NEW DEVELOPMENTS IN APPLIED RESEARCH FOR SEVERE CONVECTION FORECASTING IN THE HAZARDOUS WEATHER TESTBED, NORMAN, OK, U.S.A.

John Kain[1], Steven Weiss[2], Michael Coniglio[1], Ming Xue[3,4], Fanyou Kong[3,4], Morris Weisman[5], Matthew Pyle[6], Ryan Sobash[4], Craig Schwartz[5], David Bright[2], Jason Levit[2], Gregory Carbin[2]

[1]*NOAA/National Severe Storms Laboratory, Norman, OK, U.S.A*
[2]*NOAA/NWS/NCEP/Storm Prediction Center, Norman, OK, U.S.A*
[3]*University of Oklahoma School of Meteorology, Norman, OK, U.S.A*
[4]*University of Oklahoma Center for Analysis and Prediction of Storms, Norman, OK, U.S.A*
[5]*National Center for Atmospheric Research, Boulder, CO, U.S.A*
[6]*NOAA/NWS/NCEP/Environmental Prediction Center,U.S.A*
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I. INTRODUCTION

In the United States, convection-allowing numerical weather prediction models (hereafter CAMs) emerged as potentially valuable guidance tools for next-day (*i.e.*, 12-36 h integration period) weather forecasts during the 2003 BAMEX field program (Davis et al. 2004; Done et al. 2004). Researchers and forecasters gained further confidence in CAMs during 2004 and 2005 when they were used in separate experiments to provide guidance for severe convection (Kain et al. 2006, 2008) and winter weather (Bernardet et al. 2008), respectively. This confidence was largely inspired by displays of the models' simulated reflectivity field (SRF), a field that was widely produced for the first time in these innovative tests of CAMs. The SRF can be used to infer important details about mesoscale circulations (Koch et al. 2005) and the mesoscale organizational structures of convective systems (Done et al. 2004; Kain et al. 2006; Weisman et al. 2008). Also, it hints at the presence of an entirely new set of phenomena that are generated during the integration of CAMs, but are absent in output from traditional operational models because of relatively limited resolution and the parameterization of convective processes.

Since 2004, numerous aspects of CAM output have been examined each spring during intensive examination periods known as Spring Experiments (SEs – Kain et al. 2006). These annual experiments are organized by forecasters from the NOAA Storm Prediction Center (SPC) and research scientists from the NOAA National Severe Storms Laboratory (NSSL) as part of a thriving collaboration between researchers and practitioners at the Hazardous Weather Testbed in Norman, OK. In general, the annual SEs are designed to "beta test" research tools or concepts that could be implemented in forecast operations within 1-2 years. In addition, some topics with longer-range potential have also been examined. For example, from 2007-2009 SEs included initiatives to examine CAM ensembles (e.g., Kong et al. 2008; Schwartz et al. 2009) and advanced data assimilation techniques (Xue et al. 2008; Weisman et al. 2009) that show promise but are still years away from routine operational use.

This paper focuses on aspects of CAM forecasts that have already had at least some impact in routine forecasting operations. Forecasters at the SPC have been using CAM-based guidance on a routine basis since 2004, when the NOAA Environmental Modeling Center (EMC) first started generating daily CAM forecasts for the SPC (M. Pyle, EMC, personal communication; Weiss et al. 2006). The EMC forecasts were supplemented by alternative CAM forecasts from NSSL beginning in 2006. Thus, SPC forecasters have had several years to examine CAM output and assess its potential operational utility, during both daily operations and annual SEs. Collaboration between SPC forecasters and NSSL scientists has led to the development and refinement of unique CAM output fields and innovations in the way that CAMs can be used in the operational forecasting environment. A few of these advances are highlighted here.

II. RESULTS

a. Generating probabilistic guidance for severe weather from simulated reports of severe phenomena.

Data mining of the WRF-NSSL4 model output, along with various statistical techniques, has allowed us to identify several useful "surrogates" for severe weather in 4 km model output. For example, one of these surrogates is low to mid level mesocyclones, as characterized by high values of updraft helicity (UH - see Kain et al. 2008). UH maxima have proven to be useful proxies for supercells, which are associated with a variety of severe weather at the ground. Using a technique described by Brooks et al. (1998) and Sobash et al. (2009), density plots of these surrogates can be generated and used to produce probabilistic forecasts of severe weather. This strategy can be applied to output from a single model, or multiple models (*i.e.*, an ensemble). For example, Fig. 1 demonstrates that this approach can help highlight

	WRF-EMC4	WRF-NSSL4	WRF-CAPS4	WRF-CAPS2
Dynamic Core	NMM	ARW	ARW	ARW
Horiz. Grid (km)	4	4	4	2
Vertical Levels	35	35	51	51
PBL/Turb. Param	MYJ	MYJ	MYJ	MYJ
Radiation (SW/LW)	GFDL/GFDL	Dudhia/RRTM	Dudhia/RRTM	Dudhia/RRTM
Initial Conds.	32 km NAM	40 km NAM	12 km NAM	12 km NAM
Initial Time	0000 UTC	0000 UTC	0000 UTC	0000 UTC

Table 1. Model configurations referenced in this paper.

regions of severe convective activity quite effectively and concisely, even when only a single deterministic forecast is used for input.

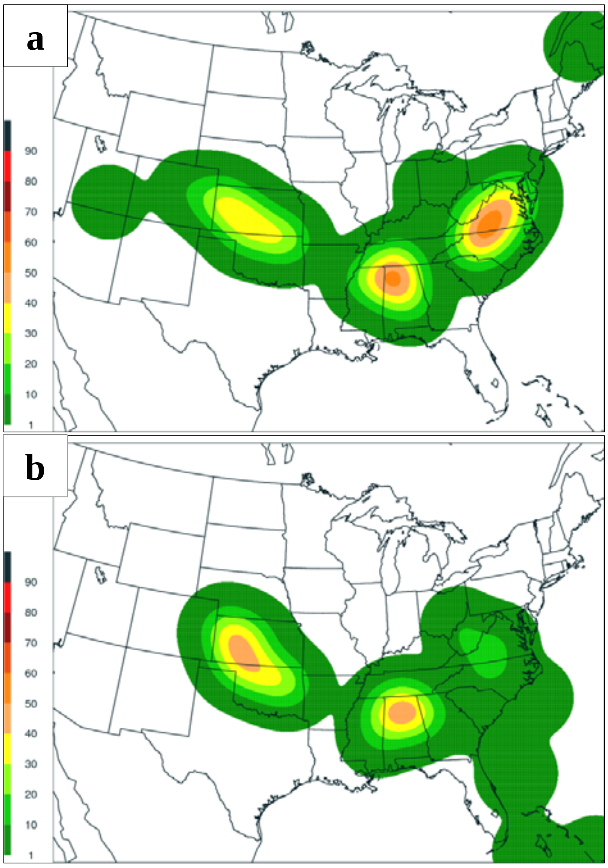

Fig. 1. a) observed reports of severe storms and b) surrogate reports of severe convection from the WRF-NSSL4 forecast, both plotted in terms of report density (see Sobash et al. 2009), valid for the period 1200 UTC 8 May – 1200 UTC 9 May 2008.

b. Quantitative Precipitation Forecasts (QPFs) and sensitivity to horizontal resolution

In the U.S., heavy rainfall does not officially fall under the category of severe convective weather, but convective rainfall prediction remains one of the most challenging forecast problems in the U.S. and elsewhere. Part of the reason for this ongoing difficulty is that NWP guidance for QPF has been deficient, especially in the warm season when convection predominates. For example, EMC's operational North American Model (NAM – see Black 1994), the primary 1-3 day forecast model in the U.S., over-predicts the coverage of lighter precipitation and under-predicts coverage of heavy accumulations (Fig. 2). But preliminary results from daily forecasts of the WRF-NSSL4 over a two year period suggest that properly configured CAMs can provide much better guidance, especially for higher precipitation thresholds. For example, the WRF-NSSL4 produced a frequency bias for next-day QPF of close to 1 for accumulations up to about 50 mm over three-hour time intervals (Fig. 2). Furthermore, for precipitation rates above a few mm/3h it performed significantly better than the NAM as measured by threat scores and "neighborhood" metrics such as fraction-skill scores (not shown).

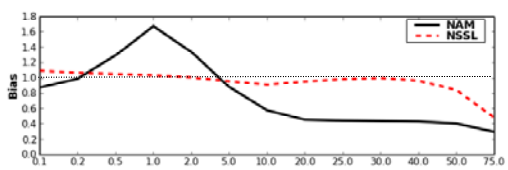

Fig. 2. Bias scores for an aggregate of 3-hourly QPFs from daily 18-36h WRF-NSSL4 and NAM forecasts over the central U.S., covering the period from April 2007 – April 2009.

These results and other related studies (e.g., Weisman et al. 2008; Clark et al. 2009) suggest that there is a significant benefit to be gained in numerical prediction by eliminating convective parameterization and decreasing grid spacing to the point where this action can be justified. There seems to be general agreement that approximately 4 km spacing is adequate for this purpose. Yet, most convective clouds are very poorly resolved on a 4 km grid, so it is natural to ask how much additional benefit would be gained by further increases in resolution. Separate studies of SE model output by Kain et al. (2008) and Schwartz et al. (2009), coupled with subjective assessments during SE2005 and SE2007, show that an additional doubling of resolution (decreasing grid length from 4 to 2 km) results in little, if any, added value for guidance related to the timing, location, and mesoscale evolution of convective activity (Fig. 3).

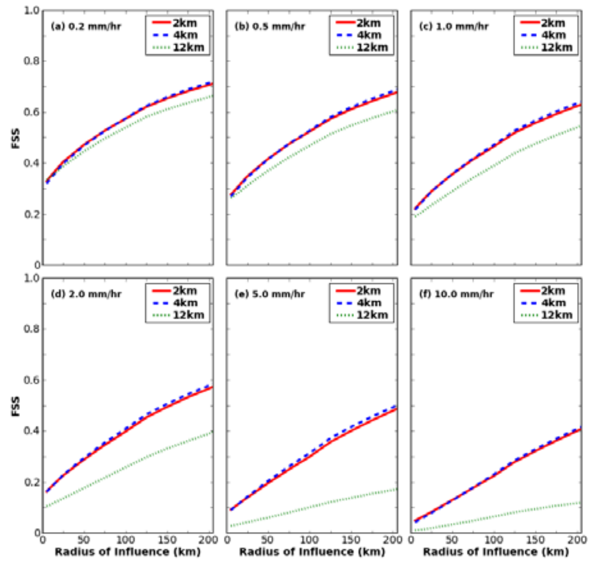

Fig. 3. Fractions skill score (FSS) as a function of radius of influence for the NAM (12km), WRF-CAPS4 (4km), and WRF-CAPS2 (2km) model configurations, aggregated during 1800-0600 UTC (f.21-f.33) over all days of SE2007 using accumulation thresholds of (a) 0.2 mm/hr, (b) 0.5 mm/hr, (c) 1.0 mm/hr, (d) 2.0 mm/hr, (e) 5.0 mm/hr, and (f) 10.0 mm/hr.

III. SUMMARY

In the United States National Weather Center in Norman, OK, there is a thriving Hazardous Weather Testbed built upon the mutual collaboration between research scientists and operational severe weather forecasters. This collaboration has led to unique and innovative advances in both forecasting and research in recent years. Advances related to CAMs have had a significant impact on the development and application of high-resolution models as guidance tools for the prediction of severe convective weather.

IV. REFERENCES (Available at http://www.nssl.noaa.gov/users/kain/public_html/ECSS-ext-abs_w_refs.pdf)