Land–Atmosphere Interactions Exhibited by Coupled Carbon–Cycle Climate Models

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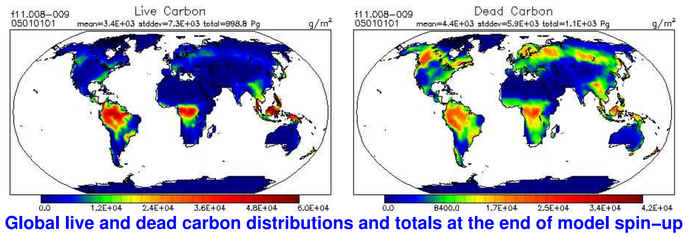
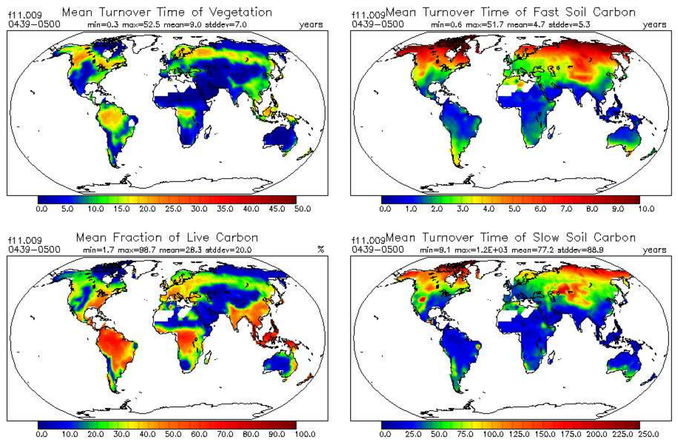
Introduction

Three different biosphere models are running within the NCAR Community Climate System Model (CCSM) and will be the subject of an upcoming Biogeochemistry Model Intercomparison Project. CN, a coupled carbon–nitrogen cycle module, has been coupled to the Community Land Model Version 3.0 (CLM3). CASA', a biogeochemistry module based on the Carnegie–Ames–Stanford–Approach (CASA) Biosphere Model, has also been coupled to CLM3. IBIS, a whole biosphere model, has been coupled to CCSM. Initially, these models will be used to carry out experiments under the Coupled Climate/Carbon Cycle Model Intercomparison Project (C4MIP) Phase 1 protocol. Presented here are preliminary results from these models.

CASA' Spin–Up Results

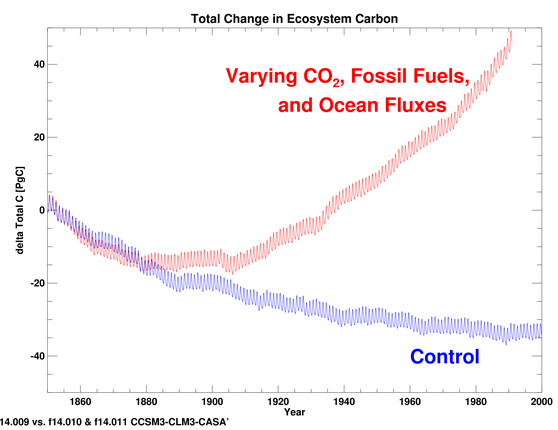


Global live and dead carbon distributions and totals at the end of model spin–up



Mean vegetation turnover time is 9.0 years, mean fast soil C turnover time is 4.7 years, and mean slow soil C turnover time is 77.2 years.
Live fraction of carbon is 28.3%.

CASA' Transient vs. Control

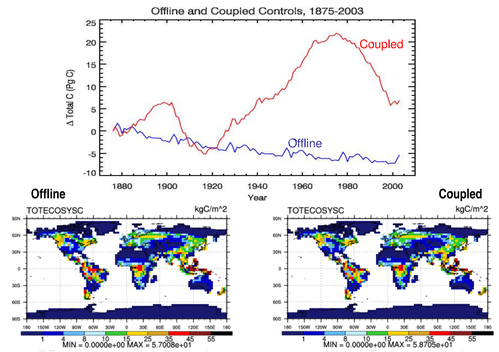


The CO_2 fertilization effect is evident in the transient C4MIP simulation as compared with a historical control run using a fixed CO_2 concentration. The transient used prescribed CO_2 with fossil fuel emissions and the OCMIP ocean carbon fluxes being advected in the atmosphere.

The CN Biogeochemistry Module

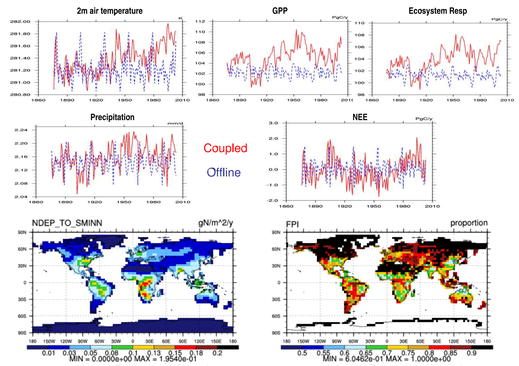
The CN biogeochemistry module, developed by Peter Thornton at NCAR, has been integrated into the Community Land Model (CLM3) and run both offline and coupled with CCSM3. The new model, based on the BIOME–BGC model, simulates a coupled carbon–nitrogen cycle within the land model which responds to atmospheric forcing and exchanges carbon with the atmosphere.

Total Ecosystem Carbon for Control Experiments



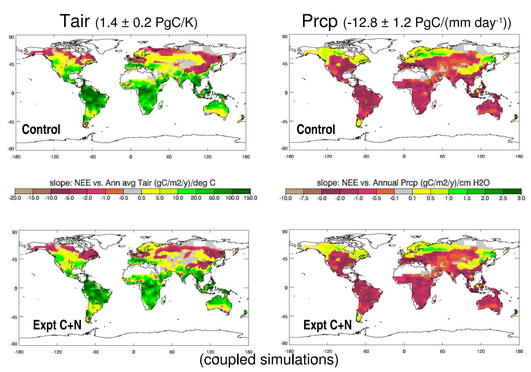
Upper plot shows the influence of SST–driven changes in temperature and precipitation in the coupled run on total land carbon. Lower plots show the spatial distributions of total carbon at the end of the two control runs.

Climate, Carbon, and Nitrogen Summaries for Control Expts



Plots show the variability of temperature and precipitation due to the SSTs and resulting effects on the carbon cycle (GPP, total ecosystem respiration, NEE). Maps show the distribution of nitrogen deposition and nitrogen limitation.

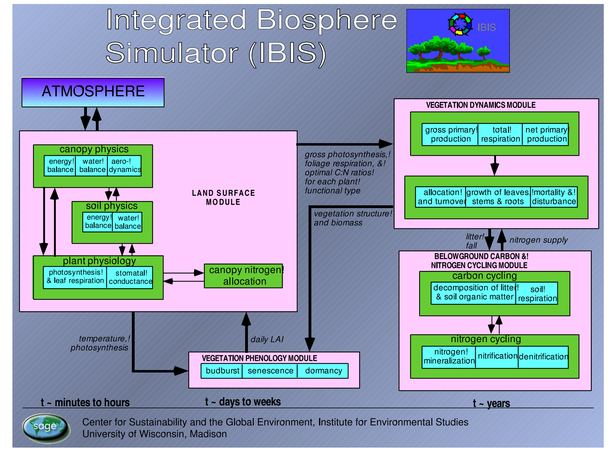
Dependence of NEE on Tair and Prcp: multiple linear regression



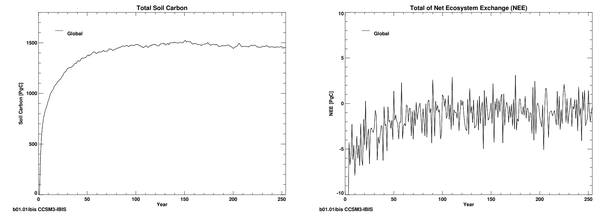
(coupled simulations)

Results from coupled experiments, using multiple linear regression to isolate the influence of temperature (left) and precipitation (right) on NEE.

Integrated Biosphere Simulator (IBIS)



IBIS is coupled to CCSM as a replacement land model by Art Mirin at Lawrence Livermore National Laboratory. IBIS is of interest to DOE for carbon cycle and carbon management studies.



A 250–year T42 spin–up run has been completed using an accelerated mode to build up the soil carbon more quickly.

CCSM Biogeochemistry Intercomparison Project

Organized by the CCSM Biogeochemistry Working Group

Objective: To intercompare terrestrial biogeochemistry models in the CCSM framework and provide new global carbon cycle diagnostics for comparison with observations. The end goal is to produce a carbon cycle model for use in future IPCC simulations.

All parts of the experimental protocol (similar to C4MIP) will be performed for each participating model––CLM3–CN, CLM3–CASA', and LSX–IBIS––on the Cray X1E at the Leadership Computing Facility (LCF) at ORNL.

- Phase 0: Offline model spin–up and simulations using new A. Dai et al. NCEP reanalysis atmospheric forcings at T42 (or 2x2.5)
- Phase 1: 500 year control run at T42 (or 2x2.5) with prognostic atmospheric CO_2
- Phase 2: 19th and 20th century transient runs alternating fossil fuel, land use, ocean fluxes, and nitrogen deposition, similar to C4MIP

DOE Program for Climate Model Diagnosis and Intercomparison (PCMDI) will make model results available to the community for further analysis.

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