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Apportionment of carbon dioxide over central Europe: insights from combined measurements of atmospheric CO_2 mixing ratios and carbon isotope composition

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The European continent, due to high population density and numerous sources of anthropogenic CO_2 emissions, plays an important role in the global carbon budget. Nowadays, precise measurements of CO_2 mixing ratios performed by both global and regional monitoring networks, combined with appropriate models of carbon cycle, allow quantification of the European input to the global atmospheric CO_2 load. However, measurements of CO_2 mixing ratios alone cannot provide the information necessary for the apportionment of fossil-fuel related and biogenic contributions to the total CO_2 burden of the regional atmosphere. Additional information is required, for instance obtained through measurements of radiocarbon content in atmospheric carbon dioxide. Radiocarbon is a particularly useful tracer for detecting fossil carbon in the atmosphere on different spatial and temporal scales.

Regular observations of atmospheric CO_2mixing ratios and their isotope compositions have been performed during the period of 2005-2009 at two sites located in central Europe (southern Poland). The sites, only ca. 100 km apart, represent two extreme environments with respect to the extent of anthropogenic pressure: (i) the city of Krakow, representing typical urban environment with numerous sources of anthropogenic CO_2, and (ii) remote mountain site Kasprowy Wierch, relatively free of local influences. Regular, quasi-continuous measurements of CO_2 mixing ratios have been performed at both sites. In addition, cumulative samples of atmospheric CO_2 have been collected (weekly sampling regime for Krakow and monthly for Kasprowy Wierch) to obtain mean carbon isotope signature ($^{14}C/^{12}C$ and $^{13}C/^{12}C$ ratios) of atmospheric CO_2 at both sampling locations. Partitioning of the local atmospheric CO_2 load at both locations has been performed using isotope- and mass balance approach.

In Krakow, the average fossil-fuel related contribution to the local atmospheric CO_2 load was equal to approximately 3.4%. The biogenic component turned out to be of the same magnitude. Both components revealed a distinct seasonality, with the fossil-fuel related component reaching maximum values during winter months and the biogenic component shifted in phase by ca. 6 months. Seasonality of fossil-fuel related CO_2 load in the local atmosphere is linked with seasonality of local CO_2sources, mostly burning of fossil fuels for heating purposes. Positive values of biogenic component indicate prevalence of the local respiration and biomass burning processes over local photosynthesis. Summer maxima of biogenic CO_2 component represent mostly local respiration activity. Direct measurements of soil CO_2 fluxes in the Krakow region showed an approximately 10-fold increase of those fluxes during the summer months.

Partitioning of the local CO_2 budget for Kasprowy Wierch site revealed large differences in the derived components when compared to urban atmosphere of Krakow: the fossil-fuel related component was ca. 5 times lower whereas the biogenic component was negative in summer, pointing to the importance of photosynthetic sink associated with extensive forests in the neighborhood of the station.

The isotope- and mass balance approach was also used to derive mean monthly ^{13}C isotope signature of fossil-fuel related CO_2 emissions in Krakow. Although the derived $\delta^{13}CO_2$ values revealed large variability, they are confined in the range of ^{13}C isotope composition being reported for various sources of CO_2 emissions in the city (burning of coal and oil, burning of methane gas, traffic).