CD –03 Periodic, Transient, and spatially inhomogeneous influences on C exchange in Amazonia

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Introduction:

The Carbon Dynamics group CD-03 investigates surface-to-atmosphere turbulent exchanges in the Amazon, focusing on carbon exchanges. We consider the symmetry between temporal and spatial discontinuities. Long term, high quality flux measurements must precede extrapolation to the basin scale, but how can one determine how representative are the sites selected for point flux measurements? If regular phenomena, many of them associated with local wind circulations exist, for example, they can be exploited to allow alternative estimates to be used. In the Santarém study area of the LBA-ECO, for example, scales of inhomogeneities range from the river-land contrast (figure 1), the agricultural field-forest contrast (figure 2), and the gap-closed canopy contrast inside the forest. Our efforts would take us to confront these less "ideal" features of the real situation. If the debate as to whether this region is a source or sink of carbon is to be resolved, careful attention to methodology is required. To achieve our goals, we analyze the data sets from the 3 tower fluxes sites (primary forest, logged forest, and an agricultural field), and 8 meteorological stations that form a mesoscale network in the region.

Also a special attention is to understand how changes in agricultural practices in the Amazon alter carbon exchanges in clear areas (table 1). Another study is to relate light availability to the ecosystem to cloudiness, and to determine the result effect in the NEE, net ecosystem carbon exchange (CLOUDINESS and PBL BUDGET).

New initiatives aim to quantify canopy structure to relate this structure to turbulent fluxes (CANOPY STRUCTURE), determine the impact of the forest gaps to the forest-atmosphere exchange (GAP STUDY), improve understanding of the respiration rate in forests by studying subcanopy flows (DRAINO)

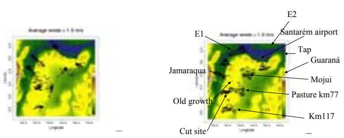

Figure 1: Wind vectors of the network of meteorological stations and flux tower sites in the Santarém Region. The panels show the hourly averaged wind speed for wind speed higher than 1.5 m/s (right) and lower than 1.5 m/s (left).

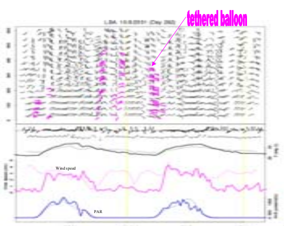

Figure 4.4: (Top panel) Time series of the meteorological barbs for the wind speed measured by the sodar (black), and from the tethered balloon (magenta) at several levels. (Bottom panel) Time series of the wind vectors for the km 67 and km77, temperature (black), wind speed (magenta), and PAR (blue). The solid lines corresponds to km 77, and the dashed lines to km 67 data. Note the decoupling of the wind speed and temperature at nighttime between the agricultural field (km 77) and the primary forest (km 67) in contrast with to the strong coupling in the daytime.

Cover	Period	NEE (mg CO2 m^{-2} s^{-1})	Total Carbon (Kg C/m^2)
Pasture wet	Apr –Jun 2001	-0.10 ±0.02	-0.21±0.04
Pasture dry	Aug - Oct 2001	-0.02 ±0.01	-0.07±0.02
Bare soil	Nov - Dec 2001	+0.08 ±0.02	+0.09±0.03
Rice crop	Mar – June 2002	-0.17 ±0.02	-0.36±0.04
Pasture/ Bare soil	Jan-Dec 2001	-0.035±0.01	-0.30±0.08
Bare soil/Rice	Jan-Jun 2002	-0.036±0.014	-0.16±0.06

Table 1: NEE values from all land use change at km 77. Negative values indicate uptake of CO_2, positive values efflux of CO_2. The error in *NEE* corresponds to the standard error of the mean. (Sakai et al., 2003)

Proposed work: CLOUDINESS and PBL BUDGETS

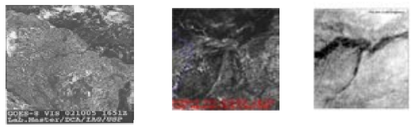

Figure 3: Collaboration with Univ. de São Paulo. Satellite images from the Santarém Region. Left panel: Dry season fair weather Cu; Center: 1-km resolution near Santarém; Right: Santarém region, average low cloud frequency. (Images obtained extracted from IAG-USP web site).

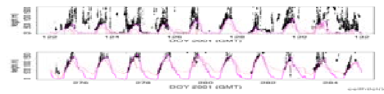

Figure 4: Time series of the cloud base measurements from ceilometer (dots), and the lifting condensation level (LCL) calculations from km 67 (red), and km 77 (magenta). During the wet season (top graph) there are more clouds. Notice that the PBL height depends on the km 77 meteorological conditions rather than on the local measurements of T and q at the forest.

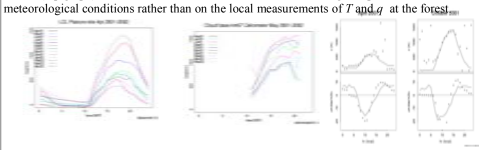

Figure 5: Hourly averaged values for LCL (left), cloud base (middle) during the year, CO_2 fluxes (bottom right) using the the accumulation method (dots) and tower measurements (solid lines) for April (wet season), and October (dry season). Notice that the PBL height is deeper in the dry season.

Proposed work: Fluxes & CANOPY STRUCTURE

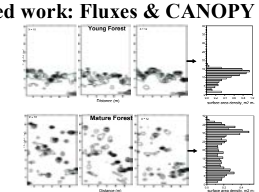

Figure 6: Examples of range finder system operated from the forest floor (Parker, SERC). Three adjacent height sections with contours of surface area density, each 30 m in the horizontal (the size of a TM pixel) in two forests at the Smithsonian Environment Research Center (SERC: a young (50 yr) organized canopy and a mature (110 yr) canopy with more diffuse surface area – the surface area profiles to the right are the average over 31 slices in each plot. The LAI's are 5.5 for the younger and 4.8 for the older and the rugosities are 2.9 and 9.2 m respectively. The hypothesis is that canopy structure affects the subcanopy fluxes in regular ways across different ecosystems.

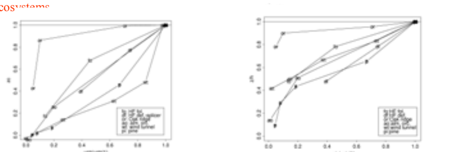

Figure 7: Profiles of the friction velocity using two normalized heights. Left: vertical axis a 'canopy density optical depth' (zc); Right: one using z/h (h is the canopy height. Notice that using zc, there are two classes of curves, for broadleaf and needle leaf forests. (Sakai, 2000)

GAP STUDY

Location – km 83:

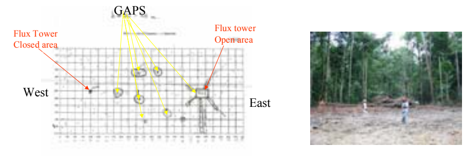

Figure 8: Left – sketch of the gap positions surrounding the km 83 towers. Right – photograph of the chosen gap to install a 65 m high tower flux. The hypothesis is that large gaps represent preferred regions for canopy-atmosphere exchange. Measurements made near such gaps exaggerate the flux of any constituent element at the surface.

Large Eddy Simulations (LES) (Acevedo and Fitzjarrald, 2003):

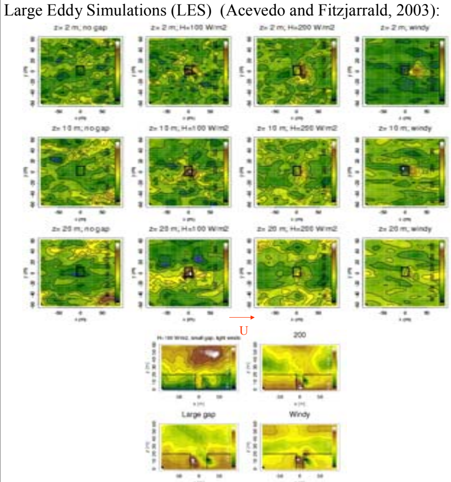

Figure 9: (Top 16) Averaged scalar flux using a LES model at four levels and four different simulations. In each case the position of the gap is indicated by a thick solid line. The horizontal speed is 5 ms^{-1} in the wind case (from right to left). (Bottom 4) Vertical cross section of the scalar flux in each simulation. Thick solid line is the canopy boundary. The gap was found to anchor scalar fluxes emitted at the surface. The local value can 3 times larger than the horizontal average. Observation tower must be away from gaps, but, at the same time, determination of area-averaged fluxes from these observations should consider the fact that fluxes are higher near the gaps

CO_2/H_2O (UCI)	T/RH	Sonic 2D	Sonic3D	IR Sensors
64			64 (UCI)	
	60			
50				
	45			
40		**40**		
35	**35**			
	30	**30**		
			25	
20	**20**			**20/20**
		15		
10	**10**			
6	**6**			
		5		
3				
1.4				
0.7				**0.7**
	0.5			
0.35				
0.1				

Figure 10: Levels of instruments from CD-03 and CD-04 groups (UCI) to be deployed at the gap site flux tower.

Proposed work: DRAINO-LBA-ECO

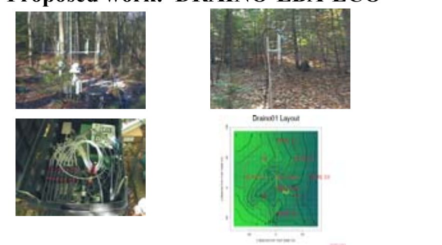

Figure 11: DRAINO experiment implemented in a deciduous forest in Massachusetts (HF) (Staebler, 2003). A similar setup will be installed at several sites in Brazil. (Top left) instruments intercomparison, (top right) 2D sonic, and a CO_2/H_2O inlet, (bottom right), data acquisition, multiposition valve, and a CO_2/H_2O analyzer, (bottom left) schematics of the instruments deployed with the flux tower at the center. Hypothesis: regular subcanopy flows on calm nights can explain imbalances in the carbon budget through horizontal advection. This may be the reason that eddy flux and vertical storage lead to estimates may times smaller than what is sometimes observed in chambers

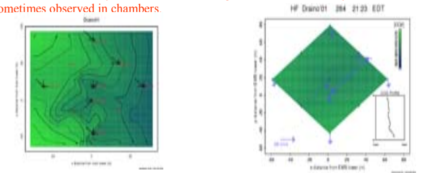

Figure 12: Results from the HF DRAINO' 2001 campaign. Left – nocturnal wind roses. All anemometers are 1.5 m above ground. Solid lines are the contours of the terrain topography. Right - CO_2 concentration and wind vectors. Also the CO_2 vertical profile of the tower flux is shown in the site panel. At this site, drainage flows were observed in 1/3 of all nights. However, only 1/3 of nights with CO_2 flux 'deficits' were associated with drainage flows.

Summary and Future work

Ongoing projects:

• *Monitoring the land use change* at km 77. Continuous measurements of heat, water vapor, and CO_2 fluxes, components of the radiation balance, and other measurements will allow us to estimate intraseasonal sensitivity of crop growth to rainfall events.
• *Local circulation studies*. The regular appearance of a combined drainage/land breeze of the escarpment above the Tapajos river has been common knowledge. We observe this feature in Jamaraqua station (close to the river). We expect air draining down the slope above the village of Jamaraqua should integrate the respiratory CO_2 emitting from the ecosystem in the airshed.
• *The characterization of the nocturnal boundary layer* and the transition to convective conditions (see UFSM CD-03 poster).
•*Boundary layer budgets*. Estimating regional budgets of CO_2, heat, and water vapor is essential to "regionalizing" the information obtained at the flux tower sites. We have demonstrated that one can estimate boundary layer thickness using the ceilometer cloud base record.

Future work:

• *Canopy Architecture/subcanopy light environment studies*. With the assistance of Dr. Geoffrey Parker (SERC) we intend to determine the vertical and horizontal vegetation structure at the km 67 and km 83 sites using the TRAC system). Also a network of pyranometers were installed in km 67 site to determine the light regime (not shown).
• *Gap study*. To validate the LES simulations, that large gaps represent preferred regions for canopy-atmosphere exchange, a second flux tower close to the existing tower at km 83 will be instrumented (see table 2).
•*DRAINO-LBA*. To understand how subcanopy motions affect carbon budget measurements we have performed pilot studies at HF forest. We will perform similar observations in the two forest sites in Santarem (km 67 and km 83), and Manaus (ZF-2).

Acknowledgements:

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Using the budget method to estimate nighttime surface fluxes

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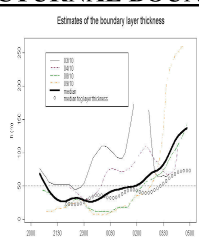
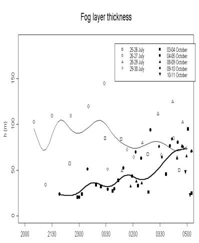
ABSTRACT

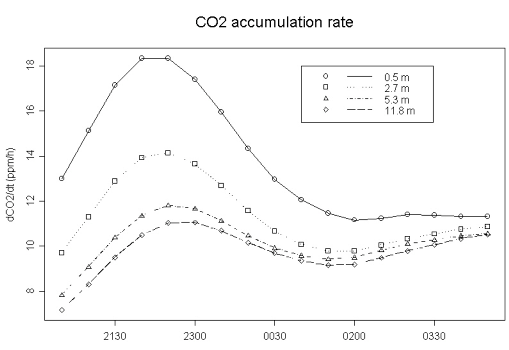
Nocturnal vertical profiles of temperature, humidity and winds were observed at an Amazon deforested site during two campaigns in 2001 using tethered balloon soundings. The site is characterized by very weak winds at night, so that there is insufficient nocturnal turbulence and the eddy correlation technique fails to detect fluxes. The time evolution of the profiles is used to determine surface fluxes at early morning and nighttime, using a budget method. Early in the morning, the estimated fluxes are in very good agreement with those observed by eddy correlation at a nearby micrometeorological tower. At night, soil heat storage and transport accounts for most of the net radiation *Q**, while the sensible and latent heat fluxes estimated from the vertical profiles represent less than 50% of *Q**. The height to which this fluxes converge, so that the energy budget closure is achieved is of the order of 50-100 m, in good agreement with the thickness of the fog layer. Comparison of temperature and humidity accumulation to that of CO_2 shows that vertical profiles of both concentration and flux of CO_2 must decrease sharply with height if the variation of all variables is restricted to the same layer.

NOCTURNAL BOUNDARY LAYER THICKNESS



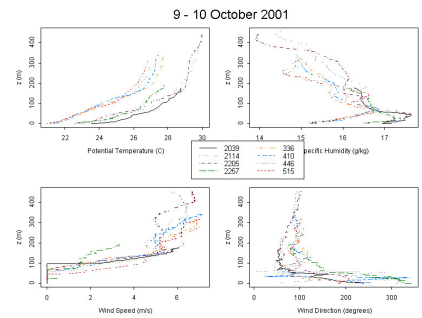


CO_2 ACCUMULATION LAYER

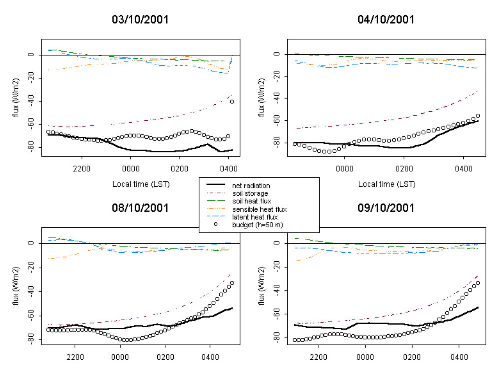


THE CAMPAIGNS

VERTICAL PROFILES



NIGHTTIME FLUX ESTIMATES (using h=50 m)



CONTINUATION

The importance of accurately knowing the conditions in which accumulation occurs in the nocturnal surface layer comes from the difficulty of determining surface fluxes during the period. The main aim of future work is to extend the present analysis to infer the surface fluxes and profiles throughout the boundary layer from tower observations and limited remote sensing of the boundary layer thickness alone. The analysis presented here points in that direction, but a more detailed study must include observations of the CO_2 profiles and their evolution. This is planned during Phase 2 of LBA-ECO.

REFERENCES

Acevedo, OC, Moraes, OLL, Silva, R, Fitzjarrald, DR, Sakai, RK, Staebler, RM, Czikowsky, MJ: 2003, Estimation of Nighttime Surface Fluxes from Vertical Profiles of Scalars at an Amazon Pasture Site, submitted to *Global Change Biology*, LBA-ECO special issue.

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