Northumbria University NEWCASTLE

AWI

PML Plymouth Marine Laboratory

CACOON

Changing Arctic Carbon cycle in the cOastal Ocean Near-shore project

by the **CACOON** team:

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Olga Ogneva

PhD student

Dr Paul Overduin

Co-investigator

Dr Juri Palmtag

Postdoctoral researcher

Dr Ricardo Torres

Co-investigator

Changing Arctic Ocean

Natural Environment Research Council

SPONSORED BY THE

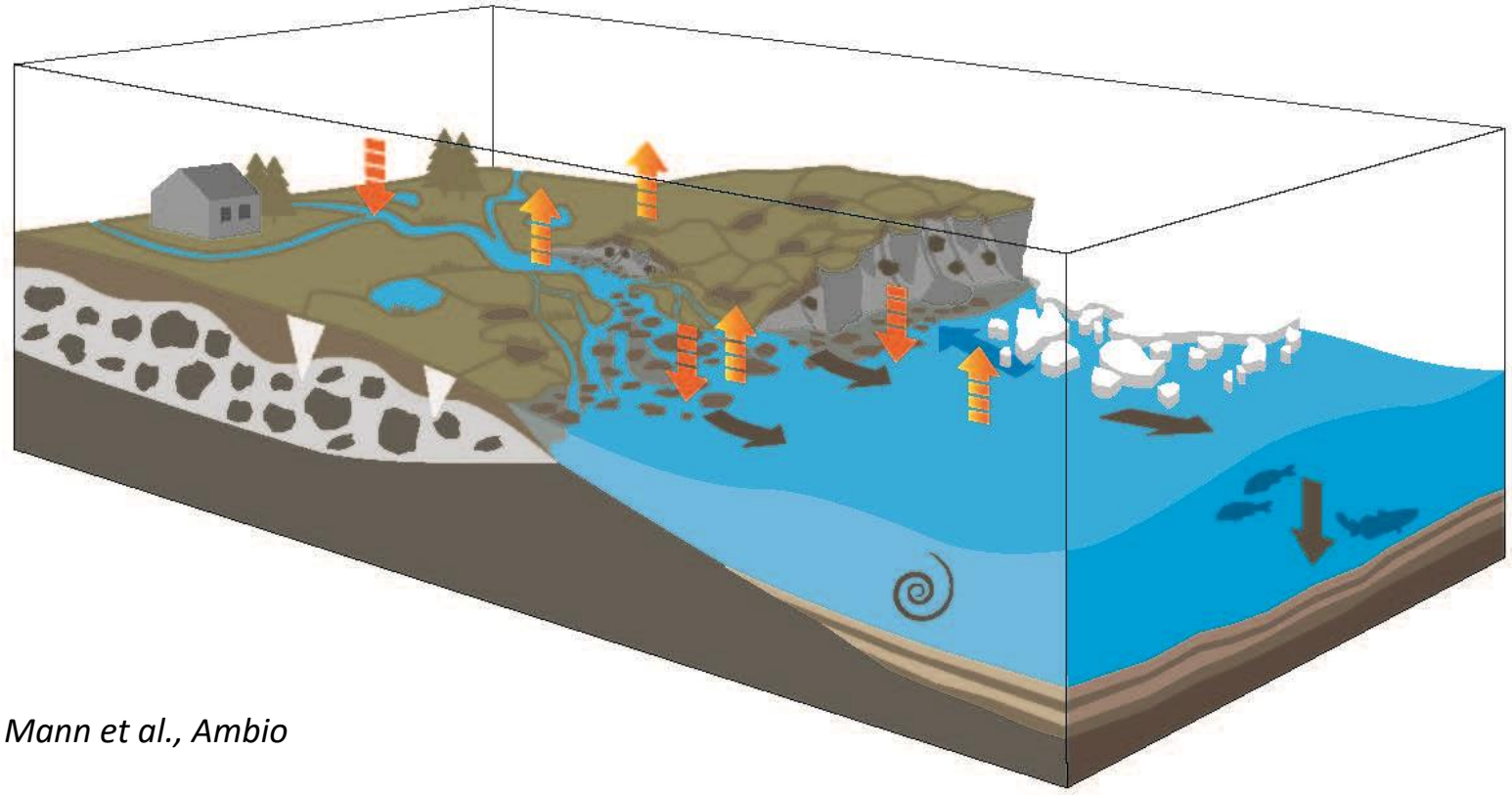
Federal Ministry of Education and Research

UKRI Natural Environment Research Council

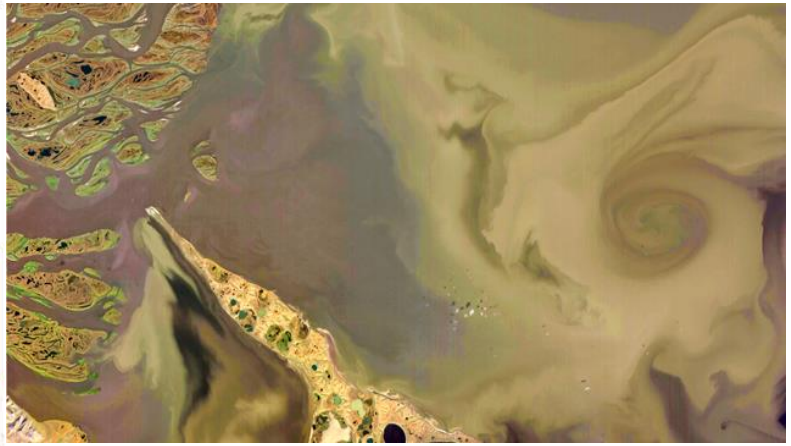
Mission: Assessing the dynamic interface between land and ocean

Our major research question:

*How will changing **freshwater export** and terrestrial **permafrost thaw** influence the near shore?*

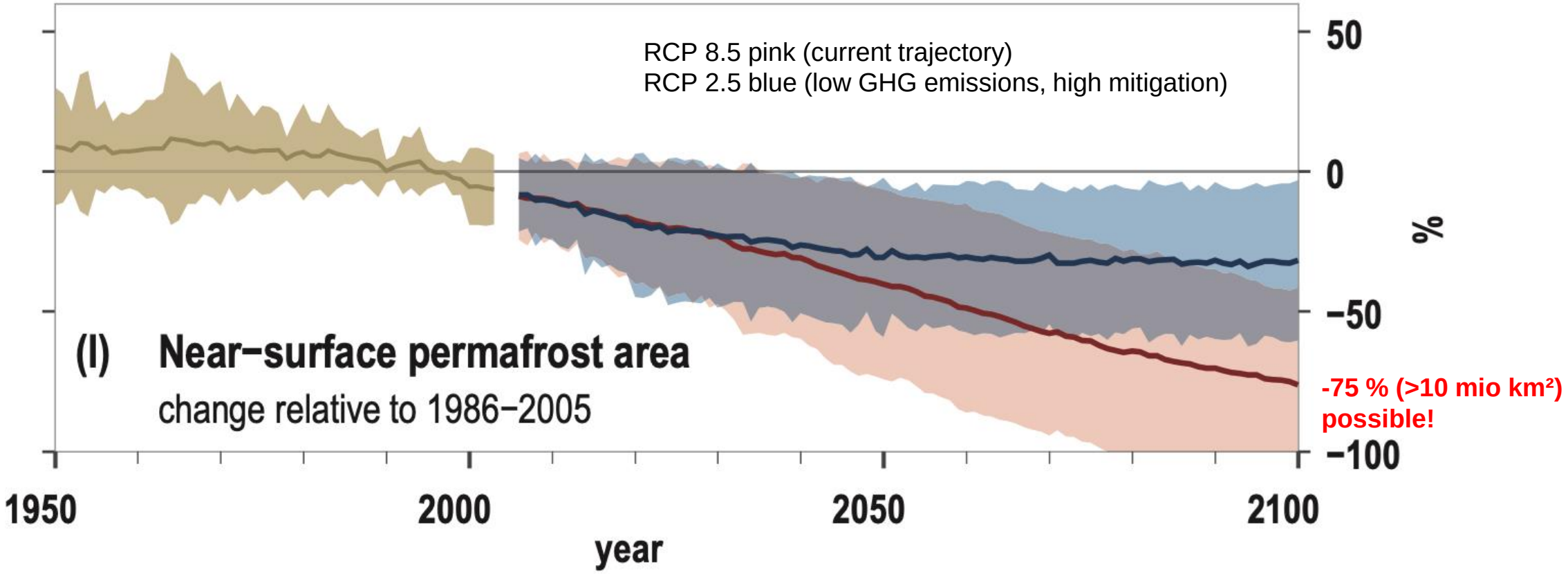


Mann et al., Ambio



Sediment in the Lena Delta nearshore zone

Loss of permafrost in Northern hemisphere (3 m depth)



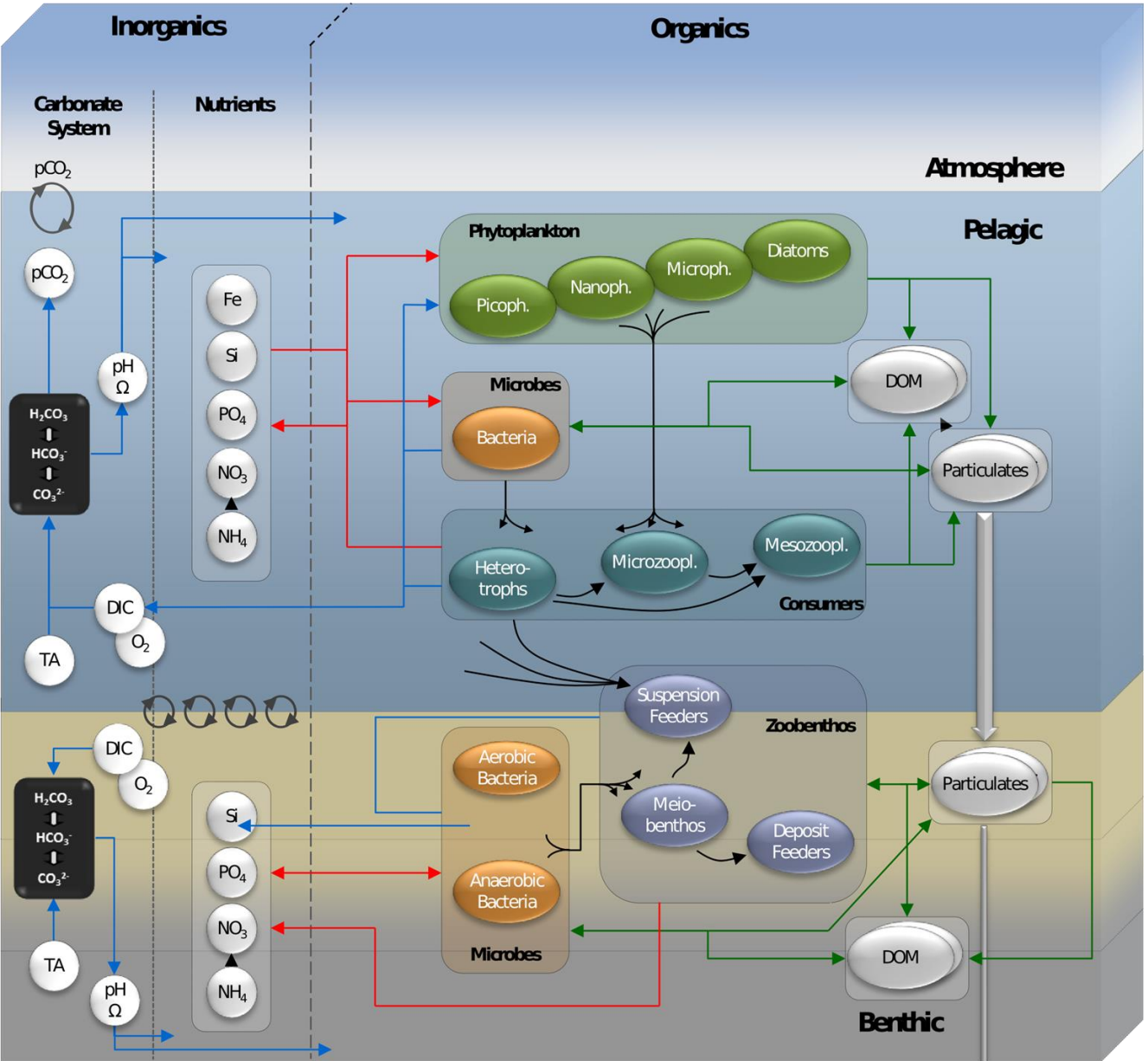
IPCC, 2019: Technical Summary [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, E. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In: ***IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*** [H.- O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. *In press*.

Approach: Field + lab work

4 successful field campaigns across Lena and Kolyma nearshore

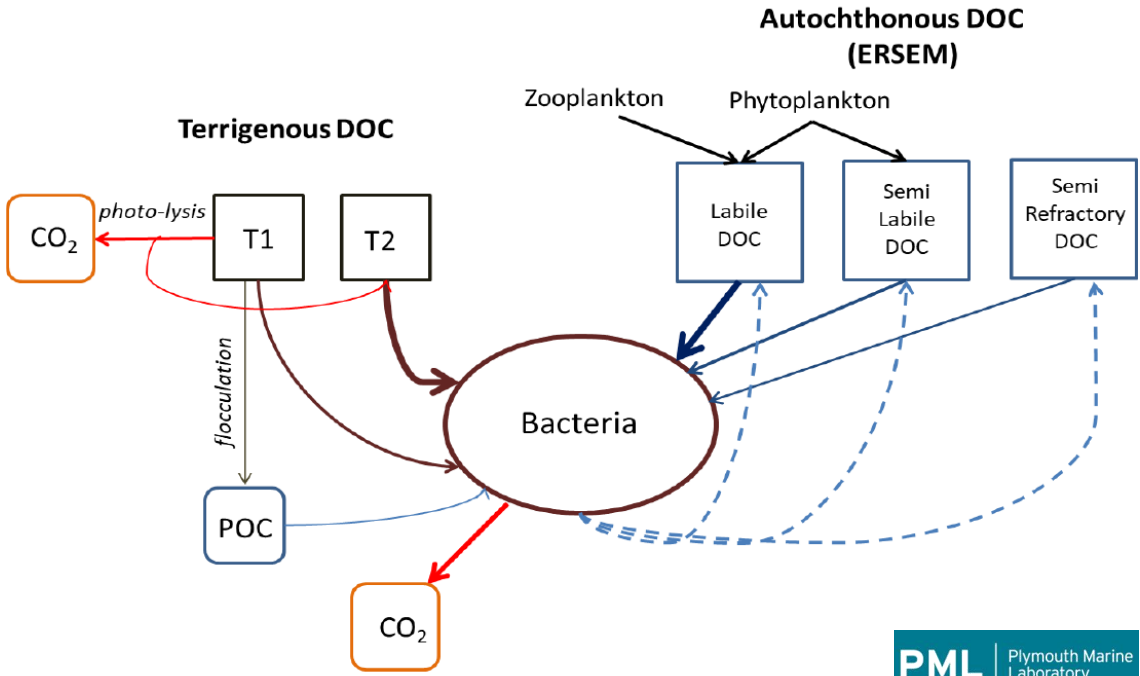
- Kolyma: Transects throughout the year
- Lena: CACOON Ice & CACOON Sea

Approach: modelling



Schematic description of the main processes describing the interactions between bacteria and organic carbon, which are represented within the ERSEM (European Regional Seas Ecosystem) model.

Addition of terr-OC element

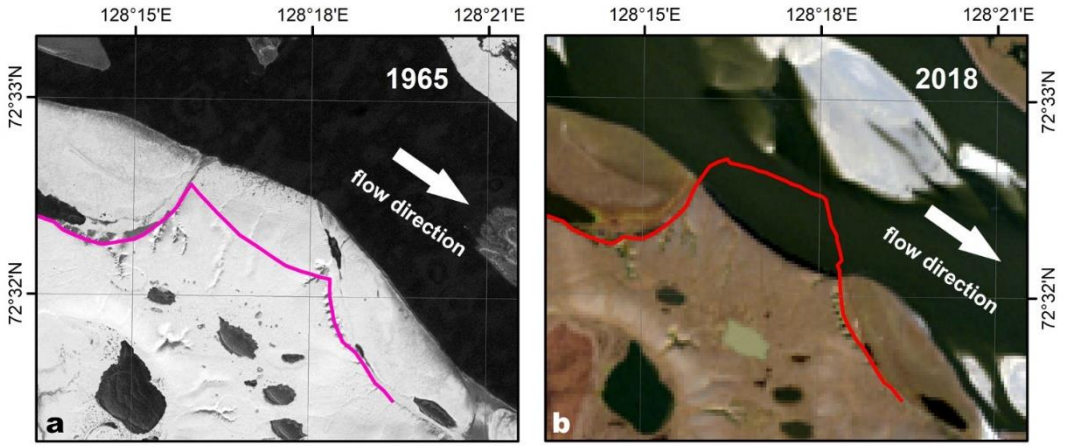


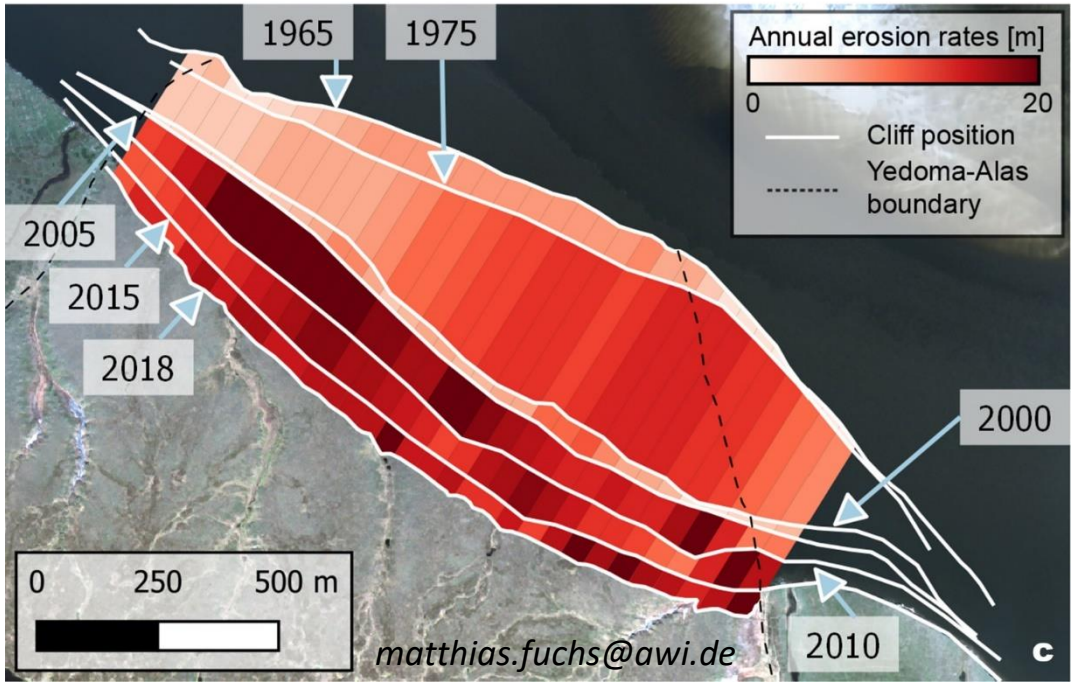
Scientific outcomes

Rapid Fluvio-Thermal Erosion of a Yedoma Permafrost Cliff in the Lena River Delta

Erosion rates and C release at a ice-rich Yedoma cliff (27.7 m height) covering 53 years (1965-2018)

- Total erosion: 322 – 679 m (1965-2018)
- Current erosion rate: 15.7 m per year (2015-2018)
  - 5.2 x 10^6 kg OC per year (2015-2018)
  - 0.4 x 10^6 kg N per year (2015-2018)

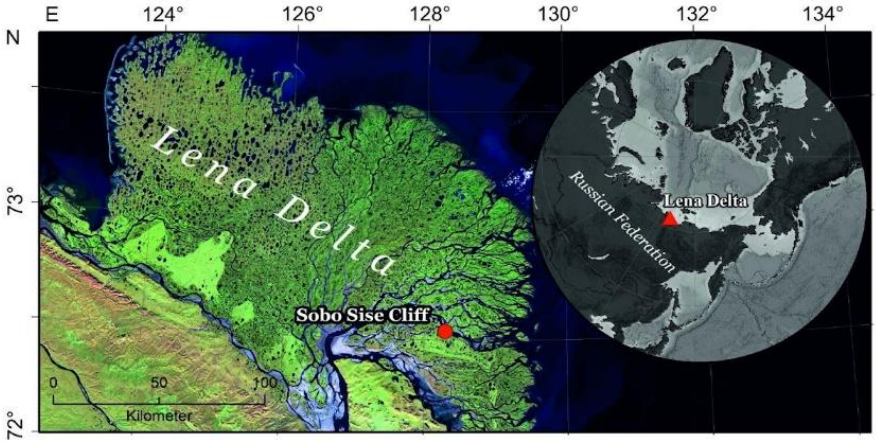


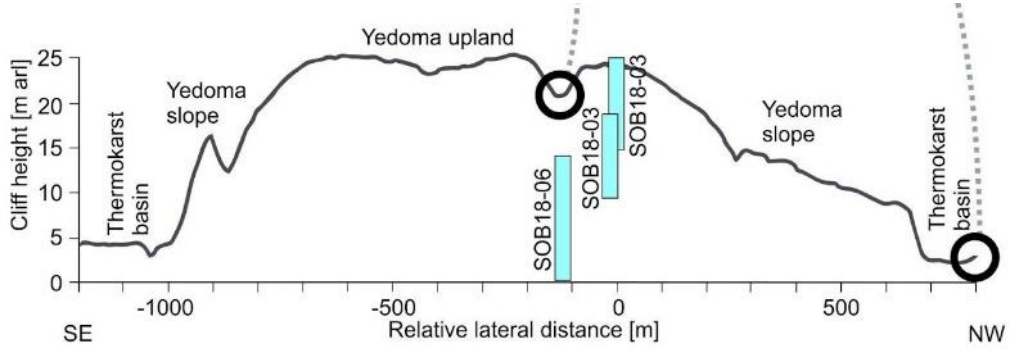


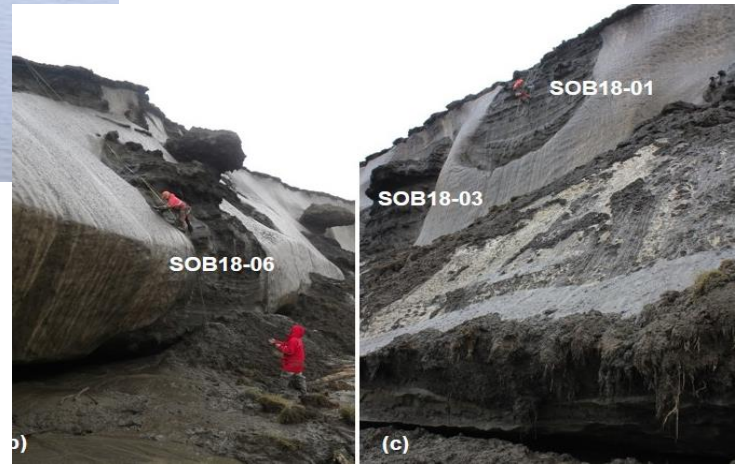
Fuchs et al. (2020)

Scientific outcomes

Organic Matter Characteristics of a rapid eroding permafrost cliff







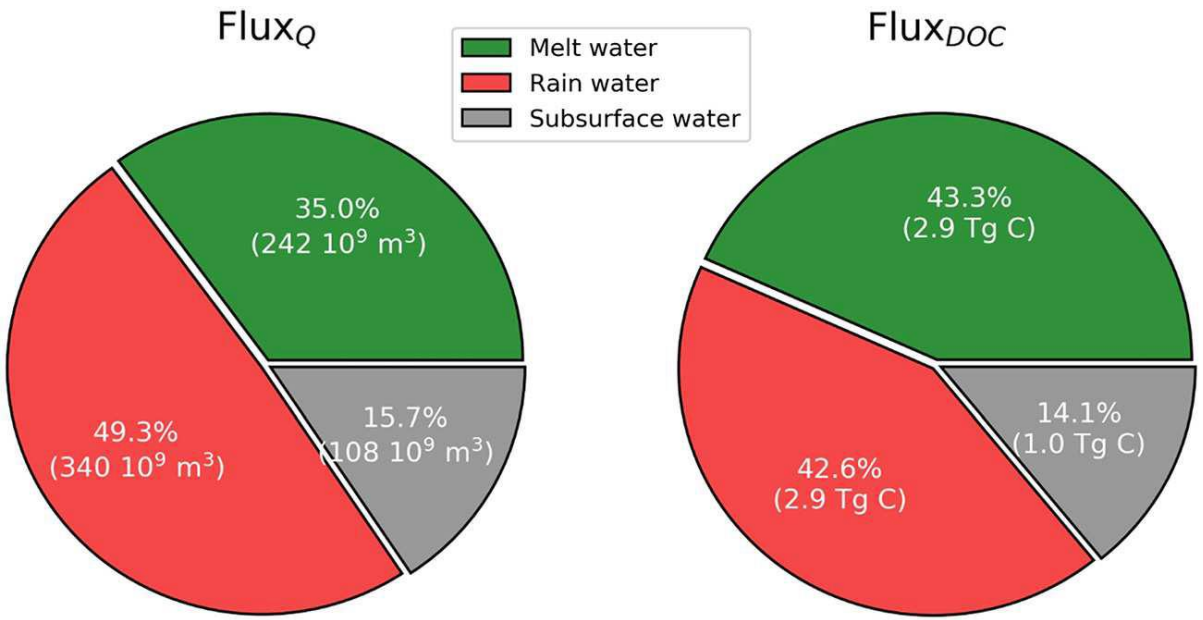
- High C content (Ø5.13 wt%) & high OM quality (C/N: Ø 13.24)
- Yedoma deposition during the relatively warm MIS 1 and MIS 3 associated with more microbial activity than during the colder MIS 2
- High degradation potential of OM that rapidly enters the fluvial & offshore aquatic ecosystem

Haugk et al., in review

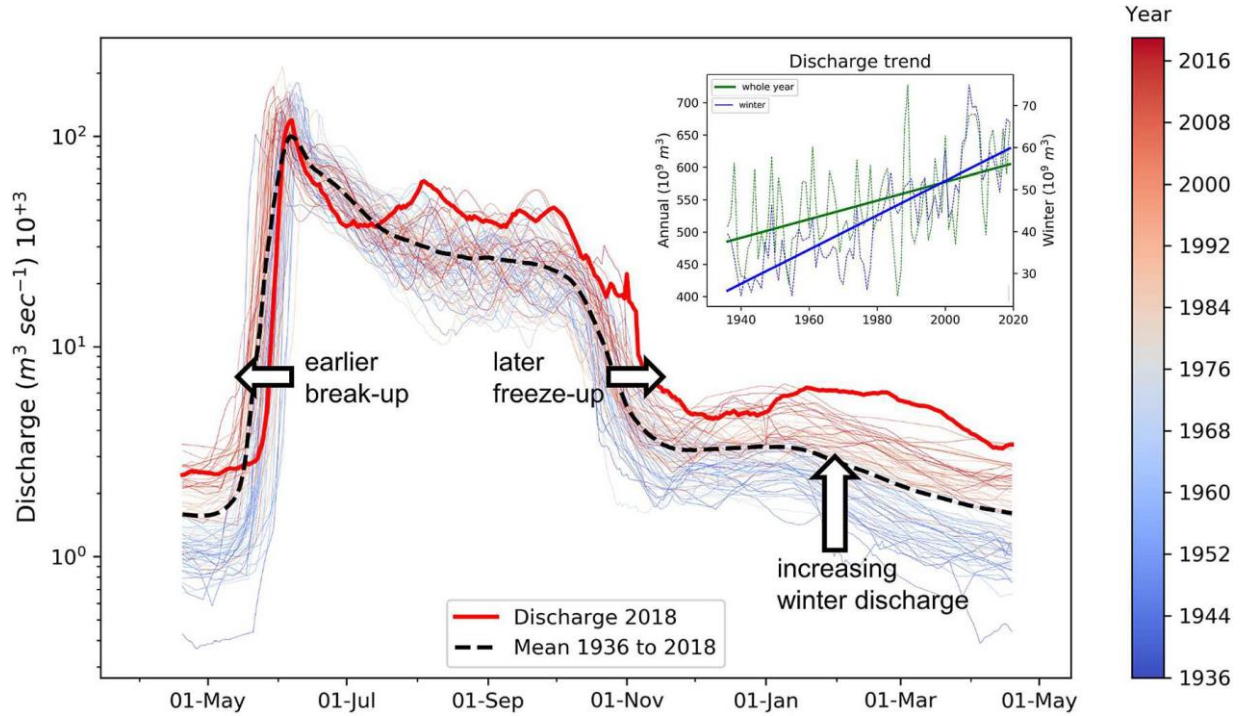
Scientific outcomes

Identifying Drivers of Seasonality in Lena River Biogeochemistry and Dissolved Organic Matter Fluxes

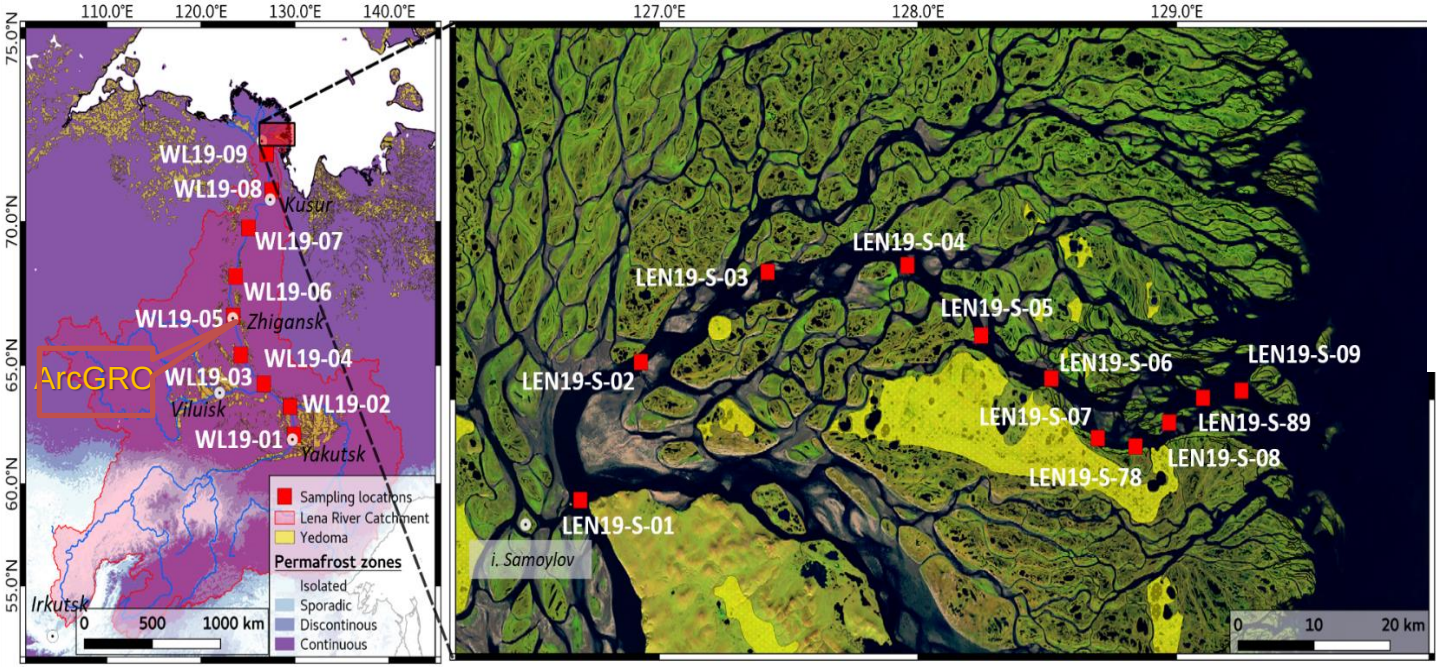
- Precipitation and melt waters Control seasonal variability in Arctic runoff
- Melt water and rain water accounted for 84% of the discharge flux and 86% of the DOC flux

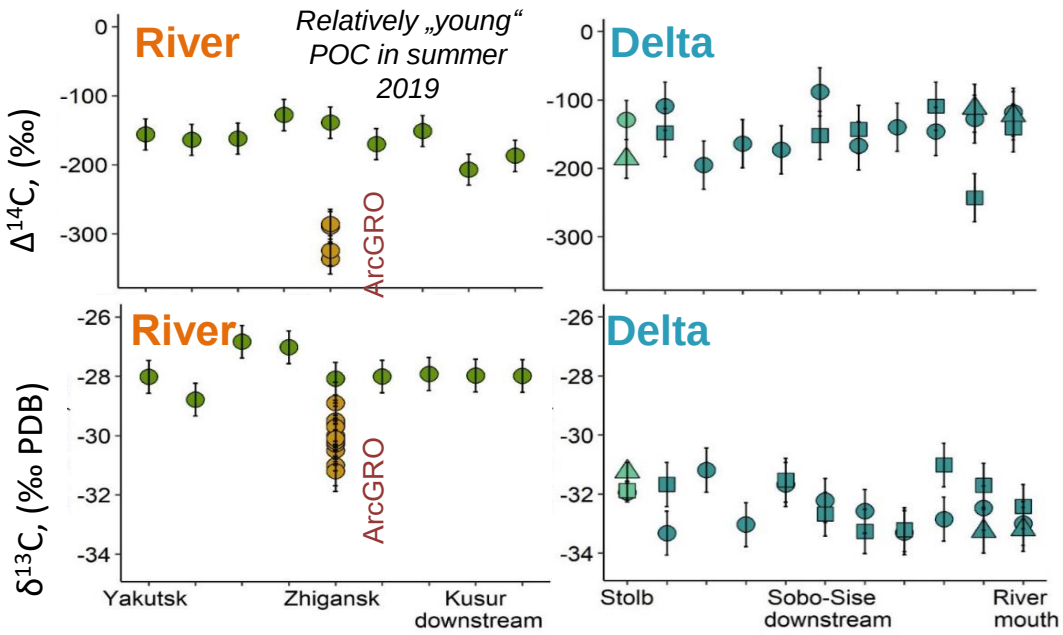


Juhls et al. (2020)



POC: From Yakutsk to the Lena mouth:





- ✓ TSM and POC decrease during the transit from Yakutsk to the Lena Delta
- ✓ Deltaic POC is depleted in ^{13}C relative to the riverine POC due to the dominance of phytoplankton as its source. Riverine POC mostly occurs from the soils of the Lena watershed area
- ✓ POC ^{14}C signature for riverine and deltaic samples does not differ from each other, which suggests an additional input of old permafrost OM in the Lena delta.

Check out our posters

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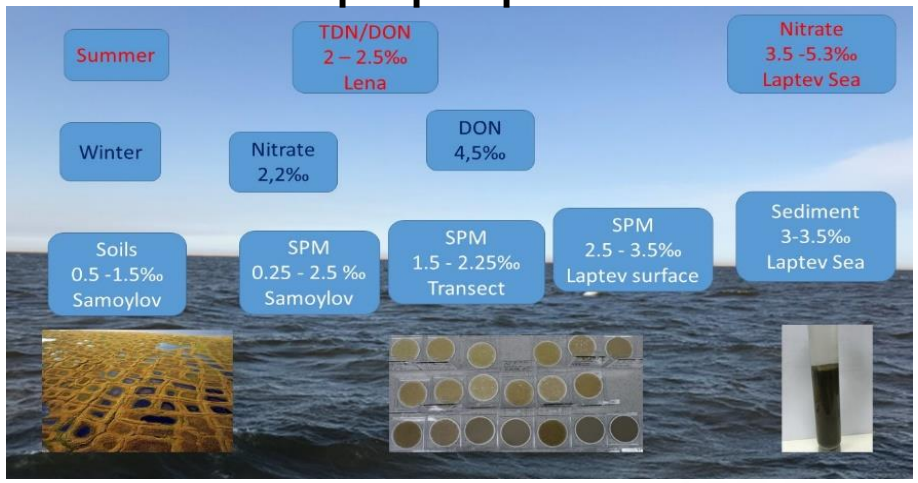
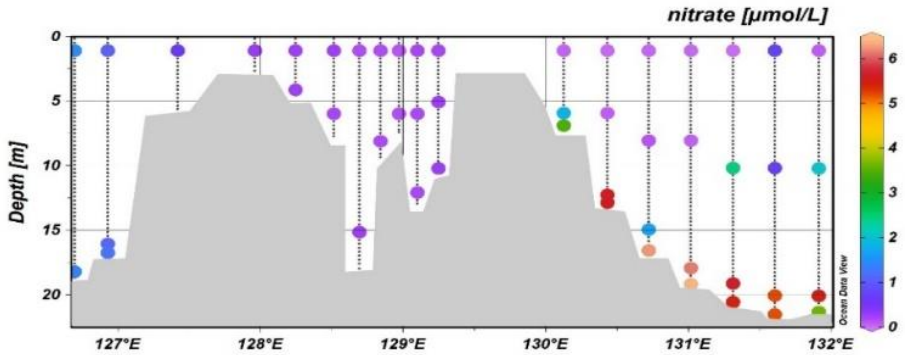
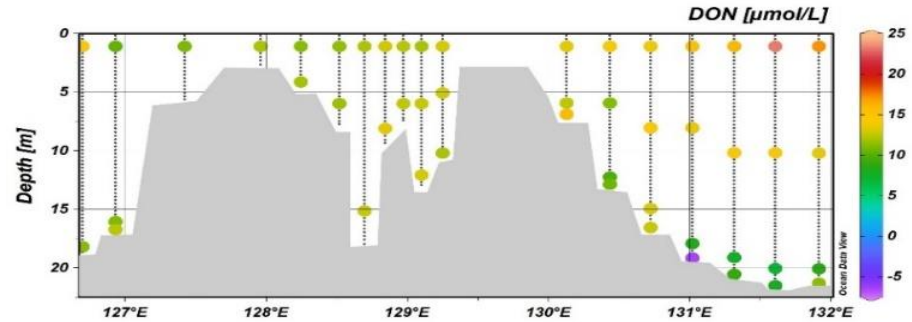
Nitrogen and their stable isotopes in the Lena Delta

EISPAC CACOON

Isotopic perspective







- ✓ Thawing permafrost increase the transport of organic matter from the River and Delta to the Arctic Ocean
- ✓ Lena Delta region source of reactive nitrogen
- ✓ Higher reactive nitrogen in the aquatic and marine environment enhance the primary productivity in the Artic Ocean and potential N2O emissions
- ✓ Nitrogen: DON plus PON, nitrate just in winter
- ✓ POC ^{14}C signature for riverine and deltaic samples does not differ from each other, which suggests an additional input of old permafrost OM in the Lena delta.
- ✓ Enrichment of the nitrogen 15N stable isotope composition from soils over SPM and DON/Nitrate to the Arctic Ocean

Sanders et al., Accepted for Ambio

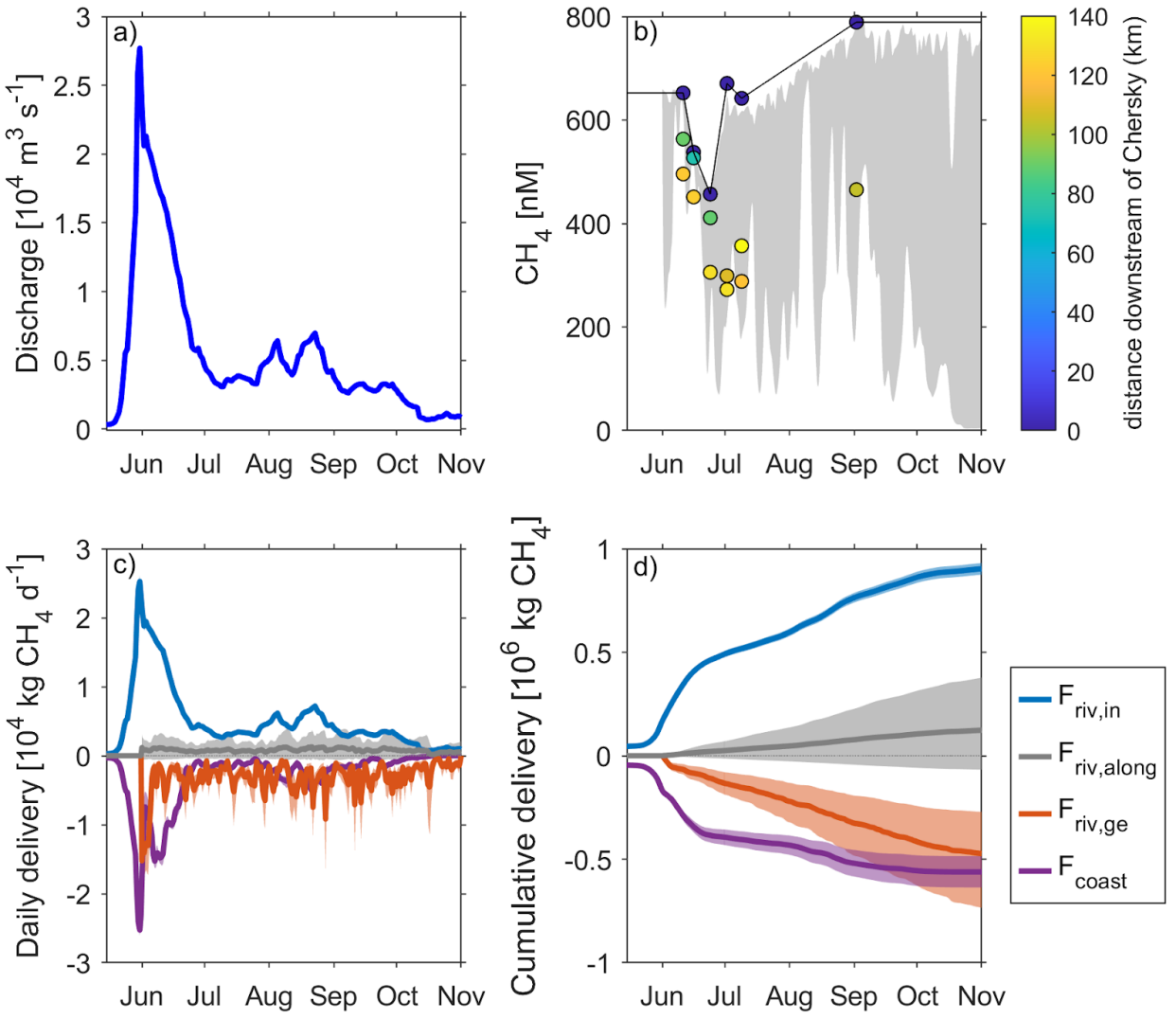
Check out our posters

Seasonal CH_4 and CO_2 concentrations, Kolyma river

Supersaturated CH_4 concentrations with up to 24 000% throughout the open water season acts as a source to the coastal sea.

Conservative annual river input of 0.6 Gg CH_4 yr^{-1} and 170 Gg CO_2 yr^{-1} from the Kolyma to the coastal sea, with an additional atmospheric flux of 0.5 Gg CH_4 yr^{-1} and 40 Gg CO_2 yr^{-1} to the atmosphere.

Spring runoff responsible for 50% of the annual cumulative transport of CH_4 and CO_2.



Palmtag et al., in prep.

Scientific outcomes

https://doi.org/10.5194/essd-2021-256
Preprint. Discussion started: 10 September 2021

Open Access Earth System Science Data Discussions

High-resolution bathymetry models for the Lena Delta and Kolyma Gulf coastal zones

Matthias Fuchs[1], Juri Palmtag[2], Bennet Juhls[1,3], Paul Overduin[1], Guido Grosse[1,4], Ahmed Abdelwahab[1,4], Michael Bedington[5], Tina Sanders[6], Olga Ogneva[1], Irina V. Fedorova[7], Nikita S. Zimov[8], Paul J. Mann[2], Jens Strauss[1]

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[5]Plymouth Marine Laboratory, Plymouth, UK
[6]Helmholtz-Zentrum Hereon, Institute for Carbon Cycles, Geesthacht, Germany
[7]St. Petersburg State University, Institute of Earth Science, St. Petersburg, Russia
[8]North-East Scientific Station, Pacific Institute for Geography, Far-East Branch, Russian Academy of Sciences, Cherskiy,

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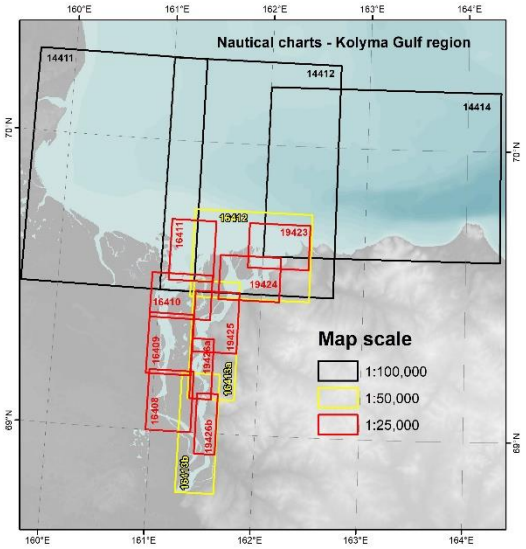

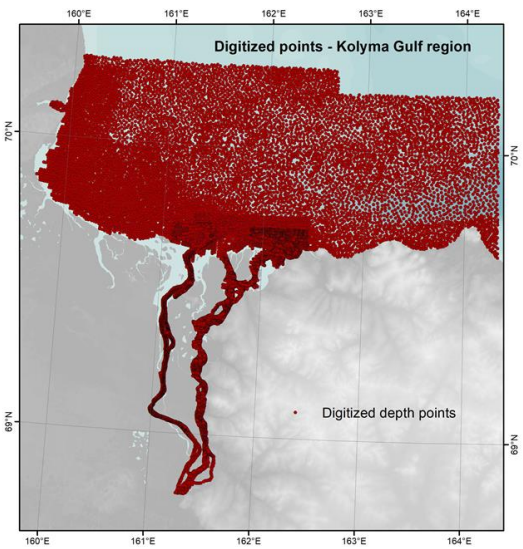

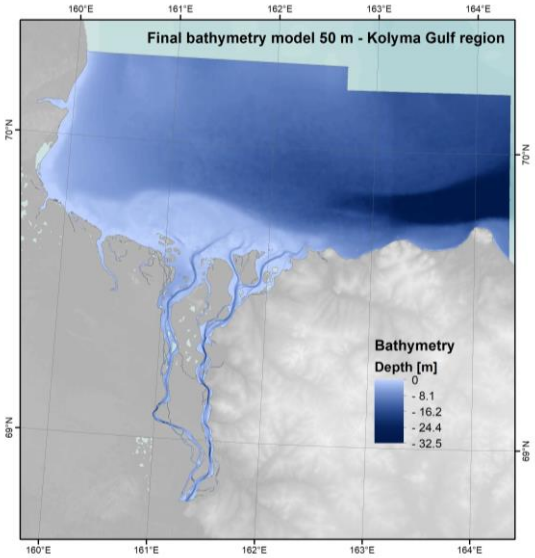

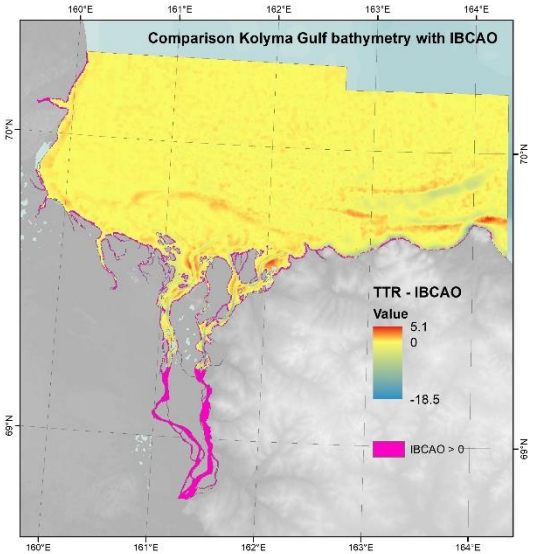

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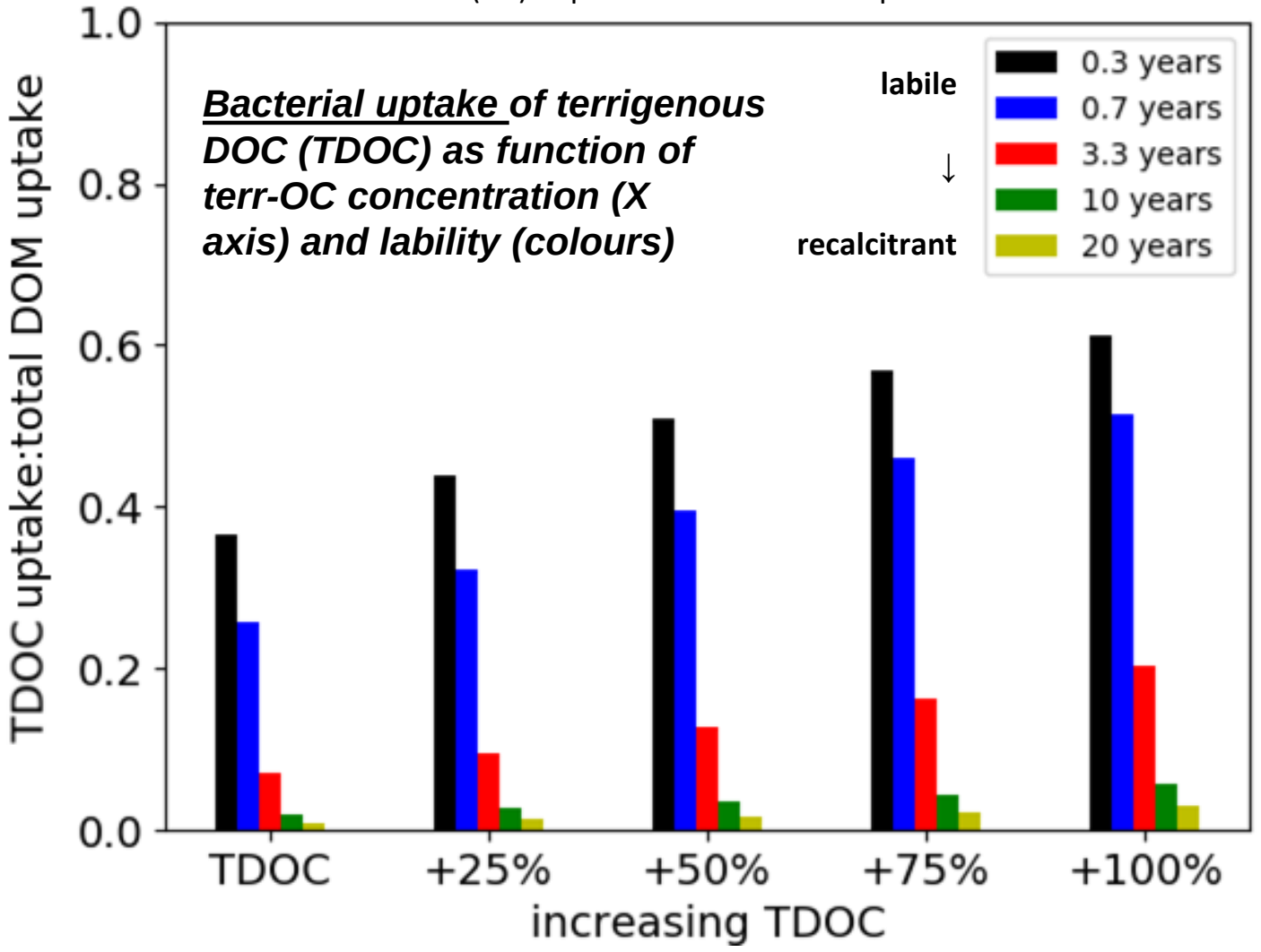
1d Modelling: Sensitivity of bacteria DOC uptake to increasing terrigenous DOC concentration and lability

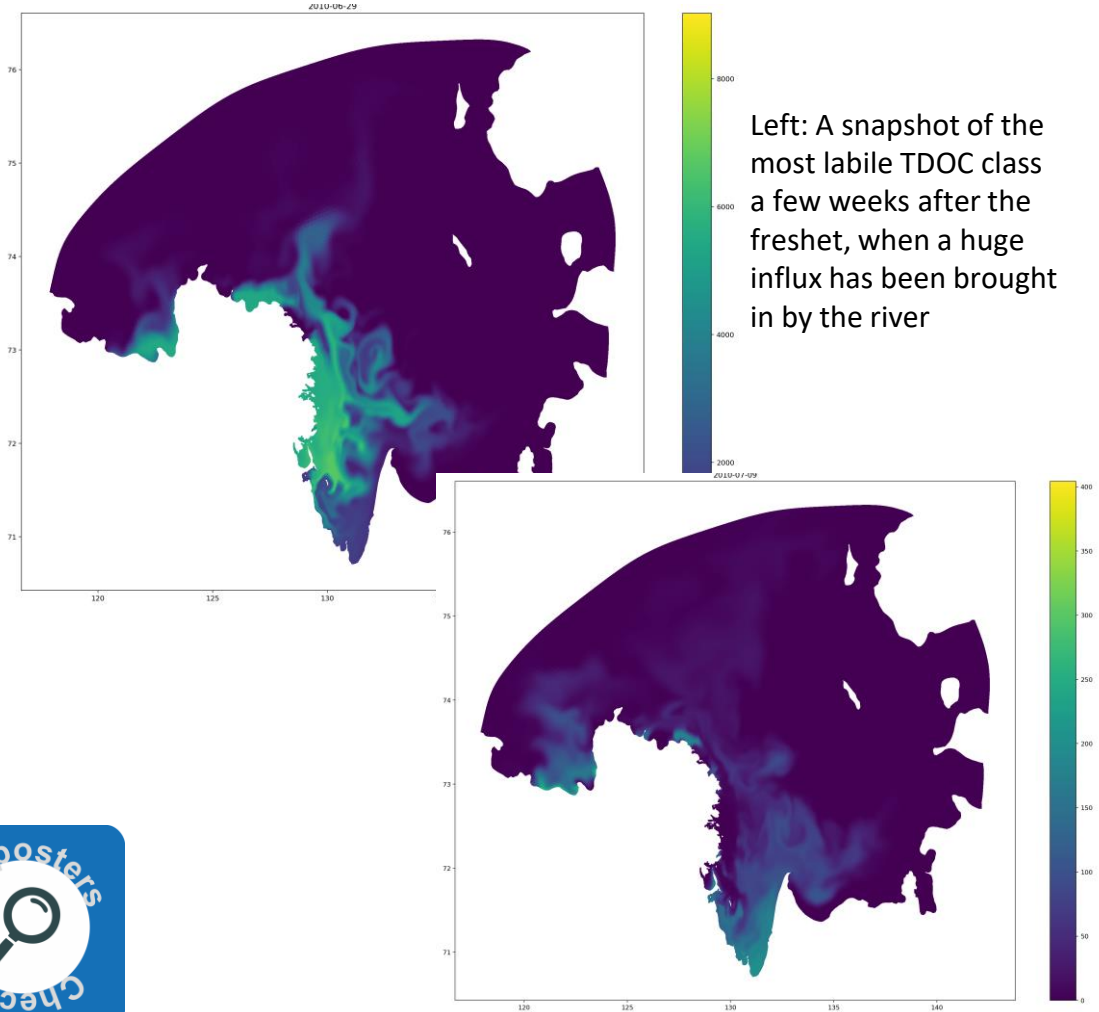
- The fraction of terrestrial dissolved organic carbon (TDOC) used by bacteria increases dramatically if TDOC has a life time <1 year
- Since bacteria have low growth efficiency most of TDOC is respired
- If TDOC has high life time, autochthonous DOC remains the main source of carbon regardless of the amount of TDOC considered

GOTM-ERSEM (1D) implementation in the Laptev Sea



Submitted to BGL

Coupled 3d hydrodynamic model (FVCOM) with biogeochem. model adapted specifically for studying TDOC input (Arctic-ERSEM)



Left: A snapshot of the most labile TDOC class a few weeks after the freshet, when a huge influx has been brought in by the river

Experiments focus on how the impact of terrestrial dissolved organic carbon (TDOC) when the river flow and character of the TDOC is altered to match future scenarios.

Hydrodynamic model includes

- tides
- surface forcing (wind, precipitation, heating)
- ice cover
- river inflow
- lateral boundary conditions (temp + salinity)

Biogeochemical model includes:

- lower trophic levels (zooplankton, phytoplankton, bacteria, benthic species)
- carbonate system
- classes explicitly modelling TDOC, with aging, photo degradation, etc.

Bedington et al., in prep.

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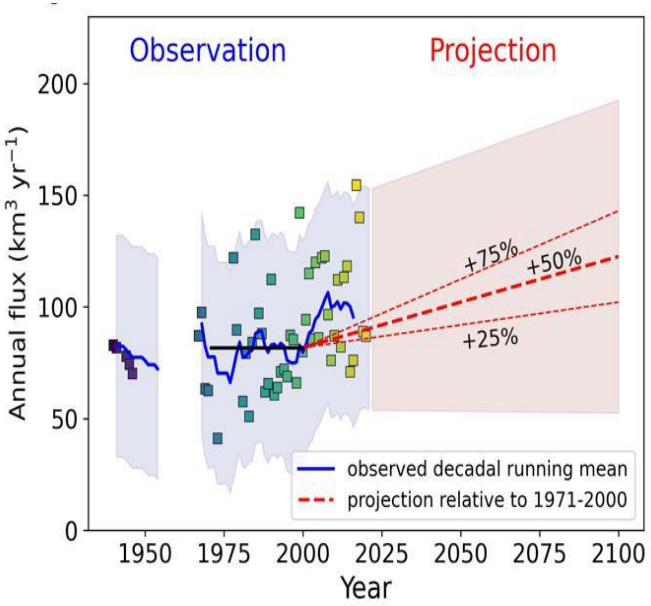
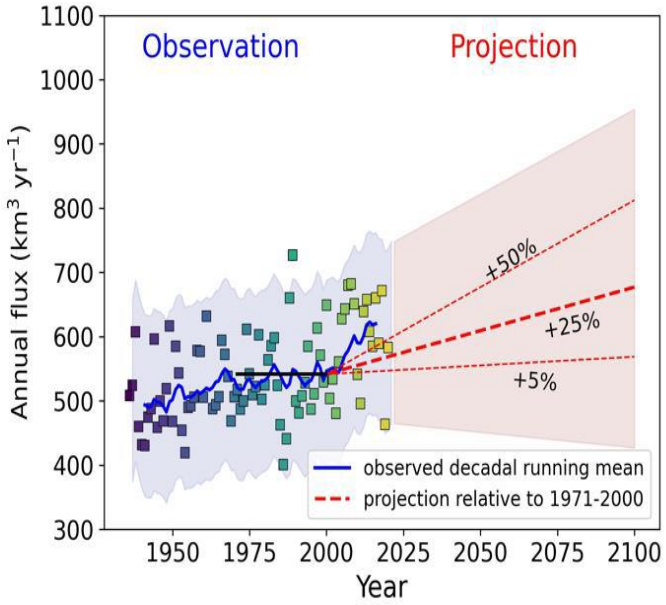
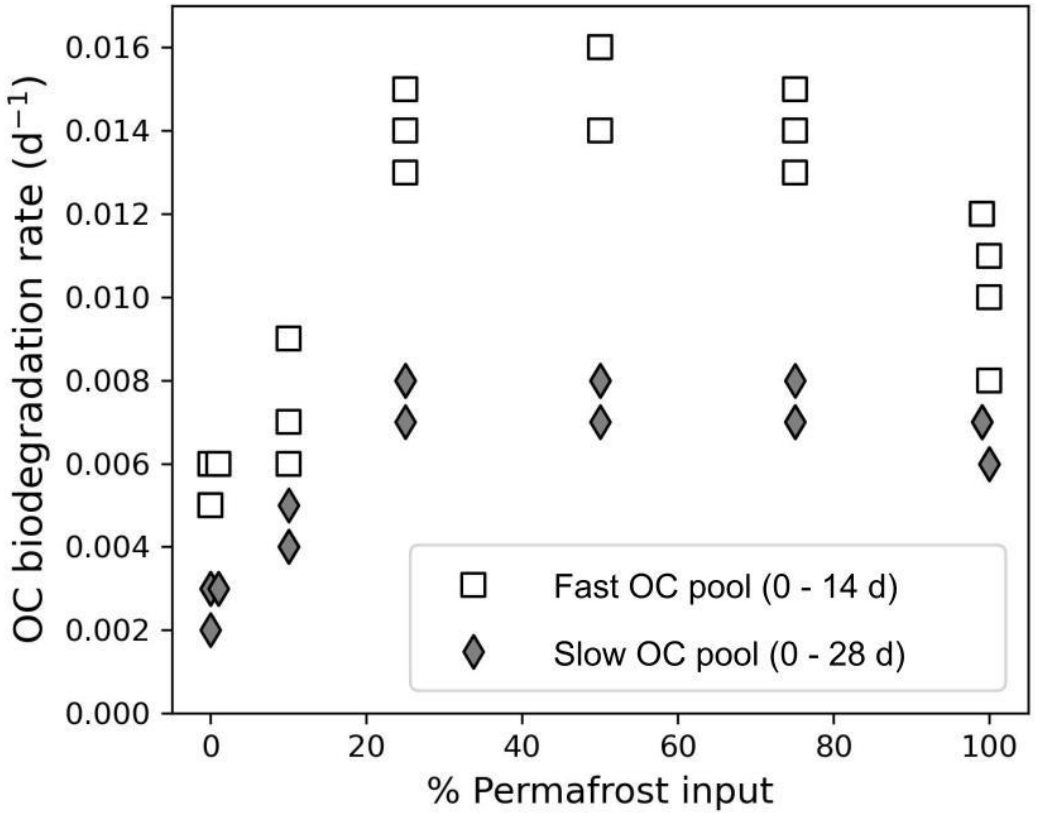
Degrading permafrost river catchments and their impact on Arctic Ocean nearshore processes







- We demonstrate that the unique composition of terrestrial permafrost-derived OC can cause significant increases to aquatic carbon degradation rates (20 to 60% faster rates with 1% permafrost OC)

- Terrestrial OC degradation rates increased almost linearly with increasing permafrost OC contributions to the total DOC pool, up to approximately a 25% subsidy

Mann et al., accepted for Ambio

Summary of key scientific findings

I. Increased terrigenous dissolved organic carbon (DOC) supply and lability may turn Arctic shelves into a net CO_2 source (Polimene – in review).

II. Future permafrost thaw and increasing runoff will cause a substantial shift in biolability to nearshore DOC pool (Mann et al - accepted).

III. Fast response and rapid erosion fuels landscape degradation and near shore sediment and organic carbon supply (Fuchs et al., 2020; Haugk, in review).

IV. Coastal nearshore regions emit CH_4 throughout the open water period and are susceptible to increase under future change (Palmtag - pending submission).

V. Precipitation and melt waters control seasonal variability in Arctic runoff (Juhls et al 2020)


CACOON
Thanks!

Published / accepted peer-reviewed CACOON publications

- *Angelopoulos, M., Overduin, P. , Westermann, S., Tronicke, J., Strauss, J. , Schirrmeister, L., Biskaborn, B. K., Liebner, S., Maximov, G. M., Grigoriev, M.N. and Grosse, G. (2020)* ***Thermokarst lake to lagoon transitions in eastern Siberia: Do submerged taliks refreeze?*** *Journal of Geophysical Research: Earth Surface. https://doi.org/10.1029/2019JF005424*

- *Barth, N. (2020). Olaf Otto Becker:* ***Siberian Summer****. Germany: Hatje Cantz*

- *Fuchs, M., Nitze, I., Strauss, J. , Günther, F., Wetterich, S., Kizyakov, A., Fritz, M., Opel, T., Grigoriev, M. N., Maksimov, G. T. and Grosse, G. (2020)* ***Rapid Fluvio-Thermal Erosion of a Yedoma Permafrost Cliff in the Lena River Delta****, Frontiers in Earth Science, 8 (336), https://doi.org/10.3389/feart.2020.00336*

- *Jenrich M, Angelopoulos M, Grosse G, Overduin PP, Schirrmeister L, Nitze I, Biskaborn BK, Liebner S, Grigoriev M, Murray A, Jongejans LL and Strauss J (2021)* ***Thermokarst Lagoons: A Core-Based Assessment of Depositional Characteristics and an Estimate of Carbon Pools on the Bykovsky Peninsula****. Front. Earth Sci. 9:637899. doi: 10.3389/feart.2021.637899*

- *Jongejans, L., Mangelsdorf, K., Schirrmeister, L., Grigoriev, M. N., Maksimov, G. T., Biskaborn, B. K., Grosse, G. and Strauss, J. (2020)* ***n-Alkane Characteristics of Thawed Permafrost Deposits Below a Thermokarst Lake on Bykovsky Peninsula, North- eastern Siberia****, Frontiers in Environmental Science, 8 (118) https://doi.org/10.3389/fenvs.2020.00118*

- *Juhls, B. , Stedmon, C. A., Morgenstern, A., Meyer, H., Hölemann, J., Heim, B. and Povazhnyi, V. (2020)* ***Identifying Drivers of Seasonality in Lena River Biogeochemistry and Dissolved Organic Matter Fluxes, Frontiers in Environmental Science****, 8, p. 53. https://doi.org/10.3389/fenvs.2020.00053*

Published / accepted peer-reviewed CACOON publications

- *Juhls, B., Antonova, S., Angelopoulos, M., Bobrov, N., Grigoriev, M., Langer, M., Maksimov, G., Miesner, F. and Overduin, PP. (2021)* ***Serpentine (Floating) Ice Channels and their Interaction with Riverbed Permafrost in the Lena River Delta, Russia****, Frontiers in Earth Science, 9 (548), https://DOI=10.3389/feart.2021.689941*

- *Mann P, Strauss J, Palmtag J, Dowdy K, Ogneva O, Fuchs M , Bedington M , Torres R , Polimene L, Overduin P, Mollenhauer G , Grosse G, Rachold V, Sobczak W, Spencer R, and Juhls B.* ***Global importance of degrading permafrost river catchments on Arctic Ocean nearshore waters.*** *Accepted for AMBIO.*

- *Nitzbon, J., Westermann, S., Langer, M., Martin, L. C. P., Strauss, J. , Laboor, S. and Boike, J. (2020)* ***Fast response of cold ice-rich permafrost in northeast Siberia to a warming climate****, Nature Communications, 11 (1) https://doi.org/10.1038/s41467-020- 15725-8*

- *Sanders T, Fiencke C, Fuchs M , Haugk C, Juhls B ,Mollenhauer G, Ogneva O , Overduin P , Palmtag J , Povazhniy V, Strauss J, Tuerena R, Zell N and Dähnke K.* ***Rapid changes in the Arctic increase the nutrient input from thawing permafrost to the nearshore area of the Arctic Ocean****. Accepted for AMBIO.*

- *Wetterich, S., Kizyakov, A., Fritz, M., Wolter, J., Mollenhauer, G. , Meyer, H., Fuchs, M. , Aksenov, A., Matthes, H., Schirrmeister, L., and Opel, T. (2020).* ***The cryostratigraphy of the Yedoma cliff of Sobo-Sise Island (Lena delta) reveals permafrost dynamics in the central Laptev Sea coastal region during the last 52 kyr****, The Cryosphere, 14, 4525-4551, https://doi.org/10.5194/tc-14-4525- 2020,*

Published datasets

Jongejans, L. L. and Strauss, J. (2020) Bootstrapping approach for permafrost organic carbon pool estimation, https://doi.org/10.5281/zenodo.3734247

Nitze, I., Fuchs, M., Strauss, J. , Günther, F., Wetterich, S., Kizyakov, A., Fritz, M., Opel, T., Grigoriev, M. N, Maksimov, G., Laboor, S., Grosse, G. (2020):Erosion rates of the Sobo-Sise yedoma permafrost cliff in the Lena River Delta derived from remote sensing imagery. PANGAEA, https://doi.org/10.1594/PANGAEA.918507, https://doi.org/10.1594/PANGAEA.918490, and https://doi.org/10.1594/PANGAEA.918505

Fuchs, M., Palmtag, P., Juhls, B., Overduin, P. P., Grosse, G., Abdelwahab, A., Bedington, M., Sanders, T., Ogneva, O., Fedorova, I. V., Zimov, N. S., Mann, P. J., and Strauss, J.,: High-resolution bathymetry model for the Lena Delta region. PANGAEA, https://doi.pangaea.de/10.1594/PANGAEA.934045 (dataset in review), 2021a.

Fuchs, M., Palmtag, P., Juhls, B., Overduin, P. P., Grosse, G., Abdelwahab, A., Bedington, M., Sanders, T., Ogneva, O., Fedorova, I. V., Zimov, N. S., Mann, P. J., and Strauss, J.,: High-resolution bathymetry model for the Kolyma Gulf region. PANGAEA, https://doi.pangaea.de/10.1594/PANGAEA.934049 (dataset in review), 2021b.

Fuchs, M., Palmtag, J., Ogneva, O., Sanders, T., Aksenov, A. O., Polyakov, V. I., and Strauss, J.: Conductivity, temperature and depth (CTD) measurements during the CACOON cruises in 2019, PANGAEA, https://doi.pangaea.de/10.1594/PANGAEA.933187, (dataset in review), 2021c.

Palmtag, J. and Mann, P. J.: Kolyma river and near shore CTD measurements throughout the open water season using a HYDROLAB HL7 multiparameter probe, summer 2019. *British Oceanographic Data Centre*, National Oceanography Centre, NERC, UK, https://doi.org/10.5285/c10a2798-40cc-7648-e053-6c86abc07c3c, 2021.

Palmtag, J., Strauss, J., Ogneva, O., Aksenov, A., Fuchs, M., Mann, P. J.: Lena river delta and near shore CTD short time logs under ice using a HYDROLAB HL7 multiparameter probe, spring 2019. *British Oceanographic Data Centre*, National Oceanography Centre, NERC, UK, https://doi.org/10.5285/c0f9eff8-0efa-1044-e053-6c86abc0ce9f, 2021.