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Reduced uncertainty of regional scale CLM predictions of net carbon fluxes and leaf area indices with estimated plant-specific parameters

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Reliable estimates of carbon fluxes and states at regional scales are required to reduce uncertainties in regional carbon balance estimates and to support decision making in environmental politics. In this work the Community Land Model version 4.5 (CLM4.5-BGC) was applied at a high spatial resolution (1 km^2) for the Rur catchment in western Germany. In order to improve the model-data consistency of net ecosystem exchange (NEE) and leaf area index (LAI) for this study area, five plant functional type (PFT)-specific CLM4.5-BGC parameters were estimated with time series of half-hourly NEE data for one year in 2011/2012, using the DiffeRential Evolution Adaptive Metropolis (DREAM) algorithm, a Markov Chain Monte Carlo (MCMC) approach. The parameters were estimated separately for four different plant functional types (needleleaf evergreen temperate tree, broadleaf deciduous temperate tree, C3-grass and C3-crop) at four different sites. The four sites are located inside or close to the Rur catchment. We evaluated modeled NEE for one year in 2012/2013 with NEE measured at seven eddy covariance sites in the catchment, including the four parameter estimation sites. Modeled LAI was evaluated by means of LAI derived from remotely sensed RapidEye images of about 18 days in 2011/2012. Performance indices were based on a comparison between measurements and (i) a reference run with CLM default parameters, and (ii) a 60 instance CLM ensemble with parameters sampled from the DREAM posterior probability density functions (pdfs). The difference between the observed and simulated NEE sum reduced 23% if estimated parameters instead of default parameters were used as input. The mean absolute difference between modeled and measured LAI was reduced by 59% on average. Simulated LAI was not only improved in terms of the absolute value but in some cases also in terms of the timing (beginning of vegetation onset), which was directly related to a substantial improvement of the NEE estimates in spring. In order to obtain a more comprehensive estimate of the model uncertainty, a second CLM ensemble was set up, where initial conditions and atmospheric forcings were perturbed in addition to the parameter estimates. This resulted in very high standard deviations (STD) of the modeled annual NEE sums for C3-grass and C3-crop PFTs, ranging between 24.1 and 225.9 gC m^{-2} y^{-1}, compared to STD = 0.1 – 3.4 gC m^{-2} y^{-1} (effect of parameter uncertainty only, without additional perturbation of initial states and atmospheric forcings). The higher spread of modeled NEE for the C3-crop and C3-grass indicated that the model uncertainty was notably higher for those PFTs compared to the forest-PFTs. Our findings highlight the potential of parameter and uncertainty estimation to support the understanding and further development of land surface models such as CLM.