Geophysical Research Abstracts
Vol. 13, EGU2011-8490-1, 2011
EGU General Assembly 2011

Response of Sphagnum mosses to drought: Modeling critical transitions in water and carbon budgets using hydrophysical properties of three contrasting species

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Peatlands cover only 3% of the Earth's land surface but store 30% of all terrestrial soil carbon. The majority of peatlands is situated in the boreal zone, where they are generally dominated by peat-forming bryophytes of the genus Sphagnum, which are consequently key species in relation to carbon storage and climate change. Typically, Sphagnum species are distributed along a microtopographical gradient, ranging from wet depressions (hollows) to elevated and dry hummocks. Each habitat is occupied by different Sphagnum species as a result of morphological and physiological characteristics. Morphological characteristics of Sphagnum species alter the ability to conduct and retain water in the apical living part (capitula), which jointly affects growth and sequestration of carbon. Furthermore, a lack of rainfall reduces capitulum water content and depresses CO2 uptake of Sphagnum, even at water tables close to the surface. Most photosynthetic activity is restricted to the top 1-2 cm of the moss layer, stressing the importance of capitulum water content for moss photosynthesis.

In contemporary vegetation models, the carbon balance is coupled to moisture conditions by empirical relationships with groundwater levels. In this way however, processes in the vadose zone are bypassed, given that the effect of small rainfall events is neglected. To test the consequences of neglecting fine-scaled hydrological processes for estimates on carbon assimilation, we developed an ecohydrological model using hydrophysical characteristics of the capitula layer of three contrasting Sphagnum species along the hummock – hollow gradient (S. fuscum, S. balticum, S. majus).

For intact cores (depth 0 – 10cm) of three contrasting Sphagnum species the (un)saturated hydraulic conductivity, water retention characteristic and storage capacity were determined. The data were used to parameterize an ecohydrological model based on Richards equation for unsaturated water flow. This model is used to determine capitulum water content for three climate scenarios with contrasting rainfall patterns, but similar total rainfall (a few big rainfall events, many small rainfall events, average summer). Consequences for photosynthetic assimilation rates were inferred from existing photosynthetic response curves and compared with results of a null-model using a standard empirical relationship between photosynthetic rate and groundwater level. Our results contribute to a better understanding of vadose zone processes and lead toward a more accurate prediction of carbon budgets in peatlands.