Temporal variation of 13C signature of soil respiration in a beech forest ecosystem measured with a tunable diode laser spectrophotometer

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State of the art

- ✓ Variable ^{13}C natural abundance in photosynthates (and by extension in $\delta^{13}C$) and rapid changes due to variable carbon fractionation during photosynthesis
- ✓ Transfer of the temporal variation in photosynthate $\delta^{13}C$ along the plant-soil pathway and retrieving in each plant compartment and in ecosystem respiration
- ✓ Possibility to study pathways and rates of carbon transfer within plants and to the soil from photosynthetic fixation up to respiratory loss from the ^{13}C signatures

Objectives

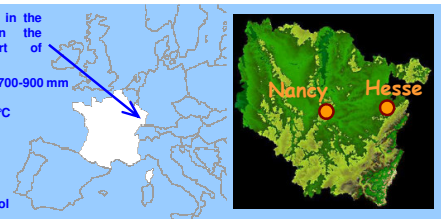
- ➔ Retrieving of the fine temporal variation of $\delta^{13}C$ of photosynthate in soil respiration?
- ➔ Range of variation in $\delta^{13}C$ of respired CO_2 at different time scales (hourly, daily, seasonal)?
- ➔ Relationships between these variations and the climate conditions that affect canopy functioning?

- ✓ To validate *in situ* high frequency measurements of $^{13}CO_2$ and $^{12}CO_2$ fluxes using a Tunable Diode Laser Spectrophotometer (TDLS) as a promising tool for the monitoring of carbon isotopic fractionation (Table 1)
- ✓ To examine short term as well as seasonal variations in isotopic signature of the respired CO_2 at phenological key periods (Figures 2 and 3)

Study site

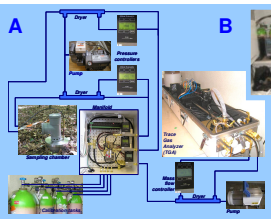
Study site located in the Hesse forest, in the northeastern part of France

- ➔ annual rainfall: 700-900 mm
- ➔ average annual temperature: 10 °C
- ➔ 85% beech
- ➔ 35 year old
- ➔ 15 m height
- ➔ soil: gleyic luvisol



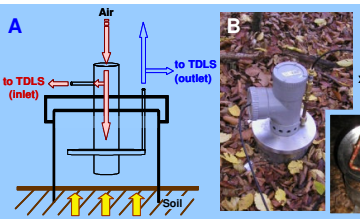
Field device

Plumbing diagram of the Tunable Diode Laser Spectrophotometer (TDLS, A) used to monitor continuously the $^{12}CO_2$ and $^{13}CO_2$ composition of soil respiration, and pictures of the installation in the Hesse forest (France): inside and outside views of the mobile lab (B)



Soil chamber

Schematic representation of the chamber functioning (A), outside and inside pictures of the stainless steel collar and chamber (B), and disposal of the 3 measurement collars (C1, C6, and D3) in the field (C) – The black crosses and small numbers indicate the positions of the collars used for the Keeling plot gas samplings



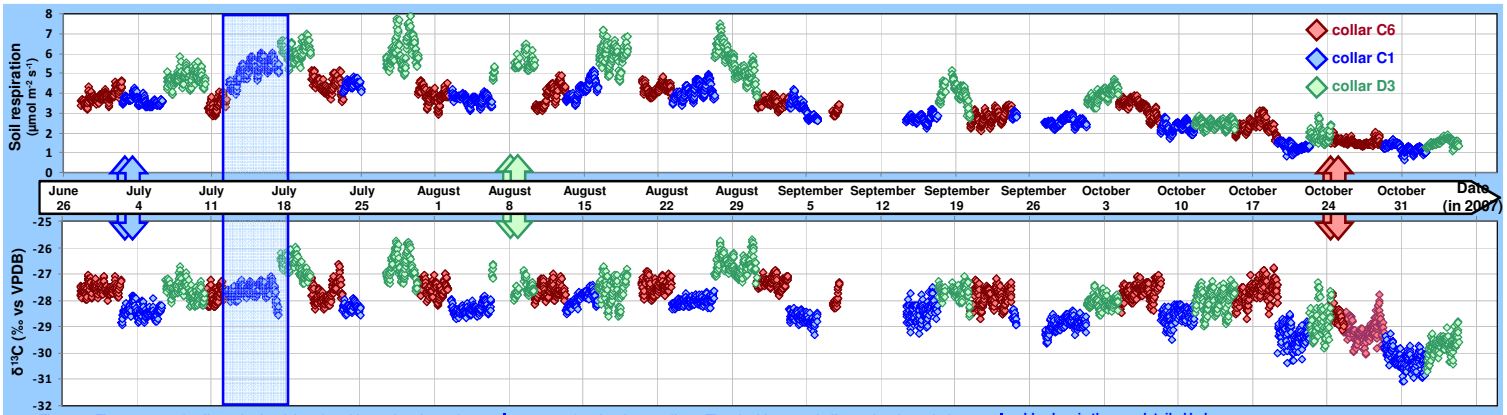


Figure 1. Time course of soil respiration (above) and its carbon isotopic composition ($\delta^{13}C$, below) during the period June 28 to November 5, 2007 for the three collars. The double rows indicate the days during which the traditional Keeling plots were established. The period in the blue box is the one detailed below.

Cross validation of the experimental setup

Comparison of the three methods allowing us to estimate the $\delta^{13}C$ signature of the soil respired CO_2:

1. Keeling plots established from gas samples collected at increasing CO_2 concentrations and analyzed by MS
2. Difference between chamber outlet and inlet $^{12}CO_2$ and $^{13}CO_2$ values measured with the TDLS
3. Keeling plots on overnight accumulation of $^{12}CO_2$ and $^{13}CO_2$ measured with the TDLS

Table 1. Values of carbon isotopic composition ($\delta^{13}C$) of soil respiration obtained with the methods 1, 2, and 3 described above at 6 dates during the growing season. Means of 6 values ± SE when indicated.

Period		July 2 - 3		August 8 - 9		October 24 - 25	
1	12h-17h	-28.6‰ ± 0.4	-28.1‰ ± 0.2	-28.8‰ ± 0.2	-28.6‰ ± 0.3	-29.1‰ ± 0.9	-28.8 ‰ ± 0.4
2	12h-17h	-28.7‰	-28.0‰	-27.8‰	-27.3‰	-28.3‰	-29.0‰
	20h-6h	-27.5‰	-28.4‰	-28.3‰	-26.4‰	-28.9‰	-28.6‰
3	20h-6h	-28.8‰ ± 0.2	-29.0‰ ± 0.2	-28.1‰ ± 0.1	-28.6‰ ± 0.2	-30.3‰ ± 0.4	-29.2‰ ± 0.6

➔ Maximum difference of ±1‰ among the results obtained with the 3 methods

Daily time course (30 min. means)

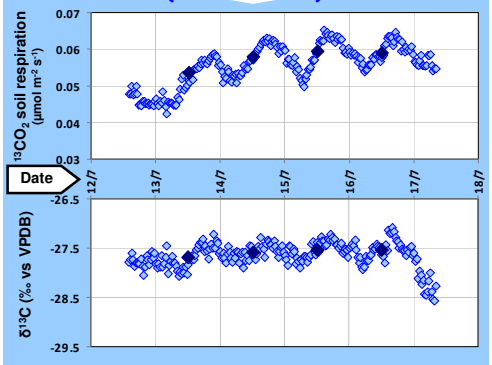


Figure 2. The time course of soil respired $^{13}CO_2$ (above) and of $\delta^{13}C$ of soil respiration (below) for the collar C1 during the period July 12-18, 2007 showed clear daily trends, with an increase during daytime and a decrease during nighttime for both traits – Dark dots are daily means

Seasonal time course (24 h. means)

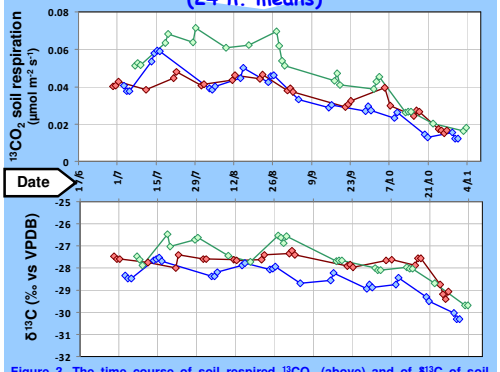


Figure 3. The time course of soil respired $^{13}CO_2$ (above) and of $\delta^{13}C$ of soil respiration (below) for the 3 collars (C1, C6, and D3) during the period June 29 to November 3, 2007 showed a δ13C included between -26.5‰ and -30‰, a slow decrease of both traits from the end of August to the end of the growing season, and a reduction of the between-collar differences with time

Relationships with climate

Time lag (day)	PAR	RH	T_{air}	T_{soil}	SWC
0	0.74	-0.67	0.94	0.92	0.30
1	0.79	-0.64	0.90	0.84	0.47
2	0.66	-0.39	0.73	0.71	0.65
3	0.46	-0.08	0.41	0.58	0.79
4	0.21	0.27	0.05	0.56	0.91
5	0.20	0.34	0.01	0.59	0.92
6	0.46	0.08	0.17	0.64	0.93
7	0.46	-0.10	0.49	0.68	0.92

Table 2. Pearson correlation coefficients between $\delta^{13}C$ of soil respiration and climate: PAR = photosynthetically active radiations, RH = Vaisala relative humidity, T_{air} = air temperature, T_{soil} = soil temperature at -5 cm depth, SWC = soil water content at -10 cm depth, with an increasing time lag – Based on seasonal daily means of collar C1 – Decreasing coefficients with time, except for SWC

In conclusion

- ➔ The TDLS is a reliable method to monitor the $\delta^{13}C$ signature of soil respiration
- ➔ Daily as well as seasonal variations in the $\delta^{13}C$ signature of soil respired CO_2 were observed
- ➔ Variations of more than 3‰ for $\delta^{13}C$ and more than 6 µmol m^{-2} s^{-1} for soil respiration were observed at seasonal scale
- ➔ $\delta^{13}C$ seemed to be affected by the climatic conditions of the current day… except for SWC
- ➔ The climatic determinism of the $\delta^{13}C$ of soil respiration needs further studies

To read about

Bowling, D.R., S.D. Sargent, B.D. Tanner and J.R. Ehleringer. 2003. Tunable diode laser absorption spectroscopy for stable isotope studies of ecosystem-atmosphere CO_2 exchange. Agricultural and Forest Meteorology. 118: 1-19.

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Ngao, J., D. Epron, C. Bréchet and A. Granier. 2005. Estimating the contribution of leaf litter decomposition to soil CO_2 efflux in a beech forest using ^{13}C-depleted litter. Global Change Biology. 11: 1768-1776.