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MESOSCALE MODELING OF SIGNIFICANT SEVERE WEATHER AND FLASH FLOOD EVENTS AT WFO JACKSON, MS

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1. INTRODUCTION

The National Centers for Environmental Prediction (NCEP) Workstation Eta (WS-Eta) model is a version of the operational Eta model (Black 1994) designed to run at the workstation level. The model is highly configurable, allowing the user to modify grid domain, spacing, and convective parameterization scheme, for example. The National Weather Service Forecast Office in Jackson, MS (WFO JAN) is currently running the WS-Eta operationally, and has run the model on past heavy rainfall and severe weather cases. This paper will describe the WS-Eta's performance in modeling these events, and show the potential benefits of running a mesoscale model at the local level.

2. MODEL CONFIGURATION

The NCEP WS-Eta is currently run twice a day (0000 and 12000 UTC) at the WFO JAN (JAN) on a single-processor, 1.4 GHz AMD Athlon system, with 1.0 GB RAM. The WS-Eta is run non-hydrostatically, using a horizontal grid spacing of 5 km and a grid domain of 55x91x45 gridpoints. The model does not employ a convective parameterization scheme, with precipitation generated explicitly from the model. Boundary conditions are provided by the NCEP operational Eta model. Forecast output from the model is available at one-hourly resolution out to 24 hours. The temporal and spatial resolution of the model was chosen to allow the model to run quickly enough so that the forecasters would have sufficient time to view the model output, but yet be able to become familiar with output from a fine spatial resolution model.

The model can also be run in "hindcast" mode, which allows users to re-run the model for a specific event using different combinations of model configurations. In the following cases, the WS-Eta was run on two specific events. In one case, the model was run using different convective parameterization schemes (no scheme versus Kain-Fritsch (K-F)). Figure 1 shows the domain over which the model is run, which covers roughly the WFO JAN County Warning and Forecast Area (CWFA).

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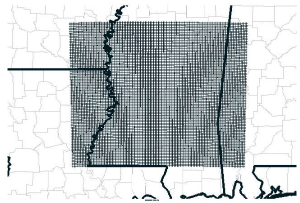

Figure 1. WFO JAN WS-Eta domain.

3. SIGNIFICANT WEATHER EVENTS

3.1 4 April 2001 Flash Flood Event

A mesoscale heavy rainfall event occurred across parts of Mississippi between 2000 UTC and 0200 UTC on 4 April 2001. Six hour rainfall amounts of 15 to 30 cm (6 to 12 in) occurred in about a 20 mile wide swath from north central into east central Mississippi (see Fig. 2). Significant flash flooding resulted, with over $2M in damage and a presidential disaster declaration.

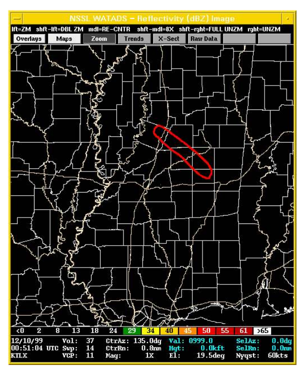

Figure 2. Location of heaviest rainfall (oval) associated with 4 April 2001 flash flood event.

This heavy rainfall event occurred in the absence of significant synoptic scale forcing. When a convective outflow boundary became quasi-stationary just to the south of the area indicated in Fig. 2, numerous thunderstorms developed along this boundary in a very moist and unstable environment (precipitable water values around 40 mm (1.6 in); K Index values in excess of 40 deg C; lifted index values near -10 deg C). As thunderstorms developed back to the northwest along the boundary, they moved repeatedly over the same narrow area during a 4 to 6 hour period, resulting in extremely heavy rainfall totals.

The operational models had little skill in providing accurate forecast guidance for this mesoscale event, even at short time ranges. Operational Eta model quantitative precipitation forecasts from the 1200 UTC 4 April run for this area showed rainfall amounts of less than 1 cm (0.25 in). Furthermore, the model indicated no focusing mechanism for convection in this area; instead, the model moved a boundary well to the south of this area into far southern Mississippi. Even the shorter term RUC model had difficulties, including underforecasting the amount of instability and moisture which would be over the area (e.g., 6 hour forecast of K-index valid at 2100 UTC had values in the lower 30's across the region; 1800 UTC JAN sounding had a value of 43).

Forecasts from the WFO JAN hindcast run of the WS-Eta initialized at 1200 UTC 4 April gave forecast guidance much more indicative of the potential for a heavy rainfall event. Figure 3 shows a 6 hour QPF forecast from 2000 UTC to 0200 UTC from the WS-Eta for the area where the heavy rain occurred. The model forecast a narrow axis of rainfall of 5 to 10 cm (2 to 3 in) during this time over about half of the spatial area where the rainfall actually occurred. While only capturing about half of the observed amounts, this QPF forecast would have provided much better guidance to the forecaster of the potential for a heavy rainfall event in this area. It is important to note, however, that the model did also show other small scale areas of heavy rainfall of somewhat lesser amounts within the model domain which did not occur.

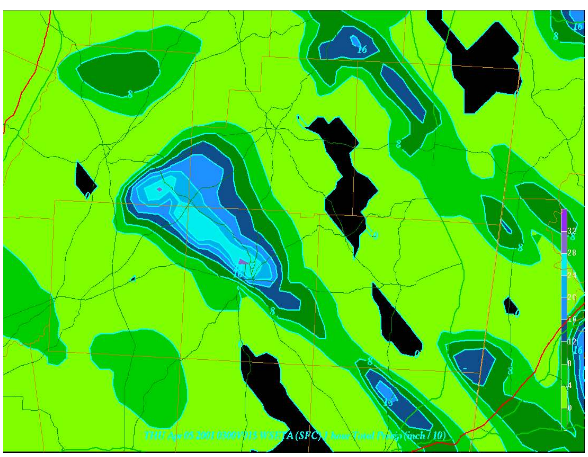

Figure 3. Total precipitation from the WFO JAN WS-Eta model from 2000 UTC to 0200 UTC 4 April 2001 in inches. Northwest to southeast axis in center of figure shows rainfall amounts of 5 to 10 cm (2 to 3 in).

Perhaps more importantly, the model did very accurately forecast the position of the boundary where the heavy rainfall producing thunderstorms developed. This boundary could clearly be seen in the surface wind forecasts and forecasts of mean sea level pressure from the model. Hourly forecasts of these parameters indicated that the boundary would be quasi-stationary over the area for about a 4 hour period. When combined with the fact that observed soundings indicated a very moist and unstable atmosphere over the area, knowledge that a boundary could become quasi-stationary over the area for several hours could have been an important short-term forecast clue that a localized very heavy rainfall event could occur in this area.

3.2 24 November 2001 Tornado Outbreak

A significant outbreak of severe thunderstorms and tornadoes occurred across parts of the lower Mississippi Valley, Mid-South, and Gulf Coast regions on 24 November 2001. A number of strong and violent tornadoes occurred during the region on this day, with several fatalities and millions of dollars in damage being the result.

For the county warning and forecast area (CWFA) of the Jackson, MS, (JAN) National Weather Service (NWS) Weather Forecast Office (WFO), the main impact of this outbreak occurred during the early morning hours between 0000 LST and 0800 LST. During this time period, eight tornadoes occurred across parts of extreme southeast Arkansas, extreme northeast Louisiana, and parts of northwest and central Mississippi. Two of these tornadoes produced damage rated as F4 on the Fujita-Pearson Damage scale, while two more produced damage rated as F3. One of the F4 tornadoes moved through a highly populated area in the northwest part of the Jackson, MS metropolitan area. A total of five people were killed in the Jackson CWFA during this event, and 95 people were injured.

The four strong to violent tornadoes which occurred on this morning were associated with three long lived supercell thunderstorms which moved across the region. The first two strong to violent tornadoes occurred with a supercell that moved through northeast Louisiana, southeast Arkansas, and northwest Mississippi between 0530 and 0900 UTC. A strong tornado occurred from a supercell that moved across northeast Louisiana and west central Mississippi between 0800 and 1030 UTC. A violent tornado then occurred from a supercell that progressed across southwest and central Mississippi between 0900 and 1200 UTC.

While conditions were identified as much as 48 hours in advance of this event as being favorable for potential supercell development across the Jackson CWFA, the most favorable area for development was expected to be across southern Missouri and northwest Arkansas. The National Centers for Environmental Prediction's (NCEP) Storm Prediction Center had placed this area in a "moderate" risk of severe thunderstorms, while the western part of the Jackson CWFA was only in a "slight risk" of severe weather. This was due to the fact that the moderate risk area was forecast to be closer to a mid level shortwave trough and associated deepening surface low which was expected to move from northwest Kansas to northwest Missouri during the night of 23 November.

Another potential problem with supercell development over the Jackson CWFA was an apparent lack of instability. Model forecasts from the Operational Eta model (Fig. 4) initialized from between 18 and 30 hours prior to the event, and the RUC model initialized 6 to 9 hours prior, showed Convective Available Potential Energy (CAPE) values ranging from 300 J kg^{-1} to 1200 J kg^{-1} across the area affected by the tornado outbreak. In actuality, the 1200 UTC 24 November sounding from JAN showed a CAPE value in excess of 2000 J kg^{-1}.

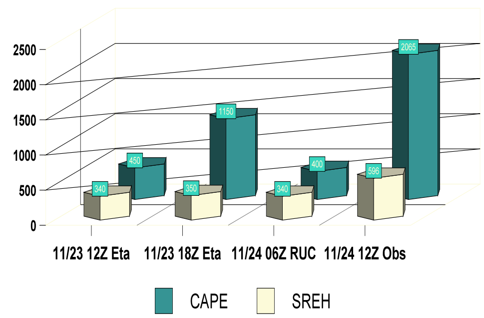

Figure 4. Graph of model forecasts of CAPE and storm-relative helicity (SREH) at JAN with 1200 UTC 24 Nov JAN observed values.

Forecasts of convective initiation were another issue with this forecast scenario. The operational Eta model showed very little in the way of convection developing in the warm sector, except for a convective squall line just ahead of the front. This convection was not forecast to enter the JAN CWFA until after 0900 UTC, and only affect the extreme northwest parts of the CWFA between 0900 and 1200 UTC . The only QPF forecast by the model that temporally and spatially approximated the development of the storms ahead of the squall line were very light (less than 0.15 cm (0.05 in)) rainfall amounts over central Mississippi between 0900 and 1200 UTC.

Two hindcast reruns of the WS-Eta were made for this event, both initialized at 1800 UTC 23 November. The first rerun was the standard JAN WS-Eta described above. The second was the same, except for the use of the Kain-Fritsch (K-F) cumulus parameterization scheme.

With regard to convective initiation, the normal JAN WS-Eta configuration run had a similar QPF forecast as the operational WS-Eta, with little in the way of QPF shown. Conversely, the K-F WS-Eta configuration QPF forecasts did show the development of convection across southeast Arkansas, northeast Louisiana, and northwest Mississippi between 0600 and 0900 UTC. Additionally, the model QPF forecast for 0900 to 1200 UTC appears to show several convective cells moving across southwest and central Mississippi, in a relatively close approximation to what was observed (Fig. 5). However, the model did also forecast convective development in the 0600 to 1200 UTC timeframe over eastern Mississippi which did not occur.

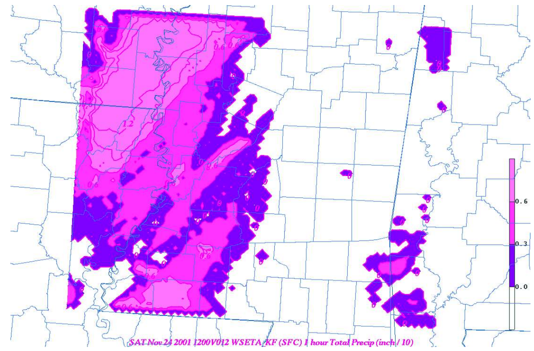

Figure 5. Total precipitation from the Kain-Fritsch version of the WS-Eta from 0900 UTC to 1200 UTC 24 November 2001.

Forecasts of instability were handled better by both version of the WS-Eta than the operational models. Both WS-Eta versions showed much stronger destabilization across the area affected by the tornado outbreak, with the normal JAN WS-Eta configuration showing CAPE values in excess of 1750 J kg^{-1} over most of the western two-thirds of the model domain by 1200 UTC. The K-F version of the model had slightly lower values. From a subjective perspective, the models' forecast of a smooth destabilization through the 0600 to 1200 UTC also seems more reasonable than the operational Eta, which indicated some destabilization over the area between 0300 and 0900 UTC, but then followed by a decrease in CAPE across western and central Mississippi between 0900 and 1200 UTC.

4. OPERATIONAL IMPLICATIONS

While only two cases, these events help to demonstrate the potential utility of a local mesoscale model in the operational environment. An important role these models can play is to show output from a model with an alternative physics scheme from the national operational model. This was particularly demonstrated in the 24 November 2001 case, in which instability was forecast more accurately by the WS-Eta models than by the operational model. This was likely due to the fact that the models were not using the Betts-Miller-Janjic convective scheme, which operational experience has suggested can incorrectly overreduce forecasts of CAPE in areas of scattered convection. Locally run models can be used in an ensemble type method to show the forecaster alternate forecast scenarios utilizing models with different physics and parameterization schemes than the operational models.

Additionally, a fine scale local model can provide forecasts of key meteorological parameters which can be utilized in situations when mesoscale processes will dominate. This was shown in the 4 April

2001 case, in which mesoscale forcing along an outflow boundary was the mechanism for driving a localized flash flood event. A model run on such a small domain as the JAN configuration will be most useful in this type of an environment in which synoptic scale forcing is weak, and features propagating into the model from the model boundary will not contaminate and overwhelm the model forecast.

These two cases did show that mesoscale models can have some skill in capturing mesoscale features such as boundaries, supercell storms, etc. However, they also demonstrated that the model can often develop spurious features which do not verify. For the cases outlined here, the mesoscale models seemed to be most useful in terms of showing signals to the forecaster that could be a hint of something developing outside of the operational model forecasts, e.g., a persistent outflow boundary or much greater instability. The utility of actual model QPF was somewhat more limited, as while the models did show some convection which actually developed as forecast, the models also forecast significant convective development which never materialized.

A critical question which may face the operational community in the future is how to integrate mesoscale model output into the forecast process. Many forecasters are familiar with the tools of synoptic forecasting such as quasi-geostrophic theory and isentropic diagnostics, but are not generally as familiar with how to apply output from mesoscale (or storm scale) models. One of the main goals of running this model at WFO JAN was to familiarize forecasters with the “look and feel” of a fine scale mesoscale model. The current configuration has some drawbacks, particularly that the small domain needed to run such a high resolution can potentially lead to boundary condition errors. However, these potential drawbacks are currently being outweighed by the fact that forecasters are gaining some familiarity with the type of model which will become a more utilized forecast tool in the near future. Additionally, running the model at a 5 km resolution will give forecasters the opportunity to incorporate model data into forecasts prepared using the Interactive Forecast Preparation System (IFPS) at the same horizontal resolution being utilized in the IFPS Graphical Forecast Editor (GFE).

5. FUTURE WORK

WFO Jackson is currently working with the meteorology program at Jackson State University (JSU) to develop a local mesoscale model ensemble system, utilizing members from the WS-Eta, MM5, and the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) model. This system would likely involve WFO JAN running two versions of the WS-Eta, one non-hydrostatically with explicit precipitation, and another hydrostatic version with the K-F cumulus parameterization scheme. Both versions would run with larger spatial domains than currently utilized, in an effort to reduce potential errors from boundary conditions. JSU would run multiple version of the MM5 and COAMPS models with differing physics packages, to produce a several member ensemble. Plans are to develop visualization techniques which would enable forecasters to utilize the output from these models in an efficient manner.

ACKNOWLEDGMENTS

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