Accelerated Climate Model for Energy

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Accelerated Climate Model for Energy
“ACME”

(Pending) Multi-Laboratory model development
Science Focus Area (SFA)

1. Consolidate 6 multi-Lab ESM projects into 1
2. Develop model to directly support energy
mission and BER science, climate projection
3. Improve the Community Earth System Model
(CESM) for optimal performance on DOE
Leadership Class Facility Computers (LCF’s)
Earth System Modeling (ESM) context

ESM mainly supports CESM development, in 3 areas:

1. SciDAC Lab-led projects (about 20%), FY11-16. Co-managed with Computing (ASCR)
   a) “Multi-scale” scale-aware physics for variable mesh dycores (MPAS-O and CAM-SE)
   b) “PISCEES” variable mesh ice sheets
   c) “ACES4BGC” atmosphere, ocean and land BGC, tracer transport

2. University-led projects (about 20%), mainly also SciDAC, some paleo-climate, some “TES-CLM”
   • Current (ESM-RGCM) solicitation (under review), would support collaboration with ACME, SciDAC, or CESM-trunk

3. Laboratory collaborative projects (about 60%)
## Model development in 6 laboratory collaborative projects

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Each Lab doing similar work on multiple projects
Projects overlapping in scope
** Not efficient **

1. **Restructure ESM Lab project portfolio**
   Reduce 6 projects to 1
ACME: ultra-high-resolution climate modeling

Ultra-high resolution (12-25 km atmosphere and land, 15 km ocean) 80 year simulation:

• 1970-2010 hindcast, validation and calibration using observations

• 2010-2050 projection, with uncertainty characterization.

Performance of the full coupled climate system will be central and overarching for the project.
2. ACME to address DOE-relevant Science

1. How do the hydrological cycle, and water resources, interact with the climate system on local to global scales?
   Including soil hydrology and terrestrial systems

2. How do biogeochemical cycles interact with global climate change?

3. How do rapid changes in cryospheric systems interact with the climate system?
   Including high latitude permafrost and boreal system responses

4. How do short-term variations in natural and anthropogenic forcings interact with natural variability and contribute to the rates of regional and global environmental change?
3. ACME to upgrade model to run on DOE computers

Existing and upcoming multi-core computational architectures at the Leadership Class Facilities (LCF’s) challenge all science applications.

ACME plans to adapt to these architectures by upgrading the climate codes in 3 areas:

1. Improve code performance to optimize performance on DOE machines (toward non-hydrostatic, 12 km)
2. Develop simulation/evaluation workflow to enable rapid model testing (e.g. using TES, satellite data, ILAMB)
3. Software to improve and accelerate model development process; automated tuning and testing; modularity to facilitate process research input (e.g. BGC terrestrial, subsurface processes)
ACME timeline

- **Summer 2012**: discussions about DOE imperative to adapt CESM to next generation computer architectures
- **Winter 2012**: workshop on DOE-climate-computing (whitepaper)
- **Spring 2013**: establish leadership “Council” of 13 to coordinate 7 Labs across climate/computation modeling disciplines.
- **Summer 2013**: invitation for proposal
- Monthly “team-building” face-to-face meetings as proposal is constructed. Weekly Council calls.
- **Winter 2013**: proposal submitted
- **March 2014**: proposal review
- **May 2014**: Team responds to reviews
ACME Links within DOE

**Terrestrial, Subsurface**
Detailed process field and modeling research support ACME-CLM development

**Regional and Global Climate Modeling**
Model analysis, diagnostics:
- SFAs: BGC feedbacks, Water cycle, Extremes, Cloud feedbacks, High-latitudes

**ASR/ARM**
Detailed process field and modeling research support ACME-CAM development

**Integrated Assessment**
Human-Climate interactions
- Energy and human impacts
- Possible pathways

**Advanced Scientific Computing Research (ASCR)**
e.g. SciDAC partnerships develop ACME branch

**Data Informatics**
Data processing, management
Model-observation platforms
ACME-MB: ACME HQ Management Board

DOE Community: YOU are the first customer and partner in ACME

ACME-MB established to coordinate programs at DOE

Climate model analysis (RGCM): 1PM
Integrated assessment (IAR): 1PM
Terrestrial (TES/ESS): 4 PMs
Atmosphere (ASR): 2 PMs
Data Informatics: 1PM
Computing (ASCR): 2 PMs

Facilities managers

Meet monthly; format for specific engagement TBD
ACME Links to other climate modeling activities

ACME aims to pioneer high resolution climate modeling using new computer architectures, and share successes with broader community

CESM:
- ACME would be a development branch of CESM with its own coupling capability; ACME code to be released (to CESM)
- NCAR/CESM engagement in ACME proposal and through the FOA

Other Centers:
- Modular codes with HPC capabilities to be shared
- DOE-NOAA MOU: potential for joint efforts
- Other potential engagement in multi-agency HPC efforts (e.g. ESPC, NUOPC)
ACME-Land goals

• ACME proposes significant global land model developments in order to address:
  – How do land and atmosphere interact at high resolution in a global climate system?
  – What are potential significant climate-carbon feedbacks, and how do these depend on vegetation and nutrient dynamics and microbial processes?

• ACME will also modularize code, enabling development of sub-components and testing of processes
Hydrology
Maoyi Huang (PNNL), Peter Thornton (ORNL)

Subsurface thermal hydrology:
CLM-PFLOTRAN: Developed under NGEE Arctic, expand to globe, couple in BGC

Runoff:
VIC scheme runoff

Rivers and floodplains:
MOSART river transport

Couple these 3
Vegetation
Charlie Koven (LBNL)

Age-class and time since disturbance
- Begin with CLM-ED, some of ED2
- Introduce nutrient coupling

Vertical canopy interactions from ED2
- Introduce vegetation heat storage

Root hydrology and dynamics
- Hydraulic redistribution and compensatory uptake
Biogeochemical Processes
Peter Thornton, Bill Riley

Riverine processes and transport
-Integrate aquatic reactions (C, N, P)
-Integrate with runoff and rivers
-Add particulates

Prognostic phosphorus
-CLM-CNP
-Integrate with PFLOTRAN

Explicit microbes
-Integrate SOM models, chemistry, methane model
-Couple to PFLOTRAN
-Nitrification, biological N fixation
Coupled system processes
Ruby Leung (PNNL) and Beth Drewniak (ANL)

Orographic downscaling
- Use watersheds as gridcells
- Implement T and precip downscaling scheme
- Sub-grid elevation classes

New crop schemes
Model evaluation, uncertainty quantification
Team; Dan Ricciuto (ORNL)

Hydrology evaluation

Vegetation evaluation

BGC evaluation

Uncertainty quantification
-Sensitivity
-Parameter-space optimization
-Bayesian inference methods or parameter uncertainty propagation
Code architecture and functional unit testing
Dali Wang (ORNL)

Use current refactoring efforts

Integrate with ACME testbed and workflow

Functional unit testing
- Prototype for photosynthesis
- Extend to other subroutines
ACME-ESS potentials…

Tell us how ACME might support and use your research to solve critical terrestrial and climate questions!

DOE
– Dorothy Koch (ACME PM, model development)
– Renu Joseph (global model analysis PM)
– Dan, Mike, Dave (TES/ESS PMs)

ACME
– Peter Thornton: ACME Council “Land” POC
– Peter Thornton, Bill Riley: ACME Terrestrial Team Leads
Questions?

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ACME-Tasks and leads

8 ACME Land Tasks:
1. Represent runoff partitioning with VIC model
   Maoyi Huang (PNNL)
2. Model age and size classes, time-since-disturbance
   Charlie Koven (LBNL)
3. Support grid and subgrid (structured and unstructured)
   Forrest Hoffman (ORNL)
4. Support elevation and orographic downscaling
   Ruby Leung (PNNL)
5. Provide uncertainty quantification for land model
   Dan Ricciuto (ORNL)
6. Conduct code modularization and functional unit testing for land model
   Dali Wang (ORNL)
7. Develop unified carbon cycle for prognostic land use/land cover
   Peter Thornton (ORNL)
8. Develop agricultural, crops, including bioenergy
   Beth Drewniak (ANL)