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Non-invasive mapping of local oxygen patterns in porous media: influence of plant roots and soil structure

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In soils and sediments there is a strong coupling between local biogeochemical processes and the distribution of water, electron acceptors, acids, nutrients and pollutants. Soil structures such as aggregates, roots, layers, macropores and wettability differences occurring in natural soils enhance these patchiness. The always fluxes of water and energy make it a living and dynamic system.

We follow a new route to non-invasively map the dynamic distribution of water and biogeochemical parameters at the interface of plant roots and soil. We have focused on the distribution of oxygen for unsaturated and saturated situations, but also pH mapping, and others are possible in the future. We use single plant-soil systems in laboratory containers. To begin with, we fabricated and installed sensor foils for fluorescence dye imaging of O_2 in such glass containers, so called planar optodes. Then we took time series for visualization of oxygen changes forced by lupine roots and soft rush in sand. Moreover, we visualized the oxygen deficits induced in built finer grained layers and aggregates. The changing water content was mapped in parallel by neutron radiography.

Each monitoring period of the pattern of oxygen induced by lupine roots covered about two days. We observed that for high water saturation the oxygen concentration decreased substantially in parts of the container. The accompanying neutron radiography proved that these locations are spatially directly correlated to roots, which could be detected individually. The observed oxygen deficits close to the roots result from respiration, as long as the re-aeration from atmosphere is restricted by the high water content. In a similar way we mapped the formation of oxygen pattern in heterogeneous structured soils. The build in aggregates and layers were water saturated and therefore limited oxygen diffusion resulting in areas of oxygen depletion. For saturated conditions, the growing roots of soft rush induced a oxygen increase mainly at their tips, but oxygen deficits around the other parts.

In conclusion, with our coupled non-invasive imaging set-up we were able to monitor with high spatial and temporal resolution the dynamics of oxygen and water content at the root-soil interface and in heterogeneous structured soils.