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Assessing the impact of subsea permafrost thaw on carbon release from the Arctic shelf seafloor

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Subsea permafrost thaw within the warming Arctic shelf progressively unlocks an estimated 2822 (1518–4982) Pg of organic carbon (OC). Microbial processes then convert this organic carbon into methane (CH_4) and dissolved inorganic carbon (DIC), which, if released to the Arctic Ocean, could exacerbate Arctic Ocean acidification and global warming. However, the overall impact of this subsea permafrost thaw depends on how much the released carbon reaches the Arctic Ocean and in which form. Within the upper marine sediments, anaerobic methane oxidation (AOM) effectively consumes dissolved CH_4, but simultaneously increases both DIC and alkalinity (TA) influencing local carbonate chemistry and creating favourable conditions for carbonate precipitation. Carbonate precipitation not only sequesters both permafrost- and methane-derived carbon, but also consumes TA. Therefore, the rate of Arctic Ocean acidification and Arctic CO_2 fluxes not only depends on the permafrost-derived CH_4 and DIC fluxes but also on the rates of AOM, authigenic carbonate precipitation, which act as key regulators of the benthic carbonate biogeochemistry.

In this study, we use a reaction-transport model on the panarctic scale to quantify seafloor DIC and TA fluxes in response to estimated subsea permafrost derived CH_4 and DIC fluxes to the upper marine sediment for three different climate scenarios (SSP1-2.6, SSP2-4.5, SSP5-8.5) over the period 1900-2300. For all three scenarios, model results confirm that AOM is a highly effective microbial barrier that consumes all the dissolved CH_4 flux. In turn, the regulating role of AOM on seafloor DIC and TA fluxes is dwarfed by the high subsea permafrost-derived DIC fluxes that drive high rates of authigenic carbonate precipitation and, thus, consumes TA. Overall, the model predicts that subsea permafrost thaw could release, in 2300, 15 (SSP1) – 95 (SSP5) TgC/yr as DIC and 10 (SSP1) – 50 (SSP5) Teq/yr as TA. This panarctic TA/DIC benthic efflux ratio slightly lower than 1 for SSP1 and SSP2, and substantially lower than 1 for SSP5 thus indicate that subsea permafrost thaw will amplify Arctic Ocean acidification and might impact the efficiency of the Arctic Ocean CO_2 sink, especially under SSP5.