17.8

CONVECTIVE CONTAMINATION AND THE POOR FORECASTS THAT FOLLOW

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1. Introduction

The motivation for this investigation originates from the difficulty in forecasting Mesoscale Convective Systems (MCS) as noted by Gallus et al. (2004), and Jankov and Gallus (2004a and b). Given the difficulty in forecasting such events (ie. low summer QPF verification statistics), we look at one likely source for model errors: model generated initial conditions (ICs). We seek to identify a few cases where model error due to convection (from a 3 hour forecast) is present in the data assimilation first guess. The errors we identify have only partially been explored by Baldwin et al. (2002, hereafter B02). B02 noted that the Betts-Miller-Janic (BMJ) convective scheme left readily identifiable signatures in the vertical profiles of dew point and temperature due to deep and shallow convection. B04 further concluded that the lack of detail in vertical profiles (ie. removal of capping inversion, pseudo-moist adibatic lapse rates, etc.) was a signature of the BMJ scheme.

Active convection in the model first guess may not be removed by assimilating regular observations especially when the resolution of the model is coarser than that of observations. Thus the signatures of the convection may still be present. The signature left by the model convection will result in a convergent zone outside the convection while within the model convection a divergence signature will be present. This preconditioning (where the model ICs precondition the development of precipitation) is a result of the contamination. Simply reanalyzing observations back onto the ICs will not necessarily resolve the issue, especially at fine resolution. We speculate that only through reassimilating all the observations can there be any hope of removing or minimizing the contamination.

What does this contamination look like? Can it be seen by scrutinizing the ICs? The contamination may not be readily identifiable simply by looking at model state variables. Perhaps dynamic variables, such as divergence, may be used to see the effect of convection. B02 showed that vertical profiles of temperature and dew point could be ascertained for the presence of previous or current convection.

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We hypothesize that model convection should be identifiable as:
1. reduction in moist static energy,
2. displacement of convergence zones, or
3. enhancement of convergent/divergent areas.

Here we compare Penn. State University/National Center for Atmospheric Research mesoscale model version 5 (PSU/NCAR MM5) simulations using ICs obtained from the ETA and AVN models with the AVN as the control since it is much coarser in horizontal resolution. ETA and AVN are the primary tools for the initialization of high resolution mesoscale models such as MM5, workstation ETA, and now the Weather Research and Forecasting (WRF) model. Few if any studies in the last 5 or 6 years have used anything but other model data to initialize their mesoscale model.

We used MM5 to simulate 3 cases which were suspected of having model ICs problem due to poor model simulations of precipitation (compared to observations) both in an operational and research setting. The 4 June 1999 and 10 July 2000 cases were part of the studies by Jankov and Gallus (2004a and b) and the 31 May 1999 case was poorly simulated with numerous model configurations by Correia and Arritt (2003, hereafter CA03).

2. Data and methodology

We used the non-hydrostatic sigma coordinate MM5. We chose typical physical parameterizations including the MRF planetary boundary layer (PBL) scheme, mixed phase (Reisner) microphysics, Dudhia simple radiation, 5 layer soil model, and the Kain-Fritsch 2 convective scheme. The model used 57 vertical levels on a 10km grid. The 31 May 1998 case used 70 $\times$ 150 grid points while the rest used 90 $\times$ 100. All model data were interpolated to the MM5 grid where the integrated mean divergence in the column was removed and surface information from the parent model was used. These simulations were run for 24 hours.

Model initial conditions were obtained from the 40km Eta model and the AVN 1° by 1° resolution data. Boundary conditions were updated every 12 hours using the analysis valid at each time from the respective model data.

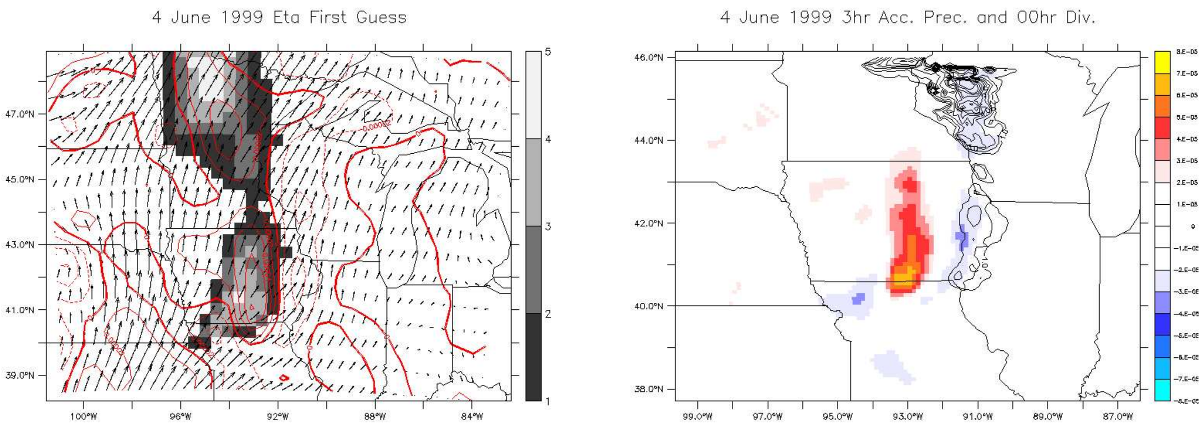

FIG. 1: 1200 UTC 4 June 1999 a)Model first guess from the Eta model showing 900 hPa wind vectors, convective precipitation (shaded every mm from 1) and divergence (contoured every 1×10^{-5} $s^{-1}$from -9 to 10) and b) Initial condition from the Eta model showing divergence (shaded), wind vectors at 900 hPa and total 3 hr accumulated precipitation (contoured every mm) from MM5.

3. Simulations

3.1 *4 June 1999*

On 4 June 1999, an MCS developed to the rear of another MCS. This system organized quickly and by 12 UTC began forming a cold pool. By 15 UTC the system strengthened and took on the appearance of a bow echo although high wind reports did not begin until 1648 UTC. This bow echo left Iowa shortly after 0000 UTC 5 June 1999 and moved into Alabama by the next morning.

The ETA equivalent potential temperature was reduced relative to the AVN from the surface to 900 hPa by 8-14K in the region where this bow echo developed (not shown). The divergence signature in southern Iowa came from the BMJ cumulus scheme used in the data assimilation process (Figure 1a). This signature produced convergence on its eastern periphery and was responsible for generating precipitation over the following 3 hours (Figure 1b). The reduction in moist static energy is a signature of the BMJ scheme and in this case prevents the development of the bow echo MCS. Jankov and Gallus (2004b) noted that small improvements occurred when the relative humidity was adjusted based on radar reflectivity for this system. Thus it is possible to insert the system after the assimilation process to improve upon the contamination.

3.2 *31 May 1998*

A mid level disturbance propagated from far western South Dakota to eastern South Dakota by 0000 UTC 31 May 1998 and triggered a couple of tornadic supercells. These supercells eventually merged with a forming line of convection along a eastward moving cold front. The developing squall line immediately began producing damaging wind, hail and tornadoes. As the system grew in size, a derecho MCS evolved from 0800 UTC through 1200 UTC over Wisconsin and Michigan.

CA03 modelled this event with varying PBL, microphysics, and cumulus schemes. The evolution of all the different model configurations was similiar given the microphysics contained ice processes. CA03 argued that gravity waves helped the modelled system attain realistic propagation characteristics. These gravity waves evolved 2 hours into the simulation and originated from within a broad convergence zone. Thus without the convergence zone this simulation would have been worse. The convergence zone came from the development of model convection (Figure 2a) which acted to reduce the vector wind speeds within this area while the low level jet to the south strengthened (not shown).

The ETA ICs for this case showed a strong west-east convergence pattern in southern Minnesota which led to the immediate production of precipitation. Since a comparison with the AVN ICs is lacking it is difficult to discern if the ICs were convectively contaminated. However, in viewing ETA model output from this period, it is not surprising that the ETA precipitation (Figure 2b) covers the same area (ie. forming along the warm front as over-running).

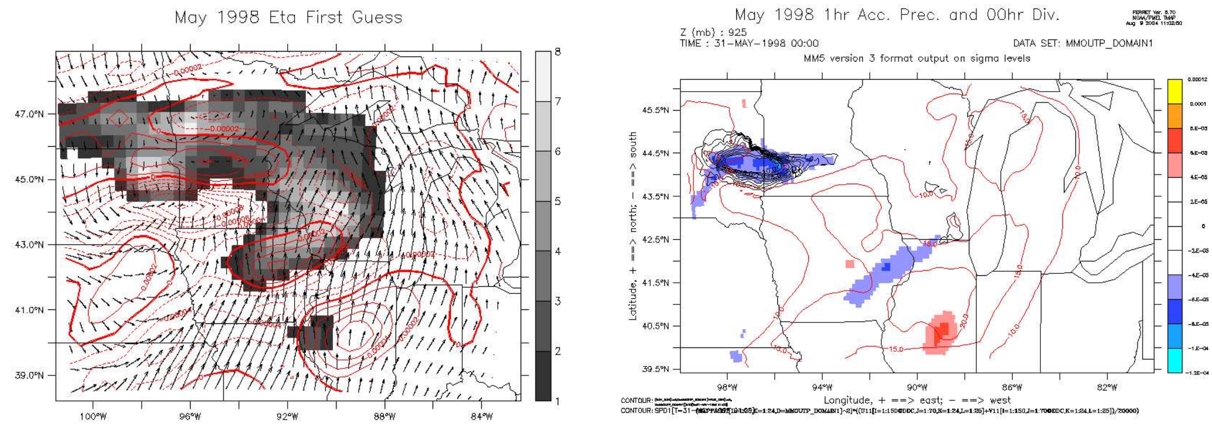

FIG. 2: Same as Figure 1 except for 0000 UTC 31 May 1998 with divergence calculated at 925 hPa.

3.3 *10 July 2000*

The MCS of 10 July began in the eastern third of South Dakota and propagated southeast along a frontal boundary through Iowa and southern Minnesota. This event was classified as strongly forced by Jankov and Gallus (2004a) and was not well predicted in spatial coverage, precipitation amount and timing.

The 3 hour forecast used as the model first guess showed copious amounts of precipitation focused over northwest Iowa, northeast Nebraska, southeast South Dakota, and southwest Minnesota (figure 3a). Thus the low level winds were convergent around the periphery of this model generated system.

The simulation using the ETA model ICs showed a 500hPa northwesterly flow jet streak propagating southeast through Iowa which was coupled to a low level jet from the southwest (not shown). In addition, an area of strong covergence was present across Nebraska. The AVN ICs contained both the mid and low level jets, with the mid level jet having 5 m s^{-1}slower wind speeds. The convergence zone across Nebraska was virtually absent in the AVN ICs. Additionally the ETA equivalent potential temperature was reduced by 10-15 K from that of the AVN ICs (not shown), where the first guess had developed the convection (reduced moist static energy). One maximum of -15 K lay just to the northwest of the Nebraska convergence zone with another maximum close to the position of the observed MCS.

The 1 hour forecasts (Figure 3b) for this case had precipitation developing along the frontal zone in Iowa for both model ICs, but the ETA simulation contained much heavier precipitation amounts and focused precipitation along both the convergence zone and the front. The forecasts failed to generate the MCS that was present in the northwestern portion of the domain and even when precipitation did develop it did not organize; that is, frontal overrunning appeared to be the mode of convective initiation and maintenance.

4. Discussion

A variety of signatures were found in model ICs that represented model convection. Scrutinizing model ICs can lead to identification of these features, provided one has a different model IC to compare to. This may aid in the identification of events that can be modelled “out of the box” to ascertain system characteristics or even model performance. Understanding the role of these contaminated ICs may help alleviate some of the summer QPF problem (Fritsch and Carbone 2004).

Methods to correct the poor ICs (i.e. insert the observed MCS into the model) may come from radar data assimilation as noted earlier, but also cold pool schemes which may insert the effect of the observed system by introducing the divergence/convergence signatures along with thermodynamic information. This work is underway.

5. Future Work

Future work should be performed to simulate these events with observations reintroduced through 3DVAR procedures recently developed by Barker et al. (2004) to remove the contamination. Reanalyzing observations back onto the model grid can not remove the effects that 3DVAR produces with re-

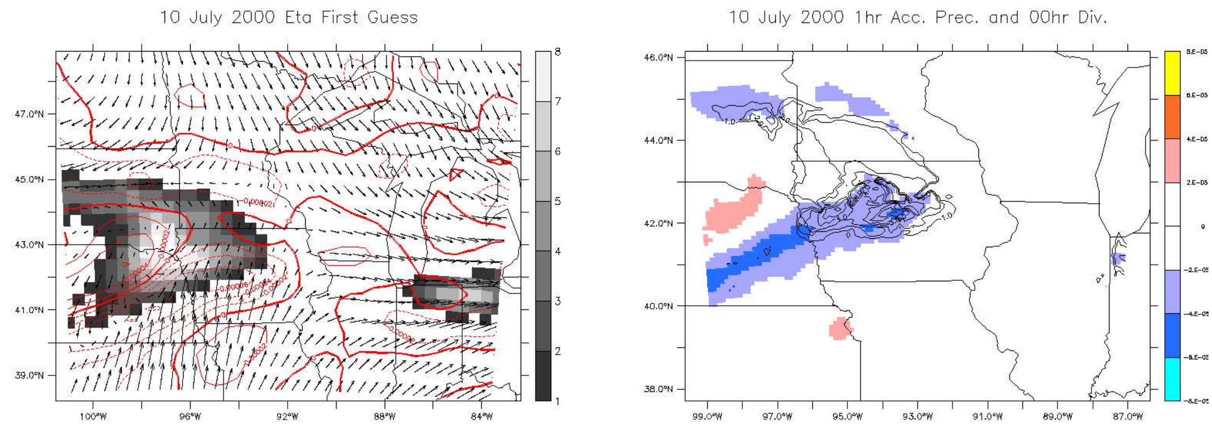

FIG. 3: Same as figure 1 except for 0000 UTC 10 July 2000.

spect to vertical and horizontal influence from even a single observation.

The simulations reported here may have suffered from small domain size due to lateral boundary condition effects. Increasing the domain size and/or forcing frame would allow a more complete evaluation to ascertain the boundary condition impact. Most importantly, data assimilation should be attempted with a model at high resolution with explicit representation of convection. This may remove the contamination from poorly forecast systems and also alleviate some potential boundary condition issues. This may help not only in the modelling aspect, but also to facilitate the increasing need for high resolution observations and the efficient and maximal use of high resolution surface data. Increased model resolution should demand high resolution observations.

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6. References

Baldwin, M. E., J. S. Kain and M. P. Kay, 2002: Properties of the convection scheme in NCEP's Eta model that affect forecast sounding interpretation. *Wea. Forecasting*, **17**, 1063-1079.

Barker, D. M., W. Huang, Y.-R. Guo, A. J. Bourgeois, and Q. N. Xiao, 2004: A three-dimensional variational data assimilation system for MM5: Implementation and initial results. *Mon. Wea. Rev.*, **132**, 897-914.

Fritsch, J. M. and R. E. Carbone, 2004: Improving quantitative precipitation forecats in the warm season. A USWRP research and development strategy. *Bull. of the Amer. Meteor. Soc*, **85**, 955-965.

Gallus, Jr., W, J. Correia Jr, and I. Janokv, 2004: The 4 June 1999 Derecho event: The ultimate challenge for numerical weather prediction? Preprints, 22nd Conf. on Severe Local Storms. Hyannis, MA, Amer. Meteor. Soc..

Jankov, I. and W. A. Gallus Jr., 2004: Some contrasts between good and bad forecasts of warm season MCS rainfall. *Journ. of Hydromet.*, **288**, 122-152.

Jankov, I. and W. A. Gallus Jr., 2004: MCS rainfall forecast accuracy as a function of large-scale forcing. *Wea. Forecasting*, **19**, 428-439.

Warner, T. T., R. A. Peterson and R. E. Treadon, 1997: A tutorial on lateral boundary conditions as a basic and potentially serious limitation to regional numerical weather prediction. *Bull. of the Amer. Meteor. Soc*, **78**, 2599-2617.