Micrometeorology, CO2 and H2O Exchange of a Tropical Rainforest Before and After Selective Logging

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INTRODUCTION

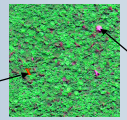
The large uncertainties in tower-based measures of tropical forest NEE have been discussed at length during the course of LBA, and are due to our limited understanding of meteorological processes controlling forest-atmosphere exchange. The problem is most evident during the night, where tower-based measures of NEE likely underestimate respiration. Recent studies have attempted to find how and where this 'missing' CO2 leaves the ecosystem (Staebler et al. 2004).

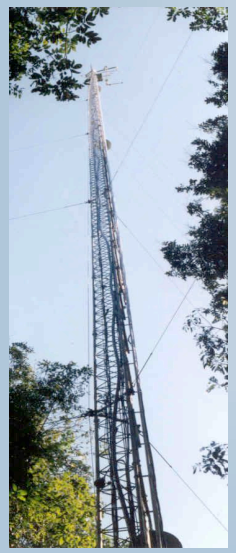
The micrometeorology of forest gaps, both natural and due to logging, are of interest because they may behave differently than intact forest. In terms of carbon dioxide exchange, they possibly act as chimneys with preferential venting of CO2 that may not be detected by eddy covariance. Here we address the following questions:

1. Do forest gaps exhibit different meteorology compared to intact forest (ie, is there evidence of CO2 venting via gaps)?
2. If venting is occurring, does it have a large effect on tower-based estimates of tropical forest NEE?

To study the microclimate of gaps we use data from two identical, 65 meter tall towers 400 meters apart (aligned with the wind direction) in the Tapajos National Forest. The towers were instrumented similarly to measure turbulent fluxes at 64 meters, and the CO2/H2O profile between 0.1 and 64 meters. Both towers are in an area of forest selectively logged, but one is in a large gap (diameter ~50 m) created by the logging.

IKONOS image: Gaps are pink.





COMPARISON BETWEEN TOWERS

CORRELATIONS ON DIEL TIME SCALES

The wind, temperature, CO2 and H2O were remarkably similar for the two towers over the course of a typical day (FIGURE 1). This indicated that, to first order, the tower footprints were similar (ie, the effect of the gap was not dominant).

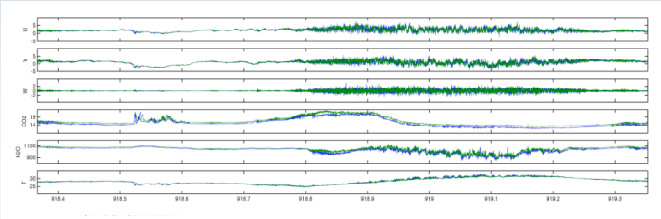
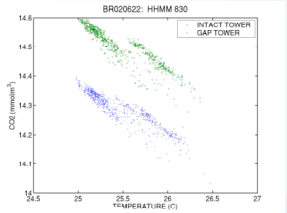


FIGURE 1. Time series of wind, temperature, CO2 and H2O at 64 meters: intact forest (blue) and forest gap (green) on July 19, 2002. Sampling period was 2.5 seconds.

CORRELATIONS ON SHORTER TIME SCALES

The wind and scalar quantities were also correlated at shorter time scales (FIGURE 2). During daytime, the strong correlation *between CO2 and temperature* indicated there was vertical mixing between canopy and tower top heights. The strong correlation *between towers*, evident in the similarity of their scatter plot patterns, suggests horizontal homogeneity.

FIGURE 2. Daytime 30-minute "scatter plot" of raw 2.5 second data points for CO2 against temperature (10:30AM local time). Tower 1 is shown as blue points, tower 2 as green.



At night, the CO2 and temperature often lost their tight correlation, as turbulent mixing was reduced by the stably-stratified surface layer, and the above-canopy and below-canopy air became decoupled. Even so, the *between-tower* correlation was remarkable, as fine details of the scatter plot are similar at the top of the towers (FIGURE 3). This indicated that horizontally homogeneity remained at night, and local effects again did not appear to be dominant.

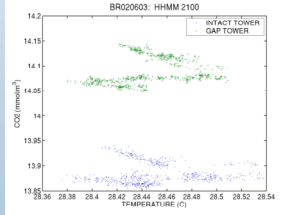


FIGURE 3. Night time 30-minute "scatter plot" of raw 2.5 second data points for CO2 against temperature (9:00PM local time).

NOTE: three papers were published in the Ecological Applications LBA special issue based on the year of data before logging:1) Miller et al. **Tower-based and Biometry-based Measurements of Tropical Forest Carbon Balance**; 2) Goulden et al. **Physiological Controls on Tropical Forest CO2 Exchange**; and 3) Rocha et al. **Seasonality of Water and Heat Fluxes Over a Tropical Forest in Eastern Amazonia**. Reprints are available at http://www.ess.uci.edu/~lba/safe (username: cd04, password: secure).
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GAP AND INTACT PROFILES

The *daytime* CO2 profile was well mixed (ie, flat) at both towers (FIGURE 4, 12pm profile). At dusk, the boundary layer became stably stratified and CO2 accumulated below the canopy (7pm profile). The profile shape was fully developed by 8pm and remained throughout the night (5am profile).

At dawn, CO2 in the gap profile was evacuated more quickly and to lower height than in the intact forest (7am profile). This suggests some venting of CO2 in the gap. As the morning progressed, CO2 was evacuated from the intact profile also (9am profile).

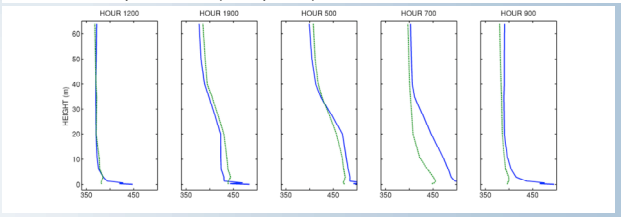

FIGURE 4. CO2 and H2O profile in the intact forest (blue) and gap (green) at 1200, 1900, 0500, 0700, and 0900 local time. Each profile represents the average for 30 days (January 2003).

EFFECT OF GAPS ON TOWER-BASED NEE

The mean daily cycle of CO2 flux shows more positve (upward) flux during both day and night at the gap tower ($F_{C,GAP}$) relative to the intact tower ($F_{C,INTACT}$, FIGURE 5). Integrated, the difference amounts to 3-4 TC ha-1 yr-1.

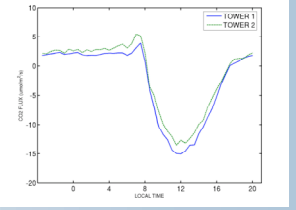

FIGURE 5. Daily CO2 flux at 64 m. Intact tower (blue) and gap tower (green), from 1 year of 30 minute-averaged fluxes.

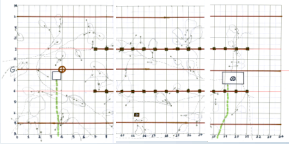

FIGURE 6. Gap map based on post-logging survey; 10-15% area was characterized as gap.

We combine this difference with the forest gap area after logging (FIGURE 6) to estimate the contribution of gap venting ($F_{C,VENT}$) to the integrated NEE,

$$F_{C,\mathrm{VENT}} = \frac{\text{GAP AREA}}{\text{FOREST AREA}} \times \left(F_{C,\mathrm{INTACT}} - F_{C,\mathrm{GAP}}\right)$$

$$F_{C,\mathrm{VENT}} \approx 0.15 \times 4 = 0.6 \text{ T C ha}^{-1}\text{yr}^{-1}$$

The estimated "gap-effect" on NEE (~0.6 T C ha^{-1} yr^{-1}) is small compared to the 'missing' night time loss (~4 T C ha^{-1} yr^{-1}, Miller et al. 2004). To be of comparable magnitude to the night-time losses at this site would require the gap-intact forest NEE difference to be 20 T C ha^{-1} yr^{-1} or more.

In conclusion, while some CO2 venting may occur in the gaps, it does not have a large effect on the tower-based estimate of NEE.