Characterizing the spatial variability of ice water content in and below mixed-phase clouds

B08

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1. Summary

We investigate the spatial variability of ice water content (IWC) & snowfall formation processes in mixed-phase clouds (MPCs).

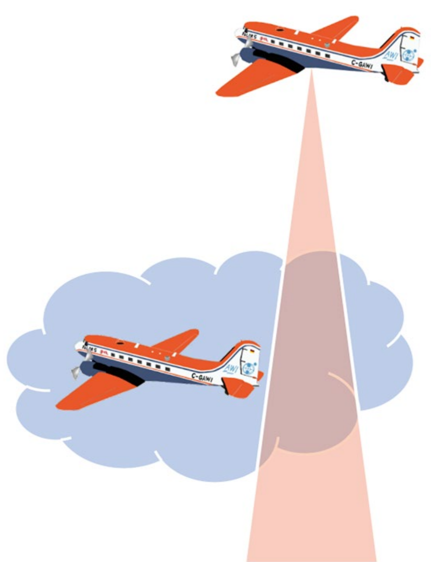
Research questions

Q1 How can we combine in situ and remote sensing aircraft measurements to study spatial variability of MPCs?

Q2 What determines gradients of IWC and what are the dominant ice formation & ice growth processes?

Q3 How do the observed IWC gradients and ice mass fluxes differ from those present in the ICON-LEM model (**E03**)?

We thus contributed to **CCA3** "Arctic Mixed-Phase Clouds".



2. Achievements phase II

A riming-dependent parameterization of scattering by snowflakes using the self-similar Rayleigh-Gans Approximation

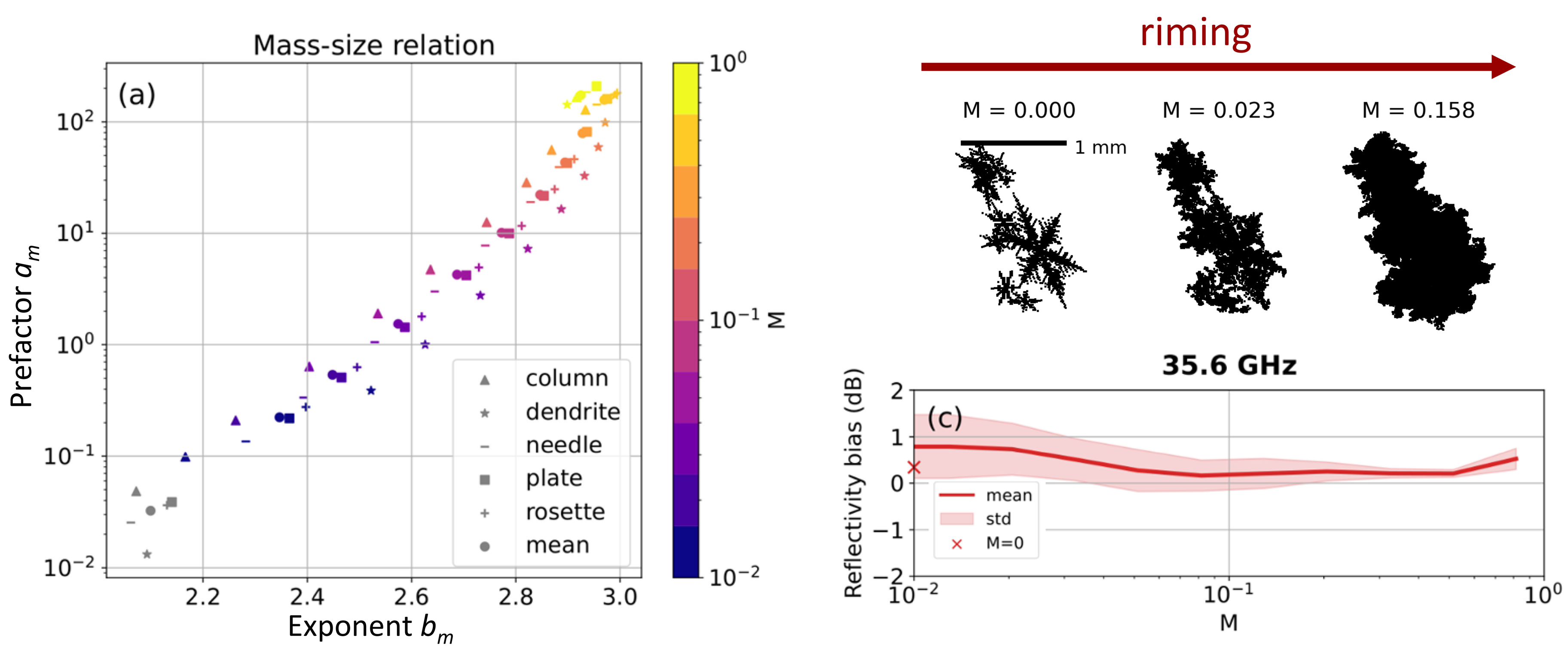


Fig. 1: a) Results of the mass-size power-law fits for the studied monomer crystal types and normalized rime mass M values. b) Example aggregate of dendrites with increasing M. c) Radar reflectivity (35.6 GHz) bias using the riming-dependent parameterization for a sample of exponential size distributions as a function of M.

- **Motivation**: Parameterize physical (mass-size, area-size) and scattering properties of ice particles as a function of **normalized rime mass *M*** (= ratio of rime mass and mass of a size equivalent graupel particle) for closure between in situ and remote sensing observations
- Parameterization based on synthetic ice particles with aggregation and riming model
- Allows to consistently estimate radar backscattering cross-section σ_b of a particle given its size and degree of riming quantified by *M*
- Assuming exponential size distributions mean reflectivity bias below 1 dB

Video in Situ Snowfall Sensor (VISSS) in Ny–Ålesund

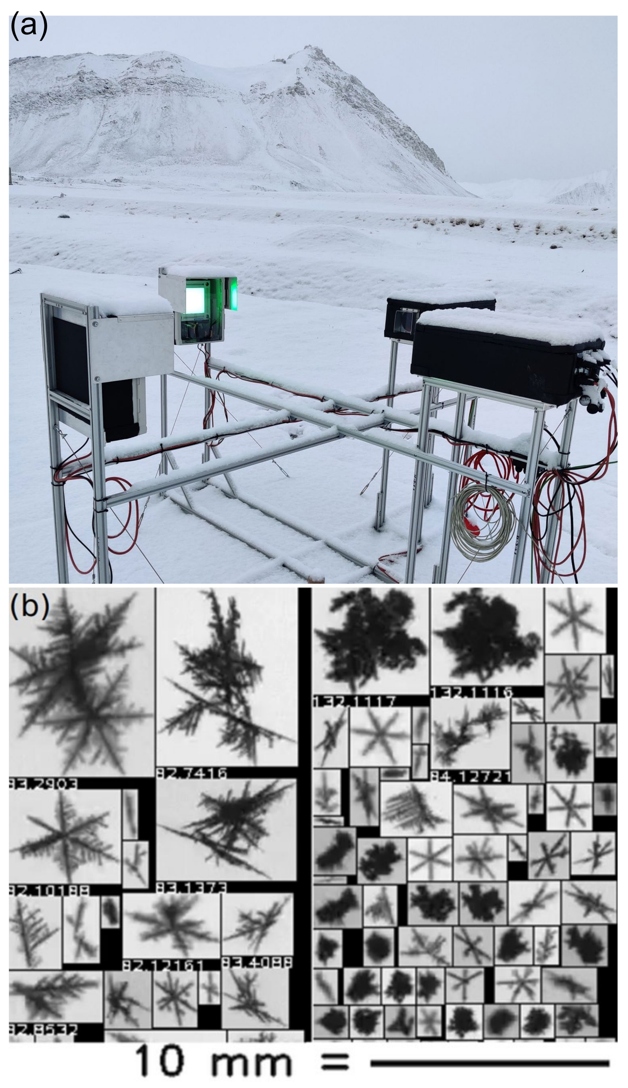


Fig. 2: a) The VISSS at NYA. b) Example measurements.

- **Motivation**: Optical images of snowflakes provide insight into dominant snowfall formation processes
- **E02** and **B08** deployed an updated VISSS in Ny–Ålesund in fall 2021
- Two cameras facing green backlights
- High resolution (0.04 mm/pixel) grayscale images
- High observation frequency (250 Hz)
- Open source hardware design
- Data processing tools developed and published in phase II
- Distributions of particle size, aspect ratio, and complexity
- Ny–Ålesund data published

Hypothesis

Spatial variability of ice water content (IWC) in and below mixed-phase clouds (MPCs) is regulated by the dominant ice formation and ice growth processes.

Quantifying riming from airborne data during HALO-(AC)³

In collaboration with **B03** & **B05**, we developed two methods to quantify *M* based on:

1) Closure of reflectivity & in situ particle size distribution ("Combined method")

- Collected about 4 hours of collocated cloud measurements
- Optimal Estimation scheme to retrieve *M*
- Parameterizations from used in PAMTRA radar simulator

2) Particle shape ("In situ method")

- Riming typically leads to more spherical particles
- Empirical relation between shape and *M* (and size) based on synthetic particles
- Only in situ data needed
- Requires sufficient particle counts

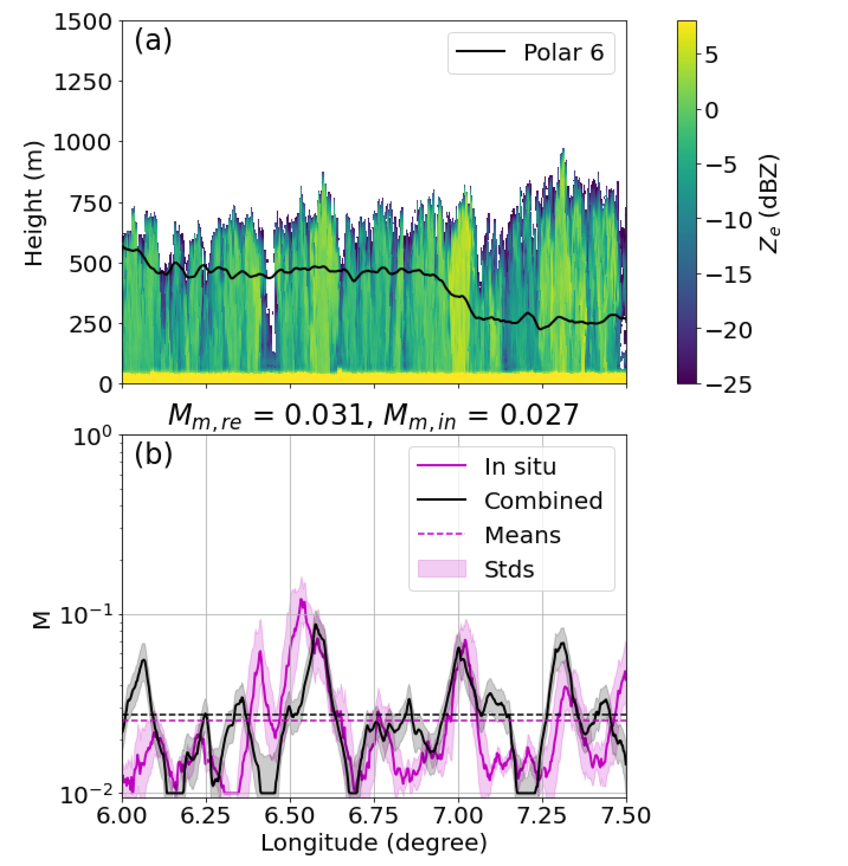


Fig. 3: a) Radar reflectivity Z_e and in situ aircraft altitude. b) M results of both methods.

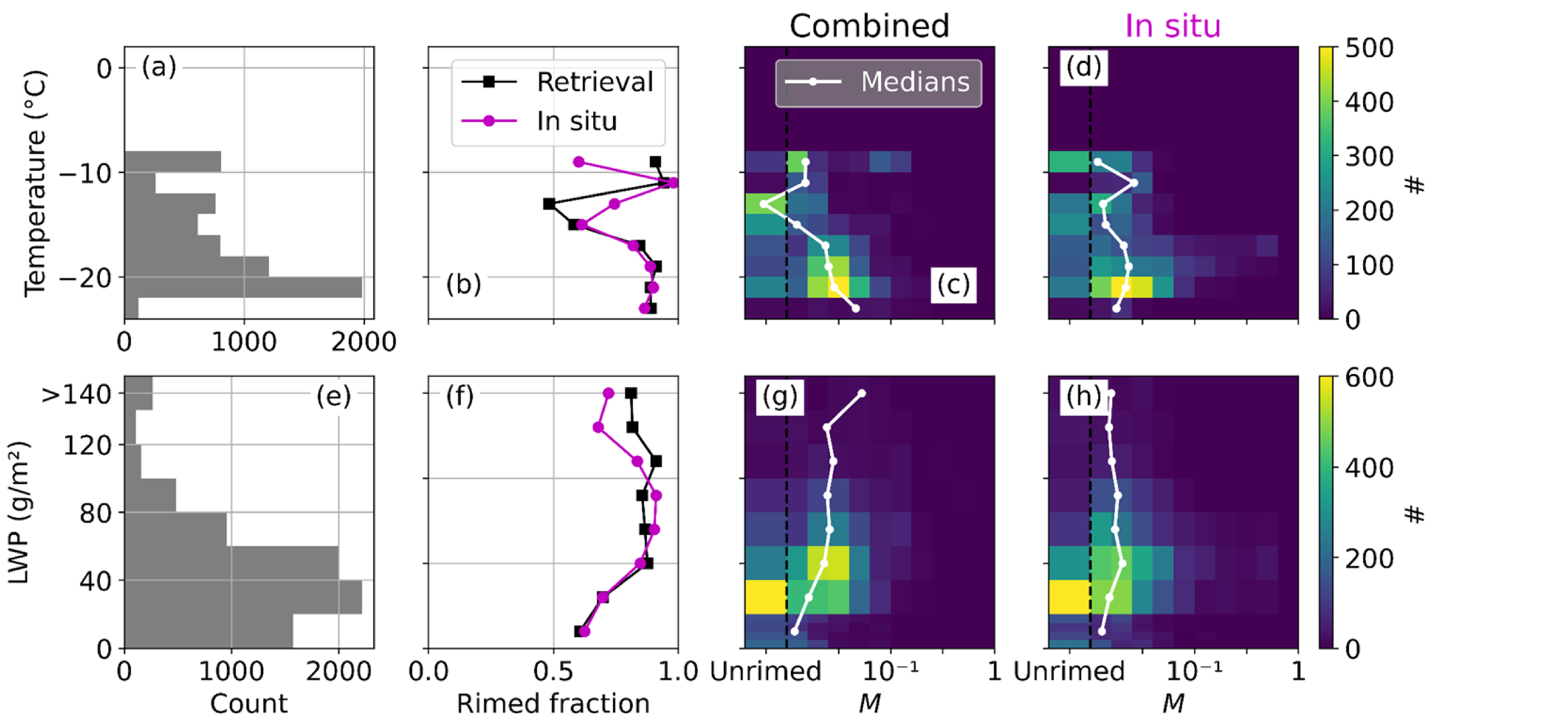


Fig. 4: Riming during collocated flight segments depending on (a)-(d) Polar 6 noseboom temperature, (e)-(h) retrieved LWP. Columns: 1) amount of data per bin, 2) rimed fraction assuming M<0.01 to be unrimed, 3) and 4) 2D histograms of M.

Liquid containing clouds at the North Slope of Alaska demonstrate sensitivity to local industrial aerosol emissions

- Characterized spatial footprint of changes in cloud properties related to local, anthropogenic emissions at the North Slope of Alaska
- Found reduction in cloud effective radius r_e by up to 1.0 µm related to localized pollution
- Changes of r_e increase cloud-reflected shortwave radiation by up to 0.8 Wm^{-2}

3. Outlook & Legacy

- Use the derived *M* to evaluate occurrence of riming during HALO-(AC)³
- Analyze IWC and riming variability in ICON-LEM
- VISSS hardware and software ready for process studies
- VISSS and developed methods will be used in **E05** in phase III

VISSS quicklooks

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