

Integrating tide-driven wetland soil redox and biogeochemical interactions into a land surface model

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Redox cycles, geochemistry, and pH are recognized as key drivers of subsurface biogeochemical cycling in terrestrial and wetland ecosystems but are typically not included in terrestrial carbon cycle models. These omissions may introduce errors when simulating carbon cycling and greenhouse gas emissions in systems where redox interactions and pH fluctuations are important, such as coastal systems where sulfate inputs from seawater combined with saturated soil conditions can influence biogeochemistry. 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, sulfate reduction, sulfide oxidation, and methane production and oxidation as well as pH dynamics along with iron oxide and iron sulfide mineral precipitation and dissolution. We used the model framework to simulate biogeochemical cycling in tidal wetlands subject to either saltwater or freshwater inputs driven by tidal hydrological dynamics. In simulations with saline tidal water inputs, sulfate reduction led to accumulation of sulfide, higher dissolved inorganic carbon concentrations, lower dissolved organic carbon concentrations, and lower methane emissions than simulations with freshwater tidal inputs. Model simulations compared well with measured porewater concentrations and surface gas emissions from coastal wetland field sites in the Northeastern United States. These results demonstrate how directly simulating biogeochemical reaction networks can improve land surface model simulations of subsurface biogeochemistry and carbon cycling in tidal wetland systems.