Assimilation Experiment of the Nerima Heavy Rainfall with a Cloud Resolving Nonhydrostatic 4 Dimensional Variational Data Assimilation System

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1. Introduction

The Forecast Research Department of the Meteorological Research Institute (MRI) has been developing a high-resolution nonhydrostatic 4 dimensional variational assimilation system (NHM-4DVAR) based on the Japan Meteorological Agency nonhydrostatic model (JMA-NHM) since April 2002 in the collaboration with the Numerical Prediction Division of JMA. The aim is to apply a 4DVAR technique to the mesoscale convective cloud system with a cloud resolving resolution less than 2 km. Since the 4DVAR gives the optimized 3 dimensional field between the model dynamics and the observation, it seems that 4DVAR provides numerical models more suitable initial conditions to simulate the convective system if observed data are well utilized.

We applied the NHM-4DVAR to the Nerima heavy rainfall event occurred at 21 July 1999. Seko et al. (2005) applied the JMA hydrostatic Meso 3DVAR and NHM-3DVAR to this event and reproduced associated heavy rainfall, but a statistical relation between the relative humidity and updraft velocity was introduced. In this report, assimilating observed data with NHM-4DVAR, deep convection under the weak environmental forcing associated with the heavy rainfall is successfully reproduced.

2. NHM-4DVAR

The tangent linear model and the adjoint model of NHM-4DVAR are based on the year 2002 version of JMA-NHM. A prototype version for dry dynamics was initially developed (Honda et al., 2003). Advection term of water vapor is included (Kawabata et al., 2004), and the perturbations of the lateral boundary conditions are also newly considered, associated with the control variables.

A set of control variables is designed for high resolution 4DVAR. Horizontal wind (u, v), vertical wind (w), nonhydrostatic pressure, potential temperature, surface pressure and pseudo relative humidity (Dee and Da Silva, 2002) were chosen. We do not consider any balance mode of control variables except for the hydrostatic pressure, because it is difficult to define balance mode in high resolution such as 2 km and short time scale.

The Radial Wind data derived by the Doppler radars (RW), the GPS Precipitable Water Vapor (PWV) data and the surface observation data are available as the high temporal and spatial resolution data (Kawabata et al., 2005).

3. Assimilation experiment

NHM-4DVAR with a horizontal resolution of 2 km is applied to the assimilation experiment. The assimilation window is from 0500 UTC to 0600 UTC, 21 July 1999 which includes the generation time of the Nerima cells but excludes their mature stage. The forward model is a full-scale JMA-NHM which includes 5 category cloud microphysical processes, while the adjoint model is a simplified model. The horizontal domain is 240 km x 240 km which covers the Kanto plain. In NHM-4DVAR, RW data are assimilated with 1 minute interval by every elevation angle and the RW data from 0.7 to 5.4 degree elevation angle are used for assimilation to remove undesirable high elevation angle data. GPS-PWV data are assimilated with 5 minutes interval, and the surface wind and temperature data observed by the Automated Meteorological Data Acquisition System (AMeDAS) of JMA are assimilated with 10 minutes interval. After the assimilation, we performed a 3 hour forecast with the assimilated initial field.

The time sequence of the cost function J with respect to iteration numbers is shown in Fig. 1. Total value of J becomes half and decreases with a log scale. Most part of this decrease is by the decrease of the cost of RW data. Because the costs of GPS-PWV data and the surface observation are minimized well and the orders of each cost function value are same orders of the number of each observations, the minimization process successfully converged.

Figure 2a shows composite rainfall amount observed by radar corrected by AMeDAS rain gage data. A heavy rainfall area over 100 mm/hour exists around Nerima. But in the first guess field (Fig. 2c). any strong rainfall area does not exist. On the other hand, in the forecast field (Fig. 2b), location and intensity of the Nerima cells were well reproduced, and other convective areas were also reproduced except for their intensities. Figure 3 shows the time sequence of rainfall amount in every 10 minutes observed by rain gage of AMeDAS at Nerima and the forecast at a model grid point near Nerima cells. Both rainfall amounts are about 15 mm to 25 mm between 0630 UTC and 0710 UTC and their time sequence are quantitatively in good agreement. These facts show that the lifetime and the intensity of Nerima cells were well reproduced.

References

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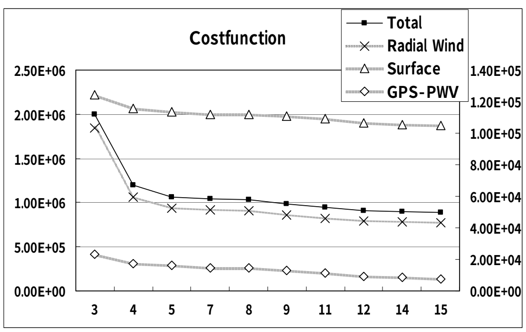

Fig. 1. Time sequence of the value of the cost function J. ‘Total’ and ‘RW’ use the left Y-axis and ‘Surface’ and ‘GPS-PWV’ use the right Y-asis.

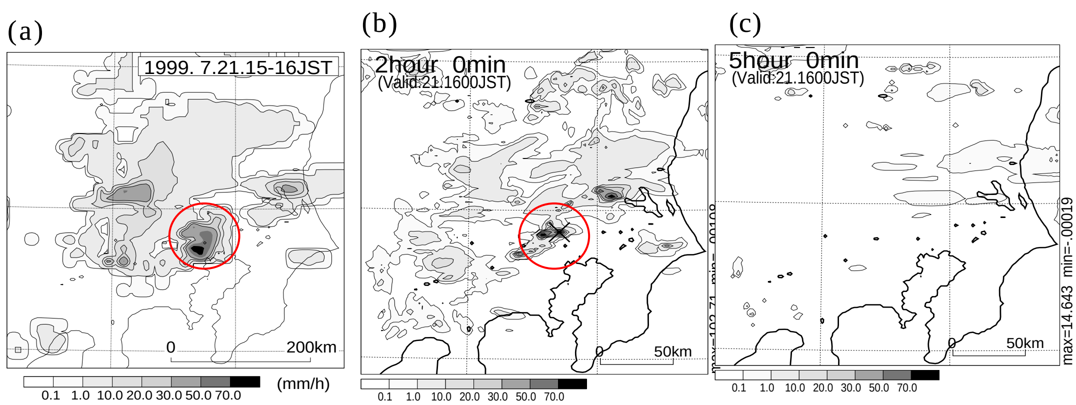

Fig.2. 1 hour accumulated rainfall amount from 0500 UTC to 0600 UTC. (a) is Radar-AMeDAS analysis, (b) is forecast result and (c) is the first guess field. Red circles show the Nerima cells.

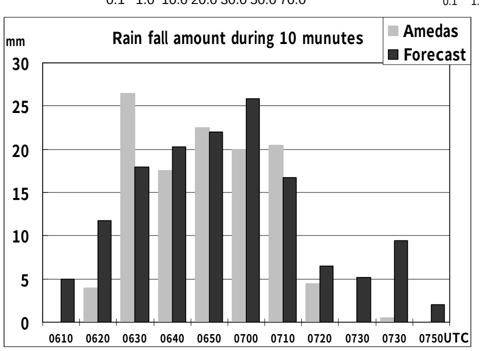

Fig. 3. Time sequence of rainfall amount in every 10 minutes. Gray bars show observation at Nerima. Black bars show forecasting result at the developing point of Nerima heavy rainfall.