Seasonal controls on the exchange of carbon and water in an Amazonian rainforest

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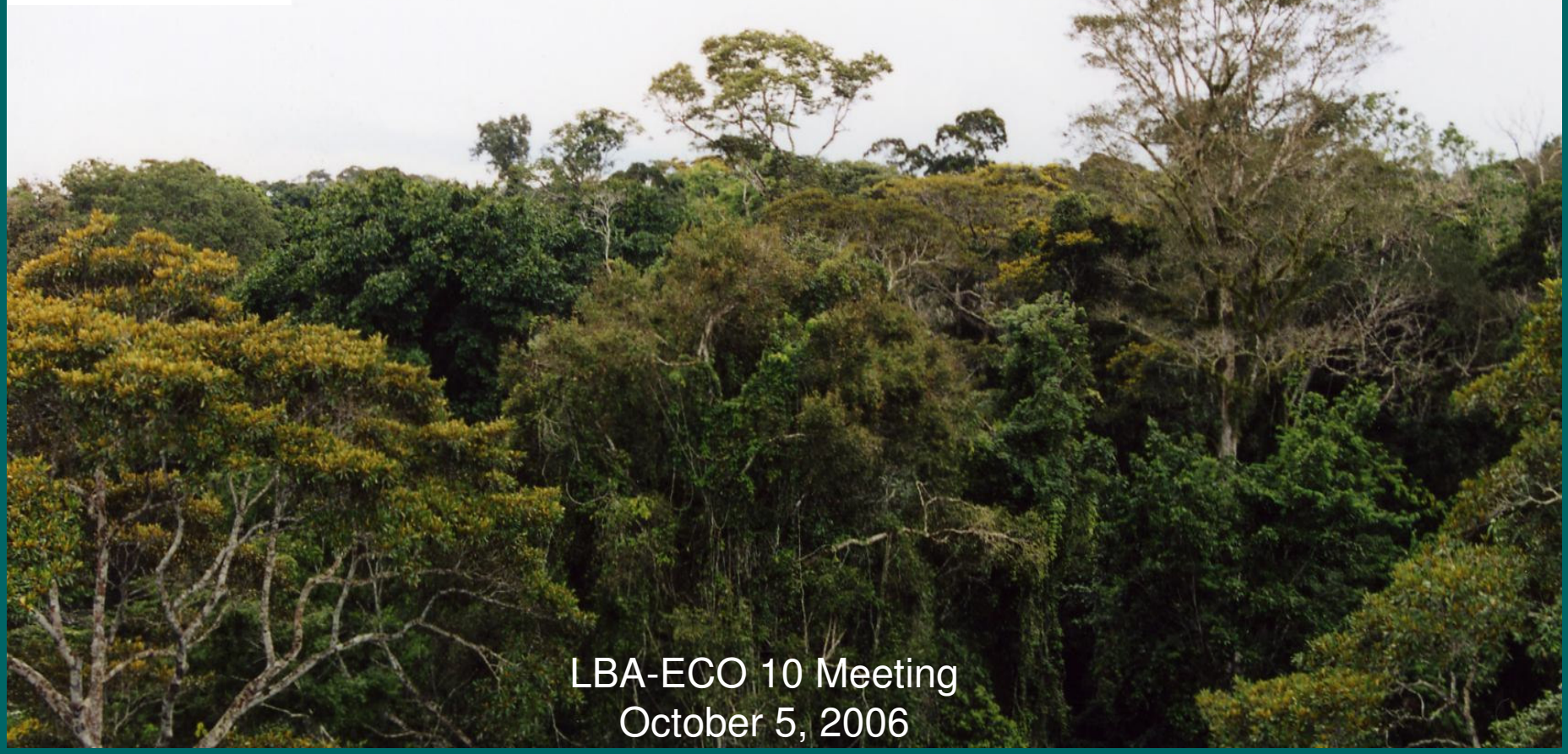

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Both model results and field studies show wide variability in the patterns and the seasonality of forest growth, respiration, and water exchange

Huete et al. [2006] found rainforest 'green-up' during the dry season

Rainforests are clearly able to grow in the dry season, but sites have reported

- more CO_2 uptake during the dry season [*Saleska et al.*, 2003; *Goulden et al.*, 2004],
- less uptake during the dry season [*Malhi et al.*, 1998; *Araujo et al.*, 2002; *von Randow et al.*, 2004], &
- no seasonality in the exchange patterns [*Carswell et al.*, 2002]

ET was also found to vary widely across sites

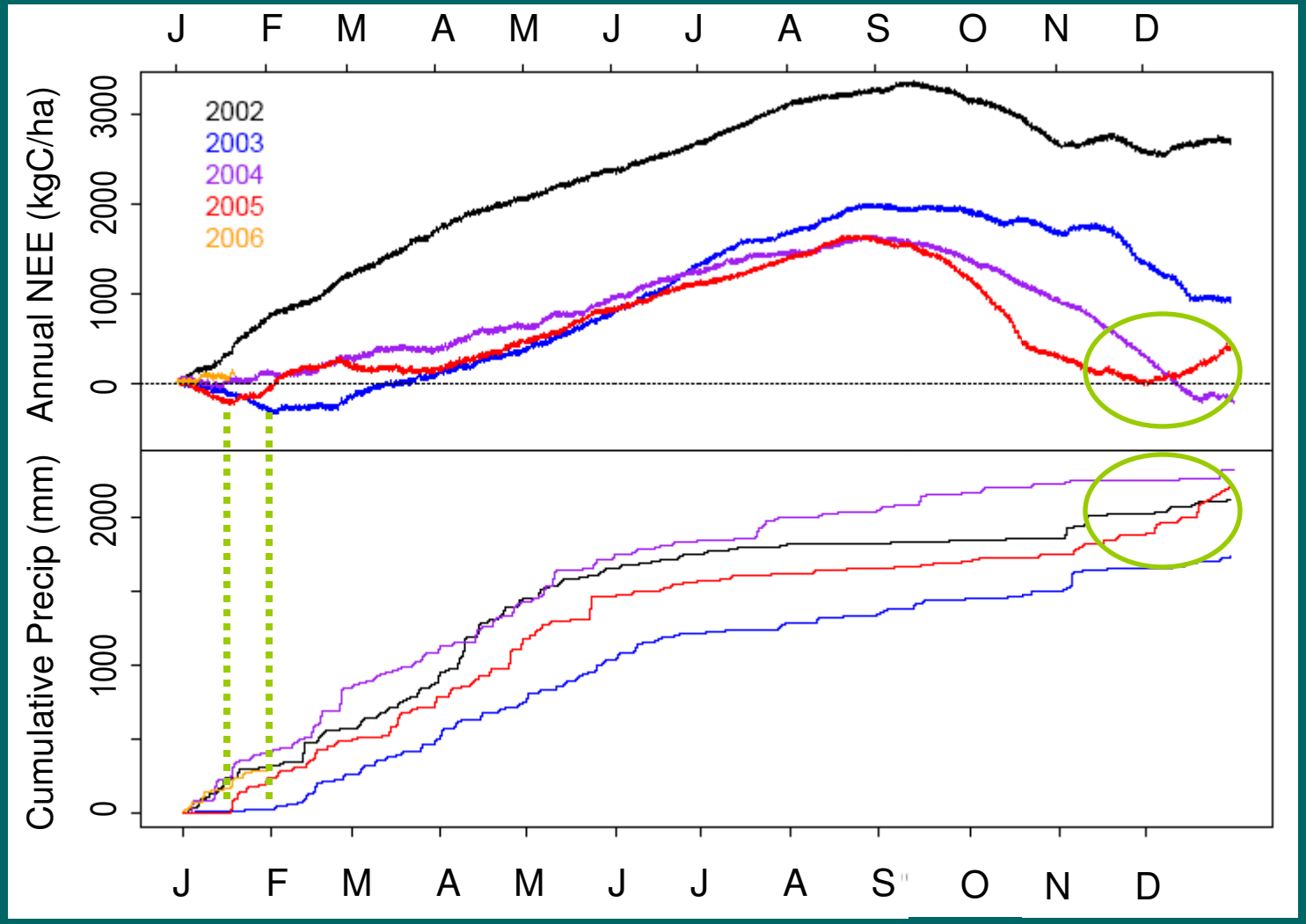
- maximized during the dry season [*Hutyra et al.*, 2005; *de Rocha et al.*, 2004; *Carswell et al.*, 2002; *van Randow et al.*, 2002],
- maximum during the wet season [*Malhi et al.*, 2002; *Vourlitis et al.*, 2002]

Global Climate Models generally predict decreases in ET during the dry season, in phase with precipitation

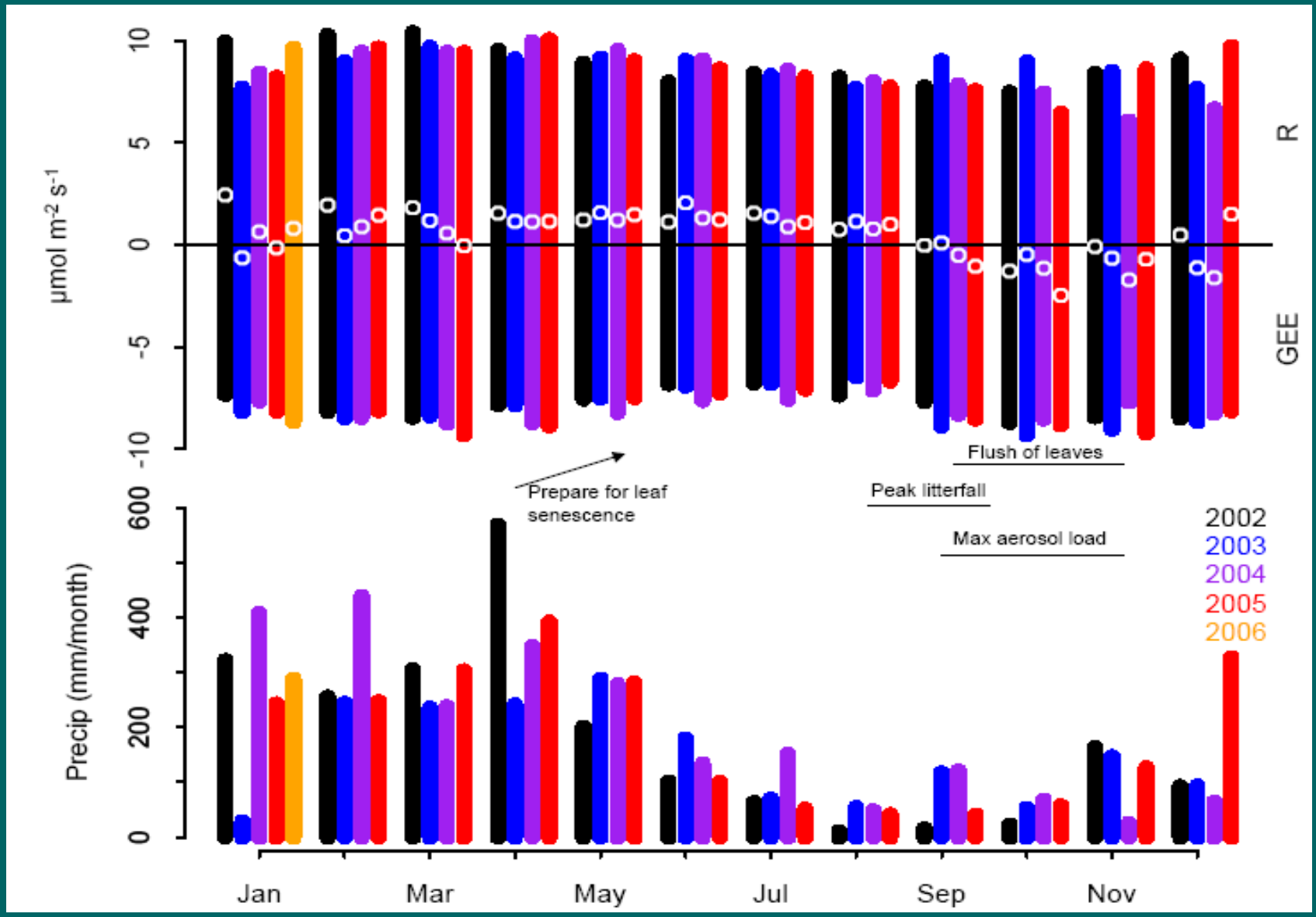
This divergence is likely due to differences in the actual water availability for the vegetation, soils, phenology, and radiative drivers.

Tapajos km67 site description & methods

- Primary forest
- on ‘flat’ terrain with a closed canopy (z~40-45m)
- water table is very deep, ~100m
- 5 month dry season (July 15 –December 15)
- 64m tall tower, presenting data from 2002-2006
- used closed path IRGAs to measure eddy flux and profiles
- Split net ecosystem exchange (NEE) into gross ecosystem exchange (GEE) and respiration (R)
    - Nighttime (u* filtered) data was used to calculate R, gaps were filled using a trimmed mean of measured R (no temperature relationship)
    - GEE = NEE – R during the daytime with a hyperbolic fit with PAR was used to fill gaps.

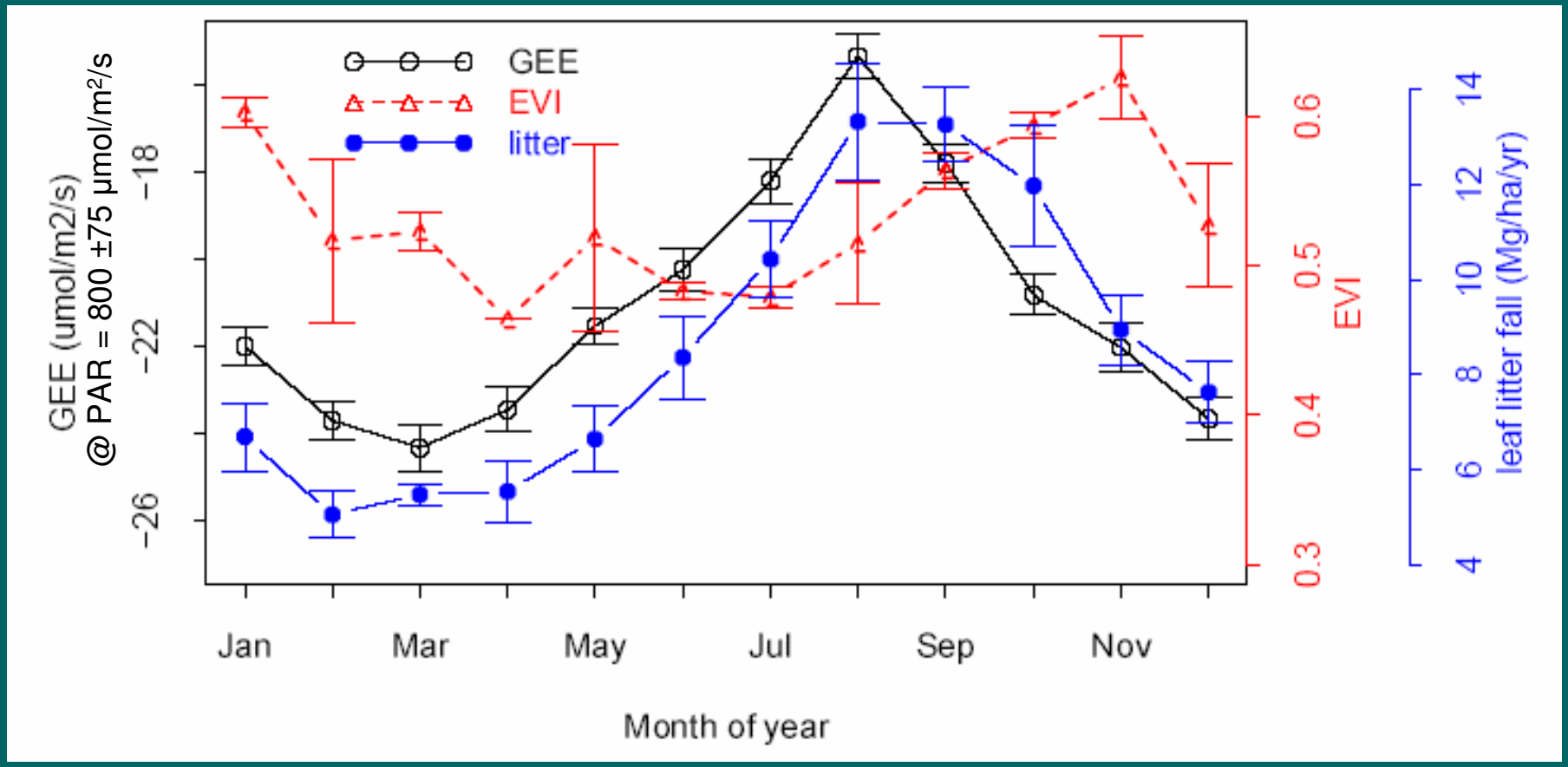


Climate anomalies exerted a strong control on the inter-annual variations in the net carbon balance.



We observed reduced GEE during the early dry season, but the decline began before the onset of the dry season, and GEE began to increase before the start of the rainy season each year.

Quantifying the phenological affects on GEE:



Leaf litterfall rates explained 76% of the observed variance in monthly GEE & 86% of the variance by lagging the litterfall by one month.

EVI explained 56% of the observed variance when EVI was lagged by 3 months.

But, there is also aerosol affects that are influencing both GEE and EVI …

mean EVI data provided by A. Huete

Respiration:

$R = R_a + R_h$

Temperature and soil moisture typically vary inversely but both simultaneously influence R

Exponential or Arrhenius equations are typically used to describe the relation between respiration and temperature, those relationships did not hold true at this site over this time interval.

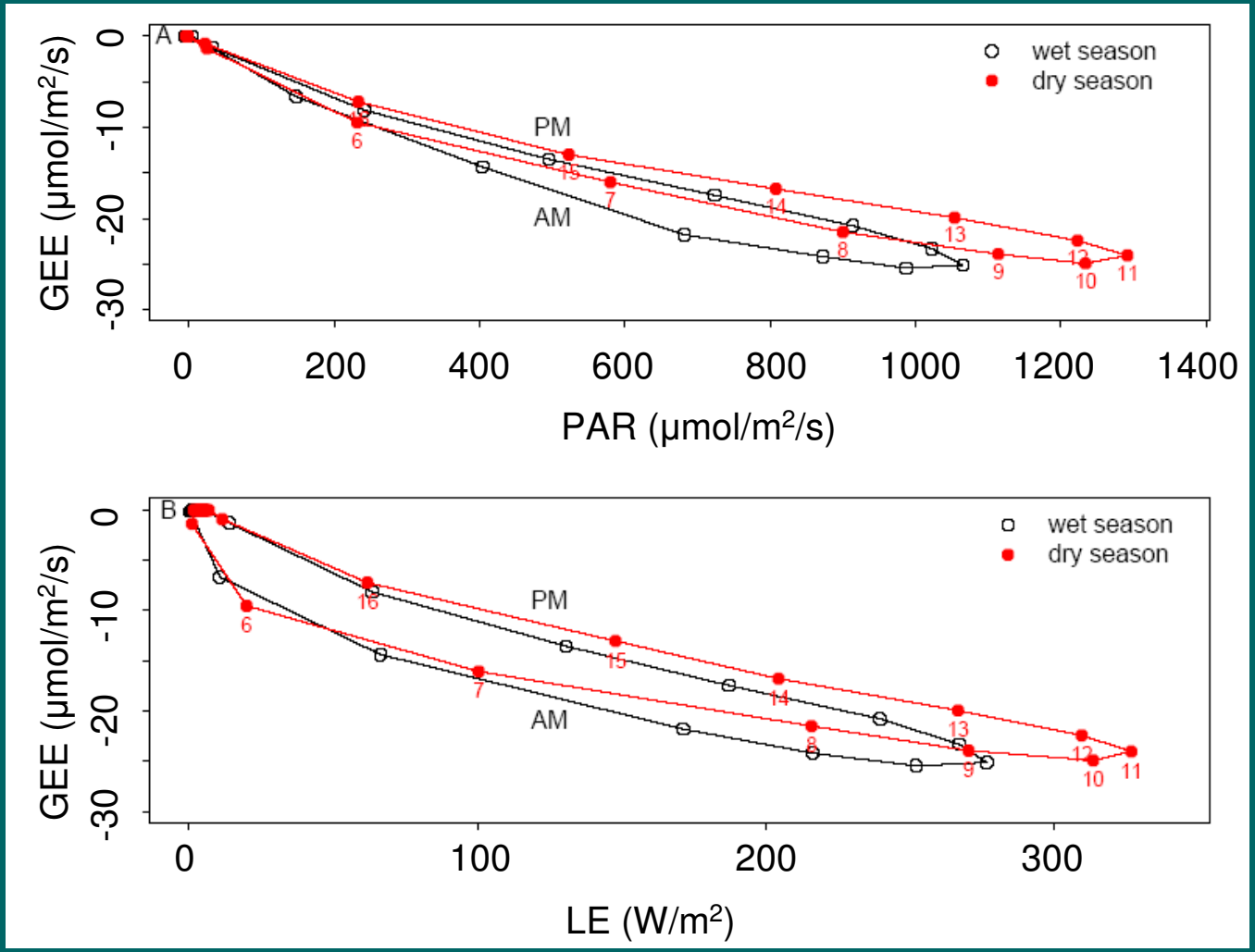
Summary of explained variance (R^2) and best regression equations used to estimate R

	$\bar{T}_{daily\,\max}$ (°C)	$\sum P$ (mm)	$\bar{T}_{daily\,\max}$ & $\sum P$	Best Model
Hourly time scale	-	-	-	-
Daily time scale	0.05	-	-	-
Weekly time scale	0.12	0.06	-	-
14-day time scale	0.29	0.24	0.32	$R = 22.9 - 0.51*T_{max} + 0.05*P$
21-day time scale	0.45	0.32	0.47	$R = 25.1 - 0.58*T_{max} + 0.03*P$
Monthly time scale	0.67	0.54	0.72	$R = 26.1 - 0.62*T_{max} + 0.03*P$
Seasonal time scale	0.92	0.45	0.92	$R = 39.9 - 1.1*T_{max}$

Why isn't temperature a good predictor for R on short time scales?

- could be an artifact of high mean temperature ($\overline{T_{canopy}}$ = 24.8^{o}C)?
- the small temperature range (less than 10^{o}C diurnally and across seasons)?
- perhaps the entire temperature range is within a broad optimum?

Implication…
If this is generalizable, the ecosystem models of tropical forests based on exponential relationships between respiration and temperature may over-predict short-term variability in the response



Both LUE and WUE were significantly higher in the morning than afternoon.

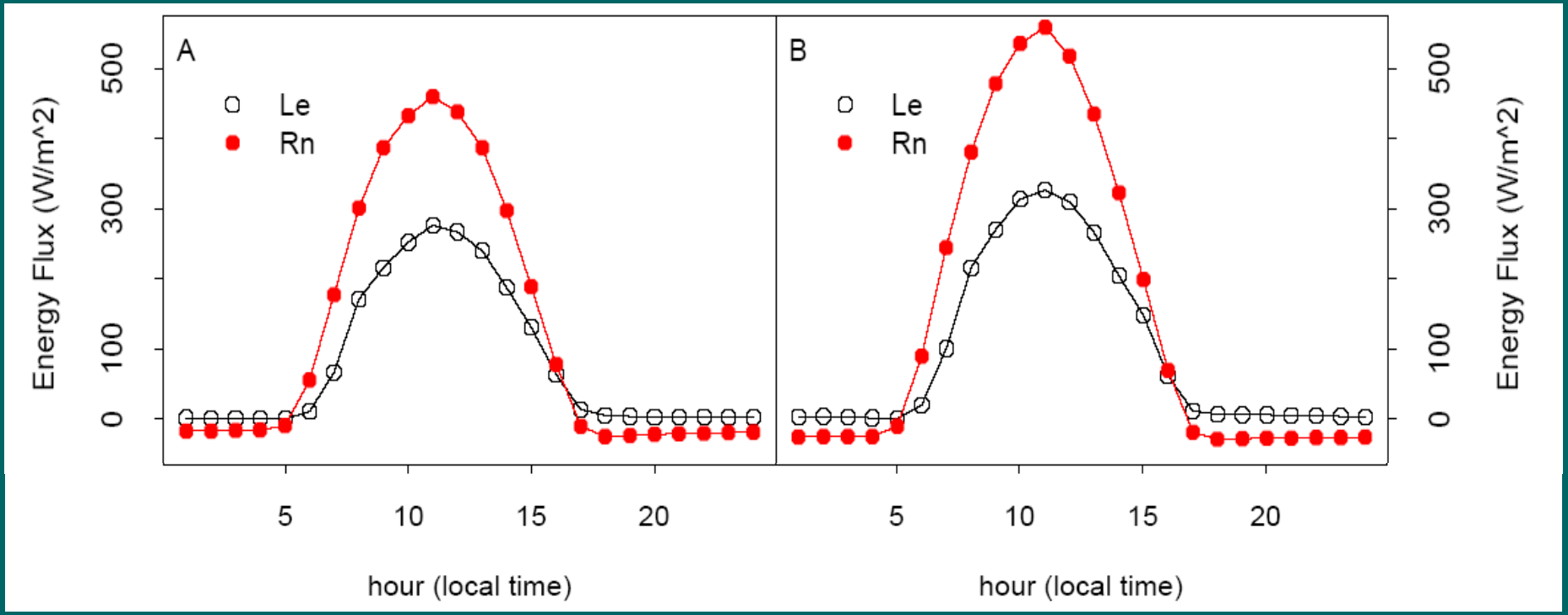
Diurnal conductance limitations may be a major cause of the am/pm GEE differences, but it could also be due to plant circadian rhythms, or metabolic or enzymatic limitations.

Is forest growth water limited?

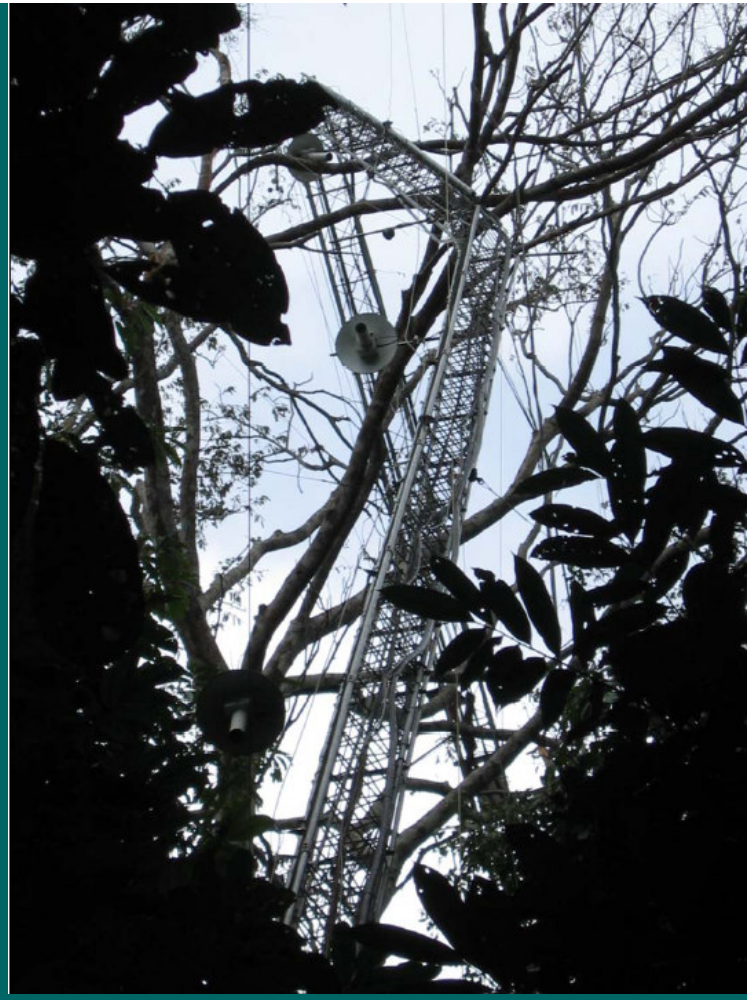
- ET from 0. 7 to 6.2 mm day^{-1}, $\overline{ET_{wet}}$ = 2.9 ± 0.2 & $\overline{ET_{dry}}$ = and 3.4 ± 0.2 mm day^{-1}

- Annually ET/P = 0.5 (1116mm/2111mm), 0.6 (1114/1740), 0.5 (1137/2311), 0.5 (1123/2201) for 2002-2005, respectively

- dry season ET/P = 1.8 (503mm/279mm), 1.2 (522/448), 1.3 (514/402), 1.4 (536/383) for 2002-2005, respectively.



Summary & Conclusions



• R was lower during the dry season due to moisture limitations.

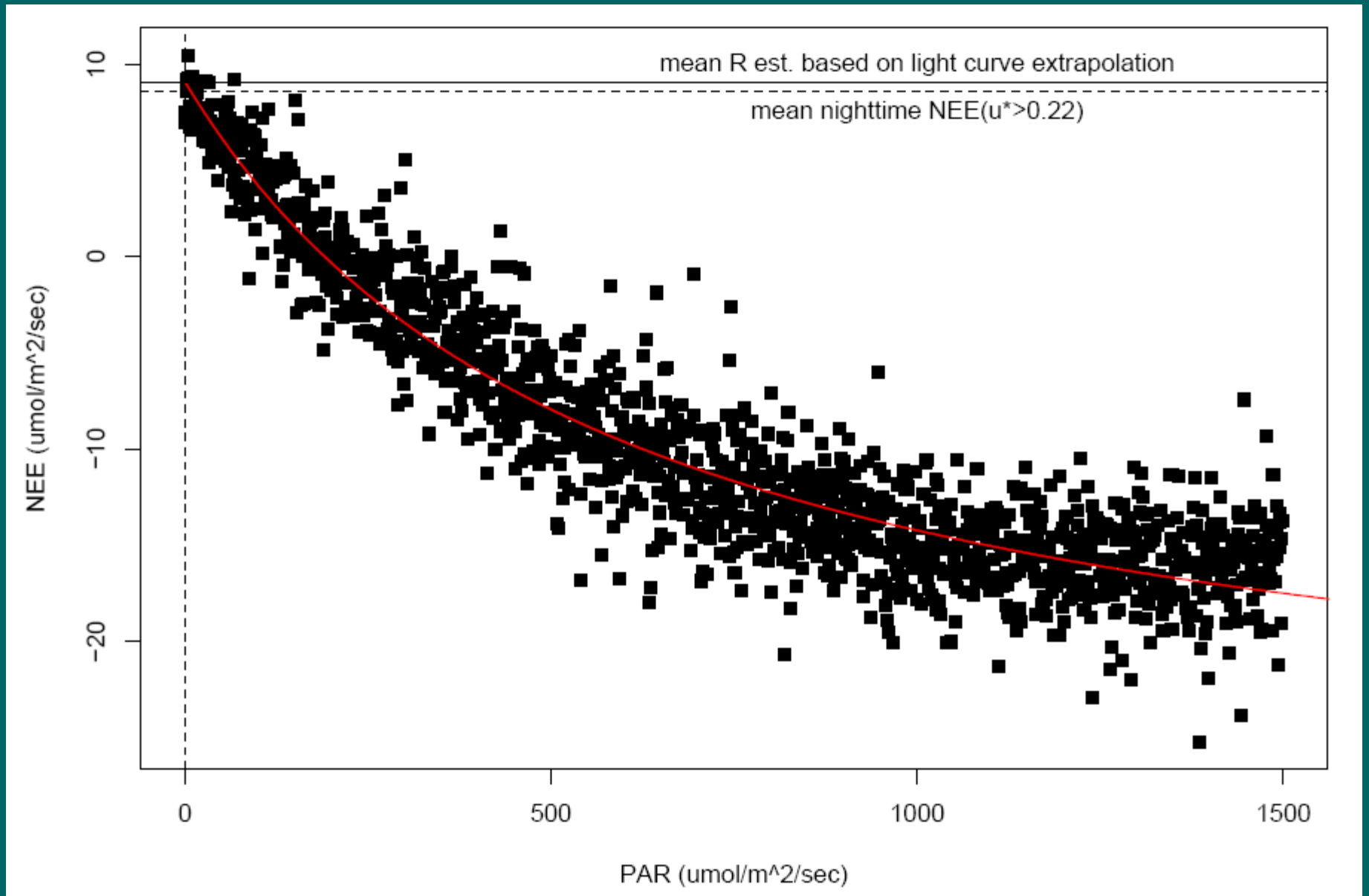
• We found no relationship with R and temperature on short time scales.

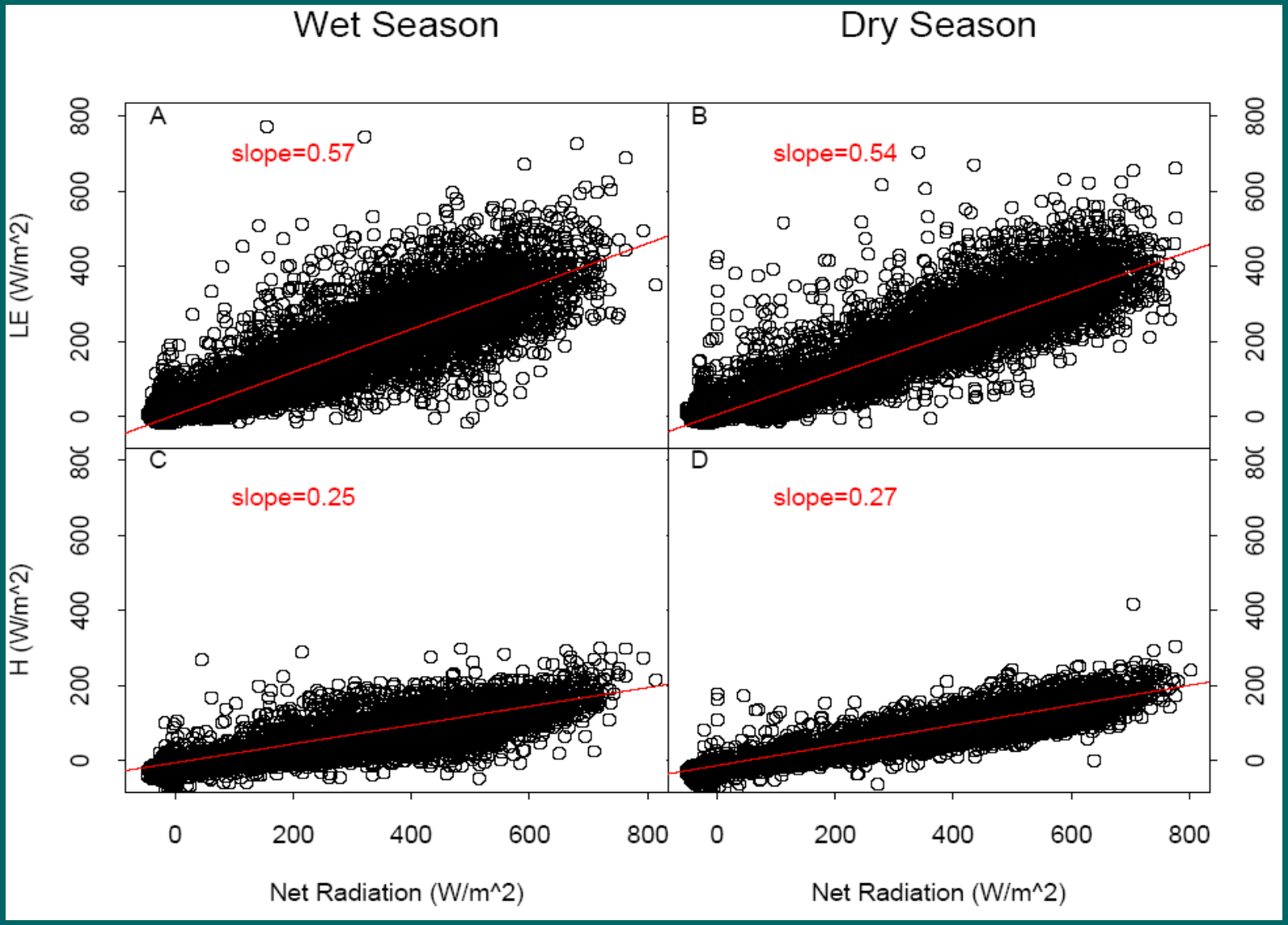
• We found no significant signs of water limitation on growth

• The seasonal course of GEE was controlled by phenology with GEE rates declining before leaf senescence (late wet season) and increasing after new leaf elongation (mid-dry season).

• This site is on average a net source for C to the atmosphere, 888 ± 216 kg C ha^{-1} yr^{-1}, with an observed range of -221 ± 453 (uptake) to 2677 ± 488 (loss). Ecosystem respiration dominated the observed variability in NEE.

• Climate anomalies exerted a strong influence on the net carbon exchange mainly through effects on ecosystem R


mean R est. based on light curve extrapolation
mean nighttime NEE(u*>0.22)
NEE (umol/m^2/sec)
10
0
−10
−20
0
500
1000
1500
PAR (umol/m^2/sec)



There was no significant seasonal difference in the energy allocation in contrast to the findings reported in Mahli et al. 2002