Applications of WRF Data Assimilation System at the NCAR Data Assimilation Testbed Center

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1. Introduction

Data assimilation is a core component of any earth system model, and has provided many of the major advances in Numerical Weather Prediction (NWP) in recent years. The advent of advanced, internationally coordinated observing systems (e.g., the National Polar-Orbiting Operational Environmental Satellite System, NPOESS) and new observation types (e.g., hyperspectral sounders, GPS radio occultation, dual polarization Doppler radar) means that this trend is likely to continue for the foreseeable future. In addition, the development of advanced data assimilation techniques such as four-dimensional variational data assimilation (4D-Var) and the Ensemble Kalman Filter (EnKF) continue to provide a great opportunity for the research community and may eventually be leveraged by operational centers to enhance their data assimilation systems.

To leverage the efforts of the research community and operational centers is a major motivation for establishing a data assimilation testbed. To enable this capability, the Data Assimilation Testbed Center (DATC) has been created as a joint collaboration between NCAR's Mesoscale and Microscale Meteorology (MMM) Division and Research Application Laboratories (RAL) since August, 2006. The DATC is located within RAL's Joint Numerical Testbed (JNT) and works closely with MMM and the Joint Center for Satellite Data Assimilation (JCSDA) to accelerate testing and evaluation of the latest development of data assimilation components.

Initially, the DATC was solely supported by the Air Force Weather Agency (AFWA). Within one year, the DATC successfully expanded to a number of testbeds supported by various domestic and international agencies, including AFWA, the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), the Korean Meteorological Administration (KMA), and the Taiwanese Civil Aeronautics Administration (CAA).

This paper provides a summary of the on-going work at the DATC to test WRF-ARW and the WRF Data Assimilation System (WRF-DA) and a preview of future plans as well.

2. Testbed Strategy

The DATC has built a framework in which extended testing can be conducted. The strategy to ensure testing is performed thoroughly includes the following three-step procedure:

- Define reference configuration related to model, namelists, testing period, testing suite scripts and verification package.
- Run "benchmark" defined by above reference configuration.
- Perform "sensitivity" tests by varying components of the reference configuration (typically only namelists are modified).

For current WRFDA testing, an end-to-end model system available at the DATC includes: the WRF Preprocessing System (WPS); WRF-ARW: WRF-DA (3D-Var, 4D-Var, EnKF and Hybrids); and the WRF-DA verification package. The whole system was run in either cold-start mode (using an independent analysis/forecast product as the first-guess for WRF-DA) or cycling mode (using a previous forecast as the first-guess) for an extended period of time so that the capability and stability of the whole system and the varying components of the system can be examined closely.

3. Status and Some Results

Currently, the DATC has various project testbeds active in varying domains. Extended tests of the end-to-end system have been conducted in these domains to assess the impact of different observation types (e.g., radar, radio-occultation refractivity, radiance, etc) and different system configurations (e.g. model top, resolution, cycling, etc) on short-range forecasts. Some results are briefly described in this paper. More details can be found from separate talks and posters.

The Antarctic Mesoscale Prediction System (AMPS) is a real-time forecast system supported by NSF-Office of Polar Programs (OPP). The purpose of the AMPS Testbed is to test the impacts of DA cycling, model configuration and new satellite types in its 60km domain. The testing period was October, 2006.

Figure 1 shows the impact of the model top configuration by comparing the 36-hour U, V, T and Q forecasts with the radiosonde observations from the experiments with the model top at either 50mb (red curve) or 10mb (green curve). Impressively, moving the model top to 10mb (WGPS_10mb) results in a remarkable reduction of the bias (not shown) and RMSE of all forecast fields throughout the vertical range.

Figure 2 shows the bias profiles from a month of 36-hour forecasts from the experiments with (WGPS_10mb) and without (NOGPS_10mb) Global GPS radio-occultation refractivity assimilation, with respect to all radiosonde observations in the domain. The assimilation of GPS data generally reduces the biases of U, V and T and reduces their RMSEs at least up to 70mb. The forecast impact on Q is quite marginal.

The AFWA Testbed has varying domains from its domain theaters. The main purpose of the testbed is to ensure the AFWA forecast and data assimilation system thoroughly tested. Figure 3 shows the results from the impact of AMSU radiances in its east-Asian domain. Verified by various observation types, the direct radiance assimilation shows positive impact on the short-term forecast at least beyond 24 hours.

The Korean Meteorological Administration (KMA) testbed has two embedded domains: 10km and 3.3km. The testing period is July-August, 2007 Changma season. The impacts of radar data assimilation and the model resolution on forecasts were examined. Figure 4 shows the cycling of the forecast and DA system reduces the biases of the 24-hour U, V and T forecasts at most of vertical levels. Figure 5 shows that the radar radial velocity data assimilation is able to reduce biases of temperature and moisture forecasts in the lower troposphere.

By working closely with MMM and the WRF Developmental Testbed Center (DTC), the DATC has hosted international visitors performing various testing tasks. The current visitors include one from the India Meteorology Department (IMD) and one from the Indian Institute of Technology (IIT). They are working to leverage the gap between two DA systems (WRF-DA and GSI) on the WRF model with two physics cores (WRF-ARW and WRF-NMM).

4. Plans for the coming year

In the coming year, the DATC will keep working on the existing testbeds and begin building new testbeds as required. We will test the impact of various capabilities through extended period testing. The DATC will also deliver testing reports to operational agencies and centers. These reports will include an impact assessment in terms of a) scientific verification and validation, b) computational performance, and c) potential technical changes required to implement upgrades.

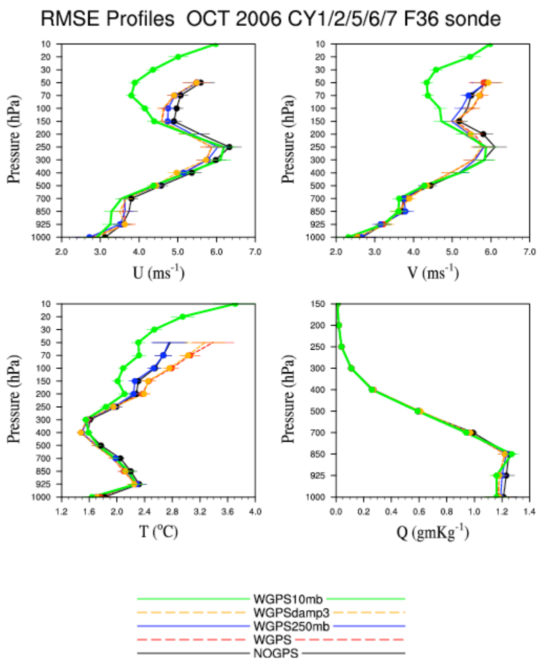

Fig. 1 Vertical profiles of the RMSE of the 36 hour U, V, T and Q forecasts from NOGPS (black), WGPS (red), WGPS_250mb (blue), WGPS_damp3 (orange) and WGPS_10mb (green) during the testing time period, with respect to radiosonde observations within the AMPS domain. Units: m/s

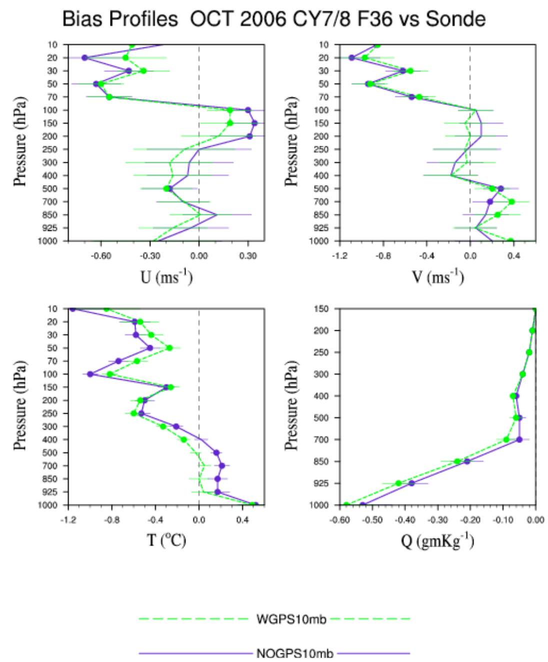

Fig. 2 Same as Fig. 1, except for the bias of 36 hour forecasts from NOGPS_10mb and WGPS_10mb.

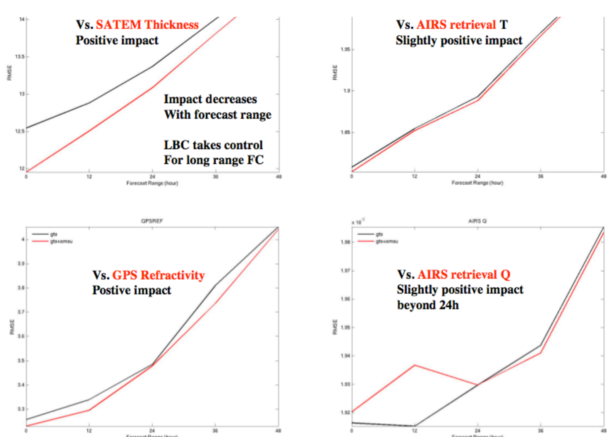

Fig. 3 The RMSE of the varying forecasts verified against unassimilated observations listed in the plot for the AFWA east-Asian domain.

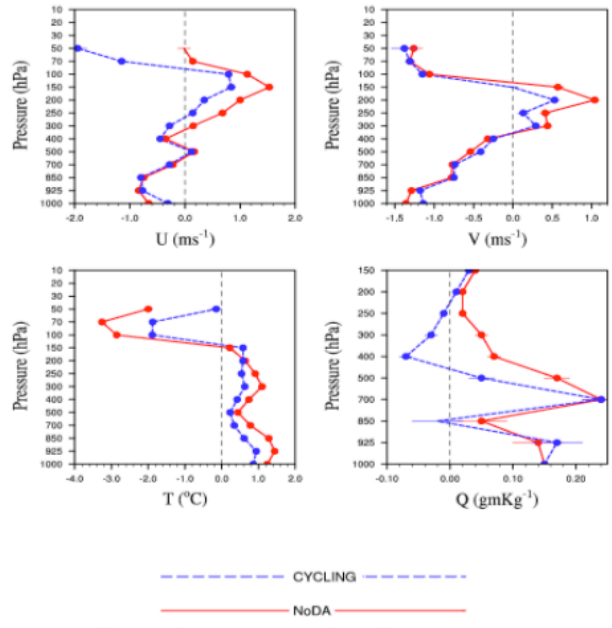

Fig. 4 Vertical profiles of the bias of the 24 hour U, V, T and Q forecasts from NODA (red) and CYCLING (blue) during the testing time period, with respect to radiosonde observations within the KMA domain. Units: m/s for U and V, K for T and g/kg for Q.

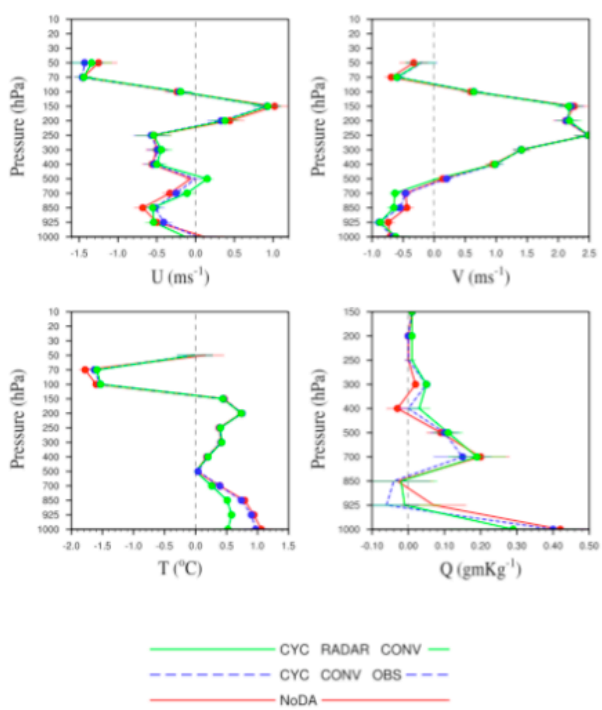

Fig. 5 Same as Fig.4, except for the biases for the NODA (red), CYCLING (blue) and CYCLING_RADAR (green) experiments.