Preliminary Results from the CASA' Module Coupled to CCSM3 for C4MIP

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Introduction

The CASA' biogeochemistry module, based on the Carnegie−Ames−Stanford Approach (CASA) Biosphere Model, has been coupled to the Community Land Model Version 3.0 (CLM3). It may be run in offline (land only), CAM standalone (atmosphere + land), or fully coupled CCSM3 mode (atmosphere + land + ocean + sea ice). As in previous work by Fung et al. with CSM1, this version of the Community Climate System Model will be used for a variety of experiments to understand the interactions and feedbacks between climate and the terrestrial biosphere. Initially, the model will be used to carry out experiments under the Coupled Climate/Carbon Cycle Model Intercomparison Project (C4MIP) Phase 1 protocol.

Presented here are a number of enhancements to CCSM3 (implemented by software engineers at NCAR and DOE Labs) to support biogeochemistry studies with the model. The CASA' module and C4MIP protocol are described and preliminary results from the first spin−up run are shown.

CCSM3 Modifications for Biogeochemistry

- Restore I and F configurations to CCSM3; CSIM vector modifications had disabled thermodynamic ice capabilities (Julie Schramm)
- Add code to CLM3 to support prescribed land cover change using dynamic plant functional types (PFTs) (Mariana Vertenstein)
- Repair soil water deficiencies in CLM3 which significantly reduce net primary production (NPP), particularly in the Amazon (Peter Thornton and others)
- Modify the data atmosphere model (datm) to read hourly atmospheric data generated by CAM from F configuration runs (Brian Kauffman)
- Add code to the ice model (csim) in thermodynamic mode to support data cycling of prescribed ice cover (Forrest Hoffman and Julie Schramm)
- Add code to the data ocean model (docn) to support data cycling of prescribed sea surface temperatures (Forrest Hoffman)
- Complete the integration, vectorization, and testing of CASA' in CLM3 (Forrest Hoffman, Jasmin John, Inez Fung, and Sam Levis)
- Vectorize the CLM3−CN code to support its use on the Cray X1 and Earth Simulator (Forrest Hoffman and Peter Thornton)
- Modify the coupling code used by all component models in CCSM3 to enable exchange of carbon fluxes and other tracers (Mariana Vertenstein, Jeff Lee, and Rob Jacob)
- Modify the CCSM3 scripts to support all these new features (Jeff Lee and Mariana Vertenstein)

C4MIP Experiments

- Coupled Climate/Carbon Cycle Model Intercomparison Project (C4MIP) − an international project organized by the International Geosphere−Biosphere Programme − Global Analysis, Integration, and Modelling (IGBP−GAIM) and the 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 a 20th century (1900−2000) transient simulation
  - Phase 2 − a fully coupled model experiment for future climate
- The primary objective of Phase 1 is to examine the simulations of the 20th century atmospheric carbon dioxide and the fluxes at the land surface
- The terrestrial biosphere model must be spun up to
  - Equilibrate to near pre−industrial conditions defined as 1850 carbon dioxide using repeated cycles of 1875−1899 SSTs
  - Force the model by two cycles of 1875−1899 SSTs, increasing carbon dioxide from 1850 to 1899
- Spin−up of terrestrial carbon pools could take thousands of simulated years

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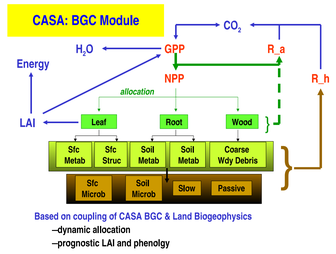
Further Results Available at
http://climate.ornl.gov/c4mip/

The CASA' Biogeochemistry Module

The CASA' biogeochemistry module previously coupled to LSM1 in CSM1 was adapted to CLM3 biogeophysics in CCSM3. CASA' computes net primary production (NPP) from CLM's gross primary productivity (GPP) and allocates carbon among 3 live pools: leaf, root, and wood. These pools feed 9 other dead pools that include litter, coarse woody debris, and various soil pools with different turnover times. CASA' calculates heterotrophic respiration and net ecosystem exchange as well as prognostic leaf area index (LAI) and phenology.



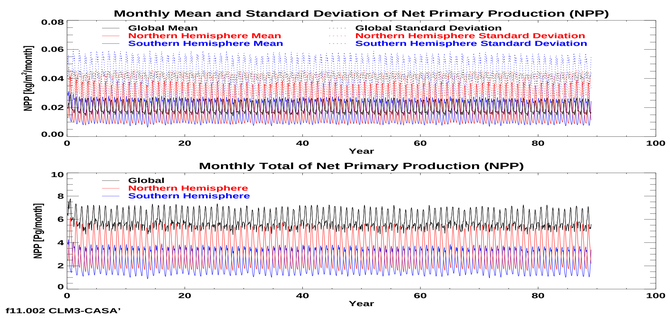
Now coupled into CCSM3, CASA' can provide carbon fluxes from the terrestrial biosphere into the atmosphere. Moreover, the land surface model is forced by atmospheric carbon dioxide concentrations resulting in feedbacks between the land and atmosphere.

C4MIP CASA' Spin−up Strategy

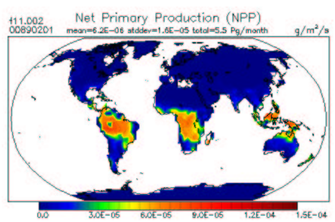
- 200 year CCSM3 F run using CLM3−CASA'
  - use 1850 CO2 forcing
  - cycle through 1875−1899 SSTs and ice cover; use 1900 prescribed land cover
  - save hourly CAM data in final 25 years
- 1500 year CCSM3 I run using CLM3−CASA'
  - cycle through 25 years of CAM output from above
- 50 year CCSM3 F run using CLM3−CASA'
  - increase CO2 from 1850 to 1899 levels
  - cycle twice through 1875−1899 SSTs and ice cover; use 1900 prescribed land cover
- 100 year CCSM3 F run using CLM3−CASA'
  - transient simulation for 1900−2000
  - use prescribed land cover, SSTs, ice cover, ocean carbon fluxes, and fossil fuel emissions

Preliminary Results

Spin−up of the first CCSM3 F run has begun on the IBM Power 4 (cheetah) at ORNL, and the simulation is out to almost 100 years. Terrestrial carbon pools in CASA' were initialized to spun−up carbon pools from the CSM1 version of the model. Shown here are results from the first 89 simulation years.



NPP has the correct seasonal cycle and distribution by hemisphere.



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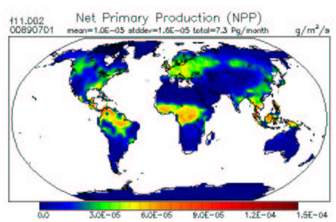

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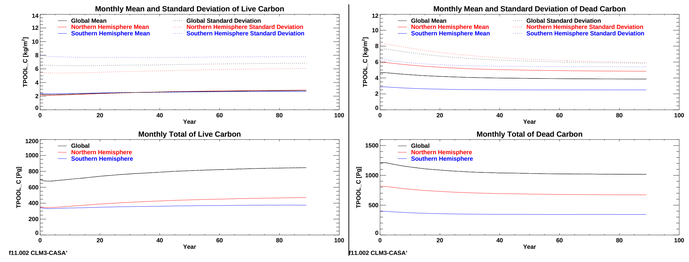
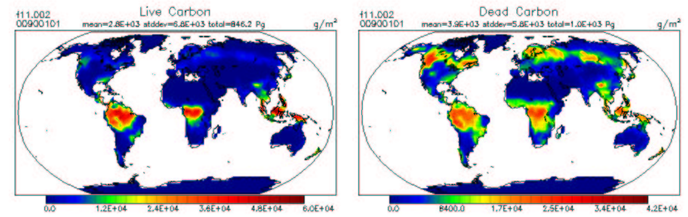
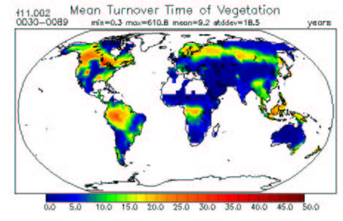
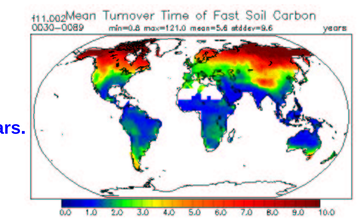
Preliminary Results (continued)



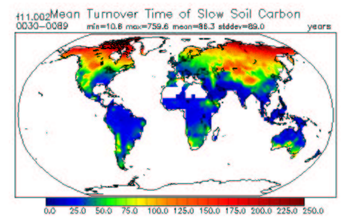




Mean vegetation turnover time is 9.2 years. Woody vegetation turnover time is 20−30 years.



Mean turnover time for the six fast soil carbon pools combined is 5.6 years.



Mean turnover time for the three slow soil carbon pools combined is 86.3 years.

Conclusions

The CASA' biogeochemistry module coupled to the Community Land Model and run within CCSM3 appears to be giving reasonable results. The distribution of carbon fluxes appears to be correct as does the distribution of biomass and soil carbon. The carbon pools have not yet reached equilibrium, so an acceleration scheme will be employed for pools with the longest turnover times. To speed model throughput, the C4MIP simulation will soon be moved to the Cray X1 at ORNL. Participation in C4MIP Phase 2 is planned with the CCSM3−CASA' model in the future.

ACKNOWLEDGEMENTS

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