Implementation of sequential bias estimation and correction in GEOS-5 DAS

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INTRODUCTION

A simplified multivariate sequential background bias correction scheme (Dee and da Silva 1998; Radakovich et al 2001) has been implemented in the fifth generation of the Goddard Earth Observing System Data Assimilation System (GEOS5 DAS*), and compared with a control experiment without background bias correction.

SCHEME

The simplified sequential bias correction scheme is define as:

$$w_k^a = (w_k^f - b_{k-1}^f) + \delta w_k^a$$

$$\delta w_k^a = K_k[w_k^o - H_k(w_k^f - b_{k-1}^f)]$$

$$b_k^f = \beta\, b_{k-1}^f - \gamma.\delta w_k^a$$

where H_k is the observation operator, K_k is a gain matrix, w_k represents state, δw_k is the analysis increment, and β is the damping factor for bias forecast model. The background bias b is modeled to capture the persistent and diurnal components. Bias with persistent and diurnal cycle components:

$$b^f(t) = a^0 + a^c \cos \omega t + a^s \sin \omega t$$

Three Fourier series coefficients:

$$a_k^0 = \beta\, a_{k-1}^0 - \gamma.\delta w_k^a$$

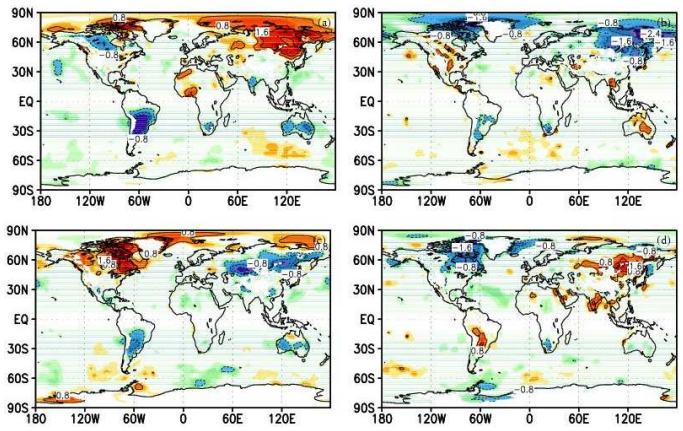
$$a_k^c = \beta\, a_{k-1}^c - 2\gamma.\delta w_k^a \cos\ \omega t$$

$$a_k^s = \beta\, a_{k-1}^s - 2\gamma.\delta w_k^a \sin\ \omega t$$

EVIDENCE OF BIAS

The time-averaged analysis increments reveals the systematic nature of the analysis correction being made by the DAS, the fact that it is non-zero can be attributed to biases in the background. Background bias contains not only a persistent component, but also a diurnal and possibly other periodic components as shown in Figure 1.

Figure 1: February 2006 monthly mean analysis increment of 850hPa temperature for 4 different analysis times (a) 00Z, (b) 06Z, (c) 12Z, and (d) 18Z.



RESULTS

Impacts of the bias correction are studied in terms of observation-minus-background (OmB), forecast-minus-analysis (systematic error), and forecast skill. The study also illustrates the interaction of the bias correction with the quality control (QC) and the satellite bias correction (SBC) of the DAS.

Obs-Background

The bias correction reduces the root-mean-square (RMS) residuals of different variables at different pressure levels over different regions as shown in Figure 2. The spectra of the time series of OmB in Figure 3 show whitening in both the persistent component and the diurnal component.

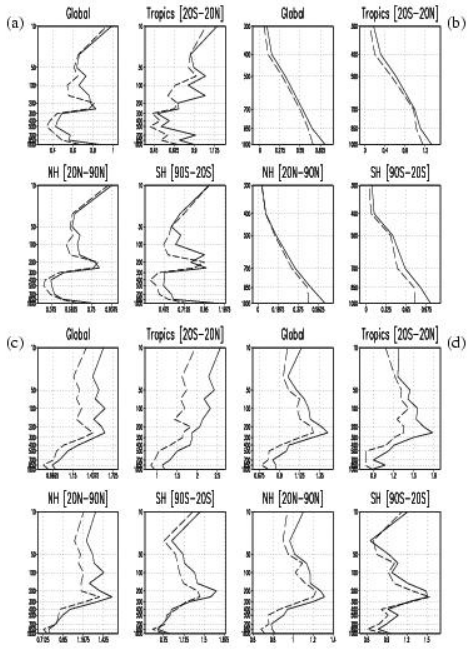


Figure 2: RMS mean bias of (a) temperature, (b) water vapor, (c) zonal wind, and (d) meridional wind residuals of observation minus background over four different regions in Feb 2006. The solid lines are for control run without bias correction, and the dashed lines for bias correction experiment.

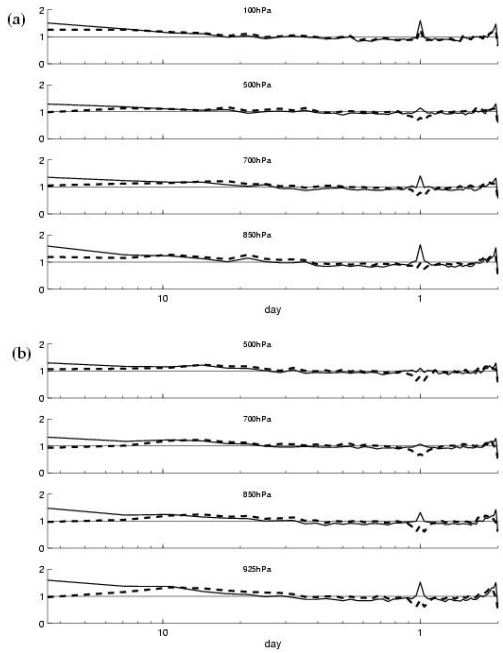


Figure 3: Averaged normalized power spectral of (a) temperature and (b) water vapor mixing ratio observation-minus-background residual time series from February 2006 global rawinsonde data. Light solid curve: control run, and heave dashed line: bias correction experiment.

Interaction with QC and satellite bias correction

Both QC decision and satellite bias correction in GEOS-5 DAS are based on the information iteratively derived from OmB, which is initially contaminated by a mixture of biased observations, deficiencies in the forward observation simulation models, as well as the bias in the background states representing the atmosphere. With the background bias correction it becomes possible to at least partially filter out background bias from the total OmB which changes the satellite bias estimation (figure 5). In combination with different QC decisions the DAS system could end up with quite different analyses even with the same observations as shown in Figure 4.

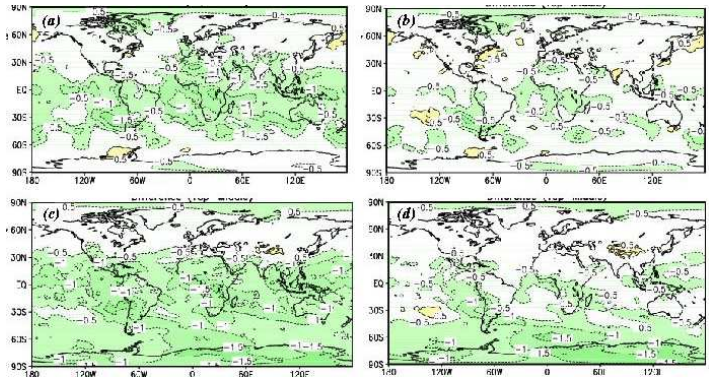


Figure 4: Monthly mean difference of 150hPa temperature against ECMWF and NCEP analysis. (a): control run against ECMWF, (b) bias correction experiment against ECMWF, (c): control run against NCEP, and (d): bias correction experiment against NCEP.

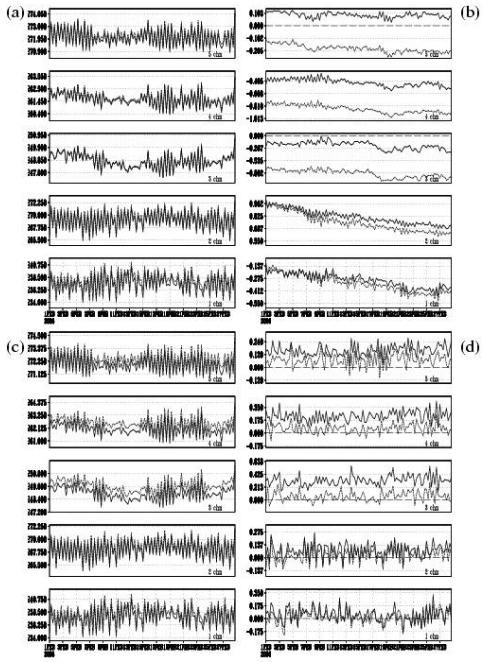


Figure 5: Time series of global averaged NOAA-17 AMSU-b (a) observations, (b) estimated bias, (c) bias-corrected observations by satellite bias correction scheme, and (d) the residuals of bias-corrected-observation minus bias-corrected-background. The solid lines are for control run, and the dashed lines are for bias correction experiment.

Systematic error reduction

The positive impact of the bias-corrected background can be demonstrated in Figure 6 by vertical cross-sections of the 5 day forecast states.

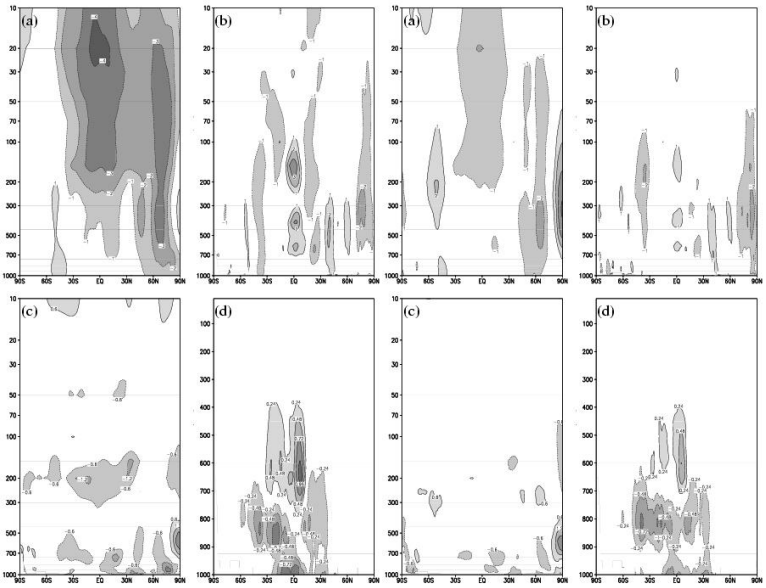


Figure 6: Vertical-latitude cross section of zonally averaged 120-hour forecast errors against analysis of (a) geopotential height, (b) temperature, (c) zonal wind, and (d) specific humidity. Left panel: control run; and Right panel: bias correction experiment.

Improvements in forecast skill statistics

Impacts on the forecast skill is studied in terms of (1) rawinsonde observation residuals with the 5-day forecasts, and (2) regional RMS differences between forecast and analysis states. The comparison shows improvement due to background bias correction.

Figure 7: Mean bias and standard deviation of (a) temperature, (b) water vapor, (c) zonal wind, and (d) meridional wind residuals of observation minus 5day forecast over four different regions in Feb 2006. The solid lines are for control run without bias correction, and the dashed lines for bias correction experiment.

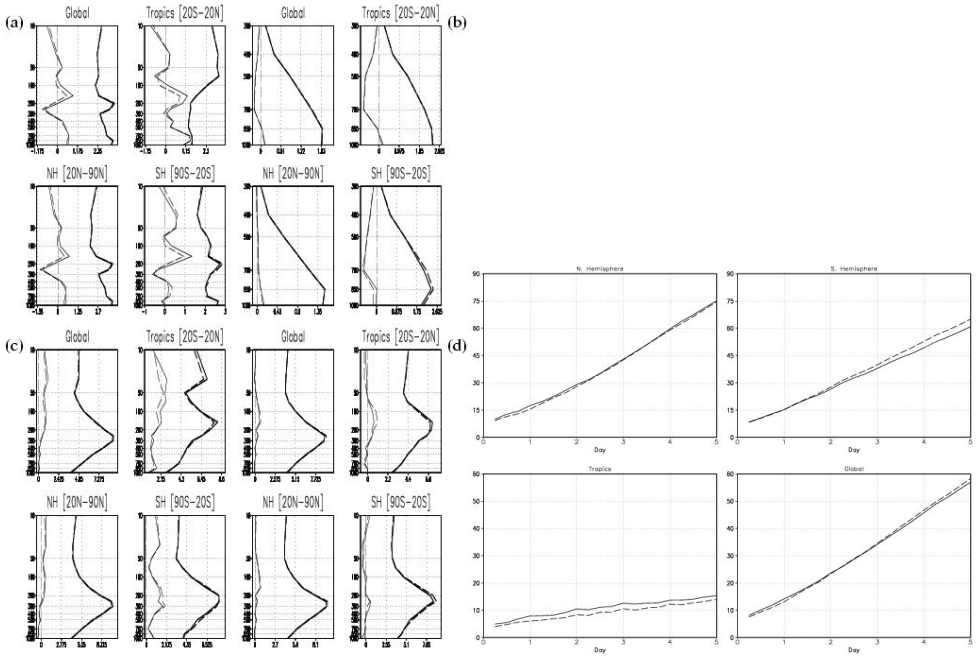


Figure 8: Root mean square errors versus forecast lead time for 500hPa geopotential height average over four regions: Northern Hemisphere extra Tropics from 20N-80N, Southern Hemisphere extra Tropics from 80S to 20S, Tropics from 20S to 20N, and the globe. The solid line is for control run without bias correction, and the dashed line for bias correction experiment.

REFERENCES

* http://gmao.gsfc.nasa.gov/systems/geos5

Dee, P. D., and A. M. da Silva, 1998: Data assimilation in the presence of forecast bias. *Quart. J. Roy. Meteor. Soc.*, **124**, 269-295.

Radakovich, J. D., P. R. Houser, A. M. da Silva, and M. G. Bosilovich, 2001: Results from global land-surface data assimilation methods. Prof. Fifth Symp. Integrated Observing Systems, Alb N.M., 132-134pp.