Linking ecosystem demography modeling and field experiments to understand tropical forest response to novel disturbance regimes

Jennifer A. Holm[1], Charles D. Koven[1], Rosie A. Fisher[2], Ryan G. Knox[1], Robinson I. Negrón-Juárez[1], Jeffrey Q. Chambers[1,3], Daniel Magnabosco Marra[4,5,6], Sami W. Rifai[7], Niro Higuchi[6], Lara Kueppers[1]

[1] Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA 94720, USA
[2] National Center for Atmospheric Research, Boulder, CO 80301, USA
[3] Department of Geography, University of California, Berkeley, Berkeley, CA 94720, USA
[4] Institute of Biology, University of Leipzig, Johannisallee 21 04103 Leipzig, Germany
[5] Max Planck Institute for Biogeochemistry, Jena, Germany
[6] Brazil's National Institute for Amazonian Research, Manaus -AM, Brazil
[7] School of Forest Resources and Conservation, University of Florida, Gainesville, FL 32603, USA

ESS PI Meeting Abstract:

Changing climates and disturbance regimes of the 21st Century will push tropical ecosystems into novel states that have no-analog in the recent historical record. In addition, inaccurate simulations of tropical forests contributes to multiple biases in Earth System Models (ESMs) and results in disagreement among models regarding whether tropical forests will be future carbon sources or sinks. Vegetation demography, plant competition among tree size classes, mechanistic mortality, and plant functional traits strongly control carbon dynamics and energy budgets of the Earth's surface. These processes have not been represented in the widely used Community Land Model (CLM) until the recent inclusion of the Ecosystem Demography (ED) model into CLM 4.5, i.e., CLM-ED, which is the base model for further development in the NGEE-Tropics Project. The goal of this study was to compare ecosystem demography model predictions to field measurements across gradients in tropical carbon cycling and community composition in Amazonia. Models include a dynamic, individual-based demographic gap model, ZELIG-TROP, and the Ecosystem Demography v.2 (ED2) and CLM-ED dynamic vegetation models. Field measurements were used to generate both model parameterization and benchmarking datasets for the Amazon Basin as a whole, and the northwest Amazon (NWA) and the Central Amazon (CA) separately.
When comparing models of different scales, CLM-ED over-estimated biomass in the >100 cm size class by 90+ Mg ha^{-1}, thus largely overestimating aboveground biomass, and over predicts growth and mortality rates compared to field data. ED2 underestimated the aboveground biomass stock (231 vs. 312 Mg ha^{-1}) for a CA forest, and similar to CLM-ED exhibits fast growth and mortality rates leading to an over prediction of the Central Amazon carbon sink. Model validations of ZELIG-TROP confirmed that the NWA and CA simulations successfully reproduced observed values of net primary productivity, biomass, and leaf area index, and mortality rates, but predicted slightly lower growth rates. Modeling the existing tree mortality gradients across Amazonia is a complex task, yet essential to reliable prediction of carbon storage in a warmer climate. Using ZELIG-TROP, we evaluated the response of Amazonian forests to elevated mortality rates. The simulated NWA with doubled mortality rates (from 2% to 4%) was found to have a significant decrease in biomass (29.6%) and a slight decrease in NPP compared to a control simulation. However, there was a non-significant shift in community composition in the NWA forests (Wilcoxon rank sum, $Z=0.95$, $p=0.34$). When mortality was doubled in the CA significant changes in basal area and community composition were observed ($Z=2.28$, $p=0.02$) but this shift did not generate a community composition representative of the observed NWA. Our modeling results suggest that species composition in CA is more sensitive to a doubling of mortality rates than in NWA leading to a larger decrease in biomass in CA (41.9%).