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austro CONTROL

SEVERE HAIL SIZE DISCRIMINATION USING DUAL-POLARIZED WEATHER RADAR DATA.

A DUAL-WAVELENGTH COMPARISON BETWEEN "C" AND "S" BAND.

6th European Conference on Severe Storms (ECSS 2011)
3 - 7 October 2011, Palma de Mallorca, Balearic Islands, Spain

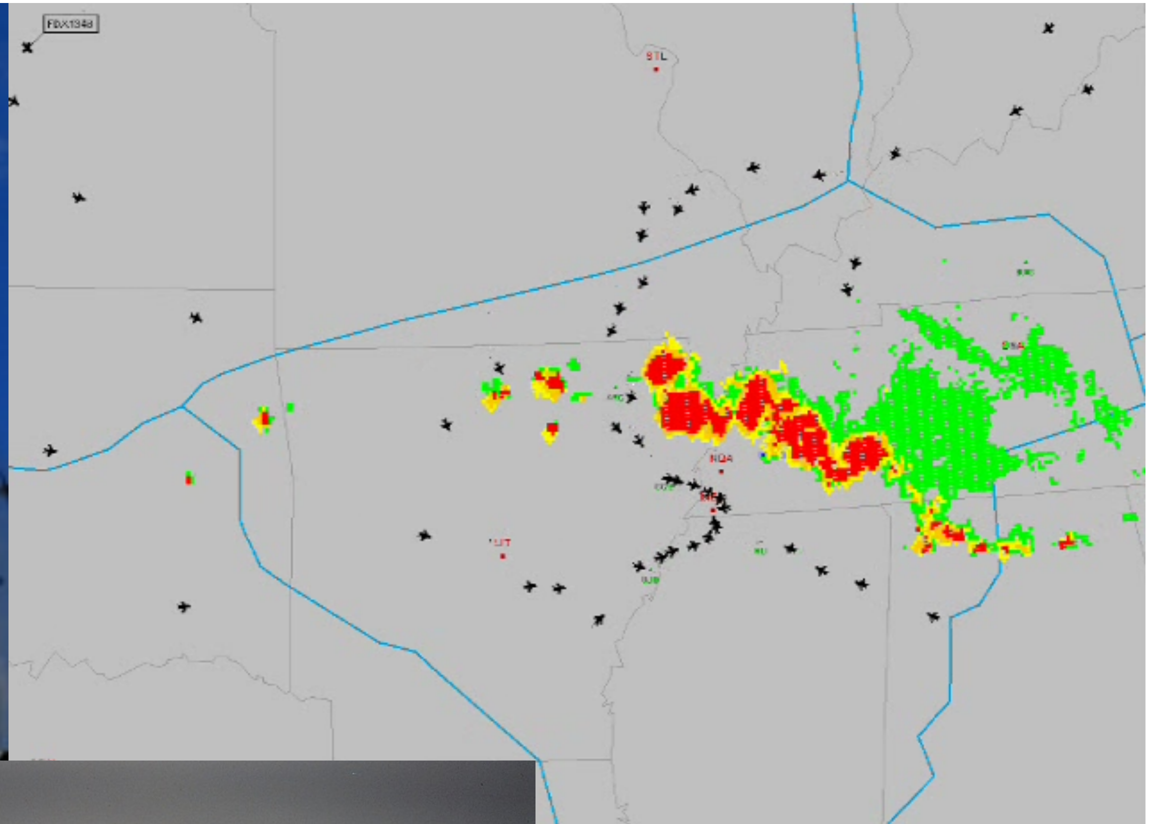
Rudolf Kaltenboeck, Alexander Ryzhkov

SAFETY IS IN THE AIR

Outline

- Motivation
- Data
- Methodology
- Results
  - hail backscattering effects
  - average profiles within hail bearing storm
- Attenuation – differential phase
- Conclusion - Outlook

Motivation



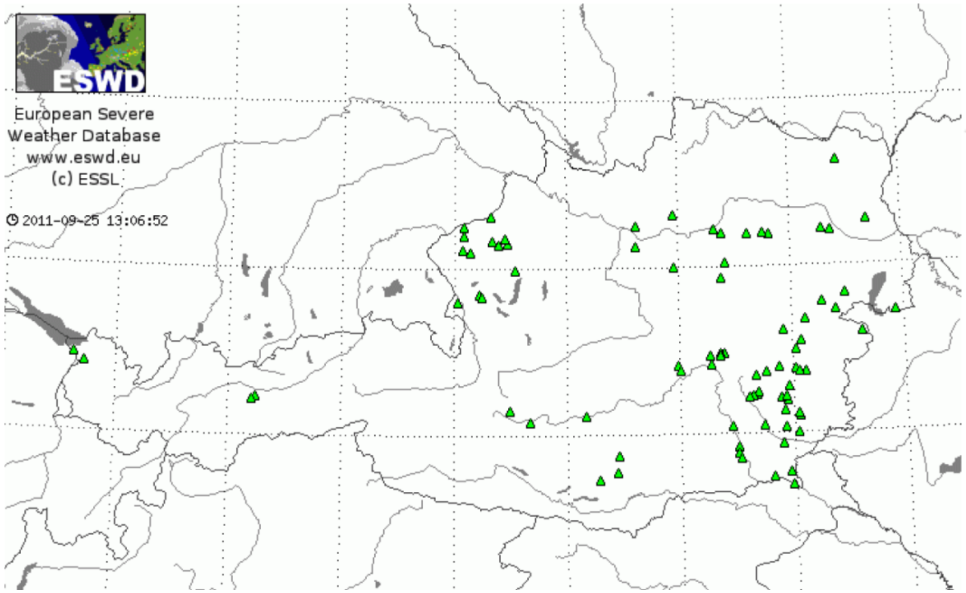
aviation

weather radar

hail

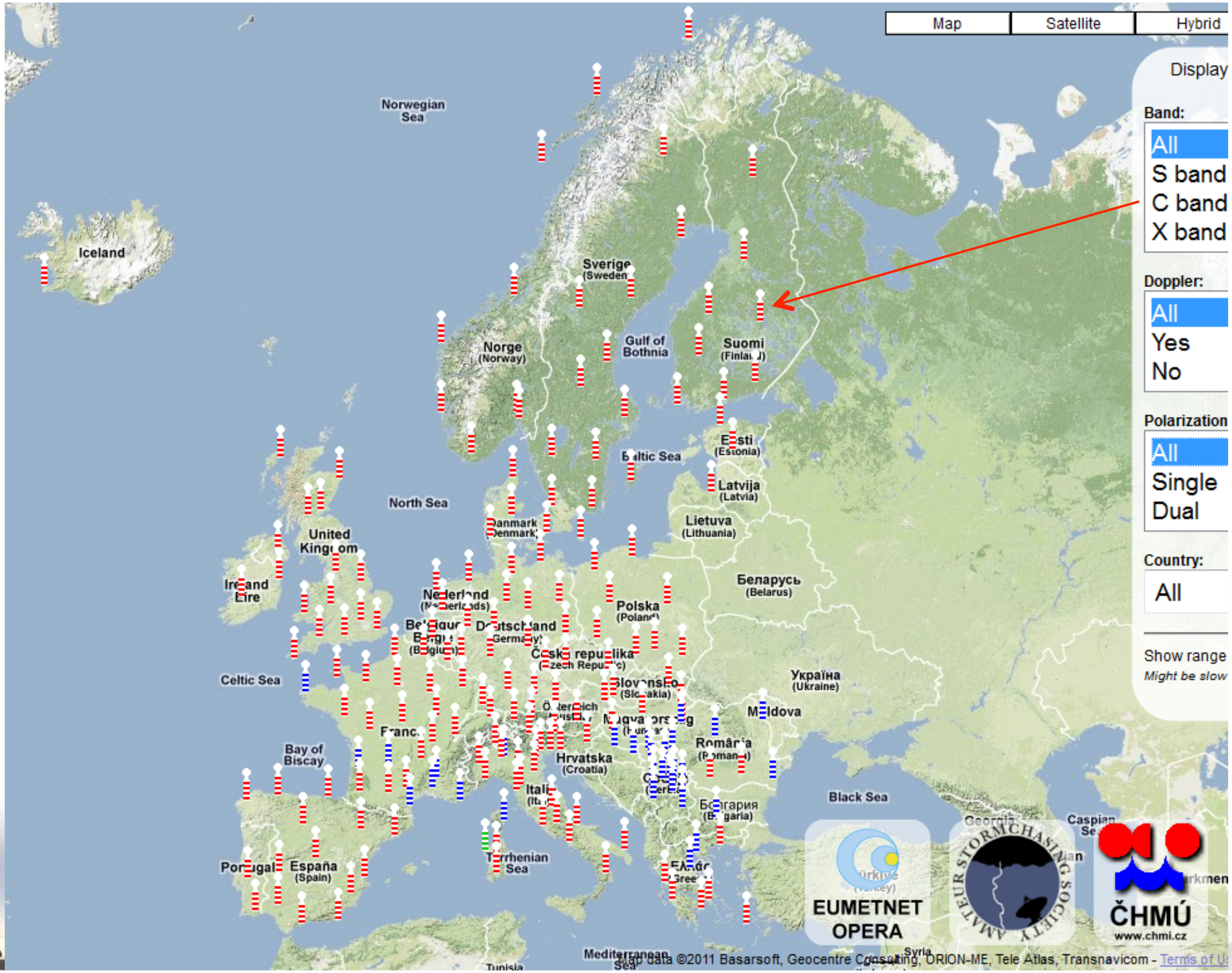
Motivation

- new installed dual polarized weather radars (C-band) in Austria



Motivation

Operational European Weather Radars
OPERA database:



Dec. 2010

Motivation
Operational European Weather Radars OPERA database:

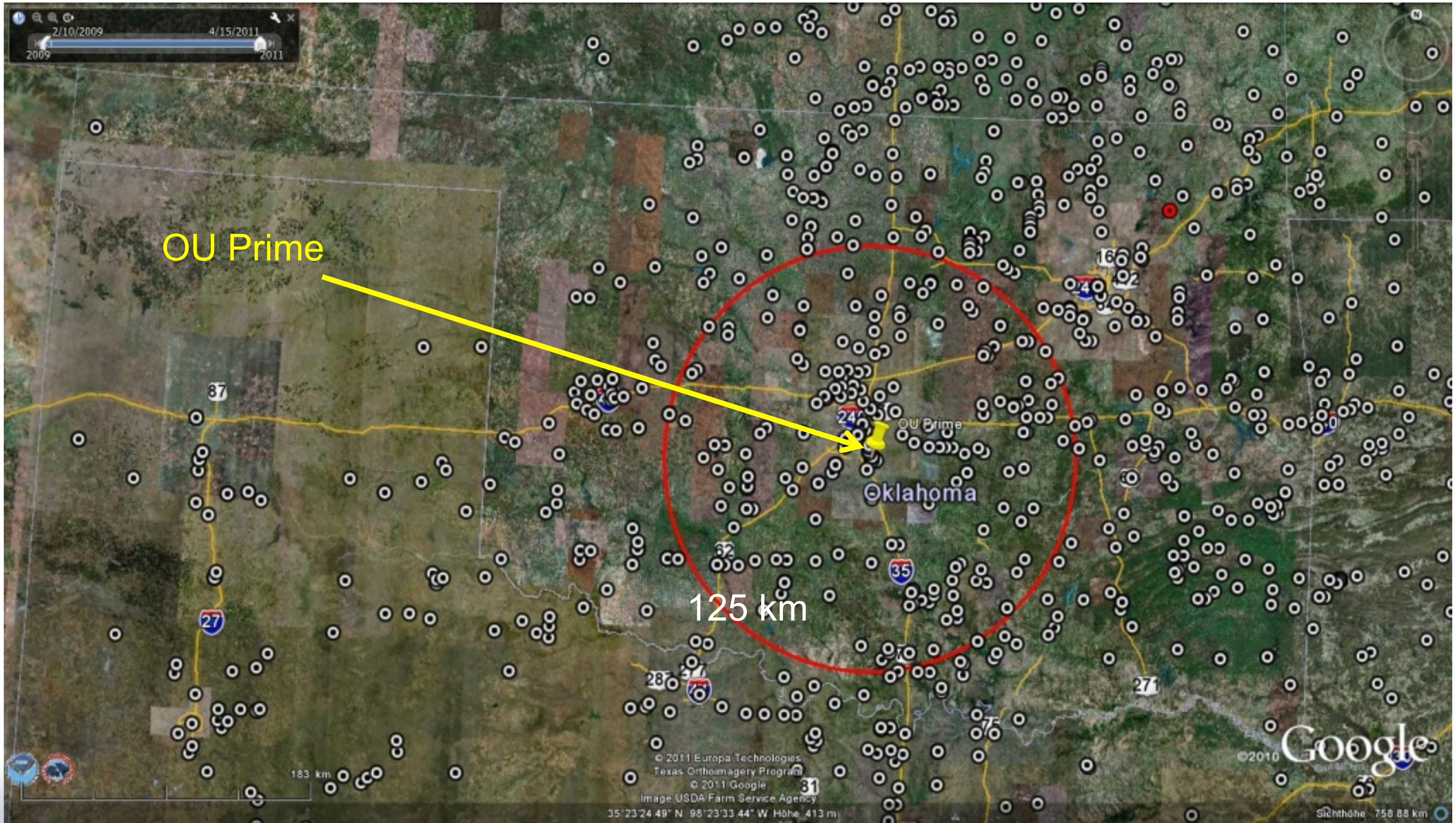
Dec. 2010

Aim

Large Hail D > 2.5 cm
Giant Hail D > 5 cm

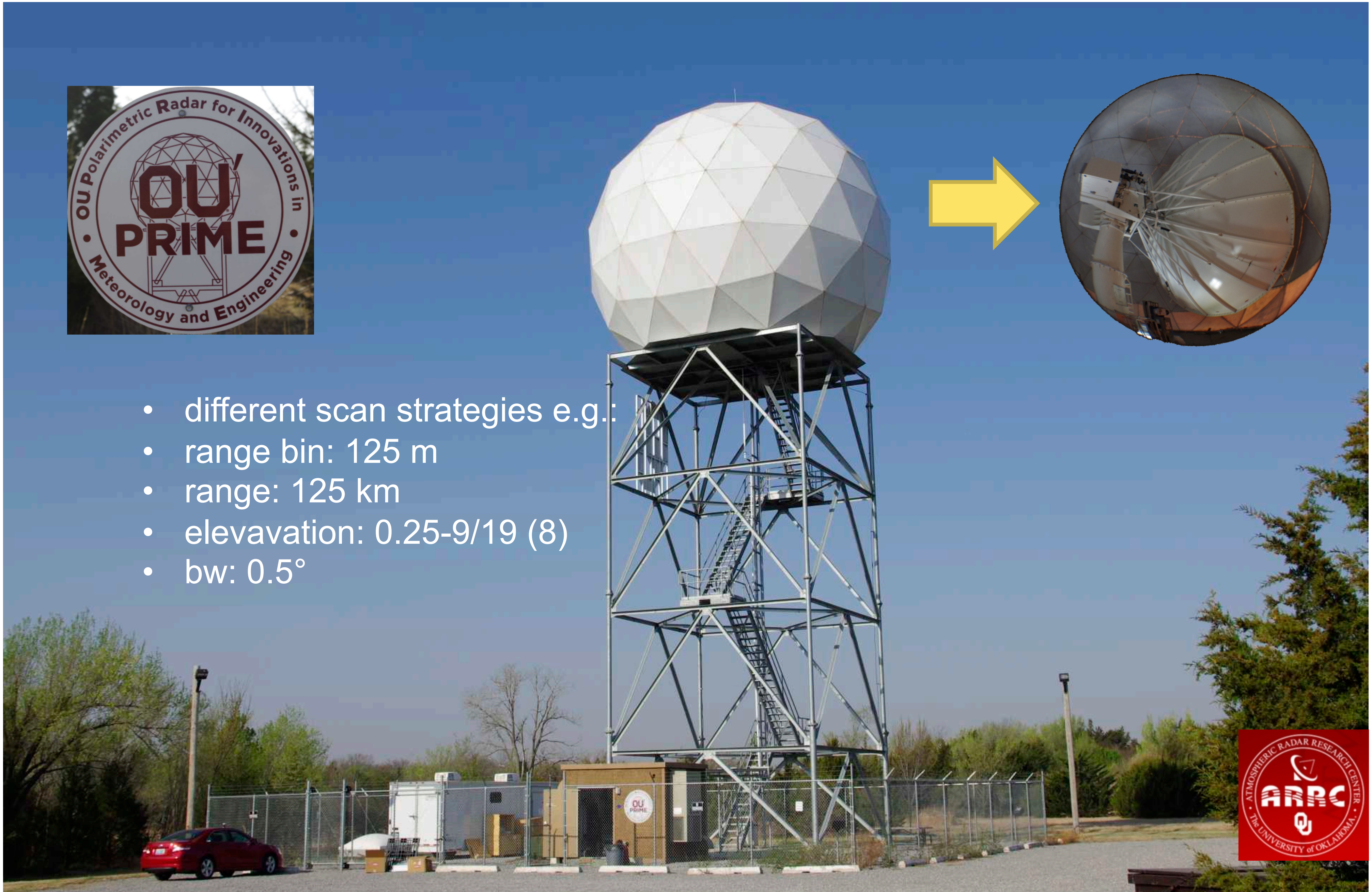
Data

SPC hail reports for Okalhoma, 2/2009-4/2011



>2 cm

Data: OU-PRIME C-band

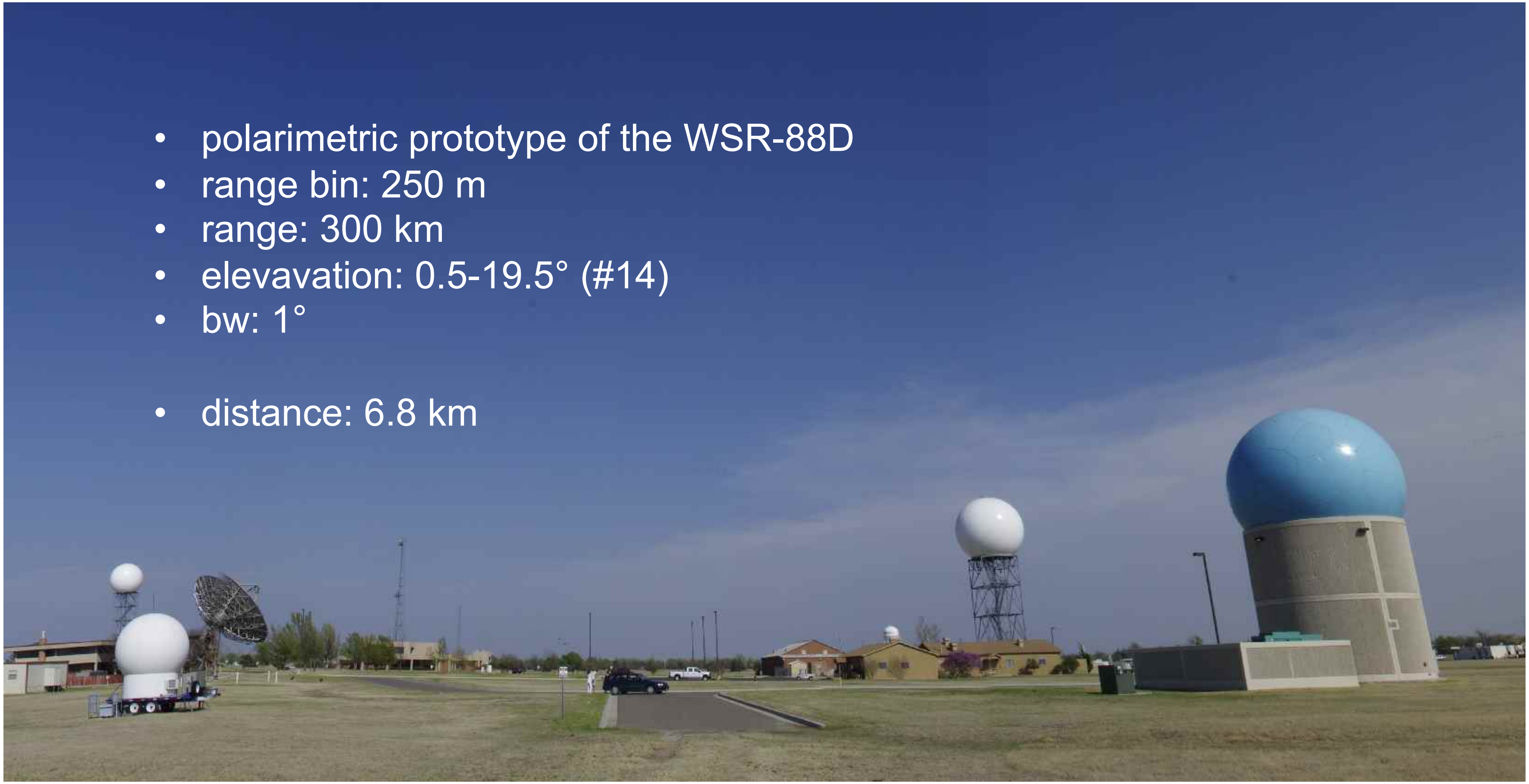


- different scan strategies e.g.:
- range bin: 125 m
- range: 125 km
- elevavation: 0.25-9/19 (8)
- bw: 0.5°

Data: KOUN S-band

- polarimetric prototype of the WSR-88D
- range bin: 250 m
- range: 300 km
- elevavation: 0.5-19.5° (#14)
- bw: 1°

- distance: 6.8 km



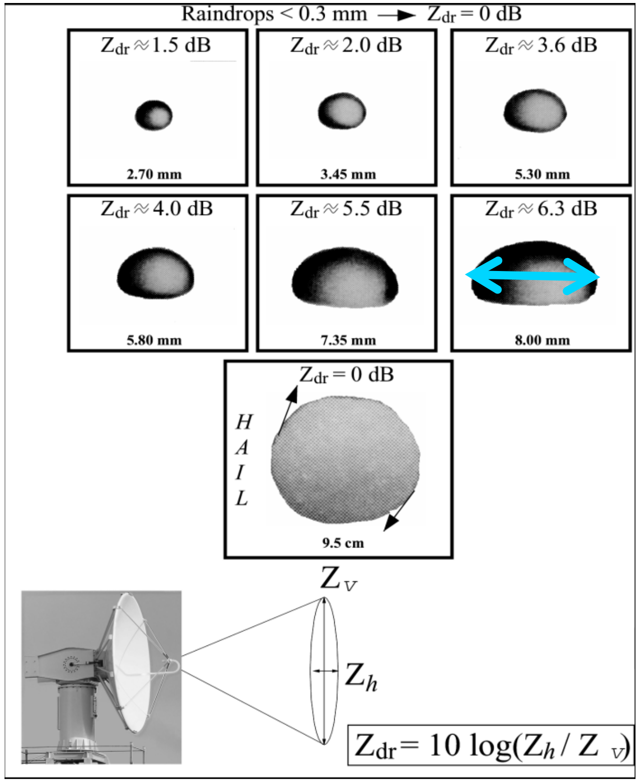
KCRI
NEXRAD-ROC

KOUN
NEXRAD

NWRT
PAR

Data: Dual Polarized Moments used in this study

- Differential Reflectivity Z_{DR}
  - depends on the particle size, shape, orientation, density, and water content
- Cross-Correlation coefficient ρ_{hv}
  - correlation between horizontally and vertically polarized weather signals
  - decrease indicate variety of HM, tumbling, mixture water / ice, irregular shape, resonance size, rapid shape deformation, large hail
- Differential Phase as quality parameter
  - specific (propagation) + backscatter diff. phase
- Simultaneous mode: no LDR



Bringi+Chandrasekar, 2001

Maximum Hail Size: Single Pol

- Max-Reflectivity or VIL in relation to freezing level height
- Echo-Top
- Probability of hail … maximal expected hail size (severe hail index – deptends on temperature-height weighting function and kinetic energy of hail)

(e.g. Waldvogel, 1979; Donavan and Jungbluth, 2007; Edwards and Thompson, 1998; Witt et al., 1998)

Maximum Hail Size: Dual Pol

- polarimetric characteristics of hailstones depend on their size, shape, falling behavior, and are strongly affected by the degree of melting and the probing radar wavelength.

- better quality of hail detection (FAR reduced)
- **location** of hail in the storm
  - including its height above ground

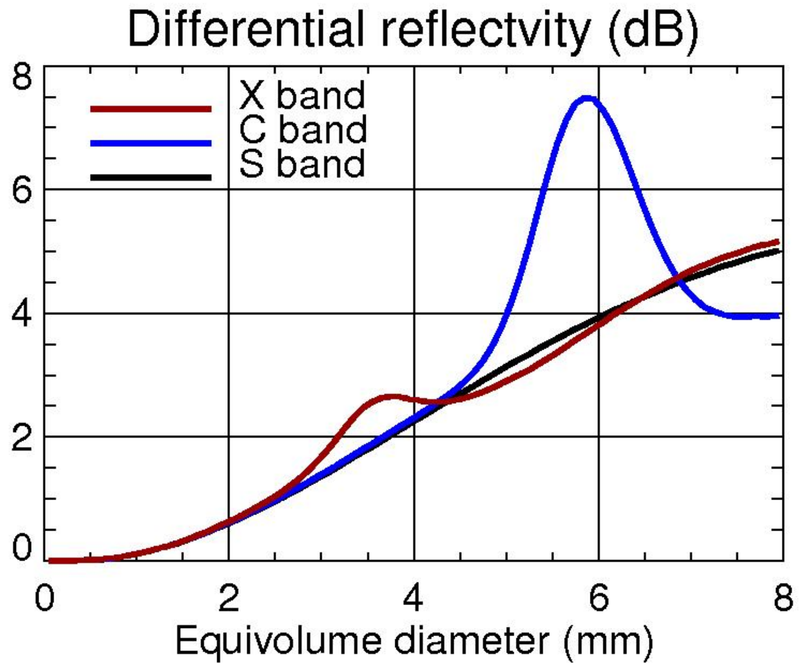
- S-band
  - hail differential reflectivity HDR (e.g. Aydin et al., 1986, Depue et al., 2007)
  - HCA (e.g. Park et al. 2009) - no hail size

- S/C/(X)-band:
  - melting hail – polarimetric characteristics of large hail

  (e.g. Ryzhkov et al., 2009, Borowska et al., 2010; Kumjian et al., 2010, Picca and Ryzhkov, 2011, Tabery et al., 2009)

Data: Dual Polarized Moments

C-band: resonance effects

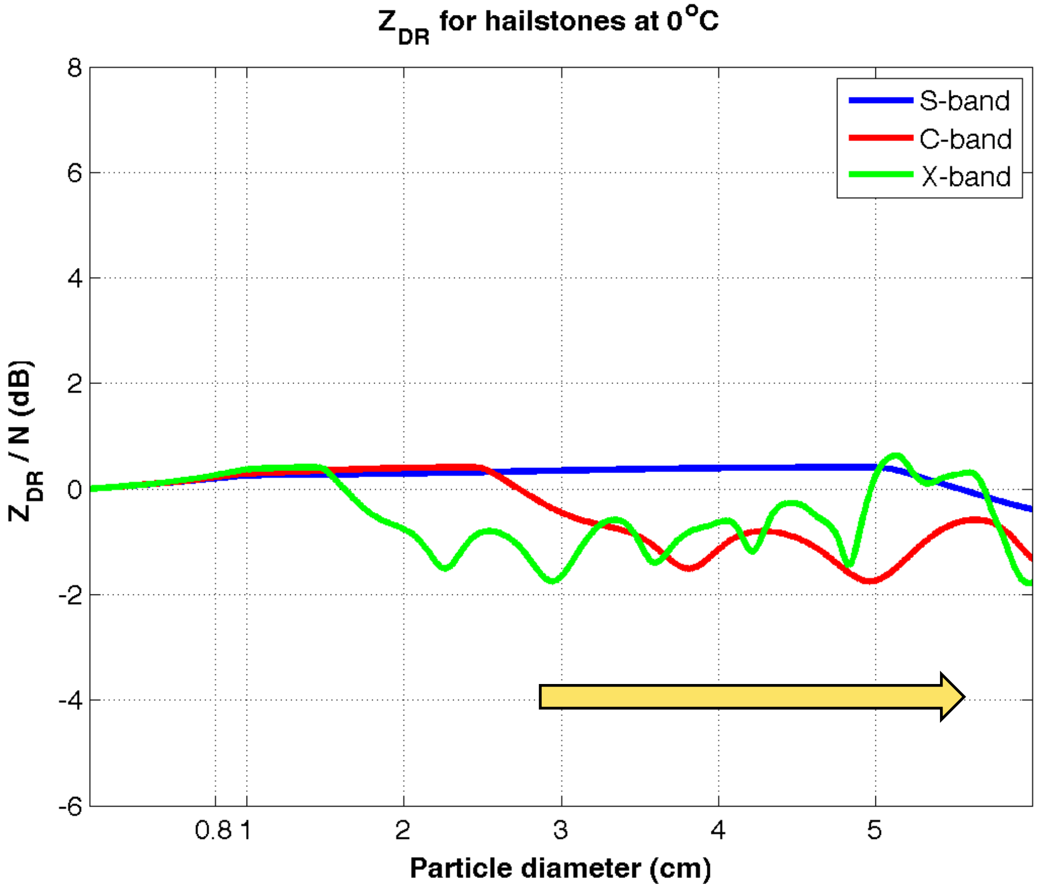


Strong attenuation and differential attenuation in hail at C band further complicates the issue of hail detection / sizing

Data: Dual Polarized Moments

C-band: resonance effects

dry hail / graupel

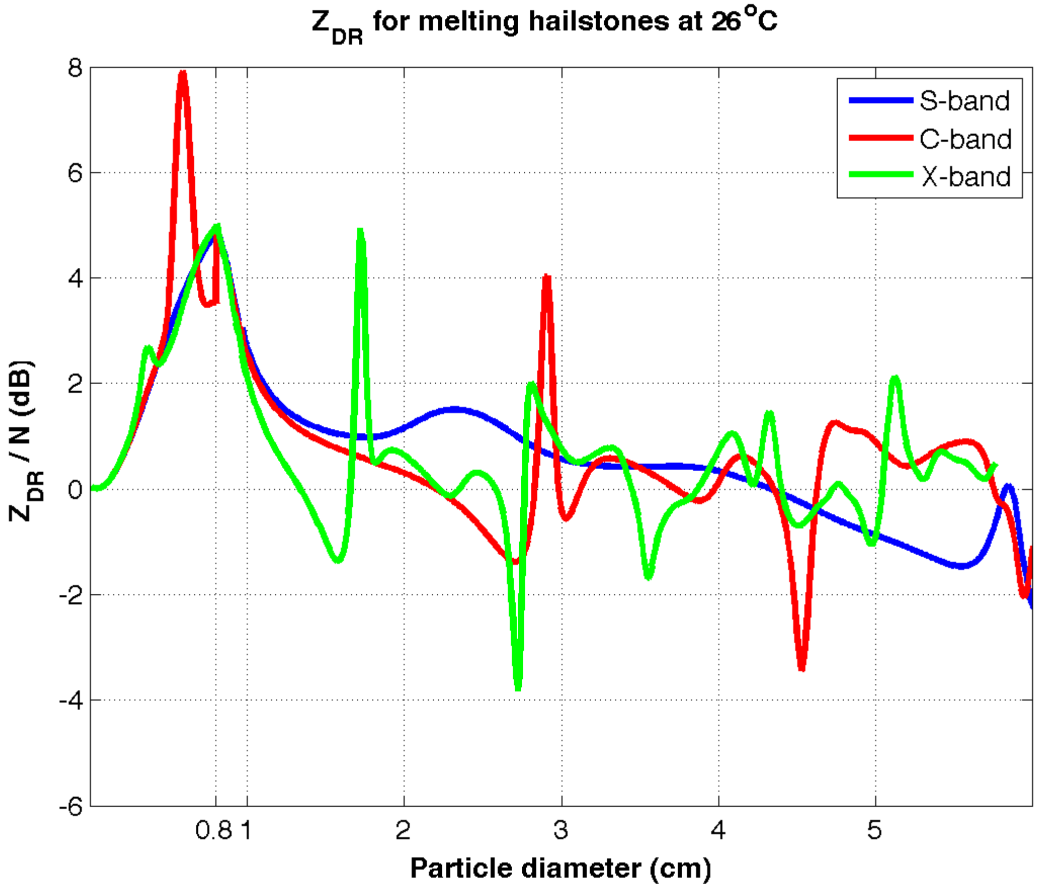


- Strong attenuation and differential attenuation in hail at C band further complicates the issue of hail detection / sizing

Data: Dual Polarized Moments

C-band: resonance effects

rain - mixed with melting hail



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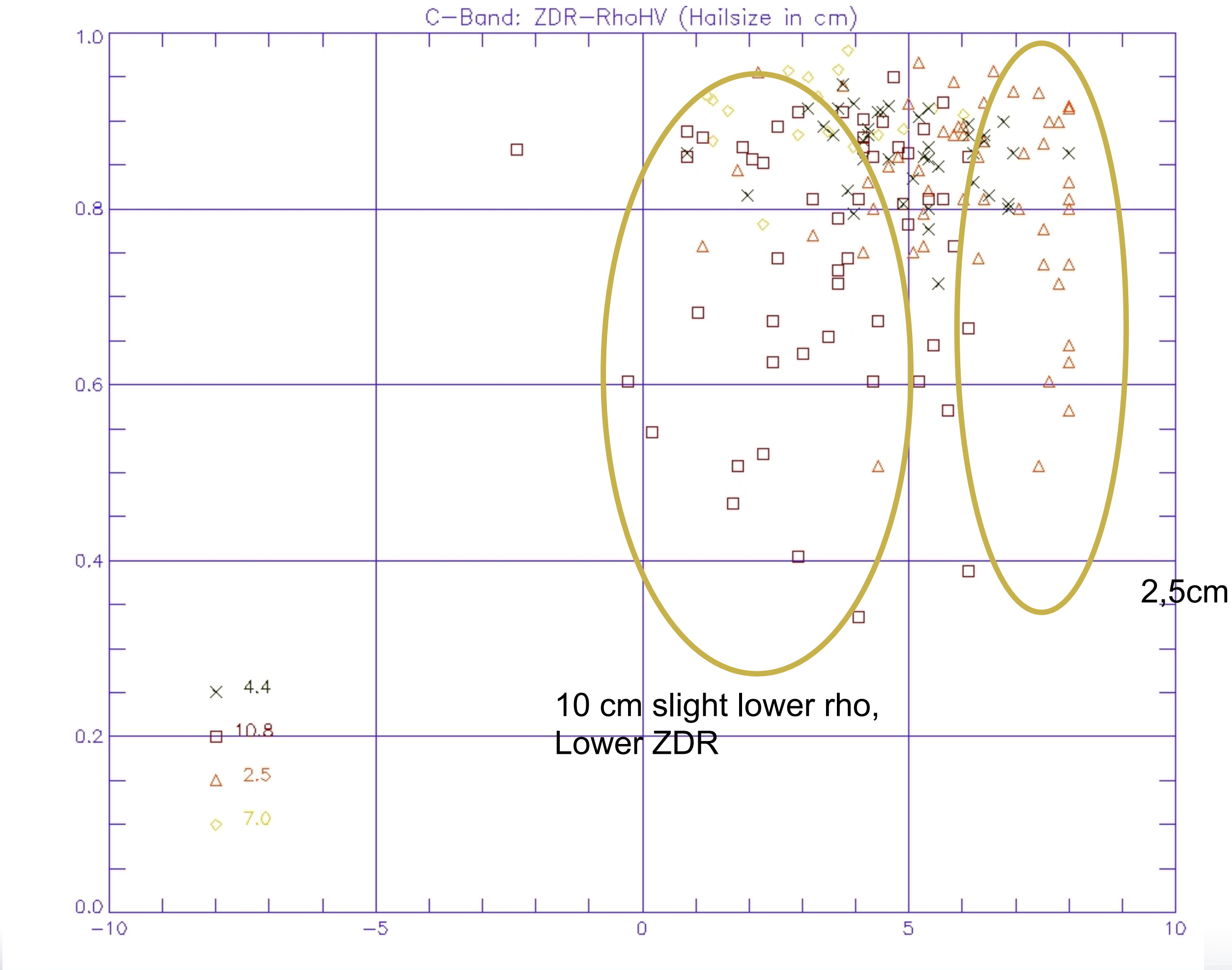
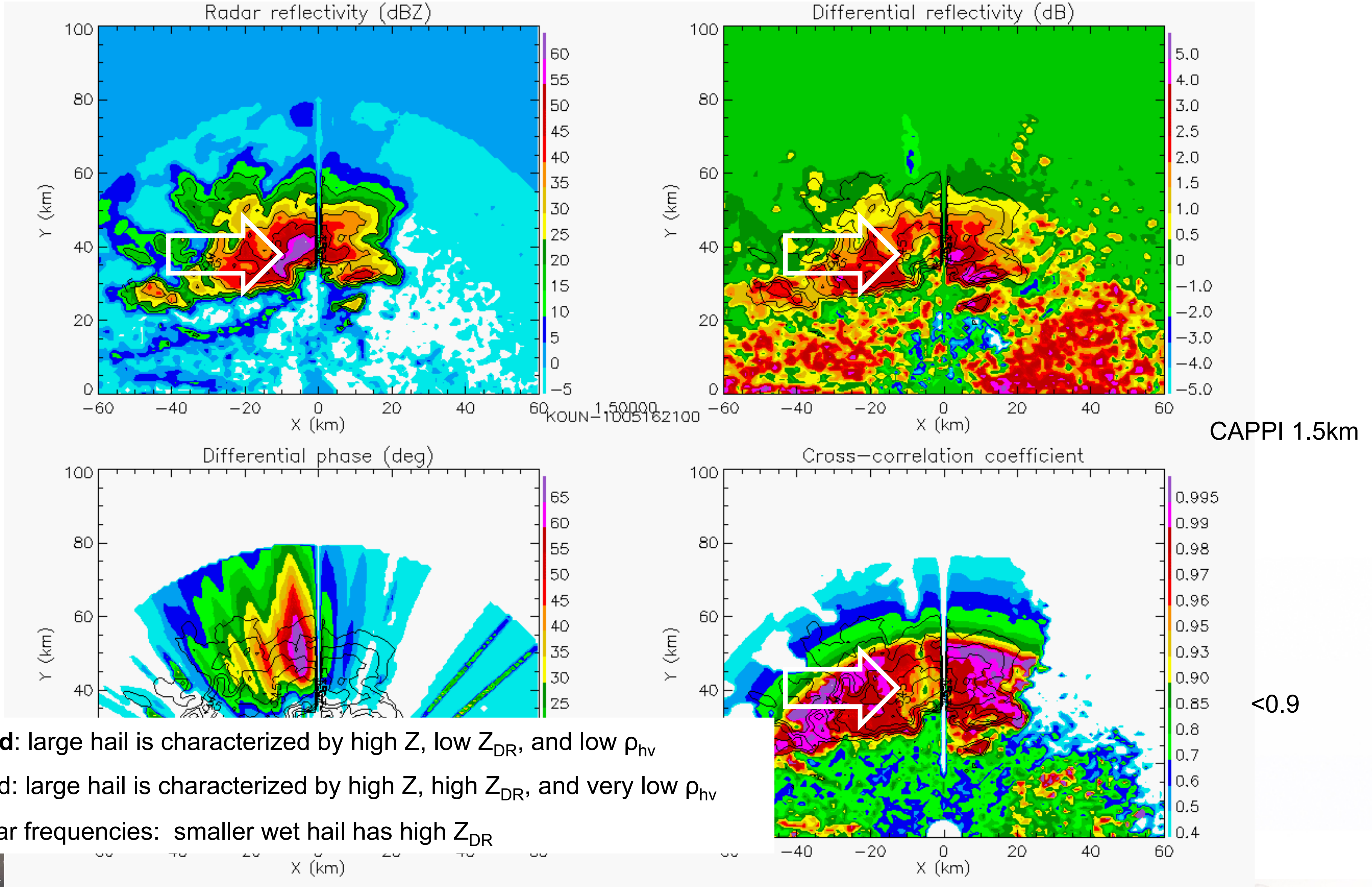
Data: Dual Polarized Moments

C-band: resonance effects

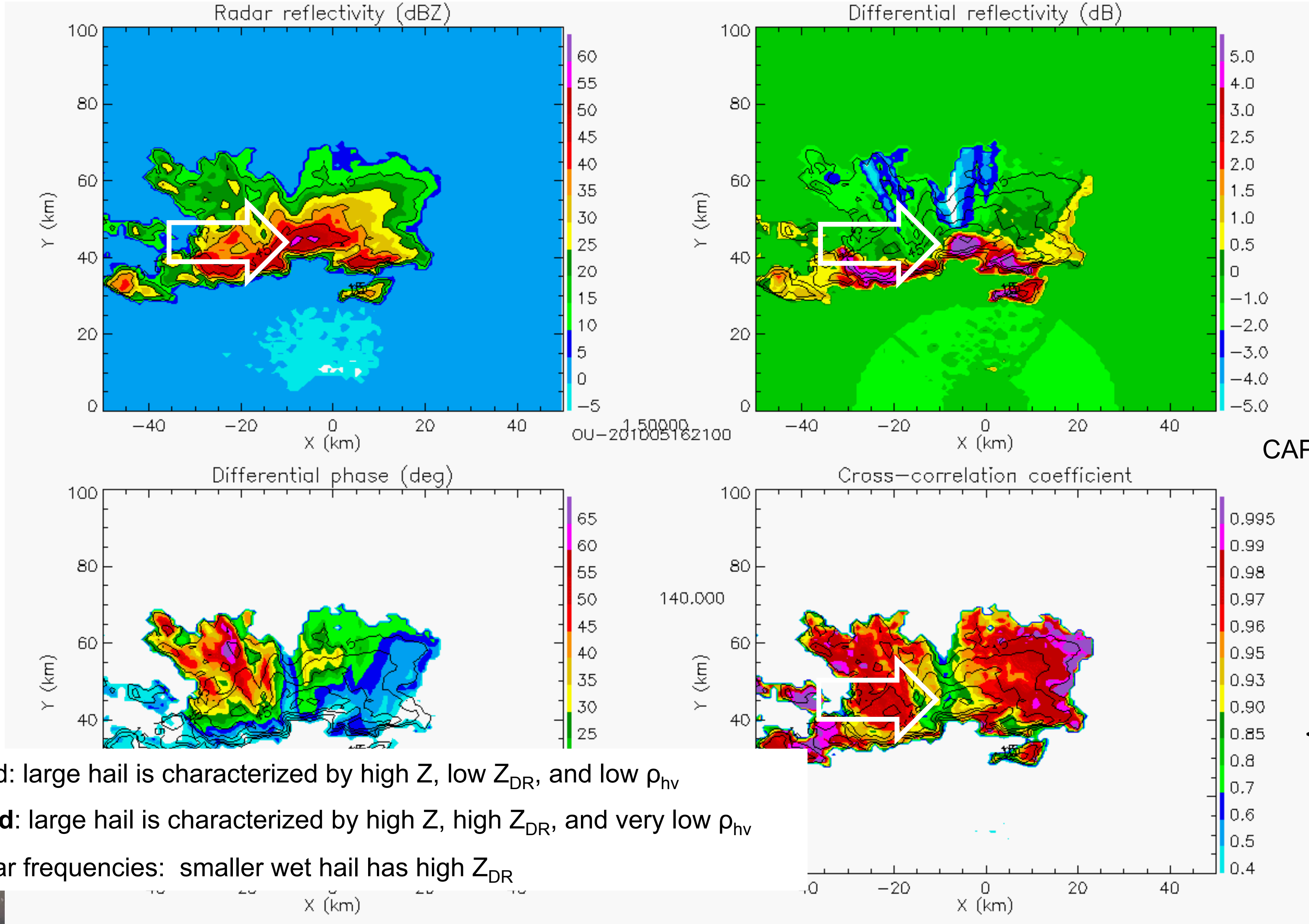


Hail-diameter: 10cm
***S-band** – wet hail below freezing level*



- **S-band**: large hail is characterized by high Z, low Z_{DR}, and low ρ_{hv}
- C-band: large hail is characterized by high Z, high Z_{DR}, and very low ρ_{hv}
- all radar frequencies: smaller wet hail has high Z_{DR}

Hail-diameter: 10cm
C-band *– wet hail below freezing level*



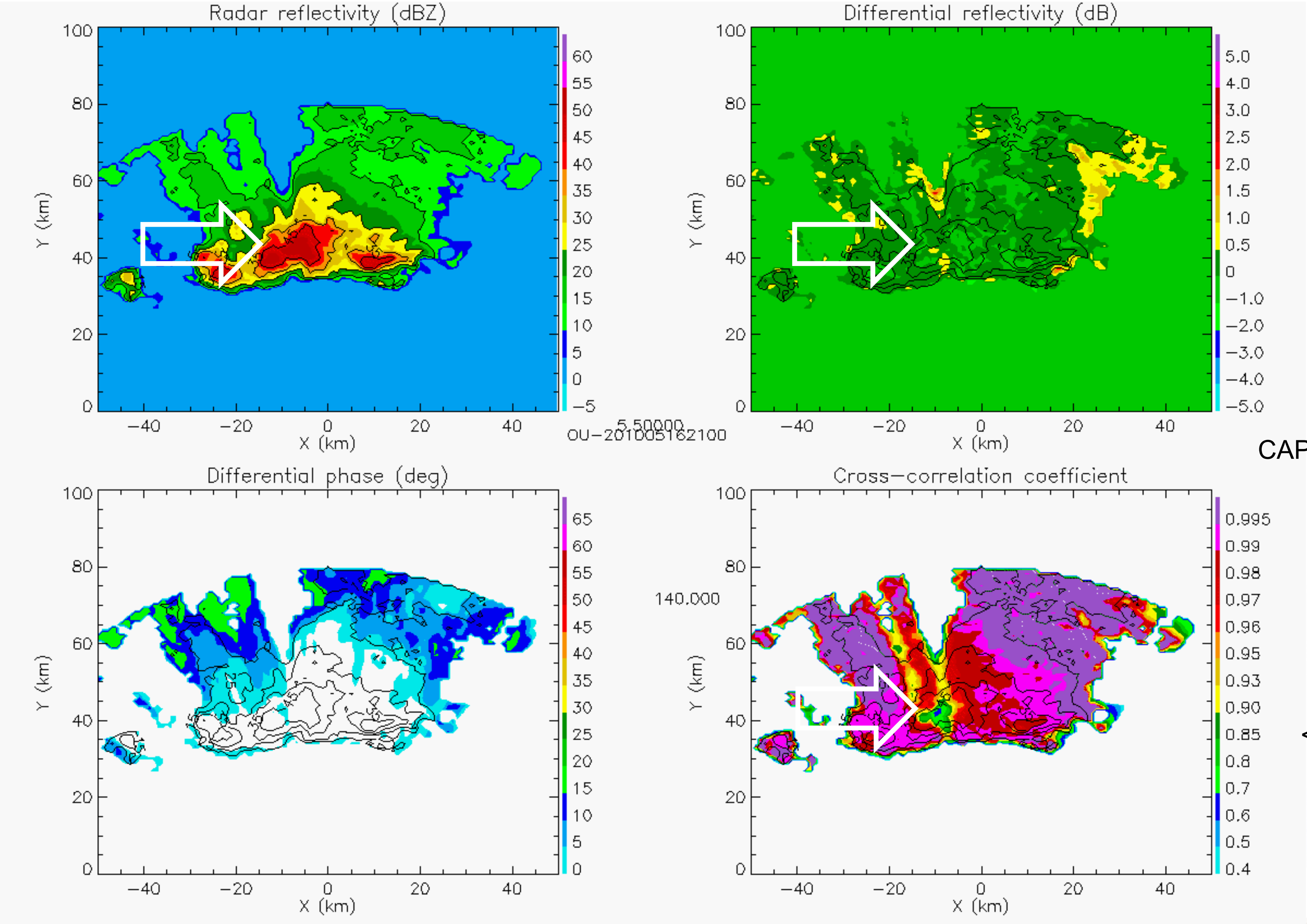
>5dBZ

CAPPI 1.5km

<0.8

- S-band: large hail is characterized by high Z, low Z_{DR}, and low ρ_{hv}
- **C-band**: large hail is characterized by high Z, high Z_{DR}, and very low ρ_{hv}
- all radar frequencies: smaller wet hail has high Z_{DR}

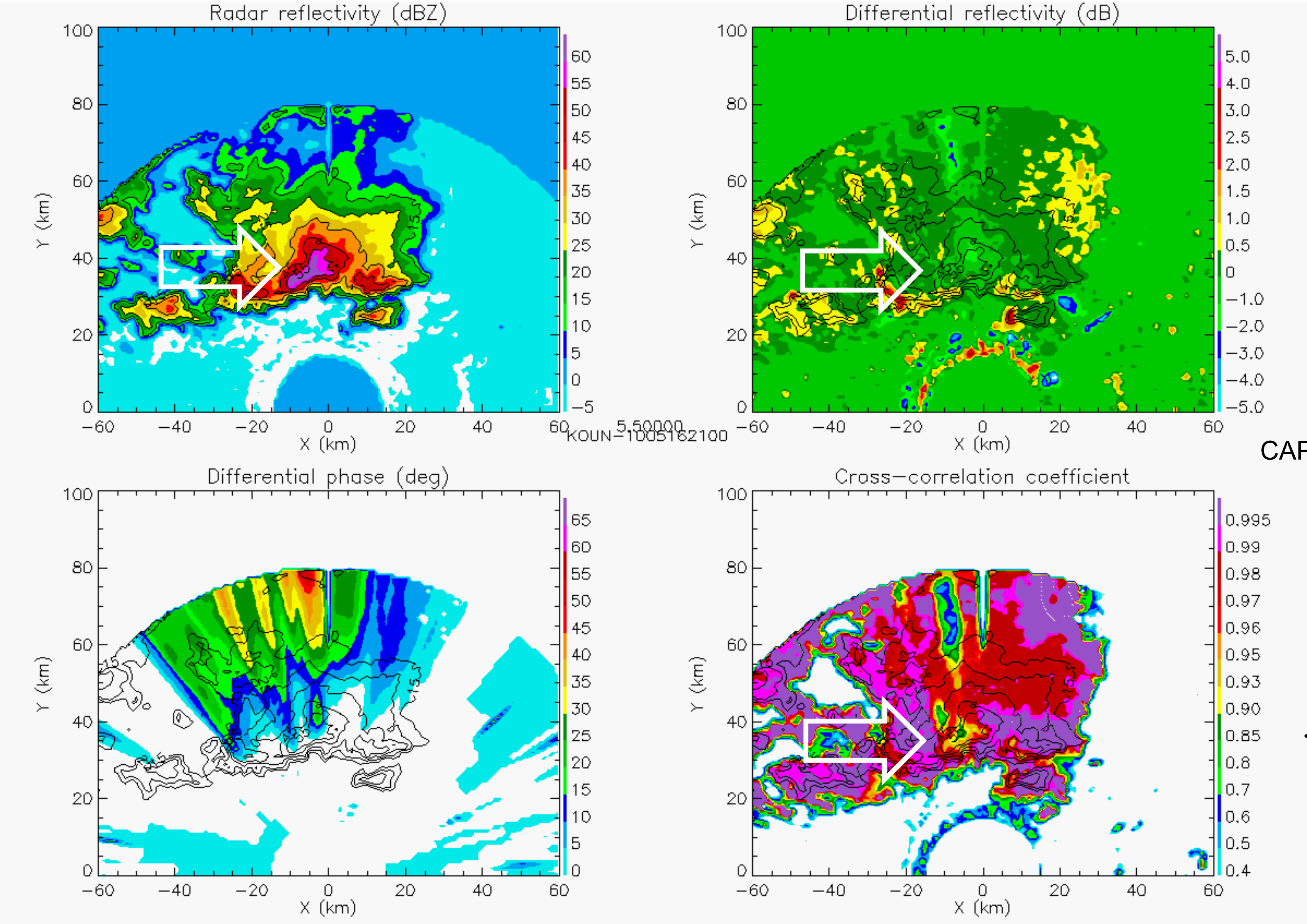
Hail-diameter: 10cm
***C-band** – dry hail aloft*



CAPPI 5.5km

<0.7

Hail-diameter: 10cm
S-band – dry hail aloft



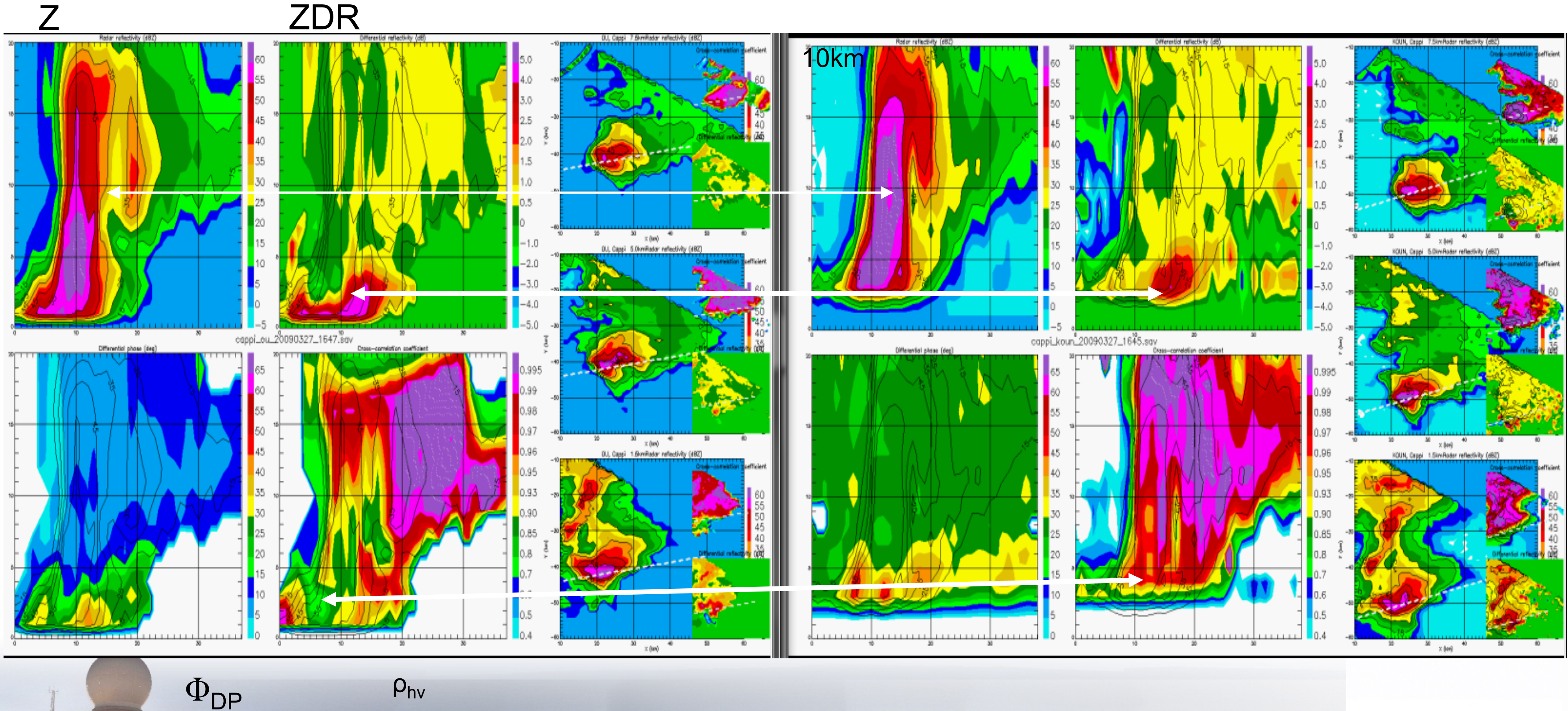
CAPPI 5.5km

<0.9

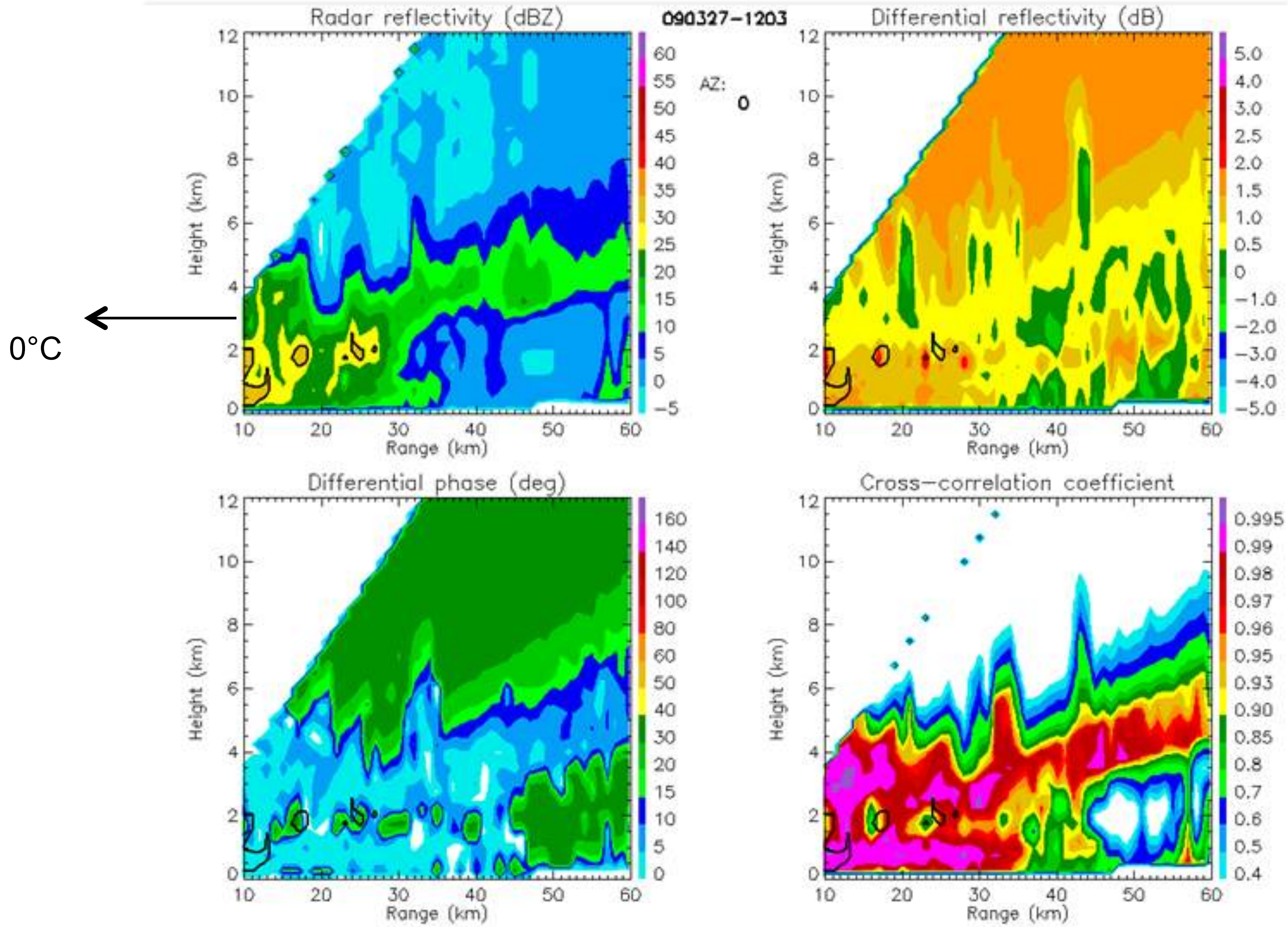
Cross section
hail size 2,5 cm

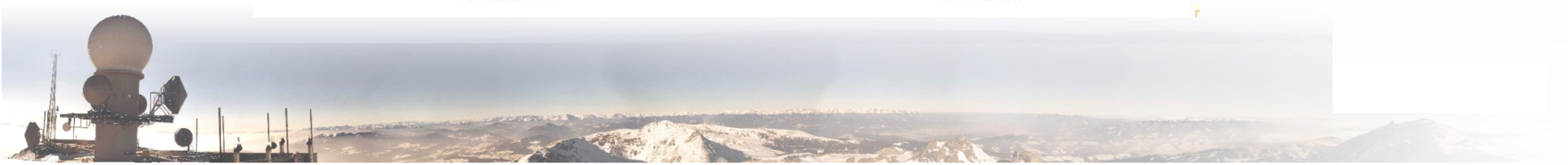
- C-band

S-band

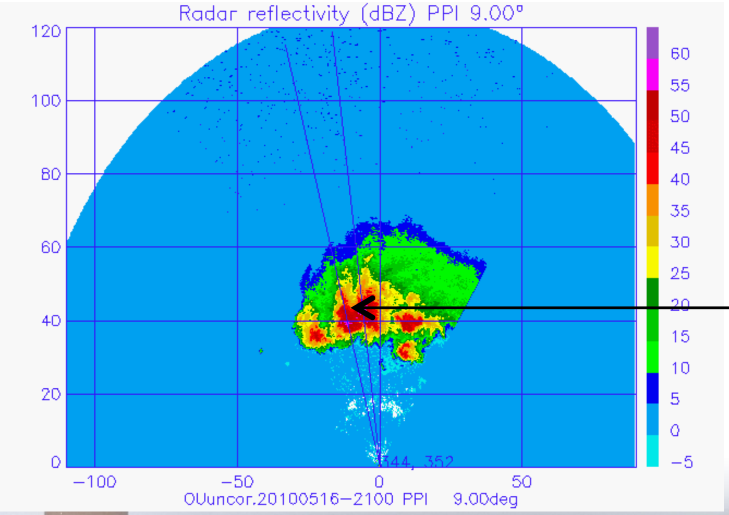


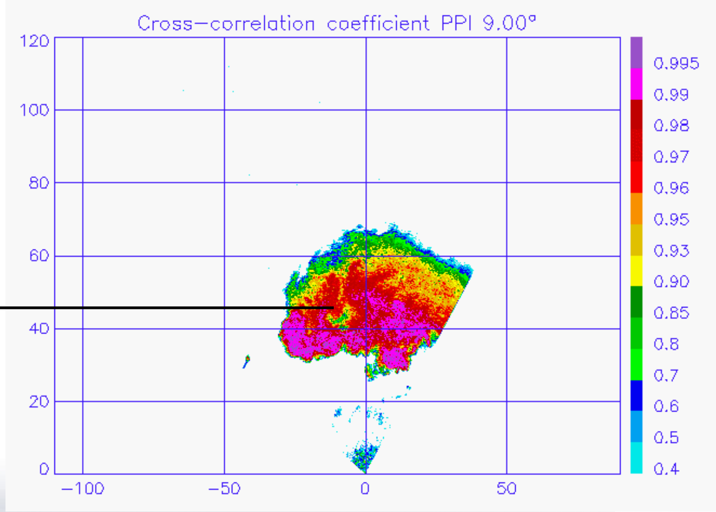
Weak Convection – thermal plumes
C-band





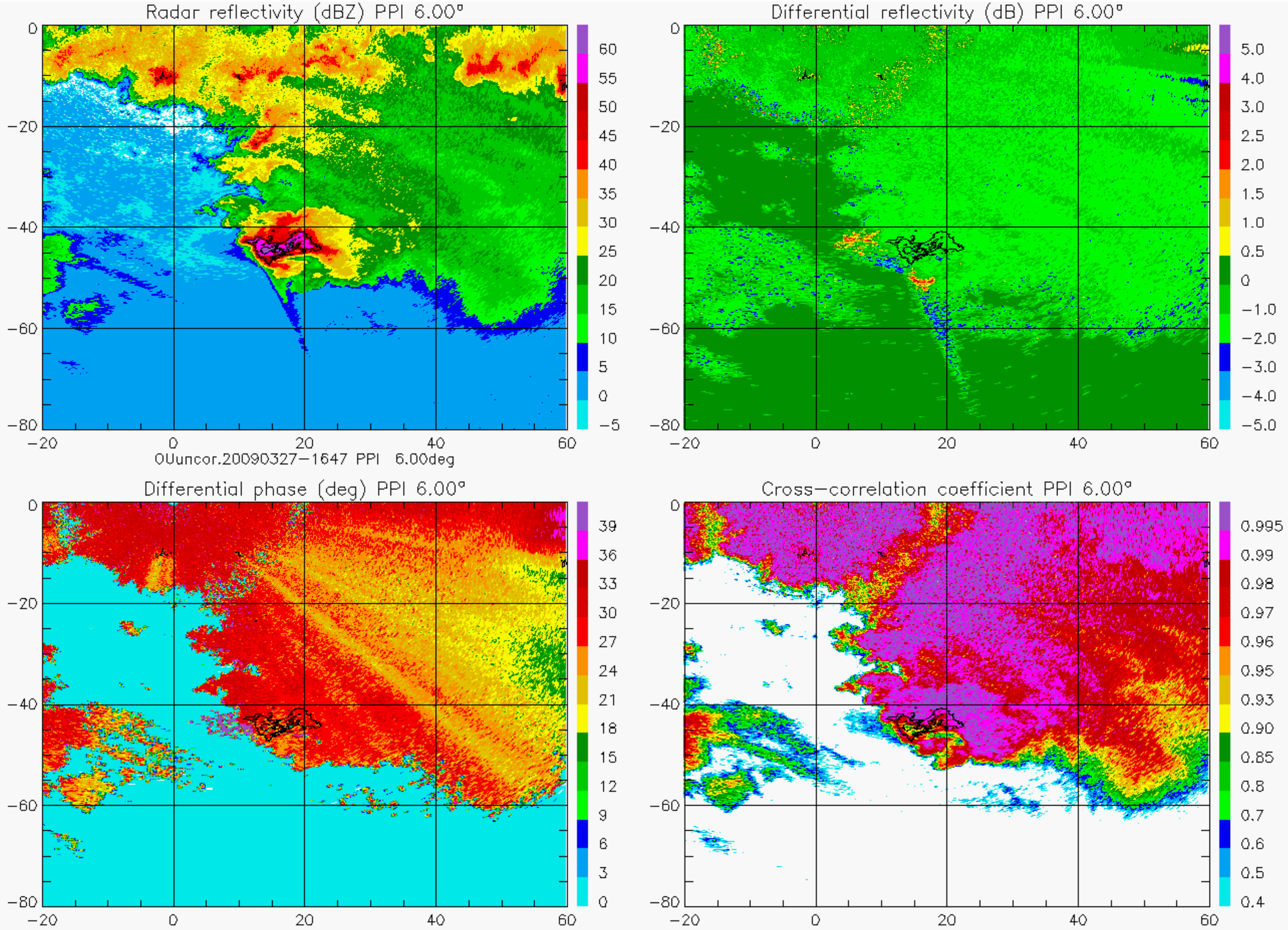
Dry hail aloft



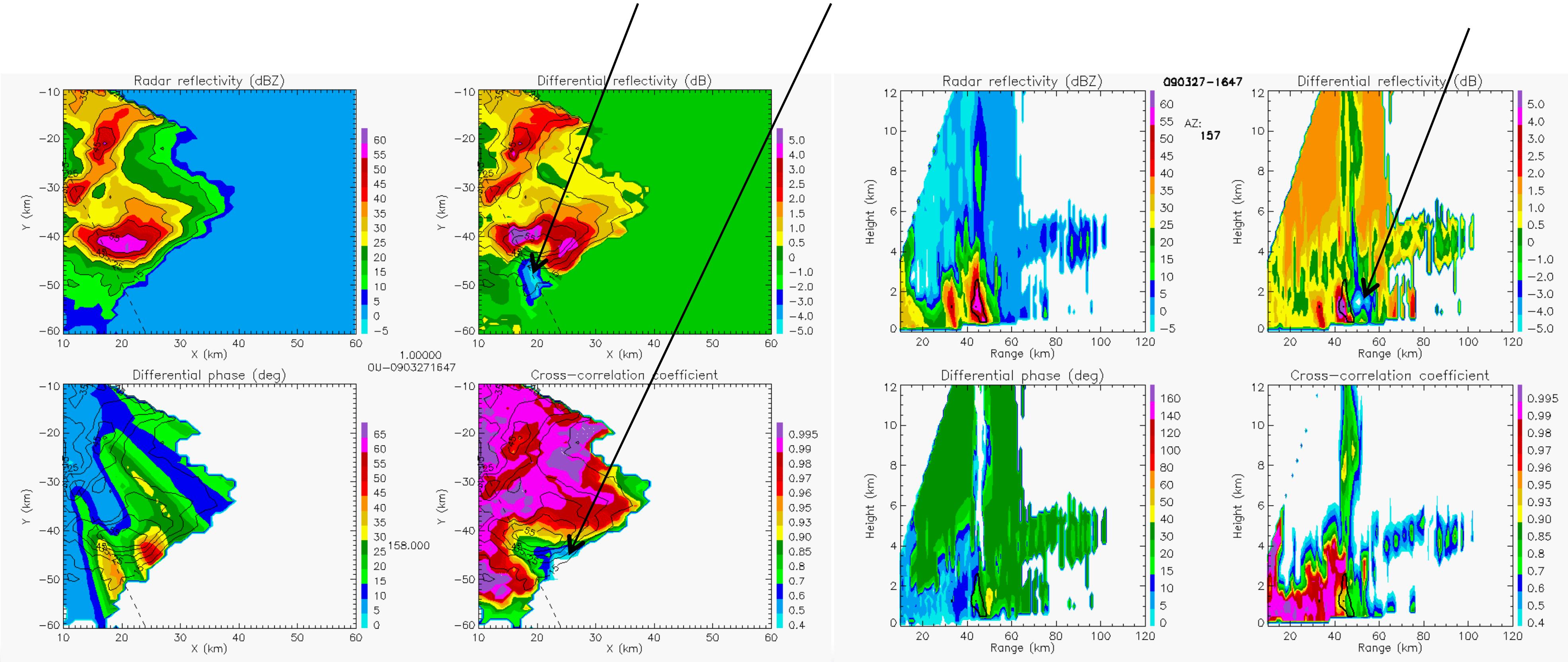


HAIL BACKSCATTERING EFFECTS WHICH AFFECT DUAL POL MOMENTS AND CORRESPONDING VERTICAL STRUCTURE

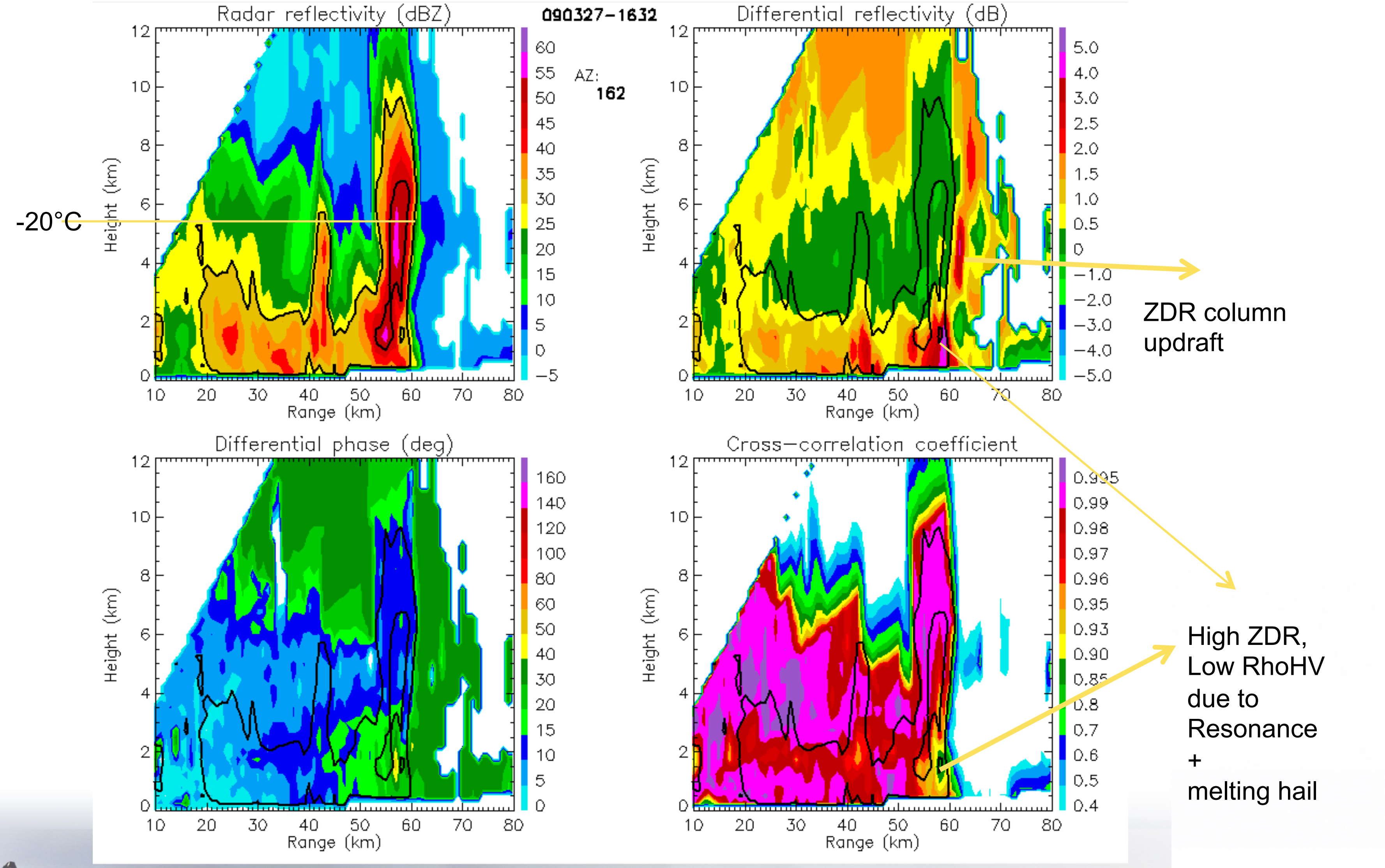
TBSS C-band
three scatter signature signal



LOW RhoHV due to ZDR gradient, SNR C-band



ZDR Column + Side-lobe effects
C-band

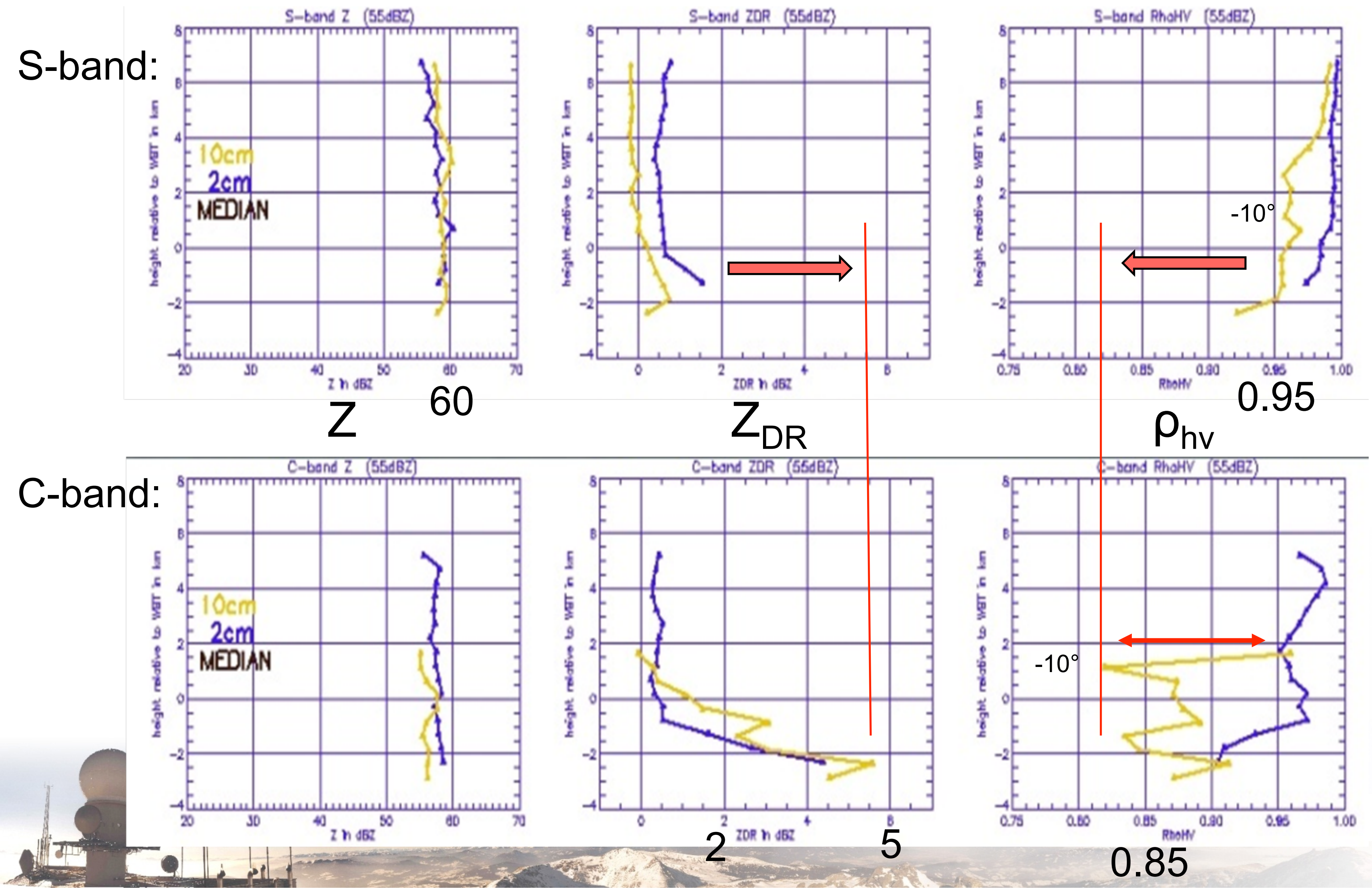


vertical profile: hail: 2 - 10cm

$Z \geq 55dBZ$

vertical profile: hail: 2 - 10cm

Z ≥ 55dBZ

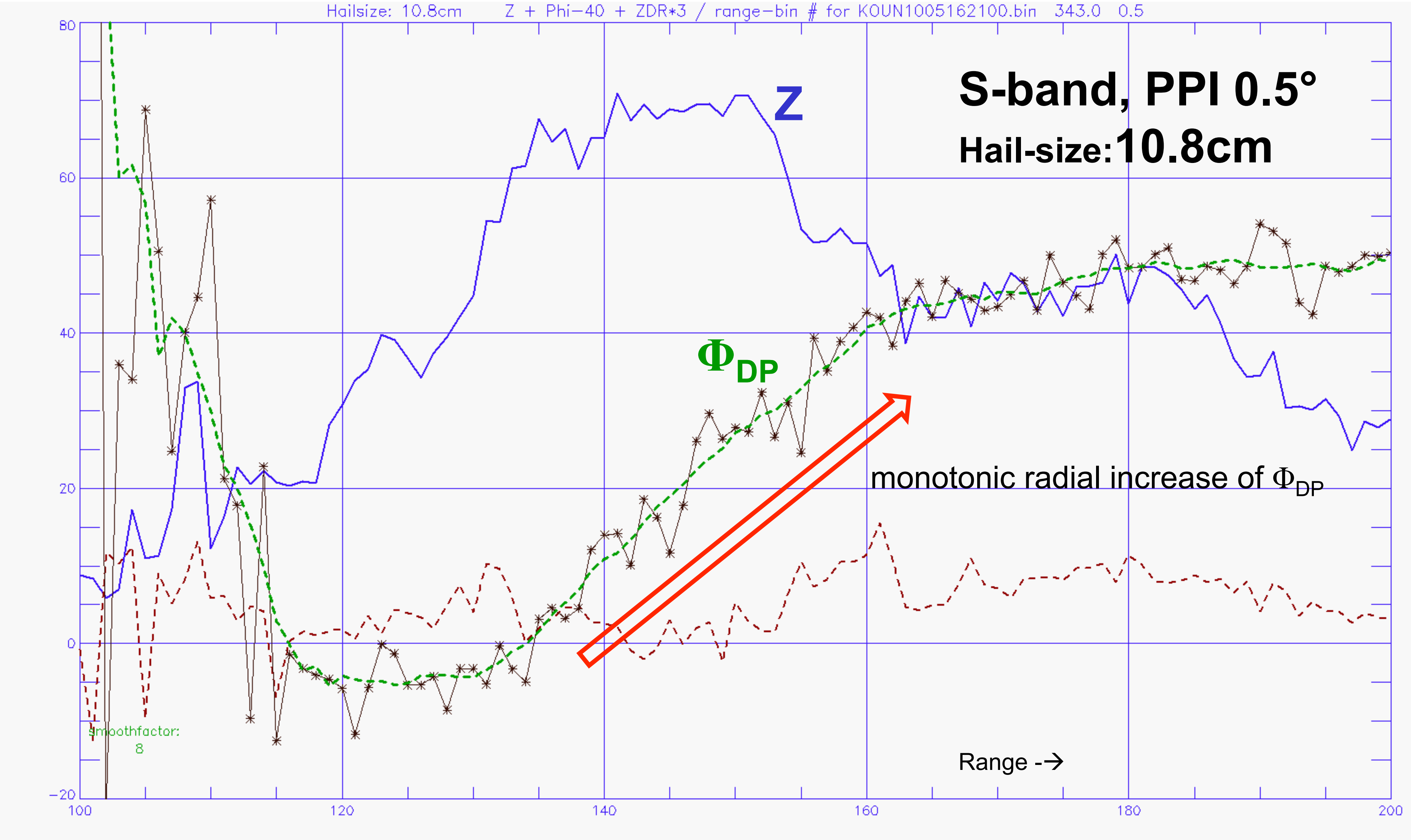


Φ_{DP} hail size dependence for C-band

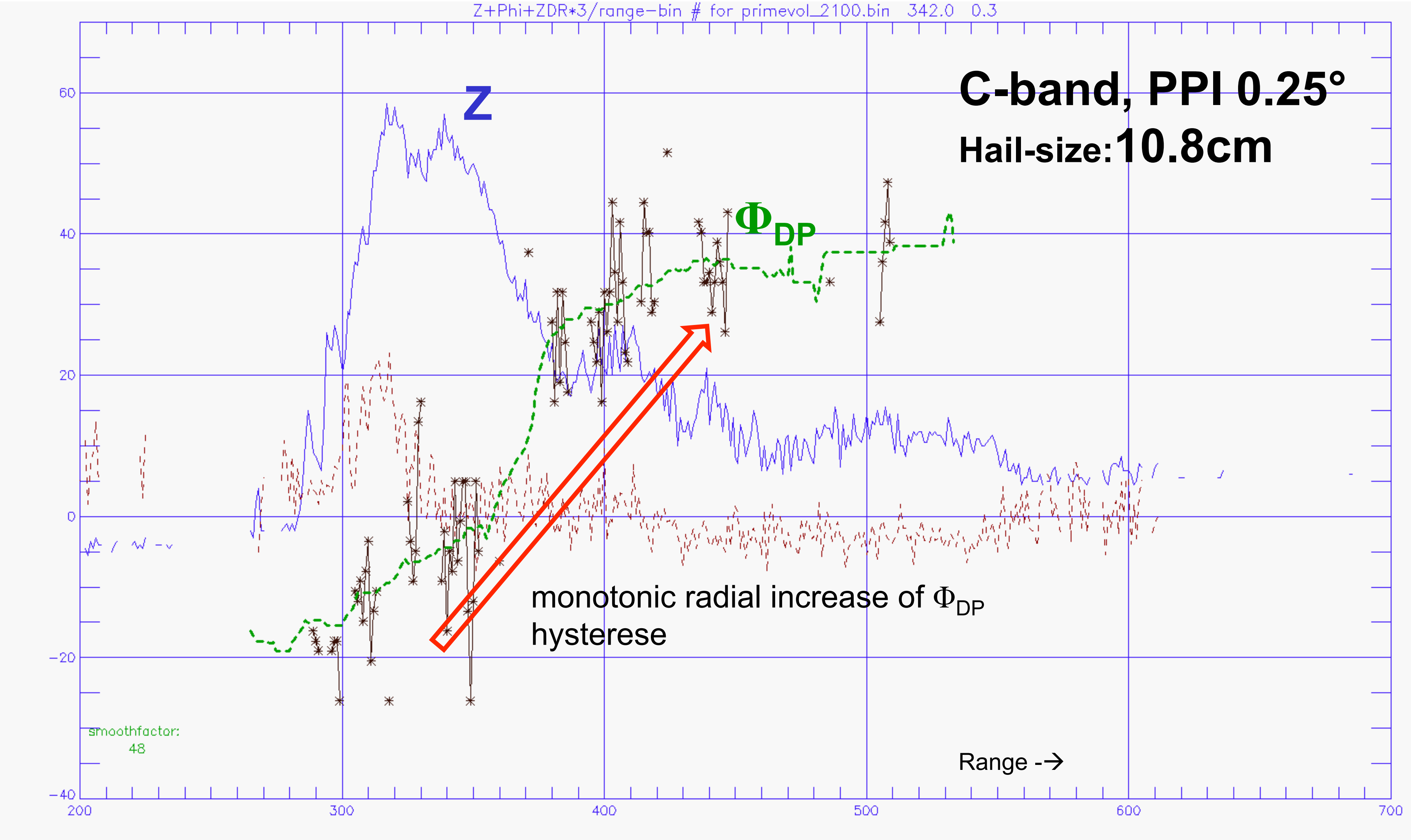
nonmonotonic radial dependcies of Φ_{DP}

- below freezing level

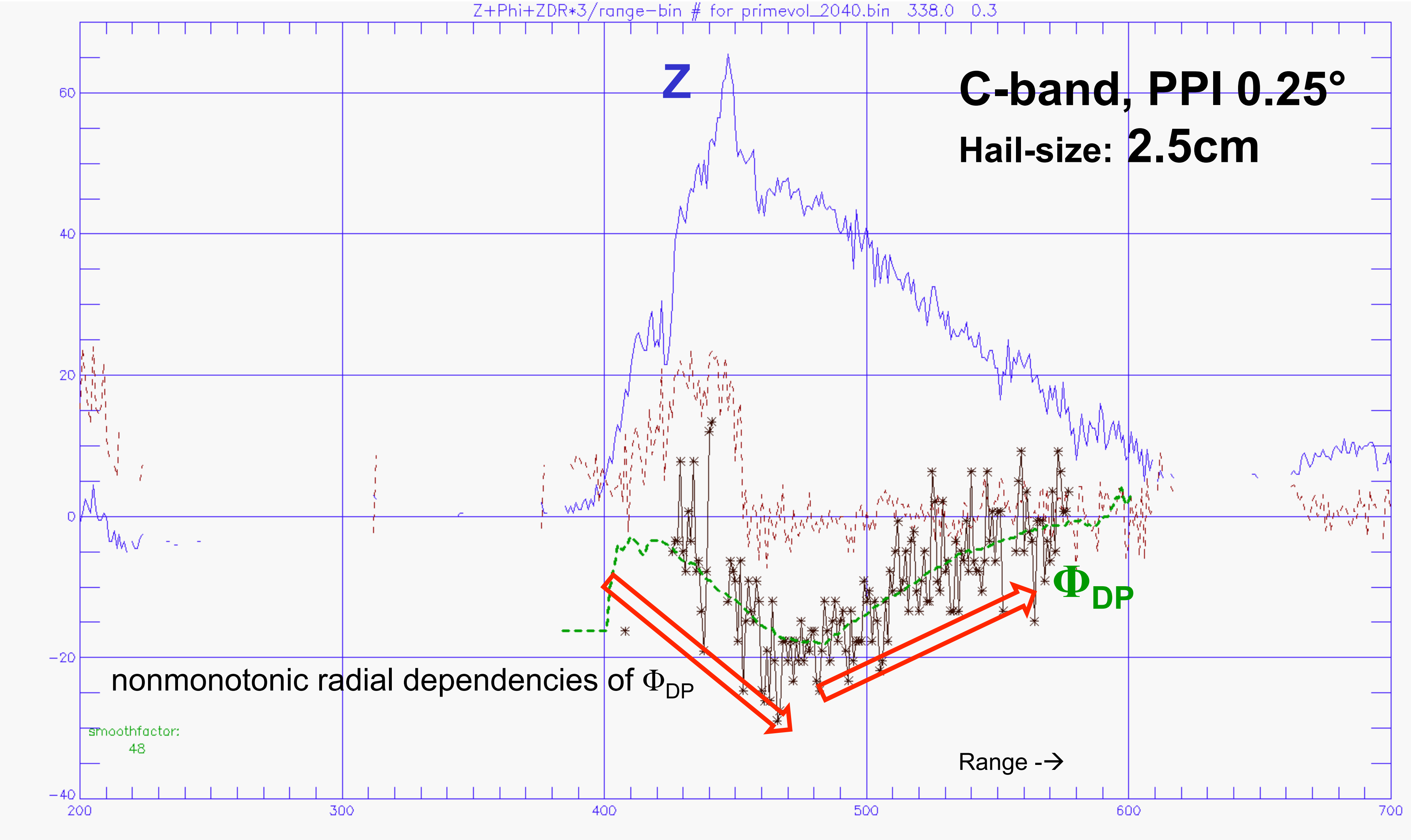
Φ_{DP} hail size dependence for C-band



Φ_{DP} hail size dependence for C-band

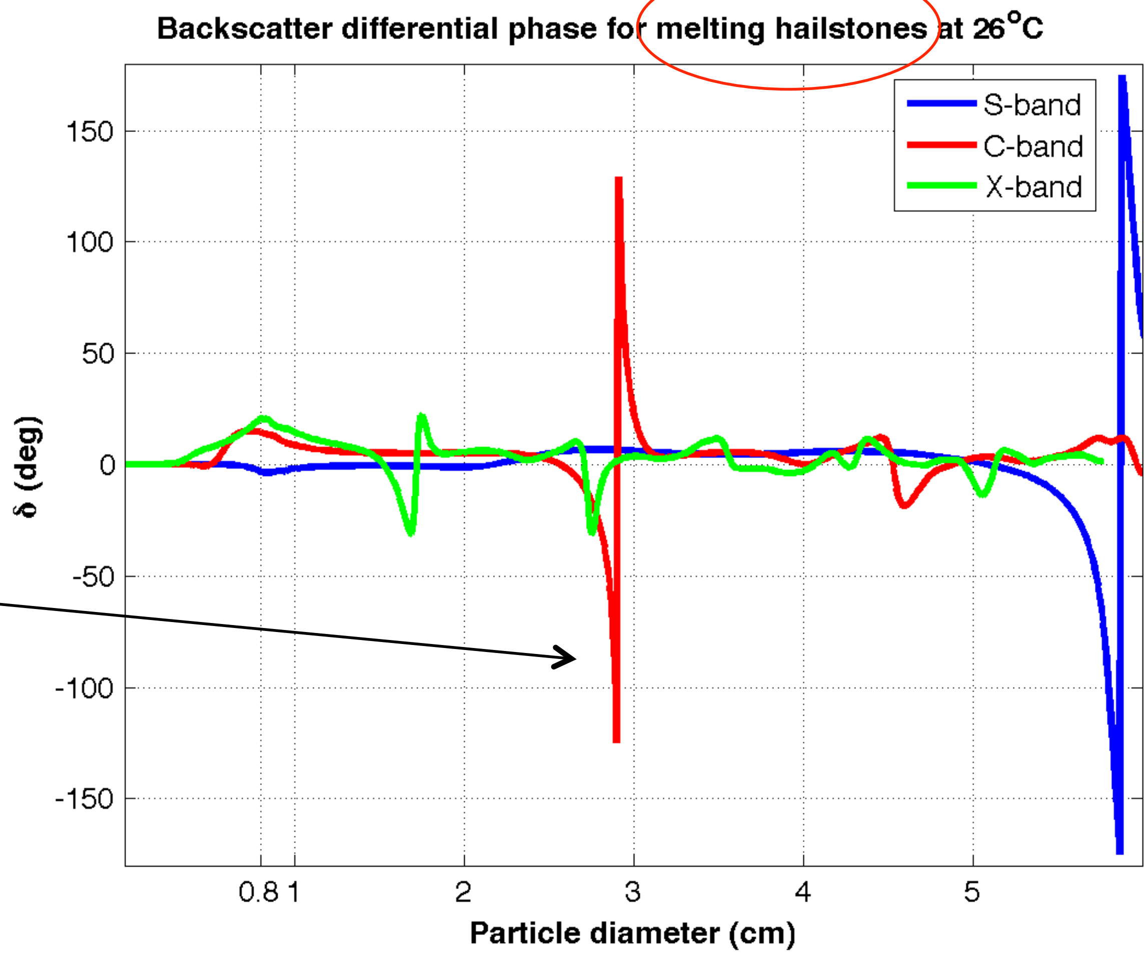


Φ_{DP} hail size dependence for C-band



Φ_{DP} hail size dependence for C-band

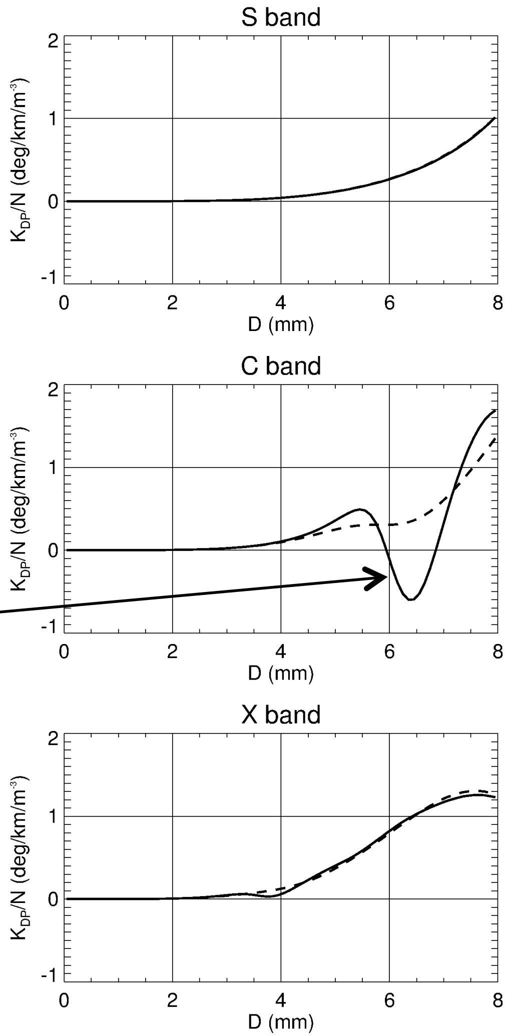
nonmonotonic radial dependencies of Φ_{DP}



Φ_{DP} hail size dependence for C-band

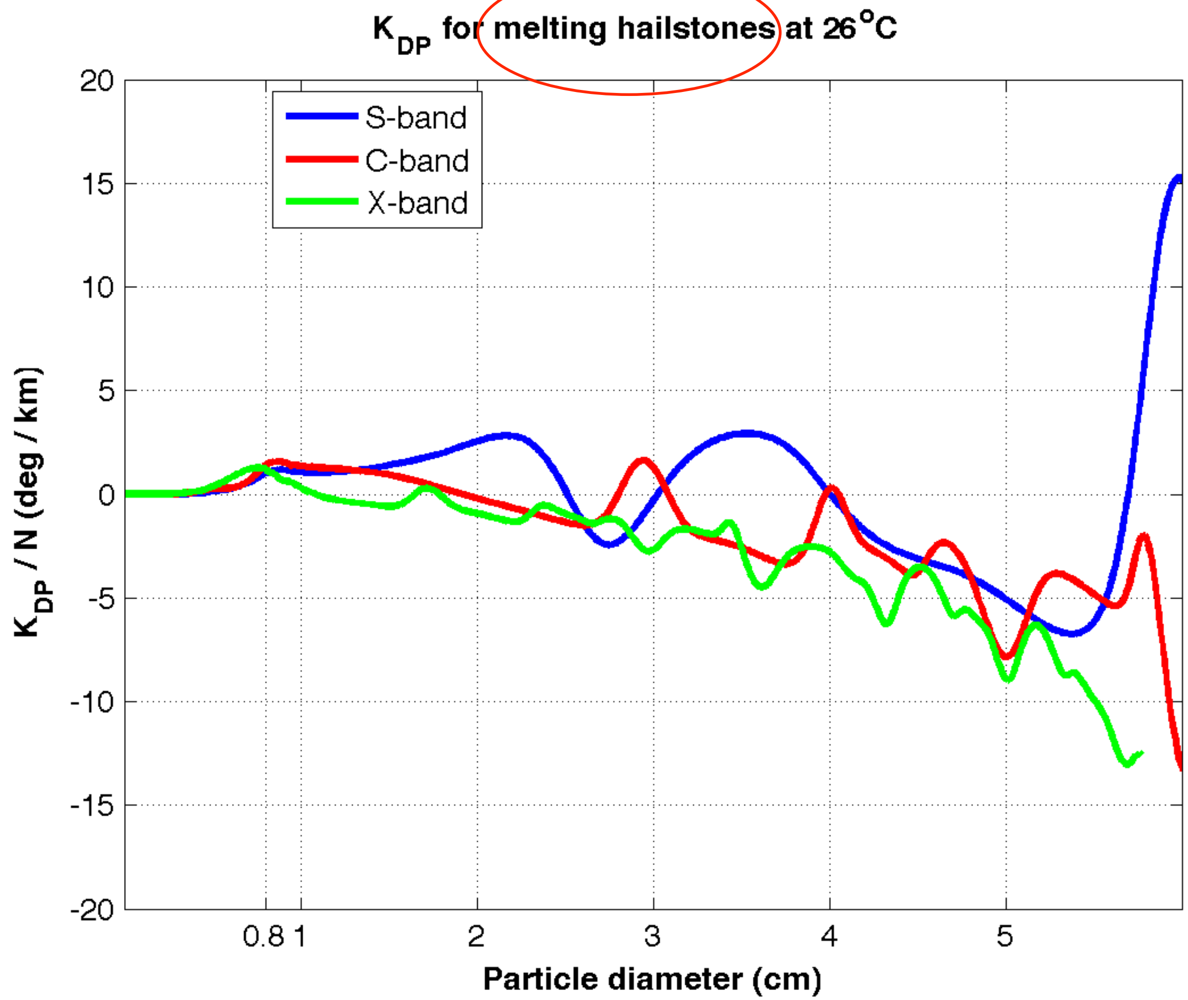
nonmonotonic radial dependencies of Φ_{DP}

associated with large raindrops
originated from melting hail



Φ_{DP} hail size dependence for C-band

nonmonotonic radial dependencies of Φ_{DP}



Conclusion

Comparison of Z_{DR} and ρ_{hv} changes below wet bulb freezing level height for two hail classes:

		MEDIAN		Standard-Deviation	
		Large hail	Giant hail	Large hail	Giant hail
Z_{DR}	C band	+4dBZ	**+7dBZ**	1.4dBZ	2.2dBZ
Z_{DR}	S band	+1dBZ	+1.5dBZ	1.1 dBZ	0.8dBZ
ρ_{hv}	C band	0.91	**0.84**	0.04	0.09
ρ_{hv}	S band	0.94	0.92	0.02	0.06

Comparison of ρ_{hv} at -10°C wet bulb temperature height for two hail classes:

ρ_{hv}	MEDIAN		Standard-Deviation	
	Large hail	Giant hail	Large hail	Giant hail
C band	0.95	**0.82**	0.04	0.09
S band	0.94	0.92	0.02	0.06

Conclusion

- location of hail within the storm
- vertical profiles of polarisation moments efficiently utilized for hail size discrimination
- C-band hail features are much more pronounced
- below freezing level:
  - strong increase in Z_{DR}
  - strong decrease in ρ_{hv}
- hail generation at -10 °C
  - strong decrease in ρ_{hv}

Ongoing Work

- extend dataset
- hail cases from Austria
  - C-band
  - additional small hail reports (D < 2cm)
- verification
- attenuation C band + nonmonotonic radial dependcies of Φ_{DP}
- trend analyses -> Nowcasting


Thank you for your attention!
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