PRELIMINARY RESULTS OF NET ECOSYSTEM EXCHANGE OF GREENHOUSE GASES (CO$_2$, CH$_4$, H$_2$O) AT WETLAND OF BIEBRZA NATIONAL PARK, POLAND

Krzysztof Fortuniak*, Włodzimierz Pawlak**

Department of Meteorology and Climatology, Faculty of Geographical Science, University of Łódź, Poland
*E-mail: kfortun@uni.lodz.pl,
**E-mail: wpawlak@uni.lodz.pl

Introduction

A detailed knowledge on the net surface exchange of greenhouse gases is essential for reliable climate modeling both in local and global scale. The wetlands play an important role in climatic system due to their significant contribution to carbon exchange and specific surface energy balance. Situated in northeastern Poland the Biebrza Valley, is the largest wetland of the country and one of the largest in Central Europe. It is 110 km long, up to 20 km wide and consist more than 250 km$^2$ of swamps. The area is famous due to its unique European ecological value being a result of a combination of the relatively extensive use of the area, the occurrence of large peat deposits, the yearly natural large flooding and the presence of mire ecosystems that become habitats for rare plant communities and protected animal species. This natural wetland ecosystem was alternated by human activities in nineteenth and twentieth century by construction of the Woznawiejski and Augustowski Canals (1820-1860) and drainage works in 1950-1990 which led to the mineralization of peat cover (Grygoruk et al. 2011). Recently different environmental-restoration strategies are introduced to re-cultivate degraded peatlands. For that reason, biological and chemical processes at the area may differ than other wetlands. On the other hand, this processes can be regard as typical for a large part of eastern Poland where irrigation made a few decades ago altered natural ecosystem.

The main goal of the present work is to recognize a net ecosystem exchange of main greenhouse gases (H$_2$O,CO$_2$, CH$_4$) for such type of wetlands. It is of key importance for understanding of their role in the climatic system. We present results of continuous measurement of turbulent fluxes of greenhouse gases made with the aid of open-path eddy-covariance (EC) system. The eddy-covariance method is the most direct and accurate way to estimate net exchange of the mass, energy and momentum between the surface and the atmosphere, but because of availability of the commercial sensors, restriction of the site location and other methodological problems, the grow of EC network is limited to last two decades. Still, only a few EC systems works in Poland and only two of them are located on wetlands: the system presented below and another one working in Rzecin (Western Poland).

Site location, instrumentation and data processing

The Biebrza Valley is subdivided by morphological features into three major units, defined as the Upper, Middle and Lower Basin (Okruszko 1990). The measurement site (53°35'30.8"N, 22°53'32.4"E, 110 m asl) is located in the Middle Basin on the very flat surface near to the village Kopytkowo south to the famous peatland called “Czerwone Bagno”. The small river Kopytków flows in the nearest neighborhood of the site, but it is completely overgrown with reeds (Fig. 1). The mixture of reeds, sedges and rushes characteristic for Biebrza wetlands compose homogenous surroundings of the site. A few separate houses is located in the distance about 500 m south-east from the site.

A typical open-path eddy-covariance measurement system consists of three fast respond sensors: a sonic anemometer (RMYoung 81000) and two gas analyzers (Li7500 – H$_2$O/CO$_2$ and Li7700 – CH$_4$) operating with 10 Hz frequency. The middle of the path of the eddy-covariance system is on the height 3.5 m above the ground. The 90% source area for such height is approximately a circle with diameter about 500 m. The outputs from sensors, governed by CR5000 datalogger (Campbell Sci.),

Fig. 1. Site location and a view on the measurement screen
are organized in 15 min files and stored on the PC connected to the logger. The eddy-covariance system is complemented by slow-respond sensors giving information on: radiation balance – net radiometer (CNR1 allowing for independent measurements of downward and upward shortwave and longwave radiation) and two PAR sensor faced up and down mounted on the horizontal arm at the height 2.7 m in a distance more than 3 m from the box; heat flux to the ground – ground heat flux plates; soil moisture – volumetric water content sensor; precipitation – standard rain gauge; two temperature and humidity probes (HMP60, Vaisala, Finland) at height 0.5 and 2 m; atmospheric pressure sensor, cup anemometer and wind wane.

The data processing scheme used in fluxes calculation highly affects the results. The entire impact of post-processing method can reach 5-20% for energy fluxes and even 50% in CO
2 (Mauder and Foken, 2006). To minimize these effect we followed the procedure commonly used by EC groups recommended by Aubinet et al. (2012). The data processing scheme includes:

- spikes elimination;
- outranged values elimination based on physical thresholds;
- cross-wind correction as implemented in sonic anemometer;
- coordinate transformations to natural wind coordinate system with double rotation (Kaimal and Finnigan, 1994);
- covariance maximization in the window +/– 2 s;
- 1 hour block averaging;
- humidity correction of sensible heat flux from sonic temperature measurements;
- correction for mass imbalance (Webb et al., 1980);
- correction for spectral losses (Horst, 2003).

In data analysis we checked stationarity conditions using three tests: the test proposed by Foken and Wichura (1996) with a critical value of RNFW = 0.3; the non-stationarity ratio, NR, given by Mahrt (1998) with a critical value of NR = 2; and the relative covariance stationarity criterion introduced by Dutaur et al. (1999) with a critical value of the relative covariance stationarity coefficient, RCS = 0.5.

Results and discussion

The measurements of the turbulent fluxes and other meteorological parameters started in Kopytkowo in November 2012. Present analysis covers more than one year of continuous measurements November 2012 – January 2014. The winter 2012/2013 was relatively cold and long with a negative temperature lasting from the beginning of December 2012 to the end of the first decade of April 2013. The ground was frozen and cover by patches of the snow in this period. In the end of April the mean daily temperature grew to 10-12°C. In summer 2013 the five days mean temperature oscillated between 14°C and 22°C, but the daily maxima exceeded 32°C at the beginning of August. Since mid-August the temperature regularly dropped to the 0°C at the beginning of December, but it was in general positive to the mid-January when negative values around -15°C was recorded. Precipitation in the analyzed period exhibits typical for the region annual course with lowest totals in winter and the highest summer season (Fig. 2). Still, the highest monthly total, above 135 mm, was recorded in September.

The mean monthly values of the net turbulent flux of methane are positive (upward) and follow the temperature (Fig. 2). The emission in the winter 2012/2013 was on the level 0.02 g·m⁻²·day⁻¹. It raised rapidly in May and reached maximum in June – above 0.24 g·m⁻²·day⁻¹. Next it decreased continuously to the level about 0.06 g·m⁻²·day⁻¹ in September and remained at this level all Autumn months. In December it dropped by about a half, but because the winter 2013/2014 was milder than the previous one, the net CH₄ flux was in general higher. The total annual methane emission in the year 2013 was on the level 33 g·m⁻² which gives almost 25 g·m⁻² of carbon.

The annual course of carbon dioxide is characterized by a negative net flux (accumulation) in the growing season and close to zero or slightly positive
values in the rest of year. The highest accumulation of \( \text{CO}_2 \) almost 15 \( \text{g·m}^{-2}\text{·day}^{-1} \), was recorded in June, during the most intensive grow of vegetation. In next summer months the absolute \( \text{CO}_2 \) flux systematically decreased. The total annual \( \text{CO}_2 \) uptake in 2013 was almost 845 \( \text{g·m}^{-2} \), which gives 230 \( \text{g·m}^{-2} \) of carbon. Comparing the annual emission of carbon in \( \text{CH}_4 \) and accumulation in \( \text{CO}_2 \) uptake, the total annual storage of the carbon at Biebrza wetlands can be estimated as about 200 \( \text{g·m}^{-2} \).

The evaporation (\( \text{H}_2\text{O} \) flux) also show a clear annual course related to the temperature. There is also clear relation to the precipitation. However, as the swamp Fig. 2 Mean monthly net flux of \( \text{CO}_2 \) and \( \text{CH}_4 \) (positive flux means net emission, negative – uptake) and evaporation vs. precipitation totals in Kopytkowo in the period November 2012 – January 2014. Hydrological system the local precipitation is not necessary a steering variable for the latent heat flux. The highest evaporation, above 90 \( \text{mm·day}^{-1} \), was recorded in July. The lowest, close to zero, in the winter months 2012/2013, when the swamp was totally frozen.

**Conclusions**

The flux measurements with the aid of eddy-covariance method allows to estimate average net turbulent exchange for the area of diameter about 500 m. It allows for more realistic estimation of spatial fluxes than given by other techniques (e.g. chamber method). The longer than one year measurements of the net ecosystem exchange of main greenhouse gases made in Kopytkowo shows that Biebrza wetlands are in general sink of carbon. The emission of carbon in methane is balance by its accumulation in carbon dioxide uptake during a vegetation season.

**Funding for this research was provided by the Polish National Centre of the Science under project UMO-2011/01/B/ST10/07550.**