Process-level assessments of Arctic mixed-phase clouds

E03

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1. Summary

Characterization of Arctic mixed-phase clouds (MPC) and their contribution to Arctic amplification and the evolution of the Arctic system by use of unprecedented remote sensing observations and cloud-resolving simulations.

Research questions

Q1 How comparable are modeled and observed MPC properties at Ny-Ålesund to the surroundings including other surface types?

Q2 How strongly does the model performance depend on the circulation weather type? And why?

Q3 How important are the modeled representation of Cloud Condensation Nuclei (CCN) and Ice Nucleating Particles (INP), water phase transitions and moisture supply for the persistence and dissolution of low-level MPC?

Contributions to SQ1 & SQ3, coordination of CCA3

2. Achievements phase II

- Statistical characterization of MPC by observations and cloud-resolving simulations at hectometer scale (with E02)
- Installation of 35-GHz polarimetric cloud radar, and publication of quality-controlled data set (with E02)

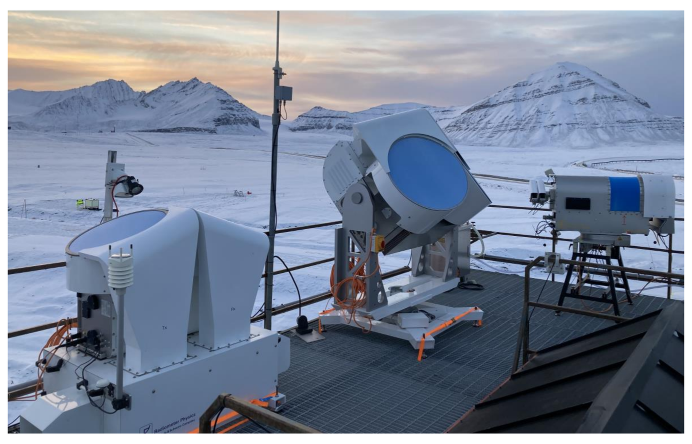

Fig. 1: Measurement setup at Ny-Ålesund

Observational analysis of ice-growth processes in low-level MPCs

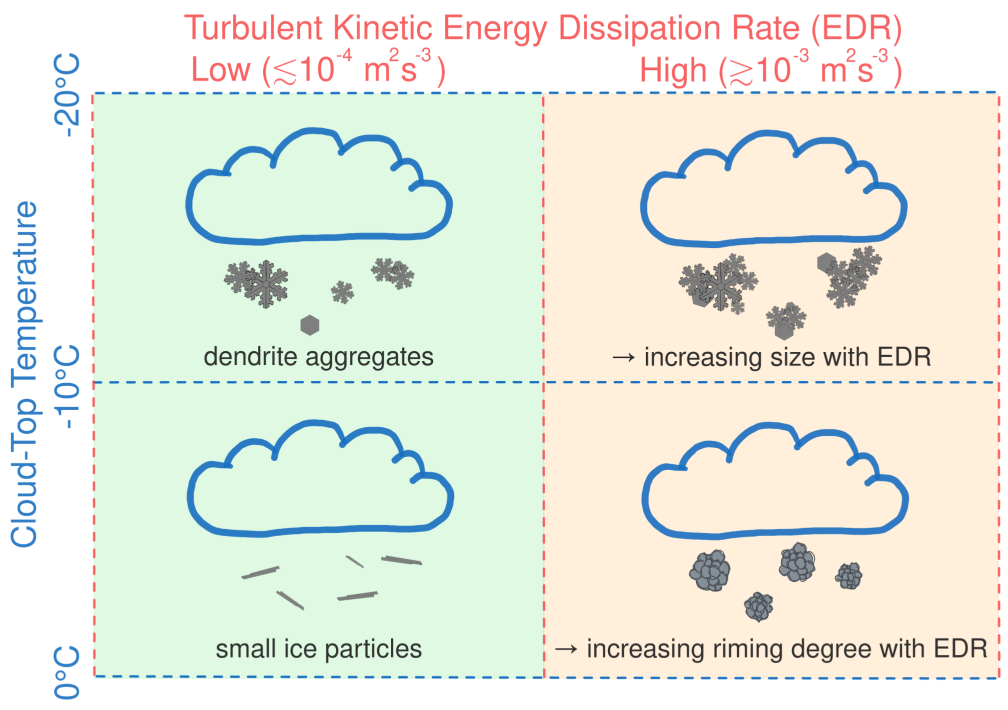

Fig. 2: Observed relations between cloud-top temperature and EDR and precipitation characteristics in low-level MPCs.

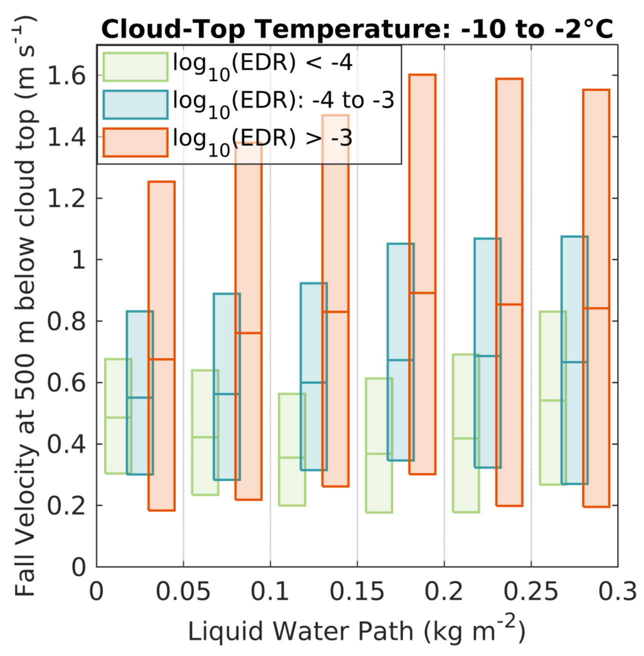

Fig. 3: Quartiles of mean Doppler velocity at 500 m below cloud top in liquid water path and EDR classes.

Aggregation and riming strongly depend on thermodynamic and turbulence conditions (Fig. 2). Riming is dramatically enhanced by increasing EDR, suggesting that turbulence is an essential component needed for riming (Fig. 3).

Performance of the ICON model in the Arctic

Multi-month evaluation of high-resolution simulations against observations

- (Thermo-)dynamics & water vapor captured very well
- Too many pure ice clouds in simulations
- Microphysical parameterization exaggerates ice formation

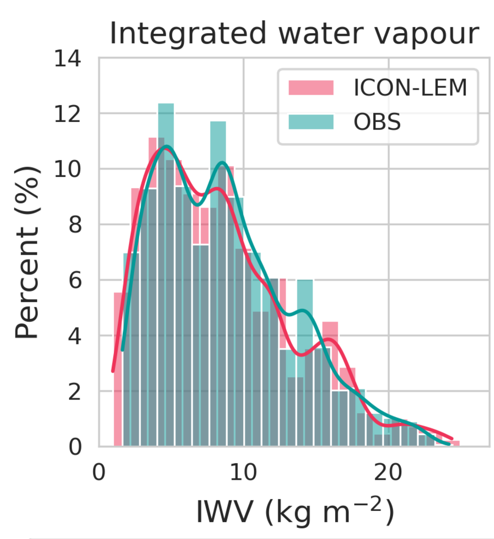

Fig. 4: Distributions of Integrated water vapor for ICON-LEM and observations.

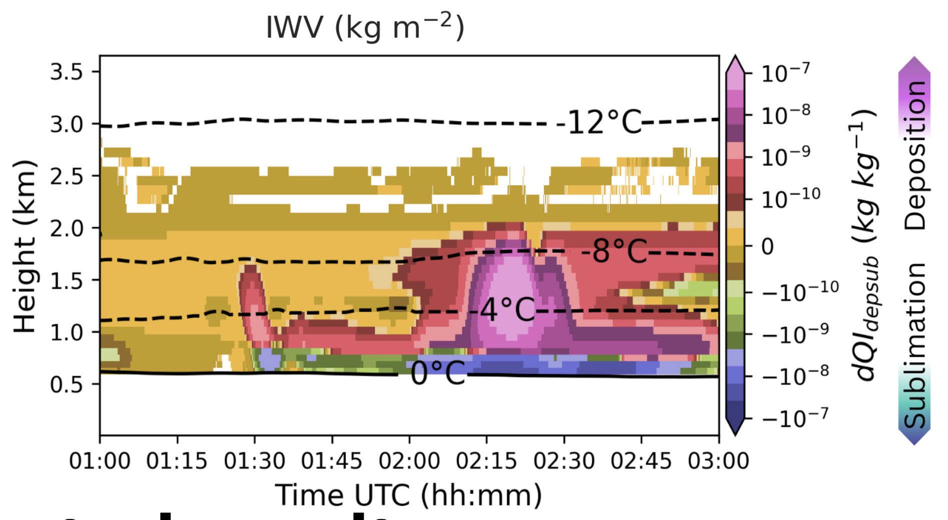

Fig. 5: Simulated change of ice mass due to deposition and sublimation in a low level mixed-phase cloud on Oct 04, 2022.

Hypothesis

The representation of Arctic mixed-phase clouds at Ny-Ålesund is on the small scale strongly dependent on local effects, but on the large scale representative for a larger area.

3. Research plan phase III

WP1 Assessment of spatial cloud variability at and around Ny-Ålesund

- Analysis of spatial variability in airborne observations and existing simulations (B03)
- Sensitivity analysis with respect to surface type and the island effect (E02, B03)
- Contribution to COMPEX with forward simulations and suggested flight pattern (B03)

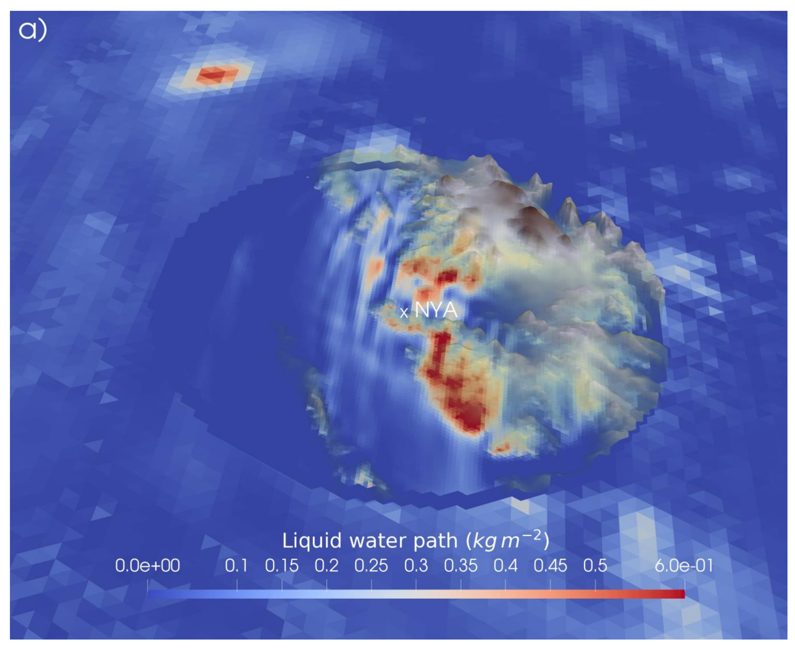

Fig. 6: Oct 04, 2022 ICON-simulated spatial distribution of LWP around Ny-Ålesund

WP2 Influence of CCN/INP on model representation

- Benchmark our simulations by CCN/INP observations (B04, A02, Z04)
- Perform sensitivity simulations to estimate signal strength and required complexity
- Suggest adjusted but still simple assumptions for simulations of Arctic MPC

WP3 Super-cooled liquid water and water phase transitions

Characterize liquid layers and water phase transitions through worldwide unique G-band radar (GRaWAC) measurements

- Analyse MPC properties linked to immediate moisture environment in intensive observation period (IOP4H2O) at Ny-Ålesund (E02, E05, B05)
- Develop and apply liquid layer retrievals based on multi-frequency radar suite
- Assess liquid layer representation in ICON-LEM and multi-radar space

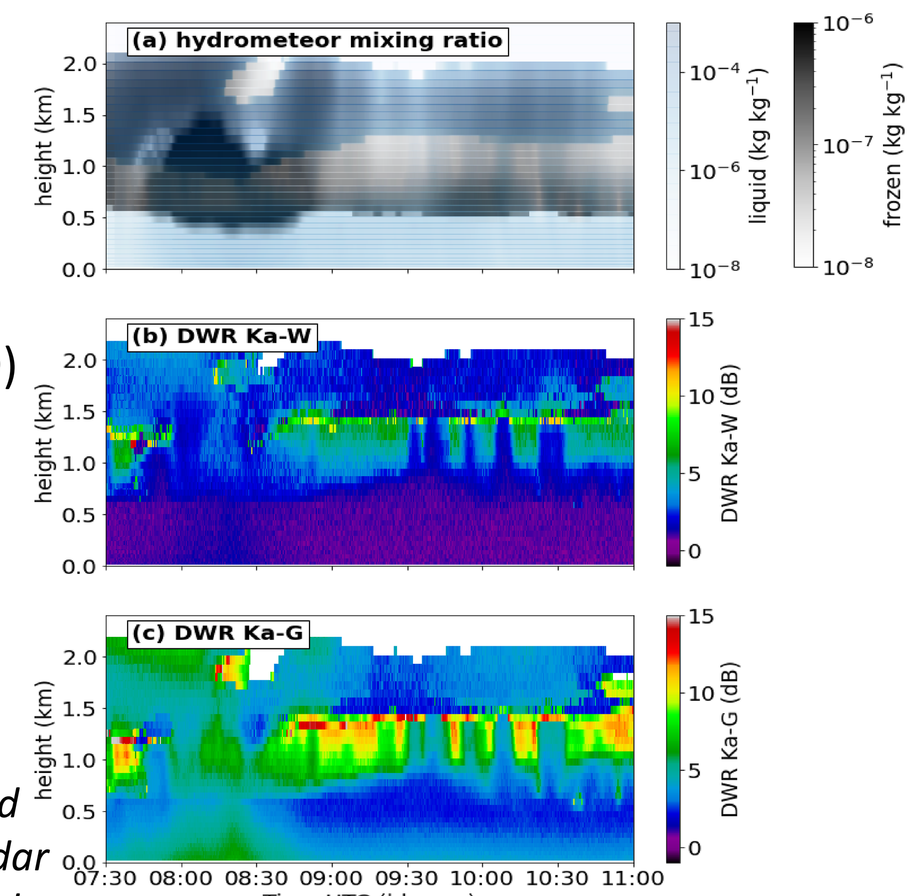

Fig. 7: Oct 04, 2022 ICON-simulated (a) frozen and liquid hydrometeors and simulated differential radar reflectivities (DWR) for (b) Ka-W and (c) Ka-G-band.

WP4 Influence of circulation weather types on MPC representation

- Analyze model performance for different circulation weather types (D01, E02)
- Use results to interpret the robustness of global climate simulations and their applied cloud parameterization

WP5 MPC across the scales (CCA3)

- Link airborne measurements and simulations to characterize MPC across different spatial scales
- Combine high-resolution and coarse-resolution simulations to challenge and improve cloud physics parameterizations

4. Legacy & Major expected results

Project Legacy

- Applicability of complex hectometer-resolution simulations with ICON-LEM of MPC under Arctic conditions, daily simulations at Ny-Ålesund since September 2020
- Data set of triple-frequency radar observations at an Arctic supersite
- Improved process understanding of Arctic MPC
- Advanced use of cloud-resolving simulations for campaign planning and support

Major expected results within phase III

- Assessment of spatial variability of Arctic MPC at around Ny-Ålesund
- Unprecedented G-band radar measurements embedded in multi-radar observations will improve understanding of observed and simulated water phase transitions
- Insights on representativeness of climate prediction with respect to MPC - considering evolution of circulation weather types and available CCN/INP

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