B21C-1970: Modeling the Space-Time Destiny of Pan-Arctic Permafrost DOC in a Global Land Surface Model: Feedback Implications

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Most global climate models do not represent the unique permafrost soil environment and its respective processes. This significantly contributes to uncertainty in estimating their responses, and that of the planet at large, to warming. Here, the production, transport and atmospheric release of dissolved organic carbon (DOC) from high-latitude permafrost soils into inland waters and the ocean is explicitly represented for the first time in the land surface component (ORCHIDEE-MICT) of a CMIP6 global climate model (IPSL). This work merges two models that are able to mechanistically simulate complex processes for 1) snow, ice and soil phenomena in high latitude environments, and 2) DOC production and lateral transport through soils and the river network, respectively, at 0.5° to 2° resolution. The resulting model is subjected to a wide range of input forcing data, parameter testing and contentious feedback phenomena, including microbial heat generation as the active layer deepens. We present results for the present and future Pan-Arctic and Eurasia, with a focus on the Lena and Mackenzie River basins, and show that soil DOC concentrations, their riverine transport and atmospheric evasion are reasonably well represented as compared to observed stocks, fluxes and seasonality. We show that most basins exhibit large increases in DOC transport and riverine CO_2 evasion across the suite of RCP scenarios to 2100. We also show that model output is strongly influenced by choice of input forcing data. The riverine component of what is known as the ‘boundless carbon cycle’ is little-recognized in global climate modeling. Hydrological mobilization to the river network results either in sedimentary settling or atmospheric ‘evasion’, presently amounting to 0.5-1.8 PgC yr^{-1}. Our work aims at filling in these knowledge gaps, and the response of these DOC-related processes to thermal forcing. Potential feedbacks owing to such a response are of particular relevance, given the magnitude of the permafrost carbon pool.

Plain Language Summary

When plant material is produced in very cold regions of the world, some of it does not decompose because of these low temperatures and is stored in the soil. Over thousands of years, this soil layer builds up substantially, containing vast quantities of carbon. Large areas of mostly Arctic land underlain by these permafrost soils are at risk of a process reversal due to climatic warming, due to the creeping of heat down the soil layer at increasing frequency and magnitude. This has the potential to unlock this ancient carbon vault and release it back into the wider environment, including back to the atmosphere, which would cause even more warming. However, things are not so simple. The soil material could be dissolved in water, transported into the river or seabed sediments (where they would remain 'locked in') or consumed by organisms and released to the atmosphere. The purpose of this work is to unravel the fate of this matter in its journey from soil stability to part of a complex hydrological network. In doing so, we hope to provide part of the answer to the question: 'How significant will the contribution of permafrost thaw be to continued climatic warming?'

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