Implementation of a New Background Error Covariance Matrix in the Variational Bias Correction Scheme for the JMA Global 4D-Var System

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1. Introduction

The Japan Meteorological Agency (JMA) has been using a variational bias correction scheme (VarBC) operationally to correct biases of satellite radiance data in the JMA global four-dimensional variational (4D-Var) data assimilation system (DAS) since May 2006 (Sato, 2006). The background error covariance matrix (BECM) for VarBC strongly constrains the behavior of bias correction coefficients, and consequently has a large effect on the accuracy of analysis and forecasting. JMA introduced a new BECM for VarBC in the JMA global 4D-Var system in August 2008.

2. New background error covariance matrix for VarBC

The new BECM for VarBC was basically estimated from Dee (2004) and Sato (2006) by considering the balances of each term of the cost functions in 4D-Var, the amount of increment in bias correction coefficients in a single analysis, and the relationship between sampling errors and the number of the data. The new BECM for VarBC is given as follows:

$$\mathbf{B}_{\alpha,\beta} = \begin{cases} inf^2 / N_{var} & \alpha = \beta \\ 0 & \alpha \neq \beta \end{cases} \quad (1) \qquad N_{var} = \begin{cases} N / \{\log_{10}(N/N_0) + 1\} & N \geq N_0 \\ N_0 & N < N_0 \end{cases} \quad (2)$$

where $\mathbf{B}_{\alpha,\beta}$ *represents a component of the BECM for VarBC*, α *and* β *are the row and column respectively*, N *is the number of data*, $N_0 = 400$, $inf = \sigma_{system} / \sigma_d$ *represents the inflation factor*, σ_{system} *is the standard deviation (STD) of the observation errors in DAS*, *and* σ_d *is the STD of the observations minus the first guesses in the real data.*

The inflation factor is the ratio of the standard deviation of observation errors in DAS to the standard deviation of departures (observations minus first guesses) estimated from the real data, and absorbs discrepancies between the theoretical and real DAS. The standard deviations of the new BECM are about ten times as large as those of the old BECM; accordingly, VarBC with the new BECM (VarBC_new) represents a more adaptive bias correction scheme than that under the old BECM (VarBC_old). Analysis and forecast cycle experiments were carried out to evaluate the impact of VarBC_new on the accuracy of both analysis and forecasting in August 2007 and January 2007. The introduction of VarBC_new to DAS explicitly and statistically results in a significant reduction in analysis and forecasting errors for most areas, levels and variables (Fig. 1).

3. Properties of VarBC

Here we describe some of the properties of VarBC. First, since VarBC_new has a large BECM, a long-term three-month cycle experiment was carried out to check its stability. Fig. 2 shows the statistics of radiosonde temperature departures (observation minus first guess). There is no time-evolution of the statistics, indicating that VarBC_new is fully stable. Second, we investigated the dependencies of analysis and forecasting on other BECM settings. A cycle experiment was carried out with a very large BECM (VarBC_LG) in which the standard deviations of the BECM were about ten times as large as those of VarBC_new. The results show that VarBC_LG has a level of accuracy comparable to that of VarBC_new (Fig. 3). It can therefore be inferred that if the BECM is set to a level equal to or larger than that of VarBC_new, analysis and forecasting accuracy is maintained. This is because the number of satellite data in a single analysis is in the order of thousands, and the sampling errors become sufficiently small; accordingly, the dependency of analysis and forecasting accuracy on background bias correction coefficients is very small, and careful BECM setting is not necessary. Third, we carried out other one-month cycle experiments to compare VarBC_new with other bias correction schemes, a static scheme and an adaptive offline scheme. The experiments showed that VarBC_new has the best accuracy of the three bias correction schemes (Fig. 3).

References

Dee, D. P., 2004: Variational bias correction of radiance data in the ECMWF system. *Proceedings of the ECMWF workshop on assimilation of high spectral resolution sounders in NWP*, Reading, UK, 28 June – 1 July 2004, 97 – 112.

Sato, Y., 2006: Introduction of variational bias correction technique into the JMA global data assimilation system. *CAS/JSC Research Activities in Atmospheric and Oceanic Modelling,* 37, 1 – 19.

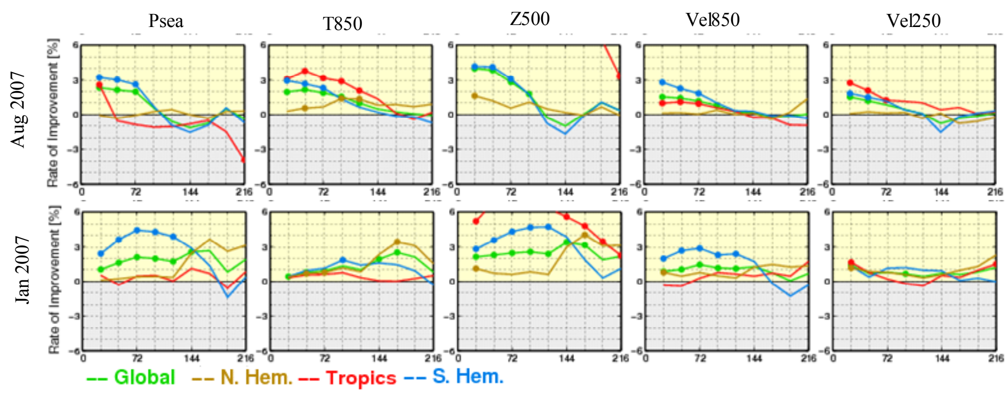

Fig. 1 Rate of improvement in the RMSE of forecast errors for sea level pressure, 850 hPa temperature, 500 hPa geo-potential height, 850 hPa and 250 hPa wind velocity. The improvement rate is defined as (CNTL-TEST)/CNTL, where CNTL and TEST are the RMSE of the cycle experiment with VarBC_old and VarBC_new, respectively. The dots on the score lines represent statistical significance.

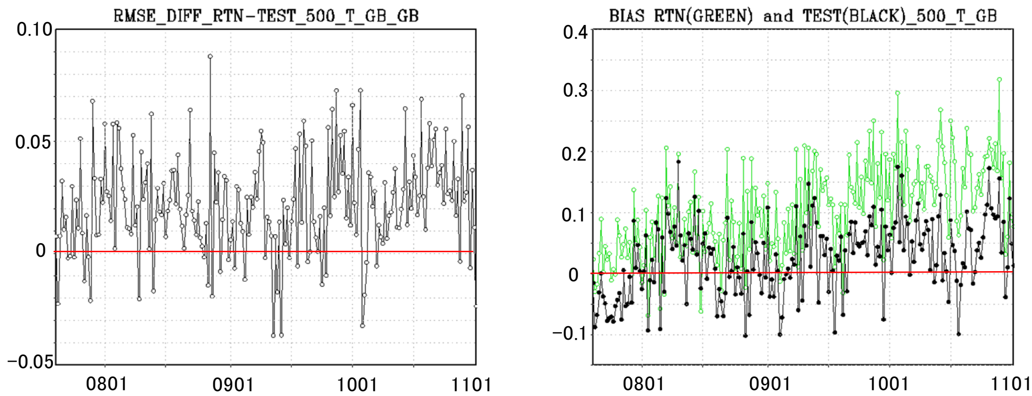

Fig. 2 The figure on the left shows differences in the RMSE of departures of radiosonde temperature at 500 hPa between VarBC_new and VarBC_old (VarBC_old minus VarBC_new). The figure on the right shows the biases of the departures. The green line is VarBC_old, and the black line is VarBC_new.

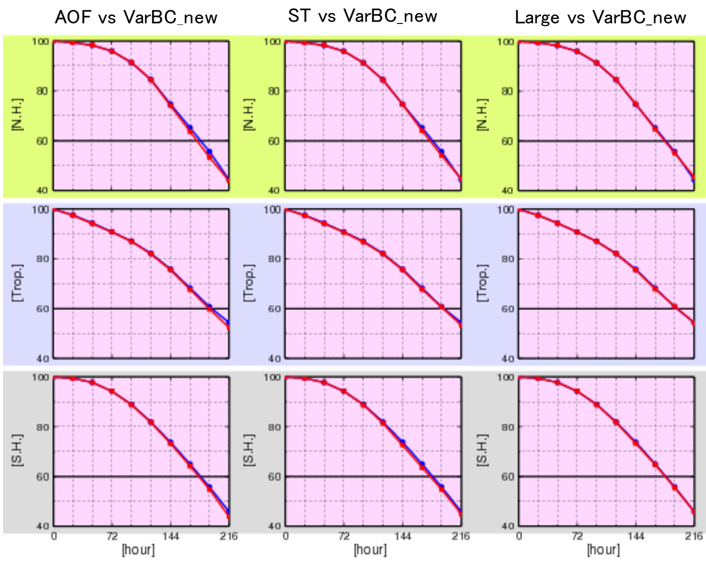

Fig. 3 Anomaly correlation (AC) of 500 hPa geo-potential height. The red lines show the AC of each cycle experiment. The leftmost column is the adaptive offline cycle, the central column is the static cycle, and the rightmost column is the VarBC_LG cycle. For each experiment, the top row is NH, the middle is TP and the bottom is SH. The blue lines show the AC of VarBC_new cycle.