INVESTIGATIONS OF THE LAND BIOTIC O_2:CO_2 EXCHANGE RATIOS IN PHOTOSYNTHESIS AND RESPIRATION

E. Kozlova, A.C. Manning, A. Jordan and W. Brand.

Max Planck Institute for Biogeochemistry, PO Box 10 01 64, 07745 Jena, Germany
ekozlova@bgc-jena.mpg.de

ABSTRACT
Accurate estimations of the land biotic O_2/CO_2 exchange ratios are required to allow quantification of the land/ocean carbon sink partitioning from atmospheric measurements of both O_2 and CO_2 concentrations.

This study shows atmospheric O_2 and CO_2 mixing ratios as well as their diurnal cycles over a three day period in May 2005 from flask samples collected at 3 different heights (1, 4 and 12m) in an undisturbed forest in central Germany. An average O_2/CO_2 ratio of 0.99 was estimated with very little variation between the three different heights. In addition, the "night time" average value of atmospheric O_2/CO_2 ratio did not show any significant difference from the average "daytime" value.

INTRODUCTION
Oxygen and carbon dioxide are inversely coupled in the processes of photosynthesis, respiration and fossil fuel combustion and therefore have quantifiable O_2:CO_2 molar exchange ratios. This fact, along with a general O_2:CO_2 decoupling in oceanic processes, allows quantification of the land/ocean carbon sink partitioning from atmospheric measurements of both O_2 and CO_2 concentrations [*Keeling and Shertz*, 1992] . However, this approach requires accurate estimations of the land biotic O_2:CO_2 exchange ratios. A global average value of -1.1±0.05 [*Severinghaus*, 1995] has been used in all recent global carbon sink calculations. However, this value and its uncertainty are not well constrained. A change of 0.1 in this ratio has the potential to change the land and ocean carbon sinks (in equal and opposite directions) by as much as 0.4 Pg C/y (this assumes a very large land sink of 4 Pg C/y, which nevertheless was observed for short periods in the 1990s). The uncertainty in land biotic sink estimates caused by a change in this ratio increases in direct proportion to the size of the sink itself and, therefore, is more relevant to analyses of regional carbon sinks as well as their interannual variability, rather than decadally averaged global carbon sinks [*Manning and Keeling*, 2005].

METHODOLOGY
Our sampling site is located within Hainich National Park (51º04'46" N, 10º27'08" E) in central Germany. The forest can be considered to be essentially undisturbed since it was taken out of management in the 1930s. The dominant species are beech, ash and maple, with small stands of spruce. One-litre glass flasks were filled with air samples collected from three different heights below the canopy (1, 4 and 12m) approximately every 3-4 hours for 3 days (from 14 through 16 May 2005). Samples were analysed in our laboratories for CO_2 concentrations, with a gas chromatograph equipped with a Flame Ionization Detector (Agilent Technologies, model 6890), and O_2 concentrations, with a mass spectrometer (Finigan Mat, model Delta Plus XL).

RESULTS AND CONCLUSIONS
Fig. 1 shows O_2 and CO_2 concentrations, illustrating clear diurnal cycles in both species. Here we show only the second one and half days of data due to heavy rainfall in the first period which resulted in difficulty to collect the samples at the desired frequency, and less clear diurnal cycles. Maximum CO_2 concentrations (400 to 423 ppm, including data not shown in the Fig.) were observed during night time and, especially just before sunrise (4:30 am). The lowest CO_2 levels (376 to 390 ppm) were observed between midday and just before sunset (8:00 pm). O_2 concentrations were very well anti-correlated with CO_2, with maximum values (-370 to -380 per meg) in the afternoon due to net photosynthetic activity of the forest and minimum values in the night and early mornings (-500 to -560 per meg).

The O_2/CO_2 ratios were calculated for each sampling height (1, 4 and 12 m) and are shown in Fig. 2. The values were very homogeneous (0.97 to 0.99 moles of O_2 consumed per mole of CO_2 produced) with very good r^2 correlation values (0.95 to 0.98). To separate the influence of photosynthesis and respiration on the atmospheric O_2/CO_2 ratios, the "night time" and "daytime" values were also estimated (the data were separated based on sunrise and sunset). The "night time" average value of atmospheric O_2/CO_2 ratio (0.98) did not show any significant

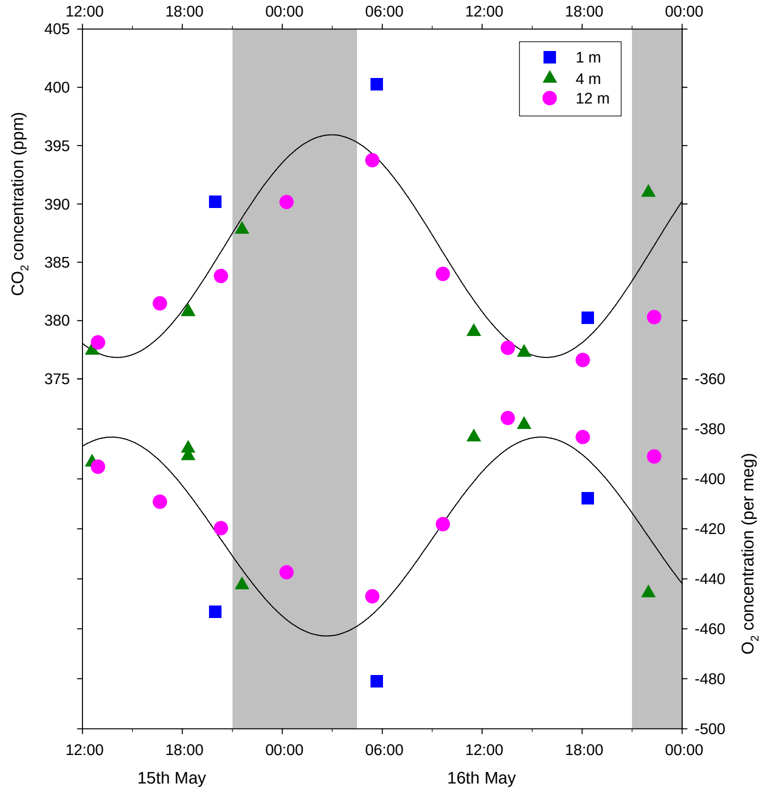

Fig. 1 (above) CO_2 (ppm) and O_2 (per meg) concentrations over a 1.5 day period (May 15 through 16) in Hainich Forest. A simple sinusoidal curve was used to fit all data. The squares (blue) correspond to samples collected from 1m, triangles (green) from 4m, and circles (pink) from 12m height. The shaded areas represent the time period between sunset and sunrise.

Fig. 2 (below) The average atmospheric O_2/CO_2 exchange ratios from 1, 4 and 12m over the whole period of sampling (3 days). The same symbols as used in Fig. 1 show the samples from the three different heights.

difference from the "daytime" average value (0.99). The "night time" data showed slightly better correlation (r^2 = 0.98) than the daytime (r^2 = 0.95). This could possibly be explained because daytime data are influenced by a mix of photosynthesis and respiration processes, whereas night time data are influenced only by respiration.

All estimated O_2/CO_2 ecosystem exchange ratios were much lower than the global average value of 1.10 typically used in land/ocean sink partitioning calculations. However, further investigations of O_2/CO_2 exhange ratios are required before making a conclusion about over- or under-estimation of this global average value.

REFERENCES

Keeling, R.F., and S.R. Shertz, Seasonal and Interannual Variations in Atmospheric Oxygen and Implications for the Global Carbon-Cycle, *Nature*, *358* (6389), 723-727, 1992.

Manning, A.C., and R.F. Keeling, Global oceanic and land biotic carbon sinks from the Scripps atmospheric oxygen flask sampling network, *in press*, *Tellus*, 2005.

Severinghaus, J.P., Studies of the terrestrial O_2 and carbon cycles in sand dune gases and in Biosphere 2, Ph.D. thesis, Columbia University, New York, U.S.A., 1995.