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Flood effects on efflux and net production of nitrous oxide in river floodplain soils

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Floodplain soils are often rich in nutrients and exhibit high spatial heterogeneity in terms of geomorphology, soil environmental conditions and substrate availability for processes involved in carbon and nutrient cycling. In addition, fluctuating water tables lead to temporally changing redox conditions. In such systems, there are ideal conditions for the occurrence of hot spots and moments of nitrous oxide emissions, a potent greenhouse gas. The factors that govern the spatial heterogeneity and dynamics of N2O formation in floodplain soils and the surface efflux of this gas are not fully understood. A particular issue is the contribution of N2O formation in the subsoil to surface efflux.

We studied this question in the floodplain of a restored section of the Thur river (NE Switzerland) which is characterized by a flashy flow regime. As a consequence, the floodplain soils are unsaturated most of the time. We showed earlier that saturation during flood pulses leads to short phases of generally anoxic conditions followed by a drying phase with anoxic conditions within aggregates and oxic conditions in larger soil pores. The latter conditions are conducive for spatially closely-coupled nitrification-denitrification and related hot moments of nitrous oxide formation. In a floodplain zone characterized by about one meter of young, sandy sediments, that are mostly covered by the tall grass Phalaris arundinacea, we measured at several time points before and after a small flood event N2O surface efflux with the closed-chamber method, and assessed N2O concentrations in the soil air at four different depths using gas-permeable tubings. In addition, we calculated the N2O diffusivity in the soil from Radon diffusivity. The latter was estimated in-situ from the recovery of Radon concentration in the gas-permeable tubings after purging with ambient air. All these data were then used to calculate net N2O production rates at different soil depths with the gradient method. In addition, temperature, volumetric water content, as well as ammonium, nitrate and dissolved organic carbon in the soil solution were monitored at different depths in the observation plots.

During not flood-affected conditions we observed weak diffusive gradients between subsoil and top soil, and net N2O production was maximum in the top soil. During the drying phase after a flood, diffusive gradients between subsoil and topsoil were more pronounced, and net N2O production in the subsoil increased. At all conditions, N2O efflux was more strongly correlated with N2O concentrations in the subsoil than those in the top soil. The complex interactions between soil moisture on one hand, and C and N substrate limitation on the other hand in determining N2O production at different soil depths will be discussed. Finally, the results will be put into the context of our earlier and ongoing studies that aim at elucidating the governing factors of spatial heterogeneity and dynamics of N2O emissions in floodplain soils.