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FUSING OBSERVATION- AND MODEL-BASED PROBABILITY FORECASTS FOR THE SHORT TERM PREDICTION OF CONVECTION

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1. INTRODUCTION

A number of research studies indicate that the recent history of convection contains a great deal of information on its future state out to 6 hours and beyond (e.g., Golding 2000). The scale of the convective feature often determines the length of time that it will persist and thus be predictable through extrapolation alone (Wilson et al. 1998). Additional work has been done in developing heuristic models of convection that can be used to predict the Lagrangian evolution (growth and decay) of convection (Hand 1996; Pierce et al. 2000; Megenhardt et al. 2004). The National Convective Weather Forecast (NCWF-2) combines extrapolation and a heuristic approach to produce 0-2 hr probabilistic forecasts of convection that are available in real-time for use by the aviation community. This system has been extended out to 6 hours following the method outlined in Section 2.

It is known that while observation-based techniques perform well in the very short term (e.g., 0-2 hr), their skill decreases rapidly with lead time due to storm evolution. On the other hand, despite efforts to assimilate a myriad of data streams (including that from radar), the skill of numerical weather prediction models continues to be lacking at lead times less than 3 hr. To mitigate poor skill of RUC in predicting convective precipitation at short lead times, Weygandt and Benjamin (2004) developed a probabilistic approach that takes into account uncertainty inherent in the modeling system's ability to forecast the exact timing and location of convection. The new product called the RUC Convective Probability Forecast (RCPF) is being tested for operational use by the Aviation Weather Center (AWC).

The goal of this study is optimally blend the RCPF with the 1-6 hr NCWF to take advantage of the lead-time dependent relative skill of each method. Data from the spring and summer of 2005 are used to develop verification statistics for RUC-based and NCWF 1-6 hr probabilistic forecasts including CSI, POD, FAR, and Bias as a function of lead time. These performance parameters are then used to develop a weighting function that varies with lead time and time of day. The RUC-based and 1-6 hr NCWF probabilistic forecasts are then blended using this weighting function to produce a single merged probabilistic forecast. The new merged forecasts are then evaluated using data collected during the first two weeks of August 2005 with results being intercompared with the individual components of the system.

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2. COMPARISON OF MODEL AND OBS-BASED TECHNIQUES

Both NCWF and the RCPF forecast products are given as probabilities. The probability that convection will occur at a given point is determined using a spatial filter. The spatial filter differs in these two systems with NCWF using an elliptical filter following Wolfson et al. (1998) and RCPF using a square filter (Weygandt and Benjamin 2004). In both systems, a somewhat arbitrary threshold is used to determine the areas affected by convection strong enough to impact aviation. In NCWF the thresholded forecast variable is an extrapolated interest field (see Megenhardt et al. 2004) similar to VIL (a derived-product available from the WSR-88D radar network; Klazura and Imy 1993) while in the RCPF, the threshold forecast variable is the convective rainfall rate. In the RCPF, a threshold of 1 or 2 mm hr-1 is used depending on time of day and longitude. The probability that convection will be present at a given location and time is determined by dividing the number of gridpoints where the threshold is exceeded within the filter area by the total number of gridpoints encompassed by the filter.

In NCWF the filter size is a function of lead time while in the RCPF system the filter size is fixed at 180 km. The NCWF filter size increases from

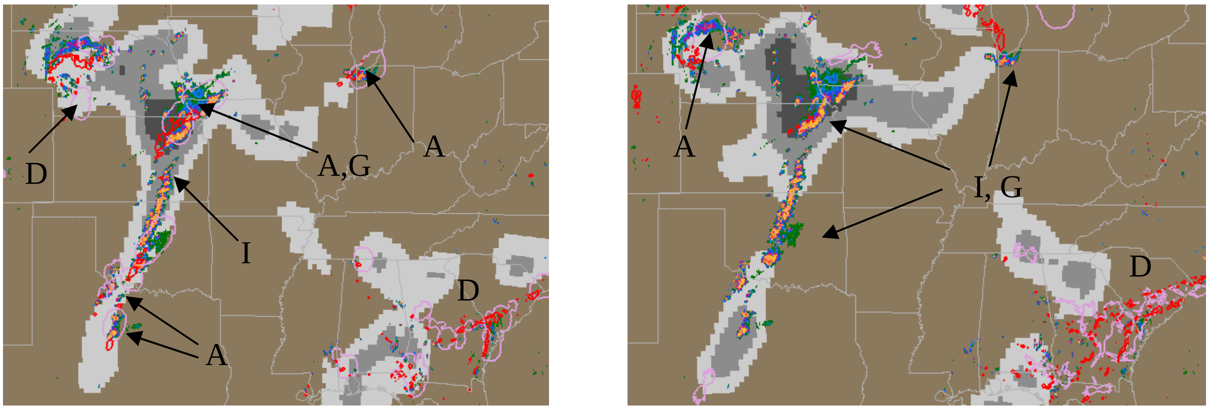

Figure 1. Probablistic forecasts from the RCPF (gray shades) and NCWF (pink contours) systems during a convection initiation event that occurred over S. Great Plains on 4 June 2005 for forecast lead times of (a) 2 and (b) 4 hours issued at 2200 and 2000 UTC, respectively. The NCWF data are contoured at the 10% probability level. The RCPF probabilities are contoured at 25, 50 and 75%. WSI radar reflectivity data at forecast time (red contours depicting radar echoes > 35 dBZ) and valid time (reflectivity maps showing dBZ > 25). The valid time is 2400 UTC. "G", "I", "A" and "D" denote regions of storm growth, initiation, advection and dissipation, respectively.

60 km at a leadtime of 1 hr to 180 km at a lead time of 3 hrs, following Germann and Zawadski (2004). The filter size remains fixed between 3 and 6 h. Since the RUC has a grid mesh of 20 km, the filter encompasses a total of 81 grid points. While in the NCWF system, the filter is run on a 4 km grid, so that even the 60 km filter spans a much greater number of grid points (225) yielding better statistical information (e.g., more detail in the distribution of convective intensity within the filter). The NCWF was calibrated using 4 km WSI data while the RCPF was calibrated to perform well relative to the more coarse 40 km National Convective Weather Detection (NCWD) data. These differences in the way the two probabilistic forecasts were generated must be accounted for before blending can be performed.

The probability forecasts from NCWF and RCPF for a single late spring afternoon (4 June 2005) are compared to illustrate their relative strengths and weaknesses (Figure 1). This case included a squall line initiation event that occurred in the Southern Great Plains and widely scattered cellular convection associated with large-scale instability characteristic of the SE US throughout much of the year. Storm cells initiated along a dryline/cold front around 2130 UTC and formed into a squall line by 0000 UTC. A second related area of convection to the north over northeast KS initiated around 1930 UTC and remained nearly stationary while growing in size. The widely-scattered storms in the southeast are typical of storms in this region exhibiting an evolution that is closely tied to the diurnal cycle.

There are a number of features that standout in the subjective comparison of the RCFP and NCWF forecasts of convection (Figure 1). Storm extrapolation works well at 2 hrs in areas where existing storms are not evolving much (such as the 2hr forecast of cells moving east at the southern tip of Lake Michigan and moving north near Dallas). Note that the 4 hour extrapolations miss these areas of convection because they had not formed as of 2000 UTC. In areas where storms are dissipating (see southeastern US), extrapolation fails. The RCPF handles areas of initiation along the dryline fairly well at leadtimes of 2 and 4 hours, but overdoes initiation in the SE US and also tends to paint large areas with convective probabilities or coverages greater than 25%. Extrapolation captures areas of convection that RCPF misses at a leadtime of 2 hours with far fewer false alarms than the RCFP. However, during periods of storm initiation, the NCWF will underpredict storm coverage and areas. This is exasperated at the longer leadtime (Fig. 1b).

The strengths of the RCPF include its ability to predict regions and time-of initiation at lead times up to 8 hours and its ability to depict the nature (linear vs widespread) of storms in the vicinity of synoptic-scale boundaries. The strengths of the NCWF are its ability to extrapolate existing storms - particularly at the shorter leadtimes and its ability to depict increasing uncertainty in storm location/coverage with increasing leadtime.

Statistical analyses of all the NCWF and RCPF forecasts produced on June 4th are depicted in Figure 2. It is seen that both systems have do not adequately treat the overnight dissipation storms. This is evidenced by the increasing biases and decreasing CSI scores between 3

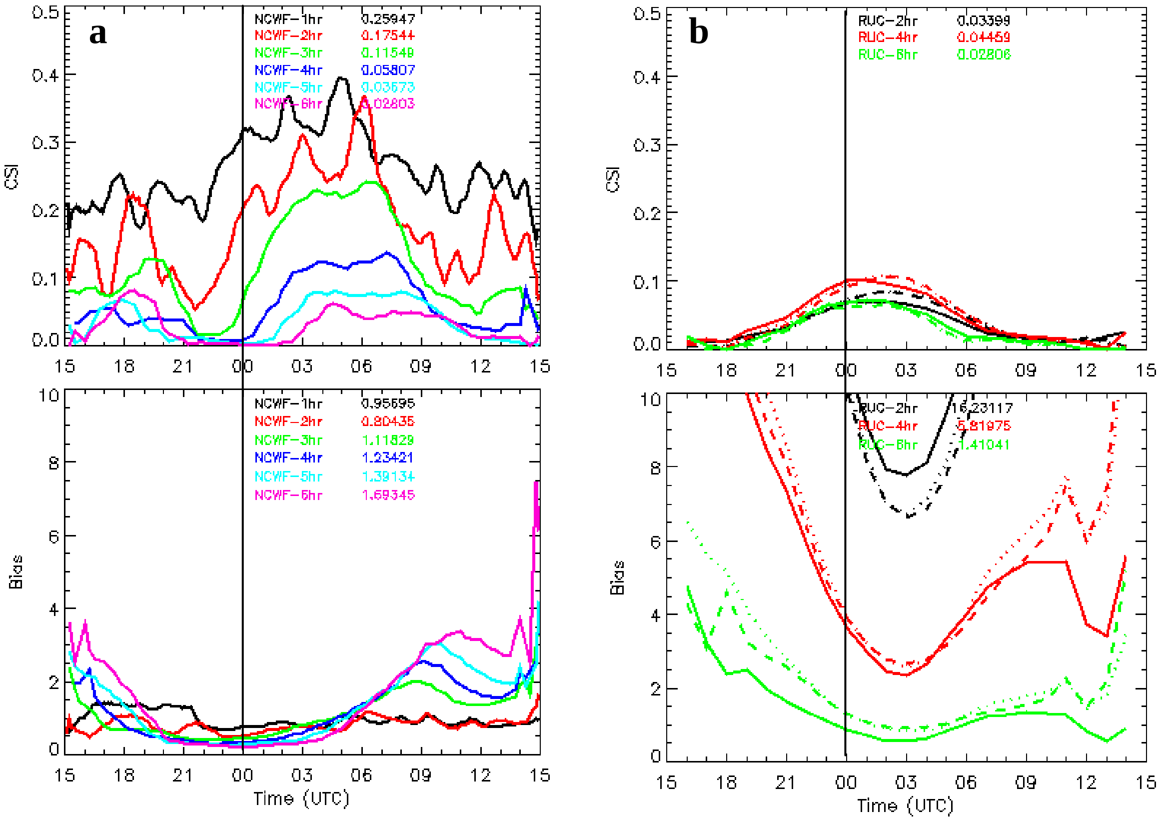

Figure 2. Time series of CSI and Bias for the 24-hour period beginning on 04 June 2005 at 1500 UTC for the (a) NCWF (1-6 hr forecast) and (b) RCPF (2, 4 and 6 hr forecasts). The NCWF and the RCPF forecasts were verified with observed coverage maps at the 20% probability level. Coverage maps calculated from radar reflectivity data thresholded at 35 dBZ. The 20% probability level was used to calculate the verification statistics for NCWF. Verification for the RCPF forecasts was performed at three probability levels (25%, 50% and 75% - different line types). Vertical lines give valid time for the 2- and 4-hr forecasts discussed in Fig. 1.

and 12 UTC. NCWF does poorly during the late morning/early afternoon (20-03 UTC) when storms are initiating while the RCFP performance peaks during this period. Also note that the NCWF CSI scores for lead times of 1-3 hours are much greater than those found at any leadtime for the RCFP.

Figure 3 demonstrates how CSI and Bias varies with leadtime for the two systems as a function of time of day for a two week period in August 2005. The point at which the model skill exceeds the skill of extrapolation is between 3 and 4 hours in the mean. During the afternoon hours this cross over is earlier (between 2 and 3 hours) due to RCPF's ability to capture initiation. Overnight, the crossover is later due to problems with treating nocturnal convection and storm dissipation in the model. Note that the NCWF bias-1 increases with leadtime at night due to lack of a dissipation term and increases with leadtime during the day due to initiating storms.

The RCFP tends to greatly overpredict the area spanned by a coverage greater than 5 % at all times of day. As discussed earlier, this large

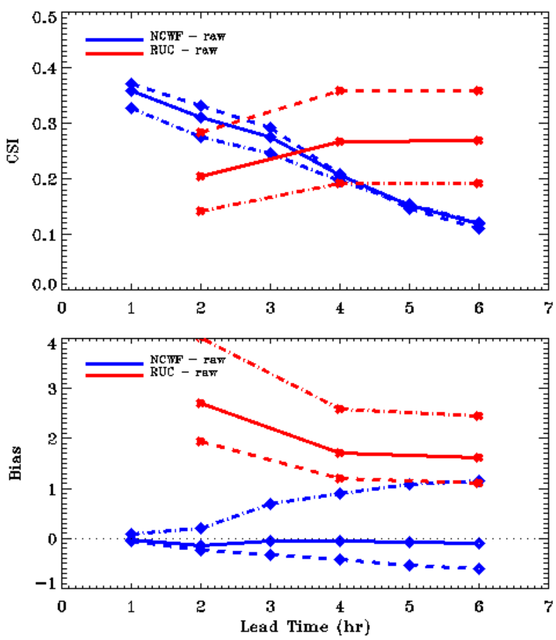

Figure 3. Performance of RCFP (red) and NCWF (blue) as a function of leadtime for all times (solid) nighttime (dot-dashed) and daytime (dashed) calculated for 1-14 August 2005.

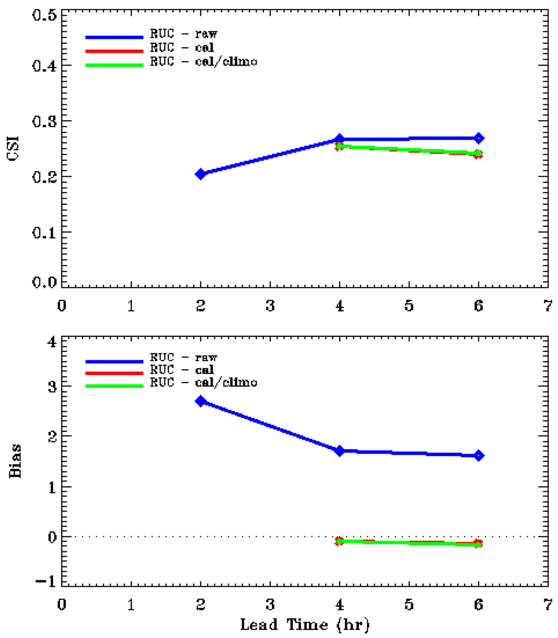

Figure 4. Time series of CSI and Bias calculated for the period 1-14 August 2005 for RCFP – uncalibrated (blue) and calibrated (red/green).

bias arises because the RCFP was originally tuned to perform well against the NCWD. A procedure was developed to re-calibrate the RCFP using verification statistics from the month of June 2005 with the aim of finding the RCFP coverage the maximizes CSI and minimizes abs|Bias -1| for coverages of 5%, 10%, 20%, 40% and 60%. The net effect of this calibration was assessed by applying the calibration procedure to two weeks of data in August 2005 (Figure 4). Note the large reduction in bias is achieved while maintaining CSI at its precalibrated level.

3. DIURNAL CLIMATOLOGIES FOR DISSIPATION

Since neither the RCFP nor the NCWF are able to adequately treat the overnight dissipation of convection, we developed a scheme for dissipating convection based on the observed diurnal trends in the occurrence of convection. The climatological occurrence of convection exceeding 40 dBZ developed from the NEXRAD WSR-88D radar network (Knievel et al. 2004) is used to calculate the relative change in coverage of 40 dBZ storms as a function of time of day for leadtimes of 3-6 hours. Maps of this parameter calculated for a leadtime of 6 hours are shown in Figure 5 for two time periods. Between 15 and 21 UTC the coverage is increasing throughout the US, particularly in the east and southeast. Between 21 and 03 UTC, coverage is decreasing across the east, with the largest changes seen in the southeast. At the same time, the nocturnal maximum of convection can be seen in the high planes.

Maps of the fractional change, D, are the applied as a multiplicative mask to the NCWF and RCFP forecasted coverages. The new converages are obtained following $P_d(l) = P(l)*D(l)$ where P_d is the trended probability, P is the original probability (from RCFP or NCWF) and "l" is the lead time. The fractional changes are only applied where $0 < D < 0.9$. Thus, it used only to dissipate convection. Statistical analyses reveal the importance of including this term in the extrapolation algorithm (Figure 6). Less of an impact on the RCFP is seen. Note that most of the climatology based-trending occurs between 00 and 08 UTC and has a beneficial impact on the skill scores, particularly in reducing the bias in NCWF extrapolation forecasts.

4. METHODOLOGY FOR BLENDING

The NCWF 1-6 hr extrapolation and calibrated RCPF are combined after first applying the climatological dissipation. These "value-added" fields are combined using a weighted average that is a function of relative skill scores similar to that discussed by Golding (2000). Since extrapolation performs best at leadtimes less

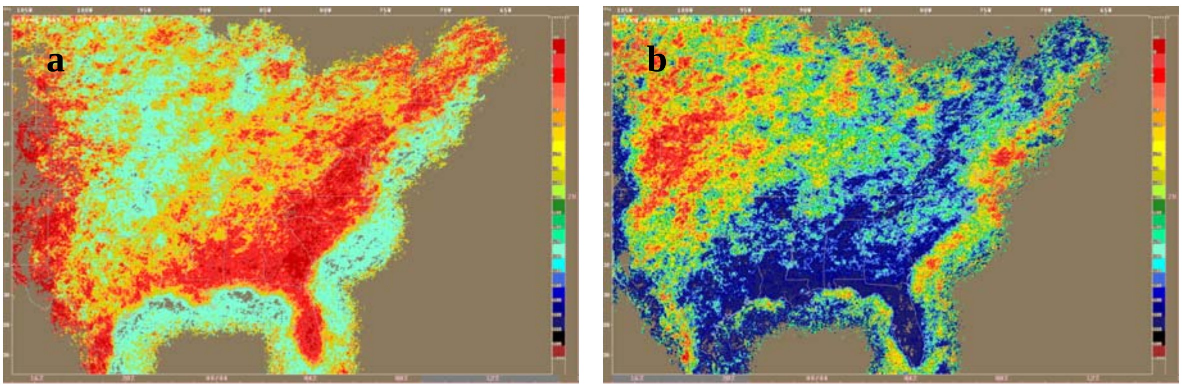

Figure 5. Six hour fractional change in area coverage of reflectivity greater than 40 dBZ from 6 summers (1998-2004) of WSR-88D data. Time periods are from (a) 15 to 21 UTC and (b) 21 to 03 UTC.

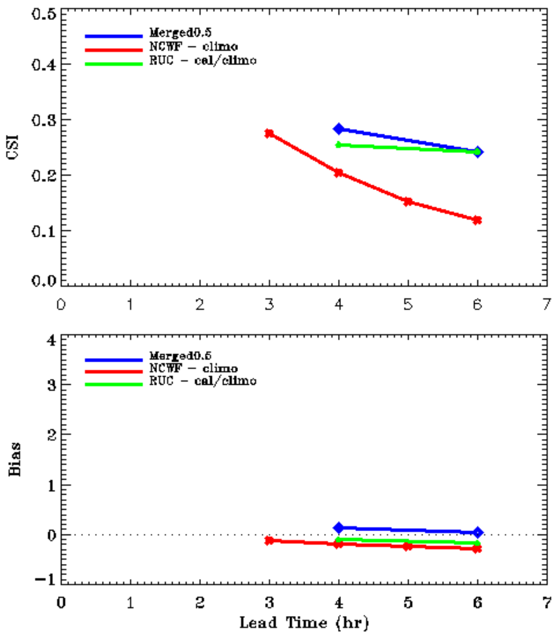

Figure 7. CSI and Bias scores calculated for a 15 day period 1-14 August 2005 for RCFP-calibrated and dissipated (green), NCWF with climatological dissipation and merged RCFP/NCWF using equal weights for 4 and 6 hour lead times.

than three hours, most of the weight is given to extrapolation. At longer leadtimes the greater weights should shift to the RCFP. For demonstrative purposes, Figure 7 depicts the skill scores for the blended system using weights set to 0.5 for leadtimes of 4 and 6 hours. It is seen that while the combined system has greater skill than the individual systems, using this simple weighting scheme does not take full advantage of the relative skill and strengths of the two systems. Current research, for the operational system (NCWF6 – to be operational this spring) is aimed at optimizing these weighting functions which will be allowed to vary as a function of leadtime and time of day.

Additional research will be conducted to ascertain whether the weighting functions may be developed that vary regionally and as a function of synoptic regime.

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