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Use of guidance from the high-resolution Weather Research and Forecasting (WRF) model to forecast severe convective storms in the United States

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Introduction

In recent years, it has become especially evident that the type of severe convective weather that occurs (tornadoes, hail, or damaging winds) is often closely related to the convective mode (or morphology) that storms exhibit, such as discrete cells, squall lines (or quasi-linear convective systems (QLCS)), or multicellular convective systems. In addition, some severe storms develop as dynamically unique classes of thunderstorms such as supercells and bow echoes, which are believed to produce a disproportionate number of tornado and widespread straight-line wind damage events, respectively. Thus, accurate severe weather forecasts are dependent on forecasters being able to properly predict properly not only where and when severe thunderstorms will develop and how they will evolve over the next 4 – 7 hours, but also the convective mode(s) that are most likely to occur.

Spring Program Background

The co-location of numerous federal and university meteorological organizations in Norman, Oklahoma has enhanced the ability to address operationally relevant research problems, particularly those involving severe convective weather. Over the past five years an annual event known as the Storm Prediction Center (SPC)/National Severe Storms Laboratory (NSSL) Spring Program has been conducted during the climatological peak severe weather season. It attracts a wide cross section of local and visiting forecasters and researchers, and the underlying structure allows forecasters to evaluate new tools or concepts that emanate from the research community, while immersing research scientists in the challenges, needs, and constraints of the operational forecasting environment. This approach promotes forecast improvements by accelerating the transfer of science and technology into forecast operations at the SPC and by providing researchers with the knowledge to formulate research strategies that will directly benefit operational forecasting.

Spring Program 2004

The 2004 SPC/NSSL Spring Program was a multi-agency collaborative exercise that explored the utility of the Weather Research and Forecasting (WRF) model for severe weather forecasting. The program was conducted from April 19 through June 4, with a primary goal of comparing multiple versions of experimental high-resolution WRF forecasts (4 km grid spacing and explicit precipitation physics) and mesoscale versions of the WRF using $\sim$10 km grid spacing and parameterized convection with an operational "benchmark" model, the 12 km Eta. The high-resolution WRF model domains covered two-thirds of the United States, and consisted of: 1) WRF Mass Core run at NCAR, 2) the WRF Mass Core run through University of Oklahoma/CAPS with a state-of-the art data assimilation system (ADAS) including Level II radar data, and 3) WRF NMM core run at NCEP/EMC. The NCAR and EMC runs were initialized only with 40 km Eta model data. These versions allow a meaningful comparison of the two basic physics cores plus an examination of the impact of a dynamic data assimilation system on the model predictions.

During the seven week experimental period nearly 50 forecasters, model developers, research scientists, and university faculty, including contributors from numerous NOAA research and forecasting organizations, ten major universities, the Air Force Weather Agency, NCAR, and international visitors from Canada and Finland, participated in the program. On most days there were five or six panel members with a wide variety of backgrounds contributing to the daily forecasting and evaluation activities.

Model utility was examined from the perspective of SPC severe weather forecasters, who are interested in the ability of these models to provide useful guidance about convective initiation, intensity, mode, and evolution. A forecasting component included the formulation of two short-range forecasts of severe convection valid during the afternoon and evening. The control forecast utilized guidance from current operational models (Eta, RUC, and NCEP SREF) to provide a control benchmark of the current state of convective forecasting; an experimental forecast, incorporating additional guidance from the 0000 UTC WRF model runs, followed shortly thereafter. The primary motivation for this forecasting exercise was to determine: 1) if there is new and useful information in the high-resolution WRF runs from a forecaster perspective, and 2) whether severe weather forecasts can be improved when forecasters have access to new near-stormscale models using explicit precipitation physics, compared to mesoscale models with parameterized convection. In other words, is the value-to-cost ratio high enough to justify the enormous computer and communications resources required to produce national model guidance at 4 km grid spacing in an operational setting?

Summary of Results

A next-day subjective evaluation of the WRF runs and operational Eta model was conducted by rotating panels of experts comparing hourly model forecasts of precipitation with corresponding radar images to assess model skill in predicting convective initiation, evolution and mode. The quality of the human produced control and experimental severe weather forecasts was also evaluated using severe weather reports supplemented by radar data and warning information. Post-program analysis of both the human forecasts and model guidance suggests that the high-resolution output can be a valuable addition to the severe weather forecasting arsenal. Based on mean subjective verification ratings assigned by the weekly panels, the high-resolution WRF models provided more useful information on convective mode compared to the Eta, and one of the high-resolution configurations performed significantly better than the Eta model in all three categories of convective initiation, evolution, and mode. The skill of the mesoscale WRF versions was judged to be similar to that of the Eta. Objective verification metrics appear to corroborate the relative subjective ratings. Likewise, experimental probabilistic forecasts issued by the weekly teams after they had examined high-resolution output were rated as more skillful, on average, than control forecasts that were prepared using only routine operational data for guidance. Objective verification of the two human forecasts also confirmed a small but measurable improvement in forecast skill when the high-resolution output was used.