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Understanding the Response of Photosynthetic Metabolism in Tropical Forests to Seasonal Climate Variations

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This project focuses on one of the fundamental questions in terrestrial system science and tropical forest ecology: what controls the response of photosynthesis in evergreen tropical forests to seasonal variations in climate? Photosynthesis seasonality in Amazon tropical forests simulated by state-of-the-science Earth system models largely disagrees with observations: while modeled soil hydrologic dynamics during drought spells dictate water shortage and, as a result, constrained photosynthesis, satellite-based retrievals of forest “greenness” and tower-based measurements of carbon dioxide exchange indicate that production remains nearly constant or increases during dry periods. This research addresses this paradigm by providing insights on seasonal climate-photosynthesis relations in two tropical forests of the Brazilian Amazon, across a gradient of dry season length between Manaus (with a short dry season) and Santarem (with a long dry season). The methods involve intensive field campaigns to measure physiological and hydraulic characteristics of leaves and trees, camera systems to monitor forest growth at tree crown and canopy scales, and ecohydrologic system continuously tracking water tree flows and their level of hydration. The integration of individual tree responses over a range of light exposure conditions highlights temporal changes of the forest response to 2015-2016 El Nino conditions as well as variability of tree-scale carbon and water uptake strategies. Analysis of hydraulic relations in trees shows a spectrum of successfully co-existing strategies, ranging from tight control against xylem failure, to a near lack of regulation of the water flux through the stomata. These strategies also exhibit coupling with tree growth patterns and dynamics of non-structural carbohydrates, hinting the linkage between individual tree drought response and ecosystem-scale dynamics. We conclude that representation of hydraulic traits is necessary for reliable modeling of the seasonal dynamics of photosynthesis. Tower-based phenology cameras show that synchronization of new leaf growth shifts canopy composition toward younger, more light-use efficient leaves, thus explaining large seasonal increases in ecosystem photosynthesis. We present a new scheme to include such age-dependent variation among individual leaves and crowns into models and incorporate it into state-of-the-art eco-hydrological model Thetys & Chloris (T&C). Using simulations, we assess the impact of leaf phenology on the seasonality of biosphere-atmosphere exchanges in the Amazon across a range of sites, suggesting a new strategy for mapping traits to function of tropical forests in the next generation of predictive models of ecosystem dynamics.