Influence of lateral boundary perturbations on the mesoscale EPS using BGM and LETKF

Kazuo Saito*, Hiromu Seko*, Masaru Kunii*, Masahiro Hara* and Takemasa Miyoshi **
** Meteorological Research Institute, Tsukuba, Ibaraki 305-0052, Japan, ** Maryland University*
ksaito@mri-jma.go.jp

The Meteorological Research Institute (MRI) has been developing mesoscale ensemble prediction systems, collaborating with the Numerical Prediction Division of JMA. The development was also performed as a link of the WWRP Beijing Olympic 2008 Research and Development Project (B08RDP). In the B08RDP project, five initial perturbation methods were developed, including a mesoscale breeding growing mode (BGM) method and a method which employs the local ensemble transform Kalman filter (LETKF). In this report development of above two initial perturbation methods based on the mesoscale model and influence of lateral boundary perturbations on the mesoscale EPS are presented.

A mesoscale BGM method based on the JMA nonhydrostatic model (NHM) was developed by Saito et al. (2007; WGNE research activity report), where the magnitude of the bred perturbations, was evaluated by the moist total energy norm by Barkmeijer et al. (2001):

$$TE = \frac{1}{2}\iint \{(U_P - U_C)^2 + (V_P - V_C)^2\} + \{\frac{c_p}{\Theta}(\theta_P - \theta_C)^2\}$$

$$+ w_q \frac{L^2}{c_p\Theta}(q_P - q_C)^2 dSdP + \frac{1}{2}\int \{\frac{R\Theta}{P_r}(P_{seaP} - \theta_{seaC})^2\} dS.$$

Here, Θ=300K、Pr=800hPa, w_q=0.1. In this study, following modifications have been added:

1) Horizontal resolution of NHM in the breeding cycle was set 15 km and normalized bred vectors were added as the increment to the initial condition of the 15 km EPS.

2) In normalization, the total energy norm was computed below 5.3 km and the normalization factor was defined by the square root of the ratio to the norm computed by statistical analysis errors in the JMA mesoscale analysis. 80 % of following values were adopted; PS: 0.6 hPa, U, V: 1.8 m/s*(Kg/m3), θ: 0.7 K, RH: 10 %.

3) In all breeding cycles, saturation adjustment was applied to the perturbed fields in the hybrid model plane.

Lateral boundary perturbations are given by an incremental method which uses perturbations from the JMA one-week global EPS. Perturbations are interpolated in time and space to 3 hourly lateral boundary conditions of NHM following Saito et al. (2008; WGNE research activity report).

Figure 1 shows time the evolution of ensemble spreads in the B08RDP verification area (30N-45N, 115E-125E) by the BGM method. Initial seed of the breeding was given by the JMA one-week EPS at 12 UTC of 2 July 2008, and 6 hourly 2 day breeding cycles with a horizontal resolution of 40 km were conducted to obtain the initial perturbation increment at 12 UTC of 4 July. Without the lateral perturbation (Fig. 1a), growth of the ensemble spread is slow and reach the limit after FT=24. When the lateral perturbation was implemented in the forecast, ensemble spreads in the later half of the forecast period become larger (Fig. 1b) while the growth of spreads in the initial stage is not large. Figure 1c shows ensemble spreads when the lateral boundary perturbations were implemented in breeding cycles. Ensemble spreads become larger from the early stage of the forecast, and continue to increase throughout the forecast period. Spread of the surface temperature becomes largest in the day time (FT=12-21), corresponding to the diurnal change.

Figure 2 shows distribution of ensemble spread of temperature at 850 hPa level. Without the lateral boundary perturbation in breeding cycle (Fig.2a), initial spread is confined to small areas around the disturbance in China.

Figure 3 indicates RMS errors of ensemble means at FT=24 against the initial condition. RMSEs become smallest if the lateral boundary perturbation is implemented for both breeding cycles and the ensemble forecast.

Similar experiments were applied to the initial perturbation method using LETKF. Here, ensemble transform in NHM-LETKF (Miyoshi and Aranami, 2006; SOLA) were applied to create initial perturbations. Forecast analysis cycle is 6 hourly and horizontal resolution is 40 km as in the BGM method.

Figure 4 shows the time evolution of ensemble spreads by the LETKF method. Similar tendencies with the BGM method are seen; if the lateral boundary perturbation is omitted in the forecast analysis cycles (Fig.4a), the growth of spreads in the initial stage is not large. When the lateral boundary perturbations are implemented in the forecast analysis cycles (Fig. 4b), ensemble spreads become larger and continue to increase throughout the forecast period. The diurnal change become more distinct, however, the amplitude is smaller than that of BGM.

Distribution of initial perturbation (Fig. 5) is similar to that of BGM. If the lateral boundary perturbations are not implemented in the forecast analysis cycles (Fig. 5a), spreads near lateral boundary are small, which suggests the underestimation of the forecast error. Spreads over East China and Japan are smaller than BGM method corresponding to the observation density. This means that the magnitude of initial ensemble spreads in the LETKF method reflects the analysis error. However, this advantage of the LETKF method to the BGM method was unclear in the statistical scores such as the RMSE of ensemble mean. Localization and sampling errors may affect the synoptic structure in the initial perturbation in the LETKF method.

Reference

Saito, K., M. Kunii, H. Seko, M. Yamaguchi and K. Aranami, 2008: Implementation of lateral boundary perturbations into mesoscale EPS. CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modelling, 37, 3.11-3.12.

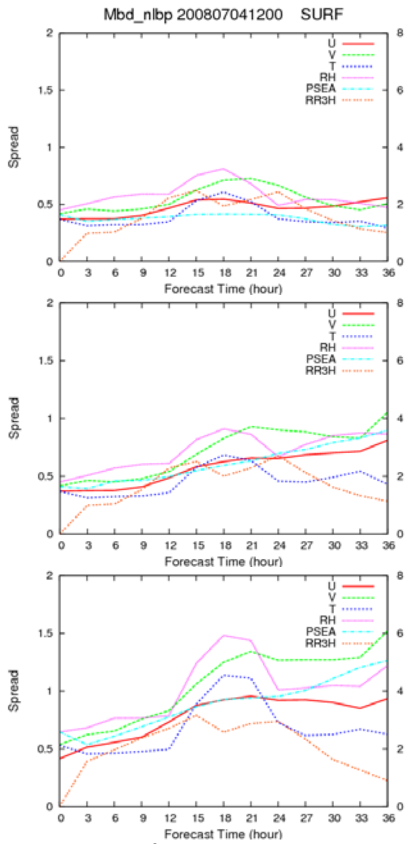

Fig. 1. Time evolution of the 11 member ensemble spreads of surface elements in the B08RDP verification area by the BGM method. Initial time is 4 July 2008. a) Without the lateral boundary perturbations. b) Lateral boundary perturbations only for the forecast. c) Lateral boundary perturbations for both in breeding cycles and the forecast.

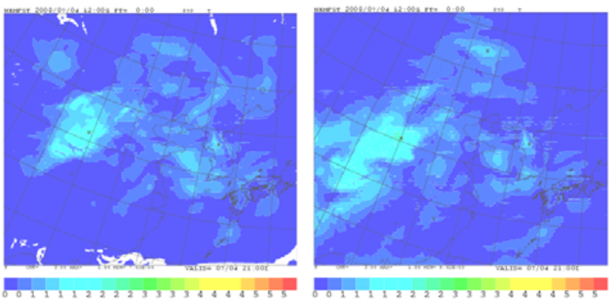

Fig. 2. Initial ensemble spread of the temperature at 850 hPa level. a) Lateral boundary perturbations only for the forecast. b) Lateral boundary perturbations for both in breeding cycles and the forecast.

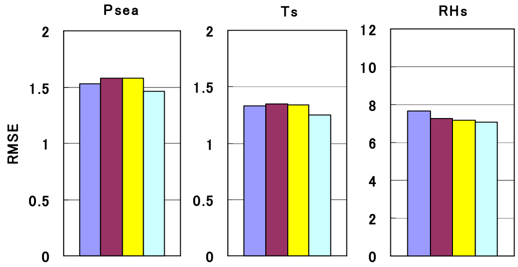

Fig. 3. RMS errors of ensemble means at FT=24 against the initial condition. (analysis at 12 UTC on the day after). Average of 3-4 July 2008. Blue: control, Brown: without lateral boundary perturbations, Yellow: Lateral boundary perturbations only for forecast. Light blue: Lateral boundary perturbations for both in breeding cycles and the forecast.

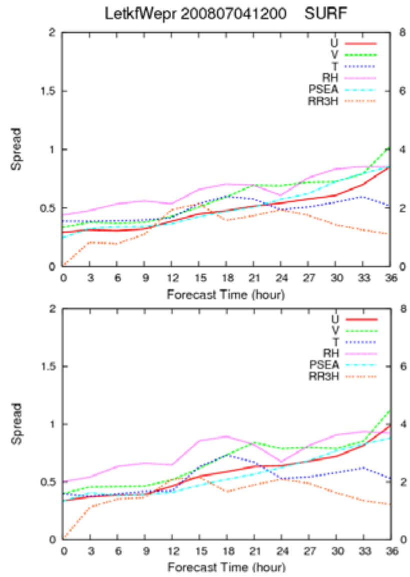

Fig. 4. Same as in Fig. 1b and 1c, except for the LETKF method.

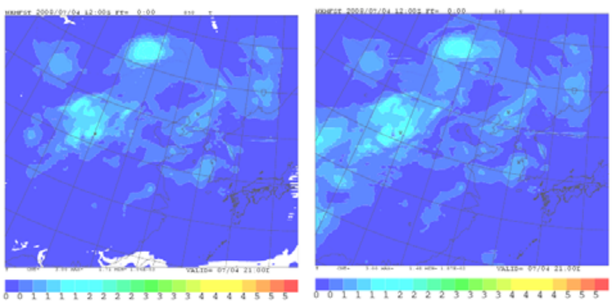

Fig. 5. Same as in Fig. 2, except for the LETKF method.