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Advancing the Mechanistic Understanding and Model Representation of Photosynthesis and Transpiration Processes of Tropical Evergreen Forests

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Accurate representation of tropical evergreen forest photosynthesis and stomatal conductance in Terrestrial Biosphere Models (TBMs) is a critical component of improving the ability of TBMs to capture the huge fluxes of carbon and water exchanged by tropical evergreen forests. Here we have addressed two key questions; (1) how can TBMs represent tropical evergreen forest photosynthetic seasonality and (2) what existing formulations are best suited to represent tropical evergreen forest stomatal conductance?

Photosynthetic seasonality in tropical evergreen forests results in an annual seasonal fluctuation in CO_2 assimilation of about 6.25 Pg CO_2 over the Amazon basin. We explored alternative options for the incorporation of this quantitatively important seasonality in TBMs that employ the Farquahar, von Caemmerer & Berry (FvCB) representation of CO_2 assimilation. We developed a two-fraction leaf (sun and shade), two-layer canopy (upper and lower) photosynthesis model to evaluate how three components of phenology, i.e. leaf quantity, quality, and within-canopy variation in leaf longevity affect photosynthetic seasonality. This approach identified a parsimonious formulation for representing tropical evergreen forest photosynthetic seasonality in TBMs and highlighted the importance of leaf quality and its within-canopy variation for accurate representation of canopy-scale photosynthetic seasonality.

A critical component of TBM representation of carbon and water fluxes is the formulation used to determine stomatal conductance. Using a large data set we collected of diurnal measurements of CO_2 assimilation and stomatal conductance, we assessed the ability of three leaf level models to simulate observed stomatal conductance and evaluated the importance of accounting for variation between species. Our results showed that stomatal conductance models that accounted for vapor pressure deficit (VPD) performed better than those that did not include VPD in their formulation. We also found that including species specific parameterization of stomatal slope – a key model input – improved model skill. Interestingly, our analysis showed that stomatal slope could be approximated by a commonly measured leaf trait -leaf mass per area and soil moisture content.