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On the derivation of specific yield and soil water retention characteristics in peatlands from rainfall, microrelief and water level data – Theory and Practice

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Water level depth is one of the crucial state variables controlling the biogeochemical processes in peatlands. For flat soil surfaces, water level depth dynamics as response to boundary fluxes are primarily controlled by the water retention characteristics of the soil in and above the range of the water level fluctuations. For changing water levels, the difference of the integrals of two soil moisture profiles (ΔAsoil), of a lower and a upper water level, is equal to the amount of water received or released by the soil. Dividing ΔAsoil by the water level change, results into a variable that is known as specific yield (Sy).

For water level changes approaching the soil surface, changes in soil water storage are small due to the thin unsaturated zone that remains. Consequentially, Sy values approach zero with an abrupt transition to 1 in case of inundation. However, on contrary, observed water level rises due to precipitation events at various locations showed increasing Sy values for water level changes at shallow depths (Sy = precipitation/water level change; Logsdon et al., 2010). The increase of Sy values can be attributed in large parts to the influence of the microrelief on water level changes in these wet landscapes that are characterized by a mosaic of inundated and non-inundated areas. Consequentially, water level changes are dampened by partial inundation. In this situation, total Sy is composed of a spatially-integrated below ground and above ground contribution.

We provide a general one-dimensional expression that correctly represents the effect of a microrelief on the total Sy. The one-dimensional expression can be applied for any soil hydraulic parameterizations and soil surface elevation frequency distributions. We demonstrate that Sy is influenced by the microrelief not only when surface storage directly contributes to Sy by (partial) inundation but also when water levels are lower than the minimum surface elevation.

With the derived one-dimensional expression we developed a novel approach for the in situ determination of soil water retention characteristics that is applicable to shallow groundwater systems. Our approach is built on two assumptions: i) for shallow groundwater systems with medium- to high conductive soils the soil moisture profile is always close to hydrostatic equilibrium and ii) over short time periods differences in total water storage due to lateral fluxes are negligible. Given these assumptions, the height of a water level rise due to a precipitation event mainly depends on the soil water retention characteristics, the precipitation amount, the initial water level depth and, if present, the microrelief. We use this dependency to determine water retention characteristics (van Genuchten parameter) by Bayesian inversion. Our results demonstrate that observations of water level rises, caused by precipitation events, contain sufficient information to constrain the water retention characteristics around two dip wells in a Sphagnum bog to plausible ranges. We discuss the possible biases that come along with our approach and point out the research that is needed to quantify their significance.