Variability and trends of water vapor in the Arctic

B05

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MOTIVATION

Water vapor in the Arctic

- Crucial greenhouse gas contributing to Arctic Amplification: **Water vapor feedback**
- Vertical structure linked to other mechanisms like lapse-rate feedback → **CCA1**
- Monitoring water vapor in the Arctic over sea ice:
  - Satellite products: Can strongly differ up to 30 % [1]
  - Reanalyses: Trend patterns agree, regional trend magnitudes disagree [2]

➢Better observational data sets and time series with uncertainties needed

HYPOTHESIS

The consideration of temporal and regional variability of water vapor is necessary to establish the role of water vapor for Arctic amplification.

WATER VAPOR FROM SPACE

Satellite Retrieval: Microwave radiometry

- Retrieval: Inverting **forward model** by **optimal estimation method** (OEM) [3]
- Self-consistent retrieval of geophysical parameters + their uncertainties
- Based on dual-polarized satellite brightness temperatures T_B from AMSR-E/2, frequency channels: (6.9, 10.7, 18.7, 23.8, 36.5, 89.0) GHz
- Arctic-wide + daily coverage; since 2002

Comparison MOSAiC campaign

- Temporal variability + warm air intrusions are visible in integrated water vapor (IWV) retrieval (Fig. 5)
- Bias, attributed to treatment of surface emissivity in the model
- T_B at high frequencies affected by snow: Currently not treated in the model

Information Content Analysis

- Information from 23 + 89 GHz channels: Increase for IWV + LWP (liquid water path)
- Improved consideration of these channels in forward model → Improved IWV retrieval

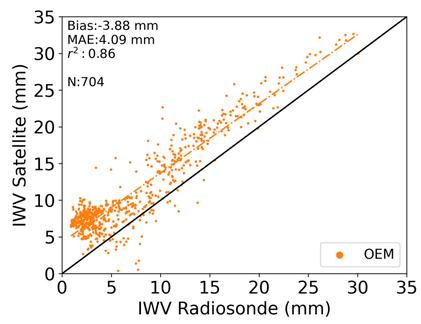

Fig. 1: IWV from radiosondes vs. retrieved values.

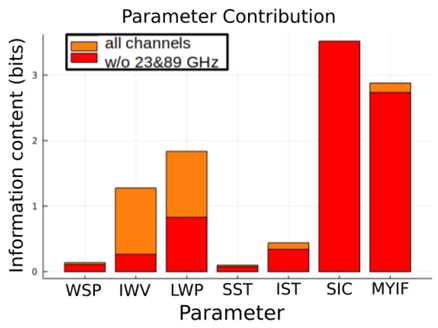

Fig. 2: Information content from each parameter: Wind (WSP), water vapor (TWV), liquid water (LWP), surface temperature (SST + IST), ice concentration (SIC), multiyear ice (MYIF)

WATER VAPOR FROM GROUND

Retrieval overview:

Radiometer	Training data	Retrieval type	Retrieved quantities
HATPRO (22 – 58 GHz)	Ny-Ålesund radiosondes	**Quadratic regression**	IWV, LWP, T & hum. prof.
MiRAC-P (183 – 340 GHz)	ECMWF ERA Interim reanalysis	**Neural Network**	IWV, in progress: LWP, hum. prof.

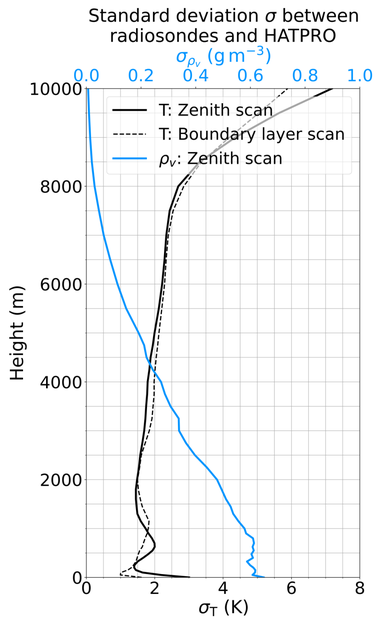

Fig. 3: Temperature and humidity standard deviations profiles over 1417 – 1439 radiosondes during MOSAiC.

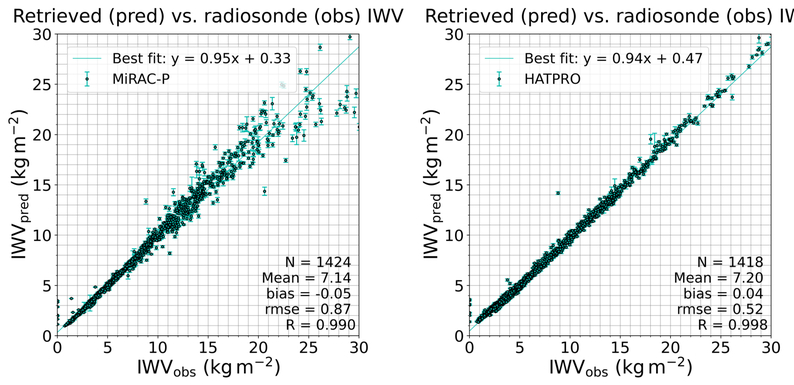

Fig. 4: Radiosonde vs. retrieved IWV (left: MiRAC-P, right: HATPRO).

- Temperature and humidity inversions are challenging for microwave radiometers → Synergy with high-frequency MiRAC-P
- IWV retrieval performance depends on moisture load when considering either MiRAC-P or HATPRO

INTERCOMPARISON OF IWV PRODUCTS: RESULTS FROM THE MOSAiC CAMPAIGN

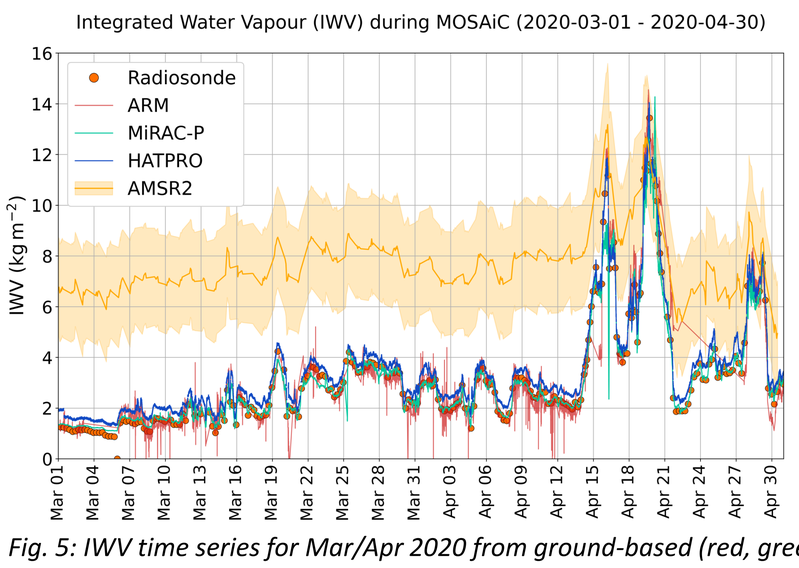

Fig. 5: IWV time series for Mar/Apr 2020 from ground-based (red, green, blue), satellite (yellow) MWRs and from radiosondes (orange dots).

MOSAiC expedition

- Extensive measurements, including radiosondes and three passive microwave radiometers (MWRS): HATPRO, MiRAC-P, and the two-channel ARM MWR
- March: Low temperatures, very dry winter conditions (IWV in range 0.7 – 2.0 mm)
- 16th and 19th April: Two warm air intrusions, high values of IWV (12 – 14 mm)
- Bias for our satellite product compared to all MWR and radiosonde measurements
- Excellent agreement of MWR products to each other with HATPRO (MiRAC-P) performing better in humid (dry) conditions
- IWV variability well captured by all methods → Warm air intrusions and atmospheric rivers are well identified and satellite data still useful for spatial context → **CCA4**

CONCLUSION & OUTLOOK

- Ground-based microwave radiometers are suitable for satellite retrieval evaluation
- Include snow and better surface parametrization in forward model for AMSR2 retrieval → Reduce bias
- Synergetic retrieval combining the two MWRs to improve humidity profile resolution
- Investigate humidity inversion characteristics and capability to resolve them with satellite observations (**WP3**)
- Analyze variability and trend in satellite and ground-based IWV in comparison to atm. reanalyses
- Exploit ground- and satellite-based IWV retrievals to quantify Arctic wide water vapor feedback
- Additional data from the upcoming WALSEMA and HALO-$(AC)^3$ campaign will help to evaluate water vapor retrievals in the marginal sea ice zone and during warm air intrusions and cold air outbreaks

REFERENCES

- [1] S. Crewell et al., 2021. Atmos. Meas. Tech.14, no. 7, 4829–4856, doi:10.5194/amt-14-4829-2021
- [2] Rinke et al., 2019. J. Clim., 32, 6096-6116, doi:10.1175/JCLI-D-19-0092.1
- [3] Scarlat et al., 2017. IEEE J-STARS, 10

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