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Direct monitoring of wind-induced pressure-pumping on gas transport in soil

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Gas exchange between soil and atmosphere is important for the biogeochemistry of soils and is commonly assumed to be governed by molecular diffusion. Yet a few previous field studies identified other gas transport processes such as wind-induced pressure-pumping to enhance soil-atmosphere fluxes significantly. However, since these wind-induced non-diffusive gas transport processes in soil often occur intermittently, the quantification of their contribution to soil gas emissions is challenging.

To quantify the effects of wind-induced pressure-pumping on soil gas transport, we developed a method for in situ monitoring of soil gas transport. The method includes the use of Helium (He) as a tracer gas which was continuously injected into the soil. The resulting He steady-state concentration profile was monitored. Gas transport parameters of the soil were inversely modelled.

We used our method during a field campaign in a well-aerated forest soil over three months. During periods of low wind speed, soil gas transport was modelled assuming diffusion as transport process. During periods of high wind speed, the previously steady diffusive He concentration profile showed temporary concentration decreases in the topsoil, indicating an increase of the effective gas transport rate in the topsoil up to 30%. The enhancement of effective topsoil soil gas diffusivity resulted from wind-induced air pressure fluctuations which are referred to as pressure-pumping. These air pressure fluctuations had frequencies between 0.1 and 0.01 Hz and amplitudes up to 10 Pa and occurred at above-canopy wind speeds greater than 5 m s^{-1}. We could show the importance of the enhancement of the gas transport rate in relation with the wind intensity and corresponding air pressure fluctuations characteristics.

We directly detected and quantified the pressure-pumping effect on gas transport in soil in a field study for the first time, and could thus validate and underpin the importance of this non-diffusive gas transport process. Our method can also be used to study other non-diffusive gas transport processes occurring in soil and snow, and their possible feedbacks or interactions with biogeochemical processes.