# Global Coupled Climate and Carbon Cycle Modeling

Presented by

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Research partially sponsored by the (1) Climate Change Research Division (CCRD) of the Office of Biological and Environmental Research (OBER), and (2) Mathematical, Information, and Computational Sciences (MICS) 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 Sciences (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 National Center for Atmospheric Research (NCAR) is operated by the University Corporation for Atmospheric Research (UCAR) and receives research funding primarily from the National Science Foundation (NSF).

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# What is C-LAMP?

- CCSM Biogeochemistry Working Group project to compare model capabilities and effects in the coupled climate system and to understand processes important for inclusion in the Earth System Model for the IPCC Fifth Assessment Report (AR5).
- Models currently running within the CCSM framework are
  - **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).
- Project is developing observational datasets and metrics for evaluation of any terrestrial carbon models (a BGC diagnostics package for CCSM).
- PCMDI is archiving and distributing results via the Earth System Grid like CMIP3 and 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 are running on the Cray X1E vector supercomputer in the National Center for Computational Sciences (NCCS) at Oak Ridge National Laboratory.

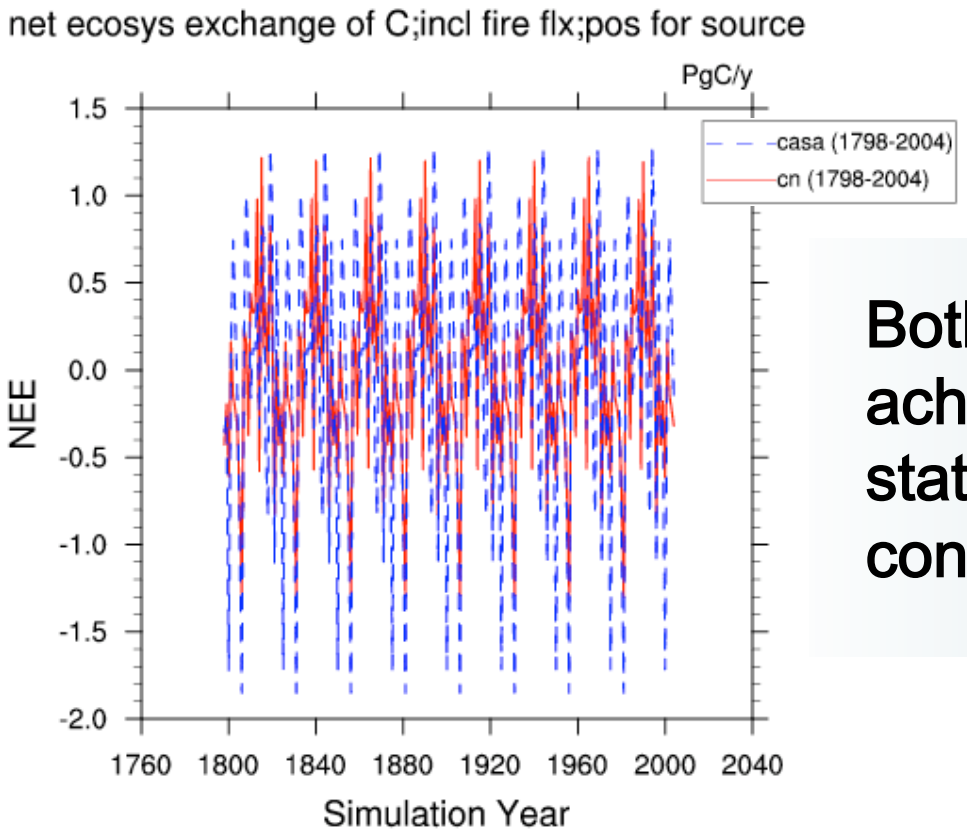
## Cray X1E (Phoenix)

- 1024 processors (MSPs)
- 2048 GB memory
- 18.08 Tflops/s peak

# CCSM C-LAMP protocol

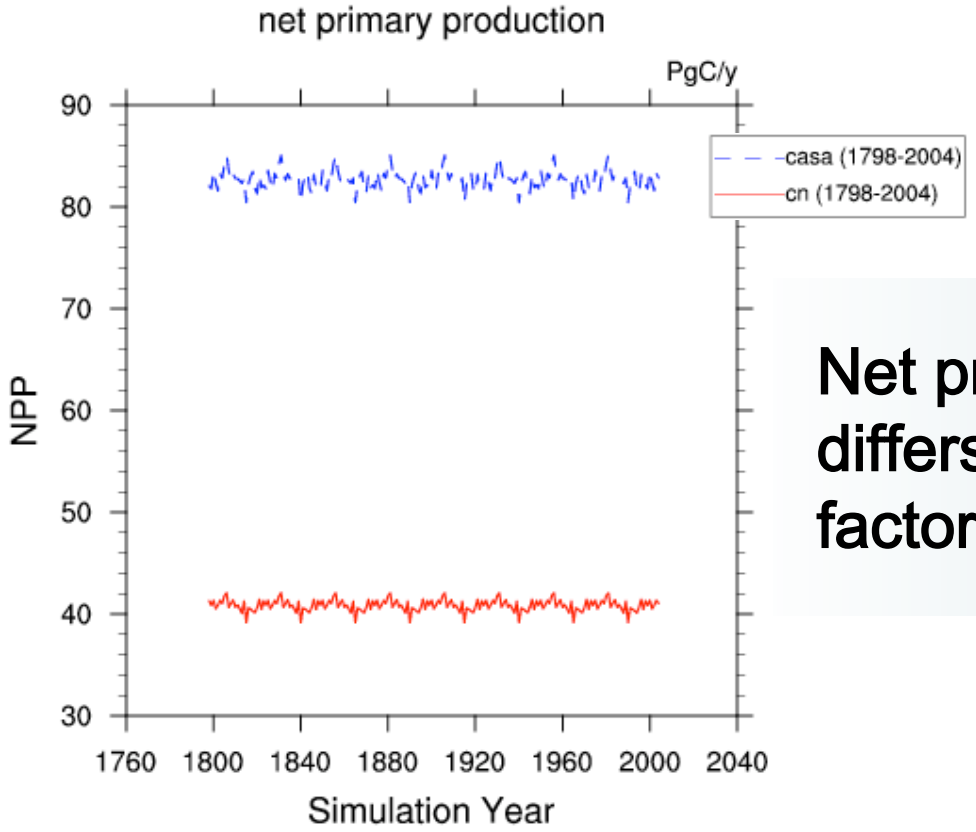
- **Experiment 1:** Models forced with an improved NCEP/NCAR reanalysis climate data set (Qian et al. 2006) to examine the influence of climate variability, prescribed atmospheric $CO_2$, and land cover change on terrestrial carbon fluxes during the 20th century (specifically 1948–2004).
- **Experiment 2:** Models coupled with an active atmosphere (CAM3), prescribed atmospheric $CO_2$, 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 (~2.8º × 2.8º), spectral Eulerian dycore, 1º × 0.27º-0.53º 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




Both models achieved steady state in the offline control simulations.

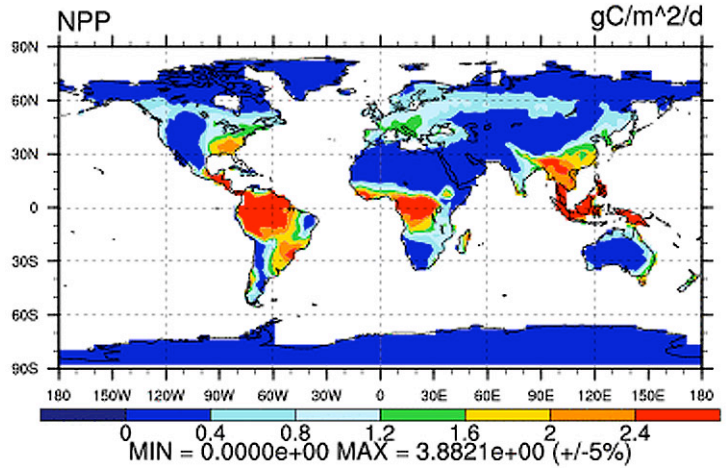
# Experiment 1.2: Net primary production



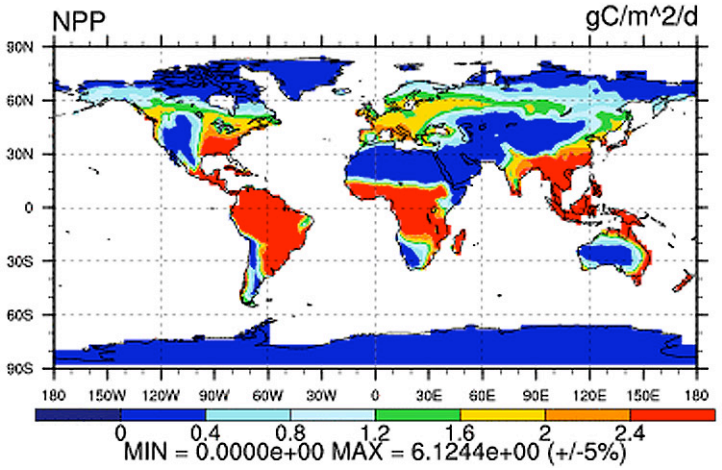

Net primary production differs by about a factor of two.

# Experiment 1.2: Spatial pattern of NPP

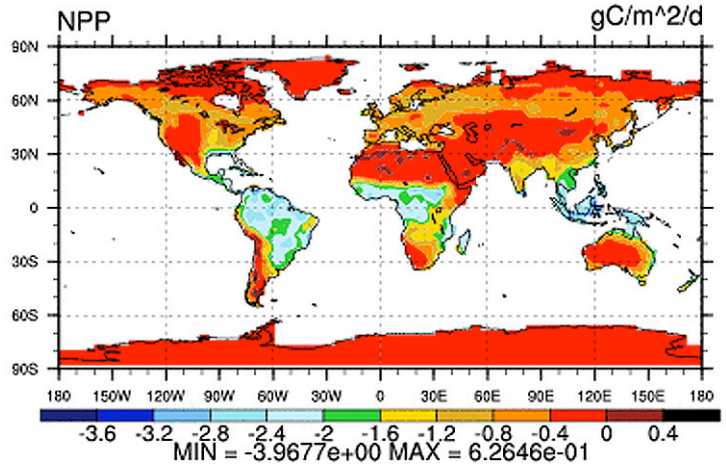
cn (yrs 1980-2004)



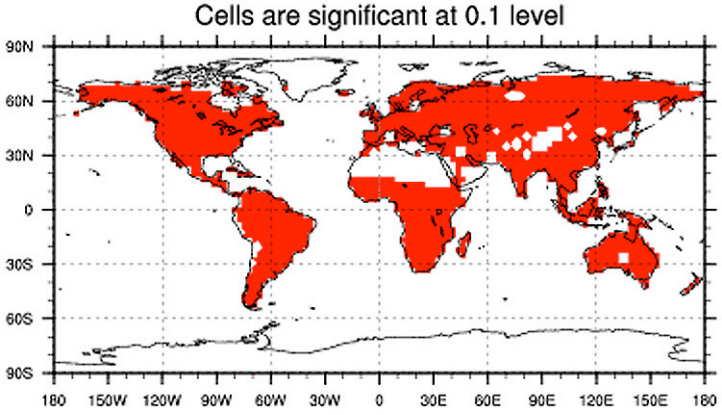

casa (yrs 1980-2004)




Case 1 - Case 2




T-Test of two means at each grid point



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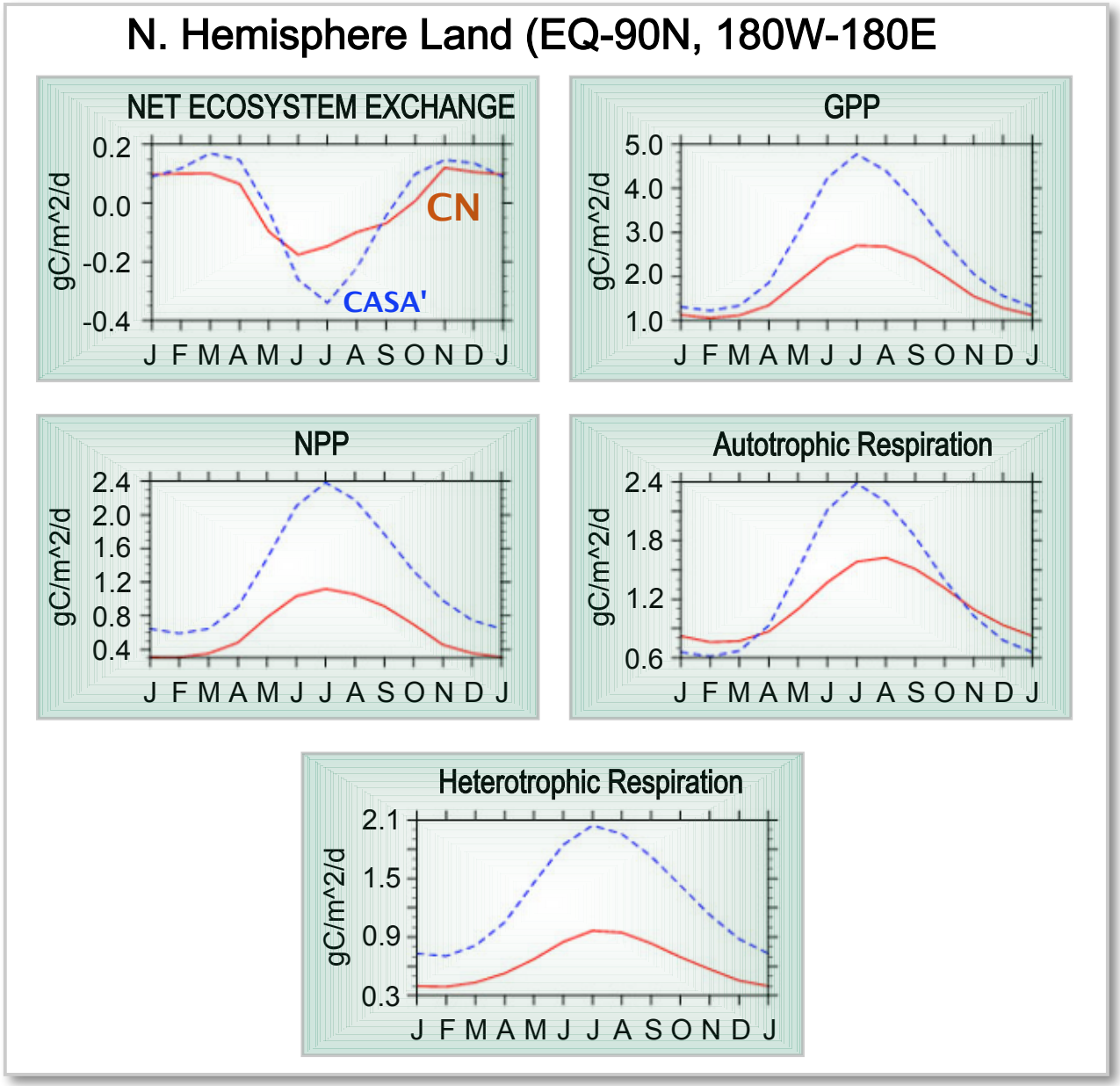
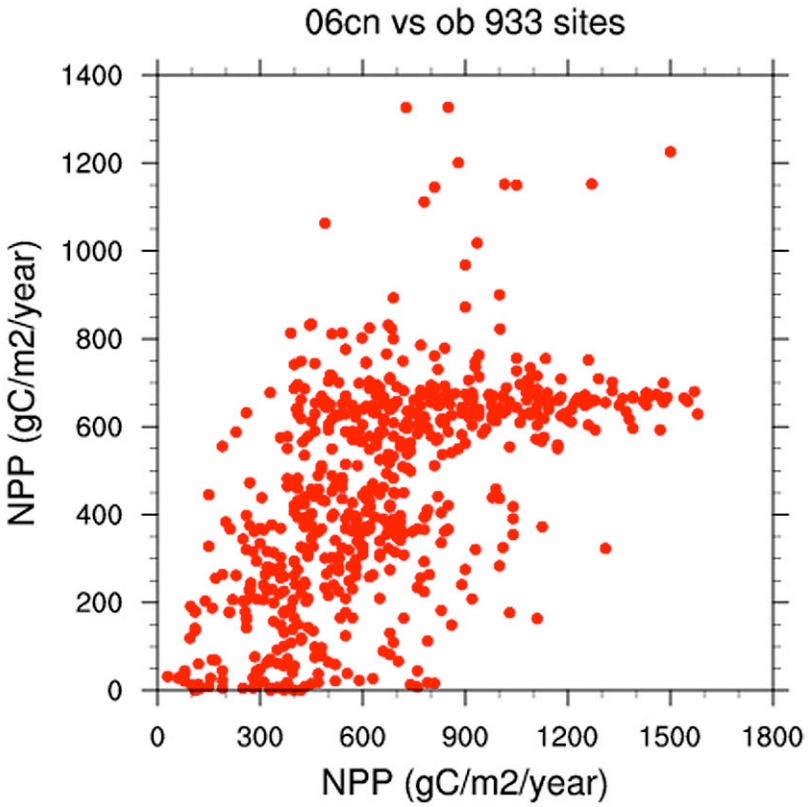
# Experiment 1.2: Seasonal exchanges

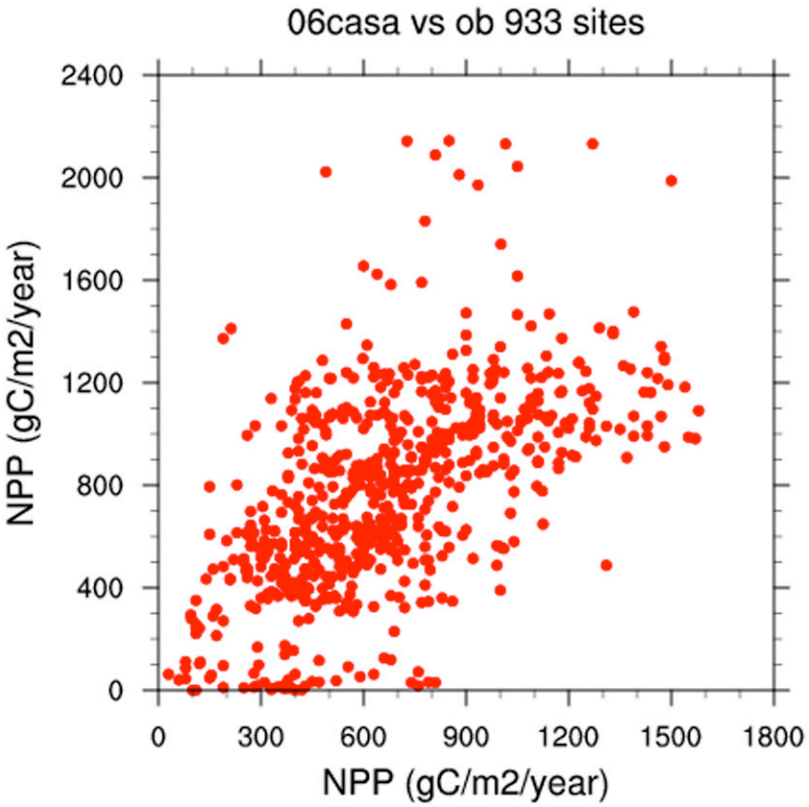



Seasonal exchanges in both models may be too weak.

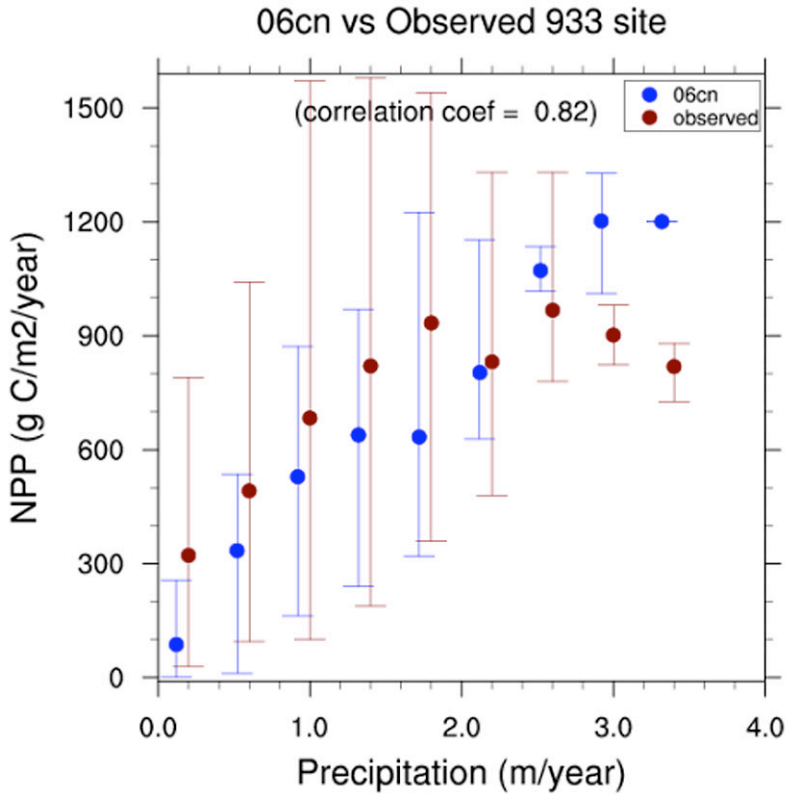
# Experiment 1.2: Model NPP vs. observations

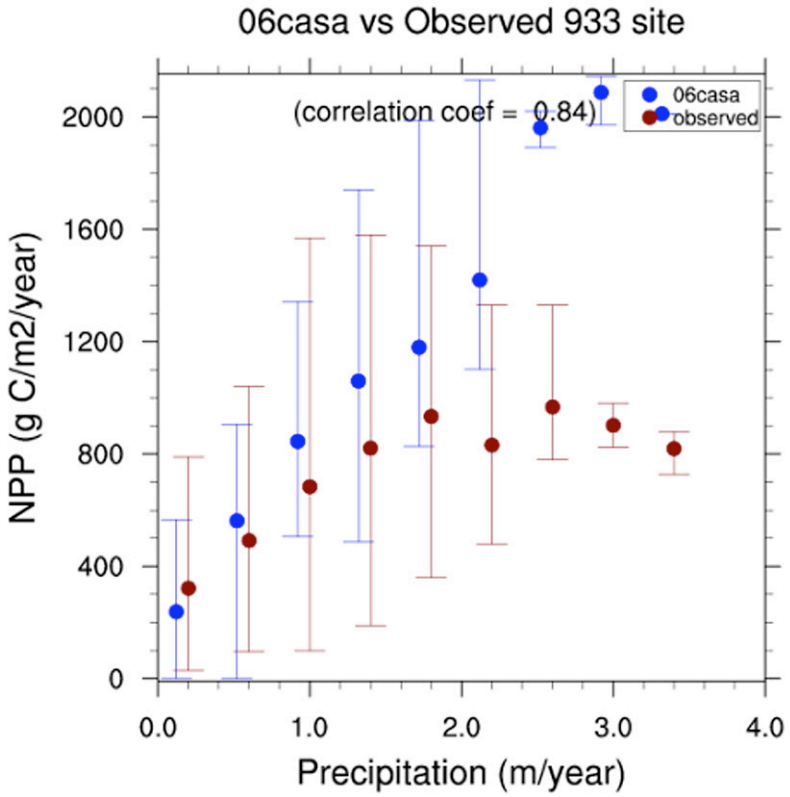
**Net primary production observations compiled by the Ecosystem-Model Data Intercomparison Team.**



# Experiment 1.2: Precipitation vs. NPP




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



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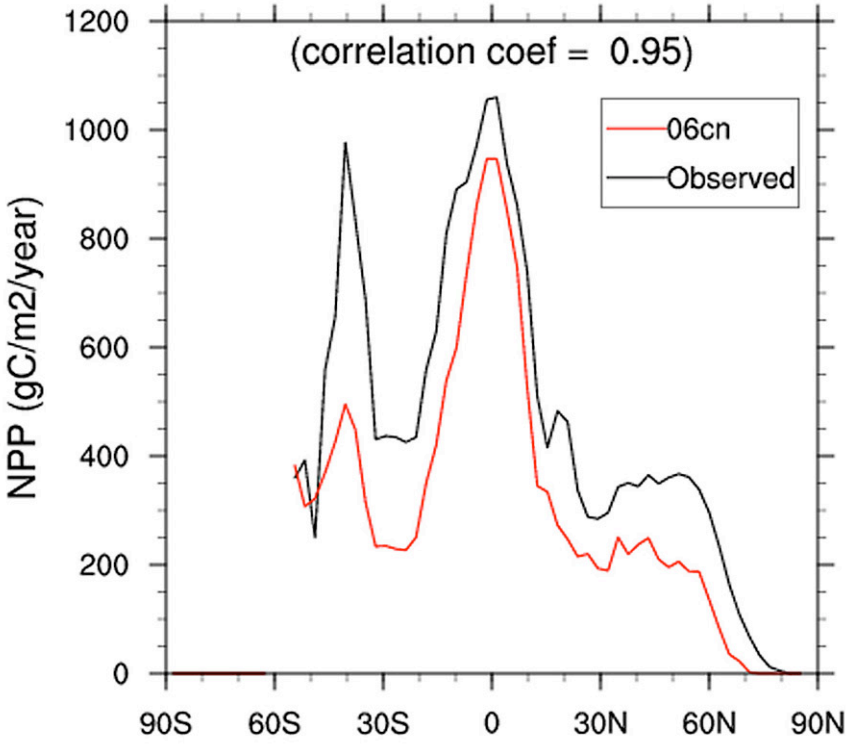
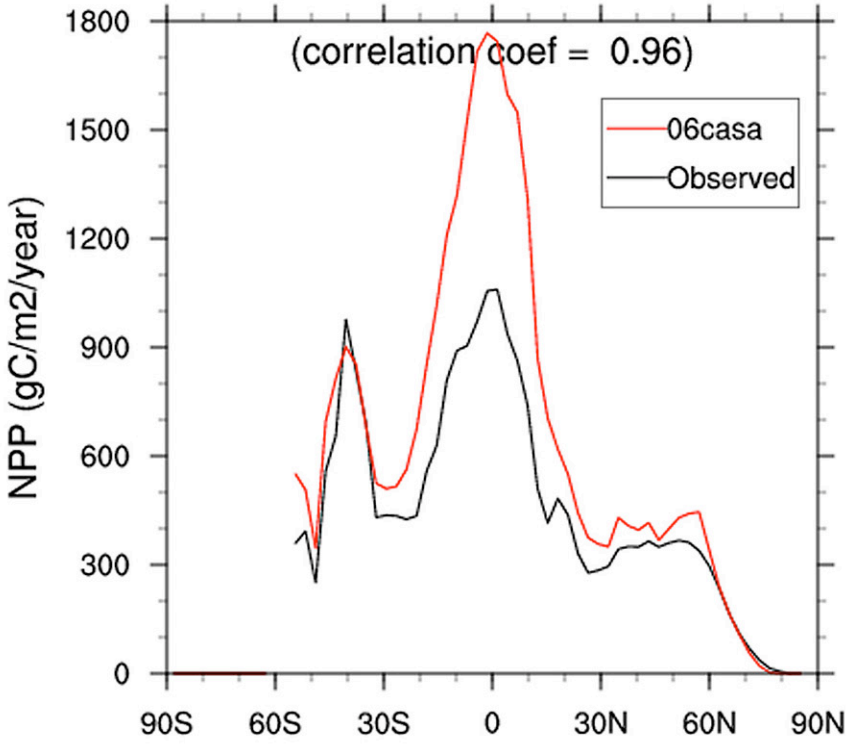
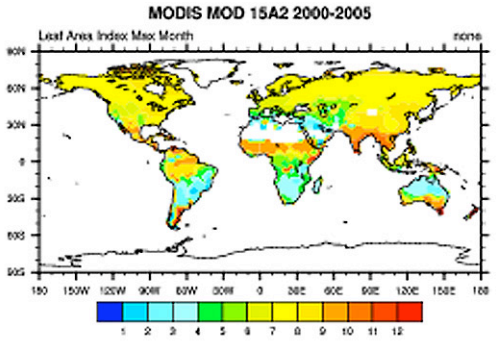
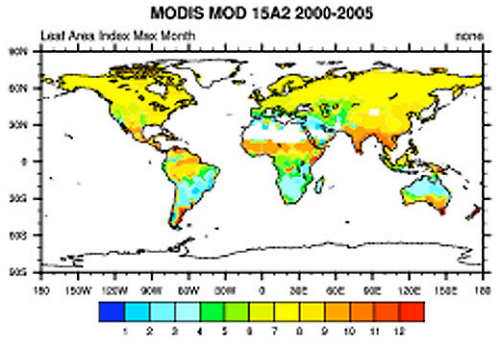
# Experiment 1.2: Control vs. MODIS NPP

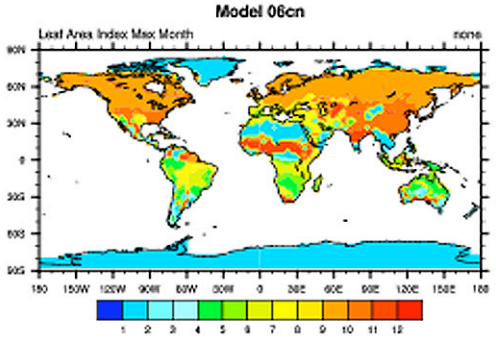


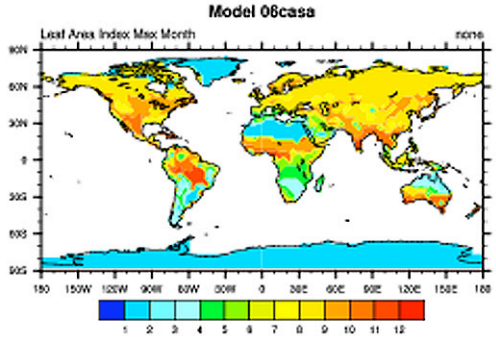



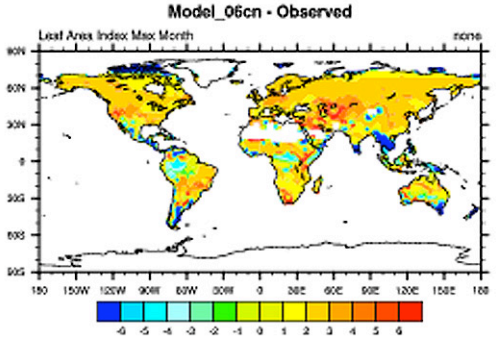
# Experiment 1.2: Control vs. MODIS LAI phase

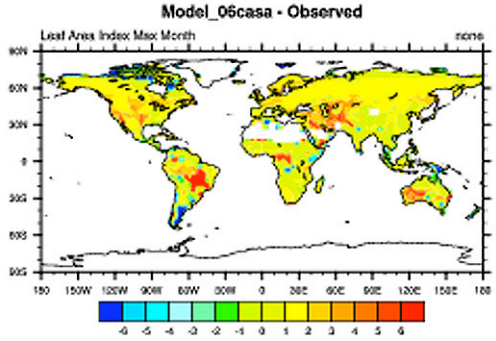


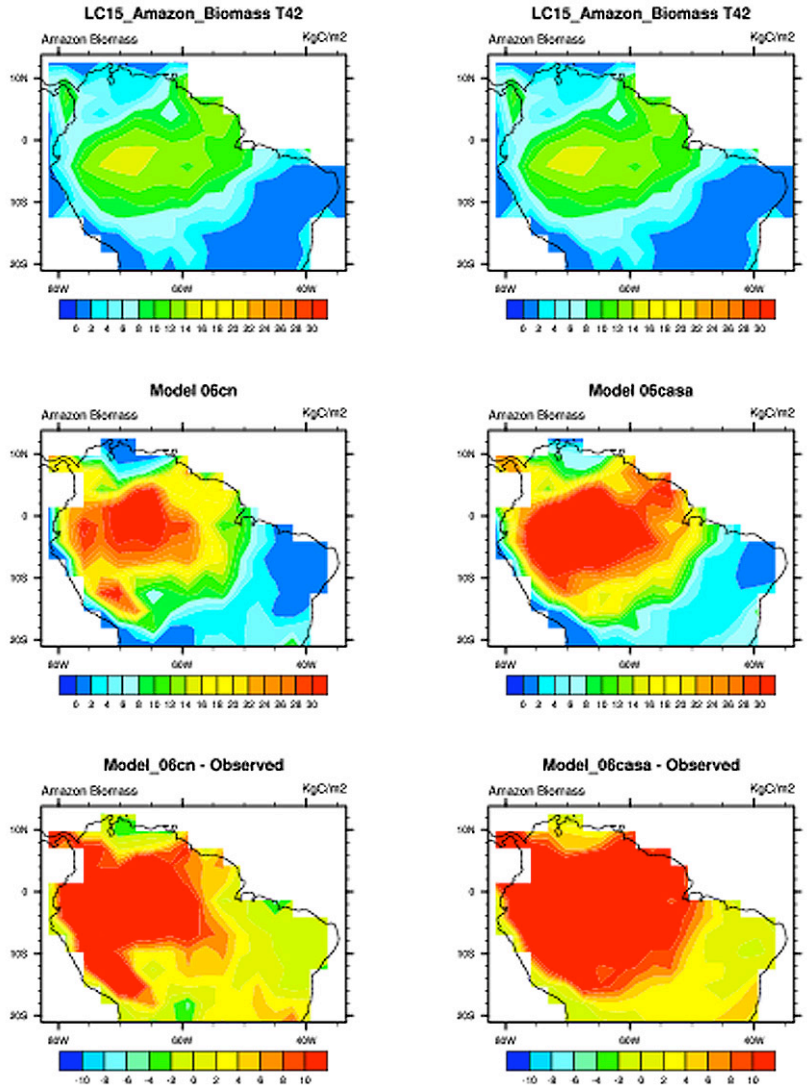




**MODIS LAI phase: Timing of peak LAI**

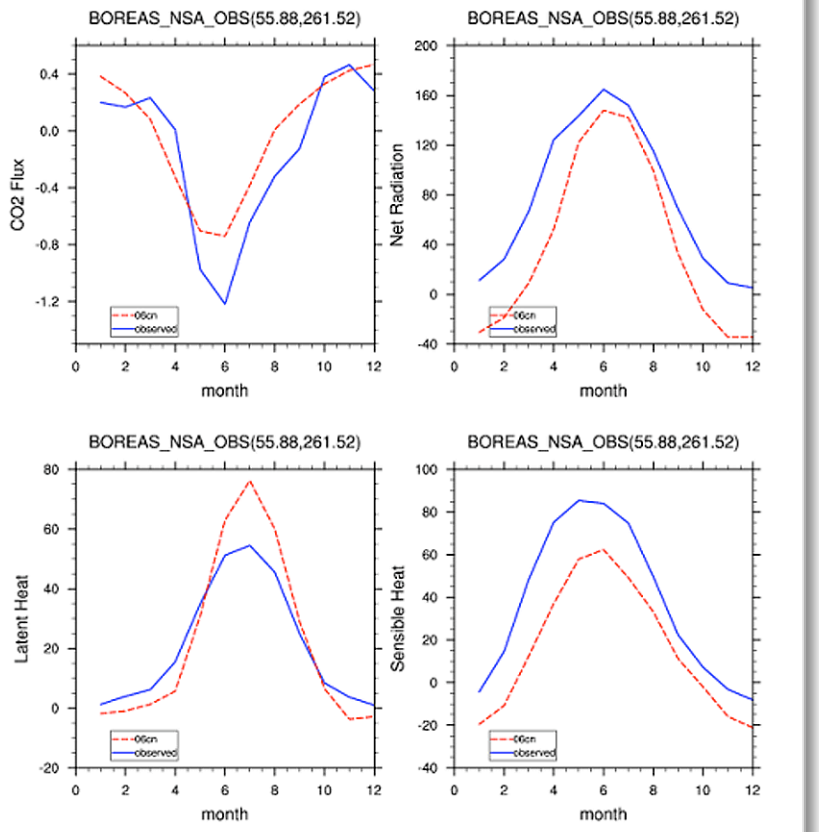
# Experiment 1.2: Amazon aboveground biomass



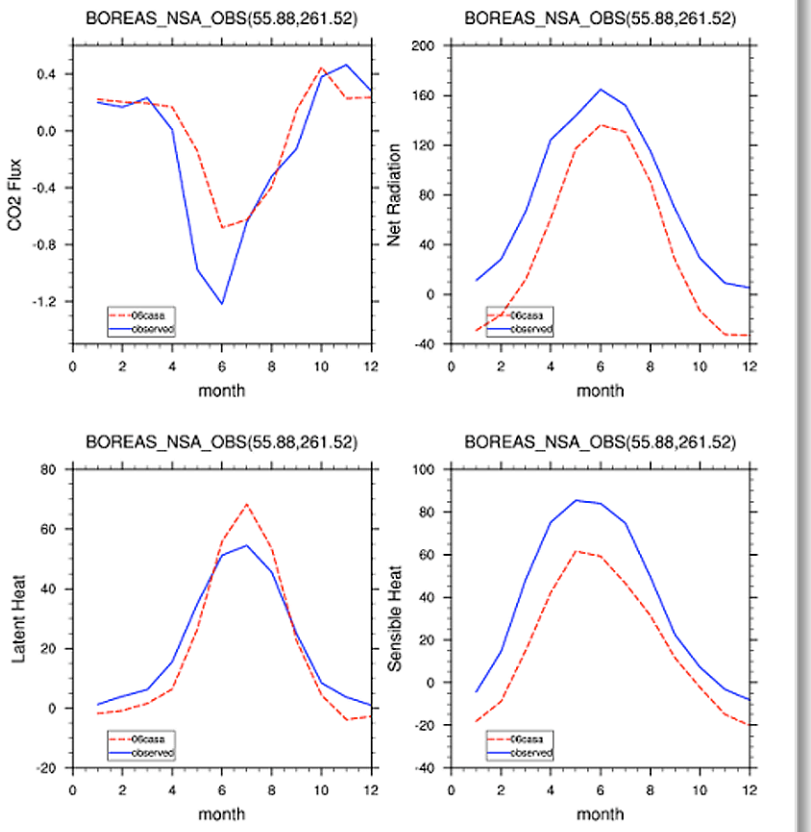

Model comparisons with maps of Amazon aboveground biomass from Saatchi et al. 2007, "Distribution of aboveground live biomass in the Amazon basin," *Global Change Biology* **13**, 816–837.

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

## CN vs Observations




## CASA' vs Observations



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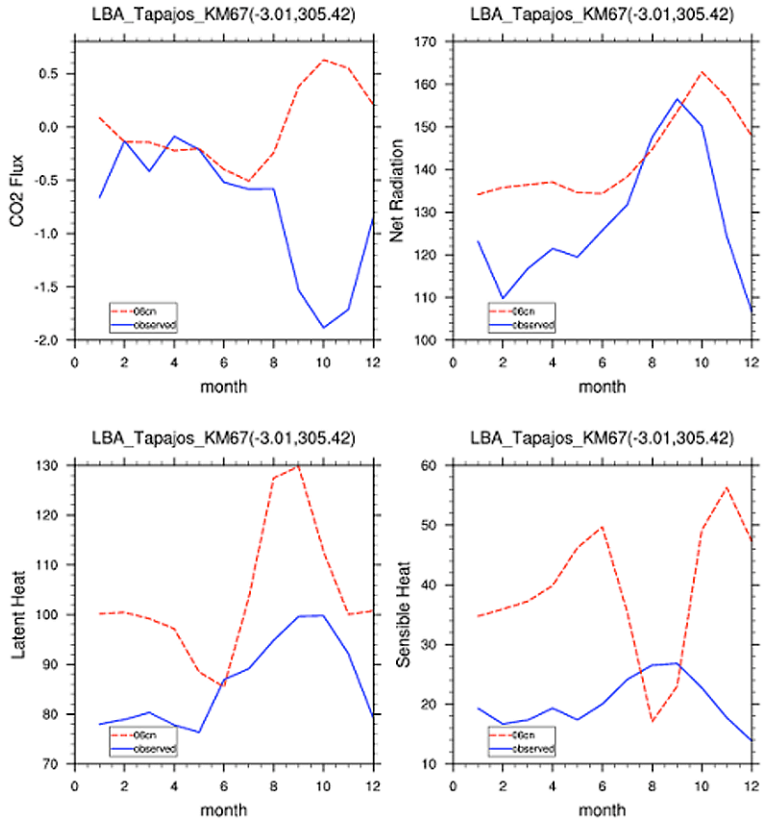
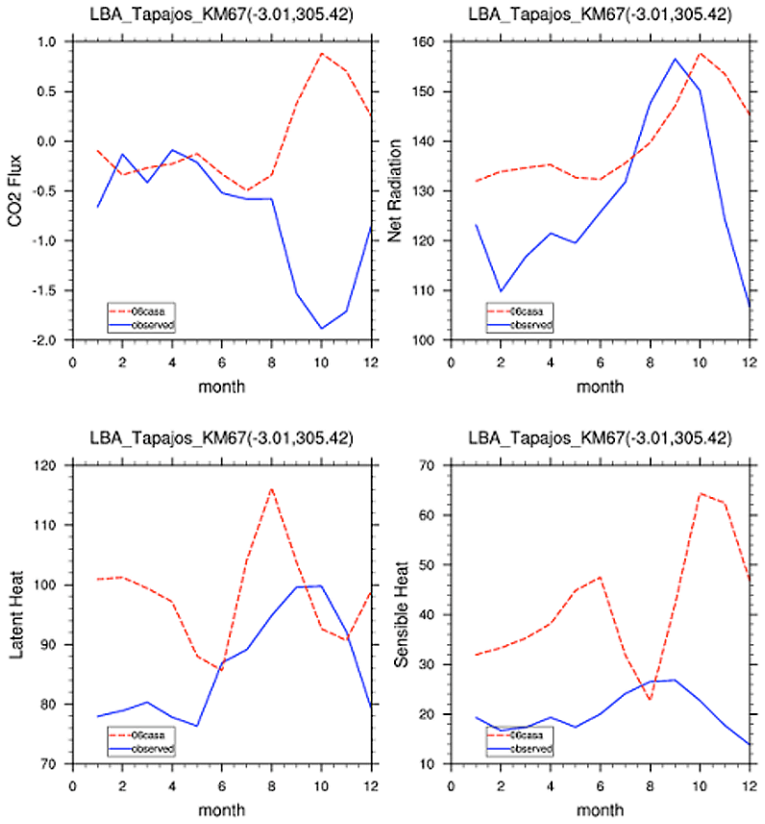
# Experiment 1.2:
# Control vs. FLUXNET observations (Tapajos)

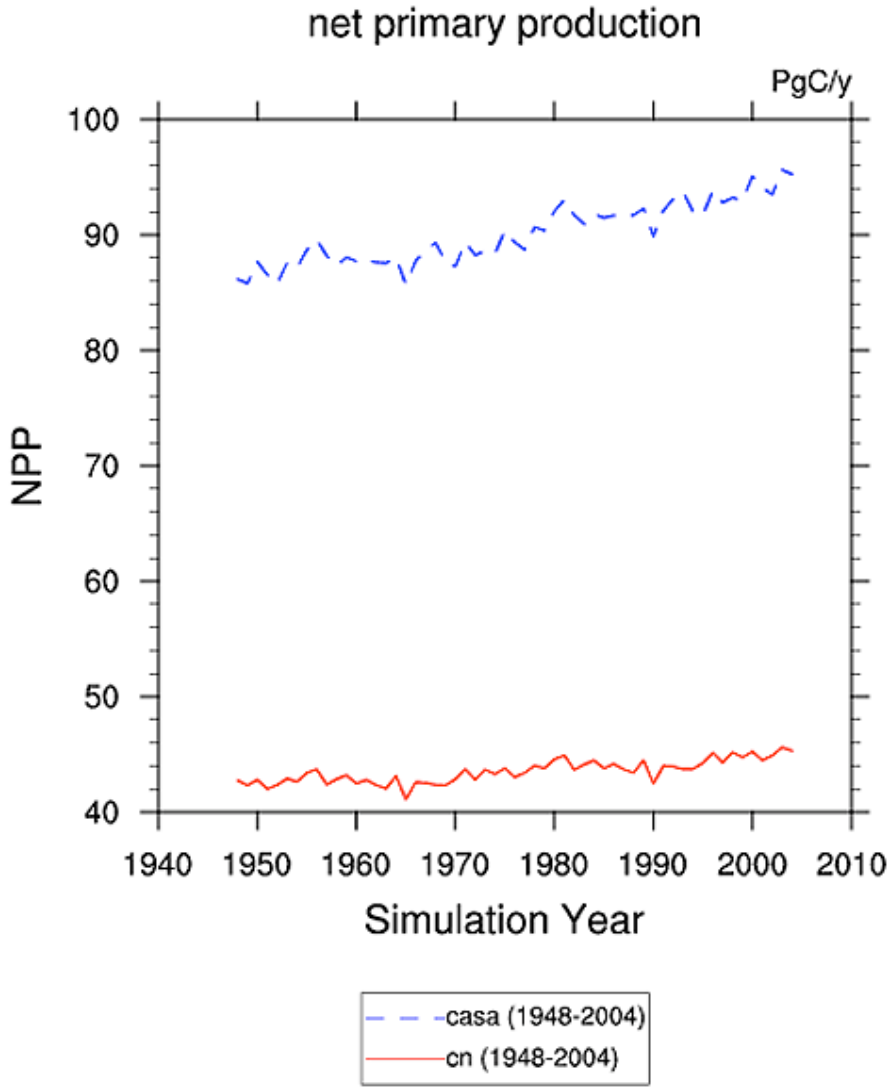
## CN vs Observations



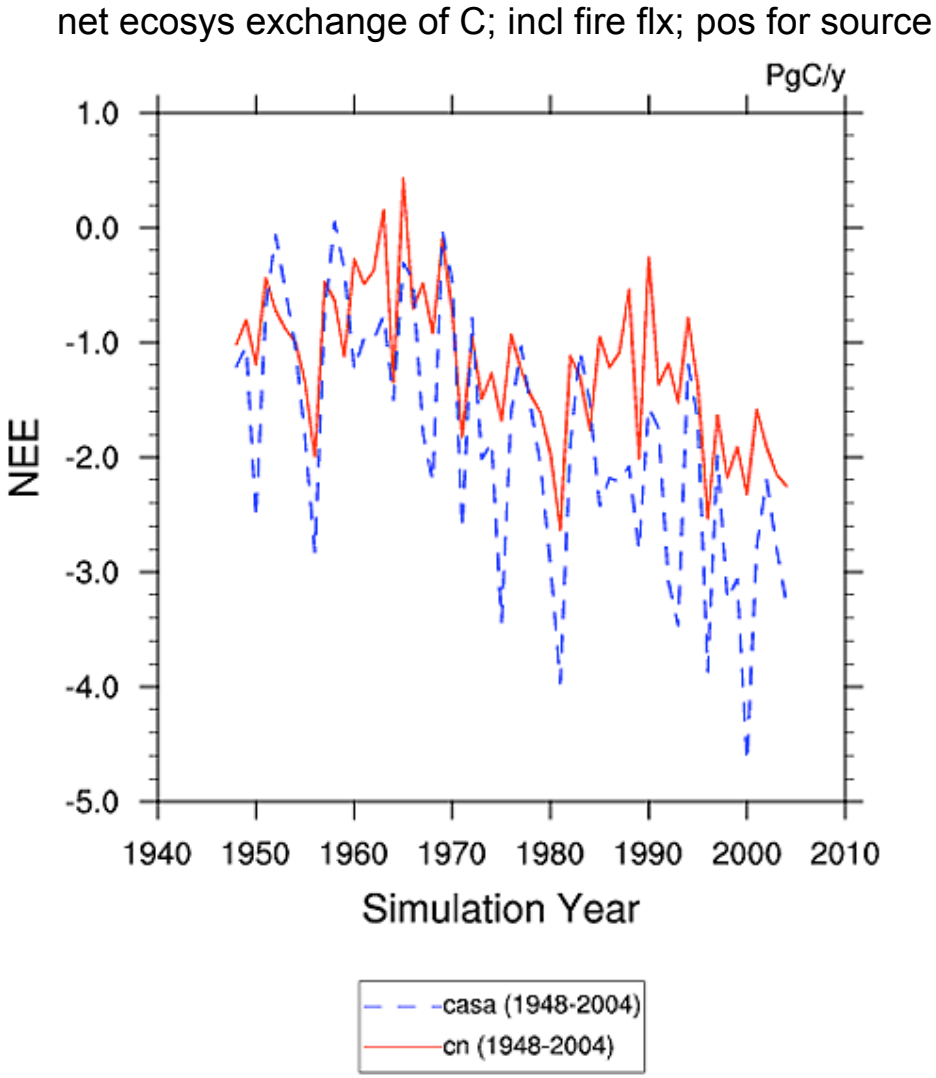

## CASA' vs Observations



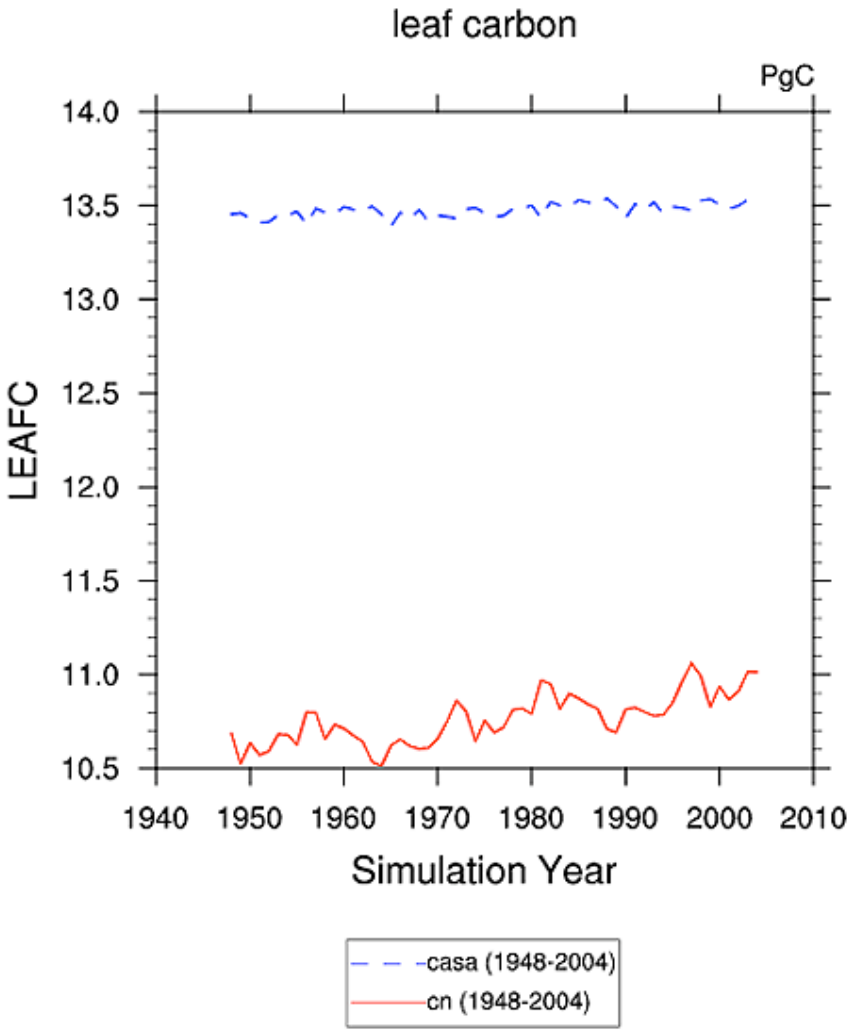
# Experiment 1.4: Net primary production

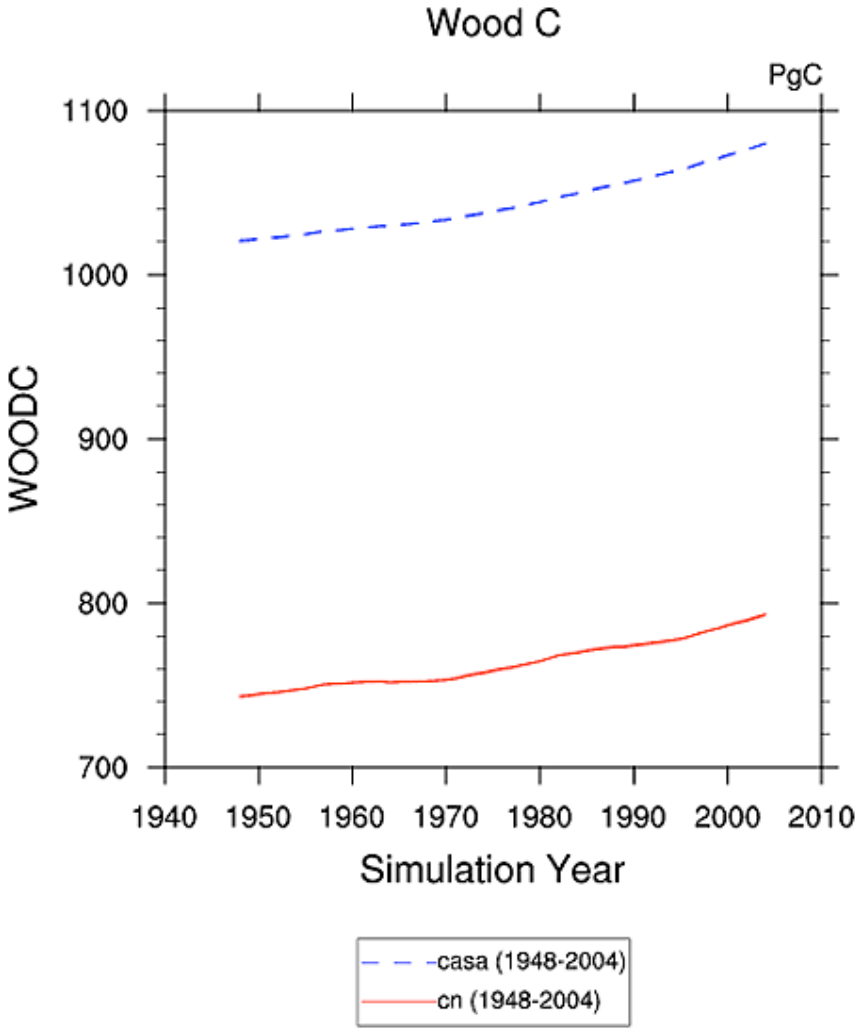


# Experiment 1.4:
# Net ecosystem exchange



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



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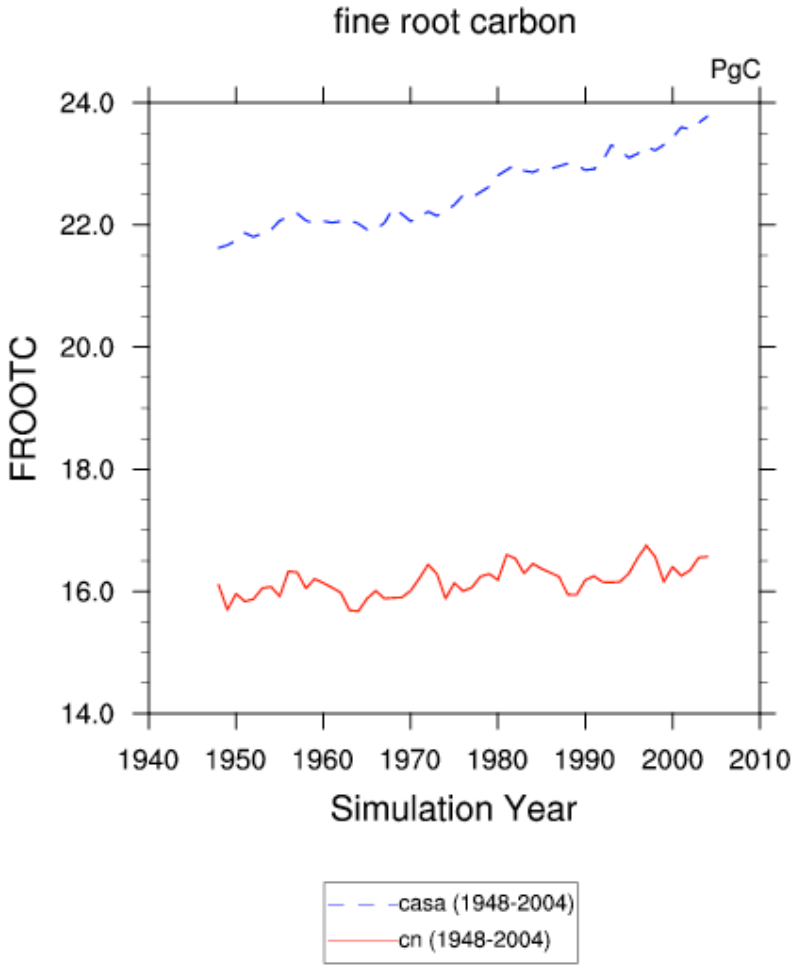
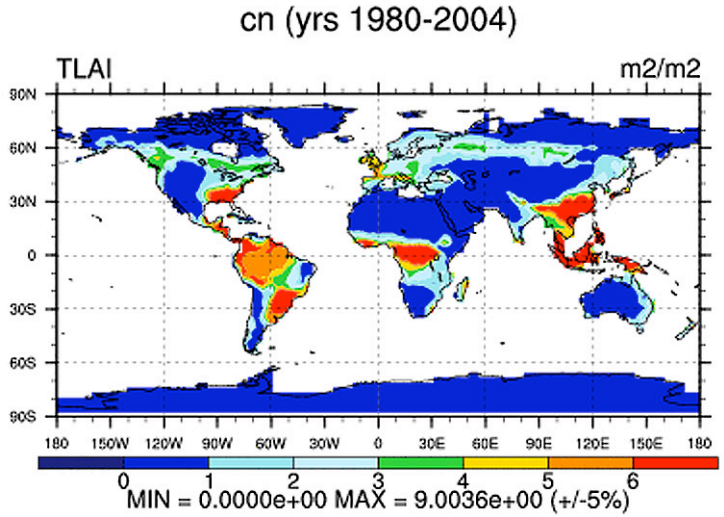
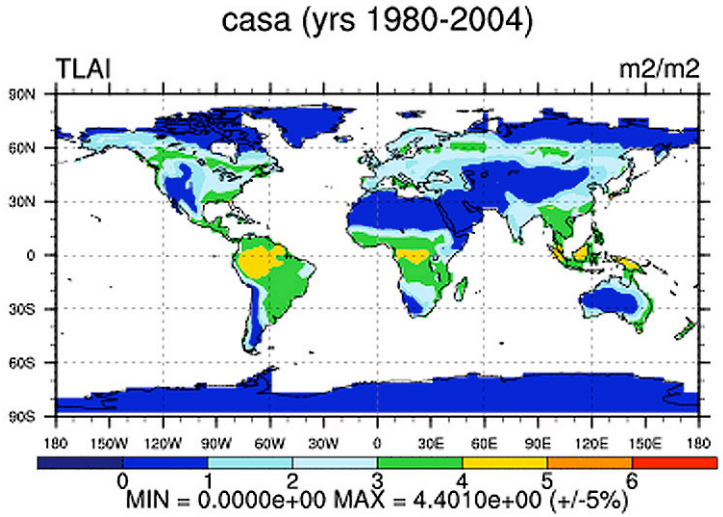
# Experiment 1.4: Live C pools (fine root)

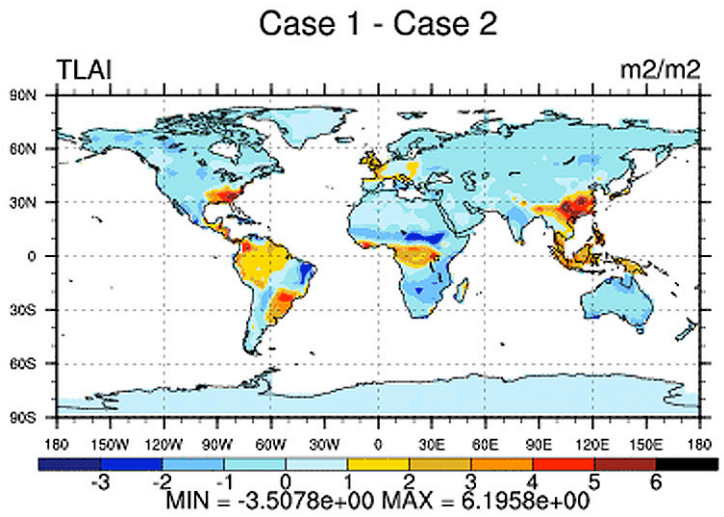


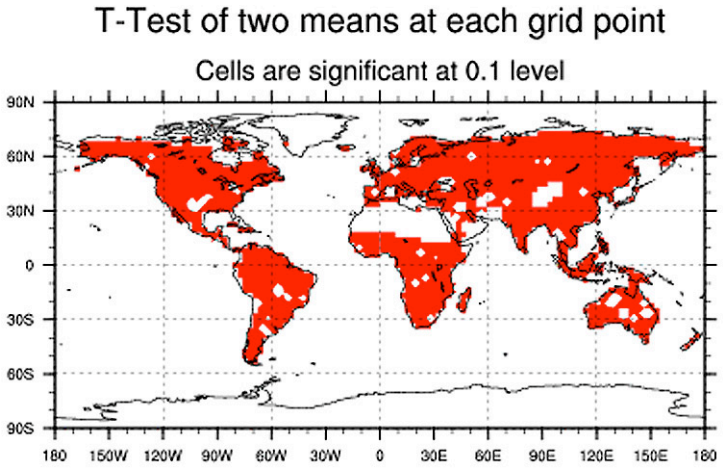

- CLM3-CASA' has higher productivity than CLM3-CN.
- CLM3-CASA' has stronger fertilization response to increasing $CO_2$ than CLM3-CN.
- Concurrent studies have shown that CLM3-CN
  - carbon-only mode has sensitivity near the mean of $C^4MIP$ carbon models,
  - carbon-nitrogen mode has lower sensitivity to rising $CO_2$ because of increasing N limitation (Thornton et al., in press).

# Experiment 1.4: Mean annual leaf area index



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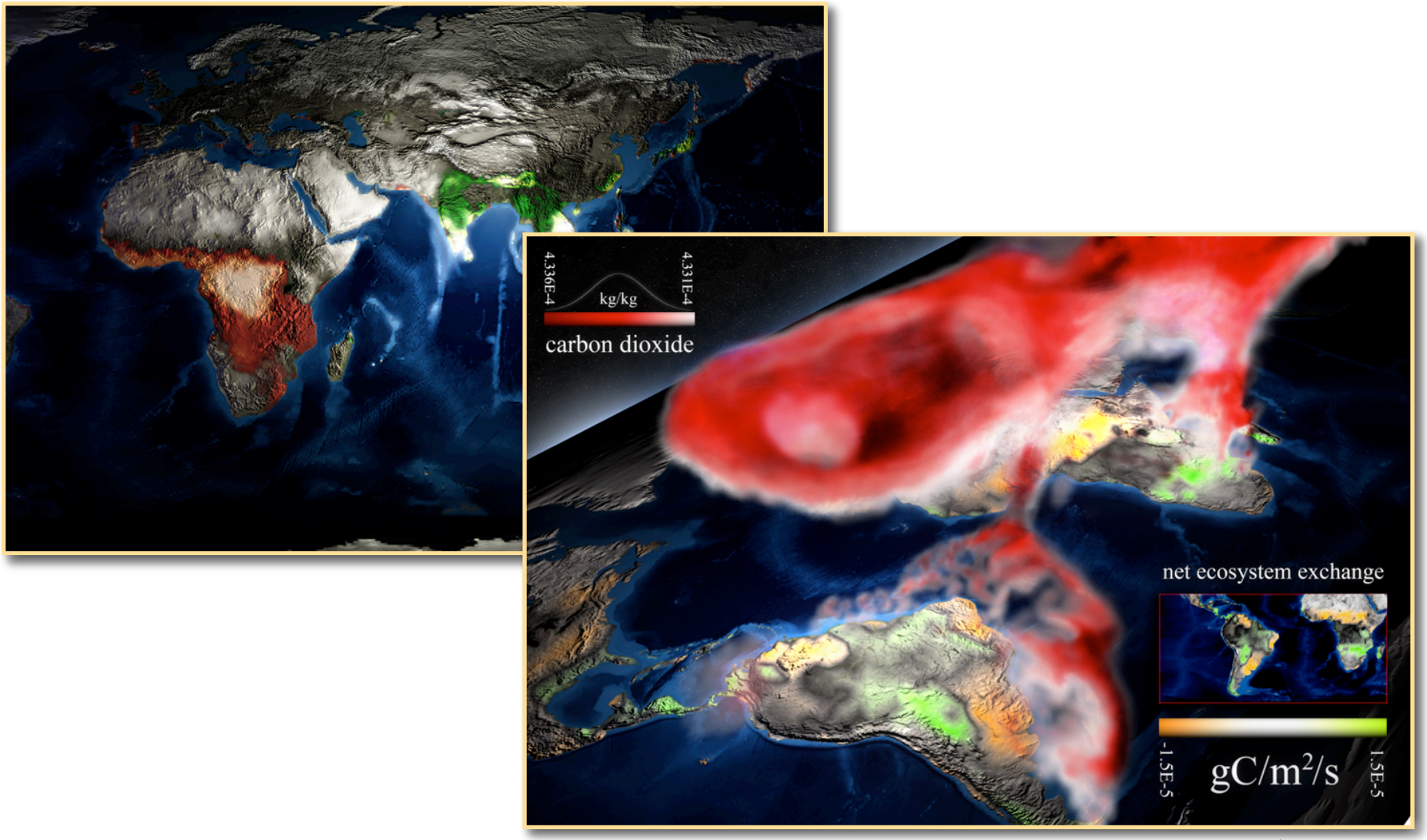
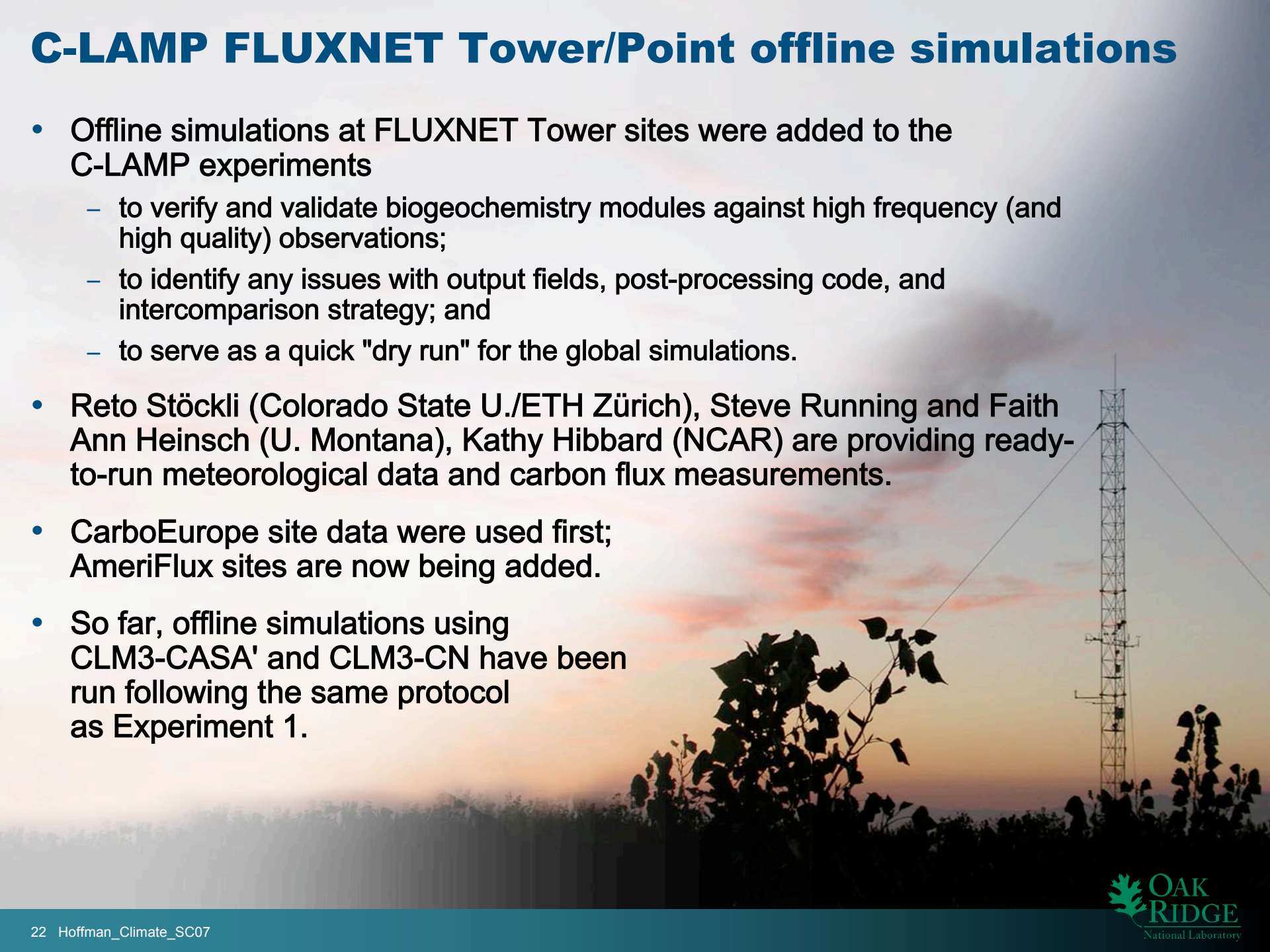
# Visualizing Net Ecosystem Exchange and Respired $CO_2$ in the Atmosphere



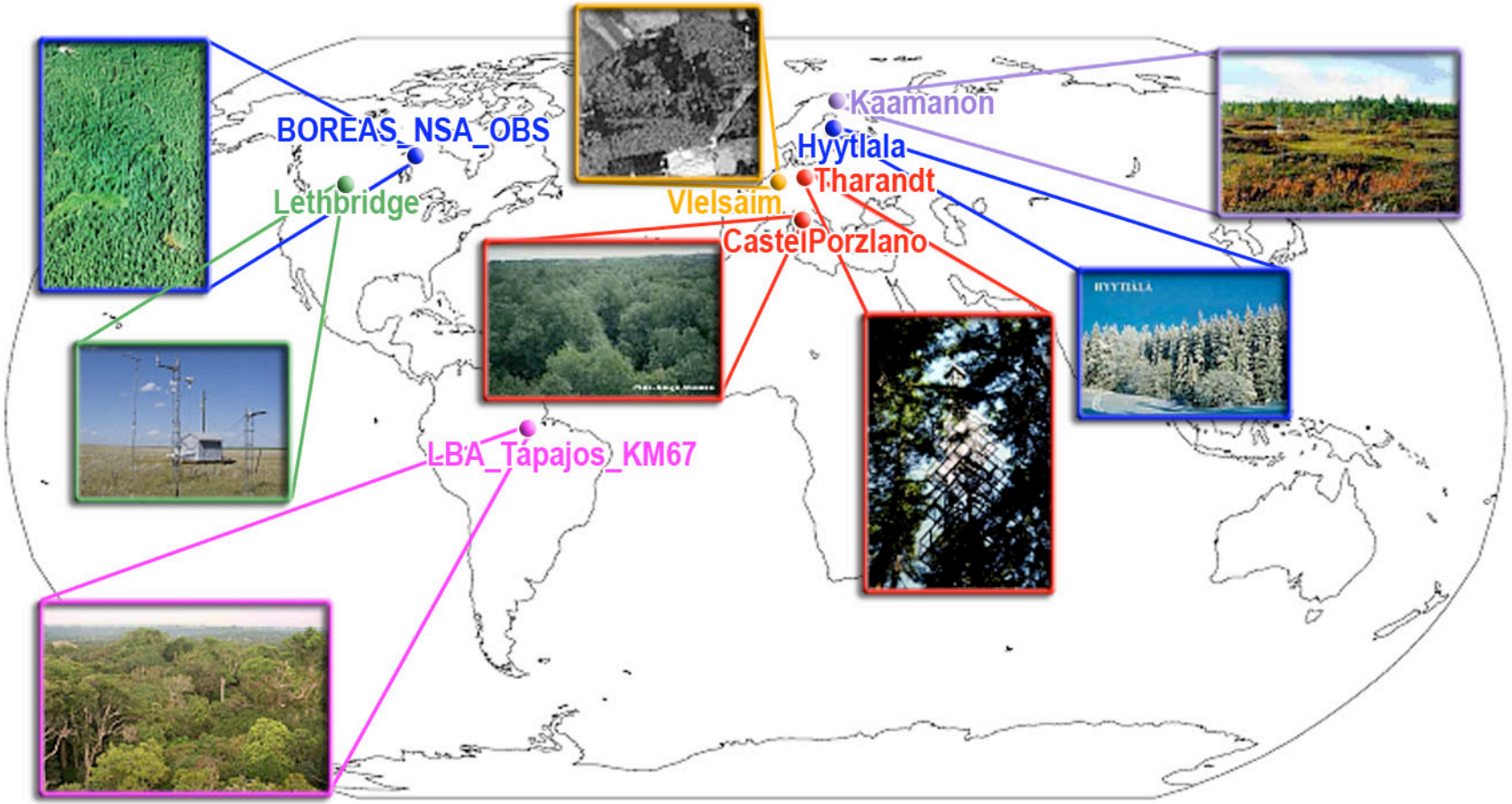
# C-LAMP FLUXNET Tower/Point offline simulations

- 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; and
  - 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 are 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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