Assessment of a Fully Coupled Global Model Based on CCSM3 Using the IBIS Biogeochemistry and Dynamic Global Vegetation Model

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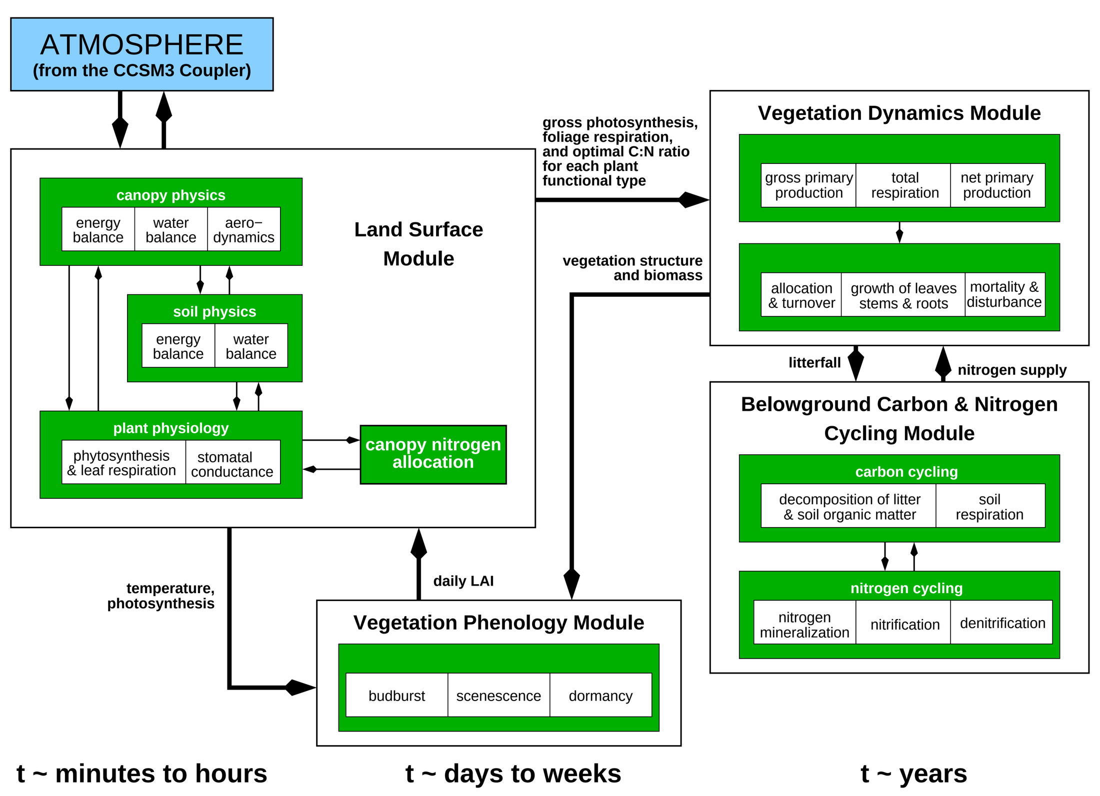
Introduction

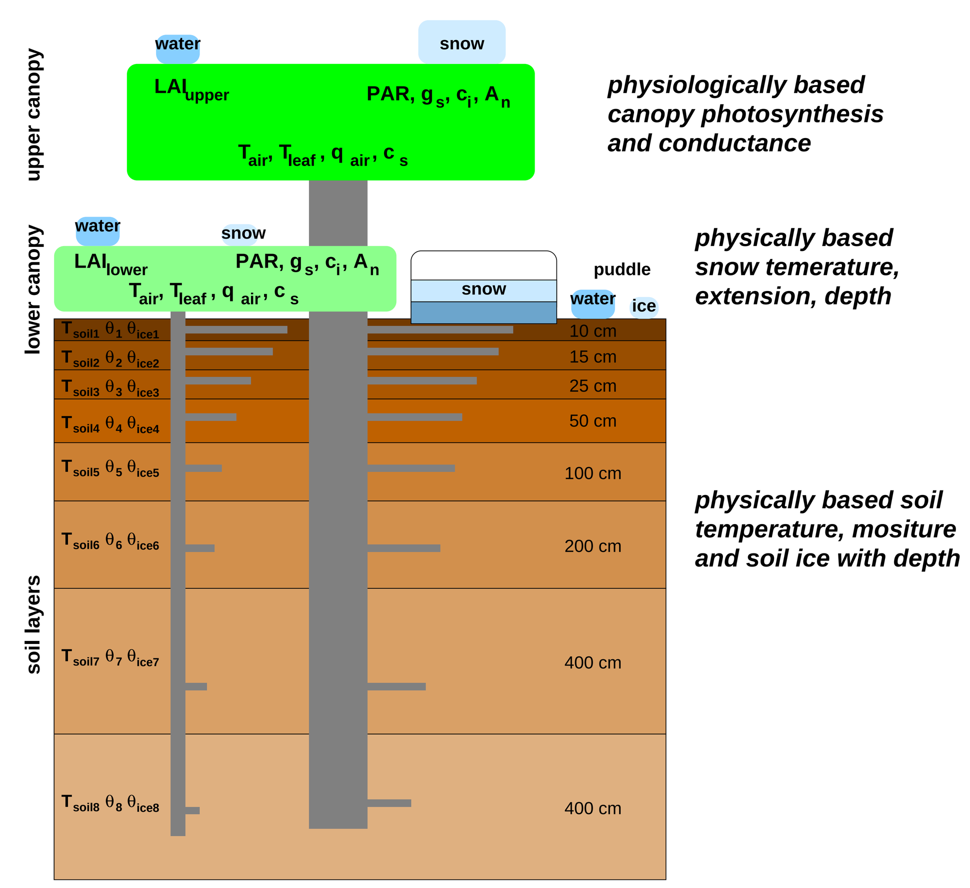
- In an effort to build on the work of Thompson, et. al, and offer an alternative terrestrial biogeochemistry model in CCSM3, a 1000−yr simulation of the IBIS (Integrated Biosphere Simulator) model coupled to CCSM3 was undertaken at Oak Ridge National Laboratory
- The fully coupled simulation used CAM3 (with the Eulerian dycore), POP1.4, the CSIM ice model, and LSX−IBIS in place of CLM3 at T42gx1v3 resolution
- The results of this simulation are described below

Integrated Biosphere Simulator (IBIS)

- The Integrated Biosphere Simulator (IBIS) from Jon Foley's group at the University of Wisconsin, Madison, was coupled to the Parallel Climate Transitional Model (PCTM) and used for C4MIP Phase 2 and related climate change experiments (Thompson et al., Bala et al.)
- IBIS was recently coupled to the CCSM3 as a replacement land model by Art Mirin at Lawrence Livermore National Laboratory
- IBIS represents surface physics, canopy physiology and plant phenology with a two−level canopy, vegetation dynamics and competition, and carbon and nutrient dynamics.
- Hence it is of interest to DOE carbon cycle modelers, plant physiologists, researchers studying carbon sequestration, and carbon management decision−makers



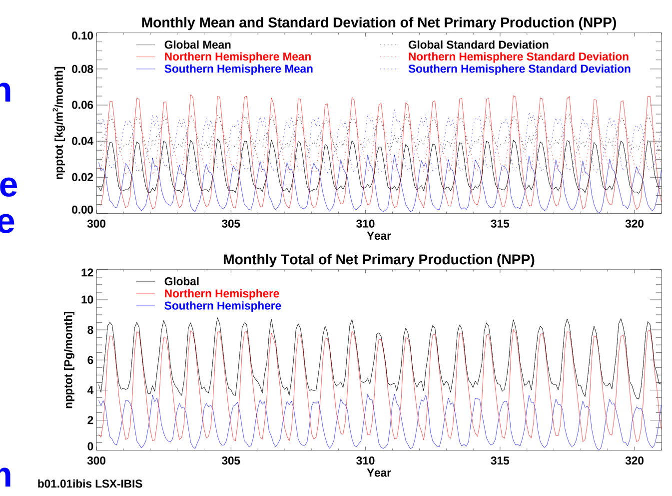
IBIS consists of hierarchically organized, interacting model components operating with different time steps forced by an atmosphere model.

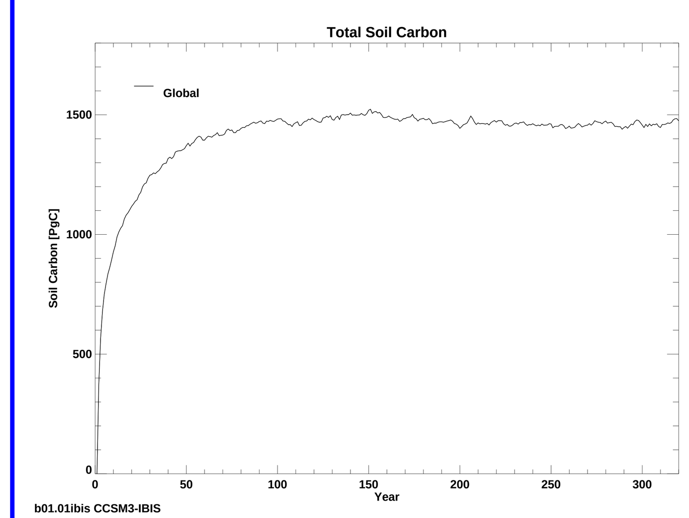


The IBIS land surface contains two layers of overlapping vegetation and eight soil layers. The model simulates photosynthesis, growth and maintenance respiration, and soil biogeochemistry.

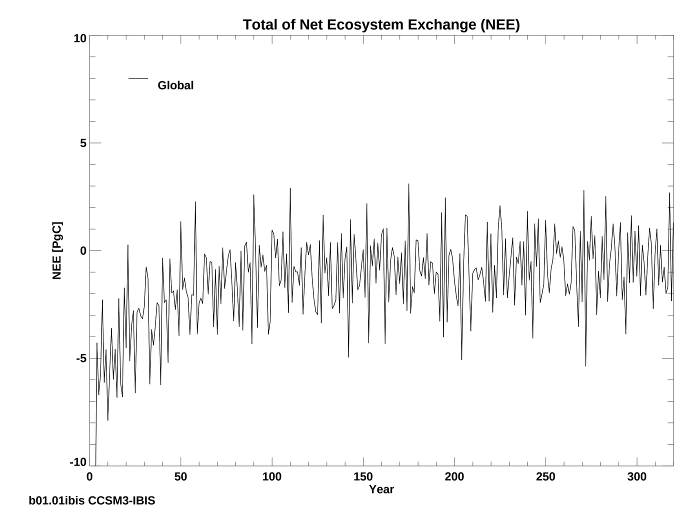
IBIS Carbon Pool Spin Up

- The IBIS carbon pools were spun up in the first portion of the 1000−yr CCSM3−IBIS. The spectral atmospheric dynamical core of CAM was run at T42 (2.5x2.5 degree) resolution
- The land surface was forced with a constant carbon dioxide concentration of 355 ppm
- Soil carbon was started at zero, but the run used an accelerated spin−up mode
- NPP has the correct seasonal cycle and distribution, and it is ~72 Pg/year
- These plots show that soil carbon was near equilibrium by year 350 and NEE was also approaching equilibrium





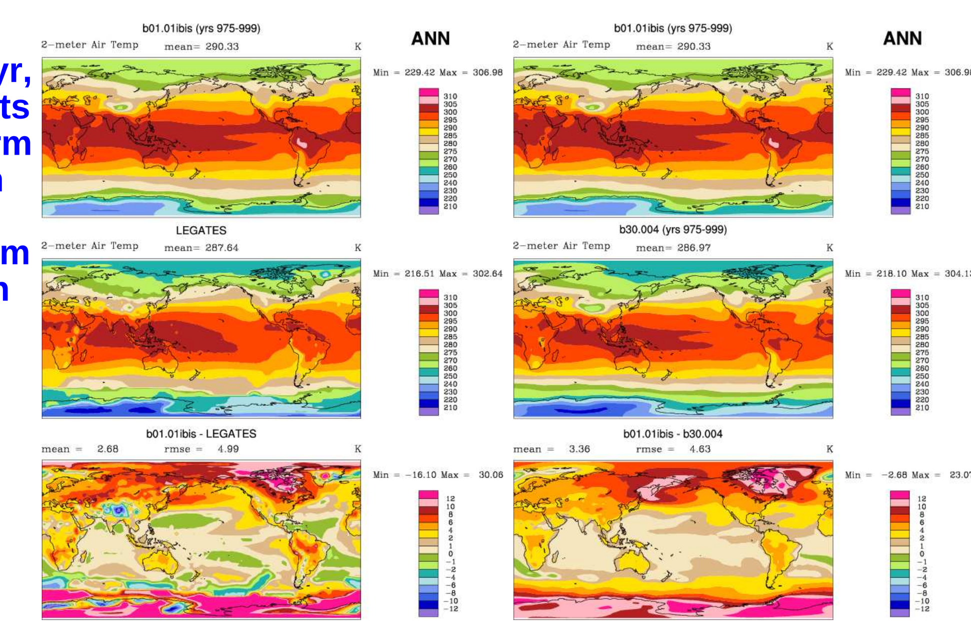
Global Total Soil Carbon



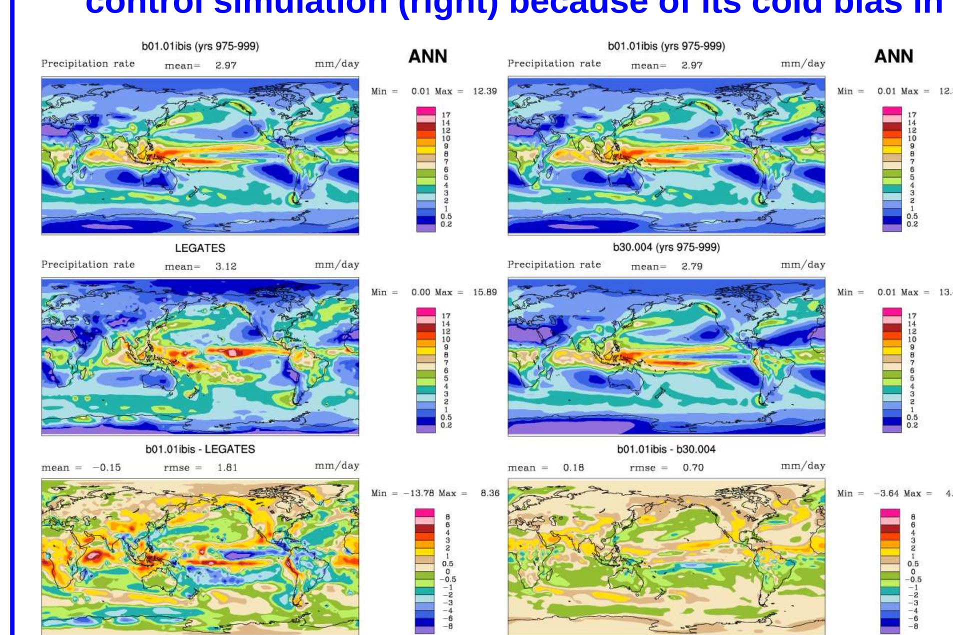
Net Ecosystem Exchange of Carbon

Climate Evaluation

- After almost 1000−yr, CCSM3−IBIS exhibits an 8−10 degree warm bias in the northern high latitudes and a 10−12 degree warm bias in the southern high latitudes as compared with observations.
- The warm bias appears stronger in the Northern Hemisphere when compared with a standard CCSM3 control simulation (right) because of its cold bias in the same region.

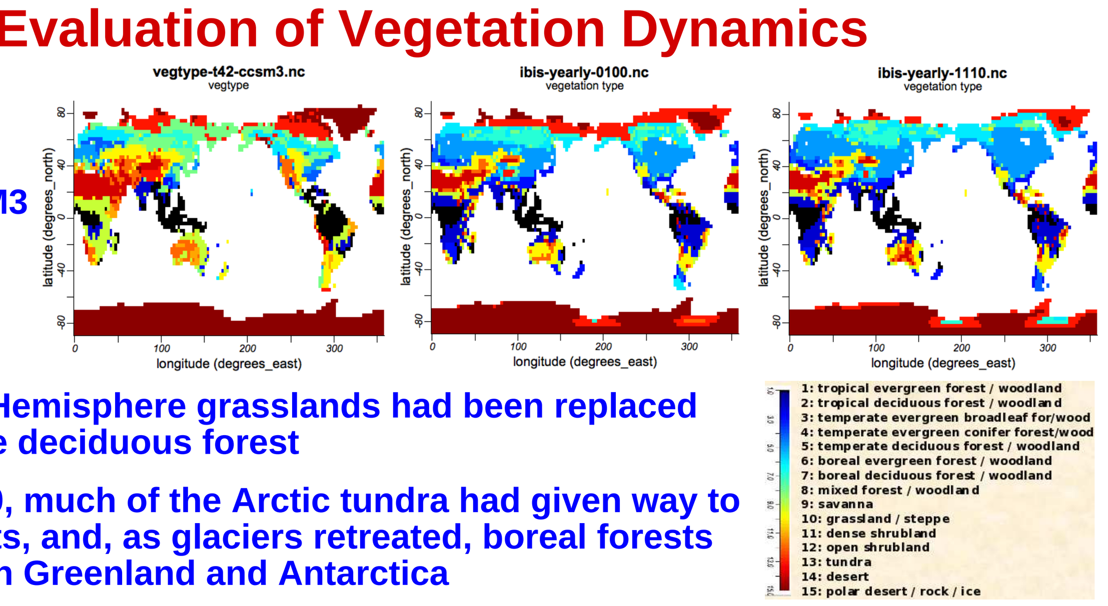


- The CCSM3−IBIS precipitation rate is broadly consistent with observations, but when differenced with observations (left) it exhibits patterns of strong differences.
- However, when compared with the standard CCSM3 control run (right), the precipitation rate is very similar with differences less than 2 mm/day.



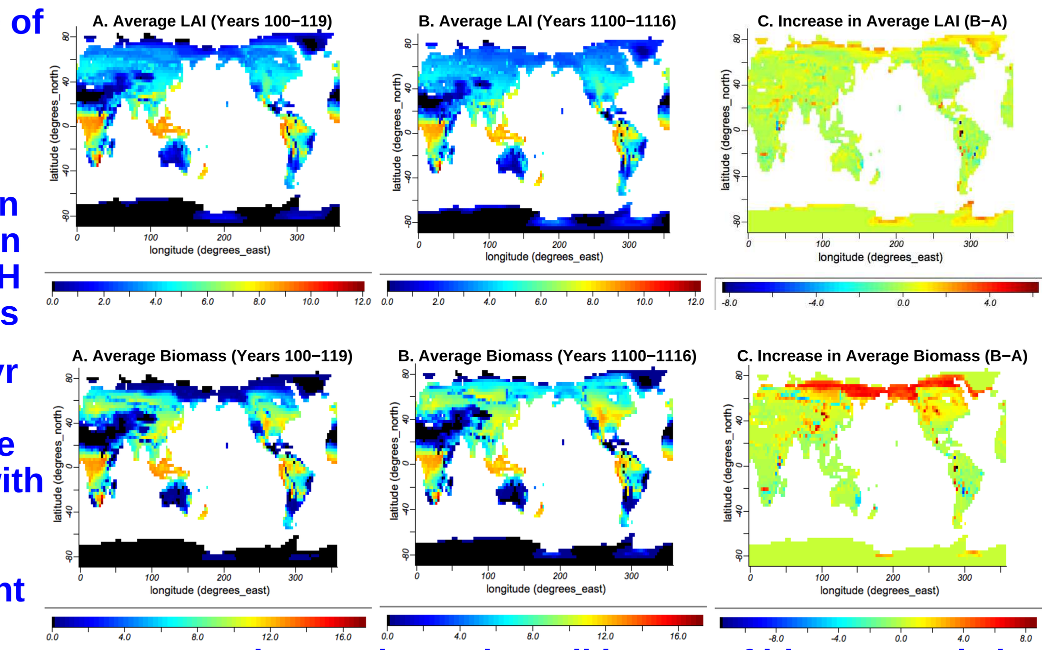
Evaluation of Vegetation Dynamics

- The run was started with the standard CCSM3−CLM3 vegetation distribution
- By year 100, much of the large North Hemisphere grasslands had been replaced by temperate deciduous forest
- By year 1110, much of the Arctic tundra had given way to boreal forests, and, as glaciers retreated, boreal forests sprung up on Greenland and Antarctica



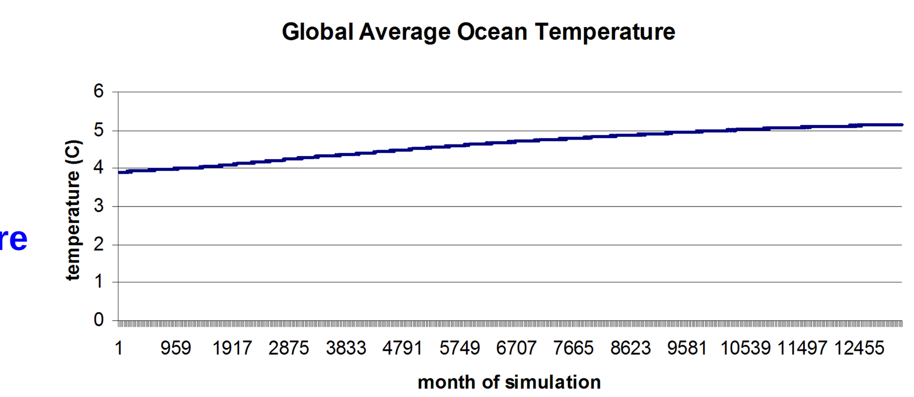
Evaluation of Vegetation Dynamics (cont.)

- A 20−yr average of LAI early in the run compared with a 17−yr average late in the run shows an increase in LAI in the NH Arctic and SH Antarctic regions
- Similarly, a 20−yr average of bio−mass early in the run compared with a 17−yr average late in the run shows significant increases in NH boreal forests across present−day tundra and small losses of biomass only in eastern Australia and the middle of South America

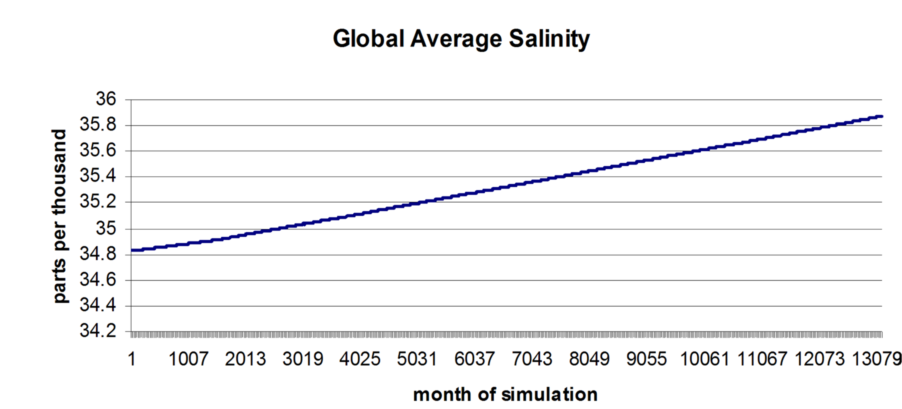


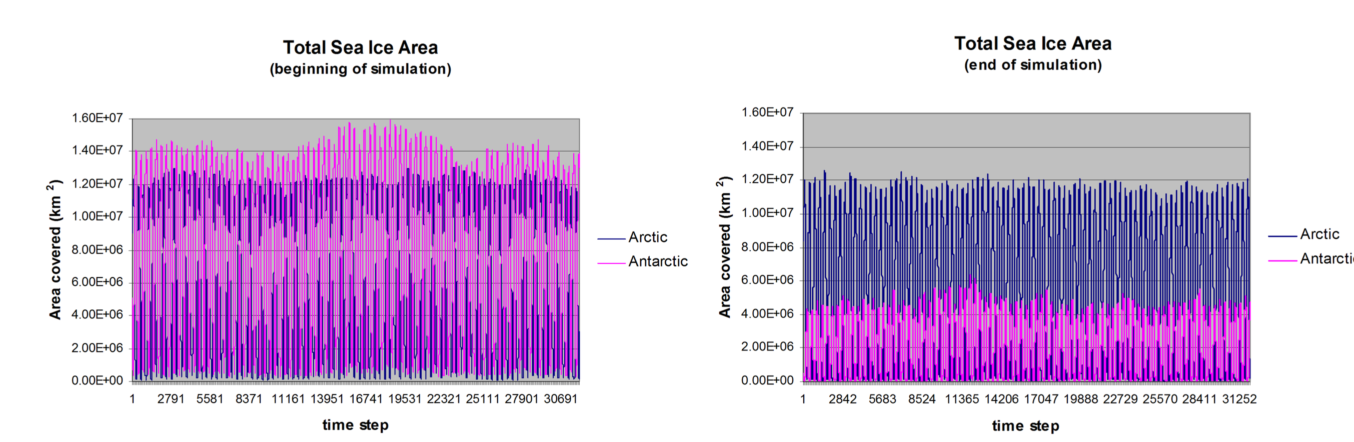
Global Ocean and Sea Ice Trends

- Over the course of the 1000−yr run, global average ocean temper−atures increased by more than one degree C



- In addition, ocean salinity increased by almost 3.5%





- By the end of the model run, Antarctic sea ice area had dropped dramatically

Conclusions and Next Steps

- The 1000−yr CCSM3−IBIS spin up and control simulation demonstrated successful coupling of the IBIS model into the CCSM3 framework
- However, the simulated climate warms significantly, leading to a significant loss of permafrost, sea ice, and glaciers
- The IBIS carbon cycle approached equilibrium and the vegetation dynamics appeared to respond correctly to rapid warming conditions
- IBIS may have helped fuel the warming through vegetation dynamics−climate feedbacks
- CCSM3−IBIS needs to be tuned to provide realistic climate predictions
- Next, IBIS will be run with NCEP/NCAR Reanalysis atmospheric data to see how the dynamic vegetation responds to observed climate
- Future spin up runs will be performed with pre−industrial carbon dioxide concentrations with pre−industrial land cover

Acknowledgements

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