

Accelerated Climate Model for Energy

BER Advisory Committee



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U.S. DEPARTMENT OF
ENERGY

Office
of Science

Office of Biological
and Environmental Research

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



New Science using new capabilities

Science drivers

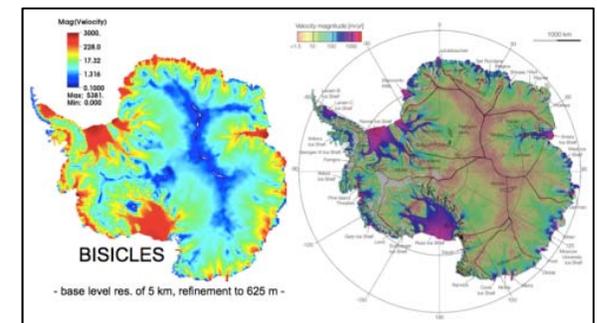
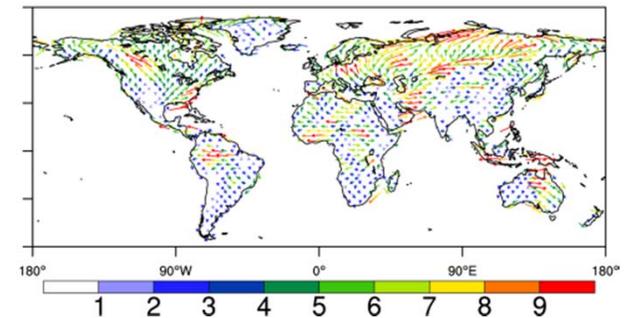
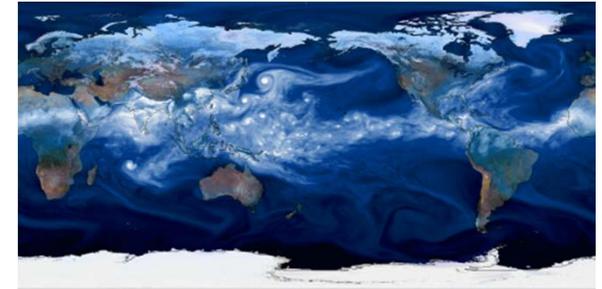
Water cycle: How do the hydrological cycle and water resources interact with the climate system on local to global scales?

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

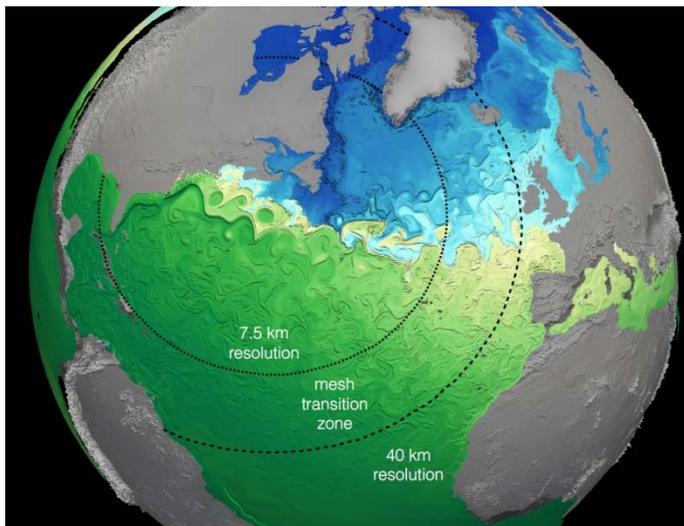
- Resolutions to resolve extreme phenomena
(15-25 km coupled; <10 km using adaptive grids)
- Integration of the human/energy component
(energy-water sector interdependence, bioenergy)
- Dynamic coupling of ice-ocean, sea-level rise



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	Yellow			Yellow			
LANL	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	
LBNL	Yellow			Yellow			Yellow
LLNL	Yellow	Yellow		Yellow	Yellow	Yellow	
ORNL	Yellow				Yellow	Yellow	Yellow
PNNL	Yellow	Yellow		Yellow			Yellow
SNL	Yellow					Yellow	
BNL	Yellow						

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

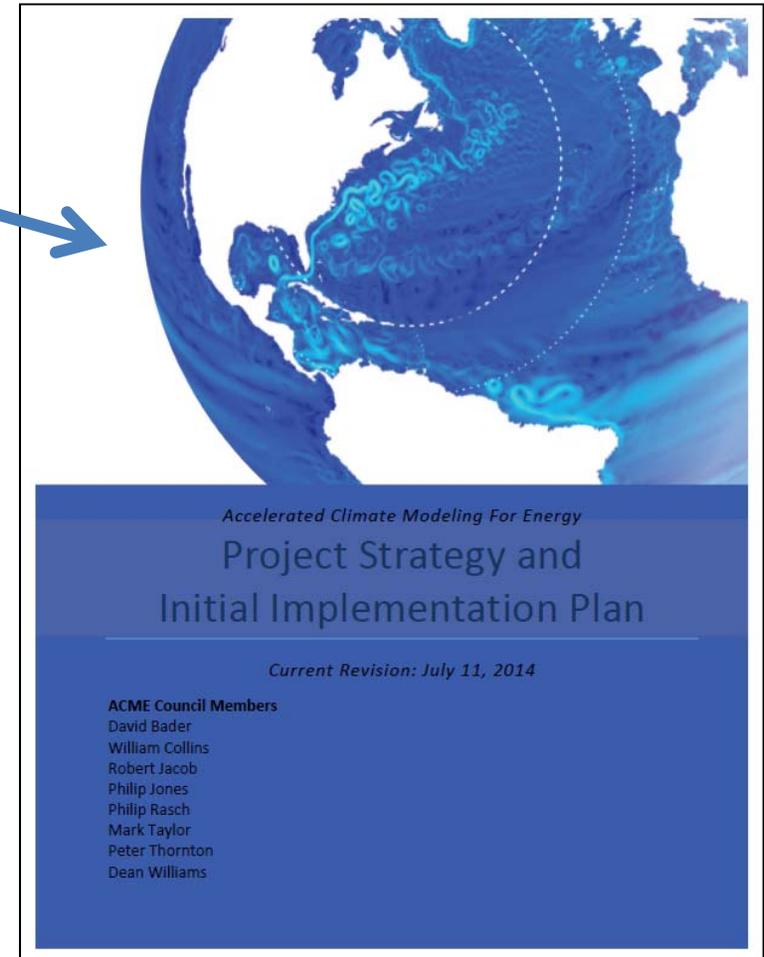
- Develop a concise and visionary document describing the project. Available on-line
- Careful consideration of the treatment of the energy/societal components.

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

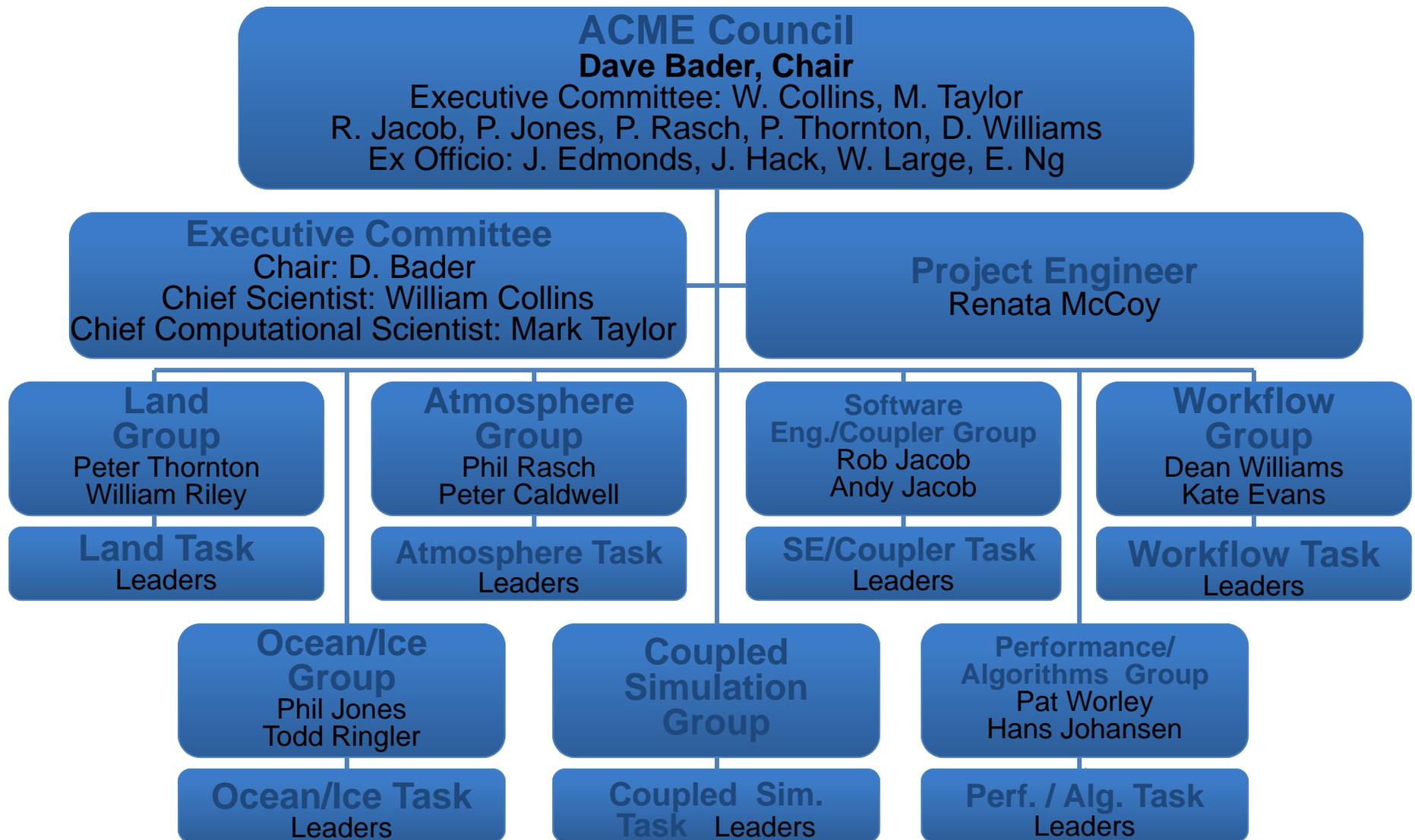
Management and progress review, January 2015

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

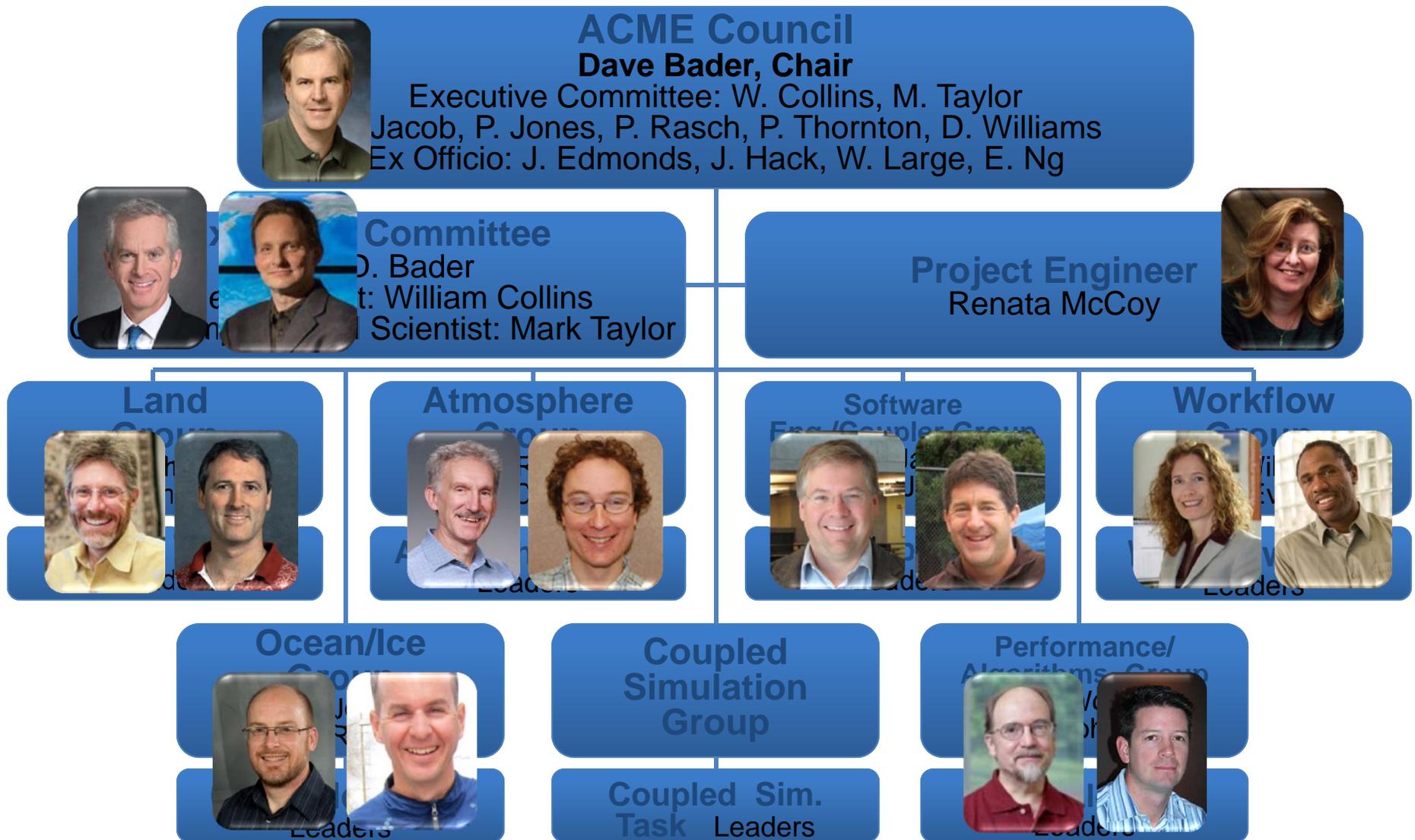


<http://climatemodeling.science.energy.gov/projects/accelerated-climate-modeling-energy>

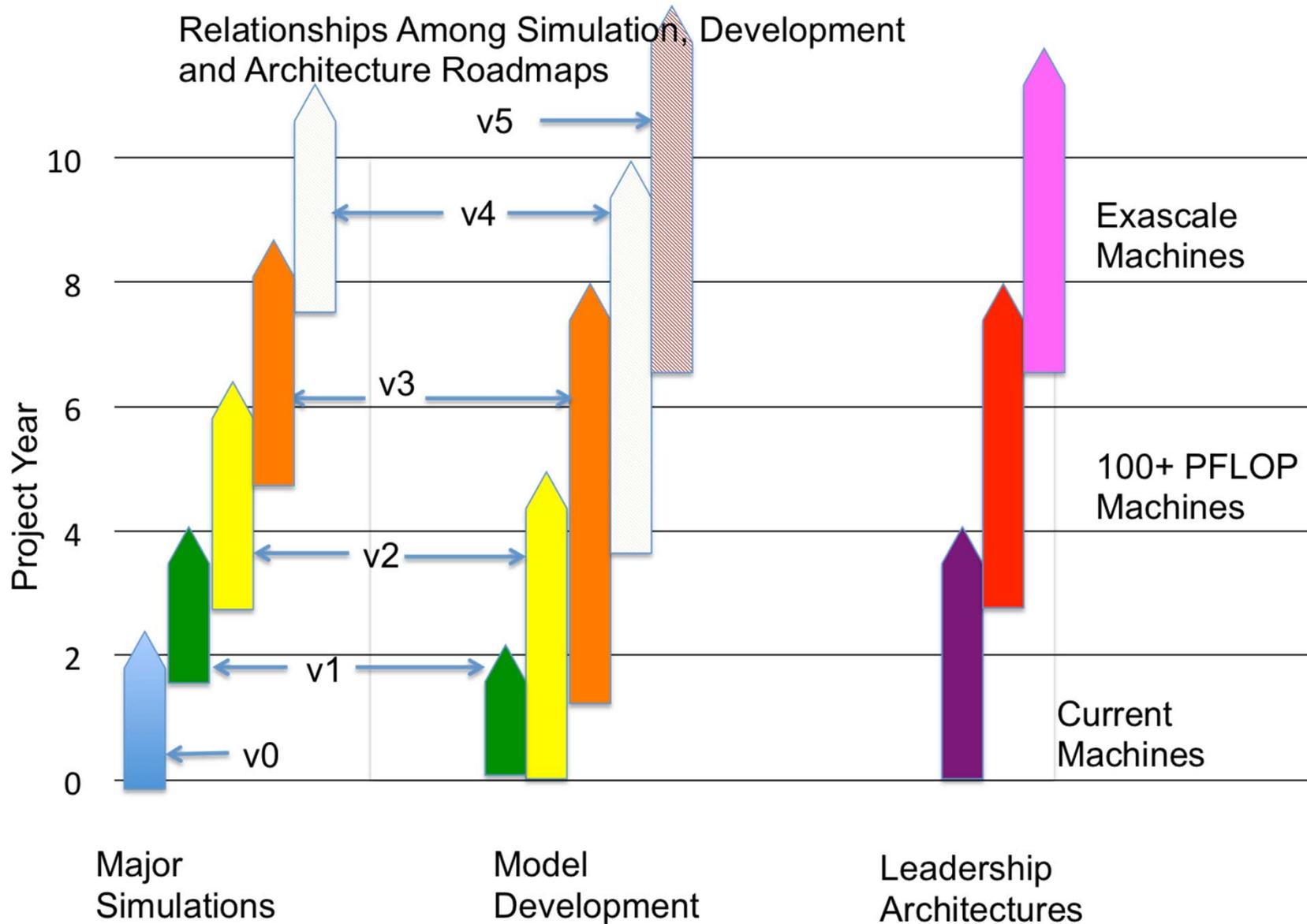
ACME management structure



ACME management structure



ACME development Roadmap



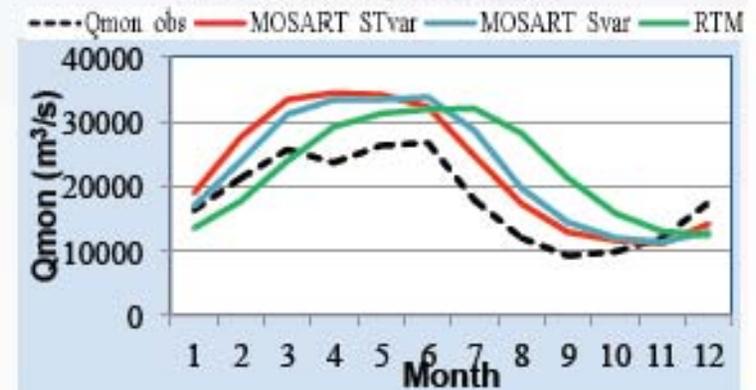
Water Cycle Experiment Strategy

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

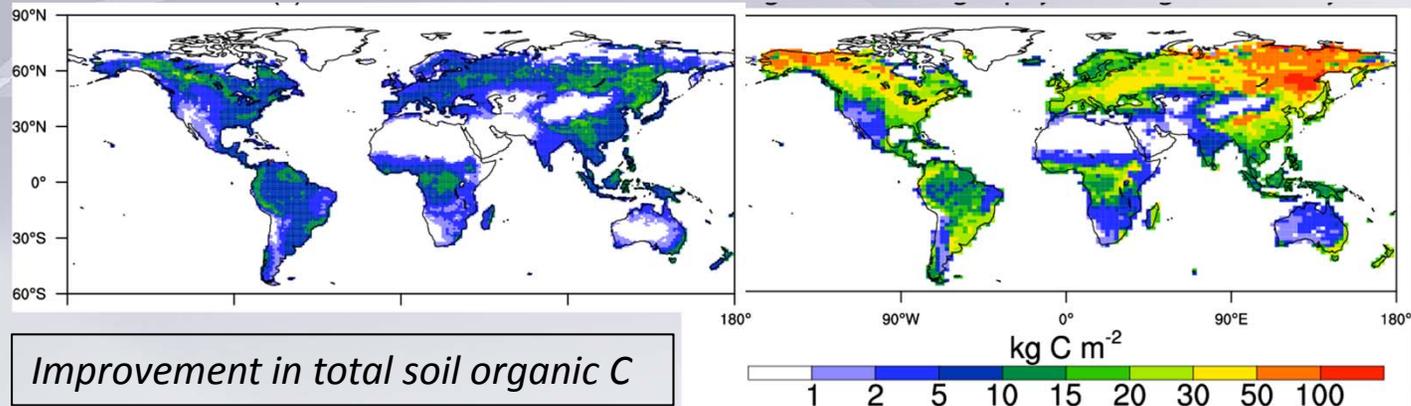
Seasonally inundated river basins in central Amazon



Monthly Mean Flow



Biogeochemical Experiments



Science Question

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

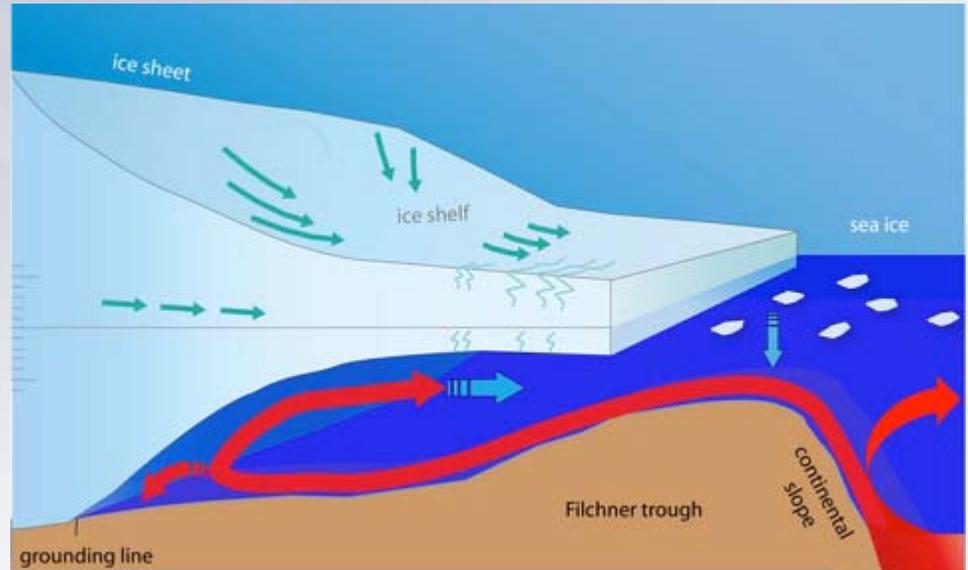
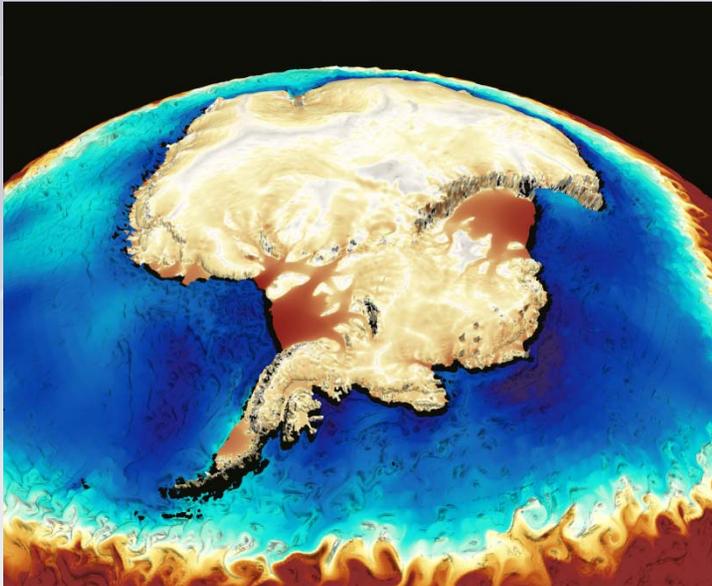
Motivation

- 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

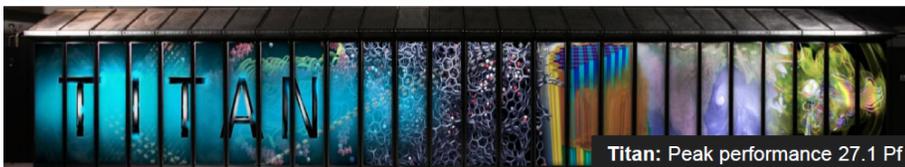
Power concerns for large supercomputers are driving the largest systems to either Hybrid or Many-core architectures

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

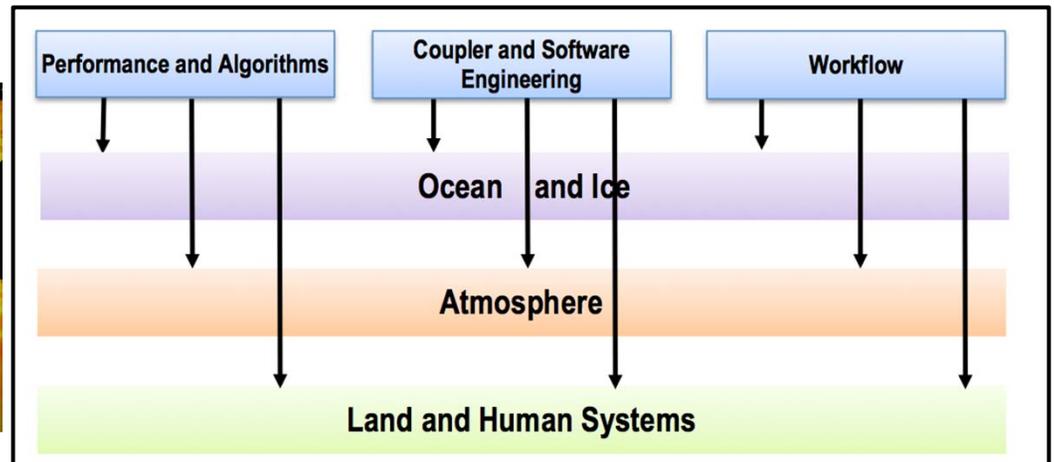
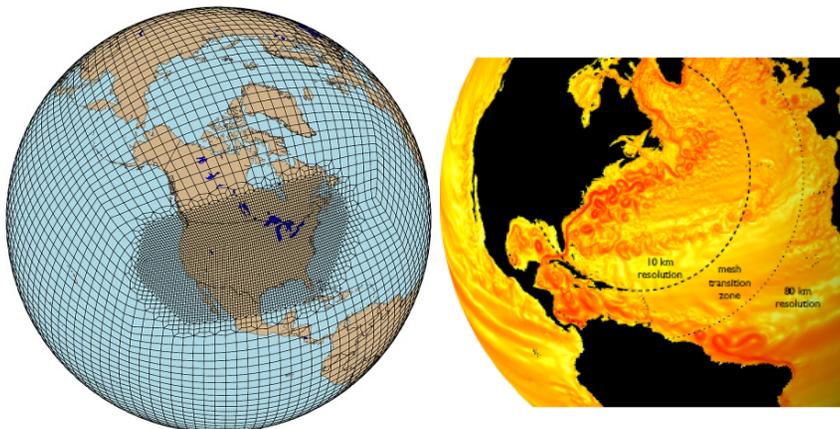
Workflow

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

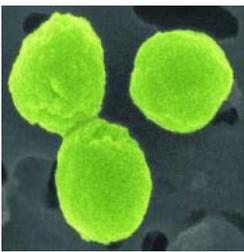
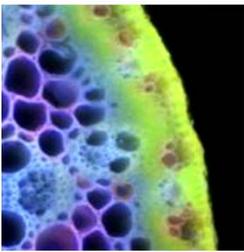
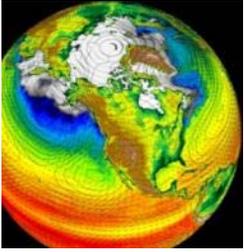
Engagement of “Community”

- 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/>



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