Development of a BGM method with the JMA nonhydrostatic mesoscale model

Kazuo Saito
Meteorological Research Institute, Tsukuba, Ibaraki 305-0052, Japan; ksaito@mri-jma.go.jp

In the previous report (Saito et al., 2006a), we conducted a mesoscale ensemble prediction experiment for a case of the 2004 Niigata heavy rain where initial perturbations of the ensemble members were given by normalized perturbations from the JMA operational one week ensemble prediction system (global EPS). Downscaling of global EPS is one of the promising methods, which offers detailed scenarios of mesoscale phenomena corresponding to possible synoptic situations. However, the operational global EPS is designed for the one week forecast so that the initial perturbations are adjusted to obtain appropriate spread of the synoptic fields. Therefore, the initial perturbations of the global EPS are not necessarily best for mesoscale prediction. Indeed, in Saito et al (2006a), though some perturbed members succeeded to predict a band-shaped intense rainfall area in the later half of the forecast period, rainfall amounts of ensemble members varied widely in the initial stage.

The breeding mode (BGM) method is a typical way to produce initial perturbations in the ensemble prediction. It selectively raises the lyapunov vectors in the breeding cycle and is widely used in several operational EPSs including the JMA global EPS and the NCEP's Short Range Ensemble Forecast (SREF) system. Development of a BGM method which employs the self breeding cycle with the JMA mesoscale model is underway.

A self breeding cycle has been constructed using the JMA nonhydrostatic model (JMA-NHM). Specifications of the experiment are listed in Table. 1. The domain and resolutions are same that of the JMA operational mesoscale model (Saito et al., 2006b), while the horizontal resolution of the JMA operational model has been enhanced to 5 km since March 2006. To evaluate the magnitude of the bred perturbations, the moist total energy norm by Barkmeijer et al. (2001),

$$TE = \frac{1}{2}\iint \{(U_P - U_C)^2 + (V_P - V_C)^2\} + \{\frac{c_p}{\Theta}(\theta_P - \theta_C)^2\} + w_q \frac{L^2}{c_p \Theta}(q_P - q_C)^2 \, dSdP$$

$$+ \frac{1}{2}\int \{\frac{R\Theta}{P_r}(P_{seaP} - P_{seaC})^2\} dS,$$

is employed. Here, according to the JMA global EPS, the values of Θ =300 K, P_r = 800 hPa and w_q=0.1 are used and the norm is computed less than 5.3 km AGL height. Targeting the 2004 Niigata heavy rain event, 12 hourly twelve self breeding cycles are conducted from 12 UTC 09 July to 12 UTC 12 July 2004. The moist total energy norms are computed by the differences between the control runs and perturbed runs, and the bred perturbations of all prognostic variables except soil temperatures are normalized 12 hourly. The normalization coefficients are determined by the square root of ratios between the total energy norms of perturbed runs and a standard norm, which is computed by prescribed values of model variables (0.35 hPa for MSL pressure, 1.0 m/s for U and V, 0.4 K for θ and 5 % for relative humidity, respectively). In 18 hour forecasts from 12 UTC 12 July, initial conditions of 24 members are given by 12 sets of positive and negative perturbations which are normalized twice to the breeding cycle. In the perturbed initial conditions, mixing ratio of the water vapor is limited by the saturation mixing ratio.

Figure 1 shows 6 hour accumulated rain over northern Japan (rectangle in Fig. 3a) in case initial perturbations are given by the global EPS. In both averaged and peak values, rainfall amounts of ensemble members varies widely in the initial stage (FT=0-6). Figure 2 shows the corresponding result where initial perturbations are given by the BGM method. The variation of rainfall amount in initial stage is reduced, which means that the initial perturbations are more appropriate for mesoscale prediction. In the later half of the forecast period (FT=12-18), the variety of precipitation amount reaches 2 times in averaged values and 3 times in peak values. Figure 3 shows simulated 3 hour rainfall in member 'M03p' at FT=18 for BGM method. A band-shaped intense rainfall area similar to observation is predicted.

Table 1. Specifications of the preliminary BGM experiment.

Breeding cycle	12 hours (5 members)
Horizontal resolution (grid size)	Δx=10km (361×289) , Lambert conformal
Vertical levels	40 levels, Δz=40-1180 m
Initial condition for control run	JMA operational Mesoscale 4D-Var analysis
Breeding cycle	12 hours (12 cycles)
Lateral boundary condition	JMA operational Regional model 3 hourly (no perturbation)
Dynamics	HE-VI scheme, Δt=40 sec, Δτ=11.4 sec
Cloud microphysics	3 ice bulk method
Convective parameterization	Modified Kain-Fritsch scheme
Turbulence	Diagnostic TKE
Ground temperature	Prognostic 4 soil levels, (no initial perturbations)

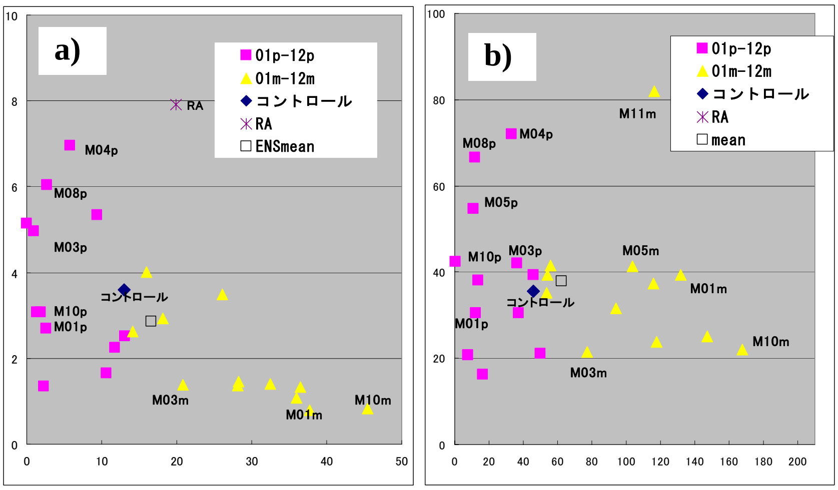

Fig. 1. a) Averaged 6 hour accumulated rain over northern Japan (rectangle in Fig. 3. Horizontal axis is for FT=00-06, while vertical axis is for FT=12-18. **b)** Same as in a), but for maximum rainfall amount. Initial time is 12 UTC 12 July 2004. In case initial conditions are given by Meso 4D-Var with normalized perturbations by the Global EPS.

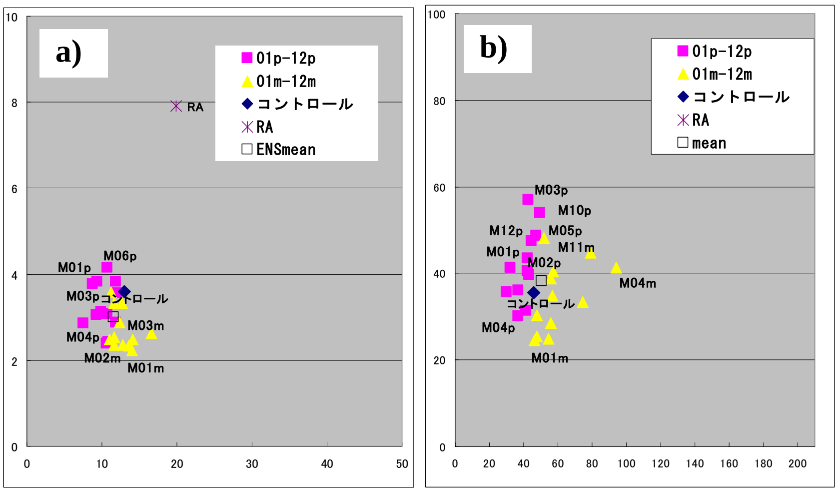

Fig. 2. Same as in Fig. 1. In case initial perturbations are given by the BGM method.

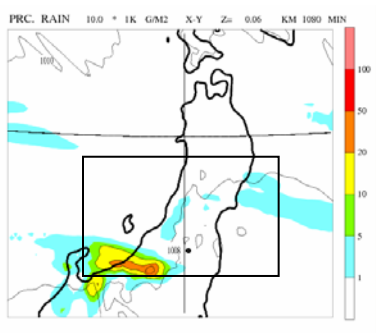

Fig. 3. Simulated 3 hour rainfall of member 'M03p' at FT=18. Initial perturbation is given by the BGM method.

References

Saito, K. M. Kyouda and M. Yamaguchi, 2006a: Mesoscale Ensemble Prediction Experiment of a Heavy Rain Event with the JMA Mesoscale Model. *CAS/JSC WGNE Research Activities in Atmospheric and Oceanic Modelling*. **36**, 5.49-5.50.

Saito, K., T. Fujita, Y. Yamada, J. Ishida, Y. Kumagai, K. Aranami, S. Ohmori, R. Nagasawa, S. Tanaka, C. Muroi, T. Kato and H. Eito, 2006b: The operational JMA nonhydrostatic mesoscale model. *Mon. Wea. Rev.*, **134**, 1266-1298.