Accelerated Climate Model for Energy

BER Advisory Committee

ACME
Accelerated Climate Modeling
for Energy

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Overview

- **Officially launched in July 2014, ACME is a branch of the Community Earth System Model (CESM), i.e., within the family of models jointly supported by DOE and NSF**

- **ACME is supported by DOE to serve mission needs:**
  - ❖ **Advance a set of science questions that demand major computational power and advanced software**
  - ❖ **Provide the highest resolution for climate science (15-25 km), with adaptable grids <10 km**
  - ❖ **Fully coupled climate simulation, time horizon: 1970-2050**

- **Code designed to effectively utilize next and successive generations DOE Leadership Class computers, through exascale**

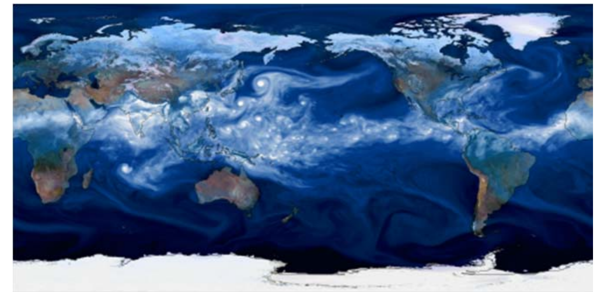
- **Project based on a consolidation of previous DOE Laboratory model development projects, and is therefore a more efficient use of existing resources**

ACME
Accelerated Climate Modeling for Energy

New Science using new capabilities

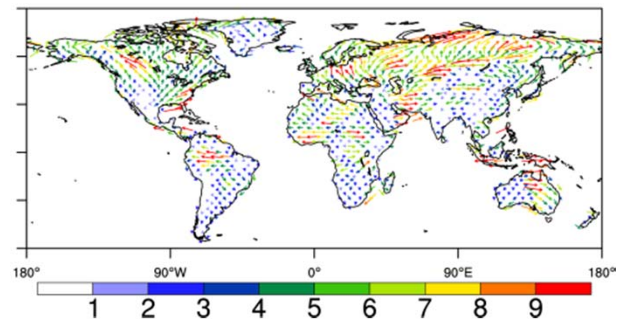
Science drivers

Water cycle: **How do the hydrological cycle and water resources interact with the climate system on local to global scales?**



Biogeochemistry: **How do biogeochemical cycles interact with global climate change?**

Cryosphere: **How do rapid changes in cryospheric systems interact with the climate system?**



New capabilities to address

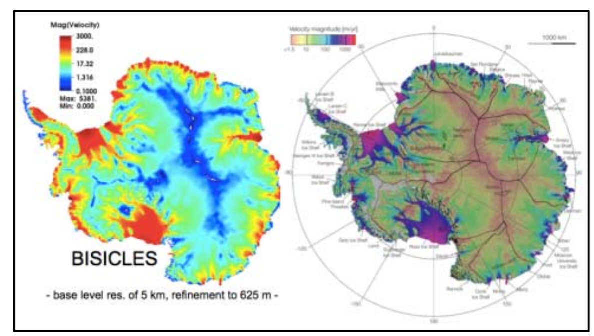
- **Resolutions to resolve extreme phenomena**

  (15-25 km coupled; <10 km using adaptive grids)

- **Integration of the human/energy component**

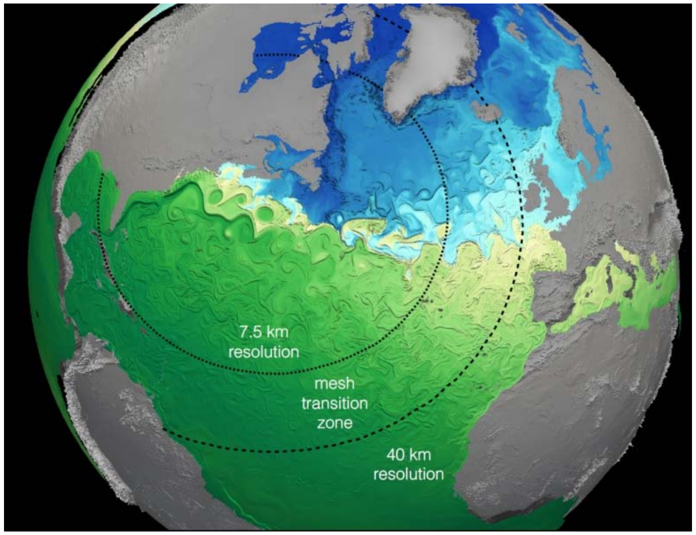
  (energy-water sector interdependence, bioenergy)

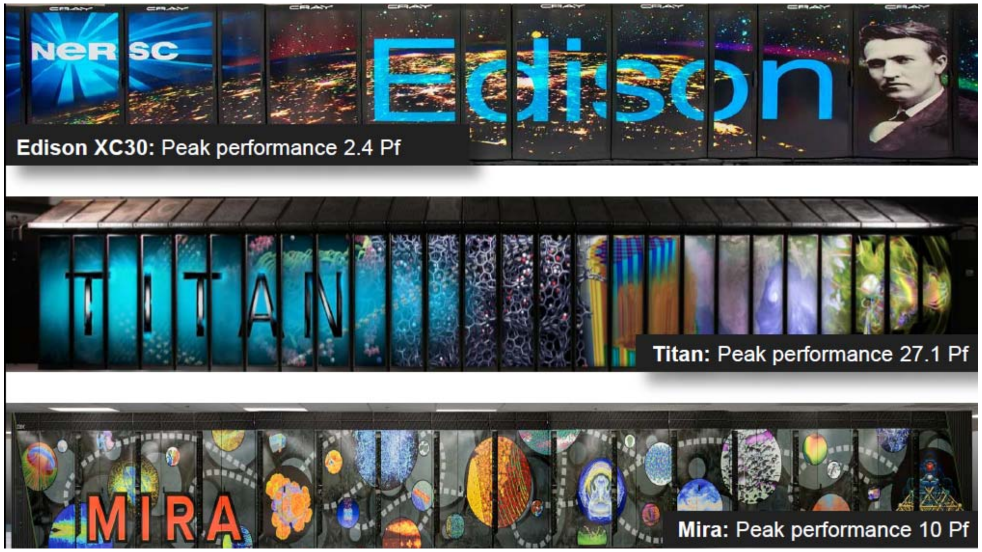
- **Dynamic coupling of ice-ocean, sea-level rise**



ACME will be the first model to exploit DOE's next generation Leadership Class Computers

- ASCR (Computing Office) acquires cutting edge, increasingly disruptive computational facilities, which are exceedingly challenging for all domain scientists to effectively use.
- ACME embraces this challenge, risk, and opportunity as it develops software and algorithms to efficiently utilize current and future computer architectures.





Programmatic rationale:
Before ACME DOE sponsored 7 model-development activities across 8 Labs

	CSSEF	Polar	COSIM	IMPACTS	UV-CDAT	Hi-Res	iESM
ANL							
LANL							
LBNL							
LLNL							
ORNL							
PNNL							
SNL							
BNL							

ACME combines and coordinates

	ACME	iESM
ANL		
LANL		
LBNL		
LLNL		
ORNL		
PNNL		
SNL		
BNL		
Other	NCAR, UC-Irvine, Scripps, NYU-Poly, U-MD, Kitware	

ACME: from proposal…to approved project

Reviewed by panel March 2014

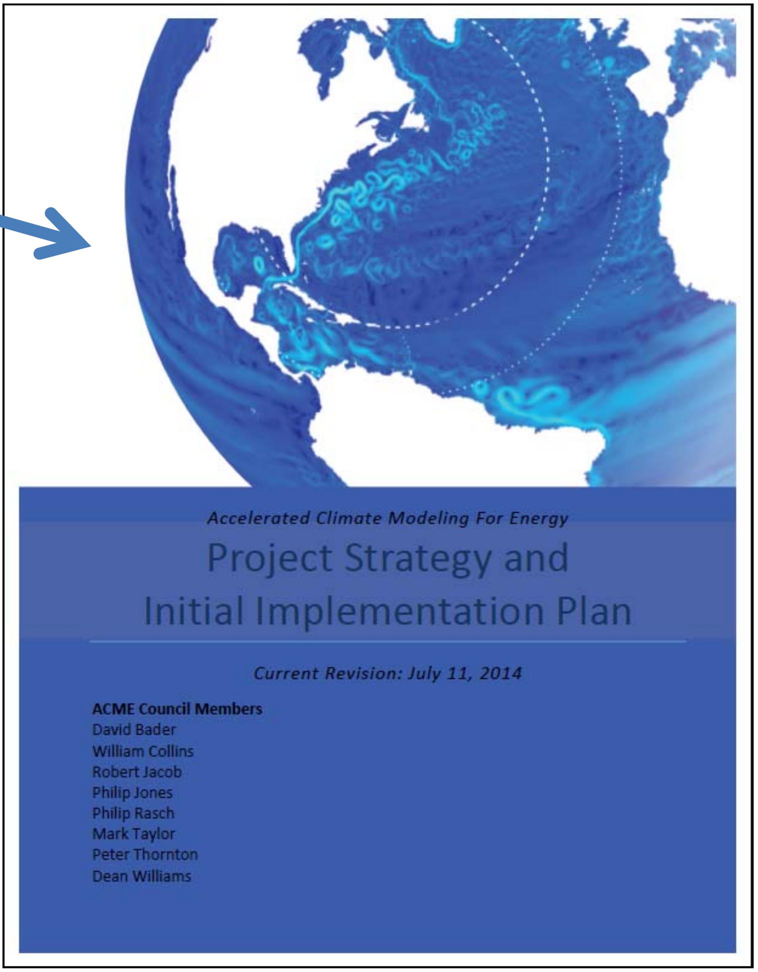
- **Develop a concise and visionary document describing the project. Available on-line**
- **Careful consideration of the treatment of the energy/societal components.**

BER approved project, July 2014

- **BER held a community workshop in October 2014 to consider how best to address and model energy/societal elements, together with Integrated Assessment and Impacts Adaptation Vulnerability approaches and communities**
- **Follow-up review after 6 months**

Management and progress review, January 2015

- **Panel review was very positive on science outputs to-date and management processes**


Accelerated Climate Modeling For Energy

Project Strategy and
Initial Implementation Plan

Current Revision: July 11, 2014

ACME Council Members
David Bader
William Collins
Robert Jacob
Philip Jones
Philip Rasch
Mark Taylor
Peter Thornton
Dean Williams

http://climatemodeling.science.energy.gov/projects/accelerated-climate-modeling-energy

ACME management structure

ACME Council
Dave Bader, Chair
Executive Committee: W. Collins, M. Taylor
R. Jacob, P. Jones, P. Rasch, P. Thornton, D. Williams
Ex Officio: J. Edmonds, J. Hack, W. Large, E. Ng

Executive Committee
Chair: D. Bader
Chief Scientist: William Collins
Chief Computational Scientist: Mark Taylor

Project Engineer
Renata McCoy

Land Group
Peter Thornton
William Riley

Land Task Leaders

Atmosphere Group
Phil Rasch
Peter Caldwell

Atmosphere Task Leaders

Software Eng./Coupler Group
Rob Jacob
Andy Jacob

SE/Coupler Task Leaders

Workflow Group
Dean Williams
Kate Evans

Workflow Task Leaders

Ocean/Ice Group
Phil Jones
Todd Ringler

Ocean/Ice Task Leaders

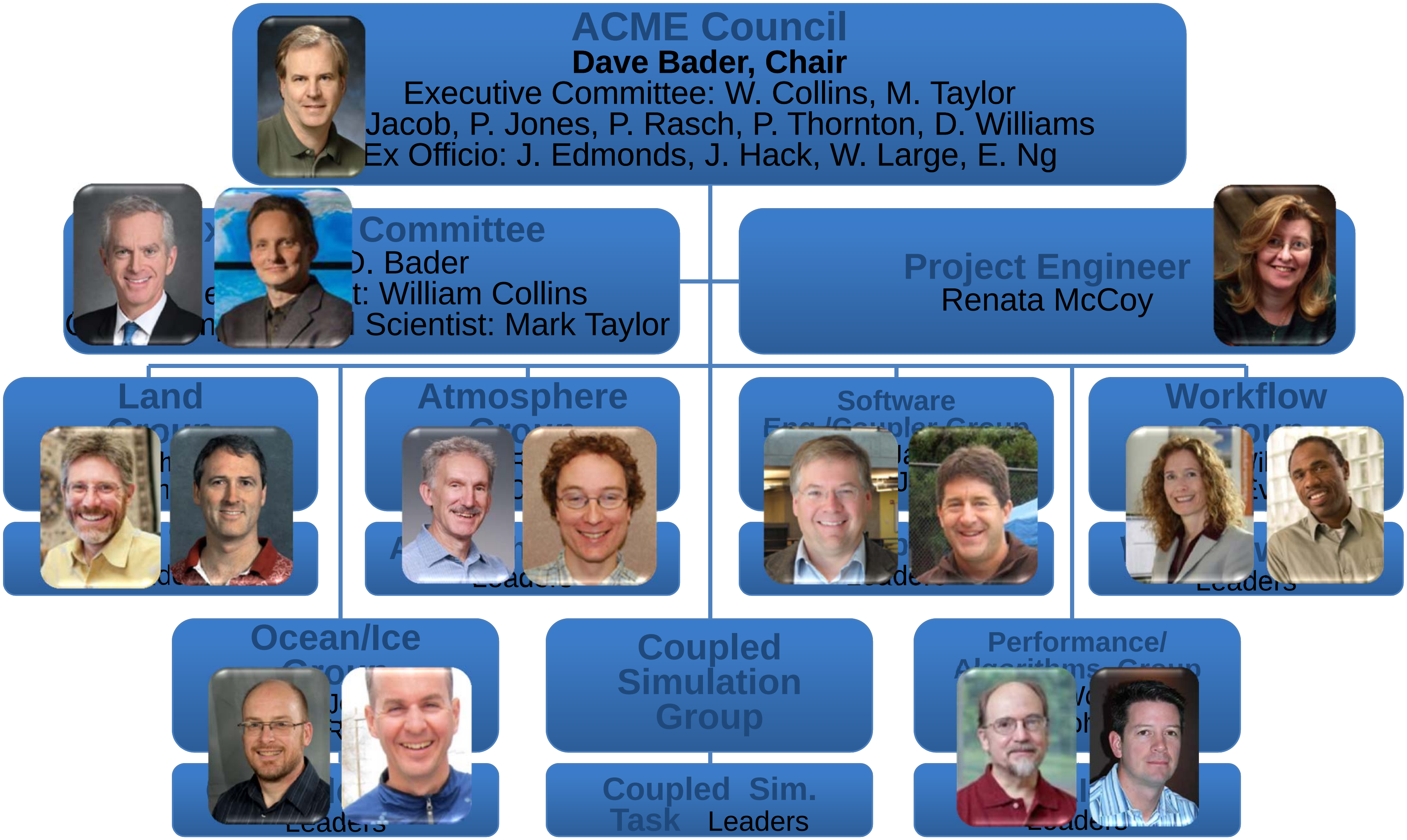
Coupled Simulation Group

Coupled Sim. Task Leaders

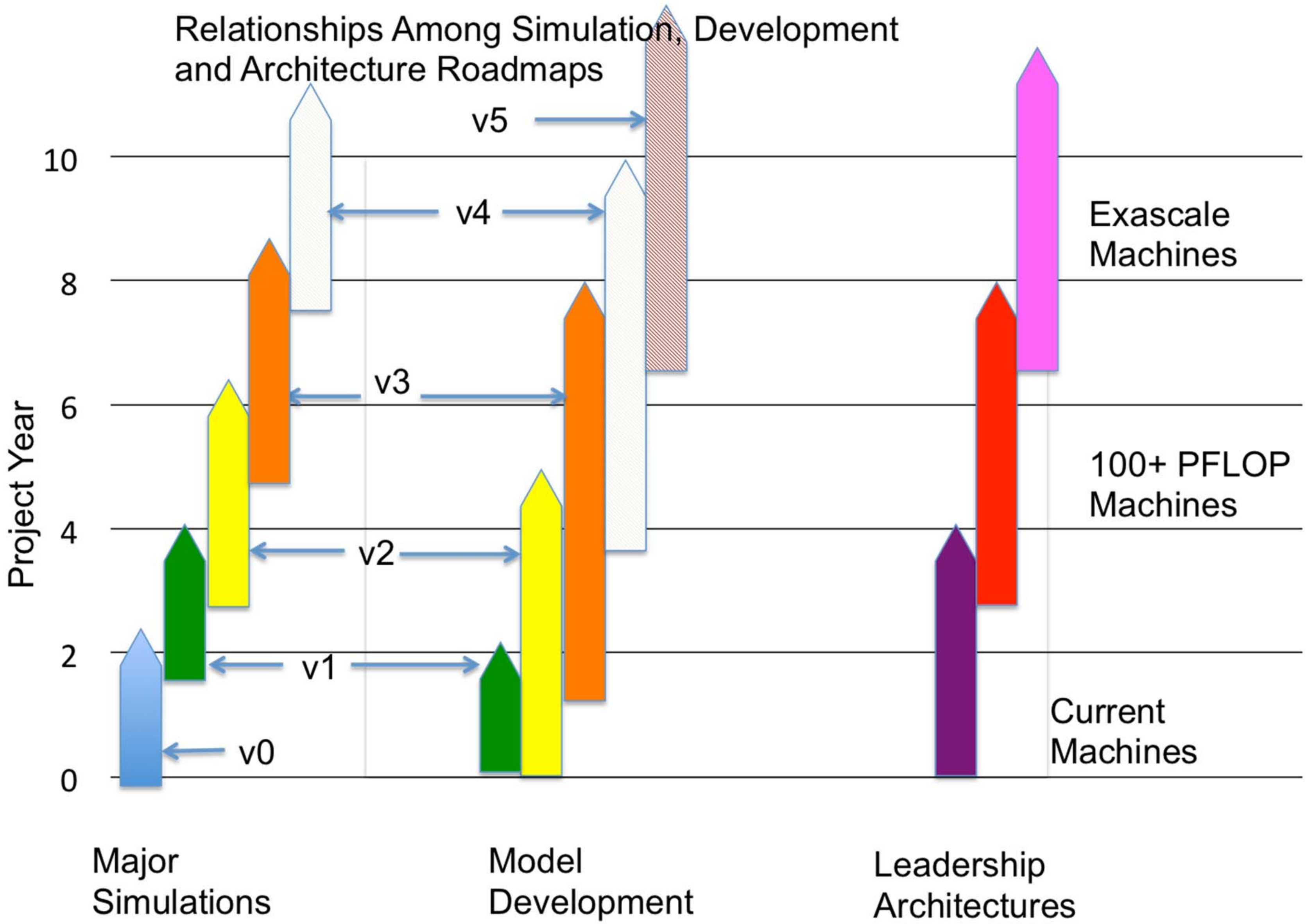
Performance/ Algorithms Group
Pat Worley
Hans Johansen

Perf. / Alg. Task Leaders

ACME management structure



ACME development Roadmap



Water Cycle Experiment Strategy

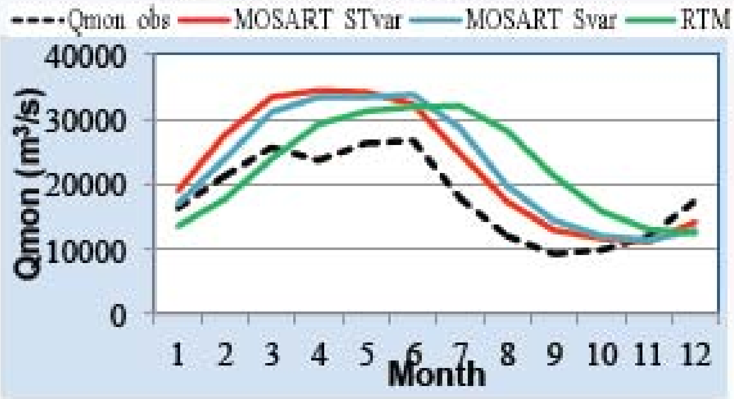
- **Explore the role of physical processes and parameterization in climate models influencing river flow and fresh water supply.**

Seasonally inundated river basins in central Amazon

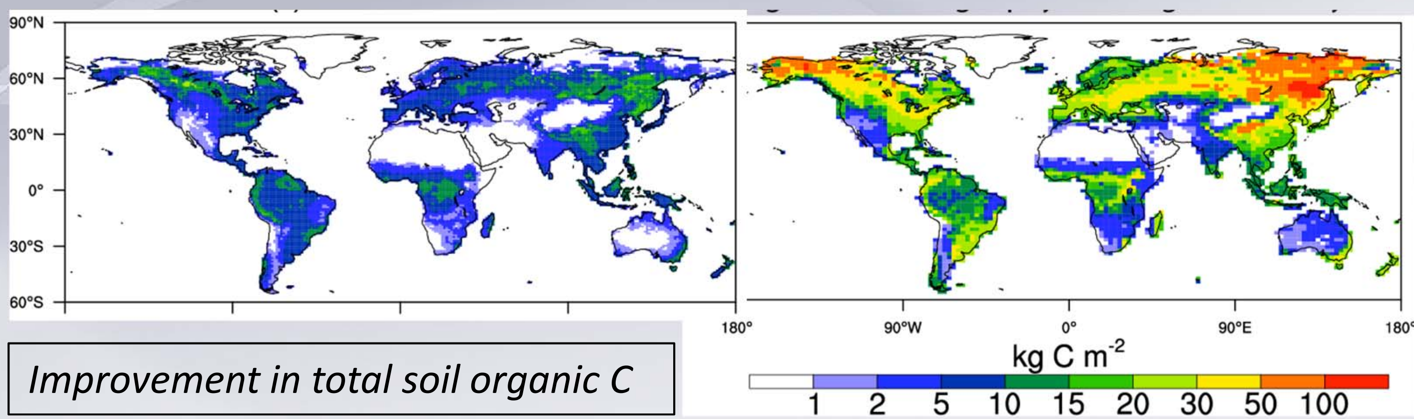
- **Produce accurate simulation of river flow for major river basins: Mississippi, Amazon, Ganges**

- **These basins represent very different:**
  - Climatic and hydrologic regimes
  - Large-scale ocean-atmosphere interactions
  - Regional land-atmosphere interactions
  - Local human activities

Monthly Mean Flow



Biogeochemical Experiments



Improvement in total soil organic C

Science Question

- What are the impacts of nutrients on terrestrial C-Climate feedbacks?

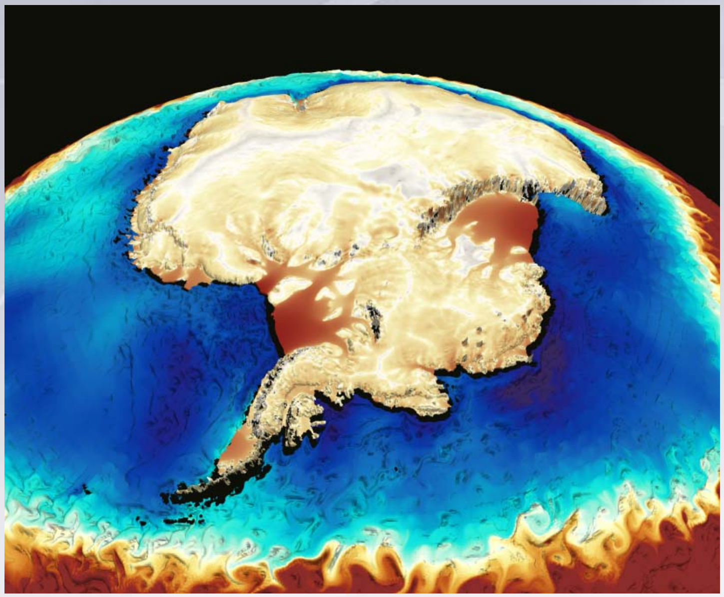
Motivation

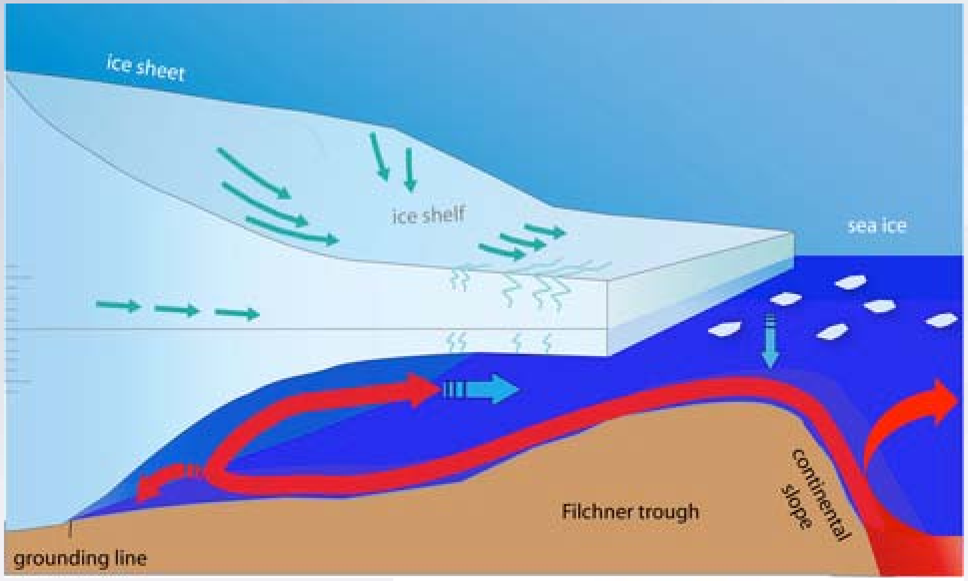
- Globally, many ecosystems are N, P, or N and P limited
- Current nutrient-enabled models show poor performance compared to observations

Goals

- Quantify impacts on C-climate system feedbacks by nutrients (nitrogen, phosphorus)
- Investigate structural uncertainty in representations of nutrient controls on C-cycle dynamics

Cryospheric Experiments





Coupling of new dynamic ice sheet to new MPAS (Model Prediction Across Scales) variable-mesh ocean and sea-ice to simulate ice-sheet instability, calving, and sea-level rise

DOE-ASCR: Two computational architecture paths for today and future leadership systems

Power concerns for large supercomputers are driving the largest systems to either Hybrid or Many-core architectures

Hybrid Multi-Core (like Titan)

- CPU / GPU hybrid systems
- Small number of very powerful nodes, with multiple CPUs and GPUs per node
- Multiple levels of memory – on package, DDR, and non-volatile

Many Core (like Sequoia/Mira)

- 10's of thousands of nodes with millions of cores
- Homogeneous cores
- Multiple levels of memory – on package, DDR, and non-volatile

http://science.energy.gov/~/media/ascr/ascac/pdf/meetings/20141121/Bland_CORAL.pdf

Significant challenge for ACME to design code for both architecture types!

ACME computation

Performance

Design code to run on DOE's Leadership Class computers, both existing and next-generation; internode, intranode parallelism.
Engage in "early-user" facility programs (NERSC-NESAP; OLCF-CAAR)

Software design

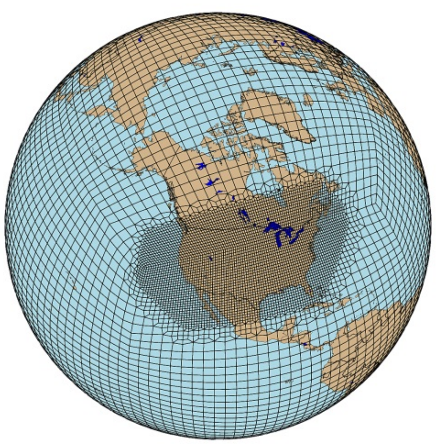
Software development for portability, and rapid testing; modularity

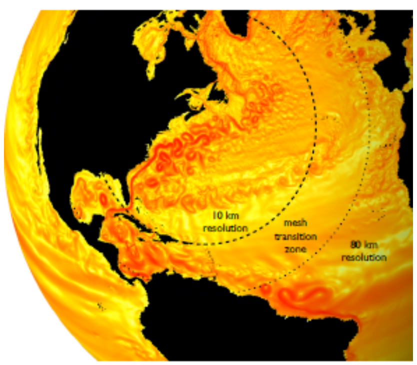
Workflow

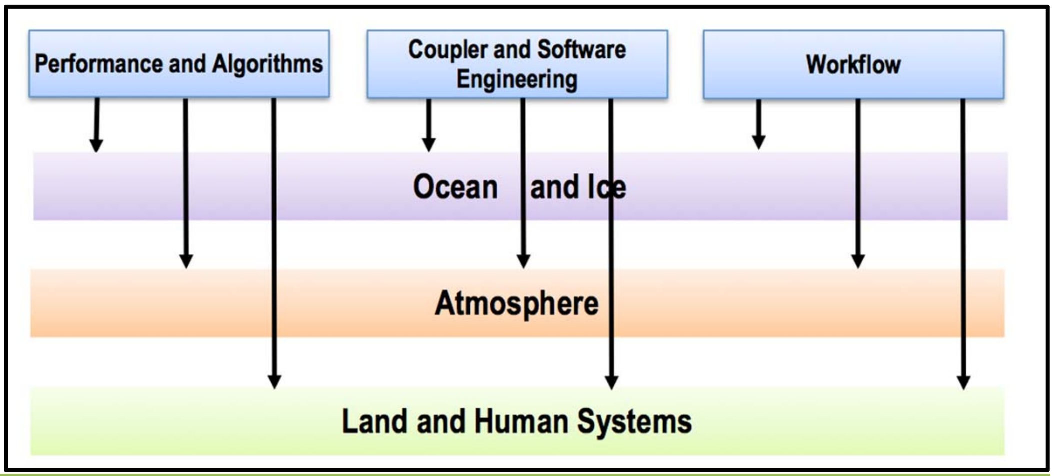
End-to-end model configuration, testing, validation, analysis, provenance

Algorithm

Variable mesh refinement, physics, in regions of interest or requirement.
New algorithm design affected by computer architecture.







ACME next steps

Energy/societal component

- **Proposal is invited on GCAM-ACME carbon cycle, water management, biofuel-crops; to engage IAR**

ASCR engagement

- **Active discussions on ACME collaboration**
- **SciDAC4 (computational partnership program)**
- **NERSC/OLCF/(ALCF) early-user programs**

Engagement of "Community"

- **BER SFAs, NGEE's, ARM-LES**
- **University projects and partners**

ACME v1 code and simulation release: July 2017

- **New ocean, ice, convection scheme, coupled regional refinement system (ocean-ice-atmosphere), BGC-CNP, watershed hydrology, sub-grid orography**

Thank you!

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ACME:
http://climatemodeling.science.energy.gov/projects/accelerated-climate-modeling-energy

Earth System Modeling:
http://science.energy.gov/ber/research/cesd/earth-system-modeling-program/