Accelerated Climate Model for Energy

BER Advisory Committee

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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
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

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

Committee
Chair: D. Bader
Scientist: William Collins
Scientist: Mark Taylor

Project Engineer
Renata McCoy

Land Group
Peter Thornton
William Riley

Atmosphere Group
Phil Rasch
Peter Caldwell

Ocean/Ice Group
Phil Jones
Todd Ringler

Software Eng./Coupler Group
Rob Jacob
Andy Jacob

Workflow Group
Dean Williams
Kate Evans

Performance/Algorithms Group
Pat Worley
Hans Johansen

Coupled Simulation Group
Coupled Sim. Task Leaders
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

Monthly Mean Flow

Seasonally inundated river basins in central Amazon
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
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

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

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