4.3 THE IMPACT OF CHOICE OF CONVECTIVE SCHEME ON SYNOPTIC FEATURES IN THE NCEP ETA MODEL

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1. INTRODUCTION

The role of the convective parameterization in a model is often thought of as primarily impacting the precipitation locations and amounts predicted by the model – the different schemes with different triggers, vertical transports, and such respond differently to the ambient synoptic (and mesoscale) pattern in the model and generate different patterns of precipitation. The schemes, however, are capable of actually driving the synoptic scale. Both shallow (non-precipitating) and deep convection parameterized by the model can alter the tracks and intensities of synoptic-scale cyclones, and these impacts are not limited to the "warm season."

The operational Eta model employs the Betts-Miller-Janjic (Betts 1986, Janjic 1994; hereafter BMJ) convective scheme. Full details of the parameterization will not be discussed, but this is a convective adjustment scheme, designed to nudge the environment towards an equilibrium state. This scheme simply looks for instability and, if it finds it, will generate deep convection if sufficient moisture is available. Kain et al. (1998) discuss concerns about the ability of this scheme to perform at higher resolutions in the Eta model. This paper was written when the Eta was run at a horizontal resolution of 29 km (a special configuration known as the "MesoEta"; the model is now run at a resolution of 12 km.

2. EXPERIMENTS

A warm-season case and a cold-season case, each in which the precipitation forecast from the operational Eta demonstrated significant shortcomings, were selected for tests. The model was rerun with alternate convective schemes at a horizontal resolution of 12 km with 60 levels. Each run used the same initial conditions from the operational run; a separate assimilation cycle was not run for each.

The primary competitor for the BMJ scheme in these runs is the Kain-Fritsch convective scheme (Kain and Fritsch, 1993; hereafter KF). This is a mass-flux scheme with a trigger based on parcel theory. Parcels are given an upward perturbation based on the ambient vertical velocity to see if they can reach the level of free convection. The Ferrier convective scheme (Ferrier, 2004; hereafter FER) is a modified version of the BMJ scheme designed to generate more meaningful structure in precipitation patterns. Among the changes include updated tables and calculated values for equivalent potential temperature, removal of the cloud efficiency functionality, and new limits for how high a parcel can be lifted to its condensation and free convection levels as well as an increase in the depth searched for candidate parcels. Another test is made using no deep convective parameterization (hereafter NO DEEP). It allows the model grid-scale microphysics to remove instability and generate precipitation. It has a tendency to have "runaway" grid-scale processes generate unreasonably high, localized amounts of precipitation, but at the least, it can be helpful in diagnosing aspects of deep convective feedback in other runs.

3. CASE 1: 09 DECEMBER 2002

The 1200 UTC Eta model cycle for 09 December 2002 showed potential for a significant winter storm in the mid-Atlantic region, beginning as early as the next afternoon. Fig.1 shows the verification for 0600 UTC 11 December, with a weak surface low pressure center east of the North Carolina coast. Fig. 3 shows the surface observations valid at 06Z 11 December indicating that precipitation did not arrive in the Washington, DC area until the following early morning (after 42 hours into the model cycle). The 42-hour Eta forecast is shown in Fig. 2. The surface low is predicted too far to the west and is too intense. The result is that heavy precipitation is generated in the mid-Atlantic far too early. The 42-hour forecast shows over 0.25" of liquid in the Washington, DC area, and another 0.25" was predicted for this region in the previous 6 hours (not shown). Given the forecasted vertical profiles, freezing rain was likely at the onset, and the timing of the operational forecast would have placed the evening rush hour in peril.

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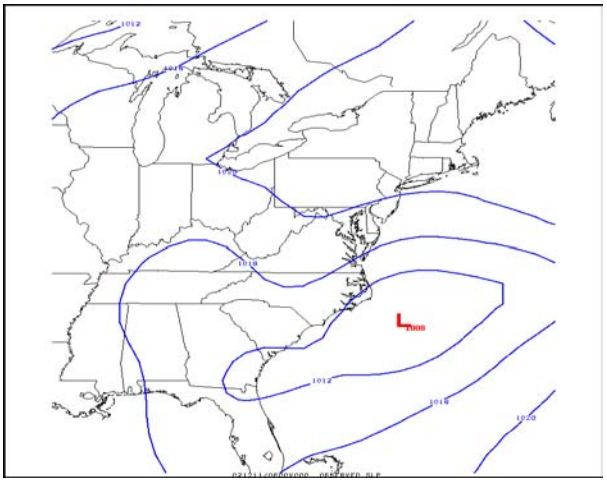

Fig.1. Surface analysis valid 0600 UTC 11 December 2003.

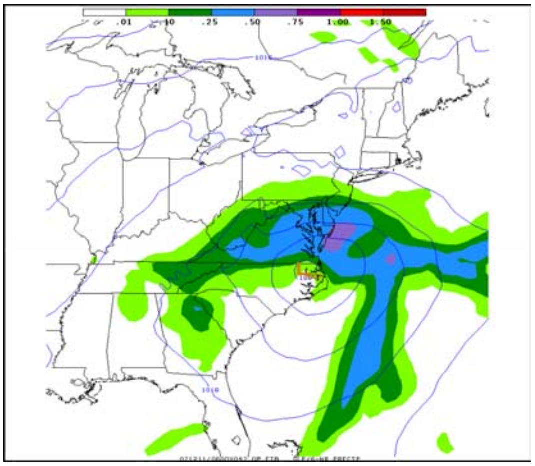

Fig. 2. 42-hour Eta model forecast of sea level pressure (blue lines, hPa) and 6-hour total precipitation (inches, colored) valid 0600 UTC 11 December.

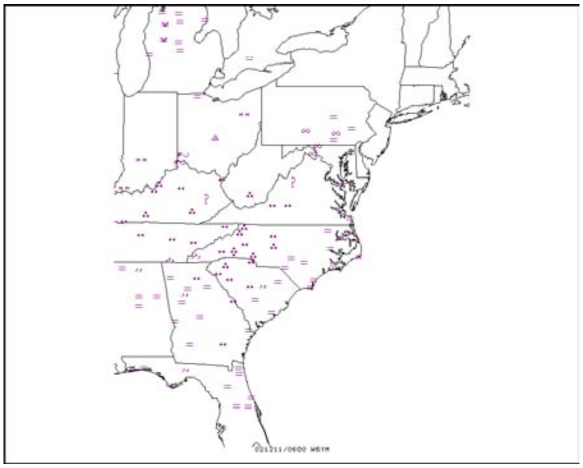

Fig.3. Surface observations, 0600 UTC 11 December 2002.

Fig. 4 shows the 42-hour forecast from the KF run. At first glance, the sea level pressure pattern looks fairly similar to the BMJ run, with the primary cyclone shifted only slightly east over North Carolina.. A closer inspection, however, of the pressure field reveals differences of over 6 hPa compared to the BMJ run over southeastern Virginia. The different orientation of the isobars results in stronger onshore flow in the BMJ run, creating the erroneous moderate precipitation into the Washington, DC area. Both runs, however, incorrectly predict heavy precipitation across southeastern Virginia. After this time period, the BMJ run takes its low pressure center more to the north, while the KF run takes it more to the northeast (not shown), so that by 54 hours, sea level pressure differences between the two runs (Fig. 5) are up to 12 hPa.

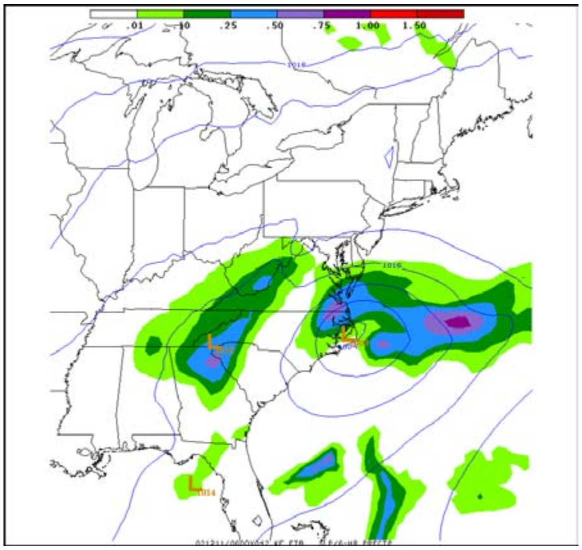

Fig. 4. Same as in Fig. 2, except for the KF run.

Fig. 6 shows the same forecast from the FER run. The forecast of the Carolina low is much improved, with the center weaker and further to the east. It breaks out precipitation in the Washington, DC area a little too fast, but it is still a significant improvement over the BMJ run. It also handles the maximum over western North Carolina and eastern Tennessee fairly well, although it creates spurious heavy precipitation across central Florida. The NODEEP run (not shown) has its primary surface low further east than the BMJ run, but it still too intense, and it is still too quick to bring precipitation into the mid-Atlantic region.

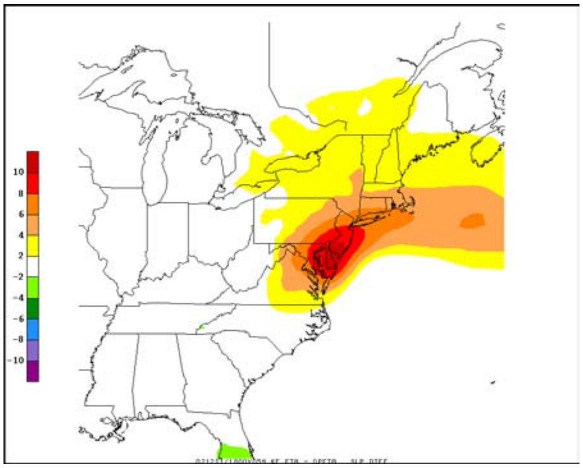

Fig. 5. Sea level pressure difference (hPa) KF-BMJ.

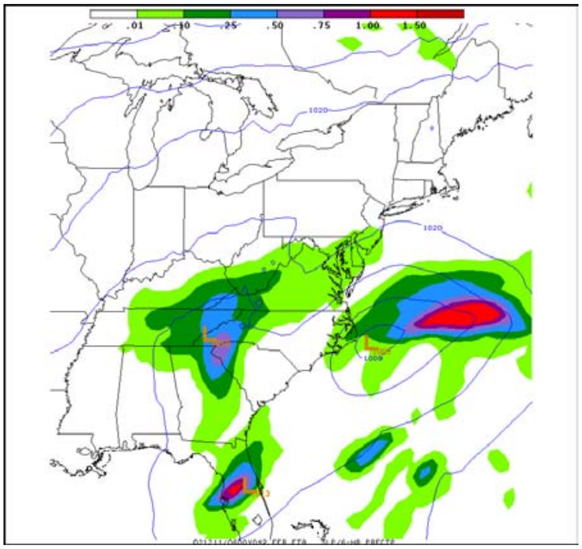

Fig. 6. Same as in Fig. 2, except for the FER run.

4. CASE 2: 06 JUNE 2003

The second case involves a warm-season overrunning rainfall event with embedded convective elements in the mid-Atlantic region in the late spring of 2003. Fig. 7 shows surface observations valid at 1600 UTC 7 June 2003. An area of heavy rain is clearly evident across central and eastern Maryland, south-central Pennsylvania, and across to the Delaware coast. This time is fairly representative of the 6-hour period between 1200 and 1800 UTC for which model precipitation forecasts will be examined. Observed heavy rainfall at the start of this time period was a little further to the west, and it was a little further east by the end, but this plot serves as a decent snapshot of the 6 hours.

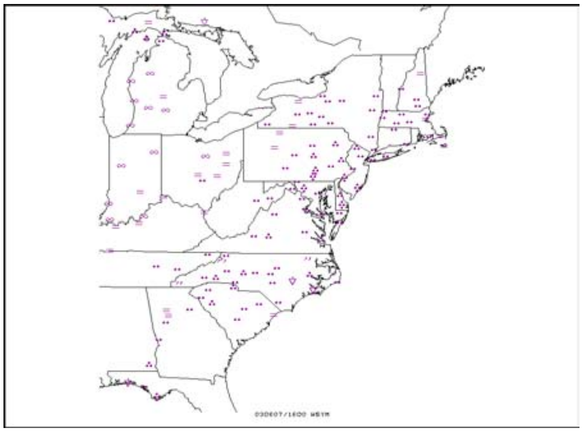

Fig. 7. Surface observations at 1600 UTC 7 June 2003.

Fig. 8 shows the operational Eta model 6-hour total precipitation forecast valid from 1200 to 1800 UTC on this same day. The axis of heavy precipitation is located too far to the north and west. This area of precipitation can be traced back to eastern Tennessee and Kentucky during the previous night. It moves to the northeast and moves across northern New England during the next 24-hour period. Fig. 9 shows the same 6-hour rainfall forecast from a run made with the KF convective scheme. The heavier rainfall is further to the southeast, closer to the observations.

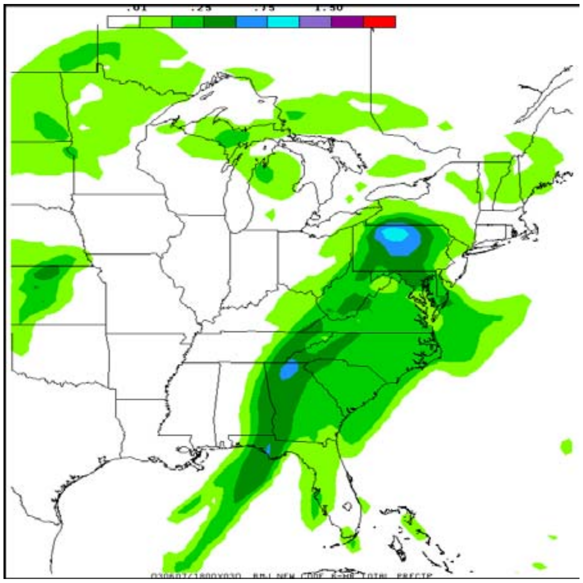

Fig. 8. 6-hour forecast of total precipitation from the operational Eta model valid 1800 UTC 7 June 1993.

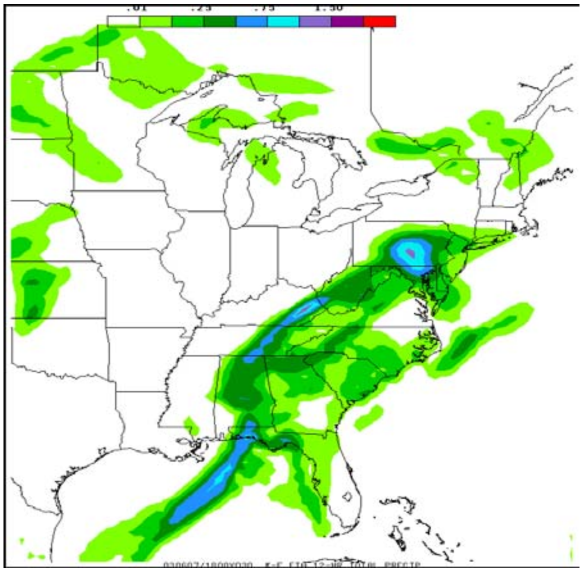

Fig. 9. Same as in Fig. 8, except for the model run made with the Kain-Fritsch convective scheme.

The KF run is far from perfect; it misses some of the observed rainfall across southeastern Virginia and northeastern North Carolina. The BMJ run hits more of this, although this appears to be a result of the scheme triggering over a widespread area with much of the warm sector predicted to receive between 0.10 and 0.25 inches of precipitation. The KF run contains more "mesoscale structure," although some of it is incorrect.

The differences in the convection patterns between the two runs lead to some noticeable differences in the surface predictions. Figs. 10 and 11 compare the sea level pressure and 2-meter dew point forecasts. The BMJ run actually develops a spurious closed surface low pressure center in its region of heavy convective rainfall over northwest Pennsylvania. The circulation brings higher dew points north to the New York border. The model then tracks this low (not shown) into New England where its accompanying heavy rainfall axis is too far to the north and west.

5. DISCUSSION

It should be noted that a full analysis of the details on how the convective processes in the model feed back to the synoptic scale in these cases has not been completed at the time of the preparation of this article. It is hoped that this will be presented at the conference. One can make a fairly educated guess to surmise the processes with the different warm season case evolutions. The BMJ scheme generates a large area of deep convection which moves to the northeast and generates a spurious surface low pressure center which leads to more precipitation too far to the north and west.

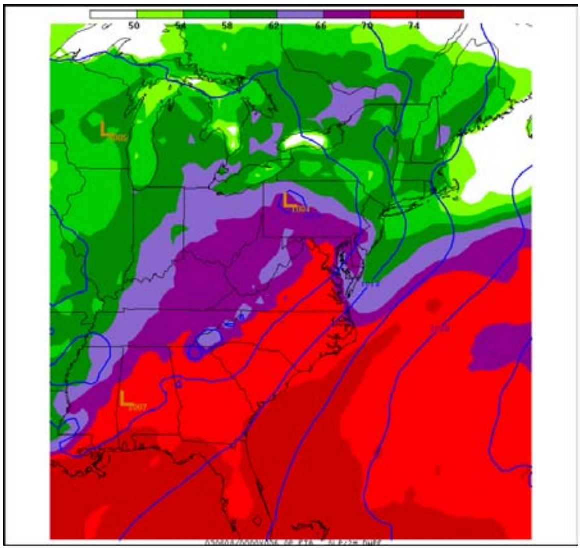

Fig. 10. Sea level pressure (contoured every 4 hPa) and 2-meter dew point (filled colors) from operational Eta valid 0000 UTC 8 June 2003.

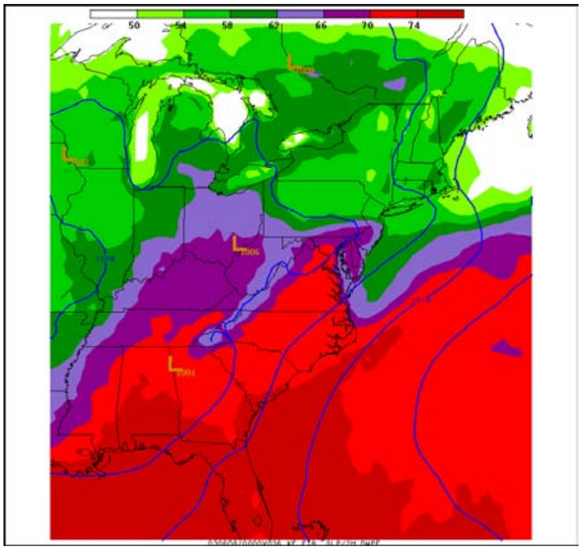

Fig. 11. Same as in Fig. 10, except for KF run.

The winter case appears to be more confusing. The BMJ, KF, and FER runs produce very different solutions along the North Carolina coast. The differences in the amounts and locations of deep convection that the different runs produce (not shown), however, are not large. Amounts of convective available potential energy prior to the intensification of the coastal storm are also not large. It is very possible that shallow convective processes are modifying the environment in the region in question, but no direct impact has been found at this time.

6. REFERENCES

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