Micrometeorology of a Tropical Rainforest Before and After Selective Logging

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OVERVIEW AND MEASUREMENTS

We are using micrometeorology to study carbon exchange between a tropical forest and the atmosphere in Tapajos National Forest, Para, Brazil. Continuous eddy covariance and profile storage measurements began in June 2000 from a 65 meter tall tower (photo at right).

- The forest in the "footprint" of the tower measurements remained intact (or primary) for the first 14 months of measurements. We used these data, along with biomass measurements based on 3 forest inventories between 1984 and 2000 that include the tower footprint, to establish a carbon balance for this site (see **Pre-Logging Carbon Balance and Night-time Problems**).
- Between September and December 2001, 700 hectares of forest, including the tower footprint, were selectively logged. The instruments remained in place during the logging, and measurements have continued to the present. Ground based surveys were conducted after the logging to quantify the extent of the logging. We are comparing the micrometeorological measurements from before and after the logging to assess its impact on the carbon cycling of the forest (see **Effect of Selective Logging**).
- The micrometeorology of forest gaps, both natural and due to logging, are of interest because they may behave differently than intact forest. In terms of carbon dioxide exchange, they possibly act as chimneys with preferential venting of CO2 that may not be dectected by eddy covariance. To study the microclimate of gaps, after the logging an additional 65 meter tall tower was installed 400 meters upwind (east) of the original tower, in a large gap created by the logging. This tower was instrumented similar to the original tower, and data from the two towers are being compared to address the affect of gaps. (see **Tower Inter-Comparison and Gap Micrometeorology**).

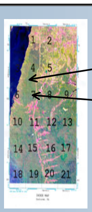
TOWER TOP (64 m)

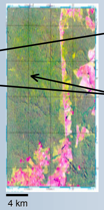
Momentum Flux	CSAT3
Heat Flux	CSAT3
CO_2/H_2O Flux (1)	LiCor 7500
CO_2/H_2O Flux (2)	LiCor-7000
PAR (up/down)	LiCor
Solar Radiation	Kipp & Zonen
Net Radiation	REBS Q*7
Rain	Tipping Bucket

TOWER TOP INSTRUMENTS

ELEVATOR CARRIAGE

65 meter tower





Km 67 TOWER (control)

Km 83 TOWER

PROFILE MEASUREMENTS

CO_2/H_2O	LI-7000 (12 levels, 0.1 to 64 m)
Wind speed	Cups (64, 50, 40 m)
Wind vector	2D Sonics (30, 20, 1.3 m)
Temperature	CS107 (64, 40, 30, 20, 10, 2 m)

EFFECT OF SELECTIVE LOGGING

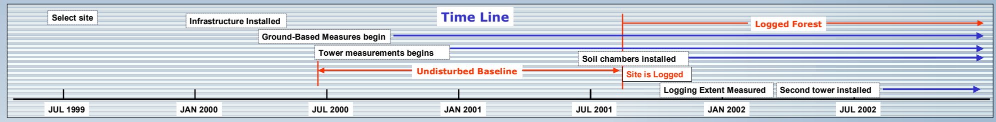
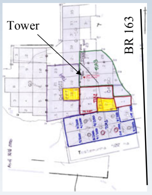


Figure 4 Logging Map



- About 700 hectares was logged between September and December 2001 (Time Line and Figure 4, area outlined in green). After the logging, ground-based measurements were made to quantify the extent of the logging disturbance (Figures 5, 6, 7, 8).
- The daily cycles of Net Ecosystem Exchange (NEE) during the 2001 dry season after the harvest showed less afternoon uptake and less nighttime efflux (respiration) than during the 2000 pre-harvest dry season (Figure 9). The reduction is of order 15%, consistent with the fraction of gaps left by the logging (Figure 8). However, the difference between pre- and post-logging during wet season is less, suggesting the forest may begin its recovery quickly.
- The km 67 tower*, in an un-logged area of the same forest (16 km north), acts as a control for the logging experiment. The two towers show close agreement in net carbon exchange prior to the logging (Figure 10, a u*-filter with threshold of 0.2 ms^{-1} was applied to both datasets, see Pre-Logging Carbon Balance and Night-time Problems). After the logging there was greater carbon loss than at the control site, a combination of decreased production (due to less leaf area) and increased respiration (due to increased slash created by the logging).
- We will continue to monitor the forest's recovery over the next few years.

* Km 67 data provided by Wofsy, et al.

Figure 9 Average Daily Cycles of NEE

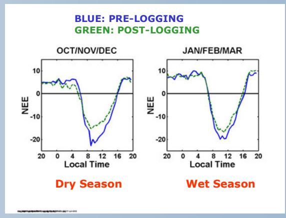


Figure 10 Comparison with km 67 tower

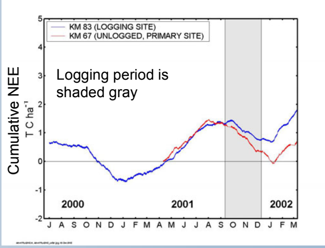
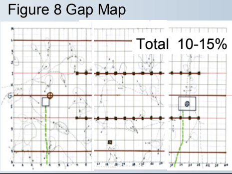


Figure 5 Logging Patio

Figure 6

Figure 7

Figure 8 Gap Map



PRE-LOGGING CARBON BALANCE AND NIGHT-TIME PROBLEMS

THE NIGHT TIME PROBLEM

- The "**raw**" tower-based carbon balance indicated a big sink, consistent with other tower-based results in Amazonia (Malhi et al. 1998, Figure 1). But, biomass inventories at the site spanning 16 years (1984 to 2000) indicated approximate carbon balance, or a small carbon source (Figure 1).
- The tower-based result likely overestimates C uptake due to underestimation of respiration during calm, stable nocturnal periods. Applying a so-called **u*-filter**, where NEE during night time periods with little turbulent mixing are replaced with observations from more turbulent periods (Figure 2), had a dramatic affect on the annual sum, and reconciles the tower- and biomass results (Figure 1).

Figure 1

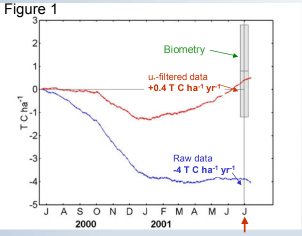


Figure 2

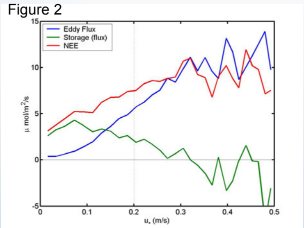
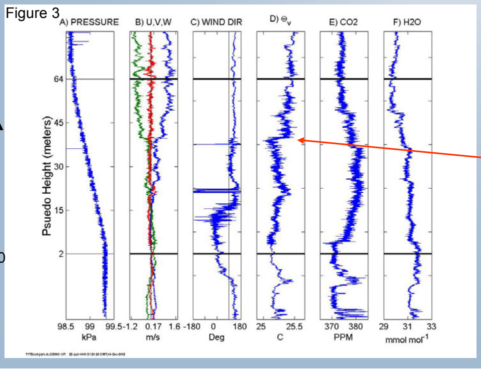


Figure 3



ELEVATOR PROFILES

- The elevator used to lower instruments for servicing provides a unique opportunity to examine the structure of the forest microclimate. The barometric sensor mounted to the elevator allows us to approximate the altitude of the elevator (Figure 3A). It takes about 11 minutes to raise or lower.
- The profile shown was made at 6:30pm local time (after sundown). The temperature shows a sharp increase at the canopy height of 35 meters (Figure 3D) - this thin stable layer acts to decouple the air above and below, as evidenced in the reduced winds below 35 meters (Figure 3B).
- The wind direction below the inversion is more variable, and below 20 meters is 90 degrees different than the wind direction above the canopy (Figure 3C).
- The CO2 respired by plants and soil has begun to accumulate below the inversion as the stable layer inhibits mixing with above canopy air (Figure 3E)

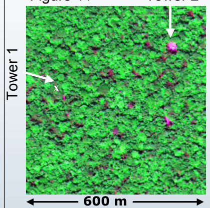
Three papers have been accepted to the Ecological Applications LBA special issue based on the year of data before logging:

Miller et al. **Tower-based and Biometry-based Measurements of Tropical Forest Carbon Balance**
Goulden et al. **Physiological Controls on Tropical Forest CO2 Exchange**
Rocha et al. **Seasonality of Water and Heat Fluxes Over a Tropical Forest in Eastern Amazonia**

Drafts are available at http://www.ess.uci.edu/~lba/safe (username: cd04, password: secure)

TOWER INTER-COMPARISON AND GAP MICROMETEOROLOGY

Figure 11



Post-logging IKONOS image. Gaps created by the logging appear in pink.

- We were concerned that forest gaps (both natural and due to logging) correspond to altered radiation environments that create the possibility of localized preferential exchange of CO2 (venting) that is missed by eddy covariance.
- A second 65 meter tower was installed in a large gap created by the logging, about 400 meters east (upwind) of the original tower, and was instrumented for eddy flux (open path IRGA), and profile measurements (LiCor 7000), similar to the original tower (Figure 11 and photo).
- Preliminary analyses indicate that, to first order, the mean quantities and fluxes (averaged over 70 days) from the two towers are remarkably similar (Figures 12-17). This suggests that gaps do not act as significant preferential pathways for exchange between the forest and atmosphere.

Figure 12

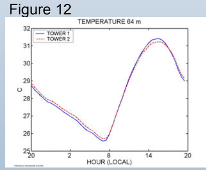


Figure 13

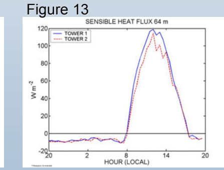


Figure 14

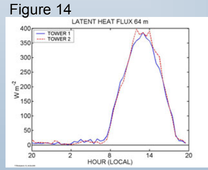


Figure 15

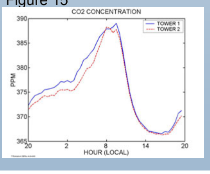


Figure 16

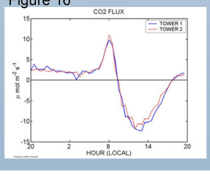
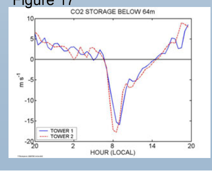


Figure 17



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