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Importance of Non-Diffusive Transport for Soil CO_2 Efflux in a Temperate Mountain Grassland

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A key focus in climate change is on the dynamics and predictions of the soil CO_2 efflux (SCE) from terrestrial ecosystems. Limited knowledge of CO_2 transport through the soil restricts our understanding of the various biotic and abiotic processes underlying these emissions.

Diffusion is often thought to be the main transport mechanism for trace gases in soils, an assumption that is reflected in the increasing popularity of the flux-gradient approach (FGA). Based on Fick's law, the FGA calculates soil CO_2 efflux from CO_2 concentration profiles, given good estimates of the diffusion coefficient. The latter can be calculated via different commonly used models, and solid-state sensors allow continuous high-frequency measurements of soil CO_2 concentrations with minimal disturbance to the soil conditions in a cost-effective way.

Fast growing evidence of pressure pumping and advection, makes it impossible to disregard non-diffusive gas transport when evaluating diel and day-to-day dynamics of soil CO_2 emissions. We have analyzed combined measurements from solid-state sensors and soil chambers to gain insight in the CO_2 transport mechanisms in a grassland site in the Austrian Alps.

The FGA-derived efflux underestimated the chamber efflux by 10 to 87% at our site, depending on which model was used for calculation of the diffusion coefficient. We found that the actual transport rates correlated well with irradiation and wind speed, even more when the soil moisture content was below 33%. These findings suggest that bulk soil air transport was enhanced by pressure changes induced by wind shear at the surface and by local heating of the soil surface.

Considering the importance of non-diffusive transport processes is a prerequisite when using solid-state CO_2 concentration measurements to estimate soil CO_2 efflux at any given site.