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
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
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
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/