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Spatially explicit methane emissions from the largest wetland complex in North America: Past, present and future

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Almost half of all biogenically-produced methane is emitted from small lakes and wetlands. The Prairie Pothole Region (PPR) is the largest wetland complex in North America (10th largest in the world), and contains 5–8 million wetlands and lakes, which can potentially influence continental and global methane budgets. However, there is considerable uncertainty of past, current and future emissions of methane from PPR wetlands due to a lack of landscape-scale models based on PPR-specific data. We used a bottom-up approach to develop a spatially explicit, temporally dynamic model of wetland and lake methane emissions from the PPR. Using a dataset of >20,000 static-chamber flux measurements, we first developed a chamber model to understand functional relationships between methane fluxes and covariates, and then upscaled to the landscape using GIS and remotely sensed proxies for each covariate. Covariates in the chamber model included water-filled pore space (WFPS), hydroperiod, soil temperature, wetland size, land cover, and normalized difference vegetation index (NDVI). Proxies for upscaling included the Dynamic Surface Water Extent (for WFPS, hydroperiod, and area) and NDVI based on Landsat imagery, ClimateNA (for soil temperature), and the North American Land Change Monitoring System (for land cover). Methane emissions increased nonlinearly with increasing WFPS, soil temperature and NDVI, and was greater in wetlands surrounded by grasslands compared to cropland due to low organic carbon substrates in sediment of cropped wetlands. Methane flux had a hump-shaped relationship with area, with the highest emissions in mid-sized wetlands (1-4 ha) that had relatively long hydroperiods and high vegetation cover, whereas methane flux from water bodies >10 ha was negligible due to their relatively high sulfate concentrations. Despite the potential for high total emission from the PPR as would indicate from global models, total emissions were relatively low (~5 and 100 Gg methane) per year during historic dry (1991) and current wet years (2011), respectively, with wetland extent is the primary driver of regional emissions. Future warmer temperature scenarios (under RCP 8.5) indicate that annual methane emissions from the PPR could double.