Results from the Carbon–Land Model Intercomparison Project (C–LAMP) and Availability of the Data on the Earth System Grid (ESG)

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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.

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://www.climatemodeling.org/bgcmip/

C–LAMP Datasets and Model Output

- Special attention is being given to the development of intercomparison metrics and diagnostics relevant to the carbon cycle
- Seasonal and diurnal cycles will be analyzed and compared with observational datasets from AmeriFlux/Fluxnet towers, MODIS/satellites, and GlobalView
- Model output and post–processing data will be rewritten using PCMDI's Computer Model Output Rewriter (CMOR)
- Model output and post–processing data will be made available to the wider science community by PCMDI via the Earth System Grid (ESG) for further analysis
- The first model output datasets will soon be available on the ESG server at http://esg2.ornl.gov/

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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

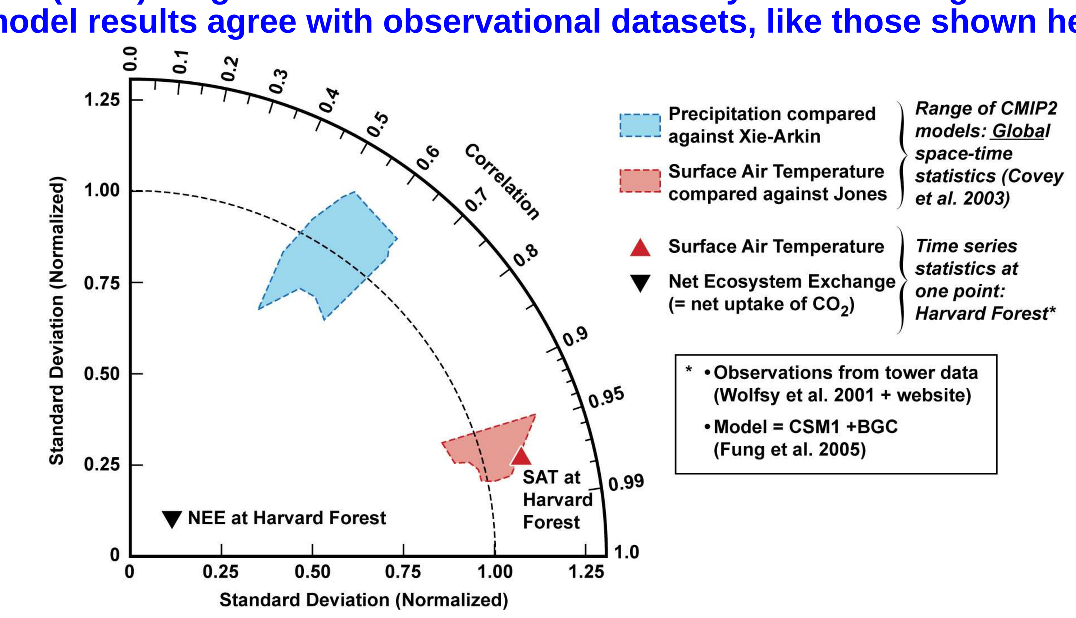
Cray X1E

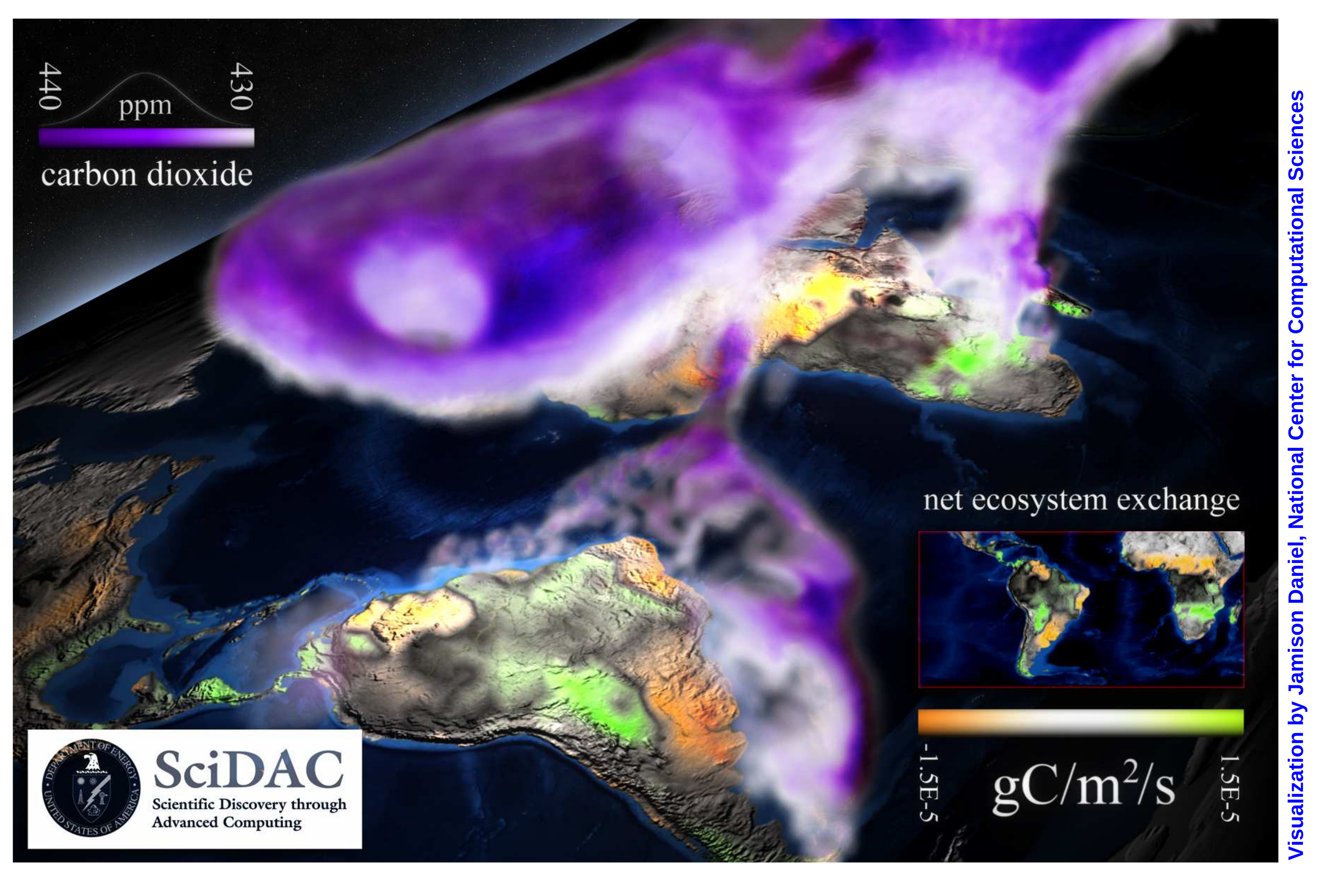
- 256 interleaved "dual–core" SMP nodes
- 4 Multi–Streaming Processors (MSPs) per node
- 4 Single Streaming Processors (SSPs) per MSP
- Two 32–stage, 64–bit wide vector units running at 1.13 GHz and one 2–way superscalar unit running at 400 MHz per SSP
- 2 MB E–cache per MSP
- 8 GB of memory per interleaved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

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

Diagnostics and Visualization

Taylor (2001) Diagrams will be used to statistically show the degree to which model results agree with observational datasets, like those shown here.

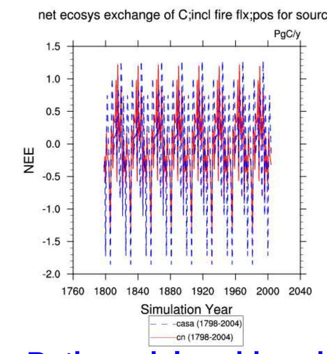




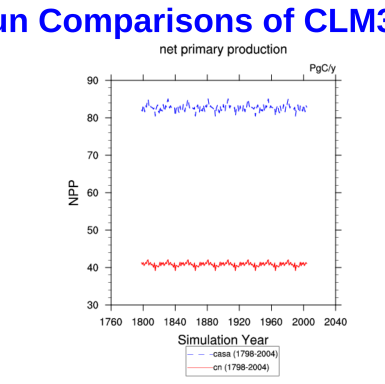
In these simulations, the carbon dioxide from various sources is advected individually as tracers in the atmosphere model. Here, carbon dioxide from the land (net ecosystem exchange), shown on the land surface, is separately advected in the atmosphere, shown as plumes above the land.

Preliminary Results from Experiment 1

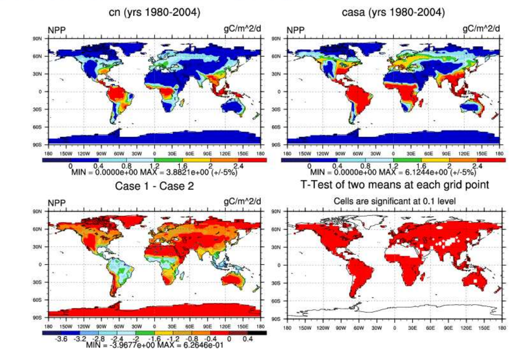
Control Run Comparisons of CLM3–CN and CLM3–CASA'



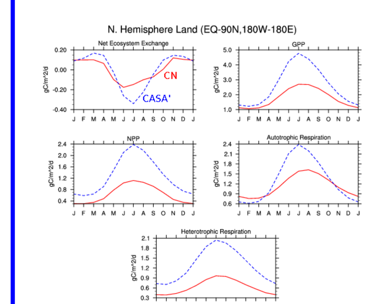
Both models achieved steady state



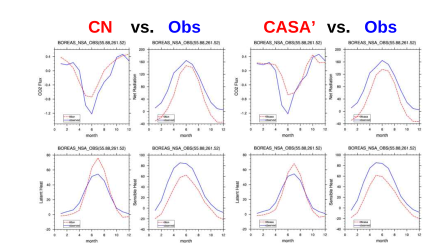
Net primary production differs by a factor of two



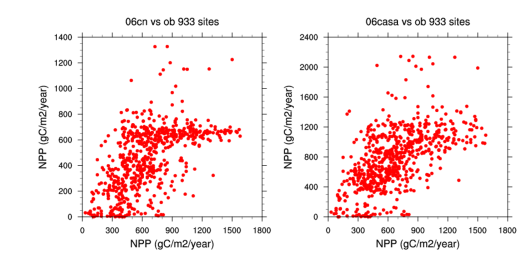
Spatial patterns of annual NPP differ between the models



Seasonal exchanges are weak in both models

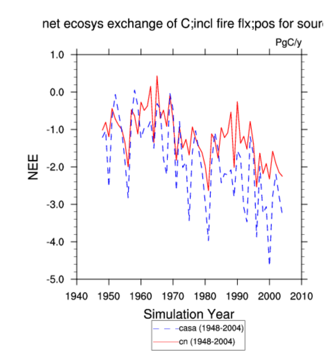


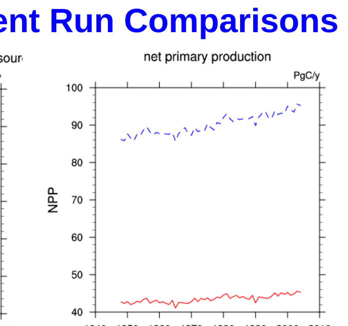
Comparison with FLUXNET Observations (BOREAS)



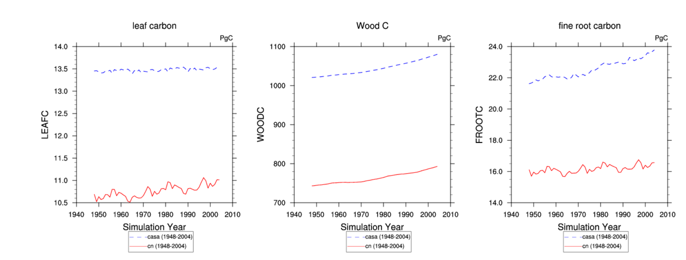
Net primary production observations compiled by the Ecosystem–Model Data Intercomparison (EMDI) Team

Transient Run Comparisons of CLM3–CN and CLM3–CASA'





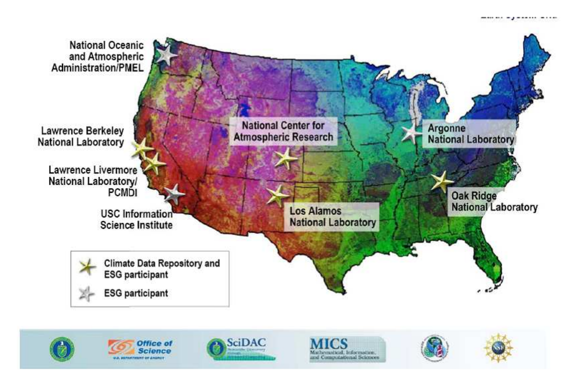
CASA' exhibits a stronger fertilization response to increasing atmospheric carbon dioxide



Live carbon pools respond differently to changing climate, increasing carbon dioxide, and changing nitrogen deposition

CLM3–CN has a lower sensitivity to rising carbon dioxide because of increasing nitrogen limitation.

Model Output Delivered via the Earth System Grid



The Earth System Grid (ESG) is a virtual collaborative environment that links distributed centers, users, models, and data in a Grid computing environment. The primary goal of ESG is to support the infrastructural needs of the national and international climate community by providing crucial technology to securely access, monitor, catalog, transfer, and distribute data. The next generation ESG Center for Enabling Technologies (ESG–CET) will support petabyte dataset volume in a distributed environment through the federation of data centers.

The C–LAMP model output from Experiment 1 will soon be available to the community on the new ESG node at Oak Ridge National Laboratory.

Acknowledgements

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