When Is the Permafrost Carbon Tipping Point?

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Permafrost in the Arctic contains as much as 950 Gt of organic matter, frozen since the last ice age 20,000-30,000 years ago. As permafrost thaws in the 21st century, this organic matter will decay, increasing atmospheric carbon dioxide and amplifying the climate warming rate, creating a positive permafrost carbon feedback on climate. The permafrost carbon tipping point occurs when respiration due to the decay of thawed permafrost organic matter overpowers enhanced plant uptake due to longer growing seasons, changing the Arctic from a carbon sink to a source. The permafrost carbon tipping point represents an abrupt change in high latitude carbon balance and signals the start of the permafrost carbon feedback. None of the combined carbon-climate models used in the Fourth IPCC Assessment account for the permafrost carbon feedback in their projections of 21st century climate. We add permafrost carbon dynamics to the Simple Biosphere/Carnegie-Ames-Stanford Approach (SiBCASA) model and use the ERA40 reanalysis as input weather. To represent future climate change, we scale the ERA40 air temperature assuming a linear, 4 °C century^{-1} temperature increase in the Arctic between 2000 and 2200. Point simulations indicate that even a modest increase in active layer depth could result in local tipping points by 2100. We expand this analysis to the entire Arctic region and estimate the timing of the permafrost carbon tipping point and the potential strength of the permafrost carbon feedback in terms of the amount of carbon released into the atmosphere by 2200.

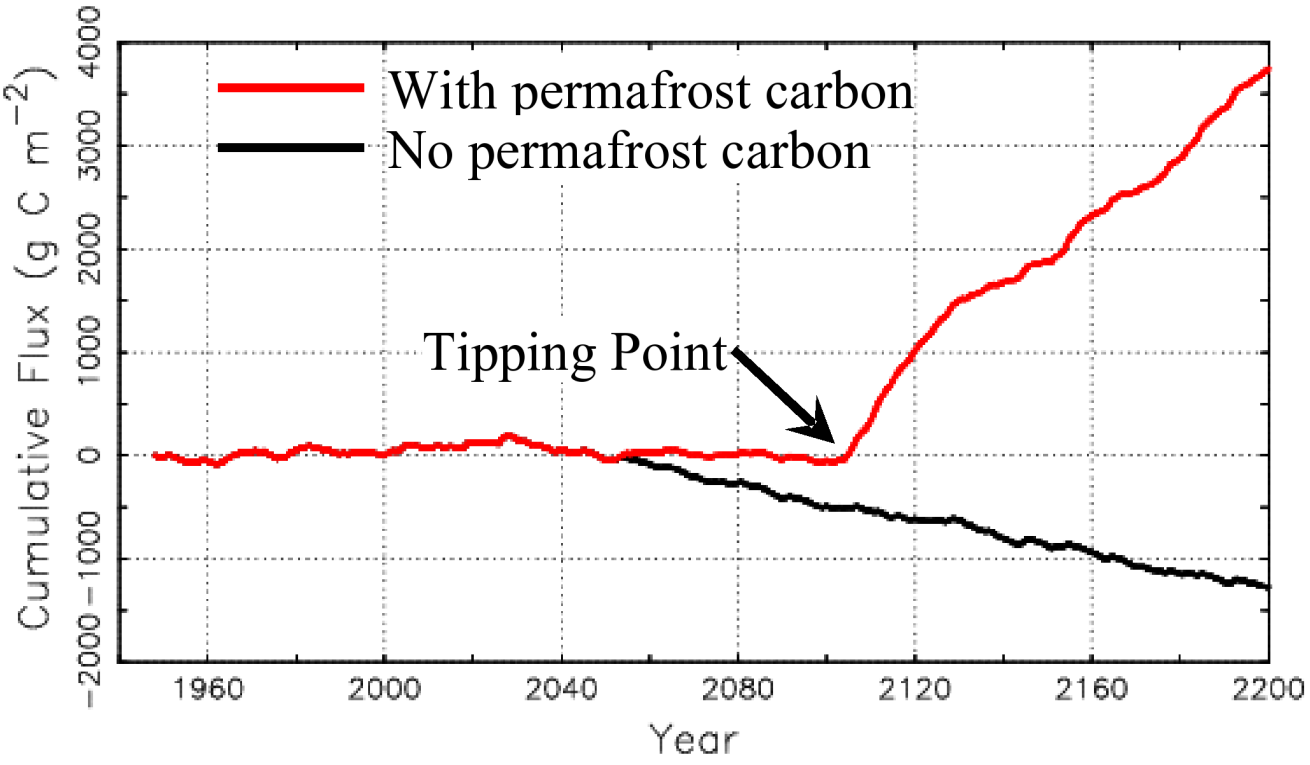

Figure 1. Cumulative simulated net carbon flux for a point in central Siberia (positive is net release to the atmosphere). The simulation without permafrost carbon (black) shows cumulative net uptake driven by longer growing seasons. The simulation with permafrost carbon shows a distinct tipping point in 2105 where respiration due to the decay of permafrost carbon overpowers the enhanced uptake due to longer growing seasons.