PROM – IMPRINT

Understanding Ice Microphysical Processes by combining multi-frequency and spectral Radar polarImetry aNd super-parTicle modelling

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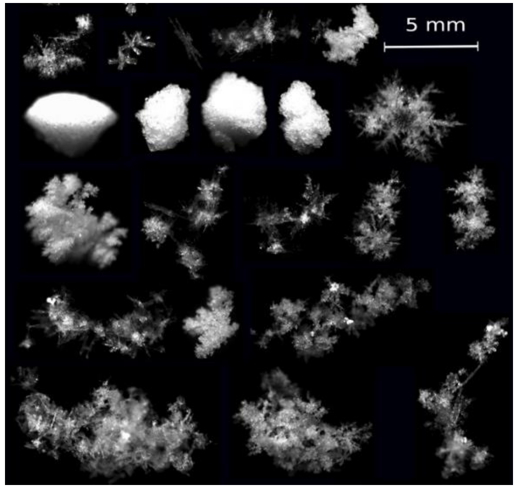
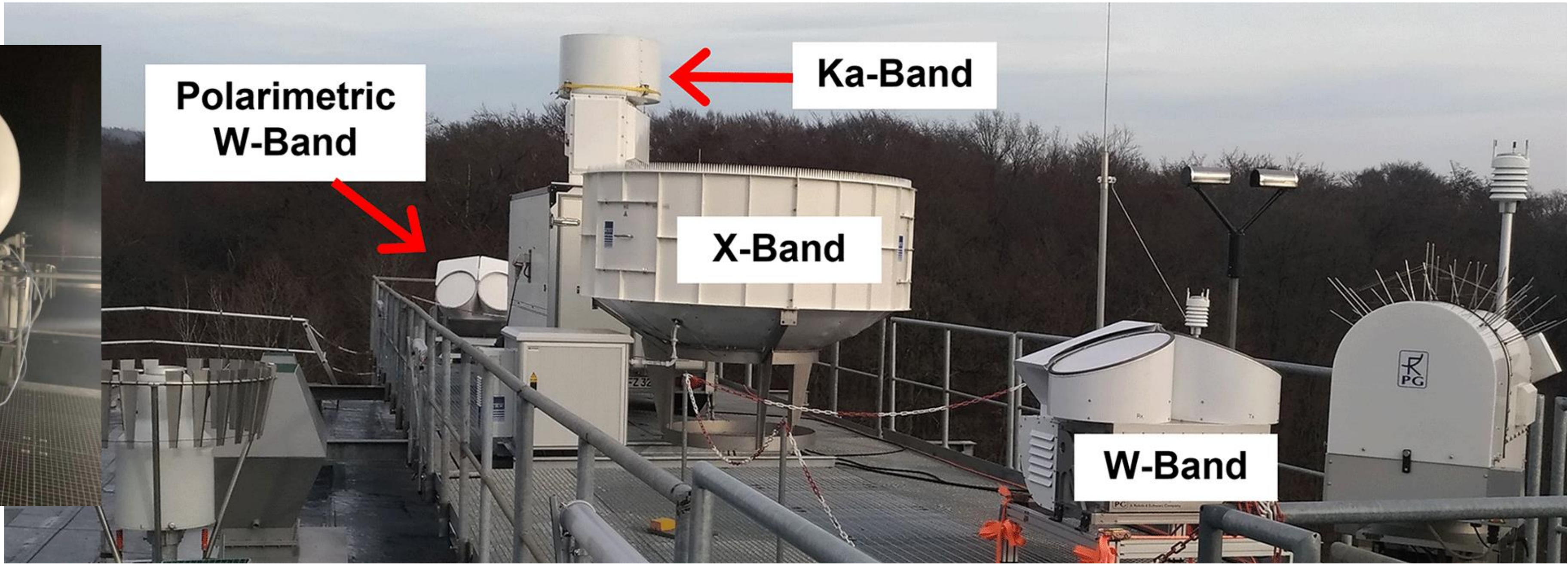
IMPRINT objectives and achievements



T. Garret, U. Utah

- Increase understanding of key **ice microphysical process (IMP):**
  - **Aggregation**
  - **Riming**
  - **Secondary Ice**
- **Observational approach:** Combined observations using spectral Polarimetry and Multi-frequency radar
- **Modelling approach:**
  - McSnow (1D): Lagrangian super-particle model allows to implement very detailed ice microphysics
  - Case studies combining McSnow and observations linked by forward simulations

Novel polarimetric radar observations



Tripex-pol

- Nov 2018 – Jan 2019
- Zenith X,Ka,W-Band
- Scanning pol. W-Band
- 15 Radiosondes

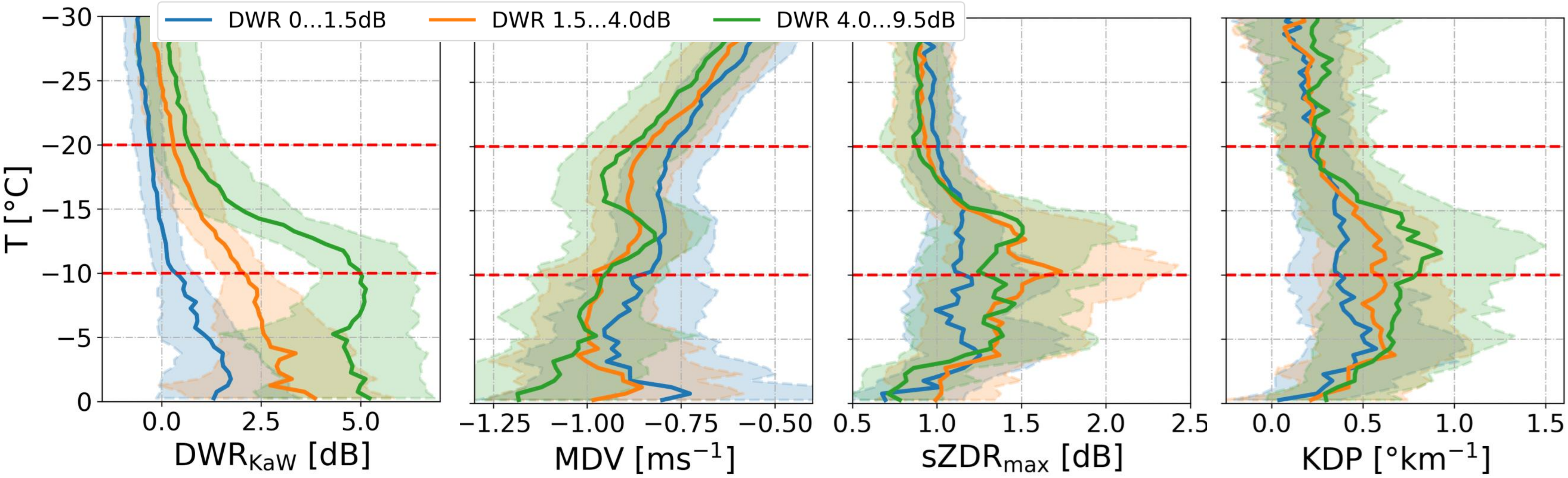
Tripex-pol-scan

- Dec 2021 – Feb 2022
- Zenith X-Band
- Scans with pol. W-Band and Ka-Band
- 50 Radiosondes

Observations were used in many studies!

- Myagkov et al. 2020: evaluation of the reflectivity calibration of W-Band radars based on observations in rain
- Mroz et al. 2020: Triple-frequency Doppler retrieval of characteristic raindrop sizes
- Trömel et al. 2021: Overview: Fusion of radar polarimetry and numerical atmospherical modeling
- Mroz et al. 2021: Linking rain into ice microphysics across the melting layer in stratiform rain: a closure study
- Karrer et al. 2022: Differences of microphysical processes in the melting layer found for rimed and unrimed snowflakes using cloud radar statistics
- Vogel et al. 2022: Using artificial networks to predict riming from Doppler cloud radar observations
- von Terzi et al. 2022: Ice microphysical processes in the dendritic growth layer: a statistical analysis combining multi-frequency and polarimetric Doppler cloud radar observations

Key findings von Terzi et al. 2022



Aggregation in the DGL is correlated to

- MDV slow down at -14°C
- Increase in sZDRmax
- Increase in KDP

}

- Source of ice particles in DGL needed
- **Fragmentation? → FRAGILE project**

Work Area 2: McSnow

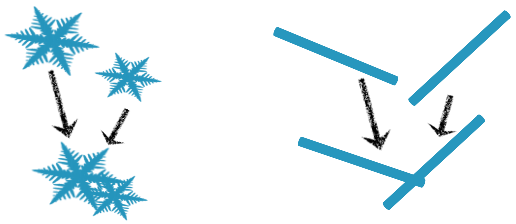
- Successful implementation of
  - Habit prediction + shape dependent riming
  - Secondary ice processes (Hallett-Mossop, Fragmentation based on Philipps et al. 2017)

→ Welss et al. 2023, James (under review)

- 1D case studies
  - Investigating influence of dendritic growth on polarimetric variables (von Terzi 2023, PhD Thesis)
  - Impact of second mode on aggregation (von Terzi 2023, PhD Thesis)
  - Dendrite case study (Publication planned)
  - Needle case study (Publication planned)

Work Area 2: McSnow – Habit prediciton

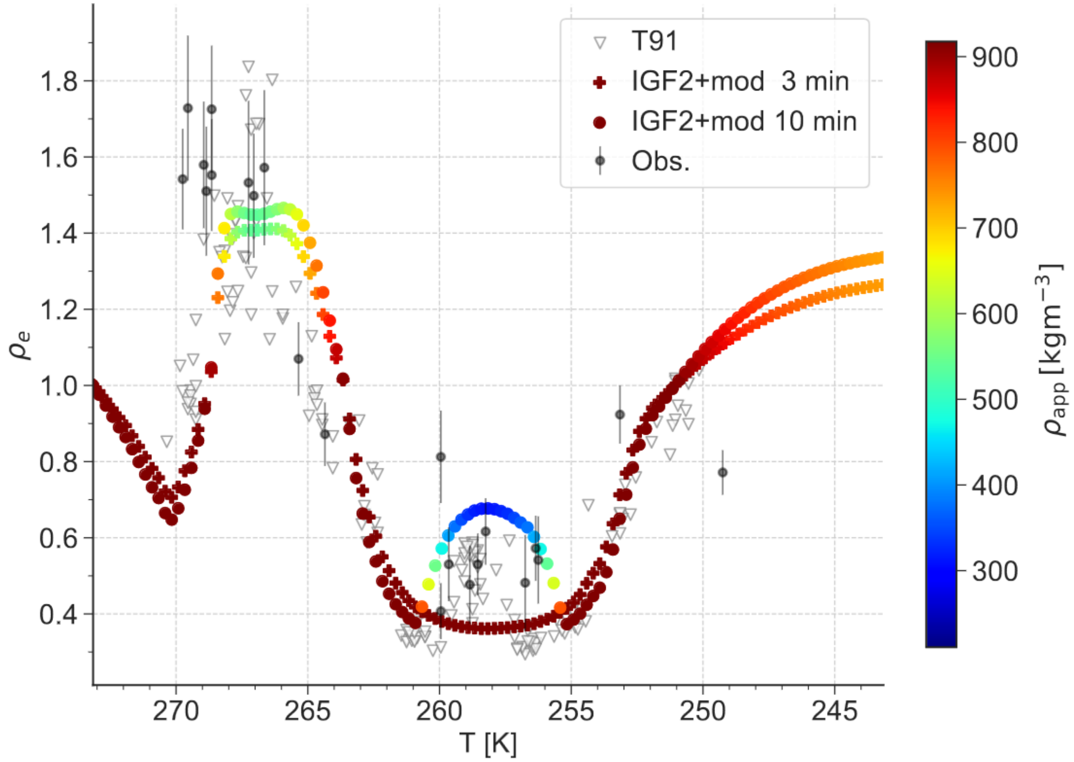
- Habit of ice particles determines:
  - Interaction with other particles:



  - Interaction with electromagnetic waves

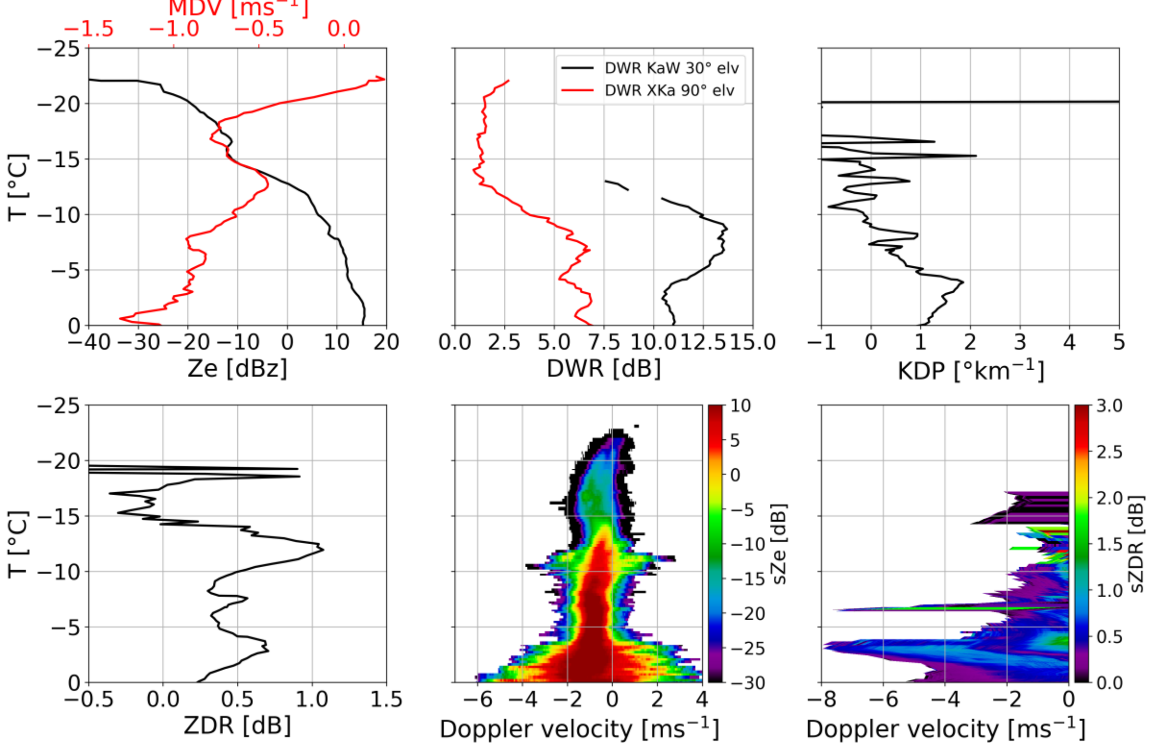
→Predicting the habit is crucial for understanding IMP and linking model to (polarimetric) radar observations

- Habit prediction was evaluated against and adapted with polarisability ratio (ρ_e) observations

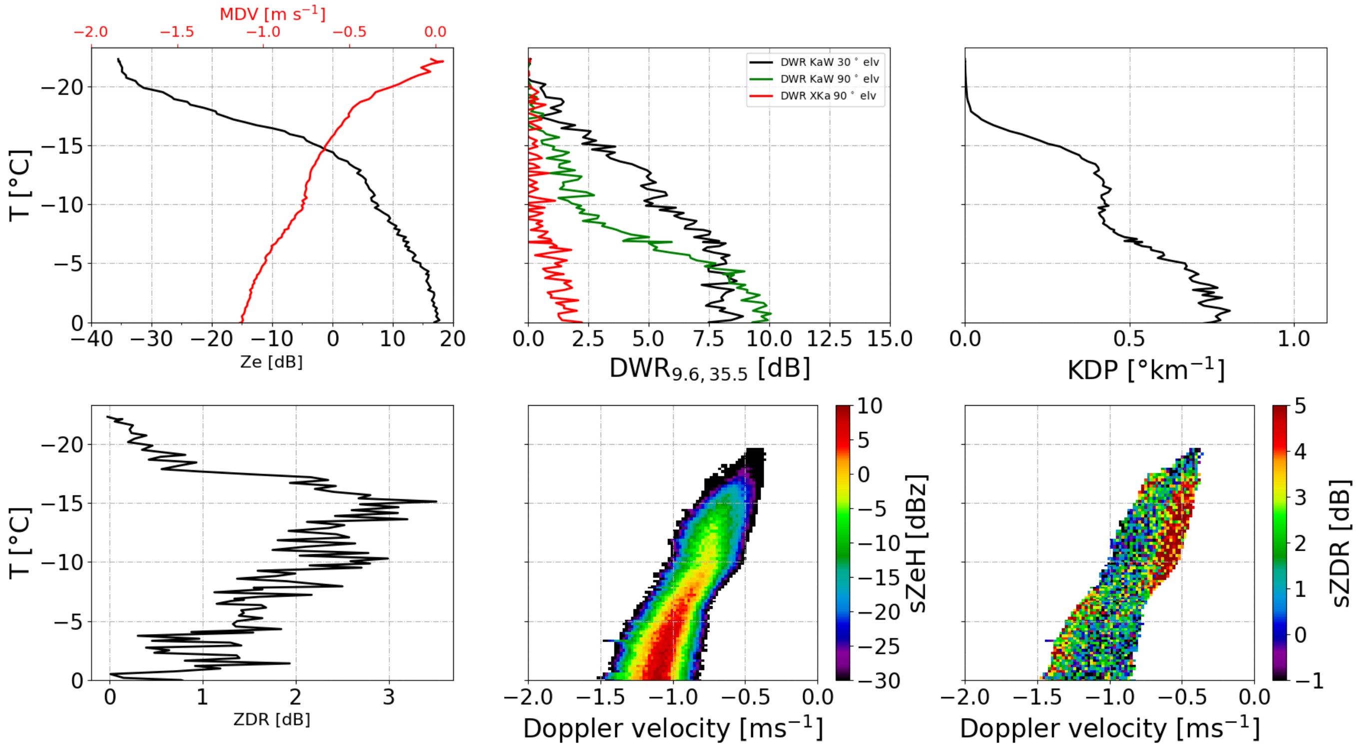


Work Area 2: McSnow – 1D case study

Observation



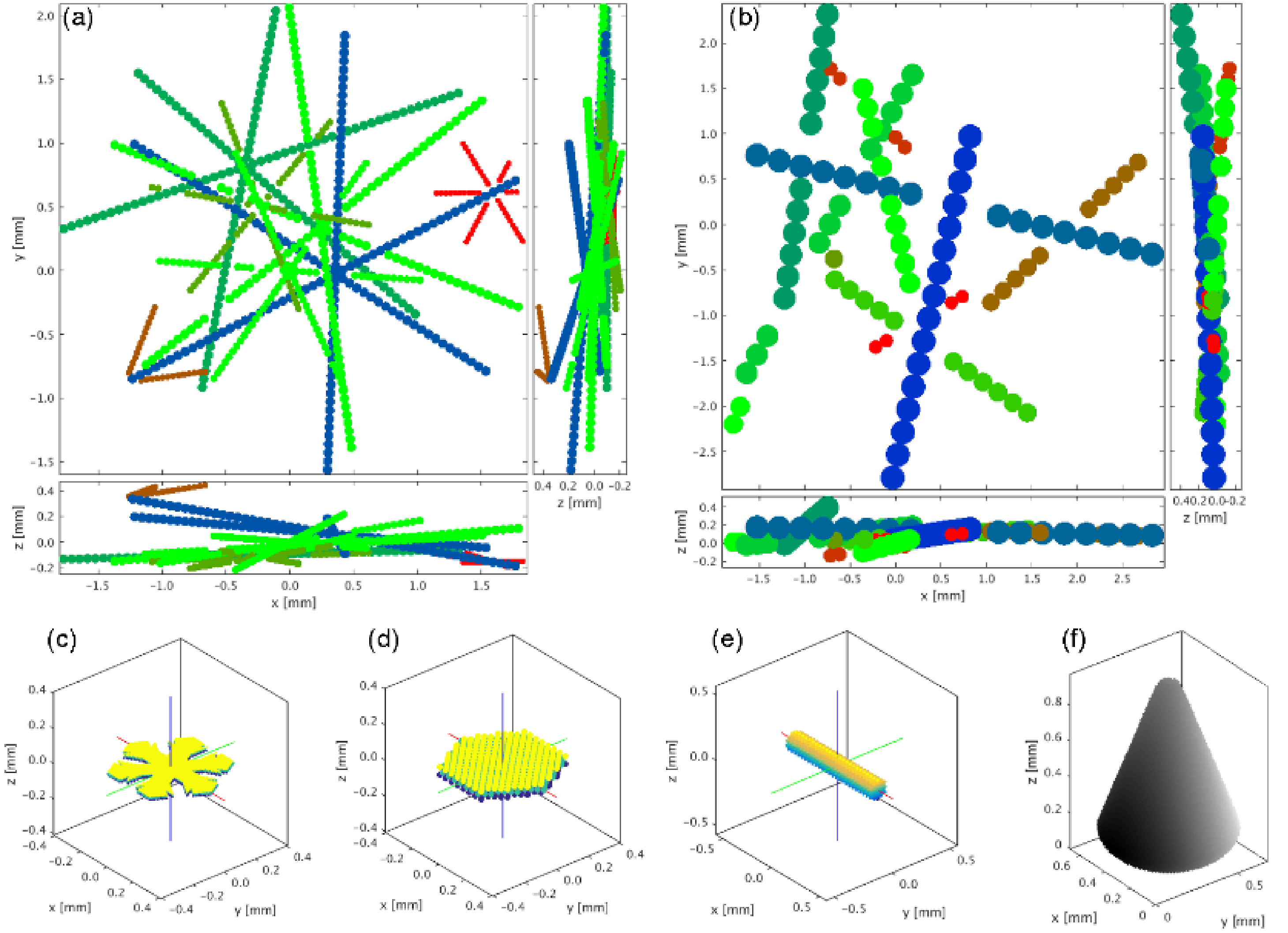
Simulation



McSnow is able to represent observations (with some caveats)!

Work Area 3: (polarimetric) forward simulations

- PAMTRA-pol with Lu database:
  - Lu only has a few shapes, which did not represent McSnow simulations



Lu et al. 2016

Work Area 3: (polarimetric) forward simulations

- PAMTRA-pol with Lu database:
  - Lu only has a few shapes, which did not represent McSnow simulations
  - McSnow output was difficult to input into PAMTRA because it does not follow predefined mD/AD/phiD-relations or PSD shapes
- McRadar:
  - Interface between pyTmatrix, snowScatt (Ori et al. 2021) and McSnow
  - Includes noise and turbulence convolution

Ways forward: my talk for PROM-Fragile on wednesday

What we achieved during IMPRINT – publications

Polarimetric and multi-frequency Radar observations

- Myagkov et al. 2020: Calibration evaluation
- Mroz et al. 2020: Triple-freq. retrieval of raindrop sizes
- Trömel et al. 2021: Overview
- Mroz et al. 2021: Retrieving IMP across the melting layer
- Vogel et al. 2022: predict riming from radar observations
- Karrer et al. 2022: statistical analysis of melting
- von Terzi et al 2022: Statistical analysis of the DGL

Comparison Radar – Model

- Ori et al. 2020: Evaluation of ICON with radar observation
- Bringi et al. 2020: case study of Hurican Dorian

Forward simulation

Scattering properties of snowflakes

- Ori et al. 2021: snowScatt

Modelling: McSnow and ICON

- Welss et al. 2023: McSnow 2.0 (under review)

What we achieved during IMPRINT – summary

Polarimetric and multi-frequency Radar observations

Comparison Radar – Model

Modelling: McSnow and ICON

Aggregation in the DGL might be linked to
- Updraft at -15°C
- second spectral mode
- Growth of new ice crystals
- Fragmentation
  → FRAGILE

- McSnow is principally able to reproduce key observational freatures
- Second mode does not enhance aggregation
- Ice particles need to be nucleated within DGL to reproduce pol. observations

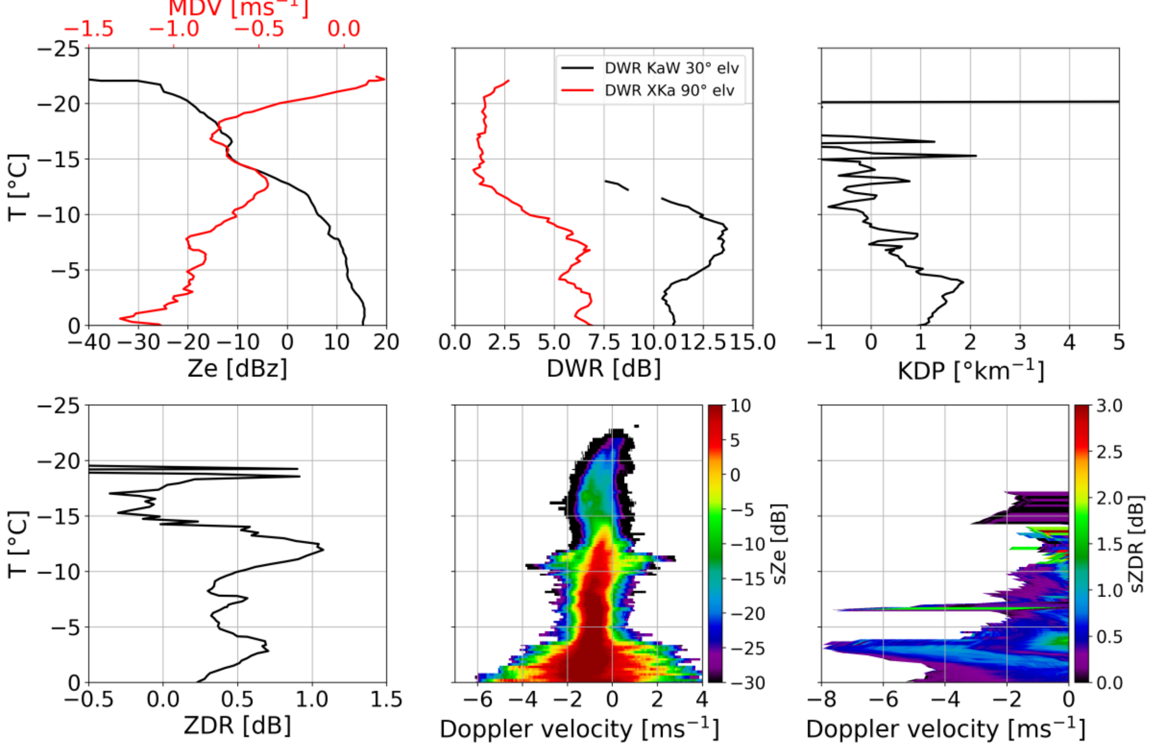
- Key IMPs implemented in McSnow (habit prediction, riming, SIP)

Thanks for your attention! Questions?

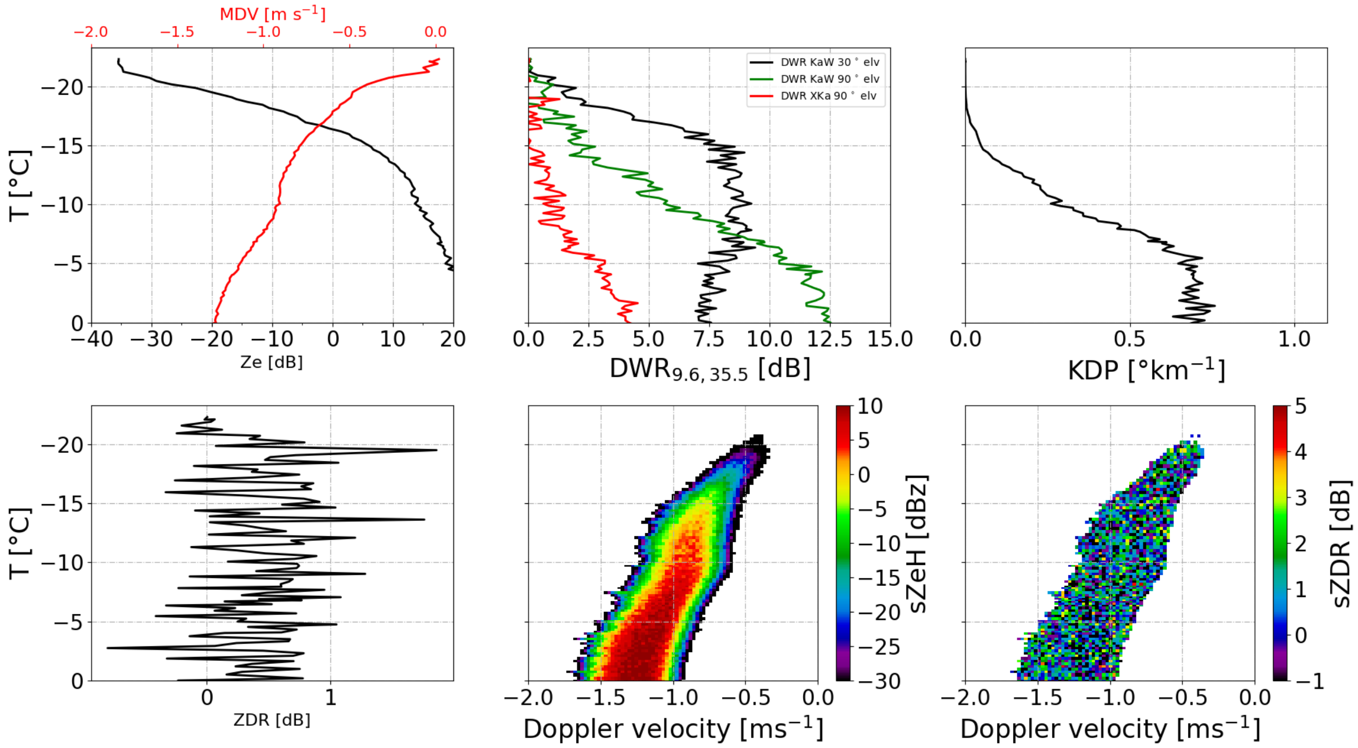
Appendix

Work Area 2: McSnow – 1D case study

Observation



Simulation without Habit prediction

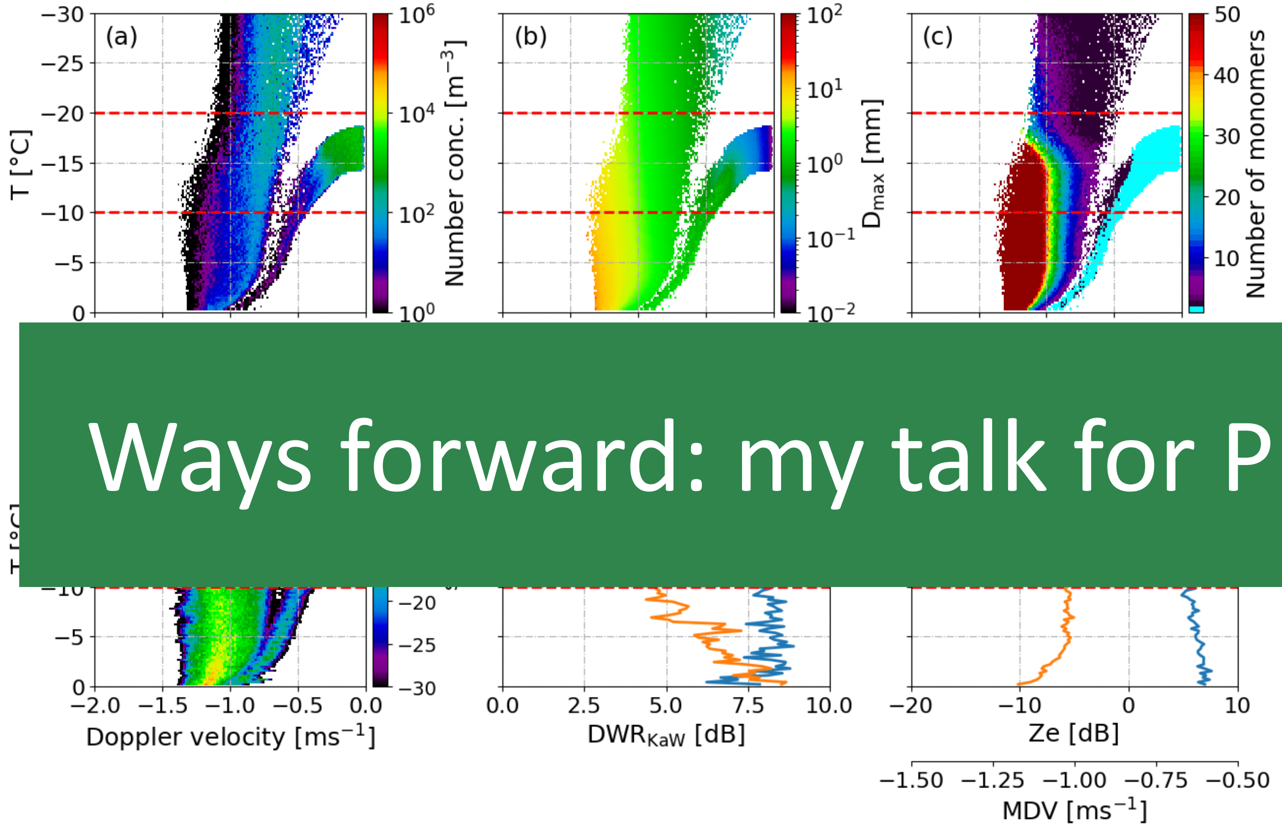


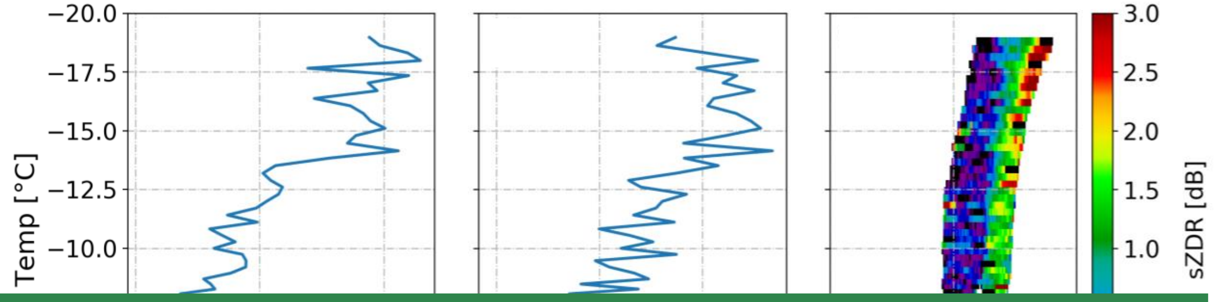
- McSnow is able to represent observations

Work Area 3: (polarimetric) forward simulations

SSRGA → multi-frequency

Tmatrix → polarimetry





Ways forward: my talk for PROM-Fragile on wednesday

Problem: no polarimetry

Problem: no convergence for smaller wavelengths