

NGEE–Tropics

Poster Abstract Package
2021 ESS PI Meeting

Title: Next-Generation Ecosystem Experiments (NGEE)-Tropics Phase 2 Overview

Jeffrey Chambers[1*] (PI), Stuart Davies[2], Rosie Fisher[3], Kolby Jardine[1], Michael Keller[4], Charles Koven[1], Lara Kueppers[1], Ruby Leung[5], Nathan McDowell[5], Gilberto Pastorello[1], Alistair Rogers[6], Charuleka Varadharajan[1], Anthony Walker[7], Jeffrey Warren[7], Chonggang Xu[8]

[1]Lawrence Berkeley National Laboratory, Berkeley, CA; [2]Smithsonian Tropical Research Institute, Washington, DC; [3]Centre national de la recherche scientifique, France; [4]United States Forest Service, Washington, DC; [5]Pacific Northwest National Laboratory, Richland, WA; [6]Brookhaven National Laboratory, Upton, NY; [7]Oak Ridge National Laboratory, Oak Ridge, TN; [8]Los Alamos National Laboratory, Los Alamos, NM.

Contact: (jchambers@lbl.gov)

Project Lead Principal Investigator (PI): Jeff Chambers, Berkeley Lab

BER Program: ESS

Project: NGEE-Tropics

Project Website: https://ngee-tropics.lbl.gov

Project Abstract: Tropical forests cycle more CO_2 and water than any other biome and are critical in determining Earth's energy balance. Yet processes controlling these tropical forest-atmosphere interactions that regulate the climate system are not well represented in the current generation of Earth system models (ESMs). In support of BER's mission to advance a predictive understanding of Earth's climate and environmental systems, the Next Generation Ecosystem Experiments (NGEE)-Tropics aims to deliver a greatly improved predictive understanding of tropical forests and Earth system feedbacks to changing environmental drivers over the 21st Century. A strong synthetic coupling of modeling and experiment-observational methods (ModEx) is the fundamental approach toward attaining this goal, with the grand deliverable a representative, process-rich tropical forest ecosystem model (the Functionally Assembled Terrestrial Ecosystem Simulator – FATES), extending from bedrock to the top of the vegetative canopy-atmosphere interface, in which the dynamics and feedbacks of tropical ecosystems in a changing climate can be modeled at the scale and resolution of a next generation E3SM grid cell. Phase 2 of NGEE-Tropics is structured around three Research Focus Areas (RFAs) that will advance understanding and model representation of tropical forest processes at the individual (RFA1), community to regional (RFA2), and regional and global (RFA3) scales in E3SM-FATES. Science activities within these RFAs are organized into ModEx Work Packages (WP). The WPs are coordinated to enable the delivery of RFA-level goals for FATES development and evaluation, and to apply FATES for addressing science questions at site to continental scales. This overview will highlight activities that synthesize across RFAs and WPs toward addressing integrative science questions.

Title: Data-model Fusion For Tree Community-scale Water Sourcing Depths In Tropical Forests

Rutuja Chitra-Tarak[1*], Cynthia Wright[2*], Chonggang Xu[1], Jeffrey Warren[2]

[1]Los Alamos National Lab, Los Alamos, NM; [2]Oak Ridge National Lab, Oak Ridge, Tennessee.

Contact: (rutuja@lanl.gov; wrightcl1@ornl.gov)

Project Lead Principal Investigator (PI): Jeff Chambers, Berkeley Lab

BER Program: ESS

Project: NGEE-Tropics

Project Website: http://ngee-tropics.lbl.gov

Project Abstract: Diverse trees in the same forest may or may not be exposed to a drought depending on their water-sourcing depths. Estimating tree water-sourcing depths, or effective rooting depths (ERD), at the scale of the whole tree community is thus imperative to predict drought-induced mortality of a forest, but we are critically limited by data for ERD. This is especially challenging for tropical forests with hundreds of tree species and hundreds of thousands of trees.

We proposed a new data-model fusion approach, wherein data for water-sourcing depths for a functionally representative set of tree species in a forest informs a novel, community-scale model of ERD. The ERD model leverages commonly collected community-scale tree growth re-censuses and estimates the concurrent dynamics of water-availability vertically belowground to inversely estimate ERD. We successfully applied this approach as a proof-of-concept for 29 canopy tree species at Barro Colorado Island (BCI), Panama (Chitra-Tarak et al. *In Press*). Furthermore, this work highlighted that tree species whose water transport systems are considered more vulnerable to dehydration--based solely on their above-ground hydraulic traits--were, in fact, more buffered by deep-water access, experienced lesser drought exposure and had lower mortality rates across El-Nino droughts of a variety of intensity and duration.

Future work will involve MODEX development at multiple tropical sites validated with expanded measurements for ERD at BCI, Panama and new measurements at other intensively studied NGEE-Tropics sites, such as Manaus, Brazil, San Lorenzo, Panama and Luqillo, Puerto Rico, leveraging existing data for forest dynamics, hydrology and above-ground hydraulic traits. For ERD data estimates, we will use stable water isotopes as natural plant water source tracers. These leverage isotopic gradients due to evaporative enrichment of shallow soils vs. deep soil water to estimate ERD, when compared to the isotopic ratios of plant stem water. ERD will be determined by comparing isotopic composition of plant water with that of below ground water using established mixing models.

Publications:

Chitra-Tarak, Rutuja et al. “Hydraulically-vulnerable trees survive on deep-water access during droughts in a tropical forest.” *New Phytologist* (*In press*) [https://doi.org/10.1111/nph.17464].
Chitra-Tarak, Rutuja et al. “Soil Water Potentials (1990-2018) from a calibrated ELM- FATES, and rooting depth analyses scripts, PA-BCI, Panama. 2.0.” *NGEE-Tropics Data Collection.* (dataset). (2020) [http://dx.doi.org/10.15486/ngt/1696806]

Title: How Do Plant Hydraulic Traits Shape Species Demography and Distribution in a Wet Tropical Forest?

Alexandria Pivovaroff[1*], Nate McDowell[1], Elizabeth Agee[2], S. Joseph Wright[3], Jeffrey Chambers[4]

[1]Atmospheric Science and Global Change Division, Pacific Northwest National Laboratory, Richland, WA; [2]Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN; [3]Smithsonian Tropical Research Institute, Balboa, Panama; [4]Climate and Ecosystem Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA.

Contact: (alexandria.pivovaroff@pnnl.gov)

Project Lead Principal Investigator (PI): Jeff Chambers, Berkeley Lab

BER Program: ESS

Project: NGEE-Tropics

Project Website: https://ngee-tropics.lbl.gov/

Project Abstract: Climate change, including drought and warming temperatures, is impacting tropical forests around the world. This has implications for community dynamics, species' demography, and biogeochemical cycles. We investigated how species' hydraulic and drought response traits were associated with demography and regional distribution across a moisture gradient in tropical forests in Panama. We used long-term census data from Barro Colorado Island along with species occurrence data at 72 sites across the isthmus of Panama, and we collected species' archived trait data from the TRY Database, Xylem Functional Trait Database, NGEE-Tropics Data Archive, and other published sources. Focusing on evergreen species, we found a life history strategy trade-off, with species having high mortality rates, fast growth rates, and high recruitment rates on one end of the continuum, following a "live fast, die young" strategy. On the other end of the continuum were species with low mortality rates, slow growth rates, and low recruitment rates, following a "slow and steady" strategy. Xylem vulnerability to cavitation (P_{50}) was coordinated with these demographic trade-offs, as "live fast, die young" species had more vulnerable P_{50} and "slow and steady" species had more resistant P_{50}. Further, across 72 sites spanning a moisture availability gradient, wetter sites had higher photosynthetic rates and more vulnerable turgor loss point, while drier sites had lower photosynthetic rates and more resistant turgor loss point. These life history strategy trade-offs reveal how species' traits shape demography and distribution.

Title: An Improved Representation of the Effect of Photosynthesis on Stomatal Conductance Leads to More Stable Estimation of Conductance Parameters and Improves the Goodness-of-fit Across Diverse Datasets

Julien Lamour[1*], Kenneth Davidson[1,2], Kim Ely[1], Gilles Le Moguédec[3], Andrew Leakey[4,5,6], Qianyu Li[1], Shawn Serbin[1], Alistair Rogers[1]

[1]Environmental & Climate Sciences Department, Brookhaven National Laboratory, Upton, NY, USA; [2]Department of Ecology and Evolution, Stony Brook University, Stony Brook, NY, USA; [3]AMAP, Université Montpellier, INRAE, Cirad CNRS, IRD, 34000 Montpellier, France; [4]Department of Plant Biology, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA; [5]Department of Crop Sciences, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA.

Contact: (jlamour@bnl.gov)

Project Lead Principal Investigator (PI): Jeff Chambers, Berkeley Lab

BER Program: ESS

Project: NGEE-Tropics

Project Website: https://ngee-tropics.lbl.gov/

Project Abstract: Stomata play a key role in plants and forests by controlling the rates of transpiration and CO_2 diffusion between the leaf and the atmosphere. Modeling stomatal conductance (g_{sw}) is therefore essential to predict water and CO_2 exchange in plants and ecosystems. For given environmental conditions at the leaf surface (CO_2 concentration and vapor pressure deficit or relative humidity), models generally assume a linear relationship between stomatal conductance and photosynthetic CO_2 uptake (A), despite observations of a possibly nonlinear behavior. However, leaf level response curves of stomatal conductance to changes in photosynthesis are rare, particularly in the tropics, a factor which may have limited the study of this phenomenon. Here, we measured the response of g_{sw} and A to different irradiance spanning natural conditions from high irradiance to full dark in the leaves of six tropical species at different leaf phenological stages. We showed that the relationship between g_{sw} and A was non-linear, with a weak effect of increasing A on g_{sw} when A was low and a stronger effect when A was high. We reformulated the popular Unified Stomatal Optimization (USO) model to account for this phenomenon and to estimate the conductance parameters g_0 and g_1. This improved the goodness of fit and reduced bias in parameter estimates, resulting in a robust estimate for different irradiances. Previously undetectable relationships between conductance parameters and other leaf properties were revealed. The benefits of the nonlinear formulation were also demonstrated in data collected from attached and detached leaves, growth at ambient temperature and high CO_2, and various species from different environments. We propose that this empirical modification of the USO model can simplify data collection for parameterization and improve model performance in a wide range of applications. We also discuss the reasons for the nonlinearity in the g_{sw} response. We showed that a more complex conductance model based on the theoretical optimality framework does predict a nonlinearity at the transition between light-limiting and light-saturating photosynthetic rate. However, we also showed that the assumption on which optimality theory is based, that the marginal cost of water gain is constant, was not verified in our data, so that the more complex optimal models may not fully represent this phenomenon.

Title: Stem and Leaf Respiration in Tropical Ecosystems

Kolby J. Jardine[1], Malyia-Mason S. East[1], Liliane M. Teixeira[2], Leticia Cobello[2], Charlie Koven[1], Chonggang Xu[3], Emily Robles[1], Bruno O. Gimenez[2], Niro Higuchi[2], Daisy Souza[2], Sienna Levine[1], and Jeffrey Q. Chambers[1]

[1]Lawrence Berkeley National Laboratory, Berkeley, CA; [2]National Institute for Amazon Research, Brazil; [3]Los Alamos National Lab, Los Alamos, NM.

Contact: (kjjardine@lbl.gov)

Project Lead Principal Investigator (PI): Jeff Chambers, Berkeley Lab

BER Program: ESS

Project: NGEE-Tropics

Project Website: https://ngee-tropics.lbl.gov/

Project Abstract: Tropical forests fix more CO_2 than any other terrestrial ecosystem. However, they are also a major source of CO_2 through respiration (60GtC year^{-1}), several times more than anthropogenic emissions. High respiration rates constrain net primary productivity with estimates of carbon use efficiency (CUE) around 30% in the Amazon. For this project, we first described how autotrophic respiration is treated in the ecosystem dynamics model, Functionally Assembled Terrestrial Ecosystem Simulator (FATES). We then synthesize monthly stem growth and CO_2 efflux measurements from 80 trees in a diverse, tropical forest in the central Amazon. In addition, we analyzed real-time stem CO_2 efflux together with canopy temperature and sap velocity for 3 trees during the day and night. These two datasets were organized and shared in the Next Generation Ecosystem Experiments Tropics (NGEE-T) data archive. A positive linear correlation was found between stem growth rates and stem CO_2 efflux. CUE of stems was estimated as high as 80% for fast growing trees in the Amazon with 15 +/- 3% of carbon allocated to woody tissue released as CO_2. This compares favorably with the fraction of respiration per unit growth (11%) currently used in current ecosystem dynamics models, including the Functionally Assembled Terrestrial Ecosystem Simulator (FATES). Stem CO_2 efflux was suppressed by 10-50% during the day compared to the night demonstrating the importance of nighttime measurements. The results show high stem respiration rates are associated with high CUE of wood production during fast tree growth. We suggest future modelling and field observations should focus on quantifying maintenance (R_m) and growth (R_g) respiration of stems and how they vary with plant functional types (fast versus slow-growing), nutrient concentrations, environmental variables, and sapwood allometry.

Title: Tree Mortality Risk Factors in Tropical Forests

Daniel Zuleta,[1*], Gabriel Arellano,[2], Sean M. McMahon,[3], Helene C. Muller-Landau,[4], Salomón Aguilar,[4], Sarayudh Bunyavejchewin,[5], Dairon Cárdenas,[6], Chia-Hao Chang-Yang,[7], Alvaro Duque,[8], Musalmah Nasardin,[9], Rolando Pérez,[4], I-Fang Sun,[10], Yao Tze Leong,[9], Stuart J. Davies[1]

[1]Forest Global Earth Observatory, Smithsonian Tropical Research Institute, Washington, DC; [2]Ecology and Evolutionary Biology, University of Michigan; [3]Smithsonian Environmental Research Center, Edgewater, MD; [4]Smithsonian Tropical Research Institute, República de Panamá; [5]Department of National Parks, Wildlife and Plant Conservation, Thailand; [6]Instituto Amazónico de Investigaciones Científicas Sinchi, Bogotá, Colombia; [7]Department of Biological Sciences, National Sun Yat-sen University, Kaohsiung, Taiwan; [8]Departamento de Ciencias Forestales, Universidad Nacional de Colombia Sede Medellín, Medellín, Colombia; [9]Forest Research Institute Malaysia, Selangor, Malaysia; [10]Center for Interdisciplinary Research on Ecology and Sustainability, National Dong Hwa University, Taiwan.

Contact: (ZuletaD@si.edu)

Project Lead Principal Investigator (PI): Jeff Chambers, Berkeley Lab

BER Program: ESS

Project: NGEE-Tropics

Project Website: https://ngee-tropics.lbl.gov/

Project Abstract: Understanding the causes and consequences of tropical tree mortality is paramount to obtaining more accurate predictions of the future of tropical forests and the carbon cycle-climate feedbacks. Yet, the main mechanisms and pathways by which trees die remain unknown. This is especially problematic in the tropics, where the high levels of species diversity result in a variety of responses to the conditions to which the trees are exposed. We used 99,858 observations of tree-level conditions and subsequent survival of 31,203 trees of 1,977 tree species in 14 census intervals to estimate how conditions relate to survival. This study was conducted within six large-scale (24-50 ha) tropical forest plots of the ForestGEO network in the Neotropics (Amacayacu ,Colombia; Barro Colorado Island, Panamá) and Asia (Fushan, Taiwan; Huai Kha Khaeng, Thailand; Khao Chong, Thailand; Pasoh, Malaysia). We defined a condition as a risk factor for a species if it was associated with at least a two-fold increase in mortality, and quantified the prevalence, lethality, and contribution to total forest mortality of 19 risk factors. Besides the relatively well-known susceptibility of small, light-limited trees, we found trunk and crown damage were the conditions conferring the greatest risk of death. Other commonly studied risks such as those related to large tree size, liana infestation or herbivory were relatively less important at the forest level. Having a leaning trunk, or being defoliated constituted other important risk factors that have rarely been documented in tropical forests. We also found that the widely used modes of death (standing, broken, and uprooted) were not always associated with previously assigned mortality risk factors. Future research should focus on the links between these mortality risk factors, their climatic drivers, and the physiological mechanisms leading to tree death to help improve predictions of the future of tropical forests.

Title: Nutrient Cycling in FATES-ELM

Ryan Knox[1*], Charles Koven[1], William Riley[1], Jennifer Holm[1], Xiaojuan Yang[2], Rosie Fisher[3], Qing Zhu[1], Jinyun Tang[1], Xinyuan Wei[2] and Anthony Walker[2]

[1]Lawrence Berkeley National Laboratory, Berkeley, CA; [2]Oak Ridge National Laboratory, Oak Ridge, TN; [3]Évolution & Diversité Biologique, University of Toulouse Paul Sabatier III, Toulouse, France.

Contact: (rgknox@lbl.gov)

Project Lead Principal Investigator (PI): Jeff Chambers, Berkeley Lab

BER Program: ESS

Project: NGEE-Tropics

Project Website: https://ngee-tropics.lbl.gov/

Project Abstract:Nitrogen and phosphorus play a critical role in growth and function of terrestrial ecosystems. Their availability in plants can limit tissue growth as well as modify physiological function. Incorporating the cycling of nitrogen and phosphorus into ecosystem models is an important step in estimating and/or predicting the evolution of terrestrial ecosystem structure and global carbon budget. Here we present the first version of fully coupled nitrogen and phosphorus dynamics between the Functionally Assembled Terrestrial Ecosystem Simulator (FATES) and the Energy Exascale Earth System Model (E3SM). This coupling enables 1) FATES plants to participate in competitive acquisition of nutrients in the soil with mineral surfaces (for phosphorus) and microbes, 2) impose mechanistic and conservative growth limitations on fates plants due to competitive uptake, and 3) return organic nitrogen and phosphorus to the decomposing litter pools. Here we describe and perform some verification of the model coupling.

Title: Linking Resource Availability to Pantropical Forest Response and Resilience to Cyclone Disturbance

Barbara Bomfim,[1]* Anthony Walker,[2] William H. McDowell,[3] Jess K. Zimmerman,[4] Yanlei Feng,[5] Mingjie Shi,[6] Charles Koven,[1] Michael Keller,[7] Lara Kueppers[1,5]

[1]Climate and Ecosystem Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA; [2]Environmental Sciences Division and Climate Change Science Institute, Oak Ridge National Laboratory, Oak Ridge, TN; [3]University of New Hampshire, Durham, NH; [4] Universidad de Puerto Rico, Rio Piedras Campus, San Juan, Puerto Rico; [5]University of California Berkeley, Berkeley, CA; [6] Land System Modeling, Pacific Northwest National Laboratory, Richland, WA; [7]International Institute of Tropical Forestry, USDA Forest Service, San Juan, Puerto Rico.

Contact: (bbomfim@lbl.gov)
Project Lead Principal Investigator (PI): Jeff Chambers, Berkeley Lab
BER Program: ESS
Project: NGEE-Tropics
Project Website: https://ngee-tropics.lbl.gov/

Project Abstract: Tropical cyclones have global environmental and socio-economic impacts, causing nearly \$26 billion y^{-1} in damage. Because these disturbances are becoming stronger and occurring at higher latitudes in recent decades, understanding the mechanisms governing their influence on forest response (resistance) and resilience (pace of return to pre-disturbance values) is necessary. We conducted a meta-analysis to investigate the effect of soil resource availability, namely total soil phosphorus (P) concentration, on site-level forest response and resilience to cyclones pantropically. We evaluated cyclone-induced and post-cyclone litterfall mass (g/m^2/day) and P and nitrogen (N) fluxes (mg/m^2/day) and concentrations (mg/g), indicators of ecosystem function, and essential conduits for nutrient recycling in forest ecosystems. Across 73 case studies in Australia, Guadeloupe, Hawaii, Mexico, Puerto Rico, and Taiwan, total litterfall (sum of leaf, fine wood, reproductive and miscellaneous fractions) mass flux increased from ~2.5 ± 0.3 to 22.5 ± 3 g/m^2/day due to cyclones. Individual mass flux responses varied from a negligible change in Taiwan with Haima to an instantaneous flux that was ~2 times the annual input in Bisley, Puerto Rico with Irma. Relative to pre-cyclone means, leaf litterfall P increased by 58.6 ± 2.3% and N concentration by 21.6 ± 1.2% after cyclones. Soil P and wind speed positively moderated immediate litterfall mass flux responses to cyclones. Total litterfall mass flux reached pre-disturbance levels within one year of the disturbance. Litterfall N and P concentrations remained higher than pre-disturbance levels during the same period. A significant interaction of soil P with time since the cyclone and gale wind duration best explained ($R^2 = 0.4$) the variability in the litterfall mass flux resilience. Our pantropical findings corroborate the prediction, based on single-site studies in Australia and Hawaii, that forests on low-P soils are less responsive and likely less resilient to cyclones than forests on high-P soils. Forest response in the face of intensifying cyclone disturbance will be determined, in part, by soil resource availability.

To further understand the forest resistance and resilience and associated carbon dynamics, we use ELM-FATES with cyclone-induced tree mortality (separated from other FATES mortality factors) added. We perform simulations with varied tree mortality fractions and find that both early and late-successional evergreen broadleaf forests respond to cyclone disturbance with total biomass reductions. Leaf biomass and leaf area index responds non-linearly to cyclones, suggesting a rapid closure of the canopy and fundamental needs of reasonable simulation of forest structure and biomass recovery following cyclones.

Title: FATES-SPITFIRE: Dynamic Ecosystem Assembly Through Interaction of Disturbance, Vegetation Strategies and Canopy Structure in the Tropics

Jacquelyn Shuman,[1*] Rosie Fisher,[1,2] Charlie Koven,[3] Ryan Knox,[3] Lara Kueppers,[3] Sam Levis,[3] and Chonggang Xu,[4]

[1]National Center for Atmospheric Research, Boulder, CO; [2]Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique (CERFACS), Toulouse, France; [3]Lawrence Berkeley National Laboratory, Berkeley, CA. [4]Los Alamos National Laboratory, Los Alamos, NM.

Contact: (jkshuman@ucar.edu)

Project Lead Principal Investigator (PI): Jeff Chambers, Berkeley Lab

BER Program: ESS

Project: NGEE-Tropics

Project Website: https://ngee-tropics.lbl.gov/

Project Abstract: For global scale simulation, a new axis of biogeography driven by fire disturbance is needed within Vegetation Demographic Models (VDM). Within the tropics, the location of forests and savannas are determined through the interaction of climate conditions, fire disturbance frequency and vegetation traits and state. Utilizing the Functionally Assembled Terrestrial Ecosystem Simulator (FATES), a size-structured VDM, with the fire behavior and effects module SPITFIRE, we explore thresholds of survival and resulting biogeography for simulations with trees that have contrasting fire tolerance traits and a C4 grass. Fire tolerance strategy is based on tree bark thickness, crown size and foliage resistance to heat, which are key fire-tolerance traits across woody plants. Within South America, observations demonstrate that trees within stable forest areas with traditionally low fire disturbance have thinner bark than trees in savanna areas that experience regular fire disturbance. SPITFIRE has been adapted within FATES to calculate scorch height at the plant level, to calculate grass fuel moisture based on climate, and to use spatially and temporally varying lightning ignitions. Simulations capture observed patterns for vegetation productivity, aboveground biomass and seasonal burned area for the recent historical period. Simulated biogeography of the fire-tolerant vs. -intolerant trees corresponds to observations of tree bark thickness variability across South America. Fire disturbance limits tree extent, with wetter, low disturbance areas retaining a higher stable tree fraction of the fire-intolerant tree. Transitional and drier areas with intermediate to high fire disturbance demonstrate dominance of trees or grasses conditional on fire frequency. Without fire, the fire-intolerant tree, which has lower wood density and thinner bark, is dominant and accumulates extensive biomass across the region. FATES-SPITFIRE tracks size-structured plant mortality and captures 'fire-trap' dynamics where fire-tolerant trees escape fire by achieving a canopy height above the flames or through fire resistant traits. These fire-vegetation feedbacks are critical for projection of ecosystem resilience and shifts under current and future conditions.

Title: Quantifying Spatial and Temporal Variation in Tropical Forest Canopy Disturbance Using Drone Photogrammetry

K.C. Cushman[1*], Raquel Fernandes Araujo[1], Jeffrey Chambers[2], Stuart Davies[3], Matteo Detto[4], Samuel Grubinger[5], Carlos Henrique Souza Celes[1], Robinson I. Negrón-Juárez[2], Milton Garcia[1], Jonathan P. Dandois[4], and Helene C. Muller-Landau[1]

[1]Smithsonian Tropical Research Institute, Balboa, Panama; [2]Earth & Environmental Sciences, Lawrence Berkeley National Laboratory, Berkeley, CA; [3]Forest Global Earth Observatory, Smithsonian Institution, Washington D.C.; [4]Princeton University, Princeton, NJ; [5]University of British Columbia, Vancouver, Canada. [4]Johns Hopkins University, Baltimore, MD.

Contact: (cushmank@si.edu)

Project Lead Principal Investigator (PI): Jeff Chambers, Berkeley Lab

BER Program: ESS

Project: NGEE-Tropics

Project Website: https://ngee-tropics.lbl.gov/

Project Abstract: Tree damage and mortality are important controls over carbon stocks and fluxes in tropical forests—these processes are also key uncertainties in current Earth system models. Tropical tree damage and mortality are currently uncertain because their rates are low, requiring frequent and large-scale observations to quantify variation, which is infeasible with labor-intensive traditional field methods. In this study, we used 3D drone photogrammetry to locate canopy disturbances from tree damage and mortality at ~ monthly (for 50 ha) and multiannual (for 1350 ha) intervals over 5 years on Barro Colorado Island (BCI), Panama. We found that on average approximately 2% of the forest is affected by canopy disturbance every year. Importantly, our data quantify high spatial and temporal variation in canopy disturbance rates. Spatially, disturbances occur more frequently on ridges, areas with high or low slope, older forests, and on certain geographic formations. Temporally, disturbance rates are positively associated with extreme precipitation events. Visual inspection of before and after drone imagery revealed that 23% of canopy disturbance (by area) is associated with tree damage (branchfalls), while the other 77% is associated with tree mortality (treefalls). Our results are relevant for improving mechanistic understanding of carbon cycling in this well-studied landscape, and for the representation of tree damage and mortality in ecosystem models.

Title: Coupled modeling of hillslope hydrology and ecosystem dynamics at Manaus and BCI

Lingcheng Li[1*], Yilin Fang[1], Ruby Leung[1]

[1]Pacific Northwest National Laboratory.

Contact: (lingcheng.li@pnnl.gov)

Project Lead Principal Investigator (PI): Jeff Chambers, Berkeley Lab

BER Program: ESS

Project: NGEE-Tropics

Project Website: https://ngee-tropics.lbl.gov/

Project Abstract: Tropical forests play important roles in the coupled land-atmosphere system by contributing to a large fraction of precipitation through evapotranspiration. Combined climate change and topography are likely to have large and diverse impacts on plant water availability, with consequential effects on vegetation dynamics and the regional and global water cycles. We have developed an integrated model that couples E3SM Land Model (ELM), an ecosystem dynamics model (FATES), and a three-dimensional hydrology model (ParFlow) to explicitly resolve hillslope topography and subsurface flow for a better understanding of the processes that drive plant water availability and tropical forest dynamics. Numerical experiments are conducted at Barro Colorado Island, Panama, and the Asu catchment, Manaus. Differing in terrain features and rainfall seasonality, the two sites provide useful testbeds for evaluating the coupled model. Model results are analyzed to identify the main physical processes that drive the observed forest structure and dynamics and to study the modulation of hillslope processes on how drought affects plant water availability and vegetation.

Title: Gradients and Environmental Controls of Stem Number Density, Tree Height and Volume in the Brazilian Amazon Using Lidar Crown Detection

António Ferraz[1,2,*], Michael Keller[1,3,4], Sassan Saatchi[1,2], Marcos Longo[5], Jean Ometto[6]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA; [2]Institute of the Environment and Sustainability, University of California, Los Angeles, CA; [3]International Institute of Tropical Forestry, USDA Forest Service, Rio Piedras, Puerto Rico; [4]Embrapa Agricultural Informatics, Campinas, SP, Brazil; [5]NASA Postdoctoral Program Fellow, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA; [6]National Institute for Space Research (INPE), São José dos Campos, SP, Brazil.

Contact: (Antonio.A.Ferraz@jpl.nasa.gov)

Project Lead Principal Investigator (PI): Jeff Chambers, Berkeley Lab

BER Program: ESS

Project: NGEE-Tropics

Project Website: https://ngee-tropics.lbl.gov/

Project Abstract: Tropical forests are critical to the function of the Earth system, but their tree size distribution is largely unknown because of the lack of systematic forest inventory that, in addition, limits the capabilities of satellites-based estimates (e.g. GEDI) as they critically rely on widespread reference observations. The size structure of forests is critical to demographic vegetation models such as FATES.As an alternative to ground inventory, we measure trees individually using high density airborne lidar data to estimate their structural properties by direct retrieval or through allometric models. We applied a lidar crown detection method to 470 randomly sampled airborne lidar plots (6.25ha each) collected in 2016 from a larger survey that randomly sampled terra *firme* forests across the entire Brazilian Amazon. For trees > 10 m tall, we calculated plot-level averaged values for stem number density (mean, 5^{th}-95^{th} percentile: 396, 281-509 trees ha^{-1}), average maximum tree height (43.9 m, 28.8-58.9 m), crown packing (19.7%, 9.2-26.8%) and basal area (28.2 m^2 ha^{-1}, 9.3-39 m^2 ha^{-1}). We found strong regional patterns with significant decreases in stem number density from northwest to northeast. In contrast, the gradient in tree height follows the opposite trend. The crown packing strongly decreases from northwest to southeast, whereas basal area follows a northeast-southwest gradient. Using a linear statistical model, we assessed environmental and disturbance controls (topography, soil fertility, forest fragmentation, climate, canopy-atmosphere interaction and climate stressors) on forest structure. We found that tree height and basal area are predominantly responses to topography and climate, crown packing is positively correlated with climate stressors (e.g. water deficit) and stem number density is also controlled by climate conditions. The explanatory power of the environmental factors is moderate and it varies when considering the entire Brazilian Amazon or regions individually. Our individual tree crown measurements represent a major advance to quantify the variability of the Amazon forest structure. While this approach does not replace detailed forest survey, it nonetheless provides consistent forest structure data where heretofore there was none.

Title: Tropical Forests and Emerging Hot Droughts

Charlie Koven[1*], Jeffrey Q. Chambers[1,2], Lin Meng[1], Gilberto Pastorello[1], Chonggang Xu[3], Rosie Fisher[4]

[1]Lawrence Berkeley National Lab, Berkeley, CA, USA; [2]University of California, Berkeley, Berkeley, CA, USA; [3]Los Alamos National Lab, Los Alamos, New Mexico, USA; [4]Centre national de la recherche scientifique, France.

Contact: (cdkoven@lbl.gov)

Project Lead Principal Investigator (PI): Jeff Chambers, Berkeley Lab

BER Program: ESS

Project: NGEE-Tropics

Project Website: https://ngee-tropics.lbl.gov/

Project Abstract: Under a warmer climate, precipitation variation will interact with changes to surface air temperature and humidity to drive strongly increased VPD during droughts. Understanding the response of tropical forests to these hot droughts is critical to projecting ecosystem feedbacks to climate change. The 2015 drought represents an early indicator of these dynamics, as it showed strongly increased VPD as compared to previous droughts, and thus serves as an example of these emerging events. We will present results showing results from the 2015 drought in the Amazon, the timing of emergence of different VPD thresholds from CMIP6 models, and FATES simulations of physiological responses to these VPD anomalies.