An Overview of Dual Polarization Weather Radar Applications

Joint Polarization Experiment

JPOLE

Information Briefing for the NEXRAD TAC Meeting

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Outline

- The KOUN Proof of Concept System
- JPOLE
- Advantages of Dual Polarization Radar
  - Data Quality
  - Rainfall Estimation
  - Hydrometeor Classification
  - Discrimination Between Rain and Snow
  - Tornado Detection

Polarimetric Variables

1. **Reflectivity factor Z at horizontal polarization**

   - Measure of size and concentration of scatterers

2. **Differential reflectivity Z_{DR}**

   - Measure of median drop diameter

   - Useful for rain / hail / snow discrimination

3. **Differential phase Φ_{DP}**

   - Efficient for accurate rainfall estimation

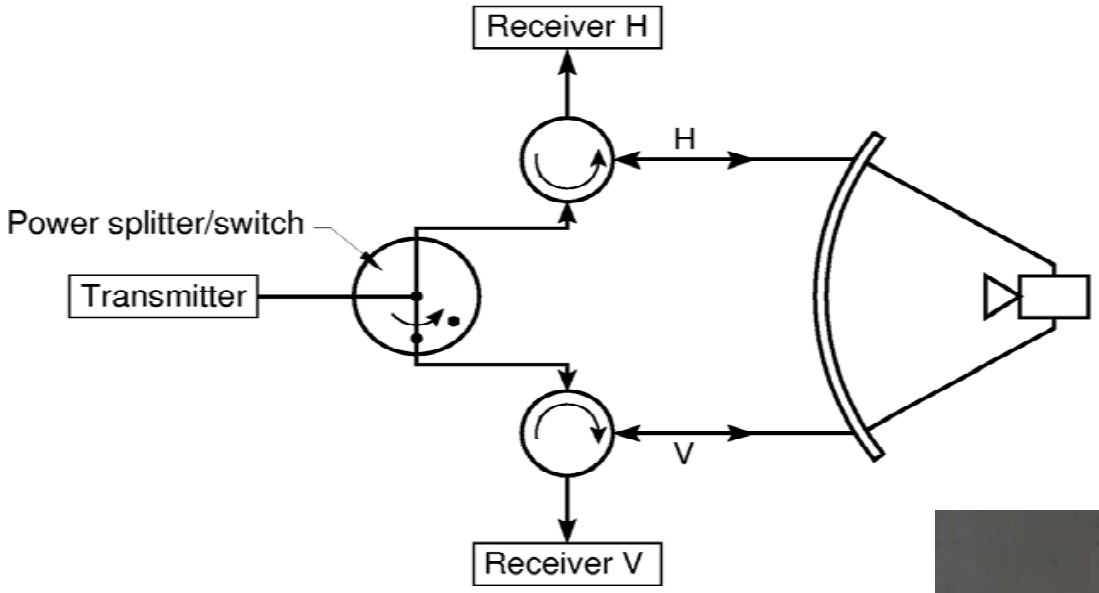
   - Immune to radar miscalibration, attenuation, and partial beam blockage

4. **Cross-correlation coefficient ρ_{hv}**

   - Indicator of mixed precipitation

   - Efficient for identifying nonmeteorological scatterers

Polarimetric Radar Configuration



New Major Components

- Dual-pol feed horn
- Dual rotary joint and associated waveguide
- Additional elevation rotary joint
- Additional identical receiver

JPOLE Objectives

April 2002 – June 2003

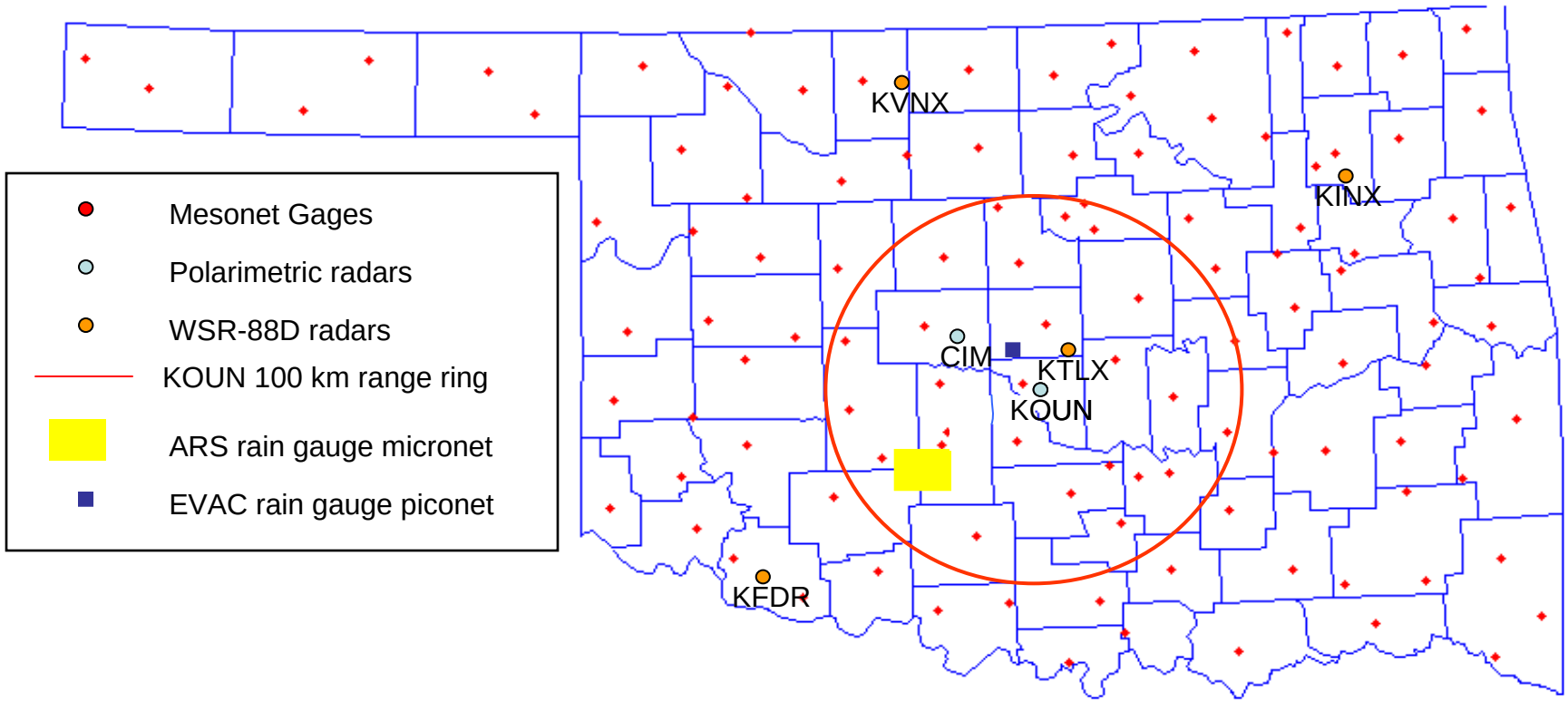
- Evaluate engineering design (simultaneous transmission, compatibility with WSR-88D, quality of multiparameter radar data)

- Evaluate the capability for classification of meteorological and nonmeteorological scatterers , hail/rain, rain/snow discrimination

- Validate the quality of rainfall measurements using two gage networks: Oklahoma Mesonet and ARS Micronet

- Deliver radar variables and products (results of classification and rainfall estimation) to the Norman NWS Office for evaluation and feedback

JPOLE Instrumentation and Dataset

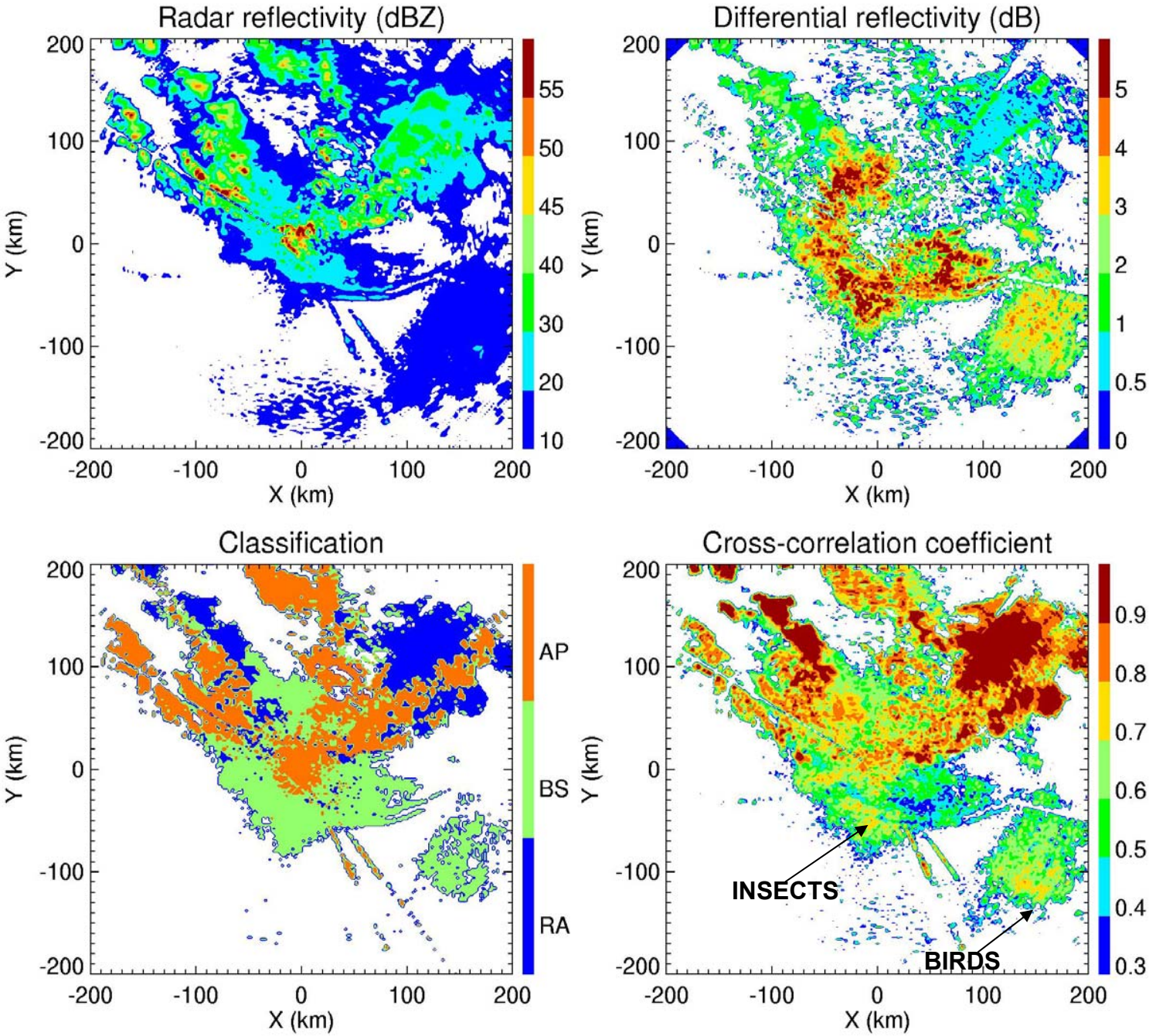


- 98 events have been observed during JPOLE
- 24 rain events (50 hours) are validated with the ARS micronet (42 gages)
- 22 rain events (83 hours) are validated with the Mesonet (108 gages)

Major Advantages of a Dual-Polarization Radar

- Improvement in Radar Data Quality
- More Accurate Rainfall Estimation
- Capability to Identify Different types of Meteorological and Nonmeteorological Scatterers

Data Quality: Identification & Filtering of Non-Meteorological Echo



Classification Legend

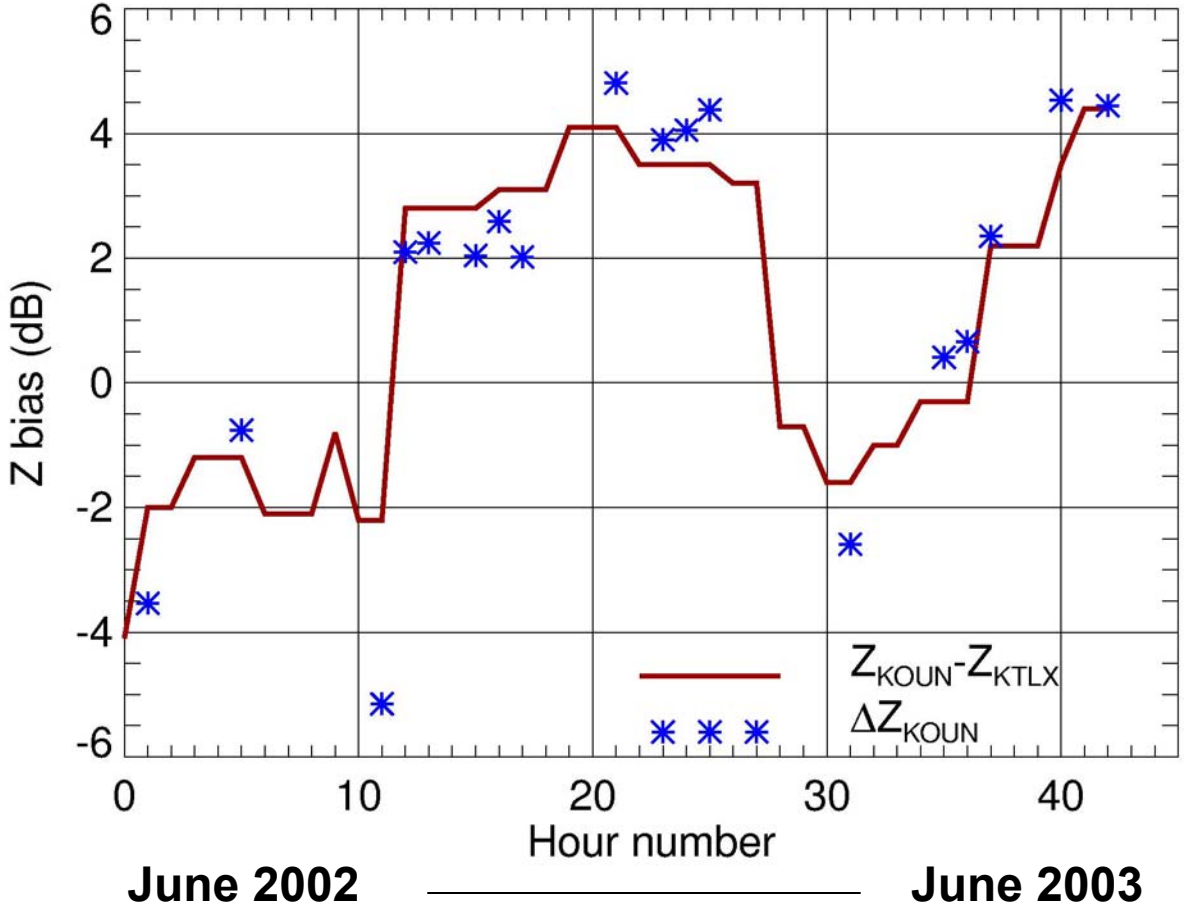
AP – Ground Clutter / Anomalous Propagation

BS – Biological Scatterers (insects, birds)

RA – Rain

Data Quality: Radar Calibration

21 days (43 hours) of observations

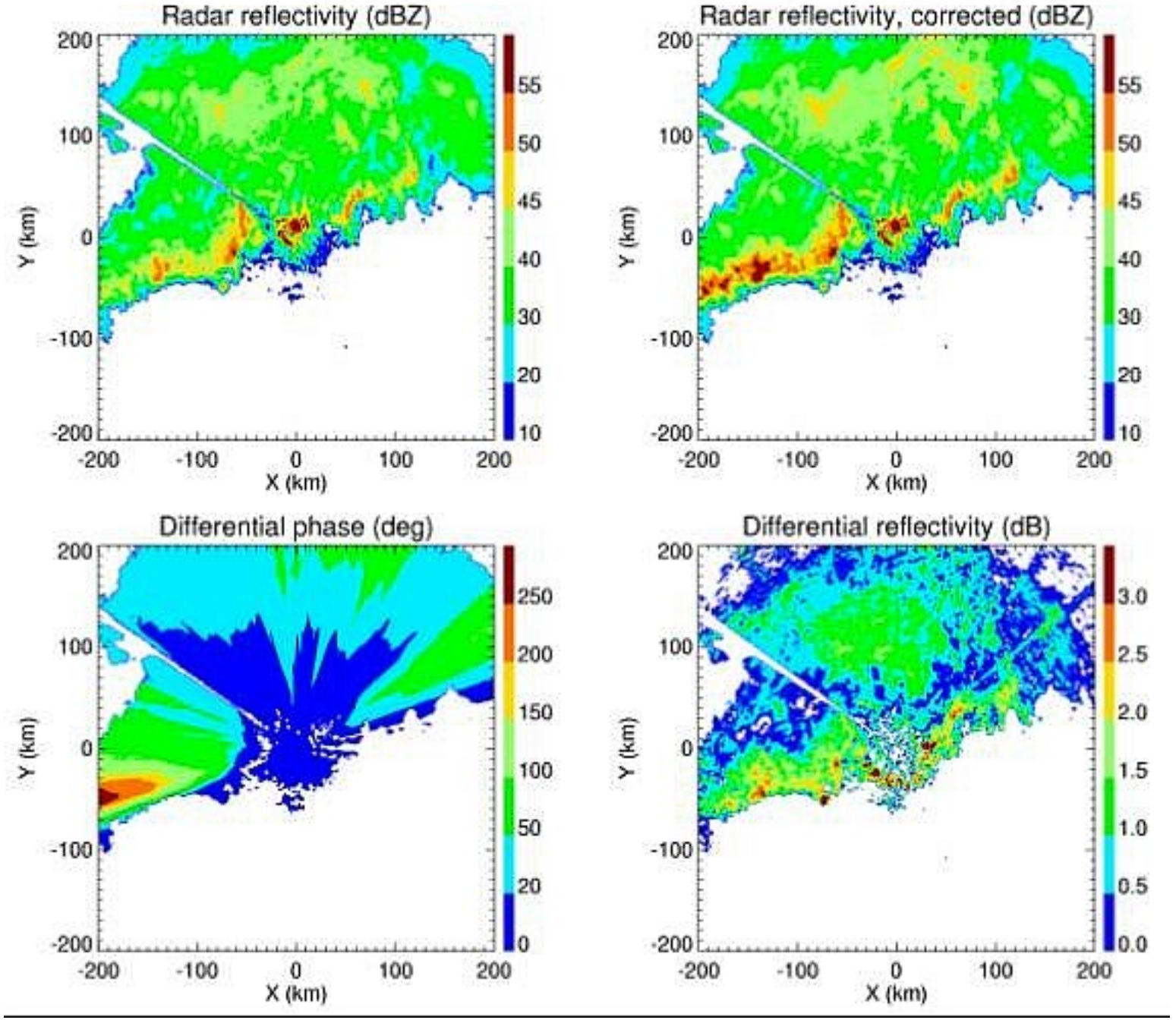


June 2002 ——— June 2003

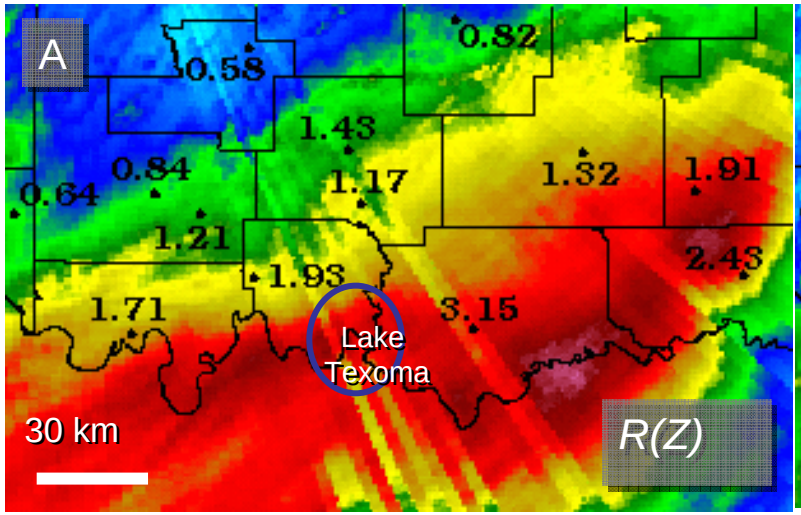
——— Direct comparisons between KOUN and KTLX

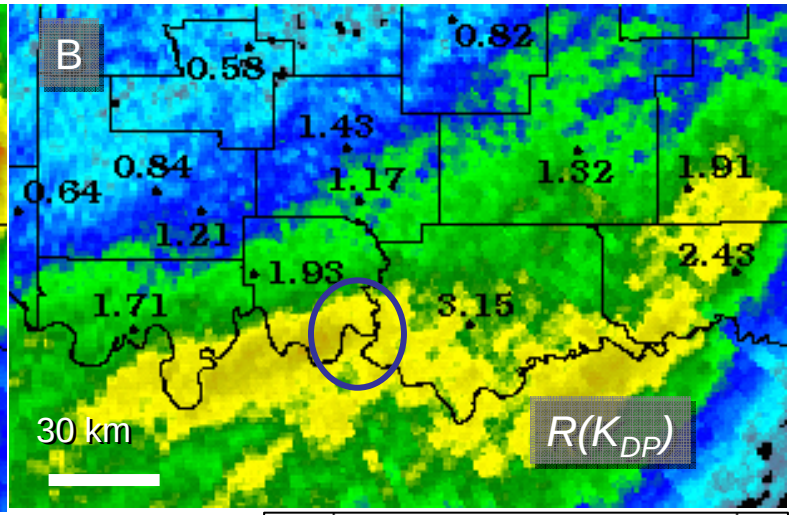
* * * * * * Polarimetric self-calibration

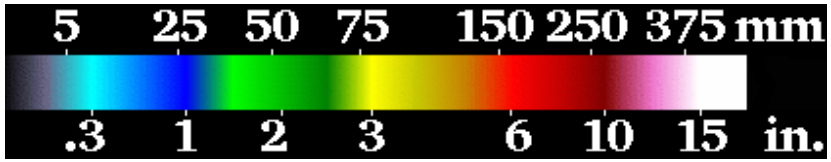
Data Quality: Correction of Radar Reflectivity for Attenuation

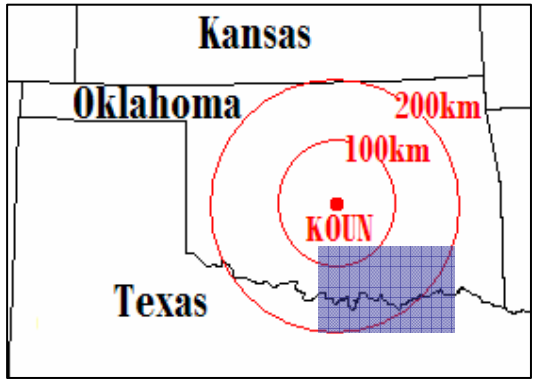


Data Quality: Partial Beam Blockage









18 – 20 October 2002

48-hour rain accumulation map from

A. conventional R(Z) relation

B. polarimetric R(K_{DP}) relation

Data Quality: A Summary

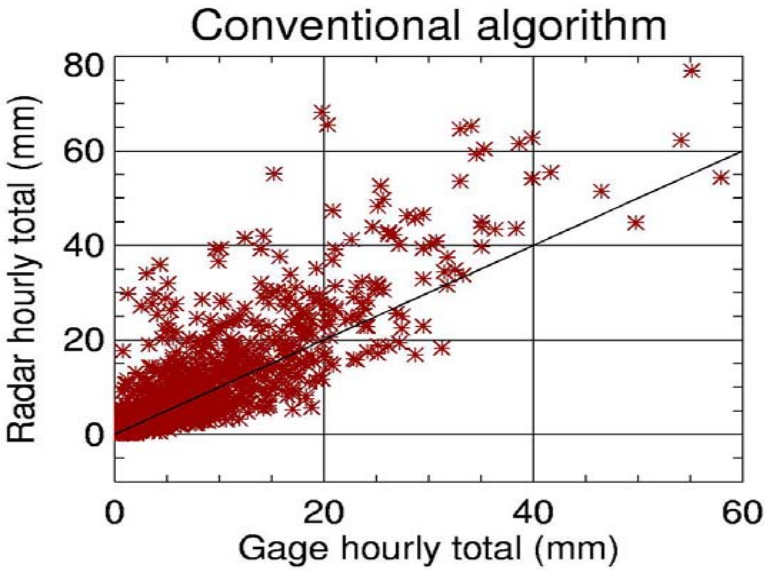
- Polarimetric classification algorithm identifies and removes about 99% of non-meteorological echoes.

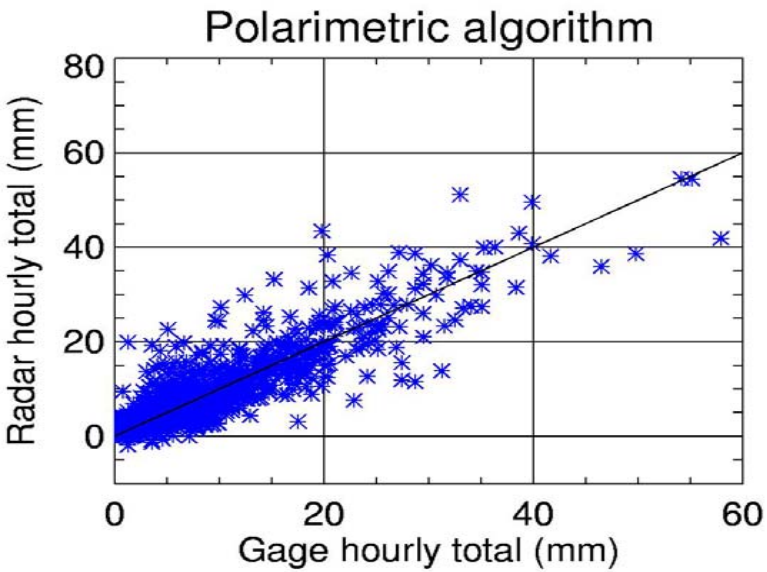
- The biases of radar reflectivity factor due to radar calibration errors, partial beam blockage, and attenuation can be substantially reduced with a polarimetric radar

- Doppler wind measurements in clear air are improved by discriminating between passive tracers of wind and turbulence (mostly insects) and scatterers that contaminate the retrieved wind profiles (mostly birds)

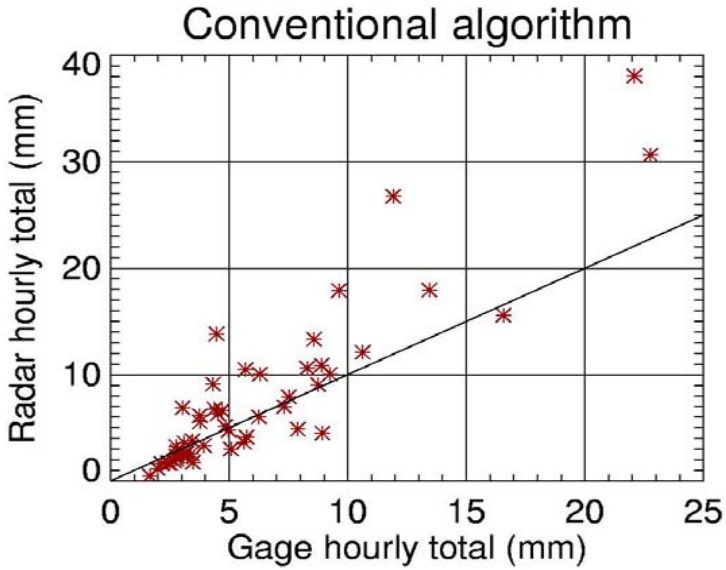
Polarimetric Rainfall Estimation

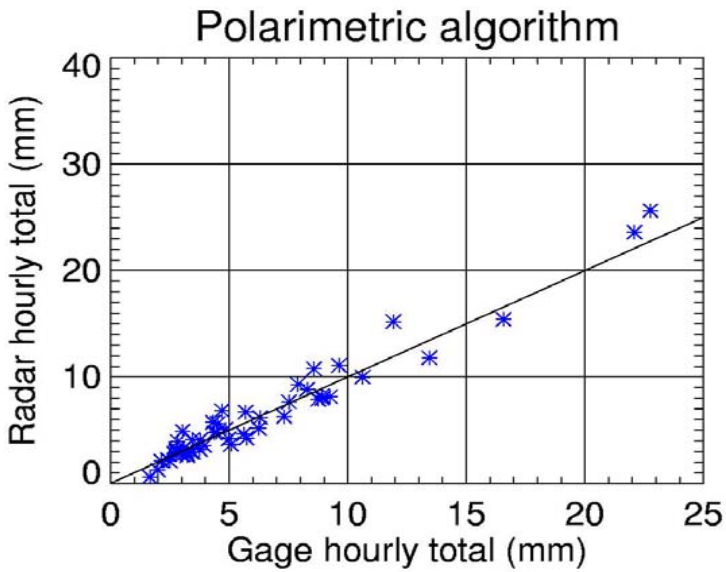
Point Estimates



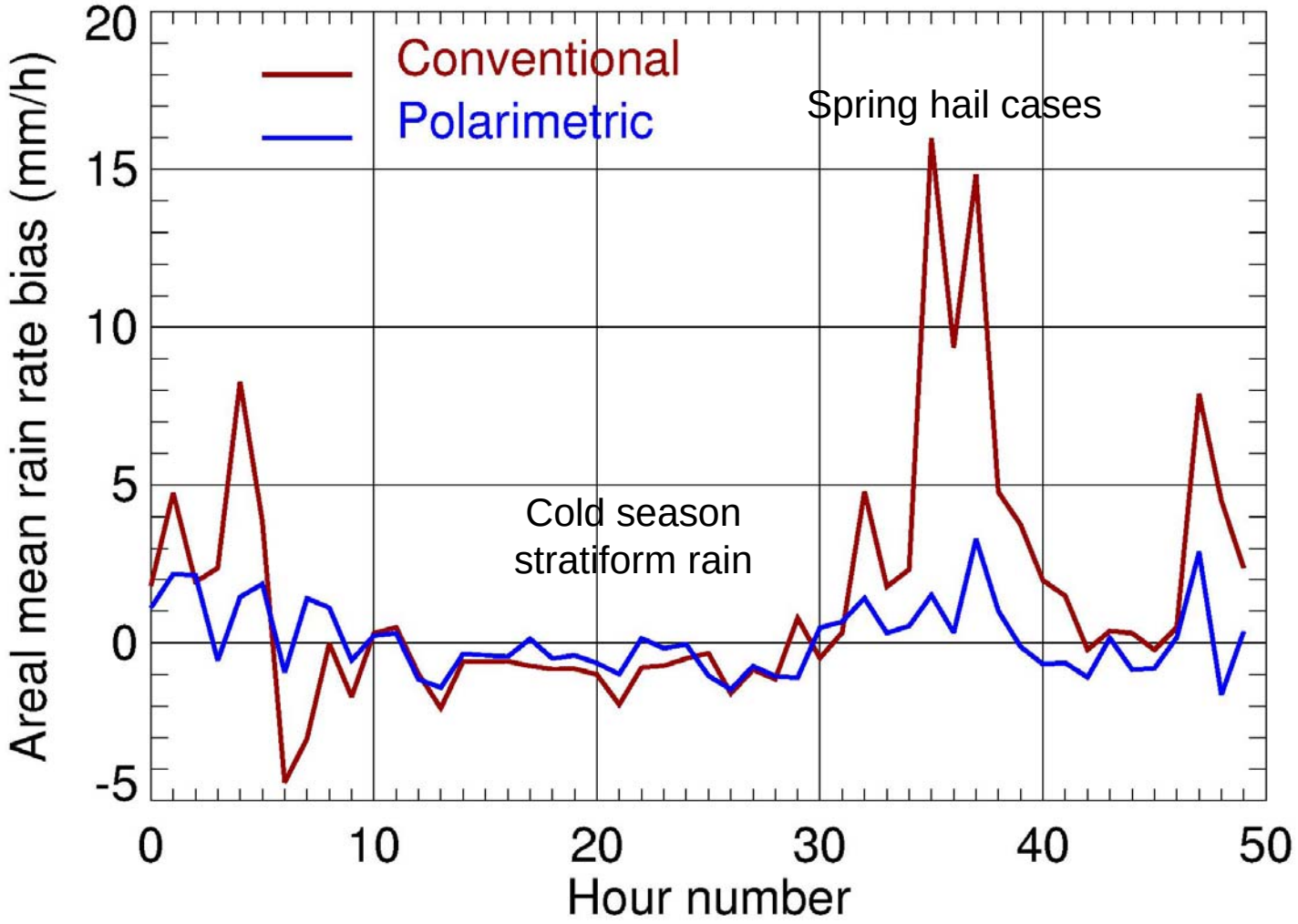


Areal Estimates





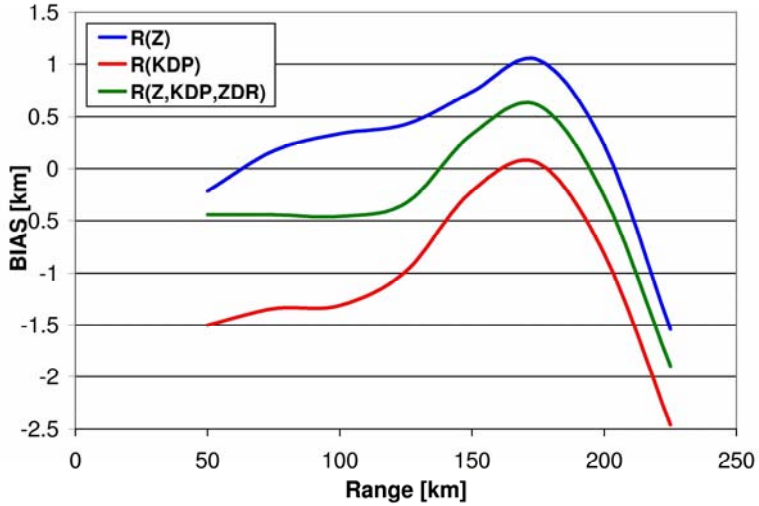
Polarimetric Rainfall Estimation

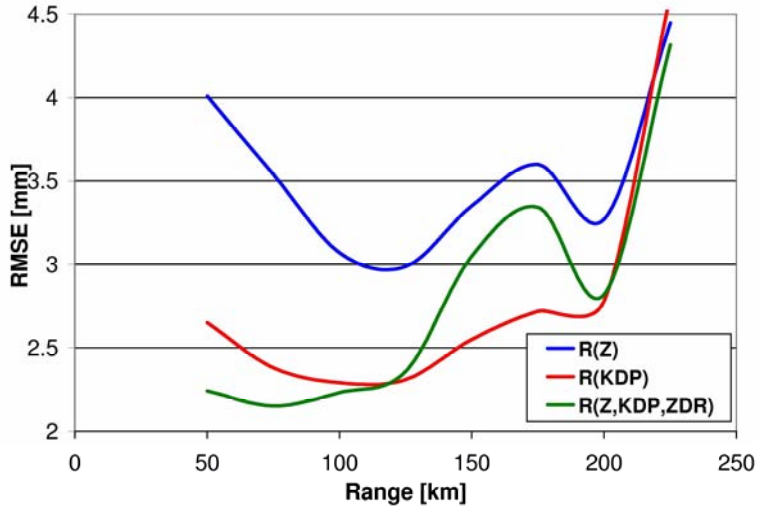


The bias in areal rain rates estimated from radar using conventional and polarimetric algorithms

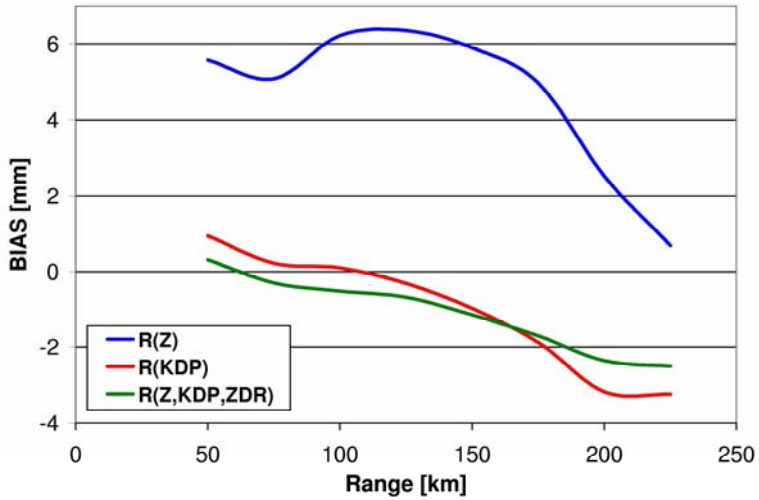
The Quality of Rainfall Estimation as a Function of Range

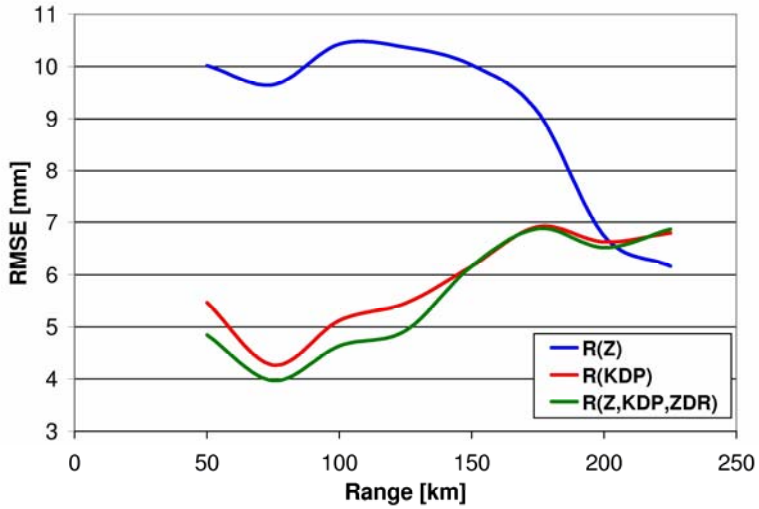
“Cold season” events





“Warm season” events





Polarimetric Rainfall Estimation: Summary

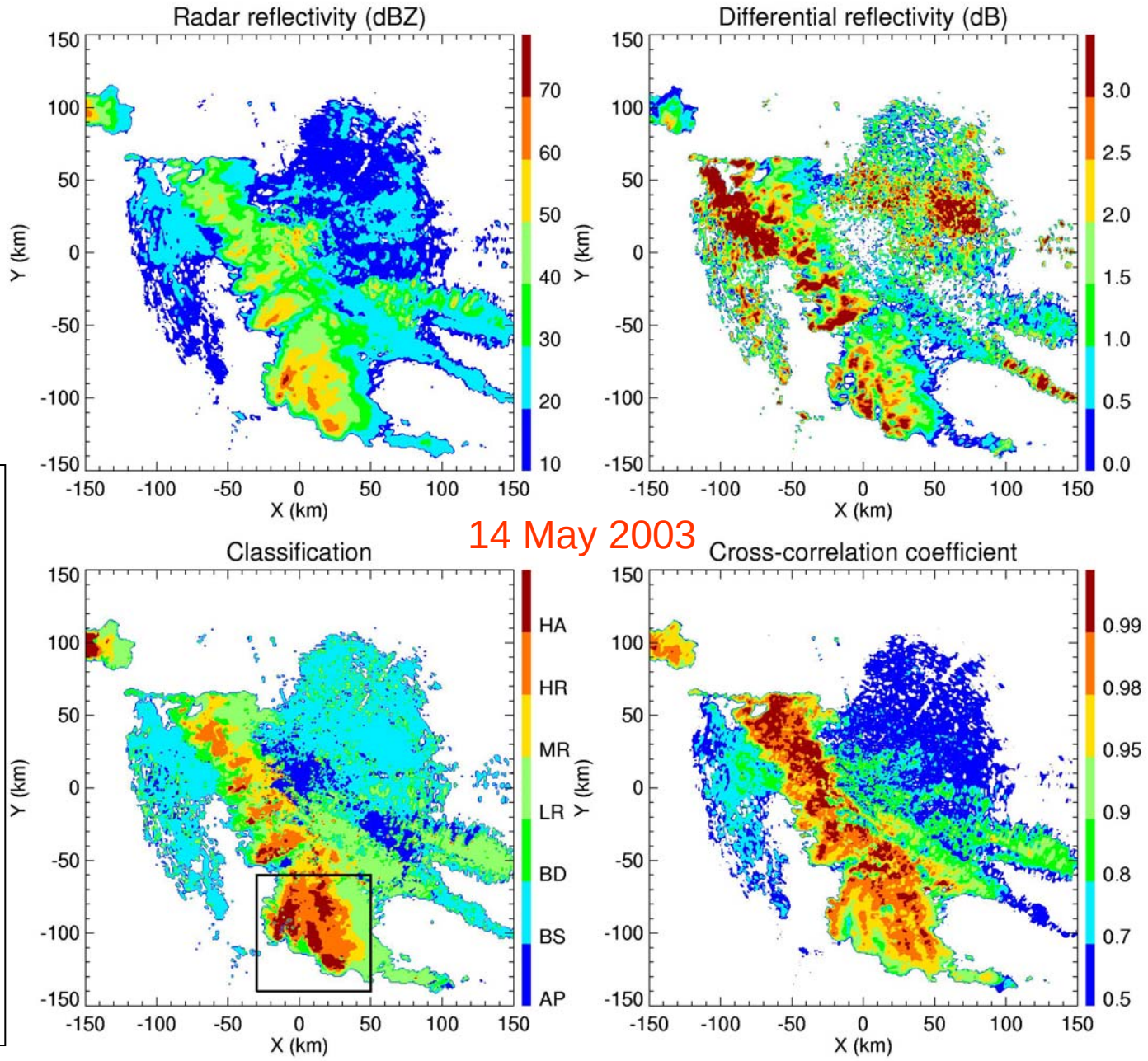
• Conventional and polarimetric rainfall estimation algorithms have been validated using 108 Oklahoma Mesonet and 42 ARS Micronet gages during JPOLE.

• The polarimetric algorithm outperforms the conventional one in terms of bias and RMS error. The RMS error of the one-hour total estimate is reduced 1.7 times for point measurements and 3.7 times for areal rainfall estimates.

• Most significant improvement is achieved in areal rainfall estimation and in measurements of heavy precipitation (often mixed with hail).

• The polarimetric method is more robust with respect to radar calibration errors, beam blockage, attenuation, DSD variations, and presence of hail than the conventional R(Z) method.

Hydrometeor Classification: Hail Detection



Classification Legend

HA – Hail / Rain

HR – Heavy Rain

MR – Moderate Rain

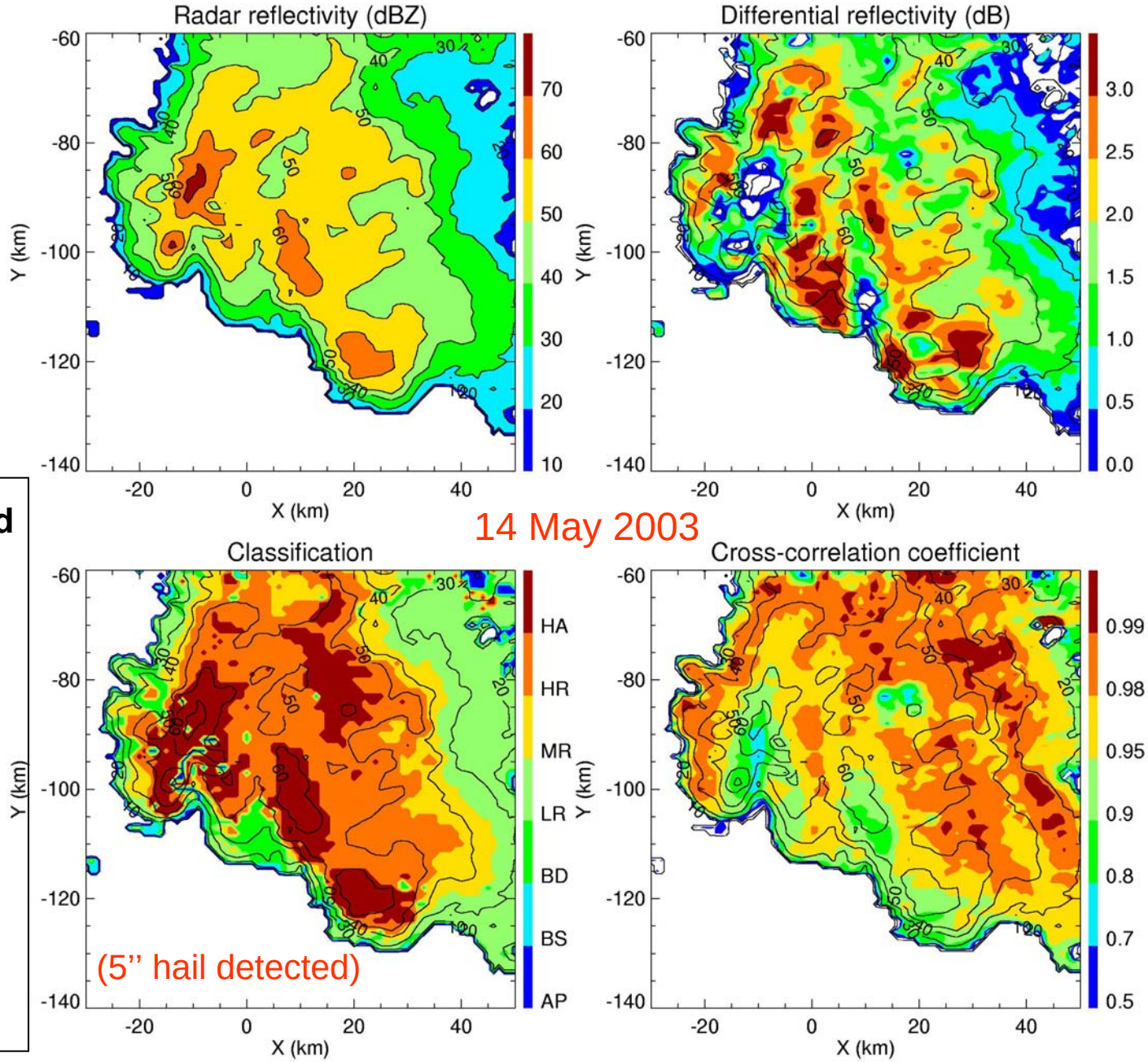
LR – Light Rain

BD – 'Big Drops'

BS – Biological Scatterers

AP – Ground Clutter/ Anomalous Propagation

Hydrometeor Classification: Hail Detection



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Hail Detection: A Summary of Validation during JPOLE

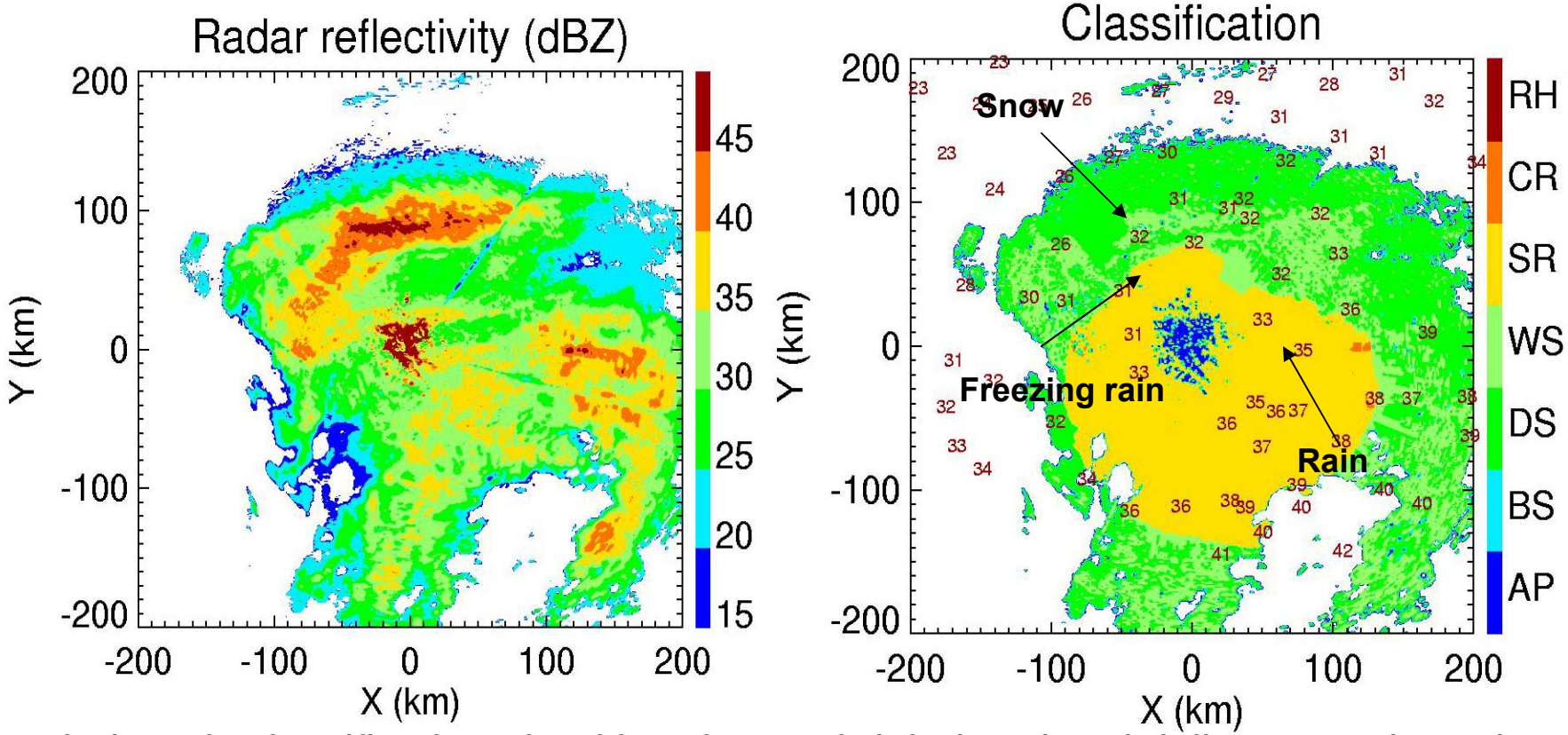
- Hail Detection Statistics
  - Conventional Hail Detection Algorithm

    POD=88%, FAR=39%, CSI=0.56
  - Polarimetric Hail Detection Algorithm

    POD=94%, FAR=8%, CSI=0.86
- Conventional method provides probability of hail in a storm, whereas polarimetric algorithm determines location of hail within the storm

Discrimination between Rain and Snow

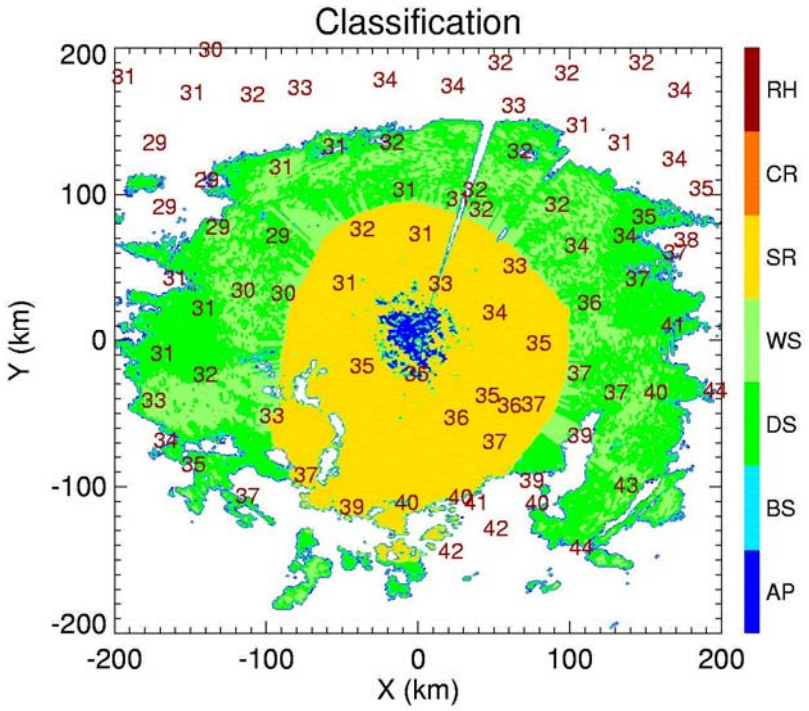
Freezing rain on 4 December 2002, El =0.5°, numbers indicate surface temperatures (F°)



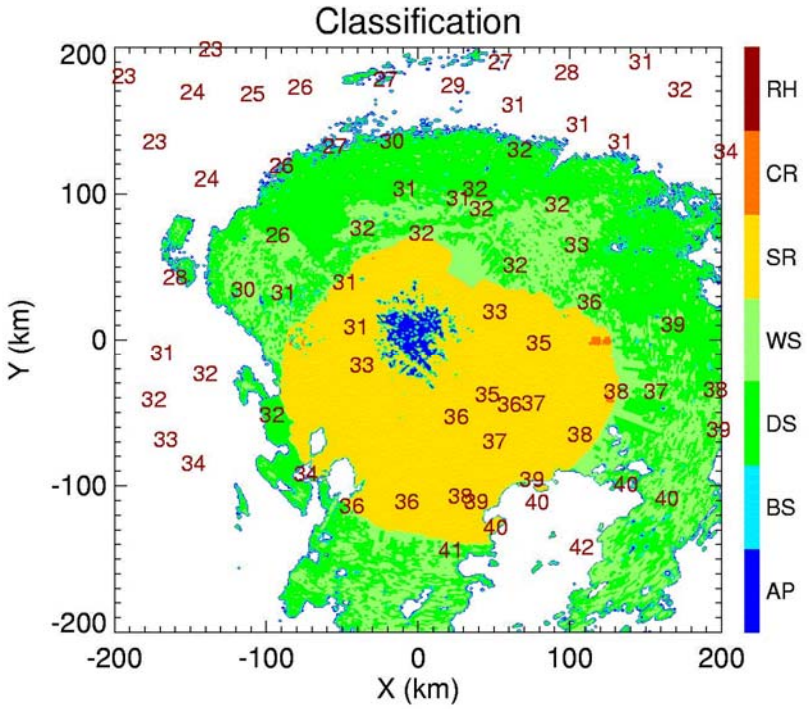
- Polarimetric classification algorithm detects bright band and delineates rain and snow
- Combined use of polarimetric data and surface temperatures identifies freezing rain
- Discrimination between rain and snow at the lowest scan is necessary to correctly estimate amounts of precipitation (liquid or frozen)

Evolution of rain / snow boundary for the freezing rain event on 3 – 4 December 2002

12/03/02 1803 UTC



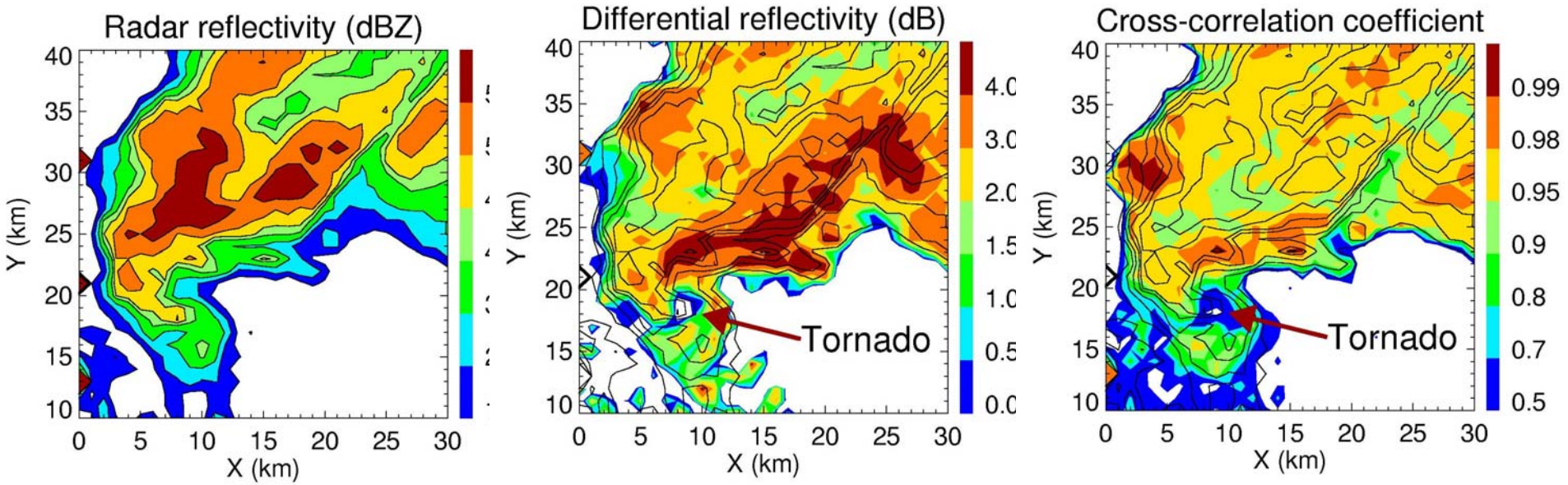
12/04/02 0302 UTC



El = 0.5°, overlaid numbers indicate surface temperatures (°F)

Polarimetric Tornado Detection

Oklahoma City tornado on 8 May 2003



Tornadic debris has distinct polarimetric signature

Summary

- Basic concepts of meteorological applications of polarimetric radars have been developed during more than 20 years of research studies at NSSL and other organizations
- The polarimetric NEXRAD proof-of –concept was tested on the KOUN WSR-88D radar during JPOLE project in Oklahoma
- Validation of rain measurements using two gage networks shows substantial improvement if a polarimetric method is applied
- Unique ability of dual-polarization radar to classify radar echoes proved to be very advantageous for data quality improvement, identification of hail, discrimination between snow and rain, and tornado detection.
- All benefits of polarization diversity are realized without compromising existing functions of the WSR-88D radars
- Assimilation of polarimetric radar data into numerical models will enhance the quality and value of predictions of hazardous weather events