

## Symposium 24: Linking Field Experiments and Modeling Toward Understanding Changes to Tropical Ecosystems

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### Exploring Interactions between Tropical Forest and the Climate System over the 21<sup>st</sup> Century

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Tropical forests interact with the global carbon cycle in three major ways. First, intact tropical forests have been identified as a major sink for carbon, presumably driven by enhanced productivity under the rising concentration of atmospheric CO<sub>2</sub>. Second, deforestation and degradation of tropical forests result in large CO<sub>2</sub> emissions. Thirdly, regrowth of secondary forests on anthropogenic landscapes is estimated to be an additional large carbon sink. Yet there are large uncertainties in the current magnitude of these fluxes, and how they will change over the next 100 years under a changing atmosphere and warming climate. Toward projecting carbon cycle responses over the next century, current treatment of tropical forests in Earth system models (ESMs) is rudimentary at best, and a major research effort is required to codify our best process based knowledge into ESM representations of tropical forest functioning. This effort will require both a rigorous knowledge assessment using the available data, and new field investigations that target improved representations of critical processes. This talk will focus on ESM representation and data availability for three process areas: (1) forest carbon cycle-hydrology interactions, (2) disturbance and recovery processes (both natural and anthropogenic), and (3) pantropical variability in nutrient constraints on productivity.

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### GEM-Traits: A new global database linking tropical tree diversity to ecosystem function via functional traits

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Predicting changes in the structure, function, and diversity of tropical forest communities in a rapidly changing world is a major research challenge in ecology. There is a need to develop a predictive framework that translates changes in community composition to changes in ecosystem biomass, productivity, and biogeochemical function. Recently, a trait-based approach, where the key traits that underlie whole-plant performance are measured within and across species, has been heralded as the basis to develop a more predictive ecology. Traits are properties of an individual that ties its performance (e.g., reproduction, growth, and metabolism) to climatic drivers (e.g., precipitation and temperature) and are allowed to vary within and across species. Here, we discuss the conceptual motivation, methods and data management surrounding the creation of a new relational database linking tropical tree diversity to ecosystem function via functional traits. Then, using data extracted from this database from 5,025 leaves (605 trees) in Peru, we investigate the scaling of productivity along a 3500 m elevation gradient. In light of our results, we suggest sampling strategies for future trait and carbon cycling field campaigns that will lead to global-level analyses and rewarding collaborations via GEM-Traits.

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### The AmazonFACE research program: assessing the effects of increasing atmospheric CO<sub>2</sub> on the ecology and resilience of the Amazon forest

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The existence, magnitude and duration of a supposed “CO<sub>2</sub> fertilization” effect in tropical forests remains largely undetermined, despite being suggested for nearly 20 years as a key knowledge gap for understanding the future resilience of Amazonian forests and its impact on the global carbon cycle. Reducing this uncertainty is critical for assessing the future of the Amazon region as well as its vulnerability to climate change. The AmazonFACE (Free-Air CO<sub>2</sub> Enrichment) research program is an experiment of unprecedented scope in an old-growth Amazon forest near Manaus, Brazil – the first of its kind in tropical forest. The experimental treatment will simulate an atmospheric CO<sub>2</sub> concentration [CO<sub>2</sub>] of the future in order to address the question: “How will rising atmospheric CO<sub>2</sub> affect the resilience of the Amazon forest, the biodiversity it harbors, and the ecosystem services it provides, in light of projected climatic changes?” AmazonFACE is divided into three phases: (I) pre-experimental ecological characterization of the research site; (II) pilot experiment comprised of two 30-m diameter plots, with one treatment plot maintained at elevated [CO<sub>2</sub>] (ambient +200 ppmv), and the other control plot at ambient [CO<sub>2</sub>]; and (III) a fully-replicated long-term experiment comprised of four pairs of control/treatment FACE plots maintained for 10 years. A team of scientists from Brazil, USA, Australia and Europe will employ state-of-the-art methods to study the forest inside these plots in terms of carbon metabolism and cycling, water use, nutrient cycling, forest community composition, and interactions with environmental stressors. All project phases also encompass ecosystem-modeling activities in a way such that models provide hypothesis to be verified in the experiment, which in turn will feed models to ultimately produce more accurate projections of the environment. Resulting datasets and analyses will be a valuable resource for a broad community, especially ecosystem and climate modelers, and policy-makers.

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#### **Drought impact on forest carbon dynamics and fluxes in Amazonia**

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In 2005 and 2010, the Amazon basin experienced two strong droughts, driven by shifts in the tropical hydrological regime possibly associated with global climate change as predicted by some global models. Tree mortality increased following the 2005 drought and regional atmospheric inversion modelling showed basin-wide decreases in CO<sub>2</sub> uptake in 2010 compared to 2011. But the response of tropical forest carbon cycling to these droughts is not fully understood and there has not been a detailed multi-site investigation in situ. Here we use several years of data from a network of 13 one hectare forest plots throughout South America, where each component of NPP, autotrophic and heterotrophic respiration is measured separately, to develop a better mechanistic understanding of the impact of the 2010 drought on the Amazon forest. We find surprisingly that totalNPP remained constant throughout the drought. However, towards the end of the drought, autotrophic respiration, especially in roots and stems, declined significantly compared to measurements in 2009 made in the absence of drought, with extended decreases in autotrophic respiration in the three driest plots. In the year following the drought, totalNPP continued to remain constant but the allocation of carbon shifts towards canopyNPP and away from finerootNPP. Both leaf-level and plot-level measurements indicate that drought suppresses photosynthesis. Scaling these measurements to the entire Amazon using rainfall data, we estimate that drought suppressed Amazon-wide photosynthesis in 2010 by 0.38PgC(0.23-0.53PgC). Overall, we find that during episodic drought, instead of reducing total NPP trees prioritized growth by reducing autotrophic respiration. This suggests that trees reduce investment in tissue maintenance and defence, in line with eco-evolutionary theories which hypothesize that trees are competitively disadvantaged in the absence of growth. We propose that weakened maintenance and defence investment may, in turn, cause the increase in tree mortality following drought observed at our plots.

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#### **Will forests grow back after deforestation?**

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