The Isotopic Signature of Ecosystem Respiration in a Temperate Beech Forest

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Motivation and Objective

Respiration provides important information about the terrestrial carbon cycle. The stable isotopic composition of respired CO_2 has been e.g. used to identify the transfer time of assimilates from photosynthesis to respiration (see e.g. [1]) and to partition net CO_2 fluxes (see e.g. [2]).

The objectives of this study are:

- Testing the new Isotope Ratio Infrared Spectrometer (IRIS) Delta Ray (Thermo Scientific, Bremen) to measure the isotopic composition of ecosystem respiration $R^{13}_{eco}C$ and $R^{18}_{eco}O$
- Characterizing the measured seasonal variability of $R^{13}_{eco}C$ and $R^{18}_{eco}O$
- Analyzing the correlation between this variability in $R_{eco}{}^{13}C$ and different meteorological variables

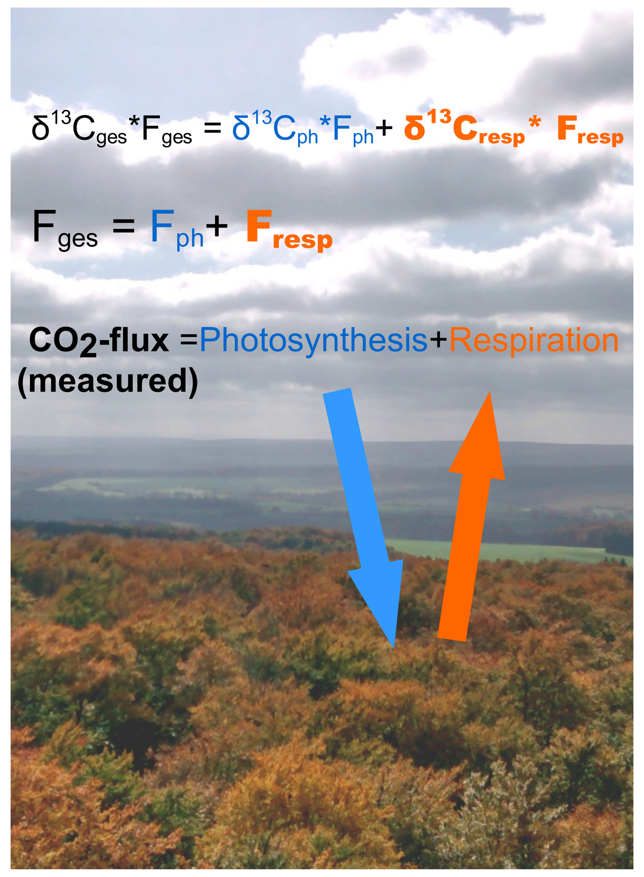


Figure 1: An example for using the isotopic composition of respiration: flux partitioning

Methods

- **Measurement campaign:** Three months in a managed beech forest in autumn 2015
- **Set up:** Measurement of CO_2 concentration, $\delta^{13}C$ and $\delta^{18}O$ in 9 different heights
- **Instrument:** Isotope Ratio Infrared Spectrometer (IRIS) Delta Ray (Thermo Scientific, Bremen) with automatic calibration.
- **Method:** Based on a Keeling Plot approach we calculated the isotopic composition of ecosystem respiration $R^{13}_{eco}C$ and $R^{18}_{eco}O$

Figure 2: Field site: managed beech forest

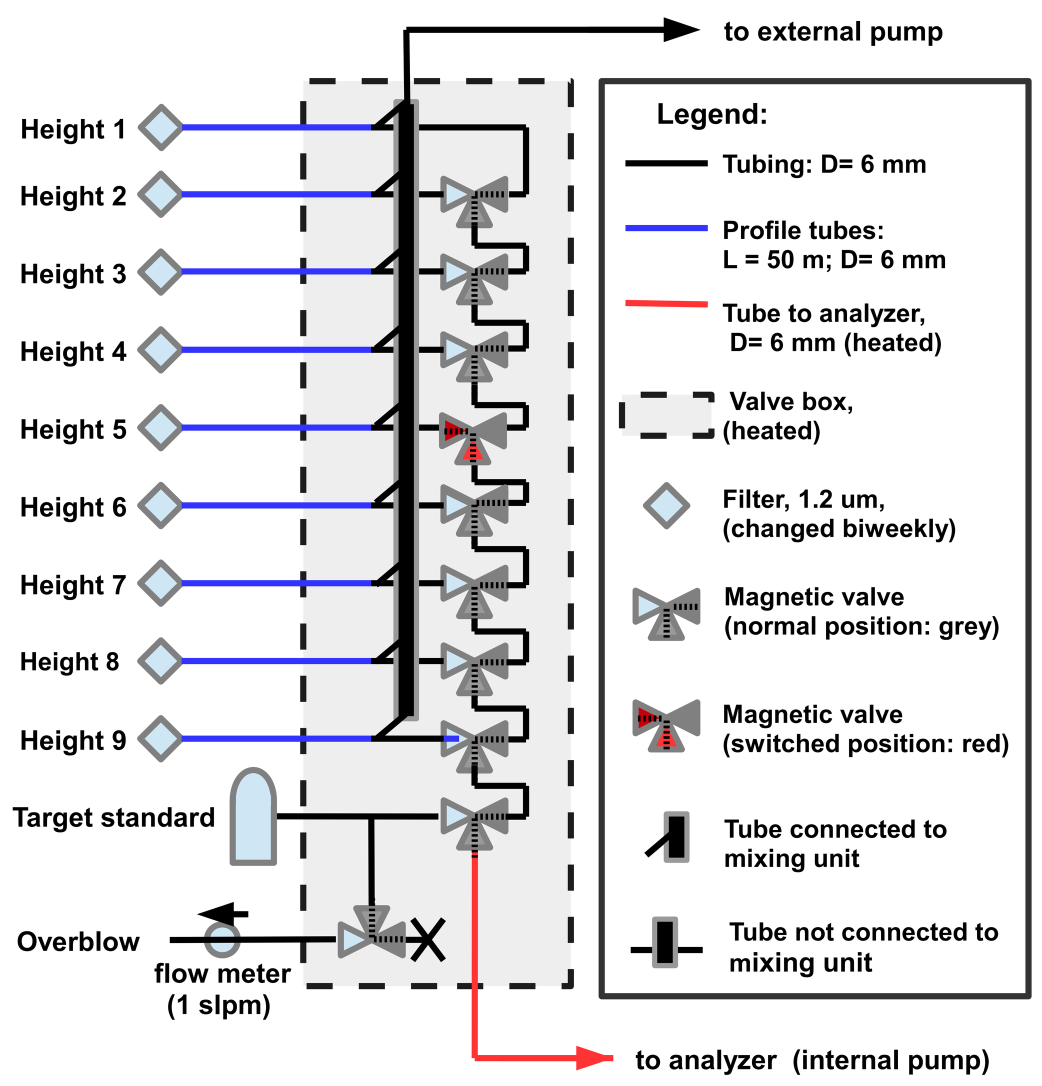


Figure 3: Plumbing of the profile system

Our 30 minutes measurement cycle consisted of:

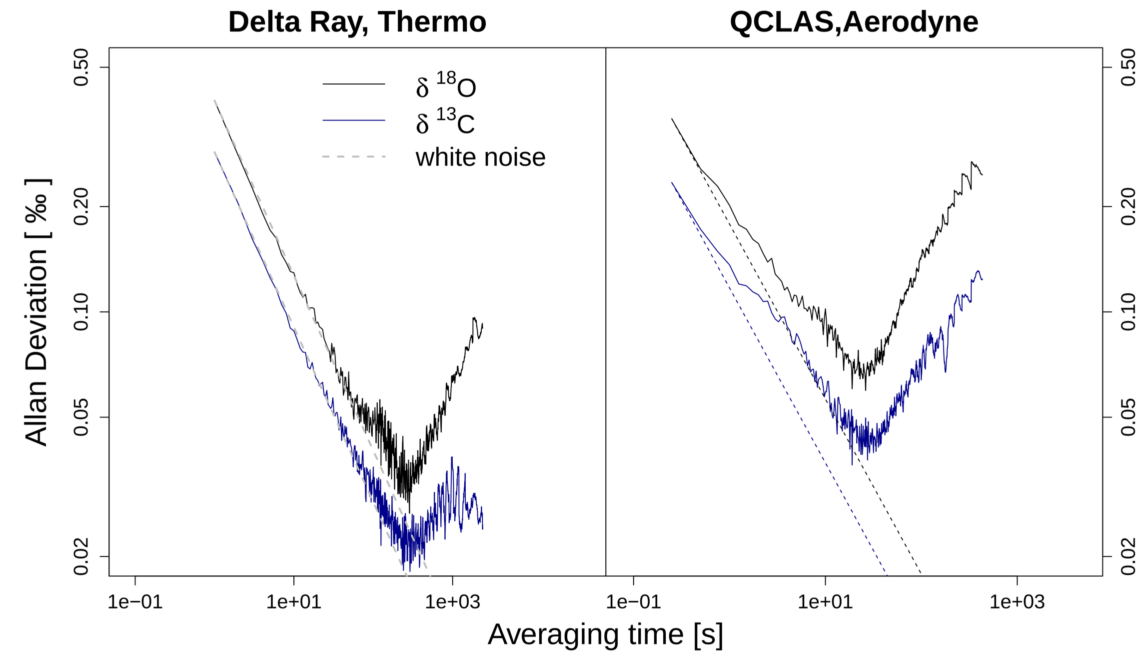
- Measuring all nine heights (app. 2.5 min /height)
- Measuring a target standard (syn. air with app. 400 ppm CO_2 - app. 2.5 min)
- Internal calibration (2.5 to 5 min)

Results

Instrument performance

Precision

- Our measurement time was 20 s and the cell turnover time app. 12 s
- Allan deviation $\sigma_A(20s) < 0.1‰$ for both δ-values (c.f. Figure 4).



	Delta Ray $\delta^{13}C$ [‰]	Delta Ray $\delta^{18}O$ [‰]	QCLAS $\delta^{13}C$ [‰]	QCLAS $\delta^{18}O$ [‰]
σ_A (0.25 s)			0.36	0.24
σ_A (1 s)	0.40	0.29	0.20	0.14
σ_A (20 s)	0.09	0.06	0.07	0.05
σ_A (80 s)	0.05	0.03	0.12	0.07
min(σ_A)	0.03	0.02	0.06	0.04

Figure 4: Allan deviation σ_A for different averaging times of the isotope ratio infrared spectrometer IRIS (Thermo Scientific), compared to a 4Hz quantum cascade laser based spectrometer QCLAS that was running in parallel (Aerodyne Research Inc.)

Long-term stability under field conditions

The measured concentrations and δ-values for our target gas tank are shown with metadata in figure 5 and a comparison of the target measurements to laboratory measurements are shown in table 1. Because the tanks δ-values were outside the calibration range, this reflects the long-term accuracy only in the case of concentration.

	Field Meas.	Lab Meas.
C [ppm]	396 ± 0.2	396.5 ± 0.1
$\delta^{13}C_{meas}$ [‰]	-37.9 ± 0.2	-37.0 ± 0.02
$\delta^{18}O_{meas}$ [‰]	-35.8 ± 0.2	-34.7 ± 0.2

Table 1: Left: Average over all target measurements - excluding all time spans marked with diff. colors in fig. 5, Right: High precise laboratory measurements of the same gas tank at MPI Biogeochemistry in Jena, Germany . Errors denote standard deviations in both cases.

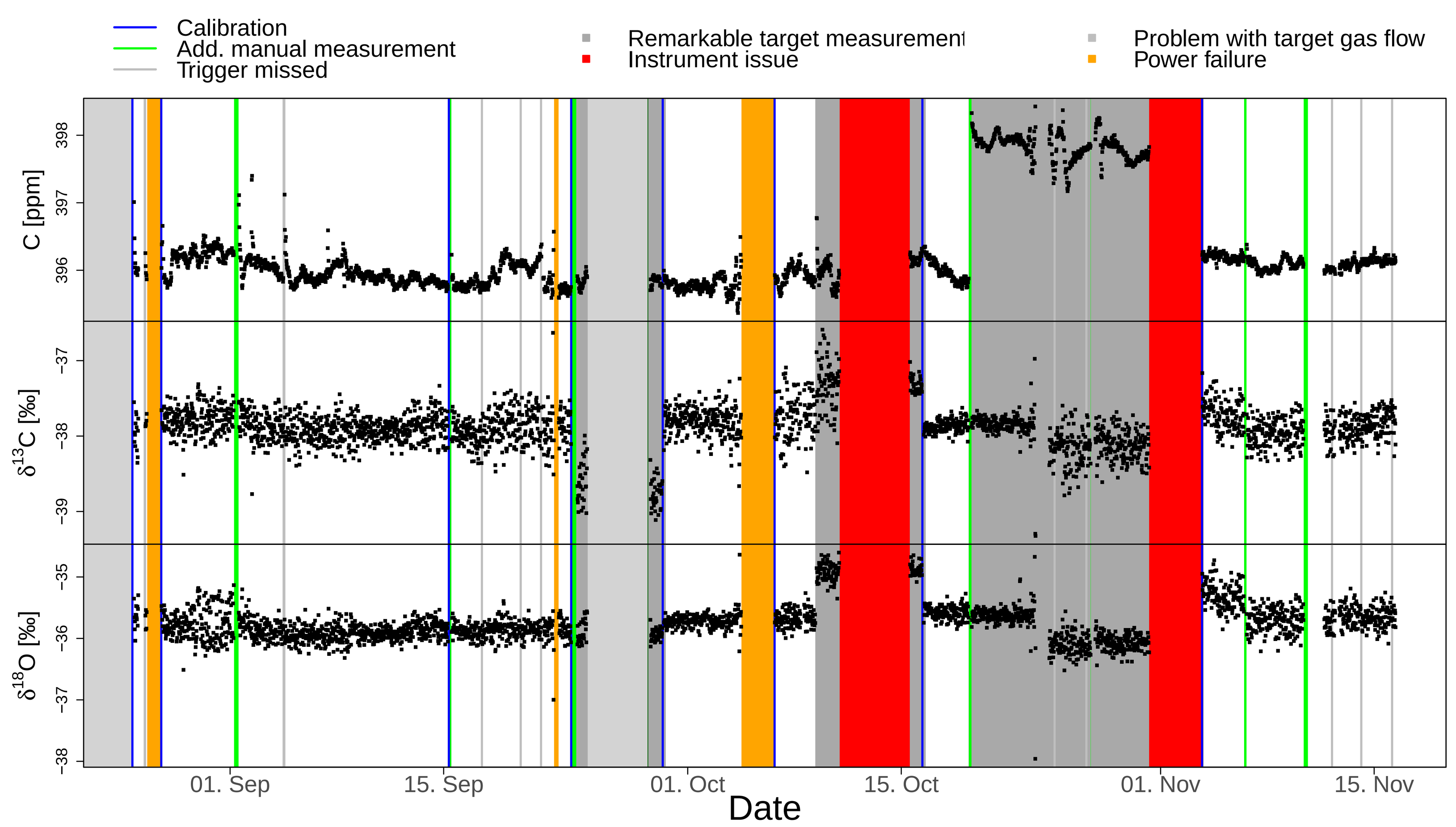


Figure 5: Time series of concentrations and δ-values for target measurements with color-coded meta-data

Variability on seasonal timescale

The isotopic compositions of ecosystem respiration $R_{eco}{}^{13}C$ and $R_{eco}{}^{18}O$ show variations on seasonal timescales that exceed the measurement error (shown in figure 6). Additionally, they both change their behavior after the first (singular) snow event.

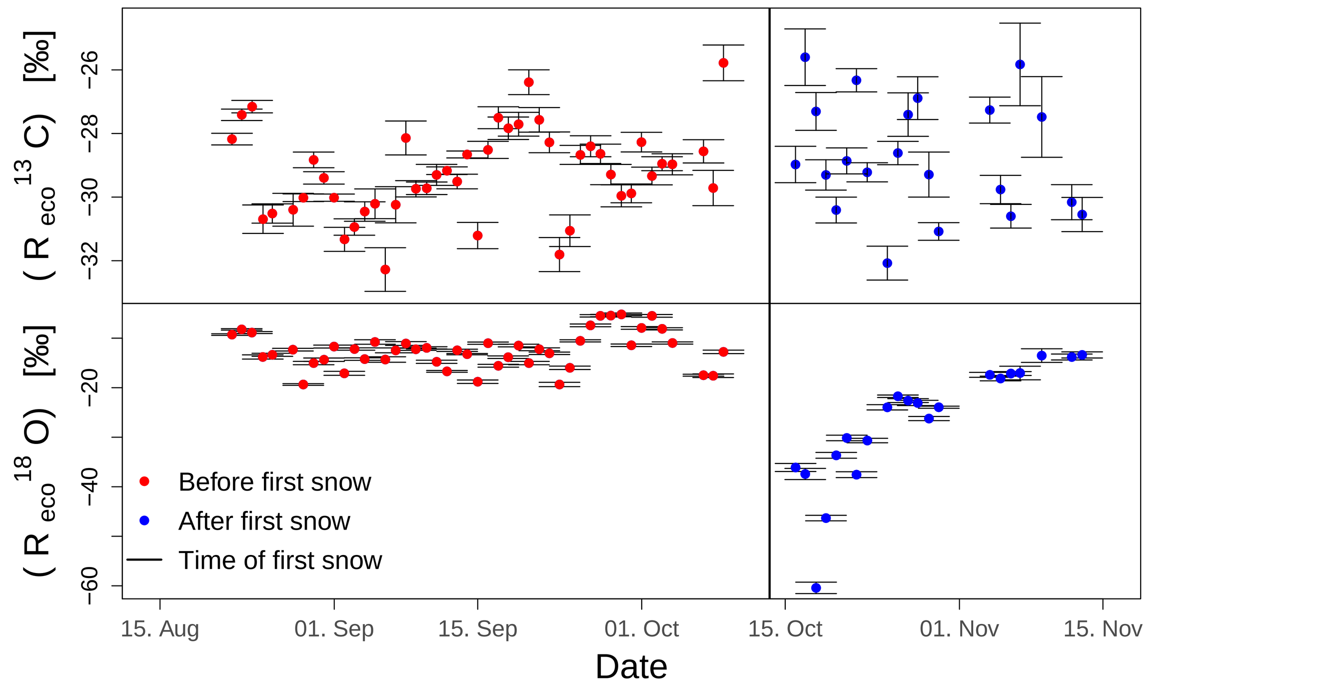


Figure 6: Seasonal variability of the isotopic signatures of respiration, errorbars denote the resp. standard error

Among all n-day-sums over meteorological variables we tested, we found the strongest correlation between $R^{13}_{eco}C$ (before first snow) and the 2-day-sum of net radiation R_n with a time lag of 2 days. This significant, moderate, negative correlation can be interpreted in the following way:

$$R_n \uparrow \Rightarrow \text{Photosynthesis} \uparrow$$
$$\Rightarrow {}^{13}\text{C-Discrimination} \uparrow$$
$$\Rightarrow R^{13}_{eco}C \downarrow$$

For a period of high water availability (radiation is limiting)

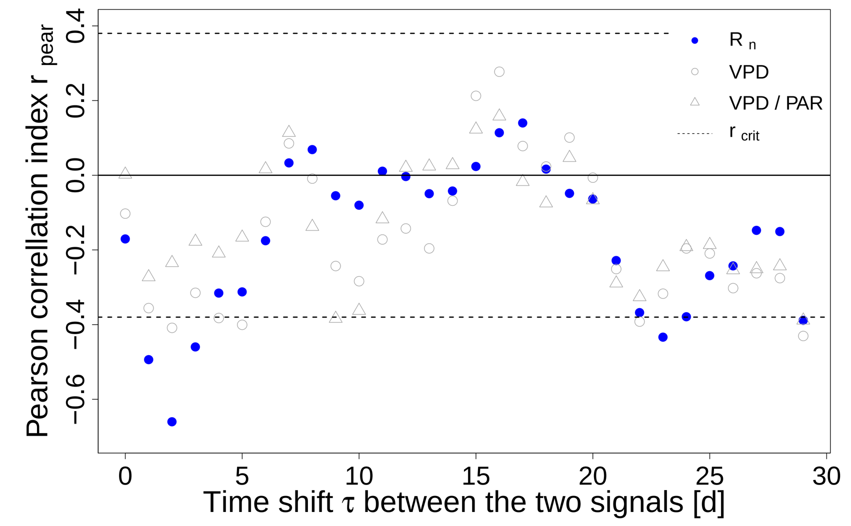


Figure 7: Pearson correlation for $R^{13}_{eco}C$ and net radiation R_n, vapor pressure deficit (VPD) and the ratio of VPD and photosyn. active radiation (PAR) (period before first snow)

Main conclusions

- The instrument showed sufficient accuracy and long term stability to analyze the seasonal variability of the isotopic composition of respiration in both ^{13}C and ^{18}O.
- Before the first snow in autumn 2015 ^{13}C discrimination was controlled dominantly by photosynthesis (and therefore radiation) and not by the stomata (and therefore VPD).
- The time lag between photosynthesis and respiration during this period was 2-3 days.
- After the first snow event this correlation between photosynthesis and radiation vanished abruptly, yielding that the strong seasonal variations in $R^{13}_{eco}C$ were not controlled by photosynthetic flux for this period.

References

[1] A. Ekblad and P. Högberg. Natural abundance of 13C in CO2 respired from forest soils reveals speed of link between tree photosynthesis and root respiration. *Oecologia*, 127(3):305–308, 2001.

[2] R. Wehr and S.R. Saleska. An improved isotopic method for partitioning net ecosystem-atmosphere CO2 exchange. *Agricultural and Forest Meteorology*, 214-215:515–531, 2015.

Acknowledgements

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