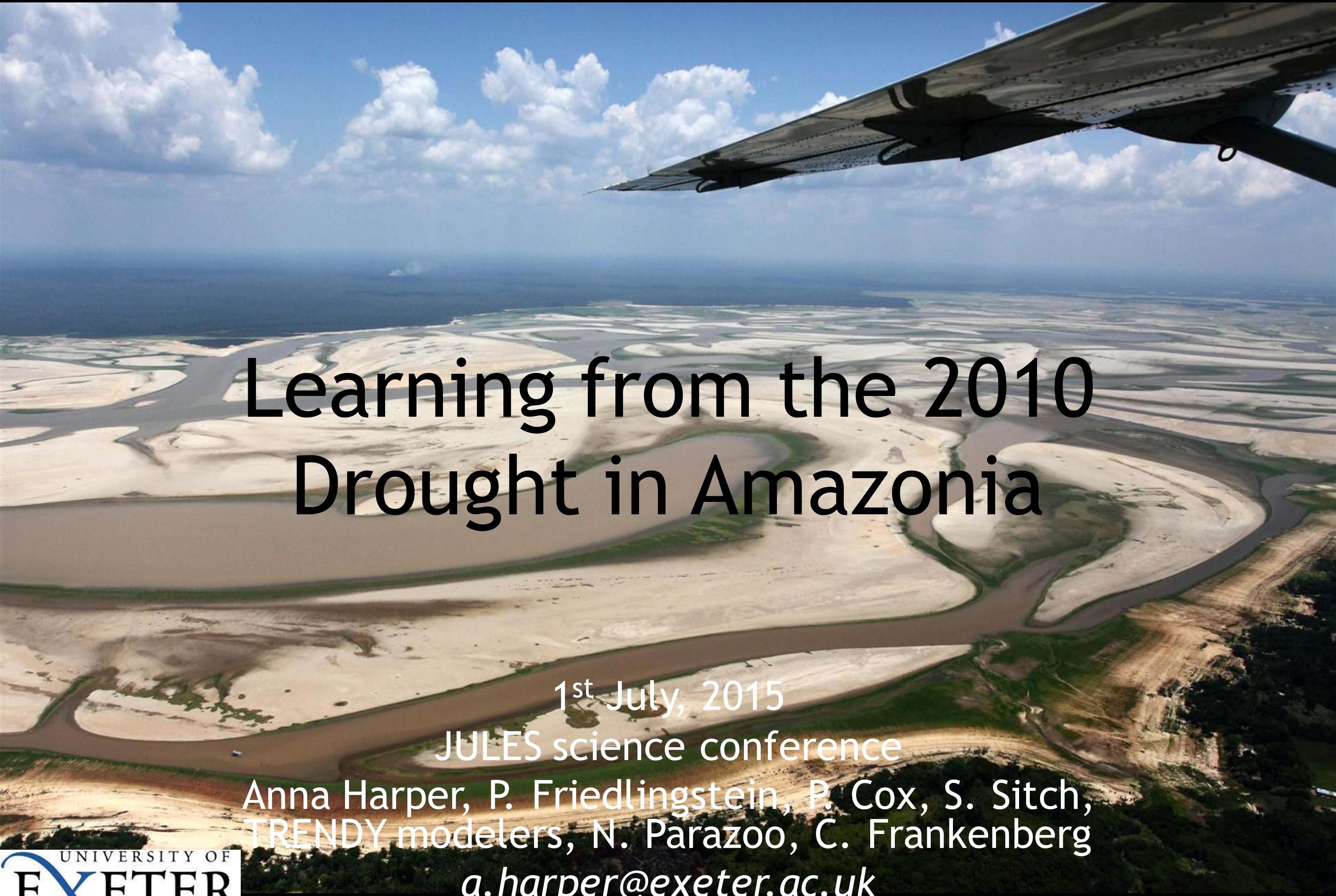

Learning from the 2010 Drought in Amazonia

1st July, 2015

JULES science conference

Anna Harper, P. Friedlingstein, P. Cox, S. Sitch, TRENDY modelers, N. Parazoo, C. Frankenberg

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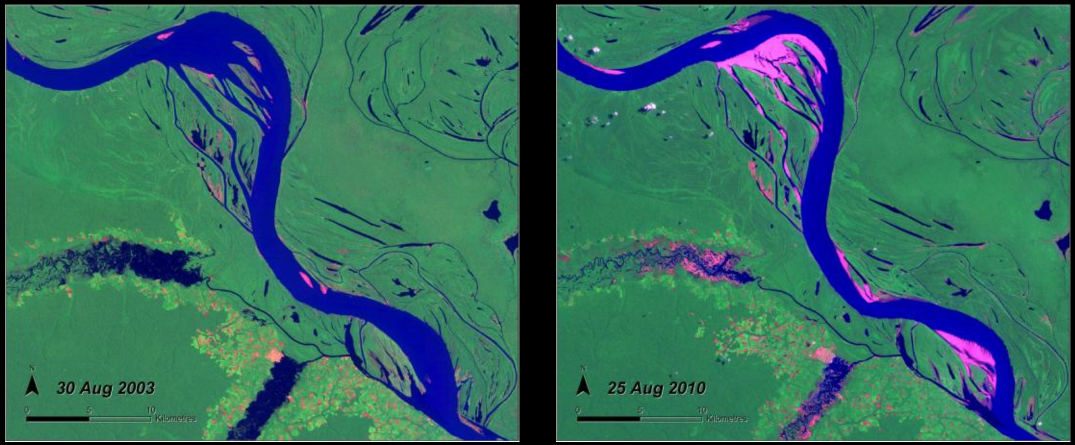
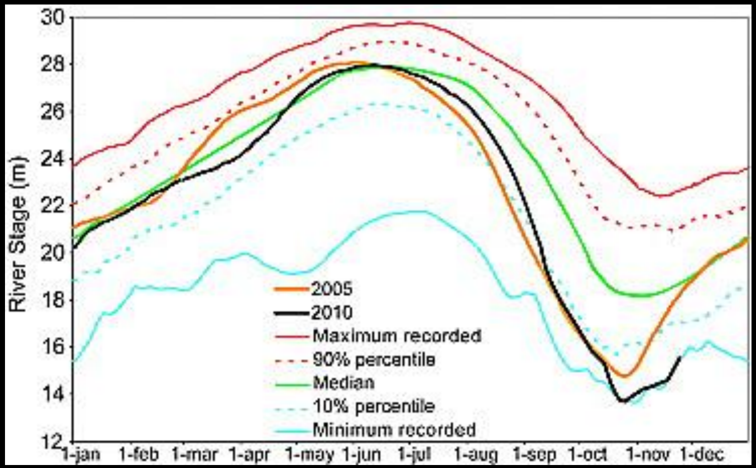
Outline

- What do we know?
- What can we learn?
- Where do we go next?

- Rio Negro water level in Manaus was the lowest in the 109-year record in October, 2010.
- Rio Solimoes also reached record low levels in Oct. 2010.
- 2010 drought affected nearly 5 million km^2 of vegetated area.



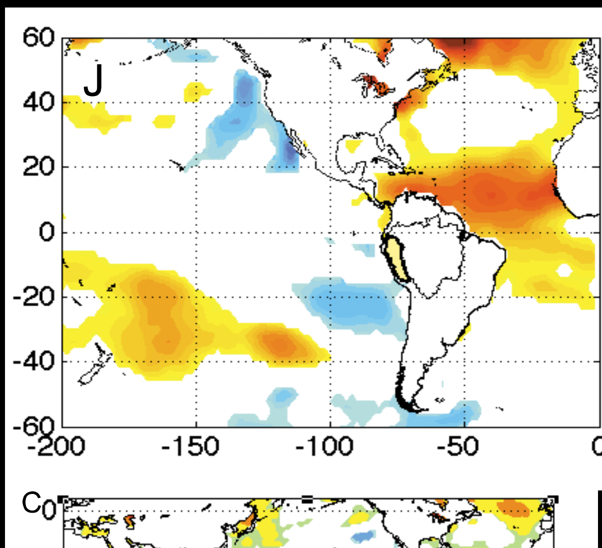
Sand bars (pink) exposed in 2010, visible in satellite images (http://na.unep.net/geas/)



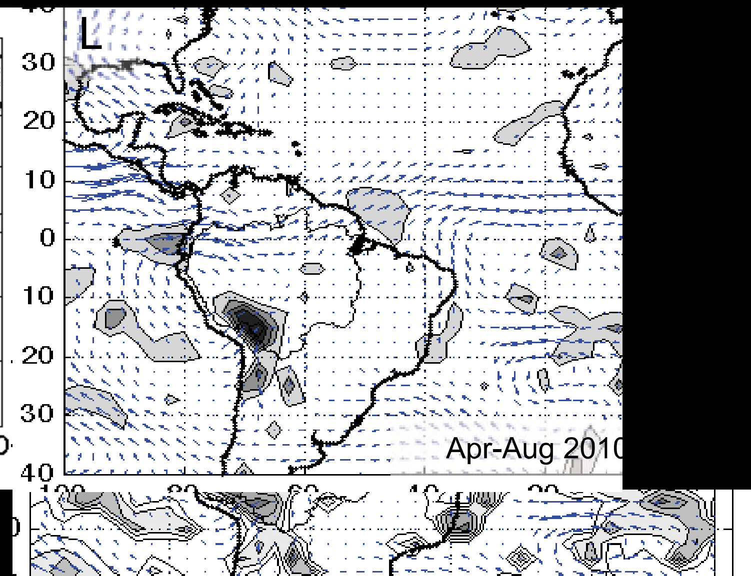
Xu et al., GRL, 2011; Espinoza et al., GRL, 2011

Causes of 2010 drought

Anomalous SSTs

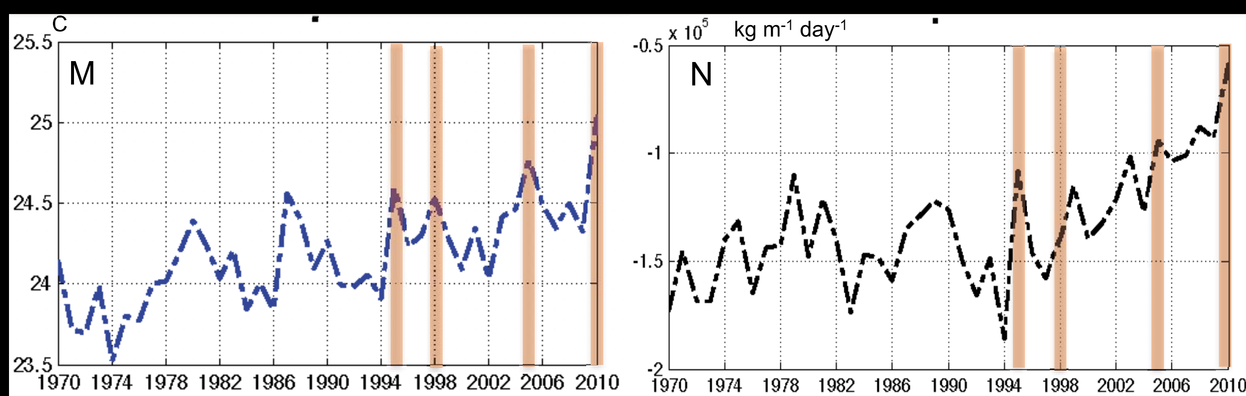


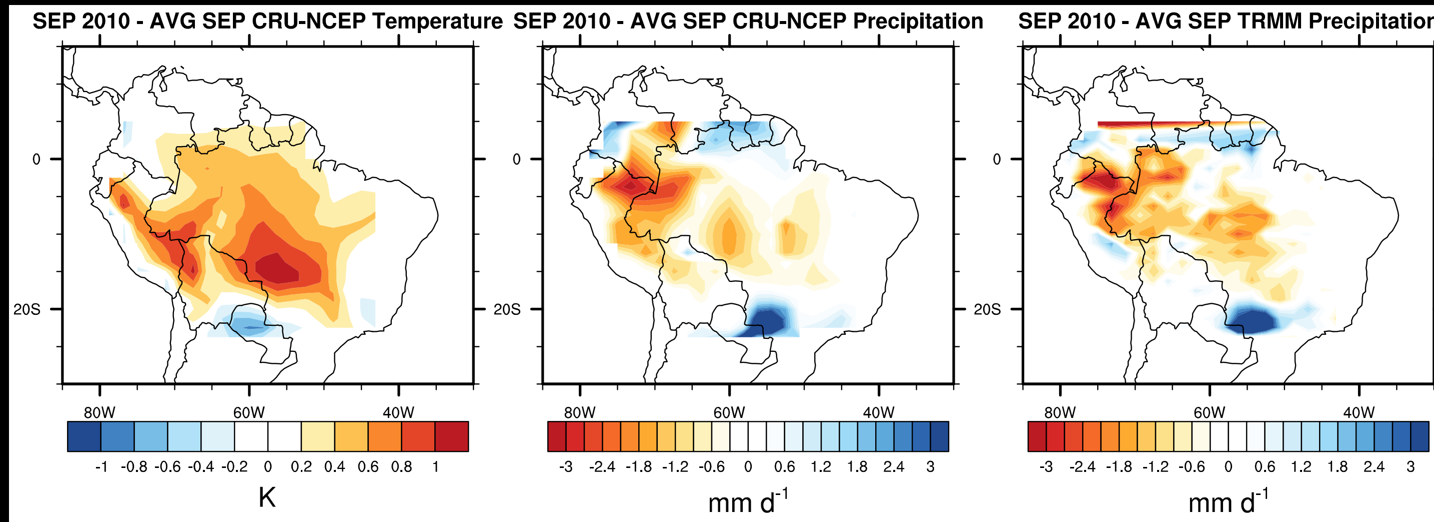
Vertically integrated water vapor flux vapor anomalies



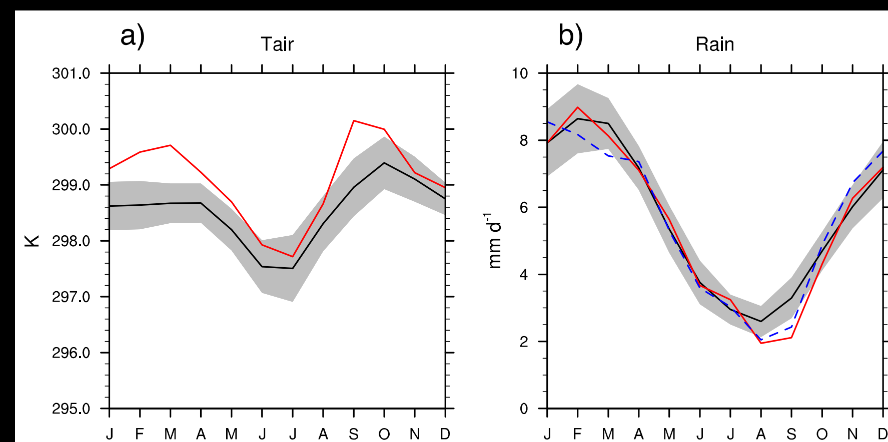
Meridional moisture flux from 0-15S

Tropical North Atlantic SSTs





- There is a tendency for an increase in dry and very dry events, especially in the southern Amazon during the dry season.
- Warming in the tropical North Atlantic can lengthen the dry season and delay wet season onset.
- In 2010, this situation was preceded by a drier than usual wet season.



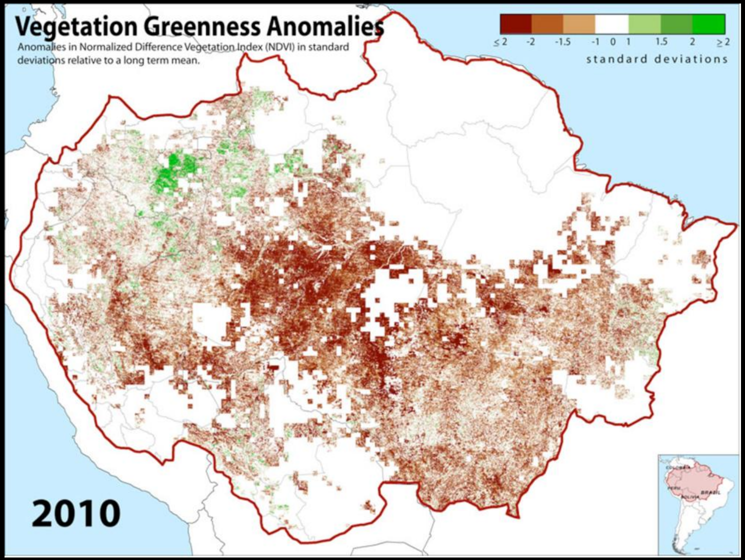
Marengo et al., GRL, 2011
Harper et al., in prep

Evidence for drought impacts

- Vegetation indices (NDVI, EVI)
- Atmospheric profile measurements
- Inversions based on profile measurements
- Forest inventory data
- Chlorophyll fluorescence

Vegetation impacts

- Widespread, severe declines in vegetation greenness over 51% of the forests affected by rainfall deficits in 2010.
- Declines persisted following the end of the dry season drought.
- Estimated 2.2 GtC of committed emissions from drought-induced mortality.

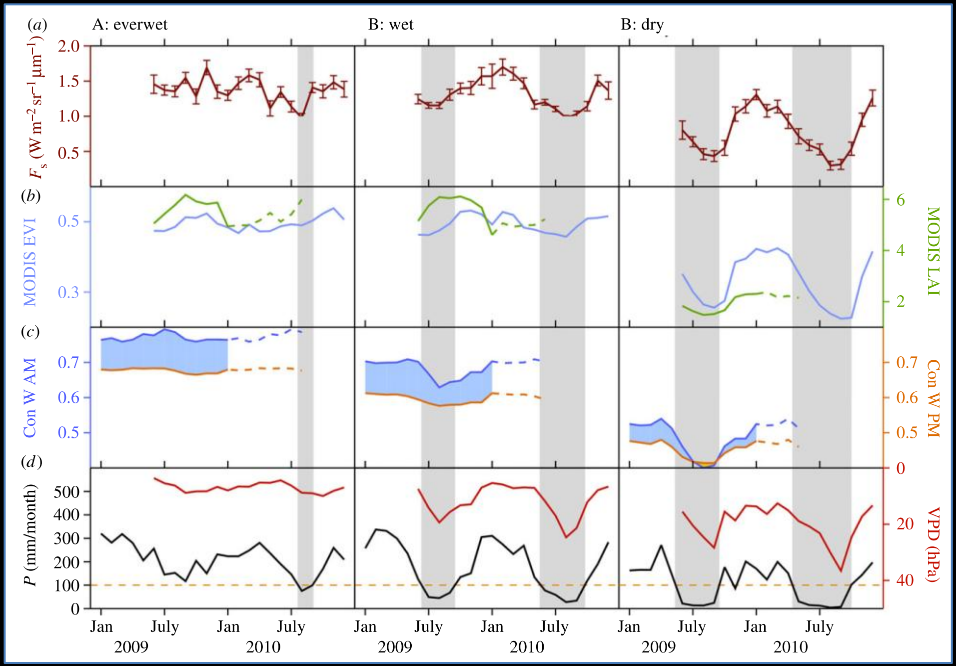


http://na.unep.net/geas/newsletter/images/Oct_11/anomalies.png

Xu et al., GRL, 2011;
Espinoza et al., GRL, 2011;
Lewis et al., Science, 2011

Drought impacts

- Drought suppressed Amazon-wide photosynthesis by 0.38 PgC, midday basin-wide GPP was reduced by 15% compared to 2009, associated with canopy water stress.
- Total NPP was constant, but autotrophic respiration in roots and stems declined significantly toward the end of the drought. Implies that trees prioritized growth.
- Following the drought, NPP was allocated to canopy more than fine roots.



Doughty et al., 2015: Nature;
Lee et al. 2013, PNAS.

Background

Typical carbon sink in the Amazon switched to a carbon source in 2010.

Region	Source	Method	Annual uptake (gC m^{-2} d^{-1})	Annual uptake (PgC yr^{-1})
		Observations		
All Amazon forests	Gatti et al. 2014	Top-down using aircraft measured CO_2	0.10±0.06	0.25±0.14
Undisturbed Amazon forests	Phillips et al. 2009; Gloor et al. 2012	Bottom-up using RAINFOR data	0.16±0.11	0.39±0.27
Undisturbed Tropical American forests	Pan et al. 2011		0.17	0.42

Region	Source	Method	2010 uptake (gC m^{-2} d^{-1})	2010 uptake (PgC yr^{-1})
		Observations		
All Amazon forests	Gatti et al. 2014	Top-down using aircraft measured CO_2	-0.19±0.07	-0.48±0.18
Undisturbed Amazon forests	Gatti et al. 2014	Top-down using aircraft measured CO_2, excluding fire emissions	0.01±0.09	0.02±0.22

Harper et al., in prep

Background

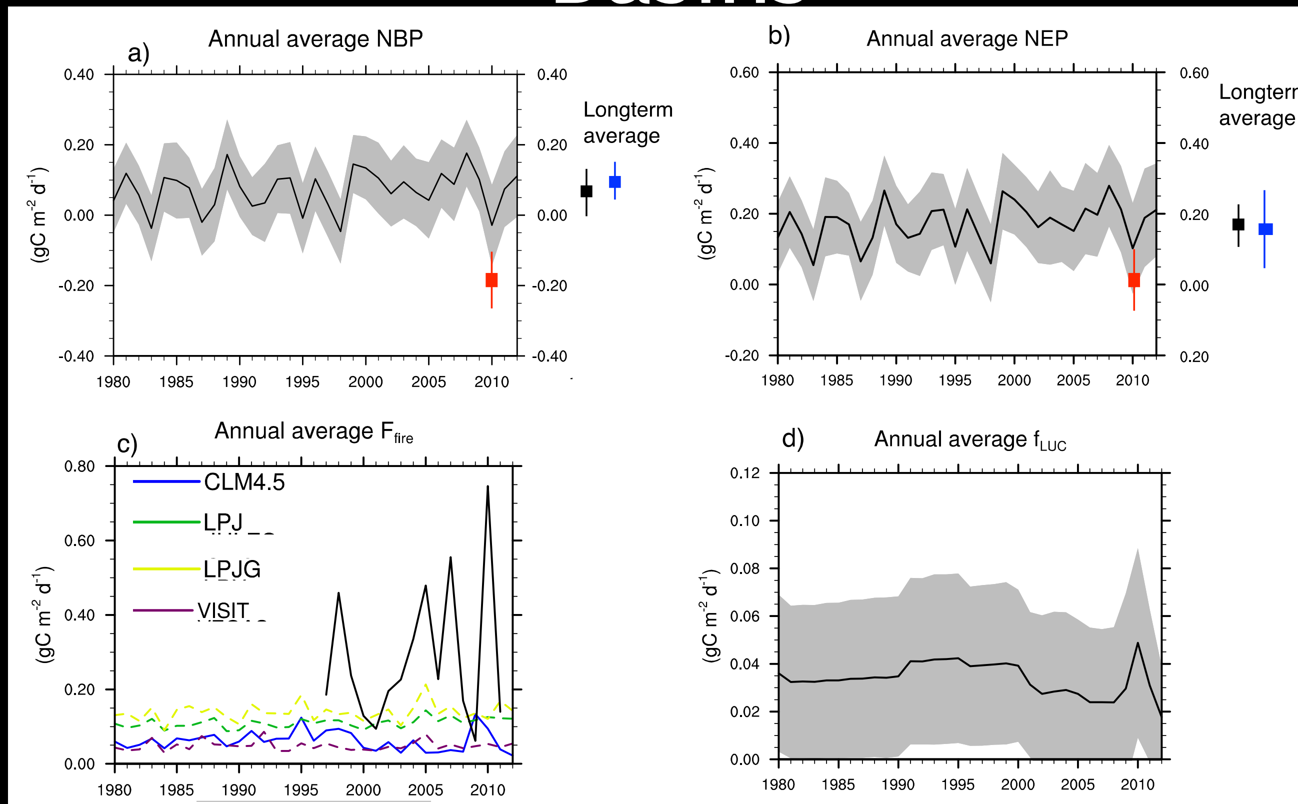
- Are models able to capture these basin-scale responses?
- Was an anomaly in GPP or Respiration more to blame for anomalous 2010 NEP?
- What was the effect on NPP?

Flux	Observed difference: 2010-2011 (PgC/yr)
NBP	-0.73
Fire	0.22
GPP	-0.38±0.15 -0.25±0.15 -0.52
NPP	No change at forest plots.
Ra	Drought reduced maintenance Ra in stems and roots
NEP	-0.37
Rh	No change?

Methods

- TRENDY experiment S3: CO_2 + climate + land use change
- 10 DGVMs ran from PI-2012

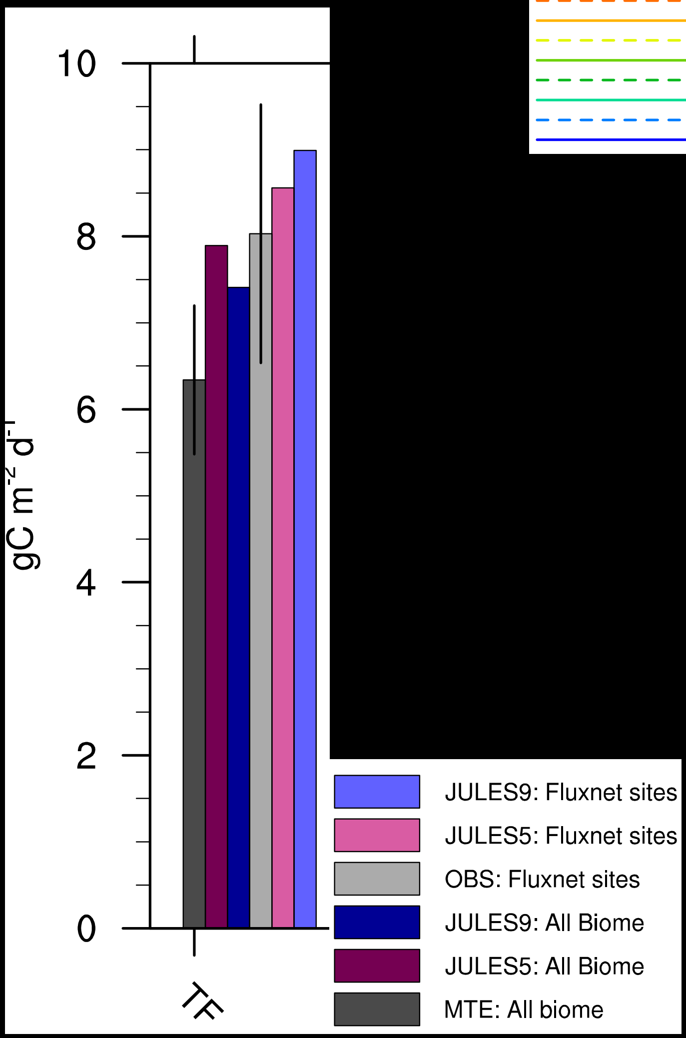
Results: Amazon+Tocantins River Basins

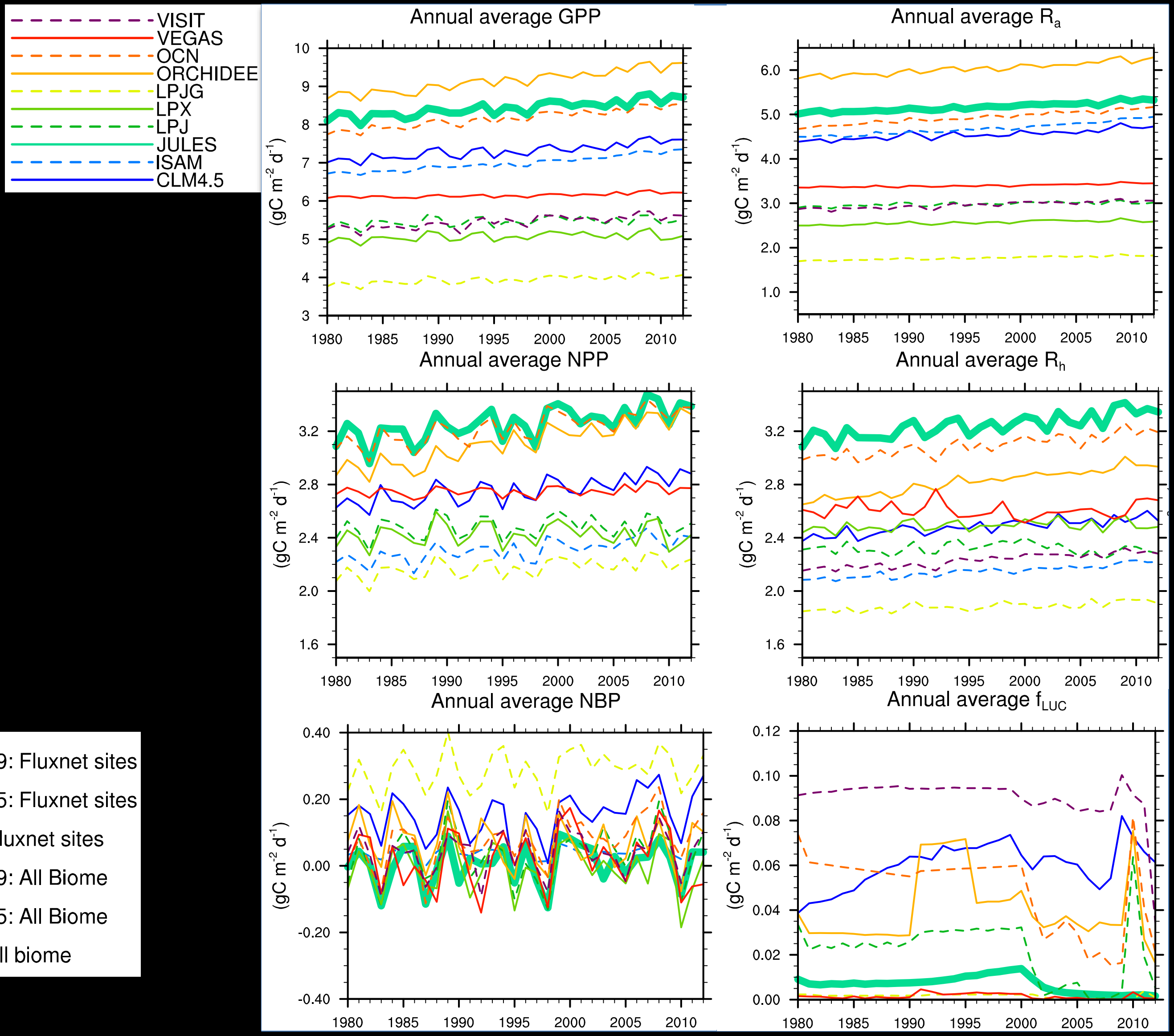


- $NBP = GPP - R_h - R_a - F_{fire} - F_{LUC}$
- $NEP = GPP - R_h - R_a$
- The difference between NEP and NBP is fire and land use emissions – indicating these fluxes were underestimated in the models during the drought.

Harper et al., in prep

JULES fluxes





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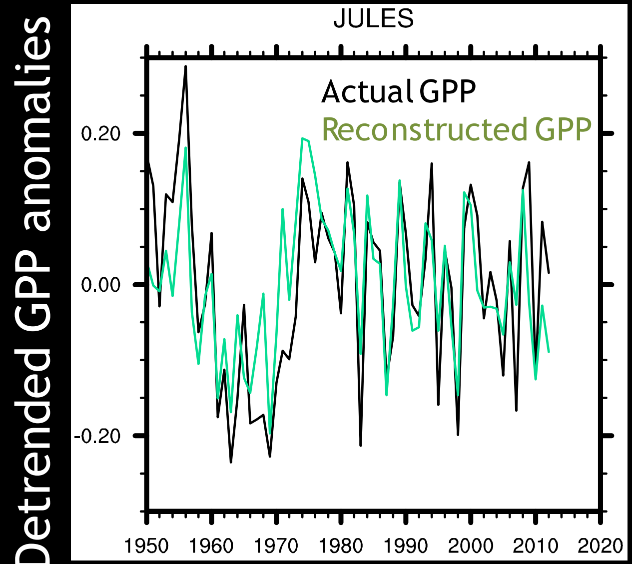
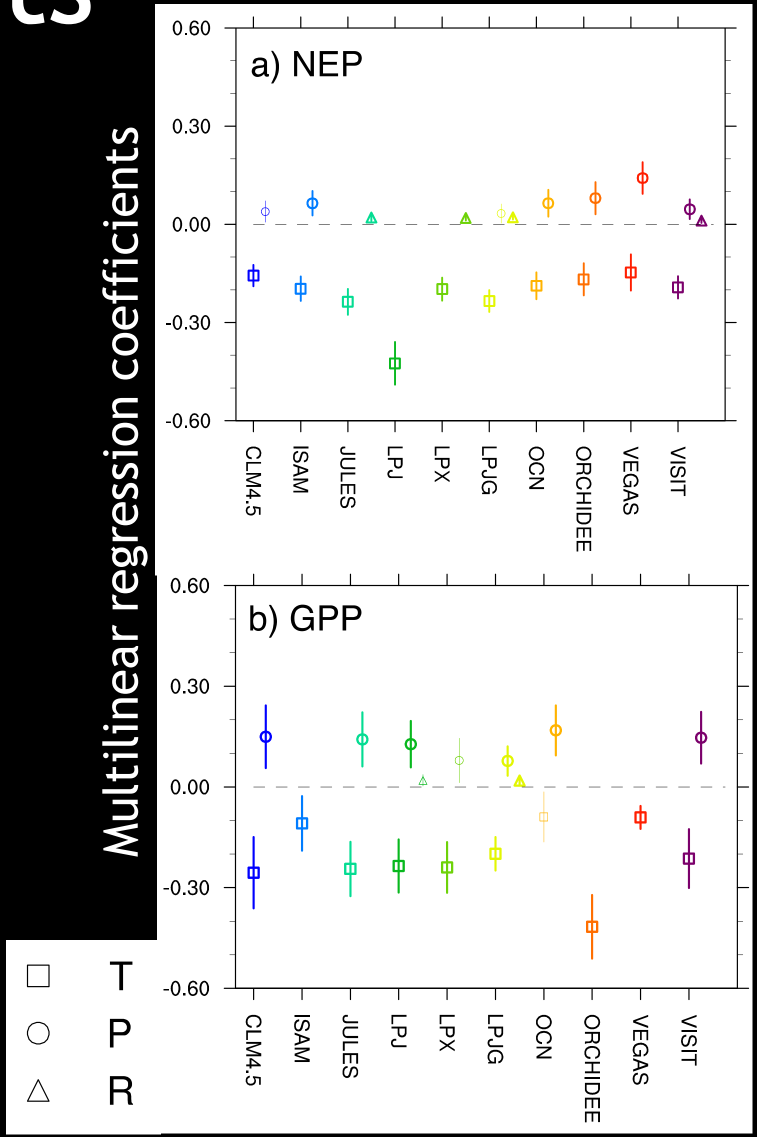
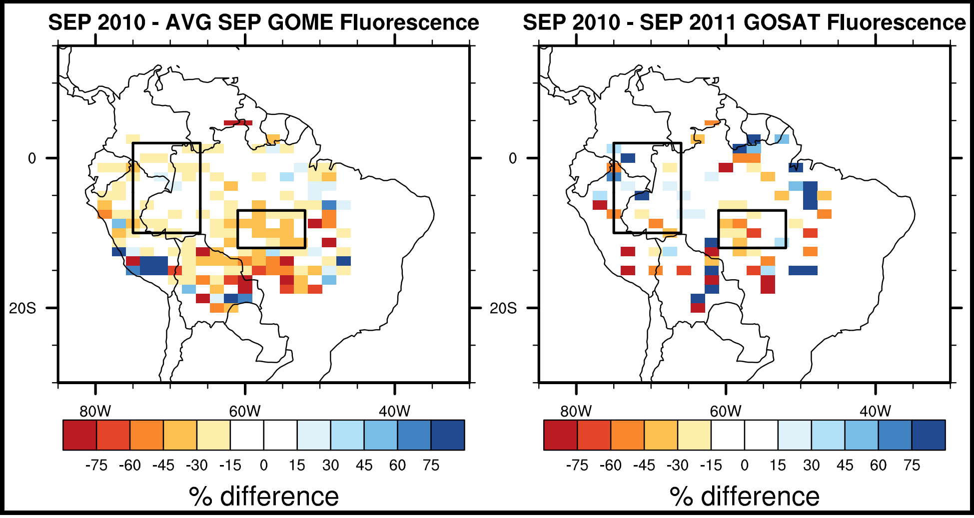
Results

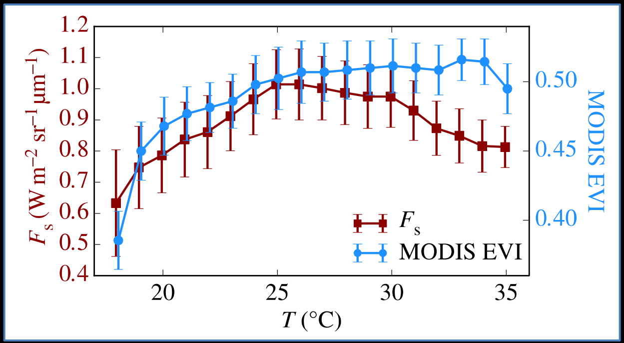
- Modeled reductions in GPP were reasonable in 2010 – but were they for the correct reasons?
- 57% of the variation in JULES' interannual, detrended GPP can be recreated *from temperature and precipitation anomalies alone*.

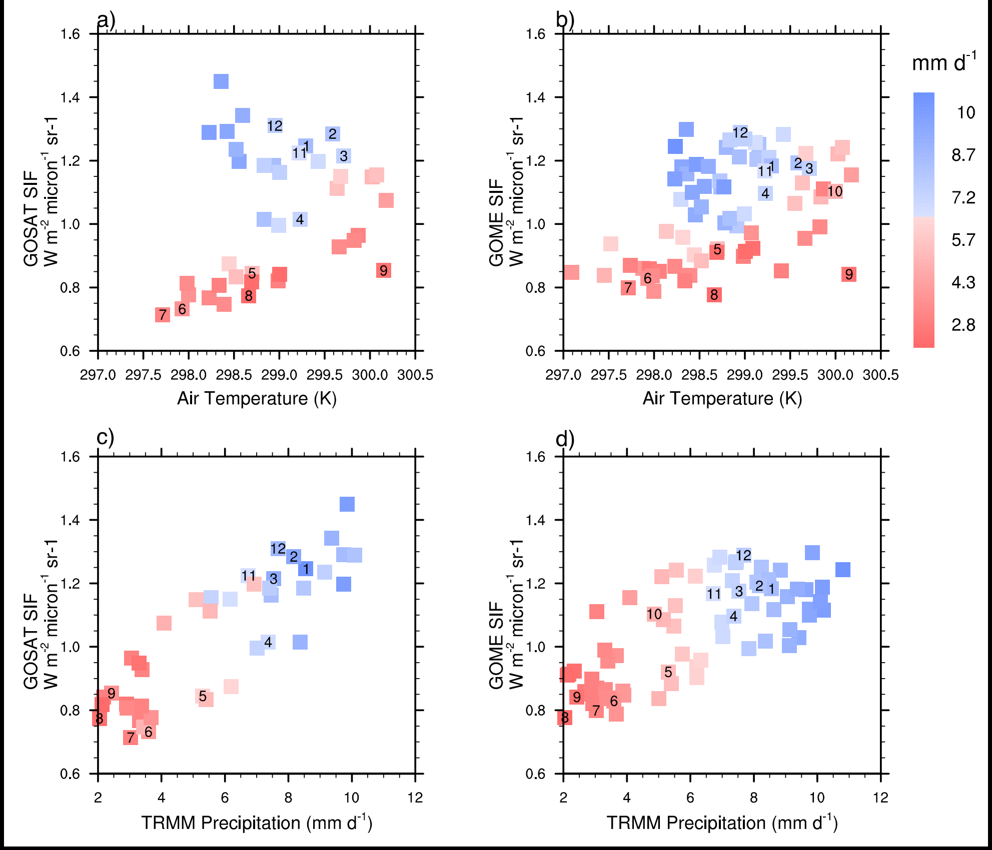




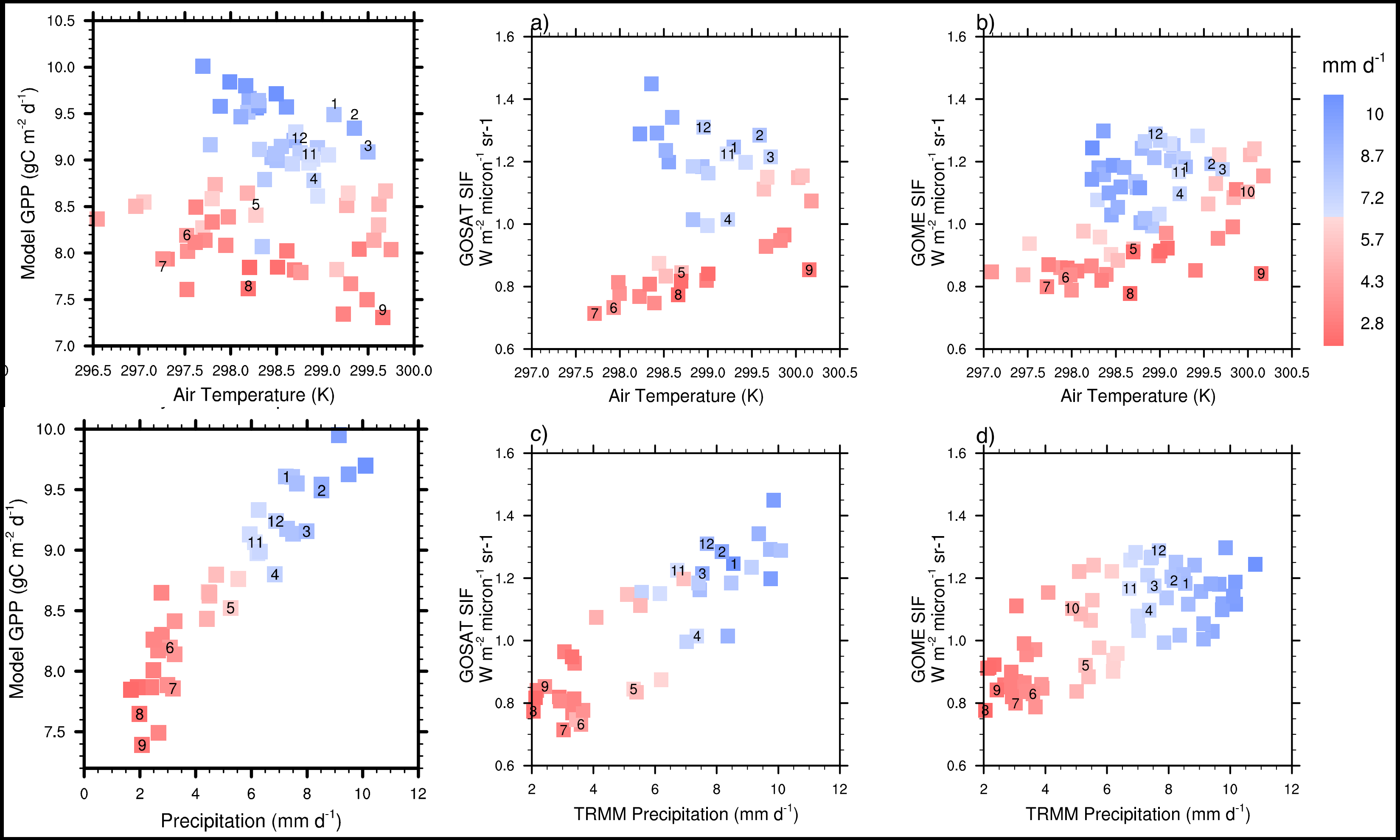
- How can we assess basin-wide temperature sensitivity?
- Fluorescence: observable from satellites



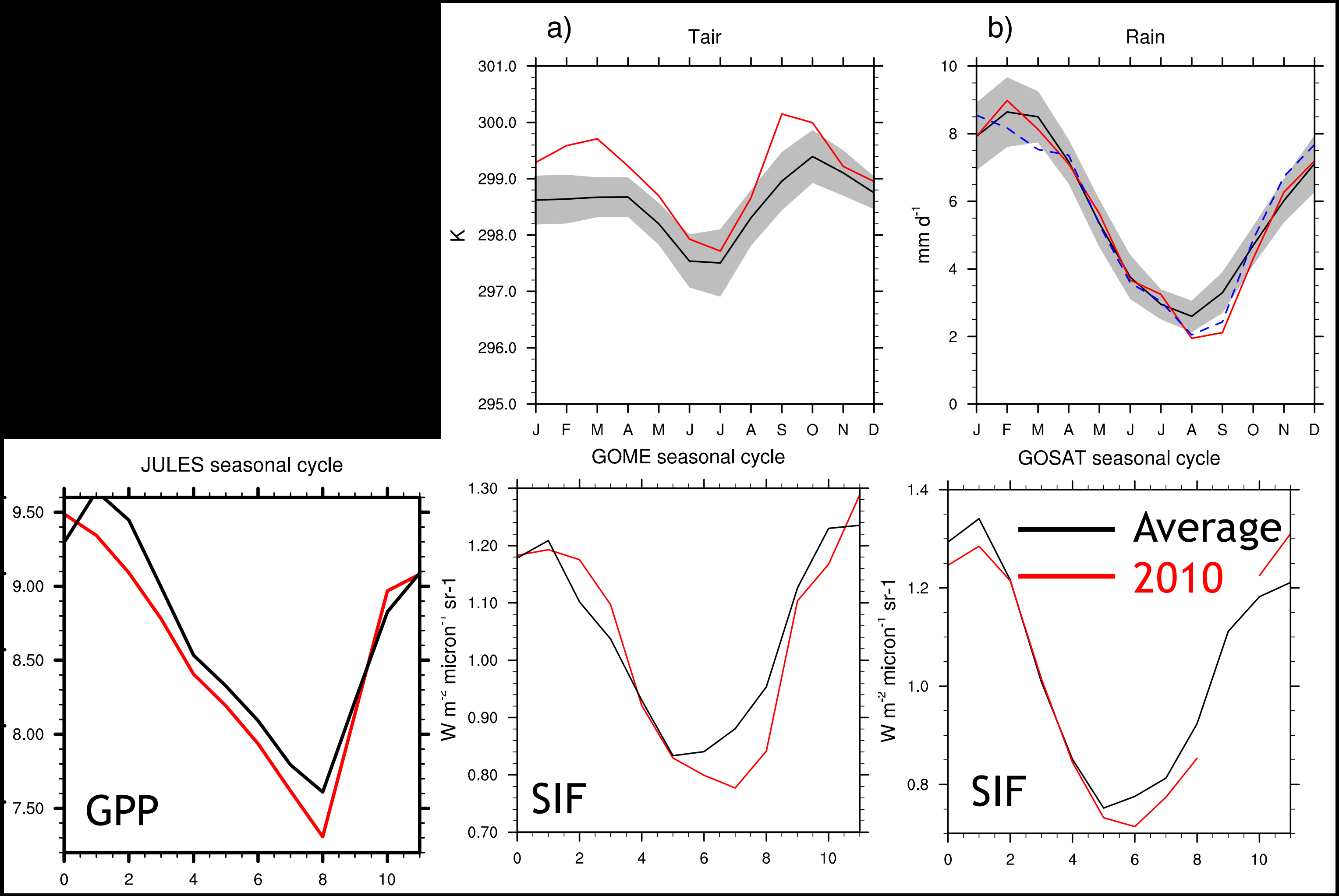




Results: Temperature sensitivity



Implication of temperature sensitivity



Conclusions

- GPP in the models is still over-sensitive to temperature, and undersensitive to precipitation and radiation (agrees with findings from Galbraith et al. 2010, Rowland et al. 2015).
  - What is the role of seasonal phenology?
- There is now a tropical PFT (not used in these experiments), but what other diverse plant types would help capture complex responses in the Amazon?
- It would help to have carbon storage
  - Nonstructural carbohydrates can store previously assimilated carbon to be used during times of drought (Doughty et al. 2015).
- Many processes still missing: Fires, temperature acclimation, and mortality

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Results: Temperature sensitivity