

# Global Coupled Climate and Carbon Cycle Modeling

*Presented by*

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# What is C-LAMP?

- The Carbon-Land Model Intercomparison Project (C-LAMP) was established to compare terrestrial biogeochemistry models against best-available ground- and satellite-based observational data to quantitatively compare model capabilities in coupled climate system models and to understand processes important for inclusion in the Community Climate System Model (CCSM) for the IPCC Fifth Assessment Report (AR5)
- Initial models run for C-LAMP operate within the CCSM framework
  - **CLM3-CASA'**—Carnegie/Ames/Stanford Approach Model previously run in CSM1.4 (Fung),
  - **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 PCTM (Thompson).
- C-LAMP is accumulating observational data sets from DOE, NASA, NOAA, and NSF data centers, and these are used to evaluate the performance of carbon models via a new diagnostics package
- PCMDI is archiving and distributing model results via the Earth System Grid as a prototype for BGC fields for IPCC AR5

# Computational climate science end station

- **C-LAMP** is a **Biogeochemistry Subproject** of the **Computational Climate Science End Station** (Warren Washington, PI), now in its second year
- The models were run on the **Cray X1E** vector supercomputer in the **National Center for Computational Sciences (NCCS)** at **Oak Ridge National Laboratory**

## Cray X1E (Phoenix)

- 1,024 processors (MSPs)
- 2,048 GB memory
- 18.08 Tflops/s peak

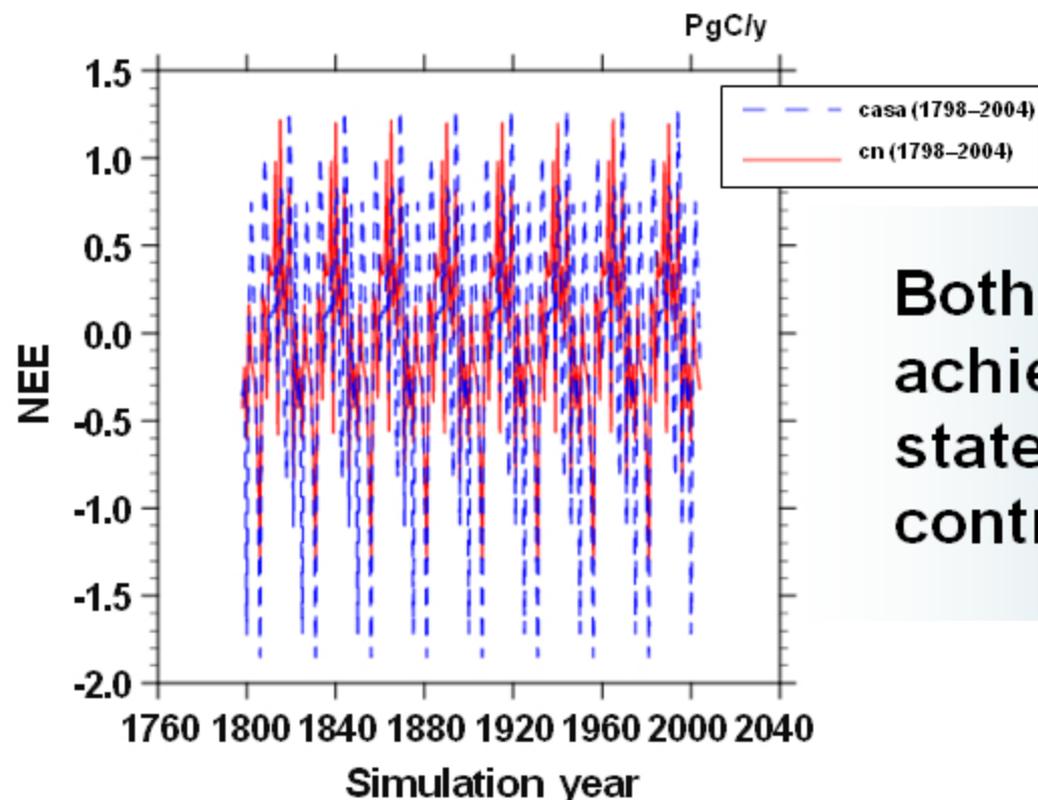


# CCSM C-LAMP protocol

- **Experiment 1:** Models forced with an improved NCEP/NCAR reanalysis climate data set (Qian et al. 2006) to examine the influence of climate variability, prescribed atmospheric CO<sub>2</sub>, and land cover change on terrestrial carbon fluxes during the 20th century (specifically 1948–2004)
- **Experiment 2:** Models coupled with an active atmosphere (CAM3), prescribed atmospheric CO<sub>2</sub>, prescribed sea surface temperatures, and ocean carbon fluxes to examine the effect of a coupled biosphere-atmosphere for carbon fluxes and climate during the 20th century
- **Future:** Fully coupled simulations with ocean biogeochemistry
- CCSM3.1 partially coupled (“I” and “F” configurations) run at T42 resolution (~2.8° × 2.8°), spectral Eulerian dycore, 1° × 0.27°-0.53° ocean and sea ice data models (i.e., T42gx1v3)
- Experimental protocol, output fields, and metrics for model evaluation are available at <http://www.climatemodeling.org/c-lamp/>

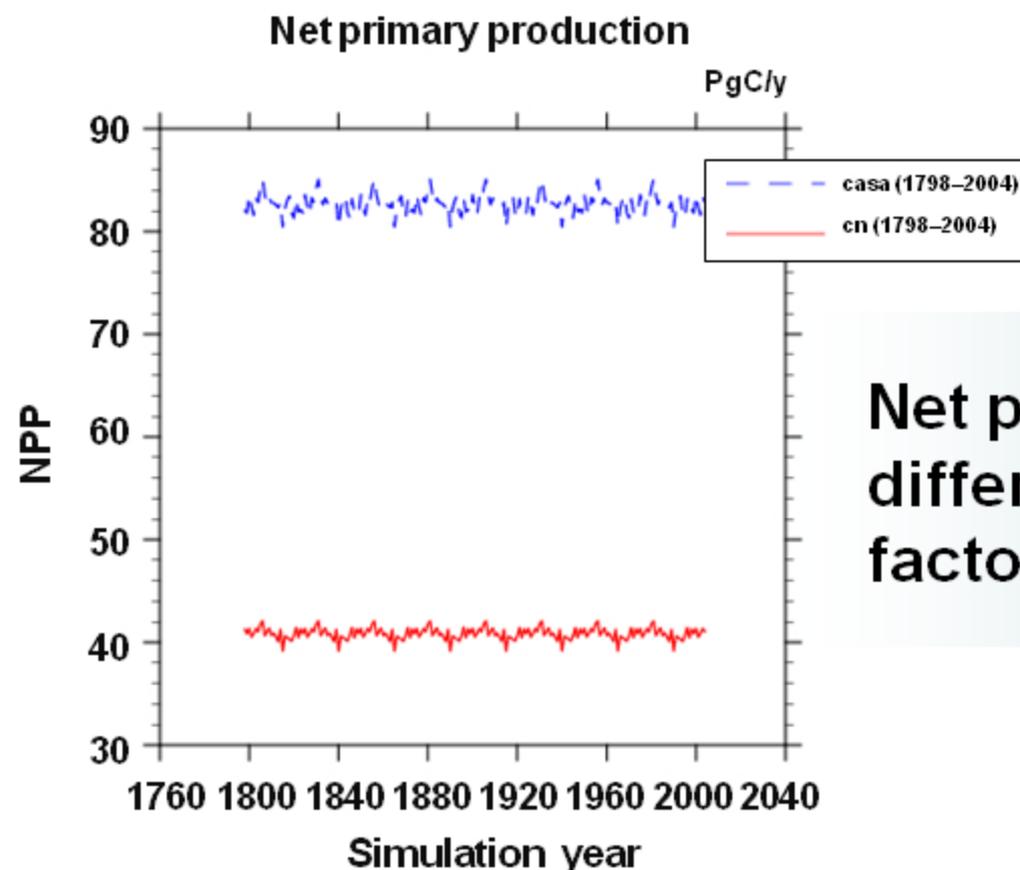
# Experiment 1.2: Net ecosystem exchange

Net ecosys exchange of C;incl fire flx;pos for source



Both models  
achieved steady  
state in the offline  
control simulations

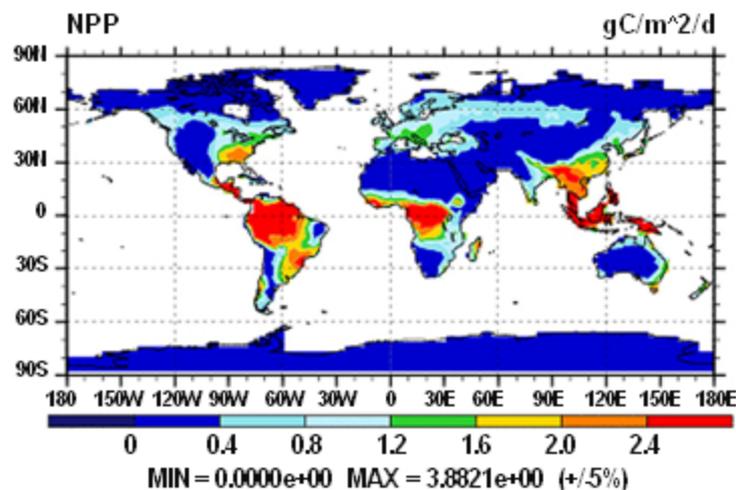
# Experiment 1.2: Net primary production



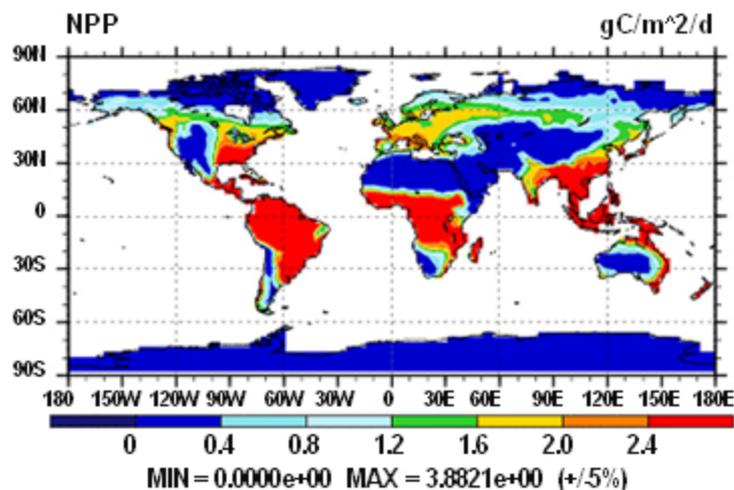
Net primary production differs by about a factor of two

# Experiment 1.2: Spatial pattern of NPP

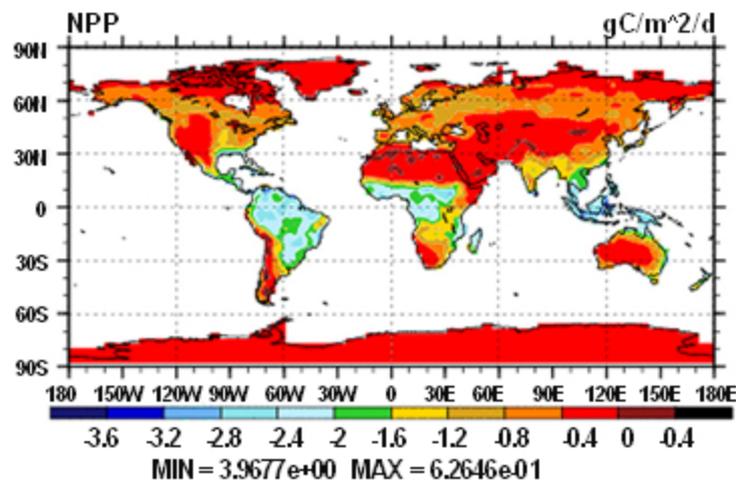
CN (yrs 1980-2004)



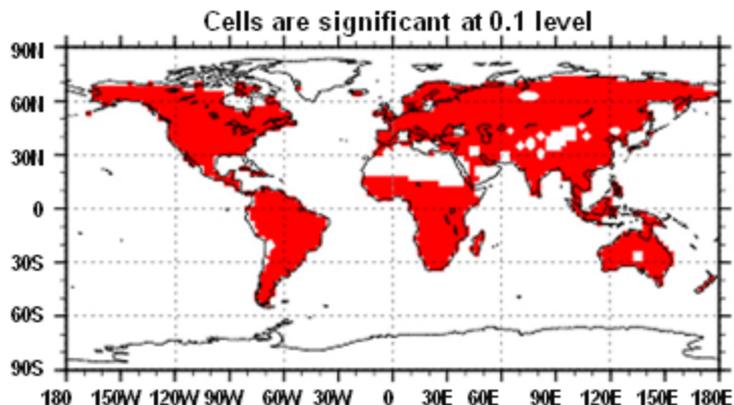
CASA (yrs 1980-2004)



Case 1–Case 2

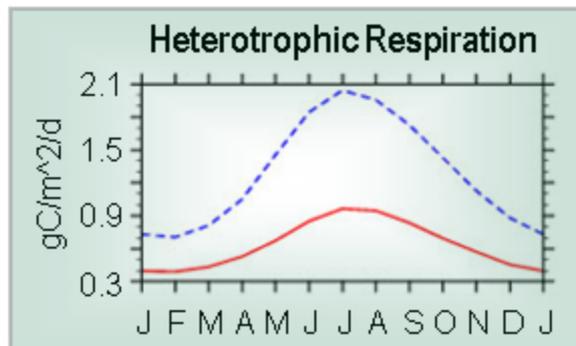
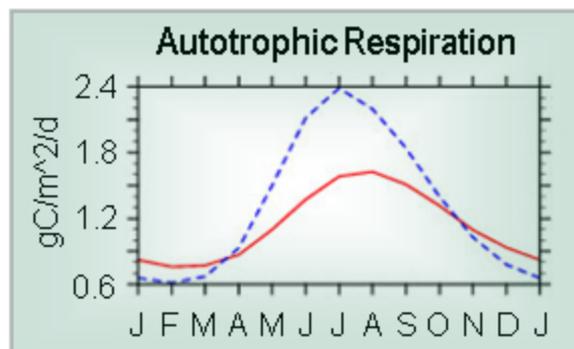
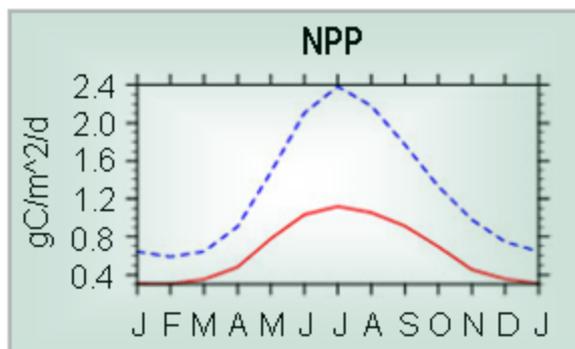
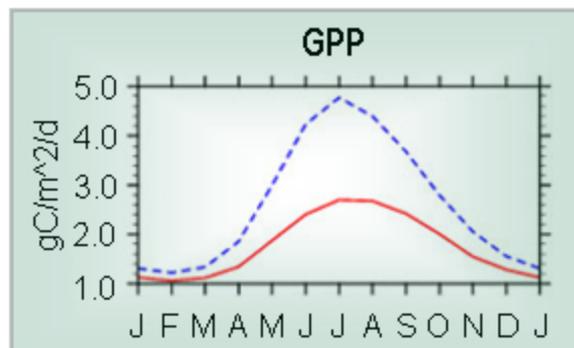
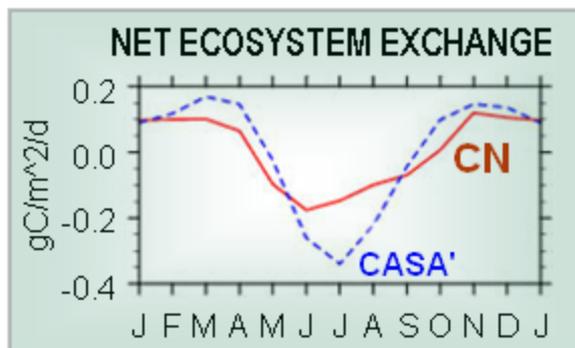


T-test of two means at each grid point



# Experiment 1.2: Seasonal exchanges

## N. Hemisphere Land (EQ-90N, 180W-180E)

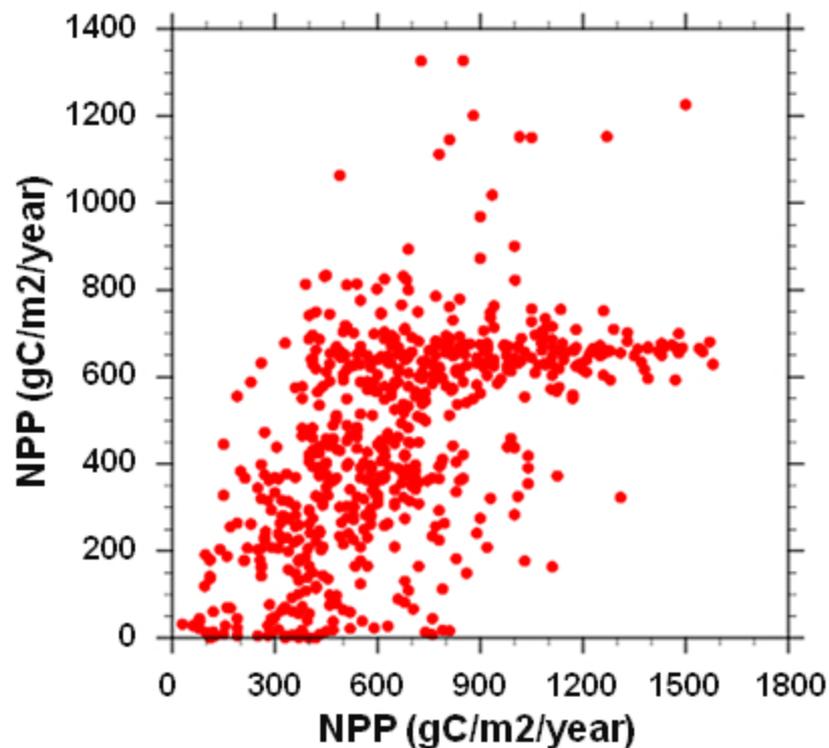


Seasonal exchanges in both models may be too weak

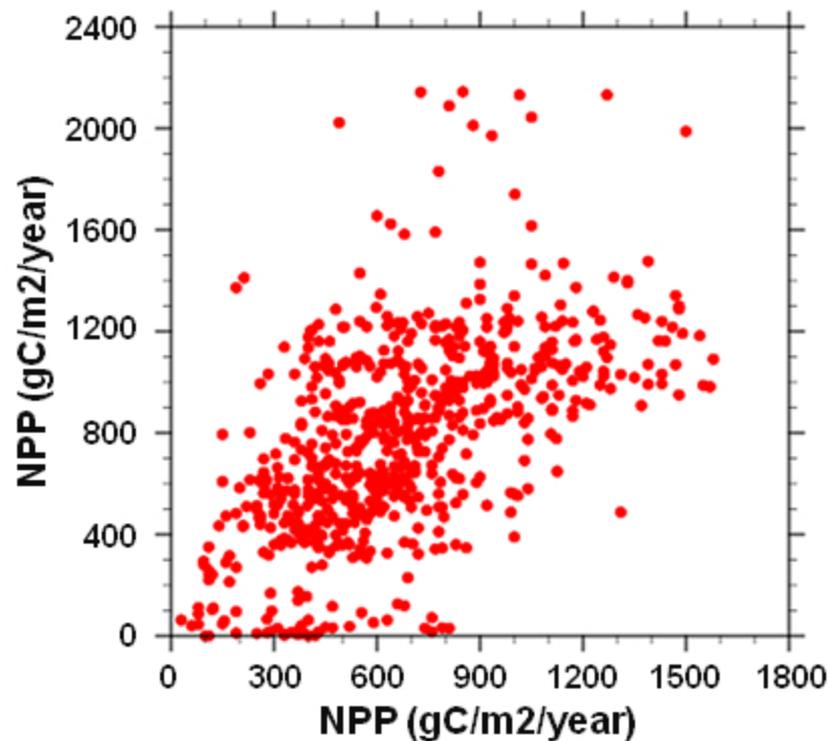
# Experiment 1.2: Model NPP vs. observations

Net primary production observations compiled by  
the Ecosystem-Model Data Intercomparison Team

06cn vs. ob 933 sites

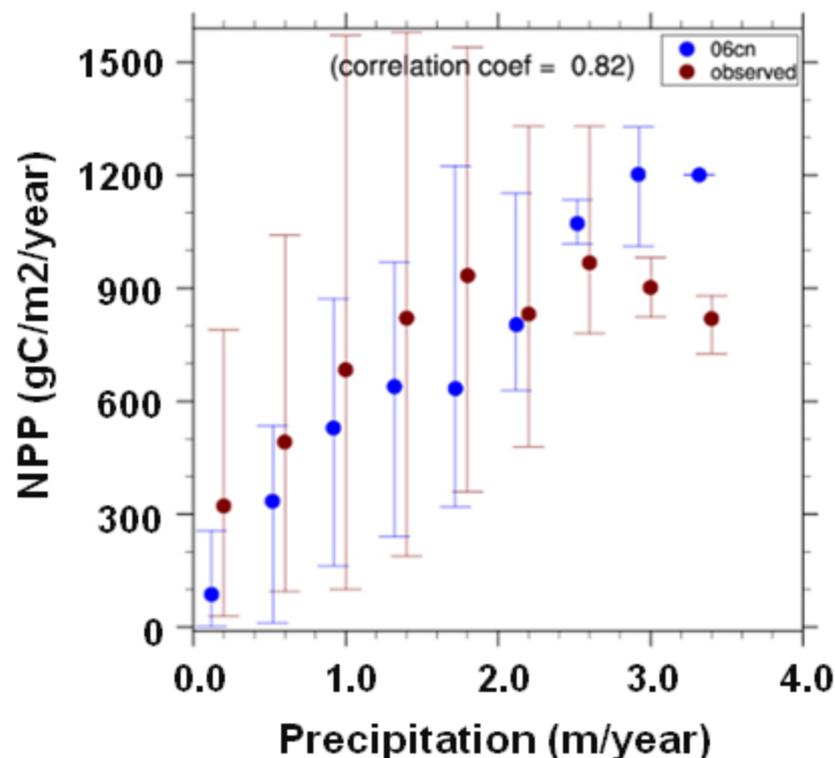


06casa vs. ob 933 sites

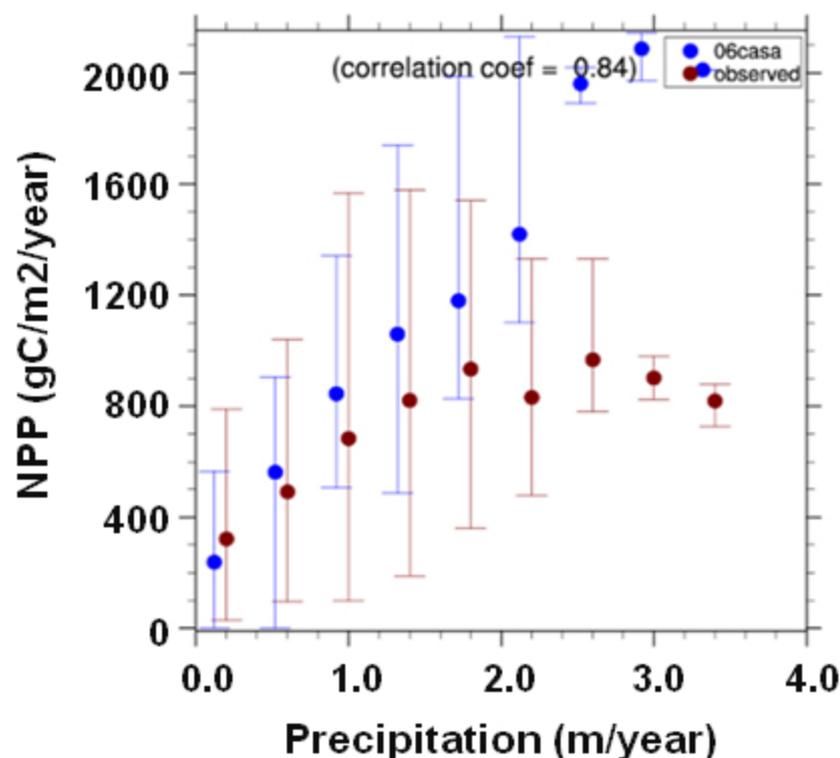


# Experiment 1.2: Precipitation vs. NPP

06cn vs. ob 933 sites

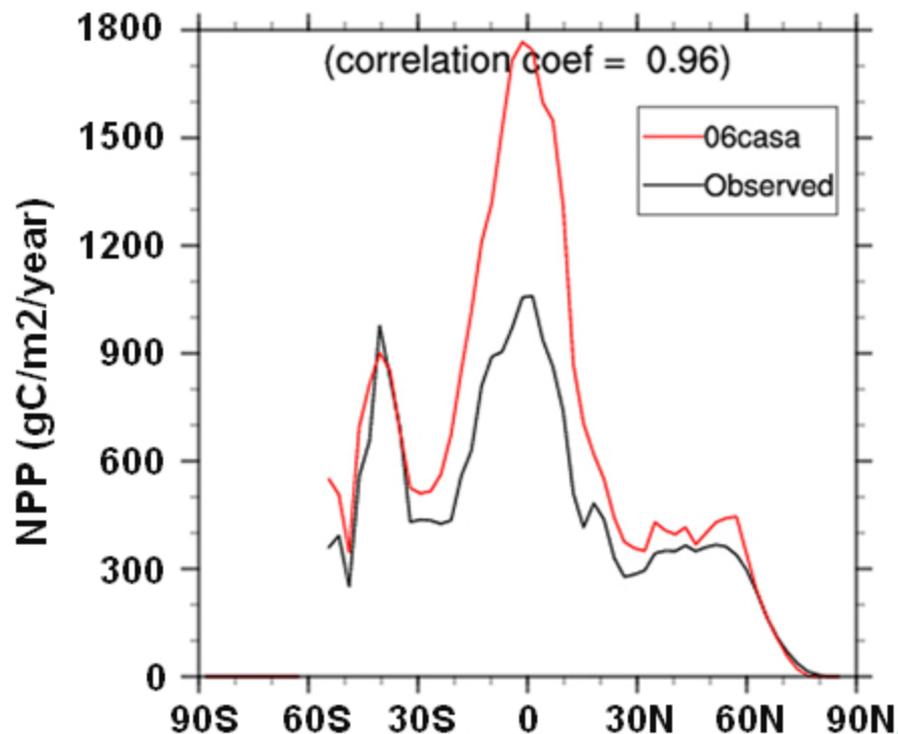
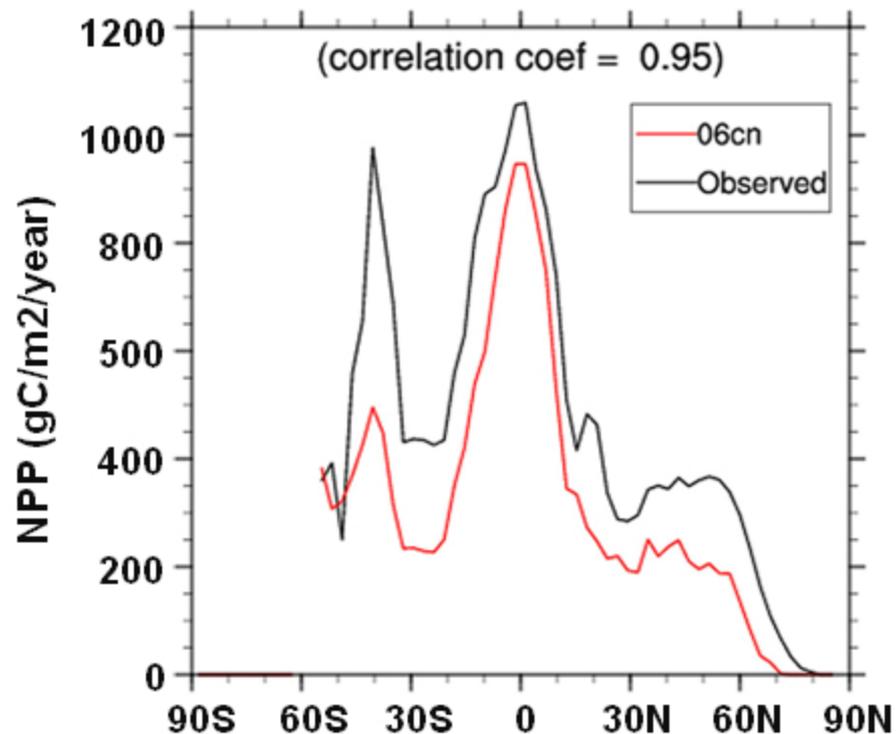


06casa vs. ob 933 sites

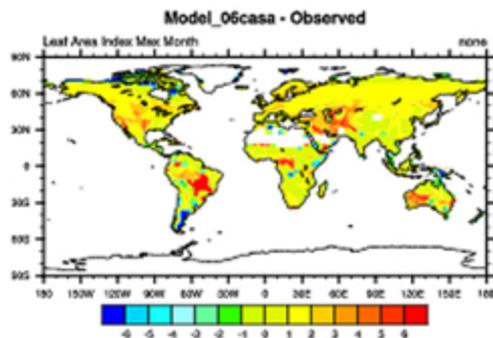
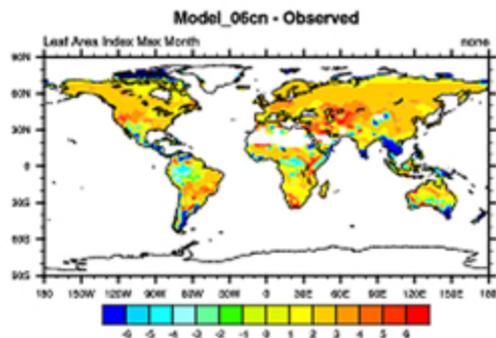
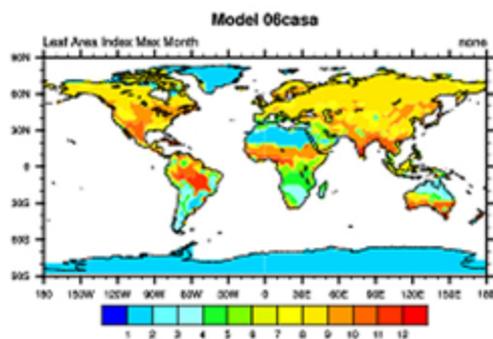
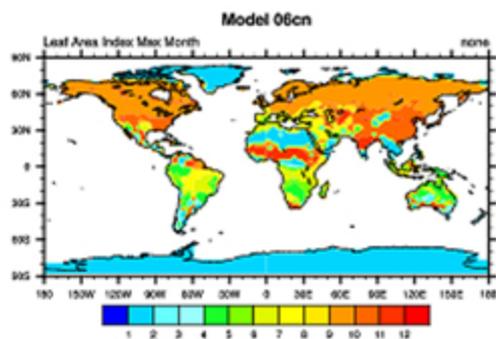
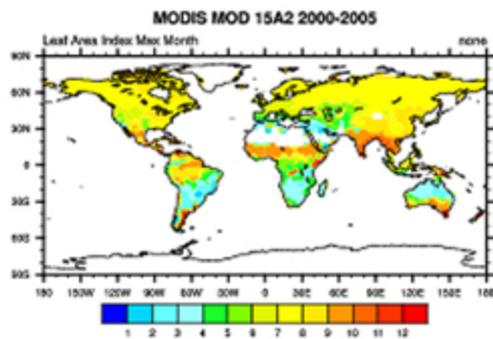
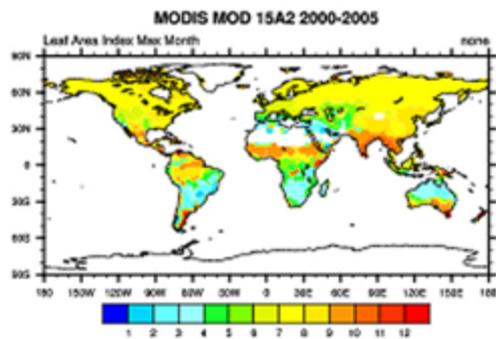


Net primary production observations compiled by the Ecosystem-Model Data Intercomparison Team; NPP observations normalized by observed precipitation; Model NPP normalized by forcing precipitation

# Experiment 1.2: Control vs. MODIS NPP

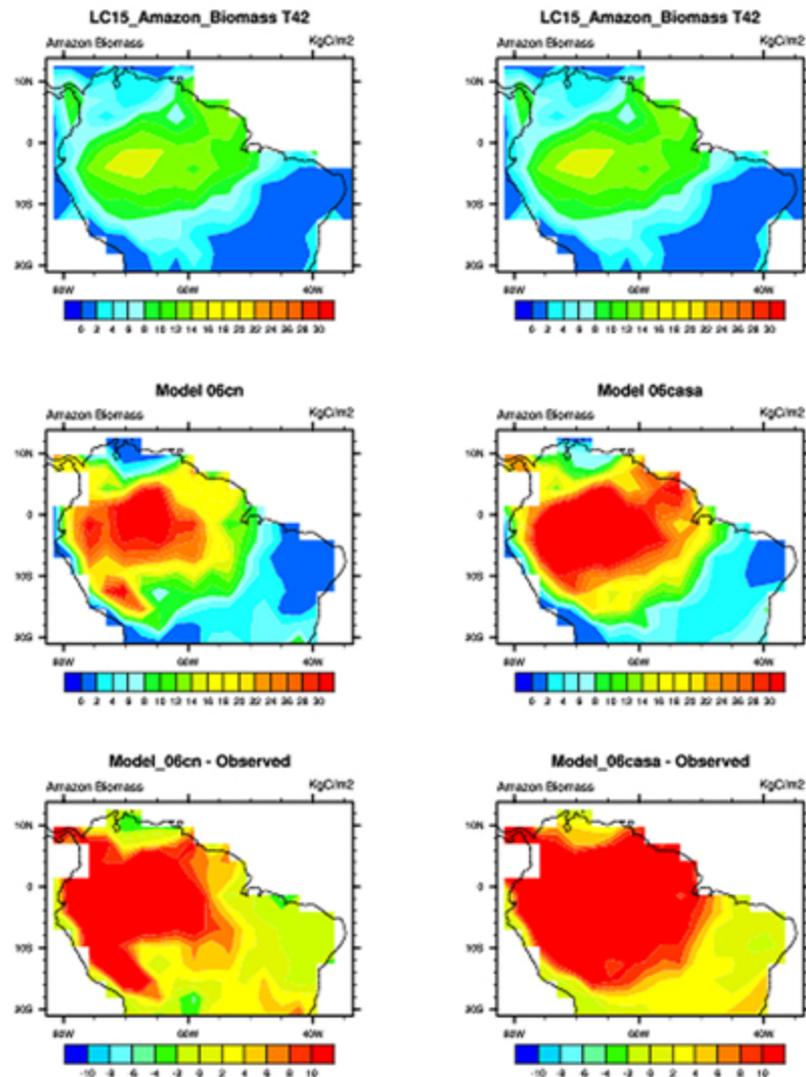


# Experiment 1.2: Control vs. MODIS LAI phase



**MODIS LAI phase:  
Timing of peak LAI**

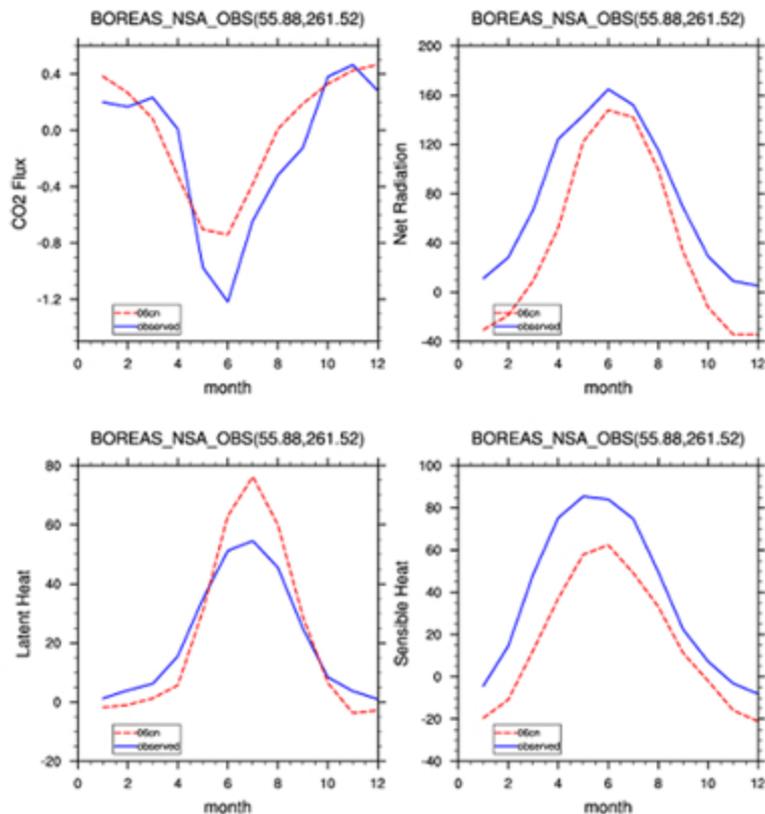
# Experiment 1.2: Amazon aboveground biomass



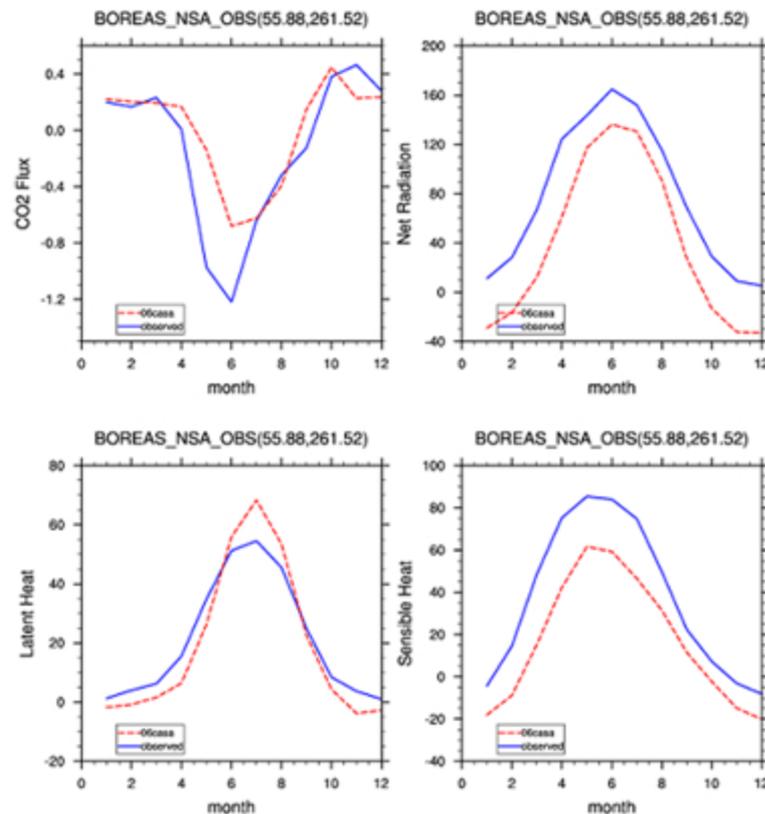
Model comparisons with maps of Amazon aboveground biomass from Saatchi et al. 2007, "Distribution of aboveground live biomass in the Amazon basin," *Global Change Biology* 13, 816–837

# Experiment 1.2: Control vs. FLUXNET observations (BOREAS)

## CN vs. Observations

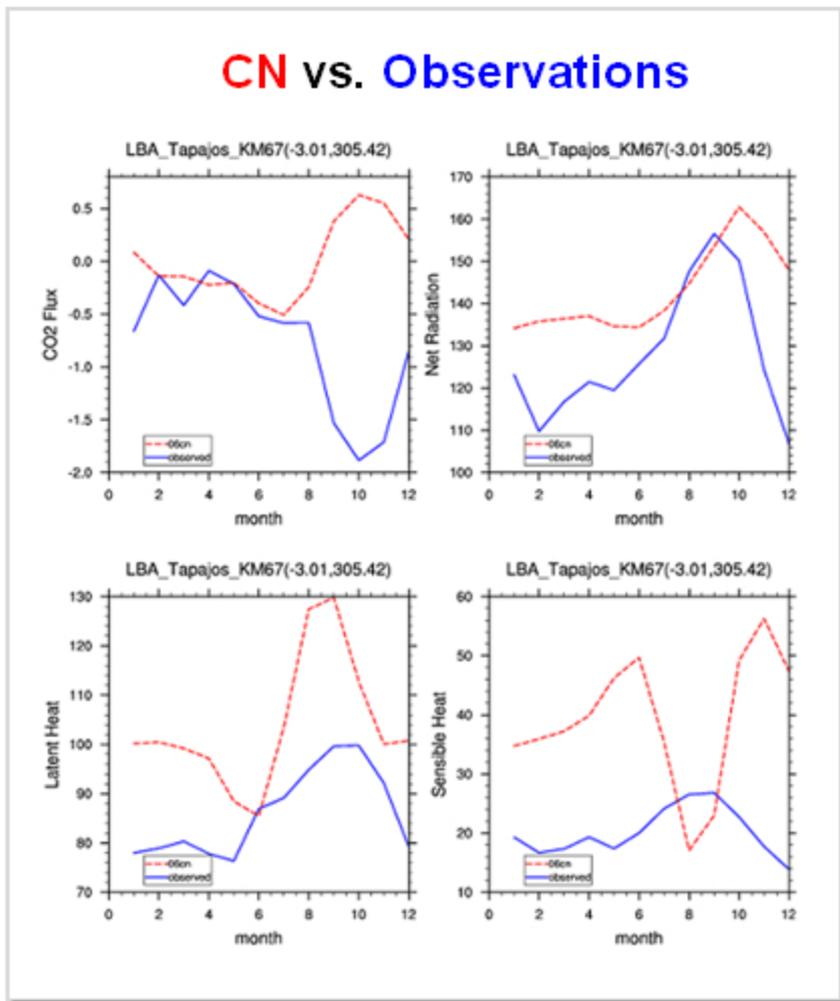


## CASA' vs. Observations

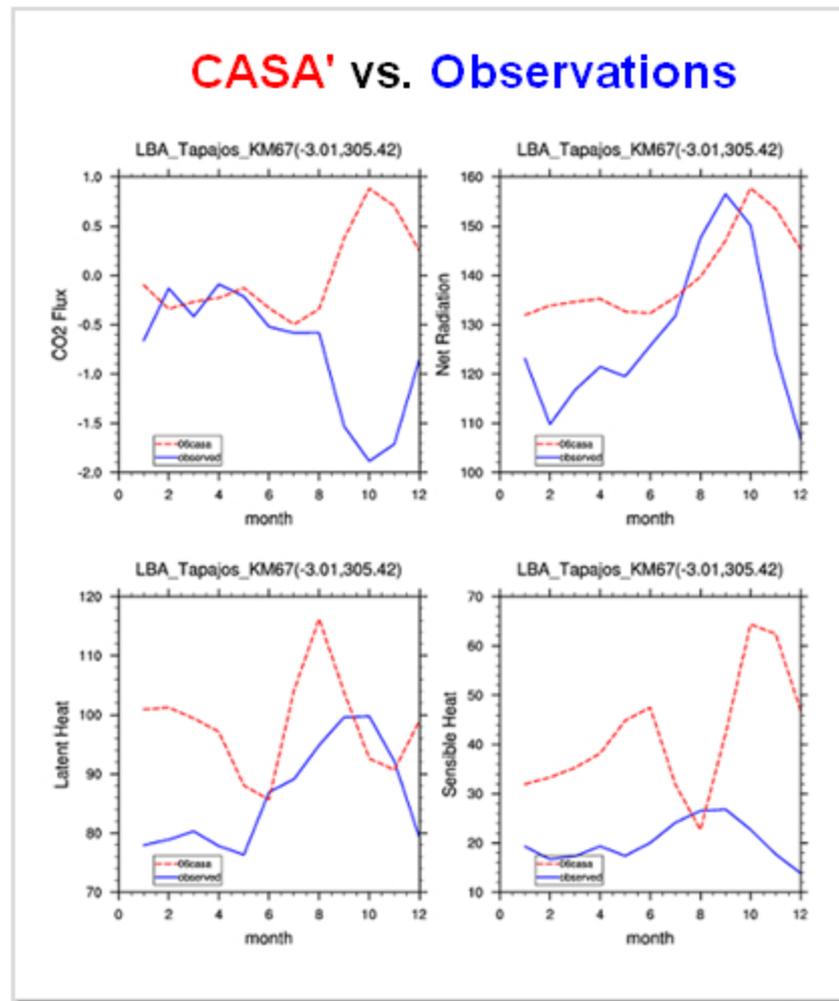


# Experiment 1.2: Control vs. FLUXNET observations (Tapajos)

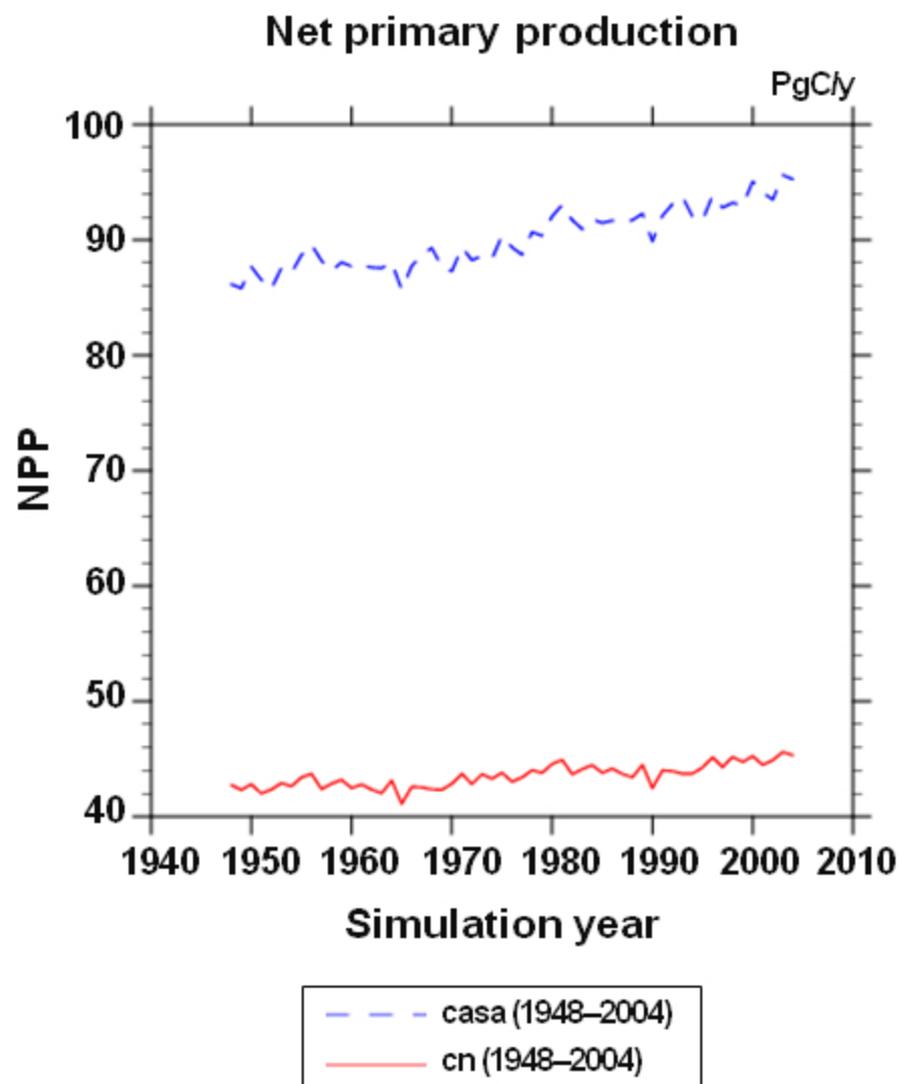
## CN vs. Observations



## CASA' vs. Observations

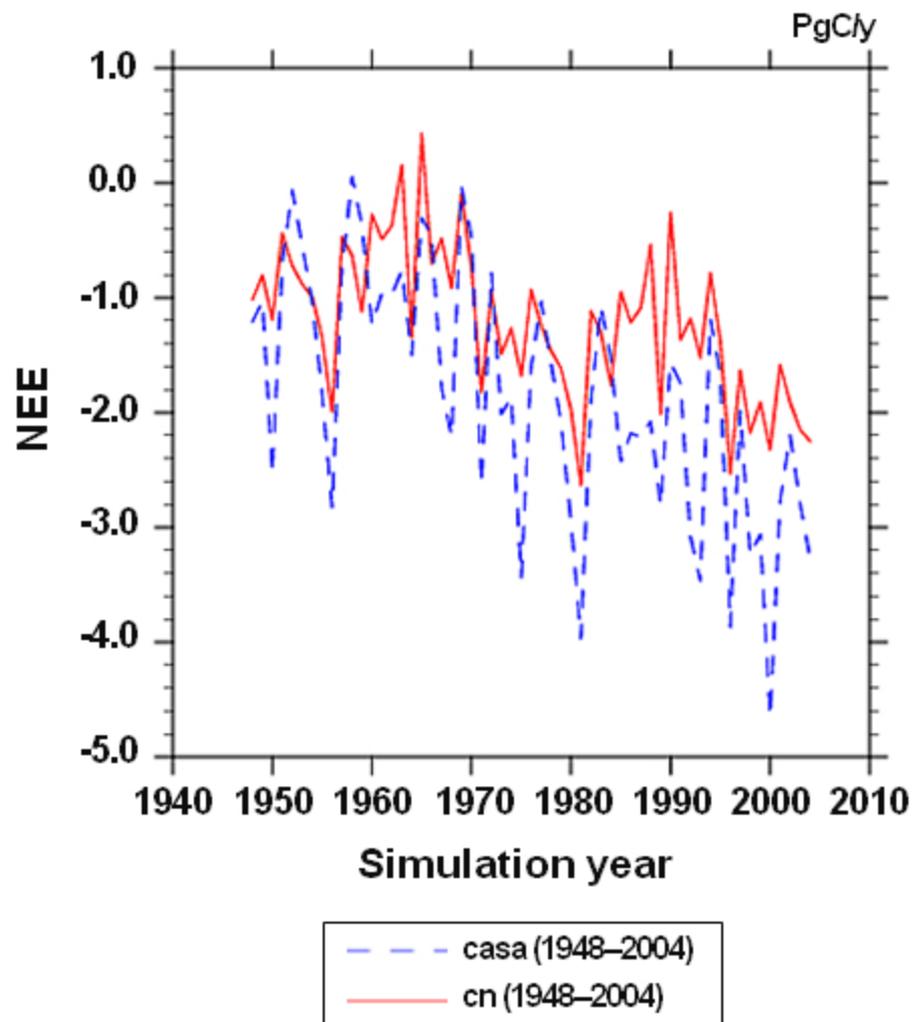


# Experiment 1.4: Net primary production



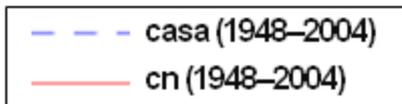
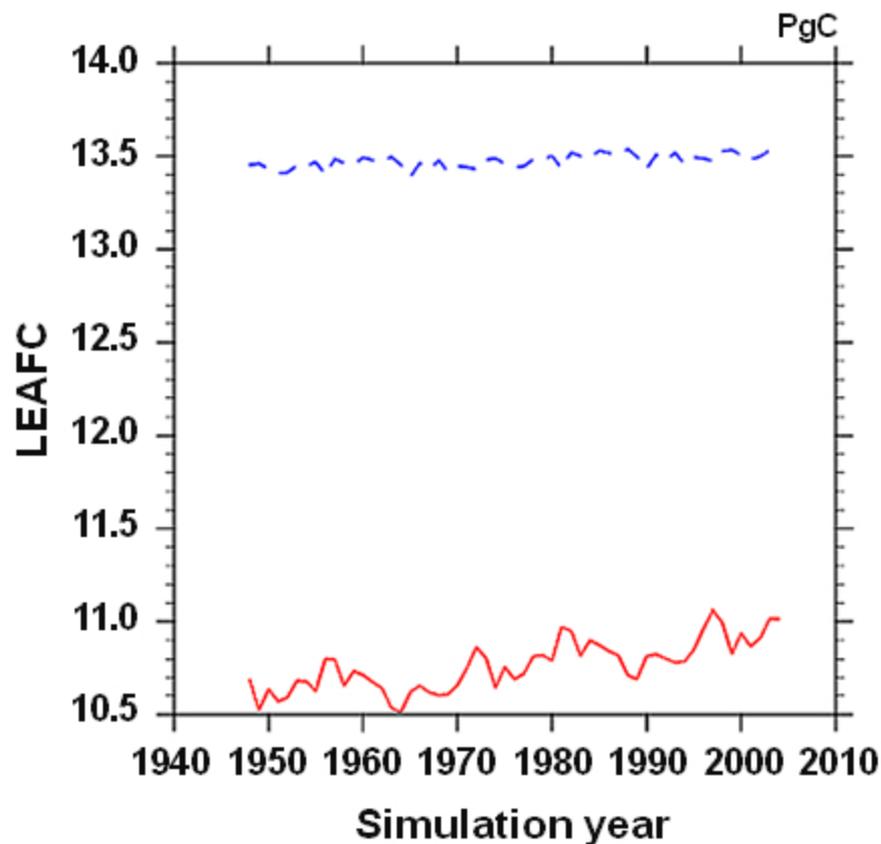
# Experiment 1.4: Net ecosystem exchange

Net ecosystem exchange including fire flux

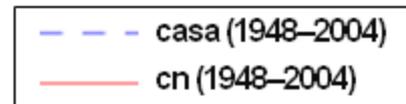
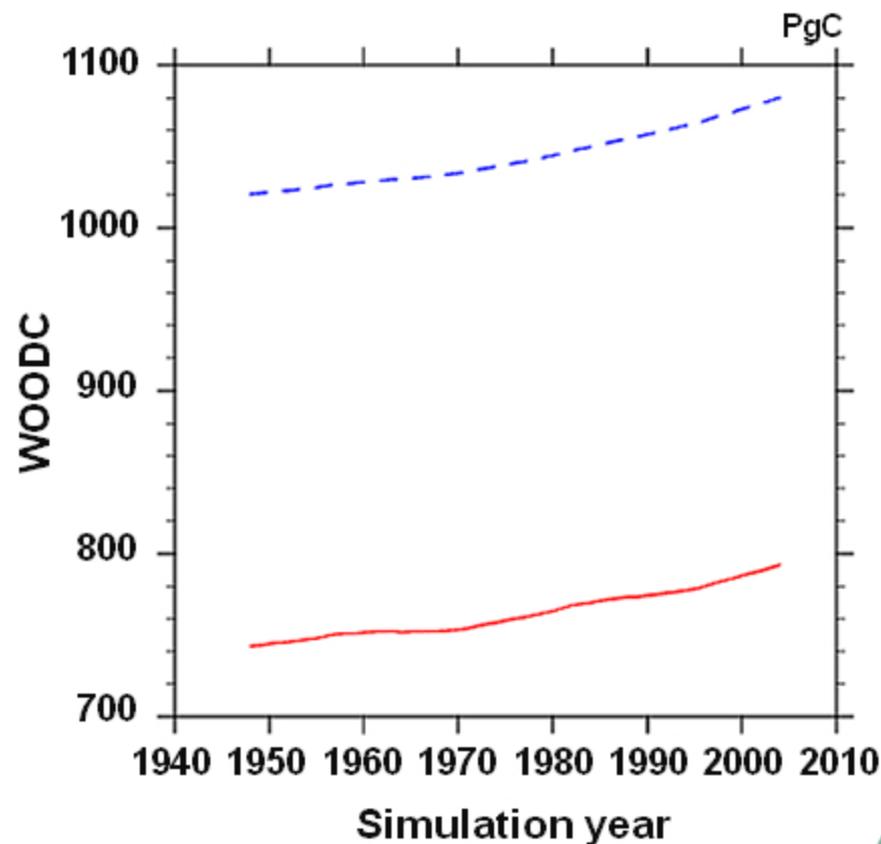


# Experiment 1.4: Live C pools (leaf and wood)

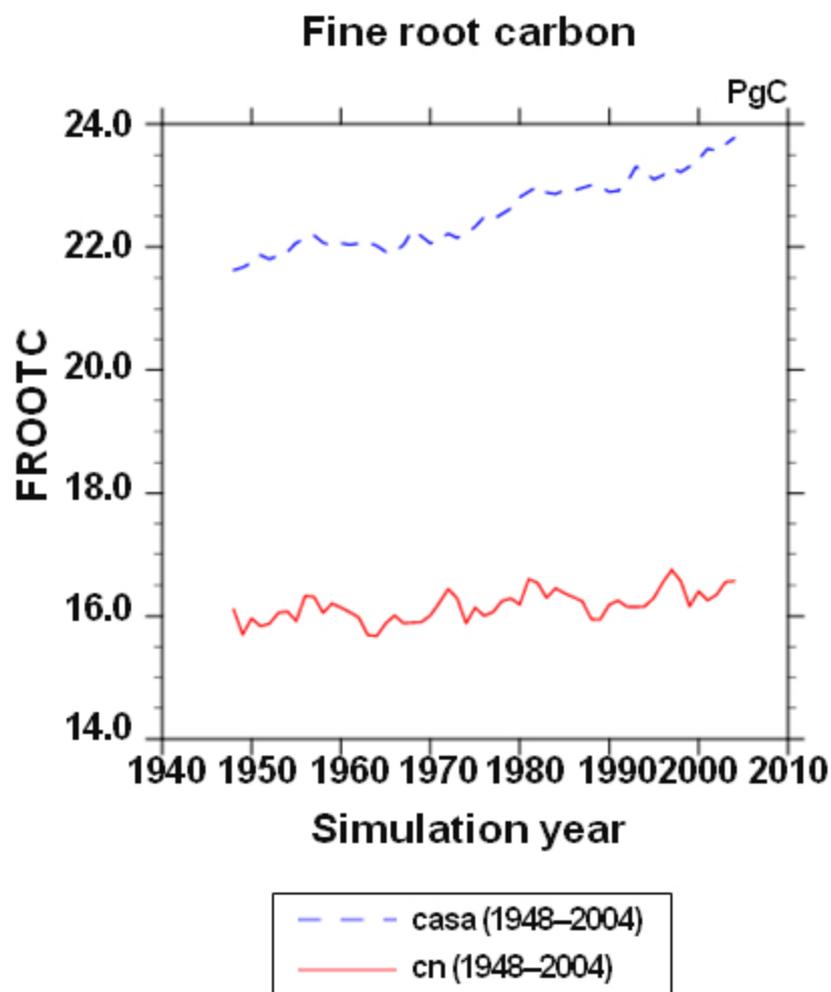
### Leaf carbon



### Wood C



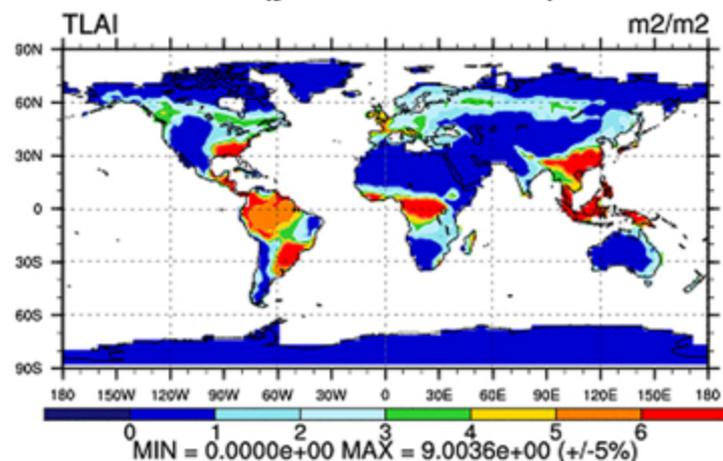
# Experiment 1.4: Live C pools (fine root)



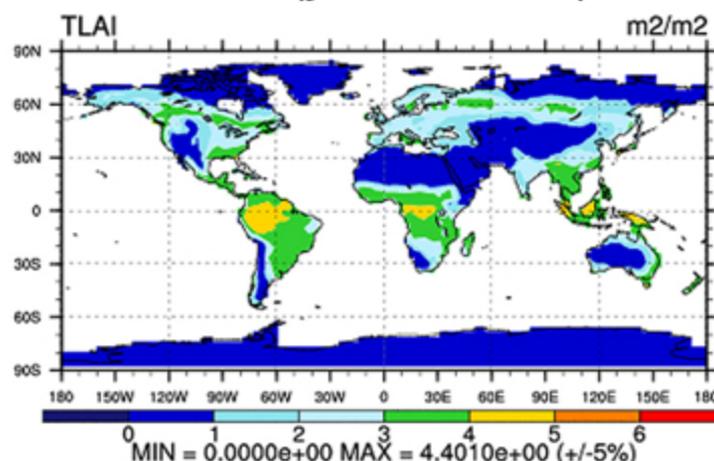
- **CLM3-CASA'** has higher productivity than CLM3-CN
- **CLM3-CASA'** has stronger fertilization response to increasing CO<sub>2</sub> than CLM3-CN
- **Concurrent studies have shown that CLM3-CN**
  - carbon-only mode has sensitivity near the mean of C<sup>4</sup>MIP carbon models
  - carbon-nitrogen mode has lower sensitivity to rising CO<sub>2</sub> because of increasing N limitation (Thornton et al., in press)

# Experiment 1.4: Mean annual leaf area index

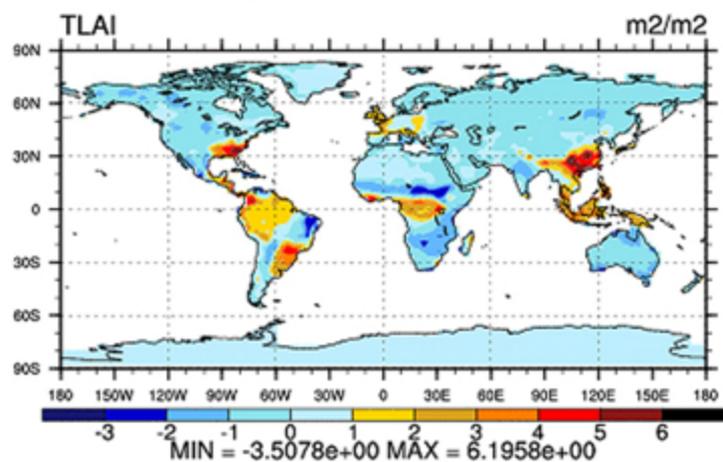
CN (yrs 1980–2004)



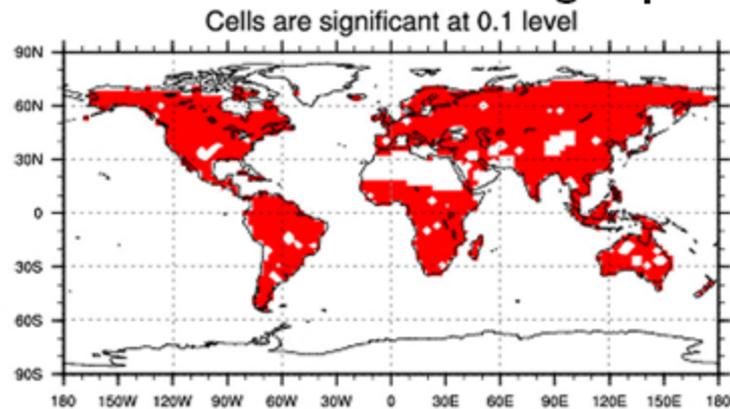
CASA (yrs 1980–2004)



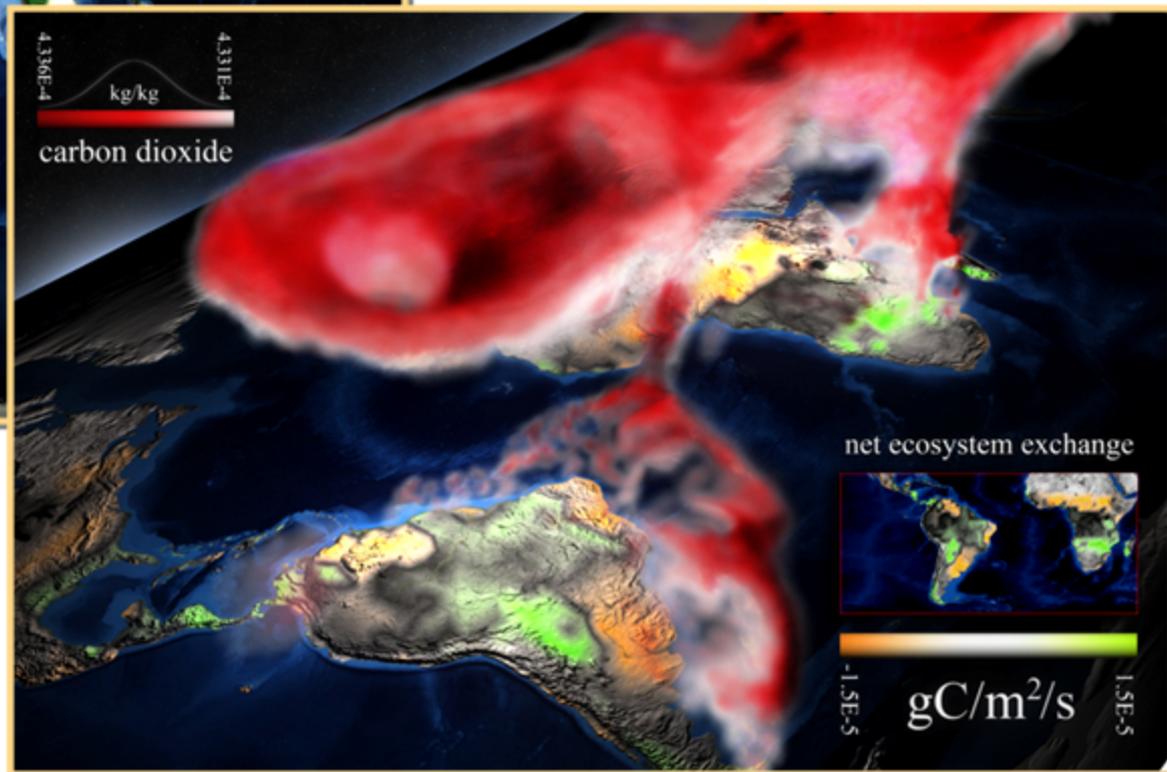
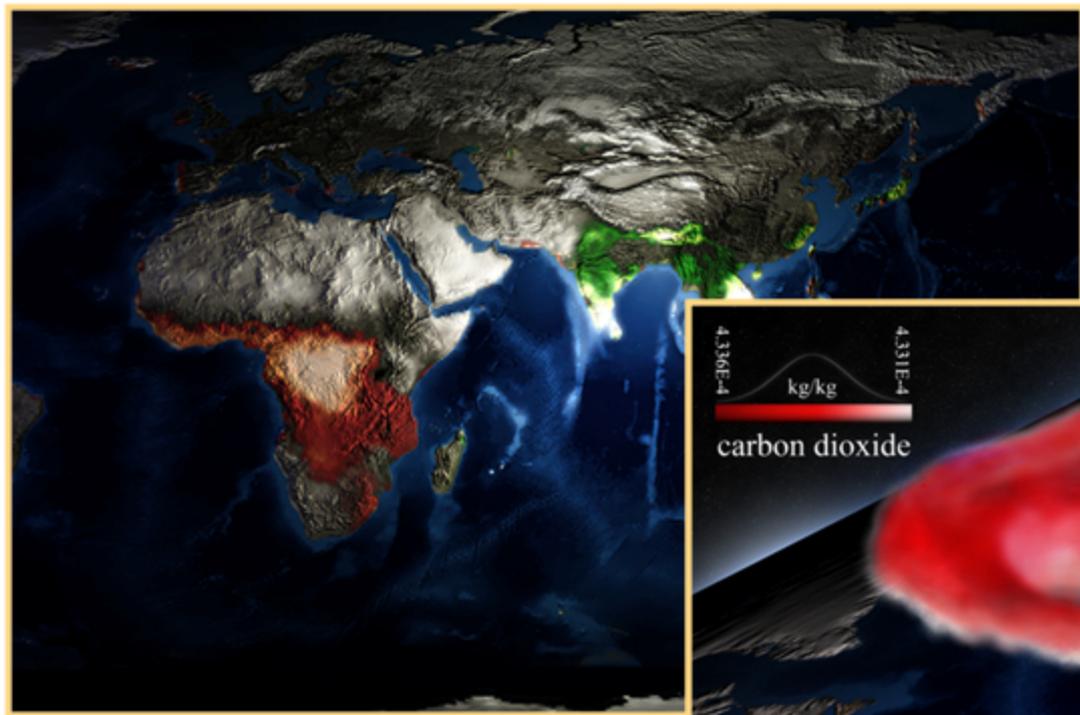
Case 1–Case 2



T-test of two means at each grid point



# Visualizing net ecosystem exchange and respired CO<sub>2</sub> in the atmosphere

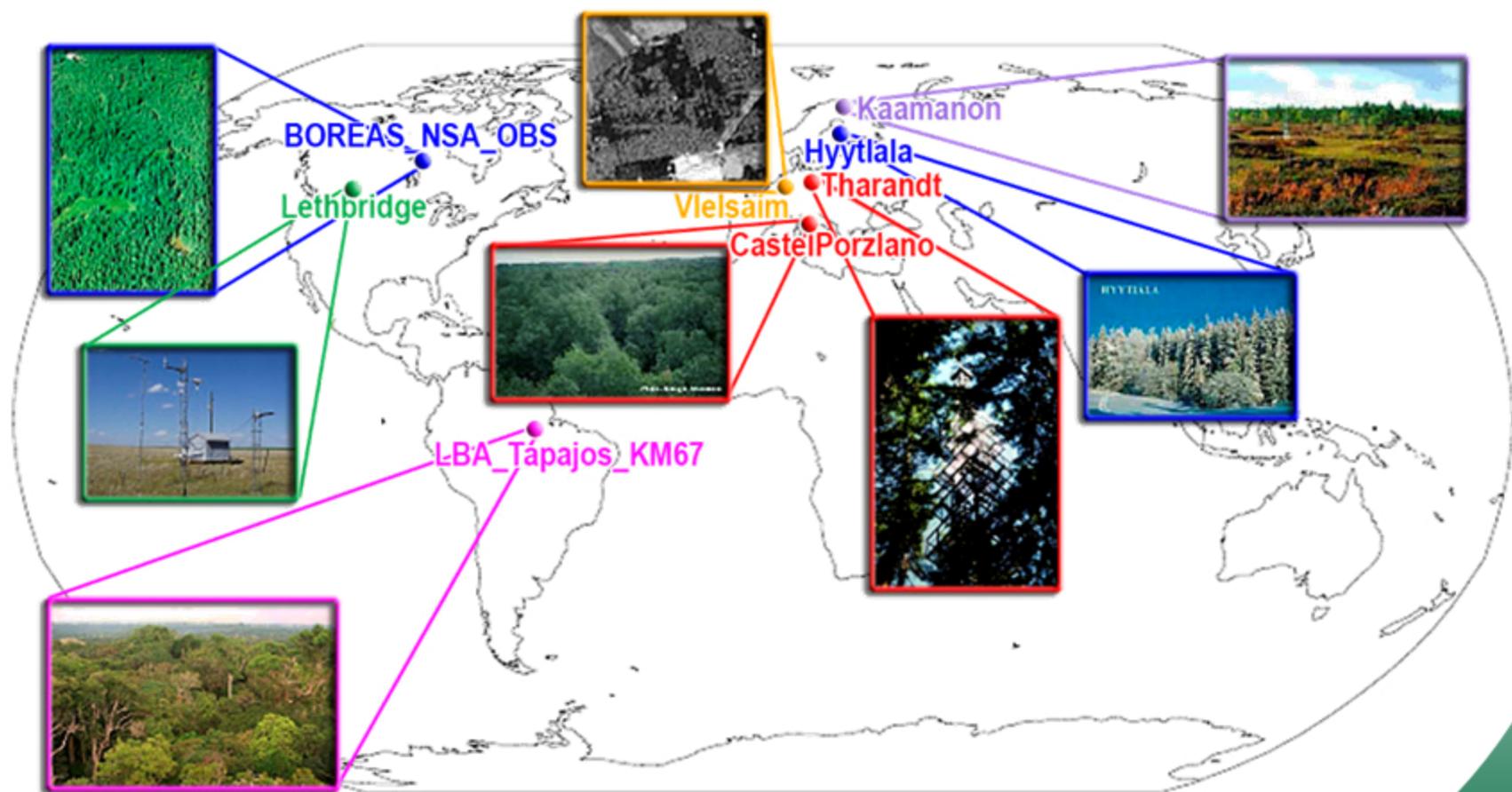


# C-LAMP FLUXNET Tower/Point offline simulations

- Offline simulations at FLUXNET Tower sites were added to the C-LAMP experiments
  - To verify and validate biogeochemistry modules against high-frequency (and high-quality) observations
  - To identify any issues with output fields, post-processing code, and intercomparison strategy
  - To serve as a quick "dry run" for the global simulations
- Reto Stöckli (Colorado State U./ETH Zürich), Steve Running and Faith Ann Heinsch (U. Montana), Kathy Hibbard (NCAR) are providing ready-to-run meteorological data and carbon flux measurements
- CarboEurope site data were used first; AmeriFlux sites are now being added
- So far, offline simulations using CLM3-CASA' and CLM3-CN have been run following the same protocol as Experiment 1

# FLUXNET Tower sites used for offline model intercomparison

CarboEurope and AmeriFlux site meteorology is being used to spin up and force model experiments; sites were chosen to maximize the coverage of land cover types in the models



# Contact

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