9.3 COMPARISON OF THE GSI/ETKF REGIONAL HYBRID USING WRF/ARW WITH THE GSI/LETKF AND GSI/EnKF REGIONAL HYBRIDS

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1. INTRODUCTION

Most major operational forecast centers are using, or soon will be using, a variational hybrid data assimilation cycling system. Most of those systems use the ensemble transform Kalman filter (ETKF), the localized ensemble transform Kalman filter (LETKF), or a variant of the ensemble Kalman filter (EnKF), to generate the ensemble perturbations for each cycle. Due to under-sampling of the ensemble probability space and rank deficiency ETKF formulation, all those schemes use some type of inflation to enhance the ensemble variance (the square root of which is called the ensemble spread). Mizzi (2012) examined whether the type of ETKF inflation made a significant difference in the 12-hr forecast root-mean square error (RMSE). Mizzi (2012) found that: (i) the type of ETKF inflation scheme mattered, (ii) the TRNK scheme, a variant of the Wang et al. (2003) inflation scheme, called the TRNK scheme, produced significantly lower 12-hr forecast RMSE compared to other inflation scheme, and (iii) too many or too few ETKF observations significantly degraded the forecast skill.

This study continues the work of Mizzi (2012) by expanding the ensemble size from 20 to 60 members and by comparing the 12-hr forecast skill of the Gridpoint Statistical Interpolation (GSI)/ETKF regional hybrid with that from the GSI/LETKF and GSI/EnKF hybrids to determine whether the type of perturbation generation scheme makes a significant difference in forecast skill. For this study, we used an ETKF with the NCAR/MMM TRNK ETKF inflation scheme, an LETKF similar to that of Hunt et al. (2007), and the Data Assimilation Research Testbed (DART) EnKF. Our results show that the type of perturbation generation scheme mattered in that the GSI/ETKF regional hybrid gave substantially lower 12-hr forecast RMSE compared to the GSI/LETKF and GSI/EnKF forecast RMSEs.

II. EXPERIMENTAL SETUP

We used the NCAR/MMM Regional Hybrid Testbed (MRHT) to conduct the comparative regional hybrid cycling experiments presented in this paper. MRHT is a community resource for developing and testing hybrid cycling strategies. It contains an 80-member initial ensemble dataset for a continental United States domain with 200km horizontal resolution and 28 vertical levels. The dataset covers the Hurricane Dean test period (August 15, 2007 to September 15, 2007). The observations are in the prep.bufr, ob.ascii, and obs.seq formats. MRHT contains scripts and code to conduct hybrid cycling experiments with the GSI and

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WRFDA variational data assimilations codes, the Wang et al. 2003 (WG03), Wang et al. 2007 (WG07), Bowler et al. 2008 (BW08), and TRNK ETKF inflation codes, and the ETKF, LETKF, and DART-based EnKF perturbation generation codes. It uses modular programming and is sufficiently flexible to provide facile incorporation of new algorithms, contains post-processing scripts and codes, and it available at https://svn-hybrid-testbed.cgd.ucar.edu with an access code obtained from the author.

For this study, we used a 60-member ensemble, with cycling every 12 hr, from August 15, 2007 12Z to September 11, 2007 12Z. We compared the GSI/ETKF regional hybrid using TRNK inflation, the GSI/LETKF and the GSI/EnKF regional hybrids. The LETKF used a 3,000 km localization radius and a multiplicative inflation of 1.036. The EnKF used prior inflation of 2.0 (no posterior inflation), inflation damping of 0.9, an initial inflation standard deviation of 0.6, and lower bound inflation standard deviation of 0.6. The EnKF settings are as recommended by the DART literature.

The verification analysis uses radiosonde and surface synoptic observations.

III. EXPERIMENTAL RESULTS

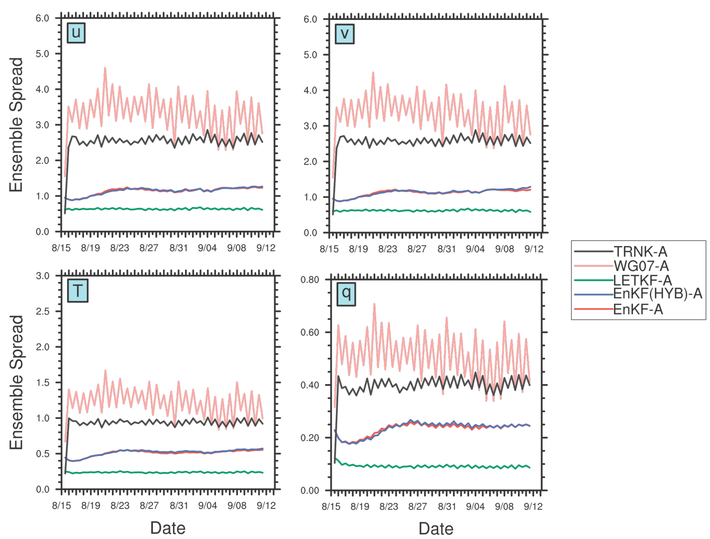

Figure 1. Posterior ensemble spread for the GSI/ETKF(TRNK), GSI/ETKF(WG07), GSI/LETKF, and GSI/EnKF regional hybrids.

Figure 1 shows the posterior ensemble spread for the different regional hybrid formulation. It shows that the GSI/ETKF(WG07) scheme produced the greatest spread, the GSI/ETKF(TRNK) produced the second largest spread, and the GSI/LETKF produced the least spread. The WG07 and TRNK results are consistent with Mizzi (2012). We suspect that the LETKF is producing too little spread and are experimenting with alternative inflation algorithms.

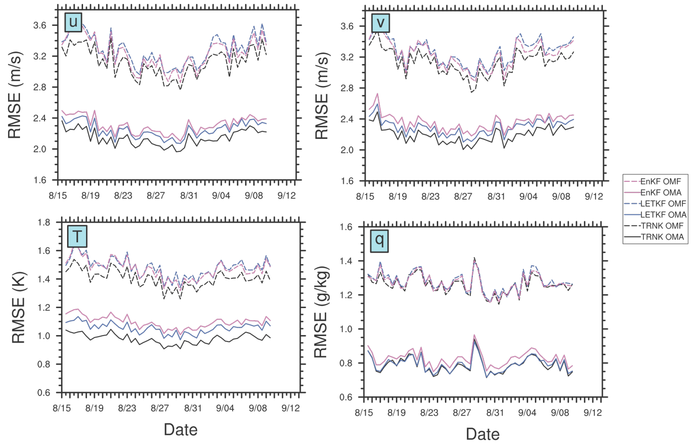

Figure 2. Analysis fit and 12-hr forecast RMSE for the GSI/ETKF(TRNK), GSI/LETKF, and GSI/EnKF regional hybrids.

Figure 2 show the analysis fit and 12-hr forecast RMSE for the various regional hybrids. In each panel, the lower curves display the analysis fit and the upper curves display the forecast RMSE. These results show that throughout the cycling period for *u*, *v*, and *T*: (i) the GSI/ETKF hybrid consistently produced the lowest forecast RMSE, (ii) the GSI/EnKF hybrid consistently produced the highest forecast RMSE, and (iii) the GSI/LETKF produced moderate forecast RMSE. For *q*, the all hybrids produced comparable forecast RMSE. We have conducted sensitivity experiments for the GSI/LETKF and found that decreasing the localization radius decreases the forecast RMSE. We conducted sensitivity experiments for the GSI/EnKF based on recommendations in the DART literature but have not improved the forecast skill. Those experiments are on-going.

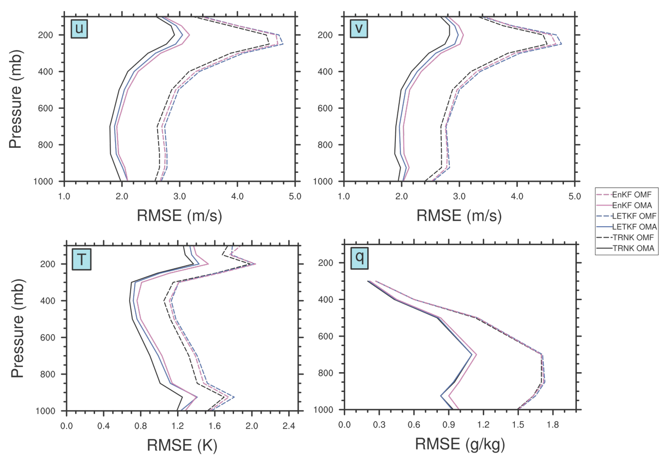

Figure 3. Vertical profiles of the domain averaged analysis fit and 12-hr forecast RMSE for the GSI/ETKF(TRNK), GSI/LETKF, and GSI/EnKF regional hybrids.

Figure 3 show the same results as Fig. 2 except it is presented as vertical profiles. Qualitatively the results are similar to Fig. 2. However, Fig.3 also shows that the relative relationships for the forecast RMSE in Fig.2 remain true throughout the troposphere.

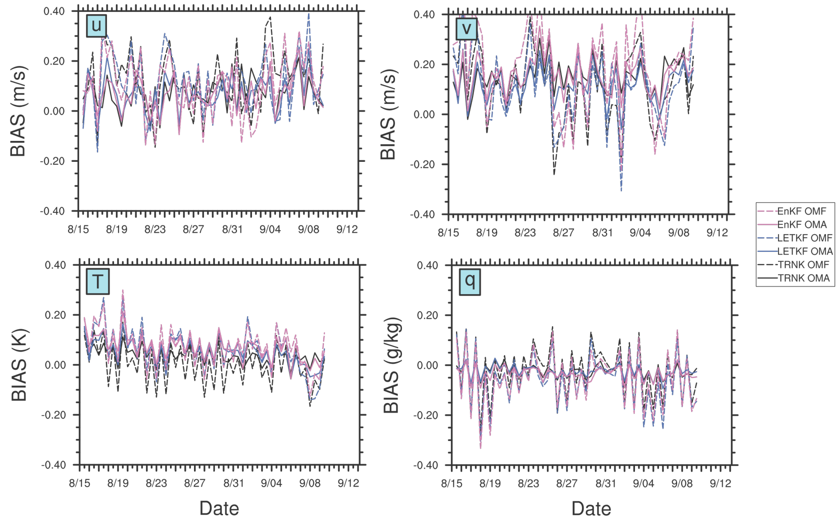

Figure 4. Analysis and 12-hr forecast bias for the GSI/ETKF(TRNK), GSI/LETKF, and GSI/EnKF regional hybrids.

Figure 4 shows the analysis and 12-hr forecast bias for the various hybrids. These results show that throughout the cycling period, for all meteorological variables: (i) the analysis and forecast bias are comparable, (ii) the analysis bias is comparable for the different hybrids, and (iii) the forecast bias is comparable for the different hybrids. This figure also shows that the *u*, *v*, and *T* biases are generally small and positive while the *q* bias is generally small and negative.

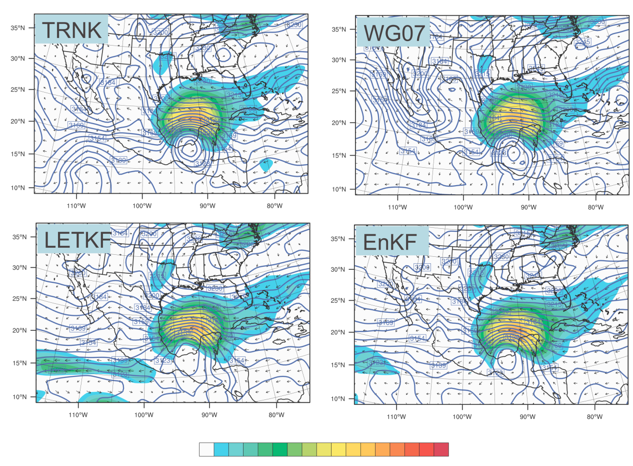

Figure 5. 700 mb height (8 m increments) and shaded wind speed for Hurricane Dean on August 21, 2007 12 Z from the various hybrids.

Figure 5 shows 700 mb height and shaded wind speed contours for Hurricane Dean on August 21, 2007 at 12Z. When reviewing this figure, remember that the GSI/ETKF hybrid produced the lowest 12-hr forecast RMSE. Figure 5 shows that the hurricane center and wind speeds are comparable for all the hybrids. However, the ETKF-based hybrids produced: (i) a lower central pressure (indicated by one additional closed height contour), and (ii) greater structure in the height field to the west of the hurricane center.

When these results are combined with the substantial differences in the forecast RMSE from Figs. 2 and 3, we conclude that the perturbation generation scheme in a hybrid cycling algorithm matters. Currently, we are conducting tests to determine whether: (i) the differences in Figs. 2 and 3 are significant, and (ii) the differences between the panels of Fig. 5 are significant.

IV. SUMMARY

We presented results from comparison of the GSI/ETKF(TRNK), GSI/LETKF, and GSI/EnKF regional hybrids applied to the Hurricane Dean test case (August 15, 2007 12Z to September 11, 2007 12Z). Our results show that the type of perturbation generation scheme used in a hybrid cycling algorithm mattered. We found that the GSI/ETKF(TRNK) scheme consistently produced the lowest 12-hr forecast RMSE throughout the troposphere and throughout the study period. We also found that the GSI/ETKF(TRNK) analysis and 12-hr forecast bias were comparable to those from the other hybrids. Initial sensitivity experiments showed that lowering the localization radius for the GSI/LETKF hybrid improved the forecast skill, but that varying the DART-based EnKF parameters for the GSI/EnKF hybrid did not improve forecast skill.

We also looked at forecasts for the 700 mb height and wind speed in the vicinity of Hurricane Dean after six days of cycling with the various hybrids. Those results showed that the various hybrids produced comparable hurricane eye locations and wind speeds. But, the GSI/ETKF hybrids produced: (i) a lower central pressure (indicated by one additional closed height contour), and (ii) greater structure in the height field to the west of the hurricane center.

Taken together, these results show that: (i) the type of perturbation generation scheme used in hybrid cycling mattered, and (ii) the preferred scheme appears the GSI/ETKF. We are continuing to investigate the robustness of those conclusions with additional sensitivity experiments, and statistical significance studies.

V. REFERENCES

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