AmeriFlux

- Poster Abstracts -

For the

- 2025 AmeriFlux Annual Meeting -

Posters with odd numbers (1,3,5,...) ---> Wednesday Poster Session

Posters with even numbers (2,4,6,...) ---> Thursday Poster Session

Topic: Urban and Managed Lands Poster 1

M. Altaf Arain

Evaluating the impacts of climate extremes, disturbances, and management on carbon fluxes in forest and agricultural ecosystems in the Great Lakes region

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Canada's forests cover 367 million hectares (Mha, 37% of land area), while agricultural lands cover 62.2 Mha (6.3% area). Approximately 61% of Canada's forests (~225 Mha) are managed or plantation forests, historically acting as carbon (C) sinks. However, many of these forests are becoming net C sources due intensified climate stresses and natural disturbances e.g. wildfires, insect infestations, heat stresses, droughts etc. Climate warming is also accelerating the hydrological cycle, thereby altering forest and crop growth patterns, water balances and feedbacks. If properly managed, Canadian forests and agricultural lands can sequester significant C and support Natural Based Climate Solutions. However, their role as C sinks or sources depends on climate factors and land management practices. In this study, eddy covariance flux measurements in an age sequence (85-, 50-, and 22-years old as of 2024) of conifer (white pine) plantations, a managed deciduous (>90-yr old Oak) forest and an agricultural field located in southern Ontario, Canada are examined to determine the impact climate variability, extreme weather and disturbance (i.e. infestation and thinning) events. Results showed that the younger conifer stands were more efficient in C uptake and water use despite exhibiting greater sensitivity to heat and water stress. The deciduous forest, though more resilient to climate stresses was a large C source due to a spongy month infestation early in the growing season. An experimental Variable Retention Harvesting (VRH) study showed that maintaining dispersed retention of 55% basal area is the optimal forest management practice to enhance forest growth, transpiration and C uptake. Agricultural site was C sink during the corn years, C neutral when tobacco was planted and C source or neutral during sweet potato years. This study helps to assess the vulnerability of managed forests and agricultural ecosystems to climate change, extreme weather and disturbance events in the Great Lakes region.

Topic: Remote Sensing Poster 2
Daphna Uni

Drought response in three conifer species detected by sap flow and proximal thermal remote sensing

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Dryland forests of the southwest US face a warming and changing hydroclimate, yet our ability to monitor and predict vegetation-drought dynamics over large regions remains limited. Here, we examine drought responses and predictability of sap flow for three species, (Douglas fir, ponderosa pine, and southwestern white pine) over two consecutive years. We collected tree-scale sap flow velocity and evaluated its relationship with soil water content (SWC) and vapor pressure deficit (VPD). Next, we identified the soil moisture threshold beyond which sap flow was no longer limited by SWC. We also assessed whether proximal remote sensing of canopy temperature and canopy-to-air temperature difference (ΔT) can capture ecosystem-scale drought response dynamics. Significant sap flow reductions occurred in response to drought periods, but sap flow quickly recovered following large rainfall events. When SWC was below a threshold of ~7 % , SWC and sap flow were positively correlated, indicating water-limited conditions, while above this threshold only VPD and sap flow were positively related, indicating atmospheric demand limited conditions. Species differences were minor, but ponderosa pine sap flow responded most rapidly to soil dehydration. ΔT was significantly correlated with sap flow, but the relationship switched from positive (R= 0.79 – 0.92) during the pre- and post-monsoon to negative during the monsoon (R= -0.31 – -0.48). This shift likely reflects a transition from soil moisture supply to atmospheric demand limitation during wetter periods. These findings highlight the potential of combining tree-scale sap flow measurements with thermal remote sensing to enhance understanding of vegetation-drought dynamics in dryland forests.

Topic: General Science Session Poster 3

David Moore

Ecosystem ecology of North America

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Carbon, water, and energy exchanges between land and atmosphere drive ecosystem function and climate feedbacks. Seasonal patterns and environmental sensitivities differ widely across North American biomes and are influenced by direct and interactive controls. Here, we leverage up to 25 years of half-hourly eddy-covariance measurements from the AmeriFlux network to compute multi-decadal seasonal climatologies of net ecosystem exchange (NEE), gross primary productivity (GPP), ecosystem respiration (RECO), and evapotranspiration (ET) across major vegetation types (deciduous and evergreen forests, grasslands, shrublands) and biome regions (boreal, temperate, Mediterranean, arid). We analyze these with reference to state factors, interactive and direct controls. For each site, we derive seasonal means and interannual anomalies, then aggregate by biome to characterize characteristic flux timing and magnitude. We further quantify relationships between flux variability and key environmental drivers—climate, geology, elevation and also direct meteorological controls (air temperature, precipitation, and vapor pressure deficit)—using linear regression and composite analyses. This continental-scale synthesis reveals distinct seasonal flux signatures among biomes and highlights biome-specific sensitivities to climatic drivers, providing a benchmark for model evaluation and improving projections of ecosystem responses to future climate variability.

Topic: Data processing Poster 4
Peter Isaac

Towards a unified, semi-automated QC system for flux tower data.

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Many sites in regional flux tower networks use instruments from either one of 2 manufacturers, giving a high degree of consistency at the front end of the data pipeline. The FLUXNET2025 initiative, using the ONEFlux processing pipeline, gives a high degree of consistency at the back end of the data pipeline. However, between these start and end points, there is a wide range of approaches to common issues such as data quality control and format that differ from network to network. Using standardised approaches to quality control will improve the consistency of data products across regional networks and greater automation of these approaches will decrease the time required for, and the subjectivity in, this processing step.
We compare the approaches to quality control of flux tower data that are used by ICOS, AmeriFlux, NEON and TERN to establish common areas that may serve as a starting point for a unified approach. We also compare the efficacy of semi-automated quality control approaches including partially supervised, AI techniques and the Structural Similarity Index. We expect that conclusions drawn from these comparisons of techniques across networks and across approaches will help guide the Global flux tower network to a more consistent treatment of data between measurement and final processing.

Topic: Remote Sensing Poster 5
Housen Chu

Flux Scaling as the Final Frontier: Challenges and Opportunities Across Scales

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Understanding and scaling land-atmosphere fluxes remains one of the final frontiers in Earth system science. While flux networks like AmeriFlux and NEON have matured into cornerstones for in situ monitoring, spatial integration with remote sensing and modeling still lacks systematic workflows and common standards. This is especially the case for supporting practical applications in agriculture, forestry, and urban planning.

Last year's installation of the workshop series "Remote Sensing and Fluxes Upscaling for Real-world Impact" brought together over 200 researchers, practitioners, and policymakers to address this challenge. Participants established shared vocabulary and conceptual frameworks, such as varying dimensional awareness during scale transitions, and developed a roadmap to improve spatial joins, scale matching, and flux partitioning across domains and disciplines. This year's workshop installation is held in conjunction with the AmeriFlux Annual Meeting.

Here, we present key outcomes from the workshop series and discuss next steps toward community-coordinated workflows for spatialized flux integration. We highlight technical hurdles such as scale-emergent behavior in land surface heterogeneity, energy balance closure, and non-linear interactions between flux and state variables. These challenges underscore the importance of resolving flux footprints at high resolutions, deploying UAV-based thermal and hyperspectral imaging, and developing machine learning emulators that respect physical constraints.

We also discuss cross-cutting needs including open-source interoperability, benchmark-ready uncertainty quantification, and actionable formats for decision support. Ongoing efforts include planning an AGU25 follow-up workshop and building early-career

engagement through the CarbonDew Community of Practice.

This team poster aims to spark discussion on how the flux community can establish harmonized foundations for multi-scale synthesis: connecting point-based observations with remote sensing, modeling, and management decisions in climate-smart land, water, and carbon stewardship.

Topic: General Science Session Poster 6
Cove Sturtevant

When and where the Modified Bowen Ratio method works

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While the eddy covariance (EC) method is the most direct approach for measuring ecosystem-scale surface-atmosphere exchange, it is not possible to use in all applications, often due to the inability to measure scalar concentrations at a sufficiently high frequency. The Modified Bowen Ratio (MBR) method is among a suite of alternatives deemed the flux gradient approach in which the surface-atmosphere flux is calculated by multiplying the vertical concentration gradient of the target scalar by an eddy diffusivity. In the MBR method, the challenge of estimating the eddy diffusivity is simplified by backing it out of concurrent EC and concentration gradient measurements of another scalar (the tracer) in which high frequency measurements are available. This approach has been used with varying success across a range of studies, yet until now there has been insufficient infrastructure to comprehensively define the set of conditions under which it works. The standardized and highly instrumented sites of the National Ecological Observatory Network distributed across a wide range of ecosystems provide the infrastructure to address this gap. In this study we explore the factors that generate comparable CO2 and H2O fluxes between EC and MBR methods. We found generally good agreement between MBR and EC methods after excluding profile levels below the canopy and concentration gradients without a sufficient signal to noise ratio. Good agreement between MBR and EC occurred most often for profile levels near the canopy top and slightly stable conditions. The diel average pattern of the flux could successfully be reproduced from MBR estimates with a sufficient sample size. However, the large degree of data filtering sometimes biased the ecosystem conditions sampled, especially for short-statured, dry ecosystems.

Topic: Modeling, novel methods Poster 7
Abdul Wahed Nab

Benchmarking and Advancing Evapotranspiration Estimates with AmeriFlux Data: A Priestly-Taylor Jet Propulsion Laboratory (PT-JPL) vs. Penman-Monteith (PM) Synthesis

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Evapotranspiration (ET) is a key component of the terrestrial water cycle, yet significant uncertainties remain in regional estimates across different land cover types and climatic conditions. Leveraging the AmeriFlux network, we compare two widely used models: the semi-empirical Priestley-Taylor Jet Propulsions Laboratory (PT-JPL) and a bucket-type Penman-Monteith (PM) framework across 92 sites spanning various landcover types. Driven by AORC meteorological forcing with static inputs of surface properties from MODIS, both models are calibrated (2018– 2022) and validated (2022–2024) against the eddy-covariance fluxes. We used the Shuffled Complex Evolution (SCE) for parameter optimization, tuning 15 PM and nine PT-JPL parameters. One-at-a-time (±5–30 %) and 1000-member Latin Hypercube perturbations quantify parameter sensitivities and posterior uncertainty. Model performance was assessed using statistical metrics, including Kling–Gupta Efficiency Skill Score (KGEss), Nush Sutcliff Efficiency (NSE), coefficient of determination (R^2), Root Mean Square Error (RMSE), and Bayesian Information Criterion (BIC). Results show that PM consistently outperformed PT-JPL across twelve land cover types in both calibration and validation periods. In calibration, PM achieved mean KGEss = 0.87, NSE = 0.84, RMSE = 15.18 W/m², and R^2 = 0.89, whereas PT-JPL had KGEss = 0.81, NSE = 0.48, RMSE = 27.67 W/m², and R^2 = 0.55. Similar results were observed in validation. The resulting BIC indicates that the calibrated PM offers a better and more parsimonious fit than PT-JPL in 71 % of sites. To address the residual bias of both models, we deploy a two-layer deep neural network (DNN) as a post-processor. Preliminary trials suggest potential daily RMSE reductions of 20–35 %. Further analysis across climate zone reveals that PM remains accurate across the full aridity gradient, while PT-JPL's skill drops steadily as conditions become drier. This study advances hydrological modeling by providing a robust, cross-validated comparison of two widely used ET models across diverse climate zones and ecosystems using the AmeriFlux observations. By delivering a calibrated, validated, and uncertainty-quantified ET framework, it supports more accurate water balance assessments and land–atmosphere interaction studies.

Topic: Modeling, novel methods Poster 8

Benju Baniya

Non-structural carbon dynamics and partitioning in a shortleaf pine forest

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Plants allocate photosynthetically fixed carbon (C) between immediate metabolic needs, biomass production, and non-structural carbon (NSCs), which can be further partitioned between storage and exudates. The stored NSC, comprising soluble sugars, starch, and lipids, is a buffer between carbon supply and demand. Currently, these pools are not well captured in ecosystem models because of recognized deficiencies in both conceptual representations and relevant observational data. Here we present an ecosystem-level estimate of C allocation to or from the NSC pool (FNSC) as the difference between gross primary productivity (GPP), plant respiration (Rp), and biomass production (BP) in a shortleaf pine forest. Over three years of study, annual GPP remained relatively stable (1827-2053 g C m^{-2} yr^{-1}) but FNSC varied. FNSC ranged from 320-478 g C m^{-2} yr^{-1} in dry years (2022-2023) and 298 g C m^{-2} yr^{-1} in the wet year (2024), representing 15-24% of annual GPP. Moreover, annual FNSC exceeded biomass production (BP) in the dry years (BP=170-233 g C $m\text{-}^{2}$ $yr\text{-}^{1}$) but not in the wet year (331 g C $m\text{-}^{2}$ $yr\text{-}^{1}$). FNSC peaked in the early growing season (May-July), lagging behind BP, and was inversely related to both BP and plant water status. While FNSC varied considerably among years, how much of it remains in plants as storage requires further investigation. Preliminary tissue NSC analyses in 2024 suggested that only <20% was retained in the plant, and the rest was likely exuded into the soil. These findings are consistent with the surplus carbon hypothesis, which posits sink strength-driven C allocation, and can serve as the conceptual foundation on which to build next-generation carbon allocation algorithms.

Topic: Urban and Managed Lands Poster 9

Nidhi Vinod

Trait determinants of Ecosystem Functions

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Understanding how plant species composition and functional traits shape ecosystem fluxes is critical for improving modelling predictions of forest-ecosystem interactions. While it is well recognized that vegetation influences heat, water, and carbon exchange, the extent to which specific traits and community composition drive these processes remains unclear. In this study, we measured over 50 plant traits—including hydraulic, leaf economic spectrum, size-related, and gas exchange traits—using standardized protocols across 10 ecologically diverse sites across continental U.S.A. By collecting trait data directly from the field rather than relying on compiled databases, we tested associations with ecosystem traits calculated using flux variables. Our findings reveal strong and consistent relationships between community-weighted trait means and ecosystem-scale flux traits, highlighting the functional linkage between plant traits and ecosystem processes, thus furthering the field of modelling to predict forest response to climate change

Topic: General Science Session Poster 10

Ivan Mauricio Cely Toro

Evaluating Coordinate Rotation Methods for Eddy Covariance Measurements in a Deciduous Forest in Complex Terrain.

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The exchange of energy, water, and carbon dioxide between the atmosphere and terrestrial ecosystems is commonly quantified using the eddy covariance (EC) technique due to its practicality and suitability for long-term measurements. However, EC relies on several assumptions, and when these are not met, corrections are necessary to ensure data quality. One essential correction is coordinate rotation, which aligns the sonic anemometer's coordinate system with the average wind direction (streamlines), often assumed to be parallel to the terrain surface. This step is particularly important in complex terrain. The rationale behind tilt correction methods is to remove the contribution of the mean vertical wind component (w) from turbulent fluxes. Two main approaches are used for tilt correction, differing in their timescales and underlying assumptions. On one hand, online methods are applied at the end of each averaging period, such as the double rotation (DR) and triple rotation (TR) methods. On the other hand, offline methods are applied to ensembles of observations over longer periods, with the planar fit (PF) method being the most widely used. A variant of PF, known as sector-wise planar fit (SPF), applies the correction based on wind direction sectors and may offer improved accuracy in heterogeneous terrain. In this study, we analyze energy, water, and carbon fluxes measured using EC over a temperate deciduous forest with complex terrain in the Appalachian region. Although PF is widely recommended for long-term EC measurements, its implementation is site-specific. Preliminary results compare turbulent fluxes derived using DR, TR and PF (including SPF), across different wind directions, times of day, atmospheric stability classes, and seasons. The objectives of this work are to: (1) propose guidelines for selecting and applying PF methods based on terrain characteristics; (2) assess the influence of atmospheric stability, diurnal and seasonal variation on planar fit coefficients; and (3) evaluate the impact of coordinate rotation choice on cumulative flux estimates.

Topic: General Science Session Poster 11
Parisa Pourabedini

Interactions Between Hydrological Regime and Carbon Budget in Old Woman Creek Wetland

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Wetlands are critical ecosystems that provide a wide variety of environmental benefits, such as flood control, water purification, and sedimentation. Another important feature of wetlands is their ability for carbon sequestration. In fact, while they store a considerable amount of carbon, they may offset a significant portion of the global warming benefits of their carbon sink by emitting substantial amounts of methane, a potent greenhouse gas. Understanding the physical factors that affect the process behind carbon cycling and methane production would enhance our ability to model and predict this unique ecosystem and, as a result, assist in sustainable natural resource management. One of the main factors that can alter greenhouse gas dynamics in wetlands is hydrology, and specifically, water level. Old Woman Creek (OWC), a wetland on the southern shore of Lake Erie, is among the highest methane emitting wetlands in the world. Its connection to the lake is regulated by a natural barrier that alternates between open and closed states, which create variable hydrological conditions. These fluctuations make OWC a valuable site for investigating how hydrology influences carbon dynamics in coastal wetlands. This study aims to integrate different carbon components in the carbon cycle, such as dissolved organic carbon (DOC) inflow and outflow, CH_4 and CO_2 fluxes, and carbon sequestration to assess the overall carbon balance of the system. We use eddy covariance flux tower data to estimate CO_2 and CH_4 fluxes of the wetland. We combine that with soil core to estimate long-tern carbon sequestration, and hydrological data and water quality observations for DOC concentrations to calculate inflow and outflow fluxes. We utilize GeoStudio modeling under different hydrological conditions to estimate DOC seepage during time that the

barrier is closed. Preliminary findings suggest that despite high methane emissions, OWC functions as a net carbon sink. Overall, results highlight the importance of incorporating multiple carbon pathways and hydrologic variability to characterize wetland carbon budgets.

Topic: General Science Session Poster 12

Marlee York

Multiscale climate drivers of extreme carbon sinks and sources in the western USA

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Increasing climate variability is impacting the carbon cycle in unprecedented ways, demanding an understanding of the conditions leading to extreme carbon flux states. Spatiotemporal variation in drivers of carbon fluxes is poorly characterized; therefore, we sought to determine the strength and influential timescales of key environmental drivers governing unusually high daily gross primary production (GPP) or ecosystem respiration (Reco) fluxes across diverse ecosystems in the western USA. We obtained CO2 flux data for 14 AmeriFlux eddy covariance flux tower sites (11-22 years/site) across the western USA to understand the drivers of extreme CO2 sinks (extreme GPP) and sources (extreme Reco). We computed environmental covariates across multiple timescales (day, week, month, year), including temperature, vapor pressure deficit (VPD), short-wave radiation, soil moisture, and precipitation, along with site-level characteristics (e.g., mean annual precipitation [MAP] and temperature [MAT]). To account for seasonality, we defined extreme sink and source states as those GPP and Reco values exceeding a site-level 95th quantile spline regression. We then used random forest classification models to evaluate the importance of different covariates for classifying between extreme and “nominal” fluxes. Previous month precipitation quantity and variability were important predictors of extreme sinks and sources. These covariates improved classification accuracy by 13.7% and 14%, respectively, and their effect was shown to be most influential in water-limited sites. A positive relationship was observed between increasing temperature and its influence on extreme sources (9% improvement). At the month-long timescale for temperature, a shift to negative effects in sites with high MAT suggest important interactions between temperature effects across different timescales at warmer sites. This study lends insight into how precipitation conditions and temperature interactions across timescales differentially influence extreme carbon flux states along gradients of water availability and temperature in the arid and semi-arid ecosystems of the western USA.

Topic: General Science Session Poster 13
Carolina Ramírez

Water, energy and carbon dynamics over an intercropped sun-grown coffee and corn system

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The energy dissipation and the evapotranspiration processes, are factors involved in the ecosystem net carbon exchange and are determinants in the ability of a self-regulating system to balance high carbon emissions. To discover these relationships, a corn production system intercropped with coffee was monitored during the first 19 months after the system establishment, to determine the flux of energy, water, gases, and carbon by implementing the eddy covariance technique. From the net carbon exchange ecosystem balance, during the first cycle of corn intercropped with coffee, 63 g C m-2 was fixed. For the next phase of coffee culture, maintaining the corn stalks and coffee branches, 5.4 g C m-2 was emitted. In the second cycle with intercropped corn, the fixation was 291 g of C m-2; and in the last period of the first reproductive stage of the coffee trees, 172 g C m-2 was fixed. Throughout the analysis period, the system behaved as a carbon sink with a potential fixation between 4.7 and 5.6 ton C ha-1. The energy, measured as net radiation, was estimated at 274.53 ± 5.2 W m-2 day-1, and it was dissipated mainly as sensible heat (26.5% - 53.6%), latent heat (45.7% - 71, 9%) and soil heat (0.5% - 1.6%). The crop coefficient (Kc) in the coffee vegetative stage in the monoculture, fluctuated between 0.79 ± 0.05 and 0.99 ± 0.04. For the intercropping system with corn, the Kc was calculated at 0.84 ± 0.05, 1.05 ± 0.06, 1.60 ± 0.09, and 1.22 ± 0.05 for the vegetative, pre-flowering, maximum foliar development and harvest maturity stages of corn, respectively.

Topic: Modeling, novel methods Poster 14
Naveen Reddy MadiReddy

Predicting Future Changes in CO_2 Fluxes Under Increased Severe Storm Events at Plum Island Ecosystem, MA

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Coastal salt marshes are highly efficient natural carbon sinks, sequestering atmospheric CO_2 and playing a critical role in the global carbon budget. However, their role as long-term carbon sinks is increasingly vulnerable to climate change, particularly the rising frequency and intensity of severe storm events. While the impacts of sea level rise (SLR) on these systems have received considerable attention, the short-term impacts of storm events on CO_2 fluxes—Net Ecosystem Exchange (NEE), Gross Primary Production (GPP), and Ecosystem Respiration (Reco)—remain underexplored, especially across different marsh zones. This study investigates the influence of severe storm events on CO_2 fluxes in high and low marsh zones of the Plum Island Ecosystem (PIE), Massachusetts, USA using a decadal (2013–2024) dataset. This dataset integrates eddy covariance flux measurements, meteorological records, and NOAA tidal height and storm information. An event-based framework was developed to analyze flux anomalies during a 3-day (and sub-daily) window surrounding each storm. Key drivers include storm intensity characterized by rainfall intensity and tidal amplitude, which influences flooding extent. A machine learning model (XG_Boost) will be trained on this integrated dataset captured short-term flux responses, aiming to reveal marsh-specific sensitivity, with high marshes exhibiting more pronounced disruptions by interacting hydrometeorological drivers. Including tidal height as a predictor is anticipated to enhance model performance and reflects its critical role in modulating carbon exchange during and after storm events. Future Scenario-based projections using CMIP6 data (SSP2-4.5 and SSP5-8.5) will be used to simulate flux responses under increasing storm frequency and intensity by 2050. This research is expected to provide a framework for anticipating CO_2 flux disturbances in response to future climate extremes, highlighting the importance of integrating tidal processes and storm metrics into blue carbon models, with implications for carbon accounting and wetland resilience planning.

Topic: General Science Session Poster 15
Maricar Aguilos

Linking Hydrological Stress to Ghost Forest Formation: Thresholds for Tree Mortality in Coastal Ecosystems

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Prolonged flooding is reshaping coastal forest ecosystems, leading to widespread tree mortality and the emergence of ghost forests. This persistent hydrological stress also disrupts carbon cycling, undermining the stability of coastal carbon sinks. To better understand the ecological consequences of these changes, we analyzed daily eddy covariance flux data collected from a wetland forest in North Carolina, USA, over the period 2009–2019. Our study examined temporal dynamics of net ecosystem exchange (NEE), gross primary productivity (GPP), and ecosystem respiration (RE) under both flooded and non-flooded conditions, and assessed their relationships with observed patterns of tree mortality. Using Generalized Additive Modeling (GAM), we identified groundwater table depth (GWT), leaf area index (LAI), NEE, and net radiation (Rn) as key predictors of mortality transitions ($R^2 = 0.98$). Specifically, elevated GWT may be linked to root anoxia; reduced LAI indicated diminished canopy productivity; increased NEE suggested physiological stress; and higher Rn contributed to evapotranspiration-induced stress. Receiver Operating Characteristic (ROC) analysis revealed critical early-warning thresholds for tree mortality: GWT = 2.23 cm, LAI = 2.99, NEE = 1.27 g C m^{-2} d^{-1}, and Rn = 167.54 W m^{-2}. These thresholds offer a foundation for forecasting mortality risk and developing early-warning systems. Our findings underscore the central role of hydrological variability in driving coastal forest degradation. The threshold-based framework presented here supports proactive management strategies aimed at enhancing forest resilience in the face of rising sea levels.

Topic: Modeling, novel methods Poster 16

Ngoc Nguyen

Widespread underestimation of rain-induced soil carbon emissions from global drylands

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Dryland carbon fluxes, particularly those driven by ecosystem respiration, are highly sensitive to water availability and rain pulses. However, the magnitude of rain-induced carbon emissions remains unclear globally.
Here we quantify the impact of rain-pulse events on the carbon balance of global drylands and characterize their spatiotemporal controls. Using eddy-covariance observations of carbon, water and energy fluxes from 34 dryland sites worldwide, we produce an inventory of over 1,800 manually identified rain-induced CO_2 pulse events. Based on this inventory, a machine learning algorithm is developed to automatically detect rain-induced CO_2 pulse events. Our findings show that existing partitioning methods underestimate ecosystem respiration and photosynthesis by up to 30% during rain-pulse events, which annually

contribute 16.9 ± 2.8% of ecosystem respiration and 9.6 ± 2.2% of net ecosystem productivity. We show that the carbon loss intensity correlates most strongly with annual productivity, aridity and soil pH. Finally, we identify a universal decay rate of rain-induced CO_2 pulses and use it to bias-correct respiration estimates. Our research highlights the importance of rain-induced carbon emissions for the carbon balance of global drylands and suggests that ecosystem models may largely underrepresent the influence of rain pulses on the carbon cycle of drylands.

Topic: General Science Session Poster 17
Jiaming(Jamie) Duan

Understanding rangeland carbon dynamics using standardized observations: applications for upscaling with machine learning models

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Rangelands cover a large portion of the United States and play a critical role in the terrestrial carbon cycle. This study developed a standardized multi-source dataset based on eddy covariance observations from the AmeriFlux Network and the National Ecological Observatory Network (NEON), integrating remote sensing, site metadata, and gridded global meteorological datasets to investigate rangeland carbon dynamics across the western and midwestern U.S. We examined the influence of plant functional type (grass, grass-shrub, grass-tree), climate, and disturbance on seasonal and annual carbon exchanges: net ecosystem exchange (NEE), gross primary productivity (GPP), ecosystem respiration (RECO). Grass-tree ecosystems exhibited the highest seasonal carbon sequestration from April to October (–97.19 g C/m^2), while the grass ecosystems showed the highest seasonal carbon uptake (721.35 g C/m^2). Grass–shrub ecosystems had the lowest seasonal respiration (240.61 g C/m^2). Plant functional type shaped carbon-water interactions. Grasslands had the highest evapotranspiration (455 mm), while grass–tree systems showed the highest water use efficiency (316.03 g C/m^2). Climate strongly influenced annual carbon fluxes through temperature and water availability, whereas seasonal fluxes correlated weakly with precipitation and temperature. Grazing effects were not evident likely due to its interactions with climate and plant community composition. Latent heat showed a strong relationship with carbon fluxes in seasonal observations and ranked as the most important meteorological predictor in the Random Forest (RF) model trained with the tower-based dataset. RF models, trained with tower-based and ERA5 data along with Normalized Difference Vegetation Index (NDVI), identified NDVI as the top predictor for NEE, GPP, and RECO. Performance of using ERA5 in RF models was comparable to tower-based data, enabling assessments in data-sparse regions. The proposed multi-source dataset supports model development, carbon budget evaluation, and model calibration and validation, providing a foundation for scalable carbon monitoring and sustainable rangeland management.

Topic: Urban and Managed Lands Poster 18

Khayrun Nahar Mitu

Land Cover Controls on Microclimate: A Case Study from an Urban Golf Course in Phoenix

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In arid urban environments where extreme heat is a defining challenge, localized land cover profoundly impacts microclimatic conditions. This study presents a comparative analysis of an irrigated golf course and an adjacent asphalt parking lot in Phoenix, Arizona, focusing on summer conditions. During summer 2024, we instrumented two adjacent sites (~550 m apart), one of which is a fully irrigated golf course interior (US-PX2) and the other an impervious vehicle lot (US-PX4). High-frequency (10 Hz) measurements, obtained via eddy covariance towers, provide continuous data on latent and sensible heat fluxes, water vapor, and carbon exchange. Complementing this, 30-minute averaged data for key microclimatic components, including air temperature, humidity, soil moisture availability, and wind, collectively reveal the distinct microclimates shaped by varying land uses. Midday air temperatures at the vehicle lot frequently exceeded 45 °C, approximately 3–5 °C higher than those measured inside the park. Relative humidity dropped below 15% over the asphalt, with vapor pressure deficits often surpassing 5 kPa, compared to an RH of 25–35% and VPD near 2-5 kPa in the turfgrass site. Latent heat flux over the golf course peaked around 500 W m^2 due to sustained moisture availability, while the vehicle lot reached no more than half of that. Sensible heat flux at the parking lot routinely exceeded 400 W m^{-2}, more than twice that observed over the vegetated surface. Vegetation converts a significant share of net radiation into cooling the air, whereas pavement converts nearly all of this energy into heating the air and surrounding materials. Both sites experienced predominantly westerly winds during the daytime. We also used satellite-derived land surface temperature (LST) and NDVI to characterize the spatial variability in vegetation cover and surface thermal response. These findings demonstrate that land cover choices create distinct microclimates over small spatial scales (~500 m) and underscore the role of urban vegetation in moderating extreme heat. Our efforts can inform the development of climate-resilient urban design strategies in desert regions.

Topic: General Science Session
John Lenters

Poster 19

New AmeriFlux sites on the Great Lakes: Unique datasets for large-lakes research, management, and public safety

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Turbulent fluxes of energy, water, and carbon are the ultimate drivers of most lake ecosystem processes, yet only about 2% of the sites within the AmeriFlux network are categorized as "water bodies." This gap in lake flux observations is beginning to be addressed with the addition of two new AmeriFlux sites on Lake Superior (US-GL1 and US-GL2), as well as additional sites that are planned for Lakes Erie and Ontario. In this presentation, we discuss the 17-year history of the Great Lakes Evaporation Network (GLEN), its recent and ongoing integration with AmeriFlux, and the impact the flux observations have had on Great Lakes research and management. We highlight results from the two longest-running sites on Lake Superior, where flux observations have been used to improve lake-effect snowfall forecasting, hydrodynamic modeling, and our understanding of lake-ice-atmosphere interactions. The uniqueness of open-water, offshore observations over large lakes also highlights the challenges of maintaining long-term, high-quality datasets that are valuable not only for research, but also public safety and water resource management.

Topic: General Science Session Poster 20

Dohee Kim

Diurnal dynamics of Carbon allocation and respiratory costs under water stress using flux-based estimates

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Carbon (C) assimilated during daytime is transiently stored in foliar tissues and subsequently allocated to sink organs during the night. These processes - assimilation, metabolite synthesis, storage, and transport - are strongly regulated by plant hydraulic status, which varies diurnally and with water stress. Here, we analyze the dynamics of mass balance residuals from standard and isotopic eddy covariance flux partitioning approaches, interpreting it as allocation to non-structural carbon (NSC) pool. The study was conducted in an 80-yr old extensively managed shortleaf pine forest in East Texas. Aboveground respiration made a progressively higher fraction of gross ecosystem productivity (GEP) during afternoons of high vapor pressure deficit (VPD) days, indicative of elevated respiratory costs under water stress. Similar effects were observed both in conventional and isotopic flux partitioned data, even though the formulation and numeric estimates of different respiration fluxes differ greatly between these methods. We hypothesize that the greater respiratory demand under high VPD may be attributable to rising photorespiration, leaf starch saturation and the activation of more energy intensive biosynthesis of lipids, as well as production of antioxidants and activation of alternative oxidase pathways. In contrast, non-foliar and soil respiration declined in proportion with declining GEP under high VPD, except for soil CO_2 efflux measured with soil chambers, suggesting a GEP-independent component involved. We will discuss observational and conceptual support for the regulation of different respiration components by substrate availability.

Topic: Urban and Managed Lands Poster 21

Sarah Bungard

Species-Specific Growth Responses to Hydraulic Stress

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Climate change, including altered precipitation patterns, is impacting growth and survival of tree species in forest ecosystems globally. Changing intensity of water stress may shape carbon allocation decisions resulting in variable annual growth among tree species with implications for carbon cycling modeling. We aim to link the direction and timing of growth responses to characteristics of water stress with species-level hydraulic strategy traits and relate the aggregate behavior of different species to ecosystem-level gross primary production. We measured gross primary production as well as environmental factors indicative of water stress including soil water content, vapor pressure deficit, and photosynthetically active radiation were measured at the footprint of the US-UMB tower. We concurrently recorded annual stem growth over a 21-year period using band dendrometers. Yearly stem growth rates for each species were compared to mean environmental factors over three-month seasonal periods and growing/dormant seasons up to three years prior. Across timescales, the growth of isohydric species was negatively correlated with factors indicative of water stress, while the growth of anisohydric species was positively correlated with more stressful conditions. Our results demonstrate that increasingly frequent droughts under future climate conditions may favor anisohydric species, as long as the drought events are mild enough to preclude hydraulic failure and mortality through embolism. These contrasting trends reiterate the need to account for different hydraulic trait strategies in carbon modeling even within the temperate deciduous forest functional type. At the ecosystem level, average growth was negatively correlated with GPP for the current and prior year, reflecting complex spatial and temporal carbon allocation patterns that vary among species. Examining long term growth trends can help provide insights into which species will be most vulnerable to changing climate conditions and how ecosystem-scale carbon sequestration may be affected.

Topic: General Science Session Poster 22

Kyle Arndt

Elevated methane emissions and carbon cycling in a retrogressive thaw slump in northern Alaska

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Warming is occurring at a faster rate in the Arctic than the global average causing rapid changes including thawing permafrost. Rapid thawing of permafrost can lead to disturbances like retrogressive thaw slumps (RTS) where landslide-like formations create depressions and large landscape changes. These disturbances are wide-spread throughout the arctic but not much is known about the impact RTS's have on carbon fluxes. Here, through use of the Ameriflux Rapid Response program, we have instrumented the first eddy covariance tower measuring fluxes from a RTS (US-RTS) about 10 km south of the Toolik Field Station on the north slope of Alaska. Initial results show methane emissions 3-4 times as high when the footprint is over the RTS as when the footprint is over surrounding acidic moist tussock tundra. There is also enhanced diurnal cycling of CO2 fluxes with higher daytime sinks and higher nighttime respiration from the RTS compared to surrounding tundra. We will also be conducting a chamber survey this August to quantify fine-scale differences in fluxes from different areas within the RTS from the active headwall, to areas that have had longer to recover and feature regrowth of vegetation. These will also be used in combination with tower derived fluxes to ecosystem representation of tower derived fluxes. Until now, mass loss from RTS has been calculated from a loss of elevation but the surface-atmosphere exchange has not been quantified.

Topic: General Science Session Poster 23

Angela Che Ing Tang

Evapotranspiration partitioning in tidal wetlands across hydrological, salinity, and vegetation gradients

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Coastal wetlands play a disproportionately large role in global carbon sequestration relative to their limited spatial extent. However, evapotranspiration (ET)—a key regulator of wetland hydrology and vegetation dynamics—remains poorly characterized in these systems. ET consists of two primary components: abiotic evaporation (E) and biotic transpiration (T). Understanding how ET is partitioned into E and T is critical for quantifying ecosystem water use, predicting vegetation responses to environmental change, and accurately modeling surface energy and carbon budgets in coastal wetlands.

Most ET partitioning studies focus on water-limited uplands, whereas saturated coastal wetlands pose unique challenges due to continuous inundation and complex surface-atmosphere interactions. Common methods used for ET partitioning often assume that stomatal fluxes (i.e., T) dominate over non-stomatal fluxes (i.e., E), an assumption that may not hold in wetlands. The Flux Variance Similarity (FVS) method, which has shown promising results in many upland ecosystems, remains unexplored in coastal wetlands, highlighting the novelty and significance of its application.

Here, we applied the FVS method to partition high-frequency water vapor fluxes at three AmeriFlux sites in the Plum Island Ecosystem (Massachusetts), spanning gradients in hydrology, salinity, and vegetation. The sites include:

• a persistently flooded marsh dominated by Typha angustifolia (C3) (US-PLo);
• a regularly inundated low marsh dominated by Spartina alterniflora (C4) (US-PLM); and
• an intermittently flooded high marsh co-dominated by C4 species including S. alterniflora, S. patens, and Distichlis spicata (US-PHM).

We found that the less saline Typha marsh showed the highest T, likely due to sustained water availability and dense canopy. In contrast, more saline low and high marshes

exhibited strong seasonal variation in T/ET and E/ET ratios. Our findings highlight the applicability of the FVS method in saturated coastal environments and reveal how interactions among plant functional type, salinity, and tidal regime shape ET partitioning in tidal wetlands.

Topic: General Science Session Poster 24
Patrick Murphy

Environmental Drivers of Canadian High Arctic Carbon Fluxes

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The high-Arctic is particularly vulnerable to climate change, especially due to terrestrial permafrost thaw. Terrestrial net ecosystem exchange (NEE) and ecosystem methane (CH_4) fluxes are two major contributors to the carbon budget in this region, and tracking changes is important to understanding how permafrost thaw will exacerbate global change. While carbon fluxes are measured at sites across the Arctic, spatial gaps in these in-situ measurements have led to uncertainties in estimating pan-Arctic carbon budgets. To help fill these data gaps, we installed new eddy covariance flux towers in previously unrepresented areas of the Canadian high-Arctic in summer of 2024. Now that these towers have now operated for more than 1 year, we can determine some of the drivers and budgets of carbon dioxide and methane fluxes. Like other high-latitude ecosystems, both new sites show a strong response to incoming shortwave radiation, but unlike other sites, soil temperature and moisture appear to have a weaker relationship with NEE and CH_4 flux. Despite being at similar latitudes in the Canadian Archipelago, there are also large differences between these two sites – one is a cold, dry grassland tundra that is a small CO_2 sink and CH_4 source in the summer, while the other site is a polar desert that has relatively small fluxes of both gasses. Together, these two new high-Arctic sites will improve our understanding of the complexity of terrestrial Arctic carbon fluxes.

Topic: General Science Session Poster 25
Yang Li

Spring Phenology Modulates Ecosystem Responses to Compound Drought-Heat Events Across North America

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Ecosystems are increasingly threatened by compound drought-heat (CDH) events. While global warming has led to a widespread advancement of the growing season across the Northern Hemisphere, the role of spring phenology (start of growing season, SOS) in modulating CDH impacts remains poorly understood. These effects likely depend on the timing of droughts and vary along aridity gradients and across biomes.
In this study, we use eddy covariance-derived Gross Primary Productivity (GPP) and satellite-derived Leaf Area Index (LAI) across North America sites to assess how ecosystems respond to CDH events. Specifically, we ask:
(1) How does spring vegetation phenology influence GPP and LAI responses to CDH events?
(2) How do these phenological effects vary across aridity gradients and interact with drought timing?
We hypothesize that earlier SOS alters the magnitude and direction of CDH impacts on GPP and LAI, depending on both drought timing and regional ecological context. Our results show SOS shifts can either alleviate or exacerbate CDH impacts depending on when and where drought occur. Specifically, earlier SOS appears to alleviate CDH impacts in humid regions under early and late growing seasons droughts, whereas delayed SOS tends to exacerbate CDH effects across all climate zones and drought timings.
Our findings aim to inform improvements in Earth system models by incorporating phenological dynamics and CDH events, enabling more accurate predictions of ecosystem function under future climate change.

Topic: General Science Session Poster 26
Wen Zhang

Ecosystem Responses to Intra-Annual Rainfall Variability in Western U.S. Drylands

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Drylands play a critical role in global carbon and water cycles and are particularly sensitive to inter- and intra-annual variability in precipitation. The southwestern United States—which is largely composed of drylands—has been experiencing a long-term drought in addition to a shift toward more intense, less frequent precipitation events. However, the differential response of carbon and water fluxes to changes in inter- versus intra-annual rainfall variability remains poorly understood. Here, we leverage data from 25 eddy covariance flux towers across the western United States to: 1) examine how gross primary productivity (GPP) and evapotranspiration (ET) respond to changes in inter- versus intra-annual rainfall variability; 2) Assess how these responses differ across plant functional types; and 3) Evaluate the extent to which land surface models capture these observed ecosystem responses. These findings will help improve the representation of dryland ecosystems in process-based models and enhance predictions of ecosystem functioning under future environmental change.

Topic: General Science Session Poster 27

John Frank

The magnitude and uncertainty of spectral attenuation and correction in eddy-covariance water-flux measurements using enclosed-path infrared gas analyzers

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Water vapor exchange between the land-atmosphere is a fundamental process in ecology, hydrology, and meteorology with the eddy covariance technique often used to measure evaporation, transpiration and sublimation. Spectral attenuation of water vapor measurements causes the amount of H2O transported in high-frequency eddies to be underestimated, resulting in reduced water fluxes. While this attenuation is well known to be a function of relative humidity (RH) and spectral corrections are standard in a data processing workflow, commonly available data processing tools can inadequately evaluate the magnitude and uncertainty of these corrections on measured fluxes. We focus on four years of H2O fluxes from US-GLE with simultaneous measurements from two infrared gas analyzers: enclosed path LI-7200 and open path LI-7500. We propose a methodology to detect the half-power frequency (fc) “in situ” from only the enclosed-path H2O spectra or “de facto” from the spectral transfer function between the two analyzers. We investigate the relationship between fc and RH for various “in situ” methodologies, including from this study and Ibrom et al. 2007 as implemented via EddyPro software, and demonstrate that a heuristic uncertainty is between 2× and 0.5× the “de facto” frequency. Based upon this, monthly H2O flux correction factors show that spectral corrections are typically 10% in the summer and 40% in the winter with uncertainty rangeing from 5-100%. Monthly LI-7200 vs. LI-7500 H2O flux regression slopes, which ranged from 0.6 to 0.95 without correction, ranged between 0.9 to 1.1 after correction, and the total cumulative H2O flux increased by 24% with correction, with an uncertainty interval of 12-46%. Using EddyPro, the “in situ” corrections of Fratini and Horst had similar results, adding between 26-28% more water

flux with uncertainty intervals ranging from 15-53%; the Ibrom correction was less effective and the “analytic” corrections of Massman and Moncrieff were insufficient. We conduct an abbreviated analysis from US-Cwt comparing a month of an enclosed path EC155 to a LI-7500 and found that spectral attenuation resulted in similar relationship with RH and the “de factor” fc ranged between 0.003 to 3 Hz. Finally, we summarize uncertainty intervals in H2O fluxes at various AmeriFlux sites where EddyPro was forced to perform calculations using 2× and 0.5× the “in situ” fc.

Topic: Flux footprint analysis Poster 28
Lindsey Bell

Flux Footprint Analysis Reveals Directional, Vegetation-Driven Variation in Productivity at a Semiarid Riparian Forest

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Eddy covariance (EC) estimates bulk exchanges of carbon, water, and energy between the land and atmosphere. The accuracy of time-integrated average fluxes requires that measurement systems are situated downwind of homogeneous vegetation on flat terrain. However, because vegetation is rarely homogenous, persistent variation in wind direction may result in sampling vegetation with different structure or function. Advances in mathematical simulations of how the downwind sampled area changes with wind speed and direction (called footprint models) enable analysis of fluxes integrated over shorter time periods or more narrowly defined wind directions and climatic conditions. This relaxes the requirement for homogeneity and enables quantification of spatial variability of vegetation across the EC tower footprint. While many flux footprint studies have focused on correcting for or characterizing pronounced ecosystem heterogeneity, few have investigated the influence of subtle heterogeneity in an assumed homogeneous environment. In this analysis, we use the Kljun et al. (2016) footprint model to investigate variation in gross primary productivity (GPP) across a forested ecosystem in the southwestern United States. We find a subtle but consistent directional pattern in GPP across seasons, contributing up to 20% variability across the footprint, and evaluate the influence of topography, meteorological drivers, seasonality, and overstory structure in directional flux sampling. Finding no significant directional relationships between GPP and these four drivers, we infer that an uneven distribution of vegetation photosynthetic capacity around the tower results in directional variability in GPP. Our results underscore the potential of combining flux footprint models with auxiliary geospatial, vegetation, and meteorological data at apparently homogeneous tower sites to detect subtle ecological patterns within flux tower footprints.

Topic: Urban and Managed Lands Poster 29

Xiangmin Sun

Long-term eddy covariance measurement of carbon flux and evapotranspiration over a pasture site in the US Midwest

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The US beef industry currently emits 257.5 million tons of CO_2 equivalent per year, with 64% attributed to grazing, particularly from the extensive pastures of the Great Plains. As one of the top beef-producing states, Nebraska is a hotspot for beef greenhouse gas emissions and holds substantial potential for efficiently mitigating these emissions. Cattle grazing can alter the CO_2 exchange pattern for natural grasslands. Despite growing interest, long-term observation and accurate quantification of the CO_2 budget for grazing pastures remain scarce due to the diversity of ranching operations in terms of ranch size, management, and region. In this study, we employed the eddy covariance method to calculate carbon budgets from a Long-Term Agroecosystem Research pasture close to Lincoln, Nebraska. With an area of approximately 11.3 hectares, the pasture is continuously grazed during the growing season, typically from April to October. The cattle population density is approximately 2.2 cattle per hectare, which is representative of the region's typical grazing practices. This pasture shows substantial variation in the sign and strength of the annual CO_2 budgets. The annual cumulative sum of CO_2 flux ranged from 235 g C m^{-2} (carbon source) in 2022 to -116 g C m^{-2} (sink) in 2019. The driest year in this analysis is 2022, with an annual precipitation of 447 mm, while 2019 is a wet year with the second-highest annual precipitation of 939 mm. We also investigated the effects of other biological and meteorological factors, such as phenology, solar radiation, and memory effects of antecedent soil moisture. This quantification and analysis of the carbon balance or net ecosystem production of the pasture can facilitate management practices to achieve climate-smart grazing and enhance carbon sequestration in extensive pastures of the Great Plains and beyond.

Topic: General Science Session Poster 30
Angie Abarzua

Soil Influences on Gross Primary Productivity Across Various Eddy Covariance Sites in the United States

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Soil plays a crucial role in supporting plant life through various interactions and processes, such as the nutrient and water cycles, where its properties enable the retention and provision of these resources for plant growth and subsistence. The relationship between soil and plants is complex but mediates ecosystems response to changes in environmental conditions. We studied the relationships between time averaged Gross Primary Productivity (GPP) and soil properties across a range of soil and vegetation types based on data from 164 flux towers across the United States. We obtained soil data from different sources classified as Observed Data (OD), which includes information retrieved from Biological Ancillary Disturbed Metadata (BADM) of Ameriflux and the National Ecological Observatory Network (NEON), and Estimated Data (ED) from the Gridded National Soil Survey Geographic Database (gNATSGO). We created a soil classification based on the fertility and development of different soil orders (SFD) to relate them to GPP. The findings showed that the SFD classification has a significant effect on GPP. To further explore this effect, we analyzed various soil properties likely to influence GPP. In both OD and ED sources, we found that pH and pH buffering calcium carbonates had significant correlations with GPP. Electrical conductivity, magnesium (Mg), and sodium (Na), which were only available in the OD, were also significantly related to GPP. Organic matter, effective cation exchange capacity, and available water storage and content showed significant relationships when using ED but we did not find relationships using OD. We discovered that soil properties explain nearly 40% of the variation in GPP across 57 eddy covariance sites, and when we integrated mean climate factors, the models accounted for over 80% of GPP. To enhance our understanding, it is essential to obtain more observational soil data to more accurately explain this relationship in future research.

Topic: Remote Sensing

Poster 31

e schwartz

The Impact of Canada's Record-Breaking Forest Fires on Water and Carbon Fluxes Across the Upper Midwestern United States

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Wildfires can influence regional air quality through particulate matter emissions and ozone formation. The aerosols in smoke can scatter incoming shortwave radiation and increase the fraction of diffuse radiation. Diffuse radiation has been theorized to increase water and carbon fluxes under moderate diffuse fractions until an optimal point, after which higher diffuse fractions are theorized to decrease fluxes. In 2023, a record number of Canadian wildfires occurred, and smoke transported across regions of the United States (US) led to extreme air quality events and visibility reductions. We test the impact of these wildfire smoke events on ecosystem water and carbon fluxes using a suite of ground- and space-based observations between May 13th and July 3rd across the upper Midwestern US. We use aerosol optical depth (AOD) measurements from the AErosol RObotic NETwork (AERONET) and eddy covariance measurements from the National Ecological Observatory Network (NEON) and FLUXNET to assess site-level impacts of smoke plumes on evapotranspiration (ET), net ecosystem exchange (NEE), and gross primary productivity (GPP). The incorporation of remote sensing observations from the MODerate resolution Imaging Spectroradiometer (MODIS) and ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) provides a broader spatial context to the site-level observations. We compare the 2023 events to multi-year (2018-2022) and post-fire (2024) periods to assess differences from historical conditions and the short-term ecological impacts of wildfire smoke events. At most NEON and FLUXNET sites in forests and wetlands, ET and NEE or GPP are enhanced at moderate AOD ($0.375 < AOD < 0.875$). However, ET and NEE or GPP are suppressed at high AOD ($AOD > 1$) during active wildfire events. We also discuss the impacts of the diffuse-light fertilization effect in the context of phenological changes.

Topic: General Science Session Poster 32
Brian Wang

AmeriFlux Management Project Site Visits Framework: The Gift to the Community That Keeps On Giving (After 25 Years!)

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AmeriFlux is a coalition of site teams that voluntarily contribute their eddy covariance data to be processed and shared by the AmeriFlux Management Project (AMP). As such, there are a variety of instrument models and configurations used across the network. AMP implements measures to ensure data quality by providing loaner instruments and calibration standards at no cost to sites. To ensure inter-comparability, the AMP Tech team conducts comprehensive site visits that bring a carefully calibrated portable eddy covariance system (PECS) to AmeriFlux sites, where an inter-comparison is conducted over two weeks in the growing season.

In total, 298 days of inter-comparison across 61 site visits were performed from 2013 to 2023. The main flux variables (FC, H, LE) have an average regression slope of 0.97, 1.03 and 1.04 between the PECS and the in situ systems. Across all individual visits, the inter-comparisons of flux and meteorological variables showed regression slopes within 1+/-15%. A quantitative approach will decompose site visit differences (PECS vs site) into systematic and random errors for all variables measured by the PECS.

Altogether 282 recommendations were given from the 61 site visits. Here, we qualitatively grouped them into four categories. The largest share of recommendations addresses calibration and maintenance issues, implying the need for dedicated human effort to ensure the long-term data quality. Another quarter of recommendations prompted site teams to refine their high-frequency/data processing routines.

A quarter of recommendations identified inherent sensor issues or more complex issues. The smallest share of recommendations is related to the physical placement of the instruments, such as sensor shadowing. These issues would have been hard for a single system to identify, which highlights the importance of collaboration and dedicating time to refine site setup.

Topic: General Science Session Poster 33
Adam Young

Evaluating High-frequency Spectral Correction Algorithms in the National Ecological Observatory Network (NEON)

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Accurate and unbiased flux datasets derived from eddy covariance systems are critical to better understand and study surface-atmosphere interactions and ecological dynamics, from local to regional scales. Producing and delivering quality flux products requires near-continuous collection of high-frequency (e.g., 20 Hz) data in conjunction with efficient processing algorithms, including despiking routines, coordinate rotation, and spectral corrections. The focus of this presentation is to critically evaluate the spectral correction algorithm used to account for high-frequency losses in flux data products published by the National Ecological Observatory Network (NEON). NEON operates a network of 47 flux towers across all major ecoclimatic domains in the United States, using enclosed-path infrared gas analyzers to measure H_2O and CO_2 concentrations. This widespread monitoring necessitates an efficient, semi-empirical approach for applying high-frequency spectral corrections. NEON specifically uses a wavelet-based method by Nordbo and Katul (2012; hereafter denoted as NK12), which is both single-pass and flexible enough to handle non-ideal conditions. However, recent analyses have suggested there remains significant room for improvement in the energy-balance closure at NEON sites, particularly in relation to underestimating latent heat fluxes. To investigate and isolate the effect the NK12 method might be contributing to these imbalances, we conducted an intercomparison with methods more closely aligned with community standards (e.g., ICOS) implemented using EddyPro software, such as transfer function methods described by Fratini et al. 2012. These intercomparisons will provide valuable insight into not only the drivers of energy imbalance observed at NEON sites, but also serve as a broader evaluation of advantages and disadvantages of various high-frequency spectral correction algorithms.

Roel Ruzol

Variability in flux estimates based on different spectral corrections and time lag detection methods in a closed-path eddy covariance system

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Many eddy covariance setups use fast-response, closed-path gas analyzers to quantify short-term variations in the concentrations of CO2 and water. While closed path analyzers offer many advantages (e.g. better performance during adverse weather, less susceptible to sensor heating, and less correction for air density fluctuations) they can suffer from attenuation or signal loss. This signal loss occurs as gas molecules travel through intake tubing and adhere or “stick” to tube surfaces, mixing the air parcels and dampening the high-frequency fluctuations in gas concentrations. In addition, these transport processes can create lags between the gas of interest and vertical wind signals. Signal loss and time lags during gas transport need to be accounted for to derive accurate estimates of gas fluxes. Signal losses in eddy covariance setups are often corrected for through spectral correction techniques, especially for high frequency observations, while time lag correction approaches are used to identify the cross-correlation peak between gases and vertical wind signals. Although many spectral and time-lag correction procedures are well-developed, more evidence on how they perform in different ecosystems under different instrumentation setups (e.g. tubing length) are needed. Here, we tested three time lag detection approaches and four spectral correction techniques on two tubing lengths (40 m vs 1 m) to assess their impact on estimates of CO2 and water fluxes. Our initial results suggest that water fluxes are more sensitive to spectral correction and have higher variability on time lag estimates than CO2. Furthermore, tubing length appears to have a greater effect on signal loss and time lag on water vapor than CO2. As we continue the comparison throughout the growing season, we expect to see more conclusive results.

Topic: Remote Sensing Poster 35

Himal Acharya

Warming shortens growing season but enhances ecosystem productivity efficiency in tidal marshes

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Tidal marshes are invaluable to global carbon balance for their ability to sequester carbon. Changes in phenology of marsh vegetation could affect carbon balance and ecosystem sustainability yet the interannual variation in vegetation phenophase remains unexplored. To asses the impact of changing climate on ecosystem productivity, phenology and resiliency, we used Phenocam imagery extracted GCC, remotely sensed NDVI using MODIS, Eddy covariance measurements, and meteorological variables. We found out that the growing season length (sum of spring, summer and autumn) is getting shorter over the years with dormancy starting earlier. Increasing mean summer temperature and hotter summer days have been attributed to this trend. Even though growing season is getting shorter, gross primary production hasn't been changing significantly due to significant increase in ecosystem productivity (gross primary production per unit temperature). The decreasing trend in the growing season length would be disrupted after hitting a tilting point. After hitting a tilting point, the trajectory of the growing season is yet to be explored and likely to be a function of vegetation type and response of vegetation to the climate attributes.

Topic: AI+ML Poster 36

Leila Hernandez Rodriguez

Developing MeaningFlux, a GUI Tool for Eddy Covariance Data Analysis

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We are developing MeaningFlux, an open-source graphical user interface (GUI) aimed at making eddy covariance (EC) data more accessible and easier to analyze. Built in Python, the tool combines intuitive data visualization with machine learning and information theory methods to support meaningful interpretation of flux tower datasets. Our goal is to support both new and experienced users across networks. At this stage, we are actively seeking feedback from the EC community to refine functionality, prioritize features, and ensure the tool meets real-world research needs.

Jose Abraham Gamez-Lucero and Teresa M. Ibarra-Montes

Challenges facing agroecosystems in the face of climate change in the arid zones of northwestern Mexico

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In Mexico's arid and hot regions, surface water flows are scarce, and agriculture relies primarily on groundwater. Rising global temperatures have placed significant stress on ecosystems, especially agroecosystems, which must cope with increased water demand, sustain productivity, and guarantee their economic viability. In this regard, within the Mexican ecosystem network (MEXFLUX), Eddy covariance (EC) towers have been installed on perennial crops to evaluate their water requirements, carbon sequestration capacity, and ecophysiological response to abiotic stress. Currently, there is a database covering nearly 17 years (7 years for pecan trees, 8 years for table grapes, and 2 years for asparagus). Preliminary results show that pecan trees have a Gross primary productivity (GPP) of 2,005 gC/m2/year, 46% of which corresponds to Ecosystem Respiration (RECO), with a water requirements (ET) of 1,409 mm/year and WUEe of 1.43 gC/mm/year. During the fruit-filling stage, periods of stress due to high temperatures have been observed, which have reduced stomatal opening and photosynthetic capacity. In the case of grapevines, a GPP of 1,835 gC/m2/year has been recorded, 72% of which corresponds to RECO, with a water consumption of 1,140 mm/year and an WUEe of 1.60 gC/mm/year. In this crop, high-temperature stress and reduced postharvest irrigation have increased RECO, decreasing Net Ecosystem Carbon Exchange NEE. Both crops show their highest GPP during spring (May-June), while RECO peaks in summer, associated with litter decomposition. Throughout the measurement period, heat waves and low atmospheric humidity were recorded, resulting in foliage burn in both crops due to leaf temperatures of 45 to 48°C, especially under reduced irrigation conditions. Applications of biostimulants, sunscreens, etc. have been observed to reduce their impact, but increase production costs, affecting profitability. Therefore, further research on these inputs is needed to optimize their use, reduce costs, and sustain agricultural activity in arid regions.

Topic: Community and network building Poster 38
Roel Ruzol

USDAFlux: Flux Tower Aid Group for USDA-affiliated tower teams

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The USDA Flux Tower Aid Group (USDAFlux) is a new community of scientists, technicians, and graduate students working with eddy covariance towers across the U.S., aiming to connect USDA-affiliated flux tower teams, foster regional collaboration, and share solutions to common challenges. We bring together those who maintain, operate, and use data from USDA flux tower sites, hosting regular meetings to exchange ideas, troubleshoot issues, and share experiences—from improving instrumentation performance to streamlining data processing and automation—and helping sites successfully submit their data to AmeriFlux. By building connections across site teams, we seek to strengthen relationships with universities, federal and state agencies, and private companies, broadening support for USDA flux tower operations nationwide. Whether you're a site manager, technician, graduate student, postdoc, or researcher working with USDA flux tower data, we invite you to join and be part of this collaborative effort.

Representativeness of AmeriFlux and NEON networks in terms of carbon and water flux estimates

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Monitoring terrestrial carbon, water, and energy fluxes is crucial for understanding biogeophysical processes on Earth's surface. Over the past three decades, eddy covariance (EC) techniques have been extensively utilized to measure these fluxes at the ecosystem scale, providing essential continuous data at (half-)hourly temporal resolution. However, these measurements commonly experience an energy imbalance issue: the sum of sensible and latent heat fluxes is often lower than the measured available energy (the difference between net radiation and heat storage flux) at FLUXNET sites. Identified contributors to this imbalance include instrument biases, incomplete accounting for storage
fluxes, differing footprints among variables, and assumptions inherent in the EC methodology. Recently, the NEON network has established 47 EC sites across the United States, featuring more comprehensive instrumentation setups, including improved storage flux measurements. Nevertheless, the extent to which flux measurements from the AmeriFlux and NEON networks are directly comparable remains unclear.
Here, we investigate two key aspects: the persistent energy balance closure problem and the spatial representativeness of the two networks. Our analysis reveals a comparable energy imbalance (approximately 20% underestimation of turbulent heat fluxes) at both AmeriFlux and NEON sites under similar climate conditions, and under warm climate conditions, AmeriFlux additionally exhibits a larger imbalance. Spatially, NEON sites, predominantly located in moderate climate zones, show weaker carbon sinks compared to AmeriFlux sites. Leveraging more than two decades of continuous flux observations across diverse biomes and climate regimes, AmeriFlux provides the foundational scope that, alongside NEON's systematic monitoring network, enables robust quantification of uncertainties in carbon and water fluxes and assessment of ecosystem responses to climate change.

Juan Carlos Guerrero

Advancing N2O Isotopic and Concentration Measurements Using Picarro's New PI5131-i N2O Analyzer and Sage Gas Autosampler

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Nitrous oxide (N2O) is a potent greenhouse gas that contributes to global warming and ozone depletion. Precise measurements of its stable isotopes are essential for understanding nitrogen cycling across soil, ocean, atmospheric, and wastewater systems. In response to the growing demand for high-precision N2O isotope analysis, Picarro introduces the PI5131-i isotopic and gas concentration analyzer.
This instrument enables simultaneous measurements of site- specific isotopic signatures (δ15Nα, δ15Nβ) along with bulk δ15N and δ18O. It is based on robust mid-infrared, laser-based cavity ring-down spectrometry (CRDS) technology, with significant new software and hardware enhancements, ensuring a reliable and stable measurement platform. In this paper, we present the analyzer's newest capabilities and discuss its performance metrics for continuous N2O
isotopic measurements, including precision and long-term stability and its performance when combined with the Sage autosampler for discrete gas sample measurements.
The Sage gas autosampler is Picarro's new high-throughput, discrete small volume gas sample measurement solution. Sage can seamlessly combine with the PI5131-i analyzer and provide hassle-free, easy-to-use, high throughput N2O concentration and isotopic measurement capability for a variety of earth and environmental science applications.

Perspective on the FLUXNET2025 Meeting in Brisbane, Australia

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The FLUXNET2026 meeting, held in Brisbane, Australia in July of 2025, brought together over 90 scientists from all over the world. The meeting provided an important opportunity to cross-pollinate ideas across geographic regions, research networks, and career stages. Regional flux network updates were a central part of the program, highlighting the impressive amount of energy and work being put into expanding flux monitoring networks globally and the valuable ecosystem dynamics these networks help reveal. Breakout sessions focused on issues related to agricultural flux measurements, carbon accounting, ecophysiology, BADM submission and usage, remote sensing and the upcoming FLUXNET data initiative. The meeting reinforced the importance of global coordination in enhancing the societal value and applicability of FLUXNET research.

Maricar Aguilos

Expanding Flux Science Through Art, Storytelling, and Broader Community

Maricar Aguilos and the FLUXNET outreach working group

The FLUXNET outreach working group extends flux science beyond typical research activities, fostering community outside academia. Here we share outcomes from two ongoing projects. fluxART (https://fluxnetart.github.io) invited artists and scientists in a one-year residency to engage in creative inquiry about ecosystem fluxes. Meet the Fluxers Podcast (https://meetthefluxers.github.io/) features conversations with guests from diverse disciplines, sectors and career stages, highlighting how authentic relationships and co-production in flux science drives discovery and enhances the societal relevance.

Topic: Urban and Managed Lands Poster 43
Katya Esquivel

Carbon and Water Flux Dynamics in a Pecan Orchard: Multi-Year Analysis

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Although tree crop systems in semi-arid managed environments may play a key role in regional carbon budgets, our understanding of their underlying biophysical behavior remains limited. This study investigates carbon and water fluxes in a mature, flood-irrigated pecan orchard located in Far West Texas, using eddy covariance and remote sensing to examine how environmental drivers and management shape seasonal and interannual dynamics.
We analyze nearly three years of half-hourly eddy covariance data (May 2022 to December 2024) to assess variability in net ecosystem exchange (NEE), gross primary productivity (GPP), ecosystem respiration (Reco), evapotranspiration (ET), evaporation (E) and transpiration (Tr). Standard flux processing techniques are applied to gap-fill and partition NEE into GPP and Reco. ET is further separated into E and Tr using the underlying water use efficiency method. To estimate phenological transitions, we use remotely sensed vegetation indices to define the start and end of the growing season. A structural equation model (SEM) is employed to quantify the relative influence of key drivers, including vapor pressure deficit (VPD), soil moisture (SM), net radiation and phenology, on carbon and water fluxes.
Emerging patterns reveal strong seasonal variability in both CO_2 uptake and ET, driven by a combination of meteorological conditions and irrigation management. Preliminary results indicate that the orchard consistently acts as a net carbon sink during the growing season and, though close to carbon neutral at the annual scale, remains a marginal net sink over the study period. This research contributes to an improved understanding of carbon and water cycling in irrigated orchard systems in dryland environments and seeks to inform agricultural practices under changing climate conditions.

Topic: Modeling, novel methods Poster 44

Yang Li

Advancing land-atmosphere interaction research with AI foundation models

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Foundation models—large-scale AI systems trained on massive and diverse datasets—are rapidly advancing scientific discovery across climate, ecological, and Earth system sciences. For eddy covariance (EC) flux research, foundation models offer unique opportunities to address long-standing challenges in spatial representation and generalization, data sparsity and gaps, integration of heterogeneous data, and scaling carbon, water and energy fluxes from sites to regional and global levels.

In this presentation, we examine the potential and challenges of applying foundation models to EC and land-atmosphere interaction research. As a case study, we present our application of Prithvi EO 2.0, an Earth Observation AI foundation model developed by NASA and IBM, to estimate daily ecosystem carbon fluxes across more than 100 flux sites spanning hot to cold and arid to humid climate gradients. Prithvi was pre-trained on 4.2 million Harmonized Landsat-Sentinel-2 image time series. Fine-tuned with eddy covariance data and ERA5-Land meteorological inputs, Prithvi EO 2.0 outperforms conventional machine learning models, including Random Forest, XGBoost, and ResNet (a convolutional neural network), achieving up to 15% increase in explained variation (R2), with particularly superior performance in heterogeneous landscapes. These results highlight the ability of foundational models to capture spatial representations relevant to ecological processes across environmental gradients. We conclude with a discussion of key challenges, ranging from large-scale training requirements, benchmarking standards, to interpretability, calling for coordinated, community-driven efforts to drive responsible development and application of foundation models in support of ecosystem science and management.

Topic: General Science Session Poster 45
Susana Alvarado-Barrientos

ManglarIA, leveraging AI to monitor carbon flux in Mexico's priority mangrove sites

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Mangrove ecosystems play a crucial role in climate regulation through carbon sequestration and greenhouse gas exchange. However, net ecosystem exchange (NEE) of CO2 fluxes in mangroves can be highly sensitive to climate-induced disturbances. Despite this vulnerability, studies overlook the dynamic responses of both natural and restored mangroves to disturbances. ManglarIA led by World Wildlife Fund, and partner institutions such as ENDESU A.C., CENITT A.C., members of the Laboratorio Nacional Conahcyt: MexFlux, and the Comisión Nacional de Áreas Naturales Protegidas (CONANP) aim to fill this knowledge gap. In this project, two eddy covariance towers, micrometeorological sensors, and phenocams will be deployed in Marismas Nacionales Biosphere Reserve and Ría Lagartos Biosphere Reserve (Nayarit and Yucatan, Mexico) to monitor CO2 fluxes. These sites are priority areas for monitoring under Mexico's National Restoration Plan for 2025–2030.

By combining artificial intelligence and standardized data protocols (eg. Ameriflux), ManglarIA seeks to (1) identify temporal and seasonal patterns of carbon fluxes in natural and restored mangroves, and (2) assess environmental drivers of flux variability under varying disturbance conditions.

This project underscores the critical need for direct and continuous monitoring of mangrove ecosystems to support climate-smart conservation and restoration efforts. The insights generated will strengthen national and international climate change mitigation

strategies and support evidence-based ecological conservation of mangrove ecosystems across Mexico.

Topic: General Science Session Poster 46
Nicola Ferrier

The Sage Grande Testbed

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The Sage Grande Testbed is an open artificial intelligence testbed that supports edge computing and intelligent sensing. The platform allows researchers to develop new AI algorithms and measurement strategies. After a decade of experience, our current project is set to deploy 300 new state-of-the-art AI-enabled platforms across the USA, and in every state. Scientists can explore next-generation AI-enabled infrastructure for real-time monitoring of sensor data for many applications including wildfire, flooding, and agriculture. As edge computing platforms become more powerful, they can support bigger AI models, including large language models (LLMs). In the future, scientists will be able to use natural language prompts and AI agents to program their sensing strategies and collect relevant data. With new AI-enabled infrastructure, Sage can provide users with new ways to write programs and control Sage nodes.

Topic: Regional Networks Poster 47
Enrico Yepez

Operational advancements of the MexFlux network on its fifteenth anniversary

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The MexFlux network, a conglomerate of 13 public Mexican universities and research institutions with 10 active flux sites and historical flux data spread across Mexico, is celebrating its fifteenth anniversary. In 2010 we committed to exchange the best available science on carbon and water fluxes to better understand the function of neotropical ecosystems in Mexico. Slowly but steadily, after navigating three lustrums of multiple challenges, today we present three cornerstones of community consolidation that will guide the next decade of MexFlux' goals. 1) Generational change and commitment to train and engage new generations. Today, under the leadership of an empowered new generation of MexFlux scientists -predominantly women- we have constructed a space for dialogue among ourselves, and with our peers in North and Latin America, as well as an agenda to train a new generation of Spanish-speaking flux scientists. We will present the results of TAFE, "Taller de Aprendizaje de Flujos Ecosistemicos", a workshop funded by the US Department of Energy in collaboration with MexFlux which represents the culmination of efforts of the MexFlux-AmeriFlux alliance to foster the engagement of flux science instructors and students from 10 countries of the Americas. 2) Commitment to sustain flux measurements in Mexico. MexFlux gathers soil, plant and atmospheric scientists that share common curiosity and goals to research both, the magnitude and the overarching controls of water and carbon fluxes in ecosystems across Mexico´s diverse and complex landscape. The number of active flux sites is small but the effort to add sites continues. Four new observatories will be operational in 2025-2026, including two mangrove forests; one in the Pacific and one in the Atlantic, and two distinct forest types

previously unmonitored in Mexico (a tropical rainforest in the Yucatan peninsula and a managed conifer forest in Durango). 3) Organizational milestones and governmental recognition. Today, MexFlux is recognized by our federal government with the distinction of: “Laboratorio Nacional” (a national governmental strategy to support networks´ capabilities poised to solve national problems), which in addition to recognizing the potential of MexFlux to deliver science-based solutions to some our national environmental problems, the network will, for the first time, receive financial resources from the Mexican government to advance our goals in the next three years.

Topic: General Science Session Poster 48

Andrew Richardson

5000 Site-years of data in the the new PhenoCam v3 dataset

Effects of variation in changing climate, snowmelt date, and traits on water fluxes in the East River Watershed, Colorado

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Plants are an important driver of variation in Evapotranspiration (ET). However, recent global climate models predict increased temperature, earlier snowmelt, and vapor pressure deficit (VPD) in western North America. We test the hypotheses that (i) changing climate; (ii) shifts in snowmelt date; (iii) and variation in plant traits are key drivers of evapotranspiration. We used a long-term (17 year) dataset of peak carbon and water flux measures of alpine, meadow, and shrubland vegetation along a 1,000m elevational gradient in Colorado, USA. Daytime light, dark, and nighttime water flux measures based on an instantaneous field method using a closed chamber field 'tent' allowed us to estimate night and daytime transpiration, T, evaporation, E, and ET at peak phenological stage. While both daytime ET and nighttime E increased with elevation, we observe no elevational change in daytime 'dark' evaporation rates suggesting that shifts in ET are due to shifts in T and not E. Over the last 17 years, we have shown a decrease in interannual peak season ET but no change in nighttime E or daytime E, with time again showing a strong response to vegetation transpiration. Mid-elevation sites showed stronger decreases in ET with time. Assessing the independent effect of snowmelt date shows that peak season ET increases with later snowmelt dates suggesting that forecasted earlier snowmelts will further reduce peak ET. Long-term monitoring of vegetation water flux shows that 38.1%, of the interannual variability in peak ET can be explained by just site, year, and snowmelt date effects. However, additional analyses indicate a possible larger role of variation in vegetation traits and biomass in controlling peak season ET. Nonetheless, since the start of our monitoring, we have observed a ~10% decrease in daytime peak season ET across the gradient. Hotter and drier conditions (greater VPD) appear to impact plant water use rapidly, but shifts in plant traits and biomass may disproportionately impact ET. Future projections of SPEI indicate increased reductions of ET in this watershed. Our results suggest that increasing VPD due to climate change and changing snowmelt as well as shifts in plant trait composition together, may have large effects on ET. As plant water use influences recharge rates in the watershed, these results suggest that over the past decade, plant impacts on recharge rates have been impacted.

Topic: General Science Session Poster 50
Rodrigo Vargas

Spatial representativeness of MexFlux as a regional FLUXNET network

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Environmental observatory networks are fundamental in advancing scientific understanding of biogeochemical processes. FLUXNET is a global network of regional eddy covariance networks that measure ecosystem-scale exchanges of greenhouse gases (i.e., CO2, CH4, H2O) and energy between the biosphere and the atmosphere. MexFlux is the eddy covariance network of Mexico, a megadiverse country with many underrepresented ecosystems within FLUXNET. This study evaluates the representativeness of MexFlux by assessing its ability to capture the statistical and spatial heterogeneity of annual gross primary productivity (GPP) and evapotranspiration (ET) within Mexico. Results show that MexFlux underrepresents areas with intermediate values of GPP (~1000-3000 g m-2 yr-1) and ET (~500-1000 mm yr-1). Our study also demonstrates that adding 20 strategically located sites improves the representativeness of MexFlux while preserving the historical distribution of the network. Mountain regions, tropical forests, and urban sites may remain underrepresented in any network configuration, highlighting the challenges of monitoring this country. We highlight the advantages of strategic network configuration; however, specific network objectives, individual research interests, opportunities, and constraints must be considered when establishing new study sites. We argue that enhancing interoperability across conceptual, technological, organizational, and cultural pillars is critical for MexFlux's sustainability and ability to integrate effectively with AmeriFlux.

Topic: Modeling, novel methods Poster 51
Joseph Gaudard

Fluxible: an R package to calculate ecosystem gas fluxes from closed-loop chamber systems in a reproducible and automated workflow.

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Measurements of gas fluxes are widely used when assessing the impact of global-change drivers on key aspects of ecosystem functioning. Working at a smaller scale than eddy covariance flux towers, closed-loop chamber systems allow for comparisons between experimental treatments.
Such ecosystem gas fluxes are typically calculated from field-measured gas concentrations over time inside the chamber, using a linear or exponential model and manually selecting good quality data.
This approach is highly time-consuming and prone to potential bias that might be amplified in subsequent steps, as well as having major reproducibility issues. The lack of a reproducible and bias-free approach creates challenges when combining global-change studies to make biome and landscape-scale comparisons.

The Fluxible R package aims to fill this critical gap by providing a workflow that eliminates the need for individual evaluation of each flux, thereby reducing the risk of bias and making the process more reproducible. Users set specific data quality thresholds and selection parameters a priori, which are applied to the entire dataset. The package runs the calculations without prompting the user to make

subjective decisions, making it convenient to integrate into an open science pipeline. Quality flags and graphs are provided at the end of the process for a visual inspection. The package is organized as a toolbox with one function per step, facilitating flexibility and processing of other environmental variables present in the dataset.

Using the Fluxible R package makes the workflow reproducible, time efficient, and increases compatibility across studies.