Seasonal variability of soil CO_2 flux and its stable isotope composition in an urban area: case study from Krakow, southern Poland

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Introduction

Numerous studies have been performed focusing on biogenic CO_2 emissions, including characterization of soil CO_2 fluxes for different ecosystems. Stable isotope composition of CO_2 carries additional information with respect to the origin of this trace gas.

The presented work is an attempt to characterize stable isotope signature of biogenic CO_2 on the areas with different anthropogenic influence.

Location

The soil CO_2 flux and its carbon and oxygen isotope signature was measured on the monthly basis from July 2009 to June 2010. The measurements were performed at four locations within the metropolitan area of Krakow, representing different level of anthropogenic influence.

A : the site located in direct neighborhood of a busy street (with the heaviest impact);

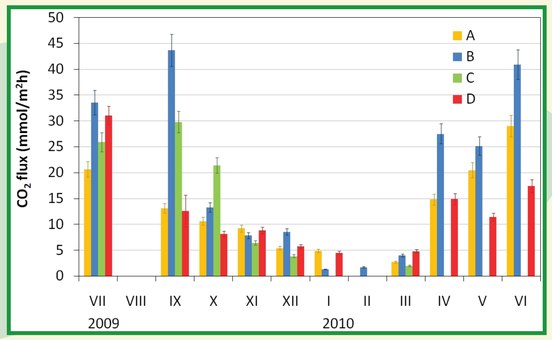
B : placed within green recreation area (medium anthropogenic influence);

C : inside the university campus (medium influence);

D : at the outskirts of the city, at the distance of ca. 12 km from the city center (minor influence).

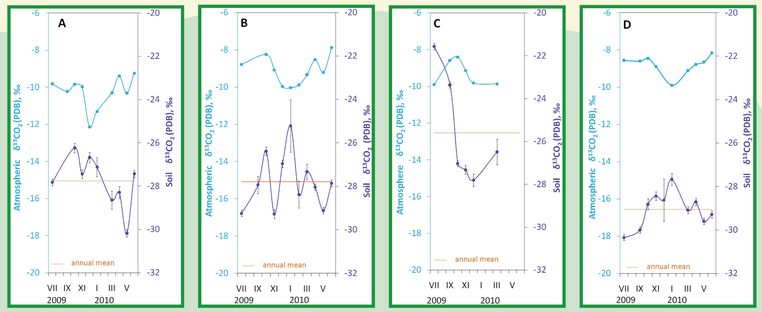
Seasonal variability of soil CO_2 flux

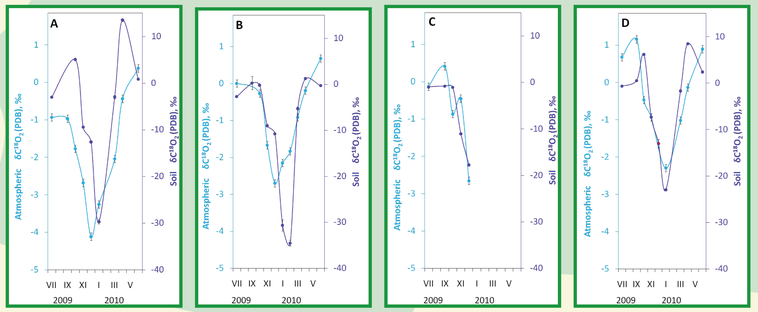
The soil CO_2 flux reveals a strong seasonal variation, which is a consequence of natural biospheric activity cycle. Maximum values of the CO_2 flux were measured during late summer (up to 43.7±3.1 mmol $m^{-2}h^{-1}$). The minima were observed during winter, with the values fluctuating between 1 and 3 mmol $m^{-2}h^{-1}$. Large differences between measurement sites were observed particularly during summer (up to ca. 21 mmol $m^{-2}h^{-1}$).



Isotopic composition

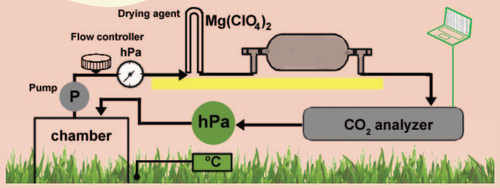
The carbon isotopic signature of soil CO_2 ($\delta^{13}C$) fluctuated at three sites between -26 and -30‰ (VPDB scale). Such values of $\delta^{13}C$ indicate a dominating role of C3-type vegetation cover existing there. At measurement site C, the carbon isotope signature of soil CO_2 flux was less negative (fluctuating around -21‰) pointing to significant contribution of C4-type vegetation in this area.





Contruary to $\delta^{13}C$, $\delta^{18}O$ values of soil CO_2 flux revealed strong seasonal variations. During summer they fluctuated around 0‰ (VPDB-CO_2) at all measurement sites, while during winter very negative $\delta^{18}O$ values were observed. Extreme value of -34.5±0.6‰ was recorded in February 2010. While the carbon isotope composition of soil CO_2 flux is primarily controlled by isotopic signature of the respired CO_2 (both autotrophic and heterotrophic component), its oxygen isotope composition is controlled in the first instance by isotopic composition of the soil moisture which varies in accordance with $\delta^{18}O$ values in local precipitation. Another important parameter is the temperature at which the isotope exchange between soil CO_2 and soil moisture takes place.

Methodology



$$f = \frac{p \cdot V \cdot \frac{dC}{dt}}{R \cdot T \cdot A}$$

f – soil CO_2 flux (mmol · m^{-2} · h^{-1}),
V – chamber volume (m^3),
p – atmospheric pressure (Pa),
$\frac{dC}{dt}$ – gradient ot CO_2 increase under the chamber (mmol · mol^{-1} dry air · h^{-1}),
R – universal gas constant,
T – temperature of air under the chamber (K),
A – soil surface area under the chamber (m^2).

The soil CO_2 flux was measured using a closed chamber system coupled with Vaisala CARBOCAP sensor. The isotopic signature of the respired CO_2 was determined with the aid of two samples collected to 1-liter glass flasks, one at from the atmosphere at the beginning of the experiment, and the second from the chamber at the end of the measurement cycle. Two component mixing model was applied to calculate isotopic signatures of the CO_2 source.

Conclusions

Large seasonal variability of soil CO_2 flux was observed in the study area: from ca. 5 mmol/m^2h during winter months, up to 35 mmol/m^2h during summer. During summer months, significant differences between four measurement sites reaching ca. 30 mmol/m^2h were observed (e.g. site B and D in September), pointing to large spatial variability of this parameter controlled by site-specific factors.

While ^{13}C content in atmospheric CO_2 at four observation sites revealed clear anthropogenic signal with lowest $\delta^{13}C$ values observed in the location with heaviest impact (site A), the soil CO_2 flux does not bear visible signs of ^{13}C-depleted sources of carbon in the soil.

Oxygen isotope composition of atmospheric carbon dioxide and soil CO_2 flux revealed distinct seasonal cycle, with isotopically depleted values during winter. While $\delta^{18}O$ values observed in local atmospheric CO_2 varied between ca. +1 and -4‰ (V-PDB), in accordance with other atmospheric data available for central Europe, extreme ^{18}O-depletions reaching -35‰ were recorded in soil CO_2 flux during winter. They go well beyond the expected values, taking into account the ^{18}O isotope composition of soil moisture in the study area. Reasons of these unexpected $\delta^{18}O$ values are currently investigated.

Acknowledgements

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