Sensitivity of Vegetation in CLM3.5 Biogeochemical Models to Drought Stress in the Amazon Forest

QuickTime™ and a
decompressor
are needed to see this picture.

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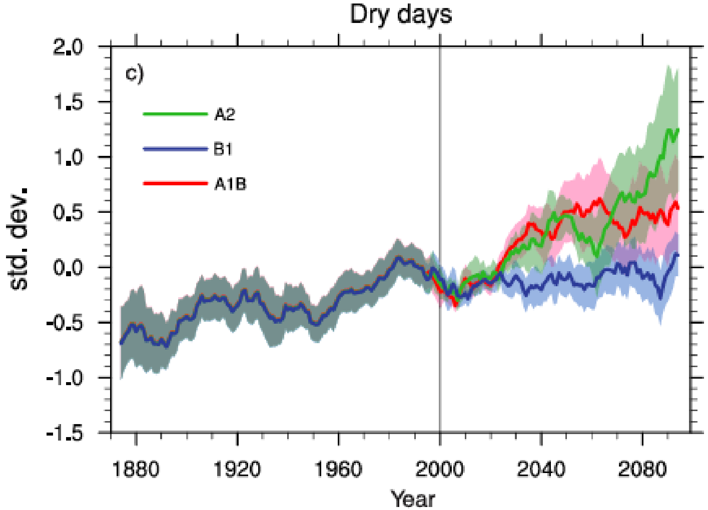
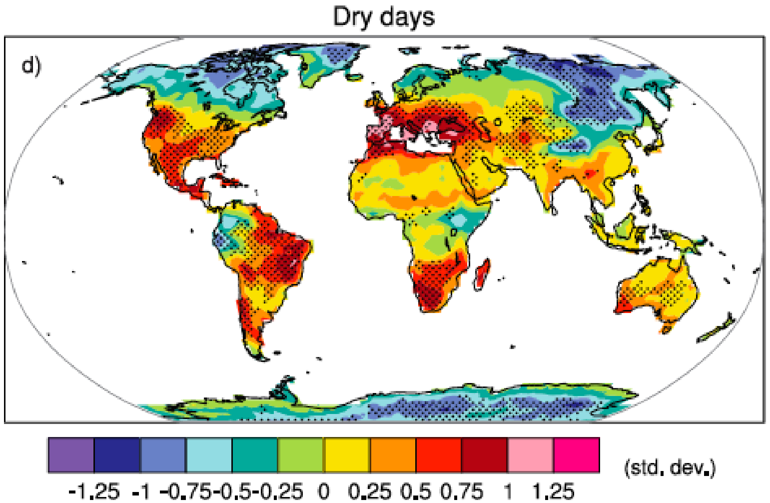
http://en.wikipedia.org/wiki/Amazon_Rainforest

Motivation

Expected increase in frequency and intensity of drought





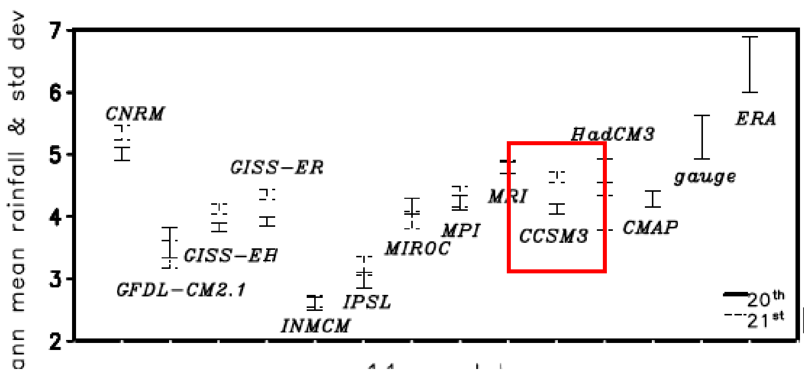
Meehl et al. 2007

And associated vegetation die-off

Breshears et al. 2009

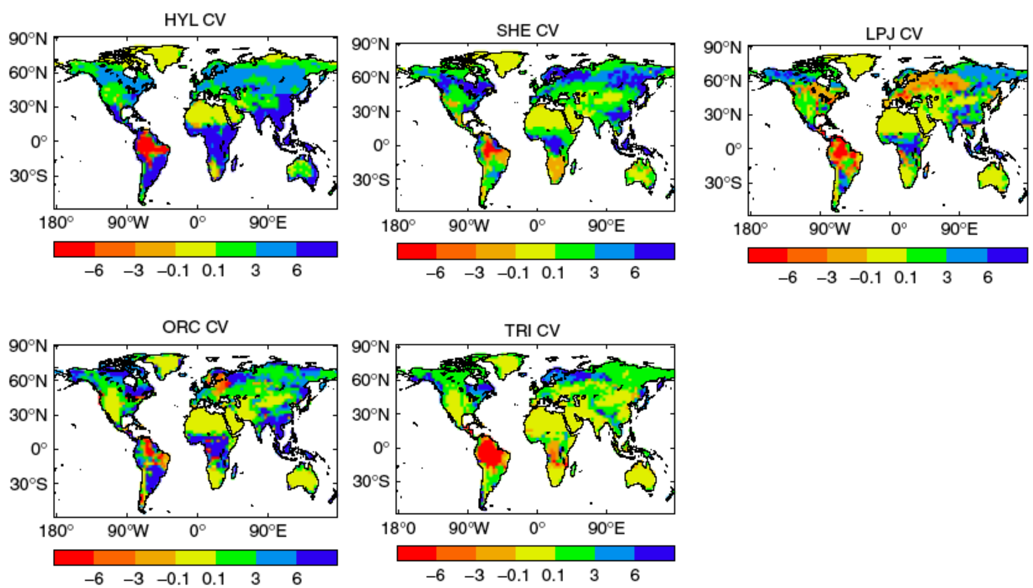
Motivation

CCSM3 with no carbon cycle: more rain in Amazon

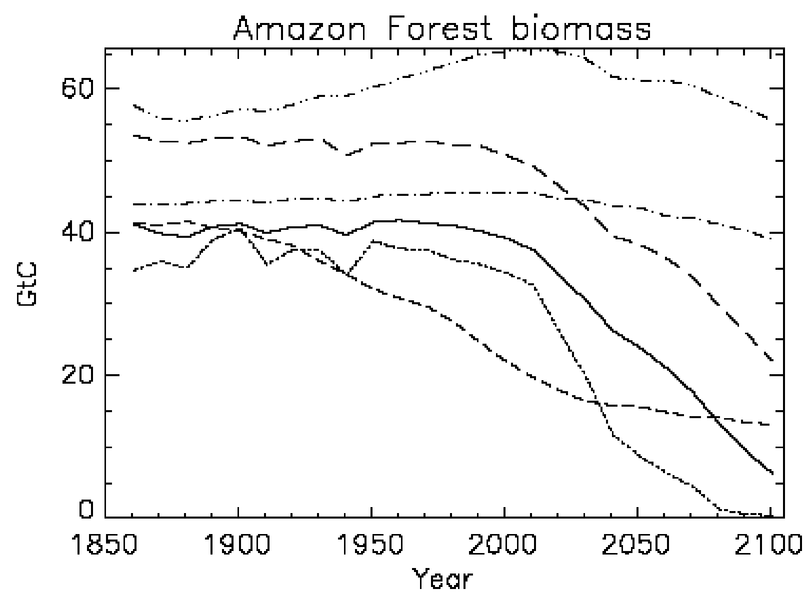


Li et al. 2006

CAM-CLM3 with DGVM simulates Amazon forest die-back with a **positive feedback** involving reduced ET, vegetation, precipitation (Bonan and Levis, 2006)



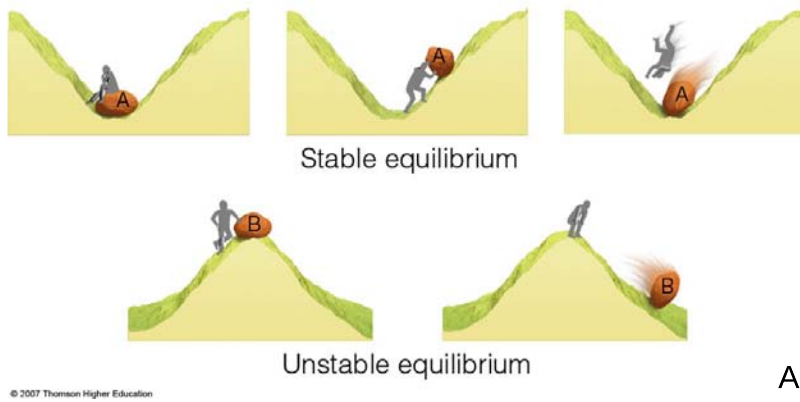
Sitch et al. 2008



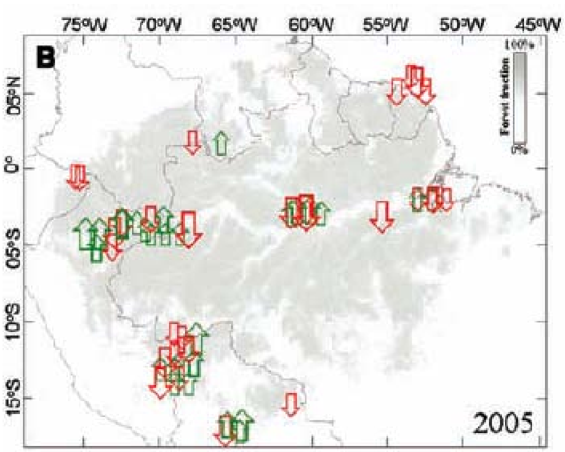
Cox et al. 2004

Motivation

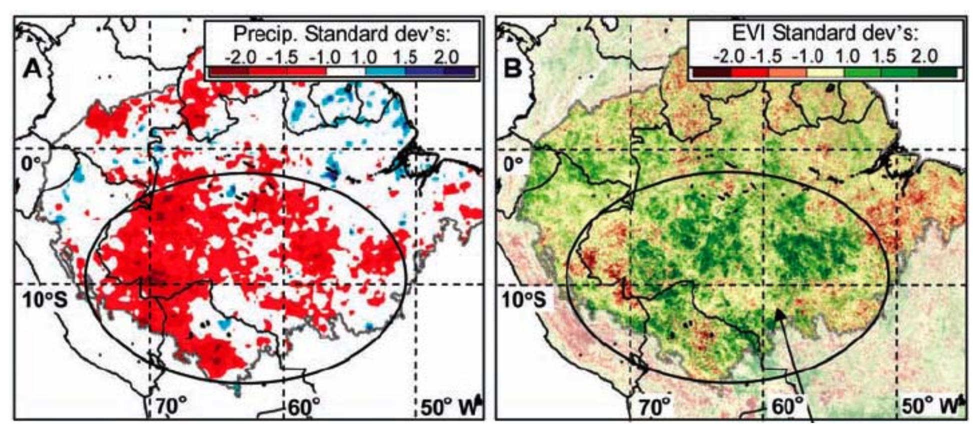
Question: Is the sensitivity of vegetation to drought realistic in biogeochemical & dynamic vegetation models?



Ahrens, 2008



Philips et al, 2009

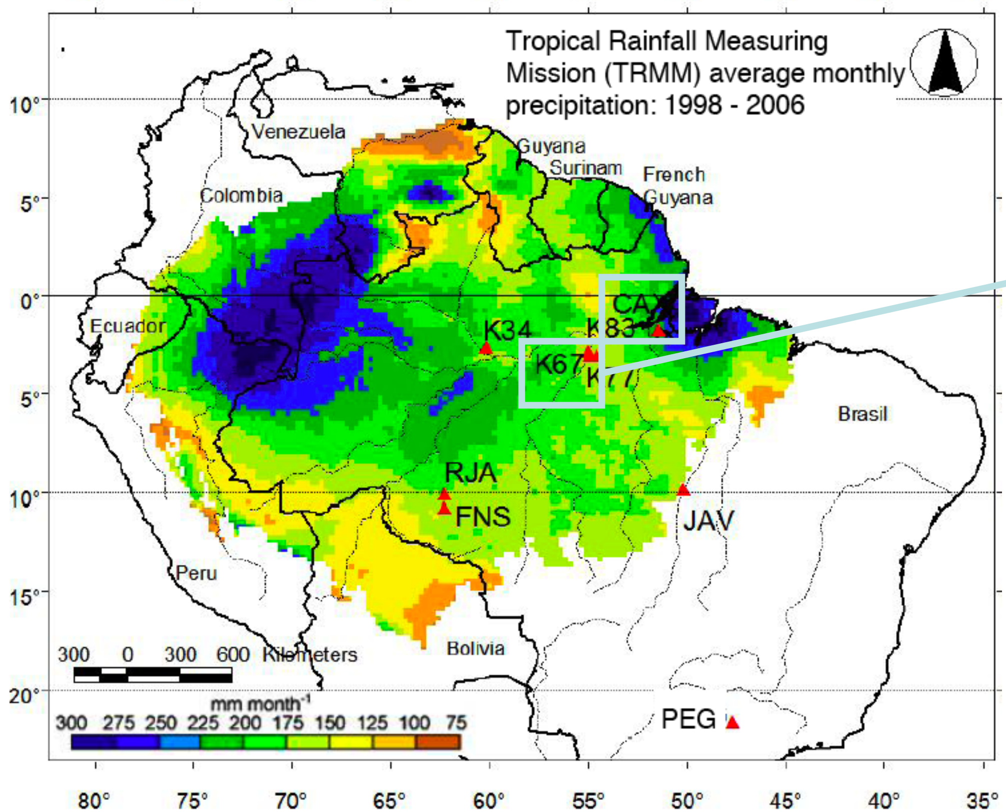


Saleska et al.2007

Method : Throughfall Exclusion Experiment

Response of vegetation to artificial drought was observed over > 4 years in the eastern Amazon forest (Tapajos & Caxiuana)

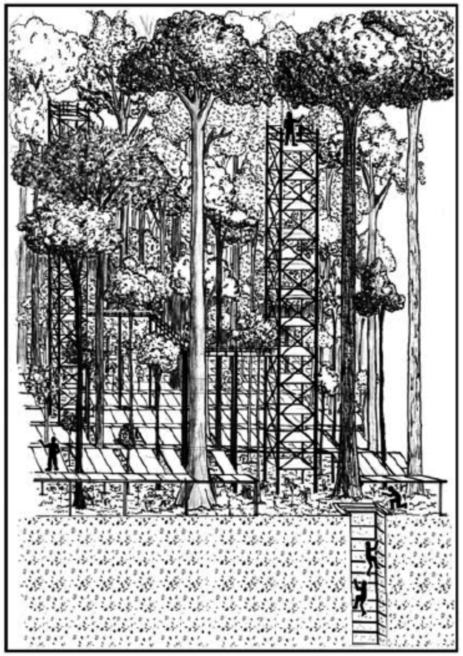
Nepstad et al. 2002;2007, Brando et al. 2008; Fisher et al. 2007, and others



Map from Restrepo-Coupe et al. in review

Two 1-ha plots
For control &
TEE

~ 5km south of
KM67 flux tower



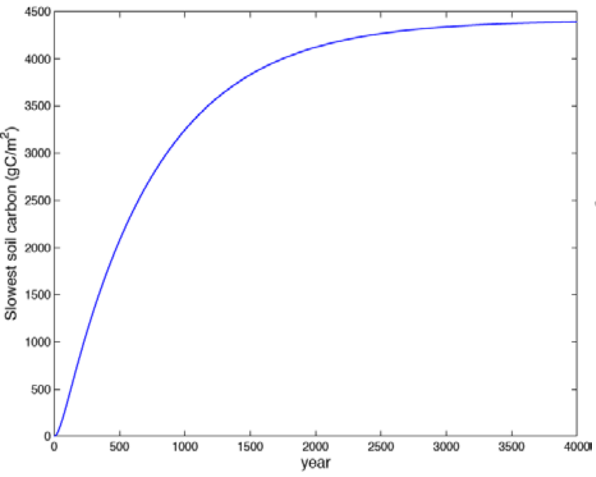
Method : Throughfall Exclusion Experiment

Their experiment was simulated by CLM3.5-CASA, CN and DGVM

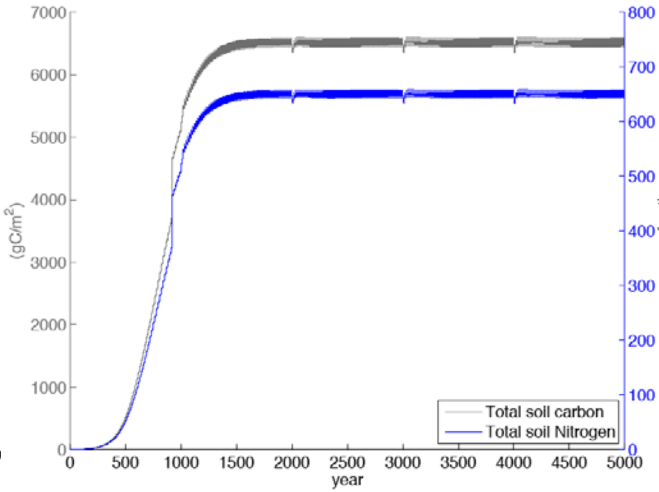
Spin-up: 4000 yrs for CLM3.5-CASA, 5000 yrs for CLM3.5-CN, 1000 yrs for CLM3.5-DGVM by cycling 15 years of atmospheric forcing data.

Surface data: vegetation type, vegetation fractional cover, soil texture are obtained from observation from Nepstad et al. 2002 and LBA-MIP data for KM67 tower.

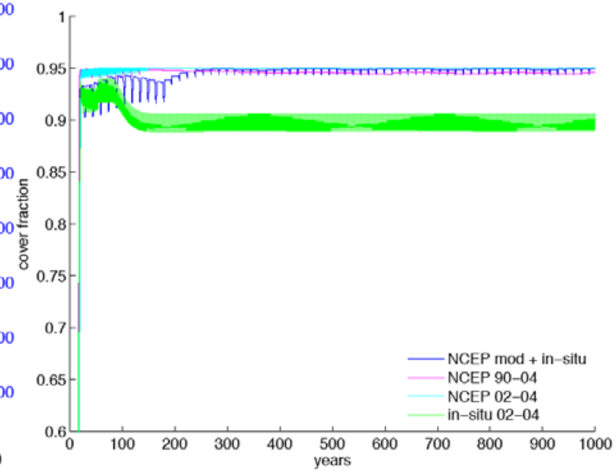
CASA: Slowest (passive) soil C pool



CN: Total soil C & N



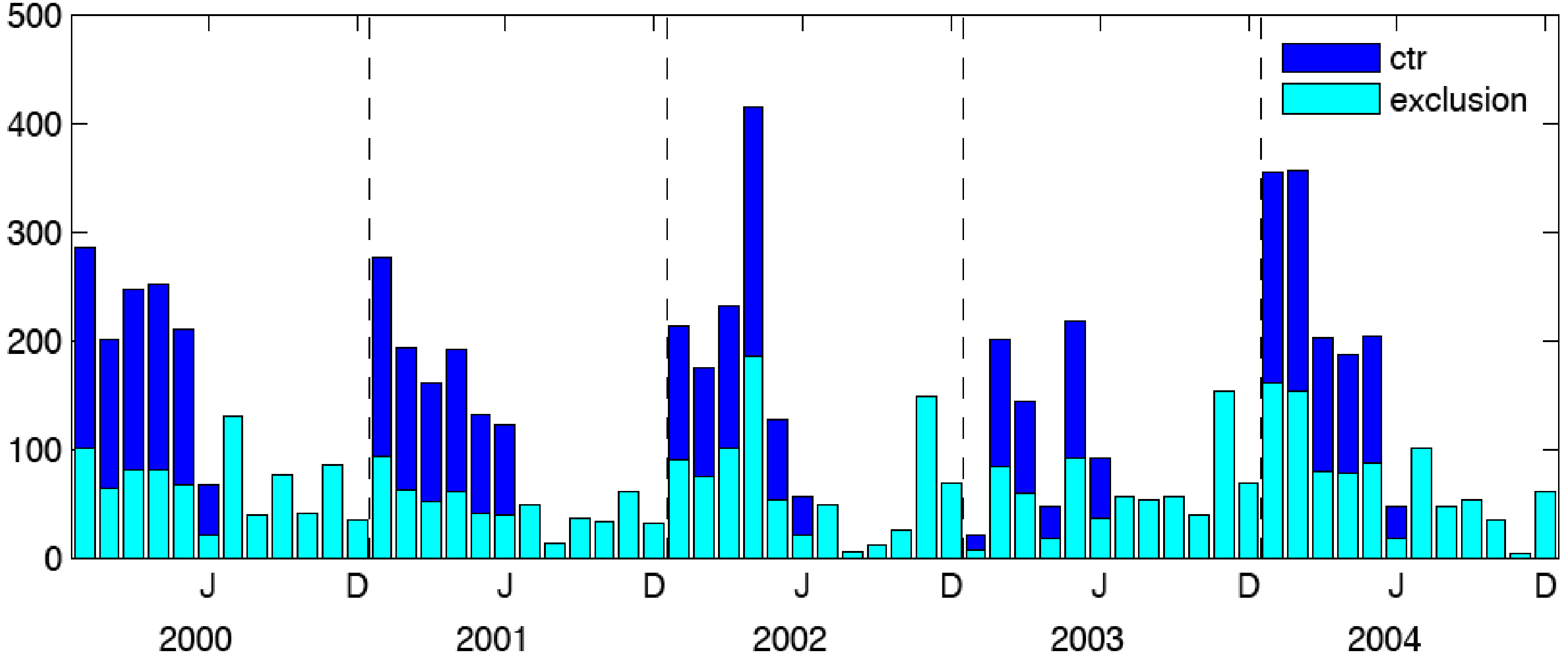
DGVM: Tropical Evergreen tree cover fraction



Method : Throughfall Exclusion Experiment

Their experiment was simulated by CLM3.5-CASA, CN and DGVM

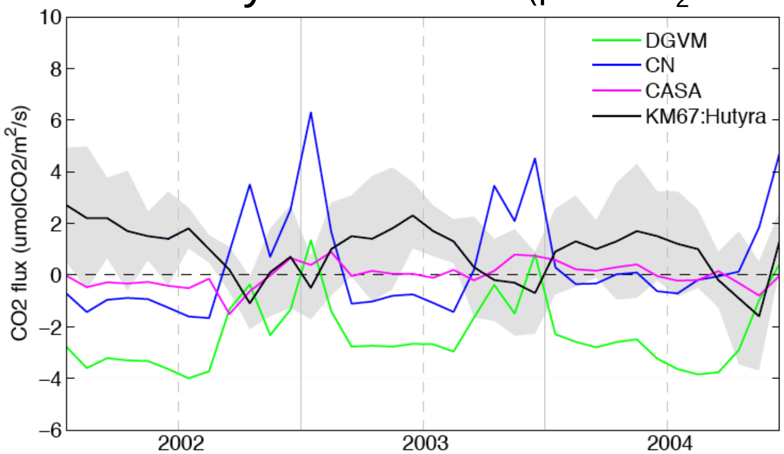
~ 70% of the throughfall is excluded during the wet season from 2000 - 2004, following Nepstad et al. 2002.



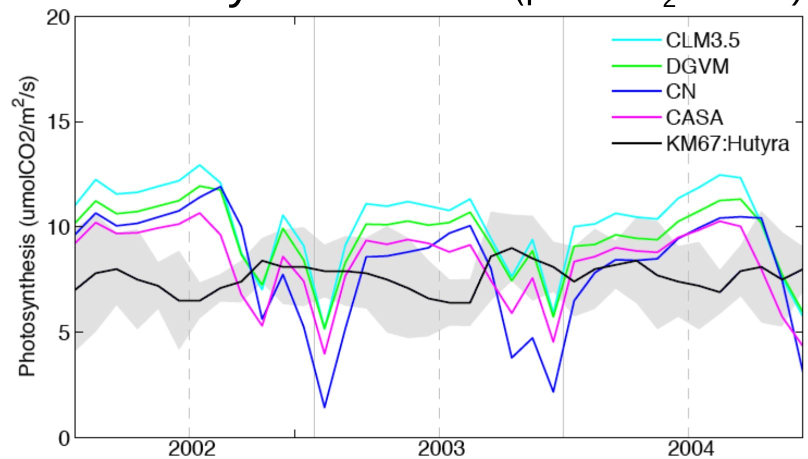
Model performance without Throughfall Exclusion, at KM67

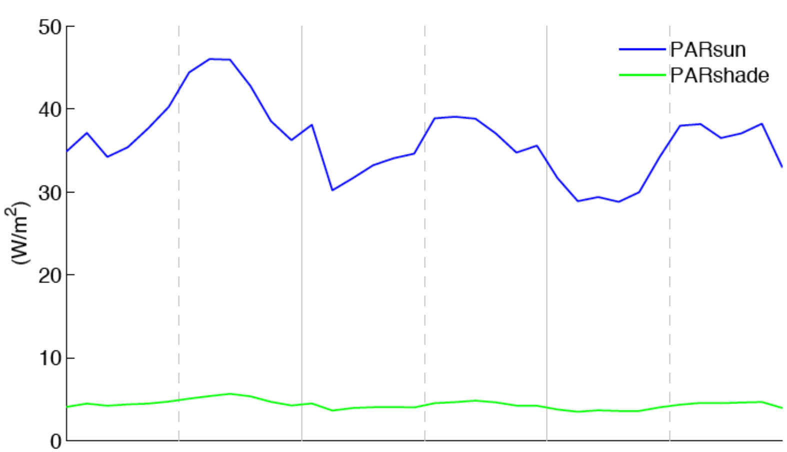
CLM3.5 has difficulties to simulate carbon exchange in this region: tropical forest with dry season.

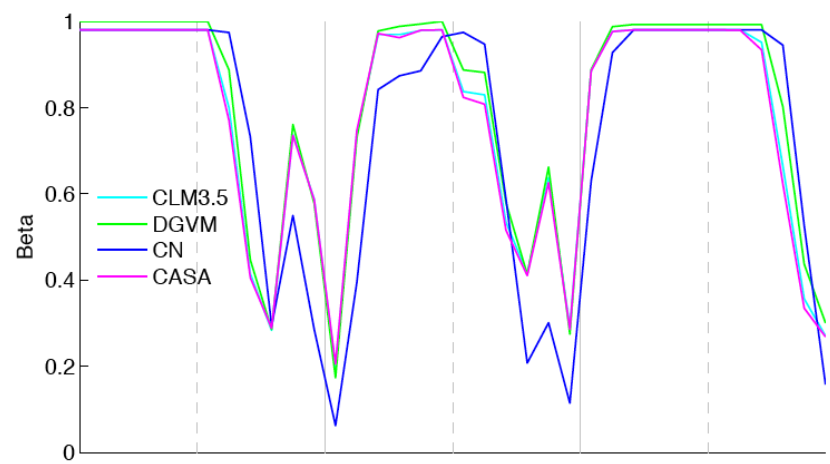
Monthly mean NEE (μmolCO_2 m^{-2} s^{-1})



Monthly mean GPP (μmolCO_2 m^{-2} s^{-1})

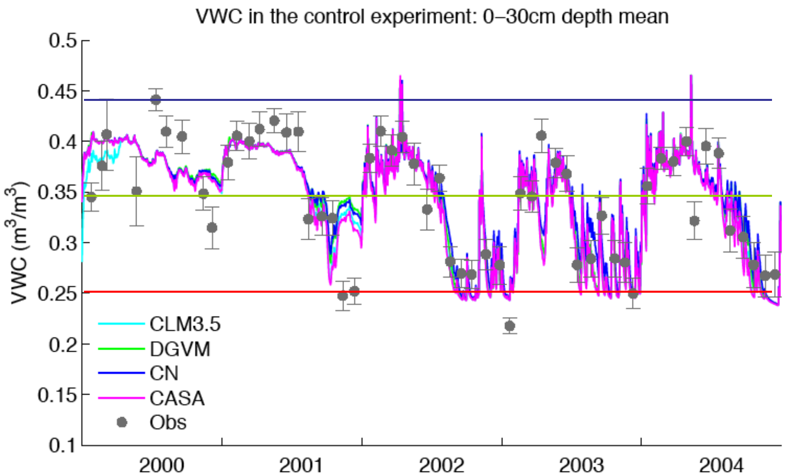


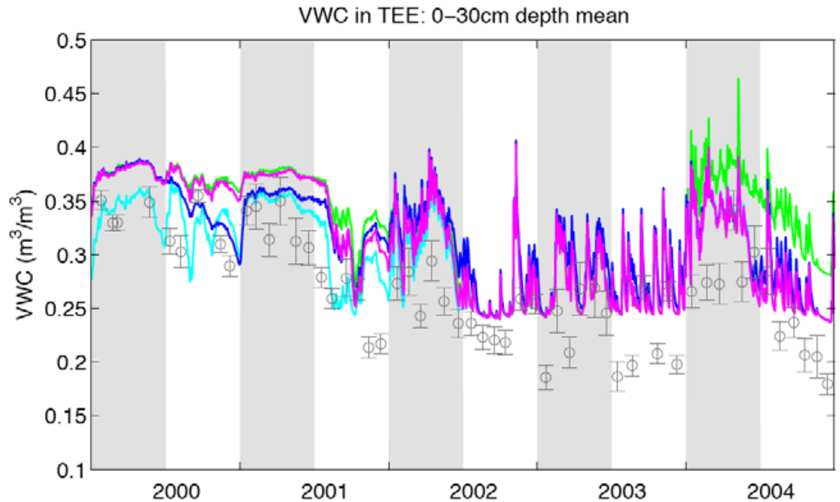


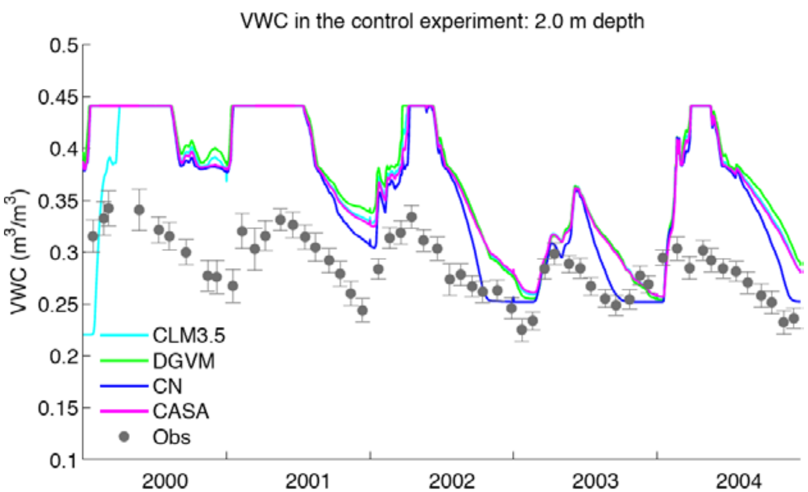


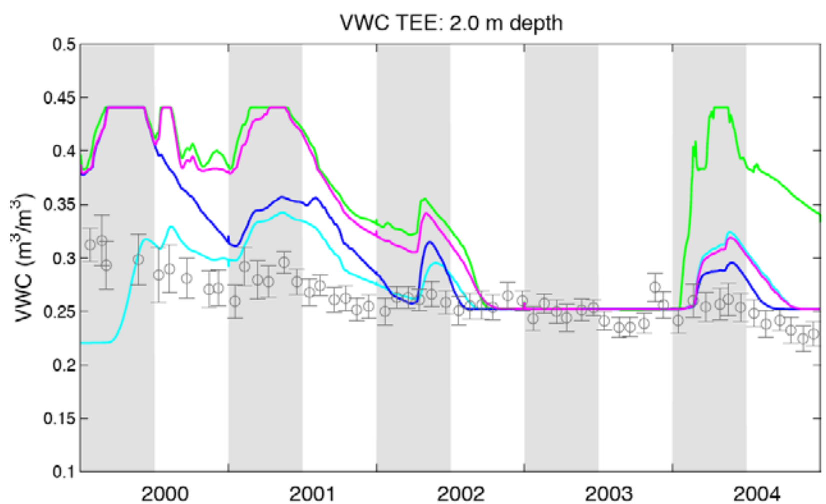
TEE Results : Soil Moisture

Better agreement at shallow depth, but too wet at deeper layers.





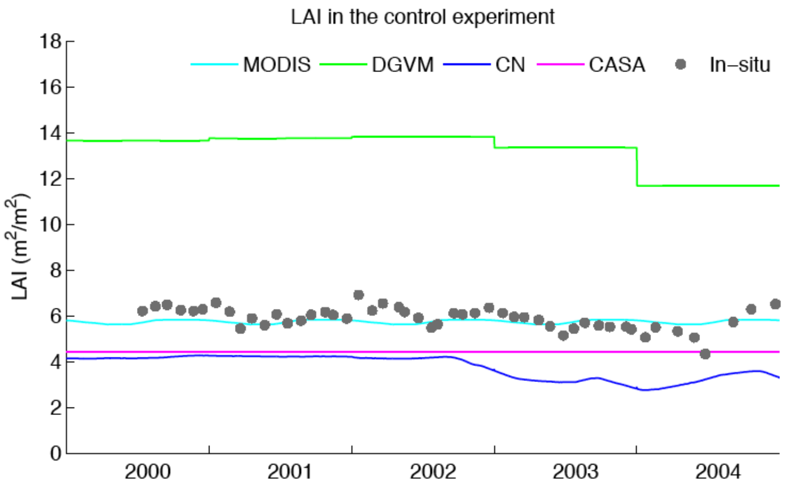


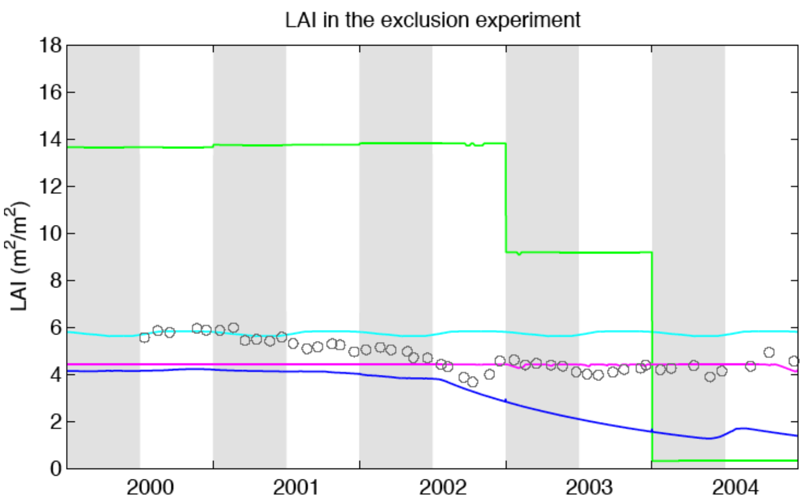


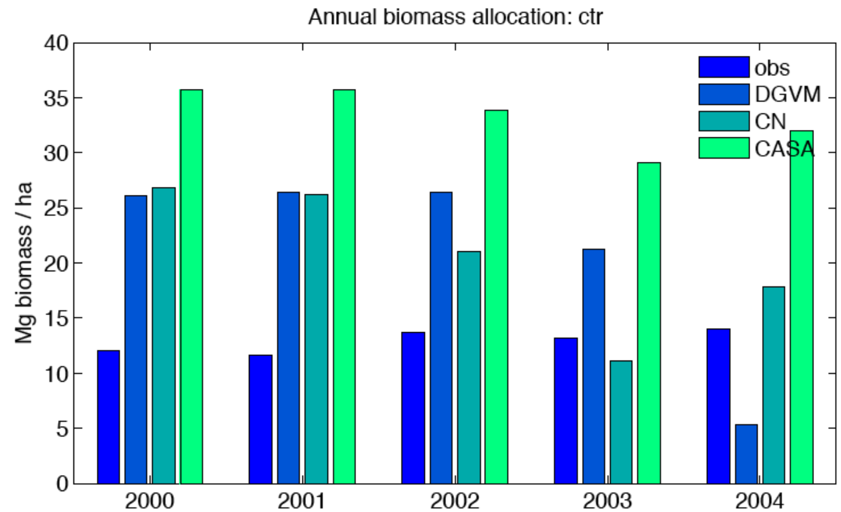
TEE Results : LAI & Annual NPP

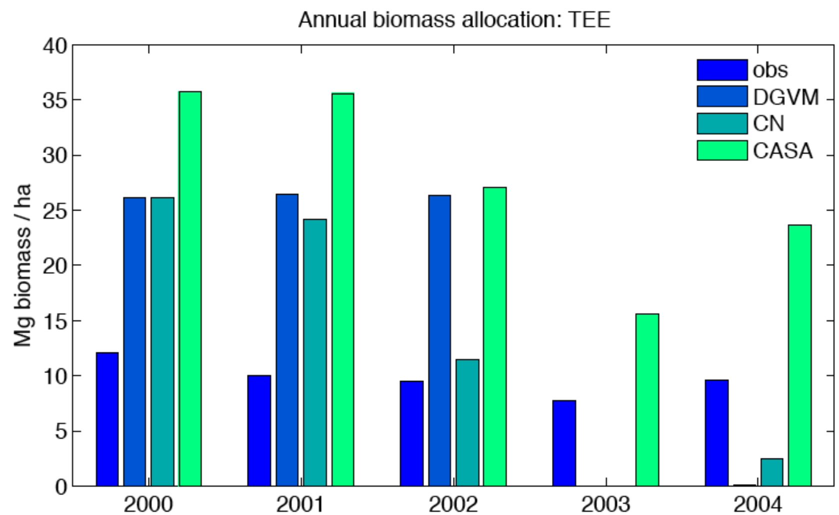
All models overestimate annual NPP.

CN and DGVM are too sensitive to drought stress.





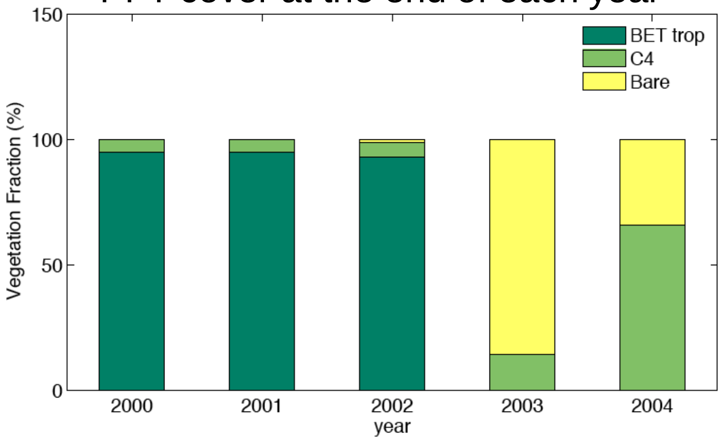




TEE Results : Vegetation dynamics

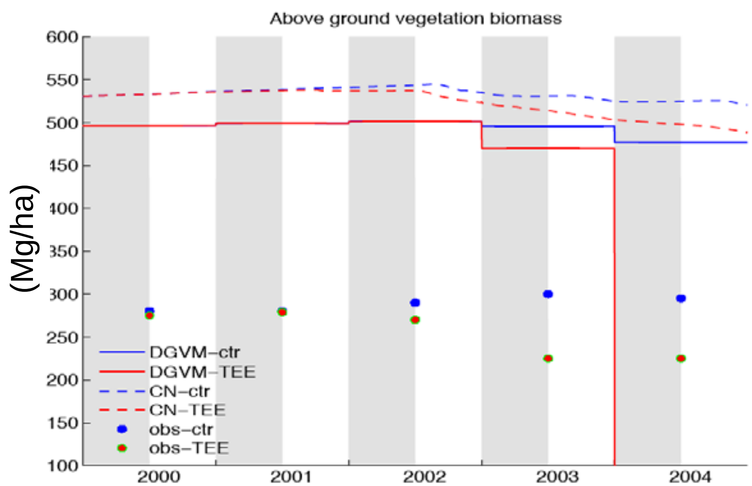
DGVM simulates 100% mortality for BET tropical after 2003.
Observed annual mortality was 9% at the highest.

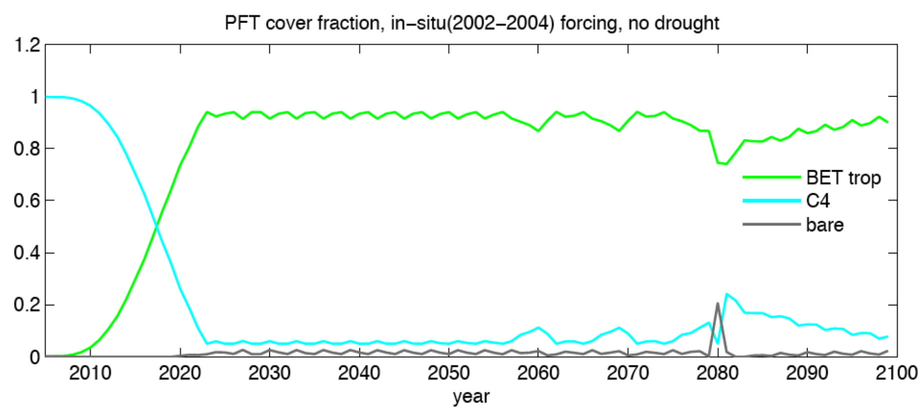
PFT cover at the end of each year



"Despite the death of 9% of all trees ≥ 10cm dbh in 2003, litterfall recovered fully during the first post-treatment year (2005), and wood production, which was 42% of the control plot in 2003, climbed to 77% that of the control plot in 2005" Brando et al. 2008

Aboveground biomass





Summary and future work

1. Disagreement on LAI, ANPP, AGB of tropical evergreen forest in the eastern Amazon.

2. CN and (especially) DGVM are too sensitive to drought stress

How to better treat the relationship of negative annual NPP with dieoff ?

How realistic is the sensitivity of respiration to biomass and drought ? (e.g., constant biomass throughout the year; overestimation of biomass with reasonable/underestimated respiration)

How to better represent water stress for the tropical broadleaf evergreen PFT ? (e.g., water stress (β) function, Baker et al. 2008)

How realistic is the carbon allocation relationships for this PFT ? (e.g., underestimation of LAI with overestimation of ANPP)

Questions, comments, suggestions?

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