The surface energy and radiation balances

The energy balance closure

Fluxes measured over a tower

$$F_c = \rho \overline{w'c'}$$ **CO2**

$$\lambda E = \lambda \overline{w'q'}$$ **water vapour (or latent heat)**

$$H = \rho c_p \overline{w'T'}$$ **sensible heat**

$$\zeta = \rho(\overline{w'u'}^2 + \overline{w'v'}^2)^{1/2} = \rho u_*^2$$ **momentum**

where u_* = friction velocity

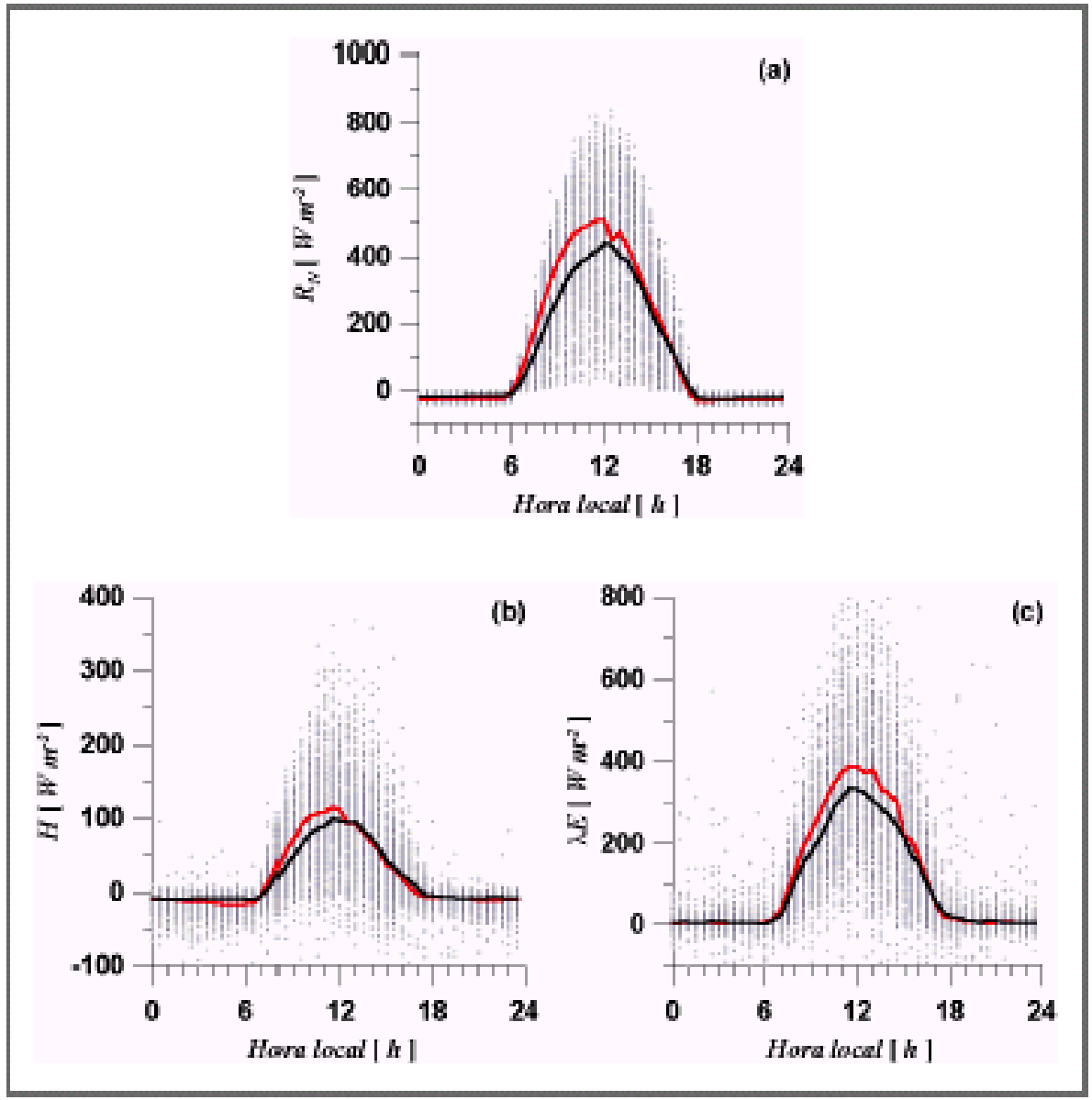


Figura 4.31: *Variabilidade do ciclo diurno dos valores médios de 30 min de: (a) saldo de radiação R_N [$W\,m^{-2}$]; e dos fluxos turbulentos de (b) calor sensível H [$W\,m^{-2}$] e (c) calor latente λE [$W\,m^{-2}$]. As curvas representam o ciclo diurno médio nas estações seca (em vermelho) e úmida (em preto).*

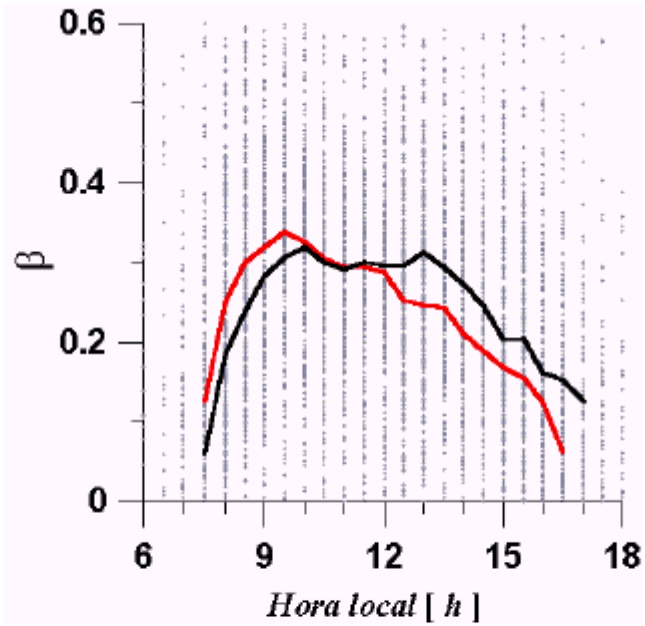


Figura 4.32: *Variabilidade do ciclo diurno dos valores médios de 30 min da razão de Bowen (β). As curvas representam o ciclo diurno médio nas estações seca (em vermelho) e úmida (em preto).*

The Bowen ratio = H / E

over a tropical rain forest

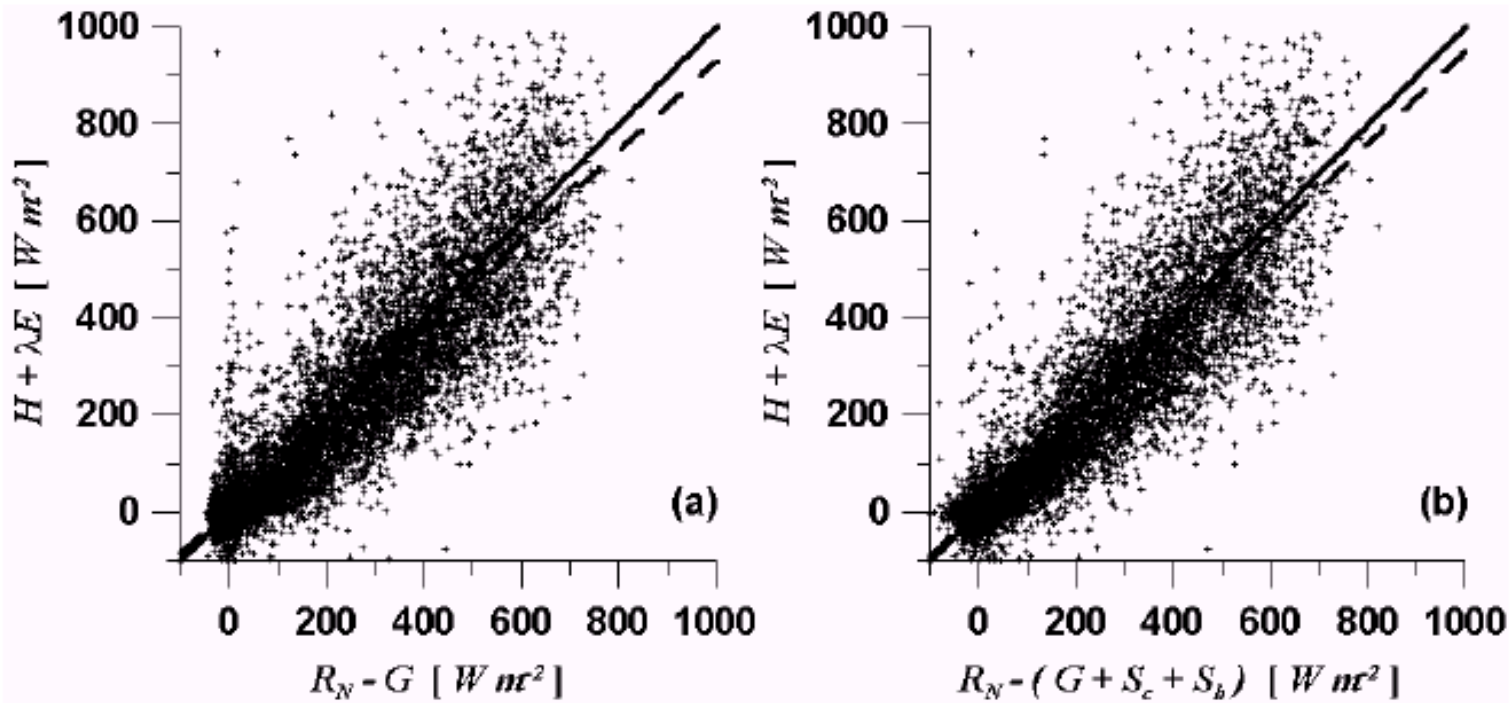
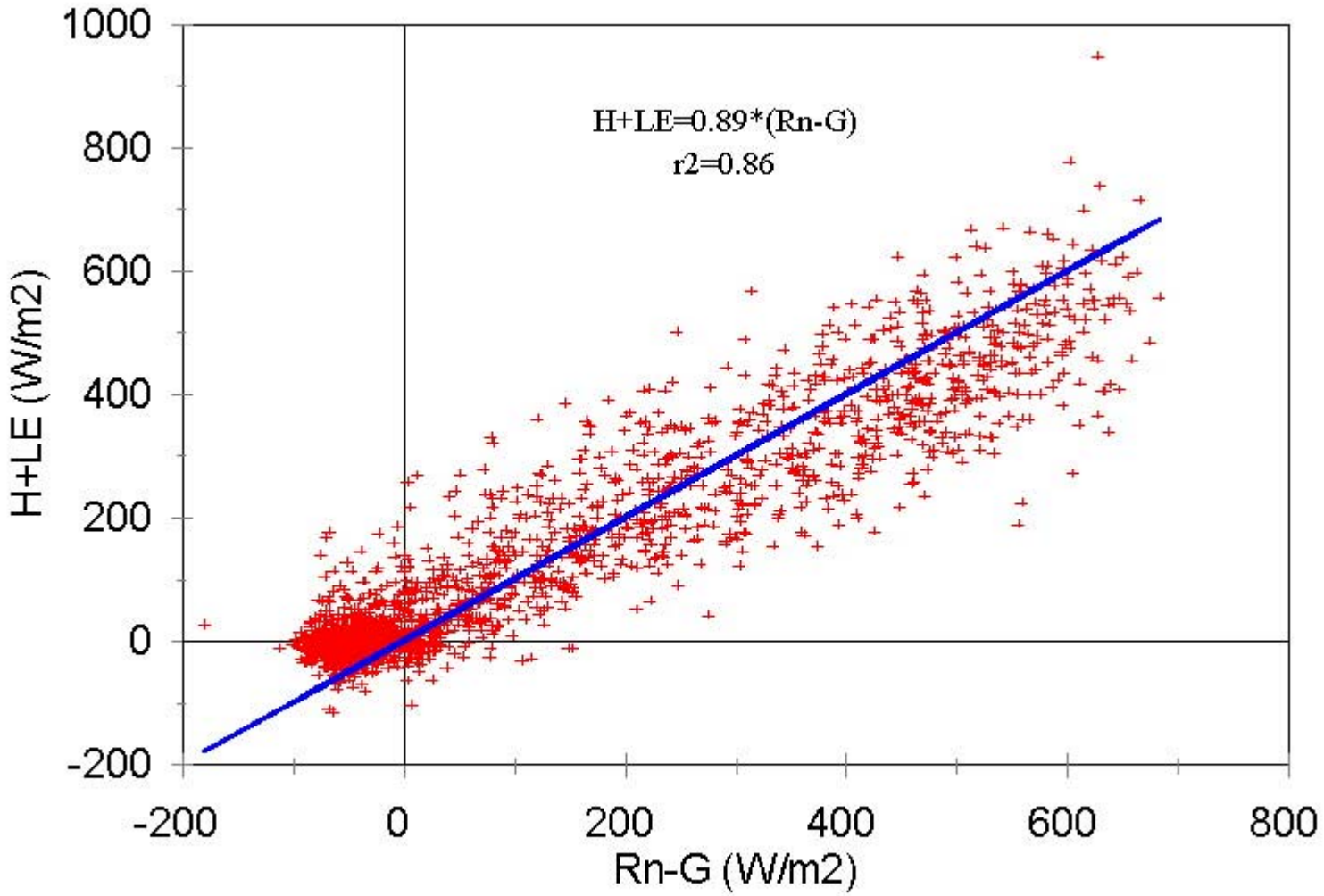


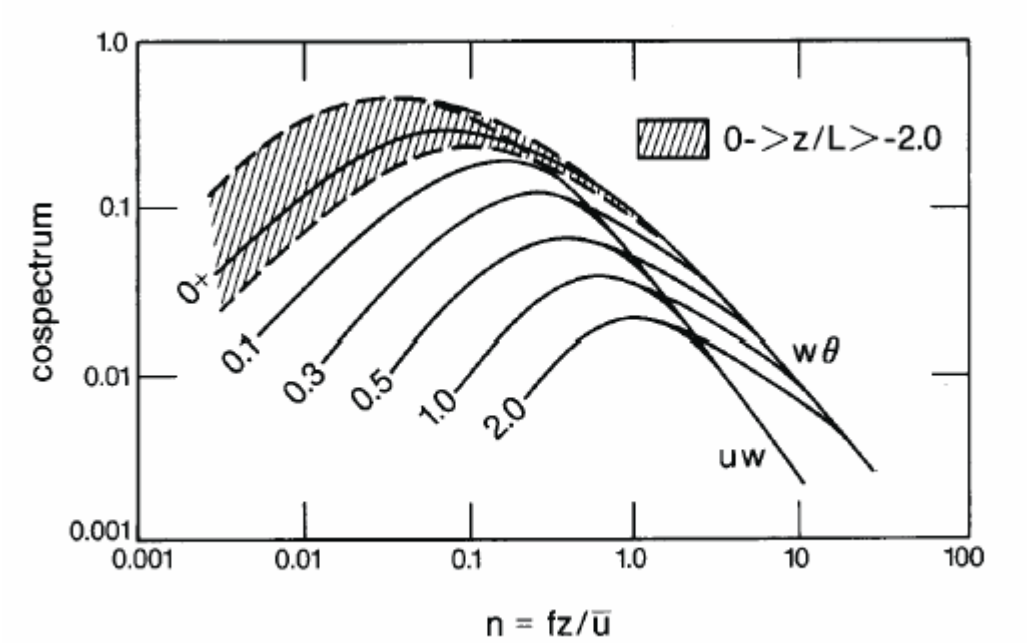
Figura 4.17: *Soma dos fluxos turbulentos de calor sensível (H) e calor latente (λE) em relação à energia disponível no sistema, estimada como: (a) diferença entre o saldo de radiação (R_N) e o fluxo de calor sensível no solo (G); e (b) diferença entre o saldo de radiação (R_N) e a soma do fluxo de calor sensível no solo (G) e, a energia armazenada no dossel (S_c) e biomassa (S_b). A linha sólida representa a curva de proporção [1:1] e a linha tracejada o ajuste linear (a) $y = (0{,}923 \pm 0{,}004)\, x + (7{,}7 \pm 0{,}8)$, $R^2 = 0{,}84$; e (b) $y = (0{,}945 \pm 0{,}003)\, x + (4{,}1 \pm 0{,}8)$, $R^2 = 0{,}85$.*


H+LE=0.89*(Rn-G)
r2=0.86
H+LE (W/m2)
Rn-G (W/m2)
1000
800
600
400
200
0
-200
-200
0
200
400
600
800

Sugar cane

Filters and constraints

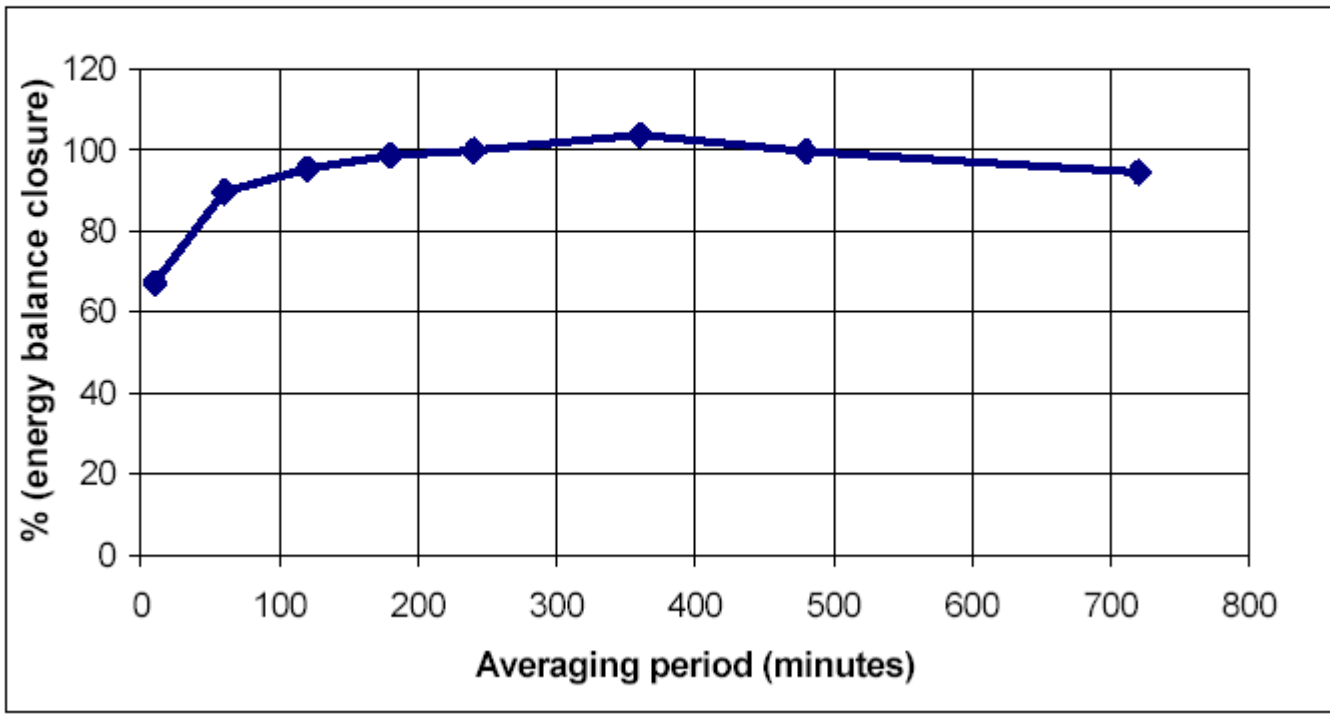
(part I)



19.2 Normalized surface layer cospectra of $u'w'$ and $w'\theta'$, shown varying with stability parameter z/L_{MO}. From Kaimal and Finnigan Ch2, Fig 2.18. f is frequency in Hz.

Source: Finnigan et al 2002

19.3 Ratio of total energy flux, $H+LE$ to available radiant energy, $Rn-G$ at Manaus for different averaging and rotation periods. From Finnigan et al (2001)



Source: Finnigan et al 2002

Height and averaging constraints

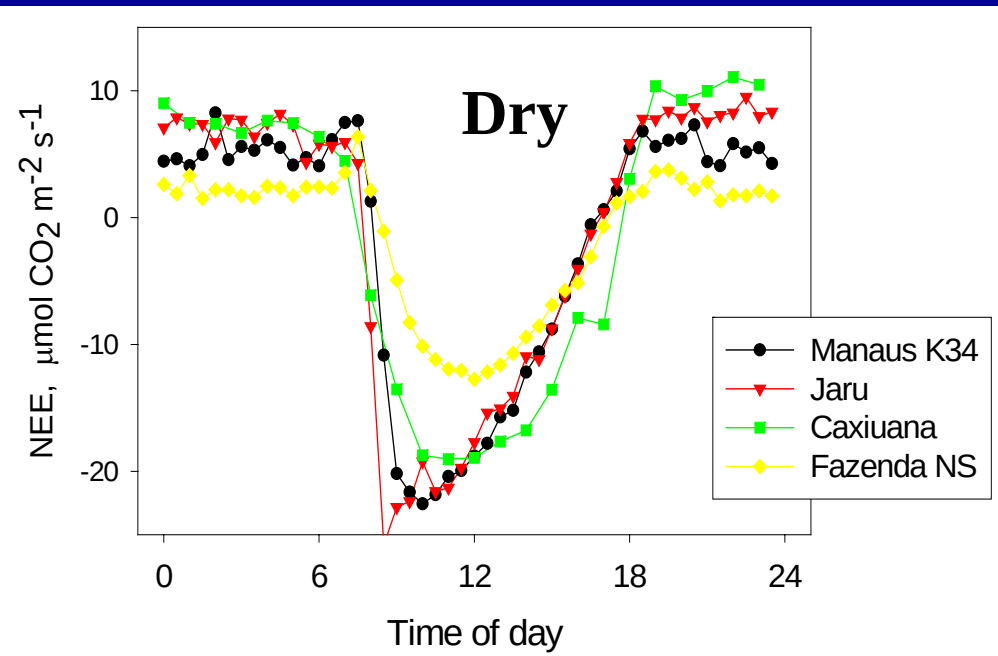
minimum height 3 m, and above 1/3 of canopy height

measurements 5 / sec = 5 Hz

T >= 30 min

The eddy covariance technique: estimating diel cycle, seasonal variability and long term balances

Mean Diurnal trend of CO_2 fluxes at four sites

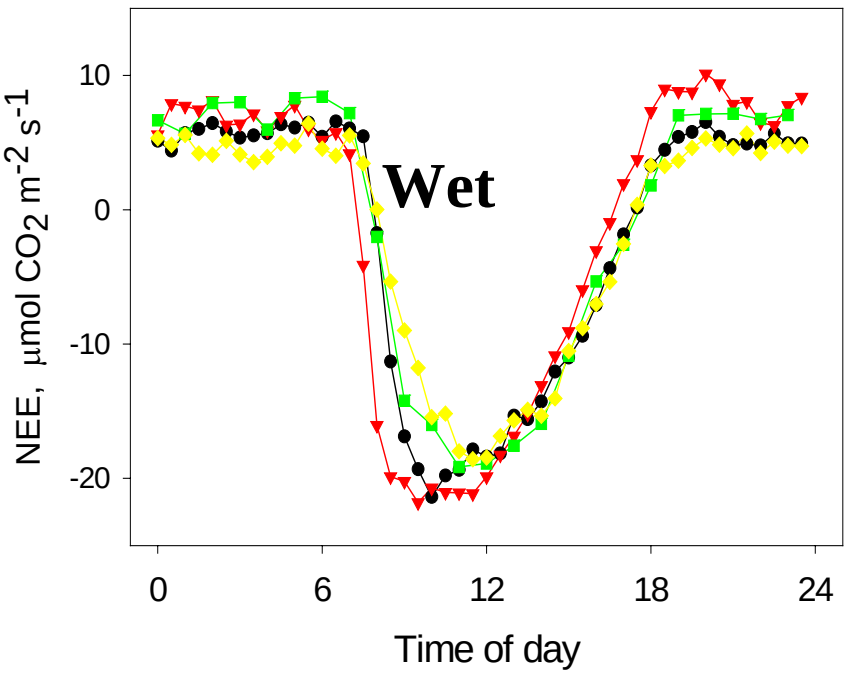


Dry seasons:

- Forest peak uptake similar, nights different.
- Pasture lower uptake!

Wet seasons:

- Forests and pasture very similar.
- Source: B. Kruijt (Alterra).



Eddy covariance represent reasonably the diel cycle and seasonal variability over ecosystems

Sampling errors are to 5%, Calibration errors (IRGAs) 3%

Time-lags between velocity and scalar 2%

2. At night, low wind and thermal stratification prevent

CO2 (exiting leaves and soil) to reach the IRGA,

consequently underestimating the flux.

It can be reduced thru:

- estimating storage term correctly

- work with ideal hypothesis (of flat and uniform terrain)

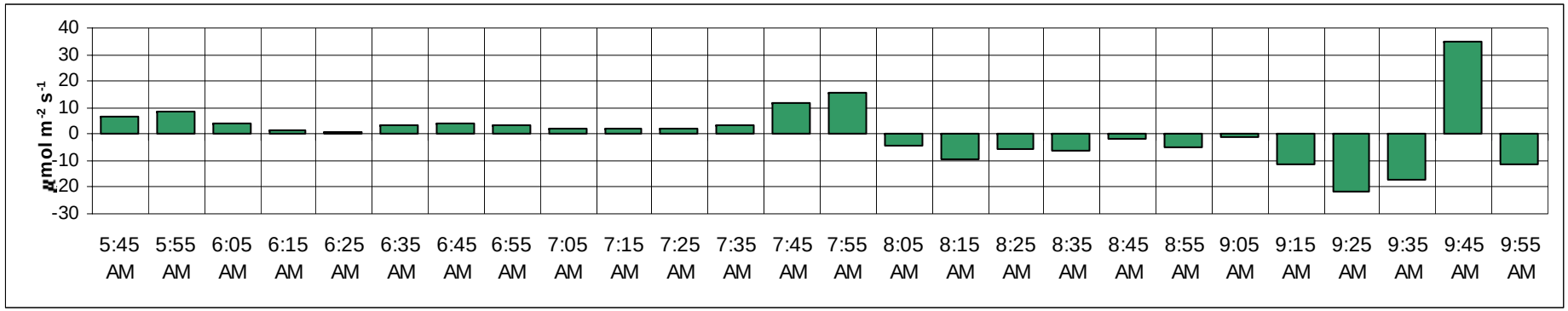
- fill gaps (absence of data) and ...

- and fill events under large uncertainties with alternative approaches
*similar wind and climate conditions at near days,

*models fitted on other observations, like chambers, sap flow, and the eddy covariance as well)

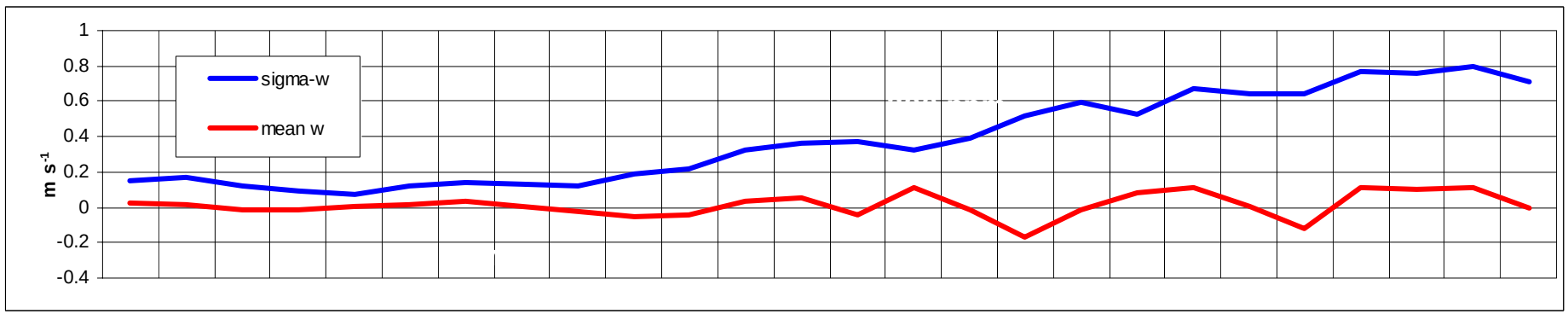
Some patterns of CO2 profile within a dense forest canopy

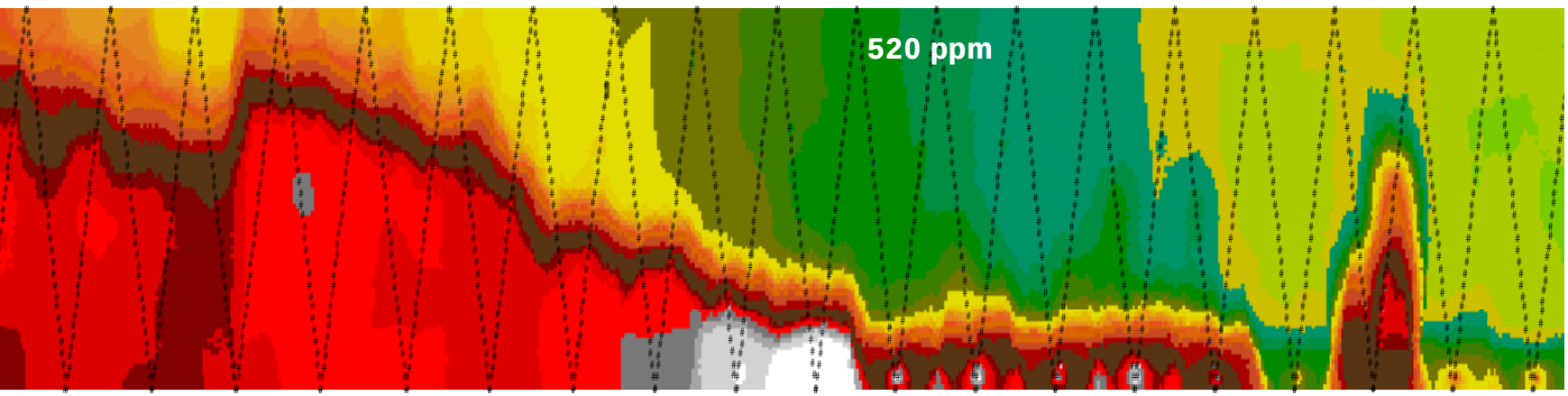
Carbon dioxide flux



The Dawn Transition

Wind speeds and standard deviation source Y. Malhi





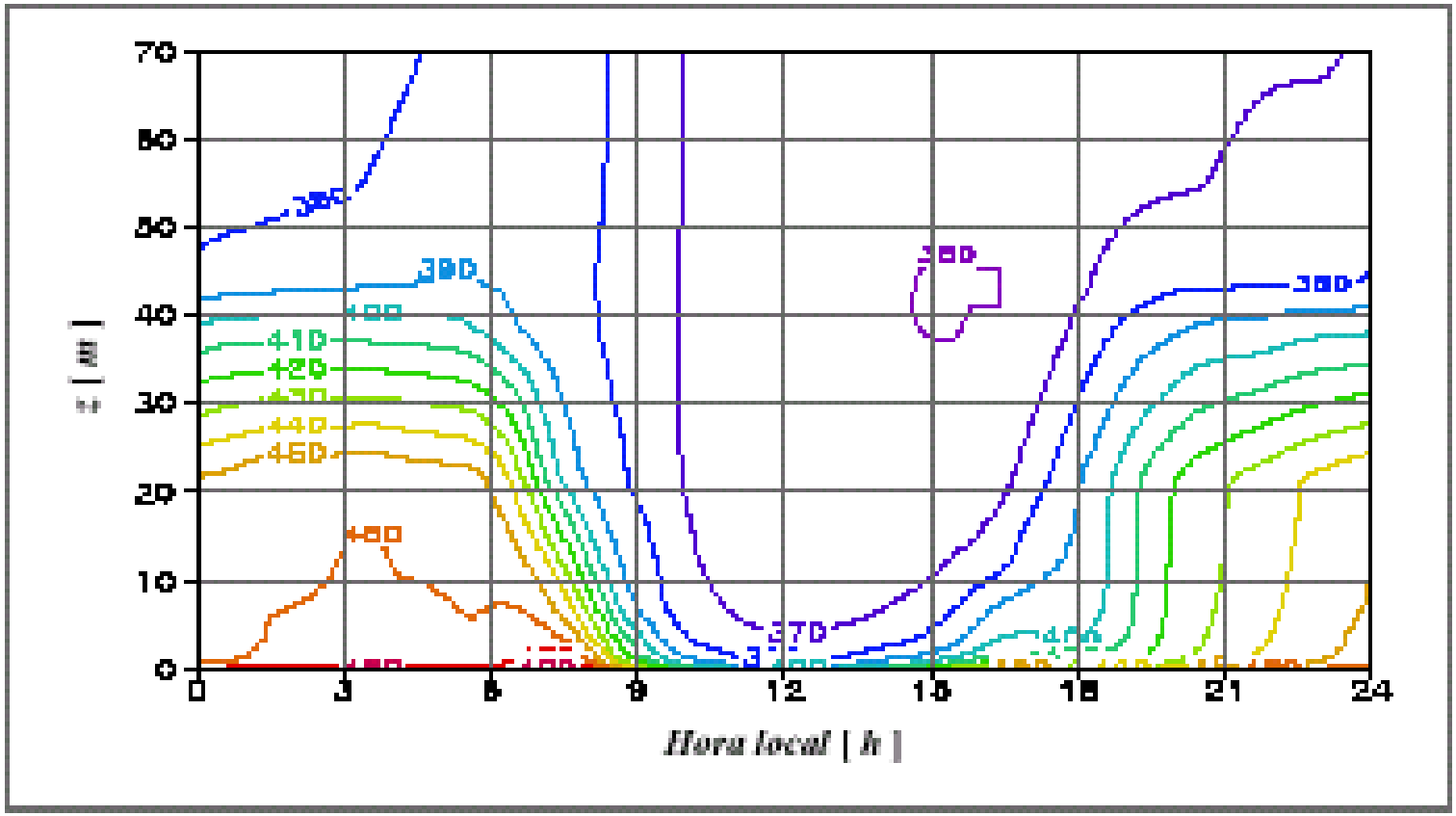
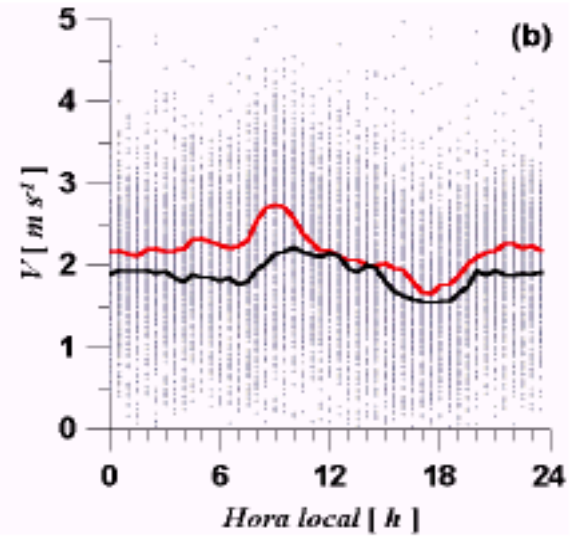
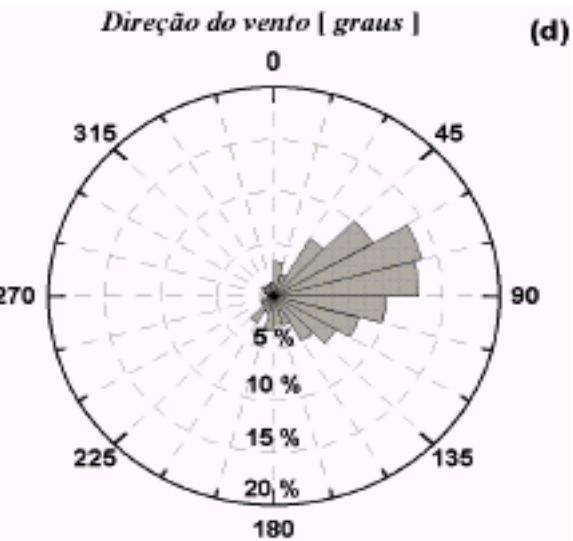
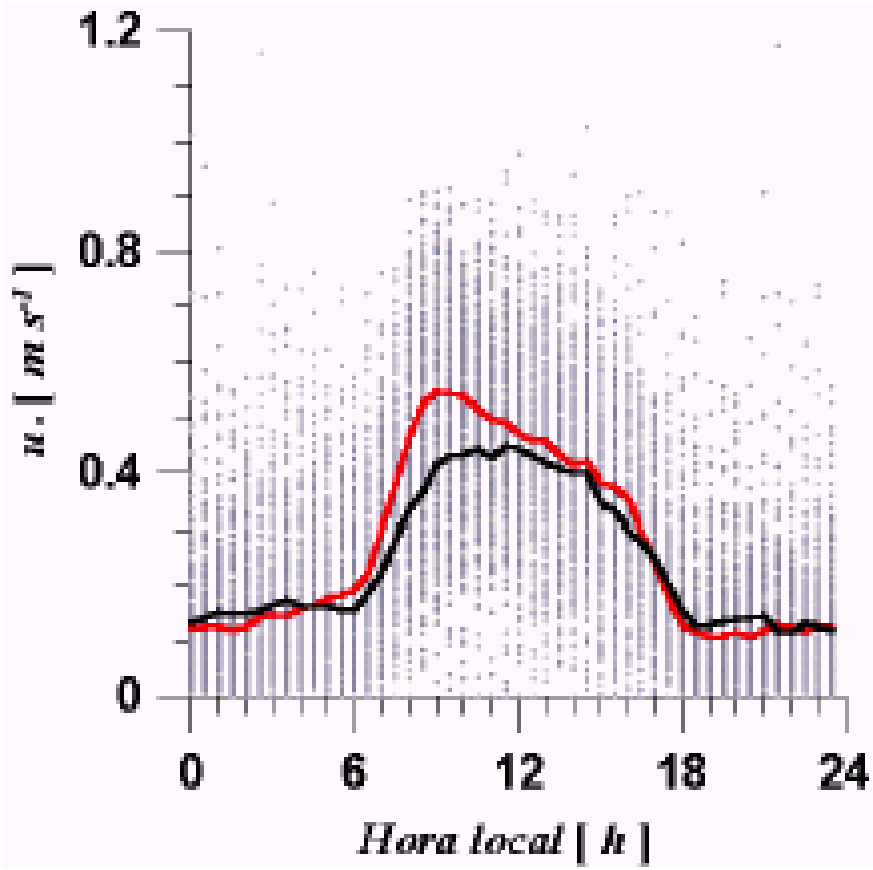


Figura 4.16: *Secção vertical do ciclo diurno médio da concentração de CO_2 [ppm], desde a superfície até o topo da torre (64 m).*

CO2 concentration between 0 and 70 m within a dense forest canopy profile







Average wind speed and friction velocity (u_*) at tropical forest (Rain forest in Santarém km83) (in m/s)

Problems may exist with the ecosystem flux estimation

(... They are site-specific)

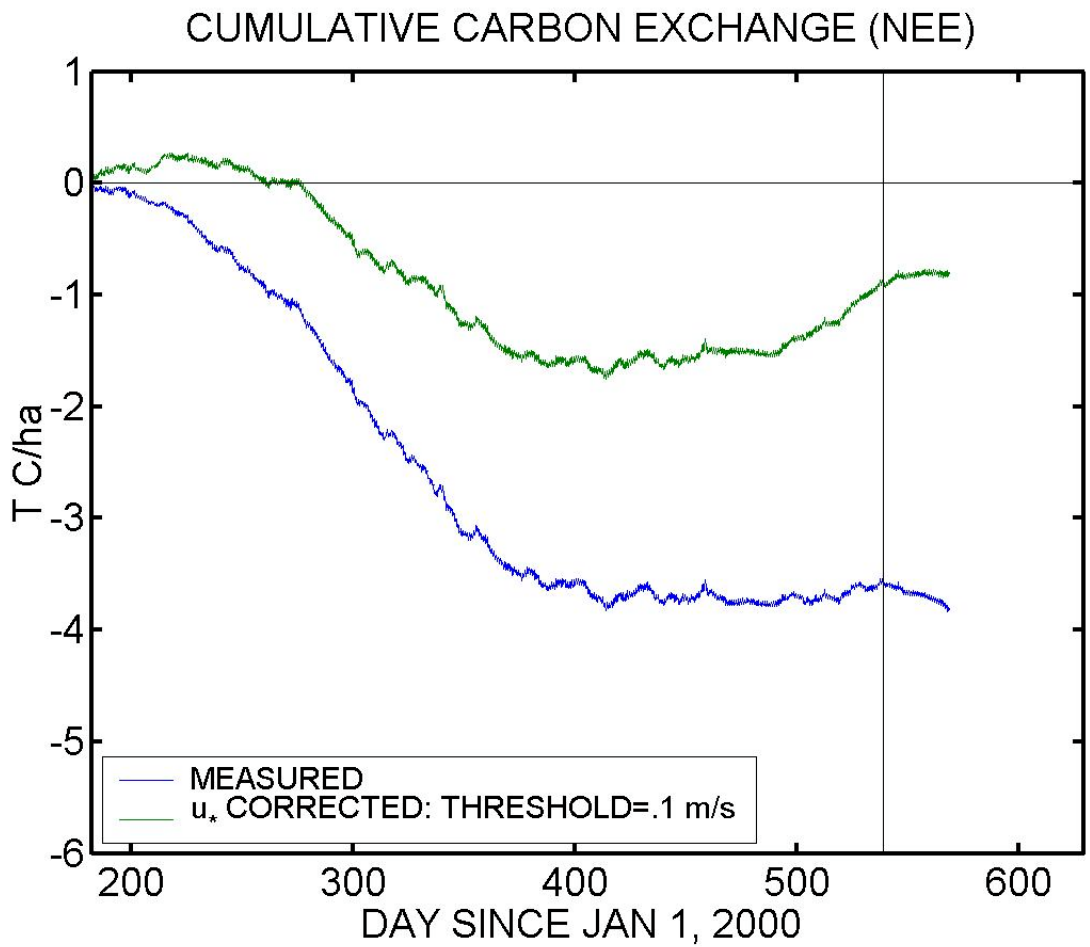
1. During low mixing conditions (mostly nightime), for the calculation of annual sum,

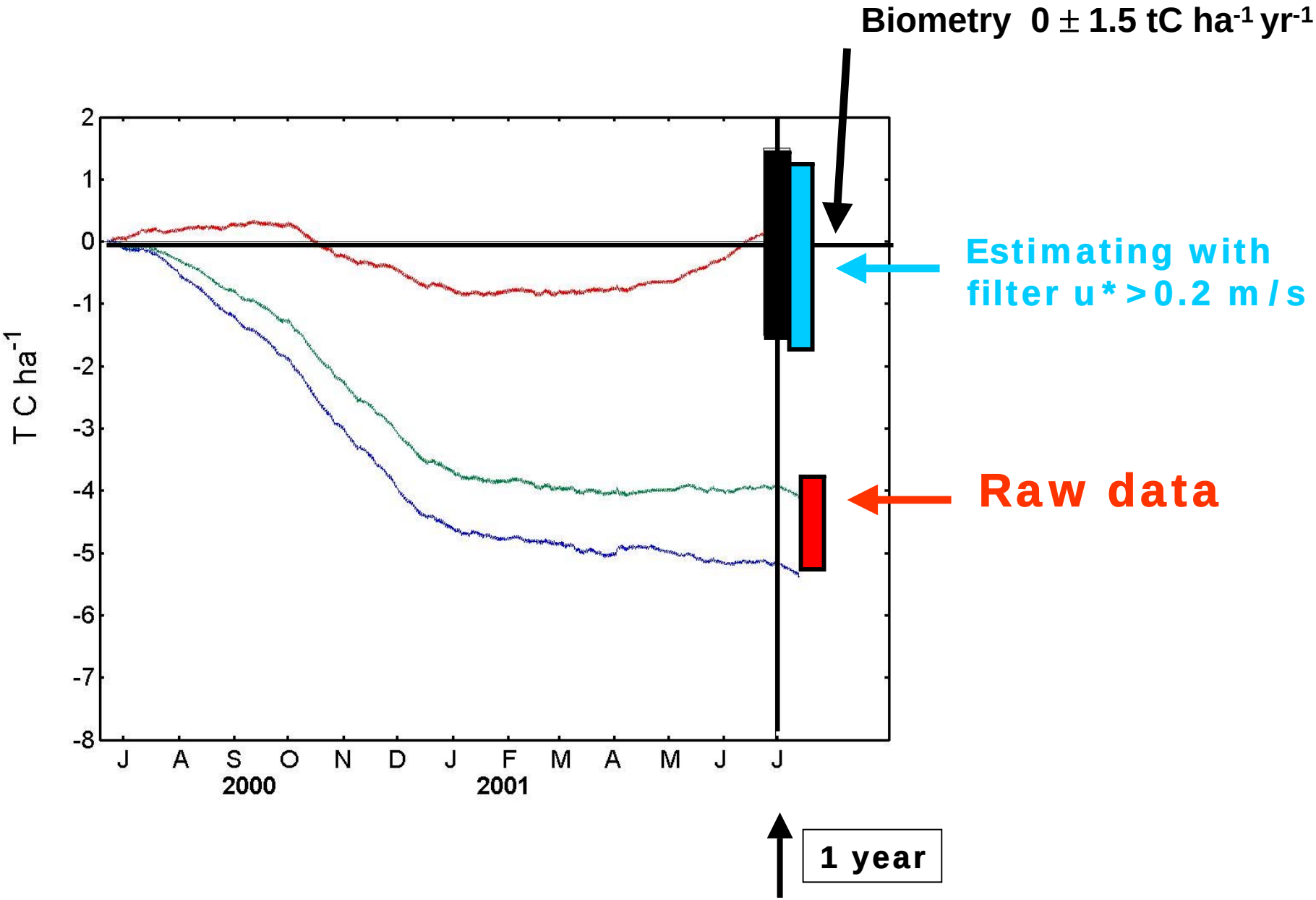
data must be replaced

a criteria (filter): low u_* (low mechanical mixing)

u_* Correction

A dramatic effect!

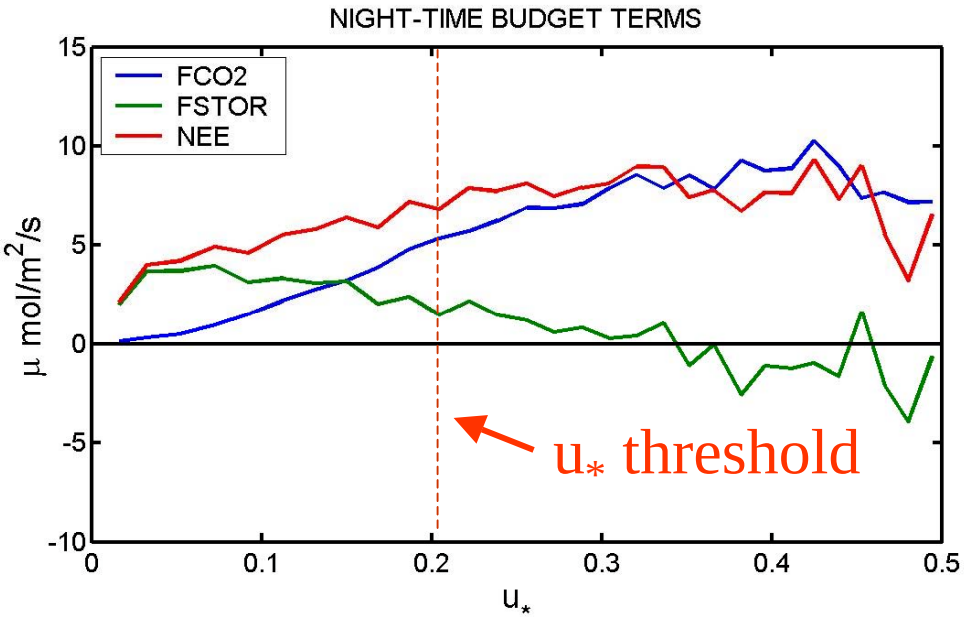


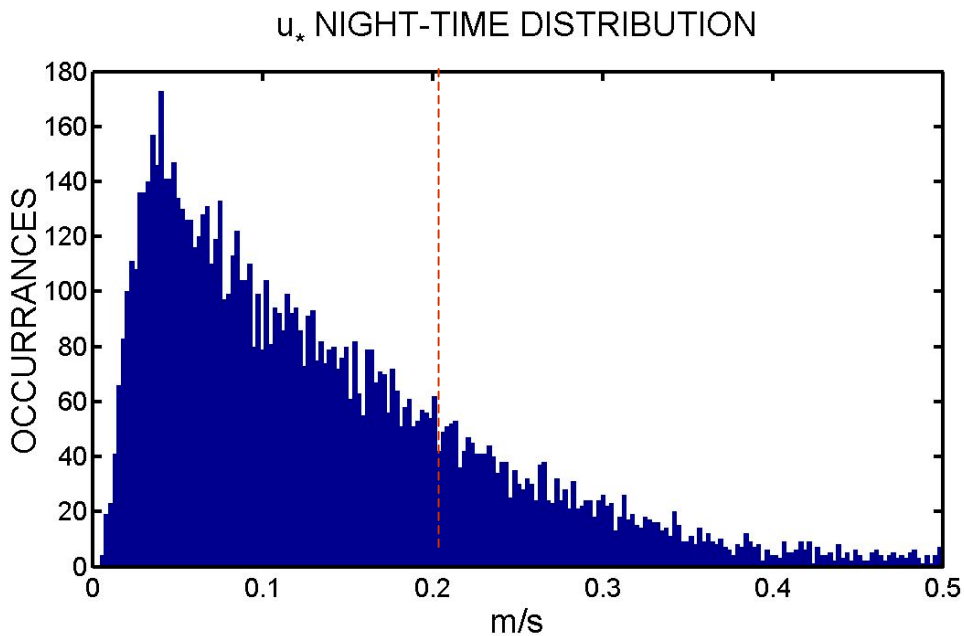

Biometry 0 ± 1.5 tC ha-1 yr-1
Estimating with filter u* > 0.2 m/s
Raw data
1 year
T C ha-1
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
J A S O N D J F M A M J J
2000
2001

u_* Correction

Assumption: NEE and u_* are independent

Difficulty: Most nights are calm.





Recomendations

a. Problems may exist with the ecosystem CO2 flux estimation:

- they are however site-specific, and might be prevented as much as possible (based on previous discussion);

b. Measured turbulent fluxes can underestimate the available energy, and several reasons (that should be minimized in the design implementation), can be:

- advection from heterogeneous areas outside the tower fetch;

- different footprints viewed by the tower and the radiation sensors, respectively;

- wind blowing from an undesirable wind sector (can be related to sonic position);

- flux calculation (period of time, underestimate some frequencies)

c. About tower implementation:

- choose a platform that distorpts the air flow as less as possible;

- place it on a position compatible with the eddy covariance hypothesis;

- height: maximum height compatible with the desired fetch, but constrained to minimum height of sonic position;

- ground all systems.

d. Sonic and IRGA

- position compatible with prevailing wind direction

- less disturbed as possible by tower;

- IRGA calibration, if closed path (automatic every 6h gives extreme accuracy; if every 15 days give moderate accuracy, but still viable for flux calculation since drifts are prevented); if open path (automatic calibration is less viable, 15 days viable if no other conditions discalibrate the device);

- Tend to be a place for birds watching the landscape (prevent it using non-toxic repellents), or others masts at higher levels.

e. about site selection

- - Hypothesis of homogeneous surface

- When working over agricultural lands, take notes and quantify the effects of irrigation, fertilization, burning, tillage, herbicides

- Keep good communication with owners;

regional representativy: Is the site you're working with regionally representative ? Varieties of vegetation, soil type, climate and harvest management are representative ?