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Assessing environmental drivers of vegetation greenness by integrating multiple earth observation data in the LPJmL dynamic global vegetation model

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Recently produced satellite datasets of vegetation greenness demonstrate a widespread greening of the earth in the last three decades. These positive trends in vegetation greenness are related to changes in leaf area, vegetation cover and photosynthetic activity. Climatic changes, CO_2 fertilization, disturbances and other land cover changes are potential drivers of these greening trends. Nevertheless, different satellite datasets show different magnitudes and trends in vegetation greenness. This fact raises the question about the reliability of these datasets. On the other hand, global vegetation models can be potentially used to assess the effects of environmental drivers on vegetation greenness and thus to explore the environmental reliability of these datasets. Unfortunately, current vegetation models have several weaknesses in reproducing observed temporal dynamics in vegetation greenness. Our aim is to integrate multiple earth observation data sets in a dynamic global vegetation model in order to 1) improve the model's capability to reproduce observed dynamics and spatial patterns of vegetation greenness and 2) to assess the spatial and temporal importance of environmental drivers for the seasonal to decadal variability of vegetation greenness.

For this purpose, we developed a data integration system for the LPJmL dynamic global vegetation model (LPJmL-DIS). We implemented a new phenology scheme in LPJmL to better represent observed temporal dynamics of FAPAR (fraction of absorbed photosynthetic active radiation). Model parameters were globally optimized using a genetic optimization algorithm. The model optimization was performed globally against 30 year FAPAR time series (GIMMS3g dataset), against 10 year albedo time series (MODIS) and global patterns of gross primary production as up-scaled from FLUXNET eddy covariance measurements. Additionally, we directly prescribed satellite observations of land and tree cover in LPJmL to better represent global vegetation distribution by still keeping major processes of vegetation dynamics like mortality and competition among plant functional types. We prescribed observed burnt areas from the GFED dataset as well as from the Alaskan and Canadian national fire databases in LPJmL to better reproduce observed fire dynamics. We evaluated LPJmL with optimized parameters against independent data streams. LPJmL with a new phenology scheme and optimized parameters better represents spatial patterns of gross primary production, biomass, soil organic carbon, evapotranspiration and tree cover than the original model. LPJmL-DIS is able to reproduce spatial patterns and observed temporal dynamics of FAPAR from seasonal to decadal scales in all major biomes.

We performed several model experiments to disentangle the spatial and temporal importance of temperature, radiation, water availability, CO_2 fertilization, fire activity and permafrost changes on the seasonal to decadal variability of vegetation greenness. Our results indicate that water availability is a major driver for the seasonal to decadal variability of vegetation greenness in tropical, temperate and boreal biomes. The developed LPJmL data integration system enables to reanalyse recent trends in vegetation greenness and their environmental drivers by combining earth observation data of multiple environmental variables in a consistent process-based global vegetation model framework.