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The Importance of Soil pH in Controlling Organic Carbon Transformations in Arctic Polygon Tundra

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Accurately simulating CO_2 and CH_4 emissions from high latitude soils is critically important for reducing uncertainties in soil carbon-climate feedback predictions. The signature ice-wedge polygons in Arctic tundra have a high level of heterogeneity in soil thermal regime, hydrology and oxygen availability, which limits the application of current land surface models using simple moisture response functions. We synthesized data from incubations of Arctic soils across a wet-to-dry permafrost degradation gradient from low-centered to flat- and high- centered polygons to assess the Community Land Model Carbon Nitrogen (CLM-CN) decomposition cascade with extended anaerobic organic carbon transformations, including fermentation, iron reduction, and methanogenesis reactions. Modification of the Windermere Humic Aqueous Model (WHAM) enabled us to approximately describe the measured soil pH buffering capacity with model simulations. Separate parameterizations of pH response functions for fermentation, iron reduction and methanogenesis improved the simulation of pH evolution, including the initial pH drop due to organic acid accumulation caused by fermentation and then a pH increase due to iron reduction and methanogenesis. Accurate representation of pH evolution also significantly improved CO_2 prediction as the speciation of CO_2 between gas, aqueous and solid (adsorbed) phases were better simulated under varying pH. These results provided critical insights into the process of soil decomposition, and demonstrated the importance of soil pH in controlling biogeochemical reactions in the Arctic.