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Dissolved neodymium isotopes trace origin and spatiotemporal evolution of modern Arctic sea ice

Georgi Laukert, Dorothea Bauch, Ilka Peeken, Thomas Krumpen, Kirstin Werner, Ed Hathorne, Marcus Gutjahr, Heidemarie Kassens, and Martin Frank

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Motivation

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Tracking Arctic sea ice will become more challenging in the near future

Poorly ice-covered areas will increase due to climate change

- *This is particularly challenging for automated tracking approaches based on satellite-derived sea-ice motion products, given that tracking is discontinued if the ice concentration drops below a threshold value (e.g. <20%, Krumpen et al., 2019)*

Field observations based on **chemical tracers** are therefore needed:

1. They will support satellite-derived sea-ice observations allowing for verification of the calculated trajectories. In addition, in case the tracking is discontinued due to low ice concentration, the early stage of sea-ice growth can be reconstructed
2. They can be used independently of other tracking approaches, for example to determine the origin and evolution of individual ice floes permanently separated from large ice fields

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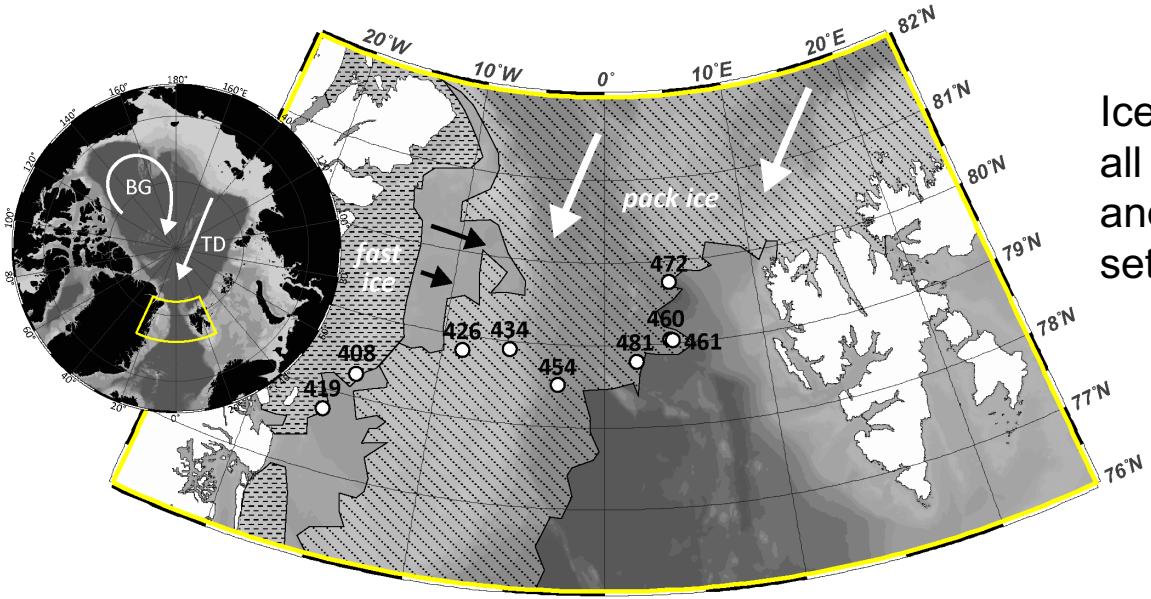
Nd isotopes are a powerful provenance tracer

- Nd isotopes have been successfully applied to trace ocean circulation in the Arctic Ocean (AO) and the adjacent seas (Laukert et al., 2017, GCA & EPSL., 2019, CG).
  - ➢ The potential of Nd isotopes to serve as a water mass and pack ice tracer in the AO results from pronounced ε_{Nd} differences between the distinct marine and riverine sources, which feed the surface waters of the different sea-ice formation regions

- For the first time we measured dissolved Nd isotopes (expressed as ε_{Nd}) in snow, sea ice and seawater collected at different sites in the Fram Strait in 2014:
  - ➢ All samples were processed under clean room conditions; filtration, chemistry and measurement techniques followed approved GEOTRACES protocols
  - ➢ Auxiliary parameters such as salinity, stable oxygen isotopes and rare earth element concentrations have been determined for comparison

Methods

Sampling across the Fram Strait and on the NE Greenland Shelf in 2014



Ice stations cover all types of sea ice and hydrographic settings present

Most of the 1-year and multi-year ice has been advected from the Arctic Ocean

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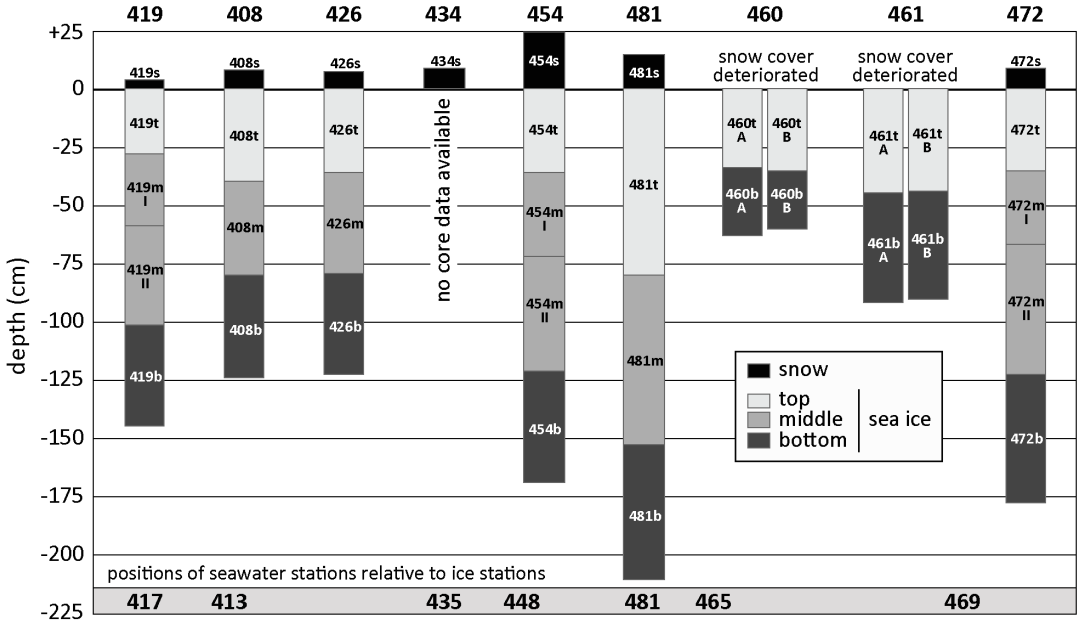
Top, middle and bottom sections of the ice cores were sampled



Notes regarding the resolution:

- *The low sampling resolution results from the high amount of sample volume required for Nd isotope analysis*
- *This resolution will be increased in the future by taking multiple cores at one site and by combining core intervals of corresponding depths*

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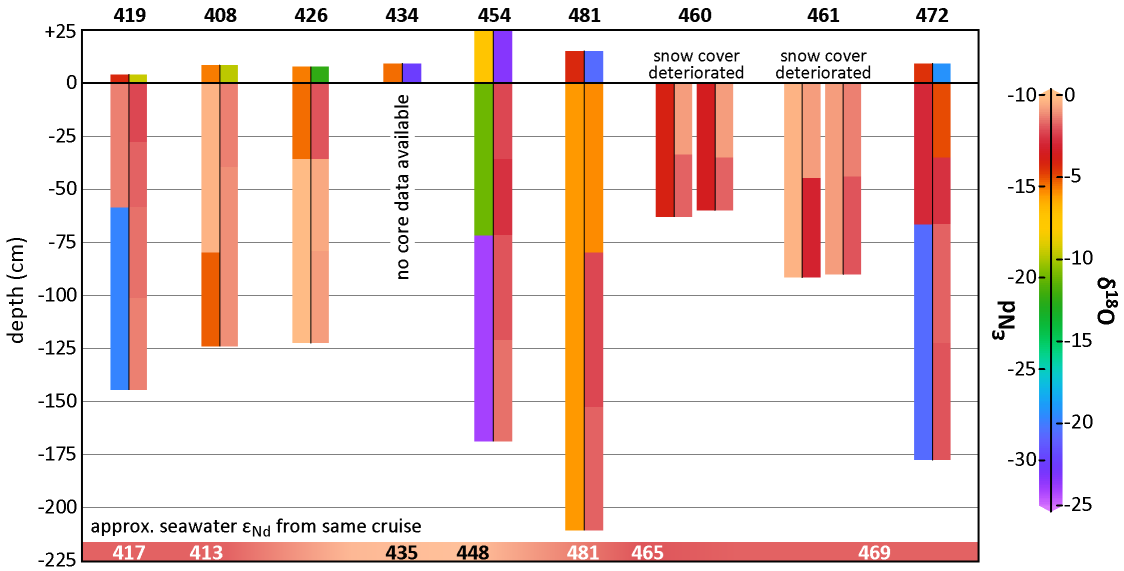
Spatial distribution of Nd (left) and O (right) isotopes



- The distributions of ε_{Nd} and $\delta^{18}O$ differ significantly
- The snow cover has distinct signatures, which are completely different from the ice cores
- Bottom sections of three ice cores have highly unradiogenic ε_{Nd} signatures whereas no significant change in $\delta^{18}O$ (and S) is observed

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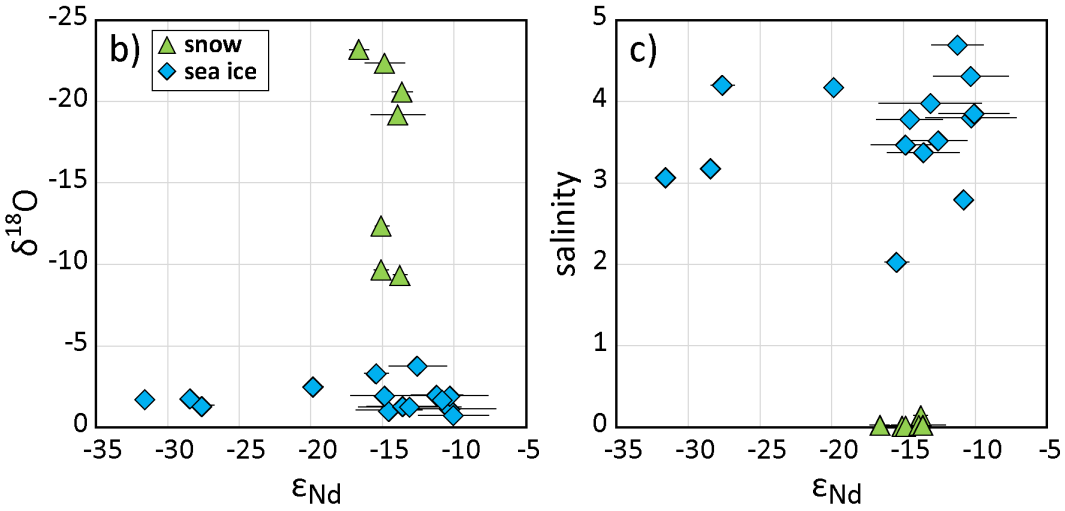
Comparison between ε_{Nd} and other hydrographic parameters



Sea ice:

- Constant $\delta^{18}O$ (below -5 ‰) but highly variable ε_{Nd} reaching highly unradiogenic signatures in three samples
- No correlation between ε_{Nd} and other parameters

Snow cover:

- Salinity is zero for essentially all samples
- Low but highly variable $\delta^{18}O$ at rather constant ε_{Nd}

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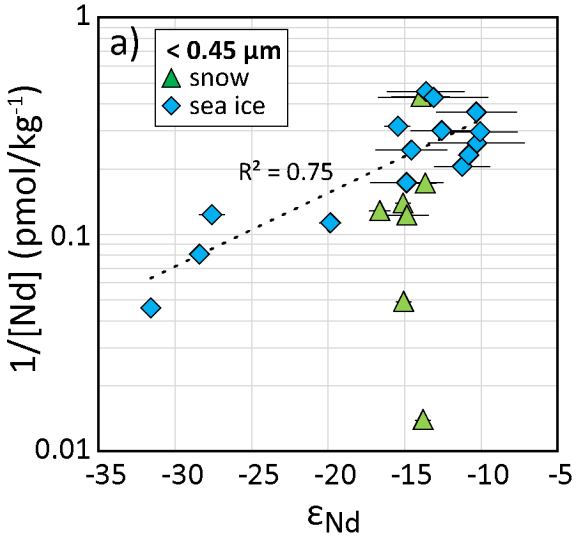
Relationship between ε_{Nd} and Nd concentrations ([Nd])



- Sea-ice Nd concentrations are highest for the samples with the least radiogenic ε_{Nd} signatures
- Such a relationship has also been observed for seawater in the Fram Strait and elsewhere in the Arctic Ocean (Laukert et al., 2017, GCA & EPSL, 2019, CG)

➢ The ice signal mirrors the seawater signal despite brine rejection, which allows the use of Nd isotopes to reconstruct sea ice origin and evolution

➢ Three Arctic-derived ice floes with least radiogenic signatures in the bottom sections acquired their Nd from Greenland meltwaters prior to their advection to the sampling sites

Conclusions

We present a new application of ***radiogenic Nd isotopes*** to provide unique information on the origin and spatiotemporal evolution of modern Arctic sea ice

- *Most sea-ice floes in our study formed from well-mixed waters in the central Arctic Ocean, which is reflected by their Nd isotope signatures and confirmed by a satellite-based tracking approach*
- *Three ice floes, however, incorporated Greenland meltwater along their travel to the Fram Strait (e.g. during growth and transport), which is recorded in ε_{Nd} and [Nd], but not in S and $\delta^{18}O$*
- *Exchange between sea ice and seawater or snow was limited during growth-free periods*

General conclusions:

- The seawater ε_{Nd} signal is incorporated into the sea ice during sea-ice growth and preserved during sea-ice transport, supporting the use of ε_{Nd} as a tracer of sea ice origin and evolution
- Pronounced ε_{Nd} differences between the distinct Arctic marine and riverine sources have been recorded by the sea ice while variations in S and $\delta^{18}O$ are at the same time small
- **Our new approach facilitates reconstruction of sea ice pathways and is particularly useful for tracing individual sea-ice floes, which will be important in the near future**