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How Permafrost-Affected Arctic Rivers May Become Net Carbon Sinks Over the 21st Century

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The rivers of the Arctic permafrost region discharge about 11% of the global volumetric river water flux into oceans, doing so into an ocean (the Arctic) with 1% of global ocean water volume and a very high surface area: volume ratio, making it comparatively sensitive to influxes of terrestrially derived matter. This river flux is sourced from precipitation as either rain or snow, which, upon initial contact with the landscape has the immediate potential to interact with carbon(C) in one of two ways: Water running over carbonate or silicate –bearing rocks will cause a reaction whose reactant requires the uptake of atmospheric CO_2, which is subsequently transported in river water. This 'inorganic' C derived from interaction of water, atmosphere and lithosphere thus represents a C storage or 'sink' vector. In addition, water interacting with organic matter in tree canopies, litter or soil can dissolve C contained therein, and transfer it via surface and subsurface water flows into rivers, whereupon it may either be metabolised to the atmosphere or exported to the sea. Recent improvements in understanding of terrestrial C dynamics indicate that this hydrologic transfer of organic matter represents the dominant fate of organic carbon, after plant and soil respiration are accounted for. In the context of amplified Arctic anthropogenic warming, the thermal exposure imposed on the permafrost C stock with expectations of enhanced future precipitation point toward substantial shifts in the lateral flux-mediated organic and inorganic C cycle. However, the complex totality of the processes involved make prediction of this shift difficult.

Here, we build upon previous advances in earth system modelling to include the production and lateral transport of dissolved organic C (DOC), respiration-derived CO_2, and rock-weathering derived alkalinity in a global land surface model (ORCHIDEE) previously developed to specifically resolve permafrost-region processes. By subjecting the resulting model to state of the art soil, water, vegetation and climatology datasets, we are able to reproduce existing lateral transport processes and fluxes, and project them into the future. In what follows, we show that while Pan-Arctic alkalinity exports and attendant CO_2 uptake increase over the 20th and 21st Centuries under warming, DOC fluxes decline largely as a result of deeper soil water flow-paths and the resulting changes in carbon-water interactions. Rather than displaying a clear continuous (linear or non-linear) temperature sensitivity, future Arctic DOC release can increase or decrease with temperature depending on changes in the thermal state and hydrologic flow paths in the deep

soil. The net marine effect of these fluxes is to decrease future terrestrially derived seawater acidification. Conversely, our simulations show that CO_2 uptake from chemical weathering exceeds its evasion from river water, meaning that when weathering is considered, the inland water carbon cycle shifts from being a net C-source to a sink. Further, this sink increases into the 21^{st} C, partially buffering soil C loss from permafrost thaw.