led to the development of new metrics (e.g. neighborhood approach). Due to the experimental nature of the SSEF, this ensemble information is not readily accessible to forecasters at National Weather Service Weather Forecast Offices (WFOs) in real-time. However, Clark et al. 2009 indicated that even a small ensemble (~5 members) of high resolution model output may significantly help forecasters to assess the overall uncertainty of a forecast.

This "poor man's" ensemble approach will be evaluated to see if a small ensemble of high resolution models can provide additional enhancement to a forecaster's situational awareness prior to a high impact event. The event of interest in this study is a tornado outbreak of nine tornadoes that occurred over the northern plains on 22 May 2010, including a violent EF4 tornado that narrowly missed the town of Bowdle, South Dakota (Figure 1).

Figure 1. Image of the Bowdle, SD EF4 Tornado on 22 May 2010. Image courtesy of Chris Karstens.

2. PRECONVECTIVE ENVIRONMENT

The large scale upper air pattern on the morning of 22 May 2010 was dominated by a broad mid to upper tropospheric trough over the western United States and a mean ridge over the Mississippi River Valley. The northern plains were influenced by a diffluent upper flow regime on the southern periphery of a southwesterly upper jet streak at 250mb, characterized by peak upper tropospheric winds in excess of 125 knots (Figure 2a). At 500 mb, several low amplitude shortwave troughs embedded in the mean southwesterly flow were expected to move northeastward across the central and northern plains during the afternoon providing the impetus for at least modest synoptic scale ascent (Figure 2b).

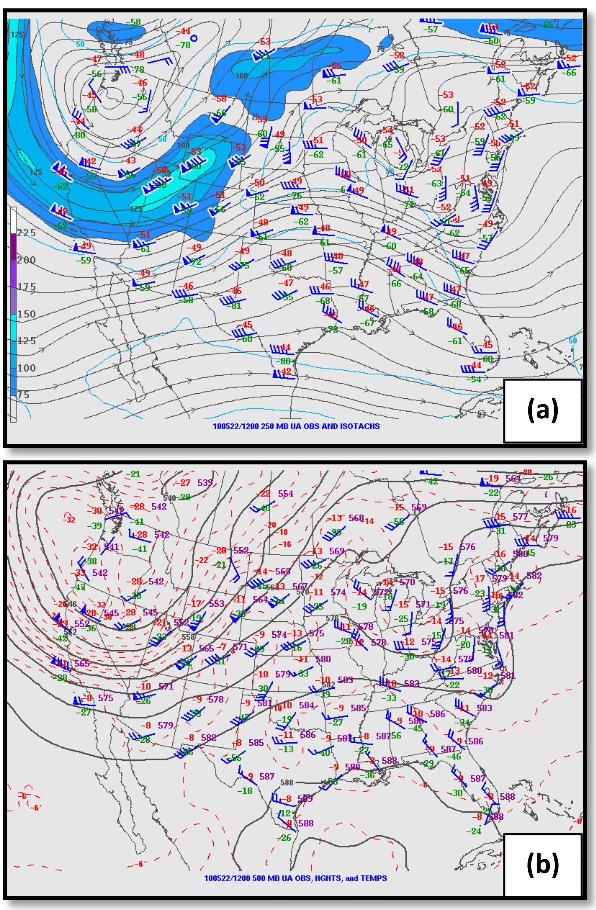

Figure 2. (a) 250mb and (b) 500mb objective analysis on 1200 UTC 22 May 2010.

At 700 mb, a warmer and drier airmass associated with a strengthening elevated mixed layer (EML) was poised to advect east-northeastward into the Dakotas (Figure 3a). Meanwhile, a potent 50 knot low-level jet at 850 mb continued to transport an increasingly moist boundary layer airmass northward into the region (Figure 3b).

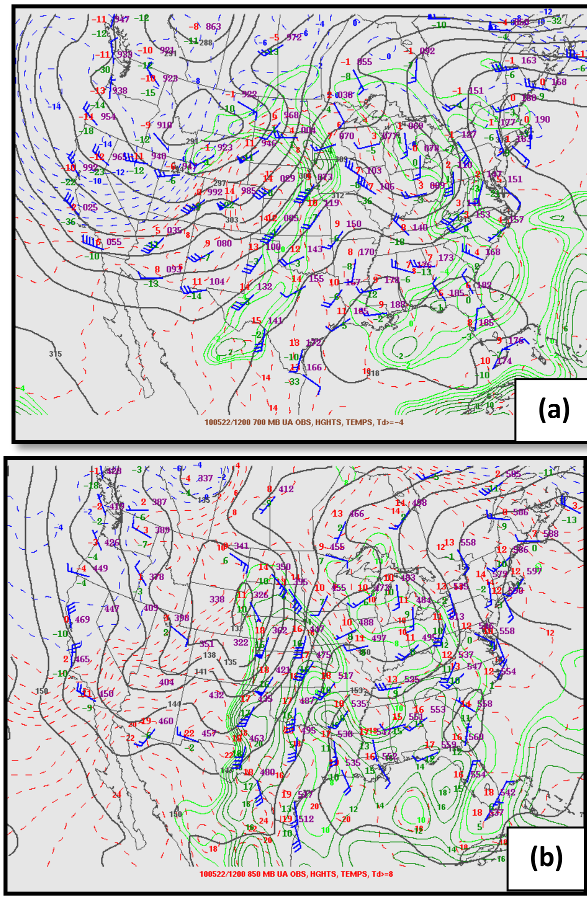

Figure 3. (a) 700mb and (b) 850mb objective analysis on 1200 UTC 22 May 2010.

The 1200 UTC observed sounding at Aberdeen, South Dakota (KABR) on 22 May 2010 (Figure 4a) indicated a deeply saturated profile, due to residual morning convection, with only limited instability. A special sounding was released at 2000 UTC at KABR to assess changes in both the thermodynamic and kinematic environment. At 2000 UTC, it was evident that the atmosphere had become significantly more unstable with MLCAPE values approaching 2000 J/KG (Figure 4b). Lower tropospheric wind profiles were also very conducive for severe thunderstorms due to very strong deep layer shear (~50 knots) and a strongly veered low level wind profile in the lowest 3 KM. An obvious forecast concern for the initiation of deep convection at 2000 UTC was the existence of a pronounced elevated mixed layer. Mid-level (700mb) temperatures had warmed to near +12C, resulting in the potential for a significant capping inversion (MLCIN values near -250 J/KG) to inhibit deep convection.

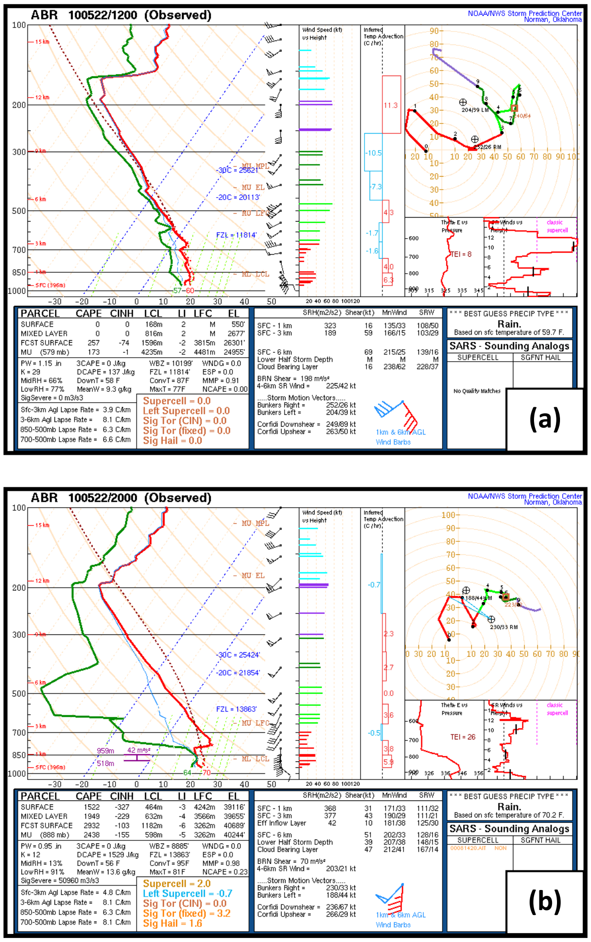

Figure 4. (a) 1200 UTC and (b) 2000 UTC observed sounding at Aberdeen, South Dakota (KABR) on 22 May 2010.

3. SHORT RANGE ENSEMBLE FORECAST

Short Range Ensemble Forecast (SREF) system (Du et. al 2006) products have been demonstrated to assist forecasters with the prediction of high impact weather, including severe convective storms (Weiss et. al 2006, Korotky 2006, Bright et al. 2004). Among the suite of SREF guidance parameters, probability products, combined probability products, plume diagrams, and “postage stamp” displays have all proven to be effective. In this study, probability products, combined probability products, and “postage stamps” will be evaluated to assess the kinematic and thermodynamic environments across South Dakota on the evening of 22 May 2010.

3.1 Probability, Combined Probability, and Postage Stamp Plots

Figure 5 depicts the following probability of exceedance plots valid at 0000 UTC on 22 May 2010: (a) 0-6KM shear exceeding 40 knots, (b) MLCAPE exceeding 2000 J/KG, (c) the significant tornado parameter (STP) exceeding 1, and (d) supercell composite parameter (SCP) exceeding 3. Note that a majority of the indices had high probabilities (>90%) of meeting or exceeding critical thresholds across central and eastern South Dakota. Thus, any storms forming in this environment would have a high probability of becoming severe.

The combined probability of MUCAPE greater than 1000 J/KG, 0-6KM shear greater than 40 knots, and convective precipitation greater than 0.01” is depicted in Figure 5e. Note that the combined probability values are quite low (1% to 5%) over central and eastern South Dakota due to the fact that many of the ensemble members failed to initiate convection over the region. This is further illustrated by examining the ensemble quantitative precipitation forecast (QPF) from each individual ensemble member using the “postage stamp” approach (Figure 5f). Note that only a few ensemble members have initiated convection over central and eastern South Dakota by 00 UTC on 23 May 2010.

Thus, while the SREF guidance indicated a kinematic and thermodynamic environment favorable for severe convection on the evening of 22 May 2010, the primary forecast challenge continued to focus on convective initiation. More specifically, would deep convection initiate at all during the afternoon/evening of 22 May, or will the environment remain “capped?”

4. HIGH RESOLUTION MODEL GUIDANCE

One of the principal goals when forecasting the potential for a high impact convective event is to correctly anticipate the timing of convective initiation and resultant convective mode (e.g. isolated cells, cluster of cells, squall line, etc). Numerous studies (e.g. Fowle and Roebber 2003; Done et al. 2004; Kain et al. 2006; Weisman et al. 2008; Kain et al. 2008a; Schwartz et al. 2008) have indicated that convective-allowing high resolution models

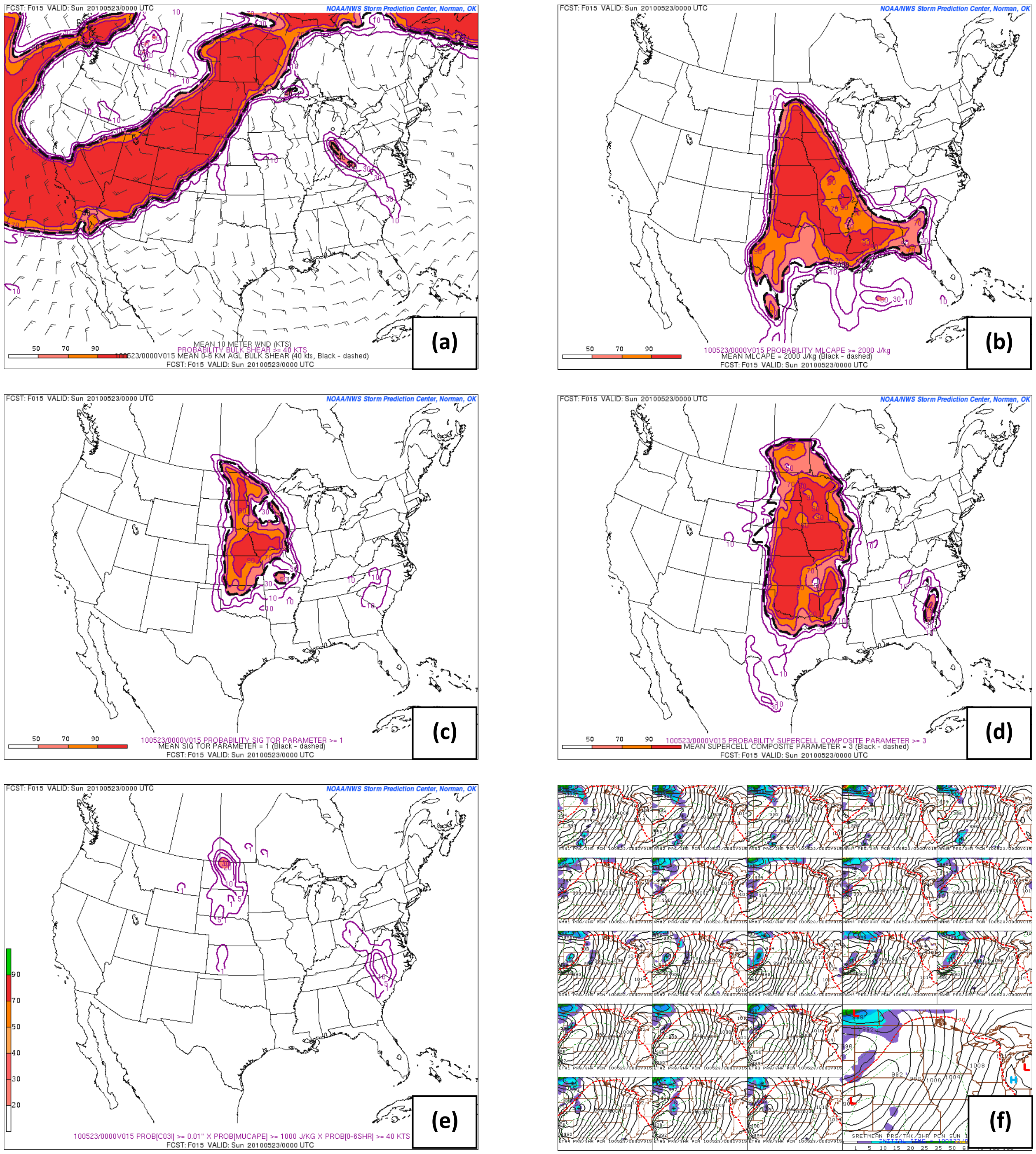

Figure 5: 15-hour SREF forecast valid at 0000 UTC 23 May 2010. (a) Probability 0-6KM Shear > 40 knots, (b) Probability of MLCAPE > 2000 J/KG, (c)Probability of Significant Tornado > 1, (d) Probability of Supercell Composite Parameter > 3, (e) Combined probability of CP > 0.01" x MUCAPE > 1000 x 0-6KM Shear > 40 knots, and (f) Postage stamp QPF.

Model Name	Core	IC/BC	Radar Data	Mp_phy	Sw_phy	Sf_phy	Pbl_phy
NSSL WRF	ARW	NAM	No	WSM6	Dudhia	Noah	MYJ
SPC WRF	NMM	NAM	No	Ferrier	GFDL	Noah	MYJ
NCAR WRF	ARW	RUC/GFS	RUC	Thompson	Goddard	Noah	MYJ
ABR WRF	ARW	GFS	No	WSM6	Goddard	Noah	YSU

Table 1: Model configurations of the small member, high resolution ensemble.

have shown skill in this realm, especially in a qualitative sense. An efficient method to examine convective initiation and convective evolution is through an evaluation of the model precipitation fields, including simulated radar reflectivity displays. This allows forecasters to see predictions of precipitation systems in the same visual framework as observed radar images. This permits a direct comparison between model forecasts and observational data. In addition, the high resolution model output often contains detailed mesoscale and near-stormscale structures, such as squall lines and bow echoes, which resemble convective storm echoes observed in actual radar data (Koch et al. 2005). Thus, high resolution models have the potential to provide unique guidance to severe weather forecasters regarding the key topics of convective initiation, evolution, mode, and intensity. This study evaluated the simulated reflectivity products from four convective-allowing models that were readily available to NWS operational forecasters on 22 May 2010. All of the models were initialized at 0000 UTC on 22 May 2010 and were available to forecasters by 9am CDT on 22 May 2010. See Table 1 for a description of the models examined.

Figures 6, 7, and 8 illustrate the simulated reflectivity products from each of the high resolution models valid at 2100 UTC on 22 May, 0000 UTC on 23 May, and 0300 UTC on 23 May. The observed base reflectivity product (BREF) is also shown for each time interval. At 2100 UTC (Figure 6), all four high resolution models indicated convective initiation would remain unlikely across South Dakota. By 0000 UTC (Figure 7), three of the four high resolution models indicated convective initiation over central and north-central South Dakota with individual cellular storms the “most probable” convective mode, although a transition to a more linear mode was also indicated. The BREF at 0000 UTC showed one discrete supercell over north-central South Dakota, which at the time was producing a violent EF4 tornado. Recall that the SREF guidance at 0000 UTC indicated a very low likelihood of convective initiation. By 0300 UTC (Figure 8), convective initiation was almost assured. The model-derived convective mode strongly suggested upscale growth to a southwest to northeast oriented squall line, with embedded stronger cells (supercells?). The corresponding BREF at 0300 UTC indicated a strong correlation to this trend in both time and space.

5. DISCUSSION AND CONCLUSIONS

This case study demonstrated the complimentary advantages of examining lower resolution SREF probability forecasts and a small ensemble of high resolution model guidance in tandem during a potentially high impact event. In this event, the SREF was able to provide synoptic scale guidance suggesting a favorable severe weather environment. Meanwhile, the small ensemble of high resolution guidance was able to provide additional uncertainty information regarding convective initiation and convective mode. Even though individual model-derived details regarding convective initiation, mode, and evolution did not exactly match each other, a majority of the models accurately predicted the primary region of severe thunderstorm (supercell) development. Output from each ensemble member also provided an assessment of forecast spread and possible “clustering” of solutions. Consequently, forecasters were able to use this information to enhance their situational awareness by anticipating a “window of opportunity” for convective initiation and better predict the “most likely” convective mode and evolution. This unique information led to enhanced severe weather wording in various NWS forecast products (e.g. HWO, AFD) and led to increased staffing prior to the event. In addition, forecasters initiated a non-routine severe weather conference call to state and local emergency managers regarding the potential for severe weather. Feedback from emergency managers mentioned that details regarding the timing and location of severe weather, along with the primary threats (large hail, damaging winds, and tornadoes) proved to be extremely valuable for planning purposes.

This study demonstrates the potential benefit of incorporating a small member, high resolution ensemble into the forecast process. It is assumed that, ultimately, a larger and more diverse SSEF will provide even more useful uncertainty information to operational forecasters. Until such time, this methodology may provide a bridge to assist operational forecasters better assess the uncertainty of a high impact event by leveraging the strengths of an ensemble prediction system and the storm scale details provided from high resolution model guidance.

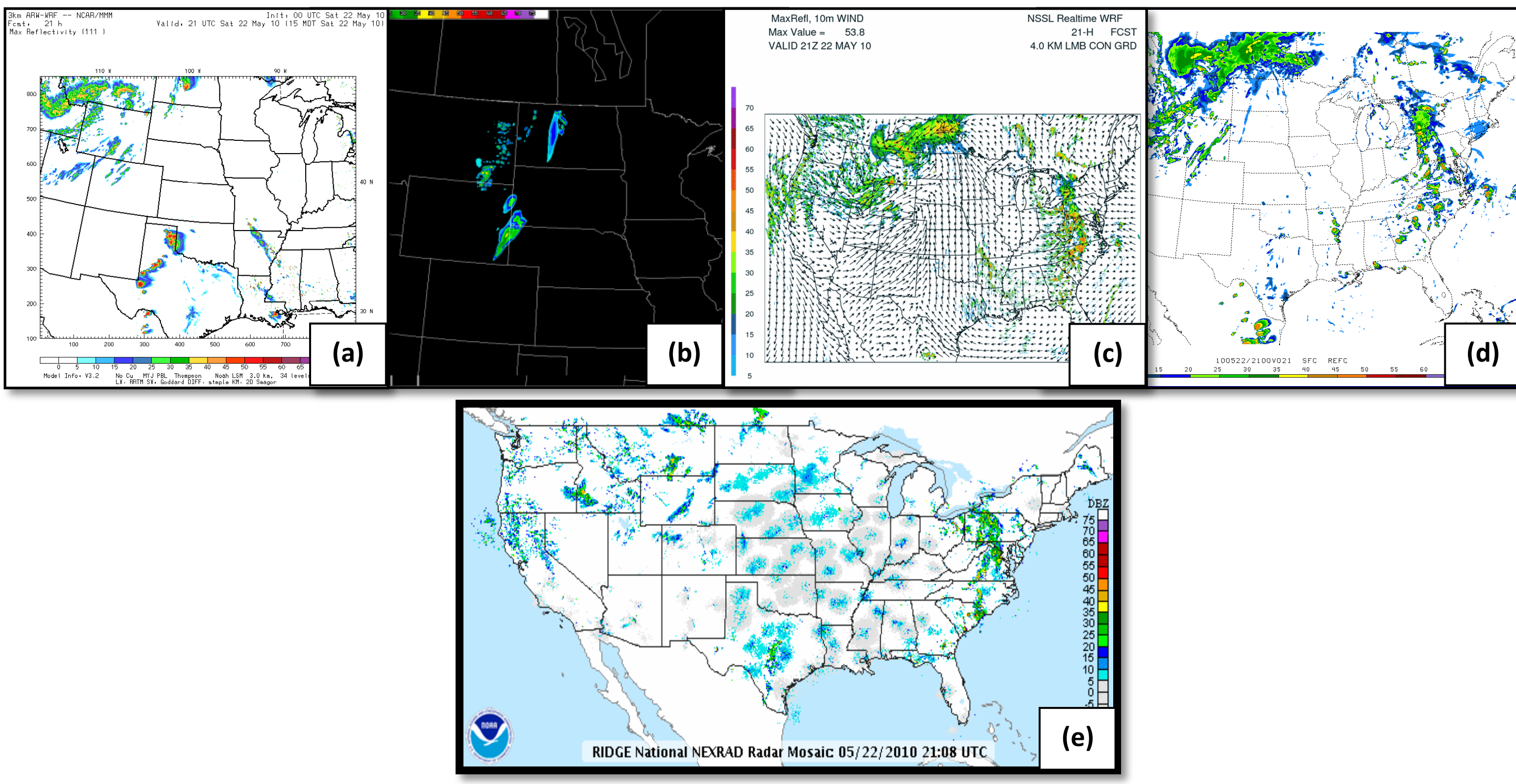

Figure 6: 21-hour forecast valid at 2100 UTC 22 May 2010 from the (a) NCAR WRF, (b) ABR WRF, (c) NSSL WRF, (d) SPC WRF. The observed base radar reflectivity (e) is also shown.

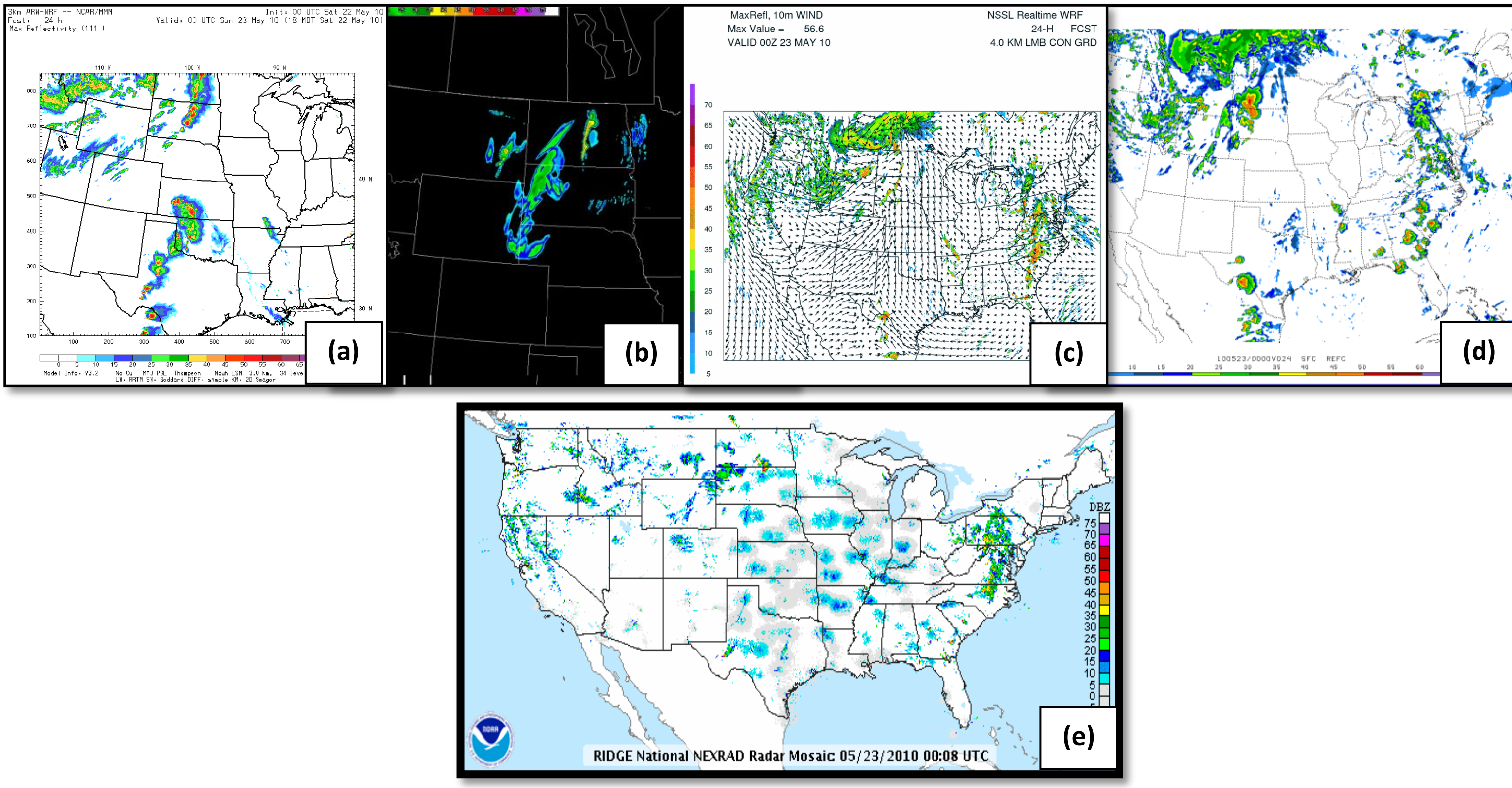

Figure 7: 24-hour forecast valid at 0000 UTC 23 May 2010 from the (a) NCAR WRF, (b) ABR WRF, (c) NSSL WRF, (d) SPC WRF. The observed base radar reflectivity (e) is also shown.

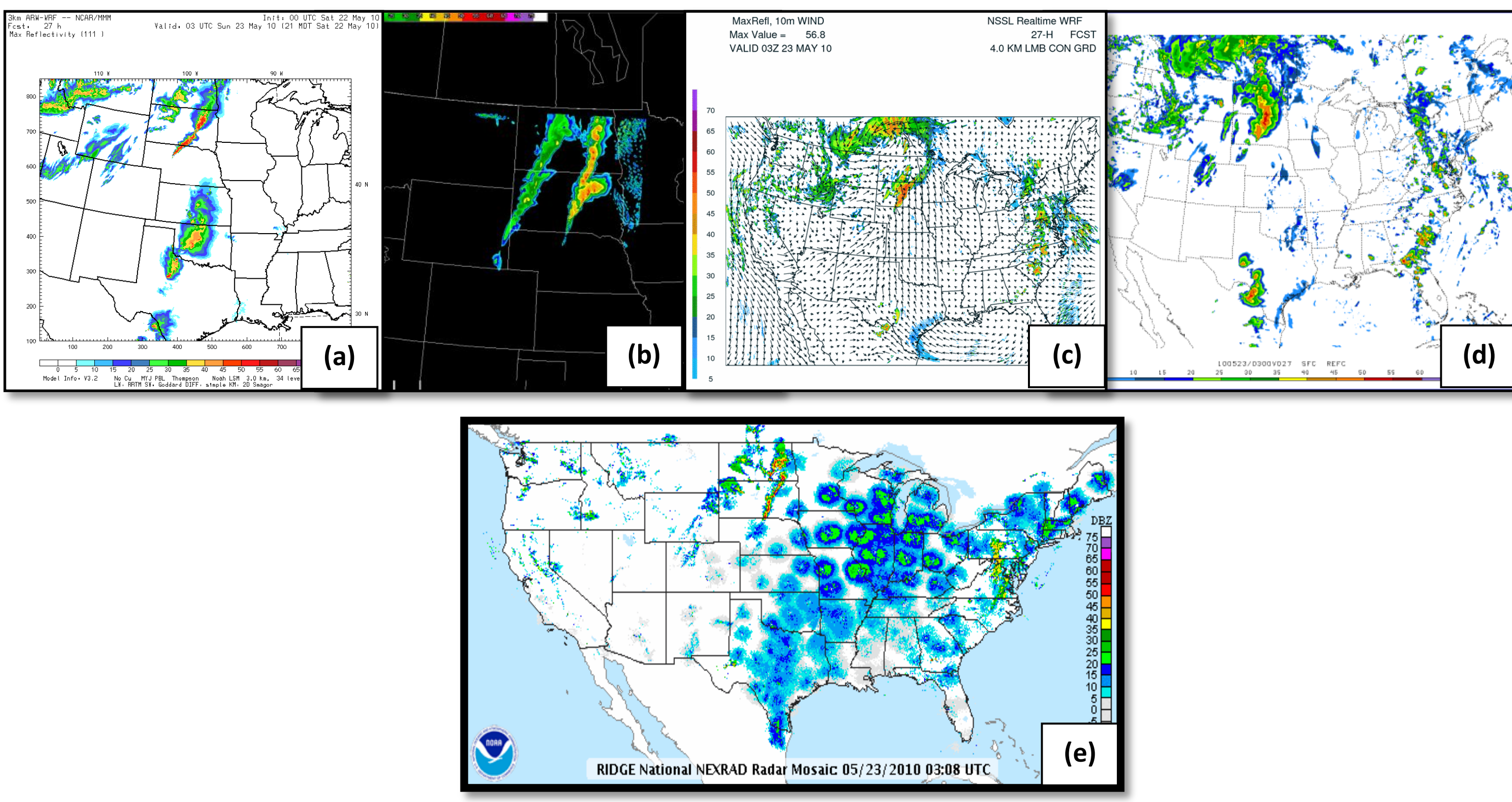

Figure 8: 27-hour forecast valid at 0300 UTC 23 May 2010 from the (a) NCAR WRF, (b) ABR WRF, (c) NSSL WRF, (d) SPC WRF. The observed base radar reflectivity (e) is also shown.

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