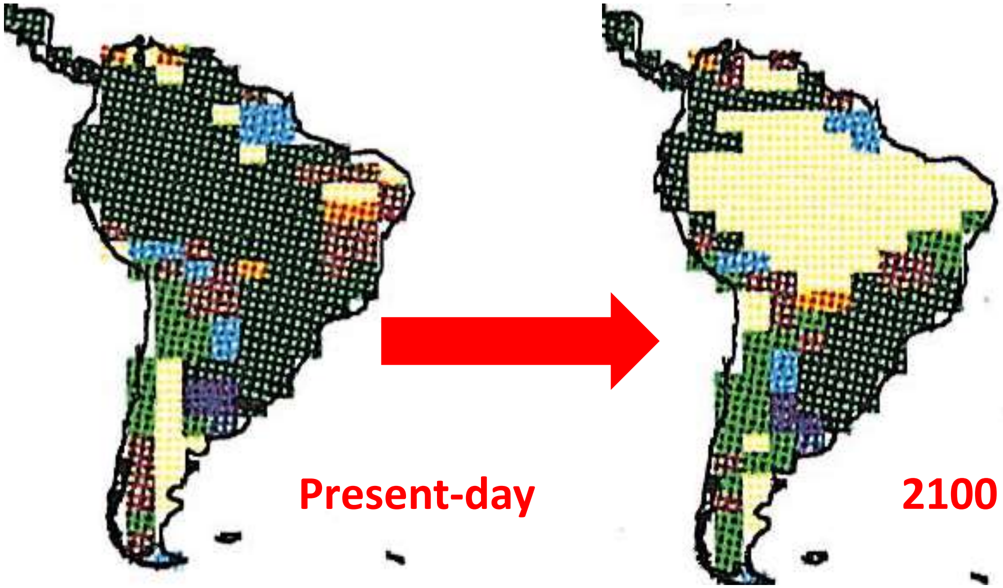
Evaluation of the ecosystem dynamics of Amazonian rainforests with 4 global vegetation models

David Galbraith, Naomi Levine, Brad Christofferson, Hewlley Imbuzeiro, Tom Powell, Yadvinder Malhi, Patrick Meir, Antonio Carlos Lola da Costa, Marcos Costa, Scott Saleska, Paul Moorcroft

d.r.galbraith@leeds.ac.uk

Background: Amazon Die-back



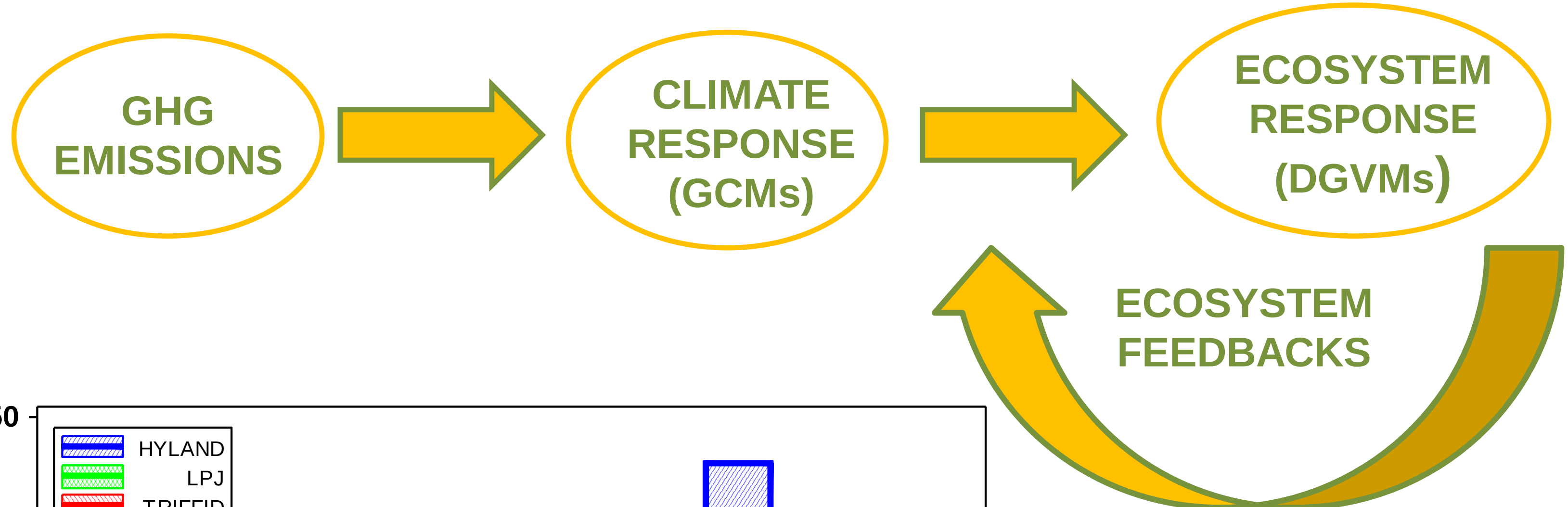
White et al. 1999, Global Environmental Change; Hybrid model forced with HadCM3 data

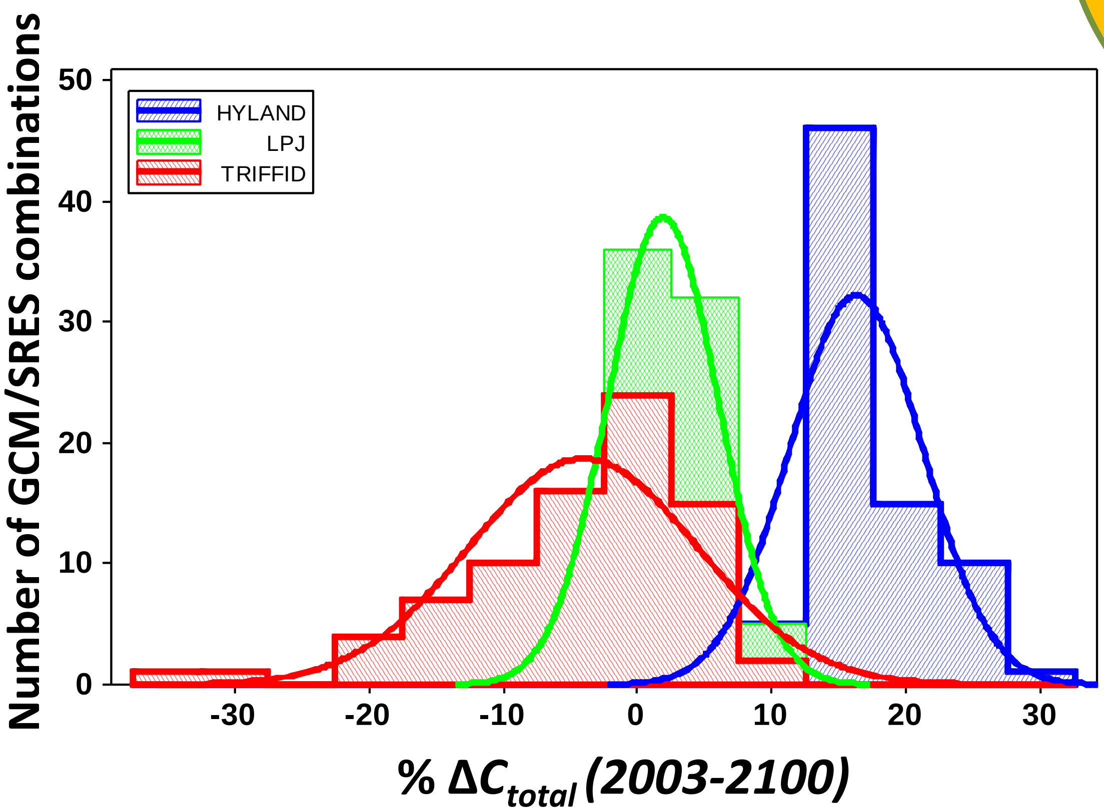
Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model

Peter M. Cox*, Richard A. Betts*, Chris D. Jones*, Steven A. Spall* & Ian J. Totterdell†

Cox et al. (2000), Nature

The land surface is an important element of overall uncertainty in future changes in Amazonian C stocks





240-member ensemble (20 GCMs, 4 SRES Scenarios, 3 DGVMs)

Key Result: DGVMs explain 2/3 of the variance in modelled changes in Amazonian C stocks.

How can we reduce uncertainty in simulations of climate change impacts on Amazonian rainforests?

Answer: Bringing global vegetation models closer to field data

- Historically, there has been little evaluation of the performance of global vegetation models in the tropics
- There is now a large amount of field data from the Amazon that can be used to evaluate/improve global vegetation models
- These data now allow model processes to be probed at a level of detail that was not possible before now

The Amazon-Andes Initiative Project

- Approach: Comprehensive evaluation and further development of the predictive capabilities of four state-of-the-art terrestrial ecosystem models against a suite of field measurements from Amazonia collected over a range of spatial and temporal scales.
- 2 Phases: 1) Site-level simulations, including drought experiments. 2) Regional simulations.

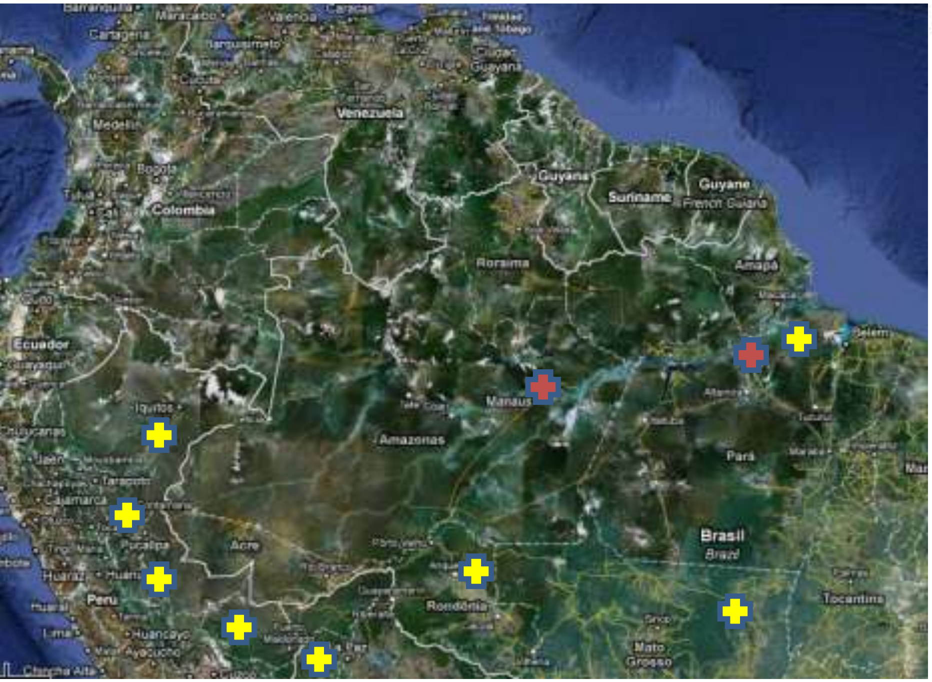
Principal Investigator: Paul Moorcroft, Harvard

Modelling Groups: Arizona (CLM-DGVM), Harvard (ED2), Oxford (JULES), Viçosa /Woods Hole (IBIS)

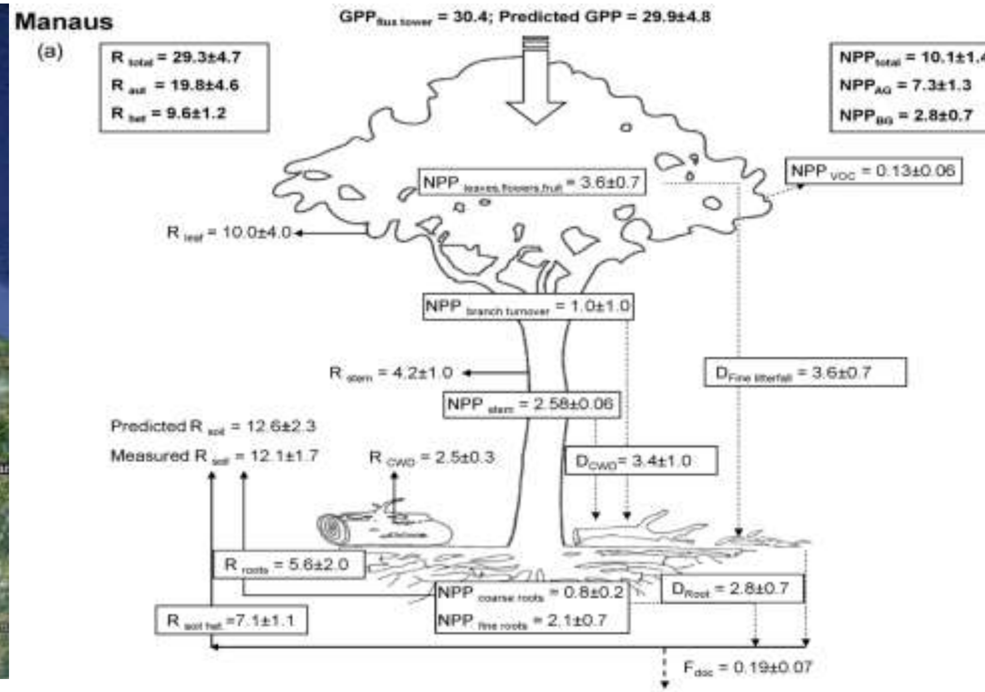
Site-level Evaluation Data for Amazonian Rainforests

- ✓ **Flux tower data (Present-day carbon, water and energy exchange) (LBA-MIP)**
- ✓ **Forest plot inventory data (Biomass trends)**
- ✓ **Data from Intensive C-cycle sites (Individual components of the carbon cycle)**
- ✓ **Data from drought experiments (Rainforest resilience to drought)**

Intensive C-cycle sites (1)



Malhi *et al*. 2009

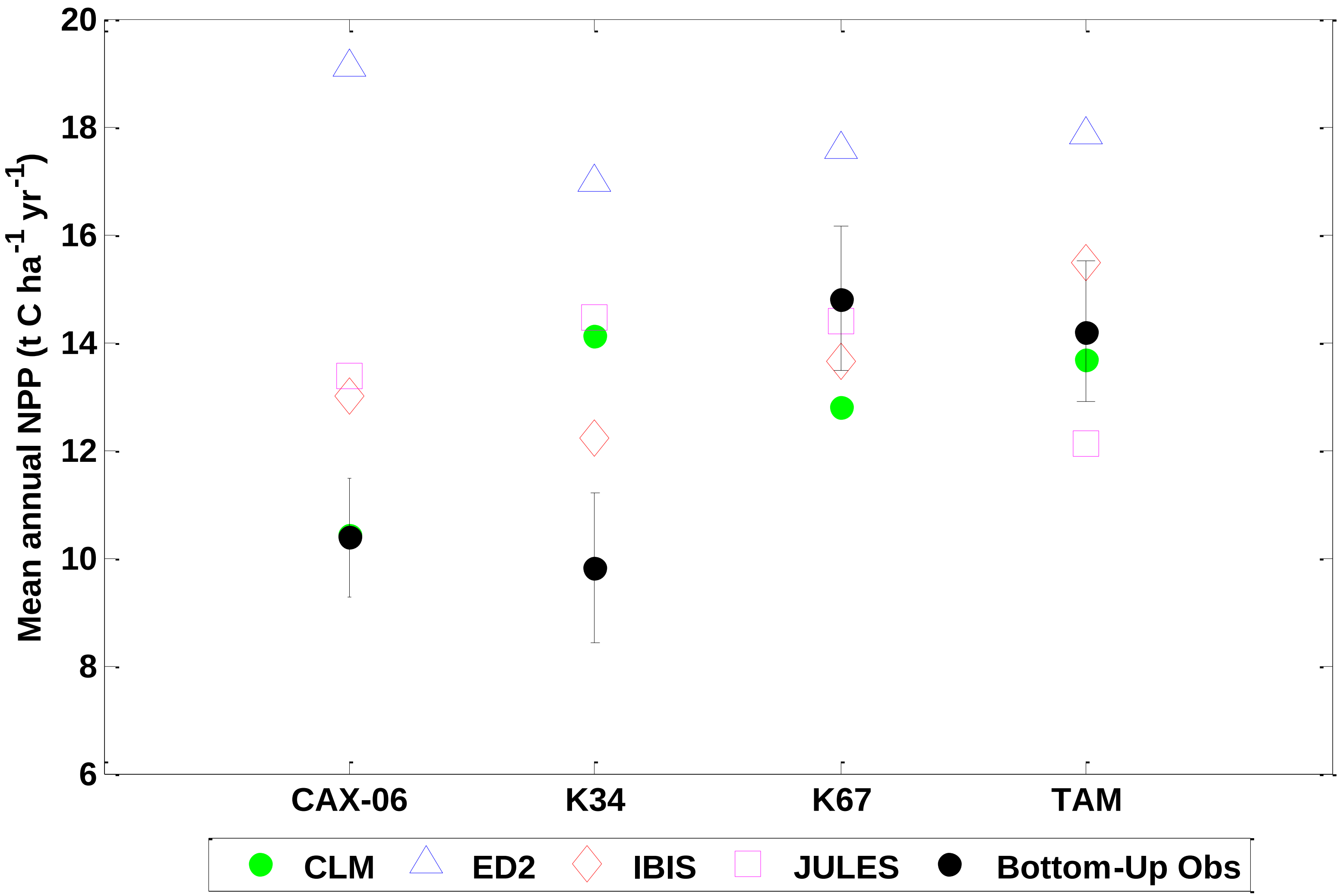


GPP TOO HIGH, RESPIRATION TOO HIGH , CUE TOO LOW **RIGHT NPP** ✘

GPP TOO LOW, RESPIRATION TOO LOW , CUE TOO HIGH **RIGHT NPP** ✘

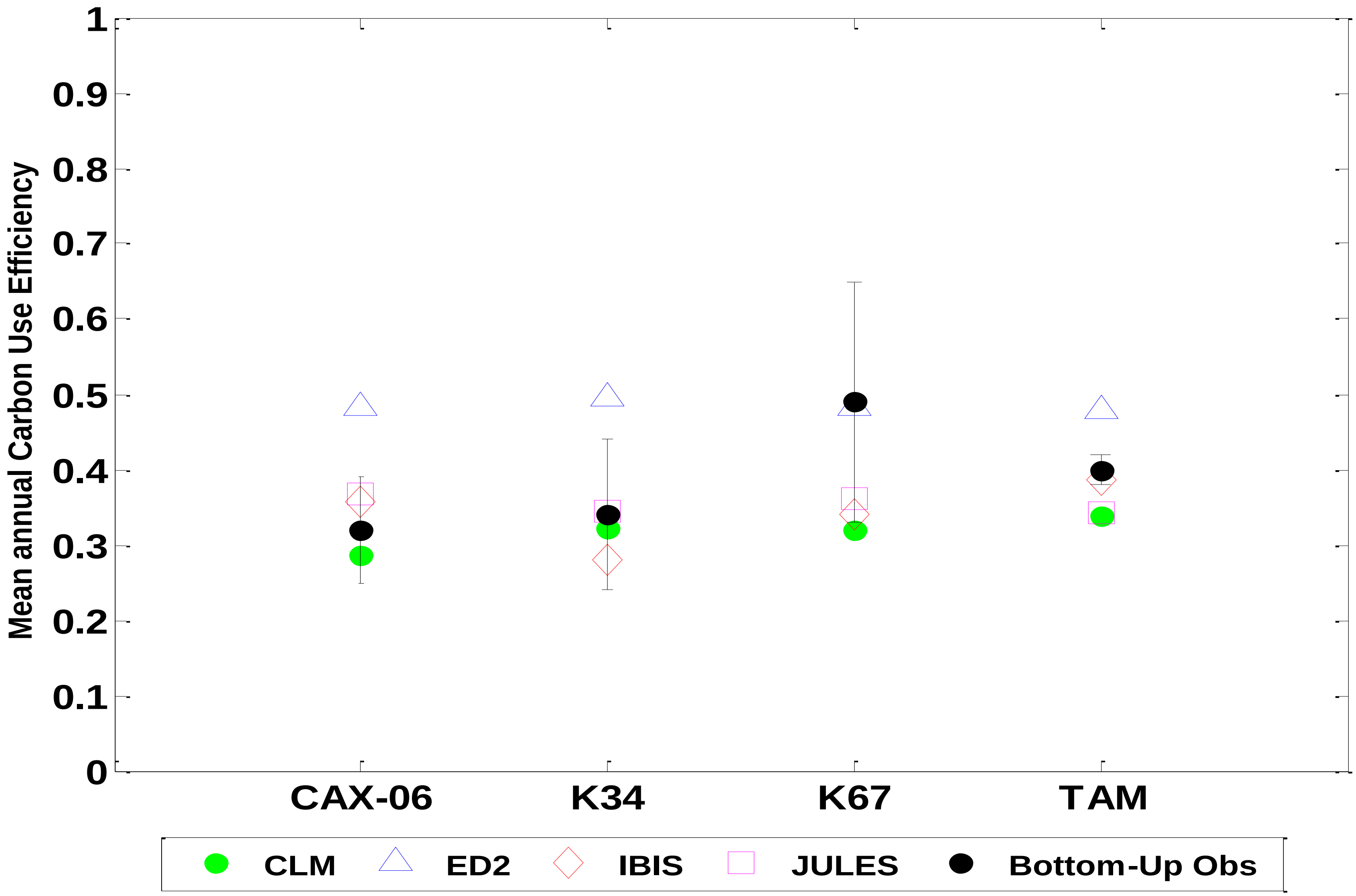
GPP RIGHT, RESPIRATION RIGHT, CUE RIGHT **RIGHT NPP** ✓

NPP for 4 lowland Amazonian sites



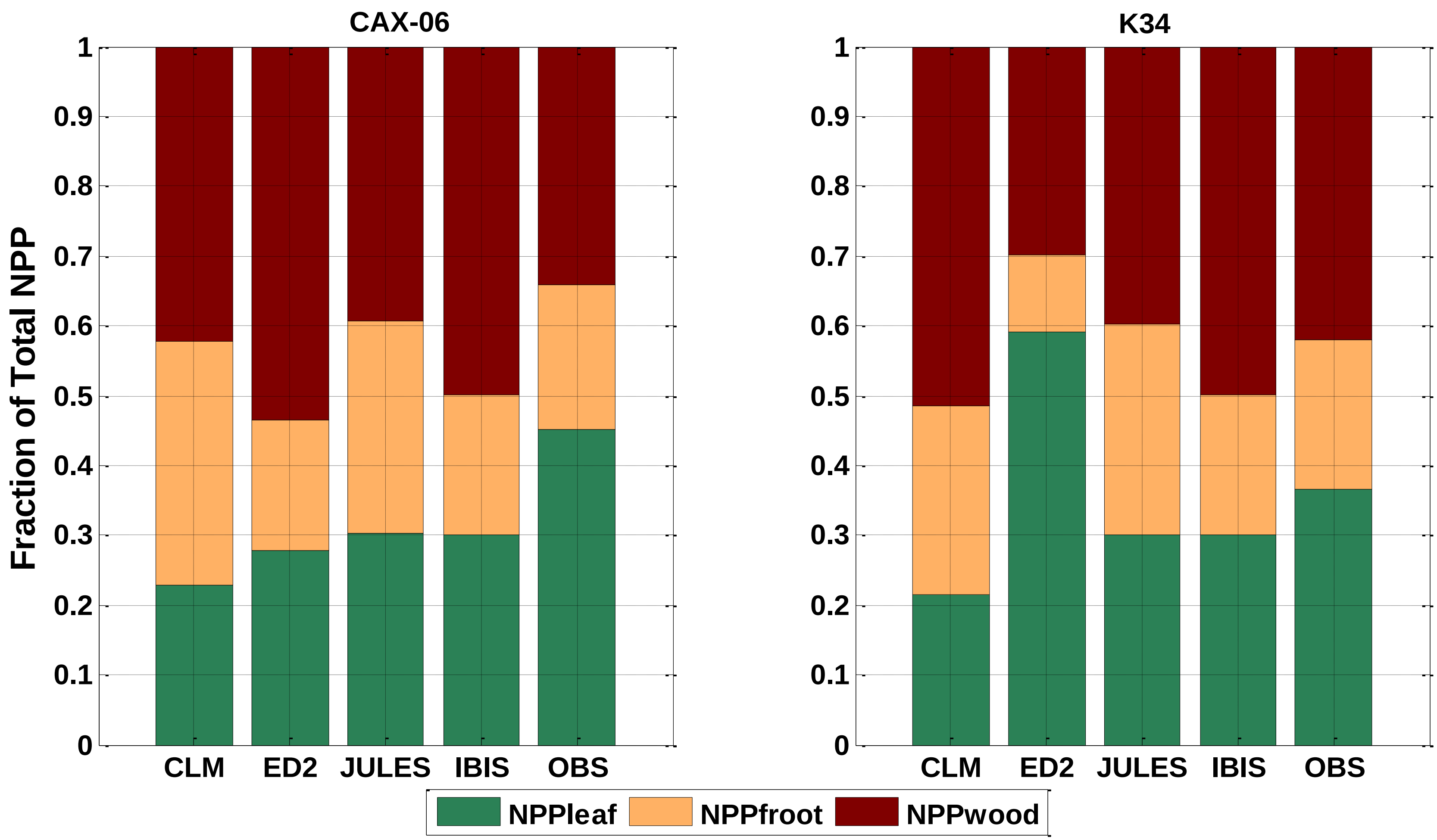
Models generally over-simulate NPP at the less productive forest sites, but many models are within the error of the observations at the more productive sites. ED2 NPP always higher than the other models. High NPP relative to obs is better than low NPP relative to obs!

Carbon Use Efficiency (NPP/GPP) for 4 lowland sites



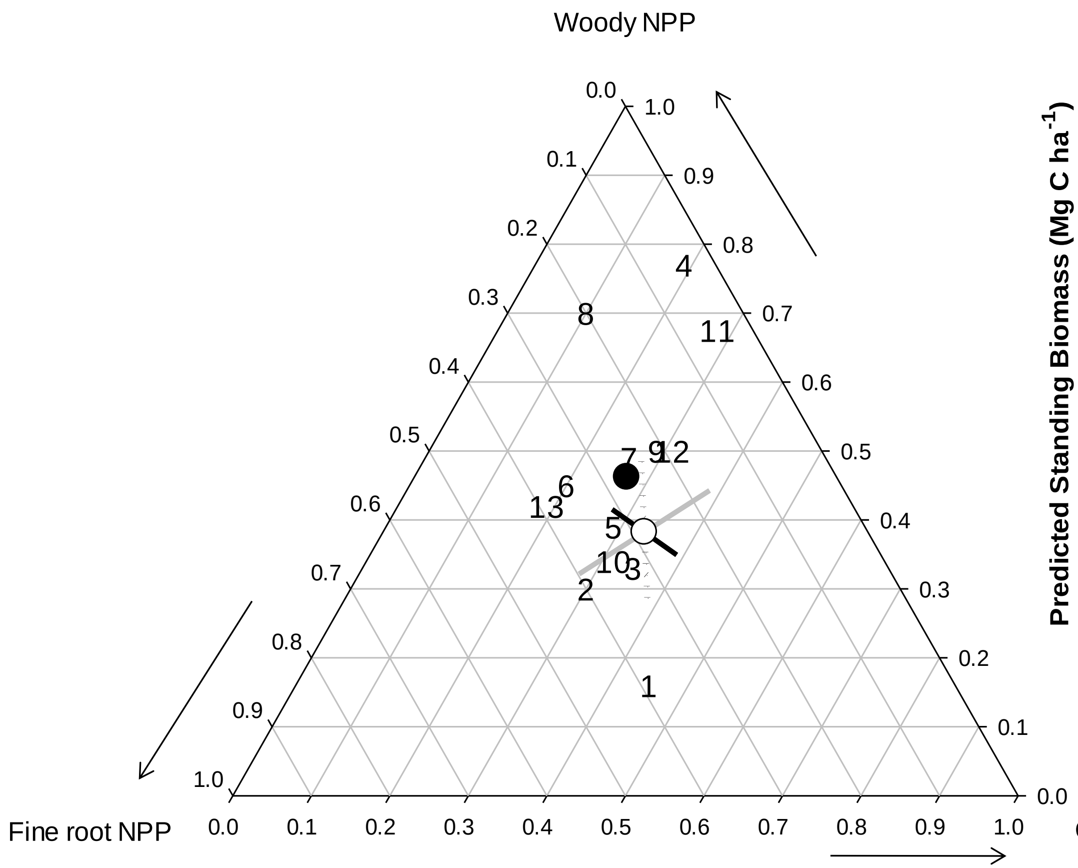
Most models simulate CUE within the error bounds of the observations. CUE simulated by ED2 generally higher than observations (except in K67). Modelled CUE shows little variation across sites.

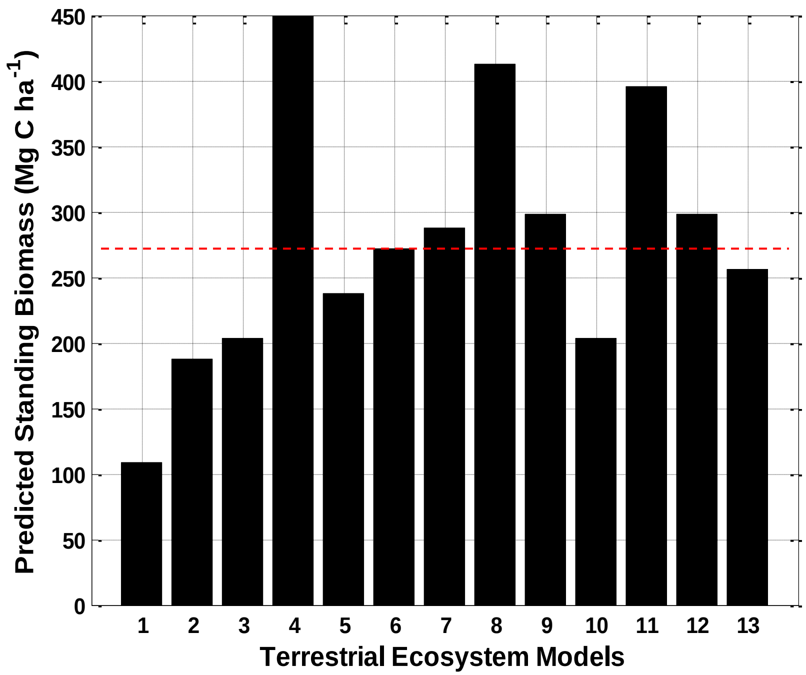
Results: NPP Components for slower-growing, less dynamic forests



General tendency towards underestimation of canopy NPP and overestimation of wood NPP fraction. Woody NPP usually the largest simulated NPP component.

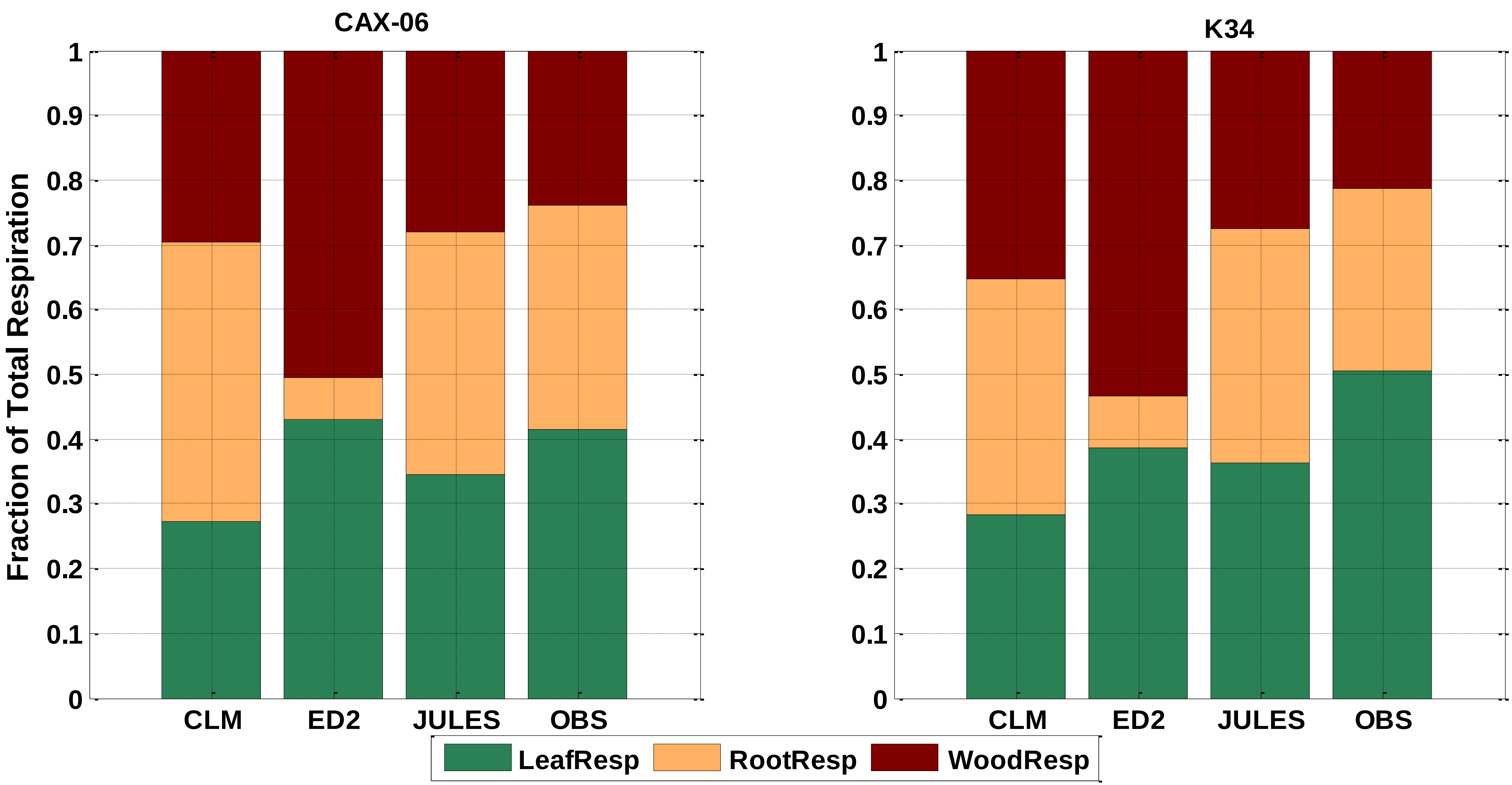
Carbon Allocation in tropical forests as simulated by 13 terrestrial ecosystem models





Malhi *et al.*, Philosophical Transactions of the Royal Society (2011)

Autotrophic Respiration Components for slow-growing, less dynamic forests

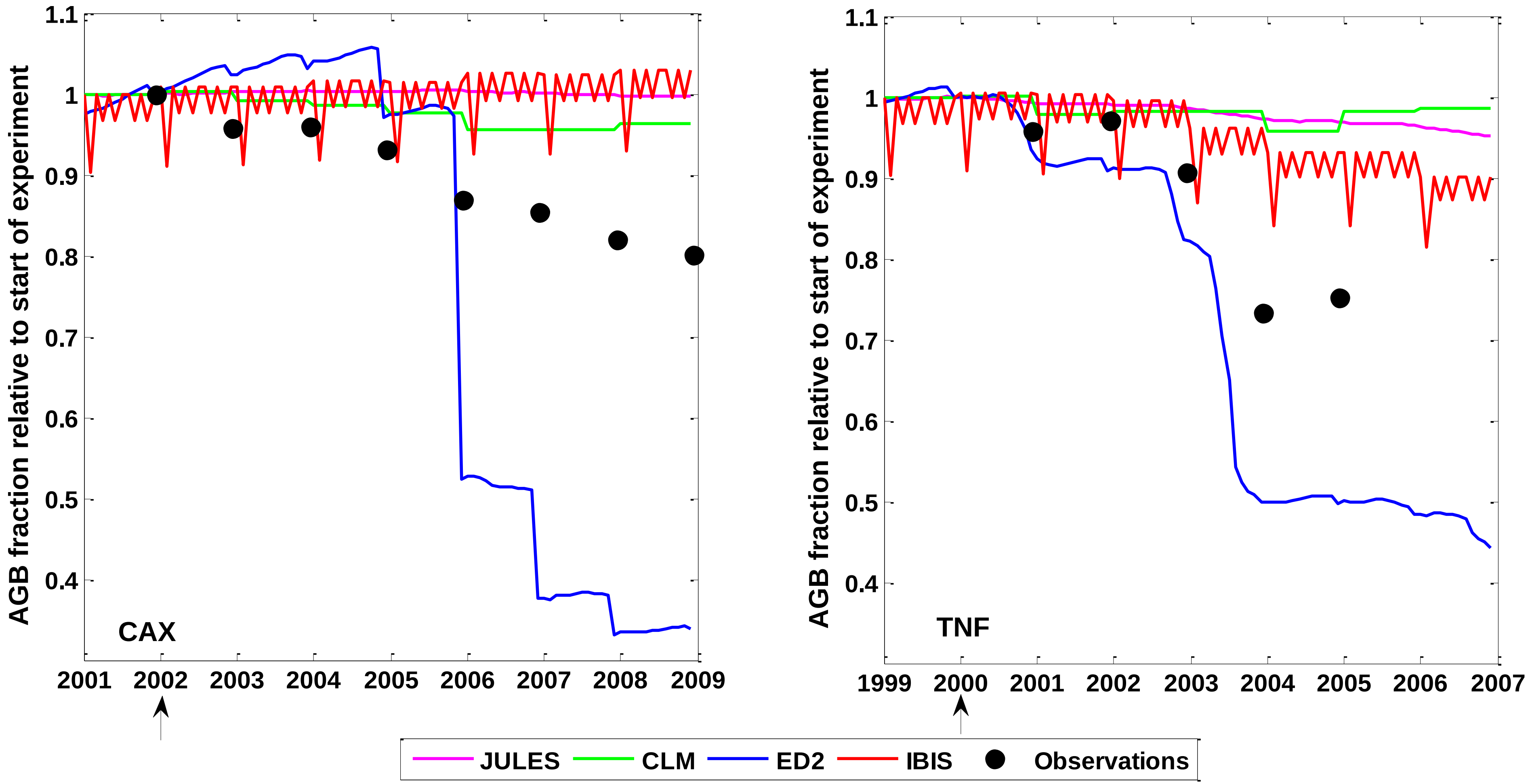


Amazonian Drought Experiments

- Caxiuanã National Forest, Pará, Brazil
- 50 % Rainfall Exclusion (2002 – present) from 1-ha treatment plot

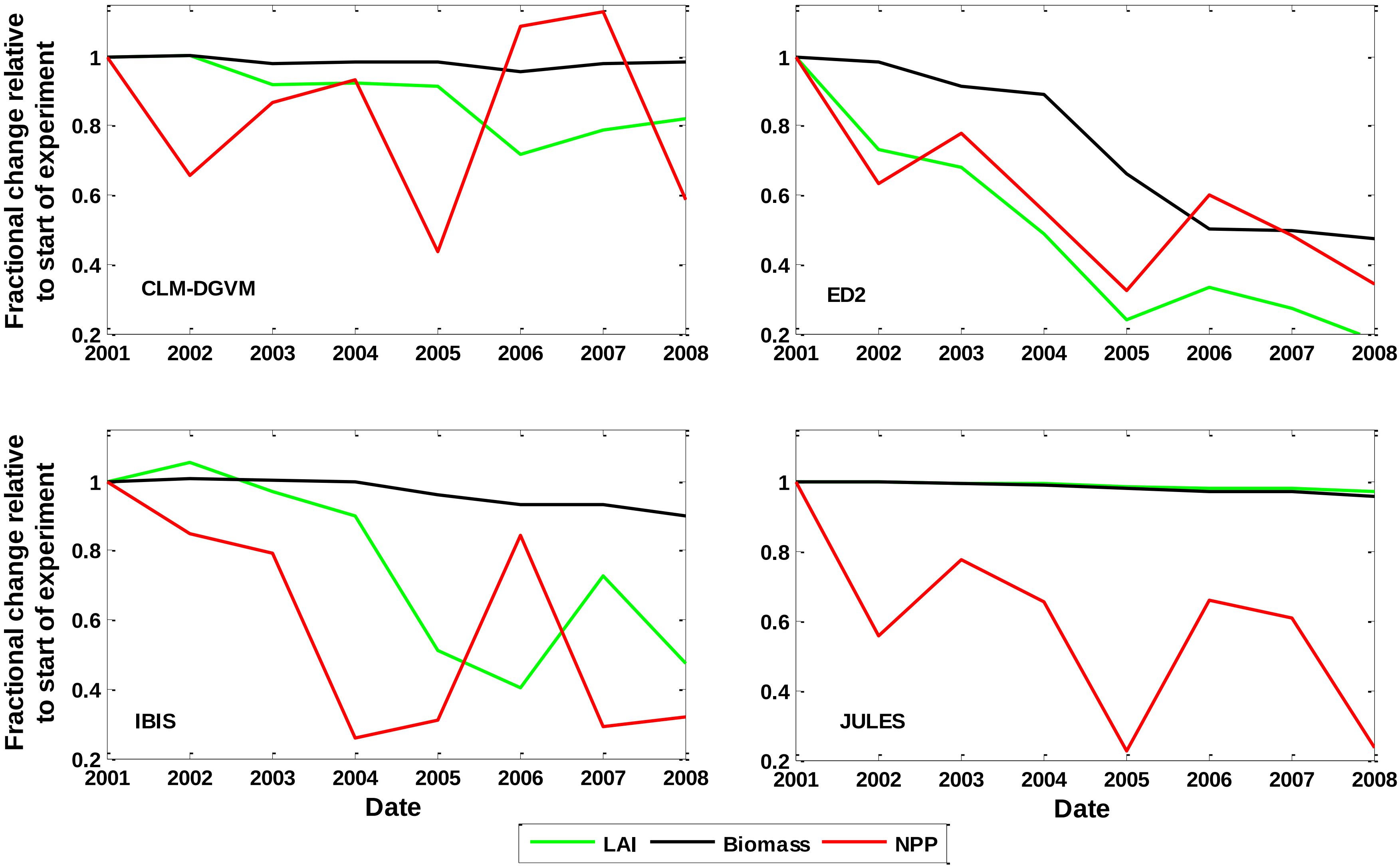
Images from Antonio Lola da Costa

Drought impacts on aboveground biomass

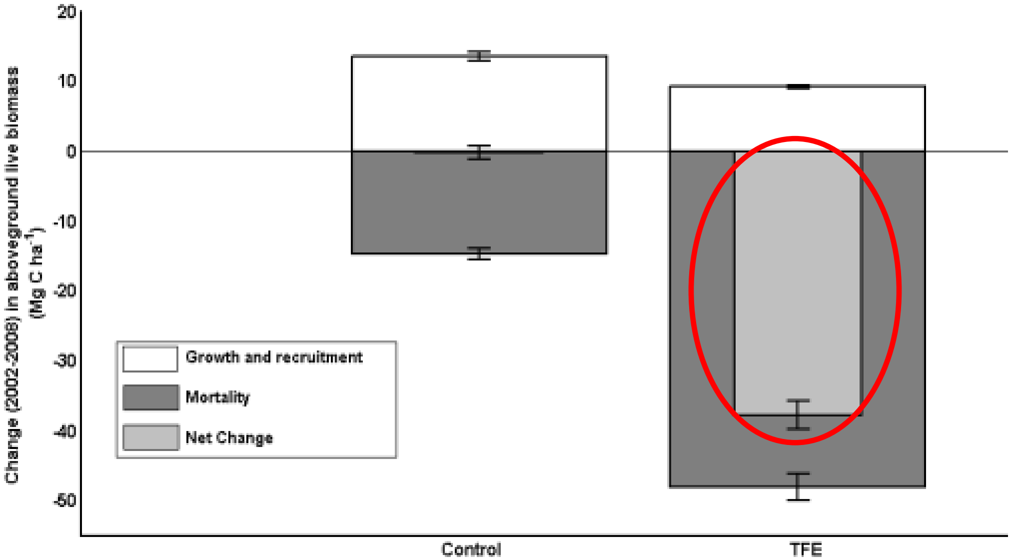


Models fail to capture observed biomass dynamics at the TFE sites. 3 models (CLM, IBIS, JULES) are too insensitive, 1 model (ED2) is over-sensitive.

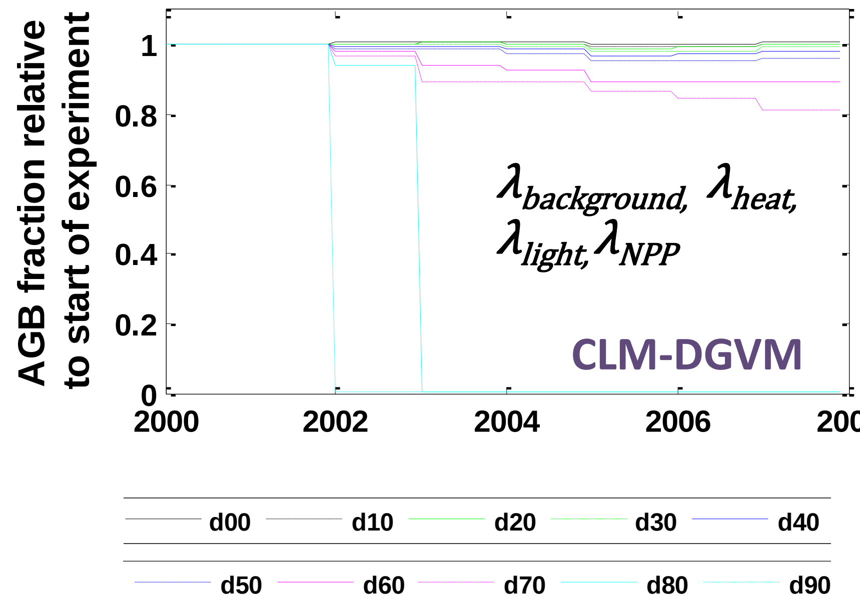
Timing of process response to drought: NPP/LAI/Biomass Responses at Tapajós

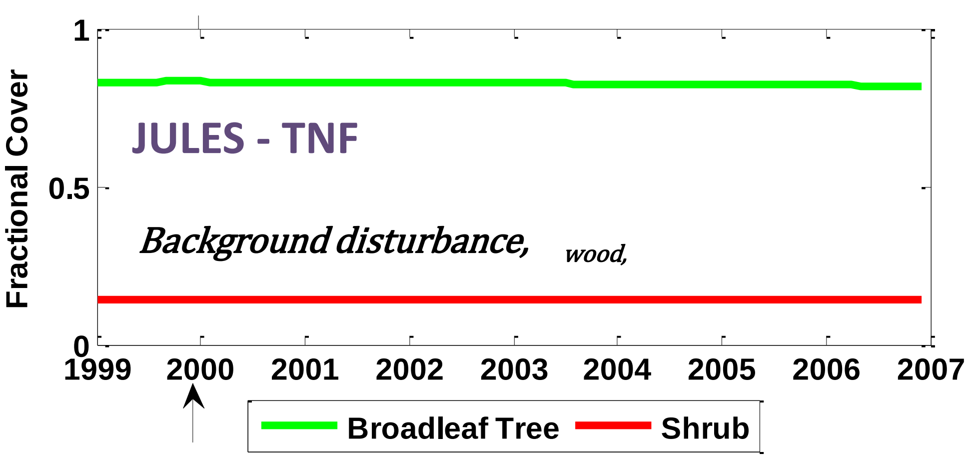


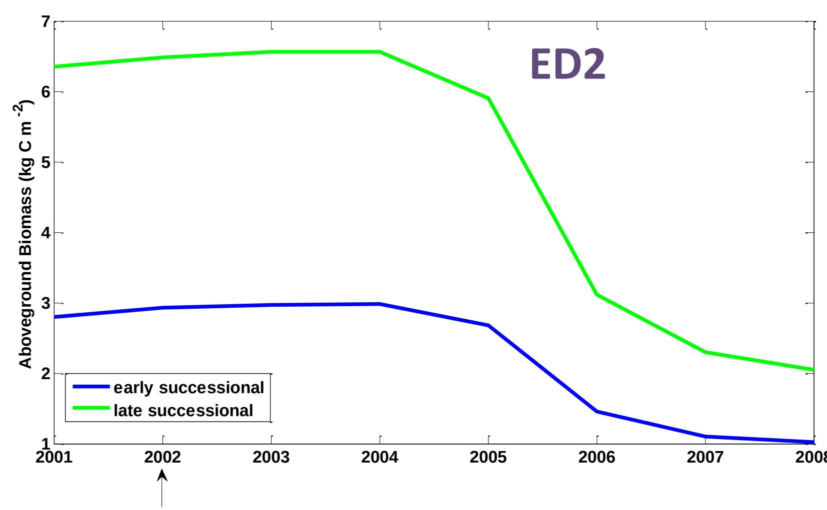
Mortality processes are key for capturing drought impacts on biomass



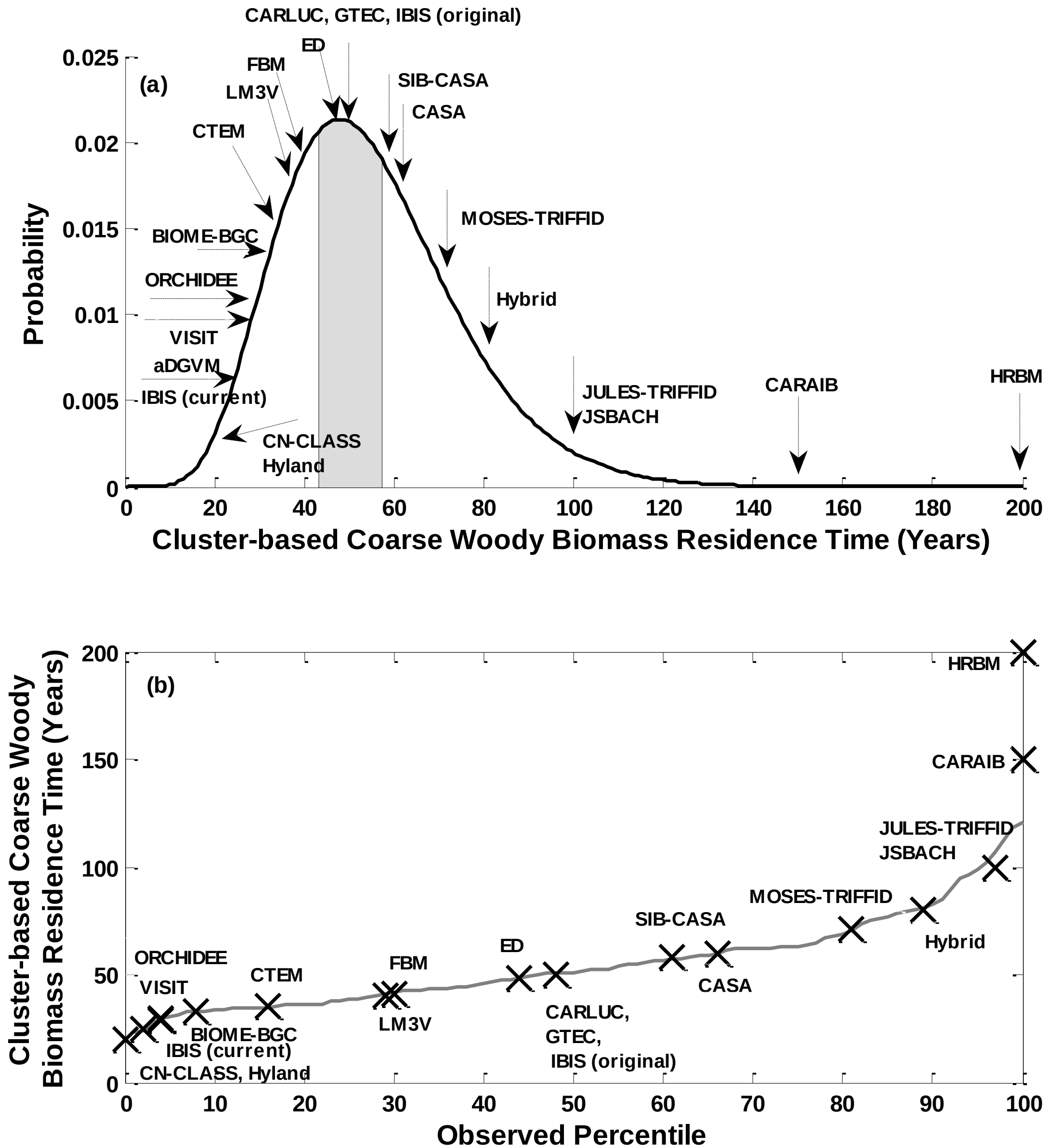
da Costa *et al.* 2010; reduction of ~ 20% following 7 years of drought





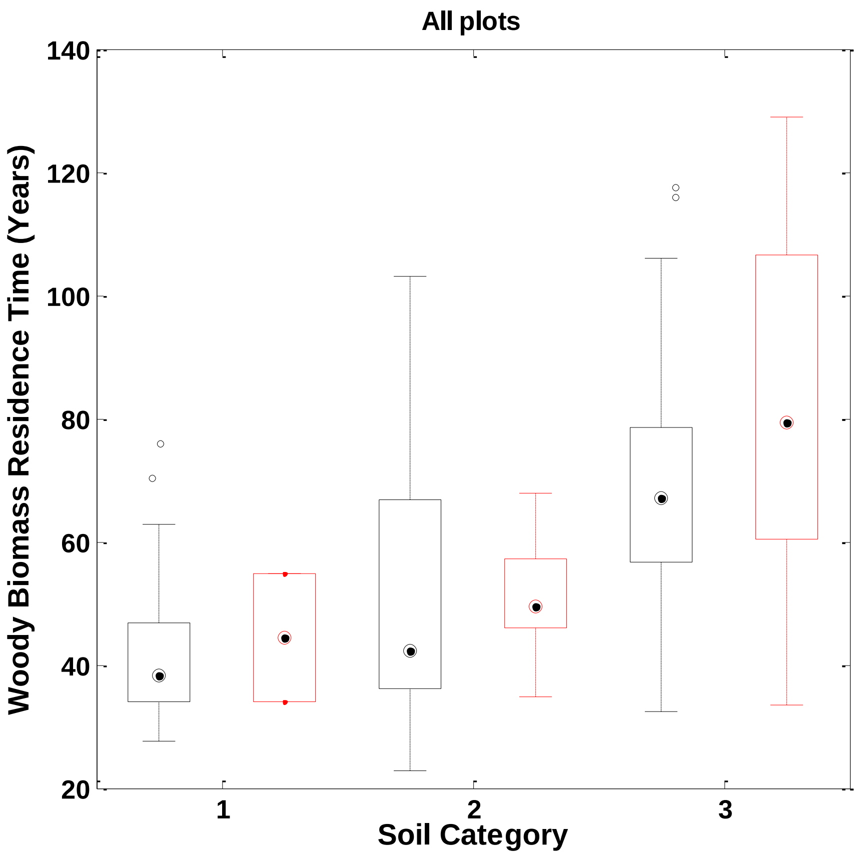


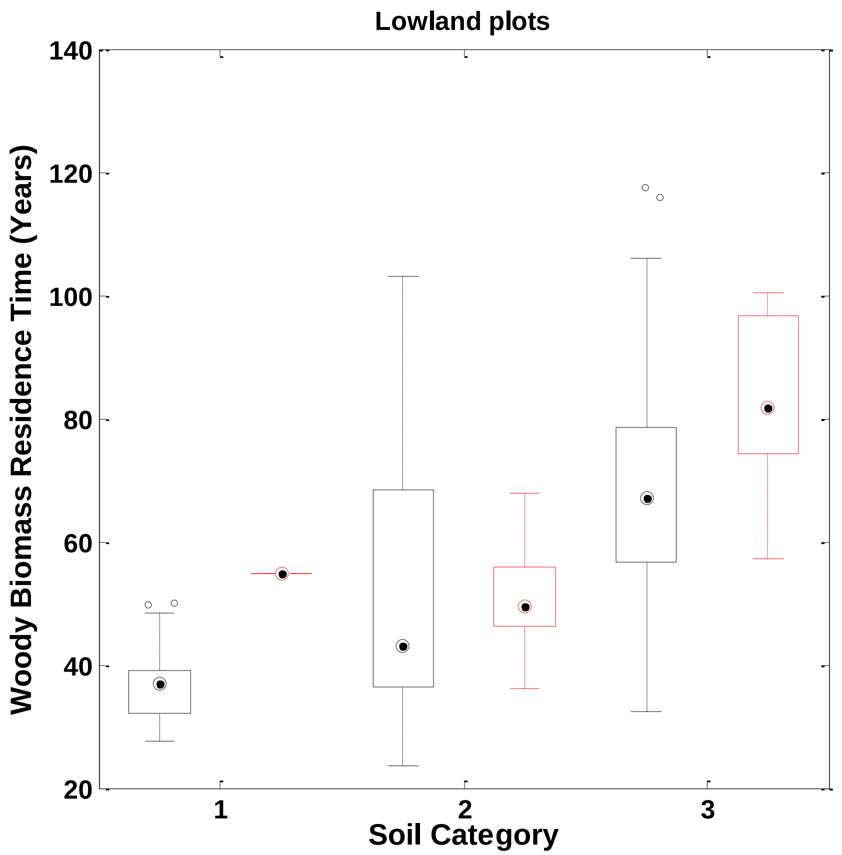
Woody Biomass Residence Time in Global Vegetation Models



Galbraith *et al.*, in review

Edaphic Controls on Woody Biomass Residence Times of Tropical Forests





Galbraith et al., in review

Summary

- There is now more Amazonian field data than ever and it can be used to evaluate vegetation models
- Intensive C-cycle data allows comprehensive evaluation of respiration and NPP allocation that has hitherto not been possible – there is considerable divergence across models in the simulation of these processes
- Current models struggle to reproduce results from drought experiments – some processes are too sensitive while others are too insensitive
- Improved representation of mortality is an immediate priority for DGVM development