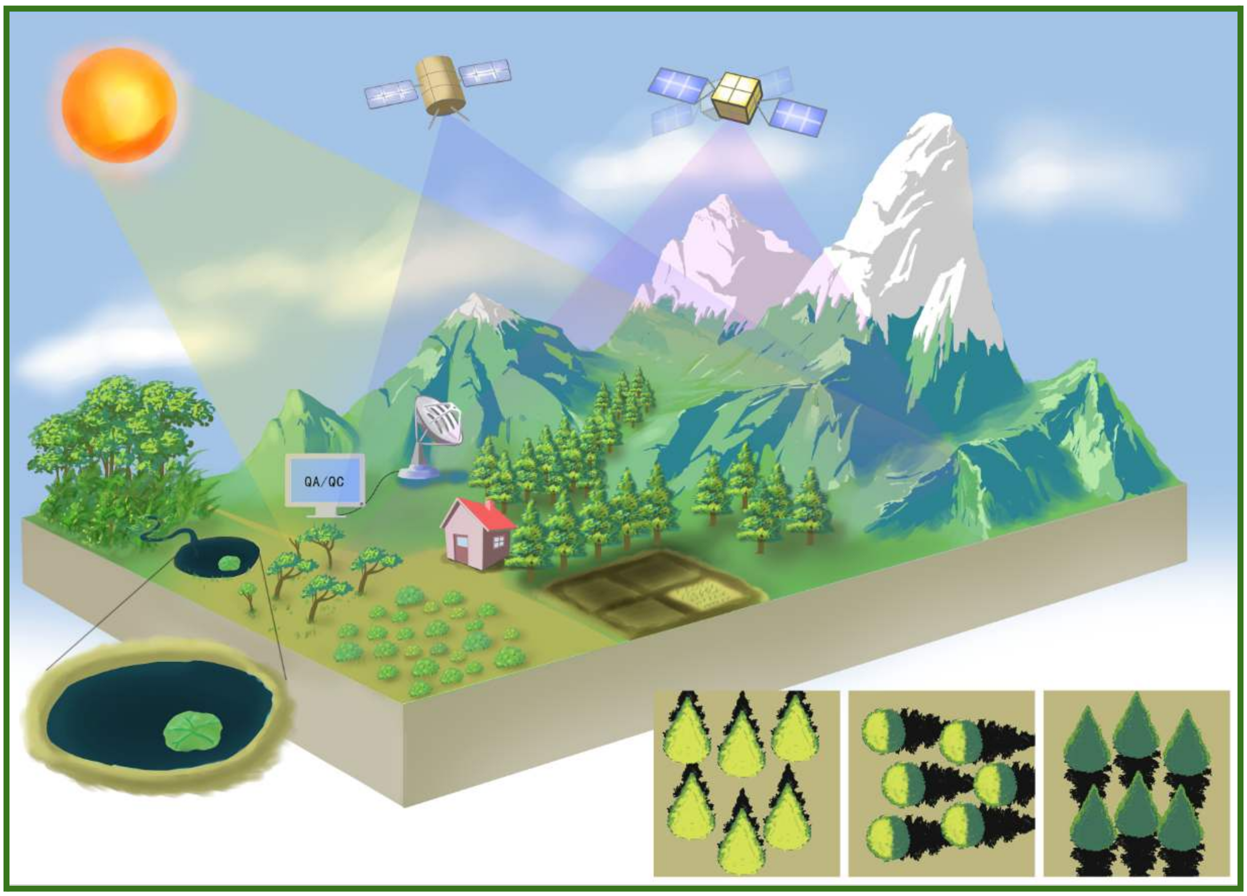
2nd Annual

Eastern Regional Dynamic Global Modeling Conference

Marine Biological Laboratory, Wood Hole, Massachusetts, USA, April 5-7, 2024



Credit: Min Chen (personal communication; Zeng et al. 2022, Nature Reviews, 3:477-493)

ER-DGVM-C. Marine Biological Laboratory, Woods Hole, Massachusetts, USA
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2nd Annual
Eastern Regional Dynamic Global Vegetation Modeling Conference
April 5-7, 2024

Welcome

Dear Conference Attendee:

Welcome to the 2nd Annual Eastern Regional Dynamic Global Vegetation Conference (ER-DGVM-C). Building upon the inaugural meeting last year, the overarching goals of this ER-DGVM-C meeting are to forge closer ties among members of the vegetation modelling science community and to improve connections between the vegetation modeling community and researchers acquiring field measurements and remote-sensing measurements that are critical for parameterizing and evaluating the predictive capabilities of dynamic vegetation models.

Echoing the second of these goals, the theme of this year's meeting is: "Predicting Terrestrial Ecosystem Responses to Climate Change: Linking Models and Measurements". Strengthening the connections between models and measurements is increasingly important given the burgeoning complexity of modern dynamic vegetation model formulations. Incorporating additional processes such as nutrient limitation, dynamic patterns of plant allocation, and land-use dynamics, into dynamic vegetation models is increasing the degree of realism in model formulations, but placing new demands on the numbers of parameters that need to be specified, and on the number of model outputs that need to be evaluated against empirical measurements. We hope that the presentations and discussions at this year's ER-DGVM-C meeting will help advance this much-needed two-way synergy between ecosystem models and measurements.

We would like to thank our sponsors, SpectraVista and Spectral Evolution, for their generous support. Their instruments have served our community extensively in characterizing the physiology and behavior of vegetation, and their properties that might be discerned by satellite remote sensing.

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,

Paul Moorcroft
Conference Co-Chair
Harvard University

Nancy Y. Kiang
Conference Co-Chair
NASA Goddard Institute for Space Studies

Hannah Liddy
AIMES Executive Officer
Columbia University

2nd Annual Eastern Regional
Dynamic Global Vegetation Modeling Conference
(ER-DGVM-C)

CONFERENCE PROGRAM

FRIDAY, APRIL 5, 2024

4:00-6:00 pm Check-in, set up posters

6:00-7:00 pm Dinner in dining hall

7:00-7:10 pm Welcome and Opening Remarks

7:10-8:40 pm FRIDAY EVENING ORAL SESSION: FUNCTIONAL DIVERSITY

8:40 pm POSTERS MIXER SESSION

SATURDAY, APRIL 6, 2024

7:00-8:15 am Breakfast in dining hall

8:15-9:50 am SATURDAY MORNING ORAL SESSION: PREDICTING ECOSYSTEM CHANGE

9:50-10:20 am SATURDAY MORNING ORAL SESSION 2: LEAF MEASUREMENTS

10:20-10:30 am Coffee break

10:30-12:00 SATURDAY MORNING ORAL SESSION 2B: PHENOLOGY AND PHOTOSYNTHESIS FROM REMOTE SENSING

12:15 pm Group photo

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

1:00-4:45 pm FREE TIME for impromptu meetings, walks, soccer, etc.

4:45-6:00 pm Pre-dinner snacks by POSTERS

6:00-7:00 pm Dinner in dining hall

7:10-8:45 pm SATURDAY EVENING ORAL SESSION 3: ECOSYSTEM DISTURBANCE

8:45 pm POSTERS MIXER SESSION

SUNDAY, APRIL 7, 2024

7:00-8:50 am Breakfast in dining hall

9:00-9:15 am SUNDAY MORNING ORAL SESSION 1: LAND MANAGEMENT

9:15-9:45 am SUNDAY MORNING ORAL SESSION 2: REMOTE SENSING OF VEGETATION STRUCTURE

10:00-10:20 am COFFEE BREAK

9:55-10:55 am SUNDAY MORNING ORAL SESSION 2 continued

11:00-11:30 am Student and postdoc presentation awards, announcement of next co-chairs and date

11:30-12:00 pm Conference feedback and general discussion

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

Conference End

2nd Annual Eastern Regional
Dynamic Global Vegetation Modeling Conference
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ORAL & POSTER SCHEDULE

Updated: April 1, 2024

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

FRIDAY, APRIL 5, 2024			
	FRIDAY EVENING ORAL SESSION: FUNCTIONAL DIVERSITY		
7:00	Paul Moorcroft, Nancy Kiang, Hannah Liddy	Welcome and opening remarks	
7:10	Xiangtao Xu (KEYNOTE)	Trait-based modeling of tropical forest structure and dynamics: Critical dimensions of plant functional diversity	Assistant Professor, Cornell University
8:00	Jennifer Kowalczyk	Towards coexistence: data-driven FATES simulations across the Amazon	Postdoctoral Fellow, Lawrence Berkeley National Laboratory
8:15	Ryan Pavlick	Perspectives from the NASA Terrestrial Ecology Program	Program Manager, NASA Terrestrial Ecology
8:30	Poster Pop-Up Talks	1-minute 1-slide talks for poster presenters ● **Binyuan Xu** - Transforming Amazonia: A 70-year history of deforestation and agricultural dynamics ● **Cameron Coles** - Time-series method for mapping spongy moth defoliation in northeastern US using Sentinel-2 imagery ● **Naiqing Pan** - Future prediction of terrestrial carbon uptake and nitrous oxide emissions ● **Dongchen Zhang** - Harmonizing terrestrial carbon cycle observations over CONUS NEON Sites: Assessing the information contributions of multiple data constraints ● **Francesca Lingo** - Mapping bird-friendly coffee farms using remote sensing and machine learning ● **Xinyi Yang** - Impact of fire on terrestrial carbon dynamics: A global analysis using the dynamic land ecosystem model (DLEM) ● **Mazen Nakad** - Tropical forest responses to climate extremes: A modeling analysis using an individual-based demographic vegetation model	
8:40	**FRIDAY EVENING POSTER SESSION & MIXER**		

SATURDAY, APRIL 6, 2024			
	SATURDAY MORNING ORAL SESSION 1: PREDICTING ECOSYSTEM CHANGE		
8:30	Michael Dietze (KEYNOTE)	Multisensor data assimilation to support terrestrial carbon cycle and disturbance Monitoring, Reporting, Verification, and Forecasting	Professor, Boston University
9:20	Malcolm Itter	Making more with continuous forest inventory data: A dynamical spatio-temporal model to predict forest change	Assistant Professor, University of Massachusetts Amherst
9:35	Mira Kelly-Fair	Modeling Mangrove Futures in Belize: Informing coastal resilience in a changing climate	Graduate Student, Boston University
	SATURDAY MORNING ORAL SESSION 2: LEAF MEASUREMENTS		
9:50	Jiameng Lai	Impacts of mesophyll diffusion on the long-term increase in global Carbon-13 discrimination and water use efficiency	Graduate Student, Cornell University
10:05	McKenzie Woodman	Advancement in NIR Reflectance measurements of small leaves and pine needles and analysis of differing spectral resolution.	Spectral Evolution
10:20	**COFFEE BREAK**		
	SATURDAY MORNING ORAL SESSION 2B: PHENOLOGY AND PHOTOSYNTHESIS FROM REMOTE SENSING		
10:30	Dave Schimel (KEYNOTE)	Don't call them traits: New remote observation of vegetation form and function	Group Leader, NASA JPL, California Institute of Technology
11:20	Leila Mirzagholi	Widespread legacy effects of early-season vegetation activity on autumn leaf senescence constrain global growing season extensions	Postdoc, MIT
11:35	Rong-Yu Gu	Phenologies: Defining seasons through different indicators in land-atmosphere interactions perspective	Graduate Student, Columbia University
11:50	Zhenqi Luo	Estimating global Gross Primary Production (GPP) from satellite Solar-Induced chlorophyll Fluorescence (SIF) with a mechanistic model	Graduate Student, Cornell University
12:05	Poster Pop-Up Talks	1-minute 1-slide talks for poster presenters ● **Yongfa You** - Long-term impacts of climate-smart agricultural practices on the net GHG balance of U.S. croplands under future climate change scenarios	

		Melissa Linares - Assessing the Impact of the ACTS Canopy Radiative Transfer Scheme on Land Surface Albedo Simulations in the NASA GISS Earth System Model **Tao Han** - Rapid and accurate automatic segmentation of individual trees from terrestrial laser scanning point cloud **Coral del Mar Valle Rodríguez** - Monitoring Changes in Vegetation Optical Depth and Canopy Water Content with GNSS Signals at a Tropical Moist Forest **Shufen Pan** - Land use and land cover change in the United States since the Colonial Era (1630-2020): Annual and 1 km grid data for supporting DGVM modeling **Lora Murphy** - Predicting the fate of tropical forests under intensifying hurricane regimes **Yanlan Liu** - Decadal legacy effect of fires on the spatial structure of forests across CONUS	
12:15	**GROUP PHOTO**		
12:20	**LUNCH**		
1:00	**SUNSHINE, FREE TIME, IMPROMPTU MEETINGS**		
4:45	**PRE-DINNER SNACK BREAK BY POSTERS**		
6:00	**DINNER**		
	SATURDAY EVENING ORAL SESSION 3: ECOSYSTEM DISTURBANCE		
7:10	Lucy Hutyra (KEYNOTE)	Forests on the Edge - Biogeochemical changes with forest fragmentation	Professor, Boston University
8:00	Xiaonan Tai	How to model ecosystem response to disturbance and post-disturbance recovery	Professor, New Jersey Institute of Technology
8:30	Katja Irob	Sustaining Savanna Stability: Browsing Herbivores and Functional Diversity as Keys to Resilience	Postdoctoral Scholar, Hebrew University of Jerusalem
8:45	**SATURDAY EVENING POSTER SESSION & MIXER**		

SUNDAY, APRIL 7, 2024			
	SUNDAY MORNING ORAL SESSION 1: LAND MANAGEMENT		
9:00	Hanqin Tian	Improving model representation of land management to support land-based climate solution: An overview of DLEM and NMIP Modeling Activities	Professor, Boston College
	SUNDAY MORNING ORAL SESSION 2: REMOTE SENSING OF VEGETATION STRUCTURE		
9:15	Matthew Duckett	Using Multispectral Imagery from Drones and Satellites to Estimate Biomass of Intertidal Vegetation	Graduate Student, Nearview LLC, University of New Hampshire
9:30	Wenge Ni-Meister	Leveraging GEDI Waveform Measurements for Large-Scale Aboveground Biomass Estimation	Professor, CUNY Hunter College
9:45	Liling Chang	Remote-Sensing Constrained Future Predictions of Ecosystem Dynamics in California's Sierra Nevada	Assistant Professor, University of Birmingham
10:00	**COFFEE BREAK**		
10:20	Ying Sun (KEYNOTE)	Probing global photosynthesis for climate mitigation and food security: New insights from innovative tracers through remote sensing and Earth system models	Associate Professor, Cornell University
11:00	Student and postdoc presentation awards, announcement of next co-chairs and date		
11:30	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.

Cameron Coles	Time-series method for mapping spongy moth defoliation in northeastern US using Sentinel-2 imagery	Graduate student, Cornell University
Coral del Mar Valle Rodríguez	Monitoring Changes in Vegetation Optical Depth and Canopy Water Content with GNSS Signals at a Tropical Moist Forest	Graduate student, Cornell University
Tao Han	Rapid and accurate automatic segmentation of individual trees from terrestrial laser scanning point cloud	Postdoc, Cornell University
Melissa Linares	Assessing the Impact of the ACTS Canopy Radiative Transfer Scheme on Land Surface Albedo Simulations in the NASA GISS Earth System Model	Graduate student, CUNY Graduate Center
Francesca Lingo	Mapping bird-friendly coffee farms using remote sensing and machine learning	Graduate student, Hunter College
Yanlan Liu	Decadal legacy effect of fires on the spatial structure of forests across CONUS	PI, Ohio State University
Mazen Nakad	Tropical forest responses to climate extremes: A modeling analysis using an individual-based demographic vegetation model	Postdoc, Columbia University
Lora Murphy	Predicting the fate of tropical forests under intensifying hurricane regimes	Research staff, Columbia University
Naiqing Pan	Future prediction of terrestrial carbon uptake and nitrous oxide emissions	Postdoc, Boston College
Shufen Pan	Land use and land cover change in the United States since the Colonial Era (1630-2020): Annual and 1 km grid data for supporting DGVM modeling	PI, Boston College
Binyuan Xu	Transforming Amazonia: A 70-year history of deforestation and agricultural dynamics	Graduate student, Boston College
Xinyi Yang	Impact of fire on terrestrial carbon dynamics: A global analysis using the dynamic land ecosystem model (DLEM)	Graduate student, Boston College
Yongfa You	Long-term impacts of climate-smart agricultural practices on the net GHG balance of U.S. croplands under future climate change scenarios	Postdoc, Boston College
Dongchen Zhang	Harmonizing terrestrial carbon cycle observations over CONUS NEON Sites: Assessing the information contributions of multiple data constraints	Graduate student, Boston University

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ORAL AND POSTER ABSTRACTS

(Alphabetical order)

Remote-Sensing Constrained Future Predictions of Ecosystem Dynamics in California's Sierra Nevada

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

[1]Harvard University, [2]University of Birmingham, [3]University of Sussex, [4]Lawrence Berkeley National Laboratory, [5]National University of Singapore, [6]University of Maryland

Abstract. California's Sierra Nevada harbors a rich diversity of ecosystem types, largely influenced by climate conditions, soil types/properties, and elevations. The diverse ecosystems, however, have been threatened by climate change and disturbance events. For accurate predictions of the future fates of the ecosystems under climate change, we assimilated remote sensing derived ecosystem structure and composition to initialize a cohort-based terrestrial biosphere model. More specifically, we used the vertical profiles of Plant Area Index (PAI) derived from the Global Ecosystem Dynamics Investigation (GEDI) measurements and the estimates of fractional composition from imaging spectrometry data. Then, we ran model simulations forced by different future climate scenarios until the end of the century (2099). Our objectives were to 1) evaluate the impacts of different initialization methods on long-term model predictions by comparing the remote-sensing initialized versus the traditional potential vegetation simulations, and 2) examine differing responses of the diverse ecosystems in an elevational transect region in California's Sierra Nevada. Regarding objective (1), we found long-lasting impacts of initial ecosystem states on model predictions of ecosystem structure and composition. At the multi-decadal scale, the impacts of initialization are larger than the impacts of climate scenarios. Regarding objective (2), the study region was predicted to sequester additional atmospheric CO2 by the end of the century. The net carbon gain mainly reflected increases in the abundance of deciduous and coniferous trees in grass-dominated woodland savannas in low- elevations, and increases in coniferous trees in forests in mid- to high-elevations. However, both aboveground biomass (AGB) and leaf area index (LAI) of deciduous trees were predicted to decline in mid- to high-elevations by the end of the century.

Key words: climate change impacts; terrestrial biosphere modeling; ecosystem dynamics; California's Sierra Nevada.

Time-series method for mapping spongy moth defoliation in northeastern US using Sentinel-2 imagery.

Cameron Coles[1], Valerie Pasquarella[2], Christie Goodale[1], Xiangtao Xu[1]

[1]*Department of Ecology and Evolutionary Biology, Cornell University, Ithaca, NY; cjc378@cornell.edu, xx286@cornell.edu, clg33@cornell.edu*
[2]*Harvard Forest, Harvard University, Petersham, MA; vpasquarella@fas.harvard.edu*

Abstract. European spongy moth (formerly European gypsy moth, *Lymantria dispar dispar*) is an invasive insect in the northeastern United States whose outbreaks can cause extensive defoliation. The consequences of multi-year outbreaks can be seen in all parts of the ecosystem including shifting tree species composition, altered food sources and habitat for other organisms, as well as effects on carbon cycling, soil nutrient dynamics, and more. However, our understanding of forest susceptibility and resilience to spongy moth outbreaks is limited by a lack of high-quality data that can quantify defoliation across space and time. Remote sensing has proven useful for mapping defoliation, though current techniques and products typically use coarser resolution MODIS and Landsat observations to characterize defoliation events. We used Sentinel-2 MSI data to create higher spatial resolution defoliation estimates of *Lymantria* outbreaks in upstate New York, USA from 2019 to 2022. Our approach utilizes average linear declines (covering 2019 to 2022, when Level 2a data is available) in enhanced vegetation index (EVI) during the growing season (June through August) modeled by a Theil-Sen regression to identify and quantify extended periods of low EVI indicative of defoliation. This approach is more robust to sparse data than harmonic methods built on year-round data used in previous studies. Our defoliation estimates better match the spatial variability in Lymantria outbreaks seen in ground observations and align well with *in situ* measurements of percent decline in leaf area index which will be beneficial for future modeling efforts. Annual maps of defoliation will be compared to climatic (land surface temperature, precipitation, etc.) and ecological (species composition, tree mast quantity, historical defoliation record, etc.) data to explore the key environmental drivers of spongy moth outbreaks.

Key words: spongy moth; *Lymantria dispar dispar*; remote sensing; insect outbreak.

MULTISENSOR DATA ASSIMILATION TO SUPPORT TERRESTRIAL CARBON CYCLE AND DISTURBANCE MONITORING, REPORTING, VERIFICATION, AND FORECASTING

M.C. Dietze [1], D. Zhang[1], Q. Li[2], S.P. Serbin[3]

[1]*Department of Earth & Environment, Boston University, Boston, MA; dietze@bu.edu, zhangdc@bu.edu*

[2]*Environmental and Climate Sciences Department, Brookhaven National Lab, Upton, NY; qli1@bnl.gov*

[3]*Biospheric Sciences, NASA Goddard Space Flight Center, Greenbelt, MD; shawn.p.serbin@nasa.gov*

Abstract. Terrestrial ecosystems are a major sink for anthropogenic carbon (C) emissions, and are increasingly being employed for climate mitigation, yet they continue to represent the largest source of uncertainty in the global C cycle because of their complexity and heterogeneity. By iteratively fusing process-based models with observations, data assimilation represents a powerful approach for reducing uncertainty in both near-term forecasts and the monitoring, reporting and validation (MRV) associated with international and voluntary carbon markets. Here we report on efforts to deploy such a system for North America using the PEcAn toolbox, the SIPNET model, and a wide-range of top-down (NASA GEDI and Landtrendr aboveground biomass, MODIS leaf area, and SMAP soil moisture) and bottom-up (Ameriflux carbon and water fluxes, SoilGrids soil C) data constraints. Value of information analyses find not only strong direct constraints from different data sources (e.g. MODIS leaf area constrains modeled leaf area) but also significant indirect constraints, both across space and across pools and fluxes, but with soil C remaining the largest source of uncertainty despite novel advances in assimilating soil C products. Furthermore, the assimilation of pool data improves 35-day forecasts of C fluxes more than the assimilation of fluxes themselves. Reducing our assimilation frequency from annual to monthly reduced MRV uncertainty due to improvements in the seasonal cycles of leaf area, soil moisture, and land-atmosphere fluxes. Finally, we report on methodological advances in our algorithms aimed at improving our ability to assimilate discrete disturbance events, a major source of land C emissions.

Key words: data assimilation, carbon reanalysis

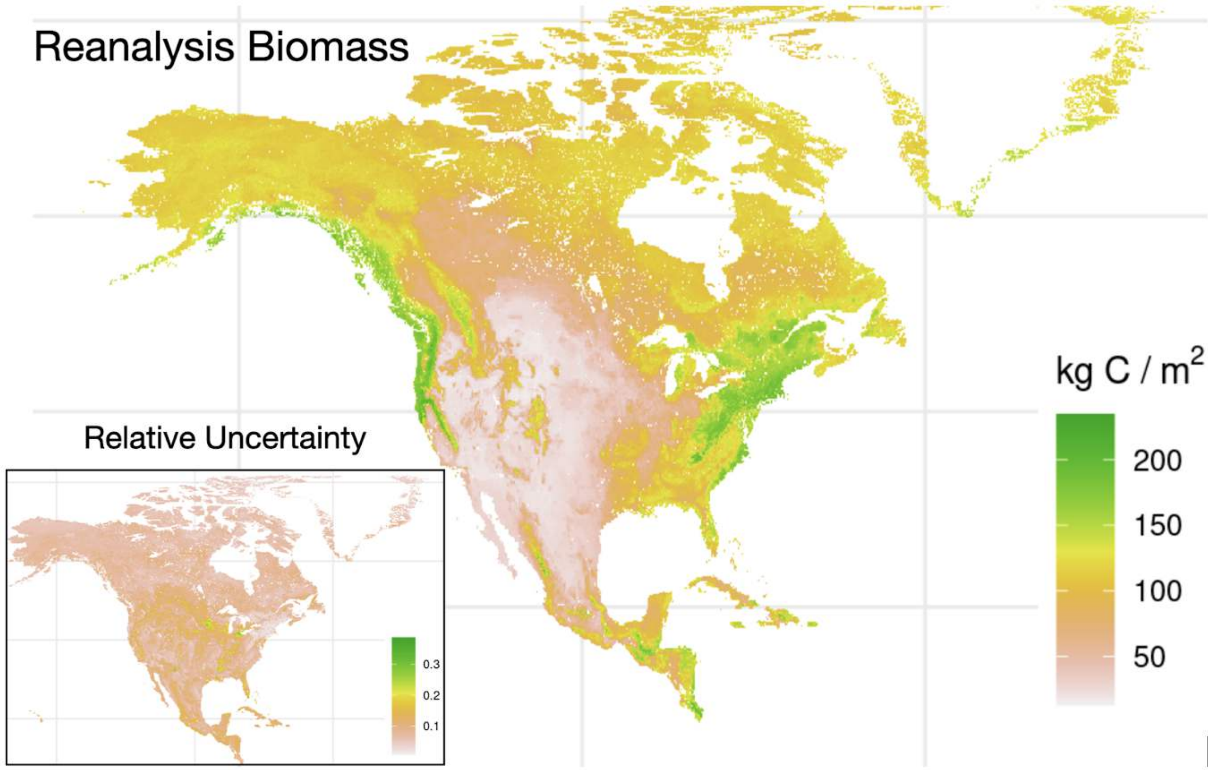

Figure 1. PEcAn carbon reanalysis map of aboveground biomass. Uncertainties in inset map are proportional (e.g. 0.2 = 20%).

Using Multispectral Imagery from Drones and Satellites to Estimate Biomass of Intertidal Vegetation

Stefan Claesson (PhD) [1], *Ernst Linder (PhD)* [1,2], *Matthew Duckett* [1,2], *Christopher Shipley* [1]

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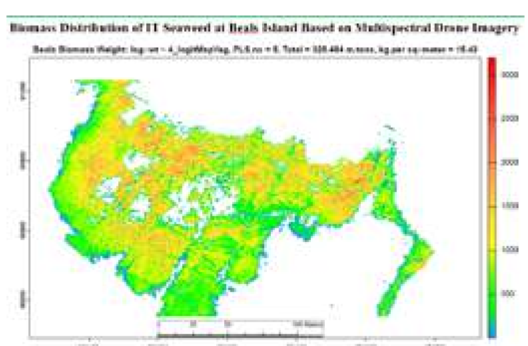
[2] *University of New Hampshire, Durham, NH, United States. Department of Mathematics and Statistics.*

Intertidal (IT) seaweeds along the coast of the northern American Atlantic have become increasingly important as a resource for consumer products, fertilizer, human food, domestic animal feed and others. IT seaweeds are also a crucial component of the food chain of marine organisms. Whether the motivation lies in resource harvesting, or resource conservation, stakeholders require frequent assessment of the available biomass of IT seaweeds. However, in-situ biomass measurements are expensive, sparse, and necessitate extensive extrapolation that may result in unreliable estimates.

The use of remote sensors and Uncrewed Aerial Systems (UASs) can offer a less expensive and more accessible alternative to acquiring extensive in-situ information relevant to biomass estimation. We obtained lab measurements of hyper-spectral reflectance data, along with canopy depth and weight measurements, for a collection of in-situ biomass samples at different sites along the coastline of Maine. Functions of down-sampled multi-Spectral (MS) reflectance data are then used to train Partial-Least-Squares (PLS) models for weight and canopy depth. Our PLS models were then fed MS data from concurrent UAS flights at our collection sites to obtain predictions of total biomass for each site. Our results indicate that our estimates (weight in tons) of predicted total biomass for a collection site can be closely approximated by a model for canopy depth due to the presence of a linear relationship between depth and weight at the logarithm scale. As depth measurements are easier to obtain than weights, our method can be utilized for improving biomass model training with more densely sampled in-situ quantities, and consequently, improved biomass estimates.



Phenologies: defining seasons through different indicators in land-atmosphere interactions perspective

Rong-Yu Gu[1], Aya Lahlou[1], Linnia Hawkins[1,2], Pierre Gentine[1]

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[2]*National Center for Atmospheric Research, Boulder, CO; lh3194@columbia.edu*

Abstract. The accurate representation of phenology, essential for modeling land responses to the atmosphere, has gained widespread attention. Active seasons are characterized by denser leaves, increased water and gas exchange between the land surface and the lower atmosphere, and greater carbon uptake from terrestrial ecosystems. Despite all three phenomena indicating phenology, they actually govern atmospheric responses on different time scales. Structural changes impact roughness, influencing turbulence and surface wind speed; alterations in surface fluxes seasonally affect boundary layer development and cloud frequency; and productions influence the annual atmospheric CO2 concentration. Previous studies have predominantly focused on the greening trend and the lengthening of the season over the past decades, mostly relying on observations of leaf area index (LAI) and gross primary production (GPP). However, few studies have addressed the differences in defining seasons through different indicators. In this study, we compared the start of season (SOS) and the end of season (EOS) in structure, greenness, evapotranspiration (ET), and production metrics through flux tower and satellite observations. SOS and EOS were determined using a fixed threshold approach, in which the smoothed indicators reached 30% of the annual range. Results reveal a 20-day difference in SOS from structure, greenness to production, and a one-month difference in EOS from production, greenness to structure in evergreen needleleaf forests, deciduous broadleaf forests, and grasslands. EOS exhibits wider variability among indicators than SOS. Contrary to the hypothesis, the onset of ET does not always fall between greenness and production onset, possibly due to snowmelt and evaporation occurring before plant transpiration starts. Additionally, satellite observations contribute to a better understanding of the SOS and EOS differences among indicators across biomes. We compared vegetation optical depth (VOD), LAI, ET and contiguous solar-induced fluorescence. While the structural metrics from flux tower sites diverge in defining SOS and EOS, even in the same biome, VOD shows more clustered results. The study emphasizes the time differences among phenological indicators in defining SOS and EOS. These time differences demonstrate that structural and greenness changes regulate fluxes and productions. We should look at phenologies, rather than a single cycle of phenology, to evaluate the model performance on land-atmosphere interactions.
Key words: phenologies; land-atmosphere interactions; structure; greenness; evapotranspiration; gross primary production.

Rapid and accurate automatic segmentation of individual trees from terrestrial laser scanning point cloud

Xiangtao Xu, Tao Han

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Abstract. Vegetation structure is important to understand forest ecosystems and is becoming increasingly critical in monitoring and modeling forest dynamics. The advances in terrestrial laser scanning (TLS) during the last decade provide exciting opportunities to measure detailed three-dimensional forest structure at millimeter spatial resolution. However, a major bottleneck of TLS application in forest ecology is individual tree segmentation. Existing methods of tree segmentation from 3D point cloud often require an amount of work in manual intervention or parameter tuning. In addition, small trees and complex canopy structure are often hard to resolve in those methods. Methods based on deep learning are promising but limited by high-quality training data set across diverse forest types, which are not available yet. Here, we presented a novel automated unsupervised algorithm called FLIP (Forest Lidar Integrated toolset in Python) for individual tree segmentation. The algorithm clusters raw point clouds into linear connected segments (LCUs) that represent branch/stem segments based on geometrical features and then assemble LCUs into individual trees based on connectivity and topology. The algorithm is also computationally efficient and can take advantage of multi-core CPUs with multi-processing. We tested FLIP over TLS data from temperate forests of different composition and complexity. Our results show FLIP can more robustly identify small stems and thin branches compared with existing tree segmentation methods. Additional tests in boreal and tropical forests are under way. Overall, FLIP can help to digest the ever-increasing forestry TLS data and improve our understanding in forest structure diversity and dynamics.

Key words: tree segmentation, point cloud, FLIP, forestry.

KEYNOTE TALK

FORESTS ON THE EDGE - BIOGEOCHEMICAL CHANGES WITH FOREST FRAGMENTATION

Lucy R. Hutyra[1], Jonathan Thompson[2], Sarah Garvey[1], Luca Morreale[1,3]

[1]*Department of Earth & Environment, Boston University, Boston, MA; lrhutyra@bu.edu*
[2]*Harvard Forest, Harvard University, Petersham, MA,* [3]*Smithsonian Conservation Biology Institute, Marshall, VI*

Abstract. Fragmentation transforms the environment along forest edges, altering forest growth and biogeochemical cycling. In temperate forests, approximately 17.5% (217 million hectares) of forests located within 30 m of a non-forest edge. Using a combination of remote sensing, the Forest Inventory and Analysis data, and direct field observations, we find that forest edges have systematically altered carbon cycling and biogeochemistry. We find that temperate forest edges exhibit increased forest growth and biomass with no change in total mortality relative to the forest interior. At forest edges adjacent to anthropogenic land covers, we report increases of 36.3% and 24.1% in forest growth and biomass, respectively. Inclusion of edge impacts increases estimates of forest productivity by up to 23% in agriculture-dominated areas, 15% in the metropolitan coast, and +2% in the least-fragmented regions. Increasing soil carbon losses via respiration have been observed at rural forest edges, but this process was suppressed at urban forest edges. Despite significant diverging trends in edge soil carbon losses between urban and rural sites, we did not find comparable differences in soil % carbon or microbial enzyme activity, suggesting an unexpected decoupling of soil carbon pools and fluxes at forest edges. Forest edges reflect legacies of anthropogenic land-use and modern human management, and this must be accounted for to understand biogeochemistry and carbon cycling across fragmented landscapes. Despite the abundance across the landscape and altered biogeochemistry, we find that forest edges are systematically under-sampled and under-estimated, with ecosystem models not currently capturing these dynamics.

Key words: carbon cycle, forest edges, urbanization, forest fragmentation

Sustaining Savanna Stability: Browsing Herbivores and Functional Diversity as Keys to Resilience

Katja Irob[1,2], Niels Blaum[3], Britta Tietjen[2]

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[2]Theoretical Ecology, Freie Universität Berlin, Berlin, Germany; *britta.tietjen@fu-berlin.de*
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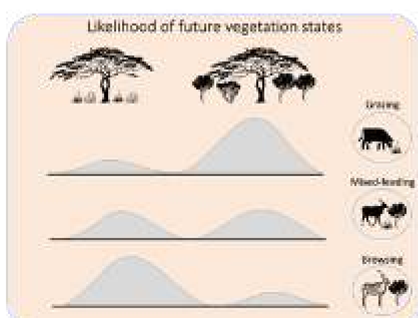
Abstract. Savannas, characterized by water scarcity and degradation, face heightened vulnerability due to uncertain water availability stemming from climate change. This poses significant risks to ecosystem services and rural livelihoods dependent on them. Compounding the challenge, the lack of consensus among climate models on precipitation change complicates future planning for land managers. Consequently, Savanna rangeland management must develop strategies to maintain resilience and avert tipping points amid climatic uncertainty.

Our study investigates the impact of climate change and rangeland management on Savanna ecosystem degradation in southern Africa, offering insights applicable to semi-arid Savannas worldwide. Using projections from 10 global climate models, we simulated the effects of anticipated temperature and precipitation changes on water resources and vegetation, including shifts in cover, functional diversity, and tipping points from grass to shrub dominance. Employing the EcoHyD ecohydrological model, we evaluated three rangeland management options (grazer-dominated, browser-dominated, and mixed feeder communities) at varying animal densities.

Our findings underscored intensive grazing as the principal driver of increased degradation risk under changing climatic conditions across all scenarios. Degradation manifested as reduced available water for plant growth, diminished vegetation cover, loss of functionally important plant species, and inefficient water resource utilization, leading to tipping points. In the face of climate uncertainty, integrating browsers and managing mixed herbivore communities emerged as the most effective strategy for farmers to safeguard livelihoods and ensure ecosystem stability. This approach sustained greater plant functional diversity, fostering a resilient ecosystem crucial for buffering against adverse climatic conditions, postponing or preventing tipping points.

Key words: climate change, ecohydrological modelling, management strategies, resilience, Savanna ecosystems, tipping points, wildlife



Making More With Continuous Forest Inventory Data: A Dynamical Spatio-Temporal Model to Predict Forest Change

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Models of forest dynamics are an essential tool to predict forest ecosystem responses to global change. These predictions are used to make management and policy decisions to maintain forest health, function, and ecosystem services. To maximize the utility of such predictions, contemporary models of forest dynamics must address the uncertainty in forest demographic processes under no-analog conditions. Dynamical spatio-temporal models (DSTMs) applied within an iterative, near-term forecasting framework are a particularly powerful tool in this setting given that they quantify and partition uncertainty in demographic models and noisy forest observations, propagate uncertainty to predictions of adaptive management outcomes, and refine predictions based on new monitoring data and improved ecological understanding. A major challenge to the application of DSTMs in applied forest ecology has been the lack of a scalable, theoretical model of forest dynamics that generates predictions at the stand level—the scale at which management decisions are made. We address this challenge by integrating a matrix projection model motivated by the well-known McKendrick-von Foerster partial differential equation for size-structured population dynamics within a Bayesian hierarchical DSTM informed by continuous forest inventory data. The model provides probabilistic predictions of species-specific demographic rates and changes in the size-species distribution of stands in response to climate, disturbance, and alternative management approaches. We apply the model framework to predict the long-term dynamics (60+ years) of stands under alternative management scenarios within the Penobscot Experimental Forest in east-central Maine. We conclude with a discussion of how the DSTM can be scaled up to predict regional forest dynamics assimilating new inventory data as it becomes available.

Key words: forest dynamics, Bayesian hierarchical model, data integration, probabilistic prediction

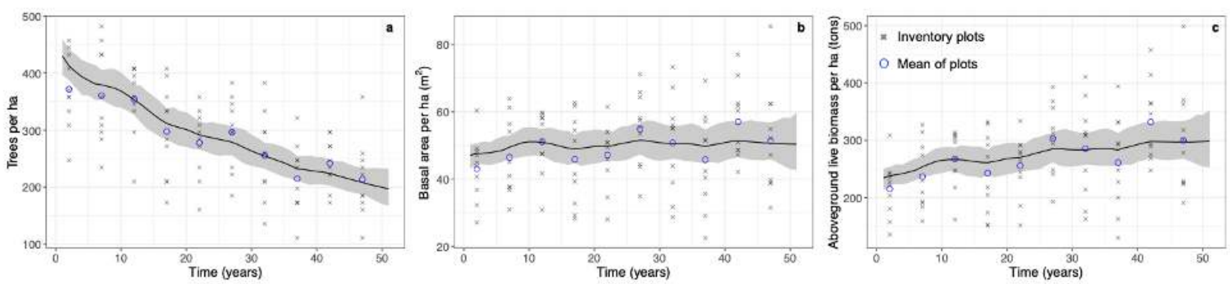

Figure 1. Probabilistic predictions of change in white pine forest density over a 50-year period in terms of trees (a), basal area (b), and aboveground live biomass (c) per hectare. Solid line represents posterior mean density, while shaded region corresponds to 95 percent credible interval.

MODELING MANGROVE FUTURES IN BELIZE: INFORMING COASTAL RESILIENCE IN A CHANGING CLIMATE

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Abstract. Climate change-driven increases in storm frequency and intensity underscore the urgent need to understand the dynamic nature of coastal ecosystems. Mangroves, particularly in locations like Belize, provide essential services, including coastal protection, carbon sequestration, and vital fish habitat, supporting local livelihoods and tourism-driven economies. However, these ecosystems face mounting pressures from anthropogenic and climate-based changes.
This study employs a Multi-scale Integrated Model of Ecosystem Services (MIMES) to forecast potential mangrove distribution and structural changes in Placencia, Belize. The model integrates historical data, climate change impacts (including flooding and drying), population growth, and local and international economic pressures to generate scenarios of future mangrove distribution. Additionally, we map littoral forests, which are crucial for biodiversity and carbon sequestration.
Our findings aim to empower local communities and NGOs in developing evidence-based policies and strategies to protect these vital coastal ecosystems. This research highlights the potential of scenario modeling to support climate-resilient coastal management, ensuring the continued benefits mangroves provide to communities and ecosystems in the face of a changing world. This study is part of a NSF-funded COPES grant, "Large-scale CoPe: Reducing Climate Risks with Equitable Nature-based Solutions: Engaging Communities on Reef-Lined Coast." This project aims to develop a collaborative, inclusive process to measure the risk reduction benefits of nature-based solutions (NBS) like coral reef and mangrove restoration.
Key words: mangroves; system modeling; carbon sequestration; coastal communities; dynamic modeling.

Figure 1. Distribution of mangrove forest around Placencia, Belize in 2017

Towards coexistence: data-driven FATES simulations across the Amazon

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The Functionally Assembled Terrestrial Ecosystem Simulator (FATES) vegetation demography model has the potential to help us predict how the Amazon rainforest and surrounding regions may respond to different climate change and land use scenarios. Work is ongoing to test and calibrate FATES across the Amazon and to develop plant functional types (PFTs) based on observed tropical tree traits. Representing tree functional diversity is important for understanding forest resilience, but modeling coexistence between PFTs has proven challenging as it requires balancing key parameters representing trade-offs in life-history strategy. Here we present progress in achieving coexistence between data-driven PFTs representing early and late-successional evergreens and drought-deciduous trees. While early-successional evergreens completely dominated the region in initial FATES simulations, modifying crucial parameters related to carbon balance and mortality has increased the degree of PFT coexistence in our simulations, and recent code improvements have increased late-successional persistence in the understory. The development of these PFTs for the Neotropics and the progress in regional-scale modeling with FATES represent significant steps towards our ultimate goal of land-atmosphere coupled simulations.

IMPACTS OF MESOPHYLL DIFFUSION ON THE LONG-TERM INCREASE IN GLOBAL CARBON-13 DISCRIMINATION AND WATER USE EFFICIENCY

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Abstract. Much information of photosynthesis and carbon cycling was embedded in the stable carbon isotope, as plants discriminate against heavier carbon isotope. The process of isotope discrimination has been implemented in most terrestrial biosphere models (TBMs), mainly following the standard equation by Farquhar et al. With National Center for Atmospheric Research (NCAR) Community Land Model (CLM5), we found this standard equation cannot reproduce the historical long-term increase of isotope discrimination as deduced from atmospheric 13C/12C measurements. We attributed such a mismatch to the missed representation of photorespiration and, particularly, mesophyll diffusion. Updating the discrimination equation by leveraging a mechanistic mesophyll diffusion model developed by Sun et al. (2014), we reproduce the trend towards a larger discrimination under higher CO_2 levels: globally the trend is 0.014‰ ppm^{-1}, consistent with atmospheric measurements. A significant proportion of this trend can be explained by mesophyll effects, with large variations among different climate regimes and biomes. Explicit consideration of mesophyll diffusion also leads to a larger response of water use efficiency (WUE) to climate change (CO_2 enhancement) and environmental stresses. Our results have implications for advanced modeling of isotopic discrimination and therefore for a better understanding of land carbon cycle under changing climate.

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Assessing the Impact of the ACTS Canopy Radiative Transfer Scheme on Land Surface Albedo Simulations in the NASA GISS Earth System Model

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Abstract: This study aims to assess the accuracy of land surface albedo simulations using the latest version of the National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies (GISS) Earth System Model. Specifically, we compare the model's surface albedo estimates with and without the Analytical Clumped Two-Stream (ACTS) canopy radiative transfer scheme developed for the Ent Terrestrial Biosphere Model (TBM) with MODIS albedo. Modifications to the snow masking were implemented in the new model runs, grid-level snow masking was retained in one run and turned off in another. The changes to snow masking allowed us to examine the effects of these changes in detail. Our results suggest that the addition of the ACTS scheme to ModelE significantly enhances the accuracy of land surface albedo estimations. The albedo simulations in the Northern Hemisphere from the new model runs were closer to MODIS than those from the original model, which demonstrates an improvement in the accuracy of albedo estimates. The results from the comparison of the new run and original model, indicated that the new run estimates a higher albedo in the mid-latitude regions (40N to 60N). This suggests that the new model run is more reflective in these areas and should therefore exhibit cooler temperatures. This observation aligns with the surface air temperature results, where the new run shows consistently cooler temperatures in these regions when compared to the original model. These comparisons between the albedo and temperature results provide evidence supporting the hypothesis that the addition of the ACTS canopy radiative transfer scheme can improve the accuracy of land surface albedo in the ModelE. The integration of the ACTS scheme into the latest version of the ModelE represents a significant step forward in the ability of the NASA GISS Earth System Model to predict land surface albedo.

Mapping Bird-Friendly Coffee Farms Using Remote Sensing and Machine Learning

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Abstract

Coffee, a globally significant agricultural commodity, is largely produced in South America. The production of coffee involves a range of systems, from full-sun monoculture to agroforestry featuring a diverse canopy of shade trees. Shade coffee systems support a higher level of biodiversity than full-sun monoculture, offering refuge for both migratory and resident bird species. Conversion from shaded coffee to monoculture coffee farms to increase yields has resulted in declines in bird populations. This research investigates if remote sensing data can differentiate structural fauna in coffee growing practices, including sun coffee, shaded coffee, and highly shaded "bird-friendly" coffee and distinguish between these coffee growing practices and natural forests, urban regions, and areas with shrubs. By leveraging LiDAR technology and multispectral Sentinel-2 satellite data alongside machine learning techniques, the structural characteristics of coffee farms, forests, urban areas, and shrub regions are evaluated in Cundinamarca, Colombia. Specifically, the study assesses the effectiveness of remote sensing technologies, particularly the inclusion of LiDAR-derived canopy height data, in accurately mapping existing coffee plantations and improving land cover classification accuracy. Utilizing Google Earth Engine for geospatial data analysis, Sentinel-2 imagery, canopy height, elevation, texture, and other climate features coupled with machine learning models, this research demonstrates the accuracy of different machine learning models in classifying different regions and types of coffee cultivation. We found that the inclusion of LiDAR data significantly enhances the model's performance in distinguishing between land cover types, highlighting the importance of structural vegetation attributes in the classification process. Furthermore, the models' ability to predict land cover types in new regions suggests their applicability in broader geographical landscapes. This study emphasizes the effectiveness of integrating remote sensing and machine learning techniques in accurately mapping shade coffee plantations, distinguishing between natural forests and bird-friendly coffee plantations, and predicting new regions for sustainable coffee cultivation, ultimately contributing to biodiversity conservation and sustainable agricultural practices.

Key words: bird-friendly, agroforestry, remote sensing, machine learning, land cover classification

Decadal legacy effect of fires on the spatial structure of forests across CONUS

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The increasing occurrence of wildfires has led to reduced and fragmented forest cover, distorting ecosystem carbon sequestration and water resources across the globe. Existing studies analyzing large-scale postfire recovery typically rely on spatially aggregated measures such as average greenness or biomass, while neglecting the spatial structure of forest patches. However, multiscale evidence has shown that forest edges and small patches in fragmented forests exhibit ecological functions distinct from intact forests, such as lower carbon sink, higher sensitivity to heat stress, faster mortality, and lower biodiversity. Assessing postfire responses of ecosystem functions and resources therefore requires quantifying the recovery of not only total forest area but also patch distribution and the fraction of forest edges. Here we address this knowledge gap from a data-driven perspective by integrating the Monitoring Trends in Burn Severity (MTBS) product during 1984-2019, and the National Land Cover Database (NLCD) maps during 2001-2021 at a 30 m resolution across CONUS. We used an image segmentation approach to delineate forest patches after fires, measured the area and the edge fraction (the ratio between squared perimeter and area) of each patch, and quantified their statistical distributions. We found that the probabilistic distributions of patch area and edge fraction distributions typically followed power laws. Comparing the exponents of the power law distributions between burned and control areas, we found burned areas have more small patches with high edge fraction and less big patches, indicating fragmented landscapes. The exponents of burned areas gradually recovered toward those of unburned areas, which represents the spatial structural recovery of forests. However, the recovery rates varied substantially across bioclimatic regions, faster in the southeastern US and northwestern US, slower in southwestern US and the Mountain states. Even in the fast-recovery regions, the fraction of forest edges took around 20 years to reach full recovery, longer than the time to full recovery of forest patch area. Using a random forest model, we found high fire severity, steep slopes, and postfire droughts were the most important factors limiting the recovery rate of forest spatial structure. Our findings provide an observation-based benchmark on long-term spatial structural recovery of forests, which could potentially be integrated with dynamic vegetation models for improved simulations and assessment of postfire ecosystem functions.

Estimating global Gross Primary Production (GPP) from satellite Solar-Induced chlorophyll Fluorescence (SIF) with a mechanistic model

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Abstract. Direct measurement of gross primary production (GPP) beyond a single leaf is a core challenge that prevents accurate quantification of global GPP and its spatiotemporal dynamics. Recent advancements in satellite Solar-Induced chlorophyll Fluorescence (SIF) retrieval offer promising opportunities, but so far incorporating satellite SIF to estimate GPP across scales is based solely on empirical linear scaling, an assumption that does not always hold at short timescales and stress conditions. In this study, we employ a process-based model, based on the mechanistic light reaction (MLR) model, to establish the link between SIF, electron transport rate (ETR), and GPP at the canopy scale using SIF retrievals from TROPOspheric Monitoring Instrument (TROPOMI) onboard Sentinel-5p. Our approach is applied across diverse NEON (National Ecological Observatory Network) ecoregions during the growing seasons of 2018-2021. We compare GPP estimates obtained from the conventional linear scaling approach and our mechanistic MLR-based approach with eddy-covariance (EC) flux tower measurements. Additionally, we analyze cross-biome variability in GPP estimates by incorporating ancillary information from hyperspectral reflectance spectra. Our findings highlight the potential of MLR for enabling satellite SIF for global GPP estimation, and the mechanistic advantage of MLR over the widely-accepted linear SIF-GPP scaling.

Key words: *Satellite Solar-Induced chlorophyll Fluorescence (SIF); Gross primary production (GPP); Mechanistic Light Reaction (MLR) model*; *global scale*.

WIDESPREAD LEGACY EFFECTS OF EARLY-SEASON VEGETATION ACTIVITY ON AUTUMN LEAF SENESCENCE CONSTRAIN GLOBAL GROWING SEASON EXTENSIONS

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Abstract. Predicting future growing-season lengths is critical for understanding the impacts of climate change on various ecological zones, including forests, savannas, shrublands, and grasslands. This task is complex due to the nuanced interplay between climate factors and plant productivity. Utilizing satellite-derived vegetation productivity datasets, our recent studies have identified a consistent negative correlation between early-season productivity until peak vegetation greenness and autumn phenology across these biomes, revealing that early-season and late-season warming influence leaf senescence in contrasting ways. Specifically, warming prior to the peak of greenness accelerates senescence onset, while increased temperatures after the peak extend its duration. In this talk, I will synthesize findings from our recent studies focusing on i) the temporal trends of phenological changes across different biomes and the primary drivers of shifts in autumn senescence, ii) assessing the importance of both external environmental influences (such as temperature, precipitation, and radiation) and the internal responses of vegetation (productivity), and iii) exploring ways to incorporate these remote sensing-derived insights into Dynamic Global Vegetation Models (DGVMs), to improve predictions and understanding of terrestrial ecosystems responses to climate change.

PREDICTING THE FATE OF TROPICAL FORESTS UNDER INTENSIFYING HURRICANE REGIMES

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Abstract. Rapid climate change is anticipated in tropical regions over the coming decades with a potential large shift in future disturbance regime. Cyclonic storms represent the dominant natural disturbance in many coastal tropical forests and predicting the effects of changing storm regimes on these ecosystems remains a key challenge for global change research. Here, we use a terrestrial biosphere model Ecosystem Demography 2 (ED2) to predict carbon fluxes of a Puerto Rican tropical forest under realistic disturbance scenarios. Hurricanes are expected to increase in frequency and severity in the North Atlantic, and the composition of Puerto Rican forests has been shown to be quite sensitive to disturbance. We developed a hurricane damage module in ED2 based on historic hurricane events and tree damage data, and parameterized the model with species-specific tree physiological data. We parameterized an additional tree plant functional type, the palm, to improve the model's ability to capture tropical forests. Simulation results under different possible future storm regimes suggest that tropical forests may turn from carbon sinks into carbon sources. We present our model results and a discussion of key challenges in the modeling of tropical forest systems.

Tropical forest responses to climate extremes: a modeling analysis using an individual-based demographic vegetation model

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Abstract. Examining how tropical forests respond to climate extremes, including droughts and elevated air temperatures linked to increased atmospheric carbon dioxide levels, is essential given their significant role in carbon and water cycling. Previous research has demonstrated the sensitivity of tropical forests to water availability and rising temperatures. In this study, we delve into this crucial subject using the Biome Ecological strategy simulator (BiomeE), an individual-based demographic vegetation model. BiomeE effectively simulates intricate interactions among plant traits, soil biogeochemical processes, and disturbance events, providing valuable insights into forest structural and computational dynamics. Initially, FLUXNET data from tropical forests were utilized to guide the model until vegetation demography stabilized. Subsequently, various scenarios were introduced to simulate climate extremes, and their effects on forest structure post-equilibrium were observed. The simulation results highlight the impact of environmental stressors on vegetation dynamics, as well as carbon and water cycling in tropical forests. The findings from this study contribute to our comprehension of the repercussions of climate extremes on tropical forests.
Key words: tropical forest; drought; demographic vegetation model, carbon and water cycles

Leveraging GEDI Waveform Measurements for Large-Scale Aboveground Biomass Estimation

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The study presents an innovative method for directly estimating aboveground biomass density (AGBD) using the lidar waveform measurements from the Global Ecosystem Dynamics Investigation (GEDI) instead of relying on derived products like height metrics, commonly used in similar studies. The model incorporates GEDI waveforms and stem diameter-tree height and crown size-height allometric relationships, resulting in a unified formula for AGBD estimation. We leverage continental (NEON and FIA) and global (TALLO) vegetation structure measurements to assess the spatial variability of these allometric relationships. This approach can be readily applied at continental and global scales without additional calibration.

We evaluated the model at the plot level in diverse environments, including temperate forests in the northeastern U.S., montane forests in the western U.S., and tropical forests in central Africa, yielding promising accuracy. Its application in the continental U.S. utilizing GEDI measurements resulted in a Root Mean Square Error (RMSE) of 21 Mg/ha compared to Forest Inventory and Analysis (FIA) biomass data. The results showcased the model's capability in accurately estimating aboveground biomass at a large scale using GEDI waveform measurements. In conclusion, this study presents a promising and precise approach to estimating aboveground biomass density at a continental scale, utilizing GEDI waveform measurements, thereby offering valuable insights for forest ecosystem monitoring and carbon storage management.

FUTURE PREDICTION OF TERRESTRIAL CARBON UPTAKE AND NITROUS OXIDE EMISSIONS

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Abstract:
Nitrogen additions to terrestrial ecosystems tend to enhance the net uptake of carbon, while stimulating the emissions of nitrous oxide (N_2O) which is a potent long-lived greenhouse gas. Moreover, changes in climate, atmospheric CO_2 concentration and land use affect both carbon and nitrous oxide fluxes within terrestrial ecosystems, as the carbon and nitrogen cycles are tightly coupled. In this study, we use the Dynamic Land Ecosystem Model (DLEM) to predict the future changes of global terrestrial ecosystem CO_2 and N_2O fluxes during the 21st century, based on different SSP-RCP-N scenarios developed in the International Nitrogen Management System (INMS) project. By setting up a series of simulation experiments, we evaluate the contributions of different driving factors including anthropogenic nitrogen inputs, climate change, CO_2 concentrations, and land use change. Our results suggest that in scenarios of "business-as-usual" and "low N regulation", the cooling effect of nitrogen-induced carbon sequestration will be largely offset by the warming effect resulting from the increasing N_2O emissions. Our findings underscore the importance of effective nitrogen management in combating global warming.

Key words: terrestrial ecosystem; CO_2; N_2O; future prediction.

LAND USE AND LAND COVER CHANGE IN THE UNITED STATES SINCE THE COLONIAL ERA (1630–2020): ANNUAL AND 1 KM GRID DATA FOR SUPPORTING DGVM MODELING

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The land of the conterminous United States (CONUS) has been transformed dramatically by humans over the last four centuries through land clearing, agricultural expansion and intensification, and urban sprawl. High-resolution geospatial data on long-term historical changes in land use and land cover (LULC) across the CONUS are essential for predictive understanding of natural–human interactions and land-based climate solutions for the United States. A few efforts have reconstructed historical changes in cropland and urban extent in the United States since the mid-19th century. However, the long-term trajectories of multiple LULC types with high spatial and temporal resolutions since the colonial era (early 17th century) in the United States are not available yet. By integrating multi-source data, such as high-resolution remote sensing image-based LULC data, model-based LULC products, and historical census data, we reconstructed the history of land use and land cover for the conterminous United States (HISLAND-US) at an annual timescale and 1 km × 1 km spatial resolution in the past 390 years (1630–2020). The results show widespread expansion of cropland and urban land associated with rapid loss of natural vegetation. Croplands are mainly converted from forest, shrub, and grassland, especially in the Great Plains and North Central regions. Forest planting and regeneration accelerated the forest recovery in the Northeast and Southeast since the 1920s. The geospatial and long-term historical LULC data from this study provide critical information for assessing the LULC impacts on regional climate, hydrology, and biogeochemical cycles as well as achieving sustainable use of land in the nation.

KEYNOTE TALK

DON'T CALL THEM TRAITS: NEW REMOTE OBSERVATION OF VEGETATION FORM AND FUNCTION

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Abstract. Vegetation function in models is defined by equations that include parameters, often called traits, now, that determine quantitative responses to the environment. Prominent among these characteristics are structural traits influencing light harvesting and competition, and the leaf economic spectrum (LES), traits controlling vegetation growth from conservative, high resource efficiency types that grow slowly to high growth rate but less efficient types. Models are parameterized around these traits from remarkably small data bases and categorized into relatively few types (for example, tropical forests with ~ 90% of plant species are one type). New airborne and space-based sensors are providing massive infusions of data regarding structural and functional characteristics, in many cases, perhaps all, revealing them to be not only far more variable than the plant functional type suggests, but dynamic in ways that are different from the paradigm. We will present data on spatial, within and between species variation, seasonal variation and pan-tropical variation showing spatial-temporal variation showing that not only are the PFT categories limiting, new data suggests the entire paradigm is misleading. Rather than being defining characteristics of types, the LES is a set of characteristic response functions, and the LES traits state variables that respond in characteristics ways. We show early simulations of sensitivity and note that the widening availability of not-really-traits data may allow a fundamental reparameterization of land models to better correspond to reality.

KEYNOTE TALK

PROBING GLOBAL PHOTOSYNTHESIS FOR CLIMATE MITIGATION AND FOOD SECURITY: NEW INSIGHTS FROM INNOVATIVE TRACERS THROUGH REMOTE SENSING AND EARTH SYSTEM MODELS

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Abstract. Photosynthesis is one of the most important biological processes on the Earth planet, by which food is produced to feed the world and CO2 is sequestered into terrestrial ecosystems from the air, acting as the key negative feedback to mitigate climate change. However, quantifying global photosynthesis and projecting its future trajectories is extraordinarily challenging, as this process cannot be measured directly at scales beyond a single leaf. To confront these challenges towards advancing the predictive understanding of global photosynthesis as well as the resulting carbon-climate feedbacks and food production, this presentation will introduce two innovative photosynthetic tracers, i.e., Solar-Induced chlorophyll Fluorescence (SIF) and carbonyl sulfide (OCS), both of which are mechanistically linked to photosynthetic machinery via the light reaction and CO2 diffusions from the air to leaf chloroplast, respectively. These two mechanistic tracers at the molecular level can now be remotely sensed from satellite platforms with increasing precision, spatial and temporal resolutions (thanks to the recent advances in remote sensing technology). These measurements can also effectively inform Earth System Models (ESMs) to improve their parameterization and simulations of global photosynthesis and the subsequent carbon cycle dynamics for both natural and agriculture systems. I will share our recent findings empowering SIF and OCS in inferring global/regional photosynthesis, crop production, and water use efficiency under changing climate.

Key words: Global Carbon Cycle, Photosynthesis, SIF, OCS,

How to model ecosystem response to Disturbance and post-disturbance recovery

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Abstract. Climate change is increasing the frequency and severity of forest disturbances like wildfire, drought, heat waves, and insect outbreaks. These can severely affect forest health and vitality by causing tree mortality or reducing their ability to provide the full range of goods and services. More importantly, understanding forest responses and dynamics after disturbance events and the underlying driving mechanisms is crucial to project future forest composition, dynamics, and functions. Process-based ecosystem models offer valuable tools to make predictions about forest functions and inform mitigation strategies to help ecosystems better cope with climate change. We will present the most recent progress and challenges in using models to incorporate disturbance and recovery representation towards developing science-based climate change solutions.

Key words: coupled plant hydraulics-groundwater hydrology modeling, forest mortality, post-disturbance recovery

IMPROVING MODEL REPRESENTATION OF LAND MANAGEMENT TO SUPPORT LAND-BASED CLIMATE SOLUTION: AN OVERVIEW OF DLEM AND NMIP MODELING ACTIVITIES

Hanqin Tian[1,2] and the EDGE group

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Abstract:

DGVM has been used as a common tool for quantifying global carbon and GHG budgets, however, much uncertainty still exists in part because most of existing DGVMs poorly represent action-level land management activities. For supporting climate action, particularly achieving net-zero emissions in agriculture and forestry sectors, it is clearly needed to better represent land management practices in DGVM. In this presentation, we provide an overview of how we have enhanced the representation of climate-smart agriculture and forestry (CSAF) practices in the Dynamic Land Ecosystem Model (DLEM). We have applied the advanced DLEM to quantify and attribute net GHG budget in different sectors (cropland/soil, forestry, etc.) and countries (US, China, etc.) In addition, we used the simulated C and N fluxes derived from the NMIP to show large uncertainty and divergence among the coupled C-N models, underscoring the urgency of better model representation for land management practices for the implementation of climate action.

Monitoring Changes in Vegetation Optical Depth and Canopy Water Content with GNSS Signals at a Tropical Moist Forest

Coral del Mar Valle Rodríguez[1], Cameron Coles[1], Vincent Humphrey[2], Xiangtao Xu[1]

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Abstract. Tropical forests are experiencing greater hydroclimatic variability, emphasizing the need for precise monitoring of vegetative water content (VWC) dynamics to understand ecosystem sensitivity to changes in moisture. The main observation of VWC is through Vegetation Optical Depth (VOD), a measure of how much the VWC attenuates signal. Microwave remote sensing offers a promising solution, directly detecting VWC shifts through the sensitivity of the dielectric constant to free water volume within vegetation.[1] VOD is also increasingly used to constrain biomass and water hydrodynamics in terrestrial biosphere models. Current satellite-based top-down VOD products have large footprint and are influenced by many factors such as soil moisture, which can be difficult to validate[XX1] . By pairing ground-based Global Navigation Satellite System (GNSS) antennae to quantify microwave signal-to-noise ratio differences under clear sky and understory conditions[2] in Luquillo LTER, Puerto Rico, we address the limitations of satellite-based VOD products. This approach allows sub-daily temporal resolution estimates of hemispherical VOD and canopy water content. We will be demonstrating our observations after several months of continuous data collection in the tropical moist forest. This explorative study will contribute to the understanding of drivers of satellite VOD products, ecohydrological processes in a tropical forest, and their vulnerability to drought.

Key words: GPS Signals, Microwave Remote Sensing, Vegetation Optical Depth, Canopy water content.

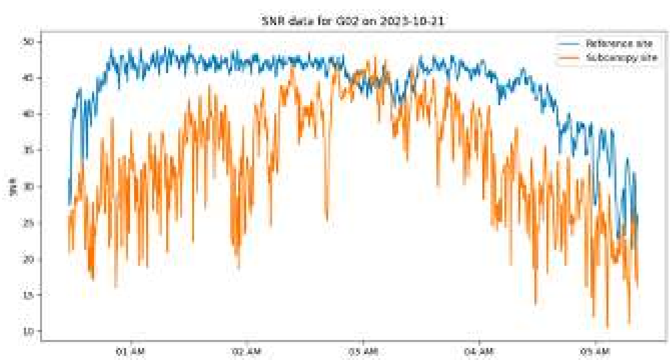

Figure 1. Graph depicting the fluctuation in signal-to-noise ratio of satellite G02 between a reference and subcanopy site on a sub-daily scale during October 21st, 2023.

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Advancement in NIR Reflectance measurements of small leaves and pine needles and analysis of differing spectral resolution.

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Abstract. With rapidly changing environmental conditions due to climate change, novel UV-VIS-NIR remote sensing techniques for vegetation are critical to observe environmental metrics. Capturing reflectance data of small vegetation samples such as pine needles, blades of grass, and tiny leaves is a technical challenge to overcome. The very small field of view needed for the measurement, as well as the required high sensitivity of the spectrometer can be an obstacle in obtaining high quality data. To combat this challenge, researchers have taken to measuring the combined spectrum of many small samples bunched together. Arranging mats or needle holders, in turn, enhance mutual shading of adjacent needles, multiple scattering, or re-absorption. (Rajewicz et al. 2019) There is also difficulty in repeatability that should be avoided. The resulting measurements will represent an average of the spectral features of all samples, not necessarily of the individual sample. Advancements in field and laboratory vegetation spectra are needed to study small leaves. To address this problem, we deployed Spectral Evolution's novel leaf clip reflectance probe and small leaf adapter using both a standard and high-resolution spectroradiometer. This method allows for reflectance measurements of individual needles and more control on the target. 3 types of small vegetation samples were measured with this method including small leaves and two species of pine needles. The enhanced spectral resolution combined with the ability to control the field of view, targeting individual needles allows for more accurate measurements of small vegetation samples.
KEYWORDS (5): UV-VIS-NIR, VEGETATION, HYPERSPECTRAL, SPECTROMETER, REFLECTANCE

Transforming Amazonia: A 70-Year History of Deforestation and Agricultural Dynamics

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Abstract. The Amazon basin is a global hotspot for land use change, characterized by significant cropland expansion and deforestation. Developing high-resolution and long-term land use/land cover (LULC) data is essential for a deeper understanding of natural-human interactions and addressing the impacts of climate change on carbon and nitrogen cycles. In this study, we integrated multiple data sources, including high-resolution remote sensing imagery-based LULC data, model-based crop type data, and census data, to reconstruct the dynamics of land-use change and crop types in the Amazon since 1950 at annual time scales and a 1km×1km spatial resolution. The results showed that cropland in the Amazon has increased rapidly through encroachment into tropical rainforests over the past 70 years, and the composition of crop types in the Amazon has changed significantly. The newly developed LULC and crop type data provide important insights for assessing the impacts of land use change and cropland expansion on regional carbon and nitrogen cycles. Moreover, these data are instrumental for the development of national policies and sustainable development strategies aimed at protecting the Amazon's ecosystem and biodiversity.

KEYNOTE TALK

TRAIT-BASED MODELING OF TROPICAL FOREST STRUCTURE AND DYNAMICS: CRITICAL DIMENSIONS OF PLANT FUNCTIONAL DIVERSITY

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Abstract. Parameterization of modern terrestrial biosphere models (TBMs) is increasingly based on plant ecophysiological traits. Such trait-based approach allows for assimilation of accumulating trait observations to reduce uncertainty and is likely to be more robust to predict ecosystem dynamics under novel climate regimes. However, the translation of plant traits to forest demographics (growth/mortality/recruitment) that are more relevant for long-term ecosystem changes can be elusive, especially in the hyper-diverse tropical forests where functional diversity can become a "curse of dimensionality" for designing and parameterizing TBMs. In this presentation, I will first demonstrate how leading dimensions of inter-specific variations in plant functional traits (related to light and water use) influence predictions of Ecosystem Demography 2 (ED2) model and what critical dimensions are still missing. Second, I will highlight the importance of intra-specific trait plasticity, which is often not considered in TBMs, for modeling tropical forest structure and regrowth. Finally, I will discuss the opportunity and challenges of using Eco-Evo Optimality theory to constrain the dimensions of functional diversity for TBMs.

Key words: trait-based modeling; plant functional diversity; forest demographics, trait plasticity, optimality theory

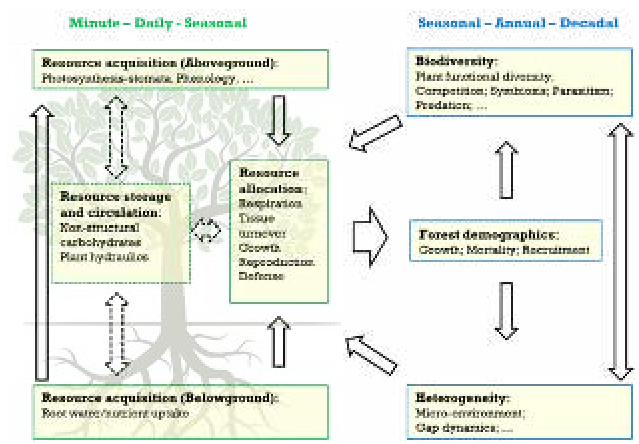

Figure 1. Key process-based modules (rectangles) within modern trait-based TBMs, separated into individual-level physiological processes (green) that operate from minute to seasonal scales and community to ecosystem-level ecological processes (blue) that operate beyond seasonal times scales. Arrows denote the dominant direction of interactions between modules. The emerging explicit modeling of resource storage and circulation is shown as dashed box and arrows. The figure is adapted from Xu & Trugman (2021).

IMPACT OF FIRE ON TERRESTRIAL CARBON DYNAMICS: A GLOBAL ANALYSIS USING THE DYNAMIC LAND ECOSYSTEM MODEL (DLEM)

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Abstract. Terrestrial ecosystems play a critical role in the global climate system, acting as significant carbon sinks while being highly sensitive to environmental changes. This research focuses on the influence of fires on the carbon dynamics of terrestrial ecosystems over the past 50 years in the context of climate change, including both the immediate emissions from fires and the subsequent alterations in carbon storage and ecosystem productivity. Utilizing the Dynamic Land Ecosystem Model (DLEM) fed with historical data on burned areas, our study provides a comprehensive analysis of the effects of fire on key carbon flux metrics— Pyrogenic Carbon Emissions (PCE), Gross Primary Productivity (GPP), Terrestrial Ecosystem Respiration (TER), and Net Ecosystem Productivity (NEP)—at a global scale. By exploring the impacts of historical fire trends on these parameters, our findings aim to offer valuable insights for forest management strategies in mitigating the adverse effects of future wildfires on terrestrial carbon budgets. This study not only contributes to our understanding of fire's role in terrestrial carbon cycling but also supports the development of informed responses to climate change challenges.
Key words: Fire; Terrestrial Ecosystem; Carbon dynamics; Climate change.

Long-term impacts of climate-smart agricultural practices on the net GHG balance of U.S. croplands under future climate change scenarios

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Abstract: Agriculture plays a pivotal role in the Earth's climate through releasing or sequestering carbon dioxide (CO_2) and releasing non-CO_2 greenhouse gases (GHGs) such as nitrous oxide (N_2O) and methane (CH_4). Recently, climate-smart agricultural (CSA) practices, such as reduced tillage and cover cropping, have gained widespread advocacy for their potential to mitigate GHG emissions and/or enhance SOC sequestration. Nevertheless, the long-term impacts of implementing CSA practices on the regional net GHG balance (i.e., sum of SOC sequestration and emissions of N_2O and CH_4) under future climate change scenarios are still uncertain, although such comprehensive macro-level analysis could offer valuable insights towards achieving carbon-neutral climate goals. In this study, we used the Dynamic Land Ecosystem Model (DLEM) to predict the impacts of future climate change and the implementation of various CSA practices (including nitrogen fertilization regulation, reduced tillage, cover cropping, and crop rotation) on the net GHG balance of U.S. croplands across various future climate scenarios, including SSP126, SSP245, and SSP585, representing sustainability, middle of the road, and business-as-usual trajectories, respectively. Simulation results indicated that the implementation of CSA practices will significantly reduce national net GHG balance, with average reduction rates of 19%, 10%, 28%, and 18% for no tillage, nitrogen fertilizer use reduction, cover cropping, and crop rotation, respectively. Additionally, the diverse mitigation potential under different climate scenarios underscores the imperative for comprehensive, scenario-specific CSA strategies to meet the dual goals of climate change mitigation and food security. Our regional study holds important implications for effectively implementing and optimizing CSA practices to address climate change issues in the agricultural sector, which also aligns with carbon reduction goals and supports climate-resilient farming systems.

Harmonizing terrestrial carbon cycle observations over CONUS NEON sites: Assessing the information contributions of multiple data constraints

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Abstract. Accurate assessments of the terrestrial carbon cycle are crucial for understanding ecosystem processes, tracking climate change impacts, and the monitoring, reporting, and verification (MRV) of international and voluntary carbon accounting. The fusion of process-based modeling and field and remote sensing observations has the potential to provide more accurate and precise estimates than either alone. However, these approaches might be susceptible to complex uncertainties, leading to a lack of understanding of potential biases in the system. The value-of-information (VOI) analysis undertaken in this study, which assesses the benefits of acquiring additional data, presents an opportunity to quantitatively evaluate the information contribution across observations and spatial domains, which were largely unknown before. In this study, we used a novel block-based Tobit Gamma Ensemble Filter (TGEnF) to assimilate four data streams (wood, leaf, soil carbon, and soil water) into the process-based ecological model (SIPNET) across the CONUS (contiguous U.S) NEON (National Ecological Observatory Network) sites from 2012 to 2021. The results showed that not only did we greatly reduce uncertainty among the directly constrained pools but that many pools and fluxes were able to share information across observations and space. These indirect constraints helped identify conflicts among data streams and between the model and data spatially, which provides the insights for further improving the model predictions by knowing precisely when, where, and what types of observation should be taken.

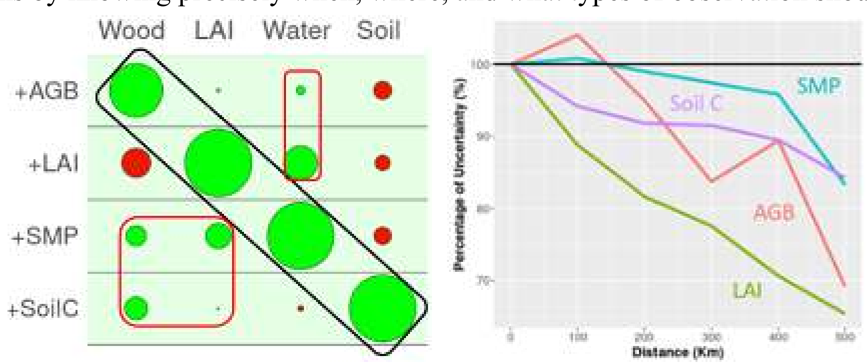

Figure 3. The uncertainty reductions by direct constraints from observations (AGB, LAI, SMP, etc.) (black box on the left figure, the larger the green dots are, the less uncertain the variables will be) and indirect constraints: 1) across-variable constraints from indirect observations and correlations among variables (red boxes on the left figure); 2) across-space constraints from spatial correlations at different spatial scales (distances among locations within which the covariance will be considered).

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