

Atmospheric water vapour isotopes in the Arctic at the interface with sea ice and open ocean

'A storytelling of the Arctic water cycle through the lenses of water stable isotopes'

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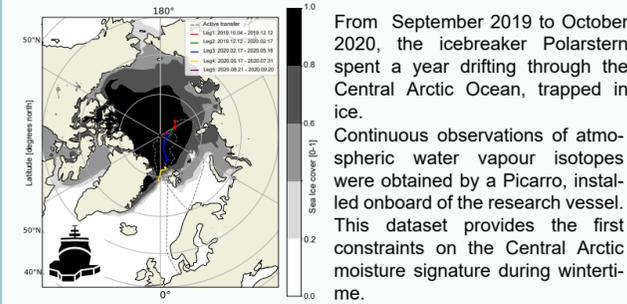
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The Arctic is the key area of global climate change

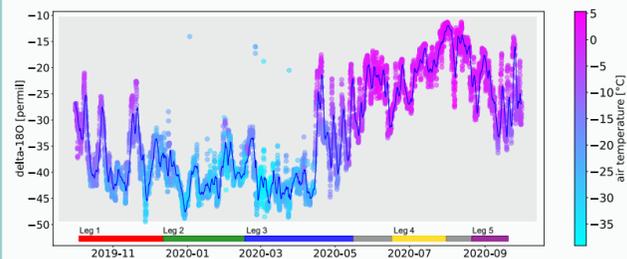
- The Arctic has warming rates exceeding twice the global average and model uncertainties larger than any other part of the planet.
- Recent alterations of the Arctic water cycle include a downtrend of sea ice and the increase in specific humidity and precipitation; the atmospheric moistening is, in turn, contributing to the Arctic amplification of global warming.
- Improvements in observations, process understanding, and modeling capabilities are needed to better quantify the atmospheric role in the Arctic water cycle and its changes.

What we talk about when we talk about MOSAic?

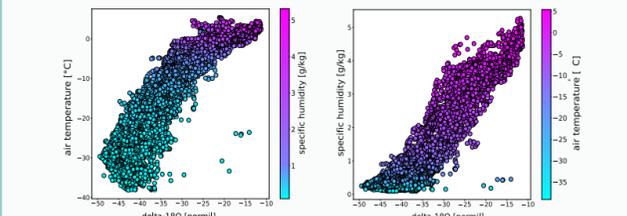


A continuous time series of water vapour isotopes

The calibration of the raw Picarro measurements included (i) correction for humidity-concentration dependence of the isotopic composition; (ii) correction of the instrumental drift; (iii) correction for deviations from the VSMOW-SLAP scale. The calibrated dataset, originally measured at the frequency of 1Hz, is here aggregated to 1h values.



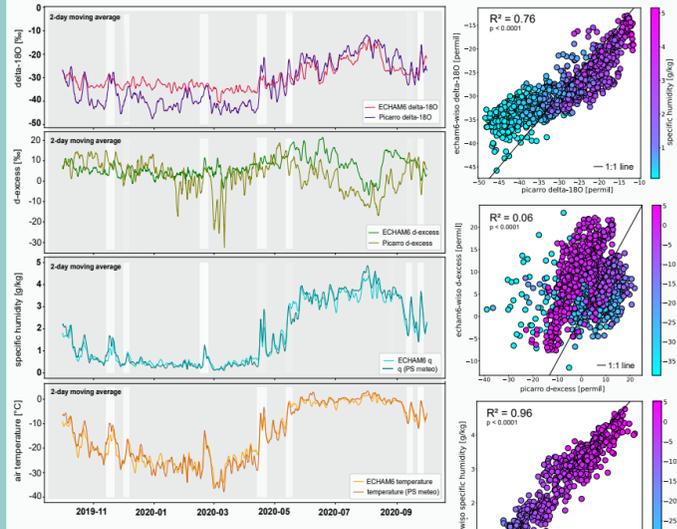
A seasonal cycle is observed, characterized by depleted values in winter and enriched values in summer. Further, positive isotopic excursions at the synoptic time scale are observed throughout the year.



Significant positive relationships were found both with air temperature and specific humidity.

The ECHAM6-wiso simulation

The latest model release ECHAM6-wiso nudged to the ERA5 reanalysis data is used to run a high-resolution isotope simulation (T127L95 truncation, 0.9°x0.9°, 95 vertical layers). Here we present the comparison of measured isotopic variations from MOSAic and corresponding modelling results.



- Excellent agreement for temperature and humidity values, both for seasonal variability and synoptic changes.
- Good agreement in the atmospheric vapour delta-18O, although a seasonal bias is observed: the model overestimates winter values while it underestimates summer values. Relative changes and synoptic-scale excursions are better captured in the moist and warm conditions of spring and summer.
- Poor agreement between measured d-excess values and their analogous modelled values.

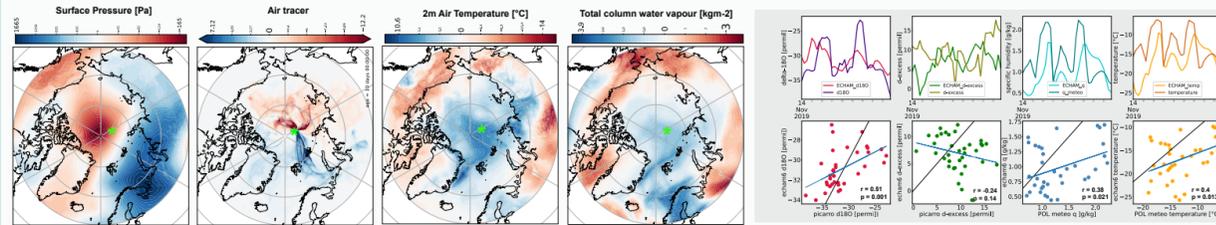
Synoptic events: anomalous warm & moist air intrusions

Anomalous meteorological events during the MOSAic expedition were independently identified and reported in literature (Rinke et al., 2021). These synoptic events consisted in poleward intrusions of humid and warm air masses breaking into the Arctic from lower latitudes. These air intrusions differ by sourcing region, pathways, as well as associated temperatures and humidity levels.

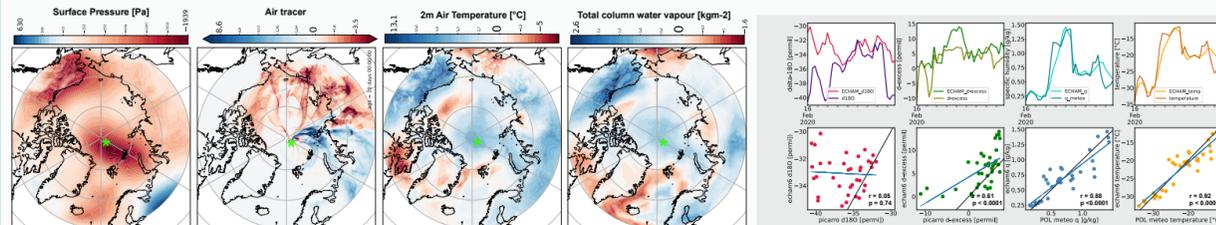
Thus, they represent suitable case studies to:

- investigate how meteorological conditions imprint the isotopic signature of the Arctic.
- assess the performance of a state-of-the-art AGCM to capture ocean-sea ice-atmosphere exchange processes in different seasons and meteorological conditions.

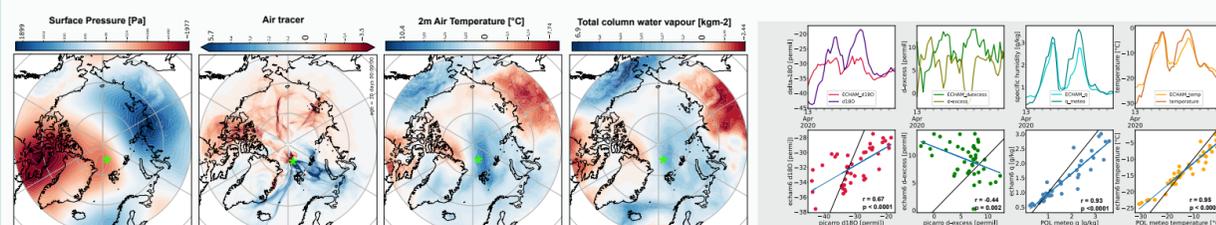
Selected synoptic meteorological events and related isotopic signals



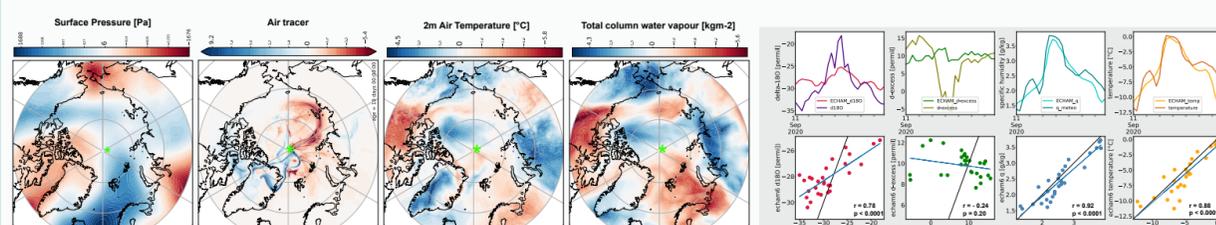
SYN1
Nov 16-20 2019
What happened?
Intrusion of North Atlantic warm and humid air, associated with two cyclonic events passing over the MOSAic track.
To note: moderate model-observation match for delta-18O and meteorological values (T and q)



SYN2
Feb 18-22 2020
What happened?
Short-lived event, intrusion of warm and moist continental air from northwestern Siberia
To note: only event with insignificant correlation for delta-18O, but significant correlation for d-excess.



SYN3
Apr 14-21 2020
What happened?
Southerly warm air advection bringing climatologically (1979-2020) record-breaking high temperatures and moisture.
To note: best retrieval of q and T, apparent negative correlation between modelled and observed d-excess values.



SYN4
Sep 15-17 2020
What happened?
Warm air mass intrusion from northern Greenland associated with moisture and temperature increases above melting point.
To note: magnitude of isotopic excursions strongly underestimated by ECHAM6, despite accurate q and T representation.

Wrap up thoughts

All the independently detected anomalous meteorological events find correspondence in the isotopic records, however..

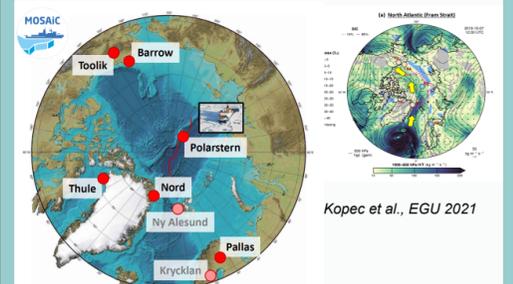
- The magnitude of the isotopic changes simulated by ECHAM6 is lower than the observed excursions: different spatial resolution.
- No apparent relationship between air masses origin and pathway and model-data agreement: no bias related to region-specific processes.
- Overall, poor agreement between modelled and observed d-excess: under(mis-)representation of exchange processes involving kinetic fractionation.

Potential missing processes ?



Beyond Polarstern and MOSAic

The isotopic observations collected during MOSAic will be put in a broader, regional context by comparison with simultaneous, coordinated measurements from a set of coastal stations across the pan Arctic Water Isotope Network (AWIN) coordinated by Jeffrey Welker.



Pairing of the isotopic observations along the trajectories of storm tracks suggests that the sea ice extent is significantly related to the d-excess fingerprint of the atmospheric moisture (Kopec et al., in prep).

Eventually..

An in-depth comparison of the measured isotope variations across this unique Arctic network with corresponding modelling results is expected to improve our understanding of the spatio-temporal variations within the coupled atmosphere-ocean-sea ice system.