Comparison of Global Model Results from the Carbon-Land Model Intercomparison Project (C-LAMP) with Free-Air Carbon Dioxide Enrichment (FACE) Manipulation Experiments

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Free-Air CO_2 Enrichment (FACE) manipulation experiments have been carried out at a handful of sites to gauge the response of the biosphere to significant increases in atmospheric [CO_2]. Early synthesis results from four temperate forest sites suggest that the response of net primary productivity (NPP) is conserved across a broad range of productivity with a stimulation at the median of 23±2% when the surrounding air [CO_2] was raised to 550 ppm (Norby, *et al.* 2005). As a part of the Carbon-Land Model Intercomparison Project (C-LAMP), a community-based model-data comparison activity, the authors have performed a global FACE modeling experiment using two terrestrial biogeochemistry modules, CLM3-CASA' and CLM3-CN, coupled to the National Center for Atmospheric Research (NCAR) Community Climate System Model (CCSM). The two models were forced with an improved NCEP/NCAR reanalysis data set and reconstructed atmospheric [CO_2] and N deposition data through 1997. At the beginning of 1997 in the transient simulations, global atmospheric [CO_2] was abruptly raised to 550 ppm, the target value used at the FACE sites. In the control runs, [CO_2] continued to rise following observations until 2004, after which it was held constant out to year 2100. In both simulations, the last 25 years of reanalysis forcing and a constant N deposition were applied after year 2004.

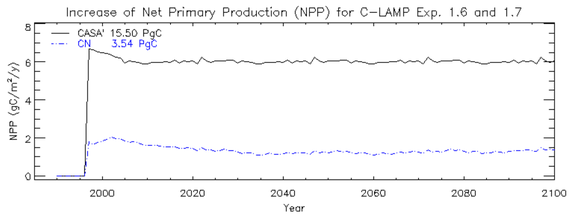

Figure 1: The global net primary production (NPP) of both models increased immediately when atmospheric [CO_2] was raised to 550 ppm on January 1, 1997.

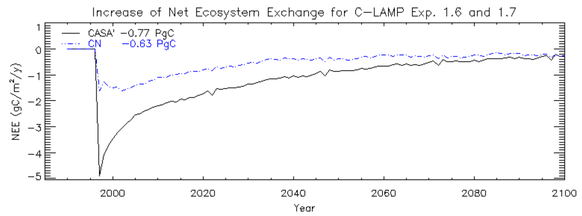

Figure 2: Global net ecosystem exchange (NEE) immediately dropped when atmospheric [CO_2] was raised to 550 ppm on January 1, 1997, and then began tending toward zero as ecosystems began equilibrating at the new atmospheric [CO_2].

Table 1: Across all biomes and globally, the NPP responses from both models are weaker than those reported for the four FACE sites. The response of the CN model is much weaker because of N limitation.

Biome	CASA′ Model		CN Model	
	NPP Increase	β_L	NPP Increase	β_L
Temperate Forests	14.93%	0.37	7.80%	0.19
Tropical Forests	14.84%	0.37	12.12%	0.30
Boreal Forests	12.86%	0.32	8.27%	0.20
Shrubs	16.32%	0.40	6.15%	0.15
Grasses	17.98%	0.44	10.27%	0.25
Crops	18.64%	0.46	5.62%	0.14
All Vegetated	**16.69%**	**0.41**	**10.17%**	**0.25**
Global	**16.93%**	**0.42**	**10.25%**	**0.25**

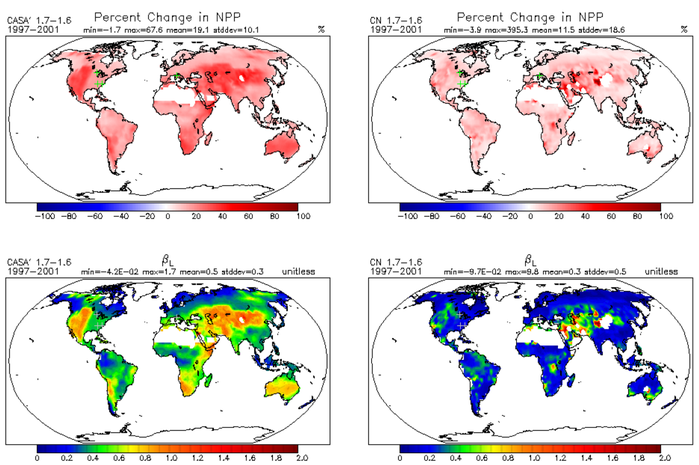

Figure 3: These global maps show the percent NPP increase (above) and the corresponding ßL sensitivity from the CLM3-CASA' (left) and CLM3-CN (right) models. The plus (+) symbols identify the four temperate forest FACE sites described by Norby, *et al.* For CLM3-CASA', the largest responses occur in arid regions of western North America and central Asia, suggesting that responses are most strongly influenced by increased water use efficiency for this model. CLM3-CN exhibits consistently weaker responses than CLM3-CASA' with the strongest responses in central Asia, but significantly constrained by N limitation.

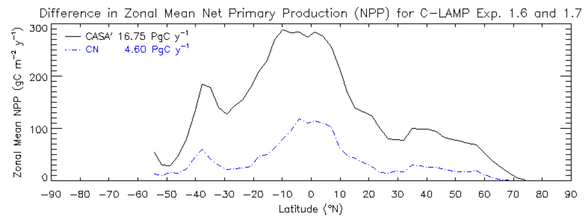

Figure 4: Zonal mean NPP increases show that model responses vary widely geographically with a decreasing trend of NPP increases from 40°N to 70°N.

Site Name	Longitude (°E)	Latitude (°N)	Measurement		CASA′ Model		CN Model	
			NPP Increase	β_L	NPP Increase	β_L	NPP Increase	β_L
DukeFACE	-79.08333	35.96666	28.0%	0.69	16.4%	0.41	6.2%	0.15
AspenFACE	-89.61666	45.66666	35.2%	0.87	15.6%	0.39	12.4%	0.31
ORNL-FACE	-84.33333	35.90000	23.9%	0.59	17.3%	0.43	5.2%	0.13
POP-EUROFACE	11.80000	42.36666	21.8%	0.54	20.0%	0.49	5.7%	0.14
		4 Site Mean	**27.2%**	**0.67**	**17.3%**	**0.43**	**7.4%**	**0.18**

Table 2: Median NPP increases from each of the four FACE sites, identified on the maps in Figure 3 at left with plus (+) symbols, are compared against the modeled NPP increases for the nearest 2.8°×2.8° grid cell for the CASA' and CN models. These grid cells contain a mixture of plant functional types (PFTs), and modeled NPP increases are averages across these PFTs.

Conclusions and Next Steps

While both the CLM3-CASA' and CLM3-CN models exhbited a weaker response than reported by Norby, *et al.* (2005), the global model results may not be unreasonable because 1) only four mid-latitude temperate forest sites were included in the analysis, 2) the model results are somewhat confounded by averaging over various plant functional types (PFTs) in large grid cells, and 3) more recent results from the ORNL FACE site show a significantly weaker NPP increase in later years, probably due to nutrient limitation (see Figure 5).

To better evaluate a wider range of models, Norby is leading a FACE model intercomparison project (FACE-MIP) in which a variety of international modeling groups are participating by running their models in single-point mode forces with site meteorology. Additional longer-term FACE experiments are needed in tropical and boreal forest biomes to better gauge ecosystem responses to increased atmospheric [CO_2].

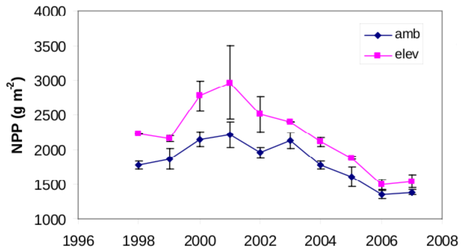

Figure 5: The NPP from ambient (blue) and elevated (magenta) [CO_2] FACE plots at ORNL show a significant reduction in NPP increase after 2003 and possibly leveling off in 2007. This change in NPP response is likely the result of N limitation and drought. From Norby, *et al.*

References

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The Carbon-Land Model Intercomparison Project (C-LAMP)
http://www.climatemodeling.org/c-lamp/
For more information, contact Forrest M. Hoffman at forrest@climatemodeling.org

C-LAMP is a sub-project of the Computational Climate Science End Station led by Dr. Warren Washington, using computing resources at the U.S. Department of Energy's National Center for Computational Sciences (NCCS). This research was partially sponsored by the Climate Change Research Division (CCRD) of the Office of Biological and Environmental Research (OBER) and the Computational Science Research and Partnerships (SciDAC) Division of the Office of Advanced Scientific Computing Research (OASCR) within the U.S. Department of Energy's Office of Science (SC). This research used resources of the National Center for Computational Science (NCCS) at Oak Ridge National Laboratory (ORNL), which is managed by UT-Battelle, LLC, for the U.S. Department of Energy under Contract No. DE-AC05-00OR22725. The Lawrence Livermore National Laboratory is managed by Lawrence Livermore National Security, LLC, for the U.S. Department of Energy under Contract No. DE-AC52-07NA27344. The National Center for Atmospheric Research (NCAR) is operated by the University Corporation for Atmospheric Research (UCAR) and receives research funding primarily from the U.S. National Science Foundation (NSF).