I. Background

Understanding the role of terrestrial ecosystems in governing the isotopic composition of atmospheric CO₂ requires knowledge of environmental controls of δ₁³C and δ₁⁸O of CO₂ in biosphere-atmosphere CO₂ exchange. Heterotrophic respiration contributes approximately half of the total respiratory backflow of CO₂ from terrestrial ecosystems to the atmosphere, but too little is known about environmental controls of C and O isotopic signatures of CO₂ released from soils to be able to reliably quantify the contribution of different CO₂ flux components (photosynthesis, above- and belowground autotrophic as well as heterotrophic respiration) to net ecosystem CO₂ exchange.

II. Experiment

The dependencies of δ₁³C and δ₁⁸O of CO₂ from heterotrophic soil respiration on soil temperature and soil moisture were investigated. Samples of the organic layer (O) and humified A horizon (Ah) of a Norway spruce (Picea abies (L.) Karst) forest (Höglwald close to Augsburg, Germany) were incubated at different temperature and moisture levels in gas-tight incubation tubes (extainers), followed by isotope-ratio mass spectrometer (IRMS) analysis of the CO₂ formed during heterotrophic soil respiration. The increase of CO₂ mixing ratios during the incubation period, monitored by IRMS at different sampling times, allowed for calculation of the δ₁³C and δ₁⁸O of the respiratory source of the CO₂ by the Keeling plot methodology.

III. Method

Samples of the O layer below the needle litter and of the Ah horizon were taken on the 10th of May 2007 and 30th of August 2007, taken back to the lab on the same day, and kept refrigerated at 5°C until incubation and analysis. Preparation of refrigerated soil samples started two days prior to analytical determination of the δ₁³C and δ₁⁸O of soil-respired CO₂. First, samples were sieved at 4 mm in order to homogenate the sample material and to exclude fine roots. Subsequently, the sieved samples of O and Ah horizon were air-dried for one night. Then, some g of soil material, depending on the temperature and humidity treatment, were placed into 20 mL exetainers (Labco Ltd., UK). For each temperature and moisture level and each horizon 18 replicates were analyzed. The specific amount of water required to achieve the target soil moisture level was added to each extainer. To avoid drying of samples, the extainers were sealed with parafilm. Samples were then incubated for one night at the respective temperature, which was controlled with a custom-made sample tray connected to a water bath. The parafilm was removed and the samples were aerated for another 1–2 hours before sealing the extainers with the appropriate septum screw caps prior to IRMS analysis with a gas bench coupled to a continuous-flow mass spectrometer (Delta+XP, ThermoFisher, Bremen, Germany).

IV. Results

Values for δ₁³C are given in ‰ vs. PDB, values for δ₁⁸O in ‰ vs. SMOW. MWHC = maximum water holding capacity.

![Fig. 1: Increase in headspace CO₂ mixing ratios above soil from the O layer and from the Ah horizon, respectively, during a 20 h measurement period.](image1)

![Fig. 2: Keeling plots for the determination of δ₁³C of soil-respired CO₂ treatment at 10°C and 50% MWHC (R² = 0.986 and 0.998 for Ah and O, respectively).](image2)

![Fig. 3: δ₁³C (top panels) and δ₁⁸O (bottom panels) at different temperature (left panels) and soil moisture levels (right panels), expressed as % of MWHC, for soil samples of the organic layer and Ah horizon. Significant linear relationships between δ₁³C and temperature as well as between δ₁⁸O and water holding capacity were found.](image3)

![Fig. 4: δ₁⁸O values for each temperature treatment (differently coloured symbols) at different soil moisture levels for Ah (top) and O horizon (bottom).](image4)

![Fig. 4: δ₁³C of soil-respired CO₂ determined for Ah (top panels) and organic layer (bottom panels) with δ₁³C of soil carbon (left panels) and with soil C/N ratios (right panels). Red lines display best linear fit (blue encircled data point omitted), including all data results in a linear fit indicated by the blue line.](image5)

V. Summary

The δ₁³C of the CO₂ respired from root-free organic layer and Ah horizon did not show any significant relation to soil water content. In contrast, δ₁³C had a negative significant linear relationship with temperature. Data fluctuated around an average δ₁³C of -25.6‰ for the Ah horizon and -26.4‰ for the organic layer, reflecting the fact that the organic layer was more depleted in ¹³C than the Ah horizon. Likewise, the CO₂ from the organic layer was more depleted in ¹⁸O than the CO₂ from the Ah horizon. In contrast to the δ₁³C results, no significant relationship of δ₁⁸O to temperature could be observed. However, a highly significant decrease in δ₁⁸O of respiratory CO₂ from both soil layers with increasing soil moisture was found, decreasing from an average of +14‰ vs. SMOW at 25% MWHC to +4‰ at 100% MWHC.

---

Contact: Dr. Nicolas Brüggemann (nicolas.bruengemann@imk.fzk.de) Tel.: +49-(0)8821-183226, Fax: +49-(0)8821-183294

KIT – a cooperation between Karlsruhe Research Center and University of Karlsruhe

Forschungszentrum Karlsruhe

In der Helmholtz-Gemeinschaft