Development of a Tool for Weather Forecasting/Reanalysis and a Method for Improving the Performance of the Tool using Doppler Radar Data

Background

Heavy rainfall/snowfall or strong winds accompanied by severe storms are main causes of meteorological disasters that damage facilities operated by electric power companies. It is important that disastrous phenomena are forecast or reanalyzed with high accuracy in terms of helping swift recovery activities in disasters or considering prevention schemes before disasters. The use of forecast/reanalysis data distributed by national meteorological centers is indispensable. Data with a higher spatiotemporal resolution are, however, needed for users in electric power companies who watch weather and associated disasters in specific regions. Then, the use of a mesoscale numerical meteorological model with data from meteorological centers is a promising approach for forecasting or reanalysis with a higher resolution and for any region. In that sense, an automatic driver or system for a mesoscale model is hopefully useful. Meanwhile, the performance of a mesoscale model depends on the accuracy of initial and boundary conditions. This motivates us to develop a data assimilation method to modify initial conditions or the atmospheric state at some leading time of forecasts. Assimilation of Doppler radar observations is expected to improve the performance for storm cases.

Objectives

The objective of this study is twofold. One of objectives is to develop a system which can forecast or reanalyze meteorological phenomena automatically based on the WRF model [*1]. The other is to develop a method of three-dimensional variational data assimilation (3-D Var) using Doppler radar data and to evaluate the method in terms of the improvement of short-range (0-6 hours) precipitation forecasting.

Principal Results

1. Development of Meteorological Application and Research System (MARS)

This system is designed for performing automatically all processes such as downloading meteorological datasets from national meteorological centers, forecasting/reanalysis by the WRF model, and uploading outputs on the Web (Fig.1). A supercomputer is not necessarily needed for the system, but the system can work on a PC workstation. It is noteworthy that MARS can be applied to real-time forecasting with lead times up to a couple of days as well as to reanalysis of disastrous meteorological phenomena offline.

2. Development and evaluation of a method to assimilate Doppler radar data into the WRF model

An assimilation method to modify the atmospheric state of a mesoscale model is developed in a collaborative research project with U.S. National Center for Atmospheric Research (NCAR). The method is based on a 3-D Var technique using Doppler radar observations. Because simplified dynamics and physics are considered in the method, the method can retrieve the atmospheric state physically, and it is a feature for the method to retrieve model variables that are not related directly to observations. As a result of the evaluation through idealized tests, the assimilation method works reasonably well to improve the retrievals of meteorological variables and forecasts of severe storms (Fig.2). Impact of assimilation lasts 6 hours at least in tests, and assimilation of radial velocities is of primary importance to forecast more accurate location of convections.

Future Developments

The assimilation method has to be applied to real radar data for verifying the usefulness of the method to forecasting severe storms. After that, the method will be introduced to MARS. Furthermore, MARS will be applied to a variety of issues such as forecasting of disasters associated with severe weather as well as forecasting of daily demand of electricity. The combined use of a hydrological model or a computational fluid dynamics (CFD) model with MARS will be also examined.

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References

S. Sugimoto, et al., 2005, “Assimilation of multiple-Doppler radar data with WRF-3DVAR system: Preliminary results in observing system simulation experiments,” 32nd Conf. on Radar Meteorol., American Meteorological Society, JP1J.17.

K. Wada, et al., 2007, “Development of regional weather analysis and forecast system: MARS,” CRIEPI Report N06016 (in Japanese).

＊1：The Weather Research and Forecasting model is a kind of a mesoscale meteorological model. It is developed as an operational and research model by the U.S. meteorological community, of which National Center of Atmospheric Research (NCAR) is the main center.

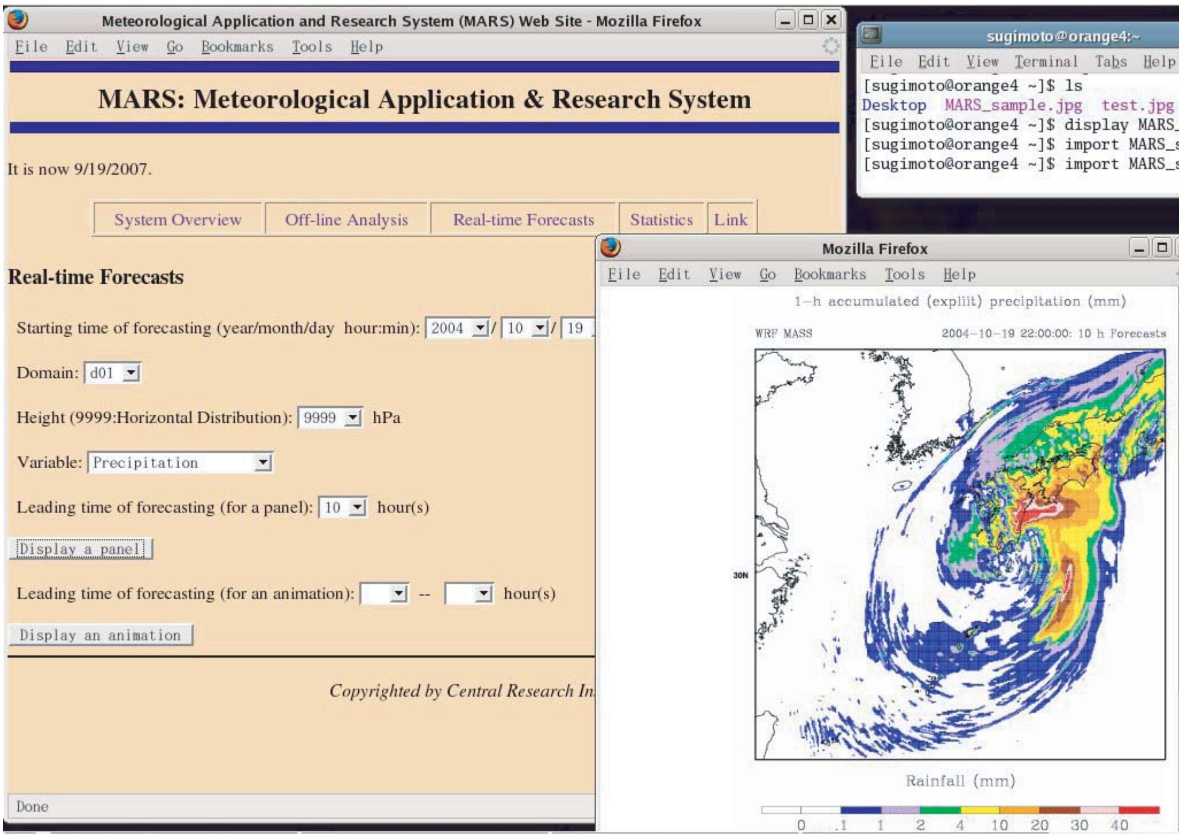
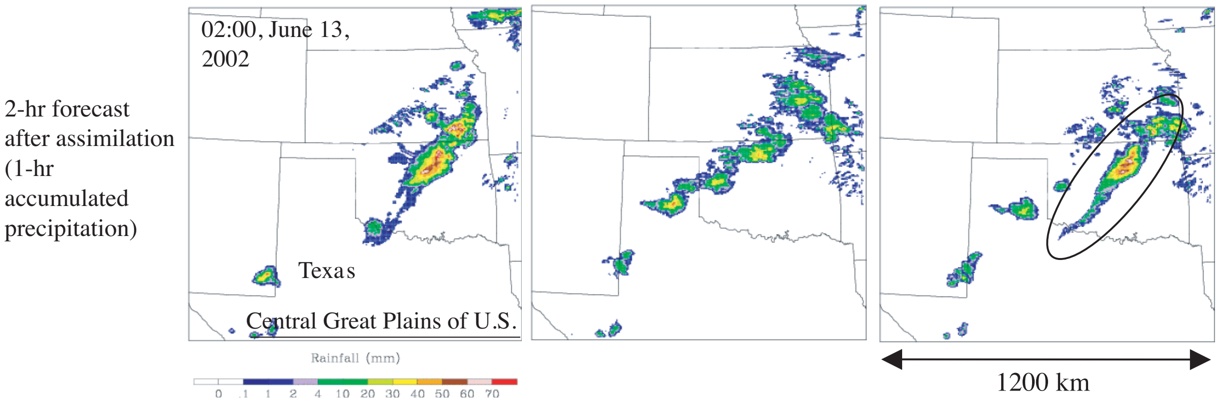


Fig.1 A web browser of MARS (Distribution of 1-hour accumulated precipitation is displayed.).

A panel and an animation of meteorological variables forecasted in real-time can be viewed easily at any time on a PC within an intranet. Meteorological variables including winds, humidity, temperature, pressure, and precipitation are displayed by a web browser. It takes about 6 hours to finish 36-hour forecasting in the case where a domain spans 500 km × 500 km in east-west and north-south directions.



(a) Truth (b) No-assimilation (c) Assimilation

Fig.2 Impact of radar data assimilation on precipitation forecasting.

Two WRF model runs are performed with different initial and boundary conditions. Then, the truth of the atmosphere is assumed to be computed perfectly by one of the runs (panel (a)). On the other hand, the other run (the control run) is assumed to have forecast errors (panel (b)). Doppler radar observations are simulated based on the truth run for 25 U.S. WSR-88D radar sites, and they are assimilated to modify the atmospheric state computed by the control run. A result of WRF model run with the modified state (panel (c)) indicates that radar data assimilation improves significantly forecasting of severe storms (circled).