BGC Feedbacks Scientific Focus Area

Quantifying Feedbacks and Uncertainties of Biogeochemical Processes in Earth System Models

Laboratory Research Manager:
Forrest M. Hoffman (ORNL)

Senior Science Co-Lead:
William J. Riley (LBNL)

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Biogeochemistry–Climate Feedbacks SFA participation in the

AGU FALL MEETING
San Francisco | 14 – 18 December 2015

American Geophysical Union (AGU) Fall Meeting
Moscone Center, San Francisco, California, USA
December 14–18, 2015

The BGC Feedbacks Scientific Focus Area (SFA) is identifying and quantifying the feedbacks between biogeochemical cycles and the climate system, and quantifying and reducing the uncertainties in Earth System Models (ESMs) associated with those feedbacks. The BGC Feedbacks SFA is contributing to the integration of the experimental and modeling science communities, providing researchers with new tools to compare measurements and models, thereby enabling DOE to contribute more effectively to future climate assessments by the U.S. Global Change Research Program (USGCRP) and the Intergovernmental Panel on Climate Change (IPCC).

1 Schedule of Town Halls, Sessions, and Presentations

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15:25–15:40 B13H-08: The global turnover time distribution of soil carbon derived from a meta-analysis of radiocarbon profiles MW 2004
Yujie He (University of California Irvine) et al. 14

18:15–19:15 TH15C: DOE Scientific Successes as Part of the International Land Model Benchmarking (ILAMB) Project MW 2006
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Tuesday, December 15, 2015

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08:00–12:20 B21E-0513: Design and application of a community land benchmarking system for Earth system models MS Poster 0513
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08:00–12:20 B21E-0514: Tropical precipitation-carbon cycle links in CMIP5 Earth system models MS Poster 0514
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Robinson Négron Juárez (Lawrence Berkeley National Laboratory) et al. 17

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Shanlin Wang (Los Alamos National Laboratory) et al. 33

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Jon Weiner (University of California Berkeley) et al. 34

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Umakant Mishra (Argonne National Laboratory) et al. 35

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Rui Mei (Oak Ridge National Laboratory) et al. 36

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Yujie He (University of California Irvine) et al. 11

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Charles D. Koven (Lawrence Berkeley National Laboratory) et al. 37

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Benjamin Sulman (Princeton University) et al. 37

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Jitendra Kumar (Oak Ridge National Laboratory) et al. 11

13:40–18:00 IN43A-1721: Scalable algorithms for unsupervised classification and anomaly detection in large geospatiotemporal data sets MS Poster 1721
Richard T. Mills (Intel Corporation) et al. 39

Friday, December 18, 2015

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James T. Randerson (University of California Irvine) et al. 39

2 Town Halls

Monday, December 14, 2015

TH13F: The Energy–Water Nexus – Ongoing Science Activities and Future Opportunities with the Department of Energy

Energy and water systems are increasingly interconnected and face a number of complex challenges. The U.S. Department of Energy (DOE) and National Laboratories recognize that successfully addressing challenges and opportunities at the nexus requires strategic research investments and coordination among institutions, researchers, and practitioners on data, modeling, and analysis; technology development and deployment; and regional stakeholder engagement. This town hall provides an opportunity for scientists, stakeholders, and program representatives from DOE and other agencies to discuss existing research activities (including intersections with highly coupled systems such as land/agriculture and interdependent infrastructure) and to describe funding opportunities in FY 16 and beyond.

Monday, December 14, 2015 12:30–13:30
Moscone West 2008

Primary Contact:
Robert Vallario (U.S. Department of Energy)

Presenters:
Gary Geernaert (U.S. Department of Energy)
Diana Bauer (U.S. Department of Energy)
J. Arnold (U.S. Army Corps of Engineers)
Ian Kraucunas (Pacific Northwest National Laboratory)
Robin Newmark (National Renewal Energy Laboratory)
Vincent Tidwell (Sandia National Laboratories)

TH15C: DOE Scientific Successes as Part of the International Land Model Benchmarking (ILAMB) Project

The International Land Model Benchmarking (ILAMB) project is a model–data comparison and integration activity designed to assess and improve the performance of land surface models. The Biogeochemistry–Climate Feedbacks project, supported by the Regional and Global Climate Modeling (RGCM) Program within the U.S. Department of Energy, is developing model evaluation metrics and diagnostics, and is incorporating them into an open source software package for community use and improvement. This town hall will highlight new metrics, offer updates on ILAMB package development, and solicit input from the Earth system modeling and the in situ and remote sensing measurements communities.

Monday, December 14, 2015 06:15–07:15
Moscone West 2006

Primary Contact:
Gary Geernaert (U.S. Department of Energy)

Presenters:
Renu Joseph (U.S. Department of Energy)

Forrest M. Hoffman (Oak Ridge National Laboratory)
William J. Riley (Lawrence Berkeley National Laboratory)
James T. Randerson (University of California Irvine)
David M. Lawrence (National Center for Atmospheric Research)

Tuesday, December 15, 2015

TH23C: A Critical Gap in Data Management: Integration Workflows for Models and Data

There is increasing support for the development of open-source community-based tools and standards that address the rapid increase and diversity of scientific data, as well as the data management policies from funding agencies (e.g., DOE, NSF). However, this development often focuses only on observational data and model output, without considering workflows and algorithms to integrate models and data. Resolving this missing link is critical to improve our productivity and to meet validation requirements. In this Town Hall, we highlight recent interdisciplinary and cross-project efforts in environmental/ecosystem science to address this gap, and seek input from the community on possible approaches.

Tuesday, December 15, 2015 12:30–13:30
Moscone West 2008

Primary Contact:
John Moulton (Los Alamos National Laboratory)

Presenters:
Haruko Wainwright (Lawrence Berkeley National Laboratory)
Timothy Scheibe (Pacific Northwest National Laboratory)
David Lesmes (U.S. Department of Energy)

TH23F: Decadal USGCRP Science Assessment of the Carbon Cycle in the US and North America: The 2nd State of the Carbon Cycle Report (SOCCR-2)

The 2nd State of the Carbon Cycle Report (SOCCR-2) is currently under development as a Highly Influential Scientific Assessment of the U.S. Global Change Research Program (USGCRP). This will be a follow-up to the 1st SOCCR (2007), a Synthesis and Assessment Product (SAP 2.2) of USGCRP's 2nd National Climate Assessment (NCA). The focus of SOCCR-2 will be on US (national and biogeographical regions) and North American carbon stocks and fluxes, with analysis of interactions with fluxes and processes in the oceans and across the globe, and, in the context of interactions with global scale carbon budgets and global change impacts in managed and unmanaged systems. Relevant carbon management science perspectives and tools for supporting and informing decisions, as addressed in and related to the White House Climate Action Plan (2013), US Carbon Cycle Science Plan (2011), USGCRP Strategic Plan (2012) will be included. This town hall will provide an opportunity for the broader AGU scientific community to discuss the report as well as provide an opportunity for the community to engage/provide input on the SOCCR-2 vision, writing and production process.

Tuesday, December 15, 2015 12:30–13:30
Moscone West 2007

Primary Contact:
Gyami Shrestha (U.S. Carbon Cycle Science Program)

Presenters:
Nancy Cavallaro (U.S. Department of Agriculture)
Daniel Stover (U.S. Department of Energy)
Zhiliang Zhu (U.S. Geological Survey)

TH23I: DOE's Trait-Based Modeling Approach for Next Generation Ecosystem Experiments (NGEE)

Understanding and predicting how ecosystems change and interact with climate is challenging the climate modeling community to adequately represent vegetative functions. Current land models typically assume small numbers of plant "types" based upon similar characteristics/roles in ecosystem function. This functional type approach limits our ability to represent dynamic changes in response to climate or environment. A new framework is being developed by DOE's NGEE's with the Accelerated Climate Model for Energy (ACME) that represents plants using trait-based methods, which dynamically represent key vegetation characteristics. This town hall will highlight current developments in trait-based modeling approaches and discuss future research opportunities.

Tuesday, December 15, 2015 12:30–13:30
Moscone West 2003

Primary Contact:
Daniel Stover (U.S. Department of Energy)

Presenters:
Stan Wullschleger (Oak Ridge National Laboratory)
Lara Kueppers (Lawrence Berkeley National Laboratory)

Wednesday, December 16, 2015

TH33F: NGEE Arctic Data Management Town Hall 2015

Join the Data Management Team of the DOE-sponsored NGEE (Next-Generation Ecosystem Experiments) Arctic project to learn about Phase 1 data developments and future plans for Phase 2. Highlights cover the present data collection, existing and planned data management tools; challenges working across multiple laboratories/institutions and scientific disciplines; and data workflows. Project-generated datasets will improve representation of complex interactions of arctic land surface and subsurface processes in Earth System Models (ESMs). Open discussion about our data management approach and plans and potential science and data collaboration opportunities are encouraged.

Wednesday, December 16, 2015 12:30–13:30
Moscone West 2005

Primary Contact:
Tom Boden (Oak Ridge National Laboratory)

Presenters:
Stan Wullschleger (Oak Ridge National Laboratory)
Peter E. Thornton (Oak Ridge National Laboratory)

Thursday, December 17, 2015

TH43H: The AmeriFlux Network: Celebrating Its 20th Anniversary

2016 brings the AmeriFlux Network's 20th anniversary. Since it was launched in 1996 with 15 sites, more than 200 sites have joined the network, linking ecosystem-flux and process-scale studies across the Americas. The DOE AmeriFlux Management Project (`http://ameriflux.lbl.gov/`) serves the community of flux sites and data users, enhancing data quality, innovative measurements, and synthesis. Join the town hall to hear news about the network, exchange ideas, learn about Decembers major new data release, and participate in this kickoff of 20th anniversary activities.

Thursday, December 17, 2015 12:30–13:30
Moscone West 2004

Primary Contact:
Margaret Torn (Lawrence Berkeley National Laboratory)

Presenters:
Dennis Baldocchi (University of California Berkeley)
Sebastien Biraud (Lawrence Berkeley National Laboratory)
Deb Agarwal (Lawrence Berkeley National Laboratory)
Tom Boden (Oak Ridge National Laboratory)
Dario Papale (Tuscia University)
Daniel Stover (U.S. Department of Energy)
Gilberto Pastorello (Lawrence Berkeley National Laboratory)

Friday, December 18, 2015

3 Sessions Organized

Monday, December 14, 2015

Tuesday, December 15, 2015

B21E: New Mechanisms, Feedbacks, and Approaches for Improving Predictions of the Global Carbon Cycle in Earth System Models I Posters

Tuesday, December 15, 2015 08:00–12:20
Moscone South Posters 0510–0528

Swirl: Global Planetary Processes

Primary Convener:
Forrest M. Hoffman (Oak Ridge National Laboratory)

Co-conveners:
Atul Jain (University of Illinois Urbana Champaign)
James T. Randerson (University of California Irvine)
J. Keith Moore (University of California Irvine)

Chairs:
James T. Randerson (University of California Irvine)
J. Keith Moore (University of California Irvine)

Index Terms:
0428 Carbon cycling
0439 Ecosystems, structure and dynamics
1615 Biogeochemical cycles, processes, and modeling
1622 Earth system modeling

B23J: New Mechanisms, Feedbacks, and Approaches for Improving Predictions of the Global Carbon Cycle in Earth System Models II

Tuesday, December 15, 2015 13:40–15:40
Moscone West 2010

Swirl: Global Planetary Processes

Primary Convener:
Forrest M. Hoffman (Oak Ridge National Laboratory)

Co-conveners:
Atul Jain (University of Illinois Urbana Champaign)
James T. Randerson (University of California Irvine)
J. Keith Moore (University of California Irvine)

Chairs:
Forrest M. Hoffman (Oak Ridge National Laboratory)
Atul Jain (University of Illinois Urbana Champaign)

Index Terms:
0428 Carbon cycling
0439 Ecosystems, structure and dynamics
1615 Biogeochemical cycles, processes, and modeling
1622 Earth system modeling

Wednesday, December 16, 2015

Thursday, December 17, 2015

B41E: Novel Approaches for Moving Beyond Plant Functional Types and Considering Future Vegetation Distributions I Posters

Thursday, December 17, 2015 08:00–12:20
Moscone South Posters 0474–0488

Primary Convener:
Abigail Swann (University of Washington)

Co-conveners:
Ryan Pavlick (Jet Propulsion Laboratory)
Yueyang Jiang (Marine Biological Laboratory)
Marie Dury (Oregon State University)

Chairs:
John Kim (U.S. Forest Service)
Abigail Swann (University of Washington)
Charles D. Koven (Lawrence Berkeley National Laboratory)
Christopher Still (Oregon State University)

Index Terms:
0429 Climate dynamics
0439 Ecosystems, structure and dynamics
1622 Earth system modeling
1632 Land cover change

B41G: The Depth Attenuation of Soil Organic Carbon Storage, Turnover, and Fate: Observations, Data Synthesis, and Modeling I Posters

Thursday, December 17, 2015 08:00–12:20
Moscone South Posters 0505–0515

Primary Convener:
Yujie He (University of California Irvine)

Co-conveners:
Jennifer Harden (U.S. Geological Survey)
Evan Kane (Michigan Technological University)

Chairs:
Jennifer Harden (U.S. Geological Survey)
Yujie He (University of California Irvine)

Index Terms:
0414 Biogeochemical cycles, processes, and modeling
0428 Carbon cycling
0429 Climate dynamics
0486 Soils/pedology

B43L: The Depth Attenuation of Soil Organic Carbon Storage, Turnover, and Fate: Observations, Data Synthesis, and Modeling II

Thursday, December 17, 2015 13:40–15:40
Moscone West 2008

Primary Convener:
Yujie He (University of California Irvine)

Co-conveners:
Jennifer Harden (U.S. Geological Survey)
Evan Kane (Michigan Technological University)

Chairs:
Yujie He (University of California Irvine) Jennifer Harden (U.S. Geological Survey)

Index Terms:
0414 Biogeochemical cycles, processes, and modeling
0428 Carbon cycling
0429 Climate dynamics
0486 Soils/pedology

IN43A: Big Data in the Geosciences: New Analytics Methods and Parallel Algorithms Posters

Thursday, December 17, 2015 13:40–18:00
Moscone South Posters 1717–1723

Primary Convener:
Jitendra Kumar (Oak Ridge National Laboratory)

Co-conveners:
Forrest M. Hoffman (Oak Ridge National Laboratory)

Chairs:
Jitendra Kumar (Oak Ridge National Laboratory)
Forrest M. Hoffman (Oak Ridge National Laboratory)

Index Terms:
0480 Remote sensing
1906 Computational models, algorithms

1914 Data mining
1932 High-performance computing

Friday, December 18, 2015

4 Presentation Abstracts

Monday, December 14, 2015

GC11F-1082: How will shrub expansion impact soil carbon sequestration in Arctic tundra?

Multiple lines of evidence suggest that plant productivity, and especially shrub abundance, is increasing in the Arctic in response to climate change. This greening is substantiated by increases in the Normalized Difference Vegetation Index, repeat photography and field observations. The implications of a greener Arctic on carbon sequestration by tundra ecosystems remain poorly understood. Here, we explore existing datasets of plant productivity and soil carbon stocks to quantify how greening, and in particular an expansion of woody shrubs, may translate to the sequestration of carbon in arctic soils.

As an estimate of carbon storage in arctic tundra soils, we used the Northern Circumpolar Soil Carbon Database v2. As estimates of tundra type and productivity, we used the Circumpolar Arctic Vegetation map as well as the MODIS and Landsat Vegetation Continuous Fields, and MODIS GPP/NPP (MOD17) products.

Preliminary findings suggest that in graminoid tundra and erect-shrub tundra higher shrub abundance is associated with greater soil carbon stocks. However, this relationship between shrub abundance and soil carbon is not apparent in prostrate-shrub tundra, or when comparing across graminoid tundra, erect-shrub tundra and prostrate-shrub tundra. Uncertainties originate from the extreme spatial (vertical and horizontal) heterogeneity of organic matter distribution in cryoturbated soils, the fact that (some) permafrost carbon stocks, e.g. yedoma, reflect previous rather than current vegetative cover, and small sample sizes, esp. in the High Arctic.

Using Vegetation Continuous Fields and MODIS GPP/NPP (MOD17), we develop quantitative trajectories of soil carbon storage as a function of shrub cover and plant productivity in the Arctic (¿60N). We then compare our greening-derived carbon sequestration estimates to projected losses of carbon from thawing permafrost.

Our findings will reduce uncertainties in the magnitude and timing of the carbon-climate feedback from the terrestrial Arctic, and thus provide guidance for future climate mitigation and adaptation strategies.

Monday, December 14, 2015 08:00–12:20
Moscone South Poster 1082

Authors:
Claudia Czimczik (University of California Irvine)
Sandra Holden (University of California Irvine)
Yujie He (University of California Irvine)
James T. Randerson (University of California Irvine)

GC12B-08: The Alaska Land Carbon Assessment: Baseline and projected future carbon storage and greenhouse-gas fluxes in ecosystems of Alaska

The Alaska Land Carbon Assessment was conducted to inform mitigation and adaptation policies and land management decisions at sub-regional, regional, and national scales. Ecosystem carbon

balance of Alaska was estimated for two time periods, a historical period (1950–2009) and a projected period (2010–2099) by synthesizing results for upland, wetland, and inland aquatic ecosystems. The total area of Alaska considered in this assessment was 1,474,844 km^2, which is composed of 84 percent uplands, 12 percent wetlands, and 4 percent inland waters. Between 1950 and 2009 the upland and wetland ecosystems of the state sequestered an average of 4.4 TgC/yr, which is almost 2 percent of net primary production (NPP) by upland and wetland ecosystems. However, this sequestration is spatially variable with the northern boreal sub-region losing C because of fire disturbance and other sub-regions gaining carbon. For inland aquatic ecosystems, there was a net combined carbon flux through various pathways of 41.2 TgC/yr, or about 17 percent of upland and wetland NPP. The greenhouse gas forcing potential of upland and wetland ecosystems of Alaska was approximately neutral during the historical period, but the state as a whole could be a source for greenhouse gas forcing to the climate system from methane emissions from lake ecosystems, which were not considered in the assessment. During the projected period (2010–2099), carbon sequestration of upland and wetland ecosystems of Alaska would increase substantially (18.2 to 34.4 TgC/yr) primarily because of an increase in NPP of 8 to 19 percent associated with responses to rising atmospheric CO_2, increased nitrogen cycling, and longer growing seasons. Although C emissions to the atmosphere from wildfire increase substantially for all of the projected climates, the increases in NPP more than compensate for those losses. The analysis indicates that upland and wetland ecosystems would be sinks for greenhouse gases for all scenarios during the projected period. However, as in the case of the analysis of the historical period, there is an uncertainty as whether the state could be a net source for GHG if emissions of CH4 from lakes in Alaska were considered.

Monday, December 14, 2015 11:20–11:30
Moscone West 3014

Authors:
A. David McGuire (University of Alaska Fairbanks)
Helene Genet (University of Alaska Fairbanks)
Yujie He (University of California Irvine)
Sarah Stackpoole (U.S. Geological Survey)
David D'Amore (USDA Forest Service)
Scott Rupp (University of Alaska Fairbanks)
Bruce Wylie (U.S. Geological Survey)
Xiaoping Zhou (USDA Forest Service)
Zhiliang Zhu (U.S. Geological Survey)

B13H-08: The global turnover time distribution of soil carbon derived from a meta-analysis of radiocarbon profiles

Soil is the largest terrestrial carbon reservoir and may influence the sign and magnitude of carbon cycle feedbacks under climate change. Soil carbon turnover times provide information about the sensitivity of carbon pools to changes in inputs and warming. The spatial and vertical distribution of soil carbon turnover times emerges from the interplay between climate, vegetation, and soil properties. Radiocarbon levels of soil organic matter can be used to estimate soil carbon turnover using models that take into account radioactive decay over centuries to millennia and inputs of ^{14}C from atmospheric weapons testing ("bomb carbon") during the second half of the 20th century. By synthesizing more than 200 soil radiocarbon profiles from all major biomes and soil orders, we 1) explored the major controlling factors for soil carbon turnover times of surface and deeper soil layers; 2) developed predictive models (tree-based regression, support vector regression and linear regression models) of $\Delta^{14}C$ that depends on depth, climate, vegetation, and soil types; and 3) extrapolated the predictive model to produce the first global distribution of soil carbon turnover times to the depth of 1 m.

Preliminary results indicated that climate and depth were primary controls of the vertical distribution of $\Delta^{14}C$, contributing to about 70% of the variability in our model. Vegetation and soil order exerted similar level of controls (about 15% each). The predictive model performed reasonably well with an R^2 of 0.81 and RMSE (root-mean-squared error) of about 50‰ for topsoil and 100‰ for subsoil, as estimated using cross-validation. Extrapolation of the predictive model to the globe in combination with existing soil carbon information (e.g., Harmonized World Soil Database) indicated that more than half of the global total soil carbon in the top 1 m had a turnover time of less than 500 years. Subsoils (30–100 cm) had millennium-scale turnover times, with the majority (70%) turning over between 1000 and 5000 years. This study provides a data-constrained estimate of the global distribution of soil carbon turnover times and may help to constrain the performance of Earth system models used to evaluate future scenarios of change.

Monday, December 14, 2015 15:25–15:40
Moscone West 2004

Authors:
Yujie He (University of California Irvine)
James T. Randerson (University of California Irvine)
Steven Allison (University of California Irvine)
Margaret Torn (Lawrence Berkeley National Laboratory)
Jennifer Harden (U.S. Geological Survey)
Lydia Smith (University of California Berkeley)
Tessa van der Voort (ETH Zurich)
Susan Trumbore (Max Planck Institute for Biogeochemistry)

Tuesday, December 15, 2015

B21E-0512: Functioning of the ocean biological pump in the oxygen minimum zones

Oxygen minimum zones occur at mid-depths in the water column in regions with weak ventilation and relatively high export of organic matter from surface waters. They are important ocean for ocean biogeochemistry, and potentially for climate, as sites of water column denitrification and nitrous oxide production. Denitrification is the dominant loss process for fixed nitrogen in the oceans, and can thus affect the ocean inventory of this key nutrient. Denitrification is less energetically efficient than oxic remineralization. Larger zooplankton, which feed on sinking particles, are not present in the lowest oxygen waters. Both of these factors suggest that the remineralization of sinking particles may be slower within the OMZs than in more oxygenated waters. There is limited field evidence and from some modeling studies that remineralization is slower (remineralization length scales are longer) within OMZ waters. In this talk, I will present results from the Community Earth System Model (CESM) ocean component attempting to test this hypothesis. Comparing model results with observed ocean biogeochemical tracer distributions (i.e., phosphate, oxygen), I will examine whether slower remineralization within low oxygen waters provides a better match between simulated and observed tracer distributions. Longer remineralization length scales under low oxygen conditions would provide a negative feedback under global warming scenarios.

The biological pump would transfer organic materials to depth more efficiently as ocean oxygen concentrations decline and the OMZs expand.

Tuesday, December 15, 2015 08:00–12:20
Moscone South Poster 0512

Authors:
J. Keith Moore (University of California Irvine)

B21E-0513: Design and application of a community land benchmarking system for Earth system models

Benchmarking has been widely used to assess the ability of climate models to capture the spatial and temporal variability of observations during the historical era. For the carbon cycle and terrestrial ecosystems, the design and development of an open-source community platform has been an important goal as part of the International Land Model Benchmarking (ILAMB) project. Here we developed a new benchmarking software system that enables the user to specify the models, benchmarks, and scoring metrics, so that results can be tailored to specific model intercomparison projects. Evaluation data sets included soil and aboveground carbon stocks, fluxes of energy, carbon and water, burned area, leaf area, and climate forcing and response variables. We used this system to evaluate simulations from the 5th Phase of the Coupled Model Intercomparison Project (CMIP5) with prognostic atmospheric carbon dioxide levels over the period from 1850 to 2005 (i.e., esmHistorical simulations archived on the Earth System Grid Federation). We found that the multi-model ensemble had a high bias in incoming solar radiation across Asia, likely as a consequence of incomplete representation of aerosol effects in this region, and in South America, primarily as a consequence of a low bias in mean annual precipitation. The reduced precipitation in South America had a larger influence on gross primary production than the high bias in incoming light, and as a consequence gross primary production had a low bias relative to the observations. Although model to model variations were large, the multi-model mean had a positive bias in atmospheric carbon dioxide that has been attributed in past work to weak ocean uptake of fossil emissions. In mid latitudes of the northern hemisphere, most models overestimate latent heat fluxes in the early part of the growing season, and underestimate these fluxes in mid-summer and early fall, whereas sensible heat fluxes show the opposite trend.

Tuesday, December 15, 2015 08:00–12:20
Moscone South Poster 0513

Authors:
Mingquan Mu (University of California Irvine)
Forrest M. Hoffman (Oak Ridge National Laboratory)
David M. Lawrence (National Center for Atmospheric Research)
William J. Riley (Lawrence Berkeley National Laboratory)
Gretchen Keppel-Aleks (University of Michigan Ann Arbor)
Charles D. Koven (Lawrence Berkeley National Laboratory)
Erik Kluzek (National Center for Atmospheric Research)
Jiafu Mao (Oak Ridge National Laboratory)
James T. Randerson (University of California Irvine)

B21E-0514: Tropical precipitation-carbon cycle links in CMIP5 Earth system models

Semi-arid ecosystems are increasingly thought to account for a large percentage of interannual variability in land CO_2 uptake, associated with variations in climate drivers such as precipitation. These connections motivate the need for understanding environmental influences beyond tropical rainforest land uptake. It is critically important to investigate connections between the current sensitivity of semi-arid ecosystems to climate as to discern future trends in the strength of the land sink for anthropogenic CO_2. To better inform future projections of carbon balance in earth system models (ESMs), we used a set of Coupled Model Intercomparison Project (CMIP5) ESMs to investigate trends and partitioning of recent CO_2 uptake (1980–2005) from tropical and subtropical regions. We quantified model-to-model differences in net biome productivity (NBP) over semi-arid and tropical regions as well as the sensitivity of NBP to temperature and drought stress for each landcover type. Our results revealed a large spread in NBP among models and between regions. We compared our findings to reanalysis and in situ observations to develop benchmarks for global models and to further probe model-driver relationships in order to constrain long-term projections.

Tuesday, December 15, 2015 08:00–12:20
Moscone South Poster 0514

Authors:
Samantha Basile (Univeristy of Michigan Ann Arbor)
Gretchen Keppel-Aleks (University of Michigan Ann Arbor)

B21E-0515: Observed allocations of productivity and biomass, and turnover times in tropical forests are not accurately represented in CMIP5 Earth system models

A significant fraction of anthropogenic CO_2 emissions is assimilated by tropical forests and stored as biomass, slowing the accumulation of CO_2 in the atmosphere. Because different plant tissues have different functional roles and turnover times, predictions of carbon balance of tropical forests depend on how earth system models (ESMs) represent the dynamic allocation of productivity to different tree compartments. This study shows that observed allocation of productivity, biomass, and turnover times of main tree compartments (leaves, wood, and roots) are not accurately represented in CMIP5 (Coupled Model Intercomparison Project Phase 5) ESMs. In particular, observations indicate that biomass saturates with increasing productivity. In contrast, most models predict continuous increases in biomass with increases in productivity. This bias may lead to an over-prediction of carbon uptake in response to CO_2 or climate-driven changes in productivity. Compartment-specific productivity and biomass are useful benchmarks to assess terrestrial ecosystem model performance. Improvements in the predicted allocation patterns and turnover times by ESMs will reduce uncertainties in climate predictions.

Tuesday, December 15, 2015 08:00–12:20
Moscone South Poster 0515

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B21E-0516: Evaluation of two decomposition schemes in Earth system models against LIDET, ^{14}C observations and global soil carbon maps

Soils contain the largest pool of carbon in terrestrial ecosystems. Soil carbon dynamics and associated nutrient dynamics play significant roles in regulating global carbon cycle and atmospheric CO_2 concentrations. Our capability to predict future climate change depends to a large extent on a well-constrained representation of soil carbon dynamics in ESMs. Here we evaluate two decomposition schemes—converging trophic cascade (CTC) and Century—in CLM4.5/ACME V0 using data from the long-term intersite decomposition experiment team (LIDET), radiocarbon (^{14}C) observations, and Harmonized World Soil Database (HWSD). For the evaluation against LIDET, we exercise the full CLM4.5/ACME V0 land model, including seasonal variability in nitrogen limitation and environmental scalars (temperature, moisture, O_2), in order to represent LIDET experiment in a realistic way. We show that the proper design of model experiments is crucial to model evaluation using data from field experiments such as LIDET. We also use ^{14}C profile data at 10 sites to evaluate the performance of CTC and CENTURY decomposition scheme. We find that the ^{14}C profiles at these sites are most sensitive to the depth dependent decomposition parameters, consistent with previous studies.

Tuesday, December 15, 2015 08:00–12:20
Moscone South Poster 0516

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B21E-0517: Implementation of a canopy air space scheme into the Community Land Model

A single-layer Canopy Air Space Scheme (CASS) is implemented into the Community Land Surface Model version 4.5 (CLM4.5) in this study. It considers the canopy storages for heat, water, and trace gases that are generally neglected in the CLM4.5 surface flux calculation algorithm. Moreover, the CASS introduces prognostic equations for the surface variables and eliminates the CLM4.5 Crank-Nicolson iterative solution for computing surface skin temperature, which usually brings residual errors into the model and causes numerical instability. Two off-line simulations (one with the CASS and the other with the origin CLM4.5 scheme) were conducted and their results were compared with the FLUXNET observations. Preliminary results show that compared with the origin CLM4.5 scheme, the CASS has similar or better skills in representing land surface exchanges for heat, water and carbon under several biome types. The implementation of the CASS into the CLM4.5 not only improves the land model skills, but also provides a modeling framework to incorporate more complex canopy processes into the land surface model, such as bi-directional emission schemes for various trace gases and multi-layer canopy energy balance models.

Tuesday, December 15, 2015 08:00–12:20
Moscone South Poster 0517

Authors:
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B21E-0518: Evaluation of vegetation biomass in CMIP5 models over the northern high-latitudes

Global vegetation biomass stores huge amounts of carbon and is thus important to the global carbon budget. For the past few decades, different observation-based estimates and modeling of biomass in above- and below-ground vegetation components have been comprehensively conducted. However, uncertainties still exist, in particular for the simulation of biomass magnitude, tendency, and the response of biomass to natural and anthropogenic drivers. To elucidate these uncertainties, this study compares vegetation biomass of sixteen Earth System Models (ESMs) from the Coupled Model Intercomparison Project Phase 5 (CMIP5) archive with latest observation-based data over the Northern High-Latitudes. Results demonstrate that the models exhibit large variability of vegetation biomass, and the model ensemble mean underestimates temperate forest total biomass but overestimates boreal forest total biomass compared to the observational data. Moreover, both the model outputs and the observational data show individual biomass components are highly sensitive to the change of precipitation across different biomes. Possible causes behind inter-model and model-observation differences, such as the discrepancies of climatic conditions, the carbon allocation schemes, prescribed vegetation distributions, representation of disturbances as well as spin-up processes in the ESMs, are investigated and will be discussed.

Tuesday, December 15, 2015 08:00–12:20
Moscone South Poster 0518

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B21I-01: Leveraging atmospheric CO_2 observations to constrain the climate sensitivity of terrestrial ecosystems

A significant challenge in understanding, and therefore modeling, the response of terrestrial carbon cycling to climate and environmental drivers is that vegetation varies on spatial scales of order a few kilometers whereas Earth system models (ESMs) are run with characteristic length scales of order 100 km. Atmospheric CO_2 provides a constraint on carbon fluxes at spatial scales compatible with the resolution of ESMs due to the fact that atmospheric mixing renders a single site representative of fluxes within a large spatial footprint. The variations in atmospheric CO_2 at both seasonal and interannual timescales largely reflect terrestrial influence.

I discuss the use of atmospheric CO_2 observations to benchmark model carbon fluxes over a range of spatial scales. I also discuss how simple models can be used to test functional relationships between the CO_2 growth rate and climate variations. In particular, I show how atmospheric CO_2 provides constraints on ecosystem sensitivity to climate drivers in the tropics, where tropical forests and semi-arid ecosystems are thought to account for much of the variability in the contemporary carbon sink.

Tuesday, December 15, 2015 08:00–08:15
Moscone West 2004

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B23G-0669: Drivers of the increasing mean annual CO_2 cycle in the CESM

The observed increase in the amplitude of the CO_2 annual cycle indicates that climate change and CO_2 fertilization are altering patterns of terrestrial carbon exchange. We investigated the drivers of trends in the mean annual cycle of atmospheric CO_2 in the Community Earth System Model (CESM) in simulations run until 2300. In these simulations, the amplitude of the mean annual cycle (averaged over the Northern Hemisphere) increases by 10% over the historical period and by 50% by 2100. Growing season productivity gains are responsible for most of the amplification, resulting in a strengthening global land carbon sink.

We separated the effects of CO_2 radiative forcing (climate change) and fertilization by enhanced CO_2 mole fractions by analyzing two separate simulations, one fully-coupled and one in which CO_2 exerted no additional radiative forcing. Climate change and fertilization both increase the Northern Hemisphere CO_2 annual cycle amplitude until the year 2300, with the largest amplitude gains occurring in the mid and high latitudes. CO_2 fertilization drives the amplitude increase over the northern midlatitudes through 2300 and over the Arctic after 2100. Climate change is responsible for most of the amplitude increase over the Arctic before 2100. In contrast, climate change reduces the CO_2 annual cycle amplitude over the tropics. While the mid latitude fertilization effect dominates the global CO_2 amplitude response, the shift of the terrestrial biosphere to carbon source at the end of the 23rd century indicates that the tropical climate change drives the net terrestrial carbon flux.

Tuesday, December 15, 2015 13:40–18:00
Moscone South Poster 0669

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B23G-0662: Nonlinear interactions between climate and atmospheric carbon dioxide drivers of terrestrial and marine carbon cycle changes from 1850 to 2300

Quantifying feedbacks between the global carbon cycle and Earth's climate system is important for predicting future atmospheric CO_2 levels and informing carbon management and energy policies. We applied a feedback analysis framework to three sets of Historical (1850–2005), Representative Concentration Pathway 8.5 (2006–2100), and its extension (2101–2300) simulations from the Community Earth System Model version 1.0 (CESM1(BGC)) to quantify drivers of terrestrial and ocean responses of carbon uptake. In the biogeochemically coupled simulation (BGC), the effects of CO_2 fertilization and nitrogen deposition influenced marine and terrestrial carbon cycling. In the radiatively coupled simulation (RAD), the effects of rising temperature and circulation changes due to radiative forcing from CO_2, other greenhouse gases, and aerosols were the sole drivers of carbon cycle changes. In the third, fully coupled simulation (FC), both the biogeochemical and radiative coupling effects acted simultaneously. We found that climate-carbon sensitivities derived from RAD simulations produced a net ocean carbon storage climate sensitivity that was weaker and a net land carbon storage climate sensitivity that was stronger than those diagnosed from the FC and BGC simulations. For the ocean, this nonlinearity was associated with warming-induced weakening of ocean circulation and mixing that limited exchange of dissolved inorganic carbon between surface and deeper water masses. For the land, this nonlinearity was associated with strong gains in gross primary production in the FC simulation, driven by enhancements in the hydrological cycle and increased nutrient availability. We developed and applied a nonlinearity metric to rank model responses and driver variables. The climate-carbon cycle feedback gain at 2300 was 42% higher when estimated from climate-carbon sensitivities derived from the difference between FC and BGC than when derived from RAD. These differences are important to quantify and understand because different model intercomparison efforts have used different approaches to compute feedbacks, complicating intercomparison of ESMs over time. Underestimating the climate-carbon cycle feedback gain would result in allowable emissions estimates that would be too low to meet climate change targets.

Tuesday, December 15, 2015 13:40–18:00
Moscone South Poster 0662

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B23J-01: Diagnosing drought in a changing climate

Predictions of future climate impacts such as drought rely heavily on metrics based on changes in rainfall and changes in the demand for water from the atmosphere. However, the underlying driver of climate change is the increasing concentration of atmospheric carbon dioxide (CO_2), which simultaneously increases temperature globally and modifies the water needs of plants. Although the influence of CO_2 on plant stomatal conductance and transpiration is well established, the relative impact of this physiology on different drought metrics has not been rigorously assessed. We find that predictions of increasing drought stress derived using atmospheric demand metrics in many regions (including potential evapotraspiration and Palmer Drought Stress Index) correspond to places where Earth system models show stable or increasing water availability on land when assessed using the difference between precipitation and evapotranspiration. Approximately 70% of the increase in global water availability is a direct result of the effect of CO_2 reducing plant water needs. Current models predict a decoupling of water flux and carbon flux, which require revisions to how aridity is measured and drought is calculated under changing CO_2.

Tuesday, December 15, 2015 13:40–13:55
Moscone West 2010

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B23J-02: Implementation ambiguity: The fifth element long lost in uncertainty budgets for land biogeochemical modeling

Previous studies have identified four major sources of predictive uncertainty in modeling land biogeochemical (BGC) processes: (1) imperfect initial conditions (e.g., assumption of preindustrial equilibrium); (2) imperfect boundary conditions (e.g., climate forcing data); (3) parameterization (type I equifinality); and (4) model structure (type II equifinality). As if that were not enough to cause substantial sleep loss in modelers, we propose here a fifth element of uncertainty that results from implementation ambiguity that occurs when the model's mathematical description is translated into computational code. We demonstrate the implementation ambiguity using the example of nitrogen down regulation, a necessary process in modeling carbon-climate feedbacks. We show that, depending on common land BGC model interpretations of the governing equations for mineral nitrogen, there are three different implementations of nitrogen down regulation. We coded these three implementations in the ACME land model (ALM), and explored how they lead to different preindustrial and contemporary land biogeochemical states and fluxes. We also show how this implementation ambiguity can lead to different carbon-climate feedback estimates across the RCP scenarios. We conclude by suggesting how to avoid such implementation ambiguity in ESM BGC models.

Tuesday, December 15, 2015 13:55–14:10
Moscone West 2010

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B23J-03: Terrestrial carbon storage dynamics: Chasing a moving target

Terrestrial ecosystems have been estimated to absorb roughly 30% of anthropogenic CO_2 emissions. Past studies have identified myriad drivers of terrestrial carbon storage changes, such as fire, climate change, and land use changes. Those drivers influence the carbon storage change via diverse mechanisms, which have not been unified into a general theory so as to identify what control the direction and rate of terrestrial carbon storage dynamics. Here we propose a theoretical framework to quantitatively determine the response of terrestrial carbon storage to different exogenous drivers. With a combination of conceptual reasoning, mathematical analysis, and numeric experiments, we demonstrated that the maximal capacity of an ecosystem to store carbon is time-dependent and equals carbon input (i.e., net primary production, NPP) multiplying by residence time. The capacity is a moving target toward which carbon storage approaches (i.e., the direction of carbon storage change) but usually does not attain. The difference between the capacity and the carbon storage at a given time t is the unrealized carbon storage potential. The rate of the storage change is proportional to the magnitude of the unrealized potential. We also demonstrated that a parameter space of NPP, residence time, and carbon storage potential can well characterize carbon storage dynamics quantified at six sites ranging from tropical forests to tundra and simulated by two versions (carbon-only and coupled carbon-nitrogen) of the Australian Community Atmosphere–Biosphere Land Ecosystem (CABLE) Model under three climate change scenarios (CO_2 rising only, climate warming only, and RCP 8.5). Overall this study reveals the unified mechanism unerlying terrestrial carbon storage dynamics to guide transient traceability analysis of global land models and synthesis of empirical studies.

Tuesday, December 15, 2015 14:10–14:25
Moscone West 2010

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B23J-04: Interactions between soil organic carbon concentration and soil thermal and hydraulic dynamics and its impact on soil carbon storage in northern high-latitudes

Northern high-latitudes (NHLs) regions are estimated to contain half of world's soil carbon and the dynamics of soil carbon fluxes in these regions will likely impact the global climate. However, the dynamics of soil carbon fluxes in these regions is likely to be significantly altered by increasing temperatures, resulting in a positive feedback on future climate. Processes that are most likely to generate strong carbon cycle feedbacks through redistribution of soil organic carbon (SOC) concentration (e.g., cryoturbation and dissolved organic carbon movement) and subsequently change soil thermal and hydraulic dynamics are poorly represented in Earth system models (ESMs) and thus have not been well-studied. We will present a multi-layer soil biogeochemical model that was implemented into a land surface model, the Integrated Science and Assessment Model (ISAM), to explicitly represent vertical heterogeneity of SOC profiles due to cold region processes and their impacts on soil thermal and hydraulic properties. The newly implemented ten-layer soil biogeochemical model, which extends down to 3.5 meters, includes two types of physical processes for estimating SOC distribution with depth: 1) diffusion, representing SOC movements through bioturbation/cryoturbation, and 2) convection, which describes SOC movements in the liquid phase. Soil type-dependent diffusion and advection rates applied in this model were calibrated and validated using SOC profile data from across the Pan-arctic region. The resulting calibrated and validated coupled model was also driven by future climate projections from CMIP5 output at different sites with varying soil types to study the impact of future climate change on SOC storage.

Tuesday, December 15, 2015 14:25–14:40
Moscone West 2010

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B24E-04: Influences of vegetation phenological shifts on water and energy cycle

Remote sensed vegetation indices and field measurements have demonstrated that climate change has influenced vegetation phenology. The phenological changes are expressed in shifts in the timing of spring vegetation activity and the length of the active growing season. According to NDVI data from NOAA and GIMMS, the length of the active growing season north of 45°N has extended by 12 days due to 8 days advancement in spring and 4 days prolongation in autumn between July 1981 and June 1991. The same NDVI dataset from July 1981 to December 1999 has shown the growing season increased by 18 days in Eurasia and 12 days in North America. Phenology regulates vegetation interactions with climate by influencing the energy, water and carbon cycles. Here, we use observations and the Community Land Model 4.5 (CLM4.5) in offline mode and coupled with CESM to evaluate influences of shifts in phenology on energy and water budget and partitioning and on interactions with the atmosphere. Satellite retrieved leaf area index (LAI) is used to prescribe shifts in vegetation phenology in CLM4.5. We find that phenological advancement of 12 days over the past few decades can result in monthly mean changes of (-5–$7\ \mathrm{W\,m^{-2}}$) in latent heat and (-5–$9\ \mathrm{W\,m^{-2}}$) in sensible heat balance over wide regions. We will discuss (1) the capability of current climate models to predict the impacts of phenological shifts on climate change, (2) seasonal to annual changes in energy and water cycles in response to phenological shifts, (3) the spatial heterogeneity in phenological-induced energy and water partitioning in different plant functional types across regions and continents, and (4) phenology and plant-climate interactions in changing climate.

Tuesday, December 15, 2015 17:00–17:20
Moscone West 2006

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Wednesday, December 16, 2015

B31A-0523: Future vegetation dynamics and associated land surface feedbacks from 2010 to 2100 in the high latitudes under a changing climate

Landcover is expected to change in the high latitudes in the future due to warming climate, precipitation changes, and rising carbon dioxide content. Past studies have shown that changes in land-cover will be associated with changes in vegetation, primarily tree line migration and shrubification. These changes in vegetation can feedback to climate through the balance of plant carbon uptake due to increased availability of nitrogen and release of carbon to the atmosphere from increased decomposition. In addition to the carbon cycle feedbacks, changes in vegetation can also change the surface energy and water balances through modifications in land surface albedo and evapotranspiration. However there is a lack of studies that attempt to understand how vegetation

changes in the future interacts with permafrost degradation and deep soil carbon that can subsequently change the terrestrial carbon balance and surface energy balance in the coming century. In this study, we use a mechanistic ecosystem model (ecosys) to model vegetation dynamics under changing climate at high latitudes, and quantify changes in carbon, water, and energy balance associated with these vegetation changes.

Wednesday, December 16, 2015 08:00–12:20
Moscone South Poster 0523

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B31C-0556: Carbon and nutrient responses to fire and climate warming in Alaskan arctic tundra

Fire frequency has dramatically increased in the tundra of northern Alaska, which has major implications for the carbon budget of the region and the functioning of these ecosystems that support important wildlife species. We applied the Multiple Element Limitation (MEL) model to investigate both the short- and long-term post-fire succession of plant and soil carbon, nitrogen, and phosphorus fluxes and stocks along a burn severity gradient in the 2007 Anaktuvuk River Fire scar in northern Alaska. We compared the patterns of biomass and soil carbon, nitrogen and phosphorus recoveries with different burn severities and warming intensities. Modeling results indicated that the early regrowth of post-fire tundra vegetation was limited primarily by its canopy photosynthetic potential, rather than nutrient availability. The long-term recovery of C balance from fire disturbance is mainly determined by the internal redistribution of nutrients among ecosystem components, rather than the supply of nutrients from external sources (e.g., nitrogen deposition and fixation, phosphorus weathering). Soil organic matter is the principal source of plant-available nutrients and determines the spatial variation of vegetation biomass across the North Slope of Alaska. Across the North Slope of Alaska, we examined the effects of changes in N and P cycles on tundra C budgets under climate warming. Our results indicate that the ongoing climate warming in Arctic enhances mineralization and leads to a net transfer of nutrient from soil organic matter to vegetation, thereby stimulating tundra plant growth and increased C sequestration in the tundra ecosystems.

Wednesday, December 16, 2015 08:00–12:20
Moscone South Poster 0556

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B31D-0597: Characterizing organic matter lability in Alaskan tundra soils using mid-infrared spectroscopy

Soils in permafrost regions contain large amounts of soil organic carbon (SOC) that is preserved in a relatively undecomposed state due to cold and often wet conditions, yet the potential lability of these SOC stocks is still largely unknown. Traditional methods of assessing SOC lability (e.g., laboratory incubation studies) are labor intensive and time consuming. Fourier-transform mid-infrared spectroscopy (MidIR) provides a means to quickly estimate SOC quantity and quality based on the wealth of spectral information. In this study, we explored the possibility of linking MidIR spectra with SOC lability in Arctic tundra soils. Soils from four sites on the North Slope of Alaska were used in this study: a wet non-acidic tundra site in the coastal plain (CP), two moist acidic tundra sites between the northern foothills and the coastal plain (HC and SH), and another moist acidic tundra site in the northern foothills (HV). Active-layer organic and mineral soils and upper permafrost soils from the four sites were incubated for 60 days at −1, 1, 4, 8 and 16°C. Thawed soils were allowed to drain to field capacity. Carbon dioxide (CO_2) production was measured throughout the study. The chemical composition (e.g., total organic carbon and nitrogen) and MidIR spectra of soil samples were obtained before and after the incubations. CO_2 production varied among soils and temperatures. CO_2 production was greatest at 16°C for CP and SH organic layers and for HC and HV permafrost layers. These trends among soil layers and sites remained similar at all temperatures. We found a good correlation between MidIR and cumulative 60-day CO_2 production across different soils and temperatures. Characteristic MidIR bands and band ratios previously identified in the literature were also correlated with total CO_2 production. For example, several band ratios (such as the ratio of aliphatics to clay or the ratio of lignin or phenolics to minerals) in the mineral active layer were highly correlated with respired CO_2, suggesting such ratios might serve as useful lability indicators. Further investigation of characteristic MidIR bands and band ratios for additional soils and for longer term incubations are needed to fully assess their utility as indicators of the relative degradation state and potential decomposability of permafrost-region soils.

Wednesday, December 16, 2015 08:00–12:20
Moscone South Poster 0597

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B31D-0618: Bioavailable carbon and the relative degradation state of organic matter in active layer and permafrost soils

The decomposability of soil organic carbon (SOC) in permafrost regions is a key uncertainty in efforts to predict carbon release from thawing permafrost and its impacts. The cold and often wet environment is the dominant factor limiting decomposer activity, and soil organic matter is often

preserved in a relatively undecomposed and uncomplexed state. Thus, the impacts of soil warming and permafrost thaw are likely to depend at least initially on the genesis and past history of organic matter degradation before its stabilization in permafrost. We compared the bioavailability and relative degradation state of SOC in active layer and permafrost soils from Arctic tundra in Alaska. To assess readily bioavailable SOC, we quantified salt (0.5 M K_2SO_4) extractable organic matter (SEOM), which correlates well with carbon mineralization rates in short-term soil incubations. To assess the relative degradation state of SOC, we used particle size fractionation to isolate fibric (coarse) from more degraded (fine) particulate organic matter (POM) and separated mineral-associated organic matter into silt- and clay-sized fractions. On average, bulk SOC concentrations in permafrost were lower than in comparable active layer horizons. Although SEOM represented a very small proportion of the bulk SOC, this proportion was greater in permafrost than in comparable active layer soils. A large proportion of bulk SOC was found in POM for all horizons. Even for mineral soils, about 40% of bulk SOC was in POM pools, indicating that organic matter in both active layer and permafrost mineral soils was relatively undecomposed compared to typical temperate soils. Not surprisingly, organic soils had a greater proportion of POM and mineral soils had greater silt- and clay-sized carbon pools, while cryoturbated soils were intermediate. For organic horizons, permafrost organic matter was generally more degraded than in comparable active layer horizons. However, in mineral and cryoturbated horizons, the presence of permafrost appeared to have little effect on SOC distribution among size fractions. Future studies will investigate the utility of using organic matter pools defined by SEOM and particle size to predict the bioavailable pools characterized through more time-consuming long-term incubation studies of permafrost region soils.

Wednesday, December 16, 2015 08:00–12:20
Moscone South Poster 0618

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GC31E-1226: Global energy consumption for direct water use

Despite significant efforts to quantify the mutual inter-dependence of the water and energy sectors, global energy for water (EFW) remains poorly understood, resulting in biases in energy accounting that directly affect water and energy management and policy. We firstly evaluate the global energy consumption for direct water use from 1973 to 2012 with sectoral, regional and process-level details. Over the 40-year period, we detected multiple shifts in EFW by county and region. For example, we find that India, the Middle East and China have surpassed the United States as the three largest consumers of EFW since 2003, mostly because of rapid growth in groundwater-based irrigation, desalination, and industrial and municipal water use, respectively. Globally, EFW accounts for 1–3% of total primary energy consumption in 2010, of which 52% is surface water, 36% is groundwater, and 12% is non-fresh water. The sectoral allocation of EFW includes municipal (45%), industrial (29%), and agricultural use (26%), and process-level contributions are from source/conveyance (41%), water purification (19%), water distribution (13%) and wastewater treatment (22%). Our evaluation suggests that the EFW may increase in importance in the future due to growth in population and income, and depletion of surface and shallow aquifer water resources in water-scarce regions. We are incorporating this element into an integrated assessment model (IAM) and linking it back to energy balance within that IAM. By doing this, we will then explore the impacts of EFW on the global energy market (e.g., changes in the share of groundwater use and desalination), and the uncertainty of future EFW under different shared social pathway (SSP) and representative concentration pathway (RCP) scenarios, and consequences on the emission of greenhouse gases as well. We expect these EFW induced impacts will be considerable, and will then have significant implications for adaptive management and policy making.

Wednesday, December 16, 2015 08:00–12:20
Moscone South Poster 1226

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B31F-01: Improving predictions of large scale soil carbon dynamics: Integration of fine-scale hydrological and biogeochemical processes, scaling, and benchmarking

Numerical model representations of decadal- to centennial-scale soil-carbon dynamics are a dominant cause of uncertainty in climate change predictions. Recent attempts by some Earth System Model (ESM) teams to integrate previously unrepresented soil processes (e.g., explicit microbial processes, abiotic interactions with mineral surfaces, vertical transport), poor performance of many ESM land models against large-scale and experimental manipulation observations, and complexities associated with spatial heterogeneity highlight the nascent nature of our community's ability to accurately predict future soil carbon dynamics.

I will present recent work from our group to develop a modeling framework to integrate pore-, column-, watershed-, and global-scale soil process representations into an ESM (ACME), and apply the International Land Model Benchmarking (ILAMB) package for evaluation. At the column scale and across a wide range of sites, observed depth-resolved carbon stocks and their ^{14}C derived turnover times can be explained by a model with explicit representation of two microbial populations, a simple representation of mineralogy, and vertical transport. Integrating soil and plant dynamics requires a process-scaling' approach, since all aspects of the multi-nutrient system cannot be explicitly resolved at ESM scales. I will show that one approach, the Equilibrium Chemistry Approximation, improves predictions of forest nitrogen and phosphorus experimental manipulations and leads to very different global soil carbon predictions. Translating model representations from the site- to ESM-scale requires a spatial scaling approach that either explicitly resolves the

relevant processes, or more practically, accounts for fine-resolution dynamics at coarser scales. To that end, I will present recent watershed-scale modeling work that applies reduced order model methods to accurately scale fine-resolution soil carbon dynamics to coarse-resolution simulations. Finally, we contend that creating believable soil carbon predictions requires a robust, transparent, and community-available benchmarking framework. I will present an ILAMB evaluation of several of the above-mentioned approaches in ACME, and attempt to motivate community adoption of this evaluation approach.

Wednesday, December 16, 2015 08:00–08:15
Moscone West 2008

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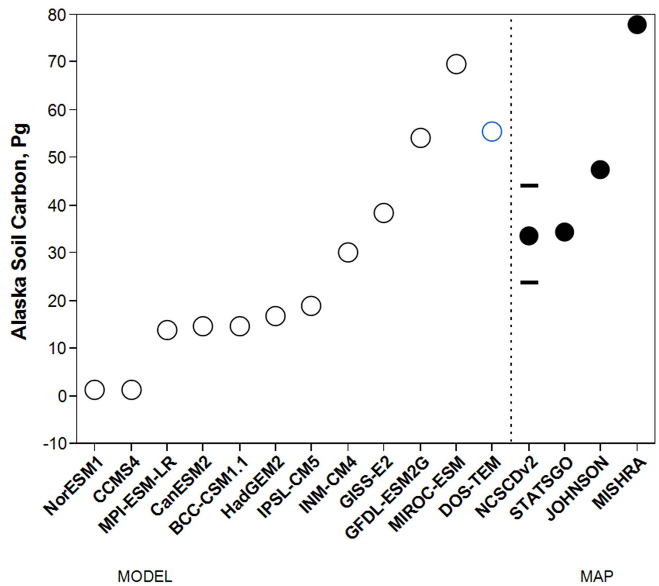
B31F-08: Using multiple soil carbon maps facilitates better comparisons with large scale modeled outputs

The choice of method applied for mapping the soil carbon is an important source of uncertainty when comparing observed soil carbon stocks to modeled outputs. Large scale soil mapping often relies on non-random and opportunistically collected soils data to make predictions over remote areas where few observations are available for independent validation. Addressing model choice and non-random sampling is problematic when models use the data for the calibration and validation of historical outputs. One potential way to address this uncertainty is to compare the modeled outputs to a range of soil carbon observations from different soil carbon maps that are more likely to capture the true soil carbon value than one map alone. The current analysis demonstrates this approach in Alaska, which despite suffering from a non-random sample, still has one of the richest datasets among the northern circumpolar regions. The outputs from 11 ESMs (from the 5^{th} Climate Model Intercomparison Project) and the Dynamic Organic Soil version of the Terrestrial Ecosystem Model (DOS-TEM) were compared to 4 different soil carbon maps. In the most detailed comparison, DOS-TEM simulated total profile soil carbon stocks that were within the range of the 4 maps for 18 of 23 Alaskan ecosystems, whereas the results fell within the 95% confidence interval of only 8 when compared to just one commonly used soil carbon map (NCSCDv2). At the ecoregion level, the range of soil carbon map estimates overlapped the range of ESM outputs in every ecoregion, although the mean value of the soil carbon maps was between 17% (Southern Interior) and 63% (Arctic) higher than the mean of the ESM outputs. For the whole state of Alaska, the DOS-TEM output and 3 of the 11 ESM outputs fell within the range of the 4 soil carbon map estimates. However, when compared to only one map and its 95% confidence interval (NCSCDv2), the DOS-TEM result fell outside the interval and only two ESM's fell within the observed interval. Overall, these results challenge how we view the accuracy of soil carbon reference data and our interpretation of model output validity. The example in Alaska also gives a reference for understanding similar issues when using soil carbon maps for comparison within other data-sparse northern circumpolar regions.



Wednesday, December 16, 2015 09:30–09:45
Moscone West 2008

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H33L-08: Disentangling climatic and anthropogenic controls on global terrestrial evapotranspiration trends

We examined natural and anthropogenic controls on terrestrial evapotranspiration (ET) changes from 1982-2010 using multiple estimates from remote sensing-based datasets and process-oriented land surface models. A significant increased trend of ET in each hemisphere was consistently revealed by observationally-constrained data and multi-model ensembles that considered historic natural and anthropogenic drivers. The climate impacts were simulated to determine the spatiotemporal variations in ET. Globally, rising CO_2 ranked second in these models after the predominant climatic influences, and yielded decreased trends in canopy transpiration and ET, especially for tropical forests and high-latitude shrub land. Increased nitrogen deposition slightly amplified global ET via enhanced plant growth. Land-use-induced ET responses, albeit with substantial uncertainties across the factorial analysis, were minor globally, but pronounced locally, particularly over regions with intensive land-cover changes. Our study highlights the importance of employing multi-stream

ET and ET-component estimates to quantify the strengthening anthropogenic fingerprint in the global hydrologic cycle.

Wednesday, December 16, 2015 15:25–15:40
Moscone West 3022

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Thursday, December 17, 2015

A41R-03: Impact of land use and land cover change on climate and air quality in the CESM

Land use and land cover change (LULCC) impacts climate by directly emiting CO_2 as well as modifying indirect CO_2 sinks in the future. LULCC also modifies aerosol and reactive gas emissions, modifying ozone and methane lifetimes, as well as directly emitting methane and nitrous oxide. Finally, LULCC modifies land albedos. Here we consider multiple land use scenarios within the context of the CESM, and the net impact of LULCC on climate and compare to other anthropogenic forcings. These comparisons suggest that LULCC contributes 40% to climate change today, and out to 2100. The contribution from LULCC varies strongly by country and when the land use conversion occurs.

Thursday, December 17, 2015 08:30–08:45
Moscone West 3008

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B42C-08: A simplified, data-constrained approach to estimate the permafrost carbon-climate feedback: The PCN Incubation-Panarctic Thermal (PInc-PanTher) scaling approach

We present an approach to estimate the feedback from large-scale thawing of permafrost soils using a simplified, data-constrained model that combines three elements: soil carbon (C) maps and profiles to identify the distribution and type of C in permafrost soils; incubation experiments to quantify the rates of C lost after thaw; and models of soil thermal dynamics in response to climate warming. We call the approach the Permafrost Carbon Network Incubation–Panarctic Thermal scaling approach (PInc–PanTher). The approach assumes that C stocks do not decompose at all when frozen, but once thawed follow set decomposition trajectories as a function of soil temperature. The trajectories are determined according to a 3-pool decomposition model fitted to incubation data using parameters specific to soil horizon types. We calculate litterfall C inputs required to maintain steady-state C balance for the current climate, and hold those inputs constant. Soil temperatures are taken from the soil thermal modules of ecosystem model simulations forced by a common set of future climate change anomalies under two warming scenarios over the period 2010 to 2100.

Thursday, December 17, 2015 12:05–12:20
Moscone West 2004

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A43C-0302: Impacts of marine ecodynamics on the dimethyl sulfide (DMS) production

Dimethyl sulfide (DMS) is a biogenic organosulfur compound which contributes strongly to marine aerosol mass and the determination of cloud condensation nuclei over the remote oceans. DMS concentrations are directly controlled by marine ecosystems. Various marine mircoorganisms play different roles in the DMS production. Changes in phytoplankton production and community composition can alter the production and distributions of DMS. Observation based estimates showed significant changes in phytoplankton biomass in the last few decades; and climate models also project a reduced marine primary production and shifts in the plankton community structure in the future climate. Here we investigate the contribution of individual phytoplankton functional groups to the DMS production and fluxes to the atmosphere using the improved marine ecosystem-biogeochemical module of the Community Earth System Model (CESM). We will examine the impacts of shifts in phytoplankton community composition on DMS distributions in a RCP climate scenario. We will show changes in the DMS flux due to individual phytoplankton groups, and the subsequent impacts on cloud radiative forcing.

Thursday, December 17, 2015 13:40–18:00
Moscone South Poster 0302

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B43C-0549: Mapping vegetation canopy structure and distribution for Great Smoky Mountains National Park using LiDAR

A major challenge in forest management is the inaccessibility of large swaths of land, which makes accurate monitoring of forest change difficult. Remote sensing methods can help address this issue by allowing investigators to monitor remote or inaccessible regions using aerial or satellite-based platforms. However, most remote sensing methods do not provide a full three-dimensional (3D) description of the area. Rather, they return only a single elevation point or landcover description. Multiple-return LiDAR (Light Detection and Ranging) gathers data in a 3D point cloud, which allows forest managers to more accurately characterize and monitor changes in canopy structure and vegetation-type distribution. Our project used high-resolution aerial multiple-return LiDAR data to determine vegetation canopy structures and their spatial distribution in Great Smoky Mountains National Park. To ensure sufficient data density and to match LANDSAT resolution, we gridded the data into $30\,\text{m} \times 30\,\text{m}$ cells. The LiDAR data points within each cell were then used to generate the vertical canopy structure for that cell. After vertical profiles had been created, we used a k-means cluster analysis algorithm to classify the landscape based on the canopy structure. The spatial distribution of distinct and unique canopy structures was mapped across the park and compared to a vegetation-type map to determine the correlation of canopy structure to vegetation types. Preliminary analysis conducted at a number of phenology sites maintained by the Great Smoky Mountains Institute at Tremont shows strong correspondence between canopy structure and vegetation type. However, more validation is needed in other regions of the park to establish this method as a reliable tool. LiDAR data has a unique ability to map full 3D structures of vegetation and the methods developed in this project offer an extensible tool for forest mapping and monitoring.

Thursday, December 17, 2015 13:40–18:00
Moscone South Poster 0549

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B43I-0659: Identifying the main drivers of soil carbon response to climate change in arctic and boreal Alaska

Boreal and arctic regions represent the largest reservoir of carbon among terrestrial biomes. Most of this carbon is stored deep in the soil in permafrost where frozen organic matter is protected from decomposition. The vulnerability of soil carbon stocks to a changing climate in high latitudes

depends on a number of physical and ecological processes. The importance of these processes in controlling the dynamics of soil carbon stocks vary across regions because of variability in vegetation composition, drainage condition, and permafrost characteristics.

To better understand the main drivers of the vulnerability of soil carbon stocks to climate change in Alaska, we ran a process-based ecosystem model, the Terrestrial Ecosystem Model. This model explicitly simulates interactions between the carbon cycle and permafrost dynamics and was coupled with a disturbance model and a model of biogenic methane dynamics to assess historical and projected soil carbon dynamics in Alaska, from 1950 to 2100.

The uncertainties related to climate, fire regime and atmospheric CO_2 projections on soil carbon dynamics were quantified by running simulations using climate projections from 2 global circulation models, 3 fossil fuel emission scenarios and 3 alternative fire management scenarios.

During the historical period [1950–2009], soil carbon stocks increased by 4.7 TgC/yr in Alaska. Soil carbon stocks decreased in boreal Alaska due to substantial fire activity in the early 2000's. This loss was offset by carbon accumulation in the arctic. Changes in soil carbon stocks from 2010 to 2099 ranged from 8.9 to 25.6 TgC/yr, depending on the climate projections. Soil carbon accumulation was slower in lowlands than in uplands and slower in the boreal than in the arctic regions because of the negative effect of fire activity on soil carbon stocks. Tundra ecosystems were more vulnerable to carbon loss from fire than forest ecosystems because of a lower productivity. As a result, the increase in fire frequency in Western Alaska induced a net soil carbon loss for half of the future climate projections.

Overall, these results have implications for land management strategies and illustrate the importance of taking into account permafrost dynamics and disturbance regimes in assessing responses of soil carbon in high latitude ecosystems.

Thursday, December 17, 2015 13:40–18:00
Moscone South Poster 0659

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B43I-0671: Capturing spatial heterogeneity of soil organic carbon under changing climate

The spatial heterogeneity of the land surface affects water, energy, and greenhouse gas exchanges with the atmosphere. Designing observation networks that capture land surface spatial heterogeneity is a critical scientific challenge. Here, we present a geospatial approach to capture the existing spatial heterogeneity of soil organic carbon (SOC) stocks across Alaska, USA. We used the standard deviation of 556 georeferenced SOC profiles previously compiled in Mishra and Riley (2015, *Biogeosciences*, 12:3993–4004) to calculate the number of observations that would be needed to reliably estimate Alaskan SOC stocks. This analysis indicated that 906 randomly distributed observation sites would be needed to quantify the mean value of SOC stocks across Alaska at a confidence interval of ±5 $kg\,m^{-2}$. We then used soil-forming factors (climate, topography, land cover types, surficial geology) to identify the locations of appropriately distributed observation sites by using the conditioned Latin hypercube sampling approach. Spatial correlation and variogram analyses demonstrated that the spatial structures of soil-forming factors were adequately represented by these 906 sites. Using the spatial correlation length of existing SOC observations, we identified 484 new observation sites would be needed to provide the best estimate of the present status of SOC stocks in Alaska. We then used average decadal projections (2020–2099) of precipitation, temperature, and length of growing season for three representative concentration pathway (RCP 4.5, 6.0, and 8.5) scenarios of the Intergovernmental Panel on Climate Change to investigate whether the location of identified observation sites will shift/change under future climate. Our results showed 12–41 additional observation sites (depending on emission scenarios) will be required to capture the impact of projected climatic conditions by 2100 on the spatial heterogeneity of Alaskan SOC stocks. Our results represent an ideal distribution of observation sites across Alaska that captures the land surface spatial heterogeneity and can be used in efforts to quantify SOC stocks, monitor greenhouse gas emissions, and benchmark Earth System Model results.

Thursday, December 17, 2015 13:40–18:00
Moscone South Poster 0671

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GC43C-1205: Sensitivity of land surface modeling to parameters: An uncertainty quantification method applied to the Community Land Model

Uncertainties in land parameters could have important impacts on simulated water and energy fluxes and land surface states, which will consequently affect atmospheric and biogeochemical processes. Therefore, quantification of such parameter uncertainties using a land surface model is the first step towards better understanding of predictive uncertainty in Earth system models. In this study, we applied a random-sampling, high-dimensional model representation (RS-HDMR) method to analyze the sensitivity of simulated photosynthesis, surface energy fluxes and surface hydrological components to selected land parameters in version 4.5 of the Community Land Model (CLM4.5). Because of the large computational expense of conducting ensembles of global gridded model simulations, we used the results of a previous cluster analysis to select one thousand representative land grid cells for simulation. Plant functional type (PFT)-specific uniform prior ranges for land parameters were determined using expert opinion and literature survey, and samples were generated with a quasi-Monte Carlo approach-Sobol sequence. Preliminary analysis of 1024 simulations suggested that four PFT-dependent parameters (including slope of the conductance-photosynthesis relationship, specific leaf area at canopy top, leaf C:N ratio and fraction of leaf N in RuBisco) are the dominant sensitive parameters for photosynthesis, surface energy and water fluxes across most PFTs, but with varying importance rankings. On the other hand, for surface ans sub-surface runoff, PFT-independent parameters, such as the depth-dependent decay factors for runoff, play more important roles than the previous four PFT-dependent parameters. Further analysis by conditioning the results on different seasons and years are being conducted to provide guidance on how climate

variability and change might affect such sensitivity. This is the first step toward coupled simulations including biogeochemical processes, atmospheric processes or both to determine the full range of sensitivity of Earth system modeling to land-surface parameters. This can facilitate sampling strategies in measurement campaigns targeted at reduction of climate modeling uncertainties and can also provide guidance on land parameter calibration for simulation optimization.

Thursday, December 17, 2015 13:40–18:00
Moscone South Poster 1205

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B43L-01: Comparing global soil models to soil carbon profile databases

As global soil models begin to consider the dynamics of carbon below the surface layers, it is crucial to assess the realism of these models. We focus on the vertical profiles of soil C predicted across multiple biomes form the Community Land Model (CLM4.5), using different values for a parameter that controls the rate of decomposition at depth versus at the surface, and compare these to observationally-derived diagnostics derived from the International Soil Carbon Database (ISCN) to assess the realism of model predictions of carbon depthattenuation, and the ability of observations to provide a constraint on rates of decomposition at depth.

Thursday, December 17, 2015 13:40–13:55
Moscone West 2008

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B43L-02: Vertical soil carbon distributions in the contiguous United States: Effects of land cover and history of cultivation

Soils contain the largest pool of carbon in most terrestrial ecosystems. The vertical distribution of these large carbon pools contains important information about the factors affecting soil formation and soil organic matter preservation. In addition, the depth distribution of organic matter is associated with its stability and resilience to climatic and ecological changes. We fit the vertical distribution soil organic carbon (SOC) concentration using an exponential model in order to calculate empirical parameters Z*, representing the characteristic vertical scale of the decline in SOC concentration with depth, and C_{surf}, representing the approximate SOC concentration in the uppermost layer of mineral soil. A higher value of Z* indicates a longer vertical scale, and therefore a slower decline with depth. This calculation was applied to a set of over 28,000 soil profiles in the coterminous United States. Limiting the analysis to fits with an $r^2 > 0.9$ yielded more than 15,000 estimates of Z* and C_{surf} from soil profiles representing a variety of different ecosystems. We used this large dataset to test hypotheses related to the impacts of soil type, ecosystem type, and land use history on soil carbon stocks and vertical distributions. SOC concentration near the surface and its rate of decline with depth were both strongly dependent on land use, with cultivated soils having the lowest C_{surf} and highest Z* and forest soils having the highest C_{surf} and lowest Z*. These effects were more pronounced in forest soil orders (alfisols and spodosols) than in prairie soil orders (mollisols). Cultivation lowered SOC concentrations throughout the soil profile, and these effects were visible in currently forested ecosystems with a history of cultivation, indicating that the effects were persistent after reforestation. These results will be useful for both assessing land use effects on soil carbon stocks and evaluating ecosystem.

Thursday, December 17, 2015 13:55–14:10
Moscone West 2008

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B43L-06: Recent advances in modeling depth distribution of soil carbon storage

Depth distribution of soil carbon storage determines the sensitivity of soil carbon to environmental change. We present different approaches that have been used to represent the vertical heterogeneity of soil carbon both in mapping and modeling studies. In digital soil mapping, many studies applied exponential decay functions in soils where carbon concentration has been observed to decline with depth. Recent studies used various forms of spline functions to better represent the vertical distribution of soil carbon along with soil horizons. These studies fitted mathematical functions that described the observations and then interpolated the model coefficients using soil-forming factors and used maps of model coefficients with depth to predict the SOC storage at desired depth intervals. In general, the prediction accuracy decreased with depth and the challenge remains to find appropriate soil-forming factors that determine/explain subsurface soil variation. Models such as Century, RothC, and Terrestrial Ecosystem Model use the exponential depth distribution functions of soil carbon in their model structures. In CLM 4.5 the soil profile is partitioned into 10 layers down to 3.8 m depth and the carbon input from plant roots is assumed to decrease following an exponential function. Not accounting for soil horizons in representing biogeochemistry and the assumption of globally uniform soil depth remain major sources of uncertainty in these models. In this presentation, we will discuss the merits and demerits of using various profile depth distribution functions to represent the vertical heterogeneity of soil carbon storage.

Thursday, December 17, 2015 14:55–15:10
Moscone West 2008

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IN43A-1721: Scalable algorithms for unsupervised classification and anomaly detection in large geospatiotemporal data sets

The increasing availability of high-resolution geospatiotemporal datasets from sources such as observatory networks, remote sensing platforms, and computational Earth system models has opened new possibilities for knowledge discovery and mining of ecological data sets fused from disparate sources. Traditional algorithms and computing platforms are impractical for the analysis and synthesis of data sets of this size; however, new algorithmic approaches that can effectively utilize the complex memory hierarchies and the extremely high levels of available parallelism in state-of-the-art high-performance computing platforms can enable such analysis. We describe some unsupervised knowledge discovery and anomaly detection approaches based on highly scalable parallel algorithms for k-means clustering and singular value decomposition, consider a few practical applications thereof to the analysis of climatic and remotely-sensed vegetation phenology data sets, and speculate on some of the new applications that such scalable analysis methods may enable.

Thursday, December 17, 2015 13:40–18:00
Moscone South Poster 1721

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Friday, December 18, 2015

B53J-04: Continental asymmetry in climate-induced tropical drought: Driving mechanisms and ecosystem response

Current theory does not adequately explain diverging patterns of future drought stress predicted by Earth system models (ESMs) across tropical South America, Africa, and equatorial Asia. By 2100 for the Representative Concentration Pathway 8.5 (RCP 8.5) many models predict significant decreases in precipitation across northeastern South America and Central America. In contrast, most models predict increasing levels of precipitation across tropical Africa and equatorial Asia. Using the Community Earth System Model v1.0 with RCP 8.5 simulations to 2300, we found that this longitudinal precipitation asymmetry intensified over time and as a consequence, terrestrial carbon losses from the neotropics were considerably higher than those in Africa and Asia. Carbon losses in some areas of the Amazon in a fully coupled simulation exceeded 15 $\mathrm{kg\,C\,m^{-2}}$ by 2300, relative to estimates from a biogeochemically-forced simulation in which atmospheric carbon dioxide and other greenhouse gases did not influence the atmospheric radiation budget. Variations in the amount of neotropical drying varied considerably among CMIP5 ESMs, and we used several types of analysis to identify driving mechanisms and to reduce uncertainties associated with these projections. CMIP5 models in general underestimated North Atlantic sea surface temperatures and the strength of the Atlantic meridional overturning circulation (AMOC). Models that more accurately simulated North Atlantic SSTs during the historical era had smaller mean precipitation biases and predicted greater neotropical forest drying than other models. This suggests that future drought stress in northern South America and Central America may be larger than estimates derived from the multi-model mean. Analysis of idealized radiatively coupled, biogeochemically coupled and fully coupled CMIP5 model simulations indicated that the direct effects of atmospheric carbon dioxide on plant physiology also was an important factor driving asymmetric precipitation change

across the tropics, and had a similar pattern as changes induced solely from greenhouse gas effects on atmospheric radiation. We conclude by discussing the implications of the continental drought asymmetry for the vulnerability of tropical forests to fire, agriculture, and tree mortality.

Friday, December 18, 2015 14:25–14:40
Moscone West 2008

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Notes

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