Organic carbon in subsea permafrost: a globally significant but inert carbon pool

Frederieke Miesner (Alfred Wegener Institute Helmholtz Centre for Marine and Polar Research), Pier Paul Overduin (Alfred Wegener Institute Helmholtz Centre for Marine and Polar Research), Guido Grosse (Alfred Wegener Institute Helmholtz Centre for Marine and Polar Research), Jens Strauss (Alfred Wegener Institute Helmholtz Centre for Marine and Polar Research), Moritz Langer (Department of Earth Sciences, Vrije Universiteit Amsterdam), Sebastian Westermann (Department of Geosciences, University of Oslo), Thomas Schneider von Deimling (Alfred Wegener Institute Helmholtz Centre for Marine and Polar Research), Victor Brovkin (Max Planck Institute for Meteorology, Hamburg) and Sandra Arndt (Department of Geosciences, Environment and Society, Université libre de Bruxelles).

Abstract

Subsea permafrost underlays 2.4 million km^2 of the Arctic Shelf, an area equaling ~18% of the terrestrial permafrost region. Most of it was inundated at some point after the last glacial maximum and is in an advanced state of warming. How much organic carbon (OC) accumulated, how this carbon pool was affected by permafrost presence and degradation over time, how much carbon still remains today and how much of it may be mobilized are major unknowns in the global carbon cycle. Recent estimates of OC decomposition from thawing submarine permafrost were as high as 8 Tg OC per year in methane alone.

Here, we combine a numerical model of sedimentation and permafrost evolution with simplified carbon turnover to estimate accumulation and microbial decomposition of organic matter on the pan-Arctic shelf over the past four glacial cycles (450 kyr). Organic carbon decomposition is modeled with a reactivity continuum model using inversely determined parameters from incubation experiments and liquid water content within the permafrost as the limiting factor rather than temperature alone. We find that Arctic shelf permafrost is a long-term carbon sink storing 2822 (1518 - 4982) Pg OC, two to four times the amount stored in lowland permafrost. Although subsea permafrost is currently thawing, prior microbial decomposition and organic matter aging would limit decomposition rates to less than 48 Tg OC per year even if all frozen sediment deposited in the past 450 kyr thawed immediately. Since actual thaw rates are orders of magnitude lower, true emissions due to subsea permafrost thaw are also orders of magnitude lower than this. The OC pool in shelf permafrost is therefore largely immobilized.

Compared to the organic matter in thawing permafrost large emissions are more likely derived from older and deeper sources as shelf's frozen lid, the permafrost, becomes more permeable.