# Variability and trends of water vapor in the Arctic

B05

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## 1. Summary

Unique **water vapor (WV)** data sets of ship-based and airborne campaigns + Existing long-term and upcoming satellite and reanalysis data

→ Role of water vapor in Arctic amplification on different temporal and spatial scales

Research questions

**Q1** Can we quantify the relevance of the water vapor feedback on Arctic amplification?

**Q2** Can we explain the strong differences between different water vapor products (reanalyses, satellites) using long-term and campaign-based reference measurements?

**Q3** How important is the vertical distribution of water vapor for the downward terrestrial radiation and the resulting impact on Arctic amplification?

Contribution to CCA4 & SQ1, SQ2 and SQ3

## Hypothesis

**Improved observations of spatio-temporal water vapor variability help to quantify the role of water vapor for Arctic amplification.**

## 2. Achievements phase II

### Campaign activities

Contributing to unique observational data records of WV in the central Arctic for

MOSAiC
2019-2020
central Arctic

ATWAICE
summer 2022
marginal ice zone

microwave radiometers MiRAC-P (183-340 GHz) & HATPRO (22-58 GHz), radiosondes,...

HALO-$(AC)^3$
Mar-Apr 2022

lidar, microwave radiometers, dropsondes

### Retrieval development and application using **microwave** observations

**Ground-based**:

- New integrated water vapor retrieval using higher (≥183 GHz) frequencies → improved accuracy in dry conditions
- Application & evaluation of retrieved T and WV profiles, liquid water path and integrated water vapor for MOSAiC
- Synergy of MiRAC-P/HATPRO for improved integrated water vapor (IWV) & WV profiles

**Satellite-based**:

- New multi-parameter retrieval (AMSR2) including new microwave forward model with sea ice & snow

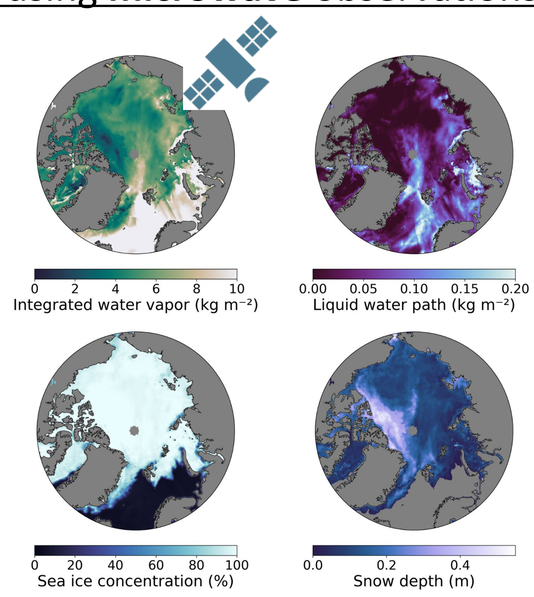
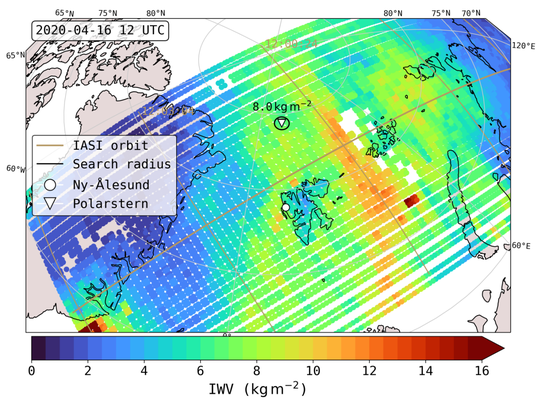



*Fig. 1: Arctic-wide multi-parameter retrieval on 19 April 2020.*



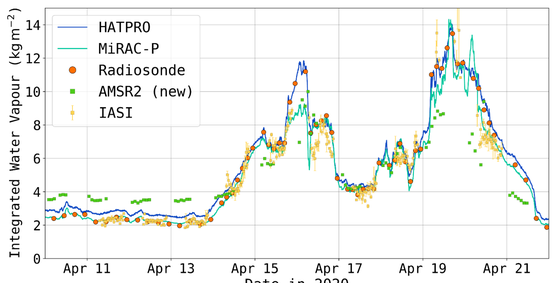




*Fig. 2: IWV from the Infrared Atmospheric Sounding Interferometer (IASI) compared to Polarstern observations and new AMSR2 retrieval during MOSAiC.*

### Evaluation of satellite products, reanalyses and regional models

- Evaluation of IWV from satellite products and reanalyses for ACLOUD campaign
- Analysis of a warm air intrusion in April 2020 during MOSAiC and impact on sea ice concentration
- Analysis of moisture intrusion event

### Impact of water vapor on downward terrestrial radiation

- Assessment of moisture inversions in the Arctic
- Analysis of the sensitivity of downward terrestrial radiation to changes in integrated water vapor and its representation in reanalyses (E04)

## 3. Research plan phase III

### WP1 Water vapor in the central Arctic and its changes

**Ground-based**: synthesis of observed and modeled water vapor products

- MWR **reference water vapor products** for campaigns and Ny-Ålesund (E02)
- Support WV retrieval synergy (new G band radar; COMPEX/IOP4H2O campaigns)
- Impact of water vapor variability on atmospheric column (E02, E04)
- Evaluation of limited area models, atmospheric reanalyses and satellite products

**Satellite-based**: long-term water vapor changes

satellite retrieval phase I (AMSU-B/MHS/AMSR) + satellite retrieval phase II (multi-parameter, AMSR-E/2)

→ Application to whole available satellite time series (2002 - today)
Spatial and long-term variability of WV and trends
Intercomparison of products (incl. external data sets, e.g., IASI, MIRS)
Comparison to atmospheric reanalysis (ERA5)
Local vs. remote moistening (E06)

→ uncertainty estimates

### WP2 Vertical water vapor structure and terrestrial radiative effects

- Impact of water vapor on downward terrestrial radiation (DTR)

IWV, WV profile & inversions (MOSAiC, supersites, radiosondes)

Radiation obs. + Radiative transfer model → Impact on DTR ↔ DTR-IWV sensitivity in ERA5 (with E04)

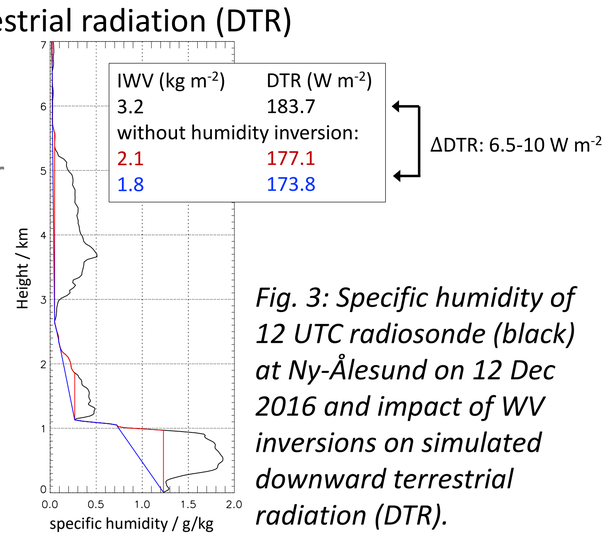



*Fig. 3: Specific humidity of 12 UTC radiosonde (black) at Ny-Ålesund on 12 Dec 2016 and impact of WV inversions on simulated downward terrestrial radiation (DTR).*

- Small-scale variability of vertical WV structure
  - Airborne HALO-$(AC)^3$ ocean-sea ice transects & high-resolution modeling
  - Ship-based ATWAICE ocean-sea ice transects

### WP3 Next-generation satellite WV observations in the Arctic

- Adaptation of current retrievals to new satellites:
  Inclusion of additional channels (165.5 GHz, 183.3±3/±7 GHz) of AMSR3 (2025)
- Assessment of WV products from new satellite capabilities:
  AMSR3, IASI-NG (MetOp-SG A, Q1 2025), MW Imager & Ice Cloud Imager (MetOp-SG B; Q4 2025), Arctic Weather Satellite/EPS-Sterna (2025, 2029)

## 4. Legacy & Major expected results

### Project Legacy

- Improved retrieval methods beneficial for future satellite missions and ground-based observations
- $(AC)^3$ data sets will lead to new long-term WV climate data records for the Arctic

### Major expected results within phase III

- Homogeneous long-term satellite and ground-based water vapor data sets
- Better understanding of spatial and temporal water vapor variability and impact on atmospheric column, in particular downward terrestrial radiation
- Better estimates of water vapor trends and their uncertainties

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