Modeling Wetland Redox Biogeochemistry and Vegetation Function at Site to Continental Scales

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Redox cycles, geochemistry, and pH are recognized as key drivers of subsurface biogeochemical cycling in wetland ecosystems but are typically not included in land surface models. Vegetation responses to inundation and salinity are also key factors in coastal wetland function and are not included in large-scale land models. These omissions may introduce errors when simulating carbon cycling and greenhouse gas emissions in systems where tidal influences, redox interactions, and pH fluctuations are important, such as coastal regions where sulfate concentrations associated with saltwater influence can drive biogeochemical contrasts across salinity gradients. Here, we coupled the Energy Exascale Earth System Model (E3SM) Land Model (ELM) with geochemical reaction network simulator PFLOTRAN, allowing geochemical processes and redox interactions to be integrated with land surface model simulations. We implemented a reaction network including aerobic decomposition, fermentation, iron oxide reductive dissolution and dissolved iron oxidation, sulfate reduction, sulfide oxidation, methanogenesis, methane oxidation, and pH dynamics. We used the model framework to simulate biogeochemical cycling and methane production across redox gradients in coastal wetlands across gradients of salinity. In addition, we incorporated plant functional responses to water level and salinity and parameterized salt marsh and mangrove plant functional types in the model. Model simulations were parameterized using laboratory incubations and literature values and evaluated using measured porewater concentrations and surface gas emissions from wetland field sites across coastal regions of the United States. These results demonstrate how directly simulating biogeochemical reaction networks and coastal vegetation function can improve land surface model simulations of subsurface biogeochemistry and carbon cycling in wetland ecosystems and highlight the value of porewater biogeochemical data for evaluating process-based wetland biogeochemical models.