Climate and Environmental Sciences Division

BERAC update

October 28, 2015

G. Geernaert
BER/CESD
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”

Big data analytics
- Complex data, more sophisticated analytics, interagency collaborations
- Metadata compatibility – models, observations, server side analysis
- Metrics, skill, and UQ
## Workshops – these matter “a lot”

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

<table>
<thead>
<tr>
<th>Funds</th>
<th>Program lead</th>
<th>Issued</th>
<th>Proposals</th>
<th>Panel</th>
<th>Selected</th>
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</thead>
<tbody>
<tr>
<td>FY15</td>
<td>Atmospheric System Research – ARM ENA, and ARM NSA science leads</td>
<td>May 27, 2014</td>
<td>5</td>
<td>Nov 7, 2014</td>
<td>2</td>
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<tr>
<td>FY15</td>
<td>Atmospheric System Science – annual FOA</td>
<td>Aug 5, 2014</td>
<td>96</td>
<td>Feb 17-20, 2015</td>
<td>15</td>
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<tr>
<td>FY16</td>
<td>Environmental System Science – annual FOA</td>
<td>Oct 7</td>
<td></td>
<td></td>
<td>spring</td>
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<tr>
<td>FY16</td>
<td>ASR – annual</td>
<td>Oct 2</td>
<td></td>
<td></td>
<td>spring</td>
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<tr>
<td>FY16</td>
<td>ASR - data products</td>
<td>Oct 2</td>
<td></td>
<td></td>
<td>spring</td>
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<tr>
<td>FY16</td>
<td>Modeling – development, downscaling, etc.</td>
<td>Late November</td>
<td></td>
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### Management updates: Major reviews in FY 2015

<table>
<thead>
<tr>
<th>Lab</th>
<th>Program</th>
<th>Type</th>
<th>Review 2015</th>
<th>Outcome</th>
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</thead>
<tbody>
<tr>
<td>NGEE Tropics</td>
<td>ESS</td>
<td>Project new</td>
<td>Mar 18-19</td>
<td>Accept</td>
</tr>
<tr>
<td>ORNL</td>
<td>SBR</td>
<td>SFA</td>
<td>April 16</td>
<td>Accept</td>
</tr>
<tr>
<td>ANL</td>
<td>SBR</td>
<td>SFA</td>
<td>April 27</td>
<td>Accept</td>
</tr>
<tr>
<td>LLNL</td>
<td>SBR</td>
<td>SFA</td>
<td>April 27</td>
<td>Accept</td>
</tr>
<tr>
<td>CDIAC (ORNL)</td>
<td>Data, ESS</td>
<td>Project renewal</td>
<td>May 19-20</td>
<td>Not accepted, resubmit</td>
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<tr>
<td>ORNL</td>
<td>TES spruce</td>
<td>SFA</td>
<td>June 23-24</td>
<td>Accepted</td>
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<tr>
<td>LLNL</td>
<td>RGCM, ASR</td>
<td>SFA</td>
<td>Aug 18-19</td>
<td>Accepted/revision</td>
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<tr>
<td>PNNL</td>
<td>RGCM</td>
<td>SFA</td>
<td>Aug 20-21</td>
<td>Accepted/revision</td>
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<tr>
<td>NGEE Arctic-2</td>
<td>TES</td>
<td>Phase 2</td>
<td>August</td>
<td>Accepted</td>
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<tr>
<td>PNNL</td>
<td>IA</td>
<td>SFA</td>
<td>Sept 9-10</td>
<td>Accepted</td>
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### Management updates: 2015-2016. PI meetings

<table>
<thead>
<tr>
<th>Title</th>
<th>Program(s)</th>
<th>Location</th>
<th>Date in 2015/2016</th>
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<tbody>
<tr>
<td>ARM/ASR Facility PI meeting</td>
<td>ARM, ASR</td>
<td>Tysons</td>
<td>March 16-20, 2015</td>
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<tr>
<td>ESS PI meeting</td>
<td>TES, SBR</td>
<td>Bolger</td>
<td>April 28-29, 2015</td>
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<tr>
<td>ESS PI meeting</td>
<td>TES, SBR</td>
<td>Bolger</td>
<td>April 28-29, 2015</td>
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<tr>
<td>ACME PI meeting</td>
<td>ESM</td>
<td>Bolger</td>
<td>May 5-7, 2015</td>
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<tr>
<td>EASM PI meeting</td>
<td>RGCM</td>
<td>Rockville</td>
<td>Aug 31 – Sept 2, 2015</td>
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<td>ESS PI meeting</td>
<td>TES, SBR, EMSL</td>
<td>DC area</td>
<td>Apr 26-27, 2016</td>
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<tr>
<td>ARM-ASR joint PI meeting</td>
<td>ARM / ASR</td>
<td>Tysons</td>
<td>May 2-5, 2016</td>
</tr>
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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
• 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)
ARM Climate Research Facility deployments
Stereo photogrammetry reveals substantial drag on cloud thermals

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.

Approach

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

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

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

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

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.

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)

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

Xin Jing1, Nathan J. Sanders2, Yu Shi3, Haiyan Chu3, Aimée T. Classen4, Ke Zhao1, Litong Chen5, Yue Shi1,6, Youxu Jiang7 & Jin-Sheng He1,5

• **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 multifunctionality, 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.

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 UO₂ oxidation in the Rifle Aquifer

Scientific Achievement
Oxidation of subsurface uraninite (UO₂) 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. UO₂ 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 UO₂ oxidation in-situ in the Rifle aquifer over multiple seasons.
– After oxidation, UO₂ was characterized using synchrotron x-ray spectroscopy, electron microscopy, and chemical extraction methods.

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). UO₂ dissolution proceeds rapidly at these times. Lower right: Naturally abundant Ca²⁺ atoms (green) bond to U sites at surfaces of UO₂ nanoparticles, slowing oxidation.

Climate change and the permafrost carbon feedback


• **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.
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

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.

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.

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

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.

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

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

Simulations conducted at the National Energy Research Scientific Computing Center (NERSC)
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 concentrates nowadays (augmenting size proportionally to status-quo) and
  • By changing size and spatial distribution 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.

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.

Thank you!

Gary Geernaert
Gerald.Geernaert@science.doe.gov
http://science.energy.gov/ber/research/cesd/