Terrestrial Biogeochemistry Intercomparison Experiments

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Introduction

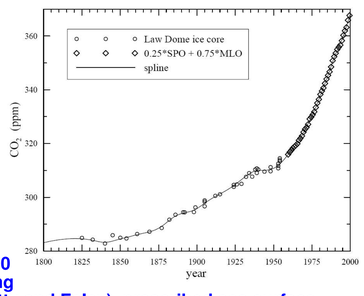
As general circulation models (GCMs) evolve and improve, there is increasing interest in applying them to understand the potential for global climate change. The global carbon cycle is of particular importance since it is thought to have a significant impact on global temperatures. A wide array of carbon 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 capaility within the CCSM for use with runs supporting the Intergovernmental Panel on Climate Change Fifth Assessment Report.

C4MIP Experiments

- Coupled Climate/Carbon Cycle Model Intercomparison Project (C4MIP) –– an international project sponsored by the International Geosphere–Biosphere Programme – Global Analysis, Integration, and Modelling (IGBP–GAIM) and World Climate Research Programme – Working Group on Coupled Modelling (WCRP–WGCM) to compare coupled model results in two phases:
  - **Phase 1** – controlled experiment using prescribed sea surface temperatures (SSTs), sea ice cover, land cover change, ocean carbon fluxes, and fossil fuel emissions with active atmosphere and land surface models exchanging carbon over the 20th century (1900–2000)
  - **Phase 2** – fully coupled model experiments for future climate
- Many modeling groups completed Phase 2 experiments, without performing Phase 1 experiments, and contributed results to the IPCC Fourth Assessment Report (Friedlingstein 2005)
- Within the Community Climate System Model (CCSM) framework, two terrestrial biogeochemistry models coupled to the Community Land Model Version 3 (CLM3) are running Phase 1 at T31 resolution (3.75x3.75 degrees)
  - CLM3–CN (Carbon–Nitrogen) model by Thornton
  - CLM3–CASA' (Carnegie and Stanford Approach) model by Fung et al.
- The SciDAC Climate Consortium Project has assisted in implementing, vectorizing, and testing the CASA' model and is carrying out the Phase 1 experiments with this 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.)



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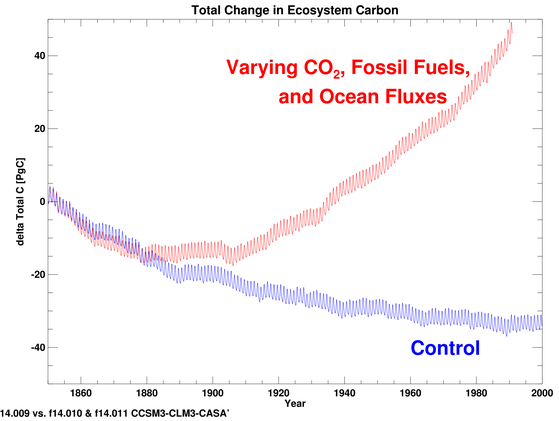
CASA' C4MIP Runs

The following runs using CLM3–CASA' coupled with CAM in the BGC version of CCSM3 have been completed on the Cray X1E at ORNL. Landuse Change experiments will require additional software engineering to implement the carbon distribution scheme prescribed by the C4MIP protocol.

Current CLM3-CASA′ C4MIP Runs

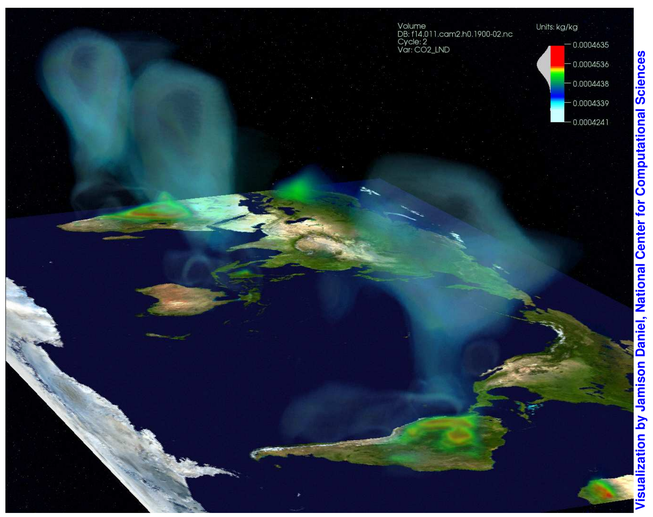
Case Name	Description	Start Date	End Date	CO_2	Fossil Fuel	Ocean Fluxes	Landuse Change
f11.008	First portion of spin-up	0001-01-01	0066-12-31	Constant	Off	Off	Off
f11.009	Second portion of spin-up	0067-01-01	0500-12-31	Constant	Off	Off	Off
f14.009	Historical Control	1850-01-01	2000-12-31	Constant	Off	Off	Off
f14.010	CO_2 ramping run	1850-01-01	1899-12-31	Varying	Off	Off	Off
f14.011	Transient	1900-01-01	2000-12-31	Varying	On	On	Off
f14.012	Transient	1900-01-01	2000-12-31	Varying	On	Off	Off
f14.013	Transient	1900-01-01	2000-12-31	Varying	Off	On	Off
f14.014	Transient/ Extended ramp	1900-01-01	2000-12-31	Varying	Off	Off	Off

Analysis of these runs has recently begun. However, the model appears to behave as expected as evidenced by the following comparison of the f14.011 transient run against the f14.009 historical control run.



f14.009 vs. f14.010 & f14.011 CCSM3-CLM3-CASA'

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.



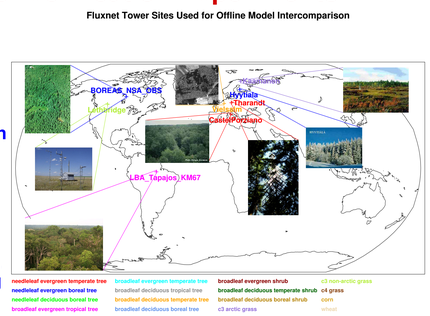
In these simulations, the carbon dioxide from various sources are advected individually as tracers in the atmosphere model. Here, carbon dioxide from the land (net ecosystem exchange) is shown as plumes during Feb. 1900.

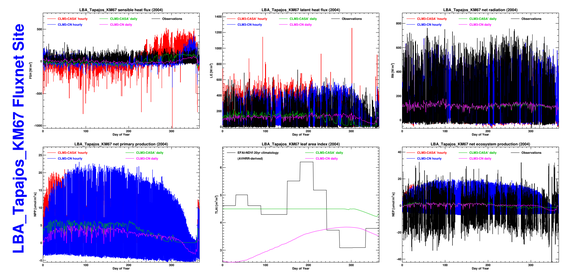
CCSM Carbon Land Model Intercomparison Project (C–LAMP)

- 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/

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.





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