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Comparison of carbon dioxide fluxes over sandy grassland vegetation as measured by the eddy-covariance technique and by open system chamber

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ABSTRACT Within the frame of an EU sponsored study (Greengrass) CO_2 flux measurements were started on differently managed grassland ecosystems. We utilized two techniques – eddy-covariance (EC) and open system gas exchange chamber (OC) – to measure CO_2 fluxes and compare the results of the two different methods. The study period presented in this paper covers 2003 and 2004, when the weather conditions were substantially different. OC measurements were made during the nine measurement campaigns in the two years. In comparison with EC the open system chamber proved to be a good tool for gas exchange measurements in grasslands.
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KEY WORDS

CO_2 flux
open chamber technique
grassland

Accurate measurements of CO_2 fluxes are necessary for understanding of carbon cycling in grassland ecosystems. Most of the studies on carbon cycling are based on meteorological methods – eddy covariance and Bowen ratio (Saigusa et al. 1998; Frank and Dugas 2001; Sims and Bradford 2001; Suyker et al. 2003; Kato et al. 2004), but several chamber techniques are also in use (Angell and Svejcar 1999; Oechel et al. 2000; Balogh et al. 2002; Czóbel et al. 2002; Juhász et al. 2002; Steduto et al. 2002). The advantages of the chamber methods are that we exactly know where the fluxes came from, while the micrometeorological methods have a great uncertainty to appoint this; providing information on the spatial physiological heterogeneity of vegetation (Fóti et al. 2002); easier partitioning the net ecosystem exchange (NEE); lower costs compared to micrometeorological methods. Most of the soil respiration measurements use closed or open chamber methods, but micrometeorological methods are also used to measure soil respiration rate (Verma 1990).

The chamber methods are often criticized (Dugas et al. 1997) because of the uncertainties of the chamber effects (temperature, radiation and wind conditions inside the chamber), but are frequently used due to low cost and ease of use. More studies have found good agreement between micrometeorological and chamber methods (Dugas et al. 1997; Angell and Svejcar 1999; Steduto et al. 2002). Despite the long time of carbon dioxide flux measurements and the great variability of techniques there is no standard chamber method.

The open system chamber method which used in this study was developed to reduce the chamber effects, but the disturbance of the soil respiration and the boundary layer caused by the continuous air flow over the surface – especially close to the fan - still pose problems.

The aim of this study was to compare the eddy fluxes with the open chamber. The paper describes the chamber flux measurements and its comparison with the eddy covariance measurements.

Materials and Methods

Study site

The study was conducted in Bugacpuszta (46°41'31"N, 19°36'06"E, 140 m asl.), Hungary, in the context of the European Greengrass project. The climate is temperate continental yearly precipitation is about 500 mm, the mean annual temperature is 10.3°C. The vegetation is semi-arid sandy grassland and represents one of the westernmost occurrences of the Eurasian steppe zone.

Eddy covariance (EC) method

NEE has been measured by a Gill Sonic R2 Anemometer/ Thermometer and a Li-Cor 7500 Open Path CO_2/H_2O IRGA (LI-COR, Inc., USA). Spike detection and removal was performed by calculating averages and standard deviations in moving windows using the method of Vickers and Marth (1997). The values considered as spikes were discarded from the time series. As the Li-Cor 7500 measures the molar density of CO_2 and H_2O and the fluctuation of these variables are affected by environmental conditions, so the Webb-Pearman-Leuning correction (Webb et al. 1980) was applied to the data.

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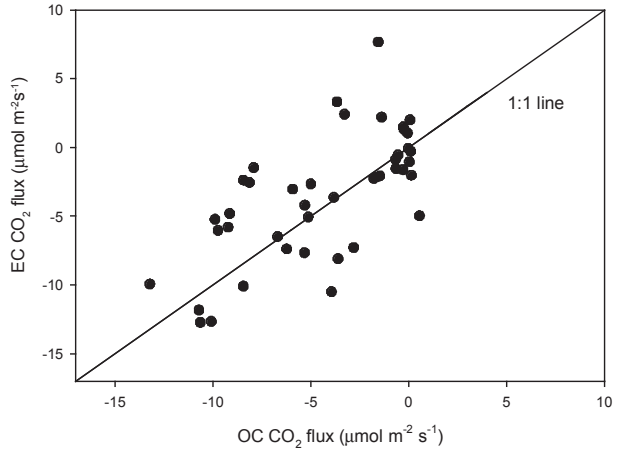

Figure 1. Half-hourly averages of CO_2 fluxes measured by the two different techniques. The 1:1 line is shown. Negative fluxes mean carbon uptake.

Open system chamber (OC) method

NEE of CO_2 was measured regularly (four times in 2003 and five times in 2004) by using a portable IRGA (CIRAS-2, PP Systems, Hitchin, UK). This instrument samples the air in an open-path round shape water-clean perspex-chamber (similar characteristics to other NEE measuring chambers, which are described by Czóbel 2002) with a hemispherical top and a diameter of 60 cm. The air was blown through the chamber by an outer fan using constant flow rate of 1.38 meters per second. No collar was used with this chamber.

Measurements using OC were made at the same location in the field during each visit in this study. The chamber was placed over the plot continuously during the measurements. The differential CO_2 concentration (*i.e.* the CO_2 concentration difference between the air samples taken from the chamber inlet and outlet), temperature, photosynthetically active radiation and relative humidity were recorded in every 10 seconds.

Results and Discussions

CO_2 fluxes obtained with OC compared well with the eddy fluxes under most conditions. The daily patterns of carbon dioxide flux rates were in the same range, but in some cases the chamber fluxes were higher (*i.e.* following thew conventional notation it means more negative) than the eddy ones. Comparing the half-hourly averages of EC and OC CO_2 fluxes, the OC fluxes had a bit higher values than the ones measured by the EC method (Fig. 1).

Figure 1 shows the relationship between the two different methods based on the half-hour averages of CO_2 fluxes. The scatter is large, but while the eddy technique got samples from larger grass patches from different directions, the open chamber was mesuring exactly the same plot throughout the study.

Literature data on technique comparisons for measuring CO_2 fluxes with open chambers are very scarce and in most of the studies closed systems were used. Angell et al. (2001) and Dugas et al. (1997) compared the Bowen ratio technique with closed chamber system, finding good agreement, but these chambers are not useable for continuous monitoring of the CO_2 gas exchange. The automatic closed chamber system made by Steduto et al. (2002) is a good tool for measuring CO_2 fluxes continuously, but the open chambers are simpler and the chamber effect is much smaller, than in the closed systems. The disadvantages of the open system are the problems caused by the continuous air stream (sharply differing from the natural conditions) and higher sensitivity to the CO_2 concentration fluctuations in the reference air. However, the latter is ususally caused by the person carrying out the mesurements and is therefore insignificant when making meaurements in unattended/automatic mode.

Although the results showed the open system chamber to be a useful device for gas exchange measurements, more tests over different grasslands and under various circumstances are needed for the exact characterisation of these measurements. Under the hot and dry conditions, which are frequent in summer in Hungary the open system will be the better choice for gas exchange measurements as opposed to the closed one. The main reason is that due to the slow rates under these conditions, the measurements may take several minutes, and during this period significant and artificial gradients of temperature and the concentrations of the measured gases will inevitably build up in the closed system.

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