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Combining SMOS soil moisture and JRC-TIP FAPAR for better constraining global carbon fluxes during 2010-2015 within CCDAS

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The terrestrial carbon cycle constitutes a key component of the global carbon budget due to its large sink and sensitivity to climate change. Terrestrial biosphere models exhibit large uncertainties in simulated carbon fluxes, which impact global carbon budget assessments. The land surface carbon cycle is tightly controlled by both soil hydrology and plant phenology, both of these are susceptible to climate change. In this context, accurate soil moisture as well as phenology observations can help to improve modelling of carbon fluxes in a model-data fusion framework. In the present study, we employ the Carbon Cycle Data Assimilation System (CCDAS) to simultaneously assimilate SMOS L3 surface soil moisture, JRC-TIP FAPAR (Fraction of Absorbed Photosynthetically Active Radiation) and CO_2 concentrations from flask measurements over the period from 2010-2015 at global scale. We find that simultaneous assimilation of SMOS soil moisture and JRC-TIP FAPAR observations considerably improves simulated soil moisture in regions where the prior model simulation shows poor correlations with the SMOS data. Also at global scale the model performance improves as demonstrated by the fit of simulated CO_2 concentrations against measurements at flask sites from the GlobalViewplus dataset, including data from sites withheld from assimilation for validation purposes. The model shows good agreement of inter-annual variability in simulating NEP and GPP with independent datasets from atmospheric inversion and eddy covariance observations. In general, CCDAS obtains smaller annual mean NEP values (1.73 PgC/yr) compared to atmospheric inversions (2.16 PgC/yr) and an (unconstrained) ensemble of Dynamic Global Vegetation Models (DGVMs) (2.91 PgC/yr). This study demonstrates the high potential of combining soil moisture and FAPAR in constraining the terrestrial biosphere carbon cycle, which results in more reliable simulations of inter-annual variability. Further development in model structure and utilization of more datasets in the assimilation will be highly beneficial for deriving an improved global carbon flux product.