# Radar Data Quality Control and Assimilation at the National Weather Radar Testbed (NWRT)

Dr. Qin Xu
CIMMS, University of Oklahoma,
100 E. Boyd (Rm 1110), Norman, OK 73019
phone: (405) 325-3041 fax: (405) 325-7614 email: qxu@gcn.ou.edu

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## LONG-TERM GOALS

Study and develop advanced approaches for radar data quality control (QC) and assimilation that will not only optimally use Doppler wind information from WSR-88D and Terminal Doppler Weather Radar (TDWR) but also take full advantage of rapid and flexible agile-beam scans from the phased array radar at NWRT.

## OBJECTIVES

Develop new variational methods to improve the existing radar wind analysis system so it can be applied to any radar scans to produce real-time vector wind displays and monitor data quality. Study radar data quality problems and develop statistically reliable quality control (QC) techniques. Explore new data assimilation techniques to optimally use the phased array scan capabilities.

## APPROACH

Extract main features exhibited in each type of data quality problems, and find proper QC parameters to quantify the extracted features. Monitor and record various QC parameters and related background information (by running the above real-time system). Collect independent observations from multiple sources (Dual-Polarization radar, radiosondes, wind profilers and satellites) for "ground truth" verifications of quality problems identified by QC parameters. Use the recorded QC parameter time series and "ground truth" verifications to develop statistically reliable data QC techniques.

Develop integrated approaches in radar data quality control, error covariance estimation and radar data assimilation. Upgrade the existing 3.5-dimensional variational (3.5dVar) radar data assimilation technique with improved error covariances, and explore possible combinations with the ensemble Kalman filter technique to optimally use radar high-resolution observations and phased array scan capabilities.

The PI, Dr. Qin Xu, is responsible to derive basic formalisms and technical guidelines for the implementations. The data collections and QC algorithm developments are performed by project-supported research scientists at CIMMS, the University of Oklahoma. Collaborations between this project and the development of the NWRT phased array radar is coordinated by Douglas Forsyth, Chief of NSSL's Radar Research and Development Division. Dr. Alan Q. Zhao at NRL Monterey and

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14. ABSTRACT
**Study and develop advanced approaches for radar data quality control (QC) and assimilation that will not only optimally use Doppler wind information from WSR-88D and Terminal Doppler Weather Radar (TDWR) but also take full advantage of rapid and flexible agile-beam scans from the phased array radar at NWRT.**

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Dr. David Parrish at NOAA/NCEP (and their colleagues) perform pre-operational tests as the radar data QC algorithms and assimilation packages are developed and delivered.

## WORK COMPLETED

The radar wind analysis system (Liu et al. 2003) was further automated and used to monitor radar data quality problems and collect related information for ground truth verifications. To study data quality problems caused by migrating birds and sea clutters, additional level II data were collected during the 2004 and 2005 spring and fall seasons from the Oklahoma City KTLX radar and from the Boston KBOX radar on the east coast. Polarimetric radar observations from the NSSL KOUN radar, clear sky satellite nighttime IR images, and rawindsonde observations were collected to discriminate bird echoes from meteorological scatterers and thus to obtain the ground truth information on migrating-bird contamination for these seasons. The related statistics were accumulated and added to the data base for the proposed QC studies.

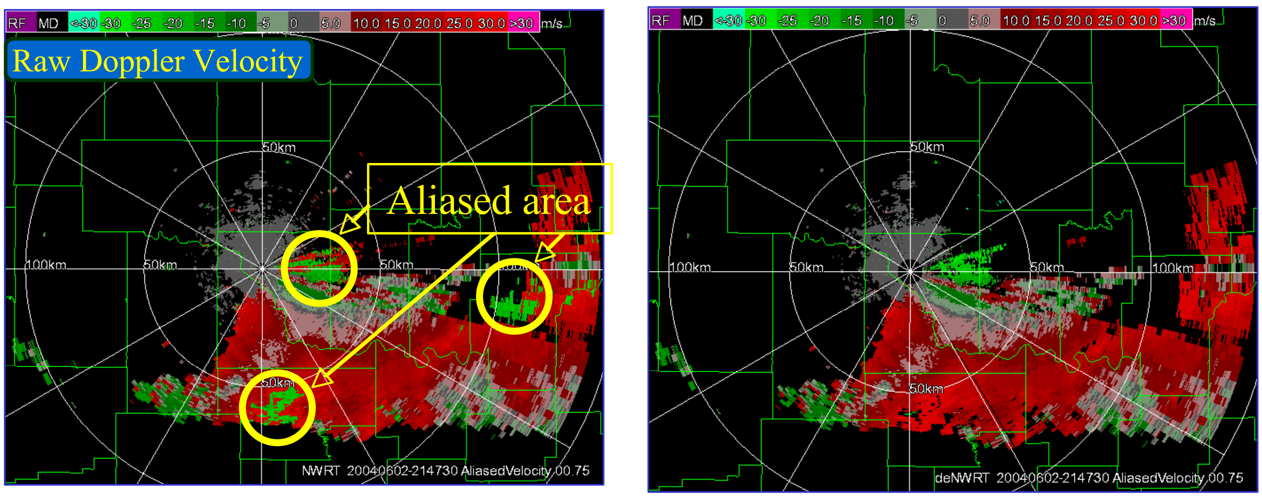
The version-1 radar data QC package was completed and delivered to NRL Monterey. To facilitate the application of this package to Navy's radar data ingestion system, unclassified samples of Navy radar data were obtained from NRL Monterey and then a converter was coded to read the Navy radar data. With this converter, the delivered QC package (written in Fortran 90) can be adapted to Navy's radar data ingestion system (coded in Fortran 77 without mix-compiling). The converter was delivered to NRL Monterey and then implanted there. Unclassified Navy radar data obtained from NRL Monterey were also converted into NetCDF format for interactive display and detailed data quality check by using WDSS II (Warning Decision Support System-Integrated Information) at NSSL. The QC package was then further improved for Navy's radar data QC.

Numerical experiments were conducted to assimilate phased array radar data and to improve numerical analyses and predictions of severe storms. Through these experiments, the 3.5dVar radar data assimilation package was upgraded. Efforts were also made to develop integrated approaches in three important aspects: (i) Phased array radar data QC to meet the high-quality standard required by data assimilation; (ii) Estimation of phased array radar velocity observation error and background wind error covariances; (iii) Using the estimated error covariances to optimize phased array radar data assimilation.

## RESULTS

By using the Bayesian statistical decision theory, a probabilistic QC technique was developed to identify and flag migrating-bird contaminated sweeps of level II velocity scans at the lowest elevation angle using three identified QC parameters.  The QC technique can use either each single QC parameter or all the three in combination. While the single-parameter QC technique is useful for evaluating the effectiveness of each QC parameter, the multi-parameter QC technique is much better than any of the three single-parameter QC techniques (as verified by using independent ground truth information). When the multi-parameter QC technique is used for real applications (with no ground truth information), the probabilities of wrong decision can be also estimated quite reliably (as indicated by the tested percentages of wrong decision). The detailed techniques were presented in two recent publications (Zhang et al. 2005a; Liu et al. 2005b).

The three-step radar velocity dealiasing technique (Gong et al. 2003) was simplified and integrated into the 3.5-dimensional variational (3.5dVar) radar data assimilation package. The simplified dealiasing performs only two steps: reference check and continuity check. This first step uses reference velocities from the predictions of the Navy's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS, Hodur 1997). This step is computationally more efficient than the reference check in the three-step dealiasing that uses reference velocities computed by the modified VAD and classical VAD methods from the same radar data. The two-step dealiasing is found to be effective for phased array radar velocity data QC (as shown Fig. 1) and better than the operationally used technique for conventional Doppler radar velocity data QC.




(a) (b)

***Fig. 1. Phased array radar observed radial velocity (a) and dealieased radial velocity (b) at 21:47 UTC on 2 June 2004. The aliased velocity areas are highlighted by yellow circles in (a).***

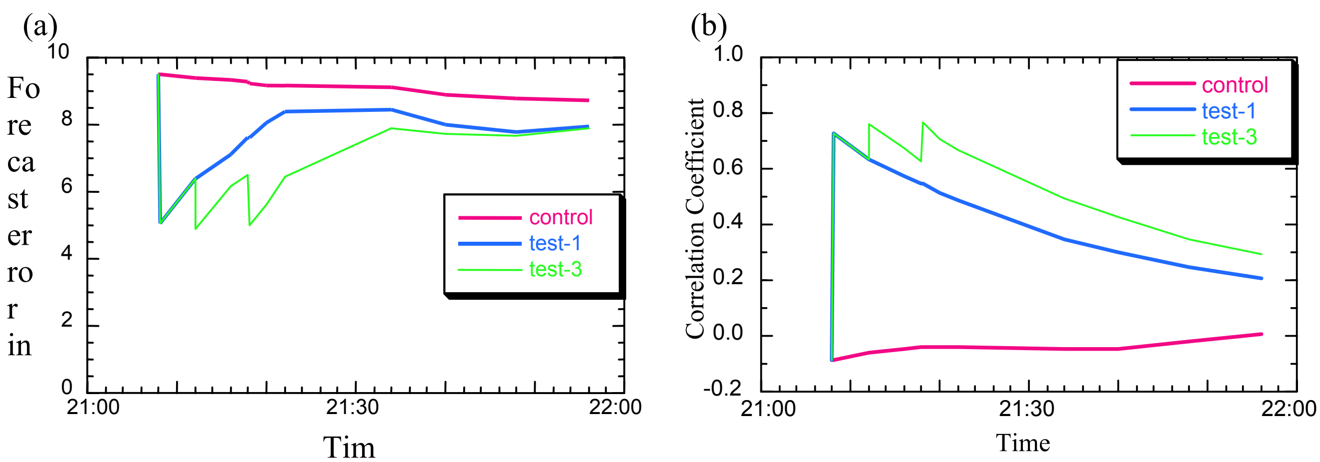



***Fig. 2. (a) RMS differences between the model-produced (analyzed or predicted) and observed radial-velocity fields. (b) Spatial correlation coefficients between the model-produced and observed reflectivity fields. The red curves are for the COAMPS control run without using radar data. The blue curves are for the test-1 run with three phased array radar volume scans assimilated through one cycle from 2108 to 2112 UTC. The green curves are for the test-3 run with nine phased array radar volume scans assimilated through three cycles from 2108 to 2120 UTC on 2 June 2004.***

With the fast phased array radar scans, radial-velocity innovation (observation minus forecast background) data can be accumulated rapidly and used nearly real time to estimate the radar radial-velocity observation error and background wind error covariances. To take this advantage, the innovation method was reformulated to estimate these error covariances and a proper data thinning strategy was designed to improve the computational efficiency. The 3.5dVar radar data assimilation package was upgraded to use the estimated error covariances. This led to an integrated approach in phased array radar data assimilation. This approach was applied to phased array radar data collected for a squall line on 2 June 2004 to improve COAMPS analyses and predictions. The results are highlighted in Fig. 2, and the details are presented in Xu et al. (2005b).

## IMPACT/APPLICATIONS

Fulfilling the proposed research objectives will improve our basic knowledge and skills in radar data QC and assimilation, especially concerning how to optimally use rapid-scan radar data to improve numerical analyses and predictions of severe storms and other hazardous weather (including chemical-biological warfare environmental conditions). New methods and computational algorithms developed in this project will be delivered to NRL Monterey for operational tests and applications, in connection with another ONR funded project entitled "Real-Time Meteorological Battlespace Characterization in Support of Sea Power 21" led by John Cook at NRL Monterey.

## TRANSITIONS

The version-1 radar data QC package was made available to NCEP for operational tests and applications. Based on the feedback from NCEP, the code was upgraded and delivered to NRL Monterey. A radar data converter was also coded to read the Navy's radar data. This converter was delivered to NRL Monterey to adapt the QC package to the Navy radar data ingestion system (Harasti et al. 2005). The upgraded 3.5dVar radar data assimilation package was delivered to NRL Monterey for nowcast applications and COAMPS radar data assimilation (Zhao et al. 2005a,b).

## RELATED PROJECTS

Radar Velocity Data Quality Controls (funded by NOAA/USWRP and NCEP to NSSL and OU).
Easy-to-Use Interface for Radar Data Quality Control and Error Estimation (funded by NOAA HPCC to NSSL and OU)

6.2 Shipboard Data Assimilation System/Doppler Radar (funded by ONR to NRL Monterey).
6.2 Data Assimilation for Mesoscale Prediction (base funding BE-435-009 to NRL Monterey).
Error Covariance Estimation and Representation for Mesoscale Data Assimilation (funded by ONR to OU).

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