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Modeling ecohydrological controls on net CO_2 exchange of a boreal fen

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Hydrology is one of the key controls governing peatland carbon balance under current and future climatic conditions. Seasonal variations in soil water content and water table depths can alter the balance between peatland primary production and respiration and so cause a peatland to change between a sink and a source of carbon. Seasonal and interannual variation in peat hydrology can affect primary production and respiration through its influence on evapotranspiration, plant water and nutrient uptake and on microbial decomposition. Simulating ecohydrological controls on current and future net ecosystem productivity (NEP) of peatlands thus demands models with coupled soil-plant-atmosphere schemes for gases, water, energy, carbon and nutrients (N, P). We combined a 3-dimensional water transport scheme and prognostic water table dynamics with an existing ecosystem model ecosys in order to examine the hydrological controls on seasonal and interannual variability in NEP of a rich fen in Alberta, Canada. Simulated hourly ecosystem energy and CO_2 fluxes along with hourly near surface soil water contents and daily water table depths correlated very well (R2 $\sim$ 0.80) with measurements at the site from 2003 to 2009, during which the water table declined gradually. We compared modeled and measured fluxes at hourly and seasonal time scales in years with contrasting weather and water table depths in order to see how water table fluctuations altered the diurnal and seasonal patterns of NEP. In the model, shallow water tables limited root and soil aeration, slowing root and microbial growth, and hence nutrient uptake. This reduced gross primary productivity (GPP) but also ecosystem respiration (RE), so that the peatland remained a substantial net C sink. In the model, deeper water tables caused more rapid microbial and root growth, and hence more rapid mineralization and nutrient uptake, and hence greater GPP. Deeper water tables also caused near-surface drying which slightly reduced near surface peat decomposition. However this reduction was offset by more rapid decomposition in deeper peat layers so that total RE increased. Concurrent increases in GPP and RE caused simulated and measured NEP to change in complex ways with deeper water tables. These complex changes in seasonal and annual CO_2 exchange with changes in hydrology can be simulated with models that represent basic processes for soil-plant-atmosphere transfers of gases, particularly O_2, as well as those of water and energy. Such models can provide a predictive capability for how peatland productivity might change with hydrology under future climates.