SciDAC CCSM Consortium: Overview and Recent Progress

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(On behalf of all the consorts)

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(short update to presentation given at March 16, 2005 SEWG meeting)
Community Climate System Model Consortium Project

Building a fully coupled, global climate model that provides state-of-the-art computer simulations of the Earth’s past, present, and future climate states

The SciDAC CCSM Consortium consists of PI: P. Jones⁴, J. Drake⁵, Site-Contacts: C. Ding², S. Ghan⁶, P. Cameron-Smith³, J. Larson¹, W. Collins⁷, W. Washington⁷, S.-J. Lin⁸, Co-Is: J. Baumgardner⁴, T. Bettge⁷, L. Buja⁷, S. Chu⁴, T. Craig⁷, P. Duffy³, J. Dukowicz⁴, S. Elliot⁴, D. Erickson⁵, M. Ham⁵, Y. He², F. Hoffman⁵, E. Hunke⁴, R. Jacob¹, J. Larson¹, J. Lamarque⁷, W. Lipscomb⁴, M. Maltrud⁴, D. McKenna⁷, A. Mirin³, W. Putman⁸, W. Sawyer⁸, J. Schramm⁷, T. Shippert⁶, R. Smith⁴, M. Vertenstein⁷, P. Worley⁵, W. Yang²

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Project Goals

• To advance the state of the art in climate modeling by adding to the functionality of the model as well as designing the model to take advantage of the modern scalable high performance computing systems.
• Maintain state of the art, production ready, community simulation capabilities (specifically, the CCSM on DOE supercomputers).

The overarching goal of the project is to accelerate the rate of development of successive generations of coupled climate models, and accelerate the porting of the models to new architectures. To sustain accelerated development, two software engineering objectives must be achieved and maintained in the CCSM: model extensibility and performance portability.
Recent SE Foci

- Release of CCSM for use in the IPCC fourth assessment report.
- Port and validation of CCSM to the Cray X1.
- Papers for special issue of IJHPCA on software engineering in climate and weather models.
Special Issue of IJHPCA

Preface
A. Patrinos

Overview of the Software Design and Parallel Algorithms of the CCSM
G. Carr, J. Drake, P. Jones

Performance Portability in the Physical Parameterizations of the Community Atmospheric Model
P. Worley, J. Drake

A Scalable Implementation of a Finite-Volume Dynamical Core in the Community Atmospheric Model
A. Mirin, W. Sawyer

Cross-Platform Performance of a Portable Communications Module in the NASA Finite Volume General Circulation Model
W. Putnam, S-J. Lin, B-W. Shen

High Resolution Mesh Convergence Properties and Parallel Efficiency of a Spectral Element Atmospheric Dynamical Core
J. Dennis, A. Fournier, W. Spotz, A. St-Cyr, M. Taylor, S. Thomas, H. Tufo

Vectorizing the Community Land Model (CLM)
F. Hoffman, M. Vertenstein, H. Kitabata, J. White III

A Performance Model of the Parallel Ocean Program
D. Kerbyson, P. Jones

The Model Coupling Toolkit: A New Fortran90 Toolkit for Building Multi-Physics Parallel Coupled Models
J. Larson, R. Jacob, E. Ong, Guo

Cp6: The New Extensible, High-Performance Parallel Coupler for the Community Climate System Model
A. Craig, R. Jacob, B. Kauffman, T. Bettge, J. Larson, E. Ong, C. Ding

MxN Communication and Parallel Interpolation in CCSM3 Using the Model Coupling Toolkit
R. Jacob, J. Larson, E. Ong

Coupling Multi-Component Models by MPH on Distributed Memory Computer Architectures
Y. He, C. Ding

Distributed and Implementation of Earth System Modeling Framework Components
W. Collins, G. Theurich, C. DeLuca, A. Trayaonv, P. Li, W. Yang, C. Hill
Current Foci:
SE Support for 2005 Deliverables

- High resolution climate change simulations using CCSM3 on vector systems
- Carbon cycle simulations using CCSM3 for Coupled Climate Carbon Cycle Model Intercomparison Project (C4MIP)
- Coupled climate-carbon cycle model simulations with interactive land and chemistry
Quarterly Metrics

Performance metrics for coupled climate-carbon-sulfur cycle model:

• Q1: Implement Ocean Biogeochemistry in POP2.0 and add to CCSM
• Q2: Implement a CCSM3 coupler to exchange carbon and sulfur between components
• Q3: Test Coupled Model
• Q4: Run Coupled Model including carbon and sulfur cycles with an interactive land.

These are DOE reporting requirements.

Don't Panic
Other SE-related Activities

• Parallel I/O (using parallel netcdf)
  – Successfully implemented in SLD dycore
• Single-executable CCSM (via MPH)
  – Proof of concept implementation / coordinating with ESMF
• Coupler (cpl6) and Toolkit (MCT):
  – portability enhancements (Cray X1, NEC SX, Fujitsu VPP, SGI Altix, 32 and 64-bit reals, …)
  – multi-language support (via BABEL)
• Architecture studies (using POP and CAM/CLM primarily):
  – Cray X1E, Cray XD1, Cray XT3, IBM BG/L, IBM p690 cluster with HFS interconnect, SGI Altix
Other SE-related Activities

- Atmospheric Model Improvements:
  - Empirical studies of sources of load imbalances in physical parameterizations and efficacy of current load balancing schemes, for both standard physics and with subgrid orography. (See IJHPCA papers.)
  - (additional) Support for MPI-1 collectives, MPI-2 and Co-array Fortran one-sided implementations of global communication operators.
  - Spectral dycores: generalized domain decompositions for reduced grid.
  - FV dycore:
    - vectorization and X1-specific optimizations (See poster.)
    - version synchronization (with NASA and NOAA)
Other SE-related Activities

- C4MIP support
  - Data cycling capabilities in CSIM and DOCN
  - CLM/CASA’ integration and vectorization
  - CLM/CN vectorization
  - LSM/IBIS integration
  - Coupler updates to support land CO2 forcing from CAM
- CCSM port, validation, and optimization on the Cray X1
  - Including re-optimization and re-validation as CCSM and system software evolve
- POP model development: HYPOP, POP2 vectorization, …
- CICE model development: cache/vectorization, …
Expected Future SE-related Activities

Include …

- Support for high resolution runs
- Exploiting new HPC architectures
- Support for additional atmospheric chemistry, including
  - Efficient transport
  - Load balancing
- Supporting new packages, dycores, components, …
  - (Helping) clean up and generalize interfaces
  - Exploring new grid systems and dycores
  - Testing methodology