Urban and rural site regional fossil fuel CO_2 observations from Hungary using multi elevation sampling

M. Molnár (1), L. Haszpra (2), I. Major (3), I. Svetlík (4)

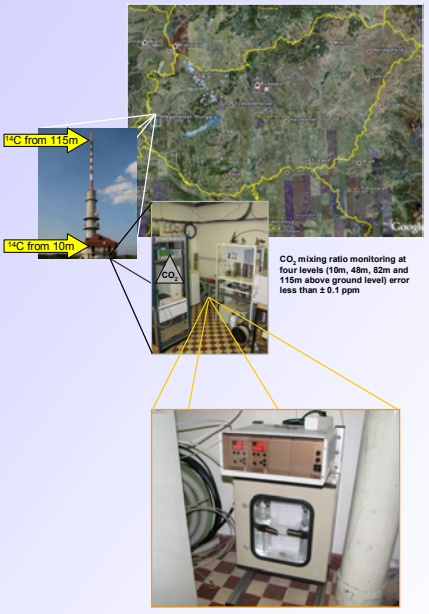
(1) MTA ATOMKI, Debrecen, Hungary (mmol@namafia.atomki.hu, +36-52-509-213); (2) Hungarian Meteorological Service (OMSz), Budapest, Hungary;

(3) University of Debrecen, Debrecen, Hungary; (4) Nuclear Physics Institute AS CR, Prague, Czech Republic

Introduction

Nowadays one of the most burning questions for the science is the rate and the reasons of the recent climate change. Greenhouse gases (GHG), mainly CO_2 and CH_4 in the atmosphere could affect the climate of our planet. However, the relation between the amount of atmospheric GHG and the climate is complex, full with interactions and feedbacks partly poorly known even by now. The only way to understand the processes, to trace the changes, to develop and validate mathematical models for forecasts is the extensive, high precision, continuous monitoring of the atmosphere. Fossil fuel CO_2 emissions are a major component of the European carbon budget. Separation of the fossil fuel signal from the natural biogenic one in the atmosphere is, therefore, a crucial task for quantifying exchange flux of the continental biosphere through atmospheric observations and inverse modelling. An independent method to estimate trace gas emissions is the top-down approach, using atmospheric CO_2 concentration measurements combined with simultaneous radiocarbon (^{14}C) observations. As adding fossil fuel CO_2 to the atmosphere, therefore, leads not only to an increase in the CO_2 content of the atmosphere but also to a decrease in the $^{14}C/^{12}C$ ratio in atmospheric CO_2.

Rural site at Hegyhátsál (HHS)



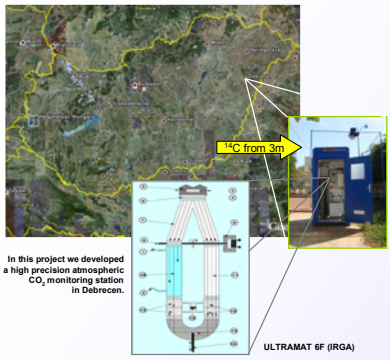
Atmospheric $^{14}CO_2$ sampling unit with two lines (developed by ATOMKI)

Monitoring sites

Location selected for urban atmospheric CO_2 observations is a city in East Hungary (47°32'N, 21°38'E). Its climate is characterized by dry summers and rather cold winters compared to other parts of the country. The area of the city covers 462 km^2 and it is only 85 m above sea level, which means that it is situated in a small basin. **Debrecen** with its almost 205 thousand inhabitants is the second largest town and industrial centre in Hungary. There is, among others, one natural gas based power plant in the city (95 MW). Institute of ATOMKI where a new observation station is installed is located close to the centre of the city.

Synchronised $^{14}CO_2$ sampling and measurements with urban observations started in a rural site at **Hegyhátsál** to have solid regional reference level for fossil fuel CO_2 calculations in the city air. The measurements are carried out on a 117 m tall, free-standing TV and radio transmitter tower owned by Antenna Hungária Corp. The tower is located in a flat region of western Hungary (46°57'N, 16°39'E), at an altitude of 248 m above sea level. This observation station is surrounded by agricultural fields (mostly crops and fodder of annually changing types) and forest patches. Measurements of CO_2 mixing ratio profiles, temperature, humidity and wind profiles began in September 1994. Flux measurements began in April 1997. The tower is also a NOAA/CMDL global air sampling network site (site code: HUN) (Conway et al., 1994).

Urban site at Debrecen (City)

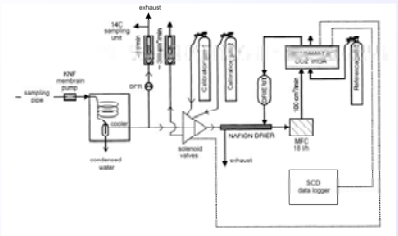


$^{14}CO_2$ sampling and on-site CO_2 measurement

Radiocarbon samplers have been installed in Debrecen (sampling point at 3 m above the ground level) and Hegyhátsál (sampling points at 10 m and 115 m above the ground level) were developed in ATOMKI to obtain integrated samples for measuring of ^{14}C in chemical form as CO_2. In all cases the sampler inlets are connected into the exhaust pipe after the back pressure regulator of the gas handling line of the applied CO_2 analyser's.

The CO_2 is trapped in bubblers filled with 500 ml 3M NaOH solution. Similar type of ATOMKI samplers are routinely used in environmental $^{14}CO_2$ monitoring around a nuclear power plant (NPP) in Hungary since 1991 (Veres et al. 1995, Molnár et al. 2007).The sampling period is 4 weeks, the flow rate of sampling is stabilized at 10.0 liter/h. A detailed description of the sampling devices is given by Uchrin and Hertelendi (1992). We measured the ^{14}C activity of the samples using proportional counting method in ATOMKI (Csongor and Hertelendi 1986; Hertelendi et al. 1989).

A mobile and high-precision atmospheric CO_2 monitoring station was developed in this project. The system is designed for the continuous, unattended monitoring of CO_2 mixing ratio in the near surface atmosphere based on an infrared gas analyser (IRGA) with a setup which is very similar to that described by Zhao et al (1997), and used for the measurements reported by Bakwin et al (1995 and 1998) and Haszpra et al. (2001 and 2008). In the station an above described ATOMKI type atmospheric $^{14}CO_2$ sampling unit was also installed with two independent sampling lines (sampling points at 10 m and 115 m above the ground level) .



Layout of the setup of gas handling line used in the field CO_2 monitoring system developed in ATOMKI. For more detals see Poster #15 by Molnár et. al.

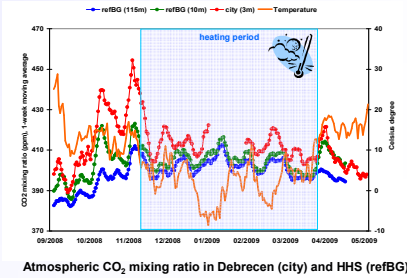
Results and discussion

During the winter of 2008/09 we measured the mixing ratio and radiocarbon content of atmospheric CO_2 at Debrecen and the reference station simultaneously. It was concluded that trends in CO_2 mixing ratio variations in time are very similar at the three different sampling points (2 m above ground in Debrecen, 10 m and 115 m above ground in Hegyhátsál). Air quality in Debrecen during September of 2008 seemed to be relatively clear from the point of view of its CO_2 content at least. When winter came closer in October, with lover outside temperature and less sunshine hours the CO_2 content of air was increased in general at all the three sampling points, but this effect was more intensive closer to the ground level.

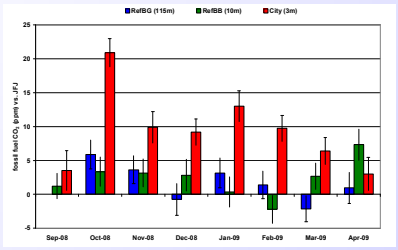
Using Hungarian reference $^{14}CO_2$ observations from the two elevations (10 m and 115m) in the rural site at Hegyhátsál (HHS) we could report atmospheric fossil fuel CO_2 component in the city of Debrecen in regional scale. On the other hand, if we apply the Jungfraujoch (Swiss Alps) data from Levin et al. 2008 and 2009 as reference we could report the Debrecen fossil fuel CO_2 in a continental scale. There were no significant differences between the two scales as Hegyhátsál observation in Hungary provided quite similar background results to the dedicated continental background observation station at Jungfraujoch in the Swiss Alps located more than 3000m above the sea level.

Similarity of the monthly average of the $^{14}CO_2$ results at 10 m and 115 m in Hegyhátsál also suggests that this station could not be strongly affected by local ground level anthropogenic fossil fuel sources. Small but significant difference between 10 m and 115 m observations only appeared in the spring (April) of 2009, but also this time the extrapolated Jungfrujoch results still remained very close to the 115 m $\Delta^{14}C$ data from HHS.

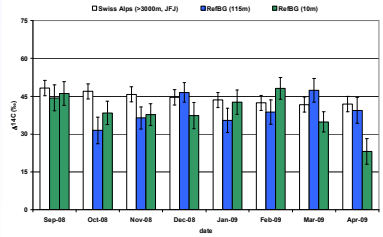
According to our radiocarbon observations it was clearly indicated that there was not significant amount of fossil fuel CO_2 in the air of Debrecen city during September in 2008. The observed urban fossil fuel CO_2 maximum in the middle of winter seems to be realistic as domestic heating is mainly based on fossil fuels in Hungary and outside temperature minimum was also in the middle of winter (first two weeks of January). The level of maximum in January was about 10-15 ppm fossil fuel CO_2 in the urban air, similar like in Heidelberg city in Germany (15-20 ppm) reported by Levin et al. 2008 and like in Krakow city (20ppm) in Poland reported by Rozanski (Rozanski 2009). Furthermore we observed also a significant maximum (~20ppm) in fossil fuel CO_2 during October of 2008 in Debrecen. Its explanation and possible source identification needs more study as meteorological conditions, especially because the main wind directions remained very similar during the whole observation period (Sept 2008-April 2009) in Debrecen.



Atmospheric CO_2 mixing ratio in Debrecen (city) and HHS (refBG)

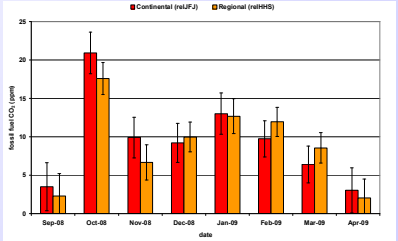


Fossil fuel CO_2 trend in the city and refBGs (HHS) vs. Swiss Alps (JFJ)



Atmospheric $\Delta^{14}C$ trend in the Hungarian BGs (HHS) and in the Swiss Alps

JFJ data from Levin et al. 2008 and I. Levin, pers. com.



Fossil fuel CO_2 trend in the city vs. continental and regional BGs

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