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General considerations for modeling water table dynamics in peatlands

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A basic and universal characteristic of peatlands is that the water table frequently rises near the surface of the soil profile. Surface peat is naturally loose and open-structured, and often has microtopographic features; the water table frequently rises above the level of local depressions. Therefore, water table fluctuations in peatlands cause rapid changes in the permeability and effective porosity of the medium through which flow occurs. We use a simple model based on Boussinesq's equation to explore the challenges that arise from these basic and universal physical aspects of peatland hydrology. We show that simulation of water table fluctuations in peatlands requires precipitation data with a high temporal resolution, and careful attention to the time derivative for accuracy of the mean water tables and correct water balance for two reasons. First, large vertical gradients in specific yield can result in large mass balance errors analogous to errors from naive discretization of the Richards equation; a change of variables from water table elevation to water storage can eliminate these errors and also speed up calculations by allowing larger time steps. Second, large vertical gradients in permeability near the peat surface cause a strongly nonlinear response to precipitation, so that time-averaged precipitation data or neglect of diurnal cycles of evapotranspiration results in erroneously high water levels, and careful time stepping is required around rain storms. Consideration of these features of peatland hydrology results in efficient hydrologic models that can be used to predict spatial and temporal patterns in greenhouse gas uptake and emissions in peatlands.