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Effects of drying and rewetting on electron flow in a northern temperate fen

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Peatlands cover about 450 million ha of the earth's surface and play an important role in the global carbon cycle, storing substantial amounts of carbon and acting either as a source or sink for atmospheric carbon. In the context of climate change and greenhouse gases, peatlands have gained increasing attention. There exist studies evaluating the carbon budgets of peatlands at the present state, but less is known how they develop under a changing climate in the future. According to climate scenarios, we expect higher temperatures accompanied by an increasing frequency of extreme meteorological events such as pronounced drying and rewetting cycles. To date, however, the relevance of such changes in climate and the internal feedbacks of carbon turnover in peatlands are not well identified.

We evaluated these feedbacks in a comprehensive laboratory study. Three intact cores (60 cm diameter, 60 cm depth) from a northern temperate fen were incubated (15˚ C; 12h/12h day/night cycle) for 6 months. Two cores had the original vegetation (grasses and sedges, few mosses). To assess the influence of vegetation, the plants of the third core had been removed. Each core was equipped with soil moisture sensors, piezometers, soil gas samplers, logging CO_2-sensors, Rhizon® soil solution samplers and a pore water peeper. The gas exchange was measured via a static chamber approach using a collar (20 cm Ø) inserted at the peat surface.

After 4 weeks, the water table of all cores was adjusted to 10 cm below surface and kept constant by artificial precipitation. After 8 weeks of equilibration, we began to dry out two cores – one with and one without vegetation – by stopping precipitation.

The third core (with vegetation) was kept at high water table as a control. We dried out for about 50 days, leading to a water table drop of ∼40 cm. Thereafter, we rewetted rapidly by simulating a 20 mm/d rain event till the water table was back up at 10 cm. We monitored changes in solute concentrations (Cl^-, SO_4^{2-}, NO_3^-, PO_4^{3-}, $Fe^{2+/3+}$, H_2S, CO_3^{2-}, CH_4, acetate), gas concentrations (CO_2, CH_4 and H_2 in equilibrium with the water phase), solid phases (total CNS, reduced sulphur) and soil moisture during the drying and rewetting cycle.

Pronounced drying and rewetting lead to a transient state in the peat ecosystem with the system not being able to equilibrate. Profiles in CO_2/CO_3^{2-} followed closely the water table rise and drop (2-5 mmol/l below, 1-2 mmol/above the water table), whereas methanogenesis lagged behind. While the electron acceptor pool (NO_3^-, $Fe^{(III)}$, SO_4^{2-}) was renewed in the upper profile during drying out, there was still some methane detectable above the water table in the rhizosphere of the vegetated core, indicating anoxic micro-environments. After the rapid rewetting, thermodynamically preferred electron acceptors were consumed first, before methane concentrations increased till >20% by volume in the gas samplers (eq. to 390 μmol/l). Acetate and H_2 as metabolic intermediates accumulated (up to 1300 μmol/l and 8 nmol/l) in the first 2 weeks after the water table rise before decreasing again and adjusting below 100μmol/l (Actetate) and below 1 nmol/l (H_2).

This study demonstrates the impact of a changing climate on carbon turnover in peatland ecosystems. While a permanently high water table only allows little renewal of electron acceptors named above and thus promotes methanogenesis, a recycling of electron acceptors during more frequent drying and rewetting cycles impedes methanogenesis and may increase losses in the form of CO_2 and DOC.