Other Weather Applications

Advancements in Phased Array Weather Radar Research

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Outline

- Development Platforms
- Data Quality Improvements
- Additional Weather Products
- Recent Technology Advancements

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- ***Development Platforms***
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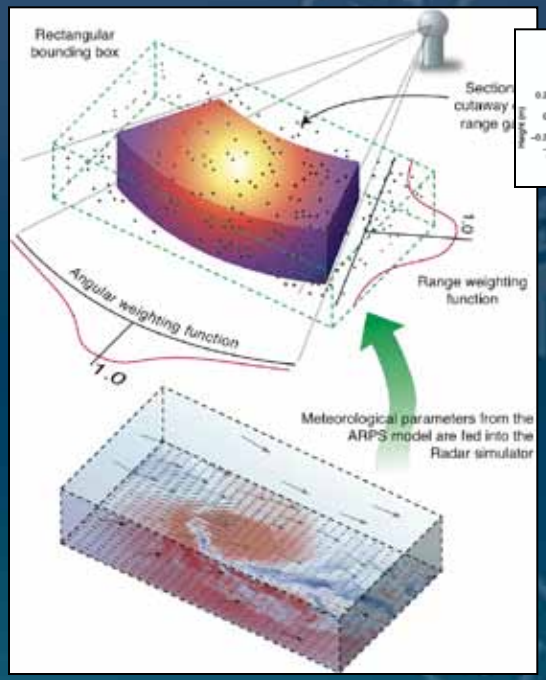
NWRT Phased Array Radar

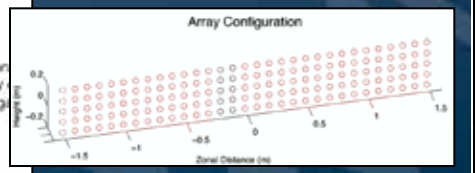
USA's first research facility dedicated to phased array radar meteorology

Weather Radar Simulator for Signal/Array Processing Studies

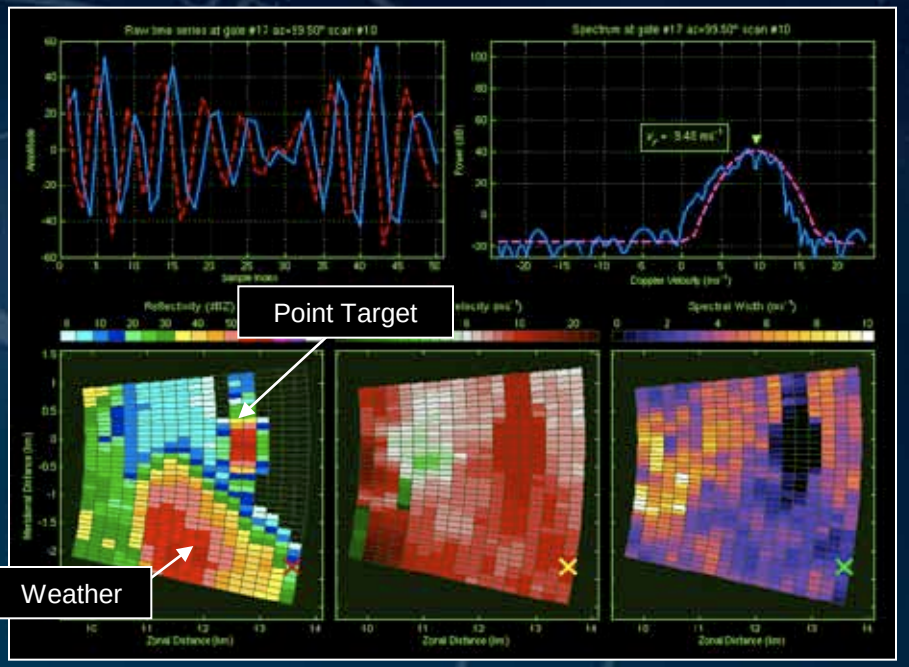
- Would like to develop/study advanced signal/array processing algorithms using realistic, I/Q time-series radar data
- Real experimental data are not *controlled* or *flexible*
- Solution is an advanced radar simulator using high-resolution numerical weather simulation data as input fields



Conceptual diagram of model-based radar simulator capable of simulation of realistic, complex time-series data



Simulated phase array antenna
155 elements
17 degree coverage
10,000 scatterers



Example simulator output with mixed *weather* and *point target*

Possible Applications

- Multi-function (weather surveillance and target tracking)
- Neural network training under varying conditions
- Simulation of advanced radar designs (non-planar arrays, multi-frequency, etc.)
- Spatial filter design for clutter mitigation
- Resolution enhancement using high-resolution beamforming
- Optimization of beam scanning strategies using phased array radars

B. L. Cheong, R. Palmer, M. Xue

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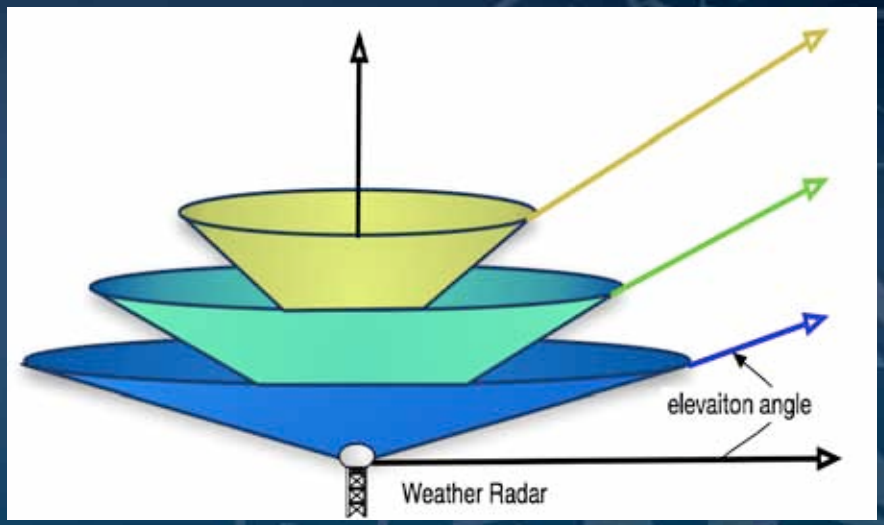
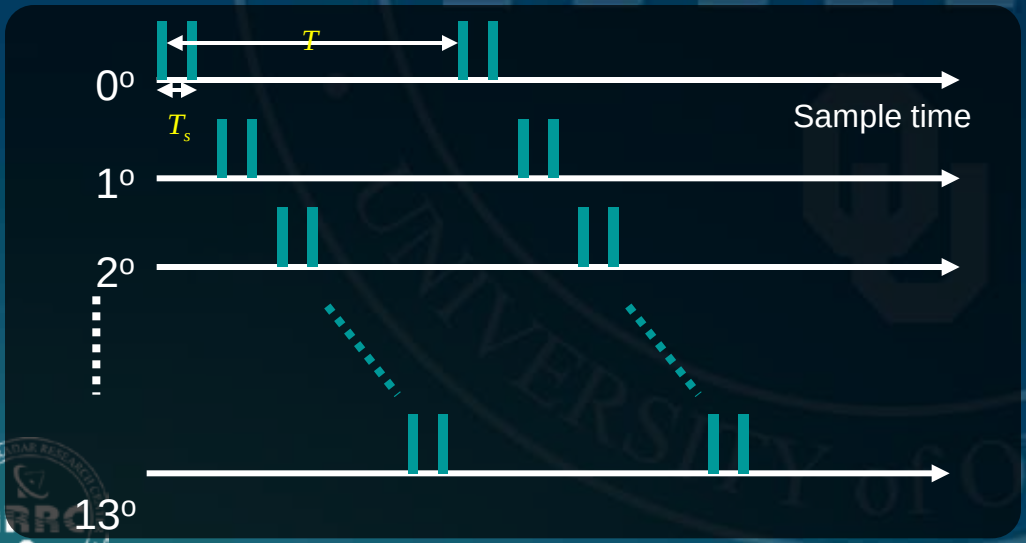
Beam Multiplexing (BMX)



Limitation of Scan Rate in Weather Radar

Increase rotational rate Û degrade data accuracy

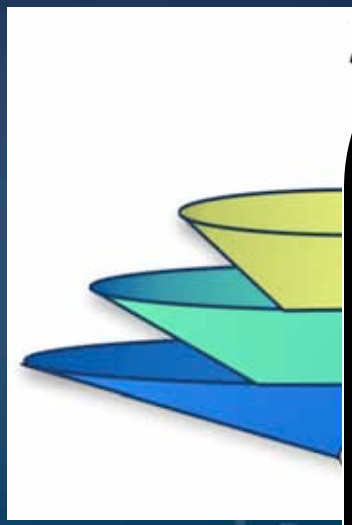
Goal: Increase the data update time and maintain the data accuracy



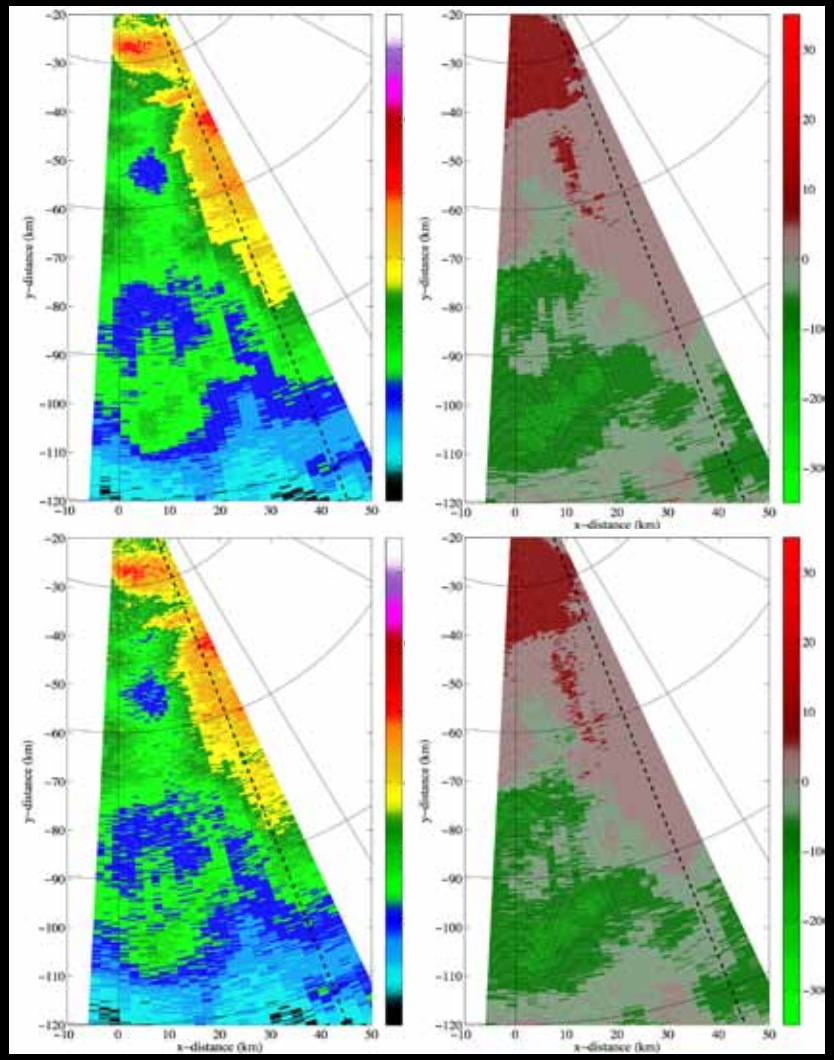
BMX is developed to exploit the idea of collecting independent samples and maximizing the usage of radar resources

T. Yu, M. Orescanin, C. Curtis, D. Zrnic, D. Forsyth

Beam Multiplexing (BMX)



BMX



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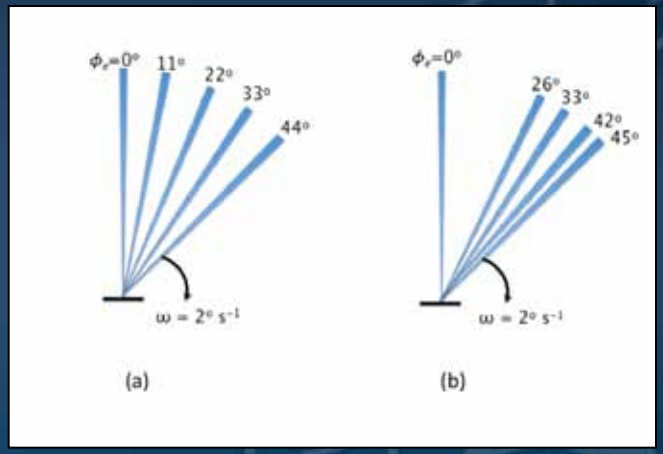
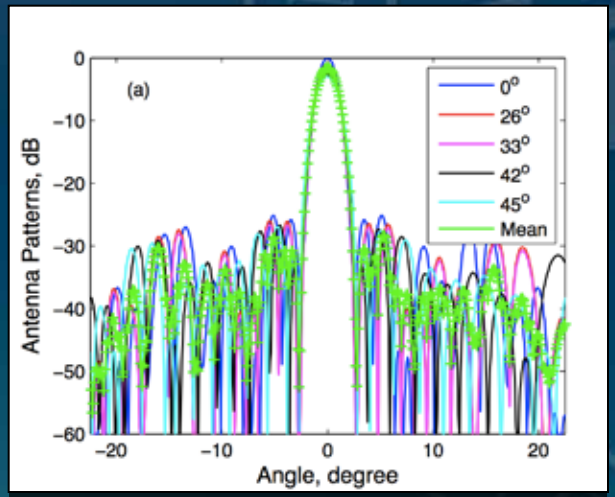
T. Yu, M. Orescanin, C. Curtis, D. Zrnic, D. Forsyth

Multi-Pattern Clutter Mitigation

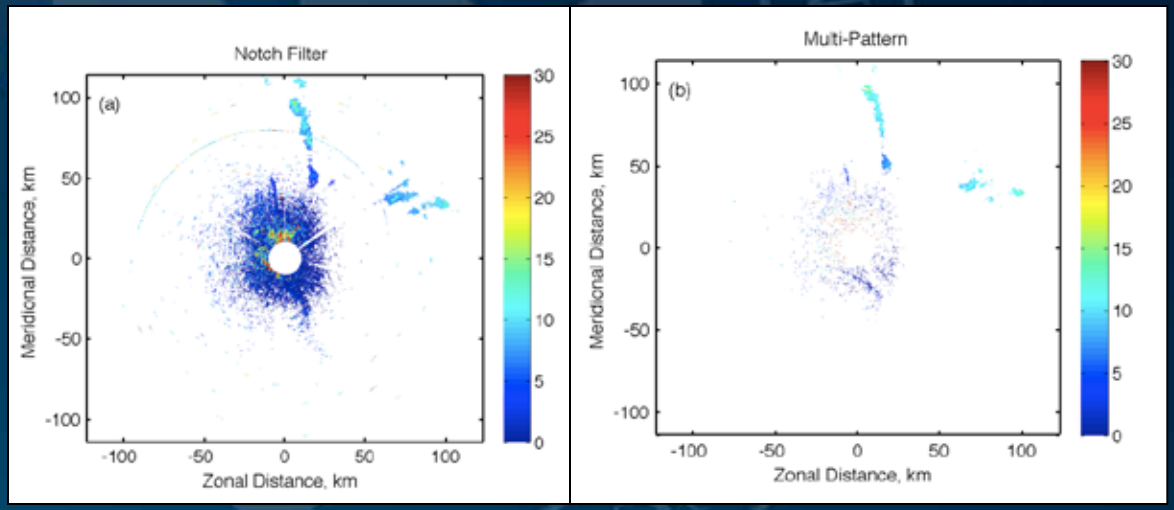


$$\chi = \sum_{j=1}^{N} std\left(\left|f(\phi_{ei},\phi_j)\right|^2\right)$$

Maximize pattern difference to optimize results



Patterns different for different E-beams

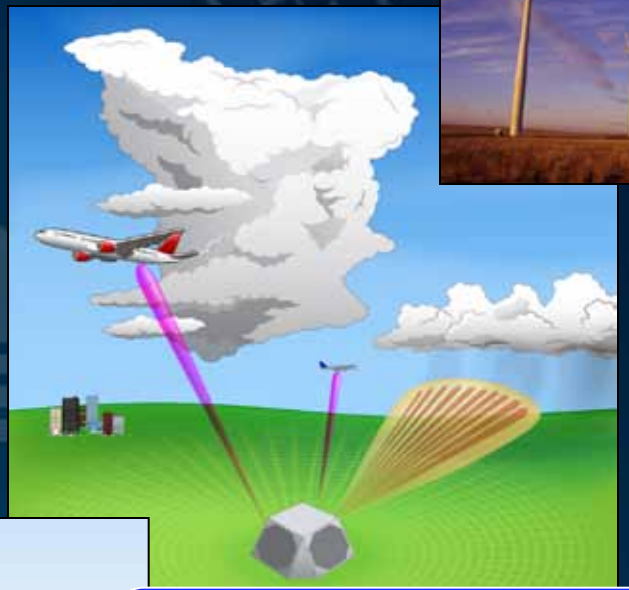


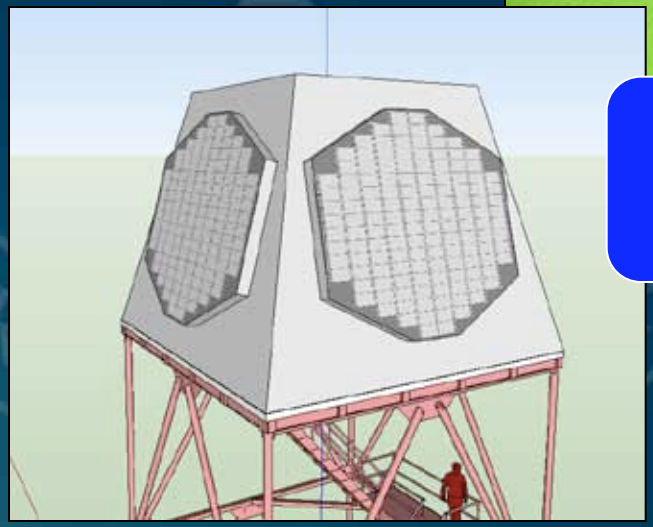
- Mitigate clutter including moving targets
- Calibrate signal power for weather measurements

G. Zhang, Y. Li, R. Doviak, D. Priegnitz, J. Carter, C. Curtis

Clutter Mitigation Using Adaptive Arrays

- Unlike dish antennas, the phased array antenna pattern can be adapted to minimize off bore-sight clutter
- Mitigated clutter can be stationary or non-stationary (aircraft, wind turbines, etc.)
- Computationally expensive so may be implemented on subarrays or auxiliary elements





Goal is to determine complex weight for each element of the array

R. Palmer, K. Le

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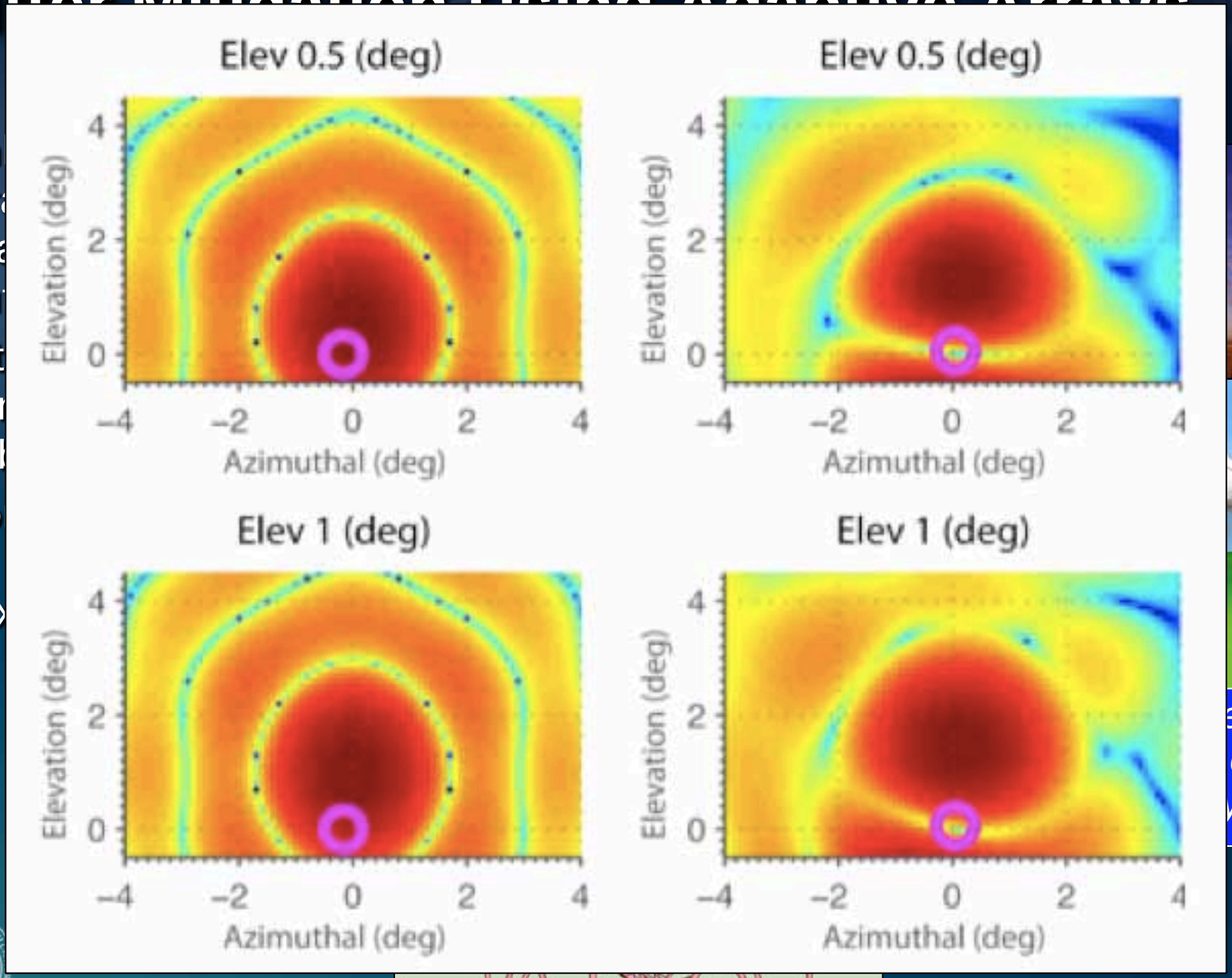

each

R. Palmer, K. Le

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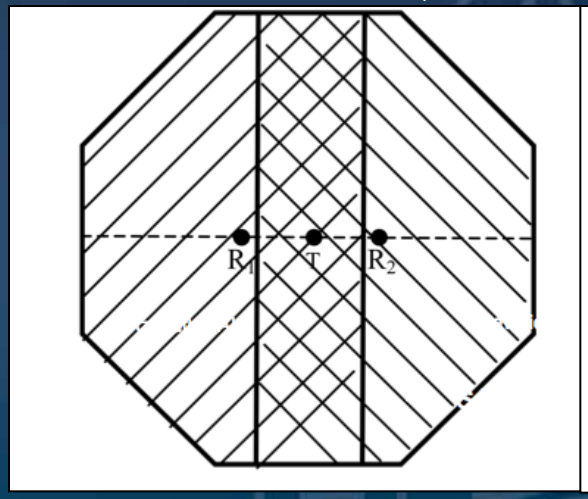
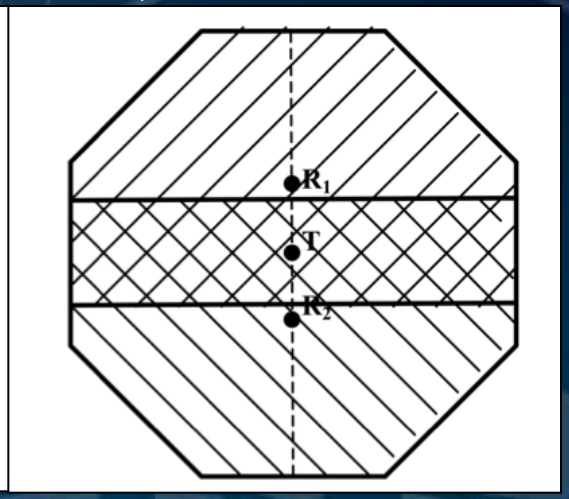
Spaced Antenna Interferometry (SAI)

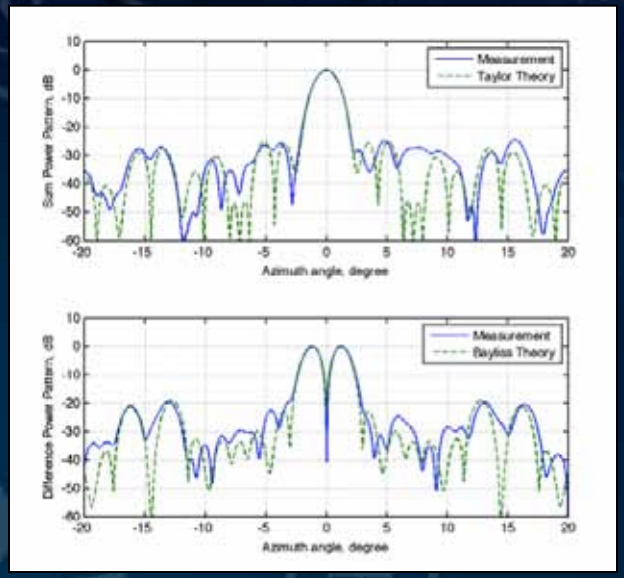
SPY-1 three channels: Sum, Azimuth difference, Elevation difference



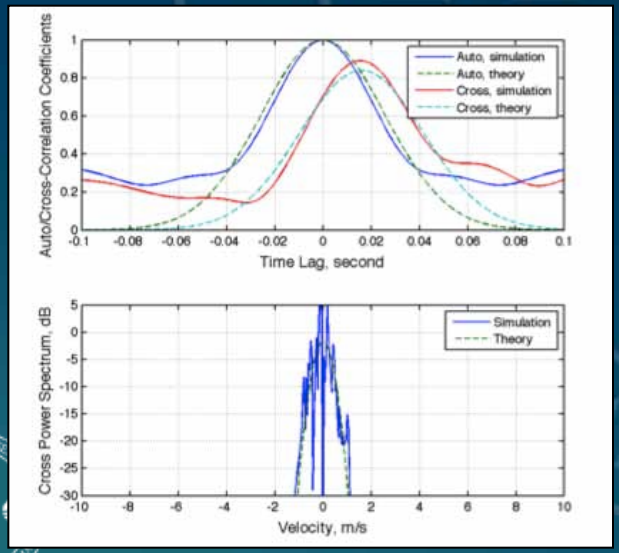
Azimuth SAI



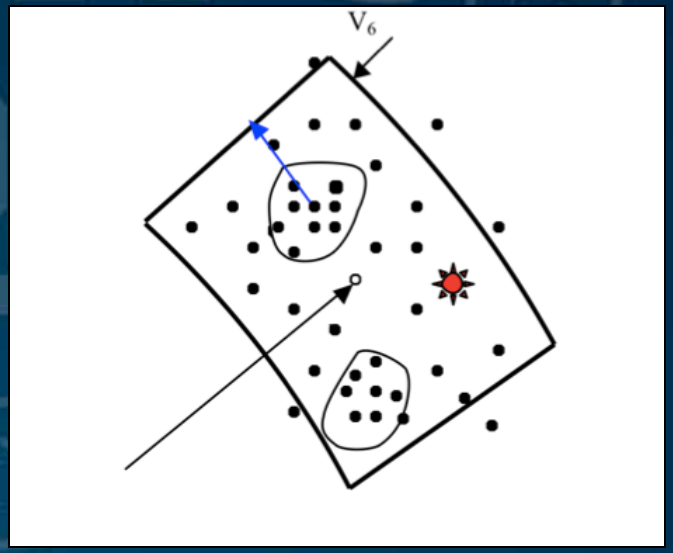
Elevation SAI



Pattern measurements & calibration



SAI Crossbeam Wind (Zhang & Doviak, 2007)

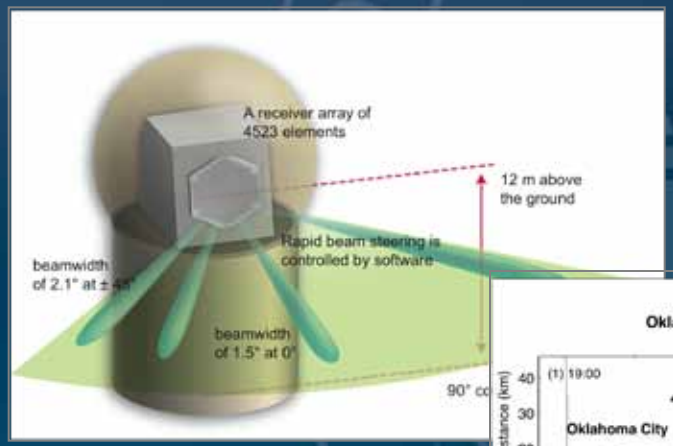


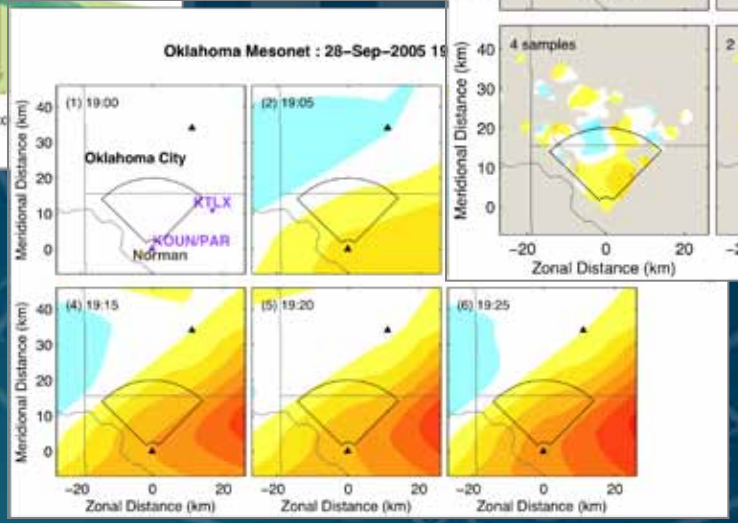
Subvolume Inhomogeneity (Zhang & Doviak, 2008)

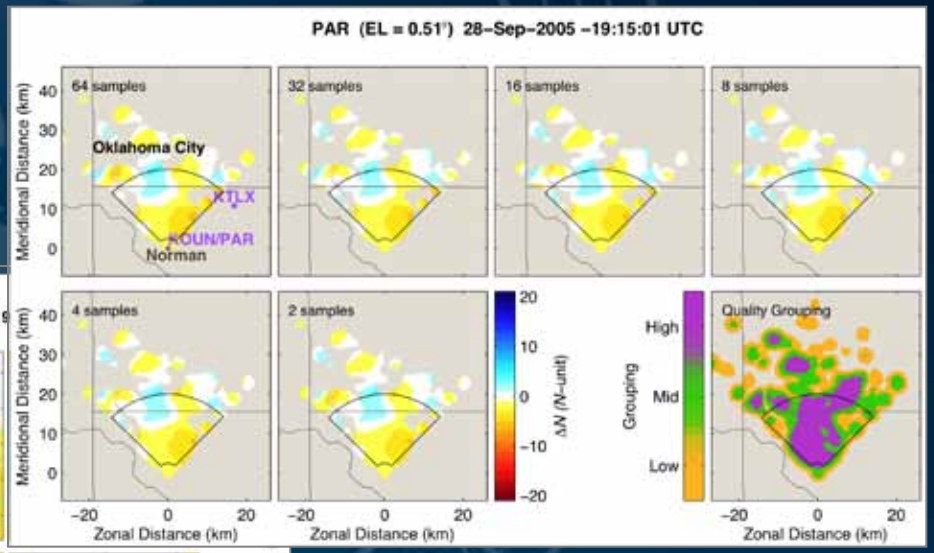
G. Zhang, R. Doviak

Rapid Measurement of Moisture Fields Using Phased Array Radar

- Conventional radar processing does not allow measurement of moisture
- Moisture fields extremely important for forecasting storm initiation
- Phased array moisture measurements can be accomplished extremely rapidly and reliably
  - Only two pulses needed for estimation (< 1 sec)
  - No beam smearing which distorts measurement







- Currently producing real-time moisture measurements with the PAR
- Recently funded NSF grant to study data assimilation of radar-derived moisture field

B. Cheong, R. Palmer, T. Yu, D. Zrnic, D. Forsyth

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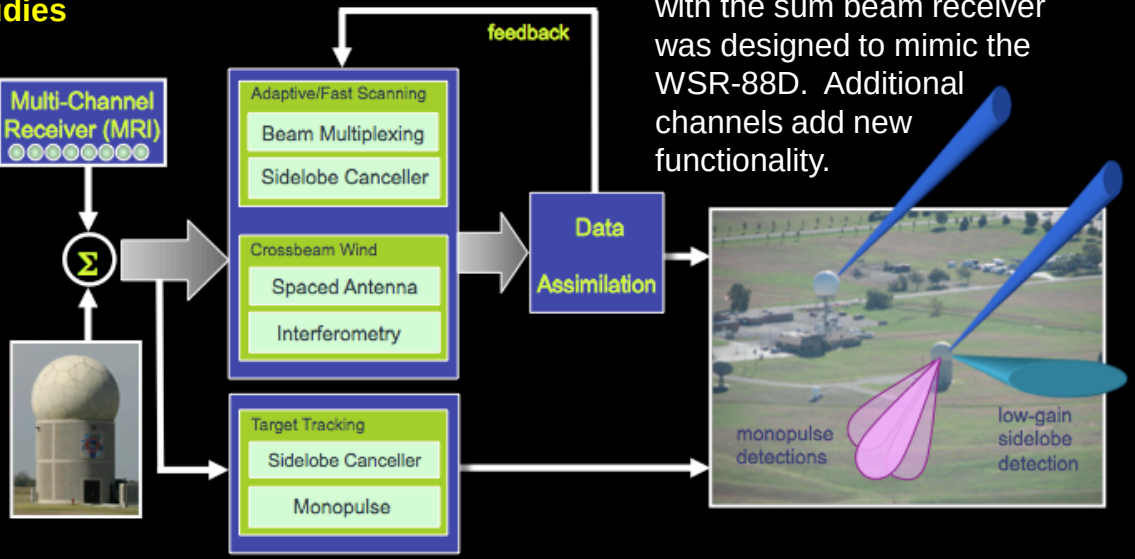
Multi-Channel Receiver

- A teamwork effort: OU and NSSL
- To digitize 8 channels on the NWRT Phased Array Radar
- Upgrades funded by NSF-0723132

Advanced Atmospheric Studies



The original NWRT system with the sum beam receiver was designed to mimic the WSR-88D. Additional channels add new functionality.

RF distribution and commercial digital Rx

RF down-conversion

Will be completed in early 2010

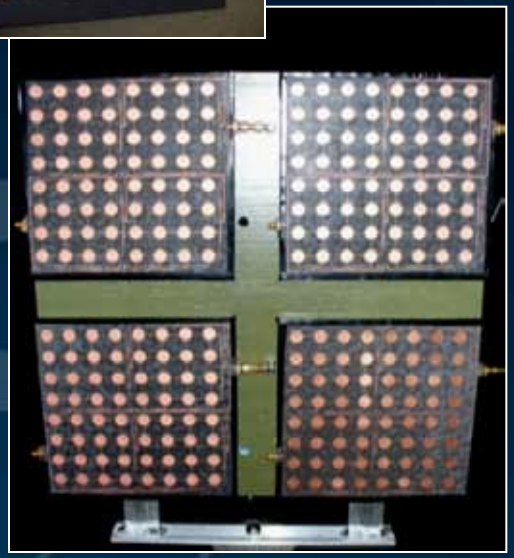
M. Yeary, J. Crain, A. Zahrai, R. Kelley, I. Ivic, J. Meier, C. Curtis, Y. Zhang, R. Palmer, T.-Y. Yu, G. Zhang, R. Doviak, P. Chilson, M. Xue, and Q. Xu

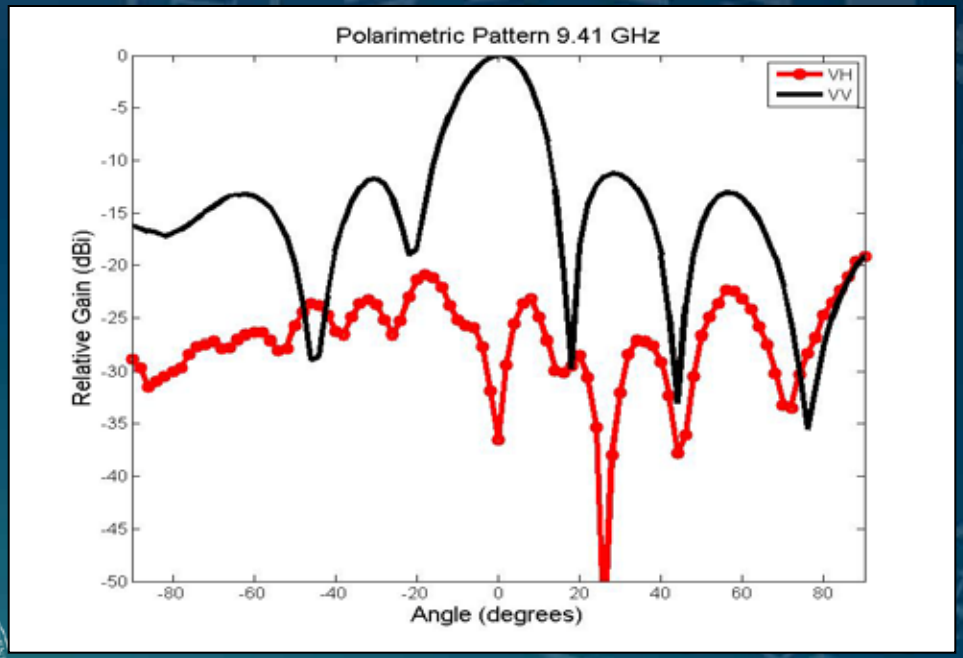
Atmospheric Imaging Radar (AIR)

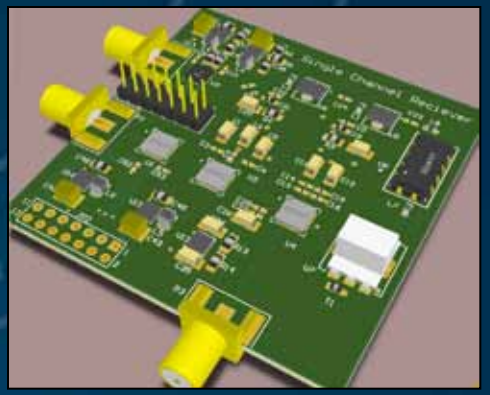
R. Palmer, Y. Zhang, M. Yeary, B. Cheong, M. Biggerstaff, T. Yu, X. Wang, G. Zhang, R. Doviak

Polarimetric Antenna System and Scanning Technology

- Current focus on X-band, element-by-element polarimetric control of patch arrays and innovative feedline network
- Broadside dual-polarized array used for airborne forward-looking hazard sensing
- MMIC-based integrated receivers with on-channel polarization state control
- Measured radiation pattern of 4x4 subarray has achieved 36 dB cross-pol isolation







R. Zhang, A. Huston, Y. Pan

Summary

- **Phased array radars offer…**
  - Rapid updates via BMX
  - Advanced clutter mitigation using (1) Multi-Pattern, (2) Adaptive Arrays
  - Wind turbine clutter mitigation
- **Phased array radars offer new products…**
  - Cross-beam wind / shear (potential for 3D wind fields)
  - Rapid moisture measurements (refractivity)
  - Rapid wind & moisture updates important for fire weather applications
- **New technologies being developed to support future weather applications**
  - 8-channel receiver on the NWRT
  - Polarimetric array design, polarization calibration / cylindrical arrays (prov. patent)
  - Imaging radar demonstration