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Improving Process-based Modeling of Terrestrial Ecosystem Productivity Through Mapping Leaf Chlorophyll Content and Maximum Carboxylation Rate

Jing Chen, Holly Croft, and Gang Mo
Toronto, Canada (jing.chen@utoronto.ca)

In recent decades, process-based models are developed for estimating the spatial and temporal distributions of terrestrial carbon sources and sinks. However, one of the largest uncertainties in these models is the unknown spatial distribution of the maximum leaf carboxylation rate (Vcmax) that controls the photosynthetic carbon uptake by plants. Previous attempts to correlate Vcmax with leaf nitrogen content (LNC) were not successful because it is difficult to retrieve LNC from remote sensing data and its relationship to Vcmax is confounded by many factors. Here, we demonstrate for the first time that it is feasible to derive leaf chlorophyll content (LCC) at the global scale using currently available remote sensing data and LCC is better correlated to Vcmax than LNC. A series of LCC maps at the global scale are derived from the European Medium-spectral Resolution Imaging Spectrometer (MERIS) data. Data used in retrieving LCC include: (1) Cloud-free composite MERIS images in bands 5, 7, 9, 10, and 12 every 7 days in 2011 at its original resolution of 300 m over the entire global landmass; (2) corresponding MERIS leaf area index (LAI) data; (3) a global clumping index map at 500 m resolution derived from MODIS data; and (4) Leaf chlorophyll data collected at 248 ground sites from 2002 to 2014 for 6 plant functional types across the globe for the purpose of validation. Global LCC maps are produced every 7 days at 300 m resolution in 2011. The Locally Adjusted Cubic-Spline Capping (LACC) algorithm is used to produce temporally smoothed LCC seasonal variation for each pixel. LNC and Vcmax data in the global TRY database and additional ground datasets are used to convert LCC to Vcmax using a leaf nitrogen allocation model. The spatiotemporal information of Vcmax derived in this way is used in a process model BEPS based on the Farquhar's model to calculate global GPP at hourly time step and 1 degree resolution. Compared with model results based on assigned constant Vcmax25 (Vcmax normalized to 25C) values for different plant functional types without seasonal variations, the modeled GPP results with Vcmax25 derived from LCC shows larger spatial and temporal variations which are more compatible with eddy-covariance tower flux data at over 140 sites across the globe.