The Sensitivity of X-Band Polarimetric Radar Observables to Melting Hails

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OUTLINE

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- Sensitivity Study
- Observations
- Summary and Outlook

Background

- Polarimetric observables:
  - reflectivity (Z)
  - specific differential phase (K_{dp})
  - differential reflectivity (Z_{dr})
  - copolar correlation coefficient (ρ_{hv})

- Polarimetric radar as an efficient tool for hail detection
  - To identify hails
  - To improve the knowledge on storm development
  - To determine hail sizes for damage evaluation

X-band polarimetric radar at Meteorological Institute in Bonn, Germany

Background

→ Polarimetric fingerprints of melting hails below the 0°C level

- Sensitivity of polarimetric observables to hail melting processes
  - Information on hail size distribution?
  - Improvement of hail parameterization scheme ?

X-band polarimetric radar at Meteorological Institute in Bonn, Germany

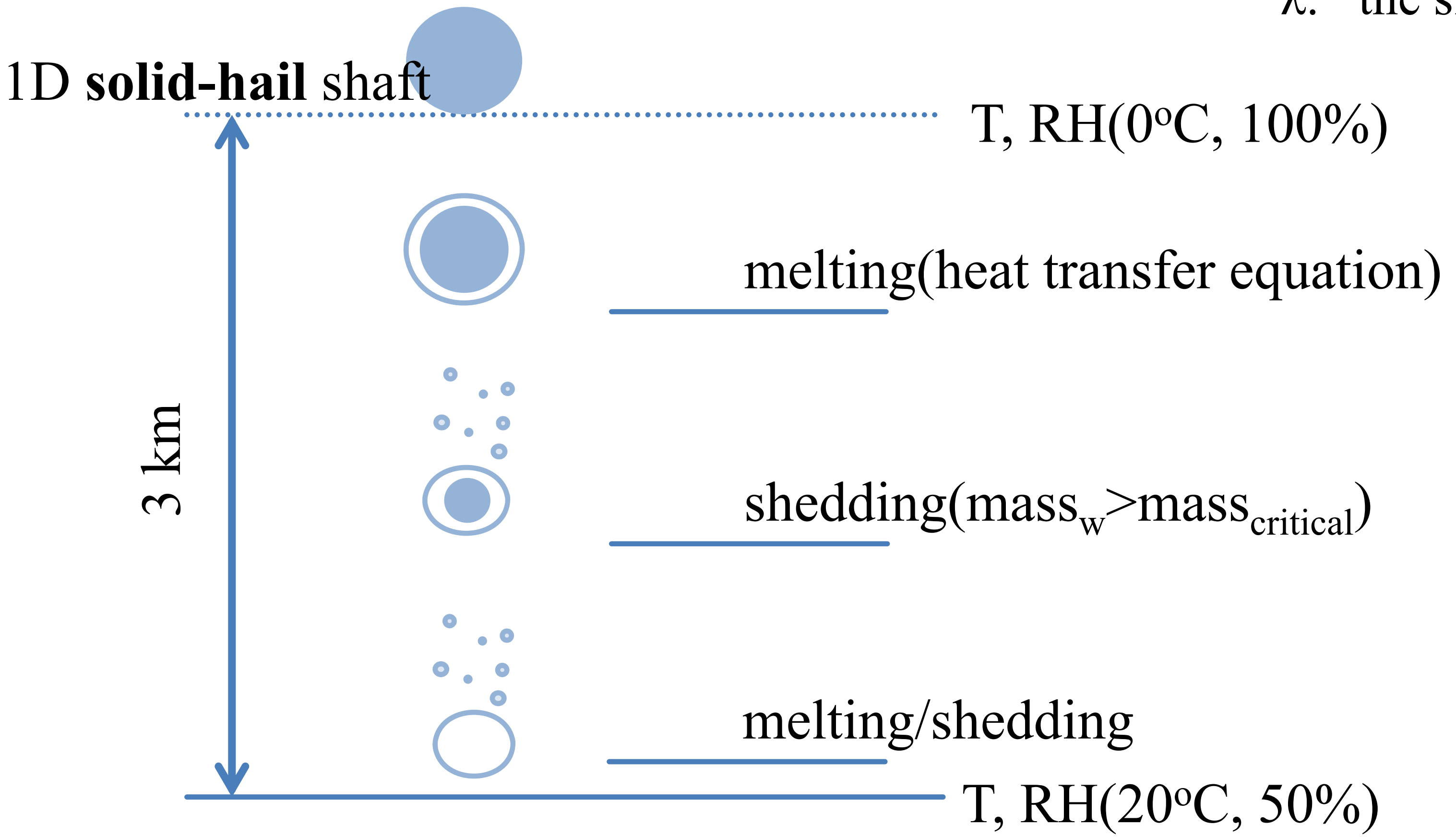
Model description

Initial hail size distribution: $N(D) = N_0 D^{\mu} \exp(-\lambda D)$

N_0: the intercept

μ: the shape parameter

λ: the slope parameter



Model description

Initial hail size distribution: $N(D) = N_0 D^{\mu} \exp(-\lambda D)$

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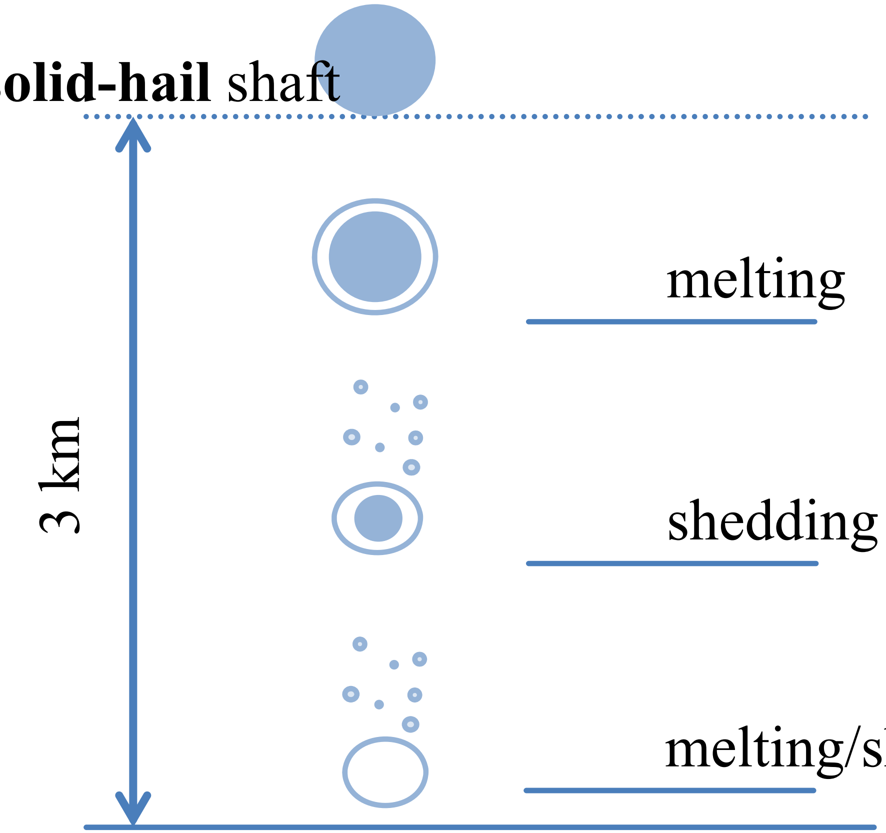
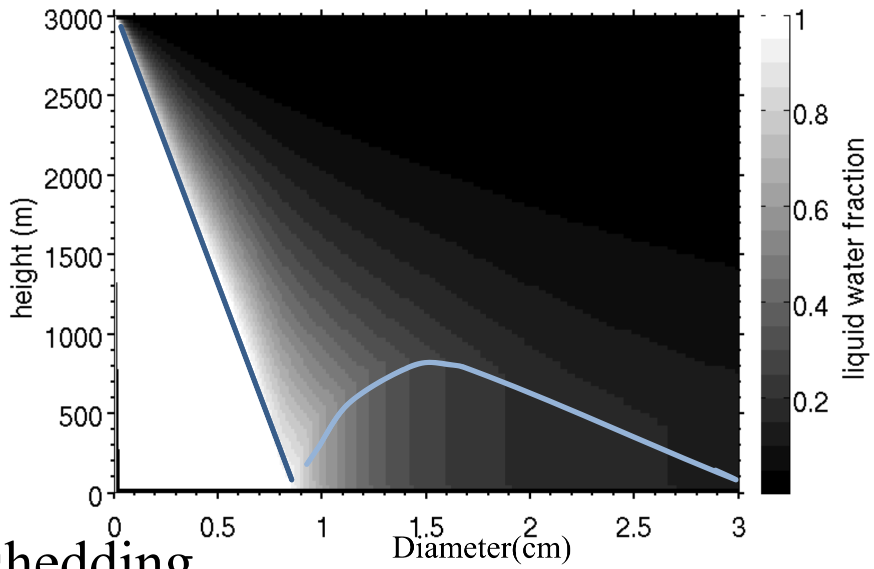
1D **solid-hail** shaft

T, RH(0°C, 100%)





T, RH(20°C, 50%)

Model description

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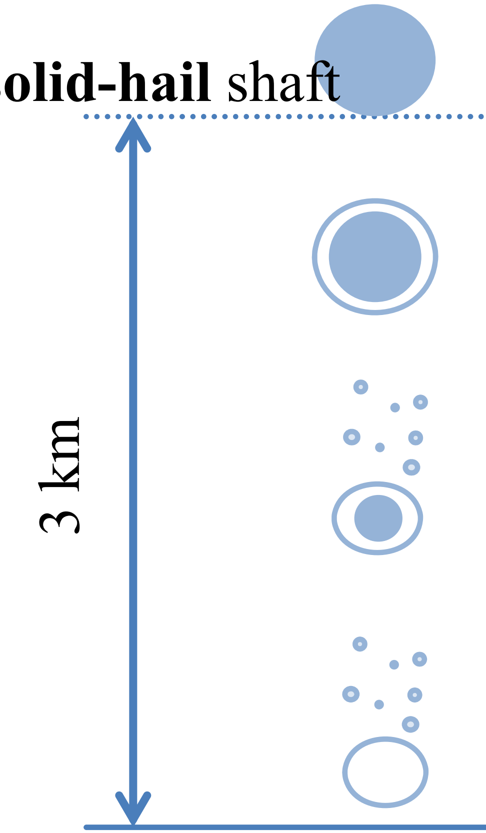
1D **solid-hail** shaft



T, RH(0°C, 100%)

Scattering calculation
- T-matrix
- Mixture of ice and water

$$Z_h = \frac{4\lambda^4}{\pi^4 K} S_{hh,b} S_{hh,b}^*$$

$$Z_{dr} = Z_h - Z_v (dB)$$

$$K_{dp} = \lambda \operatorname{Re}(S_{hh,f} - S_{vv,f})$$

$$\rho = \frac{S_{hh,b} S_{vv,b}^*}{\sqrt{S_{hh,b}^2 S_{vv,b}^2}}$$

T, RH(20°C, 50%)

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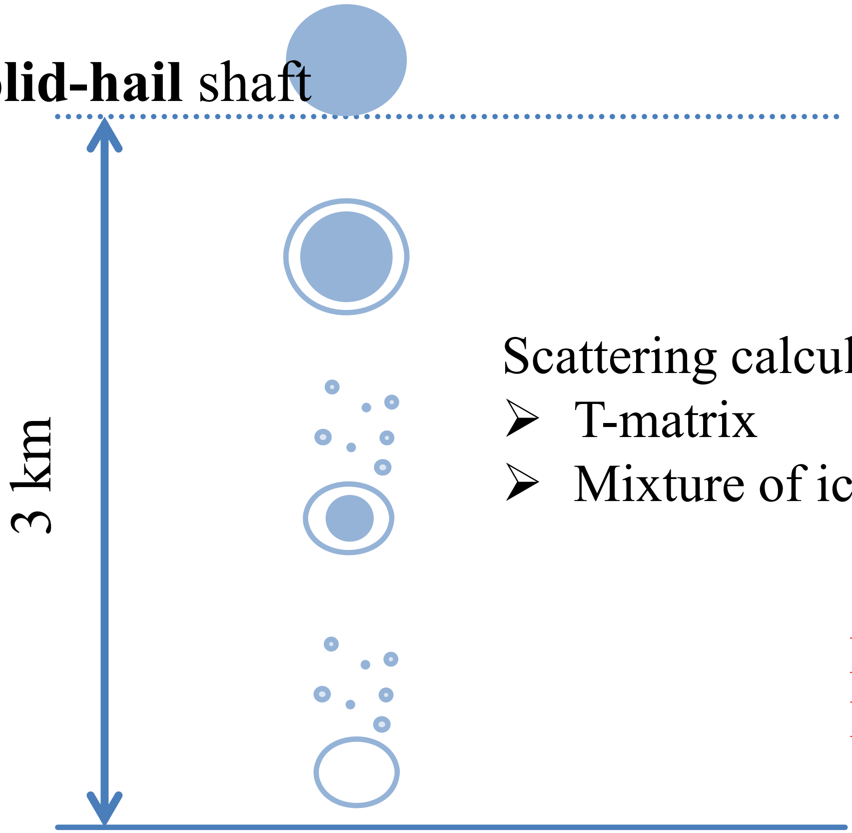


Scattering calculation
- T-matrix
- Mixture of ice and water

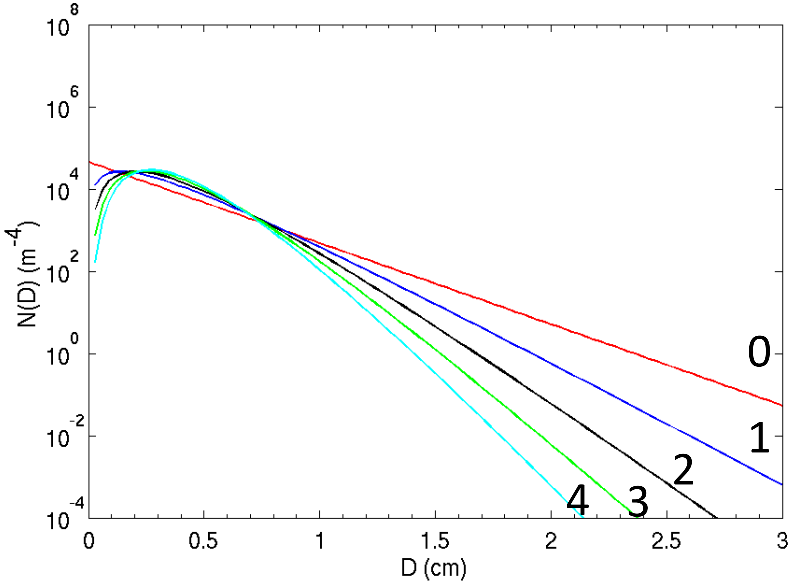
μ: the shape parameter
D_h: mean volume diameter
L_h: hail liquid water content

T, RH(20°C, 50%)

Sensitivity

$$N(D) = N_0 D^{\mu} \exp(-\lambda D)$$

Smaller μ (same L_h)
→ broader hail size distribution



Sensitivity

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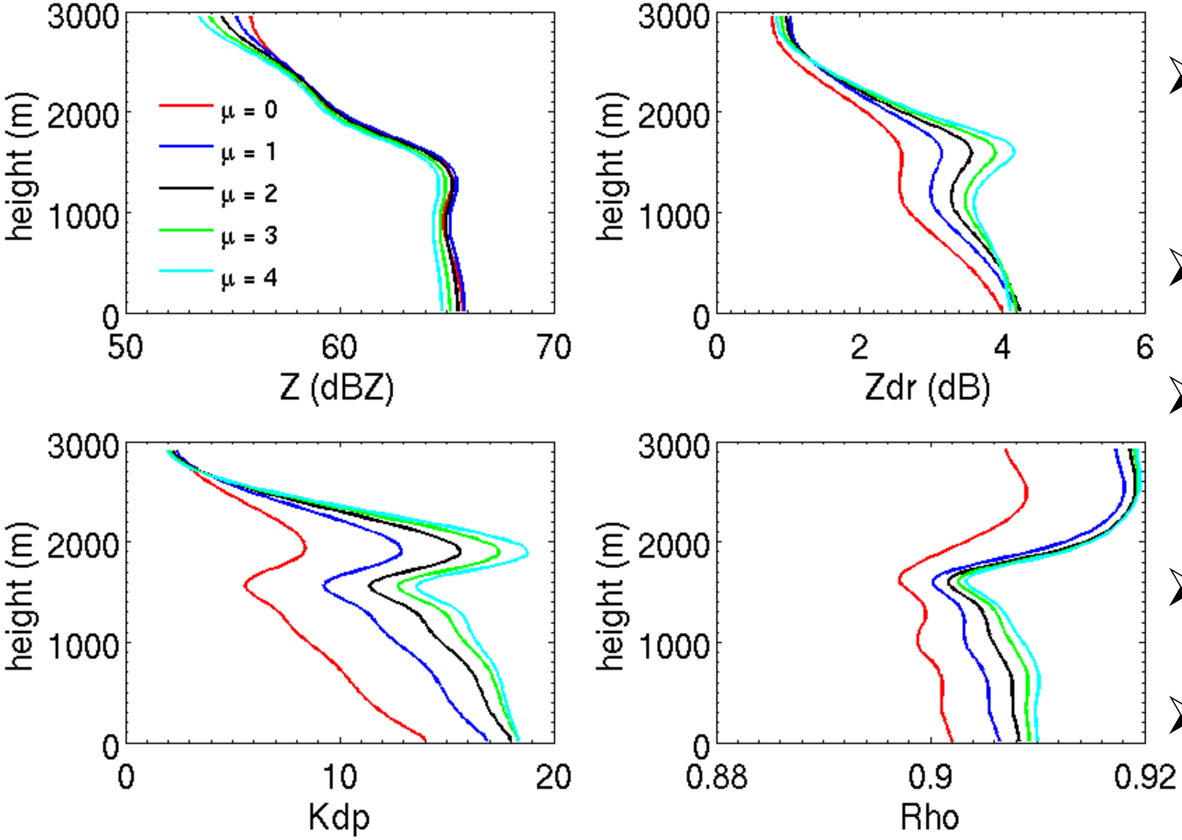
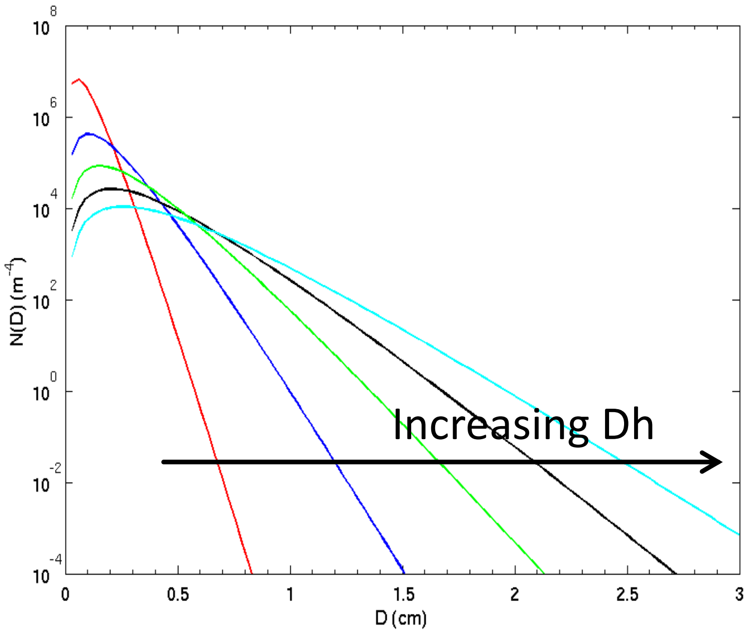


- Gradual increase of Z/Zdr/Kdp due to hail melting
- Z>60dBz, Zdr>3dB, Kdp>10 deg/km
- Polarimetric fingerprint due to hail melting below 0°C level
- Same altitudes of maxima values
- Zdr/Kdp/ρ_{hv} --- μ-dependent

Sensitivity

$$N(D) = N_0 D^{\mu} \exp(-\lambda D)$$

Increasing D_h (same L_h)
→ More large hails



Sensitivity

$$N(D) = N_0 D^{\mu} \exp(-\lambda D)$$

Increasing D_h (same L_h)
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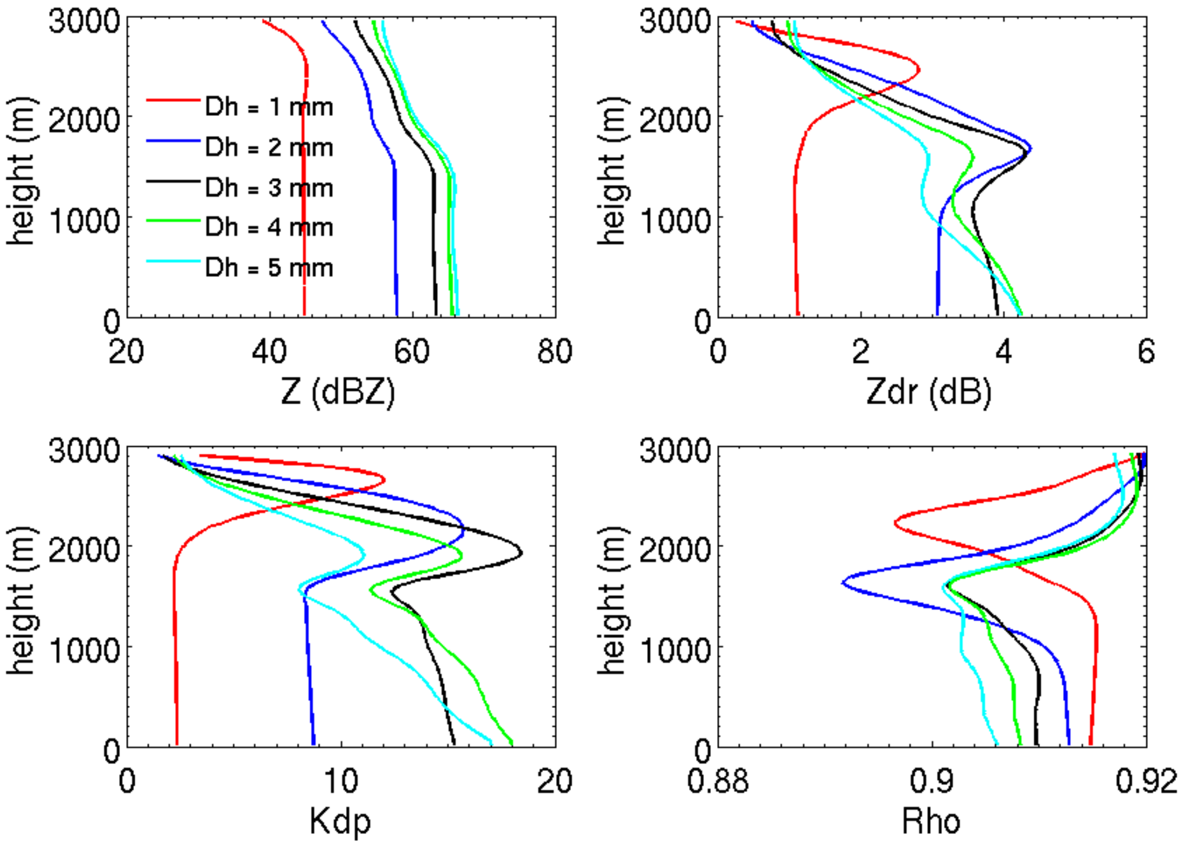
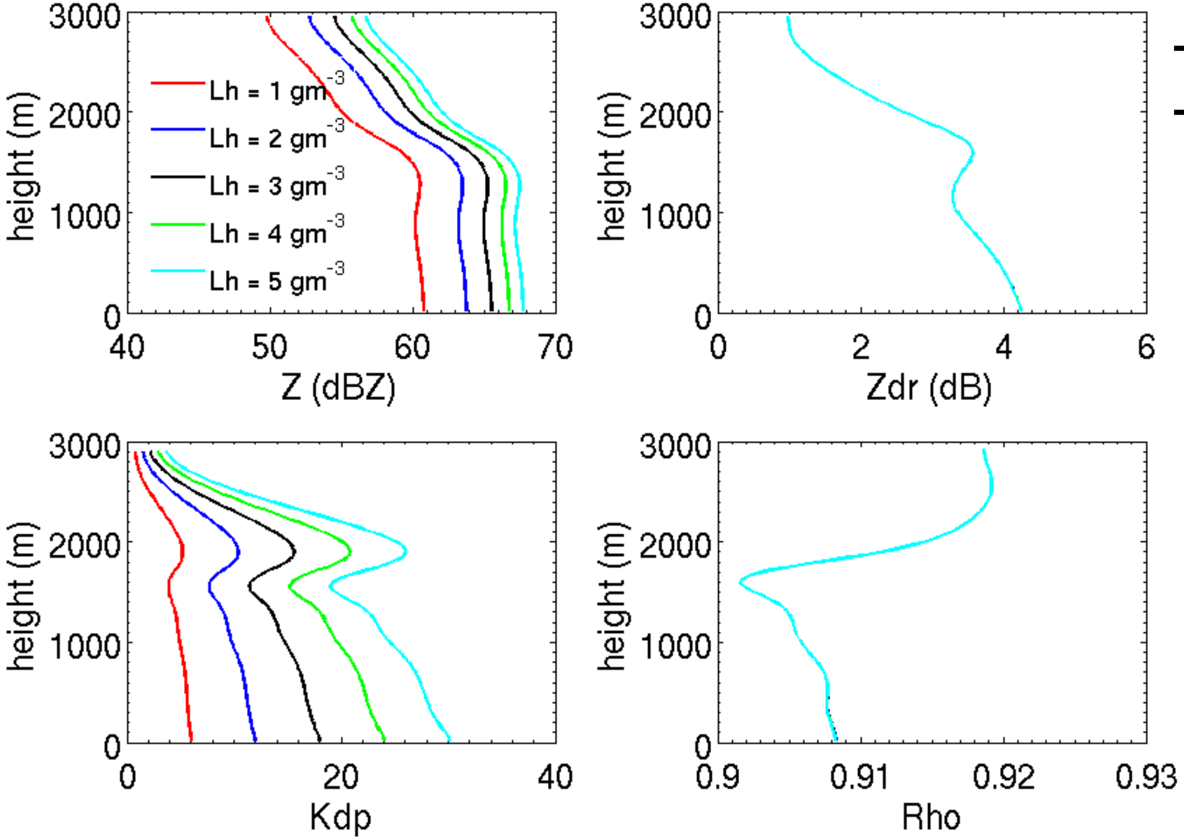


- Smaller hails: melting layer lower than 0◦C levels: similar to brightband
- Larger hails: Zdr and Kdp increasing towards the surface
- Altitudes of maxima values varying with D_h
- All polarimetric observables D_h-dependent

Sensitivity

$$N(D) = N_0 D^{\mu} \exp(-\lambda D)$$



Increasing L_h

→Increasing Z and Kdp

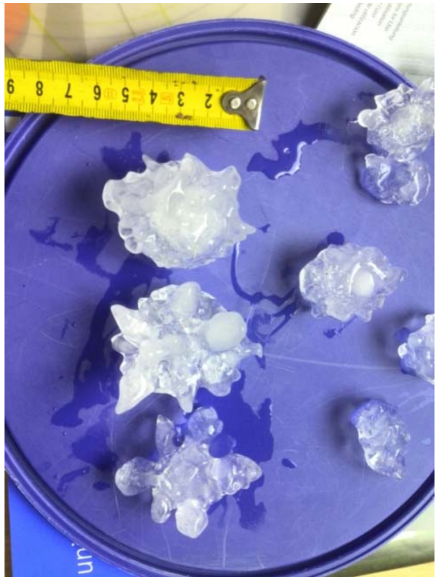
→No change of Zdr and ρ_{hv}

Observations

One case on 05.07.2015

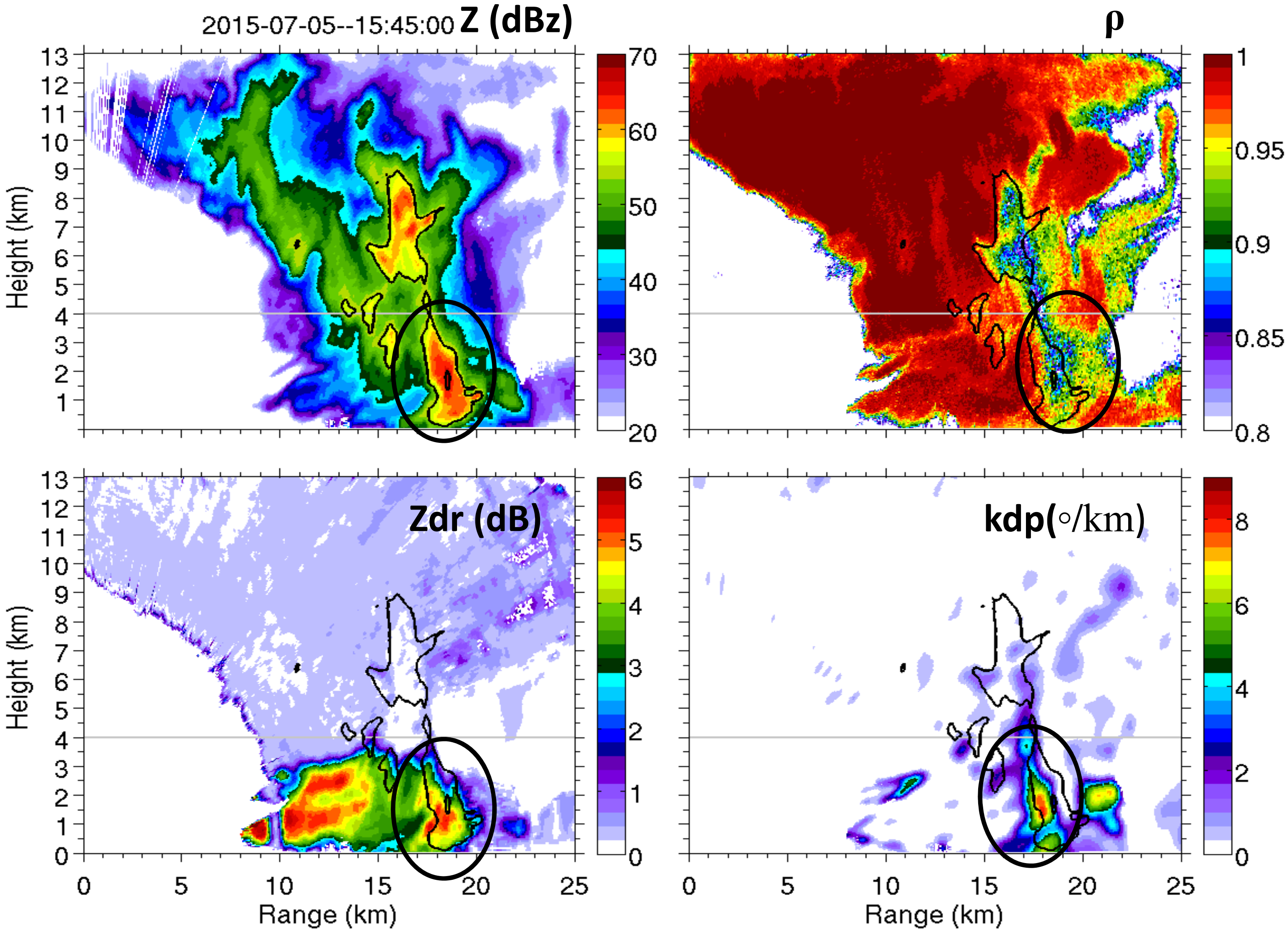
(More details on Tuesday, 4:00 pm, 6B.3)

Observed hail larger than 3 cm



Observations

One case on 05.07.2015, observed by the X-band polarimetric radar in Bonn



Summary and Outlook

- Z reaches up to 60 dBz, Zdr>3 dB, ρ_{hv}<0.9 and Kdp > 10°/km due to hail melting at X-band
  - Consistent with polarimetric radar observation
- Melting hails enhance Z/Zdr/Kdp and reduces ρ_{hv}.
  - Zh/Kdp depend on hail amounts and mean sizes while Zdr/ρ_{hv} mainly depend on mean sizes.
- Polarimetric characteristics of hail melting strongly depend on height.
  - Water fraction of melting hails
  - Locations of maxima Z/Zdr/Kdp/ ρ_{hv} mainly Dh-dependent

Effects Parameters	Magnitude of (Z,Zdr,Kdp,ρ_{hv})	'Hail melting maixima' (Z,Zdr,Kdp,ρ_{hv})	
D_h	Y	Y	Larger hails melt slowly.
L_h	Y	N	Increasing L_h enhances Z/Kdp.
μ in hail size distribution	Y	N	Increasing μ doesn't change height where maxima polarimetric variables occur.

Summary and Outlook

- Rain water shedded from hail assumed to be Marshal-Palmer size distribution (uncertainties of rain rate estimation at ground)
- The melting processes of soft hails from dry growth – not finished
- Uniform mixture of ice and water to calculate hail scattering

→ Evaluation of hail melting scheme with polarimetric observations

Thanks for your attention !