Project: **1142**

Project title: **Nunataryuk WP8**

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Project aim

The aim of the work on the Nunataryuk project in the reporting period has been to set up a data flow allowing to feed the HAMOCC model with benthic fluxes of dissolved inorganic carbon (DIC), methane and alkalinity arising from thawing of subsea permafrost (SSPF) in addition to the standard forcing. These data are created by feeding the sediment chemistry model BRNS (performed at the ULB) by SSPF thawing rates calculated by the SSPF model developed during the previous years in bm1142.

Resolution change of forcing data

The SSPF thawing published in Wilkenskjeld et al. (2022) was based on low resolution (T31) MPI-ESM runs. This work suggested that the most important dynamics of the SSPF thawing takes place before year 2300. The T31 resolution, however, is insufficient to provide reliable results from HAMOCC. Therefore the r1i1p1f1 runs of the SSP1-2.6, SSP2-4.5 and SSP5-8.5 CMIP6 scenarios were extended to year 2300 according to the CMIP6 protocol (though land use change data for SSP2-4.5 were not available after 2100) using the MPI-ESM in the LR setup (T63 resolution). Afterwards the offline SSPF version of JSBACH was used to recalculate the SSPF thawing rates. Since the CMIP6 runs are colder than the previously used T31 runs by about 1K, the recalculated thawing rates (Fig. 1) are lower than those presented in Wilkenskjeld et al. (2022) by 5-10%, but otherwise the results are very similar (geographical patterns, timing of larger changes, etc.).

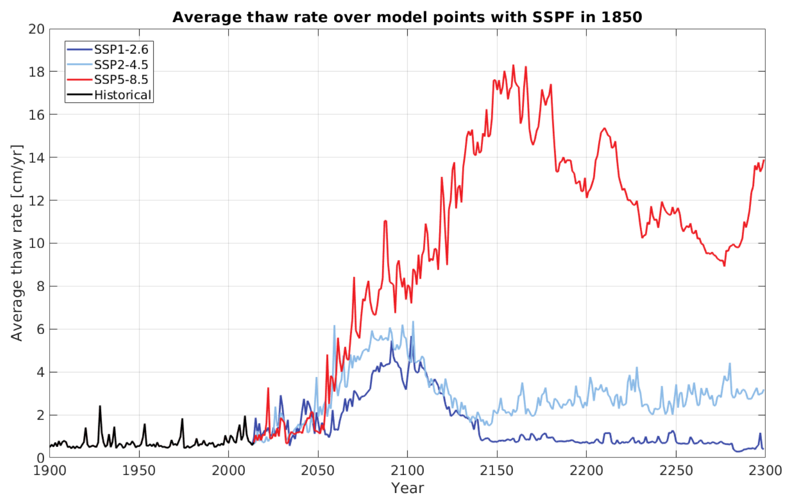

Figure 1: Pan-arctic average thaw rate (lowering of the top of ice containing sediments) over model points with SSPF in 1850 (242 of 18432 points, 2.89 mill. km^2).

Benthic emissions

The carbon stored in the thawing SSPF sediments are made available for degradation – mainly to methane which eventually escapes the sediments and into the water column. The quality of the stored carbon (that is how easily and thus at which rate it can be degraded) is, however, largely unknown. Therefore 3 different possible reactivity scenarios (best guess rates: “average”, “low” rates and “high” rates respectively) with different degradation parameters were run using the BRNS sediment model, forced with the output of the MPI-ESM and the thaw rates presented above as well as an assumed amount of sediment carbon. This gives as output benthic fluxes of methane (Fig. 2, Arndt et al., in preparation), DIC and alkalinity (not shown) into the ocean.

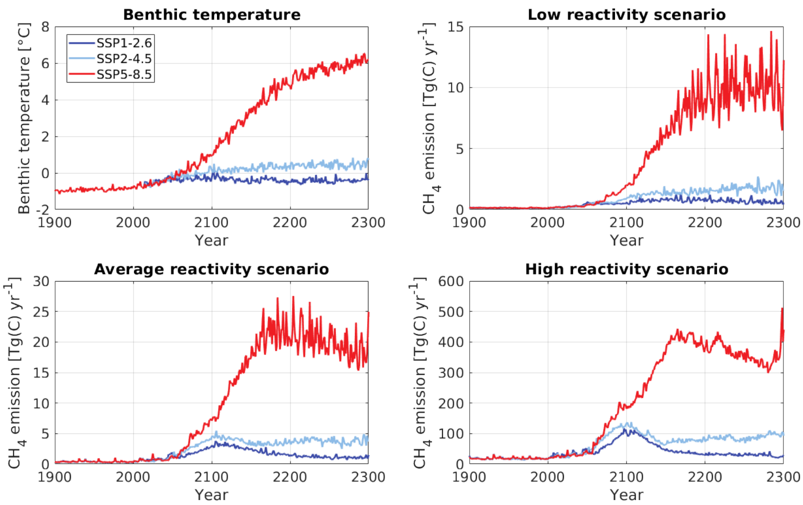

Fig. 2. Benthic temperature and benthic methane emissions to the ocean according to the different reactivity and climate scenarios.

This shows that the methane emissions largely follows the local benthic temperature (BT), though with a tendency of decreasing after a period of essentially constant BT. However, the choice of reactivity scenario alters the result by more than 1 order of magnitude. Our conclusion is that it is unlikely but possible that carbon degradation following thawing of SSPF will contribute significantly to global methane emissions in the future. However, our study ignores that thawing of SSPF will eventually allow captured reservoirs of gaseous methane to escape to the benthic interface. Also ignored are eventual contributions from dissociating methane hydrates, which however are more located on the shelf break whereas SSPF is found on the shelf itself. Addressing these contributions would require an entirely different experimental setup.

Oceanic processes

The released methane, DIC and alkalinity alter the biochemistry of the oceanic water, e.g. the capability of ocean water to take up CO_2. To address these changes, the fluxes are fed into HAMOCC, which however to not directly handle methane. Therefore a bubble model was developed at the ULB, emulating the oxidation of methane in the water column and calculating the fraction of methane escaping to the atmosphere. According to this model, about 10 to 70% of the methane escapes, largely depending on water depth and initial bubble size, whereas water temperature and salinity are only 2^{nd} order effects.

We have developed the HAMOCC model in MPI-ESM to include benthic input of inorganic carbon and alkalinity from subsea permafrost. The model has been successfully tested with simple homogeneous input. We plan to run the model with more realistic input data from BRNS when the final data for the different SSP scenarios are available. These runs will also include the chemical influence of the methane oxidization in the water column.

References

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