Precipitation and snowfall: Processes, extremes and impacts

E04

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1. Summary

Building on our achievements, we aim in Phase II to:

- compile new multi-parameter, multi-data set for precipitation and snowfall for at least the past 10 years
- quantify anomalous moisture transport, precipitation efficiency and their drivers
- quantify impact of increased water vapour on precipitation amount and efficiency
- estimate surface and tropospheric warming by anomalous moisture events

Research questions:

Q1 What is the specific role of **anomalous moisture transport** for precipitation and snowfall, and what is the related impact on surface and tropospheric warming?

Q2 What are the **relationships between changes** in temperature, water vapour and precipitation, and snowfall amount and efficiency?

2. Achievements phase I

I. **Established the methodology** to compare satellite data with model output via forward modeling simulator (PAMTRA, Passive and Active Microwave TRAnsfer)

II. **Improved knowledge about the differences in precipitation** magnitude and phase, and their variability and trends among the commonly used global reanalyses and most recent high resolution Arctic System Reanalysis (ASRv2)

Fig. 1: Seasonal adjusted total precipitation and fraction of frozen precipitation averaged poleward of 70°N, based on daily mean data.

III. **Description of spatio-temporal features of snowfall** using CloudSat data, and their representation in regional climate model including first regime identification

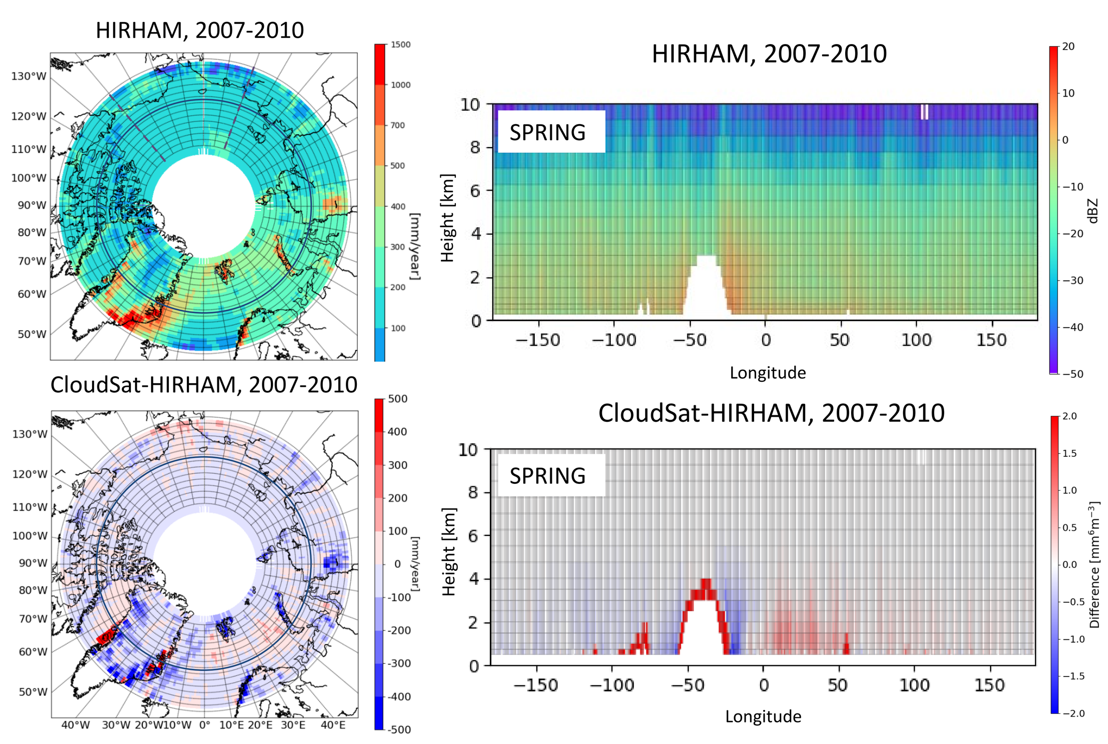


Fig. 2: Left: Yearly mean snowfall accumulation from regional climate simulations (HIRHAM5, above) and difference to CloudSat (below).

Right: For a latitude band of 72-73°N (marked with circle) mean radar reflectivity profile forward-modeled with HIRHAM5 and PAMTRA (top) and difference to the CloudSat observations (below).

IV. **Trends of cyclone characteristics** from an ensemble of reanalyses and regional models (Arctic Cordex) allowing quantification of uncertainty of recent changes and their representation in models, and estimate of future projection.

Hypothesis

Changes in atmospheric conditions and sea-ice decline lead to significant modifications in regional moisture transport and snowfall patterns in the Arctic, which significantly affects the surface energy budget.

3. Research plan phase II

WP1: Compiling observational data

- MOSAiC, **HALO-(AC)³**, various satellite data, e.g. EarthCare (2021) for vertical snow profiles, reanalyses data, e.g.ERA5, and synthetic observations (PAMTRA)

WP2: Ensemble of Arctic-focused ICON simulations

- Case studies for cyclone and atmospheric river events to improve understanding of precipitation process; sensitivity towards microphysics, resolution etc.

WP3: Processes, extremes, and impacts

- Analysis of individual events of (extreme) cyclones, identification and characterisation of moisture transport, and related weather patterns, meteorological and surface conditions
- Observation-to-model and model-to-observation approaches method: effects of air temperature and cloud phase on precipitation and rain-snow partitioning
- Relationship between water vapour, precipitation amount and efficiency
- Estimation of surface and tropospheric warming by anomalous moisture events

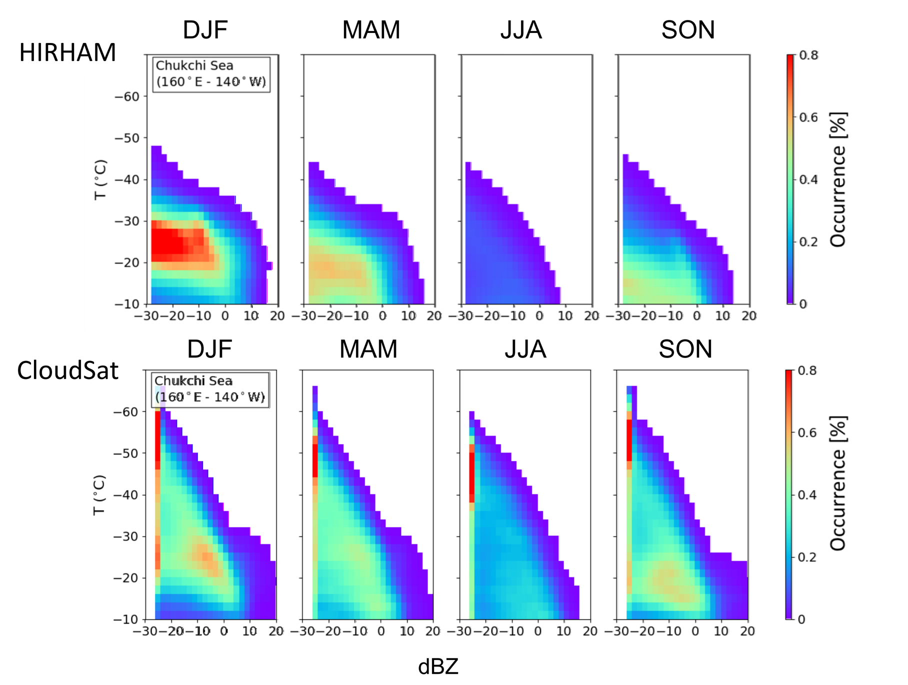


Fig. 3: Example of model-to-observation approach. Radar reflectivity occurrence by temperature for different seasons (2007-2010) compiled from regional climate simulations (HIRHAM5) and subsequent radar simulator (PAMTRA) as well as the corresponding CloudSat measurements tom). Both have been sampled for nal matching. The model and rvations are seeing similar features ased e.g. ice clouds in DJF and snow vth process at -15°C in SON. CloudSat rves higher reflectivites in DJF, referring to snowfall.

WP4: Crosscutting activity "Airmass transport & transformation"

- Synthesis of observations and modeling results from various (AC)³ sub-projects
  - anomalous moisture transport into the Arctic
  - related air transformation (affected by atmospheric and surface conditions)
  - impact on the surface energy budget

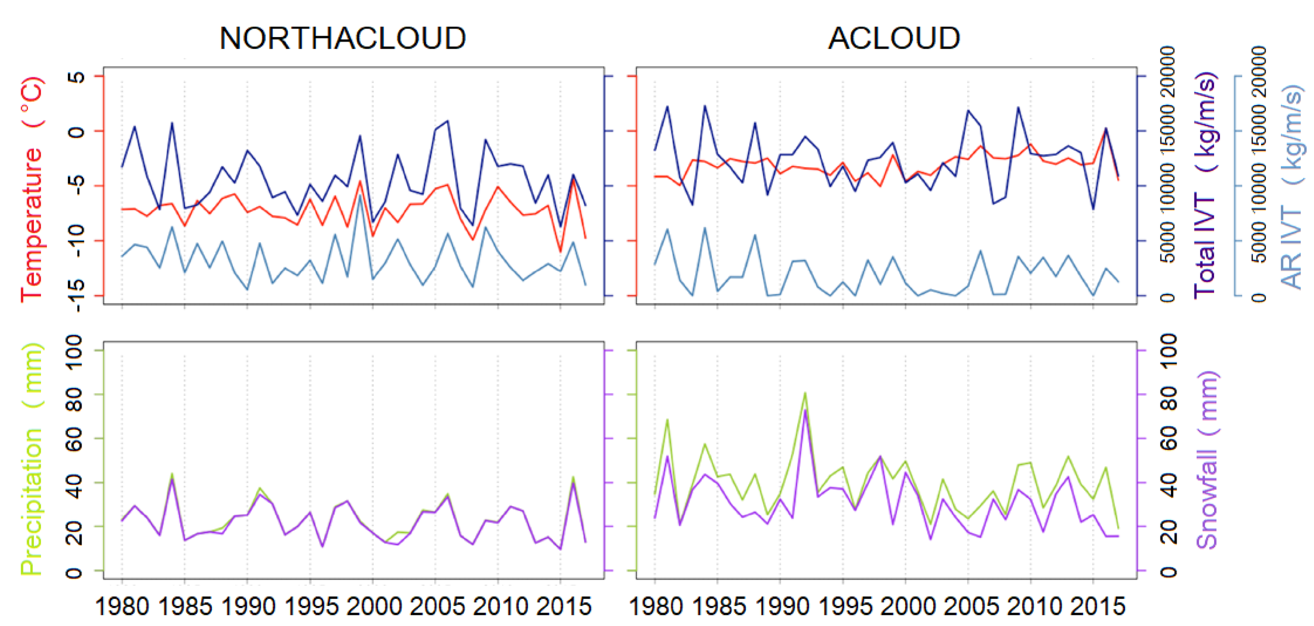
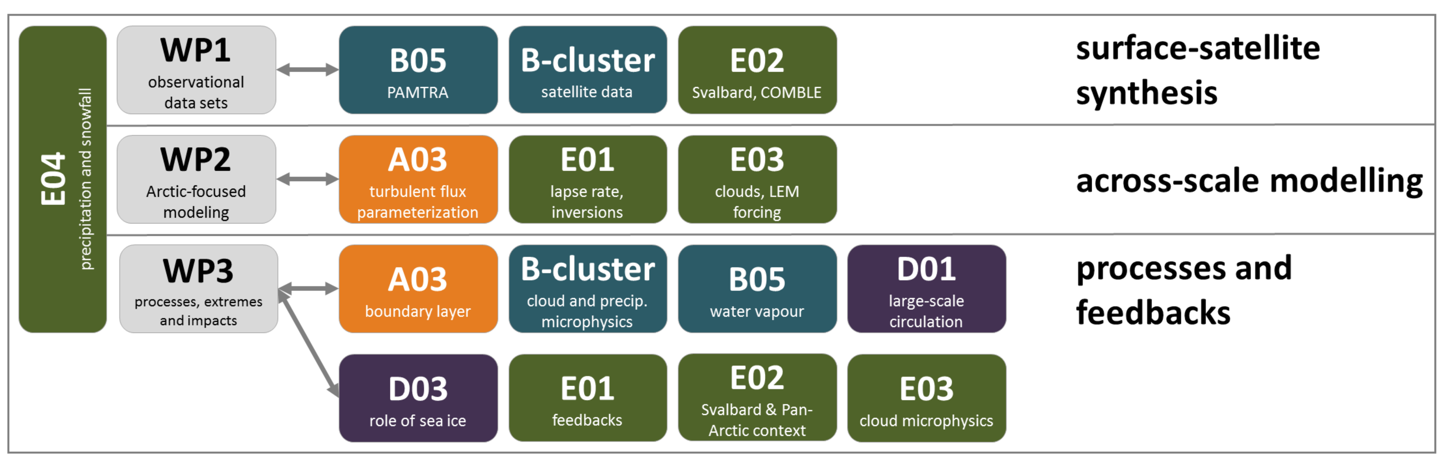


Fig. 4: Reanalysis data (MERRA-2) presented at grid cells of ACLOUD (79°N, 12°E) and North ACLOUD (82°N, 10°E) sites based on monthly data for May. Guan & Waliser (2015) AR catalog is used to identify AR-related IVT (integrated water vapor transport) values. Temperature, total and Atmospheric River (AR)-related vertically integrated water vapor transport (above), total precipitation and snowfall (bottom) .

4. Role within (AC)³ & perspectives

Crosscutting activities and collaborations within (AC)³

- Leading crosscutting activity on "Air mass transport and transformation"
- Contribution to crosscutting activity on "Mixed-phase clouds"



Perspectives

- Investigation of long-term hydrometeorological climate change
- Exploitation of long-term satellite data: account more than two decades
- High-resolution Arctic-focused ICON simulations: present & future climate
- ICON coupled modelling: relationship between cyclones and air mass transformation and the sea ice-ocean system

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(AC)³ ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms

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