Identifying Lagrangian matches of air masses during MOSAiC and ISLAS2020 using stable water isotope measurements

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ISLAS ISotopic Links to Atmopheric water's Sources

BJERKNES CENTRE for Climate Research

This presentation is part of a project that has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (Grant agreement No. 773245).

MOSAiC International Arctic Drift Expedition

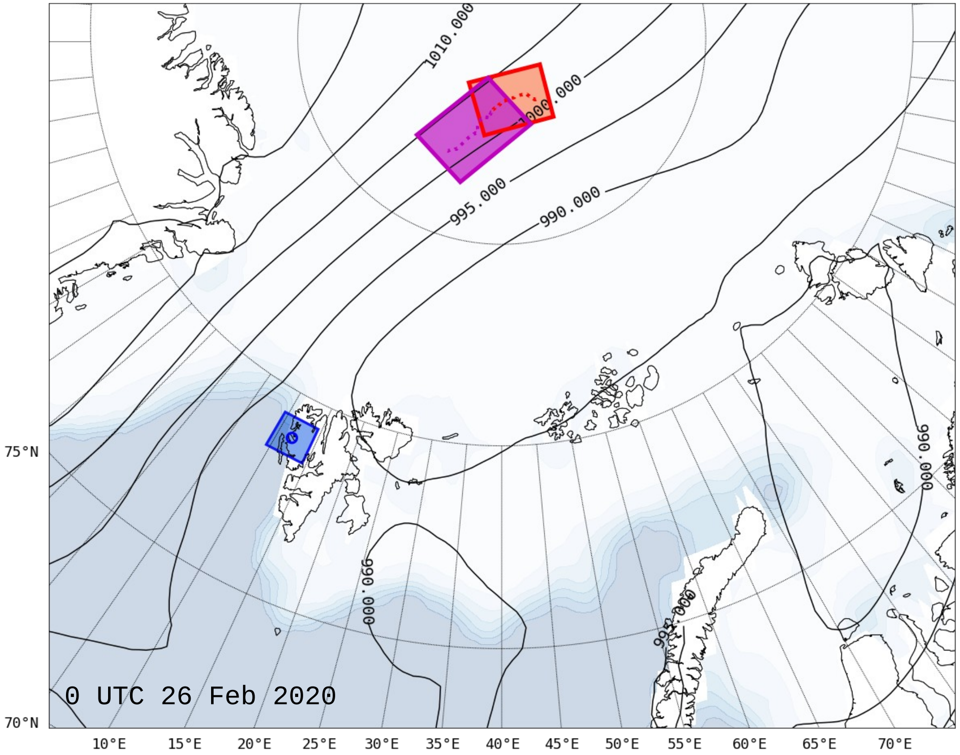
ISLAS2020 & MOSAiC
Cold air outbreaks 25-27 Feb and 8-12 March 2020

Isotopic composition of water vapour

- at Polarstern position during **MOSAiC** from 20 - 29 Feb
  Brunello et al. (2023)
- in Ny Ålesund during **ISLAS2020** from 25 Feb - 15 March 2020
  Seidl et al. (2026)

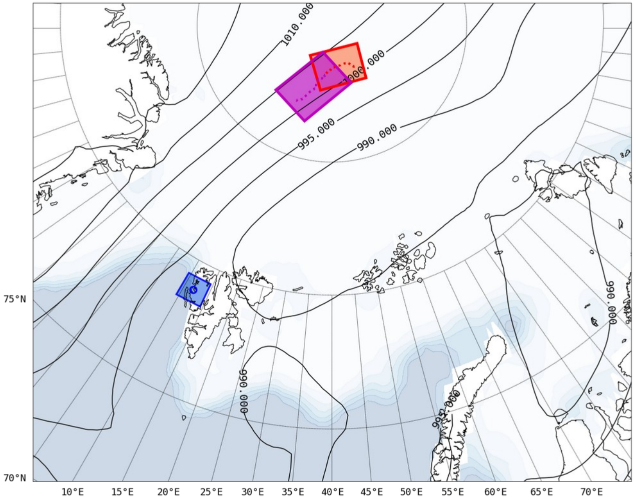
Two cold air outbreaks:

- measuring same air at Polarstern and Ny Ålesund?
- Stable water isotopes as process tracers: large-scale transport vs. small-scale processes

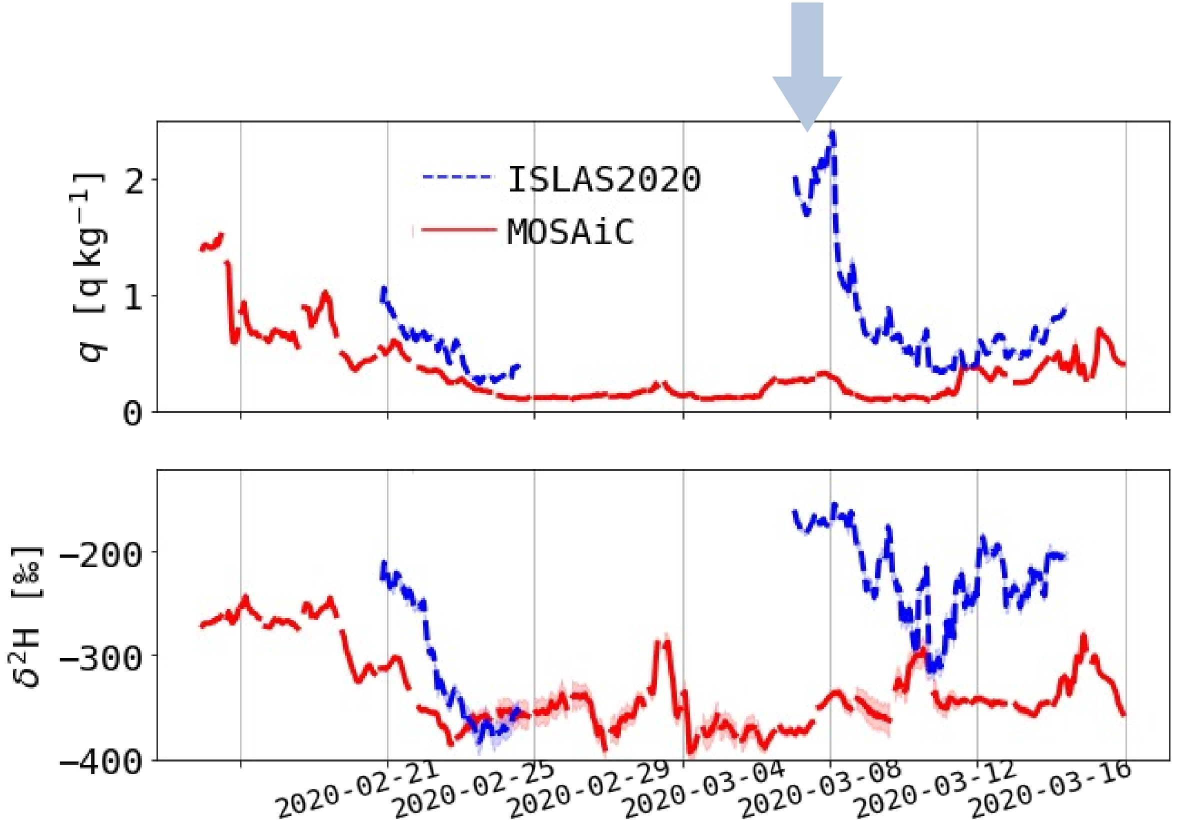


Brunello, C. F., et al. (2023). Contrasting seasonal isotopic signatures of near-surface atmospheric water vapor in the Central Arctic during the MOSAiC campaign. JGR: Atmos https://doi.org/10.1029/2022JD038400
Seidl, A. W., Johannessen, A., Dekhtyareva, A., Huss, J. M., Jonassen, M. O., Schulz, A., Hermansen, O., Thomas, C. K., and Sodemann, H.: The ISLAS2020 field campaign: studying the near-surface exchange process of stable water isotopes during the arctic wintertime, ESSD https://doi.org/10.5194/essd-18-1969-2026

ISLAS2020
Cold air outbreaks 25-27 Feb and 8-12 March 2020



Break-up of sea ice in fjord



Looking for Quasi-Lagrangian matches - Tools

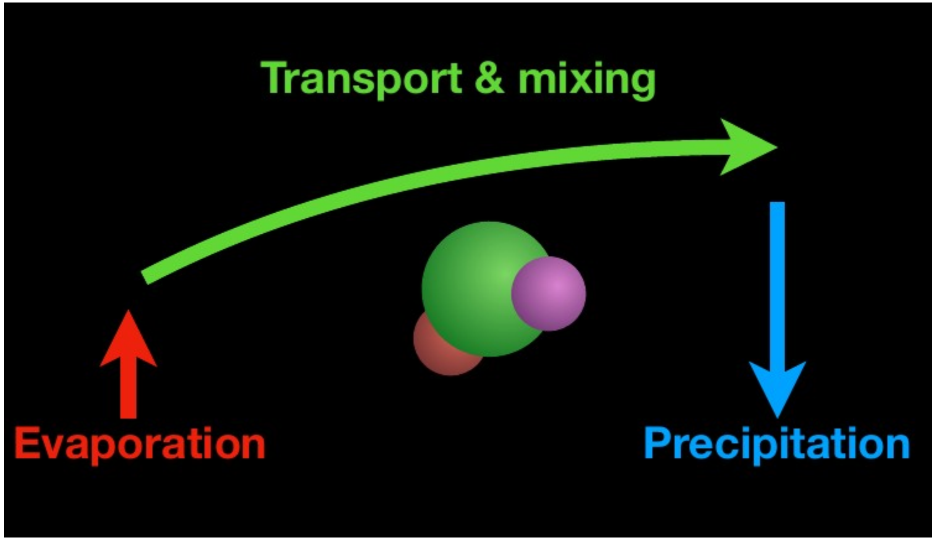
LAGRANTO: Sprenger and Wernli (2015)

- air parcel trajectories based on era5 wind fields
- starting ***backward*** trajectories up to 50 hPa above ground at 25 location within 50 km of Ny Ålesund

FLEXPART: Stohl et al. (1998)

- particle dispersion model based on era5
- starting ***forward*** trajectories (daily plumes) up to 1000m above ground from Polarstern

Measurements of **stable water isotopes** in water vapour using Picarro laser spectrometers on MOSAiC and ISLAS



Isotope variables: δ^2H, $\delta^{18}O$

d-excess: $d = \delta^2H - 8 \cdot \delta^{18}O$

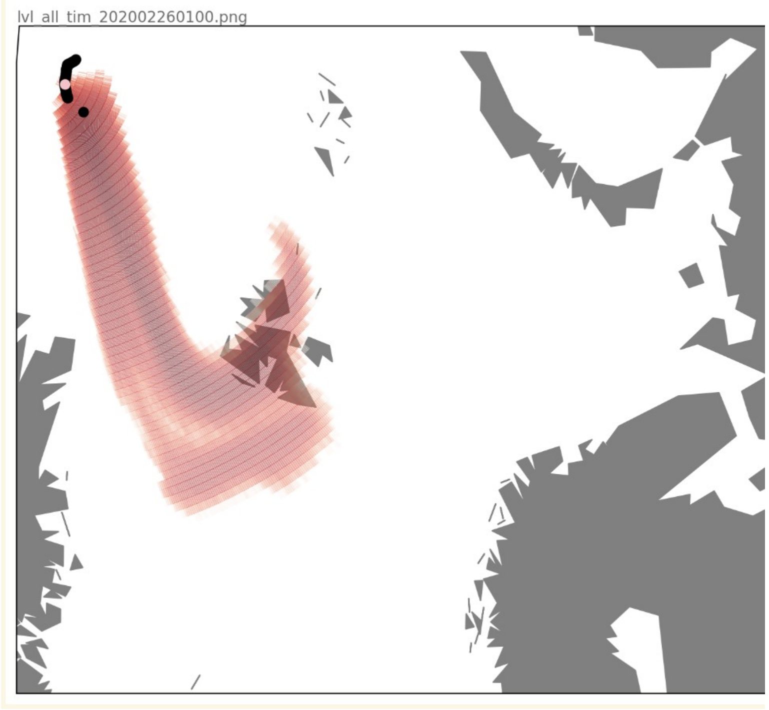
Sprenger, M. and Wernli, H.: The LAGRANTO Lagrangian analysis tool – version 2.0, Geosci. Model Dev., 8, 2569–2586, https://doi.org/10.5194/gmd-8-2569-2015, 2015.

Stohl, A., Hittenberger, M., and Wotawa, G.: Validation of the Lagrangian particle dispersion model FLEXPART against large scale tracer experiment data, Atmos. Environ., 32, 4245–4264, 1998.

Quasi-Lagrangian matches for MOSAiC and ISLAS2020

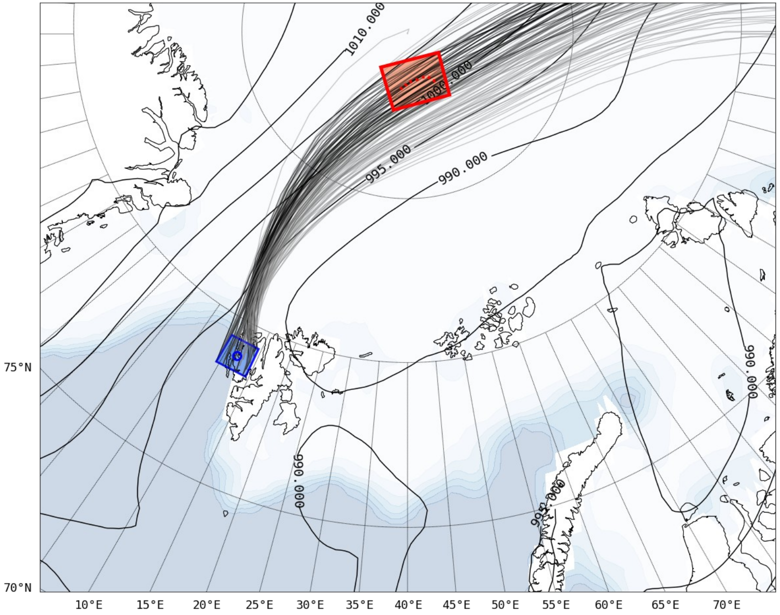
FLEXPART

Air parcel concentration at 01 UTC 26 Feb launched on 25 Feb from Polarstern



LAGRANTO

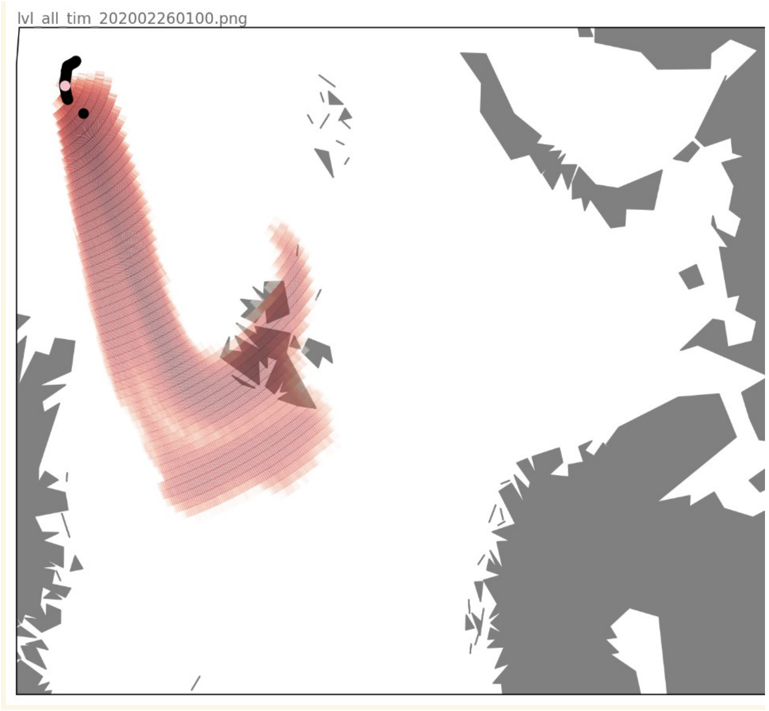
Backward trajectories launched at 03 UTC 26 Feb in Ny Alesund



Quasi-Lagrangian matches for MOSAiC and ISLAS2020

FLEXPART

Air parcel concentration at 01 UTC 26 Feb
launched from on 25 Feb from Polarstern



LAGRANTO

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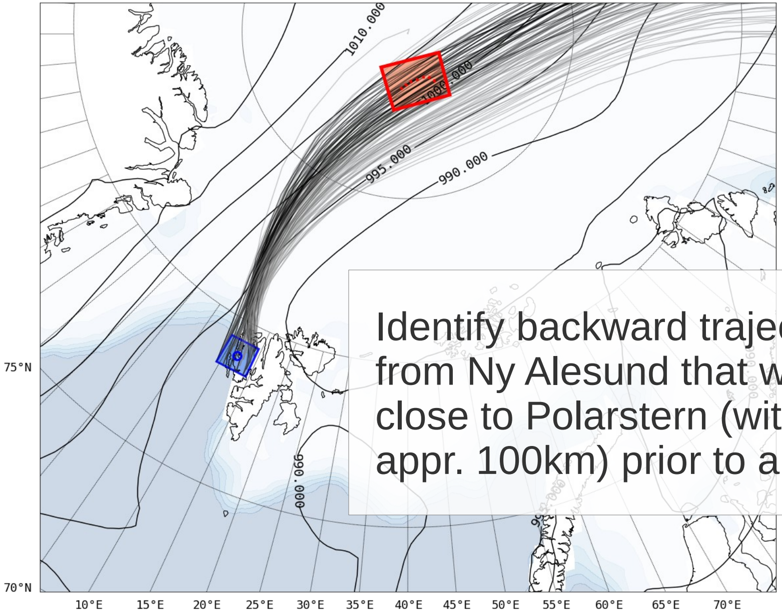
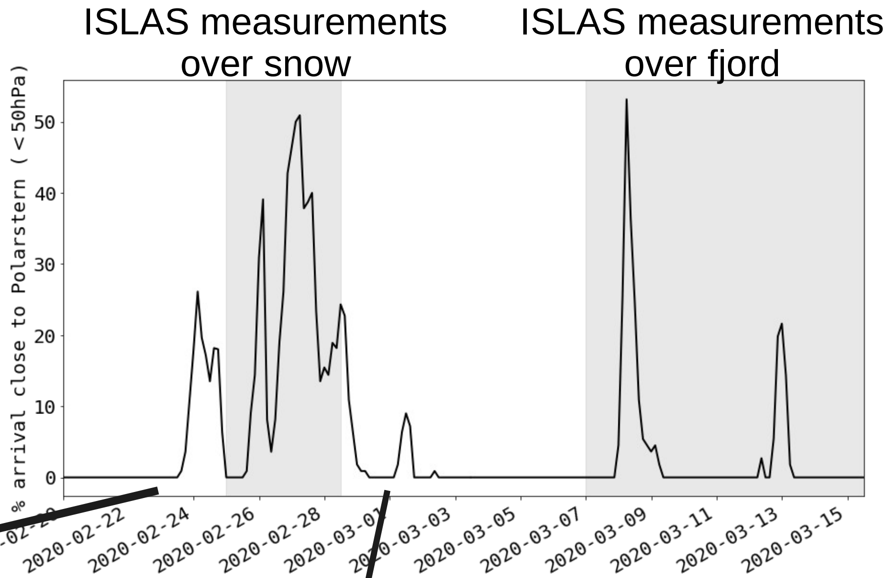
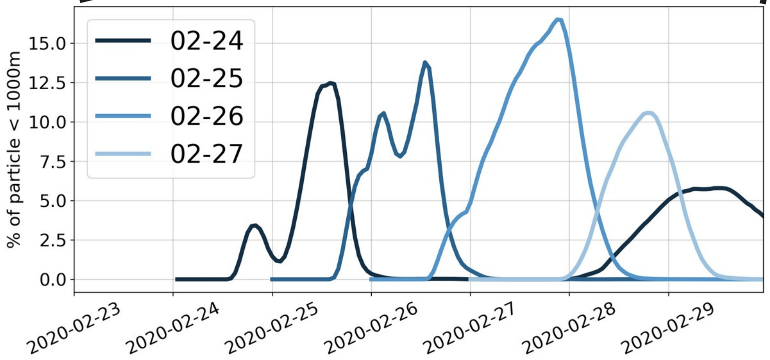


Identify backward trajectories from Ny Alesund that were close to Polarstern (within appr. 100km) prior to arrival

Quasi-Lagrangian matches for MOSAiC and ISLAS2020

Between 15 - 50% of trajectories arriving from MOSAiC location during CAOs





FLEXPART plumes arriving in Ny Alesund from Polarstern

Quasi-Lagrangian matches for MOSAiC and ISLAS2020

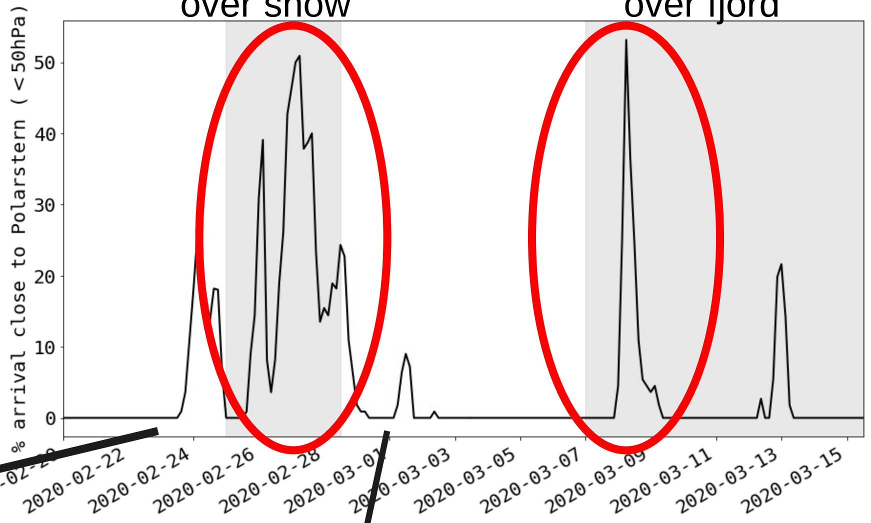
Between 15 - 50% of trajectories arriving from MOSAiC location during CAOs

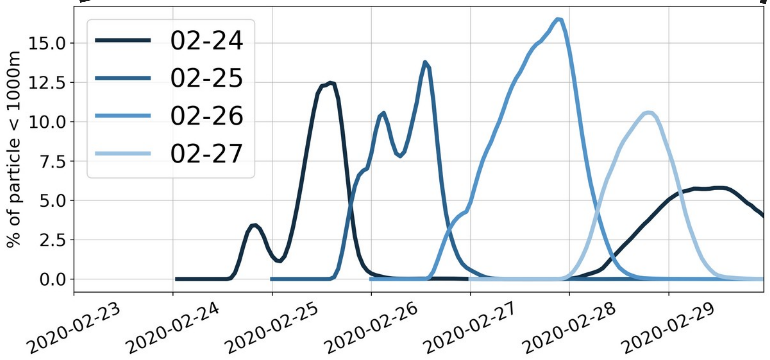
2 focus periods

➔ calculate mean travel time from MOSAiC to ISLAS for each launch time

ISLAS measurements over snow

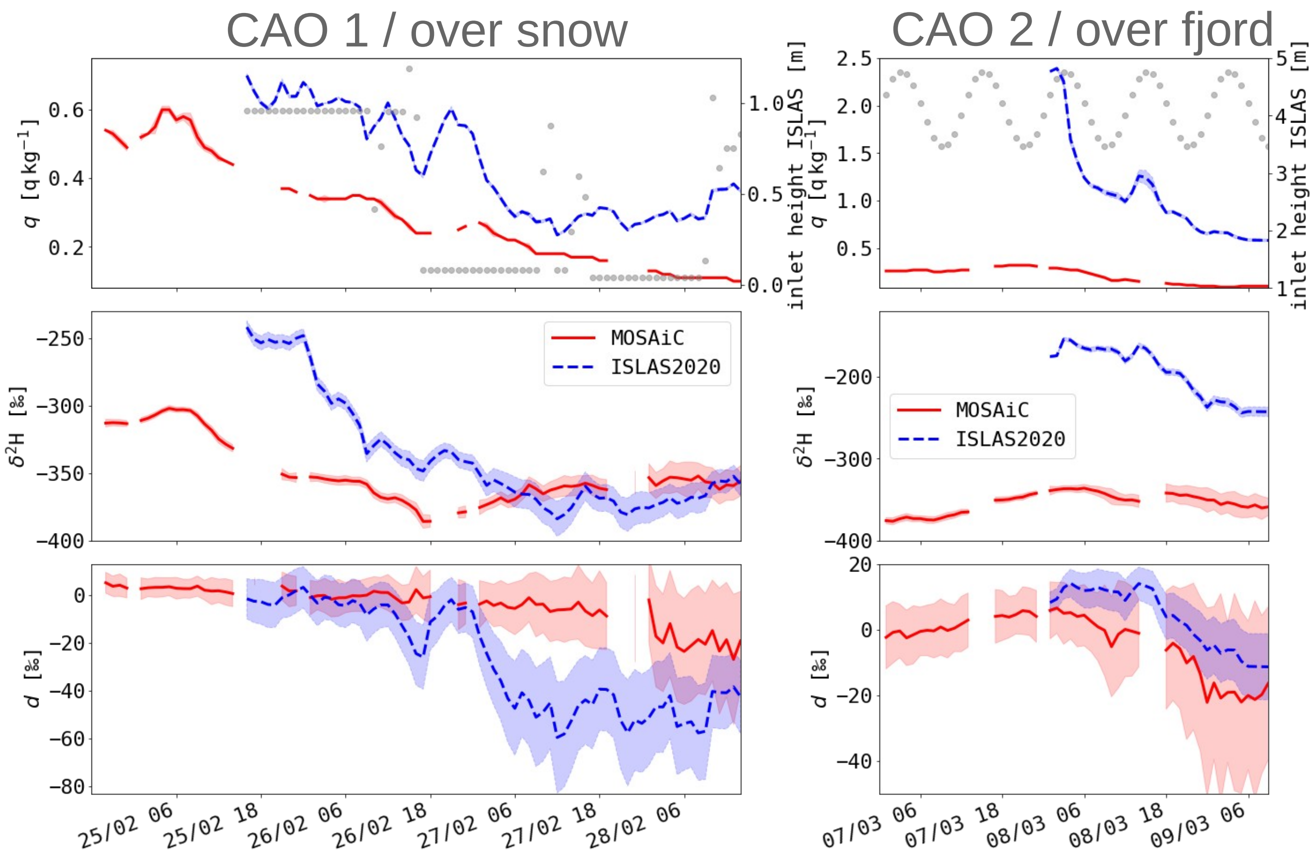
ISLAS measurements over fjord

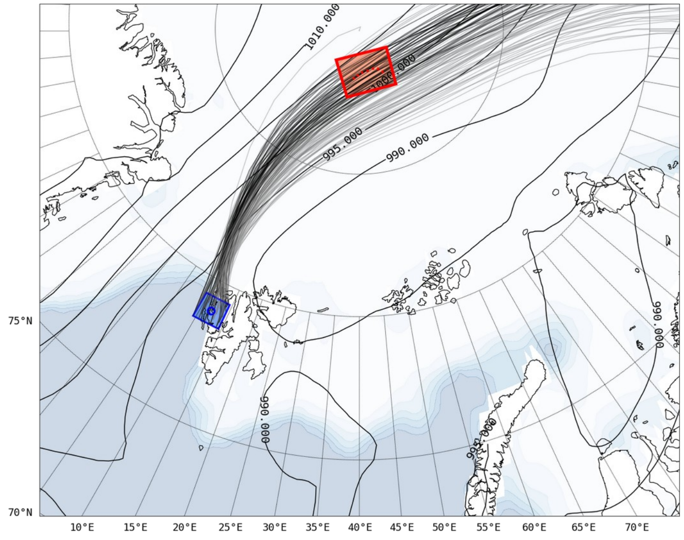




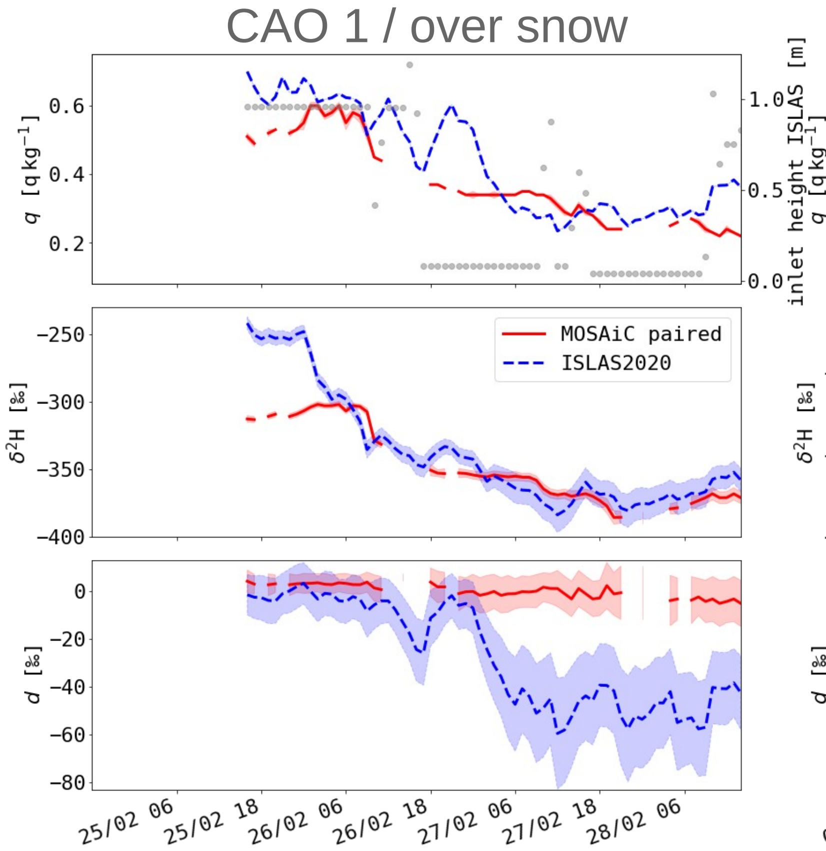
FLEXPART plumes arriving in Ny Alesund from Polarstern

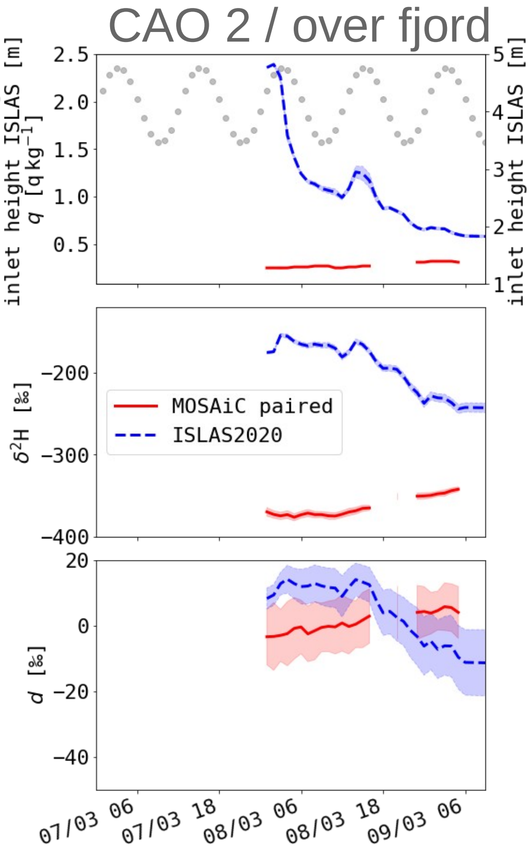
Quasi-Lagrangian matches for MOSAiC and ISLAS2020

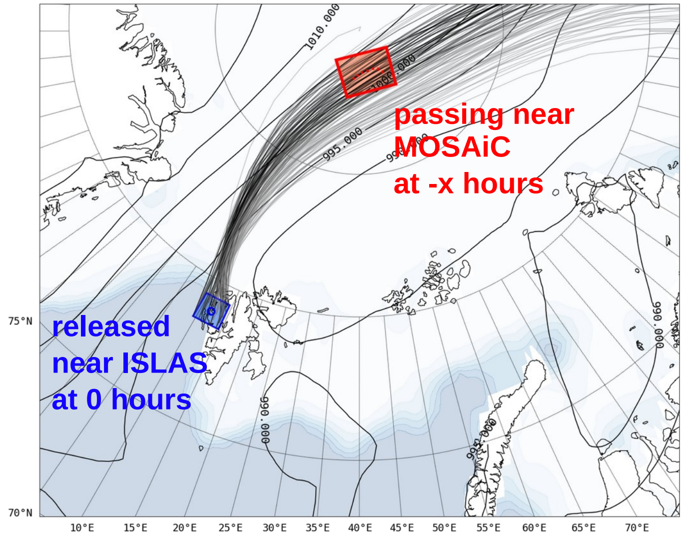




Quasi-lagrangian matches for MOSAiC and ISLAS2020





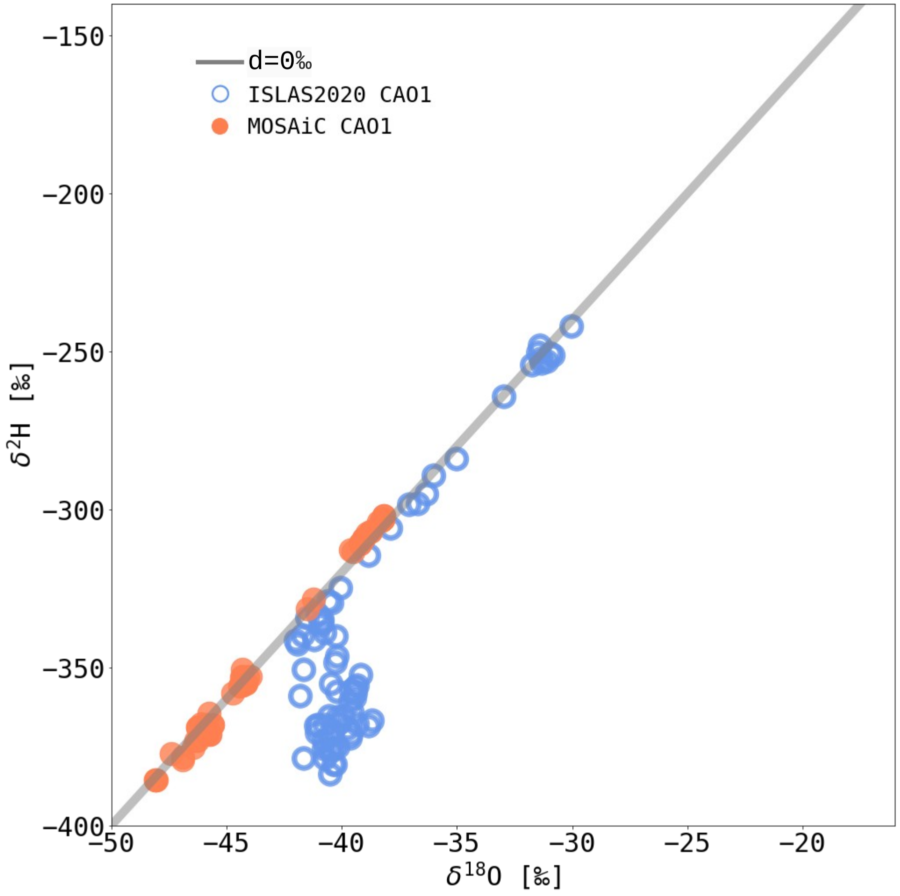


- Decrease in q and δD agreeing between the two measurement sites
- d-excess decreases more strongly at ISLAS site

Quasi-Lagrangian matches for MOSAiC and ISLAS2020

CAO 1

- MOSAIC: d-excess ≈ 0 ‰
- ISLAS deviates from 0 ‰ -line starting 27 Feb (negative d-excess)



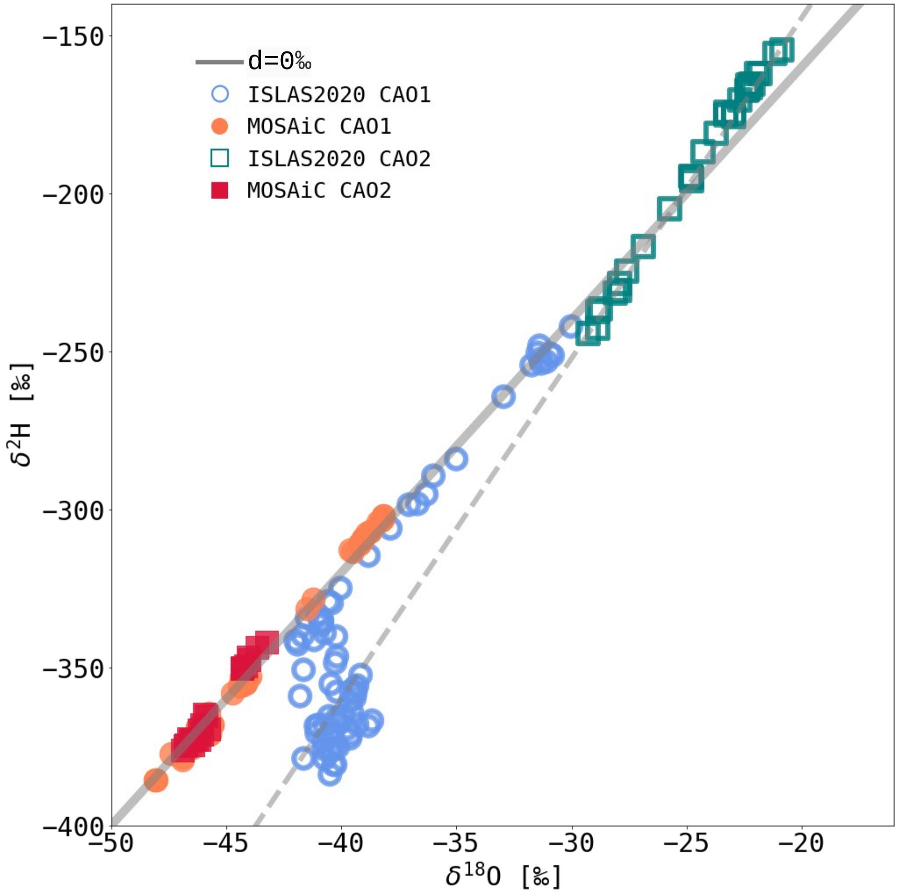
Quasi-Lagrangian matches for MOSAiC and ISLAS2020

CAO 1

- MOSAIC: d-excess ≈ 0 ‰
- ISLAS deviates from 0 ‰ -line starting 27 Feb (negative d-excess)

CAO 2

- ISLAS at enriched end of phase-space and mixing line with negative d-excess



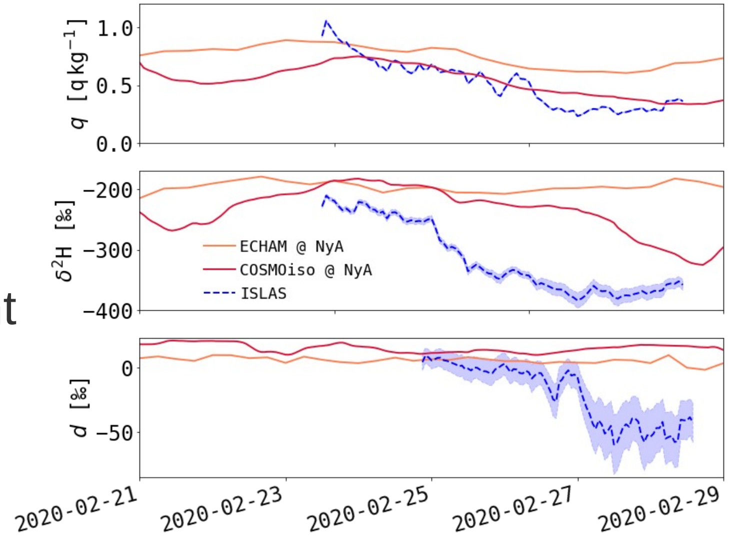
Conclusions & Outlook

- Two periods of large-scale Quasi-Lagrangian match between MOSAiC and ISLAS2020

- Identification of small-scale surface exchange and mixing processes changing isotopic composition of water vapour between central Arctic and ice edge

Potential next steps

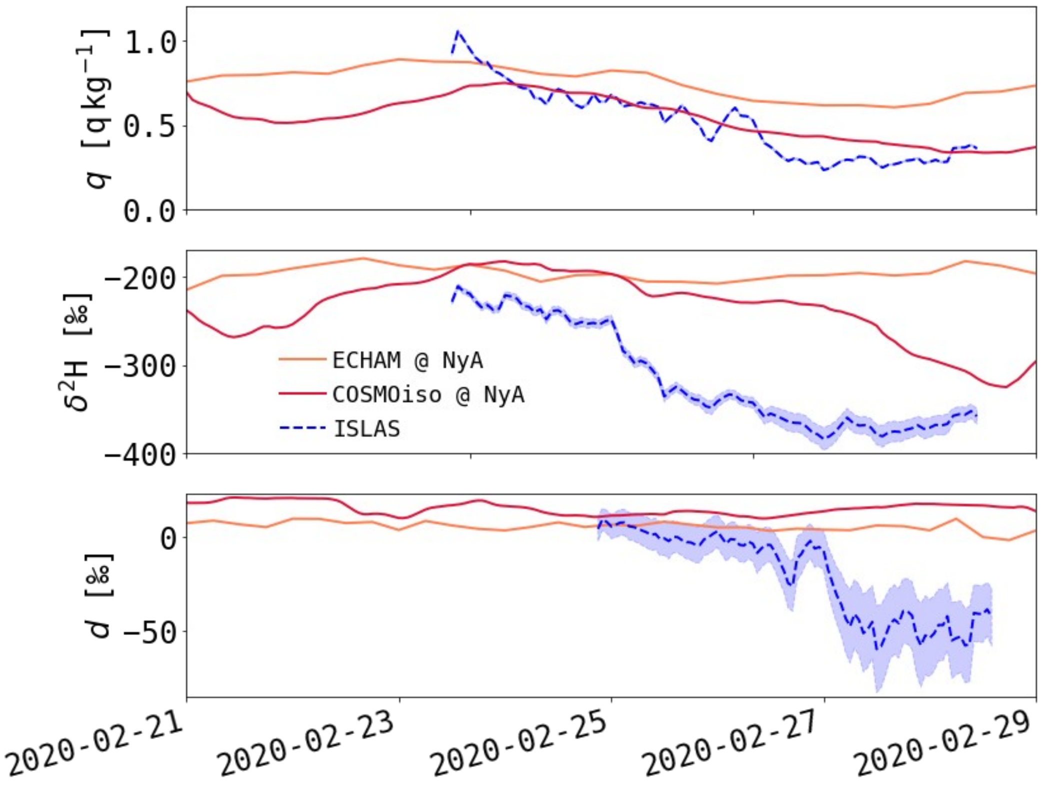
- How well can isotope-enabled models simulate water vapour transport?
- Application of Quasi-Lagrangian matching to different datasets and events → deposition processes in clouds can leave similar d-excess signals



Modelling comparison ECHAM5-wiso and COSMOiso

CAO 1

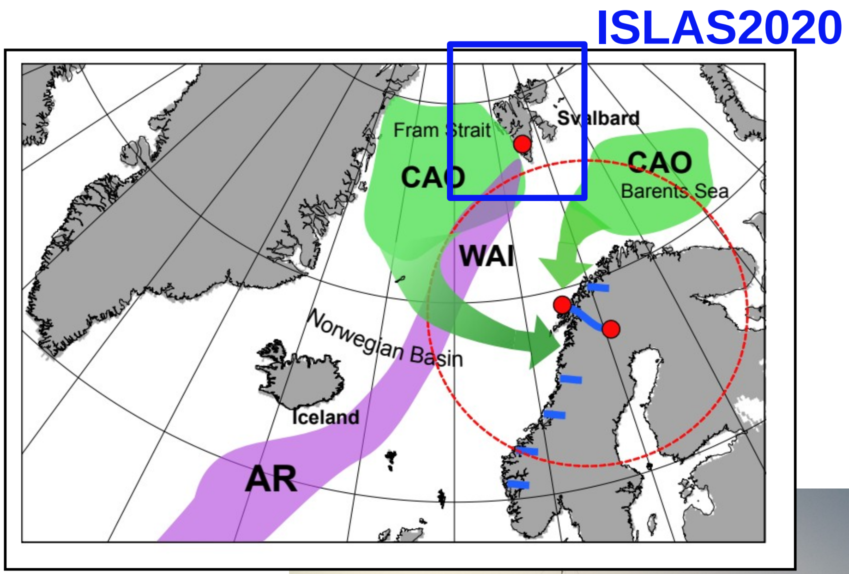
- Current model domain does not include Polarstern location
- Specific humidity evolution agrees well observations in Ny Alesund
- DD to high in models, COSMOiso captures decrease from 25 to 29 Feb.
- D-excess too high and does not capture variability in obs → surface deposition not represented

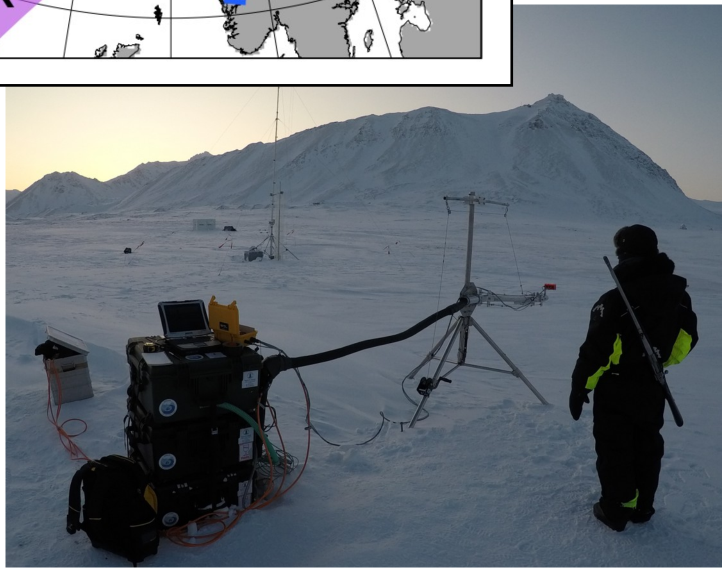


ISLAS 2020

Field campaign at Ny Ålesund

- 25 Feb - 15 March 2020
- Monitoring Arctic water vapour at sea ice edge
- Measurement of stable water isotopes in water vapour with near-surface vertical profiling system
  Seidl et. al. 2022





Seidl, A. W., Sodemann, H., and Steen-Larsen, H. C.: A modular field system for near-surface, vertical profiling of the atmospheric composition in harsh environments using cavity ring-down spectroscopy, Atmos. Meas. Tech., 16, 769–790, https://doi.org/10.5194/amt-16-769-2023, 2023.