EVALUATION OF ETA MODEL FORECASTS OF MESOSCALE CONVECTIVE SYSTEMS

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1. INTRODUCTION

Research scientists at the National Severe Storms Laboratory (NSSL) have been running an experimental version of the Eta model (Black 1994) for several years. Output from this model has been provided to forecasters at the Storm Prediction Center for use in convective forecasting and evaluation . The difference between this version of the Eta model and the operational version lies mainly in the convective parameterization scheme (CPS) used in their configuration . The experimental Eta contains the Kain-Fritsch CPS (Kain and Fritsch 1993 - hereafter EtaKF) whereas, the operational Eta contains the Betts-Miller-Janjic CPS (Betts 1986; Janjic 1994 - hereafter Eta). Differences between these two versions of the Eta in the prediction of organized mesoscale convective systems (MCSs) have frequently been noted by forecasters and research scientists at NSSL/SPC; yet, these differences have never been systematically examined, providing motivation for this study.

Results from this study are obtained through a subjective evaluation of 0000 UTC and 1200 UTC Eta and EtaKF forecast variables. Specifically, 3h and 6h QPF, model forecast Upward Vertical Velocities (UVV), and EtaKF Updraft Mass Flux (UMF) are examined to determine strengths and weaknesses of model forecasts in the 12 to 24 hour time frame. These fields were chosen because they are examined frequently during the operational forecasting process at the SPC.

A total of eight cases from the 2000 and 2001 warm seasons are evaluated. The primary criterion for choosing these events is their characterization as long-lived, forward propagating MCSs with well-defined leading-line/trailing-precipitation organization (see Houze et al. 1990). All events occurred during the warm season, and are mainly severe wind producing events.

2. ETA AND ETAKF CONFIGURATIONS

Aside from its use of a different CPS, the EtaKF differs from the operational Eta in its formulation for horizontal diffusion. Specifically, it uses a fourth order scheme, while the Eta uses a second order formula. The fourth order approach reduces the amount of damping that the model imposes on meso-alpha scale atmospheric structures. In addition, EtaKF integrations are made using a domain which is only a subset of that used by the Eta (see http://www.nssl.noaa.gov/etakf for a graphical depiction).

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2.1 The Betts-Miller-Janjic Scheme

The BMJ scheme is a convective adjustment scheme. Whether or not activation of parameterized convection occurs is determined using cloud layer moisture and convective available potential energy (CAPE). In particular, the scheme will normally activate convection if CAPE exists for some parcels in the lowest 200 mb of a sounding, although activation may be in the form of shallow (non-precipitating) convection if the atmosphere is not sufficiently moist over a deep layer (Baldwin et al. 2002). Whenever CAPE exists and deep-tropospheric moisture exceeds a certain temperature dependent threshold, the scheme induces a deep convective adjustment from the LCL to the level of neutral buoyancy and produces convective rainfall. If the cloud-layer moisture is insufficient and CAPE exists or if the CAPE layer is too shallow, the BMJ scheme will switch to "shallow", non-precipitating convection. Both modes of convection adjust the grid-point environment toward a sub-saturated, predefined temperature and dew point profile when activated.

2.2 The Kain-Fritsch Scheme

The KF scheme is a mass-flux scheme that uses a simple cloud model to portray the vertical redistribution of mass in a column. In the KF CPS, parcel theory is used to determine convective initiation. When parcels originating in the lower troposphere are able to reach their level of free convection (LFC) and continue to rise for some specified depth (~ 4 km), deep convection is activated. See Kain and Fritsch (1992, 1993) for additional details. If a parcel reaches its LFC but does not continue to rise high enough for deep convection to activate, shallow (non-precipitating) convection is activated. Convective adjustment in the KF scheme does not conform the modeled atmosphere to specific profiles; instead, simple models of updrafts, downdrafts (deep convection only), and local compensating vertical motions are used to make adjustments.

3. METHODOLOGY

The first component of this evaluation involves a comparison of the Eta and the EtaKF. In order to examine model performance, a subjective, numerical rating scale was created. Initiation and progression of MCSs were evaluated separately. In particular, the placement of the quantitative precipitation forecast (QPF) and upward vertical velocity (UVV) field and the shape and orientation of the model signal were scored on a scale from –2 to 2 with a score of 2 representing an excellent forecast and –2 representing a poor forecast.

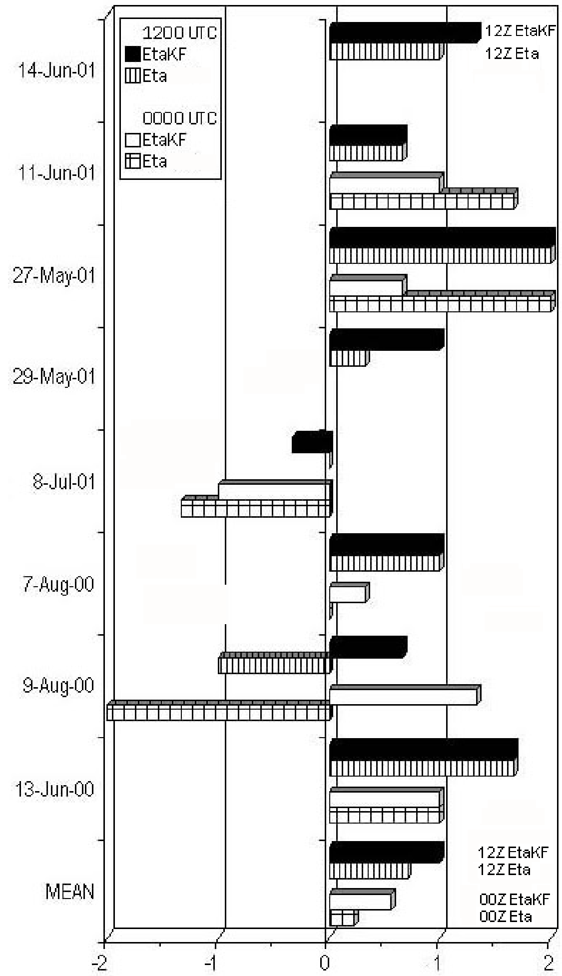

Fig. 1: Bar chart showing scores by case and overall mean for initiation: 0000 UTC Eta (grid); 0000 UTC EtaKF (white); 1200 UTC Eta (vertical stripes); 1200 UTC EtaKF (black).

The *intensity* of the QPF and UVVs was not taken into account when rating the models in order to avoid discrepancies that might occur due to the different horizontal resolutions of the model display grids.

The second element of the evaluation focuses on the EtaKF only. This involves an assessment of the parameterized updraft mass flux (UMF – see Kain et al. 2002), an output field that is unique to the EtaKF configuration. The UMF is a measure of parameterized convective intensity, so the evaluation focuses on comparing UMF to an observed measure of intensity; specifically, Vertically Integrated Liquid (VIL) values from radar. Data collection for this study was done in a manner that allows for the most accurate correlation possible. For example, the UMF or VIL value used is an average of maximum values present. Also, to avoid discrepancies that might occur do to timing of initiation, for a given case, VIL and UMF values were aligned at the initiation time of the actual convective system (radar) and model signal respectively, and were progressed using the same time intervals. For example, if the actual MCS initiation time was 1800 UTC but the EtaKF forecast initiation at 2100 UTC, the values at those times would be compared. The next pair of values to be compared would be from 1900 UTC and 2200 UTC (or 2100 UTC and 0000 UTC depending on the amount of time between UMF forecasts). This method assumes that initiation time does not effect forecast system progression in order to compensate for variations in start time.

It is important to note that this evaluation is based on a comparison of UMF with observed measures of *convective intensity, given that the model captured the fundamental characteristics of the event*. In particular, it is a conditional measure of correlation, sampled only when both the model and the real atmosphere have convective activity in the same region. For this study, data was collected only for those events in which UMF was predicted within 100 km of observed convective activity.

4. RESULTS OF THE MODEL PERFORMANCE EVALUATION

4.1 Initiation

The EtaKF was found to initiate systems better than the Eta (Fig. 1). In twelve of the fourteen model run times evaluated, the EtaKF produced forecasts that were adequate or better in the mean. The EtaKF received a higher mean score for the 0000 UTC and 1200 UTC forecasts as compared to the Eta. This result is consistent with the observations of forecasters during the 2000 and 2001 NSSL/SPC Spring Program (Janish et al. 2001).

The difference in the mean scores, however, is not statistically significant, according to a standard t-test. This is partially because only eight cases were examined. Another important factor, however, is that the Eta had highly variable results in terms of quality (especially in the 0000 UTC runs). As a result, statistical analysis yielded a high standard deviation, implying considerable uncertainty in the mean.

Although not statistically significant, the difference between the guidance offered by the two versions of the Eta model is noteworthy. In cases for identical forecasts when EtaKF and Eta verified, it was found that in 11 out of the 14 possible forecasts (about 79%) the EtaKF performed better than or was equal to the Eta in subjective evaluation of convective initiation.

Figure 2 exemplifies one type of initiation failure/success. While the operational Eta clearly did not initiate a signal for the event (Fig. 2a), the EtaKF, though slightly off in terms of placement, produced a clearly identifiable signal for initiation (Fig. 2b). Note that other types of initiation problems were observed. These were basically variations between the models in the placement of and area covered by the QPF.

4.2 Progression

Subjective evaluations of Eta and EtaKF forecasts of MCS *progression* did not favor either configuration in a consistent manner. There was little difference in overall scores, yet there were dramatic differences between the

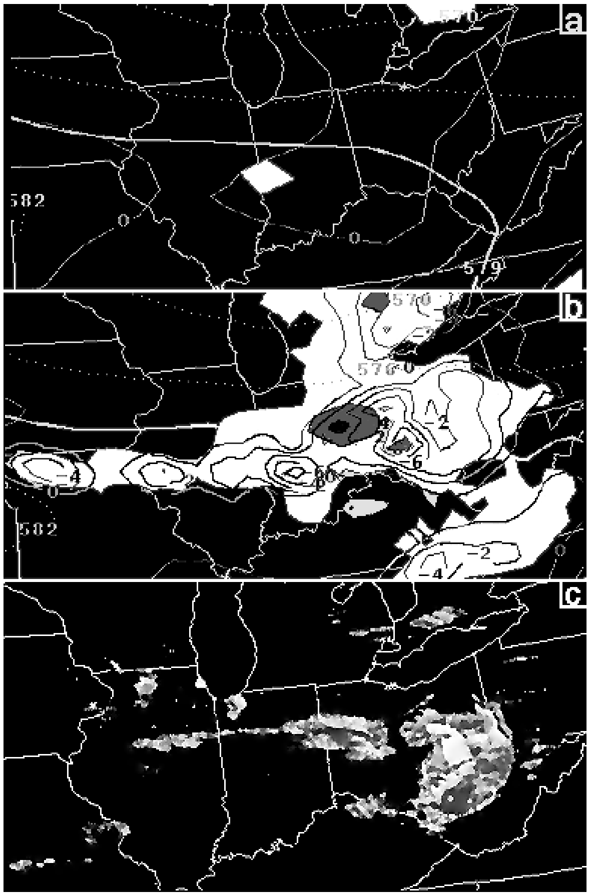

Fig. 2: 6h QPF from (a) Eta and (b) EtaKF and (c) 1h total base reflectivity, valid 1800 UTC 9 August 2000.

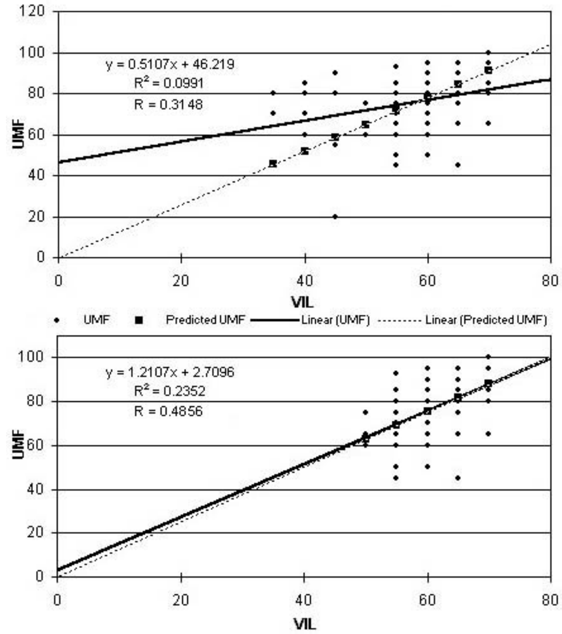

Fig. 3: UMF shown in percent value, VIL values shown in kg□m^-3. (a) Scatter plot and fit line illustrating UMF and VIL correlation with all ranges of VIL included. (b) Scatter plot and fit line illustrating UMF and VIL correlation with values of VIL below 50 kg□m^-3 removed.

two model runs in individual events. Thus, no particular model was preferred in this regard. Some characteristic behaviors were particularly notable though. For example, when the EtaKF had errors in forecasting progression, it tended to propagate systems too quickly and in the direction of the mean cloud layer wind (850-300 mb), instead of into the instability axis or low-level jet as was commonly observed. Conversely, the Eta seemed to progress systems too slowly when it contained errors in its signal.

The EtaKF bias to progress the model generated convective system with the mean wind may, in fact, be a significant finding. In six of the eight EtaKF cases examined, an intense 700-500 mb UVV maximum occurred coincident with high precipitation rates. In addition, a predominance of grid-resolved precipitation over parameterized precipitation was noted. In each of these cases, parameterized precipitation activated near the location of actual MCS initiation, and in seven of eight cases that activity progressed in the direction of the mean deep-layer wind. This occurrence, therefore, may be a useful signal that atmospheric conditions are conducive to the formation of well-organized MCSs. This finding is also significant to model interpretation in that the guidance given by the EtaKF for the progression of a MCS must be used with caution. Since a strong signal is present in most of these events for initiation and forecasts of progression are often in error, the explicit use of model initiation may lead to an incorrect assumption of higher confidence in the model forecast progression. A bias correction to deviate the model signal towards the LLJ, or instability axis if it is forecast to progress in the direction of the mean wind, is recommended.

4.3 Updraft Mass Flux

Updraft mass flux is another output field of the KF parameterization scheme considered in this study. It is, primarily, a measure of convective intensity that is derived through the entire atmosphere (Kain and Baldwin 2000); therefore, it was hypothesized that it might correspond well with VIL values. Results from this portion of the study did show a positive linear correlation between UMF and VIL (Fig. 3a). This correlation is stronger with the VIL values below 50 kg×m^-3 removed (Fig. 3b). Removing the lower range of VIL values increased the correlation coefficient by 17%. The lower VIL values were removed given that convection takes time to intensify in the real atmosphere, but the model maximizes UMF once the convective scheme is turned on, yielding high UMF values at low VIL ranges. Removing these values gives, therefore, a more realistic linear regression. Correlations in this study are not exceptionally strong, but this study only focused on intense convective situations. A better correlation may be found using a wider variety of events.

5. CONCLUSION

Results obtained from studies such as this are important in the development of subjective, event-specific forecasting support. Since the models do not possess the same physics as the atmosphere, accuracy is not guaranteed, and well-defined structures are not always resolved. This can make the interpretation of model forecasts and behavior in certain situations difficult. Programs such as the NSSL/SPC Spring Research Program help motivate research such as this through the testing of specific forecasting techniques and products (Janish et al. 2001). The time spent evaluating and verifying forecasts and model performance of severe and non-severe convective initiation and evolution allows new ideas to be generated, resulting in new research findings that have operational relevance.

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