11 A.5 FIRST GUESS BIAS CORRECTION IN THE ENSEMBLE-BASED DATA ASSIMILATION SYSTEM FOR THE GLOBAL FORECAST SYSTEM (GFS) MODEL

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1. INTRODUCTION

An ensemble-based data assimilation (EDA) system was developed and tested for the NCEP GFS model (Whitaker et al. 2008). Studies comparing the EDA with the NCEP GSI have shown that forecasts initialized with the analyses generated by the EDA were better than that generated by the GSI. Figure 1 shows the latest comparison results of the GFS EDA and the GFS GSI. Various efforts are currently being made to further improve the EDA system.

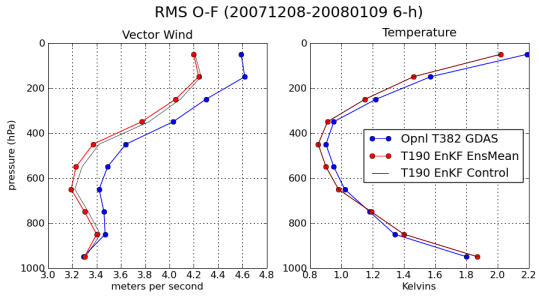

Figure 1. Comparison of the GFS EDA at T190L64 resolution vs. operational GSI at T382L64 resolution. All operational observations except precipitation retrievals were assimilated by GFS EDA. Root-mean-square fit of the 6-hour wind forecast to in-situ obs is on the left and that for temperature is on the right. The blue line is for operational GSI at T382 resolution and red line is for 6-hour ensemble mean forecast initialized by the EDA analysis ensemble. The black line is the single forecast from the EDA ensemble mean analysis.

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The EDA theory is based on the assumption that both the first guess and observations are unbiased, which in reality is not true. For example, the blue line in figure 3 shows that the first guess bias for temperature can be as large as ~1K around 750mb, and first guess bias for wind can be as large as ~1m/s around 200mb. The purpose of this study is to explore methods to correct bias in the first guess of the GFS EDA system.

2. BIAS ESTIMATION METHOD

The assumption behind our bias estimation method is that systematic component of the analysis increments (difference between the first guess and the analysis) in the GFS EDA system reflects the systematic model bias (Dee 2005). In the first trial, we simply used the average of the analysis increments over previous one month period to estimate the bias in the following month. In the second trial, we adopted the decaying averaging method and applied it to the analysis increments (Z. Toth, personal communication).

3. EXPERIMENT DESIGN

We ran the operational GFS model assimilating both conventional observations and AMSU radiances every 6 hours. Because of the limited computing resources, GFS was run with T62 horizontal resolution and 64 levels. 64 ensemble members were used.

The benchmark run where no first guess bias correction was made started at 00Z Dec 1 2007

and ended at 18Z Jan 31 2008. In the first set of bias correction experiment, the bias was calculated by averaging the analysis increments during 00Z Dec 6 2007~18Z Jan 6 2008. This bias was then used to correct the first guess for new runs starting at 00Z Jan 7 2008 and ending at 18Z Jan 31 2008. In the second set of experiment, the estimated bias at time t, x_t^{bias} was calculated using

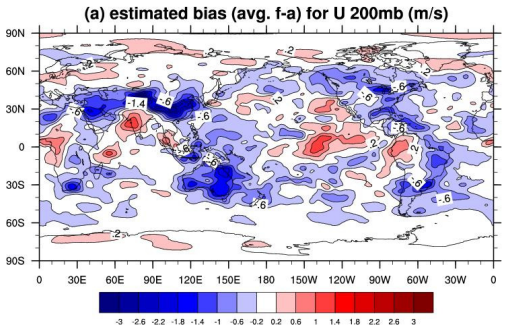
$$x_t^{bias} = (1-w)x_{t-2}^{bias} + wx_{t-1}^{inc.} \quad (1)$$

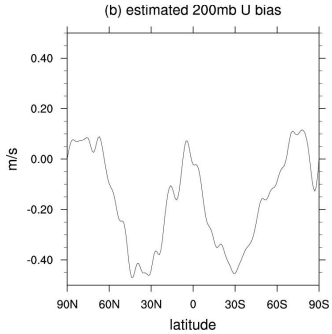
where x_{t-2}^{bias} is the estimated bias at time $t-2$ and $x_{t-1}^{inc.}$ is the analysis increment at time $t-1$. w is the weight. A weight of 20% was used in the current experiment. The verification was conducted for the period of 00Z Jan 13 ~ 18Z Jan 31 2008.

4. RESULTS

4.1 ESTIMATED BIAS

Figure 2 shows a few examples of estimated bias. For 200mb zonal wind (Fig 2ab), there is systematic negative bias around $30°$, suggesting weaker Hadley cell circulation in the model first guess field. For 750mb temperature (Fig 2c), there is systematic negative bias between $30^{\circ}N$ and $30°S$.





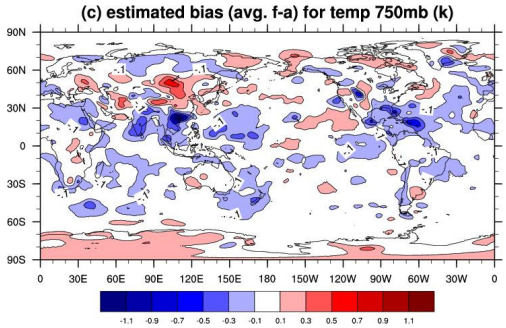
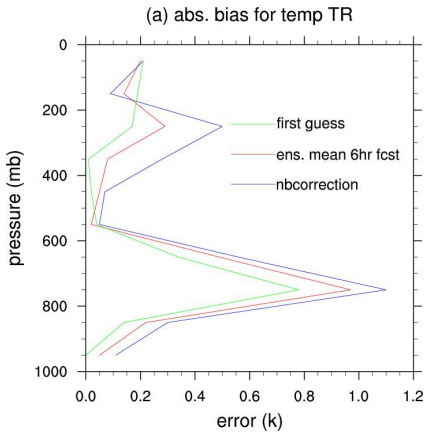
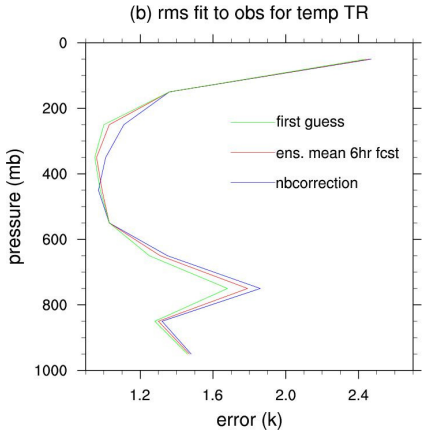


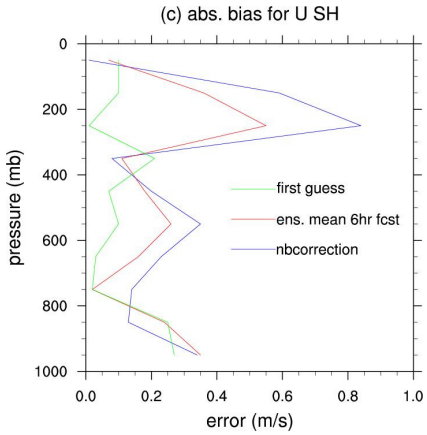
Figure 2. (a) estimated bias for 200mb zonal wind; (b) zonally averaged estimated bias for 200mb zonal wind; (c) estimated bias for 750mb temperature.

4.2 VERIFYING FIRST GUESS AGAINST IN-SITU OBSERVATIONS

To test if the bias removal method can improve the analysis and the forecast, we verified the first guess and 6-hour ensemble mean forecast against the in-situ observations. Note that the difference between the first guess and the 6hr ensemble mean forecast is that the former is obtained by bias correcting the latter. Both the root-mean-square fit to observations and the systematic difference of the fit to observations are shown in figure 3. Tropical temperature and Southern Hemisphere zonal wind are shown since those are the variables and regions that the benchmark has the biggest bias. Compared to the benchmark ("nbcorrection"), the bias corrected first guess has smaller bias and rms error, indicating the estimated bias contains correct information about the true bias. 6-hour ensemble mean forecast is also improved compared to the benchmark, although the improvement was smaller than the bias corrected first guess, which suggests the improvement due to bias correction was retained during the data assimilation cycle, but not fully retained.







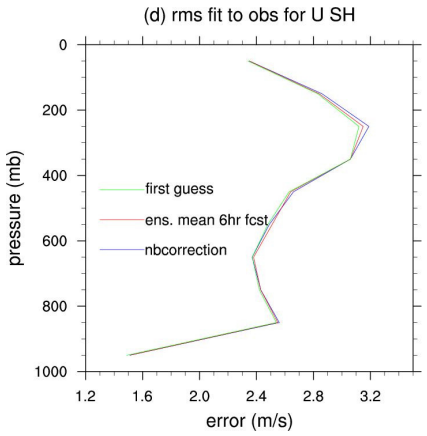


Figure 3. Systematic differences between first guess and in-situ observations and rms fit of the first guess to in-situ observations for Tropical temperature (a, b) and for Southern Hemisphere zonal wind (c, d). The blue line is the benchmark where no bias correction is made. The green line is for the bias corrected first guess. The red line is the ensemble mean 6-hour forecast.

4.3 RESULTS FOR DECAYING AVERAGING BIAS ESTIMATE

Using bias estimated by decaying averaging method did not show further improvement (Fig.4). In upper levels 200mb~400mb, it performed a little worse than using the simple averaging of the analysis increments. Experiments are undertaken to see sensitivity of the results to the choice of weight w.

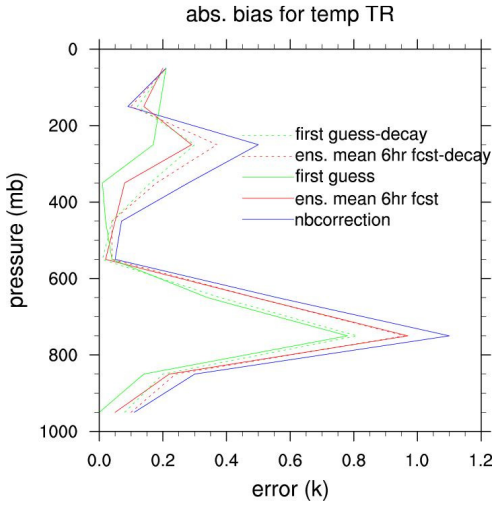


Figure 4. same as figure 2a except adding the results for bias estimated by decaying averaging (as opposed to simple averaging) of the analysis increments.

5. CONCLUSION

In this study, we explored a simple method to estimate the first guess bias in the ensemble-based data assimilation system for the NCEP GFS model. The bias was estimated by averaging the previous analysis increments in the assumption that systematic model bias should be reflected in the systematic component of the analysis increments.

The averaged analysis increments did reveal systematic bias (e.g., weaker Hardly cells) in the first guess of the GFS EDA system. Our results showed that the first guess and the analysis were improved after the bias correction, which indicated that the estimated bias contained correct information about the true bias.

The current bias estimation method did not consider the diurnal cycle. Experiments are undertaken where the biases were calculated based on the time of a day.

6. REFERENCES

Whitaker, J., T. Hamill, X. Wei, Y. Song, Z. Toth, 2008: Ensemble data assimilation with the NCEP Global Forecast system. *Mon. Wea. Rev.*, **136**, 463-482.

Dee, D., 2005: Bias and data assimilation. *Q. J. R. Meteorol. Soc.,* **131**, 3323-3343.