Carbon balance and response to seasonal and long-term forcing at Tapajós Forest old-growth site, Km 67

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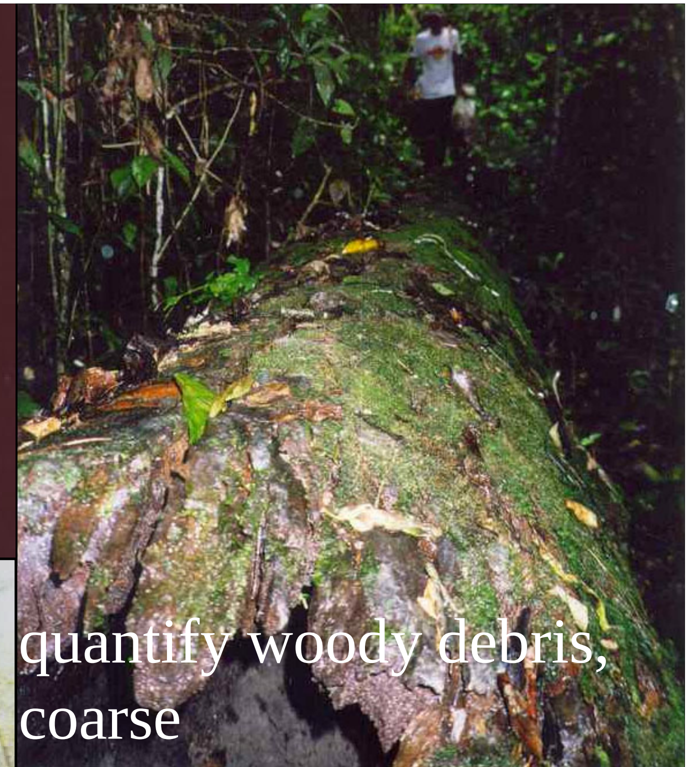
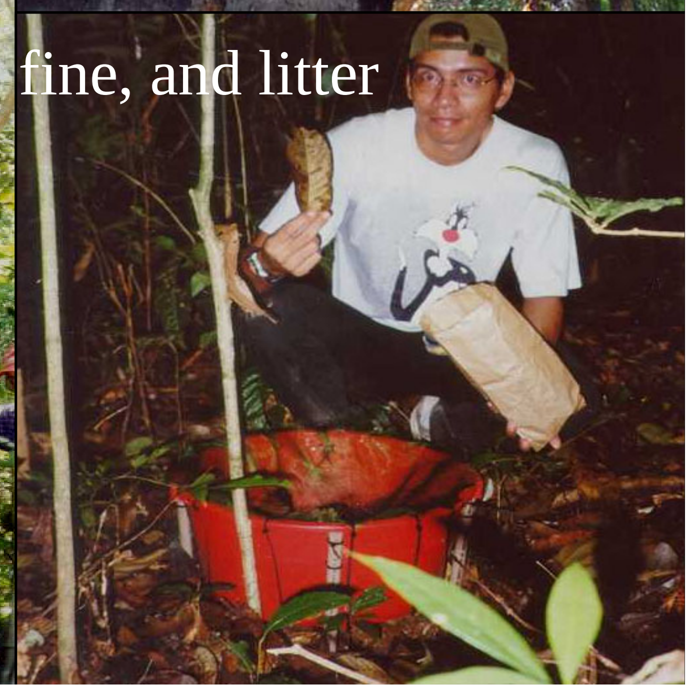
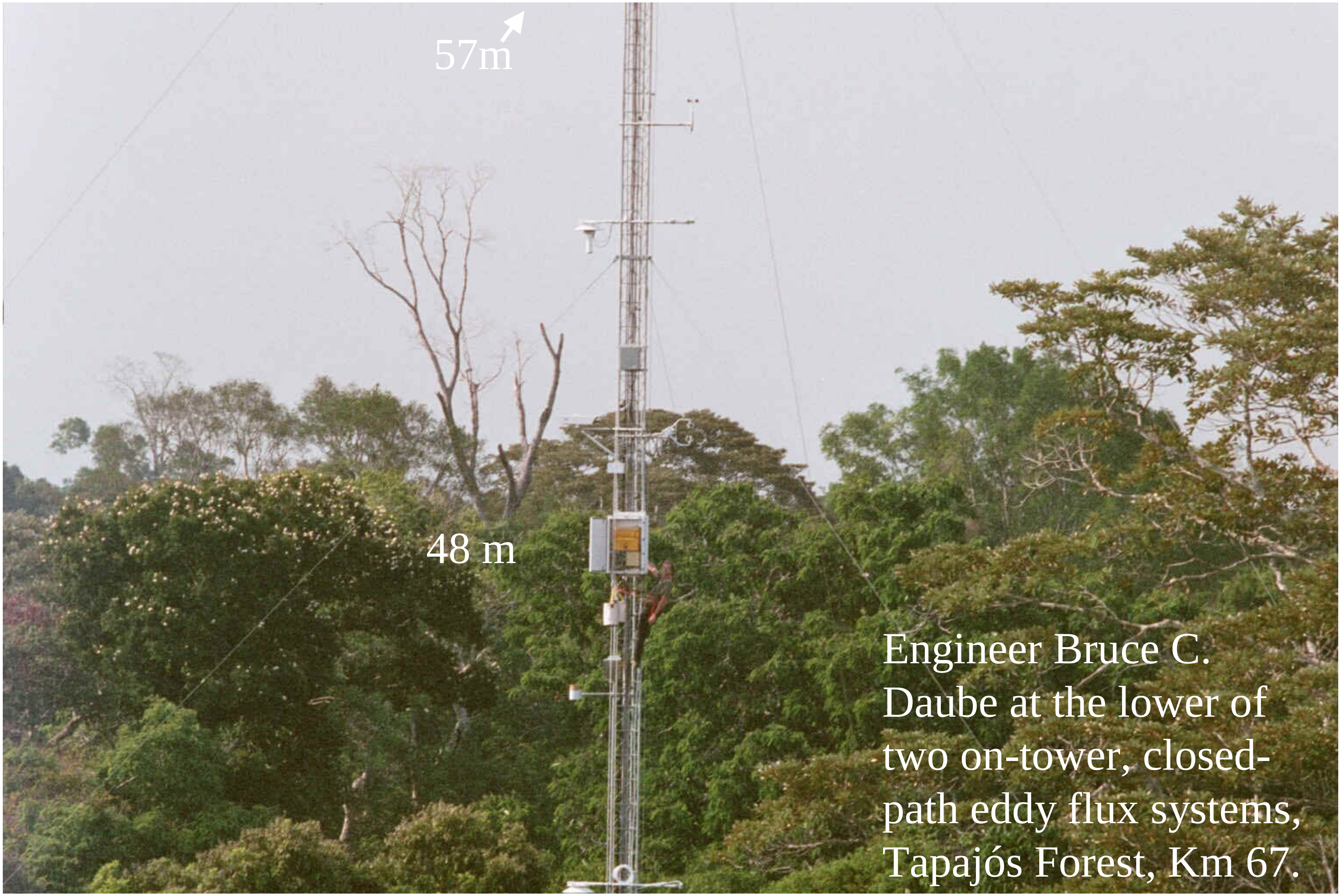
Measuring the C balance of the Tapajós Forest:

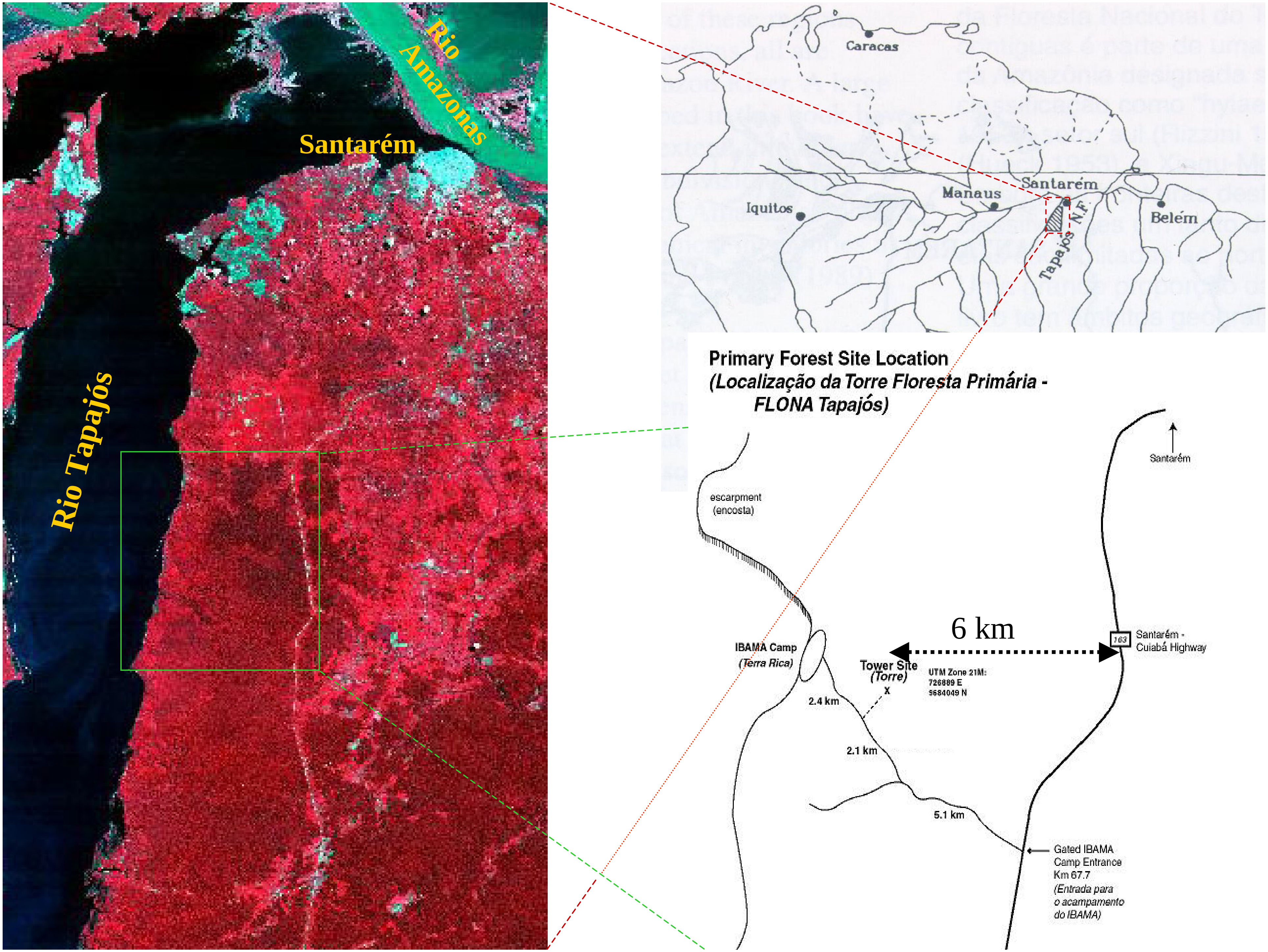
the good old-fashioned way, with biometric forest data, …





…and the new way, with eddy flux measurements




Rio Amazonas
Santarém
Rio Tapajós
Caracas
Iquitos
Manaus
Santarém
Belém
Tapajós N.F.
Primary Forest Site Location
(Localização da Torre Floresta Primária - FLONA Tapajós)
escarpment
(encosta)
Santarém
6 km
IBAMA Camp
(Terra Rica)
Tower Site
(Torre)
X
UTM Zone 21M:
726889 E
9684049 N
163
Santarém - Cuiabá Highway
2.4 km
2.1 km
5.1 km
Gated IBAMA Camp Entrance Km 67.7
(Entrada para o acampamento do IBAMA)

• **Biometric methods for C balance:**

+ what you see is what you get; long-term average; biological factors, disaggregation; technologically simple

-response to environmental forcing factors, below-ground inaccessible, aggregation errors

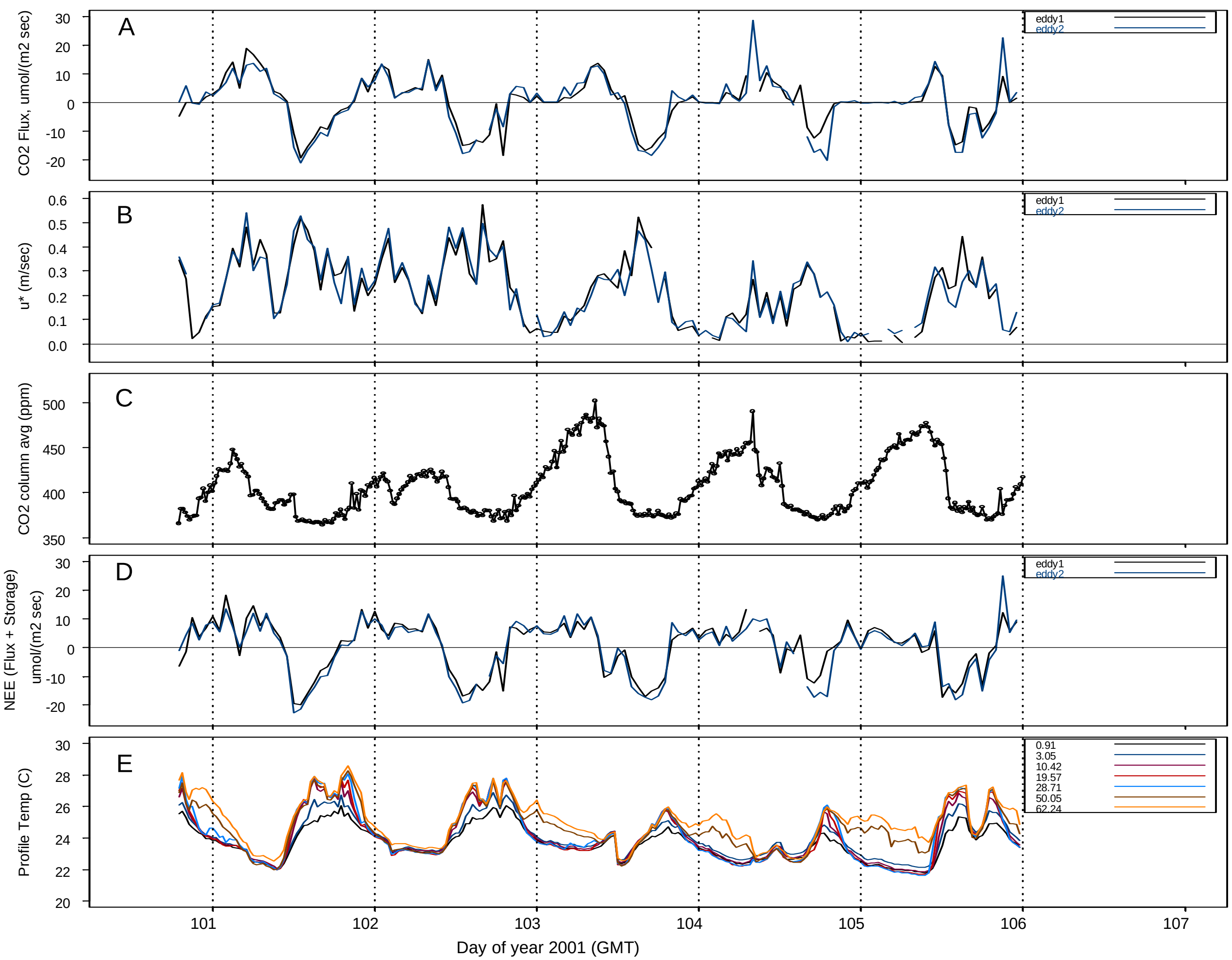
•**Eddy flux methods for C:**

+ response to environmental forcing factors, below-ground included; aggregation included.

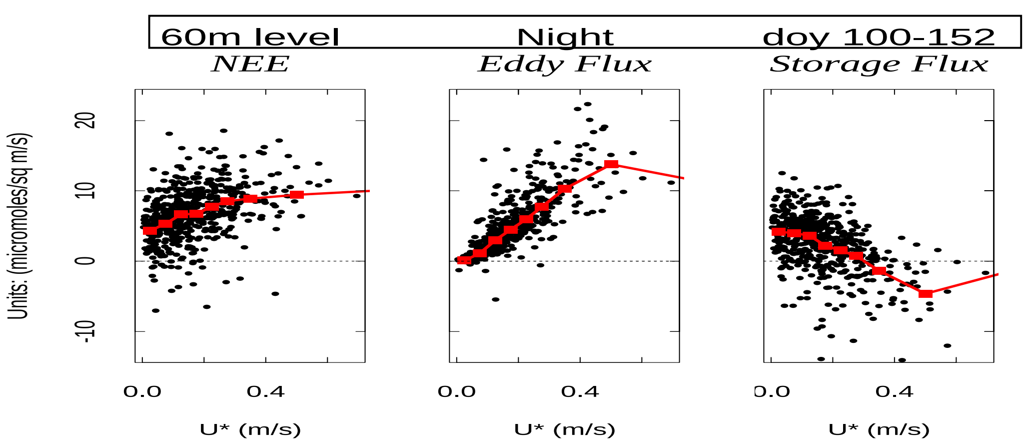
-long term averages require validation; technologically intensive; limited disaggregation

Validation against independent ecosystem-scale data

- *continuous soil flux chambers (Crill and Keller)*
- *continuous atmospheric Rn measurements (Martens and Shay)*
- *eddy flux and biometric data from Km 83 control period (Goulden, de Rocha)*



Hourly time series of data from the Primary Forest eddy flux tower at km 67 in Tapajós National Forest: (A) Eddy flux of CO_2 for eddy1 (58m) and eddy2 (47m); (B) friction velocity (u*); (C) mean CO_2 concentration 0-60m ("canopy storage"); (D) net ecosystem exchange (NEE = Eddy flux + d/dt<storage>); and (E) temperature profiles. On *windy nights* (days 100-102, U*>0.2 m/s (B)) CO_2 efflux (A) is strongly positive, temperature profiles (E) are well-mixed; CO_2 storage (C) is low, and NEE (D) ≈ flux (A). On *calm nights* (104-105), flux (A) and u* (B) are virtually zero, temperature profiles (E) are stratified, and CO_2 storage is high, causing NEE to be significantly higher than eddy flux.

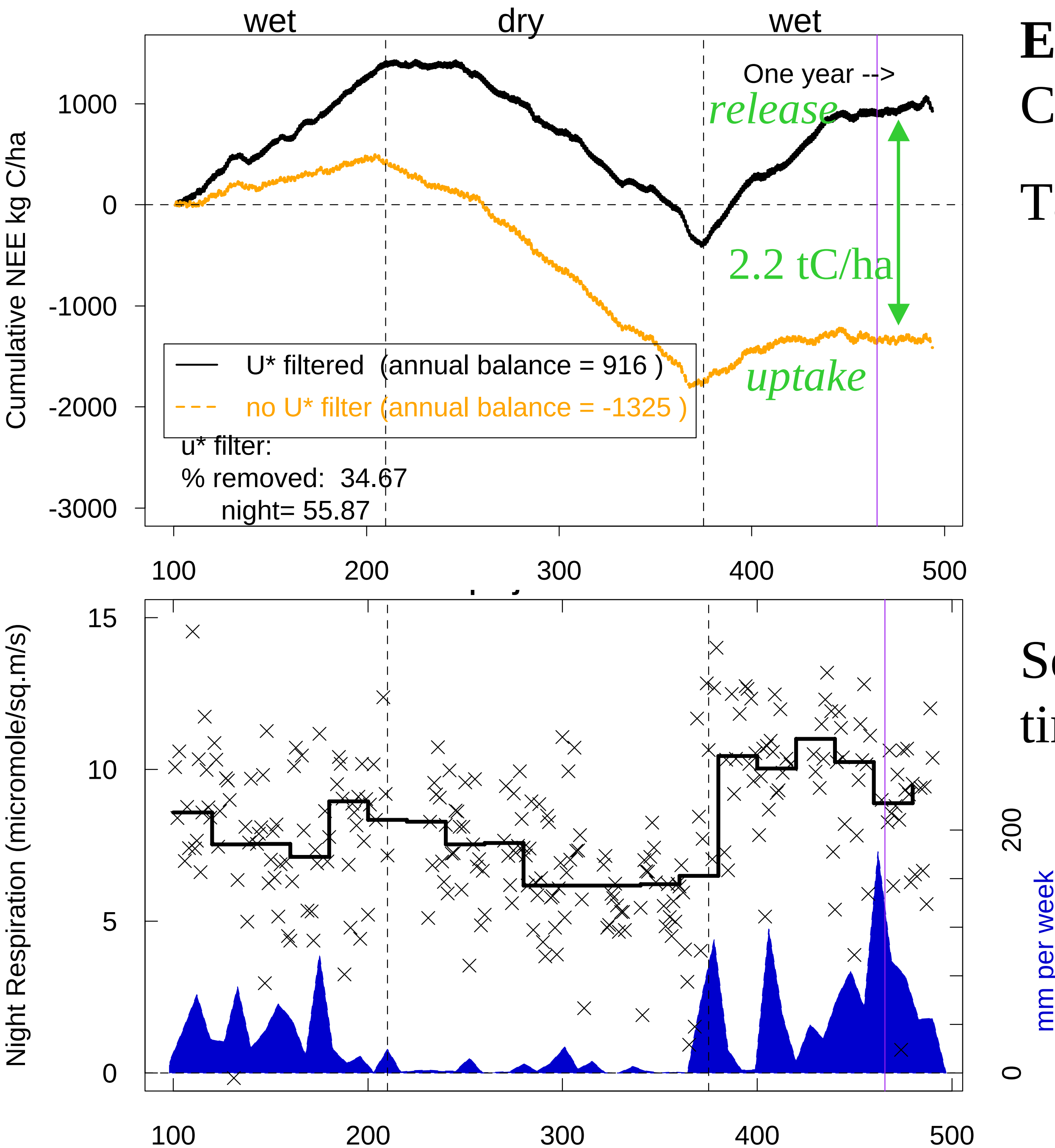


Relationship between friction velocity (u = √(-1 x momentum flux) and measured values of <u>nighttime</u> NEE at 58 m (left) and its components, eddy flux (middle) and storage flux (right). As U* → 0, eddy flux decreases and storage flux increases as expected, but their sum (NEE) declines somewhat for u* < 0.2 m/sec. The associated "lost flux" is relatively small at this compared to some other LBA sites, amounting to roughly 1 ton C/ha/year between filtered and unfiltered data.*

Eddy flux data:

Cumulative carbon balance

Tapajós old-growth forest



Day of year (01-01-2001 = day 1)

Seasonal cycle of night-time respiration

Seasonal cycle of rainfall

1^{st} Comparison:

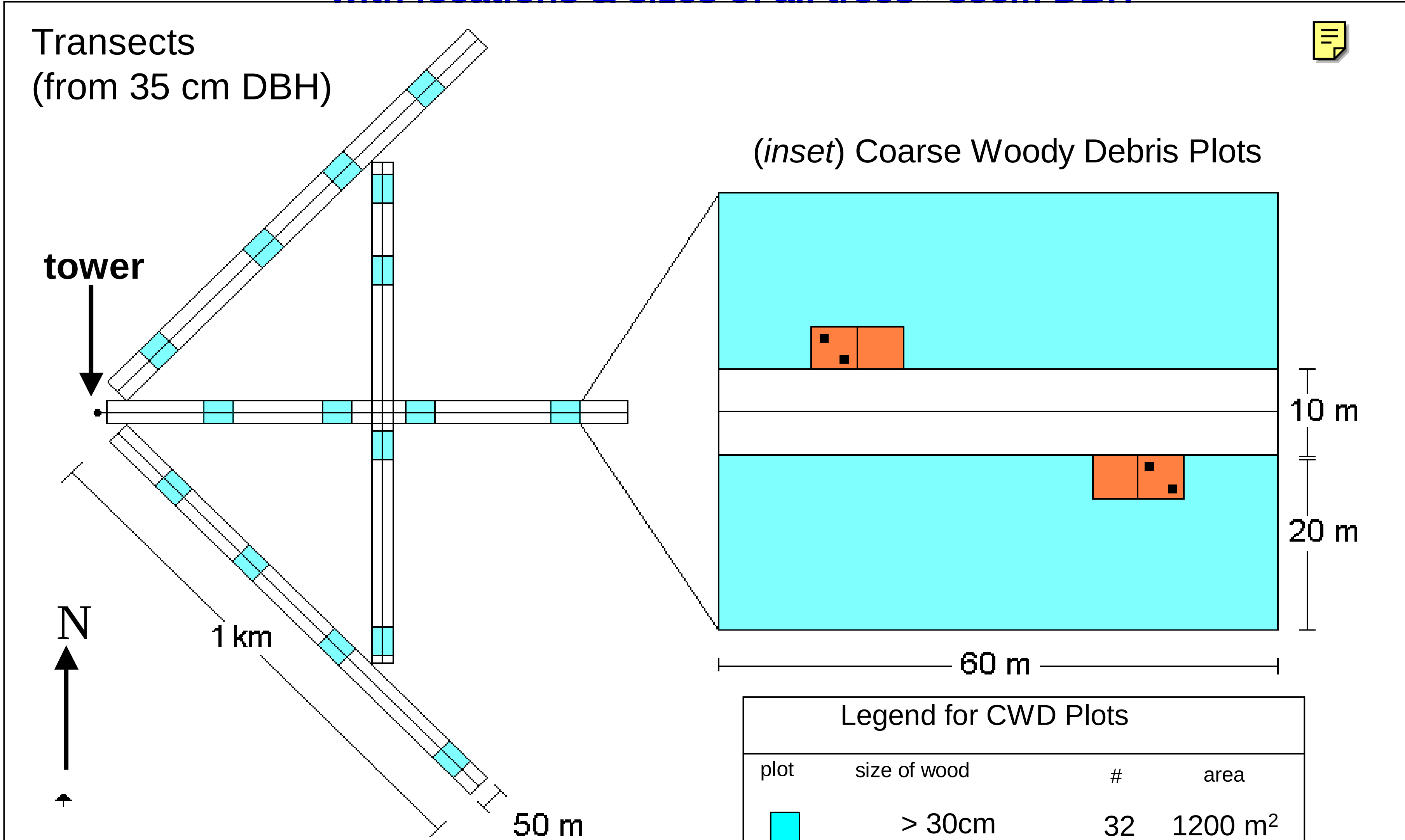
eddy flux data (1 year)

with

forest ecological and biometric data (2 years)

(*measurements from Harvard, CENA***)**

Biometry plots upwind of flux tower,
with locations & sizes of all trees >35cm DBH



Legend for CWD Plots

plot	size of wood	#	area
cyan	> 30cm	32	1200 m^2
orange	10 - 30 cm	64	25 m^2
black	2 - 10 cm	64	1 m^2

(*20 ha, 2800 trees, stratified*)

pools

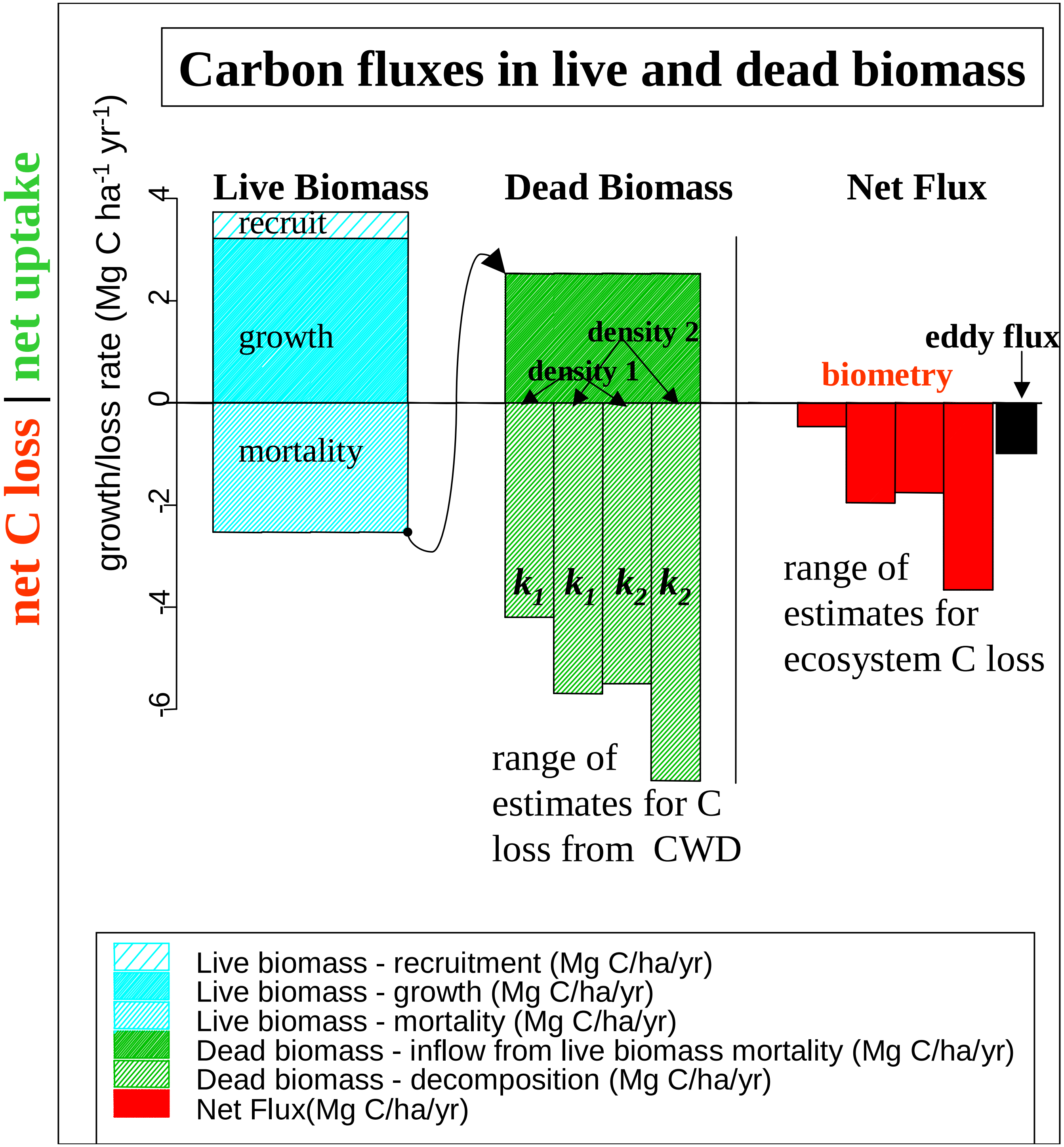
Biometric Carbon Budget at Tapajos Forest two-years of measurements.

*The forest shows **net release** of carbon to the atmosphere, as a consequence of losses from the pool of dead biomass in excess of growth.*

	— *choice of allometry* —		
Total aboveground (Mg C ha^{-1})	A	B	C
Live Biomass (n=2799)	145.3 (±5.7)	155.5 (±8.8)	161.9 (±11.3)
Dead Biomass (n=1000)	32.6 (± 3.6)	41.4 (± 4.8)	43.8 (± 4.8)
Range of Total Pool	177.9 (±6.8) to 205.7 (±11.9)		

fluxes

Components flux (Mg C ha^{-1} yr^{-1})	Range	
Live Flux (1000 dendro's, 2800 repeat DBH)	+1.1 to 1.5	
Dead Flux (CWD x Decay class x k_d)	-1.7 to -6.0	
Total Flux (Mg C ha^{-1} yr^{-1}, *losses)*	**-0.2 to -4.9**	**-0.9 eddy**

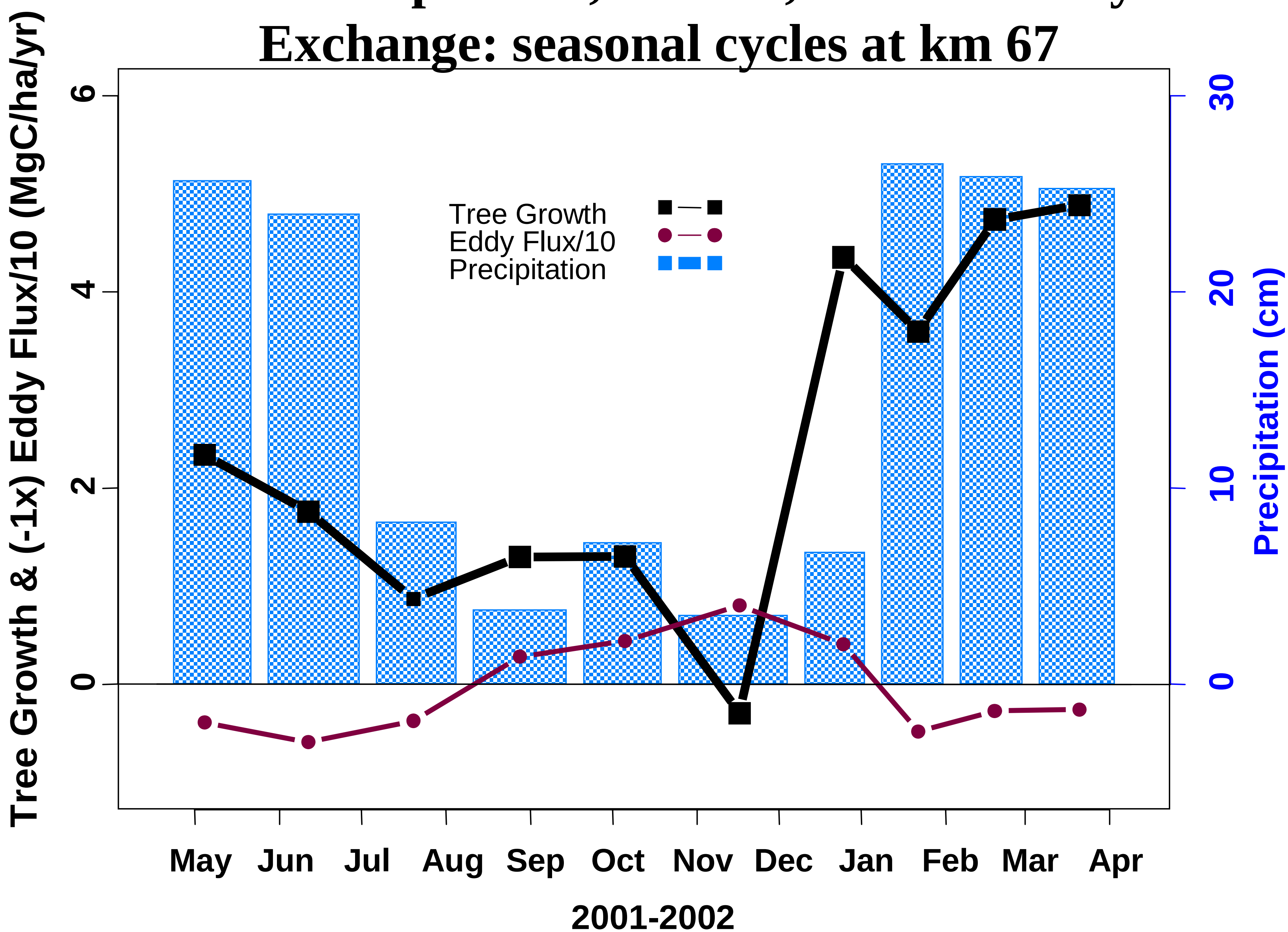


C. Net Flux for the Tapajos Forest between 1999 and 2001. The magnitude of the net flux is dependent on the density and turnover time of the dead biomass. Calculations were made using a range of literature values for ρ and k.

All indicate negative net flux(loss) over the two year interval.

(Turnover times were based on Chambers et al. 2001a, density values were based on Clark et al. 2002 and Delaney et al. 1998).

Rate of bole expansion, rainfall, and Net Ecosystem Exchange: seasonal cycles at km 67



2^{nd} Comparison:

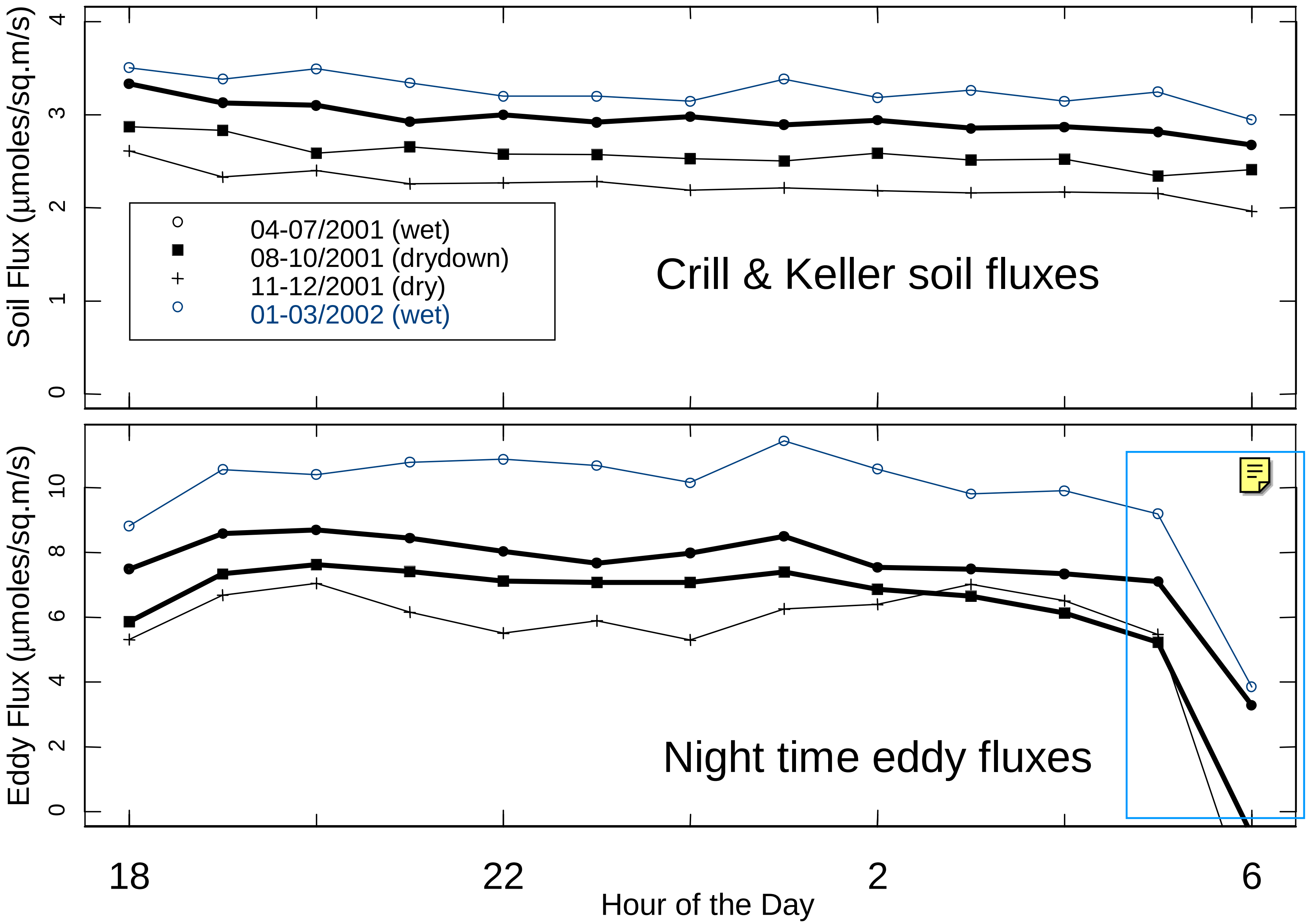
eddy flux data

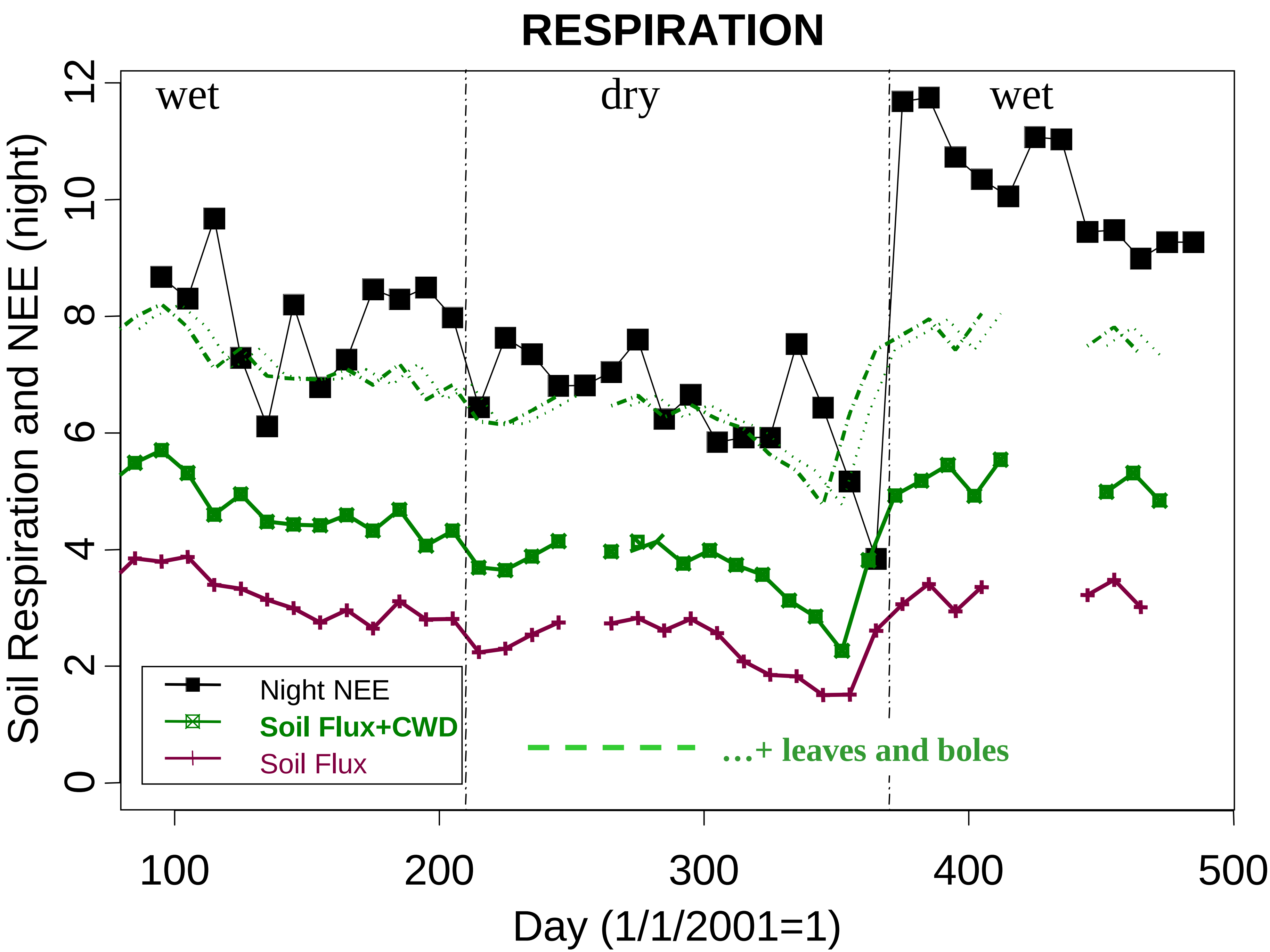
with

continuous soil flux chamber data

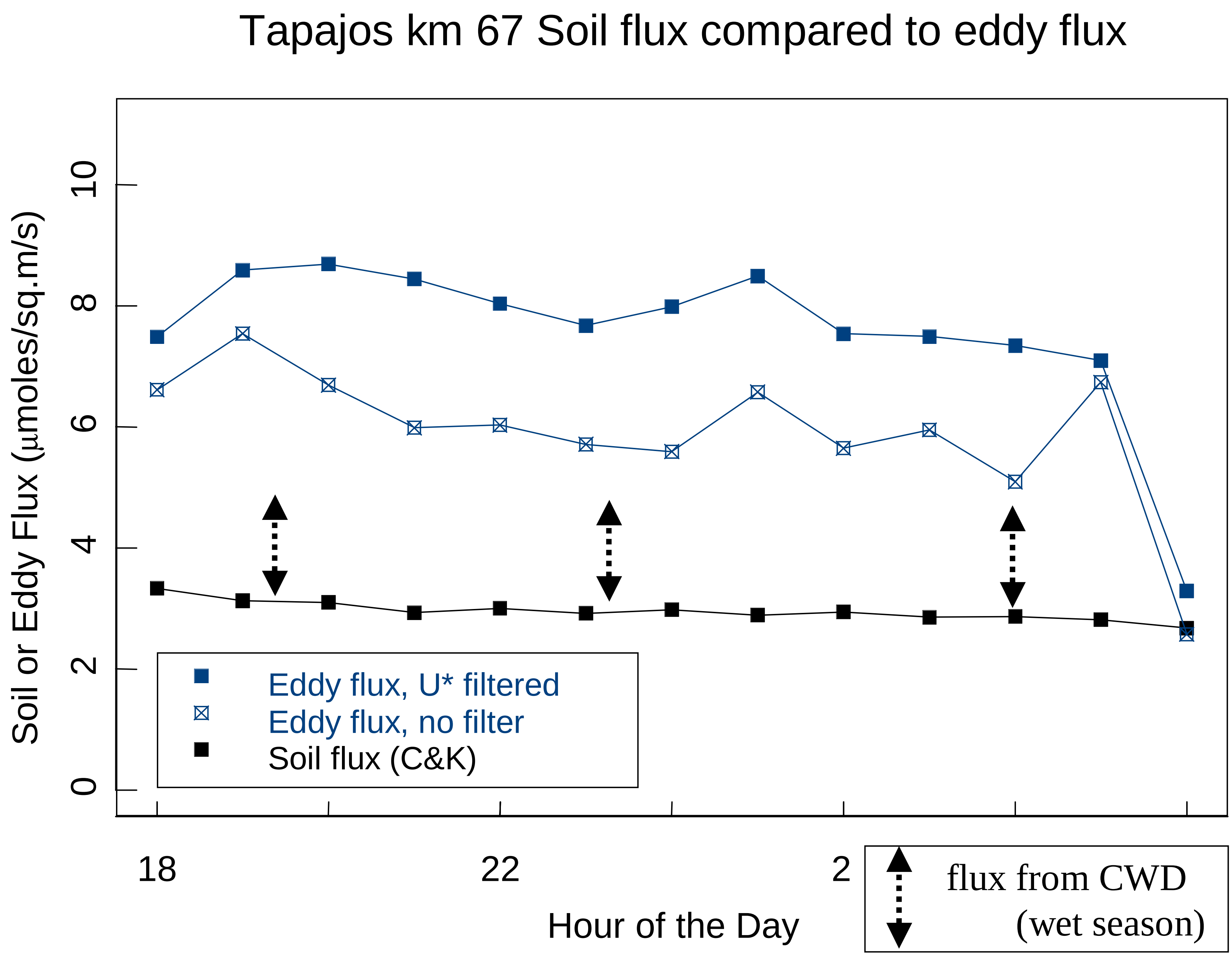
(*measurements from Crill, Keller, de Mello***)**

Tapajos: Night respiration (eddy) compare to soil flux





RESPIRATION
wet
dry
wet
Soil Respiration and NEE (night)
0
2
4
6
8
10
12
100
200
300
400
500
Day (1/1/2001=1)
Night NEE
Soil Flux+CWD
Soil Flux
…+ leaves and boles



Tapajos km 67 Soil flux compared to eddy flux
Soil or Eddy Flux (μmoles/sq.m/s)
0
2
4
6
8
10
Eddy flux, U* filtered
Eddy flux, no filter
Soil flux (C&K)
18
22
2
Hour of the Day
flux from CWD
(wet season)

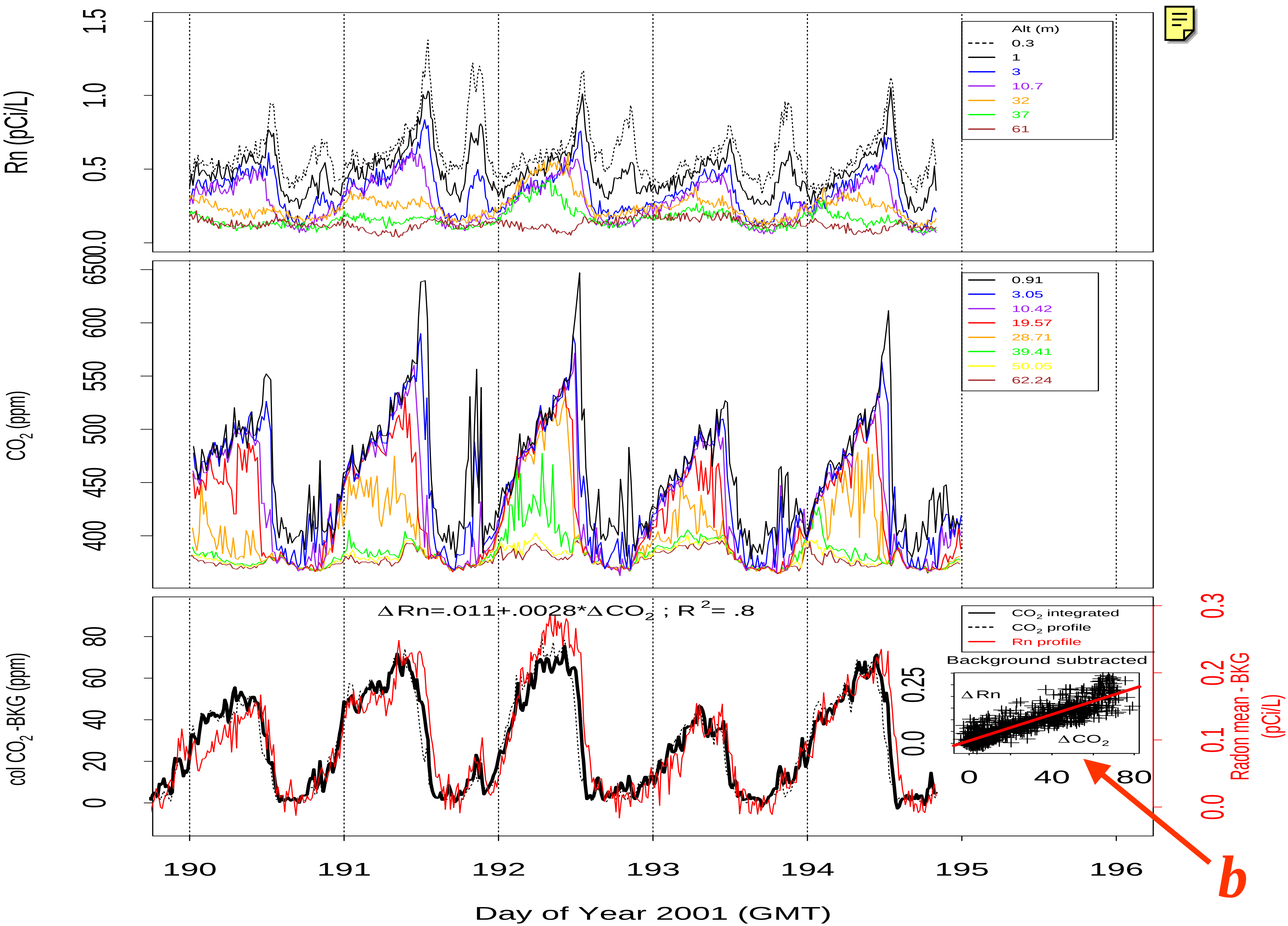
3^{rd} Comparison:

eddy flux data

with

continuous atmospheric radon (Rn) measurements

(*Martens*, *Shay*, *Moraes*, *Menlovitz*, *Crill*, *Moura*)



$$(\langle Rn\rangle - Rn_t) = 0.011 + 0.0028\cdot(\langle CO_2\rangle - CO_{2\text{-}t}),\ R^2=0.8$$

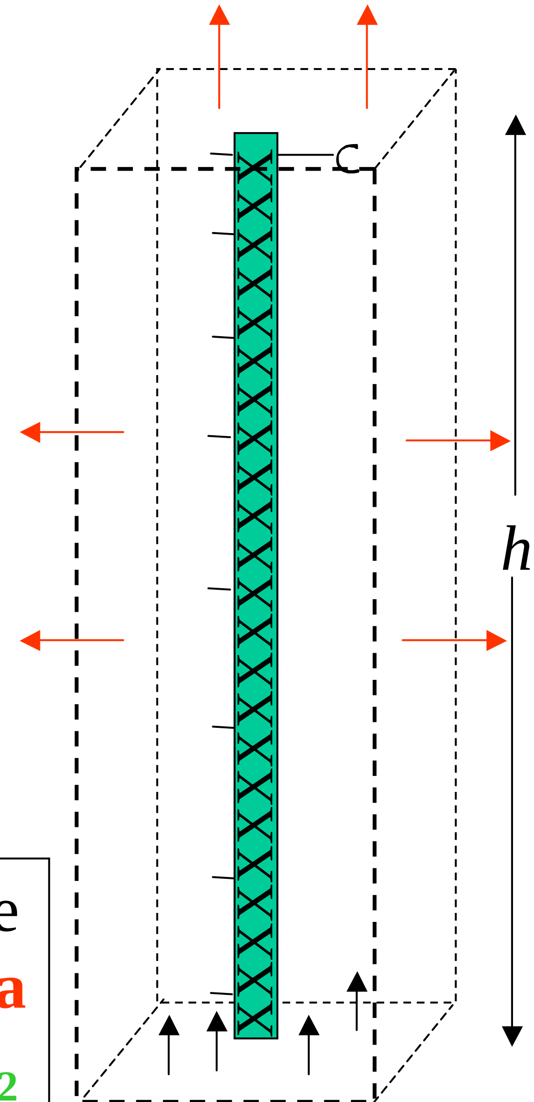
Radon data from C. Martens, T. Shay, and O. Moraes.

Rn: *surface (soil) flux = storage flux +* *atmospheric transport flux*

atmospheric transport flux =

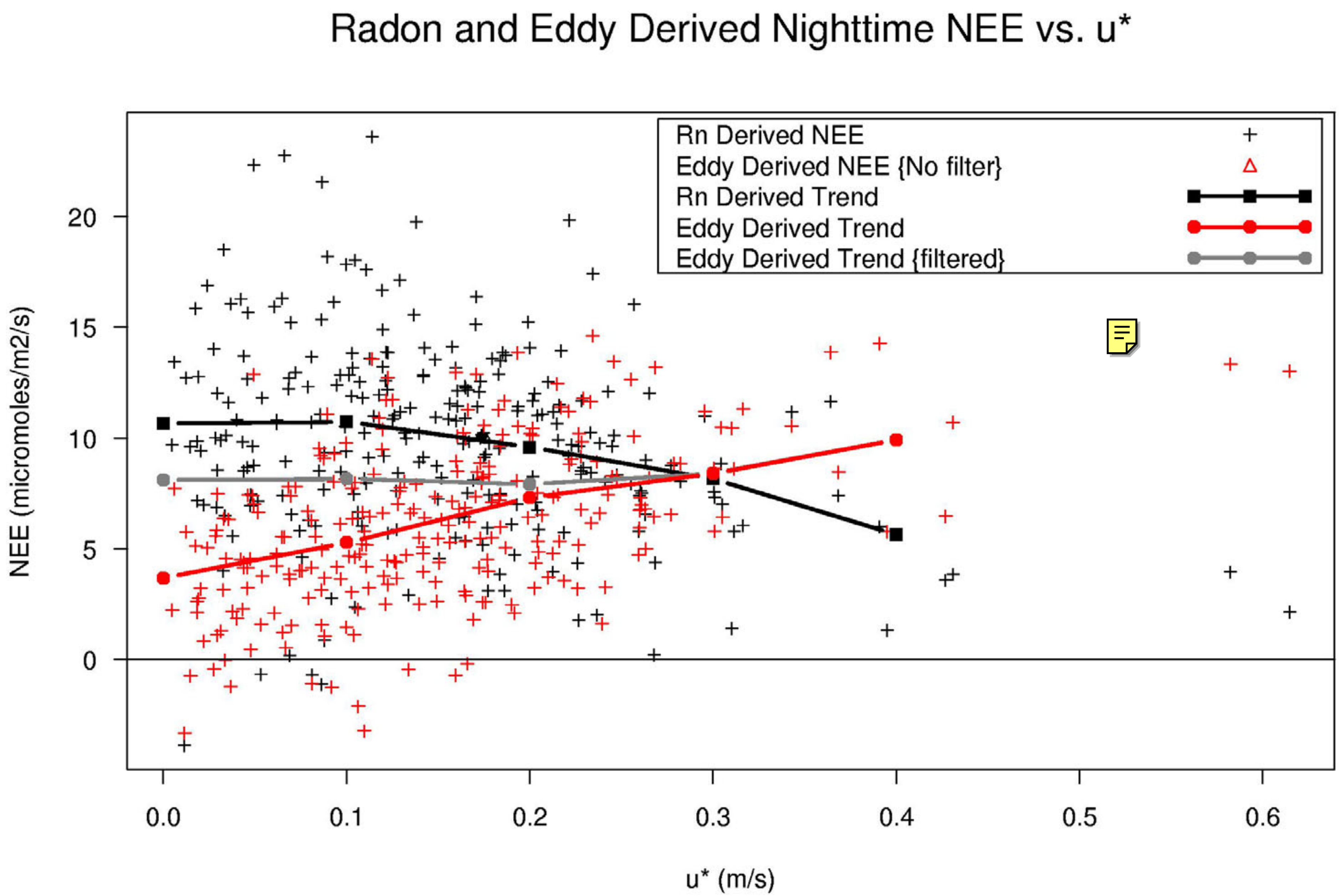
surface (soil) flux – storage flux

measured directly



Independent CO_2 Net Ecosystem Exchange can be derived from **atmospheric and soil emission data for Rn**, plus **atmospheric concentrations of CO_2** (omitting reference to eddy flux data)(night only).

$$NEE = (1/h)\, \partial/\partial t \int CO_2\, dz + b \times \text{Rn-transport flux}$$


Radon and Eddy Derived Nighttime NEE vs. u*
Rn Derived NEE
Eddy Derived NEE {No filter}
Rn Derived Trend
Eddy Derived Trend
Eddy Derived Trend {filtered}
NEE (micromoles/m2/s)
u* (m/s)
0
5
10
15
20
0.0
0.1
0.2
0.3
0.4
0.5
0.6

Summary and Conclusions

1. The Tapajós old growth forest is **losing** carbon to the atmosphere. Trees are growing rapidly, but high mortality and decay of the large pool of CWD more than offsets growth. *This result may be the legacy of ENSO events of the 1990's (cf. ecological plots…).*

2. The seasonal dependence of Net Ecosystem Exchange shows uptake in the dry season and loss in the wet season. It's opposite to tree growth rates, due to the dominance of decomposition processes.

3. The **carbon budget of the forest** from **eddy flux measurements**, including application of a U*-filter derived from site data, is tested and validated by detailed comparison with three other data sets of: **biometry/forest mensuration**, **continuous soil fluxes**, and **continuous measurements of atmospheric Rn**. Comparison with **km 87 data** provides additional confirmation. The results represent a collaboration among the numerous groups doing research in LBA at km 67.