Diagnosing moisture sources, transport and transformation with water vapor isotopes from satellites and in atmospheric modeling

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E06

1. Summary

Research questions

Q1 How well can water vapor isotope signals retrieved from satellite be linked to different **moisture processes** and **source regions** and can they capture **transport** events?

Q2 How well does the **isotope-enhanced ICON model** simulate water isotope patterns in the Arctic, and the transformation mechanisms during transport events, and can the model be improved?

Q3 What are **changing mechanisms of meridional advective heating** for each season, and how does this interact with past and future Arctic amplification?

Main contribution to **SQ2** and **CCA4**

2. Preliminary work

Satellite Retrievals of Water Isotopes

- Hydrological processes such as evaporation and condensation are mass-dependent
- Measurements of the isotopic composition of atmospheric water vapor provide constraints on water transport, mixing, phase changes
- Developed total column retrieval of δD $(= \frac{HDO/H2O}{R_{reference}} - 1) \times 1000)$ in water vapor for TROPOMI satellite (ESA Sentinel-5p+Innovation)
- Generated and evaluated global, multi-year dataset.
- Value of TROPOMI water isotope data has been demonstrated for Tropical regions,
- Benefits of synergistic use with upper-troposphere data from infrared IASI satellite (M. Schneider, KIT)

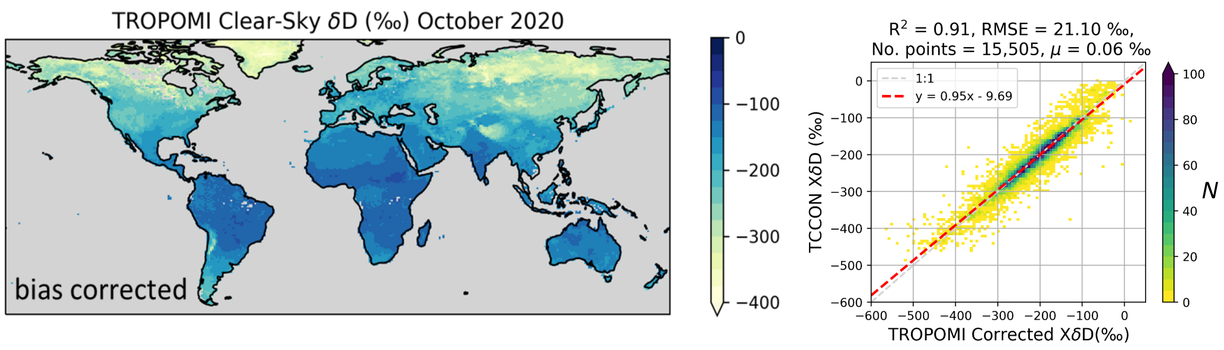

Fig. 1: TROPOMI δD retrieval over land for Oct. 2020 (left) and global validation against ground-based TCCON network (right)

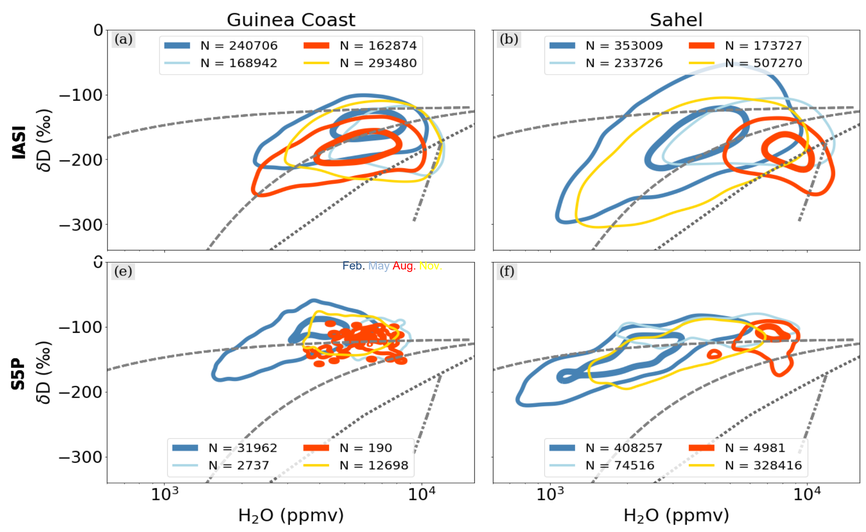

Fig. 2: TROPOMI (S5P) and IASI {H_2O, δD} pair data over Guinea coast (left) and Sahel (right) for 4 different months compared to theoretical curves for Rayleigh condensation, mixing and Super-Rayleigh processes

ICON atmosphere modeling

ICON model at km resolution

- Isotope enhancement in collaboration with Stephan Pfahl/FU Berlin and Roland Ruhnke (KIT Karlsruhe)
- Team in Leipzig experienced in evaluating clouds and precipitation in the ICON model

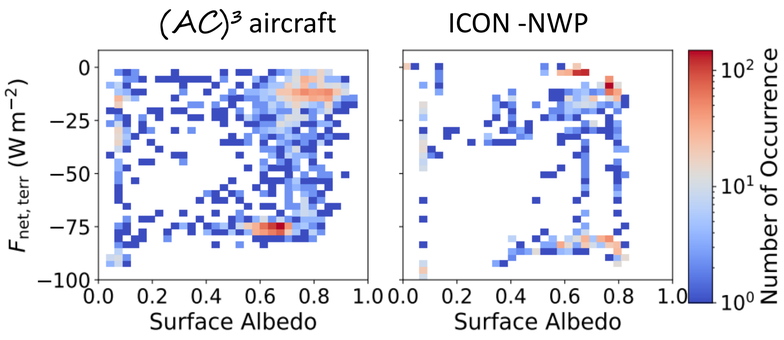

Fig. 3: Example for process-oriented evaluation

Hypothesis

Satellite retrievals of water vapor isotopes over the Arctic provide diagnostics on moisture sources, transport and transformation and allow constraining simulations of changing meridional transport

3. Research plan phase III

WP1 Water isotope satellite retrievals and validation

- Expand and advance existing TROPOMI water isotope retrieval towards Arctic to improve data quality and increase coverage (retrieval over clouds and sea ice)
- Evaluation against available ground-based column data from Ny-Ålesund and four additional sites (with E02)

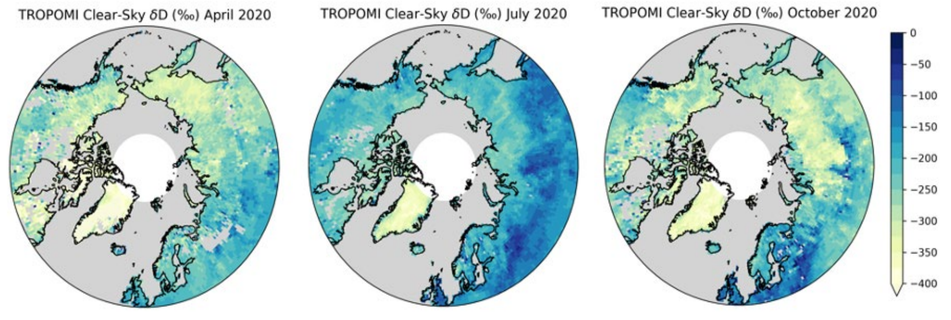

Fig. 4: TROPOMI δD over high latitudes for April, July and Oct. 2020. To increase coverage, retrievals over ice and clouds will be investigated.

WP2 Analysis and interpretation of satellite water isotope data

- Characterize observed spatial and temporal variabilities in from TROPOMI (land/sea-ice) and IASI (land and ocean) and identify signals of warm air intrusions in cloud-free observations(collaboration with E04)
- Interpretation using moisture source diagnostic (LAGRANTO) to investigate physical processes along transport paths and origins of moisture (with Mercator Fellow H. Sodemann)

WP3 Isotope-enhanced ICON modeling and evaluation with satellites

- Setup isotope-enhanced kilometer-resolution ICON model in the numerical-weather-prediction setting (ICON-NWP) in collaboration with FU Berlin and KIT
- Case studies of moisture intrusion, quantify role of midlatitude moisture sources vs. transformation during transportation (with E04).
- Sensitivity studies of model parameterization and model resolution evaluation

WP4 Assess processes for present-day, pre-climate change and future

- Compile statistics of meridional moisture transport and for intense transport cases, associated hydrological processes in CMIP6 models for 1950s | Satellite period | late 21st Century.
- Assess overall transport vs. intense transport events
- Evaluate model skill across GCM ensemble for cases with satellite analysis and isotope-enhanced ICON
- Aim to use relationships as emergent constraint

4. Legacy & Major expected results

Project Legacy

- We expect continued support for satellite observations of water isotopes by ESA and EUMETSAT, especially for upcoming Sentinel-5 and IASI-NG that will allow full synergistic retrievals
- Contributions to the isotope-enhanced ICON model will be fed back to the national modeling community

Major expected results within phase III

- Improved, well characterized TROPOMI water vapor isotope dataset for the Arctic
- Improved understanding of isotopic signatures in the Arctic and their relationship to meteorological and dynamic conditions
- Application of isotopic signatures for process-oriented constraint on moisture transport in Arctic amplification

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