

Carbon and Water Exchange in Amazonian Rainforests

Lucy R. Hutyra



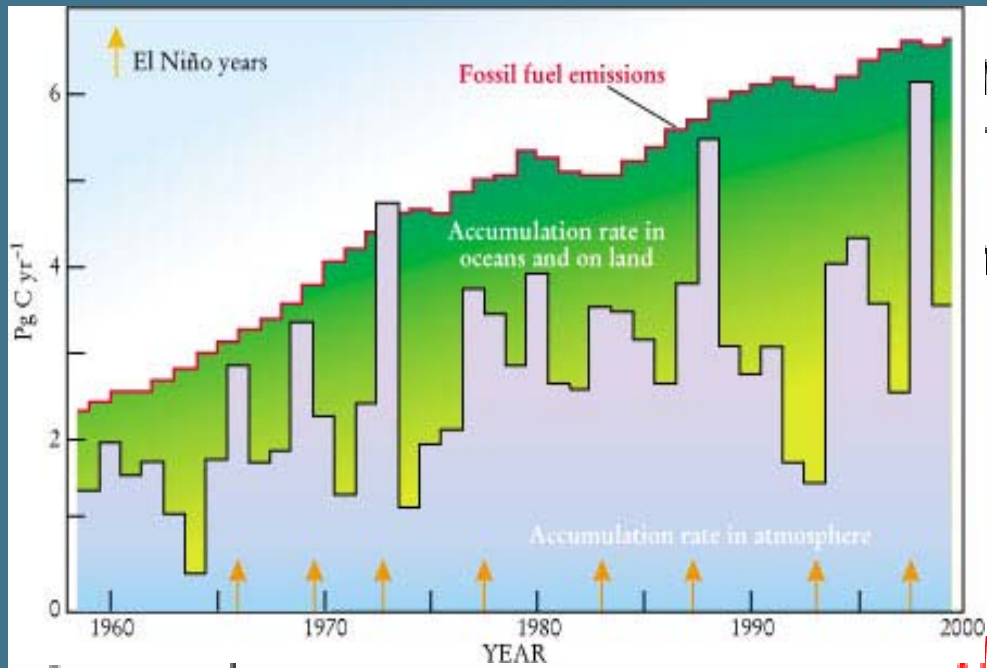
Water Center Seminar

February 19, 2008

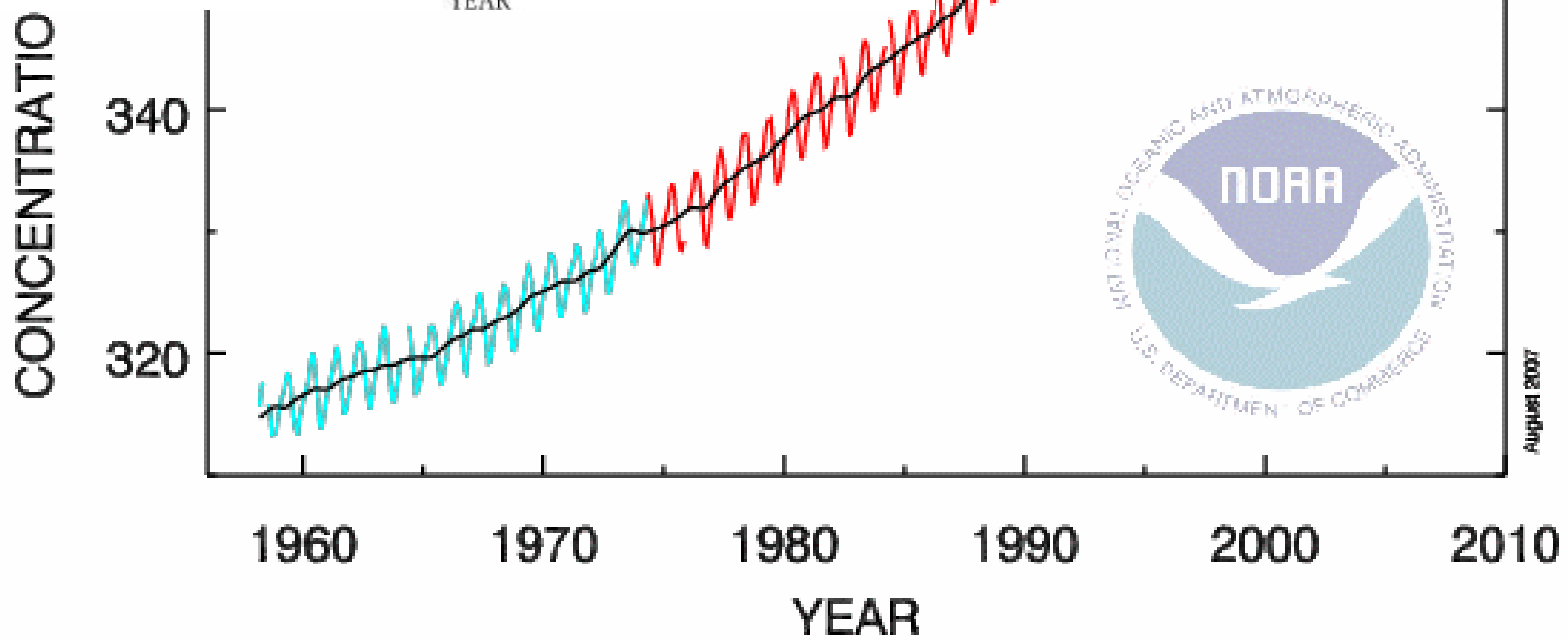


- Scientific background & Amazonian characteristics
- Controls on the net ecosystem exchange of CO₂, photosynthesis, and respiration
- Is forest growth currently water limited?
- How does logging impact the carbon exchange processes?

Mauna Loa Observatory



CO₂ Concentration



August 2007



Tropical rainforests occupy about ~12% of the terrestrial surface, and contain ~ 50% of the carbon stored in terrestrial biomass [*Whittaker and Likens, 1975*].

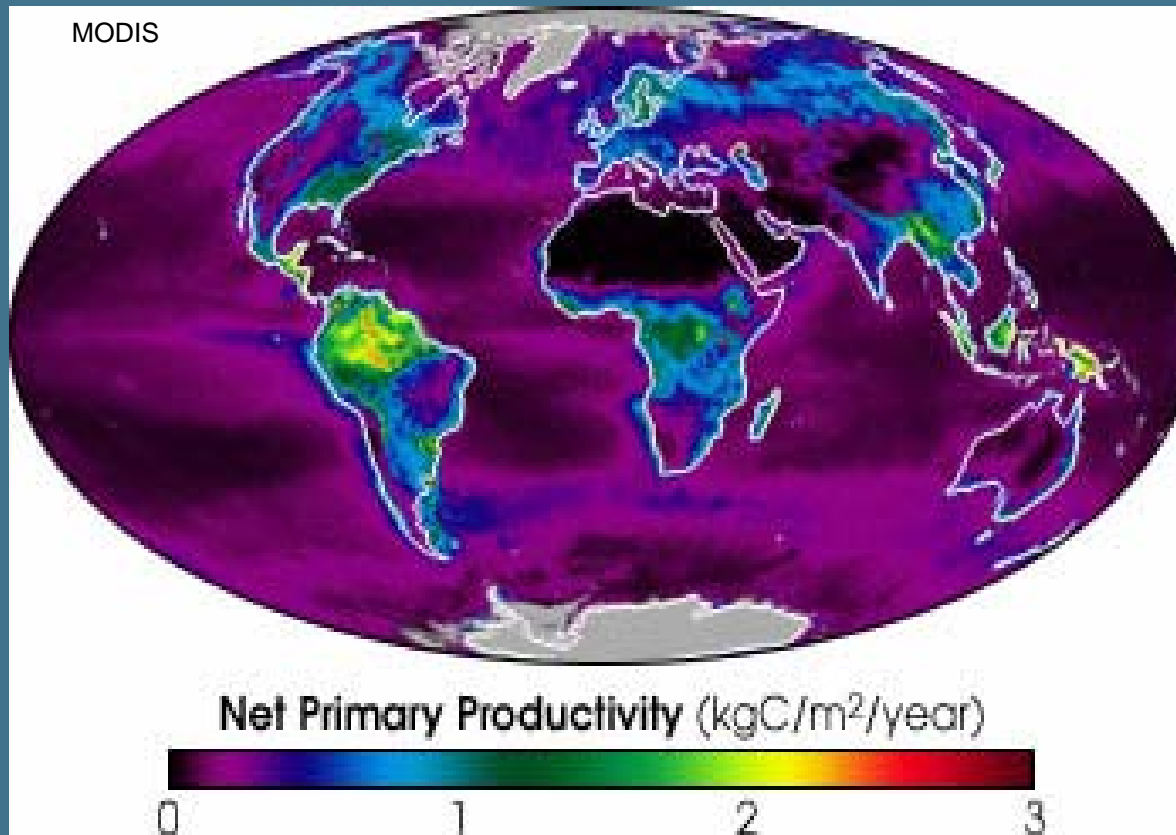
The Amazon at a Glance

- Basin area 7 million sq km (2.7 million mi²)
- 1/4th of the world's species
- 20% of world's flow of freshwater
- 7 trillion tons of water evaporated each year
- Average Brazilian Deforestation: 18,000 km² since 1990
- % Deforested: 16 (650,000 km²)
- Population: Approximately 30 million
- Indigenous Population: 20 million
- 70 billion tons of carbon stored in biomass
- Amazonian Countries: Brazil; Peru, Ecuador, Bolivia, Colombia, Venezuela, Guyana, French Guyana and Surinam.



Is the Amazon a source or sink of atmospheric CO₂?

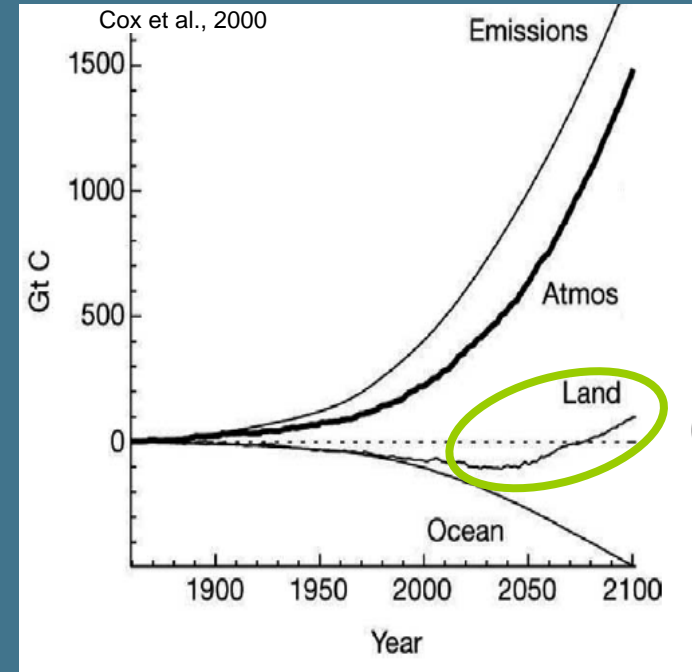
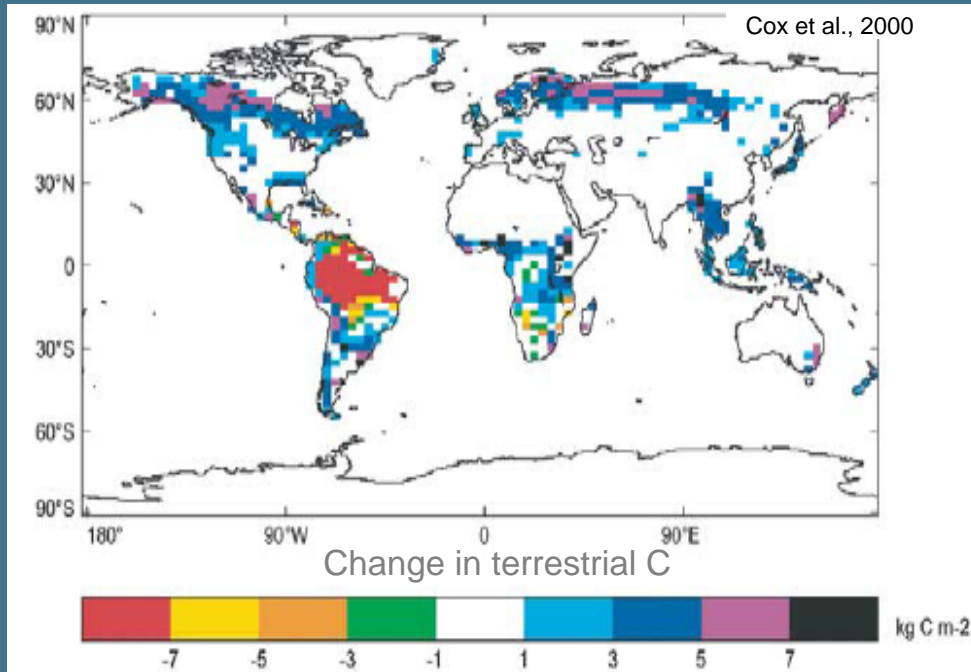
Amazonian rainforests are estimated to be a sink for carbon, ranging from 0.3 to 1.0 Pg C yr⁻¹ [*Baker et al.*, 2004; *Andreae et al.*, 2002].



If there is a carbon sink, is it stable?

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“Amazonia emerges as especially vulnerable ecosystem with significant risks from drought, climate-induced forest dieback, and wildfire” [Scholze *et al.*, 2006; IPCC]



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So, we're left with big questions and unclear answers.

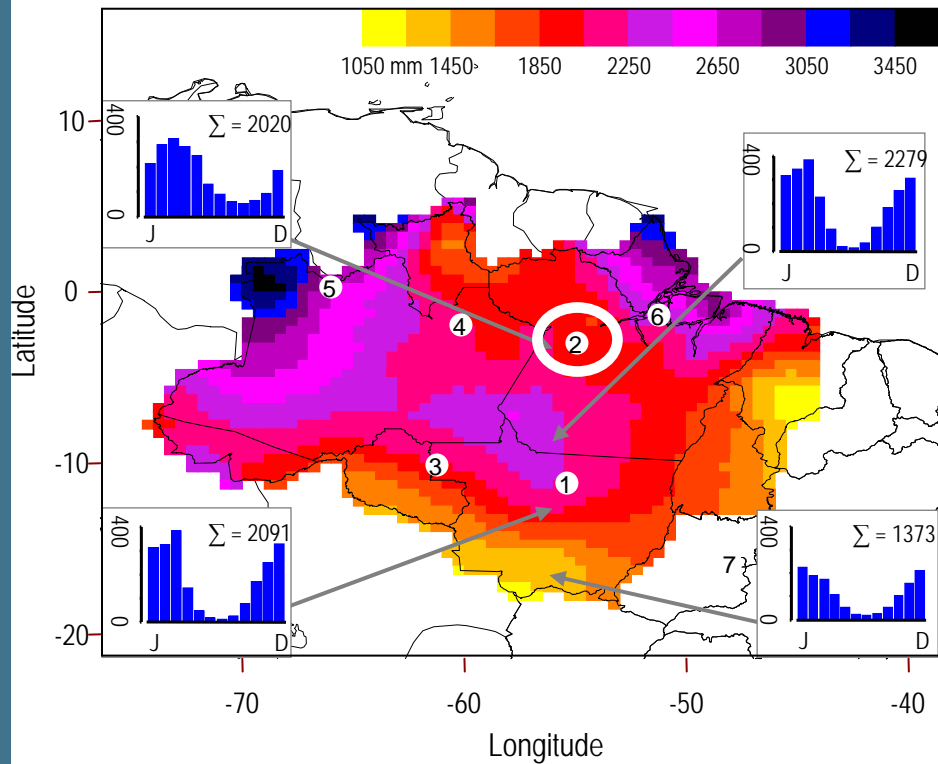
One of the big challenges is that we don't have a solid grasp of the mechanisms that control carbon exchange. Further, we don't know how exchange processes will adjust with a changing climate and continued deforestation.



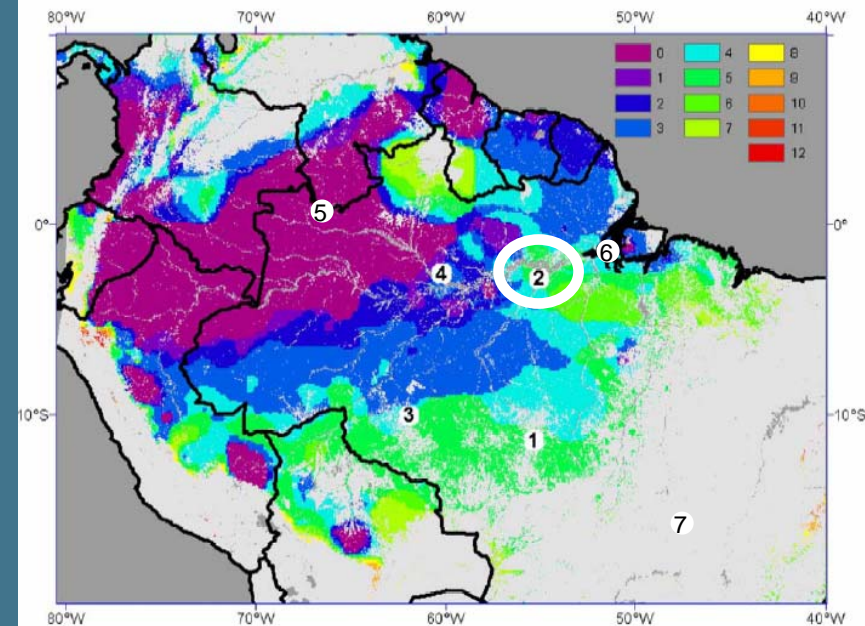
MODIS

High spatial variability in both the annual precipitation and the length of the dry season

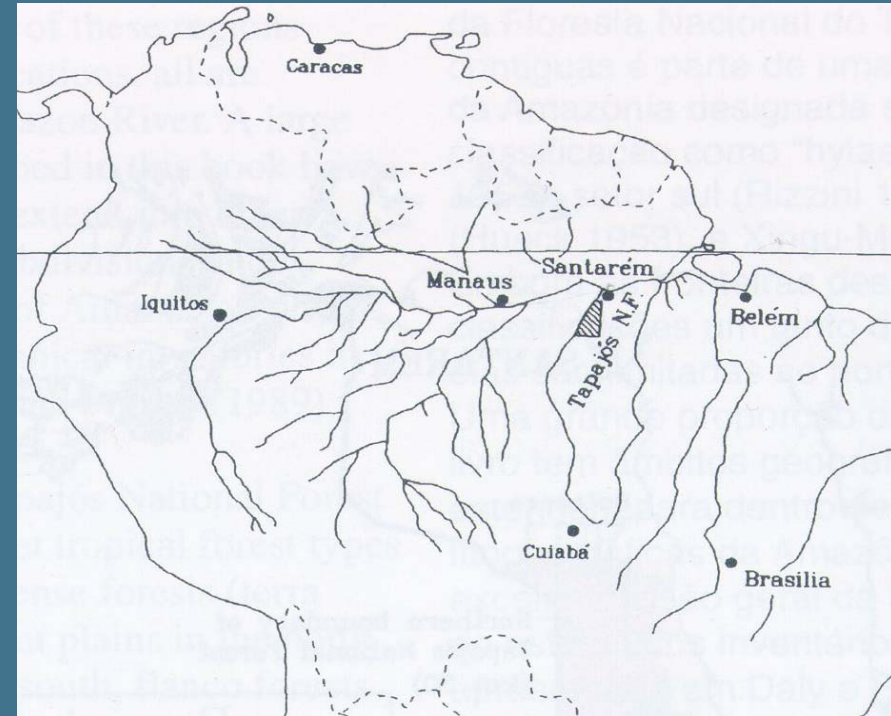
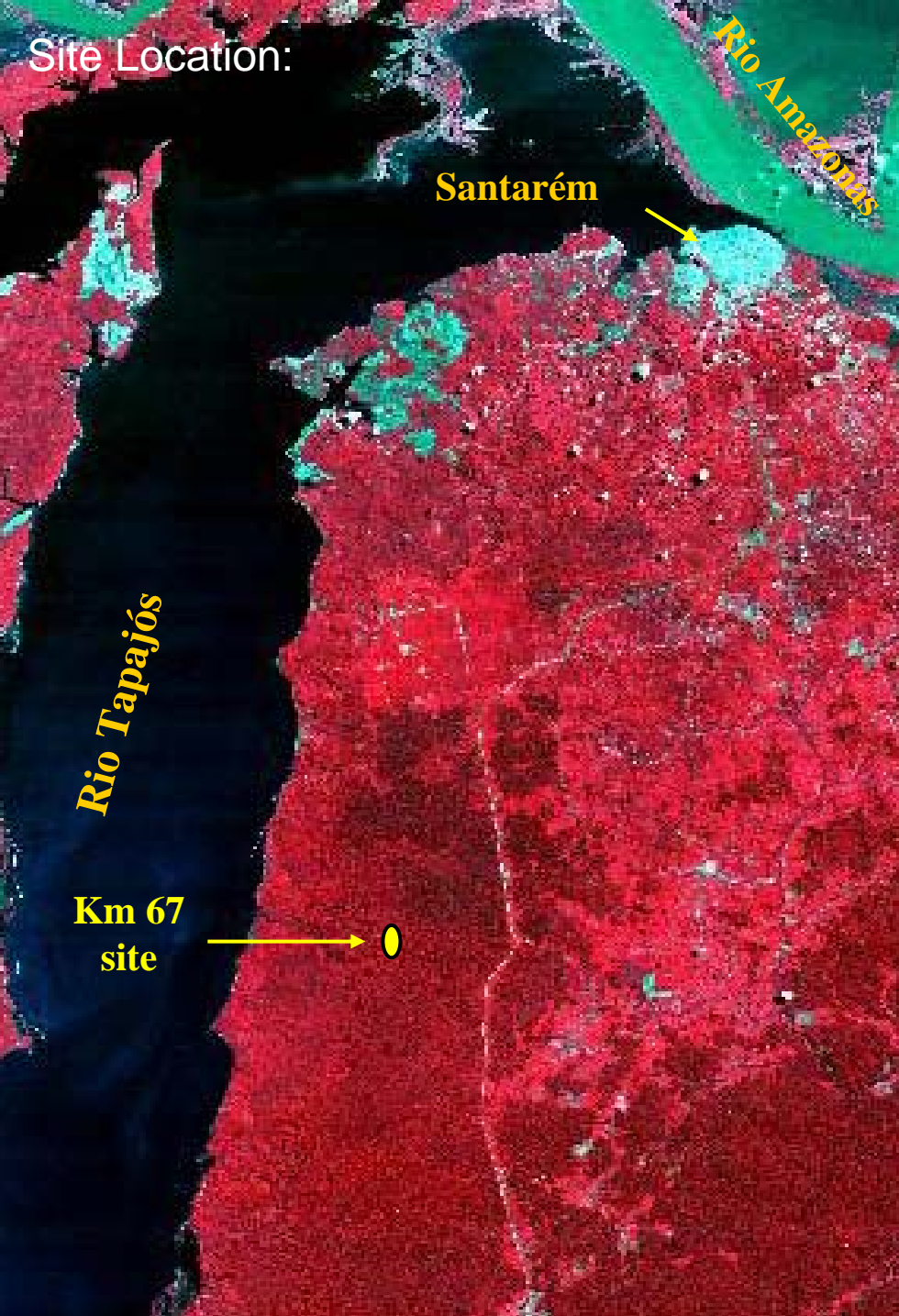
Annual Precipitation

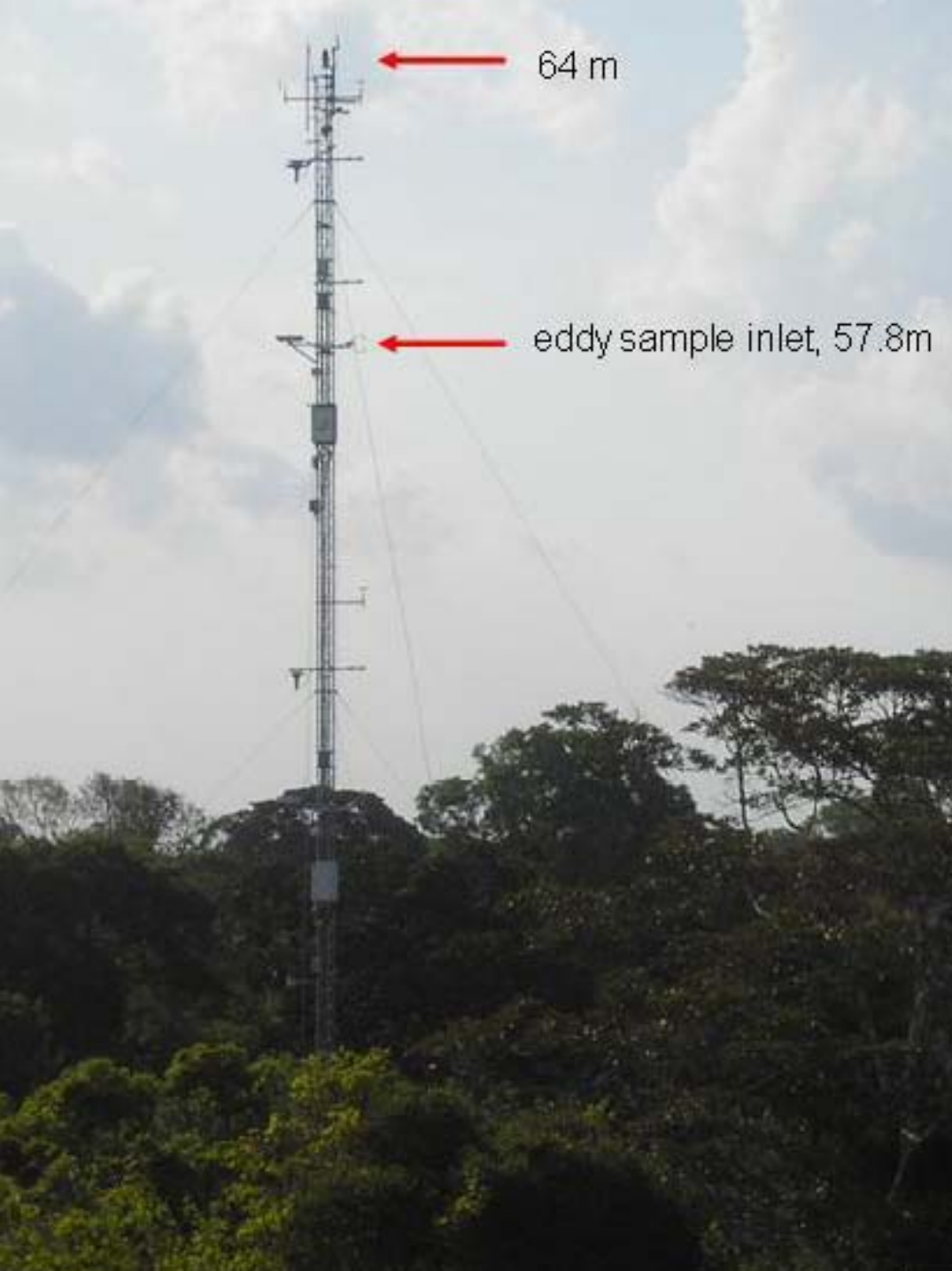


Dry season Length



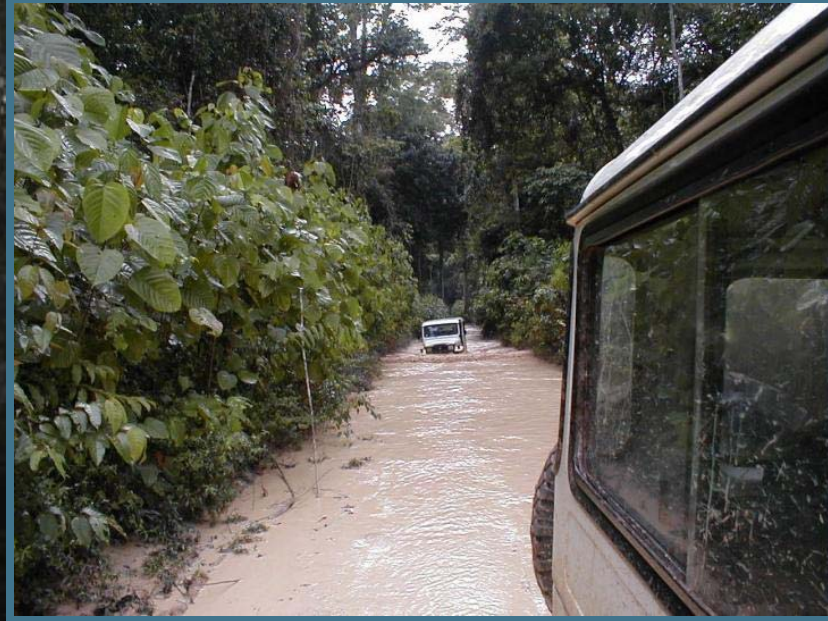
Site Location:





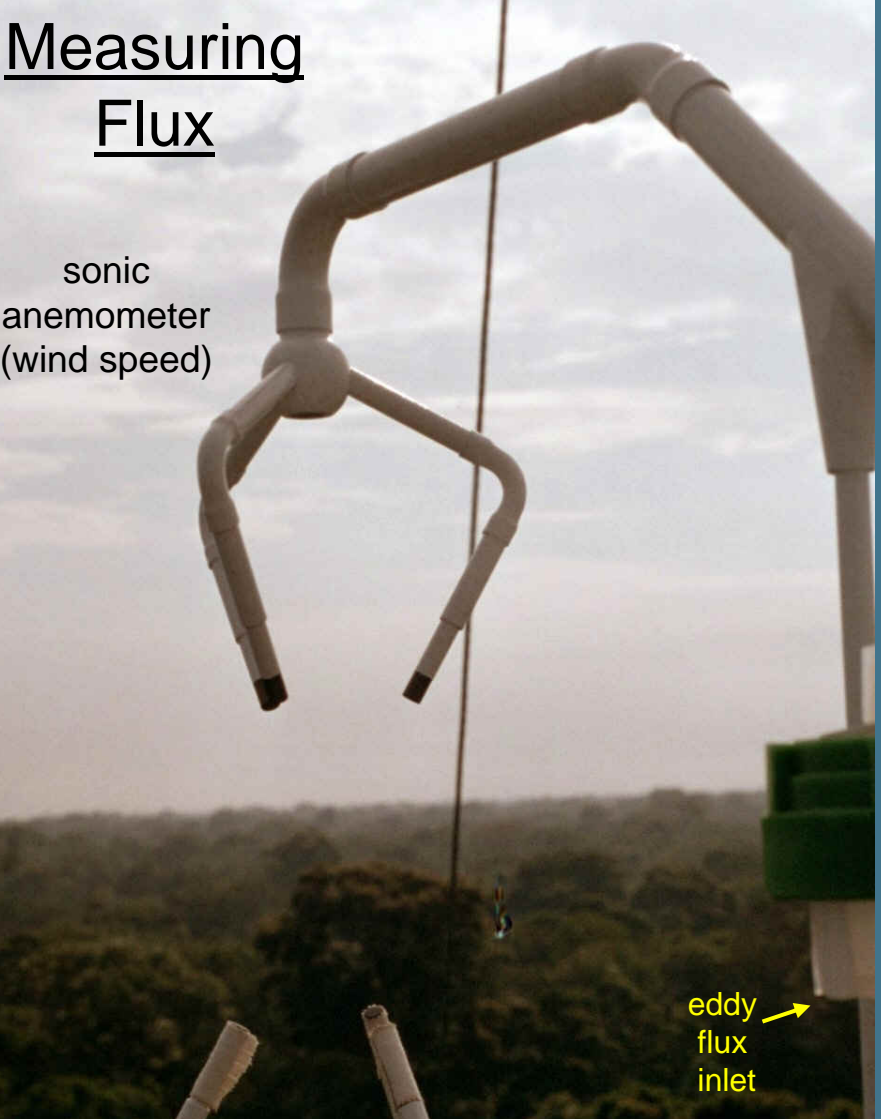
Primary, tropical rainforest:

Flat terrain,
closed canopy (~45m)
clay soils,
deep water table,
5 month dry season



Measuring Flux

sonic anemometer (wind speed)

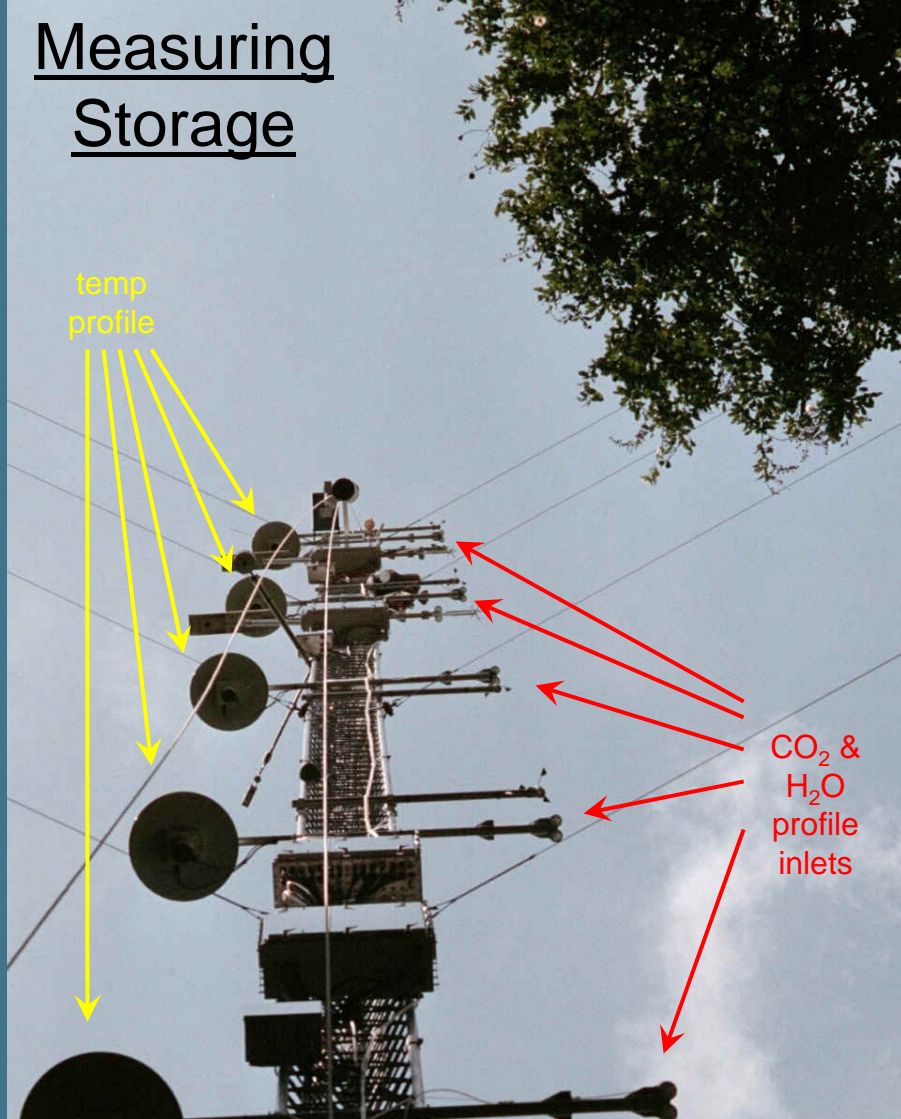


eddy flux inlet

Measuring Storage

temp profile

CO₂ & H₂O profile inlets



Definition: Net Ecosystem Exchange:

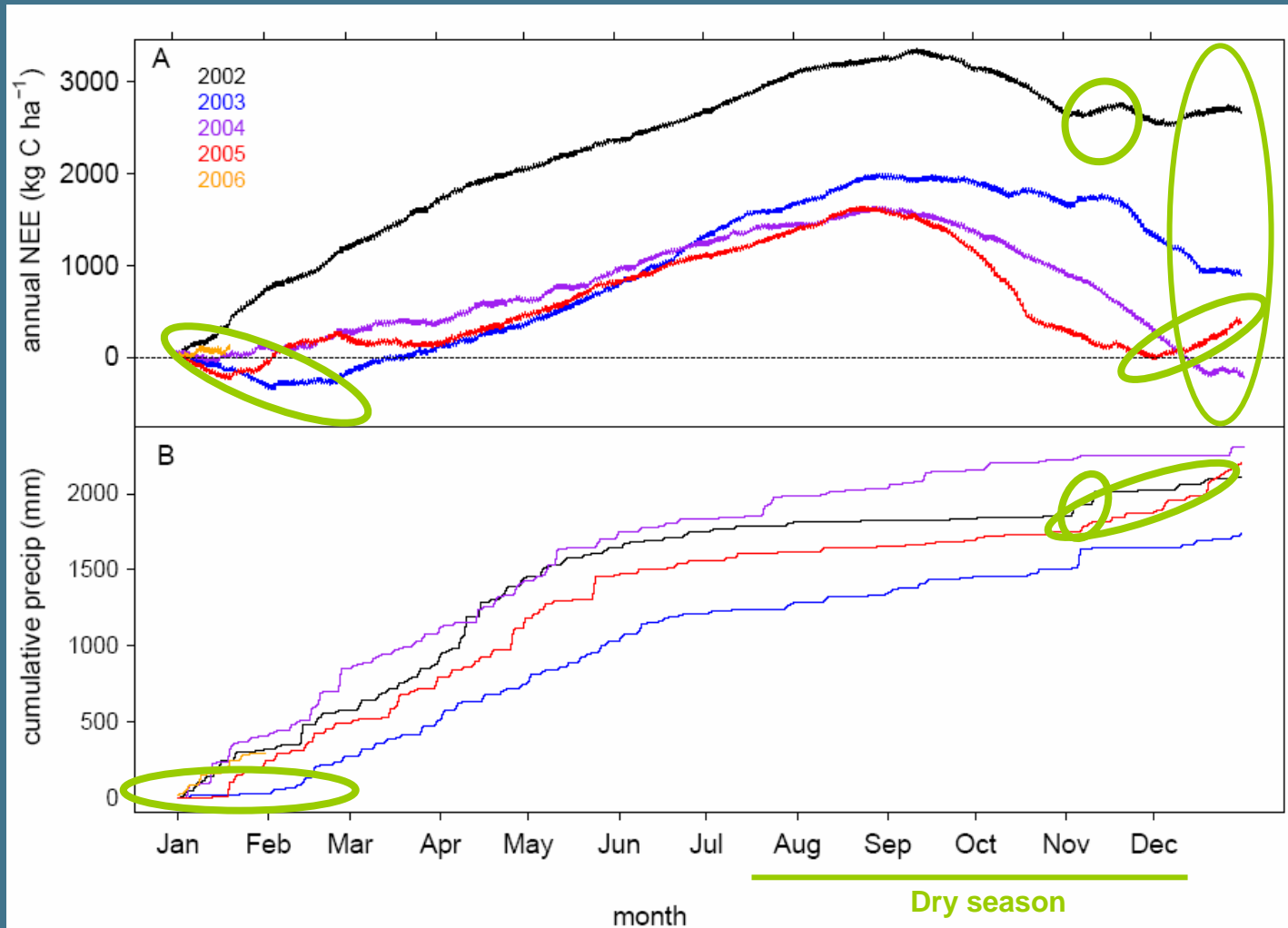
$$NEE = \underbrace{\text{Eddy Flux}}_{\text{Flux out the top}} + \underbrace{\frac{d}{dt} \langle \text{canopy storage} \rangle}_{\text{"Storage flux"}}$$

What are the controls on the Net Ecosystem Exchange of CO₂ (NEE)?

$$\text{NEE} = \text{respiration} - \text{photosynthesis}$$

(C loss) (C uptake)

→ **small residual**

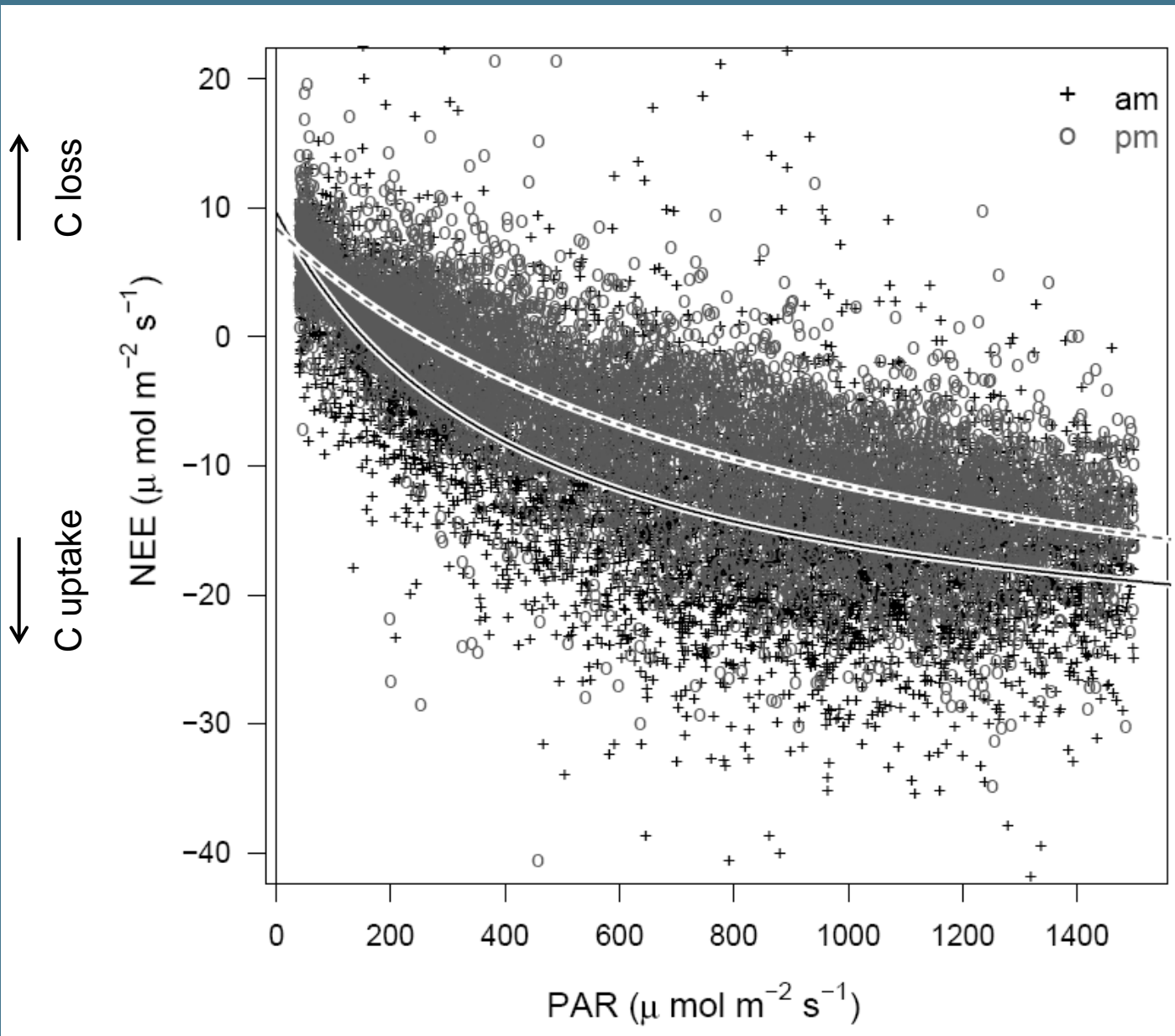


- strong seasonality

- large inter-annual variability

- sensitive to dry season P

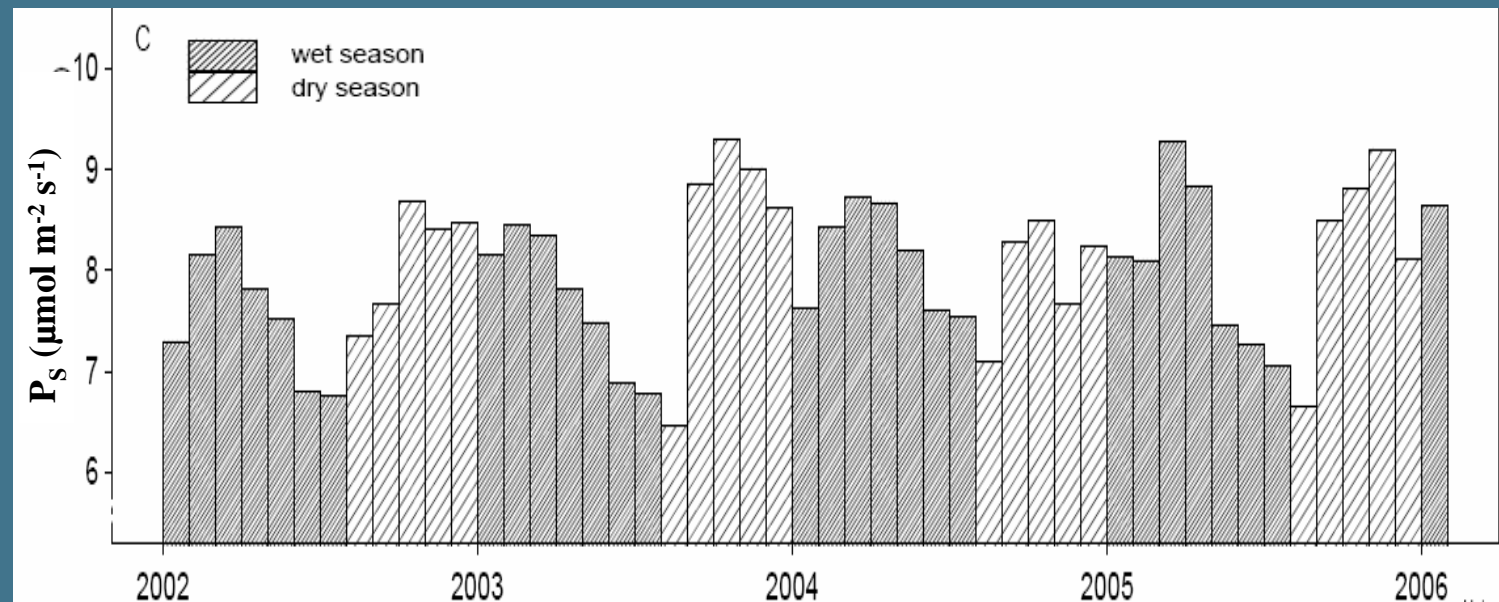
What are the controls on photosynthesis?



- Light

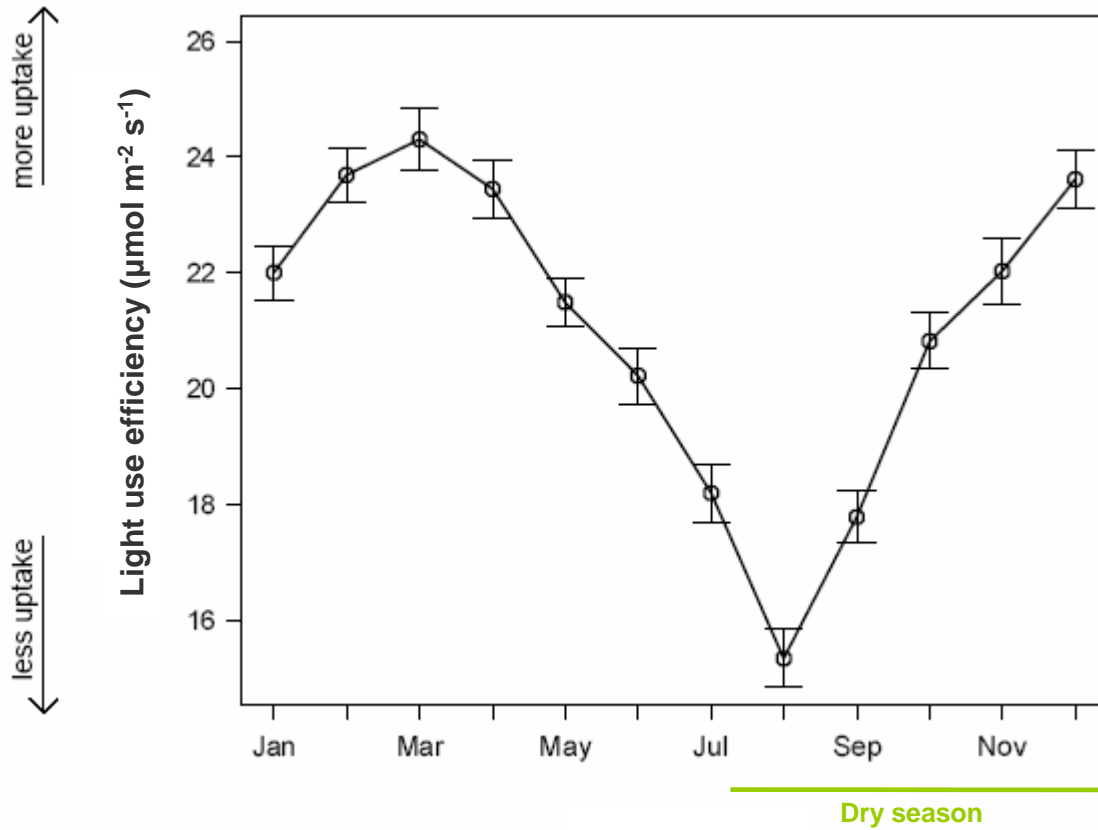
What are the controls on photosynthesis?

- Light
- Seasonality

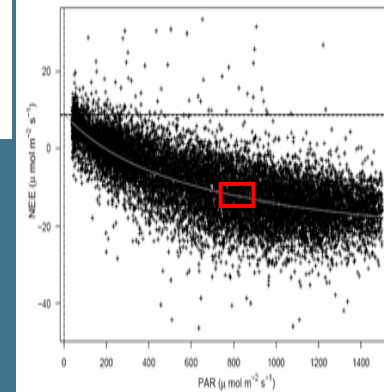


But, both light & moisture change seasonally...

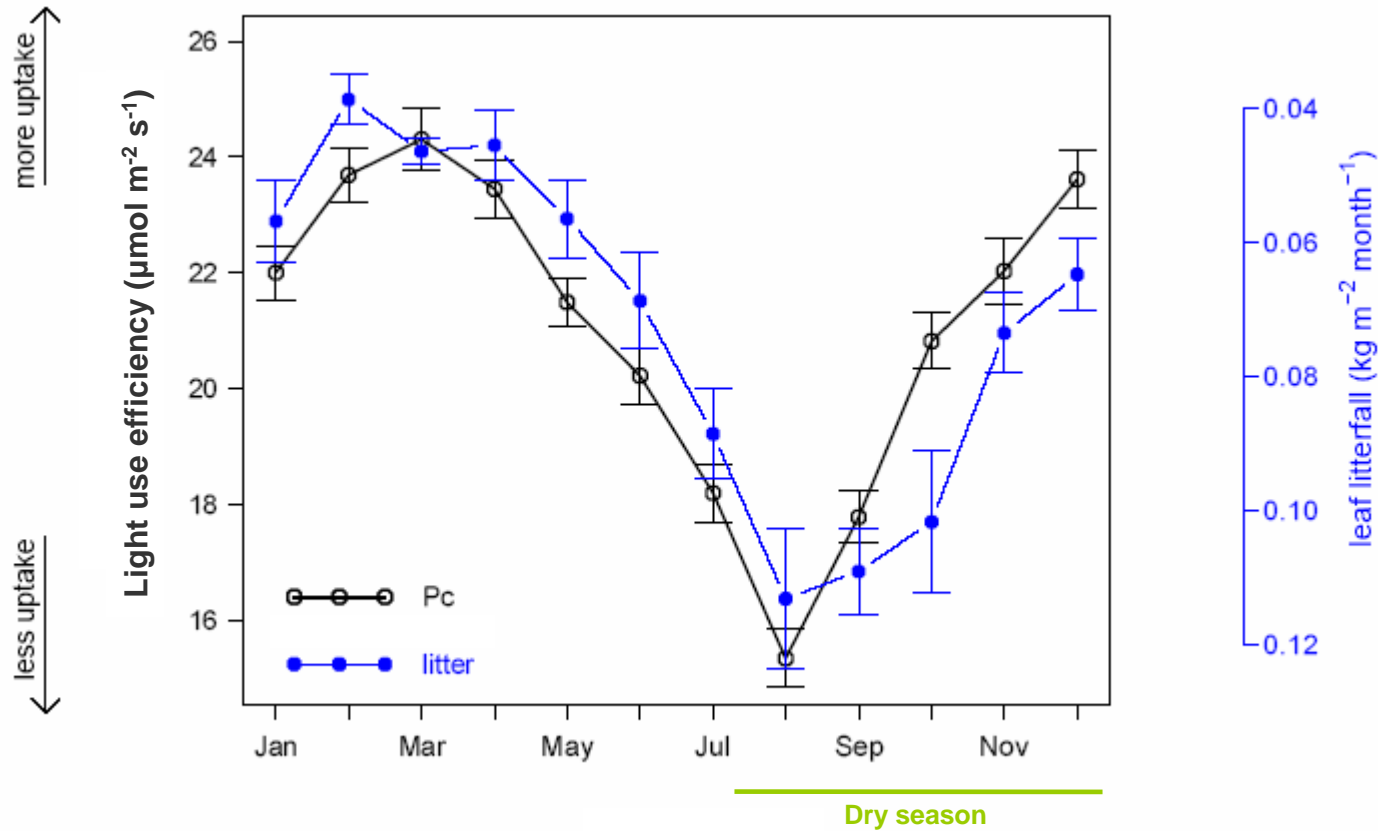
What are the controls on photosynthesis?



- Light
- Seasonality



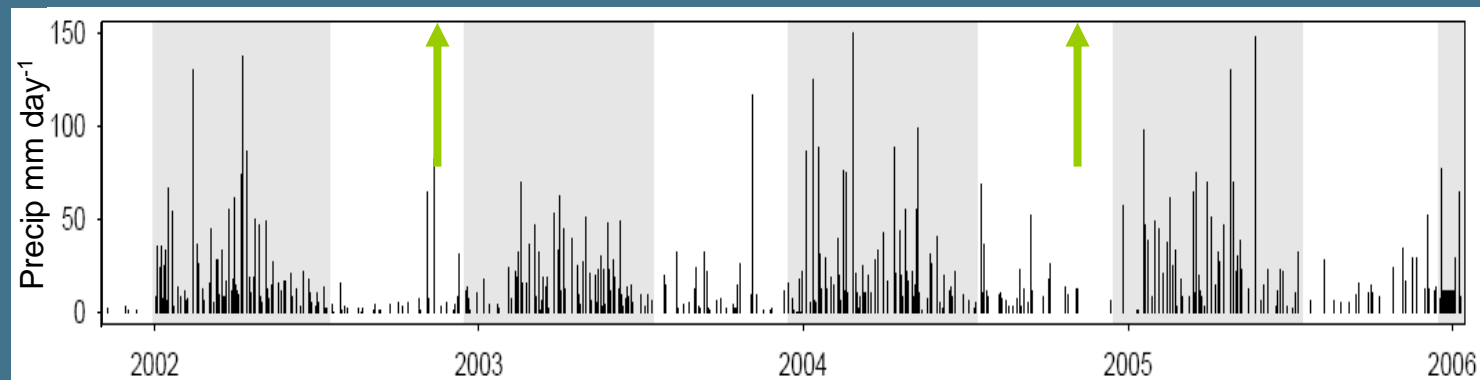
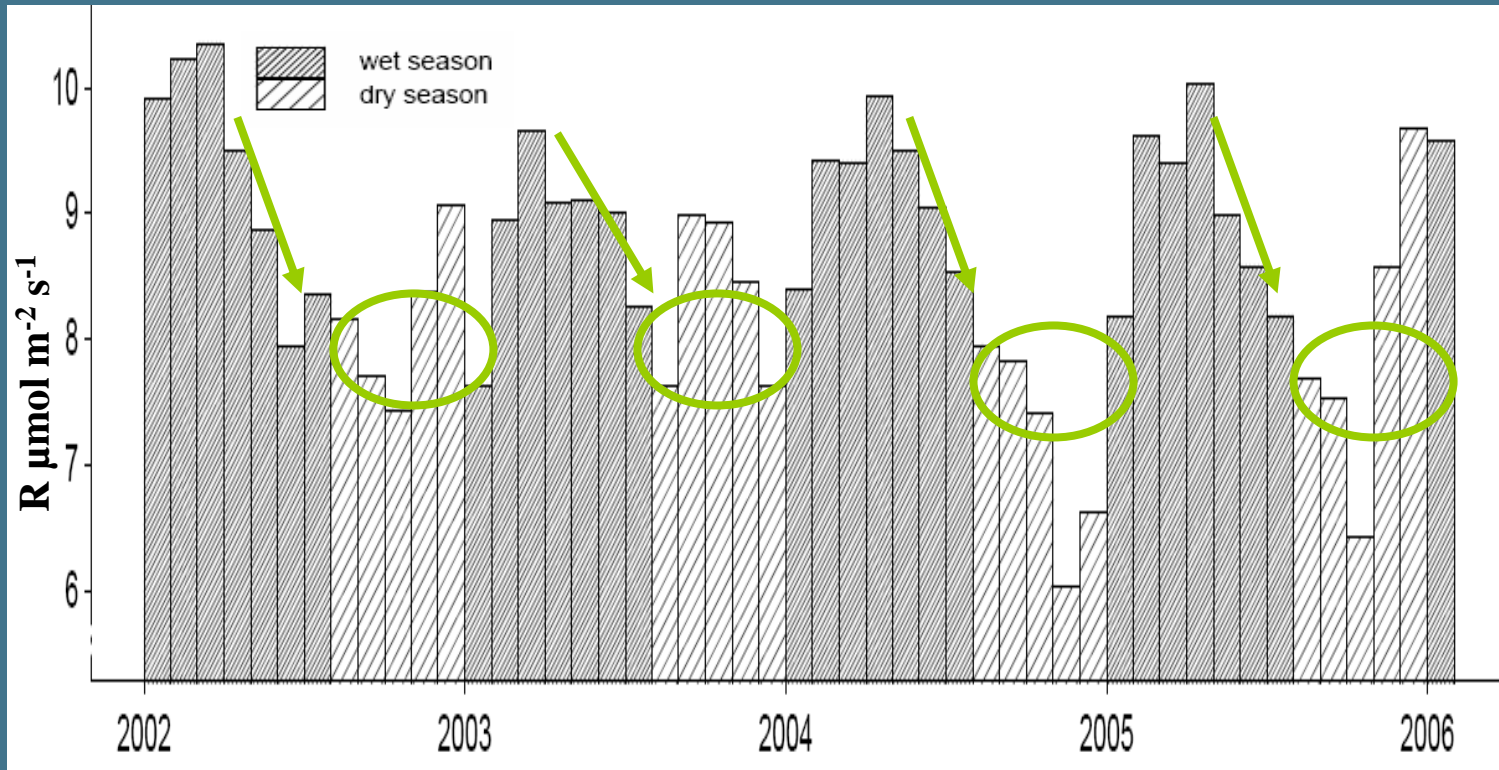
What are the controls on photosynthesis?



- Light
- Seasonality
- Phenology

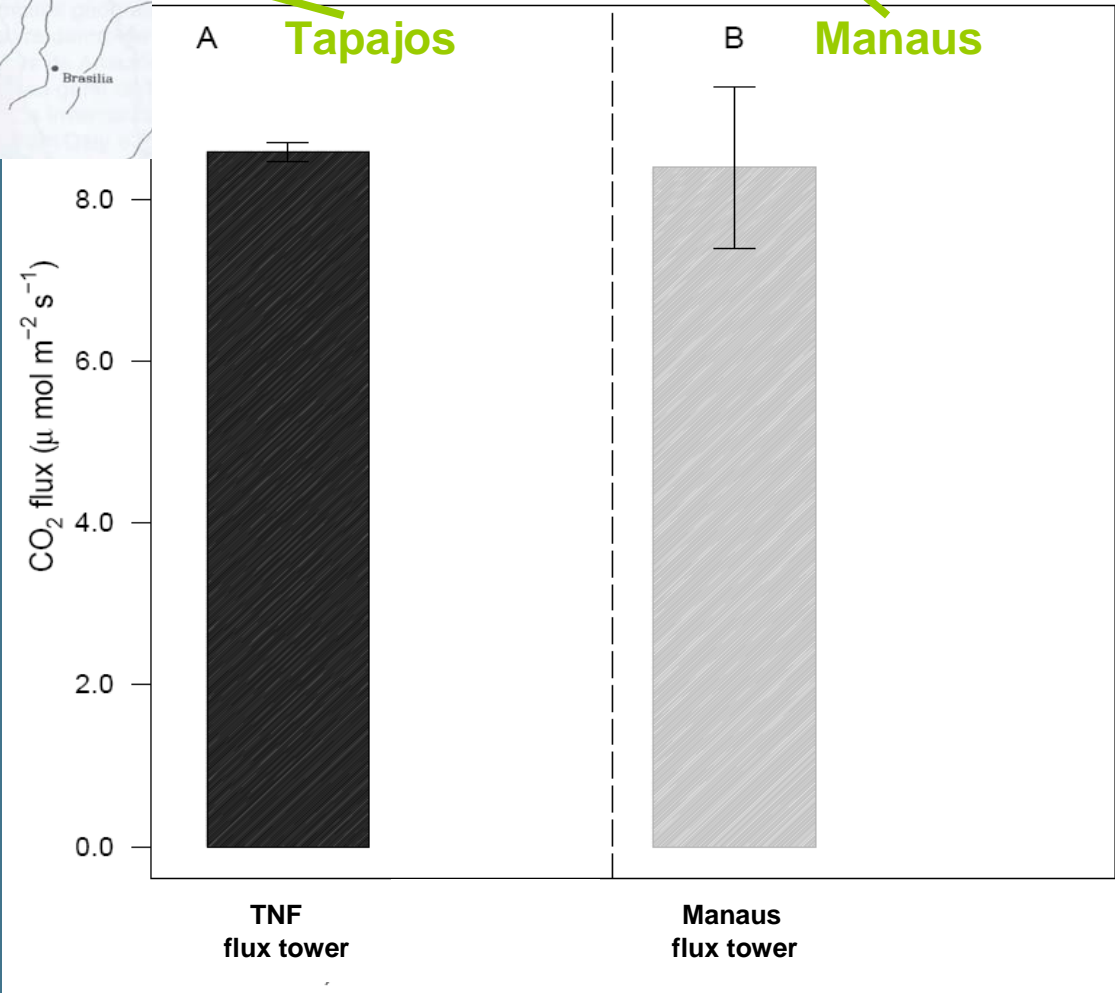
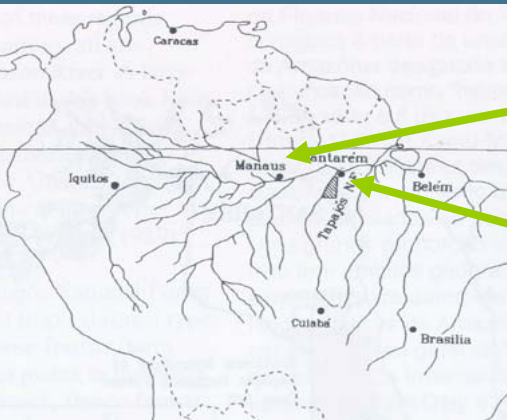
What are the controls on respiration?

$$R_{\text{total}} = R_{\text{autotrophic}} + R_{\text{heterotrophic}}$$



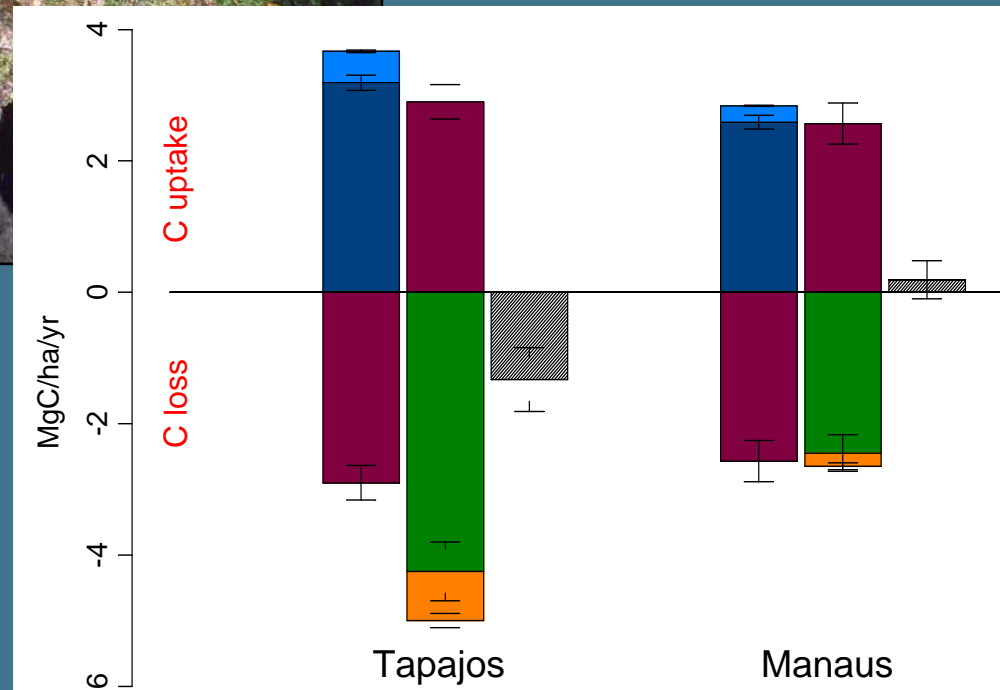
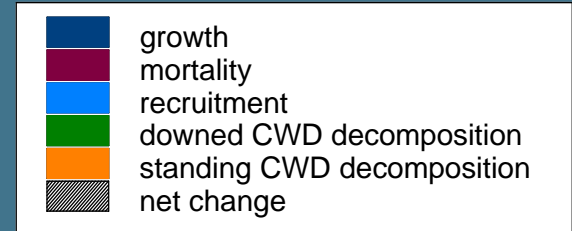
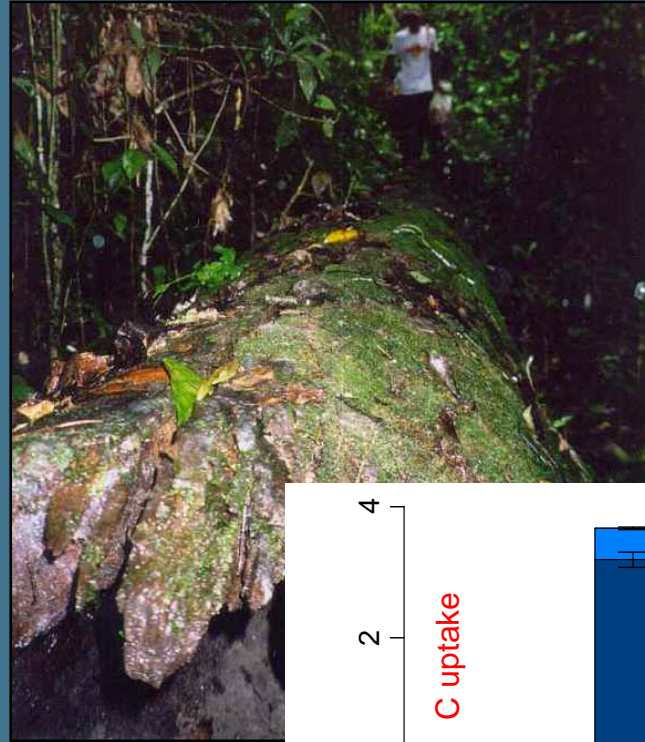
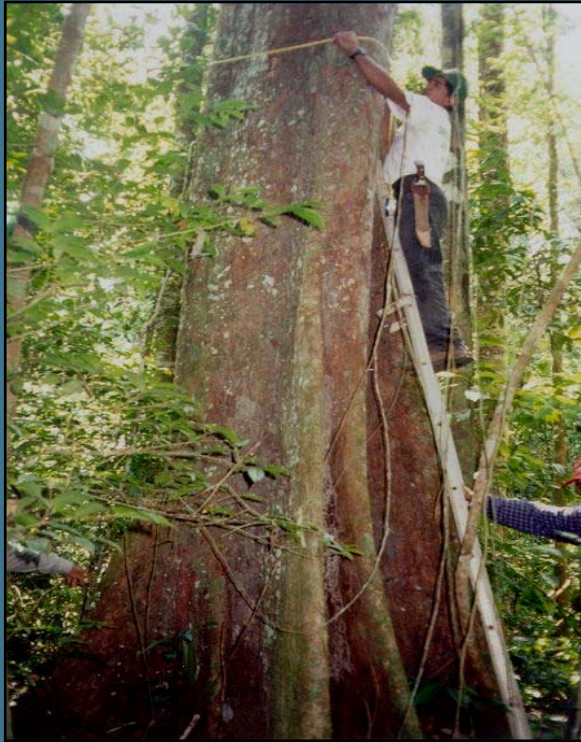
- seasonality
- late wet season decline in autotrophic R
- dry season reductions in heterotrophic R
- sensitive to precip anomalies
- No significant relationship w/ temperature on short timescale

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- seasonality
- late wet season decline in autotrophic R
- dry season reductions in heterotrophic R
- sensitive to precip anomalies
- No significant relationship w/ temperature on short timescale
- similar total R as Manaus, but diff seasonality

What is happening within the forest to driver the net patterns of exchange?



Is forest growth currently water limited?

- Annual ET/P was ~ 0.5 , regardless of the total incoming P
- Dry season ET/P was 1.2 – 1.8, with very little variation in ET
- Water is withdrawn from several meters depth to maintain dry season ET

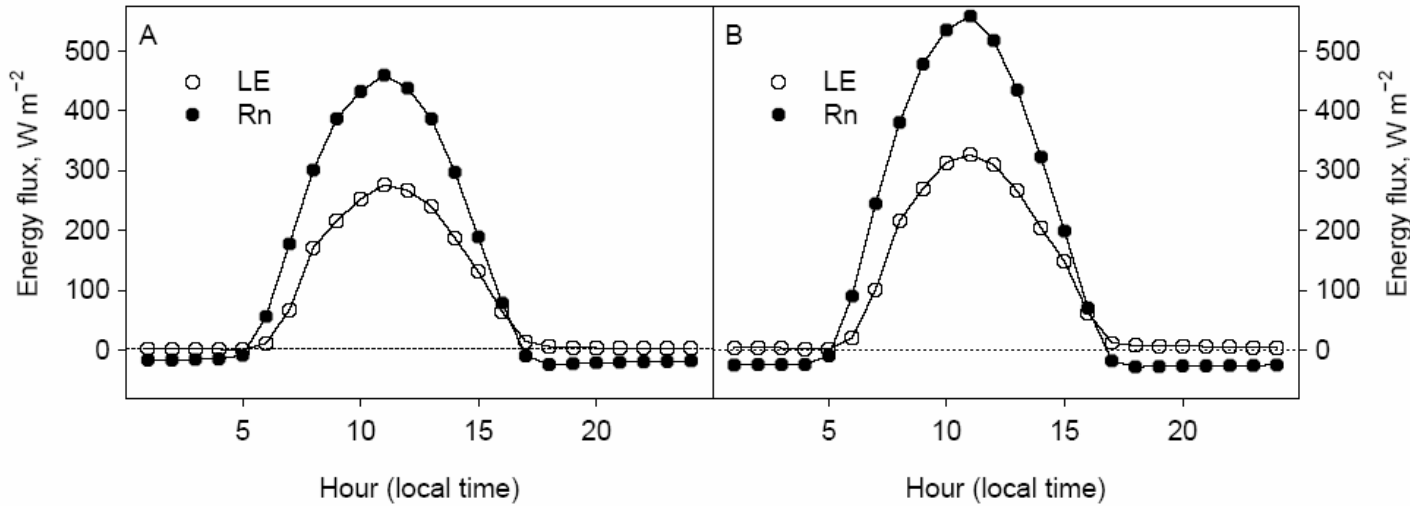
Although this site is in the 27th %tile for dryness, we found no signs of water limitation on plant growth ...



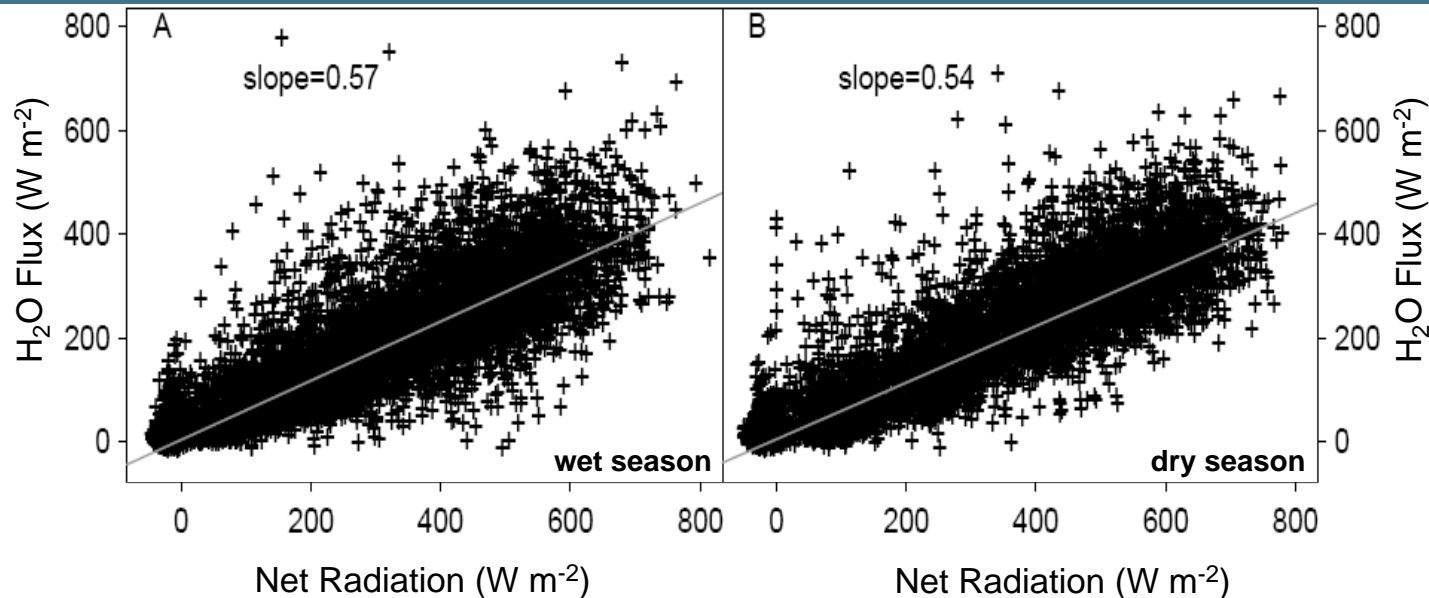
Is forest growth water limited?

Wet Season

Dry Season

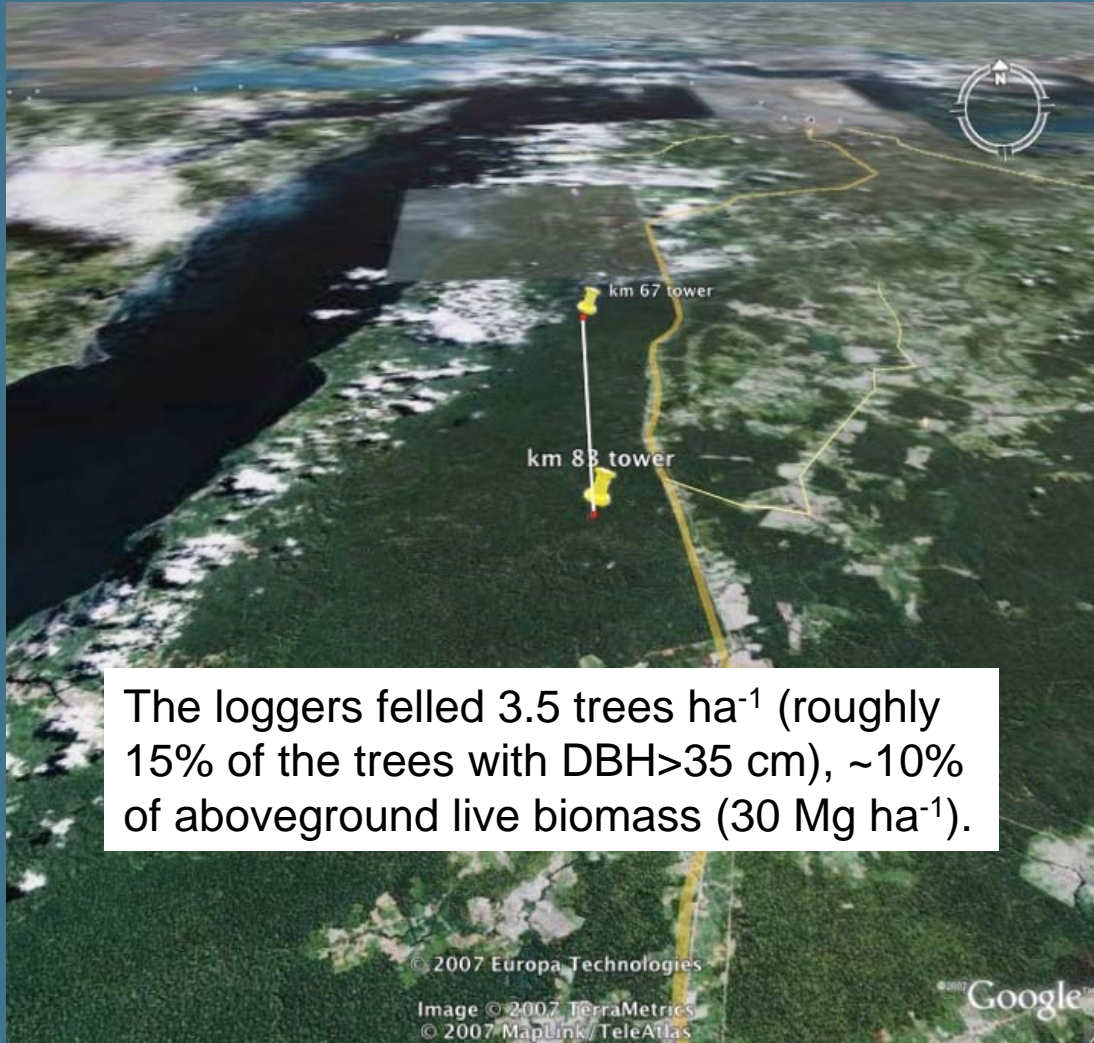


Latent heat flux (LE) closely followed the diel patterns in net radiation (Rn) and temperature.



No seasonal difference in the evaporative fraction

How does logging impact the carbon exchange processes?



The loggers felled 3.5 trees ha⁻¹ (roughly 15% of the trees with DBH>35 cm), ~10% of aboveground live biomass (30 Mg ha⁻¹).



Creates additional CWD



Exports C



Creates gaps in the canopy

Photos: S. Miller

Note: the logging at this site was reduced impact, not the standard method used across the Amazon



RIP: April 16, 2001 - January 16, 2006

Summary:

The TNF was small source of carbon to the atmosphere

Both photosynthesis and respiration had very distinct seasonal patterns.

Photosynthesis decreased late in the wet season & increased during the mid-dry season, in phase with phenology.

No current signs of water limitation on photosynthesis, ET insensitive to incoming precipitation.

Respiration decreased during the dry season when temperatures were highest and moisture was lowest.

Reduced impact logging resulted in an increase in carbon uptake over the several years of observation

Any changes in temperature and precipitation are likely to affect the ecosystem C balance and the distribution of vegetation across the Amazon. But, the likelihood of Amazonian forest collapse is still unclear.

Thanks!

