Process-level understanding of sublimation and evaporation of precipitation

E05

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1. Summary

We aim to better understand atmospheric sublimation and evaporation, which are embedded in the feedback loops of Arctic amplification.

Research questions

Q1 How much precipitation sublimates/evaporates below clouds at different Arctic sites?

Q2 Which large- & small-scale drivers influence atmospheric sublimation & evaporation?

Q3 Can we improve the sublimation process and its feedback mechanisms in ICON-LEM?

We thus contribute to SQ1 and CCA1, CCA3, and CCA4.

2. Research rational

State-of-the-art

- Precipitation links the Arctic atmosphere and cryosphere through snowfall & rain
- Large sublimation losses in dry sub-cloud layers (e.g. Ny-Ålesund (NYA), Antarctica)
- Sublimation depends on complex, hydrometeor dependent properties and can feed back on (sub-)cloud properties → atmospheric models struggle with simulating sublimation rates correctly
- Feedbacks might be altered by shift from snowfall to rain (and sublimation to evaporation) in a warming Arctic

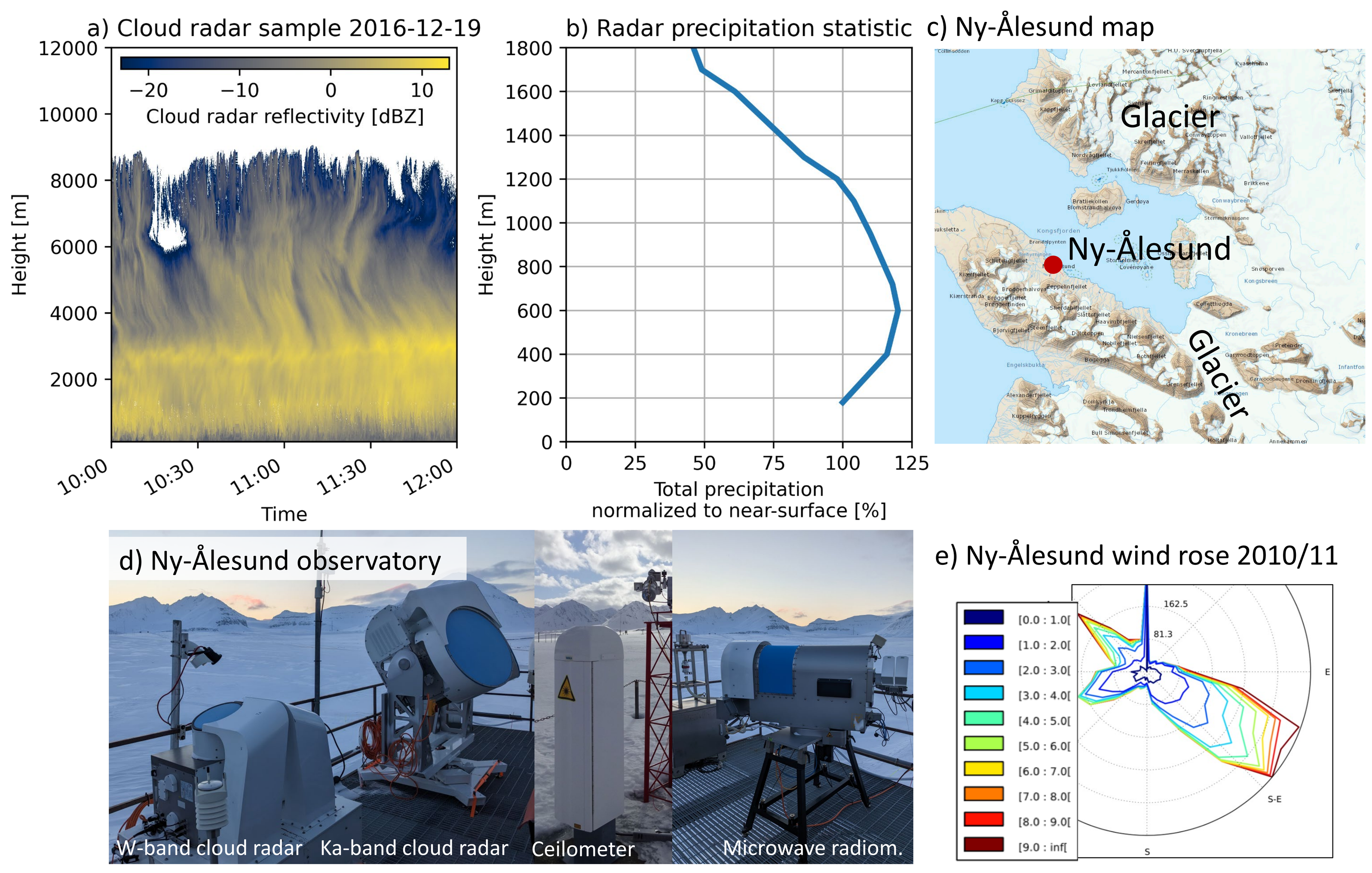

Fig. 1: Motivation for studying sublimation at Ny-Ålesund. a) Cloud radar observation of partial sublimation on 2016-12-19 b) Total precipitation amount as a function of height normalized to near-surface precipitation based on one year of observations c) Map of area (source: Norwegian Polar Institute) d) Atmospheric remote-sensing instrumentation e) wind rose.

Preliminary work

- Ny-Ålesund: near-surface snowfall amounts are reduced by > 20 % compared to observations at 600 m altitude (see Fig. 1b)
- Applicants have extensive experience with advanced remote sensing cloud and precipitation observations as well as retrieval development (B07)
- Open-source Video In-Situ Snowfall Sensor (VISSS) has been developed in phase II for high quality in-situ observations at Ny-Ålesund

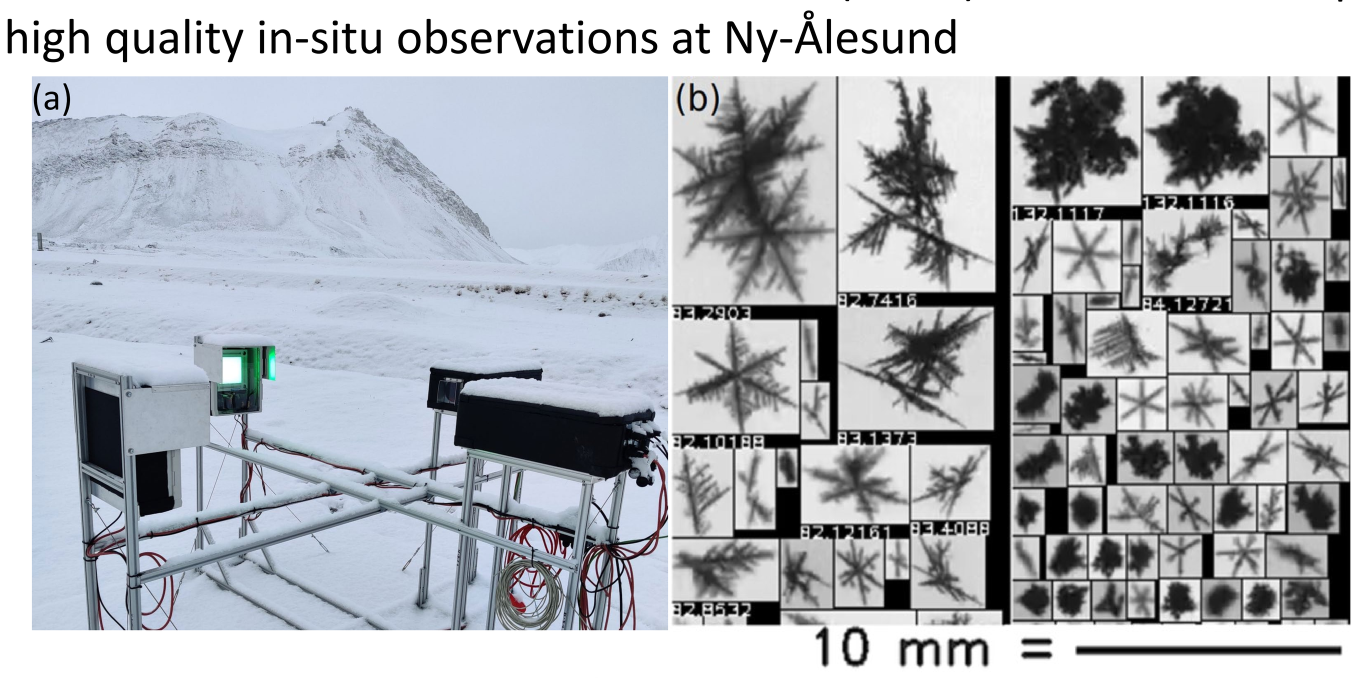

Fig. 2: a) The VISSS at Ny-Ålesund. b) Example measurements.

Contributions

- SQ1: process-level understanding of sublimation and evaporation embedded in Arctic amplification feedback loops

Hypothesis

Atmospheric sublimation and evaporation are not only influenced by large-scale atmospheric drivers but also by small-scale (sub-)cloud properties and impact cloud properties through feedback mechanisms.

3. Research plan phase III

- Combination of observational and atmospheric modeling approaches
- Participation in targeted observational campaigns: intensive observation period for water in all its phases (IOP4H_2O in Ny-Ålesund) with additional radiosondes for atmospheric moisture profiles and the G-band Radar for Arctic Water vapor And Clouds (GRAWaC) & Clouds over cOMPlEX environment (COMPEX; airborne campaign with Polar 5 based in Longyearbyen)
- Develop methods for NYA and apply to other data sets: North Slope of Alaska (NSA), MOSAiC, (AC)³ airborne campaigns

WP1 Campaigns (ALL)

IOP4H_2O Ny-Ålesund & airborne COMPEX & data sets from phase I and II

WP2 Investigation of sublimation and evaporation from the ***remote sensing perspective***

Postdoc (UNI-L1 HKL)

WP2.1: Quantify snowfall sublimation and rainfall evaporation
- Improve virga detection tool
- Determine vertical sublimation/evaporation evolution

WP2.2: Microphysical and small-scale drivers
- Assess influence of precipitation particle type, thermodynamic phase, surface coupling, turbulence

WP2.3: Influence of large-scale (synoptical) drivers
- Relate humidity & wind profiles to synoptic classification (E02)
- Assess ICON large-scale sublimation/evaporation (D01)

WP3 Investigation of sublimation from the ***in–situ perspective***

PhD (UNI-L2 MM)

WP3.1: Analyze particle type-dependent sublimation using in situ VISSS data
- Develop machine learning particle shape classification for VISSS
- Compare VISSS particle type with remote sensing sublimation estimates

WP3.2: Retrieve coefficients of capacitance and ventilation factor parameterizations as a function of particle type and turbulence
- Develop Optimal Estimation retrieval to determine sublimation parameterization considering particle type & turbulence
- Use radar reflectivity profiles and VISSS PSDs as retrieval input

WP4 Model Evaluation (ALL)

Perform process-level modeling to evaluate sublimation parameterizations and quantify sublimation-atmosphere feedbacks using ICON-LEM
- Use nested ICON-LEM setup at Ny-Ålesund with E03 and Z04
- Evaluate impact of using standard and new (WP3.2) sublimation parametrizations
- Test abilities of model for simulating spatial and temporal evolution of sublimation (WP2)

4. Role within (AC)³ and major expected results

Major expected results within phase III

- Publication of VISSS & remote-sensing campaign data sets: IOP4H_20, COMPEX
- Climatologies of sublimation/evaporation from remote-sensing perspective
- Development of new sublimation parameterization
- Assessment of impact of sublimation on the following:
  - cold pool formation influencing convection (CCA1)
  - mixed-phase cloud lifetime (CCA3)
  - air mass transformations (CCA4)
- Evaluation of representation of sublimation process in ICON-LEM

Perspectives

- Application of developed methods to other stations (e.g., Greenland, Antarctica)
- Assessment of satellite-based surface precipitation estimates based on developed sublimation- & evaporation climatologies

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