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Co2 fluxes and concentration patterns over Eurosiberia: A study using terrestrial biosphere models and the regional atmosphere model REMO

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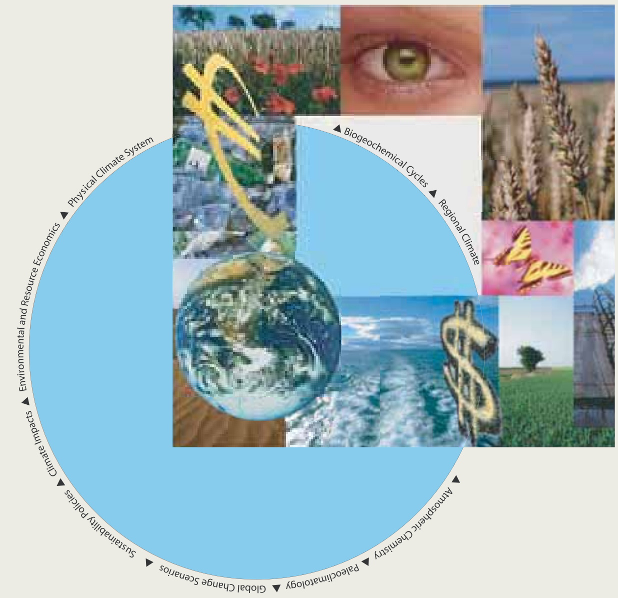

ABSTRACT

Regional scale studies on the carbon cycle have gained growing importance and play a crucial role in the understanding of biosphere-atmosphere interactions. Terrestrial biosphere modelling is an essential tool in the application of regional carbon budget estimates. However, the reliability of the estimates from the models is always questionable due to the uncertainties and limitations associated with the choice of the model, the input data, as well as the representation of the ecosystem processes. The current study investigated the contribution of the terrestrial biosphere to the intra-annual variability of atmospheric CO_2 concentrations over Eurosiberia. Because of the strong seasonal signal from the biosphere and the related seasonal variation of atmospheric CO_2 content, this study focuses on an annual time scale rather than synoptic variations. Two terrestrial biosphere models, BETHY and BIOME-BGC, were used in a number of experiments with various meteorology inputs to simulate the biosphere fluxes at single stands, and have been tested for their sensitivity to varying input parameters. Fluxes from the light-use efficiency model TURC, derived from a previous study, were included for comparison. The simulations were then extended to regional scale by applying the models to Eurosiberia. The uncertainties in the terrestrial biosphere fluxes were assessed by using an "ensemble" of the two models and different input vegetation maps that largely control the ecosystem processes included in the models. The range of flux estimates provides an indication of the uncertainties related to flux simulations. The regional fluxes were subsequently used as input to the atmospheric transport model REMO to simulate the atmospheric concentrations. The propagation of the biosphere fluxes in the concentrations was investigated via the CO_2 concentration variations at different levels in the atmosphere.

The performance of BETHY and BIOME-BGC was tested against eddy covariance measurements at selected FLUXNET sites across Eurosiberia. The models adequately represented the seasonal cycles of the fluxes despite the limitations in the input data and the use of different input datasets. A sensitivity analysis of the models showed that model parameterisations and assumptions, the surface inputs and the different ways that the models handle these inputs play an important role in the estimation of the fluxes. While the use of modelled meteorology (instead of observations) leads to acceptable results, a proper representation of the site characteristics is equally important, and particularly parameters that relate to the availability of water (rooting depth and precipitation) sometimes leads to a breakdown in the simulated fluxes.

When extending local scale CO_2 flux exchange to regional scale, uncertainties are incorporated with the choice of the models and the input data provided to the models. Significant differences were seen in the simulated fluxes between BETHY and BIOME-BGC in the different experiments. As it is a basic assumption in the models that on an annual basis the net ecosystem fluxes balance out, it is not clear whether the biosphere in Eurosiberia act as a source or a sink on an annual scale. However, in winter both models, as well as TURC suggested that the biosphere behaves as a source. The net carbon release ranged from ~500 TgC in TURC to over 1000 TgC in BETHY and BIOME-BGC. In summer the models agree that the biosphere acts as a sink but with a wide range in the amounts of carbon uptake, the values ranging from ~800 TgC from BIOME-BGC, to almost 2500 TgC from BETHY. The large differences in the simulated fluxes may at least partly be attributed to the vegetation map used in the models that is very important in determining the regional patterns and the seasonality of the simulated biosphere fluxes. The variability in the fluxes is in turn propagated in the atmospheric CO_2 when transported over the region using the transport model REMO.

The simulated CO_2 concentrations in the lowest atmosphere level, that is at ground level up to approximately 34m, showed a relatively high variability mainly due to the contribution of the biosphere. The variability was also visible at the planetary boundary layer height (~300m above ground) although the amplitude of the fluctuations was less than at the ground level. Above the planetary boundary layer, at approximately 3000m, as the air gets mixed the concentration variability decreases reflecting the reduced signal of the local terrestrial fluxes in atmospheric CO_2 concentrations. However, depending on the strength of the flux contributions the influence of the biosphere can still be seen in the planetary boundary layer. This was especially the case for the concentrations derived from BETHY-simulated fluxes. The concentrations derived from TURC and BIOME-BGC fluxes showed similar patterns but with lower values.

The present study demonstrates the influence of fluxes from the terrestrial biosphere on the seasonal variation in the CO_2 concentrations in the lower atmosphere over Eurosiberia. Above the planetary boundary layer, however, the signal of the biospheric fluxes virtually disappears. Higher in the atmosphere also the differences between the model experiments became less prominent. Future studies of regional CO_2 fluxes and concentrations should take other sources of uncertainties, apart from the input vegetation maps, into account in a similar manner as was done here, in other words by adopting a larger ensemble of model experiments. For long-term studies of regional carbon budgets multi year runs should be performed.