Mesoscale ensemble prediction experiment of a heavy rain event with the JMA mesoscale model

Kazuo Saito* Masayuki Kyouda and Munehiko Yamaguchi****

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

*** Numerical Prediction Division, Japan Meteorological Agency*

Performance of mesoscale NWP has been improved by the recent progress of high resolution models and data assimilation methods. However, several difficulties have remained in prediction of severe mesoscale meteorological phenomena such as the heavy rainfall, especially when the environmental forcing is weak. One of the reasons is that mesoscale severe events are often very sensitive to the initial condition, and small errors in the analysis sometimes yield large differences in the prediction of rainfall. Idea of the ensemble prediction should be introduced into the mesoscale NWP to overcome such the problem. In recent years, several national forecast centers started their trials of mesoscale/regional ensemble predictions, but no general methods have been established yet for the prediction of heavy rains. In this study, we performed a preliminary ensemble prediction experiment for a heavy rainfall event in Japan with the JMA nonhydrostatic mesoscale model (JMANHM; Saito et al., 2006). Influences of the initial and lateral boundary conditions on the rainfall prediction are investigated.

A torrential rain occurred in northern Japan on 13 July 2004. The operational JMA hydrostatic mesoscale model (MSM) failed to predict observed concentration of the heavy rain. Predictions by JMANHM with a horizontal resolution of 10 km and operational JMA regional model (RSM) were also insufficient (Fig. 1). Kato and Aranami (2005) studied this case and showed that a high-resolution (1.5 km) version JMANHM can reproduce a band-shaped rainfall concentration, but the predicted precipitation intensity was weaker than the observation.

A downscale experiment is conducted using the JMA global ensemble prediction system (Global EPS) as the initial and boundary conditions of JMANHM. Same specification as in the operational version is employed (horizontal resolution 10 km, 361 x 289 grid points and 40 vertical levels). Figure 2c shows the averaged 6 hour accumulated rains over northern Japan (rectangle in Fig. 3a) predicted by JMANHM. These are similar to those by the Global EPS (Fig. 2a). Control runs (blue diamonds) underestimate the rain in both the initial stage (FT=00-06) and the period of the heavy rainfall (FT=12-18). Most members that the bred perturbations are added (red squares) further underestimate the rain in the initial stage (FT=00-06). On the other hand, members that the bred perturbations are subtracted (yellow triangles) tend to further underestimate the rain in the period of the heavy rainfall. These tendencies may be attributed by that the initial perturbations of the Global EPS are bred vectors by the BGM method, and they tend to reduce the moisture in the rainfall areas because the change of the moisture is limited by the saturation. The maximum rainfall values also have similar tendencies, but are quantitatively different. The global EPS (Fig. 2b) significantly underestimate the maximum rainfall amount compared with the observation (76 mm and 180 mm in the initial and heavy rainfall stages, respectively; not shown). On the other hand, JMANHM (Fig. 2d) predicts larger maximum rainfall, though most members still underestimate the rain. Affects of the lateral boundary condition (LBC) on the rainfall prediction are investigated by adding sensitivity experiments whose LBCs are changed (cross marks in Figs. 2c and 2d). The rainfall amounts were almost unchanged in both averaged and maximum values until FT=06, and the changes were small even in FT=12-18.

Figures 2e and 2f show the result of an ensemble prediction with JMANHM, where the initial conditions are given by the Meso 4D-Var analysis with perturbations by the Global EPS. In this experiment, the lateral boundary condition is given by RSM as in the operational NWP, while the Global EPS perturbations are added to the analysis after a normalization considering the errors of the Meso 4D-Var analysis. Significant quantitative improvement is seen in both the averaged and maximum values of predicted rainfall. Many perturbed members predict larger maximum rainfall than the control run. Figure 3 shows 3 hour accumulated rainfall by four members 'M03p', 'M04p', M06p' and 'M08p'. Intense band-shaped rainfall areas similar to observation (Fig. 1a) are predicted.

References

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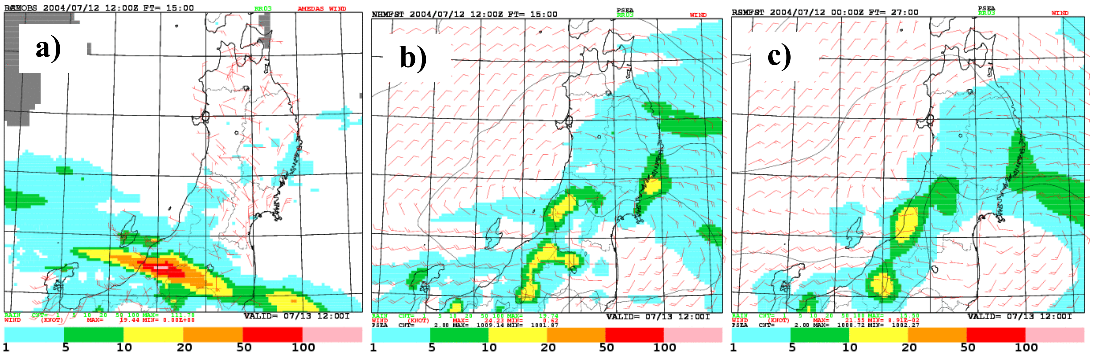

Fig. 1. a) Observed rainfall from 00 to 03 UTC 13 July 2004. **b)** Corresponding 3 hour rainfall from FT=12 to FT=15 by JMA mesoscale model. Initial time is 12 UTC 12 July 2004. **c)** Same as in b) but prediction by JMA regional model whose initial time is 00 UTC 12 July 2004.

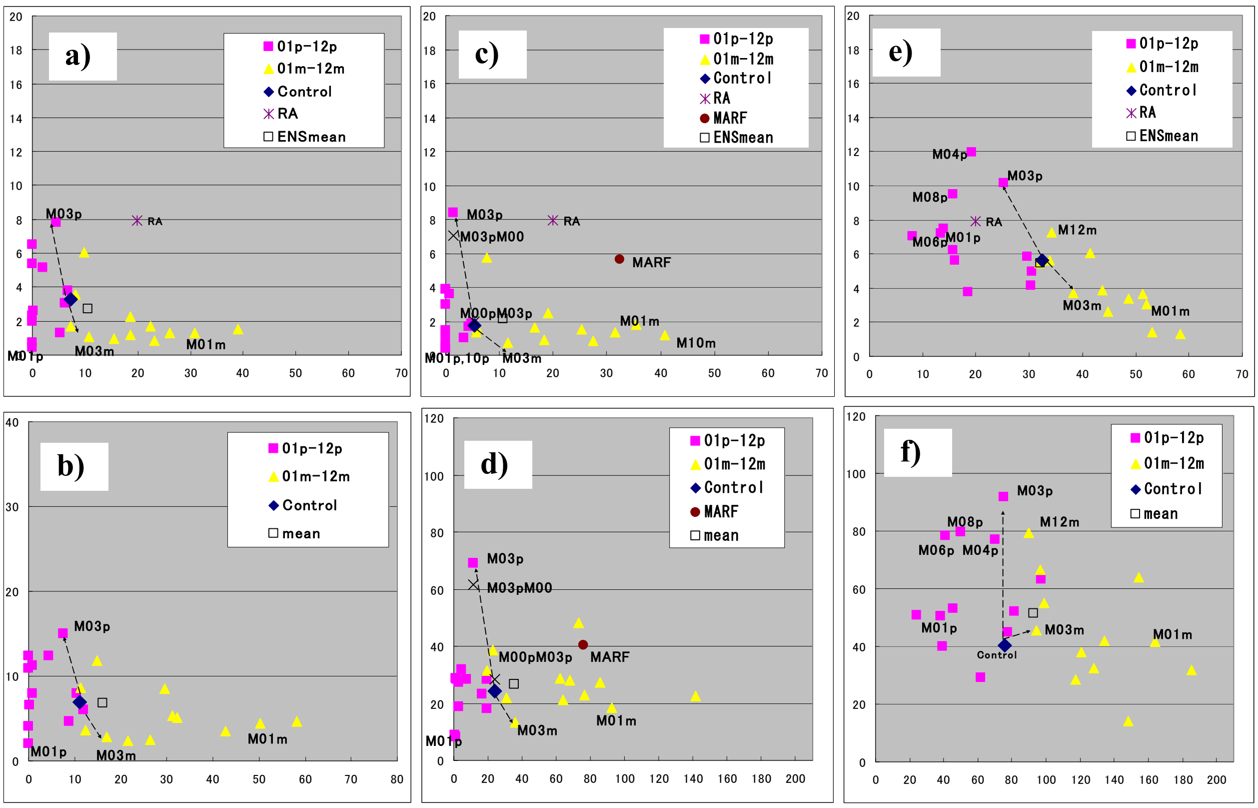

Fig. 2. a) Averaged 6 hour accumulated rain over northern Japan (rectangle in Fig. 3a) by Global EPS. Horizontal axis is for FT=00-06, while vertical axis is for FT=12-18. **b)** Same as in a), but for maximum rainfall amount. **c), d)** Same as in a), b) but 10 km JMANHM. Initial and lateral boundary conditions are given by Global EPS. Scale of hte horizontal axis is changed. **e), f)** Same as in c) d) but initial conditions are given by Meso 4D-Var with normalized perturbations by the Global EPS, and lateral boundary condition is by RSM.

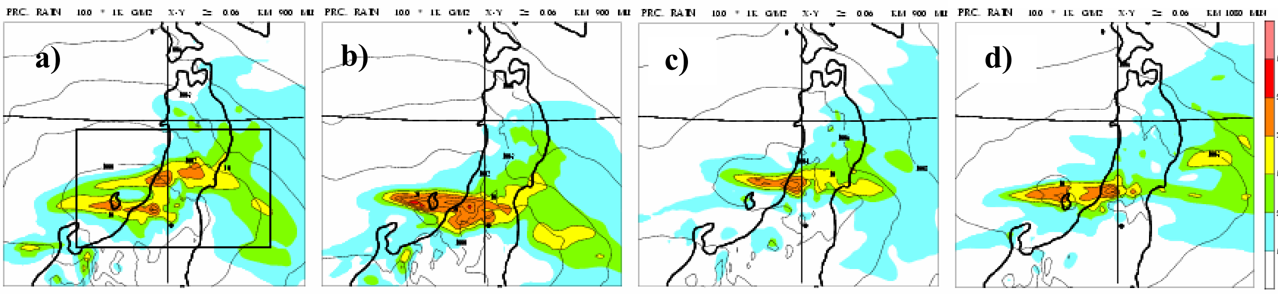

Fig. 3. Simulated 3 hour rainfall from FT=12 to FT=15 by JMANHM. Initial time is 12 UTC 12 July 2004. Initial conditions are given by Meso 4D-Var with perturbations by Global EPS, and lateral boundary condition is RSM. **a)** Member 'M03p' **b)** Member 'M04p' **c)** Member 'M06p' **d)** Member 'M08p' for FT=15 to FT=18.