Improvement of JMA's Meso-scale Analysis background errors

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1. Introduction

JMA's Meso-scale NWP system incorporates forecast called Meso-Scale Model (MSM) and objective analysis called Meso-scale Analysis (MA) using 4D-Var data assimilation. Recent investigation showed that the background error (BGE) covariance of the MA, which had been unchanged since 2009, was no longer consistent with the error characteristics of the first guess in the current system. Single observation experiments also revealed that related modeling often resulted in artificial analysis increments. To address these problems, the forecast error statistical samples needed for evaluation of BGE covariance were updated and the modeling approach was revised. The details and impacts of these changes are described below.

2. Details of changes

i) Update of forecast error statistical samples

The BGE covariance of MA is evaluated using the NMC method (Parrish and Derber 1992) with statistical processing of forecast error samples over a long period. The previous BGE covariance was evaluated from operational MSM runs covering data for 2005. In order to more appropriately represent error characteristics in the current Meso-scale NWP system, the error statistics were updated using samples obtained from the latest 2014 – 2015 MSM runs. The new BGE variances were approximately halved, while the vertical correlation was left largely unchanged and the horizontal correlation became only slightly shorter.

ii) Revision of BGE covariance modeling

The modeling of BGE covariance is based on eigenvalue decomposition of vertical error covariance. The previous modeling involved specification of the horizontal error correlation in the eigen space, and correlations among different eigen modes were ignored. As a result, horizontal correlations in the real space transformed from the eigen space were non-trivial and deviated from actual values, causing artificial analysis increments. To address this, the modeling of BGE covariance was revised so that the horizontal correlation is specified in real space (Bannister 2003), making it closer to the actual values.

3. Single observation experiments

The new BGE was developed using updated forecast error samples and by applying the new modeling as discussed in Section 2. Assimilation tests based on single observations with 3D-Var revealed the specific properties of the updated and previous BGEs. Figure 1 shows a typical difference in increments from the two assimilations using the same background and observation. Figure 1 (a) with the new BGE shows a weaker increment than (b) with the old BGE, corresponding to smaller variance of the updated BGE. In addition, the previous BGE modeled in the eigen space did not provide a true representation of the actual error profile in the real space, and produced widely spreading increments. In extreme cases, the previous BGE generated completely distorted increments as shown in Fig. 2.

4. Impact of the updated BGE on MA and MSM

A one-month analysis-forecast cycle experiment indicated that the new BGE had positive impacts on the operational MA and MSM. In this real-case experiment, increments were generally small due to the minor variance of the updated BGE, and analysis values showed farther departure from observations in the assimilation window (three hours up to the initial forecast time) than in the experiment with the previous BGE. The departure from observation values

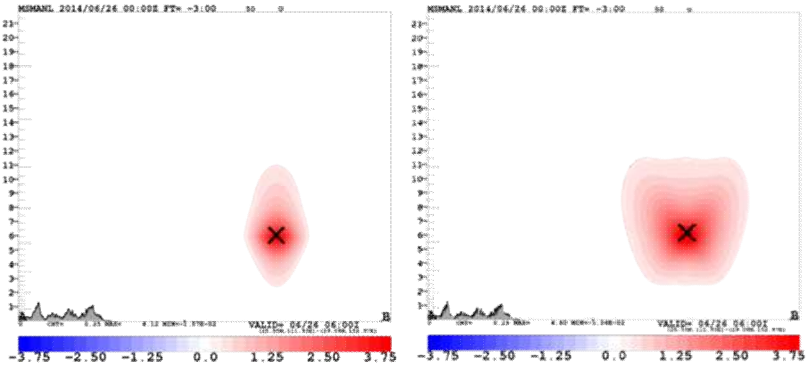

Fig. 1. Analysis increments from a 3D-Var run with (a) the updated BGE and (b) the previous BGE based on assimilation of a single zonal wind observation (marked ×) with a value 5 m/s above the background value (observation error: 1 m/s). The figure shows a north-south vertical cross section.

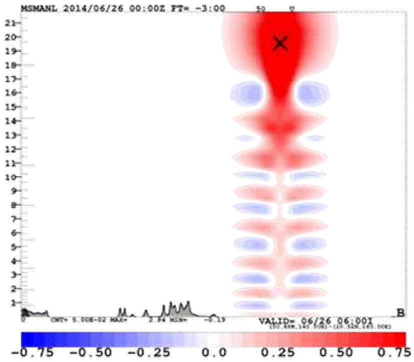

Fig. 2. Analysis increment from a 3D-Var run with the previous BGE based on assimilation of a single zonal wind observation (marked ×) with a value 5 m/s above the background value (observation error: 1 m/s). The figure shows an east-west vertical cross section.

decreased in the next three-hour forecast for most types of assimilated observations. In addition, sound and gravity wave oscillation and rapid drift of temperature, water vapor and wind in the early stages of forecasts are moderated. It can be inferred that analysis with the previous BGE resulted in excessive reliance on observations.

A supplementary experiment indicated that both the forecast sample updates and the covariance modeling revision helped to improve precipitation prediction accuracy. By way of example, in the experiment with the updated BGE, heavy rain in the Tohoku region was consistently predicted with locational accuracy despite long lead times of up to 39 hours (Fig. 3; 36-hour forecast). Warm moisture flowing from Typhoon Neoguri (located west of the region in the figure) toward the Baiu front also appears to be represented more adequately.

5. Summary

JMA has improved its MA BGE covariance with updated forecast error statistical samples and a revision of related modeling. The issue of artificial analysis increments was solved by the change in covariance modeling. The smaller variances from the updated BGE enhance the balance of the analysis, leading to moderation of undesirable oscillation and drift. The updates have been shown to have improved the accuracy of the Meso-scale NWP system. While analytical balance is affected by both BGE and observation errors, only BGE was updated in this work. Accordingly, optimization of observation errors based on the system with the improved BGE will be addressed as a future task.

References

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Parrish, D. and J. Derber, 1992: The National Meteorological Center's Spectral Statistical-Interpolation Analysis System. Mon. Wea. Rev., 120, 1747 – 1763

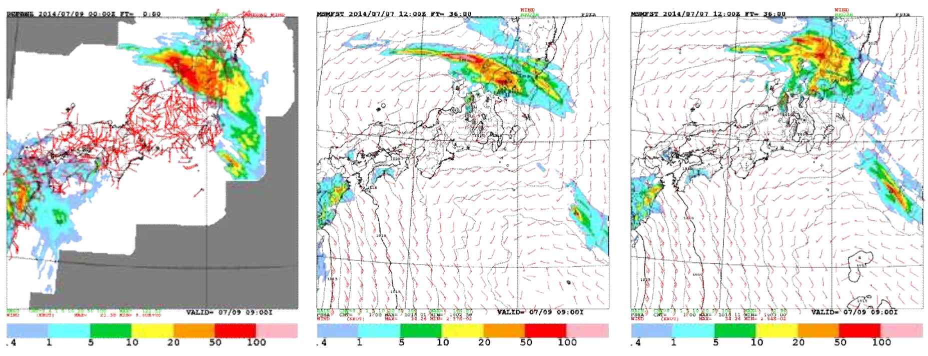

Fig. 3. 3-h accumulated precipitation valid at 00 UTC 9 Jul. 2014. (a) Observation. (b) 6-h forecast with the updated BGE. (c) 6-h forecast with the previous BGE.