Can we realistically represent tropical drought stress in models?

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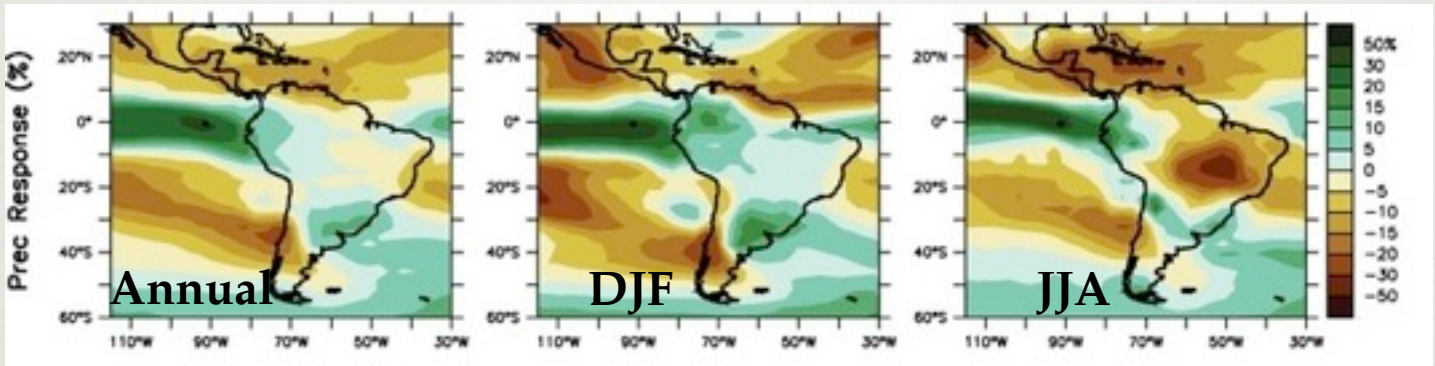
How will the Amazon forest respond to decreased precipitation?



IPCC 2007, Fig. 11.15. **Changes in 21st century precipitation**, A1B scenario

How do we answer this question?

- Observations of forest response to seasonal and longer term drought
- Improved understanding of feedback processes between the forest and local climate
- Use what we learn to improve our climate and ecosystem models

Using observations from two rainfall exclusion experiments, we test an ecosystem model's drought response.

Amazon Drought Experiments

	Tapajos	Caxiuana
location	2.8979S, 54.9528W	1.717639S, 51.46W
time of exclusion	2000 - 2004, wet season only	2002 - 2008, all year
soil texture	80-90% clay, 2-18% sand	12-19% clay, 75-83% sand
mean annual rainfall	2000 mm (600-3000)	2272 (+/- 193) mm*
vegetation	78% trees, 21% lianas, 1% palms	
laterite layer	Not in the top 12 m	Yes: .3-.4 m thick at 3-4 m depth
water table	100 m deep, 150 m above nearest river (Tapajos River: 13 km away)	As shallow as 10 m in wet ssn, site is 15 m above river level in dry ssn

Table 1. Comparison of the two exclusion experiments. Information is from Nepstad et al. (2002) for Tapajos and Costa et al. (2010) for Caxiuana, unless otherwise noted.
* Fisher et al. 2007

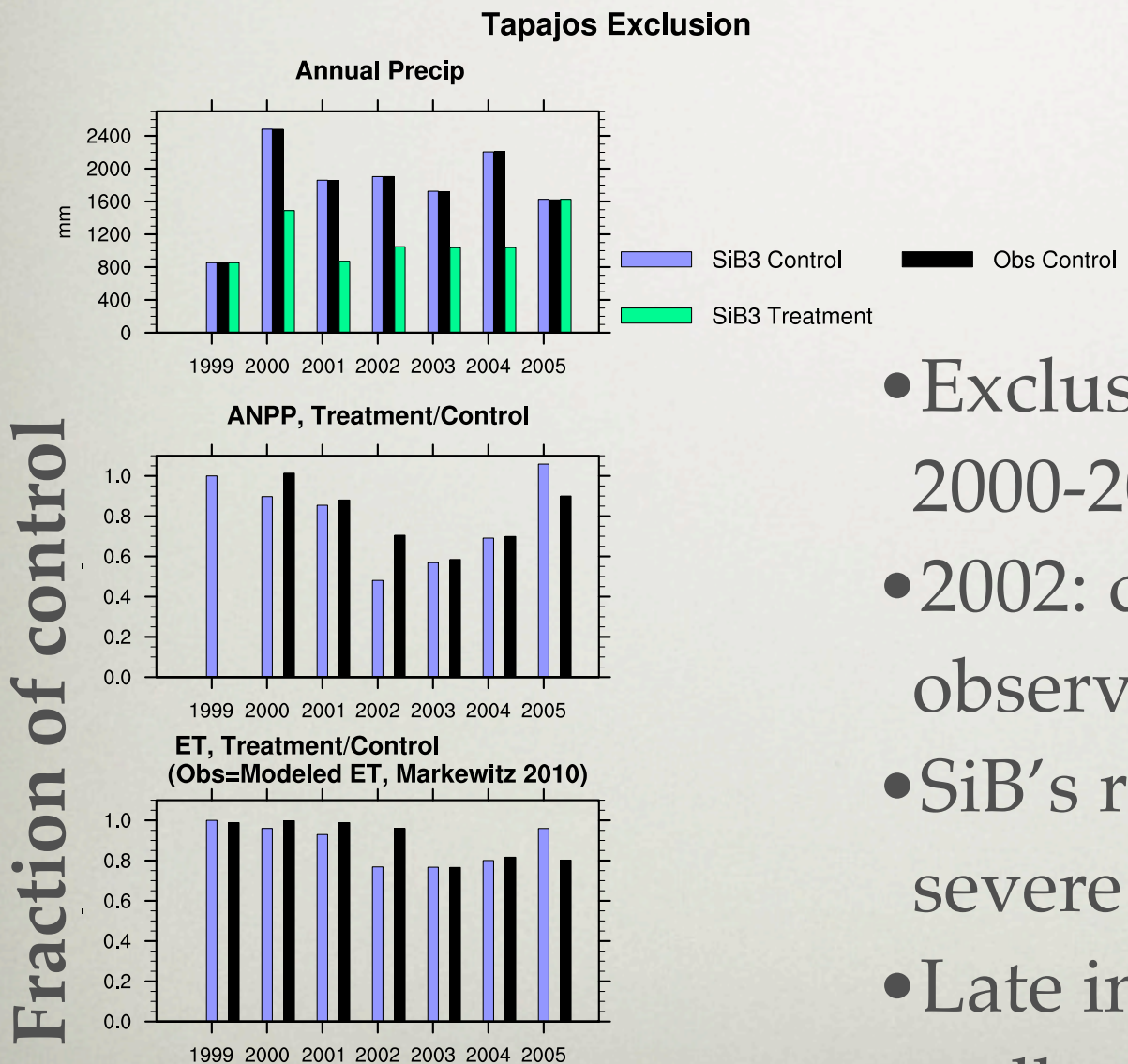
Amazon Drought Experiments

- Both experiments found initial period of resilience followed by large increases in tree mortality after 3-4 years
- Decreased NPP (both sites) and sap flow (Caxiuana)

Can we replicate the effects of multiyear drought?

- Simple Biosphere model (SiB3): Captures seasonal fluxes of carbon and water throughout the Amazon - but how does it handle longer-term dryness?
- Tapajos: 5-year drought using meteorology from Km83 tower
- Caxiuana: 4-year drought with met. from nearby tower

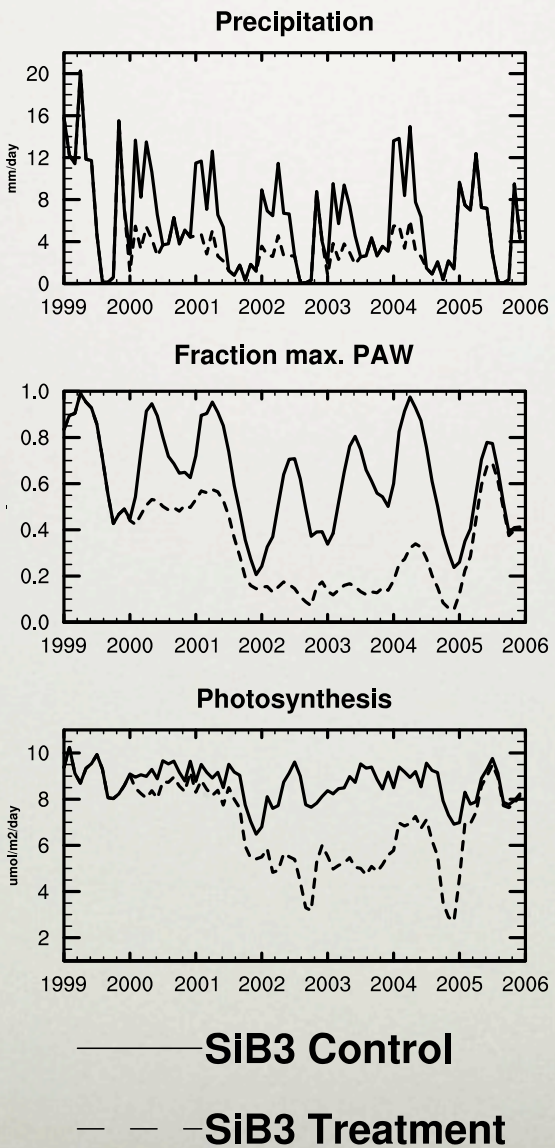
Drought effect on NPP & ET - Tapajos

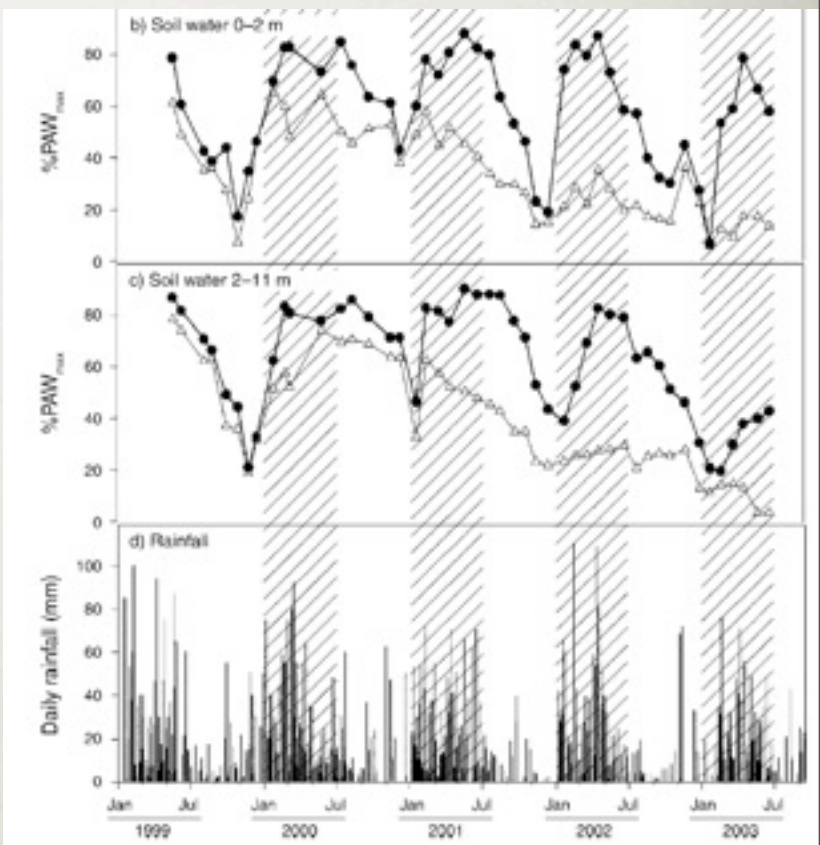


- Exclusion ran from 2000-2004
- 2002: decrease in ANPP observed
- SiB's response is too severe
- Late in drought SiB does well

Drought effect on NPP & ET - Tapajos

Dry season of 2001 triggers threshold in drought response (215 mm July-Dec., 35 mm/mo)

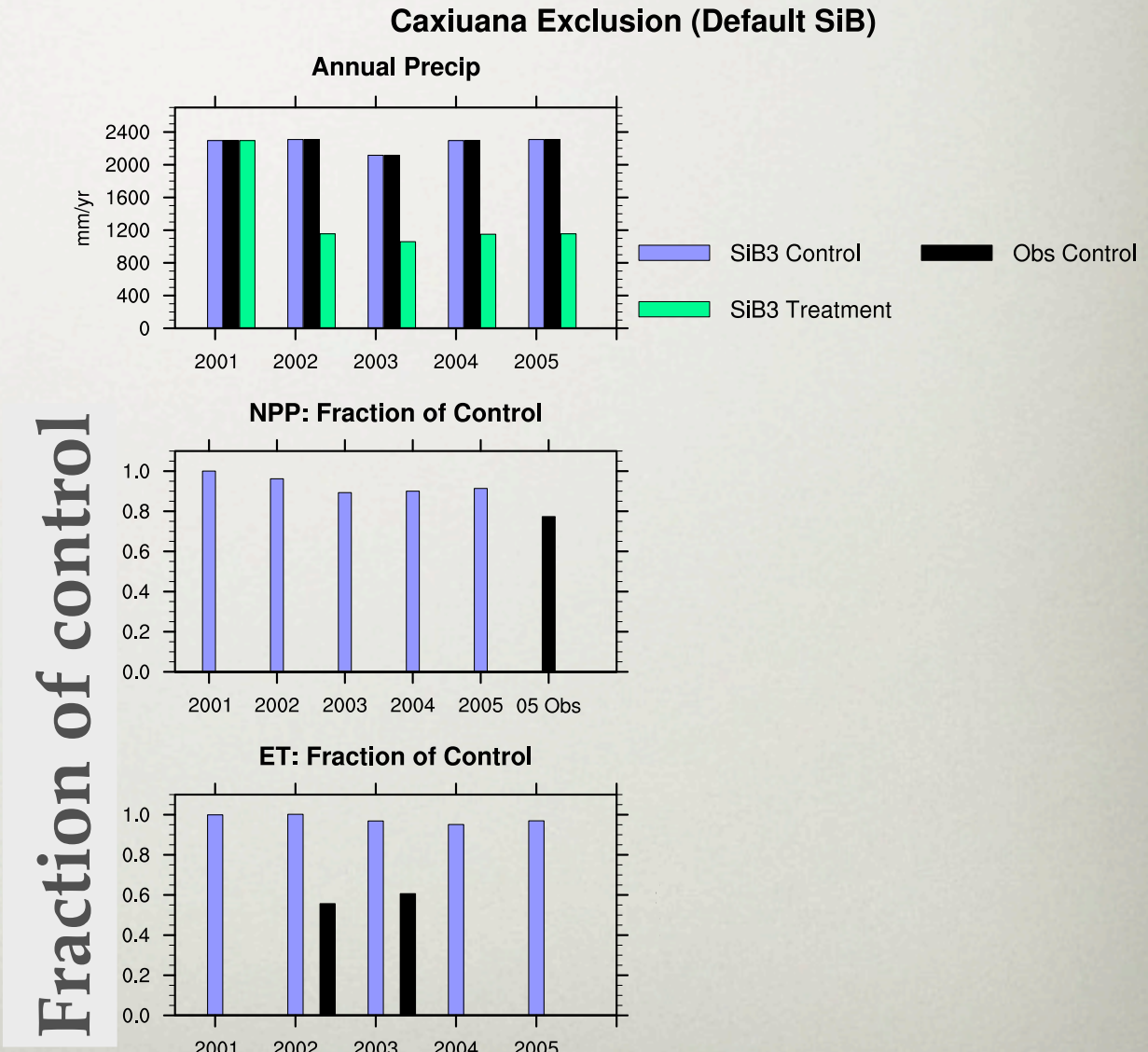




Nepstad et al. 2007
Figure 2

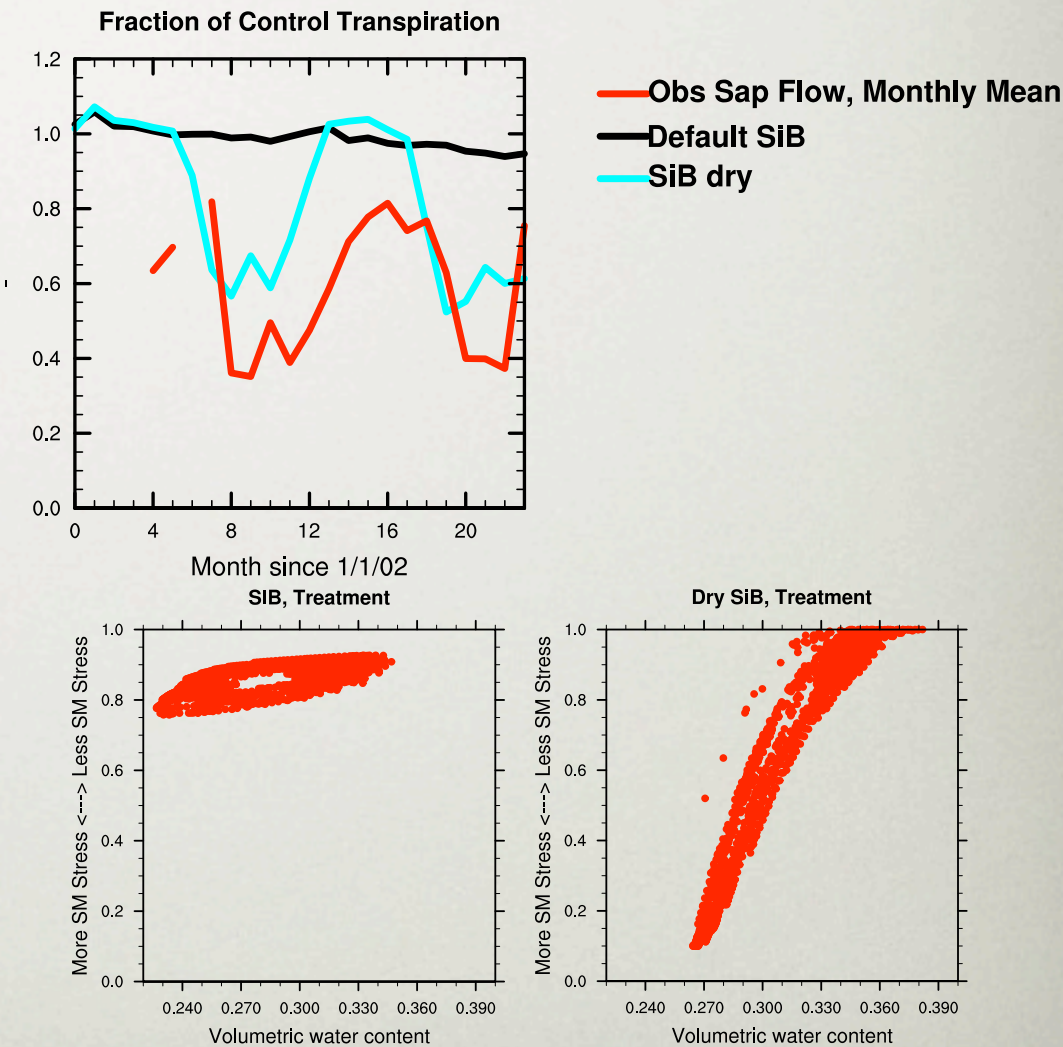
Drought effect on NPP & ET - Caxiuana

- SiB has almost no drought response at Caxiuana.
- NPP observed in 2005
- Sap flux measured 2002-2003



Drought stress at Caxiuana

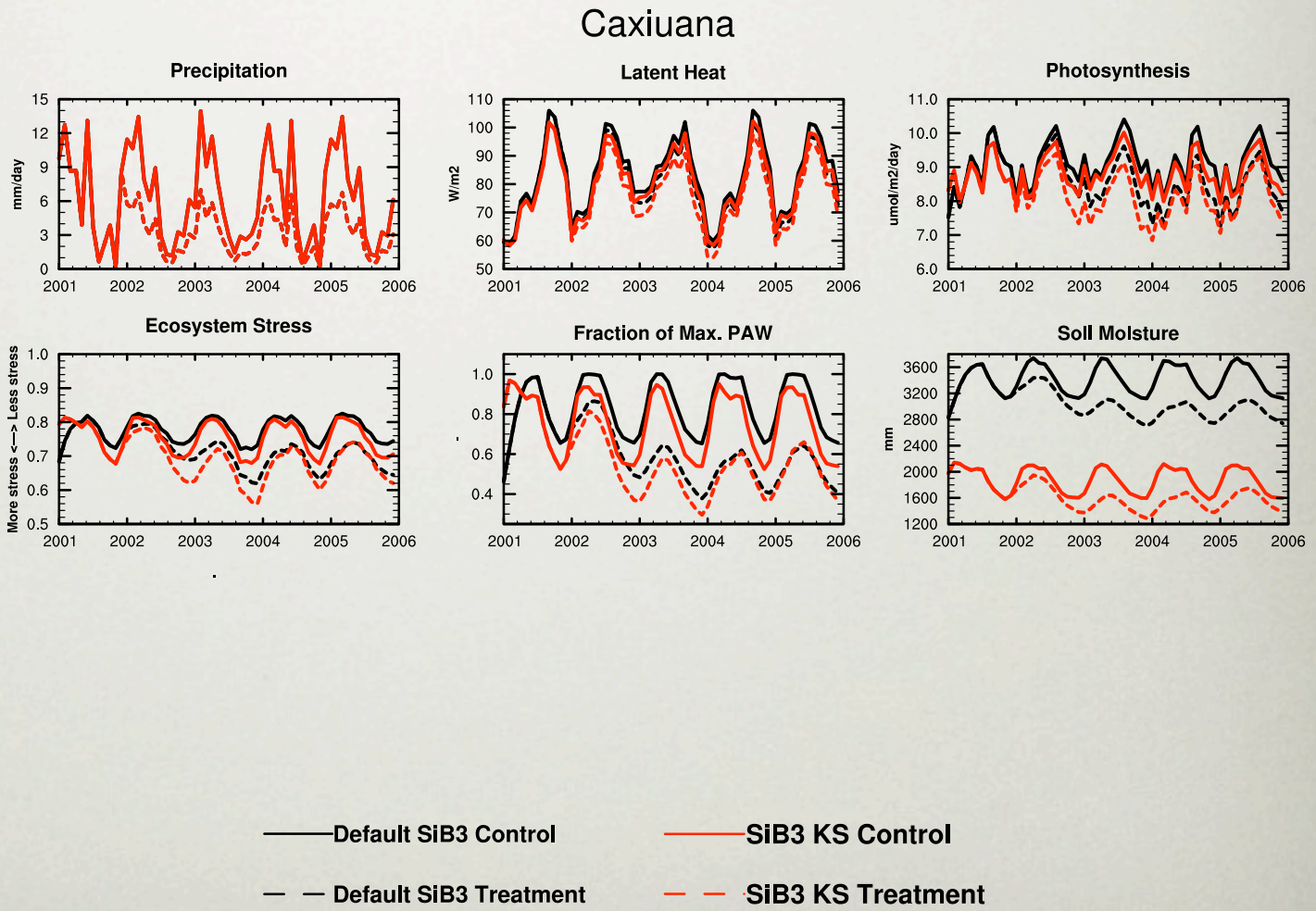
- SiB3 weights root fraction by soil water in each layer and stress occurs only at very low VWC
- Discounting the effects of deep roots and changing calculation of soil moisture stress makes response more realistic.



wilt point = 0.212, field capacity= 0.364

Checking model against reality

- "Kitchen Sink" run: observed soil texture, LAI, root density, and an effective laterite layer.
- Lots of changes but still limited drought response (LH and photosynthesis).



What's keeping us from representing tropical drought?

- Soil texture, parameters
- Root fraction with depth
- Homogeneous canopy
- Soil moisture/water potential relationship (Clapp & Hornberger)

Can we represent tropical drought stress?

- Decently at Tapajos, slightly overestimate drought severity, timing of thresholds in resilience are good
- At Caxiuana, very little drought stress in current version of SiB3
- Results from other land surface models can help elucidate missing factors