Component fluxes of the carbon balance of Europe and their uncertainty

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Abstract

Quantifying the carbon budget of a continent is a formidable task, which can only be tackled by taking a suite of complementary measurements going from the scale of ecosystems up to the overlying atmosphere, and by using a hierarchy of models to integrate between these scales. An integrated observation strategy is based on a combination of 1) knowledge of ecosystem processes derived from eddy flux towers and ecological studies, 2) spatially extensive and repetitive remote sensing retrievals of biophysical vegetation parameters, 3) ecosystem models driven by variable climate, soil properties, and land cover and 4) atmospheric CO2 and tracers concentration measurements assimilated into transport models.

The CARBOEUROPE and the North American Carbon Plan NACP are maybe the two largest research experiments which have undertaken the deployment of an integrated carbon observation strategy over large land masses with diverse ecosystems, contrasted climate regimes, and nearly ubiquitous fossil fuel emissions. Both experiments rely on dense measurements, and on a combination of top-down and bottom-up measurements, but their sampling strategy is quite different. The atmospheric sampling, especially in the vertical, is much more intensive over North America than over Europe. Yet, the geographic distribution of the C fluxes over the European continent is more complex than over North America, which would deserve a denser atmospheric network. Over Europe, fossil and biospheric fluxes are mixed everywhere, with many small 'hot-spot' areas where high fossil emissions are dispersed over complex terrain, such as for instance the Mediterranean coastal cities, making the detection of atmospheric signals more difficult. Also, the European continent has only one ocean boundary instead of two for North America, which makes the closure of the atmospheric top-down mass balance (REF) more difficult. The density of ecosystem flux towers is on the other hand larger over Europe. Now, the two experiments are running through their mid-term. It is necessary for CARBOEUROPE which involves 400 scientists in very diverse fields, to make a synthesis of the knowledge gained on the European carbon balance. Results from a new assessment of the European carbon balance and component fluxes, and of its driving forces will be presented. It has been initiated as a cooperative work crosscutting among the different tasks and sub-projects of the CARBOEUROPE project.

A quantitative breakdown of the European carbon balance into its component fluxes is provided, including, of course, fossil fuel emissions, but also net primary productivity and

decomposition release of CO_2, and the other fluxes resulting from harvest, fire disturbances and export to rivers. A detailed regional estimation of these fluxes was not attempted. Also, there are inevitable inconsistencies in the various input dataset and methodologies, which have only be partially harmonized by adjusting the flux estimates to the same domain: the EU area (4.3 10^6 km^2). First, the fossil fuel emissions are discussed, and their regional trends and errors. Next, we provide 'best estimates' of the component carbon fluxes for forests, for croplands and for managed grasslands. We focused on estimating the Net Primary Productivity (NPP) and heterotrophic respiration (HR) component fluxes, and the carbon sequestration efficiency defined as the ratio of NBP to NPP.

Grassland soils were found to be by far the largest C sink per unit area (234 gC m-2 y-1) and show an average uptake rate much larger than the one of forests (50 gC m-2 y-1), despite intensive forest management and C saving sylvicultural practices in western Europe. In contrast, cropland soils are almost C neutral, or a small sink, which implies a downward revision of former estimates of a large source. We also estimated NPP at the continental level using various methods. The most productive ecosystems were found to be the grasslands, followed by croplands and forests. Grasslands also have the largest C sequestration efficiency (= 32%), defined as the ratio of NBP to NPP. This is about twice the value of forests. Overall, we obtain a European NBP of 181 TgC y-1 over the EU area, distributed into 110 TgC y-1 for grasslands, 11 TgC y-1 for croplands and 60 TgC y-1 for forests, three biomes which altogether cover 76% of the total EU area. The total NBP uncertainty, estimated from the range of estimates from different methods, is 129 TgC y-1, decomposed into 77 TgC y-1 for grasslands, 24 TgC y-1 for cropland and 28 TgC y-1 for forests. Other EU vegetated area: shrubland vegetation in Mediterranean areas, wetlands, and urban ecosystems, is not covered by sufficient data for NBP to be safely estimated at the continental level, and deserves further studies.