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New methodology to measure continuously the δ13C of soil CO2 efflux and concentration at different depths by laser spectrometry

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The use of the carbon isotopic composition of CO2 (δ13C-CO2) is a promising tool to improve our knowledge about the mechanisms of CO2 production within soil. Temporal fluctuations of δ13C-CO2 soil efflux reflect the influence of climatic and edaphic conditions on (i) partitioning between the respiration sources, (ii) CO2 production intensity and (iii) CO2 transport from soil layers to surface. A better understanding of fractionation processes affecting CO2 during this transport is required to obtain quantitative information about the CO2 production.

The differences in transport (diffusion, advection) properties between 13CO2 and 12CO2 cause a fractionation during CO2 transfer from sources to the surface, creating a decrease of δ13C-CO2 at surface compared to air contained in soil pores. Short-term fluctuations of this apparent fractionation is expected in case of (i) changes in diffusive properties of the soil (soil water content, temperature) and/or (ii) air pressure variations created by turbulence. As a consequence, at this time scale, the difference between δ13C-CO2 of soil atmosphere and δ13C-CO2 of soil CO2 efflux is very variable and difficult to interpret. With tunable diode laser spectrometer (TDLS) it is now possible to measure δ13C-CO2 with high frequency. TDLS offers then the possibility to quantify δ13C-CO2 of soil efflux (by coupling with soil chamber, Marron et al. 2009) and soil atmosphere if (i) soil air sampling doesn't disturb the natural environment and (ii) soil air collected is diluted to reduce the high soil CO2 concentrations (several thousand ppmv) to values measurable by the TDLS (inferior to 1000 ppmv). To solve these limitations, we have adapted a method (Gut et al. 1998) based on the diffusion of soil pore air within a tube through a membrane having a high permeability to gases and being hydrophobic. These tubes have been placed horizontally at different depths in the soil. An air flowing in tubes allows CO2 circulation up to a diluting system composed by mass flow controllers and free CO2 injection. The output of this diluting system is coupled to the TDLS and measurements permit then to establish a vertical profile of the isotopic signature of soil CO2 concentration at hourly scale.

Laboratory tests were performed to prove the absence of membrane influence on the δ13C-CO2. The membrane tube has been placed in a chamber where gases with different CO2 concentration and δ13C were introduced. Results didn't show any fractionation for 13C during diffusion through the membrane. The δ13C difference between gas inside and gas outside the tube was always inferior to the TDLS precision (0.2 ‰). In addition, some tests in the field have proved (i) that soil CO2 concentrations and δ13C are not significantly affected by our system functioning (observation of natural evolution) and (ii) that the values obtained are coherents with results from IRMS (R^2=0.98) and with efflux measurements.

This new methodology seems to be a very effective technique for measuring the δ13C-CO2 vertical profile of soil atmosphere and to understand fractionation processes that occur during this transfer. Moreover, incorporation of data collected using our methodology in mechanistic models of CO2 transport processes will permit to assess the vertical profil of sources contributions to CO2 efflux and will provide news insights into soil carbon dynamics.