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Isotopic fingerprints of fluvial-derived greenhouse gases document pervasive permafrost thaw

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In the northern circumpolar regions, continued climate change promotes abrupt and pervasive thawing of organic-rich permafrost soils, rendering any associated carbon susceptible to mobilization and degradation. Permafrost-derived dissolved and particulate organic carbon entrained into aquatic systems is highly degradable and rapidly mineralized to carbon dioxide (CO_2). Thus, signals of permafrost disturbances are short-lived and easily missed. Here, we explore the isotopic composition of dissolved CO_2 and methane (CH_4) to fingerprint the presence of widespread permafrost thaw in Arctic watersheds. We investigate spatial and seasonal variations in the stable and radiocarbon isotopic signatures of dissolved gases in two river networks in Northern Alaska. Isotopic evidence suggests that the CO_2 compositions are homogenous along the fluvial continuum and integrate geogenic and biogenic sources across the watershed. From spring to fall, mixing modeling predicts a systematic depletion in the stable and radiocarbon isotopic signatures of dissolved CO_2 sources. We attribute this pattern to increasing contributions of aged carbon in response to a deepening of the active layer. As percolating groundwater accesses deeper soil horizons, CO_2 produced by root respiration and heterotrophic oxidation of organic matter is leached and transported to streams and rivers. In contrast, we observe no clear relationships between CH_4 compositions and landscape properties. Stream CH_4 is likely influenced by local inputs from streambeds, adjacent water-saturated soils, and lake outflows. Our findings demonstrate that greenhouse gases dissolved in fluvial systems are sensitive to the release of aged carbon from thawing permafrost.