Moisture intrusions: Processes and climatological impacts

E04

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1. Summary

Research questions

Q1 How do air mass transformation processes during moisture intrusions affect the precipitation and its phase?
Q2 Which processes determine the impact of moisture intrusions on the surface energy budget?
Q3 What are potential changes in moisture intrusion characteristics and impact in the future?

Coordination of CCA4, contribution to SQ1, SQ2, & SQ3.

Hypothesis

Moisture intrusions and related air mass transformations along the path into the Arctic lead to significant impacts on precipitation and surface energy budget, which imply sea-ice feedbacks.

2. Achievements phase II

Intrusions: Impacts on precipitation & surface energy budget (SEB)

with focus on selected Atmospheric River (AR) cases during ACLOUD and AFLUX campaigns, and MOSAiC

- Contributions to **precipitation by ARs**, cyclones, and fronts quantified by a newly developed method

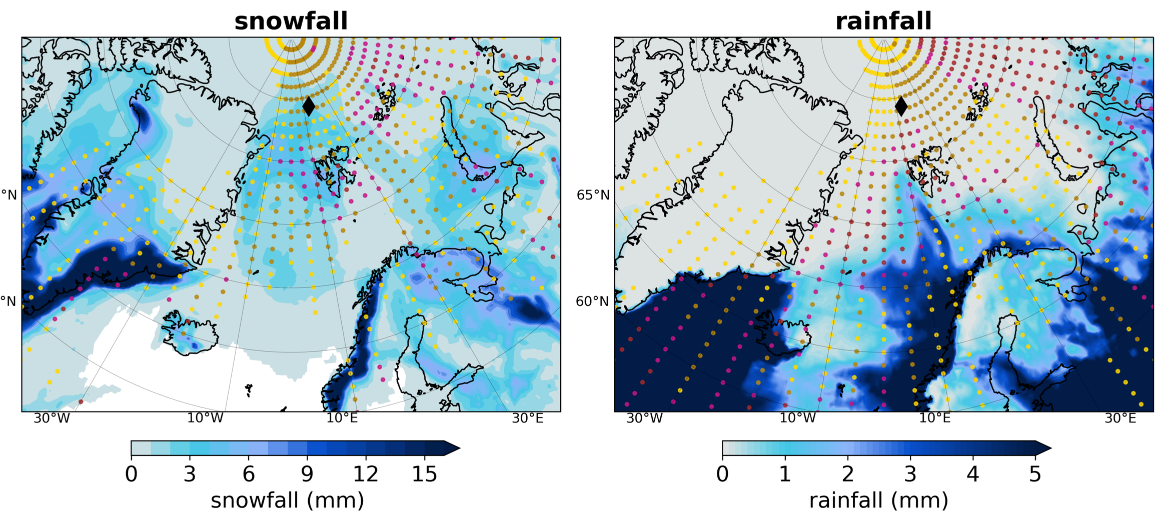

Fig. 1: Total accumulated snowfall (left), and rainfall (right) for 14-21 April 2020 based on ERA5. Colored dots represent contribution of ARs.

- Analysis of **air mass transformation processes** (moisture cycling via clouds, precipitation) and SEB effects

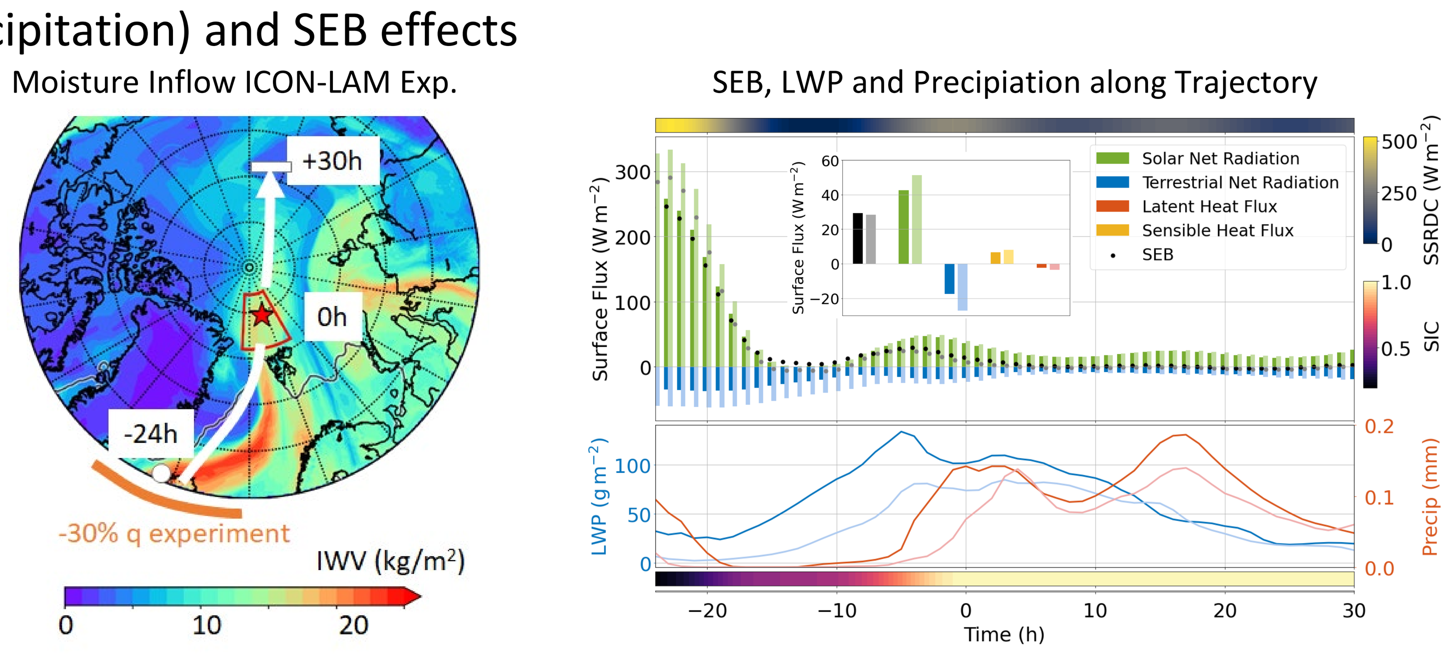

Fig. 2: (left) IWV on 19 April, 12 UTC. (right) SEB, terrestrial and solar radiation (top), LWP and precipitation (bottom) along trajectories (mean is shown). Time is relative to 19 April, 12 UTC. At the bottom/ top: sea-ice concentration (SIC)/surface clear-sky short-wave downward radiation of climatology (SSRDC, ERA5). Small plot: mean of SEB along trajectories. Dark/light colors: CTRL/EXP. Sign convention of fluxes: positive downward.

- Relative role of **water vapor and cloud-radiation feedbacks** for SEB impact

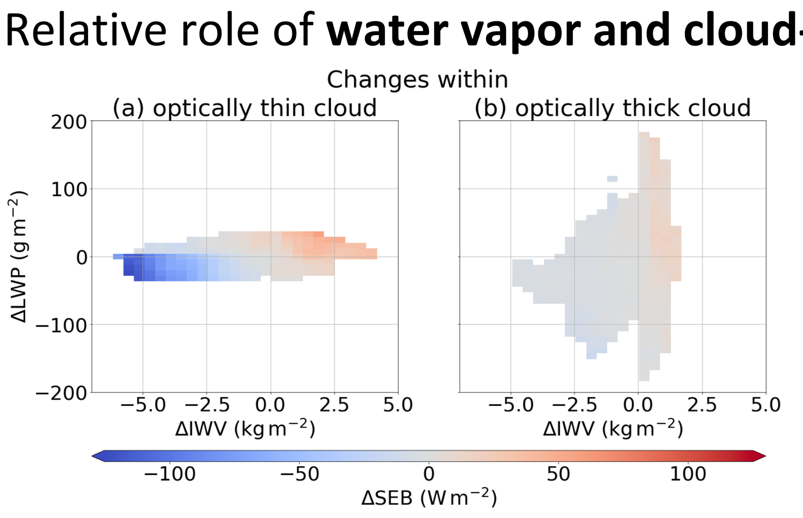

Fig. 3: Averages of SEB differences (EXP-CTRL) for gridpoints within detected AR shape, sorted by difference in IWV and LWP for subset of grid points associated with liquid-bearing optically thin (left) and thick clouds (right). The threshold LWP of 30 gm^{-2} is used to separate optically thin and thick liquid-bearing clouds.

Snowfall observations: Limitations & new perspectives from satellites

- Uncertainty of **light precipitation** in the central Arctic and model skill is related to circulation **weather regimes**
- **New observations** from ground-based supersites and **satellite retrievals** to better quantify the amount of snowfall & its uncertainty (start cooperation with CNR ISAC)

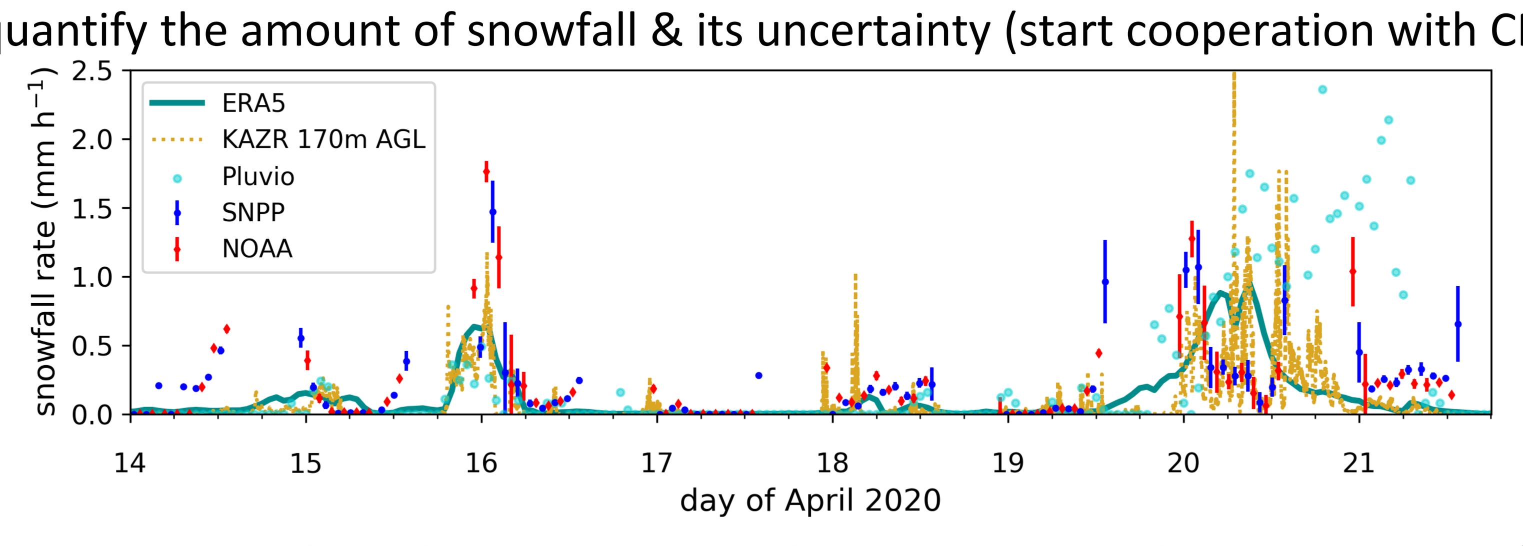

Fig. 4: Time series of snowfall at RV Polarstern for 14-21 April 2020 from ERA5, satellite (NOAA, SNPP), and ground-based (Pluvio, KAZR) measurements.

3. Research plan phase III

WP1 Event-based process understanding

- Case studies for HALO-$(\mathcal{AC})^3$ campaign and MOSAiC for detailed understanding of air mass transformation processes
- Ground-based (AWIPEV, Bear Island) and satellite (ATMS, EarthCARE and Ice Cloud Imager) measurements, and reanalyses
- km-scale ICON-LAM simulations for Eulerian and Lagrangian (LAGRANTO) analysis, and sensitivity studies (e.g., cloud microphysics E03)
- Focus on precipitation characteristics and SEB

WP2 Climatological surface impacts of moisture intrusions

- Climatological analysis of moisture intrusions: seasonal, interannual and regional variability, recent changes, impacts on precipitation and SEB
- Uncertainty quantification (AR identification algorithm)
- Link to changes in circulation, moisture and its transport (B05, E06)

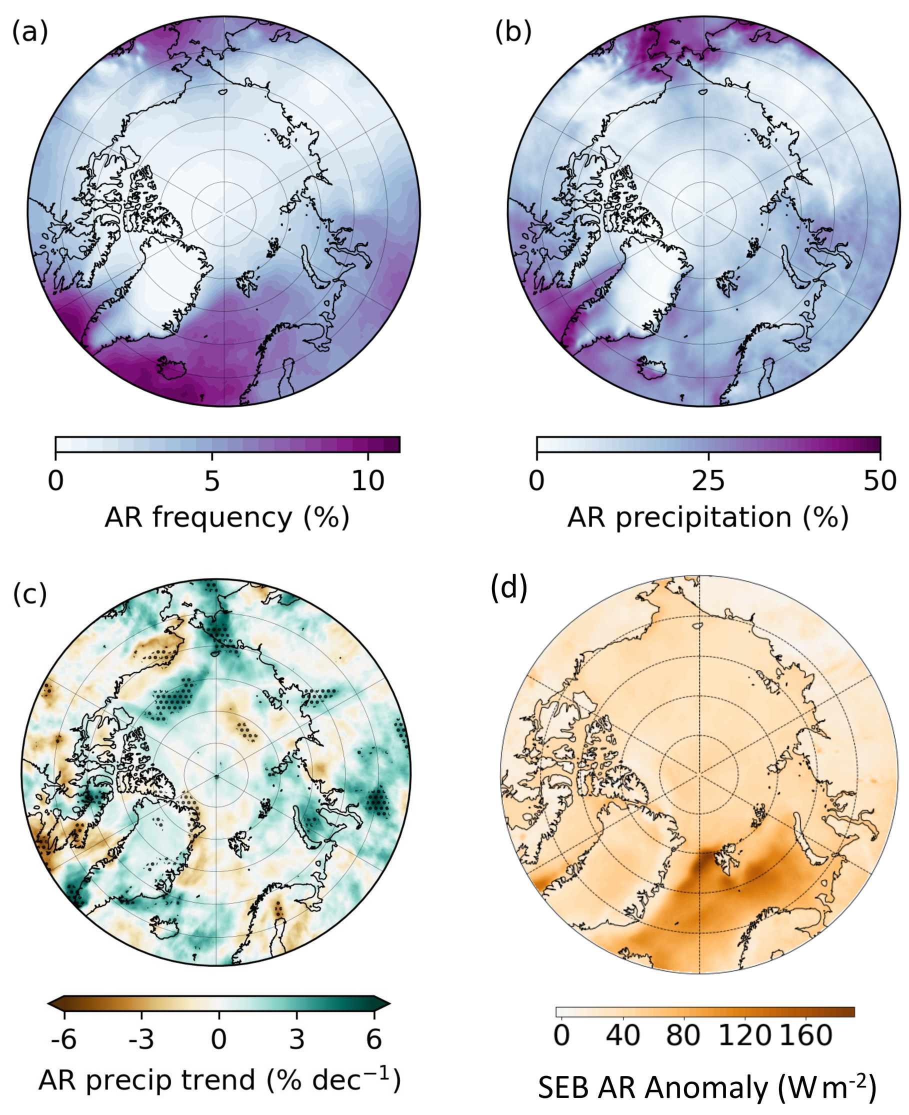

Fig. 5: Climatological analysis of ARs in April, based on hourly ERA5 climatology (1979 - 2021) and AR detection algorithm by Guan-Waliser. (a) AR frequency of occurrence, (b) fraction of ARs responsible for total precipitation, (c) trend of (b). Black dots denote trends that are statistically significant at the 0.1 level, (d) anomaly of SEB related to ARs.

WP3 Moisture intrusions in the future climate

- CMIP6 global coupled climate model simulations for the 21st century, with focus on models representing high and low Arctic amplification
- Changes in frequency of occurrence, pathways, duration, and intensity of ARs
- Impacts on precipitation (rain vs. snowfall) and SEB
- Effects of modified large-scale atmospheric circulation patterns, cyclones and retreating sea-ice cover

4. Legacy & major expected results

Project legacy

- Synergetic methods for quantitative snowfall assessment
- Model-derived AR data base for evaluating future Arctic climate projections

Major expected results within phase III

- Improved air mass transformation understanding
- Spatiotemporal variations of Arctic ARs and their surface impacts
- Future changes in ARs and their impacts incl. uncertainty estimates

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