Simulations of contemporary European carbon balance: competing roles of rising CO_2 and climate change

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Introduction

The aim of the Continental Integration component of CarboEurope is to quantify and understand the regional scale carbon balance of the European continent, and its contribution to the global carbon cycle. One aspect of this is through bottom-up modelling with process based models such as the Joint UK Land Environment Simulator (JULES).

JULES is the land surface component of the Hadley Centre Global Climate Model (GCM). Climate change simulations with the GCM (Cox et al., 2000) have shown a significant sensitivity of the global carbon cycle to changes in climate, resulting in reduced terrestrial carbon storage and accelerated climate change. Here, we use the same land surface and carbon cycle models driven by observed climate to simulate the carbon balance of the European domain and examine its causes.

Both rising CO_2 levels and changing climate might be expected to affect the terrestrial carbon cycle. Here, we investigate the separate impact of these factors on the net. carbon balance of the European land surface. We find increased productivity and carbon storage due to elevated CO_2 generally exceeds any reduction in carbon storage due to climate change. The impact of rising CO_2 is greatest in the south of the continent where water limited ecosystems benefit most from increased water use efficiency.

1. Simulating the contemporary European carbon balance

a. JULES
JULES is a UK community land surface and dynamic vegetation model. See **www.jchmr.org/jules**

b. Results
We follow the CarboEurope bottom-up modelling protocol (see Mona Vetter et al., inter-comparison) to simulate the carbon balance of Europe over the 20th century.

Figure 1 shows the mean carbon balance (NEP) of the region over the years 1998-2002.

Future work in CarboEurope will investigate the impact of anomalous climate years such as 2003 and 2005, but here we focus on the mean response.

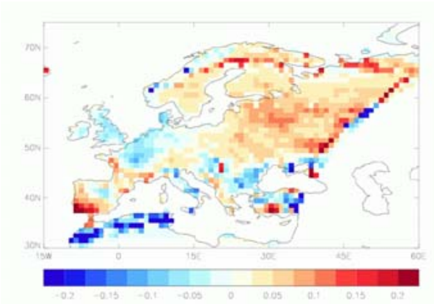

***Figure 1**. Contemporary European carbon balance. 1998 – 2002 mean NEP (gC/m2/day).*

For different sub-regions within Europe we can quantify the recent carbon balance:

Northern Europe	Western Europe	Central Europe	Eastern Europe
12	15	31	52

***Table 1**. Contemporary European carbon uptake by region. 1980 – 2005 mean NEP (TgC/yr).*

Global terrestrial carbon uptake is around 2Gt/yr. Here, we calculate a European average uptake of 0.11Gt/yr.

For this first set of simulations we neglect any impact of land management, land use change or dynamic vegetation. Clearly across Europe, land management has a significant impact on carbon stores. It has been estimated that European forests have doubled in size since 1950, so our estimate is likely to be too low.

2. Impact of CO_2 fertilisation

- We repeated the simulation but kept atmospheric CO_2 at a constant (pre-industrial) level (no CO_2 run).
- The results of this experiment show the impact of climate change alone on European carbon balance.
- The difference between the simulations shows the impact of CO_2 fertilisation on European carbon balance.
- Results show increased NEP: increasing CO_2 results in additional uptake and storage by the land.
- This increase is greater in the south – there is a clear latitudinal gradient of increased uptake.
- The increase is consistent across all sub-regions.
- The increase does not affect inter-annual variability or sensitivity to climate variations.

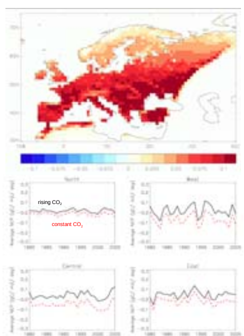

***Figure 2**. Top - Mean NEP difference standard & no CO_2 run (gC/m2/day). Bottom – European NEP (gC/m2/day) by region*

3. Productivity and storage changes

- To investigate what causes the changes in uptake we look at vegetation productivity (NPP) – figure 3a.
- We see that it exhibits the same north-south gradient as in NEP.
- We attribute this to increased water use efficiency in water limited ecosystems.
- Under higher CO_2 levels, plants close stomata and transpire less water, increasing resistance to drought.

- This is reflected in soil moisture stores.
- The impact of increasing CO_2 is to reduce evapotranspiration and leave more moisture in the soil (figure 3b).

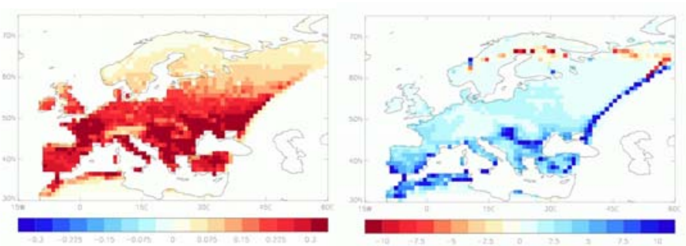

***Figure 3**. a) NPP difference (gC/m2/day) standard and no CO_2 run. b) soil moisture difference (mm) standard and no CO_2 run.*

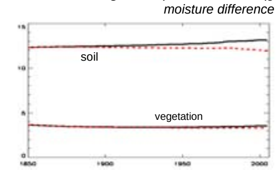

***Figure 4**. European carbon storage (Gt) for the standard run (full line) and no CO_2 simulation (dashed line).*

- However, the increased productivity does not result in increased carbon storage in biomass.
- Instead, it is stored in the soil (figure 4).
- Approximately 1.2Gt more carbon accumulated in the soil in the standard simulation compared to the no CO_2 run, with only a small increase in the amount accumulating in the vegetation (0.2Gt).

Conclusions and future work

- We have simulated the contemporary carbon balance of the European continent:
  - Part of the CarboEurope bottom-up modelling inter-comparison
- We have separated the impact of climate change and rising CO_2
  - Increasing CO_2 levels have led to:
    - Increased carbon uptake by European vegetation.
    - Especially in water limited ecosystems.
    - Increased soil organic carbon storage rather than additional biomass.

- Future work will need to:
  - Include land management processes.
  - Identify and quantify other important mechanisms:
    - Nutrient limitation.
    - Fire.

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