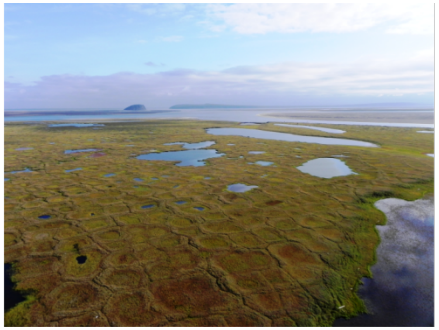
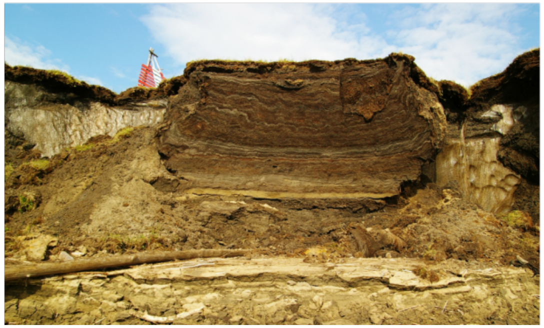
Federal Ministry of Education and Research

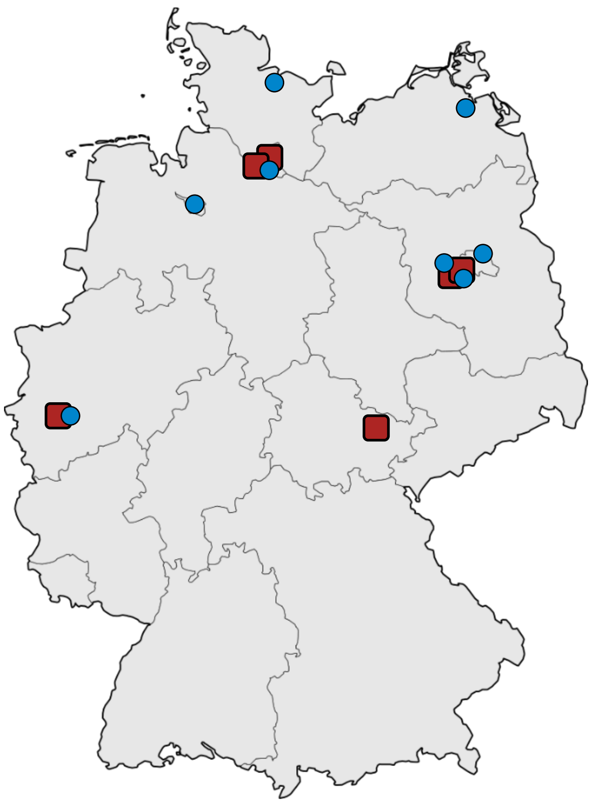
KoPF
Kohlenstoff im Permafrost

Eva-Maria Pfeiffer, Hamburg
Irina Fedorova, Saint Petersburg
and Russian & German colleagues


Carbon in Permafrost

KoPf will improve - based on observations and numerical simulations - the process understanding of the effects of changing climate on permafrost carbon



The project adresses the research questions:

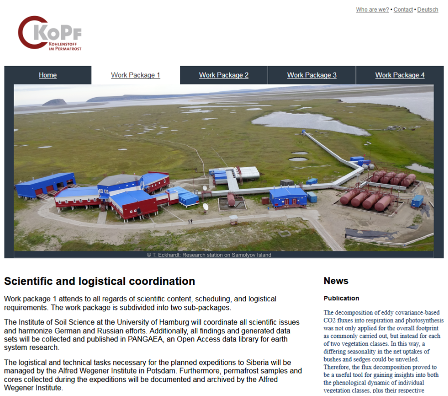
- *Will Arctic Permafrost regions turn from a sink to a source of atmospheric CO_2?*
- *How fast and which parts of thawed organic matter are transformed to greenhouse gases?*
- *How is permafrost disturbance affecting carbon pools and fluxes?*

Work packages

SPONSORED BY THE Federal Ministry of Education and Research

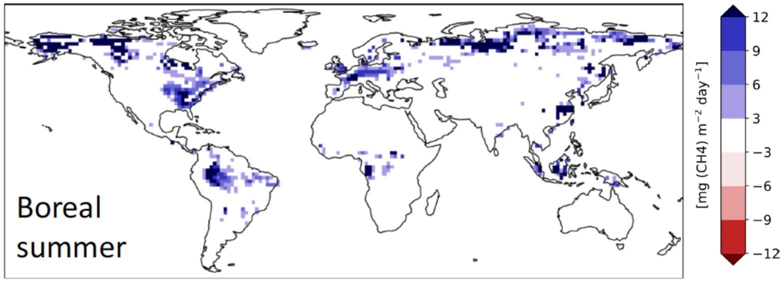
WP 1

Scientific & logistic coordination, support of young scientists, outreach, advice



WP 2

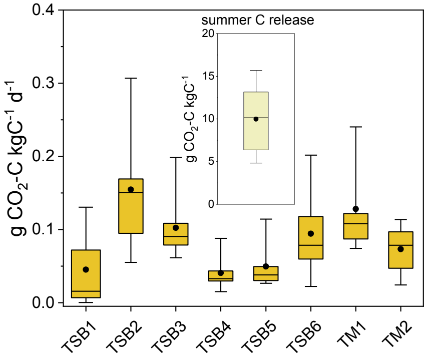
Projections of impacts of permafrost degradation on regional and global greenhouse gas emissions



De Vrese et al, *in progress*

WP 3

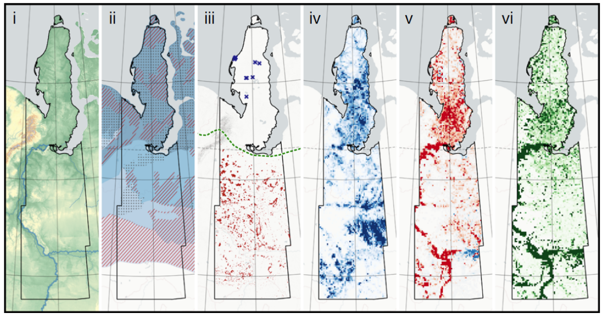
Regulation of microbial greenhouse gas formation in thawing permafrost



Knoblauch et al, *in prep*

WP 4

Spatial heterogeneity and temporal variability of permafrost landscapes and their greenhouse gas fluxes



Nitze et al, 2018 *Nature Communications*

Coordination – WP 1

WP 1a

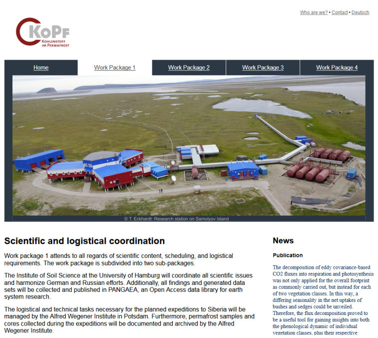
Scientific coordination

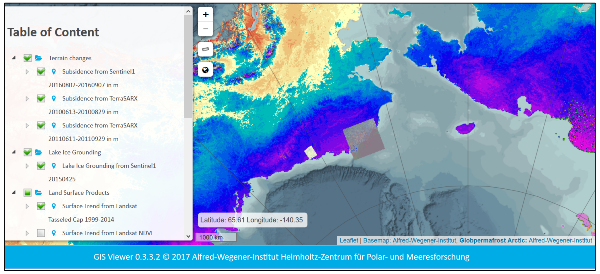
- Organize workshops
- Public relations
- Support for guest scientists and young researchers
- Coordinate common publications

WP 1b

Logistic coordination

- Preparation, implementation and post-processing of expeditions
- Buildup and care of „KoPf“ data-catalogue
- Archiving of valuable permafrost samples





Eva-Maria Pfeiffer, Tim Eckhard University of Hamburg
Guido Grosse, Anne Morgenstern, AWI Helmholtz Centre for Polar and Marine Research Potsdam

Dmitry Bolshiyanov, Arctic and Antarctic Research Institute St.Petersburg
Mikhail Grigoriev, Melnikov Permafrost Institute Yakutsk
Irina Federova, State University St.Petersburg
Leonid Tsibizov, Trofimuk Institute, RAS Nowosibirsk

Permafrost modelling – WP 2

KOPF Kohlenstoff im Permafrost

Sponsored by the Federal Ministry of Education and Research

Main objective:

To quantify impacts of degrading permafrost on Arctic carbon budget using ESM and atmospheric inversion models

Main research question:

- Will Arctic turn from a sink to a source of CO_2?
- How well can spatio-temporal patterns in GHG emissions in Siberia be observed and modeled?

Victor Brovkin, Philipp de Vrese, Veronika Gayler, MPI for Meteorology
Mathias Göckede and Martin Heimann, MPI for Biogeochemistry

Alexey Eliseev, Igor Mokhov, Institute for Atmospheric Physics RAS, Moscow
Victor Stepanenko, Lomonosov State University, Moscow
Sergey & Nikita Zimov, Northeast Science Station, Chersky

Permafrost modelling – WP 2

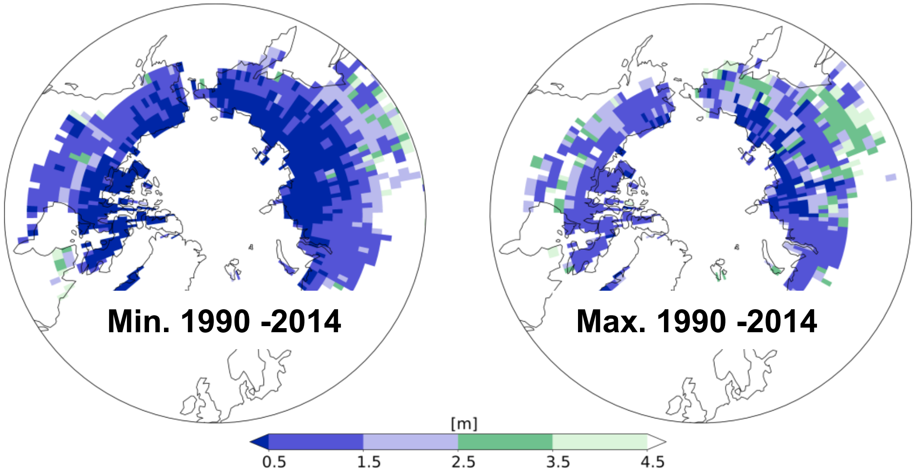
SPONSORED BY THE
Federal Ministry of Education and Research

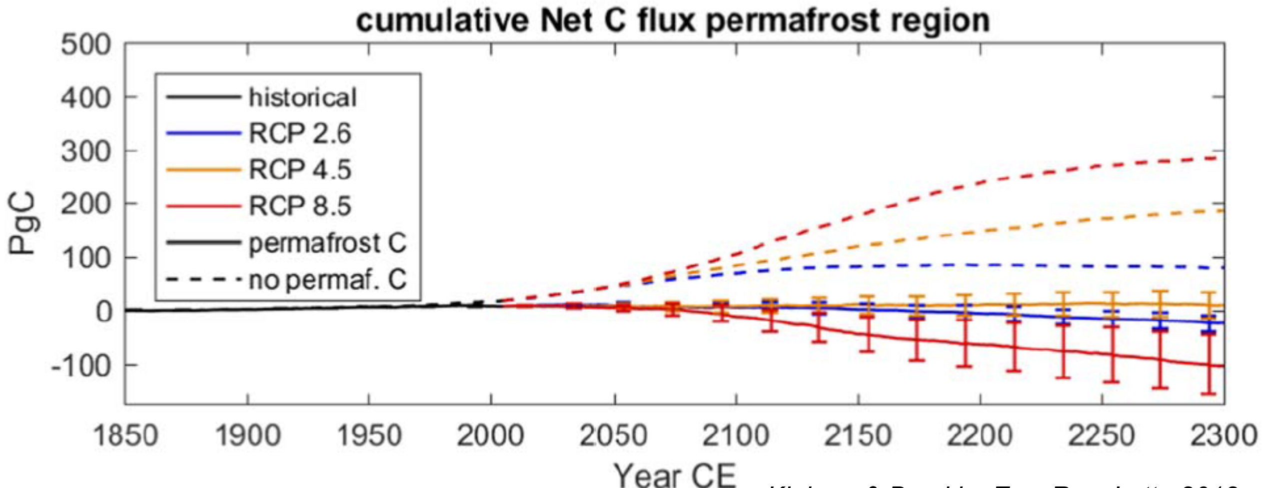
KoPF Kohlenstoff im Permafrost

Projections of permafrost thaw and GHG emissions using the MPI Earth System Model *(MPI-M, Brovkin, WP2.1)*

- Extent of near surface permafrost well captured
- Permafrost region will remain a net carbon sink at moderate warming scenario (RCP4.5)

Simulated annual maximum thaw depths





Kleinen & Brovkin, Env. Res. Lett., 2018

Permafrost modelling – WP 2

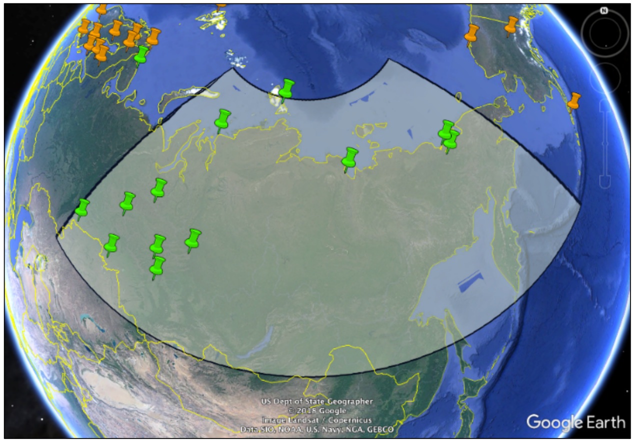
KoPf
Kohlenstoff im Permafrost

Sponsored by the Federal Ministry of Education and Research

Projections of permafrost thaw and GHG emissions using the MPI Earth System Model *(MPI-M, Brovkin, WP2.1)*

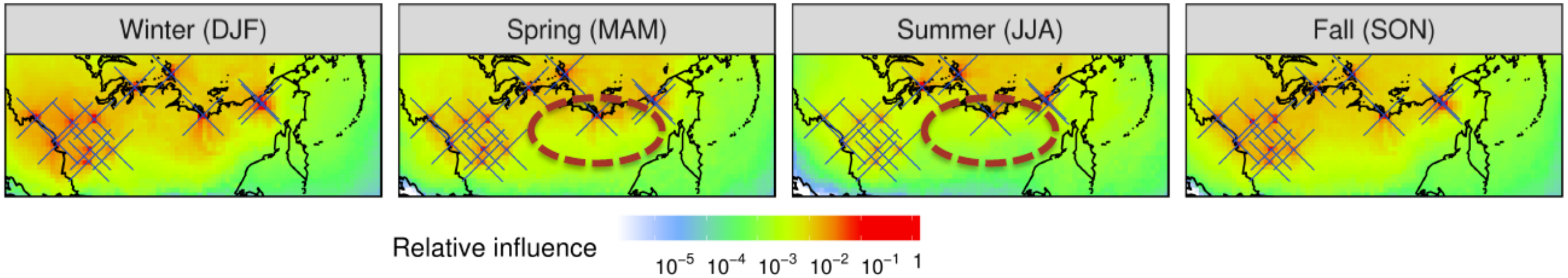
Atmospheric inverse modeling to constrain greenhouse gas emissions within Siberia *(MPI-BGC, Goeckede, WP2.2)*

Siberian Tower Network



- Limited data coverage in Central East Siberia during spring and summer
- General agreement between process model and atmospheric observations

Tower network field of view: Seasonal shifts in focus areas



C process studies – WP 3

KOPF
KOHLENSTOFF IM PERMAFROST

SPONSORED BY THE
Federal Ministry of Education and Research

Main objective:

To better understand the regulation of microbial greenhouse gas formation in thawing permafrost

Main research questions:

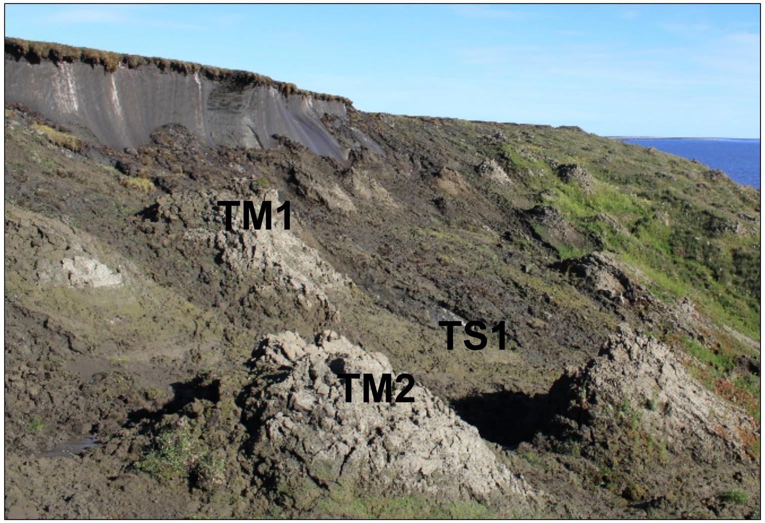
- How fast may permafrost organic matter be transformed into CO_2 and CH_4 after thaw?
- What is the source of the CO_2 and CH_4 released from thawing permafrost?
- Which impact has the microbial community on trace gas fluxes from thawing permafrost?

Christian Knoblauch, Tim Eckhard, Eva-Maria Pfeiffer (Universität Hamburg)
Janet Rethemeyer, Philipp Wischhöfer, Jan Melchert (University of Cologne)
Susanne Liebner, Sizhong Yang (GFZ Helmholtz Centre Potsdam)

Evgeny Abakumov (St. Petersburg State University)
Pavel Barsukov (Institute of Soil Science and Agrochemistry, RAS, Novosibirsk)
Elizaveta Rivkina (Institute for Physicochemical and Biological Problems of Soil Science, RAS, Pushchino)

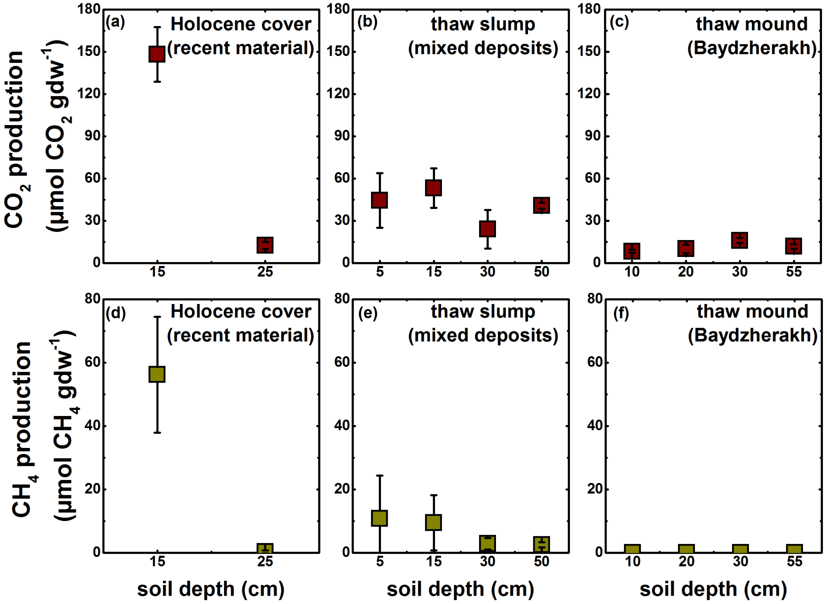
C process studies – WP 3

SPONSORED BY THE
Federal Ministry of Education and Research



Greenhouse gas fluxes from thawing permafrost *(UHH, WP3.1)*

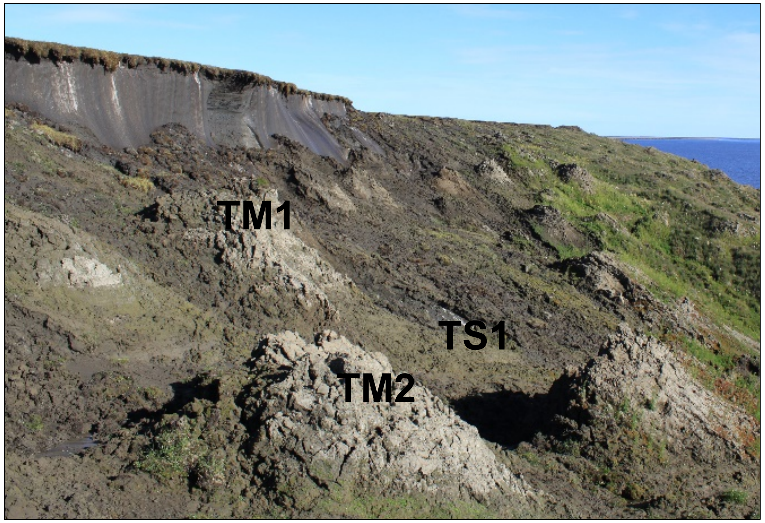
- High CO_2 production from recently thawed permafrost from thaw slump (TS) bottom soils
- Absence of CH_4 production and CH_4 emission from thermokarst mounds (TM)



C process studies – WP 3

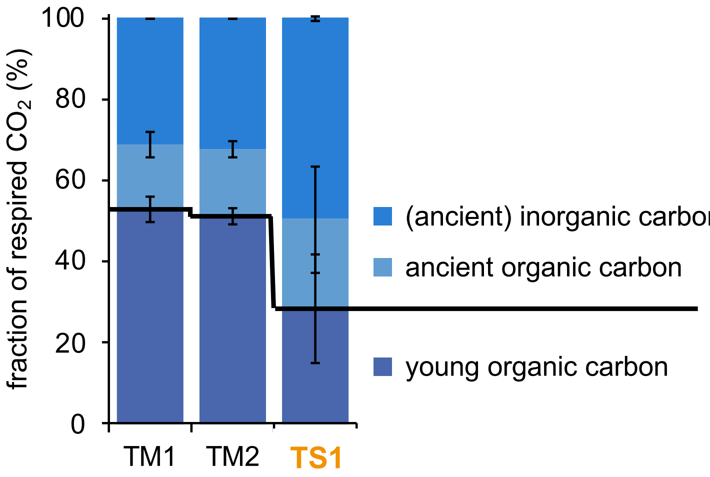
KoPF Kohlenstoff im Permafrost

Sponsored by the Federal Ministry of Education and Research



Identification of greenhouse gas sources by ^{14}C analysis *(University of Cologne, WP3.2)*

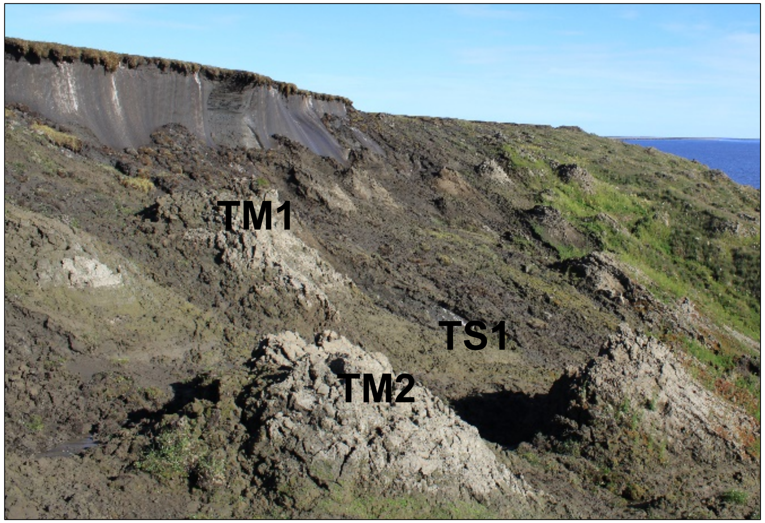
- Ca. 50% ancient C is released as CO_2 from freshly exposed Yedoma (*TM – thaw mound*).
- Admixtures of fresh C promotes respiration of ancient C (*TS – thaw slump).*

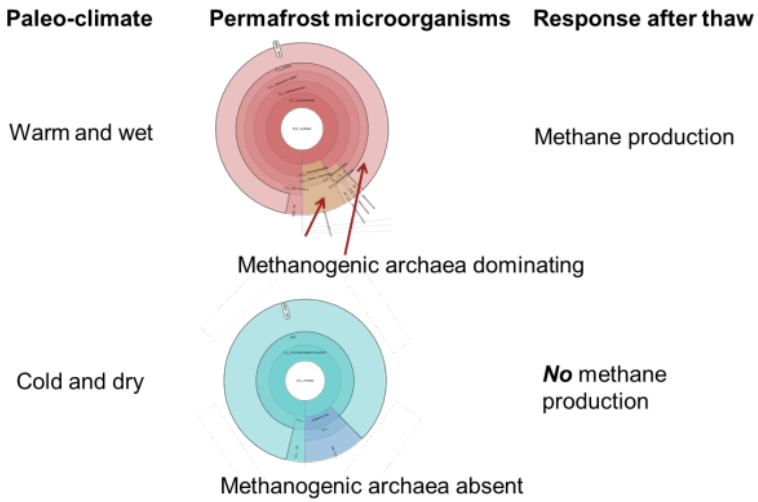


C process studies – WP 3

KOPF Kohlenstoff im Permafrost

Sponsored by the Federal Ministry of Education and Research





Regulation of microbial greenhouse gas formation in thawing permafrost *(GFZ Potsdam, WP3.3)*

- Microbial community from Eemian permafrost samples highly active after thaw
- Initial microbial community and palaeo-climate determine methane production after thaw (Holm et al., *submitted*),

Observing permafrost changes - WP 4

KoPF Kohlenstoff im Permafrost

Sponsored by the Federal Ministry of Education and Research

Main objective:

To conduct analysis of spatial heterogeneity and temporal variability of permafrost landscapes and their trace gas fluxes

Main research questions:

- What are the major predictors of the inter-annual variability of summer GHG fluxes?
- What is the impact of rapid disturbances and how does ground ic govern subsequent permafrost thaw dynamics?
- How are land cover changes affecting carbon pools in high latitudes? *(tbc)*

Ulrike Herzschuh, Guido Grosse, Ingmar Nitze, Birgit Heim, Alexandra Runge, Iulia Shevtsova (AWI Helmholtz Centre for Marine and Polar Research Potsdam)
Lars Kutzbach, Norman Rößger, David Holl (Universität Hamburg)

Lyudmila Pestrayakova (Northeastern State University Yakutsk)
Alexey Fague (Trofimuk Institute of Petroleum Geology and Geophysics, SB RAS, Novosibirsk)
Mikhail Grigoriev (Melnikov Permafrost Institute Yakutsk)

Observing permafrost changes - WP 4

KoPF Kohlenstoff im Permafrost

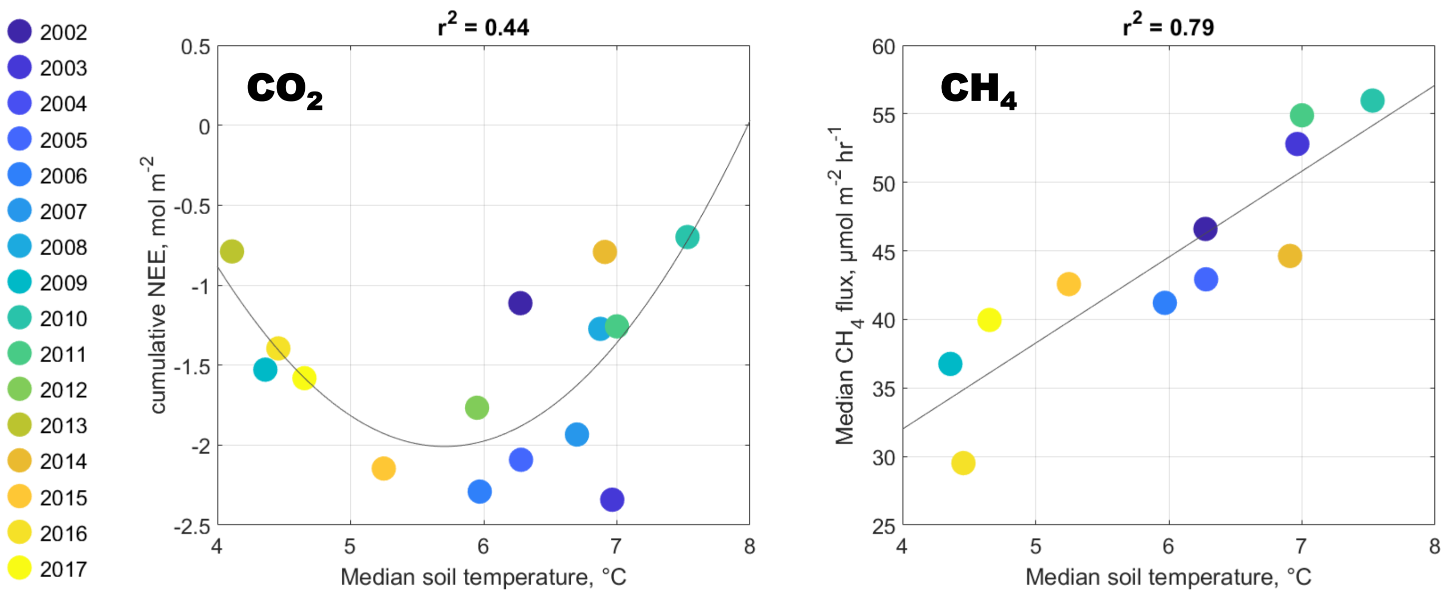
Sponsored by the Federal Ministry of Education and Research

- **GHG fluxes**
- Disturbance
- Biomass

Inter-annual variability of summer GHG fluxes

(UHH, Kutzbach et al. , WP4.1)

- Soil temperature is a very good predictor of inter-annual variability of warm-season GHG budgets
- Highest net CO_2 uptake at moderate soil temperatures



Observing changes in permafrost – WP 4

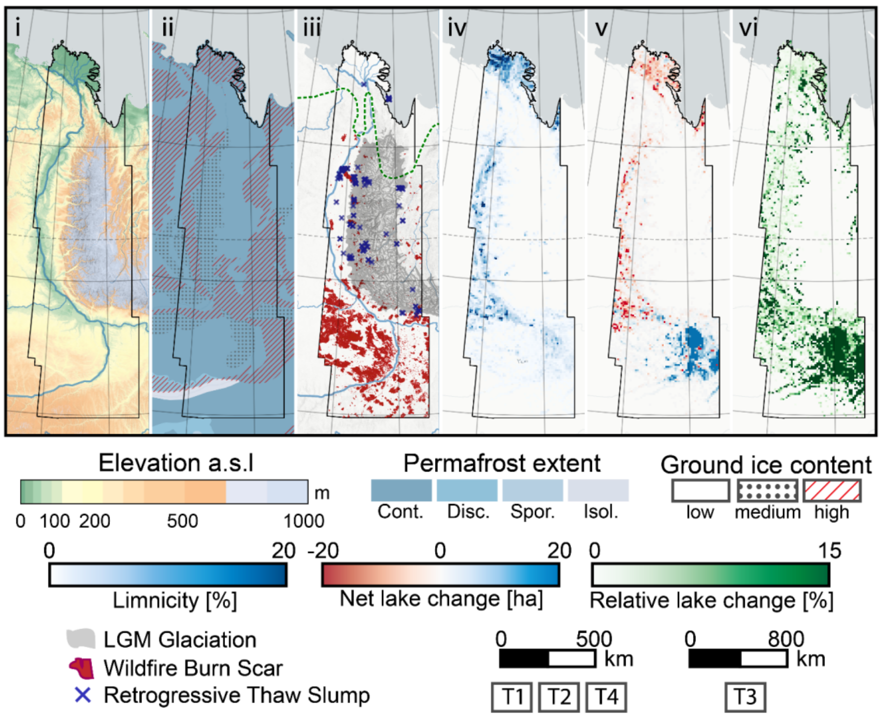
KoPF
KOHLENSTOFF IM PERMAFROST

SPONSORED BY THE
Federal Ministry of Education and Research

- GHG fluxes
- **Disturbance**
- Biomass

Regional permafrost disturbance trends

(Grosse et al., AWI, WP4.2)



Nitze et al. (2018), *Nature Communications.*

Nitze et al (2019) mapped permafrost region disturbances across the Arctic and Subarctic for 1999-2014

- First spatially consistent mapping of typical permafrost region disturbances across 4 large N-S transects
- Include thermokarst lakes, wildfires and thaw slumps
- Disturbances are a major driver of permafrost change and carbon release on global scale

Observing permafrost changes - WP 4

KoPF Kohlenstoff im Permafrost

SPONSORED BY THE Federal Ministry of Education and Research

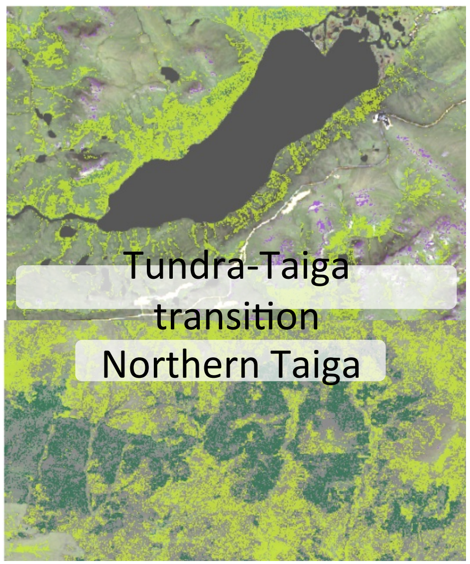
- GHG fluxes
- Disturbance
- **Biomass**

Above Ground Biomass and Carbon

(Herzschuh et al., AWI, WP4.3)

- Increasing shrub tundra, but slow treeline migration
- Disturbances increase aboveground carbon cycling

land cover change (2001-2017)

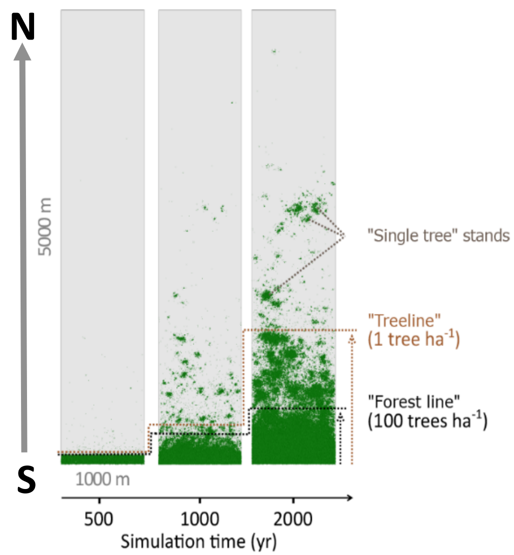


shrubification

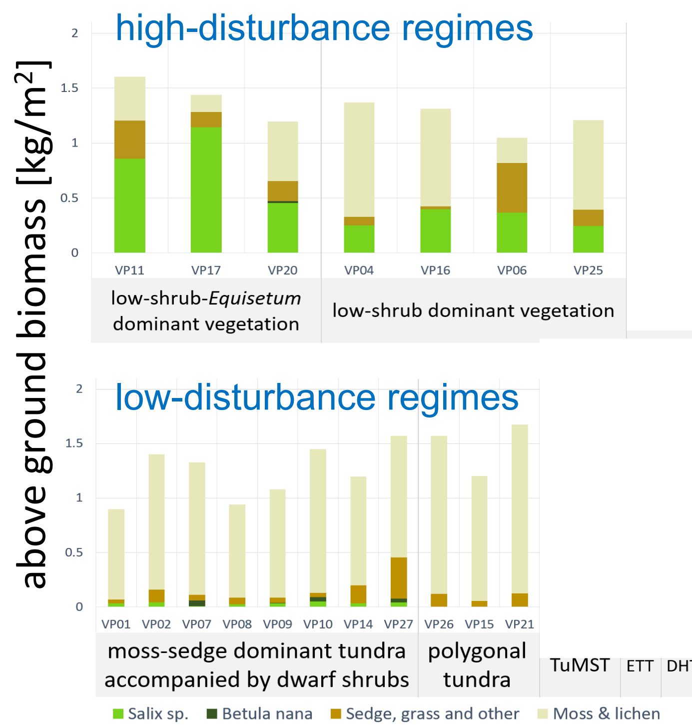
tree infilling

Shevtsova et al., in prep.

treeline advance



Kruse et al. 2019, Biogeosciences



Data: Lena Delta18 Expedition

Perspectives – open questions

Interactions of climate, ecosystem structure and biogeochemical cycles in Eurasian permafrost catchments during past, present and future

Scientific challenges:

- Can we explain past vegetation, CO_2 and CH_4 dynamics with our current understanding of biogeochemical processes?
- Did permafrost carbon-climate feedbacks contribute to CO_2 and CH_4 concentration rises during the Holocene?
- Will landscapes of northern latitudes become an increasing sink or source of CO_2 and CH_4?
- What is a realistic remaining emission budget in order to keep the global 1.5 °C change goal when considering vegetation shifts and permafrost thawing?

Perspectives – common tools

KoPF
Kohlenstoff im Permafrost
Sponsored by the Federal Ministry of Education and Research

Interactions of climate, ecosystem structure and biogeochemical cycles in Eurasian permafrost catchments during past, present and future

- Large spatial gradient of observational sites will be used for a space-for-time substitution approach to study long-term climate change impacts on ecosystem processes.
- A west-east transect will cover different precipitation regimes and two north-south transects will represent boreal-tundra shifts.
- A combination of lake and terrestrial sites will enable to understand landscape-scale processes.
- A combination of process based land and hydrological models will be parametrized by existing and new datasets from these sites.
- Coupled atmosphere-land simulations by the MPI-ESM will clarify biophysical (vegetation shifts) and biogeochemical (soil C release) feedbacks to climate change.

Discussion - next steps

SPONSORED BY THE
Federal Ministry of Education and Research

Understand land-aquatic-atmosphere interactions in changing permafrost landscapes using paleo records, recent biogeochemical process observations, vegetation shifts and process-oriented modelling

- Feedbacks between terrestrial and aquatic systems in degrading permafrost landscapes
- Effects of subaquatic permafrost thaw on GHG dynamics
- Lateral fluxes and turnover rates between soil-vegetation-complexes and water bodies in limnic systems
- Microbial GHG production and consumption in permafrost soils and waterbodies

- Reconstructing past catchment-waterbody carbon fluxes by combining biogeochemical and ecological research on modern ecosystems with paleo-limnological approaches