Expert Assessment of Organic Carbon Stocks and Vulnerability in Subsea Permafrost

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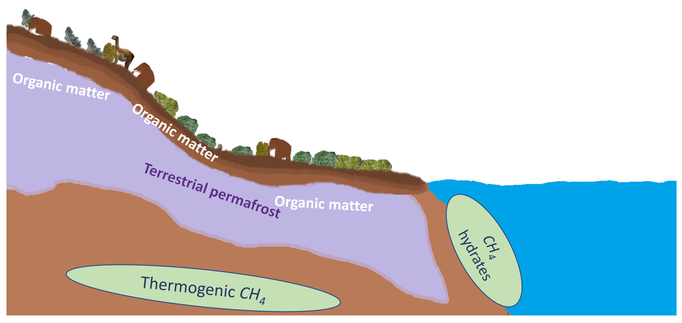
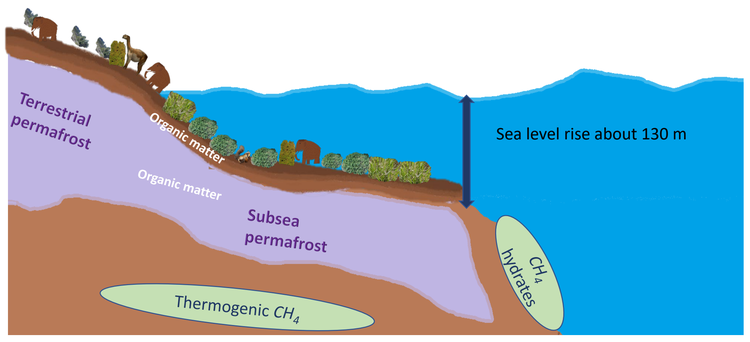
Does subsea permafrost carbon matter?

During the Last Glacial Maximum (26,500 BP)



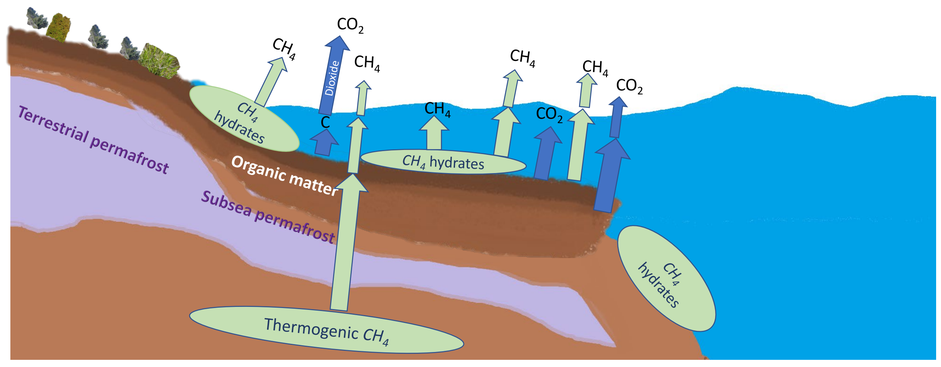
- Subsea permafrost (perennially frozen sediment, soil, and other material) exists under portions of the shallow continental shelves of the Arctic Ocean [1,2]. This permafrost formed prior and during the Last Glacial Maximum (LGM) when unglaciated portions of the exposed continental shelves accumulated hundreds of billions of tons of carbon in soil profiles from undecomposed plant material [3,4].

Ice-sheet and glacial melt caused huge sea-level rise (14,000 BP)



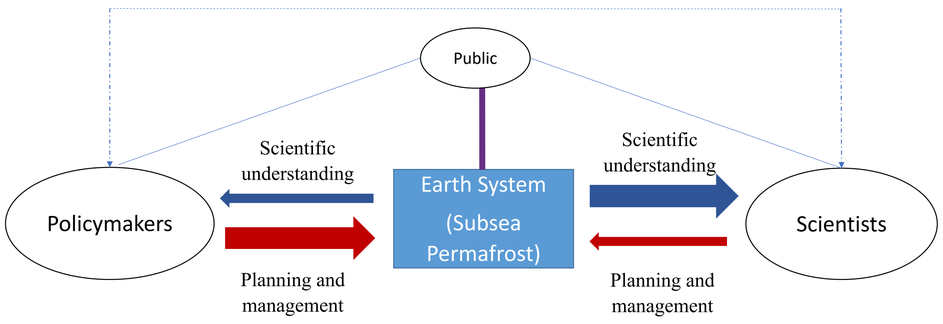
- As ice sheets and glaciers melted after the Last Glacial Maximum, sea level rose ~130 m. This inundated several million square kilometers of terrestrial permafrost and the organic matter it contained.

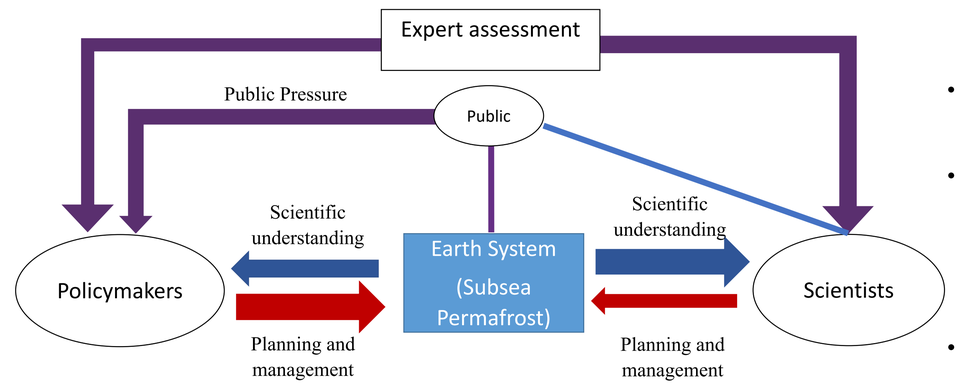
Since inundation, subsea permafrost degrades and releases CO_2 and CH_4

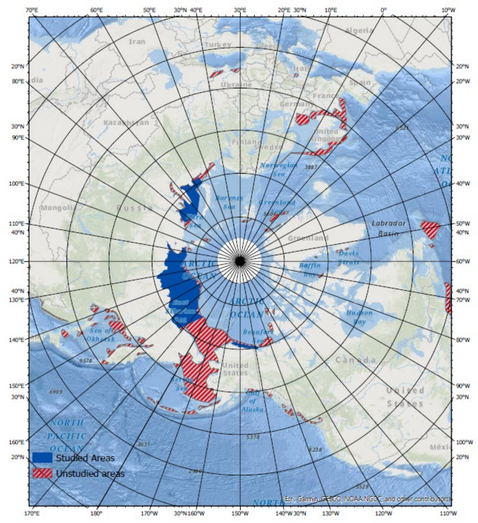


- Ever since it was flooded, the subsea permafrost has been thawing, which could potentially release CH4 and CO2 from its large carbon pool. The continental shelves of the Arctic Ocean and surrounding seas contain large stocks of organic matter and CH_4 hydrates. The size of these carbon deposits and their vulnerability to climate change are highly uncertain, though it has been hypothesized that they may influence the global climate system on decadal to centennial timescales.

Combining expert estimates to quantify risk and predict subsea permafrost climate feedback







Map of the studied and unstudied areas of subsea permafrost base on the review papers. Based on subsea permafrost map from Lindgren et al. 2016

- Expert assessment methods have long been used to support decision making with the best available information
- A questionnaire with 12 major questions was designed that asked experts to provide estimates of the magnitude and timing of subsea permafrost carbon stocks and fluxes in the past, present and future for two warming scenarios from the most recent IPCC radiative forcing scenarios (RCP4.5 and RCP8.5).
- For each question, the experts provide estimations for three confidence intervals, in addition to expertise level, confidence level, sources of uncertainty.

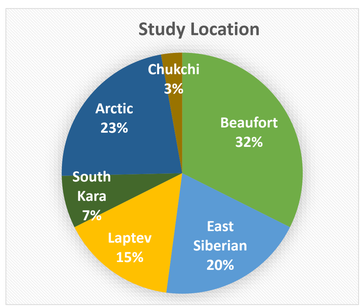
Conclusions

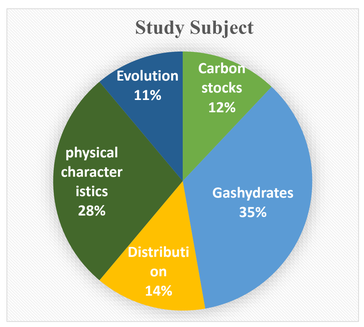
- Experts estimated that 300 (100 to 700; median and interquartile range) gigatons of carbon (GtC) is currently stored in organic matter on the continental shelves of the Arctic Ocean, a decrease of ~45% since the LGM
- Current methane hydrate stocks were estimated at 35 GtC (11.25 to 103.75) and current fluxes of CH_4 and CO_2 to the atmosphere were estimated at 3.5 teragrams (Tg)/yr (2.5 to 7.5) and 26 Tg/yr (1.37 to 42.25) respectively.
- Estimates of changes in future emissions of CH_4 and CO_2 were highly uncertain, though was general agreement that a policy-relevant increase of carbon emissions could occur by 2100 and 2300. At 2050, for RCP4.5, 5.68 Tg/yr (2.79 to 6.51) CH_4 and 38.4 Tg/yr (18.36 to 168.75) CO_2 emissions were estimated. For RCP8.5, 4.42 Tg/yr (0.87 to 9.04) CH_4 could be emitted by 2050 and, 41.6 Tg/yr (19.21 to 188.75) CO_2 .
- While these estimates will certainly be revised by future research, expert assessment is an important way to inform policy makers and the public about the possible magnitude of the subsea permafrost feedback to climate change.

Meta-analysis of previous studies

- We reviewed nearly 100 academic papers from 1949 to 2019, including all that were returned when we searched subsea permafrost to understand the current state of knowledge ,uncertainties and identifying the experts of the field.
- Critical research questions are:

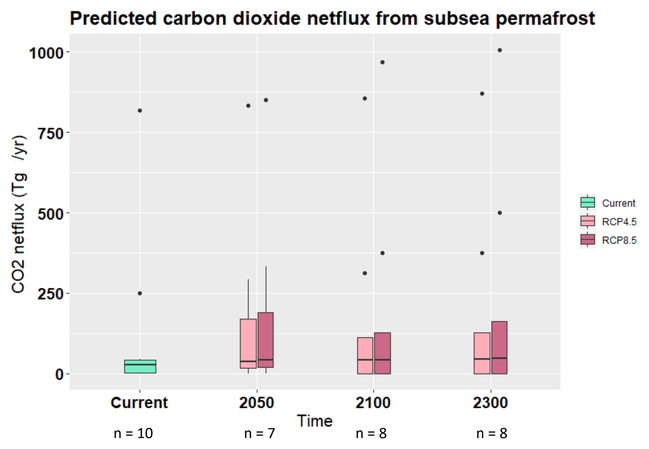
1. Assess risks of abrupt CO2 and CH4 release, two of the major anthropogenic greenhouse gases,
2. Provide a critical long-term perspective on vulnerability of carbon currently being thawed from subsea permafrost
3. Generate first-order estimates of energy resources on the continental shelves.

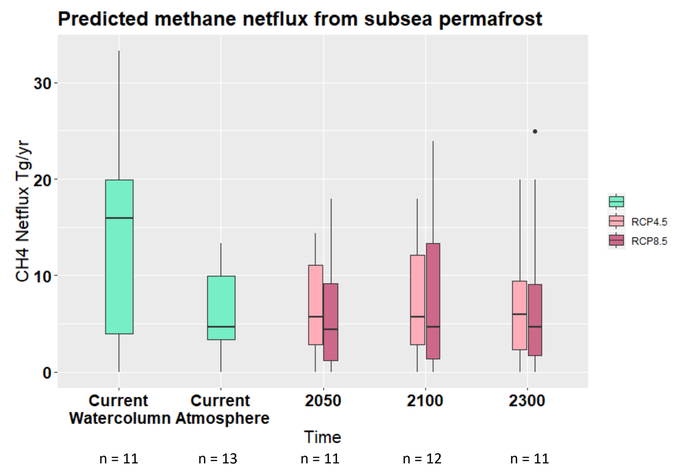


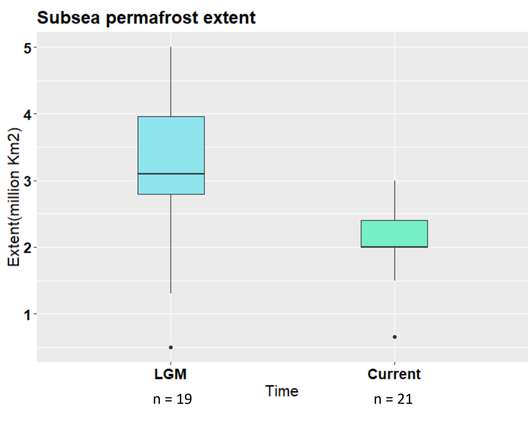


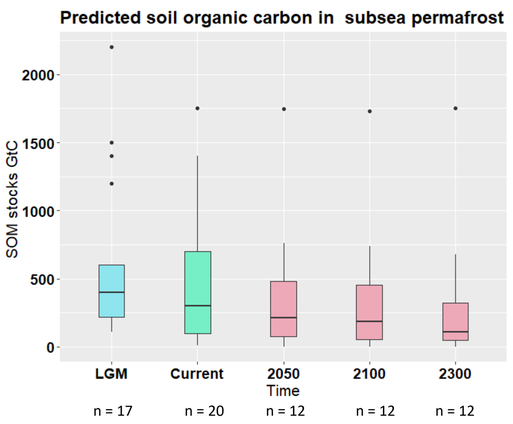
Participating Experts	
Number of respondents	23
Female: Male ratio	8:15
Age average	41
Average self-rate (1 is exclusively field research and 5 is exclusively modeling research)	2.55
General Field	Ecosystem Ecology: 5 Biogeochemistry: 7 Geophysics: 8 Others
Average years of expertise	7.8 years
Primary geographic regions of expertise	Beaufort:7 East Siberian, Chukotka, Laptev: 8 Qinghai Tibetan Plateau: 1 Arctic: 8

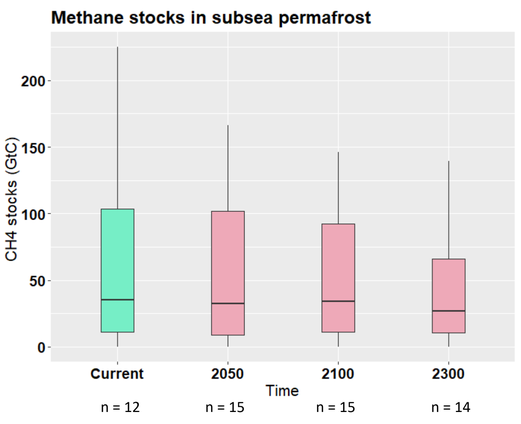
Subsea permafrost warming and carbon release











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