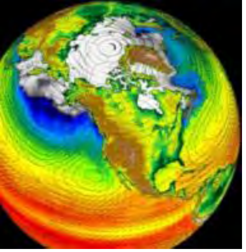
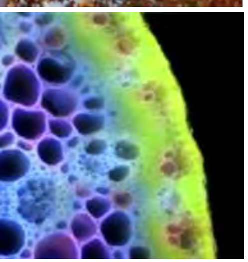



Terrestrial Ecosystem Science

Terrestrial Ecosystem SCIENCE

Environmental System Science Principal Investigator Meeting
Potomac, MD

April 26-27, 2016

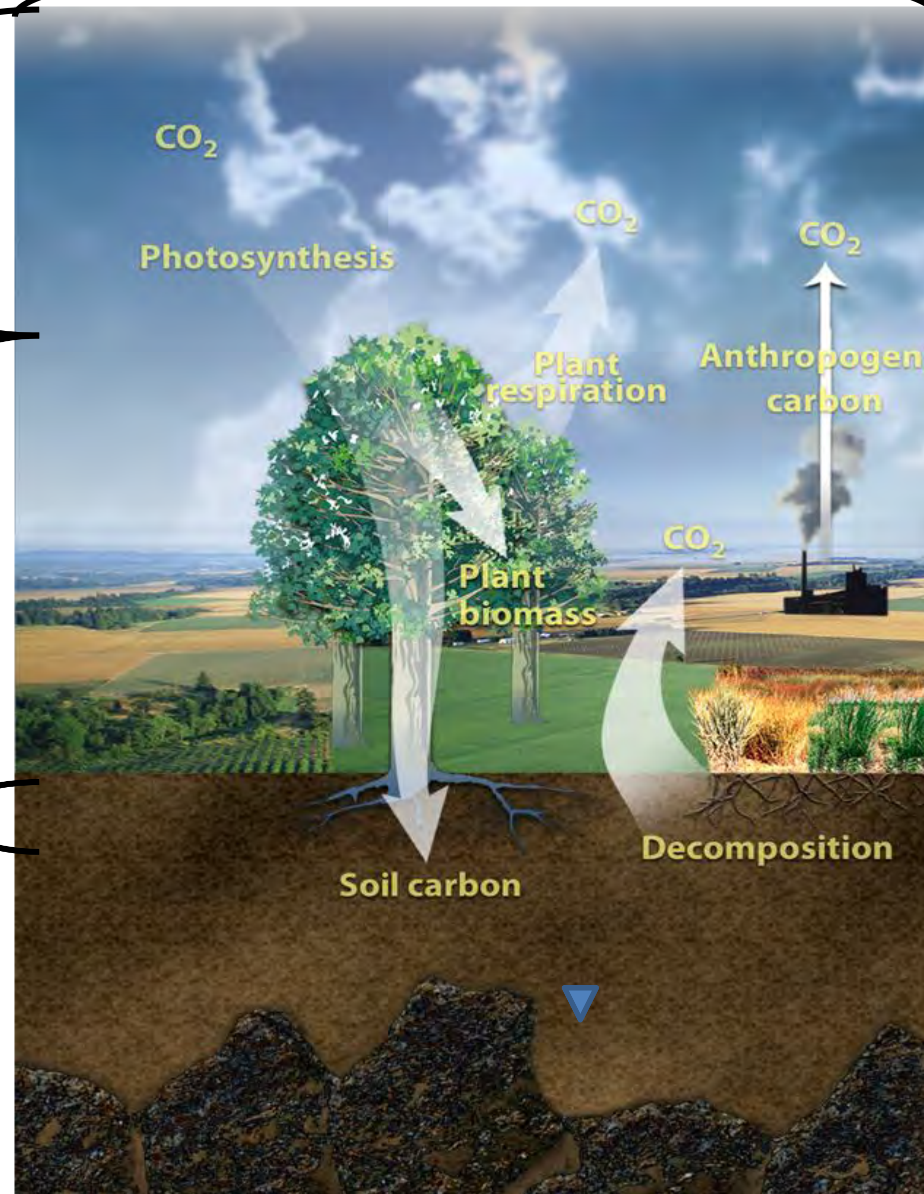
Jared L. DeForest, Ph.D.
Daniel B. Stover, Ph.D.

Climate and Earth System Modeling

Atmospheric System Science

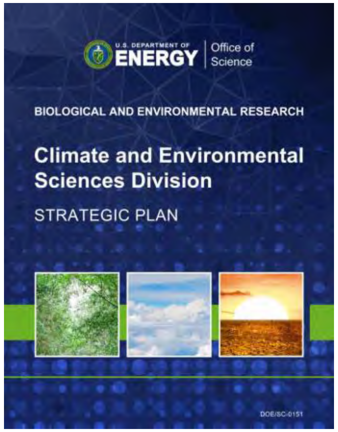
Terrestrial Ecosystem Science

Subsurface Biogeochemical Research



Climate & Environmental Sciences Division (CESD) Strategic Plan

1. Synthesize new process knowledge and innovative computational methods advancing next generation, integrated models of the human-earth system.
2. **Develop, test and simulate process-level understanding of atmospheric systems and of terrestrial ecosystems extending from bedrock to the top of the vegetative canopy.**
3. Advance fundamental understanding of coupled biogeochemical processes in complex subsurface environments to enable systems-level prediction and control.
4. Enhance the unique capabilities and impacts of the ARM and EMSL scientific user facilities and other BER community resources to advance the frontiers of climate and environmental science.
5. Identify and address science gaps that limit translation of CESD fundamental science into solutions for DOE's most pressing energy and environmental challenges.



http://science.energy.gov/~/media/ber/pdf/CESD-StratPlan-2012.pdf

Climate and Environmental Science Division
(FY 2016 Funding Levels)

- Research Programs
  - Climate and Earth System Modeling ($98.6M)
  - Atmospheric Systems Research ($26.4M)
  - Environmental Systems Science
    - Terrestrial Ecosystem Science ($40.0M)
    - Subsurface Biogeochemical Research ($23.2M)
  - Climate Data Informatics/Management ($7.1M)
- Facilities
  - Atmospheric Radiation Monitoring (ARM) Climate Research Facility ($65.4M)
  - Environmental Molecular Sciences Laboratory ($43.2M)

Terrestrial Ecosystem Science (TES) Program

Goal: The TES program seeks to improve the representation of terrestrial ecosystem processes in Earth system models, thereby improving the quality of climate model projections and providing the scientific foundation of solutions for DOE's most pressing energy and environmental challenges.

Approach: A model-inspired fundamental research approach focusing on processes and ecosystems that are:

- Globally/regionally significant;
- Climatically sensitive;
- Insufficiently understood or inadequately represented in predictive models

Collaborative interactions as an Environmental Systems Science group with the Subsurface Biogeochemistry Research (SBR) Program.

Terrestrial Ecosystem SCIENCE

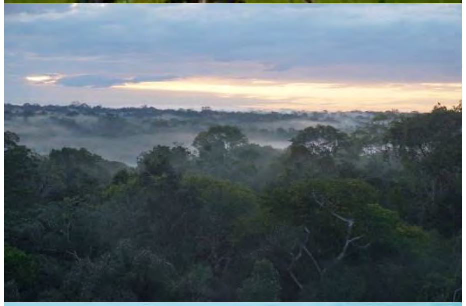
Terrestrial Ecosystem Science

Research Approach

- Observations (e.g., AmeriFlux network)
- Large-scale, long-term field studies and manipulations (e.g., NGEE: Arctic & Tropics, SPRUCE)
- Synthesis (e.g., NACP and FACE)
- Research questions in the context of needs, process and structure of Earth system models

Funding to both universities and DOE National Laboratories

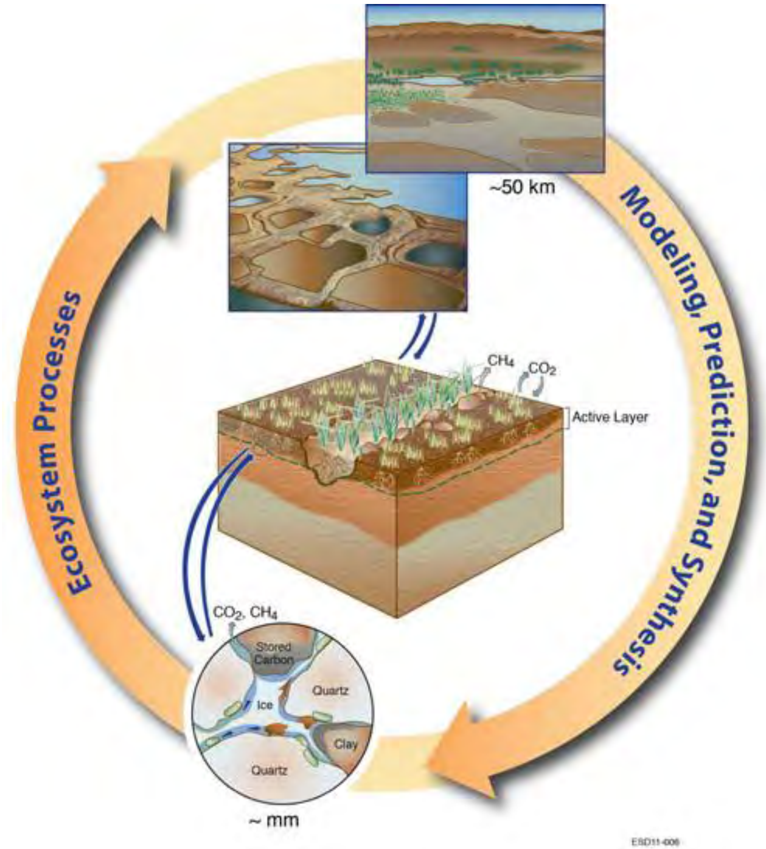
- Annual university Funding Opportunity Announcement (FOA)
- Science Focus Areas (SFA)



Coupled Model-Experimental Linkages (ModEx)

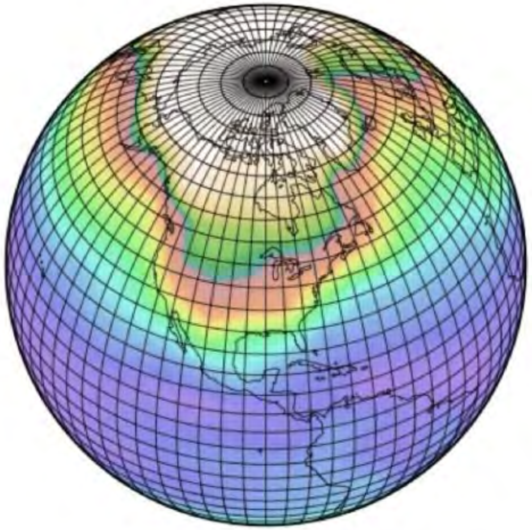
- DOE's goal is to: *To advance a robust predictive understanding of Earth's climate and environmental systems and to inform the development of sustainable solutions to the Nation's energy and environmental challenges.*

- "Predictive understanding" is code for ModEx.
- Our goal is to coordinate process and modeling science to maximize scientific outcomes.
- This is not a one-way street, it is an iterative dialog (*a "new" way to do business*).
- We also recognize the importance of and role for "discovery science".



Next Generation Ecosystem Experiments (NGEE)

- The 2008 Ecosystem Workshop
  - identified several critical ecosystems as important regions of climate prediction uncertainty that require DOE and community attention.
  - "NGEE concept" grew out of this workshop report, to advance experimental concepts that leverages other DOE strengths and mission needs.



NGEE focuses on systems that are:

- Globally important;
- Climatically sensitive;
- Insufficiently understood or represented in coupled models; and
- Feasible

NGEE – Arctic

Goal: Advance the predictive understanding of the structure and function of Arctic terrestrial ecosystems in response to climate change.

Objectives:

- Development of 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 (ESM) grid cell (i.e., approximately 30x30 km grid size).

Approach:

- Collaborative effort among DOE National Laboratories and universities, led by Oak Ridge National Laboratory.
- Interdisciplinary, multi-scale approach to advance predictive understanding through iterative experimentation and modeling.
- Opportunities for leveraging through external collaboration (DOE and other agencies).

NGEE – Tropics

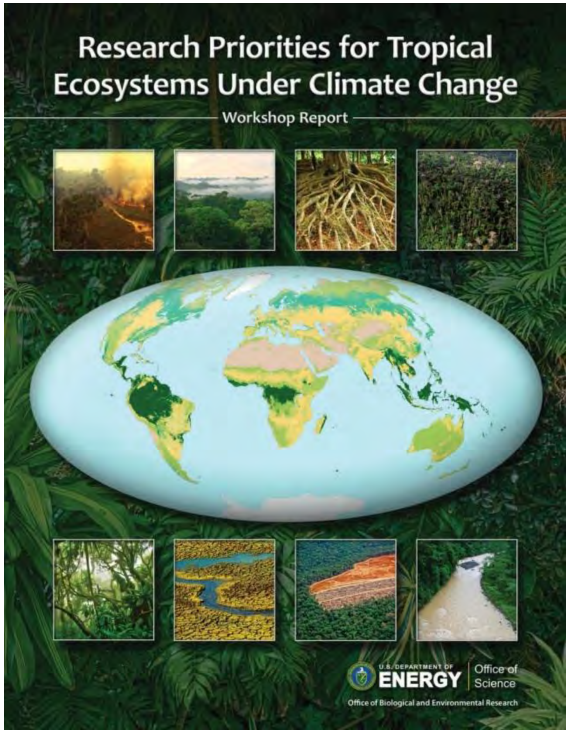
Goal: Improve our understanding of ecosystem-climate feedbacks due to changes in precipitation, temperature, nutrient cycling and disturbance in tropical forests.

Objectives:

- Development of a representative, process-rich ecosystem model, extending from bedrock to the top of the vegetative canopy-atmospheric interface, in which the evolution and feedbacks of tropical ecosystems in a changing climate can be modeled at the scale/resolution of a high resolution next generation Earth system model (ESM) grid cell.

Approach:

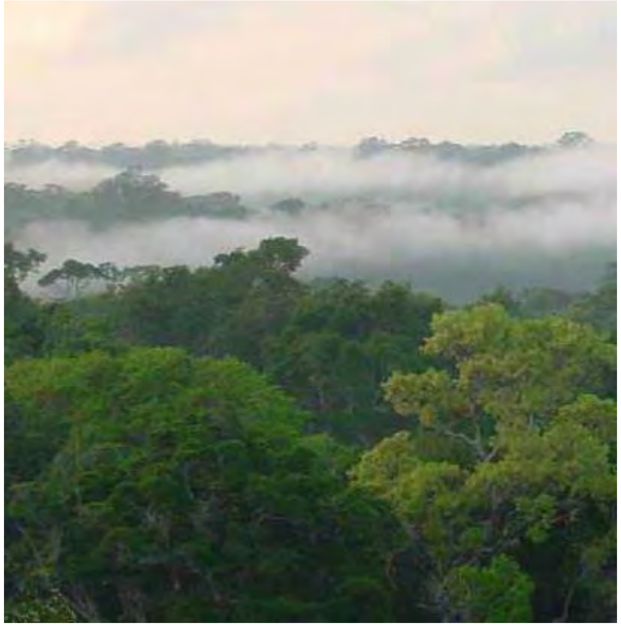
- Collaborative effort among DOE National Laboratories and universities, led by Lawrence Berkeley National Laboratory.
- Interdisciplinary, multi-scale approach to advance predictive understanding through iterative experimentation and modeling.



NGEE – Tropics

2016 is the first full year of the experiment

- **NGEE – Tropics** is:
  - a model informed field study that results in iterative refinement of high resolution predictive models.
  - based on field studies in the most climate sensitive tropical geographies that provides a high scientific return on investment.
  - utilize a distributed network of focused research sites
  - employ a unique trait-based modeling approach



SPRUCE

- Spruce-Peatland Responses Under Climatic and Environmental Change - An experiment to test responses of high-carbon, high-latitude ecosystems to various levels of warming (as much as +9^{O}C) with or without elevated CO_2.

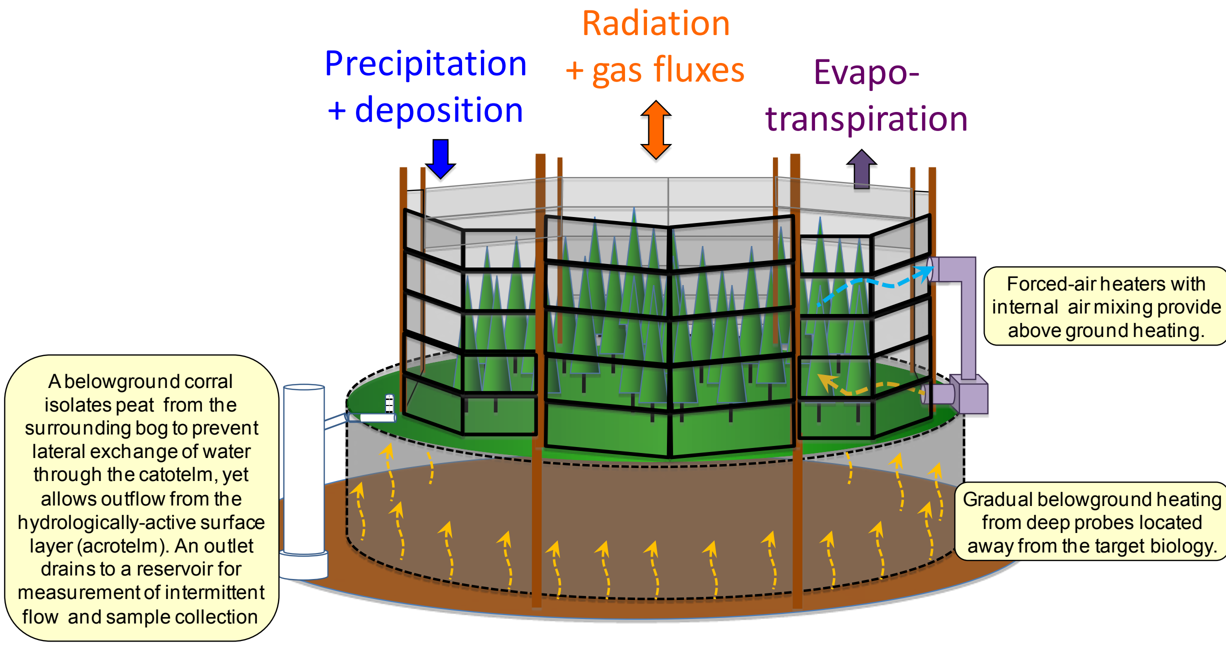
Key Science Questions:

•Will deep belowground warming in the future release 10,000 years of accumulated carbon from peatlands that store 1/3 of the earth's terrestrial carbon? At what rate?

•Will releases of C be in the form of CO_2 or CH_4 with 30 times the warming potential?

•Are peatland ecosystems and organisms vulnerable to atmospheric and climatic change? What changes are likely?

•Will ecosystem services (e.g., regional water balance) be compromised or enhanced by atmospheric and climatic change?



SPRUCE

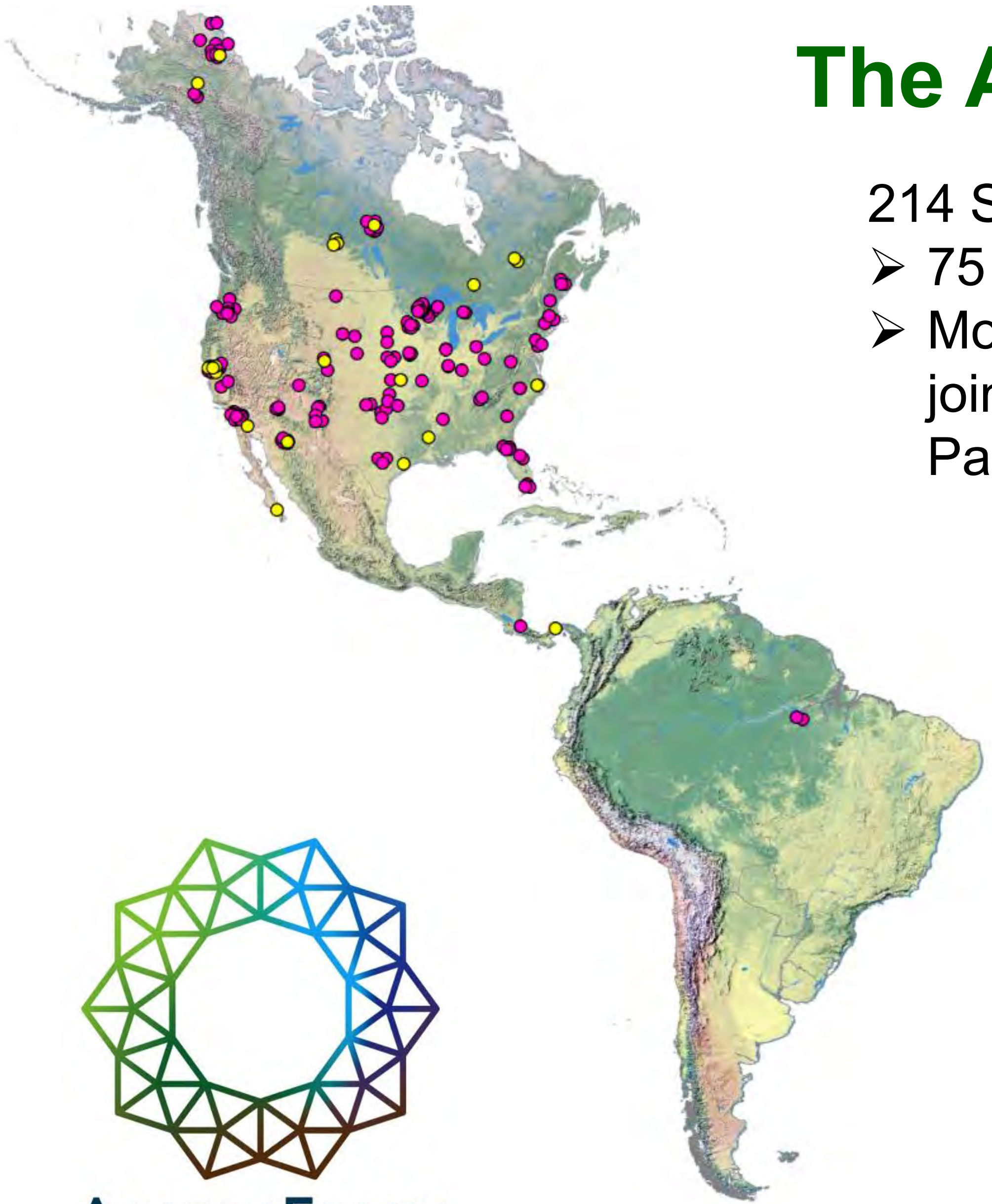
+CO_2

+°C

Officially launched August 2015

- Deep soil heating started June 2015
- Air warming started August 2015
- CO_2 enrichment is expected to start in a few months

The AmeriFlux Network



214 Sites in the AmeriFlux Network

- 75 sites have submitted data since 2010
- More than 36 sites have joined or re-joined since 2012 (U.S., Canada, Panama, Mexico)

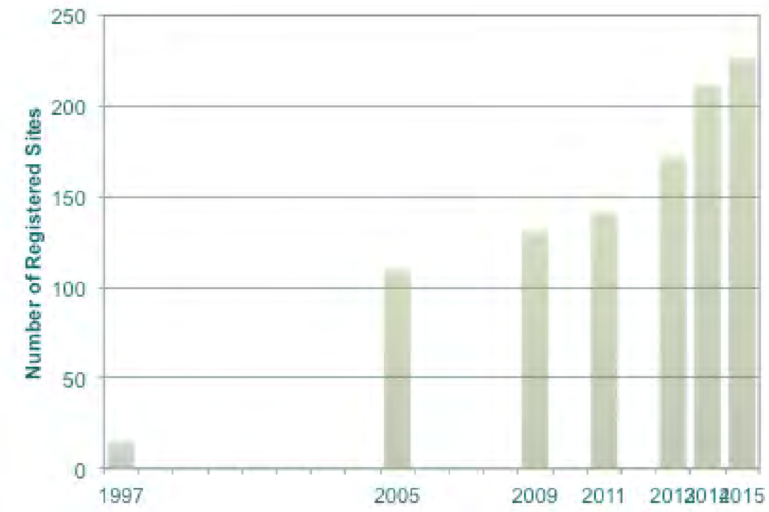
AmeriFlux Management Program Support:

- Contracts for operations
- Data managers' trainings*
- QA/QC intercomparisons, calibrations, loaners*
- Safety Training*
- Assistance with data and metadata processing

** Offered to whole network!*

AmeriFlux

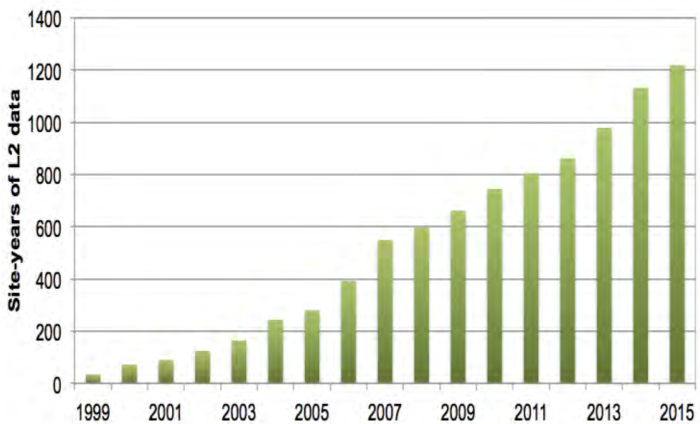
Happy 20th Birthday, AmeriFlux!



- AmeriFlux launched 1996
  - 15 sites in 1997
  - 105 sites in 2005
  - 227 sites in 2015

Events

- AmeriFlux meeting with **AmeriFlux@20** theme
  - Location—Boulder, CO
  - Target date—September 21-23, 2016
- 2016 ESA session (Bev Law)
- 2016 AGU session



Site-years of AmeriFlux data available at CDIAC

Looking Ahead and Strategic Plans

- Strategic Research Interests in:
  - Role of belowground processes in the carbon cycle
  - Support large-scale coupled modeling and process research projects as well as large-scale, long-term ecosystem studies
  - Arctic and tropical ecosystems and their feedbacks in a changing climate
  - Analyze long-term ecosystem observational records to inform and evaluate models
  - Trait-based approaches to improve our predictive understanding
  - Terrestrial-aquatic interfaces (workshop fall of 2016)
- Connect projects closely to other research activities within CESD, within BER, and among the other Federal agencies.
- Forge strong programmatic coordination with the BER Scientific User Facilities (ARM, EMSL and JGI) Lunch session, Room 3

EMSL

ARM
CLIMATE RESEARCH FACILITY

JGI
JOINT GENOME INSTITUTE
DEPARTMENT OF ENERGY

Interagency and International Coordination

- USGCRP Carbon Cycle interagency working groups
  - Currently organizing the 2nd State of the Carbon Cycle Report (SOCCR-2)
- Interagency Arctic Research Policy Council
- Arctic Council/Arctic Monitoring and Assessment Program
- DoD's Strategic Environmental R&D Program (SERDP)
  - Environmental Restoration and Sustainable Infrastructure focus areas
  - Natural Resources and Climate Change focus areas

TES Program Update

- FY-14 NASA ROSES Joint Solicitation - $5M ($8.2M over 3 year)
  - 10 awards, Jointly supported with NASA, USDA, and NOAA
- FY-15 ESS Annual University Solicitation - $9.7M over 3 years
  - 185 Pre-apps, 117 full applications, 11 awards
- FY-16 ESS Annual University Solicitation
  - Currently under review
- FY-17 NASA ROSES Joint Solicitation (deadline June 15, 2016)
  - Jointly supported with NASA, USDA, and NOAA
  - TES: 3.1.2 Carbon Dynamics in Arctic/Boreal Terrestrial Ecosystems
- Office of Science Graduate Student Research (deadline May 11)
  - Provides support for Ph.D. student to pursue parts of graduate research at DOE labs
- DOE Early Career Solicitation
  - FY-13 (Rebecca Newman, University of Washington)
  - FY-14 (Joel Rowland, LANL)
  - FY-16 (Tropical forest ecology, currently under review)

ARTICLE

Received 16 Jan 2015 | Accepted 25 Jul 2015 | Published 2 Sep 2015 DOI: 10.1038/ncomms9159 OPEN

The links between ecosystem multifunctionality and above- and belowground biodiversity are mediated by climate

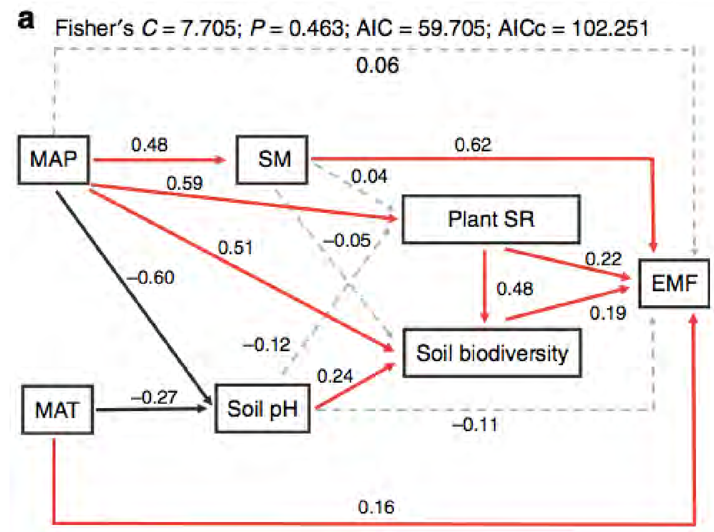
Xin Jing[1], Nathan J. Sanders[2], Yu Shi[3], Haiyan Chu[3], Aimée T. Classen[4], Ke Zhao[1], Litong Chen[5], Yue Shi[1,6], Youxu Jiang[7] & Jin-Sheng He[1,5]

- **Background:** Most of the world's biodiversity is in soil, yet we poorly understand how it influences ecosystem function or responds to climate change.

- **Approach:** Used Structural Equation Modeling to tease apart the effects of climate, soil and biodiversity on multiple ecosystem functions (aka ecosystem multifuncitonality, EMF) on the Tibetan Plateau.

- **Results:** A suite of biotic and abiotic variables account for up to 86% of the variation in EMF, with a combined effects of above- and belowground biodiversity accounting for 45% of the variation in EMF.

- **Impact:** First, including belowground biodiversity in models can improve the ability to explain and predict EMF. Second, regional scale variation in climate can determine the effects of biodiversity on EMF. This study received international media coverage promoting the idea that more attention needs to be paid to soil biodiversity.



Black arrows = Negative path
Red arrows = Positive path

Jing, Xin, Nathan J. Sanders, Yu Shi, Haiyan Chu, Aimée T. Classen, Ke Zhao, Litong Chen, Yue Shi, Youxu Jiang, and Jin-Sheng He. 2015. The links between ecosystem multifunctionality and above-and belowground biodiversity are mediated by climate. Nature communications. DOI: 10.1038/ncomms9159

Global Change Biology

Global Change Biology (2015) 21, 2111–2121, doi: 10.1111/gcb.12860

OPINION

Urgent need for warming experiments in tropical forests

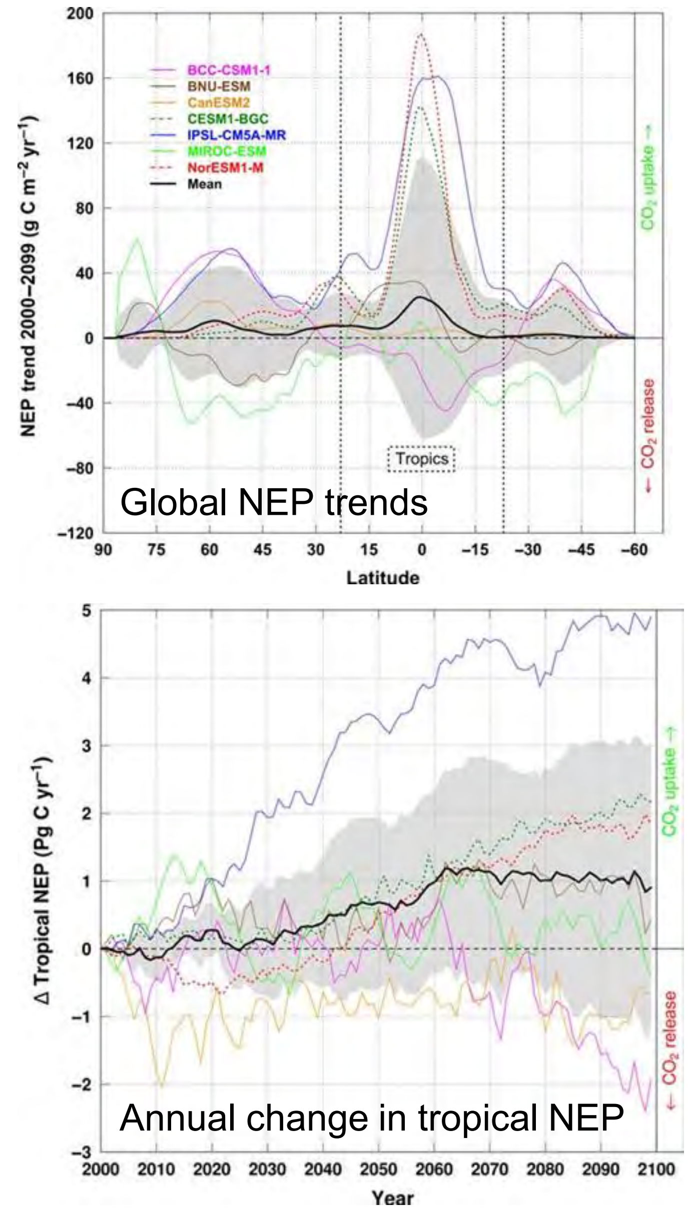
MOLLY A. CAVALERI[1], SASHA C. REED[2], W. KOLBY SMITH[3] and TANA E. WOOD[4,5]

- **Background:** Tropical forests have a strong, disproportional influence on global carbon exchange, yet there is great uncertainty about its response to climatic change.

- **Approach:** Investigate model uncertainty of tropical latitudes using a Coupled Model Intercomparison Project Phase 5 (CMIP5) analysis from seven climate models.

- **Results:** Net Ecosystem Production (NEP) model variability was three times greater in the tropics than other latitudes responding to a warmer climate. Overall, it is unclear if tropical forests will be a source or a sink for atmospheric CO_2.

- **Impact:** Tropical forests may represent our largest uncertainty in modeling future climate. This opinion paper stresses that multi-faceted warming experiments are vital to accurately predict future tropical forest carbon balance.



Cavaleri, Molly A., Sasha C. Reed, W. Kolby Smith, and Tana E. Wood. 2015. Urgent need for warming experiments in tropical forests. Global change biology 21(6): 2111-2121. doi: 10.1111/gcb.12860.

REVIEW

doi:10.1038/nature14338

Climate change and the permafrost carbon feedback

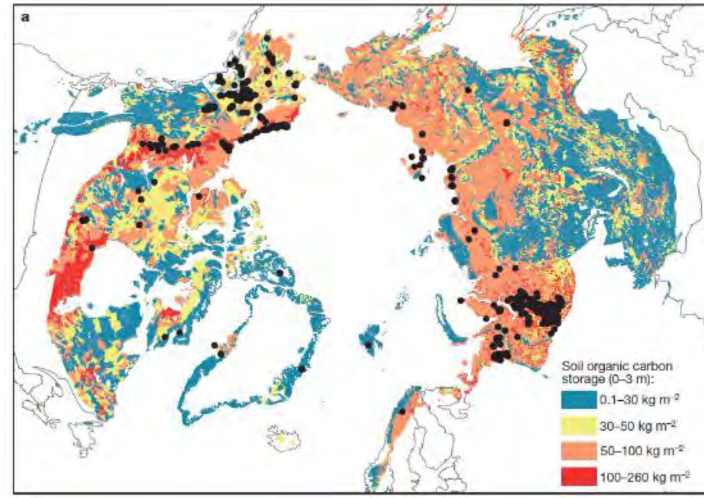
E. A. G. Schuur[1,2], A. D. McGuire[3], C. Schädel[1,2], G. Grosse[4], J. W. Harden[5], D. J. Hayes[6], G. Hugelius[7], C. D. Koven[8], P. Kuhry[7], D. M. Lawrence[9], S. M. Natali[10], D. Olefeldt[11,12], V. E. Romanovsky[13,14], K. Schaefer[15], M. R. Turetsky[11], C. C. Treat[16] & J. E. Vonk[17]

- **Background:** The Arctic stores an estimated 770±100 Pg carbon belowground and warming can release great amounts of carbon stored in permafrost, but we poorly understand the processes and mechanisms involved in this response.

- **Approach:** Synthesize research on: large-scale estimates of where permafrost carbon is; decomposition dynamics of permafrost under laboratory incubations; and efforts to include these processes in Earth system models (ESMs); abrupt processes such as thermokarst lake formation.

- **Results:** Abrupt permafrost carbon releases appear unlikely, but long-term, slow carbon losses (~92 Pg carbon) in response to warming over the next 100 years is projected by all modeling approaches.

- **Impact:** In a warming world, permafrost carbon emissions will constitute a significant feedback to climate change, making climate change happen faster then we would expect based on projected emissions from human activities alone.



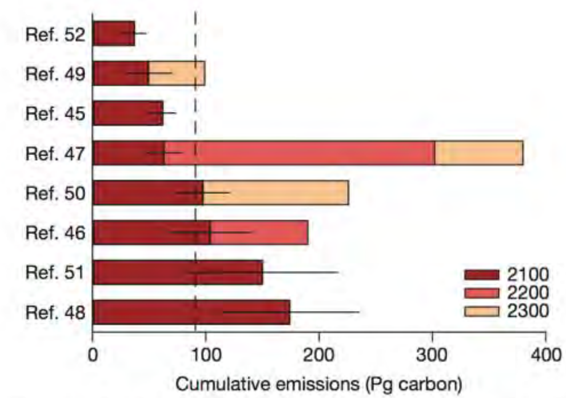


Figure 3 | Model estimates of potential cumulative carbon release from thawing permafrost by 2100, 2200, and 2300. All estimates except those of refs 50 and 46 are based on RCP 8.5 or its equivalent in the AR4 (ref. 97), the A2 scenario. Error bars show uncertainties for each estimate that are based on an ensemble of simulations assuming different warming rates for each scenario and different amounts of initial frozen carbon in permafrost. The vertical dashed line shows the mean of all models under the current warming trajectory by 2100.

Schuur, E. A. G., A. D. McGuire, C. Schädel, G. Grosse, J. W. Harden, D. J. Hayes, G. Hugelius et al. 2015. Climate change and the permafrost carbon feedback. *Nature* 520:7546: 171-179. doi:10.1038/nature14338.

FOREST ECOLOGY

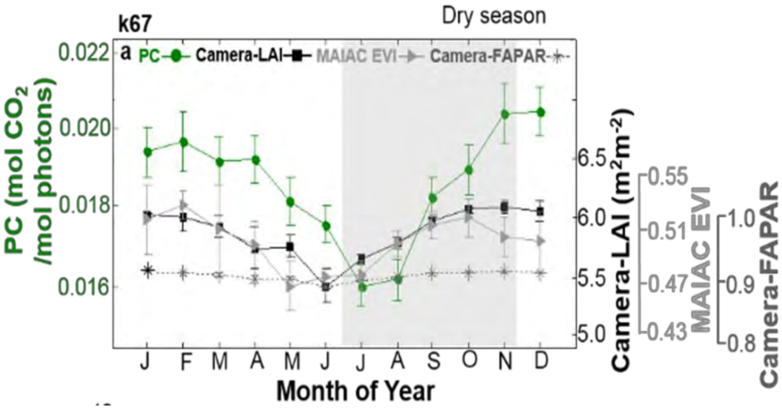
Leaf development and demography explain photosynthetic seasonality in Amazon evergreen forests

- **Background:** While most tropical forests are evergreen, their ability to photosynthesize is seasonal, which rises in the dry season and the cause was under debate.

- **Approach:** Cameras were used to monitor leaf changes throughout the canopy and CO2 was measured to quantify changes in photosynthesis.

- **Results:** During the dry season, old leaves senesce and replaces by more photosynthetically-efficient new growth.

- **Impact:** Results elucidate how tropical forests regulate their seasonal efflux of CO_2 and helps reconcile the discrepancy between direct observations of photosynthesis with changes in canopy "greenness" observed from remote sensing. By not assuming constant canopy greenness, models can be transformed to improve our ability to predict how tropical forest function in a changing climate.



Wu, J., L.P. Albert, A.P. Lopes, N. Restrepo-Coupe, M. Hayek, K.T. Wiedemann, K. Guan, S.C. Stark, B. Christoffersen, N. Prohaska, J.V. Tavares, S. Marostica, H. Kobayashi, M.L. Ferreira, K. Silva Campos, R.da Silva, P.M. Brando, D.G. Dye, T.E. Huxman, A.R. Huete, B.W. Nelson, S.R. *Saleska*. 2016. Leaf development and demography explain photosynthetic seasonality in Amazon evergreen forests. *Science*. Vol 351, Issue 6276, pp. 972-976.

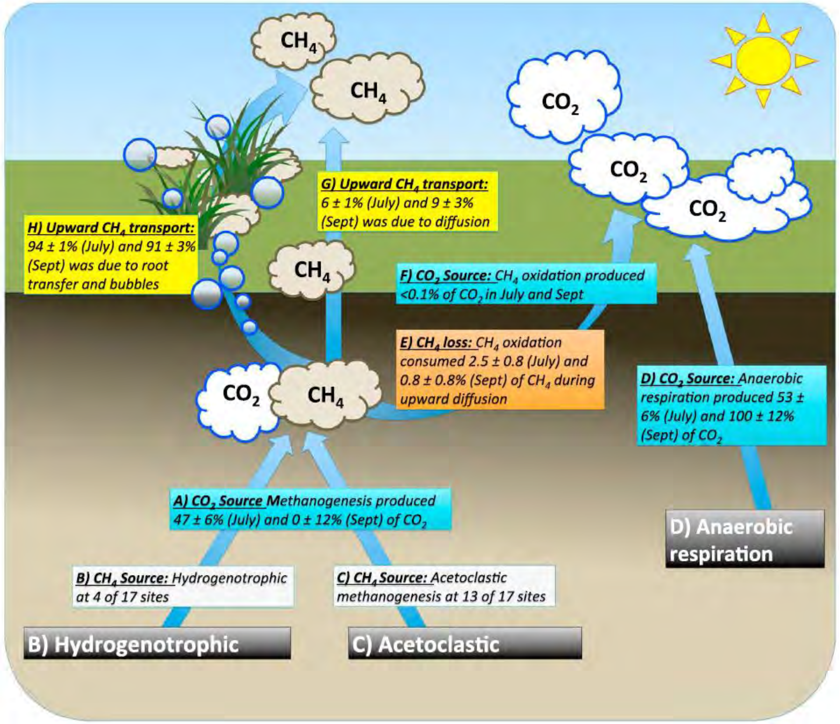
Pathways and transformations of dissolved methane and dissolved inorganic carbon in Arctic tundra watersheds: Evidence from analysis of stable isotopes

- **Background:** Permafrost soils have the potential to release vast amounts of CO_2 & CH_4 into the atmosphere. However, predicting this release is challenging due to substantial landscape heterogeneity.

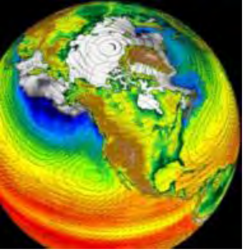
- **Approach:** This study quantified stable isotopes of dissolved carbon and CH_4 in Barrow, AK to estimate CH4 pathways and transformations.

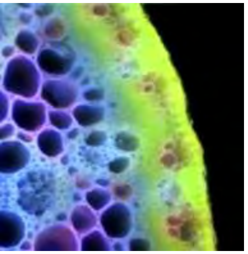
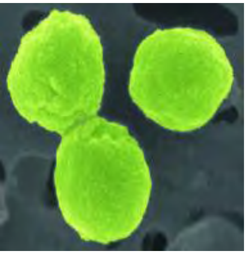
- **Results:** The majority of subsurface CH4 was transported upward by plants and ebullition (bubbling), thus bypassing the potential for CH4 oxidation.

- **Impact:** Results highlight the importance of micro topography and temporal variability when trying to predict CH_4 efflux from Arctic systems and will lead to improved model accuracy..



Throckmorton, H.M., Heikoop, J.M., Newman, B.D., Altmann, G.L., Conrad, M.S., Muss, J.D., Perkins, G.B., Smith, L.J., Torn, M.S., Wullschleger, S.D. and Wilson, C.J., 2015. Pathways and transformations of dissolved methane and dissolved inorganic carbon in Arctic tundra watersheds: Evidence from analysis of stable isotopes. *Global Biogeochemical Cycles*, *29*(11), pp.1893-1910.



Terrestrial Ecosystem
SCIENCE

Questions?