Backscatter differential phase
- estimation and variability.

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Diapositive 1

c1 Hier können dann die Logos der Forschungseinrichtungen platziert werden
chrstein; 28/01/2011

Outline

1. **Introduction**

2. **δ in rain**
   - **Estimation of δ**
   - **DSD analysis with respect to Z_{DR}-δ-relation**

3. **δ within the melting layer**
   - **Estimation of δ**
   - **The impact of non-uniform beam filling**
   - **Variability of δ at X, C, and S-bands**

4. **Conclusions**

Introduction

- The measured total differential phase Φ_{DP} shift consists of the 2 components:

$$\Phi_{DP} = \delta + 2\int_0^r K_{DP}(s)ds = \delta + \varphi_{DP}$$

where
Φ_{DP} = total differential phase,
φ_{DP} = differential propagation phase,
K_{DP} = specific differential phase,
δ = backscatter differential phase.

- For accurate rainfall estimation using K_{DP} backscattered and propagation components of Φ_{DP} need to be separated before specific differential phase K_{DP} is estimated from the range derivative of Φ_{DP}.

- Perturbations of the Φ_{DP} profile through the melting layer can be attributed either to δ or effects of nonuniform beam filling (NBF).

- Benefits of using δ is its direct relation to the prevalent size of hydrometeors
  - δ can be used for more accurate retrieval of hydrometeor size distributions
  - δ should be generally correlated with Z_{DR}, can serve as a proxy for Z_{DR}

Backscatter differential phase δ of raindrops

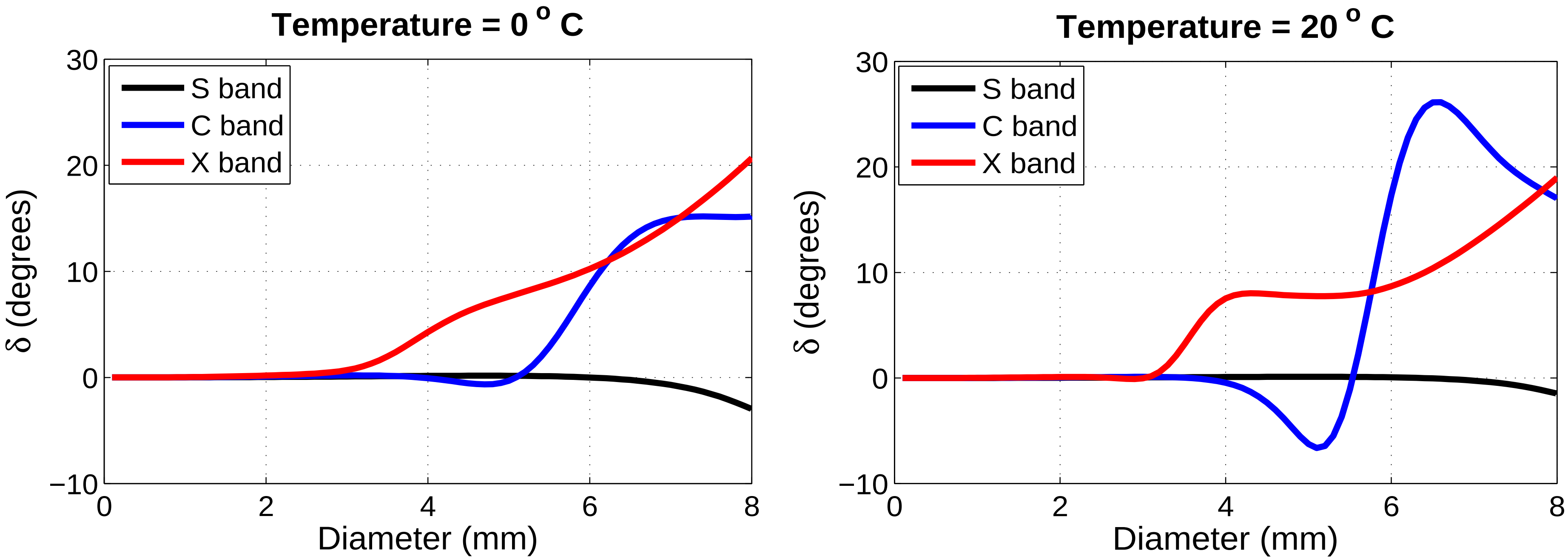

Fig. Simulated δ as a function of equivolume raindrop diameter for different wavelengths and temperatures.

➡ **δ in rain depends on λ and T and increases with raindrop size.**

Estimation of δ in rain

Application of the ZPHI-method (Testud et al., 2000) and the slightly modified self-consistent method proposed by Bringi et al. (2001):

- **External constraint: $\Delta\phi_{DP} = \phi_{DP}(r_2) - \phi_{DP}(r_1)$ with ranges r_1 and r_2 from the radar**
- **2 relationships** $A_h = \beta Z_h^b$ **and** $A_h = \alpha K_{DP}$ **with β, α =fkt(drop shape, T)**

$$A_h(r) = \frac{[Z_a(r)]^b f(\Delta\phi_{DP})}{I(r_{1;}r_2) + f(\Delta(\phi_{DP}) I(r;r_2)}$$

where

$$I(r;r_2) = 0.46b \int_r^{r_2} [Z_a(s)]^b ds,$$

$$I(r_1;r_2) = 0.46b \int_{r_1}^{r_2} [Z_a(s)]^b ds$$

$$f(\Delta\phi_{DP}) = 10^{0.1\alpha b \Delta\phi_{DP}} - 1$$

The selfconsistent method (Bringi et al., 2001) , slightly modified, searches for optimal α and b by comparing calculated and measured Φ_{DP}:

$$\min_{\alpha,b} \Delta\varphi = \sum_{i=1}^{N} |\varphi_{DP}^{cal}(r_i;\alpha;b) - \Phi_{DP}(r_i)|$$

where

$$\varphi_{DP}^{cal}(r,\alpha;b) = 2\int_{r_1}^{r} \frac{A(s;\ \alpha;\ b)}{\alpha} ds$$

Estimation of δ in rain

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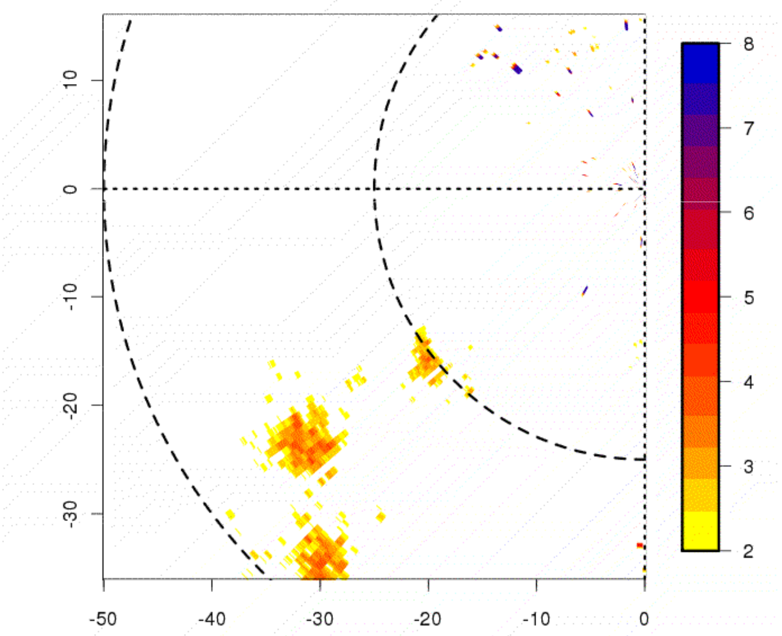


Fig: PPIs of δ for the BoXPol observations on June 22, 2011 between 11:11UTC and 11:26 UTC.

Differences between Φ_{DP} and φ^{cal}_{DP} calculated via the ZPHI-method reveal statistical fluctuations and δ.

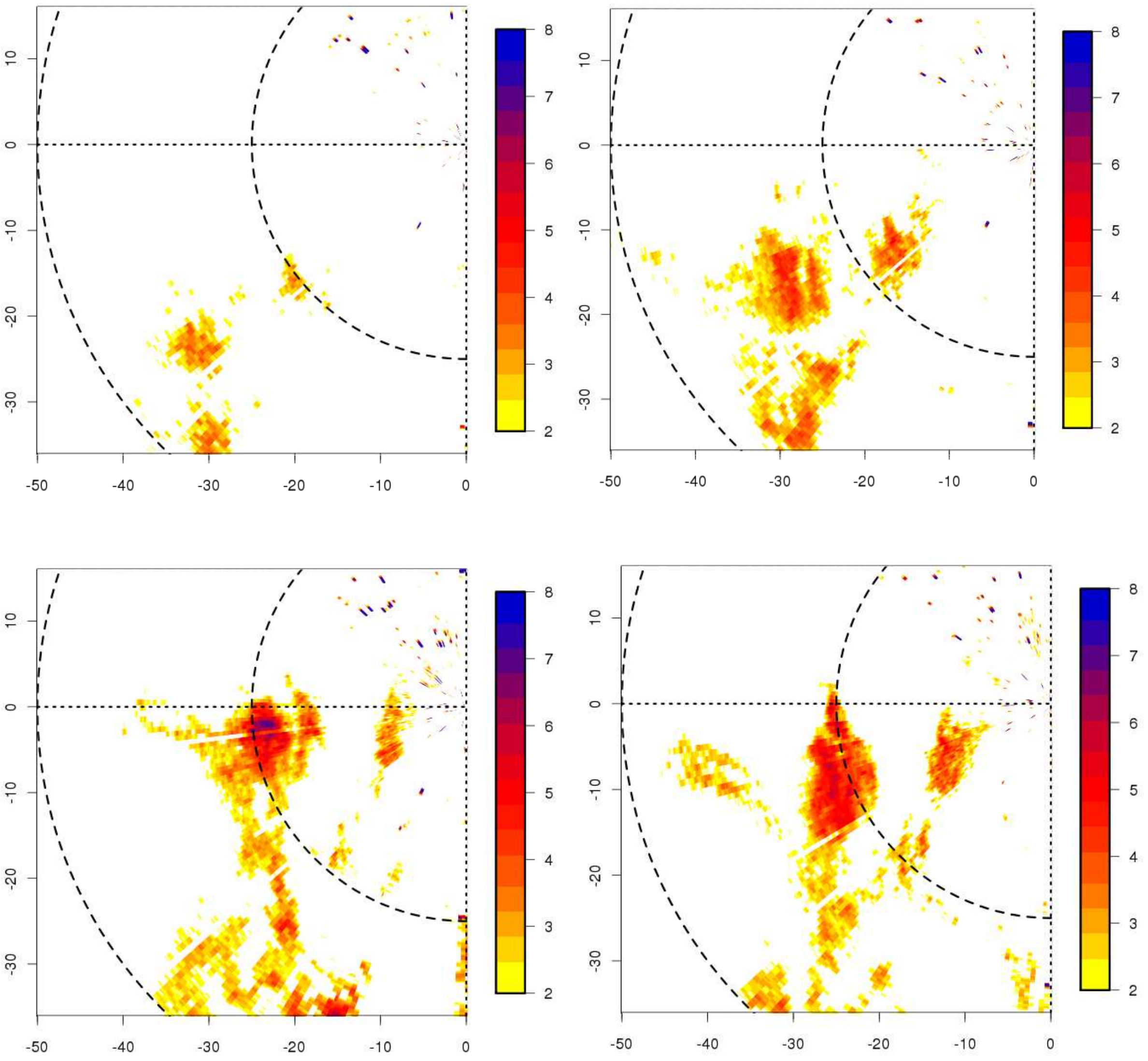
$\rho_{HV}>0.9$ is used as criterion for seperating δ perturbations and the ones caused by noise.

Pro: Method provides reasonably robust estimates of δ and K_{DP} in pure rain outside areas affected by NBF or low S/N ratios. Spatial and temporal coherency of retrieved δ can be demonstrated.

Con: Less suitable for areas with high K_{DP}.

Reliability of the method for δ detection

Example:
PPIs of δ for the BoXPol observations on June 22 between 11:11UTC and 11:26UTC.



Pro:

→ Spatial and temporal coherency of retrieved δ can be demonstrated.

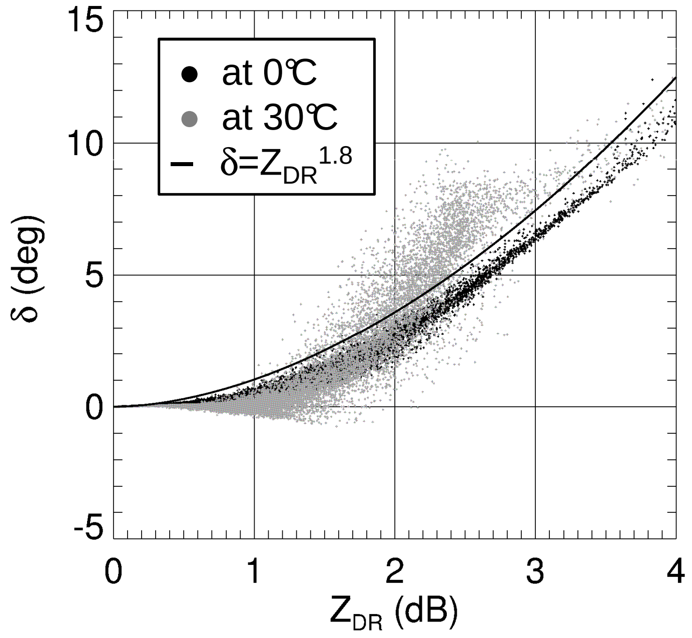
Con:

→ Less suitable for areas with high K_{DP}.

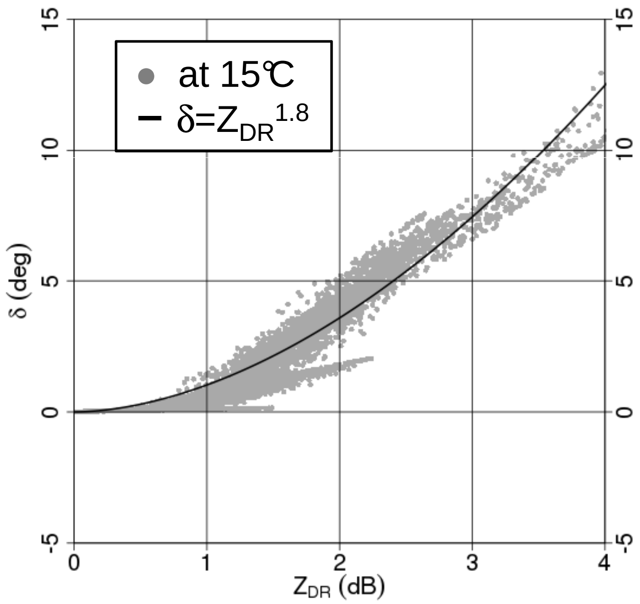
Z_{DR}-δ relationships

Simulations for X-band based on..

2DVideo measurements in Oklahoma, USA



Parsivel measurements in Bonn, Germany

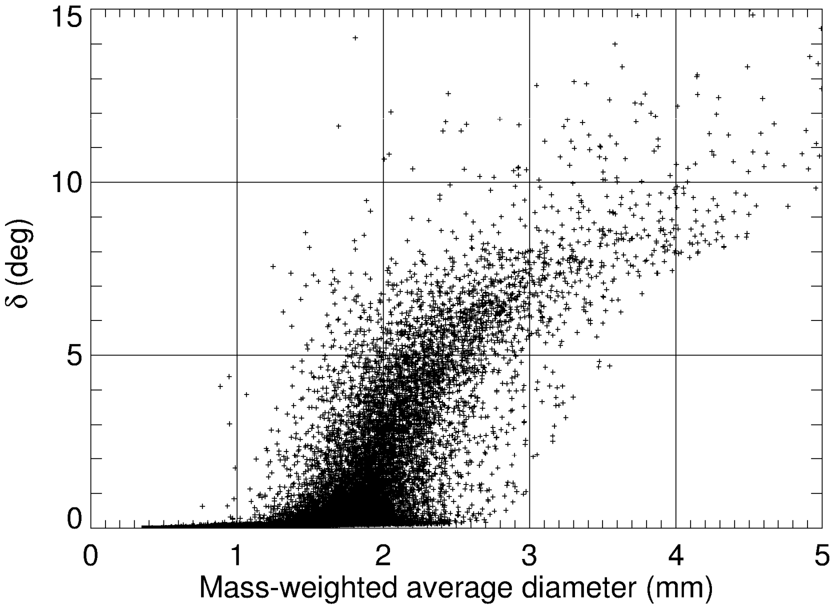


- **The overwhelming part of variability can be related to the temperature of raindrops.**
- **The impact of differences in DSDs seems to be small.**

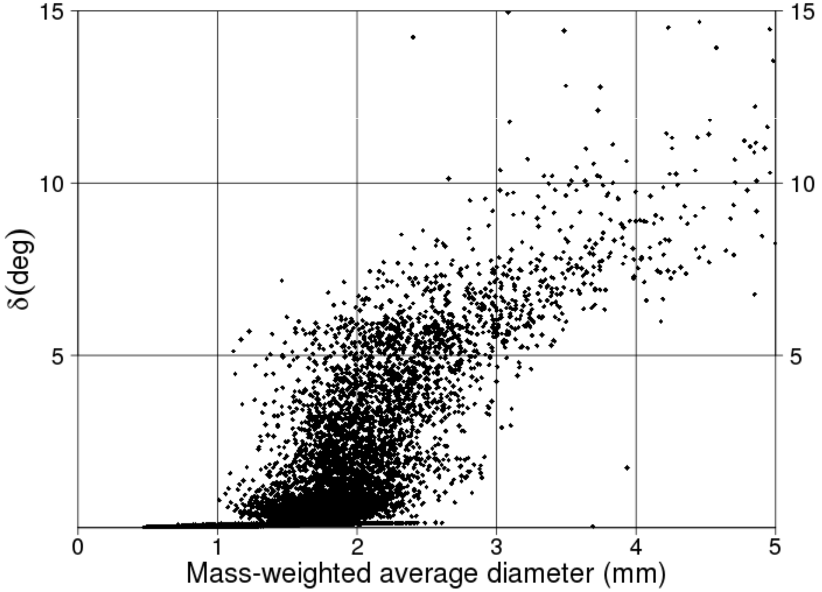
Backscatter differential phase δ
- another parameter for characterizing dropsizes -

Simulations for X-band at 15 ℃ based on..

2DVideo measurements in Oklahoma, USA



Parsivel measurements in Bonn, Germany



Backscatter differential phase δ in the melting layer

Observed bumbs in differential phase Φ_{DP} may be associated either with

1. **backscatter differential phase δ**
2. **nonuniform beamfilling (NBF):** $\Delta\Phi_{DP} = 0.02\Omega^2 \frac{d\Phi_{DP}}{d\theta}\frac{dZ}{d\theta}$ (Ryzhkov et al., 2007)

Method for reliable δ-estimation in the melting layer:

➡ **Calculate azimuthally averaged radial profiles of Φ_{DP} from measurements at higher elevation angles**

- **forward propagation contribution is minimized**
- **suppress fluctuations of Φ_{DP} caused by reduction of ρ_{HV} within the melting layer,**
- **impact of NBF is minimized**

Backscatter differential phase δ in the melting layer

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Method for reliable δ-estimation in the melting layer:

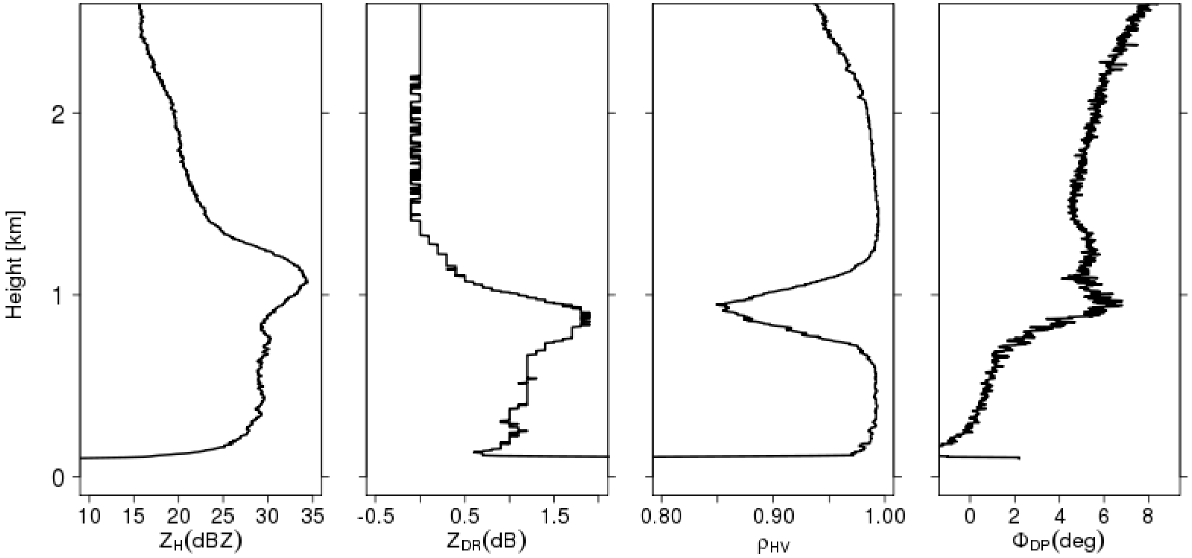


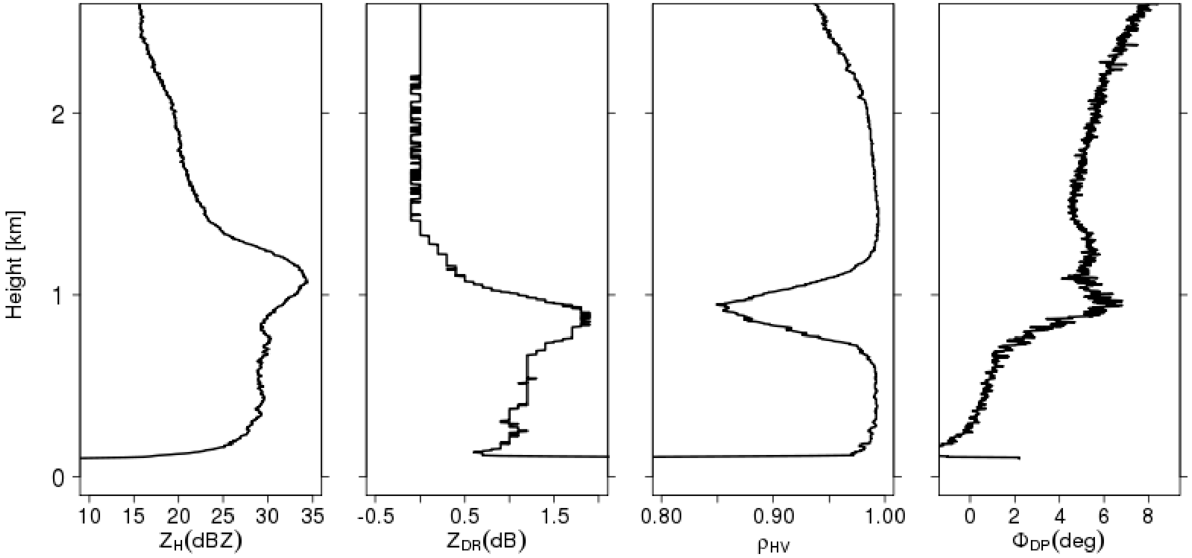
Fig. Azimuthally averaged quasi-vertical profiles from the polarimetric X-band radar in Bonn (BoXPol), Germany, obtained on 04 December 2011, at 20:51 UTC, from the PPI at elevation 7°.

Backscatter differential phase δ in the melting layer

Observed bumbs in differential phase Φ_{DP} may be associated either with

1. **backscatter differential phase δ** $\delta_{obs,X} = 3°$
2. **nonuniform beamfilling (NBF)** $\Delta\Phi_{DP} = 0.11°$

Method for reliable δ-estimation in the melting layer:



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Variability of δ within the melting layer at X, C, and S bands

-Observations at X-band (BoXPol), $\delta_{obs,X} \approx 7°$-

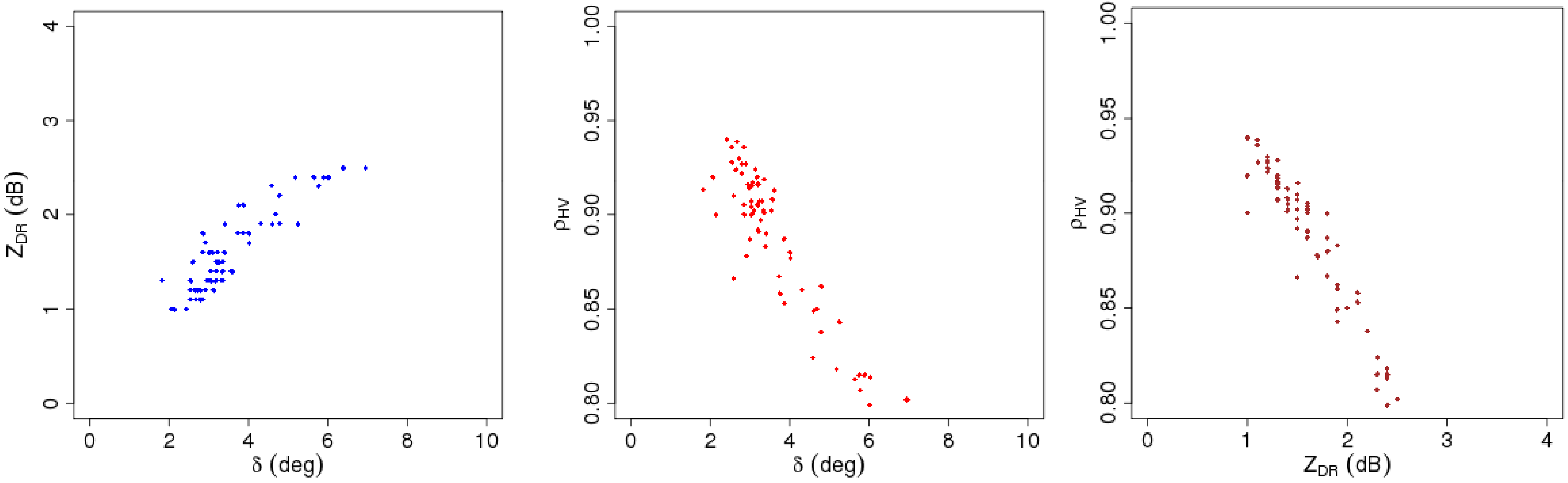

Fig. Magnitudes of the extremes of Z_{DR}, ρ_{HV}, and δ in the melting layer observed with BoXPol at 7° elevation on December 04, 2011 between19:36UTC and 22:29UTC.

Variability of δ within the melting layer at X, C, and S bands

-Observations at X-band (BoXPol), $\delta_{obs,X} \approx 7°$-

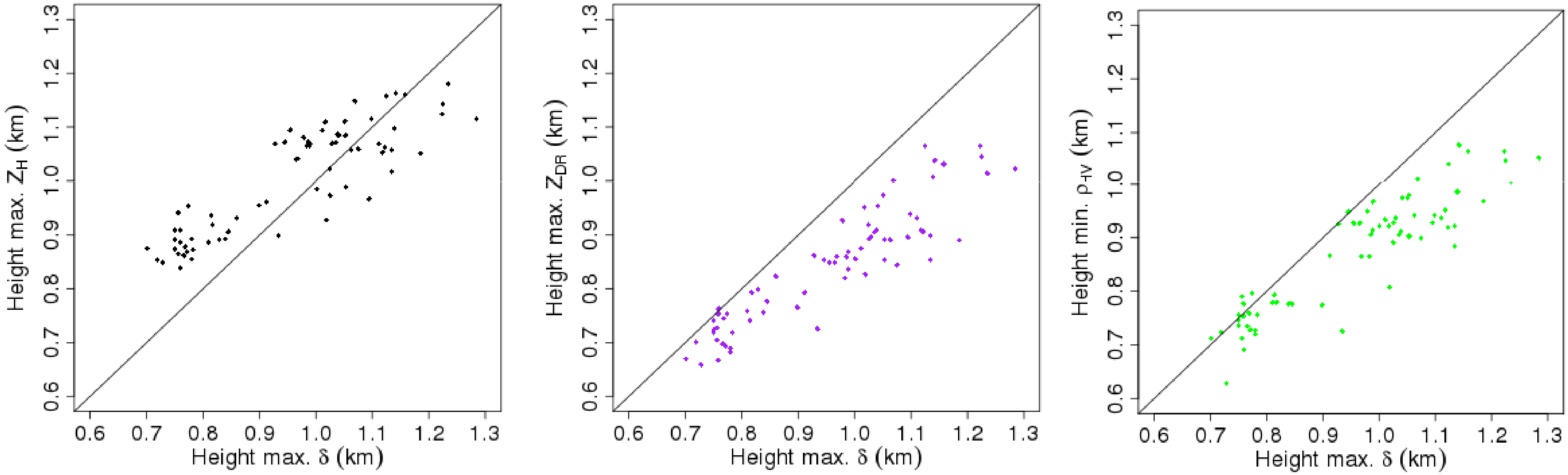

Fig. Relative heights of the extremes of Z_{DR}, ρ_{HV}, and δ in the melting layer observed with BoXPol at 7° elevation on December 04, 2011 between19:36UTC and 22:29UTC.

Variability of δ within the melting layer at X, C, and S bands

- Simulations -

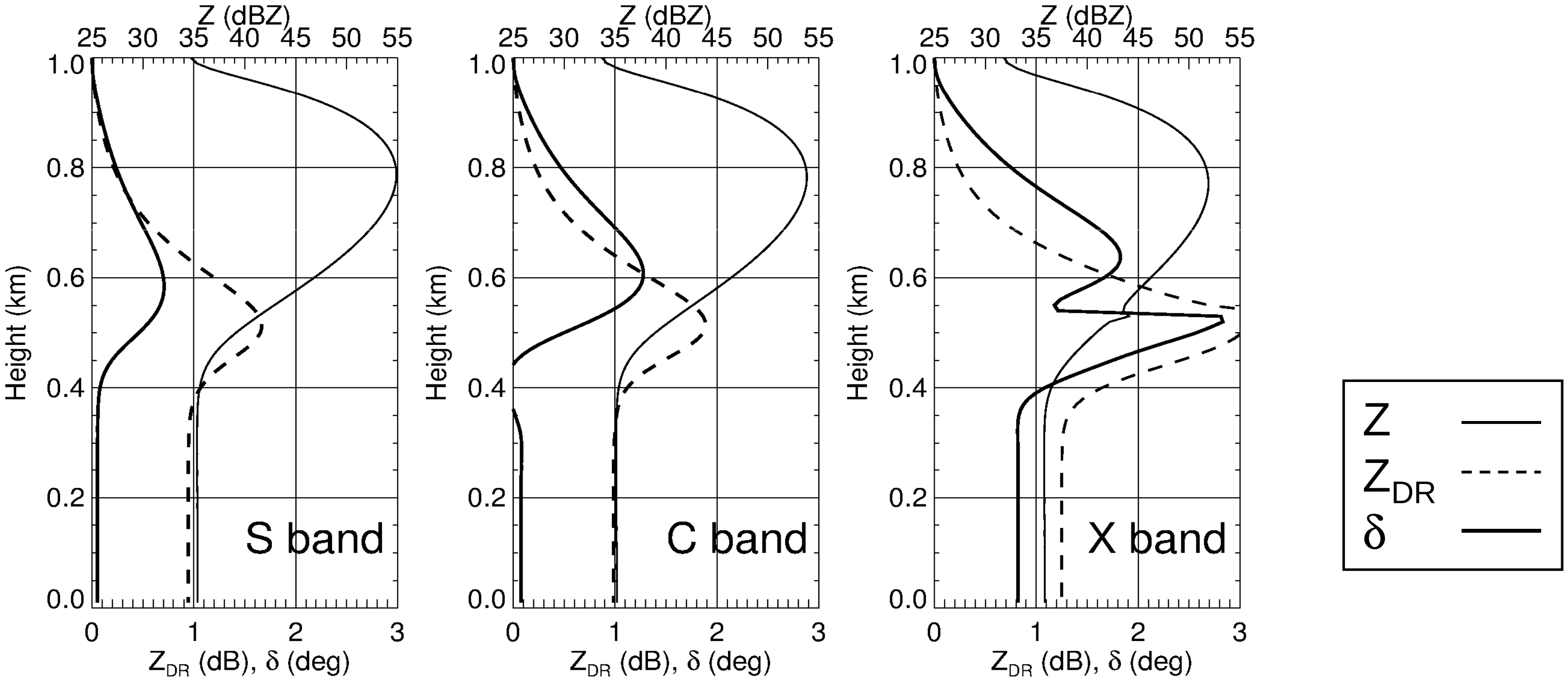

Fig. Simulated vertical profiles of Z, Z_{DR}, and δ within the melting layer at S, C, and X bands. Freezing level is at 1 km, temperature lapse rate is 6.5 °/k m, relative humidity is 100%, and rain rate near the surface is 5 mm/h.

Variability of δ within the melting layer at X, C, and S bands

-Observations at X-band (JuXPol), $\delta_{obs,X} \approx 7.5°$-

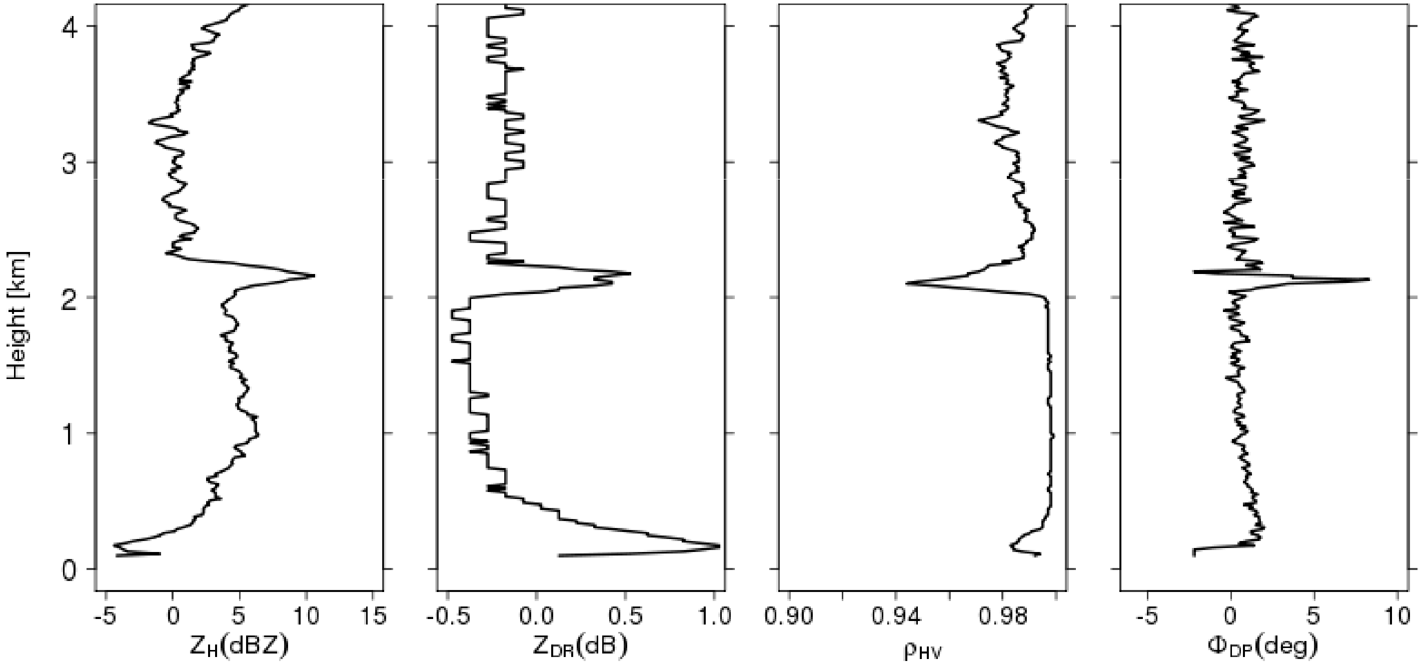

Fig: Azimuthally averaged quasi-vertical profiles from the polarimetric X-band radar in Jülich (JuXPol), Germany, obtained on 24 September 2010, at 4:50 UTC, from the PPI at elevation 37°.

Variability of δ within the melting layer at X, C, and S bands

- Observations at C-band (OU-PRIME), $\delta_{obs,C} \approx 6°$ -

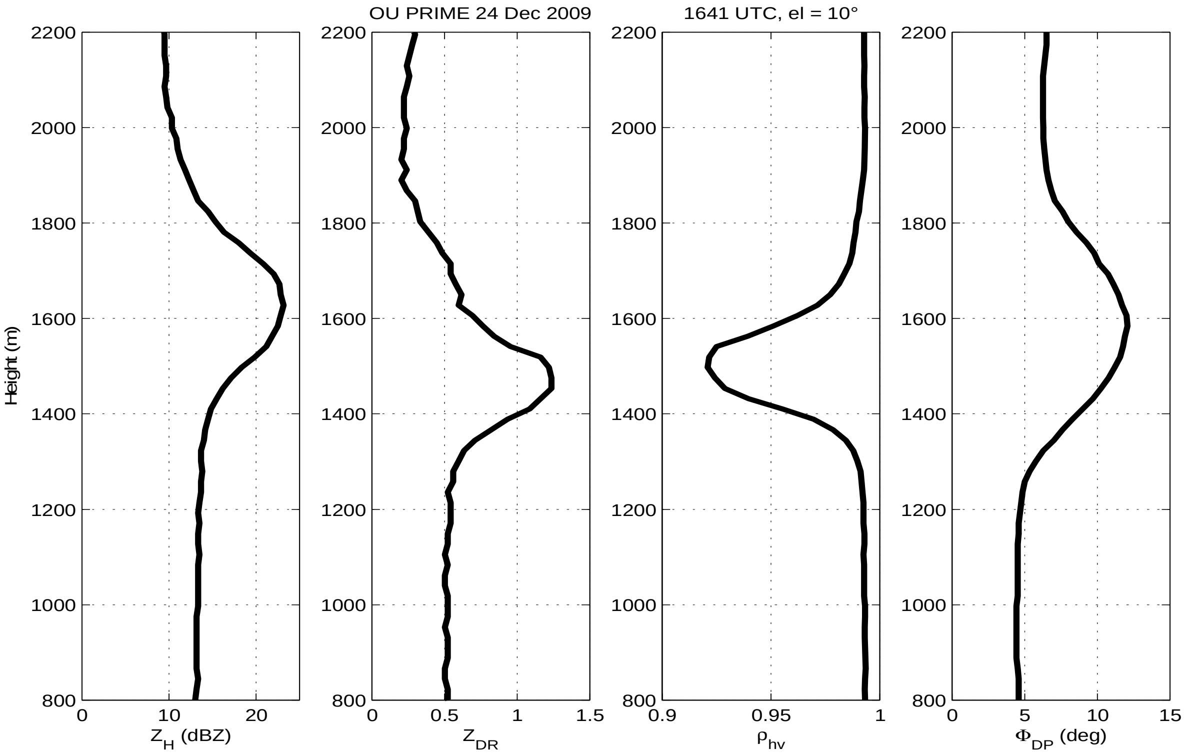

Fig: Azimuthally averaged quasi-vertical profiles from the C-band University of Oklahoma Polarimetric Radar in Meteorology and Engeneering (OU-PRIME), USA, obtained on 24 December 2009, at 16:41 UTC, from the PPI at elevation 10°.

Variability of δ within the melting layer at X, C, and S bands

- Observations at S-band (KATX), $\delta_{obs,S}$≈ 5.5°-

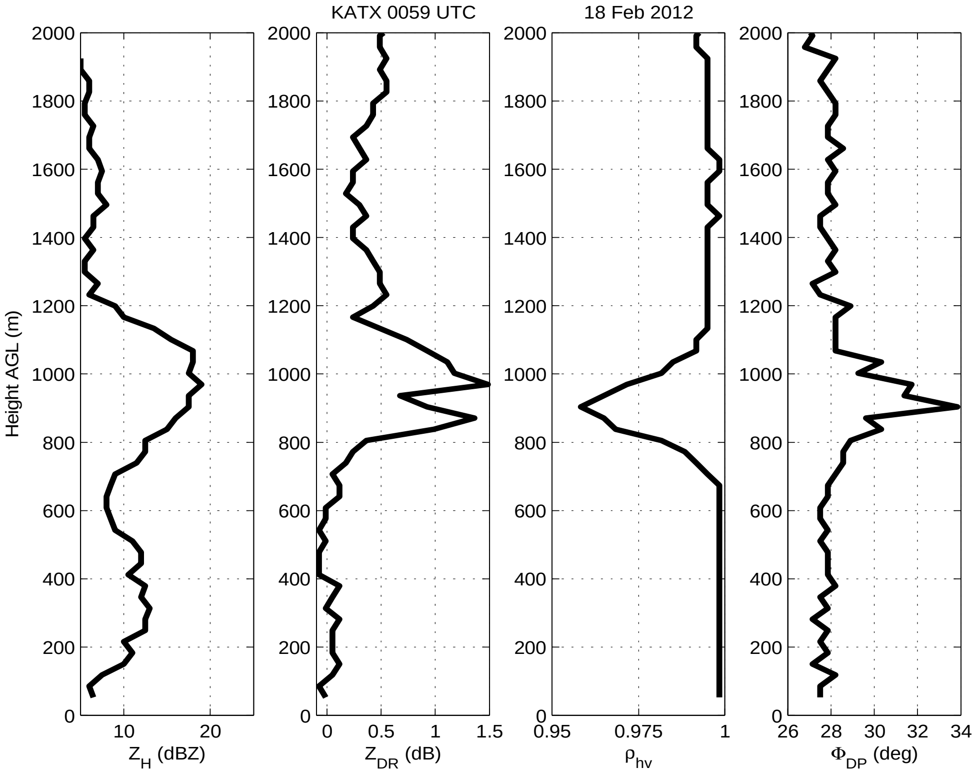

Fig: Azimuthally averaged quasi-vertical profiles from the KATX polarimetric WSR-88D S-band radar near Seattle, Washington, USA, obtained on 18 February 2012, at 00:59 UTC, from the PPI at elevation 7.5°.

Conclusions

- New methods for estimating δ in rain and in the melting layer have been suggested.

1. Estimating δ in rain is based on the ZPHI method and provides reasonably robust estimates of δ and K_{DP} in pure rain.

   → Relevant for quantitative precipitation estimation, especially at X band

2. Reliable estimates of δ within the melting layer of stratiform precipitation can be obtained via azimuthal averaging of radial profiles of Φ_{DP} at high antenna elevations.

   → Method enables to examine microphyiscal properties of the melting layer and likely to estimate maximal size of melting snowflakes.

- Large disdrometer datasets collected in Oklahoma and Germany confirm a strong interdependence between backscatter differential phase δ and differential reflectivity Z_{DR}.

  → δ and Z_{DR} are differently affected by particle size spectra and can complement each other for particle size distribution (PSD) retrievals.

Thank you!

Trömel, S., Kumjian, M., Ryzhkov, A., Simmer, C.: Backscatter differential phase - estimation and variability. To be submitted next week to JAMC.