13A.6

Radar Data Assimilation in a Regional Model of KMA

Duk-Jin Won[1], Eun-Ha Lim[1] and Qingnong Xiao[2]
[1]Korea Meteorological Administration, Seoul, Korea
[2]National Center for Atmospheric Research, Boulder, Colorado, U.S.A.

1. INTRODUCTION

Doppler radar data is an important source for mesoscale weather analysis and forecasting. An assimilation of Doppler radar data for short-term numerical weather forecasting or nowcasting has been considerable parts. The purpose of this research is to examine the assimilation impact of Doppler radar radial velocity and reflectivity on the prediction in Korea Peninsula. The three-dimensional variation data assimilation (3dVar) system for use with the Penn State/Ncar mesoscale model (MM5) is used to enable the assimilation of radial velocity and reflectivity. This research includes also multi-radar data preprocessing, development of observation operators and MM5 3dVar analysis. Observation operators for Doppler radial velocity and reflectivity are developed and implemented in Korea Meteorological Administration(KMA) regional 3dVar and forecasting system which has the 3-hr cycling and Incremental Analysis Updates(IAU) scheme.

2. METHOD

a. Radar data preprocessing

Radar data for assimilation are from four radar sites, two of KMA S-band radars(Jindo and Mt. Kwangduk) and two of U.S. air force NEXRADs (Gunsan and Pyungtaek). Fig. 1 shows radar sites and the observational range. In overlapping area, maximum reflectivity data are used and Gunsan radial velocity has higher priority to Pyungtaek date.

Radar data are transformed into the model grid using SPRINT and CEDRIC software developed by Mohr and Vaughan(1979). It reduces redundant data (especially near the radar) and high frequency features to convert to grid data. To calculate unfolded radial velocity at a grid point, the wind profile of model forecast filed is used. Fig. 2 illustrates the flow of radar data preprocessing.

b. 3dVar analysis

The 3dVar system developed by Barker *et al*.(2003, 2004) is used in this study. The preconditioned control variables are stream function, velocity potential, unbalanced pressure and specific humidity q. Horizontal and vertical correlation are represented by recursive filter and EOF.

In order to include a capability of doppler reflectivity assimilation, a control variable is modified as the total water q_t. q_t is the summation of vapor water(q_v), cloud water(q_c) and rain water(q_r), q_t=q_v+q_c+q_r. Because q_t is used in the background error statistics, the statistical information from q_v, q_c and q_r are all included. NMC method with the difference of 24-h and 12-h forecasts was used to carry out the background error statistics.

The 3dVar has been modified to include vertical velocity(w) increments. This is important when radar data are included in the analysis and for

* *Corresponding author address*: Duk-Jin Won, Numerical Weather Prediction Division / Korea Meteorological Administration 460-18 Shindaebang-2dong Dongjak-gu Seoul 156-720 Korea; e-mail : djwon@kma.go.kr

small scale convective weather system.

The observation operator for Doppler radial velocity is

$$V_r = u\frac{x - x_i}{r_i} + v\frac{y - y_i}{r_i} + (w - V_T)\frac{z - z_i}{r_i}$$

where (*u,v,w*) are the wind components, (*x,y,z*) are the radar location, (x_i, y_i, z_i) are the location of the radar observation, r_i is the distance between the radar and the observation, and V_T is terminal velocity.

The observation operator for Doppler radar reflectivity is derived analytically by assuming the marshal-Palmer distribution of raindrop size. The Z-q_r relation between the rainwater and reflectivity(dBZ) is(Sun and Crook 1997) :

$$Z = 43.1 + 17.5\log(\rho q_r)$$

where Z is reflectivity in the unit of dBZ and q_r is the rainwater mixing ratio.

3. EXPERIMENT

Doppler radar data are assimilated at every 3 hours into the 3dVar analysis with 10km resolution from 0000 UTC July 15th to 1200 UTC July 15th 2004. Fig. 3 shows the forecasting system for the radar data assimilation and numerical simulations.

Total 4 experiments are designed. Table 1 listed the experiments, R3DR is the experiment using MM5 3DVAR without radar data assimilation, R3DR+RV is the experiment using MM5 3DVAR with radial velocity assimilation, R3DR+RF is the experiment with Doppler reflectivity assimilation, and R3DR+RVRF with both radial velocity and reflectivity assimilations. Fig. 4 shows analysis increments of wind fields and temperature fields at 700 hPa. Solid lines are temperature analysis increments, shadings are wind speed increments and arrows are wind increments vector. Assimilation of radial velocity (Fig. 4(b), (d)) improves the rainfall forecast compared to the experiment without radar data or reflectivity assimilation. R3DR+RV(Fig. 4(b)) is similar to R3DR+RVRF(Fig. 4(d)) and R3DR(Fig. 4(a)) is similar to R3DR+RF(Fig. 4(c)). The impact of radial velocity assimilation is more effective than the reflectivity assimilation in this study.

Fig. 5 compares analysis increments of R3DR(Fig. 5(a)) with R3DR+RV(Fig. 5(b)) at 500 hPa. The assimilation of radial velocity increases increments of wind and temperature fields. The wind increments distribution with radar data assimilation(Fig. 5(b)) increase on the Yellow Sea. As results of radar data assimilation, the wind increment is increased from low level to high level.

Fig. 6 shows the forecasted(Fig. 6(a) ~ (d)) and observed(Fig. 6(e)) 3hr rainfall. From the comparison of the rain observation, R3DR+RV and R3DR+RVRF(Fig. 6(b), (d)) obtained better results than the R3DR and R3DR+RF(Fig. 6(a), (c)). The rain band patterns of radar data assimilation, especially including radial velocity, are closer to the observation.

4. CONCULUSION

To assimilate radial velocity and reflectivity data, the 3dVar system includes analyses of vertical velocity increments and total water mixing ratio q_t is used as a control variable. Wind and temperature analysis increment is increased as radar data assimilation is adapted. Assimilation of both reflectivity and radial velocity data can extend the positive impact on rainfall forecast. Especially, Radial velocity appears to have stronger positive impact than the reflectivity assimilation in this case.

REFERENCES

Barker, D. M., W. Huang, Y.-R. Guo, A.J. Bourgeois, and Q. Xiao, 2004: A three-dimensional variational(3DVAR) data assimilation system for use with MM5:

Implementation and initial results. *Mon. Wea. Rev.*, **13 2**, 897-914.

Barker, D. M., W. Huang, Y.-R. Guo, and A. Bourgeois, 2003: A Three-Dimensional (3DVAR) Data Assimilation System For Use With MM5. NCAR. Tech Note, **68pp.**

Mohr, C. G., and R. L. Vaughan, 1979: An economical procedure for Cartesian interpolation and display of reflectivity data in three-dimensional space. *J. Appl. Meteor.*, **18**, 661-670

Sun, J., and N. A. Crook, 1997: Dynamical and microphysical retrieval from Doppler radar observations using a cloud model and its adjoint. Part I: Model development and simulated data experiments. *J. Atmos. Sci.*, **54**, 1642-1661.

Table 1. 3dVar radar data assimilation experiments(cold start at 0000 UTC 15 July, 3 hr cycling frecast to 1200 UTC 15 July 2004).

Experiment	Radar Data Type
R3DR	No
R3DR+RV	Radial velocity
R3DR+RF	Reflectivity
R3DR+RVRF	Radial velocity and reflectivity

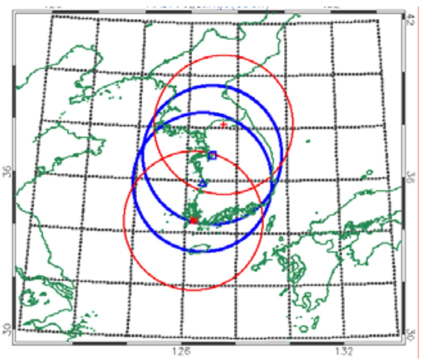

Fig. 1. Radar sites and observational range. * : Jindo, + : Mt. Gwangduk, △ : Gunsan and □ : Pynuntaek(red line : KMA S-Band, blue line : Nexrad).

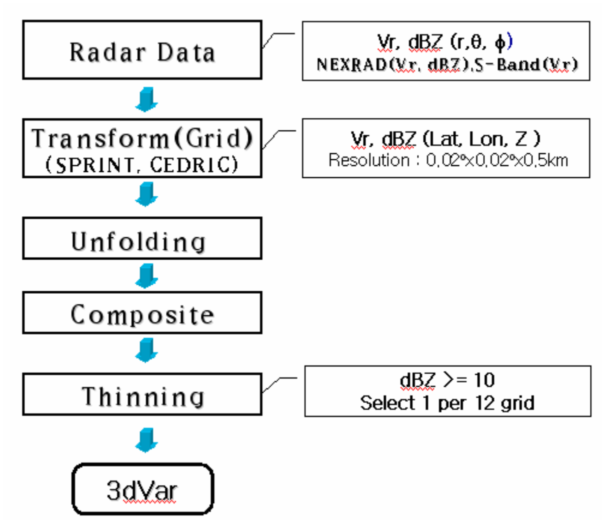

Fig. 2. The sketch of the radar data preprocessing.

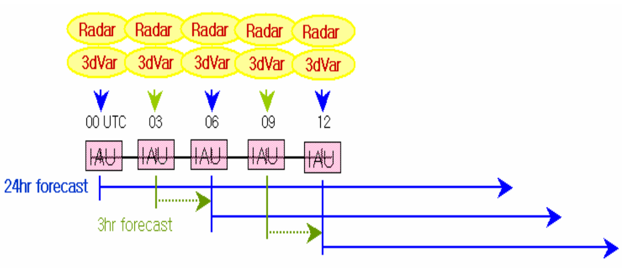

Fig. 3. The experimental design for the radar data assimilation and numerical simulations.

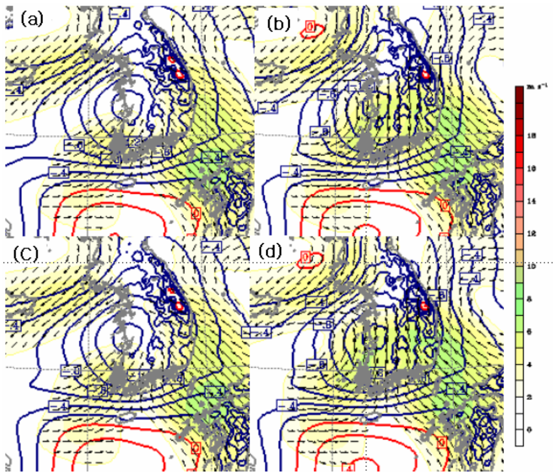

Fig. 4. Analysis increments of wind fields and temperature fields at 700 hPa(0000 UTC July 15th 2004). (a) R3DR, (b) R3DR+RV, (c) R3DR+RF and (d) R3DR+RVRF. Contours are temperature (℃) increments, shading are wind speed (m/c) increments and arrows are increment wind vectors.

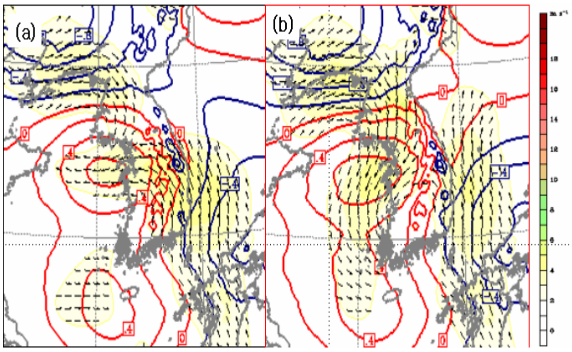

Fig. 5. Same as Fig. 2 but (a) R3DR and (b) R3DR+RVRF at 500 hPa.

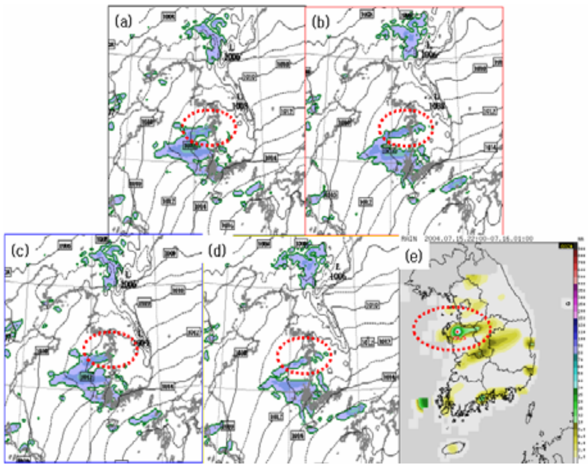

Fig. 6. 4-hr forecasted the amount of 3-hr rainfall(mm) from 1200 UTC July 15th 2004(valid time is 1600 UTC). (a) R3DR, (b) R3DR+RV, (c) R3DR+RF, (d) R3DR+RVRF and (e) observation.