The SciDAC2 CCSM Consortium Project: A Scalable and Extensible Earth System Model

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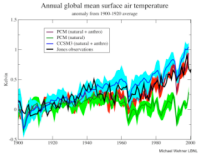
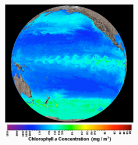
Scientific Challenge

To determine the range of possible climate changes over the 21st century and beyond through simulations using a more accurate climate system model that includes the full range of human and natural climate feedbacks with increased realism and spatial resolution





Objective

The primary objective of this proposal is to develop, test, and exploit a first generation of Earth system models based upon the CCSM. We will bring to the community a new well-validated version of CCSM that will run efficiently on thousands of processors and include significant model enhancements.

Improvements to the representation of carbon and chemical processes for treatment of greenhouse gas emissions and aerosol feedbacks will be performed in collaboration with the DOE *Atmospheric Science* Program, DOE *Atmospheric Radiation Measurement* Program, and DOE *Terrestrial Carbon Program.* This project will enable climate change simulations required for scheduled national and international climate change assessments to which the CCSM is committed as part of the *National Climate Change Science Program* (CCSP) strategy.

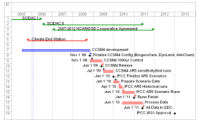
Collaborations

Scientific Applications (SAs) and Partnerships(SAPs)

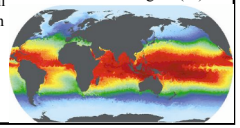
Brookhaven National Laboratory Robert McGraw
Oak Ridge National Laboratory Patrick Worley
Argonne National Laboratory Kotamarthi Rao

Centers for Enabling Technology Collaborations

Earth System Grid (ESG) - Dean Williams
Performance Engineering (PER) – Bob Lucas
VACET – Wes Bethel ; SDM - Ari Shoshani
TOPS – David Keyes; ITAPS - Lori Diachin
APDEC - Phil Colella



Computational Climate End Station for Climate Change Science
- Warren Washington (PI)

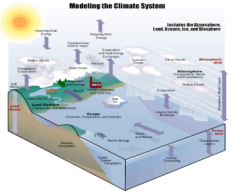


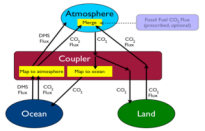
Sea surface temperatures simulated on 0.1° displaced pole grid using the POP2 code

Goals and Deliverables

Over the next five years, we will pursue this objective through four integrated goals:

1. Extend the capabilities of the Community Climate System Model (CCSM) to include representations of biological, ecological, chemical, and aerosol processes that will allow scientists and policy-makers to simulate climate and climate change using a comprehensive Earth system model,
2. Provide the necessary software and modeling expertise to rapidly integrate new methods and model improvements,
3. Pursue the development and evaluation of innovative methods in the coupled context of the CCSM, and
4. Improve the performance, portability and scalability of the CCSM on available and future computing architectures for use in national and international assessments of climate change.





Tasks and Organization

Earth System Model

- Terrestrial carbon cycle and dynamic vegetation
- Atmospheric chemistry and aerosol dynamics
- Ocean ecosystems and biogeochemical coupling
- Feedbacks between atmospheric composition and biogenic emissions

Model Integration and Evaluation

- Integration and unit testing
- New icesheet and ocean models
- New atmospheric dynamics: finite volume (cubed sphere), discontinuous Galerkin, others(icosahedral)
- Frameworks for model evaluation

Computational Performance

- Scalablity to thousands of processors, load balance, (fault recovery)

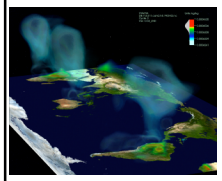
Current Activities

Model Integration and Evaluation:

Software enabling integration:
- Model Coupling Toolkit (MCT 2.3.0) released (1/10/07)
- Optimized coupling strategies
- New methods for model evaluation (w/ Rao)

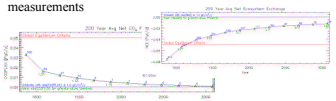
Current Activities (cont.)

Biogeochemical Coupling:

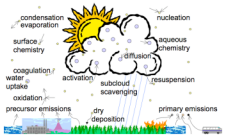


Atmospheric CO2 resulting from ecosystem respiration from the CLM3-CASA'

Carbon Land Model Intercomparison (C-LAMP):
- Determine the best set of terrestrial biogeochemistry process representations to include a future release of CCSM
- Three models coupled to CCSM3: CLM3-CASA', CLM3-CN, and LSX-IBIS
- Experiments are being performed with changing climate, CO2, nitrogen, and land use
- Comparison with high frequency, high quality flux tower measurements

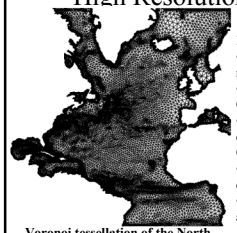


Aerosols and Atmospheric Chemistry



- Aerosols alter cloud properties and the distribution of radiation in the atmosphere
- Development of a faster chemistry package for the troposphere and lower stratosphere
- Introduction of modal and moment representations of aerosol dynamics modeling aerosol size distribution
- Modeling the surface emissions of pollutants changes atmospheric radiation

High Resolution Ocean and Cryosphere:



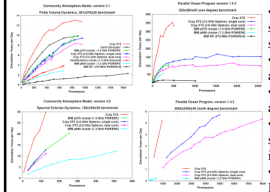
Voronoi tessellation of the North Atlantic with 85K cells - Gunzburger and Ju

Ice sheet model:
- Largest missing piece of physical climate model and necessary for sea level rise prediction
- Variable resolution for melting at margins of ice sheet

Ocean vertical grids:
- Arbitrary Lagrangian-Eulerian vertical grid for deep ocean circulation with good resolution in the surface mixed layer

Ocean horizontal grids:
- Eddy-resolving simulations required for adequate simulation of ocean circulation
- Unstructured grids provide ability to focus grids in eddy-active regions at reduced cost

Scalability and Performance:



Software enabling scalability:
- Collecting performance data to quantify and identify scalability limiters. Modifying code to improve scalability:
- Enabling different degrees of parallelism in physics and dynamics of atmosphere model.
- Identifying and eliminating nonscalable memory allocations.
- Working with Pnetcdf developers and CCSM software engineers to implement a single parallel I/O interface across all CCSM components.
- Validating software solutions on large Cray XT3 and IBM BlueGene systems.

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Project Web Page: www.scidac.gov/climate/earth.html