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Environmental controls on Pan-Arctic wetland methane emissions

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Environmental conditions such as soil temperature and moisture, incident solar radiation, and atmospheric carbon dioxide concentration are important environmental controls on methane emissions from northern wetlands. We investigated the spatio-temporal distributions of influence of these factors over northern wetland methane emissions via the Variable Infiltration Capacity (VIC) model. We simulated methane emissions from wetlands across the Pan-Arctic domain over the period 1948-2006, with annual average emissions of 35.1±6.7 TgCH4/year. From control simulations that each held one environmental factor constant, we characterized sensitivities to air temperature, precipitation, incident long- and short-wave radiation, and atmospheric [CO_2] as a function of average summer air temperature and precipitation. Trade-offs between air temperature and precipitation caused maximal emissions to occur along a line in precipitation-temperature space with a slope of approximately 13 mm month-1 / K, leading to separation of wetlands into various combinations of water-limited and temperature-limited regimes. Emissions from relatively warm and dry wetlands in the southern (permafrost-free) portion of the domain tended to be positively correlated with precipitation and negatively correlated with air temperature, while emissions from wetter and colder wetlands further north (permafrost) tended to be positively correlated with air temperature. Over the period 1960-2006, emissions increased by 20%, over 90% of which can be attributed to climate change, with summer air temperatures explaining the majority of the variance. We estimated future emissions in response to CMIP5 model projections under the RCP4.5 scenario via two methods: (1) the VIC model and (2) the temperature- and precipitation-dependent sensitivities computed from the historical simulation. The two methods yielded similar projections of emissions, with end-of-century emissions at 142% of present-day levels, accompanied by an expansion of the area of water-limited wetlands. Both the magnitude of the increase in emissions and the widespread drying of wetlands are corroborated by other recent process-based studies.