A New 4D-Var for Mesoscale Analysis at the Japan Meteorological Agency

Yuki Honda and Ken Sawada
Numerical Prediction Division, Japan Meteorological Agency
1-3-4 Otemachi, Chiyoda-ku, Tokyo 100-8122, JAPAN
(e-mail: honda.yuuki@met.kishou.go.jp)

1. Introduction

The Japan Meteorological Agency (JMA) has operated a mesoscale numerical weather prediction system, the Mesoscale Analysis and Mesoscale Model (MSM), for disaster prevention and aviation forecast since March 2001. The current operational mesoscale analysis system is a four-dimensional variational data assimilation system (Meso 4D-Var), which has been used since March 2002 (Ishikawa and Koizumi 2002). A hydrostatic spectral model was adopted as a time integration operator in the Meso 4D-Var. Although this model used to be a forecast model of MSM, it was replaced with a fully-compressible nonhydrostatic grid model (JMA-NHM) in September 2004 (Saito et al. 2006). Since the analysis by a 4D-Var is optimized for an adopted forecast model, it is desired to adopt the same forecast model for the forecast and the analysis. For this reason, a new JMA-NHM based four-dimensional variational data assimilation system, JNoVA, has been developed (Honda et al. 2005). In 2008, the Meso 4D-Var will be replaced with this JNoVA.

2. Specifications of the new Mesoscale Analysis (JNoVA)

The detailed specifications of the JNoVA are described in Honda et al. (2005). The main modifications of the JNoVA after Honda et al. (2005) are the introduction of the incremental formulation (Courtier et al. 1994) and the new control variables based on Barker et al. (2004). The differences between the JNoVA and the Meso 4D-Var are listed in Table 1. The analysis is performed every 3 hours. Since the data assimilation window of the Meso 4D-Var is 6 hours, the former 3 hours are overlapped with the latter 3 hours of the previous data assimilation window. Although the observation data assimilated in the previous analysis are not used in the next analysis, the data reported after the data cut off time of the previous analysis are assimilated in the next analysis. So more observation data are assimilated in the Meso 4D-Var than the JNoVA. Besides this, the length of the assimilation window and the iteration number are also advantageous to the Meso 4D-Var. Meanwhile, the resolution of the JNoVA is higher than that of the Meso 4D-Var.

Table 1: The difference between the Meso 4D-Var and the JNoVA

	Meso 4D-Var	JNoVA
Adopted Forecast Model	Hydrostatic Spectral Model	Nonhydrostatic Grid Model (JMA-NHM)
Balance of Control Variables	Geostrophic Balance with Surface Friction	Nonlinear Balance (Barker et al. 2004)
Penalty Term	Suppress Time Tendency of Divergence	Incremental Digital Filter
Resolution:Outer/Inner/Layers	10km / 20km / 40layers	5km / 15km / 40layers
Data Assimilation Window	6hours	3hours
Iteration Number	40 –60 times	30 times

3. Performance of the JNoVA

To compare the performance of the JNoVA with that of the Meso 4D-Var, the experimentation has been conducted under almost the same conditions to the operational system in summer (2004/8/1 ~ 8/31) and in winter (2005/12/19 ~ 2006/1/15).

From the verification using the upper-air observation and the surface observation, the accuracy of the wind forecast of the JNoVA is the same as that of the Meso 4D-Var. As for the temperature and the humidity, the lower atmosphere of the JNoVA becomes cooler and moister than that of the Meso 4D-Var, so that the mean errors of the temperature and the humidity are improved in both seasons (Fig. 1). Their root mean square errors (RMSEs) are also reduced in winter although they are degraded in summer (not shown). In winter, the RMSEs of the surface variables of the temperature and the dew point of the analysis by the JNoVA are also well improved (not shown).

Fig.2 shows the score of the quantitative precipitation forecast (QPF) of 3 hourly accumulated precipitation (RR3).

In winter, the QPF of the JNoVA is better than that of the Meso 4D-Var in the range of RR3 ≤ 5mm. Although the score of RR3 ≥ 10mm of the JNoVA is worse than that of the Meso 4D-Var, the ratio of the occurrence of RR3≥ 10mm is less than 5% of all RR3. Most of the precipitation in winter is snow and RR3 is less than 5mm. On the other hand, the score is almost the same in summer although the performance of RR3 ≤ 5mm is a little degraded. This is because the QPF of the JNoVA tends to spread the precipitation area of the weak rain.

In general, the JNoVA shows the similar performance to the Meso 4D-Var and the forecast of the JNoVA sometimes shows better results than that of the Meso 4D-Var (Fig.3). However, the degradation of the QPF is a crucial problem. After resolving this problem, the JMA will replace the Meso 4D-Var with the JNoVA in 2008.

The horizontal resolution of the analysis of the JNoVA is twice higher than that of the Meso 4D-Var. Besides, it would reduce the development cost of the MSM since the same forecast model, JMA-NHM, is used in forecast and analysis. These factors would be benefits of this upgrade of the operational mesoscale analysis system.

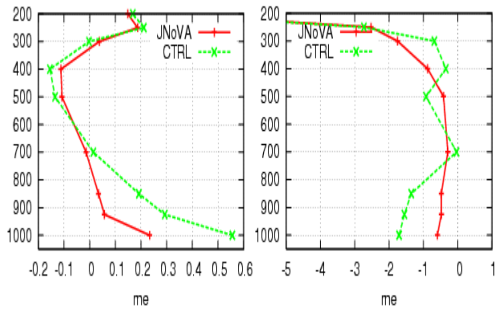

Fig. 1: Mean error of temperature (left) and relative humidity (right) of 3 hour forecast.

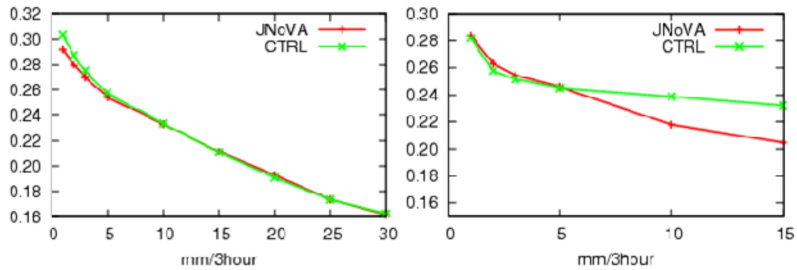

Fig. 2: Equitable threat score of 3hourly accumulated precipitation forecast in summer (left) and winter (right). The red and green line shows the results of the JNoVA and the Meso 4D-Var (CTRL), respectively. The horizontal axis is the threshold value of the rainfall amount.

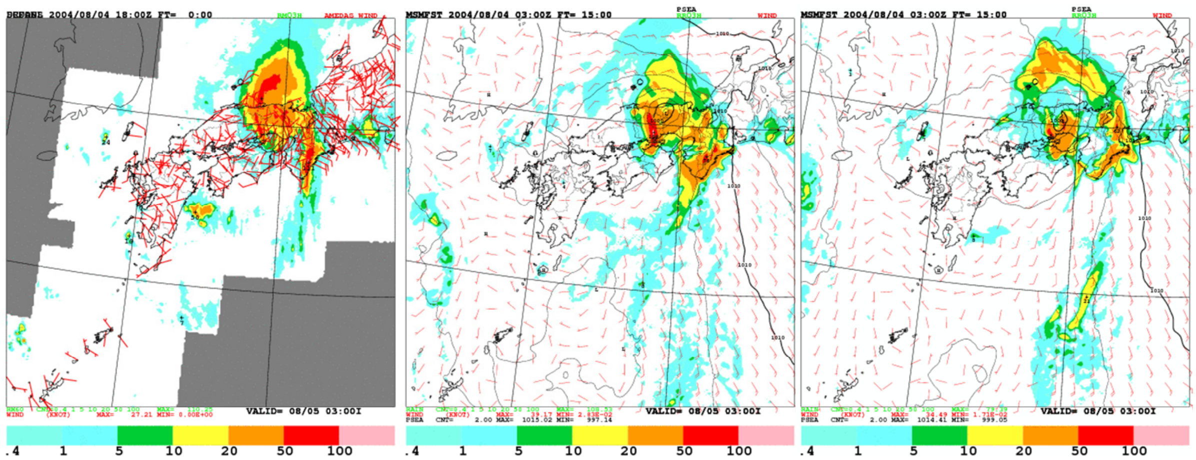

Fig. 3: 3 hourly accumulated rainfall of QPE (Radar-raingauge Analyzed Precipitation) (left), 15-hour forecast from the initial field analyzed by the JNoVA (middle) and that from the initial field by the Meso 4D-Var. The initial time is 03 UTC on 4th August, 2004.

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