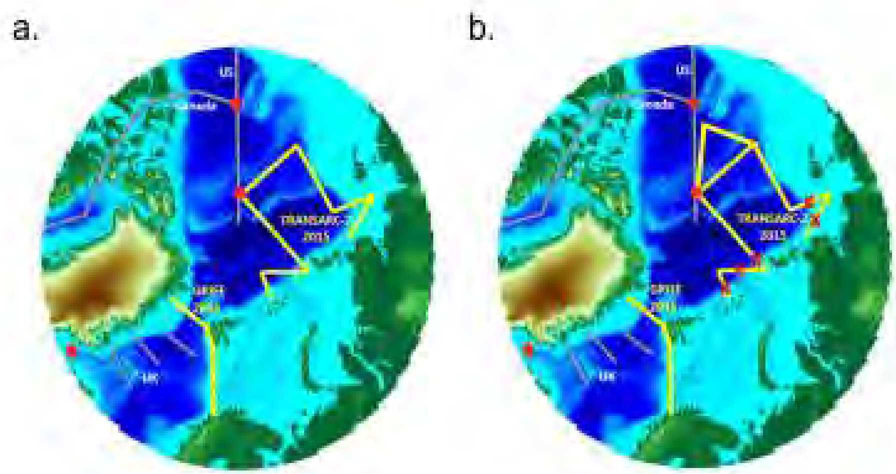
Overview of European Data and Synthesis – Casacuberta, Slagter



a) The original cruise track, and b) a rough visualization of the alternative proposed cruise track of TransArc II when permission to sample in the EEZ of Russia is refused. Red crosses indicate the parts of the original cruise track that will not be sampled then.

Accomplishments:

The Arctic GEOTRACES program has been tremendously successful

- **Dozens of papers**
- **Student involvement, Training,Theses**
- **Post-Doc training**
- **International cooperation (e.g. intercalibration)**

Goals:

- **Build on International cooperative activities**
- **Pan-Arctic synthesis papers**

International cooperative activities – Can we build on this?

Fitzsimmons

- Intercalibrated with Canadian Arctic GEOTRACErs (Jay Cullen and Kristin Orians), and initial intercalibration has been successful.
- Currently working on intercalibration with German Arctic GEOTRACErs. We have been pursuing joint publication of the US and Canadian Arcitc GEOTRACES data with Jay Cullen's group (he is writing up joint Cd, while we are writing up joint Fe).

Lam

Conducting intercalibration with US, German, French and Canadian colleagues

Kadko- intercalibrated ^{7}Be with W. Geibert and others. Manuscript being prepared.

Kadko, Landing, Buck

Coordinating upcoming Arctic expedition (MOASAIC, 2019-2020) with W. Geibert (Germany) and others.

Shiller

- Received samples from the Canadians and should soon receive samples from the Dutch so that we can do V and some other elements.
- Also, the Russians took some Barents Sea samples for us last summer and we are hoping they can actually get delivered to us.

Granger

- Canada GEOTRACES nitrate isotope analyses were conducted in the Granger laboratory by Nadine Lehmann (graduate student) from Markus Kienast's group at Dalhousie University.
- Intercalibration of Granger with Frank Dehair's group in Belgium.

Synthesis Topics from Previous Data Meetings

- Effect of Transpolar Drift on Central Arctic Geochemistry ✓
  (seen in Trace elements, ^{7}Be, ^{228}Ra)

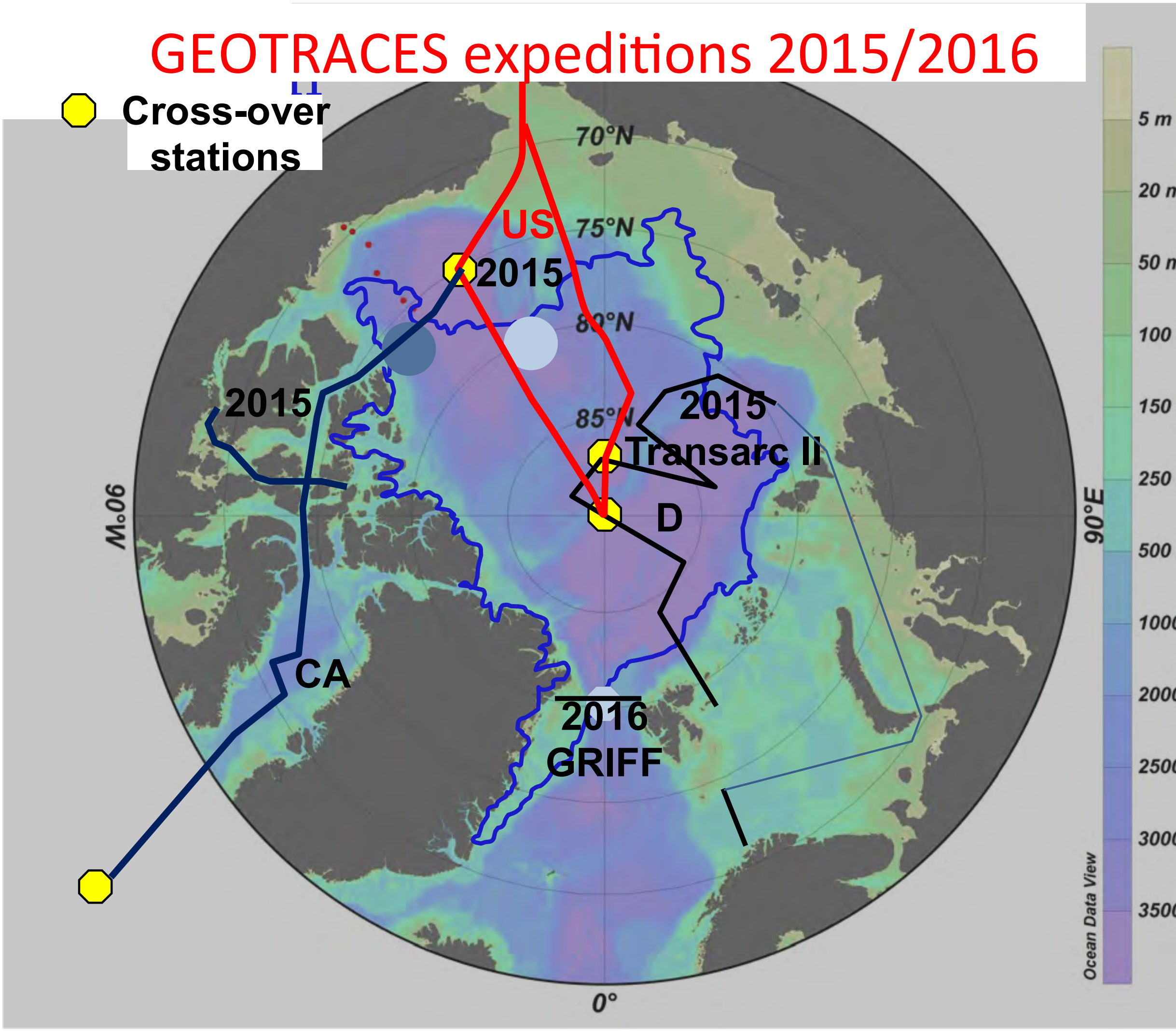
Rutgers van der Loeff, M., L. Kipp, M.A. Charette, W.S. Moore, E. Black, I. Stimac, A. Charkin, D. Bauch, O. Valk, M. Karcher, T. Krumpen, N. Casacuberta, W. Smethie, R. Rember (2018) Radium Isotopes across the Arctic Ocean show Time Scales of Water Mass Ventilation and Increasing Shelf Inputs. JGR Oceans.

Kadko D., A. Aguilar-Islas, C. Bolt, C.S. Buck, J. N. Fitzsimmons, L. T. Jensen, W.M. Landing, C. M. Marsay, R. Rember, A. M. Shiller, L. M. Whitmore, and R. F. Anderson (2019) The residence times of trace elements determined in the surface Arctic Ocean during the 2015 US Arctic GEOTRACES expedition. Mar. Chem. 208, 56-69. doi.org /10.1016/ j. marchem. 2018.10.011

Charette et al., (in review) The Transpolar Drift as a Source of Riverine and Shelf-Derived Trace Elements to the Central Arctic Ocean. Submitted to: Journal of Geophysical Research-Oceans

- Hydrography and circulation (or restrictions of it), among the deep basins that were sampled
- Bioactive metals
- Nepheloid layer
- Marginal Ice Zone
- Shelf Processes (redox reactions, shelf-basin exchange)
- Halocline ventilation and geochemical features of shelf sources

Granger, J., Sigman, D.M., Gagnon, J., Tremblay, J., Mucci, A., (2018). On the properties of the Arctic halocline and deep water masses of the Canada Basin from nitrate isotope ratios. J. Geophys. Res. Oceans,123,5443–5458. https://doi.org/10.1029/2018JC01411



GEOTRACES
Pan-Arctic Synthesis Meeting

16th February 2020

N. Casacuberta & H. Slagter

Publications

11 published papers
5 papers submitted
Others in preparation
6 PhD Thesis
Processed data → Pangaea

Ocean Sci., 16, 1–14, 2020
https://doi.org/10.5194/os-16-1-2020

Ocean Science EGU

Decrease in ^{230}Th in the Amundsen Basin since 2007: far-field effect of increased scavenging on the shelf?

Ole Valk[1], Michiel M. Rutgers van der Loeff[1], Walter …
Robert Lawrence Edwards[5], Yanbin Lu[6], Viena Puigc…
William Smethie[11], and Matthieu Roy-Barman[12]

AGU100 ADVANCING EARTH AND SPACE SCIENCE
Journal of Geophysical Research: Oceans
RESEARCH ARTICLE
10.1029/2018JC014168

Tracing the Three Atlantic Branches Ente… the Arctic Ocean With ^{129}I and ^{236}U

N. Casacuberta[1,2], M. Christl[1], C. Vockenhuber[1], A.-M. Wefing[1,2], L. Wacker[1], P. Masqué[3,4],
H.-A. Synal[1], and M. Rutgers van der Loeff[5]

AGU100
JGR Oceans
RESEARCH ARTICLE
10.1029/2018JC014399

Tracing Atlantic Waters Using ^{129}I and ^{236}U in the Fram Strait in 2016

A.-M. Wefing[1,2], M. Christl[1], C. Vockenhuber[1], M. Rutgers van der Loeff[3]
and N. Casacuberta[1,2]
[1]Laboratory of Ion Beam Physics, ETH Zurich, Zurich, Switzerland, [2]Environmental Physics, Institute of Biogeo…

Key Points:
- In 2016, inflowing Atlantic waters to the Arctic Ocean have lower ^{129}I and ^{236}U concentrations than outflowing Arctic waters

AGU100 ADVANCING EARTH AND SPACE SCIENCE
Global Biogeochemical Cycles
RESEARCH ARTICLE
10.1029/2017GB005738

Rapid Changes in Anthropogenic Carbon Storage and Ocean Acidification in the Intermediate Layers of the Eurasian Arctic Ocean: 1996–2015

Adam Ulfsbo[1,2], Elizabeth M. Jones[3,4], Núria Casacuberta[5,6], Meri Korhonen[7],
Benjamin Rabe[8], Michael Karcher[8,9], and Steven M.A.C. van Heuven[3]

Key Points:
- Rapid decadal accumulation of basin-wide anthropogenic carbon in the Arctic and intermediate layers of the Nansen and Amundsen Basins

AGU100 ADVANCING EARTH AND SPACE SCIENCE
Journal of Geophysical Research: Oceans
RESEARCH ARTICLE
10.1029/2018JC013888

Radium Isotopes Across the Arctic Ocean Show Time Scales of Water Mass Ventilation…

Michiel Rutgers van der Loeff[1], Lauren …
Erin Black[2], Ingrid Stimac[1], Alexander Cha…
Michael Karcher[1], Thomas Krumpen[1], …
and Robert Rember[9]

Key Points:
- The increase of ^{228}Ra in central Arctic surface waters points at stronger sediment water exchange due to the longer ice-free season on Arctic shelves

AGU100 ADVANCING EARTH AND SPACE SCIENCE
Geophysical Research Letters
RESEARCH LETTER
10.1029/2018GL079829

Importance of Hydrothermal Vents in Scavenging Removal of ^{230}Th in the Nansen Basin

O. Valk[1], M. M. Rutgers van der Loeff[1], W. Geibert[1], S. Gdaniec[2], M. J. A. Rijkenberg[3,4],
S. B. Moran[5], K. Lepore[6], R. L. Edwards[7], Y. Lu[8], and V. Puigcorbé[9]
[1]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany, [2]Department of

Key Point:
- The first 230Th time series in the Arctic shows that a hydrothermal event caused scavenging removal of 230Th in the Nansen Basin

frontiers in Marine Science
ORIGINAL RESEARCH

Dissolved Fe in the Deep and Upper Arctic Ocean With a Focus on Fe Limitation in the Nansen Basin

Micha J. A. Rijkenberg[1], Hans A. Slagter[1], Michiel Rutgers van der Loeff[2], Jan van Ooijen[1]
and Loes J. A. Gerringa[1]*

ELSEVIER
journal homepage: www.elsevier.com/locate/marchem

Organic Fe speciation in the Eurasian Basins of the Arctic Ocean and its relation to terrestrial DOM

H.A. Slagter[a,*], H.E. Reader[b], M.J.A. Rijkenberg[a], M. Rutgers van der Loeff[c], H.J.W. de Baar[a,d],
L.J.A. Gerringa[a,*]
[a] Department of Ocean Systems, NIOZ Royal Netherlands Institute for Sea Research and Utrecht University, Den Burg, The Netherlands
[b] National Institute for Aquatic Resources, Technical University of Denmark, Charlottenlund, Denmark
[c] Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany
[d] University of Groningen, Groningen, The Netherlands

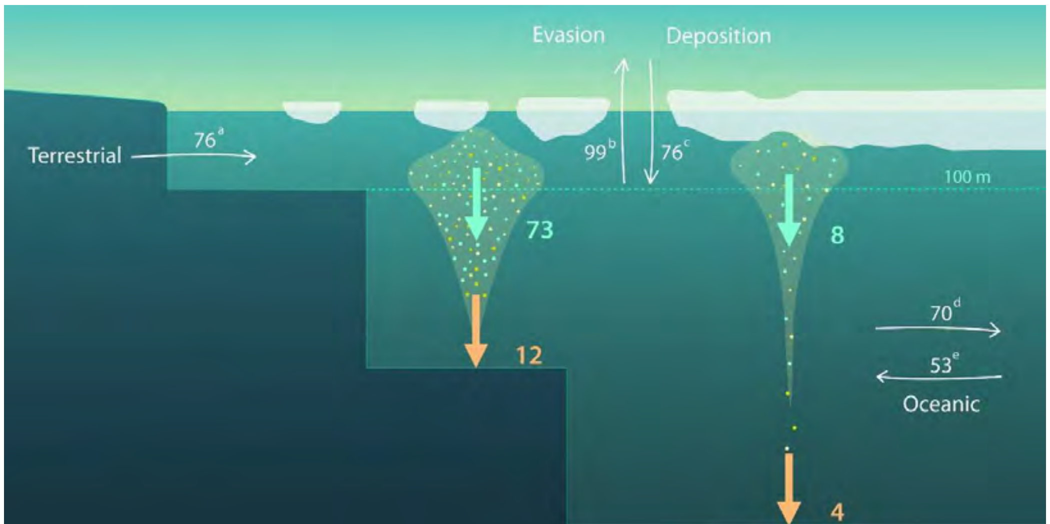
L-E. HEIMBURGER et al. (submitted to GEOTRACES special issue in ACS Earth and Space Chemistry)

A refined Hg export flux in the Arctic ocean using Th-234 and particulate Hg

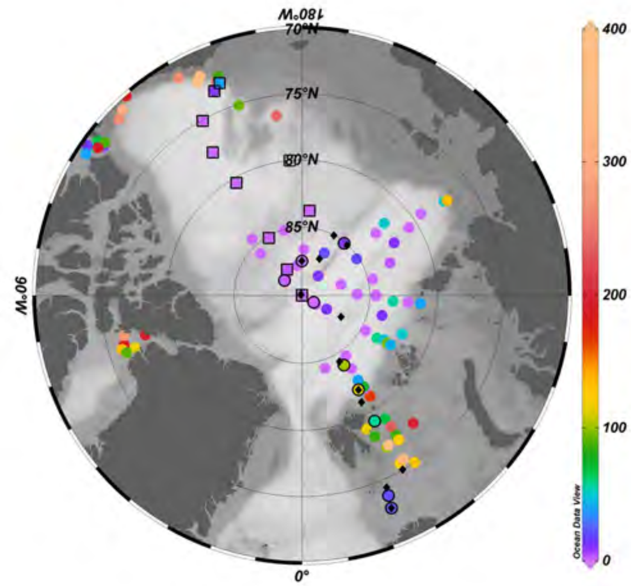
MARSEILLE MARINE MERCURY LAB

Mediterranean Institute of Oceanography

lars-eric.heimburger@mio.osupytheas.fr



Refined Hg mass balance study, fluxes in Mg y^{-1}



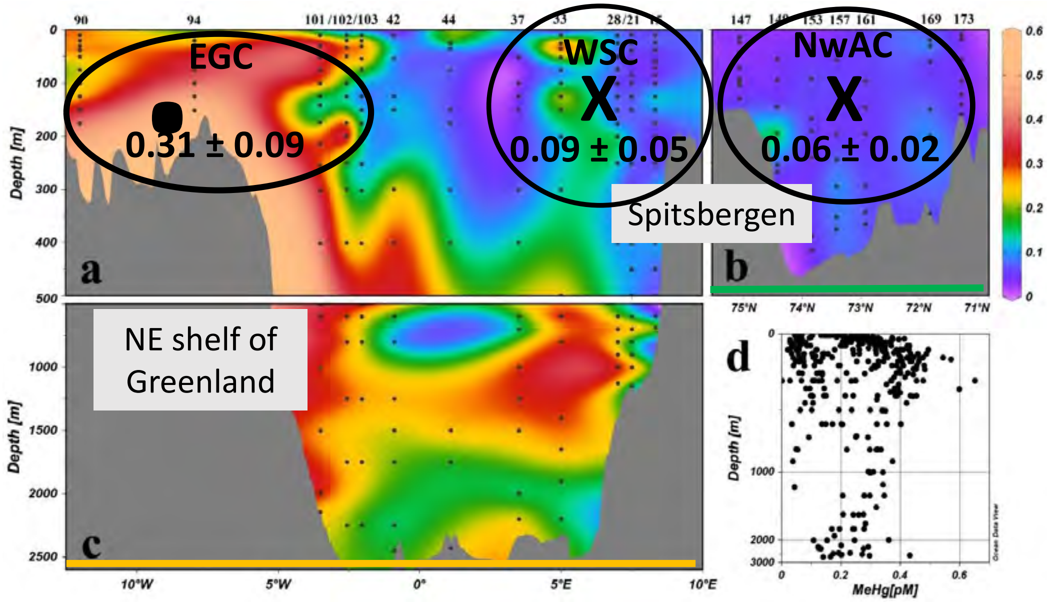
pHg export flux ng m^{-2} d^{-1}

Take-home message:
Hg export fluxes below 100 m depth in the Arctic Ocean is with 81 Mg·y-1, at least 2x than what was published before.

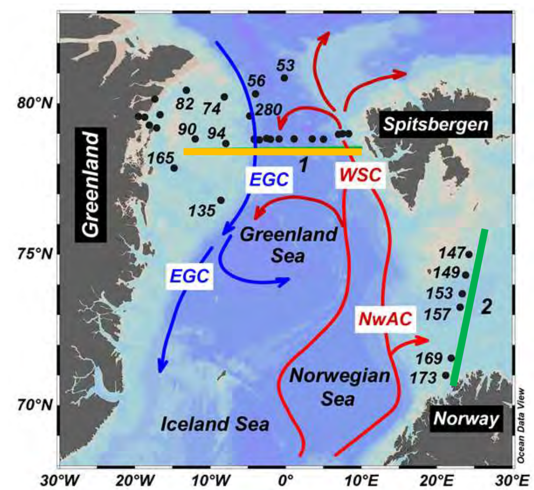
MARSEILLE MARINE MERCURY LAB
mio Mediterranean Institute of Oceanography
lars-eric.heimburger@mio.osupytheas.fr

PETROVA et al. (not published)

MERCURY SPECIES EXPORT from the Arctic to the Atlantic Ocean



MeHg = 0.23 ± 0.14 pM <0.05 – 0.65 pM, n = 387
tHg = 1.10 ± 0.56 pM0.20 – 4.81 pM, n = 586 (not shown)



EGC – East Greenland Current
WSC – West Spitsbergen Current
NwAC – Norwegian Atlantic Current

Take-home message:

i. The shallow MeHg maximum found in the Arctic Ocean (100-300m depth) was observed in the EGC.

ii. Total Hg inflow at Fram Strait of 41 ± 6 Mg y^{-1} (7 ± 1 Mg y^{-1} as MeHg) and tHg outflow from the Arctic Ocean of 52 ± 9 Mg y^{-1} (12 ± 2 Mg y^{-1} as MeHg) => net export of 11 ± 7 Mg y^{-1} tHg and 50% as MeHg (5 ± 2 Mg y^{-1}).

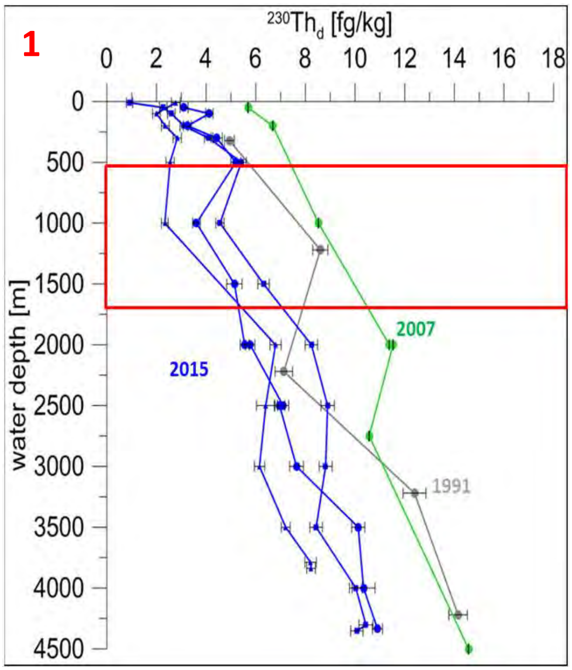
iii. The Arctic Ocean is a MeHg bioreactor transforming iHg into MeHg.

O. VALK et al. (*Accepted* in Ocean Science Discussions)

CIRCULATION CHANGES IN THE AMUNDSEN BASIN

Ole.valk@awi.de

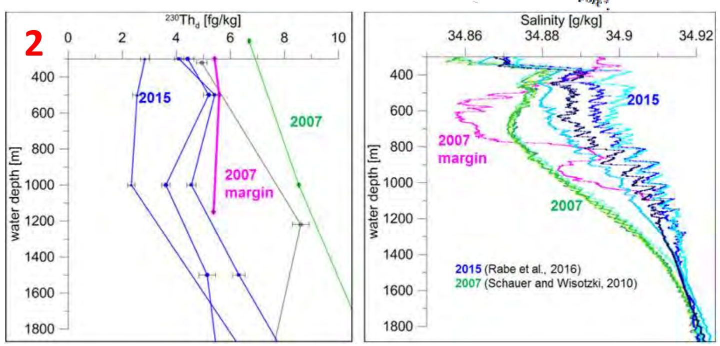
Dissolved ^{230}Th Amundsen Basin
1991 - 2015



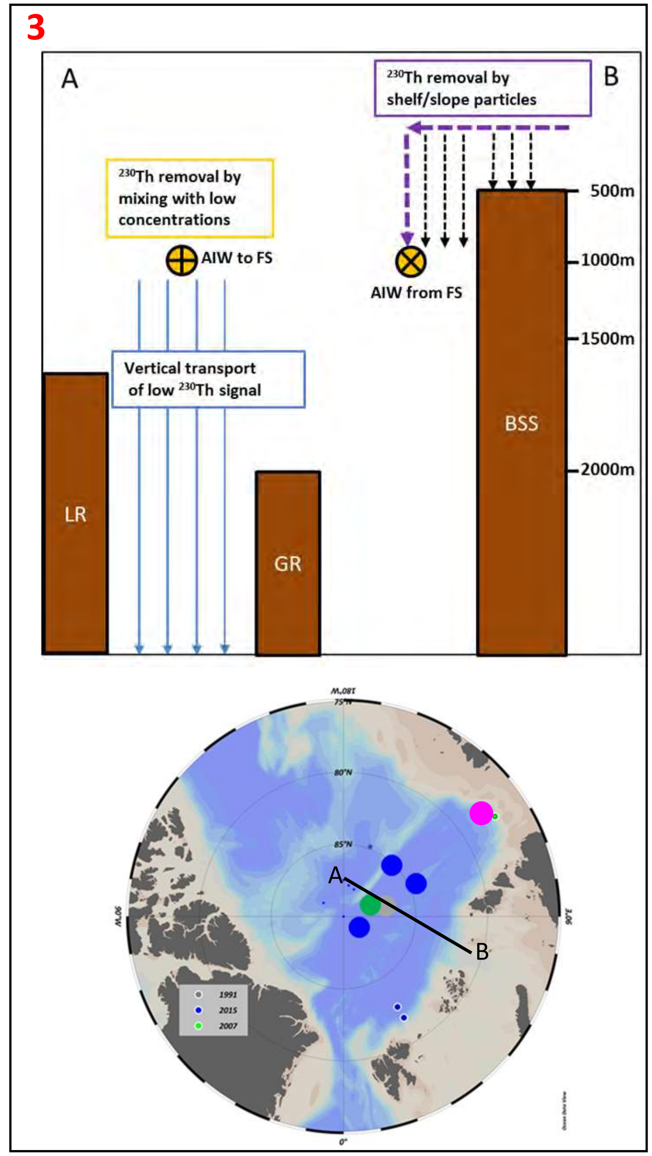

Decrease in ^{230}Th in the Amundsen Basin since 2007: far-field effect of increased scavenging on the shelf?

Ole Valk, Michiel M. Rutgers van der Loeff, Walter Geibert, Sandra Gdaniec, S. Bradley Moran, Kate Lepore, Robert Lawrence Edwards, Yanbin Lu, Viena Puigcorbé, Nuria Casacuberta, Ronja Paffrath, William Smethie, and Matthieu Roy-Barman

Ocean Science
EGU



Take-home message:
Scavenging along inflow passages affects the entire Eurasian Basin.

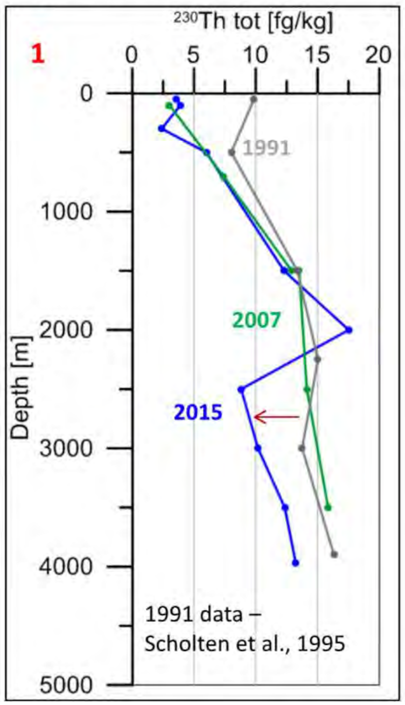


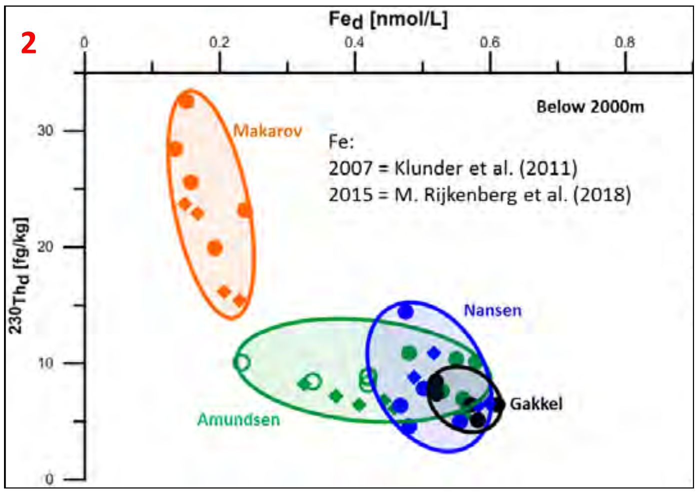
O. VALK et al. (2018), GRL

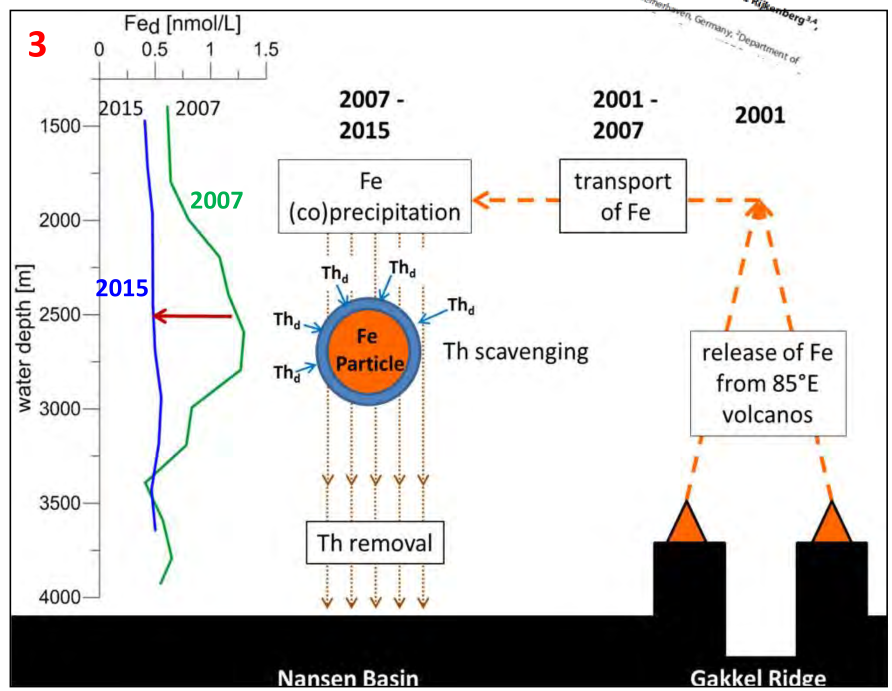
^{230}Th IN THE NANSEN BASIN: Importance of hydrothermal vents in scavenging removal of ^{230}Th.

Ole.valk@awi.de

^{230}Th Nansen Basin 1991- 2015
Hydrothermal scavenging







Take-home message:
Sporadic eruptions cause huge scavenging events in the Nansen Basin.

Valk et al. (2019) https://doi.org/10.5194/os-2019-49

M. Rutgers van der Loeff et al. (2018) JGR

RADIUM ISOTOPES ACCROSS THE ARCTIC OCEAN

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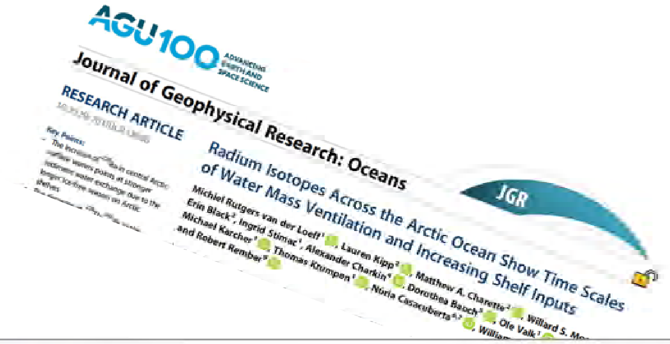
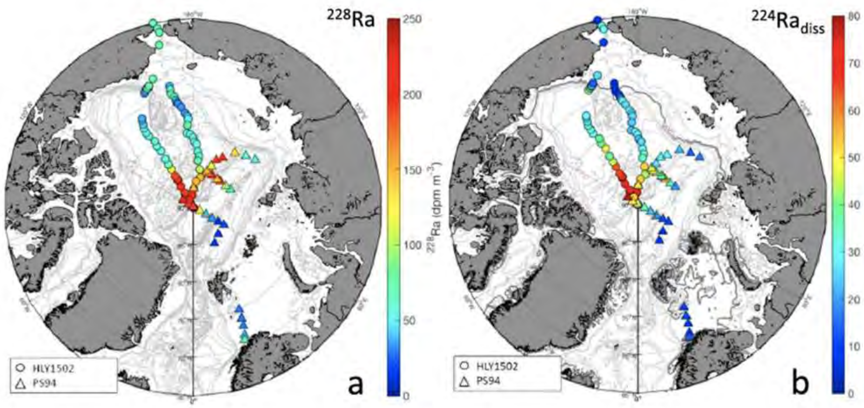
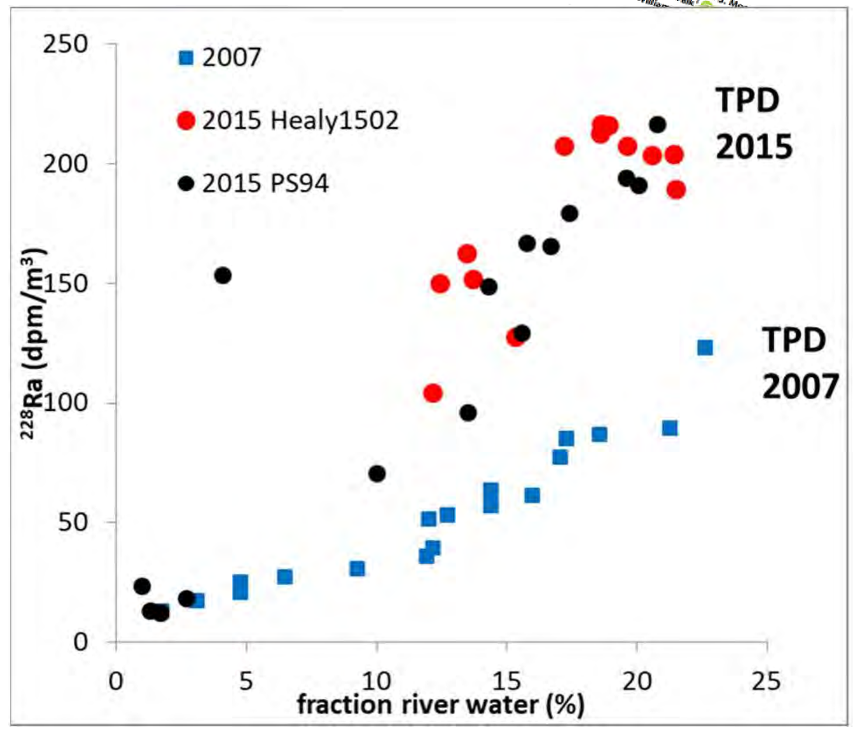

AGU100
Journal of Geophysical Research: Oceans
RESEARCH ARTICLE
Radium Isotopes Across the Arctic Ocean Show Time Scales of Water Mass Ventilation and Increasing Shelf Inputs
Michiel Rutgers van der Loeff, Lauren Kipp, Matthew A. Charette, Willard S. Moore, Erin Black, Ingrid Stimac, Alexander Charkin, Dorothea Bauch, Ole Valk, Michael Karcher, Thomas Krumpen, Núria Casacuberta, William, and Robert Rember
JGR





Take-home messages:

i. **^{228}Ra increased in central Arctic surface water**, likely due to longer ice-free period on shelf and resulting increased wave action

ii. ^{228}Th/^{228}Ra excess (100-1500m depth) linked to export production.

iii. Deep water enrichment of 226Ra implies ventilation times of ca. 480 years in CB/MB, supporting earlier estimates.

M. Rutgers van der Loeff et al. (*in preparation*)

RADIUM ISOTOPES IN THE FRAM STRAIT

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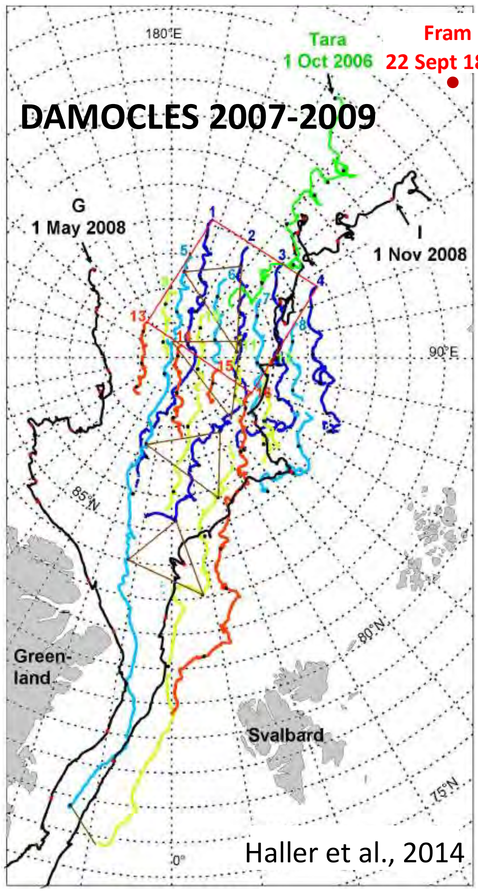
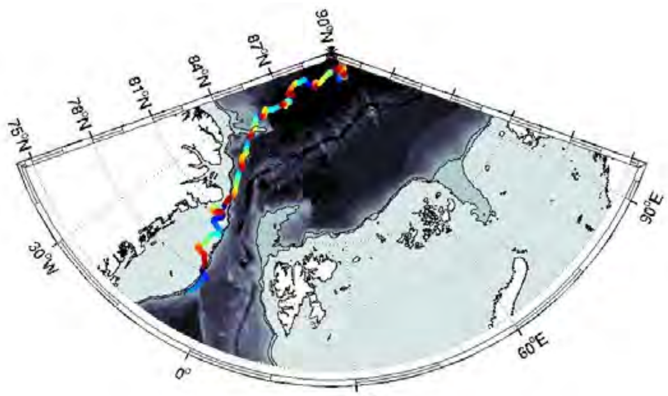
Ice Buoy Trajectories

Do surface waters follow te same route?



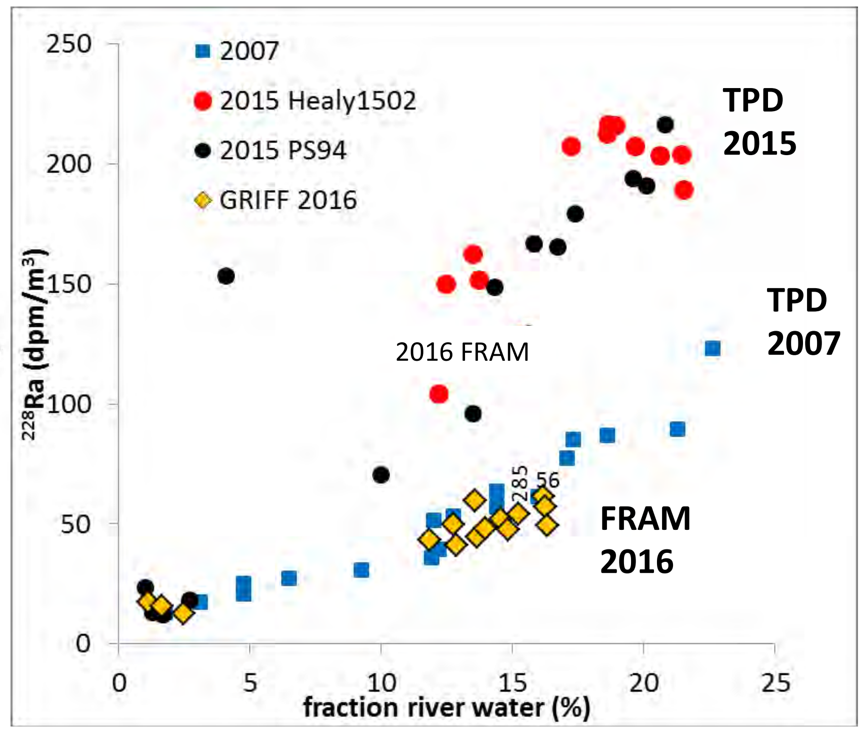
IAOOS16 Ice Tethered Buoy 2015-2016

GN04: Deployment 5 Sept 2015 89°00N, 61°10E
GN05: Recovery 10 Aug 2016 76°43N, 6°20W



Christine Provost, LOCEAN, UPMC

^{228}Ra in FRAM Strait 2016:



shelf and glacier stations removed

M. Rutgers van der Loeff et al. (*in preparation*)

RADIUM ISOTOPES IN THE FRAM STRAIT

mloeff@awi.de

Ice Buoy Trajectories

Do surface waters
follow te same route?

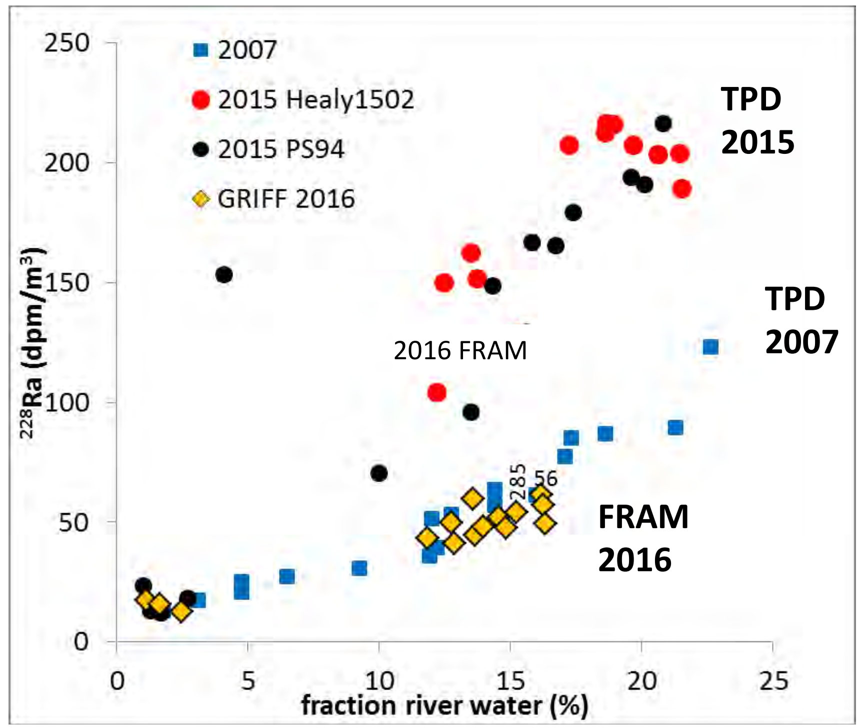
Why is ^{228}Ra so low in the FRAM Strait/ East Greenland Current?

- decay?
  ^{129}I and ^{236}U data:
  age difference is just 2 years:
  decay insufficient
- Admixture of recirculating water from Fram Strait or Nansen Basin?
  ^{129}I and ^{236}U data:
  incompatible
- Admixture of aged low-^{228}Ra water from Canada Basin?
  found there by
  Kipp et al., JGR-O, 2019
  likely

Take-home messages:

i. Surface waters (PSW) in the TPD do not follow the ice track neither in speed nor in direction.
ii. The EGC contains 30% less ^{228}Ra as expected from transport and radioactive decay, probably due to dilution with aged Surface waters from Canada Basin.

^{228}Ra in FRAM Strait 2016:



shelf and glacier stations removed

N. CASACUBERTA et al. (*2018*) JGR + new data from US cruise

^{129}I AND ^{236}U IN THE ARCTIC OCEAN 2015 – PS94 + US HEALY.

ETH Zürich

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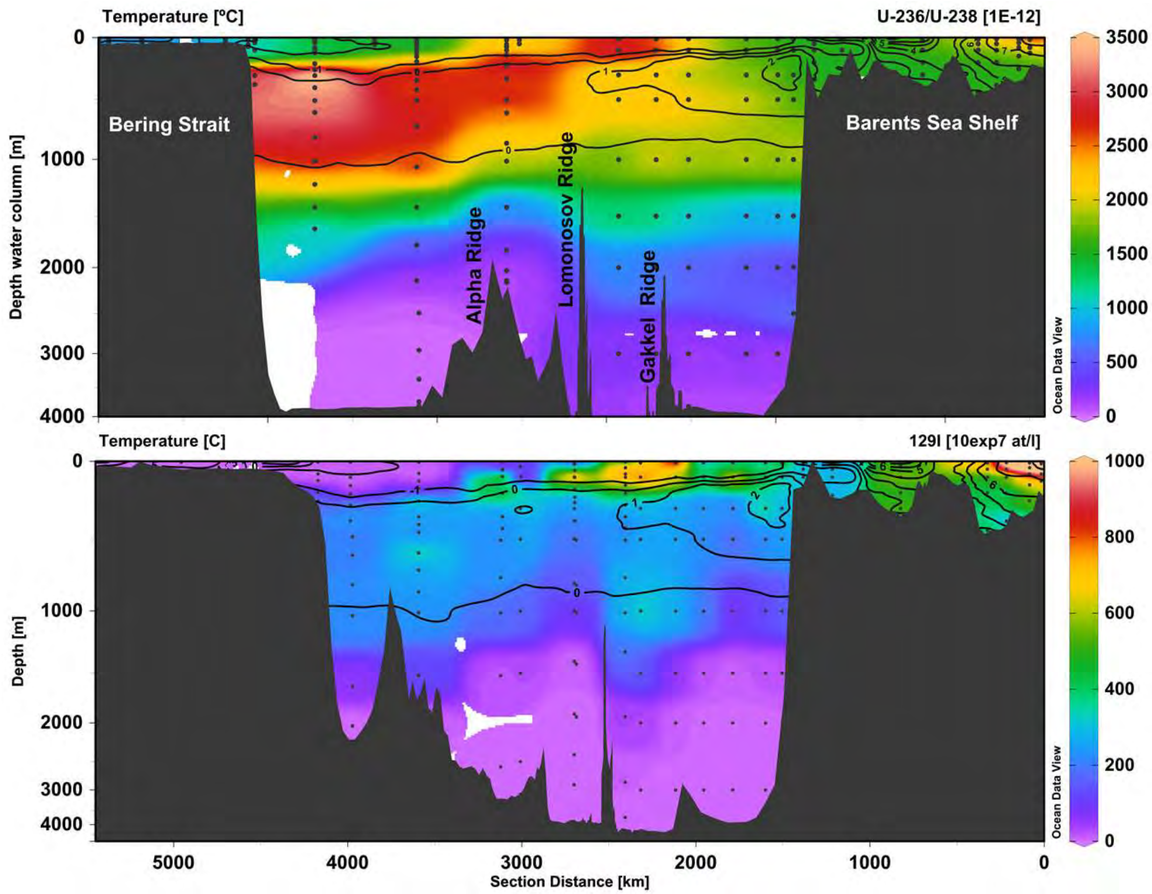
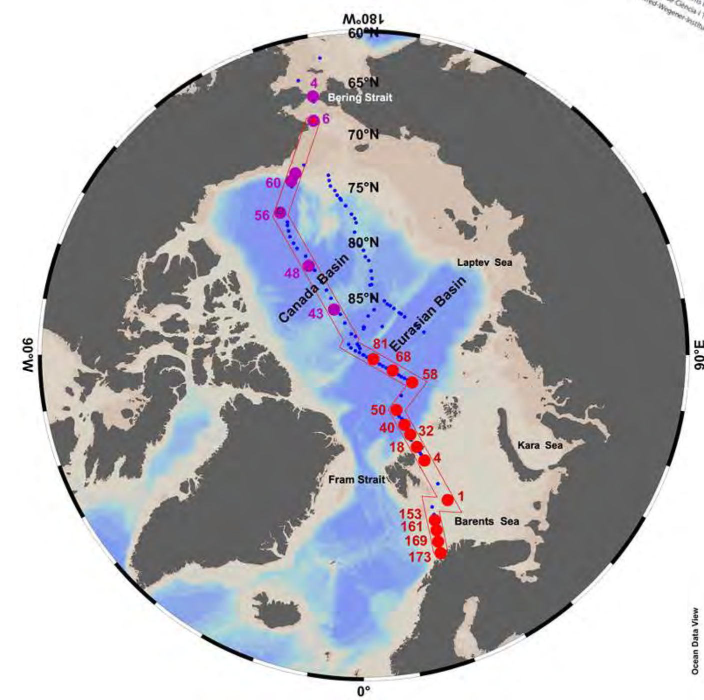
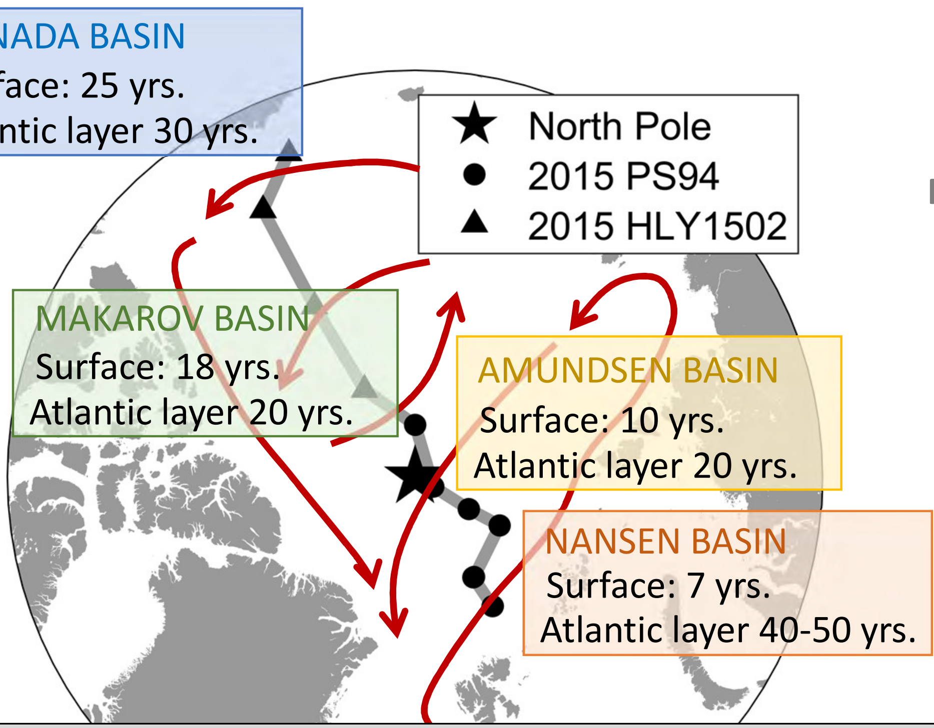
AGU100 ADVANCING EARTH AND SPACE SCIENCE
Journal of Geophysical Research: Oceans
RESEARCH ARTICLE
Tracing the Three Atlantic Branches Entering the Arctic Ocean With ^{129}I and ^{236}U
N. Casacuberta[1,2], M. Christl[1], C. Vockenhuber[1], A.-M. Wefing[1,2], L. Wacker[1], P. Masqué[3,4], H.-A. Synal[1], and M. Rutgers van der Loeff[5]
[1]Laboratory of Ion Beam Physics, ETH Zurich, Zurich, Switzerland, [2]Institute of Biogeochemistry and Pollutant Dynamics, Environmental Physics, ETH Zurich, Zurich, Switzerland, [3]School of Science, Centre for Marine Ecosystems Research, Edith Cowan University, Joondalup, Western Australia, Australia, [4]Departament de Física and Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, Bellaterra, Spain, [5]AWI-Geochemistry, Alfred-Wegener-Institut
JGR



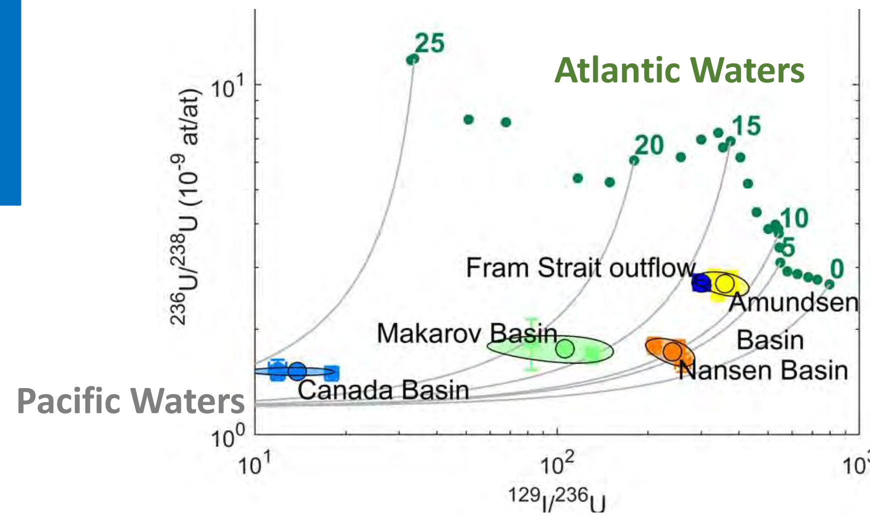


A.M. WEFING et al. (*in prep*) + new data from US cruise (E. Chamizo, M. Lopez-Lora, T. Kenna, J. Smith)

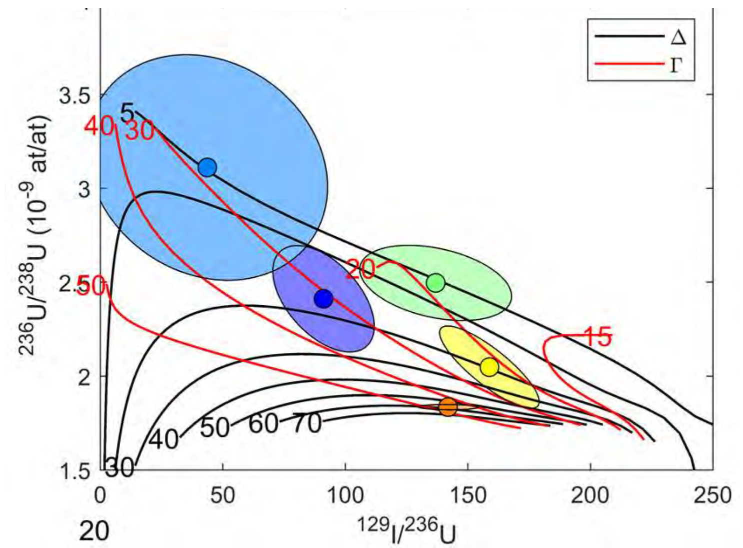
^{129}I AND ^{236}U IN THE ARCTIC OCEAN 2015.



POLAR SURFACE WATERS: binary mixing model



ATLANTIC LAYER: Transit Time Distribution (TTD)



Take-home messages:

i) Shorter circulation times in PSW compared to AL.

ii) Mean ages in the Nansen Basin are the greatest → dilution.

Wefing et al. (2021) https://doi.org/10.5194/os-17-111-2021

A-M. WEFING et al. (*2019*) JGR

^{129}I and ^{236}U in the FRAM STRAIT: 2016 - 2018

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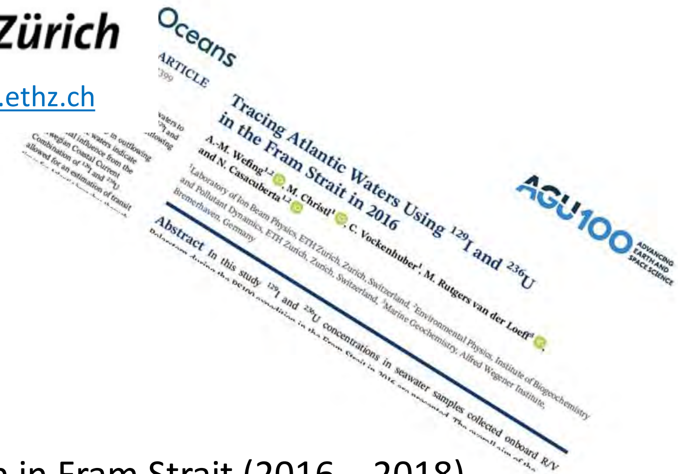
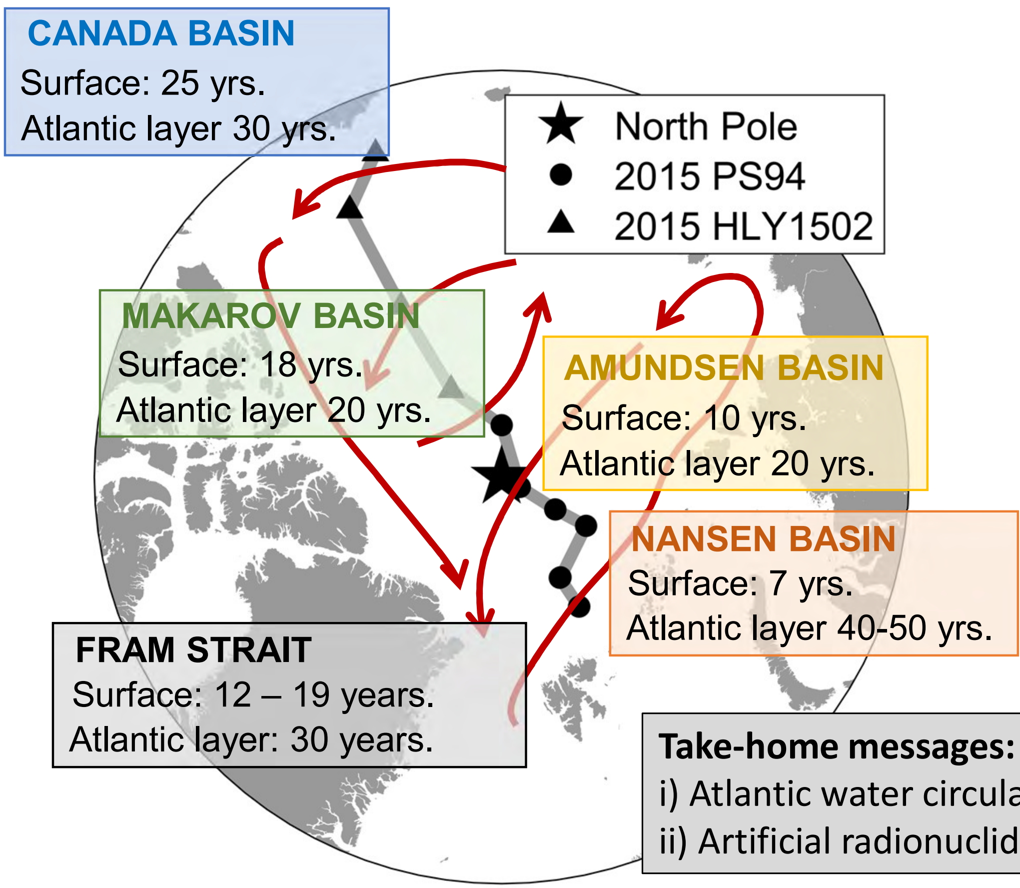
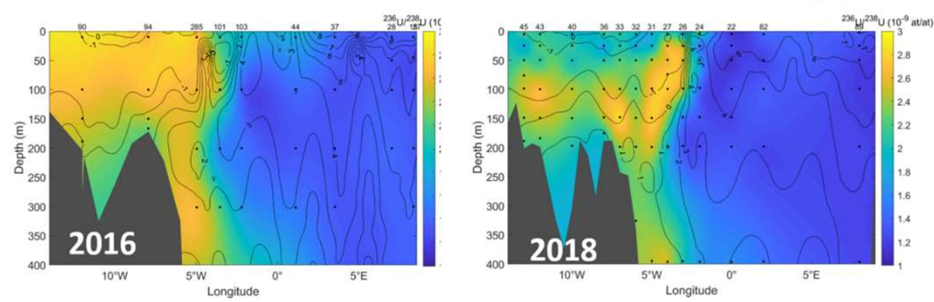




^{236}U distribution in Fram Strait (2016 – 2018)



Take-home messages:

i) Atlantic water circulation times to Fram Strait constrained for the first time.

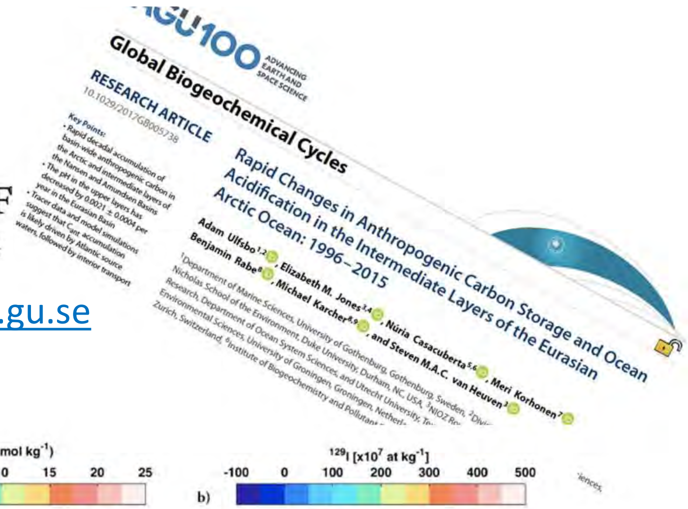
ii) Artificial radionuclides as tracers of Pacific Waters (freshwaters) in the FS.

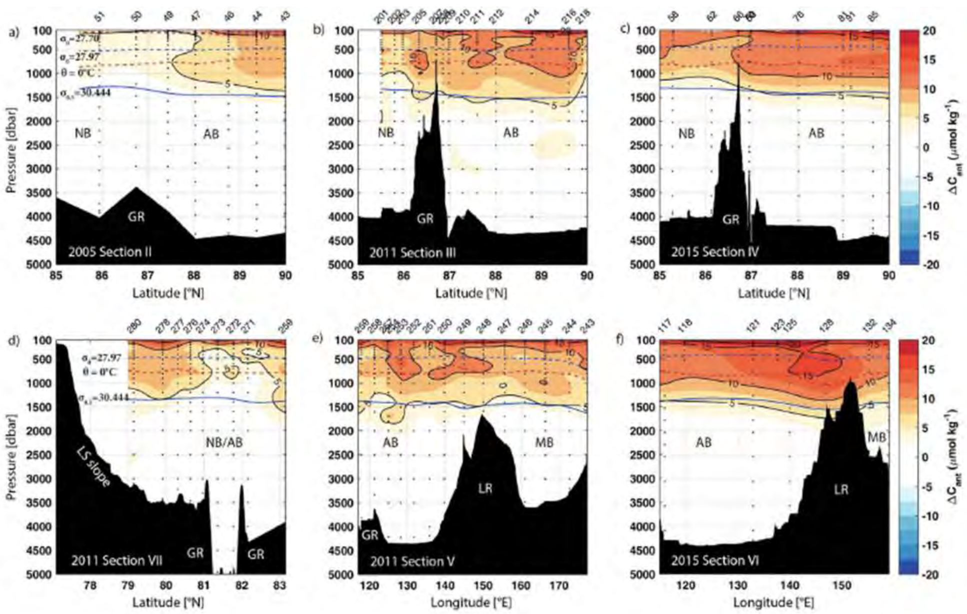
A. ULFSBO et al. (2018), GBC

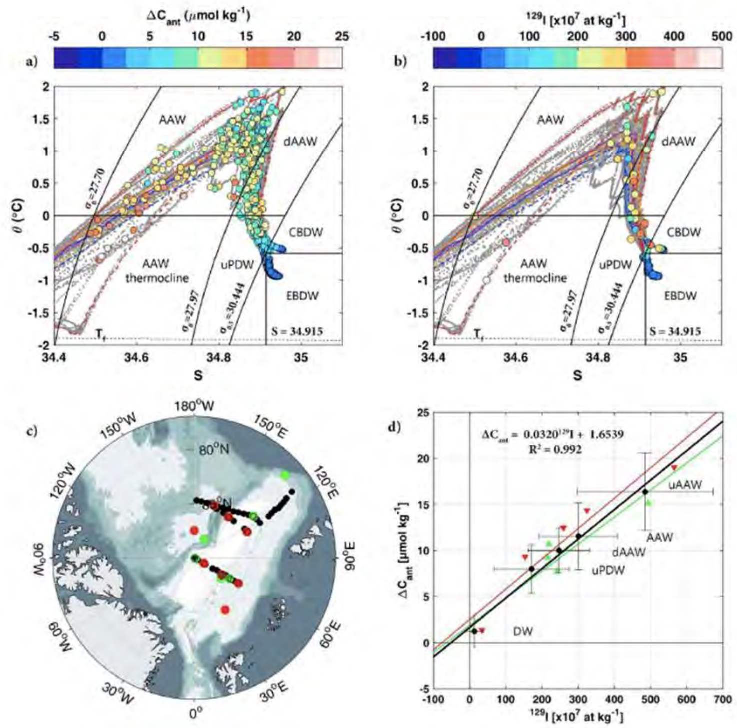
CHANGES IN ANTHROPOGENIC CARBON STORAGE

UNIVERSITY OF GOTHENBURG

adam.ulfsbo@marine.gu.se





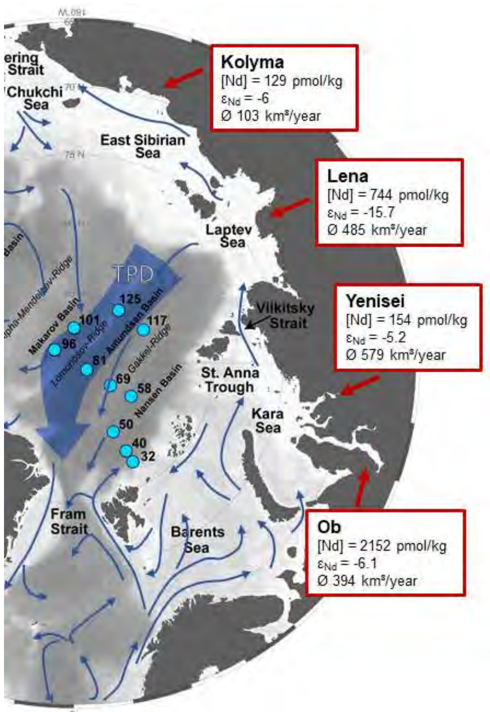


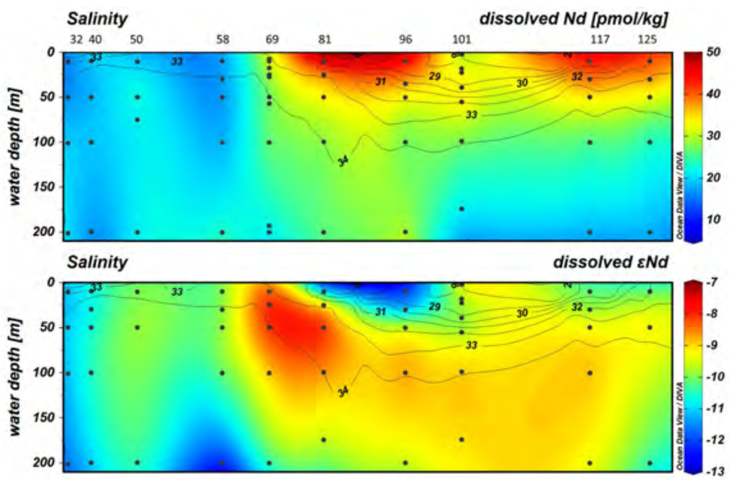
Take-home message:
increase of anthropogenic carbon in the intermediate layers of Eurasian Basin → increaseing concentrations of anthropogenic carbon in source waters of Atlantic origin entering the Arctic Ocean.

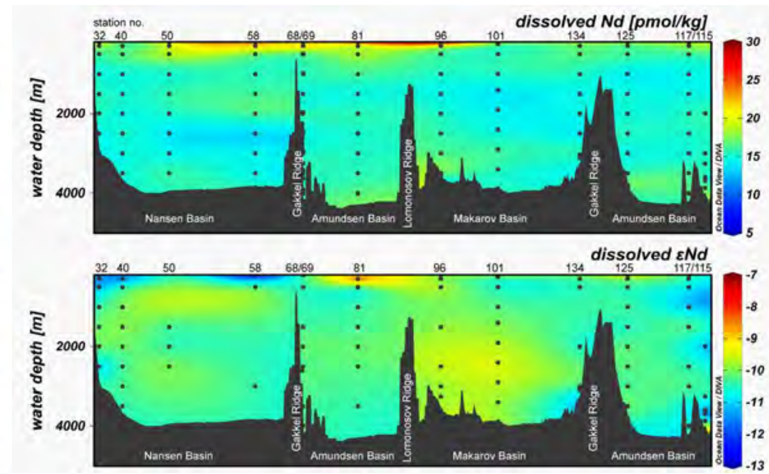
R. PAFFRATH, K. PAHNKE (not published)

Rare Earth Elements (REE) and ε_{Nd}, GEOTRACES GN04 section

(ICBM, University of Oldenburg)
ronja.paffrath@uni-oldenburg.de







Surface:

- Exceptionally high surface [REE] in the Transpolar Drift indicate transport of REE from Siberian rivers
- Diverse εNd allows to distinguish between the different river sources

Deep waters:

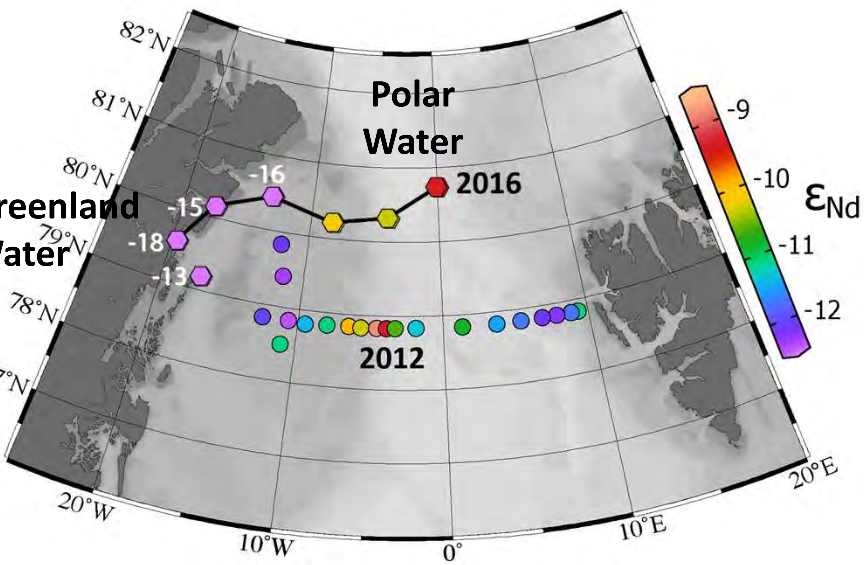
- Constant ε_{Nd} signatures are due to similar source water ε_{Nd} signatures and little release of REEs from particles.
- Uniform[REE] at >500 m water depth reflect: i) deep water mixing times shorter than REE residence time; ii) no or low net release from particles.

Paffrath, R., Laukert, G., Bauch, D., Rutgers van der Loeff, M., Pahnke, K., 2021. Separating individual contributions of major Siberian rivers in the Transpolar Drift of the Arctic Ocean. Sci. Rep. 11, 8216. https://doi.org/10.1038/s41598-021-86948-y.
Paffrath, R., Pahnke, K., Böning, P., Rutgers van der Loeff, M., Valk, O., Gdaniec, S., Planquette, H., 2021. Seawater-Particle Interactions of Rare Earth Elements and Neodymium Isotopes in the Deep Central Arctic Ocean. Journal of Geophysical Research: Oceans 126, e2021JC017423. https://doi.org/10.1029/2021JC017423.

G. Laukert et al. (in prep.); Laukert et al. (2017)

TRACING POLAR WATERS WITH NEODYMIUM ISOTOPES

GEOMAR
glaukert@geomar.de

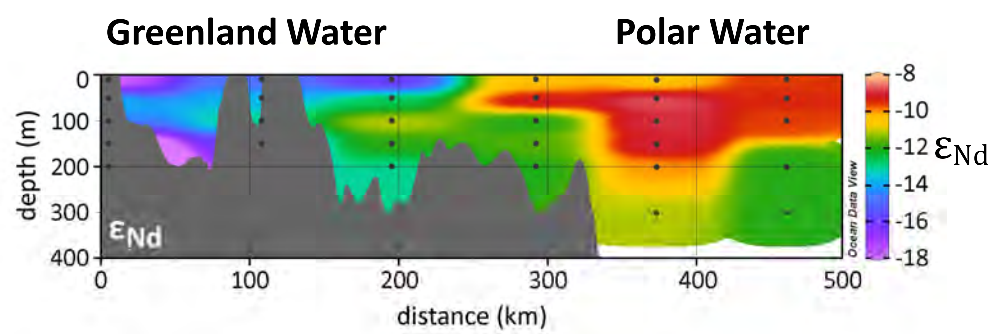


M.Sc. study by Jan Dreyer (2018):

Water mass mixing and freshwater inputs on the North-East Greenland shelf derived from dissolved neodymium isotopes and rare earth elements

B.Sc. study by Florian Schreiber (2018):

Radiogenic neodymium isotopes as tracers of water masses advected to the Fram Strait



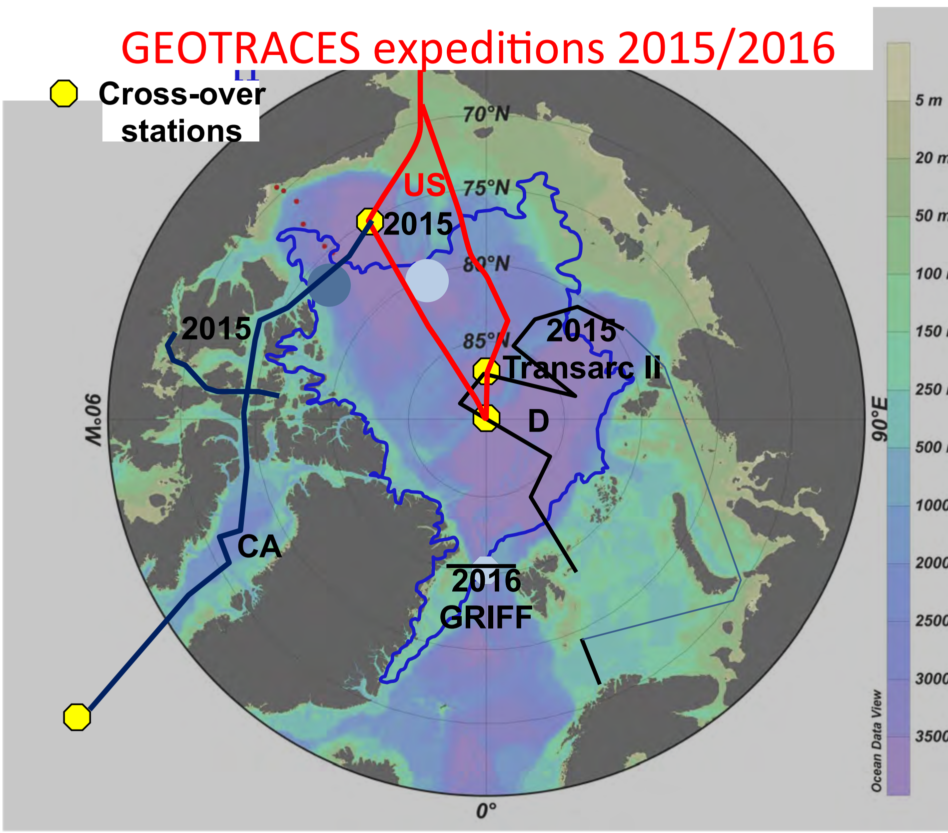
Take-home messages:

i) Nd isotopes allow identification of Arctic-derived and Greenland-derived (fresh)waters

ii) Nd isotope data do not comply with water mass analyses based on nutrient relations

New contact information: georgi.laukert@dal.ca

General compilation



CIRCULATION TRACERS
- ^{228}Ra, ^{236}U, ^{129}I → circulation times.
- ΔC_{ant}, ^{129}I → atlantification

WATER MASS SOURCES
- ^{228}Ra, ^{236}U, ^{129}I → circulation times.
- εNd, $^{129}I/^{236}U$ → Atlantic vs. Pacific waters, rivers.
- ^{228}Ra → shelf waters.

PARTICLE EXPORT PROCESSES
- pHg, ^{230}Th, ^{228}Th, ^{234}Th

TEIs BIOGEOCHEMISTRY ?
(Hans Slagter)

Royal NIOZ is part of the institutes organisation of NWO, in cooperation with Utrecht University

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Royal Netherlands Institute for Sea Research

Preliminary ICP-MS data expedition PS94

Gerringa, L.J.A.; Middag, R.; Laan, P.; Rutgers vd Loeff, M., Slagter, H.A.*; Rijkenberg, M.J.A.

Chief scientist PS94: Ursula Schauer

* Current affiliation: Max Planck Institute for Chemistry, Mainz, Germany

Ocean Sciences 2020 Arctic synthesis workshop, San Diego, CA, USA.

Dissolved Cd, Co, Cu, Fe, Mn, Ni, and Zn in the Arctic Ocean

L. J. A. Gerringa, M. J. A. Rijkenberg, H. A. Slagter, P. Laan, R. Paffrath, D. Bauch, M. Rutgers van der Loeff, R. Middag

https://doi.org/10.1029/2021JC017323

Whole depth profiles

metals in nM/L
nutrients in µM/L

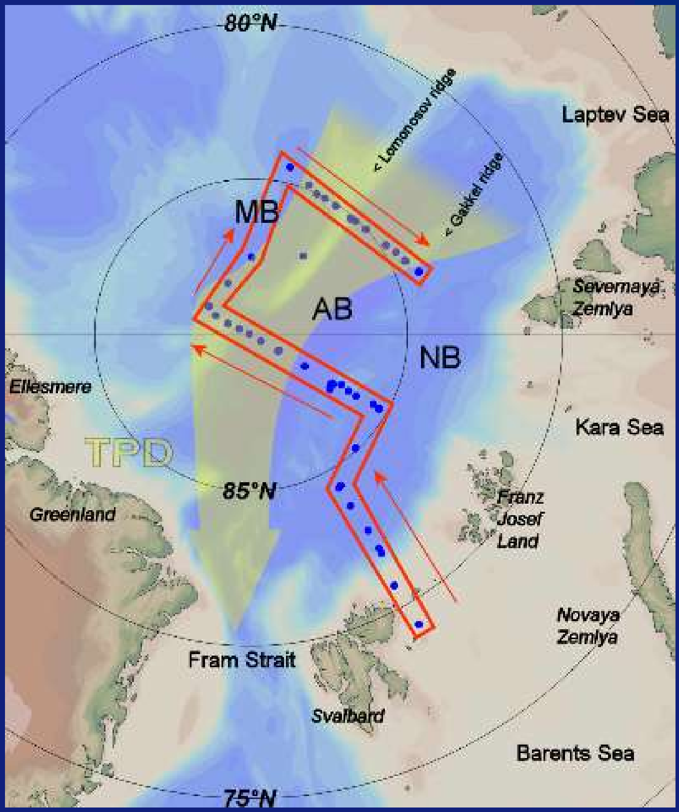
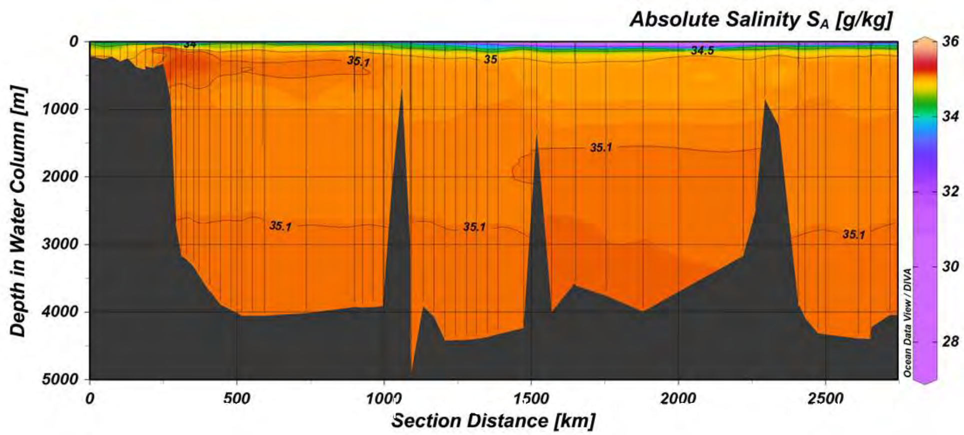
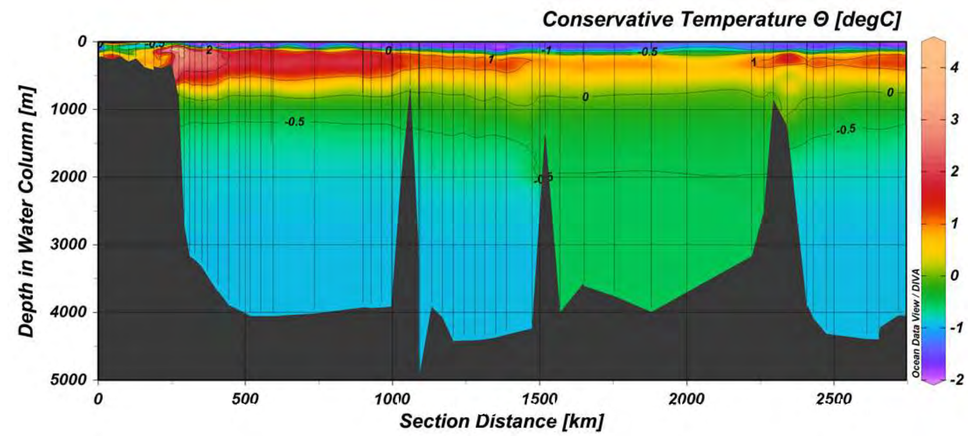


Figure: cruise track in the Central Arctic, crossing the TransPolar Drift (TPD) and the Nansen, Amundsen and Makarov basins (NB, AB, MB, respectively).
Estimated TPD boundary plotted after Slagter et al. (2017).

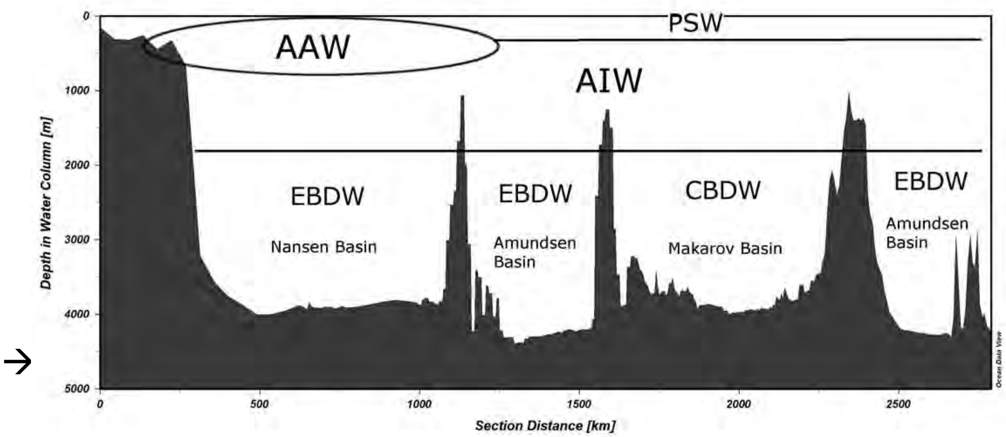
Preliminary ICP-MS data PS94 – Whole depth profiles - Hydrography



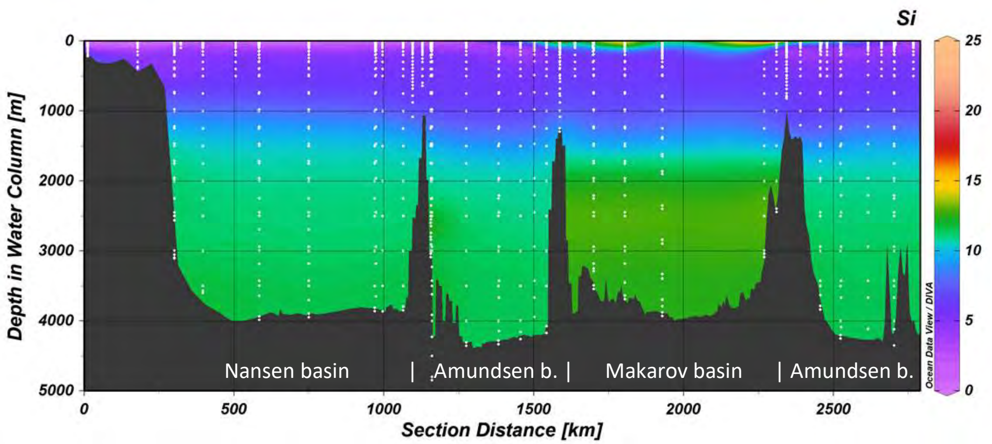


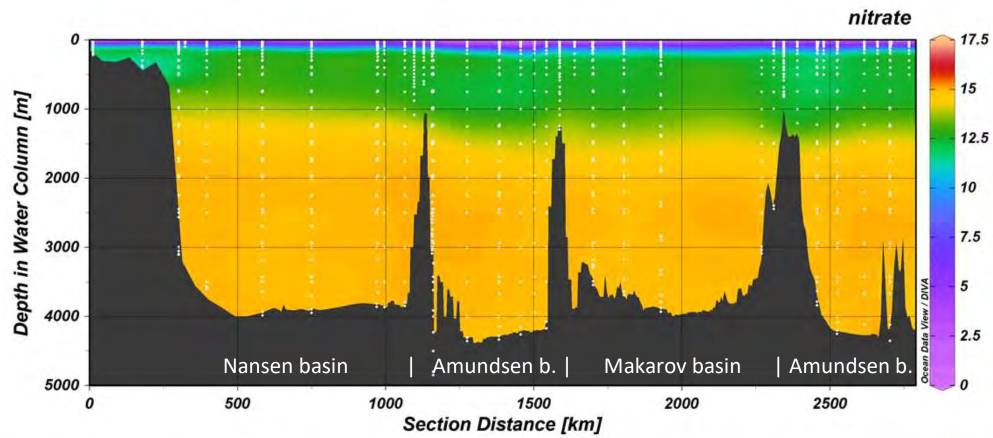
Physical oceanography: Rabe et.al (2016)

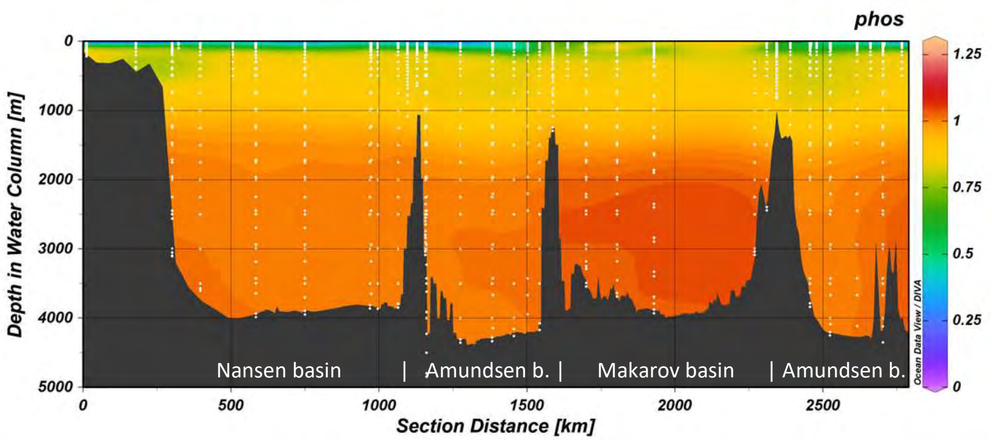
Watermasses referred to after Rudels (2010, 2012) →



Preliminary ICP-MS data PS94 – Whole depth profiles - Nutrients

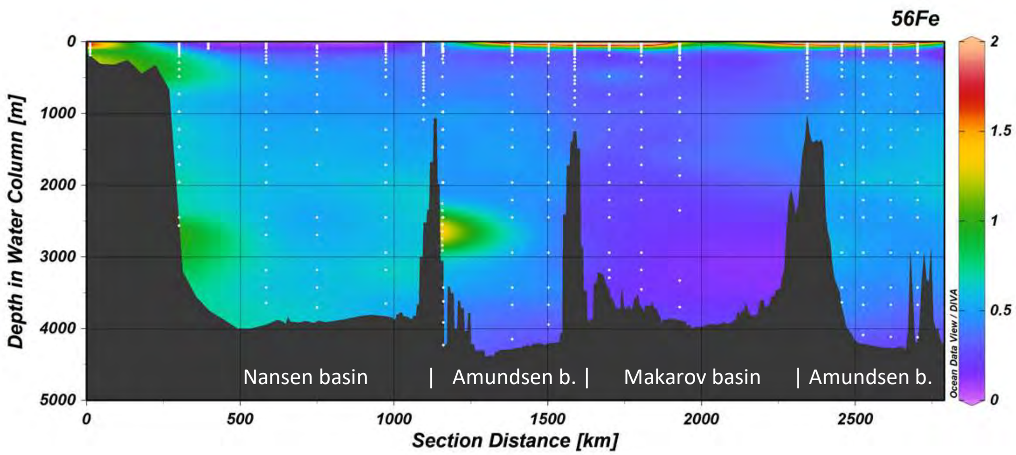


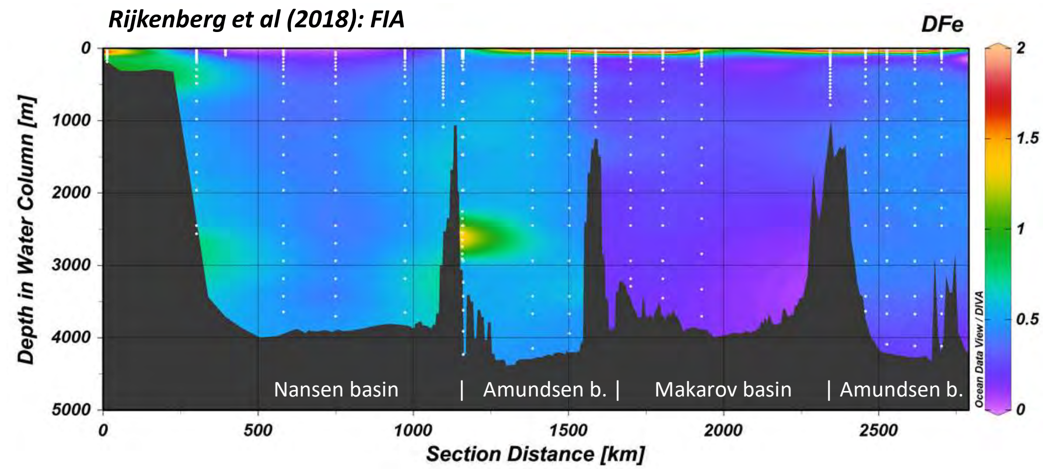


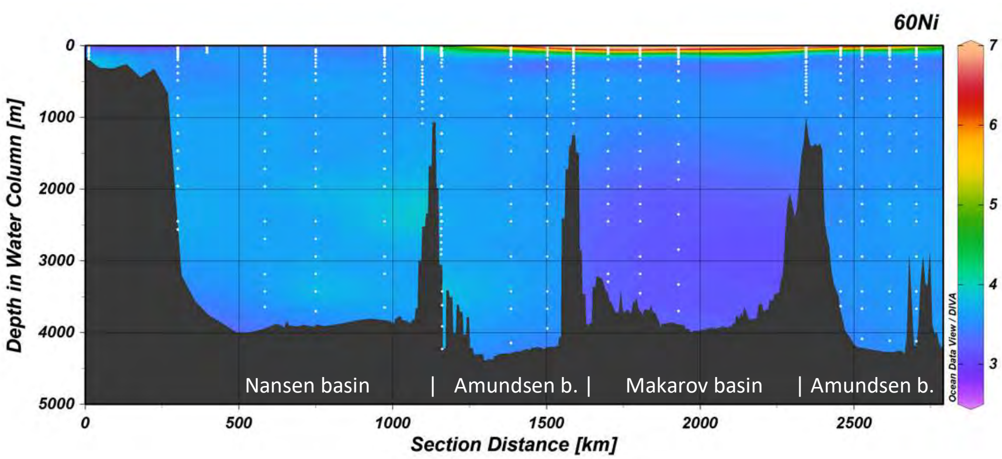


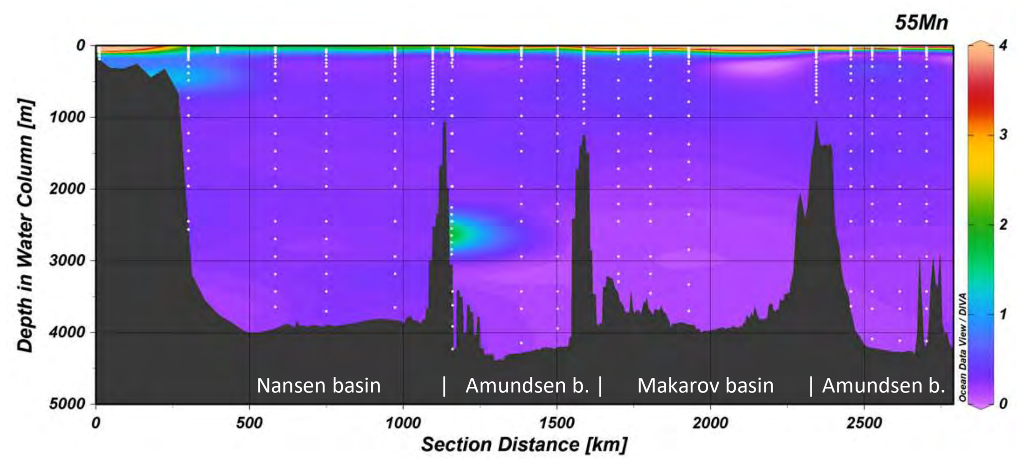
Nutrients: van Ooijen, et al. (2016)

Preliminary ICP-MS data PS94 – Whole depth profiles

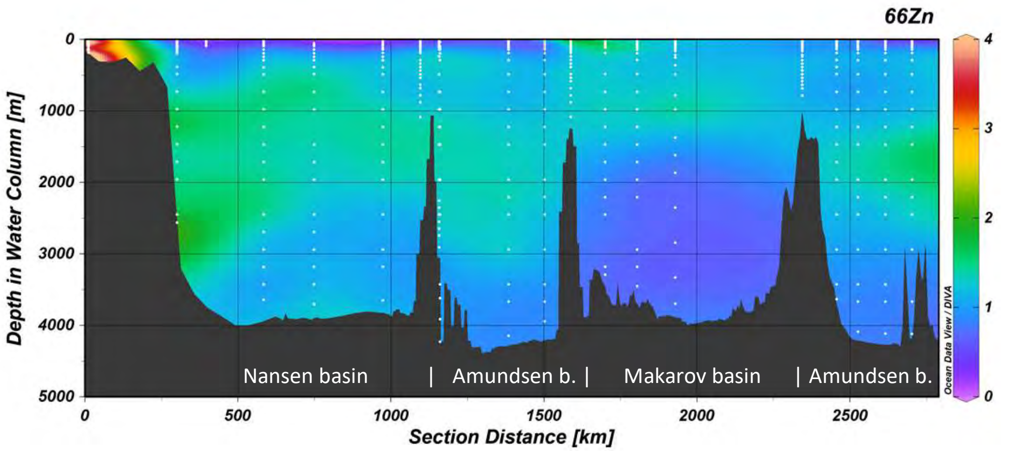


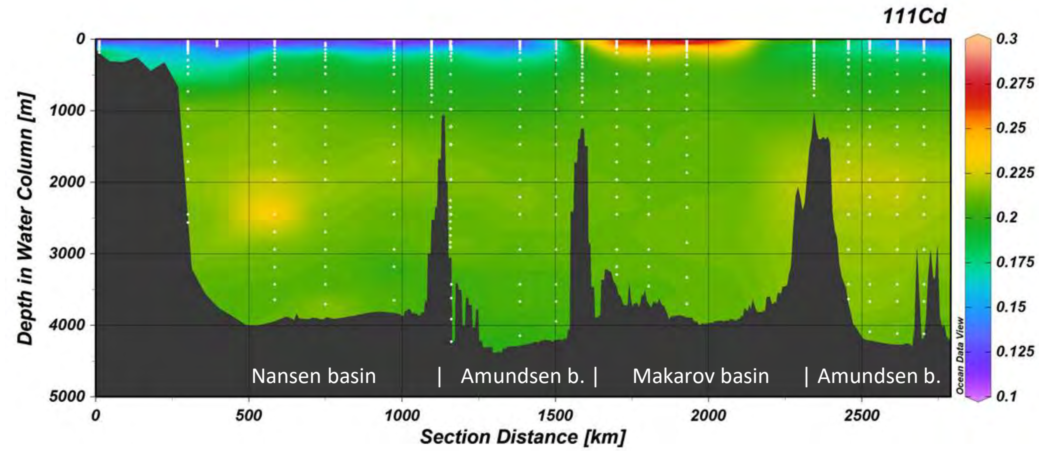


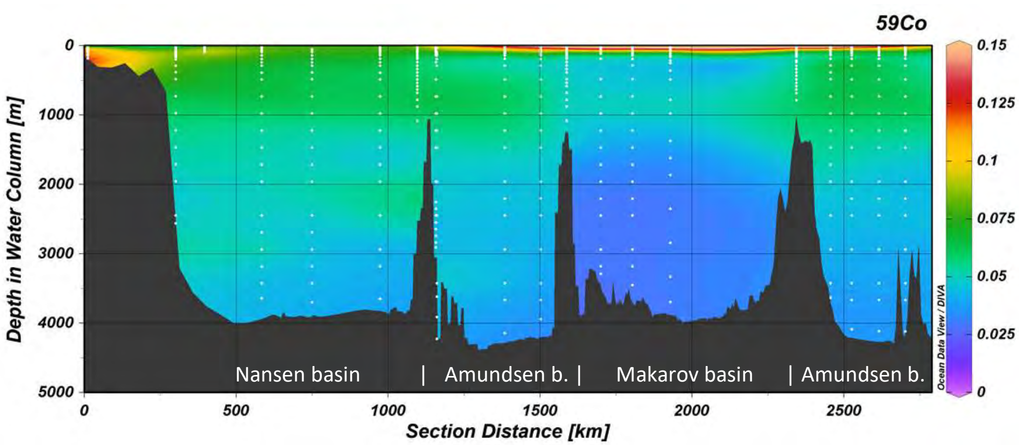


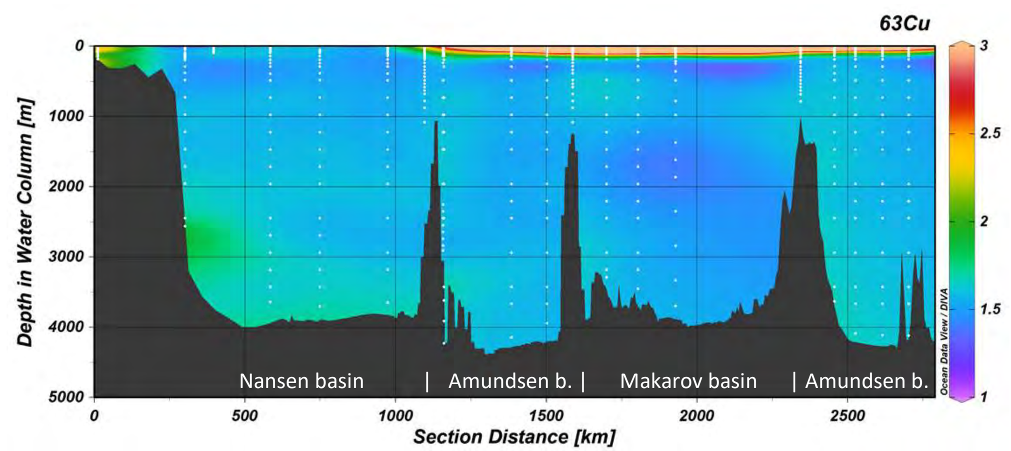


Preliminary ICP-MS data PS94 – Whole depth profiles









Upper 500 m

metals in nM/L
nutrients in µM/L

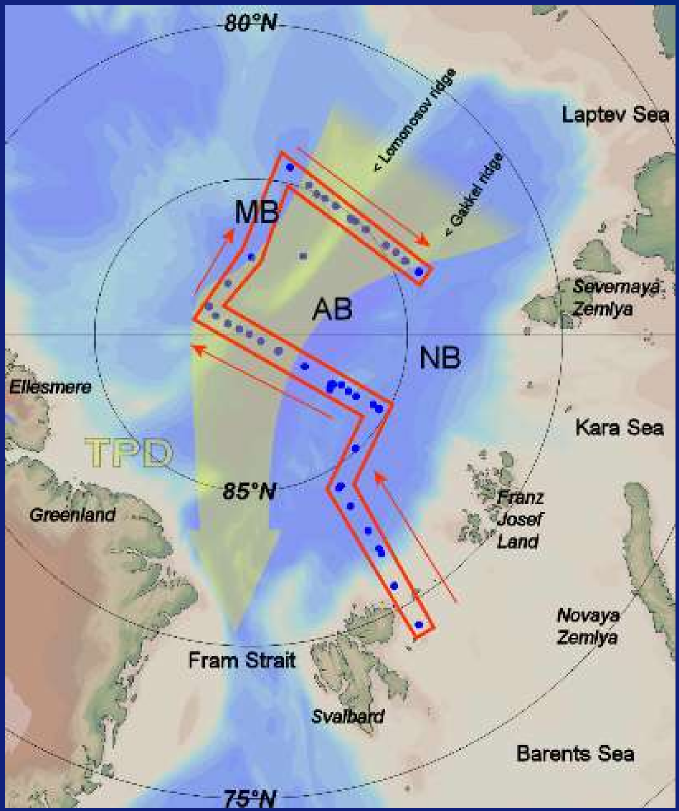
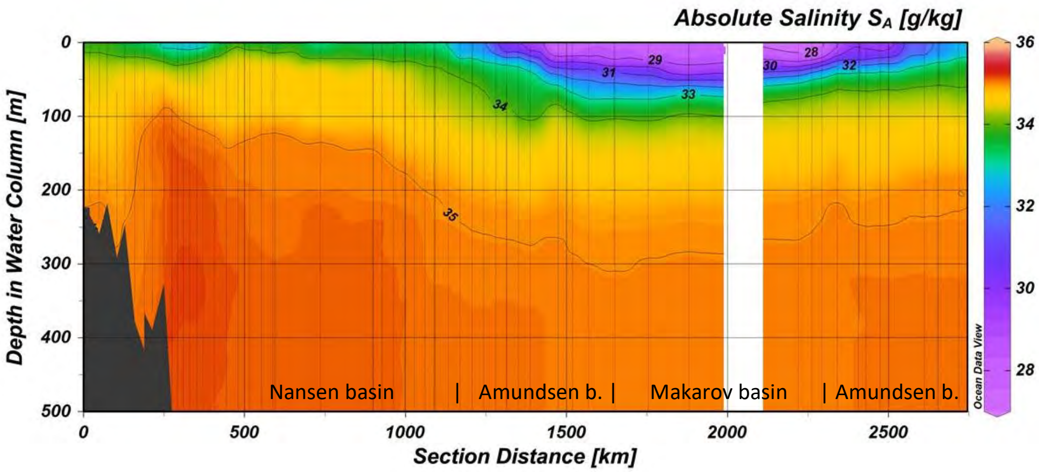
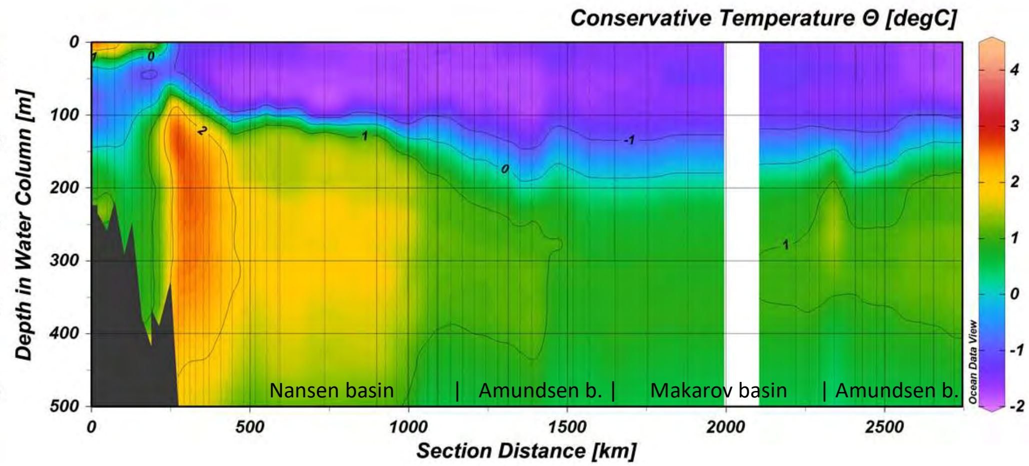


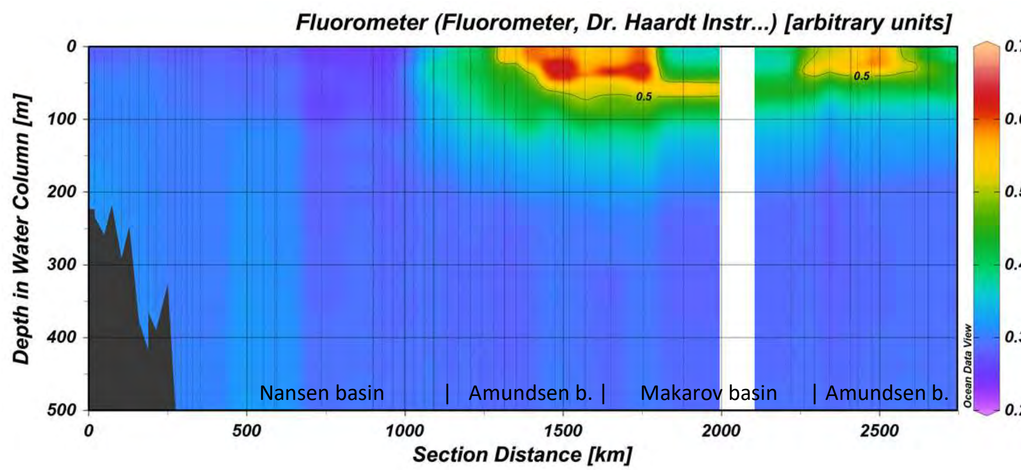
Figure: cruise track in the Central Arctic, crossing the TransPolar Drift (TPD) and the Nansen, Amundsen and Makarov basins (NB, AB, MB, respectively).
Estimated TPD boundary plotted after Slagter et al. (2017).

Preliminary ICP-MS data PS94 – Upper 500 m - Hydrography





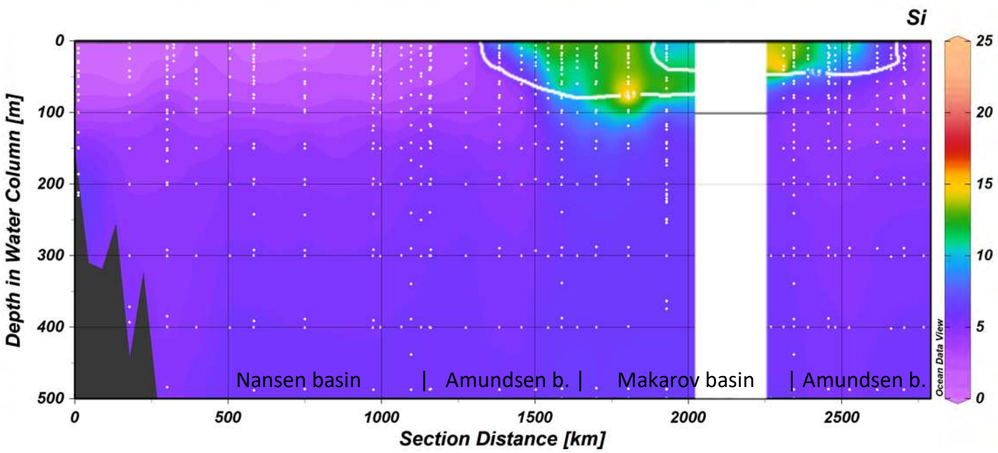
Physical oceanography: Rabe et.al (2016);

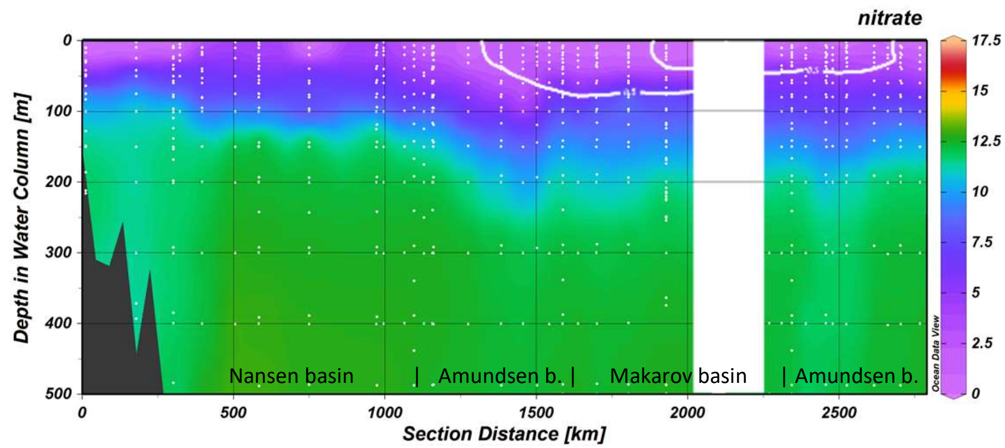


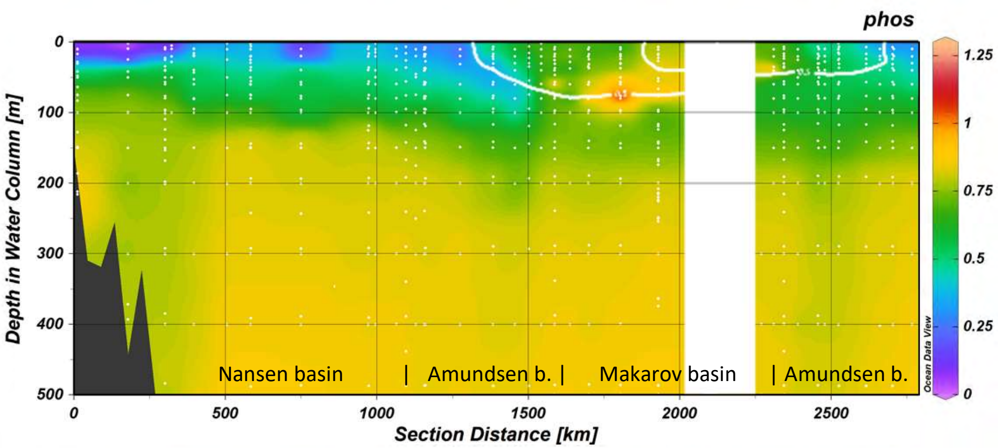
Definition TransPolar Drift = 0.5 au. FDOM; following Slagter et al (2017)

Preliminary ICP-MS data PS94 – Upper 500 m - Nutrients

TPD boundary contour (0.5 a.u. FDOM) after Slagter et al. (2017).



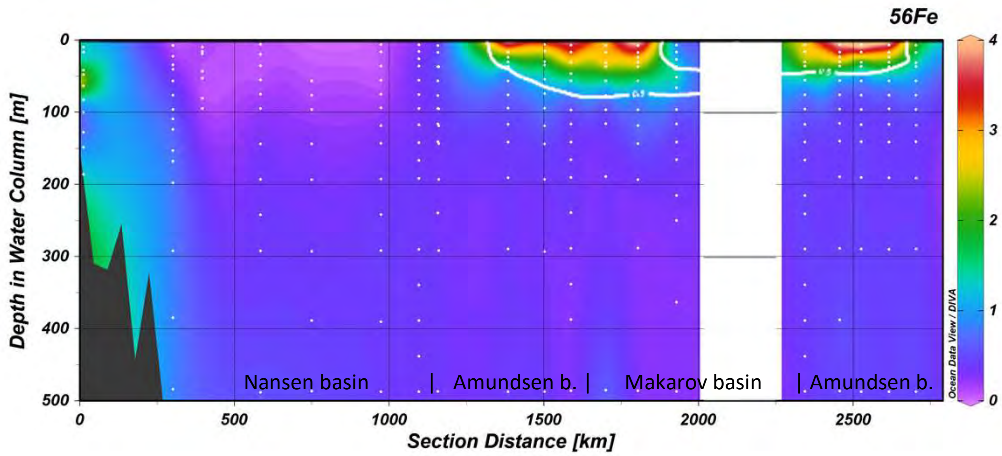


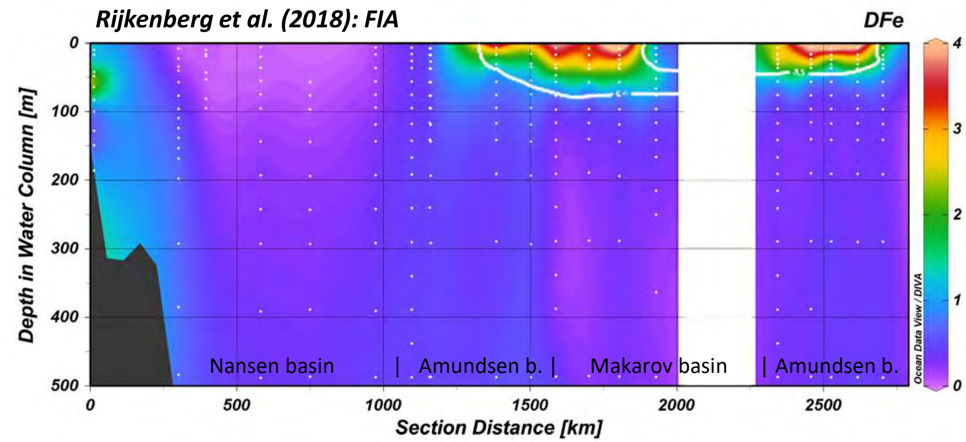


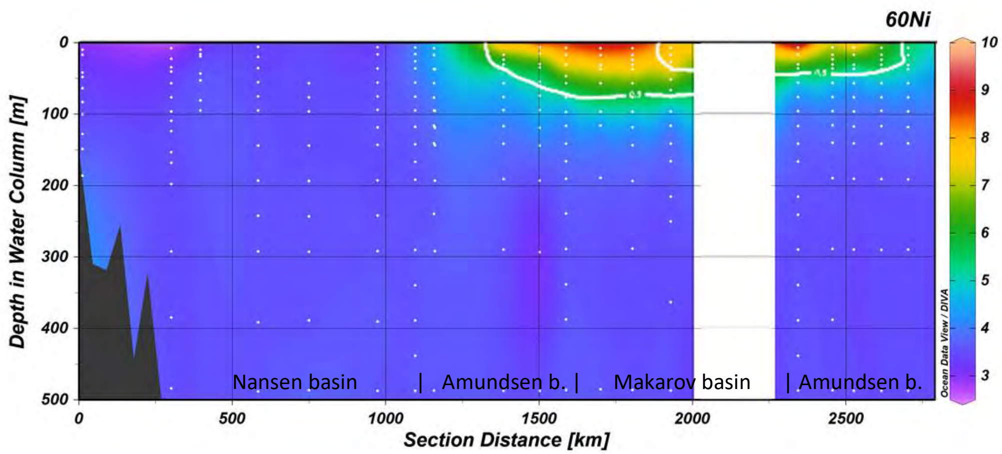
Nutrients: van Ooijen, et al. (2016)

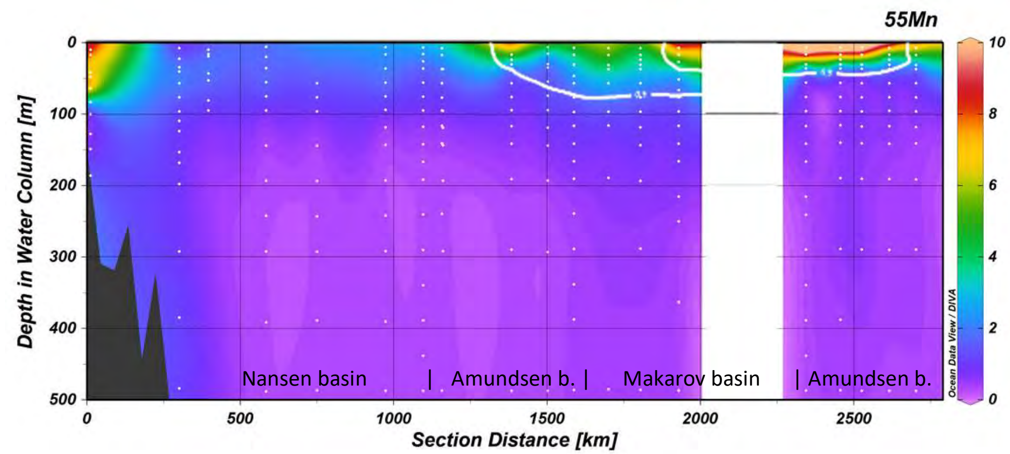
Preliminary ICP-MS data PS94 – Upper 500 m

TPD boundary contour (0.5 a.u. FDOM) after Slagter et al. (2017).



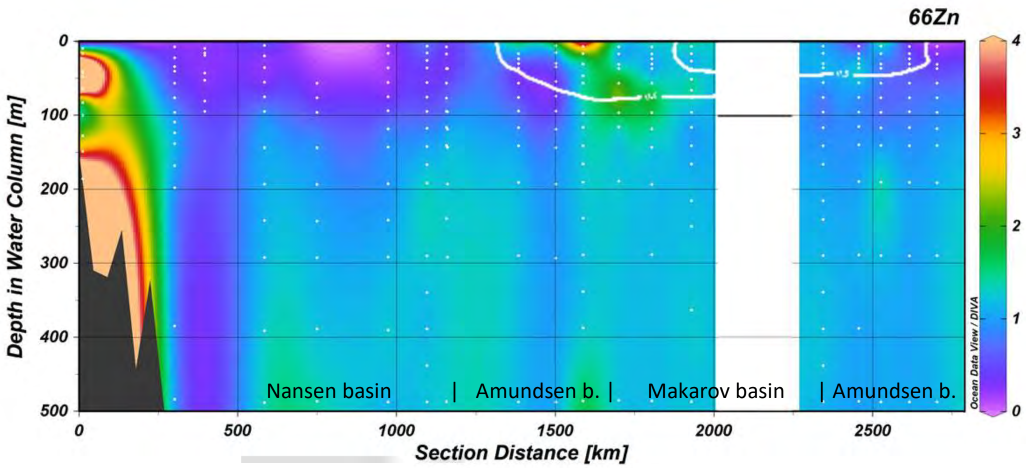


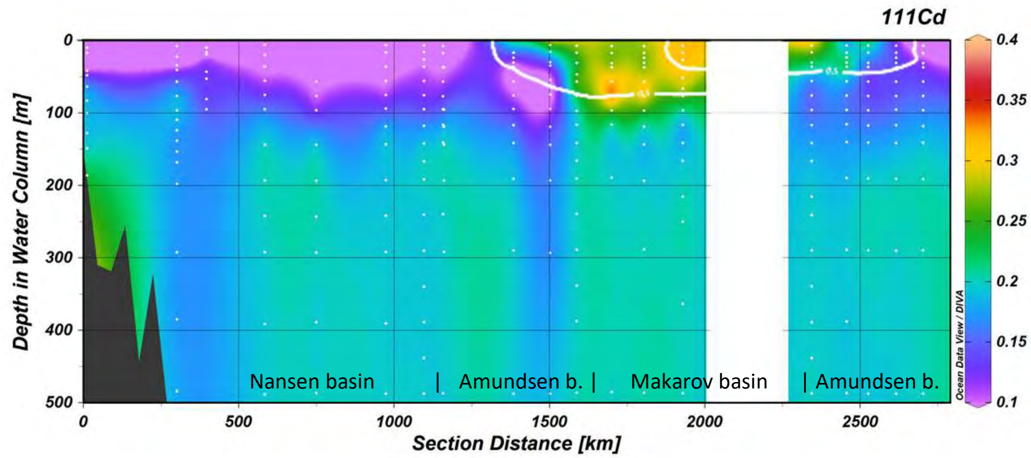


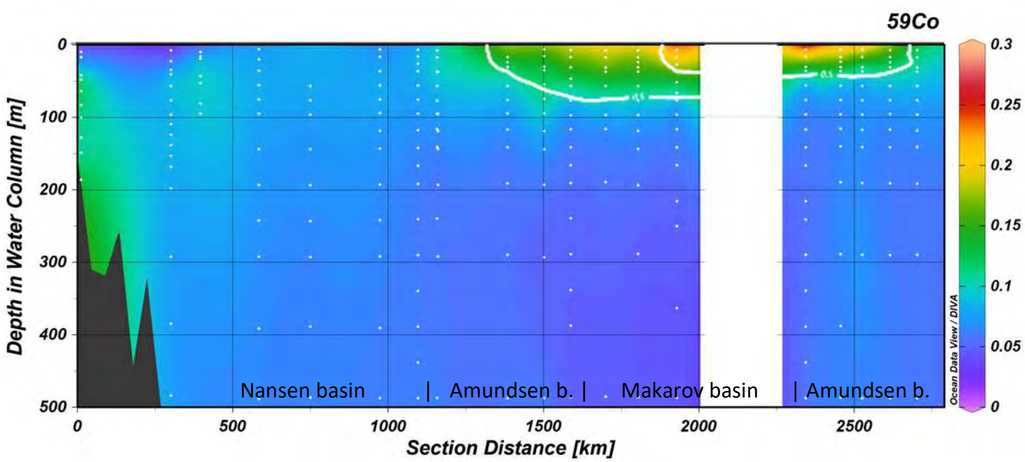


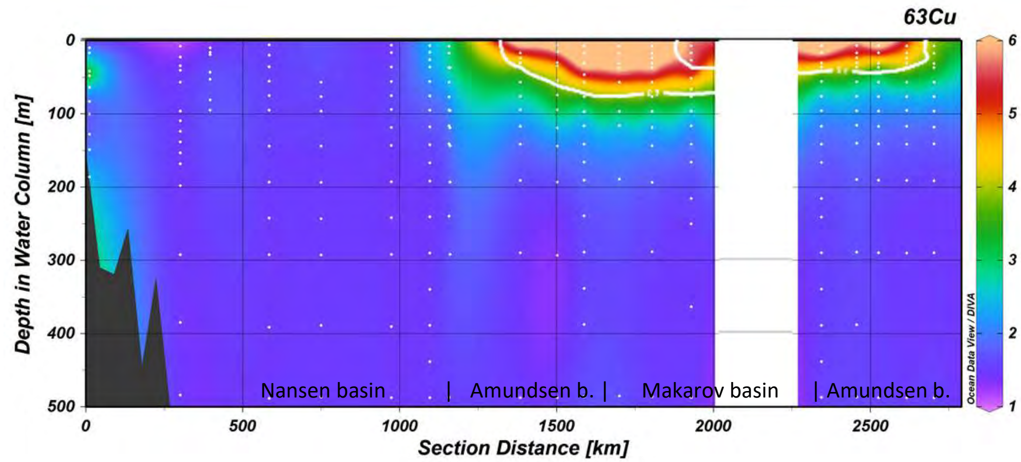
Preliminary ICP-MS data PS94 – Upper 500 m

TPD boundary contour (0.5 a.u. FDOM) after Slagter et al. (2017).









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NIOZ Royal Netherlands Institute for Sea Research
NWO Utrecht University

Thank You

Corresponding author: loes.gerringa@nioz.nl

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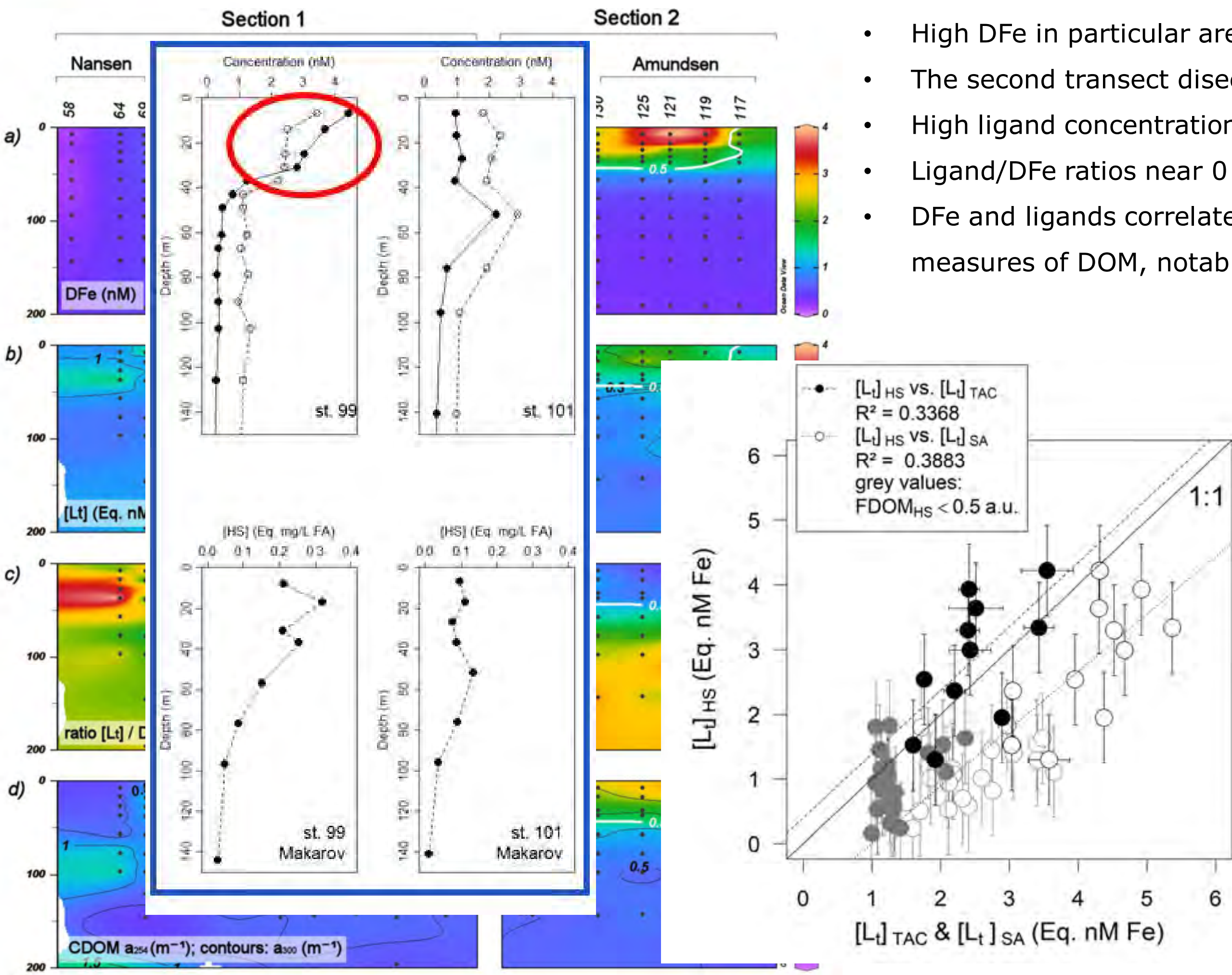
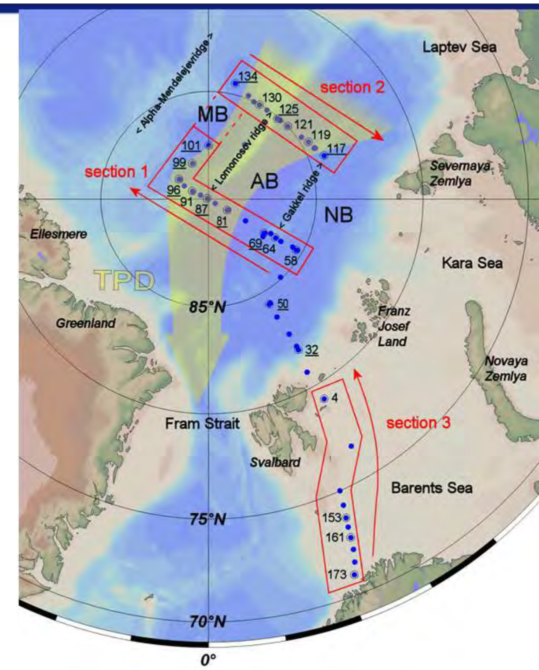
Fe speciation in the Arctic Ocean



- High DFe in particular areas of two transects.
- The second transect disects the TPD.
- High ligand concentrations to bind DFe.
- Ligand/DFe ratios near 0 inside the TPD.
- DFe and ligands correlate strongly with measures of DOM, notably humic substances.



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