Radar Meteorology

*The **application of radar** to the **study of the atmosphere**, and to the **observation and prediction of weather**.*

NSSL Doppler Radar

Cimarron dual-polarized radar

Dual-polarized WSR-88D

Phased Array Weather Radar

CLAMPS

Pam Heinselman
NOAA NSSL, former CIMMS Research Scientist (Jan 1995- Feb 2009)


RADAR
DATA
LIGHTNING
MOBILE
STORM
SUPERCELL
DOPPLER
OBSERVATIONS
DUAL
VORTEX2
WIND
TWO
ANALYSES
WEATHER
FIELD
BAND
REFLECTIVITY
MICROPHYSICAL
THUNDERSTORMS
THUNDERSTORM
TORNADIC
TORNADOES
CHARACTERISTICS
DISDROMETER
ASSIMILATION
RESULTS
INSTRUMENTATION
APPROACH
POLARIMETRIC
RELATIONSHIPS
VERIFICATION
OCCURRED
NEAR
RING
ENKF
MAY
DEPLOYED
ROTATION
WELL
ALSO
GROUND
RADARS
NOXP
STORM
SCHEME
STUDY
REVIEW
ELECTRIFICATION
ORIGINS
MOBILE
NATIONAL
PERIOD
ACTIVITY
DIFFERENTIAL
COLLECTED
AMONG
CLUTTER
BIGGERSTAFF
OBSERVATIONAL
SECOND
SCALE
KINEMATIC
APPLIED
HYDROMETEOR
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TORNADOES
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COMPARED
ELECTRICAL
DOI:10
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EXPERIMENT
ATTENUATION
DIFFERENT
SINGLE
ATMOSPHERIC
STORMS
REGION
LIGHTNING
UTC
ELECTRIFICATION
RADAR
TELEX
WSR


RADAR
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MODEL
POLARIMETRIC
DIRECTION
SCHEME
GRADIENTS
WEATHER
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OBSERVED
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HOWEVER
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FUNCTION
SPLITTING
FORECASTING
ADAPTATION
POWER
GEOSCIENCE
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MAGNITUDE
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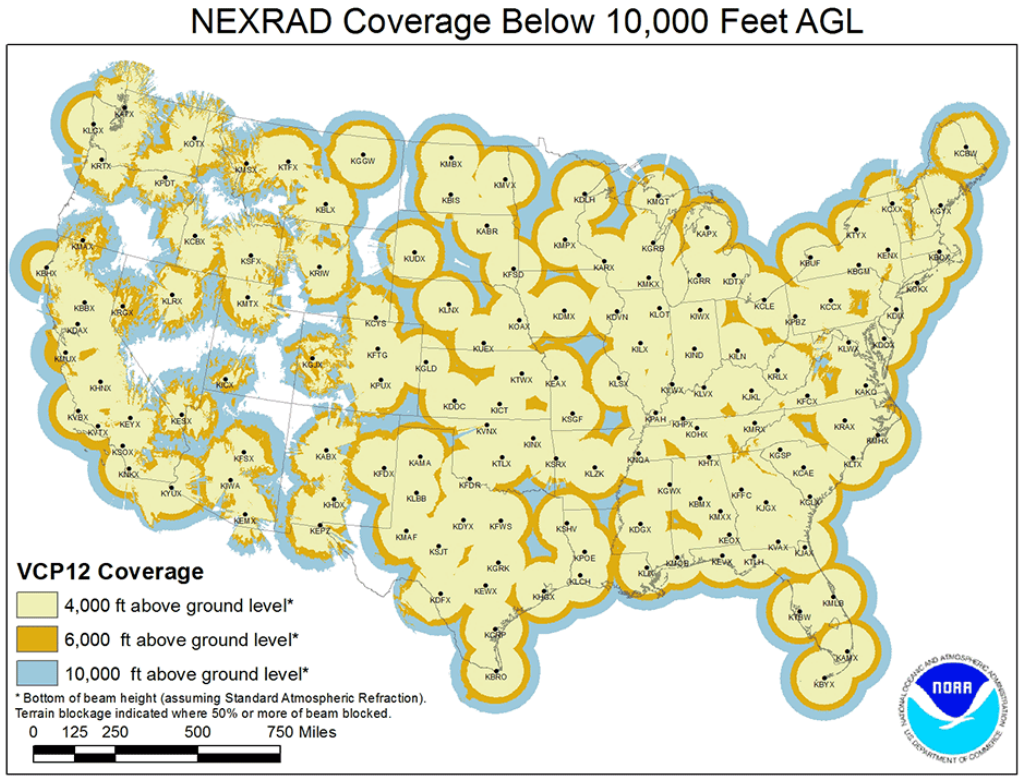
GIVEN
TORNADOES

WSR-88D Network Installation: Set the stage for CIMMS Research

National opportunity to study the atmosphere and improve weather prediction

1995 Gold Medal

National Severe Storms Laboratory, for “achieving scientific and technical breakthroughs leading to the continuous improvements in the national network of Doppler radars (WSR-88D).”



Verification of the Origins of Rotation in Tornadoes Experiment: VORTEX

Rasmussen (1994, BAMS)

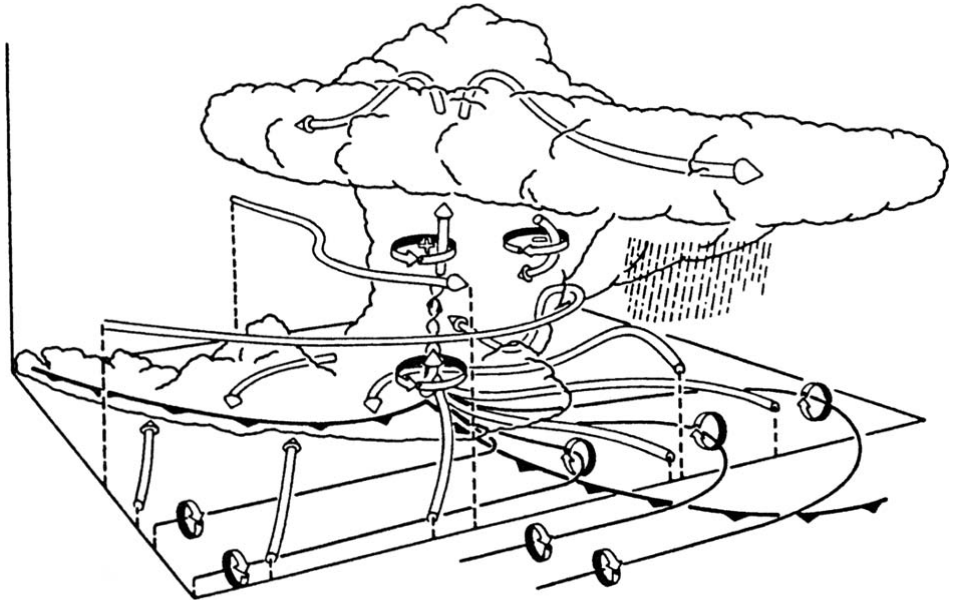
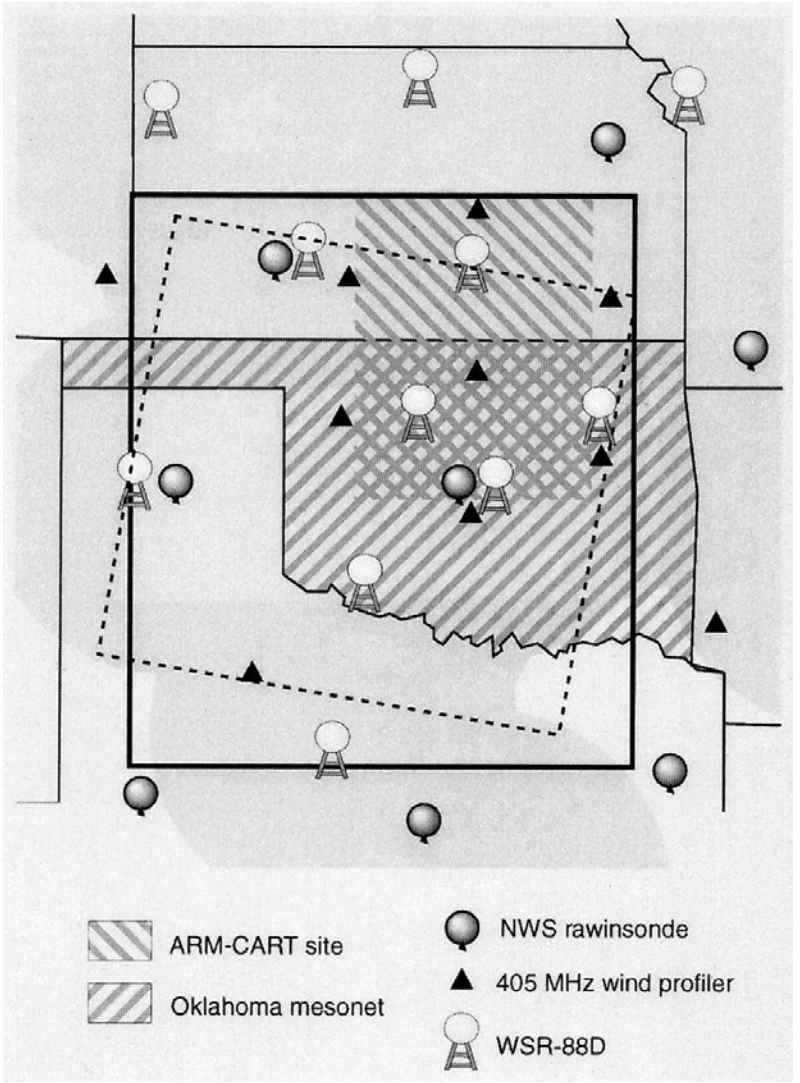


FIG. 1. (a) Schematic model of the processes hypothesized to be important in generating baroclinic vorticity leading to tornadogenesis in a supercell (from Klemp 1987): "The storm is evolving in westerly environmental wind shear and is viewed from the southeast. The cylindrical arrows depict the flow in and around the storm. The thick lines show the low-level vortex lines, with the sense of rotation indicated by the circular-ribbon arrows. The heavy barbed line marks the boundary of the cold air beneath the storm." (Reproduced with permission from the *Annual Review of Fluid Mechanics,* Volume 19. ©1987 Annual Reviews, Inc.)



Rasmussen joins CIMMS in 1994

Plus: P-3, ELDORA, portable radars

Use of WSR-88D data, VORTEX 1, VORTEX 2, and other field programs lead to improved understanding of severe storm processes

Tornadogenesis with and without a dynamic pipe effect

Tornadoes and tornadic storms

A preliminary survey of rear-flank descending reflectivity cores in supercell storms

Total Lightning Observations and Tools for the 20 May 2013 Moore, Oklahoma, Tornadic Supercell

The Bow-Echo and MCV experiment (BAMEX): Observations and Opportunities.

Verification of the Origins of Rotation in Tornadoes Experiment 2: VORTEX2

Design and deployment of a portable, pencil-beam, pulsed Doppler radar

The evolution of low-level rotation in the 29 May 1994 Newcastle-Graham, Texas storm complex during VORTEX

The Association of Significant Tornadoes with a Baroclinic Boundary on 2 June 1995

The initiation of moist convection at the dryline: Forecasting issues from a case study perspective

Influences of the Local Environment on Supercell Cloud-to-Ground Lightning, Radar Characteristics, and Severe Weather on 2 June 1995

Automated detection of the bright band using WSR-88D radar data

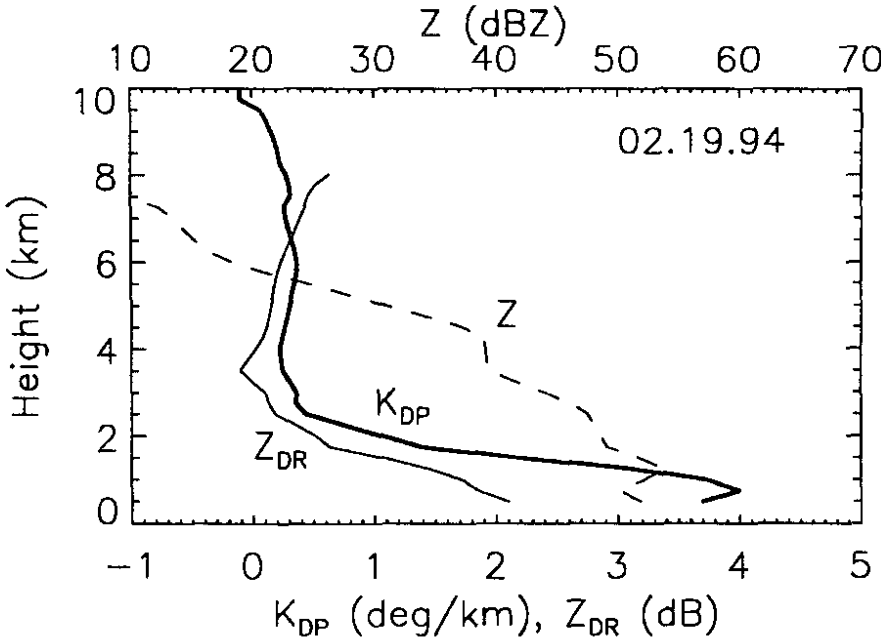
Doppler Radar Observations of Anticyclonic Tornadoes in Cyclonically Rotating, Right-Moving Supercells

Cimarron Dual-polarization Radar

Rain in Shallow and Deep Convection Measured with a Polarimetric Radar

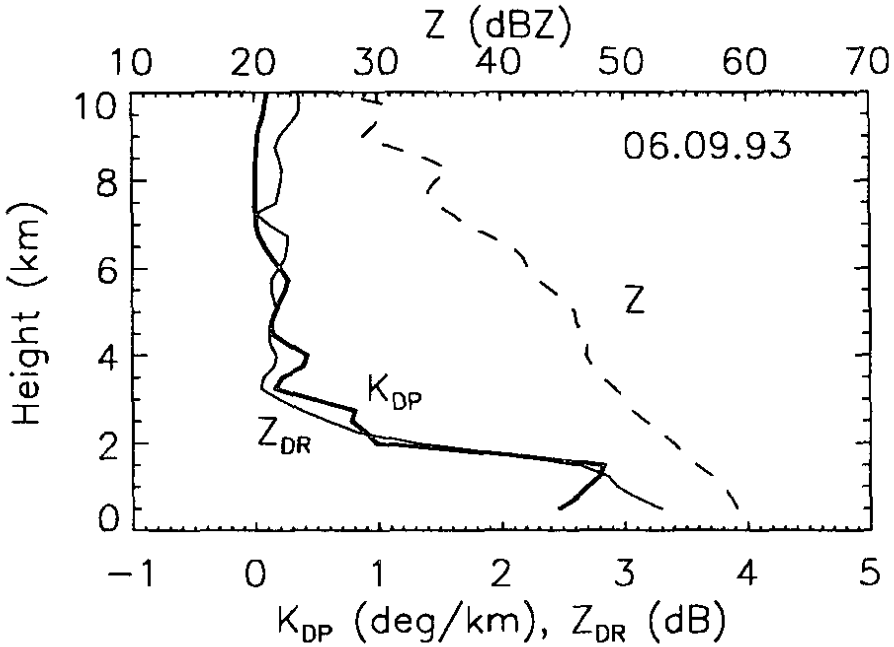
Ryzhkov and Zrnic (1996, JAS)

Shallow Convection

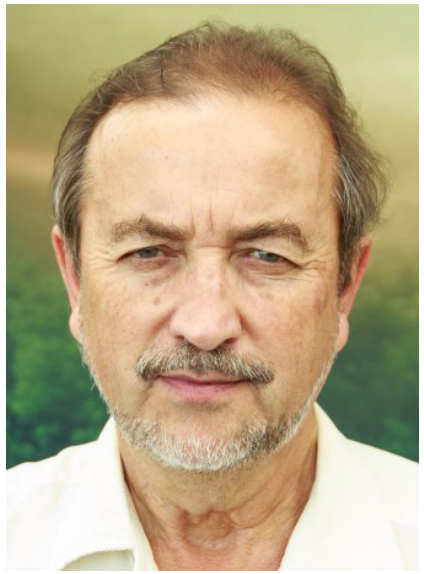


Large number of small drops near the ground ($K_{DP} > Z_{DR}$)

Deep Convection



Presence of large drops near the ground ($Z_{DR} > K_{DP}$)



Ryzhkov joins CIMMS in 1996

Rainfall estimates using $R(K_{DP})$ were more accurate than rainfall estimates using R(Z)

Selling Point: Improved Rainfall Estimation

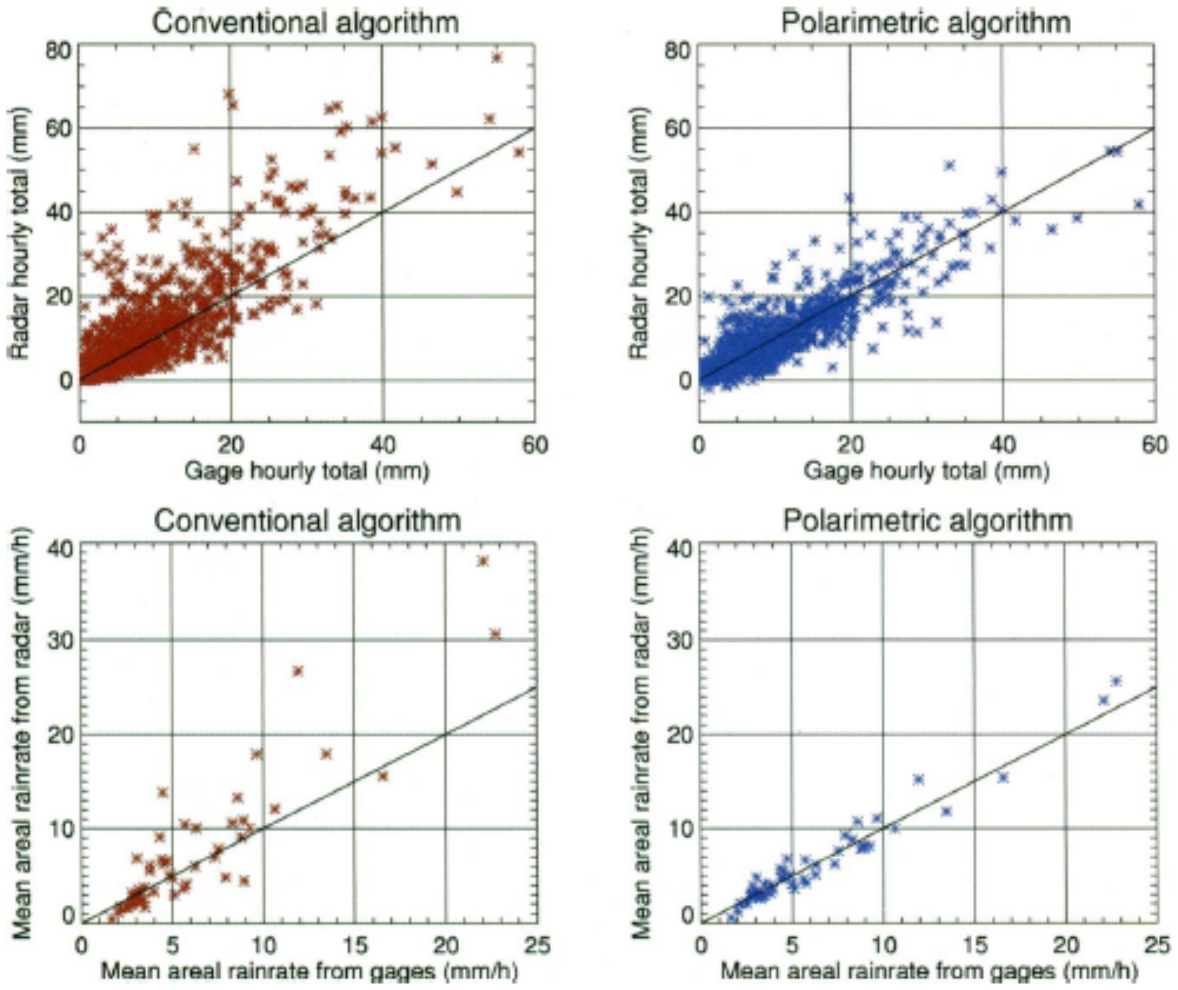
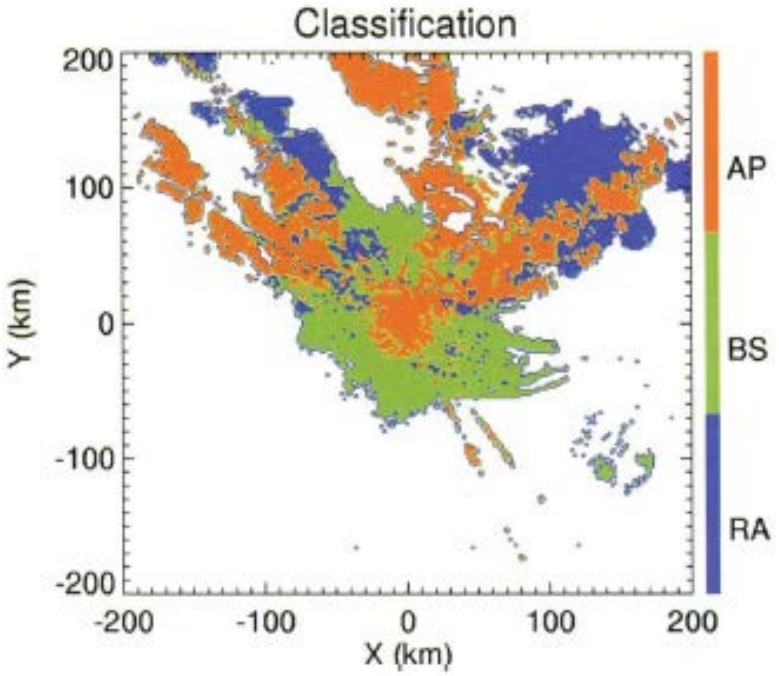


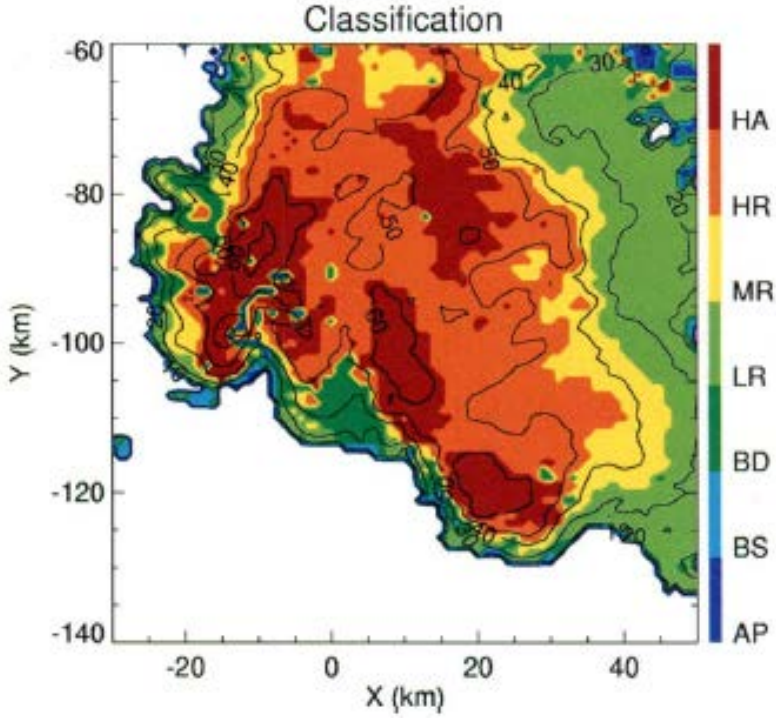
FIG. 2. (top) One-hour accumulations and (bottom) mean areal rain rates from gauges vs their estimates from the $R(Z)$ and $R(Z, K_{DP}, Z_{DR})$ algorithms (24 rain events, 50 h of observations). Ryzhkov et al. 2005 (BAMS)

Other goodies…

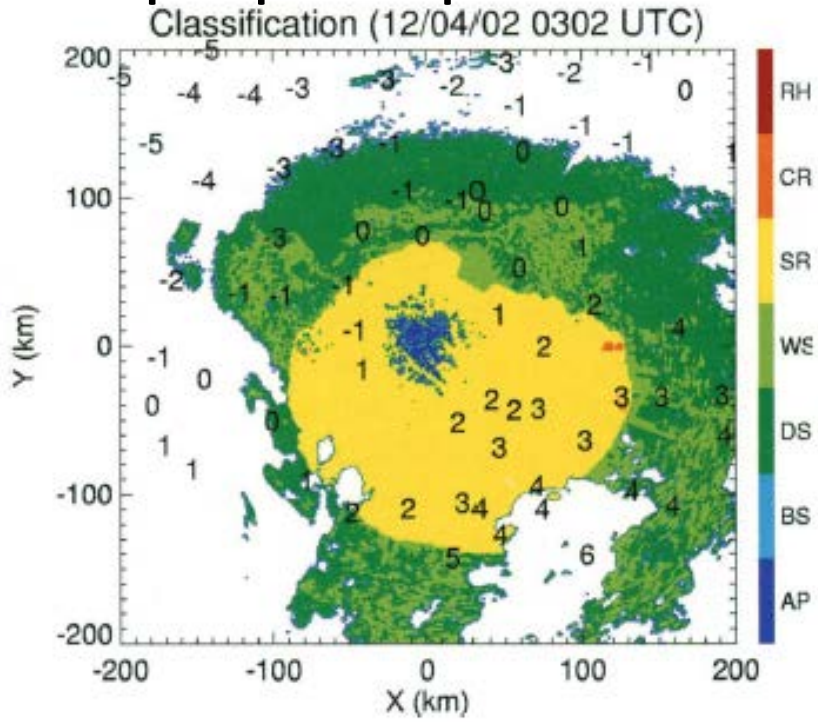
Improved Data Quality



Identification of hail and rainfall intensity



Identification of winter precipitation particles



2014 Gold Medal

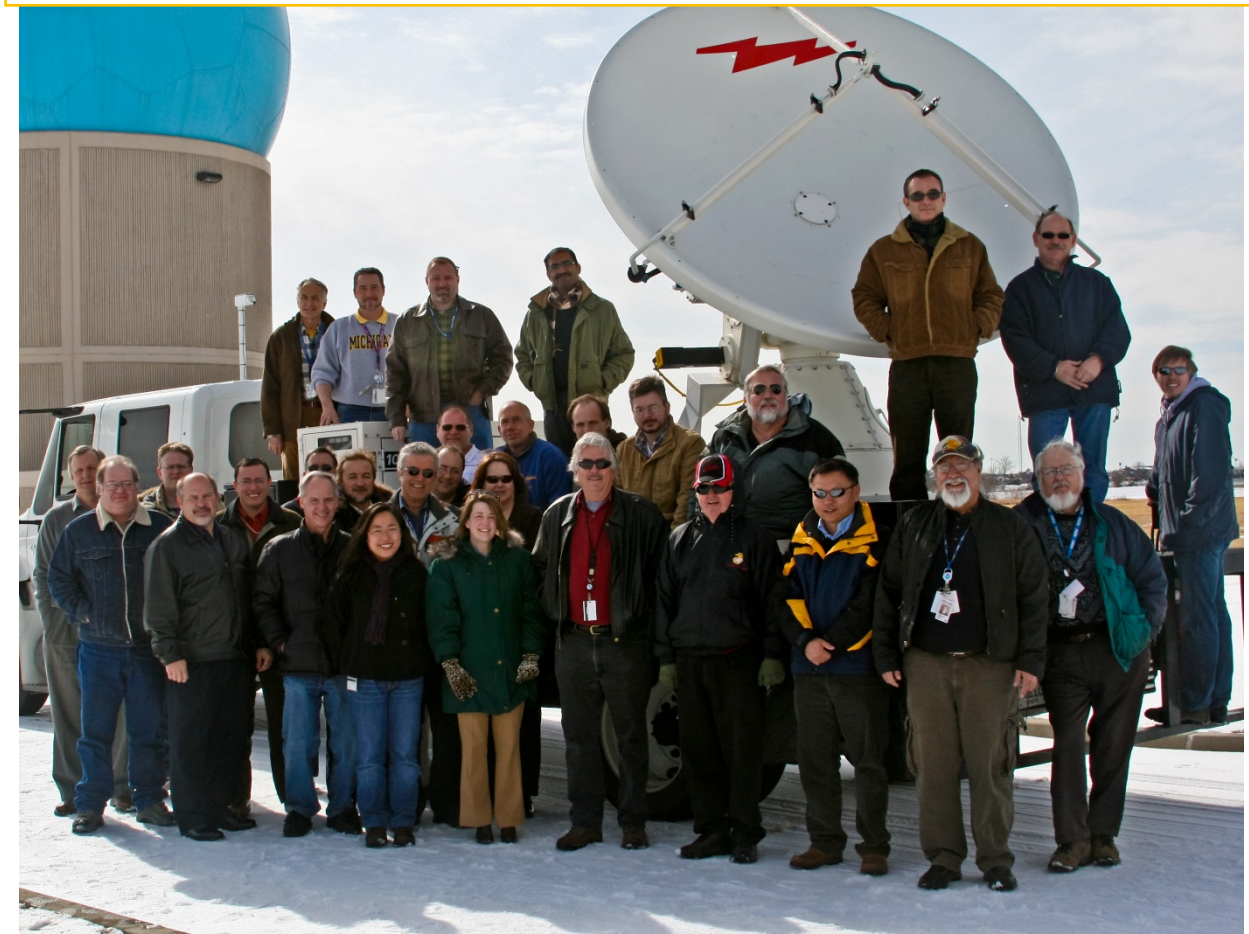
Office of Science and Technology, Office of Operational Systems, Office of Climate, Water and Weather Services, and **National Severe Storms Laboratory**, for "*developing and implementing Dual-Polarization technology on the Next Generation Weather Radar network to improve weather hazards warning services*."

Ryzhkov et al. 2005 (BAMS)

RRDD folks who made the National Weather Radar Testbed Possible

2011 Gold Medal

NSSL/CIMMS Radar Research and Development Division, for "scientific and engineering excellence in adapting military phased array radar technology to improve U.S. weather radar capabilities."

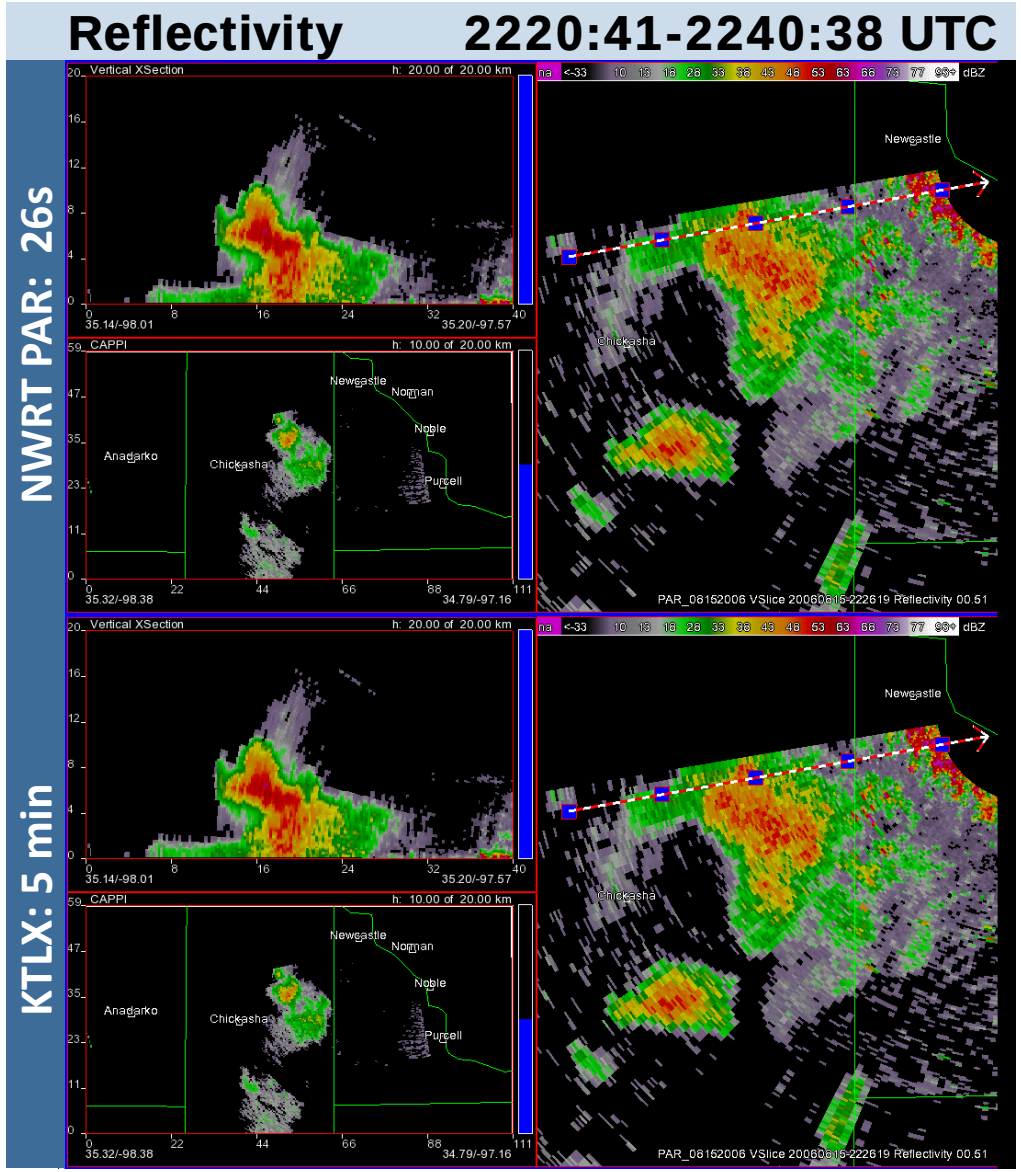


Phased Array Radar Meteorological Research

Q: Does rapid, adaptively scanned radar data improve understanding of severe weather processes?

Q: If so, can this information be used to produce more accurate and timely warnings?

Science: Temporal Sampling Matters



Heinselman, P. L., D. L. Priegnitz, K. L. Manross, T. M. Smith, and R. W. Adams, 2008: Rapid sampling of severe storms by the National Weather Radar Testbed Phased Array Radar. *Wea. Forecasting*, **23**, 808–824.

Heinselman and Torres 2011: High-temporal-resolution capabilities of the National Weather Radar Testbed phased-array radar. *J. Appl. Meteor. Climatol.*, **50**, 579–593.

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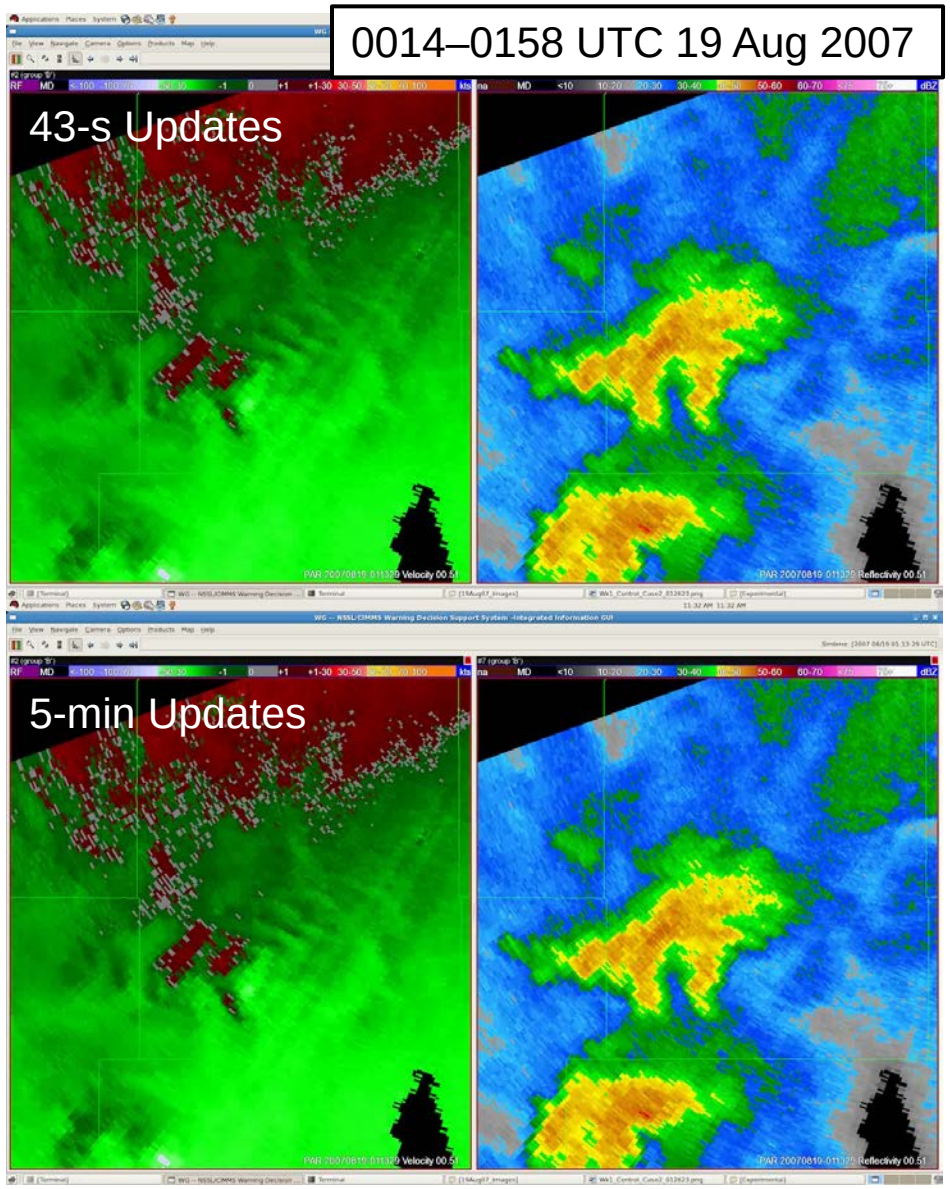
Newman and Heinselman 2012: Evolution of a quasi-linear convective system sampled by phased array radar. *Mon. Wea. Rev.,* **140**, 3467–3486.

Tanamachi, R. L., P. L. Heinselman, L. J. Wicker, 2015: Impacts of a storm merger on the 24 May 2011 El Reno, Oklahoma tornadic supercell. *Wea. Forecasting*, **30**, 501–524.

Kuster, C. M., P. L. Heinselman, and T. J. Schuur, 2016: Rapid-update radar observations of downbursts occurring within an intense multicell thunderstorm on 14 June 2011.

Operations: Temporal Sampling Matters



LaDue et al. 2010: Strengths and limitations of current radar systems for two stakeholder groups in the Southern Plains. *Bull. Amer. Meteor. Soc.*, **91**, 899–910.

Heinselman et al. 2012: Exploring impacts of rapid-scan radar data on NWS decisions. *Wea. Forecasting*, **27**, 1031–1044.

Heinselman, P., D. LaDue, D. M. Kingfield, and R. Hoffman, 2015: Tornado warning decisions using phased array radar data. *Wea. Forecasting*, **30**, 57–78.

Bowden et al. 2015: Impacts of phased array radar data on forecaster performance during severe hail and wind events. *Wea. Forecasting*, **30**, 389–404.

Kuster, C. M., P. L. Heinselman, and M. Austin, 2015: 31 May 2013 El Reno Tornadoes: Advantages of rapid-scan phased array radar data from a warning forecaster's perspective. *Wea. Forecasting*, **30**, 933–956.

Bowden, K. A, and P. L. Heinselman, 2016: A qualitative analysis of NWS forecasters' use of phased-array radar data during severe hail and wind events. *Wea. Forecasting*, **31**, 43–55.

Bowden, K. A., P. L. Heinselman, and Z. Kang, 2016: Exploring applications of eye-tracking in operational meteorology research. *Bull. Amer. Meteor. Soc.*, e-View doi: http://dx.doi.org/10.1175/BAMS-D-15-00148.1

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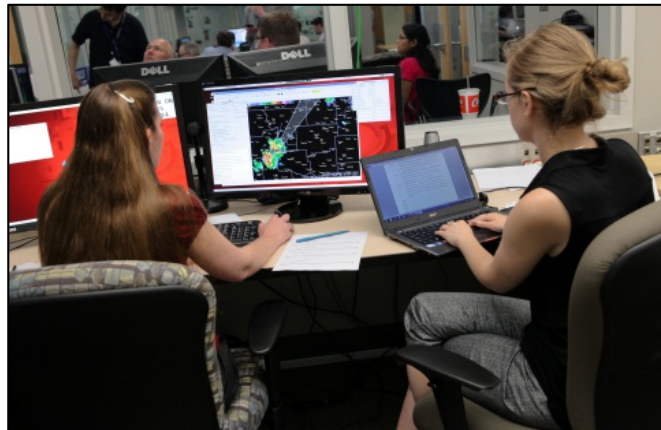
Overall Results

In the cases examined, 1-min updates provide more detailed information about storm processes that:

1) *advance scientific understanding and*
2) *improve forecasters' situational awareness,*

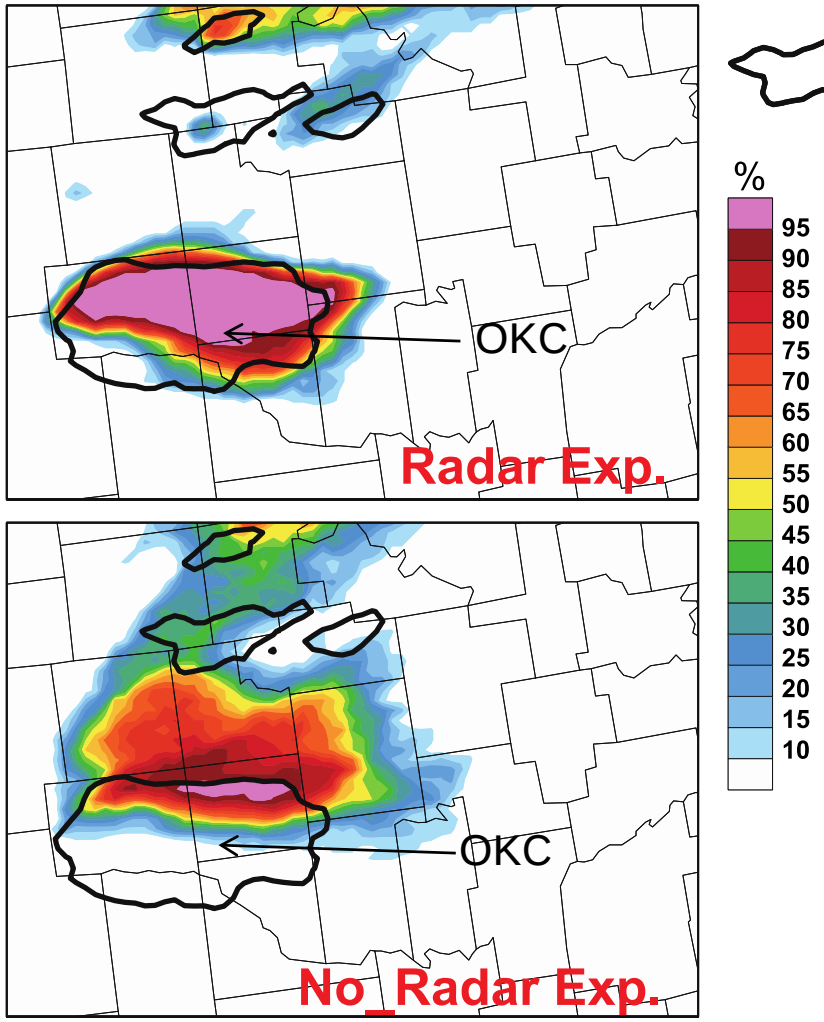
ability to make mastery decisions, and performance in terms of severe and tornado warning lead times, POD, and FAR



Warn-on-Forecast:

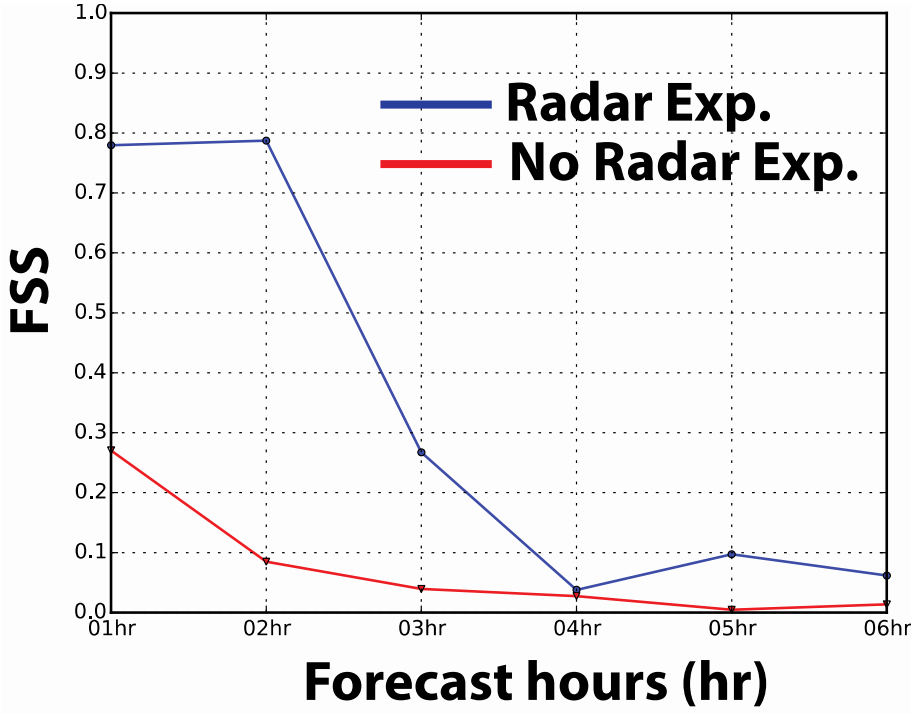
Radar Data Matters

Prob. of 0-3 h PQPF > 25 mm



Stage-IV 25 mm rainfall contour

Fractional Skill Score (FSS)



Higher FSS scores are better

Credit: Yussouf

What next?

- Late night data collection. 
- Development of data collection experiments to advance understanding of in-storm microphysics and microphysical processes, how they relate to storm dynamics, thermodynamics, and specific weather hazards (lightning, extreme rainfall, hail, wind, and tornadoes).
- Surprise discoveries 
- Development of techniques:
  - QC for observational and numerical modeling studies
  - Forward operators for dual-polarization parameters
  - Visualization of ADT data with other data sources for research and testbed studies (AWIPS)
- Exploration of usefulness of data as a part of the warning decision process
  - A new acronym to replace PARISE? PPARISE? ATDEs?