DOE Earth System Modeling Program

CESM Activities

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SSC/CAB/WG Breckenridge
Climate & Environmental Sciences Division Strategic Goals (Strategic Plan soon available)

1. Synthesize new process knowledge and innovative computational methods advancing next generation, integrated models of the human-earth system.

2. Develop, test and simulate process-level understanding of atmospheric systems and of terrestrial ecosystems extending from bedrock to the top of the vegetative canopy.

3. Advance fundamental understanding of coupled biogeochemical processes in complex subsurface environments to enable systems-level prediction and control.

4. Enhance the unique capabilities and impacts of the ARM and EMSL scientific user facilities and other BER community resources to advance the frontiers of climate and environmental science.

5. Identify and address science gaps that limit translation of CESD fundamental science into solutions for DOE’s most pressing energy and environmental challenges.
Climate and Earth System Modeling is part of the U.S. Department of Energy’s Office of Biological and Environmental Research (BER) Climate and Environmental Sciences Division (CESD). Our focus is on the development, evaluation, and use of regional and global models, development of Earth system models, and development of integrated assessment models to determine the impacts and possible mitigation of climate change.

Climate and Earth System Modeling is supported by three research programs: Earth System Modeling, Regional & Global Climate Modeling, and Integrated Assessment of Global Climate Change.

This website will share CESM’s climate modeling activities and progress. Check back soon for more highlights.
Flyers!

AGU Town Hall on DOE climate modeling and LC computing
ESM/DOE priorities for CESM

1. High and/or variable resolution atmosphere and ocean for increased predictability needed by energy

2. Cloud-climate interactions, to reduce largest climate response uncertainty, and to improve precipitation and hydrology needed for energy

3. Terrestrial carbon and other land systems, needed for carbon-climate response, hydrology, biofuels

4. Cryosphere and ocean systems, land/sea-ice/ocean interactions, needed for sea-level rise, coastal infrastructure

5. Human-energy-climate interactions, needed to support future energy systems
DOE FY12 CESM component development investments

1. CLM 9M (includes “human” processes)
2. CAM, aerosols, clouds, chem 7M
3. POP, MPAS, ocean biogeochemistry 6M
4. CISM, CICE 2.4M
5. Coupled system 3M
6. “Testbeds” 4M
7. Visualization 4M
Projects may be multi-lab (11), single lab ("Science Focus Area") or University-led (10).

DOE pursues 2 main CESM development thrusts:

1. System processes
   A. Clouds, aerosols (cloud feedbacks, precip extremes)
   B. Terrestrial (carbon cycle, climate-terrestrial interactions)
   C. Human-climate coupling (and energy)
   D. Cryosphere (sea-level, albedo feedbacks)

2. "Next Generation"
   A. High or variable resolution (ocean, atmos, cryo)
   B. Enhanced performance or analysis on LC computers
   C. Testbeds, uncertainty characterization methods to calibrate models with measurements
IMPACTS: INVESTIGATION OF THE MAGNITUDES AND PROBABILITIES OF ABRUPT CLIMATE TRANSITIONS
Collins PI, 2008-13

- Methane: from clathrate sediments, in water column, atmosphere

- Boreal Arctic feedbacks: Methane biogeochemistry, lake upgrade in CLM
  Shrub height feedbacks (Bonfils et al., ERL, 2012; IOP select paper)

- Megadroughts, positive feedbacks from vegetation, soil (CLM4VIC)
  Dust

- Ice-sheet – ocean interface, important for simulation of WAIS stability

- POP adjoint for AMOC stability
“Polar”: Improving the characterization of Clouds, Aerosols and the Cryosphere in Climate Models
2009-2013 Jones, Rasch PI’s

**Cryosphere, ocean:**
- Sea-ice strength, melt rates: chlorophyll, salinity effects
- Ice sheet mass-balance
- Arctic ocean circulation
- Ocean biogeochemistry

**Atmosphere:**
- Aerosol transport and deposition
- Arctic clouds, COSP simulator

**Coupled Systems**
iESM: Improving the Representation of Human-Earth System Interactions, 2009-13

- Create a first-generation iESM with both the human components of an integrated assessment model (GCAM) and the CESM
- PNNL (Edmonds), LBNL (Collins), ORNL (Thornton) and the U of Maryland

Initial experiments focusing on land use illustrate the importance of including albedo effects of land use change in future calculations of radiative forcing (submitted to Science)

- First version of code coupling land systems of GCAM and CESM is largely complete and being prepared for release to the CESM community.
- AGU Session at Fall 2012 meeting
Ultra High Resolution Global Climate Simulation to Explore and Quantify Predictive Skill for Climate Means, Variability and Extremes

Hack, PI, 2010-14

- Simulate climate, non-linear interactions at very high resolution (T85, T341)
- Extremes

- Balancing, tuning is challenging!
- Land-model spin-up slow
- Migrating to CAM-SE, will benchmark variable mesh simulations

- POP, CICE at 0.1 degrees;
- Initialization challenges
- Influence of CICE on AMOC

- High-res Aerosol effects on climate: black carbon stabilizes marine stratus
Cross-cutting Themes and Labs to advance CESM to address high priority DOE climate research

**Testbeds for CESM:** Uncertainty Quantification and data for model calibration

**3 Components:**
- Atmosphere
- Land
- Ocean and Sea-Ice

**3 Research Directions:**
- Hydrologic simulation improvement
- Variable-resolution numerical methods
- Carbon cycle uncertainty reduction

**9 Labs:**
- ANL
- BNL
- LANL
- LBNL
- LLNL
- ORNL
- PNNL
- SNL
- NCAR
The CSSEF testbed and development system was designed by the crosscutting Data Infrastructure and Testbed team based on requirements set by CSSEF modelers and observational scientists.

Uncertainty quantification is built-in: A power wall visualization of a Monte Carlo sensitivity study involving 1000 single-point model simulations of the Community Land Model with carbon-nitrogen biogeochemistry (CLM-CN) at the Niwot Ridge flux tower in Colorado is demonstrated.
1. Multiscale Methods for Accurate, Efficient, and Scale-Aware Models of the Earth System
Bill Collins, PI
LBNL, LANL, PNNL, ORNL, SNL, UCAR, UW-M, CSU, UCLA

Will introduce accurate and computationally-efficient treatments of interactive clouds, convection, and eddies into the next generation of CESM at resolutions approaching the characteristic scales of these structures and deliver these process treatments and constituents that are scientifically useful over resolutions ranging from 2 to 1/16 degrees.
2. Predicting Ice Sheet and Climate Evolution at Extreme Scales (PISCEES)
Bill Lipscomb, PI
LBNL, LANL, ORNL, SNL, UCAR, MIT, FSU, U-SC, UT-Austin

Develop two ice sheet dynamical cores:
1) finite-volume, structured, Chombo adaptive mesh
2) finite-element, unstructured MPAS mesh

3. Applying Computationally Efficient Schemes for BioGeochemical Cycles (ACES4BGC)
Forrest Hoffman, PI
ORNL, SNL, LLNL, PNNL, LANL, ANL, UCAR

1) new tracer advection scheme, supporting thousands of species in atmosphere and ocean models
2) Improving organic emissions, chemistry
Climate model analysis and visualization 2010-2013, 3 projects

1. Ultra-scale Climate Data Analysis Tools (UV-CDAT)
   Williams, PI

2. Visual Data Exploration and Analysis of Ultra-large Climate Data
   Bethel, PI

3. “parVis”
   Jacob, PI

AGU Session at Fall 2012 meeting
Ultra-scale Climate Data Analysis Tools (UV-CDAT)
On ESGF, tools include CDAT, DV3D, ParaView, VisIt, and R
Visual Data Exploration and Analysis of Ultra-large Climate Data
TECA: Toolkit for Extreme Climate Analysis

Science need:
- General Framework for Spatio-temporal pattern recognition
- Need a generic framework for exploiting parallelism across
  - spatial locations
  - time slices
  - ensemble members
- Allow developers to focus on creating new detection techniques

Solution:
- Developed TECA framework
- Refactored cyclone, extra-tropical cyclone and atmospheric river detection codes
- TECA paper accepted for publication in ICCS Workshop on Data Mining in Earth System Science
**Official Release 1.0.0**

**UV-CDAT = CDAT · VisTrails · ParaView · VisIt · DV3D · R**

1.0.0 Official Release – May 9th, 2012

1.0.0 Beta Release – April 4th, 2012

1.0.0 Alpha Release – February 20th, 2012

Downloads – 130+ Downloads for beta version in less than 2 weeks

Usage – 600+ different users from 400+ machines logged using UV-CDAT since alpha release

Release and presentations can be found at the following URLs: [http://uvcdat.llnl.gov/](http://uvcdat.llnl.gov/)

User support mailing list: uvcdat-support@llnl.gov
ParVis

Analysis: ParCAL: Parallel Climate Analysis Library, fast calculations on e.g. unstructured grids (PnetCDF, MOAB, Intrepid)

Visualization: ParNCL: speed up NCL

Diagnostic workflows: Swift task parallelism

Hardware adaptation (GPU’s, clouds)
### University-led “SciDAC” projects doing CESM development

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<th>Project</th>
<th>Leader</th>
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<td>Physics and Dynamics Coupling Across Scales in the Next Generation CESM: Meeting the Challenge of High-Resolution</td>
<td>Bacmeister</td>
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<td>A Flexible Atmospheric Modeling Framework for the CESM</td>
<td>Randall</td>
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<td>A Petascale Non-Hydrostatic Atmospheric Dynamical Core in the HOMME Framework</td>
<td>Tufo</td>
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<td>Chemistry in CESM-SE: Evaluation, Performance and Optimization</td>
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<td>Interactive Photochemistry in Earth System Models to Assess Uncertainty in Ozone and Greenhouse Gases</td>
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<td>Development of hybrid 3-D hydrological modeling for the NCAR Community Earth System Model (CESM)</td>
<td>Zeng</td>
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<td>Building Improved Optimized Parameter Estimation Algorithms to Improve Methane and Nitrogen Fluxes in a Climate Model</td>
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<td>Improving the Representation of Coastal and Estuarine Processes in Earth System Models</td>
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<td>Improving CESM Efficiency to Study Variable C:N:P Stoichiometry in the Oceans</td>
<td>Primeau</td>
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<td>Development of an Isotope-Enabled CESM for Testing Abrupt Climate Changes</td>
<td>Otto-Bleisner</td>
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Final thoughts

- Consolidation towards “process” and “next generation” tracks in CESM development.
- Use Testbeds and work with RGCM to develop and apply metrics to measure model improvement.
- Long-term goal is to optimize model complexity, resolution, performance (speed) for climate projection.
- PR: website including publication and news content, flyers, Town Halls, special sessions
Thank you!

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http://www.climatemodeling.science.energy.gov/