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 has begun the implementation of dual polarization, and the integration of weather data from several FAA radar systems. This paper briefly 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 includes a modern digital signal processor (DSP) and a digital receiver. The ORDA is in the system test

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phase of production development, and is scheduled to be deployed in 2005-2006.

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 have been analyzed to validate the KOUN implementation for its engineering design, data accuracy and potential operational issues.

A decision briefing was presented to the NEXRAD Program Management Committee on Nov 19, 2003 that recommended initiation of a WSR-88D Dual Polarization implementation program. The Dual Polarization program initiation was approved, production development is under way, and deployment is scheduled in 2007-2009.

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], and is in the operational development phase of a formal program to acquire data from all TDWR sites for routine operational use [10].

3. SCIENTIFIC OPPORTUNITIES

3.1 ORPG Products Deployed

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.

- 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,

New , or enhanced, products and capabilities scheduled for deployment in the year or two include:

- Improved storm cell identification and tracking,
- Boundary detection and projection,
- Display products to take advantage of Super Resolution data from the ORDA,
- Displays of extended Doppler processing range.

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 2nd 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. This technique could provide valuable additional information for model initialization and other pre-storm analyses of severe weather potential. The technique has been formally submitted to the NWS for approval.

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. Istok [10] presents a more complete discussion of the status of NWS programs for FAA data use.

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 to offer CODE to the broader radar development community. CODE is now supported on PC-Linux platforms [11], and is available to the public from ftp://ftp.nws.noaa.gov/software/88D_CODE/.

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 [12]. 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. The addition of data from FAA radars offers further opportunities.

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.

5. REFERENCES

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

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[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

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[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

[10] NWS Use of FAA Radar Data - Progress and Plans, Istok, M., R. Okulski, R. Saffle, P. Pickard, B. Bumgarner, 21st IIPS, paper 5.3

[11] The Current Linux-Intel WSR-88D CODE Distribution and a Summary of How It Is Being Used in Research, Development, and Operations, Ganger, T., M. Istok, W. Blanchard, 21st IIPS, paper P1.1

[12] An Update on WSR-88D Level II Data Collection and Distribution, Cragg, P., W. Blanchard, T. Sandman, 21st IIPS, paper P1.14
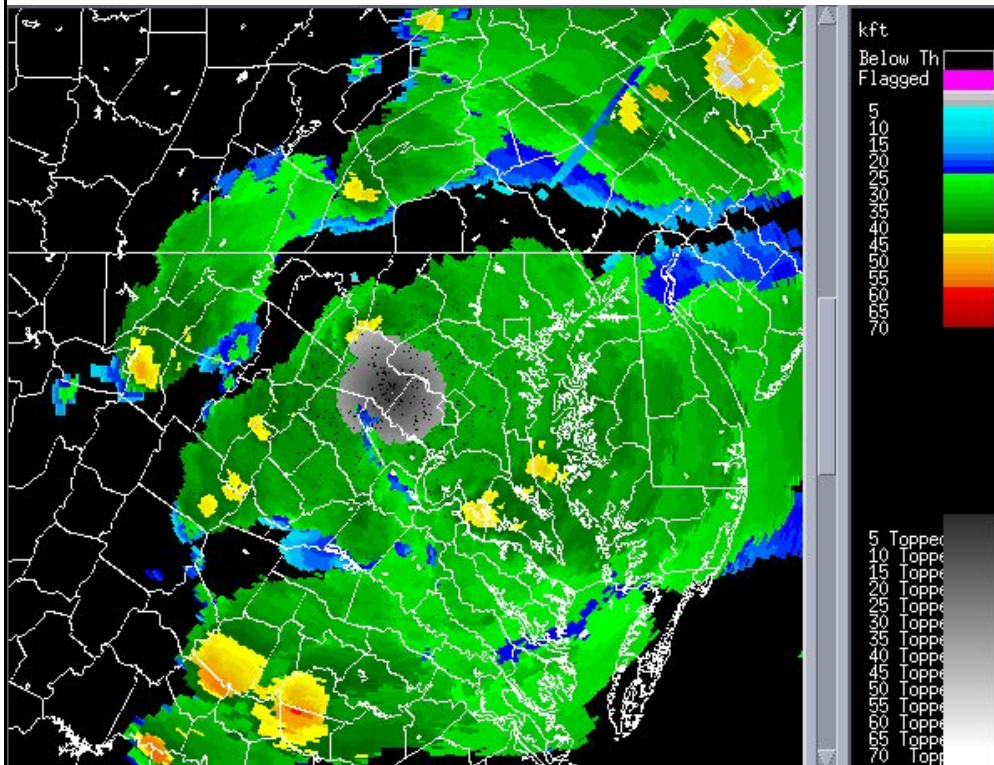
**Full Resolution (8-bit) Reflectivity and Velocity Images
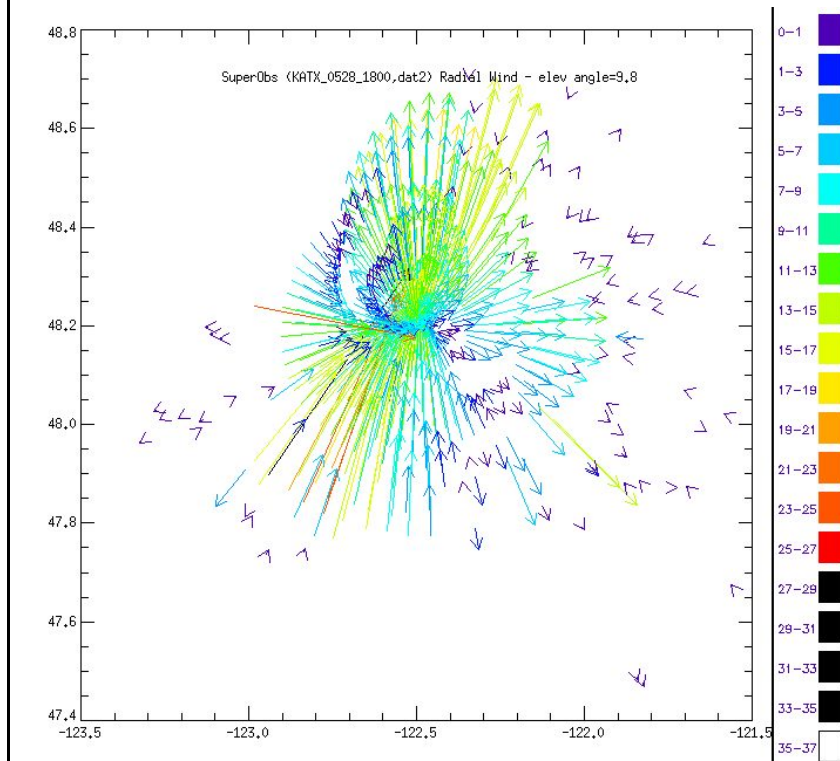Wasola, MO, F2 Tornado, August 13, 2002**
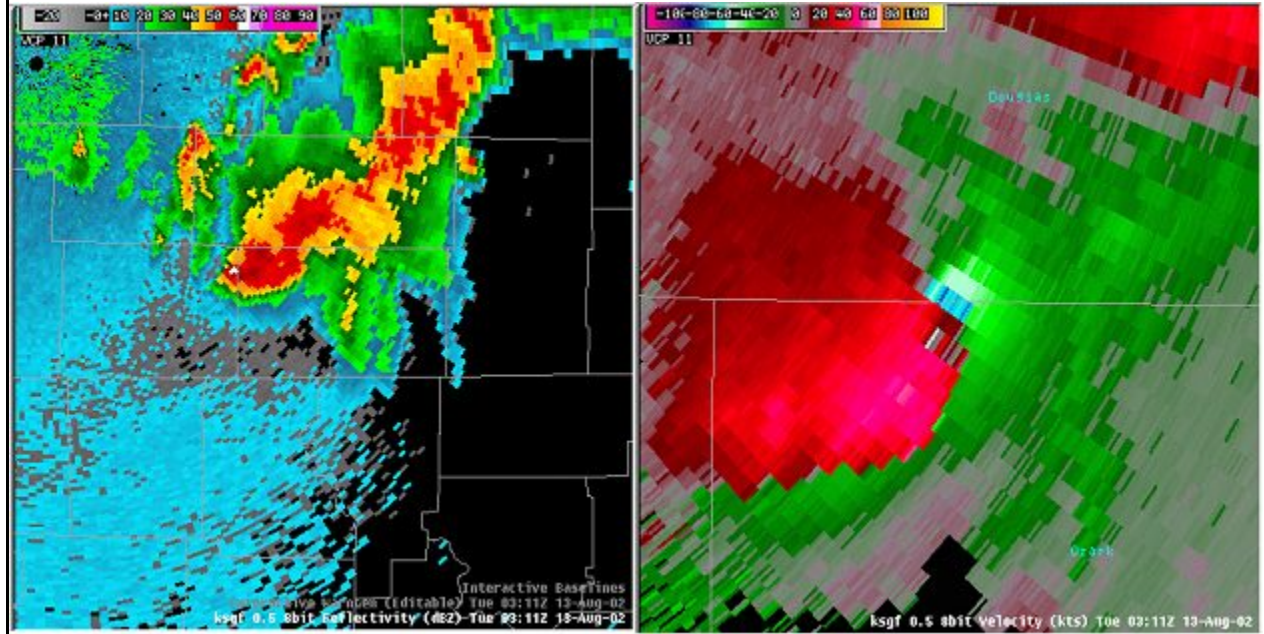
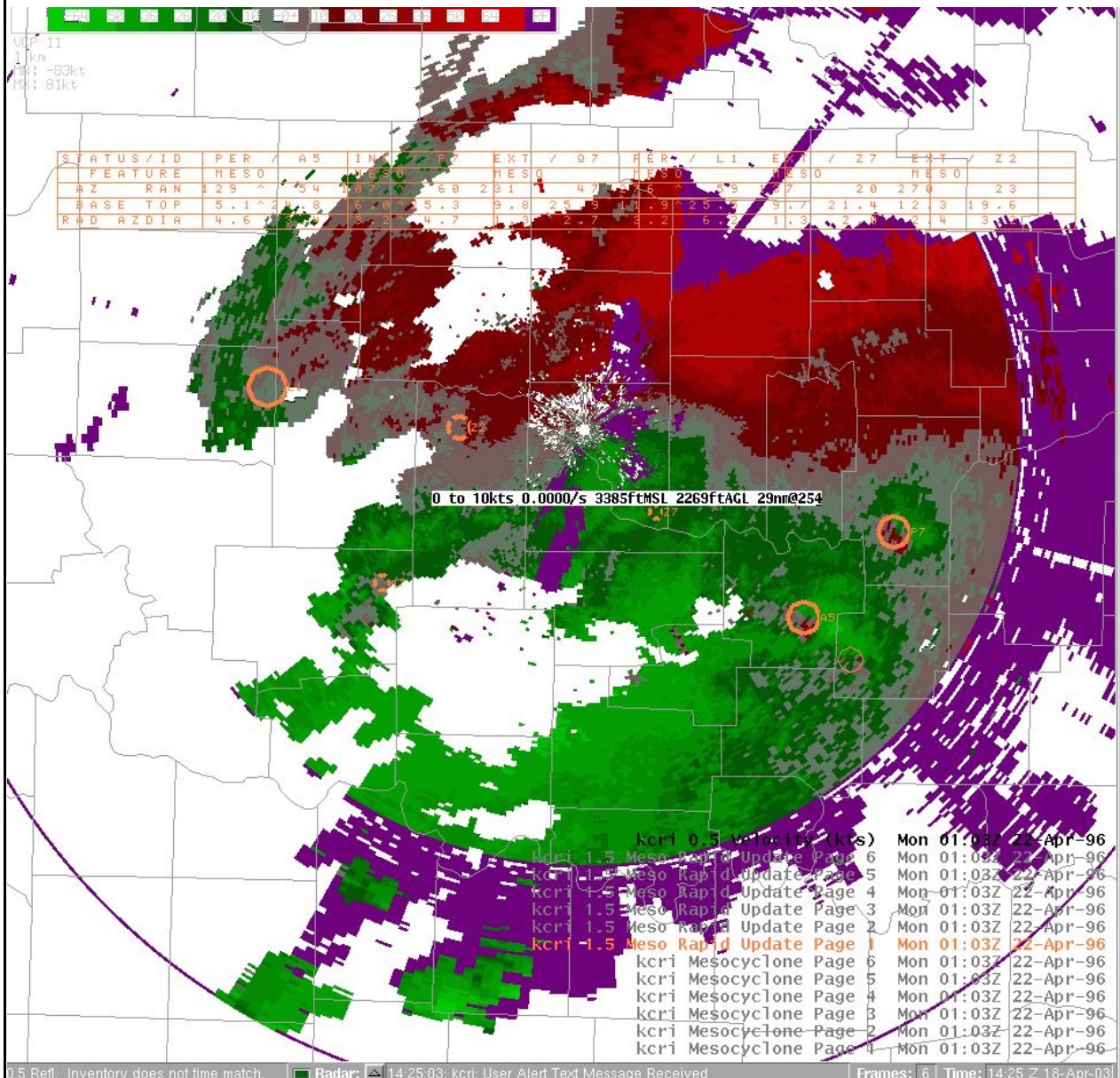**High Resolution Vertically Integrated Liquid Water (VIL)**
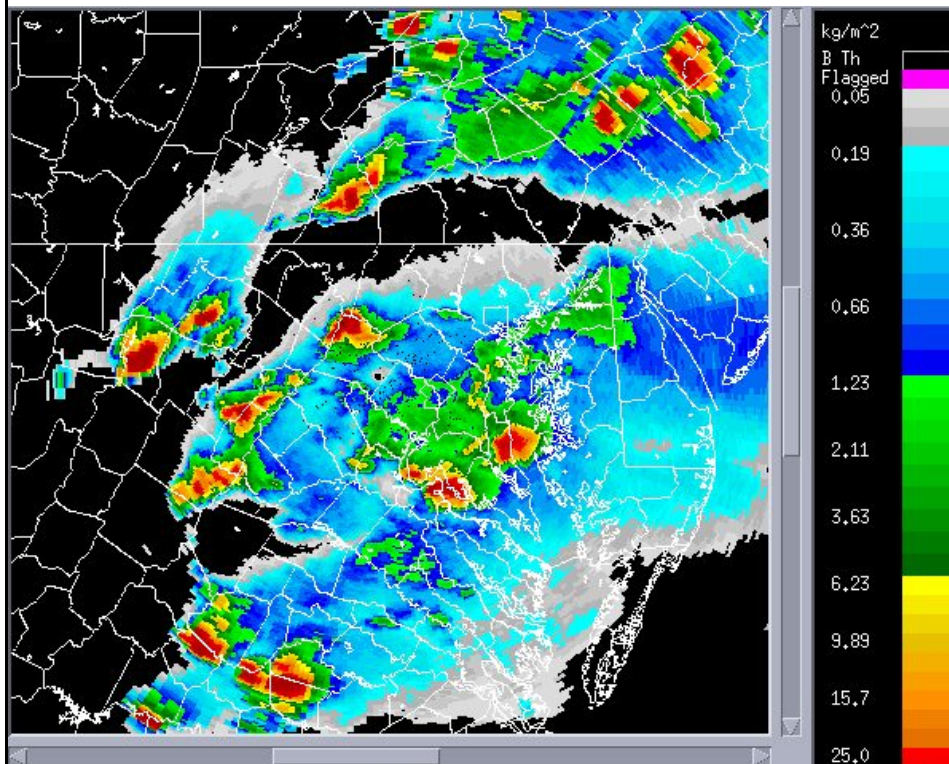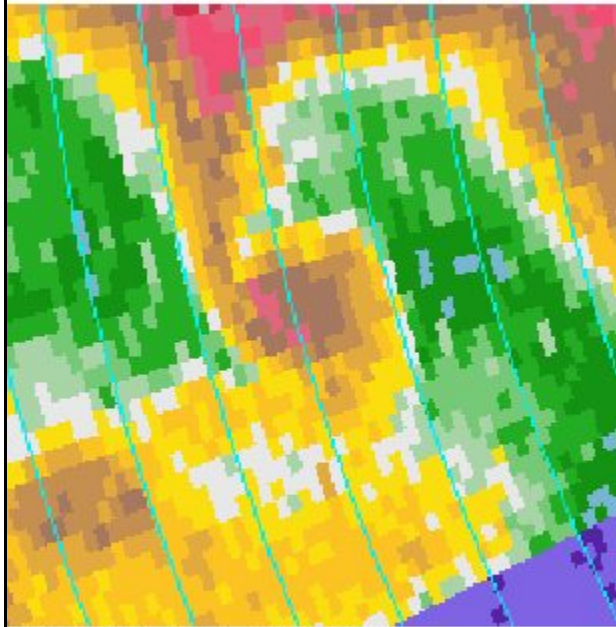
High Resolution Echo Tops

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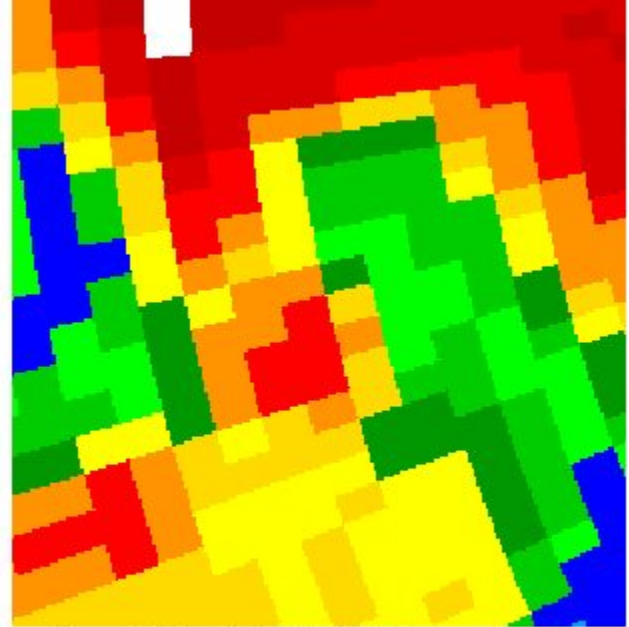## Quality Controlled Velocity Data for Model Initialization

SuperObs (KATX_0528_1800.dat2) Radial Wind - elev angle=9.8

Mesocyclone Rapid Update After 1.5º Elevation Cut

VCP 11
1 km
MN: -83kt
MX: 81kt

STATUS/ID	PER / A5	IN / P7	EXT / Q7	PER / L1	EXT / Z7	EXT / Z2
FEATURE	MESO	MESO	MESO	MESO	MESO	MESO
AZ RAN	129 ^ 54	107 60	231 47	8 59	20 270	23
BASE TOP	5.1^20.8	6.0^5.3	9.8 25.9	41.9^25.5	9.7 21.4	12.3 19.6
RAD AZDIA	4.6 3	3.2 4.7	1.3 2.7	3.2 6.2	1.3 2	4 3

0 to 10kts 0.0000/s 3385ftMSL 2269ftAGL 29nm@254

kcri 0.5 Velocity (kts)   Mon 01:03Z 22-Apr-96
kcri 1.5 Meso Rapid Update Page 6   Mon 01:03Z 22-Apr-96
kcri 1.5 Meso Rapid Update Page 5   Mon 01:03Z 22-Apr-96
kcri 1.5 Meso Rapid Update Page 4   Mon 01:03Z 22-Apr-96
kcri 1.5 Meso Rapid Update Page 3   Mon 01:03Z 22-Apr-96
kcri 1.5 Meso Rapid Update Page 2   Mon 01:03Z 22-Apr-96
kcri 1.5 Meso Rapid Update Page 1   Mon 01:03Z 22-Apr-96
kcri Mesocyclone Page 6   Mon 01:03Z 22-Apr-96
kcri Mesocyclone Page 5   Mon 01:03Z 22-Apr-96
kcri Mesocyclone Page 4   Mon 01:03Z 22-Apr-96
kcri Mesocyclone Page 3   Mon 01:03Z 22-Apr-96
kcri Mesocyclone Page 2   Mon 01:03Z 22-Apr-96
kcri Mesocyclone Page 1   Mon 01:03Z 22-Apr-96

0.5 Refl. Inventory does not time match   ■ Radar: △ 14:25:03: kcri: User Alert Text Message Received   Frames: 6   Time: 14:25 Z 18-Apr-03

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
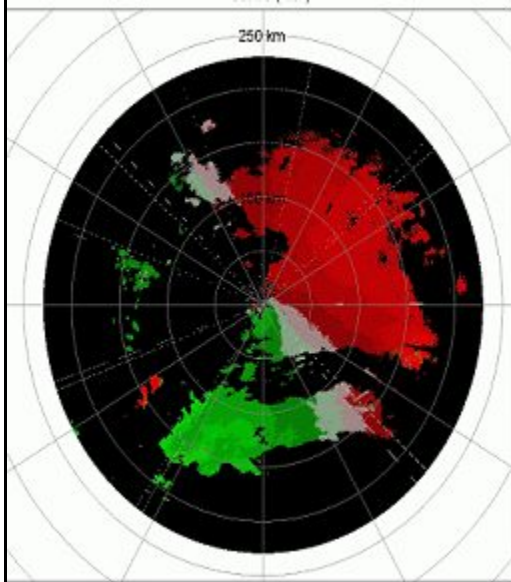
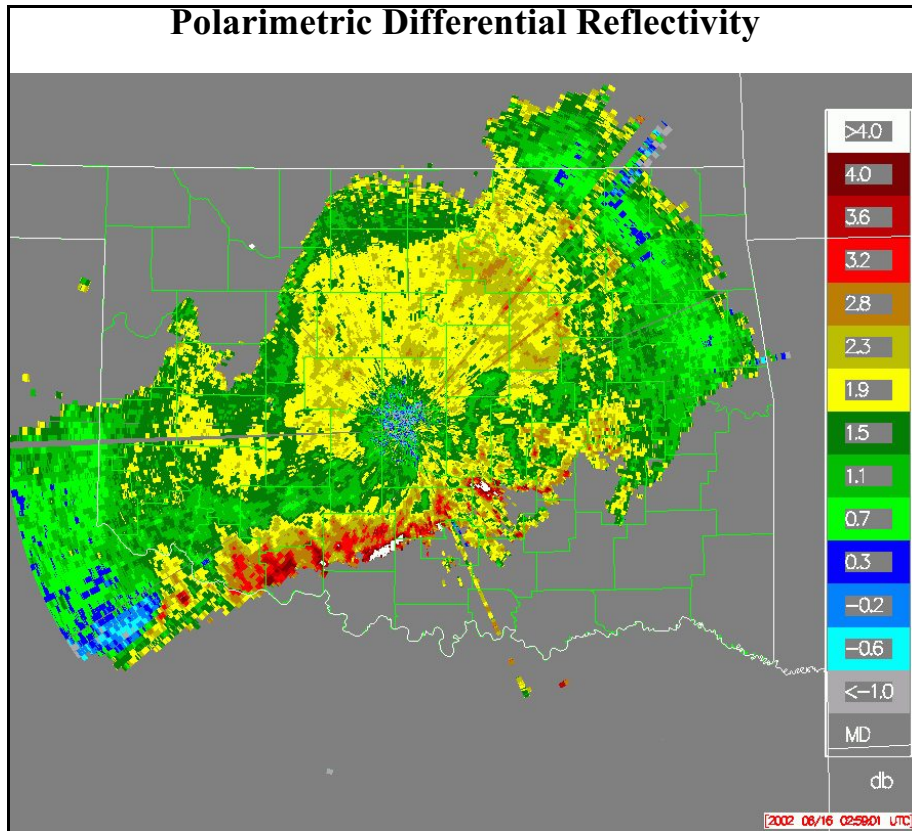**KTLX Operational Display**
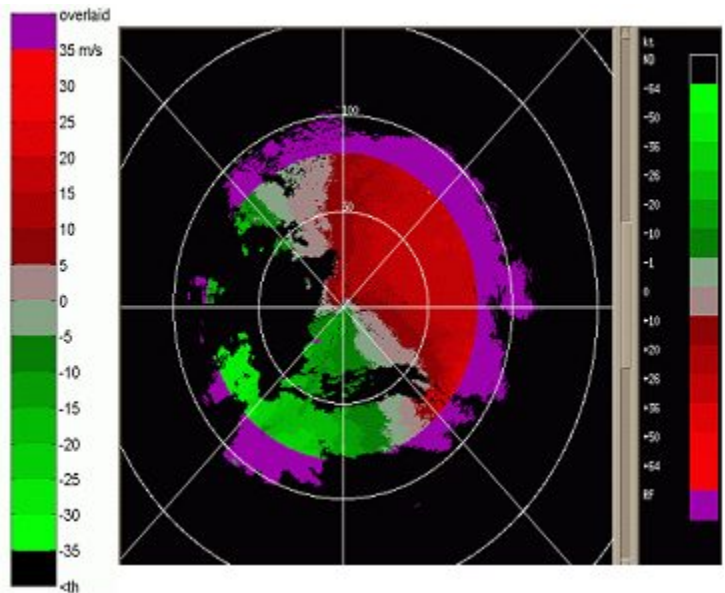
S-Z Phase Coding Mitigation of Velocity and Range Folding
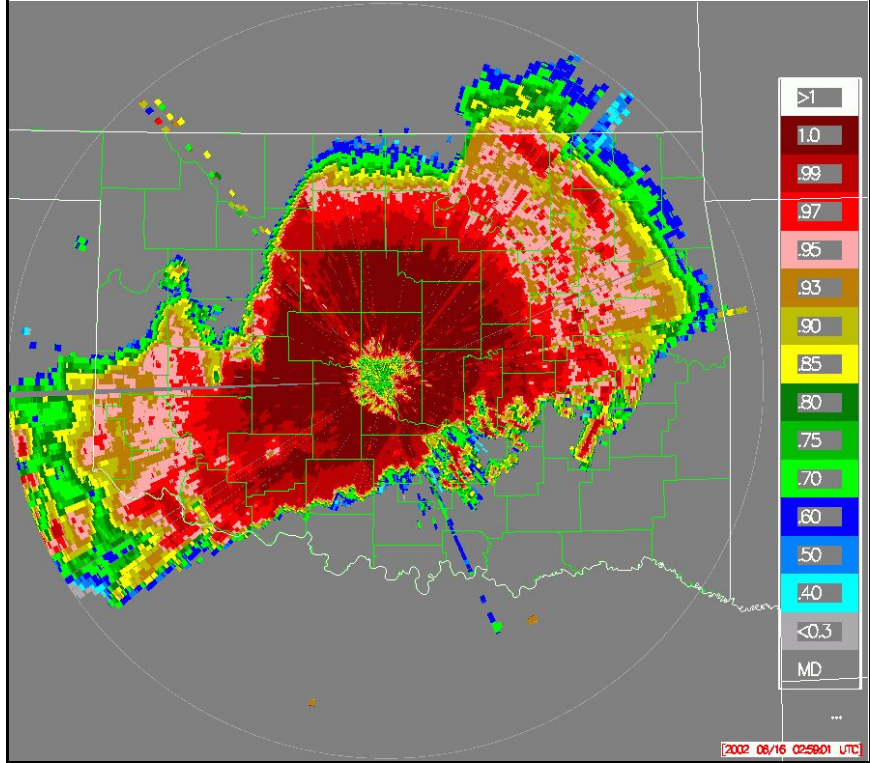
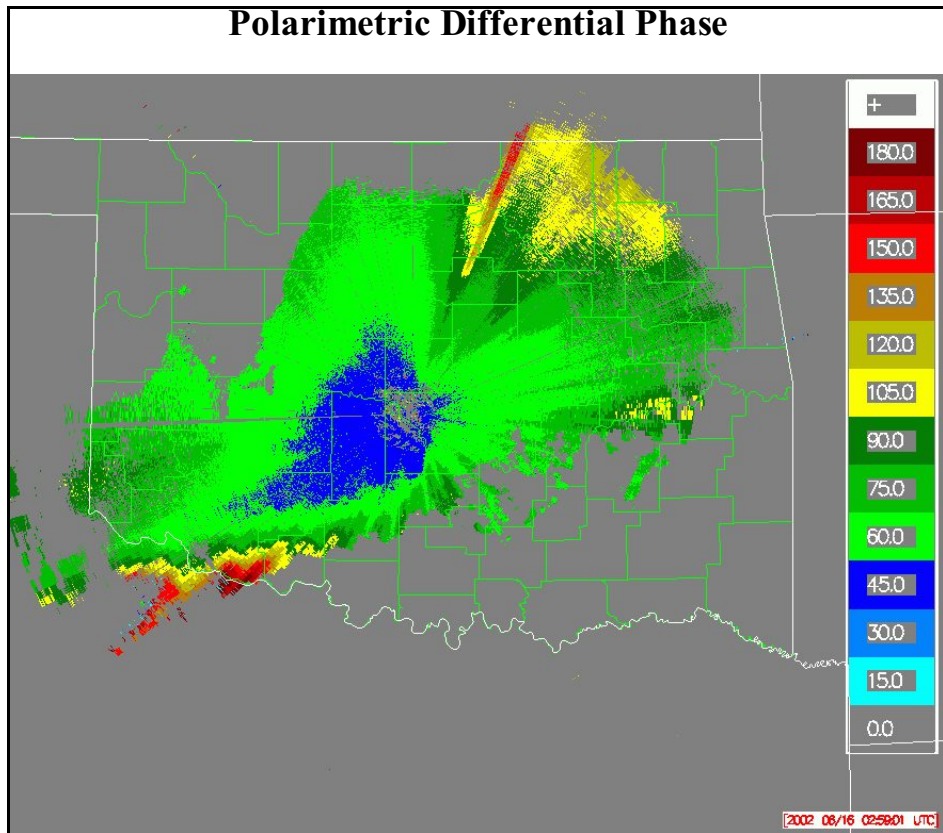**With S-Z Processing**   **Without Phase Coding**
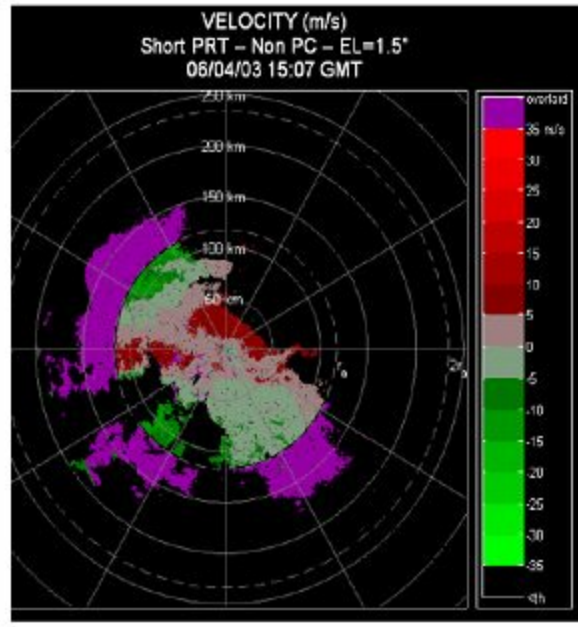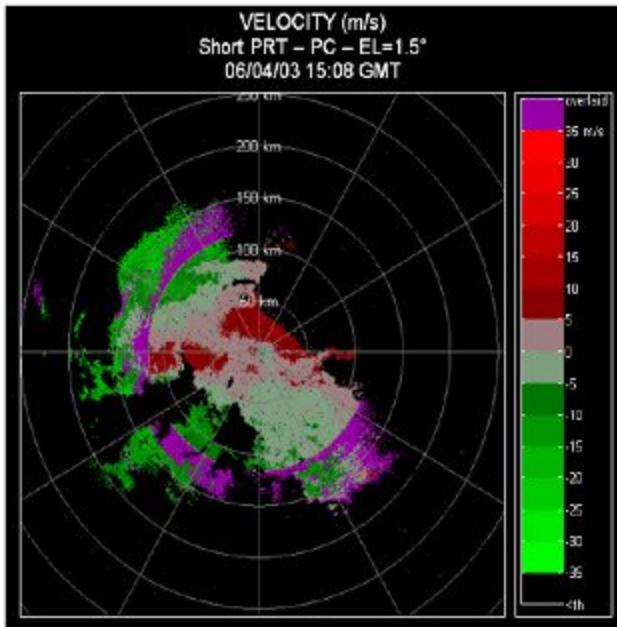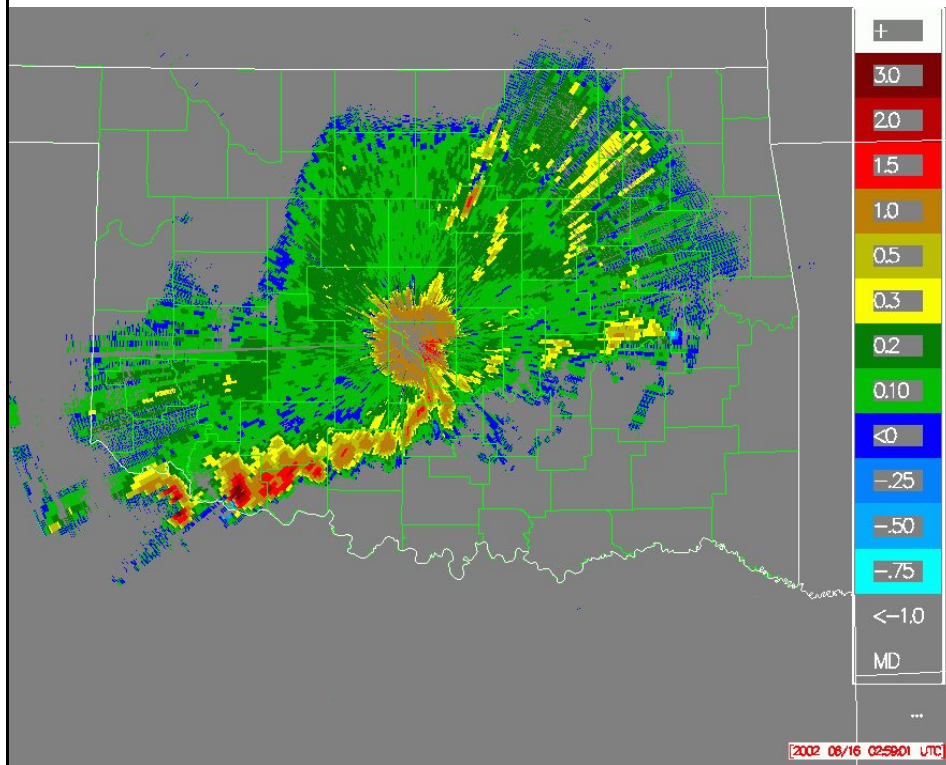

Polarimetric Differential Reflectivity

Polarimetric Correlation Coefficient

Polarimetric Differential Phase

Polarimetric Specific Differential Phase

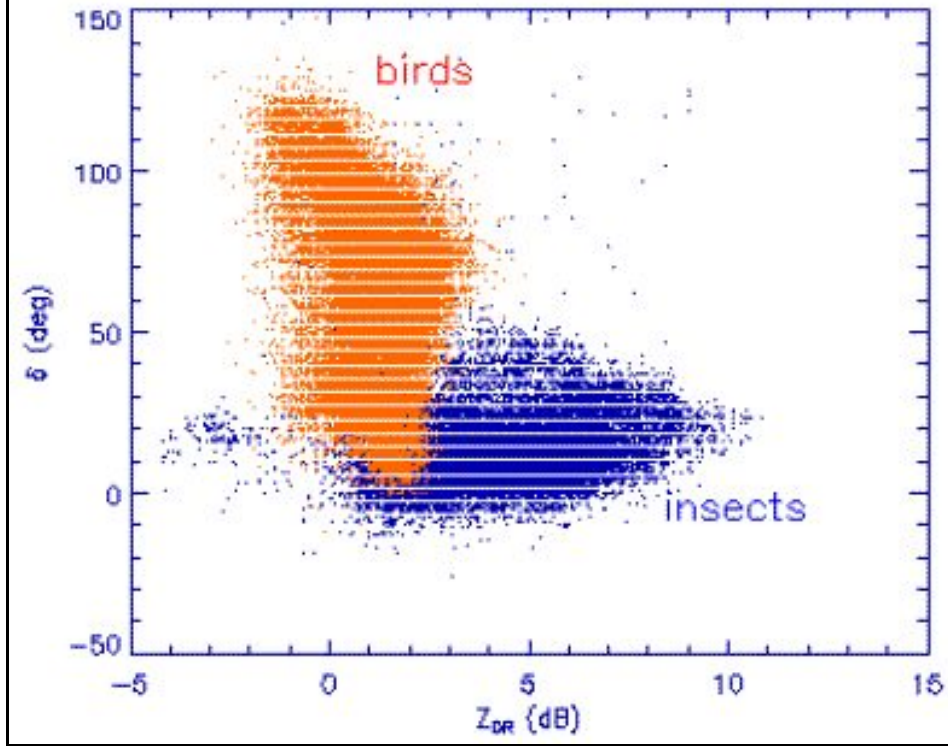**Polarimetric Hydrometeor Classification
Hail Storm Activity**
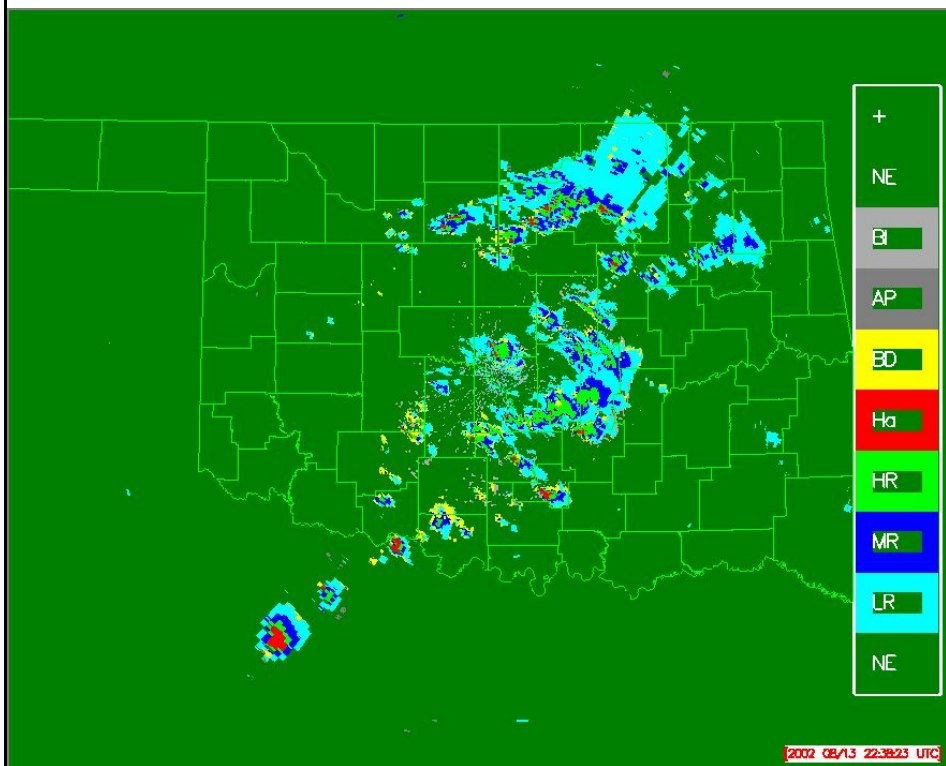
Hydrometeor Classification Based on Polarimetric Data
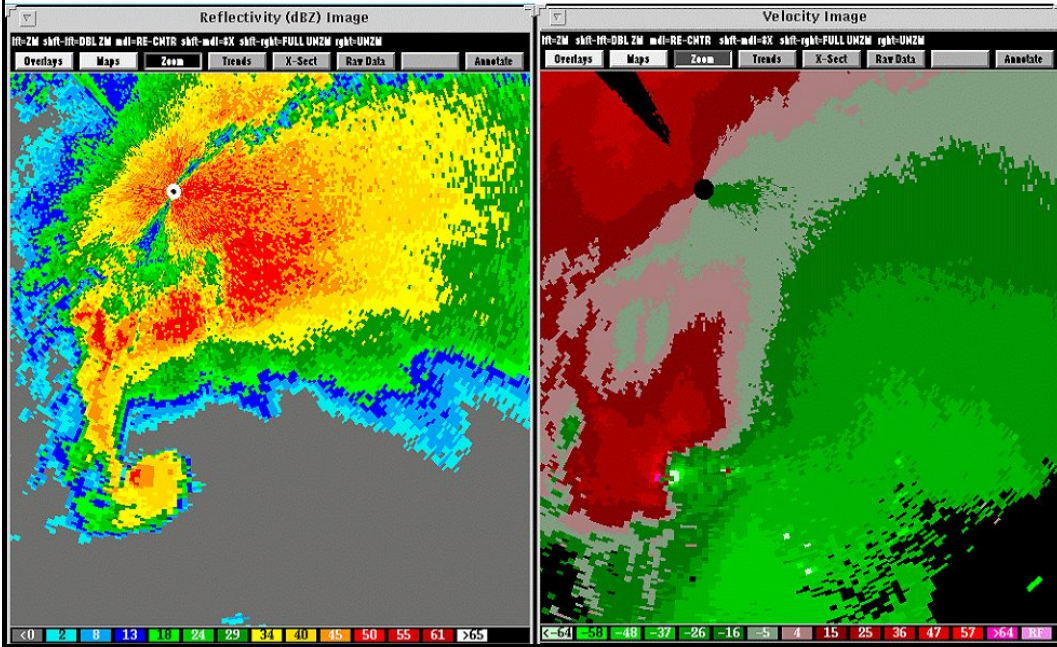## Winter Precipitation – Including Freezing Rain
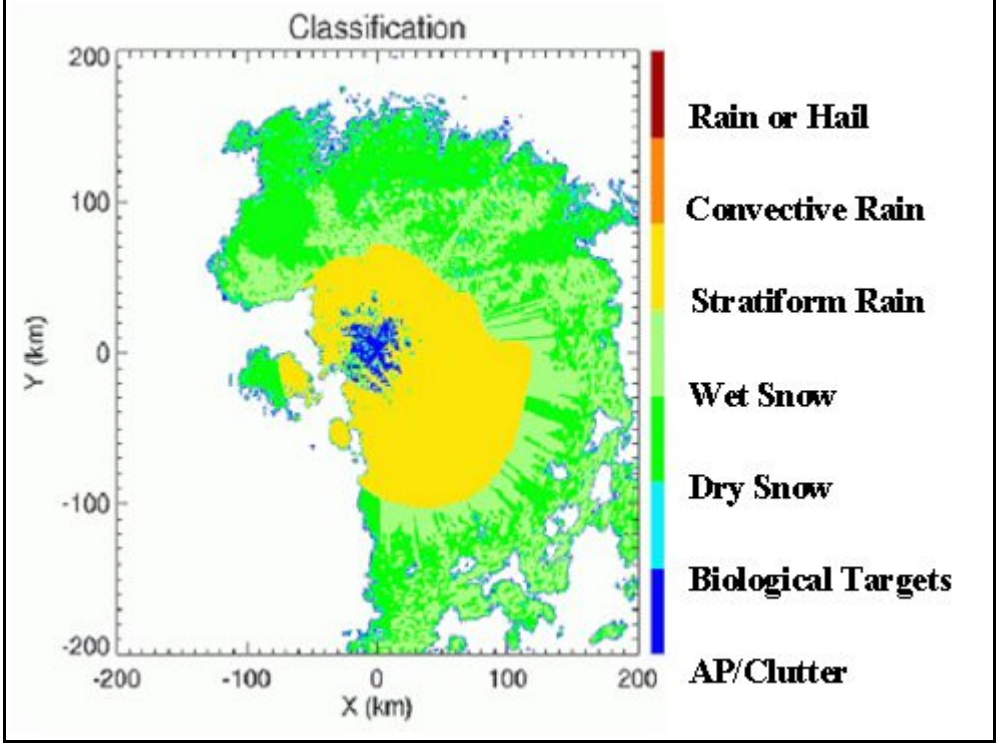
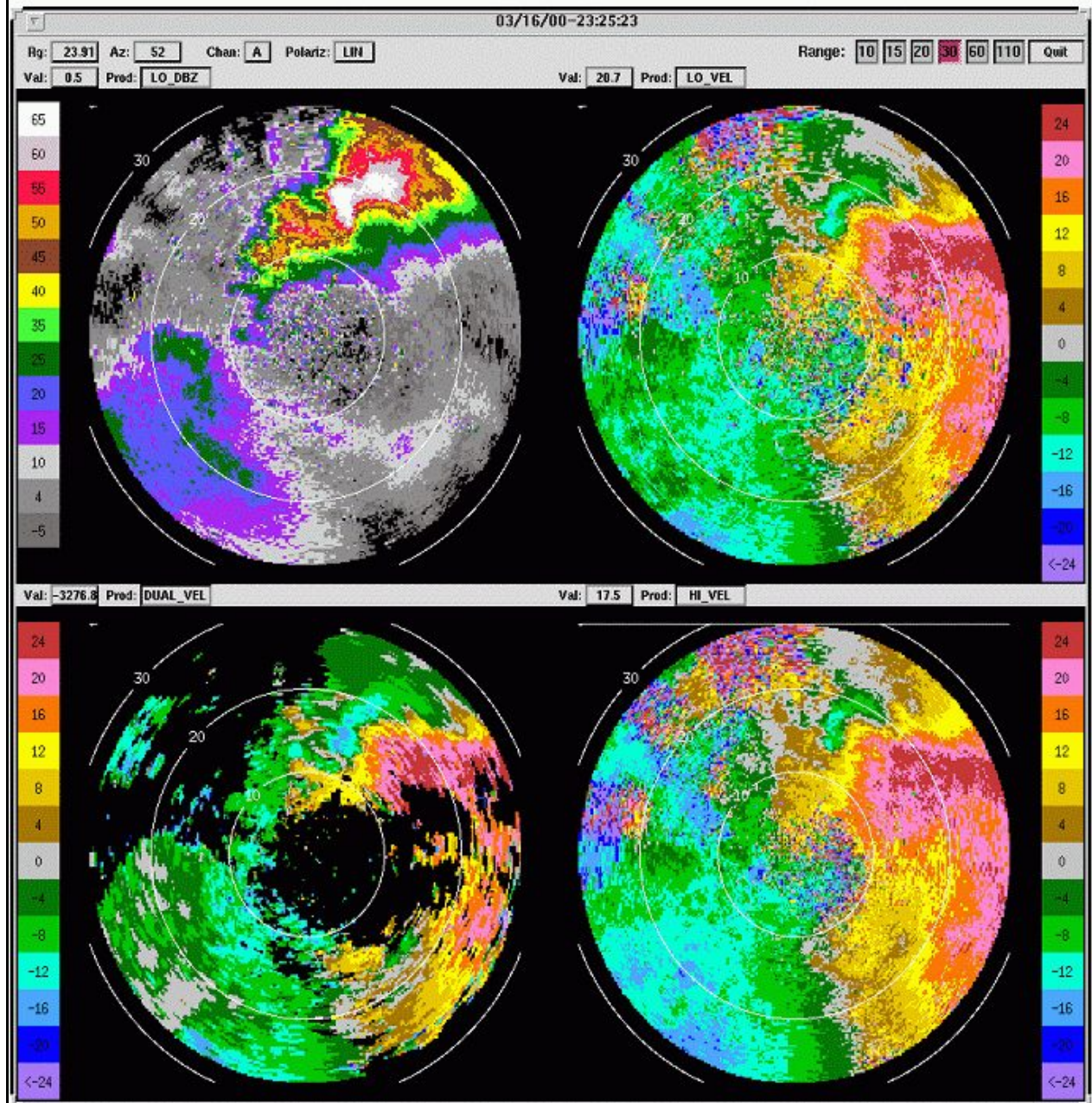# Rainfall Estimation Based on Polarimetric Specific Phase Differential
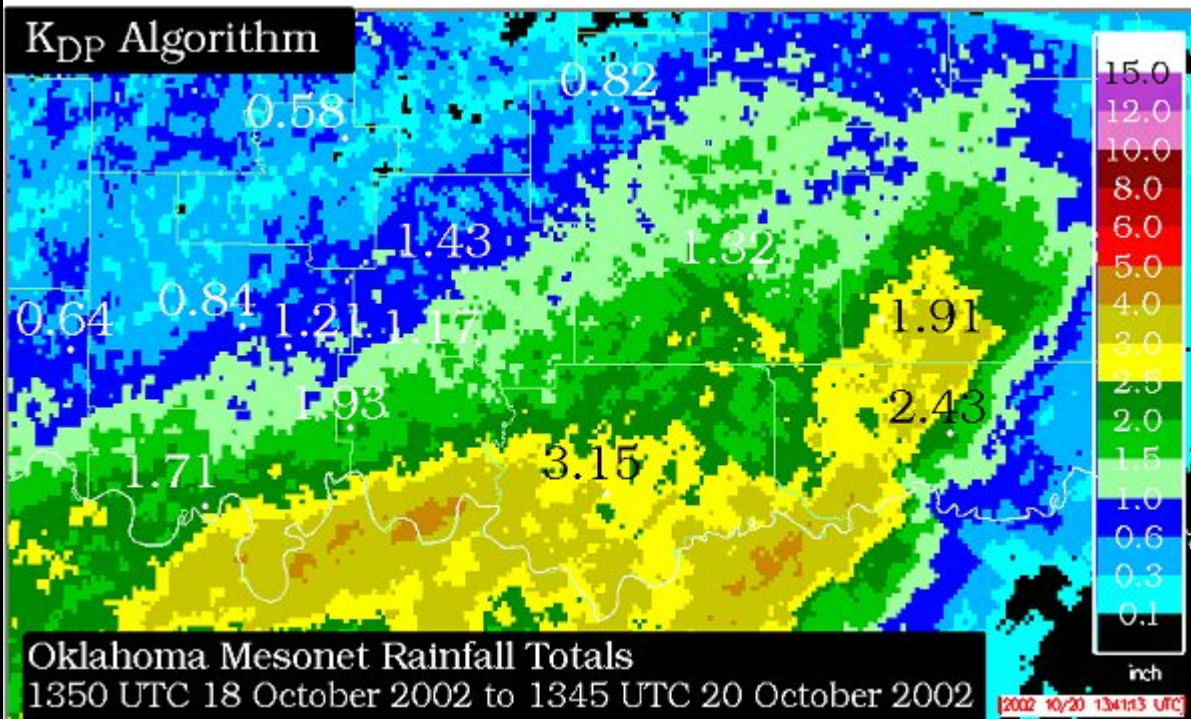
Birds and Insects Discrimination Using
Differential Phase and Differential Reflectivity

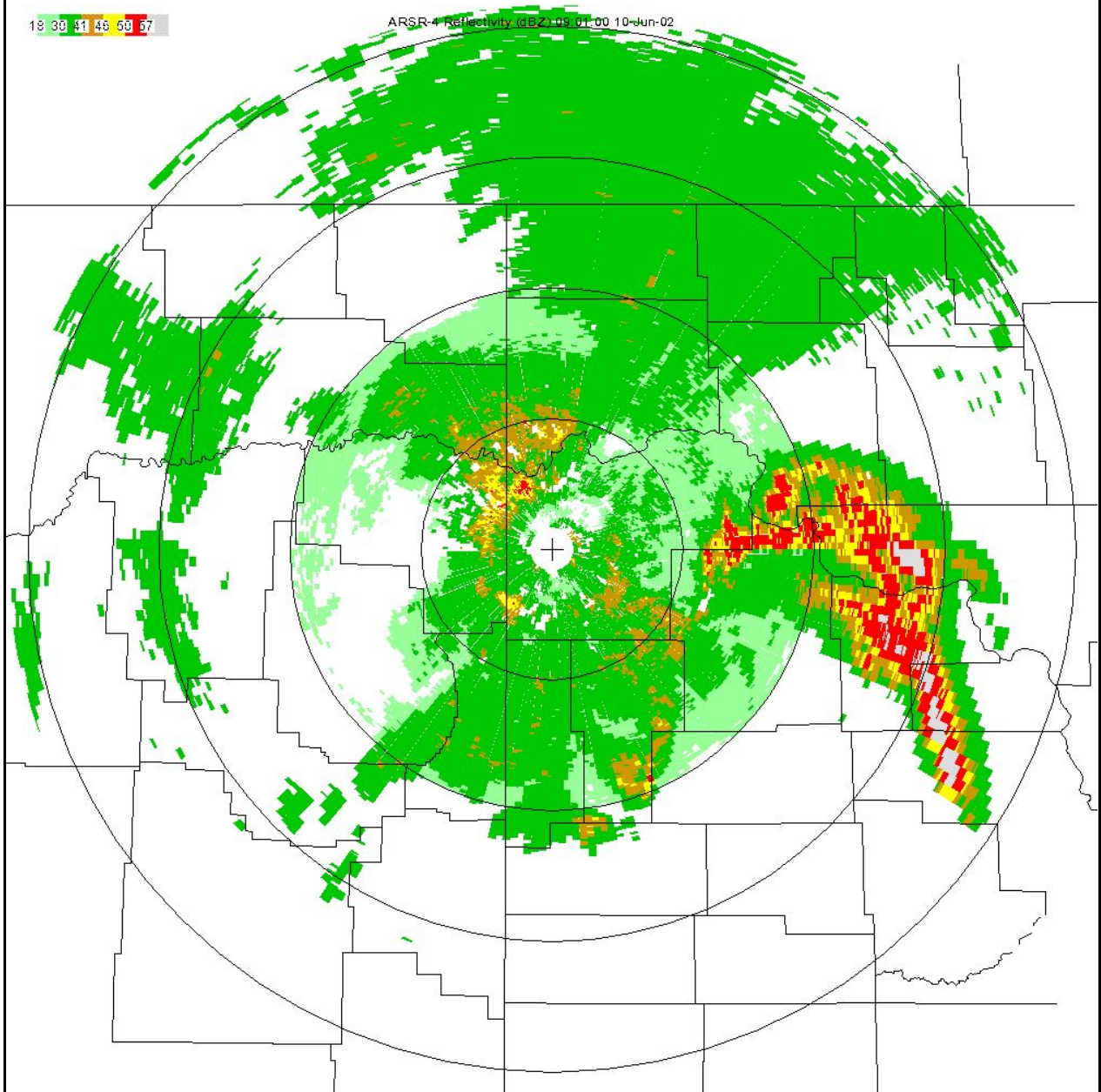# Oklahoma City Tornado: May 3, 1999
TDWR Base Reflectivity and Base Velocity

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

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

ARSR-4 Reflectivity (dBZ) 09:01:00 10-Jun-02

18 30 41 46 50 57

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