

Isotopic composition of water vapour in the Central Arctic during the MOSAIC campaign: local versus distant-moisture sources

Camilla F. Brunello, H. Meyer, M. Mellat, M. Casado, A. Rinke, S. Bucci, M. Dütsch, Martin Werner



The Arctic water cycle is changing rapidly

1 Arctic sea ice is decreasing

Article | [Open Access](#) | Published: 01 April 2022

Unprecedented decline of Arctic sea ice outflow in 2018

Hiroshi Sumata , Laura de Steur, Sebastian Gerland, Dmitry V. Divine & Olga Pavlova

2 Arctic atmosphere is moistening

Editorial Type: [Article](#)

Trends of Vertically Integrated Water Vapor over the Arctic during 1979–2016: Consistent Moistening All Over?

A. Rinke¹, B. Segger¹, S. Crewell², M. Maturilli¹, ... [View More +](#)

Print Publication: 15 Sep 2019

3 Arctic moisture serves as new source of precipitation

Arctic sea-ice loss fuels extreme European snowfall

Hannah Bailey , Alun Hubbard², Eric S. Klein³, Kaisa-Riikka Mustonen¹, Pete D. Akers⁴, Hannu Marttila⁵ and Jeffrey M. Welker ^{1,6}

4 The origin of Arctic moisture is still debated

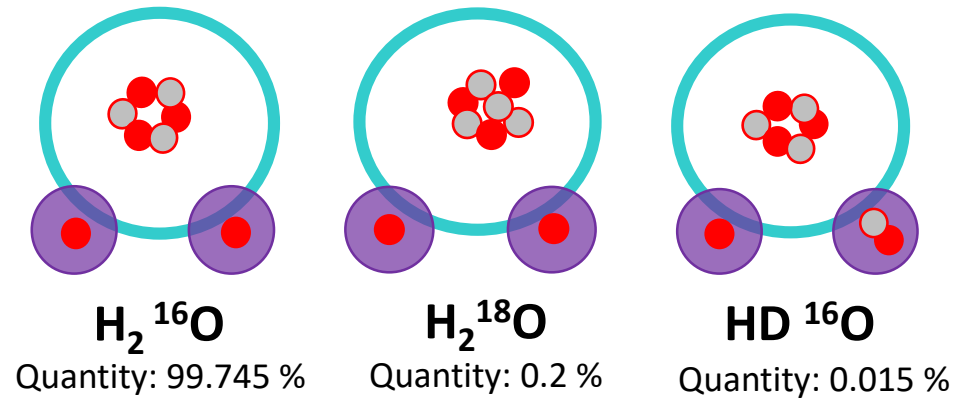
Origin of Arctic water vapor during the ice-growth season

Naoyuki Kurita 

First published: 29 January 2011 | <https://doi.org/10.1029/2010GL046064> | Citations: 87

Water stable isotopes as a tracer of the water cycle

Several **isotopologues of water** exist in the Earth's water cycle

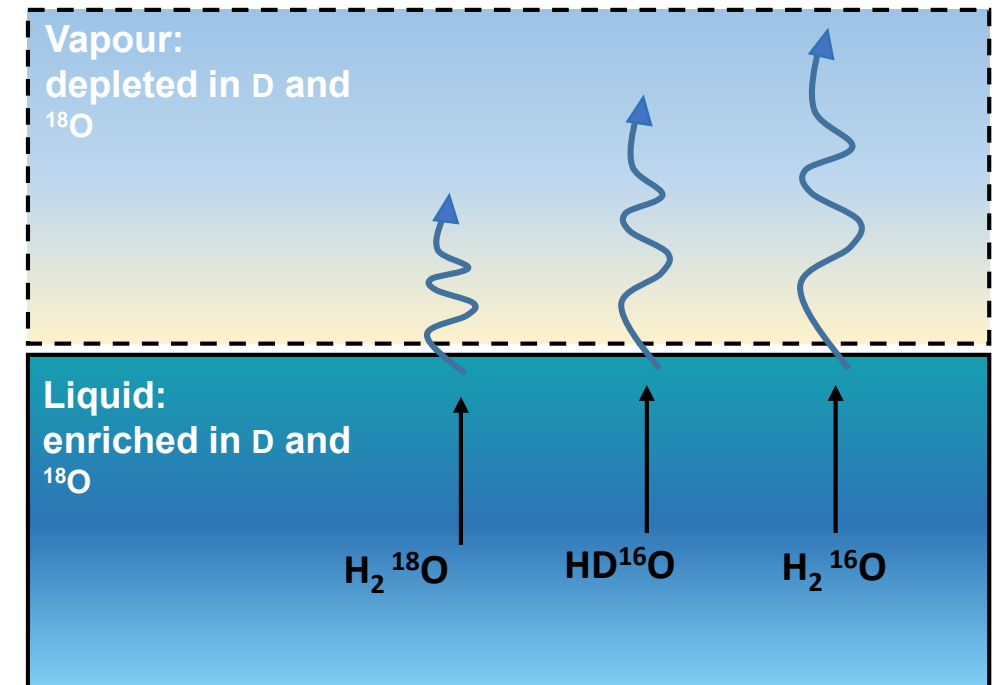


The isotopic composition is expressed as a ratio as a deviation from a standard:

$$\delta^{18}\text{O} = \left(\frac{\left(\frac{^{18}\text{O}}{^{16}\text{O}} \right)_{\text{sample}}}{\left(\frac{^{18}\text{O}}{^{16}\text{O}} \right)_{\text{standard}}} - 1 \right) \times 1000$$

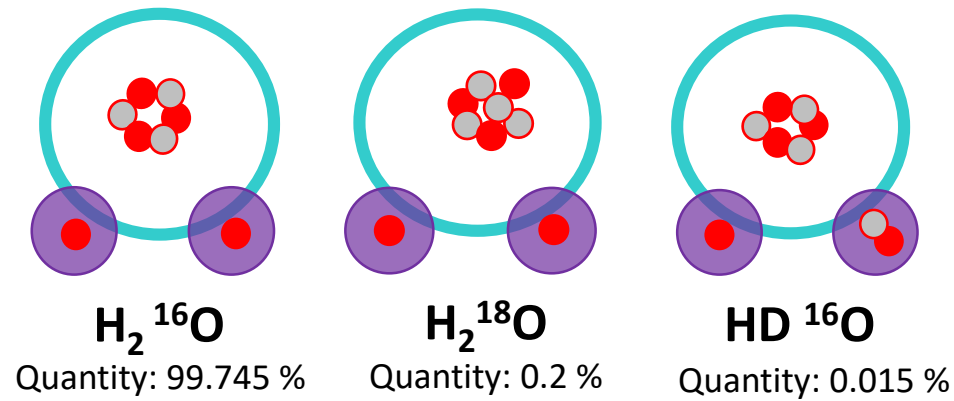
Common standard: Vienna – Standard Mean Ocean Water (V-SMOW)

Fractionation causes an enrichment of light isotopes in the vapour phase, while heavy isotopes stay in the liquid phase



Water stable isotopes as a tracer of the water cycle

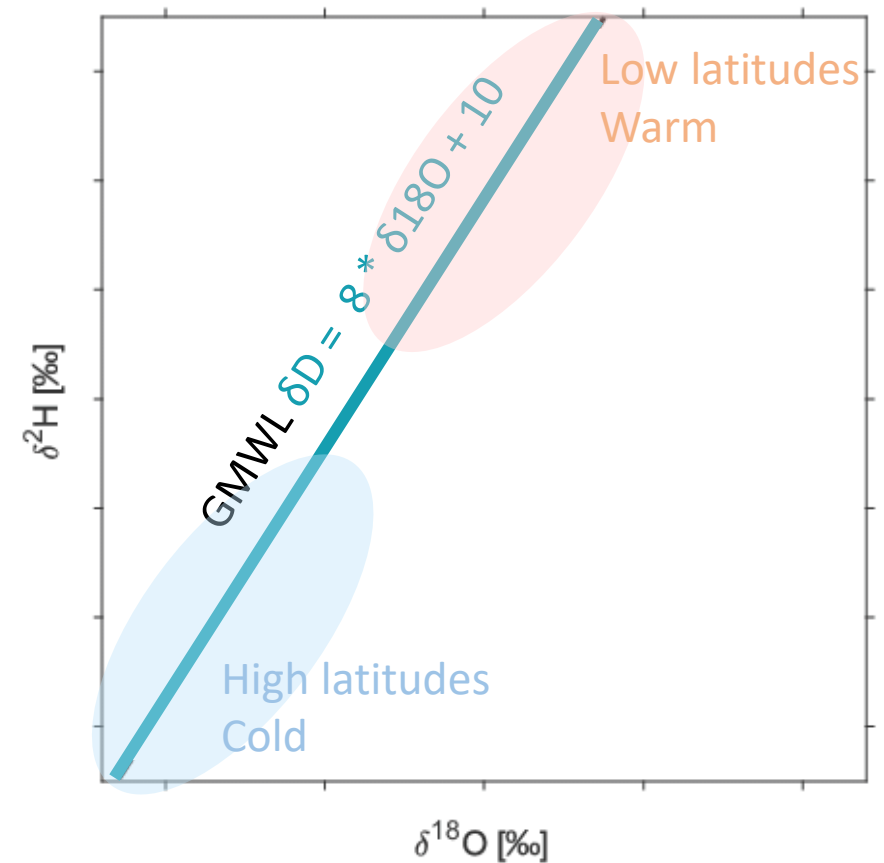
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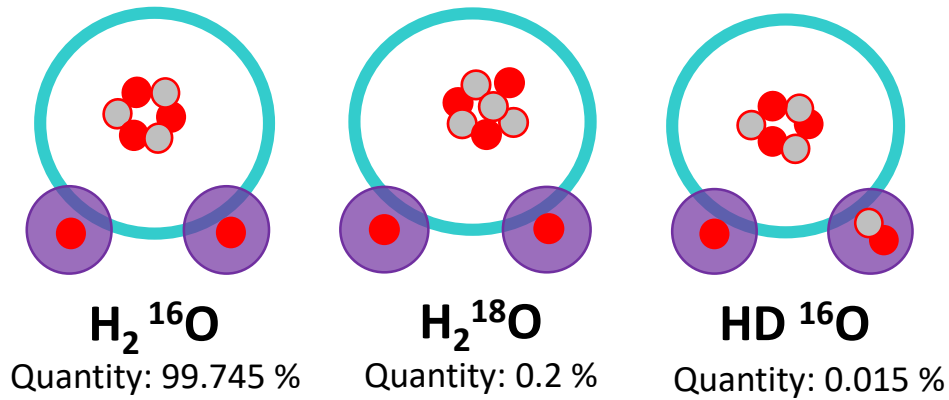
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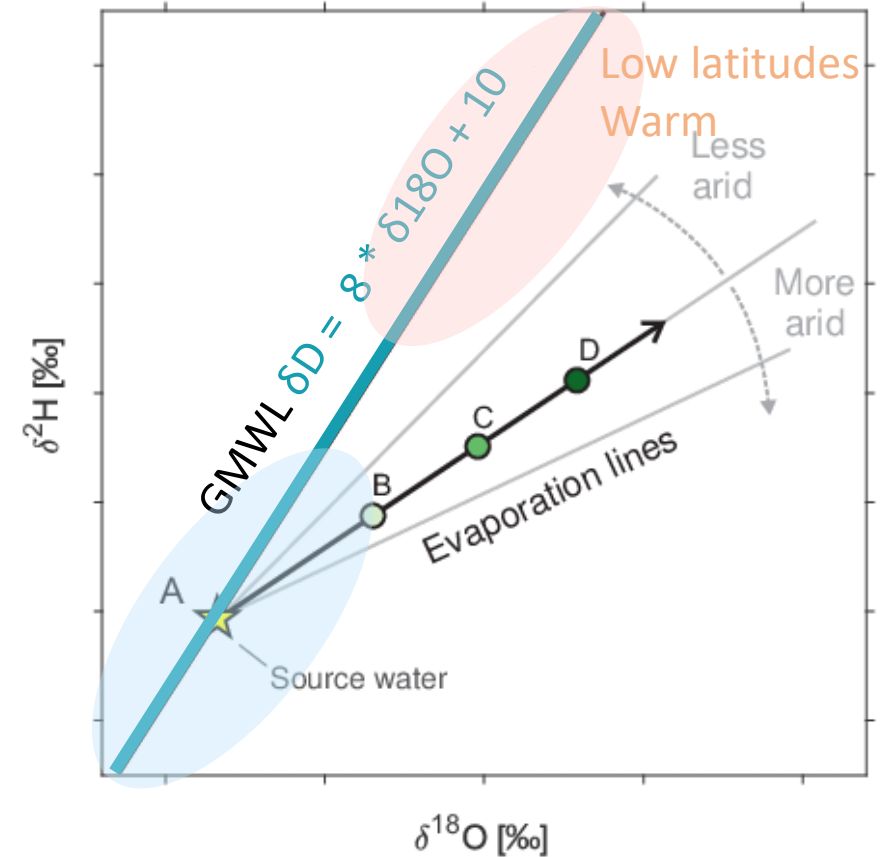


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Deuterium excess = $\delta\text{D} - 8 * \delta^{18}\text{O}$



Changes of water Isotopes in the Arctic Sea ice, Ocean and Atmosphere CiASOM

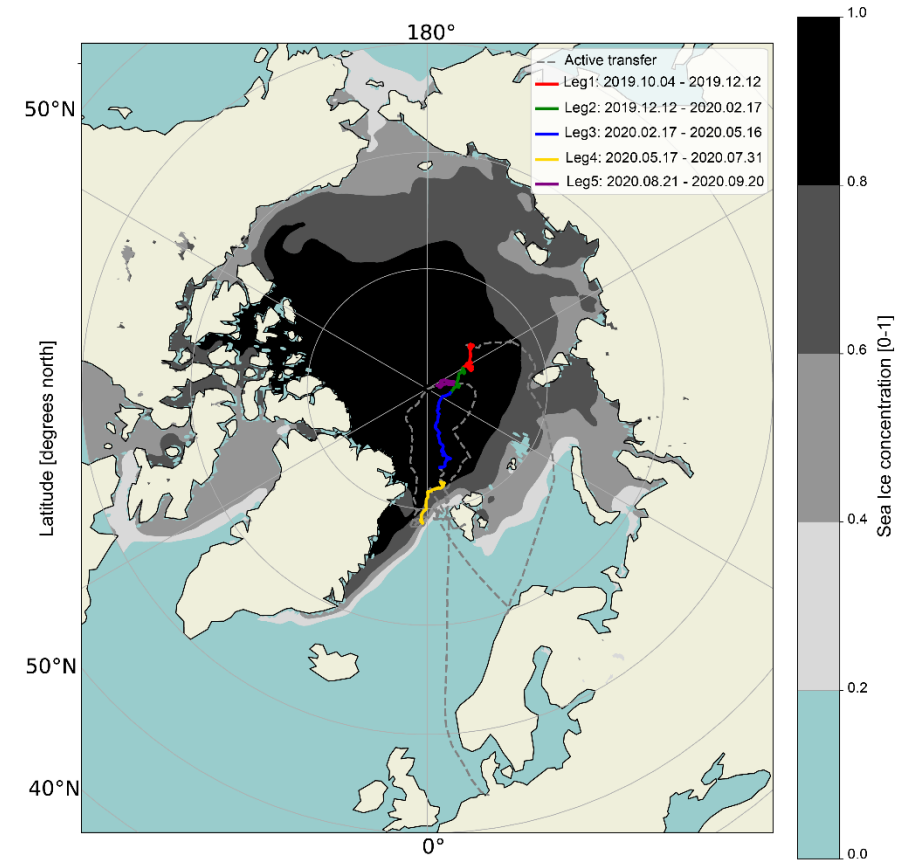
DISCRETE SAMPLING OF
SEA ICE, OCEAN, SNOW,
MELT PONDS

CONTINUOUS MONITORING OF
ATMOSPHERIC VAPOUR
ISOTOPES

REGIONAL NETWORK OF
LAND-BASED
OBSERVATIONS

AWINN, Jeff Welker

ISOTOPE ENHANCED –
ATMOSPHERIC GCM



*Drifting track during the MOSAiC campaign (oct 2019
– sept 2020)*

Changes of water Isotopes in the Arctic Sea ice, Ocean and Atmosphere CiASOM

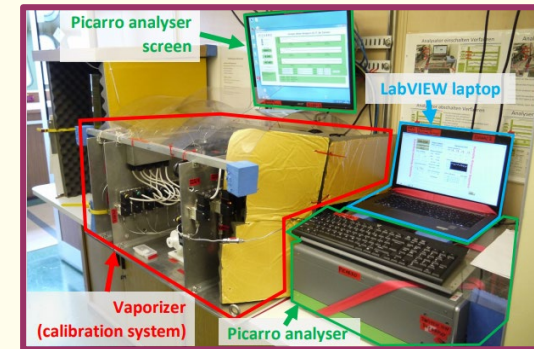
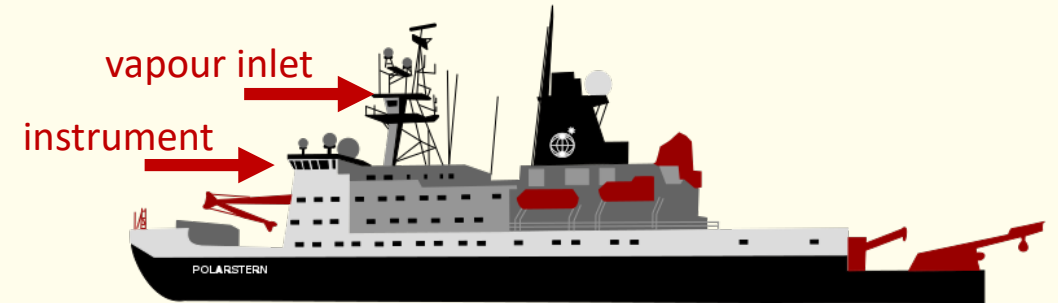
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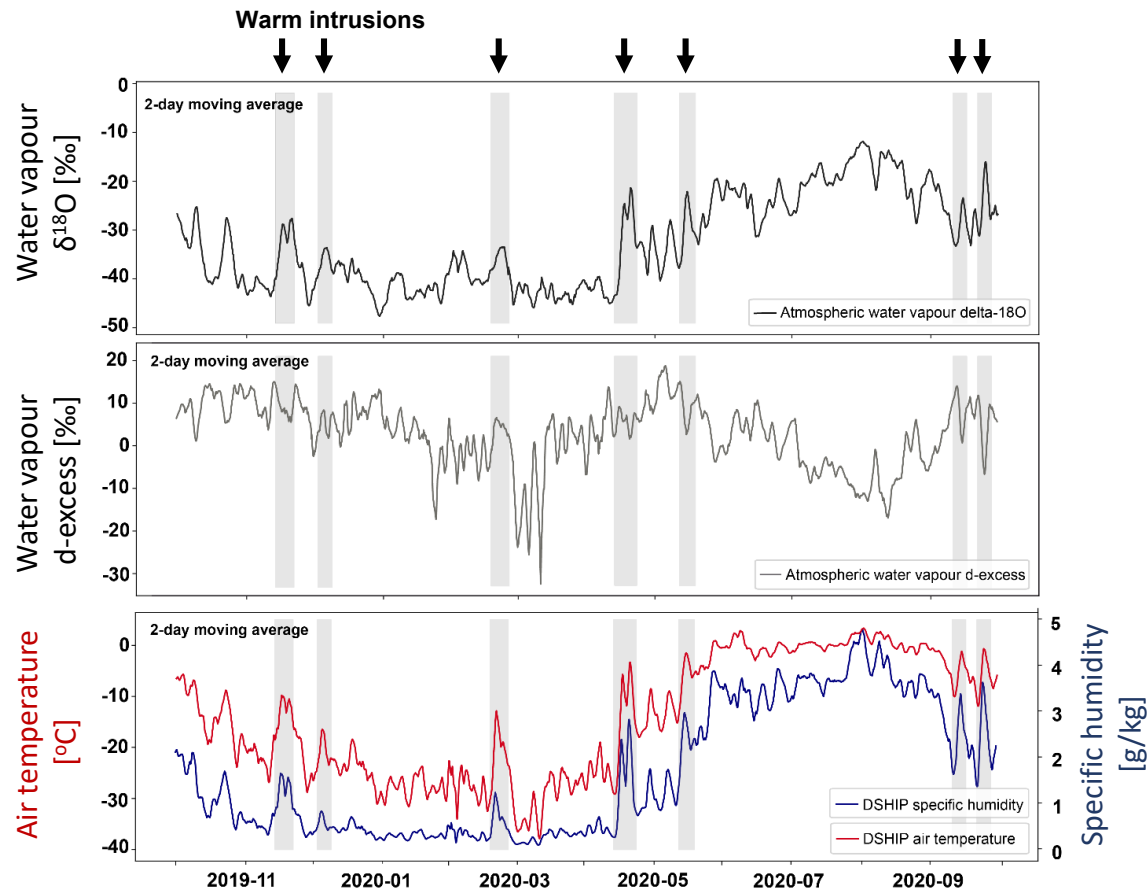
AWINN, Jeff Welker

ISOTOPE ENHANCED –
ATMOSPHERIC GCM

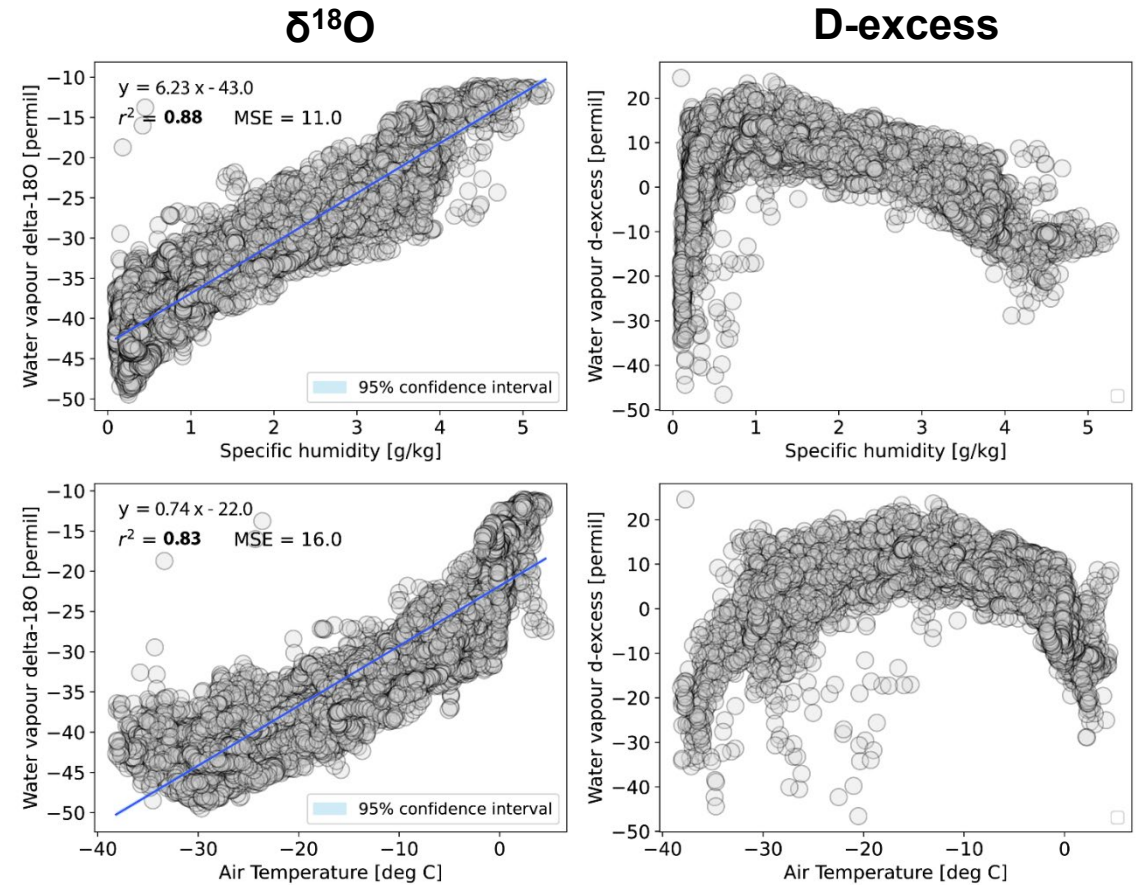


*Laser spectrometer installed on deck A,
in the aerology laboratory.*

Seasonal correlations with local temperature and specific humidity

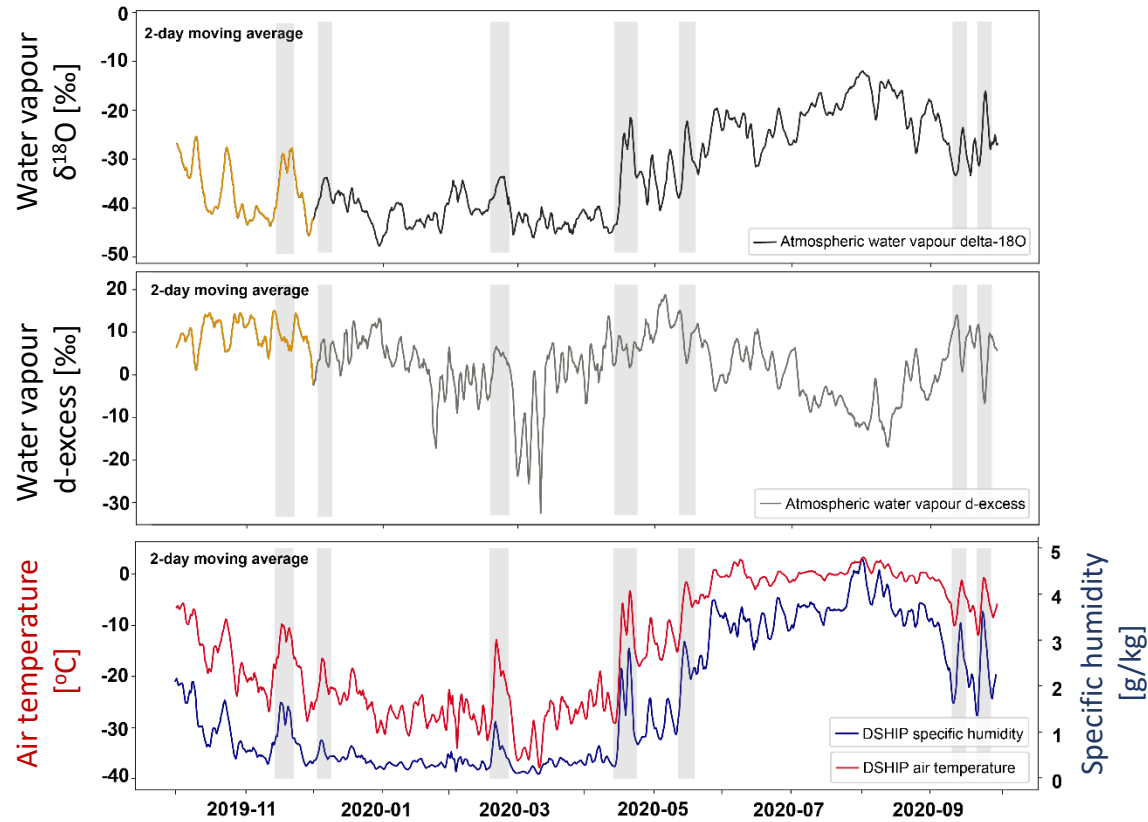


Annual

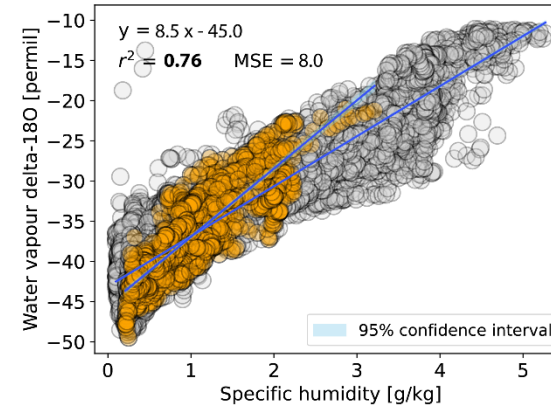


Seasonal correlations with local temperature and specific humidity

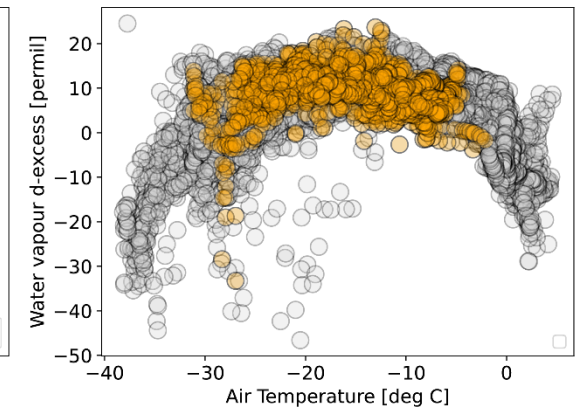
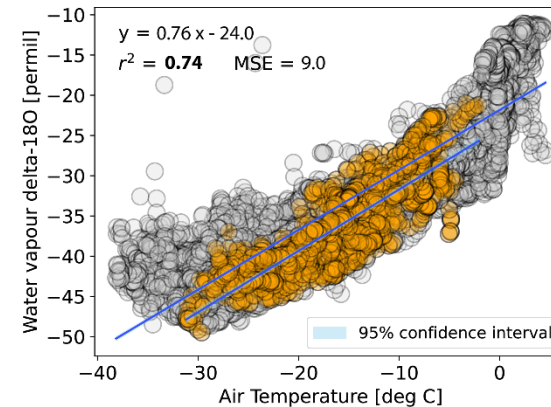
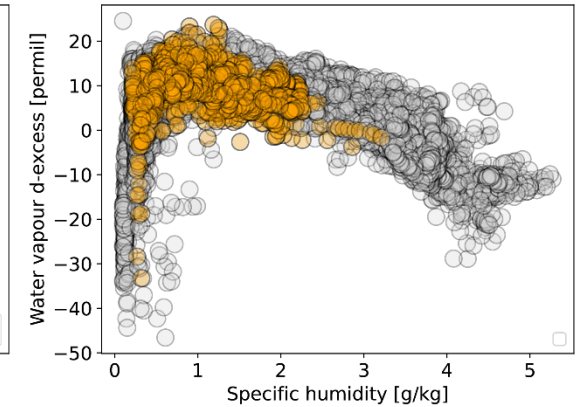
Autumn - ON



$\delta^{18}\text{O}$

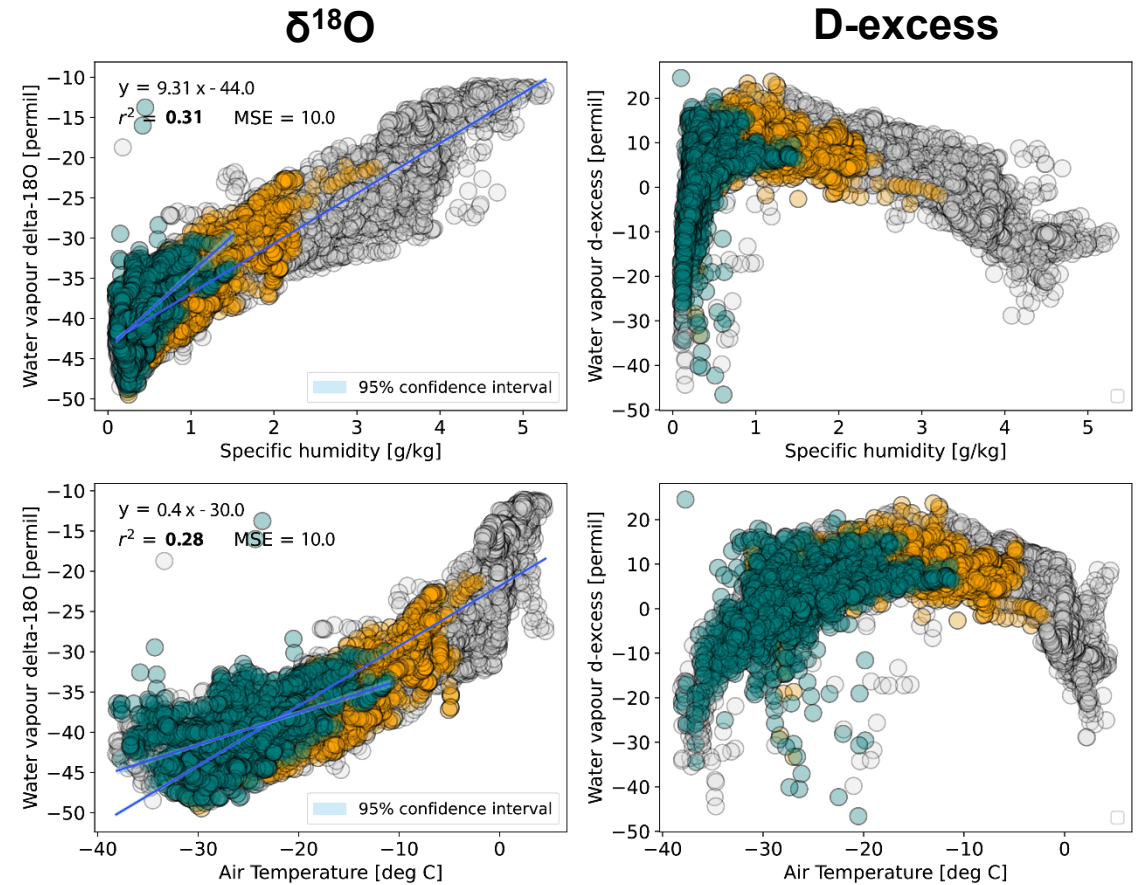
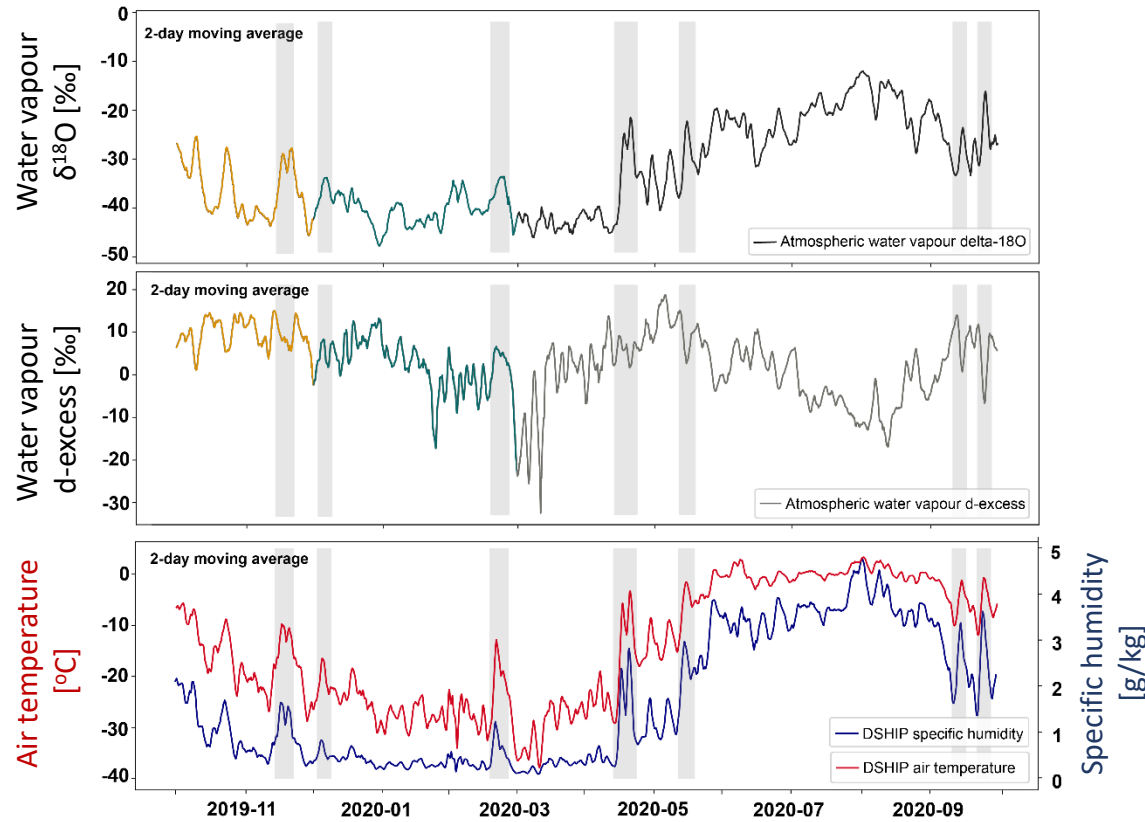


D-excess



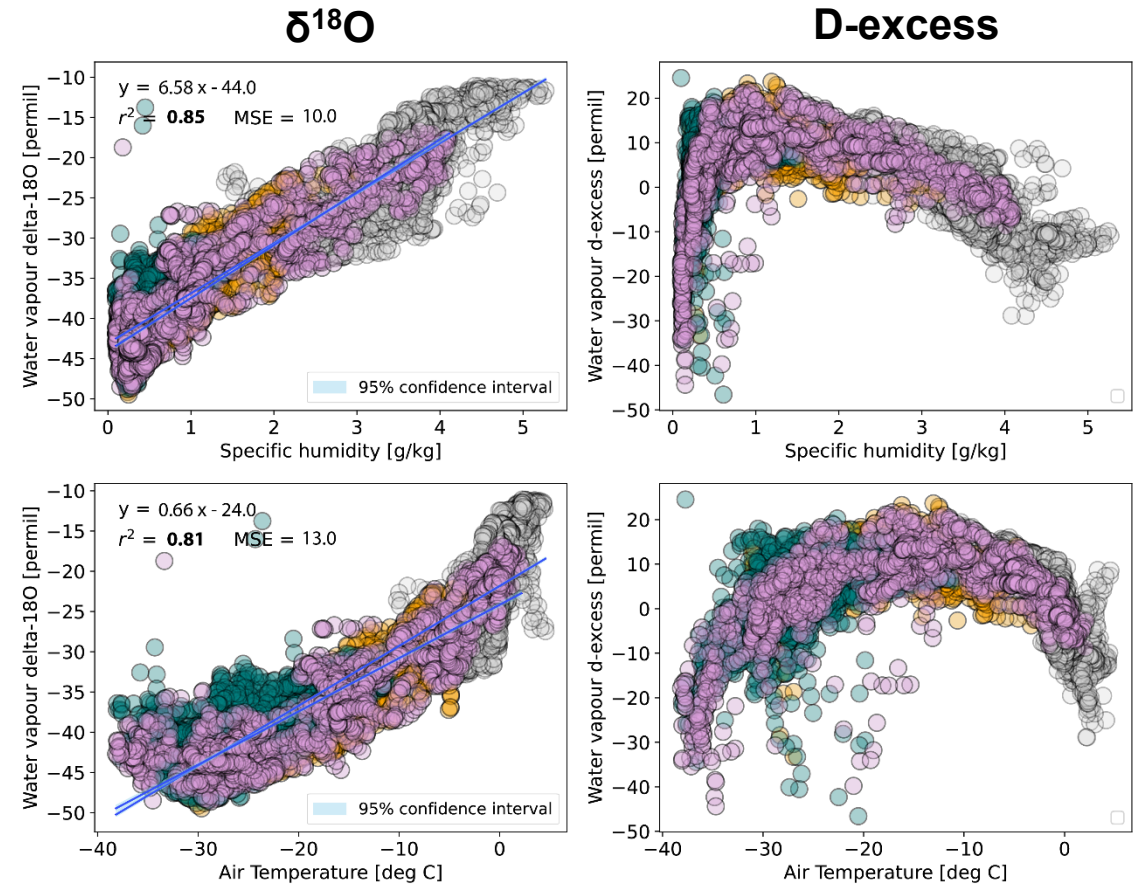
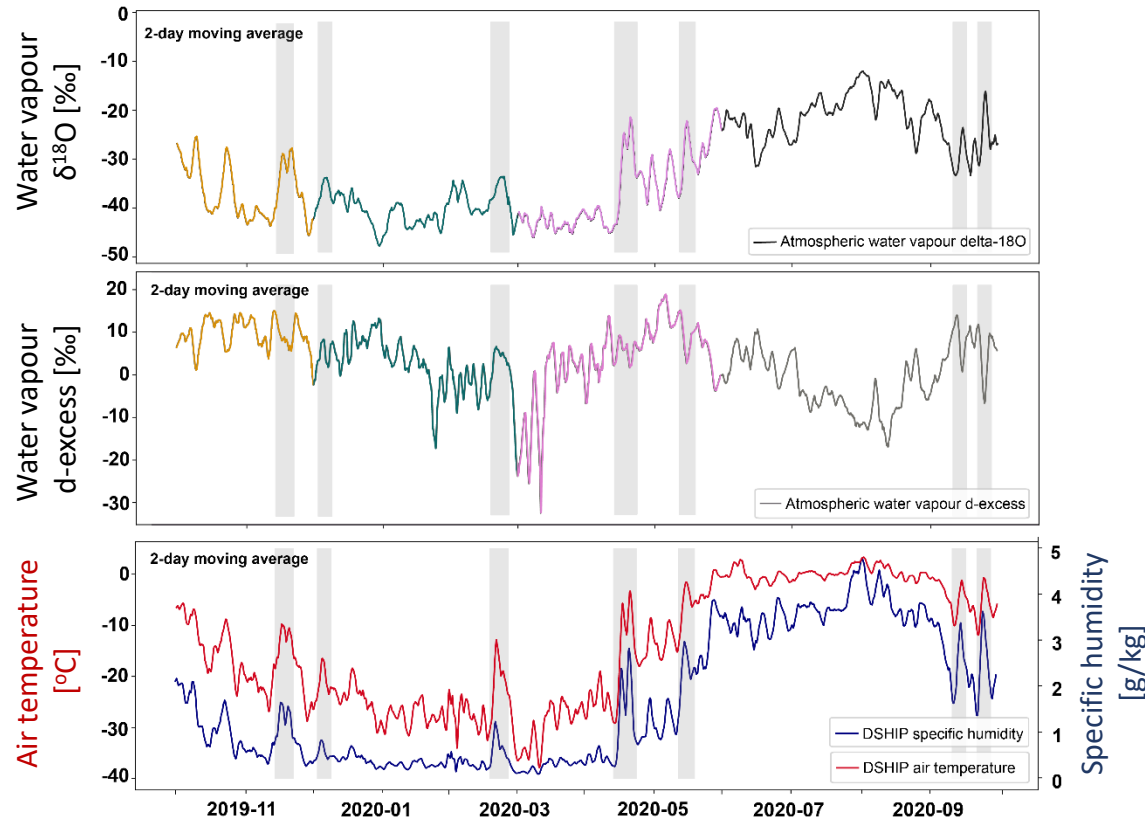
Seasonal correlations with local temperature and specific humidity

Winter - DJF



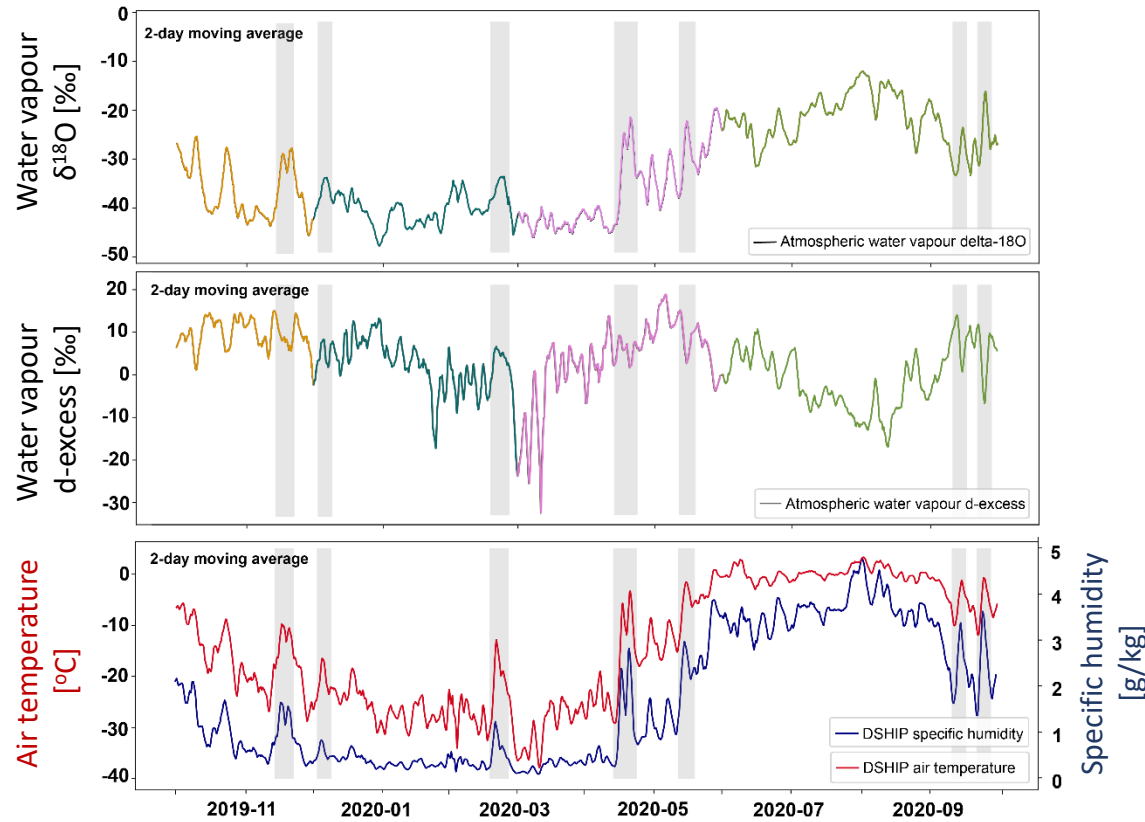
Seasonal correlations with local temperature and specific humidity

Spring - MAM

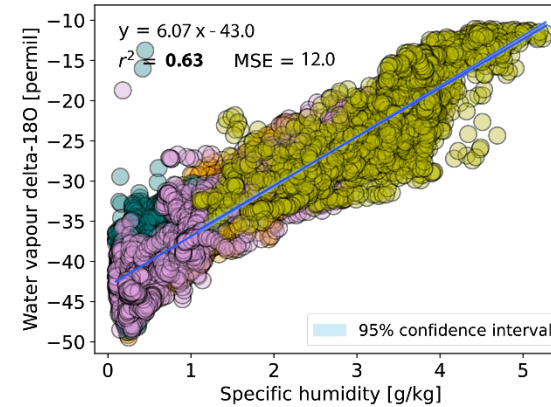


Seasonal correlations with local temperature and specific humidity

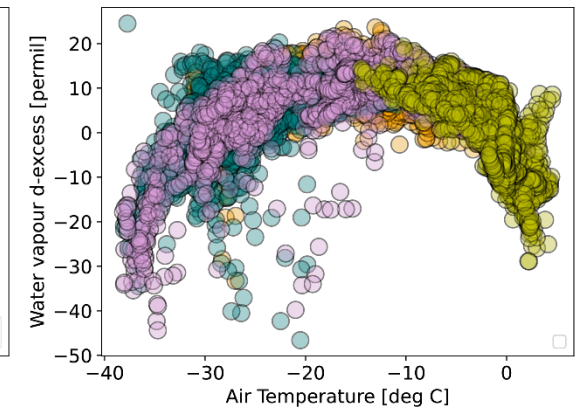
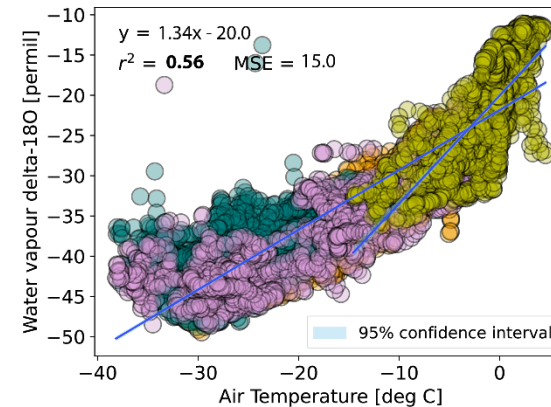
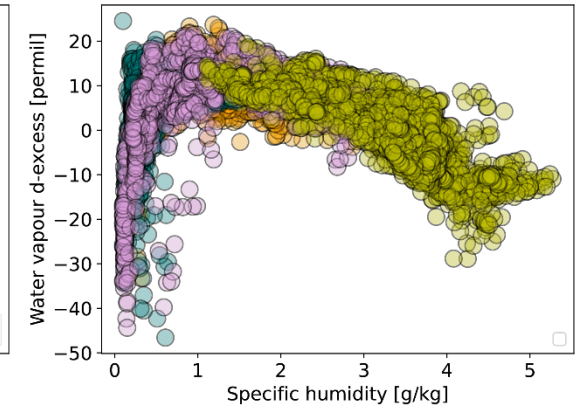
Summer - JJAS



$\delta^{18}\text{O}$

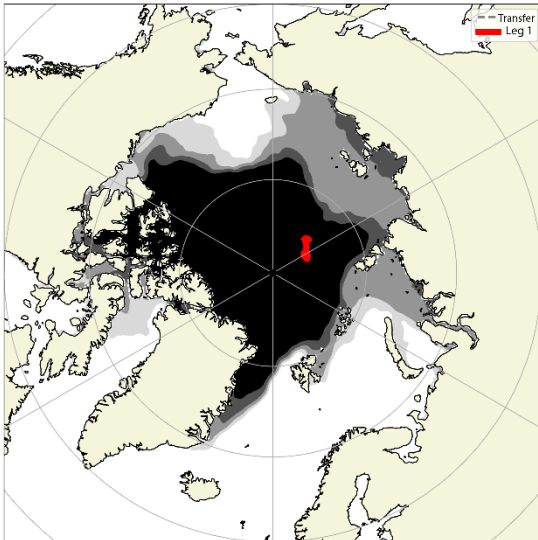


D-excess

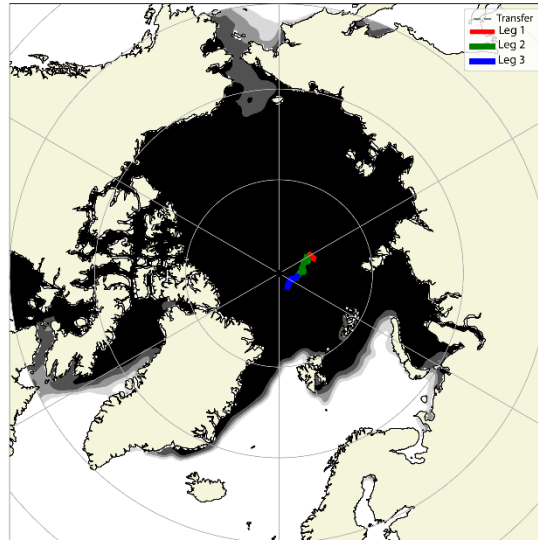


Deuterium excess as a diagnostic for the evaporative sources

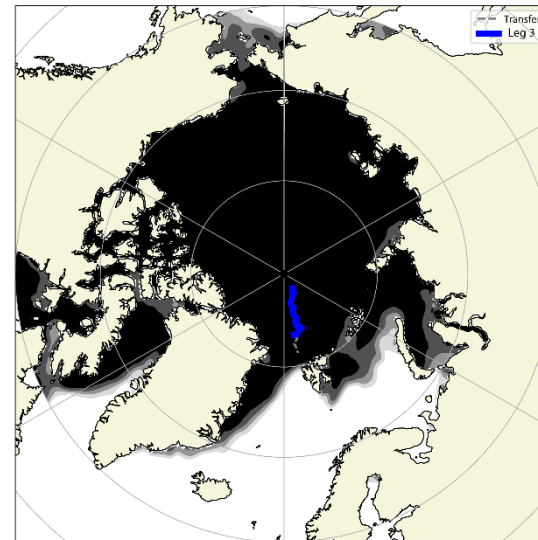
Autumn - ON



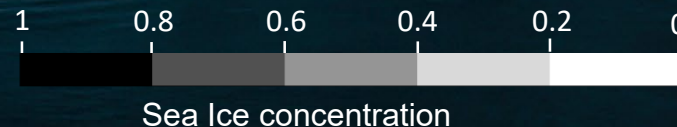
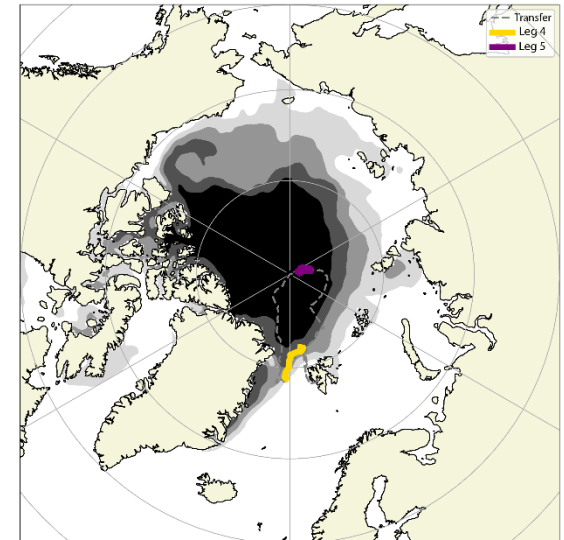
Winter - DJF



Spring - MAM

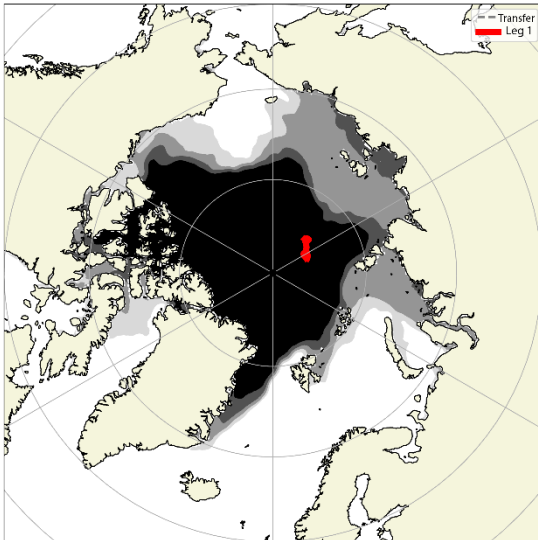


Summer - JJAS



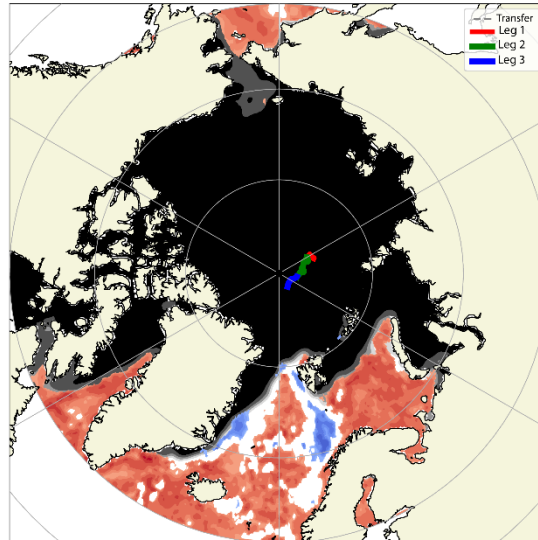
Deuterium excess as a diagnostic for the evaporative sources

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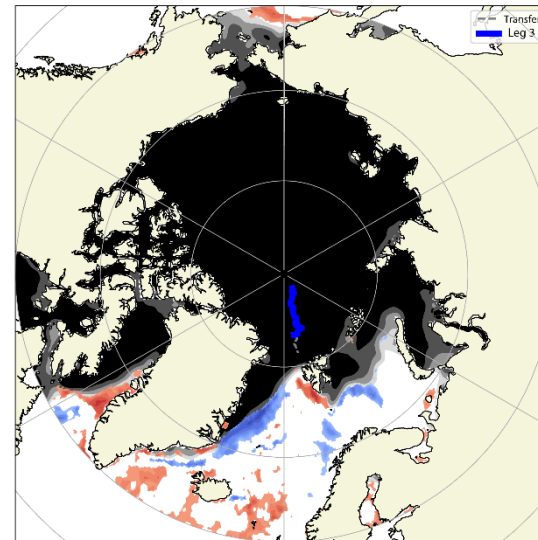
No correlation with SST.
H1: local moisture recycling.

Winter - DJF



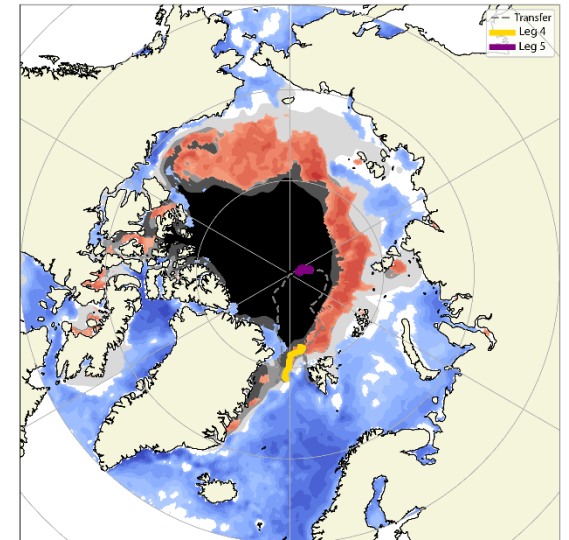
Positive correlation with large-scale SST.
H1: long distance advection.

Spring - MAM

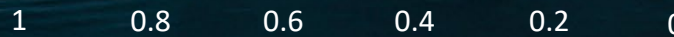


Low, sparse correlation.
H1: in-Arctic recycling and source transition.

Summer - JJAS



Positive correlation with Arctic open ocean.
H1: injection of moisture from the retreating sea ice margin.



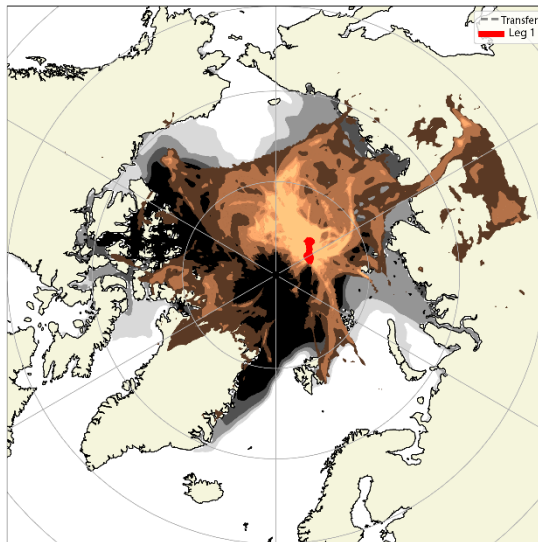
Sea Ice concentration



Correlation coefficient Pearson's r

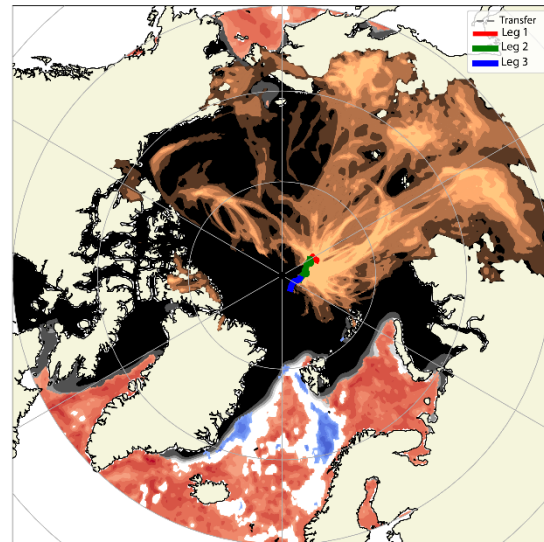
Flexpart backward simulation: residence time

Autumn - ON



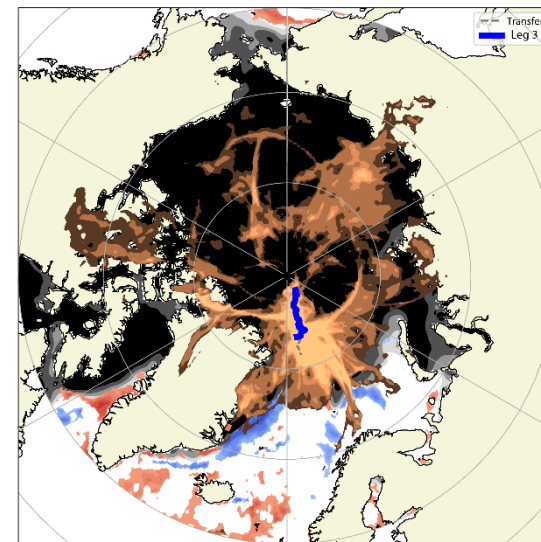
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Local moisture recycling.

Winter - DJF



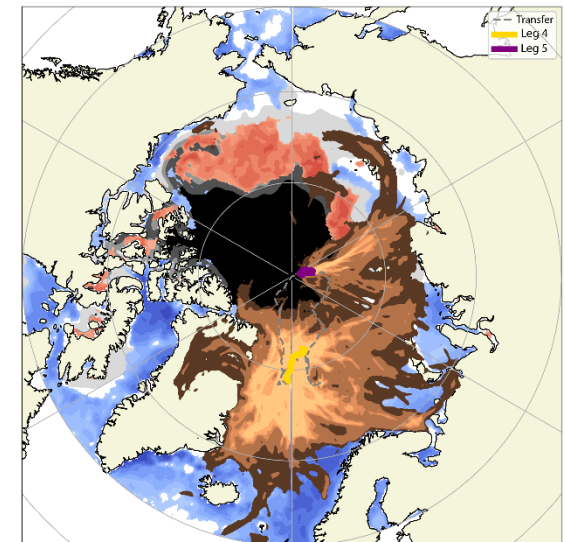
Positive correlation with large-scale SST.
Long distance advection from Siberia.

Spring - MAM

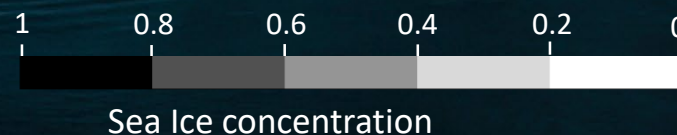
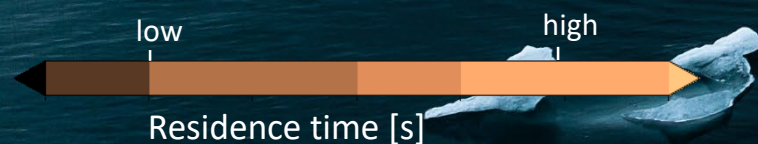


Low, sparse correlation.
In-Arctic recycling and source transition.

Summer - JJAS

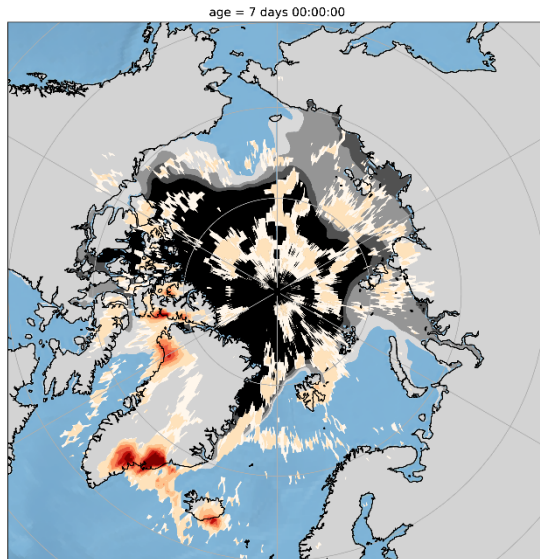


Positive correlation with Arctic open ocean.
Injection of moisture from the retreating sea ice margin.



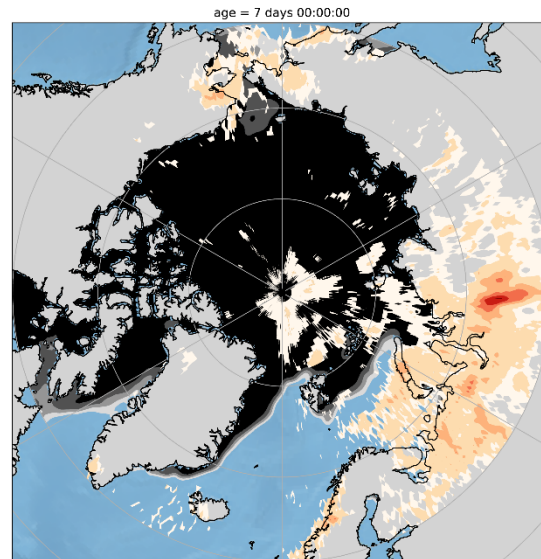
Flexpart backward simulation: moisture uptake

Autumn - ON



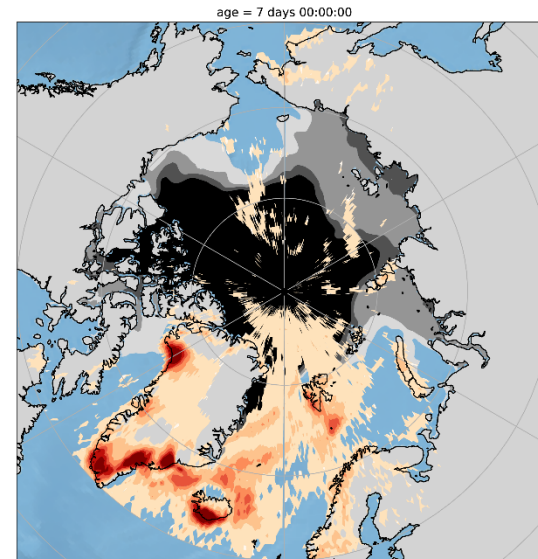
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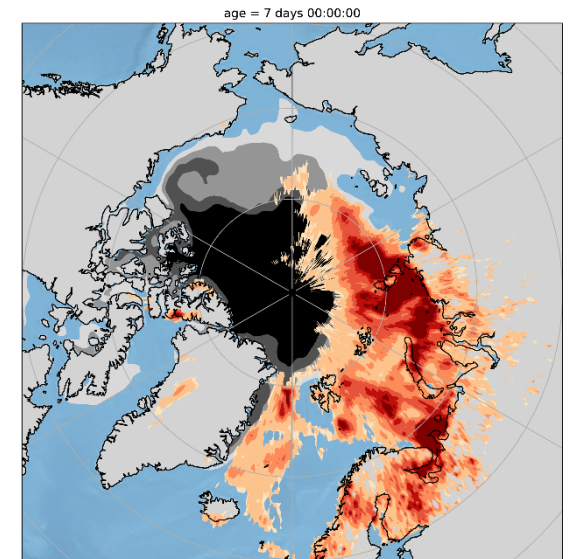
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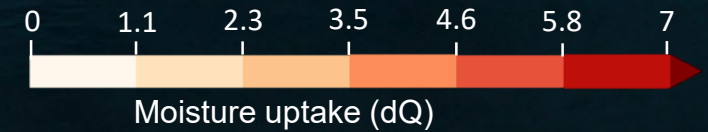
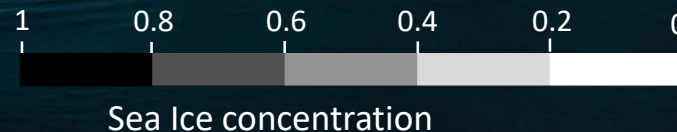


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Conclusions and outlook

DISCRETE SAMPLING OF SEA
ICE, OCEAN, SNOW, MELT
PONDS

CONTINUOUS MONITORING OF
ATMOSPHERIC VAPOUR
ISOTOPES

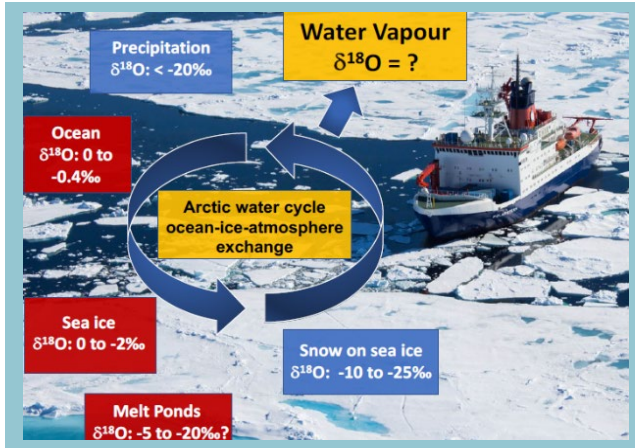
REGIONAL NETWORK OF
LAND-BASED OBSERVATIONS

ISOTOPE ENHANCED –
ATMOSPHERIC GCM

We presented one year of high resolution water vapor isotope measurements from the central Arctic

- **The $\delta^{18}\text{O}$ signal correlates with local air temperature and specific humidity**
- **The d-excess reveals seasonal changes in the moisture sources:**
 - **Autumn:** interaction with in-Arctic hydrological compartments
 - **Winter:** distant advection from Siberia
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Conclusions and outlook



CONTINUOUS MONITORING OF ATMOSPHERIC VAPOUR ISOTOPES

REGIONAL NETWORK OF LAND-BASED OBSERVATIONS

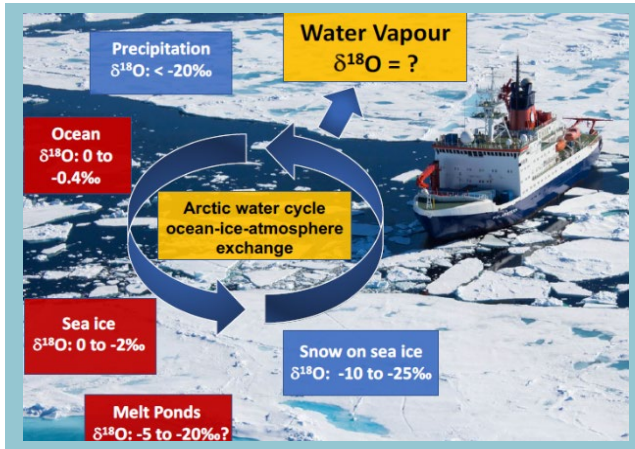
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★ Presentation by [Moein Mellat](#) : 'Isotope measurements of the Arctic water cycle and exchange processes between seawater, sea ice, and snow during MOSAIC'.

Conclusions and outlook



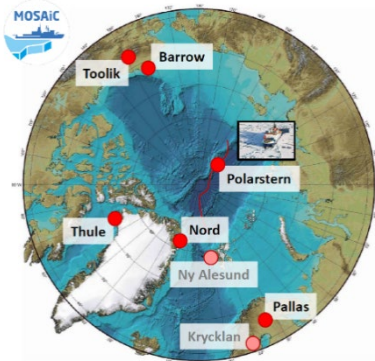
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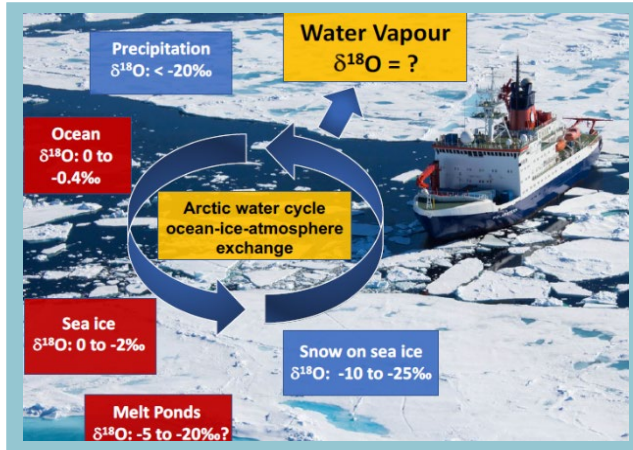
paired observations from stations connected during synoptic events



ISOTOPE ENHANCED – ATMOSPHERIC GCM

★ Kopec et al., Pan-Arctic water vapour isotope measurements reveal sea ice-ocean-atmosphere interactions during MOSAiC. *under revision for JGR Atmosphere*

Conclusions and outlook



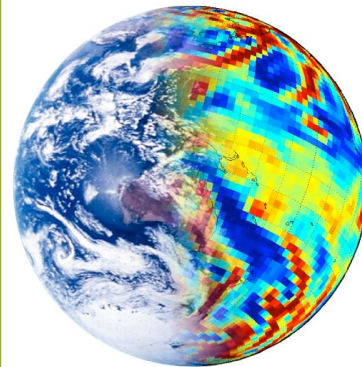
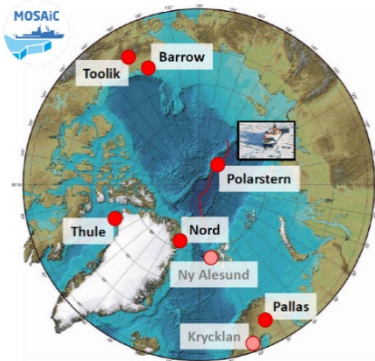
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paired observations from stations connected during synoptic events



- global atmosphere model (resolution: $0.9^\circ \times 0.9^\circ$, T127L95)
- simulation nudged to ERA5
- explicit simulation of isotopes in the water cycle



Poster presentation with first data-model comparison available at:

https://watercycle.w.uib.no/files/2021/11/Brunello_IsotopeWorkshop_2021_poster_final-1.pdf