# Terrestrial Biogeochemistry in the Community Climate System Model (CCSM)


Forrest M. Hoffman (1), Inez Fung (2,3), Jim Randerson (4), Peter Thornton (5), Jon Foley (6), Curtis Covey (7), Jasmin John (3), W. Mac Post (1), Mariana Vertenstein (5), Reto Stöckli (8), Steve Running (9), Faith Ann Heinsch (9), David Erickson (1), John Drake (1)

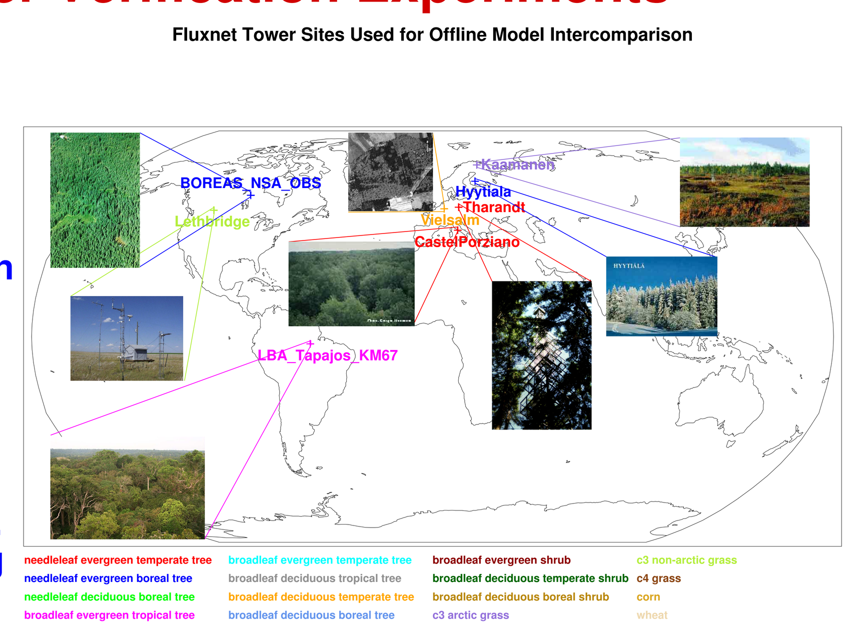
(1) Oak Ridge National Laboratory, (2) Lawrence Berkeley National Laboratory, (3) University of California Berkeley, (4) University of California Irvine, (5) National Center for Atmospheric Research, (6) University of Wisconsin Madison, (7) Lawrence Livermore National Laboratory/Program for Climate Model Diagnosis and Intercomparison, (8) Colorado State University, (9) University of Montana

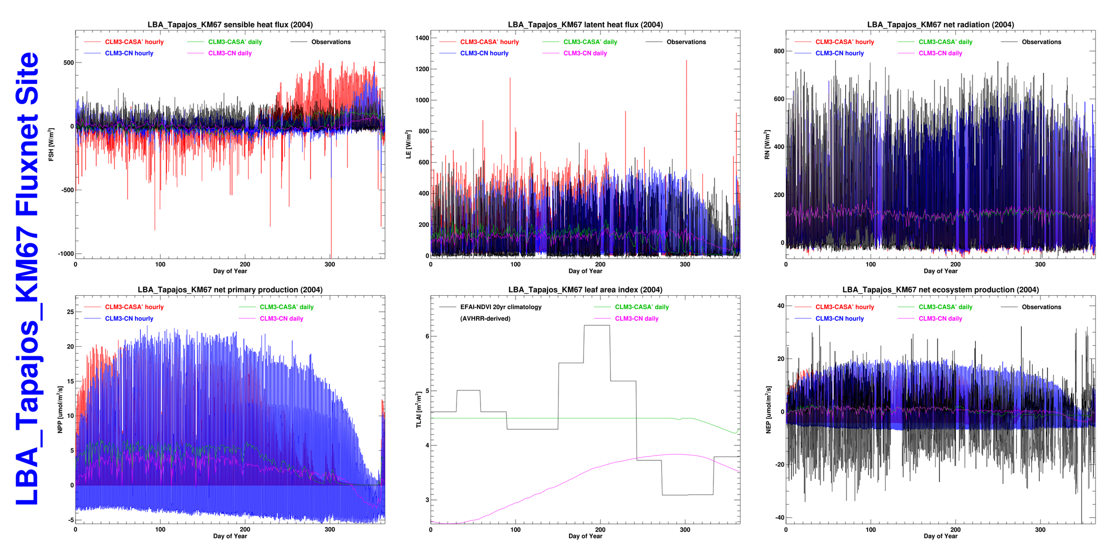

## Introduction

As general circulation models (GCMs) evolve and improve, there is increasing interest in applying them to understand the potential for global climate change. The global carbon cycle is of particular importance since it is thought to have a significant impact on global temperatures. A wide array of carbon models have been coupled to GCMs, and recent work has shown that coupled interactive biogeochemical models can yield useful results for climate change studies (e.g., Friedlingstein et al. 2005). Described here are intercomparison experiments using three such models coupled to the Community Climate System Model (CCSM). Two of these models, CASA' and IBIS, were previously coupled to GCMs, and a brand new model––called CN and also running in the CCSM framework––are part of a more–directed model intercomparison project specific to CCSM. It is expected that the results of this intercomparison will lead to the deployment of a production terrestrial biogeochemistry capability within the CCSM for use with runs supporting the Intergovernmental Panel on Climate Change Fifth Assessment Report.

## Fluxnet Tower Verification Experiments

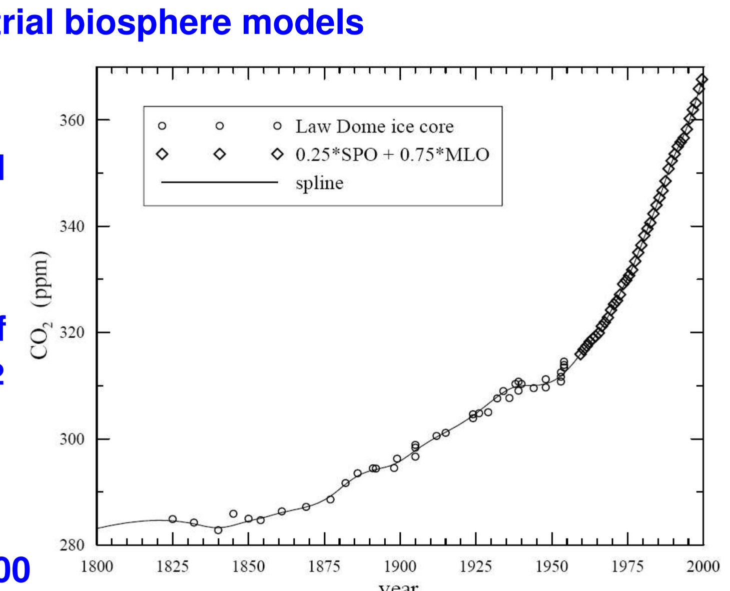
A series of offline experiments are being performed using Fluxnet site meteorology data over a range of land cover types following the C–LAMP Experiment 1 protocol to gain additional early insights into the differences between these three land biogeo–chemistry models. To date, eight sites have been run with hourly output using CLM3–CASA' and CLM3–CN. IBIS runs will be forthcoming once the NCEP driver code is added to that model.




## C4MIP Phase 1 Protocol

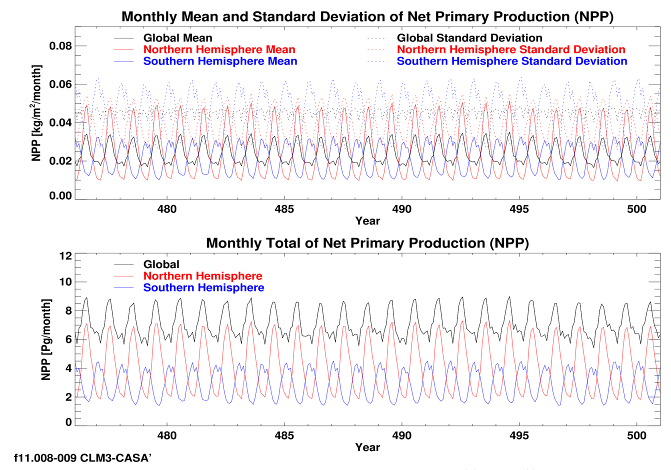
- C4MIP Protocol –– at http://www.c4mip.cnrs–gif.fr/protocol.html
- The primary objective is to examine the simulations of the 20th century atmospheric carbon dioxide and the carbon dioxide fluxes at the land surface in the coupled atmosphere–terrestrial biosphere models
- The terrestrial biosphere model must be spun up to
  - Equilibrate to near pre–industrial conditions defined as 1850 $CO_2$ using repeated cycles of the 1875–1899 SSTs
  - Force the model by two cycles of 1875–1899 SSTs, increasing $CO_2$ from 1850 to 1899
- The reconstructed carbon dioxide forcing is shown in the figure here

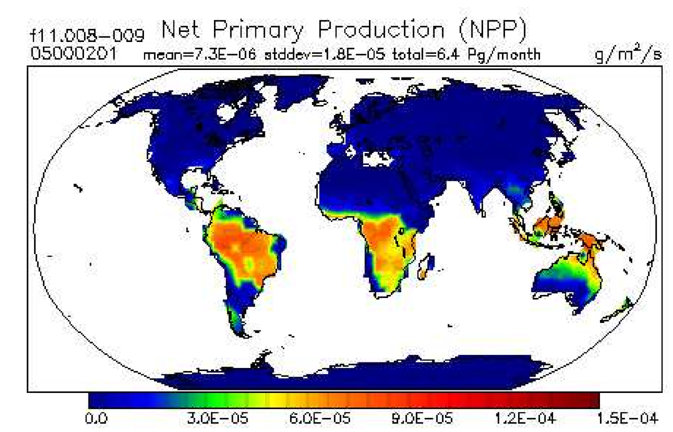


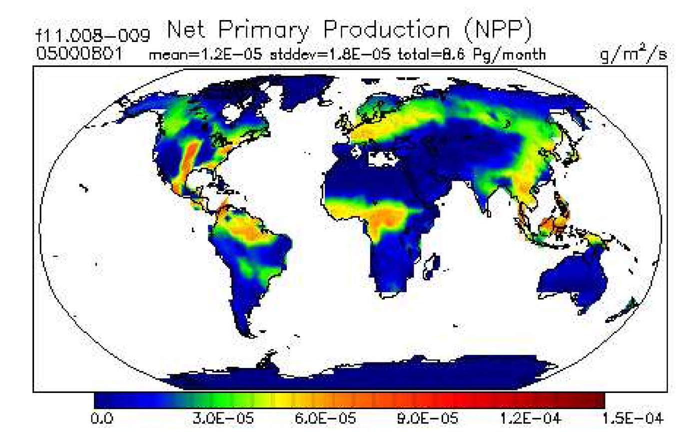

- Transient simulations for 1900–2000 use prescribed land cover (including agricultural change from Ramankutty and Foley), prescribed sea surface temperatures and corresponding sea ice cover (Hadley), prescribed ocean carbon fluxes (from OCMIP), and fossil fuel emissions (Marland et al.)

## CASA' Net Primary Production

CASA' was spun up with the BGC version of CCSM in the F configuration (i.e., active land and atmosphere) on the Cray X1E at T31 resolution (about 3.75x3.75 degrees). Carbon pools were initialized with spun–up pools from a previous CSIM1.4 simulation. The new pre–industrial spin–up run, forced with Hadley sea surface temperatures, extended out beyond 500 years.

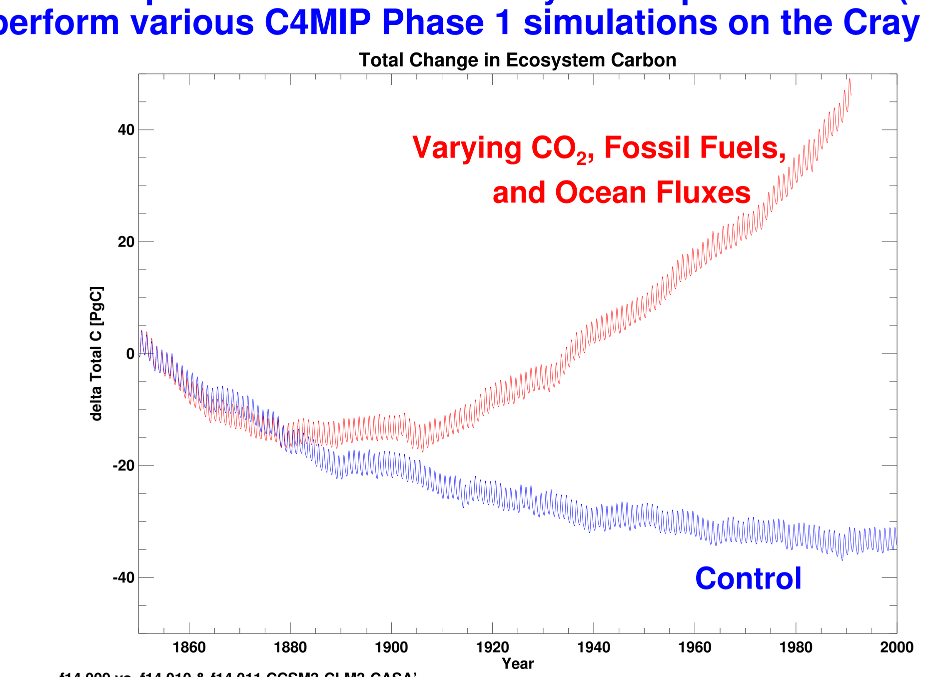


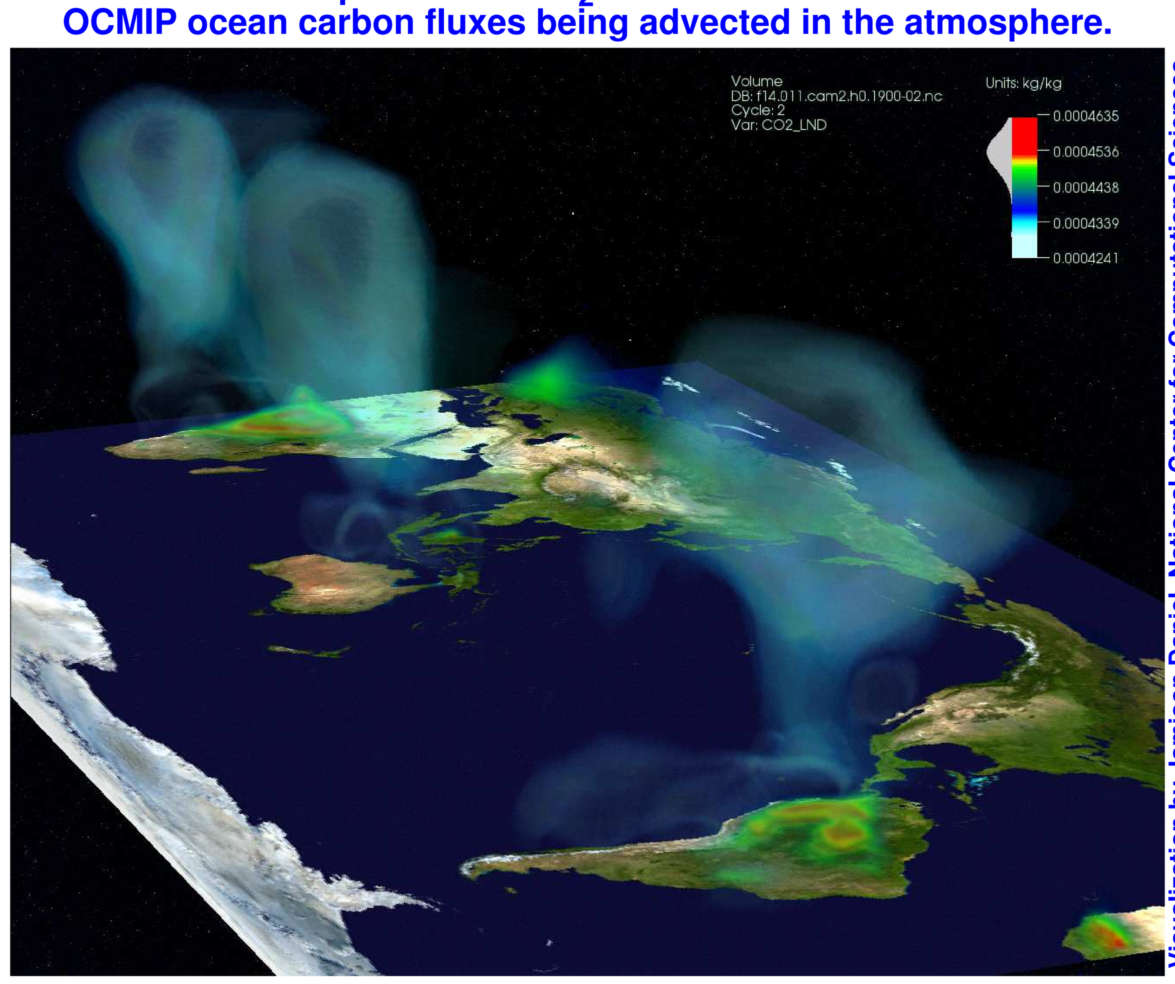




## CASA' C4MIP Runs

CLM3–CASA' coupled with the Community Atmosphere Model (CAM) has been used to perform various C4MIP Phase 1 simulations on the Cray X1E at ORNL.




The $CO_2$ fertilization effect is evident in the transient C4MIP simulation as compared with a historical control run using a fixed $CO_2$ concentration. The transient used prescribed $CO_2$ with fossil fuel emissions and the OCMIP ocean carbon fluxes being advected in the atmosphere.



Visualization by Jamison Daniel, National Center for Computational Sciences

In these simulations, the carbon dioxide from various sources are advected individually as tracers in the atmosphere model. Here, carbon dioxide from the land (net ecosystem exchange) is shown as plumes during Feb. 1900.


## Acknowledgements

Research partially sponsored by the Climate Change Research Division (CCRD) of the Office of Biological and Environmental Research (OBER) and the Mathematical, Information, and Computational Sciences (MICS) Division of the Office of Advanced Scientific Computing Research (OASCR) within the U.S. Department of Energy's Office of Science (SC). This research used resources of the National Center for Computational Sciences (NCCS) at Oak Ridge National Laboratory (ORNL), which is managed by UT–Battelle, LLC, for the U.S. Department of Energy under Contract No. DE–AC05–00OR22725. The National Center for Atmospheric Research is operated by the University Corporation for Atmospheric Research (UCAR) and receives research funding primarily from the National Science Foundation (NSF).


## CCSM Carbon Land Model Intercomparison Project (C–LAMP)

- An intercomparison of terrestrial biogeochemistry models running in the CCSM3 framework is being organized by the CCSM Biogeochemistry Working Group (BGCWG)
- The objectives are to compare model capabilities and effects in the coupled climate system and to understand processes important for inclusion in the coupled model for simulations supporting the IPCC Fifth Assessment Report
- Current terrestrial models running within the CCSM framework are
  - CLM3–CASA' – Carnegie/Ames/Stanford Approach model previously run in CSM1.4 for C4MIP Phase 2 (Fung et al.)
  - CLM3–CN – coupled carbon and nitrogen cycles based on the BIOME–BGC model (Thornton)
  - LSX–IBIS – Integrated Biosphere Simulator from U. Wisconsin previously run in the Parallel Climate Transitional Model (PCTM) for C4MIP Phase 2 (Thompson, Foley, Mirin, Post, Erickson)
- The experimental protocol is being developed by Inez Fung, Jim Randerson, and Peter Thornton with input from all members of the CCSM BGCWG
- The protocol involves a series of simulations at T42_gx1v3 resolution that borrows from but improves upon the C4MIP Phase 1 protocol
  - Experiment 1 – "offline" biosphere model runs (CCSM I configuration) forced with new NCEP/NCAR Reanalysis datasets (A. Dai et al.)
    - Spin–up
    - Control run (1798–2004)
    - Climate varying run (1948–2004)
    - Climate and carbon dioxide varying with nitrogen deposition (1798–2004)
    - Climate and carbon dioxide varying with nitrogen deposition and landuse
  - Experiment 2 – coupled land–atmosphere model runs (CCSM F configuration) with prescribed SSTs, sea ice and carbon dioxide
    - Spin–up
    - Control run (1800–2004)
    - Climate varying run (1800–2004)
    - Climate and carbon dioxide varying with nitrogen deposition (1800–2004)
    - Climate and carbon dioxide varying with nitrogen deposition and landuse
- Complete protocol, metrics, and output approach are described and available for comment at http://climate.ornl.gov/bgcmip/

## Computational Climate Science End–Station A Leadership Computing Facility (LCF) Project

- C–LAMP is a subproject of the Computational Climate Science End Station (Dr. Warren Washington, PI), a Leadership Computing Facility (LCF) project at the National Center for Computational Sciences (NCCS) located at ORNL
- Experiments 1 and 2 outlined above, along with corresponding ocean biogeochemistry runs, are presently being performed on the Cray X1E


### Cray X1E

- 256 interleaved "dual–core" SMP nodes
- 4 Multi–Streaming Processors (MSPs) per node
- 4 Single Streaming Processors (SSPs) per MSP
- Two 32–stage, 64–bit wide vector units running at 1.13 GHz and one 2–way superscalar unit running at 400 MHz per SSP
- 2 MB E–cache per MSP
- 8 GB of memory per interleaved node (partitioned)

1024 processors (MSPs), 2048 GB of memory, and 18.08 TFlop/s peak

Office of Science
U.S. DEPARTMENT OF ENERGY

THE UNIVERSITY WISCONSIN MADISON

Berkeley
University of California