TES PI Meeting Abstracts
April 23-24, 2012

NAME: Robert Andres
INSTITUTION: OAK RIDGE NATIONAL LABORATORY
COLLABORATORS: GREGG MARLAND, APPALACHIAN STATE UNIVERSITY
ABSTRACT TITLE: Temporal, Spatial, and Uncertainty Aspects of Carbon Dioxide Emissions from Fossil Fuel Combustion: Highlights of Recent TES Funding
PROGRAM AREA: National Laboratory Research (SFA)

ABSTRACT: Recent TES funding has led to improvements in our understanding of fossil fuel carbon dioxide emissions, especially in terms of their temporal distribution, spatial distribution, and uncertainties associated with those emissions. Research continues on all three of these areas with ongoing TES support.

Temporally, monthly inventories of fossil fuel carbon dioxide emissions have been completed from January 1950 to December 2008. The basic spatial unit of data is at the scale of nations (which then can be summed to regional and global totals). These data are available in numerical tables or graphically distributed. One of the primary results of this monthly research is that the global monthly time series is statistically significantly different from a uniform distribution throughout the year.

Spatially, the annual and monthly data are gridded at a one degree latitude by one degree longitude scale. This data presentation format has proven so useful to the broader community that others have made several attempts to improve upon the gridding methodology originally published in 1996 (Andres et al., Global Biogeochem. Cycles 10:419-429). Each of these gridding attempts suffer from spatial, temporal and/or coverage uncertainties. The full evaluation of gridding distributions is hampered by the lack of physical, independent measurements of fossil-fuel-carbon-dioxide emissions at relevant spatial and temporal scales.

Research on uncertainties associated with fossil fuel emissions has been concentrated in two areas: global totals and gridded distributions. A new global uncertainty estimate has been prepared. This new estimate focuses on calculating the global uncertainty as the combination of individual national uncertainties. This is a stark departure from the last comprehensive uncertainty study of global fossil fuel emissions which was conducted by Marland and Rotty (1984, Tellus B, 36:232–261) who approached the issue from the standpoint of evaluating the individual terms used in the carbon dioxide generation calculation. The new uncertainty estimate is time dependent and ranges from 2.6 to 4.8% (2 sigma) per year and is much smaller than the time-independent 6.1 to 10.2% (90% confidence interval) per year of Marland and Rotty (1984). Uncertainty work on gridded distributions has only just begun and is not sufficiently mature enough for publication.

Peer-reviewed publication of this work continues. To date, TES funding has contributed to 15 major publications over the last two years as well as meeting abstracts, presentations, and interactions.

NAME: Vanessa Bailey
INSTITUTION: Pacific Northwest National Laboratory
COLLABORATORS: Benjamin Bond-Lamberty, Pacific Northwest National Laboratory; Chongxuan Liu, Pacific Northwest National Laboratory

ABSTRACT TITLE: The Response of Pore-Scale Soil Biogeochemical Processes to Changing Climate
PROGRAM AREA: National Laboratory Research (SFA)

ABSTRACT: The biogeochemical mechanisms controlling the balance between soil C accrual and mineralization across landscapes occur at the pore scale where microbial and geochemical reactions occur, but the products of these reactions have important macroscale effects on greenhouse gas fluxes that impact climate. In turn, climate change will perturb these fundamental processes, affecting reaction rates and products. To assess the effects of changing climate on soil C cycling, we are leveraging an existing transplant experiment initiated in 1994 in which 30x30-cm soil cores were transplanted between a hotter, drier location at the base of Rattlesnake Mountain (310 m, 28.5°C air average monthly maximum, 224 mm y-1) at the Arid Lands Ecology Reserve (WA) and a cooler, moister location near the top of the mountain (844 m, 23.5°C air average monthly maximum, 272 mm y-1). Replicate 3.5-cm (diameter), 15-cm deep soil cores drawn from this experiment will be brought into the lab and placed in environmental chambers simulating both climate conditions for 100 days, such that we can monitor their gas fluxes and temperature sensitivities under ongoing transplant conditions, and under a return to their original climate state. Tomographic reconstructions will allow us to determine if the increased moisture and perturbed environmental conditions have altered the physical structure of the soils. Subsets of the cores brought into the lab will be destructively sampled to measure key degradative processes (cellulose degradation), microbial community structure, and C and N chemistry. This information will be integrated using both pore-scale and continuum-scale models coupling physical and biogeochemical processes and classic biogeochemical models (e.g. Biome-BGC) to interpret experimental results and develop new hypotheses about the feedback of changing climate on C and N stability and dynamics in soils. Linking process measurements with microbial community structure will advance our current understanding of the microbial controls on these decomposition processes.

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NAME: Dennis Baldocchi
INSTITUTION: University of California, Berkeley
COLLABORATORS: Siyan Ma; Joe Verfaillie
ABSTRACT TITLE: Findings from a decade-plus study of comparative carbon, water and energy fluxes from an oak savanna and an annual grassland in the Mediterranean climate of California
PROGRAM AREA: Carbon Flux

ABSTRACT: We have been collecting carbon and water fluxes of an oak savanna and annual grassland in the Mediterranean climate of California since 2000. This long and continuous and comparative data record gives us an unprecedented ability to understand and quantify the interannual variations in carbon, water and energy exchange of contrasting functional types and how they respond to the highly variable annual precipitation inputs.

Our scientific approach uses the eddy covariance to measure the net and gross fluxes of trace gases between ecosystems and the atmosphere. We augment these measurements with a variety of mechanistic studies that examine the physiological and biophysical control on these fluxes. These efforts involve laboratory and field measurements on the exchange of gases from the soil, leaves and plants, like understory eddy flux measurements, pre-dawn water potential, photosynthetic capacity, soil respiration, soil moisture, monitoring the water table and excavation of roots. To upscale our flux measurements we rely on an assortment of remote sensing measurements. These efforts include measuring light transmission through vegetation, monitoring hyperspectral reflectance of the vegetation, time series of canopy photos to monitor phenology and LIDAR surveys of vegetation structure.

Based on data through the 2010 hydrological year we find that net ecosystem exchange, ecosystem photosynthesis and respiration are -101 +/- 67, 1302 +/- 195 and 1193 +/- 161 gC m-2 y-1, respectively, for the oak savanna, indicating it is a sink for carbon. In comparison, the annual grassland is carbon neutral; its mean annual sums for net ecosystem exchange, ecosystem photosynthesis and respiration are 19 +/- 109, 814 +/- 251 and 833 +/- 251 gC m-2 y-1, respectively.

Together we digest, distill and evaluate this information fluxes and biophysical structure and function of the canopies through a hierarchy of biophysical models, derived from the CANVEG family. Our most recent efforts have been to build on the efforts from our field work to develop two contrasting models. One model, CANOAK-3D, simulates the complex three-dimensional light environment of the savanna to compute photosynthesis and leaf energy balance fluxes. The other model, the Breathing Earth System Simulator--BESS, runs with remote sensing information derived from MODIS to produce flux information on carbon and water exchange at high spatial resolution (1-5 km) across the globe, from days to years. Both models were found to perform well, when compared with data from either the savanna site or the Ameriflux network.

NAME: Holly Barnard
INSTITUTION: University of Colorado
COLLABORATORS: Paul Brooks, University of Arizona; Thomas Pypker, Michigan Technological University
ABSTRACT TITLE: Carbon-water cycling in the critical zone: baseline studies of ecosystem processes across complex terrain
PROGRAM AREA: Carbon Flux

ABSTRACT: Most of the terrestrial carbon sink in mid-latitudes is found in forested, complex terrain where topography drives interactions with climate and vegetation. However, the links between vegetation, hydrology, and climate that control carbon sequestration in biomass and soils remain poorly understood in these complex systems. The goal of our newly funded research is to advance our understanding and improve our ability to predict how spatial and temporal variability in surface hydrology affect the global carbon cycle. In 2011, we focused on collecting baseline data to address two objectives: to test hypotheses about sources of variation in both below- and aboveground carbon and water stores and fluxes with regard to landscape structure; and to mechanistically assess how soil physical and biological properties determine flow paths of water from the soil surface to the atmosphere via transpiration or to stream channels. Here, we present data from a subalpine hillslope dominated by lodgepole pine (Pinus contorta) at the Niwot Ridge Ameriflux site on the Colorado Front Range that aims to improve the process-level understanding of the source and fate of water between subsurface storage and forest uptake. Initial stable isotope results from xylem water samples indicate transpiration source water is isotopic-ly similar to snow melt and deep soil moisture. However, transpiration appears to respond to rain events. Lodgepole pine sap flux increases by 15-30% within 24 hours of monsoon events and decreases over 72 hours or until subsequent rainfall. Furthermore, soil moisture in deep layers (60 and 70 cm) responded to large summer rain events of 0.7 mm and greater. Understanding the mediation of hydrologic processes by trees like lodgepole pine will improve modeling of hydrological and ecological processes and knowledge of forest susceptibility to climate change and other disturbance impacts. In addition, we will present data from both continuous and repeated measurements of soil respiration across a landscape catena.

NAME: Elizabeth Belshe
INSTITUTION: University of Florida
COLLABORATORS: Edward Schuur, University of Florida; Rosvel Bracho, University of Florida; Ben Bolker, McMaster University
ABSTRACT TITLE: Permafrost thaw, spatial heterogeneity, and landscape carbon balance.
PROGRAM AREA: Carbon Flux

ABSTRACT: The future carbon (C) balance of high latitude ecosystems is dependent on the sensitivity of biological processes (photosynthesis and respiration) to the physical changes occurring with permafrost thaw. But predicting C exchange in these ecosystems is difficult because the thawing of permafrost is not a uniform and homogeneous process. We measured net ecosystem exchange (NEE) of C using eddy covariance (EC), in a tundra landscape visibly undergoing thaw, during two 6-month campaigns in 2008 and 2009. We developed a spatially explicit quantitative metric of permafrost thaw based on variations in microtopography and incorporated it into an EC carbon flux estimate using a generalized additive model (GAM). This model allowed us to make predictions about C exchange for the landscape as a whole, and for specific landscape patches throughout the continuum of permafrost thaw and ground subsidence. On average between the years, areas with the highest permafrost thaw took up 17.7% more and respired 3.3% more C than the average landscape. Areas with the least thaw took up 15% less and respired 5.1% less than the landscape on average. By incorporating spatial variation into the EC C estimate, we were able to determine how thaw affect C flux. Overall, permafrost thaw increases the amplitude of the C cycle by stimulating both C release and sequestration. As the next step, we are quantifying the spatial distribution and extent of permafrost thaw within the watershed by developing a land cover classification using a combination of elevation, slope, and spectral characteristics of an IKONOS image. Preliminary results indicate that thaw is occurring in areas with the highest organic C content and deepest active layer thawing.

NAME: Graham Bench
INSTITUTION: Lawrence Livermore National Laboratory
COLLABORATORS:
ABSTRACT TITLE: A liquid sample interface for rapid 14C analysis by accelerator mass spectrometry
PROGRAM AREA: Biogeochemistry

ABSTRACT: Current Accelerator Mass Spectrometry (AMS) measurement has typically required that carbon containing materials be converted to graphite for analysis. Considerable human handling is required, and the process suffers from low sample throughput (<100 samples processed per day) and long turnaround times (~2 days) at a current cost of hundreds of dollars per sample. Many users have been slow to adopt AMS because of the high cost and complexity of sample preparation and resulting slow turnaround times for analysis.

A technological need, widely voiced by industrial and academic investigators in recent years, has been for a user-friendlier AMS interface, including far less cumbersome sample preparation. To facilitate sample preparation and reduce analysis times from days to minutes, we have developed an online, directly-coupled, liquid sample interface that allows analysis without first converting a sample to graphite. The liquid sample interface rapidly converts the carbon content of samples suspended or dissolved in a liquid to CO2 gas and directly transports the gas to a gas-accepting ion source for real-time 14C AMS analysis. This interface eliminates complex and time-consuming human handling of samples and enables direct coupling of an HPLC or other liquid separation technology to the spectrometer for real-time AMS analysis. The ability to handle liquid samples and continuous flows of liquid will enable more widespread and routine use of AMS in biomedicine and environmental applications.

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NAME: Scott Bridgham
INSTITUTION: University of Oregon
COLLABORATORS: Bart Johnson, University of Oregon; Laurel Pfeifer-Meister, University of Oregon; Timothy Tomaszewski, University of Oregon
ABSTRACT TITLE: Pushing limits: Altered temperature and precipitation differentially affect plant species inside and beyond their current ranges
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: There is increasing evidence that climate change is leading to shifts in plant speciesâ€™ geographic ranges. It is projected that many species will need to establish viable populations beyond their current ranges or risk extinction in coming decades. However, current understanding of how range distributions may shift in response to climate change is based on observed historical shifts and model projections. Although recently observed range shifts offer strong empirical evidence of climate change impacts, it is impossible to decouple climate effects from those of other environmental changes. Because many factors at both local and regional scales control speciesâ€™ range-limits, experimentation is essential to test the underlying mechanisms. To this end, the main objective of this project is to determine how climate change will affect the distribution of native plants in Pacific Northwest (PNW) prairies. We embedded a fully factorial manipulation of temperature (+2.5 to 3.0Â°C) and wet-season precipitation intensity (+20% above ambient) into a 520-km latitudinal climate gradient in three upland prairies in the PNW, with increasingly severe Mediterranean climate conditions from north to south. Treatments were initiated in 2010, and in the fall, twelve native forbs and grasses that have their northern range limits within the PNW were seeded into each plot. Germination, survivorship, plant size, and seed set were measured in 2011.

For speciesâ€™ planted within their current range, increased temperature negatively impacted germination rates, but this negative heating effect disappeared when the species were moved poleward beyond their current range. Germination also presented the most significant hurdle to speciesâ€™ success. Once species were able to germinate, a speciesâ€™ current range no longer impacted survivorship, plant growth, or fecundity. Instead, warming negatively impacted survivorship regardless of current range, but if individuals were able to survive, they grew bigger and produced more seeds in the heated treatments. Increased plant growth in the heated treatments could be explained by an indirect effect of increased nutrient availability. We found minimal effects of added precipitation on any life-history stages, but when significant, increased precipitation decreased germination and survivorship. Our results are consistent with predictions that many species will need to expand their ranges poleward or higher in elevation to successfully maintain viable populations. However, multiple years of data will be necessary to understand if, once established, these speciesâ€™ will be able to maintain positive population growth. Our experiment demonstrates the utility of embedding manipulative climate experiments within regional climate gradients.

NAME: Gil Bohrer
INSTITUTION: The Ohio State University
COLLABORATORS: Peter Curtis, The Ohio State University; Valeriy Ivanov, University of Michigan; Karina Schafer, Rutgers University
ABSTRACT TITLE: Plot-level measurements and modeling of sap flux - providing a mechanistic link between stomata conductance and soil moisture
PROGRAM AREA: Biogeochemistry

ABSTRACT: Current models for transpiration assume a coupling between stomatal conductance and soil moisture through empirical relationships that do not resolve the hydrodynamic process of water movement from the soil to the leaves. Hydraulic limitations in forest ecosystems are common and are known to control transpiration when the soil is drying or when vapor pressure deficit is very large, but can also impact stomatal apertures under conditions of adequate soil moisture and lower evaporative demand. The Finite-Elements Tree-Crown Hydrodynamics model (FETCH), simulates water flow through the tree as a simplified system of porous media conduits. It explicitly resolves spatiotemporal hydraulic stresses throughout the tree's hydraulic system that cannot be easily represented using other stomatal-conductance models. By enabling mechanistic simulation of the effects of hydrodynamic stresses on stomata conductance, FETCH modeling system enhanced our understanding of the role of forest structure, growth and disturbance history in determining the tradeoffs between water and light in forest ecosystems. A simplified version of FETCH can rapidly represent a full forest patch using a small number of representative size/type trees, whose distribution in the forest plot can be derived from remote sensing. This type of simulation can be readily incorporated in a land-surface model, to dynamically resolve the effects of hydrodynamic stresses at short (minutes-hours) and long (days-seasons) time scales.

We compare two sites: the Forest-Accelerated-Succession site (FASET) and its control plot, at the footprint of the UMBS Ameriflux tower. Soil moisture, eddy flux and sap flux observations where available throughout the growing season in both sites. The FASET experiment simulates the transition from late-mid successional forest, dominated by tall and relatively uniform canopy of aspen and birch, to a heterogeneous late-successional mixed deciduous forest. The treatment occurred in 2008, and canopy structure has been drastically modified since then. The FASET canopy is, on average, shorter, more open and more heterogeneous. We conducted FETCH simulations using simplified branch-scale tree structures of 3 contrasting trees of different sizes and species. By comparing the simulation results with eddy-flux observations we identified periods where stomatal conductance was lower than projected for a particular set of conditions. These periods were identified at two different time scales: short-term, intra-daily stresses that are typical for early afternoons in high light conditions and longer stress periods where the soil is dryer than usual. We showcase the potential application of this modeling approach as a component in a land-surface model.

NAME: David R. Bowling
INSTITUTION: Dept. of Biology, University of Utah
COLLABORATORS: Sean P. Burns, Dept. of Geography, University of Colorado, and National Center for Atmospheric Research; Russell K. Monson, Dept. of Ecology and Evolutionary Biology, University of Colorado; Britton B. Stephens, National Center for Atmospheric Research
ABSTRACT TITLE: Biosphere-atmosphere exchange of CO2 isotopes over six years at the Niwot Ridge Ameriflux forest
PROGRAM AREA: Biogeochemistry

ABSTRACT: Much of what we know about global and regional carbon cycle processes comes from long-term measurements at sites which are intentionally located away from local sources and sinks. Flux towers provide information on comparatively small scales at locations with important local biological CO2 exchange. To address the inherent spatial scaling mismatch between these approaches, studies are needed which focus on comparisons between them.

In the alpine tundra of Niwot Ridge (here called the tundra site), Colorado, above timberline, very long records of CO2 mole fraction (NOAA, since 1968) and the carbon isotope composition (d13C) of CO2 (U. of Colorado, 1990) exist, providing a wealth of information about continental exchange and insight into free troposphere processes. These data are generated from weekly/biweekly flask samples, and hence have relatively poor time resolution.

CO2 flux measurements have been conducted at the Niwot Ridge AmeriFlux forest since 1998 – this site is located 500 m lower in elevation and ~3 km distant from the tundra site, and allows for a paired-site comparison, with the tundra site acting as the "background" air influencing and influenced by the forest site. In Sept 2005, we initiated an on-going, long-term study of CO2 and d13C at the forest and tundra sites. New measurements are of 2 types: 1) high-resolution, high-precision (< 0.05 ppm) CO2 at the tundra site, and 2) high-resolution, high-precision CO2 (< 0.05 ppm) and d13C (~0.25 permil) at the Niwot Ridge Ameriflux forest. Both data sets involve multiple measurement heights and sampling frequency is on the order of minutes.

Comparisons of the high-frequency data with the flask data at the tundra site show important spatial and temporal differences. These differences will be examined in the context of local and regional carbon cycle processes. The unique information provided by the high-frequency measurements will be highlighted. Public access to these data will be emphasized to encourage broad use within the scientific community.

NAME: Eoin Brodie
INSTITUTION: Berkeley Lab
COLLABORATORS: Janet R. Jansson, Nicholas J. Bouskill, Jinyun Tang, William J. Riley, Susan S. Hubbard, Margaret S. Torn
ABSTRACT TITLE: Understanding and Modeling the Microbial Processes Driving Terrestrial Biogeochemical Cycles
PROGRAM AREA: Biogeochemistry

ABSTRACT: Microbes drive soil organic carbon transformations and loss as CO_2, and there is growing evidence that accurate prediction of soil carbon dynamics requires explicit representation of microbes in terrestrial biogeochemistry models (TBMs). However, explicit description of microbial activity in TBMs is challenging, due to the immense functional and physiological diversity of the microbes in soil and the complexity of microbe-environment interactions that govern their diversity and activity. In the LBNL TES and CESM SFAs, we are developing an integrated experimental-modeling framework that uses experimental manipulations to test predictions regarding the interactions--among environmental conditions, microbial populations, and organic matter molecular structure--that regulate the turnover of soil organic matter. These trait-based models are being incorporated into a modified version of the Community Land Model to simulate explicitly the interactions among environmental conditions and microbial biomass and activity. Here we discuss approaches, including metagenomics, to identify and parameterize microbial traits and give examples of insights derived from trait-based modeling.

One application of trait-based models is the representation of the functional diversity (guilds) of nitrifying organisms in soil. These guilds are represented by probability distribution functions for enzyme kinetics (substrate affinities and maximum uptake rates), growth rates and substrate-use efficiency derived from ecophysiology studies or genomic/metagenomic data. Simulations to date have demonstrated the abundance of different nitrifier guilds to change over time as a function of NH_3 and O_2 concentrations. As these communities diverge, the rate at which NH_3 is drawn down is impacted and changes in diversity feedback to altered N_2O production rates.

To better understand the identities and functions of soil microbial communities and their response to environmental perturbations (e.g. permafrost thaw), we are also employing a range of “omics” approaches. For example, soils across a natural thaw gradient in Alaska were analyzed by metagenomics, metaproteomics and metatranscriptomics. These data revealed significant differences in functional capacity and expression in multiple pathways related to carbon, nitrogen and sulfur cycling between permafrost, seasonally thawed active layer and thermokarst bog soils.

The processes governing soil carbon cycling occur, and vary, on fine spatial scales (nm-µm) and it is increasingly clear that observations made at these scales are critical to predicting change at larger (m-km) scales. Our future goals involve the integration of biological, physical, chemical and hydrological measurements across these scales eventually within a hierarchical modeling framework to facilitate scaling.

NAME: Edward Brzostek
INSTITUTION: Indiana University, Dept. of Geography
COLLABORATORS: Danilo Dragoni, Indiana University, Department of Geography; Richard Phillips, Indiana University, Department of Biology
ABSTRACT TITLE: An increasing gap between the end of the aboveground growing season and the carbon uptake season fuels greater labile carbon production in a deciduous forest in south-central Indiana, USA
PROGRAM AREA: Carbon Flux

ABSTRACT: From 1998-2008, there has been an increase in net ecosystem production (NEP) observed at the AmeriFlux site in the Morgan-Monroe State Forest in Indiana, USA. Warmer fall temperatures are the primary driver increasing NEP by extending the end of carbon (C) uptake season (Us). During this extension of the Us, there is little to no aboveground growth suggesting that a large amount of C is being allocated elsewhere, most likely to labile C reserves or to belowground pools. Our objectives were to examine whether the end of aboveground growing season (AGs) responds in a similar manner to the Us end and to model the amount and allocation of C assimilated after the AGs end. For each year from 1998-2010, we determined the phenology of the AGs using bi-weekly measurements of diameter growth on over 150 trees. Using both biometric and eddy-covariance data, we modeled the amount of C assimilated after the AGs end and the C reserves required to initiate leaf, wood, and root production the following spring. In contrast to the Us, we found that the end of the AGs was controlled by day length. However, there was a soil moisture threshold above which day length determined the AGs end and below which drought caused an earlier end to the AGs. Because day length imposed a limit on the AGs end, there was an increasing gap between the end of the AGs and the Us over time. In the model, this gap resulted in more C assimilated after the end of the AGs that was not needed to fuel growth in the spring. These results suggest that an interaction between warmer fall temperatures and drought may increase the amount of labile C reserves and/or allocation of labile C to roots and rhizosphere microbes.

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NAME: Edward Brzostek
INSTITUTION: Indiana University, Department of Geography
COLLABORATORS: Danilo Dragoni, Indiana University, Department of Geography; Richard Phillips, Indiana University, Department of Biology
ABSTRACT TITLE: Impacts of severing belowground carbon allocation on carbon and nitrogen cycling in temperate forest soils
PROGRAM AREA: Biogeochemistry

ABSTRACT: The transfer of labile carbon (C) by roots to soil microbes in the rhizosphere (i.e., the soil immediately surrounding roots) may subsidize the production of extracellular enzymes and increase rates of C and N cycling in soils. The objectives of this research were to investigate whether the stimulation of extracellular enzyme activity in the rhizosphere compared to surrounding bulk soil (i.e., rhizosphere effect) differs between tree species that form associations with ectomycorrhizal (ECM) or arbuscular mycorrhizal (AM) fungi and to examine whether these trees differ in the impacts of severing belowground carbon allocation on soil C and N cycling. We conducted this research at the AmeriFlux site in the Morgan-Monroe State Forest in Indiana, USA. Monthly, over the 2011 growing season, we measured the rhizosphere effects on enzyme activity and N cycling in soils from 8m radius plots dominated by either ECM or AM trees. To experimentally reduce root C inputs, we girdled half of these plots in July 2011. We found that the rhizosphere effect on extracellular enzyme activities was greater in ECM soils than in AM soils. In particular, higher rates of N-acquiring enzyme activity increased the availability of N in ECM rhizospheres relative to the bulk soils. Girdling led to a larger decline in enzyme activity and rates of N cycling in the rhizosphere and bulk soil of ECM trees than AM trees. In both ECM and AM soils, however, there has yet to be a decline in soil respiration. These results contribute to the growing evidence that tree roots, in particular ECM roots, enhance soil-N cycling and extracellular enzyme activity by transferring labile C to the rhizosphere and suggest that changes in belowground C allocation will have larger impacts on rhizosphere processes in ECM stands.

NAME: Andrew Burton
INSTITUTION: Michigan Technological University
COLLABORATORS: Donald Zak, University of Michigan; Mark Kubiske, US Forest Service Northern Research Station; Kurt Pregitzer, University of Idaho
ABSTRACT TITLE: Impacts of Elevated CO2 and O3, Alone and in Combination, on the Functioning of a Northern Forest Ecosystem
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: From 1998 through the middle of the 2009 growing season, we examined the interacting effects of elevated CO2 and O3 on above- and belowground ecosystem processes in an aggrading northern forest ecosystem. This study utilized a free-air carbon dioxide enrichment (FACE) facility in Rhinelander, Wisconsin to compare the responses of rapid-growing shade intolerant trembling aspen and paper birch to those of slower growing shade tolerant sugar. Three replicate FACE rings were established in 1997 for a factorial combination of four treatments (CO2, O3, CO2+O3 and control). During summer, 2009, we harvested the above- and belowground components of the experiment. Allometric relationships from this harvest were used with annual diameter and height measurements to determine biomass increments for the experiment's final years. Under elevated CO2, enhanced NPP (26%) was sustained. "Progressive N limitation" did not occur, as trees growing under elevated CO2 obtained greater amounts of 15N tracer and soil N through greater root exploration of soil and more rapid rates of litter decomposition. Elevated CO2 altered soil C accrual, at least in the pure aspen community. After 11 years, there were no main effects of CO2 or O3 on surface soil (0-20 cm) C content across communities, but in the aspen, elevated CO2 caused a significant decrease in soil C. Elevated O3 tended to completely eliminate the positive CO2 effect on NPP in early years, but in later years only dampened it. In the final three years, compensatory growth of O3-tolerant individuals, after decline of sensitive individuals, resulted in equivalent annual NPP increment under ambient and elevated O3. Total biomass at the end of the experiment remained lower under elevated O3 due to effects earlier in the experiment. The CO2 and O3 treatments were continued for one year of vegetative sprout regrowth in 2010. During that year, slight, but non-significant differences in height corresponded to initial treatment responses of the original experiment. Gas exchange for these young trees showed greater Amax and lower stomatal conductance for trees in the CO2 and CO2+O3 treatments. Stem sections from the harvest were placed in the treatment rings to examine wood decomposition. Wood density was greater than the control for wood grown under elevated CO2 and higher for wood grown under elevated O3. During one year of decomposition, mass loss for birch and aspen was greatest for wood grown under elevated CO2 and for wood from all treatments placed in the elevated CO2 rings.

NAME: Elliott Campbell
INSTITUTION: UC Merced
COLLABORATORS: Joe Berry, Carnegie Institution for Science; Ulrike Seibt, UCLA; Margaret Torn, LBNL
ABSTRACT TITLE: Quantifying Carbon-Climate Processes at the Regional Scale Using Atmospheric Carbonyl Sulfide
PROGRAM AREA: Carbon Flux

ABSTRACT: Regional flux partitioning represents a critical knowledge gap due to a lack of robust methods for regional-scale flux partitioning and large uncertainties in forecasting carbon-climate feedbacks. Atmospheric carbonyl sulfide (COS) analysis has the potential capability for partitioning the regional carbon flux into respiration and photosynthesis components. This emerging approach is based on the observation that continental atmospheric CO2 gradients are dominated by net ecosystem fluxes while continental atmospheric COS gradients are dominated by photosynthesis-related plant uptake. Here we use a new COS eddy flux system, COS airborne monitoring data, and atmospheric modeling tools to quantify the climate sensitivity of carbon flux processes at the regional scale. The ARM Southern Great Plains site is hosting a spring field deployment of this new measurement system. The multi-scale analysis provides evidence to demonstrate a new COS technique to the terrestrial ecology community and an understanding of how COS should be incorporated into comprehensive investigations of ecosystem processes.

NAME: Allison Chan
INSTITUTION: University of Utah
COLLABORATORS: Nicole Trahan, University of Colorado; Dave Bowling, University of Utah
ABSTRACT TITLE: The carbon isotopic composition of soil respiration in the decade following disturbance by bark beetle or stem girdling
PROGRAM AREA: Carbon Flux

ABSTRACT: The carbon isotopic composition of soil respiration in the decade following disturbance by bark beetle or stem girdling

Chan, Allison M.1; Trahan, Nicole A.2; Bowling, David R.1
1 Department of Biology, University of Utah, Salt Lake City, UT 84112 2 Department of Ecology and Evolutionary Biology, University of Colorado, Boulder CO 80309

Recent outbreaks of mountain pine beetle have caused large-scale tree mortality in western North America, which can lead to fundamental changes in carbon cycling. When a tree is infected, the flow of photosynthate is disrupted. This causes the roots and their symbionts to die, eliminating the autotrophic component of soil respiration. Mycorrhizal fungi are enriched in 13C compared to plant tissues. As the dead fungal biomass is consumed by soil heterotrophs, the δ13C of CO2 in heterotrophic soil respiration may become more enriched as the fungal biomass is consumed. We investigated this response by measuring soil respiration in chronosequences of stem-girdled plots at the Niwot Ridge AmeriFlux site, and beetle-killed plots at the Fraser Experimental Forest, both in Colorado. Stem girdling was used to simulate beetle attack because it kills trees by a similar mechanism. Plots at Niwot Ridge included live trees and 7 years of girdled plots extending back to 2002. Plots at Fraser included live trees and three age classes of beetle-killed trees, within a similar chronosequence. We used automated soil chambers and both automated and manual soil-gas sampling at three depths to determine if there is an isotopic effect associated with disturbance. Consistent with our expectations, we found an enrichment in δ13C of approximately 1‰ in the two years following girdling which was absent in subsequent years. At both sites, seasonal mean δ13C decreased by about 1‰ at all depths 3-4 years after disturbance, but returned to values close to control plots in the following 4-6 years. At both sites, seasonal mean δ13C was enriched by about 1‰ at the OA interface compared to the 10 and 30 cm depths, which were similar. These results lend support to the hypothesis that mycorrhizal biomass is consumed in the first few years following major disturbance to their plant hosts.

NAME: Janet Dewey
INSTITUTION: University of Wyoming
COLLABORATORS: Jeff Hatten, Mississippi State University; Karen McNeal, Mississippi State University; Scott Roberts, Mississippi State University
ABSTRACT TITLE: Using volatile organic compounds to separate heterotrophic and autotrophic forest soil respiration
PROGRAM AREA: Carbon Flux

ABSTRACT: Research on soil respiration is complicated by the fact that CO2 is an end member which carries very little information about its source. Therefore, partitioning soil respiration into autotrophic and heterotrophic sources requires methods that are destructive, invasive, and/or expensive. In this study we have proposed to investigate a new method using the flux of volatile organic compounds (VOCs) from the soil as indicators of CO2 source and below ground processes to non-invasively disentangle this multisource signal. We hypothesize that the composition and quantity of soil VOCs can be used to separate the respiration associated with roots (autotrophic respiration) and soil organic matter mineralization (heterotrophic respiration). We further contend that the contribution of each autotrophic component, including root respiration, microbial mineralization of root litter, and microbial mineralization of root exudates, can be determined using this approach. We have initiated a greenhouse study of soil respiration and VOC efflux where each respiration component is isolated utilizing pots with and without plants, litter bags, and destructive sampling. The impact of tree species, diurnal cycles, and soil moisture regime will be assessed within the boundaries of this greenhouse study. The objectives of the project are to: 1) Determine the VOCs that uniquely indicate each component of soil respiration; 2) Test the effectiveness of this method over a range of soil moisture conditions; 3) Determine if diurnal cycles affect soil respiration and soil VOC efflux; and 4) Determine if VOCs can uniquely indicate below ground root production of biomass. This research has been recently initiated and we will show the experimental design and recently collected data during this presentation.

TES PI Meeting Abstracts
April 23-24, 2012

NAME: Jean-Christophe Domec
INSTITUTION: North Carolina State University
COLLABORATORS: John S King, North Carolina State University; Asko Noormets, North Carolina State University; Sari Palmroth Palmroth, Duke University
ABSTRACT TITLE: Interactive effects of nocturnal transpiration and climate change on the root hydraulic redistribution and carbon and water budgets of three contrasting unmanaged forests
PROGRAM AREA: Carbon Flux

ABSTRACT: Deep root water uptake and hydraulic redistribution (HR) has been shown to play a major role in forest ecosystems during drought, but little is known about the impact of climate change and soil characteristics on HR and its consequences on water and carbon fluxes. Using data from two old growth sites of the western USA and one mature site of the eastern USA, and simulations with the process-based model MuSICA, the objectives of this study were to determine whether HR can 1) mitigate the effects of soil drying and 2) have important implications for carbon uptake and net ecosystem exchange (NEE). At the dry old-growth ponderosa pine stand (P), characterized by deep sandy soil, HR increased dry season tree transpiration (T) by up to 45%, and such an increase impacted NEE through major changes in gross primary productivity (GPP). Deep-rooted trees did not necessarily translate into a large volume of HR unless soil texture allowed large water potential gradients to occur, as it was the case at the wet old-growth Douglas-fir/mixed conifer stand (D). At the Duke mixed hardwood forest (H) characterized by a shallow clay-loam soil, HR was low but not negligible, representing up to 10% of T. In the absence of HR, it was predicted that at the P, D and H sites, annual GPP would have been diminished by 39%, 27% and 10%, respectively. Under future climate conditions (elevated atmospheric CO2 concentration and temperature) HR was predicted to be reduced by up to 26%, 19% and 7% at the P, D and H sites, respectively; reducing the resilience of trees to precipitation deficits. Increased vapor pressure deficit at night under future conditions was sufficient to drive significant night T at all sites, which reduced HR, because the plant and the atmosphere became a sink for hydraulically redistributed water pools. Under future conditions, T was predicted to be marginally reduced in all sites. Future conditions would stimulate GPP by 18-24% at the P and D sites, and by only 12% at H site. As a consequence, in all sites, water use efficiency was predicted to improve dramatically with future conditions. Our simulations highlighted the interactive effects of temperature and elevated CO2, and showed that the negative effect of drier nights on HR would be greater under future climate conditions. Our work enhances our confidence in accurately predicting how HR impacts forest carbon balance by establishing a direct link between plant root functioning and carbon fluxes.

NAME: Danilo Dragoni
INSTITUTION: Indiana University - Department of Geography
COLLABORATORS: Faiz Rahman, Indiana University; Eddie Brzostek, Indiana University; Richard Phillips, Indiana University
ABSTRACT TITLE: Integrating observations of forest-atmosphere interaction over different temporal and spatial scales: preliminary results from an intensive campaign at the Morgan-Monroe state Forest in south-central Indiana
PROGRAM AREA: Carbon Flux

ABSTRACT: The integration of different observation strategies is critical to improve our understanding of the mechanisms and controls involved in land-atmosphere interactions and improve the performances of prognostic and diagnostic land-surface models. We present the preliminary results of a 2-year intensive observation campaign at the Morgan-Monroe State Forest AmeriFlux site in south-central Indiana. The main goal of this campaign was to examine the environmental responses observed at different spatial scales (from leaf to landscape) for the dominant tree species in the forest, during the vegetative season and phenological transition periods. The already on-going eddy-covariance and biometric measurements were integrated with a suite of observations from leaf to landscape scale over the 2011 growing season. A 80-foot lift boom allowed multiple measurements of leaf plant-physiology and chemistry on different classes of leaves (mainly sunlit and shaded) during the growing season (e.g., gas exchange, light response, leaf water potential, nitrogen and carbon content, and spectral reflectance). Transpiration was measured at the tree level using sap flow techniques and associated with local measurements of soil moisture. High resolution canopy spectral reflectance was taken at regular interval using a sensor mounted on an aircraft flying over the forest. These measurements were integrated at larger scale using MODIS observations. The very preliminary results (the campaign will continue in 2012), show clear and distinct responses to environmental variability, between the dominant species, particularly to periods of low soil moisture But also, these species show distinct patterns in their physiological and phenological traits when environmental conditions are in general more favorable.

NAME: Danilo Dragoni
INSTITUTION: Indiana University- Department of Geography
COLLABORATORS: Faiz Rahman, Indiana University; Eddie Brzostek, Indiana University; ,
ABSTRACT TITLE: Trends in fall phenology across the deciduous forests of the Eastern U.S.A.
PROGRAM AREA: Carbon Flux

ABSTRACT: Decadal trends in delay of the end of the season (EOS) have been recently observed across a large fraction of the forested areas in the Northern hemisphere. However, the spatial patterns of EOS variability and its environmental forcings at the local scale are largely unknown within deciduous forests. In this study, we investigated short- and long-term changes in EOS and its relationship with variability of air temperature and precipitation across the deciduous forests of the Eastern USA from 1989 to 2008. We used high-resolution (1km2) satellite data in conjunction with meteorological measurements. Our results show strong evidence of widespread delay in EOS throughout a larger area than what was previously reported. Equally important, the results show that EOS variability and EOS response to summer air temperature varied significantly across the Eastern USA. EOS response to climate variability was in general correlated with the latitude of the forest, but different patterns for different areas were observed as well. No clear relationship was observed between EOS and precipitation, probably because of the complexity of the link between water relations and senescence mechanisms and controls in deciduous trees. Overall, our results show the importance of local scale heterogeneity (likely driven by both biotic and abiotic factors) in determining significantly different patterns in the relationship between EOS and climate variability across Eastern USA.

NAME: James Ehleringer
INSTITUTION: University of Utah
COLLABORATORS: Chun-Ta Lai, San Diego State University; James Randerson, University of California, Irvine; Xueri Dang, San Diego State University
ABSTRACT TITLE: Improving representation of drought stress, urban metabolism, and fire emissions in climate carbon models: a measurement and modeling focus in the western USA
PROGRAM AREA: Carbon Flux

ABSTRACT: Our project combines current data acquisition, long-term data analyses, and modeling at physiological-to-continental scales to identify regional factors impacting the carbon cycle in the western U.S. Our goal is to collect data and develop/test models to improve our understanding of the role of drought, urban metabolism, and fire impacts on the terrestrial carbon cycle in the western U.S. We are developing new ways to evaluate the representation of drought stress, urban metabolism, and fire emissions in the Community Land Model. In this poster we describe progress in seven distinct components: (a) continuation of long-term CO2, 13CO2, and Keeling-plot data collections at coniferous forest and urban ecosystem sites; (b) transect-based data acquisition of high precision CO2, CO, CH4, 13CO2, and 14CO2 using a mobile vehicle to span between long-term monitoring stations; (c) 14C vegetation observations to quantify the fractions of net carbon fixation derived from fossil fuel sources, (d) analyses of our decadal records of atmospheric CO2 (concentration and carbon isotope ratio) and the carbon isotope ratio of respired CO2 from AmeriFlux coniferous and deciduous forests in the eastern and western U.S., (e) systematic boundary layer (BL) modeling that improved our understanding of the seasonal and interannual variability of surface CO2 fluxes using vertical transport information from community model outputs (NCAR/NCEP Reanalysis and ECMWF Interim Analysis) to estimate 2002-2007 regional-scale net CO2 fluxes at four AmeriFlux sites in the U.S. (3 forest and 1 grassland); (f) development and verification of a multi-box model to predict fossil fuel emissions driven by atmospheric CO2 observations, observed winds, and modeled biospheric fluxes; and (g) advances in parameterization of the Community Land Model.

NAME: R. Dave Evans
INSTITUTION: Washington State University
COLLABORATORS: Bob Nowak, University of Nevada Reno; Stan Smith, University of Nevada Las Vegas; Kiona Ogle, Arizona State University
ABSTRACT TITLE: Whole-ecosystem exposure to elevated carbon dioxide increases total ecosystem carbon and nitrogen in the Mojave Desert
PROGRAM AREA: Biogeochemistry

ABSTRACT: Arid ecosystems are predicted to be among the most responsive to global change and their response is globally significant considering their extensive spatial coverage. Although carbon cycling in arid lands is an important component of the global carbon budget, there is substantial uncertainty about the potential impacts of global change drivers, such as elevated CO2, on arid land carbon budgets. Studies suggest that productivity may be stimulated by elevated CO2 directly due to enhanced plant water-use efficiency. The indirect impacts of elevated CO2 on ecosystem productivity may also be constrained by available nitrogen, but little is known about how the importance of the nitrogen constraint or how the nitrogen cycle may be affected by global change drivers. Here we present the carbon and nitrogen mass budgets of a Mojave Desert ecosystem after ten years of exposure to elevated CO2. The Nevada Desert Free-Air Carbon Enrichment Facility (FACE) was established in 1997 to evaluate the response of an intact Mojave Desert ecosystem to elevated CO2. The CO2 concentration of the atmosphere in the elevated treatment was maintained at 513 uL/L until harvest in 2007. At harvest time, all aboveground biomass for 2/3 of each plot was harvested and soils and roots were removed down to 1 m depth and analyzed for total carbon and nitrogen. We observed significantly greater carbon (10,800 versus 9,200 kg C/ha, P=0.004) and nitrogen (1,400 versus 1,100 kg N/ha, P=0.002) in elevated compared to ambient CO2 treatments. Differences between treatments were due solely to greater C and N in soils across all cover types, and no differences were observed in above and belowground plant biomass. Companion research shows that increased soil C was from increased root exudation, microbial residues, and episodic increased litter input under elevated CO2, and these increased C inputs in turn stimulated production of inorganic nitrogen. Results from the Nevada Desert FACE Facility demonstrate that arid lands may represent large sinks of atmospheric CO2, and the strength of this sink is currently controlled by water, and not nitrogen, availability.

NAME: Adrien Finzi
INSTITUTION: Boston University
COLLABORATORS: Ram Oren, Duke University; John Drake, Boston University
ABSTRACT TITLE: The Duke Forest FACE Experiment: Synthesis and Moving the Science Forward
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: The Duke FACE experiment ran from September 1996 through October 2010, about 14 years. During the course of the experiment, the research site experienced two major droughts, an ice storm and hurricane conditions, affording us an opportunity to understand the role of climate extremes on forest productivity under elevated CO2. Despite climatic variability and nutrient limitation, forest productivity was significantly and sustainably enhanced by elevated CO2 on the order of 20-30% yr-1. This enhancement in NPP was the result of many adjustments in ecosystem processes, and this poster will present decadal-scale syntheses of ecosystem responses to elevated CO2 including photosynthesis, NPP & C storage, carbon allocation, SOM decomposition and microbial processes.

The substantial investment by the DOE enabled long-term experimental treatment at the Duke FACE site. In addition to understanding site-specific results, it is valuable asking the following question: What new avenues of research were spawned from this work? This poster presentation will address one major avenue for new research: the belowground interactions between plants and microbes that drive aboveground responses to climatic and atmospheric change. Based on our work at the Duke FACE site, we highlight three important areas for future empirical and model development:

1. The role of belowground plant-C allocation on microbial and exoenzyme activity. We will present data from the Duke FACE site showing that rhizosphere processes were the key to sustaining the long-term enhancement in forest productivity under eCO2 and use this result as a platform to motivate an explanation for the diversity of productivity responses to elevated CO2 among experiments.
2. Developing new, mechanistically based biogeochemical models rather than defaulting to “classic” 3-soil pool CENTURY-type models. Our Duke work and subsequent modeling with next-generation soil biogeochemistry models suggest decomposition of SOM in “classic” models may not accurately forecast terrestrial-C balance owing to missing microbial, enzymatic and biophysical controls.
3. Coupling belowground plant-C allocation with mechanistically based biogeochemical models. The priming of SOM decomposition appears critical to understanding the partitioning of heterotrophic and autotrophic soil respiration. Here we present a meta-analysis of rhizosphere processes and incorporate these data into a new, numerical model to show that ca. 10-40% of heterotrophic soil respiration (excluding the autotrophic component) is derived from the small volume of soil surrounding plant roots. This has major implications for understanding and modeling processes controlling C balance in terrestrial ecosystems.

NAME: David Fitzjarrald
INSTITUTION: ASRC, University at Albany, SUNY
COLLABORATORS: Sergey Kivalov, ASRC, University at Albany, SUNY
ABSTRACT TITLE: Clouds and the temporal quality of incident light in two forested ecosystems
PROGRAM AREA: Carbon Flux

ABSTRACT: There has been very little work to link the time series of incident radiation with the type and cover fraction of clouds. We present results of studies from two study areas: a) The Harvard Forest EMS tower in Massachusetts and b) the LBA-ECO km67 tower in the eastern Amazon Basin. Data at both sites were synchronized into 1-sec averages for global long- and short-wave components. Cloud type and cover is retrieved from local or regional ceilometer measurements.

The high-frequency shortwave radiation data were normalized against the calculated clear sky irradiance to limit effects of the diurnal irradiance change. Results from indicator function and wavelet analyses are presented.On a partly cloudy day, dark/light transitions i When in situ and/or satellite based estimates of cloudiness are also available, we associate this response further with cloud type and cover fraction.

The scientific questions associated with this research are: a) Is enhanced uptake observed in high and middle-latitude forests on cloudy days the result of more complete illumination by diffuse radiation, or is it a consequence of receiving sporadic bursts of high light levels?

NAME: David Genereux
INSTITUTION: North Carolina State University
COLLABORATORS: Christopher Osburn, North Carolina State University; Steven Oberbauer, Florida International University
ABSTRACT TITLE: Water-carbon links in a tropical forest: how interbasin groundwater flow affects carbon fluxes and ecosystem carbon budgets
PROGRAM AREA: Biogeochemistry

ABSTRACT: This new project is quantitatively exploring the importance, for carbon cycling, of the link between the tropical rainforest and the deeper hydrogeological system on which it sits. Tropical forests are an important component of the global carbon cycle, and yet even the basic issue of whether they operate as net sources or sinks with respect to carbon remains a primary research question and the subject of sometimes-conflicting analyses. Full accounting of carbon inputs and outputs is a critical issue and one closely linked to the hydrologic cycle. Recent water and carbon data from the lowland rainforest at La Selva Biological Station in Costa Rica suggest that interbasin groundwater flow (IGF, regional groundwater flow beneath watershed topographic boundaries) strongly influences concentrations and fluxes of dissolved organic carbon (DOC) and dissolved inorganic carbon (DIC). The influence of IGF on carbon dioxide degassing from streams, wetlands, and soils is presently not known but may be significant. The project focuses on the potentially significant links between IGF (a common groundwater process detected at watersheds world-wide) and carbon cycling in tropical forests.

We have begun collection of new data (carbon concentrations, chemical and isotopic characteristics, soil respiration, net ecosystem exchange (NEE) of carbon dioxide between the atmosphere and forest, carbon dioxide degassing rates in streams, and stream discharge) to show how IGF influences carbon fluxes and the overall carbon budget of this tropical rainforest ecosystem. Two small watersheds (one with significant inputs by IGF, the other without) are being used as the field study units for flux and budget accounting in the ecosystem. Preliminary analyses show, for example, that IGF increases streamwater DIC concentration by a factor of about 12 and stream-based watershed export of DIC by a factor of about 70; for DOC, concentration was actually reduced by a factor of about 0.67 while export increased by a factor of 3.5. A significant quantity of carbon is moving into the ecosystem via IGF, and out of the ecosystem via other fluxes (including streamflow and atmospheric exchange of carbon dioxide). Data collection and analysis related to carbon chemistry and fluxes is ongoing. We are beginning to study the impact of IGF on DOC quantity and quality, including whether "old" DOC from IGF is relatively "protected" from biological degradation, thus facilitating its hydrologic export from watersheds via stream flow.

NAME: Matthew Germno
INSTITUTION: US Geological Survey, Forest and Rangeland Ecosystem Science Center
COLLABORATORS: Keith Reinhardt, Idaho State University; Cristina Castanha, Lawrence Berkeley National Lab; Lara Kueppers, University of California, Berkeley
ABSTRACT TITLE: Ecophysiological variation in two provenances of Pinus flexilis seedlings across an elevation gradient from forest to alpine
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: Climate change is predicted to cause upward shifts in forest tree distributions, which will require seedling recruitment beyond current forest boundaries. However, predicting the likelihood of successful plant establishment beyond current species' ranges under changing climate is complicated by the interaction of genetic and environmental controls on seedling establishment. To determine how genetics and climate may interact to affect seedling establishment, we transplanted recently germinated seedlings from high-and low-elevation provenances (HI and LO, respectively) of Pinus flexilis in common gardens arrayed along an elevation and canopy gradient from subalpine forest into the alpine zone and examined differences in physiology and morphology between provenances and among sites. Plant dry mass, projected leaf area and shoot:root ratios were 12–40% greater in LO compared with HI seedlings at each elevation. There were no significant changes in these variables among sites except for decreased dry mass of LO seedlings in the alpine site. Photosynthesis, carbon balance (photosynthesis/respiration) and conductance increased >2x with elevation for both provenances, and were 35–77% greater in LO\r\nseedlings compared with HI seedlings. There were no differences in dark-adapted chlorophyll fluorescence (Fv/Fm) among sites or between provenances. Our results suggest that for P. flexilis seedlings, provenances selected for above-ground growth may outperform those selected for stress resistance in the absence of harsh climatic conditions, even well above the species' range limits in the alpine zone. This indicates that forest genetics may be important to understanding and managing species' range adjustments due to climate change.

NAME: Miquel Gonzalez-Meler
INSTITUTION: University of Illinois at Chicago
COLLABORATORS: Neil Sturchio, University of Illinois at Chicago; Timothy Filley, Purdue University; Jeffrey Welker, University of Alaska Anchorage
ABSTRACT TITLE: Effects of increased snowpack thermal insulation on soil carbon of an Alaskan tussock tundra assessed with natural and anthropogenic radioisotopes.
PROGRAM AREA: Biogeochemistry

ABSTRACT: Permafrost soils cover 8.6% of the Earth land area but contain 50% of the global soil organic carbon (SOC) pool, 20-25% of which may be stored in the upper 30 cm. Predicted warming in northern latitudes may lead to strong forcing feedbacks on the climate system through enhanced decomposition of SOC. Atmospheric air warming may lead to increases winter precipitation in the Arctic, resulting in a deeper snow cover with consequent soil thermal insulation. Warmer soils may elicit summer and winter decomposition rates decreasing the SOC pool but also stimulate primary productivity increasing inputs of organic matter to soils of different chemical nature. The long- (14-year) and short-term (2 years) effects of snow pack accumulation on Arctic SOC dynamics in moist acidic tundra (using fence experiments at Toolik Lake, AK) were measured by using natural and anthropogenic radionuclides (14C, 40K, 210Pb, 137Cs) to identify changes in geomorphology and SOC dynamics in surface layers. The soil vertical 137Cs activity profile was altered in the treatment plots sites likely due to compression by higher snow pack, exposing deeper C to the near-surface. As a consequence, bulk densities increased up to 4- and 2-fold in the long and short-term experiments, respectively, when compared to control sites. Cumulative SOC density within the top 30 cm increased significantly at the long-term treatment site compared to the control site, whereas no significant changes were found between short-term treatment and corresponding control site. When measured at equivalent depth (i.e. depth corrected for snow pack compression), snow-pack thermal insulation resulted in a net loss of SOC of about 3 and 1 kgCm-2 after 2 and 14 yrs of treatment respectively, but SOC increased in the organic layer by about 2 and 8 kgCm-2, respectively, perhaps by addition of new C inputs over time as revealed by radiocarbon data. The consequences of these effects on C quality, decomposability, chemical recalcitrance of SOC, and CO2 and CH4 emissions are currently being studied.

NAME: Christopher Gough
INSTITUTION: Virginia Commonwealth University
COLLABORATORS: Peter Curtis, Ohio State University; Gil Bohrer, Ohio State University; Knute Nadelhoffer, University of Michigan

ABSTRACT TITLE: Sustained canopy light-use efficiency supports forest carbon storage resistance to moderate disturbance
PROGRAM AREA: Natural Disturbance

ABSTRACT: Disturbances to forests such as those caused by herbivory, wind, pathogens, and age-related mortality may subtly alter canopy structure, with consequences for carbon (C) cycling. At the University of Michigan Biological Station, we initiated an experiment that examines forest C storage following subtle canopy disturbance. The Forest Accelerated Succession ExperimenT (FASET), in which >6,700 aspen and birch trees were stem girdled within a 39 ha area, is investigating how C storage changes as Great Lakes forests broadly undergo a transition in which early successional canopy trees die and give way to an assemblage of later successional canopy dominants. The experiment employs a suite of C cycling measurements within paired treatment and control meteorological flux tower footprints.

Our findings indicate that NEP resistance to disturbance was supported by physiologically favorable canopy structural shifts during defoliation followed by the rapid replacement of lost leaf area. Continued high canopy light-use efficiency and absorption sustained NEP following disturbance, even when leaf area in the treatment forest temporarily declined by nearly half its maximum. Sustained physiological functioning of the canopy was likely mediated by structural changes that altered light distribution within the canopy and prompted increased C uptake by lower canopy vegetation, thereby compensating for upper canopy defoliation. Leaf area recovered to pre-disturbance levels four years following girdling as diminished aspen and birch LAI was replaced by that of later successional canopy dominants.

We conclude that NEP resistance to disturbance depends not only on rapid replacement of lost leaf area, but also on shifts in forest structure that sustain physiological functioning of the canopy during defoliation. These findings indicate that structural changes in the canopy should be considered in addition to trajectories of leaf area recovery when predicting the extent and duration of disturbance-related shifts in forest C storage.

NAME: Michael Goulden
INSTITUTION: UC Irvine
COLLABORATORS: Greg Winston, UC Irvine; Scot Parker, UC Irvine; Aaron Fellows, UC Irvine
ABSTRACT TITLE: Physiological, demographic, competitive and biogeochemical controls on the response of California's ecosystems to environmental change
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: We are using (1) manipulations of water and nitrogen input in nearby grassland and shrubland ecosystems, (2) measurements of ecosystem-atmosphere exchange using eddy covariance in six different ecosystem types including grassland and shrubland, and (3) field surveys along natural climate gradients. Our goals are to better understand the sensitivity of Southern California's ecosystems to multiple environmental changes, and the effect of ecological change on land-atmosphere CO2 and energy exchange.

The manipulations and field surveys show rapid shifts in the abundance of existing species within plant communities in response to purposeful or natural changes in water input. The relative importance of grass species changed rapidly in the water input manipulations; the relative importance of tree species changed rapidly in response to natural decadal precipitation variation. The flux tower and manipulation measurements indicate this process, which we refer to as species reordering, has only a modest effect on land-atmosphere carbon and energy exchange.

The flux towers indicate larger shifts in land-atmosphere exchange are possible with changes in dominant plant functional type. An extreme example of this process, which we refer to as a biome shift, would occur if a grassland replaced a forest. The manipulations are beginning to hint at a biome shift from shrubland to grassland in the dry treatments. The site's shrubs are deeply rooted and the grasses shallowly rooted. The dry treatment decreased water availability in the deeper soil, which drove shrub mortality and allowed the grasses to proliferate. The flux towers indicate a biome shift from shrubland to grassland results in a relatively large change in carbon and energy exchange. We believe biome shifts of this type, which are poorly understood and modeled, will play a key role in determining the magnitude of terrestrial feedback to climate change.

NAME: Lianhong Gu
INSTITUTION: Oak Ridge National Laboratory
COLLABORATORS:
ABSTRACT TITLE: Towards a next generation of eddy covariance technologies
PROGRAM AREA: Carbon Flux

ABSTRACT: In this presentation, I will first review the history and theoretical foundation of the eddy covariance technique. I will point out that the conventional eddy covariance theory has several conceptual inconsistencies and is inaccurate. I will then reformulate the eddy covariance theory from a new perspective. The reformulated eddy covariance theory is self-consistent and precise. The conventional eddy covariance theory is found to be a special case of the reformulated theory but only valid under limited conditions. This implies that past flux measurements will need to be corrected in order to avoid biases. The reformulated theory also suggests a new direction for a next generation of eddy covariance technologies that would employ N2 or Ar gas as a constraining constituent to better resolve flux processes over target surfaces.

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NAME: Chad Hanson
INSTITUTION: AmeriFlux QA/QC Oregon State University
COLLABORATORS: Andres Schmidt, Oregon State University; Stephan Chan, Oregon State University; Beverly Law, Oregon State University
ABSTRACT TITLE: Overview of AmeriFlux QA/QC Lab Activities
PROGRAM AREA: Carbon Flux

ABSTRACT: The AmeriFlux QA/QC lab's mission is to reduce uncertainties in flux measurements and improve data quality within and among AmeriFlux sites. Our approach is to conduct ~10-20 robust site comparisons each year between a high quality portable eddy covariance system (PECS) and site systems. The site comparisons provide an opportunity to work collaboratively with PIs and technicians to identify and resolve measurement errors. We identify uncertainties associated with implementation of software routines through the use of standardized 'Gold-Files'. The repeated site visits maintain continuity of data quality when there is turnover of personnel at sites and as improvements are made to measurement techniques and technologies. In order to help sites maintain their own internal QA/QC protocols, we provide reference PAR and temperature sensors that are calibrated in house and also produce and distribute high precision secondary CO_2 standards for the network.

We serve as a resource for measurement strategies by providing up to date protocols on the AmeriFlux website, and by identifying and evaluating emerging technologies that are relevant to the flux community. We continue to lead and participate in AmeriFlux synthesis activities with seven publications and also communicate our findings through talks, posters, and reports to the AmeriFlux leadership and broader community.

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NAME: Paul Hanson
INSTITUTION: Oak Ridge National Laboratory
COLLABORATORS: Randall Kolka, USDA Forest Service; Colleen Iversen, Oak Ridge National Laboratory; Richard Norby, Oak Ridge National Laboratory
ABSTRACT TITLE: Spruce-Peatland Responses Under Climatic and Environmental Change An In Situ Warming by CO2 Manipulation of a Characteristic High-Carbon Ecosystem
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: Identification of critical environmental response functions for terrestrial organisms, communities, and ecosystems to rapidly changing climate conditions are needed to evaluate ecological consequences and feedbacks. Such research has the most 'real-world' relevance when conclusions are drawn from controlled manipulations operating in natural field settings. We are constructing an experimental platform to address climate change response mechanisms in a Picea/Larix/Sphagnum ombrotrophic bog ecosystem located in northern Minnesota. This ecosystem located at the southern extent of the spatially expansive boreal peatland forests is hypothesized to be especially vulnerable to climate change and to have important feedbacks on the atmosphere and climate. The replicated experiment will allow us to test mechanisms controlling vulnerability of organisms and ecosystem processes changes for multiple levels of warming (up to +9°C) combined with elevated CO2 exposures (900 ppm). New methods for whole-ecosystem warming at plot scales of 12 to 14-m diameter have been developed for this study. Through the execution of this experiment we will quantify thresholds for organism decline or mortality, limitations to regeneration, biogeochemical limitations to productivity, and changing greenhouse gas emissions to the atmosphere. The experiment will allow for the evaluation of responses across multiple spatial scales including: microbial communities, bryophyte populations, various higher plant types, and some faunal groups. Direct and indirect effects of these experimental perturbations will be tracked and analyzed over a decade for the development and refinement of models needed for full Earth system analyses.

NAME: Brady Hardiman
INSTITUTION: The Ohio State University
COLLABORATORS: Peter Curtis, The Ohio State University; Gil Bohrer, The Ohio State University; Christopher Gough, Virginia Commonwealth University
ABSTRACT TITLE: Maintaining high rates of carbon storage in old forests: A mechanism linking canopy structure to forest function
PROGRAM AREA: Carbon Flux

ABSTRACT: Recent FLUXNET observations demonstrate that, against expectations, some forests maintain high carbon storage rates for centuries, though the underlying mechanisms remain poorly understood. To evaluate canopy structural influences on forest C storage, we tested the hypothesis that age-related increases in canopy structural complexity improve resource-use efficiency. We measured canopy radiation absorption (fAPAR), N mass, and aboveground NPP (ANPP; ~50% of total NPP) in 40 stands across a chronosequence spanning 160 years of forest development in Northern Lower Michigan. We used ground-based LiDAR to quantify canopy structural complexity as an integrated metric of the 3D arrangement of canopy leaf area.

Results support our hypothesis that increasing canopy complexity over the course of forest development mediates greater resource-use efficiency in these forests. Canopy complexity (rugosity) increased significantly with forest age but LAI was stable across stands older than 50 years. Rugosity had a bigger influence on ANPP than did LAI, demonstrating the greater importance of leaf area arrangement than leaf area quantity on stand growth. Forest stands with more structurally complex canopies had higher light and nitrogen use efficiencies (LUE & NUE), and thus had higher ANPP. Our observations suggest a mechanism by which increasing canopy complexity improves resource-use efficiency, maintaining high rates of ANPP through at least two centuries of forest development.

Our results indicate that neglecting canopy structural complexity may lead to significant underestimation of C storage potential in old-growth and maturing second-growth forests by models of ecosystem C exchange. We are using ongoing empirical studies to improve regional model simulations of terrestrial C storage by incorporating the key influence of canopy structure on forest C storage.

Hardiman B.S., Bohrer G., Gough C.M., Vogel C.S. & Curtis P.S. (2011) The role of canopy structural complexity in wood net primary production of a maturing northern deciduous forest. Ecology, 92, 1818-1827

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NAME: Daniel Hayes
INSTITUTION: Oak Ridge National Laboratory
COLLABORATORS: W. Mac Post, ORNL; Robert Cook, ORNL; Yaxing Wei, ORNL
ABSTRACT TITLE: Reconciling estimates of the contemporary North American carbon balance among an inventory-based approach, terrestrial biosphere models, and atmospheric inversions
PROGRAM AREA: Modeling

ABSTRACT: Although the exact contribution is uncertain, North American (NA) ecosystems are thought to have a significant influence on the global carbon budget by acting as a large sink of atmospheric CO2 in recent decades. Assessments of the continental carbon balance have been based on various scaling approaches, including top-down atmospheric inverse models (AIMs) and bottom-up terrestrial biosphere models (TBMs), which vary widely in their estimates of the magnitude, timing and spatial pattern of sources and sinks of atmospheric CO2. A suite of results on NA ecosystem carbon flux from extant model simulations (based on both AIMs and TBMs) have been organized by the North American Carbon Program (NACP). Here, we assemble and analyze available inventory-based data on NA ecosystem carbon cycle components as an additional perspective alongside the NACP models. We develop an inventory-based approach for estimating net ecosystem exchange (NEE) over NA that notably retains information on the spatial distribution of the vertical fluxes as well as accounting for lateral transfers.

The total inventory-based NEE estimate of a -327 ± 252 TgC yr-1 sink for NA was driven primarily by CO2 uptake in the Forest Lands (-248 TgC yr-1) and in the Crop Lands (-297 TgC yr-1) sectors. These sinks are counteracted by the CO2 source estimated for the Other Lands sector (+218 TgC yr-1), where much of the forest and crop products are returned to the atmosphere through consumption and decay. The ecosystems of Mexico are estimated to be a small net source (+18 TgC yr-1) due to land use change. We compare these inventory-based estimates with results from the TBMs and AIMs, where the mean continental-scale NEE estimate for each ensemble is -511 TgC yr-1 and -931 TgC yr-1, respectively. Additional fluxes not measured by the inventories, though highly uncertain, could add an additional -239 TgC yr-1 to the inventory-based NA sink estimate, thus suggesting some convergence with the modeling approaches. Depending on the approach, the estimates of the NA sink presented here represent between 18% and 52% of continental fossil fuel emissions over this same time period.

NAME: Caitlin Hicks Pries
INSTITUTION: University of Florida
COLLABORATORS: Edward Schuur, University of Florida; K. Grace Crummer, University of Florida; Susan Natali, University of Florida
ABSTRACT TITLE: Using Ä14C and ä13C to Partition Ecosystem Respiration in Tundra Undergoing Permafrost Thaw and Warming
PROGRAM AREA: Carbon Flux

ABSTRACT: Ecosystems underlain by permafrost contain vast stores (1672 Pg C) of soil carbon (C). As climate warming causes permafrost soils to thaw, this soil C that was previously protected from decomposition is released into the atmosphere as CO_2 or methane, causing further climate warming. However, warming can also increase plant productivity and therefore C storage, a negative feedback to climate change. We quantified whether plants or soil were driving increases in ecosystem respiration (Reco) in a natural gradient of permafrost thaw and in a permafrost warming experiment (CiPEHR) using Ä14C and ä13C to partition Reco into four sources—two autotrophic (above- and belowground plant structures) and two heterotrophic (shallow and old soil). We sampled the Ä14C and ä13C of sources using incubations and the Ä14C and ä13C of ecosystem respiration using field measurements. We measured how source contributions change seasonally and with increasing permafrost thaw in the gradient and how they change with summer, winter, and annual warming in the experiment. Contributions of autotrophic respiration and old soil respiration increased with deepening permafrost thaw. In the experiment, autotrophic respiration increased relative to the control as a result of warming with the largest increases occurring in the annual warming treatment, but there were no increases in old soil respiration. These different results for old soil contributions are likely due to the duration of warming; thaw has been ongoing for at least two decades in the gradient but warming has occurred for only two years in the experiment. Therefore, warming in permafrost ecosystems may at first lead to increases in plant respiration, a likely neutral or negative feedback to climate change, but may eventually lead to increases in old soil respiration, a likely positive feedback to climate change.

NAME: Larry Hinzman
INSTITUTION: University of Alaska Fairbanks
COLLABORATORS: Cathy Wilson, Los Alamos National Laboratory; Alessio Gusmeroli, University of Alaska Fairbanks; Vladimir Romanovsky, University of Alaska Fairbanks; W. Robert Bolton, University of Alaska Fairbanks; Robert Busey, University of Alaska Fairbanks; Jessica Cable, University of Alaska Fairbanks; William Cable, University of Alaska Fairbanks; Jessica Cherry, University of Alaska Fairbanks; Eugenie Euskirchen, University of Alaska Fairbanks; Anna Liljedahl, University of Alaska Fairbanks; Sergei Marchenko, University of Alaska Fairbanks; A. David McGuire, University of Alaska Fairbanks
ABSTRACT TITLE: Permafrost and Hydrologic Dynamics, and their role in Arctic Climate Change
PROGRAM AREA: Natural Disturbance

ABSTRACT: Arctic ecosystems differ substantially from those in temperate regions, largely due to the interactions of extremes in climate and land surface characteristics. In particular, the presence of permafrost strongly affects hydrologic processes, and regional warming is affecting its distribution and status. Ice-rich permafrost prevents infiltration of rainfall or snowmelt water, often maintaining a moist to saturated active layer where the permafrost table is shallow even in regions that are considered cold-arid. Permafrost also blocks the lateral movement of groundwater, and acts as a confining unit for water in sub- or intra-permafrost aquifers. However, as permafrost degrades, profound changes in interactions between groundwater and surface waters occur. These changes affect the partitioning among the water balance components with subsequent impacts to the surface energy balance and essential ecosystem processes. The Arctic permafrost also constitutes a reservoir of carbon which, if released by further degradation, would elevate the effect of GHG emissions on global climate. Our current understanding of the cascade of impacts from climate warming to the system, and consequent feedbacks to climate, is poor.

Most simulations of arctic climate project sustained increases in temperature and gradual increases in precipitation over the 21st century. However, none of these models correctly represent the controls that permafrost exerts on hydrological, ecological, and climatological processes. If warming continues as projected, we should expect permafrost degradation, increased in soil water storage capacity and accordingly, large-scale surface drying. A drier surface would in turn result in reduced evapotranspiration (ET). Serreze et al., 2003 have demonstrated that ~25% of high-latitude summer precipitation results from locally recycled evapotranspiration. A decrease in ET fluxes would therefore lead, all else equal, to a decrease in precipitation. Since no GCM currently includes realistic treatment of permafrost impacts on surface hydrology, we contend that extant simulations of 21st century high-latitude climate change are very uncertain, although at this point is not possible to quantify these errors. Further, since soil moisture controls atmosphere-ecosystems interactions and permafrost degradation rates, projections of high latitude GHG emissions must also be considered highly uncertain.

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NAME: David Hollinger
INSTITUTION: Northern Research Station, USDA Forest Service
COLLABORATORS: Eric Davidson, Woods Hole Research Center; Andrew Richardson, Harvard University
ABSTRACT TITLE: Longterm C Flux patterns in an undisturbed Coniferous forest and relationship to a changing climate
PROGRAM AREA: Carbon Flux

ABSTRACT: The goal of this research is to understand factors controlling longterm C exchange in eastern subboreal, coniferous forest. Net annual carbon uptake is increasing in such stands located at the Howland forest in central Maine, USA, at a rate of about 7 g C m-2 y-1. This increase is correlated to several factors including warmer spring and fall conditions. Interestingly, the increase in uptake is apparently being driven more by a decrease in respiration than increasing photosynthetic uptake. We are investigating the partitioning of respiration in this forest to learn more about these processes via manipulation (trenching) and stable isotope studies. New eddy flux measurements of methane exchange show that the forest ecosystem at Howland is a weak net source of CH_4 (~0.5 g CH_4 m-2 y-1) and that these emissions increase with temperature.

NAME: Julie Jastrow
INSTITUTION: Argonne National Laboratory
COLLABORATORS: Michael Miller, Argonne National Laboratory; Sarah O'Brien, Argonne National Laboratory; Roser Matamala, Argonne National Laboratory
ABSTRACT TITLE: Integrating the Relationships among Soil Organic Matter, Aggregate Structures, and the Microbial Community
PROGRAM AREA: National Laboratory Research (SFA)

ABSTRACT: In soils with a legacy of long-term exploration by roots, a hierarchical aggregate structure often develops. As fibrous roots grow, they exert pressures and locally dry the soil causing soil particles to be pushed and drawn together at the same time that exudates and rhizodeposits support a diverse microbial and faunal community. Roots and the hyphae of associated mycorrhizal fungi serve as a flexible latticework that enmeshes and stabilizes larger aggregates. Because root turnover often occurs within the inner space of soil aggregates, the decomposition process leads to the formation and stabilization of microaggregates within macroaggregates and development of an aggregate hierarchy. The resulting physical structure feeds back to impact decomposer access to substrates, air, water, and nutrients, thereby affecting decomposition and soil carbon cycling and sequestration. In our past work (Jastrow et al., 1998, Soil Biol. Biochem. 30:905), we used path analysis (causal modeling) to demonstrate that the recovery of stable macroaggregate structures less than a decade after the restoration of perennial grassland was driven by roots and mycorrhizal hyphae, with lesser relative contributions from microbial biomass, soluble carbohydrates, and bulk soil organic matter (SOM). More recently, we reported that this recovering grassland system has steadily accrued soil carbon for 30 years (Matamala et al., 2008, Ecol. Appl. 18:1470; O'Brien et al., 2010, Global Change Biol. 16:2573). Here, we reverse conceptual focus to investigate the influence of aggregate structure on the soil microbial community and attendant effects on the accumulation of SOM. With our original data, we construct a new causal model to explore (1) the integrated roles of macroaggregate structure as the habitat for soil microbes and as a mechanism for the physical protection of particulate organic matter (POM) and (2) the outcome of that interplay on the accrual of mineral-associated organic matter. We also use measurements of more recent samples from this grassland, including physically isolated soil fractions and phospholipid fatty acids, to examine the interrelationships among aggregate hierarchy, the microbial community, and the nature and spatial location of accumulated soil carbon. Bacterial groups separated among soil fractions based on the relative availability of labile carbon substrates. Fungi, especially saprophytic fungi, were tied primarily to POM. However, mycorrhizal fungi maintained a stronger association with the components of macroaggregates than any other microbial group – even 20 years after the initial recovery of aggregate structure.

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NAME: Julie Jastrow
INSTITUTION: Argonne National Laboratory
COLLABORATORS: Sarah O'Brien, Argonne National Laboratory; Thomas Boutton, Texas A&M University
ABSTRACT TITLE: Soil Carbon and Nitrogen Dynamics in Deciduous Forest Exposed to Twelve Years of Atmospheric CO2 Enrichment
PROGRAM AREA: National Laboratory Research (SFA)

ABSTRACT: The impact of atmospheric CO2 enrichment on soil organic matter (SOM) dynamics and stocks will depend on the interplay between plant responses, the soil's capability to protect and stabilize SOM against decomposition, and nutrient availability. Information on C and N allocation to functionally meaningful SOM pools and their dynamics can improve our understanding of soil responses and facilitate predictions of the potential for long-term stabilization. At the sweetgum free-air CO2 enrichment (FACE) experiment in Oak Ridge, Tennessee, we used (1) repeated sampling over time, (2) the 13C tracer provided by the fossil fuel source of fumigation CO2, and (3) physical fractionation to determine the fate and dynamics of FACE-derived detritus inputs to SOM. Samples collected in years 0, 3, 5, 8, 10, and 12 of the experiment were fractionated to separate particulate organic matter (POM) and silt- and clay-associated organic matter protected by occlusion in stable microaggregates from their more readily dispersible counterparts. In this aggrading system, significant linear increases in bulk soil C and N occurred in the surface 5 cm of both ambient and elevated CO2 treatments during the first 10 years of the experiment, but accrual rates doubled in response to CO2 enrichment -- with no treatment differences in C:N ratio. "New" FACE-derived C accounted for the 10-year increase in bulk soil C and also replaced 19% of the "old" pretreatment C. The difference in SOM accrual between elevated and ambient treatments occurred mostly in fine POM and silt-sized fractions. Initially, occlusion within microaggregates facilitated much of this accrual. But, in years 8 and 10, transfer of microaggregate-occluded C and N to less protected pools occurred in response to prolonged drought. The drought ended before conclusion of the experiment, and we expect data (in process) for year 12 to provide clues to recovery dynamics. However, the sensitivity of physical protection mechanisms to climate has implications for the potential long-term stability of accrued SOM in this system and those with similar soil characteristics. Beyond the CO2 treatment responses, the dynamic changes in this system -- coupled with the isotopic tracer -- contribute mechanistic understanding and quantitation of SOM cycling and stabilization that is required by models.

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NAME: Gabriel Katul
INSTITUTION: Duke University
COLLABORATORS: Danielle Way, Duke University; Stefano Manzoni, Duke University; Amilcare Porporato, Duke University
ABSTRACT TITLE: Constraining the simultaneous effects of elevated CO2, temperature, and shifts in rainfall patterns on ecosystem carbon fluxes using multi-scale resource optimization theories
PROGRAM AREA: Carbon Flux

ABSTRACT: Increases in atmospheric carbon dioxide concentrations (ca) will lead to changes in the climate that alter mean air temperature (Ta) and precipitation (P) patterns. The ability of terrestrial ecosystems to absorb ca is sensitive to these climatic conditions, as well as to ca, thereby creating a feedback that has the potential to accelerate warming. To describe the feedback, the primary pathways by which elevated ca, Ta, and changing P patterns simultaneously impact ecosystem photosynthesis and respiration must be quantified. Our objective is to produce a synthesis that capitalizes on the strengths of different models and incorporates the important feedbacks of the soil-plant-atmosphere system at pertinent spatial and time scales. Results from our work (year 1) on using an optimization modeling approach to capture stomatal responses to elevated ca, changes in Ta, vapor pressure deficit and leaf water potential will be presented using a meta-analysis on published data sets, spanning many climatic conditions and functional types. Our future work will focus on scaling-up from leaves to the canopy to provide a mathematically usable form for coarse-scale models at two time scales: short time scales (<1 h), where leaf area density and autotrophic biomass can be assumed constant, and longer time scales (e.g., seasonal or longer), where changes in these quantities are large.

Over the course of the coming two years, we will continue work on the other components of this project, including modeling of autotrophic and heterotrophic respiratory processes. Autotrophic processes reflect changes in biomass in pools determined using standard biomass budget equation, which we are modifying to accommodate carbon allocation rules derived from resource optimization theories that explicitly consider soil and foliage nutrition. For heterotrophic processes, at least three interacting soil carbon pools must be considered: litter, more stabilized SOM, and microbial biomass. Rates of decomposition, nitrogen mineralization, nitrification, and de-nitrification are being modeled together with soil moisture and temperature. Our final goal is to use a novel dimension reduction approach to simplify the multi-dimensional phase-space of this detailed model to a system of a few ordinary differential equations and prepare this simplified model for incorporation into existing climate-carbon models.

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NAME: Ralph Keeling
INSTITUTION: Scripps Institution of Oceanography
COLLABORATORS: Steve Piper, Scripps Institution of Oceanography; Heather Graven, Scripps Institution of Oceanography; Lisa Welp, Scripps Institution of Oceanography
ABSTRACT TITLE: Changing land metabolic activity as seen from atmospheric records
PROGRAM AREA: Carbon Flux

ABSTRACT: Long term records of atmospheric CO2 concentration and isotopic abundance at background sites are providing increasingly graphical insights into the changing function of the land biosphere, particularly in the Northern Hemisphere. The amplitude of the seasonal cycle at Mauna Loa has increased by 15% since measurements began in 1958, although the pace of increase has been irregular. Most of the increase occurred from 1970 to 1980. Since the early 1980s, there have been large swings in amplitude but not any obvious overall trend. In contrast, much larger increases in amplitude have been detected at surface sites further north, including Barrow Alaska, although the records are less complete. Extensive airborne surveys of CO2 concentrations over the North Pacific and Arctic conducted as part of the International Geophysical Year (IGY) from 1958 to 1961 and more recently the Hiapers Pole-to-Pole (HIPPO) campaign from 2009 to 2011 document a large increase in the amplitude of the seasonal cycle, in excess of 50%, at both 500mb and 700mb over wide latitude bands extending from 30N to nearly the North Pole. The airborne data reinforce the impression from the Barrow record that large changes have occurred over the past half century in the metabolic activity of the northern boreal forests, favoring a strong increase in the seasonal uptake and release of CO2. Isotopic time series from surface stations also provide insights into global metabolic activity. A recently discovered correlation between variations in the oxygen isotopic composition of CO2 with the Southern Oscillation can be exploited to derive estimates of global land gross primary production, leading to an estimate of 150-175 Pg/yr over the past few decades - higher than the conventionally accepted value of 120 Pg/yr. These results will be discussed in the context of model results that predict the response of global GPP and seasonal uptake to changing CO2 and climate.

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NAME: Ralph Keeling
INSTITUTION: Scripps Institution of Oceangraphy
COLLABORATORS: Lisa Welp, Scripps Institution of Oceanography; Heather Graven, Scripps Institution of Oceanography; Steve Piper, Scripps Institution of Oceanography
ABSTRACT TITLE: Constraints on land biospheric carbon cycling from long-term isotopic CO2 records from the Scripps CO2 program
PROGRAM AREA: Carbon Flux

ABSTRACT: The Scripps CO2 Program not only maintains the longest time series of CO2 concentrations (since 1957), but also maintains the longest time series of stable isotopic abundances (δC and δ18O) of CO2 since 1977. Through collaboration with Lawrence Livermore National Laboratory, Scripps also maintains the longest accelerator-based time-series of radiocarbon (Δ14C) in CO2, extending back as 1992 based on archived CO2 aliquots from flask samples. A major reason for extending these records is to provide critical new insights into the exchange of CO2 exchange with tropical and northern ecosystems beyond what is evident from shorter records, e.g. from the NOAA GMD program. Early applications of δC data emphasized their use in distinguishing land and ocean sinks and their variability associated with El Nino events. However, δC is more recently being used to resolve variations in isotopic discrimination in plants. Combined seasonal cycles in CO2 and δC provide a constraint on long-term and time varying water use efficiency of land ecosystems. The δ18O of CO2 has recently provided new constraints on the exchange time of CO2 with the terrestrial biosphere. The redistribution of moisture and rainfall in the tropics during an El Nino increases the d18O of precipitation and plant water, and this signal is passed to atmospheric CO2 by biosphere-atmosphere gas exchange. The decay time of these El Nino anomalies in δ18O are useful in constraining estimates of global gross primary production. The Δ14C observations in clean marine air provide constraints on carbon transfer rates between all major carbon reservoirs (ocean, land, atmosphere). These data are also critical for emergent application of radiocarbon in CO2 to quantify fossil-fuel emissions. Fossil fuel burning alone would produce a depletion in northern hemisphere air of 15 permil today but the observed deficit is 6 permil owing to additional processes – uptake of radiocarbon in the southern oceans and release of radiocarbon by the northern land biosphere. These isotopic time series in δC, δ18O, and Δ14C provide critical tests of carbon cycle models used to forecast changes in the biosphere and are complementary to results from process studies and field studies, such as the AmeriFlux project, by providing key metrics of changes on larger space and time scales.

NAME: Joel Kostka
INSTITUTION: Georgia Institute of Technology
COLLABORATORS: Jeffrey Chanton, Florida State University; William Cooper, Florida State University; Christopher Schadt, Oak Ridge National Laboratory
ABSTRACT TITLE: The response of soil carbon storage and microbially mediated carbon turnover to simulated climatic disturbance in a northern peatland forest: revisiting the concept of soil organic matter recalcitrance
PROGRAM AREA: Biogeochemistry

ABSTRACT: Peatlands sequester one-third of all soil carbon and currently act as major sinks of atmospheric CO2. The ability to predict or to simulate the fate of stored carbon in response to climatic disruption remains hampered by our limited understanding of the controls of C turnover and the composition and functioning of peatland microbial communities. The overall goal of this project is to investigate the lability of soil organic matter and the composition of decomposer microbial communities in response to the climatic forcing of environmental processes that determine carbon storage and sequestration in peatlands. The proposed project is conducted in northwestern Minnesota at the Marcell Experimental Forest (MEF) where ORNL has established a Climate Change Response Scientific Focus Area known as Spruce and Peatland Response Under Climatic and Environmental Change (SPRUCE). The abundance, community composition, and activity of microbial communities were investigated at bog and fen sites which contained contrasting reactivity of dissolved organic matter (DOM) linked to plant species composition. Multi-domain community composition was determined by pyrosequencing of Bacterial and Archaeal 16S rRNA and fungal ITS gene targets. DOM quality and the microbial processing of DOM were assessed through concentrations of dissolved organic carbon, C/N ratios, optical properties of DOM, and activities of laccase and peroxidase enzymes. Estimated microbial richness (Chao1) was >2 times higher on average at the fen than at the bog, in agreement with a higher labile DOM content and enhanced enzyme activities at the fen. Statistical analyses showed distinctly different spatial distribution patterns between bacterial and fungal communities. Fungal distribution did not covary with pH and DOM optical properties, and was vertically stratified, with a prevalence of Ascomycota and Basidiomycota near the surface and elevated Zygomycota in the subsurface. In contrast, bacterial community composition largely varied between environments with the bog dominated by Acidobacteria (61% of total sequences) while the Firmicutes (52%) dominated in the fen. In addition, acetoclastic Methanosarcinales were dominant (65-91% of Archaeal sequences) in the bog, in contrast to a more diverse fen archaeal community dominated by hydrogenotrophic methanogens. To our knowledge, this study represents the first detailed characterization of peatland microbial communities that includes all domains of life. Our studies indicate that the structure and function of prokaryotic communities covaries with the recalcitrance of dissolved organic matter in bog and fen environments, whereas fungal communities respond differently to environmental pressures, including the quantity and quality of DOM along peatland vegetation gradients.

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NAME: Lara Kueppers
INSTITUTION: University of California, Merced
COLLABORATORS: ATWE PIs, various; Cristina Castanha, Lawrence Berkeley National Laboratory and University of California, Berkeley; Andrew Moyes, University of California, Merced
ABSTRACT TITLE: Alpine Treeline Warming Experiment: Will warming promote uphill species range shifts?
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: To experimentally test model projections of subalpine tree species' uphill migration with climate change, we established the Alpine Treeline Warming Experiment (ATWE) at Niwot Ridge, CO. Common gardens subject to warming and watering treatments are replicated at three sites: near the lower limit of subalpine forest (Subalpine), within the alpine-treeline ecotone (Treeline), and in the alpine tundra, beyond the current elevation ranges of the species (Alpine). In 2010, preliminary results show growing-season duration was 33 days longer, air temperature was 5.1° C greater, and vapor pressure deficit was 0.5 kPa greater in the Subalpine compared to the Treeline and Alpine. The Alpine had higher soil moisture than the Treeline and Subalpine, but in both 2010 and 2011 had many days below 16% volumetric water content, a threshold observed to reduce seedling stomatal conductance.

In all sites, preliminary results indicate the heating and watering treatments expanded the microclimate envelopes into which subalpine tree seedlings might recruit. In 2010 and 2011, daily 5-10 cm soil temperature was greater in heated and heated+ watered plots, while moisture was lower in heated plots and slightly greater in watered plots. Surface soil (0.5 cm) temperatures were also raised by heaters but had diel extremes more than twice as large as those at 5-10cm. Variability in treatment effects among sites is partially explained by higher wind speeds (and convective fluxes) and greater heater failures due to more extreme winter weather in the Alpine and Treeline compared to the Subalpine.

Seeds of two subalpine species were sown each year since 2008 to quantify germination and survival and their dependence on climatic factors. Preliminary results indicate timing of seed germination was controlled by growing degree days, with earlier germination in the Subalpine and in heated plots. In 2010, limber pine survival decreased with increasing growing degree days and with the number of days that soil volumetric water content was below 8%. This soil moisture threshold corresponded with seedling water potentials of -4 MPa and shutdown of stomatal conductance and photosynthesis in first year seedlings, suggesting shallow soil water availability is critical to seedling establishment within and beyond this species' range.

Early results from the ATWE indicate that contrary to expectations, warming may not promote seedling establishment at Treeline and in the Alpine if it leads to longer warmer growing seasons and extended periods with low soil moisture. Consistent with expectations, warming may reduce seedling establishment in Subalpine forest.

NAME: Brian LaFranchi
INSTITUTION: Lawrence Livermore National Laboratory
COLLABORATORS: John Miller, NOAA/ESRL; Scott Lehman, INSTAAR, University of Colorado; Thomas Guilderson, Lawrence Livermore National Laboratory
ABSTRACT TITLE: Observations of atmospheric 14CO2 at three tall towers in the continental United States
PROGRAM AREA: Carbon Flux

ABSTRACT: Atmospheric radiocarbon in CO2 (14CO2) represents an important observational constraint on emissions of fossil-fuel derived carbon into the atmosphere, facilitating carbon cycle studies and the validation of fossil fuel emissions inventories. For these purposes, sampling of whole air for 14CO2 is underway at 8 tall towers in the continental United States, part of the NOAA/ESRL Global Monitoring Division tall tower network. Here we present an overview of 14CO2 observations across 1.5-2 years, from 3 of these towers: one outside of Denver, Colorado (BAO; 40.05 °N, 105.01 °W), one in northern Wisconsin (LEF; 45.94 °N, 90.27 °W), and a third in northern Maine (AMT; 45.03 °N, 68.68 °W). Whole air samples were collected at each site 2-3 times per week and analyzed for 14C by accelerator mass spectrometry (AMS). The 3 sites each have distinguishing features providing a unique case study for testing the utility of 14CO2 observations across different continental regions experiencing a range of anthropogenic vs biogenic and near-field vs far-field factors, thus representing a large spectrum of conditions under which 14CO2 observations are expected to be used to infer surface fluxes.

In this study we will explore a range of issues related to the use of 14CO2 observations to partition variability of CO2 mixing ratios into its biogenic and fossil components for better understanding surface-atmosphere exchange of CO2 and other trace gases important to air quality and climate change, including CH4, N2O, C2H2, CO, a suite of halo-carbons, and SF6. We will focus our analysis on understanding the regional differences of emissions and surface exchange in relation to those predicted by bottom-up inventories such as Vulcan, Edgar, NEI, and Carbon Tracker. We will also explore a number of ancillary issues related to understanding the geographical differences in surface fluxes through 14CO2 observations, such as: selection of background reference sites, the influence of photochemistry, and the influence of CO2 respiration from older soil carbon pools.

NAME: Monique Leclerc
INSTITUTION: University of Georgia
COLLABORATORS: Robert Kurzeja, Savannah River National Laboratory; Matthew Parker, Savannah River National Laboratory; David Werth, Savannah River National Laboratory
ABSTRACT TITLE: The Aiken AmeriFlux Site: Innovative Methods of Atmosphere-Terrestrial Carbon Exchange Measurements and Modeling
PROGRAM AREA: Carbon Flux

ABSTRACT: The present study takes place at the Aiken AmeriFlux site, located in one of the most carbon-rich regions of the US. This unique site has been fully operational for approximately two years, and was included in the AmeriFlux network in 2011, providing an unprecedented dataset in a region of the Southeast that has been a gap in the network. It benefits the conditions necessary in a robust flux program, a sound footprint climatology, a large supporting infrastructure, site measurements by highly trained personnel and a complete suite of supporting modeling, boundary-layer instrumentation, intensive tracer field campaigns, and soil and plant measurements. The Aiken site presents the researchers with an opportunity to refine the understanding, measurement methods, and protocols of data analysis associated with the magnitude of carbon uptake by terrestrial ecosystems. In spite of recent efforts by the carbon science community, uncertainty in estimating carbon fluxes in terrestrial ecosystems remains high, and a refinement of the methods of determining fluxes is critical.

The project combines experiments and modeling to provide new, near-term results ---many of them site cross-cutting--- to markedly improve our predictive capability to describe the processes affecting atmospheric CO2 exchanges. In concert with the Savannah River National Laboratory, the study (i) provides a more robust determination of the mechanisms regulating the exchange of CO2 with the atmosphere using a combination of powerful techniques, including sodars, RASS, microbarographs, and perfluorocarbon releases; (ii) quantifies the uncertainty associated with measurements of CO2 exchange between the atmosphere and ecosystems; and (iii) models terrestrial carbon processes at scales ranging from the flux tower footprint to the regional scale using revised carbon exchange information. Several intensive field campaigns using advanced technologies have been performed in this project, and peer-review publications have appeared while others are under way. These include the use of (i) perfluorocarbon tracers to better track and document the exchange of carbon in nocturnal stable conditions; (ii) lidars and microbarographs to document the presence of gravity waves, which lead to overestimation of nocturnal fluxes ("flux inflation"); and (iii) sodars to detect the presence of low-level jets (LLJ), which modulate the turbulent surface-atmosphere exchange. Particular attention has been given to the LLJ impact on the morning transition and to the validity of the shear-sheltering theory.

Flux data collected as part of the repository of the AmeriFlux network, analysis and interpretation of that dataset is presented at that meeting.

NAME: Keith Lewin
INSTITUTION: Brookhaven National Laboratory
COLLABORATORS: John Nagy, Brookhaven National Laboratory
ABSTRACT TITLE: Free Air CO2 Enrichment (FACE) Facility Engineering and Operations
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: Brookhaven National Laboratory (BNL) developed the FACE technology for exposing managed and natural ecosystems to elevated levels of carbon dioxide, ozone and other air pollutants under open-field conditions. This technology has been adopted worldwide for climate change experiments. BNL has been directly involved in establishing and managing FACE experiments in meadows, crops, and forests in multiple locations in the USA as well as in Switzerland, Germany, New Zealand, Panama, and Australia. This work has been funded by DOE and other organizations. In addition to carbon dioxide and ozone treatments, some FACE experiments include interactions with nutrients, water availability and temperature. The large experimental volumes available in FACE experiments have allowed extensive, cross disciplinary studies covering many potential climate change impacts.

BNL is collaborating with non-DOE partners to update and advance FACE technology and to assist with the design and management of climate change experiments. These new designs are targeted towards research in globally important but currently understudied ecosystems and to incorporate climate change effects into crop variety screening studies. Current activities include updating the FACE control hardware and software to take advantage of recent technological advances and to be compatible with cropping systems such as rice paddies that in the past have proven difficult for the introduction of FACE technology. BNL is collaborating with the U. S. Forest Service and UC Berkley to establish and test a prototype open field warming facility in a semi-dry tropical forest in Puerto Rico. This prototype will use an array of infrared heaters to warm a 20 m diameter plot with a 10+ meter canopy height. BNL is also working with the International Rice Research Institute to incorporate elevated [CO2] into future variety screening trials.

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NAME: Jiafu Mao
INSTITUTION: ORNL
COLLABORATORS: Peter Thornton, ORNL; Xiaoying Shi, ORNL; Wilfred Post, ORNL
ABSTRACT TITLE: Remote sensing evaluation of CLM4
PROGRAM AREA: National Laboratory Research (SFA)

ABSTRACT: Accurate simulation and prediction of terrestrial carbon/water states and fluxes are considerably important to reduce the uncertainty of the land-climate feedbacks under global warming. Comprehensive evaluation of global ecosystem model like the Community Land Model version 4 (CLM4), is hindered by the lack of observation at continental and global scales. Remote sensing techniques provide near-real time metrics related to global ecosystem dynamics, such as the LAI, NDVI, FPAR, ET, GPP and forest carbon stocks, at fine spatiotemporal scales. Here we will display two recent researches on the remote sensing evaluation of CLM4 gross primary production and vegetation growth. The monthly GPP simulated by CLM4 at a half-degree resolution is first compared with satellite estimates of GPP from the MODIS (Moderate Resolution Imaging Spectroradiometer) GPP product (MOD17) for the 10-yr period, January 2000-December 2009. Then we will describe how the CLM4 and the satellite-derived NDVI are applied to examine the spring NDVI changes in response to climate, CO_2 fertilization, nitrogen deposition and land use land cover change effects on the inter-annual timescale over the northern mid-high latitudes (>25 °N) for the recent decades (1982-2004).

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NAME: Jiafu Mao
INSTITUTION: ORNL
COLLABORATORS: Peter Thornton, ORNL; Daniel Ricciuto, ORNL; Jeffrey Warren, ORNL
ABSTRACT TITLE: PiTS based simulation and improvement of CLM4
PROGRAM AREA: National Laboratory Research (SFA)

ABSTRACT: The Partitioning in Trees and Soil (PiTS) project was established to improve the parameterization of C partitioning routines in existing ecosystem models by exploring mechanistic model representations of partitioning tested against field observations and manipulations. These short-term field data sets are currently been employed to test the carbon-nitrogen version of the Community Land Model version 4 (CLM4). Our objective has been to understand and simulate the C partitioning and flux within plants and into soil varying with changes in gross primary production (GPP) and environmental drivers. There have been ongoing model simulations and developments based on measured or estimated values of biomass pools, foliar physiology, soil characteristics, and site environmental conditions. Here we will show some progresses and future work in the CLM4 setting up and validations against this pine stand observations.

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NAME: Jonathan Martin
INSTITUTION: Oregon State University
COLLABORATORS: Andres Schmidt, Oregon State University; Beverly Law, Oregon State University
ABSTRACT TITLE: A Recent Deviation Of Climate And Forest C Processes Between A Wet And Dry Forest In The PNW, USA.
PROGRAM AREA: Carbon Flux

ABSTRACT: Climate change projections for the Pacific Northwest Region of United States include higher summer temperatures and increased spring snowmelt, which is expected to increase drought stress in the region's forests. Yet, the relative change in climate and forest impacts may vary within the region, which includes mesic coastal and semi-arid forests, where the semi-arid forests rely more on winter snowpack. Detailed environmental and ecosystem measurements were combined with long term climate records (PRISM) and tree ring chronologies to examine climate and ecosystem C fluxes at three temporal scales for AmeriFlux sites in mature coastal Douglas-fir (Marys River MF site), and mature semi-arid ponderosa pine (Metolius MP site). We hypothesized that [1] the previous 100 years of climate change would not be equal between sites, and [2] the forests would display separate controls and varying sensitivity to climatic drivers for the following C components and processes: above ground primary production (ANPP), heterotrophic respiration (Rh), litter inputs, and net ecosystem productivity (NEP). 100 years of climate data show an increase of minimum dry season temperatures of 0.10 and 0.17 °C per decade at the coastal fir site and semi-arid pine site, respectively; with smaller increases during the wet season but greater between sites (0.06 and 0.14 °C per decade; coastal fir site and semi-arid pine, respectively). Since 1950, precipitation trends were flat at both sites during the dry season and during the winter at coastal fir site; however, the wet season precipitation at the semi-arid pine site declined significantly (1.9 mm per year). Since 2000, temperatures have declined and precipitation has increased across both sites and seasons concurrent with a decreasing Pacific Decadal Oscillation Index (PDOI). Anomalies of tree rings spanning 30 years were similar between sites and related to precipitation; however the dominant driver changed from precipitation to temperature at the semi-arid pine site in the current decade. 10 years of detailed measurements of site climate and C fluxes show differential climate controls. Litter inputs, ANPP, and Rh at the coastal fir site were correlated to precipitation while these C fluxes were more strongly correlated to temperature at the semi-arid pine site. Because of the recent regional cooling, localized atmospheric conditions at the two sites diverged with a site wide vapor pressure deficit decrease but increased cloudiness at the coastal fir site only. ANPP at the semi-arid pine site increased as vapor pressure deficit decreased while ANPP at the coastal fit site had a decreasing but insignificant trend as cloudiness increased. At both sites, trends of NEP increased due to decreasing Rh and litter inputs, but NEP was driven by temperature at the semi- arid pine site and weakly by precipitation at the coastal fir site. The data indicate [1] that climatic trends are similar but unequal across the region, [2] that forest growth and ecosystem C dynamics at two diverse sites are sensitive to similar drivers but recent climate shifts have not had equal influcenc, and [3] the complexity of NEP across differing regional climates and highlight the variation of C sequestration that is not accounted for by simple vegetation growth metrics.

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NAME: Jonathan Martin
INSTITUTION: Oregon State University
COLLABORATORS: Claire Phillips, Center for Accelerator Mass Spectrometry, Lawrence Livermore National Laboratory; Andres Schmidt, Oregon State University; Beverly Law, Oregon State University
ABSTRACT TITLE: High Frequency Analysis Of The Complex Linkage Between Soil CO2 Fluxes, Photosynthesis, And Environmental Variables
PROGRAM AREA: Carbon Flux

ABSTRACT: High frequency soil CO_2 flux data are valuable for providing new insights in to the processes of soil CO_2 production. A record of hourly soil CO_2 fluxes from a semi-arid ponderosa pine stand was spatially and temporally deconstructed in attempts to determine if variation could be explained by logical drivers using (1) CO_2 production depths, (2) relationships and lags between fluxes and soil temperatures, or (3) the role of canopy assimilation in soil CO_2 flux variation. Relationships between temperature and soil fluxes were difficult to establish at the hourly scale because diel cycles of soil fluxes varied seasonally with the peak of flux rates occurring later in the day as soil water content decreased. Using a simple heat transport/gas diffusion model to estimate the time and depth of CO_2 flux production, we determined that the variation in diel soil CO_2 flux patterns could not be explained by changes in diffusion rates or production from deeper soil profiles. We tested for the effect of gross ecosystem productivity (GEP) by minimizing soil flux covariance with temperature and moisture using only data from discrete bins of environmental conditions (±1 ºC soil temperature at multiple depths, precipitation free periods, and stable soil moisture). GEP was identified as a possible driver of variability at the hourly scale during the growing season, with multiple lags between ~5, 15 and 23 days. Additionally, the chamber specific lags between GEP and soil CO_2 fluxes appeared to relate to combined path length for carbon flow (top of tree to chamber center). In this sparse and heterogeneous forested system, the potential link between CO_2 assimilation and soil CO_2 flux may be quite variable both temporally and spatially. For model applications, it is important to note that soil CO_2 fluxes are influenced by many biophysical factors, which may confound or obscure relationships with logical environmental drivers and act a multiple temporal and spatial scales; therefore, caution is needed when attributing soil CO_2 fluxes to covariates like temperature, moisture and GEP.

NAME: Roser Matamala
INSTITUTION: Argonne National Laboratory
COLLABORATORS: Miquel A. Gonzalez-Meler, University Illinois at Chicago; Scott L. Graham, University of Canterbury; David R. Cook, Argonne National Laboratory

ABSTRACT TITLE: Biological invasions impact ecosystem properties and can affect climate predictions
PROGRAM AREA: National Laboratory Research (SFA)

ABSTRACT: Climate change models vary widely in their predictions of the effects of climate forcing, in part because of difficulties in assigning sources of uncertainties and in simulating changes in the carbon source/sink status and climate-carbon cycle feedbacks of terrestrial ecosystems. We studied the impacts of vegetation and weather variations on carbon and energy fluxes at a restored tallgrass prairie in Illinois. The prairie was a strong carbon sink, despite a prolonged drought period and vegetation changes due to the presence of a non-native biennial plant. Changes from natives to a non-native forbs species had the strongest effect in reducing net ecosystem production and increasing sensible heat flux and albedo, which may result in positive feedbacks on warming. Here we show that non-native species invasions can alter the ecosystem sensitivity to climatic factors often construed in models.

NAME: Roser Matamala
INSTITUTION: Argonne National Laboratory
COLLABORATORS: Julie Jastrow, Argonne National Laboratory; Karis McFarlane, Lawrence Livermore National Laboratory; Paul Hanson, Oak Ridge National Laboratory
ABSTRACT TITLE: Climatic and edaphic controls over root decomposition and labile components of mineral-associated soil organic matter
PROGRAM AREA: National Laboratory Research (SFA)

ABSTRACT: Soil organic matter (SOM) represents the largest reservoir of C in terrestrial ecosystems and climate change is expected to modify soil C dynamics. Root decomposition might represent the primary source of SOM in most ecosystems. Thus, data on how climate and edaphic factors affect root decomposition, the transfer of root-derived materials to soil, and the dynamics of SOM pools with decadal-scale turnover times are needed to better define the pools and transfer functions used in models. As part of the Enriched Background Isotope Study (EBIS), we established 14C-enriched root-litter manipulations at four AmeriFlux sites representing the climatic extent of Eastern deciduous forest. These sites cover a range of mean annual temperature and precipitation ranging from 6.2 to 12.8 C and 750 to 1400 mm. We followed root decomposition and incorporation of root-derived C into soil at each site. We also used natural abundance 14C to assess variations in the turnover of acid-hydrolyzable and acid-resistant C pools in the mineral-associated dense fraction of site soils. Acid hydrolysis preferentially isolates polysaccharides and N-rich compounds, which are often microbial in origin and potentially more bioavailable than the acid-resistant fraction, which typically exhibits millennial turnover times. We found that remaining root mass averaged 73% after the first summer and 58% after the second summer across all sites. The finest roots (roots 0.5<diam<1mm) lost 60-40% of their mass during the first summer and then changed little over winter. Root decay constants were significantly affected by climate and edaphic factors. Soils in root incubation bags showed 14C enrichment after only one month, suggesting that root C was quickly transferred to SOM, perhaps mostly as microbial residues. After the first month, soil 14C enrichment exhibited cyclic dynamics that varied by site, which were likely related to site differences in microbial activity and edaphic factors affecting SOM stabilization. On average, about 60% of the C in the soil dense fraction was hydrolyzable. In the upper 5 cm of mineral soil horizons, the turnover time of this potentially bioactive pool ranged from <30 years to centuries and varied predictably with climate, modified by edaphic conditions. Below 5 cm, turnover times increased significantly, suggesting that conditions favorable for decomposition attenuate rapidly. Overall, we found climatic and edaphic effects on root decomposition dynamics and the turnover of a biochemically labile pool of mineral-associated SOM, which can contribute to model parameterization and validation.

NAME: Kyle Maurer
INSTITUTION: The Ohio State University
COLLABORATORS: Gil Bohrer, The Ohio State University; Chris Vogel, University of Michigan Biological Station; Peter Curtis, The Ohio State University
ABSTRACT TITLE: Changes to canopy structure drive shifts in flux ejection-sweep dynamics at the Forest Accelerated Succession ExperimenT (FASET)
PROGRAM AREA: Carbon Flux

ABSTRACT: Downdrafts (sweeps) and updrafts (ejections) are the primary mechanisms for the transfer of momentum, heat, and mass in the atmosphere. These phenomena are important in forested regions, where sweeps and ejections may play a large role in the overall carbon and water exchange between the canopy air and the atmospheric boundary layer. At the Forest Accelerated Succession ExperimenT (FASET), we disturbed 39 ha of forest by girdling all canopy-dominant early-successional aspen and birch trees, leading to a large mortality event, followed by a shift in forest structure that is typical of a more mature successional stage. We found that the disturbance stage (1-3 years after girdling) was characterized by an uncoupling of carbon assimilation rates at two neighboring AmeriFlux eddy-flux towers, the manipulated site (US-UMd) and its undisturbed control (US-UMB) both at the University of Michigan Biological Station (UMBS) cluster site. Using these above-canopy towers and concurrent meteorological towers inside the canopy at each site, we measure shifts in sweep-ejection characteristics at each site inside the canopy sub-layer (CSL) and above the canopy at the transition between the roughness sub-layer (RSL) and the atmospheric surface layer (ASL). We also calculate the differential contribution to scalar flux from sweeps and ejections (ΔS0). We find a large shift in sweep-ejection dynamics at the FASET site, most likely due to the change in forest structure. These findings provide insight to the effects of intermediate disturbance and canopy structure on mixing rate and scalar exchange between the canopy and the atmosphere.

NAME: Kyle Maurer
INSTITUTION: The Ohio State University
COLLABORATORS: Gil Bohrer, The Ohio State University; Lingli He, University of Michigan; Valeriy Ivanov, University of Michigan
ABSTRACT TITLE: Modeling the effects of increasingly heterogeneous canopy environments on flux dynamics using a high-resolution, forest-resolving large-eddy simulation (RAFLES)
PROGRAM AREA: Modeling

ABSTRACT: Turbulent eddies control the flux of carbon, water and other gases between forested environments and the atmosphere. Inside the canopy, eddy correlation length is very small and surface heterogeneity due to tree-crown structures occurs at these scales. Computer simulations, particularly Large-Eddy Simulations (LES), provide the foundation to test the sensitivity of flux exchange and turbulent mixing to small scale processes, such as successional- or disturbance-driven changes to canopy structure. At the Forest Accelerated Succession ExperimenT (FASET), we disturbed 39 ha of forest by girdling all canopy-dominant early-successional aspen and birch trees, leading to a large mortality event, followed by a shift in forest structure that is typical of a more mature successional stage. We use the Regional Atmospheric Modeling System (RAMS)-based Forest Large-Eddy Simulation (RAFLES) to investigate the consequences of increasingly heterogeneous forest environments to canopy-atmosphere exchange. The model environment was determined by remote sensing of the actual forested area of interest using airborne Light Detection and Ranging (LiDAR) measurements and eddy-flux gas exchange measurements at two neighboring AmeriFlux eddy-flux towers, the manipulated site (US-UMd) and its undisturbed control (US-UMB) both at the University of Michigan Biological Station (UMBS) cluster site. We find changes to observed domain-averaged flux dynamics with increasingly heterogeneous canopy environments, as well as changes to simulated small-scale fluxes, which cannot be directly measured from flux towers.

NAME: Karis McFarlane
INSTITUTION: Lawrence Livermore National Laboratory
COLLABORATORS: Paul Hanson, Oak Ridge National Laboratory; Margaret Torn, Lawrence Livermore National Laboratory; Roser Matamala, Argonne National Laboratory; Julie Jastrow, Argonne National Laboratory
ABSTRACT TITLE: Plant Litter to Mineral Soil Sinks: Tracking Carbon Flux into Soil Sinks in Temperate Broadleaf Forests in the Eastern US with Radiocarbon
PROGRAM AREA: National Laboratory Research (SFA)

ABSTRACT: The Enriched Background Isotope Study focusing on AmeriFlux Sites (EBIS-AmeriFlux) uses unique radiocarbon-enriched materials to characterize the rate of carbon flux from litter sources to mineral soil sinks in four Eastern deciduous forests spanning a range of climatic and soil conditions. Beginning in 2007, radiocarbon-enriched leaf and root litter and humus were deployed at the University of Michigan Biological Station (MI-UMBS), Bartlett Forest (NH-BF), Harvard Forest (MA-HF), and Baskett Research and Education Area in the Missouri Ozarks (MO-OZ). In addition to investigating rates of carbon transfer from litter to bulk organic horizons and mineral soil, we used soil fractionation to separate bulk mineral soil into three pools of varying stability. These fractions included three density fractions: a free-light (unprotected), occluded-light (physically protected), and dense (mineral-associated). Dense fractions were subsequently acid hydrolyzed to yield a mineral-associated and unreactive acid-resistant fraction. Prior to enriched litter applications, background levels of radiocarbon were used to calculate turnover times of these fractions at the four sites, providing valuable information on soil carbon cycling for these sites and the ecoregion. These soil fractions allow for the identification of which soil organic matter pools incorporate carbon from experimental sources and determination of pool-specific transfer rates. We present background data that characterizes soil carbon dynamics at our sites and results from the first three years of enriched-leaf and -humus applications and first year of enriched-root decomposition experiments. Patterns in soil carbon stocks reflected differences in climate and soil texture and ranged from 55 to 170 Mg C ha-1 at MI-UMBS and NH-BF, respectively. Patterns in turnover times for soil fractions could not be explained by climate alone, but by site-specific factors including soil mineralogy, texture, and fauna. Little carbon from enriched humus has been incorporated into mineral soil, but carbon from enriched leaves has been incorporated in organic horizons at all sites and into mineral soil at MO-OZ and MI-UMBS. Radiocarbon values for surface soil density fractions at MO-OZ show that leaf-C has entered all three density fractions, although the rate of transfer is higher for the light fractions than the dense fraction. After 1 year, root-derived 14C was detected in all three soil-density fractions isolated from MO-OZ, but not in fractions from NH-BF. These data allow for calculation of annual transfer rates for carbon from plant litter sources to mineral soil sinks and provide quantitative differences in flux rates at different sites and from different plant-C sources.

NAME: Bill Munger
INSTITUTION: Harvard University, SEAS
COLLABORATORS: Leland Werden, Harvard University, SEAS; David Foster, Harvard University, Harvard Forest; Julian Hadley, Harvard University, Harvard Forest
ABSTRACT TITLE: Contrasting Carbon Budgets for Deciduous and Coniferous Stands at Harvard Forest.
PROGRAM AREA: Carbon Flux

ABSTRACT: New England forests are a mixture of deciduous and coniferous species with disturbance histories ranging from intensive agriculture abandoned in the late 1800s to permanent woodlots historically used for timber but never cleared. Flux towers and biometry plots established at the Harvard Forest Long-Term Ecological Research (LTER) seek to quantify and understand the contrasting carbon budgets across this gradient in species composition and land-use history. By making continued long-term observations at a pair of nearby sites, representative of the conifer- and deciduous-dominated forest, we can detect differences in climate response and successional trajectories. Furthermore, observations of carbon fluxes and biomass in hemlock establish baseline conditions to compare against as this site is infected by Hemlock Wooly Adelgid (HWA), an insect that attacks eastern hemlock.

The Environmental Measurement Site (EMS) is in a stand dominated by red oak and red maple with the oldest trees established prior to 1895 on abandoned pasture. Scattered pines and patches of hemlock make up as much as 44% of the basal area in the area northwest of the tower and are present as small saplings in the understory and mid canopy. The Hemlock (HEM) tower is located adjacent to a nearly pure stand of eastern hemlock with some individuals up to 230 years old. The site has not been affected by any stand-clearing disturbance since European settlement. Permanent vegetation plots are associated with each tower site to quantify changes in above-ground biomass, litter inputs, and woody debris.

Comparison of the hourly fluxes at EMS and HEM towers highlights their physiological differences. In 2010 the peak rate of hourly $CO2$ uptake for the deciduous stand was about 50% higher than the peak rate of the conifer stand. The reduced magnitude of $CO2$ uptake during summer months by conifers is partly offset by an extended growing season that starts earlier and ends later by 1.5 – 2 month compared to the active season for deciduous stands. The small component of conifers, which is less than 10% of overall biomass, is exposed to incoming light in the spring and before the deciduous canopy emerges the small conifers contribute to $CO2$ uptake rates that are about 30% of the corresponding rates in the hemlock stand.

Biomass accumulation in above-ground wood has been remarkably similar for hemlock and deciduous-dominated stands over the last decade. Even though the hemlock stands is older, it is still actively accumulating carbon.

NAME: Richard Norby
INSTITUTION: Oak Ridge National Laboratory
COLLABORATORS: Colleen Iversen, Oak Ridge National Laboratory; Jeffrey Warren, Oak Ridge National Laboratory; Joanne Childs, Oak Ridge National Laboratory
ABSTRACT TITLE: Final Harvest of Oak Ridge FACE Experiment Confirms Stability of Allometric Relationships
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: A free-air CO2 enrichment (FACE) experiment was established in 1997 in a sweetgum plantation at the Oak Ridge National Laboratory. Two 25-m diameter plots, each with approximately 90 trees, were exposed to ~550 ppm CO2 from May 1998 until September 2009 (12 growing seasons) and compared with three similar plots in ambient CO2. The final year of the experiment afforded the opportunity for destructive sampling that had previously been precluded. Sixteen trees were cut and dissected to determine crown structure and allometric relationships between wood mass and tree height and basal diameter. Woody root systems were excavated and weighed. Soil pits (90 cm deep) permitted much more detailed analysis of root distribution and soil C and N content than had been possible with minirhizotrons and soil cores.

Leaf area distribution within the crown was similar in trees grown in ambient and elevated CO2. Maximum leaf area density occurred at 2-4 m crown depth, and nitrogen distribution followed a similar pattern. Canopy structure, or the distribution of leaf area in relation to canopy depth, remained remarkably stable during the 12 year experiment, even as the top of the canopy increased from 18 to 23 m above ground. The allometric relationship used throughout the course of the experiment to estimate wood production proved to be robust, even though the trees had grown well beyond the size of the trees used to establish the relationships initially. Woody root mass, however, was underestimated by the previously established allometric equation. Nevertheless, our conclusion that net primary productivity and its response to elevated CO2 declined during the 12-year experiment is not changed. Analysis of fine-root distribution in the soil pits confirmed the minirhizotron observations that elevated CO2 stimulated root production deeper in the soil. Carbon isotope analysis indicated that substantial FACE-derived carbon inputs, primarily from fine roots, were incorporated in soil organic matter pools throughout the soil profile. Total soil C content was 19% greater in elevated CO2 plots than in ambient plots.

Although there are many reasons for continuing experiments such as the FACE experiments for as many years as funding and infrastructure allow, the possibility of destructive sampling at the end of the experiment provides many opportunities for new and informative data.

NAME: Robert Nowak
INSTITUTION: University of Nevada Reno
COLLABORATORS: Beth Newingham, University of Idaho; Cheryl Vanier, University of Nevada Las Vegas; Stan Smith, University of Nevada Las Vegas
ABSTRACT TITLE: Standing crops of aboveground and belowground biomass are not significantly different after ten years of elevated CO2 in the Mojave Desert
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: Elevated atmospheric CO2 ([CO2]) is assumed to increase primary production, particularly in desert systems through stimulatory effects on plant water-use efficiency. We examined the effects of elevated [CO2] at the Nevada Desert FACE (Free-Air CO2 Enrichment) Facility (NDFF) in an intact Mojave Desert ecosystem. At the NDFF, ambient and elevated [CO2] treatments were applied continuously over a 10-year period to 25 m diameter plots. Average [CO2] for the ambient CO2 treatment over the entire experiment was 375.4 ppm (SD = 9.1); for the elevated CO2 treatment, plots were fumigated 78% of the time with an average [CO2] during fumigation of 550.1 ppm (SD=33.1) and over all time of 513.2 ppm (SD=66.9). We found no significant effect of elevated [CO2] on total perennial plant standing crop (whether expressed as biomass, C, or N) or on perennial plant cover at the end of the experiment. Regardless of [CO2] treatment, perennial cover increased over the ten years of the experiment whereas total aboveground biomass at the beginning of the experiment was similar to that at the end. Perennial biomass allocations to vegetative vs. twig vs. woody shoot biomass, to fine vs. coarse vs. woody root biomass, or to total root vs. total shoot biomass were not differentially affected by elevated [CO2], although leaf area index increased under elevated [CO2]. Previous results have shown that elevated [CO2] increased growth of annual plants, especially an exotic grass (Bromus madritensis subsp. rubens), and increased shoot production of perennial species in wet years during the ten-year period of CO2 treatments at the NDFF. Together, these results indicate that (1) elevated [CO2] stimulates production in the Mojave Desert under certain pulse events, but this stimulation is highly variable, and (2) given the episodic nature of precipitation cycles and resulting resource availability in the Mojave Desert, the pulsed increased production could not be maintained during subsequent drought periods even with continuous exposure to elevated [CO2]. Thus, future effects of rising [CO2] will primarily depend on future precipitation regimes, and the current high variability in productivity from year to year will be greatly increased as atmospheric CO2 continues to increase.

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NAME: Robert Nowak
INSTITUTION: University of Nevada Reno
COLLABORATORS: Derek Sonderegger, Northern Arizona University; Scot Ferguson, University of Nevada Reno; Kiona Ogle, Arizona State University
ABSTRACT TITLE: Temporal dynamics of root growth under long-term exposure to elevated CO2 in the Mojave Desert
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: Quantifying below ground carbon fluxes and stocks presents one of the greatest challenges to understanding and predicting the terrestrial carbon cycle. Arid and semi-arid ecosystems cover >35% of the terrestrial biosphere and are considered "below-ground dominated", yet little is known about the impacts of rising atmospheric CO2 and natural precipitation and temperature cycles on the long-term dynamics of root biomass and below-ground carbon cycling in deserts. This study addresses this issue by evaluating root dynamics in an intact desert ecosystem exposed to 10 years of elevated CO2. The objectives are to: (1) quantify the temporal dynamics of root standing crop, production, and mortality under long-term exposure to elevated CO2; and (2) investigate how elevated CO2 interacts with variable precipitation, temperature, and microsite heterogeneity to affect root dynamics. We evaluated minirhizotron data from 168 tubes placed under two dominant shrub species (Larrea tridentata and Ambrosia dumosa) and along community transects at the Nevada Desert FACE Facility in the Mojave Desert. Fine root production, mortality, and standing crop were visually quantified every four weeks for four years (2003-2007). The data were synthesized within a Bayesian framework that incorporates a temporally dynamic model of root production, which explicitly includes the effects of precipitation and temperature history, CO2 treatment, cover type, and biological inertia. CO2 treatment interacts significantly with biological inertia for each cover class, where plants under elevated CO2 initiate fine root growth sooner and sustain growth longer, with the net effect of increasing the growth and subsequent die-back cycle under elevated CO2. Our results also indicate complex CO2 treatment effects of antecedent soil water that are dependent on cover type and phenological period: fine root growth under elevated CO2 is enhanced more than that under ambient CO2 during certain times of the year when antecedent soil water is relatively high. Fine root production is strongly affected by precipitation events, but the relationship between fine root production and individual precipitation events is not direct nor immediate: substantial lag times occur between precipitation and fine root production. Finally, the lack of significant temperature effects on fine root production or mortality was quite surprising, especially considering the importance of temperature for biological processes.

NAME: Elise Pendall
INSTITUTION: University of Wyoming
COLLABORATORS: Williams David, University of Wyoming; Morgan Jack, USDA-ARS; Heisler-White Jana, TriHydro, Inc
ABSTRACT TITLE: Carbon cycling in a native grassland exposed to elevated CO2 and warming: A role for priming?
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: Terrestrial ecosystem carbon cycling has the potential to mitigate or exacerbate climate change, depending on relative responses to rising temperatures and atmospheric CO2 concentrations, and possible indirect effects mediated through soil moisture and nutrient availability. The Prairie Heating and CO2 Enrichment (PHACE) experiment is being conducted in a native semiarid grassland near Cheyenne, Wyoming, to examine the independent and combined effects of elevated atmospheric CO2 (380 vs. 600 ppm during the growing season) and warming (+1.5/3C day/night above ambient) on ecosystem processes. Net primary production (NPP) is a commonly measured component of the C cycle but it does not reflect the full C balance. Measurement of net ecosystem exchange (NEE) of CO2 using a canopy gas exchange chamber system allows estimates of net C storage as well its underlying processes of gross primary production (Pe) and ecosystem respiration (Re). We measured NPP, NEE, Pe, Re, microbial respiration (Rh), litter decomposition, and soil C stocks over four years to assess potential for C cycle feedbacks at PHACE. We hypothesized that C cycling would be stimulated by elevated CO2, diminished by warming, and that C losses would be greatest in the combined elevated CO2 and warming treatment, owing to moisture-related effects.

Aboveground biomass production and Pe were stimulated by elevated CO2 in years of average or below-average precipitation. Belowground biomass was stimulated by elevated CO2 after a 2-year lag, and Re was stimulated by the combined elevated CO2 and warming treatment during the first four years at PHACE. Despite stimulation of NPP in most years, net C uptake measured with the canopy gas exchange chamber was reduced in elevated CO2 treatments, especially when combined with warming. The net C losses with elevated CO2 were consistent with stimulated Rh on root-exclusion plots. Soil C pools in the top 15-cm increased with warming but were not altered significantly by elevated CO2. Numerous lines of evidence therefore point to a potential role for priming enhanced decomposition of soil organic matter in the elevated CO2 treatment: increased input via NPP is offset by increased Rh under elevated CO2, leading to a lack of soil C storage. In this semiarid grassland, soil C accumulated with warming, probably due to soil drying, but soil C storage was compromised by elevated CO2 due to stimulated heterotrophic respiration. Ecosystem biogeochemistry models should incorporate these effects to improve forecasts of climate-carbon cycle feedbacks.

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NAME: William Pockman
INSTITUTION: University of New Mexico
COLLABORATORS: Nate McDowell, Los Alamos National Laboratory
ABSTRACT TITLE: Physiological mechanisms determining survival and mortality during drought in pinon-juniper woodlands in New Mexico, USA.
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: In pinon-juniper woodlands of the southwestern US, severe drought in 2000 - 2003 led to extensive pinon mortality (> 90% at some sites) but low juniper mortality (< 25%). The mechanisms proposed to explain such differential mortality include 1) hydraulic failure â€“ the complete loss of water transport due to xylem cavitation, 2) carbon starvation - energetic limitations associated with water stress and prolonged stomatal closure to avoid hydraulic failure, and 3) interactions among these two mechanisms and plant pathogens. To test these mechanisms, we manipulated ambient rainfall on twelve 40 x 40 m plots in a pinon-juniper woodland at the Sevilleta LTER to impose water availability similar to long-term extremes of precipitation. Each block included four treatments: ambient control, drought diverting 45% of rainfall using clear plastic troughs, cover-control to assess effects of plastic troughs without diverting precipitation, and irrigation applied as 4-6 19 mm applications to increase growing season water availability. We measured soil moisture, air and soil temperature, and sap flow of target trees, with periodic measurements that included plant water potential, branch growth, canopy leaf area, leaf level gas exchange and above- and below-ground non-structural carbohydrates (NSC).

In August 2008, after one year of treatment, extensive pinon mortality occurred in the two hillslope drought plots with shallow soils. Starting in 2010, after three years of treatment, juniper in these plots exhibited progressive dieback and eventually mortality in 3 trees by early 2012. A hydraulic model parameterized with site data, indicated that while neither pinon nor juniper exhibited hydraulic failure, hydraulic limitations in both species were greater in the drought plots, with pinon experiencing the greatest reduction of conductivity. All of the pinon that died in 2008 exhibited high levels of bark beetle activity and infection by xylem-occluding Ophiostoma fungi, potentially exacerbating the hydraulic limitation of drought by occluding the xylem. Growing season accumulation of foliar NSC was reduced in individuals of both species that died compared to ambient control trees. Although clear treatment differences were evident in the third, relatively flat, block with deeper soils, neither pinon nor juniper have exhibited drought related mortality through early 2012. Thus, evidence is consistent, but not conclusive, with an interdependent process of hydraulic failure and carbon starvation leading to mortality. A comparison of experimental data with six process models, including CLM, suggested that models hold promise for simulating drought stress and mortality despite a wide range of process representation.

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NAME: Sasha Reed
INSTITUTION: U.S. Geological Survey
COLLABORATORS: Timothy Wertin, U.S. Geological Survey; Kirsten Coe, Cornell University; Jayne Belnap, U.S. Geological Survey
ABSTRACT TITLE: Climate change effects in drylands
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: Arid and semi-arid ecosystems cover ~40% of the earth's terrestrial surface and comprise ~35% of the United States, yet we know surprisingly little about how climate change will affect these widespread landscapes. Like many dryland regions, the Colorado Plateau in southwestern U.S. is predicted to experience climate change as elevated temperatures and alterations to the timing and amount of annual precipitation. We are using a factorial warming and supplemental rainfall experiment on the Colorado Plateau to explore how expected changes in climate will affect plant and soil crust community composition and biogeochemical cycles. While some of the ecosystem responses we have observed to date were expected, many of the results have been surprising. For example, an increase in the frequency of small summer rainfall events (with a very small increase in total precipitation) reduced moss cover from ~25% of total surface cover to <2% after only one growing season, while increased temperature had no effect. This striking mortality of a dominant organism suggests that dryland responses to climate change can be much more rapid than expected, and that a seemingly subtle climatic change can induce effects similar (or larger) than those from physical disturbance (e.g., grazing, off-road vehicle use). Furthermore, the observed mortality was the result of water additions, highlighting our inadequate understanding of the relationship between climate and function in drylands. A complementary laboratory study identified a biogeochemical mechanism behind the mortality: these small precipitation events caused a negative moss carbon balance, while larger events maintained net moss carbon uptake. In addition, when looking at carbon flux in native grasses, we found that elevated temperatures significantly reduced net photosynthesis during the beginning of the growing season, when plants were most active. Lowered net photosynthesis correlated with lowered relative growth rates, reproductive output, and soil respiration rates, suggesting a strong biogeochemical link between carbon cycling and biological response in a warmer world. In addition, future changes in surface albedo are expected as the cover of individual ecosystem components change with changing climate. This poster will highlight these results as well as others, and together will suggest that changes to climate could dramatically affect the structure and function of dryland ecosystems – with the carbon cycle both driving and responding to change and with significant implications for future climate.

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NAME: Peter Reich
INSTITUTION: University of Minnesota
COLLABORATORS: Rebecca Montgomery, University of Minnesota; Sarah Hobbie, University of Minnesota; Roy & Artur Rich & Stefanski, University of Minnesota
ABSTRACT TITLE: Boreal Forest Warming at an Ecotone in Danger (B4WARMED): Early Results and Future Directions
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: In 2009, we began to address the potential for climate warming to alter tree species composition at the boreal-temperate forest ecotone through effects on two life history stages – germinant establishment and juvenile growth and survival. Specifically, our study addressed the hypothesis that warming would enhance the growth and survival of seedlings of temperate species at the cold edge of their range but reduce growth and survival of seedlings of boreal species at the warm edge of their range. To test this hypothesis, we established an experiment at two sites in northern Minnesota just inside the southern limit of boreal forest: Cloquet, a more southern site, and Ely, a site 150 km further north. At each site, we established 48 3-m diameter plots in open and closed canopy conditions, with three levels of plant (via infrared lamps) and soil (via buried cables) warming (ambient, +1.8 °C, and +3.6 °C), and an additional ambient treatment without buried soil heating cables. Across all plots we planted 11,616 seedlings and ≈200,000 seeds of 11 temperate and boreal tree species. We completed three years of experimental warming with comprehensive measurements of plant performance such as phenology, photosynthesis, respiration, growth, and survival and of soil processes such as CO_2 flux and net nitrogen mineralization. Major findings to date include (i) evidence (from establishment via seed, growth of planted seedlings, and leaf net CO_2 exchange) that warming adversely impacts several boreal species while having positive impacts on several temperate species, (ii) all species show acclimation of phenology and the temperature response of photosynthesis and respiration, and (iii) physiological responses to warming are influenced by the magnitude of soil water deficit caused by variation in ambient rainfall. In 2012 we are beginning a second phase of the study that focuses on understanding the sensitivity of warming effects to soil moisture variability by implementing a treatment that reduces ambient rainfall in a subset of plots. Our objectives are (i) to study how soil moisture modulates the patterns and mechanisms of warming effects on diverse physiological, organismal, and ecosystem processes by incorporating three years of rainfall manipulation into the ongoing manipulation of plant and soil temperature, while (ii) elucidating the long-term (six-year) response of these same processes to continued warming. This second stage maintains the original goals while focusing on new knowledge that can help to advance synthetic understanding and quantitative modeling of carbon fluxes under a changing climate.

NAME: Daniel Ricciuto
INSTITUTION: Oak Ridge National Laboratory
COLLABORATORS: Peter Thornton, Oak Ridge National Laboratory; Paul Hanson, Oak Ridge National Laboratory; Gautam Bisht, Oak Ridge National Laboratory

ABSTRACT TITLE: Advances in the Community Land Model in simulating ecosystem observations and experiments
PROGRAM AREA: Modeling

ABSTRACT: A key challenge in terrestrial carbon cycle model development is how to convey information from local to global scales using a consistent modeling framework. The most comprehensive information about terrestrial processes exists at the scales of flux tower and manipulative experiment footprints. To take advantage of these extensive datasets, the Community Land Model (CLM4CN), which is typically used for global simulations, has been streamlined to run point (single-gridcell) simulations efficiently. This updated model, known as PTCLM, has been run for 15 flux tower sites as part of the North American Carbon Program (NACP) site interim synthesis. By comparing model output to eddy flux observations, several model shortcomings were identified and the model structure was improved with regards to nitrogen cycling and the temperature responses of photosynthesis and respiration. New versions of PTCLM, parameterized using site-level data, are currently being developed for DOE-funded experimental sites including the Throughfall Displacement Experiment (TDE), Free-Air Carbon Enrichment (FACE) sites, the Enriched Background Isotope Study (EBIS), Spruce and Peatland Responses Under Climatic and Environmental Change (SPRUCE) and Partitioning in Trees and Soil (PiTS). For the experiments that are currently active, we are realizing a unique opportunity for feedback between the model and experiments that is influencing the design of the simulations and the observations. We are also developing a capability to perform large ensembles of simulations of PTCLM in a high performance computing (HPC) environment for the purpose of performing parameter sensitivity studies and data assimilation (parameter optimization). The complexity of PTCLM presents some challenges for parameter optimization, since many simulations must be performed. Data assimilation methodologies are also being tested with the Local Terrestrial Ecosystem Carbon (LoTEC) model, which runs more efficiently. Parameter optimizations have been performed at several NACP flux tower sites and for the TDE experiment site.

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NAME: Alistair Rogers
INSTITUTION: Brookhaven National Laboratory
COLLABORATORS:
ABSTRACT TITLE: Carbon and nitrogen dynamics in Pinus taeda grown at elevated carbon dioxide concentration with supplemental N supply
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: Carbon and nitrogen dynamics in Pinus taeda grown at elevated carbon dioxide concentration with supplemental N supply\r\nNAIK D, LASOTA SA, WOHL SR, NETTLES WR, LEE MJ, JOHNSEN KH, ROGERS A\r\nBrookhaven National Laboratory, Upton, NY 11973, USA(DN, SAL, SRW, WRN, MJL, AR). USDA-Forest Services, Research Triangle Park, NC 27709, USA (KHJ).

Increased understanding of the effects of elevated carbon dioxide concentration (e[CO2]) on the ability of forests to absorb and store atmospheric C requires improved knowledge of ecosystem C and N cycling. Our objective was to help address this challenge by advancing understanding of whole plant C and N dynamics. Specifically, the ability of Pinus taeda (loblolly pine) to utilize the additional photosynthate produced at e[CO2], and the extent to which C utilization may be limited by N supply. We measured elemental N content, the major transient C and N metabolite pools, and the activity of sixteen enzymes associated with C and N metabolism in canopy, shoot, stem and root tissue from loblolly pine sampled at dawn on six occasions during the final growth season at the Duke Forest FACE experiment, where loblolly pines were exposed to ambient +200 µL L-1 CO2 for 14 years and, in the final 6 years, an annual addition of ammonium nitrate in one half of each experimental plot (11.2 g N m-2 y-1). Levels of nonstructural carbohydrates in needles were low and there were no effects of e[CO2] or fertilization on carbohydrate content. There was no effect of e[CO2] on fine root carbohydrate content but fertilization reduced carbohydrate content, consistent with the assimilation of N into amino acids. There was no effect of e[CO2] on N content in needles or roots, but a significant and marked increase due to fertilization (needles 18%, fine roots 50%, coarse roots 74%). Analysis of free amino acid pools also revealed a significant and marked increase with fertilization (fine roots 75%, needles 85%), but no effect of e[CO2]. There was no effect of e[CO2] on needle or fine root protein content but fertilization resulted in a small but significant 10% increase. Enzyme activity data from needles in trees grown at e[CO2] showed a marked increase in the activity of enzymes associated with glycolysis and N metabolism. Fertilization also increased enzyme activity but the effect was greatest in trees grown at c[CO2]. These data show that after 14 years of CO2 enrichment there was no evidence for sink limitation of C utilization at e[CO2] and no evidence for a CO2 induced decrease in tissue N content or N metabolism. These preliminary data suggest that loblolly pine grown at e[CO2] have sufficient N to capitalize on the extra C provided at e[CO2], consistent with observations of nutrient cycling at this site.

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NAME: Kathleen Savage
INSTITUTION: The Woods Hole Research Center
COLLABORATORS: Scott Saleska, University of Arizona; Adrien Finzi, Boston University; Rick Wehr, University of Arizona
ABSTRACT TITLE: Partitioning CO2 fluxes with isotopologue measurements to understand mechanisms of belowground forest carbon cycling
PROGRAM AREA: Carbon Flux

ABSTRACT: Terrestrial ecosystems are an important and dynamic component of the Earth's climate system, and models are the primary basis for understanding the future interactions between terrestrial ecosystems and the climate. Although temperate forests in the northern mid-latitude of the United States are important net sinks for anthropogenic CO2 , the balance between sinks (GPP) and sources (respiration) may change under future climate change scenarios. Two key facts about temperate forests, that they sequester substantial carbon, but that their long-term trends in sequestration are poorly predicted by models, indicates the importance of understanding these ecosystems.

Model simulations of belowground processes are difficult to test, largely because of the intractable difficulties associated with making the necessary observations. Integrating traditional observations (plot trenching and root rhizotron observations), new experimental methods (artificial roots that can trickle isotopically labeled model "exudate" into soil), and recent technology (highly sensitive laser absorption spectrometers) that brings new capability for real time observations of the isotopologues of CO2, will bring new and more reliable insights into belowground processes. These will in turn enable new and more rigorous tests of model-simulated processes belowground, thereby providing new data and tools to the broader modeling community.

We will integrate newly developed instrumentation (Aerodyne Research Quantum Cascade Laser, QCL) for continuous insitu observations of the isotopologues of CO2, together with the trenching technique to partition components of belowground carbon flux (autotrophic and heterotrophic). During the summer of 2012 pre treatment soil respiration data will be collected using an automated, multiplexed system of 6 soil respiration chambers. A 5 x 5m plot was previously identified and will contain 3 of the automated chambers, each paired with 3 chambers in an adjacent control plot. In the fall of 2012, the trenching treatment will begin and we will trench the previously defined 5m x 5m plot to a depth of 50cm.

These measurements, in conjunction with measurements made by our colleagues, of the isotopic composition of NEE using the eddy covariance technique will provide a new method for partitioning NEE between GPP and ecosystem respiration, as well as partitioning of respiration between aboveground and belowground, and partitioning of belowground respiratory fluxes between components influenced by autotrophic and heterotrophic processes. This data will provide valuable insight into belowground processes.

NAME: Karina Schafer
INSTITUTION: Rutgers University
COLLABORATORS: Heidi Renninger, Rutgers University; Kenneth Clark, USDA Forest Service; Nicholas Skowronski, USDA Forest Service
ABSTRACT TITLE: EFFECTS OF A PRESCRIBED BURN ON THE WATER USE AND PHOTOSYNTHETIC CAPACITY OF PITCH PINES (PINUS RIGIDA L.) IN THE NEW JERSEY PINE BARRENS
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: Wildfires are an important ecological component of the New Jersey Pine Barrens (NJPB). However, increasing encroachment by human development has made it necessary to manage these systems. Early-spring prescribed burns are the main strategy to decrease wildfire risk; however little is known about how fires affect the physiology of the trees found there. Spring prescribed burns, while occurring during the natural wildfire window, likely differ from natural wildfire due to lower fire intensity, and longer duration of heat flux, given the backing nature of these fires. Therefore, we estimated sapflow and photosynthetic parameters before and after a late-March prescribed fire in burned and unburned pitch pine trees (Pinus rigida L.) to determine how water use and photosynthetic capacity change after a prescribed fire in the NJPB. Water use was similar in both sites before the fire but significantly lower in the burned trees immediately following the fire. After about a month, water use of the burned trees was significantly higher and these differences lasted into the summer. Maximum photosynthetic assimilation at saturating CO_2 and carboxylation efficiency also increased significantly between pre- and post-fire measurements in the burned trees suggesting increased photosynthetic capacity resulting from the fire. These data suggest that more water was available to trees after a prescribed fire presumably due to decreased shrub cover. Photosynthetic capacity also increased, possibly due to increased nitrogen availability. Increased access to water and greater water-use efficiency are both important for tree growth, specifically in the NJPB, a very water- and nutrient-limited system

NAME: Andres Schmidt
INSTITUTION: Oregon State Universirty
COLLABORATORS: Chad Hanson, Oregon State Universirty; Stephen Chan, Oregon State Universirty; Beverly Law, Oregon State Universirty
ABSTRACT TITLE: Assessment of uncertainties in the AmeriFlux network
PROGRAM AREA: Carbon Flux

ABSTRACT: One of the primary goals of the AmeriFlux QA/QC laboratory is to reduce site uncertainties at the measurement and data processing levels. To this end, we maintain two portable eddy covariance systems (PECS) as transfer standards that travel to a subset of AmeriFlux sites every year. Terrestrial ecosystem-atmosphere exchange of carbon, water and energy have been measured for over a decade at many sites globally. To minimize measurement and analysis errors, quality assurance data have been collected over short periods along-side tower instruments at AmeriFlux research sites. Theoretical and empirical error and uncertainty values have been reported for many components of the eddy covariance technique but until recently it has not been possible to constrain network level variation based a direct comparison of site-by-site measurements. Paired observations, although rare in practice, offer one means to obtain real world error estimates for flux observations and corresponding uncertainties, respectively. In this study, we report the relative errors from the AmeriFlux QA/QC site intercomparisons for the 81 most recent site visits (2002 – 2011). Relative errors, including random and systematic errors, are presented for meteorological and radiation variables, gas concentrations, and the turbulent fluxes. The lowest relative errors (< 2%) were found for the meteorological parameters while the largest relative errors were found for latent heat and CO_2 fluxes. The mean RE for CO_2 flux was close to theoretical predictions with an average of -6.8% (underestimation by the tower instruments). Sensible and latent heat fluxes exhibited mean RE of -1.3% and -4.9%, respectively. Deviation around the mean was also largest for the turbulent fluxes, approaching 20%. Because the data collected during QA/QC site visits are used to identify and correct errors, our results represent a conservative estimate of uncertainties. Overall, the presented results confirm the high quality of the network data and underline its status as a valuable data source for the research community.

NAME: Edward Schuur
INSTITUTION: University of Florida
COLLABORATORS:
ABSTRACT TITLE: Effects of experimental warming of permafrost on ecosystem carbon balance in Alaskan tundra
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: Approximately 1700 billion tons of soil carbon are stored in the northern circumpolar permafrost zone, more than twice as much carbon than currently contained in the atmosphere. Permafrost thaw, and the microbial decomposition of previously frozen organic carbon, is considered one of the most likely positive feedbacks from terrestrial ecosystems to the atmosphere in a warmer world. Yet, the rate and form of release is highly uncertain but crucial for predicting the strength and timing of this carbon cycle feedback this century and beyond. Here we report results from an ecosystem warming manipulation —the Carbon in Permafrost Experimental Heating Research (CiPEHR) project—where we increased air and soil temperature, and degraded the surface permafrost. We used snow fences coupled with spring snow removal to increase deep soil temperatures and thaw depth (winter warming) and open top chambers to increase growing season air temperatures (summer warming). Winter warming increased depth-integrated soil temperature by 1.5o C, which resulted in a 10% increase in thaw depth that persisted into the following winter. Surprisingly, the 2 kg C m-2 contained in the additional thawed soil in the winter warming plots in the Year 1 of the experiment did not result in significant changes in cumulative growing season respiration, which may have been inhibited by soil saturation at the base of the active layer. However, the limited effect of deep soil warming during the growing season contrasted with the large increase in winter respiration, which in sum doubled the net loss of carbon dioxide to the atmosphere on an annual basis. While most changes to the abiotic environment at CiPEHR were driven by winter warming, summer warming (mainly air) effects on plant and soil processes resulted in 20 percent increases in both gross primary productivity. These patterns appeared to strengthen as the warming manipulation continued. By Year 3, gross primary productivity in the summer and the winter warming treatments increased by 50% and 100% respectively relative to control. Increased uptake offset respiration increases such that warming appeared to have little overall net change in ecosystem carbon balance demonstrating the potential for plant uptake to offset, at least in part, increases in ecosystem respiration in response to climate change. This initial response to warming quantifies the vulnerability of organic C stored in near surface permafrost to temperature change, and corresponds to the initial stages of permafrost degradation observed from a thaw gradient at the same location.

NAME: Melinda Smith
INSTITUTION: Yale University/Colorado State University
COLLABORATORS: David Hoover, Colorado State University; Alan Knapp, Colorado State University
ABSTRACT TITLE: Ecosystem responses to severe drought and heat waves: Distinguishing between climate extremes vs. extreme climatic events
PROGRAM AREA: Ecosystem Manipulation

ABSTRACT: Climate extremes, such as heat waves and drought, are expected to increase in their frequency and intensity with forecast climate change. The goals of our research were to determine when and if climate extremes result in extreme climatic events (ECE) – defined as a statistically rare climate extreme(s) resulting in a statistically rare or unusual ecosystem response(s) - and to explore the mechanisms underlying ecosystem responses to the climate extremes. We examined the responses of the tallgrass prairie ecosystem to simulated heat waves under well-watered (ambient) and severe drought conditions over a two-year period. The severe drought treatment (33% of ambient rainfall) was imposed using passive rainout shelters deployed during the growing season in 2010 and 2011. The severe drought treatment resulted in a 50% reduction in soil moisture when compared to the ambient rainfall treatment. The heat wave treatments were imposed for two weeks in mid-July at four levels (+0, +4, +7 and +11 degrees C above ambient). The effects of the simulated climate extremes on aboveground net primary productivity (ANPP) were assessed. In 2010, ANPP was not significantly reduced; however, in 2011, the severe drought treatment resulted in a 60% reduction in total ANPP. Although the heat wave treatments exceeded Kansas state records, the heat-waves did not significantly impact ANPP. In both years, growing season rainfall was well below the 5th percentile of rainfall for that period based on a 25 year record, but this climate extreme only resulted in a extreme reduction in ANPP in 2011. Thus, we found that similar climate extremes do not necessarily result in an ECE, but that how the climate extreme differentially impacts responses of key species in the ecosystem plays an important role in determining the severity of the ecosystem response to climate extremes.

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NAME: Jianwu Tang
INSTITUTION: Ecosystems Center, Marine Biological Laboratory
COLLABORATORS: Timothy Savas, Ecosystems Center, Marine Biological Laboratory
ABSTRACT TITLE: How do stem respiration, root respiration, and heterotrophic respiration influenced by photosynthesis?
PROGRAM AREA: Carbon Flux

ABSTRACT: Stem respiration from forest ecosystems is an important component of total ecosystem respiration and the forest carbon cycle. Our knowledge in understanding the variation in stem respiration and its governing drivers is limited, partially because empirical measurement of stem respiration is scarce.

The diel pattern of stem respiration and its linkage with root respiration, heterotrophic respiration, and tree photosynthesis are not widely known. We hypothesize that recent photosynthate simulates stem respiration and root respiration with different time lags due to the slow transport speed of photosynthate from tree leaves to the stem and to roots.

Our study site is at the Harvard Forest, a temperate forest. We developed a novel system to automatically measure stem respiration at an hourly frequency. We also developed an automated chamber system to measure soil respiration. We used the trenching approach to partition soil respiration into root (rhizosphere) respiration and heterotrophic respiration. We explored the difference in the diel pattern between stem respiration, root respiration and heterotrophic respiration.

Our preliminary results indicate that the diel pattern of stem respiration and soil respiration is primarily driven by the temperature variation. But the peak stem respiration and root respiration during the course of a day is influenced by tree photosynthesis with a different time lag between stem and root respiration.

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NAME: Peter Thornton
INSTITUTION: Oak Ridge National Laboratory
COLLABORATORS: Jiafu Mao, Oak Ridge National Laboratory; Xiaoying Shi, Oak Ridge National Laboratory; Daniel Hayes, Oak Ridge National Laboratory
ABSTRACT TITLE: Global land modeling advances from the ORNL TES SFA
PROGRAM AREA: National Laboratory Research (SFA)

ABSTRACT: A principal aim for the ORNL Terrestrial Ecosystem Science SFA is to improve predictive skill in the Community Land Model (CLM) through integration of model development and application with experimental and observational results. Here we present the results from several related investigations, demonstrating the integration approach, highlighting new knowledge gained, and describing implications for future global model investigations. Global-scale single forcing factor simulations have been performed to investigate the influence of changes in climate, rising atmospheric CO2 concentrations, changing anthropogenic nitrogen deposition, and land use/land cover change (LULCC) on model predictions for the historical period (1850-2009). LULCC is the strongest single factor forcing changes in terrestrial ecosystems over the historical period, rising CO2 concentration is the second most important, and nitrogen deposition and climate change are third and fourth. Interaction effects among the single factors are dominated by LULCC x CO2, with CO2 x N deposition and LULCC x N deposition second and third. Significant spatial patterns are apparent in the single factor and interaction terms. Interaction terms tend to increase in importance over time. These single factor results were used to assess the contributions of multiple forcings to trends in outflow from the world's largest rivers, pointing out regional differences in the factors driving large-scale integrated model behavior. Global model results for the recent historical period were evaluated against several global remotely sensed datasets, including leaf area index, gross primary production (GPP), and an innovative investigation of model-predicted normalized difference vegetation index (NDVI). GPP is consistently high compared to remote sensing observations in the tropics, and we are exploring the hypothesis that this overprediction is related to the treatment of nutrient dynamics. The default model includes nitrogen limitation, but excludes phosphorus limitation. We have developed global phosphorus datasets which are a necessary precursor to a global phosphorus limitation model. Using the current version of the CLM, we have run simulations within the Community Earth System Model (CESM1) to predict historical and potential future behavior of the climate system and climate-biogeochemistry feedbacks. We demonstrate that terrestrial ecosystem dynamics, including CO2 and nutrient fertilization and LULCC effects, play an important role in predicting future climate system behavior. We are contributing multiple global, single-factor CLM runs to multi-model intercomparisons, using common driver data and formal simulation protocol.

NAME: Peter Thornton
INSTITUTION: Oak Ridge National Laboratory
COLLABORATORS: William J. Riley, Lawrence Berkeley National Laboratory; Charles D. Koven, Lawrence Berkeley National Laboratory; Forrest M. Hoffman, Oak Ridge National Laboratory; Richard T. Mills, Oak Ridge National Laboratory; Scott L. Painter, Los Alamos National Laboratory; A.D. McGuire, University of Alaska Fairbanks; David E. Graham, Oak Ridge National Laboratory; Larry D. Hinzman, University of Alaska Fairbanks; Susan S. Hubbard, Lawrence Berkeley National Laboratory; Liyuan Liang, Oak Ridge National Laboratory; Richard J. Norby, Oak Ridge National Laboratory; Alistair Rogers, Brookhaven National Laboratory; Joel C. Rowland, Los Alamos National Laboratory; Margaret S. Torn, Lawrence Berkeley National Laboratory; Cathy J. Wilson, Los Alamos National Laboratory; Stan D. Wullschleger, Oak Ridge National Laboratory
ABSTRACT TITLE: Developing a Hierarchical Scaling Framework for Modeling a Dynamic Arctic Landscape in a Changing Climate
PROGRAM AREA: Modeling

ABSTRACT: An important challenge for Earth System models is to properly represent the land surface. This can be problematic, yet failure to identify and appropriately account for complexities at the landscape scale can compromise climate predictions. The Next-Generation Ecosystem Experiments (NGEE Arctic) project will address this challenge for sensitive and rapidly changing ecosystems of the Arctic tundra through a combination of direct observation and process-resolving simulation in this vast and remote landscape. A distinguishing characteristic of the Arctic tundra, especially the coastal plains of the North Slope is the existence of recognizable and quantifiable landscape units which are repeated over large domains, and which occur at multiple spatial scales. Previous landscape-scale classification efforts using remote-imagery have identified active thaw lakes and drained thaw lake basins, and ice-rich polygonal ground as three common landscape units that occur over large parts of the Arctic tundra. We will use this information to deliver improved climate predictions for the Pan-Arctic region. Our scaling approach will build on the hypothesis that the transfer of information across spatial scales can be organized around these discrete geomorphological units for which processes are represented explicitly at finer scales, with information passed to coarser scales through sub-grid parameterization of Earth System models. By extending an already well-established framework for fractional sub-grid area representations to allow dynamic sub-grid areas and hydrological and geophysical connections among sub-grid units, we expect to be able to characterize permafrost dynamics and the influence of thermokarst at multiple spatial scales in Arctic tundra landscapes. Our fundamental scaling approach will be to identify processes likely to have the largest influence on climate, based on current knowledge of the Arctic tundra system, and then to define a connected (nested) hierarchy of modeling necessary to resolve those processes. This approach allows us to begin immediately to integrate new process knowledge into a climate prediction-scale land model, while establishing a quantitative framework connecting this scale to more process-rich models implemented at finer spatial resolution and over smaller spatial domains. The consequence for NGEE Arctic is that model application efforts can begin immediately and in parallel across multiple modeling scales.

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NAME: Margaret Torn
INSTITUTION: Berkeley Lab
COLLABORATORS: Michael Schmidt, University of Zurich; LBNL TES SFA Team
ABSTRACT TITLE: Persistence of soil organic matter as an ecosystem property
PROGRAM AREA: Biogeochemistry

ABSTRACT: Globally, soil organic matter (SOM) contains more than three times as much carbon as either the atmosphere or terrestrial vegetation. Yet it remains largely unknown why some SOM persists for millennia whereas other SOM decomposes readily—and this limits our ability to predict how soils will respond to climate change. Recent analytical and experimental advances have demonstrated that molecular structure alone does not control SOM stability: in fact,environmental and biological controls predominate.

Here we show examples of the Terrestrial Ecosystem Science-supported research that has led to these new understandings. Specifically, using isotopic analysis (14C), in-situ imaging, and other advanced techniques, we have shown that rather than molecular structure, stability in soil is governed by multiple processes such as organo-mineral interactions and physical heterogeneity of soil. Plant roots and rhizosphere inputs make a large contribution to SOM, and this SOM is mainly partial degradation and microbial products and fire residues rather than humic substances. The vulnerability of deep soil carbon to microbial degradation in a changing environment, such as thawing permafrost remains a key uncertainty.

This new view of soil carbon cycling provides a road map for improving ecosystem models. There are some relatively low-hanging fruit for model development. For example, the chemistry of roots should be parameterized directly rather than using litter as a proxy and an input term is needed for fire-derived carbon. The linear decomposition cascade in some models can be replaced with cycling of organic matter into and out of microbial biomass. Longer term improvements will involve replacing texture with mineralogy; including a measure of physical structure and disruption; and explicit representations of the processes controlling the depth profile of organic matter. We will discuss ways to include this view of soil organic matter cycling in a new generation of experiments and soil carbon models, with the goal of improving predictions of the SOM response to global warming.

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NAME: Margaret Torn
INSTITUTION: Berkeley Lab
COLLABORATORS: Karis McFarlane, Lawrence Livermore National Laboratory; Rachel Porras, Berkeley Lab; Paul Hanson, Oak Ridge National Laboratory
ABSTRACT TITLE: EBIS-AmeriFlux: Decomposition and Stabilization of Leaf and Root Inputs to Soils using Physical Fractionation and Radiocarbon Measurements
PROGRAM AREA: Biogeochemistry

ABSTRACT: We investigated the influence of climate and soil mineralogy as well as leaf versus root inputs on soil organic matter (SOM) turnover in four temperate deciduous forests. As part of the EBIS-AmeriFlux experiment, 14C-labelled leaf and root litter were added to the O horizon and mineral soil, respectively. We used physical fractionation to separate free, occluded, and mineral-associated (dense fraction) SOM, at 0-5 and 5-15 cm depths. The radiocarbon content of these fractions was used to estimate the turnover times of native SOM and to investigate the stabilization of the added litters.

Differences in climate among sites only partly explained differences in native SOM turnover. Turnover times were fastest at the warmest site (Missouri) and slowest at the northeastern sites (Harvard Forest, MA and Bartlett Experimental Forest NH), rather than the coldest site (Michigan Biological Station). Overall, turnover times across sites and depths were 75–260 yr for free-light fractions, 70–625 yr for occluded-light fractions, and 90–480 yr for dense fractions.

To investigate the influence of organo-mineral associations on SOM stabilization, we correlated reactive iron and aluminum content with 14C-based turnover times. Considering all sites, plots, and depths, there was a significant increase in turnover time with oxalate extractable Al and Fe oxides (P=0.02). Within individual sites, only Harvard Forest showed a significant influence of metal oxides on turnover time, likely because Harvard Forest has a larger range in extractable Al and Fe than the other sites. In addition, turnover time at Harvard Forest was strongly influenced by poorly crystalline Fe concentrations (R2=0.82, P=0.0003). At this site, iron mineralogy is quantitatively important in stabilizing organic inputs. The Fe-OM complexes also explained variation in carbon storage (but not turnover time) at Bartlett (R2=0.90, P<0.0001).

Root carbon moved into soil fractions faster at the warmest site than the coldest, as expected. After one year, the root-derived 14C label was detected in all three soil-density fractions from Missouri, although only the two light fractions had statistically significant changes in Δ14C relative to control soils (P=0.044 and P= 0.036). Root-derived 14C was not statistically elevated in Bartlett fractions. Likewise, the labelled litter has not been incorporated into the mineral soil at Bartlett after 3 years but in Missouri has been incorporated into all three soil fractions. The rapid incorporation of litter C into mineral-associated SOM—also seen in EBIS-ORNL—is being simulated with a reactive-transport model to inform representations in land models.

NAME: Nicole Trahan
INSTITUTION: University of Colorado at Boulder
COLLABORATORS: David Moore, University of Arizona; Russell Monson, University of Arizona; David Bowling, University of Utah
ABSTRACT TITLE: Changes in forest carbon balance following mountain pine beetle disturbance
PROGRAM AREA: Natural Disturbance

ABSTRACT: Large scale tree mortality changes the balance between gross primary productivity (GPP) and total ecosystem respiration (TER). Mountain pine beetles (Dendroctonus ponderosae) have infested more than 86 million hectares of forest in the U.S.A. since 2000, leading to extensive tree mortality which is predicted to have important carbon, water and energy balance feedbacks on forest systems. Current projections, based on models linked to changes in live tree stocks, suggest a sharp and prolonged transition of forest ecosystems from carbon sinks to significant carbon sources. We compared 9-year records of GPP and TER fluxes, and parallel disturbance chronosequences in two high elevation lodgepole pine forests in Colorado U.S.A., one impacted by the beetle (Fraser Experimental Forest) and a forest free of the outbreak (Niwot Ridge). We show that on a decadal scale the impact of this tree mortality on the carbon cycle is significantly less pronounced than these predictions because of a sustained suppression of respiration after mortality. We detect no increase in respiration after mortality from scales of several square meters up to an 84 km2 valley; rather we find a decline in both GPP and respiration suggesting a dampening of the carbon cycle. The sharp decline in respiration with GPP reflects the loss of autotrophic respiration and rhizodeposition occurring with tree mortality. We find a partial and transitory recovery of respiration 5-6 years after mortality, de-coupling respiration from concurrent GPP and associated with increased incorporation of C into soil organic matter. At the same time, trees that survive beetle outbreak undergo competitive release, allocating more carbon to growth in response to enhanced resource availability. In contrast to other disturbances like fire or logging, the impact of tree mortality caused by these biotic disturbances in Western North America is likely to have a subtle, long lasting impact on the carbon cycle which will require consideration of the mechanistic linkages between GPP and respiration.

NAME: Dean Vickers
INSTITUTION: Oregon State University
COLLABORATORS: Christoph Thomas, Oregon State University; Jonathan Martin, Oregon State University; Beverly Law, Oregon State University

ABSTRACT TITLE: Five years of carbon fluxes and inherent water-use efficiency at two semi-arid pine forests with different disturbance histories
PROGRAM AREA: Carbon Flux

ABSTRACT: Five years of eddy-covariance and other measurements at a mature ponderosa pine forest and a nearby young plantation are used to contrast the carbon fluxes for long-term averages, seasonal patterns, diel patterns and interannual variability, and to examine the differing responses to water-stress. The mature forest with larger leaf area and wetter and cooler soils has a net uptake of carbon 3.3 times that of the young plantation. In the spring, photosynthesis is larger at the mature site as expected based on the difference in leaf area, however, another important factor is the reduction in springtime respiration at the mature site due to lower soil temperatures because of more shade from the canopy. Patterns of photosynthesis, inherent water-use efficiency (IWUE) and tree transpiration indicate that the young plantation responds to the seasonal drought sooner and to a more severe degree. Lower sensitivity to seasonal drought at the mature site is likely due to higher soil moisture reserves year round and a deeper root system that can access more water. Outside the seasonal drought period, the IWUE is the same at both sites, suggesting a species-specific value. Larger interannual variability at the plantation is associated with water-year drought and aggrading.

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NAME: Jeff Warren
INSTITUTION: Oak Ridge National Laboratory
COLLABORATORS: Colleen Iversen, ORNL; Rich Norby, ORNL; Peter Thornton, ORNL
ABSTRACT TITLE: Partitioning in Trees and Soil (PiTS)
PROGRAM AREA: Carbon Flux

ABSTRACT: The PiTS research project was established to test carbon (C) partitioning routines in mechanistic ecosystem models by validating model representations of partitioning with data observations collected from targeted field experiments. Our objective has been to measure C flux within and through the plant-soil system following short-term experimental manipulations of gross primary production (GPP) and C availability, and to use results to test and potentially modify partitioning routines in ecosystem models.

The first of three manipulations was a stand of young loblolly pine trees, where we labeled the foliage with a pulse of 13C-enriched CO2 and then subjected trees to light (i.e., control) or heavy shade treatments. The progression of the 13C label was tracked from the atmosphere through foliage, phloem, roots, and soil CO2 efflux. Heavy shading reduced C uptake, sap flow, stem growth and fine root standing crop, and increased residual soil water content. Although there were reductions in new C flux belowground, heavy shading did not noticeably reduce the rate of soil CO2 efflux. A second manipulation took advantage of the residual depleted δC signature of soils in previously CO2-enriched plots at the historical ORNL free-air CO2 enrichment (FACE) experiment. We girdled sweetgum trees in half of each 25-m plot to block partitioning of new C belowground, which enables us to (1) quantify effect of root C input on soil C and nutrient cycling, and (2) quantify C storage pools used for root production. A third manipulation will involve shading of individual dogwood trees, and improves upon the loblolly shading study by physically isolating the belowground system and spatially isolating treatments. We will explore soil C storage and turnover, as well as root and mycorrhizal C dynamics following 13C-labeling combined with shading treatments.

Data from each study will be used to test C partitioning routines within a point version of the Community Land Model (CLM-CN). The model will be parameterized to each site based on measured or estimated values of biomass pools, foliar physiology, soil characteristics, and site environmental conditions. CLM-CN will be modified to allow reduction in C availability within the tree due to the shading or girdling treatments, and by inclusion of a 13C partitioning module that will make use of our labeling results. Resultant changes in soil moisture, sap flow, C uptake, storage, and release will be validated against our measured data, and provide feedback for assessment of structural performance of the model.

NAME: Richard Wehr
INSTITUTION: University of Arizona
COLLABORATORS: Scott Saleska, University of Arizona; J. William Munger, Harvard University; Mark Zahniser, Aerodyne Research Inc.; Eric A. Davidson, Woods Hole Research Center; John Drake, Boston University; Adrien C. Finzi, Boston University; Paul R. Moorcroft, Harvard University; J. Barry McManus, Aerodyne Research Inc.; David D. Nelson, Aerodyne Research Inc.; Kathleen Savage, Woods Hole Research Center
ABSTRACT TITLE: Partitioning CO2 fluxes with isotopologue measurements and modeling to understand mechanisms of forest carbon sequestration
PROGRAM AREA: Carbon Flux

ABSTRACT: Ecosystem models differ widely in their predictions of how forest carbon dynamics will interact with a changing climate, one of the largest sources of uncertainty in predictions of future climate. We are investigating the mechanisms controlling carbon sequestration at the Harvard Forest by combining newly developed instrumentation for automated, in situ CO2 isotopologue measurements (including isotopologue eddy flux measurements) with novel experimental manipulations of belowground processes, as well as with traditional methods like soil chambers and plot trenching. The resulting data will be integrated in—and used to refine—the Ecosystem Demography 2 (ED2) model.

Here we focus on one key aspect of that work: partitioning the net ecosystem-atmosphere CO2 exchange (NEE) into its gross photosynthetic and respiratory components. Partitioning NEE is a longstanding problem in carbon cycle science. The most common approaches to this problem treat respiration as an empirical function of temperature (and sometimes moisture) according to nighttime data. Methods in this vein, though long-used, have been difficult to validate, and are challenged by mounting evidence of a soil respiratory response to photosynthesizing vegetation.

Isotopic flux partitioning (IFP) is an alternative method that uses the distinct influences of photosynthesis and respiration on the stable isotopic signature of the CO2 flux. Here we present the first ever IFP estimates of ecosystem photosynthesis and respiration based on direct eddy covariance measurements of the fluxes of 13CO2 and 12CO2. Our flux measurements (which also include 18O12C16O) span the 2011 growing season and constitute the first long-term continuous record of CO2 isotopologue flux in any ecosystem. These measurements were obtained using a quantum cascade laser spectrometer with a precision on par with the gold standard laboratory technique, isotope ratio mass spectrometry.\r\n\r\nThe 3379 40-minute flux measurements between May and October contain a wealth of information about ecosystem behavior. We find that on the average, ecosystem respiration shows at most minor diel variation, consistent with short-term, temperature-based extrapolation from night to day. We also observe a gradual decrease from June to September in the isotopic discrimination due to photosynthesis, while diel variation in that discrimination shows that stomata close as photosynthesis becomes increasingly light-limited in this ecosystem (as opposed to photosynthesis becoming increasingly diffusion-limited as stomata close due to water stress). The 18O12C16O fluxes evince evaporative isotopic enrichment of leaf water during the day and equilibration of the leaf and soil water isotopic compositions during the night.

NAME: Lucian Wielopolski
INSTITUTION: Brookhaven National Laboratory
COLLABORATORS:
ABSTRACT TITLE: A New Approach to Analyzing Carbon in Soil
PROGRAM AREA: Biogeochemistry

ABSTRACT: This presentation reviews the experiences gained from in situ field analyses of carbon in a variety of soils using a gamma-ray spectroscopy probe, and summarizes the unique characteristics of the system. The probe consists of a fast neutron generator (NG), producing 14 MeV neutrons that can be turned on/off, and of an array of NaI(Tl) detectors that measure the gamma-rays induced by the fast- and thermal-neutrons. Shielding materials separate the NG and the detectors, and the entire system is mounted on a 30 cm-high cart. The induced elemental gamma-rays follow the extremely fast nuclear reactions of inelastic neutron scattering (INS) and thermal neutron capture (TNC) and are independent of the chemical state of the element. Since these processes are rapid ones, the system can be used in either static- or continuous-scanning modes of operation. This novel system is referred to as the INS system.

The unique capabilities of the INS include the following: 1) In situ, non-destructive measurements, 2) multi-elemental analyses, 3) sampling of large volumes, ~0.5 m3 (~300 kg), 4) interrogation of sample 30- to 50-cm deep, and, 5) can be operated in static- and scanning-modes. These unique features enable new outlook and approaches to soil research and monitoring. Thus, the INS supports true (undisturbed) sequential studies. A single measurement no longer is a point measurement but it reflects an average value for the sampled volume, thus dramatically reducing the impact of the natural variability. Similarly, a single measurement over a large area provides a physically measured average value for the field, instead of mathematically averaged values derived from analyzing discrete cores, an approach that cannot be repeated because such a mode of sampling is destructive. Advantageously, these changes in scale fundamentally shift the sampling paradigm, along with a great reduction in cost and time for sequentially monitoring of large areas, while reducing error propagation. Modeling with INS system allows estimating the soil's carbon content to a depth of one m.

The INS system has been deployed in a variety of field types ranging from low-density organic soils in Ohio, to high-density abandoned open mine fields in Pennsylvania. In addition, the system functioned well in farmed agricultural fields in New Mexico, Alabama, Maryland, and Montana, and also in the dense forests of New Hampshire and North Carolina. INS measurements correlate closely with the standard analysis of core samples via dry combustion. The INS performance and results are detailed in this presentation.

NAME: Cathy Wilson
INSTITUTION: Los Alamos National Laboratory
COLLABORATORS: David E. Graham, Oak Ridge National Laboratory; Larry D. Hinzman, University of Alaska Fairbanks; Susan S. Hubbard, Lawrence Berkeley National Laboratory; Liyuan Liang, Oak Ridge National Laboratory; Richard J. Norby, Oak Ridge National Laboratory; William J. Riley, Lawrence Berkeley National Laboratory; Alistair Rogers, Brookhaven National Laboratory; Joel C. Rowland, Los Alamos National Laboratory; Peter E. Thornton, Oak Ridge National Laboratory; Margaret S. Torn, Lawrence Berkeley National Laboratory; Stan D. Wullschleger, Oak Ridge National Laboratory
ABSTRACT TITLE: Process Studies and Observations in the Arctic to Inform a Hierarchical Scaling Framework for Improved Climate Predictability
PROGRAM AREA: Modeling

ABSTRACT: A fundamental goal of the Next-Generation Ecosystem Experiments (NGEE Arctic) project is to improve climate prediction through process understanding and representation of that knowledge in Earth System models. Geomorphological units, including thaw lakes, drained thaw lake basins, and ice-rich polygonal ground provide the organizing framework for our model scaling approach for the coastal plains of the North Slope of Alaska. A comprehensive suite of process studies and observations of hydrology, geomorphology, biogeochemistry, vegetation patterns, and energy exchange and their couplings will be undertaken across nested scales to populate the hierarchical modeling framework and to achieve a broader goal of optimally informing process representations in a global-scale model. A central focus of this challenge is to advance process understanding and prediction of the hydrologic and thermal responses and feedbacks to thermokarst development in ice-rich ground and how climate driven changes will control the spatial and temporal availability of water for biogeochemical, ecological, and physical feedbacks to the climate system. Field activities to inform model development will be carried out across a gradient of polygonal ground nested within a drained thaw lake basin age gradient near Barrow, Alaska. Geophysical characterization of these sites will be essential as we describe critical surface-subsurface variability and interactions, as will assessments of fine-scale topography that controls local hydrology. We will investigate greenhouse gas (e.g., CO_2 and CH_4) fluxes from the decomposition of buried organic matter as a function of hydrologic variability in the landscape, with the assumption that physical and chemical factors are represented appropriately at each modeling scale. Process studies that have the greatest potential for reducing prediction uncertainty were prioritized, including studies focused on: improving the mechanistic understanding of permafrost degradation and its influence on water distribution; quantifying mechanisms and rates associated with organic carbon decomposition in Arctic soils; and developing response functions relating plant community composition and phenology to resource gradients created by high-centered and low-centered polygons and other thermokarst features. Additional studies will be used to parameterize a plant physiological model of carbon-nitrogen interactions, including measurements of active-layer nitrogen availability, litter feedbacks to soil carbon-nitrogen cycling, and plant use of available nitrogen. A metric of effectiveness for our scaling approach will be the degree to which prediction at each successive scale is improved as the result of iterative scaling.

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NAME: Stan Wullschleger
INSTITUTION: Oak Ridge National Laboratory
COLLABORATORS: David E. Graham, Oak Ridge National Laboratory; Larry D. Hinzman, University of Alaska Fairbanks; Susan S. Hubbard, Lawrence Berkeley National Laboratory; Liyuan Liang, Oak Ridge National Laboratory; Richard J. Norby, Oak Ridge National Laboratory; Alistair Rogers, Brookhaven National Laboratory; Joel C. Rowland, Los Alamos National Laboratory; Peter E. Thornton, Oak Ridge National Laboratory; Margaret S. Torn, Lawrence Berkeley National Laboratory; William J. Riley, Lawrence Berkeley National Laboratory; Cathy J. Wilson, Los Alamos National Laboratory
ABSTRACT TITLE: Improved Climate Prediction through Process-Rich Understanding of Arctic Terrestrial Ecosystems
PROGRAM AREA: Modeling

ABSTRACT: Characterized by vast amounts of carbon stored in permafrost and a rapidly evolving landscape, the Arctic has emerged as an important focal point for the study of climate change. These are sensitive systems, yet the mechanisms responsible for those sensitivities are not well understood and many remain uncertain in terms of their representation in Earth System models. Increasing our confidence in climate projections for high-latitude regions of the world will require a coordinated set of investigations that target improved process understanding and model representation of important ecosystem-climate feedbacks. The Next-Generation Ecosystem Experiments (NGEE Arctic) seeks to address this challenge by quantifying the physical, chemical, and biological behavior of terrestrial ecosystems in Alaska. Initial research will focus on the highly dynamic landscapes of the North Slope where thaw lakes, drained thaw lake basins, and ice-rich polygonal ground offer distinct land units for investigation and modeling. The project will focus on interactions that drive critical climate feedbacks within these environments through greenhouse gas fluxes and changes in surface energy balance associated with permafrost degradation, and the many processes that arise as a result of these landscape dynamics. The overarching goal of the NGEE Arctic project is to reduce uncertainty in climate prediction through improved representation of Arctic tundra processes. A focus on scaling based on process understanding and geomorphological units will allow us to deliver a process-rich ecosystem model, extending from bedrock to the top of the vegetative canopy, in which the evolution of Arctic ecosystems in a changing climate can be modeled at the scale of a high resolution Earth System Model grid cell (i.e., 30x30 km grid size). This vision includes mechanistic studies in the field and in the laboratory; modeling of critical and interrelated water, nitrogen, carbon, and energy dynamics; and characterization of important interactions from molecular to landscape scales that drive feedbacks to the climate system. A suite of climate-, intermediate- and fine-scale models will be used to guide observations and interpret data, while process studies will serve to initialize state variables in models, provide new algorithms and process parameterizations, and evaluate model performance. The NGEE Arctic project will also develop innovative communication and data management strategies as we work both within a multi-disciplinary team environment and with the larger scientific community to chart a course for an improved process-rich, high-resolution Arctic terrestrial simulation capability.