Carbon balance and seasonal patterns via eddy covariance and biometry measurements in an old-growth Amazon forest

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A. Design, Analysis Methods, and Initial Results

Figure 1. Flux tower and instrumentation (scale drawing, left). Eddy flux measurements from ground level (left) at two heights (135' and 300') to maximize fluxes and allow estimates of flux divergence; it includes: Campbell CSAT3 sonic anemometers, CO2/H2O intakes, and chilled mirror hygrometer (Edgetech Model 2000), used for fine-scale intercomparison with tower-assembled (ESAC-602). Upper eddy includes a second sonic (Gill research model HS) for backup and intercomparison. Profile instrumentation (in yellow highlight) at 8 heights measures through-canopy storage of CO2, H2O (from CO2/H2O intake), and heat (aspirated/shielded thermocouples). Analyzers (in red) for each flux level and for the profile system, contain CO2/H2O analyzer (LiCor 6262), and associated datalogging and control instrumentation. Other sensors (green): Near Infrared (220') and PAR (220', 50') sensors, total direct, and total-solar radiances (220', 105', 125', 100'), and wind gauge (135').

Figure 2 (left). Hourly time series of initial tower data: (A) Eddy fluxes of CO2 for eddy1 (150') and eddy2 (470'); (B) friction velocity (u*) - momentum flux; (C) mean CO2 concentration (CO2ppm); (D) net ecosystem exchange (NEE); (E) Eddy flux + disc storage; and, (F) temperature profiles. On which scales (days 104-105), flux (A) and u* (B) are virtually zero, CO2ppm (C) is strong positive, temperature profiles (D) are well-mixed (CO2 storage (E) is low, and NEE (F)) is flux (A). On calm nights (104-105), flux (A) and u* (B) are essentially zero.

Figure 3. Evidence for "lost flux." We expect nighttime net ecosystem exchange (NEE) (which depends only on the physiology of respiration) to be essentially independent of atmospheric turbulence in e.g., U*. Therefore, the noticeable decline in measured values of nighttime NEE (red lines, left panel) is due to eddy flux, widely paced, and changes in canopy storage, only paced at U* = 0, in evidence that flux is missing. Correcting for "lost flux," we correct for this missing flux by replacing measured NEE when U*<0.2 with values interpolated from nearby high U* NEE. When applied day and night, this correction only affects flux in the nighttime hours (Fig. 4), and amounts to roughly 2 tons C/ha/year (Fig. 5a).

Figure 4. Detailed NEE components, including effect of U* correction: corrected NEE (black square) is the sum of eddy flux (green) and canopy storage (purple). Correcting for "lost flux" fills the uncorrected NEE (pink triangle) slightly at night, but has essentially no effect during the day.

B. Summary of Main Results:

1. This Tapajos forest site was losing carbon in the first year (Fig 5a, corrected net ecosystem exchange flux).
2. This result differs from other eddy flux studies in Amazonian forests (Grace et al., 1995; Malhi et al., 1998; Grace and Malhi 2002) which show significant carbon uptake (these studies did not implement a correction for "lost flux," as discussed in Figs 3 & 4), but is consistent with independent biometric evidence at this site (see Fig 5a, and companion poster by Hutyra et al).
3. Seasonal patterns of uptake (Fig 5a) are opposite that predicted by models (e.g. Tian et al 2000), but are explained by the differential effect of precipitation on respiration losses (Fig 5b) and tree growth (Fig 5c).

References:
Tian, E., D. Running, J. Sakai, X. Jin, M. Zhao, R. Running, R. Nemani, M. Enting, M. Goward, J. Houston, and R. Nemani. 2000. Ecosystem Respiration (night NEE) and weekly rainfall Tapajos km 67
Figure 5a. Cumulative Net Ecosystem exchange (NEE), corrected with U* filter (as explained in Figs 3 & 4), with raw uncorrected fluxes shown for comparison. Corrected eddy fluxes are consistent with biometry-based estimate of these from aboveground biomass (0.3 to 0.6 Mg C/ha) during an averaging two-year period (July 1999 – July 2001, shown to the right of figure). Marked seasonal variations in NEE correlates with wet and dry seasons.
Figure 5b. Rate of Nighttime NEE (~whole-ecosystem respiration) and precipitation patterns, showing that respiration losses were strongly reduced during the dry season, presumably due to their net and litter layer. This pattern causes NEE to balance in a pattern opposite to that of tree growth (Fig 5c), and oppose that predicted by some models of Amazonian uptake (e.g. Tian et al 2000).
Figure 5c. Rate of negative NEE and tree growth (negative NEE and tree growth both indicate carbon uptake), together with precipitation patterns. Seasonal NEE variation was anticorrelated with tree growth: net ecosystem loss to the atmosphere occurred during the rainy season (January-March), when wood increment was highest, and conversely, net ecosystem uptake was observed in the dry season (September-December) when wood increment was generally low.