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Development of an analytical model for estimating global terrestrial carbon assimilation using a rate-limitation framework

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A fundamental question in climate and ecosystem science is “how does climate regulate the land surface carbon budget?” To better answer that question, here we develop an analytical model for estimating mean annual terrestrial gross primary productivity (GPP), which is the largest carbon flux over land, based on a rate-limitation framework. Actual GPP (climatological mean from 1982 to 2010) is calculated as a function of the balance between two GPP potentials defined by the climate (i.e. precipitation and solar radiation) and a third parameter that encodes other environmental variables and modifies the GPP-climate relationship. The developed model was tested at three spatial scales using different GPP sources, i.e. (1) observed GPP from 94 flux-sites, (2) modelled GPP (using the model-tree-ensemble approach) at 48654 (0.5 degree) grid-cells and (3) at 32 large catchments across the globe. Results show that the proposed model could account for the spatial GPP patterns, with a root-mean-square error of 0.70, 0.65 and 0.3 g C m-2 d-1 and R2 of 0.79, 0.92 and 0.97 for the flux-site, grid-cell and catchment scales, respectively. This analytical GPP model shares a similar form with the Budyko hydroclimatological model, which opens the possibility of a general analytical framework to analyze the linked carbon-water-energy cycles.