The European Carbon Balance
Research Highlights 2006

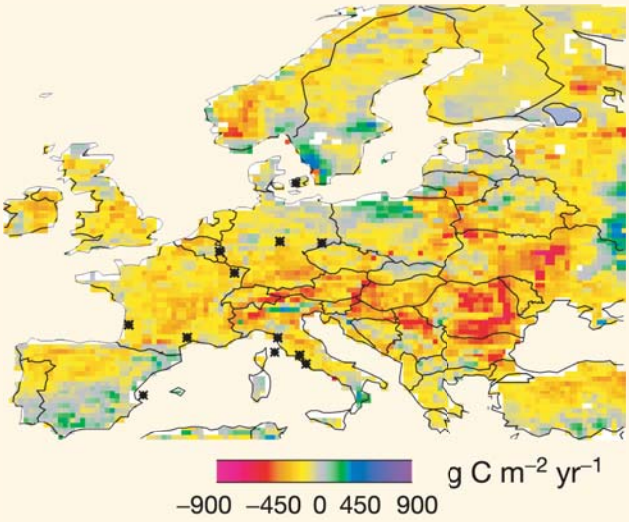
Significant carbon losses from the European biosphere during the heat and drought wave 2003

(Ciais et al., Nature 2005)

CarboEurope researchers detected a 30 per cent reduction in photosynthesis in the dry and hot year 2003, which resulted in a strong anomalous net source of carbon dioxide (0.5 Pg carbon per year) to the atmosphere and reversed the effect of four years of carbon uptake in European ecosystems. Such a reduction in Europe's primary productivity is unprecedented during the last century. That leads to the assumption that an increase in future drought events could turn temperate ecosystems into carbon sources. This would add to the positive carbon-climate feedbacks already anticipated in the tropics and at high latitudes.

Regarding the impending changes in the global climate leading to climate warming in the European continent, it is of great importance to clarify how the biosphere will adapt to altered climatic conditions. Generally, future climate warming is expected to enhance plant growth in temperate ecosystems. Thus, carbon sequestration in these regions might increase as well, enlarging the biospheric sink for CO_2. The particularly dry and hot year 2003 serves as an ideal test case for this hypothesis - July temperature in this year was 6°C above the long-term average; in contrast, rainfall was 50% less than average.

Researchers of CarboEurope-IP examined the exchange of carbon dioxide between plants and the atmosphere at 15 locations with different plant cover from crops to forests all over Europe for 2003 in comparison with the preceding five years. In contrast to the assumption, nearly all 15 analysed sites experienced a significant reduction in photosynthetic activity in 2003, especially the northern Mediterranean forests. Some of the productive temperate beech forests like the Hainich in Thuringia, Germany, showed a delayed response to the hot and dry climate – their annual net carbon gain remained high in 2003, but decreased significantly during the following growing season.



European-wide anomaly of NPP during 2003 (Ciais et al., 2005). Black dots indicate measurement sites.

In 2005, a similar but less pronounced reduction in carbon uptake was observed. The spatial pattern was different from 2003 with highest losses in carbon uptake in Eastern Europe and the Iberian peninsula, both regions with relatively few observation points.

Moreover, ecosystem respiration rates also declined at most sites although higher temperatures are generally thought to increase plant and microbial respiration. Despite the decrease in respiration rates, especially on several Mediterranean sites, ecosystems still

acted as net carbon sources because the decline in carbon uptake by reduced photosynthesis was stronger than the decline in carbon losses due to lower respiration rates.

CarboEurope-IP tried to identify the ecophysiological reasons for the reduced ecosystem productivity. Modelling results showed two main contributing factors:

- a pronounced rainfall deficit in Central and Eastern Europe
- extreme summer heat in Western Europe

Largest declines in ecosystem productivity and thus high carbon sources occurred in the Ukraine and Romania (-20%), France (-17%) and Italy (-12%). Regarding the whole of Europe, rainfall changes had a greater influence than summer air temperature change, indicating the dominant role of water limitations.
The drop in ecosystem respiration rates can be explained by two reasons:

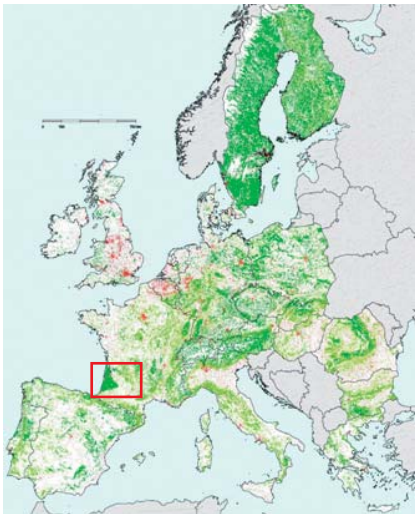
- Since plant productivity was reduced, less substrate was availability for plant respiration, thus decreasing the respiration rates.
- The pronounced soil water deficits were off-setting any potential increases in microbial respiration caused by warmer soils

Can the regional carbon balance be closed? The CarboEurope-IP Regional Experiment Strategy (CERES)

Dolman et al. (2006)

In May and June 2005, CarboEurope Scientists performed a six weeks intensive regional measurement campaign in the Les Landes Area in South-Western France in order to estimate the carbon balance of that region. The CarboEurope-IP Regional Experiment Strategy (CERES) has shown that it is feasible to obtain a consistent data set of surface and air borne observation of the fluxes and concentrations of CO_2. It has provided a wealth of data useful on its own, but particularly as comprehensive dataset to narrow down the uncertainties in regional carbon balance estimation.

The quantification of the geographical distribution of sources and sinks for carbon has considerable implications for both our understanding of the global climate and possible opportunities to mitigate climate change. Researchers work on several scales to examine the patterns of CO_2 emissions and uptake: From atmospheric CO_2 concentrations, the carbon exchange between the land and the atmosphere can be back-calculated using top-down global inversion. The results obtained by these models are robust at the (sub)continental scale but not applicable at regional or local scale



Location of the Les Landes experimental area.

On the other hand, carbon flux measurements by

eddy covariance allow determining carbon fluxes at local scale, which can then be up-scaled to larger areas via bottom-up modelling. Global and local scale meet at the regional level. However, the precise way they interact is not known yet. It remains a significant challenge to quantify the carbon balance at this “missing scale”.

The aim of the intensive measurement campaign was to test sampling strategies and to provide a wealth of carbon related data for the improvement of models and data acquisition schemes. The gathered data are used to combine the up-scaling of local measurements with the down-scaling of atmospheric CO_2 concentrations and inverse modelling at high spatial resolution in order to estimate the carbon balance of a specific region at a typical model grid resolution of 2 km every day during a full year. Such a multiple constraint approach has not been tried before at the regional level.

Adequate quantification of the carbon balance of a specific region requires the understanding how regional meteorology and land management practices influence the fluxes from land to atmosphere. Thus, in the CarboEurope IP Regional Experiment, measurements of atmospheric boundary conditions as well as carbon concentrations and fluxes within and above the vegetation are combined with data assimilation methods and various modelling techniques.

The 2005 intensive campaign laid the foundation for implementing an optimised observation network across Europe in the future, allowing for the integration of observations of different nature such as eddy covariance fluxes, plot and regional scale carbon inventories or remote sensing of atmospheric CO_2 concentrations.

The gathered data included:

- Biomass and soil sampling,
- CO_2 concentration measurements at two towers within the experimentation area,
- 10 flux stations delivering eddy covariance data from nine different types of landcover,
- trace gas determination near Biscarosse,
- 46 transects flux flights over forest and agricultural land (eddy flux data),
- 88 flights yielding profiles of the planetary boundary layer
- more than 300 flasks collected during 120 flight hours for CO_2 and trace gas concentration measurements as well as isotope analysis,
- high resolution NDVI images measured with a multi spectral scanner during 26 remote sensing flights,
- additional information concerning wind fields, height and temperature profile of the boundary layer, atmosphere temperature and dew point.
- Fourier Transform Infrared (FTIR) spectrometer measurements for retrieval of CO_2, CO, and CH_4 data at one location

The results of the CERES intensive campaign represent a significant progress towards obtaining a reasonable estimate of the carbon balance of a specific region with a multiple constraint approach combining the up-scaling of local flux and concentration measurements with the down-scaling of atmospheric data. A closer look at the gathered data underlined the importance of considering both atmospheric concentration and local flux measurements for their correct interpretation. Moreover, the experiment yielded a multitude of data which on its own represent a great achievement and help to foster model development.

The Eco Dimona airplane, performing concentration measurements and flask sampling

CarboEurope-IP in brief

CarboEurope-Integrated Project **(IP) is a European research project within the 6th Framework Programme of the EU. Over a period of five years (2004-2008), CarboEurope-IP engages 67 partner institutes in 17 countries plus about 30 associated partners, thus involving around 150 scientists and their PhD-students. The project with a budget of more than 30 million Euros, 16 million Euros of which are support from the European Commission, is coordinated by the Max-Planck-Institute for Biogeochemistry in Jena.**

Main objectives of CarboEurope-IP

The overarching aim of CarboEurope-IP is to understand and quantify the present terrestrial carbon balance of Europe and the associated uncertainty at local, regional and continental scale.

- How much CO_2 is emitted and absorbed by the European biosphere?
- What mechanisms control the CO_2 exchange in the biosphere, and how are they affected by changes in land use, climate and management?
- Are the European efforts to reduce CO_2 emissions detectable in the atmosphere?

Project Features

Integrated observations via a harmonized multi-platform atmospheric observation system and 100 ecosystem research sites are used to understand ecosystem responses to climate, land use and management. Together with advanced modelling of fossil fuel emissions and biosphere carbon exchange using a multiple constraint approach, CarboEurope-IP produces policy-relevant products like regional spatial and temporal patterns of the European carbon balance and provides scientific instruments to monitor and verify the national reports under the UN climate change convention and to control the performance of mitigation

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Literature:
Ciais P et al. (2005) Europe-wide reduction in primary productivity caused by the heat and drought in 2003. Nature 437: 529-533
Dolman, H et al. (2006) CERES, the Carboeurope Regional Experiment Strategy in les Landes, South West France, May-June 2005. submitted to the Bulletin of the American Meteorological Society

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