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Evidence for non-diffusive transport as an important mechanism determining the soil CO_2 efflux in a temperate grassland

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Research on soil respiration has largely focused on the emission of CO_2 from soils and far less on the production and subsequent transport of CO_2 from soil to atmosphere. The limited knowledge of CO_2 transport through the soil, restricts our understanding of the various abiotic and biotic processes underlying emissions of CO_2 from terrestrial ecosystems. Soil CO_2 efflux is most often measured using soil chambers, but since the early 2000s, solid-state CO_2 sensors that measure soil CO_2 concentrations at different depths, are becoming more popular. From these continuous high-frequency measurements of the CO_2 gradient, the flux can easily be calculated in a very cost-efficient way with minimal disturbance of the natural conditions. This so-called flux-gradient method is based on Fick's law, assuming diffusion to be the only transport mechanism. To test to what extend diffusion is indeed the governing transport process, we compared the CO_2 efflux from chamber measurements with the CO_2 efflux calculated from soil CO_2 concentration profiles for a grassland site in the Austrian Alps.
The four commonly used models for diffusivity that we tested, all underestimated the soil chamber effluxes and their amplitudes. What is more, we observed that transport rates correlated well with irradiation (PAR) and -below a certain soil moisture content- with wind speed. Indeed, correlation coefficients of the fits of observed transport rate versus PAR were consistently positive, and those of observed transport rate versus wind speed were positive on days that were not extremely wet (soil water content below 33%). Also, we found that the coupling of transport rate and PAR became stronger as wind speed increased.
Our results suggest that non-diffusive bulk air transport mechanisms, such as advective mass transport and pressure pumping, could considerably contribute to soil CO_2 transport at this site. We therefore emphasize the importance of investigating alternative transport processes before using solid-state CO_2 concentration measurements to estimate soil CO_2 emissions at any given site.