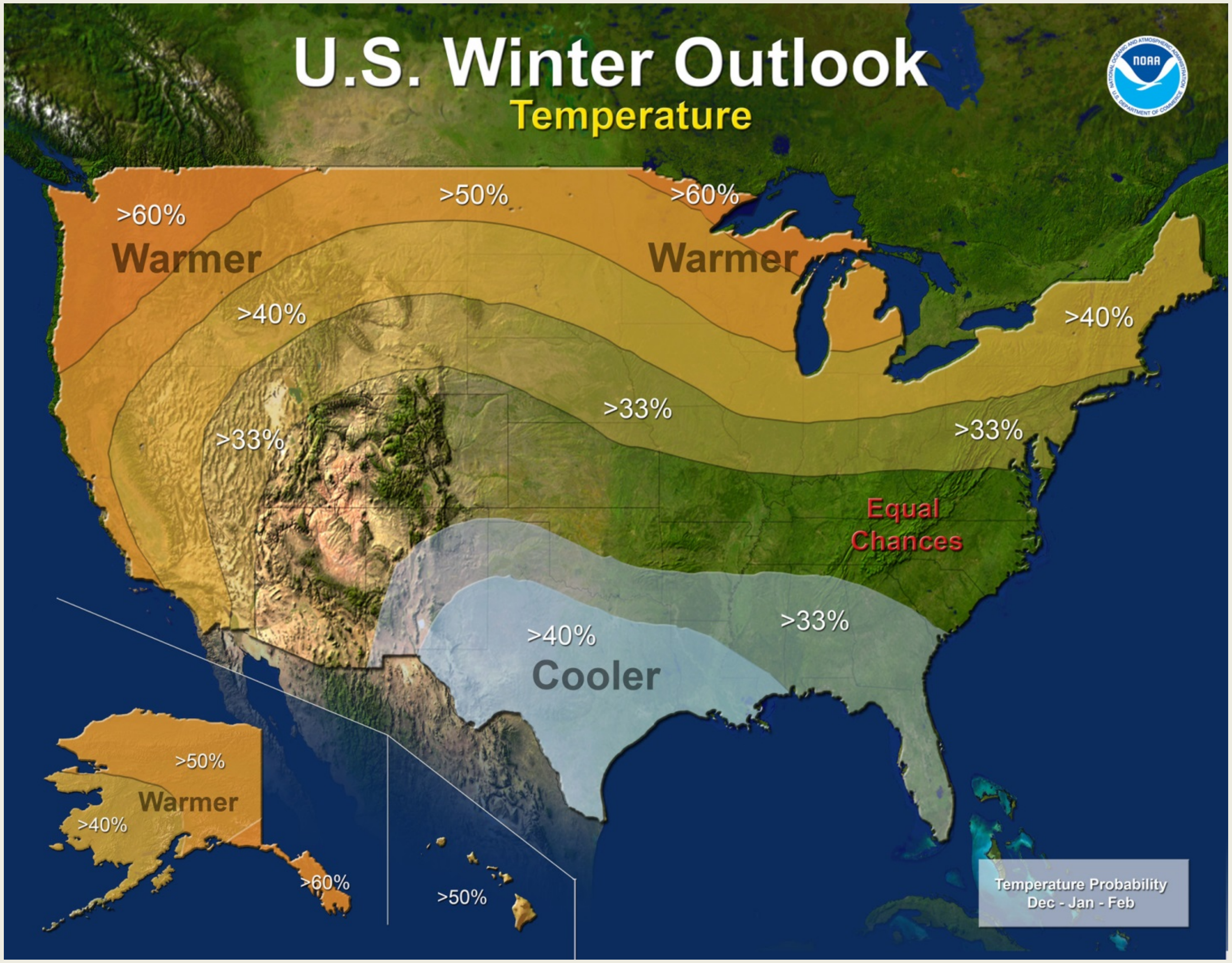
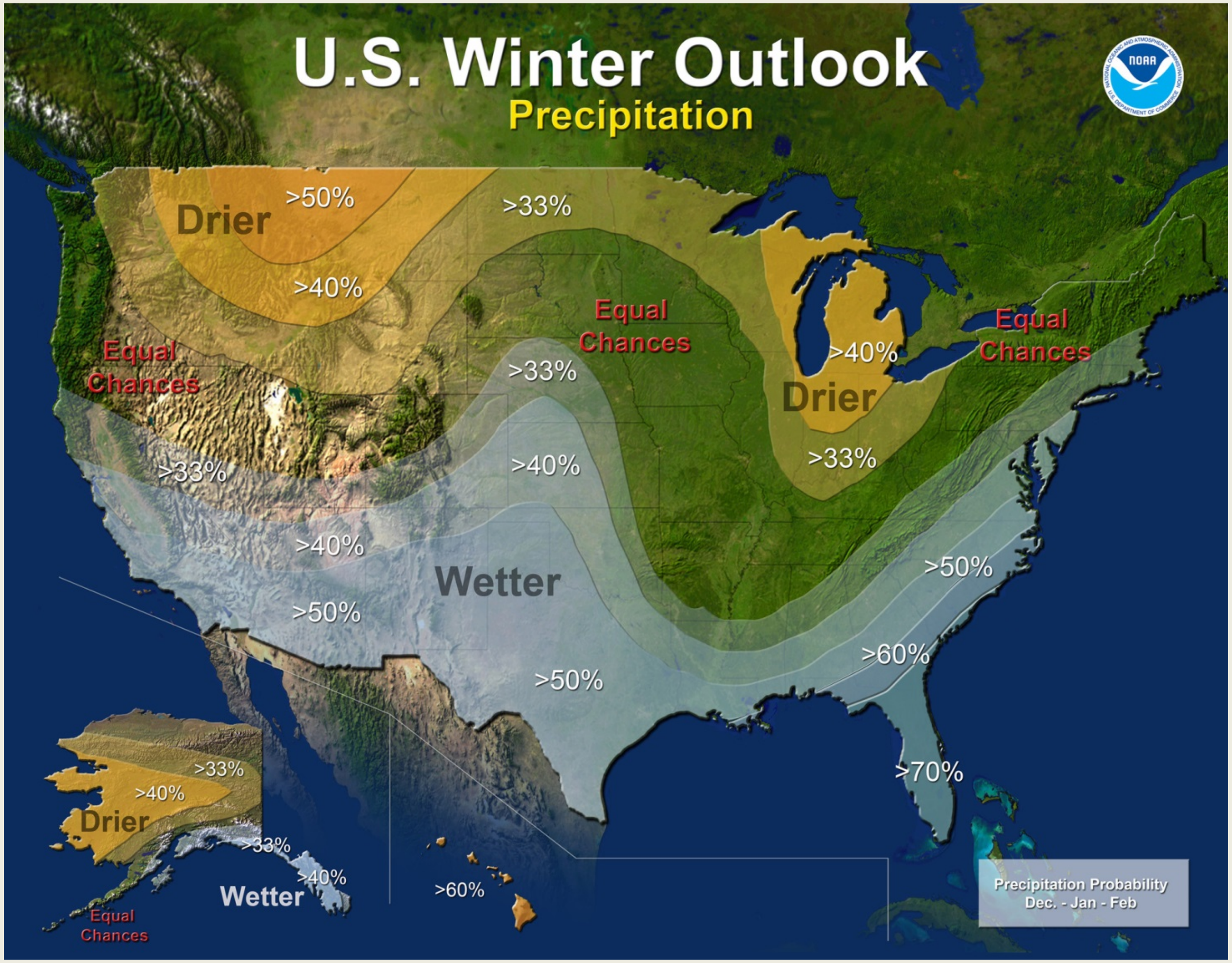
Climate and Environmental Sciences Division

BERAC update

October 28, 2015

G. Geernaert
BER/CESD


U.S. Winter Outlook
Temperature
>60%
Warmer
>50%
>60%
Warmer
>40%
>40%
>33%
>33%
>33%
Equal Chances
>40%
Cooler
>33%
>50%
Warmer
>40%
>60%
>50%
Temperature Probability
Dec - Jan - Feb


U.S. Winter Outlook
Precipitation
Drier
>50%
>40%
>33%
Equal
Chances
Equal
Chances
>33%
>40%
Drier
>33%
Equal
Chances
>33%
>40%
>33%
>40%
>50%
Wetter
>50%
>50%
>60%
>70%
>33%
>40%
Drier
>33%
>40%
Wetter
Equal
Chances
>60%
Precipitation Probability
Dec. - Jan - Feb

Outline

- Strategic update
- Administrative
- Highlights – facilities and new science

CESD updating strategic plan in FY16

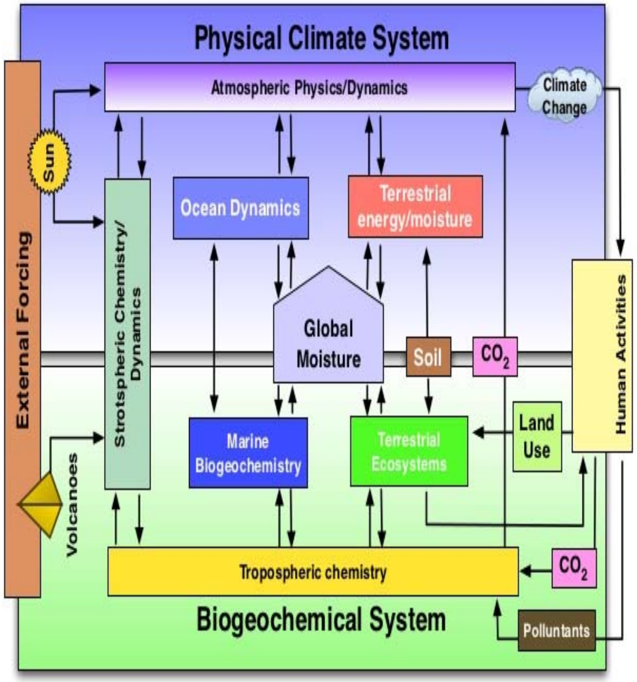
Science of prediction to understand interdependencies, variabilities, and rates of change:

- Scale aware processes / dynamics
- Physical, chemical, and biogeochemical
- Human component of climate change systems:

New topics to expect

- Problems demanding exascale computing
  - Water, extremes, cascading tipping points, etc…
- Refined set of field research priorities
- EMSL mapping more to CESD/BER science
- Extremes, and triggers for change
- Hybrid IA and IAV components
- USGCRP linkages to "seamless predictability"

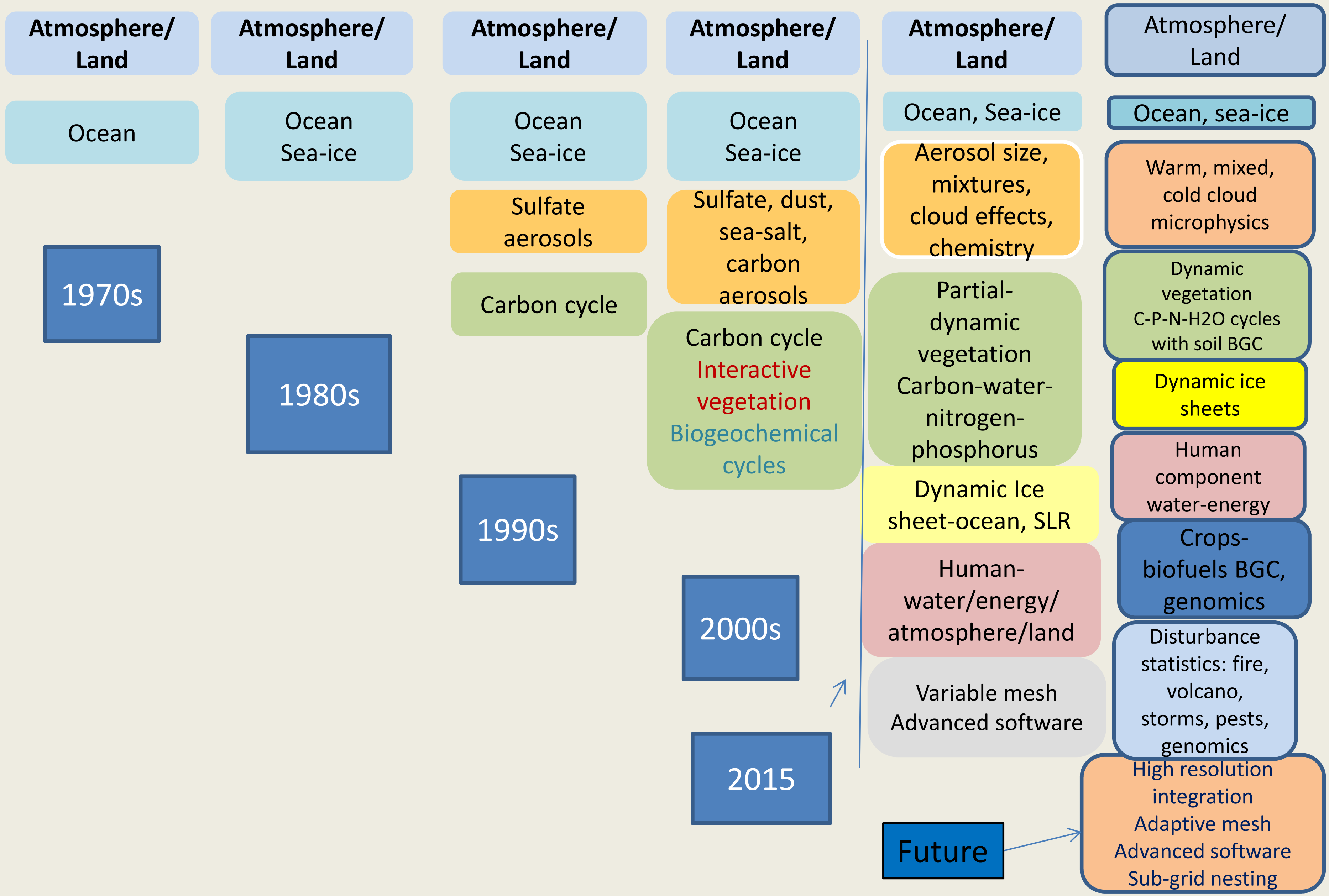
Dynamic earth system



Big data analytics

- Complex data, more sophisticated analytics, interagency collaborations
- Metadata compatibility – models, observations, server side analysis
- Metrics, skill, and UQ

Evolution of BER Climate and Earth System Modeling Architecture



Workshops – these matter "a lot"

Date	Date	Venue
Apr 30 – May 1	Model-data integration – frameworks, data, workflows	Potomac MD
May 13-14	Aerial observation needs for atmos environ sciences	Gaithersburg
June 25-19	CESM annual meeting	Breckenridge
July 27-Aug 7	Energy modeling forum (initial IA/IAV planning mtg)	Snowmass
July	ASR topical workshop on secondary organic aerosols	PNNL
Aug 13-14	Workshop on Virtual Data Integration	GTN
Sept 30 – Oct2	Workshop on High Res Modeling	NCEP
Oct 21-22	ARM-ASR-ACME Coordination workshop	GTN
Nov 17-18	Trait methods for land models	Rockville
Nov 19	ACME-NGEE coordination workshop	Rockville
Jan 2016	ASR topical workshop on absorbing aerosols	GTN
Jan 2016	ASR topical workshop on marine low clouds	ANL
Jan 26-18	Advances in math and computational climate modeling	Rockville
Feb 8-11	Mechanistic understand of watershed system dynamics	Rockville
Feb/Mar 2016	Topical workshop-IA/IAV goals and science objectives	USGCRP
March 1-3	ILAMB workshop	DC area
Summer	Terrestrial-Aquatic interface	DC area

DOE Workshop on Aerial Observation Needs for Climate and Environmental Sciences

May 13-14, 2015; Gaithersburg

Organizers: Shaima Nasiri; David Lesmes; Rick Petty

Workshop Chairs: Andy Vogelmann (BNL); Beat Schmid (PNNL); Shawn Serbin (BNL)

Objectives:

- Improve climate relevant process-level understanding of interactions among aerosols, clouds, precipitation, radiation, dynamics, and thermodynamics.
- Observe terrestrial system properties (bedrock to tree tops) across broad spatial and temporal scales => system structure, dynamics and evolution

Key findings:

- Both manned and unmanned aerial systems are essential
- Improved and miniaturized sensors are necessary to advance science
- Routine observations are as important as traditional field campaigns

Some specific needs

- Frequent *in situ* vertical profiling of aerosols across entire range of sizes
- Total ice mass and ice particle size distributions in ice and mixed-phase clouds
- High-resolution atmospheric state measurements in and out of clouds
- Campaigns using multiple sensing systems terrestrial system structure and evolution
- Frequently repeated measurements to capture system dynamics (e.g., using miniaturized sensors on UAVs)
- Integration of multiple sensors on a single platform for terrestrial science
- Integration of aerial and ground based measurements to bridge scales from points to coarse grid scales (e.g., Ameriflux Network and NGEE projects)

Management Update: Recent and projected solicitations

Funds	Program lead	Issued	Proposals	Panel	Selected
FY15	Atmospheric System Research – ARM ENA, and ARM NSA science leads	May 27, 2014	5	Nov 7, 2014	2
FY15	Environmental System Science – annual FOA	July 31, 2014	116	Mar 23-27, 2015	7
FY15	Atmospheric System Science – annual FOA	Aug 5, 2014	96	Feb 17-20, 2015	15
FY16	**Environmental System Science – annual FOA**	**Oct 7**		**spring**	
FY16	**ASR – annual**	**Oct 2**		**spring**	
FY16	**ASR - data products**	**Oct 2**		**spring**	
FY16	**Modeling – development, downscaling, etc.**	**Late November**			

Management updates: Major reviews in FY 2015

Lab	Program	Type	Review 2015	Outcome
NGEE Tropics	ESS	Project new	Mar 18-19	Accept
ORNL	SBR	SFA	April 16	Accept
ANL	SBR	SFA	April 27	Accept
LLNL	SBR	SFA	April 27	Accept
CDIAC (ORNL)	Data, ESS	Project renewal	May 19-20	Not accepted, resubmit
ORNL	TES spruce	SFA	June 23-24	Accepted
LLNL	RGCM, ASR	SFA	Aug 18-19	Accepted/revision
PNNL	RGCM	SFA	Aug 20-21	Accepted/revision
NGEE Arctic-2	TES	Phase 2	August	Accepted
PNNL	IA	SFA	Sept 9-10	Accepted

Management updates: 2015-2016. PI meetings

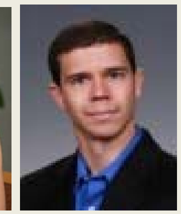
Title	Program(s)	Location	Date in 2015/2016
ARM/ASR Facility PI meeting	ARM, ASR	Tysons	March 16-20, 2015
ESS PI meeting	TES, SBR	Bolger	April 28-29, 2015
ESS PI meeting	TES, SBR	Bolger	April 28-29, 2015
ACME PI meeting	ESM	Bolger	May 5-7, 2015
EASM PI meeting	RGCM	Rockville	Aug 31 – Sept 2, 2015
ESS PI meeting	TES, SBR, EMSL	DC area	Apr 26-27, 2016
ARM-ASR joint PI meeting	ARM / ASR	Tysons	May 2-5, 2016

Developments at EMSL

Leadership Change and Scientific Hires

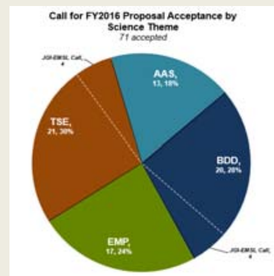
- Harvey Bolton – Interim EMSL Director
- David Stahl – Chief Scientist
- Kirsten Hofmockel – Integrative Research Lead
- John Shilling – Interim AAS Science Theme Lead





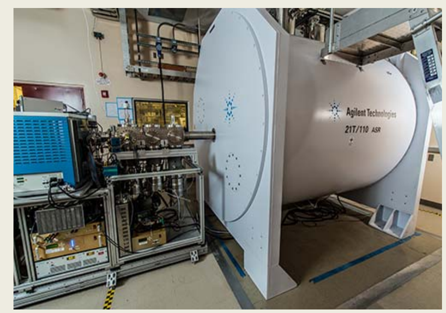
- Allison Campbell – Acting ALD at PNNL for Earth & Biological Sciences

Proposal Opportunities



- 2015 Science Theme call – 63 new projects
- 2015 EMSL-JGI call – 8 new projects

Capabilities

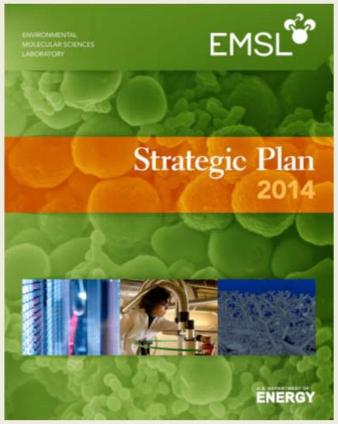


- HRMAC Project (21T Mass Spec) – First science projects underway.
- Dynamic TEM: Demonstrated (1 μsec) pulsed electron beam.

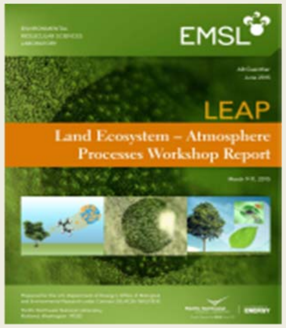
Outreach and User Activities

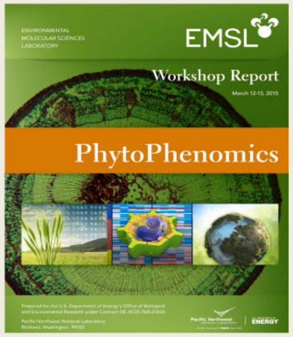
- *Molecular Bond*: Soil Organic Matter; 21T Mass Spec; Woody biomass deconstruction
- Electron Microscopy for Biol, Env and Energy Research – July 2015
- Multi-omics for Microbiomes Conference – Sept 2015

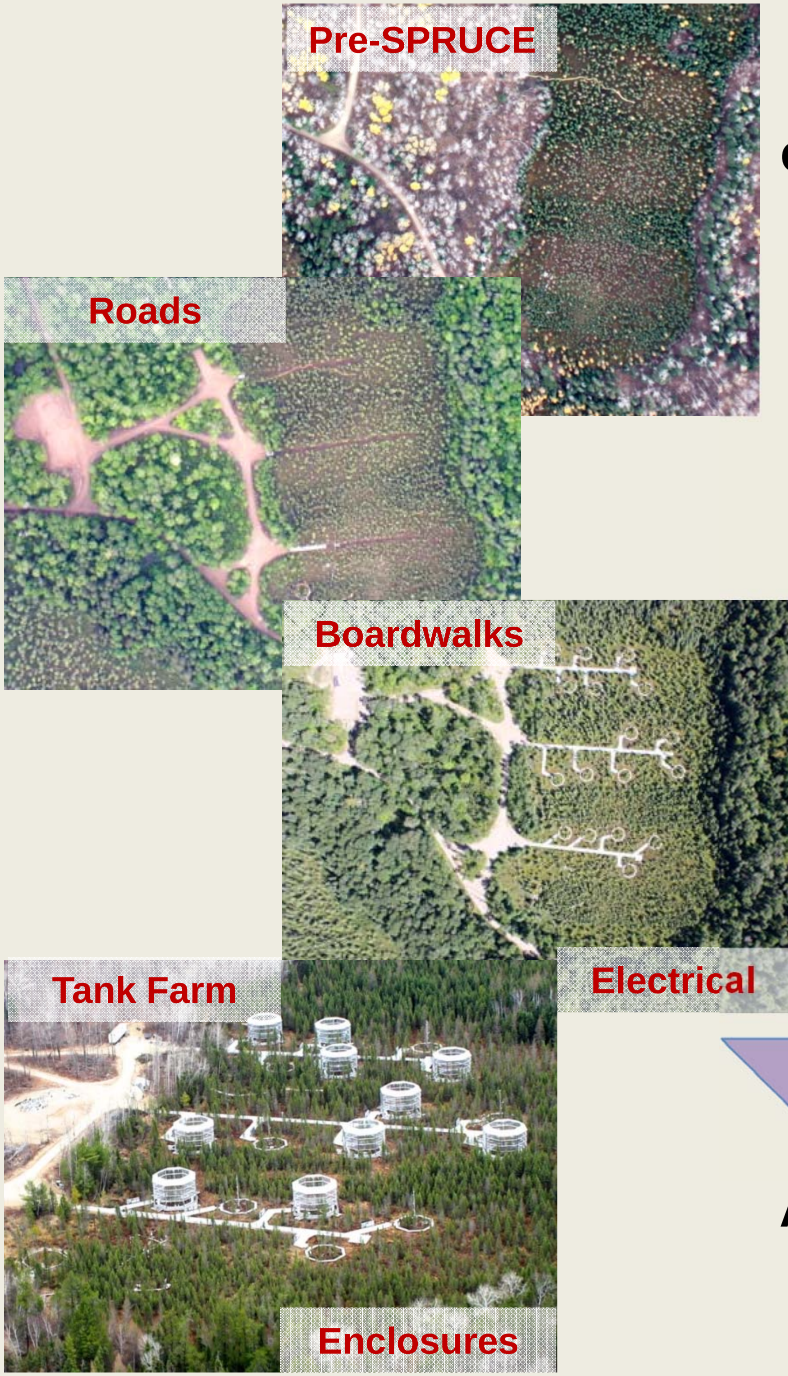
EMSL Strategic Directions and Science Planning



- **EMSL Strategic Plan – June 2015**
  - EMSL's four Science Themes drive the plan.
  - 10-year Leadership Areas for each Science Theme.
- **Computational Strategy to advance BER science – July 2015**
  - Hardware, Code optimization, Data mgmt/Storage, Infrastructure.
  - Developed with input from BER staff.
- **EMSL Outreach Strategy – late October 2015**
  - Developed with input from BER staff, users, EMSL Advisory Committees.
- **Implementing Quiet Wing, Rad Annex and HRMAC (Notable) Strategic Plans**
  - 23 projects selected from Special Science call.
- **2015 Strategic Directions Workshops**
  - Land Ecosystem – Atmosphere Processes (A. Guenther)
  - PhytoPhenomics (C. Jansson)





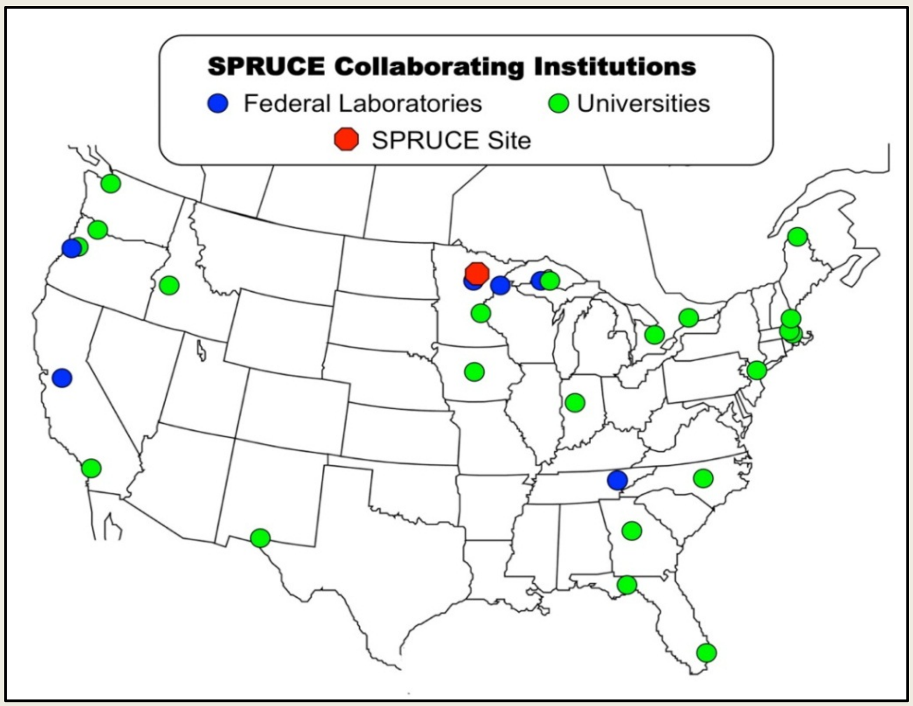


October 2011

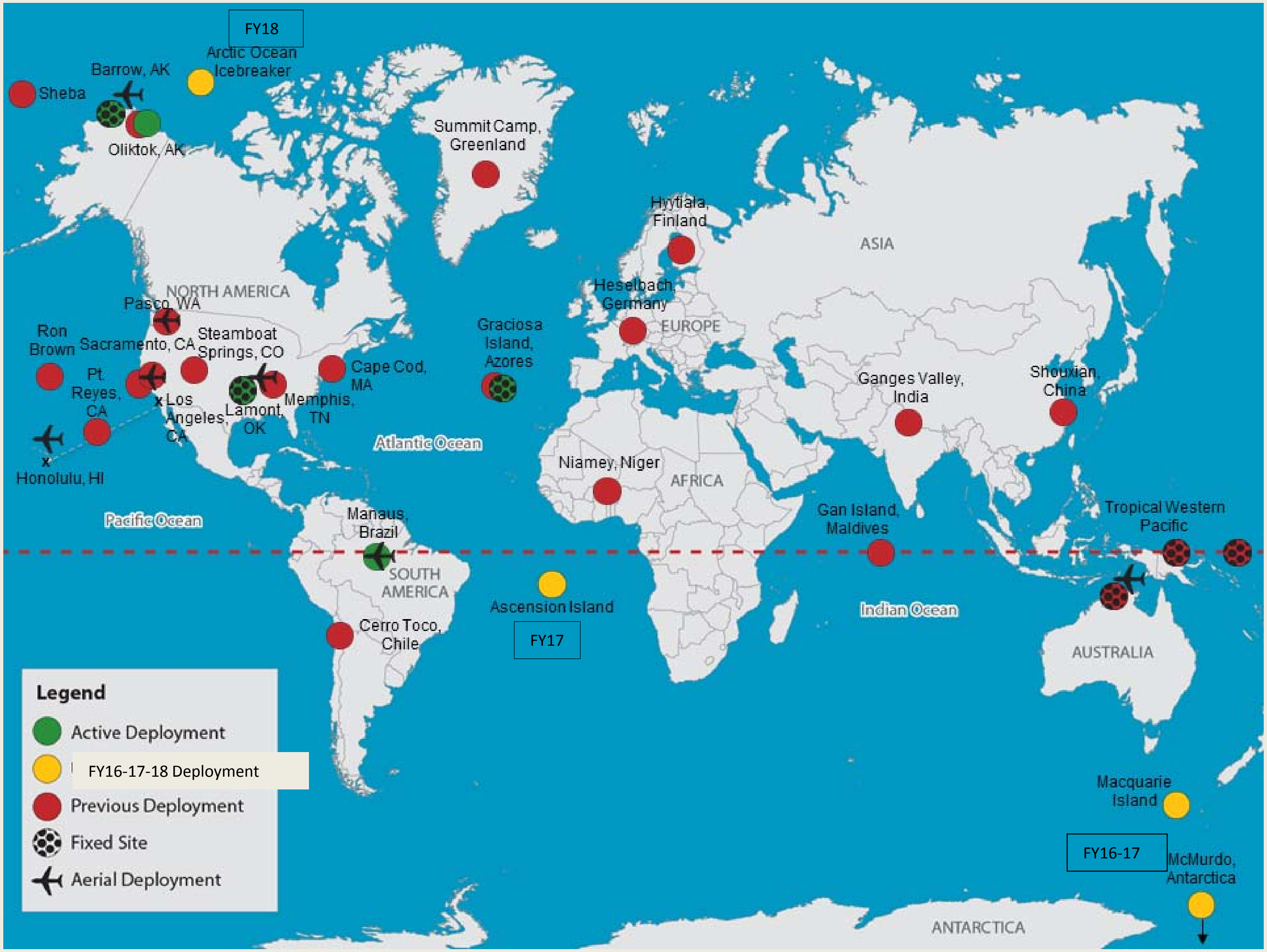
August 2015

Deep Peat Heating – June 2014 through July 2015

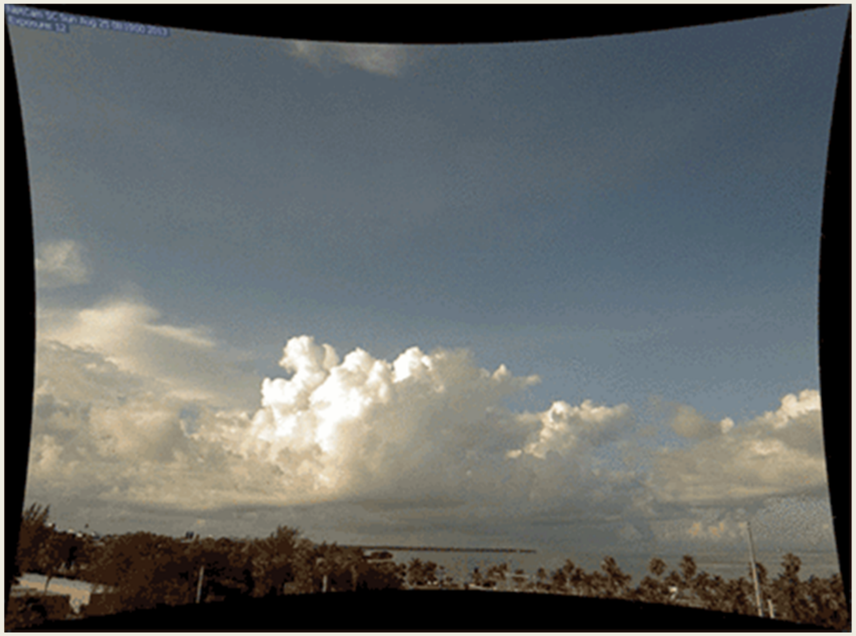
Whole-Ecosystem Warming Initiated 13 August 2015


SPRUCE Collaborating Institutions
Federal Laboratories
Universities
SPRUCE Site

ARM Climate Research Facility deployments



Stereo photogrammetry reveals substantial drag on cloud thermals



Approach

Use stereo photogrammetry to track the sizes and speeds of cloud thermals to solve a simple momentum equation: acceleration = buoyancy – drag.

Objective

Test "slippery thermal" hypothesis that drag on cloud updrafts is negligible.

Impacts

Cloud thermals are "sticky". Substantial drag (drag coefficient ~ 1) is needed to match the stereo-photogrammatic data, in situ observations and recent LES output. Theoretical calculations reveal that wave drag could be the source of this drag.

Citation: Romps, D. M., and R. Öktem (2015), Stereo photogrammetry reveals substantial drag on cloud thermals, *Geophysical Research Letters, doi:10.1002/2015GL064009.*

Fog and Rain in the Amazon

Motivation

- Amazon rain forest is a large terrestrial sink of CO2; need to accurately predict tropical climate to understand impacts on carbon cycle
- Current climate models do not correctly represent key features of diurnal and seasonal water cycles in the Amazon

Fog at eddy covariance tower K87 in the Amazon. Image courtesy of Joe Berry, Carnegie Institution for Science.

Approach

- Use observations and modeling from GOAmazon campaign to study land-atmosphere interactions that impact water cycle
- Use a modeling approach opposite to climate models: resolve small-scale convective processes and parameterize large-scale circulation
- Study combines expertise and support from TES, ASR, and ARM

Impact

- Modeling approach reduces bias in seasonal cycle of surface fluxes and precipitation
- Improvements are due to: 1) representation of morning fog layer and 2) more accurate characterization of convection and coupling with large-scale circulation
- Results highlight the importance of the coupling between the energy and hydrological cycles and the key role of cloud albedo feedback for climates over tropical continents

Reference: Anber U, P Gentine, S Wang, and A Sobel. 2015. "Fog and Rain in the Amazon." *Proceeding of the National Academy of Sciences*, 112(37), doi:10.1073/pnas.1505077112.

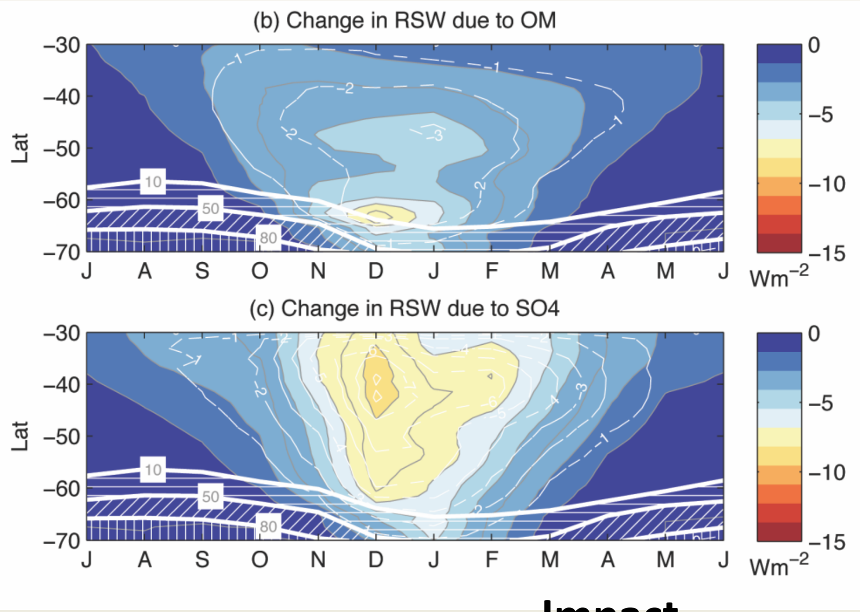
Natural Aerosols Explain Seasonal and Spatial Patterns of Southern Ocean Cloud Reflectivity

Objective

- Determine the contribution of aerosol sources from phytoplankton to variability in cloud drop number concentration and albedo (reflectivity) over the Southern Ocean

Approach

- Remove high-latitude biases from satellite measurements of cloud drop number concentration
- Determine the statistical relationships between monthly, regionally averaged values of observed cloud droplet number concentration and modeled sulfate aerosol and marine organic matter



Analysis of satellite-observed CDNC shows that marine organic matter statistically predicts a portion of geographic and seasonal variability over the Southern Ocean, with statistically significant effects on reflected shortwave (RSW) radiation (left)

Impact

- Southern Ocean clouds are highly sensitive to changes in the aerosol concentrations in the pristine environment
- For the first time, an observationally-based study shows the direction and magnitude of the effect of marine organic matter on the reflectivity of clouds.

DT McCoy, SM Burrows, R Wood, DP Grosvenor, SM Elliott, P-L Ma, PJ Rasch, and DL Hartmann. 2015. "Natural Aerosols Explain Seasonal and Spatial Patterns of Southern Ocean Cloud Albedo." *Science Advances* 1(6): e1500157. July 17, 2015. DOI: 10.1126/sciadv.1500157

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

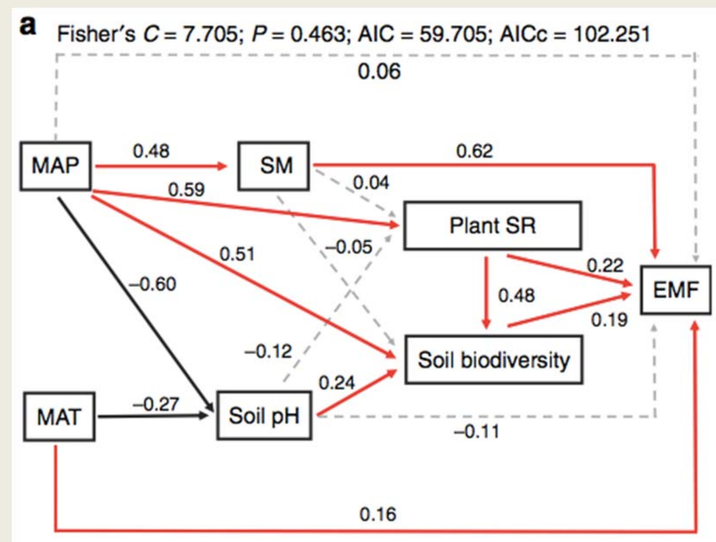
Xin Jing[1], Nathan J. Sanders[2], Yu Shi[3], Haiyan Chu[3], Aimée T. Classen[4], Ke Zhao[1], Litong Chen[5], Yue Shi[1,6], Youxu Jiang[7] & Jin-Sheng He[1,5]

- **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.

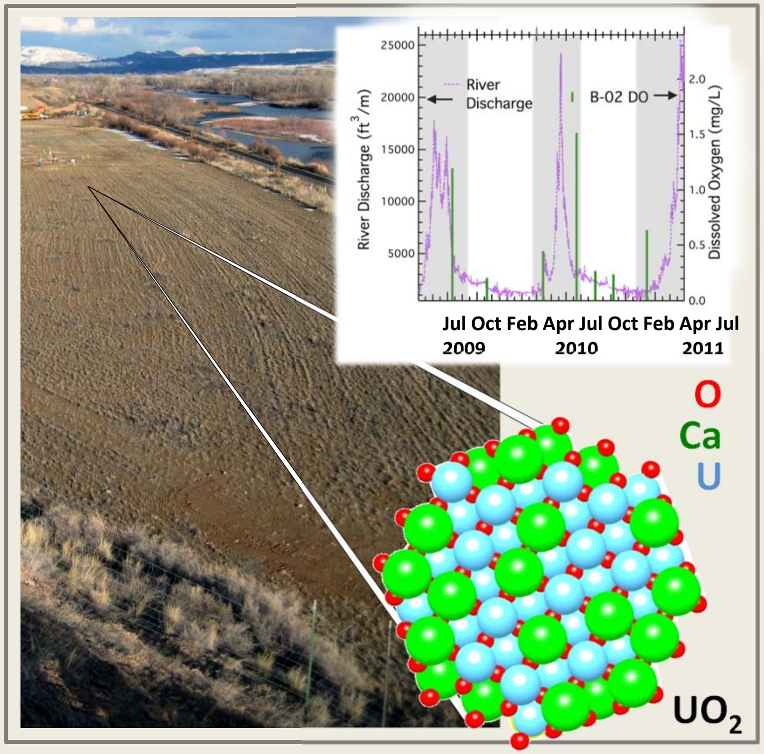
- **Impact:** First, including belowground biodiversity in models can improve the ability to explain and predict EMF. Second, regional scale variation in climate can determine the effects of biodiversity on EMF. This study received international media coverage promoting the idea that more attention needs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

Hot moments control UO_2 oxidation in the Rifle Aquifer



Dissolved oxygen concentrations in the Rifle aquifer (green bars) are briefly and sharply elevated in the early summer when the Colorado River is at high-water stage (magenta curve). UO_2 dissolution proceeds rapidly at these times. Lower right: Naturally abundant Ca^{2+} atoms (green) bond to U sites at surfaces of UO_2 nanoparticles, slowing oxidation.

J.S. Lezama-Pacheco, J. Cerrato, H. Veeramani, D.S. Alessi, E.I. Suvorova, R. Bernier-Latmani, D.E. Giammar, P.E. Long, K.H. Williams, and J.R. Bargar, *ES&T*. **49** (12), 7340 (2015)

Scientific Achievement

Oxidation of subsurface uraninite (UO_2) occurs during "hot moments" when dissolved oxygen is abundant in groundwater during seasonal meltwater runoff.

Significance and Impact

These results highlight the profound importance of summer meltwater as a driver for biogeochemical contaminant cycling in Colorado River Basin floodplains. UO_2 oxidation is rapid during hot moments and negligible the rest of the year. This study further supports models for seasonal oxidation of U(IV) in organic-rich sediments, abundant at the site, believed to help sustain the persistent U plume.

Research Details

– A method was developed to study UO_2 oxidation *in-situ* in the Rifle aquifer over multiple seasons.

– After oxidation, UO_2 was characterized using synchrotron x-ray spectroscopy, electron microscopy, and chemical extraction methods.

SSRL is a national user facility supported by DOE-BES

REVIEW

doi:10.1038/nature14338

Climate change and the permafrost carbon feedback

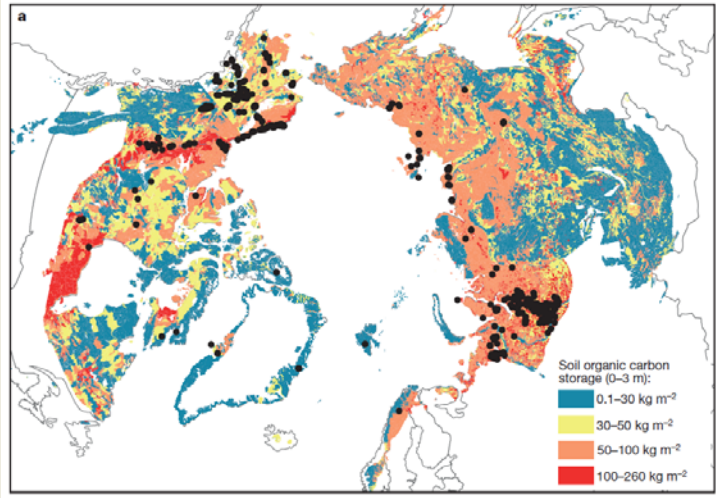
E. A. G. Schuur[1,2], A. D. McGuire[3], C. Schädel[1,2], G. Grosse[4], J. W. Harden[5], D. J. Hayes[6], G. Hugelius[7], C. D. Koven[8], P. Kuhry[7], D. M. Lawrence[9], S. M. Natali[10], D. Olefeldt[11,12], V. E. Romanovsky[13,14], K. Schaefer[15], M. R. Turetsky[11], C. C. Treat[16] & J. E. Vonk[17]

- **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.



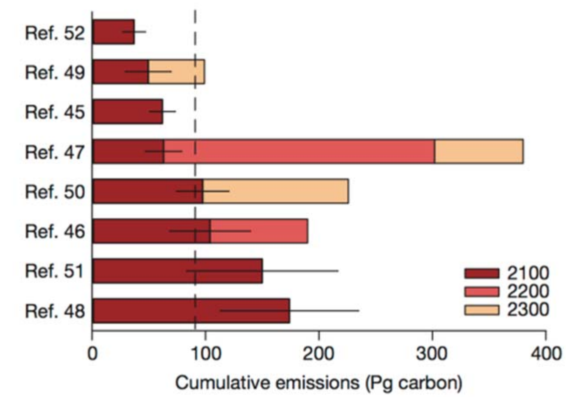
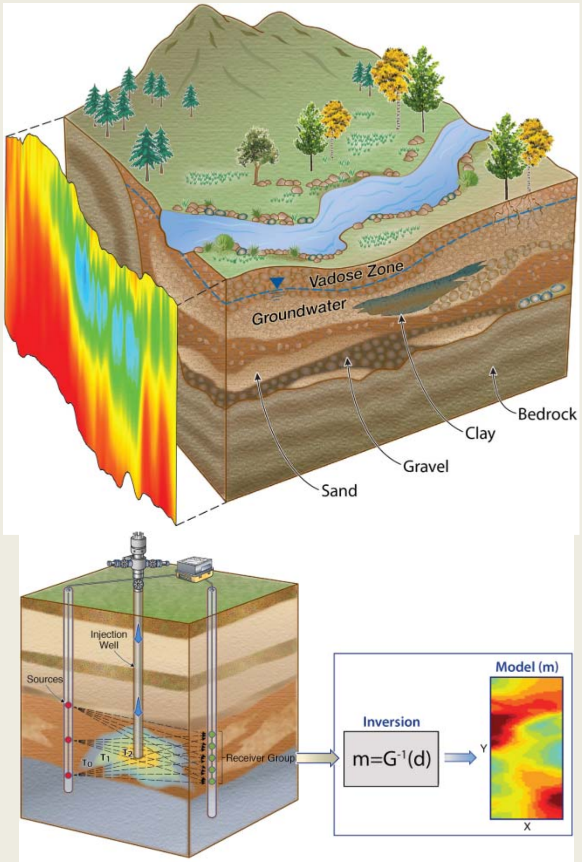


Figure 3 | Model estimates of potential cumulative carbon release from thawing permafrost by 2100, 2200, and 2300. All estimates except those of refs 50 and 46 are based on RCP 8.5 or its equivalent in the AR4 (ref. 97), the A2 scenario. Error bars show uncertainties for each estimate that are based 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.

The emergence of hydrogeophysics for improved understanding of subsurface processes over multiple scales

Andrew Binley, **Susan S. Hubbard**, Johan A. Huisman, Andre Revil, David A. Robinson, Kamini Singha, and Lee D. Slater



Figures: Inversion and integration of point measurements with geophysical data have greatly illuminated how complex environmental systems function, including controls on flow and transport of water, contaminants and critical elements.

Significance and Impact

As part of the special section dedicated to the 50 years of research on key advances in Water Resources Research, this paper documents how hydrogeophysical methods have emerged as valuable tools for investigating multi-scale hydrological processes over the past two decades. It also describes recent advances in biogeophysics and a vision for future developments relevant to watershed and ecosystem science.

Many of the pioneering advances described in the paper have been developed through DOE-BER support. Examples include joint hydrogeophysical inversion, time-lapse monitoring, zonation, biogeophysical, and coincident above-and-below ground monitoring approaches. These advances have been critical for quantifying processes and interactions associated with contaminant remediation, agriculture, water resources, and most recently, ecosystem functioning.

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Water Resources Research, 2015
doi: 10.1002/2015WR017016

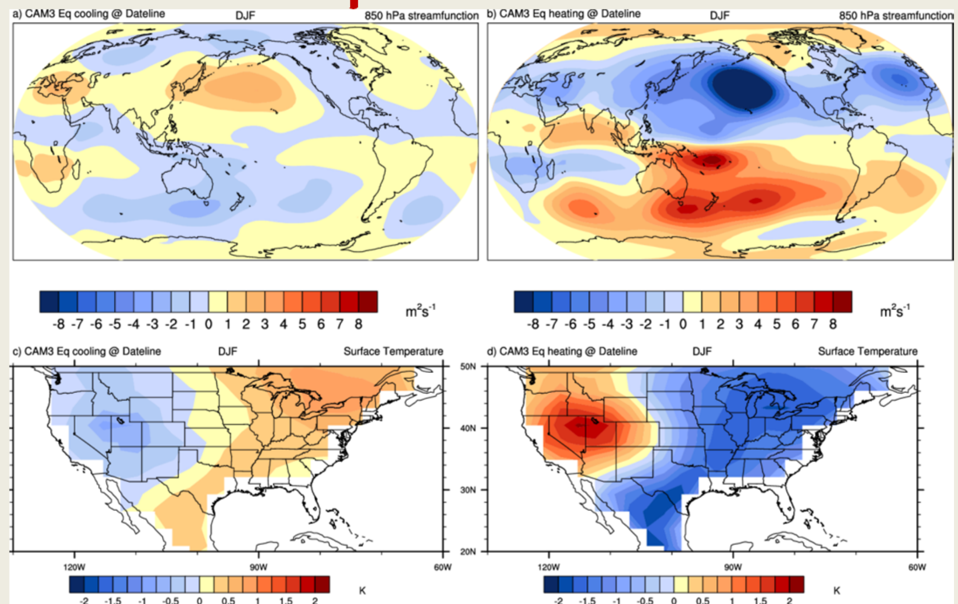
Disappearance of the southeast U.S. “warming hole” in the early 21st century is tied to the tropical Pacific

Objective

Understand why the cooling trend in the southeast U.S. from about 1950-2000, the “warming hole”, changed to a warming trend there after 2000

Approach

- The Interdecadal Pacific Oscillation (IPO) changed phase from above-normal tropical Pacific SSTs to below-normal SSTs around 2000
- Apply an atmosphere-only model with a negative specified convective heating anomaly associated with these cooler SSTs and reduced precipitation over the equatorial central Pacific to show the effects of the IPO on large-scale atmospheric circulation changes that affect U.S. temperatures



A “warming hole” over the southeast U.S. (lower right) is produced by atmospheric circulation anomalies (top right) with the positive phase of the IPO, while the pattern reverses and the warming hole disappears with the negative phase of the IPO (left panels) in the atmosphere-only model sensitivity experiments

RESULT: The negative phase of the IPO in the tropical Pacific after 2000 produced changes in atmospheric circulation that made the southeast U.S. warming hole disappear. Illustrates IPO linkage to climate variability and trends.

Meehl, G.A., J.M. Arblaster, and C.T.Y. Chung, 2015: Disappearance of the southeast U.S. “warming hole” with the late-1990s transition of the Interdecadal Pacific Oscillation. *Geophys. Res. Lett.*, doi:10.1002/2015GL064586.

Century-scale simulations of the response of the West Antarctic Ice Sheet to a warming climate

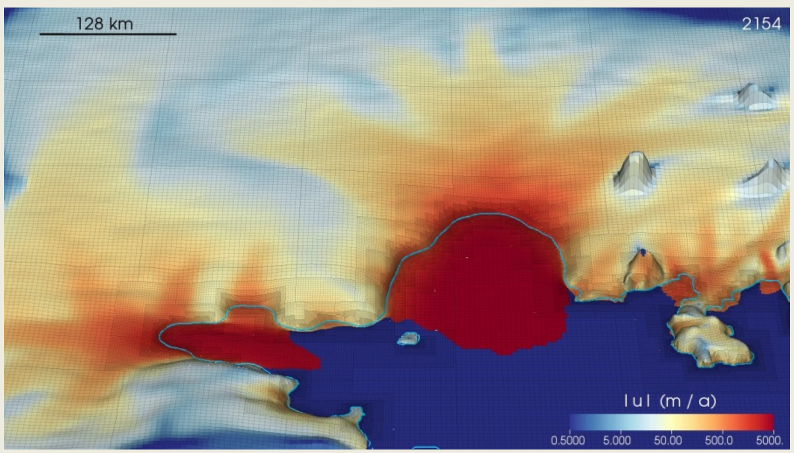
Objectives

- The 2007 & 2013 Intergovernmental Panel on Climate Change (IPCC) reports highlighted the need for better projections of the Antarctic contribution to sea-level rise (SLR)
- The West Antarctic Ice Sheet (WAIS) is particularly vulnerable due to marine forcing from warming oceans and because much of WAIS sits on bedrock below sea level
- Use global and regional climate models to generate ensemble of climate forcing scenarios to examine likely WAIS response to potential future climate forcing
- Need high (sub-kilometer) resolution to fully resolve dynamics of marine ice sheet retreat

Impact

- First fully process-based large-scale model projections of WAIS contributions to SLR, based on climate inputs from an ensemble of earth system models
- Used the Berkeley Adaptive Mesh Refinement (AMR) ice sheet model (BISICLES) to fully resolve dynamically important regions like grounding lines
- Projections range from no change to almost complete loss of the ice shelves over a few centuries, initially confined to the Amundsen Sea, with up to 0.5m SLR, in general agreement with estimates from IPCC reports
- Response is dominated by the retreat of marine ice sheets in response to warm-water incursions under Antarctic ice shelves

Amundsen Sea Embayment Ice Sheet after 200 Years of Retreat



Simulations conducted at the National Energy Research Scientific Computing Center (NERSC)

FY 2015 Accomplishments

- **First application of BISICLES, a state-of-the-art, AMR ice sheet model, to large-scale projections of WAIS response to climate forcing**
- **AMR allows for full resolution of dynamically changing grounding lines in regional- and continental-scale simulations**

Century-scale simulations of the response of the West Antarctic Ice Sheet to a warming climate", Cornford, Martin, Payne, Ng, et al, The Cryosphere, 9, 1579-1600, doi:10.5194/tc-9-1579-2015, 2015.

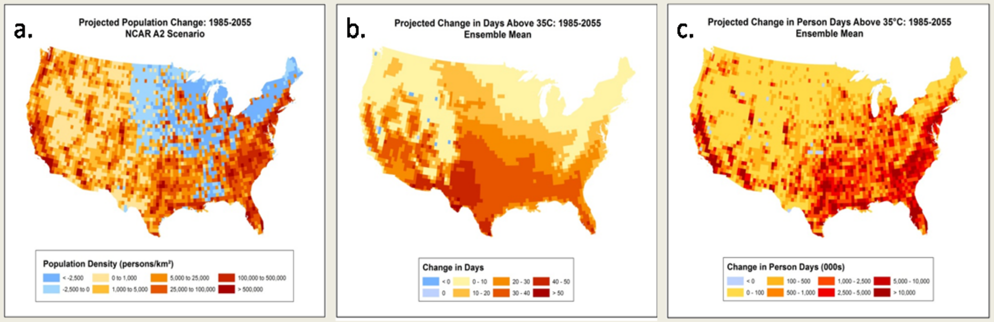
Future population exposure to U.S. heat extremes

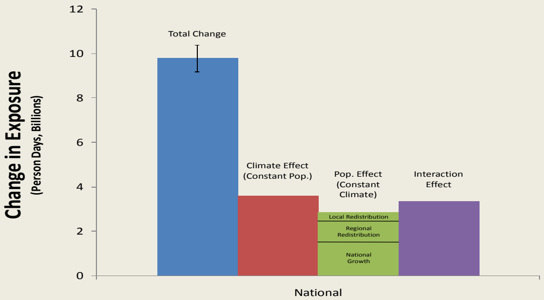
Objective

Determine the relative contribution to future population exposure to heat extremes of changes in temperature and changes in population size and distribution.

Approach

- Using a set of climate projections from NARCCAP and the NCAR population projections that are spatially resolved we perform an analysis that allows us to separate the effects of the different determinants of future changes in heat exposure by
  - holding population fixed and changing climate;
  - Holding climate fixed and changing population according to where population concentates nowadays (augmenting size proportionally to status-quo) and
  - By changing size and spatial distributon of population according to the NCAR pop model.
- We find that the two factors (changes in climate and changes in population) account for equal fractions of the total change in exposure.



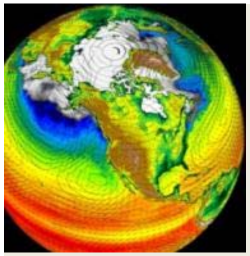


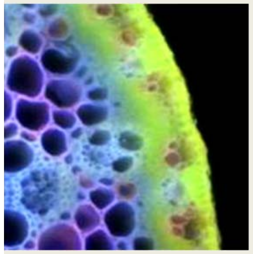
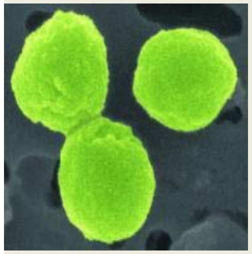
Top three panels : changes in population (left), in days with temperature above 35C (middle) and in person/days (right) by 2055 compared to 1985. Bottom panel: Total change in exposure and the three components that make it up: climate chages (red bar) population changes (green bar) and their interaction (purple bar). The latter is interpretable by people moving preferentially to places that are getting relatively hotter.

Impact

Most analyses of future changes stop at the changes in the physical climate as they are produced by climate models. Our results call attention to the need for considering future changes in the human/social dimension as well as in the physical system, to account fully for future changes in risk.

B Jones, BC O'Neill, L McDaniel, S McGinnis, LO Mearns, C Tebaldi 2015:
Future population exposure to U.S. heat extremes: *Nature Climate Change*, DOI: 10.1038/nclimate263.



Thank you!

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