Final Preport for Project **1142**

Project title: **Nunataryuk WP8**

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Summary

In a comprehensive cooperation between four institutes (MPIM, UHH, ULB, IIASA) from three European countries, we have for the first time investigated the climatic influence from fossil permafrost carbon entering the Arctic Ocean through thawing and degradation of permafrost. We determine climatic influences both from methane directly entering the atmosphere but also through a reduction of the CO2 sink in the Arctic Ocean. These effects will increase the costs of climate mitigation for the global society. In the global CH4 budget, subsea permafrost is likely to play only a minor role, but still major uncertainties remain to be resolved, which may – in extreme settings – cause it to become an important factor for the future climate. Due to lack of data, CH4 release from thawing subsea permafrost does neither include CH4 from gas reservoirs which may leak due to the thaw nor gas hydrate dissolving and should therefore be considered as an underestimate.

The future state of the subsea permafrost was modeled using a version of JSBACH (land component of MPI Earth System model) modified to run for the deep sediments using data from CMIP6-type simulations extended until year 3000 for there different climate scenarios and the data from SuPerMAP as initial conditions. We found that the thawing of the subsea permafrost strongly depends on climate scenarios and is strongest in the 22nd century (Wilkenskjeld et al, 2022). It is strongly linked to the reduction of sea ice.

Simulated JSBACH thaw rates and CMIP6-type simulation data were then used to force a pseudo two-dimensional reaction-transport model on a pan-arctic grid to simulate methane production, consumption and multiphase transport in permafrost bearing sediments and quantify seafloor methane, as well as dissolved inorganic carbon and alkalinity fluxes from the warming Arctic shelf over the period (1900-2300) and for three different climate scenarios.

We represented organic matter fluxes (particulate and dissolved, including nutrients) from coastal permafrost erosion estimated by Nielsen et al. (2022), as well as inorganic carbon from dissolution of subsea permafrost CH4 bubbles in the Hamburg Ocean Carbon Cycle Model (HAMOCC), the ocean biogeochemistry component of MPI-ESM. We found that both the oxidation of subsea permafrost methane bubbles and coastal erosion decrease the Arctic Ocean CO2 uptake from the atmosphere, especially in shallow shelf areas, where subsea permafrost is more vulnerable, and erosion rates are larger.

We were able to estimate the climate feedback of coastal permafrost erosion, for the first time, which is allowed by our representation of the Arctic Ocean CO2 response to coastal permafrost erosion with a fully coupled ESM. We find that coastal permafrost erosion exerts a positive biogeochemical feedback on climate, increasing atmospheric CO2 by 1-2 TgC/year per degree-C of increase in global surface air temperature, which translates to a climate feedback of about 10-3 W-1 m-2 °C-1 (Nielsen et al,., 2024).

Publications

Nielsen, D., **Chegini, F.**, **März, J.**, Brune, S., Mathis, M., Dobrynin, M., Baehr, J., **Brovkin, V.** & **Ilyina, T.** (2024). Reduced Arctic Ocean CO2 uptake due to coastal permafrost erosion. *Nature Climate Change*, *2024*. doi:10.1038/s41558-024-02074-3

Nielsen, D., Pieper, P., Barkhordarian, A., Overduin, P., **Ilyina, T.**, **Brovkin, V.**, Baehr, J. & Dobrynin, M. (2022). Increase in Arctic coastal erosion and its sensitivity to warming in the twenty-first century. *Nature Climate Change*. doi:10.1038/s41558-022-01281-0

Wilkenskjeld, S., Miesner, F., Overduin, P., Puglini, M. & **Brovkin, V.** (2022). Strong increase in thawing of subsea permafrost in the 22nd century caused by anthropogenic climate change. *The Cryosphere*, *16*, 1057-1069. doi:10.5194/tc-16-1057-2022