THE CONTRIBUTIONS OF ROOT SYSTEMS TO DROUGHT RESPONSE IN THE AMAZON RAINFOREST

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EXECUTIVE SUMMARY

Rising global temperatures and changing patterns of precipitation are highlighting the vulnerability of tropical forests to heat- and drought-induced stress. As a critical global ecosystem, tropical forests sequester carbon, mediate weather patterns, and have impacts far beyond their regions. This research explores the role of tree root systems in mediating the impact of strong drought events. Model simulations of tree water uptake show that different combinations of tree traits will confer different degrees of resiliency to water limitation. Results from this work may be used to more effectively direct future measurement efforts and to improve predictions of tropical forest response.

RESEARCH CHALLENGE

Tropical forests cover less than 7% of the earth's surface but play a significant role in global water, energy, and carbon cycles. Rapid changes in forest structure owing to anthropogenic activities and changing climate may have significant imprints that extend far beyond the tropical regions. Current model projections of forest response are beset by uncertainties associated with tree water uptake under water limitation. Improvements in the representation of tree response to water limitation will help refine projections and inform conservation and policy actions.

METHODS & CODES

The computational complexity of single-plant models has previously limited incorporation of root systems' hydrological models at the forest plot or ecosystem scale. Over the past decade, developments in micro- and macroscale hybridization schemes have opened the door for highly scalable models of three-dimensional root water uptake and soil water physics.

In this work, root architectures that represent the structural and spatial distribution of roots were modeled using the open source RootBox model [1]. Each tree system was assigned hydraulic parameterization (*e.g.*, root hydraulic conductivity, water potential thresholds) based on statistically generated water usage strategies. These strategies may range from risky, which favor carbon assimilation over hydraulic integrity, to conservative, which will limit carbon assimilation and therefore water uptake to protect hydraulic pathways from damage. Root water uptake has been coupled with the massively parallel flow and transport model, PFLOTRAN [2], using hybridization techniques from [3].

Using these tools, the PI explored how tree roots contributed to forest drought resilience in areas of the Amazon rainforest during the 2015–2016 El Niño drought event. To tease apart the contributions of various ecophysiological properties, ensemble modeling approaches were employed that test a multitude of risk configurations and root distributions. Each of these approaches uses spatial distributions from the field site in the Tapajós National Forest (K67) located in the eastern Amazon River Basin in Brazil and is validated with data collected from the same region.

RESULTS & IMPACT

High stem density and functional diversity present large challenges for representing individual water uptake processes. Different scenarios of root functional diversity, largely tested through rooting depth, displayed significant differences in the onset of water limitation. Partitioning of roots into different depth classes dependent on size helped to alleviate the impacts of water limitation by allowing individuals to tap into separate soil water reserves, reducing the overall hydraulic stress of the system as monitored by root collar potential.

WHY BLUE WATERS

Advances in computational platforms such as Blue Waters allow for increased model fidelity, presenting an opportunity to model forests at higher degrees of detail at the scale of individual trees. In data-scarce spaces, systems like Blue Waters provide the resources needed to run many simulations. The high number of simulations allows for understanding sources of uncertainty and targeting future measurement campaigns, saving resources and increasing the impact of difficult fieldwork.

Elizabeth Agee completed a Ph.D. in environmental engineering from the University of Michigan in 2019, having worked under the direction of Valeriy Ivanov. Agee currently is a postdoctoral associate at the Oak Ridge National Laboratory.

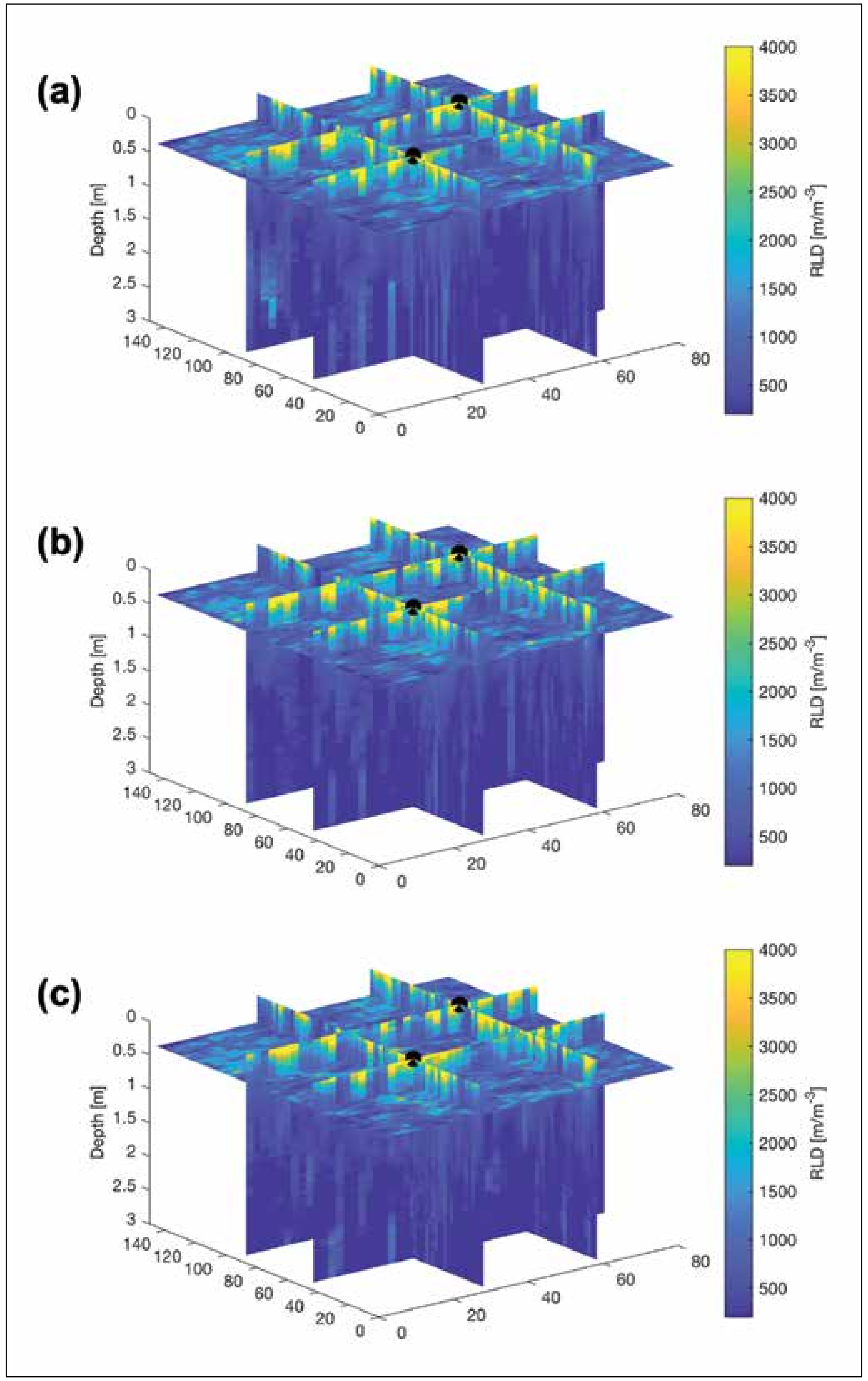

Figure 1: Three-dimensional root length density for three scenarios: (a) uniform rooting depth, (b) linear rooting depth, and (c) effective rooting depth.