A New Method for Observing Interception over an Old-Growth Forest in the Eastern Amazon Region

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Introduction

Interception of rainfall by the forest canopy and the subsequent re-evaporation into the atmosphere constitute an important part of the hydrological balance over forests. On an annual basis in a forest environment, transpiration is the dominant component of evapotranspiration (ET), followed by interception evaporation and then bare-soil and litter evaporation. However, during and following transient precipitation events, interception exceeds transpiration as the dominant component of ET, resulting in a shift in the hydrological balance. During the process of interception evaporation, the leaves are wet, so the stomatal resistance goes to zero. Under such conditions, when surface (physiological) controls are removed, very enhanced rates of ET are to be expected. Furthermore, an appreciable fraction of water vapor in the Amazon is recycled through ET, with about half of Amazon precipitation being evaporated from the forest (Salati and Vose 1984, Hutyra et al. 2005).

Conventional methods of estimating rainfall interception have yielded a wide range of results for tropical rain forests, with interception estimates ranging from 8 to over 25% of total precipitation for the Amazon (Fig. 1). There are now many more long-term eddy flux measurement sites than sites at which the individual forest water budget components (total precipitation, throughfall, and stemflow) are measured. We introduce and describe a new, alternate method for observing interception using eddy-covariance data that could be applied to other tower flux sites worldwide in varying forest types. The approach is to estimate the 'excess' evaporation that occurs following individual events, using baseline evaporation time series obtained from long time series of flux data. We present two case studies of the evaporation of intercepted water over an old-growth rain forest site of the Large-Scale-Biosphere-Atmosphere Experiment in Amazonia (LBA-ECO).

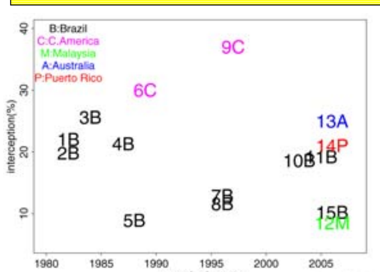
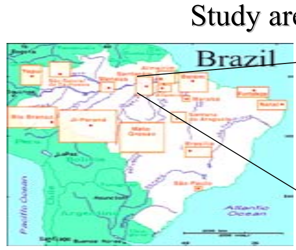
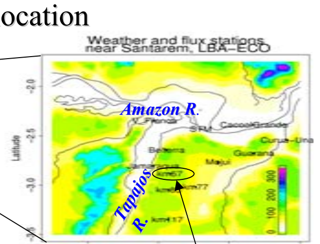


Figure 1: Interception estimates reported in the literature using conventional methods for tropical rain forest sites. Studies done in Brazil are labeled in black with 'B', Central America in pink with 'C', Malaysia in green with 'M', Australia in blue with 'A', and Puerto Rico in red with 'P'. References are numbered with citations at the bottom-right corner of the poster.

Study area location





Km 67 : LBA Old-growth rain forest site
(Lat: 2.88528 S ; Lon:54.92047 W)

Map of Brazil (top left) and a map of the weather stations and flux-measurement sites in the Santarem region (STM) of LBA-ECO (top right). Elevation (m) is shaded. Pictures are of the forest canopy at the Km67 site (canopy is about 40 m high).

Data/Instrumentation

1. Eddy covariance system at ~ 60 m height, including a Campbell CSAT 3-D Sonic Anemometer, and a Licor 6262 CO_2/H_2O analyzer
2. Precipitation gauge at 42 m height (hourly data)
3. Vaisala CT-25K Ceilometer operating during periods from April 2001 to July 2003 (30-m resolution backscatter profile every 15 seconds)
4. Radiation boom at 60 m (Lup, Ldown, Sup, Sdown)
5. Temperature, RH profile

Research Questions

1. The eddy-covariance method often fails during and shortly after precipitation events. How much of the flux is missed when these periods are not captured?
2. How much error is introduced by filling in these periods with estimated ET (Penman-Monteith equation)?
3. Do light rainfall events provide a large fraction of the re-evaporation?
4. To what extent does forest structure / type (such as changes in LAI) affect interception rates?
5. What effect does the time interval between precipitation events, and the time of day have on the interception estimates?

Methods

1. Identify precipitation events from the ceilometer backscatter profile. Advantages over using the precipitation gauge alone:
   a) Ceilometer detects all rainfall events, including light ones when the rain gauge may not catch any rainfall.
   b) Get exact starting/ending times for precipitation.
2. Calculate eddy fluxes of latent heat (LE)
   a) Form a "base state" ensemble average of the latent heat flux from the days without precipitation, in the same season as the rainfall events.
   b) Form an ensemble average of the latent heat flux for the precip. cases.

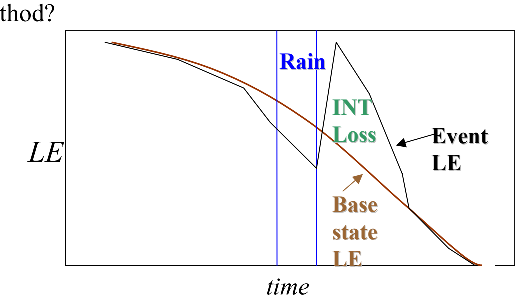
Calculation of eddy flux

Alter t=0 (starting time for flux calculation)

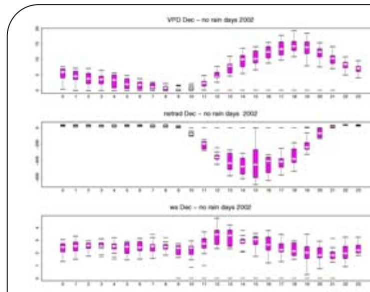
Alter length of time of flux calculation

based on the individual precip. events!

3. How can we quantify interception (INT) losses using the eddy flux method?



4. Calculate the Penman-Monteith potential evapotranspiration by hour for the base state and precipitation cases. Interception loss by event is the difference between the base state LE and the observed event LE.



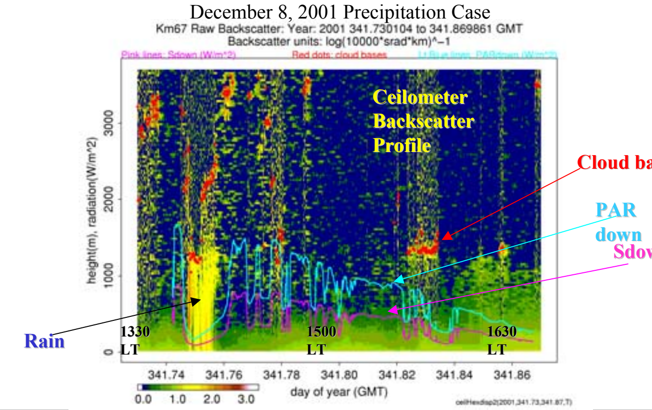
To determine the hourly base state ET for each month, work is in progress to compose days with similar weather conditions and no rain for each month. The variables being used to evaluate similar days are vapor pressure deficit (VPD), net radiation, and wind speed. Shown on the left are hourly boxplots at km67 for days without rain for Dec 2002 for VPD (top, mb), net radiation (middle,W m^{-2}), and wind speed (bottom, m/s).

	Day	Night	Total
Wet Season (Jan-Jun)	118	146	264
Dry Season (Jul-Dec)	80	49	129
All Cases	198	195	393

Precipitation Cases Identified *from Ceilometer data April 2001-July 2003*

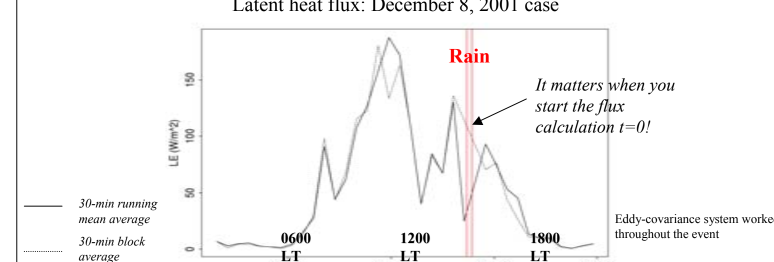
Case Studies

December 8, 2001 Precipitation Case



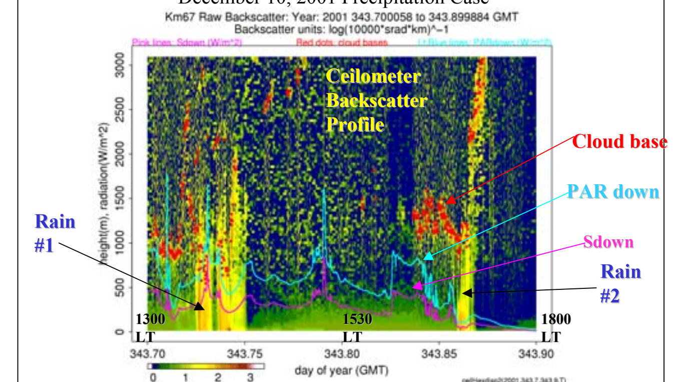
Raw ceilometer backscatter (15-second samples) from 1330 to 1650 LT on December 8, 2001 at the LBA km67 site. Backscatter units are log(1000*srad*km)$^{-1}$. Red dots indicate cloud bases (m). The pink line is the incoming shortwave radiation (Sdown, units of Wm^{-2}). The light blue line is the photosynthetically active radiation (PARdown, units of Wm^{-2}). Precipitation fell in the early afternoon during a 15-minute period from 1355 to 1410 LT, as indicated by the enhanced ceilometer backscatter echoes during this time. No precipitation was measured by the rain gauge at the site during this event.

Latent heat flux: December 8, 2001 case



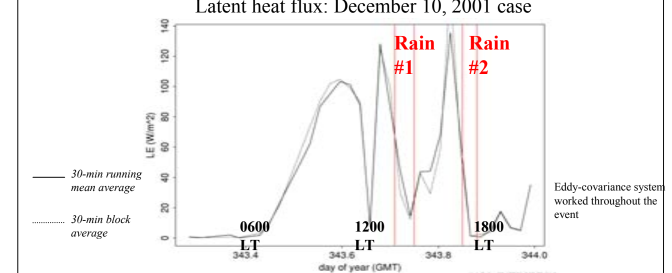
Latent heat flux (LE; W m^{-2}) for December 8, 2001 at the LBA km67 site. The black solid line indicates the latent heat flux calculated using a 30-minute running mean. The black dotted line represents the latent heat flux calculated using a 30-minute block average. The left-hand and right-hand side of the pair of vertical lines indicates the beginning and ending of a rainfall event respectively. The 30-minute running mean average showed a decreased LE to below 50 W m^{-2} during the rain followed by an abrupt increase to near 100 W m^{-2} following the rain, which was not captured by the block-averaged flux. Given the short duration of the rain event, it is important to select the proper time to start the flux calculation so that periods during and after precipitation are not mixed in the same flux calculation period.

December 10, 2001 Precipitation Case



Raw ceilometer backscatter (15-second samples) from 1300 to 1800 LT on December 10, 2001 at the LBA km67 site. The format of the plot is the same as the Dec. 8, 2001 case plot. Precipitation fell during two periods. The first event occurred in the early afternoon from 1325 to 1400 LT. A second, lighter rain shower occurred for a brief period from 1640 to 1655 LT. The on-site rain gauge recorded 0.762 mm of precipitation for the first rain event, but none for the second rainfall.

Latent heat flux: December 10, 2001 case



Latent heat flux (LE; W m^{-2}) for December 10, 2001 at the LBA km67 site. The format of the plot is the same as the Dec. 8, 2001 flux plot. LE values before the first rainfall of the afternoon exceeded 120 W m^{-2} as calculated by both averaging methods. There was a sharp decrease in LE to below 20 W m^{-2} during the first rainfall event in the early afternoon. This rain event was longer in duration than the Dec. 8, 2001 case and the block-averaged method also captured the flux minimum during rainfall followed by the abrupt flux increase following the rainfall. LE increased rapidly to its maximum for the day near 140 W m^{-2} between rains. LE decreased to near 5 W m^{-2} during the second, late-afternoon rainfall. A smaller LE increase was observed after the second rain at 1800 LT, near the time of sunset.

Continuing work

Work on analyzing the induvidual rainfall cases and assembling the ensemble averages of latent heat flux for the base state and precipitation cases will continue. Also, the Penman-Monteith potential ET for the base state and rain cases will be calculated. Data from a Canadian boreal forest (BOREAS) will be analyzed in a similar fashion to the Brazilian rain forest data to assess the differences of forest structure and type on interception evaporation losses.

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