Polarimetric signatures of ice microphysical processes and their interpretation using in-situ observations and cloud modeling (POLICE)

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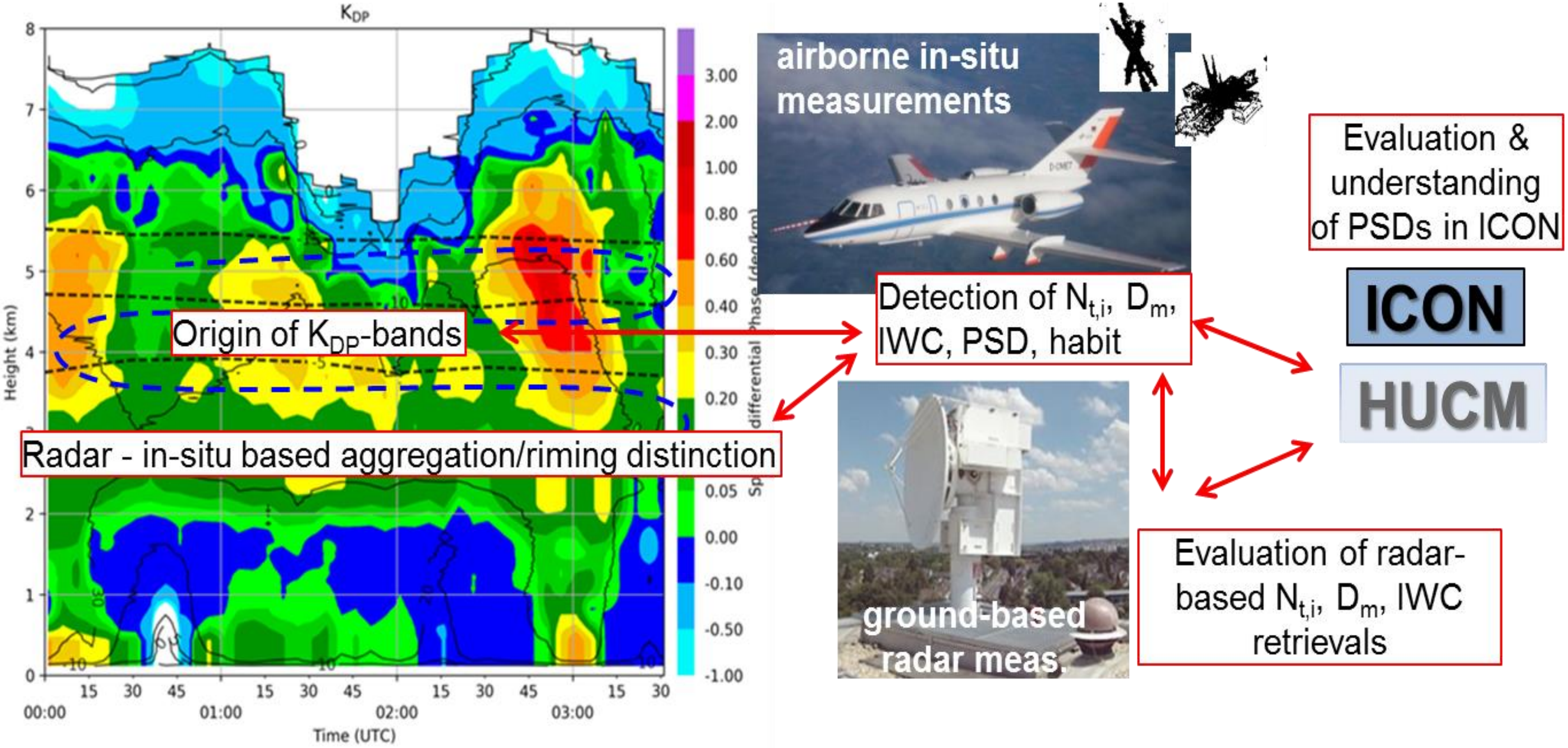
Objectives

1. **Exploitation of radar polarimetry for quantitative process detection in precipitating clouds and for model evaluation**
2. Improvement of cloud and precipitation schemes in atmospheric models based on process fingerprints detectable in polarimetric observations
3. Monitoring of the energy budget evolution due to phase changes in the cloudy, precipitating atmosphere for a better understanding of its dynamics
4. Generation of precipitation system analyses by assimilation of polarimetric radar observations into atmospheric models for weather forecasting
5. Radar-based detection of the initiation of convection for the improvement of thunderstorm prediction

Major Goals



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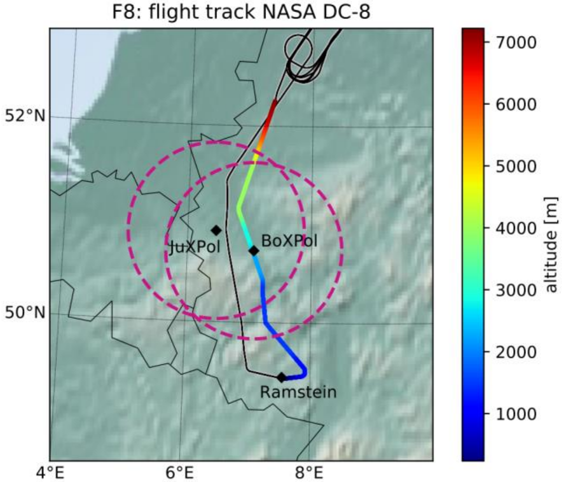
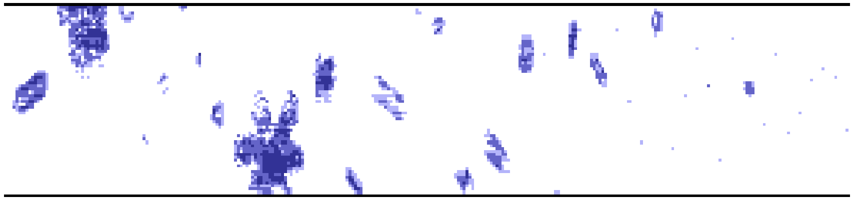
WP-1 (UNM) Existing in-situ measurements

In-situ microphysical measurements for retrieval evaluation
- ND-MAX/ECLIF campaign (2018): JOYCE-CF overflight
- ML-CIRRUS campaign (2014): in-situ measurements
- alternative: A. Heymsfield (NCAR): large dataset of in-situ and radar measurements in US



Courtesy M. Moser



Workplan:

Compose data set of cloud PSD, N_t, D_m, LWC and IWC from earlier campaigns for comparison to radar measurements, retrievals and models

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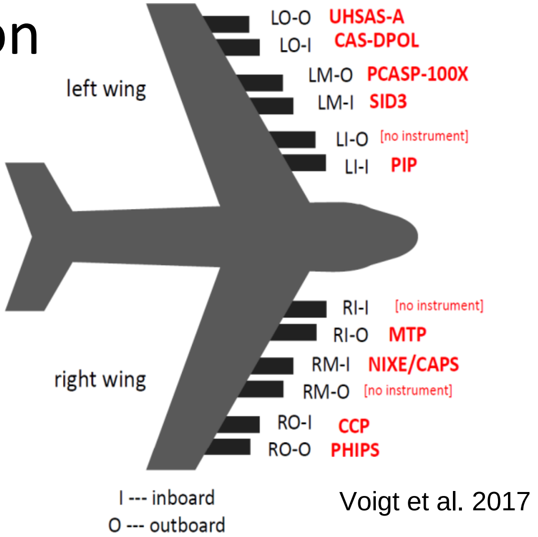
WP-2 (UNM) New in-situ measurements of microphysical cloud properties near polarimetric radars

Targeted in-situ monitoring of the DGL during
- Eco2Fly Falcon campaign in Feb/Mar 2020
- CIRRUS-HL HALO campaign in Oct-Dec 2020
- Several cloud probes to cover full size distribution and particle types

➔ new HVPS cloud probe for particle characterization



Voigt et al. 2017

+ polarimeter (irradiance)
+ WMC for water

Workplan:

Cloud instrument calibration, integration in aircraft

Evaluate data set of cloud PSD, N_t, D_m, LWC and IWC

➔ For validation of radar retrievals and models

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WP-3 (MIUB) State-of-the-art of polarimetric fingerprints

Workplan:

Perform literature review on:

- Latest understanding of K_{DP}-bands and polarimetric fingerprints of microphysical processes
- Radar data processing
- Quasi-Vertical-Profiles vs. Columnar Vertical Profile methodology

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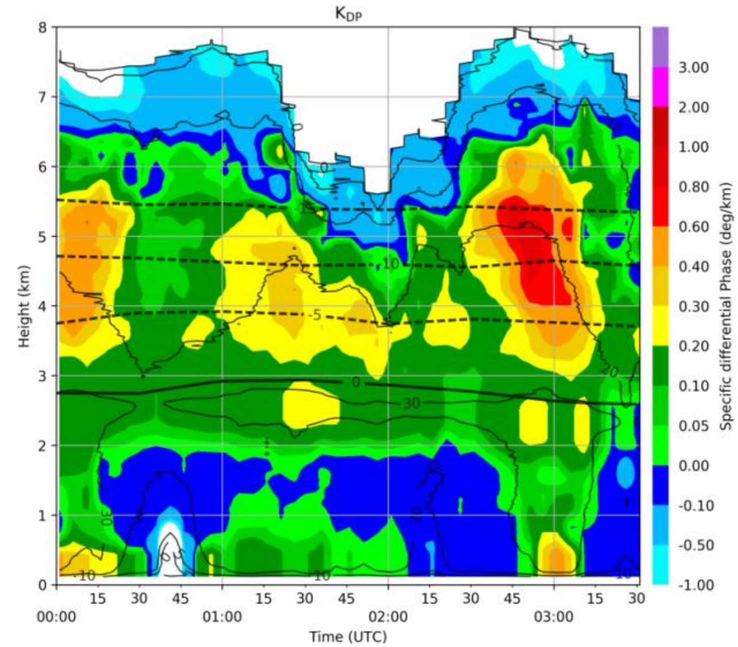
WP-4 (MIUB&UNM) What causes K_{DP}-bands in DGL ?

Competing hypotheses:

– dendrites/and or hexagonal plates with very small aspect ratio
– snowflakes with irregular shapes in high concentrations
– more isotropic ice particles with nearly spherical shapes

Workplan:

– Confront QVPs generated with BoXPol measurements (higher res. compared to DWD radars) with in-situ measurements



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WP-5 (MIUB) Evaluation of ice-microphysical retrievals

Hypotheses:

– Accuracy of most recent polarimetric ice microphysical retrievals (N_t, D_m, IWC) meet requirements for data assimilation and model evaluation/improvement

Most recent polarimetric retrievals by Ryzhkov et al. (2018):

$D_m = -0.1 + 2.0\eta$ [mm] with $\eta = \left(\frac{Z_{DP}}{K_{DP}\lambda}\right)^{1/2}$ and $Z_{DP} = z_H - z_V$,

$\log N_t = 0.1 Z_H - 2\log\gamma - 1.33$ [1/L] with $\gamma \approx 0.78\eta^2$

$IWC \approx 4.0 10^{-3} \frac{K_{DP}\lambda}{1 - Z_{dr}^{-1}}$ [g/m³] with $Z_{dr} = 10^{0.1 Z_{DR}}$

WP-5 (MIUB) Evaluation of ice-microphysical retrievals

Hypotheses:

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Most recent polarimetric retrievals by Murphy et al. (2018):

$$D_m = -0.17 + 1.41r + 0.715r^2 \text{ with } r = \left[\frac{z_{DP}}{K_{DP}\lambda}\right]^{1/3}$$

$$\log(N_{t,i}) = 0.16 + 0.1Z_H - 4.16\log(D_m)$$

$$\log(IWC) = -1.96 + \log(N_{t,i}) + 2.08\log(D_m)$$

WP-5 (MIUB) Evaluation of ice-microphysical retrievals

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Bukovčić et al. (2018): $IWC(K_{DP}, z_H) = 0.71\, K_{DP}^{0.65} z_H^{0.28}$

Hogan et al. (2006): $\log IWC(Z_H) = 0.06 \cdot Z_H - 0.0197 \cdot T - 1.7$

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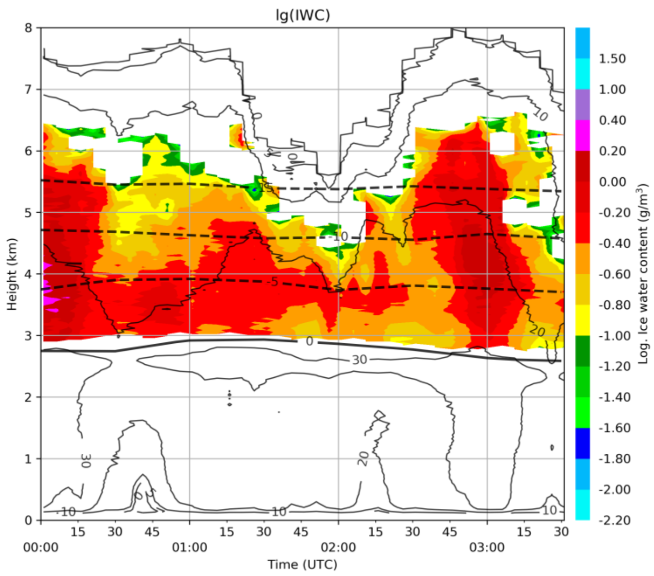
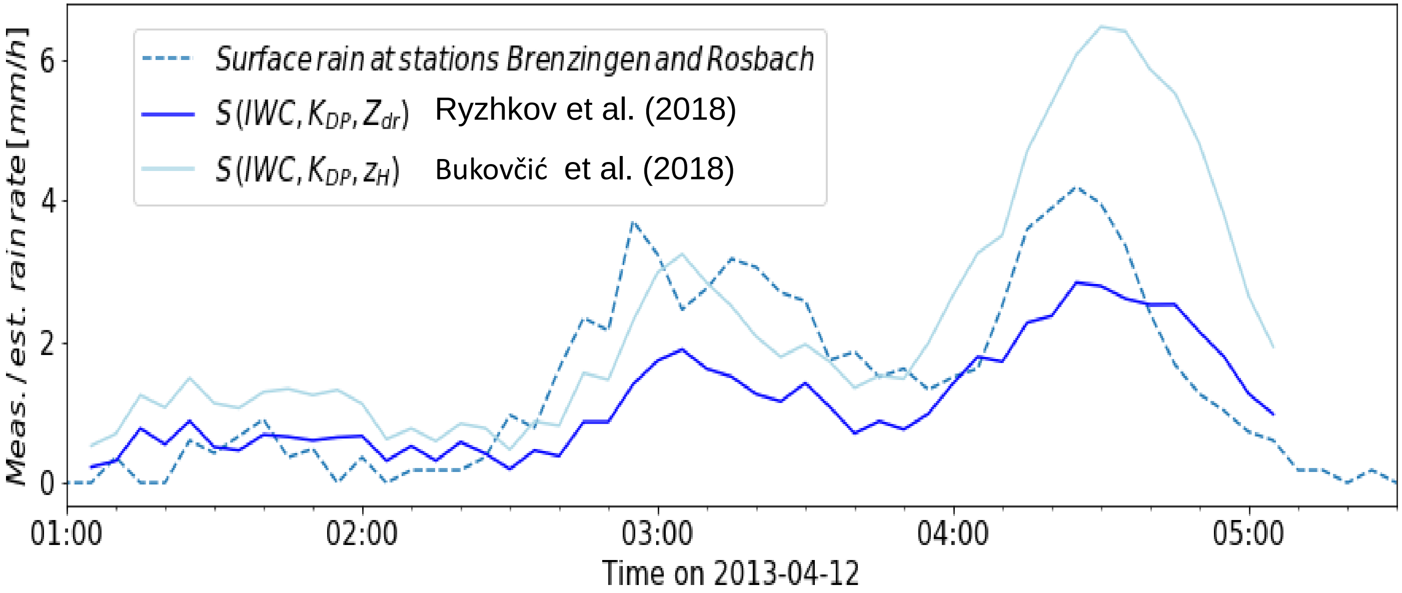


Workplan:

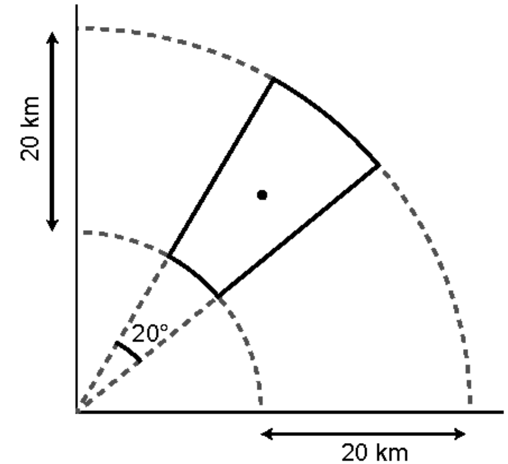
– Accuracy assessment of ice microphysical retrievals by Ryzhkov (2018), Bukovčić et al. (2018), Murphy et al. (2018), Hogan et al. (2006) .

– Application to QVPs or more localized CVPs following flight tracks.

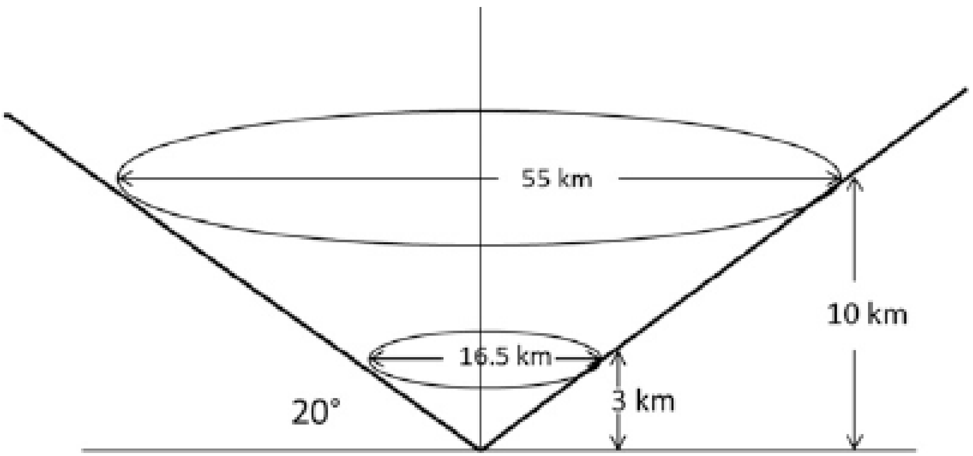
Comparison of IWC-retrievals with rain gauges measurements



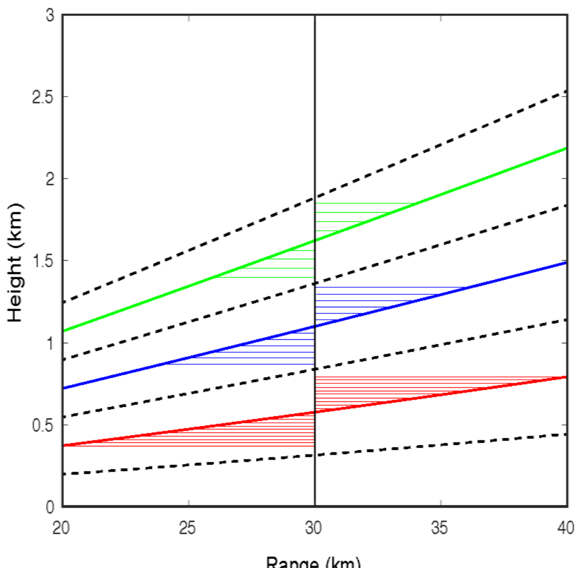
QVPs versus CVPs



Plan view of an arbitrary CVP section



Conical volume representing azimuthally averaged quasi-vertical profiles (QVPs)

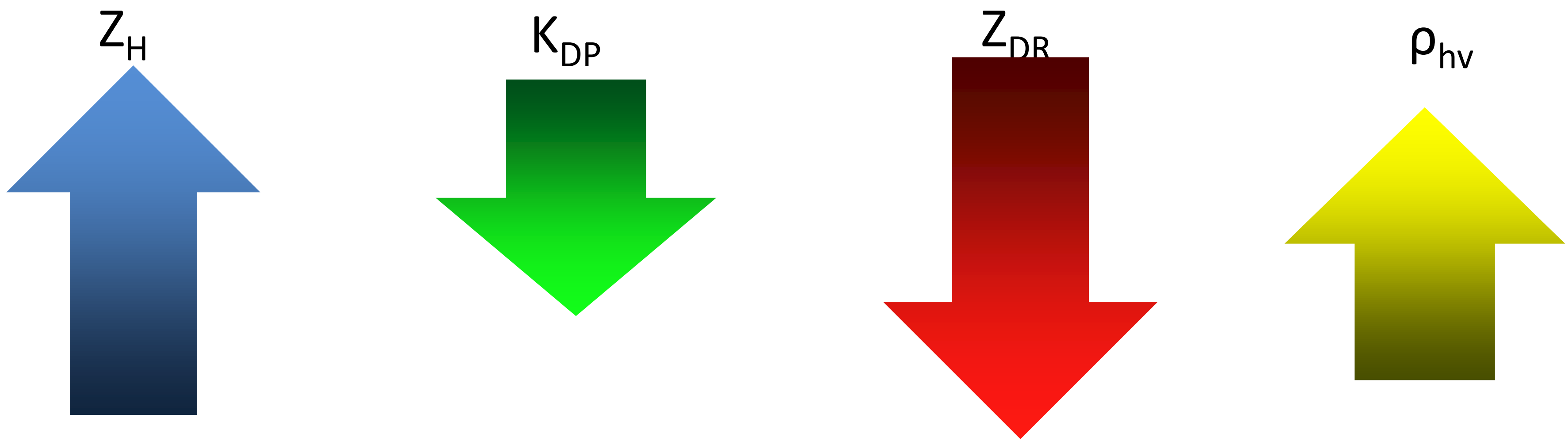


Range-height view of an arbitrary CVP section

WP-6 (UNM, MIUB) Radar algorithm development

Hypotheses:

– It is possible to distinguish between dominating aggregation and riming processes based on polarimetric weather radar measurements only

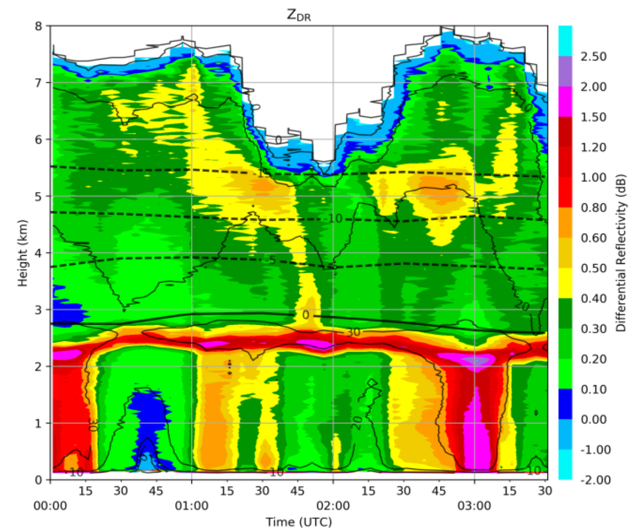


Workplan:

– Evaluate and quantify indicators using in-situ measurements, esp. reduce uncertainties in expected range of decrease in Z_{DR} and DR.

Indicators to distinguish between aggregation and riming

1. Decrease in Z_{DR} above the ML
2. More pronounced decrease in depolarization ratio DR above the ML
3. Sagging of the ML
4. Divergence and convergence zones (-> δ) point to updrafts
5. Spectral fall velocities (collecting IQ data or vertically pointing X and Ka-band radars and JOYCE-CF)
6. Dual wavelength ratios (DWR(X, Ka)>4 dB for aggregates; DWR(X, Ka)<3 dB and DWR(Ka, W)>3 dB for rimed particles)



WP-6 (UNM, MIUB) Radar algorithm development

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– It is possible to distinguish between dominating aggregation and riming processes based on polarimetric weather radar measurements only

Workplan:

– Evaluate and quantify indicators using in-situ measurements, esp. reduce uncertainties in expected range of decrease in Z_{DR} and DR.
– Develop a radar algorithm to distinguish between aggregation and riming using single area-wide available indicators, others to corroborate categorization.

WP-7 (UNM, MIUB) ICON-LAM model evaluation wrt the representation of particle type and distribution in DGL and below

Hypotheses:

- In-situ measurements combined with quality-assessed ice microphysical retrievals provide insights in the representation of hydrometeor type and distribution in ICON-LAM

Workplan:

- Identify comparable cloud sequences in QVPs/CVPs monitored by measurements and modelled by ICON-LAM
- Compare modelled hydrometeor types, concentration and sizes with in-situ measurements

WP-8 (UNM, MIUB) Reasons for deficiencies

Hypotheses:

- The coupling of the HUCM with polarimetric radar measurements uncovers the processes responsible for a potential misrepresentation of hydrometeor type and distribution

Workplan:

- Comparision between CFADs of N_t, D_m, IWC retrieved from radar and simulated from both HUCM and ICON-LAM at different heights
- Refinement of processes in HUCM will continue until a reasonable match between radar retrievals and model simulations is achieved