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Increased methane emissions due to later soil freezing in Arctic tundra ecosystems

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The concentration of atmospheric methane (CH_4), a 28-times more powerful greenhouse gas than carbon dioxide (CO_2), is increasing at the fastest rate in the last twenty years, making it critical to understand the controls on CH_4 emissions from terrestrial ecosystems. We show that autumn terrestrial CH_4 enhancements (atmospheric concentrations over background levels from in-situ tall tower measurements) in Northern Alaska are correlated with later soil freezing (R^2 = 0.28, p-value < 0.001) using a 16-year data record. The later freezing is associated with the persistence of the "zero-curtain" (soil temperatures sustained near 0°C before freezing) which, we suggest allows sustained terrestrial CH_4 emissions. Furthermore, site level ecosystem fluxes from five eddy co-variance tower sites in various Arctic tundra ecosystems in Alaska display significantly higher emission rates during zero-curtain conditions than after soil freezing at all five sites. These results suggest that CH_4 may be produced in unfrozen soils during the autumn and readily released into the atmosphere, affecting the regional terrestrial CH_4 enhancements. We also show that air temperature exhibits poor predictive ability (R^2 = 0.13, AIC = 240) on CH_4 fluxes relative to soil temperature (R^2 = 0.30, AIC = 224) during autumn and suggest that the persistence of unfrozen soil layers should be considered to improve model simulations for the Arctic in the future.