Quantifying the effect of subsea permafrost thaw on Arctic shelf dissolved inorganic carbon and alkalinity fluxes

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Permafrost thaw is one of the most pressing climate issues owing to its potential to exert strong positive feedback on global warming. While the permafrost-climate feedback discussion has, so far, mostly focused on the potential threat of terrestrial permafrost-derived methane (CH_4) emissions to the atmosphere, less attention has been to the full benthic carbon cycle response to subsea permafrost thaw and its implications for Arctic Ocean (AO) carbon cycling. The thawing of subsea permafrost is currently unlocking a vast reservoir of old, but likely bioavailable organic carbon that is converted to CH_4 and dissolved inorganic carbon (DIC) in the deep anoxic sediment. Within the shallower sediment layers, microorganisms efficiently oxidize the upward-migrating CH_4 flux via anaerobic oxidation of methane (AOM), producing DIC, alkalinity (ALK) and hydrogen sulphides. Whether the seafloor DIC flux contributes ALK to the AO or further acidifies the AO depends on the rates of authigenic carbonate precipitation and the fate of the AOM derived sulphide in the sediment. The full impact of permafrost thaw on AO carbon cycling thus still remains poorly quantified. Here, we use a one-dimensional diagenetic modelling approach to quantitatively assess the early diagenetic response to high fluxes of subsea permafrost-derived CH_4 and DIC and their impacts on DIC and ALK fluxes through the sediment-water over a wide range of plausible seafloor conditions. Model results reveal that AOM converts all of the upward-migrating dissolved CH_4 flux into DIC. High sedimentation rates and high iron-oxide deposition support high benthic ALK fluxes, while lower rates would further acidify the AO. We then apply the one-dimensional diagenetic model approach on a two-dimensional pan-Arctic shelf grid and force it with projected subsea permafrost thaw rates for three different SSP scenarios until 2300. The predicted thawing increase fuels large benthic DIC fluxes through heterotrophic DIC production in the thawing permafrost and CH_4 oxidation in the shallower sediment. In addition, the subsea permafrost derived ALK flux is further amplified by early diagenetic processes in the upper meters of the CH_4 charged sediments that produce additional ALK. Overall, the benthic ALK and DIC fluxes is up to one order of magnitude larger than typical coastal settings, with important, but yet to be quantified implications for AO pH, the carbonate system and thus CO_2 exchange.

Keywords
Subsea Permafrost; Methane; Modelling