Doppler Radar Wind Data Assimilation with the JMA Meso 4D-VAR

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1. Introduction

The Japan Meteorological Agency (JMA) has been operating a mesoscale model (MSM) with a horizontal resolution of 10km to forecast mesoscale events over and around the Japan Islands since 2001. It is widely known that the accuracy of mesoscale numerical weather prediction (NWP), especially precise prediction of heavy rainfalls, is largely affected by the accuracy of the initial condition. Therefore, in order to improve the accuracy of initial state using various observations, JMA implemented a mesoscale four-dimensional variational assimilation system (Meso 4D-Var) in March 2002.

Eight airports in Japan are currently installed with operational Doppler radars (Fig. 1). These radars for safe aviation provide radial velocity data averaged in a 5km(radial direction)×5.625 degrees(azimuthal interval) space up to the maximum detectable range 120km from each radar. The radial velocity data from six radars(except Chubu and Fukuoka) have been used in operation since March 2005 in the Meso 4D-Var. The ones from Chubu and Fukuoka have been used in operation since June 2005. At the moment, the Meso 4D-Var is used to assimilate the radial velocity data from eight radars (circles in Fig. 1) which are available at the analysis time.

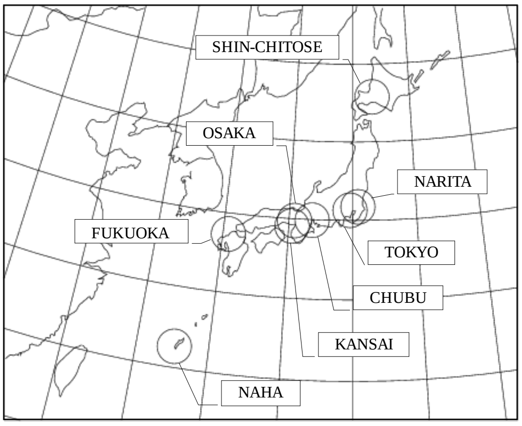

Fig. 1 Eight operational doppler radars and their maximum ranges in forecast domain of MSM.

2. Quality control and assimilation

First, in order to avoid the contribution of precipitation fall velocities to the Doppler velocities, data at the elevation angle larger than 5.9 degrees are not used. The data within 10km from a radar site are not used either because of back-scattering noise.

The provided radial velocity data are averaged values within a volume of 5km x 5.625 degrees with several information such as number of samples, standard deviation and max-min difference of wind speed within each volume. These additional informations are used for quality control. In the MSM routine, data are used only when following conditions are fulfilled.

1) the number of samples is above 10,
2) the standard deviation is below or equal to 10 ms^{-1},
3) the max-min difference is below or equal to 10 ms^{-1},
4) difference between observation and background value exceeds 10 $m\ s^{-1}$.

In addition to the above quality control, data within ±5 ms^{-1} are removed due to the inappropriateness of land-echo removal procedure.

The data are thinned to about 20km apart horizontally after the quality control process. The observation operator for radial velocity is constructed as follows:

1) *u*- and *v*- component of wind of background field at each model level are interpolated to the observation point.
2) Since widened radar beam covers several layers of model domain, background *u* and *v* at the height of beam-center are calculated assuming that the beam intensity is a Gaussian function of distance from beam center. This method is slightly modified from the one employed in Seko et al. (2004).
3) Radial component is calculated from u- and v- component at the observation point.

3. Impact of radial velocity data

Three-hourly forecast-analysis cycle was performed without and with the radial velocity data in the following period 1-15 February and 1-13 September 2004. In each period, 18-hour forecasts were made four times a day at 00, 06, 12 and 18 UTC.

Figure 2 shows the radial velocity has positive impacts on precipitation forecasts. The improvement is found for moderate rain (10 mm / 3 hour, Fig. 2) but not so apparent for weak rain (not shown).

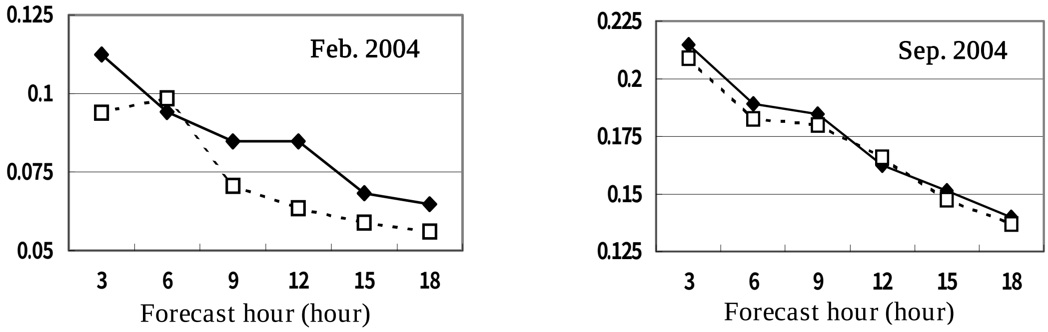

Fig.2 Threat score of precipitation forecast starting from analysis with radial velocity data (solid line) and without them (broken line). The threshold value is 10 mm per 3 hour. Left column is for the period from 1 to 15 Feb. 2004 and right column is for the period from 1 to 13 Sep. 2004.

Figure 3 shows a case of heavy rain in the experiment period. Figure 3a and 3c show, respectively, the forecast of 3-hour precipitation amount starting from the 4D-Var analysis without and with radial velocity(Vr). Figure 3b shows the corresponding observation for Radar-AMeDAS from conventional weather radar.

Without Doppler radar data, the amount of the precipitation forecast in the center of forecast domain (indicated by circle) was much smaller than that of the observation. By assimilating Vr (Fig 3c), more precipitation is predicted and it precipitation pattern is closer to the radar observation.

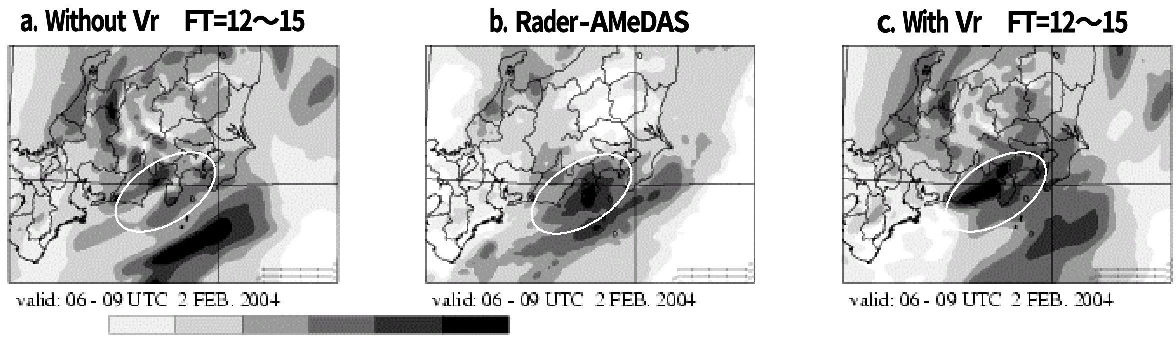

Fig.3 Forecst and observations of 3-hour precipitation amount at initial time of forecast is 18UTC 1 February 2004. Left: the forecast starting from the 4D-Var analysis without radial velocity(Vr). Center: the Radar-AMeDAS observations. Right: the forecast starting from the 4D-Var analysis with Vr.

Reference

Seko, H., T. Kawabata, T. Tsuyuki, H.Nakamura, K. Koizumi and T. Iwabuchi, 2004: Impacts of GPS-derived Water Vapor and Radial Wind Measured by Doppler Radar on Numerical Prediction of Precipitation, *J. Met. Soc. Japan*, **82**, 473-489.