International Max Planck Research School on

EARTH SYSTEM MODELLING

Uncertainties of terrestrial carbon cycle modelling: Studies on gross carbon uptake of Europe

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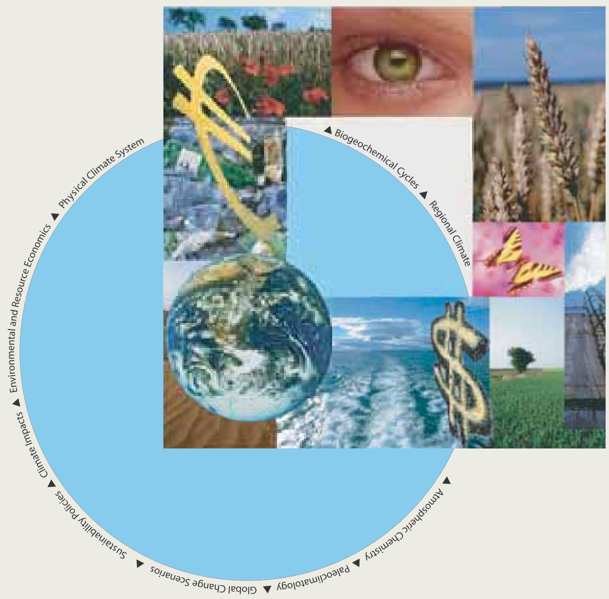
PhD Thesis prepared within the
International Max Planck Research School on
Earth System Modelling



Abstract

Gross primary production (GPP) is the flux of carbon into ecosystems via photosynthesis. GPP constitutes the single largest flux of the carbon cycle and is an important determinant of the net carbon balance. This thesis investigates uncertainties of modelling GPP for Europe. The objectives of the four major chapters are: (1) to construct a global 1km land cover map with improved characteristics for carbon cycle modelling to reduce land cover uncertainties, (2) to identify the relative importance of input data and model structure uncertainties regarding the magnitude, spatial pattern, and interannual variability of simulated GPP, (3) to assess the performance of GPP simulations for forest ecosystems across Europe using eddy covariance based GPP data, and (4) to construct a GPP model by linking remotely sensed vegetation properties with eddy covariance based GPP data and to provide a realistic bound of European GPP by comparison with other data-driven models.

On the continental scale, land cover uncertainties are found to be negligible in comparison to meteorological input data and in particular different model structures (LPJ, Orchidee, Biome-BGC). Three main factors seem to drive discrepant GPP simulations: (1) the representation of crops, (2) the representation of nitrogen dynamics, and (3) the coupling of photosynthesis and canopy conductance and the associated feedback through soil hydrology. Very little agreement of simulated interannual variability among models is highlighted. Interactions of biogeochemical cycles (water-carbon-nitrogen) play possibly a more important role than anticipated but are yet poorly understood.

Three process-oriented models LPJ, Orchidee, and Biome-BGC reproduce qualitatively observed changes of forest GPP along the gradient of mean annual temperature from boreal to Mediterranean climate. The relative root mean square error of prediction is for all three models in the order of 30% but systematic biases of all three models are observed along the climatic gradient. The models underestimate the increase of GPP from boreal to temperate climate, primarily because changes of light absorption (leaf area index) are not adequately modelled, which is likely a consequence of missing nitrogen limitation in LPJ and Orchidee.

The construction of an accurate empirical GPP model is facilitated by regressing the accumulated remotely sensed FAPAR of the growing season period with annual sums of GPP from eddy covariance flux measurements. The new GPP estimate has the advantage of being independent from uncertainties related to meteorological input data, and is compared with a neural network upscaling method (ANN), a radiation use efficiency model (MOD17+), and LPJ. Consensus regarding the mean annual spatial GPP pattern emerges between the FAPAR based GPP model and ANN (R^2=0.74). Limited agreement exists for the spatial 2003 GPP anomaly pattern also among the three diagnostic models. Mean annual GPP of Europe compares within 5% difference among the three diagnostic models and LPJ if it is accounted for bias from meteorological forcing. Conclusions are drawn regarding the use of data driven models to evaluate process-oriented models.