WetCH$_4$: A Physics-informed Machine Learning Framework Combining Field Measurements and Satellite Observations for Wetland Methane Estimation

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Methane (CH_4) is a potent greenhouse gas that has a global warming potential 28 times greater than CO_2 over a period of 100 years. Data-driven upscaling provides independent estimates of methane emissions with rich spatial information and constrained uncertainty. Here we present a machine learning framework to characterize the spatial and temporal variability of wetland methane fluxes from the Arctic to tropical ecosystems (WetCH$_4$). We trained machine learning models with field observations of methane fluxes that have considerable spatial and temporal coverage. We selected predictor variables based on the knowledge we learned from existing studies and process models. The covariates include Modern-Era Retrospective analysis for Research and Applications (MERRA2) meteorology and soil variables, Moderate Resolution Imaging Spectroradiometer Nadir Bidirectional Reflectance Distribution Function (BRDF) - Adjusted Reflectance (MODIS NBAR) products, and Soil Moisture Active Passive (SMAP) products from the Harmonized Soil Database. The impacts of covariates on model performance were evaluated. The scalable framework was applied to upscale wetland CH_4 fluxes in two case studies. For the Permafrost Pathways project, we upscaled daily methane emissions in Arctic and boreal wetlands from tower observations in the Fluxnet-CH$_4$ database. For the Carbon Monitoring System Blueflux project, we modeled CH_4 fluxes in a tropical wetland system from airborne measurements over the Everglades mangrove - salt marsh - freshwater wetland. The preliminary results indicated that wetlands in the Arctic and boreal region emitted 21-24 Tg CH_4 yr^{-1} between 2016 and 2022, while the emission intensity in tropical mangrove wetlands was on average 10 g CH_4 m^{-2} yr^{-1}.

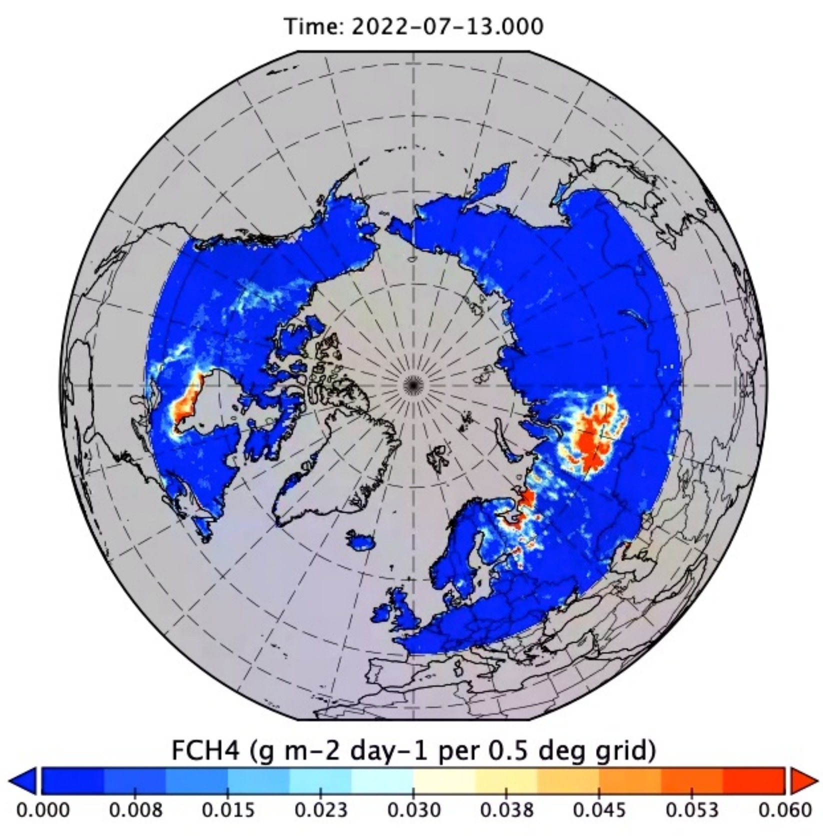

Figure 1. Upscaled spatiotemporal distributions of daily CH_4 fluxes in Arctic and boreal wetlands in July 2022.