Spatial and temporal dynamics of the terrestrial carbon cycle

Assimilation of two decades of optical satellite data into a process-based global vegetation model

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Abstract

Current understanding of the factors that determine the magnitude and temporal variations of global terrestrial uptake and release and which regions contribute most to these patterns is still incomplete. Several modelling approaches have provided estimations of the spatio-temporal patterns of net ecosystem production, but there is still a need for an improved and more realistic global carbon cycle model with good resolution that does not only simulate potential vegetation but also allows quantification of regional carbon storage and fluxes.

This PhD thesis presents the spatio-temporal distribution of terrestrial carbon fluxes for the time period of 1982 to 2002 simulated by a combination of the process-based dynamic global vegetation model LPJ (Sitch et al. 2003) and a 21-year time series of global AVHRR-fPAR data (fPAR – fraction of photosynthetically active radiation), provided by Ranga Myneni of Boston University at 0.5° resolution. Assimilation of the satellite data into the model allows improved simulations of carbon fluxes on global as well as on regional scales.

Assimilation of the fPAR data was implemented as a two-step process: after a spin-up of the potential vegetation to determine a base-line vegetation composition satellite-observed fPAR values were ingested. The fPAR value of each grid-cell was decomposed into fractions corresponding to the vegetation present at each location, where winter values were used to determine the evergreen versus deciduous fractions. In agricultural areas the model-predicted vegetation was replaced by grass; the satellite-observed fPAR provided the seasonality of planting and harvesting as well as the temporal trajectory of agricultural vegetation growth.

As it is based on observed data and includes agricultural regions, the model combined with satellite data produces more realistic carbon fluxes of net primary production (NPP), soil respiration (Rh), carbon released by fire and the net land-atmosphere flux than the potential vegetation model. It also produces a good fit to the interannual variability of the CO_2 growth rate. The current study adds to results obtained by other approaches, even though the results are not always consistently and should be seen as supporting a better understanding of the different processes contributing to the terrestrial carbon budget.

On a global scale, NPP is the main contributor to the interannual variability of net ecosystem production (NEP), whereas its magnitude and timings are mainly determined by heterotrophic respiration. The interannual variability of global NPP is dominated by tropical regions where it is mainly a function of variations in precipitation. The temperate and boreal zone NEP variations are also controlled by changes in NPP, but these are determined by changes in temperature. Net fluxes are highly correlated to El Niño-Southern Oscillation (ENSO) events in the tropics and southern mid latitudes, whereas no tele-connection to the northern hemisphere can be found. An influence of the North Atlantic Oscillation (NAO) on carbon fluxes on a latitudinal scale could not be detected. During the post-Pinatubo period

boreal NEP declined, whereas the northern temperate regions show an enhanced uptake due to increased NPP and decreased Rh. Although temperature rise was strongest in the northern latitudes during 2000 to 2002, this was not reflected in an enhanced net terrestrial uptake.

This study presents a way to assess terrestrial carbon fluxes and elucidates the processes contributing to interannual variability of the terrestrial carbon exchange. Process-based terrestrial modelling and satellite-observed vegetation data are successfully combined to improve estimates of vegetation carbon fluxes and stocks. As net ecosystem exchange is the most interesting and most sensitive factor in carbon cycle modelling and highly uncertain, the presented results complementary contribute to the current knowledge, supporting the understanding of the terrestrial carbon budget.