Tower-mounted cameras validate remotely sensed “green-up” of Amazon forest photosynthesis and reveal mechanisms underlying the seasonality of tropical forest metabolism

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The relation between surface radiation, leaf phenology, and seasonality of forest photosynthetic metabolism and water relations is of central importance in global change ecology. However, the seasonal rhythms of tropical forests remain poorly understood: they are not well-represented by models, and their remotely-sensed seasonal expressions are, controversially, claimed to be artifacts of sun-satellite geometry. Here, we aim to scale from the phenology of individual tree crowns to ecosystem photosynthesis, and to ground truth satellite-derived seasonal patterns of vegetation indices (MODIS EVI) in two evergreen tropical forests with different seasonalities (short dry season in the Cuieras Forest Reserve near Manaus, and long dry season in the Tapajos National Forest near Santarem, Brazil).

We developed a classification scheme to decompose daily images of forest tree crowns from tower-mounted three-channel cameras - a red, green, and near-infrared (RG,NIR) in the Santarem forest (2010-2012) and a red, green, blue (RGB) camera in the forest near Manaus (2010-2013). This generated time series of tree crown phenology events (leaf flushing and leaf drop) that are insensitive to artifacts of sun-sensor geometry or atmospheric contamination that may affect satellite remote sensing metrics. The camera-sensed leaf phenology is consistent with seasonal dry season green-up detected by remotely-sensed MODIS EVI in the equatorial Amazon, suggesting that these seasonal variations are not sensor artifacts.

To investigate underlying mechanisms of observed patterns, we combined camera-derived leaf phenology and litterfall observations to drive a simple 3-cohort model (with young, mature and old leaves) of leaf demography optimized (with R2 \( \geq 0.8 \)) to predict seasonality of eddy flux-derived photosynthetic Light-Use Efficiency (LUE). The demographic model predicted that leaf-cohort photosynthetic capacity increased with leaf age from young to mature leaves before declining for old leaves prior to litterfall. This predicted pattern was confirmed by age-dependent measurements (via Licor 6400) of leaf photosynthetic capacity (Vcmax).

Our results reveal the demographic and physiological mechanisms that underlie ecosystem-scale seasonal patterns in photosynthetic capacity observed by eddy flux towers and satellites. Future work funded by DOE, FAPEAM and FAPESP’s GoAmazon program will integrate detailed observations from hyperspectral and thermal imaging cameras of the canopy, dynamic range radiometric images of incoming radiation, and fine-scale observations of sap flow, leaf water potential, and canopy chlorophyll fluorescence and photosynthetic capacity. This integration will use models (DIRSIG and FLIES models) to predict seasonality of canopy reflectance and ecosystem-scale photosynthesis, and provide a basis to improve earth system models of vegetation-climate interactions.