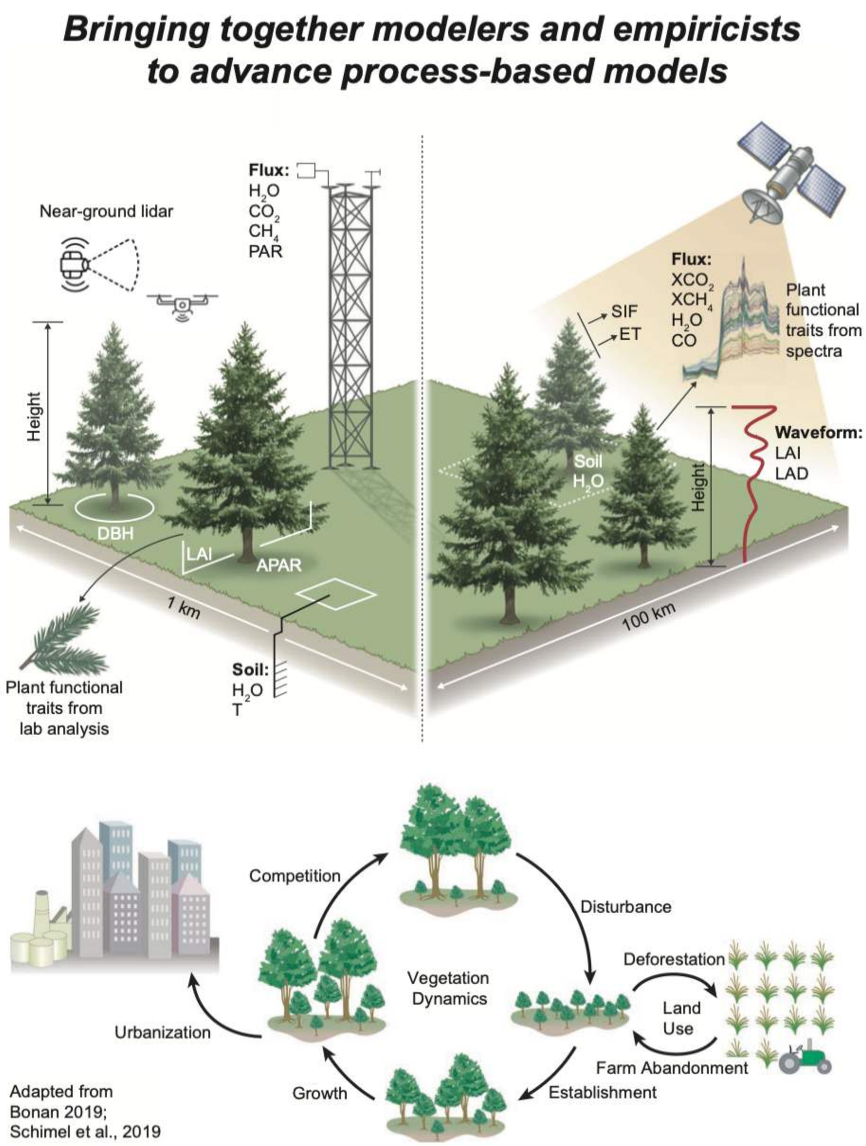
4th Annual

Dynamic Vegetation Modeling and Observations Conference

Marine Biological Laboratory, Wood Hole, Massachusetts, USA, April 8-10, 2026



Credit: Top image: Adapted from Schimel et al., 2019, New Phytologist
Bottom image: Bonan, G., 2019. Climate change and terrestrial ecosystem modeling. Cambridge University Press.

DVMOC. Marine Biological Laboratory, Woods Hole, Massachusetts, USA
https://aimesproject.org/dvmoc

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4th Annual
Dynamic Vegetation Modeling and Observations Conference
April 8-10, 2026

WELCOME

Dear Conference Attendee:

Welcome to the 4th Annual Dynamic Vegetation Modeling and Observations Conference (DVMOC). Building upon the predecessor meeting Eastern regional Dynamic Global Vegetation Conference (ER-DGVM-C), the overarching goals of the DVMOC conference are to forge closer ties among members of the vegetation modeling science community and to improve connections between the vegetation modeling community and researchers acquiring field and remote-sensing observations that are critical for parameterizing and evaluating the predictive capabilities of dynamic vegetation models.

A critical challenge to improving processed-based models is the disciplinary barrier between modelers and empiricists, which often leads to disconnects in research effort and outcomes. The theme of this year's meeting is thus: "Bringing together modelers and empiricists to advance process-based models". Strengthening the connections between models and measurements of ecosystem processes, plant communities, their interactions with other organisms, their responses to the environment, and their physiology is increasingly important given the burgeoning complexity of modern dynamic vegetation model formulations. Consequently, understanding the principles that govern vegetation processes, the landscape of available data describing these processes, and the limitations of these data is key to improving data assimilation, reducing model uncertainty, and enhancing predictive performance. We expect that the presentations and discussions at this year's DVMOC meeting will help bridge gaps in our community and advance the integration of modeling and observations.

We would like to thank our sponsor, Kudan Inc., for their generous support. Their instruments and solutions on 3D mapping provide novel and cost-effective opportunities to understand forest structure and dynamics in unprecedented detail. We are grateful to the New Phytologist Foundation, whose kind contribution supports the awards to early career researchers in our conference.

We would also like to thank the Analysis, Integration, and Modeling of the Earth System (AIMES) global research network of Future Earth. AIMES brings together Earth system scientists and scholars that work across disciplines to advance innovative, interdisciplinary ways to understand the complexity of the natural world and its interactions with human activities. We thank AIMES for their support of the research community through integrative working groups, outreach activities, and workshops like this one.

Finally, thank you to all attendees and sponsors for participating in this year's conference. We hope you will come away from it with new insights, collaborations, friendships and purpose.

Best regards,

Evan Gora
Conference Co-Chair
Cary Institute of Ecosystem Studies

Xiangtao Xu
Conference Co-Chair
Cornell University

Hannah Liddy
AIMES Executive Officer
Columbia University

4th Annual
Dynamic Vegetation Modeling and Observations Conference (DVMOC)

CONFERENCE OVERVIEW

WEDNESDAY, APRIL 8, 2026

4:00-5:30 pm Check-in, set up posters

5:00-6:30 pm Dinner in dining hall

6:30-6:40 pm Welcome and Opening Remarks

6:40-7:30 pm OPENING SESSION

7:30-7:40 pm Poster Pop-Up Talks

7:40-10:00 pm EVENING POSTER SESSION & MIXER

THURSDAY, APRIL 9, 2026

7:30-9:00 am Breakfast in dining hall

9:00-10:20 am MORNING ORAL SESSION 1: **PLANT RESPONSES TO THE ENVIRONMENT: FROM INDIVIDUALS TO ECOSYSTEMS**

10:20-10:30 am Coffee break

10:30-11:15 am MORNING ORAL SESSION 1 continued

11:15 am-12:15 pm MORNING ORAL SESSION 2: **PLANT ECOPHYSIOLOGY, INTERACTIONS, AND RESPONSES TO THE ENVIRONMENT**

12:15 pm Group photo

12:30-1:30 pm Lunch in dining hall

1:30-3:45 pm FREE TIME for impromptu meetings, walks, soccer, etc.

3:45-5:00 pm THURSDAY AFTERNOON ORAL SESSION 3: **FOREST DYNAMICS UNDER CHANGING DISTURBANCE REGIMES**

5:00-6:00 pm Dinner in dining hall

6:00-8:05 pm THURSDAY EVENING ORAL SESSION 4: **ECOSYSTEM FLUXES AND REGIONAL CARBON DYNAMICS**

8:05-10:00 pm POSTERS MIXER SESSION

FRIDAY, APRIL 10, 2026

7:30-9:00 am Breakfast in dining hall

9:00-10:20 am MORNING ORAL SESSION 1: **VEGETATION, LAND SURFACE PROCESSES, AND EARTH SYSTEM DYNAMICS**

10:35-10:50 am COFFEE BREAK

10:50-11:35 am MORNING ORAL SESSION 1 continued

11:35-11:50 am Student and postdoc presentation awards, announcement of next co-chairs and date

11:50-12:00 pm Conference feedback and general discussion

12:00-1:00 pm Lunch in dining hall

Conference End

4th Annual
Dynamic Vegetation Modeling and Observations Conference

ORAL & POSTER SCHEDULE

Updated: March 19, 2026

All talks will be held in the Meigs Room, next to the Dining Hall of the Swope Center, MBL.

WEDNESDAY, APRIL 8, 2026			
	WEDNESDAY EVENING: OPENING SESSION		
6:30	Evan Gora, Xiangtao Xu	Welcome and opening remarks	
6:40	César Terrer (KEYNOTE)	Missing Links of the Land Sink: How Soils, Microbes, and Birds Shape the Carbon Cycle	MIT
7:30	Juan Wee	Seeing the Forest through Lidar SLAM, and beyond	Kudan
7:40	Poster Pop-Up Talks	1-minute 1-slide talks for poster presenters ● Ben Bond-Lamberty ● Rong Li ● Nancy Kiang ● Lixin Lu ● Cameron Reimer ● Cameron Scholl	
7:50	**EVENING POSTER SESSION & MIXER**		

THURSDAY, APRIL 9, 2026			
	THURSDAY MORNING ORAL SESSION 1: PLANT RESPONSES TO THE ENVIRONMENT: FROM INDIVIDUALS TO ECOSYSTEMS		
9:00	Megan Blumstein (KEYNOTE)	Using Genomics to Improve Predications of Forest Response to Climate	University of Virginia
9:50	Yixin Ma	Environmental Sensitivity of Tropical Tree Woody Growth: The Role of Sink Limitation	Cornell University
10:05	Sophie Zwartsenberg	Beyond Carbon: A Turgor- and Xylogenesis-based Woody Productivity Module for ED2	Wageningen University

10:20	**COFFEE BREAK**		
10:30	Caleb Mensah	Tracking Forest Phenology in Relation to Carbon Fluxes in a Semi-Deciduous Tropical Ghanaian Forest Ecosystem	University of Energy and Natural Resources, Ghana
10:45	M. Reza Alizadeh	Causal Pathways of Trait-Mediated Land–Atmosphere Coupling in Grasslands	Michigan State University
11:00	Tao Han	The Impact of Soil Nutrients on Height Allometry Using Terrestrial Laser Scanning	Cornell University
11:15	Leila Mirzagholi	A Clumped-Foliage Canopy Radiative Transfer Model for a Demographic Dynamic Global Vegetation Model: Canopy Structure for Diurnal and Seasonal Albedo and Biomass	NASA GISS
	THURSDAY MORNING ORAL SESSION 2: PLANT ECOPHYSIOLOGY, INTERACTIONS, AND RESPONSES TO THE ENVIRONMENT		
11:30	Yidong Tong	Structural Diversity Buffers Ecosystem-Scale Transpiration Reduction Under Drought	UCLA
11:45	Matteo Detto	Species Coexistence in Forest Dynamics Models: Toward a Theory of Functional Diversity	Princeton University
12:00	Zhuoran Yu	Factors Determining the Successful Colonization of Trees by Lianas: A Model Sensitivity Analysis	University of Notre Dame
12:15	Yanlan Liu	Scaling plant hydraulic traits to predict ecosystem fluxes under drought	UCLA
12:30	**GROUP PHOTO**		
12:40	**LUNCH**		
1:30	**SUNSHINE, FREE TIME, IMPROMPTU MEETINGS**		
	THURSDAY AFTERNOON ORAL SESSION 3: FOREST DYNAMICS UNDER CHANGING DISTURBANCE REGIMES		
3:45	Ian McGregor	Quantifying Lightning Risk and Ecological Impact at Scale	Cary Institute of Ecosystem Studies
4:00	Liling Chang	Modeling Future Forest Dynamics Under Changing Fire Regimes in California	Florida State University
4:15	Xiangtao Xu	More than a Constant Background Disturbance Rate - Heterogeneity of Biomass Turnover Time in Tropical Forests	Cornell University
4:30	Yongfa You	Intensifying Compound Drought and Heatwave Events Increase Greenhouse Gas Emissions and	Virginia Tech

		Reduce Crop Yields in U.S. Croplands	
4:45	Evan Gora	The Consequences of Tropical Tree Mortality and Our Limited Understanding of Causation	Cary Institute of Ecosystem Studies
5:00	**DINNER**		
	THURSDAY EVENING ORAL SESSION 4: ECOSYSTEM FLUXES AND REGIONAL CARBON DYNAMICS		
6:00	Eric A. Davidson (KEYNOTE)	Minding our P's and Q's: How NPP and Climate Change Affect the Q10 of Heterotrophic Respiration	University of Maryland Center for Environmental Science
6:50	Jiameng Lai	Understanding the Spatio-Temporal Patterns of Amazon Productivity and its Environmental Drivers	Harvard University
7:05	Chi Chen	Light-driven acclimation sustains Amazon dry-season photosynthesis	Rutgers University - New Brunswick
7:20	Danyang Yu	Improving ELM-FATES' Seasonal Dynamics Of Photosynthesis Flux in Tropical Rainforests by Integrating Solar-Induced Chlorophyll Fluorescence (SIF)	Cornell University
7:35	Renato Braghiere	Rethinking Land Surface Modeling to Accelerate Process Development and Data-Constrained Prediction	Caltech/JPL
7:50	Yiqi Luo	Deep learning to evaluate time-dependent efficacy of carbon dioxide removal via forest restoration	Cornell University
8:05	**THURSDAY EVENING POSTER SESSION & MIXER**		

FRIDAY, APRIL 10, 2026			
	FRIDAY MORNING ORAL SESSION 1: VEGETATION, LAND SURFACE PROCESSES, AND EARTH SYSTEM DYNAMICS		
9:00	Chonggang Xu (KEYNOTE)	The MODEX Framework for Vegetation Modeling in the World of AI	Los Alamos National Laboratory
9:50	Jianing Fang	Differentiable Land Model Reveals Global Environmental Controls on Latent Ecological Functions	Columbia University
10:05	Ying Sun	Tracing and Predicting the Pulse of the Terrestrial Biosphere by Integrating Earth System Models and AI	Cornell University
10:20	Forrest Hoffman	Advancing Systematic Assessment of Terrestrial Biogeochemistry in Earth System Models	Oak Ridge National Laboratory
10:35	**COFFEE BREAK**		

10:50	Wenli Zhao	Learning the Past to Predict Extremes: Interpretable Sequential Machine Learning for Ecological Memory Across Land Surface Processes	Columbia University
11:05	Dan Short Gianotti	Stabilizing Behaviors of Vegetated Landscapes through Water-Energy-Carbon Spaces	MIT
11:20	Kaighin McColl	Large Overestimation of Projected Western U.S. Wildfire Burned Forest Area with Warming	Harvard University
11:35	Student and postdoc presentation awards, announcement of next co-chairs and date		
11:50	Conference feedback and general discussion		
12:00	**LUNCH**		
1:00	**CONFERENCE END**		

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POSTER LIST

All posters will be located outside of the Meigs Room for the duration of the conference.

Name	Title	Affiliation
Nancy Kiang	Land carbon response to positive, zero, and negative CO_2 emissions across Earth system models	NASA GISS
Ben Bond-Lamberty	Synchronously Coupling Human and Earth System Models Enables Novel Land Surface Research	Pacific Northwest National Laboratory
Rong Li	Quantifying Neighborhood and Species Interaction Effects on Tropical Tree Growth With Machine Learning and Long-Term Census Data	Cornell University
Lixin Lu	Improving Sub-Seasonal to Seasonal LAI Prediction for Earth System Model Using AI/Machine Learning	Colorado State University
Cameron Reimer	Characterizing Size Distribution of Hurricane-Induced Canopy Gaps Using Airborne and Satellite Remote Sensing	Cornell University
Cameron Scholl	Forecasting Defoliation Risk of the Invasive Spongy Moth Across its North American Range	Cornell University

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PARTICIPANT LIST

Reza Alizadeh (Professor, Michigan State University) – In-person
Land–atmosphere coupling, Soil-moisture drydown, photosynthetic pathway, Plant hydraulics
Speaker | Abstract | Website

Meghan Blumstein (Assistant Professor, University of Virginia) – In-person
forests; adaptation; genomics; prediction
Keynote | Abstract | Website

Ben Bond-Lamberty (Earth Scientist, PNNL) – In-person
Forest, Soil and Terrestrial Ecology, Terrestrial Carbon Cycling, Ecosystem Disturbance, Fire, Carbon Dioxide, Atmosphere, Climate
Poster | Abstract | Website

Renato Braghiere (Research Scientist, Caltech/JPL) – Virtual
land surface modeling; radiative transfer; model-data fusion; solar-induced fluorescence; Julia; CliMA
Speaker | Abstract | Website

Liling Chang (Assistant Professor, Florida State University) – In-person
fire impacts; terrestrial biosphere modeling; California's Sierra Nevada
Speaker | Abstract | Website

Chi Chen (Assistant Professor, Rutgers University - New Brunswick) – In-person
Radiation, Photosynthesis, Green-up, Acclimation, Amazon, Dry Season, Optimization Theory
Speaker | Abstract | Website

Eric A. Davidson (Professor Emeritus, University of Maryland Center for Environmental Science; Principal Scientist, Spark Climate Solutions) – In-person
microbes, respiration, soil, temperature
Keynote | Abstract | Website

Matteo Detto (Research Scholar, Princeton University) – In-person
successional dynamics; functional diversity; coexistence; negative density dependence
Speaker | Abstract | Website

Michael Dietze (Professor, Boston University) – In-person
Ecological forecasting, Predictability of ecological systems, Iterative forecasting & data assimilation, Terrestrial carbon cycle
Attendee | Website

Jianing Fang (PhD candidate, Columbia University) – In-person
differentiable modeling, hybrid modeling, adaptation, model-data fusion, plant trait. coordination
Speaker | Abstract | Website

Cory Garms (Senior Scientist, Spectral Sciences Inc.) – Virtual
Drones, Remote sensing, Environmental monitoring
Vendor | Website

Evan Gora (Forest Ecologist, Cary Institute of Ecosystem Studies) – In-person
tree death, forest carbon cycling, remote sensing, forest resilience
Co-Chair, Speaker | Abstract | Website

Tao Han (Postdoctoral Researcher, Cornell University) – In-person
Soil nutrients; Height allometry; Biomass; TLS; Tree segmentation
Speaker | Abstract | Website

Forrest Hoffman (Computational Earth System Scientist, and Group Leader, Oak Ridge National Laboratory) – In-person
model evaluation, metrics, benchmarking, ILAMB
Speaker | Abstract | Website

Nancy Kiang (Research Physical Scientist, NASA GISS) – In-person
Biosphere–atmosphere interactions, climate–vegetation feedbacks, photosynthesis, biogeochemical cycles, astrobiology, biosignatures, exoplanets
Organizer, Poster | Abstract | Website

Jennifer Kowalczyk (Postdoctoral Researcher, Lawrence Berkeley National Laboratory) – Virtual
ELM-FATES, NGEE-Tropics, Climate-vegetation interactions
Attendee | Website

Jiameng Lai (Postdoctoral Fellow, Harvard University) – In-person
ELM-FATES; GPP; Amazon rainforest
Speaker | Abstract | Website

Rong Li (Postdoctoral Fellow, Cornell University) – In-person
forest dynamics, tree growth, tropical forests, neighborhood competition
Poster | Abstract | Website

Yanlan Liu (Associate Professor, University of California, Los Angeles) – In-person
plant hydraulics, traits, scaling, ecosystem diversity, drought, model-data integration
Speaker | Abstract | Website

Lixin Lu (Research Scientist, Colorado State University) – In-person
LAI; Machine Learning; CNN-LSTM
Poster | Abstract | Website

Yiqi Luo (Professor, Cornell University) – In-person
Forest carbon removal, time-dependent CDR, biomass growth dynamics, machine learning (BINN)
Speaker | Abstract | Website

Yixin Ma (PhD candidate, Cornell University) – In-person
tropical forest; woody growth; sink limitation; environmental sensitivity; vegetation modeling
Speaker | Abstract | Website

Kaighin McColl (Associate Professor, Harvard University) – In-person
wildfires, aridity, climate change, projections, vapor pressure deficit
Speaker | Abstract | Website

Ian McGregor (Forest Ecologist, Remote Sensing Scientist, Cary Institute of Ecosystem Studies) – In-person
Lightning disturbance, tropical forest mortality, biomass dynamics
Speaker | Abstract | Website

Caleb Mensah (Lecturer, University of Energy and Natural Resources, Ghana) – Virtual
tropical phenology; MODIS GPP; pheno-cams; tropical forest carbon fluxes
Speaker | Abstract | Website

Leila Mirzagholi (NASA Postdoctoral Program Fellow, NASA GISS) – In-person
albedo; foliage clumping; vegetation demography; dynamic vegetation modeling
Speaker | Abstract | Website

Paul Moorcroft (Professor, Harvard University) – In-person
Ecological dynamics of terrestrial plant communities and ecosystems; biosphere-atmosphere interactions; mechanistic models of animal movement
Organizer | Website

Cameron Reimer (PhD Student, Cornell University) – In-person
Forest gaps; disturbance; remote sensing; tropical forests; LiDAR
Poster | Abstract | Website

Cameron Scholl (PhD Student, Cornell University) – In-person
Spongy moth, defoliation, biotic disturbances, carbon dynamics, remote sensing, ecological forecasting
Poster | Abstract | Website

Meicheng Shen (PhD Candidate, Michigan State University) – Virtual
Vegetation dynamics, Climate change impacts, Ecological/statistical modeling
Attendee | Website

Ziyang Tan (PhD Student, UCLA) – Virtual
Plant hydraulic traits and dynamics, model-data integration
Attendee | Website

Dan Short Gianotti (Research Scientist, Massachusetts Institute of Technology) – In-person
terrestrial ecosystem stability; water-energy-carbon coupling
Speaker | Abstract | Website

Shijie Shu (University of Maryland Center for Environmental Science) – Virtual
Earth system modeling • Land-use change • Ecological impacts
Attendee | Website

Ying Sun (Associate Professor, Cornell University) – In-person
CMIP6, AI, DL, Uncertainty, Carbon Cycle Projection.
Speaker | Abstract | Website

César Terrer (Professor, Massachusetts Institute of Technology) – In-person
carbon; vegetation; soils; nutrients.
Keynote | Abstract | Website

Yidong Tong (PhD student, University of California, Los Angeles, CA) – In-person
vegetation demographic model; plant hydraulics; transpiration; canopy structure; community competition
Speaker | Abstract | Website

Juan Wee (CEO, Kudan USA LLC) – In-person
Artificial perception, SLAM (simultaneous localization and mapping), robotics & drones, autonomous systems
Vendor | Website

Chonggang Xu (Staff Scientist, Los Alamos National Laboratory) – In-person
MODEX, plant hydrodynamics; AI; differentiable modeling; uncertainty, emulators
Keynote | Abstract | Website

Xiangtao Xu (Associate Professor, Cornell University) – In-person
biomass turnover, tropical forests, disturbance, carbon cycling, storms, vapor pressure deficit
Co-Chair | Abstract | Website

Yongfa You (Assistant Professor, Virginia Tech) – In-person
Compound droughts and heatwaves; Greenhouse gas emissions; Crop yield; U.S. croplands
Speaker | Abstract | Website

Danyang Yu (Postdoctoral Researcher, Cornell University) – In-person
Solar-induced chlorophyll fluorescence (SIF); Tropical rainforest; Seasonal carbon dynamic; ELM-FATES; Radiative transfer
Speaker | Abstract | Website

Zhuoran Yu (PhD Student, University of Notre Dame) – In-person
lianas; individual based model; Sobol' sequence; global sensitivity analysis.
Speaker | Abstract | Website

Qian Zhao (Postdoctoral Scholar, University of California, Los Angeles) – Virtual
Drought; deep learning; model-data integration
Attendee | Website

Wenli Zhao (Postdoctoral Scholar, Columbia University) – In-person
Ecological memory; Interpretable machine learning; Sequential deep learning; Land surface processes; Climate extremes; Vegetation–climate interactions.
Speaker | Abstract | Website

Sophie Zwartsenberg (PhD Student, Wageningen University and Research) – In-person
xylogenesis, turgor limitation, sink limitation, woody productivity, tropical forests, ED2, vapour pressure deficit
Speaker | Abstract | Website

4th Annual
Dynamic Vegetation Modeling and Observations Conference

ORAL AND POSTER ABSTRACTS

(Alphabetical order)

TALK:

Causal Pathways of Trait-Mediated Land–Atmosphere Coupling in Grasslands

M. Reza Alizadeh[1], Daniel Short Gianotti1[2], Dara Entekhabi[2]

[1]*Department of Civil and Environmental Engineering, Department of Biosystem and Ag, Engineering Michigan State University, MI, USA; alizad@msu.edu*
[2]*Department of Civil and Environment Engineering, MIT, MA.USA; gianotti@mit.edu, darae@mit.edu*

Abstract.

The forcing–response behavior of the vegetation–soil–atmosphere continuum shapes ecosystem water and carbon dynamics, especially during soil moisture drydowns between precipitation pulses. Although soil moisture (SM) and atmospheric vapor pressure deficit (VPD) both regulate plant function, their strong co-variation in observations can mask their distinct causal effects, with functional traits mediating how these drivers propagate through land–atmosphere feedbacks. Here we apply a causal inference framework to satellite time series of SM, VPD, and vegetation optical depth (VOD; a proxy for vegetation water content) to isolate dominant pathways linking soil and atmospheric dryness to plant water status across regional ecosystems, with particularly clear signals in grasslands across the United States. We identify two contrasting causal regimes that align strongly with photosynthetic pathway: (1) a vulnerable C3-dominated regime (65.8% of grasslands) in which plant water status is directly controlled by environmental water availability, leading to rapid desiccation as soils dry; and (2) a resilient C4-dominated regime (33.1% of grasslands) that partially decouples from surface conditions, sustaining vegetation water content and resisting the effects of increasing atmospheric and soil dryness. These trait-structured causal signatures provide observation-based benchmarks for process-based land-surface and dynamic global vegetation models that couple hydrology and land–atmosphere exchange. Integrating photosynthetic pathway–dependent regulation into Earth system models can improve predictions of drought impacts, ecosystem water–carbon trade-offs, and management-relevant outcomes in water-limited environments.

Key words: Land–atmosphere coupling, Soil-moisture drydown, photosynthetic pathway, Plant hydraulics

KEYNOTE:

Using genomics to improve predictions of forest response to climate

M. Blumstein[1,2], S. Webster[3], R. Hopkins[3,4], D. Basler[5], J. Yun[6], D. L Des Marais[6]

[1] *Environmental Sciences, University of Virginia, Charlottesville, VA; blumstein@virginia.edu*
[2]*Landscape Architecture, University of Virginia, Charlottesville, VA*
[3]*Department of Organismic and Evolutionary Biology, Harvard University; 26 Oxford St, Cambridge, MA 02138, USA*
[4]*The Arnold Arboretum; 1300 Centre St, Boston, USA 02130*
[5]*Department of Environmental Sciences, University of Basel; Schönbeinstrasse 6, 4056 Basel, Switzerland*
[6]*Civil and Environmental Engineering, Massachusetts Institute of Technology; 15 Vassar St, Cambridge, MA 02139, USA.*

Abstract
Trees are a vital stabilizing force for the climate and provide us with countless ecosystem services. Yet, forests are facing unprecedented levels of stress from pest and disease outbreaks, frequent and intense disturbance, fragmentation, and a changing climate. These stressors have already led to an increase of tree mortality events globally, altering forest composition from the regional scale to the cellular level. In response to stress, individual trees can plastically alter their traits within a generation, or species can migrate or adaptively evolve in order to persist. Given the extremity of predicted stress increases, all three will be critical for species survival.

In my talk, I will be exploring recent and newly developing work in my lab that aims to use broad-scale genomic sequencing to improve predictions of forest response to climate change. First, I test a key assumption underlying many forecasts: that space-for-time substitutions, such as urban heat islands, can reliably estimate forest responses to rising temperatures. Working with northern red oak (*Quercus rubra*), I combine genomic, phenological, and temperature data to show that urban forests harbor reduced within-species genetic diversity relative to nearby rural populations. This genetic structure systematically biases estimates of phenological sensitivity, leading to underpredictions of how strongly leaf-out advances with warming. Second, I will discuss using phonologic growth chamber experiments to parametrize process-models of phenology, then validating subsequent predictions using PhenoCam data and genomic sequences from the oak growing within the viewsheds. Together, these projects move beyond purely environmental correlations to incorporate evolutionary processes into predictive models, strengthening forecasts of forest responses to environmental change.

Key words: forests; adaptation; genomics; prediction

POSTER:

Synchronously Coupling Human and Earth System Models Enables Novel Land Surface Research

Ben Bond-Lamberty[1], Katherine V. Calvin[2], Dalei Hao[3], Eva Sinha[4], Alan Di Vittorio[5]

[1]*Joint Global Change Research Institute, Pacific Northwest National Laboratory, College Park, MD, bondlamberty@pnnl.gov*
[2]*Joint Global Change Research Institute, Pacific Northwest National Laboratory, College Park, MD, katherine.calvin@pnnl.gov*
[3]*Pacific Northwest National Laboratory, Richland, WA, dalei.hao@pnnl.gov*
[4]*Pacific Northwest National Laboratory,Richland, WA, eva.sinha@pnnl.gov*
[5]*Lawrence Berkeley National Laboratory, Berkeley, CA, avdivittorio@lbl.gov*

Abstract. Feedbacks between human societies and the broad environment affect biogeocycling, energy fluxes, and vegetation distribution at local to regional scales, but the human and land dynamics are usually modeled separately. We developed a highly novel, synchronously-coupled human component in the Energy Exascale Earth System Model (E3SM) that links the Global Change Analysis Model (GCAM) with the E3SM land and atmosphere models. Coupling these models strongly affected vegetation and land allocation in the modeled SSP2‐RCP45 scenario. At the global level the novel coupled model exhibited an increasing trend of vegetation productivity, and decreasing soil carbon, with considerable inter‐period variability. The largest changes in land allocation due to including feedbacks were in total cropland (-5% in 2075) and unmanaged forest (+3.5% in 2100), with some increase in total forest by the end of the century. Other outputs affected by the human-earth system feedbacks included crop prices, terrestrial carbon, local surface temperature, and climate extremes. Regional differences were more pronounced than global differences because the effects are driven primarily by differences in land use. This work enables the development of novel scenarios and further exploration of human-earth system feedbacks, including those linking the climate, water cycle, and energy systems.

Key words: vegetation feedbacks; human-earth systems; land use; energy.

TALK:

RETHINKING LAND SURFACE MODELING TO ACCELERATE PROCESS DEVELOPMENT AND DATA-CONSTRAINED PREDICTION

Renato K. Braghiere[1,2]

[1]*Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA; renato.braghiere@caltech.edu*
[2]*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA*

Abstract. Land surface models (LSMs) are central to weather and climate prediction, yet persistent mismatches between observation-based constraints and process-based simulations suggest that key land processes and their parameterizations are still not represented or constrained well enough. At the same time, the volume and diversity of Earth observations is rapidly expanding, including imaging spectroscopy, solar-induced fluorescence (SIF), and structurally resolved canopy products, creating a timely opportunity: rather than treating observations as a post-hoc evaluation dataset, we can design LSMs to directly interface with observables and systematically learn from them. In this talk, I will introduce ClimaLand.jl, an open, modular land surface model being developed within the Climate Modeling Alliance (CliMA). I will highlight the design principles that enable faster, safer iteration on process hypotheses — clear component interfaces, numerically robust solvers, and a modern implementation in Julia designed with performance portability in mind. I will discuss how these choices differ from established LSMs in terms of extensibility, experiment velocity, and pathways to incorporate data-driven approaches including model-data fusion, uncertainty quantification, and machine-learning-assisted parameterizations. Finally, I will show an example of bringing the model closer to observables via trait-informed canopy optics and radiative transfer, illustrating how observation-constrained process choices propagate to surface energy and carbon outcomes. I will outline a roadmap for integrating next-generation Earth observations into routine land model development and evaluation.

Key words: land surface modeling; radiative transfer; model-data fusion; solar-induced fluorescence; Julia; CliMA.

TALK:

Modeling Future Forest Dynamics under Changing Fire Regimes in California

Liling Chang[1], Shaoqing Liu[2], Alexander Antonarakis[3], Marcos Longo[4], Hao Tang[5], John David Armston[6], Ralph Dubayah[6] & Paul Moorcroft[2]

[1] Florida State University, [2] Harvard University, [3] University of Sussex, [4] Instituto Nacional de Pesquisas Espaciais, [5] National University of Singapore, [6] University of Maryland

Abstract. Wildfire plays an important role in shaping the structure, species composition, and carbon balance of California's forests and woodlands. Over the past century, however, widespread fire suppression together with increasing temperatures and aridity has disrupted historical regimes, shifting from frequent, low-severity fires toward larger and more severe events. These changes raise uncertainty and concerns about the long-term resilience of these ecosystems and their ability to maintain carbon stocks under continued climate change.

To evaluate future ecosystem responses, we integrated vertical forest structure estimates from NASA's Global Ecosystem Dynamics Investigation (GEDI) LiDAR measurements and species composition from the U.S. Forest Inventory and Analysis (FIA) program into the Ecosystem Demography model (ED2.2). The model was driven by downscaled CMIP6 climate projections spanning 2020–2099, with fire regimes produced using scenarios derived from observed patterns of burn extent and severity.

Model projections indicate strong impacts of drought stress and fire disturbance on aboveground biomass (AGB) and ecosystem composition. Less frequent large fires occurring at roughly 30-year intervals allow substantial biomass recovery but increase susceptibility to drought-related mortality, whereas more frequent severe fires (5–10-year intervals) constrain biomass accumulation and promote transitions toward pine-dominated stands. Marked spatial variability in these responses highlights the interacting roles of vegetation structure, climate forcing, and disturbance history. Overall, this work demonstrates the value of assimilating high-resolution remote sensing and inventory data into process-based models to predict forest carbon dynamics and support climate-informed management in fire-prone regions.

Key words: fire impacts; terrestrial biosphere modeling; California's Sierra Nevada.

TALK:

Light-driven acclimation sustains Amazon dry-season photosynthesis

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Abstract. Resolving the nature and drivers of photosynthetic seasonality in the Amazon is central to understanding tropical forest dynamics. A key uncertainty centers on whether this seasonality is driven by structural phenology, meteorology, or acclimation – reflecting seasonal functional adjustments to prevailing conditions. We integrate eddy covariance measurements, multi-sensor satellite retrievals, and eco-evolutionary optimization (EEO)-based modeling to elucidate the drivers. Optical, lidar, and microwave observations consistently reveal an apparent structural green-up during the dry season, predominantly in the lower canopy (< 5m). However, radiative transfer and EEO modeling suggest that such green-up plays a minor role in driving dry-season increase in photosynthesis. The dry-season photosynthesis enhancement is instead driven by greater light availability but can only be sustained through acclimation-driven increases in photosynthetic capacity, which is most evident in the upper canopy (> 5m). Further model-data analyses show that increased radiation triggers stomatal opening, elevates vapor pressure deficit, diminishes soil moisture, and reduces intercellular CO_2 concentrations, which together lead to higher photosynthesis and evapotranspiration but lower water and light use efficiencies. Our findings highlight the need for acclimation-aware models to capture Amazon's responses to changing light and water conditions.

Key words: *Radiation, Photosynthesis, Green-up, Acclimation, Amazon, Dry Season, Optimization Theory*.

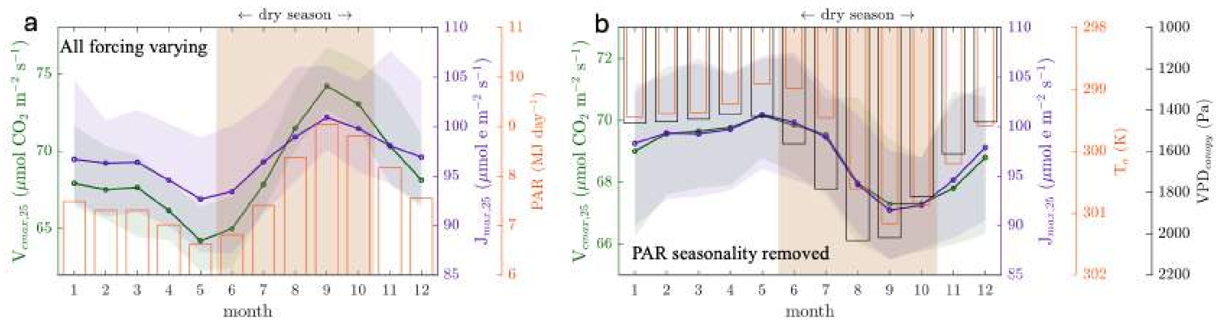

Figure 1. **Seasonality of canopy-level photosynthetic capacity, expressed by either V_{cmax} or J_{max}**. (a) Seasonal cycles of $V_{cmax,25}$, $J_{max,25}$, and PAR estimated by the EEO model with all forcings varying. (b) Seasonal cycles of $V_{cmax,25}$, $J_{max,25}$, air temperature, and canopy VPD estimated by the EEO model with PAR seasonality removed. Shaded areas indicate the interannual range. The subscript "25" indicates that V_{cmax} or J_{max} is normalized to 25 °C following ref.40. Unit of $V_{cmax,25}$ or $J_{max,25}$: μmol m^{-2} ground s^{-1}.

KEYNOTE:

MINDING OUR p's AND q's: HOW NPP AND CLIMATE AFFECT THE Q10 OF HETEROTROPHIC RESPIRATION

Eric A. Davidson

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and Spark Climate Solutions

Abstract. In temperate and boreal systems, soil respiration is usually the largest component of total ecosystem respiration, and heterotrophic respiration (HR) is usually the largest component of soil respiration. Despite its quantitative importance, HR is often modeled as a simple Q10 function based on air or soil temperature. However, numerous temperature-dependent processes besides the temperature response of respiratory enzymes also affect HR. These confounding simultaneous processes, which include soluble C production and transport, gaseous transport, soil moisture dynamics, freeze-thaw events, microbial growth, and *de novo* enzyme synthesis, can mask or amplify the observed temperature dependence of HR. Observed Q10's below 2 or above 3 usually indicate multiple temperature-dependent processes affecting HR simultaneously. These processes are dynamic and complex, so a site does not have a single Q10 value as a reliable, site-specific, emergent property to simplify modeling. Substrate supply, as affected by diffusion of soluble-C substrates in soil water films and O_2 diffusion in air-filled soil pore spaces is often dynamic. The tested, parsimonious Dual Arrhenius Michaelis-Menten (DAMM) model simulates these diffusional constraints as soil water varies, without using curve fitting. Likewise, variation in the enzymatic capacity of HR can be parsimoniously included, although appropriate parameters for its representation needs further research. This approach for HR has also been successfully applied to total ecosystem respiration, although the mechanistic linkages within plants may be more complex. Finally, DAMM has also been applied to soil fluxes of methane and nitrous oxide, again linking temperature and substrate supply via soil moisture. A common criticism of Dynamic Global Vegetation Models is that they fail to represent microbial processes, which is well taken, but to do so we will need parsimonious approaches that rely on available data with appropriate spatial and temporal resolution. I propose that proper representation of the effects of soil moisture and temperature and relatively simple indicators of the relevant enzymatic capacities provide a way forward to improve modeling of soil emissions of CO_2, CH_4, and N_2O.

Key words: microbes, respiration, soil, temperature

Figure 1. The Dual Arrhenius Michaelis-Menten (DAMM) model for heterotrophic respiration (Davidson et al., 2012, Global Change Biology, 18, 371–384). S - organic-carbon substrate; BD - bulk density; PD - particle density, D - diffusivity; Θ - volumetric soil moisture; *a* - air-filled porosity; Ea - activation energy; kM - half saturation constant; α - Arrhenius pre-exponential factor; T is soil temperature.

$$\mathbf{Sxsoluble} = \mathbf{Sxtotal} \times \boldsymbol{p} \qquad \mathbf{airfilled\ porosity} = \mathbf{1} - \frac{\boldsymbol{BD}}{\boldsymbol{PD}} - \boldsymbol{\Theta}$$

$$[\mathbf{Sx}] = \mathbf{Sxsoluble} \times \boldsymbol{\Theta}^{\mathbf{3}} \times \mathbf{Dliq} \qquad [\boldsymbol{O2}] = \mathbf{Dgas} \times \frac{\mathbf{0.2LO2}}{\boldsymbol{Lair}} \times \boldsymbol{a}^{\mathbf{4/3}}$$

$$\mathbf{RSx} = \mathbf{VmaxSx} \times \frac{[\mathbf{Sx}]}{\mathbf{kMSx} + [\mathbf{Sx}]} \times \frac{[\mathbf{O2}]}{\mathbf{kMO2} + [\mathbf{O2}]}$$

$$\mathbf{kMO2} = \boldsymbol{\alpha}\mathbf{kMO2} \times \boldsymbol{e}^{-\boldsymbol{EaO2/RT}}$$

$$\mathbf{kMSx} = \boldsymbol{\alpha}\mathbf{kMSx} \times \boldsymbol{e}^{-\boldsymbol{EakMSx/RT}}$$

$$\mathbf{VmaxSx} = \boldsymbol{\alpha}\mathbf{VmaxSx} \times \boldsymbol{e}^{-\mathbf{EaVmaxSx/RT}}$$

$$\boldsymbol{\alpha} = \mathbf{f(enzymatic\ capacity)}$$

TALK:

SPECIES COEXISTENCE IN FOREST DYNAMICS MODELS: TOWARD A THEORY OF FUNCTIONAL DIVERSITY

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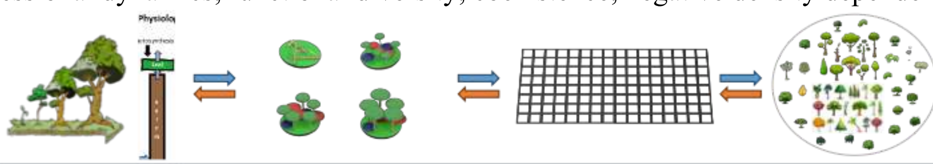
Abstract. Understanding how tree species coexist in forests remains a central challenge in ecology. I present mechanistic forest dynamics models that integrate physiological trade-offs, demographic processes, and spatial structure to explain the maintenance of high diversity under competition for light. By incorporating conspecific negative density dependence and evolutionary feedbacks, these frameworks unify coexistence theory with empirical patterns of forest diversity. Beyond advancing ecological theory, this mechanistic understanding of trait–demography interactions provides a foundation for improving the terrestrial vegetation components of global climate models, enabling more realistic predictions of biodiversity–function relationships under environmental change.

Key words: successional dynamics; functional diversity; coexistence; negative density dependence.



level of organization	plant level	forest patch	forest mosaic	metacommunity
spatiotemporal scales	plant growth/mortality (annual, plant scale)	successional dynamics (single generation)	community dynamics (multiple generations)	evolutionary time
processes	physiological processes (photosynthesis, allocation)	local interactions (resource competition, CNDD)	demographic processes (disturbances, dispersal)	selection/speciation

Figure 1. Proposed Theoretical Framework for Studying Forest Diversity. This framework captures the hierarchical structure of forest ecosystems, encompassing different levels of ecological organization—metacommunity, forest mosaic, patch, and individual plants. It integrates ecological processes across spatial and temporal scales, from evolutionary time and species selection to population dynamics, patch dynamics, and individual growth and mortality. Each level is interconnected through bidirectional interactions, ensuring that local processes influence broader patterns of forest diversity.

TALK:

Differentiable Land Model Reveals Global Environmental Controls on Latent Ecological Functions

Jianing Fang[1], Kevin Bowman[2], Wenli Zhao[1], Xu Lian[1], and Pierre Gentine[1]

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Abstract. The spatial distribution of plant functional traits observed today are living imprints of current environmental gradients and past selection, offering insight into how plants have adapted to their environments. What remains insufficiently understood is how traits combine and coordinate across environments, and whether such coordination reflects organizing principles in ecology that can improve modeling of ecosystem functional diversity and decadal-scale carbon exchange. Here we present DifferLand[1], a differentiable hybrid model that learns high-dimensional, coordinated environment–trait relationships directly from multi-modal satellite and in situ observations (Figure 1). DifferLand reveals a small number of latent axes that represent how suites of plant traits jointly shape vegetation dynamics and carbon–water fluxes, enabling the model to capture both long-term adaptation patterns and short-term responses to meteorological variability, and to outperform models that rely solely on plant functional types in spatial generalization. The spatialization network learns nonlinear interactions between plant functional attributes and environmental gradients, organizing latent ecological parameters that represent functional traits at the global scale. This latent environment–trait structure reveals large-scale patterns of ecosystem functional diversity and improves the spatial generalization of terrestrial biosphere models.

Key words: differentiable modeling, hybrid modeling, adaptation, model-data fusion, plant trait. coordination

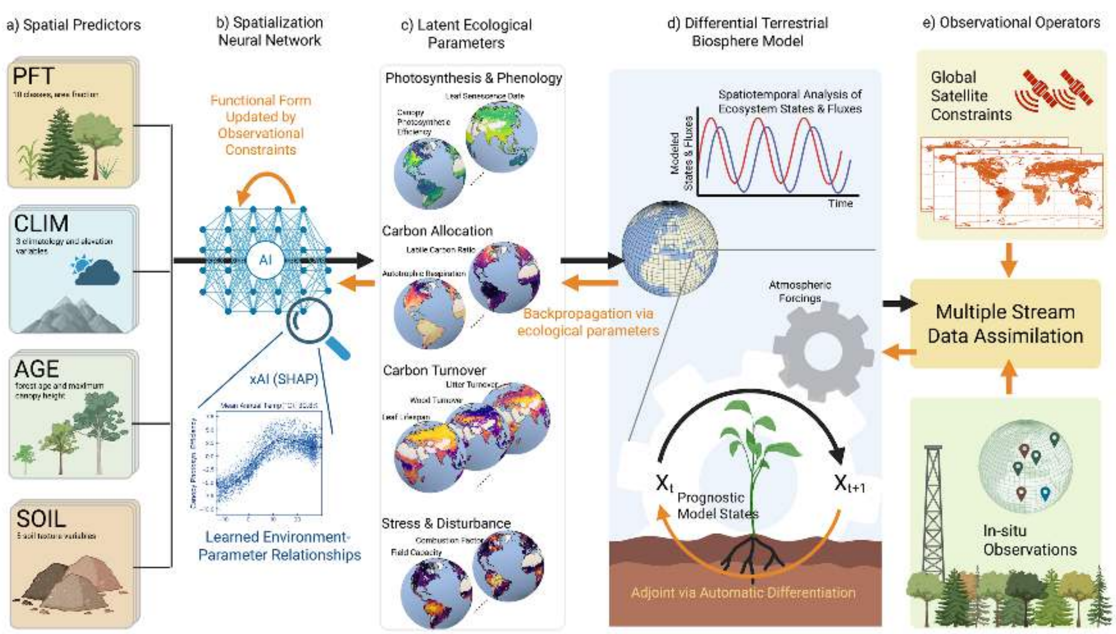

Figure 1. Schematics of the DifferLand framework.

[1] Fang, J., Bowman, K., Zhao, W., Lian, X., & Gentine, P. (2024). Differentiable land model reveals global environmental controls on ecological parameters. *arXiv preprint arXiv:2411.09654*.

TALK:

The consequences of tropical tree mortality and our limited understanding of causation

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Abstract. Tree mortality drives forest structure, composition, and carbon cycling, but its causes, consequences, and trends remain poorly constrained for tropical forests. The reasons for our limited understanding are logistical; mortality is rare, spatially clustered, and strongly size dependent, while different agents of mortality—including storms, drought, temperature stress, fire, and human disturbance—vary widely in their spatial extent, severity, and aggregation. Here, we synthesize how major mortality agents differ in their structural and compositional consequences and evaluate the extent to which these causes and trends of mortality can be detected using existing methods and tools. Using simulations, we show that even a doubling of biomass mortality, which would halve biomass carbon storage, is challenging to detect using current plot networks, raising questions about the meaning of non-significant findings or differences in forest responses to changing climate. Moreover, we show that challenging-to-detect press events such as slow increases in VPD or storm activity are more likely to cause major increases in biomass mortality than more readily-detected pulse events, such as droughts and heatwaves. Comparing the spatial and temporal scales of mortality processes with those of common observation methods (e.g., various satellites and forest plots) reveals critical blind spots in our ability to detect and attribute forest change. Resolving these limitations is essential for understanding tropical forest dynamics and improving predictions of forest responses to global change.

Key words: tree death, forest carbon cycling, remote sensing, forest resilience.

TALK:

THE IMPACT OF SOIL NUTRIENTS ON HEIGHT ALLOMETRY USING TERRESTRIAL LASER SCANNING

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Abstract. Soil nutrients are fundamental resources that regulate plant growth and ecosystem productivity, yet most nutrient‑enrichment studies have focused primarily on diameter responses while largely overlooking height growth and height allometry, key dimensions for improving our understanding in carbon stock estimates. The rapid advancement of terrestrial laser scanning (TLS) now enables unprecedented three-dimensional characterization of forest structure, offering us a powerful tool to quantify nutrient effects on tree height allometry with greater accuracy. In this study, we introduce a novel TLS workflow that integrates individual-tree segmentation with quantitative structure modeling (QSM) to evaluate how soil nutrient availability changes height allometry across species and size classes. Our results reveal that nutrient enrichment tends to disproportionately enhance height growth relative to diameter growth, particularly in smaller trees, indicating a shift toward a more vertical growth strategy under nutrient-rich conditions. We also find clear species differences, with maple exhibiting weaker height responses compared to beech under the same nutrient conditions. Overall, these findings provide an important insight for understanding how forests adjust their structural strategies under changing nutrient regimes. By capturing these nuanced allometric responses, our TLS framework can provide critical empirical constraints for ecosystem and Earth system models, improving their ability to predict forest productivity, carbon allocation patterns, and long-term carbon sequestration under future climate change.

Key words: Soil nutrients; Height allometry; Biomass; TLS; Tree segmentation

TALK:

Advancing Systematic Assessment of Terrestrial Biogeochemistry in Earth System Models

Forrest M. Hoffman[1], Nathan Collier[1], Weiwei Fu[2], Gretchen Keppel-Aleks[3], Charles D. Koven[4], Jitendra Kumar[5], David M. Lawrence[6], Elias Massoud[1], Mingquan Mu[7], Morgan Steckler[1], Min Xu[1], Qing Zhu[4], and James T. Randerson[7]

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Abstract. Driven by the increasing complexity of Earth system models (ESMs) is a growing need for comprehensive and multi-faceted evaluation of model predictions across spatial and temporal scales. Improved representations of biogeochemistry–hydrology interactions and ecosystem processes in ESMs are essential for reducing uncertainties over sub-seasonal and seasonal-to-decadal time scales. For over a decade, the terrestrial modeling community has been developing diagnostic approaches for evaluating ESM hydrological and biogeochemical process representations through the International Land Model Benchmarking (ILAMB) package (http://www.ilamb.org/), an open source benchmarking system that leverages the growing collection of laboratory, field, and remote sensing data. This benchmarking system performs comparisons of model results with best-available observational data products, focusing on biogeochemistry, hydrology, nutrients and soil organic matter, ecosystem processes and states, and vegetation dynamics. To advance understanding of biogeochemical processes and their interactions with hydrology under conditions of changes in extreme events and atmospheric composition, new methods are needed that use observations to constrain model predictions, inform model development, and identify needed measurements and field experiments. The 2025 ILAMB Hybrid Meeting was held on December 11–13, 2025, in New Orleans, Louisiana, to identify next generation benchmarking priorities. Discussions focused on high resolution for continental-to-regional domains, new seasonal-to-decadal evaluation metrics, artificial intelligence/machine learning approaches for interrogating model process representations, and new metrics for extreme events and process-specific experiments. This presentation will review the current ILAMB package capabilities and cover highlights from the 2025 ILAMB Hybrid Meeting that prioritize continued exploration and development of model evaluation and benchmarking.

Keywords: model evaluation, metrics, benchmarking, ILAMB.

POSTER:

Land Carbon Response to Positive, Zero, and Negative CO_2 Emissions Across Earth System Models

Abigail L. S. Swann[1,2*], Charles D. Koven[3], Cristian Proistosecu[4,5], Rosie A. Fisher[6], Benjamin M. Sanderson[6], Victor Brovkin[7,8], Tomohiro Hajima[9], Chris D. Jones[10,11], **Nancy Y. Kiang**[12,13], David M. Lawrence[14], Spencer Liddicoat[11], Hannah Liddy[13], Anastasia Romanou[12,15], Roland Séférian[16], Lori T. Sentman[17], Norman J. Steinert[6], Jerry Tjiputra[18], and Tilo Ziehn[19]

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Abstract. Land carbon sinks are responsible for removing about a quarter of anthropogenic CO2 emissions, and make up approximately half of total global carbon sinks. Uncertainty in the response of land carbon sinks to climate and changing atmospheric CO2 are large, and dominate the uncertainty in total carbon sinks under future climate. Understanding the carbon cycle response to net-zero and net-negative emissions has important implications for projecting future climate. Experiments in the 'flat10' model intercomparison were designed for directly estimating key climate metrics that underlie carbon budgeting frameworks. Here we characterize the response of land carbon pools and fluxes from ten emissions-driven Earth system models (ESMs) under positive, net-zero, and net-negative CO2 emissions. Although there are many differences in simulated land carbon pools and fluxes across models, we find some consistent behavior across ESMs. 1) During the positive emissions phase, carbon is gained on land primarily in vegetation pools. 2) Following net-negative emissions to the point of cumulative zero emissions, carbon is lost from land in tropical latitudes, primarily from vegetation pools, but in mid- and high-latitudes most models show net land carbon gain, primarily in soil pools. 3) Following an extended period of net-zero emissions, a majority of models again show carbon gain in mid- and high-latitudes and vegetation carbon loss in the tropics. Under net-negative emissions the timing of vegetation carbon response relative to peak emissions is relatively consistent across ESMs, but timing of soil carbon response varies widely, implying larger intermodel disagreement associated with responses of soil carbon which tends to have longer timescales relative to vegetation carbon. Our findings highlight that tropical carbon is most likely to be both gained and subsequently lost under positive, zero, declining, and negative emissions, with possible implications for carbon dioxide removal efforts.

TALK:

Understanding the spatio-temporal patterns of Amazon productivity and its environmental drivers

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Abstract. Amazon forests are crucial to the past and future dynamics of global carbon sinks, but the spatio-temporal patterns of gross primary production (GPP) in the Amazon remain poorly constrained due to scarce in-situ observations and the complex relationship between tropical carbon flues and climate variability. Field-based studies documented a GPP gradient, with higher productivity in the wetter and more fertile western Amazon and lower productivity in the drier and less fertile eastern Amazon. However, satellite remote sensing based GPP estimates and current land surface models failed to reproduce such a west-to-east decreasing longitudinal gradient in Amazon GPP; consequently, the environmental drivers for such a gradient remain largely unknown. This study uses ELM-FATES (Energy Land Model - Functionally Assembled Terrestrial Ecosystem Simulator) as the vegetation model to simulate land carbon-water fluxes. Point simulations initialized with local inventory data are conducted at several sites across the Amazon rainforest and are calibrated with in-situ eddy covariance (in eastern and central Amazon) and biometric observations (in western Amazon). Factorial simulations with varying representations of model structures and parameters will be conducted to evaluate the interactive impact of environmental factors and forest composition on GPP.

Key words: ELM-FATES; GPP; Amazon rainforest.

POSTER:

QUANTIFYING NEIGHBORHOOD AND SPECIES INTERACTION EFFECTS ON TROPICAL TREE GROWTH WITH MACHINE LEARNING AND LONG-TERM CENSUS DATA

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Abstract. Tree growth is regulated by complex interactions among tree size, species, abiotic environment, and neighborhood. Understanding the drivers of tree growth is critical for modeling the dynamics of forest biomass and biodiversity and for informing forest management. Among the factors affecting tree growth, neighborhood impact is highly uncertain and poorly represented in statistical and process-based models. Most statistical models characterize neighborhood effects using predefined indices and functional forms (e.g, log-linear relationship with the neighborhood competition index). They are thus unable to represent non-linear or spatially explicit effects, limiting our ability to investigate potentially more complex relationships. Furthermore, neighborhood effects are represented through spatially implicit light and water competition in vegetation demographic models and are rarely benchmarked directly.

In this study, we investigate the neighborhood impact on individual tree growth in two long-term tropical forest census plots: the Luquillo Forest Dynamics Plot in Puerto Rico, and the Barro Colorado Island (BCI) plot in Panama. We modeled individual tree growth using the XGBoost model based on focal tree species, diameter, various neighborhood indices, and spatial coordinates. At both sites, the focal tree species was the dominant predictor of growth, accounting for 55% of the model's total performance gain at Luquillo and 75% at BCI. Focal tree diameter was the second most important predictor, accounting for 28% and 19% of the performance gain at Luquillo and BCI, respectively. At both sites, tree growth was suppressed by neighbors, and we found enhanced suppressions by conspecific neighbors. However, neighborhood indices accounted for only 3.4% of the total performance gain at BCI, while they accounted for 10.0% at Luquillo. We also modeled tree growth with a graph neural network that can represent complex spatially explicit interactions and does not rely on predefined indices and functional forms. Preliminary results show that the graph neural network yielded similar predictive performance as the XGBoost model, indicating that the contribution of spatially explicit interactions to tree growth might be limited.

Our work provides a framework for better utilizing the accumulating forest census data to understand tree growth and forest dynamics. The findings can then improve the parameterization and process representation of growth in dynamic vegetation models, and provide insights into forest management and conservation strategies.

Key words: forest dynamics, tree growth, tropical forests, neighborhood competition

TALK:

Scaling plant hydraulic traits to predict ecosystem fluxes under drought

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Abstract. Plant hydraulics govern water transport through plants and mediate ecosystem responses to soil and atmospheric water deficits during drought. Expanding measurements of hydraulic traits and advances in hydraulic modeling have improved mechanistic predictions of ecosystem-scale water and carbon fluxes in drought. However, mismatches between individual-scale trait measurements and ecosystem-scale model representations introduce large uncertainty and obscure how drought impacts propagate across scales. Here, we synthesize four major sources of scale-induced uncertainty: trait variability, Jensen's inequality, within-community processes, and compensation errors. We then present case studies that contribute to bridging these spatial scale gaps through forward-scaling and inversion approaches. In the forward-scaling case, using the vegetation demographic model ELM-FATES, we show that the same hydraulic traits produce more buffered transpiration sensitivity to drought in structurally diverse ecosystems than in homogeneous ecosystems. This result indicates that community processes emerging from structural diversity, such as shading and competition for stratified soil water pools, modulate ecosystem-scale drought responses beyond what individual-scale physiological dynamics alone would predict. In the inversion case, we estimate ecosystem-effective hydraulic traits that allow a representative dummy plant to reproduce observed ecosystem-scale evapotranspiration (ET). Using high-resolution ECOSTRESS ET within a model–data fusion framework, we retrieve these traits from fine (210 m) to coarse (1/8°) scales. We find that community-averaged traits fail to capture ecosystem-effective traits, causing substantial biases in ET estimates, particularly in heterogeneous ecosystems. These scale-induced biases can be mitigated by propagating the probabilistic distribution of fine-scale traits through ensemble modeling rather than relying solely on the community-averages. The case studies highlight that scaling plant hydraulic traits to predict ecosystem drought responses requires appropriate characterization of trait variability and nonlinear ecophysiological processes operating from individuals to ecosystems.

Key words: plant hydraulics, traits, scaling, ecosystem diversity, drought, model-data integration

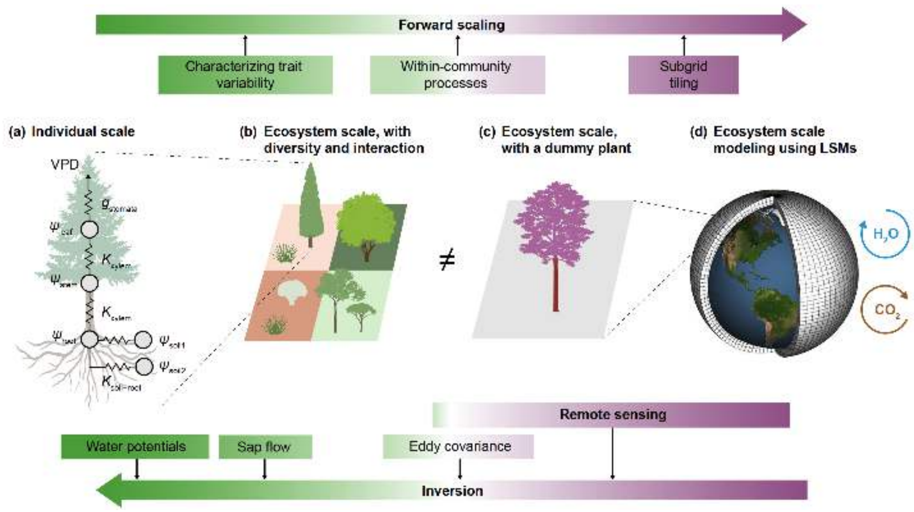

Figure 1. Conceptual diagram illustrating plant hydraulics and the scaling from individual plants to ecosystems, framed by forward and inversion approaches to bridge scale gaps (Liu, 2026).

POSTER:

Improving Sub-seasonal to Seasonal LAI Prediction For Earth System Model Using AI/Machine Learning

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Abstract.
Modeling vegetation phenology within Earth system models remains challenging due to its interannual variability, spatial heterogeneity, and complex ecosystem dynamics. Current dynamic vegetation (DV) models are driven by complex ecological processes of vegetation growth and decay, carbon and nutrient cycling, ecosystem disturbances, and weather and climate. However, integrating these DV models into operational climate prediction systems remains difficult. Consequently, many climate models prescribe Leaf Area Index (LAI) distributions using a 20-year averaged climatology derived from the Normalized Difference Vegetation Index, which limits the model's capability to respond to sub-seasonal to seasonal and interannual climate variations.

To address this issue, we developed a machine learning-based model, ConvLSTM-LAI, which leverages Convolutional Neural Network (CNN) and Long Short-Term Memory (LSTM) techniques to improve regional-scale predictions of LAI. The model is trained using long-term precipitation and temperature data from the NCDC Summary of the Day station observations, along with the Moderate Resolution Imaging Spectroradiometer (MODIS) LAI product (MCD15A3H) which was interpolated to a daily time step. ConvLSTM-LAI model is trained with daily LAI values and surface meteorological forcings at a 1-km spatial resolution to predict LAI across south-central United States. Using data from 2001 to 2020 for training, we evaluate predictions from 2021 to 2023 against MODIS LAI observations. Results show that with a lead time of 30 days, the predicted domain-averaged LAI values differ by less than 0.11 from observed values, with a correlation coefficient of 0.86, effectively capturing both seasonal and interannual variations in vegetation dynamics. Additionally, regional LAI predictions exhibit strong performance across different land cover types, including grasslands, savannas, shrublands, croplands, and mixed forests. Furthermore, model evaluation across lead times from 1 to 30 days reveals that as lead time increases, RMSE rises and correlation decreases, underscoring the difficulty of making long-term predictions for complex vegetation dynamics.

Key words: LAI; Machine Learning; CNN-LSTM

TALK:

Deep learning to evaluate time-dependent efficacy of carbon dioxide removal via forest restoration

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Abstract: Forest-based carbon dioxide removal (CDR) is widely promoted as a high-potential, nature-based climate solution, and its efficacy is time dependent because forest CDR follows the growth trajectory of aboveground biomass (AGB). However, this timing is rarely accounted for in CDR assessments, obscuring whether forest restoration can deliver meaningful CDR within 25–55-year climate horizons. In this study, we provide 1-km resolution, time-dependent estimates of forest CDR using Biogeochemistry-Informed Neural Network (BINN) for synthesis of 113,806 field-based AGB measurements from 74,048 plots across the conterminous US. We show that the window for effective forest-based CDR is limited by age-related declines in growth. Forest CDR via AGB growth peaks within 9.4–31.2 years, then weakens as forests mature, falling to 1 $MgCO_2$ ha^{-1} yr^{-1} within 51.6–108.5 years. Rather than emphasizing full CDR potential, we quantify a more attainable target, achieving 50% CDR potential. This target is reached fastest in the East South Central region within 18.9 ± 5.6 years and slowest in the Mountain region within 75.7 ± 23.9 years. Ignoring time dependence causes IPCC to underestimate CDR in young forests and overestimate it in older ones. Because forest carbon sinks take decades to develop, early action is crucial for restoration to deliver meaningful removals on near-term climate timescales.

TALK:

ENVIRONMENTAL SENSITIVITY OF TROPICAL TREE WOODY GROWTH: THE ROLE OF SINK LIMITATION

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Abstract. The future of the tropical forest carbon sink critically depends on how woody productivity responds to environmental change. However, predicting the environmental sensitivity of tropical tree woody growth remains a major challenge for process-based terrestrial biosphere models (TBMs). These models often overestimate growth sensitivity to light and underestimate sensitivity to water limitation. One likely reason is that most TBMs assume that growth is only limited by carbon source activity (photosynthesis) and neglect sink limitation, defined as direct environmental constraints on cambial cell activity and tissue formation. Despite the potential importance of sink limitation, the relative contributions of source and sink processes in explaining and predicting tropical tree growth remain poorly quantified. This knowledge gap is largely due to limited growth observations at high temporal resolution and insufficient model development. Here we developed a sink-limited growth scheme in the Ecosystem Demography Model Version 2 (ED2) and evaluated modeled growth against high-frequency dendrometer measurements from a tropical everwet forest. We found that the environmental sensitivity of observed growth aligns more closely with the sensitivity of modeled sink activity than with modeled source activity, and the agreement is stronger at daily than monthly time scale. Compared to the source-only model, the sink-limited model shows similar growth sensitivities to light and soil moisture, but a more negative response to vapor pressure deficit (VPD). In addition, the source-only model overestimates tree growth relative to observations, whereas including sink limitation reduces this bias, particularly under high light, high VPD, and in larger trees. Overall, these results provide quantitative evidence for sink limitation in a tropical everwet forest and demonstrate that its effects are stronger at a shorter time scale. Our findings suggest that TBMs need to represent sink limitation to accurately predict tropical tree growth, especially for large trees and under water stress.

Key words: tropical forest; woody growth; sink limitation; environmental sensitivity; vegetation modeling

TALK:

LARGE OVERESTIMATION OF PROJECTED WESTERN U.S. WILDFIRE BURNED FOREST AREA WITH WARMING

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Abstract. Wildfires are projected to increase with warming in the western United States. Since vapor pressure deficit (VPD) is highly correlated with wildfire burned area historically, many studies have argued that large projected increases in VPD with warming imply large increases in burned area. Here, we argue that those projections are overestimated by as much as an order-of-magnitude. First, we show that both soil moisture and VPD are well correlated with historical burned forest area. Second, we demonstrate that projected changes in VPD with warming are much larger than those in soil moisture, leading to wildly divergent projections of burned forest area: with 3 K (4 K) of warming relative to pre-industrial, the VPD-based projection is about 16 (66) times the historical burned area, whereas the soil moisture-based projection is only 2 (3) times the historical burned area. Third, we argue that the VPD-based projections are incorrect. VPD is used as a measure of atmospheric evaporative demand, but recent advances have demonstrated that VPD and related quantities are actually poor measures of atmospheric evaporative demand and overstate projected drying with warming. We conclude that the rate at which wildfire burned forest area will increase with warming has been greatly overestimated by some studies.

Key words: wildfires, aridity, climate change, projections, vapor pressure deficit.

TALK:

QUANTIFYING LIGHTNING RISK AND ECOLOGICAL IMPACT AT SCALE

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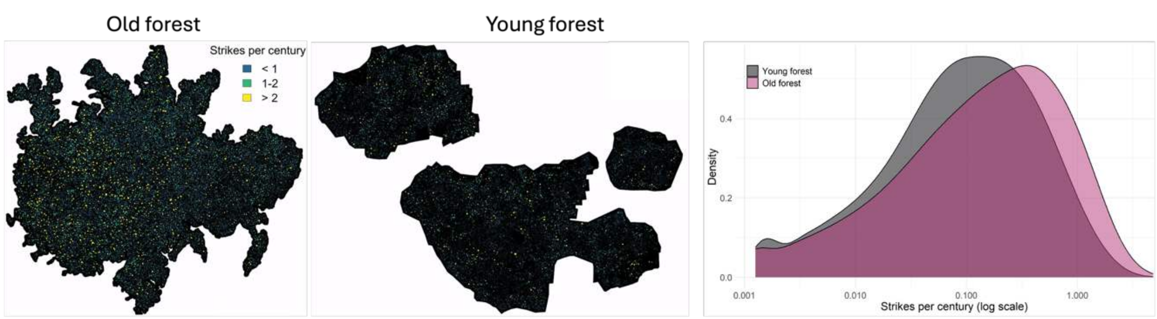
Abstract. Lightning is a major agent of disturbance in tropical forests. In aggregate, lightning strikes kill hundreds of millions of tropical trees each year, and tropical forests that experience more lightning strikes have higher biomass mortality rates, less aboveground forest biomass, and fewer large trees. However, despite strong evidence that lightning is a key disturbance, we know very little about the ecological impacts of lightning across a forest landscape – or indeed, varies between different forest types – because existing research is largely restricted to a single old-growth forest in Panama. We therefore propose applying a simple, physics-based model at scale to calculate a crown-dependent risk of being struck by lightning. The resulting risk map allows us to quantify biomass turnover from lightning disturbances, and even investigate patterns of forest resilience to lightning frequency.

Here we present the first results from assessing lightning risk at landscape scale. We focused on three different forest types in Central Panama across four field sites: old-growth (Barro Colorado Island; BCI), secondary forest (Agua Salud and San Lorenzo), and mangroves (Galeta). Preliminary analyses show that lightning risk exhibits a hump-shaped relationship with lightning severity, as measured by biomass mortality, which indicates that we can extrapolate from our measurements of lightning risk to project future forest disturbance regimes and quantify forest resilience to lightning disturbance at landscape scale. Our findings show that older forests tend to have higher lightning risk than younger forests, and we are seeing evidence of expected signals of higher lightning risk along anthropogenic edges (e.g. roads, plantation). We anticipate our results can easily integrate into global climate models and fill in a key missing component of biomass dynamics in tropical forests, especially under future climate change.



TALK:

TRACKING FOREST PHENOLOGY IN RELATION TO CARBON FLUXES IN A SEMI-DECIDUOUS TROPICAL GHANAIAN FOREST ECOSYSTEM

Victoria Imabong Ayeh[1], Caleb Mensah[1], Frederick Otu-Larbi[1], Bismark Ofosu-Bamfo[2]

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Abstract
Tropical forests play a pivotal role in global carbon cycling, yet the temporal dynamics of their carbon fluxes and phenological responses to climate variability remain understudied, especially in West Africa. In Ghana, where forests provide essential ecological services such as carbon sequestration and biodiversity support are essential, climate-induced shifts in temperature, rainfall, and seasonal variability may significantly alter forest productivity and carbon uptake. This study aims to investigate the influence of contrasting climatic conditions on forest phenology and productivity across two distinct forest types using an integrated monitoring approach. By focusing on these ecologically and climatically distinct sites, the research captures a representative gradient of forest-climate interactions in Ghana. To monitor phenological dynamics, the study integrates ground-based canopy phenology observations from static pheno-cams within a moist semi-deciduous forest site and dry semi-deciduous with satellite-derived vegetation indices to capture multi-scale phenological patterns across the forest landscapes. Simultaneously, forest productivity is evaluated using Gross Primary Productivity (GPP) estimates derived from MODIS remote sensing products, offering consistent and spatially extensive insights into ecosystem-scale carbon assimilation. Meteorological data from local weather stations are used alongside phenological and productivity metrics to explore the climatic drivers of seasonal and interannual variability in GPP. Through statistical and machine learning regression approaches, we identify key environmental variables controlling carbon uptake across the moist and dry forest systems. This study uses remote sensing and phenology monitoring to fill key data gaps and enhance understanding of how semi-deciduous tropical forests respond to climate variability. The findings further provide insights into the role of phenological shifts in regulating carbon exchange and support adaptive forest management and climate mitigation efforts. Ultimately, this work deepens knowledge of forest resilience, recovery dynamics, and improves predictions of ecosystem responses under future climate conditions.

Key words: tropical phenology; MODIS GPP; pheno-cams; tropical forest carbon fluxes.

TALK:

A Clumped-Foliage Canopy Radiative Transfer Model for a Demographic Dynamic Global Vegetation Model: Canopy Structure for Diurnal and Seasonal Albedo and Biomass

Leila Mirzagholi [1,2], Nancy Y. Kiang[2], Wenge Ni-Meister[3],
Andrew Oliphant[4], Cheuk Yin James Liu[2,5], Carlo Montes[1,2], Crystal Schaaf[6]

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Abstract. Dynamic Global Vegetation Models (DGVMs) must simulate carbon storage and land–atmosphere exchanges of energy, water, and carbon across diverse landscapes and climates. Few DGVMs have self-consistent approaches to represent canopy structural heterogeneity for three core DGVMs functions that couple with Earth System Models (ESMs): the canopy radiative transfer physics, carbon dynamics, and ecology. We investigate a geometrical optical radiative transfer (GORT) framework in the Ent Terrestrial Biosphere Model, a demographic DGVM coupled to the NASA Goddard Institute for Space Studies ESM, ModelE. The Ent Analytical Clumped Two-Stream (ACTS) model is a GORT model based on multi-cohort canopies with ellipsoidal crowns to account for the effects of vertical foliage profiles (VFPs) and clumping on canopy radiative transfer. We evaluate optimization of allometry and cohort structure (Figure 1) to reproduce observed VFP (Figure 1e), basal area (a proxy for canopy biomass), and canopy albedo across three contrasting ecosystems: temperate deciduous forest, evergreen conifer forest, and woody savanna. Simulated diurnal and seasonal canopy albedo are evaluated against Fluxnet tower and MODIS satellite observations. In addition, we conduct a sensitivity analysis of how structural heterogeneity (vertical foliage distribution, clumping, crown geometry) and surface optical properties (leaf/stem and soil reflectance) jointly control albedo. We find that the dominant control on VIS–NIR reflectance and seasonal albedo is the seasonality of leaf NIR optical properties. Accurate estimation of VFP and basal area is very sensitive to allometric parameters and vertical structure. We recommend prioritization of measurements of: leaf optical properties to include the seasonality in the NIR and both reflectance and transmittance for the radiative transfer models; and crown allometry for VFPs. This study provides an observationally- constrained framework for identifying the minimum demographic complexity required to capture canopy heterogeneity to accurately and self-consistently predict the RT physics and biomass of DGVMs. Future work will investigate whether the vertical structure that optimizes radiative and carbon dynamics also captures the ecological dynamics of community competition.

Key words: albedo; foliage clumping; vegetation demography; dynamic vegetation modeling.

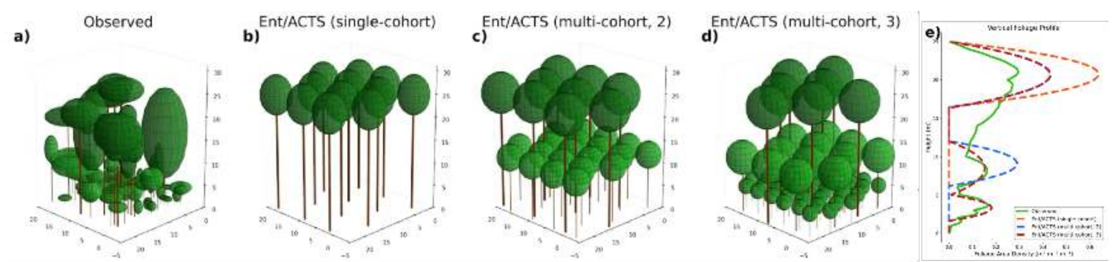

Figure 1. Schematic canopy representations of a stand in Morgan-Monroe State Forest, Indiana, USA, conserving leaf area index and canopy height, and fitting basal area and VFPs. Oblique views of (a) the observed 25m x 25m inventory plot and (b-d) the fitted single cohort, two cohort, and three cohort Ent configurations, respectively. (e) VFPs for (a)-(d).

POSTER:

CHARACTERIZING SIZE DISTRIBUTION OF HURRICANE-INDUCED CANOPY GAPS USING AIRBORNE AND SATELLITE REMOTE SENSING

Cameron J. Reimer[1], Orion Hoch[1], Tao Han[1], Xiangtao Xu[1]

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Abstract: Natural disturbances that drive forest mortality (i.e. create canopy gaps) are one of the largest sources of uncertainty in dynamic global vegetation models (DGVMs).[1] Our ability to understand the impacts of disturbances on forests is limited by our capacity to detect patterns of forest gaps at the landscape scale. Further, observed distributions of forest gaps and their apparent drivers are likely sensitive to the scale of analysis[2], which influences resulting estimates of disturbance impact and extent. In order to explore the effects of spatial scale on disturbance estimates, we compared distributions of forest gap sizes measured via aerial LiDAR and satellite remote sensing following Hurricane Maria in Puerto Rico. Forest gaps were identified using: (i) Landsat-derived (30m resolution) change in non-photosynthetic vegetation (NPV) above a specified threshold and (ii) a novel metric of crown loss derived from high-resolution aerial LiDAR point clouds measured by Goddard's LiDAR, Hyperspectral & Thermal Imager (G-LIHT). We examined whether Landsat-based metrics can detect small-scale canopy loss observed in aerial LiDAR metrics and compared gap-size distributions fit with power-law, Weibull, and Pareto functions to explore the effects of scale on gap size frequencies. We additionally explored whether gap size varies with local environmental factors known to influence gap formation using an XGBoost regression tree model to assess the influence of canopy height, canopy rugosity, species composition, land-use history, and topographic factors on forest gap size measured at different scales.
Key words: Forest gaps; disturbance; remote sensing; tropical forests; LiDAR

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[1]Pugh TAM, Arneth A, Kautz M, *et al.* Important role of forest disturbances in the global biomass turnover and carbon sinks. *Nat Geosci*. 2019;12(9):730-735. https://doi.org/10.1038/s41561-019-0427-2

[2]Chen J, Jucker T, Wang X, *et al.* Scale-dependent controls on forest gaps shaped by large trees and topographic heterogeneity. *Ecological Applications*. 2025;35(6):e70109. https://doi.org/10.1002/eap.70109

POSTER:

FORECASTING DEFOLIATION RISK OF THE INVASIVE SPONGY MOTH ACROSS ITS NORTH AMERICAN RANGE

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Abstract.
Forest pest outbreaks can alter forest carbon sinks and ecosystem services and have broad reaching impacts on the future structure and composition of forests. Effective management of outbreaks requires knowledge of when and where outbreaks may occur in advance. However, outbreak dynamics depend on a complex suite of biogeographical and meteorological factors, which are likely to change in future climate conditions. In this study, we explore the environmental drivers and impacts of defoliation from a major forest pest in northeastern temperate forests (*Lymantria dispar dispar*, LDD) to better understand the near-term and long-term risk of defoliation. We generate maps of growing-season defoliation based on satellite imagery across the North American range of LDD at a 30m resolution using the Harmonized Landsat Sentinel data fusion product. Using a hierarchical Bayesian model, we separate the effects of climatic anomalies, landcover conditions, forest and insect phenology, and spatial and temporal autocorrelation in LDD populations on the probability of severe defoliation. We also use TROPOMI SIF to estimate declines in productivity due to severe defoliation. We ask 1) can near-term LDD defoliation risk be forecasted from preceding conditions, 2) what might long-term changes to defoliation risk look like based on recent patterns, 3) what are the impacts of severe LDD defoliation on temperate forest productivity? Improved understanding of LDD dynamics and consequences will provide both valuable guidance for the immediate management of LDD and better insight into how LDD outbreaks may impact future carbon dynamics in temperature forests.

Key words: *Spongy moth, defoliation, biotic disturbances, carbon dynamics, remote sensing, ecological forecasting*

TALK:

Stabilizing Behaviors of Vegetated Landscapes through Water-Energy-Carbon Spaces

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Abstract.

Terrestrial vegetated ecosystems are complex systems that respond to internal processes, exogenous abiotic forcing variables, and the coupled feedbacks between the two. Because of this, many of their aggregate metrics lend themselves well to counter-intuitively simple dynamical systems modeling, which provides a wealth of theory related to stability, predictability, resilience, and timescales of dominant behaviors.

In a collection of studies[2][3][4], we ask which land system variables stabilize surface carbon, energy, and water fluxes. Using surface observations across networks of eddy covariance tower sites, we ask which mechanisms drive diverse ecosystems towards stable "attractors" of the water/energy/carbon system and whether local ecological diversity makes these patterns more or less predictable. We build on this using remote sensing observations to see how non-dimensional variables representing the water-, carbon-, and energy-cycle states lead to stable, intermittent, or periodic ecological function. The estimated parameters of these models create maps of stability across continental scales and across time. We use these results to open a discussion of what "stability" should mean for vegetated ecosystems.

Key words: terrestrial ecosystem stability; water-energy-carbon coupling

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[2] D. J. Short Gianotti and D. Entekhabi, "Structural and canopy water-use efficiency drivers of water-carbon coupling patterns," New Phytologist, Re-submitted to New Phytologist.
[3] D. J. Short Gianotti, K. A. McColl, A. F. Feldman, X. Xu, and D. Entekhabi, "Two sub-annual timescales and coupling modes for terrestrial water and carbon cycles," Global Change Biology, vol. 30, e17463, 2024. î DOI: 10.1111/gcb.17463
[4] D. J. Short Gianotti and D. Entekhabi, "Local and general patterns of terrestrial water-carbon coupling," Geophysical Research Letters, vol. 51, e2024GL109625, 2024. î DOI: 10.1029/2024GL109625

TALK:

Tracing and Predicting the Pulse of the Terrestrial Biosphere by Integrating Earth System Models and AI

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Abstract. Earth System Models (ESMs) remain our primary tools for predicting future climate, yet they face significant challenges and uncertainties in reliably resolving the terrestrial carbon-water dynamics under a changing climate. In the third study, we developed a novel deep learning (DL) framework based on the Autoformer architecture to constrain ESM uncertainties in future projections of terrestrial carbon dynamics using CMIP6 model ensembles. This DL framework goes beyond improving computational efficiency of ESMs as is most often pursued so far, but aims to learn the structure dependence of the model-data deviation: the aggregated outcome of existing unresolved processes and parameters. We then applied the correction of model–data deviation learned from the past to the future. Our results reveal a likely overestimation of future carbon sequestration capability by the current ESMs. This finding suggests that a sustained future increase in the terrestrial carbon sink is not guaranteed. Meanwhile, DL has markedly tightened the uncertainty range of existing ESM projections, and therefore can enhance the fidelity of future projections of carbon cycling and guide global climate actions.

Key words: CMIP6, AI, DL, Uncertainty, Carbon Cycle Projection.

KEYNOTE:

MISSING LINKS OF THE LAND SINK: HOW SOILS, MICROBES, AND BIRDS SHAPE THE CARBON CYCLE

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Abstract. Process-based dynamic global vegetation models (DGVMs) are our primary tools for projecting the future land carbon sink, yet critical uncertainties persist because key processes remain poorly represented or missing entirely. In this keynote, I synthesize a decade of work using large-scale observational datasets—from manipulative experiments to global field campaigns—to identify and constrain processes that fundamentally shape where carbon is stored on land and how it will respond to global change.

First, I review how meta-analyses of Free-Air CO_2 Enrichment (FACE) and other ecosystem-scale experiments have revealed that the fate of additional carbon under elevated CO_2 depends critically on nutrient availability and mycorrhizal association type. Plants associated with ectomycorrhizal fungi show enhanced biomass gains under elevated CO_2, while those associated with arbuscular mycorrhizae tend to allocate additional carbon belowground into soils—a trade-off between vegetation and soil carbon storage largely absent from current Earth system models.

Second, I present new results from the most comprehensive data-driven quantification of the global soil organic carbon (SOC) sink to date. By synthesizing repeated SOC measurements from over 37,000 sites worldwide, we estimate that natural soils sequestered 2.1 ± 0.27 Pg C yr^{-1} from 1992 to 2020—an order of magnitude larger than the TRENDY DGVM ensemble estimate over the same domain (0.25 ± 0.19 Pg C yr^{-1}). This result positions soils as the dominant reservoir of recent net land carbon uptake and exposes a major model–observation mismatch. The sink is driven primarily by old boreal forests, temperate grasslands, and tropical old forests, with evidence of recent weakening in the most recent decade.

Third, I highlight how biotic processes missing from vegetation models shape tropical forest carbon dynamics. Using trait-based models of animal seed dispersal function integrated with field observations from over 3,000 tropical regrowth plots, we demonstrate that disruption of seed dispersal by declining animal populations and habitat fragmentation reduces natural forest carbon accumulation rates by up to fourfold. This biodiversity–carbon linkage, currently absent from DGVMs, has direct implications for projecting forest recovery and evaluating nature-based climate solutions.

Together, these lines of evidence reveal that the processes governing the land carbon sink—nutrient and mycorrhizal controls on CO_2 fertilization, soil carbon accumulation dynamics, and animal-mediated forest regrowth—remain inadequately captured by current models. I discuss priorities for integrating these observational constraints into next-generation process-based models and for expanding the field measurements needed to benchmark them.

Key words: carbon; vegetation; soils; nutrients.

TALK:

Structural diversity buffers ecosystem-scale transpiration reduction under drought

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Abstract. Ecosystem-scale transpiration is typically estimated in land surface models using a simplified big-leaf approach, which treats the canopy as a homogenous leaf layer with averaged properties. While computationally efficient, this method neglects competition for water and light within the community and likely leads to errors in the estimated ecosystem-scale responses to climate stress. Vegetation demographic models, such as the E3SM Land Model coupled with Functionally Assembled Terrestrial Ecosystem Simulator (ELM-FATES), improve this representation by organizing vegetation into cohorts based on size, age, and plant functional type. This study investigates whether and how different canopy structure representations (homogeneous vs. diverse) impact ecosystem-scale transpiration estimates particularly under drought. Using the Chestnut Ridge site in the southeastern U.S. as a testbed, we compare two reduced-complexity modes of ELM-FATES: one mimicking the big-leaf simplification with one homogeneous cohort and the other representing diverse size-structured cohorts. While both representations share the same physiological traits and total leaf area, we find that the homogeneous structure exaggerates transpiration decline during drought, whereas the diverse structure provides a buffering effect, sustaining 14.7% more transpiration, which more closely matches with observations. We hypothesize that three size-dependent mechanisms contribute to this buffering effect: (1) varying hydraulic stress due to diverse plant water storage capacity, (2) stratified soil water uptake across rooting depths, and (3) transpiration demand mediated by size-dependent shading. These mechanisms lead to distinct drought responses across cohort sizes, which propagate nonlinearly to the ecosystem-scale response of transpiration and cannot be captured by an average-sized cohort as in the homogeneous configuration. We quantify the size-dependent drought responses of leaf water potential, root water uptake, and stomatal conductance associated with each of the three mechanisms, and partition their relative contributions to ecosystem-scale transpiration buffering. The findings will reveal key structural and hydraulic mechanisms that regulate ecosystem-scale transpiration beyond what would be predicted from individual-scale physiology alone.

Key words: vegetation demographic model; plant hydraulics; transpiration; canopy structure; community competition.

KEYNOTE:

THE MODEX FRAMEWORK FOR VEGETATION MODELING IN THE WORLD OF AI

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Abstract. The MODEX (Model–Experiment) framework, in which models guide field observations and laboratory experiments to improve our predictive understanding, has been central to advancing the Department of Energy's Next Generation Ecosystem Experiments over the past 13 years. In this presentation, I will provide several examples of how we have applied the MODEX framework to improve simulations of vegetation growth and mortality. There are two primary pathways for implementing MODEX: (1) improving model parameterization and (2) incorporating new process representations into existing models. Specifically, I will describe how we used the MODEX framework to develop and integrate three major components: LUNA for predicting photosynthetic capacity, HYDRO for plant hydrodynamics, and IMAP for insect population dynamics. While incorporating these new components enhances process realism and predictive capability, it also increases the number of model parameters, potentially amplifying uncertainty during parameter estimation. To address this challenge, I will present AI-enabled approaches designed to reduce parameter uncertainty and improve predictive performance. These approaches include (1) AI-based model emulators that accelerate computation and facilitate parameter exploration, and (2) differentiable modeling—a hybrid framework that seamlessly integrates AI with process-based models to strengthen prediction, parameter estimation, and hypothesis testing in complex dynamic vegetation systems. Finally, I will discuss emerging directions for integrating AI within the MODEX framework, including AI agents, hybrid modeling strategies, and advanced uncertainty quantification. The integration of AI into vegetation MODEX research provides powerful new tools for scientific discovery and informed decision-making under global environmental change.

Key words: MODEX, plant hydrodynamics; *AI; differentiable modeling*; uncertainty, emulators.

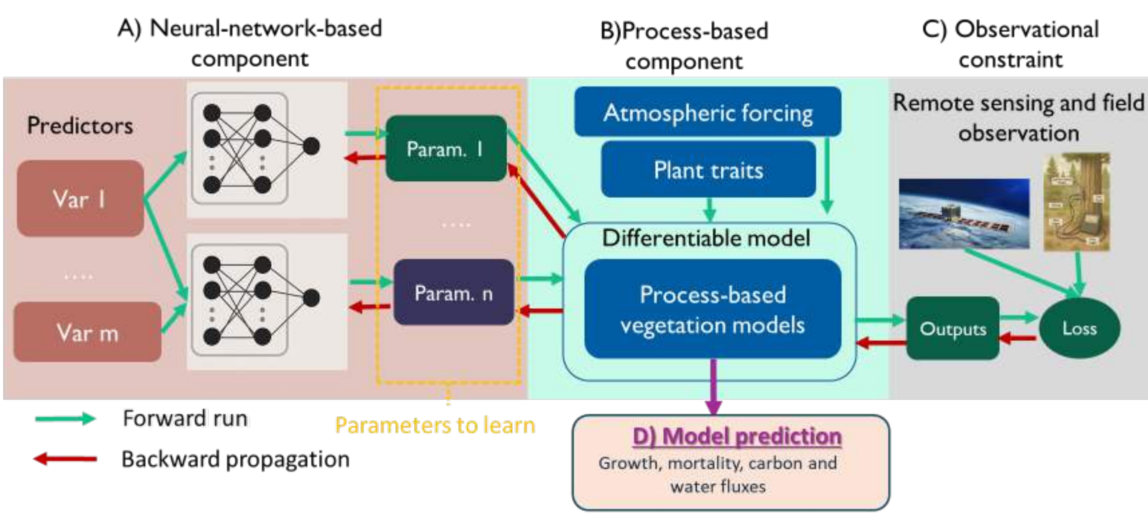

Figure 1: A hybrid differentiable modeling framework for improving vegetation dynamics prediction

TALK:

More than a constant background disturbance rate - heterogeneity of biomass turnover time in tropical forests

Xiangtao Xu[1] and Donghai Wu[2]

[1]*Department of Ecology and Evolutionary Biology, Cornell University, Ithaca, NY; xx286@cornell.edu*
[2] *South China Botanical Garden, Chinese Academy of Science, Guangzhou, China*

Abstract. The rate of forest biomass loss is essential for predicting large-scale forest dynamics and terrestrial carbon cycling. However, tree mortality and forest biomass loss are often simplified to a quasi-constant background disturbance rate across space and time in vegetation models, particularly over intact tropical forests. This model deficit largely arises from the knowledge gap in large-scale patterns of tropical biomass turnover and their environmental drivers. Here, we estimate kilometer-scale aboveground biomass turnover time (τ_{AGB}) across intact Amazonian forests by integrating satellite and field measurements. Our analysis provides continent-scale evidence of large spatial heterogeneity of τ_{AGB}, which is driven by strong nonlinear responses to elevation and climate. Convective storms, a major cause of tropical forest disturbance, are the dominant climatic driver of τ_{AGB} spatial variation, surpassing vapor pressure deficit and precipitation extremes. These findings highlight climatic sensitivities of biomass turnover critically shape tropical forest dynamics and carbon cycling and call for more mechanistic representation of disturbance and biomass turnover in global vegetation models.

Key words: biomass turnover, tropical forests, disturbance, carbon cycling, storms, vapor pressure deficit.

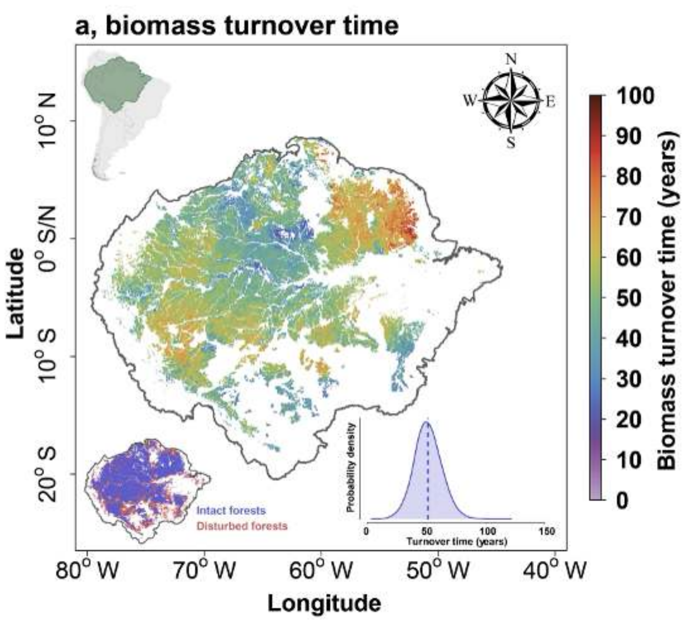

Figure 1. Spatial pattern of estimated biomass turnover time over Amazon intact forests.

TALK:

Intensifying compound drought and heatwave events increase greenhouse gas emissions and reduce crop yields in U.S. croplands

Yongfa You[1,2], Hanqin Tian[2,3], Shufen Pan[3,4], Naiqing Pan[2,3]

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Abstract. Compound drought and heatwave events are emerging as a critical driver of agricultural vulnerability in the U.S., with far-reaching implications for greenhouse gas (GHG) emissions, crop productivity, and the climate sustainability of food systems. Despite their growing importance, the combined impacts of these extremes on crop yield and GHG dynamics remain poorly understood, particularly at national scales and under future climate scenarios. Here we integrate observational datasets with simulations from the Dynamic Land Ecosystem Model (DLEM) to assess the severity, duration, and frequency of compound drought and heatwave events across U.S. croplands, as well as their impacts on crop yield and GHG emissions, during both the historical (1960–2019) and future (2020–2099) periods. Our results reveal substantial increases in the severity, duration, and frequency of compound events under higher-emission scenarios (e.g., SSP370, and SSP585). These events consistently reduce yields and amplify GHG emissions, with impacts that have intensified over recent decades and are projected to escalate further under continued warming if current management practices remain unchanged. We also evaluate the moderating role of agricultural management practices, identifying both adaptive and maladaptive responses, yet finding that current practices are insufficient to mitigate the growing risks posed by compound extremes. These findings underscore the urgent need to integrate compound extremes into climate adaptation and mitigation strategies and provide a foundation for developing approaches to reduce the carbon footprint of U.S. agriculture and ensure food security in a rapidly warming climate.

Key words: Compound droughts and heatwaves; Greenhouse gas emissions; Crop yield; U.S. croplands.

TALK:

IMPROVING ELM-FATES' SEASONAL DYNAMICS OF PHOTOSYNTHESIS FLUX IN TROPICAL RAINFORESTS BY INTEGRATING SOLAR-INDUCED CHLOROPHYLL FLUORESCENCE (SIF)

Danyang Yu[1], Marcos Longo[2], Paul R. Moorcroft[3], Robinson I. Negron Juarez[2], Jennifer Holm[2], Jennifer Kowalczyk[2], Hans Verbeeck[4], Steven De Hertog[4], Xiangtao Xu[1], Yixin Ma[1], Damien Bonal[5], Scott Saleska[6], Natalia Restrepo-Coupe[6], and Ying Sun[1]

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Abstract. Accurately simulating the seasonal dynamics of carbon fluxes in tropical rainforests remains a major challenge for terrestrial biosphere models (TBMs). Unlike temperate ecosystems, where vegetation phenology follows distinct thermal or moisture cues, tropical forests exhibit complex leaf turnover that is poorly represented in TBMs. Consequently, current TBMs often fail to capture the seasonal shifts in photosynthetic capacity, leading to persistent discrepancies between simulated gross primary productivity (GPP) and observed photosynthetic dynamics in the tropics. Solar-induced chlorophyll fluorescence (SIF), a direct proxy for photosynthetic activity, provides a powerful observational constraint for photosynthetic dynamics. In this study, we bridge the gap between satellite SIF and simulated GPP by integrating a mechanistic SIF radiative transfer module into the Energy Exascale Earth System Model Land Model, coupled with the Functionally Assembled Terrestrial Ecosystem Simulator (ELM-FATES-SIF). The new module explicitly simulates leaf-level fluorescence emission and its propagation through multilayer canopies using a two-stream radiative transfer framework, allowing the model to simultaneously predict carbon fluxes and canopy-level SIF signals. The model is evaluated against eddy covariance measurements and satellite-derived SIF products across multiple tropical rainforest sites. Our results indicate that incorporating SIF significantly improves the seasonal dynamics of SIF and GPP simulations. Crucially, the SIF-constrained simulations better capture dry-season photosynthetic increases driven by the synergy of enhanced radiation and leaf phenology. This work highlights the capability of SIF to constrain process-based model uncertainties in the tropical forest carbon cycle simulations.

Key words: Solar-induced chlorophyll fluorescence (SIF); Tropical rainforest; Seasonal carbon dynamic; ELM-FATES; Radiative transfer.

TALK:

FACTORS DETERMINING THE SUCCESSFUL COLONIZATION OF TREES BY LIANAS: A MODEL SENSITIVITY ANALYSIS

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Abstract. Lianas, woody climbing vines, can comprise up to 25% of woody stems in tropical forests and are increasing rapidly across many regions. By imposing mechanical stress on host trees and competing for light and other resources, lianas can substantially reduce forest productivity. Despite their ecological importance, lianas remain poorly represented in forest ecosystem models. This research represents a first attempt to explicitly include lianas in the individual-based forest model TROLL, a trait- and individual-based forest growth simulator operating at a 1 m^3 voxel resolution. We simulated a single liana–tree pair over a 10-year period and evaluated liana colonization success at the end of each simulation. To identify which input parameters, and their interactions are most strongly influence liana colonization success, we conducted a global sensitivity analysis using Sobol' quasi-random sequences, allowing comprehensive exploration of parameter space. Specifically, we address the following questions: 1) Which structural and physiological parameters of trees and lianas, such as initial liana leaf area, voxel-scale constraints, liana shedding rate, and host tree size, most strongly influence liana colonization success under varying light environments? 2) How do fast-growing versus slow-growing tree species affect liana colonization success across all field-measured species? 3) Which liana colonization strategy, such as prioritizing leaf production in the upper versus lower canopy, leads to the highest colonization success? Preliminary results indicate that host tree diameter at breast height (DBH), initial liana leaf area, sunlight availability, and liana leaf mass per area (LMA) are among the most influential parameters determining liana colonization success.
Key words: lianas; individual based model; Sobol' sequence; global sensitivity analysis.

TALK:

LEARNING THE PAST TO PREDICT EXTREMES: INTERPRETABLE SEQUENTIAL MACHINE LEARNING FOR ECOLOGICAL MEMORY ACROSS LAND SURFACE PROCESSES

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Abstract. Ecological memory shapes how land surface processes respond to antecedent environmental conditions, yet it remains poorly represented in process-based models, especially under climate extremes. Here, we examine the added value of interpretable sequential machine learning for learning ecological memory across three land surface processes: evaporative fraction, snow water equivalent, and ground heat flux. Using sequential deep learning frameworks together with interpretable machine learning methods, we identify when and how past hydroclimatic and biophysical states influence present-day responses. For evaporative fraction, we show that vegetation memory varies across climates and plant functional types, revealing hidden ecohydrological controls related to rooting depth, vegetation functioning, and water limitation. For snow water equivalent, sequential models better capture snow accumulation and melt by learning memory encoded in antecedent cold-season meteorological forcing and elevation-dependent landscape controls, which regulate the timing and magnitude of water availability for subsequent vegetation activity. For ground heat flux, temporal learning reveals delayed subsurface thermal responses, highlighting memory arising from soil heat transport and subsurface thermal state evolution that influences soil–vegetation coupling and the partitioning of surface energy. Across these applications, interpretable sequential machine learning improves not only predictive skill, but also process understanding by quantifying memory timescales, identifying dominant antecedent controls, and diagnosing couplings across the carbon-water-energy system. These capabilities are particularly important for predicting land surface responses to climate extremes, where pre-event states, cumulative stress, and lagged recovery often play critical roles. Our results highlight ecological memory as a general organizing principle of land surface dynamics and demonstrate the potential of interpretable temporal learning to bridge observations and process-based models.
Key words: Ecological memory; Interpretable machine learning; Sequential deep learning; Land surface processes; Climate extremes; Vegetation–climate interactions.

TALK:

BEYOND CARBON: A TURGOR- AND XYLOGENESIS-BASED WOODY PRODUCTIVITY MODULE FOR ED2

Sophie A. Zwartsenberg[1], Pieter A. Zuidema[1], Jorad de Vries[1], Xiangtao Xu[2]

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Abstract. Tropical forests play a crucial role in global carbon dynamics, yet their future under climate change and rising CO_2 remains highly uncertain. Terrestrial biosphere models are our primary tool for projecting tropical forest biomass and carbon stocks. However, these models represent woody productivity as a purely carbon-limited process, and may thereby overlook an important control on growth: turgor limitation. A growing body of empirical evidence suggests that cambial activity and xylem cell expansion strongly respond to plant turgor pressure, independently of carbon supply, and that sink limitation of growth may be as important as source limitation in many conditions.

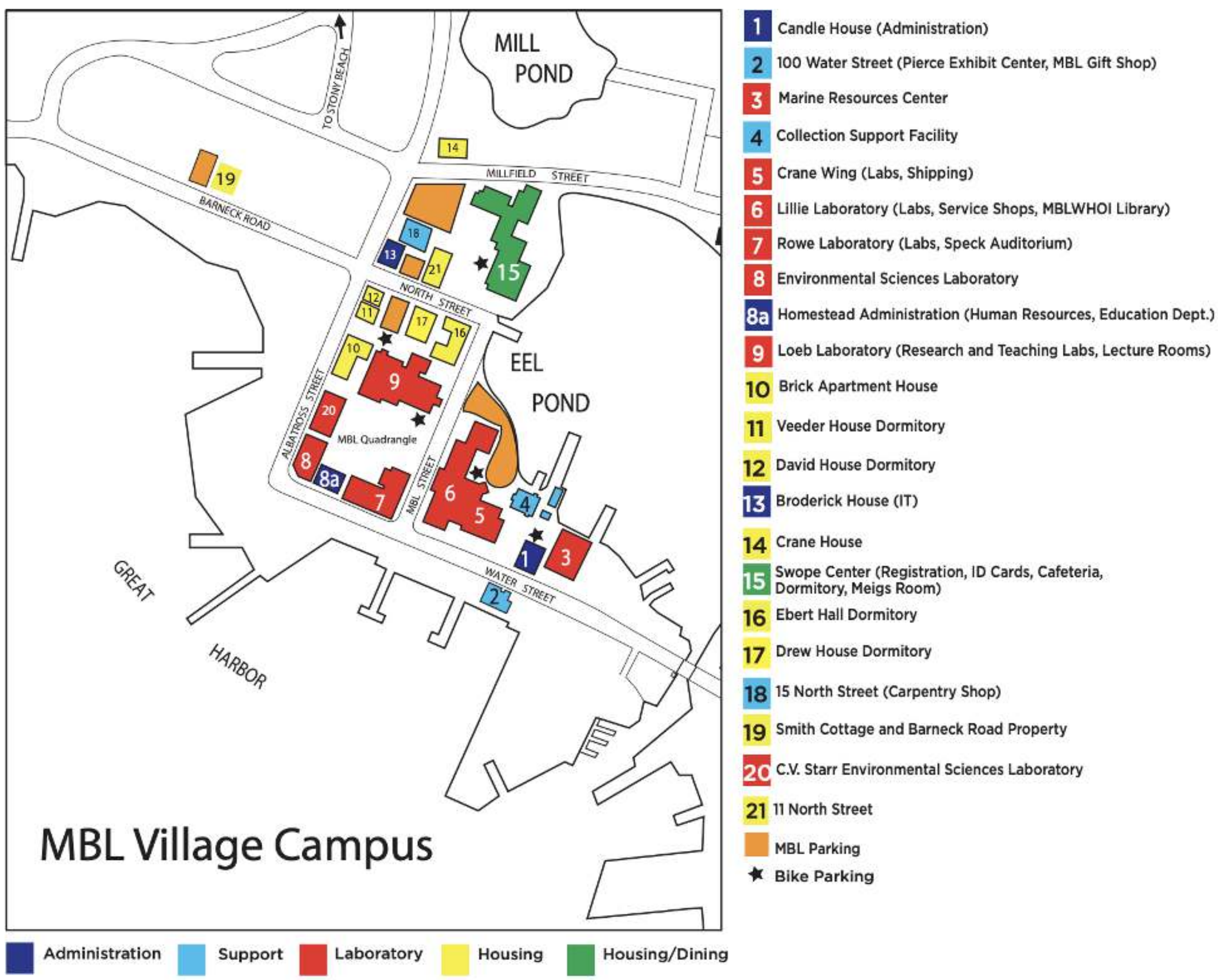
Here, we outline a mechanistic wood formation module under development for ED2. Structural growth is represented as a four-phase process including cambial initiation, cell expansion, secondary wall thickening, and maturation. Each phase is governed by distinct biophysical controls: cell expansion, causing diameter growth, is primarily limited by turgor pressure, while secondary wall thickening, giving wood its structural strength and mass, is limited by carbon availability within a developmental time window. If successfully implemented, wood density and radial growth become emergent properties, instead of being strongly informed by parameters. These emergent properties open new possibilities for model validation against wood anatomy, dendrometer and tree-ring data. The module is being developed initially for tropical angiosperms, where rising vapour pressure deficit represents a growing constraint on forest productivity. The framework aims to reduce uncertainty in tropical forest carbon projections and to provide a process-based tool for diagnosing when and where growth is turgor-limited versus carbon-limited across the tropics.

Key words: xylogenesis, turgor limitation, sink limitation, woody productivity, tropical forests, ED2, vapour pressure deficit

4th Annual
Dynamic Vegetation Modeling and Observations Conference

LOGISTICS

Conference address:
Swope Center (***location 15 on map below)***
5 North Street
Woods Hole, MA USA



Registration location:
Registration check in takes place in the main lobby of the Swope Center – 5 North St, Woods Hole MA 02543 (***location 15 on map).***

Travel:
Woods Hole is a small seaside town for which there is a Peter Pan charter bus service from New York City, Providence, and Boston, with other stops. The Marine Biological Laboratory is about a 6-minute walk from the bus and ferry terminal. For those who are driving, there is ample parking at MBL. An Event parking lot is available with MBL-issued permits for approximately 30 cars. Permits are complimentary and are available at check-in on a first come first serve basis.
Additional information can be found here:
https://www.mbl.edu/about/local-area-information/travel-information

Parking:
After check-in at the Swope Center, you'll be able to pick up a parking permit and will be directed to the appropriate lot for overnight parking.

Weather:
Woods Hole is a seaside village, and the weather can vary widely day to day (even hour to hour). You can expect temperatures to typically be a few degrees cooler than inland. A raincoat is handy for unexpected showers.

Conference and Check-in:
Registration check in takes place in the main lobby of the Swope Center. The Front Desk will provide your ID badge, parking permit (if needed), room key, and event information.

Housing check-in begins after 2:00pm. The Front Desk is typically open 2pm – 6pm on arrival day. After 5pm, the MBL Security (508-289-7217) can be called for housing check-in.

Wireless:
The MBL offers wireless guest Internet access on the "MBL-GUEST" network in all buildings on the main campus. The eduroam wireless network is also available on campus.

Site Map:
Campus Maps can be found here:
https://www.mbl.edu/about/campus-facilities-resources/campus-maps

Contact Info:
For questions about housing or check-in, please contact MBL's Housing and Conference Analyst, Kim Elber:

Email: kelber@mbl.edu
Office: 508.289.7248

For time-sensitive questions during your travel, feel free to contact Hannah Liddy via WhatsApp or SMS:
Cell: 315.571.4496