Prospects of Cloud Volume Imaging with the WSR-88D Radar

Valery Melnikov[*]
David Mechem[+]
Phillip Chilson[~]
Richard Doviak[#]
Dusan Zrnic[#]
Yefim Kogan[*]

[*]CIMMS, University of Oklahoma
[+]Dept. Of Geography, University of Kansas
[#]National Severe Storms Laboratory, OAR
[~]School of Meteorology, University of Oklahoma
valery.melnikov@noaa.gov

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Motivation

Observational sampling of 3D cloud fields has been a longstanding goal of ARM.

Cloud fields required for 3D radiative transfer calculations

Evaluation/formulation of overlap assumptions for statistical cloud schemes

The 157 WSR-88D weather radar sites exhibit a wide range of climatic regimes

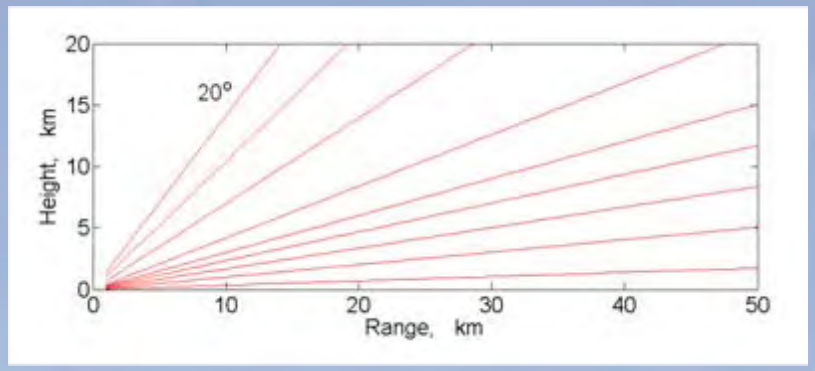
Challenges

Scanning radars can deliver 3D fields in real time. Can the WSR-88D weather radar be used for 3D cloud sounding?

Reflectivities of -25...-30 dBZ @ 10 km should be measured with a radar to robustly detect clouds. Can this sensitivity be achieved on the WSR-88D?

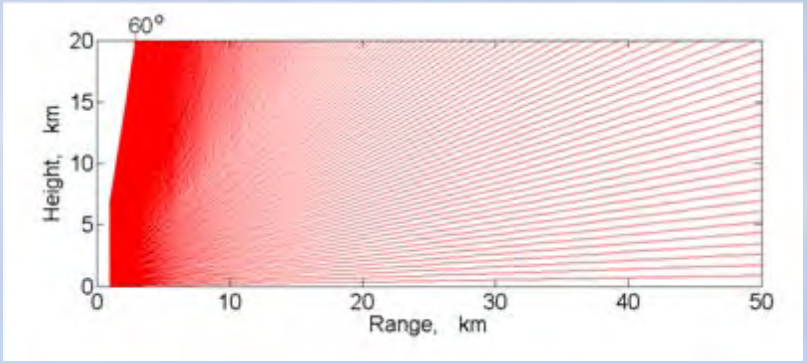
Can the WSR-88D radars be used in cloud sounding?

Volume Coverage Patterns (VCP) of the WSR-88Ds



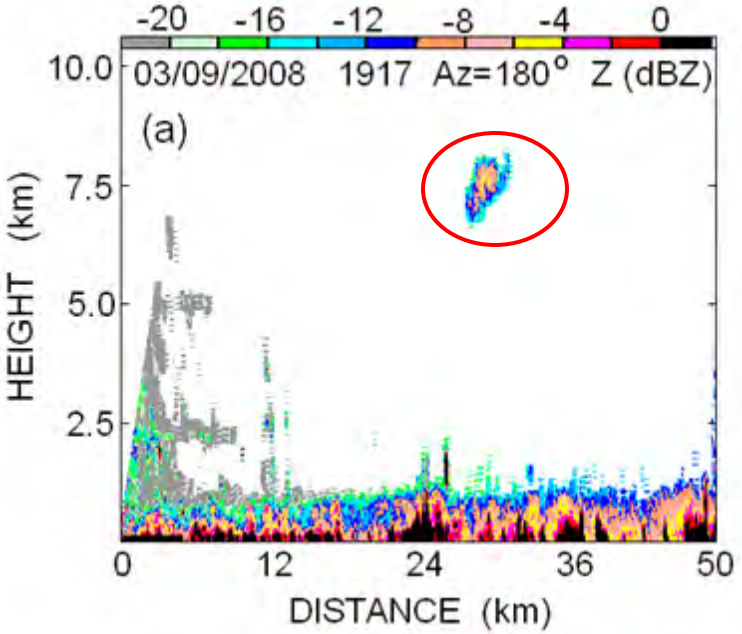
Number of samples	128
Elevation step	0.25°
Maximum elevation	60°
Ground clutter filtering up to	60°
Double range oversampling	
Noise specle remover	
Correlation estimators	

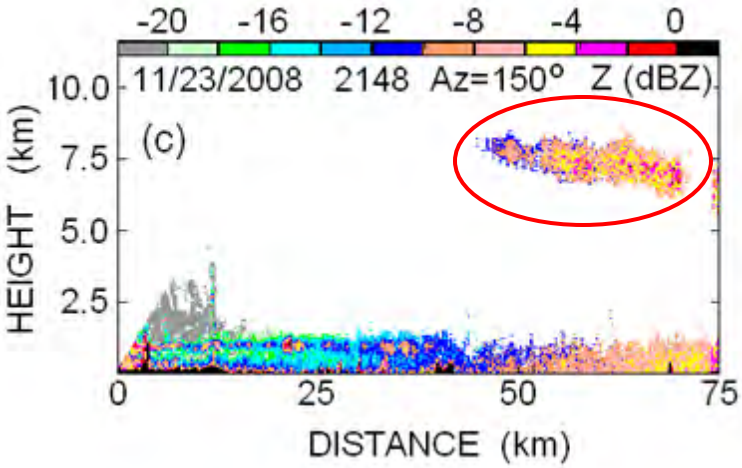
"CLOUD" VCP of KOUN



Sensitivity of KOUN with enhanced signal processing.

Radar RHIs correspond to the vertical black lines in the pictures

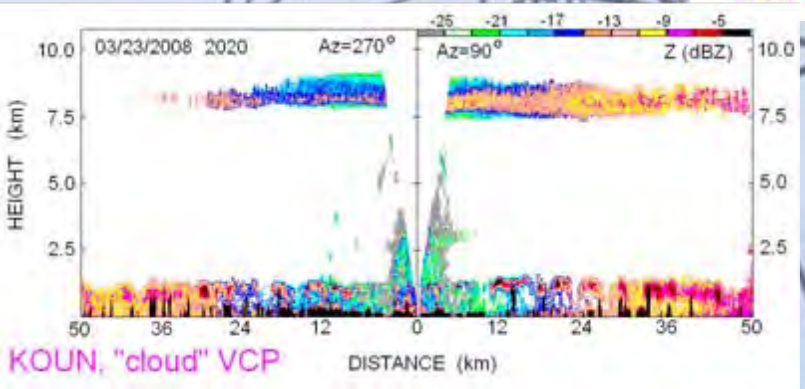




Cirrus clouds: pictures of clouds, visible satellite, WSR-88D KTLX, and KOUN images

WSR-88D KTLX 2018 UT

Visible satellite 2015 UT

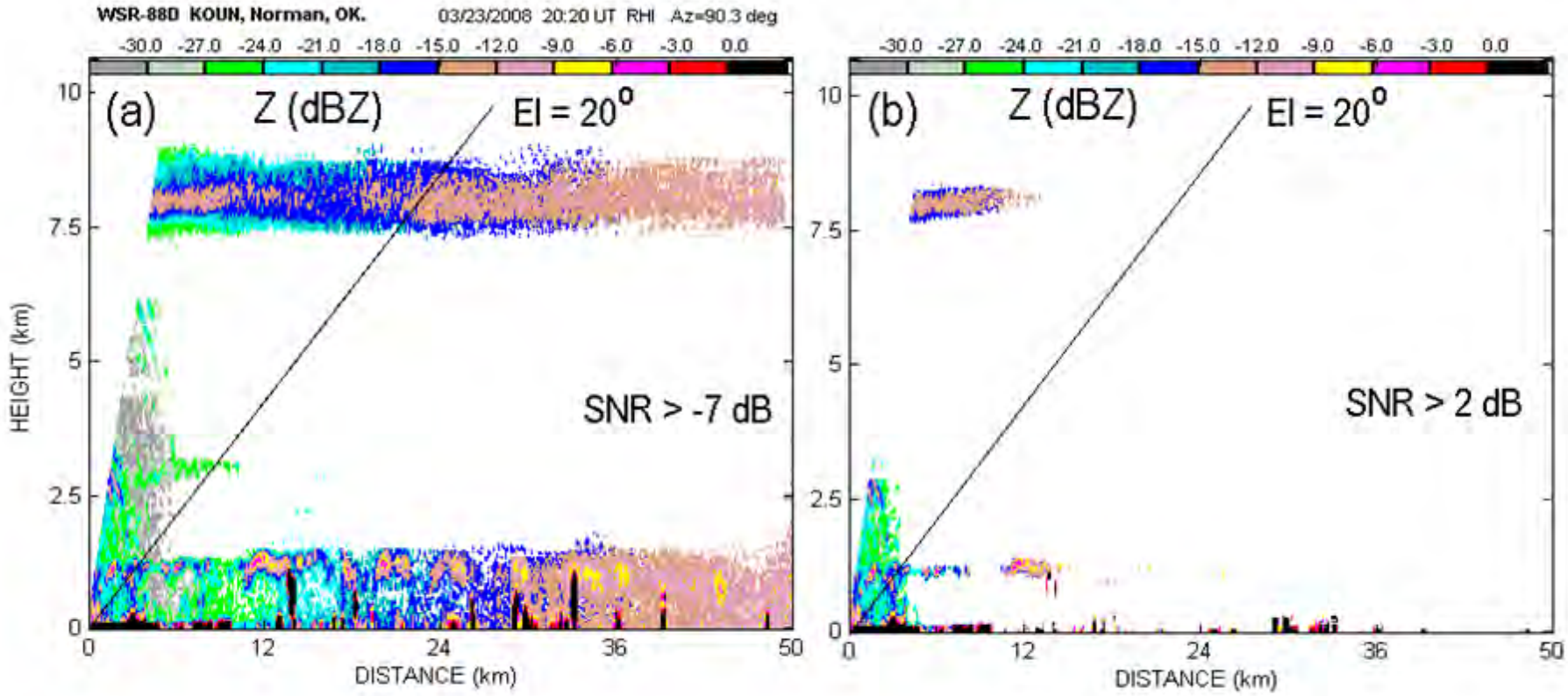


KOUN, "cloud" VCP

Comparison of sensitivity difference

KOUN cloud mode

KOUN precip mode



Experiment on cloud detectability with KOUN

15 February till 31 March, 2008; 45 days total.

8 days with precipitations, KOUN was not available

24 cloudy days without precipitation; on all those days KOUN detected clouds.

Comparison of radar parameters

	ARM MMCR	ARM WACR	NASA CPR	NOAA WSR-88D
Wavelength, mm	8	3	3	109
Antenna beamwidth, deg	0.2	0.24	0.12	0.96
Radial resolution, m	45/90	45	500	250
Two-way transversal resolution, m	17@10 km	29@10 km	1400 x 2500	82@10 km
Z_{10}, dBZ	-30 (general mode)	-26	-26	-25.5 short pulse -33 long pulse
Attenuation	Strong	Severe	Severe	Negligible
Number of systems	5	3	1	157

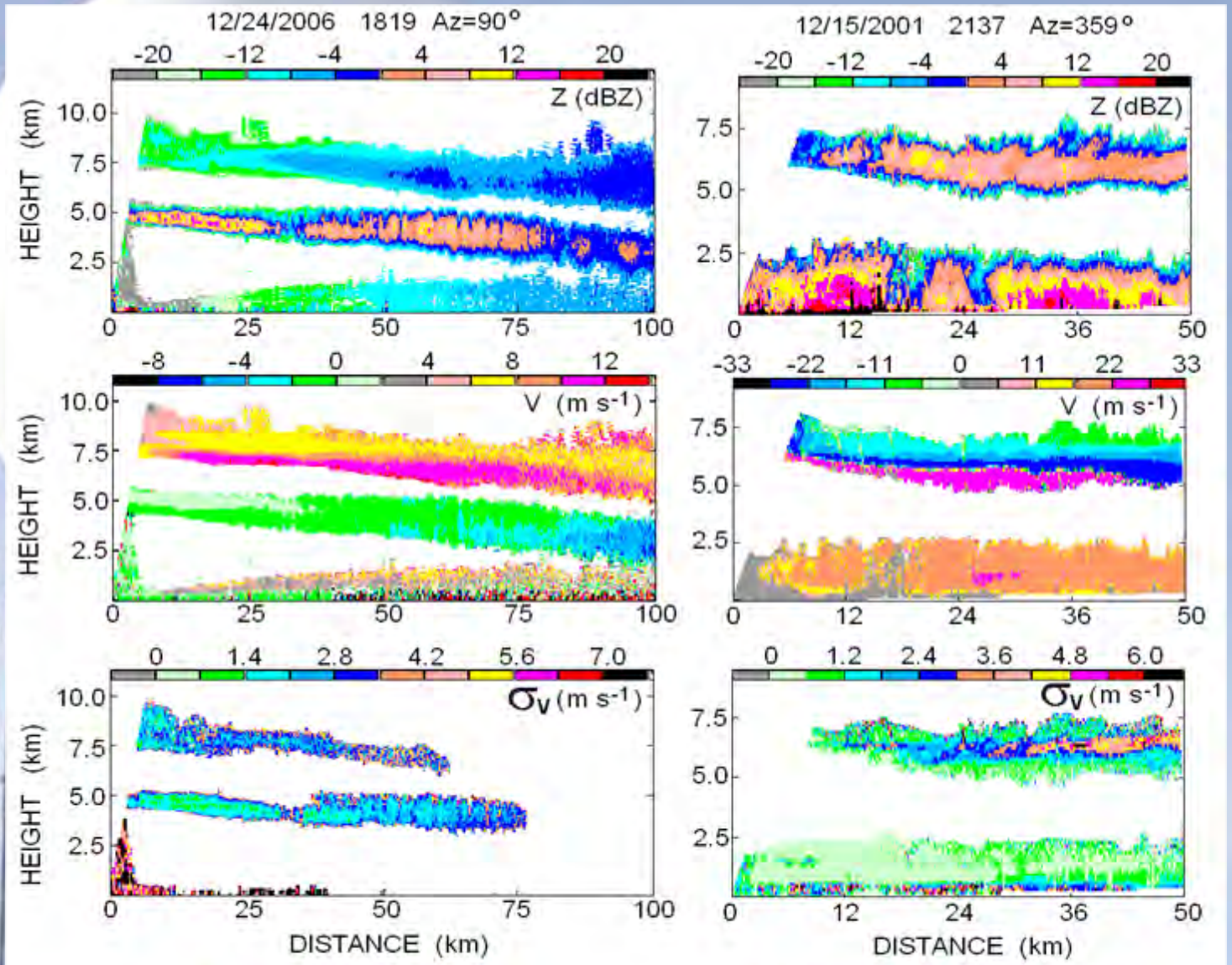
Examples of multi-layer and multi-phase clouds.

Fields of reflectivity (Z), the Doppler velocity (V), and spectrum width (σ_v)

Z

V

σ_v

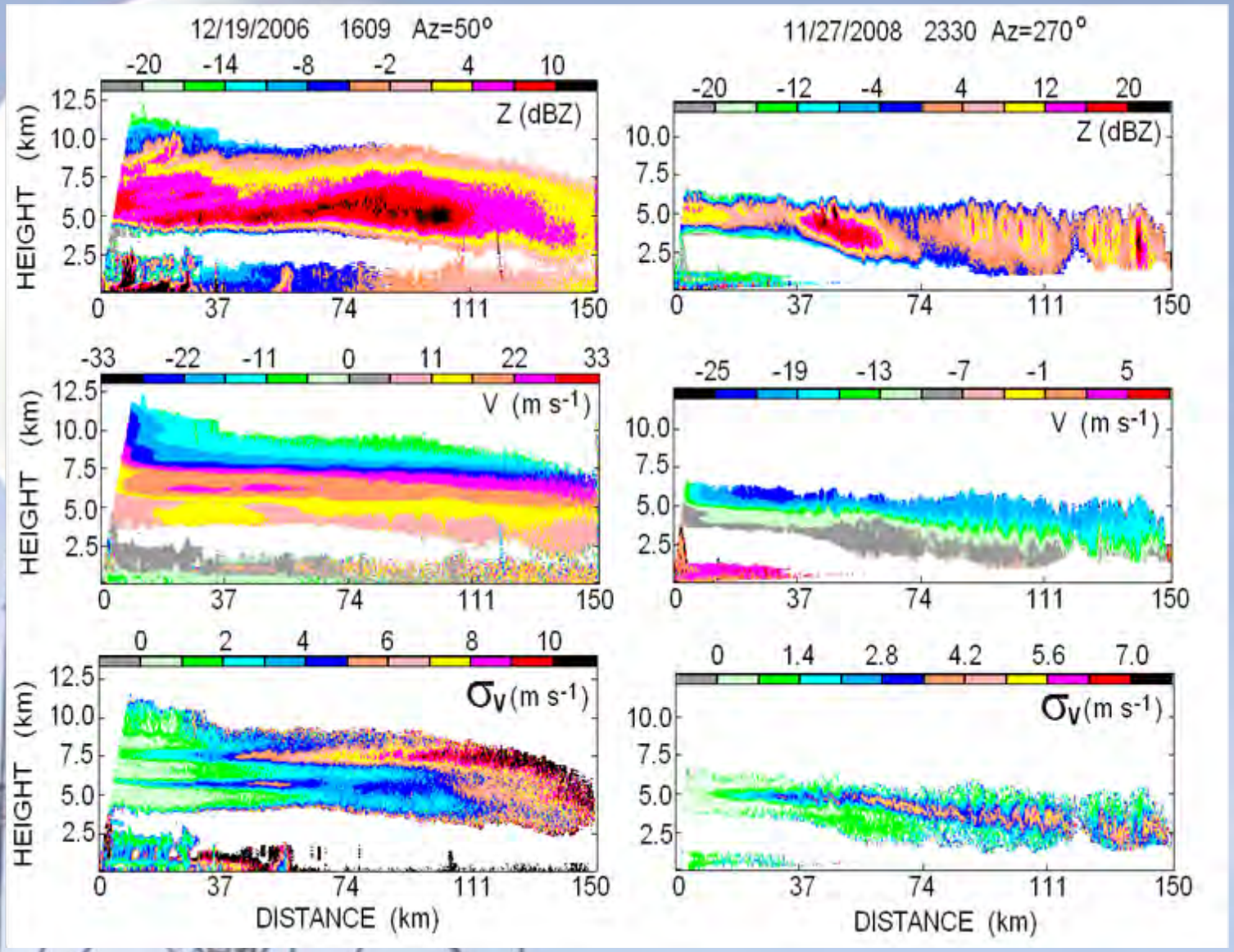


Long-range cloud observations – up to 150 km from radar

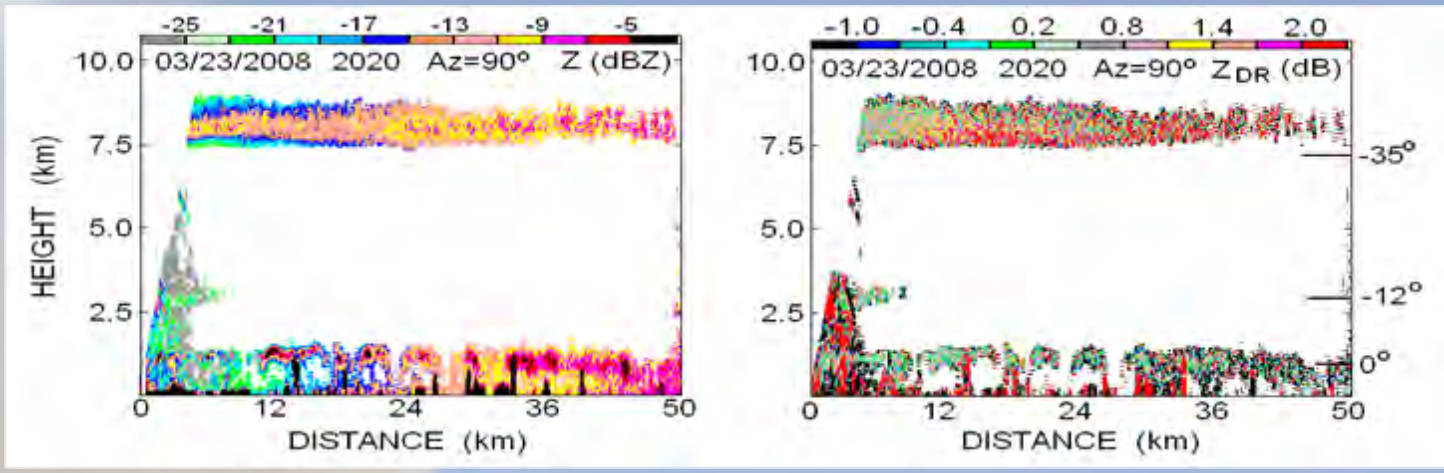
Z

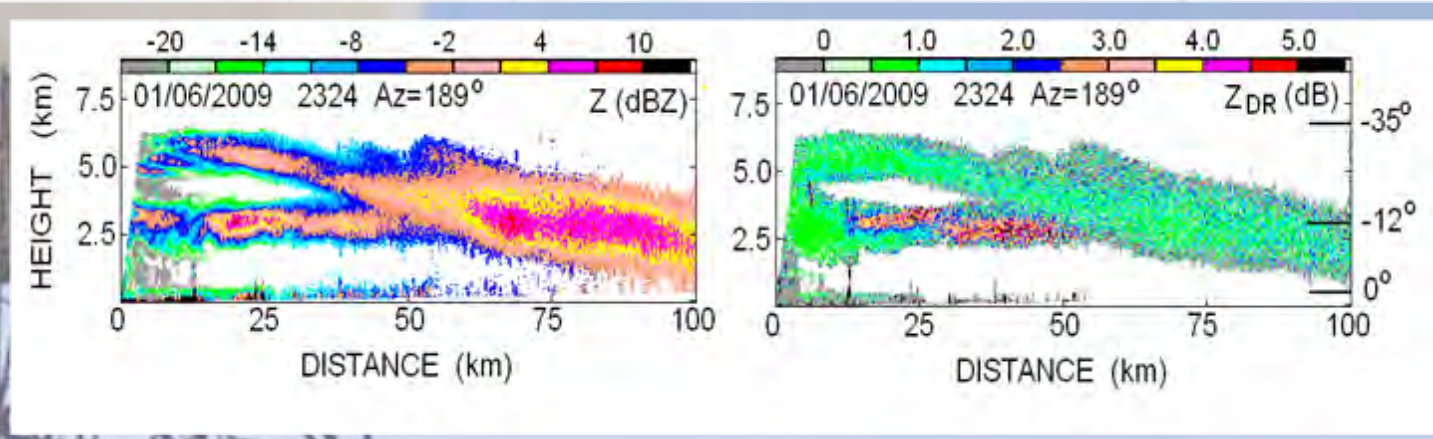
V

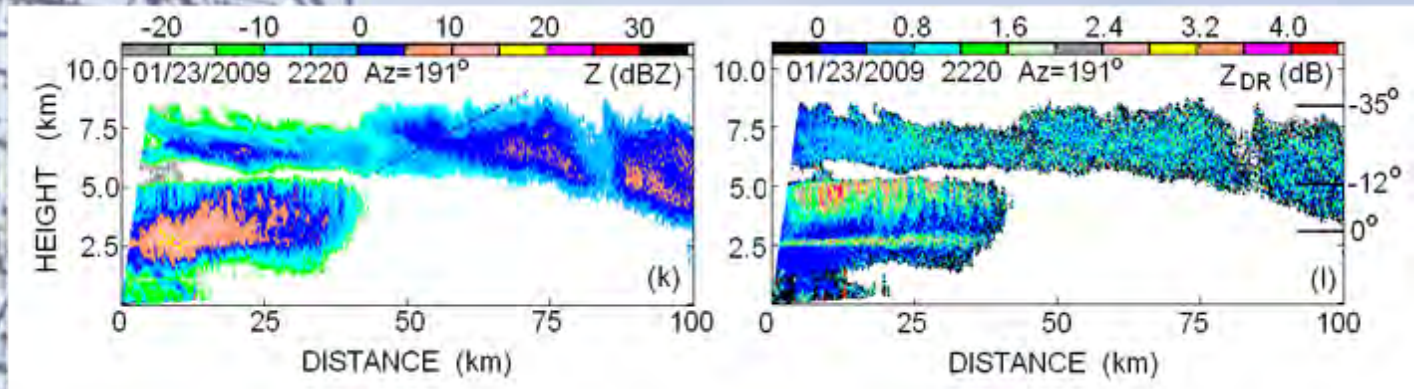
σ_v



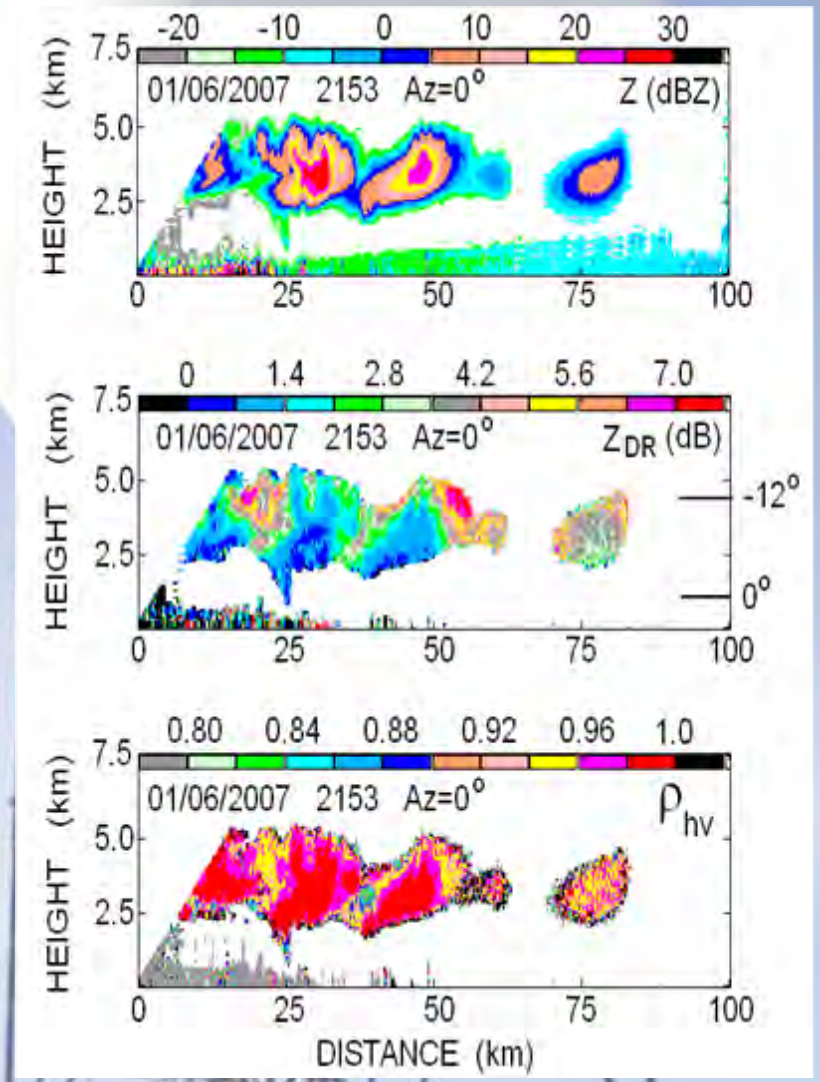
Polarimetric fields: reflectivity (Z) and differential reflectivity (Z_{DR})

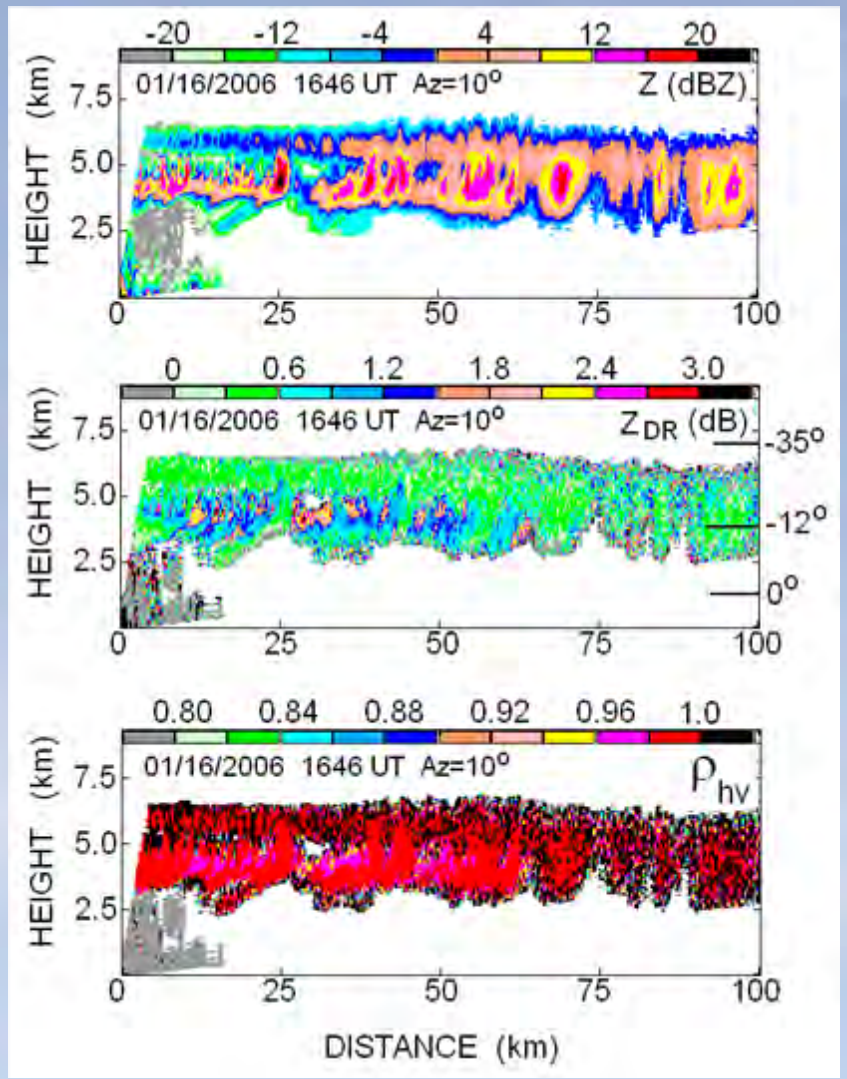




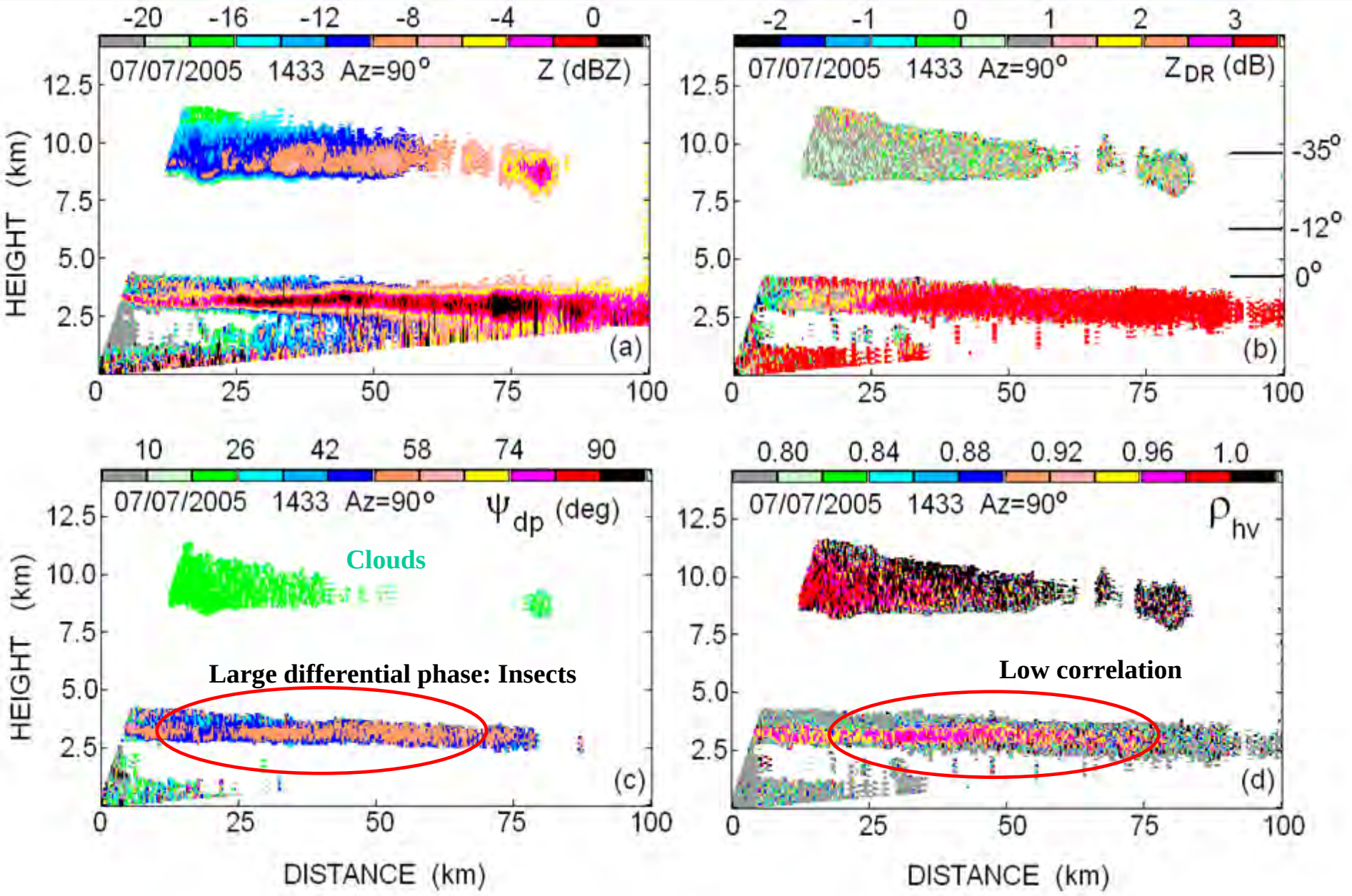


Polarimetric fields: reflectivity (Z), differential reflectivity (Z_{DR}), and the correlation coefficient (ρ_{hv})

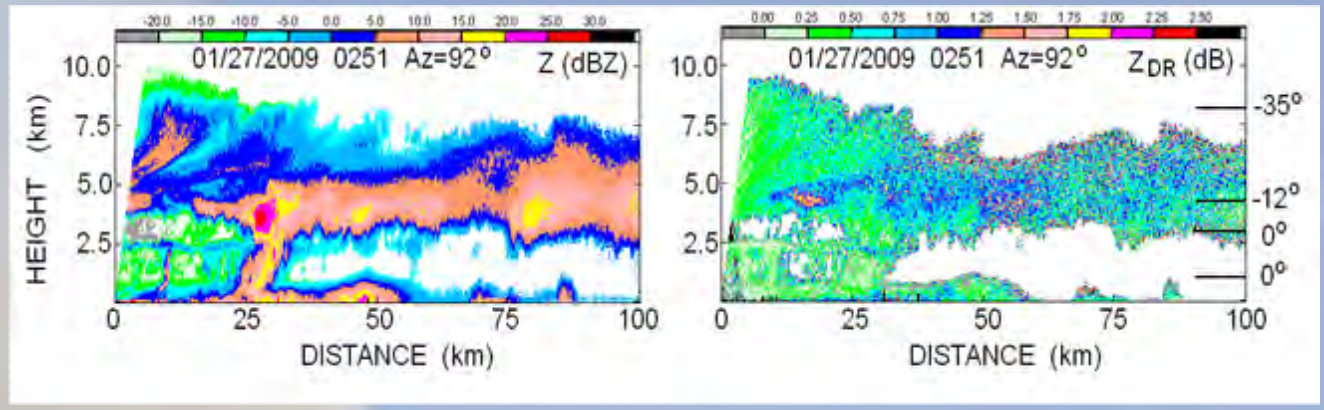


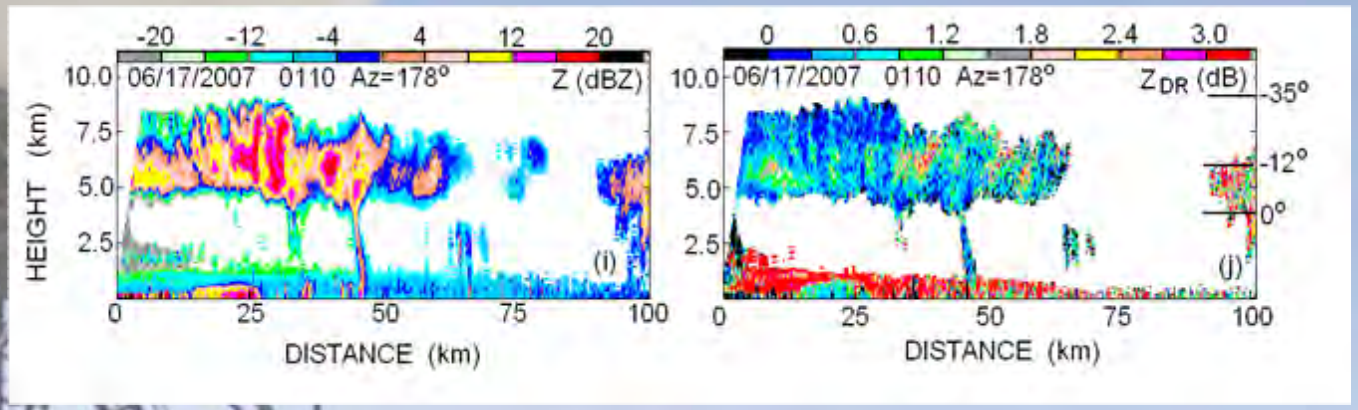


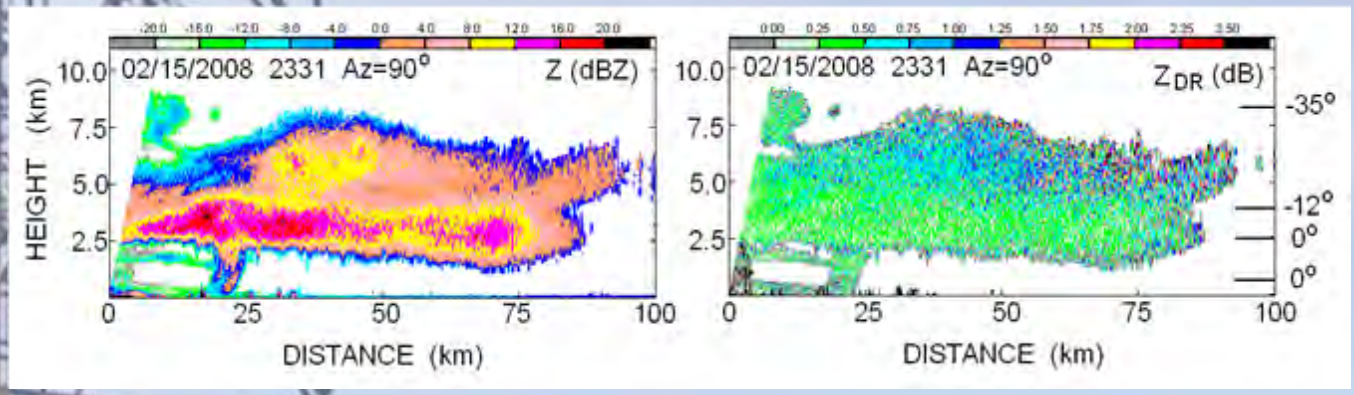
Using polarimetric measurements to identify scatterers



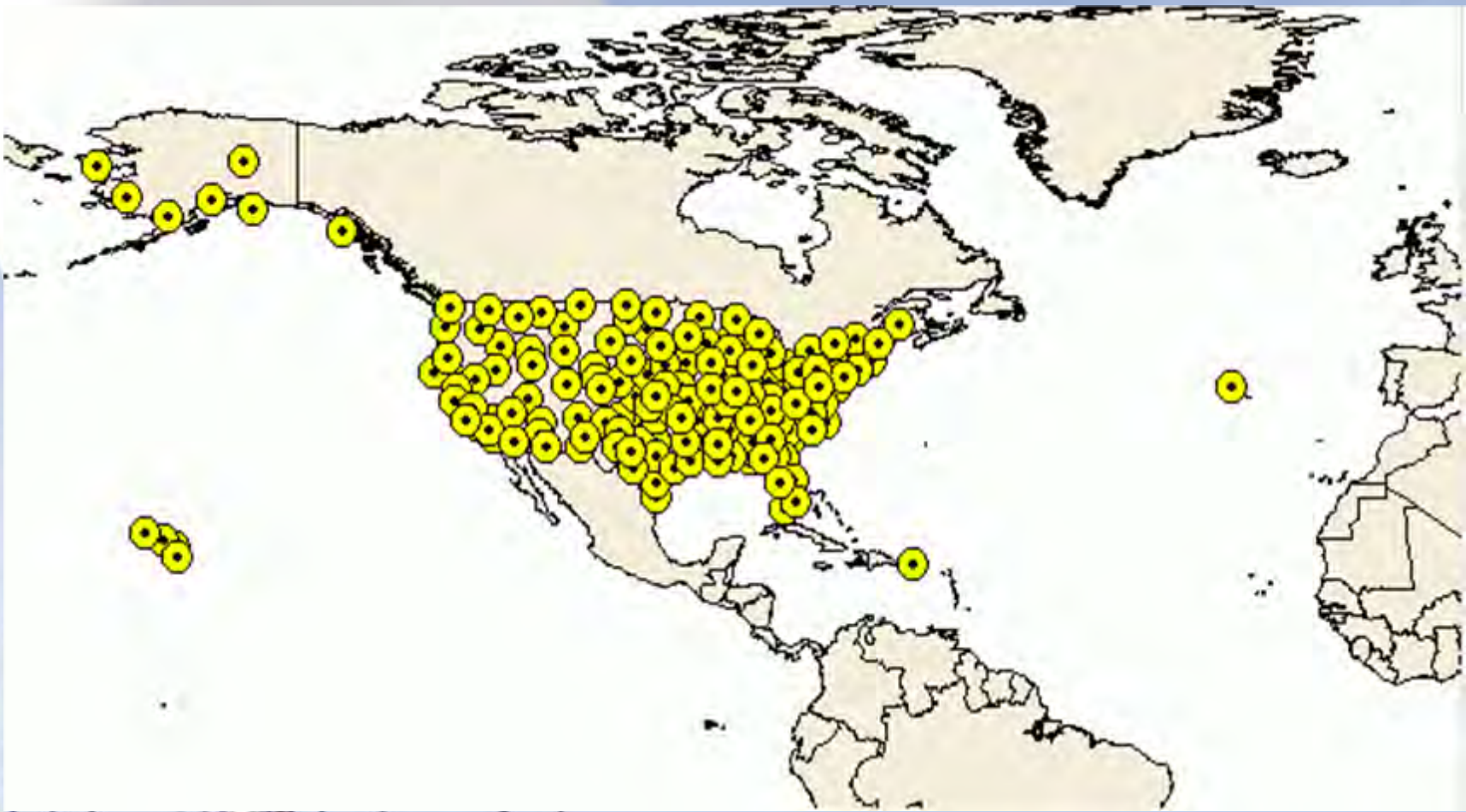
Simultaneous observations of clouds and precipitation







National US WSR-88D radar network



Conclusions

- Observations from WSR-88D KOUN illustrate the advantage of scanning Doppler polarimetric radars: near-instantaneous sampling of 3D cloud fields and their evolution

- Enhanced signal processing techniques applied to the WSR-88D increases sensitivity to -25.5 dBZ@10km in dual-polarization mode and -33 dBZ in single polarization mode

-Polarimetric capabilities of the WSR-88Ds allow for classification of hydrometeor types

-The existing NEXRAD radar network could be employed for cloud-climate studies and incorporation into NWP update cycles

Possible future work

-Design a VCP for the networking WSR-88D for 3D cloud imaging. Test the VCP remotely on one of the WSR-88Ds.

Establish detectability of clouds with the WSR-88D for different cloud types and seasons. Use enhanced signal processing on the WSR-88D. Obtain accuracy of cloud boundaries measurements with the WSR-88D comparing radar data with a ceilometer at ARM's BF-6 site.

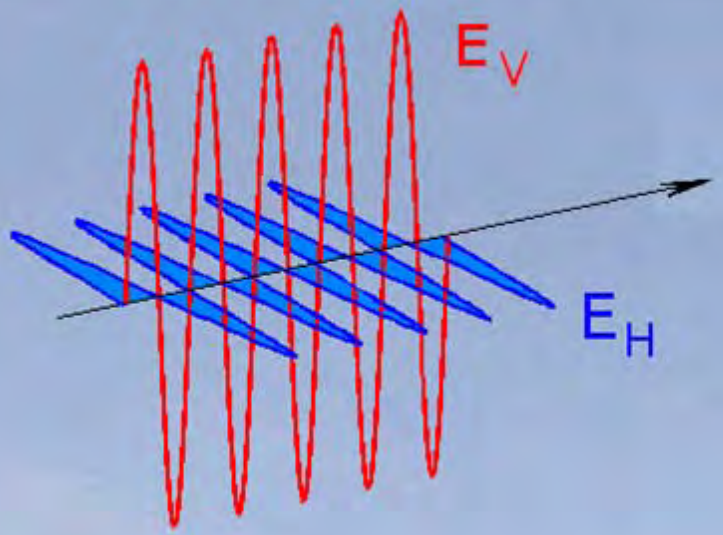
Conduct simultaneous dual-polarization measurements on the WSR-88D and mobile 3-cm X-Pol to establish limitations of dual-pol cloud observations at X-band (this is in support of ARM's activity in designing of a scanning X-band radars)

- Design methods of estimation of ice content and liquid water content in mix phase clouds using polarimetric radar measurements.


Thank
you


BACKUP

Polarimetric radar parameters



Powers in the channels

$P_h = \langle |E_h|^2 \rangle$

$P_v = \langle |E_v|^2 \rangle$

Differential reflectivity

$Z_{DR} = 10 \log (P_h / P_v)$

Correlation coefficient

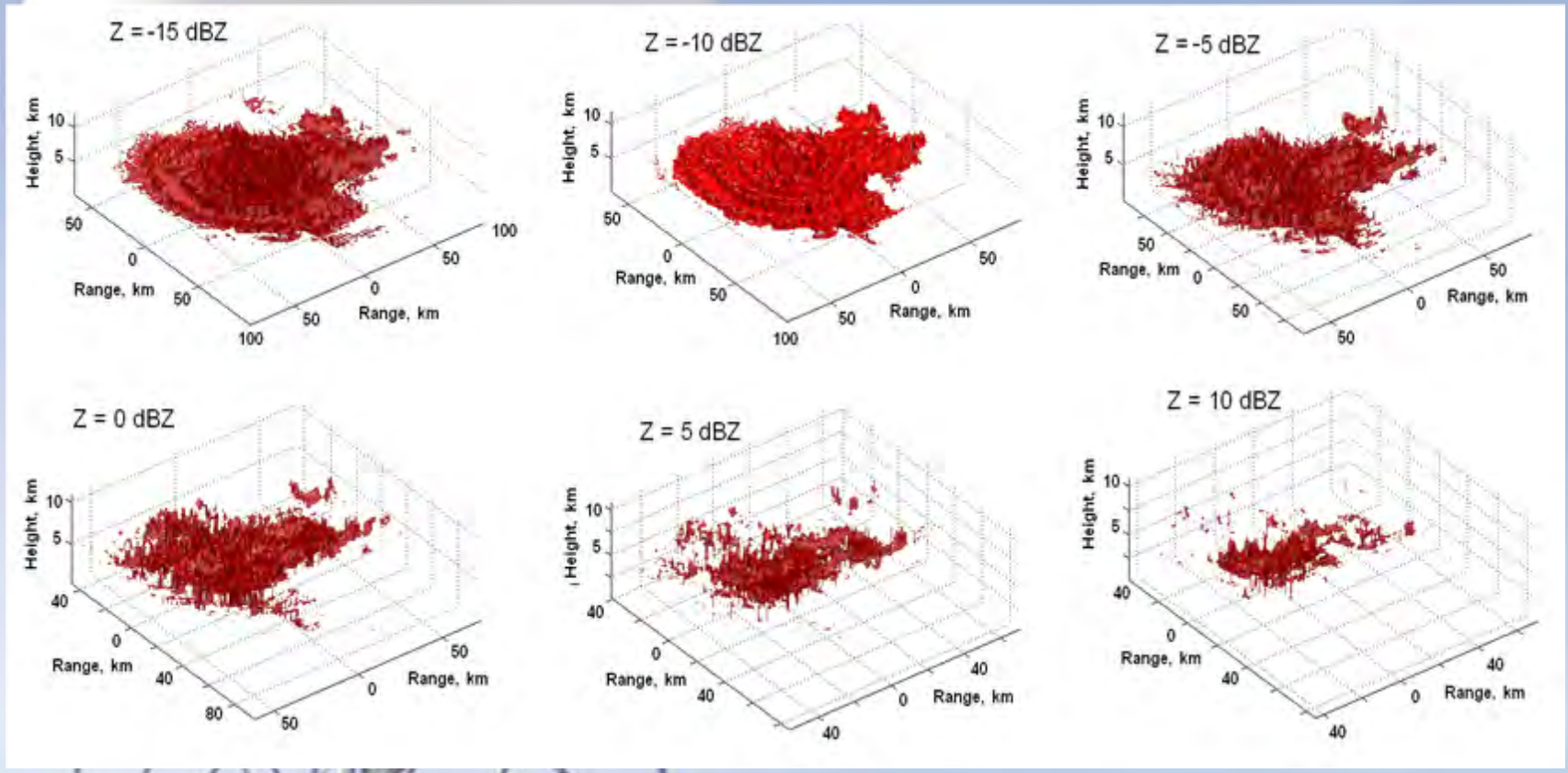
$\rho_{hv} = |\langle E_h^* E_v \rangle| / (P_h P_v)^{1/2}$

Differential phase

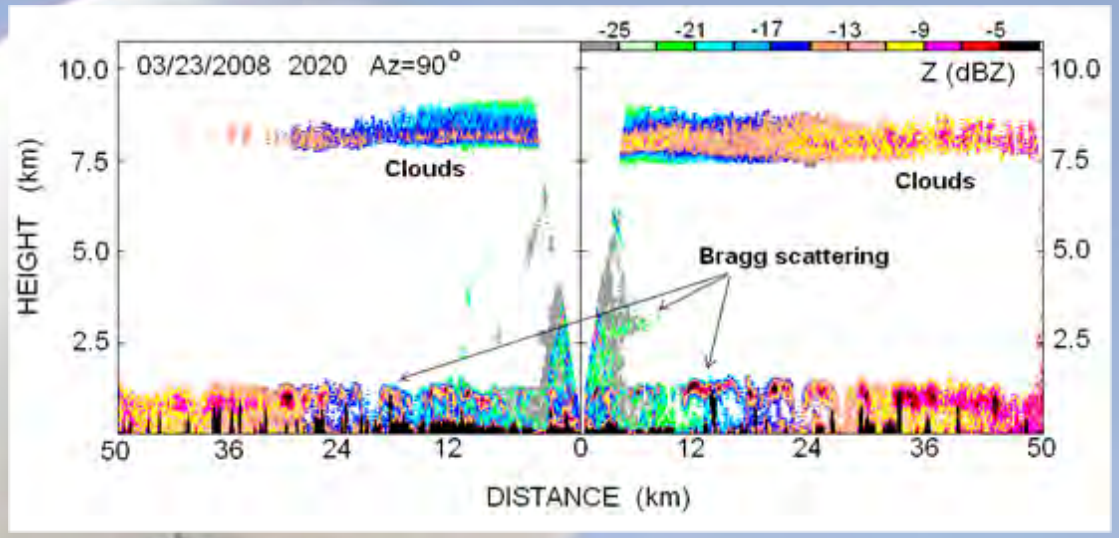
$\Phi_{hv} = \arg(\langle E_h^* E_v \rangle)$

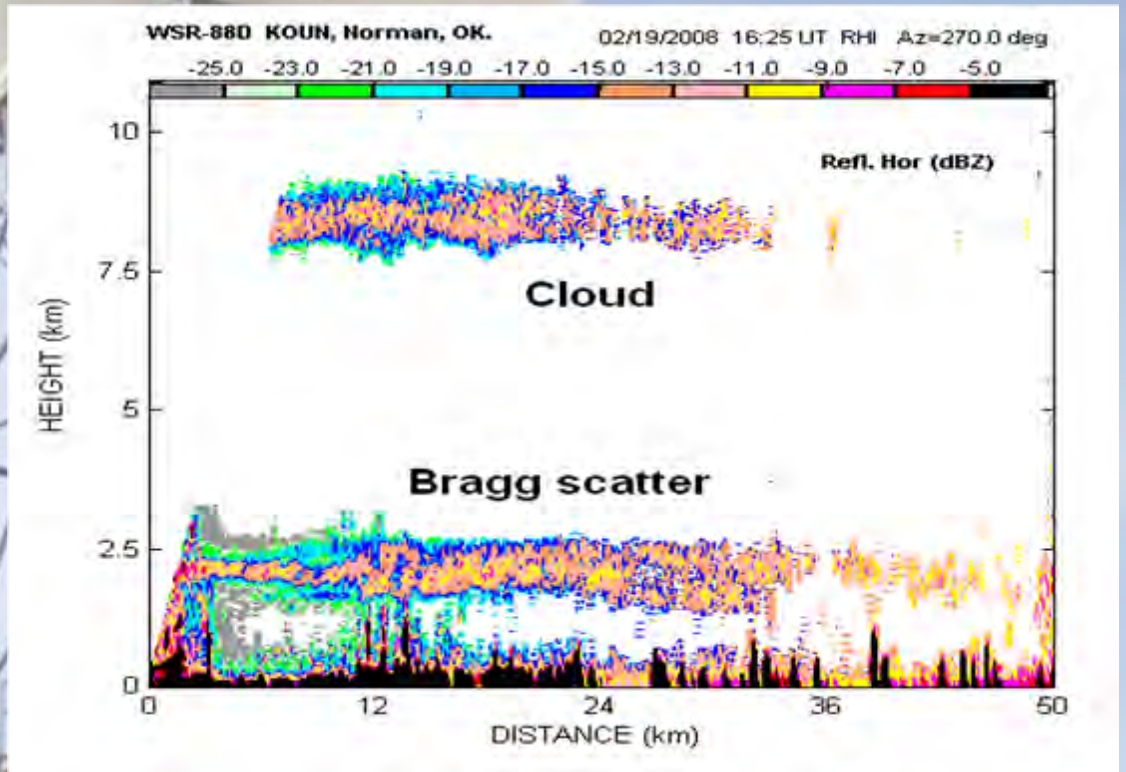
3-Dimentional cloud imaging

28 November, 2008. 0041 UT. 14 elevations



Bragg and particulate scatter





Dual-polarization 3.2-cm-wavelength radar & KOUN