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Peatland Hydrology in a Global Land Surface Modeling and Data Assimilation Framework

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Peatlands represent 50 to 70% of global wetlands and are poorly represented in global Earth system modeling frameworks. A better representation of the peatland hydrology is crucial for the quantification of global-scale peatland-related climate change sensitivities. Here we present a peatland-specific land surface hydrology module ("PEAT-CLSM") to the Catchment Land Surface Model (CLSM) of the NASA Goddard Earth Observing System (GEOS) framework. In PEAT-CLSM, a characterization of microtopography is used to determine distributions of groundwater table depth, soil moisture and surface water ponding, in contrast to the use of the catchment-scale compound topographic index distribution in CLSM. In addition, PEAT-CLSM features modified formulations of runoff and evapotranspiration and includes updated values of peat hydraulic parameters. Parameters used in PEAT-CLSM are based on literature data. Simulation experiments with both models are evaluated against a newly compiled dataset of groundwater table depth and eddy covariance observations of latent and sensible heat fluxes in 45 natural and semi-natural peatlands. For peatlands between 40°N and 75°N, CLSM's simulated groundwater tables are too deep and variable, whereas PEAT-CLSM simulates a mean groundwater table depth of -0.18 m (snow-free unfrozen period) with moderate temporal fluctuations (standard deviation of 0.09 m), in significantly better agreement with in situ observations. Relative to an operational CLSM version that simply includes peat as a soil class, the temporal correlation coefficient is increased on average by 0.16 and reaches 0.64 for bogs and 0.66 for fens when driven with global atmospheric forcing data. In PEAT-CLSM, runoff is increased on average by 50% and evapotranspiration is reduced by 21%. The evapotranspiration reduction constitutes a significant improvement relative to eddy covariance measurements. Simulation experiments are further expanded with assimilation of brightness temperature satellite data from the SMOS and SMAP missions. The assimilation system uses a spatially distributed ensemble Kalman filter to update soil moisture and groundwater table depth. Preliminary assimilation experiments indicate a further improvement for groundwater table depth in terms of unbiased root-mean-square differences and anomaly correlations compared to model-only simulations. As a last point, a comparison against other global transient groundwater level products is presented, and the general need for peatland hydrology modules in global hydrological models is discussed.