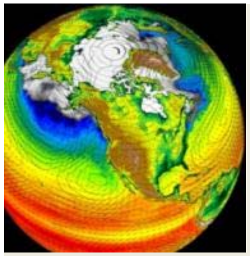
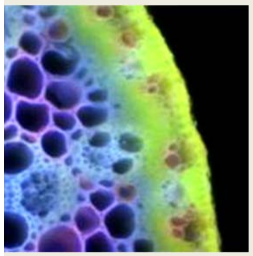
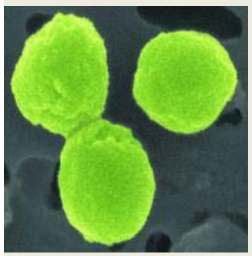


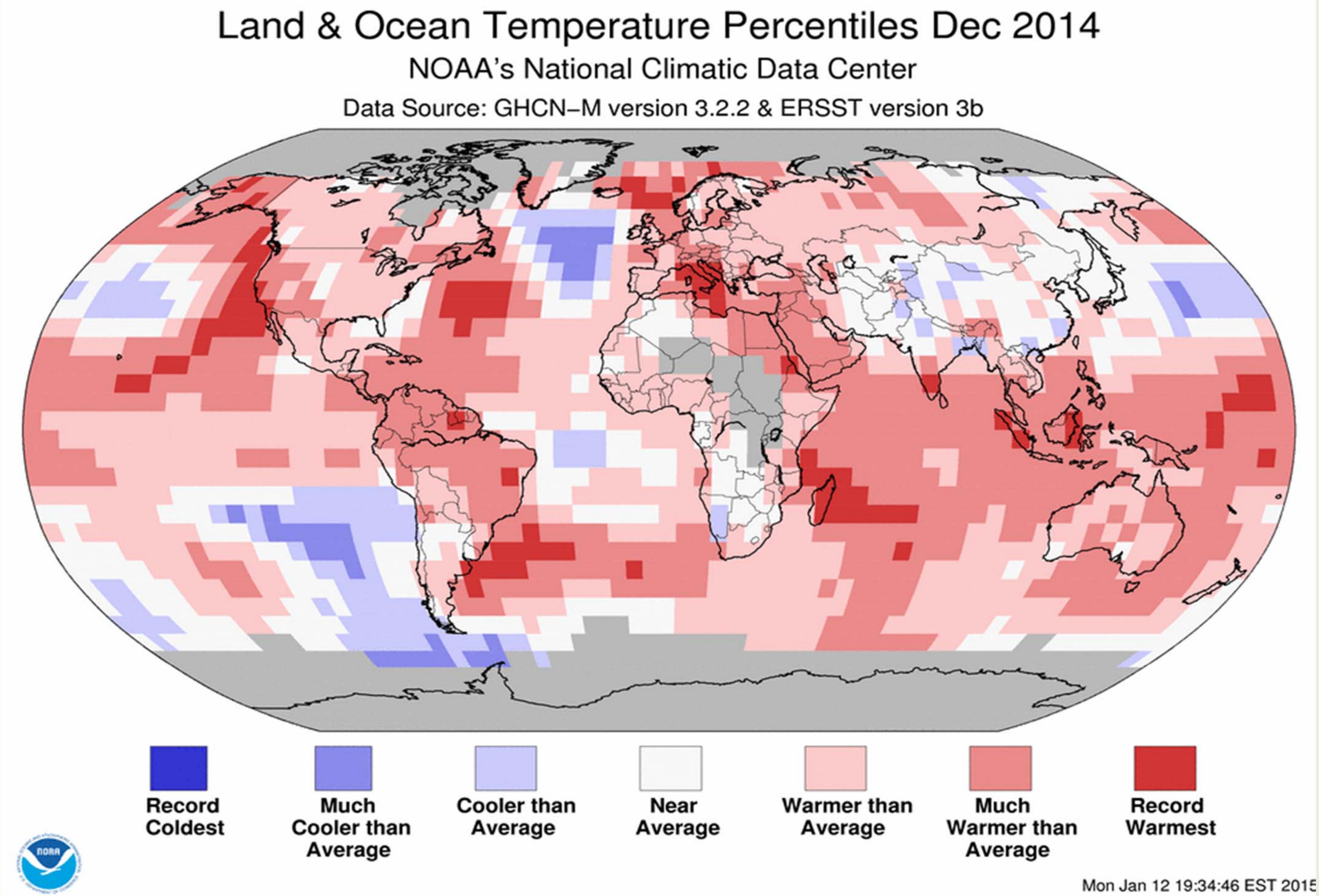




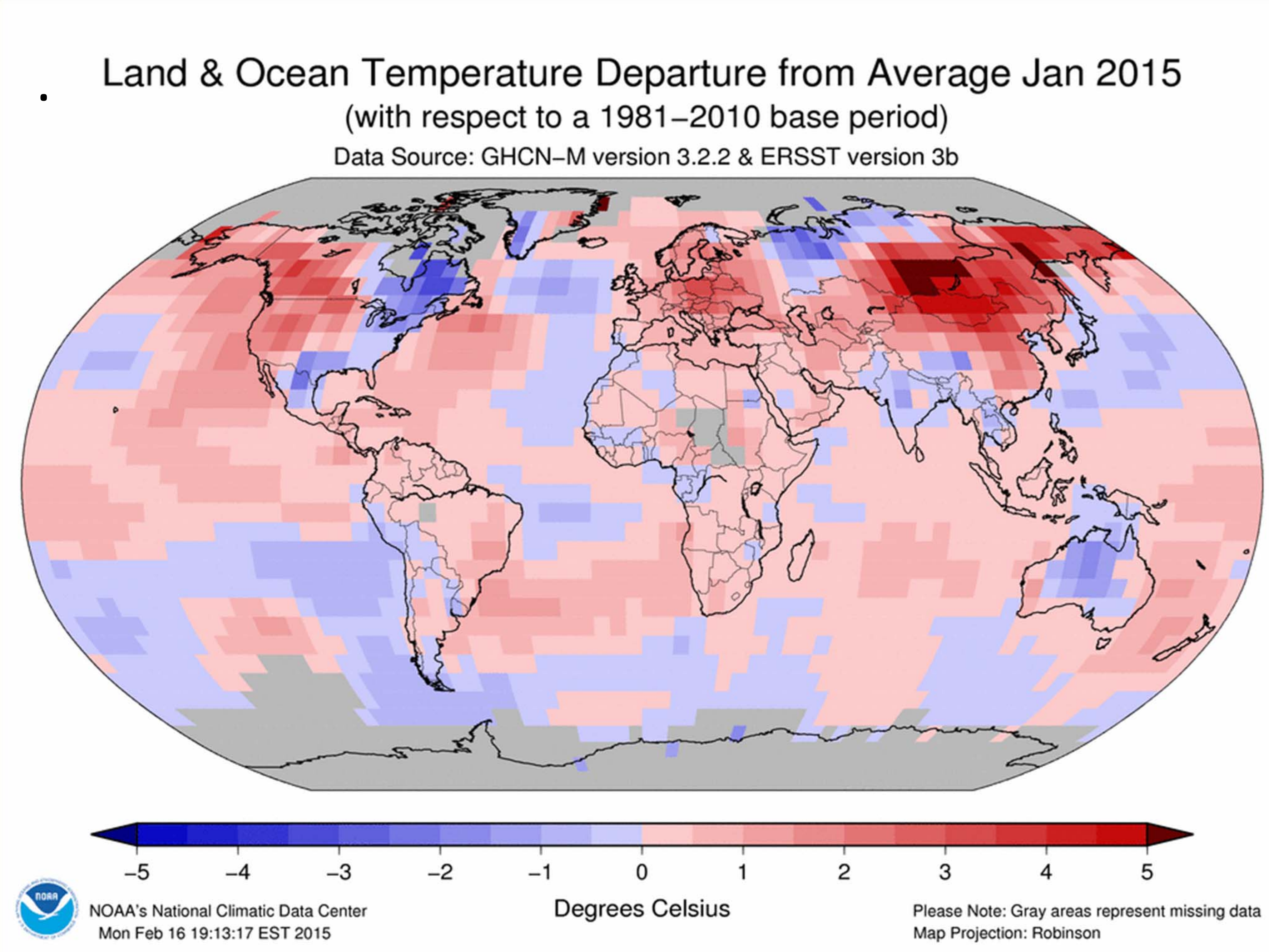
Climate and Environmental Sciences Division

BERAC update

February 26-27, 2015

G. Geernaert
BER/CESD


Land & Ocean Temperature Percentiles Dec 2014
NOAA's National Climatic Data Center
Data Source: GHCN–M version 3.2.2 & ERSST version 3b
Record Coldest
Much Cooler than Average
Cooler than Average
Near Average
Warmer than Average
Much Warmer than Average
Record Warmest
Mon Jan 12 19:34:46 EST 2015


Land & Ocean Temperature Departure from Average Jan 2015
(with respect to a 1981–2010 base period)
Data Source: GHCN–M version 3.2.2 & ERSST version 3b
−5
−4
−3
−2
−1
0
1
2
3
4
5
Degrees Celsius
NOAA's National Climatic Data Center
Mon Feb 16 19:13:17 EST 2015
Please Note: Gray areas represent missing data
Map Projection: Robinson

Outline

- Strategic update
- Administrative
- Science highlights since last BERAC

CESD long range science challenges

Science to understand the interdependencies that change over time:

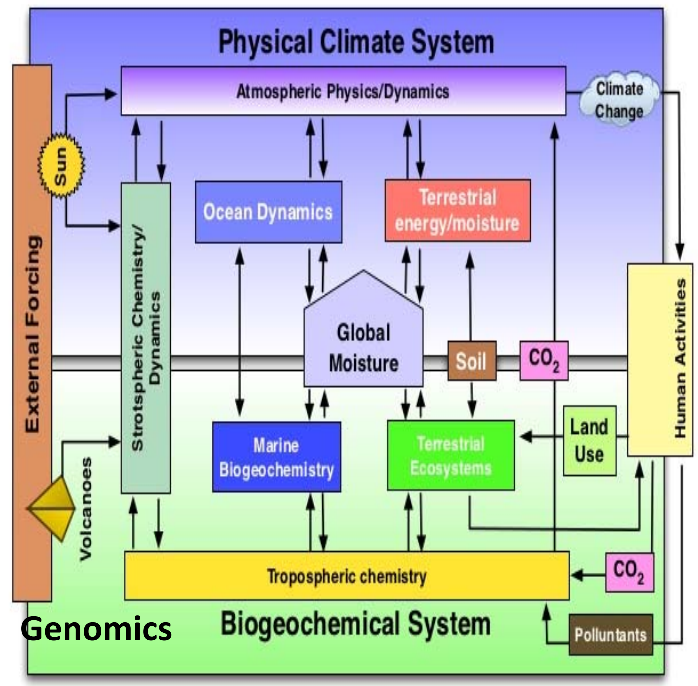
- Scale aware dynamics
- Physical, chemical, and biological attributes
- Deterministic, and nonlinear chaotic systems

System modeling to describe internal dynamics and external forcing and

responses:

- Scale aware dynamics
- System predictability
- Uncertainty

Dynamic earth system



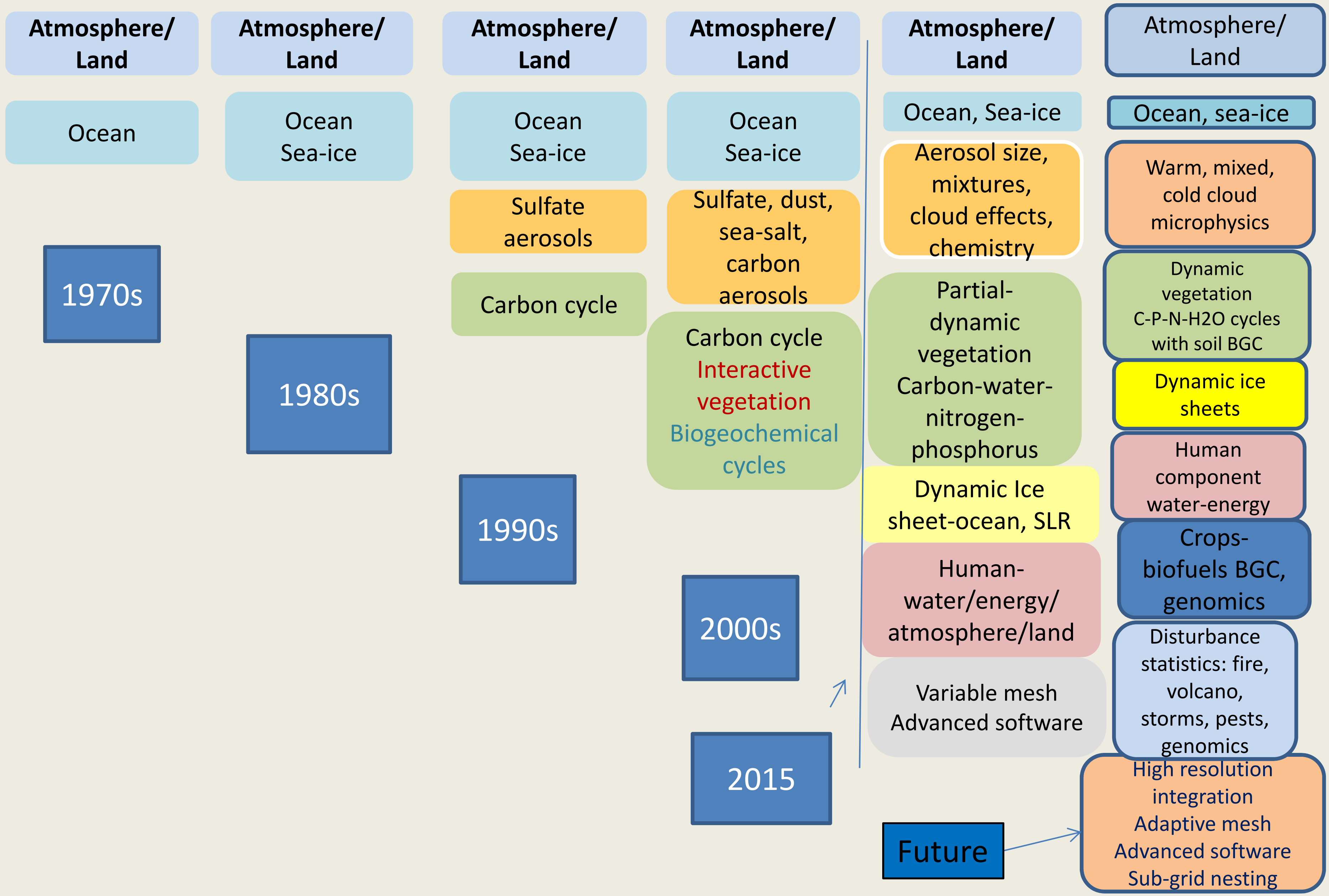
Big data analytics

- Process level physical, chemical, BGC information (generic geography)
- Metadata from various sources: compatibility, easy access, server side analyses

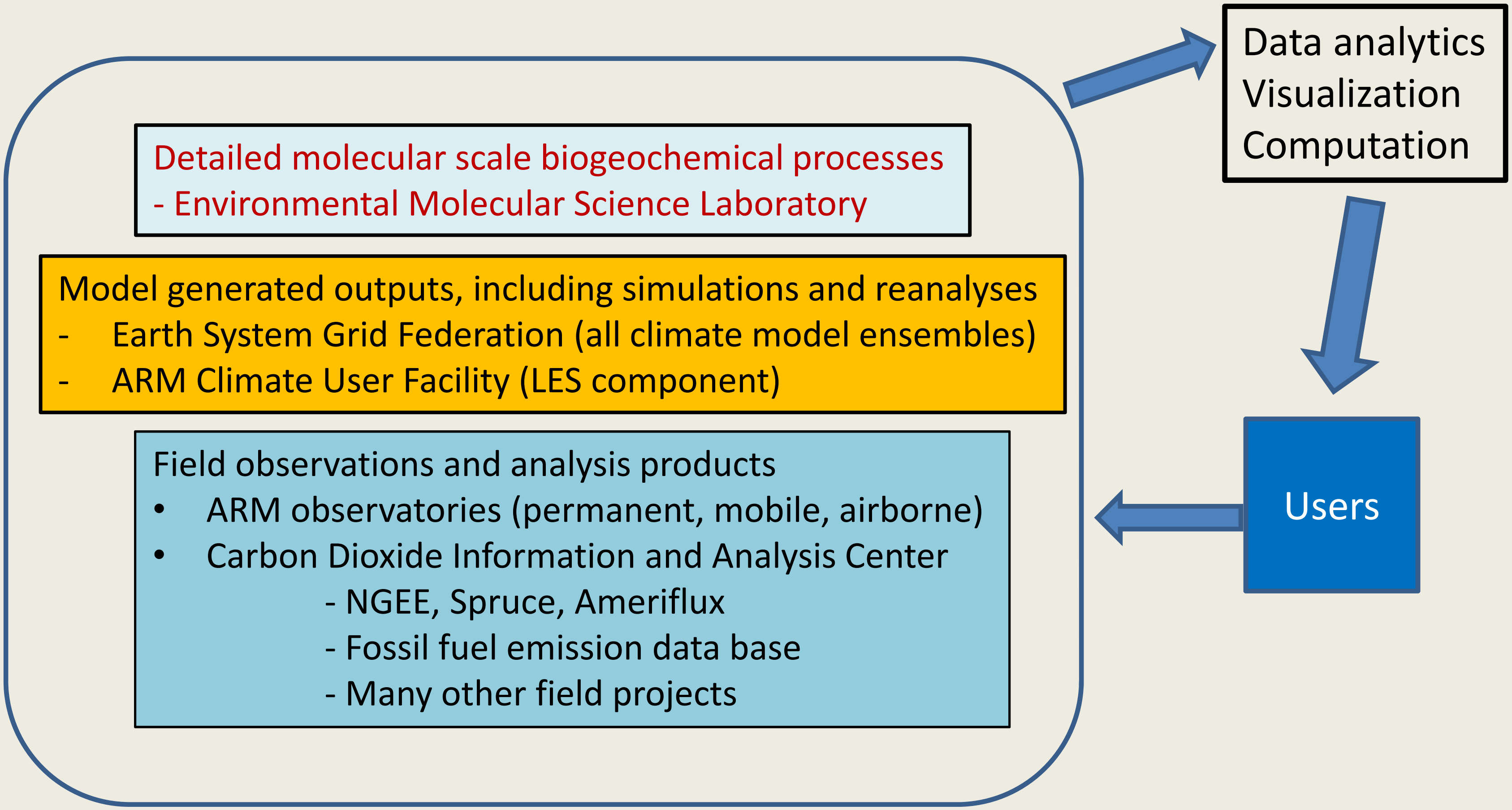
Some important scientific questions can be addressed in the era of exascale that can't easiliy be addressed now?

- **Disturbance as a trigger for climate variability and extremes?**
- **Cloud resolving processes that drive larger scale earth system change? sensitivity?**
- **Interdependencies: MJO, ENSO, AO, PDO, AMO, monsoons, and circulations?**
- **Abruptness of sea level rise?**
- **Biogeochemical, geomorphological, microbial, and ecological intedependencies for:**
  - **Water cycle: ground water and surface water interactions**
  - **Permafrost thaw**
- **Human feedbacks – economic, demographic, behavioral responses as climate feedbacks?**

Evolution of BER Climate and Earth System Modeling Architecture



Data architecture to support increasingly complex science



Refining strategic planning

- USGCRP relationship
  - Strategic plan (2012, 2015): water, arctic, model, observations
  - PCAP and Sandy: human component; weather-climate continuum; impacts-adaptation-vulnerability; decision making process; socio-behavioral-economic sciences
  - Climate Modeling Summit – February 2015 inauguration
- DOE niche:
  - Big science: system science, predictability, uncertainty
  - Facilities, computing, big data analytics
  - Bold science: asking really tough questions to drive strategy
- Role of BERAC and the community
  - Bold science frameworks
  - Feed the planning process with new ideas and opportunities
  - Input on our execution process

Recent Town Halls – community input

- ACME – a bold direction for earth system modeling: Town Hall AGU
- Climate variability of extremes: Town Hall AGU
- MODEX – NGEE, now ARM: Town Halls AGU
- Exascale computing: in ACME Town Hall AGU
- Big data analytics: Town Hall AMS
- Synergistic partnerships:
  - ASCR
  - USGCRP
  - Climate modeling summit

Management Update: Recent and projected FOA's

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	July 31, 2014	116	Mar 23-27, 2015	tbd(8-15)
FY15	Atmospheric System Research - annual	Aug 5, 2014	96	Feb 17-20, 2015	tbd(15-20)

Management updates: Major reviews in FY 2015

Lab	Program	Type	Notification	Review date	Outcome
PNNL	EMSL facility	Review	Feb 11, 2014	Sept 23-24	Accept w/revision -Jan 19
LANL	RGCM SFA	Renewal	Oct 11, 2013	Nov 13-14	Accept w/revision Feb 2; vision
NPS	RGCM RASM project	Renewal	Oct 11, 2013	Nov 13-14	Accept w/revision Feb 2; narrowed
NGEE-Tropics (LBNL+)	TES	Project new	Sept 2, 2014	Mar 18-19	
ORNL	SBR	SFA	Sept 16, 2014	April 17	
ANL	SBR	SFA	Sept 15, 2014	April 27	
LLNL	SBR	SFA	Sept 15, 2014	April 27	
CDIAC (ORNL)	Data, ESS	Project renewal	Aug 18, 2014	May 19-20	

Management updates: More reviews in 2015

Lab	Program	Type	Notification	Review date	Outcome
PNNL	RGCM	SFA	Aug 20, 2014	June-July	
ORNL	TES	SFA	Jan 16, 2014	June/July	
LLNL	RGCM, ASR	SFA	Sept 4, 2014	July-Aug	
PNNL	RGCM	SFA	Aug 20, 2014	July-Aug	
NGEE Arctic-2 (ORNL)	TES	Phase 2	Dec 11, 2014	August	
PNNL	IA	SFA	Oct 9, 2014	August	
LBNL-Ameriflux	ESS	Project		December	

Management updates: 2015 - PI meetings, workshops

Title	Program(s)	Location	Date in 2015
ACME 6-month management review	ESM	GTN	Jan 22
ACME Exascale Study Group meeting	ESM	GTN	Jan 23
Ameriflux PI meeting	TES	Omni Shoreham	Jan 29-30
BERAC workshop	BER	GTN	Jan 29-30
CMIP6 workshop and Climate Summit	CESD/USGCRP	NOAA	Feb 9-11
ARM/ASR Facility PI meeting	ARM, ASR	Tysons	March 16-20
ESS PI meeting	TES, SBR	Bolger	April 28-29
ACME PI meeting	ESM	Bolger	May 5-7
Aerial workshop	ARM/ASR/ESS	Gaithersburg Washingtonian	May 13-15
Climate-energy model interdependencies Workshop– Part 3	ESM, IA		summer

Resolution and Dynamical Core Dependence of Atmospheric River Frequency in Global Model Simulations

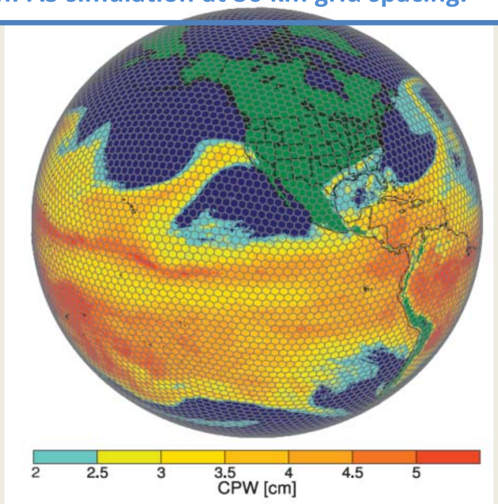
Objective

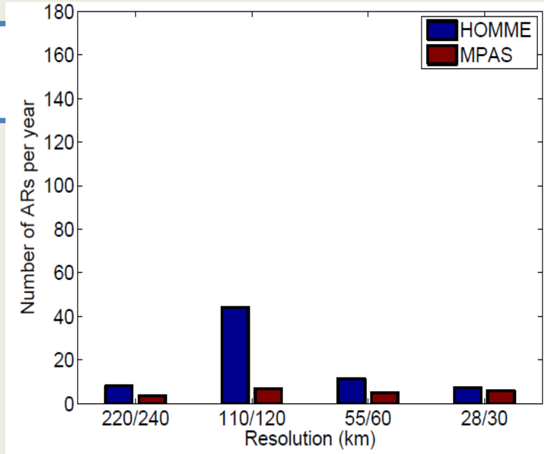
- Examine sensitivity of atmospheric river (AR) frequency to grid size and dynamical cores.
- Identify differences in climatology of large-scale conditions responsible for these sensitivities.

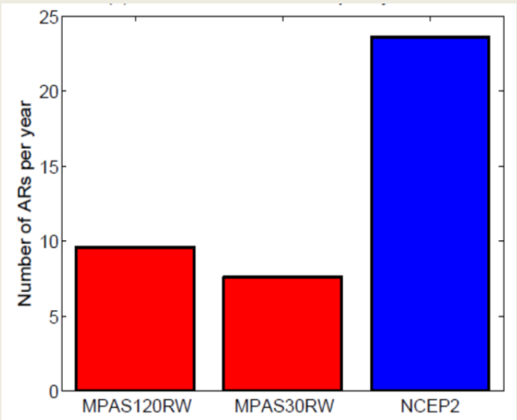
Approach

- Perform simulations with the Community Atmosphere Model (CAM4) at 240, 120, 60 and 30 km model resolutions each with the Model for Prediction Across Scales (MPAS) and High-Order Methods Modeling Environment (HOMME) dynamical cores.
- Determine AR frequency using absolute and percentile thresholds of large-scale atmospheric conditions to identify causes of the sensitivity of AR frequency to model resolution and dynamical cores.

A typical AR event detected in a real world MPAS simulation at 30 km grid spacing.







Top Right: Aquaplanet comparisons between HOMME and MPAS

Bottom Right: Real world comparisons between MPAS at two resolutions and Reanalysis

Impact

- AR frequency in CAM4 is sensitive to both model resolution and dynamical core that change the sub-tropical westerlies and the total and vertical distribution of atmospheric precipitable water content.
- This study motivates the need to reduce uncertainty in modeling AR responsible for heavy precipitation and flooding in the western U.S. and other regions.

Hagos S, LR Leung, Q Yang, C Zhao, and J Lu. 2015. "Resolution and Dynamical Core Dependence of Atmospheric River Frequency in Global Model Simulations." *Journal of Climate, early online.* DOI:10.1175/JCLI-D-14-00567.1

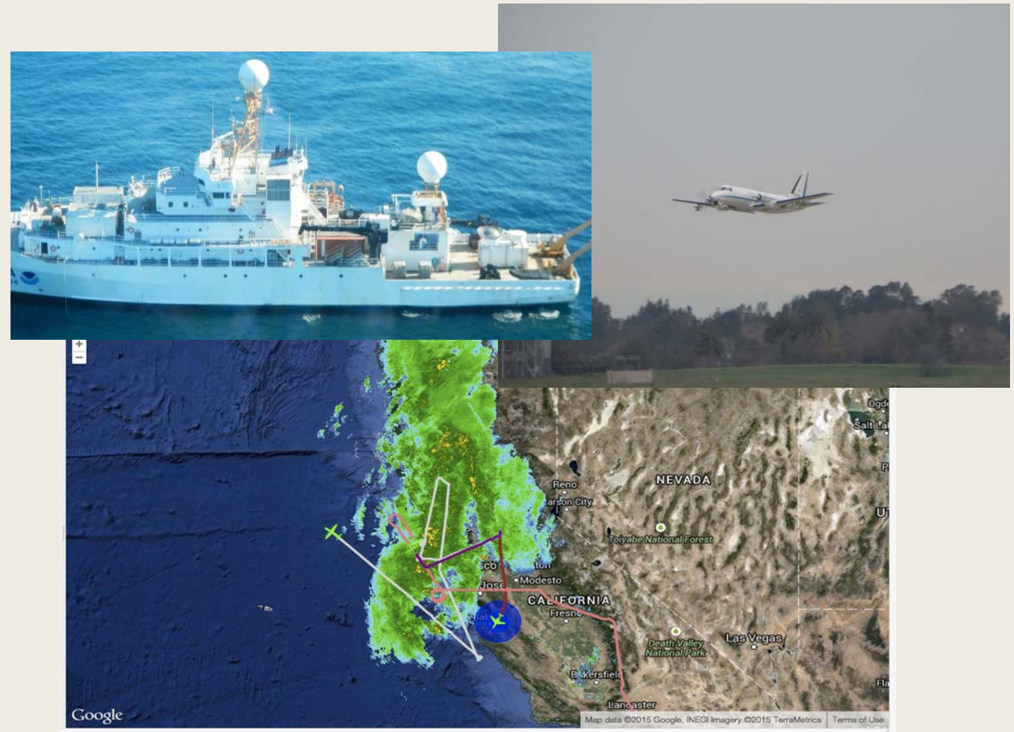
ARM Cloud Aerosol Precipitation Experiment (ACAPEX)

Motivation

- Western US snowpack is fundamental to the water supply & water cycle of the region
- Atmospheric rivers – narrow bands of water vapor associated with extratropical cyclones – lead to extreme precipitation events
- AR interaction with aerosol and cloud microphysics poorly understood in predicting AR formation and evolution

Approach

- Multi-agency field campaign [Calwater 2015] including DOE, NOAA, NASA & other agencies
- ARM Mobile Facility deployed on NOAA research ship; DOE G-1 aircraft + NOAA & NASA aircraft
- Observations of atmospheric river structure & evolution plus aerosol and cloud properties offshore and over western US mountains
- New datasets will inform regional modeling studies of western US precipitation



Impact

- Ship & aircraft have sampled two land-falling atmospheric rivers; 15 G-1 flights to date, including several coordinated with other aircraft
- Aircraft observations show that dust, soot, and sea salt transported from long distances frequently accompany atmospheric rivers & supercooled droplets frequently present in orographic clouds

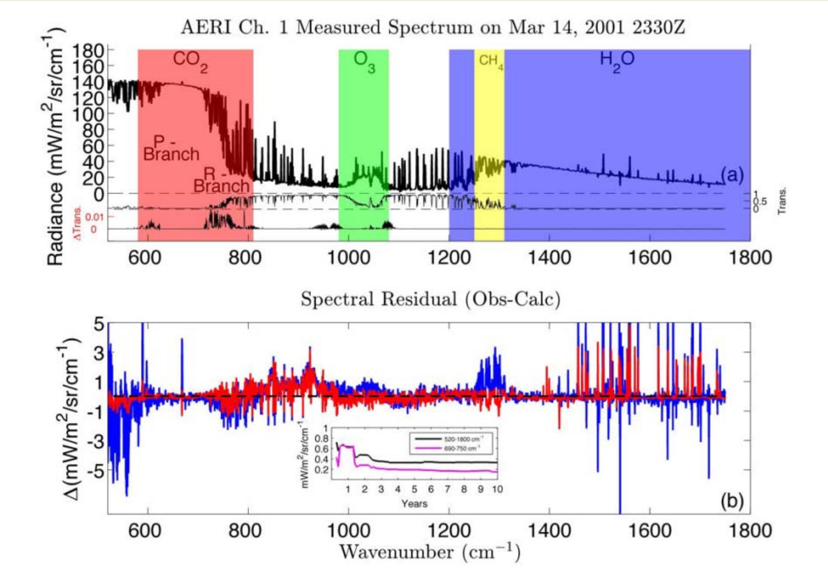
Observational Determination of Surface Radiative Forcing by Atmospheric Carbon Dioxide

Motivation and Goal

- Despite widespread theoretical modeling of the impacts of CO_2 on the Earth's energy balance, there is little direct observational evidence
- Examine long-term surface radiation measurements to determine if greenhouse effect of CO_2 is detectible at Earth's surface

Approach

- ASR scientists used 10 years of spectral infrared measurements from the ARM sites in Oklahoma and Alaska
- They conducted detailed spectral radiative transfer calculations that held CO_2 fixed and used independent measurements of clouds and water vapor from the ARM sites
- Subtracting the independent calculations from the measured spectra showed that the trends at both sites were statistically significant only in the spectral regions of CO_2 absorption



Impact

- First observational confirmation of the effect of increasing CO_2 concentrations on the surface energy balance, confirming theoretical predictions
- Increasing atmospheric CO_2 concentrations between 2000 and 2010 have led to increases in clear-sky surface radiative forcing of over 0.2 W/m^2 at mid- and high-latitudes

Reference: Feldman, D., W.D. Collins, P.J. Gero, M.S. Torn, E.J. Mlawer, and T.R. Shippert, 2015: Observational determination of surface radiative forcing by CO2 from 2000 to 2010. Nature. doi:10.1038/nature14240.

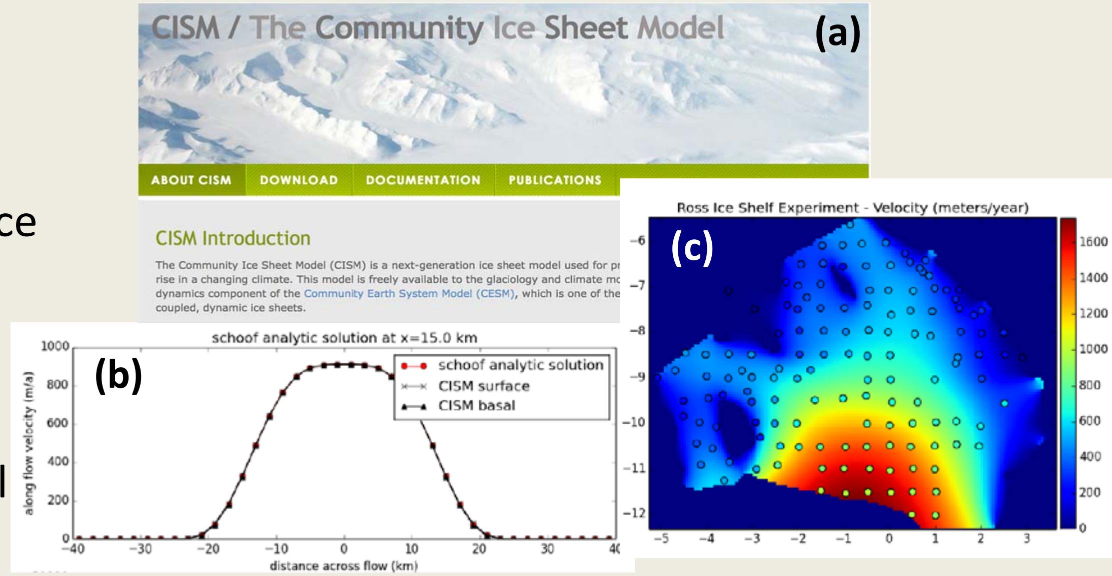
Community Ice Sheet Model (CISM) Version 2.0

Goal

Provide the glaciology and climate modeling communities with a robust, parallel, well-verified “higher-order” ice sheet model for both stand-alone and coupled climate experiments.

Approach

- Started with the UK Glimmer model (serial, shallow-ice approximation)
- Implemented scalable parallelism with interfaces to Trilinos solver libraries
- Built a 3D velocity solver with a hierarchy of flow approximations, including Blatter-Pattyn (accurate for fast-flowing ice streams, ice shelves)
- Added verification test cases
- Modified the climate model interface to support coupling to CESM/ACME
- Updated build system, documentation



(a) CISM website, http://oceans11.lanl.gov/cism/
(b) Ice speed (m/yr) simulated by CISM for the Schoof ice stream test problem, compared to the analytic solution.
(c) Ice speed (m/yr) of the Ross Ice Shelf simulated by CISM; dots show where observations are available for validation.

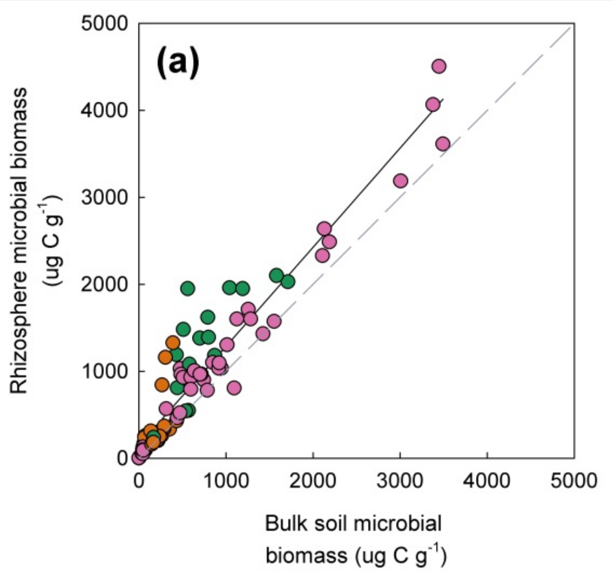
Impact

- First public release of a higher-order ice sheet model developed primarily with DOE support
- Efficient, portable code suitable for coupled climate simulations of ice-sheet evolution and sea-level rise

S.F. Price, W.H. Lipscomb, M.J. Hoffman, et al., 2014. CISM 2.0.0 Documentation, http://oceans11.lanl.gov/cism/.

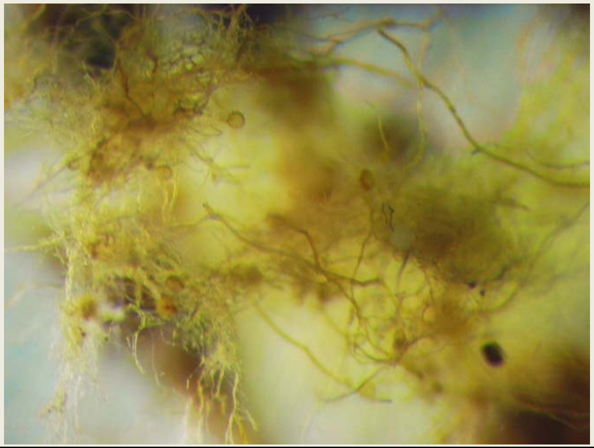
Rhizosphere Priming Is Important In Carbon and Nutrient Cycles

Background: Roots regulate microbial activity & decomposition via release of C into the soil (priming), but there is no estimate of how much soil C is vulnerable due to increased microbial activity



Approach and Results:

- **A meta-analysis found different plant systems (forest, grassland and ag) converge in the magnitude and direction of rhizosphere effects (a)**
- **Numerical modeling found the %total microbial respiration and %N mineralization from rhizosphere microbes track root depth distribution and is significantly influenced by root architecture**
- **A microbial decomposition model found root exudation in temperate *forests consumes ~4% and ~6% of GPP and NPP, respectively* (~45gC m^{-2} yr^{-1}) suggesting small inputs of root C induce disproportionately large effects on soil biogeochemistry**



Conclusion:

- **Root exudation increases with rising atmospheric CO_2 and affects the temperature sensitivity of decomposition and will be an important control over ecosystem response to global change**
- **The modeling framework developed is suitable for incorporation into current land surface models**

Finzi, A.C., R.Z. Abramoff, K.S. Spiller, E.R. Brzostek, B.A. Darby, M.A. Kramer and R.P. Phillips. 2015. Rhizosphere processes are quantitatively important components of terrestrial carbon and nutrient cycles. Global Change Biology doi:10.1111/gbc.12816.

Forest Disturbance as a Test for Gap and Big-Leaf Models

Objective

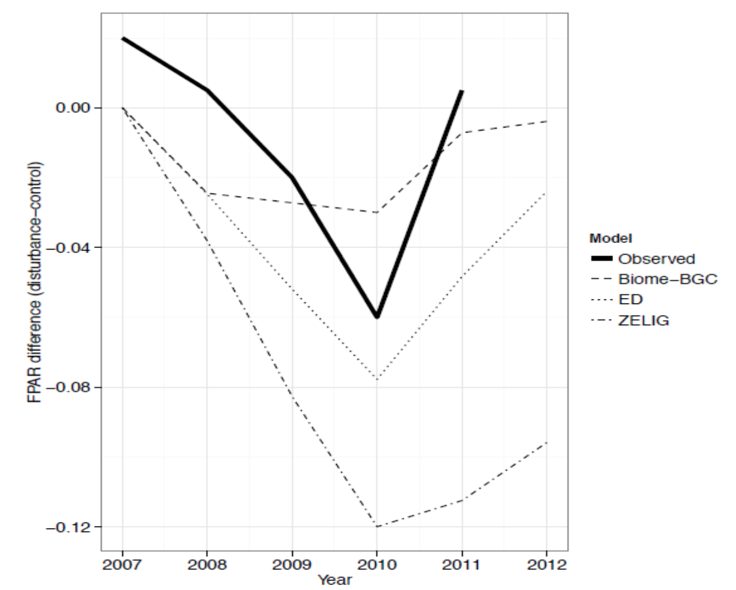
- Test whether a variety of forest models could reproduce the resilience to moderate disturbance observed in a large-scale field experiment

Approach

- Using girdled trees from the FASET experiment in Michigan, the study used a common modeling approach across three fundamentally different models and simulated the 2008-2012 experimental period
- Model performance and uncertainty was evaluated with respect to the post-disturbance carbon cycle
- Examined model structure and processes to infer weaknesses and areas of future improvement

Impact

- Forest managers, policy makers, and scientists need high confidence in ecosystem models as about 5% of U.S. forests undergo ‘ecological transition’ with high tree death in coming years.
- This work identifies weaknesses in the existing models to understand carbon cycle change in forests, and points to improvements that will strengthen model performance in forest ecosystems.



Bond-Lamberty B, JP Fisk, JA Holm, V Bailey, G Bohrer, and CM Gough. 2015. “Moderate Forest Disturbance as a Stringent Test for Gap and Big-Leaf Models.” *Biogeosciences* 12: 513-526. DOI:10.5194/bg-12-513-2015

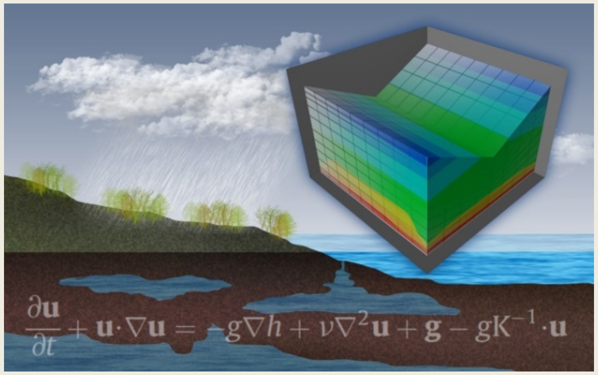
Multiscale Model Unifies Simulation of Surface and Groundwater Flow

Challenge

- Improve models of ecosystem hydrologic processes by unifying surface water and groundwater simulations.

Approach & Results

- Scientists from the University of Central Florida and PNNL developed a unified multiscale model that uses a single set of equations to simultaneously simulate fluid flow in an ecosystem containing both surface water and groundwater.
- Used the model to simulate all hydrological phenomena in surface water and groundwater for the Disney Wilderness Preserve site.



A multiscale model simulated hydrological processes in an ecosystem containing both surface water and groundwater.

Significance and Impact

- This new approach will improve the efficiency and accuracy of simulations of fluid flow in ecosystems.
- Enables greater understanding of the transport of nutrient supplies to ecologically important microbes, and biogeochemical processes affecting the production and release of greenhouse gases.

Participants:
University of Central Florida, EMSL, PNNL

Reference: Yang X, C Liu, Y Fang, R Hinkle, H-Y Li, V Bailey, and B Bond-Lamberty. 2015. "Simulations of ecosystem hydrological processes using a unified multi-scale model." *Ecological Modelling* 296:93-101.

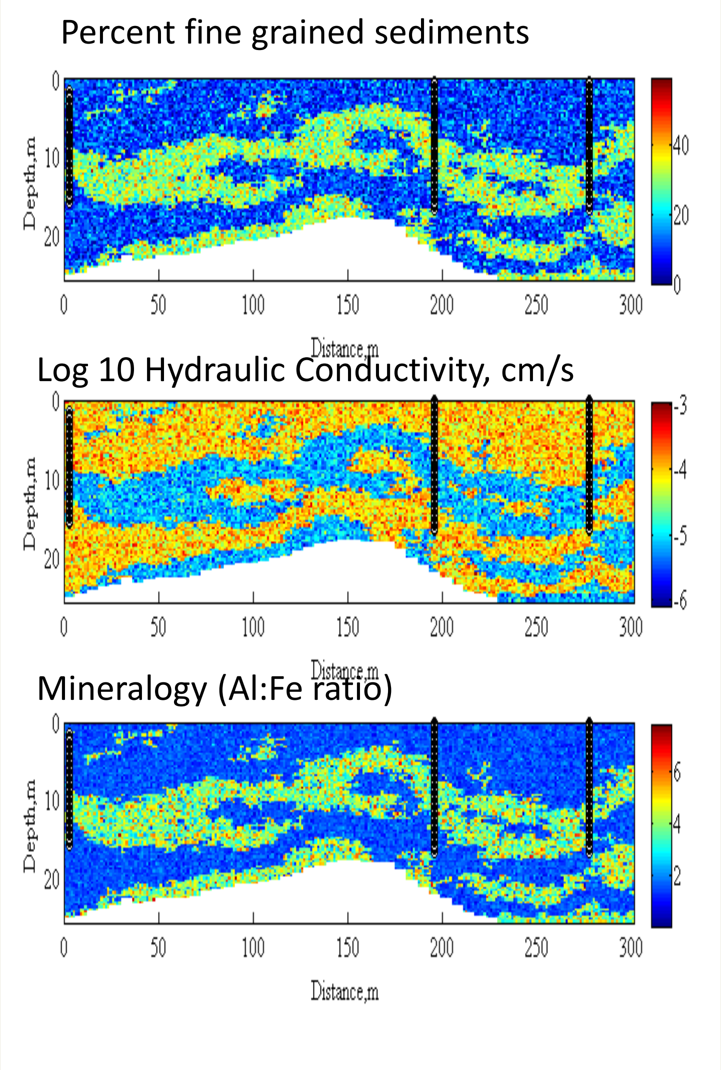
Geophysical Identification of Terrestrial Environment ‘Functional Zones’

The Science:

- A reactive facies-based approach developed to estimate hydrogeochemical properties in a contaminated sedimentary aquifer using geophysical data.
- Provides very high resolution estimates of co-varying physicochemical properties along a plume centerline
- Uncertainty quantification also performed using the parameter estimates to identify controls on and long term behavior of plume transport (Bea et al., 2014)

The Impact

- Mechanistic models of terrestrial ecosystems increasingly use reactive transport codes to represent rhizosphere through bedrock processes and interactions, based on hydrological, geochemical, and biological properties.
- Approach extended using above and below ground remote sensing datasets to characterize the distribution of ‘functional zones’ in Barrow AK, which have unique property distributions and associated soil carbon fluxes,
- The functional zone concept will allow for improved simulation of ecosystem feedbacks to climate, due to detailed representations of small scale properties that collectively control system behavior.



Wainwright, H. M., J. Chen, D. S. Sassen, and S. S. Hubbard (2014), Bayesian hierarchical approach and geophysical data sets for estimation of reactive facies over plume scales, *Water Resour. Res.*, **50**(6), 4564-4584,DOI:10.1002/2013wr013842.

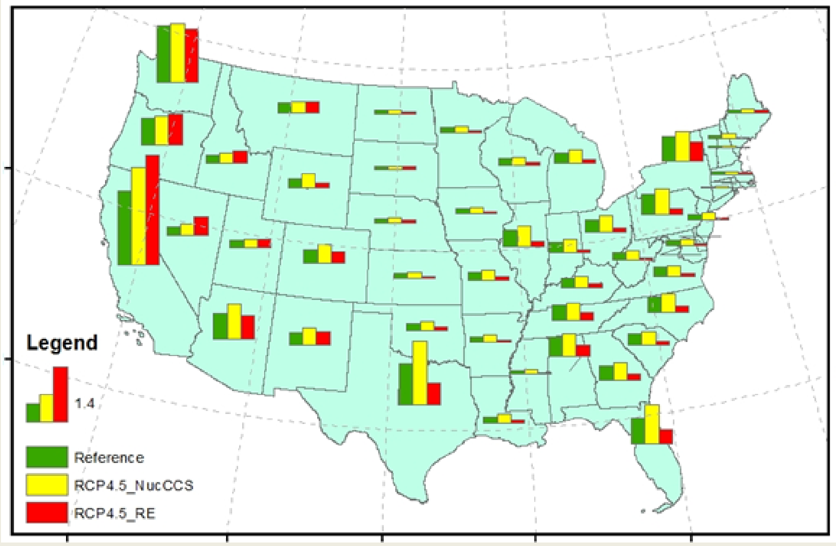
U.S. Water Demands for Electricity Generation

Objective

- What are the interactions between the U.S. electricity and water systems? What are the impacts of key factors including water-saving adaptations, climate mitigation policies, capital stock turnover, and technological advances?

Approach

- Employed an integrated modeling approach (GCAM-USA) that captures energy–water interactions at regional and national scales
- Developed detailed scenarios of the future generation portfolio and cooling technology mix
- Estimated future state-level electricity generation and associated water withdrawals and consumption under different scenarios



GCAM-USA's estimates of the state level electric-sector water consumption under the Reference, RCP4.5_NucCCS and RCP4.5_RE scenarios in 2095

Impact

- Climate mitigation strategies that encourage renewable energy reduce water consumption compared to strategies focused on carbon capture and storage and nuclear power
- The geographical and technological detail of this study provides a useful platform to explore complex systems dynamics and emerging issues at the heart of the water–energy nexus in the U.S.

Liu L, M Hejazi, P Patel, P Kyle, E Davies, Y Zhou, L Clarke, J Edmonds. 2014. "Water Demands for Electricity Generation in the U.S.: Modeling different scenarios for the water–energy nexus." *Technological Forecasting & Social Change*, in press. DOI:10.1016/j.techfore.2014.11.004.

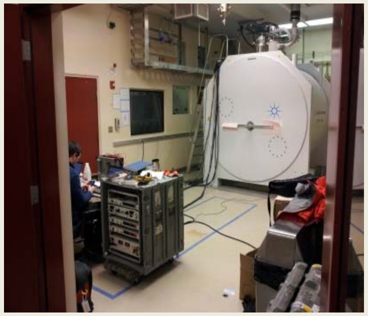
Recent and Upcoming Activities at EMSL

Science and Strategic Directions

- EMSL Response to 2014 Review: Outreach Strategy, Computational Strategy, User Input
- Multiscale Modeling workshop report (codes for CESD & BSSD simulations)

- Upcoming Workshops at EMSL
    - Land Ecosystem – Atmosphere Processes (A. Guenther) – Mar 9-10, 2015
    - Plant Phenotyping (C. Jansson) – Mar 12-13, 2015

Proposal Opportunities



- 2015 Science Theme call – due March 2, 2015
- 2015 EMSL-JGI call – Letters of Intent due April 6, 2015

Capabilities

- HRMAC: 21T magnet at field in EMSL – Spectrometer integration next
- NanoSIMS: John Cliff hired, environmental microbiologist from U. Western Australia
- EMSL's *NWChem:* Intel® Parallel Computing Center partner (https://software.intel.com/ipcc)

Outreach and User Activities

- Two *Molecular Bond* issues: Modeling/Simulation and Rad Annex
- New User Executive Committee (UEC) members
- Videos/Interviews: http://www.emsl.pnl.gov/emslweb/news?f[0]=field_type_of_news%3A4

Thank you!

Gary Geernaert
Gerald.Geernaert@science.doe.gov

http://science.energy.gov/ber/research/cesd/