5.1 NEXRAD Product Improvement - Expanding Science Horizons

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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 have since established the NEXRAD Product Improvement (NPI) Program 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 subsystem with open system hardware and software (ORPG), and is in the process of a similar replacement of the Radar Data Acquisition subsystem (ORDA). These system upgrades will enable the operational implementation of new scientific applications, and signal processing techniques to improve the radar data quality. Further, the NPI program is currently working on the potential implementation of dual polarization, and on integration of weather data from several FAA radar systems. This paper describes the status of NPI ongoing projects and explores the expanding opportunities for development and implementation of new radar science and techniques intended for the WSR-88D.

2. DEVELOPMENT STATUS

2.1 *ORDA Status*

The ORDA project [2] consists 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 will include a modern digital signal processor (DSP) and a digital receiver. The ORDA is in the production development phase, and is scheduled to be deployed in 2004-2005.

2.2 *Dual Polarization Status*

The National Severe Storms Laboratory (NSSL) has developed a prototype dual polarization capability for the NSSL WSR-88D (KOUN). Polarimetry data have been collected from KOUN under a Joint Polarization Experiment (JPOLE) [3, 9]. JPOLE data are being analyzed to validate the KOUN implementation for its engineering design, data accuracy and potential operational issues.

A decision briefing will be presented to the NEXRAD Program Management Committee on Nov 19, 2003 that will recommend initiation of a WSR-88D Dual Polarization implementation program. If the Dual Polarization program is approved, deployment is anticipated in the 2007-2009 period.

2.3 *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 (ASR) 9 and 11, and the Air Route Surveillance Radar (ARSR) 4. The NWS has been incorporating FAA data from selected FAA sites in a prototype mode for the past several years [7, 8]. NWS decisions on going forward with more extensive programs to make FAA data part of baseline operations are scheduled for late 2003.

3. SCIENTIFIC OPPORTUNITIES

3.1 *Early ORPG Products*

New, or enhanced, products that have been implemented with ORPG include:

- High resolution reflectivity and velocity data arrays,
- High resolution Vertically Integrated Liquid water,
- User defined layers of maximum Composite Reflectivity,
- Quality-controlled velocity arrays for NCEP models,
- Update of Mesocyclone algorithm output every elevation cut, instead of only at end of volume,
- High resolution Echo Tops.

New , or enhanced, products and capabilities scheduled for deployment in the near future include:

- Enhanced Mesocyclone Detection,
- Update of Tornado algorithm output every elevation cut, instead only at end of volume,
- Use of automatic detection of clutter and 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 same low level angles to mitigate range and velocity folding,
- Snow Accumulation and Liquid Water Equivalents,
- Improved storm cell identification and tracking,
- Boundary detection and projection.

3.2 ***ORDA Enhancements***

When deployed, the ORDA will support the implementation of a number of enhancements that will provide better data for scientific algorithms. Some enhancements have already been specified, and will be developed for early releases after initial ORDA deployment. These early enhancements will include:

- Range - Velocity ambiguity mitigation,
- Clutter identification and mitigation techniques,
- Radial sampling at ½ degree intervals,
- Reflectivity data at 1/4 km range resolution,
- Doppler processing to end of 2^{nd} trip,
- Doppler processing of low angle surveillance cuts,
- Provision of spectral data for forecaster analysis, and eventual automated pattern recognition analyses,
- Oversampling in range to enable faster scanning and higher resolutions while maintaining accuracy.

A potential capability with ORDA is the use of refractivity index changes (refractivity) to estimate low level water vapor in clear air within 30 - 60 km of the radar. If validated for the WSR-88D, this technique could provide valuable additional information for model initialization and other pre-storm analyses of severe weather potential. The technique is in the initial evaluation stage.

The expanded base data will be available in the ORPG to be utilized to improve current algorithms, and to support improved science.

3.3 ***Dual Polarization Benefits***

Dual Polarization takes advantage of ways in which the transmitted wave's polarization affects the backscattering of hydrometeors. With a radar with polarization diversity, information related to both the horizontal and vertical dimensions of the observed scatterers can be derived. Polarimetry in the WSR-88D will:

- Improve quantitative precipitation estimation,
- Identify hail and possibly gauge hail size,
- Identify precipitation type in winter storms,
- Identify biological scatterers and wind measurement effects,
- Identify the presence of chaff and its effects on precipitation measurements,
- Identify areas of anomalous propagation (AP) and clutter, and
- Provide improved initial conditions to numerical models.

Several polarimetric data displays and derived products have been developed by NSSL and would be ready for initial deployment with a polarimetric upgrade to the WSR-88D. They include:

- Differential Reflectivity
- Correlation Coefficient
- Differential Phase
- Specific Differential Phase
- Rainfall Estimation
- Hydrometeor Classification

3.4 ***FAA Data***

FAA radar data will initially be used to generate base reflectivity and velocity image products similar to those produced for the WSR-88D. More sophisticated use of FAA data will involve multiple Doppler wind field analyses, merging the data with WSR-88D data to produce 'best' radar data mosaics, retrieval of vertical wind profiles, and more. The NWS and NSSL will also explore applying Mesocyclone, Tornadic Vortex Signature and other WSR-88D algorithms to FAA data, particularly TDWR data. The scientific algorithms needed for optimum use of FAA data remain to be developed, offering opportunities for innovative developers.

3.5 ***Software Development Tools***

The NWS and FAA are developing software tools to enable scattered development groups to not only collaborate more effectively, but also to enhance the compatibility of their applications with the operational WSR-88D. This project, termed CODE (Common Operations and Development Environment), is designed to provide an Application Programming Interface, underlying software modules, program layout and documentation support, and other tools that are compliant with the operational system [4, 5, 6]. Through the use of CODE, the integration of new science into operational systems has been eased, leading to a shorter time period between approval of an algorithm and its operational use. CODE is now the primary development tool for NWS and FAA programmers producing ORPG compliant implementations of new algorithms.

The NWS is working with UCAR/Unidata to offer CODE to the broader radar development community. The NWS has implemented an electronic collection and dissemination of base data in near real time, using the Internet and the Unidata Local Data Manager (LDM) software. The NOAA National Climatic Data Center (NCDC) is archiving these data, and supports online retrieval of subsets of the data. CODE includes the ability to incorporate base data retrieved from NCDC, or live data, with its LDM interface, from any of the LDM WSR-88D sites.

4. SUMMARY

In summary, the NEXRAD infrastructure enhancements, dissemination of base data, and development of radar application development tools have combined to offer a heretofore unmatched environment for radar science development and operational implementation.

5. REFERENCES

[1] NEXRAD Open Systems - Progress and Plans, Saffle, R., M. Istok, L. Johnson, 17th IIPS, Albuquerque, NM, January 2001, paper 3.1

[2] NEXRAD Product Improvement - Update of WSR-88D Open Radar Data Acquisition (ORDA) Program, Cate, G., R. Hall, M. Terry, 20th IIPS, Seattle, WA, January 2003, paper 5.2

[3] Joint Polarization Experiment (JPOLE) for the WSR-88D Radar: Plans and Progress, Schuur, T., R. Elvander, J. Simensky, R. Fulton, 18th IIPS, paper 5.15

[4] The WSR-88D Common Operations and Development Environment - Status and Future Plans, Ganger, T., M. Istok, S. Shema, B. Bumgarner, 18th IIPS, paper 5.7

[5] Developmental Utilities for the WSR-88D Common Operations and Development Environment, Stern, A., M. Istok, T. Ganger, S. Dobbs, 18th IIPS, paper 5.8

[6] Experiences using WSR-88D CODE as a Developmental Tool for Radar Algorithm Development, Istok, M., A. Stern, T. Ganger, D. Smalley, D. Seo, C. McAdie, 18th IIPS, paper 5.9

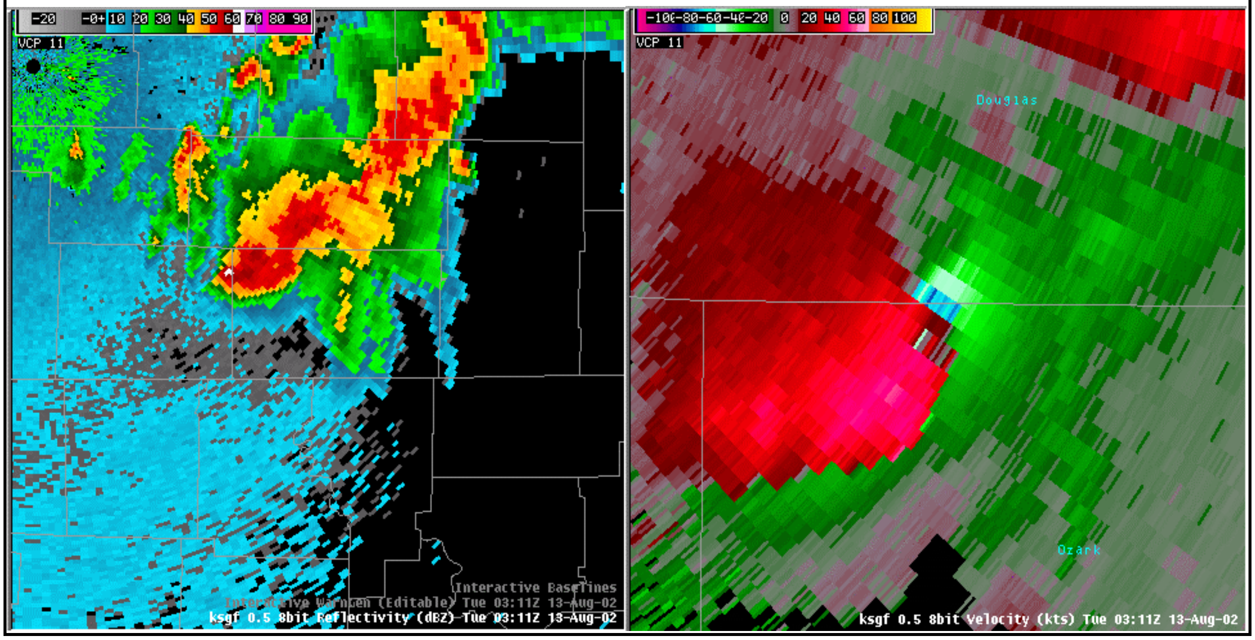
[7] Analysis and Plans for Using FAA Radar Weather Data in the WSR-88D ORPG, Stern, A., P. Pickard, W. Blanchard, B. Bumgarner, M. Istok, 18th IIPS, paper 5.6

[8] Implementing Terminal Doppler Weather Radar Data for WFO Operations, Stern, A., M. Istok, W. Blanchard, R. Saffle, B. Bumgarner, 20th IIPS, paper 12.8

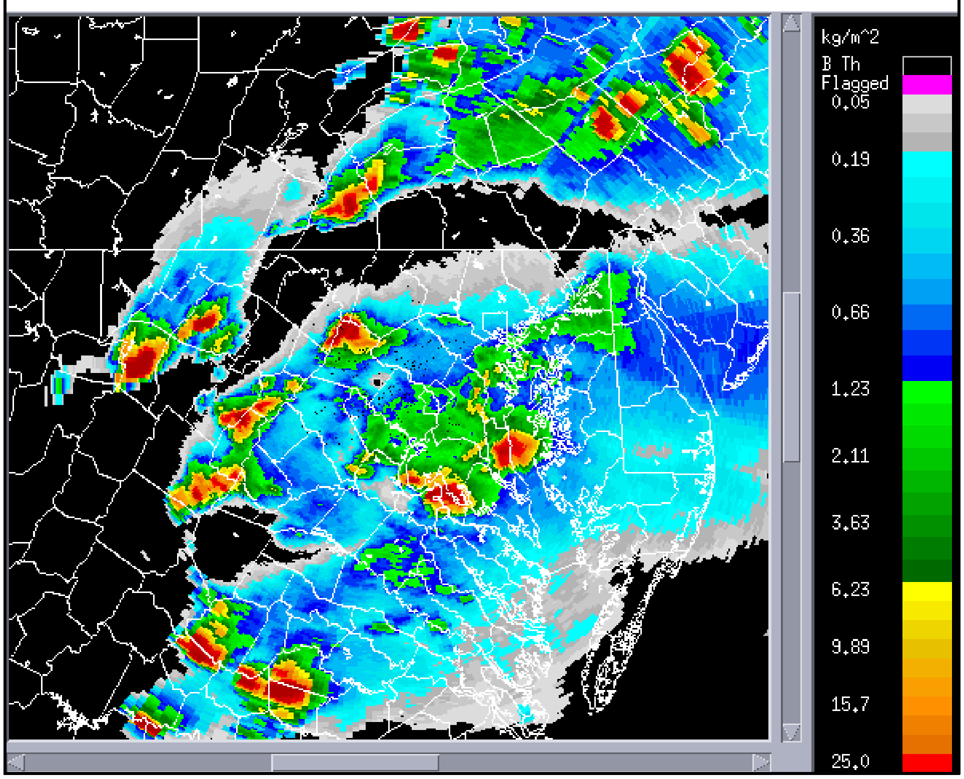
[9] The Joint Polarization Experiment – A Summary of Dual-Polarization WSR-88D Radar Data Collection and Analysis, T. Schuur, A. Ryzhkov, P. Heinselman, D. Burgess, K. Scharfenberg, 20th IIPS, paper 12.1

6. Product Examples

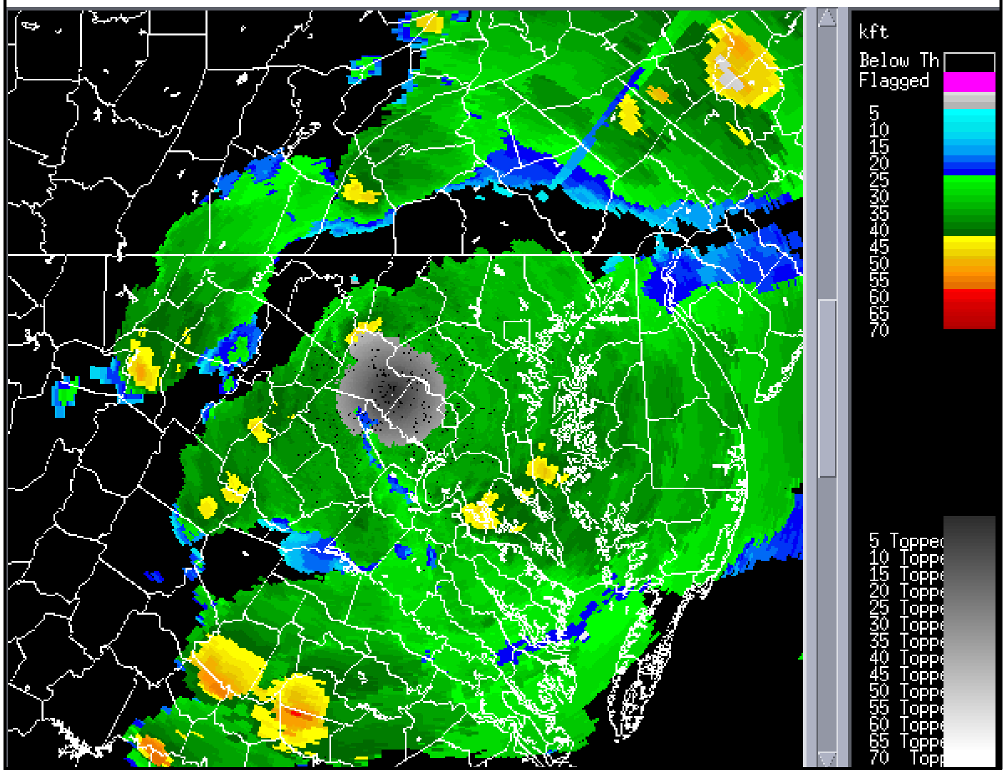
Full Resolution (8-bit) Reflectivity and Velocity Images
Wasola, MO, F2 Tornado, August 13, 2002



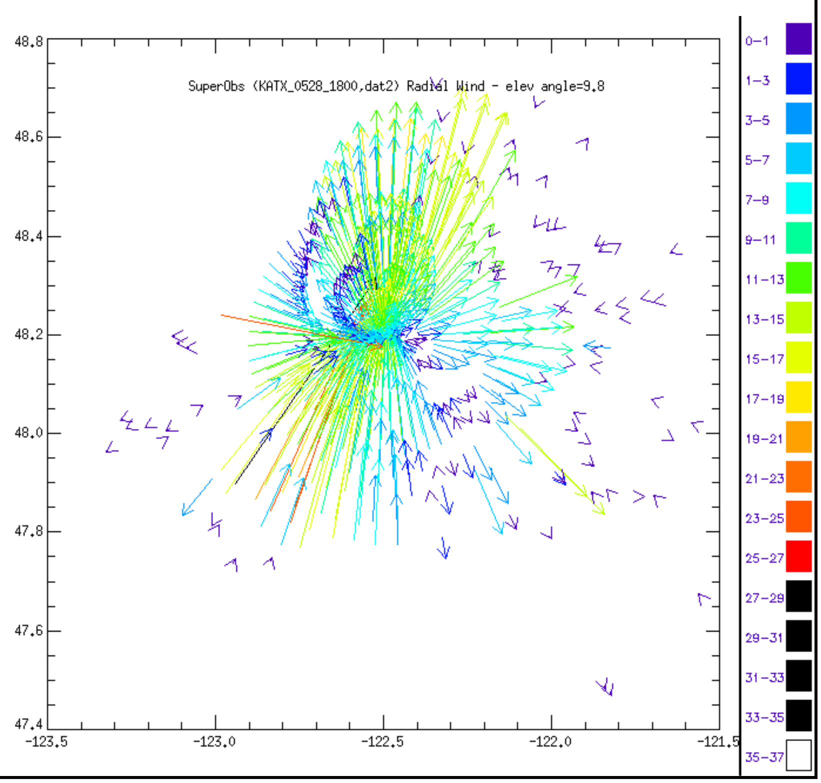
High Resolution Vertically Integrated Liquid Water (VIL)



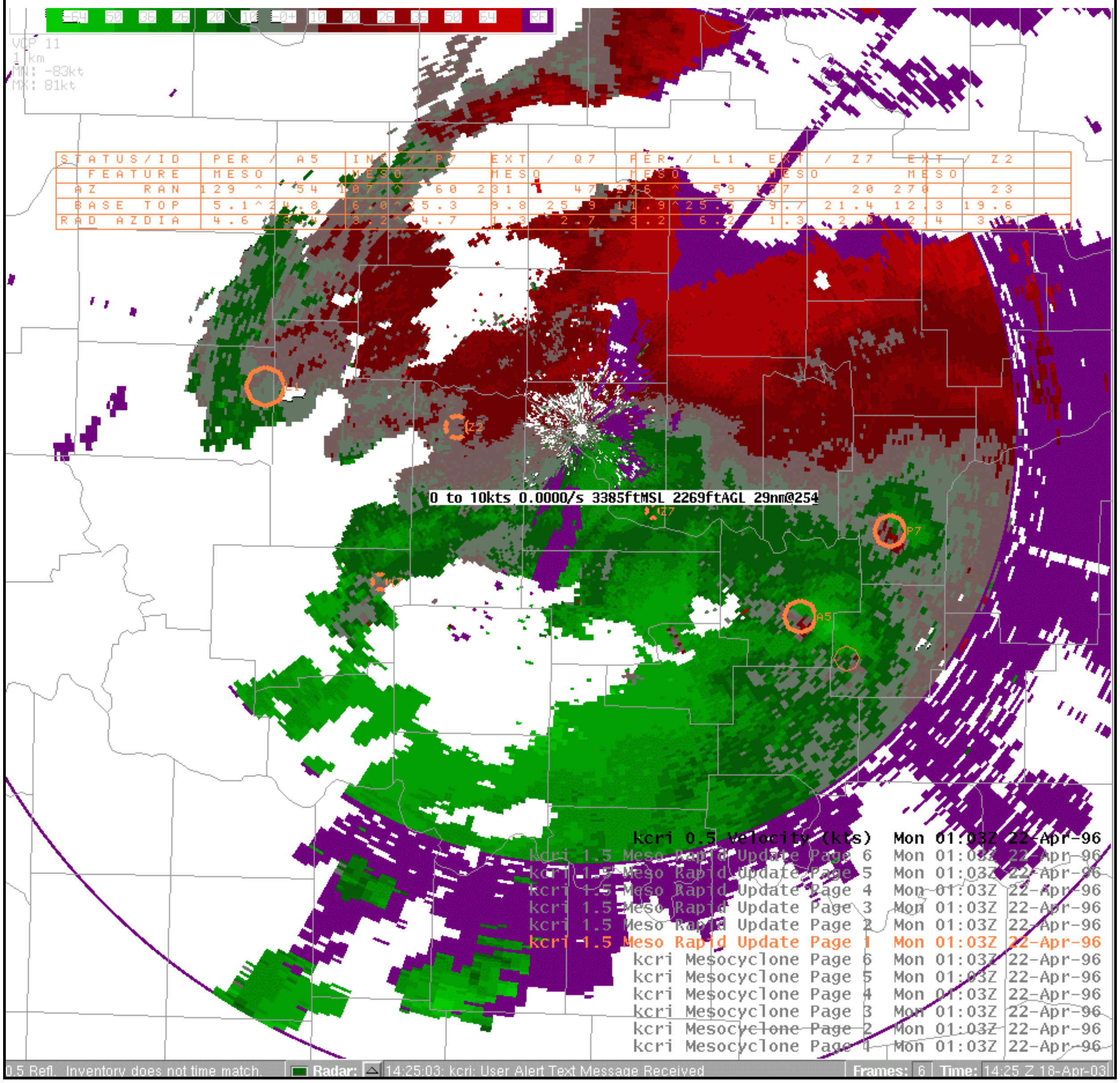
High Resolution Echo Tops



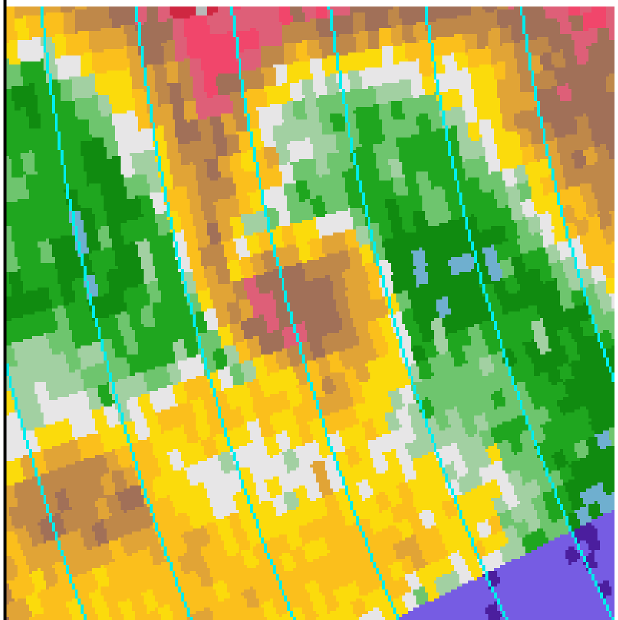
Visualization of Super Ob Product Quality Controlled Velocity Data for Model Initialization



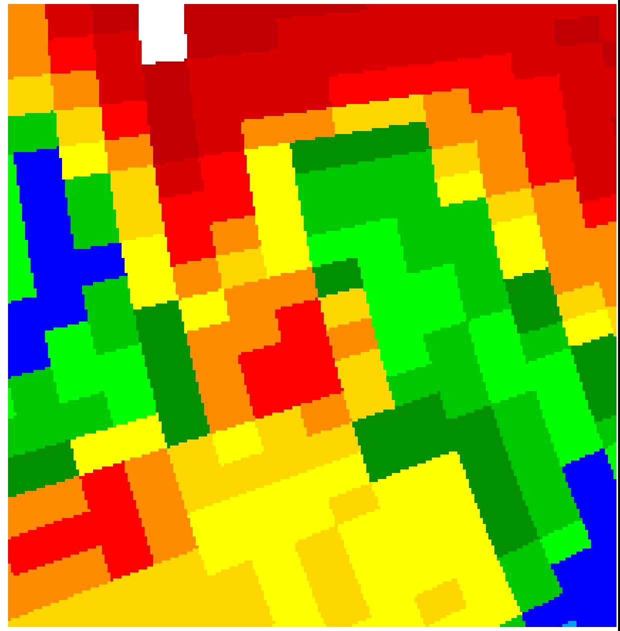
Mesocyclone Rapid Update After 1.5º Elevation Cut



Super Resolution Reflectivity Data From ORDA



ORDA Reflectivity: 0.5° x 0.25 km

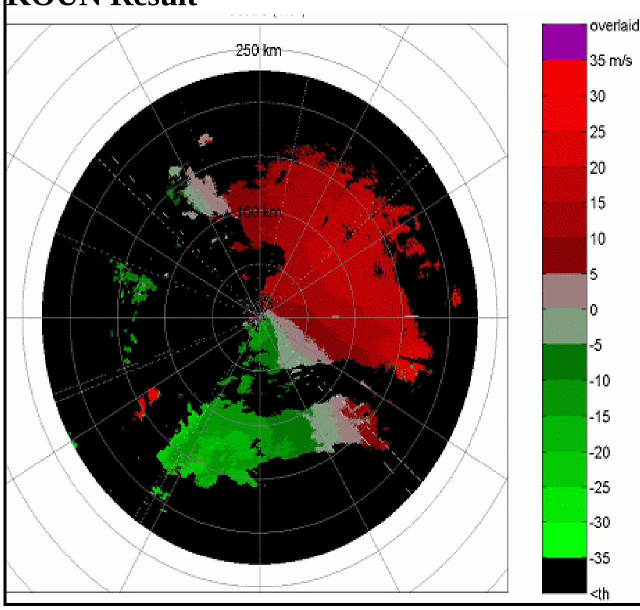


Current Reflectivity: 1.0° x 1.0 km

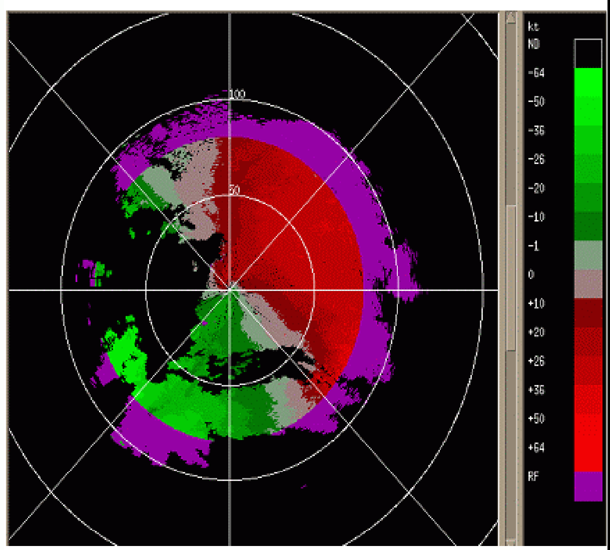
Oklahoma City May 3, 1999

Staggered PRT Mitigation of Velocity and Range Folding
NSSL KOUN 1.5 Deg Elevation

KOUN Result

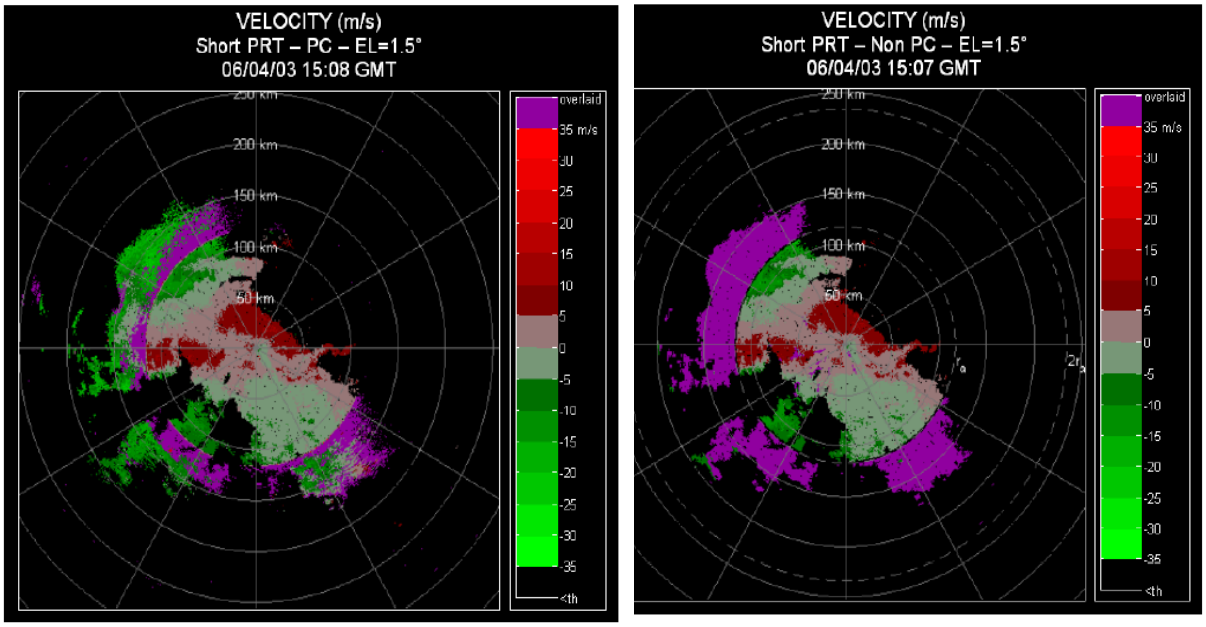


KTLX Operational Display

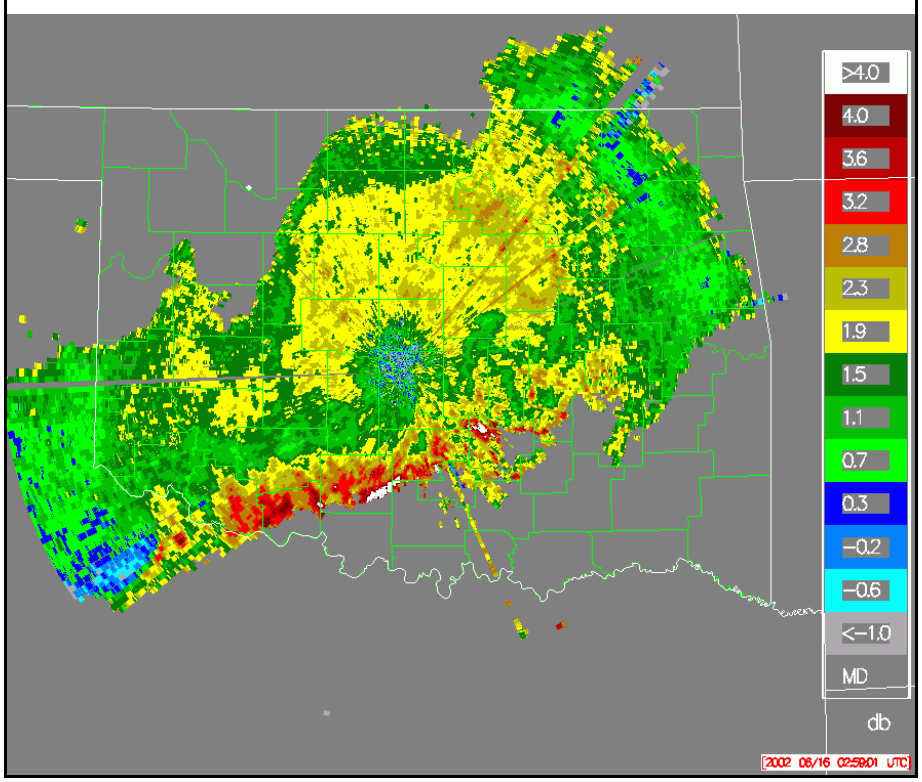


S-Z Phase Coding Mitigation of Velocity and Range Folding

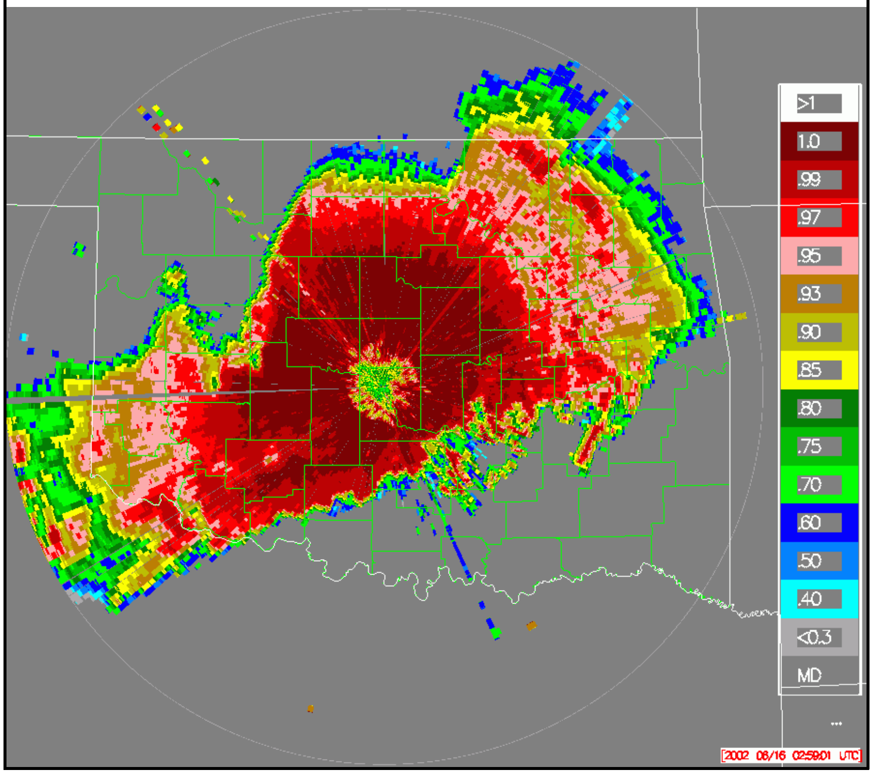
With S-Z Processing **Without Phase Coding**



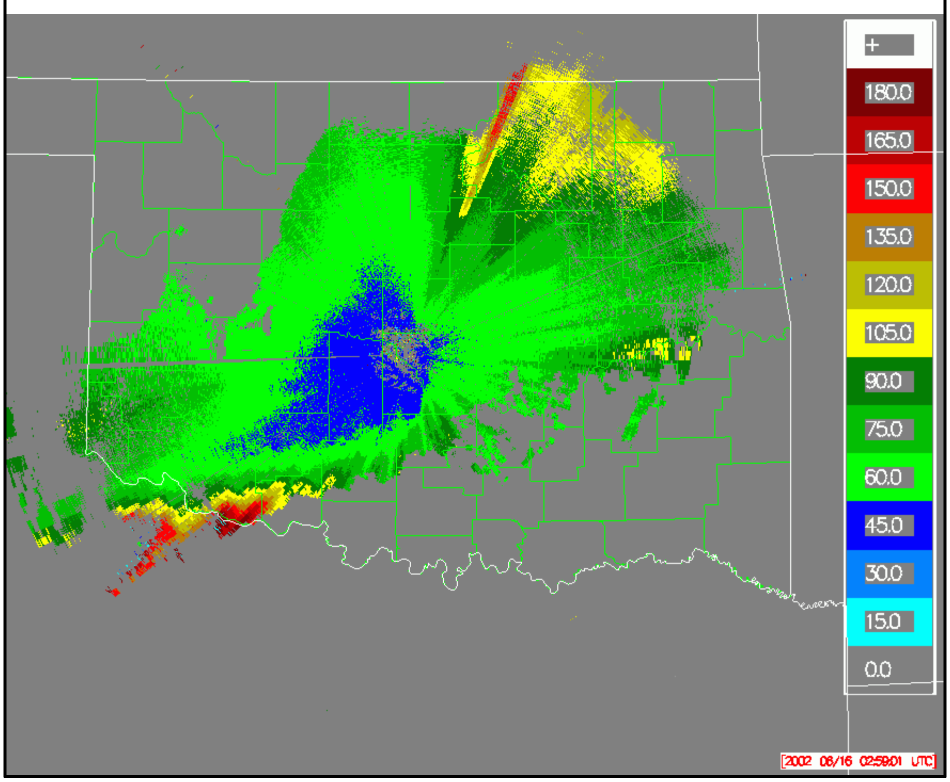
Polarimetric Differential Reflectivity



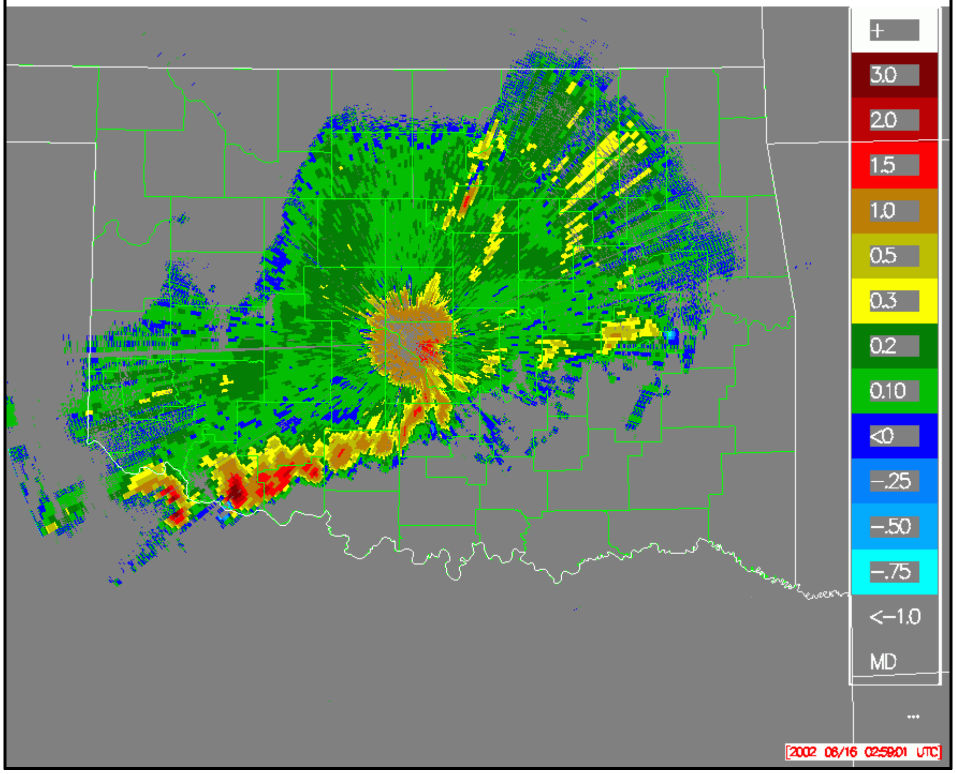
Polarimetric Correlation Coefficient



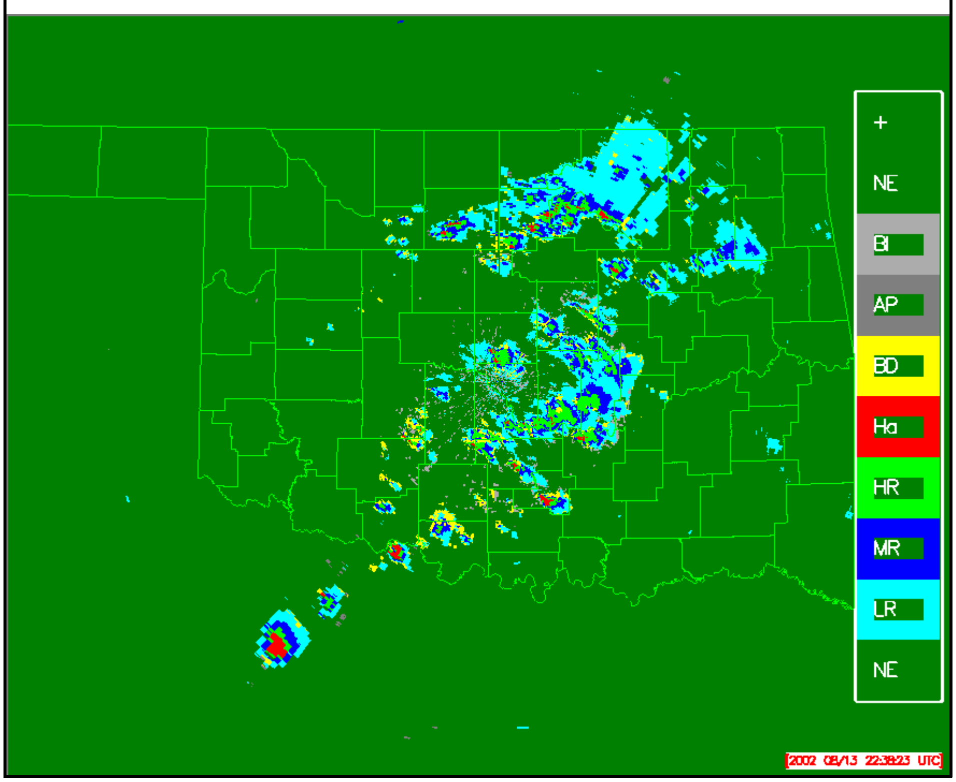
Polarimetric Differential Phase



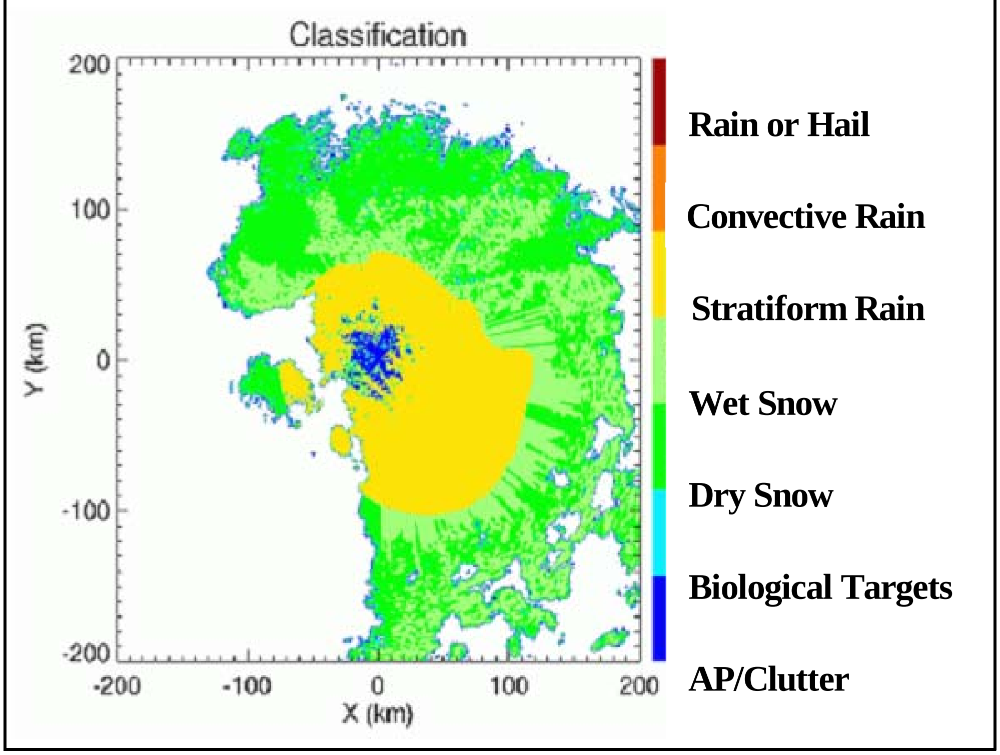
Polarimetric Specific Differential Phase



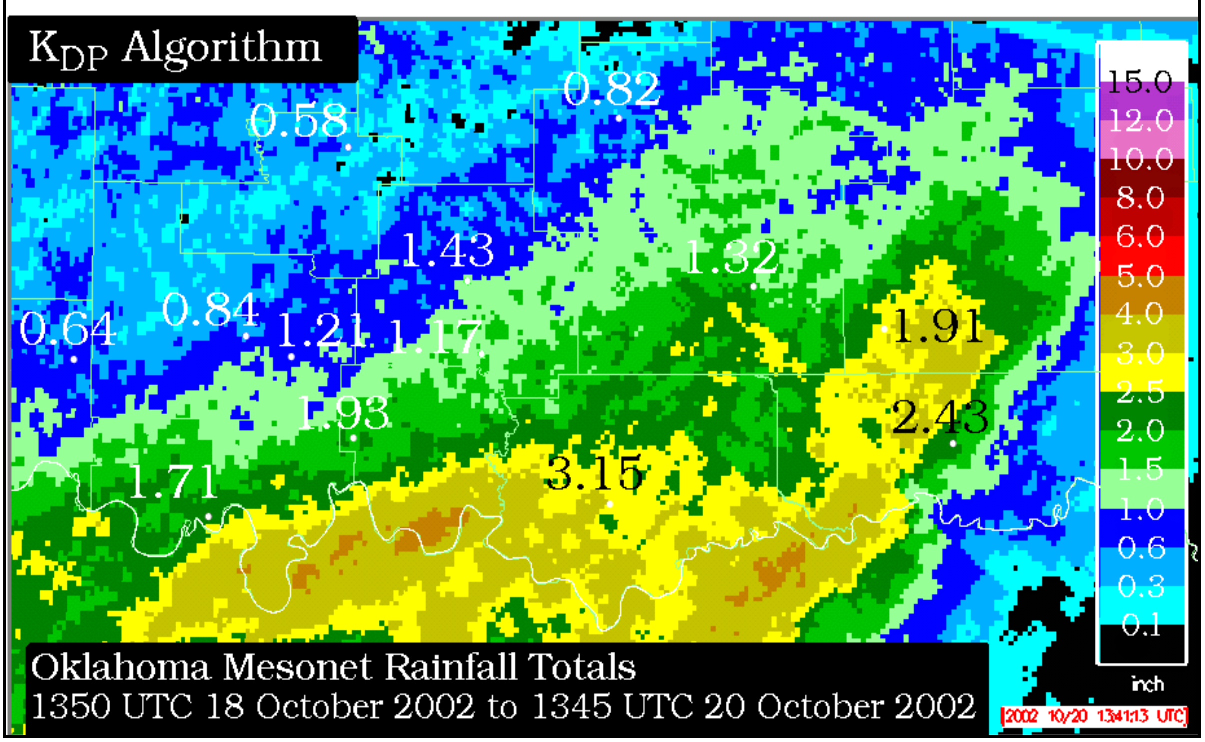
Polarimetric Hydrometeor Classification
Hail Storm Activity



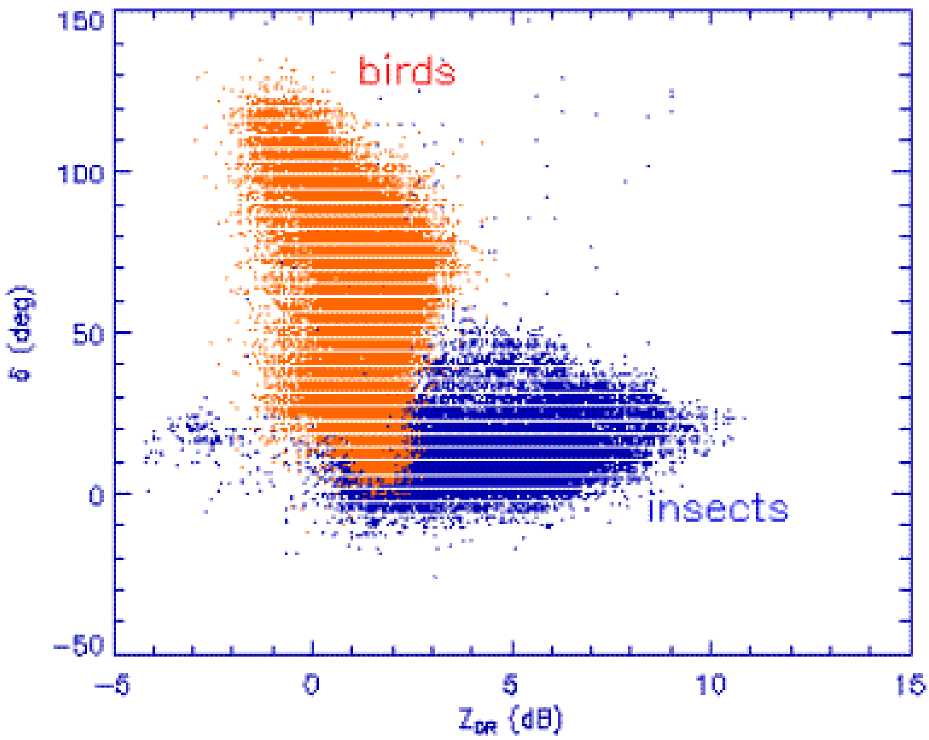
Hydrometeor Classification Based on Polarimetric Data
Winter Precipitation – Including Freezing Rain



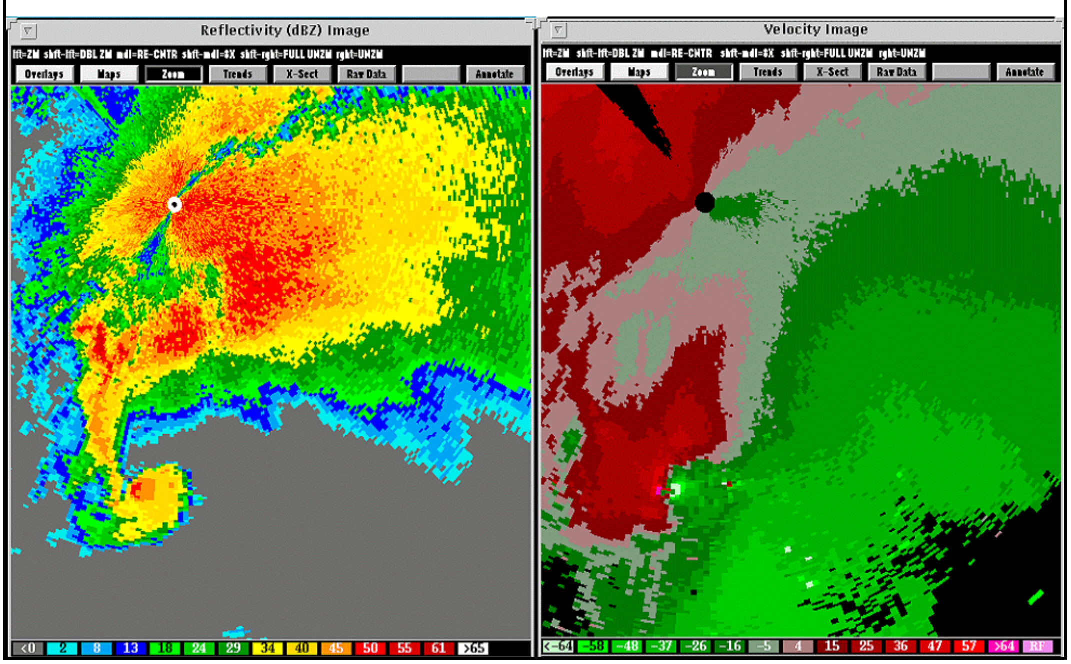
Rainfall Estimation Based on Polarimetric Specific Phase Differential



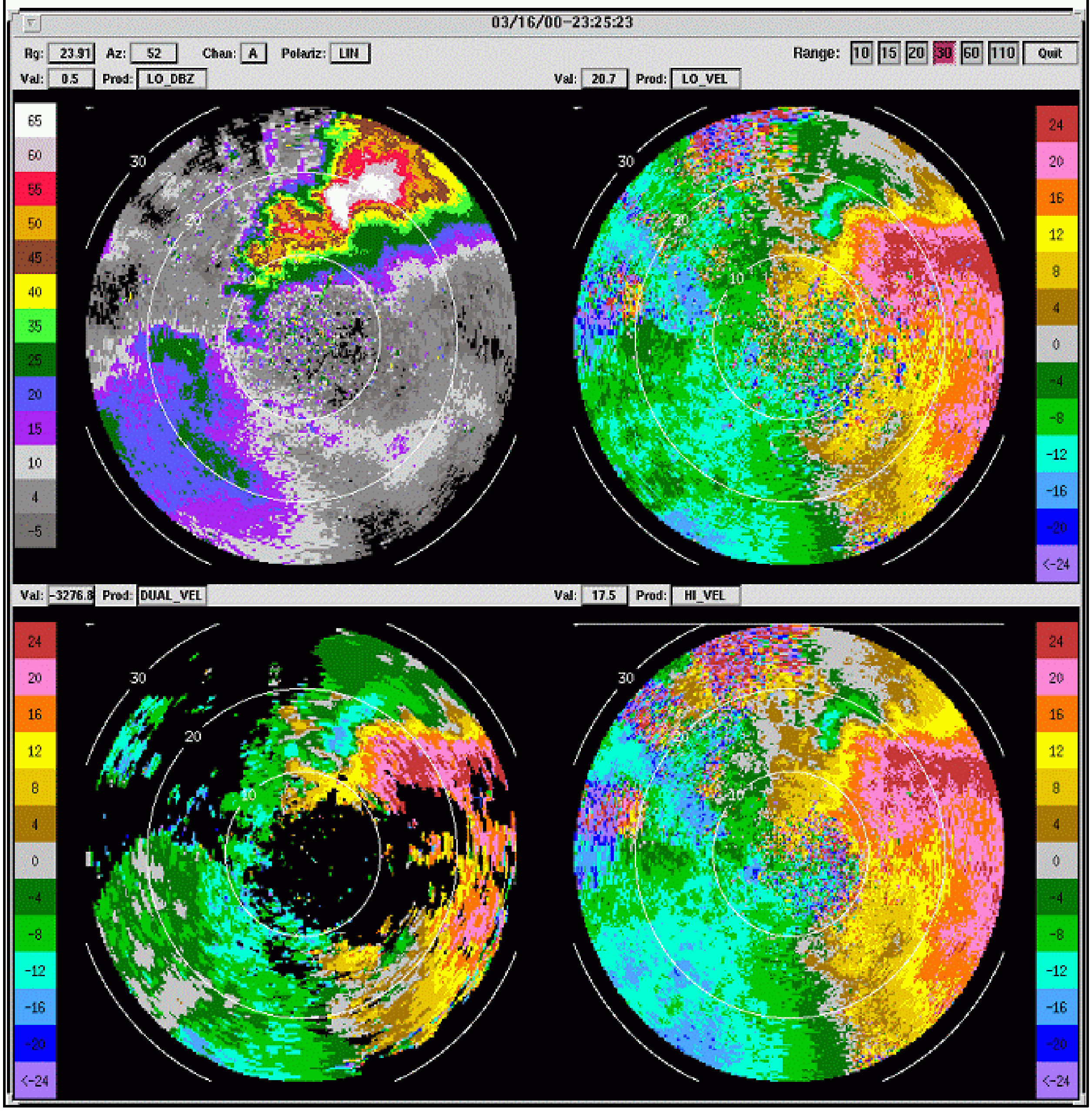
Birds and Insects Discrimination Using Differential Phase and Differential Reflectivity



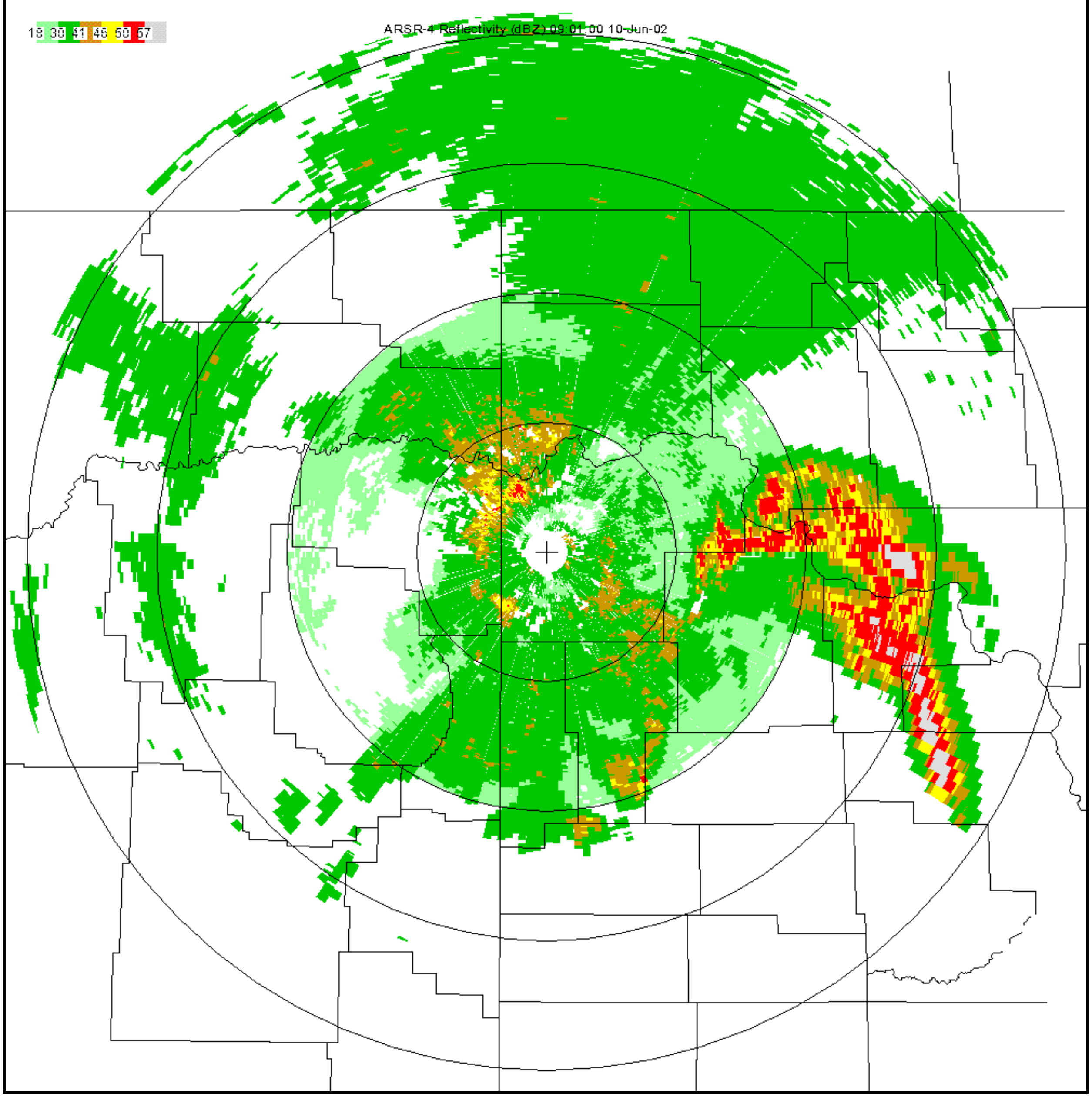
Oklahoma City Tornado: May 3, 1999
TDWR Base Reflectivity and Base Velocity



Austin, TX, Tornado: ASR-9 Reflectivity and Velocity



FAA ARSR-4 Watford City, ND
June 10, 2002 Thunderstorm Activity



FAA ASR-11 Stockton, CA
December 19, 2002 Rain Showers