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High-frequency Observations of the Isotopic Composition of Soil, Stem and Root Respiration in a Danish Beech Forest

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Introduction

Recent advances in laser technology have allowed for real-time measurements of the isotopic composition of C and O in CO_2 thereby providing new ways for partitioning ecosystem CO_2 fluxes into contributions of single processes. In this study, we present isotopic concentration data (i.e. $\delta^{13}C$) and CO_2 fluxes measured at high temporal resolution from intact soil, trenched soil, tree stems, tree roots and intact beech leaves of a Danish beech forest ecosystem by an Aerodyne Single CW-Quantum Cascade Laser Trace Gas Analyzer for CO_2 Isotopes.

Figure 1 (left): One of eight automated soil respiration chambers (8100-104 Long-Term Chamber, LI-COR Biosciences).

Figure 2 (right): The Aerodyne Single CW-Quantum Cascade Laser Trace Gas Analyzer for CO_2 Isotopes (Aerodyne Research Inc.).

Methods and Objectives

The study had the following objective:

•Combine the Aerodyne Single CW-Quantum Cascade Laser Trace Gas Analyzer for CO_2 Isotopes (Figure 1) with the LI-COR LI-8100/8150 flux chamber system to yield an isotopic signal of the CO_2 fluxes from various compartments of a forest ecosystem at a high temporal scale.

The Aerodyne laser was combined in parallel with the LI-COR LI-8100/8150 system that controlled 13 automated, closed chambers, thus providing $\delta^{13}C$ of the measured CO_2 fluxes. The chamber fluxes were each measured automatically every 2 hours. Eight of these chambers were LI-COR long term soil flux chambers (Figure 1), with four measuring fluxes from intact soil plots and 4 measuring fluxes from trenched soil plots. The remaining were custom made chambers with two measuring fluxes from tree stems, two measuring fluxes from coarse roots and one measuring fluxes from a tree branch with leaves. By applying the Keeling plot methodology to the change in $\delta^{13}C$ of CO_2 during the 5 minutes of chamber closure, the $\delta^{13}C$ of the CO_2 fluxes was determined.

Results

The system has been running since January 2016. During the cold months of winter and spring, where fluxes were low, the change in CO_2 concentration during chamber closure time was found to be too small for proper determination of $\delta^{13}C$, resulting in a low R^2 value of the keeling plot fit. However for the high fluxes during June and July a sufficient change in $\delta^{13}C$ during chamber closure time was measured resulting in a high R^2 value of the determined $\delta^{13}C$. An example of the bihourly $\delta^{13}C$ of soil CO_2 efflux can be seen in figure 3.

The average $\delta^{13}C$ of the CO_2 fluxes were calculated for each chamber for June and July (Figure 4). $\delta^{13}C$ from soil fluxes was found to be more enriched than $\delta^{13}C$ from root respiration, which has also been found in previous studies (e.g. Millard et al. 2010). No clear difference was however found between intact soils and trenched soils.

Example of bihourly $\delta^{13}C$ of soil CO_2 efflux

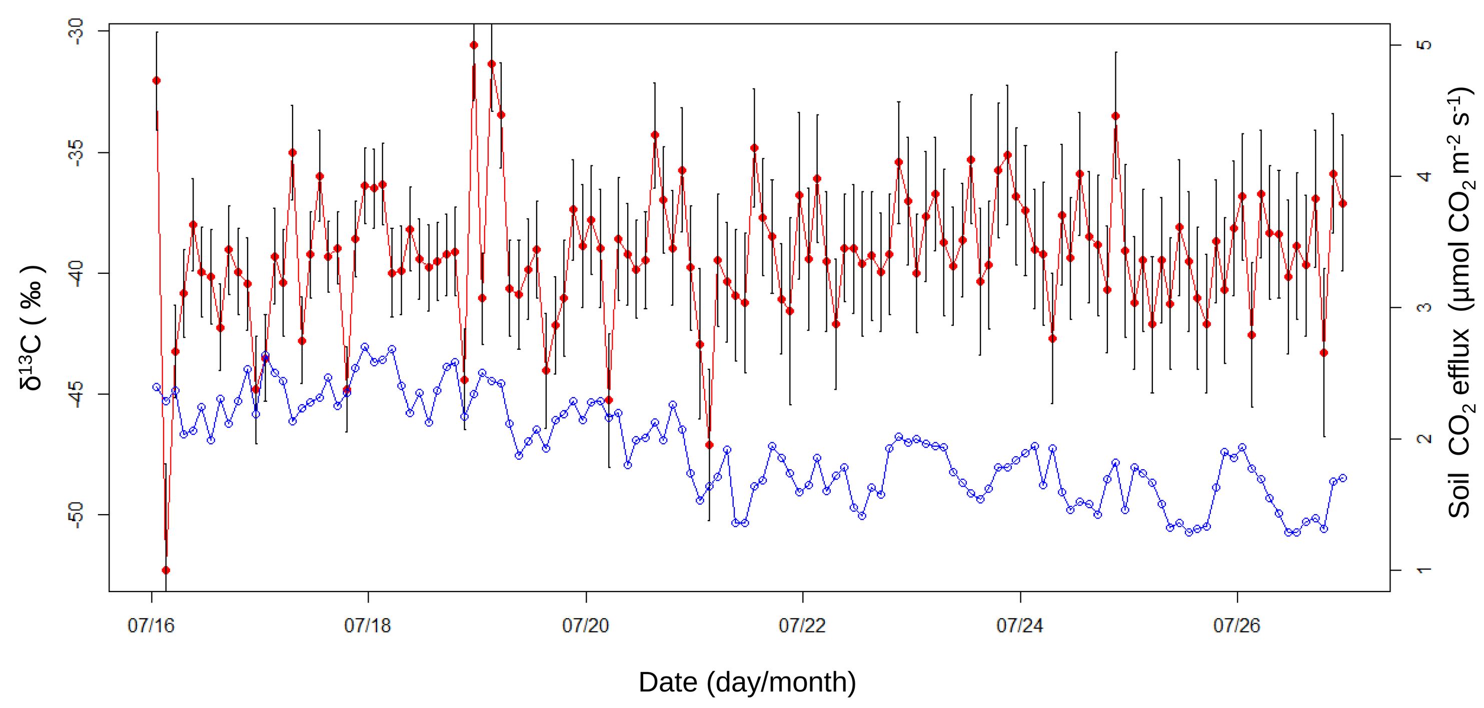

Figure 3: Example of 10 days of soil CO_2 effluxes for one trenched soil plot measured by a LI-COR soil respiration chamber (In blue), and the $\delta^{13}C$ of the respired CO_2 (In red) determined by a Keeling plot. A measurement was performed every two hours. $\delta^{13}C$ with R^2 values less than 0.90 from the Keeling plot have been removed. Error bars show standard deviation.

$\delta^{13}C$ of ecosystem CO_2 fluxes

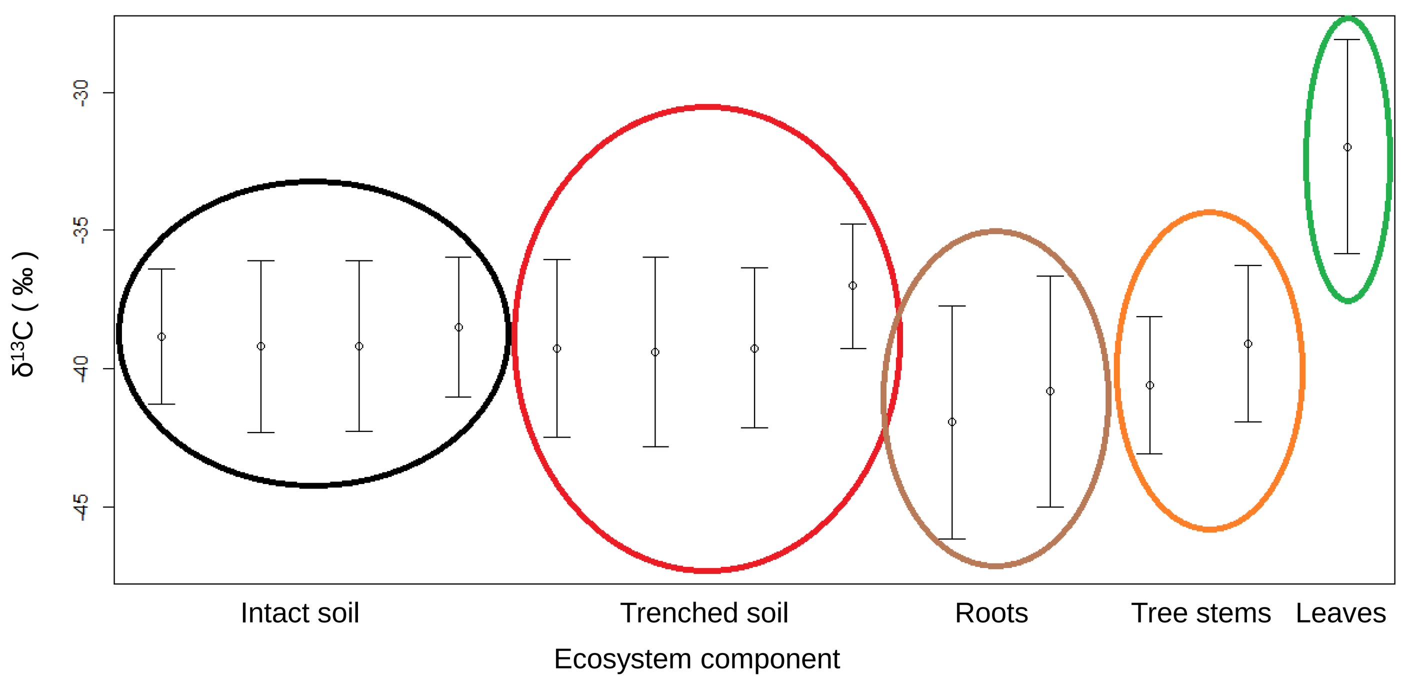

Figure 4: The determined $\delta^{13}C$ of the respired CO_2 for each individual flux chamber. Each data point is based on all measurements during June and July (only 10 days in June for the leaf chamber during daytime) for one flux chamber, after removal of $\delta^{13}C$ values with an R^2 value less than 0.90 from the Keeling plot. Error bars show standard deviation.

Conclusions and Outlook

The Aerodyne laser and the LI-COR LI-8100/8150 system was successfully combined to yield the $\delta^{13}C$ of various ecosystem CO_2 fluxes. However, the determined $\delta^{13}C$ of the respired CO_2 showed a high variation.

To increase the precision of the determined $\delta^{13}C$ we will:

•Increase chamber closure time, to increase the change in $\delta^{13}C$ during a chamber measurement.

•Try to decrease drift in the $\delta^{13}C$ signal measured by the Aerodyne laser.

Acknowledgements

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Reference: Millard, P., Midwood, A.J., Hunt, J.E., Barbour, M.M., Whitehead, D., 2010. Quantifying the contribution of soil organic matter turnover to forest soil respiration, using natural abundance $\delta^{13}C$. Soil Biol. Biochem. 42, 935–943. doi:10.1016/j.soilbio.2010.02.010