PAGE21 DEFROST COUP EU-JPI climate CAPTURE ACADEMY OF FINLAND UNIVERSITY OF EASTERN FINLAND

PERMAFROST MELTING AND CLIMATE CHANGE

CHRISTINA BIASI et al.

Department of Environmental and Biological Science

UNIVERSITY OF EASTERN FINLAND

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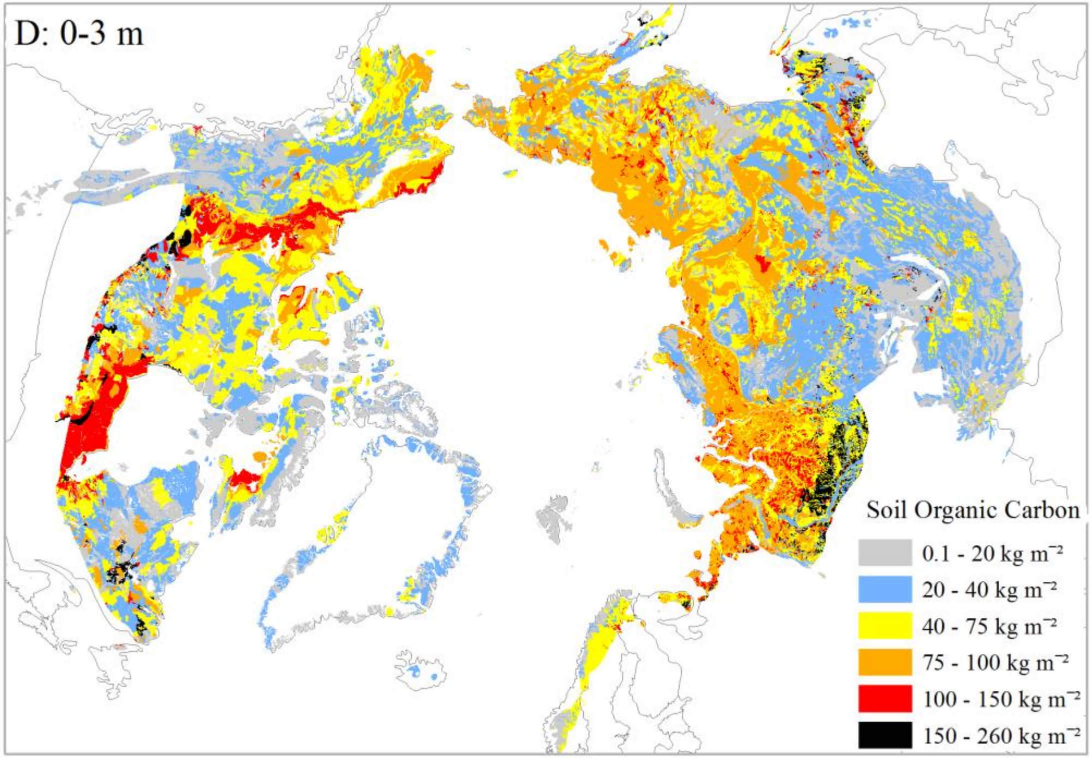
Oulu, Finland

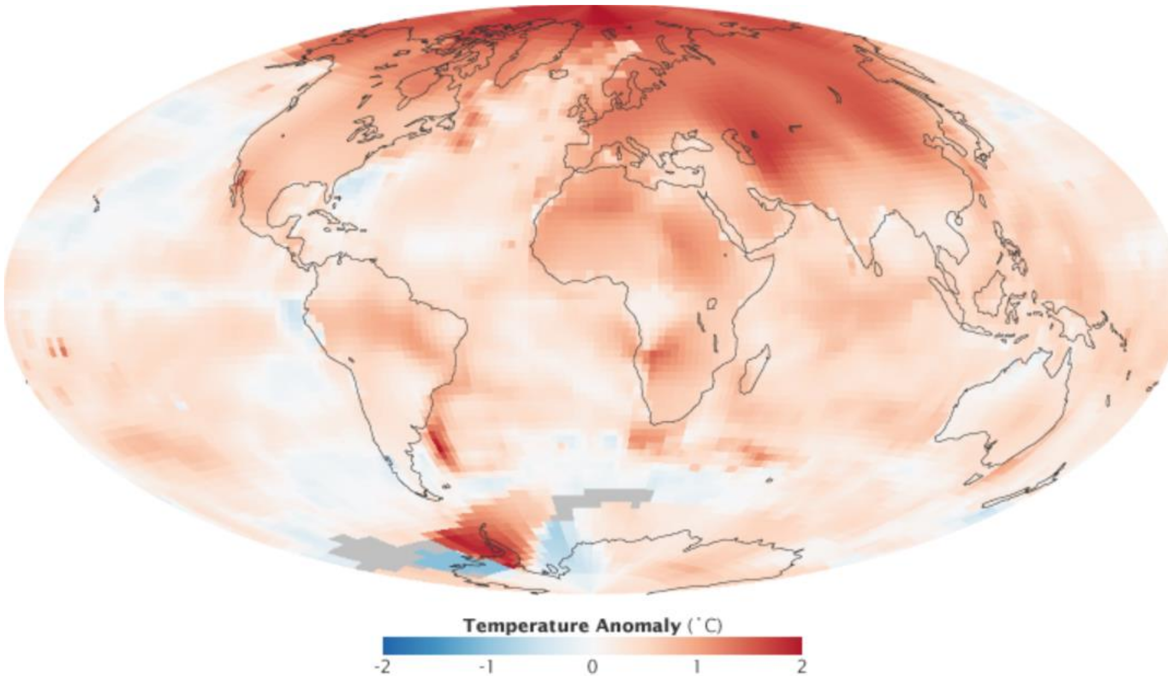
Estimated 1035±150 Pg soil C to 3 m depth in permafrost regions (about 40% of the global soil C pool)



Source: Hugelius et al., *2014 (Biogeoscience)*

High SOM stocks in northern soils:
Peatlands, permafrost, yedoma and cryoturbation

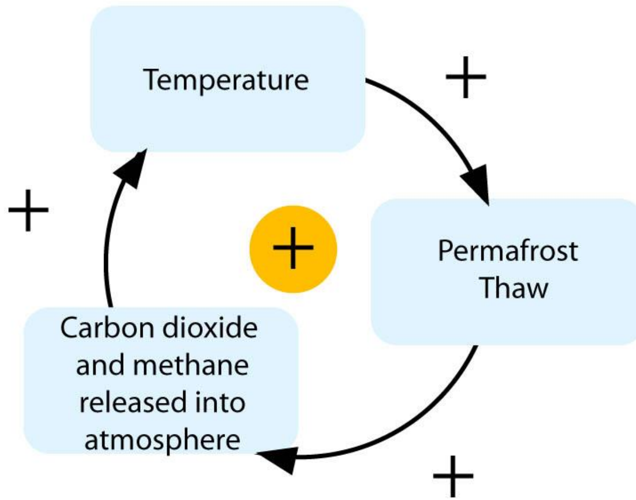
Arctic warming stronger than the global mean

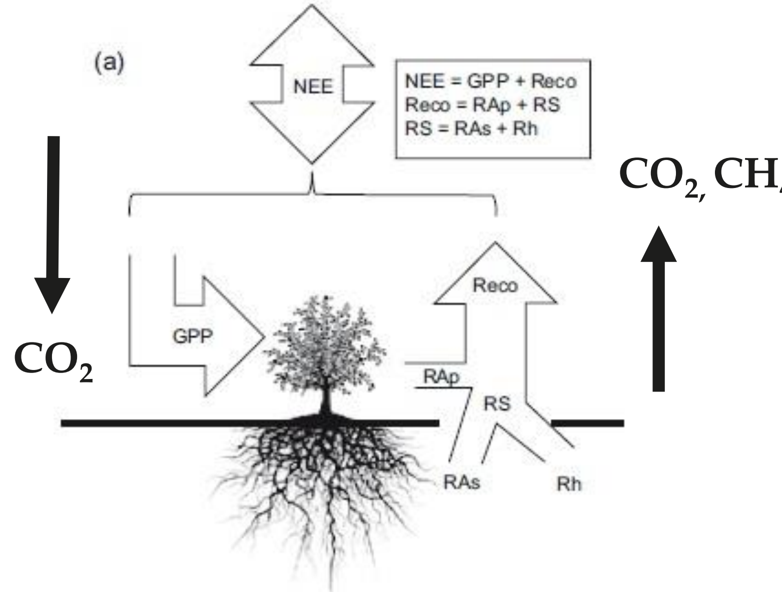


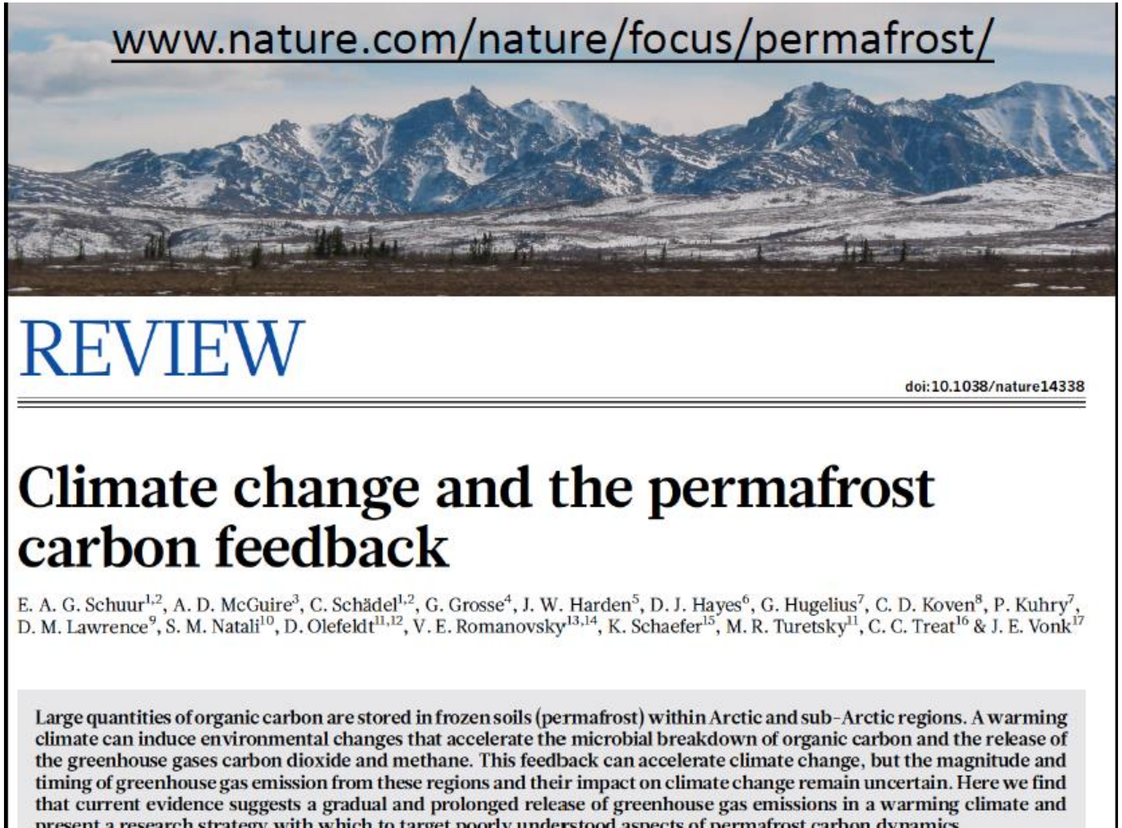
Temperatures will continue to increase (latest estimate: +8.3 degree until 2100 in the Arctic)

Arctic amplification of climate change

The permafrost-carbon feedback






www.nature.com/nature/focus/permafrost/

REVIEW

doi:10.1038/nature14338

Climate change and the permafrost carbon feedback

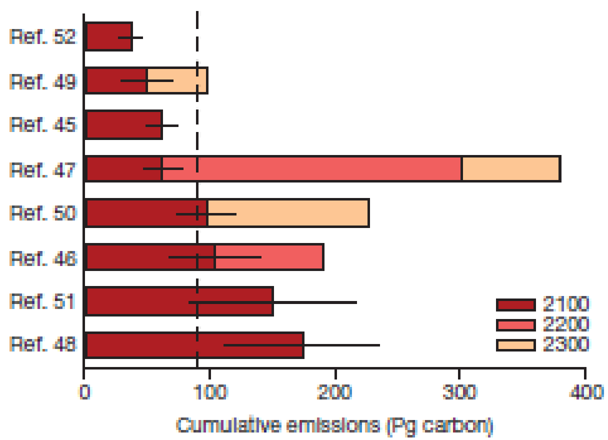
E. A. G. Schuur[1,2], A. D. McGuire[3], C. Schädel[1,2], G. Grosse[4], J. W. Harden[5], D. J. Hayes[6], G. Hugelius[7], C. D. Koven[8], P. Kuhry[7], D. M. Lawrence[9], S. M. Natali[10], D. Olefeldt[11,12], V. E. Romanovsky[13,14], K. Schaefer[15], M. R. Turetsky[11], C. C. Treat[16] & J. E. Vonk[17]

Large quantities of organic carbon are stored in frozen soils (permafrost) within Arctic and sub-Arctic regions. A warming climate can induce environmental changes that accelerate the microbial breakdown of organic carbon and the release of the greenhouse gases carbon dioxide and methane. This feedback can accelerate climate change, but the magnitude and timing of greenhouse gas emission from these regions and their impact on climate change remain uncertain. Here we find that current evidence suggests a gradual and prolonged release of greenhouse gas emissions in a warming climate and present a research strategy with which to target poorly understood aspects of permafrost carbon dynamics.

- **Climate change and the permafrost carbon feedback**
- ***Schuur et al. 2015, Nature 520, 171–179***

Projected changes

Models & exp. data



- Projected loss in permafrost C by models: on average **ca. 100 Pg** by 2100 (**about 10 %**)
- Wide uncertainity
- Increased plant uptake may in part offset the permafrost C release (estimate of + **17 Pg** by 2100)
- In the long term release of C will be higher than plant C uptake

Projected changes

Models & exp. data

+ 0.13-0.42 degree Celsius by 2100/2300 only from permafrost C

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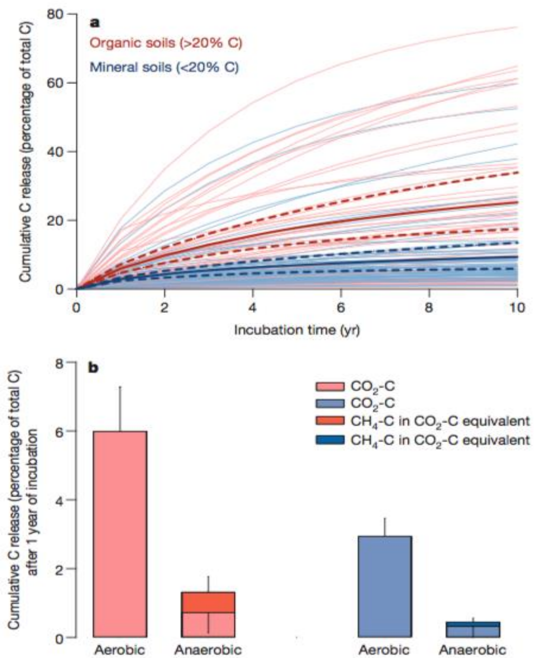
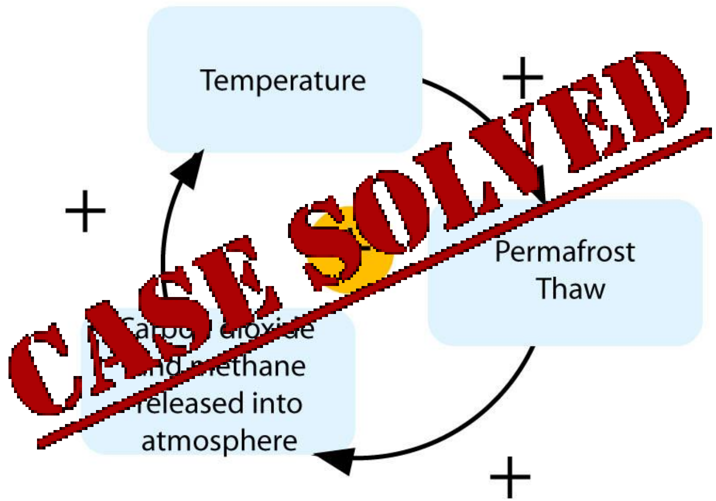
Projected changes



- C emissions from anaerobic incubations are only 15-20% of those from aerobic ones (considering GWP)
- Even lower at field conditions, where CH4 oxidation takes place
- **Thus a unit of permafrost C has greater impact on the climate if it is released under dry than wet conditions**

Schuur et al. 2015, Nature 520, 171–179
Schädel et al, Nature Climate Change, 2015

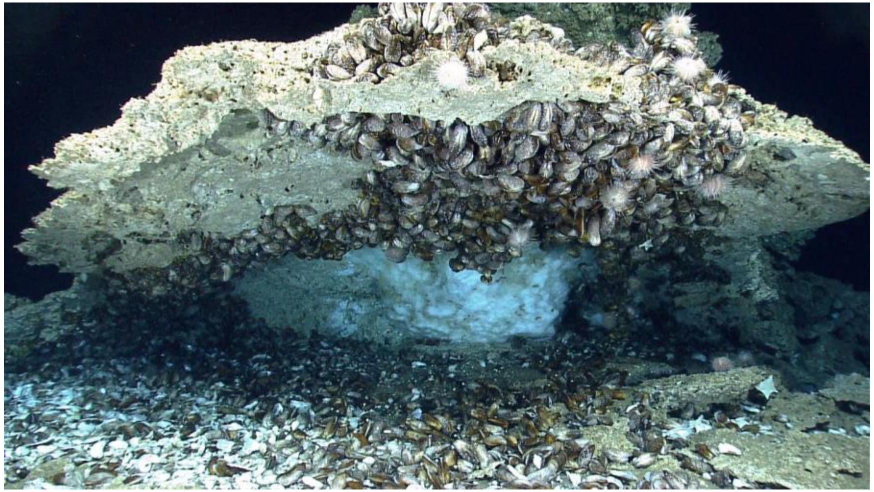
The permafrost-carbon feedback



?

Methane

- How do laboratory incubations relate back to the field? **Impact of plants?**
- Need for **longer-term anaerobic incubations** to fully capture CH_4 dynamics (Treat et al., 2015)
- Arctic methane emissions **underestimated** - they persist in winter (Donatella, PNAS, 2016)
- **Methane hydrates** from oceans and deep permafrost (Mestdagh et al., 2017)



Abrupt thaw events not yet inlcuded in the models

Thermokarst

Landforms that results from the **permafrost thaw and melting of ground ice**

Leads to:

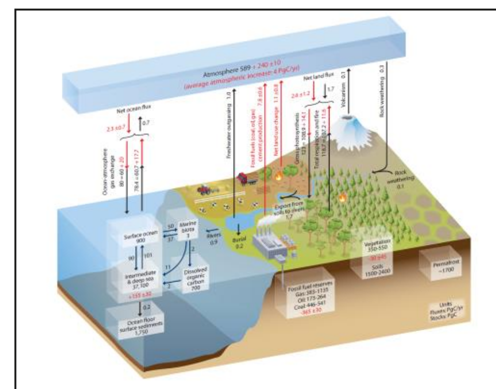
- Displacement of soil material,
- Disturbance of vegetation cover,
- Changes in drainage conditions

Important consequences for biogeochemical cycles!

Kokelj and Jorgenson, 2011

COUP aim:
to use landscape-scale process understanding to constrain uncertainties in Earth System Model projections of the permafrost-climate feedback

1 km



igure 6.1: Simplified schematic of the global carbon cycle. Numbers represent reservoir mass, also called 'carbon tocks' in PgC (1 PgC = 10^{15} gC) and annual carbon exchange fluxes (in PgC yr^{-1}). Black numbers and arrows indicate

"COUP":
Constraining uncertainties in the permafrost carbon feedback

A project of the EU Joint Programme Initiative (JPI-climate)

Funded in the call: Russian Arctic and Boreal systems

Total budget: 2,500,000 €

7 full partners
(Stockholm University, University of Helsinki, University of Copenhagen, University of Oslo, UK Met Office, Leeds University of Eastern Finland,)

4 external partners with their own co-funding
(Russia, Germany, USA, Netherlands, University of Vienna)

ACADEMY OF FINLAND

C stocks in permafrost areas

Key uncertainties: ground ice **and sediment depth**

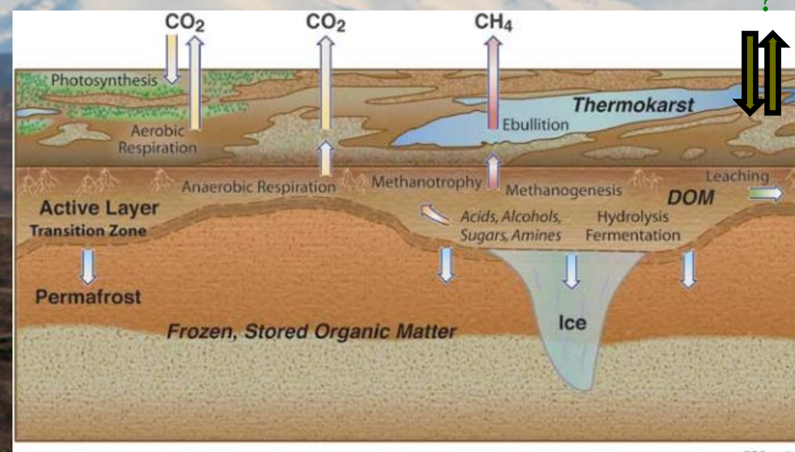
Current esimate of permafrost region SOC is ca. 1300–1400 Pg C, with an uncertainty range of 1100–1600 Pg

Permafrost non-carbon feedbacks

CO_2 sink
-110 Tg C yr^{-1}

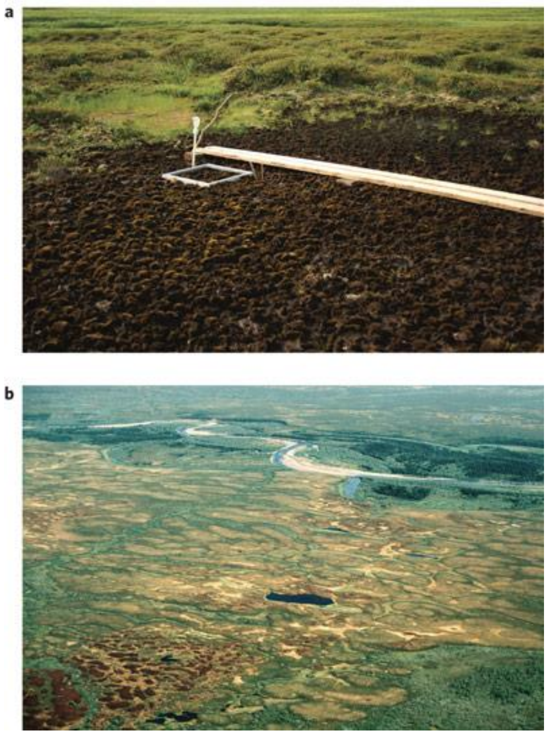
CH_4 source
+19 Tg C yr^{-1}

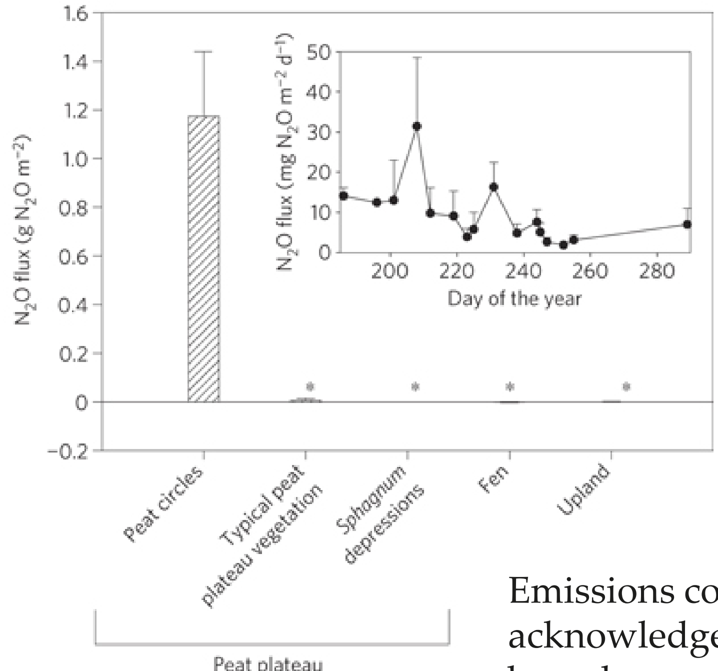
N_2O
?



Permafrost non-carbon feedbacks

High N_2O emissions found from bare peat surfaces, a common land form in permafrost peatlands.

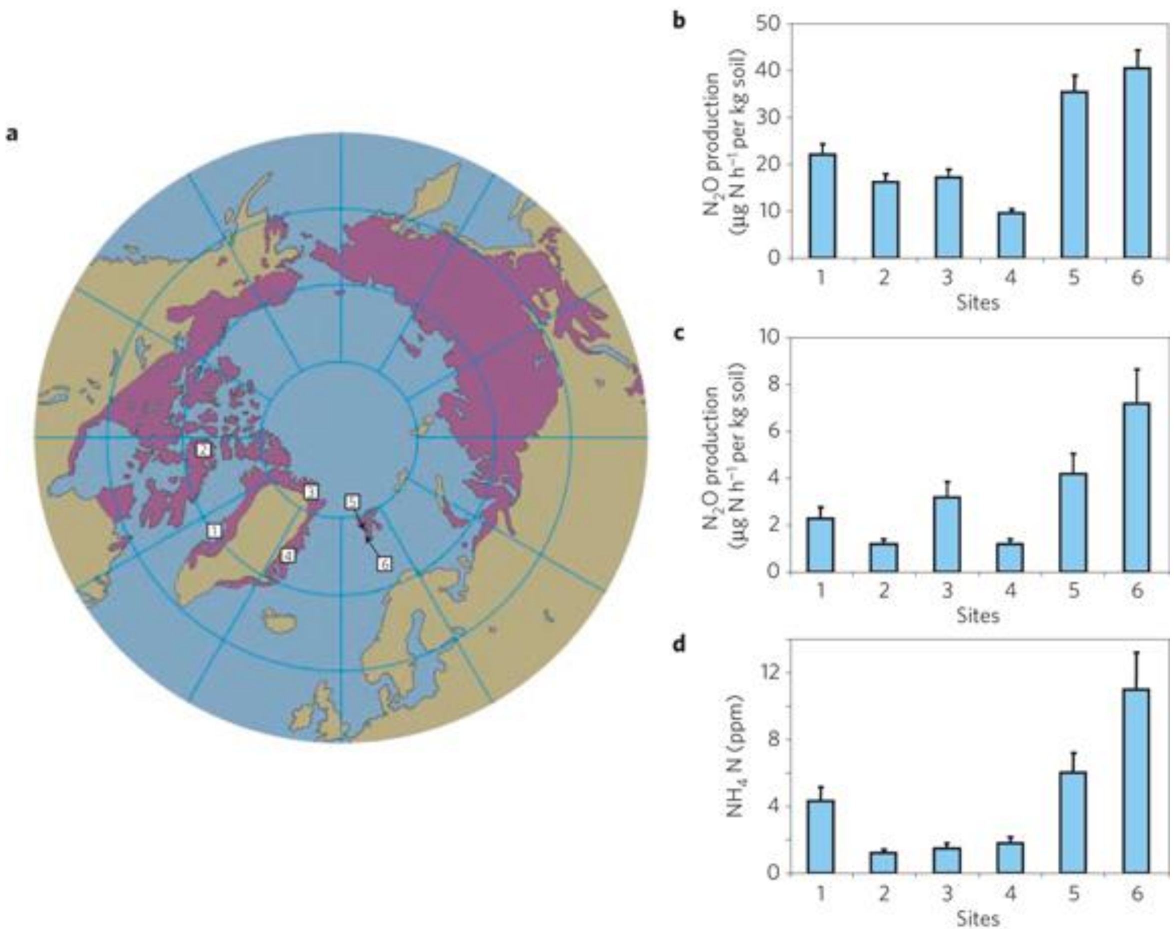




(Repo et al. 2007)

Emissions comparable to well-acknowledged N_2O sources: boreal organic croplands and tropical forest soils.

Future N_2O emissions from the Arctic: Permafrost thaw

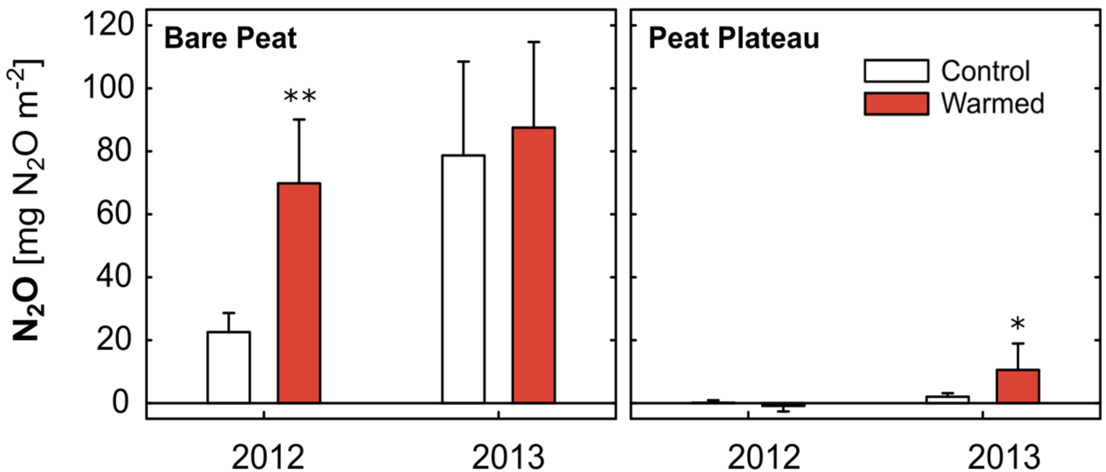


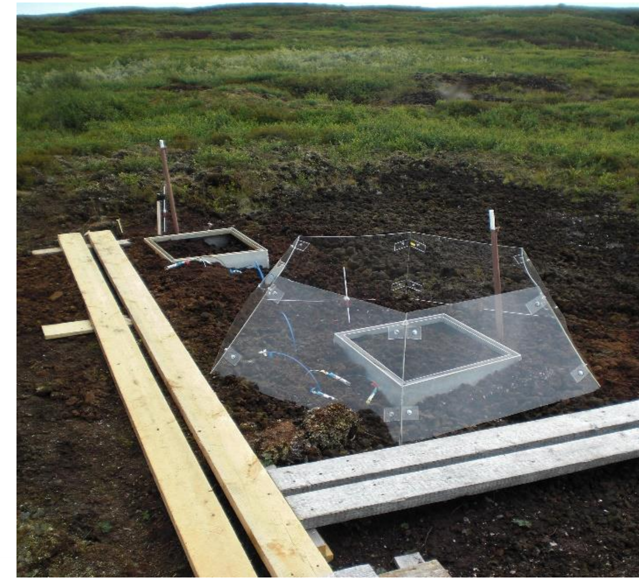
High N_2O production from arctic wetland soils after thawing, drainage and rewetting with the original melt water with high NH4+ content.

Drying and rewetting treatment imitated the drainage changes following permafrost thaw.

Elberling et al. 2010, Nature Geoscience

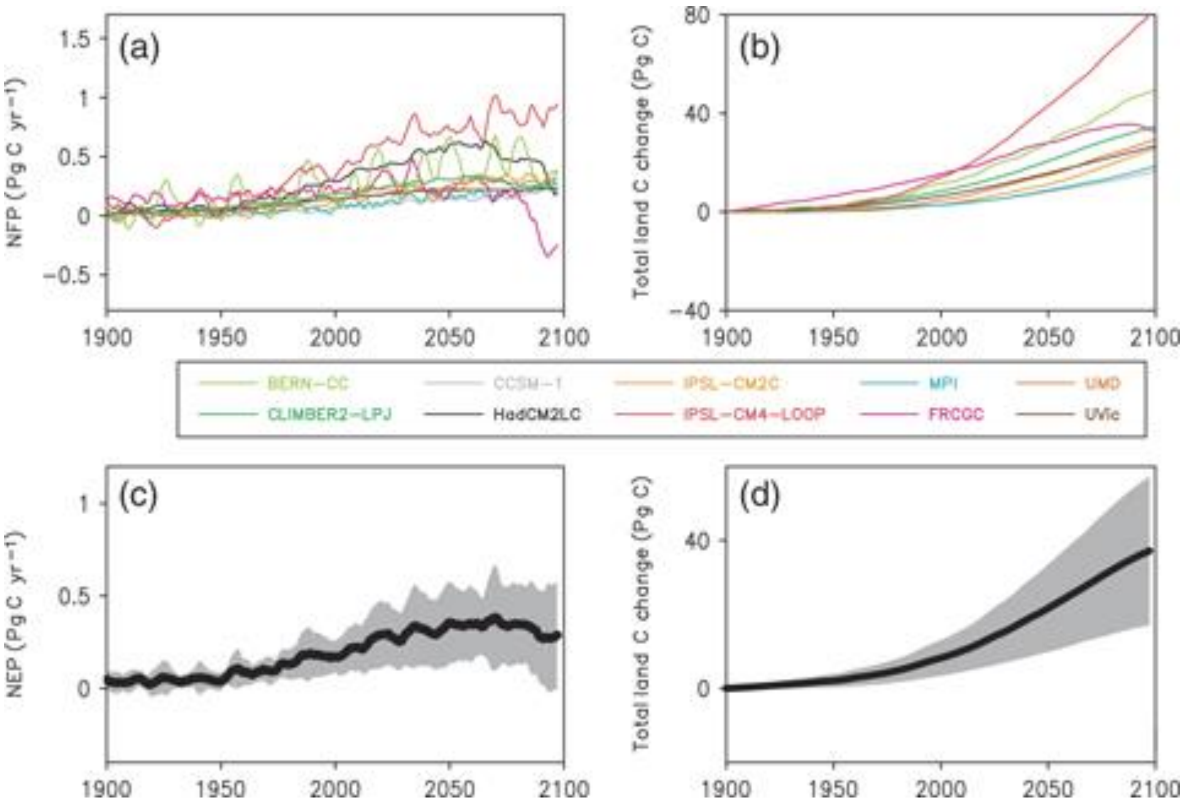
Future N_2O emissions from the Arctic: warming





In a field manipulation experiment, **air warming by ~1°C significantly increased the N_2O release** from bare peat.
Warming induced N_2O emissions also from vegetated peat plateau, covering large areas in the subarctic There, warming had an adverse effect on plant growth, which likely increased the N availability for microbial N_2O production.

Will enhanced C uptake by plant compensate for increased belowground C loss with warming?

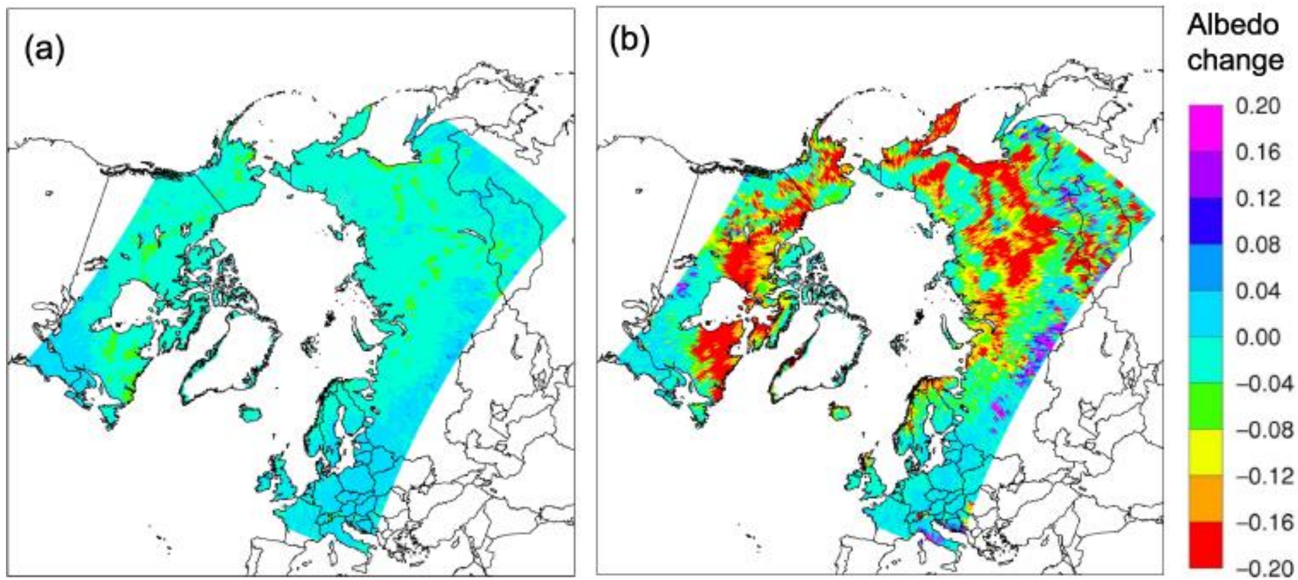


Qian et al. 2010

Changes of net ecosystem production (NEP) and total land organic carbon in the northern high latitudes (NHL) during 1901–2100 (a) and (c) NEP; (b) and (d) Total land organic carbon change.

Arctic greening

- Vegetation in the Arctic is generally limited by cold temperatures and short growing season
- Improved plant growth and changes in the vegetation composition (shrubification, tree line advance) expected with warming climate
- Increase in C sink
- Decreased albedo!



Zhang et al. 2013 **Tundra shrubification and tree-line advance amplify arctic climate warming: results from an individual-based dynamic vegetation model**

Arctic browning

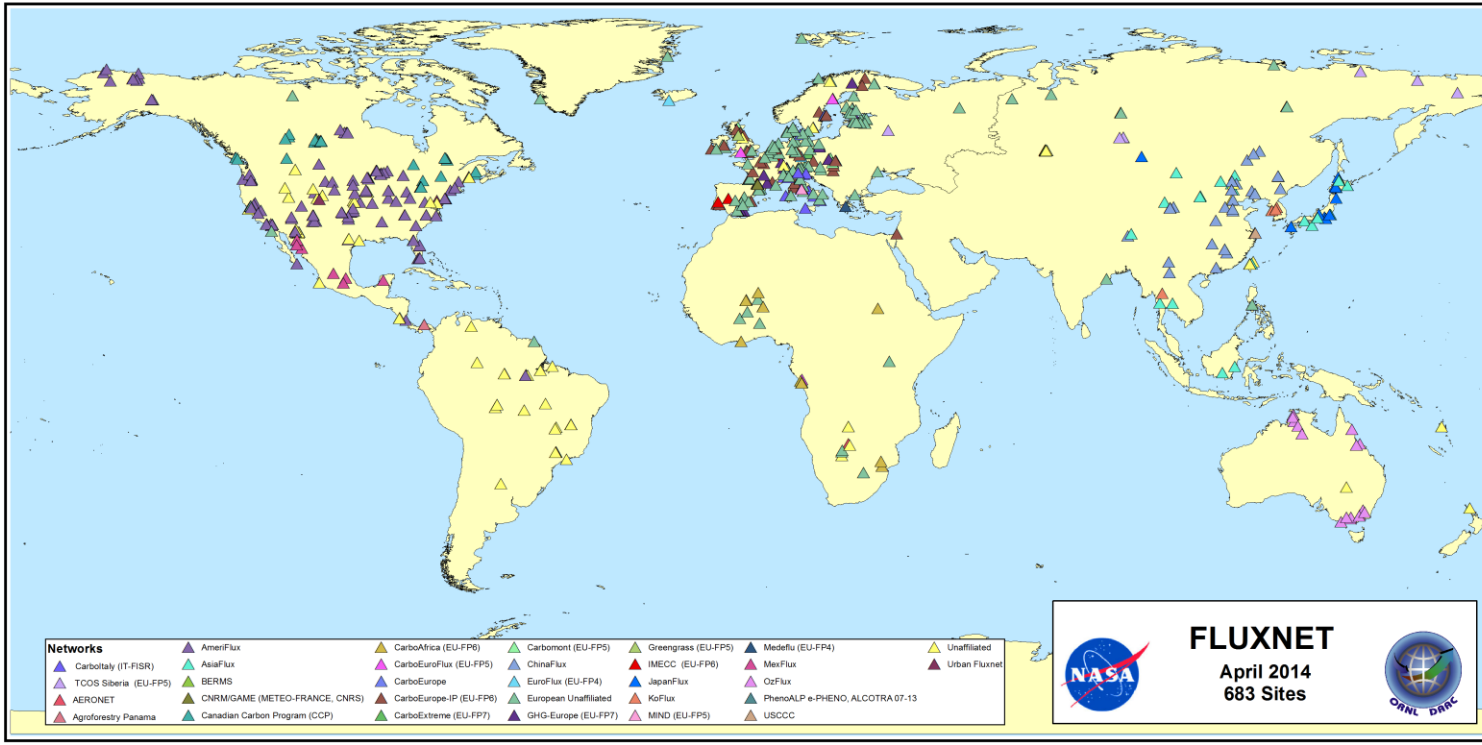
- Concept developed to describe different kinds of disturbances, opposing the greening trend
  - Thermokarst
  - Fire
  - Pest outbrakes
  - Extreme weather events
- Browning is understudied an emerging research field!

Larval outbreak of a moth in West Greenland

How to reduce uncertainties in present and future carbon/GHG balance?

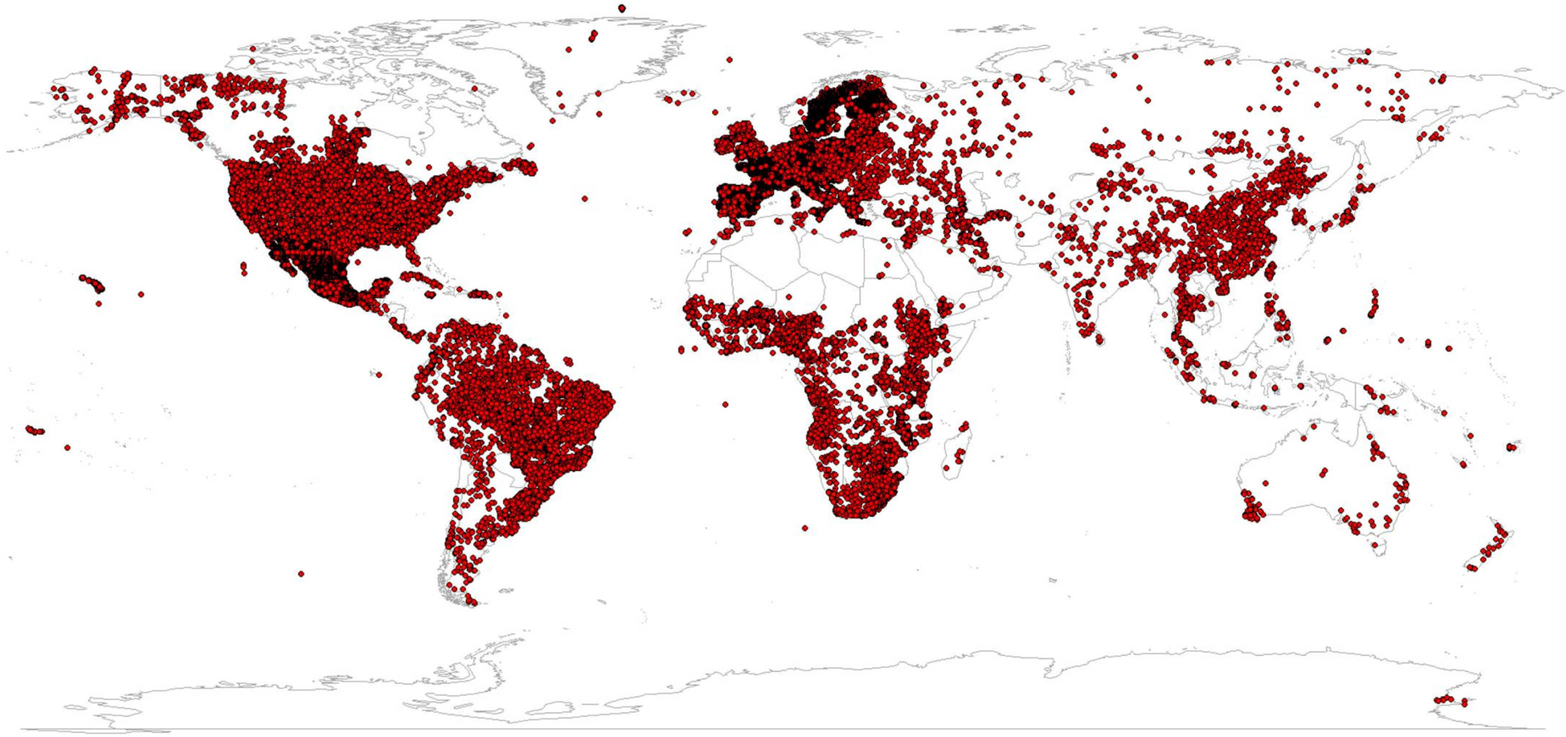
1. the **strategic placement of more CO_2 and CH_4 monitoring stations** to reduce uncertainties in predictions, inclusion of N_2O monitoring stations

Long-term GHG flux monitoring sites



Permanent sites for micrometeorological eddy covariance measurements – large gaps in the Arctic!

Soilgrids 1 km datapoints (ca. 110,000)



Hengl T, de Jesus JM, MacMillan RA, Batjes NH, Heuvelink GBM, et al. (2014) SoilGrids1km — Global Soil Information Based on Automated Mapping. PLoS ONE 9(8): e105992. doi:10.1371/journal.pone.0105992
http://127.0.0.1:8081/plosone/article?id=info:doi/10.1371/journal.pone.0105992

How to reduce uncertainties in present and future carbon/GHG balance?

1. the **strategic placement of more CO_2 and CH_4 monitoring stations** to reduce uncertainties in predictions, addition of N_2O monitoring stations
2. **improved observation networks of ground-based measurements of CO_2, CH_4 and N_2O** exchange to understand exchange in response to disturbance and across gradients of climatic and hydrological variability
3. **the effective transfer of information from enhanced observation networks into process-based models** to improve the simulation of CO_2, CH_4 and N_2O (?) exchange from Arctic tundra to the atmosphere."


HONEY, YOU BETTER GET OUT HERE!

Thank you!

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