Integrating subsea permafrost into an Earth System Model (MPI-ESM)

Stiig Wilkenskjeld¹, Paul Overduin², Frederike Miesner², Matteo Puglini³, and Victor Brovkin¹

¹Max Planck Institute for Meteorology, Hamburg, Germany
²Alfred-Wegner-Institut, Helmholtz-Zentrum for Polar and Ocean Research, Potsdam, Germany
³Université Libre de Bruxelles, Brussels, Belgium

Subsea permafrost on the Arctic Shelf originates as terrestrial permafrost which was submerged by ocean water following sea level rise during deglaciation. The thickness and depth of subsea permafrost are not well known on the circumpolar scale. Subsea frozen sediments contain organic carbon as well as preventing the upward diffusion of carbon-containing greenhouse gases. Thawing of subsea permafrost – which may accelerate as a consequence of global warming – makes this carbon available for release to the ocean-atmosphere system and thus constitutes a positive feedback to global warming. Present estimates of the carbon associated with subsea permafrost range over two orders of magnitude and are thus highly uncertain and the amount of stored organic carbon potentially huge. Due to the long time scales involved in thawing permafrost, subsea permafrost may become – especially in a future with low anthropogenic carbon emissions – a significant contributor to global carbon releases and thus to an enhanced global warming.

The best tool for estimating the effects of future carbon releases are the Earth System Models (ESMs) which, however, are – due to their computational demands – not well suited for the long time scale of build-up and degradation of subsea permafrost. We therefore apply a novel two-model approach. The multiple glacial-cycle model Submarine Permafrost Map (SuPerMap) was used to obtain the pre-industrial distribution of permafrost based on 1D modelling of heat flow driven by glacial, marine and aerial surface upper boundary conditions. This state was then used to initialize JSBACH, the land surface component of the MPI Earth System Model (MPI-ESM), which was extended to allow subsea permafrost applications. JSBACH was used to generate present-day and near-future permafrost thaw by applying historical and future scenario forcings from the MPI-ESM runs performed within the Coupled Model Intercomparison Project, CMIP6. As a first step we here present the modelled physical state (temperature and ice content profiles) of the subsea sediments on the Arctic Shelf in the pre-industrial and present states as well as in the near future. SuPerMap generated a region of cryotic (<0°C) sediment on the Arctic Shelf of 2.5 million km², more than 80% of which lay north of Eastern Siberia. In the JSBACH simulations, permafrost thawing rates accelerate after the mid-20th century. From about 2060 onwards, the choice of
shared social-economic pathway (SSP) determines the rate of thaw and up to about 1/3 of the pre-industrial cryotic area is lost before year 2100. Regional aspects of the SSP projections will be presented.