Diurnal and Seasonal Variation of δ^{13}C and δ^{18}O of Carbon Dioxide in a Norway Spruce Forest Measured with a Tunable Diode Laser Absorption Spectrometer

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I. Background

Understanding the role of terrestrial ecosystems in governing the isotopic composition of atmospheric CO_2 requires knowledge of diurnal and seasonal variations of δ^{13}C and δ^{18}O of CO_2 in biosphere-atmosphere CO_2 exchange. Tunable diode laser absorption spectroscopy (TDLAS) has recently led to great advances in stable isotope ecosystem research, as it allows for measuring stable isotope ratios in trace gases and water with an unprecedented time resolution also in the field. Here we present several months of data on mixing ratios, δ^{13}C and δ^{18}O of CO_2 at different heights and on respiration rates and δ^{13}C and δ^{18}O of CO_2 from heterotrophic and total soil respiration in a Norway spruce forest (Höglwald) close to Augsburg, Germany.

II. Method

CO_2 mixing ratios as well δ^{13}C and δ^{18}O of CO_2 were measured with a TGA100A (Campbell Scientific, USA), equipped with sampling manifold, sample pump, flow controller and air driers. Air was sampled within (2, 8, 15 m) and above the forest canopy (50 m), and total and heterotrophic soil respiration was measured close to the tower with three custom-made stainless steel chambers each, equipped with an inlet, an outlet and a vent to avoid pressure differences between inside and outside (see image at the right). Total and heterotrophic soil respiration chambers were placed on stainless steel rings of 2 and 30 cm depth, respectively, to include or to exclude roots. Rainwater was collected with a funnel and led into the chambers through a small PTFE tube. Inlet air for the chambers was provided from a 50 L buffer tank that was continuously filled by a pump with ambient air taken at 1 m height. Each height and each soil respiration chamber was sampled once within 30 min for 100 sec, of which the last 45 sec were taken as averaging period. Two reference gases (325 and 552 ppm CO_2 in air) were sampled every 15 min to monitor instrument drift.

III. Seasonal variation of mixing ratios, δ^{13}C and δ^{18}O of ecosystem CO_2

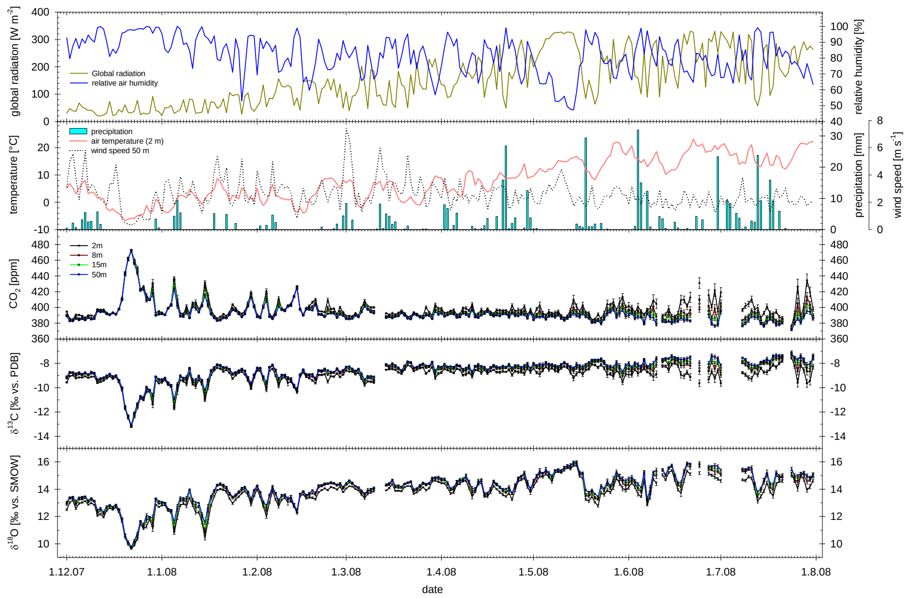

Fig. 1. Daily mean values of meteorological parameters (precipitation = daily sum), of CO_2 mixing ratios and δ^{13}C and δ^{18}O of CO_2 in and above the canopy of a Norway spruce forest (Höglwald, Southern Germany) (n = 48, ± s.e.).

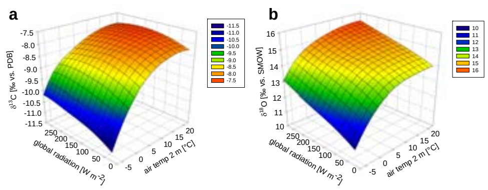

Fig. 2. 3-D-fit (Loess) of the dependencies of δ^{13}C (**a**) and δ^{18}O (**b**) of ecosystem CO_2 on global radiation and air temperature at 2 m height.

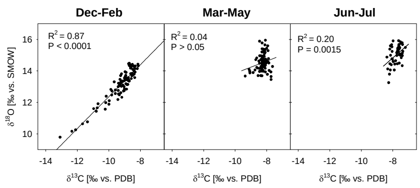

Fig. 3. Correlation of daily mean δ^{13}C and δ^{18}O of ecosystem CO_2 in winter, spring and summer.

IV. Seasonal variation of release, δ^{13}C and δ^{18}O of soil-respired CO_2

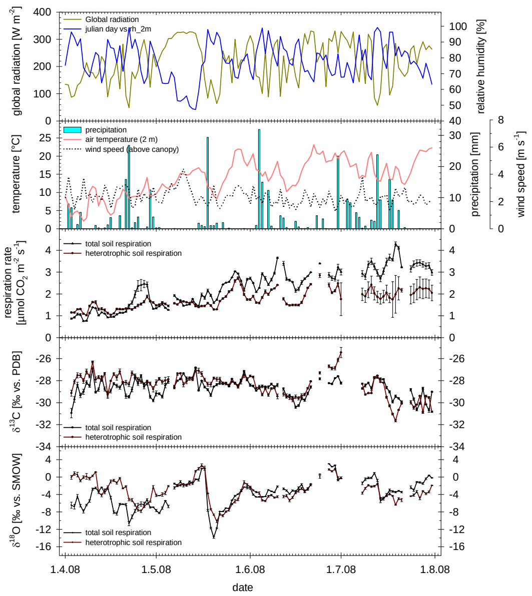

Fig. 4. Daily mean values of meteorological parameters (precipitation = daily sum), of total and heterotrophic soil respiration rates and of δ^{13}C and δ^{18}O of soil-respired CO_2 (n = 48, ± s.e.).

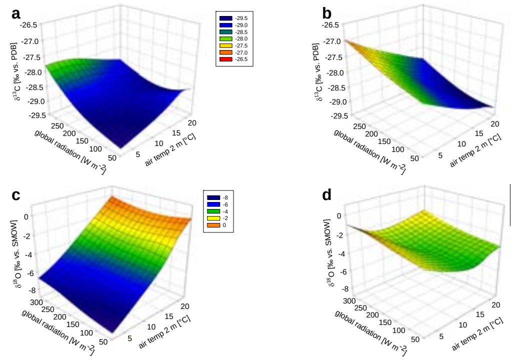

Fig. 5. 3-D-fit (Loess) of the dependencies of δ^{13}C (**a, b**) and δ^{18}O (**c, d**) of CO_2 from total (**a, c**) and heterotrophic (**b, d**) respiration on global radiation and air temperature at 2 m height.

V. Diurnal variation of δ^{13}C and δ^{18}O of ecosystem CO_2

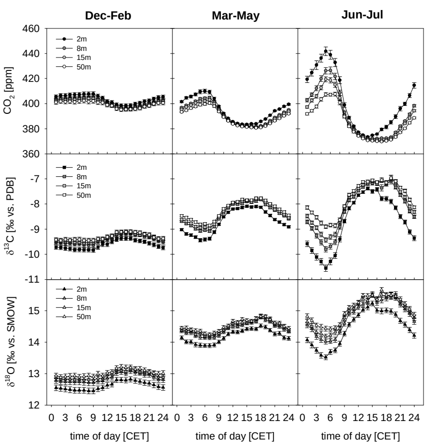

Fig. 6. Mean diurnal variation of mixing ratio, δ^{13}C and δ^{18}O of ecosystem CO_2 during winter, spring and summer at different heights of the forests (n = 122-184, ± s.e.).

VI. Diurnal variation of δ^{13}C and δ^{18}O of soil-respired CO_2

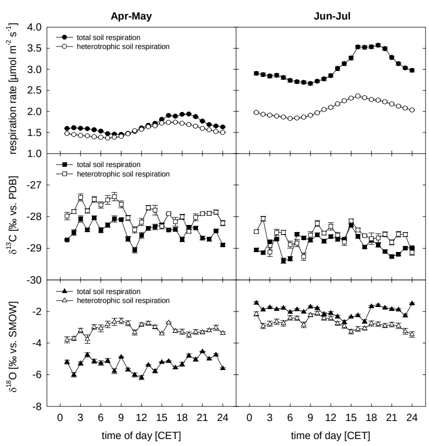

Fig. 7. Mean diurnal variation of respiration rate, δ^{13}C and δ^{18}O of CO_2 released from total and heterotrophic soil respiration during spring and summer (n = 122, ± s.e.).

VII. Summary

Ecosystem CO_2:

- Mean CO_2 mixing ratios were highest in winter and lowest in summer, δ^{13}C and δ^{18}O of CO_2 were lowest in winter and highest in summer
- Winter: δ^{13}C and δ^{18}O mirrored well the temporal variation in CO_2 mixing ratios and were closely correlated. Diurnal variation of all three variables was low.
- Spring/Summer: decoupling of δ^{13}C and δ^{18}O, with δ^{18}O following more closely changes in air temperature and global radiation than δ^{13}C. Diurnal variation was more pronounced, in summer even more than in spring.

Soil respiration:

- The daily maximum of total soil respiration occurred around 7 pm CET, the daily maximum of heterotrophic soil respiration around 4 pm CET.
- Spring: Total respiration rates were on average only slightly higher than heterotrophic respiration rates. The δ$^{13}C_{heterotrophic}$ was on average c. 1 ‰ higher than the δ$^{13}C_{total}$. The δ$^{18}O_{total}$ was on average c. 3 ‰ lower than the δ$^{18}O_{heterotrophic}$.
- Summer: Total respiration rates were on average almost twice as high as heterotrophic respiration rates. The difference between δ$^{13}C_{heterotrophic}$ and δ$^{13}C_{total}$ had almost vanished. The difference between δ$^{18}O_{heterotrophic}$ and δ$^{18}O_{total}$ was reversed, with δ$^{18}O_{total}$ being more positive.

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