REAL-TIME RADAR RADIAL VELOCITY ASSIMILATION EXPERIMENTS IN A PRE-OPERATIONAL FRAMEWORK IN NORTH CHINA

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ABSTRACT

The paper presents the results of real-time Doppler radar radial velocity assimilation experiments during the summer season of 2011 in a pre-operational framework based on WRF/WRFDA in North China. For this purpose, the radar network, data pre-processing and assimilation strategy of radial velocity are briefly introduced. From the 3-month results, no significant improvements can indeed be found against conventional observations because of the localized impact of radial velocities in space and time. But more positive signals are found from precipitation forecast skills, especially for short-term forecasts and larger thresholds.

1 INTRODUCTION

A forecast system based on WRF and WRFDA (BJRUCv2.0) is currently developing in Beijing Meteorological Bureau of China with the purpose to improve local and regional short-term meteorological forecasts for potentially dangerous weather events in North China. And assimilation of radial velocities from Doppler radar network is also a significant new feature.

In recent years, research efforts have been carried out to develop the radar data pre-processing system and assimilating strategy for the purpose of future operational implementation. And real-time radial velocity assimilation experiments have been performed in the summer of 2011.

2 THE RADAR DATA IN PRE-OPERATIONAL FRAMEWORK

There are 4 S-band and 2 C-band Doppler radars, comprising the operation radar network in North China. A radar data preprocessing system was built on the base of the counterpart of VDRAS with the functions to perform quality control, mapping and error statistics.

3 RADIAL VELOCITY ASSIMILATION IN BJRUC

3.1 ASSIMILATION STRATEGY OF RADIAL VELOCITY IN PRE-OPERATIONAL FRAMEWORK OF BJRUC

The observation operator for Doppler radial velocity in WRF 3DVAR was described in Xiao el al. (2005). But indeed, widely distributed analysis increment and degraded forecast performance were brought when radial velocities assimilated without any tuning on BE statistics or observation error. One reason is supposed that via the climatologically averaged correlations among control variables in BE of 3DVAR of BJ-RUC, the observed information spreads to a large area, which may be statistically reasonable for the observations representative for synoptic scales, such as radiosondes. But for Doppler radar observations capable of observing meso-scale and micro-scale weather system with high temporal and horizontal resolution, the current BE correlation length scales would not be so suitable.

To reduce the influence of observational innovation of radial velocity to a reasonable extent while the comparable analysis increment was still kept, a series of single observation tests has been performed with different empirical multiplicative tuning factors applied to the variance and length scales calculated via the NMC method (Barker et al. 2004). The 3DVAR analysis increment response at 700hPa to a single point of radial velocity with $1ms^{-1}$ innovation with two combinations of tuning factors for all covariance and length scales reveals that, when all of the tuning factors are set to 0.5, the magnitudes of analysis increment for u, v, t, q are comparable to the un-tuned value, while the influence area of the response are greatly reduced to an ideal value we expected for a local observation (figures not shown). As emphasized in Barker et al. (2004), although the dependence on the background state does introduce some case-dependence and using more than one observation will also help to define the results, the structures produced by BE are climatologically averages and do not specifically represent the forecast errors associated with a particular case. From this point of view, var_scalings=0.5 and length_scalings=0.5 can be regarded as reasonable combinations applied to all control variables in BE special for radial velocity assimilation.

Thereafter, we designed a two-step scheme to assimilate radial velocity along with other conventional observations, described as follows:

Step i: assimilate conventional observations including sounding, synop, ship, buoy, metar, amdar, etc., utilizing 3 times out-loop of minimization in WRF3DVAR with the regular variance and length scales (=1)of BE.

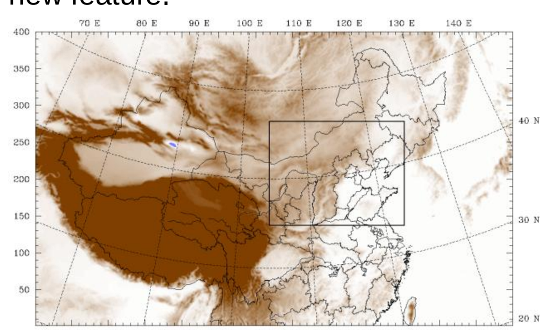
Step ii: if radial velocity observations can be searched in the assimilation time window (1.5hr), they'll be assimilated against the analysis generated after step 1 as the 1-st guess with the rescaling variance and length scales (= 0.5). In this step, radial velocity is the only type of data to be assimilated.

For a group of 7 convection cases occurring in the summer of 2009, 5 of them were squall line cases and 2 were local forced convections, the above assimilation strategy of Doppler radial velocity does lead to better short-term precipitation forecasts and in this case, the strategy will be utilized into real-time assimilation experiments during the summer of 2011 (Figs not shown).

4 REAL-TIME ASSIMILATION EXPERIMENTS

4.1 THE BJRUC PRE-OPERATIONAL FRAMEWORK

Recently the updated version of the rapid updated cycling forecast system in BMB, BJ-RUC (Chen et al. 2009) is under construction with larger forecasted domains (Fig.1). More complicated physics package and improved ability of data assimilation will be incorporated in the new system. Assimilation of radial velocity is an important new feature.



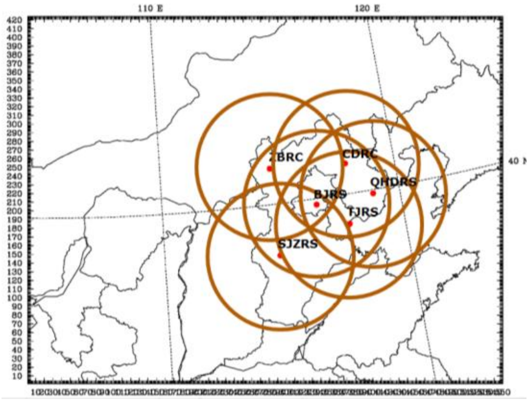


Fig 1 The model domains and radar station locations.

The forecast and data assimilation components of the pre-operational BJ-RUC system are based on WRF and WRFVARv3.3. Data assimilation and forecast run independently in the two forecasted domains with resolution of 9km and 3km, respectively. Every day, Domain1 performs two forecasts of 72h at 0000 and 1200 UTC, starting from GFS analysis as initial conditions. The forecast results will be provided to users for short-range forecast references, and will be used to generate lateral boundary conditions for Domain2 with 1-hr interval.

Domain2 runs in a so-called rapid updated cycling style, i.e. its cold-start run initiates every day at 00UTC with the global forecasts from the AVN as the background of data assimilation, while at 03/06/09/12/15/18/21UTC, the cycles will run as 'hot-start' with the assimilation backgrounds from the 3-hr forecast of the previous cycles. Its lateral boundary conditions are generated from the 72-hr forecasts with 1-hr interval of the 9-km domain using NDOWN technique. The forecast length is 24hrs.

Model physics configuration is as follows: WSM6 microphysics parameterization; the K-F cumulus parameterization of MM5 version for 27-9 domains and no cumulus for the 3-km domain; YSU PBL parameterization; RRTM long wave radiation scheme and Dudhia short wave radiation scheme (Skamarock et al. 2008) .

The data sources utilized by WRFDA for Domain2 include the conventional and intensive surface and upper-air radiosonde reports, aviation routine weather report, ship, buoy via the Global Telecommunication System (GTS). Also used are high-frequency measurements from various special networks such as the AWS and GPS/IPW maintained by BMB. The background error statistics (BES) files for each nested domain were derived based on the NMC method independently.

4.2 EXPERIMENTS DESIGN

The pre-operational experiments of BJRUCv2.0 with assimilation of radial velocity are performed during the summer season from 1 June to 31 August, 2011. In order to clearly identify the impact of radial velocity, another Domain2 experiments sharing the identical configurations with BJRUCv2.0 but without assimilation of radial velocity is also setup and runs simultaneously along with BJRUCv2.0 during the period. In this research, we name the two experiments as '3km-radar' and '3km-noradar' respectively. The forecast length of 3km-noradar is only 12hrs.

4.3 DATA MONITORING DIAGNOSTICS

Monitoring on quality of the data entering the DA system is also an important part for an operational assimilation framework.

Statistics are performed with the archived minimization results for each run during the pre-operational experimental period to further check the quality of assimilation for radial velocity, i.e. only the results from STEP ii are considered.

As shown in Fig. 2, the numbers of valid radial velocity observations available for data assimilation vary greatly from several to more than fifty thousand by run to run. One reason of the variation is due to the data loss caused by instrumental or communicating errors of radar and mostly, is due to the change of weather condition. Obviously, for the runs with much more data available for assimilation, the percentages of the data actually ingested by WRFDA are much lower. For example, there're totally 32,080 radial velocity observations available at 15UTC, Aug 23 and only 59.8% of them are assimilated. But for the run at 03UTC of the same day, 95.97% of the 18669 observations are assimilated. It's easy to understand that much more radial velocity data can be acquired when convections are approaching or occurring than clear skies.

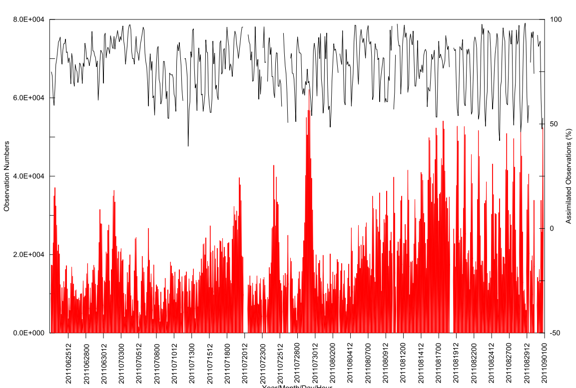


Fig 2 Time series of numbers of radial velocity observations (red bar) and the percentage of assimilated observations (black line) by WRFDA.

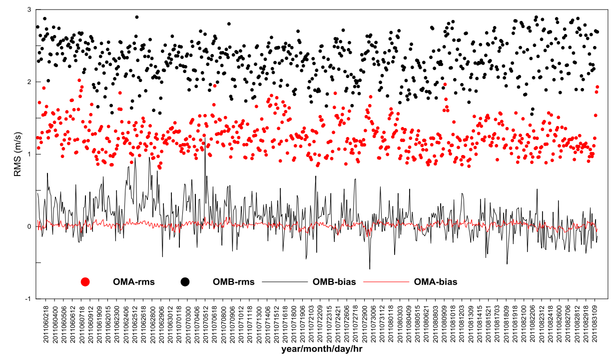


Fig 3 Time series of OMA and OMB statistics.

According to the data screening scheme in WRFDA, the observations with innovation vectors larger than five times of its observation error will be discarded. As the observation error of radial velocity assigned by the radar pre-processing system is mostly around $1ms^{-1}$, no innovations more than ±5 ms^{-1} will be introduced into the model system for each radial velocity observation. Actually, after minimization, most of the RMSEs of final analysis against observation (OMA) are reduced to nearly one-half of OMB, the domain-averaged innovation values mostly between 2-3 ms^{-1}, which is reasonable and means that the assimilation process does work properly (Fig. 3).

4.4 FORECAST SCORES

In this section, the evaluations for cycling forecasts for both experiments are detailed. Excluding the missing forecasts due to hardware failure and script errors on June 10-18, there are totally 636 cycling samples involved in the assessment for each experiment. The evaluations are performed against conventional surface and radiosonde observations. 1-hr precipitation forecasts are verified point-to-point against the 1-hr accumulated rainfall observed by the AWS network and also against the gridded quantitative precipitation estimations from radar mosaic results.

VERIFICATION AGAINST CONVENTIONAL OBSERVATIONS

The domain-averaged forecast verification scores calculated against surface observations are shown in Fig. 4. Evidently, no significant impact for 2-m temperature is introduced by the assimilation of radial velocity. But the scores for 10-m wind are slightly degraded during the first 0-6hr integration.

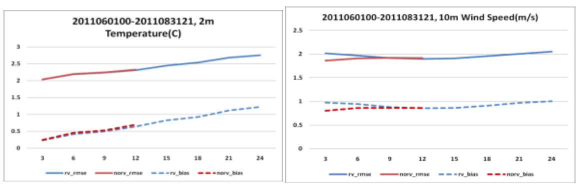


Fig 4 Surface verification results

The vertical profiles of average BIAS and RMS error against sounding observations for all the available cycling runs during the experiments period are display in Fig 5. For temperature and specific humidity, the qualities of analysis and forecast of 3km-radar are almost the same as 3km-noradar. But using observations of wind as reference, the discrepancies between the profiles of 3km-radar and 3km-noradar seem to be a little remarkable at the initial time. Considering the 2-step assimilation, conventional surface and sounding data are assimilated first and radial velocity will be assimilated thereafter, the final analysis will not be optimized simultaneously for both data types of sounding and radial velocity via variational assimilation, i.e., the final analysis will be pushed away from soundings after performing radial velocity assimilation. Take the whole range of 12-h forecasts into consideration, the prediction performance of 3km-radar with radial velocity assimilated is at least as good as that of 3km-noradar.

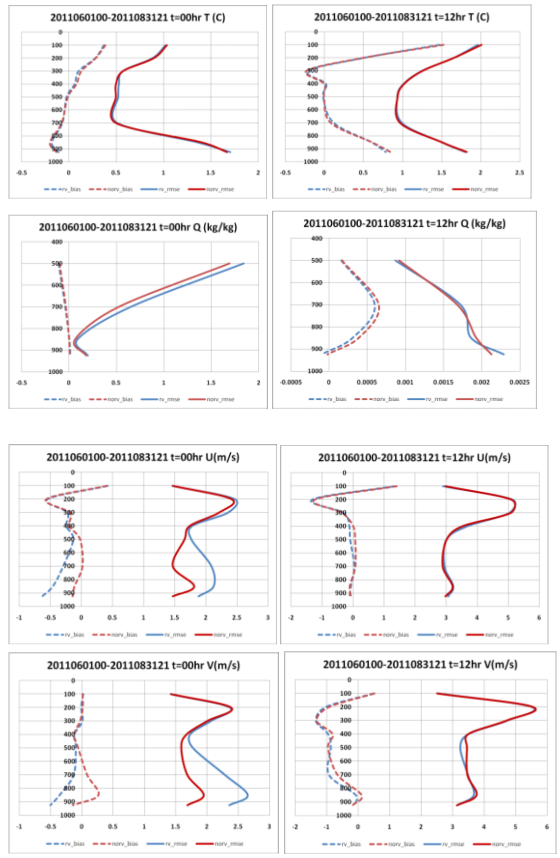
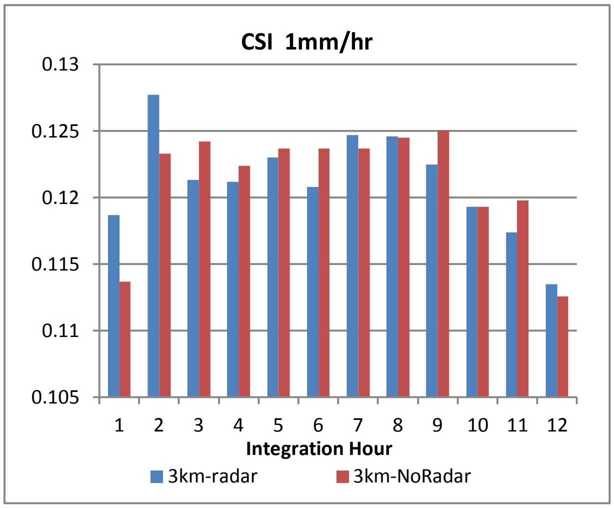


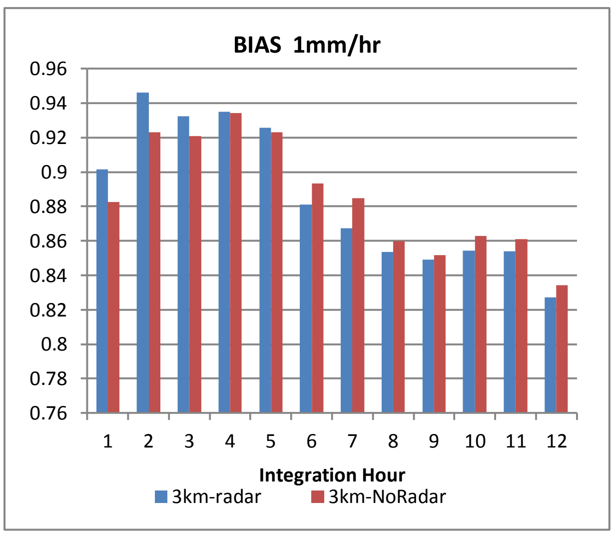
Fig 5 Verification scores against sounding observations for runs initiating from 2011060100-2011083121 for t=0hr (left column) and t=12hr (right column).

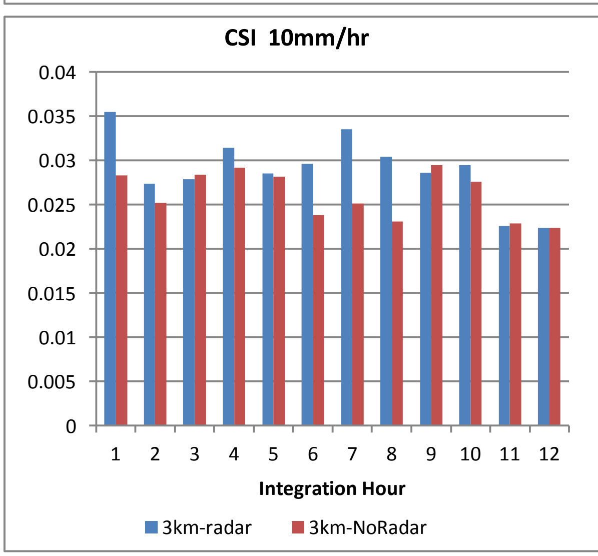
PRECIPITATION VERIFICATION

CSI and BIAS scores are calculated against the intensive 1-hr AWS rain-gauge observations with quality control. Fig 6 shows the results of the thresholds of 1.0mm/hr and 10.0mm/hr, respectively.

For smaller thresholds such as 1mm/hr, the improved precipitation forecast skills with larger CSI scores and slightly modifications of under-prediction occur at the beginning stage of forecast. But for larger thresholds (10mm/hr), the precipitation forecast skills are generally improved with larger CSI and less over-prediction. More detailed case studies will be performed in the future.







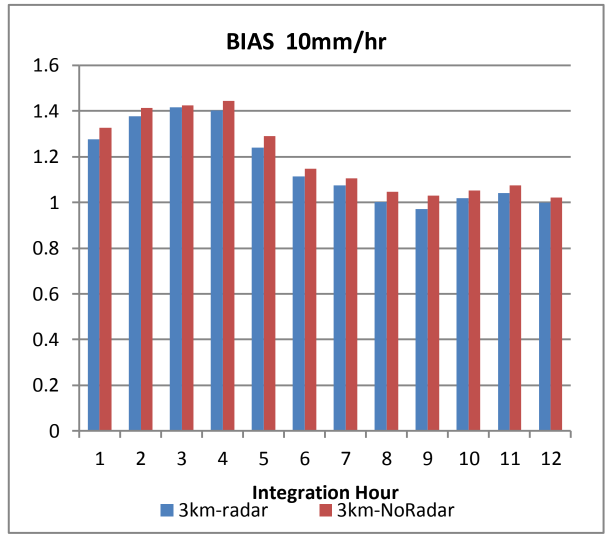


Fig 6 CSI and BIAS scores of 1-hr accumulated precipitation against the nation-wide 1-hr AWS rainfall observations for runs initiating from 2011060100-2011083121 for thresholds of 5mm/hr and 10mm/hr.

5 CONCLUSIONS

In this paper, preliminary results of real-time Doppler radar radial velocity assimilation experiments during the summer season of 2011 in a pre-operational framework based on WRF/WRFDA in North China is presented, along with the brief introduction of the radar network, data pre-processing and assimilation strategy. From the 3-month results, no significant improvements can indeed be found against conventional observations because of the localized impact of radial velocities in space and time. But more positive signals are found from precipitation forecast skills, especially for short-term forecasts and larger thresholds.

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