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Session: Implementation Plan Review & Discussion
In 2016, the Science Leadership Group (SLG) of the North American Carbon Program (NACP) formed an ad hoc committee to review the current NACP Science Implementation Strategy (Denning et al., 2005), including an evaluation of progress, an assessment of potential emerging research directions, and consideration of new implementation planning mechanisms.

A primary point of reference for this review is the 2011 U.S. Carbon Cycle Science Plan (Michalak et al., 2011). This plan recommended broad new priorities, including expanded research on the role of human activities in the carbon cycle, increased study of the direct effects of increased carbon dioxide on ecosystems, improved research and products to inform policy and management decisions, and enhanced understanding and communication of uncertainties. Additional recommendations from recent topical workshops and reports include improvement of mechanisms for long-term sustained observations and research, optimization of hierarchies of numerical models, and identification of geographic and/or ecosystem focus areas. Further guidance is expected from the broad perspectives of the Second State of the Carbon Cycle Report (SOCCR-2).

The 2005 NACP implementation strategy envisioned the phasing of program activities over time from primarily diagnostic research to growing emphasis on predictive modeling and decision support. However, current advances in NACP research highlight the continuing urgency of both diagnostic and prognostic studies (e.g., the carbon dioxide and methane “budgets”) as well as the rapid emergence of new issues and needs. These developments present an implementation planning challenge, requiring regular updates and an integration of diverse perspectives and practical limitations. Our challenge is not just to write a new NACP implementation plan, but to develop a new implementation planning process that will assure transparency and responsiveness under conditions of rapidly evolving needs, constraints, and opportunities.
Session: Linking to Decision Making
Large Uncertainties in Urban Carbon Fluxes

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Estimates of fossil fuel carbon dioxide (FFCO₂) emissions are a critical component of local, regional, and global climate agreements. Understanding the role of biogenic carbon fluxes in both rural and urban ecosystems is also necessary to close the carbon budget at regional scales. Current global inventories of FFCO₂ do not directly quantify emissions at local scales, but instead use spatial proxies to downscale national emissions. On the biogenic side, most ecosystem models neglect carbon fluxes from urban areas. We synthesize recent improvements in urban carbon flux modeling and quantify local uncertainties with the development of a new high-resolution (hourly, 1km²) bottom-up Anthropogenic Carbon Emissions System (ACES) for FFCO₂ for the year 2011 in the Northeastern US. We characterize the biogenic influence on urban carbon cycling throughout the state of Massachusetts using an ecosystem model that incorporates the urban heat island (UHI) and altered urban growing conditions. We compared ACES with three widely used global inventories, finding significant differences at both the regional (20%) and city scales (50-250%). Results from our urban ecosystem model suggest that, kilogram-for-kilogram, urban vegetation cycles carbon twice as fast as rural forests. Urban vegetation releases (RE) and absorbs (GEE) the equivalent of 11 and 14%, respectively, of anthropogenic emissions in the most urban portions of the state. We also find that UHI reduces annual biogenic carbon storage in the City of Boston by over 20% due to reduced summertime GEE. The temporal aliasing of biogenic uptake and anthropogenic emissions necessitates careful modeling of all carbon sources and sinks to understand their relative contributions to atmospheric enhancements of CO₂ over urban domains. Our results contribute to the ongoing development of a robust carbon monitoring system that accurately tracks anthropogenic and biogenic carbon fluxes at sub-national scale – a necessity for supporting climate policy at all levels of government.

Presentation Type: Plenary Talk
Lessons learned from carbon decision support in California

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California represents a unique “testbed” for carbon decision support given the state’s commitment to aggressive greenhouse gas emissions mitigation and its diverse set of landscapes, sectors and stakeholders. Carbon management in California spans nearly every spatial and governance scale from individual facilities and megacities to major forests, agricultural and oil producing regions, to international carbon trading frameworks. Multiple NACP projects have operated in this environment for several years now including NASA’s Carbon Monitoring System’s Understanding User Needs project and the NIST/NASA/NOAA funded Megacities Carbon Project. Recently, another series of multi-year projects have been initiated including the California Baseline Methane Survey (jointly funded by the California Air Resources Board and Energy Commission), the CMS Prototype Methane Monitoring System for California, and others. Collectively these projects have offered rich and sustained opportunities for carbon cycle scientists to work directly with stakeholders including local, state and national regulatory agencies, energy companies, farmers, industry groups, and NGOs. Effective carbon research and policy partnerships have been formed, reducing barriers to effective communication and improved understanding of needs, sensitivities, and opportunities. In this talk we will present case studies involving first-hand experience with carbon decision support in California covering representative sectors, regions and stakeholders. We will synthesize lessons-learned across multiple projects and identify key challenges and opportunities towards improved relevance of carbon cycle science to decision support.

Presentation Type: Plenary Talk
Assessment and management of forest carbon stocks on public lands are critical to maintaining or enhancing carbon dioxide removal from the atmosphere by the terrestrial sector of the U.S. Acknowledging this, an array of federal regulations and policies have emerged that require U.S. national forests to report baseline carbon stocks and changes over time due to disturbance and management, and to assess how management activities and forest plans will affect carbon stocks. To address these requirements with the best available science and forest monitoring methods, we compiled empirical and remotely sensed data covering the national forests (one-fifth of the area of U.S. forest land) including forest inventories, climate and atmospheric observations, and satellite imagery, and analyzed this information using a carbon modeling framework. We demonstrate how to integrate and interpret the various data with three carbon models for providing comprehensive information of past and present carbon stocks, and main drivers of observed trends, for individual national forests. The three models in this framework complement each other with different strengths: the Carbon Calculation Tool uses the nation’s forest inventory data to report baseline carbon stocks; the Forest Carbon Management Framework integrates inventory data, disturbance histories, and growth and yield trajectories to report relative effects of disturbances on carbon stocks; and the Integrated Terrestrial Ecosystem Carbon Model incorporates disturbance, climate, and atmospheric conditions to determine their relative impacts on net annual forest carbon accumulation and loss. We report the results for several U.S. national forests in the southern, northern and western U.S., and compare their carbon dynamics. Our results show that recent disturbances including fires and insect outbreaks over the past few decades are causing some forests to transition from carbon sinks to sources, particularly in the West. Meanwhile elevated atmospheric CO2 and higher nitrogen deposition are persistently increasing carbon stocks, effectively offsetting C declines due to disturbances and aging, while climate variability causes significant inter-annual variability in net carbon uptake or release. Despite these trends, climate variability introduces concomitant inter-annual variability in net carbon uptake or release. We conclude that targeting forest disturbance and post-disturbance regrowth will be critical to any management objective that involves maintaining or enhancing future carbon sequestration. Forest management strategies that seek accretion of carbon stocks must also address the impacts on other land management objectives and related ecosystem services (e.g., wildlife habitat or water yield).

Presentation Type: Plenary Talk
Improving predictive skills of global carbon cycle models toward better carbon management

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The Paris Agreement, reached at the United Nations Framework Convention on Climate Change, is the world's first comprehensive agreement to tackle climate change. It requires all ratifying Parties to put forward their strategic “nationally determined contributions” (NDCs), aimed at developing pathways towards low net greenhouse gas emissions and climate-resilient development, and ultimately at keeping global warming to within 2 ºC of pre-industrial levels. Of the 197 Parties to the convention, about two-thirds will rely on the land sink to meet their mitigation targets. Thus, it is the responsibility of the scientific community to facilitate the realization of the Paris Agreement through providing the best information on future trajectories of global carbon cycle. However, despite the decadal efforts to incorporate the current understanding of the most fundamental processes governing the global carbon cycle into models, model intercomparisons consistently show large differences in model estimates of land and ocean carbon sinks. Site-specific model intercomparisons typically report large model-data differences, with the between model uncertainty commonly being on the order of magnitude of the observed carbon flux. Such variability could be expected to average out over larger spatial scales, yet continent-wide intercomparisons yield similar results, with little agreement between models as to whether a continent is a source or sink for carbon under current climatic conditions. The large uncertainty in model predictions promotes skepticism on scientific results and hinders effective guidance on carbon management. To improve model predictive skills, the research community has made great progress in the past decade to evaluate and improve carbon cycle models. For example, knowledge has been developed to examine how predictable the carbon cycle is in land, ocean, and human emission. The analysis of predictability of carbon cycling systems offers the expectations on how much the model predictive skills can be potentially achieved. Many
diagnostic studies have identified various aspects of global carbon cycle models to be improved. Model improvement has been progressively realized through selection of better model structures, constrained model parameterization, and fully quantified uncertainty. Even so, major challenges are still ahead to integrate massive data from various observation and experimental network into Earth system models. Nevertheless, the advance in computer science makes it possible to simultaneously and interactively run models with ongoing field campaigns and experiments to feedback to model improvement. To anticipate potential surprises and abrupt changes in global carbon cycle, it is essential to develop early detecting systems to be implemented in observation networks.

**Presentation Type:** Plenary Talk
Improving carbon monitoring and reporting in forests using spatially-explicit information

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Spatially-explicit information about forests can improve the estimates of GHG emissions and removals. However, at present, remotely-sensed information on forest change is not commonly integrated into GHG reporting systems. New, detailed (30-m spatial resolution) forest change products derived from satellite time series informing on location, magnitude, and type of change, at an annual time step, have recently become available. Here we estimate the forest GHG balance using these new Landsat-based change data, a spatial forest inventory, and develop yield curves as inputs to the Carbon Budget Model of the Canadian Forest Sector (CBMCS3) to estimate GHG emissions and removals at a 30 m resolution for a 13 Mha pilot area in Saskatchewan, Canada. Our results depict the forests as cumulative C sink (17.98 Tg C or 0.64 Tg C year−1) between 1984 and 2012 with an average C density of 206.5 (±0.6) Mg C ha−1. Comparisons between our estimates and estimates from Canada’s National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) were possible only on a subset of our study area. In our simulations the area was a C sink, while the official reporting simulations, it was a C source. Forest area and overall C stock estimates also differ between the two simulated estimates. Both estimates have similar uncertainties, but the spatially-explicit results we present here better quantify the potential improvement brought on by spatially-explicit modelling. We discuss the source of the differences between these estimates. This study represents an important first step towards the integration of spatially-explicit information into Canada’s NFCMARS.

Presentation Type: Poster
Carbon cycle dynamics within Oregon’s urban-suburban-forested-agricultural landscapes: Impacts of bioenergy from additional forest harvest and conversion of non-food crops to poplar

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Land management strategies within urban-suburban, agricultural, and forested landscapes can have significant impacts on local and regional carbon and water cycles thereby contributing or mitigating effects of global climate change. Decision makers’ plans for bioenergy production have long-term implications, though lack fundamental understanding of impacts on ecosystems and atmospheric greenhouse gases. We quantify the interactions and feedbacks between proposed actions, ecosystem processes, and changes in climate on local and regional scales. This is particularly important as strategies for limiting C02 emissions are often implemented by states.

We assess the combined effects of changes in land-use and land cover (LULC) and climate on the carbon cycle over Oregon, which has a strong population-vegetation-climate gradient. To meet GHG reduction targets, Oregon’s last coal power facility was converted to burn forest harvest residues for bioenergy. Our assessment of availability of forest harvest residues shows the supply is neither sufficient nor sustainable. Forest harvest residues combined with forest thinning where fire return intervals are short produce less than half of the energy supply for the first harvest cycle, and the supply from thinning is reduced in subsequent years. Conversion of Willamette Valley non-forage grass-seed cropland to poplar could nearly supplement the remainder needed annually, but this would require fertilization and irrigation. Furthermore, the land-use change from grass crop to poplar is an unfavorable option to landowners because grass seed is a traditional cash crop. Thus, initial estimates show that burning harvest residue and thinned trees in dry areas vulnerable to fire in Oregon would not appear to provide a sustainable supply for even half of the energy needed annually and would fall short of demand within the first 25 years. Importantly, the net effect is a decrease in the net ecosystem carbon balance of Oregon’s forest sector.

Presentation Type: Poster
A year-long assessment of anthropogenic and biogenic CO2 emissions in the Boston area based on atmospheric measurements in an inversion framework

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Carbon dioxide emissions in the Boston urban region were quantified using in situ atmospheric observations in an inverse model framework, with the goal of verifying bottom-up CO2 inventories and informing policies to reduce greenhouse gas emissions. Measurements of carbon dioxide from five sites in and around Boston were combined with a high-resolution bottom up CO2 emission inventory and a Lagrangian particle dispersion model to simulate regional emissions. For comparison, we generated model emissions using both the Weather Research and Forecast model (WRF) coupled to the STILT particle dispersion model and the North American Mesoscale Forecast System (NAM) meteorology coupled to the HYSPLIT model. We demonstrate the importance of using a high resolution (1-km) emission inventory for reproducing concentrations in Boston, where emissions vary strongly on short spatial scales.

The model was run for hourly measurements for the period of July, 2013 to December, 2014, allowing for assessment of monthly and seasonal variations in CO2. We found that the inclusion of the urban biosphere in the model significantly improves the fidelity of the daily cycle of CO2, even in the fall and spring months. The impact of the biosphere on atmospheric concentrations throughout the year was also examined, as well as the net impact of the urban biosphere. The model showed very good agreement with both mean and day-to-day variations in atmospheric CO2, demonstrating the capability of this model-data approach. In the future, this method could be applied to other regional inverse modeling problems as well as satellite measurements. This study provides an important step towards the goal of providing stakeholders with the tools needed to formulate and monitor effective GHG mitigation plans.

Presentation Type: Poster
Above ground biomass and its spatial variability in a Mexican managed temperate forest

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Properly estimating above ground biomass stocks is fundamental to determine the mitigation of global climate change by forests; however, the understanding of its spatial variability is a challenge for carbon cycle science in Mexico. The aim of the study was to analyze the spatial variability of above ground biomass in a managed forest landscape using as predictors variables related to forest management (including LIDAR derived information), topography and climate. Field data come from 198 permanent plots of 400 m2 at the intensive carbon-monitoring site in Atopixco, Hidalgo, Mexico. A sequence of multivariate linear models (parametric), generalized additive models (semiparametric) and Random forest (not parametric) was fitted to relate above ground biomass with its predictors at 15 m of spatial resolution. Total above ground biomass in our study site increased with forest age from 0.0 to 223.4 Mg ha\(^{-1}\) in a 28-year-old forest stand. LIDAR variables, stand age, soil moisture and topography explain up to 80% of the spatial variability at 15 m resolution. With this information, we generate base maps necessary for decisions making about forest management practices. We conclude that the use LIDAR derived information, such as digital elevation models, for spatial characterization of above ground biomass stocks opens new possibilities for the synthesis of forest inventory data at different spatial scales.

Presentation Type: Poster
Session: Coordination of Carbon Cycle Research

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The ‘2nd State of the Carbon Cycle Report (SOCCR-2)’, an ongoing interagency Sustained Assessment activity led by the U.S. Carbon Cycle Science Program and Carbon Cycle Interagency Working Group (CCIWG), under the auspices of the U.S. Global Change Research Program (USGCRP). Following the Global Change Research Act (GCRA1990) mandates and inspired by the community-led U.S. Carbon Cycle Science Plan (2011), SOCCR-2 focuses on U.S. and North American carbon cycle processes, stocks, and flows and associated climate change impacts in managed and unmanaged systems, including soils, oceans, rivers, wetlands, coasts/blue carbon, urban areas, agriculture and forestry. Relevant carbon management science perspectives and tools for supporting and informing decisions pertinent to federally funded carbon cycle research enterprise and GCRA(1990) mandated National Climate Assessment process are included in this special interagency assessment. This presentation features an overview of the federal report development process, updates on the report development and review progress, and further NACP and Ameriflux engagement opportunities.

Presentation Type: Plenary Talk

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The second “State of the Carbon Cycle of North America Report” (SOCR-2) represents a major update based largely on research of the North American Carbon Program since the original Report was published a decade ago. The new Report includes an overview of the North American carbon budget and future projections, the consequences of changes to the carbon budget, details of the carbon budget in major terrestrial and aquatic ecosystems (including coastal ocean waters), information about anthropogenic drivers, and implications for policy and carbon management. Individual chapters focus on advances since the 2007 Report, and include new focus areas such as soil carbon, arctic and boreal ecosystems, tribal lands, as well as greater emphasis on aquatic systems and the role of societal drivers and decision making on the carbon cycle. In addition, methane is considered to a greater extent than before. SOCCRM2 is expected to provide an updated assessment and a unique perspective on the carbon cycle, which will contribute to the next U.S. National Climate Assessment, as well as providing information to support science-based management decisions and policies that include climate change mitigation and adaptation in Canada, the United States, and Mexico. Although the Report is still in the review process, preliminary findings indicate that North America is a net emitter of carbon dioxide and methane to the atmosphere, and that natural sinks offset about 25% of emitted carbon dioxide. Combustion of fossil fuels represents the largest source of emissions, but show a decreasing trend over the last decade and a lower share (20%) of the global total compared with the previous decade. Forests, soils, grasslands, and coastal oceans comprise the largest carbon sinks, while emissions from inland waters are a significant source of carbon dioxide. The Report also documents the lateral transfers of carbon among terrestrial ecosystems and from terrestrial to near-coastal ecosystems, to complete the carbon cycle accounting. Further, the Report explores the consequences of rising atmospheric carbon dioxide on terrestrial and oceanic systems, and the capacity of these systems to continue to act as carbon sinks based on the drivers of future carbon cycle changes, including carbon-climate feedbacks, atmospheric composition, nutrient availability, and human activity and management decisions. SOCCR-2 highlights key data gaps in carbon accounting frameworks, uncertainties in modeling and estimation approaches, and integrated frameworks for improving our understanding of the North American carbon cycle.

Presentation Type: Plenary Talk
Scientific information quantifying and characterizing the continental-scale carbon budget is necessary for developing national and international policy on climate change. The North American continent (NA) has been considered to be a significant net source of carbon to the atmosphere, with fossil fuel emissions from the U.S., Canada and Mexico far outpacing uptake on land, inland waters and adjacent coastal oceans. As reported in the First State of the Carbon Cycle Report (SOCCR-1), the three countries combined to emit approximately 1.8 billion tons of carbon in 2003, or 27% of the global total fossil fuel inventory. Based on inventory data from various sectors, SOCCR-1 estimated a 500 MtC/yr natural sink that offset about 30% of emissions primarily through forest growth, storage in wood products and sequestration in agricultural soils.

Here we present a synthesis of the NA carbon budget for the next report (SOCCR-2) based on updated inventory data and new research over the last decade. After increasing at a rate of 1% per year over the previous 30 years, the combined fossil fuel emissions from the three countries have leveled off to near-zero increase over the last decade. The slower trajectory is due to the economic recession along with increasing carbon efficiency, and the result is a lower share (20%) of the global total. Synthesizing inventory-based data from forest, agriculture and other sectors over the past decade results in a smaller estimate for terrestrial C uptake (400 MtC/yr, or about 20% of emissions) than SOCCR-1, but excludes potential sinks of highly uncertain magnitude. Estimates from atmospheric and biosphere models suggest stronger sinks on the order of 30 to 50% of emissions, but these vary widely within and across the ensembles. This updated report highlights key data gaps in carbon accounting frameworks and uncertainties in modeling approaches, but also highlights integrated approaches for improving our understanding of the NA carbon cycle.

**Presentation Type:** Plenary Talk
Developing the Fourth National Climate Assessment: Progress and Plans

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Building on the success of the Third National Climate Assessment (NCA), NCA4, with an anticipated release in 2018, will provide an in-depth focus on the impacts of climate change on natural and human systems at the regional level and what is being done to address those risks. Ten regional chapters, including a new chapter for the US Caribbean (Puerto Rico and the US Virgin Islands), will serve as the centerpiece of NCA4. A new and notable addition is a chapter explicitly focused on transboundary North American and other international effects, exploring the development, national security, and economic aspects of climate change. The scientific underpinning of NCA4 is provided by a number of thematic assessment products, including the upcoming 2nd State of the Carbon Cycle Report and Climate Science Special Report, and the recent Climate and Health Assessment, among other tools like State Fact Sheets, the Climate Resilience Toolkit, and scenarios products.

In addition to an update on NCA4 process and progress, we discuss the importance of robust engagement and collaboration throughout the development of NCA4, highlighting USGCRP participation in ongoing dialogues with science and policy experts at the international, state, city, and tribal levels, and with external stakeholders, such as NCA.net.

**Presentation Type:** Plenary Talk
High-Resolution Carbon Monitoring and Modeling: Continuing Prototype Development and Deployment Across Three Mid-Atlantic States, USA

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Local, national and international programs have increasing need for precise and accurate estimates of forest carbon and structure to support greenhouse gas reduction plans, climate initiatives, and other international climate treaty frameworks. In 2010 Congress directed NASA to initiate research towards the development of Carbon Monitoring Systems (CMS). In response, our team has worked to develop a robust, replicable framework to produce maps of high-resolution carbon stocks and future carbon sequestration potential. High-resolution maps of carbon stocks and uncertainty are produced by linking national 1m-resolution imagery and existing wall-to-wall airborne lidar to spatially explicit in-situ field observations such as the USFS Forest Inventory and Analysis (FIA) network. These same data, characterizing forest extent and vertical structure, are used to drive a prognostic ecosystem model to predict carbon fluxes and carbon sequestration potential at unprecedented spatial resolution and scale. Through project development, the domain of this research has expanded from two counties in MD (2,181 km2), to the entire state (32,133 km2). Currently we are expanding our framework to the tri-state region of Maryland, Pennsylvania, and Delaware (157,868 km2), covering forests in four major USDA ecological providences (Eastern Broadleaf, Northeastern Mixed, Outer Coastal Plain, and Central Appalachian). Specifically our objectives in this phase of our research are to: Refine our methodologies for producing high-resolution estimates of carbon stocks and uncertainty over the expanded domain; Initialize and run a prognostic ecosystem model for carbon at high-spatial resolution over multiple eastern states; Validate national biomass maps using FIA data and high-resolution biomass maps over an expanded domain; Demonstrate Monitoring Reporting and Verification (MRV) efficacy to meet stakeholder needs in our 3-state region, and advance a vision for future national-scale deployment.

Presentation Type: Poster
Steps towards interoperable flux data: affiliating NEON sites with AmeriFlux

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Large data collection networks have led to an increase in available information. However, interoperability of these networks is paramount to continuing to gain knowledge from their data. The eddy-covariance technique is widely applied to observe the exchange of energy and scalars between the earth’s surface and its atmosphere. One goal of the NEON project is to provide high-quality ecosystem exchange observations to the science community. To maximize the utility of these data, affiliation of NEON sites with AmeriFlux and FLUXNET is being investigated as a pilot project.

Despite differences in specific technical configurations, community involvement, and organizational structure a common rubric is to achieve data interoperability across projects. Over the past more than 20 years, the principle investigators of over 500 globally-distributed measurement sites have formed regional communities and networks such as AmeriFlux (over 100 active sites), and the global umbrella network FLUXNET (over 500 active sites). NEON hopes to increase the coverage of the AmeriFlux and FLUXNET efforts by incrementally contributing data from up to 47 NEON sites.

The first steps in developing this partnership will be presented in this poster. Initial efforts to unify syntactic formatting through adherence to data and metadata standards have begun for the first AmeriFlux affiliated NEON site, Central Plains Experimental Range. Additionally, general site information has been submitted for site level metadata. NEON plans to provide 30 minute processed fluxes to AmeriFlux, where higher-level processing (gap-filling, partitioning…) will be applied along with the other AmeriFlux and FLUXNET sites. In this way, the user communities gain increased eco-climatic coverage and increased representation of ecosystems.

Presentation Type:  Poster
Variability and Trends in the Carbon Fluxes of North American Grasslands

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In this presentation, the current understanding of the carbon fluxes (Net ecosystem exchange, gross primary production, and ecosystem respiration) in North American grasslands will be discussed with the goal to answer the following questions: 1- How does the increase in atmospheric CO2 influence the carbon fluxes?; 2- How does climate variability affect the inter and intra annual variability in the carbon fluxes?; and 3-How does phenology shifts affect the long-term monthly and annual carbon fluxes? To address these questions, a suite of data ranging from site measurements (eddy covariance flux towers) to scaled-up carbon fluxes (FLUXNET-MTE) to satellite (MODIS) data will be used to analyze the spatial and temporal variability in North American grasslands carbon fluxes. Long-term trends in FLUXNET-MTE carbon fluxes data will be presented and compared to any apparent trends in climate variables (temperature and precipitation). In addition, growing season length (GSL) will be acquired from AVHRR data (1982-2014) to highlight the relationships between changes in GSL and carbon fluxes magnitude. A summary of land surface models results will be shown highlighting the impact of the increase in atmospheric CO2 concentrations and the changing climate on North American grassland carbon fluxes. Finally, limitations and uncertainties in both measurements and land surface models accompanied with suggestions for improved estimates of grasslands carbon fluxes will be presented.

Presentation Type: Poster
Mapping organic carbon in the soils of Mexico and the United States

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Soil organic carbon (SOC) estimates across Mexico and United States are required for policy relevant research. The objective was to build capacities (analytical and institutional) to efficiently quantify the spatial variability of SOC for the top 30cm of soil depth across both countries. We used Bayesian statistics for variable selection and machine learning for upscaling SOC observations (g cm⁻², n=38150) from the field to the continental scale. The enhanced vegetation index, air temperature and the topographic wetness index were found to be the most informative predictors for SOC. The median of a model bootstrapping approach (70 vs 30%) was used to compare the explained variance of predictions (R² 0.45±0.23) and the standard deviation of all realizations (N=2000) as a surrogate of uncertainty. The SOC estimates compared in this study varied from 1.66 ± 2.16e-05 Pg to 5.75 ± 1.10e-07 Pg for Mexican territory) and from 21.53 ± 3.36e05 to 29.87 ±1.38e07 Pg for conterminous United States. We highlight important levels of remaining uncertainty and significant differences of SOC estimates associated with the number of covariates, the pixel size and the statistical performance of the modeling approaches.

Presentation Type: Poster
Overarching Key Findings of the Second State of the Carbon Cycle Report

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This poster will provide a summary of draft Key Findings from the second State of the Carbon Cycle Report (SOCCRM2) from the perspective of the five editorial lead authors. The chapters of SOCCRM2 include an overview of the North American carbon budget and future projections, the consequences of changes to the carbon budget, details of the carbon budget in major human, terrestrial, and aquatic ecosystem compartments, societal drivers, and implications for carbon management. The chapters focus on advances since the 2007 SOCCRM-1, but include new focus areas such as soils, tribal lands, as well as greater emphasis on aquatic systems, the role of societal drivers, and decision making on the carbon cycle. In addition, methane will be considered to a greater extent than in SOCCRM-1. Each chapter also contains a section focusing on national and regional accounting to complement the overarching North American framework. In conclusion, SOCCRM-2 is expected to provide an updated assessment and a unique perspective on the carbon cycle, which will contribute to the next National Climate Assessment.

Presentation Type: Poster
This is an update of chapter 17 of SOCCR2. The rise of atmospheric CO$_2$, largely attributable to human activity through fossil fuel emissions and land-use change, has been dampened by carbon uptake by the ocean and terrestrial biosphere. We outline the consequences of this carbon uptake as direct and indirect effects on terrestrial and oceanic systems and processes for different regions of North America and the globe. We assess the capacity of these systems to continue to act as carbon sinks. Rising CO$_2$ has decreased seawater pH; this process of ocean acidification has impacted some marine species and altered fundamental ecosystem processes with further effects likely. In terrestrial ecosystems, increased atmospheric CO$_2$ causes enhanced photosynthesis, net primary production, and increased water-use efficiency. Rising CO$_2$ may change vegetation composition and carbon storage, and widespread increases in water use efficiency likely influence terrestrial hydrology and biogeochemical cycling. Consequences for human populations include changes to ecosystem services including cultural activities surrounding land use, agricultural or harvesting practices. Commercial fish stocks have been impacted and crop production yields have been changed as a result of rising CO$_2$. Ocean and terrestrial effects are contingent on, and feedback to, global climate change. Warming and modified precipitation regimes impact a variety of ecosystem processes, and the combination of climate change and rising CO$_2$ contributes considerable uncertainty to forecasting carbon sink capacity in the ocean and on land. Disturbance regime (fire and insects) are modified with increased temperatures. Fire frequency and intensity increase, and insect disturbance are disrupted as temperatures move out of historical norms. Changes in disturbance patterns modulate the effects of rising CO$_2$ depending on ecosystem type, disturbance frequency, and magnitude of events. We discuss management strategies designed to limit the rise of atmospheric CO$_2$ and reduce uncertainty in forecasts of decadal and centennial feedbacks of rising atmospheric CO$_2$ on carbon storage.

**Presentation Type:** Poster
Drivers, Trends, and Management of Forest Carbon in North America

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Forest ecosystems are the largest terrestrial carbon sink on earth and their management has been recognized as a relatively cost-effective strategy for offsetting greenhouse gas emissions. In North America, forests, including urban forests, woodlands and the products obtained from them, play a major role in the carbon cycle. In this presentation we examine recent trends, drivers, and projections of U.S. and North American carbon cycle processes, stocks, and flows in the context of interactions with global scale budgets and climate change impacts in managed and unmanaged forest ecosystems. We will also highlight carbon management science and tools for informing decisions and opportunities for improving carbon measurements, observations, and projections in forests.

Presentation Type: Poster
Seasonal dynamics and inter-annual variation of solar-induced chlorophyll fluorescence and gross primary production of vegetation in North America

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The relationships between chlorophyll content, solar-induced chlorophyll fluorescence (SIF) and gross primary production (GPP) are complex and dynamic under varying plant function types, atmospheric CO2 concentration, weather and climate. Here we present a summary on (1) an in-situ observation study that integrates SIF measurements with CO2 eddy flux measurements in a tallgrass prairie site in Oklahoma, and (2) a data analysis and modeling study that combines GOME-2 SIF data (2007-2015) and GPP data (2007-2015) from the Vegetation Photosynthesis Model (VPM) that uses the concept of chlorophyll content and the fraction of photosynthetically active radiation (PAR) absorbed by chlorophyll (FPARchl), MODIS-based vegetation indices (EVI-relevant to vegetation chlorophyll content; LSWI-relevant to land surface water content), and climate data to estimate daily GPP. We report the sensitivity of various biomes in North America (Canada, USA and Mexico) to climate variability, including the severe drought in 2012. We also introduce the Geostationary Carbon Cycle Observatory (GeoCARB) mission, which was selected in December 2016 by NASA. The GeoCARB mission will provide daily SIF data for North America, Central America and South America. The unprecedented daily SIF data can be used to better understand the relationship between chlorophyll content, SIF and GPP at diurnal, daily and seasonal scales. When an integrated in-situ, airborne and spaceborne SIF observation framework is combined with other observation systems (e.g., Ameriflux), we can develop a new and improved capacity to (1) monitor, report and verify the terrestrial biospheric carbon fluxes in North America, and (2) carry out a variety of applications such as agriculture and food security.

Presentation Type: Poster
Session: Low Carbon Futures
Quantifying the role of Northern Great Plains agroecosystems in the emerging BECCS economy

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The transition toward the Bio-energy with Carbon Capture and Storage (BECCS) economy has unintended benefits and drawbacks that must be quantified to understand human-climate interactions. Some of these changes are already underway. For example, parts of the North American northern Great Plains have experienced a 6 W m$^{-2}$ decline in summertime radiative forcing since the 1970s. This regional cooling has coincided with agricultural changes, namely a 23 Mha decline of summerfallow across Canada and the U.S. In addition to climate impacts, replacing summerfallow with no-till cropping systems results in lesser soil carbon losses – or even gains – and usually confers economic benefits. This may result in a ‘win-win-win’ scenario for climate, soil carbon, and farm-scale economics, but field-scale and regional carbon consequences remain uncertain. Here, we present twelve growing seasons of eddy covariance CO$_2$ flux measurements from dryland winter and spring wheat, summerfallow, irrigated malt barley and winter wheat, and canola in Montana, USA. Growing season CO$_2$ losses from summerfallow, ca. 100 g C m$^{-2}$ per growing season, are of similar magnitude to CO$_2$ uptake by winter and spring wheat (ca. -200 and -100 g C m$^{-2}$ gs$^{-1}$, respectively). Differences among wheat treatments can be explained by previous crop residues. Growing season CO$_2$ flux in irrigated malt barley is critically determined by harvest date, which proceeds as early as late June. A precision agriculture experiment reveals pronounced field-scale spatial NDVI variability, and flux footprint analyses demonstrate its importance to field-scale CO$_2$ flux. Temporal CO$_2$ flux variability is significantly related to tower-measured NDVI, but more strongly related to the photochemical reflectance index (PRI). Ongoing research is quantifying the carbon dynamics of cover crops including pulses and biofuel crops, and integrating findings into models of the food-energy-water nexus of the Upper Missouri River Basin as it transitions toward a BECCS economy.

Presentation Type: Plenary Talk
Forest carbon futures under alternative policy strategies

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Forest carbon sequestration in the US provides a strong net offset to greenhouse gas emissions from other sectors but at slightly decreasing rates due to land use pressures, management, forest aging, and other biophysical dynamics. We evaluated the potential for policies in the forest sector to augment future forest carbon sequestration thereby increasing the net offset to CO$_2$ emissions from other sectors. We examine an additive and plausible set of scenarios for expanding forest carbon sequestration between 2017 and 2050 to define the plausible upper bounds on future offsets and compare the physical efficacy of different policy strategies in different regions. Afforestation policies are more efficacious for building the sink when compared to expanded forest product use and management to reduce forest fire occurrence. Policies in the eastern US are more efficacious than in the west. A strategy which combined afforestation, forest restoration, fire management, and expanded wood products consumption increased sequestration by 162 TgCO$_2$ eq yr$^{-1}$ in 2050 or by about 34%. While these scenarios do not address the total costs of implementing policies they are informed by costs of other land and forest based policies and provide useful insights into the potential range of effects of these types of interventions.

Presentation Type: Plenary Talk
The uncertainty in gridded estimates of anthropogenic CO2 emissions

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For both scientific and political reasons, it is important to estimate both the total quantities and the spatial distribution of anthropogenic CO2 emissions to the atmosphere. It is also important to have a realistic measure of their uncertainty. There have been multiple efforts to estimate global and national emissions of CO2 and several major efforts to estimate anthropogenic emissions on a gridded representation of the Earth's surface. We have shown that the various estimates differ substantially, even over a relatively well-characterized space like the United States. We have produced quantitative estimates of the uncertainty on multiple scales and on a one degree grid scale the uncertainty per grid space in the United States is typically on the order of 160%.

Emissions are generally estimated by: 1.) estimating the total national emissions from the amount of fossil-fuel consumed and the magnitude of other CO2 emitting processes, and 2.) using related data to estimate how these emissions are distributed within national borders. Population density, night light intensities, summary information at intermediate scales, and detailed information on point sources such as power plants and industrial processes can be used to spread these emissions spatially. Each aspect of the estimation carries spatial and magnitude uncertainty with it and can be used to understand the key drivers. A tactical understanding can then be developed to target cost effective reductions to the overall uncertainty.

We illustrate how uncertainty is impacted by the ability to attribute more emissions to point sources and we show how uncertainty varies with spatial scale. We also look at strategies for reducing uncertainty and the trade-offs between resolution and uncertainty. Finally, moving forward, we discuss some additional sources of uncertainty involved in the use of emissions inventories when used as boundary data for atmospheric flow models.

Presentation Type: Plenary Talk
Session: Tri-National Advances in Policy
International Soil Carbon Network: Advancing Soil Carbon Monitoring, Reporting, and Data Synthesis

Luke Nave, University of Michigan, lukenave@umich.edu (Presenter)

The International Soil Carbon Network (ISCN) is a community of scientists dedicated to advancing the understanding of Earth’s largest terrestrial C pool. ISCN was initiated by an 18-member Scientific Steering Group in 2009, who chartered the organization and acquired support from USDA (Forest Service; National Institute of Food and Agriculture) and the USGS, with an early focus on database development for United States soils. Since then, ISCN has grown into a body of nearly 500 scientists worldwide, engaging at levels from individual investigators, to project teams, to large scientific networks. In recent years, ISCN has become increasingly active in C monitoring, reporting, and data synthesis. In this presentation, I highlight one example from each of these activity areas:

1. Monitoring- Since 2013, ISCN has partnered with US Forest Service International Programs, USAID, and a variety of academic institutions and Forest Service program units to run annual training workshops in belowground C inventory for scientists throughout Latin America. Through the first 4 workshops, ISCN has trained 56 participants from 9 Nations in methods for all stages of belowground C inventory—from design to reporting—building capacity throughout the hemisphere.

2. Reporting- Late in 2014, ISCN began working with the Forest Inventory and Analysis (FIA) program of the USDA-Forest Service to develop a new approach, based on FIA and ISCN data, to estimate the C stocks of the Nation’s forest soils. One year later, these estimates were completed as part of the National Greenhouse Gas Inventory, and subsequently presented before the UNFCC meeting in Paris. Two years, later, at the start of 2017, the framework and estimates were accepted as a paper in Ecological Applications, with plans to continue refining the approach and estimates.

3. Data Synthesis- Researchers continue to contribute data from around the world to ISCN, increasing the availability of this common currency in C cycle science. Project teams funded by NSF, USGS, and other organizations are making use of ISCN resources as they focus on cutting-edge topics, such as soil C vulnerability, to move large-scale soil C science beyond stock assessments and into more dynamic assessments of the role of soils in the C cycle.

Presentation Type: Plenary Talk
Canada, Mexico and the US indicated in both their Nationally-Determined Contributions (NDCs) and in their national Mid-Century Strategies (MCS) to reach deep greenhouse gas emission reductions targets that the forest sector will be a key contributor towards reduced emissions and increased sinks. How this can be achieved, what mitigation options will be implemented, and their cumulative mitigation benefits to 2050 are subjects of ongoing research. Through coordination of and funding by the Commission for Environmental Cooperation, detailed analyses of the drivers of forest GHG balances and the potentials for climate change mitigation are quantified in six pilot regions across North America using a consistent modelling framework and conceptual approach that quantifies changes in carbon stocks and emissions in forests and harvested wood products as well as changes in emissions resulting from the substitution of wood products for more emissions-intensive products such as steel, concrete, plastics, and fossil fuels.

Using the Carbon Budget Model (CBM-CFS3) and an associated model of harvested wood products, each with data for the six pilot regions in Canada (British Columbia and Ontario), Mexico (Quintana-Roo and Durango) and the US (Wisconsin and South Carolina) we evaluate the changes in cumulative emissions resulting from different mitigation strategies aimed at changing forest management, rates of land-use change, and the use of harvested wood products.

Implementation of a methodologically-consistent approach allows for improved understanding of the drivers of emissions, the ranking of alternative mitigation strategies and the design of mitigation portfolios that are regionally differentiated yet contributing to the shared goals of GHG emission reductions. Preliminary results also indicate the need to commence soon with investments into forest sector climate change mitigation strategies if their potential contribution by 2050 is to be increased.

**Presentation Type:** Plenary Talk
Integrated Modeling and Assessment of Climate Change Mitigation Options in Mexico’s Forest Sector

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Mexico is the first Non-Annex I country to submit its Climate Change Mid-Century Strategy in accordance with the Paris Agreement of the UNFCCC. Crafted within Mexico’s climate and energy policy frameworks, this strategy results from the analysis of best available information and explicitly recognizes the importance of strengthening regional efforts with United States and Canada.

Since 2012, the Mexican government through its National Forestry Commission, with support from the North America Commission for Environmental Cooperation (CEC), the Forest Services of Canada and USA, the SilvaCarbon Program and research institutes in Mexico, has made progress towards the use of carbon dynamics models ("gain-loss" approach) to estimate GHG emissions for strategic landscapes in Mexico. Currently, this multi-institutional collaboration coordinated by the CEC is adapting these tools to quantify the impact of climate change mitigation options in the forest sector (2018-2050). These include mitigation scenarios of zero net deforestation, increased reforestation rates, improved forest management to increase productivity and their combinations. In Mexico, most forests are under social tenure with a wide array of management activities. Altering these activities (REDD+ strategies, the role of harvested wood products), can augment the forests’ mitigation potential.

Here we present the main steps conducted to compile and integrate information from forest inventories, remote sensing, disturbance data and ecosystem carbon transfers to generate inputs required to calibrate these models and validate their outputs. The analyses are conducted for the states of Durango and Quintana Roo, Mexico, using the CBM-CFS3 and CBM-FHW3 models with local input data and the appropriate modification of parameters to prepare Tier 3-GHG inventories. The goal of this tri-national effort is to show how the data and tools developed for carbon assessment in strategic landscapes in North America can help estimate the impact of several mitigation options consistent with national goals of GHG emission reductions.

Presentation Type: Plenary Talk
From coastal ecosystems to the International Climate Change Agenda

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Key words: coastal ecosystems, mapping, connectivity, collaborative conservation, restoration, reforestation.

The National Commission of Natural Protected Areas’ (CONANP) Climate Change agenda has started to take into consideration the carbon-rich coastal ecosystems. Since 2014, working along with the Commission for Environmental Cooperation (CEC), Mexico has mapped the distribution of its seagrasses, salt marshes and mangroves. By doing so, potential protected areas (PA) have been identified and, consequently, connectivity of ecosystems can be boosted. Measures for mitigation and adaptation to climate change inside PAs have also being applied in Sian Ka’an, La Encrucijada and Marismas Nacionales Nayarit Biosphere Reserves. This includes: measurement of carbon stocks in mangroves and seagrasses, diagnosis of conservation and vulnerability status of the ecosystems, restoration and reforestation, and elaboration of contingency and risk plans. CONANP has added these actions into the Programs for Climate Change Adaptation (PACC in Spanish), which have been developed by civil society, NGOs and government sector. CONANP has also collaborated with Parks Canada and the U.S. Forest Service for capacity building.

At the same time, the PACCs contribute to the National Strategy for Climate Change and to the Intended National Determined Contributions (INDCs) related to the matter.

International and multisectorial collaboration has been essential for the achieved goals. It has made possible the exchange of scientific data and information, the sharing of managing experiences, the construction of capacities and the creation and application of a new conservation-mitigation-adaption scheme. Local communities have also been fundamental for the success of PACCs. Finally, academia has provided the necessary data to facilitate the decision-making process.

Presentation Type: Plenary Talk
Integrated Modeling and Assessment of Climate Change Mitigation Options in the United States Forest Sector

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Following the commitments to reduce greenhouse gas emissions made by the United States at the United Nations Climate Change Conference (COP 21) in Paris, it is critical to identify and evaluate potential greenhouse gas mitigation opportunities. Forests currently offset approximately 15% of annual greenhouse gas emissions from fossil fuels in the U.S. and have the potential to play an important role in achieving these commitments for long-term climate change mitigation. Forest sector mitigation goals can be accomplished by increasing the uptake and storage of carbon both within forests as well as in harvested wood products, and by reducing emissions. With sponsorship by the North American Commission for Environmental Cooperation, we evaluated forest sector climate change mitigation strategies from 2018 to 2050 in two diverse, multi-ownership landscapes in the U.S.: coastal South Carolina and Northern Wisconsin. To achieve this, we integrated U.S. Forest Inventory and Analysis data and remotely sensed land-cover change data within a forest carbon modeling framework which includes the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3), the Carbon Calculation Tool, two harvested wood products models, and an Integrated Terrestrial Carbon (InTEC) model. We accounted for the avoided emissions associated with utilizing bioenergy in place of energy from fossil fuels, and substituting wood products for other materials in construction. For each of the pilot sites we simulated a “business as usual” baseline scenario, as well as several mitigation scenarios including reducing deforestation and increasing reforestation, increasing productivity through silvicultural practices, capturing additional harvest residues for bioenergy, increasing the proportion of harvested wood that is used for long-lived wood products and bioenergy, and increasing salvage logging after major disturbances like hurricanes. We also examined how past and projected forest carbon stocks may be affected by climate and atmospheric changes. These activities represent practical ways to sustainably manage forests for climate mitigation policies and programs in the US while minimizing tradeoffs with other ecosystem services and increasing production of forest commodities when possible. Through the evaluation of mitigation approaches for these two pilot sites, we demonstrate the data, tools, and quantitative analyses needed to evaluate climate change mitigation activities and achieve greenhouse gas reductions.

Presentation Type: Poster
Considerable Contribution of the Montreal Protocol on Reducing National Greenhouse Gas Emissions from the United States

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The control of the Montreal Protocol on chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) has not only protected stratospheric ozone, but also benefited climate. Although this global climate benefit has been quantified, the impact of the Montreal Protocol on national-scale greenhouse gas (GHG) emissions is less clear. Understanding this impact is particularly important given the nationally-based efforts on controlling GHG emissions. Within the US, the consumption of hydrofluorocarbons (HFCs) has grown substantially over the past two decades as they were replacing CFCs and HCFCs. Given such a large change in their uses, the overall emission trend of CFCs, HCFCs and HFCs is highly uncertain. In this study, we analyzed and inversely modeled atmospheric observations made in the NOAA's Global Greenhouse Gas Reference Network for deriving emissions and emission trends of CFCs, HCFCs, and HFCs over the US. Our inversion-derived emissions show distinct spatial and temporal variability for gases with distinct applications, but similar regional patterns and temporal variations for gases with similar uses; e.g., for gases applied in building insulation foams, derived per capita emissions are higher in northern states, whereas for gases used in residential air conditioning, derived per capita emissions show the opposite regional pattern. The aggregated total CO2-eq emissions of CFCs, HCFCs, and HFCs not only compare significantly to other non-CO2 GHGs, but also show a significant declining trend within the US. The reduction of their total CO2-eq emissions between 2005 and 2014 compares to 30% of the US GHG emission reduction target for 2020 required in the President’s Climate Action Plan, and 20% of the 2025 target agreed in the COP21. A larger contribution is expected for 2005 to 2020 or 2025, given continued emission declines of CFCs and HCFCs, and the implementation of the EPA’s Significant New Alternatives Policy for replacing the uses of high-GWP HFCs.

Presentation Type: Poster
Integrated Modeling and Assessment of Climate Change Mitigation Options in Canada’s Forest Sector

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Werner A Kurz, Canadian Forest Service, Natural Resources Canada, wkurz@nrcan.gc.ca (Presenter)

Managing forests to increase carbon sequestration or reduce carbon emissions, and using wood products and bioenergy to substitute for other carbon-intensive products and fossil fuels, have been shown to be effective ways to reduce greenhouse gas emissions and tackle climate change in many countries and regions.

With sponsorship by the North American Commission for Environmental Cooperation (CEC), we evaluated forest sector climate change mitigation strategies from 2018 to 2050 for two case study regions in the provinces of British Columbia and Ontario, Canada, using spatially-explicit forest inventories and disturbances at 16 ha resolution.

We examined five strategies relative to a forward-looking baseline: (1) harvesting more by increasing the utilization rate, (2) harvesting less, (3) reducing post-harvest burning of slash, (4) reducing slashburning and capturing harvest residues for bioenergy, and (5) shifting the harvested wood commodities towards longer-lived wood products.

A systems approach was used to track changes in greenhouse gas emissions and removals in forest ecosystems, harvested wood products and through the substitution of carbon-intensive products and fossil fuels with wood products and bioenergy. Models included the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) and the Carbon Budget Model Framework for Harvested Wood Products.

This quantitative analysis evaluated spatially-explicit climate change mitigation activities, relative to a baseline, and ranked activities based on the cumulative greenhouse gas reduction. Combinations of activities had the highest mitigation potential, and substitution impacts were found to be important to final rankings.

Presentation Type: Poster
Global Change Information System (GCIS)

Reid Sherman, USGCRP, rsherman@usgcrp.gov (Presenter)

The US Global Change Research Program (USGCRP), an office coordinating global change research across 13 Federal agencies, established and has been supporting the Global Change Information System (GCIS). GCIS aims to better coordinate and integrate the use of federal climate data and information by providing robust provenance and traceability for the information supporting government climate assessments and reports.

The GCIS is an open-source, web-based resource designed for use by scientists, decision makers, and the public. It provides coordinated links to a select group of information products produced, maintained, and disseminated by government agencies and organizations. As well as guiding users to global change research products selected by the 13 member agencies, the GCIS serves as a key access point to assessments, reports, and tools produced by the USGCRP. The GCIS is managed, integrated, and curated by USGCRP.

The GCIS was used with the Third National Climate Assessment, and has incorporated information provenance for all USGCRP reports since then, including the upcoming State of the Carbon Cycle Report. Reid Sherman, the GCIS Team Lead, will discuss the mission of GCIS, its value for stakeholders, and where it will go in the coming years, leading up to the Fourth National Climate Assessment and beyond.

Presentation Type: Plenary Talk
Making Ocean Acidification Data Accessible and Useable for Coastal Managers

Elizabeth Jewett, NOAA Ocean Acidification Program, libby.jewett@noaa.gov (Presenter)
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The NOAA Ocean Acidification Program has made a concerted effort to promote data accessibility and the development of information products and online tools to assist coastal managers and policy makers with decision making related to ocean acidification (OA). OA is caused by the absorption of anthropogenic CO2 by the ocean and will likely having increasing impacts on marine ecosystems. The spectrum of data products funded by the OA Program to promote data dissemination and uptake of management-relevant information include 1) infographics that summarize the various factors influencing OA in particular regions, 2) online tools that enable coastal managers to visualize how OA will manifest in their region over time and how OA may affect important fisheries, 3) seasonal forecast models that predict how OA conditions might affect particular commercial fishery sectors, 4) information products and assessments for coral reef managers and 5) regional OA data portals with built-in data visualization tools. These various products will be showcased to demonstrate the value of translating raw data into information that can be utilized by a wide range of stakeholders.

Presentation Type: Plenary Talk
A Multi-City Framework for Developing Standardized Measurement Strategies and Methods for GHG Estimation in the United States

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Cities house large populations, concentrate economic activity, and utilize a significant amount of generated energy. As such, cities and their supporting infrastructure are large sources of atmospheric emissions important to both carbon cycling and air quality. These emissions correlate with other constituents’ concerns (e.g. traffic congestion). Thus, city governments are increasingly interested in mitigating these emissions to improve sustainability within their jurisdictions. Accurate greenhouse gas (GHG) emissions estimates provide information to city governments to help aid the planning, implementation, and efficacy of sustainability policies. However, urban GHG estimation remains an active research area with many sources of uncertainty.

Domestic urban GHG studies have largely been conducted in six cities: Indianapolis (INFLUX experiment), Los Angeles (the Megacities project), Salt Lake City, Oakland, Boston, and the North Eastern Corridor of Baltimore/Washington DC (NEC-BW project). To standardize approaches, measurements and methods within these urban areas need to be continuously improved with performance benchmarking. Such benchmarking must account for both the complexities of cities themselves (e.g. population, urban form, etc.) along with the bevy of variables impacting a city’s ability to estimate its own GHG’s (e.g. meteorology, density of observations, etc.).

This work involves the development of a multi-city analysis framework that accounts for individual city characteristics along with those factors that impact the estimation of GHGs. Only through such a framework can a suite of standardized measurements and methods be identified and investigated to help city governments choose effective means to estimate their GHGs and related gaseous emissions. The presented research will compare example results from the five US domestic testbed sites within this framework. Common challenges and successes across all testbeds will also be presented. Since the testbeds are at various stages of maturity, this framework will allow results to be consistently compared to decipher best practices across cities as testbeds develop.

Presentation Type: Plenary Talk
The PEcAn project (pecanproject.org) hosted a modeling community meeting in May 2016 with the goal of identifying the needs and opportunities for cyber-infrastructure improvement under recent technological advances. We identified four main bottlenecks that the community faces: data ingestion and standardization, multi model execution and analysis across spatial and temporal scales, model-data comparison, and the proliferation of these tools and analyses into the public domain. The ingestion of an increasingly diversified set of observational and forcing data requires a flexible workflow to standardize data types across data sources and model formats. Multi model execution and analysis requires a framework capable of handling a variety of modeling structures and methods to handle model inter-comparisons. Model data comparison necessitates methods capable of handling model process and data uncertainty. Lastly, the need to make these tools accessible to others outside the modeling community requires a workflow that allows for easy access to data, models, and the analyses necessary to leverage the wellspring of information and tools the earth system modeling community has to offer. We believe these needs provide a road-map to produce a common development and user workflow accessible to the scientific community and beyond.
Carbon Flux and Soil Data Management and Interfaces

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The FLUXNET, AmeriFlux, and International Soil Carbon Network Data Management systems provide access to carbon flux data and soil carbon across the Americas. This talk will discuss the design philosophy, user services, data products, and ancillary data collection techniques of these data management systems. The existing services and upcoming services will be described as well as the philosophy and priorities. If time allows, we will also discuss the data management and user services under development for the NGEE Tropics and Upper Colorado Watershed projects. We will also solicit input regarding services desired by the data contributor and data user communities.

Presentation Type: Poster
AmeriFlux Data Management Upcoming Products

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The AmeriFlux data management system is developing new products designed to support the data contributors and data user communities. This poster will describe the upcoming products and provide an opportunity to discuss with the AmeriFlux data team desired products.

Presentation Type: Poster
Ocean Carbon Data Management - A Vision to do Better Together

Eugene Burger, NOAA Pacific Marine Environmental Laboratory, eugene.burger@noaa.gov (Presenter)
Kriza Arzayus, NOAA NCEI
Kevin M. O’Brien, U. of Washington
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Liqing Jiang, NOAA NCEI
Benjamin Pfeil, Bjerknes Climate Data Centre

We’ve all heard it - more observing, often autonomous, platforms, and the resulting increase in data volume. In spite of this reality, earth scientists, including the marine carbonate chemistry research community, often still have to process data on a single data file, mission-by-mission, or researcher-by-researcher basis. The result of this approach could be ad-hoc data QC, access, and preservation capabilities that are not scalable or long-term sustainable, but yet fulfills the immediate requirements for researchers to have their data prepared for their analysis and research. Considering the important link of these processes between the data collection and research results, it is not surprising that researchers are reluctant to change from their well-understood processes. Very few scientists, or science organizations have the luxury of time and resources to establish more robust and scalable data management solutions. In short, we have a community collecting valuable data, often relying on imperfect data management processes, and yet are reluctant to embrace new and unproven solutions. At the same time, science organizations are resource constrained to address this issue. For many years the Carbon Dioxide Information and Analysis Center (CDIAC) provided a valuable service to the marine carbonate chemistry community. The closing of this facility and its migration to NOAA’s National Centers for Environment Information (NCEI) presents scientists and data management experts with an unique opportunity.

With the migration, change is unavoidable. This reality should be embraced and the data management landscape with regards to ocean carbon data should be revisited, and ask ourselves how we can improve the critical data pathway and processing that applies to these data. No single organization has the capability to provide a solution to serve all, but broad agreement on core principles can leverage complementary efforts to create a sustainable solution that serves a wider community. Where community silos or entities exist that serve their scientific communities effectively, these should also be integrated into a new community solution. These community relationships are key to any solution and have to be embraced as part of a more comprehensive system.

This talk will present a vision of a new approach to ocean carbon data management that can deliver a streamlined data management system that reduces the data management burden for our scientists. It also suggests a data pathway that delivers uniform data processing, quality control, and efficient delivery of high quality datasets to national data centers for long-term preservation, and serves as a foundation for analysis, synthesis, and incorporation into other products, applications, and services. Such a system holds the promise for scientists and data managers from disparate organizations to combine efforts towards a solution that could accomplish objectives that serve scientists, data managers, and the tax paying public with more efficient services.

Presentation Type: Poster
Carbon cycle forecasts need to be closer to real-time: linking theory, data, models, and cyberinfrastructure

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Decisions are fundamentally about the future. However, while the carbon community has invested strongly in centennial-scale prediction, we have limited understanding of what drives forecast uncertainty and limited infrastructure to iteratively and automatically update predictions as new data become available on near-term management-relevant timescales. We begin by synthesizing the near-term forecasting challenges and opportunities identified by a NEON forecasting workshop. Next, we present a first-principles framework to understand what drives forecast uncertainty and discuss how this framework can be used to improve global forecasts. We illustrate the application of this framework to the synthesis of terrestrial data and models using the PEcAn cyberinfrastructure (pecanproject.org), and explore examples of PEcAn’s integration with both large- (e.g. NGEE-Tropics, FLUXNET, ForestGEO, LTER, NEON) and small-scale synthesis efforts and its adoption by modeling teams. Finally, we introduce the Near-term Ecological Forecasting Initiative (NEFI), an new effort to produce iterative forecasts of aquatic productivity, land fluxes, phenology, and soil microbial diversity and function through the development of reusable forecast tools and cyberinfrastructure.

Presentation Type: Poster
Scaling-based Empirical Modeling of Net Ecosystem Exchange (NEE) in U.S. Deciduous Forests

Khandker S Ishtiaq, West Virginia University, khandker.ishtiaq@mail.wvu.edu (Presenter)
Omar I Abdul-Aziz, West Virginia University, oiabdulaziz@mail.wvu.edu

A scaling-based empirical model was developed to predict the diurnal cycles of net ecosystem exchange (NEE) in U.S. deciduous forests. Different diurnal cycles of hourly NEE were scaled by the corresponding day-specific single reference observations, leading to a common dimensionless diurnal NEE cycle. The scaled cycle was then estimated with hourly observations of growing season (June-September) NEE for five U.S. deciduous forests during 1998-2015 by using an extended stochastic harmonic algorithm (ESHA). The case study forests represented a gradient in climate (temperate, continental), topography (hilly, flat), and soil type (silt, sand). The model estimations led to a parsimonious set of five parameters, which exhibited spatiotemporal robustness by collapsing into comparable ranges among the different growing season days, years, and sites. Model testing based on the site-specific (temporally averaged) and generalized (averaged over time and sites) parameter sets demonstrated good performance in predicting the NEE diurnal cycles from a single reference observation (Nash-Sutcliffe Efficiency, NSE = 0.78-0.90). The analytical model sensitivity and uncertainty measures were calculated by perturbing the parameters individually and simultaneously to further demonstrate model robustness. The site-specific and the generalized models were finally presented in a user-friendly Excel spreadsheet software. The presented models can be utilized for a robust estimation and prediction of the diurnal cycles of hourly NEE based on a single (or a limited set of) reference observation(s). The models can, therefore, be used for filling gaps in observed growing season time-series of hourly NEE at various deciduous forests of North America.

Presentation Type: Poster
The North American Carbon Program Multi-scale Synthesis and Terrestrial Model Intercomparison Project Phase II: Environmental Driver Data in 2011-2100

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Built on top of the unprecedented TBM model intercomparison testbed developed in MsTMIP Phase I, the MsTMIP Phase II is performing a series of forecast simulations that use climate and emission scenarios defined by the IPCC and CMIP5. The purpose is to evaluate the response of TBMs to future climatic conditions, with an aim to assess the sensitivity of models and terrestrial carbon fluxes to future climate. To achieve this goal, the MsTMIP team has prepared a collection of global environmental driver data sets, including climate, atmospheric CO2 concentrations, nitrogen deposition, land-use and land-cover change, and phenology, with a spatial resolution of 0.5° × 0.5° and a time span of 2011-2100. This collection of driver data was created through fusion of historical driver data prepared in Phase I and relevant variables from climate model projections (e.g. CMIP5 climate projections and ACCMIP nitrogen deposition projections) under two RCP scenarios: RCP45 and RCP85 to ensure smooth transition and consistency between environmental driver data in both Phase I and Phase II. Especially, we selected 5 CMIP5 models that span the full range of simulated climate sensitivity and created 10 realizations of climate driver data in 2011-2100 by fusing the historical CRUNCEP climate driver with each of these 5 CMIP5 model simulations under both RCP45 and RCP85 scenarios. Multiple realizations of climate driver allow their ensemble mean and spread representing the “best estimate” of the future carbon cycle dynamics and a measure of uncertainty in that estimate respectively. This collection of environmental driver data sets is currently being used to drive forecast simulations for 6 TBMs in MsTMIP Phase II. This poster describes the philosophy and methodology used to create MsTMIP Phase II environmental driver data sets and provides a summary of the driver data evaluation and comparison with Phase I driver data sets.

Presentation Type: Poster
We conducted a multi-site and multi-ecosystem analysis to determine the relative linkages of terrestrial net ecosystem exchange (NEE) with the climatic and ecohydrological indicators. A systematic data-analytics approach was applied to the hourly eddy-covariance data during 1992-2015 from 25 AmeriFLUX sites, representing six diverse ecosystems (wetland, grassland, cropland, deciduous, evergreen and mixed forests). The study sites incorporated a gradient in geographical location, topography, and climate. The data-analytics involved a sequential application of Pearson’s correlation matrix, principal component and factor analyses, and explanatory partial least squares regression modeling. Four biophysical components were identified across the diverse ecosystems. NEE was most strongly linked with the ‘radiation-energy’ component, which was followed by the ‘temperature-hydrology’, ‘ambient atmospheric CO2’, and ‘aerodynamic’ components. The estimated linkages also indicated the relative sensitivities of NEE to the individual climatic and ecohydrological drivers. The study identified a remarkable similarity in interrelations and relative linkages of NEE across ecosystems of North America, highlighting the potential of developing parsimonious (low dimensional) models to robustly predict the CO2 fluxes.

Presentation Type: Poster
Near real-time ecological forecasting of peatland responses to warming and CO2 treatment through EcoPAD-SPRUCE

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Ecological forecasting is critical in various aspects of our coupled human-nature systems, such as disaster risk reduction, natural resource management, and climate change mitigation. Novel advancements are in urgent need to deepen our understandings of ecosystem dynamics, boost the predictive capacity of ecology, and provide timely and effective information for decision-makers in a rapidly changing world. Our Ecological Platform for Assimilation of Data (EcoPAD) facilitates the integration of current best knowledge from models, manipulative experimentations, observations and other modern techniques and provides both near real-time and long-term forecasting of ecosystem dynamics. As a case study, the web-based EcoPAD platform synchronizes real- or near real-time field measurements from the Spruce and Peatland Responses Under Climatic and Environmental Change Experiment (SPRUCE), a whole ecosystem warming and CO2 enrichment treatment experiment, assimilates multiple data streams into process-based models, enhances timely feedback between modelers and experimenters, and ultimately improves ecosystem forecasting and makes the best utilization of current knowledge. In addition to enable users to (i) estimate model parameters or state variables, (ii) quantify uncertainty of estimated parameters and projected states of ecosystems, (iii) evaluate model structures, (iv) assess sampling strategies, and (v) conduct ecological forecasting, EcoPAD-SPRUCE automated the workflow from real-time data acquisition, model simulation to result in visualization. EcoPAD-SPRUCE promotes seamless feedback between modelers and experimenters, hand in hand to make better forecasting of future changes. The framework of EcoPAD-SPRUCE (with flexible API, Application Programming Interface) is easily portable and will benefit scientific communities, policy makers as well as the general public.

Presentation Type: Poster
The Application for Extracting and Exploring Analysis Ready Samples (AppEEARS): Facilitating Improved Interoperability and Usability of Heterogeneous Big Earth Data across Multiple Federal Archives

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AppEEARS is a new capability providing web-based data access, processing, and visualization services to the community. AppEEARS addresses Big Data challenges and delivers value to users by 1) significantly reducing data volumes, at-archive, based on user-defined space-time-variable subsets 2) promoting interoperability across a wide variety of datasets via format and coordinate reference system harmonization, 3) increasing the velocity of information insight by allowing interactive visualization of harmonized datasets, and 4) ensuring the veracity of data samples by making quality measures more apparent and usable, by generating standards-based metadata, and by providing data and processing provenance. Development and operation of AppEEARS is led by the NASA Land Processes Distributed Active Archive Center (LP DAAC), but also leverages other federal archive partnerships to extend the capability across a large data management network.

Presentation Type: Poster
Soil Moisture Visualizer: Bringing harmony to heterogeneous soil moisture data

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Root zone soil moisture (RZSM) is an important constraint on carbon flux, and soil moisture data may help to reduce uncertainties in carbon cycle modeling. Over the last few years, availability of RZSM data has grown considerably, due to the development of new airborne sensor capabilities (e.g. AirMOSS), wider installation of in situ networks (e.g. SoilSCAPE, COSMOS), and launch of the Soil Moisture Active-Passive (SMAP) satellite. The Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC; http://daac.ornl.gov) currently distributes about 0.7TB (8085 files) of RZSM data products.

One key challenge that may limit effective utilization of these data is their heterogeneity in terms of (1) spatial footprints (points vs gridded representation), (2) frequency (sub-hourly to daily), (3) sub-surface measurement depths, and (4) methods of measurements (in situ vs remote-sensing). We have developed an integrated visualization and subsetting platform for RZSM datasets available for North America based on open-source software libraries. Harmonizing these disparate data in a single system not only adds value to the existing data but also facilitates exploratory analysis and data discovery among different groups of stakeholders. In this poster, we describe the new RZSM data platform and share case studies that leverage the visualization system for real-world science applications.

Presentation Type: Poster
Session: Humans and the Carbon Cycle
People and Carbon

Elizabeth L Malone, Pacific Northwest National Laboratory (ret), elizabethmalone049@gmail.com (Presenter)

Social science research on the carbon cycle and climate change begins, not with the investigation into the mechanisms of these linked systems, but rather with how people live—their day-to-day occupations, how they get from one place to another, their family and other social configurations, their organizations and governance. People’s needs and wants are the starting point for investigation of how carbon is embedded in the conditions and in which they find themselves and the technologies they use. From energy sources to land management and from urban hardscapes to rural landscapes, carbon is emitted, conserved, or captured as people work, travel, eat, and perform other everyday activities and as human institutions and economic systems form and operate. Such research provides a different set of potential interventions than studies that begin with how the carbon cycle is changing, identify points of emissions, and quantify the technical potential of reducing them. People-centered research into the social embeddedness of carbon involves a wide range of scientific areas and a commitment to involvement by stakeholders. Such research leads to findings that will deepen knowledge about how social systems both persist and change and people’s multiple roles within those systems. Results can indicate pathways by which carbon emissions can be reduced and carbon sequestration increased.

Examples of this research perspective include studies of vulnerability (because dependence on systems embedded with carbon increases vulnerability), sociotechnical transitions (because low-carbon technologies can only come into use if people adopted them), social networks (because networks spread information and changes in, e.g., energy use and urban design), and social practices (because they are key to understanding how to achieve substantial and persistent emissions reductions).

Presentation Type: Plenary Talk
Cities, Carbon, and Emerging Interdisciplinary Challenges

Sara Hughes, University of Toronto, sara.hughes@utoronto.ca (Presenter)

Global and regional carbon monitoring efforts of the last 25 years have compellingly demonstrated that urban areas are key sites of carbon flux. While the details of distribution and attribution remain to be resolved, cities are where a majority of energy-related CO2 emissions arise. This is particularly the case in North America, where cities have the highest intensity of CO2 emissions of any global region. North American cities have also proven to be leaders and advocates for reducing CO2 emissions, setting ambitious targets and pioneering innovative strategies. This intersection of knowledge and innovation raises important research questions for social scientists, particularly related to the decision-making and governance processes that underpin local CO2 interventions. Research has made great strides in revealing the motivations of local decision makers, the evolution in approaches and, increasingly, the means by which city governments substantially shift CO2 emissions patterns. Recognizing the important role of cities in the carbon cycle also creates critical new interdisciplinary research opportunities and challenges. First, it heightens the imperative for collaborative work between natural and social scientists. To better understand the interdependent systems that underpin the patterns of urban CO2 emissions, natural and social scientists face two key challenges: evolving scales of analysis and contradictory mental models. Confronting these challenges requires institutional and individual commitments. Beyond these scientific challenges, understanding the intersection of people and carbon in cities, and communicating this understanding in a meaningful way, requires a commitment to engaging and co-creating with the residents of cities in the process of evaluating and managing urban carbon flows.

Presentation Type: Plenary Talk
Anthropogenic carbon emissions and stakeholder engagement in the Salt Lake City urban testbed

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The Salt Lake Valley metropolitan region in northern Utah is the locus for one of the longest running urban CO2 networks in the world. When enhanced with a) air quality observations; b) a novel, autonomous light rail-based observation system for measuring intra-urban gradients in atmospheric species; c) modeling efforts that include atmospheric simulations and high resolution emission inventories, the Salt Lake area provides a rich environment for studying anthropogenic emissions and for understanding the relationship between emissions and socioeconomic as well as land use patterns. This is especially true given the well-defined urban regions delineated by geographic features and the arid environment that reduces the influence from biological fluxes.

Furthermore, the Salt Lake area has proven to be a fruitful arena for engaging with stakeholders. The role of Salt Lake City as the political and economic hub of a state with a relatively modest population and accessible decision-makers further facilitates two-way dialogs and research between scientists and various stakeholders. Additionally, the seasonally poor air quality has generated considerable public interest in our work, providing an opportunity to discuss and investigate the co-benefits of policies aimed at reducing greenhouse gas emissions and improving air quality.

In this presentation, we highlight specific examples in which our work benefited from and contributed towards the interests of multiple stakeholders, including policymakers, air quality managers, municipal government, urban planners, industry, and the general public. Lessons that have emerged from these interactions will be discussed, along with potential difficulties that were encountered along the way.

Presentation Type: Plenary Talk
Socioecological Carbon Production in Managed Agricultural-Forest Landscapes

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Land use, land cover changes, and ecosystem-specific management practices are recognized for their roles in mediating the climatic effects on ecosystem structure and function. A major challenge is that our understanding and forecasting of ecosystem C fluxes cannot rely solely on conventional biophysical regulations from the local ecosystem to the global scale. A second challenge is to quantify the magnitude of the C fluxes from managed ecosystems and landscapes over the lifetime of the C cycle, and to deduct the various energy inputs during management. Our objective is to quantify the landscape-scale C footprint of both managed agricultural-forest landscapes and people, using the Kalamazoo watershed in southwestern Michigan as testbed. The mechanisms from both human activities and biophysical changes on ecosystem C dynamics at different temporal and spatial scales will be explored by modeling total net ecosystem C production (physical and social C fluxes), exploring the relationships through Bayesian SEM, and performing a spatially-explicit LCA on the total C production. Remote sensing technology, available geospatial data, records of management practices, survey of historical practices, a land surface model (CLM), in situ measurements of C fluxes will be used to achieve our objectives. Research tasks are: (1) model the long term dynamics of the physical C fluxes of the watershed and landscapes; (2) estimate the social C fluxes for the same time period; and (3) diagnose the mechanisms from land use, land cover changes, management practices, climatic change, and climatic extremes on the total CO2eq fluxes at the two spatial and temporal scales through LCA. The physical C will be quantified through the CLM after ecosystem-specific parameterization and independent validation.

Presentation Type: Poster
If a tree falls in a forest, does anyone care: Integrating the immediate effects of forest management activity on the carbon cycle

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The magnitude and fate of the terrestrial carbon cycle sink is sensitive to both climate variability but also to how humans manage these forests. The vast majority of forests in the world are managed by humans for timber, recreation, wildlife management, and other activities. In the upper Midwest, selective thinning and clearing of northern Hardwood forests are activities conducted by multiple landowners. However, the impact of these activities on the carbon cycle have mostly been documented from continental scale synthesis studies (e.g., Amiro et al., 2010) or from remote sensing or modeling perspectives (Becknell et al., 2015). Here, we assess direct eddy covariance based observations of stand-scale carbon fluxes and their drivers in two Northern Wisconsin experiments. In the first, a long-run mature hardwood Ameriflux site (USMWCr) was thinned in 2013 and 2014 as part of a commercial harvest. We found a 30% reduction in overstory cover reduced gross primary productivity by a similar amount but significantly increased ecosystem respiration and hint at increased temperature sensitivity, as more litter and light reached the forest floor. As a result, the forest quickly switched from a large sink to carbon neutral, unlike our control-tower, the nearby unmanaged old-growth Ameriflux site (USM Syv). In a related study, the U.S. Forest Service established a tripod eddy covariance system (Nose Lake) after clear-cut of a aspen forest. Initial analysis on the 3.5-year long dataset points towards a cumulative carbon uptake occurring during the growing season, as well as some notably large fluxes for a region with minimal vegetation. Significant positive carbon emissions in the growing season were not observed and rather the site rapidly became a sink of carbon reflecting the typical pattern of rapid succession in these systems. Results from these towers have been submitted to Ameriflux for additional syntheses and provides observational evidence for theories and models of forest management on the carbon cycle, currently being implemented and tested in the Ecosystem Demography 2 model using a management functional type approach. Findings support the idea that carbon cycle models need to be pay as much attention to forest management as to climate sensitivity.

**Presentation Type:** Poster
Being sensitive to harvested wood stocks

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Sequestration of carbon in forests is a process that can pull large quantities of carbon out of the atmosphere or prevent its release to the atmosphere, accounting for 87% of total U.S. CO2 removals from the atmosphere in 2014. Carbon mitigation efforts have thus focused much attention on reforestation, forest management, and forest based products. According to the most recent U.S. report to the UNFCCC, an estimated 18.7% of the total carbon in woody materials is contained in harvested wood (HWP and SWDS). The amount of carbon in HWP and SWDS depends on how much wood is harvested, what types of products are produced, how the products are used, the lifetime of the wood products, and how the wood is processed at the end of its primary product lifetime.

In this paper, we investigate the sensitivity of the estimated amount of carbon in wood products to the models, parameters and values used in the analysis. We use this analysis to suggest where additional study might best be used to reduce uncertainties and to improve estimates. We also demonstrate the potential for using those sensitivities to manage the stock of carbon in harvested wood and the total stock of carbon in woody materials.

Presentation Type: Poster
The Global Methane Budget: a multi-sectoral framework for integrating sources and sinks from bottom-up and top-down methodologies

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After a brief period of stabilization in the atmospheric growth rate of methane from 2000-2006, methane concentrations have sharply begun to increase once more. Between 2014 and 2015, atmospheric methane concentrations rose by roughly 10 ppb, equal to 28 Tg CH4 per year, reaching an annual average concentration of 1834 ppb in 2015. The recent evolution of atmospheric methane is now approaching the most fossil fuel intensive Representative Concentration Pathway (RCP 8.5), but the drivers of the increase remain poorly understood. Coordinated by the Global Carbon Project, the Global Methane Budget seeks to quantify the sources and sinks of methane from biogenic, thermogenic, and pyrogenic activities, and from methane oxidation mainly by the hydroxyl radical. Over 80 scientists from 15 countries contributed to the first report, published in 2016 and covering the years 2002-2012. The Global Methane Budget aligns with several of the US Global Change Research Program (USGCRP) FY17 and FY18 to focus on methane cycling within the carbon cycle framework. The budget includes data from atmospheric observations of methane concentrations, multi-sectoral inventories, and from process-based biogeochemical models and atmospheric inversions. Total emissions are estimated at 559 [540-568] Tg CH4 per year, with tropical sources (both natural and anthropogenic) representing two-thirds of total global emissions. The largest sources of uncertainty stem from biogenic emissions, in particular from wetlands, which contribute about one-third of the global total. The budget is intended to provide engagement with a diverse group of stakeholders, including those identified by USGCRP, as well as to highlight key research gaps. Future budgets will be released on a two year cycle, aiming to increase the diversity of methodologies to include isotopic constraints and observations from remote sensing missions, and to reduce uncertainties within and across sectors.

Presentation Type:  Plenary Talk
Temporal Variability in Methane Enhancements during 2012-2016 as Observed in the Indianapolis Flux Experiment

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As natural gas extraction and use continue to increase, the need to quantify emissions of methane, a powerful greenhouse gas (GHG), has grown. Large discrepancies in Indianapolis methane emissions are observed when comparing inventory, aircraft mass-balance, and tower inverse methane emissions estimates. The variability in anthropogenic emissions over time has been suggested as a cause for discrepancies between inventory and atmospheric assessments of emissions. The Indianapolis Flux Experiment (INFLUX) includes 9 towers currently hosting continuous, highly calibrated methane mole fraction measurements. This work examines the temporal variability in 2012-2016 methane data from the INFLUX network. Based on the wind direction, towers are classified as downwind or upwind and upwind towers are used as background. Major sources are identified from the observed downwind and upwind methane differences as a function of wind direction and compared to known point sources. We search for sources, both major point sources and diffuse sources, that are not accounted for in existing inventories. We also identify sources that may contaminate our regional background data, and evidence for temporal variability in emissions from any urban sources. Results indicate that methane enhancements in Indianapolis are not constant from one year to the next. Work continues to quantify the implications for total emissions and temporal variability in emissions.

Presentation Type: Poster
Leaks in natural gas infrastructure release CH$_4$, a potent greenhouse gas, into the atmosphere. The estimated emission rate associated with the production and transportation of natural gas is uncertain, hindering our understanding of the energy’s greenhouse footprint. This study presents two applications of inverse methodology for estimating regional emission rates from natural gas production and gathering facilities in northeastern Pennsylvania. First, we used the WRF-Chem mesoscale model at 3km resolution to simulate CH$_4$ enhancements and compared them to observations obtained from a three-week flight campaign in May 2015 over the Marcellus shale region. Methane emission rates were adjusted to minimize the errors between aircraft observations and the model-simulated concentrations for each flight. Second, we present the first tower-based high resolution atmospheric inversion of CH$_4$ emission rates from unconventional natural gas production activities. A year of continuous CH$_4$ and calibrated δ$^{13}$C isotope measurements were collected at four tower locations in northeastern Pennsylvania. The adjoint model used here combines a backward-in-time Lagrangian Particle Dispersion Model coupled with the WRF-Chem model at the same resolution. The prior for both optimization systems was compiled for major sources of CH$_4$ within the Mid-Atlantic states, accounting for emissions from natural gas sources as well as emissions related to farming, waste management, coal, and other sources. Optimized natural gas emission rates are found to be 0.36% of total gas production, with a 2σ confidence interval between 0.27-0.45% of production. We present the results from the tower inversion over one year at 3km resolution providing additional information on spatial and temporal variability of emission rates from production and gathering facilities within the natural gas industry in comparison to flux estimates from the aircraft campaign.

**Presentation Type:** Poster
Utilizing patch and site level greenhouse-gas concentration measurements in tandem with the prognostic model, ecosys

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Wetlands are the largest source of global methane (CH4) emissions but can also act as important carbon dioxide (CO2) sinks, creating large uncertainties in wetland greenhouse gas (GHG) budgets. A contributing factor to the challenge of GHG budgets in wetlands is that wetlands have intrinsic temporally and spatially heterogeneous land cover patterns and complex dynamics of CH4 production, oxidation, and emissions. These issues pose challenges to both measuring and modeling GHG budgets from wetlands. To better understand the generation and transport pathways of methane in wetlands we developed new observational approaches and are combining multiscale measurements with the prognostic model ecosys.

At the local scale, porewater samplers (peepers) measurements provide an undisturbed continuous observation of dissolved gasses in the porewater along a vertical gradient. Non-steady state chambers and a flux tower provided both patch- and integrated site-level fluxes of CO2 and CH4. New Typha chambers enclose entire plants and segregate the plant fluxes from soil/water fluxes. We expect ecosys to predict the seasonal and diurnal fluxes of CH4 from within each land cover type and to resolve where CH4 is generated within the soil column and its transmission mechanisms.

We found that, surprisingly, a considerable portion of methane production occurs in the aerobic region of the soil. We observed large differences in fluxes, concentration profiles and dynamics between patch types. We demonstrate the need for detailed information at both the patch and site level when using models to predict whole wetland ecosystem-scale GHG budgets.

Presentation Type: Poster
CH4 fluxes and driver dynamics

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Methane (CH4) is one of the most important greenhouse gases, second only to CO2. Since the advancement in CH4 eddy covariance flux measurements in the 1990s, monitoring of CH4 emissions is becoming more widespread. New sites are initiated each year covering a wide range of ecosystems. These valuable data are not only important for annual carbon budget calculations but also vital to the modelling community in improving their predictions on emission rates and trends.

CH4 flux measurements are not as straight forward as CO2 measurements where drivers are known, or as predictable or as easily interpretable as CO2 fluxes. Understanding their emission patterns are often still challenging. Contributing to these challenges is the limited number of ancillary measurements carried out at many sites and the lack of standardized data processing, QA/QC and gap-filling procedures. As CH4 flux fluctuations are spatially (ecosystem and latitudinal) and temporal very diverse, in many cases event based, a better understanding or interpretation of results is required. An improvement in understanding does also increase the reliability of models, predictions and gap-filling methods as annual greenhouse gas budgets rely on high quality data.

There is a high demand on simple models where relationships between CH4 and the often limited number of ancillary meteorological data can be established. These simple models should be flexible and applicable to any ecosystem, site or data time series length and have the capability to be used for prediction and explanatory analysis. That said model input variables should be as independent as possible (avoiding cross-correlation), avoiding redundant inputs as models should follow the principle of parsimony of being simple but not too simple.

Presentation Type:  Poster
Spruce and Peatland Responses Under Climatic and Environmental Change experiment (SPRUCE) is an in situ warming by elevated CO2 manipulation located in a high-carbon, Picea/Larix/Sphagnum ombrotrophic peatland located in northern Minnesota, USA. Methods for ecosystem warming at large plot scales (12-m diameter) are being used. We combined aboveground enclosure walls with an internally recirculating warm air envelope with soil deep heating to simulate a broad range of future warming treatments of as much as +9 °C. Deep belowground warming was initiated in June 2014 followed by air warming in August 2015. In June 2016 elevated CO2 atmospheres (around 900 ppm) were added to half the warming treatments in a regression design. Pretreatment characterization of the peatland with a mean peat depth of ~3 meters indicated belowground carbon stocks to be >2450 MgC ha⁻¹; an amount 15× greater than the combined above- and belowground C stocks for typical deciduous forests of the eastern US. This stored C has accumulated under saturated, cool to cold conditions since the last glaciers receded some 10,000 years ago. SPRUCE strives to evaluate if this peatland C will be rapidly released in the form of greenhouse gases under unprecedented warming. Post-treatment net surface C flux estimates in the form of CO2 or CH4 are correlated with both deep and shallow warming. The net C flux from the peatland is clearly correlated with whole-ecosystem warming. After a lag period of several months, elevated CO2 treatments also show enhanced net CO2 emissions with limited response for CH4 emissions in the first full year of treatments. The ¹⁴C-signatures of dissolved organic carbon (DOC) and evolved gases suggest C substrate origins reflect recent rather than ancient C sources, and indicate that active microbial respiration at depth is fueled by surface inputs of DOC. Carbon budgets for belowground processes and vegetation NPP contributions to the peatland are being contrasted as a measure of the resilience or sensitivity of the peatland C cycle under warming and elevated CO2 environments.

Presentation Type: Poster
Estimating Methane Emissions of Indianapolis using an Array of Compact Total-Column Spectrometers.

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The development of a compact version of the solar-tracking, total-column, Fourier transform infrared (FTIR) spectrometer has made possible new methods of estimating methane emissions from local and regional sources. Total-column methane measurements are valuable because they observe an integrated profile of concentrations, and are sensitive to variations in CH$_4$ both inside and outside of the boundary layer. In situ sensors are much more sensitive to vertical mixing and the height of the boundary layer. Transport models have uncertainties associated with these parameters, which can make computing emission fluxes from in situ measurements difficult. The portability of the latest generation of FTIR spectrometers makes it possible to quickly deploy multiple sensors across regions. Unlike tower sensors, no infrastructure is needed to deploy these spectrometers, so measurement sites can be optimized based on wind patterns and source distribution. Over the course of a two-week field campaign in the Spring of 2016, five FTIR spectrometers spaced throughout the city of Indianapolis, IN recorded five days of total-column CO$_2$ and CH$_4$ measurements. Differences between measurements at upwind and downwind sites show enhancements proportional to emission rates, and inversely proportional to wind speeds. Distinctive signals from strong point sources (such as landfills) and diffuse sources are observed. A Bayesian inversion framework has been developed to estimate spatially resolved methane emissions throughout the city from these column measurements. Results have been compared to emissions inventories development by the INFLUX project, which uses a similar method but with a network of tower-based in situ sensors. Similar field campaigns have been conducted in Boston, MA and the San Francisco Bay Area, with plans to make measurements in other cities in the future. The findings of these studies will be used to optimize a new flexible and cost-effective method of accurately monitoring emissions from urban areas.

Presentation Type: Poster
Wetlands as a Source of Atmospheric Methane: A Multiscale and Multidisciplinary Approach at SPRUCE

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Boreal peatlands contain large amounts of old carbon, protected by anaerobic and cold conditions. Climate change could result in favorable conditions for the microbial decomposition and release of this old peat carbon as CH4 or CO2 back into the atmosphere. Our goal was to test the potential for this positive biological feedback to climate change at SPRUCE (Spruce and Peatland Response Under Climatic and Environmental Change), a manipulation experiment funded by DOE and occurring in a forested bog in Minnesota. From 14C measurements of surface emitted CH4 and CO2, we found that CH4 emissions from the peat surface were on average about a decade older than CO2 emissions, and both CH4 and CO2 were dominated by recently fixed photosynthates, not older peat-derived carbon, even after short-term experimental warming increased CH4 release to the atmosphere. Hydrologic tracers measured in peat porewater profiles indicated little potential for large, episodic release of CH4 via ebullition, but also showed that subsurface hydrologic transport was surprisingly rapid at SPRUCE, likely supplying microbes with young dissolved organic carbon (DOC) and dissolved nutrients throughout the peat profile. We also identified which microbes consume CH4 at SPRUCE and found that the most active of these also fix N2. These results reflect important interactions between hydrology and biogeochemistry present at the bog and are highly relevant to interpreting experimental results, modeling the wetland response to experimental treatments, and extrapolating these findings to other boreal peatland systems.

Keywords: peatland, warming, carbon cycle, hydrology, microbiology, isotopic tracers

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Presentation Type: Poster
Calibration and Field Testing of Cavity Ring-Down Laser Spectrometers Measuring Methane Mole Fraction and the Isotopic Ratio of Methane, Deployed on Towers in the Marcellus Shale Region

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Four in-situ cavity ring-down spectrometers measuring methane, carbon dioxide and the isotopic ratio of methane were deployed at towers with heights between 46 and 61 m AGL. The study is focused on the Marcellus Shale natural gas extraction region of Pennsylvania. Two towers (East and Central) are predominantly downwind of the study region, whereas the South tower is predominantly upwind. The North tower is located in New York State, which does not allow horizontal fracking of natural gas. We describe laboratory and field calibration of the analyzers for tower-based applications, and characterize their performance in the field for the period January – November 2016. Prior to deployment, each analyzer was calibrated using high mole fraction bottles with various isotopic ratios from biogenic to thermogenic source values, diluted in zero air. Furthermore, at each tower location, three field calibration tanks are employed, from ambient to high mole fractions, with various isotopic ratios. By testing various calibration schemes, we determine an optimized field calibration method. Flask to in-situ comparisons indicate that the 11-month average bias for the isotopic ratio of methane is $-0.04\‰$ at the East tower and $0.03\‰$ at the South tower. Allan deviation results show, however, that laboratory and field calibrations and round-robin testing (at ambient levels of methane) should employ sampling times of $\sim 64$ min, in order to minimize random errors and thus optimize short-term (e.g., daily) results. The largest inter-site differences, averaged over the 11-month study period, occur between the South and East towers. The midday differences between these two towers are between $-28$ and $47$ ppb CH$_4$ and between $-0.56$ and $+0.62$‰ on 68% of days. These differences in methane and the isotopic ratio of methane in the Marcellus Shale region, while small, are detectable given the instrument compatibility demonstrated in this study.

Presentation Type: Poster
Methane Emissions from the Southwestern Marcellus Shale Based on Airborne Measurements

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Natural gas production in the United States has increased rapidly over the past decade, along with concerns about methane (CH4) leakage (total fugitive emissions) into the atmosphere and its climate impact. Quantification of CH4 emissions from oil and natural gas (O&NG) operations is important for establishing scientifically sound and cost-effective policies for mitigating greenhouse gases. We use aircraft measurements and a mass balance approach for three flight experiments on three days in August and September 2015 to estimate CH4 emissions from O&NG operations in the southwestern Marcellus Shale region. The mean CH4 emission is estimated to be 39.9±3.4 kg CH4 s−1 (or 1.26±0.11 Tg CH4 yr−1, mean±1σ). A substantial source of CH4 was found to contain little ethane (C2H6), likely due to coalbed CH4 emitted either directly from coal mines or from wells drilled through coalbed layers. Of the total CH4 emission rate, 24.7±3.4 kg CH4 s−1 (or 0.78±0.11 Tg CH4 yr−1) is estimated to be emitted by O&NG operations. We estimate the average CH4 leak rate from O&NG operations as 4.5±0.7% (3.8-5.2%). This leak rate is broadly consistent with the results from several recent top-down studies, but higher than the results from a few other observational studies as well as the leak rate specified in the US EPA CH4 emission inventory. Our leak rate suggests that for a 20-year time scale, energy derived from the combustion of natural gas extracted with current technologies from this region exerts a climate penalty compared to energy derived from coal.

Presentation Type: Poster
Data-constrained projections of methane fluxes in Northern Minnesota Peatland in response to elevated CO2 and warming

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Methane (CH\textsubscript{4}) is the simplest hydrocarbon produced by anaerobic microbes in ecosystems. The concentration of atmospheric CH\textsubscript{4} has increased by 150% since the start of the industrial age, nearly four times of the increase in CO\textsubscript{2}. CH\textsubscript{4} has 25 times the global warming potential of carbon dioxide (CO\textsubscript{2}) over a 100-year scale, and it is directly responsible for approximately 20% of global warming since pre-industrial. Wetlands are the single largest natural source, there is major concern about potential feedbacks between global climate change and CH\textsubscript{4} emissions from wetlands, as warming and atmospheric CO\textsubscript{2} are known to affect CH\textsubscript{4} emissions. Large uncertainties exist in predicting responses of methane fluxes to future climate change. The uncertainties in model predictions come from model structure, parameter values, and forcing data. In methane models, many parameters are given to an empirical value according to outdated measurements or models. It would be feasible to measure in the field if models could tell which parameter is more important for estimation of methane emission, and project a constrained value for key parameters. These feedbacks from field measurements could, in turn, testify the accuracy of the model for methane emission, as well as the optimization of model structures. We incorporated methane module to an existing process-based Terrestrial ECOsystem model (TECO-SPRUCE) to simulate methane emission in a boreal peatland forest in northern Minnesota. Key parameters were constrained using data assimilation techniques. Our results show that data assimilation could reduce forecasting uncertainties in methane emission.

**Presentation Type:** Poster
Session: Critical Regions as Global Carbon Hotspots
Northern High Latitude Carbon Dynamics

Charles Miller, NASA JPL, charles.e.miller@jpl.nasa.gov (Presenter)

North American high latitude (NHL) carbon dynamics are undergoing profound transformation. The NHL carbon dioxide (CO2) seasonal cycle has increased dramatically over the last 50 years; however, we lack a quantitative explanation of the amplitude trends and the mechanisms driving this transformation are not fully understood. Similarly, contemporary NHL carbon balance, its recent history, and its future trajectory are uncertain.

It is imperative that we significantly improve our understanding and future projections of NHL carbon dynamics due to the potential for the permafrost carbon feedback to mobilize 100 PgC or more into the Earth system over the 21st Century.

This synthesis presentation will reconcile recent results and highlight research priorities required to address three key questions:

• What state variables and processes characterize the fundamental transformation occurring in NHL carbon dynamics?

• What is the future trajectory of NHL carbon balance?

• What signals correspond to a threshold for large-scale permafrost carbon feedback and how might such a threshold be detected?

Presentation Type: Plenary Talk
The Arctic Winter Paradigm

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The Arctic Boreal Region (ARB) is by all accounts a global carbon hot spot with rapidly changing temperatures, sea ice extent and length of summer seasons that have lead to some surprising changes in the imprint that the Arctic has on atmospheric CO2 and CH4. Our study takes advantage of the recently completed the NASA CARVE EV-1 suborbital mission as well as the long term NOAA ground and aircraft-based measurements of atmospheric CO2 and CH4 which show that fall and early wintertime emissions are a dominant part of the seasonal emissions observed in the Arctic. While CO2 emissions do appear to be increasing over the last 40 years CH4 emissions are not increasing suggesting that the anaerobic pathway degradation of organic carbon is not dominant. This finding provides an important driver for the large changes in amplitude of the CO2 seasonal cycle, which is most pronounced over the Arctic, that has been observed but largely unexplained except through models which may be completely missing importance of wintertime emissions.

Presentation Type: Plenary Talk
Improved observation of belowground carbon cycling and net ecosystem exchange in natural and managed forested wetlands in the U.S. Southeast

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The world currently loses thousands of hectares of low-lying coastal wetlands every year, attributed mainly to a recent acceleration of sea-level rise (SLR). Loss of coastal wetlands threatens critical services these ecosystems provide. Coastal states and counties need to start planning and implementing adaptation and mitigation strategies now in order to decrease future costs of adjusting to climate change and SLR, and to protect vulnerable stocks of sequestered carbon (C) and limit methane (CH4) emissions. Unfortunately, precise information on how natural and managed coastal ecosystems will change in the coming decades is lacking, and monitoring of such sites is very low. Enhanced observation platforms and predictive models and scaling tools are critically needed. The objectives of the proposed project are threefold: 1) leverage previous Federal investments to sustain eddy covariance flux-tower based long-term "climate change observatory" experiments in southern forested wetlands; 2) perform a detailed study at the wetlands to determine mechanisms controlling belowground C cycling, particularly the interaction of CO2 and CH4 production with environmental driving variables; and 3) utilize the data to improve parameterization of state-of-the-art ecosystem/hydrologic models specific to forested wetlands and their linkage to larger scale models such as the Community Land Model (CLM). Our working hypothesis is that as the hydrology is forced towards wetter conditions (poorer drainage) due to SLR, emissions of CH4 will increase relative to CO2, increasing the greenhouse forcing of the system. In addition, we expect to see greater dissolved C fluxes. The project will be conducted in collaboration with the USFWS at a natural forested wetland at the Alligator River National Wildlife Refuge in Dare County, NC, and in collaboration with Weyerhaeuser NR Company in industrially managed pine plantations.

Presentation Type: Plenary Talk
Gulf of Mexico Basin Carbon flow from riverine to shelf through Blue Carbon estuaries

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The Gulf of Mexico (GOM) synthesis quantifies new Mexican mangrove and GOM seagrass investigations to complete this tropical/subtropical basin carbon budget. Mangroves are dominant GOM Corg burying 225-386 MgCorgm-2y-1, removing from atmosphere 1000 gCorgm-2y-1, supplying 25% to the shelf, while burying 22%. Mexican mangroves’ sedimentary carbon stock were higher than the Everglades and up to 3500 y old. Methods include measurements of Corg sediment/water, flux towers, isotopic flux, use of restoration sites indicating pollution effects plus Corg loss, and extent results from remote/field data. Our extent integration demonstrates GOM mangrove extent (USA=255,100ha, Mexico=283,146ha, GOM total =538,246ha) and mangrove carbon stock from 217Tg Corg to 806Tg. Seagrass extent was substantial throughout 947,300ha USA GOM and 25000ha in Mexico, with a “customized” Corg stock (20 cm depth) of 37.6Tg. GOM marshes (USA marsh 432, 600ha with burial of 96.8TgCorg) occurring chiefly in far northwest. The GOM blue-carbon habitat relations were unlike the Atlantic Seaboard: 1.) The dominance changes from Atlantic to GOM where mangroves show greater sequestration of carbon. The Atlantic has dominant marsh extents (994,500ha) with a lesser total stock of 97.2TgCorg than GOM. 2.) The subdominance changes in GOM to seagrass & northern marshes from Atlantic (only seagrasses). The Atlantic seagrass extent (401,900ha with 43.1TgCorg stock) is 40% of Atlantic marshes’ carbon extent. GOM seagrasses show a burial stock of 37.6TgCorg in 20 cm depth (estimated as 180TgCorg in 1 m burial. 3.) GOM stores more total carbon. The total Atlantic Seaboard carbon estuarine stock was total 142.5 TgCorg wherein the GOM was 347.8TgCorg. 4.) The Atlantic seaboard shelf carbon budget estimate (Najjar and Herrmann) is 18.8TgCorg m-2y-1 or 26.7TgCorg y-1 with input from rivers 3.7 TOC and 3.6 DIC TgCorg y-1, the estuarine burial 0.5TgCorg y-1, the estuarine outgassing 4.8TgCorgy-1, the flow to shelf area from estuary about 25% (with about 15% into the open ocean)

Presentation Type:  Plenary Talk
Carbon hotspots of the deep: Ocean acidification and hypoxia in coastal and estuarine waters of the North American Pacific coast and their ecological impacts

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Ocean acidification and hypoxia are significant carbon cycle problems in coastal waters along the North American Pacific coast. Upwelling throughout the California Current System exposes the continental shelf to dense, nutrient- and CO2-rich, but oxygen-poor water. It also provides the marine source water that fills the deep basins of Puget Sound, a deep glacial estuarine complex characterized by high variability and areas of restricted circulation. Throughout summer, upwelling and river inputs drive intense primary production in surface waters, which in turn drives deep-water remineralization of organic matter. This process exacerbates the low-oxygen, corrosive conditions on the shelf and in Puget Sound.

Through ship-based sampling and moored time-series, we have observed the dynamic carbon cycle in coastal and estuarine waters of the California Current System since 2006. While survey cruises provide snapshots of water-column conditions and moored sensors provide high-resolution measurements of surface conditions, there are significant observational gaps in the deep environments where the most corrosive, hypoxic conditions develop and where important benthic and demersal marine communities dwell.

Using empirical relationships for carbonate chemistry from proxy data within the California Current System and Puget Sound based on calibration data sets from research cruises, we reconstructed carbonate chemistry from near-bottom time-series of temperature, salinity, and oxygen collected throughout the Olympic Coast National Marine Sanctuary, Admiralty Inlet (sill at entrance to Puget Sound), and ORCA moorings in Puget Sound. We then compare the frequency and duration of hypoxic and reconstructed corrosive events in environments of the northern California Current System and Puget Sound. Here we will show the seasonal progression of corrosive, hypoxic conditions on the Washington shelf and in Puget Sound, highlighting differences in extent, intensity, and duration of these seasonal conditions. Further, we underscore linkages among these carbon cycle phenomena, other stressors (e.g., ocean warming or marine heat waves), and broad ecosystem impacts.

Presentation Type: Poster
High-latitude ecosystems have the potential to release large amounts of carbon dioxide (CO2) to the atmosphere in response to increasing temperatures, representing a potentially significant positive feedback within the climate system. Here, we combine satellite, airborne and tower CO2 observations to derive temporally and spatially resolved year-round CO2 fluxes across Alaska from 2012-2014. We find that tundra ecosystems are a net source of CO2 to the atmosphere annually, with high rates of respiration during early winter (September - December). Many Earth System Models cannot accurately simulate these Alaskan carbon fluxes in 2012-2014, leading the models to underestimate carbon losses from the Arctic in scenarios of future climate change.

Presentation Type: Poster
A Pan-Arctic Synthesis of Cold Season Carbon Emissions

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Over the past several decades, surface air temperatures in the Arctic have increased at approximately twice the global rate, and climate models project that this rate of warming will continue through the century, with the greatest warming occurring during the winter months. Carbon emissions during the cold season (i.e., fall, winter and spring) are an important component of annual respiratory loss, yet there are large uncertainties in local and regional estimates of cold season carbon emissions. To address these uncertainties, we conducted a pan-Arctic synthesis of cold season CO2 emissions from northern high latitude terrestrial ecosystems. We compiled data from more than 70 studies from sites located throughout the permafrost region and examined differences in cold season respiration among permafrost zones, biomes, and ecosystem types. In 2016, we established ten automated winter respiration monitoring sites across Alaska; preliminary results from those measurements will also be presented.

The synthesis results showed that cold season CO2 emissions were positively related to mean annual air temperature, growing season precipitation, and Enhanced Vegetation Index (EVI). There were significant differences in CO2 emissions among permafrost zones: CO2 emissions were greatest in the sporadic zone compared to discontinuous and continuous zones, and were significantly lower in the continuous permafrost zone. Summarized results of experimental studies showed that cold season CO2 emissions were significantly higher when soils were warmed and lower when vegetation was removed, demonstrating the sensitivity of carbon release to both rising temperatures and changes in vegetation cover in northern high latitudes. These results highlight the importance of including cold season respiration in current and future carbon estimates for the northern region, and suggest that as winter temperatures increase across the Arctic, cold season CO2 emissions may offset potential increases in plant productivity.

**Presentation Type:** Poster
Measurements and modeling of carbon turnover rates in tropical forest soils

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Tropical forests account for over half of the global terrestrial carbon sink and 29% of global soil carbon. An understanding of how carbon dynamics in this system will respond to climate change is uncertain, and the lack of large data sets to extrapolate from field experiments to land surface models is limiting. We intensively sampled three forest and two soil types in the Luquillo Experimental Forest, Puerto Rico to quantify the age and carbon content in eleven pits across the forest. This dataset is compared to soils from AmeriFlux tropical forest sites in Brazil and Costa Rica to determine if carbon storage patterns are consistent across the broader Neotropical region.

We found that the Delta 14C values measured in Puerto Rico at depths below 1 meter are widely distributed, ranging from -100 to -800 per mil. This is unlike the other four tropical forest soils currently available (from Brazil and Costa Rica), which in comparison, only range from -200 to -500 per mil at similar depths. Radiocarbon ages and carbon stocks are being used to generate robust estimates of carbon turnover times using SoilR, a model for carbon transit times. Our measured data is compared to model generated data from the Community Land Model (CLM) and Accelerated Climate Model for Energy’s land surface model (ALM).

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Keywords: Radiocarbon, carbon cycle, soil carbon, tropical forest, model-data comparison, synthesis

Presentation Type: Poster
Variation in salt marsh CO2 fluxes across a latitudinal gradient along the US Atlantic coast

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Salt marshes occur at the dynamic interface of land and ocean, where they play an important role as sink and source of carbon (C) and sediment. They continuously accumulate soil organic matter and sediment to keep their position relative to sea level. Decadal average C sequestration rates can be inferred from soil carbon density and mass accumulation rates, but cannot provide detailed information about biological and climatic controls on C cycling in these systems.

In this study, we report field measurements from salt marshes along the US Atlantic coast made at three coastal Long-Term Ecological Research (LTER) sites in Massachusetts (PIE), Virginia (VCR) and Georgia (GCE). Here, we focus on atmospheric measurements of carbon dioxide (CO2) exchange between marshes and the atmosphere that have been made for several years in areas dominated by the grass Spartina alterniflora. To constrain lateral fluxes, atmospheric flux rates will be compared to soil accumulation rates estimated from sediment cores and/or surface elevation tables. At the northernmost LTER, measurements over four years (2013-2016) indicate the marsh to be a substantial C sink of varying magnitude depending on soil salinity levels during the growing season. Overall, the atmospheric measurements indicate a larger C sequestration potential (-155gCm^-2a^-1) than derived from dated sediment cores (130gCm^-2a^-1). Net CO2 exchange at the Virginia and Georgia LTER tends to be larger than at PIE (VCR: -200-250gCm^-2 a^-1, GCE: 311gCm^-2a^-1). At the Georgia LTER, it is an order of magnitude larger than published estimates for soil C sequestration rates. This suggests that tidal loss of C is larger in the southern marshes than at PIE. We will discuss possible factors, e.g. higher soil temperatures and a longer growing season in the southern marshes or different flooding frequency and duration at the sites.

Presentation Type: Poster
Analyzing ecosystem- and plot-scale CO\textsubscript{2} exchange in a heterogeneous New England salt marsh

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With accelerating sea-level rise, salt marshes in the North-East are expected to show an increase in flooding frequency and vegetation shifts from *Spartina patens* to *Spartina alterniflora* as the marsh transitions to a lower elevation relative to sea-level. At the Plum Island Ecosystems LTER, we have set up paired eddy covariance towers in 2015 to study the CO\textsubscript{2} exchange of high- and low-elevation marsh. This set up allows us to study carbon cycling processes of the currently dominant ecosystem (*S. patens*) as well as its likely future state (*S. alterniflora*). We observed that measured ecosystem-scale CO\textsubscript{2} fluxes are in the same order of magnitude for both sites. However, the dominant marsh vegetation, the overall marsh-water ratio and the flooding frequency differ between sites: The low marsh has a lower marsh:water ratio and is flooded more frequently than the high marsh. We hypothesize that net carbon uptake is higher at the low marsh site because *S. alterniflora* has a larger leaf area than *S. patens* and that the ecosystem-scale measurements underestimate the ‘true’ marsh vegetation uptake. To analyze this, we have started plot-scale measurements of CO\textsubscript{2} exchange along vegetation transects at both sites in 2016. Preliminary plot-scale measurements indicate that production in *S. alterniflora* marshes exceeds production in *S. patens* marshes, and that marsh flooding markedly alters C exchange dynamics. We will combine biomass and elevation data with a footprint model to assess the marsh and water fractions in each eddy tower footprint. We will use this information to up-scale plot measurements of CO\textsubscript{2} exchange to the ecosystem-scale and compare this to the eddy covariance measurements. In the future, these measurements will be compared to long-term C burial rates and measurements of tidal carbon exchange.

**Presentation Type:** Poster
Empirical estimates of ecological light-use efficiency of Great Plains grasslands derived from long-term flux tower measurements

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The development of dynamic models of carbon cycling and energy flow requires measurement-based data on ecosystem-scale light-use efficiency (LUE). Measurements at flux towers within the Ameriflux and Agriflux networks represent the unique source of such data. The Great Plains megaregion of North America is one of the critical global carbon hotspots where high carbon storage is under significant risk of human disturbance. The carbon cycle of this region is highly vulnerable to climate change and anthropogenic impacts and hence plays a key role in the North American and, ultimately, the global carbon budget. To characterize spatial and temporal dynamics of the ecological LUE (= Pg/Incoming PAR) of Great Plains grasslands, we used flux tower measurements at 8 shortgrass steppes (23 site-years), 16 mixed prairies (73 site-years), and 10 tallgrass prairies (37 site years) - covering areas from Alberta to Texas. Sub-hourly CO2 flux measurements were partitioned into gross photosynthesis (Pg) and ecosystem respiration and gap-filled using a nonrectangular hyperbolic light-soil temperature-VPD-response method. Resulting Pg values were used to calculate ecological LUE at the daily and weekly scales. The mean maximum daily LUE for shortgrass steppes was 16.2 mmol CO2/mol incoming quanta, with a standard deviation of 4.9 and a range of 6.8 to 28.7 mmol/mol. Mixed and tallgrass prairies corresponding LUE characteristics were 21.2 (9.1), 6.7 to 48.1 and 32.1 (7.6), 17.0 to 47.6 mmol/mol, respectively. To match the 7-day time-step of expedited Moderate Resolution Imaging Spectroradiometer (eMODIS) NDVI composites, corresponding weekly estimates of LUE and site-specific environmental drivers were calculated. Multivariate statistical analysis revealed significant spatial trends of ecological LUE across the Great Plains region and demonstrated significant relationships between LUE, NDVI and environmental drivers. Geographically specific time series of LUE contribute a valuable empirical basis for parameterization of predictive models of carbon cycling in Great Plains grassland ecosystems

Presentation Type: Poster
Modelling Microtopographic Effects on Ecosystem Productivity in an Arctic Polygonal Landscape

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Small differences of surface elevation in polygonal landforms widely found in coastal arctic landscapes cause large variation in soil water contents (□) and active layer depths (ALD) at small spatial scales due to topographically driven movement of water and snow. Spatial variation in □ and ALD may cause large spatial variation in biogeochemical processes, plant productivity, and hence in GHG exchange and carbon storage in these landforms. In this modelling study, we test hypotheses in ecosys for topographic controls on CO2 and CH4 exchange in different polygonal features (troughs, rims and centers) against measurements of □, ALD and CO2 and CH4 fluxes recorded in 2013 as part of the NGEE Arctic at Barrow, AK. We show that much of the large spatial variation in these measurements can be explained from vertical and lateral water movement driven by elevational differences among these features. Such small-scale variation of GHG exchange in arctic polygonal landforms needs to be represented in large-scale estimates of GHG exchange in coastal arctic landscapes. Model results with meteorological data from 1981 to 2014 indicate increasing ALD and CH4 emissions from polygonal landscapes at Barrow, AK since 2000, attributed mostly to recent rises in precipitation.

Presentation Type: Poster
Carbon dioxide and methane fluxes of thawing organic-rich boreal forest-wetland landscapes in northwestern Canada

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Boreal landscapes in the Taiga Plains ecozone, Canada, store about 15% of the organic carbon (C) stocks (<3 m) in the North American permafrost zone and play an important role in the North American C cycle. Permafrost thaw in boreal ice-rich lowlands in the southern Taiga Plains induces surface subsidence and expansion of permafrost-free wetlands at the expense of boreal forests underlain by permafrost. To better constrain the spatial extent of these land cover changes and their implications for C cycle processes, we combine nested eddy covariance CO2 and CH4 flux measurements from a thawing organic-rich boreal forest-wetland landscape with flux footprint modeling, remote sensing data, paleoecological records, and downscaled climate projections.

Thaw-induced forest loss in the Taiga Plains currently transforms the composition and structure of boreal landscapes and is of equal importance for tree cover dynamics as wildfire disturbance. The associated wetland expansion increases landscape CH4 emissions inducing a net biogeochemical climate warming impact. At the current wetland expansion rate of 0.26±0.05 % yr⁻¹, landscape CH4 emissions increase by 0.034±0.007 g CH4 m⁻² yr⁻¹. Typical rates of long-term net CO2 uptake (~50 - 150 g CO2 m⁻² yr⁻¹) in these landscapes are too small to neutralize the associated climate warming effect until the end of the 21st century.

The thawing landscape still acts as a net CO2 sink taking up 73±22 g CO2 m⁻² yr⁻¹ (2015-2016). Landscape-level net CO2 uptake does not change with wetland expansion as gross primary productivity (GPP) and ecosystem respiration (ER) changes are of similar magnitude. In contrast, direct impacts of projected increases in air temperatures and decreases in incoming shortwave radiation appear to be larger. For a high warming scenario (RCP8.5), modeled increases in ER outpace increases in GPP significantly. For a moderate warming scenario (RCP4.5), ER and GPP increase are of similar magnitude.

**Presentation Type:** Poster
Enhanced terrestrial carbon uptake: critical regions responding to changes in the atmosphere and climate

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In this presentation we will focus on using decadal changes in the global carbon cycle to better understand how ecosystems respond to changes in CO2 concentration, temperature, and water and nutrient availability. Using data from AmeriFlux/FLUXNET, global carbon budget estimates, ground, atmospheric and satellite observations, and multiple process-based global vegetation models, we examine the causes and consequences of long-term changes in the terrestrial carbon sink. We show that over the past century the sink has been greatly enhanced, largely due to the effect of elevated CO2 on photosynthesis dominating over warming induced increases in respiration. We also examine the relative roles of greening, water and nutrients, along with individual events such as El Nino. We show that a slowdown in the rate of warming over land since the start of the 21st century likely led to a large increase in the sink, and that this increase was sufficient to lead to a pause in the growth rate of atmospheric CO2. We also show that the recent El Nino resulted in the highest growth rate of atmospheric CO2 ever recorded. Our results provide evidence of the relative roles of CO2 fertilization and warming induced respiration in the global carbon cycle, along with an examination of the impact of climate extremes.

Presentation Type: Poster
Biophysical controls on ecosystem-scale CO2 exchange in a brackish tidal marsh in Northern California

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Carbon (C) cycling in coastal wetlands is difficult to measure and model due to extremely dynamic atmospheric (vertical) and hydrologic (lateral) fluxes, as well as sensitivities to dynamic land- and ocean-based drivers. To date, few studies have begun continuous measurements of vertical and/or lateral C exchanges in these systems and as such our understanding of the key drivers of carbon cycling in coastal wetlands including inundation, temperature, radiation, and salinity remain poorly understood. Increasing the number of direct measurements of vertical and lateral C fluxes is a critical first step to developing a better understanding of the drivers and sensitivities of C sequestration and greenhouse gas (GHG) mitigation potential of coastal wetlands. Here we present 2.5 years of near-continuous eddy covariance measurements of CO2 and CH4 fluxes from a brackish tidal marsh in Northern California. We use a combination of wavelet analysis and information theory to analyze the interactions between whole ecosystem CO2 flux and biophysical drivers.

CO2 fluxes showed significant interannual variability, with low net CO2 uptake in the first year of the study (67 g C m⁻² yr⁻¹; March 2014 – March 2015), and considerably higher uptake the following year (295 g C m⁻² yr⁻¹; March 2015 – March 2016). Conversely, annual CH4 fluxes were similar between years (1.2 and 1.3 g C m⁻² yr⁻¹ in the first and second year, respectively). With respect to the net atmospheric GHG budget (assuming a sustained GWP of 45), the wetland was a net GHG sink of 172 g CO2eq m⁻² yr⁻¹ in 2014 – 2015, and a sink of 1004 g CO2eq m⁻² yr⁻¹ in 2015 – 2016. Our results also showed that tides significantly influenced CO2 fluxes across multiple timescales; ecosystem respiration was approximately 25% lower during spring tides relative to neap tides, and flooding resulted in an overall increase in photosynthesis on the order of 9 to 27%. While there are several mechanisms that can potentially contribute to the suppression of respiration following flooding, our results suggest that tidal effects may largely be due to the suppression of CO2 efflux from the soil as the water creates a physical barrier to gas diffusion. If this is the case, it is critical to consider lateral fluxes as flooding may also coincide with increased dissolved inorganic carbon loss from the marsh. Further research on lateral C transport is key to investigating the influence of tides on the role of coastal wetlands as C sinks or sources.

Presentation Type: Poster
Applications of Remote Sensing for Characterizing Carbon Processes in Tidal Wetlands

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Wetlands play a key role in Earth’s carbon cycle. However, wetland carbon cycling exhibits a high level of spatiotemporal dynamism, and thus, is not as well understood as carbon cycling in other ecosystems. In order to accurately characterize wetland carbon cycling and fluxes, wetland vegetation phenology and seasonal/tidal inundation dynamics must be understood as these factors influence carbon generation and transport, respectively. Here, we use radar remote sensing to map wetland properties in the Chesapeake Bay, the largest estuary in the United States with more than 1,500 square miles of tidal wetlands, across a range of tidal amplitudes, salinity regimes, and soil organic matter content levels.

We have been using ESA Sentinel-1, ALOS PALSAR-1, and PALSAR-2 radar measurements to characterize vegetation and seasonal inundation dynamics with the future goal of characterizing salinity gradients and tidal regimes. Differences in radar backscatter from various surface targets has been shown to effectively discriminate between dry soil, wet soil, vegetated areas, and open water. Radar polarization differences and ratios are particularly effective at distinguishing between vegetated and non-vegetated areas. Utilizing these principles, we have been characterizing wetland vegetation species composition and hydroperiods using supervised classification techniques including: Random Forest, Maximum Likelihood, and Minimum Distance. The National Wetlands Inventory has been used as training and validation data. Ideally, the techniques we outline in this research will be applicable to the characterization of wetlands in coastal areas outside of Chesapeake Bay.

Presentation Type: Poster
Microtopography altered the fine root distribution and dynamics

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Hummock and hollow microtopography is a unique feature of many northern and southern wetlands but its effects on belowground carbon cycling are poorly understood. The biomass distribution and dynamics of fine roots in both hummocks and hollows are studied in a freshwater forested wetland of coastal North Carolina. Fine roots are classified into live absorptive (first and second order roots) and transport roots (third up to sixth order roots) and dead absorptive and transport roots. Total mass, biomass and necromass of both absorptive and transport roots are generally significantly higher in hummock sites than in hollow sites, and the biomass of absorptive roots showes the great extent of differences between the two types of the sites. The upper horizon (Oe and Oa horizon) has significantly higher fine root densitie than the lower horizon in both hummocks and hollows, but the difference is greater in hummocks than in hollows. The difference in root mass per unit soil volume between the two horizons is greater for the absorptive roots than for other types of roots. Different types of roots exhibits different peak and trough during the study period. These results show that the hummock and hollow microtopography significantly affect fine root biomass and necromass distribution and dynamics and different orders of fine roots have quite different responses to the change in microtopography.

Presentation Type: Poster
Permafrost regions, which contain a large amount of temperature-protected organic carbon (C), could be a significant C source as climate gets warmer. Climate warming can result in physical (e.g., temperature rise and permafrost thaw) and biological (e.g., microbial community composition) changes in the permafrost regions. While it is well agreed that physical changes can accelerate C releases to the atmosphere by increasing thermodynamic reaction rates and the accessibility of soil organic C (SOC) to decomposers, how biological changes impact permafrost soil C loss is still unclear. In this study, we quantified the impact of the biological changes on soil C loss in an Alaskan tundra through combining a process-based model and a unique field experiment. Our results showed that warming increased the efficiency of vegetation in using light. In addition, warming significantly decreased the baseline turnover rates of fast and slow SOC. Our results indicate warming accelerates SOC loss in Alaskan tundra. However, the biological responses to warming partially counterbalance the acceleration of SOC loss. This study suggests that the predicted C loss in the permafrost regions may be overestimated due to the absence of the biological changes in Earth system models.
Untangling the dominant controls on seasonal vegetation dynamics and carbon uptake in semi-arid ecosystems of the southwestern US

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Recent studies based on syntheses of satellite data and terrestrial biosphere model (TBM) simulations have suggested that semi-arid ecosystems play a dominant role in the interannual variability and long-term trend in the global carbon sink, largely due to the response of gross carbon uptake to moisture availability. This is a key scientific question as uncertainties remain in the strength and location of sources and sinks of carbon at global scale, as well as in projections of the terrestrial carbon sink under climate change. However, the TBMs used in these studies have often performed poorly in comparison to data in water-limited and/or stressed ecosystems and, furthermore, it is as yet unclear whether satellite-derived vegetation indices accurately capture the seasonal dynamics in semi-arid ecosystems.

We address this issue in this study by investigating the dominant controls on vegetation growth and productivity in these ecosystems at sub-annual timescales via an analysis of site-based eddy covariance observations of gross carbon uptake, phenological activity from high resolution digital cameras and satellite-derived measures of vegetation greenness and productivity. We aim to answer the following questions: i) is moisture availability solely a limit on carbon assimilation or does it also act as a phenological trigger for leaf onset/senescence?; ii) are there critical climate-related thresholds that must be exceeded for leaf growth that are consistent across bioclimatic regions?; and iii) can satellite data reproduce the seasonal dynamics of each vegetation type as observed on the ground?

The ultimate objective of this work is to use the knowledge gained from this analysis to evaluate two TBMs (ORCHIDEE and CLM) that are routinely used in global coupled earth system model simulations, with the aim of identifying if mechanistic processes related to phenology and water stress are adequately represented in the models in semi-arid ecosystems, or, if they require further improvement.

Presentation Type: Poster
Non-linear CO2 flux response to seven years of experimentally induced permafrost thaw

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Rapid Arctic warming is expected to increase global greenhouse gas concentrations as permafrost thaw exposes immense stores of frozen carbon (C) to microbial decomposition. Permafrost thaw stimulates plant growth and could offset C loss; and C balance will depend on water drainage patterns as ice in permafrost turns to water. Our understanding of how permafrost thaw directly impacts Arctic ecosystem C dynamics is, however, still very limited.

Using data from seven years of experimental Air and Soil warming in moist acidic tundra, we show that Soil warming had a much stronger effect on CO2 flux than Air warming. Soil warming caused rapid permafrost thaw and increased ecosystem respiration (Reco), gross primary productivity (GPP), and net summer CO2 storage (NEE). To our surprise, Reco, GPP, and NEE also increased in Control, but could be explained by slow thaw in Control areas. Summer CO2 flux across treatments fit a single quadratic relationship that captured the functional response of CO2 flux to thaw, water table depth, and plant biomass. In the initial stages of thaw Reco, GPP, and NEE increased, and did not vary between treatments despite different rates of thaw. As thaw in Soil warming continued to increase linearly, ground surface subsidence created saturated micro-sites, and suppressed Reco, GPP, and NEE. However Reco and GPP remained high in areas with large Eriophorum vaginatum biomass. In general NEE increased with thaw, but was more strongly correlated with plant biomass indicating that greater soil contributions in deeply thawed areas balanced increases in GPP. These results demonstrate the importance of indirect thaw effects on CO2 flux: plant growth and water table dynamics. Winter Reco models estimated that the area was an annual CO2 source during all years of observation, and that greater CO2 loss in warm winter soils exceeded the stronger summer CO2 sink.

Presentation Type: Poster
Modeling shrub expansion under changing climate across Arctic tundra of North America

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Recent changes in species composition and increased shrub abundance in particular has been reported as a result of amplified warming in Arctic tundra. Despite these changes, the driving factors that control recent Arctic shrubification and its future trajectory remain largely uncertain. Here, we used an ecosystem model, ecosys, to mechanistically represent and explain the underlying processes of how plant functional types (PFTs) change under climate change in recent decades and in the 21st century across the Arctic tundra of North America (NA). Modeled changes in productivity of shrubs were corroborated by observed changes across different sites of the NA Arctic tundra. Preliminary modeling results are consistent with observations, showing 20 - 30 % increase in shrub productivity over the past 30 years, across the selected sites. Recent and projected warming was modeled to increase thawing of the permafrost that deepened the thaw layer, thus increasing nutrient availability and enhancing shrub growth across the Arctic tundra. Although there was spatial heterogeneity and contrasting modeled responses of co-existing Arctic PFTs, warming resulted in overall increases in shrub abundance and a reduction in growth of non-vascular plants across the tundra. Enhanced capacity of ecosystem carbon uptake from increasing dominance of woody vegetation was modeled to result in the tundra ecosystem remaining a strong carbon sink in the 21st century.

Presentation Type: Poster
Disentangling the effects of temperature and substrate availability on soil CO2 efflux

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Soil respiration (Rs) originates from multiple processes, including the decomposition of organic substrates by soil microbial communities and roots, and is strongly influenced by aboveground litter inputs as well as environmental forcing at varying periodicities. Due to the complexity of soil carbon flux, most ecosystem models still rely on either simple temperature-based or temperature/soil water-based characterization of Rs, without considering the biotic and other modulating factors. This limits our ability to predict longer-term variability in Rs across different ecosystems. To address this crucial issue, we employed wavelet (WT) and cross-wavelet (CWT) analysis to identify the time domains during which Rs is affected by three factors: soil temperature (Ts), soil water content (θ), and PAR as a proxy of photosynthesis. Using two different-aged stands of loblolly pine located along the coastal plain of North Carolina, we test the analysis results against simple conceptual models that allow interpreting the variable effects of the different factors on Rs. WT transformation of the residuals of the Q10-model fit to 30-minute Rs data yielded significant (p < 0.05) peaks at multiple periods (daily, synoptic and monthly). CWT analysis between θ on Rs revealed correlation at the synoptic scale, and between PAR and Rs at the diurnal scale. These results indicate the dominating effects of abiotic factors at longtime scales and biotic factors at short-term scales. Our work highlights the need to incorporate multiple factors in order to move beyond a simplistic, temperature-based quantification of Rs.

Presentation Type: Poster
Agricultural soil could become a sink for atmospheric carbon dioxide (CO\textsubscript{2}) as global concentrations increase. Increasing global atmospheric CO\textsubscript{2} concentrations make soil an ever important climate change mitigant because of its passive C sequestration potential. While the role of soil is important, sequestering soil carbon (C) depends upon many factors including soil type, climate, crop, tillage, nitrogen fertilization, methods and rates, cropping history and rotation, as well as the degree of soil degradation. The agricultural management practice of reduced tillage, especially no-till, can result in net C sequestration if sufficient biomass is produced and near continuous ground cover maintained. Tillage — while useful for controlling some weeds or pests — increases surface area of crop residues, while mixing plant residues in a moist, temporarily aerobic soil environment complete with primary and microbial detritus, which speeds decomposition followed by a burst of respiration. Using Bowen ratio energy balance micrometeorology we measured and compared CO\textsubscript{2} flux between till and no-till farming practices during 104 days of the 2015 growing season in north-central Ohio. Though the plots experienced unusually large precipitation during the critical part of vegetative growth impacting yield especially for the no-till, flux calculations for the period showed that no-till sequestered 263.2 g CO\textsubscript{2} m\textsuperscript{-2} (90% confidence interval -432.1 to -99.9) while the tilled plot emitted 146.4 g CO\textsubscript{2} m\textsuperscript{-2} (90% confidence interval -53.3 to 332.2). Though the results of this experiment adds observational data in support of no-till as a practice to sequester C, more data will be needed to understand and measure these differences under varying climate regimes, as is necessary to understand the potential magnitude of emissions, factors that impact those emissions, and the overall potential for agriculture to become a recognized climate change mitigant.

**Presentation Type:** Poster
Mercury in Permafrost: a Crossover with the Carbon Cycle

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Mercury (Hg) deposited onto the land surface from the atmosphere bonds with organic matter, significantly modulating the global cycling of Hg through the atmosphere, ocean, and terrestrial biosphere. In permafrost regions, sedimentation processes have resulted in a stable pool of 565 Gt carbon in the form of frozen organic matter. To estimate the amount of Hg in this frozen permafrost carbon, we measured total soil Hg concentration in 588 samples from 13 soil permafrost cores from the interior and the North Slope of Alaska. The median Hg concentration was 47.7±23.4 ng Hg g soil\(^{-1}\) and the median ratio of Hg to carbon was 1.56±0.86 µg Hg g C\(^{-1}\), independent of depth, site, age, and soil type. Using the Northern Circumpolar Soil Carbon Database (NCSCD) map of permafrost carbon and the median ratio of Hg to carbon, we estimate the northern hemisphere circumpolar permafrost land mass stores 773±441 kilotons of Hg bonded to the frozen organic matter. This makes permafrost the second largest reservoir of Hg on the planet, second only to Hg in thawed soils. The fate of the permafrost carbon as climate warms will determine the fate of the permafrost Hg: as permafrost thaws, the organic matter will decay and release Hg into the environment, with major implications for terrestrial and aquatic life, the world’s fisheries, and ultimately human health.

Presentation Type: Poster
Large-area monitoring of aboveground carbon dynamics based on gains and losses from biomass change

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In response to the high uncertainties associated with traditional approaches to forest carbon accounting, we present the results of a novel approach to quantifying terrestrial carbon emissions (losses) not only from land use change (e.g., deforestation) but also from forest degradation and disturbance while additionally accounting for regrowth (gains) in aboveground woody vegetation. The approach measures annual changes in aboveground carbon density (ACD) and does so directly, consistently, and with measurable accuracy across large areas using an array of existing commercial off-the-shelf and NASA remote sensing assets. The geographic focus is the country of Mexico where members of the project team have worked closely with the Government of Mexico as part of the USAID-supported M-REDD+ project to assist in advancing Mexico’s forest monitoring capacity. The specific objectives focus on quantifying the certainty with which extensive field, off-the-shelf airborne LiDAR (G-LiHT and M-REDD+), and NASA satellite data sources (Landsat, VIIRS, and MODIS) can be used synergistically to estimate wall-to-wall changes in ACD at varying resolutions (i.e., 30-500 m) and spatial scales (sub-national to national) over a ~15-year period (2001-2015). An independent accuracy assessment of the ACD change product is conducted leveraging permanent plot data from the Mexico National Inventory of Forest and Soil (INFyS), intensive field and micrometeorological measurements from the Mexico network of eddy covariance flux towers, and forest loss data from Hansen et al. (2013). The results of this effort, together with complementary research focused on the Amazon Basin and the pantropics, represent a fundamentally new way of quantifying carbon fluxes that significantly reduce uncertainty while leading to a more complete understanding of terrestrial carbon cycling.

Presentation Type: Poster
Is the Earth greening or browning? An update based on recent MODIS-C6 Data

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Accurately monitoring global vegetation dynamics with modern remote sensing is critical for understanding the functions and processes of the biosphere and its interactions with the planetary climate. Here we re-examined the global vegetation activity by comparing the recent MODIS Collection 6 (C6) VIs with Collection 5 (C5) VIs including Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) from Terra (2001 - 2015) and Aqua Satellites (2003 - 2015). We found substantial differences in global vegetation trends between Terra-C5 and -C6 VIs, especially EVI. From 2001 to 2015, global vegetation showed a remarkable greening trend in annual EVI from the Terra-C6 (0.28% yr⁻¹; P < 0.001), in contrast to the decreasing EVI trend from the Terra-C5 (-0.14% yr⁻¹, p < 0.01). Spatially, large portions of the browning areas in tropical regions identified by Terra-C5 VIs were not evident in Terra-C6 VIs. In contrast, the widespread greening areas in Terra-C6 VIs were consistent with Aqua-C6 VIs and GIMMS3g NDVI. Our finding of a greening Earth supports the recent studies suggesting an enhanced land carbon sink. Most of the vegetation browning trends detected by MODIS Terra-C5 VIs were likely caused by sensor degradation, particularly for the period after 2007. Therefore, previous studies of temporal vegetation trends based solely on Terra-C5 VIs may need to be reevaluated. Our new analysis offers the most updated understanding of the global vegetation dynamics during the past 15 years and contributes to better understanding the role of vegetation played in the Earth's biogeochemical and climatic systems.

Presentation Type: Poster
Forest height in open canopies from spaceborne stereogrammetry

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Stereogrammetry applied to globally available high resolution spaceborne imagery (HRSI; < 5 m spatial resolution) yields fine-scaled digital surface models (DSMs) of elevation. These DSMs may represent elevations that range from the ground to the vegetation canopy surface, are produced from stereoscopic image pairs (stereopairs) that have a variety of acquisition characteristics, and have been coupled with complementary data to examine forest height. This work explores surface elevations from HRSI DSMs derived from two types of acquisitions in open canopy forests. We find that these DSM types are associated with different surface elevations estimated from automated stereogrammetry in open canopy forests. Using the two DSM types together, the distribution of DSM-differenced heights in forests ($\mu = 6.0$ m, $\sigma = 1.4$ m) were consistent with the distribution of plot-level mean tree heights ($\mu = 6.5$ m, $\sigma = 1.2$ m). Knowledge of HRSI acquisition characteristics can be used to understand and combine stereogrammetric surface elevation estimates to map forest height at fine scales, resolving the vertical structure of groups of trees from spaceborne platforms in open canopy forests.

**Presentation Type:** Poster
Reduced uncertainty of 30 m North American Boreal Forest Cover

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Climate change has altered vegetation productivity and structure, carbon sequestration and many other processes in the higher northern latitudes. The taiga-tundra ecotone (TTE) which is the circumpolar transition zone from 50° to 75° north latitude is expected to change in form and distribution from global warming. Evidence of change has already been documented in small-scale studies but large amounts of uncertainty remains in current global estimates of circumpolar forest extent. Establishing the TTE extent is challenging because of variations in vegetation structure, site-level interactions between microclimate, topography, winter snow depth, wind, edaphic conditions and other factors. These interactions have produced TTE forest patterns that include sporadic forest cover patches to growth-stunted trees resembling shrubs. These patterns are evident at local scales, but are often not apparent in moderate resolution imagery from most earth observing satellites. Such scale problems have contributed to large TTE geographic uncertainties. Recent advances using the global archive of Landsat data have provided Tree Canopy Cover (TCC) at 30-m resolution, which may improve TTE delineation. We found 2010 TCC data overestimated forest cover by up to 15% in North America by using long latitudinal transects of portable airborne laser scanner data. We calibrated and validated our estimates of TCC for trees greater than 2 m in height and these data could provide a baseline estimate to inform analyses of forest cover change and vulnerability in response to climate change.

Presentation Type: Poster
Session: Linkages Between Aquatic-Terrestrial Carbon Cycles
Incorporating Terrestrial-Aquatic Interfaces into Earth System Research

Patrick J. Megonigal, SERC, megonigalp@si.edu (Presenter)
Vanessa Bailey, Pacific Northwest National Laboratory
Joel Rowland, Los Alamos National Laboratory
Tiffany Troxler, Florida International University
Jared DeForest, DOE
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Terrestrial-aquatic interfaces (TAI) are dynamic and complex components of the Earth system that are transitional between fully terrestrial and aquatic environments. They support exceptional rates of productivity and biogeochemical cycling, and regulate the Earth system at a level that exceeds the area they occupy. Earth and environmental science research has tended to advance separately in terrestrial, aquatic and TAI systems despite evidence that they share common processes, are ubiquitous and function as a planet-wide system. The next frontier in the effort to develop a holistic understanding of Earth surface processes is to explicitly couple the dynamics of terrestrial and aquatic systems at the TAI interface. The US Department of Energy held a workshop on 7-9 Sep 2016 to assess the state of the science in coupled terrestrial and aquatic ecosystems, and to develop a strategy to advance Earth system and environmental research at the TAI.

TAIs are best defined by characteristic processes than by ecosystem type. TAIs exhibit high temporal and spatial variation in oxygen supply, are carbon-rich soils, are high potential greenhouse gas emitters, and are sensitive to anthropogenic disturbances (e.g., pollution, fire) and climate change impacts. One useful consequence of defining the TAI by the processes they support is that the boundaries between systems is realistically vague and dependent upon the distribution of relevant processes of interest. Such a definition encourages the development of observational and modeling approaches that span upland-aquatic transitions, while remaining faithful to the process representations that are required within purely aquatic and terrestrial systems.

Because TAIs are ubiquitous, a fundamental understanding of the hallmark processes in these systems is needed to extend system-specific observations to a globally-relevant scale and to couple terrestrial, aquatic and TAI models. The challenges identified include: (i) quantifying TAI size, shape and areal extent, (ii) integrating hydrologic processes across scales and systems, (iii) improving the representation of plant and microbial traits and processes in Earth System Models, (iv) understanding and modeling the complex interactions between biological and hydrological processes that drive geomorphic change, (v) solving scientific and computational problems surrounding scale, and (vi) understanding of the feedbacks inherent in TAI systems that render them resilient to perturbations. Advancing TAI science requires creative approaches to combining experiments, models and observations, scientific teams willing to work across traditional ecosystem boundaries, and cooperation across agencies that tend to focus funding on different elements of the terrestrial-TAI-aquatic continuum.

Presentation Type: Plenary Talk
Fluxes of carbon and nutrients from upstream landscapes to the coastal ocean

Marjorie Friedrichs, Virginia Institute of Marine Science, marjy@vims.edu (Presenter)

The coastal boundary between land and ocean represents a small portion of the surface area of the earth, yet plays a major role in global carbon and nutrient cycling. The most productive marine ecosystems are located in coastal waters, which are, not coincidentally, adjacent to regions of highest human population density. As a result, these regions are particularly susceptible to anthropogenic impacts, such as those resulting from land cover and land use change. At the same time, changes in climate are posing significant stress on these regions, as witnessed by increasing temperatures, atmospheric CO2 and sea levels. Until recently, however, biogeochemical fluxes across the land-ocean boundary have been largely overlooked in terms of study on continental scales, primarily because of the challenges associated with addressing the extreme heterogeneity between adjacent systems, and the difficulties associated with developing global scale models capable of resolving the strong variability of processes occurring on relatively small time and space scales along the land-ocean interface. Over the past decade, however, considerable interdisciplinary research has focused on studying the connections between these terrestrial and marine ecosystems, and the fluxes of carbon and nutrients from upstream landscapes to the coastal ocean. In this presentation recent efforts aimed at better understanding these fluxes will be reviewed, highlighting how the combination of coupled interdisciplinary terrestrial-ocean models, satellite observations and in situ data are helping to quantify the flux of inorganic/organic carbon and nutrients from terrestrial systems to the coastal ocean.

Presentation Type: Plenary Talk
Carbon transformations and source – sink dynamics along a river, estuary, ocean continuum

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Estuaries, the transition zone between land and the coastal ocean, are highly dynamic systems in which carbon sourced from watersheds, atmosphere, and ocean may be transformed, sequestered, or exported. The net fate of carbon in estuaries, governed by the interactions of biotic and physical drivers varying on spatial and temporal scales, is currently uncertain because of limited observational data. In this study, conducted in a temperate, microtidal, and shallow North Carolina USA estuary, carbon exchanges via river and tributary input, air-water flux, burial and metabolism were monitored over two-years, with sharply different amounts of rainfall. Air-water CO2 fluxes and metabolic variables were simultaneously measured in channel and shoal by conducting high-resolution surveys at dawn, dusk and the following dawn. Carbon flows between estuary regions and export to the coastal ocean were calculated by quantifying residual transport of DIC and TOC down-estuary as flows were modified by sources, sinks and internal transformations. Between wet and dry years, riverine carbon loading fluctuated significantly; the estuary changed from net heterotrophic and a small source of atmospheric CO2 to slightly net autotrophic and a sink for atmospheric CO2. These results, as observed in other observational studies, show that riverine input, light, temperature, and land-use, are major controls on carbon cycling. A comparison of our carbon budget with that from a recent modeling study conducted on the same estuary demonstrated a five-fold difference in budget terms. Comparison of our results with other types of estuaries varying in depth, latitude, nutrification demonstrates large discrepancies underscoring the limitations of current models and datasets in representing system-scale diversity; thus, a more practical approach may be to choose a small number of representative coastal systems, coordinate research efforts to quantify the relevant fluxes and constrain a range of environmental conditions that influence carbon cycling.

Presentation Type: Plenary Talk
Estimation of Global Surface Carbon Fluxes Using Advanced Data Assimilation

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Kang et al., (JGR, 2011, 2012) developed an advanced data assimilation methodology able to recover (in a simulation mode) the surface carbon fluxes from the assimilation of realistic atmospheric CO2 measurements. After a spin-up of ~3 months, the carbon fluxes were estimated accurately at a grid-size resolution and captured quite well the natural annual cycle and the anthropogenic sources without using any prior information. The method was also tested on NCAR CAM3.5. Although due to lack of computer resources it had to stop after only 27 days of assimilation of simulated observations, the results showed convergence in Europe, where observations are relatively abundant.

In our current research, led by co-author Ning Zeng, we are assimilating both simulated and real observations into the GEOS-CHEM global model coupled with the VEGAS vegetation model, using strongly coupled LETKF Data Assimilation, with the ultimate goal of estimating global real carbon fluxes. The coupled GEOS-CHEM/VEGAS model reproduces very realistically the observed seasonal cycle of the CO2 flask data for April 2012-July 2014 at many Global View stations, after a spin-up of about 6 months. We confirmed that the LETKF Data Assimilation could also be used to estimate unmeasured parameters in VEGAS model, as long as the time scales of their associated processes are not longer than a few years.

We performed OSSE data assimilation experiments with this system and found that assimilating simulated GlobalView and OCO-2 observations, and found that using short assimilation windows (1 day) and 7-day sliding observation windows gave excellent results. We are testing assimilation of real observations and will present an overview of the results.

**Presentation Type:** Plenary Talk
Design and implementation of an atmosphere-land-ocean margin carbon program at a high-exchange coastline

Angelos K. Hannides, Coastal Carolina University, ahannides@coastal.edu (Presenter)

The study of carbon cycling in high-exchange coastlines is fraught with uncertainties and requires strategically designed observations to resolve them. Long Bay, South Carolina, is one of these high-exchange regions, dotted by rivers, coastal wetlands, sandy coastlines and an inner shelf exhibiting substantial submarine groundwater discharge, but also significant human activities related to tourism and (sub)urbanization.

The characterization of carbon cycling across these intricately connected settings poses a real challenge that cannot go unanswered, because of the urgency to address uncertainties and to better delineate human impacts on this cycle. The development of a comprehensive carbon monitoring system at Coastal Carolina University, a predominantly undergraduate university that offers degrees in marine science-related programs at all levels (current marine science enrollment at all levels: 795 students), will not only contribute to these overarching objectives but will also methodically train budding environmental/Earth scientists and will provide a localized source of scientific information on the carbon cycle, anthropogenic impacts, and possible policy implications.

Three major components are envisioned to accomplish these goals. Telemetered field stations will monitor atmospheric and aquatic carbon species concentrations and the magnitude and direction of carbon exchange, between the atmosphere and the Earth’s surface, and along the aquatic continuum from rivers to oceans through above-ground and subterranean estuaries. An (inter-) calibration/comparison facility will regularly confirm and validate sensor readings through analyses of discrete samples using conventional widely accepted methodologies. Finally, an interface component will make the program and its products available to university students as a research/education tool, as well as outreach products to local interested parties, such as K-12 schools, local governments, citizen groups etc. It is expected that all aspects of the current vision of the program will benefit greatly by discussion and input from all the experts participating in this meeting.

Presentation Type: Poster
First System-Wide Estimates of Air-Water Exchange of Carbon Dioxide in the Chesapeake Bay

Maria Herrmann, The Pennsylvania State University, maria.herrmann@psu.edu
Raymond Najjar, The Pennsylvania State University, rgn1@psu.edu (Presenter)
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Estuaries are estimated to play an uncertain but potentially important role in the global carbon cycle via the evasion of CO₂ to the atmosphere. Global estimates are uncertain due to limited data availability and the extreme heterogeneity of coastal systems. Notably, the air-water CO₂ flux for the largest estuary in the United States, the Chesapeake Bay, is yet unknown. Here we provide the first system-level CO₂ gas exchange estimates for the main stem of the Chesapeake Bay calculated using pH and alkalinity data from the Chesapeake Bay Program. Errors are propagated based on errors in pH measurement and alkalinity-salinity relationships. Estimates are made at monthly resolution from 1985 to 2013 for eight segments of the Bay. We find the main stem to be a net source of CO₂ to the atmosphere, outgassing from 2.0 to 2.2 mol m⁻² yr⁻¹ over the study period. Outgassing has high interannual variability and is greatest in the fall and winter and in the oligohaline and polyhaline portions of the Bay. Biological processes appear to control spatial and temporal variability, particularly in the upper bay.

Presentation Type: Poster
Characterizing Climate and Human Influences on Coastal Margin Carbon Dynamics Using Integrated Land-Ocean Modeling Approaches

Steven E Lohrenz, University of Massachusetts Dartmouth, slohrenz@umassd.edu (Presenter)
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Hanqin Tian, Auburn University, tianhan@auburn.edu
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Changing climate and land use practices have the potential to dramatically alter coupled hydrologic-biogeochemical processes and associated movement of water, carbon and nutrients through various terrestrial reservoirs into rivers, estuaries, and coastal ocean waters. Consequences of climate– and land use–related changes will be particularly evident in large river basins and their associated coastal outflow regions. Here, we describe a NASA Carbon Monitoring System project that employs an integrated suite of models in conjunction with remotely sensed as well as targeted in situ observations with the goal of describing processes controlling fluxes on land and their coupling to riverine, estuarine and ocean ecosystems. The nature of our approach, coupling models of terrestrial and ocean ecosystem dynamics and associated carbon processes, allows for assessment of how societal and human-related land use, land use change and forestry (LULUCF) and climate-related change affect terrestrial carbon transport as well as export of materials through watersheds to the coastal margins. The objectives of this effort include the following: 1) Provide representation of carbon processes in the terrestrial ecosystem to understand how changes in land use and climatic conditions influence the export of materials to the coastal ocean, 2) Couple the terrestrial exports of carbon, nutrients and freshwater to a coastal biogeochemical model and examine how different climate and land use scenarios influence fluxes across the land-ocean interface, and 3) Project future changes under different scenarios of climate and human impact, and support user needs related to carbon management and other activities (e.g., water quality, hypoxia, ocean acidification). This research is providing information that will contribute to determining an overall carbon balance in North America. Results can also benefit efforts to describe and predict how land use and land cover changes impact coastal water quality including possible effects of coastal eutrophication and hypoxia.

Presentation Type:  Poster
The carbon budget of Delaware Bay

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A carbon budget for Delaware Bay was constructed using a combination of historical data, empirical models, remote-sensing algorithms, process-based numerical models, and a mass balance framework that allowed some fluxes to be estimated as residuals. Budgets for two systems were constructed: tidal wetlands and estuarine open waters. Tidal wetlands have a net primary production (NPP) of 1.1 Tg C/yr, nearly twice the NPP of estuarine open waters. 76% of the organic carbon from tidal wetland NPP is respired heterotrophically in wetlands, 20% is buried, and 4% is advected to adjacent estuarine waters. 65% of the respired carbon in wetlands is degassed to the atmosphere as carbon dioxide and 14% is advected laterally as dissolved inorganic carbon to adjacent estuarine waters. In the net, tidal wetlands remove 0.39 Tg C/yr of carbon dioxide from the atmosphere. The open waters of the estuary receive 0.52 Tg C/yr from upland sources, 67% of which is from rivers and 33% from tidal wetlands. Most (79%) of the carbon received by the open waters of the estuary is exported to shelf waters, with only 12% outgassed to the atmosphere and 9% buried. The open waters of the estuary are metabolically neutral, with net primary production and heterotrophic respiration both equal to 0.64 Tg C/yr. Delaware Bay as a whole (tidal wetlands and estuarine open waters) is a sink of atmospheric carbon dioxide of 0.33 Tg C/yr.

Presentation Type: Poster
Linking carbon exchange between coastal wetland and shelf environments in the northeastern Gulf of Mexico

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The contribution of “blue carbon” from tidal wetlands to the coastal ocean in the form of dissolved and particulate organic matter (DOM and POM) represents a terrestrial-aquatic linkage of increasing importance. Across the terrestrial-aquatic interface of coastal environments, it is of utmost importance to discriminate riverine from wetland sources of DOM with respect to alterations in land-use and climate changes on its transport and reactivity in coastal waters. Results will be presented from a project that combines field observations, ocean-color satellite observations, and the outputs of a high-resolution hydrodynamic model to model the export of terrestrial- and wetland-derived DOM to shelf waters of the Gulf of Mexico from two contrasting coastal environments: river-dominated Apalachicola Bay, FL and particle-dominated Barataria Bay, LA, the latter having one of the highest rates of relative sea level rise in North America. DOM quality was assessed with parallel factor (PARAFAC) analysis of fluorescence, carbon stable isotope composition, and lignin biomarkers. Determination of dissolved organic carbon (DOC) fluxes were based on the development of algorithms between DOC and colored DOM (CDOM) absorption derived from the VIIRS ocean color sensor. Satellite-derived DOC stocks were used with the Navy Coastal Ocean Model (NCOM) for the Louisiana-Texas shelf to compute DOC flux estimates from each bay. DOM quality results were used to partition DOC fluxes between riverine and wetland sources. Combining these results, the project aims to determine the relative loss of blue carbon from tidal wetlands to the adjacent shelf waters of these different coastal environments.

Presentation Type: Poster
Linking Blue Carbon Stores To Release in Piermont Marsh, Hudson Estuary, NY

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We examine Piermont Marsh (41°N, 73°55'W) blue carbon stores through time, and link it to processes that cause carbon degradation and release. AMS C-14 dating, XRF fluorescence, and pollen analysis provide chronological control for sedimentation rates, pollution history, and local shifts in vegetation through time. As coastal eutrophication progressed, the marsh has been invaded, first by Typha angustifolia in the nineteenth century and then by Phragmites australis in the twentieth century up to the present. We present the effects of climate, vegetation, and human impact on the carbon storage of Piermont Marsh. To further investigate the carbon dynamics, root analysis on a core taken from a Phragmites site located in the marsh indicated that live Phragmites roots existed down to 300 cm. Isotope-mass balance equations were used to determine the amount of CO2 produced from methanogenesis (CO2-meth) and the amount of CH4 escape. Interior marsh sites dominated by introduced Phragmites had the greatest amount of CO2-meth (49.8 ± 10.9 mM) followed by sites dominated by native mixed vegetation (43.8 ± 10.4 mM) and lastly the mudflat (19.3 ± 8.9 mM). These findings were possibly due to the influence of labile substrates from plant roots. Phragmites has a deeper and denser root system than native vegetation that might leach labile dissolved organic carbon (DOC) into the subsurface as optical analyses and FT-ICR-MS results showed Phragmites DOC to be more reactive than DOC from native vegetation. This research provides a deeper understanding of carbon production and release in marshes, including estimates of how much Piermont marsh sequesters, assessing how much carbon dioxide and methane is being produced by methanogenesis, and finding how much the invasion of Phragmites australis has impacted the production of methane. We seek to link these stores and processes satellite measurements of vegetation and estuarine carbon.

Presentation Type: Poster
A synthesis of 20 years of pCO2 data in the US South Atlantic Bight: Can we see a clear trend through noisy data?

Wei-Jun Cai, University of Delaware, wcai@udel.edu
Janet Reimer, University of Delaware, janetr@udel.edu (Presenter)

We synthesized pCO2 observations in the US South Atlantic Bight (SAB). Observations include 8 years of NOAA OAP-funded coastal OA mooring data, OAP-funded cruises in 2007, 2012, and 2015, NSF-funded regional studies in 2005-2006 and 2013-2015, and historical VOO data from 1991 to 1996. A statistically significant increasing trend emerges from the noisy data. We also discuss the control mechanisms of the trends and the disturbances including how river export over dry-wet cycle may have influenced the coastal ocean CO2 signal.

Presentation Type: Poster
Multi-decadal increase in dissolved inorganic carbon from an east coast watershed: implications for coastal environments

Janet J Reimer, University of Delaware, janetr@udel.edu (Presenter)
Wei-Jun Cai, University of Delaware, wcai@udel.edu

Increased dissolved inorganic carbon (DIC) has been reported in several US rivers over the last few years. Increased DIC, could result in lower pH and eventually affecting coastal habitats, thus contributing to coastal ocean acidification (COA). COA has been identified as a potential threat to ecosystems and ecosystem services. Multi-decadal sampling (weekly to monthly frequency) in the Altamaha River at the Doctortown, GA, USGS site accounts for approximately 98.5% of the discharge in the Altamaha River watershed. There is an ~8 µmol kg$^{-1}$ y$^{-1}$ increase in DIC, yet no increase in TA, over the time series from October 2000 to the present. While there is no decadal trend increase in DIC flux or river stream flow, the DIC flux to the coastal zone is enhanced during high river stream flow periods. DIC:TA is also increased during the wet periods indicating decreased buffering capacity even though freshwater influx is increased. Therefore, during winter wet periods the Altamaha River estuaries, including the Duplin River, likely receive lower pH water that contribute to acidification in downstream marshes. At present, time series of this length to do exist for the Duplin River, however, increased DIC from terrestrial sources are only one potential contributing source of DIC to South Atlantic Bight (SAB) shelf waters. If we assume that DIC is increasing in all 10 of the major rivers that empty into the SAB, then there could be a substantial terrestrial influence on COA in this region.

Presentation Type: Poster
Quantifying and predicting historical and future patterns of carbon fluxes from the North American Continent to Ocean

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Carbon export through river channels to coastal waters is a fundamental component of the global carbon cycle. Changes in the terrestrial environment, both natural (e.g., climatic change, enriched CO2 concentration, and elevated ozone concentration) and anthropogenic (e.g., deforestation, cropland expansion, and urbanization) have greatly altered carbon production, stocks, decomposition, movement and export from land to river and ocean systems. However, the magnitude and spatiotemporal patterns of lateral carbon fluxes from land to oceans and the underlying mechanisms responsible for these fluxes remain far from certain. Here we applied a process-based land model with explicit representation of carbon processes in stream and rivers (Dynamic Land Ecosystem Model: DLEM 2.0) to examine how changes in climate, land use, atmospheric CO2, and nitrogen deposition have affected and will affect the carbon fluxes from North American continent to Ocean in the 20th and 21st centuries. Our simulated results indicated that terrestrial carbon export shows substantially spatial and temporal variability. Of the five sub-regions (Arctic coast, Pacific coast, Gulf of Mexico, Atlantic coast, and Great lakes), the Arctic sub-region provides the highest DOC flux, whereas the Gulf of Mexico sub-region provided the highest DIC flux. For the entire North America, neither DOC nor DIC export demonstrated a long-term trend. However, terrestrial carbon export to the arctic oceans showed increasing trends for both DOC and DIC, whereas DOC and DIC export to the Gulf of Mexico decreased in the recent decades. Future pattern of riverine carbon fluxes would be largely dependent on the climate change and land use scenarios.

Presentation Type: Poster
Dissolved Organic Matter Fate in Estuaries: Spatial Variations in Bioavailability and Photoreactivity

Laura Logozzo, CCNY, llogozz00@citymail.cuny.edu
Maria Tzortziou, CCNY, mtzortziou@ccny.cuny.edu (Presenter)
Patrick Neale, SERC, nealep@si.edu

We investigated the photobleaching and microbial degradation of dissolved organic matter (DOM) in Chesapeake Bay wetlands and estuarine waters. Water was collected at 7 sites in July 2016: 3 tidal creeks draining the Kirkpatrick and Taskinas brackish marshes and Jug Bay freshwater marsh, and 4 locations across the Rhode River sub-estuary salinity gradient. Samples were incubated at 24°C either under continuous low-level UV light for 7 days and then in the dark for 7 days, or in the dark for 14 days. We measured dissolved organic carbon (DOC) concentrations, chromophoric dissolved organic matter absorption spectra (aCDOM), and fluorescence excitation-emission matrices (EEMs). Marsh-DOM had higher initial DOC concentrations, absorption and fluorescence. PARAFAC analysis of EEMs output four components: C1, VISM-humic; C2, VISM-humic; C3, UV-humic; and, C4, protein-like. All samples had a large contribution of the humic-like components to the total fluorescence, but estuarine sites showed a higher contribution of the protein-like component than marsh sites. Jug Bay was the only marsh site that showed a relatively large contribution of the protein-like component. At the end of the light incubation, the C1 VIS-humic component had decreased by as much as 80% in the marsh sites and by 60% in the estuarine sites, indicating that wetland-DOM was more photoreactive. Dark incubations did not have a significant impact on aCDOM<sub>300</sub>, except for Jug Bay and the Rhode River Mouth (loss of 1-2% per day). Photobleaching resulted in an increase in the bioavailability of DOM at marsh sites, with aCDOM<sub>300</sub> loss of up to 3% per day.

Presentation Type: Poster
Organic Carbon Patterns and Budgets in the Long Island Sound Estuary

Penny Vlahos, University of Connecticut, penny.vlahos@uconn.edu (Presenter)
Michael M. Whitney, University of Connecticut

In this analysis, multi-year time series are assessed across the 150 km central axis of the US east coast’s Long Island Sound (LIS) estuary, in 3 distinct regions, to evaluate trends in key biogeochemical components. Dissolved and particulate organic carbon (DOC, POC), organic and inorganic nitrogen (DON, PON, TDN) and carbon to nitrogen ratios (C/N) exhibit clear seasonal trends. Concentration gradients between surface and bottom are most pronounced between April to September and converge between October to January. Annual averages across LIS from west to east show significant spatial trends. DOC gradients along the 150 km central axis equate to an eastward decrease of 0.003 mgL\(^{-1}\)km\(^{-1}\) (\(r^2 = 0.90\)) for both surface and deep waters and the POC gradients are 0.004 mgL\(^{-1}\)km\(^{-1}\) (\(r^2 = 0.78\)) and 0.001 mgL\(^{-1}\)km\(^{-1}\) (\(r^2 = 0.32\)). Surface DON and PON are 0.20 ± 0.13 mgL\(^{-1}\) and 0.16 ± 0.05 mgL\(^{-1}\) respectively and C/N ratios increase from west (13 ± 3) to east (16 ± 8). Fluxes are calculated at the boundary of each LIS region and applied to a mass balance. LIS is a net exporter of carbon during stratified summer periods for all years. Its annual net carbon export, however, varies inter-annually based on tributary flows. The heterotrophic or autotrophic nature of LIS is related to low or high river flow conditions respectively and shifts inter-annually. LIS carbon export values to the adjacent Mid Atlantic Bight continental shelf based on flow conditions over the last 20 years are estimated at 56 ± 63 x 10\(^6\) kgy\(^{-1}\).

Presentation Type: Poster
U.S. Coastal Wetland Carbon Dynamics: Successes and challenges in mapping, modeling and monitoring tidal wetland C stocks and fluxes through the NASA Carbon Monitoring System

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Coastal wetlands remove and bury atmospheric carbon (C) at a faster rate than most terrestrial or marine ecosystems due to high productivity coupled with low respiration in oxygen-poor soils. Coastal wetland C stocks can be lost catastrophically or gradually, when sea-level rise (SLR) and erosion convert wetlands to open water, or when wetlands are converted to other land uses. Conversely, coastal wetland restoration can increase C sequestration and reduce methane (CH4) emissions. Our 2014 NASA CMS Project synthesized field and satellite-derived datasets to map current C stock and flux for coastal wetlands of the conterminous US (CONUS) and, with greater certainty, for six intensively-studied “sentinel” sites. With >1 GT of C in the top meter of soil and C sequestration rates ranging from 0-500 gC m-2 y-1, intact tidal wetlands represent a significant and quantifiable component of CONUS C accounting. To address soil C stocks and accretion – the dominant “blue carbon” sink – we focused on development of an extensive validation dataset and a process-based model (Marsh Equilibrium Model - MEM) to integrate elevation and biomass inputs into C sequestration predictions. To quantify biomass change through time, we developed a robust (R2 > 0.6) hybrid mapping approach including object-based image analysis, multispectral data and RADAR. Overall, soil and biomass C stocks appear readily estimated and improved from Tier 1 default values, but national scale methane accounting lacked the data and map categories necessary to meet even default conditions. For the three major drivers of IPCC tidal wetland greenhouse gas (GHG) inventories – 1) ongoing soil C accretion in wetlands-remaining-wetlands, 2) soil C loss from eroding or drained wetlands, and 3) methane emissions – the uncertainties associated with mapped products were the greatest source of error. We suggest that maps based on novel remote sensing algorithms are capable of 1) characterizing elevation gradients within wetlands, 2) classifying intermediate salinities across landscapes, 3) detecting tidal boundaries, and 4) detecting LULCC relevant to C sequestration or loss. Given the surprising consistency in soil C density across tidal wetland categories, the
robustness of marsh biomass algorithms using widely available LandSat and Sentinel data, and validated results of MEM for wetland C accretion and resilience to SLR, we find that these map limitations – especially tidal boundaries, classification schemes, change detection and accuracy – generate the greatest uncertainty in wetland C accounting.

**Presentation Type:** Poster
Hydrologic control on CO₂ fluxes in subtropical estuaries

Xinping Hu, Texas A&M University - Corpus Christi, xinping.hu@tamucc.edu
Hongming Yao, Texas A&M University - Corpus Christi, hongming.yao@tamucc.edu (Presenter)

Hydrologic control on estuarine CO₂ flux is not well understood. This lack of understanding in part contributes to the high uncertainty in estimating global estuarine carbon budgets. Meanwhile, changing precipitation patterns and human activities such as the increasing demand for freshwater due to population increase near the coast also alter hydrologic cycle in a way that inevitably changes the amount and frequency of riverine materials delivered to the estuaries and coastal waters.

In subtropical estuaries of the northwestern Gulf of Mexico, hydrologic conditions play a significant role in determining water residence time. In a relatively narrow latitudinal gradient, estuarine water residence time varies by at least one order of magnitude, and this variation is also subject to large-scale climate patterns such as the El Niño-Southern Oscillation. In this work, we report highly variable CO₂ flux values across four estuaries of different water residence time and contrasting hydrologic conditions. A bimodal distribution of CO₂ flux can be seen as a function of salinity. Different controls such as high water pCO₂ levels at low salinities due to abundant freshwater input and high wind speed when freshwater input is scarce may explain this type of distribution. This finding may have significant implications toward understanding CO₂ budget in subtropical estuaries in general.

Presentation Type: Poster
Implications of soil erosion for greenhouse warming intensity of cellulosic biofuels derived from corn stover in the US Midwest

Xuesong Zhang, Pacific Northwest National Laboratory, xuesong.zhang@pnl.gov (Presenter)

Recent studies recognize the critical role of bioenergy in enhancing energy independence while mitigating greenhouse gas (GHG) emissions. Corn stover in the US Midwest is geographically-concentrated and abundant, thus has the potential to economically provide large amounts of feedstocks for advanced biofuels. Notably, the effect of soil erosion on soil organic carbon (SOC) dynamics was not explicitly considered in previous life cycle analysis of greenhouse warming intensity of cellulosic biofuels. Here we present a high-resolution (56 m) geospatial modeling of potential impacts of soil erosion on SOC storage as a result of corn residue removal in the US Midwest. Over a 50 years simulation period (2000-2049), SOC depletion is -100,625 and -796,801 g CO2e ha-1 yr-1, respectively, for no-residue removal and 33% residue removal scenarios when erosion is not considered. When erosion is explicitly simulated, SOC change is -669,826 and -840,868 g CO2e ha-1 yr-1, respectively, for no-residue removal and 33% residue removal scenarios. Using a marginal approach (relative SOC change between residue removal and no-residue removal scenarios), GHG emissions intensity of corn stover derived cellulosic biofuels due to SOC change is 143 (without erosion) and 35 (with erosion) g CO2 MJ-1, respectively. In order to meet the mandated 60% reduction in GHG emissions compared with gasoline (or GHG emissions of 37.5 g CO2 MJ-1 or less for cellulosic biofuels), reliably accounting soil erosion processes and associated implications for carbon cycling is necessary to ensure a carbon negative bioenergy industry in the US. As soil erosion not only alters terrestrial carbon dynamics but also influences carbon cycling in aquatic ecosystems, there is a pressing need to study soil erosion induced perturbation of both terrestrial and aquatic ecosystems and provide comprehensive assessment of how land use may intervene carbon sources and sinks.

Presentation Type: Poster
New insights into photosynthesis using tracers, fluorescence, cameras, and satellite indices, from temperate forests to the tropics

Scott Reid Saleska, University of Arizona, saleska@email.arizona.edu (Presenter)
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Loren Albert,
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Natalia Restrepo-Coupe,
Rodrigo de Silva,

New understanding of how photosynthetic metabolism is regulated, from local to global scales, is emerging from the integration of a range of novel and longstanding techniques for probing biosphere-atmosphere exchange. Here, we show how new application of tracers of photosynthesis at the ecosystem scale is revising our understanding of the behavior of temperate forest photosynthesis, and how tower-mounted phenocams, combined with satellite observations, are revealing new insights into how leaf phenology controls the seasonality of photosynthesis in tropical forests. In temperate forests, the integration of carbonyl sulfide with isotopic tracers of CO2 provides robust new estimates showing that canopy-level photosynthetic capacity is more stable throughout the growing season than suggested by conventional estimates from eddy flux towers. At the same time, in tropical forests, landscape-scale inventories of crown dynamics via repeat photography, combined with litterfall and ecosystem carbon fluxes, reconcile much-debated remote sensing controversies, and show why tropical evergreen canopies have more strongly seasonal photosynthetic capacity than previously assumed. Combining these different methods with new methods to detect solar induced fluorescence at tower sites promises to advance an integrated understanding of controls on photosynthesis across diverse biomes, and from ecosystem to regional scales.

Presentation Type: Plenary Talk
The GeoCarb Mission

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GeoCarb Science Team,

This paper presents a discussion of the GeoCarb Mission, which was recently selected as NASA’s Earth Venture Mission-2. GeoCarb will fly an instrument that will provide measurements of atmospheric carbon dioxide (CO2), methane (CH4), and carbon monoxide (CO) from geostationary orbit at roughly 85°W. The GeoCarb mission will deliver daily maps of column integrated mixing ratios of CO2, CH4, and CO over the observed landmasses at a spatial resolution of roughly 5 x 8 km.

The instrument exploits four spectral regions: The oxygen A-band for pressure and aerosols, the weak and strong bands of CO2 near 1.61 and 2.06 microns, and a region near 2.32 microns for CO and CH4. The O2 and CO2 components are very similar to the instrument aboard OCO-2, and so we envision OCO-2 in geostationary orbit with the addition of a fourth channel to measure CO and CH4, but without an oceanic capability. The chosen spectral channel for pressure and aerosols (0.765µm) permits measurement of Solar-Induced Fluorescence (SIF), which provides direct information about photosynthesis.

The 85°W slot allows observations of major urban and industrial regions in the Americas, large agricultural areas, and the expansive South American tropical forests and wetlands, which will help resolve flux variability for CO2 and CH4. As noted, the GeoCarb mission will produce daily maps at a spatial resolution of 5-8 km of the carbon gas concentrations and SIF. We believe that these persistent observations will provide the basis for a transformational improvement in our understanding of the carbon cycle, including climate-critical insights into the carbon-climate connection.

Presentation Type: Plenary Talk
NASA’s Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission: revolutionizing studies of global biogeochemistry and carbon cycles in the ocean-atmosphere system

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The new NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission is a strategic climate continuity activity that will not only extend key heritage ocean color, cloud, and aerosol data records, but also enable new insight into oceanographic and atmospheric responses to Earth’s changing climate. The primary PACE instrument will be a spectroradiometer that spans the ultraviolet to shortwave infrared region at 5 nm resolution with a ground sample distance of 1 km at nadir. This payload will likely be complemented by a multi-angle polarimeter with a similar spectral range. Scheduled for launch in 2022, this PACE instrument pair will revolutionize studies of global biogeochemistry and carbon cycles in the ocean-atmosphere system. Here, I present a PACE mission overview, with focus on instrument characteristics, core and advanced data products, and overarching science objectives.

Presentation Type: Plenary Talk
A novel modelling framework and method for model process representation sensitivity analysis

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Until now formal sensitivity analysis methods have only been available to assess model sensitivity to parametric variation but not to variation in processes representation. This has stymied efforts to evaluate ecosystem models as they combine models of many sub-systems and processes, each of which may be conceptualized and represented mathematically in various ways. We present a novel modelling framework—the multi-assumption architecture and testbed (MAAT)—that automates combination and generation of models with different representations of process during runtime. MAAT also incorporates a novel method to calculate a process representation sensitivity index. The process representation sensitivity index quantifies the variability in a model outcome caused by variability in process representation. MAAT has also been coupled with the predictive ecosystem analyzer (PEcAn) to leverage existing capabilities to run with AmeriFLUX and other site meteorology and incorporate parametric uncertainty from linked trait databases.

To demonstrate the method, a formal assessment of the sensitivity of the modeled leaf carbon assimilation caused by multiple incarnations of the Farquhar photosynthesis model and variable parameters will be presented.

MAAT and the process representation sensitivity index provides a flexible and rigorous framework for analyzing model sensitivity to process representation, parametric variability, and environmental variability.

Presentation Type:  Plenary Talk
Aerodynamic canopy height: A simple metric of canopy dynamics derived from AmeriFlux tower data

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AmeriFlux is a vast network of more than 250 eddy covariance flux sites dispersing across most of North America's ecoregions. The network provides valuable datasets of the direct and in situ measurements of fluxes and ancillary variables that are used across different disciplines and applications. Aerodynamic canopy height is one of the potential data products that is crucial to many modeling applications, but have not yet been standardly and extensively provided across the network. This study tests and generates the first network-wise data set of aerodynamic canopy heights from eddy covariance measurements. We adopt and improve the method proposed in previous study (Pennypacker and Baldocchi 2015; Boundary Layer Meteorology), and run the tests across a broad range of ecosystem types ranging from tall- to short-canopy, from closed- to open-canopy, and also from evergreen to deciduous vegetation. Our estimates are in generally good agreement with those derived from in situ measurements or LIDAR measurements. We then demonstrate and discuss the potential applications of aerodynamic canopy heights to providing the information of seasonal and interannual changes of canopy structures.

Presentation Type:  Poster
Comparing ecosystem and soil respiration: a synthesis of tower-based and soil measurements

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The net ecosystem exchange (NEE) of CO2 is the difference between CO2 assimilation and release at the ecosystem scale. Ecosystem respiration (Reco), the efflux of CO2 from the ecosystem to the atmosphere, comprises of different fluxes, including soil respiration (Rsoil) and aboveground plant respiration. Therefore, Rsoil is just a fraction of Reco and theoretically, has to be smaller than Reco at annual, seasonal or daily time scales. However, in the past few decades, several studies that estimated Reco with the Eddy Covariance technique while simultaneously measuring Rsoil have reported higher Rsoil than Reco at different time scales. In this study, we compared four different ecosystems (from forest to grasslands, and from boreal to semiarid) to study whether Rsoil is higher than Reco and to identify error sources by checking different components that could possibly produce this discrepancy between Reco and Rsoil. We found that Reco and Rsoil showed similar temporal patterns, however, Reco was not consistently higher than Rsoil from annual to diel time scales, with the difference between the two fluxes varying from site to site. The assumptions that nighttime Reco could be used for functionally estimating daytime Reco and that nighttime Reco could be estimated by nighttime NEE seem correct. However, we have identified several issues in estimating NEE and in measuring and upscaling Rsoil that could be producing an underestimation of Reco and/or an overestimation of Rsoil. Further studies have to be done to better characterize and quantify the miscalculation of Reco and Rsoil and to identify if the errors are random or systematic, since it could potentially affect the general modeling of Reco and Rsoil fluxes at larger scales.

Presentation Type: Poster
Upscaling Ameriflux observations to assess drought impacts on gross primary productivity across the US Southwest

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Both satellite observations and flux measurements provide crucial information about the Earth’s carbon, water and energy cycles. Continuous measurements from flux towers facilitate exploration of the exchange of carbon dioxide, water and energy between the land surface and the atmosphere at fine temporal and spatial scales, while satellite observations can fill in the large spatial gaps of in-situ measurements and provide long-term temporal continuity.

Here, remotely sensed and distributed meteorological inputs are used to upscale gross primary production (GPP) estimates from Ameriflux towers to the regional scale via a machine learning approach. In the development of this regional estimate we first explore temporal and spatial patterns in tower fluxes (10 years) and their coherence with patterns observed in vegetation indices (15-30 years) across the region. We demonstrate the current state of a proposed spatially continuous upscaled GPP product drawing from both ground and satellite data over the US Southwest region. The product and its components will be used to examine drought impacts on terrestrial carbon cycling across the Southwest US including the effects of drought seasonality and intensity (hot vs. cool droughts) on carbon uptake. This work helps us understand linkages between the carbon and water cycles in arid and semi-arid ecosystems and informs predictions of vegetation response to future climate conditions.

Presentation Type: Poster
UAS: a tool to better characterize flux towers footprint.

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The rapid emergence of drone technology provides a powerful tool that is complementary to ground-based and aircraft-based observations. We present the use of this new tool at AmeriFlux sites. Our current platforms are quadcopters and octocopters build by DJI and 3d-robotics, equipped with commercially available sensors to collect imagery: (1) Visible imagery: (Zenmuse X3 camera); (2) pseudo-ndvi imagery (Zenmuse X3 modified to filter solely Red + NIR). We are also presenting preliminary observations collected using an octoptere, instrumented with an open-path LI-COR 7700 and an enclosed path LI-COR 840 for CH4 and CO2 mixing ratio, respectively.

Presentation Type:  Poster
An anomalous CO2 uptake measured over asphalt surface by open-path eddy-covariance system

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Measurements of net ecosystem exchange of CO2 in desert environments made by Wohlfahrt et al. (2008) and Ma (2014) indicate strong CO2 sink. The results of these studies have been challenged by Schlesinger (2016) because the rates of the CO2 uptake are incongruent with the increase of biomass in the vegetation and accumulation of organic and inorganic carbon in the soil. Consequently, the accuracy of the open-path eddy-covariance systems in arid and semi-arid ecosystems has been questioned.

A new technology merging the sensing paths of the gas analyzer and the sonic anemometer has recently been developed. This integrated open-path system allows a direct measurement of CO2 mixing ratio in the open air and has the potential to improve the quality of the temperature related density and spectroscopic corrections by synchronously measuring the sensible heat flux in the optical path of the gas analyzer.

We evaluate the performance and the accuracy of this new sensor over a large parking lot with an asphalt surface where the water vapor and CO2 fluxes are expected to be low and the interfering sensible heat fluxes are above 200 Wm-2. For independent CO2 flux reference measurements, we use a co-located closed-path analyzer with a short intake tube and a standalone sonic anemometer. We compare energy and carbon dioxide fluxes between the open- and the closed-path systems. During periods with sensible heat flux above 100 W m-2, the open-path system reports an apparent CO2 uptake of 0.02 mg m-2 s-1, while the closed-path system consistently measures a more acceptable upward flux of 0.015 mg m-2 s-1. We attribute this systematic bias to inadequate fast-response temperature compensation of absorption-line broadening effects. We demonstrate that this bias can be eliminated by using the humidity-corrected fast-response sonic temperature to compensate for the abovementioned spectroscopic effects in the open-path analyzer.

Presentation Type: Poster
Contribution of Atmospheric Transport to North American Biogenic Flux Uncertainties

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Inferring biogenic carbon sources and sinks at ecologically- and policy-relevant regional scales using top-down methods remains a challenge to closing and monitoring the carbon budget within useful uncertainty bounds. Additional high-quality observations are now available in the form of satellite-observed column-averaged CO\textsubscript{2} (XCO\textsubscript{2}) from GOSAT and OCO-2. Even with these additional observations, it is not clear how dependent the flux estimates are on the atmospheric transport model used (e.g., model resolution and atmospheric transport error). This affects our confidence in and the relevance of regional flux estimates and uncertainties.

In an effort to quantify uncertainties due to model resolution and atmospheric transport for one inversion system, we use coarse resolution NASA CMS-Flux 4D-Var inversion system CO\textsubscript{2} global products as lateral boundary conditions and surface flux initial conditions in a 27-km resolution regional mesoscale model, WRF-Chem, for the North American domain. The CMS-Flux products are the result of assimilation of GOSAT XCO\textsubscript{2} for 2010. We run the mesoscale model forward in a small ensemble, varying only model physics parameterizations. We simulate the GOSAT XCO\textsubscript{2} from the WRF ensemble output and from the CMS-Flux optimized mole fractions using the ACOSv3.5 protocol.

We compare the simulated XCO\textsubscript{2} from both models to the GOSAT soundings, and find overall daily average agreement within ±0.6 ppm, with the largest spatial variability in summer. Comparing the vertical distribution of the WRF CO\textsubscript{2} to the CMS mole fractions, we find half the summer WRF ensemble RMSD relative to CMS to be in the lowest 15% of the column. The WRF ensemble simulated GOSAT XCO\textsubscript{2} are assimilated into the CMS-Flux Inversion system in OSSE mode to provide a measure of the uncertainty of the CMS-Flux products to differences in atmospheric transport. We discuss the implications of this ensemble transport experiment for monitoring regional carbon balances using XCO\textsubscript{2} observations.

Presentation Type: Poster
Next Generation UAS-based spectral systems for studying vegetation function - bridging the gap from field to local and global measurements

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Field, airborne and satellite spectroscopy show great potential for measuring vegetation bio-physical and functional characteristics. High resolution canopy spectra capture a synoptic record of a suite of vegetation characteristics, which co-vary in time. This project aims to bridge the gap in Earth observation between field and airborne measurements through the development of methods to make well-characterized measurements from Unmanned Aerial Systems (UAS). Our objectives are: 1) deployment of spectrometers from UAVs to generate high spectral resolution reflectance measurements, of comparable characteristics (data quality and calibration, wavelength range, resolution, etc.) to data from handheld, proximal or air/spacecraft spectrometers; 2) implement the programming and data delivery workflow to optimize data acquisition that will maximally characterize ground-level spatial variability in vegetation properties; and 3) retrieve biochemical and physiological traits from UAVs that are important to vegetation monitoring. We target the consistent retrieval of calibrated surface reflectance, as well as biological parameters including nutrient and chlorophyll content, specific leaf area and leaf area index, chlorophyll fluorescence, photosynthetic capacity - all important to vegetation monitoring and yield estimates. We are testing the technology and protocols using spatially-resolved spectroscopy measurements to characterize canopy VNIR reflectance and solar-induced (red and far-red) fluorescence, SIF.

We will report our current technology developments, and preliminary findings demonstrating the approach for collection of science quality spectra for retrieval of vegetation chlorophyll fluorescence. This effort provides a step in the development of a UAS capacity for accurate measurement of spectral reflectance at high temporal frequencies and stability to depict diurnal/seasonal cycles in vegetation function. The Next Generation UAS spectral methods will complement future NASA and ESA missions such as Landsat, HyspIRI, Sentinel-2&3, and FLEX, by providing data at various spatial and temporal scales for testing and integration with the satellite data, using a rapidly deployable and flexible approach to measure surface reflectance and to derive ecosystem parameters.

**Presentation Type:** Poster
Remote sensing retrievals of CDOM quality and DOC dynamics in eutrophic estuaries and their margins

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Estuaries are dynamic features of coastal ocean and are among the most vulnerable ecosystems under sustained climate change. Exchanges of dissolved organic carbon (DOC) between estuaries and coastal ocean have important implications for carbon sequestration in coastal zones. Recent studies demonstrated that the absorption properties of chromophoric dissolved organic matter (CDOM) (i.e., absorption coefficient aCDOM and spectral slope coefficient S), can be derived from ocean color observations and also can be reliable proxies to accurately retrieve DOC in some coastal waters. Herein we developed ocean color algorithms to accurately retrieve DOC and CDOM from ocean color remote sensing reflectance based on a synthesis of extensive field observations collected along the U. S. East and Gulf Coasts, with mean absolute percent differences (MAPD) of ~35%, 10%, and less than 20%, respectively for aCDOM(300), S275–295, and DOC estimates from MERIS, and MAPD of ~36%, 8%, and 33% for aCDOM(300), S275–295, and DOC estimates from MODIS-Aqua satellite, for aCDOM(300), S275–295, and DOC in the range of 0.2–37 m\(^{-1}\), 0.0173–0.047 nm\(^{-1}\), and 73–953 µmol/L respectively. The DOC algorithm was developed based on a strong correlation between the DOC-specific CDOM absorption coefficient and the CDOM spectral slope coefficient (Pearson R = 0.96, N = 250, p < 0.001), two properties that depend solely on the quality of carbon and therefore renders the algorithm not dependent on CDOM seasonality but more universal across broad temporal and spatial scales. Implementation to satellite imageries demonstrated the capacity of these algorithms to resolve the variability of CDOM and DOC across the estuarine–coastal waters in the study area, including extreme events. Our results also stressed that tidal stage has considerable influence on aggregated ocean color observations at the tidally influenced land–estuarine interfaces and therefore should not be neglected. The new CDOM and DOC algorithms presented in this work, if integrated appropriately into biogeochemical or hydrodynamic models, should contribute a reliable tool to scale local measurements to synoptic, long-term carbon changes from satellite observations across estuarine–coastal continuum. Additionally, we presented results of remote sensing retrievals of DOC in the Long Island Sound from the new Landsat 8/OLI sensor.

**Presentation Type:** Poster
Leaf Chlorophyll Content May Be A New Parameter To Measure At Tower Flux Sites For Upscaling Purposes

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Tower flux measurements are essential for evaluating models for large area applications. So far, upscaling of tower fluxes to regional and global scales using models is based on canopy structural parameters, such as LAI, or photosynthetically active radiation absorbed by vegetation derived from optical remote sensing data. Recent advances in space-borne remote sensing technology have made it possible to map leaf chlorophyll content (LCC) over large areas, which can be a new parameter to improve flux upscaling. We have recently produced a series of global LCC maps at 300 m resolution in 7-day intervals using MERIS data. LCC has at least two advantages over leaf nitrogen content (LNC) commonly used to adjust the leaf maximum carboxylation rate (Vcmax) in enzyme-kinetic productivity models: (1) LCC is a pigment that has strong influence on leaf optical spectra and can be much more reliably retrieved from optical remote sensing data than LNC; and (2) LCC is better correlated to Vcmax. Our recent experimental results for four deciduous tree species in 2013-15 showed that LCC has a much stronger relationship with Vcmax at 25°C (R² = 0.78, p<0.001) than LNC (R² = 0.47, p<0.001), due to the dynamic partitioning of nitrogen between and within photosynthetic and non-photosynthetic fractions. Our modeling work also demonstrated that with the use of LCC for adjusting Vcmax, carbon and water flux simulations are significantly improved, especially at the beginning of the growing season, when leaves are fully expanded while LCC is still low. Currently, few tower flux stations have regular measurements of LCC, although some have LNC measurements. We therefore propose that all tower stations make routine LCC measurements, which are highly desirable for upscaling tower fluxes to regional and global scales using newly available satellite data that allow us to retrieve LCC reliably.

**Presentation Type:** Poster
Using SIF and $X_{CO2}$ to Disentangle Photosynthesis and Respiration at regional scales.

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The OCO-2 satellite was launched on July 2, 2014, to monitor global atmospheric concentration and flux of CO$_2$ from space. With the simultaneous retrieval of solar induced fluorescence (SIF) and column CO$_2$ ($X_{CO2}$), the potential exists for simultaneous estimates of gross primary production (GPP) and net ecosystem exchange (NEE). Here we present two frameworks for disaggregating NEE into GPP and ecosystem respiration (Re). One scheme simultaneously solves for respiration and gross primary production (GPP) using a decomposition of multiplicative biases into seasonal harmonics under the constraint of solar induced fluorescence and $X_{CO2}$. The other scheme uses GPP independently estimated from OCO-2 SIF using the BETHY-SCOPE coupled modeling framework, along with a posterior uncertainty as a "tight prior" for a traditional atmospheric inversion that uses a loose prior for Re and $X_{CO2}$ to disaggregate NEE into GPP and Re via optimal estimation. We anticipate the separation of flux terms into mechanistic components will facilitate comparison to independent estimates such as eddy covariance data and inventory based data such as crop yields. Initial CO$_2$ flux results for the time period of September 2014 to August 2016 will be presented with a focus on temporal corrections to the a priori fluxes over North America.

Presentation Type: Poster
The Global Ecosystem Dynamics Investigation (GEDI)

Ralph Dubayah, University of Maryland, dubayah@umd.edu (Presenter)

Spaceborne lidar has been identified as a key technology by the international ecosystem science community because it enables accurate estimates of canopy structure and carbon and forms the basis for fusion approaches with existing and planned missions, such as the NASA’s ICESat2, ECOSTRESS and OCO3 missions, and extends the capabilities of radar missions such as the NASA-ISRO SAR, Tandem-X and the ESA BIOMASS missions. The Global Ecosystem Dynamics Investigation (GEDI) is a space-based lidar instrument scheduled for launch in late 2018. From its vantage point on the International Space Station, GEDI will provide high-resolution observations of forest vertical structure. These data will be used to address three core science questions: What is the aboveground carbon balance of the land surface? What role will the land surface play in mitigating atmospheric CO2 in the coming decades? How does ecosystem structure affect habitat quality and biodiversity? GEDI informs these science questions by making billions of lidar waveform observations per year. These canopy measurements are then used to estimate biomass and in fusion with radar and other remote sensing data to quantify changes in biomass resulting from disturbance and recovery. GEDI further marries ecosystem structure from lidar with ecosystem and habitat modeling to evaluate the impact of changes in land use and climate on carbon sequestration and biodiversity. In this poster we present an overview of the GEDI mission and its current implementation status.

Presentation Type: Poster
Mesoscale ensemble modeling of CO2 and XCO2: Insights from the Atmospheric Carbon and Transport (ACT) - America Aircraft Mission

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Current estimates of biogenic carbon fluxes over North America based on top-down atmospheric inversions are subject to considerable uncertainty. This uncertainty stems to a large part from the uncertain prior fluxes estimates with the associated error covariances and approximations in the atmospheric transport models that link observed carbon dioxide mixing ratios with surface fluxes. Specifically, approximations in the representation of vertical mixing associated with atmospheric turbulence or convective transport and largely under-determined prior fluxes and their error structures significantly hamper our capacity to reliably estimate regional carbon fluxes. To explore the limitations of mesoscale inversions, we constructed a mesoscale ensemble system that carefully samples the complexity of flux errors and transport errors in the simulated three-dimensional CO2 concentration fields. Starting from CarbonTracker Near-Real-Time flux estimates, we propagated flux error structures with an ensemble of perturbed flux realizations derived from multiple terrestrial biospheric models, all part of the Multi-scale Synthesis and Terrestrial Model Intercomparison Project (MsTMIP). We obtain transport errors from a small-size atmospheric ensemble generated by varying the different physical parameterizations of the mesoscale atmospheric model.

This work is part of the Atmospheric Carbon and Transport – America (ACT-America) mission which aims at reducing the uncertainties in inverse fluxes at the regional-scale by deploying airborne and ground-based platforms to characterize atmospheric GHG mixing ratios and the concurrent atmospheric dynamics. Two aircraft measure the 3-dimensional distribution of greenhouse gases at synoptic scales, focusing on the atmospheric boundary layer and the free troposphere during both fair and stormy weather conditions. Here we analyze two major questions of the project: (i) What level of information can we expect from the currently planned observations? (ii) How might ACT-America reduce the hindcast and predictive uncertainty of carbon estimates over North America?

Presentation Type: Poster
Improving forest carbon sequestration predictions by constraining demographic processes in an ecosystem model

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Forecasting carbon cycle from local to global scale with terrestrial ecosystem models requires capturing an accurate representation of the forest structure and the demographic processes, as well as the biogeochemical ones. However, few ecosystem models track the dynamics of fine-scale ecosystem structure explicitly, and yet fewer are calibrated with field data as the computational complexity of these models usually precludes standard data assimilation techniques for Bayesian calibration. Here we calibrate such a complex model, Ecosystem Demography model version 2 (ED2), with demographic data from a network of inventory plots by using a Gaussian Process that emulates the computationally demanding process-based model and that reduces the computation time considerably. For validation of the calibrated ED2, we compared the model outputs to results from Empirical Succession Mapping (ESM), a novel synthesis of successional patterns in Forest Inventory and Analysis data (~1 million individual tree observations from the eastern U.S.) which provides robust comparisons for ecosystem models. Our results revealed that constraining the ED2 parameters that control long-term successional processes increased the ability of the model to capture the emergent demographic patterns from ESM. Overall, better representation of changes in tree size, density and carbon in the calibrated ED2, not only improved the carbon sequestration predictions, but also reduced the uncertainties associated with these predictions.

Presentation Type: Poster
Challenging the Community Land Model with Observations from a Network of Flux Towers in Semi-Arid Ecosystems

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Recent studies suggest that inter-annual variability (IAV) in global carbon fluxes may be dominated by semi-arid ecosystems (Zhang et al. 2016; Poulter et al. 2014; Ahlström and Raupach 2015). In the US Southwest such biomes encompass a wide range of vegetation types, from grasslands, through shrub-dominated and savanna-type ecosystems, to pinon-juniper woodlands and finally coniferous forests at higher elevations. Controls over carbon and water fluxes vary between these systems, with contrasting importance of summer and winter precipitation, and snowmelt runoff.

Here, we describe on-going work using a network of flux towers with uniform instrumentation along the New Mexico Elevation Gradient (NMEG), to test both the Community Land Model (CLM) and a data assimilation system for this model employing the Data Assimilation Research Testbed (DART).

The observations suggest both intra- and inter-annual variability in precipitation affects soil moisture and productivity differently across the gradient of flux tower sites. We can compare the observed behaviour with carbon and water dynamics simulated by the Community Land Model (CLM) at these locations. This proves to be an interesting test for the model as a uniform temperate evergreen needle leaf plant functional type parameterization is used across a range of vegetation types found on the gradient. We use DART to assimilate observations of biomass, biomass increment derived from tree rings, and leaf area to adjust the modeled initial condition. This addresses shortcomings in the model spinup process, which then allows us to ask: Can contrasting meteorological forcing variables alone result in the observed variation in productivity and water use efficiencies? Or does the model need to further account for variation in species distributions through additional parameterizations? Does the assimilation of observed carbon and water fluxes improve near-term model forecasts?

Presentation Type: Poster
Long-Lived and Robust Land-Atmosphere Flux Bias Estimation using SIF and NEE

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Biospheric sources and sinks of carbon dioxide represent one of the most critical, but least understood processes in climate science. Since the 1990’s, carbon dioxide inversion models have estimated the magnitude, location, and uncertainty of carbon sources and sinks. These inversions are underconstrained statistical problems that employ aggressive statistical regularizations in both space and time to estimate quantities like net ecosystem exchange (NEE) on weekly timescales over fine spatial scales. We introduce a new framework that leverages observational constraints on estimation of corrections toward only slowly varying (seasonal to interannual) biospheric processes, which control time-averaged sources and sinks. We estimated persistent multiplicative biases to the time mean and three seasonal harmonics of gross primary production (GPP) and total respiration (RESP). The method is flexible enough to separately estimate component fluxes using additional observational constraints, including data with a high degree of uncertainty. We tested the capabilities of this method by estimating corrections to simulated component fluxes from the Simple Biosphere Model 4 (SiB4) at 35 eddy-covariance towers by assimilating both a scaled GOME-2 satellite Solar Induced Fluorescence (SIF) product as a proxy seasonal signal of GPP and direct NEE measurements from the AMERIFLUX eddy-covariance datasets between 2007 to 2015. This methodology was able reproduce proper seasonality, seasonal onset, annual amplitudes, and interannual variability of both net and component fluxes. Furthermore, the time-filtering methodology also proved to be more robust to uncertainty in the observations when compared to a control inversion that represents current global inversions.

Presentation Type: Poster
Sun-induced chlorophyll Fluorescence Auto-Measurement Equipment (FAME) designed for use at eddy covariance flux sites

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The foundation of our biosphere and civilization rests on the food and energy produced by plants using sunlight. Currently there are no readily available instruments capable of continuous and unattended monitoring of plant photosynthesis and physiological stresses in natural environments. To fill this instrument gap, we have therefore developed a prototype field-deployable system for measuring sun-induced chlorophyll fluorescence (SIF) at leaf, individual plant, or canopy-scales: Fluorescence Auto-Measurement Equipment (FAME). Sun-induced chlorophyll fluorescence is emitted from the core of the photosynthetic machinery of plants and is a vital signal of photosynthesis and physiological stress. FAME is based on a number of hardware and software innovations that make it unprecedented in terms of data quality, acquisition rate, versatility, extensibility, and ease of operation. It is a high-performance integration of software and hardware technologies. It is particularly suited for use at eddy flux sites for two reasons. First, FAME permits the measurement of additional environmental variables (e.g., broadband radiation, temperature, humidity etc.)—that are critical to the interpretation of SIF observations —at the same instant as the spectral information. Second, FAME can be easily integrated into existing data acquisition systems. The FAME prototype was successfully deployed at the Missouri Ozark AmeriFlux (MOFLUX) site in September, 2016. We will present the first results of analyses of SIF measurements obtained so far at the MOFLUX site.

Presentation Type: Poster
Using UAS based flux measurements to understand and scale AmeriFlux tower footprints.

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Quantifying the footprint representativeness of AmeriFlux sites remains an important element of scaling and synthesis research efforts. In order to increase the spatial coverage of concentration and flux measurements we developed an unmanned aerial system (UAS) that utilizes a compact high precision CO2 analyzer in combination with transport modeling. This system allows quick and inexpensive measurements of concentrations and fluxes above ecosystems in multiple locations.

In order to prove the concept and generate initial results we mapped CO2 concentration variability above the canopy and within the footprint of the US-Me6 AmeriFlux site. Based on the success of the concentration mapping, a second experiment was conducted to generate a transport modeled NEE value. This was validated against the US-Me6 tower eddy covariance flux values from the same time interval. The UAS based NEE value was generated by running WRF-STLT at a high spatial resolution to generate a footprint that coincided with the EC footprint; this footprint strength was then used in combination with a background CO2 concentration value from a nearby NOAA monitoring site and the UAS measurements to determine a flux. This approach yielded a good agreement with the EC data and shows the potential for this highly portable approach to validating scaling of tower NEE values.

Presentation Type: Poster
Peak growing season gross uptake of carbon in North America is largest in the Midwest USA

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Future regional photosynthetic carbon dioxide fluxes (gross primary production, GPP) are a first-order uncertainty in climate predictions. Large-scale CO₂ observations (e.g. remote sensing data) can provide information on the carbon cycle, but these data are not directly useful for GPP because of confounding ecosystem respiration fluxes of roughly equal magnitude but opposite direction. Recent findings on carbonyl sulfide (COS or OCS) budgets have led to the proposal that COS could be used as a tracer for regional and global GPP, but this tracer approach has yet to be applied at these large scales. Here we present the first regional assessment of GPP using COS. We focus on the North American growing season because it is a global hotspot for COS air-monitoring data and GPP uncertainty. We found that regional variability in simulated vertical COS concentration gradients were driven by variation in GPP rather than other components of the modeled COS sources and sinks. This leads to our second conclusion: in the North American growing season GPP in the Midwest USA region significantly exceeds GPP in any other region of North America. While these results are not consistent with some ecosystem models, they are supportive of new ecosystem models from the Coupled Model Intercomparison Project Phase 6 (CMIP6) with enhanced agroecosystem processes and emerging space-based estimates from sun-induced chlorophyll fluorescence. This new approach provides insight into the likely accuracy of various ecosystem land models and therefore a new tool to improve our limited understanding of how best to represent GPP.

Presentation Type: Poster
Optical Sensing of Ecosystem Carbon Fluxes from Tower-mounted Spectrometers

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Optical sampling of spectral reflectance and solar induced fluorescence provide information on the physiological status of vegetation that can be used to infer stress responses and estimates of production. To fully understand these measurements requires descriptions of temporal and bidirectional variability. The NASA FUSION tower-mounted system consists of two dual channel, upward and downward looking, spectrometers used to simultaneously collect high spectral resolution measurements of reflected and fluoresced light from vegetation canopies at multiple view angles. This comprehensive tower measurement dataset can provide insights into interpretation of satellite or aircraft observations. Data were collected in the Optimizing Production Inputs for Economic and Environmental Enhancement (OPE3) cornfields (39.03°N, 76.85°W) at USDA Beltsville Agricultural Research Center in conjunction with CO2 eddy covariance fluxes throughout the growing season. Estimates of chlorophyll fluorescence, combined with measures of vegetation pigment content and the Photosynthetic Reflectance Index (PRI) derived from the spectral reflectance are compared with CO2 fluxes over diurnal periods for multiple days. We find significant bidirectional effects. The relationships among the different optical measurements indicate that they are providing different types of information on the vegetation and that combinations of these measurements provide improved retrievals of CO2 fluxes than any index alone.

Presentation Type: Poster
Albedo change and carbon cycle: a long-term analysis using MsTMIP outputs

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Earth’s surface reflectance, or albedo, is a critical parameter for energy, water, and carbon cycle. Land surface albedo is influenced by many factors such as snow cover, soil type and wetness, vegetation cover and its greenness, and human intervention. However, there remain uncertainties in large-scale albedo, both in observation and parameterization, mainly because of spatial heterogeneity and complexity of regulating factors. Little is known about long-term (e.g., decadal) change in albedo, in spite of field and satellite monitoring. In this study, we analyzed output data of MsTMIP; five models (CLASS-CTEM-N, CLM4, CLM4VIC, SiBCASA, and VISIT) submitted data of shortwave albedo. In general, these biome models estimate surface albedo on the basis of background soil albedo, vegetation, and snow coverage, and differ in these parameterizations. The model-estimated global land surface albedo was compared with satellite products (e.g., MODIS and GlobAlbedo) for benchmarking. Latitudinal gradient and seasonal variation were properly captured in each model, but differed in the range of variability. We present preliminary results and discuss the potential impact (i.e., error propagation) of albedo on water and carbon budget simulations. Finally, we propose the necessity of extensive and continuous observation of albedo to reduce the uncertainty.

Presentation Type: Poster
Patterns and controls of water-use efficiency in an old-growth coniferous forest: analysis of fluxes and an ecosystem model

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Water use efficiency (WUE), the ratio of carbon uptake to water loss at varying spatial and temporal scales, has been widely recognized as an important physiological link between carbon and water cycling, and used to track forest ecosystem responses to climate change and rising atmospheric CO2 concentrations. Numerous studies have been conducted to estimate forest-scale WUE through either stable carbon isotope analyses composition or eddy covariance measurements. However, the sign and magnitude of WUE response to climate variability are still highly uncertain, and can vary with the time scale of analysis. This study employed the Ecosystem Demography model version 2 (ED2) to explore patterns and physiological and biophysical controls of WUE in an old-growth coniferous forest in Pacific Northwest. Long-term eddy covariance flux measurements and the stable carbon isotope composition of CO2 collected at the Wind River AmeriFlux site were used to validate model performance. We characterized and contrasted WUE responses based on flux and isotope data between wet and dry years at the site, and also quantified how model predictions of WUE varied across these years. We explored how various WUE metrics from both measurements and model predictions vary with site meteorology and radiation, including clear and cloudy days. We also investigated how different species (e.g., Douglas-fir and western hemlock) and their respective age/size cohorts differ in modeled WUE patterns through time.

Our results showed that various WUE metrics from measurements and model predictions varied with site meteorology and radiation, including clear and cloudy days. Multiple linear regression and random Forest analysis indicated that the importance of different predictors (e.g., CO2 concentration, vapor pressure deficit) varied across different time scales (i.e. half hourly, daily, monthly).

Presentation Type: Poster
Synthesis of Soil Moisture Active Passive Mission observations for monitoring global net ecosystem CO2 exchange variability

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Soil moisture is a major climatic factor regulating land-atmosphere CO2 exchange through its differential impact on vegetation growth and respiration processes. Recent studies suggest that soil water availability in semi-arid ecosystems drives much of the global inter-annual variability in net ecosystem CO2 exchange. Previous global model, empirical, and remote-sensing datasets rely on proxies for soil moisture including precipitation, humidity, and aridity indices because of the lack of comprehensive, accurate global soil moisture information. This has changed with the launch of NASA’s Soil Moisture Active Passive (SMAP) mission, which now provides global operational soil moisture observations beginning from March 31, 2015. SMAP operationally provides other value-added products (Level 4) including soil moisture (L4SM) and carbon flux (L4C). The L4C product is derived using a satellite data-driven carbon model combining SMAP L4SM with MODIS vegetation and GEOS-5 daily surface meteorology to estimate daily land-atmosphere carbon fluxes over global vegetated land areas. The L4C product includes internally consistent estimates of net ecosystem CO2 exchange (NEE), gross primary production and ecosystem respiration, and surface soil organic carbon, which are posted to a 9-km global grid while preserving sub-grid information from 1-km processing. The L4C model was calibrated using a global network of historical eddy covariance flux tower observations from the La Thuile FLUXNET synthesis, and validated by comparing against independent flux tower observation sites. L4C NEE uncertainty estimates are provided as a standard data field and found to significantly explain root mean square error (RMSE) variability across flux tower locations. The L4C fluxes compare favorably with other global carbon observations from satellite-based solar-induced fluorescence and atmospheric inversions. A model sensitivity analysis confirmed the global importance of soil moisture on NEE. The L4C product captures ecosystem impacts from recent climate anomalies, underscoring the benefit of improved soil moisture information for monitoring land-atmosphere carbon exchange.

Presentation Type: Poster
Airborne Eddy Covariance Measurement of Greenhouse Gas Fluxes: A Bridge from Flux Tower to Landscape Scales

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Airborne eddy covariance is a powerful observational tool capable of providing a near-direct measurement of surface-atmosphere exchange at ecosystem and policy relevant scales of 1 – 100 km. Our group has assembled and flown a system for eddy covariance measurements of CO2, CH4, H2O, and heat fluxes based on the NASA Sherpa aircraft. The Sherpa provides a versatile, economical platform for measuring greenhouse gas (GHG) fluxes to be used in evaluating top-down and bottom-up source/sink estimates for a wide range of applications, including evaluation of biophysical process models and their parameterizations as well as validation of top-level satellite flux products from OCO-2 and other carbon space missions. The initial system test and science flights took place in Sept 2016 based out of Wallops Flight Facility, VA. The flight series was a near-complete success across a variety of ecosystems and including several flux tower fly-bys. Data analysis is underway. Additional flights are planned for Spring (Apr-May) 2017 under support from the NASA Carbon Monitoring System Program.

Here we report on the development and objectives for the airborne system along with an overview of the initial results. The primary goal for the 2016 flight series was to demonstrate surface flux measurement ability for this new airborne system. We were also able to explore some of the limitations of the method (e.g., turbulent boundary layer and representative horizontal statistics required) and operational and time/space coverage limits on airplane deployment. Comparisons to model output will inform us as to how well the flux observations constrain model process representation and to what extent they characterize model errors. The Spring 2017 flights will begin to establish the representativeness of the experimental capability over a seasonal time frame. Continued data and model analysis, combined with satellite remote sensing, and an expanded set of airborne flights will provide an enhanced capability for quantifying net carbon emissions/storage and its uncertainties across a broader range of ecosystems and conditions.

Presentation Type: Poster
What’s missing in simulating vegetation-atmosphere carbon: Scaling from the individual to the globe in a demographic Dynamic Global Vegetation Model suited to LiDAR

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Vegetation biomass and activity are non-linear with plant height for woody plants. Site studies have demonstrated that accounting for the height demography in forest canopies significantly improves estimates of both. Dynamic global vegetation models (DGVMs) that couple with atmospheric general circulation models (GCMs) have been limited in their simulation of land carbon dynamics, as well as ecological dynamics, due to simplified representations of communities as “big leaf” or homogeneous stands. Plant demography - mixed vegetation communities - is only beginning to be introduced into such coupled models, by representing canopies in cohorts binned by height class. However, global data sets to validate their simulated vegetation communities are not available. The Ent Terrestrial Biosphere Model (Ent TBM) is a demographic DGVM coupled to the NASA Goddard Institute for Space Studies (GISS) GCM. To evaluate the model against observations, we have constructed a first version of the Ent Global Vegetation Structure Data Set (Ent GVSD) that describes plant densities by plant functional types (PFTs) derived from canopy heights from ICESat/GLAS LiDAR observations by Simard et al. (2011). This first version of the data set serves as the reference case of homogeneous canopies but with global variation in canopy heights and plant densities. We first evaluate vegetation physical properties and activity with the Ent GVSD as a boundary condition; simulated canopy albedo via the Analytical Clumped Two-Stream (ACTS) canopy radiative transfer component of the Ent TBM compared to MODIS snow-free visible and near-infrared albedo; vegetation biomass compared to inventory estimates; equilibration of carbohydrate reserve pools with climate as a test of equilibrium vegetation structure; surface-atmosphere carbon fluxes; and soil carbon compared to literature estimates and other models. Providing satellite-observed vegetation structure via the Ent GVSD leads to much faster equilibration of plant carbon reserve pools compared to a prior prescription of the GISS GCM ModelE, and excellent prediction of albedo. We analyze strengths and weaknesses pertaining to particular PFTs, seasonal diagnostics, and model biases. Next versions of the Ent GVSD will incorporate canopy height stratification of mixed communities and forest types with demography derived from ecological theory.

Presentation Type: Poster
A joint land-atmosphere carbon data assimilation system

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After decades of effort, significant uncertainties remain in the global surface carbon fluxes. In recent years, observations of the global carbon cycle in the atmosphere and on land have all intensified dramatically. It is essential to use these data for quantifying the contribution of global surface carbon fluxes. A novel joint land-atmosphere carbon data assimilation system is developed to simultaneously handle multiple modeling components and multiple streams of data. This joint assimilation system consists of an atmosphere transport model - GEOSChem, a terrestrial model – VEGAS, and a 4D-LETKF data assimilation module.

The GEOSChem model provides the 'top-down' atmosphere approach to estimate the surface carbon fluxes by assimilating atmospheric carbon observations, such as GlobalView surface flask observations, tower, aircraft and satellite observations including OCO-2

The VEGAS model provides the 'bottom-up' approach by constraining the model parameter uncertainty as well as the terrestrial carbon flux to atmosphere by assimilating land observations like satellite vegetation index, sun-induced fluorescence (SIF), and other surface-based observations for biosphere productivity.

We estimate surface carbon fluxes in each of the above components separately in an OSSE framework to investigate the possibility and limitations of the 'top-down' versus the 'bottom-up' approaches. We then combine the two approaches together through both model coupling and data assimilation coupling to provide the best constraint for estimating the global surface carbon fluxes.

Presentation Type: Poster
Evaluating a low-cost NDIR CO2 sensor for use in urban greenhouse gas monitoring

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Non-dispersive infrared (NDIR) sensors are a low-cost way to observe carbon dioxide concentrations in air, but the accuracy and precision “off the shelf” are insufficient for some scientific applications. An initial evaluation of six SenseAir K30 carbon dioxide NDIR sensors in a laboratory setting showed that without any calibration or correction, the sensors have an individual root mean square (RMS) error between ~5 to 21 parts per million (ppm) when compared to a research-grade greenhouse gas analyzer using cavity enhanced laser absorption spectroscopy. Through further evaluation, after correcting for offset and environmental variables with coefficients determined through a multivariate linear regression analysis, the calculated difference between the each of six individual K30 NDIR sensors and the higher-precision instrument had, for one minute data, a RMS error of between 1.6 ppm and 4.4 ppm. The median RMS error improved from 8.08 for off the shelf sensors to 1.89 ppm after correction and calibration, demonstrating the potential to provide useful information for ambient air monitoring. Some of these sensors have been deployed in a few locations around the Baltimore/Washington DC area and time series of these datasets will be shown.

Presentation Type: Poster
Validating the Ecosystem Demography Model Version2 for Southern Pine Forests

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The interconnected nature of climate change necessitates models with fine resolution and global coverage. Our understanding of ecosystem processes is constantly evolving and our understanding of model uncertainty and parameter error needs to grow at the pace of scientific inquiry. These two conditions are met by the Ecosystem Demography version 2 (ED2) model and the Predictive Ecosystem Analyzer (PEcAN). ED2 models fine-scale dynamics to capture ecosystem-level effects. PEcAN is a workflow that quantifies and minimizes uncertainty in parameters and predictions. Southern pine forests are of ecological and economic significance, hosting productive native forests and a thriving pine plantation industry. Models that can accurately represent the southern pine forest’s ecological processes are important for predicting how forest biodiversity and ecosystem services respond to the simultaneous impacts of forest management, invasive species, and climate change. Using PEcAN, we were able to asses ED2’s ability to model southern pine forests by benchmarking against the control plots from Duke’s Free-Air CO2 Enrichment (FACE) experiment.

Presentation Type: Poster
Constraining Belowground Carbon Turnover Times in Terrestrial Ecosystems: Insights Gained through Radiocarbon Analysis and Interpretation at AmeriFlux Network Sites

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Land-model data comparisons show that models tend to underestimate mean transit time of carbon in terrestrial ecosystems relative to measurement-based estimates largely through an underestimation of soil carbon turnover times. Radiocarbon measurements of multiple quantified pools and fluxes combined with the belowground carbon and radiocarbon modeling tool, SoilR, can provide more robust estimates for transit times than simple, single pool models reliant on assumptions of steady-state and a single time-lag. In addition, this approach can constrain carbon cycles contributing to measured transit times. Well-instrumented sites provide an excellent opportunity to combine existing data, new measurements, and modeling to constrain terrestrial ecosystem turnover times and the mechanisms behind them. Existing soil radiocarbon and carbon stock data from sites in the AmeriFlux Network are being synthesized and reanalyzed using a belowground carbon radiocarbon-modeling tool, SoilR. Current work focuses on five temperate deciduous forests. Of these, four sites were part of the Enriched Background Isotope Study, a 14C-enriched litter decomposition experiment, which will provide additional data for SoilR model validation. These observed soil profiles are also being compared to model values from CLM and ALM. Additional data, archived samples, and new sampling sites are of interest for future efforts.

Keywords: carbon cycle, forest, soil carbon, synthesis, soil carbon model, model-data comparison

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Presentation Type: Poster
Alternative carbon allocation models for the Community Land Model: testing with multiple data streams in temperate forests.

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Understanding the controls of carbon (C) allocation to different plant tissues (leaves, stem and roots) remains a central challenge for understanding long term storage of C in terrestrial ecosystems, as it determines C residence time. While networks of flux towers have provided extensive and intensive information on short-term controls of carbon uptake and storage, repeated measurements of total or component carbon stocks are relatively rare. We investigated alternative approaches to modeling carbon allocation in temperate forests by combining a modeling study with a novel dataset of biomass estimated using tree ring analysis at AmeriFlux sites. We ran the Community Land Model (CLM) for seven temperate forests in North America (including evergreen and deciduous sites) between 1980 and 2013 using different C allocation schemes: i) standard C allocation scheme in CLM, which allocates C to the stem and leaves as a dynamic function of annual Net Primary Production (NPP); ii) two fixed C allocation schemes, one representative of evergreen and the other one of deciduous forests, based on Luyssaert et al. (2007); iii) an alternative C allocation scheme, which allocated C to stem and leaves, and to stem and coarse roots, as a dynamic function of annual NPP, based on Litton et al. (2007). To evaluate these alternative model structures, we used a diverse set of observations (AmeriFlux eddy covariance towers, AmeriFlux biometric data, biomass estimates from tree-ring data, and Leaf Area Index measurements) to compare C fluxes, pools, and Leaf Area Index (LAI). CLM overestimated LAI in both evergreen and deciduous sites because the Leaf C-LAI relationship in the model did not match the observed Leaf C-LAI relationship in our sites so this relationship was modified for subsequent analyses. CLM generally overestimated Gross Primary Production and Ecosystem Respiration, and underestimated Net Ecosystem Exchange. Initial aboveground biomass in 1980 was similar to measurements for evergreen forests but was overestimated for deciduous forests. For deciduous forests, one of the alternative C allocation schemes used (based on Litton et al. 2007)) gave more realistic C stem/C leaf ratios, and highly reduced the overestimation of

Presentation Type: Poster
Quantifying planetary photosynthesis using satellite upscaling of tower based fluorescence-photosynthesis relationships

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The Grand Challenge of C Cycle Science is to understand how net terrestrial biosphere carbon uptake will evolve under future climate change and how this will impact atmospheric CO2 concentrations. Reducing uncertainties in the terrestrial biosphere C budget requires new methods to estimate and constrain the overall rate of GPP and improve the representation of seasonal phenology. Solar induced chlorophyll fluorescence (SIF) measures a direct outcome of foliar light absorption by chlorophyll, modified by biochemical feedbacks, and provides a direct proxy for the timing, duration, amplitude, and variability of photosynthesis. Recently available satellite-derived SIF observations have provided insight on environmental and phenological controls of seasonal CO2 fluxes at planetary scale and have improved quantification of CO2 balance. However, leaf-to-canopy extrapolation, biome level temporal and spatial scaling, influences of environmental conditions including water and temperature stress, radiative transfer, and relation of SIF to GPP across vegetation types and varying soil & climate conditions remain poorly quantified, and therefore limit the power of spaceborne SIF systems to monitor GPP. Here, we demonstrate with continuous GPP, SIF, and APAR data collected at Harvard Forest from 2013-2014 how field-deployable SIF spectrometers at established eddy covariance flux tower sites can help validate and refine mechanistic relationships between SIF and GPP by optimizing light use efficiency and SIF yield parameters, thereby maximizing the quantitative and predictive power of the growing number of existing (GOSAT, GOME-2, OCO-2) and planned (TROPOMI, ECOSTRESS, OCO-3, GEOCARB) satellite SIF observations for broader integrated analysis of planetary photosynthesis.

Presentation Type: Poster
Vertical propagation of the CO2 flux signal from in situ versus GOSAT data

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The recent expansion of the global CO2 observation network by new satellite missions (GOSAT in 2009, OCO-2 in 2014, TanSat in 2016) raises the tantalizing prospect of retrieving fluxes on finer (regional) spatial scales. Satellite measurements have more dense global spatial coverage compared to the in situ network but they see vertically integrated concentrations. In order to use satellite measurements to retrieve surface fluxes, a transport model is needed to connect the local scales of the fluxes to the global scales seen in the column and fill in the missing vertical structure. Thus a better understanding of transport model errors is needed, particularly in the vertical direction. In this work we study the vertical propagation of the flux signal in CO2 distributions. The flux estimates are derived from GEOS-Chem 4DVar flux inversions from either an in situ network or from GOSAT. Despite the uniform vertical sensitivity of GOSAT data, in situ data (which mainly sense the near-surface) are found to inform the mid to upper troposphere better than GOSAT data does. The persistent observation of the northern hemisphere land masses by in situ measurements produces flux signals that are carried upward and equatorward by the atmospheric model, improving the tropical CO2 field. Since a good depiction of the entire depth of the troposphere is needed to optimally extract information from satellite measurements, in situ measurements will be important for retrieving fluxes on finer spatial scales observed from satellites.

Presentation Type: Poster
Recent studies have shown an increase in the area covered by secondary tropical forests. These forests play a fundamental role in atmospheric carbon sequestration, and in the climate change mitigation. The determination of carbon accumulation potential of secondary tropical forests requires the utilization of mathematical models for estimation of tree biomass. Allometric equations have been proposed at global and regional scales, but frequently their use have produced large uncertainties in biomass estimation, since forests growth conditions and species composition differ from one site to another. We generated total biomass equations for tree species of secondary tropical forests in the Yucatan Peninsula, Mexico. We harvested 220 individuals of 22 tree tropical species with diameter at breast height ≤ 10 cm (DBH, cm). Eight models were fitted, from which two showed the best parameters of goodness of fit. The first, included DBH and total eight (H, m), and the mathematical form was $B = \exp(-\beta_0 (DBH^2 H)^{\beta_1})$. The second, included in addition to DBH and H, the wood density (Db, cm$^3$) with the structure of $B = \beta_0 (Db DBH^2 H)^{\beta_1}$. Both models explained the 92 and 95 % variance in total biomass. We compared the generated equations with the generic model proposed by Hughes et al. (1999) for similar tree size. The Hughes model estimated the biomass with an error ranging from 15.4 to 44.5 %, while the biomass estimation with the equations form study showed an error from 0.24 to 0.69 %. The generated models at local level are reliable for estimating biomass and carbon stocks for secondary tropical forests in Yucatán Peninsula.

Presentation Type: Poster
Vapor pressure deficit does not drive the seasonality of del13C of the net land-atmosphere CO2 exchange across the United States

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The seasonal pattern of the carbon isotope content (δ13C) of atmospheric CO2 depends upon local and non-local land-atmosphere exchange and atmospheric transport. Previous studies suggested that the δ13C of the net land-atmosphere CO2 flux (δsource) varies seasonally as stomatal conductance of plants responds to vapor pressure deficit of air (VPD). We studied the variation of δsource at 7 sites across the United States representing forests, grasslands and an urban center. Using a 2-part mixing model we calculated the seasonal δsource for each site after removing background influence and, when possible, removed δ13C variation of non-local sources. When comparing to previous analyses, we found a reduced seasonal amplitude in δsource (March-September) at the forest sites with little change during the growing season (0.5 ‰ increase). This small variation occurred despite significant seasonal changes in VPD at these sites, providing evidence that stomatal response to VPD is not a dominant influence upon the δ13C of land-atmosphere exchange in these forests. The grassland and urban sites had a larger seasonal variation in δsource (5 ‰) dominated by seasonal transitions in C3/C4 grass productivity, and seasonal timing of fossil fuel emissions, respectively. We conclude the land-atmosphere carbon exchange flux (net ecosystem exchange), and not its isotopic composition (δsource), is the primary driver of the seasonal pattern in δ13C of land-atmosphere CO2 exchange across the continental United States. This has important implications for studies that use δ13C of land-atmosphere exchange to constrain large-scale carbon fluxes.

Presentation Type: Poster
Use of Sidescan and Parametric Sonar Data for Seagrass Carbon Estimation

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Recent studies have shown that seagrass meadows are a globally significant carbon (C) stock, with about twice the average organic C storage per hectare as terrestrial soils. Occupying less than 0.2% of the world’s oceans, they contribute to ~10% of oceanic C burial. Unfortunately, seagrass is also among the world’s most rapidly disappearing coastal ‘blue carbon’ ecosystems. And yet, uncertainties in the estimates of seagrass C hinder the development of monitoring, reporting and verification (MRV) frameworks for blue carbon climate mitigation projects. There is an uncertainty of a factor of 2 in the current estimate of global seagrass C storage. C in seagrasses is predominantly stored in the soil sediments underlying the meadows, with less than 10% on average are in living biomass. A major reason for the uncertainty is that seagrass C pools are generally estimated from very sparse point-based sediment core sampling and visually conducted diver surveys. There are currently no spatially continuous methods of estimating seagrass C pools.

We have developed a novel technique of using hydro-acoustic data from sidescan sonars to map seagrass areas in high spatial resolution, combined with ground-penetrating parametric sonar data to estimate the profiles of carbon-rich sediment layers under seagrass bed. Combining the sidescan and parametric data in a GIS framework can provide a 3-dimensional map of seagrass C pools. Satellite-based optical remote sensing data can then be used to spatially extrapolate the sonar-based C storage information across seagrass meadows. We have tested our newly developed methods in the seagrass beds of Laguna Madre coastal lagoon, off of Texas shorelines of the Gulf of Mexico. Use of this new technology in seagrass C assessment and the results of our study will be presented in this talk.

Presentation Type: Poster
Atmospheric Flux Inversions of XCO2 and Solar-Induced Fluorescence (SIF) from OCO-2; moving towards mechanistic validation of atmospheric flux inversions

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The OCO-2 satellite was launched on July 2, 2014, to monitor global atmospheric concentration and flux of CO2 from space. We present a novel new atmospheric inversion scheme that solves for respiration and gross primary production (GPP) using a decomposition of multiplicative biases into seasonal harmonics in combination with solar induced fluorescence. We anticipate the separation of flux terms into mechanistic components will facilitate comparison to independent estimates such as eddy covariance data and inventory based data such as crop yields. Initial CO2 flux results for the time period of September 2014 to August 2016 will be presented with a focus on temporal corrections to the a priori fluxes over North America.

Presentation Type: Poster
Leaf optical properties shed light on foliar trait variability at individual to global scales

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Recent syntheses of large trait databases have contributed immensely to our understanding of drivers of plant function at the global scale. However, the global trade-offs revealed by such syntheses, such as the trade-off between leaf productivity and resilience (i.e. "leaf economics spectrum"), are often absent at smaller scales and fail to correlate with actual functional limitations. An improved understanding of how traits vary within communities, species, and individuals is critical to accurate representations of vegetation ecophysiology and ecological dynamics in ecosystem models. Spectral data from both field observations and remote sensing platforms present a potentially rich and widely available source of information on plant traits. In particular, the inversion of physically-based radiative transfer models (RTMs) is an effective and general method for estimating plant traits from spectral measurements. Here, we apply Bayesian inversion of the PROSPECT leaf RTM to a large database of field spectra and plant traits spanning tropical, temperate, and boreal forests, agricultural plots, arid shrublands, and tundra to identify dominant sources of variability and characterize trade-offs in plant functional traits. Our project has three major findings: (1) RTM absorption coefficients that are empirically calibrated are less accurate than those that are set to the actual absorption features of the underlying molecules; (2) Optical traits related to leaf size and function (pigments, water content) occupy a separate axis of variability to traits related to leaf recalcitrance (mass per area, lignin, C:N ratio); and (3) Variability in optical traits is comparable within and among species, and the contributions of additional variables to explaining this variability are highly trait-dependent.

Presentation Type: Poster
Solar-induced chlorophyll fluorescence from the Orbiting Carbon Observatory-2: Overview of the retrieval and biophysical performance

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The Orbiting Carbon Observatory-2 (OCO-2) satellite was successfully launched in July 2014. Although its primary objective is to measure the column-averaged mixing ratio of CO2, the OCO-2 spectrometers are capable of acquiring high-resolution spectra that allow for retrieval of the solar-induced chlorophyll fluorescence (SIF), a functional proxy for terrestrial gross primary productivity (GPP). Compared to existing space-borne instruments that are used for SIF retrievals, e.g., the Japanese Greenhouse Gases Observing Satellite (GOSAT) and the European Global Ozone Monitoring Experiment-2 (GOME-2), the data acquisition frequency of OCO-2 is considerably higher and the ground footprint is substantially finer. This combination of vastly improved number of measurements and spatial resolution of OCO-2 represents an advance for using space-borne SIF to study fine-scale ecological phenomenon but comes at the cost of a lack of continuous global coverage. Here we evaluate the initial two years (September 2014 onward) of OCO-2 SIF, which is retrieved by fitting the solar Fraunhofer lines within two micro-windows at 757nm and 771nm in the vicinity of the O2 A band. We demonstrate the retrieval and biophysical performance of OCO-2 SIF by comparing it with retrievals from GOSAT and GOME-2 and by examining its relationship with FLUXCOM and MODIS GPP datasets. Our results show that the OCO-2 SIF, along with the GOSAT products, closely resemble the mean spatial and temporal patterns of FLUXCOM GPP from regions to the globe. Compared with GOME-2, however, OCO-2 depicts a more realistic spatial contrast between the tropics and extra-tropics. This is most likely due to OCO-2’s smaller footprint which reduces the sub-pixel cloud contamination as well as its retrieval at wavelengths that minimize the SIF reabsorption within canopy. The retrieval precision of OCO-2, compared to GOSAT, is considerably improved, owing to both the improved single-measurement precision and data acquisition frequency. Consistent with previous findings at coarser resolutions (e.g., GOSAT, GOME-2), the linear relationship between OCO-2 SIF and GPP diverges somewhat across biomes, which has implications for scaling up GPP based on SIF. Overall, the OCO-2 SIF products are robust and valuable for monitoring the global terrestrial carbon cycle and for constraining the carbon source/sink strengths of the Earth system. Specific recommendations are made with respect to potential applications of the OCO-2 SIF products and synergistic use with other datasets. Finally, insights are offered for future satellite missions optimized for SIF retrievals based on our analysis.

Presentation Type: Poster
Reconciling the relationship between solar induced fluorescence and photosynthesis by upscaling leaf to canopy scales

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There is an emerging need to understand the variation in the relationship between solar induced fluorescence (SIF) and canopy photosynthesis as the satellite-based SIF data are being widely used to map the regional and global gross primary production (GPP). Without mechanistic understanding of this relationship and its variation diurnally and seasonally at the leaf to canopy scales, the satellite SIF cannot be fully interpreted and validated. We measured chlorophyll fluorescence and SIF at the leaf scale using a traditional pulse amplitude modulation fluorometer and a novel portable SIF system, respectively, and SIF at the canopy scale using a newly developed SIF measurement system at the Harvard Forest throughout the growing season. We also measured photosynthesis at the leaf scale and GPP from the eddy covariance data. We retrieved the full-wavelength SIF spectrum and calculated the red and infrared SIF peaks. We upscaled the leaf SIF to canopy SIF using a canopy radiative transfer model and then compared leaf-upscaled canopy SIF, directly measured canopy SIF, and canopy GPP. Our results suggested that directly measured canopy-SIF correlated well with canopy GPP at the seasonal pattern, but the leaf-upscaled canopy-SIF better reflected the diurnal pattern of GPP. We built a SIF model to simulate GPP that counts for the variation of the relationship between SIF and GPP diurnally and seasonally.

Presentation Type: Poster
Modeling terrestrial carbon dynamics by dominant plant traits and community assemblage in an Earth System Modeling framework

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Current Earth System Models (ESMs) lack the representation of plant community dynamics in their land models, which hampers their ability of capturing long-term ecosystem carbon dynamics, making them unable to realistically predict transient changes in vegetation and the feedbacks between the terrestrial carbon cycle and climate at decadal to century scales. We have developed a theoretical model of 'evolutionarily stable strategy' (ESS) based on individual plant competitions and feedbacks between plant traits and biogeochemical cycles to predict dominant vegetation types by identifying the most competitive combinations of plant traits. We implement this model in the Ent Terrestrial Biosphere Model (Ent TBM), the land ecosystem component of the NASA Goddard Institute for Space Studies (GISS) ESM, to simulate vegetation dynamics and terrestrial carbon storage as a result of changes in dominant plant traits and community assembly. We tested this model at the sites of temperate and boreal forests. Simulation results show that this model captures the successional dynamics of forests and the competitively optimal strategies at given abiotic conditions drive ecosystem carbon storage.

Presentation Type: Poster
Examining Error Structures in an Inversion Framework

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There are two primary conceptual frameworks for estimating surface carbon fluxes, bottom-up and top-down. Inventories are a bottom-up method of estimation, favored by climate policymakers, that build on estimates of carbon stocks in an area, such as crop yields or tree measurements. This method tends to be high quality where applicable, and to have high spatial resolution, but the temporal resolution tends to be annual or multiannual, and it is available mostly for crops and managed forests, with little or no data for grasslands or most wetlands. Another bottom-up method uses biogeochemical models to simulate vegetation on land and microorganisms in the ocean. The pathways and parameterizations used by these models are not well understood, and the related errors would tend to become more important for larger areas. Top-down methods, also called atmospheric inversions, apply additional constraints on these estimates using atmospheric concentration data and assumptions on the errors in the observation, transport, and initial estimate. This method has been useful for checking bottom-up estimates at various scales; however, which assumptions were made can have a large impact on the final result. This work studies those assumptions: whether existing data provide enough information to estimate some features, for example, length scale, of the error structures and to detect violations of the assumptions. To this end, a regional inversion framework solving for the error correlation length scale is presented with tests using synthetic pseudo-data. These tests are run twice; once with the spatial covariance function used in the inversion being the same as was used to generate noise in the flux fields, and once with these two functions being different. Systematic differences between these two test runs indicate what can check the form of the spatial covariance function.

Presentation Type:  Poster
NPP model fitting in the frequency domain for CO2 flux partitioning, gap-filling and linking with remote-sensing data in northern ecosystems

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The boreal and arctic regions are experiencing rapid warming trends likely to affect the carbon balance of these regions. While a “greening” trend, has sometimes been observed in response to temperature increase, there is growing concern that these ecosystems may run into a water limitation, causing reduced productivity and “browning” in response to warming.

Boreal and artic ecosystem carbon fluxes present several data processing challenges, in part due to their highly dynamic ecosystems and low signal-to-noise. Fluxes partitioning and gap-filling are two processing steps that can contribute to measurement error (Richardson et al. 2006), yet are key to linking tower-derived flux estimates with large-scale datasets such as remotely-sensed data. However, their current implementations are ill-suited to boreal and artic ecosystems as they rely on non-linear model fitting over moving windows, which constrains both the photosynthesis and respiration processes over the same temporal scale.

We developed a new model-fitting framework based on non-linear fitting in the frequency domain to derive the parameters of the NPP models as continuous functions of time. This enables the parameters relating to different processes to vary at different time scales, and provides continuous outputs that can be used for gap filling or that can be compared to measurements done at a different scales such as remote-sensing measurements.

This framework can deconvolve between 72 and 96% of the NPP variability into GPP and Reco. The obtained results are being compared to the FLUXNET estimates and linked with remote-sensing data derived from the MAIAC dataset. Such an approach could be extended to the spatial dimension so that surrounding flux towers can inform the partitioning and gap filling process. The method can be inverted from remotely sensed data for large-scale assessment of photosynthetic phenology and productivity over the ABoVE Domain.

Presentation Type: Poster
Corrected vegetation indices from MODIS MAIAC for photosynthetic phenology assessment in the ABoVE Domain

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In the face of rapid climate warming and longer growing seasons, productivity of northern ecosystems could increase. On the other hand, climate change can also lead to increased drought and disturbance, leading to reduced productivity. We need appropriate indicators to examine how climate change is affecting high latitude vegetation through changing phenology and productivity. One approach to assessing phenology and productivity involves the use of satellite vegetation indices (e.g. NDVI, EVI, CCI). In the high latitudes of the ABoVE Domain, multiple daily observations are made by MODIS Aqua and Terra satellites. A main challenge of satellite observations at high latitudes is that large and varying solar zenith angles (SZA) and view zenith angles (VZA) strongly influence the magnitude of vegetation indices derived from reflectances. To increase the accuracy of detecting seasonal and long term changes of phenology and productivity at high latitude regions, we are investigating indices corrected for viewing geometry.

This study employed a machine learning approach - random forests (RF) to minimize the influence of SZA and VZA on the variation of indices at 62 flux sites and six vegetation types in Canada and Alaska. Corrected indices are calculated by using RF to remove the viewing geometry influence on vegetation indices from satellite observations. RF models for CCI, NDVI, and EVI perform well with R-squared values between satellite observations and the out-of-bag predictions of 0.898 (p=0.000), 0.983 (p=0.000), and 0.933 (p=0.000), respectively. The model performance varies across sites, which is strongly related to the quality of satellite observations at each site. Based on this site level analysis, our next steps will be to use these methods to evaluate phenology and productivity relationships across the ABoVE domain. Future work is also needed to further verify corrected indices with independent data (e.g. ground optical measurements truth and solar-induced fluorescence).

Presentation Type: Poster
Evaluating Productivity Predictions Under Elevated CO₂ Conditions: Multi-Model Benchmarking Across FACE Experiments Using PEcAn

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As atmospheric levels of carbon dioxide levels continue to increase, it is critical that terrestrial ecosystem models can accurately predict ecological responses to the changing environment. Current predictions of net primary productivity (NPP) in response to elevated atmospheric CO₂ concentration are highly variable and contain a considerable amount of uncertainty. Benchmarking these model predictions against data are necessary, not only to assess individual models on their ability to replicate observed patterns, but also to identify and evaluate the assumptions causing inter-model differences. However, to keep up with the rate at which models are being developed, the ecosystem modeling community needs to be able to perform large scale model intercomparisons at a higher frequency than previously possible.

The Predictive Ecosystem Analyzer (PEcAn) is an informatics toolbox that wraps around an ecosystem model and can be used to help identify which factors drive uncertainty. We used PEcAn to perform a model intercomparison using models that represent a range from low to high structural complexity, across a range of Free-Air CO₂ Enrichment (FACE) experiments which provide a wide range of ecosystem properties at scales that are directly comparable to models. These tests were implemented in a novel benchmarking workflow that is automated, repeatable, and generalized to incorporate different sites and ecological models. Observational data from the FACE experiments represent a first test of this flexible, extensible approach aimed at providing repeatable tests of model process representation that can be performed quickly and frequently.

Combining the observed patterns of uncertainty between multiple models with results of the recent FACE-model data synthesis project (FACE-MDS) can help identify which processes need further study and additional data constraints. These findings can be used to inform future experimental design and in turn can provide informative starting point for data assimilation.

Presentation Type: Poster
Magnitude and Uncertainty of Carbon Pools and Fluxes in the US Forests

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Assessment of the carbon sinks and sources associated with greenhouse gas (GHG) fluxes across the US forestlands is a priority of the national climate mitigation policy. However, estimates of fluxes from the land sector are less precise compared to other sectors because of the large sources of uncertainty in quantifying the carbon pools, emissions, and removals associated with anthropogenic (land use) and natural changes in the US forestlands. As part of the NASA’s Carbon Monitoring System, we developed a methodology based on a combination of ground inventory and space observations to develop spatially refined carbon pools and fluxes including the gross emissions and sequestration of carbon at each 1-ha land unit across the forestlands in the continental United States (CONUS) for the period of 2006-2010. Here, we provide the magnitude and uncertainty of multiple pools and fluxes of the US forestlands and outline the observational requirements to reduce the uncertainties for developing national climate mitigation policies based on the carbon sequestration capacity of the US forest lands.

Presentation Type: Poster
Tidally-restricted coastal wetlands as a hotspot for carbon dioxide and methane emissions, and as a potent and untapped opportunity for anthropogenic emissions reductions

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Relative to other ecosystems, tidal wetlands display a high rate of long-term carbon storage, build large soil carbon stocks, and, where they are polyhaline, they are typically a minor source for methane. Thus, saline wetlands generally have a strong cooling effect on climate, and there is increasing interest in the science and management of carbon in coastal marine ecosystems (sometimes referred to as “Blue Carbon”). However, carbon cycle processes in tidal wetlands are sensitive to variations in physical conditions, and a range of disturbances can alter the rate and direction of net carbon and greenhouse gas exchange with the atmosphere. An important, but under-examined, disturbance that is critical to net carbon dioxide and methane flux is human-caused restriction of tidal water exchange between wetland and the coastal ocean. Blockage or restriction of tidal flows, through installation of dikes or tide gates, has been a globally-widespread practice for centuries, as a method to protect coastal infrastructure, to drain wetlands for farming and development, or to raise water tables and lower salinity for aquaculture, rice production, and mosquito and wildfowl management. Inadvertent tidal restrictions are also widespread and occur due to road, railroad and other infrastructure development, with affected wetlands often becoming freshened and flooded due to retention of freshwater drainage from the landscape. Under flooded or impounded conditions, if a sufficient decrease in water salinity occurs, then a substantial increase in CH4 emissions is likely to occur. Wetland drainage, on the other hand, exposes soil to oxygen, and promotes aerobic microbial respiration of C stocks that have accumulated over centuries to millennia. Drainage-associated soil CO2 emissions are intense per unit area, and drained tidal wetlands are significant drivers of climate change. In this presentation we will present estimates of the spatial scale of tidally-restricted wetlands in developed landscapes, and estimates of the magnitude of resulting anthropogenic carbon dioxide and methane emissions.

On the U.S. Atlantic coast, we estimate that GHG emissions in roughly 30% of tidal wetlands (~2,900 km2) are affected by tidal restrictions, with emissions in the range of 10,500 to 53,000 tonnes (t) CH4 y-1 and 0.32 to 3.1 million t y-1 CO2. Further, we will discuss policy aspects, including consideration in national GHG inventories and the concept that the globally-widespread occurrence of hydrologically-altered, degraded wetlands, and associated enhanced GHG emissions, presents an opportunity to reduce an anthropogenic GHG emission through restoration.

**Presentation Type:** Plenary Talk
The surprising role of disturbance in maintaining forest carbon sequestration: Implications for carbon science, policy and management

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Forest disturbances, such as fire, weather, pests and pathogens, and harvest, occur along a continuum of severity, with important carbon science, policy and management implications. Though severe, forest-replacing disturbance is known to have lasting negative effects on carbon sequestration, lower severity disturbances, which are increasing in frequency and extent, exert very different short- and long-term effects on forest structure and carbon sequestration. In contrast to severe disturbances that kill all or most trees, recent North American-wide syntheses and site-level studies suggest many temperate forests are broadly resistant or highly resilient to low to moderate severity disturbances killing only a subset of trees. In the long-term, following the recovery of foliage and the reorganization of canopy structure that follows disturbance, forest carbon sequestration may even increase, demonstrating low to moderate severity disturbances’ capacity to, counter-intuitively, stimulate, rather than reduce, the land carbon sink. The underlying mechanisms supporting increased, rather than decreasing disturbance, following disturbance are not entirely clear, but may be improved plant resource acquisition mediated by disturbance-caused forest structural reorganization.

Post-disturbance stability or increases in forest carbon sequestration, if widespread, have far-reaching consequences for how carbon policy makers and managers approach disturbance. A highly resilient response to disturbance suggests that policy intended to prevent more moderate forest disturbances, such as those from insect pests and pathogens that target a single tree species, may be unnecessary to maintaining the land carbon sink. In addition, ecosystem structures coinciding with both increases in tree mortality and carbon sequestration may serve as useful templates for revised forest carbon management, or silviculture, seeking to balance the economic interests of wood harvest and carbon storage. We conclude that the carbon cycling community – including carbon scientists, policy makers, and managers – should embrace a more nuanced understanding of how disturbance alters forest carbon cycling trajectories.

Presentation Type: Plenary Talk
Disturbance is a critical determinant of whether forests are a source or sink of atmospheric carbon dioxide. Several forest disturbance products have been developed using time series Landsat data for North America. These include the North American Forest Dynamics (NAFD) study, an annual Canadian forest disturbance record, and global annual forest change maps produced by the Global Land Analysis & Discovery (GLAD) group. In addition, forest changes have been mapped at 5- to 10-year intervals for CONUS, Canada, and globally using Landsat observations.

This presentation will provide a synthesis of these Landsat-based analysis products for improved understanding of North American forest disturbances. We will provide an overview of the spatial and temporal patterns of major disturbance processes over North America, calculate forest disturbance rates as a function of various causal agents and varying disturbance intensity levels, and discuss the potential impact of these disturbances on North American forest carbon stock and fluxes. Lessons learned and future directions for monitoring North American forest disturbance will also be reviewed.

Keywords: Disturbance rate, intensity, causal agent, US, Canada

Presentation Type: Plenary Talk
Urbanization and forest fragmentation, two of the most globally pervasive disturbances to terrestrial ecosystems, are projected to become more prevalent in the coming decades as the human population grows and more people migrate toward cities. Urban land covers already comprise an area equal in extent to the temperate broadleaf forest and are projected to continue expanding. Though 20% of the world’s forest is within 100 m of a forest edge, much of our understanding of the terrestrial carbon cycle comes from large, intact rural ecosystems that are largely insulated from the disturbances of urbanization and fragmentation. Thus, when carbon cycle-climate feedback models consider the effects of urbanization and forest fragmentation, it is mainly through the lens of the biomass and carbon sinks that are lost with changes in land cover (e.g., deforestation), rather than possible perturbations to the carbon cycle within the urbanized and fragmented ecosystems that remain.

Using spatial analyses, remote sensing, landowner surveys and observational field studies, we characterize the effects of urbanization and forest fragmentation on the carbon balance in southern New England. We find that forest edges have greater rates of net primary productivity and carbon storage than intact forests, partially offsetting declines from the deforestation that created the forest fragments. However, we also find that fragmentation increases the climate sensitivity of forest productivity. In the highly fragmented landscape of southern New England where nearly 20% of the forest is within 20 m of an edge, accounting for this edge growth enhancement increases regional carbon sink estimates by 13%. By contrast, forest soil respiration is unaffected by fragmentation, but we find that soil respiration rates in nearby landscaped residential areas can be more than three times those in forests. Our findings suggest that carbon fluxes in rural ecosystems are not directly transferable to fragmented and urbanizing landscapes. Therefore, accurate quantification of regional and global carbon balance necessitates accounting for perturbations to carbon cycling imposed by these disturbances.

Presentation Type: Plenary Talk
Plant hydraulic regulation of response to drought and plot-scale canopy disturbance

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Above-ground water storage in trees plays a key role in regulating transpiration in forest canopies. Plants transpire water from the stem storage. As transpiration rates are higher than the maximal recharge rate from the soil through the roots, stem and branches, the above-ground storage becomes depleted and stomata close to restrict transpiration in response to the negative xylem water potential. These hydrodynamic limitations are known to control transpiration in forest ecosystems under both wet and dry conditions. As the intra-daily dynamics of soil moisture are slower and very different from the faster dynamics of water storage in the tree xylem, the diurnal dynamics of tree-water storage leads to the observed dynamics of transpiration.

We use data from a large-scale ecological disturbance experiment. We stem girdled all early successional trees in a 39Ha treatment plot (US-UMd). The disturbance created a new set of conditions with more intense light and transpirational demands for the remaining trees in the disturbed plot. An undisturbed plot (US-UMB) acts as a control. We instrumented 60-80 trees in each plot with sap-flow sensors and a small subset of these trees where fitted with a new type of tree-water storage sensor. We use 4 years of observations of soil moisture, atmospheric conditions, tree-level and plot-level sap-flux, transpiration, stomatal conductance and tree water storage to evaluate the species-specific responses to the canopy disturbance, and to short inter-storm dry periods, characterized by extremely dry soil.

We show that the hydraulic strategies, ranging between the two extremes of isohydric and anisohydric stomata regulation determine the species’ response to disturbance. We found that these leaf-level traits are coupled with xylem and rooting strategies, to create trait complexes that characterize the whole-plant hydraulic strategy. We found that isohydric species are less competitive under canopy disturbance when the soil is dry.

Presentation Type: Poster
Disentangling fire and climate forcing on woody encroachment in grasslands

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Woody encroachment is occurring in grasslands around the globe. It is well known that the stable end member states of grassland and woody cover are influenced by climate and disturbance regimes. Here, we investigate the temporal dynamics of woody encroachment in the central U.S. in relation to underlying variability in precipitation timing and magnitude as well as fire frequency. We have developed a water balance model in order to assess the stability of species composition using the maximum Lyapunov exponents approach. The model is validated using six years of eddy covariance data at a paired grassland and woody encroachment site at the Konza Prairie LTER site are used to verify carbon and water dynamics at the daily time scale. Woody fraction data in relation to fire frequency is assessed using historical LTER records. The maximum Lyapunov exponents are used to quantify the stability of state variables including soil moisture and vegetation and diagnose the presence of tipping points in relation to woody fraction, fire frequency and precipitation variability. The sensitivity of woody encroachment to the controlling parameters of fire frequency and precipitation timing and magnitude are assessed using 100-year simulations with varying parameters. We find that the role of fire frequency exerts a dominant control over precipitation variability across a wide range of the parameter space. Understanding these spatial and temporal dynamics is essential for understanding how these ecosystems may respond to future climate change.

Presentation Type: Poster
Drought, fire, insects, and management influences on mortality and forest carbon cycling over the western US

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Across the western US, our analysis of observations shows that long-term water availability is a key constraint on tree productivity, carbon storage and carbon residence time in mature forests1. During the recent dry decade, tree mortality was dominated by harvest (50%) followed by insects (beetles; 32%) and fire (18%), with harvest having the largest impact in the coastal states, and beetles having the largest impact in the intermountain states2. To make future projections of disturbance effects on the carbon cycle, we are modifying and implementing the Community Land Model (CLM4.5) at 4-km resolution to identify where forests will be vulnerable to large-scale tree mortality resulting from drought, beetles, anthropogenic disturbances (forest management), and the interactions among these factors. We are modifying CLM4.5 by 1) integrating climatic effects on tree mortality, 2) providing a mechanism for tree mortality from bark beetles, 3) improving the current fire module to represent fire at a fine spatial resolution, and 4) determining harvests with an explicit model of the wood products sector. We modified CLM4.5 for 15 forest types with unique physiological parameters3 rather than using broad plant functional types to improve representation of physiological response to climate4. We are developing a beetle population dynamics module based on climate-beetle relationships we have identified through statistical modeling of recent outbreaks5. Our harvest module given local and regional economic conditions performs well in tests outside of CLM4.5. Next, we will implement CLM4.5 across the western US and assess how these natural and anthropogenic disturbances and future climate may influence forest carbon storage.

Citations


Presentation Type: Poster
Disturbance Distance: Quantifying Forests Vulnerability to Disturbance Under Current and Future Conditions

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Disturbances, both natural and anthropogenic, are critical determinants of forest structure, function, and distribution. The vulnerability of forests to potential changes in disturbance rates remains largely unknown. We developed a framework for quantifying and mapping the vulnerability of forests to changes in disturbance rates. By comparing recent estimates of observed forest disturbance rates over a sample of contiguous U.S. forests to modeled rates of disturbance resulting in forest loss a novel index of vulnerability, Disturbance Distance, was produced. Sample results indicate that 20% of current U.S. forestland could be lost if disturbance rates were to double, with southwestern forests showing highest vulnerability. Under a representative future climate scenario the majority of U.S. forests showed increased resilience to disturbance, which may buffer some impacts of intensified forest disturbance.

Presentation Type: Poster
Grazing alters net ecosystem C fluxes and the global warming potential of a subtropical pasture

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The impact of grazing disturbance on C fluxes from pastures in subtropical and tropical regions, and on the environment is uncertain, although these systems store >25% of global organic C, and substantially contribute (>35%) to natural sources of CH$_4$ emitted to the atmosphere. We investigated how cattle grazing influences net ecosystem CO$_2$ and CH$_4$ exchange in subtropical pastures using the eddy covariance technique. Measurements were made over several wet-dry seasonal cycles in a grazed pasture, and in an adjacent pasture during the first three years of grazer exclusion. Grazing increased soil wetness but did not affect soil temperature. By removing aboveground biomass, grazing decreased ecosystem respiration ($R_{eco}$) and Gross Primary Productivity (GPP). As the decrease in $R_{eco}$ was larger than the reduction in GPP, grazing consistently increased the net CO$_2$ sink strength of subtropical pastures (55, 219 and 187 more C m$^{-2}$ in 2013, 2014 and 2015). Enteric ruminant fermentation and increased soil wetness due to grazers, increased total net ecosystem CH$_4$ emissions in grazed relative to ungrazed pasture (27% - 80%). Unlike temperate, and arid and semi-arid pastures where differences in CH$_4$ emissions between grazed and ungrazed pastures are mainly driven by enteric ruminant fermentation, our results showed that the effect of grazing on soil CH$_4$ emissions can be greater than CH$_4$ produced by cattle. Thus, our results suggest that we should incorporate the interactions between grazers and soil hydrology affecting soil CH$_4$ emissions from subtropical pastures in biogeochemical models to accurately predict the environmental impacts of this disturbance. Although grazing increased total net ecosystem CH$_4$ emissions and removed aboveground biomass, it increased the net storage of C and decreased the global warming potential of pasture by increasing its net CO$_2$ sink strength.

Presentation Type: Poster
Structural complexity and primary production resilience across a gradient of disturbance in a Great Lakes forest ecosystem

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Regrown temperate deciduous forests of the eastern United States have functioned as century-long carbon sinks, but their capacity to store carbon in the future is in question as these ecosystems broadly transition from early to middle stages of development. As forests age, tree mortality is increasing, substantially altering ecosystem structure and, possibly, the long-term trajectory of carbon sequestration. These structural shifts and their impact on carbon storage potential are important for land managers and policy makers to characterize as they work to forecast and plan for terrestrial carbon storage in the 21st century and beyond. The goal of this study was to determine what and why different structural and biological measures of complexity confer primary production resilience upon forest plots along a gradient of disturbance.

We used an experimental disturbance at the University of Michigan Biological Station to evaluate the mechanisms underlying long-term carbon sequestration stability or decline following moderate levels of disturbance severity. Using pre- and post-disturbance stem mapping as well as structural and biological metrics, carbon storage capacity is now being measured in response to forest complexity in this experimental stand. This ongoing experiment has pointed to a compensatory subcanopy contribution in response to moderate disturbance that sustains primary production up to a threshold of 60% basal area senescence. Though sustained primary production in these plots has been attributed to increased structural complexity induced by moderate disturbance, which allows for an intact subcanopy to access resources such as light, specific biological and physical measures of complexity conferring primary production have not been identified. However, mounting evidence from our site and others suggests that complexity is a critical characteristic predicting functional resilience in a number of forested ecosystems.

We found that disturbance increased forest structural complexity, which resulted in a broader array of within-in light conditions that drove diversification of leaf-level carbon capture properties. Following a comprehensive resurvey of 60% of FASET experimental plots in the summers of 2015 and 2016, we are investigating structural and biological complexity metrics within each plot. To date, we have found that while plant biological diversity indices do not vary significantly across the disturbance gradient, variability in both leaf mass per area (LMA) and leaf-level photosynthetic output increase with increasing disturbance severity. A possible non-linear increase in available photosynthetically active radiation (PAR) may be driving this widening cone of leaf-level physiological response with increasing disturbance severity.

Presentation Type: Poster
Contributions of wildland fire to terrestrial ecosystem carbon dynamics in North America from 1990 - 2012

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Burn area and the frequency of extreme fire events have been increasing during recent decades in North America, and this trend is expected to continue over the 21st century. While many aspects of the North American carbon budget have been intensively studied, the net contribution of fire disturbance to the overall net carbon flux at the continental scale remains uncertain. Based on national scale, spatially-explicit and long-term fire data, along with the improved model parameterization in a process-based ecosystem model, we simulated the impact of fire disturbance on both direct carbon emissions and net terrestrial ecosystem carbon balance in North America. Fire-caused direct carbon emissions were 106.55±15.98 Tg C/yr during 1990-2012; however, the net ecosystem carbon balance associated with fire was -26.09±5.22 Tg C/yr, indicating that most of the emitted carbon was re-sequestered by the terrestrial ecosystem. Direct carbon emissions showed an increase in Alaska and Canada during 1990-2012 as compared to prior periods due to more extreme fire events, resulting in a large carbon source from these two regions. Among biomes, the largest carbon source was found to be from the boreal forest, primarily due to large reductions in soil organic matter during, and with slower recovery after, fire events. The interactions between fire and environmental factors reduced the fire-caused ecosystem carbon source. Fire disturbance only caused a weak carbon source as compared to the best-estimate terrestrial carbon sink in North America owing to the long-term legacy effects of historical burn area coupled with fast ecosystem recovery during 1990-2012.

Presentation Type: Poster
Changing fire frequency and carbon consumption in Alaskan black spruce forests

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Changes to the fire regime in the boreal forests of Alaska have included increases in burned area and fire frequency over recent decades. These fire regime changes alter carbon storage and emissions, especially in the thick organic soils of black spruce (Picea mariana) forests, but there is uncertainty in the overall vulnerability of these landscapes to burning, especially in stands that burn while they are still immature (~<60 years old). A better understanding of both the vulnerability of immature stands, and of the carbon emissions impact of immature stands burning, is needed. In the research presented here we first assessed geospatial and remote sensing datasets from 167 interior Alaskan fire events between 2002 and 2008 to analyze the relationship of fractional burned area (representative of the total burned area within a fire perimeter) with fire-free interval (a measure of fire frequency), vegetation, topography and the seasonal timing of burning. We then analyzed how fire frequency impacts carbon consumption in Alaskan boreal forests using a modeling framework. Interestingly, it was found that the fraction of burned area differed between mature forested areas and immature non-forested areas within the analysis. Results showed that considerable burning in interior boreal regions occurs in stands not yet fully recovered from earlier fire events (~20% of burned areas are in immature stands). These newly determined results were then incorporated into the modeling framework through adding an immature black spruce fuel type and associated ground-layer carbon consumption values. This alteration to the model lead to higher ground-layer carbon consumption (and thus total carbon consumed) for areas that burned in two years with high total burned area in Alaska (2004 and 2005). These new results provide insight into the fire-climate-vegetation dynamics within interior Alaskan boreal forests and can be used to both inform and validate modeling efforts to better estimate soil carbon pools and emissions in interior Alaskan boreal forests.

Presentation Type: Poster
Capturing species-level drought responses in a temperate deciduous forest using ratios of photochemical reflectance indices between sunlit and shaded canopies

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To classify trees along a spectrum of isohydric to anisohydric behavior is a promising new framework for identifying tree species’ sensitivities to drought stress, directly related to the vulnerability of carbon uptake of terrestrial ecosystems with increased hydroclimate variability. Despite the recognition of the carbon consequences of anisohydric and isohydric strategies for individual tree species, there have been few studies regarding whether isohydric trees produces distinct spectral signatures under drought stress that can be remotely sensed. Here, we examined the capability of four vegetation indices (PRI, NDVI, NDVI705, and EVI) to capture the differences in spectral responses between isohydric and anisohydric trees species within a deciduous forest in central Indiana, USA. Both leaf-level spectral measurements and canopy-scale satellite observations were used to compare peak growing-season spectral signatures between a drought (2012) and a non-drought year (2013). At the leaf scale, two vegetation indices (NDVI and NDVI705) failed to capture the drought signal or the divergent isohydric/anisohydric behavior. EVI successfully captured the drought signal at both leaf and canopy scales, but failed to capture the divergent behavior between isohydric and anisohydric tree species during the drought. PRI captured both drought signals and divergent isohydric/anisohydric behavior at both leaf and canopy scales once normalized between sunlit (backward direction images) and shaded (forward direction images) portions of canopy, which indicates drought stress and subsequent photosynthetic downregulation are greater in the sunlit portion of canopy. This study presents a significant step forward in our ability to directly mapping emergent isohydricity at different scales based on divergent spectral signatures between sunlit and shaded canopies.

Presentation Type: Poster
Vulnerability of North American Boreal Peatlands to Wildland Fire

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Wildfire is a common natural disturbance factor in high northern latitude (HNL) ecosystems occurring primarily through lightning ignitions. However, there is evidence that frequency of wildfire in both boreal and Arctic landscapes is increasing with climate change. In 2014 Northwest Territories (NWT) Canada had a record breaking year of wildfire, burning over 3.4 million hectares of upland forests, peatlands, and even emergent wetlands. Fire activity occurred across seasons (spring, summer and fall) in the taiga shield and boreal plains. Similar large fire years have occurred in Alaska in 2004 and 2015. Increased drying due to climate change is increasing the vulnerability of wetlands, and in particular boreal peatlands, to wildfire. Such widespread wildfire activity could cause a shift in post-fire trajectories, and peatlands may transition from to net sinks to sources of C to the atmosphere. Field and remote sensing data have been collected in the North American boreal peatlands to better understand the fire weather, hydrology, and climatic controls on boreal peatland wildfires. The goal of the research is to improve our understanding of the controls and impacts of a changing climate on the vulnerability and resiliency of boreal-taiga ecosystems through intensive study. The landscape scale quantification of wildfire effects in boreal peatlands requires development of three important mapping and monitoring capabilities specific to peatlands including: 1) methods for mapping of peatland type (e.g. bog vs. fen) and level of biomass (herbaceous, shrub, forest dominated); 2) algorithms to map burn severity to the peat surface; and 3) algorithms for mapping pre- and post-burn soil moisture with synthetic aperture radar data. Through this work we aim to reduce uncertainties of the role of boreal peatland ecosystems in the global carbon cycle and to improve carbon emission estimates from boreal wildfires.

Presentation Type: Poster
Drought Response and Recovery: How Good Are Terrestrial Biosphere Models?

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Severe drought plays a critical role in altering the magnitude and interannual variability of the net terrestrial carbon sink. Drought events immediately decrease net primary production (NPP), and drought length and magnitude tend to enhance this negative impact. However, satellite and in-situ measurements have also indicated that ecosystem recovery from extreme drought can extend several years beyond the return to normal climate conditions. If an ecosystem’s drought recovery time exceeds the time interval between successive droughts, legacy effects may reinforce the impact of future drought. Since the frequency and severity of extreme climate events are expected to increase with climate change, both the immediate and prolonged impact of drought may contribute to amplified climate warming by increasing the suppression of NPP over greater areas. However, it is unknown whether terrestrial ecosystem models capture the impact of drought legacy effects on carbon stocks and cycling. Using a suite of thirteen land surface models from the Multi-scale Synthesis and Terrestrial Model Intercomparison Project (MsTMIP), we assess models’ ability to capture drought legacy effects by analyzing the modeled vegetation response to the 2000 - 2004 turn-of-the-century drought in North America. Simulated NPP recovery from drought is examined and compared with observed recovery in growth. Through correlation analysis of NPP and climatic water deficit, we find regional differences in the strength of climate’s control over NPP. In addition, we find that the duration and magnitude of legacy effects are inconsistent across models, ranging from no detectable effects to effects lasting upwards of 4 years. Model ability to accurately simulate ecosystem response to drought is necessary in order to produce reliable forecasts of land carbon sink strength and, consequently, to predict the rate at which climate change will progress in the future. Thus, the discrepancies between legacy effects across models may indicate a critical model deficiency.

Presentation Type: Poster
Extreme events and their influence on carbon dynamics of coastal ecosystems

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Key words: salt marsh, coastal ecosystem, carbon fluxes, disturbance, flooding conditions, climate change

It is widely acknowledged that climate change has and will continue to have fundamental impacts on the natural environment and on human well-being. A relatively small change in the mean climate variable can lead to easily observed changes such as more frequent extreme weather events, like hurricanes, floods, earthquakes, droughts, rising air temperatures or shifts in the distribution of precipitation. All these phenomena are affected by global climate change. Changes in climate elements entail changes in other environmental conditions and affect the carbon balance of terrestrial ecosystems. Different ecosystems react differently in response to climate change.

In our research, our main goal was to study the influence of extreme flooding conditions on carbon dynamics in a temperate coastal ecosystem, the salt marsh. We hypothesized that the salt marsh is very resilient to wind disturbances and extreme flooding conditions. Therefore, we did not expect substantial changes in carbon dynamics following short periods of high water levels. If there are any changes we expected that the changes will be small and that the ecosystem will quickly return to equilibrium. Our assumptions were based on an analysis of carbon dynamic data in a temperate salt marsh that was influenced by a hurricane surge (Hurricane Joaquin, September 2015, ocean input) and a large flood event from a storm (September 2016, fresh water inputs, inland storm).

During the analysis we compared the environmental conditions before and after these two events. Our goal was to determine which environmental parameters changed during the two extreme events and to determine how those changes were related to each other. Through comparison and analysis of the environmental parameters, we found that the salt marsh recovered quickly after each flood event, which confirms our hypothesis that the salt marsh is resilient to flooding during extreme events.

Presentation Type: Poster
Quantifying the response and resilience of carbon dynamics in semi-arid biomes in the Southwestern U.S. to drought

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Semi-arid biomes in many parts of the Southwestern U.S. have recently experienced one of the driest decades in the past 40 years. While annual carbon uptake in semi-arid biomes of the Southwestern US is relatively low, compared to more temperate ecosystems, collectively these biomes store a significant amount of carbon on a regional scale. It is therefore of great interest to understand what impact this drought has on inter and intra annual variability in regional carbon dynamics. We use an 9 year record from 2007-2015 of continuous measurements of net ecosystem exchange of carbon (NEE) and its components (gross primary productivity (GPP) and ecosystem respiration (Re), made across a network of flux towers along an elevation/aridity gradient in New Mexico, the New Mexico Elevation Gradient (NMEG), to quantify biome-specific responses of carbon dynamics to drought over this time period. Biomes include a desert grassland, creosote shrubland, juniper savanna, piñon-juniper woodland, and ponderosa pine and subalpine mixed conifer forests. We report here on the sensitivity of seasonal and annual NEP, GPP and Re across the NMEG to drought using the Standardized Precipitation Evaporation Index (SPEI) as a measure of drought, the degree to which these biomes are exhibiting resiliency to this drought, and estimate the consequences of this drought for regional carbon balance.

In all biomes, except juniper savanna, GPP declined more than Re, as drought intensified. Both GPP and Re decreased with drought in the juniper savanna, but these fluxes are so closely coupled, NEE has remained relatively constant in this biome despite wide fluctuations in precipitation over the past decade. The decrease in C sequestration between non-drought and drought years in all other biomes across the NMEG was significant (100, 250, 100, 40 and 60 g C/m2 less sequestered in mixed conifer, ponderosa pine, PJ, creosote and desert grassland, respectively). This represents a 30, 45, 50, and 80 % decrease in carbon sink strength in mixed conifer, ponderosa pine, PJ and shrub sites, respectively.

Presentation Type: Poster
Carbon cost of agro-biofuel production in the U.S. Corn Belt: quantifying carbon dynamics and the greenhouse gas balance

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The Corn Belt, agricultural land covering a large area of the Midwestern U.S., is one of the most productive systems in the world during growing season, even exceeding Amazon Forests. Fueled by the biofuel booms of the late 2000s, the area in cultivation of corn and soybean in the U.S. has reached record high levels. Particularly in the Western Corn Belt, substantial area of grassland has been converted to corn-soybean cultivation. Intensive management practices, such as fertilizer use, irrigation, tillage, residue removal etc., have been implemented following cropland expansion to increase crop yield. Corn-soybean production was nearly doubled in recent three decades mainly due to increased corn/soy acreage and crop technical improvement. The Corn Belt has been recognized as one of the major contributors to carbon sinks in the U.S., partially because crop harvest and residue removal reduced soil respiration. In the meanwhile, 75% of the total N₂O emission in the U.S. comes from agriculture, among which the Corn Belt is the major source due to nitrogen management, and has large potential of climate mitigation. However, it remains far from certain how intensive cropland expansion and management practices in this region have affected soil carbon accumulation and non-CO₂ GHG emissions. In this study, by using a process-based land ecosystem model, DLEM (Dynamic Land Ecosystem Model), we investigated the impacts of land conversion (e.g., grassland to corn/soy), shift in cropping system (e.g., increasing percentage of continuous corn), agricultural management (e.g., amount, species, and timing of fertilizer application, tillage, irrigation, and tile drainage etc.), and climate extremes since 1980. Carbon cost, including soil carbon gain/loss and net GHG balance, of increased biomass production were comprehensively assessed, particularly in heavily disturbed landscape. The “trade-offs” between crop production and carbon cost is used to evaluate the vulnerability and sustainability of the U.S. Corn Belt.

Presentation Type: Poster
Carbon stocks in two successional stages of a dry tropical forest for the establishment of an intensive carbon monitoring site in Northwestern Mexico

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Tropical dry forest (TDF) covers 11.26% land surface in Mexico and is constantly threatened by deforestation and degradation. REDD+ has developed strategies to reduce CO₂ emissions by implementing monitoring, reporting and verification systems (MRV). Mexico has implemented intensive carbon monitoring sites (SMICs) to test REDD+ protocols. At the SMICs, ecological processes that affect the carbon reservoirs and their changes are monitored through an integration of multiscale approaches. Thus, the aim of this work is to estimate carbon stocks of TDF and describe some of the ecosystem processes that influence these stocks in two successional stages: an early succession dominated by Acacia cochliacantha (AF) and a diverse mature forest (MF) in northwestern Mexico. Using allometric equations and field sampling, stored carbon was estimated from above- and below-ground biomass, surface litter, deadwood and soil reservoirs based on standardized forest and soil national inventory methodology. In addition, we estimate litterfall production and net primary productivity (NPP) in both successional stages. Above-ground biomass C content was 43.41 ± 1.79 Mg ha⁻¹ at MF and 26.12 ± 2.46 Mg ha⁻¹ at AF. Surface litter C Content at MF was 4.51 ± 0.61 Mg ha⁻¹ and 5.34 ± 1.09 Mg ha⁻¹ at AF. MF and AF below-ground biomass C stored was 43.42 ± 1.79 and 24.27 ± 2.62 Mg ha⁻¹, respectively. Deadwood C for MF and AF were about 13 and 8 Mg ha⁻¹, respectively. Soil C stored in the top 30 cm at MF was 69.80 ± 4.76 Mg ha⁻¹ and AF was 65.60 ± 5.64 Mg ha⁻¹. Litterfall production for MF and AF were 3.19 and 3.66 Mg ha⁻¹ yr⁻¹, respectively. The next stage of this research will obtain an emission factor for deforestation as we relate the C stocks and NPP with dynamic fluxes of towards the consolidation of a long-term monitoring site.

Presentation Type: Poster

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Extensive evaluations of carbon fluxes show considerable variation in terrestrial uptake of atmospheric CO2 year-to-year. Variability in the magnitude of carbon exchange in space and time is governed by meteorology and ecology, as well as the length and timing of the growing season. There exists a large spread of projected future warming in coupled carbon cycle-climate simulations, and carbon respiration and uptake processes in terrestrial biospheres are likely to be affected as a result of climate change. This underscores the importance of improving understanding of land-atmosphere carbon exchange.

Atmospheric inversions are a primary method for estimating regional carbon fluxes and many currently use as their priors the surface flux posteriors provided by the CarbonTracker NOAA data assimilation system. The product made available in 2015 (hereafter referred to as CT2015) uses atmospheric CO2 mixing ratios from the NOAA global network of stations to optimize carbon fluxes at the surface over large ecological regions. CT2015 provides fluxes from 2000 – 2014.

CT2015 is derived as a mean of eight different posterior estimates. This suite is developed using two different terrestrial priors (land biosphere from GFEDv4.1s; GFED CMS), ocean priors (Takahashi pCO2 climatology; fluxes from the ocean inversions project), and fossil fuel priors (emissions from Miller/CDIAC; ODIAC). Here, we evaluate the suite of optimized terrestrial biogenic fluxes over North America from 2000 – 2014. To date, the range and variability of these eight posteriors over space and time have received little evaluation against flux tower observations. The goal of the present study is to determine how CT2015 biogenic fluxes change with space and time, and how representative they are of measured fluxes. We show how the range of CT2015 posteriors compares to model mean-data differences, and how this comparison varies throughout North American sub-regions and over the 15 years examined.

Presentation Type: Poster
Looking within the forest landscape mosaic: Moderate disturbances effect on forest structure, composition, and carbon storage

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Forest disturbances reshape ecosystem structure and may alter long-term trajectories of carbon sequestration. Disturbances of moderate severity, including partial harvest, fire, insects and fungal pathogens, kill only a subset of canopy trees, and are increasingly widespread across North America. Whether moderate severity disturbance alters the trajectory of carbon storage in a common way among ecosystems nested within the larger terrestrial landscape, however, is unknown.

Our main objective was to improve understanding of how different forest ecosystems within an upper Midwest, USA landscape restructure and recover following moderate severity disturbance, and to identify common mechanisms linking post-recovery changes in structure with carbon accumulation in plant biomass, or primary production. We used an experimental disturbance at the University of Michigan Biological Station in which 38 to 66% of all mature canopy trees were killed within three, 2-hectare forest stands varying substantially in pre-disturbance ecosystem structure and primary production. We observed long-term changes in stand-scale leaf quantity, primary production, and composition. We also evaluated post-recovery ecosystem physical structure and light acquisition to assess why and how the three forest ecosystems responded similarly to moderate disturbance.

Regardless of pre-disturbance ecosystem structure or productivity, primary production and leaf quantity recovered at a similar rate and extent. Moderate disturbance enhanced the structural complexity of all stands, leading to sustained or increased post-recovery primary production. We found that more structurally complex canopies were able to capture more light, and more efficiently use that light to support primary production. These results show that, while substantial canopy tree mortality temporarily reduced primary production, disturbance increased canopy diversity and complexity, and enhanced the long-term carbon storage potential of multiple ecosystem types through its effects on canopy structural reorganization and light resource reallocation and use. Improving understanding of how different ecosystems respond to disturbance is critical to informing policy and management decisions intended to maximize carbon gain across diverse landscape mosaics.

Presentation Type: Poster
Mapping Area of U.S. Forest Change Activities 1986-2010

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Estimates of forest change activities such as harvests, fires, conversions, wind storms, and insects and disease vary widely. A consistent national approach to mapping these activities in forest land may yield better information to quantify the movements of carbon between stocks and the atmosphere. We use a two step-modeling process to map disturbance causal agent through time. Validation with a probabilistic reference data set suggests that overall accuracy is around 75%. Measures of qualitative uncertainty from the random forest models results are also produced. Results show that using spatial, temporal and magnitude disturbance metrics from multiple disturbance algorithms reduces class omission and commission rates as each algorithm is tuned to capture different types of disturbance events more accurately. These are the first wall to wall maps of harvest activity in the US.

Presentation Type: Poster
Disturbance may stimulate carbon sequestration in a late-successional forest

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Deciduous forests in the eastern United States are a strong carbon (C) sink, but whether they will remain so in the future depends on disturbance extent and severity, forest age-production relationships, and how the two interact. Disturbances continue to increase continent-wide and, while ecological theory and observations maintain that forests sequester less C in late stages of development, disturbance may counterintuitively stimulate C sequestration by partially, but not fully, rewinding ecological succession. As forests age, canopy structural complexity may increase as trees die and form upper canopy gaps that release subcanopy vegetation and create a more multi-layered canopy, capable of using growth-limiting resources more efficiently to sequester C. Recent studies have found that complexity maintains C storage in mid-successional deciduous forests; whether a similar mechanism extends to late-successional forests is unknown.

We will present how an ongoing moderate disturbance is affecting the structure, composition, and function (C sequestration) of late-successional forests. Our late-successional forested study site in Northern Michigan at the University of Michigan Biological Station was recently infected by Beech Bark Disease (BBD), causing the progressive mortality of all American beech trees. American beech is distributed heterogeneously, comprising 1% to 60% of trees within fourteen plots, making it possible to examine the interplay between disturbance severity, canopy structural change, and primary production maintenance in this late-successional forest. We find primary production is increasing more in plots where BBD is most prominent. In plots with greater BBD incidence, we observed reduced canopy porosity and increasing canopy leaf area, suggesting a rapid reallocation of light and rebound of leaf area following mortality. These preliminary results, if they hold, have important implications for the policy and management of moderate disturbances in forests managed for C storage.

Presentation Type: Poster
Impact of Crop Residue Removal on the Carbon Flux of Irrigated Maize

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With government mandates to increase biofuel production, annual maize residue and other residual plant matter are the lowest cost feedstocks to produce cellulosic ethanol. However, the removal of maize residue can negatively impact soil productivity, primarily by reducing soil organic matter, soil organic carbon, soil nutrients, and soil moisture. This study seeks to determine the impact of crop residue removal in an irrigated continuous maize agricultural system on carbon storage and net productivity using both eddy-covariance measurements and modeling approaches. The study was conducted between 2010 and 2013 on sites located in Eastern Nebraska, U.S.A. as part of the Ameriflux network. The comparative site (US-Me1) that did not have crop residue removed has been continuous maize since 2001. The site that did have residue removed (US-Me2) was converted to continuous maize in 2009, prior to the removal of residue in the fall of 2010. The Re was measured to be 46.6-55.0, 86.4-87.3, and 175.0-175.1 g C m⁻² y⁻¹ less in US-Me2 compared to US-Me1, due to residue removal in 2011, 2012, and 2013 respectively. Gross primary production (GPP) on US-Me2 was higher compared to US-Me1 every year of the study but was only significantly larger (113 g C m⁻² y⁻¹) in 2013. This increase in GPP stabilized net ecosystem biome productivity (NBP) for 2013 despite trending downwards in 2011 and 2012. The net ecosystem CO₂ production (NEP) increased every year but was boosted in 2012 due to the large increase in GPP that year. The Re models agreed well with the measured values, where the sum of error for both sites over all three years was -4.6% and absolute error was 15.6%. Both the measurements and modeling indicate that maize crop residue removal decreases soil organic carbon on an annual basis compared to fields where residue is not removed.

Presentation Type: Poster
Estimation of forest disturbance intensity from Landsat data in North and South Carolinas

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Disturbance and regrowth are vital processes in determining the roles of forest ecosystem in the carbon and biogeochemical cycles. Using time series observations, the vegetation change tracker (VCT) algorithm was designed to map the location, timing, and spectral magnitudes of forest disturbance events. While these spectral disturbance magnitudes are indicative of physical changes in tree cover or biomass, their quantitative relationships have yet to be established. This study focuses on estimating disturbance intensity as measured by percent basal area removal using spectral data. Ground measurements in North and South Carolinas from Forest Inventory Analysis (FIA) data are used for training and validation of the model. The overall R2 between predicted disturbance intensity and the reference data is around 0.66, and the prediction uncertainty is 14% in North Carolina. Possible causes in the uncertainty could be the site heterogeneity and the temporal shift between ground measurements and satellite observations. A time series analysis shows that North Carolina has 28% more partial disturbance area than South Carolina although the two states have similar stand clearing area around 450 km2.

Keywords: disturbance intensity, spectral disturbance magnitude, time series, model, validation

Presentation Type: Poster
Productivity of two Australian semi-arid ecosystems after the exceptional global carbon sink anomaly of 2011.

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Australia played a significant role in the 2011 global carbon land sink anomaly; 70% of its land surface is either semi-arid or arid. Two biomes dominate the central semi-arid region: (1) Mulga-woodlands (Acacia spp.), and (2) open Corymbia savanna over hummock grass (Triodia sp. a C4 grass). Within each biome an eddy covariance tower has been in operation for the past 4 and 7 years (Mulga woodland and Corymbia savanna respectively). The aim of this study was to compare net ecosystem productivity (NEP) of these two ecosystems from 2010 to 2016. In 2011 during the global sink anomaly the Mulga ecosystem captured 131 g C m⁻² y⁻¹ while during the following 2 years it behaved as a source of carbon with -47 and -14 g C m⁻² y⁻¹ (2012 and 2013 respectively). In 2014 and 2015 it reverted to a sink, with a NEP of 23 and 45 g C m⁻² y⁻¹. The tipping-point at which this ecosystem switches between a C sink and C source is estimated to be 265 mm of annual rain. Average water-use efficiency of the Mulga across all years was 1.9 g C m⁻² mm⁻¹ H₂O. In contrast to the Mulga, the open Corymbia-savanna was a carbon source across all years (2012 to 2016), with NEP ranging between -14 and -190 g C m⁻² y⁻¹. Meteorological forces are key determinants of the intra- and inter-annual variation in NEP in these two ecosystems, but species composition is the principle cause of the different behaviours of the two ecosystems. Arid and semi-arid ecosystems are dominant ecosystems worldwide (45% of the land surface), and identifying tipping points at which ecosystems switch from being a source to a sink of carbon is important for furthering our understanding of the global carbon budget and modelling future projections of ecosystem behaviour.

Presentation Type: Poster
Over a decade perspective on ecophysiological responses of a temperate deciduous forest to droughts

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Constraining forest ecosystem responses to drought is crucial towards better understanding how these systems will function in the future because changes in precipitation patterns and increasing vapor pressure deficits are expected. The objective of this research was to examine the recovery of ecosystem water-use efficiency (WUE), photosynthetic capacity ($A_{\text{max}}$) and net ecosystem CO$_2$ exchange (NEE) after drought events in an upland oak-hickory forest. Annual minimum community predawn leaf water potentials ($\Psi_{\text{pd}}$) ranged from -0.7 to -3.8 MPa, with more negative values correlated with higher mortality rates in the subsequent year. During three “reference” wet years (minimum $\Psi_{\text{pd}} = -0.8\pm0.05$ MPa), there were slow declines in WUE and $A_{\text{max}}$ through the growing season of ~40% and ~25%, respectively. NEE displayed asymmetric seasonal cycles characterized by more rapid changes between the start of carbon (C) uptake (DOY 110–130) and maximum C uptake, compared to slower variation through the end of C uptake (DOY 280–290). During moderate to severe drought, WUE and $A_{\text{max}}$ were significantly reduced such that C uptake was shut-down starting between DOY 190 and 240. However, the recovery of ecosystem function and C uptake occurred when there were soaking rains by DOY 245—even after an extreme drought (minimum $\Psi_{\text{pd}} = -3.8$ MPa) that induced significant tree mortality in the next year. WUE recovered to pre-drought levels that were in-line or in-excess of values from similar times during wet years. Post-drought $A_{\text{max}}$ recovery was comparatively muted with values ~55% lower than pre-drought levels and ~45% below $A_{\text{max}}$ in the late-season of wet years. In summary, ecosystem function can recover to some degree, even after extreme drought. There is, however, a legacy effect on $A_{\text{max}}$, which does not reach late-season, wet-year levels. While the timing of soaking rains relative to phenology is a critical determinant of whether a recovery of ecosystem function occurs, the degree of recovery appears to be related to antecedent drought severity.

Presentation Type: Poster
Fire disturbance and its impact on terrestrial carbon cycle at multiple scales from regional to global

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Fire is a critical component of the earth system, and substantially influences the global carbon cycle. By applying the process-based Dynamic Land Ecosystem Model (DLEM) in conjunction with ground and satellite data, we developed multi-scale data sets of burned area and applied this model to investigate fire impact on the terrestrial carbon budget at various scales from conterminous US (CONUS), North America, to global. In the CONUS, we found that average area burned by large fires was $1.44 \times 10^4 \text{ km}^2 \text{ yr}^{-1}$ and carbon emissions from large fires were $17.65 \text{Tg C yr}^{-1}$ from 1984 to 2012. The large fires were associated with higher burned severity, and the contribution of large fires to burned area and fire carbon emission were becoming increasingly important. In North America, we found that fire influence on vegetation photosynthetic capacity was stronger in the boreal ecosystems than the temperate ecosystems, and the post-fire recovery time of vegetation greenness could be longer than 10 years. At global scale, our study indicated that the average global burned area was $442 \times 10^4 \text{ km}^2 \text{ yr}^{-1}$ and a notable declining rate of burned area was detected at a rate of $1.28 \times 10^4 \text{ km}^2 \text{ yr}^{-1}$. Meanwhile, we found a significant declining trend in global fire carbon emissions between the early 20th century and the mid-1980s but a significant upward trend between the mid-1980s and 2010 as a result of more frequent fires in the ecosystems with high carbon storage. Over the past 110 years, average fire carbon emissions were estimated to be $2.43 \text{ Pg C yr}^{-1}$. Under the impacts of fires, the net primary productivity and carbon sink of global terrestrial ecosystems were reduced by $4.14 \text{ Pg C yr}^{-1}$ and $0.57 \text{ Pg C yr}^{-1}$, respectively. Our study suggests that special attention should be paid to fire activities in the peatlands and tropical forests in the future to reduce fire risk and mitigate fire-induced greenhouse gases emissions.

**Presentation Type:** Poster
Impacts of land cover and land use change on carbon balance in the Midwestern U.S.: Modeling estimation and attribution during 1900-2015

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To meet the increasing food and biofuel demand, the Midwestern agricultural has become one of the most intensively human-disturbed hotspots, characterized by widespread cropland expansion and various management practices. However, the role of human activities to the carbon cycling across managed landscape remains far from certain. Therefore, in this study, based on national archive, survey data and satellite images, we comprehensively reconstructed long-term crop distribution maps in the Midwest U.S. from 1900 to 2015. Land cover and land use change (LCLUC) information derived from the reconstructed maps were incorporated into the Dynamic Land Ecosystem Model (DLEM) – a process-based biogeochemical model - to quantify the impacts of the cropland encroachment into grassland and forest on terrestrial carbon storage and fluxes. The magnitude, spatial and temporal patterns of carbon balance in the Midwest region were assessed with consideration of human management practices (e.g. fertilizer use, tillage, irrigation, tile drainage, and rotation operation). The results showed intensive crop expansion occurred in the entire study area since 1900s, in which the majority of the croplands converted were from grassland. The total NPP of corn and soybean increased at rates of 3.73 and 2.46 million tons yr⁻¹ in the Midwest since the 1960s, to which increased fertilizer uses and land cover change (i.e. corn and soybean expansion) served as essential contributors. In comparison, the belowground carbon pool has been intensively disturbed and dramatically changed due to LCLUC, while the soil carbon sequestration ability can be also enhanced by adopting optimized management strategies. Our results imply that LCLUC plays an essential role in regional and global carbon balance, and more importantly, proper land management practices have high potential in strengthening carbon sequestration of the terrestrial ecosystems in Midwestern U.S., which may serve as a major contributor to carbon sinks in the U.S.

Presentation Type: Poster
A network in flux: learning from AmeriFlux

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AmeriFlux is a network of more than 200 sites and scientists using Eddy Covariance towers to measure ecosystem CO2, water, and energy fluxes across the Americas. These data advance understanding of terrestrial ecosystems in a changing world. As an ad hoc network, AmeriFlux faces significant challenges, including ensuring that disparate sites are intercomparable, producing data sets for synthesis, forging strong community ties, and maintaining continuity of sites over the long term. To help meet those challenges and to enhance the scientific impact of AmeriFlux, DOE is supporting the AmeriFlux Management Project (AMP, ameriflux.lbl.gov). What is being learned about strengthening a network? Highly visible tech, data, and community services have attracted more than 75 new sites to the network in the past three years. Funding operations of a dozen longterm sites helps maintain continuity of data and know-how. A strong network community enables more efficient technology dissemination and more open data sharing. Finally, an organizational hub, despite having little top-down influence, allows AmeriFlux to forge new, productive partnerships with other networks and agencies like NASA and NSF. What is being learned from AmeriFlux data? Partnering with FLUXNET, ICOS, and regional flux networks, AMP produced the FLUXNET2015 synthesis dataset that is being used by scientists around the world. Recent papers have blazed new insights into the effects of atmospheric aridity on ecosystems, from leaf-to-flux level perspectives on VPD, to drought synthesis using satellite-flux inversions. We now have evidence that an enhanced terrestrial CO2 sink is offsetting anthropogenic emissions, and new understanding of how water availability shapes the global carbon cycle. Looking ahead, there is a growing need to join forces with other networks and experiments to address scientific challenges. We envision a wave of multi-network research, such as on: detection of the impacts of climate change and elevated CO2; connecting water and nutrient flows from bedrock to canopy, and energy and momentum from canopy phenology to climate; iterative validation of remote sensing; multi-flux integration (13C, CH4, N2O, plant-soil fluxes), and real-time processing of high frequency data with online diagnostics of continental metabolism.

Presentation Type:  Plenary Talk
Recent Advances of NASA's Arctic Boreal Vulnerability Experiment (ABoVE)

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ABoVE is a NASA-led field campaign taking place in Alaska and western Canada, with a wide range of interdisciplinary science objectives designed to address the extent to which ecosystems and society are vulnerable, or resilient, to environmental changes underway and expected. The first phase of ABoVE is underway, with a focus on ecosystem dynamics and ecosystem services objectives. The ABoVE leadership is fostering partnerships with several major arctic and boreal research, management and policy initiatives. Some 61 core and affiliated projects are currently active, including 380 participants from 150 institutions. Eight projects were added in late 2016 with a focus on linking field and satellite data via airborne observations and scaling approaches. The Science Team is organized around Working Groups (WGs) focused on vegetation, permafrost and hydrology, disturbance, carbon dynamics, wildlife and ecosystem services, and modeling. Additional WGs focus on airborne science, stakeholder engagement, geospatial products, and other themes. All are supplemented by infrastructure activities including data management, cloud computing, laboratory and field support. Although organized by disciplinary WGs, ABoVE research broadly focuses on the complex interdependencies and feedbacks across disciplines. Ultimately ABoVE will improve our understanding the consequences of environmental changes occurring across the study domain, as well as increase our confidence in making projections of the ecosystem responses, resiliency and vulnerability to changes taking place both within and outside the domain. ABoVE will also build a lasting legacy of collaboration through an expanded knowledge base, provision of key datasets to a broader network of researchers and resource managers, and the development of data products and knowledge designed to foster decision support and applied research partnerships with broad societal relevance. A brief overview and status update of ABoVE activities and plans, including the upcoming airborne campaigns, science team meetings, and potential for partnerships and engagement will be presented.

Presentation Type: Plenary Talk
Catalyzing continental-scale carbon cycle science with NEON’s first data and software release

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Networks of eddy-covariance (EC) towers such as AmeriFlux, ICOS and NEON are vital for providing the necessary distributed observations to address grand challenges in earth system and carbon cycle science. NEON, once fully operational with 47 tower sites, will represent the largest single-provider EC network globally. Its standardized observation and data processing suite is designed specifically for inter-site comparability and analysis of continental-scale ecological change, including rich contextual data such as airborne remote sensing and in-situ sampling bouts.

First carbon cycle products become available in 2017, including data and software. These products strive to incorporate lessons-learned through collaborations with AmeriFlux, ICOS, LTER and others, to suggest novel systemic solutions, and to synergize ongoing research efforts across science communities. Here, we present an overview of the ongoing product release, alongside efforts to integrate and synergize with existing infrastructures, networks and communities.

Near-real-time carbon cycle observations in “basic” and “expanded”, self-describing HDF5 formats become accessible from the NEON Data Portal, including an Application Program Interface. A pilot project is underway to investigate their subsequent ingest into the AmeriFlux processing pipeline, together with inclusion in FLUXNET globally harmonized data releases.

Software for reproducible, extensible and portable data analysis and science operations management also becomes available. This includes the eddy4R family of R-packages underlying the carbon cycle data product generation, together with the ability to directly participate in open development via GitHub version control and Dockerhub image hosting. In addition, templates for science operations management include a web-based field maintenance application and a graphical user interface to simplify problem tracking and resolution along the entire data chain.

We hope that this first release of NEON carbon cycle products can initiate further collaboration and synergies in challenge areas, and would appreciate input and discussion on continued development.

Presentation Type: Plenary Talk
Arctic-COLORS: Coastal Land Ocean Interactions in the Arctic Field Campaign Scoping Study

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Arctic-COLORS is a proposed field campaign under consideration by NASA's Ocean Biology and Biogeochemistry Program that aims to quantify the response of the Arctic coastal environment to global change and anthropogenic disturbances – an imperative for developing mitigation and adaptation strategies for the region. The Arctic-COLORS field campaign is unprecedented, as it represents the first attempt to study the nearshore coastal Arctic (from riverine deltas and estuaries out to the coastal sea) as an integrated land-ocean-atmosphere-biosphere system. The overarching objective of Arctic-COLORS is to quantify the coupled biogeochemical/ecological response of the Arctic nearshore system to rapidly changing terrestrial fluxes and ice conditions. This focus on land-ocean interactions in the nearshore coastal zone is a unique contribution of Arctic-COLORS compared to other NASA field campaigns in polar regions. The science of our field campaign will focus on three key science themes and several overarching science questions per theme:

(1) Effect of land on nearshore Arctic biogeochemistry

(2) Effect of ice on nearshore Arctic biogeochemistry

(3) Effects of future change (warming land and melting ice) on nearshore Arctic biogeochemistry

This field campaign will be composed of an integrative measurement approach utilizing a broad range of proven sampling approaches from a multitude of platforms including autonomous vehicles to achieve sufficient seasonal and spatial coverage to resolve the science questions proposed by the Arctic-COLORS team as well as remote sensing and development of coupled physical-biogeochemical models.

Presentation Type: Plenary Talk
Ecosystem functional diversity and the representativeness of environmental networks across the conterminous United States

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Environmental networks through data collection, data storage and data sharing, are relevant tools that help us to improve our knowledge and understanding of Earth’s biophysical processes, by hence, assessment of environmental network is need it because it provides feedback regarding current monitoring designs, and gives insights for improvement or network development. In this study, we used a time varying land surface classification that group ecosystem that share similar functional characteristics, relate to the amount and timing of carbon exchange, called ecosystem functional types (EFT). EFT were used as surrogate to represent the functional characteristics of the conterminous United States. Based on this analysis, active-inactive AmeriFlux and core-relocatable NEON sites represents 31 and 13 (out of 64 EFTs) EFT’s categories, which comprise 88% and 63% of the area of the conterminous United States, respectively. Common characteristics of non-represented areas are: high EFTs interannual variability, complex topography, and low mean Gross Primary Productivity (GPP) associate it to high GPP coefficient of variation (CV); these characteristics were usually found at arid and semiarid ecosystems. Represented areas were characterized by: low EFT interannual variability, flat topography, and medium-high mean GPP, and low CV GPP, characteristics mainly found at forested ecosystems. A core site analysis combining both networks, was based on the maximum-entropy distribution approach, using as a predictor variables EFTs, EFT interannual variability, GPP mean and CV GPP. Core site represents 46% of the Conterminous Unites States, the characteristics of non-represented and represented regions is similar than the one previously described. This could be due to a historical bias to monitor forested ecosystems. Finally, this study provides an alternative framework to assess the representativeness of environmental networks based on ecosystem functional properties and is applicable around the world.
Exploring data products in the FLUXNET2015 dataset

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The FLUXNET2015 dataset had its final update this past November and now includes data from 212 FLUXNET sites around the world. The creation of the dataset counted with efforts from many site teams and extensive coordination among regional networks. The data processing and harmonization efforts were led by the European Fluxes Database Cluster, AmeriFlux Management Project, and Fluxdata project of FLUXNET. This third FLUXNET dataset includes carbon, water, and energy fluxes along with micrometeorology and other data collected at each site, augmented with uniform products like quality checks, gap-filling of variables, and partitioning of CO2 fluxes -- all harmonized to standard data formats. The dataset also includes several new features, such as extended quality control processes and checks, use of downscaled reanalysis data for filling long gaps in micrometeorological variables, multiple methods for USTAR threshold estimation and flux partitioning, and uncertainty estimates. These new features and new implementation of data processing methods led to the generation of new data products spanning many variables and auxiliary flags. This allows for detailed exploration of the data as well as the processing methods. It is expected that the now traditional data products in the dataset (fluxes and meteorological variables) will continue to support important uses of the data, e.g., validation of remote sensing measurements and evaluation of ecosystem responses to climate, drought, heat, and disturbance events. In addition, the new data products allow novel uses of the data -- e.g., adding uncertainty information while informing earth system models -- and potentially stimulate new applications to arise. In this work we explore a few of the new data products of the FLUXNET2015 dataset, highlighting their use to understand the dataset, and its possibilities and limitations.

Presentation Type: Poster
Continental scale forest structural complexity-carbon cycling relationships

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The relationship between ecosystem structure and carbon cycling is a long-standing research interest for ecosystem science. Strong relationships between canopy structural complexity (CSC) and rates of C accumulation in plant biomass, or net primary productivity (NPP), have been demonstrated for a limited number of forest sites—with more structurally “complex” forests exhibiting greater productivity. Whether CSC-NPP relationships are broadly conserved across an array of structurally variable forest ecosystems is unknown, but the universality of this relationship has important implications for remotely sensing and modeling the terrestrial carbon cycle.

Our group is in the midst of a two-year, NSF funded project to measure CSC at over 30 field sites, spanning six ecological and climatic domains within the continental United States. Sampling locations include National Ecological Observatory Network (NEON), AmeriFlux, and other University-affiliated or independent field stations. Several CSC metrics (including canopy rugosity, rumple, canopy porosity, etc.) are being calculated at the plot and site-levels using portable canopy LiDAR (PCL) and related to co-located measurements of wood NPP estimated from the incremental change in woody biomass.

Our results suggest CSC provides additional explanatory power for predicting NPP that is independent of other commonly used forest structural attributes (e.g. leaf area index (LAI)) by augmenting quantitative prediction of canopy light capture. The inclusion of CSC metrics such as canopy porosity and deep gaps with LAI increases the explanatory power for modelling the amount of light used by the canopy (measured as fPAR - the fraction of photosynthetically available radiation). Initial results show total explained variance of fPAR in excess of 94%.

Quantification of the relationship between CSC and NPP across structurally and functionally diverse sites could transform mechanistic understanding of ecosystem structure-carbon cycling relationships and greatly improve carbon cycling models and remote sensing applications.

Presentation Type: Poster
Modeling vegetation growth and productivity based on biophysical and ecophysiological processes driven by climate variables

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Vegetation growth and productivity are primarily regulated by physical factors. To investigate the influence of climate variation on vegetation growth and productivity, climate-driven models including accurate processes are necessary. Despite such a necessity, some existing terrestrial biosphere models are unable to catch a seasonal change in the productivity, partly due to inadequate representation of physical factors that control phenology. Therefore, we developed a new prognostic model that predicts leaf dynamics in response to climate conditions: Biophysical and Ecophysiological Processes-based Model for Predicting Phenology and Productivity (BE4P). This model (i) is forced by simple climate variables and determines energy, water and carbon fluxes based on the basis of biophysical processes; (ii) predicts seasonal leaf growth and productivity on the basis of ecophysiological data; and (iii) estimates growth and productivity of a generic plant that is representative of each plant functional type (PFT). We conducted simulations of vegetation growth and productivity and evaluated the performance comparing with observations at flux tower sites. Half-hourly meteorological data to force the model were retrieved from FLUXNET. For the validation purposes, we selected 30 flux tower sites that are widely distributed across various climate zones and biomes. At almost all sites, the model successfully captured the observed leaf area index (LAI) and gross primary productivity (GPP). Proper representation of carbon allocation in the model resulted in reproduction of seasonal change in LAI. However, the performance was relatively poor for grassland probably due to inadequate representation of water restriction on leaf growth and productivity. Collectively, our results suggest that a process-based model for generic PFT can predict not only seasonal variation in vegetation growth and productivity but also their variations among sites, and that accurate prediction of the productivity requires further understanding of physical factors that control phenology to improve these processes in mechanistic models.

Presentation Type: Poster
Estimating regional forest soil respiration by integrating field measurements with remotely sensed datasets

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While large-scale estimates of gross ecosystem CO$_2$ uptake (i.e., photosynthesis) can be obtained using satellite imagery (e.g., MODIS Gross Primary Productivity (GPP) (MOD17)), analogous respiration estimates are lacking. Previous research at three subalpine sites (Fraser Experimental Forest, Niwot Ridge, GLEES) in the Southern Rocky Mountains suggests that soil respiration covaries with forest and soil properties at scales of 0.09 to 6.25 ha. We used topographic, soil and forest inventory, spectral reflectance, N deposition, and climate data in a random forests framework to predict soil respiration at these sites. Coarse woody debris, mean summertime temperature, N deposition, stand age, slope, aspect and maximum NDVI from the current and previous year were significant indicators of growing season soil respiration ($R^2 = 0.40$). Inclusion of total soil nitrogen (N) and C improved the model fit ($R^2 = 0.93$). Wintertime soil respiration was predicted by slope, aspect, N deposition, mean wintertime air temperature, previous year maximum NDVI, and annual range in NDVI ($R^2 = 0.77$). As an initial check, we first compared our model predictions to NEE from eddy covariance towers at each site. Then, we generated a continuous summertime and wintertime soil respiration product at 30 m resolution for the subalpine zone in the Southern Rockies Ecoregion. Predictions were combined with MODIS GPP as a general check of the method. This work demonstrates how multiple sources of data can be leveraged to yield regional estimates of respiration and highlights the need for more complete spatial coverage of soils data for predicting C fluxes.

Presentation Type: Poster
Towards inventory-based estimates of litter and soil carbon on managed forest land in Alaska

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Soil organic carbon (SOC) is the largest terrestrial carbon (C) sink on earth and management of this pool is a critical component of global efforts to mitigate atmospheric C concentrations. Soil organic carbon is also a key indicator of soil quality as it affects essential biological, chemical, and physical soil functions. Much of the SOC on earth is found in forest ecosystems and is thought to be relatively stable. That said, recent studies have documented the sensitivity of SOC to global change drivers, particularly in the northern circumpolar region where approximately 50% of the global SOC is stored. The Forest Inventory and Analysis (FIA) program within the United States (US) Department of Agriculture, Forest Service has been measuring litter and soil attributes in forests since 2001. These data have recently been harmonized with auxiliary biophysical and geospatial data to develop models for predicting litter and soil carbon stocks on forest land in the conterminous US. In this study we will expand on those methods using FIA data from southeast and south central coastal AK and a recent pilot study in the Alaskan interior to estimate litter and soil carbon stocks and associated uncertainties for managed forest land in Alaska. Specifically we will: 1) describe the inventory of soil variables in the FIA program, 2) compare model predictions of litter and soil carbon density with estimates from the NFI, 3) evaluate new estimation approaches to replace existing model predictions, and 4) expand estimates beyond regions with operational and pilot FIA data to the entirety of the managed forest land in Alaska.

Presentation Type: Poster
Preliminary Application of ACT-America Aircraft Measurements for Evaluation of Modeled GHG Surface Fluxes and Mole Fractions for Fair Weather Cases

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One of the primary goals of the NASA-funded Atmospheric Carbon and Transport -- America (ACT-America) field campaign is to use aircraft (C-130 and B-200) measurements of meteorological variables and trace gas concentrations to help validate model predictions of greenhouse gas (GHG) concentrations throughout the troposphere on regional scales, i.e., roughly hundreds of kilometers. While local eddy covariance networks can determine fluxes on the microscale, and measurements in regions isolated from local sources can provide global-scale constraints, substantially less is known about the magnitudes and gradients of GHG on the regional scale, due to a relative absence of applicable measurements. ACT-America will help to fill that gap by sampling GHGs in the boundary layer and upper- and lower-free troposphere for three geographical regions of the country (Midwest, Gulf Coast, and Mid-Atlantic) in all four seasons, in both meteorologically active and ‘fair-weather’ situations.

The importance of ‘fair-weather’ scenarios, in which atmospheric transport is easily accounted for (e.g., spatially homogeneous flow, no deep convection), is that measurements of surface-derived tracer concentrations can be more directly related to local surface fluxes of the tracer; thus ACT-America measurements in fair-weather scenarios can help constrain the value of regional-scale emissions of GHGs.

In this study we take a first look at the airborne measurements of CO2 concentrations for fair weather conditions during the ACT campaign of Jul-Aug 2016. For comparison, we perform Weather Research and Forecasting (WRF) simulations of CO2 concentrations over the continental United States using lateral boundary conditions and local fluxes derived from the CarbonTracker -- Near-Real Time (CT-NRT) inversion system for the period of interest. We will also use a modified box analysis to estimate the magnitude of regional CO2 fluxes implied from the aircraft measurements, and compare these to the prior regional CO2 flux estimates used in the WRF model.

Presentation Type: Poster
Understanding urban CO2 emissions and the underlying mechanisms driving these emissions requires quantification of anthropogenic emissions in the presence of biological fluxes. During the dormant season, urban CO2 fluxes are dominated by the combustion of fossil fuel (CO2ff) and emissions are relatively easy to constrain through a combination of bottom-up and top-down methods. In the growing season, however, there is a strong biogenic influence on CO2 fluxes (CO2bio) both within and outside of the urban landscape, which adds complexity to making city-wide CO2ff emission rate estimates. Fluxes of CO2bio in the urban domain significantly influence atmospheric CO2 in the urban environment, masking anthropogenic emissions.

In this talk, we will discuss the challenges associated with making summertime CO2ff emission rate measurements within the context of summertime CO2bio fluxes and identify paths toward effective approaches to separate the CO2ff and CO2bio components of net CO2 in the urban environment. In particular we will review available methods for determining CO2ff emissions including atmospheric trace gas measurements, atmospheric and biological process modeling, and high resolution observations that can segregate fluxes in space. All of these methods can be applied in some fashion to three principle atmospheric emissions measurement methods: eddy covariance flux measurements, atmospheric mass balance estimates, and atmospheric inverse flux measurements.

We will review the problems that we have encountered to date in applying these approaches, including complexity in determining the urban CO2 background, apparent contamination of CO2ff tracers in summer, and uncertainty in biological and atmospheric process modeling. We will also present progress to date, including investigation of the true urban CO2 background using process modeling, multiple towers and merged tower-aircraft observations, investigation of isotopic and trace gas signatures, the development of inverse modeling frameworks to include atmospheric tracers, biological modeling of urban emissions, aircraft mass-balance methods, and evaluation of prior estimates of biological and anthropogenic fluxes using eddy covariance and other micrometeorological methods. Results will be drawn from the Indianapolis Flux Experiment (INFLUX), a test-bed for the development and evaluation of methods for the measurement and modeling of greenhouse gas fluxes from urban environments.
The Texas Water Observatory (TWO) is a new distributed network of field observatories in the critical zone across Texas (starting at Brazos corridor) designed to improve the spatiotemporal understanding of the energy, carbon, and hydrologic cycles. The climatic and geologic gradient combined with the mosaic of land uses (cultivation agriculture, range/pasture, forest) comprised in South-Central Texas are critical to investigate the sensitivity and resilience of fertile soils and the ecosystems goods and services relative to the increasing water demand of 50 million habitants of Texas and the Gulf States. In partnership with Texas A&M Agrilife extension and USDAMARS Riesel watershed, we currently have four fully instrumented sites in operation with four additional sites in partnership with the National Wildlife Refuge and Texas A&M Agrilife extension, slated for installation in spring 2017, and several more sites with partners throughout Texas. Each site entails a series of real-time and near-real time sensor networks monitoring surface/subsurface water, carbon, and energy, and geophysical site characterization in a range of land use/land cover, climatic gradient, erosional/depositional environment, supplemented by air-space-based remote sensing platforms.

TWO is a four-prong initiative: Observatory network, Data portal, Modeling Systems, Analyses, and data assessment. Following standard protocols of national and international environmental networks, TWO will develop and maintain web-based data access portal, real-time web query, data retrieval, normalization, analysis, and interpretation. Our goal is to build a versatile platform that allows for easy interfacing across networks (Ameriflux, CZO, NEON, Oklahoma Mesonet, etc.). The Texas Water Observatory would integrate surface and groundwater fluxes, geophysical site characterization and decision-making modeling; apply, test and refine existing biophysical models; develop modeling software and provide technical assistance on problems related to models. Application of these Texas Water Observatory models for decision makers would provide critical data on climate, surface and groundwater resources, water quality, and threats to water supplies.

Presentation Type: Poster
Global trends in urbanization have led the carbon cycle community to investigate greenhouse gas (GHG) emissions from cities, with investigation goals including quantification of total emissions, determination of trends, and attribution of emissions to various economic sectors. Most efforts to quantify urban GHG emissions using atmospheric observations generally commence with establishing long-term, relatively dense networks of tower or roof-based continuous in-situ GHG measurements along with the development of an urban GHG inventory. The North-East Corridor: Baltimore-Washington DC (NECMB-W) project is a relatively new effort, a partnership between NIST, Earth Networks, University of Maryland, NOAA, and Arizona State University to estimate and determine trends in GHG (specifically CO2 and CH4) emissions from these cities. The project incorporates high-resolution emissions inventory modeling (Hestia), tower-based in-situ and flask-based GHG observations, aircraft-based observations from periodic intensive campaigns (Fluxes of Atmospheric Greenhouse Gases in Maryland, FLAGGM-MD), low-cost sensor testing and deployment, and meteorological and statistical modeling.

Here we introduce the NEC-BW work to date, focusing on the tower network, which was designed to maximize the effectiveness of the measurements for use in statistical inversion approaches for fossil-fuel derived CO2 emissions estimation. The current network design includes twelve urban sites that continuously measure CO2 and CH4 using the Earth Networks, Inc. GHG observing system based on high-precision CRDS analyzers. Additional statistical analysis helped identify four locations outside the urban area for characterizing the incoming air to the region, i.e. background sites. As the in-situ network has come online, we have applied quality-control and data processing methods for all the in-situ tower-based observations, and have developed an algorithm for calculating the uncertainty of those observations. Here we present the network design work along with initial analysis of the time series of observations from the six established (out of 16 planned) tower sites.
Understanding 16-year variations in CO$_2$ and H$_2$O Flux at an Oak Savanna and Annual Grassland in California

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Carbon and water fluxes have been measured at an oak-grass savanna area in California for more than 16 years. As shown in Ma et al. (2007) and (2016), interannual variability in net ecosystem exchange of CO$_2$ (NEE) in this area are large, mainly driven by two major ecological processes—gross primary productivity (GPP) and ecosystem respiration (Reco). By exploring the 16-year datasets, we start to understand two types of ecosystem responses—fast responses (e.g., ecophysiological and biogeochemical processes) and slow responses (e.g., ecological processes). Fast and slow responses both contribute variations in CO$_2$/H$_2$O fluxes on the annual basis. For example, variations in spring precipitation (Apr. – Jun.) could explain more than 90% of annual GPP and Reco. One the other hand, extremely wet springs reduced GPP, like in the years of 2006, 2011 and 2012. In addition, soil moisture left from those extremely wet springs, occasional groundwater extreme recharge due to snowpack melting (e.g., during the spring of 2011); dry autumns (Oct. – Dec.) and winters (Jan. – Mar.) were found in the long-term dataset. Thus, each season could introduce significant anomalies in annual carbon budgets. Moreover, the magnitude of the contribution depends on biotic and abiotic seasonal circumstances across the year and the particular sequences. For example, grass litter produced in previous seasons might increase Reco, and the effect of litter legacy on Reco was more observable in the second year of two consecutive wet springs. These findings will be useful for better predicting ecosystem carbon functions in changing climate.

Presentation Type: Poster
Greenhouse Gas Variability across Frontal Structures in the Lower Troposphere: Preliminary Findings from Atmospheric Carbon and Transport - America Summer-2016 Field Experiment

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Detailed understanding of the impact of frontal systems on the spatiotemporal variability of atmospheric greenhouse gases (GHGs) on regional scales is needed for the evaluation of transport models and for improving knowledge of GHG sources and sinks. The first Atmospheric Carbon and Transport (ACT) – America airborne field campaign (15 July- 31 Aug, 2016) was conducted across three regions (Mid-Atlantic, Upper Mid-West, and South) in the eastern United States to study the transport and fluxes of atmospheric carbon dioxide and methane. One primary goal is to measure how weather systems transport GHGs in the atmospheric boundary layer (ABL) and in the free troposphere (FT). High resolution remote and in-situ airborne observations were collected with two aircraft (NASA's C-130 and B-200), including the first systematic study of frontal gradients in GHG mole fractions.

We hypothesize that typical synoptic weather events (e.g., cold front passage) perturb the spatial heterogeneity in the atmospheric GHG concentrations both horizontally and vertically across the frontal boundaries. We will report on the frontal gradient features in GHGs based on 12 selected research flights. Preliminary analyses suggest higher front-related CO2 gradients in the ABL compared to the upper and lower FT as well as larger case-to-case variability in front-related CO2 gradients in the ABL compared to the FT. We will discuss how CO2 and CH4 spatial variability can be modified by cold fronts, prefrontal troughs and wind shifts. We will relate these findings to available meteorological observations; WRF simulations of meteorological conditions and the CO2 fields; and GHG mole fractions from the global observing network. Using both observations and simulations we will build a conceptual framework of the CO2 and CH4 gradients at frontal boundaries and obtain insights into how ABL-regimes and synoptic-scale transport interact and influence the spatial variability in the vertical and horizontal CO2 and CH4
gradients.

**Presentation Type:** Poster
Variations of net ecosystem production and evapotranspiration across a successional gradient of tropical dry forest in Northwestern Mexico

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Tropical dry forest (TDF) is a widely distributed land-cover type in America that has been impacted by human activities like agriculture and livestock. The subsequent abandonment of these areas results in various stages of succession. TDF is a seasonal ecosystem where precipitation occurs mainly in pulses causing wet-dry cycles which directly affect ecosystem processes. However, the response of water and carbon fluxes to the climate variability in areas with a different structure in the vegetation and soil is poorly understood. To this end, we compare CO2 (NEE) and water vapor flux (ET) across a successional gradient of TDF, which consists of 3 eddy-covariance sites: an abandoned site (AS), a secondary (SF) and mature forest (MF). The study site is under the influence of the North American Monsoon which provides seasonal precipitation to this entire region staring from late Jun to September. During the monsoon season of 2016, the three sites exhibited positive NEE (respiration-dominated) during the monsoon onset, but the MF was more sensitive to soil wetting, and NEE became negative (production-dominated) earlier than SF and AS. Notably the AS sustained a positive NEE until mid-July, indicating a larger respiration response to rainfall. The cumulative NEE from May-October was -280, -246 and -157 g C m$^{-2}$ in the MF, SF and AS respectively, suggesting that during the monsoon season all sites were a net sink of carbon. The ET increased when the NEE switch from respiration-dominated to production-dominated at the three sites, but ET in the AS slightly exceeded that at the MF and SF. The next step of this research is to link the climatic variability from different scales and to investigate the biophysical controls over carbon, water and energy fluxes across the successional gradient.

Presentation Type: Poster
Scaling up measurement systems to test climate-smart rice irrigation strategies

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Approximately 11% of the global 308 Tg CH4 anthropogenic emissions are currently attributed to rice cultivation. In this study, the impact of water conservation practices on rice field CH4 emissions was evaluated in Arkansas, the leading state in US rice cultivation. While conserving water, the Alternate Wetting and Drying (AWD) irrigation practice can also reduce CH4 emissions through the deliberate, periodic introduction of aerobic conditions. Seasonal CH4 emissions from a pair of adjacent, production-sized rice fields treated with continuous flood (CF) and AWD irrigation were estimated and compared during the 2015 and 2016 growing seasons using the eddy covariance method on each field. The seasonal cumulative carbon losses by CH4 emission significantly less for the AWD treatment. The substantial decrease in CH4 emissions by AWD supports previous chamber-based research and offers strong evidence for the efficacy of AWD in reducing CH4 emissions in Arkansas rice production. Plans for the 2017 measurement season will be discussed, including a mixture of EC and surface renewal micrometeorological techniques on 16 adjacent 40-acre fields under various irrigation practices in northeast Arkansas. The AWD practice is incentivized by several USDA-NRCS conservation programs and is used for carbon offsets trading, so CH4 emissions reductions are encouraged on a regional scale.

Presentation Type: Poster
Blue Carbon Monitoring: Navopatia a pilot site for seagrasses, mangroves, and participatory fisheries conservation

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Coastal ecosystems such as seagrasses and mangroves provide a wide range of ecosystem services, furthermore the well-being of about one third of the human population depends on healthy coastal systems. Some of this services include: carbon storage in their sediment and vegetation component, carbon sequestration via ecosystem processes (i.e. photosynthesis), nursery and protection for fisheries, protection from flooding, and as barriers to slow down meteorological phenomena such as hurricanes or tropical storms. Navopatia Field Station (Sonora, Mexico), was established with the main goal of habitat and bird conservation, today with interinstitutional collaborations the goals and objectives have grown. The newest monitoring objectives include carbon monitoring from seagrasses and mangroves, and a program in which the community is involved via participatory fisheries conservation. The carbon monitoring program includes 1) an eddy covariance (EC) flux tower and micrometeorological sensors on a mix Avicennia germinans and Rhizophora mangle patch, and 2) plot-transect sites to measure above and below ground carbon storage from mangroves and seagrasses (Zostera sp.). Preliminary results from above ground carbon estimates in mangroves, show high uncertainty due to allometric equations. The participatory fisheries conservation program includes 1) empowerment and building community based capacities for fisheries and environmental monitoring, 2) local awareness of the benefits and threats of the ecosystem services provided by seagrasses and mangroves, and 3) water quality monitoring program. Preliminary results from developing low cost soil sludge and sediments samplers, show that it is challenging to use the same type for mangroves and seagrasses due to the composition in the soil profile.

Presentation Type: Poster
Surface renewal application and examination over different AmeriFlux landscapes

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Some growing canopy or patchy forest sites may preclude optimal use of eddy covariance (EC) because their characteristics prevent consistent measurements in the inertial sublayer. Therefore, alternative flux measurement methods with the potential to measure in roughness sublayer are desirable. The surface renewal (SR) approach by Castellví in 2004 has been shown to independently measure surface-atmosphere fluxes with adjustments to frequent changes in the roughness sublayer depth. We are particularly interested in evaluating the SR method at cropland and forest sites where EC measurements are available for comparison. These sites are part of either the AmeriFlux or Long-term Agricultural Research networks. The main goal was to apply the SR method over the high frequency scalar time series of temperature, water vapor and CO2 concentrations with the average horizontal wind speed to test the possibility of avoiding sonic anemometry. The results showed a high agreement between sensible (H), latent (LE) and CO2 fluxes when SR was compared to EC as a reference regardless of stability conditions or underlying surface. However, a pattern of overestimation was observed for fluxes from short agricultural crops and underestimation for forest sites. There are more open questions to address in this method before recommending its universal application over different landscapes. These challenges include applying similarity based relationships in the roughness sublayer, canopy drag coefficients, the WPL term for density corrections, etc. We look forward to testing and refining this approach with contributions from across the AmeriFlux network and possibly building an R code for a universally appropriate SR processing scheme.

Presentation Type: Poster
Synthesis of four forest CO2 enrichment experiments demonstrates a strong and sustained decadal carbon sink in aggrading temperate forest biomass

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Predictive understanding of the future terrestrial carbon sink remains elusive. Forest responses to increasing CO2 are a large contributor to uncertainty in this understanding. Synthesizing data from the only four, decade long, forest CO2 enrichment experiments replicated at the forest stand scale, we show a strong, decadal-scale CO2 sink in aggrading forest biomass. Across ambient and elevated CO2 treatments, biomass increased over the decade of the experiments in a linear relationship with NPP, i.e. CO2 did not affect the relationship between biomass increment and cumulative NPP. However, because wood allocation increased as NPP increased, the retention of NPP as biomass was more efficient under increased CO2. Each forest showed strong within treatment variability in NPP suggesting that the factors governing the retention of NPP as biomass across a range of natural climatic and edaphic variability also govern the retention of CO2 stimulated NPP.

At the two sites that were not confounded by uncertainty or adaptation to frequent fire disturbance, state-of-the-art ecosystem models under-predicted the biomass stimulation by CO2. This under-prediction was caused by an under-prediction of both the NPP response to CO2 and the increase in the wood allocation fraction in response to CO2. These data, synthesized as part of the Free Air CO2 Enrichment Model Data Synthesis (FACE-MDS), project clearly demonstrate a sustained long-term stimulation of forest biomass in response to CO2 concentrations predicted for the middle of the century. Properly accounting for this CO2 stimulation of biomass in aggrading forests will be necessary for accurately projecting the future terrestrial carbon sink.

Presentation Type: Poster
MALIBU: A High Spatial Resolution Multi-Angle Imaging Unmanned Airborne System to Validate Satellite Products

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NASA’s Goddard Space Flight Center’s Multi AngLe Imaging Bidirectional Reflectance Distribution Function small-UAS (MALIBU) is part of a series of pathfinder missions to develop enhanced multi-angular remote sensing techniques using small Unmanned Aircraft Systems (sUAS). The MALIBU instrument package includes two multispectral imagers oriented at two different viewing geometries (i.e., port and starboard sides) to capture surface optical properties and structural characteristics. This is achieved by analyzing the reflectance anisotropy signal (i.e., Bidirectional Reflectance Distribution Function (BRDF) shape) obtained from the combination of surface reflectance from different view-illumination angles and spectral channels. Surface albedo, a key climate forcing variable that contributes significant uncertainties in the simulation of climate changes, can be obtained from MALIBU radiances, by integrating the BRDF over the viewing and illumination hemispheres. These surface radiation measurements (i.e., BRDF, Reflectance, and Albedo) are required by global and regional climate and biogeochemical models (GCOS-IP, 2016).

Satellite measures of surface albedo from MODIS, VIIRS, and Landsat have been evaluated by comparison with spatially representative albedometer data from sparsely distributed flux towers at fixed heights. However, the mismatch between the footprint of ground measurements and the satellite footprint challenges efforts at validation, especially for heterogeneous landscapes. The MALIBU platform that acquires extremely high resolution sub-meter measures of surface anisotropy and surface albedo, serves as an important resource of reference data to improve global land product validation efforts, and resolve the uncertainties in the various existing products generated by NASA and its international partners.

Presentation Type: Poster
U.S. Urban Testbed Projects: Methods, Uncertainties, and Goals for Future Efforts

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Urban greenhouse gas (GHG) emissions account for a large portion of overall global GHG emissions; thus, city and regional governments are essential implementers of effective GHG mitigation. To support the effort of improving measurement of GHG emissions in urban environments, several federal agencies including the National Institute for Standards and Technology (NIST), NOAA, NASA, DOE, NSF, etc. along with academic, research, and private entities have been working within a handful of domestic urban areas to improve both (1) the assessment of GHG emissions accuracy by the application of a variety of measurement technologies, and (2) the tools that can better assess GHG inventory data at urban GHG mitigation scales based upon these measurements. Research efforts have so far been focused domestically due to the quantity and quality of emission source/sink activity information and the logistical ability to instrument urban areas. Urban studies have been conducted in six U.S. metropolitan areas: Indianapolis (INFLUX experiment), Los Angeles (the Megacities project), Salt Lake City, Oakland, Boston, and the Washington/Baltimore area (the Northeast Corridor GHG Measurements project). These cities have different meteorological, terrain, demographic, and emissions characteristics and generally involve multiple measurement systems and integrated observing approaches, making them suitable test-bed environments. It is expected that the lessons that are learned can be exported to other cities both domestically and internationally.

This presentation will give an overview of urban greenhouse gas research efforts in the U.S., sharing lessons learned and identifying community needs and future goals. Overall, we stress that investment made in urban greenhouse gas research and high-quality measurements across the U.S. provides a strong platform for support and expansion of advancing measurement method capabilities with excellent potential to effectively inform mitigation efforts in the areas where it is will most likely to be applied: cities.

Presentation Type: Poster
Disaggregating fossil fuel and biogenic CO$_2$ fluxes in an urban environment using micrometeorological and trace gas measurements

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The Indianapolis Flux Experiment (INFLUX) aims to estimate anthropogenic greenhouse gas emissions at fine spatial and temporal scales over a large urban area. A challenge in the study of land-atmosphere exchange of CO$_2$ in cities is the separation of fossil fuel CO$_2$ emissions and biogenic CO$_2$ exchange. Ecosystems play an important role in the diurnal and seasonal variations of urban CO$_2$ enhancement, and the presence of biogenic CO$_2$ fluxes significantly weakens our ability to solve for fossil fuel CO$_2$ emissions in the growing season using atmospheric CO$_2$ measurements. In summer, for example, the CO$_2$ enhancement across the city grows larger, suggesting a combination of boundary layer dynamics and biogenic CO$_2$ fluxes that complicate our interpretation of atmospheric CO$_2$ observations. Here we use tower-based measurements of the vertical gradient in CO$_2$ mole fraction and eddy-covariance fluxes to detect surface CO$_2$ fluxes. We attempt to disaggregate fossil fuel and biogenic CO$_2$ fluxes using tower-based $^{14}$C and CO mole fraction measurements. We compare these measurements to estimates of bottom-up fossil fuel CO$_2$ emissions (i.e. the Hestia project) and biogenic CO$_2$ fluxes simulated from the Vegetation Photosynthesis and Respiration Model. At our most urbanized site in the center area of the city, the difference in the diurnal variation of vertical CO$_2$ and CO gradients during the growing season implies the existence of net uptake of CO$_2$. The high ratio of the CO and CO$_2$ vertical gradients in summer indicates that traffic is the main source of anthropogenic CO$_2$ emissions in the city center. Finally, we will use the micrometeorological flux measurements to evaluate the magnitude and temporal structure of surface CO$_2$ fluxes from Hestia and VPRM, and ultimately combine the two components into regional atmospheric mole fractions to solve for disaggregated, whole-city CO$_2$ fluxes in the growing season.

**Presentation Type:** Poster
Toward an operational atmospheric carbon observing network: What did we ask for, what do we have, and what is needed?

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Nearly 20 years ago, the carbon cycle science research community wrote requirements for an atmospheric observation network designed to constrain and determine ecosystem-atmosphere carbon fluxes across North America. More than a decade of atmospheric CO2 and CH4 measurements from aircraft, towers and ground-based remote sensing, in both sustained networks and shorter-term campaigns, and more than 5 years of space-based measurements of column CO2 and CH4, have exceeded this plan in some respects and fallen short in others. We are still unable to determine strong, routine constraints on continental-scale ecosystem-atmosphere carbon fluxes, but have made great strides in our understanding of the CO2 and CH4 distribution of the continental atmosphere. We have had notable success determining CO2 and CH4 fluxes in certain regions, in some cases attributing emissions to specific source sectors. The community has also expanded its scope to include determination of anthropogenic CO2 emissions using atmospheric measurements.

We will review the status of today’s North American observational system, our current ability to describe atmospheric CO2 and CH4 mole fractions and fluxes, and present examples that illustrate how we can meet the promise put forward in 1999 of atmospheric monitoring of fluxes for scientific and policy applications. We will describe the challenges facing the atmospheric measurement and monitoring effort, source attribution, accurate and precise measurement of atmospheric background values, accurate and precise measurement of the vertical structure of atmospheric CO2 and CH4 mole fractions, well-calibrated atmospheric transport analyses, and quantified uncertainty in prior flux estimates. This review will draw on results from a number of regional experiments such as the NACP MidContinent Intensive, CARAFE, COBRA, CALGEM, CALNEX, urban experiments such as Boston and INFLUX, NOAA’s aircraft programs, HIPPO, and ACT-America, and on measurements from our current long-term observational networks. We will look forward to identify where and how expanded ground-, airborne- and space-based measurements can fill gaps in our current ability to infer regional to continental carbon fluxes.

Presentation Type: Plenary Talk
A three-dimensional observation network for determining urban emissions of CO₂ and CH₄

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Cities emit the majority of greenhouse gases and pollutants, and urban regions routinely expose their large populations to elevated levels of toxic substances that are co-emitted with CO₂. Long-term monitoring networks in urban regions provide key data to determine when and where CO₂ and CH₄ emissions occur, the factors that regulate those emissions, and the ability to assess the efficacy of mitigation efforts. Most long-term carbon monitoring networks employ surface or tower in-situ sensors. Quantitatively linking these data to urban emission fluxes is challenging because atmospheric transport models struggle to accurately simulate vertical mixing, near-field dispersion, and transport in the urban environment. We describe here how to use ground-based remote sensing to probe the third dimension of the “urban dome” and overcome some of the limitations of surface networks. Hitherto, this information has been provided in limited fashion through either the use of aircraft missions, or via satellites; however, both methods only provide “snap shots” of the desired atmospheric conditions.

The development of small field-deployable Fourier transform spectrometers has enabled us to design a new three-dimensional sensor network capable of measuring gradients of greenhouse gases through the full column of the atmosphere. Solar absorption measurements provide column-averaged dry-air mole fractions of CH₄ and CO₂, and the observed differences between the column amounts across a region provide a direct measure of the mass of the target species added to the atmosphere between the sensors. Networks of three to six sensors have been successfully deployed in Boston, MA, Indianapolis, IN, and throughout the San Francisco Bay Area, CA, and we have demonstrated the ability of these networks to resolve small gradients of greenhouse gases in these regions and to provide robust measures of emission fluxes. Ongoing efforts to automate these measurements will enable longer-term deployments that can provide spatially resolved estimates of emissions.

Presentation Type: Plenary Talk
The Evolving Role of Space-Based Remote Sensing Measurements in a Continental-Scale Carbon Observing Network

David Crisp, JPL/Caltech, david.crisp@jpl.nasa.gov (Presenter)

As the ground-based, tower, and airborne carbon observing networks continue to return critical information into the North American carbon cycle, their measurements are being augmented by CO2 and CH4 observations from a growing fleet of space based remote sensing platforms. The Japanese Greenhouse gases Observing SATellite, GOSAT, has been operating since 2009, collecting dozens of high-spectral-resolution measurements of reflected sunlight in cloud free skies over North America each day. These spectra are analyzed to estimate the column-averaged dry air mole fractions of CO2 (XCO2) and CH4 (XCH4) with single-sounding precisions and regional scale biases near 0.5% (~2 ppm XCO2, ~10 ppb XCH4). In July of 2014, GOSAT was joined by the NASA Orbiting Carbon Observatory-2 (OCO-2). OCO-2 is now returning thousands of XCO2 estimates each day along four to five narrow (<10 km wide) tracks across North America. These XCO2 estimates have single sounding random errors near 0.5 ppm (0.125%), and regional scale biases that are typically < 1 ppm.

While these data are providing key insights into the calibration, analysis, and validation of space based XCO2 and XCH4 measurements, they are posing some new challenges for flux inversion models. The most significant challenges are introduced by small (< 0.25%), spatially-coherent biases that are often not well characterized. These limitations will have to be addressed before the spatial resolution and coverage of the space-based datasets can be fully exploited for regional to continental-scale studies. A much closer collaboration among the space-based, airborne, and ground-based elements of the carbon-observing network is needed to detect and characterize small-amplitude biases in the space-based products. In principal, once identified, these biases can be addressed with targeted improvements in instrument calibration and/or remote sensing retrieval algorithms, and in the flux inversion models, themselves.

Presentation Type: Plenary Talk
Catching butterflies with fishing nets: Are atmospheric greenhouse gas models adapted to current and future observing systems?

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While on the verge of deploying high resolution sensors measuring atmospheric greenhouse gases from large continents to constricted urban basins, the atmospheric top-down approach remains primarily a research-only method, contemplated by many but used by few. Despite promising results at various spatial scales, the scientific community and policy makers still rely heavily on bottom-up approaches to produce reliable carbon budgets from global to urban scales. With an unprecedented increase in observing capacity from spaceborne platforms to high-density networks, time has come to take advantage of the validation potential of atmospheric approaches. After a brief overview of the modeling tools used in GHG inversion systems, we highlight here the recent progress in atmospheric modeling that could feed into state-of-the-art top-down approaches. Data assimilation techniques that have considerably improved the capacity of forecasting systems in real-life applications are within reach of the carbon cycle community. We discuss here recent technical feats from adaptive spatial discretization techniques to the development of hybrid methods that will not only improve the methods but opens the door to producing trustworthy and accurate long-term carbon flux assessments. With the advent of geostationary missions and active measurement technologies, a systematic review of atmospheric modeling capabilities is made with the perspective of developing the next generation of assimilation systems for carbon cycle science.

Presentation Type: Plenary Talk

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The North American atmospheric carbon dioxide (CO2) measurement network has grown from three sites in 2004 to >100 in 2017. The US network includes tall tower, mountaintop, surface, and aircraft sites in the NOAA Global Greenhouse Gas Reference Network along with sites maintained by university, government and private sector researchers. The Canadian network is operated by Environment Canada. This unprecedented dataset can provide spatially and temporally resolved CO2 emissions and uptake flux estimates and quantitative information about drivers of variability, such as drought and temperature. CarbonTracker-Lagrange (CT-L) is a modeling framework developed to take advantage of newly available atmospheric data for CO2 and other long-lived gases such as methane (CH4). CT-L provides a platform for systematic comparison of data assimilation techniques and evaluation of assumed prior, model and observation errors. A novel feature of CT-L is the simultaneous optimization of surface fluxes and boundary values, taking advantage of vertically resolved data available from NOAA’s aircraft sampling program. CT-L uses sampling footprints (influence functions) from the Weather Research and Forecasting/Stochastic Time-Inverted Lagrangian Transport (WRF-STILT) modeling system to relate atmospheric measurements to upwind fluxes and boundary values. First-guess or prior fluxes are adjusted using Bayesian or Geostatistical methods to provide optimal agreement with available observations. Footprints are pre-computed and the optimization algorithms are efficient, so many variants of the calculation can be performed. For example, we can test alternate prior flux estimates, data weighting scenarios and error covariance parameterizations. CT-L is also a powerful tool for observing-system design. We are developing flux estimation strategies that use remote sensing and in situ data together, and we are investigating what new measurements would best complement the existing carbon observing system.

Presentation Type: Poster
Towards improved estimates of regional CO2 fluxes: A unified carbon and meteorological data assimilation system

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Inversion methods have been widely applied to constrain CO2 surface fluxes on global to local scales. These so-called 'top-down' methods typically use Lagrangian particle trajectory models to relate observed atmospheric CO2 concentration to CO2 surface fluxes. As the density of atmospheric CO2 observations have increased, it has become evident that the typical inversion methods are too computationally inefficient to take advantage of all available information. There has therefore been a movement in the carbon community towards advanced data assimilation schemes, which have already been developed, optimized, and refined over many decades for numerical weather prediction applications. However, most carbon data assimilation schemes neglect the uncertainties associated with the atmospheric transport of CO2, and consider only one fixed trajectory of CO2 transport using offline meteorology, assuming that the errors in the prior CO2 fluxes are much larger than the transport errors. How much transport errors affect estimated CO2 surface fluxes is still not well known.

Here we present a new unified carbon data assimilation system based on the Ensemble Kalman Filter that simultaneously assimilates meteorological and CO2 concentration observations to estimate CO2 surface fluxes. By taking the uncertainties in both prior CO2 fluxes and atmospheric transport into account, this new system will allow us to quantify the relative contribution from the two sources of errors to the final estimated CO2 fluxes, as well as give us a more accurate assessment of the uncertainties associated with the derived CO2 fluxes. We will first test the data assimilation scheme in a series of Observing System Simulation Experiments over the contiguous United States, and investigate the impact of assimilating meteorological observations, CO2 concentration from towers, and XCO2 from satellites.

Presentation Type: Poster
Observing and Simulating Spatial Variations of Forest C Fluxes and Stocks in Complex Terrain

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Terrestrial carbon (C) cycle remains the least constrained component in the global C cycle, partly due to the difficulty to quantify C sources and sinks in complex terrain. In this study, we used observations at Shale Hills Critical Zone Observatory and a biogeochemistry model - Biome-BGC to examine the spatial distribution of C stocks and fluxes in a first-order watershed. We fed the model with observed soil moisture and soil temperature to reduce the uncertainties in simulating water and energy cycle. With only three parameters constrained by observations, the model could represent the average C pools and fluxes in the watershed. The three parameters are whole-plant mortality rate, N input (deposition/fixation) and maximum decomposition rates of soil and litter C pool. Whole-plant mortality rate is crucial to aboveground C pool; N input is crucial to aboveground C fluxes (e.g. NEP); and maximum decomposition rates are crucial to soil C pool. We then applied this tuned model to six sites along the topography, and the model was able to produce the general spatial patterns of C pools in the watershed, with higher biomass and soil C in the valley and lower on the ridgetop, even though the model underestimated the spatial contrast along the topography. We also examined the effects of four environmental factors on the spatial distribution of C pools. These four environmental factors are soil moisture, soil temperature, N availability and solar radiation. Among the four factors, soil water and N availability dominated the spatial distribution of aboveground biomass. Soil water was also the most important factor controlling soil C distribution. This study highlighted the importance of accurate hydrological simulations to ecosystem modellings.

Presentation Type: Poster
CarbonTracker-Lagrange: A High-Resolution Regional Inverse Modeling System for Estimating North American CO2 Fluxes (Model Development and a Synthetic-Data Study)

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NOAA’s CarbonTracker is a global modeling system for deriving CO2 exchange between the atmosphere and Earth surface based on accurate atmospheric CO2 mole fraction measurements. Limitations in CarbonTracker’s modeling setup (e.g., optimizing scaling factors on weekly fluxes per eco-region) and relatively coarse resolution of its atmospheric transport limit its ability to retrieve the most accurate carbon fluxes. To overcome these limitations, CarbonTracker-Lagrange has been developed as a high-resolution regional inverse modeling system. CarbonTracker-Lagrange takes advantage of high-resolution regional atmospheric transport models and optimizes carbon fluxes on a grid-scale basis. In this presentation, we will discuss results from a synthetic-data experiment for the choices we made on model temporal resolution, model assimilation window, and prior error covariances. We will discuss the importance of optimizing the diurnal cycle of carbon fluxes, performing a grid-scale inversion to minimize aggregation errors, and having space- or eco-region dependent prior error covariances. Furthermore, we will show the improvement of deriving carbon fluxes with the CarbonTracker-Lagrange inversion setup relative to those using the global CarbonTracker setup.

Presentation Type: Poster
Spectral analysis of high frequency time series of pCO2w (2008-2015) at a coastal station off the Peninsula of Baja California, Mexico

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The environmental conditions of the southern region of the California Current System (CCS) varies greatly over time. Attempts to identify the processes that cause the variability of the partial pressure of CO2 in the ocean (pCO2W) are studies that have been made for decades. However, it is uncommon to generate high frequency time series of pCO2W, that allow to infer which are the drivers of change from scales of hours to interannual variability. Time series (2008-2015) were generated of surface temperature, and pCO2 data from a MAPCO2 buoy anchored at 5 km from Punta Banda (31.6º N, 116.6º W), Baja California, México, in waters 100 m deep. In addition to the data of pCO2W, the CO2 flux in the ocean-atmosphere interface (FCO2) was calculated. Spectral analysis of the time series of pCO2W and FCO2 was performed, with the objective to determine which drivers impact the variability from the scale of hours to interannual under different conditions such as El Niño, La Niña and warm ‘blob’ in the Ensenada Station. The results showed that pCO2W varies from the daily scales, (~ 15 and ~ 28 days), which are due to the changes between day - night and the upwelling cycle (intensification and relaxation). Besides, the FCO2 presented significant semidiurnal and diurnal variations, this is due to the fact that the wind plays a very important role in the calculation of the FCO2. Therefore, this system responds to the semidiurnal and diurnal changes that exist in the zone, due to convective processes, that cause change in the direction of the sea-land-sea wind during the day. For that reason, in order to identify the processes that affect the variations of pCO2W and FCO2 in a region, it is necessary to have enough data (time series) to be more certain about what is happening in the environment.

Presentation Type: Poster
Preliminary Evaluation of Surface Albedo at Fine Spatiotemporal Resolution from Landsat/Sentinel-2A Surface Reflectance and MODIS/VIIRS Surface Anisotropy

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The land surface albedo products at fine spatial resolutions are generated by coupling surface reflectance (SR) from Landsat (30 m) or Sentinel-2A (20 m) with concurrent surface anisotropy information (the Bidirectional Reflectance Distribution Function - BRDF) at coarser spatial resolutions from sequential multi-angular observations by the Moderate Resolution Imaging Spectroradiometer (MODIS) or its successor, the Visible Infrared Imaging Radiometer Suite (VIIRS). We generate four types of fine-resolution albedo products (black-sky and white-sky albedos over the shortwave broadband) generated by coupling, (1) Landsat-8 Optical Land Imager (OLI) SR with MODIS BRDF; (2) OLI SR with VIIRS BRDF; (3) Sentinel-2A MultiSpectral Instrument (MSI) SR with MODIS BRDF; and (4) MSI SR with VIIRS BRDF.

We evaluate the accuracy of these four products using ground tower measurements of surface albedo over six SURFRAD sites, four AmeriFlux sites and two NEON sites, in U.S.A. We evaluate the consistency between these four products via the pixel-by-pixel comparison of the same-day observations by OLI and MSI. All the products show good accuracies with RMSEs over these sites within 0.05. We observe little effect of the BRDF source on generating the fine-resolution albedo products when using the same fine-resolution SR, while clear but not strong effect of the SR source when using the same BRDF. The impact by the SR source is likely caused mostly by the misregistration error between the Landsat-8 and Sentinel-2A data but further investigation is needed.

The assurance of consistency between the couplings of both OLI and MSI with both MODIS and VIIRS guarantees the production of long-term records of surface albedo at fine spatial resolutions and an increased temporal resolution. Such products will be critical in studying land surface changes and the associated balances of surface energy and carbon cycle, especially over those dynamic and heterogeneous landscapes.

Presentation Type: Poster
Synoptic patterns of CO$_2$ during cold front passages: A case study from DISCOVER-AQ 2011

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Among the different dynamic processes taking place in the Troposphere, synoptic scale transport events like cold front passages are responsible for carrying large air masses, and therefore atmospheric greenhouse gases (GHG), over long distances to redistribute them across latitudes. To evaluate the capabilities of current atmospheric models to reproduce large-sale transport of GHG, a month-long simulation was conducted using the chemistry-enabled Weather Research and Forecasting Model (WRF-Chem v.3.6.1) over the 2011 DISCOVER-AQ Baltimore campaign with Carbon Tracker CO$_2$ surface fluxes and boundary conditions. During the whole campaign, two cold front passages on the 13th and 26th of July were observed. The NASA P3B aircraft collected vertical profile measurements of CO$_2$ pre- and post- events on both days. Ameriflux towers and National Weather Service (NWS) surface stations in the region also recorded CO$_2$ and atmospheric state variables. We show here the model was able to reproduce the regional scale weather patterns and to simulate the trends in CO$_2$ mole fractions during daytime when the convective boundary layer was fully developed. The model had difficulties in capturing the wind direction near the Chesapeake Bay area. Vertical profiles of CO$_2$ showed the existence of a gradient in CO$_2$ mole fractions between the atmospheric boundary layer and the free atmosphere – generally, free atmospheric concentrations of CO$_2$ are higher than the boundary layer in summer. During cold front passages, the CO$_2$ vertical gradient reversed as the concentrations in the boundary layer were higher than in the free atmosphere. After the front passed over the region, the gradient returned to the pre-frontal value over the next few days. The model results showed that synoptic scale events like cold front passages introduced air with high concentrations of CO$_2$ into the boundary layer changing the gradient; the structures of air with high CO$_2$ concentrations align with frontal boundaries while high pressure systems trapped air with lower CO$_2$ concentrations. Repeated passages of these events through the Baltimore region modify the CO$_2$ spatial gradients, explaining most of the Discover-AQ observations of the vertical distribution of CO$_2$ in the lower atmosphere. Thus, the model can be used to complement observations – help investigate large scale CO$_2$ transport in the lower atmosphere beyond the scope of the field campaign.

Presentation Type: Poster
Improving transport errors through parameter optimization in a WRF Urban modeling system for Indianapolis, IN

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Certain inversion methodologies use modeled meteorological data and observed atmospheric greenhouse gas (GHG) concentrations to estimate surface GHG fluxes. The quality of these inversions is reliant on the accuracy of the observed GHG concentration measurements and the accuracy of the modeled meteorological fields. As part of the Indianapolis Flux Experiment (INFLUX), urban meteorological simulations are examined and model parameter sensitivity experiments are performed. A variety of meteorological observations collected as part of INFLUX enables a rigorous evaluation of the modeled urban meteorology. Using these observations, the parameters in the meteorological model can be updated in an effort to reduce the modeled meteorological errors and improve the inversion flux estimates.

This study generates meteorological fields for Indianapolis, IN using the Weather Research and Forecasting (WRF) model at a 1-km resolution for the innermost domain. While the WRF model is a proven weather forecasting system, the default parameter values in the urban canopy models (UCMs) within WRF are not representative of the Indianapolis urban landscape. Available observations allow for model parameters, such as average building height and urban cover percentage, to be updated in WRF in order to allow for a more accurate representation of the urban landscape in Indianapolis. In addition, equations that estimate aerodynamic parameters, such as displacement height and roughness length, have also been updated using empirical formulas that have been developed for other urban areas. It is proposed that integrating building height data and updating the aerodynamic model parameters have the potential to positively impact the modeled atmospheric boundary layer height, wind speed, and wind direction, all of which influence the inversion flux estimates.

Presentation Type: Poster
Atmospheric evidence for a global secular increase in isotopic discrimination of land photosynthesis

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A decrease in the 13C/12C ratio of atmospheric CO2 has been documented by direct observations since 1978 and from ice-core measurements since the industrial revolution. This decrease, known as the 13C-Suess effect, is driven primarily by the input of fossil-fuel derived CO2 but is also sensitive to land and ocean carbon cycling and uptake.

Using updated records, we show that no plausible combination of sources and sinks of CO2 from fossil-fuel, land, and oceans can explain the observed 13C Suess effect unless an increase has occurred in the 13C/12C isotopic discrimination of land photosynthesis. A trend toward greater discrimination under higher CO2 levels is broadly consistent with tree-ring studies over the past century, with field and chamber experiments, and with geological records of C3 plants at times of altered atmospheric CO2, but increasing discrimination has not previously been included in studies of long-term atmospheric 13C/12C measurements. We further show that the inferred discrimination increase of 0.012 ± 0.006 ‰ ppm⁻¹ is largely explained by photo-respiratory and mesophyll effects.

This result implies that, at the global scale, land plants have regulated their stomatal conductance so as to allow the CO2 partial pressure within stomatal cavities and their intrinsic water-use efficiency to increase in nearly constant proportion to the rise in atmospheric CO2 concentration.

**Presentation Type:** Poster
Insights on temporal variations in terrestrial carbon fluxes from in situ and remote sensing CO2 observations

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Variations in atmospheric CO2 over a range of timescales may provide information about flux variations originating in distinct geographic regions. For example, interannual variations in the global growth rate are affected substantially by carbon fluxes in tropical forests and semi-arid ecosystems, while the annual cycle is driven mostly by Northern Hemisphere carbon exchange. Identifying the geographic, climatic, and human drivers of variations in atmospheric CO2 observations across a range of timescales is crucial for developing a mechanistic understanding of carbon cycling capable of accurate predictions of future carbon fluxes. Here, we analyze variations in atmospheric CO2 observations from both the NOAA surface network and remote sensing platforms, including the Total Carbon Column Observing Network (TCCON) and the Orbiting Carbon Observatory-2 (OCO-2). We quantify drivers of interannual variations in the atmospheric CO2 growth rate and on features of the mean annual cycle amplitude in relation to environmental drivers, including temperature, precipitation, and soil water availability. These results are used to evaluate carbon exchange in prognostic models. Throughout the analysis, we detail the necessity of quantifying the imprint of atmospheric transport for correctly interpreting the observations.

Presentation Type: Poster
Redefine agricultural droughts in the U.S. Corn Belt: quantify the stomatal regulation attributable to atmospheric demand and/or soil water supply using the network of eddy-covariance data

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Agricultural droughts have important economic and societal impacts for the U.S. Corn Belt. Water stress can lead to stomatal closure through two major processes: atmospheric water demand and soil water supply. However, since these two effects are closely correlated with each other and lead to the similar consequence, it is largely unclear of their specific roles on stomatal regulation for the croplands. In this study, we aim to test the hypothesis that VPD rather than soil moisture dominantly drives stomatal regulation in croplands, using the existing eddy covariance flux data network (10 sites for corn and soybean sites) and advanced statistical approaches. Contributions of VPD and soil moisture to the variation of stomatal conductance are quantified for all the sites and years. We compare differences of environmental conditions and its impacts on variations in stomatal conductance. Also, regarding data from the three Nebraska site, stomatal conductance variations attributable to VPD or soil moisture is also analyzed for irrigated- and rain-fed croplands. We have discovered that different sites show varying levels of controls of VPD and soil moisture on stomatal conductance across the growing season. Specifically, the US croplands show more sensitivity to soil moisture stress in the vegetative stage, and converts to VPD-induced stress during the reproductive stage (July-August). Our study has identified primary environmental factors affecting stomatal regulation, and improved our understanding on climate change impacts on stomatal regulation and crop production in U.S. Corn Belt.

Presentation Type: Poster
Using Flux Tower Measurements to Model the Depletion of a Tritium Oxide Plume by a Forest Canopy

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Regulatory dispersion models are used to predict the airborne transport and dispersion of plumes of hazardous material for emergency response and to determine regulatory guidelines. Many of these models assume that a logarithmic wind profile based on a given roughness length and displacement height is adequate to predict dispersion. However, airborne plumes traveling over forested environments are subject to interactions with the forest, including uptake by vegetation and the movement of airborne material into the canopy airspace where the wind profile can be markedly different than the profile above the canopy; specifically, wind speed is much lower and wind directions can vary substantially. For modeling purposes, this can lead to other issues such as the selection of an appropriate deposition or resuspension velocity. At the Savannah River Site (SRS), uncertainty over the deposition velocity of tritium oxide over the forest has led to the over-conservative practice of assuming that no tritium oxide deposition occurs.

A 3-D atmospheric dispersion model was developed to address how airborne plumes of tritium oxide interact with the forest at Savannah River Site (SRS) using a Gaussian modeling approach to predict atmospheric transport and dispersion above the forest canopy at SRS and an Advection-Diffusion model to predict dispersion within the canopy. To link the two models, an accurate rate of flux from above to within the forest canopy (or back to the atmosphere) is needed which can then be used to estimate an appropriate deposition or resuspension velocity. This can be done using mean wind and turbulence quantities measured by the Aiken AmeriFlux tower located at SRS between 2011 and 2013. The data from the tower was broken into 30 minute periods and average quantities of winds, turbulence and moisture flux were calculated for each period. By using those values in the 3-D model, the impacts to the model plume concentrations as it moves downwind can be determined and appropriate model parameters for deposition and resuspension can be calculated. Further validation of the values is required to determine their appropriateness for the forested environment, but calculated deposition velocities are consistent with published experimental studies.

Presentation Type:  Poster
Kipp & Zonen Sensors

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Kipp & Zonen is the specialist in the measurement of solar and sky radiation, from the ultraviolet to the far infrared. We offer a complete range of high quality instrumentation and accessories, from reliable cost-effective products to the best performance available. Our pyranometers, for example, are used in meteorological networks around the world.

Furthermore, our expertise and close links with the scientific community have led to high-end solutions for the measurement of atmospheric properties such as stratospheric Ozone, UV Spectra and evapo-transpiration.

Our mission is to satisfy the fundamental need to monitor atmospheric properties related to climate change, classical meteorology, agriculture, renewable energy and the available water budget.

Presentation Type: Poster