10B.1 **NEXRAD PRODUCT IMPROVEMENT – UPDATE 2009**

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1. INTRODUCTION

The Departments of Commerce (National Weather Service), Defense (Air Force Weather Agency), and Transportation (Federal Aviation Administration) initiated the Next Generation Weather Radar (NEXRAD) program to upgrade the weather radar mission support capabilities required by the three agencies. Under NEXRAD, 158 radars, termed the Weather Surveillance Radar-1988 Doppler (WSR-88D), have been installed at operational locations in the United States and selected overseas sites. The NEXRAD tri-agencies established the NEXRAD Product Improvement (NPI) Program in 1996 as a long-term activity to steadily improve WSR-88D science and technology [1]. The NPI program has completed the replacement of the Radar Product Generation (ORPG) and the Radar Data Acquisition (ORDA) subsystems of the WSR-88D with open system hardware and software. These system upgrades enable the operational implementation of new scientific applications, and signal processing techniques to improve the radar data quality and spatial resolution. Currently, the NPI program has begun the implementation of dual polarization on the WSR-88D units.

The term NEXRAD has come to encompass all efforts to bring 'next generation' weather radar capabilities to operational use, and NPI is the programmatic vehicle to manage such efforts. WSR-88D improvements comprise only part of the potential projects under an ongoing NEXRAD concept. Under NPI, the NWS is also integrating the use of weather data from FAA radars, and has begun planning for greater use of Canadian weather radar data. The NOAA/NWS has formed a Joint Radar Planning Team (JRPT) to help define a 20-year vision for weather radar support to operations, and a 'road map' for logical steps to achieve that vision. The JRPT effort enables NOAA/NWS to better set priorities and plan funding for potential new capabilities such as long range surveillance Phased Array Radar systems and low power short wavelength radar systems to better sample the boundary layer and complex terrain areas. The NWS may utilize NPI to manage selected 'path finding' activities to explore the operational benefit potential of the future radar systems.

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This paper is one of a continuing series, and is intended to keep the IIPS community up to date on the status of NPI ongoing projects, plans for WSR-88D enhancements and NWS activities in the use and development of other weather radar systems.

2. CURRENT PROJECTS

2.1 Science Implementation

The NEXRAD agencies continue to develop and deploy new and enhanced scientific algorithms on the ORPG, and have extended this activity to the ORDA. A general, high level planning schedule of anticipated enhancements through CY 2012 is presented in Section 4.

2.2 Signal Processing

The ORDA project [2] consisted of the procurement of commercial components to replace the existing RDA Status and Control (RDASC) components, the Signal Processing components, and the analog receiver. The ORDA includes a modern digital signal processor (DSP) and a digital receiver. The ORDA deployment, completed in Oct 2006, enables improvements in data spatial and temporal resolution; clutter rejection; and range/velocity ambiguity mitigation. It also provides the foundation for the addition of dual polarization to the WSR-88D.

The first major signal processing enhancement to take advantage of ORDA was the implementation of a Sachidananda-Zrnic range/velocity ambiguity mitigation technique (termed SZ-2) for the lower elevation angles of the WSR-88D Volume Coverage Patterns in 2007. A Staggered Pulse Repetition Time technique for mitigating range/velocity ambiguities at higher elevation angles is currently being tested.

A major data spatial resolution improvement was deployed in 2008 (WSR-88D Build 10) for the lower, split-cut elevation angles. Termed Super Resolution (SR), this signal processing application improves base data resolution to ¼ km by ½ degree for all moments, compared to today's 1 km by 1 degree for reflectivity and ¼ km by 1 degree for Doppler. Included with the SR deployment was an extension of Doppler processing range to 300 km from today's 230 km. SR data provide a greatly improved depiction of rotation signatures, especially for weaker storms and storms at longer ranges. The higher resolution, and extended range, data have been included in the Level II central collection and distribution for most of the WSR-88D sites.

A major improvement in clutter rejection is in final testing, and is scheduled for deployment in spring 2009. The Clutter Mitigation Decision (CMD) technique uses spectral processing in the ORDA to identify range bins with clutter likely. Only these 'clutter likely' range bins are then processed with the ORDA Gaussian Model Adaptive Processing (GMAP) clutter rejection processing. The use of CMD to automatically and dynamically define where GMAP will be applied has several benefits.

- Changes in locations of clutter (AP included) will be identified and addressed continuously.
- Tendency for forecasters to over-prescribe areas for GMAP to be applied will be mitigated.
- Precipitation estimates and velocity dealiasing quality will be improved.

2.3 Dual Polarization

Based on the National Severe Storms Laboratory (NSSL) successful demonstration of the operational utility of dual polarization data from its WSR-88D [3, 6], the NEXRAD agencies have approved an acquisition program to deploy this capability to all WSR-88D units. L3 Titan, with radar engineering support from Baron Services, was selected in Sep 2007 as the main contractor to develop, produce and deploy the dual polarization upgrades. Deployment is anticipated for 2010-2012. Initial products to be available with dual polarization are listed in Section 4, below [9].

2.4 FAA Radar Data

The FAA operates four radar systems that include channels with capabilities for processing and distributing weather data. These systems are the Terminal Doppler Weather Radar (TDWR), the Airport Surveillance Radar, Models 9 and 11 (ASR-9, ASR-11), and the Air Route Surveillance Radar, Model 4 (ARSR-4). The NWS has been incorporating FAA data from selected FAA ASR-11 and ARSR-4 sites in a prototype mode for the past several years [4, 7], conducted limited operational deployment of TDWR ingest systems for 11 TDWR sites through 2007 [5, 8] and completed deployment to the rest of the 45 TDWR sites in 2008. The NWS developed a Supplemental Product Generator (SPG), based on the WSR-88D Radar Product Generator, to ingest TDWR data and prepare base and derived products in the same format as WSR-88D base products. The TDWR data have provided valuable, even critical in some cases, information for numerous tornadic events.

The SPG architecture has recently been modified to provide WSR-88D format, AWIPS compatible products for operational use of selected ASR-11 (Erie, PA) and ARSR-4 (Watford City, ND, & Makah, WA) radars [10]. Products from these FAA radars are also being provided as part of an upgrade, currently being tested, to the NWS national radar display Web site.

3. PREVIOUS OPERATIONAL ENHANCEMENTS

3.1 WSR-88D & FAA Data 2002-2008

- 256 data level products for reflectivity, velocity, Digital Storm Total Precipitation, Vertically Integrated Liquid Water and Echo Tops,
- User defined Composite Reflectivity layers,
- Quality-controlled velocity arrays for NCEP models,
- Update of Mesocyclone and Tornado Detection algorithm output every elevation cut,
- Enhanced Mesocyclone Detection algorithm,
- Improvements in automatic mitigation of AP to improve rainfall estimations,
- VCP 12, faster (4.1 min) and with more low level angles for better vertical resolution at long ranges,
- VCP 121, multiple scans with different PRFs at low level angles to mitigate range and velocity folding,
- Sachidananda-Zrnic (SZ-2) technique for the lower, split cut elevation scans to mitigate velocity folding and recover Doppler data from range folded areas
- FAA Machine Intelligent Gust Front Algorithm (MIGFA) for gust front and other boundaries detection.
- Snow Accumulation and Liquid Water Equivalents,
- Ingest of RUC model data from AWIPS into the RPG for the radar coverage volume.
- High speed distribution of radar products to surrounding WFOs to support warning operations,
- Filtering and smoothing of input reflectivity data to improve storm cell identification and tracking.
- Deployment of ORDA.
- Technology refresh of RPG workstations with PC-Linux systems to provide processing power for science implementations in 2007 and beyond.

3.2 FAA Data 2005-2008

- NWS data connections to all 45 FAA TDWR sites,
- Prototype use of FAA ASR-11 data in Erie, PA, and ARSR-4 data in Williston, ND, and Makah, WA. Test operations in these locations indicate good capability of the FAA units to detect general snow and Lake Effect Snow.
- Full spatial resolution products for TDWR base products.
- VAD Wind Profile, User Defined Composite Reflectivity Layer, Cell Tracking, Meso-cyclone detection, Tornadic Vortex detection, rainfall estimation, Vertically Integrated Liquid Water, Echo Tops products implemented for TDWR data.

4. PLANNED ENHANCEMENTS

4.1 WSR-88D & FAA Data 2009-2012

Together, ORPG, ORDA and DP will support the implementation of a number of enhancements that will provide better data and processing capacity for new scientific algorithms. Some enhancements have already been specified, and others are in development. Also, the TDWR data support the implementation of some of the WSR-88D algorithms. The enhancements include:

- Super Resolution algorithm products (DQA, Meso, TVS) (2010 - 2012).
- Super Resolution rainfall estimation (TBD).
- Improved dual polarization precipitation estimation (2010),
- Classification of hydrometeor types (2010),
    - Rain, hail (possibly size), snow
- Classification of non-hydrometeor reflectors (2010),
    - Insects, birds, clutter/AP
- Melting Layer (2010)
- Improved data quality for numerical models (2010),
- Provision of polarimetric base data, base products and derived products (2010),
    - Differential Reflectivity,
    - Correlation Coefficient,
    - Specific Differential Phase,
    - Polarimetric rainfall rate
- Clutter Mitigation Decision algorithm in ORDA to better determine where to apply GMAP clutter filter (2009),
- Staggered Pulse Repetition Time to mitigate range and velocity ambiguities in higher elevation angles (TBD)
    - Implemented in test mode to collect data
- Doppler processing of low angle surveillance cuts (TBD),
- Provision of spectral data for forecaster analysis, and eventual automated pattern recognition analyses (TBD),
- Oversampling and whitening to enable faster scanning and higher resolutions while maintaining accuracy (TBD),
- Provision of estimates of water vapor close to the radar via refractivity measurements (TBD),

5. SUMMARY

In summary, the NEXRAD infrastructure enhancements and dissemination of base data have combined to offer a heretofore unmatched environment for radar science development and operational implementation. The addition of dual polarization and data from FAA radars offers further opportunities. Developments such as PAR and boundary layer radars extend such promise well into the future.

On a cautionary note, however, it must be noted that NWS severe weather warning forecasters utilize scientific algorithm products to complement their analyses of base data products. The development community should not ignore the need to develop more efficient, effective ways to ensure a synergy between such human analysis and objective guidance.

6. REFERENCES

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