Micrometeorology of a Tropical Rainforest Before and After Selective Logging

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OVERVIEW AND MEASUREMENTS

We are using micrometeorology to study the effects of selective logging on carbon and energy exchange between a tropical forest and the atmosphere in Tapajos National Forest, Brazil. Continuous eddy covariance and profile storage measurements began in June 2000 from a 65 meter tall tower (Goulden et al., 2004; Rocha et al. 2004).

The pre-logging annual carbon balance calculated from the tower measurements was very sensitive to the treatment of data collected during calm nighttime conditions (Miller et al, 2004), possibly due to drainage flows that removed carbon from the system that was not measured by the tower. We compared temperature profiles from the tower with satellite-based temperatues profiles to infer nighttime air-drainage patterns. (see **Nocturnal Drainage Flows**).

Selective logging occurred between September and December 2001. The measurements remained in place during the logging, and continued for 2.5 more years. Ground-based surveys quantified the extent of the logging. IKONOS imagery was used to quantify the effect of logging on the distribution of gaps in the logged area versus a nearby unlogged area, and data before and after the logging indicate changes in subcanopy climate and above canopy CO2 exchange. (see **Effect of Selective Logging**).

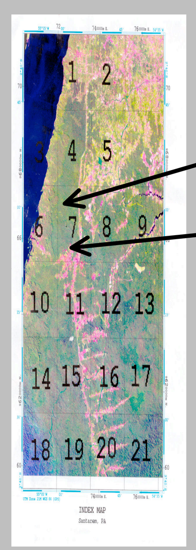
The micrometeorology of forest gaps, both natural and due to logging, are of interest because they may facilitate ventilation of the subcanopy. In terms of carbon dioxide exchange, they possibly act as chimneys with preferential venting of CO2 that may not be dectected by eddy covariance. To study the 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 potential for venting (see **Subcanopy Venting through Gaps**).

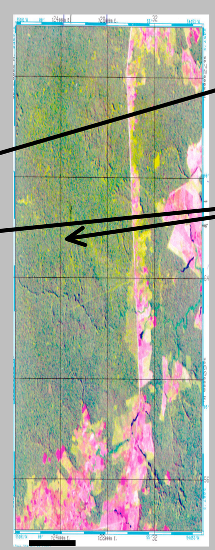
TOWER TOP (64 m)

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

TOWER TOP INSTRUMENTS

ELEVATOR CARRIAGE





4 km

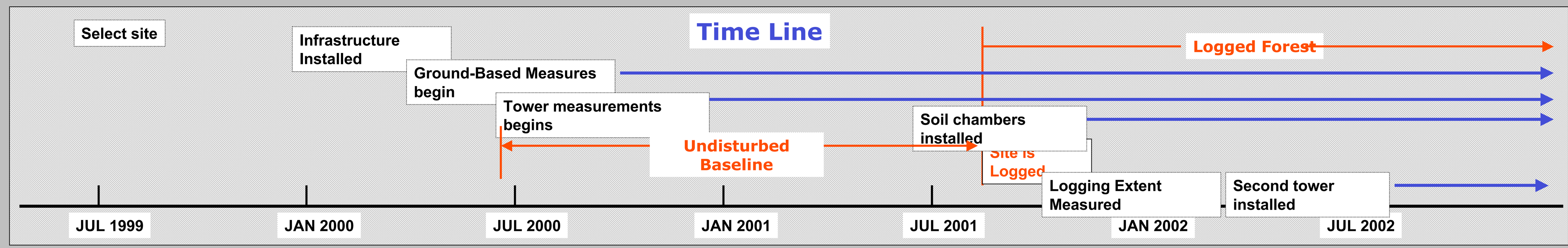
Km 67 TOWER (control)

Km 83 TOWER

PROFILE MEASUREMENTS

CO_2/H_2O	12 levels, 0.1 to 64 m
Wind	Cups 64, 50, 40 m
Wind	2D Sonics 30, 20, 1.3 m
Temp	64, 40, 30, 20, 10, 2 m

EFFECT OF SELECTIVE LOGGING



LOGGING PATIO

LOGGING GAP

- 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 (Figs 6, 7).
- The logging removed 63 trees, ~10-15 percent of the canopy, and created 44 new gaps in the 18-ha area upwind of the original tower. Gaps accounted for 4% of the area in a patch of unlogged forest that was north of the two towers and 12% of the area in the 110 ha block of forest that was selectively logged and that included the two towers. In other workds, logging increased the incidence of gaps by a factor of 3 over undisturbed forest (Fig 8).
- The daily cycle of net carbon dioxide exchange in the dry and wet seasons following logging showed less afternoon uptake and similar nighttime efflux (respiration) than during the 2000 pre-harvest year (Fig 9). This pattern is consistent with decreased photosynthesis due to canopy loss, and increased respiration due to the large amounts of slash added to the forest floor.
- After logging, the subcanopy air in the intact forest was both warmer and drier during daytime (Fig 10). The daytime temperature difference from 64-m to 10-m at the intact tower was typically ~1°C during the year before logging, except for January 2001 when frequent storms flushed the subcanopy airspace (c.f., Fitzjarrald et al., 1990). The daytime temperature difference after logging decreased to less than 0.5 °C, corresponding to a warming of the subcanopy air. Similarly, there was a marked decrease in the 64-m to 10-m water vapor gradient following logging, corresponding to a drying of the subcanopy air. Relative humidity is a good measure of the flammability of fine fuels, and the subcanopy drying following logging would be expected to increase the likelihood of ground fire (see also Uhl and Kaufmann, 1990).

IKONOS IMAGE HIGHLIGHTING GAPS

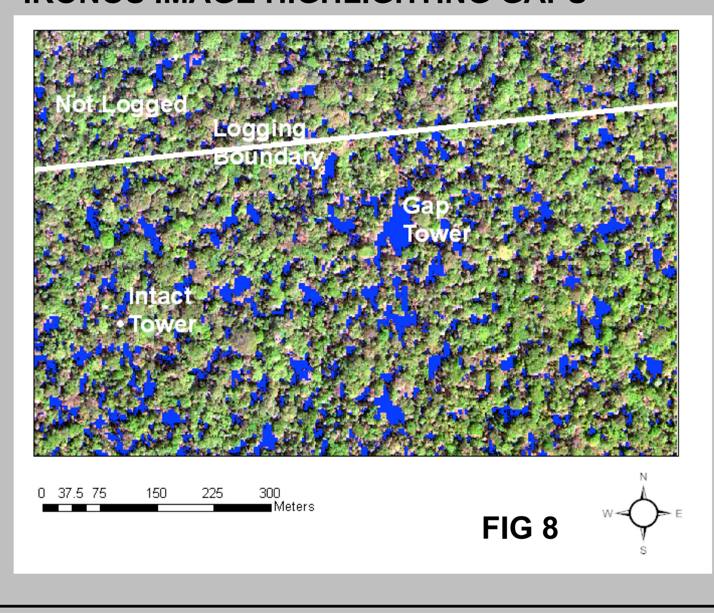


FIG 8

DAILY CYCLE OF NEE

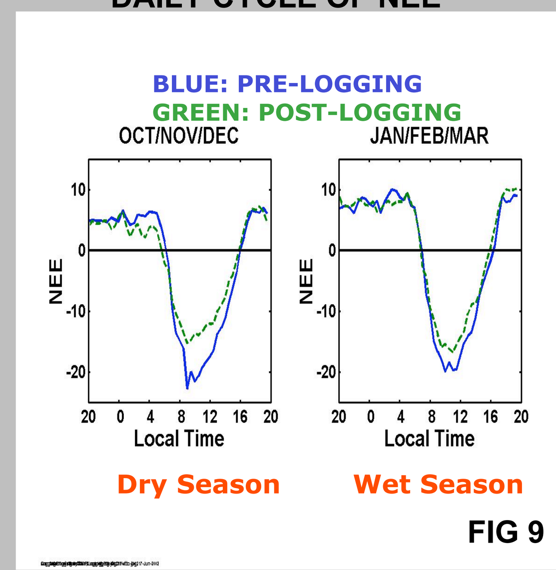


FIG 9

SUBCANOPY MOISTURE/TEMPERATURE

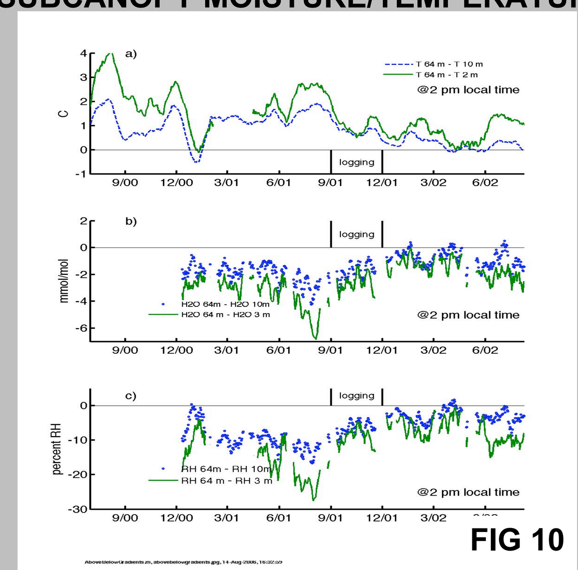


FIG 10

NOCTURNAL DRAINAGE FLOWS

SITE ANNUAL CARBON BUDGET

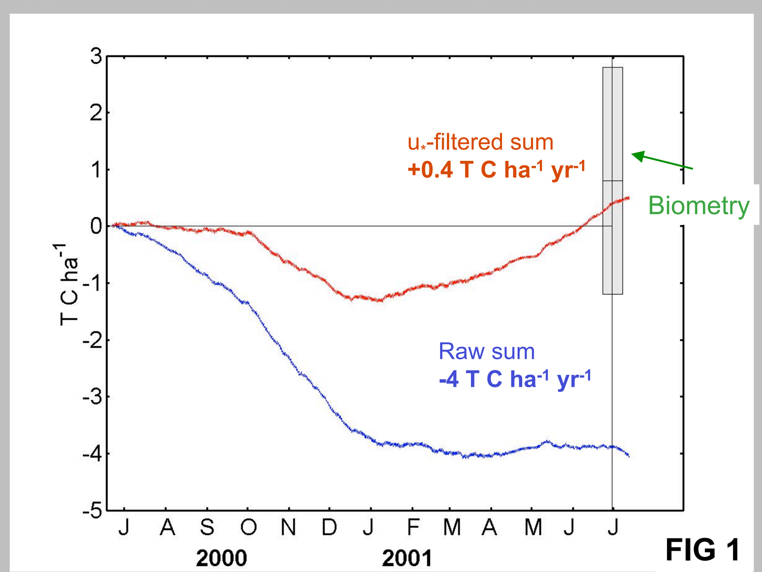


FIG 1

TOWER AND SATELLITE BASED TEMERATURE PROFILES

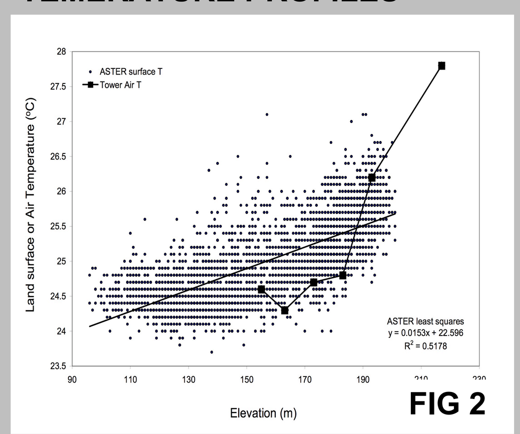


FIG 2

LAND SURFACE PROFILE AND TEMERATURE PROFILE

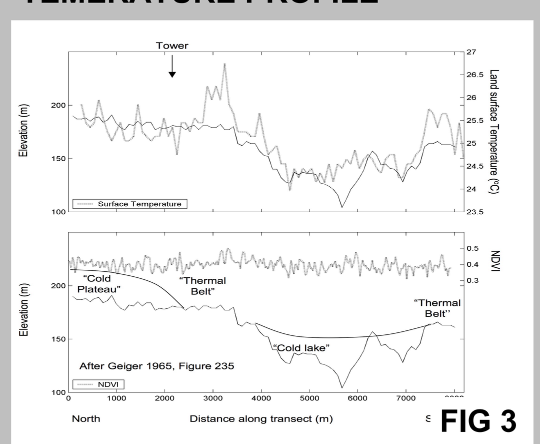


FIG 3

THE NIGHT-TIME PROBLEM

- The tower-based annual carbon exchange overestimates carbon uptake due to underestimation of respiration during calm, stable nocturnal periods (Fig. 1). Applying a so-called u_*-filter, where net ecosystem exchange (NEE) during night time periods with little turbulent mixing are replaced with observations from more turbulent periods, has a dramatic affect on the tower-based annual sum, and corrected NEE shows agreement with long term (16 year) changes in above ground biomass at the site.
- A novel approach to investigate the nighttime problem combined tower and satellite (ASTER LST) based measurements to infer cold air drainage patterns that could remove CO2 in ways not captured by the tower measurements (Figs 2-5).
- The nocturnal patterns of LST were closely related to local topography and land use (Fig 3). In general, a nearby river was warm; gullies were cold; plateau centers were cold; stream drainages were cold; pastures were particularly cold; and upper slopes and plateau edges were warm. The in-situ temperature and wind observations, combined with the observed relationship between elevation and nocturnal LST and the occurrence of warm thermal belts extending inward from the edges of plateaus, imply that cold air drainage occurs on clear nights. (Goulden et al., JGR-Atmospheres, 2005)

LOCAL TOPOGRAPHY (SRTM).

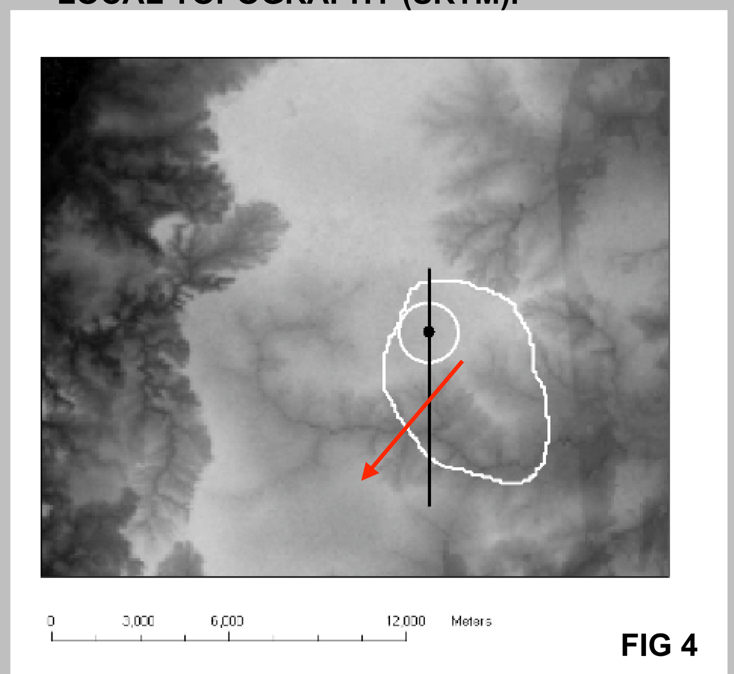


FIG 4

Higher elevation lighter. Local topographic gradient indicated by arrow. Vertical line indicates the transect shown in Fig 3.

TERMAL RADIANCE (ASTER Band 10).

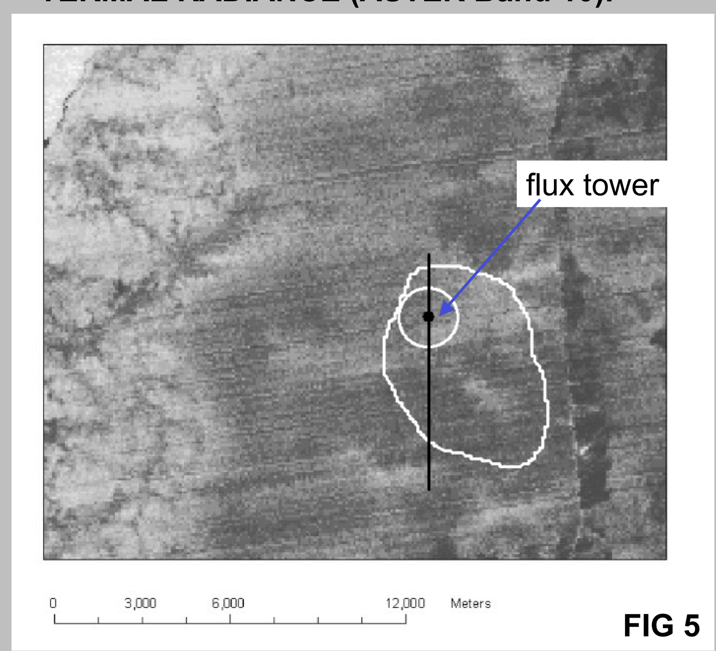


FIG 5

Higher temperature lighter

SUBCANOPY VENTING THROUGH GAPS

INTACT TOWER TEMPERATURE

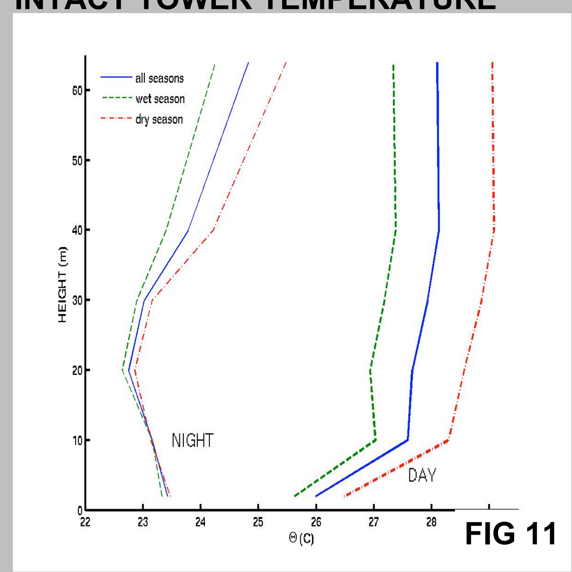


FIG 11

GAP/INTACT TOWER CO2/H2O PROFILES

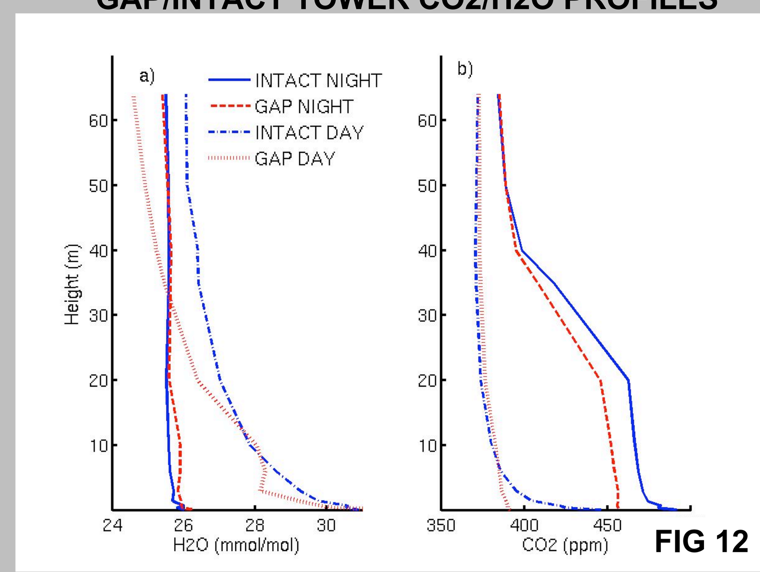


FIG 12

GAP/INTACT TOWER FLUXES

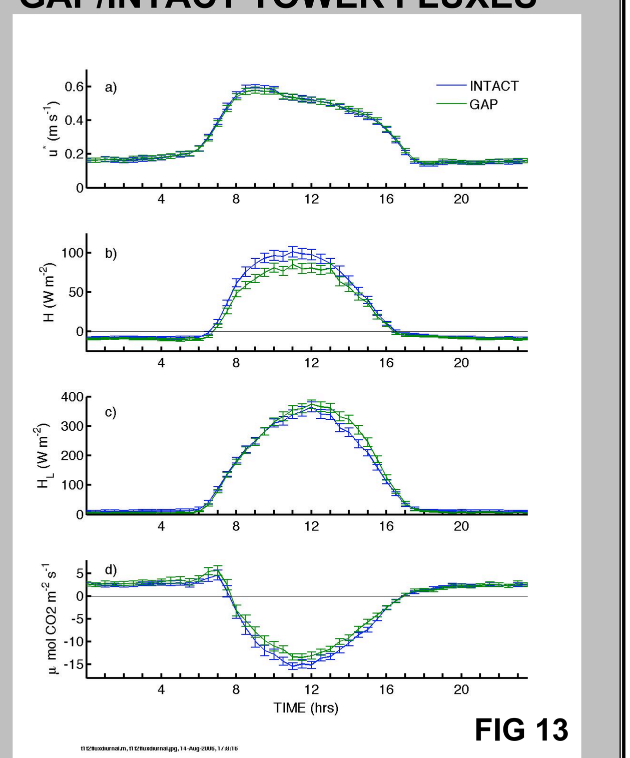


FIG 13

- A second 65 meter tower (the gap tower) was installed in a large gap created by the logging, to investigate the potential for a large gap to preferentially vent the subcanopy, possbily biasing tower flux measurements.
- The daytime difference between carbon dioxide and water vapor profiles in the gap and the intact area reflected the absence of forest canopy, with less water vapor in the gap because there was no leaf transpiration, and more CO_2 because there was no photosynthesis (Figs 11, 12).
- The daytime CO2, H2O, and heat flux differences between the towers can not entirely be explained by the local loss of canopy in the gap, but may be best explained by the venting of subcanopy air from the intact forest through the gap. The removal of canopy in the gap would be expected to reduce the local rates of CO_2 uptake and evapotranspiration, while increasing the sensible heat flux. In fact, evapotranspiration increased and sensible heat flux decreased above the gap relative to the intact forest (Fig 13).

Implications of venting on estimates of ecosystem carbon balance: Venting redistributes ecosystem respiration, and has the potential to decouple the annual sum of CO_2 exchange by eddy covariance from the ecosystem's actual carbon budget. Estimating the amount of CO2 vented through the gap requires a better understanding of the contribution of the local gap to the tower footprint. This will require experiments, observations and models designed specifically to address the effects of canopy gaps on flux footprints over tall forest.

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