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Vertical and horizontal soil CO_2 transport and its exchanges with the atmosphere

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The CO_2 efflux from soils to the atmosphere constitutes one of the major fluxes of the terrestrial carbon cycle and is a key determinant for sources and sinks of CO_2 in land-atmosphere exchanges. Because of their large global magnitude, even small changes in soil CO_2 effluxes directly affect the atmospheric CO_2 content. Despite much research, models of soil CO_2 efflux rates are highly uncertain, with the positive or negative feedbacks between underground carbon pools and fluxes and their temperature sensitivities in future climate scenarios largely unknown. Now it is necessary to change the point of view regarding CO_2 exchange studies from an inappropriately conceived static system in which all respired CO_2 is directly emitted by molecular processes to the atmosphere, to a dynamic system with gas transport by three different processes: convection, advection and molecular diffusion. Here we study the effects of wind-induced advection on the soil CO_2 molar fraction during two years in a shrubland plateau situated in the Southeast of Spain.

A borehole and two subterranean profiles (vertical and horizontal) were installed to study CO_2 transport in the soil. Exchanges with the atmosphere were measured by an eddy covariance tower. In the vertical profile, two CO_2 sensors (GMP-343, Vaisala) were installed at 0.15m and 1.5m along with soil temperature and humidity probes. The horizontal profile was designed to measure horizontal movements in the soil CO_2 molar fraction due to down-gradient CO_2 from the plant, where the majority CO_2 is produced, towards bare soil. Three CO_2 sensors (GMM-222, Vaisala) were installed, the first below plant (under-plant), the second in bare soil separated 25 cm from the first sensor (near-plant) and the third in bare soil at 25 cm from the second sensor (bare soil).

The results show how the wind induces the movement of subterranean air masses both horizontally and vertically, affecting atmospheric CO_2 exchanges. The eddy covariance tower registered net CO_2 emissions to the atmosphere mainly during windy days in the dry period. During these windy days, large wind speeds induced decreases in the soil CO_2 molar fraction both near-plant and bare soil, but also increments in the under-plant soil CO_2 molar fraction. During windy days the under-plant CO_2 can easily double its previously typical values, breaking the clear daily pattern found on previous days. These data demonstrate the need for continuous monitoring to understand correctly the behavior of soil CO_2 effluxes.