A Scalable and Extensible Earth System Model for Climate Change Science

John B. Drake
Oak Ridge National Laboratory
Phil Jones
Los Alamos National Laboratory

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CCPP Project Review

Hyatt Regency Bethesda

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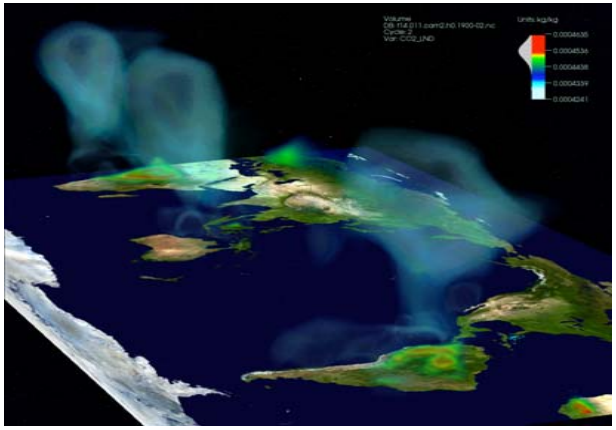
The SciDAC CCSM Consortium: Who are we?

- ***Lead PI:*** **John B. Drake, Oak Ridge National Laboratory**
- ***Co-Lead PI:*** **Phil Jones, Los Alamos National Laboratory**
- **Argonne National Laboratory (ANL) Robert Jacob, Ray Loy, Jay Larson**
- **Brookhaven National Laboratory (BNL) Robert McGraw**
- **Lawrence Berkeley National Laboratory (LBNL) William Collins*, Inez Fung*, Michael Wehner**
- **Lawrence Livermore National Laboratory (LLNL) Phillip Cameron-Smith, Arthur Mirin**
- **Los Alamos National Laboratory (LANL) Scott Elliot, Philip Jones, William Lipscomb, Mat Maltrud**
- **National Center for Atmospheric Research (NCAR) Peter Gent, Andrew Conley, Tony Craig, Jean-Francois Lamarque, Mariana Vertenstein, Warren Washington**
- **Oak Ridge National Laboratory (ORNL) Marcia Branstetter, John Drake, David Erickson, Kate Evans, James Hack*, Forrest Hoffman, W. M. Post*, Peter Thornton, Patrick Worley, Trey White**
- **Pacific Northwest National Laboratory (PNNL) Steven Ghan, Xiaohong Liu and Richard Easter**
- **Sandia National Laboratories (SNL) Mark Taylor**

- **Scientific Application Partnerships**
- **Brookhaven National Laboratory Robert McGraw**
- **Oak Ridge National Laboratory Patrick Worley**
- **Argonne National Laboratory Kotamarthi Rao *(contact Jay Larson)**

- **Centers for Enabling Technology Collaborations**
- **ESG - Dean Williams**
- **PERI – Pat Worley**
- **VIZ – Wes Bethel**
- **TOPS – David Keyes**
- **ITAPS – Lori Diachen**



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

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Objectives

The primary objective of the project is to develop, test, and exploit a first generation of Earth system models based upon the CCSM that will run efficiently on thousands of processors and include significant model enhancements.

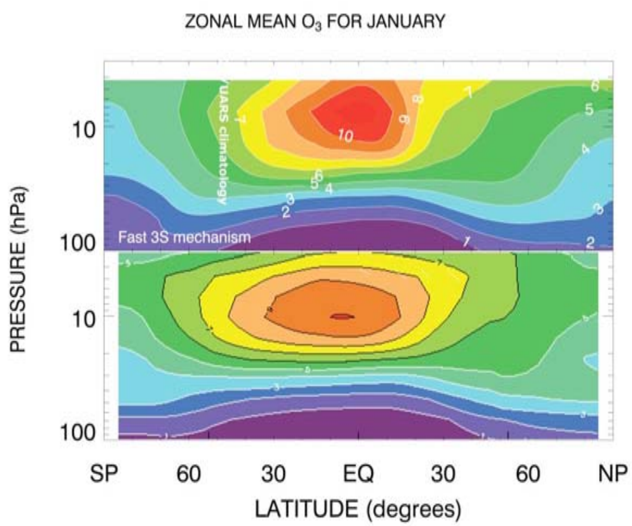
Improvements to the representation of carbon and chemical processes for treatment of greenhouse gas emissions and aerosol radiative forcing is being performed in collaboration with the DOE *Atmospheric Science* Program, DOE *Atmospheric Radiation Measurement* Program, and DOE *Terrestrial Carbon Program.* 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.

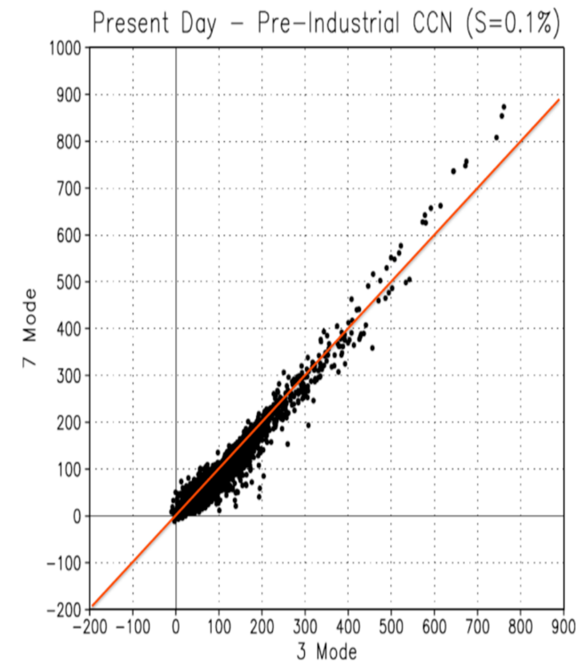
Tasks and Organization

- **Scalable and Extensible Earth System Model (SEESM)**
  - **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 ice sheet and ocean models**
  - **new atmospheric dynamics: finite volume (cubed sphere), continuous Galerkin, others**
  - **frameworks for model evaluation**
- **Computational Performance**
  - **scalability to thousands of processors, load balance, (fault recovery)**
  - **performance portability and software engineering**

Earth System Model

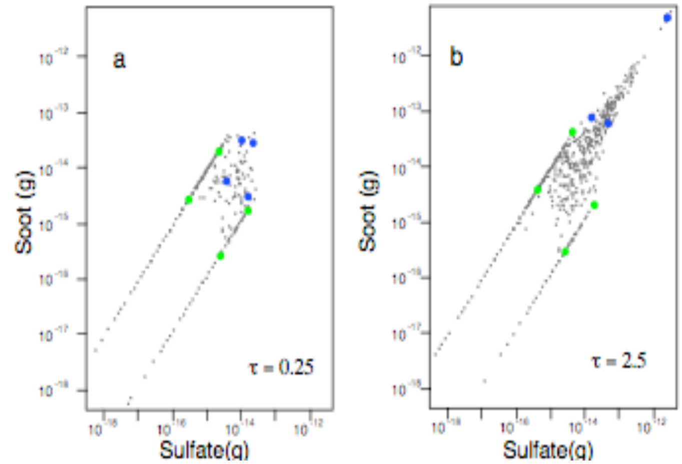
- **Super-duper-really-ultra-fast chemistry in CAM (P. Cameron-Smith)**
  - **Reduced cost 450% to 40%**
- **Aerosol modal method (S. Ghan)**
  - **Multi-mode schemes to capture aerosol mass,size distributions for cloud processes**

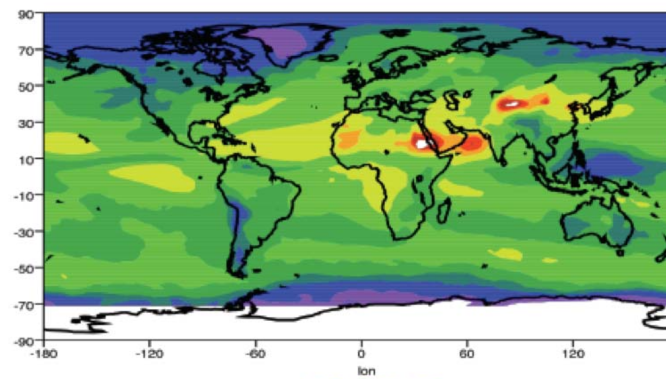




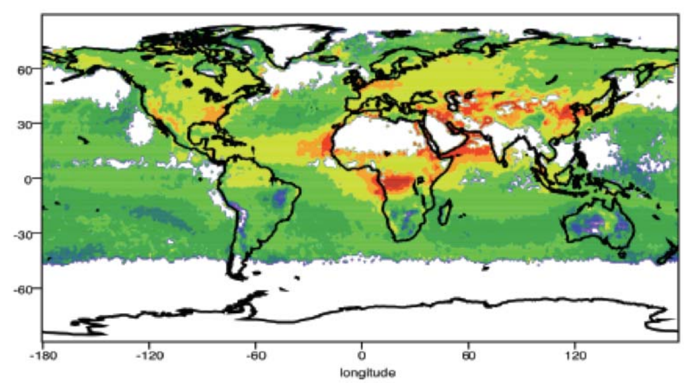
Earth System Model

- **Quadrature Method of Moments (QMOM, R. McGraw)**
  - **Faster method for treatment of aerosol distributions**
- **Aerosol validation (PNNL)**
  - **Process-level**
  - **Regional – field studies**
  - **Global**



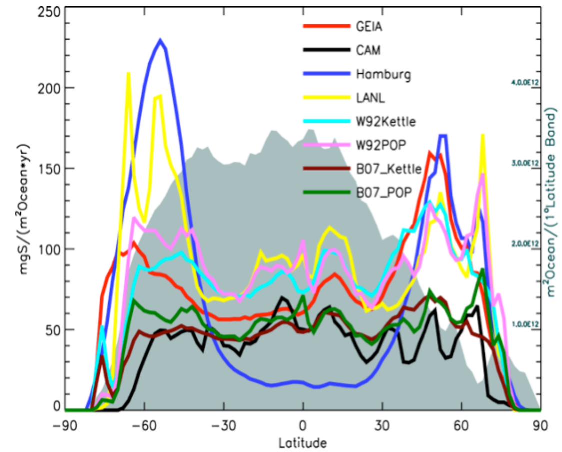


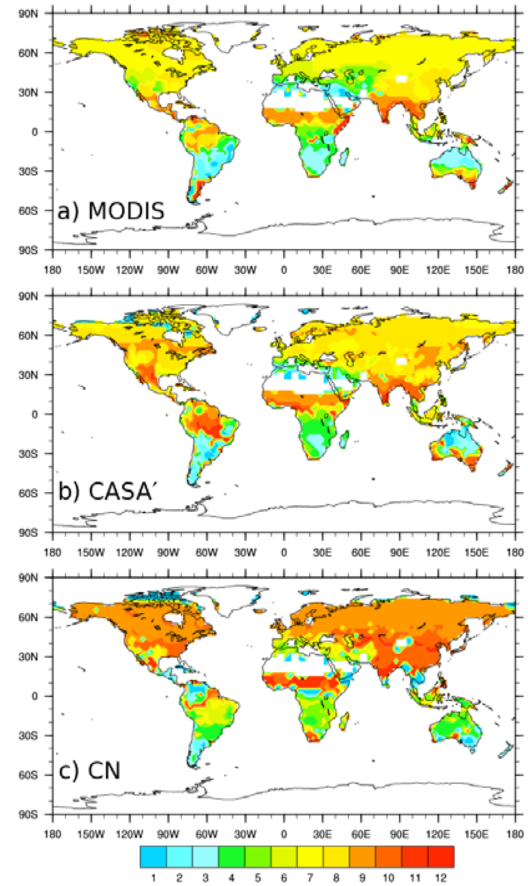
MODIS



Earth System Model

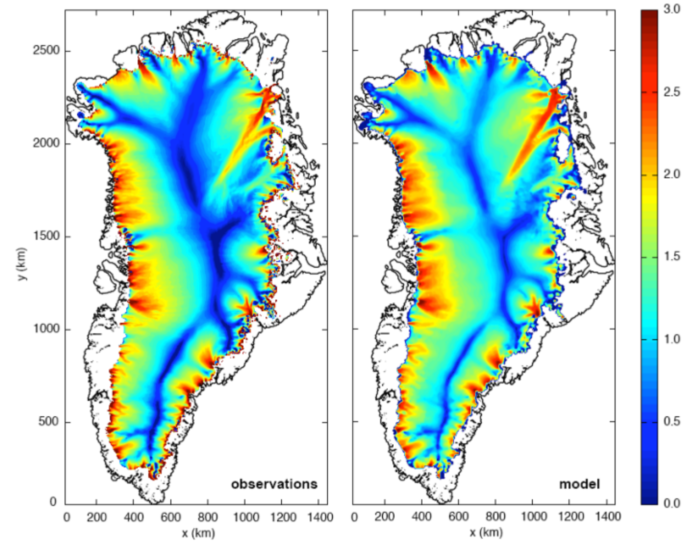
- **Coupled sulfur cycle model (P. Cameron-Smith, S. Elliot, M. Maltrud et al)**
  - **Improvements to ocean, atmosphere sulfur cycle and air-sea exchanges**
  - **New simulation hampered by physical solution**
- **C-LAMP (F. Hoffman)**
  - **Continued improvements to land and land carbon models**
  - **Coordinated experiments and distribution of data**

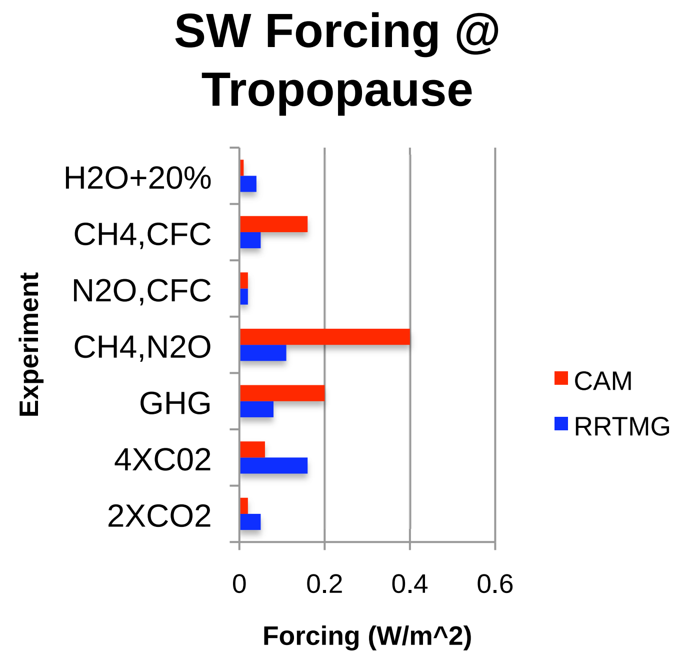




Model Integration

- **Ice sheet model (W. Lipscomb)**
  - **Coupling in CCSM (w/ T. Craig)**
  - **Mass balance scheme in CCSM**
  - **Higher-order dynamics**
  - **Parallelization and new solvers**
  - **CISM**
- **Rapid Radiative Transfer Method (Collins, Conley, Iacono)**
  - **Accurate compared to obs (ARM, CERES)**
  - **Accurate forcing by GHGs**
  - **First ESM with SW forcing by CH_4**



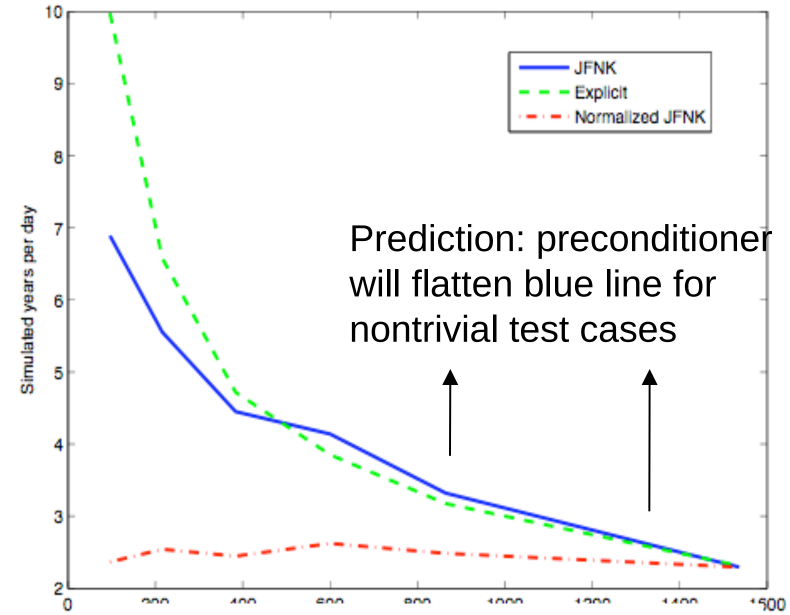


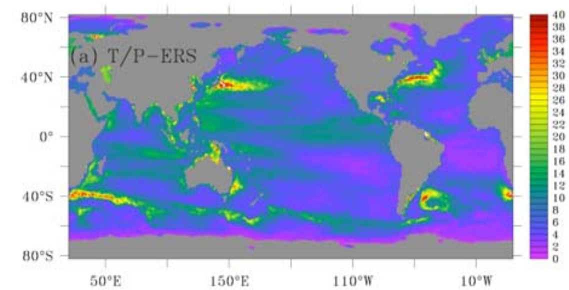
Model Integration

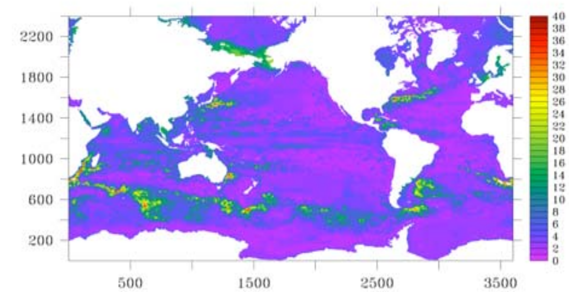
- **CAM-HOMME (M. Taylor)**
  - **Spectral element cubed sphere**
  - **Improved conservation, transport**
  - **AMIP simulations**
- **Variable resolution grids and dycores (T. Ringler)**
  - **Unstructured grids for ocean/ ice**
  - **New dycore (w/ Skamarock, Klemp)**

Model Integration

- **New implicit methods (K. Evans, W. Weijer)**
  - **JFNK schemes for CCSM**
  - **Improved spinup, equilibrium states, parameter continuation**
  - **CAM-SE and POP implemented for several time-stepping schemes**
  - **Preconditioners**
- **High resolution evaluation**
  - **High resolution coupled and uncoupled simulations**
  - **.25 FV atm – 0.1 ocean simulation**
  - **New tracers**

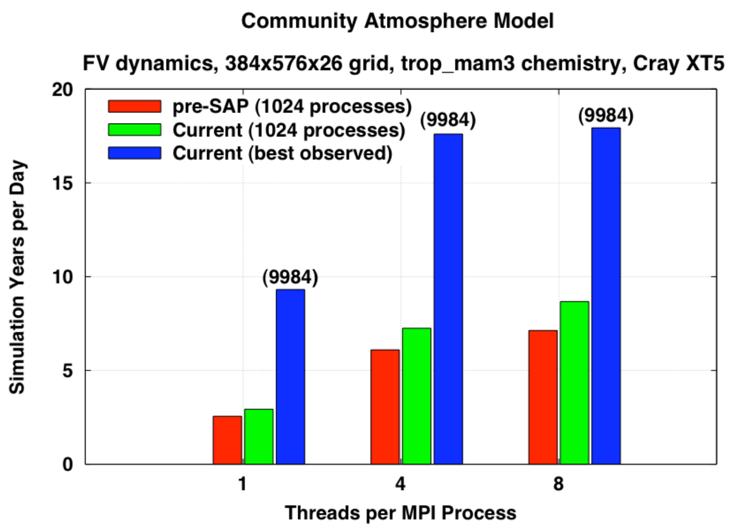






Performance

- **CAM Scalability and Performance Improvements (Mirin, Worley)**
  - **More than 2x improvements**
  - **Scalability**
  - **Exposing more parallelism**
- **Coupling, Parallel I/O (R. Jacob)**
  - **Continued work on MCT**
  - **Parallel I/O**



Future directions

- **More and better**
  - **Coupled sulfur cycle, aersols and land carbon**
  - **New dycores and numerical schemes**
  - **Integration and evaluation of new components**
  - **Performance and scalability**
- **Aiding and abetting**
  - **Focus on IPCC preparations and simulations**