LBA-ECO CD-06 CO2 Exchange in River Systems Across the Amazon Basin: 2004-2007

Summary:

This data set provides measurements of carbon dioxide flux rates, gas transfer velocity, and partial pressures of carbon dioxide at 75 sites on rivers and streams of the Amazon River system in South America for the period beginning July 1, 2004, and ending January 23, 2007.

Several campaigns occurred between June 2004 and January 2007 in the Amazon River basin, with discharge conditions ranging from low to high flow. The sampled areas span the spectrum of chemical characteristics observed across the entire basin, including, for example, both low and high pH values and suspended sediment loads.

There is one comma-delimited data file in this data set.

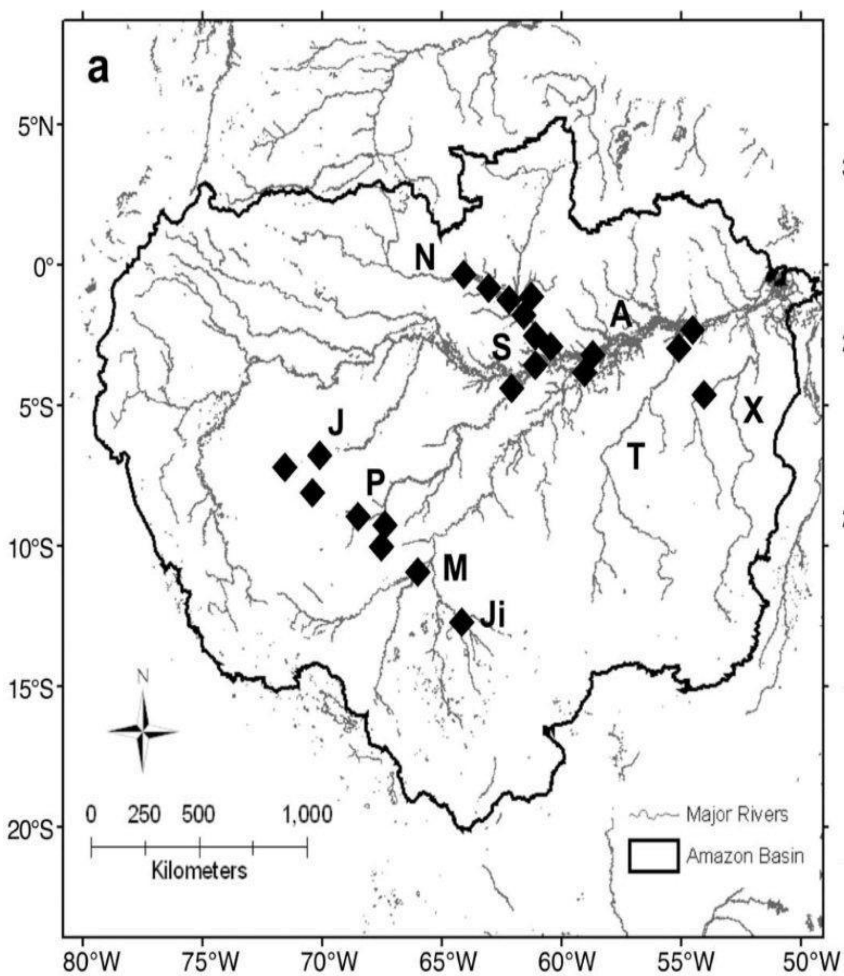

Figure 1. Map of the Amazon River basin showing the major tributaries that were sampled. A= Amazon mainstem; J= Jurua; Ji= Ji-Paraná; M= Madeira; N= Negro; P= Purus; S= Solimões (Amazon mainstem above confluence with Negro); T= Tapajós; X= Xingu (from Alin, et al., 2011).

Data Citation:

Cite this data set as follows:

Alin, S.R., and J.E. Richey. 2012. LBA-ECO CD-06 CO2 Exchange in River Systems Across the Amazon Basin: 2004-2007. Data set. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. http://dx.doi.org/10.3334/ORNLDAAC/1136

Implementation of the LBA Data and Publication Policy by Data Users:

The LBA Data and Publication Policy [http://daac.ornl.gov/LBA/lba_data_policy.html] is in effect for a period of five (5) years from the date of archiving and should be followed by data users who have obtained LBA data sets from the ORNL DAAC. Users who download LBA data in the five years after data have been archived must contact the investigators who collected the data, per provisions 6 and 7 in the Policy.

This data set was archived in November of 2012. Users who download the data between November 2012 and October 2017 must comply with the LBA Data and Publication Policy.

Data users should use the Investigator contact information in this document to communicate with the data provider. Alternatively, the LBA website [http://lba.inpa.gov.br/lba/] in Brazil will have current contact information.

Data users should use the Data Set Citation and other applicable references provided in this document to acknowledge use of the data.

Table of Contents:

1. Data Set Overview:

Project: LBA (Large-Scale Biosphere-Atmosphere Experiment in the Amazon)

Activity: LBA-ECO

LBA Science Component: Carbon Dynamics

Team ID: CD-06 (Richey / Victoria)

The investigators were Richey, Jeffrey E.; Victoria, Reynaldo Luiz; Souza, Reginaldo; Aalto, Rolf Erhart; Abdo, Mara Silvia Aguiar; Alin, Simone Rebecca; Aufdenkampe, Anthony K.; Ballester, Maria Victoria Ramos; Barbosa, Roosevelt Passos ; Bernardes, Marcelo Correa; Bezerra de Barros Lima, Roberta; Bolson, Marcos Alexandre; Bolson, Marcos Alexandre; Bonelle, Nilton ; Brito, David Silva; Cabianchi, Giovana; Cogo, Michelle Cristine; da Silva, Luis Vilmar Souza; Dalmagro, Higo Jose; de Oliveira, Carolina Barisson Marques; Deus, Fabiano Alves de; Devol, Allan H.; do Nascimento, Clive Reis ; Ellis, Erin Elizabeth; Ferro, Jaderson Coradi; Filho, Walter Jorge do Nascimento; Frickmann, Fernando Cruz; Gamero Guandique, Manuel Enrique; Gomes, Beatriz M; Gomes, Viviane ; Gouveia Neto, Sergio Candido; Hanada, Lais de Carvalho; Holtgrieve, Gordon William; Kelly Batalha Silva, Roberta; Krusche, Alex; Kurzatkowski, Dariusz; Lacerda, Francisco A. Siebra; Leite, Nei; Logsdon, Miles Grant; Macedo, Gelson de; Marcondes, Renata; Marilheuza, Campos Paro; McGeoch, Lauren ; Melo, Emanuele Gurgel de Freitas; Mendes, Francisco de Assis; Moreira, Marcelo Zacharias; Munhoz, Kelli; Neu, Vania ; Ometto, Jean Pierre; Pimentel, Tania Pena; Priante Filho, Nicolau; Rabelo, Claudenir Silva; Rasera, Maria de Fatima Fernandes Lamy ; Remington, Sonya Marie; Rodda, Sarah ; Ruiz Mateus, Neuza Maria; Salimon, Cleber; Santiago, Alailson Venceslau; Santos, Arnoldo Marcilio dos; Silva, Cleoni Virginio da; Silva, Jonismar ; Silva, Simao Correa da; Sousa, Eliete; Souzapetro, Petronio Lopes de; Toledo, Andre Marcondes Andrade; Tumang, Cristiane Azevedo; Umetsu, Cristiane Akemi ; Victoria, Daniel de Castro and Xavier, Farley de Oliveira. You may contact Alin, Simone Rebecca (simone.r.alin@noaa.gov).

LBA Data Set Inventory ID: CD06_CO2_Exchange

This data set provides measurements of carbon dioxide flux rates, gas transfer velocity, and partial pressures of carbon dioxide at 75 sites on rivers and streams of the Amazon River system in South America for the period beginning July 1, 2004, and ending January 23, 2007.

Several campaigns occurred between June 2004 and January 2007 in the Amazon River basin, with discharge conditions ranging from low to high flow. The sampled areas span the spectrum of chemical characteristics observed across the entire basin, including, for example, both low and high pH values and suspended sediment loads.

2. Data Characteristics:

Data are presented in one comma-delimited ASCII file:

CO2_chamber_flux_data.csv.

Column	Heading	Units/format	Description
1	Basin		Major river basin in which the sampling station is located
2	Location		Sampling station location usually given as nearby municipality or local name of the igarape or lake
3	Site_code		Unique site identifiers for sites used in this and other studies
4	Date	YYYYMMDD	Sample collection date
5	Time	HH:MM	Sampling time in local time reported on a 24 hour clock
6	Env_type		Description of the sampling location with special attention to the size of the water body and flow characteristics
7	Comments		Comments from field notebooks about sampling location
8	Latitude	decimal degrees	Geographic coordinates of the sampling location in decimal degrees of latitude. Where location was not measured directly it was approximated from the nearest station with measured coordinates
9	Longitude	decimal	Geographic coordinates of the sampling location in decimal

		degrees	degrees of longitude. Where location was not measured directly it was approximated from the nearest station with measured coordinates
10	Elev	km	Elevation of the sampling location reported in kilometers. Where direct measurements were not made, values were approximated from the nearest station with reported values
11	Wind_spd_avg	m per s	Average windspeed measured at 1.5 m above water independently for 3-5 minutes during the chamber sampling period and reported in meters per second
12	Wind_spd_max	m per s	Maximum windspeed at 1.5 m above water from independent measurements done for 3-5 minutes during the chamber sampling period and reported in meters per second
13	RH	%	Relative humidity of the air reported in percent
14	T_air	degrees C	Air temperature reported in degrees Celsius. Where direct measurements were not made an approximate value was used
15	T_water	degrees C	Water temperature at surface reported in degrees Celsius. Where direct measurements were not made, an approximate value was used
16	pCO2_water	ppm	Partial pressure of CO2 in the surface water reported in parts per million
17	pCO2_air	ppm	Partial pressure of CO2 in the air reported in parts per million
18	Time_start	seconds	Time at which the measurements used in the determination of the gas transfer velocity began reported in seconds
19	Time_end_1	seconds	Time at the end of the first sampling period used in the determination of the gas transfer velocity reported in seconds
20	Time_end_2	seconds	Time at the end of the second sampling period used in the determination of the gas transfer velocity reported in seconds
21	Time_end_3	seconds	Time at the end of the third sampling period used in the determination of the gas transfer velocity reported in seconds
22	pCO2_init	ppm	Partial pressure of CO2 in the chamber at the start of the measurement period reported in parts per million
23	pCO2_end_1	ppm	Partial pressure of CO2 in the chamber at the end of the first measurement period (60 seconds) reported in parts per million
24	pCO2_end_2	ppm	Partial pressure of CO2 in the chamber at the end of the second measurement period (120 seconds) reported in parts per million
25	pCO2_end_3	ppm	Partial pressure of CO2 in the chamber at the end of the third measurement period (180 seconds) reported in parts per million
26	Slope_regression	ppm per second	Slope of the regression between change in CO2 concentration in the chamber (y-axis) and time (x-axis) over the sampling period
27	SE_regression	ppm per second	Standard error of the slope of the regression
28	Press_atm	atm	Atmospheric pressure in the chamber reported in atmospheres
29	k_1	cm per hour	Gas transfer velocity calculated for the first measured time period (60 seconds)
30	k_2	cm per hour	Gas transfer velocity calculated for the second measured time

			period (120 seconds)
31	k_3	cm per hour	Gas transfer velocity calculated for the third measured time period (180 seconds)
32	u_star	m per s	Friction velocity reported in meters per second and calculated as described in the documentation
33	u_10	m per s	Mean windspeed at a height of 10 meters about the water surface reported in meters per second and calculated as described in the documentation
34	FCO2	umol CO2 per m2 per s	Air-water CO2 gas exchange flux reported in micromoles CO2 per meter squared per second
missing data are indicated by -9999; missing text data are indicated by na			

Example data records

```
Basin,Location,Site_code,Date,Time,Env_type,Comments,Latitude,Longitude,
Elev,Wind_spd_avg,Wind_spd_max ,RH,T_air,T_water,pCO2_water,pCO2_air,Time_start,
Time_end_1,Time_end_2,Time_end_3,pCO2_init,pCO2_end_1,pCO2_end_2,pCO2_end_3,
Slope_regression,SE_regression,Press_atm,k_1,k_2,k_3,u_star,u_10,FCO2

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Purus,Catuaba,na,20040701,-9999,small stream,na,-10.066,-67.606,
0.15,0,0,100,28.1,26,140.5,607.5,100,160,220,280,628.41,654.93,681.96,709.55,
0.45,0.49,0.98,-77.7,-76.3,-75,0,0,3.35
Purus,Catuaba,na,20040701,-9999,small stream,na,-10.066,-67.606,
0.15,0,0,100,28.1,26,140.5,416.84,100,160,220,280,433.43,464.54,494.15,528.64,
0.52,0.86,0.98,-155.9,-144.7,-143.3,0,0,3.83
...
Negro,Igarape 6,na,20050309,12:10,igarape - very black water,all marginal igarapes draining directly into
Negro,-0.434,-67.06,
0.0172,0,0,100,30.6,26.4,4762.2,710.1,80,140,200,251,723.795211,779.865211,846.125211,909.625211,
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Negro,Igarape 6,na,20050309,12:10,igarape - very black water,all marginal igarapes draining directly into
Negro,-0.434,-67.06,
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Ji-Parana,Muqui,IGA-30,20070123,12:08,rivers less than 100 m wide,-11.292,-62.233,
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0.907,0.003389276,0.98,34.2025519,-9999,-9999,0.02,0.6,7.41
Ji-Parana,Muqui,IGA-30,20070123,12:16,rivers less than 100 m wide,-11.292,-62.233,
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999,0.7904,
0.004594008,0.98,28.20069643,-9999,-9999,0.02,0.6,6.45
```

Site boundaries: (All latitude and longitude given in decimal degrees)

Site (Region)	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude	Geodetic Datum
Amazon Basin (Amazon Basin)	-72.7	-52.417	-0.142	-11.76	World Geodetic System, 1984 (WGS-84)

Time period:

- The data set covers the period 2004/07/01 to 2007/01/23.
- Temporal Resolution: data were collected in multiple campaigns of varying length over the study period

Platform/Sensor/Parameters measured include:

- FIELD INVESTIGATION / IR CO2 ANALYZER / CARBION DIOXIDE

3. Data Application and Derivation:

These data (both raw and calculated parameters) are suitable for assessing surface pCO2 values and air-water gas exchange.

4. Quality Assessment:

Floating chambers generate results consistent with mass balance and injected tracer methods of measuring gas exchange when the chamber is moving at the same speed as the water surface (rather than being tethered to a stationary object) and at wind speeds less than 8 to 10 m/s and low to moderate wave conditions (Kremer et al., 2003; Cole et al., 2010). Chambers with and without fans have been found to give results within the range of normal variability when used under moderately windy conditions (<5 m/s) (Kremer et al., 2003). These conditions were routinely met during our deployments.

Infrared gas analysis was done on a LICOR LI820 using the 14-cm optical bench with a detection range of 0 to 2,000 ppm carbon dioxide (CO2) and accuracy of less than 3% of reading. The unit was zeroed and spanned every field day. In addition a standard curve was run each day using standard gases of known concentrations to verify performance (approximately 300, 1,000, and 10,000 uatm CO2 in nitrogen (Scott Specialty Gases).

5. Data Acquisition Materials and Methods:

Sites and Sampling

CO2 flux and transfer velocity were measured in rivers and streams with channel widths ranging from meters to kilometers. We divided rivers into size categories of greater than and less than 100 m wide (referred to as large and small rivers, respectively) because this threshold has been used in previous basinwide outgassing estimates and is appropriate for differentiating smaller from larger channels in remotely sensed images (Richey et al., 2002; Rasera et al., 2008). The latter category includes both small rivers and streams and was chosen on the basis of recent work showing that rivers <100 m wide compose >90% of the total length of river networks and may account for >80% of the outgassing flux within individual basins (Mayorga et al., 2005; Rasera et al., 2008). However, the 100-m threshold is operational rather than physically meaningful. The category of rivers <100 m wide includes streams down to approximately 1–2 m across.

Several campaigns occurred between June 2004 and January 2007 in the Amazon River basin, with discharge conditions ranging from low to high flow. The sampled areas span the spectrum of chemical characteristics observed across the entire basin, including, for example, both low and high pH values and suspended sediment loads. See Figures 2, 3, and 4 for examples of sampling site locations.

Figure 2. Igarape Baro Branco

Figure 3. Rio Tapajos

Figure 4. Upper Rio Purus

Floating Chamber Method

To measure CO_2 fluxes and transfer velocities, we deployed floating chambers equipped with an internal fan to circulate air through the chamber (see Sebacher et al., 1983). The chamber (50 cm length, 20 cm width, and 20 cm height) was made of Plexiglas with a stopcock in the top to release air pressure. The chamber was connected via CO_2 impermeable tubing to a portable infrared CO_2 analyzer (LI820; LICOR Instruments). Air was circulated through the LI820 system via an air filter using a miniature air pump (AS200; Spectrex) with a flow of approximately 150 mL per min. Closed cell foam was used for flotation.

To take chamber measurements, we gently placed the chamber on the water surface to avoid inducing additional turbulence. Data were continuously recorded on a laptop or data logger at 1- to 5-s intervals from the time the chamber was placed on the water for 5 min or until the CO_2 accumulation curve began to flatten out. Chamber measurements on rivers with navigable channels were executed from small boats (for river size classes) while drifting with the river current. In streams and the smallest river environments, measurements were conducted from the shore, with the chamber deployed in parts of the channel where it was not pulled downstream by the current and connected to shore by way of the lines attaching it to the gas analyzer. The rope securing the chamber to the shore was not taut during any of the measurements reported here. However, these locations may not be representative of the entire cross section of the stream, as water current velocity may be lower and water depth shallower at them than in the main flow of the stream. These factors would tend to decrease and increase k_{600}, respectively. Thus, these measurements may not be representative of conditions across the entire channel.

pCO_2 Measurements:

We measured the partial pressure of CO_2 (pCO_2) at each site by headspace equilibration. A 1 L polycarbonate bottle was overflowed for two to three volume changes, with water pumped from the upper meter of the water column before being securely sealed with a stopper fitted with stopcocks (Hesslein et al., 1991). A headspace of 60 mL of ambient air (collected from upwind and overhead to avoid elevated CO2 concentrations from breath and motors, for example) was introduced while removing the same volume of water. The bottle was shaken vigorously for at least 60 s. The headspace was then removed while water was reinjected at the same rate. Air samples were also collected in syringes to measure air pCO2. All pCO2 samples were measured by infrared gas analysis on a LICOR LI820 using standards of approximately 300, 1,000, and 10,000 uatm CO2 in nitrogen (Scott Specialty Gases). Samples were run directly from syringes within 24 h of collection or were stored in vials previously flushed with nitrogen until analysis. Vial-stored pCO2 values were corrected for dilution by the nitrogen remaining in the vials after evacuation with a hand pump (15%).

Air temperature was also measured with the Kestrel 3000. Water temperature was measured with a ThermoOrion pH or dissolved oxygen probe.

Chamber Data Analysis

Air water gas exchange fluxes were calculated as follows:

Equation 1:

$$F_{CO2} = (\mathrm{d}(\mathrm{pCO_2})/\mathrm{d}t)\ (V/RT_K S)$$

where delta (pCO2)/delta t is the slope of the CO2 accumulation in the chamber (uatm s-1), V is the chamber volume (L), TK is air temperature (in degrees Kelvin, K), S is the surface area of the chamber at the water surface (m2), and R is the gas constant (L atm K-1 mol-1) (Frankignoulle, 1988). Fluxes were calculated using the first 30, 60, and 90 s of the initial CO2 accumulation in the chamber.

The k value measured during each chamber deployment was calculated as follows:

Equation 2:

$$k = (h/\alpha)\ \ln[(\mathrm{pCO}_{2w} - \mathrm{pCO}_{2a})_i/(\mathrm{pCO}_{2w} - \mathrm{pCO}_{2a})_f]\ (t_f - t_i)^{-1}$$

where h is the chamber height (cm), alpha is the Ostwald solubility coefficient (dimensionless), t is time (s), and the subscripts w, a, i, and represent water, air, initial, and final, respectively (MacIntyre et al., 1995). The Ostwald solubility coefficient can be calculated from K0 as a function of temperature as described by Wanninkhof et al. (2009).

To compare gas transfer velocity values among sites, k values were normalized to a temperature of 20 degrees C (i.e., k600) using the following equation:

Equation 3:

$$k_{600} = k_T\ (600/\ Sc_T)^{-0.5}$$

with T in degrees Celsius (Wanninkhof, 1992). where kT is the measured k value at the in situ temperature (T), ScT is the Schmidt number for temperature T, and the Schmidt number for 20 degrees C in freshwater is 600 (Jahne et al., 1987).

The Schmidt value for freshwater is calculated as a function of temperature:

Equation 4:

$$Sc_T = 1911.1 - 118.11\,T + 3.4527\,T^2 - 0.04132\,T^3$$

Ancillary Data

In addition to chamber and pCO2 measurements, we measured wind speed and air and water temperatures. Wind speed was measured for 3 to 5 min at the time of flux measurements using a handheld anemometer (Kestrel 3000) facing into the wind at approximately 1.5 m above the water surface. Wind speeds were averaged over the period of the flux measurement as described by Borges et al. (2004a, 2004b).

Wind speeds were normalized to a height of 10 m above the surface using the following equation:

Equation 5:

$$\bar{u}_z = (u_*/\kappa)\ \ln\,(z/z_0)$$

where u_bar subz is mean wind speed (m/s) at the height z, u star is friction velocity (m/s), kappa is von Karman's constant (approximately 0.40), and z0 is roughness length (10.5 m, an intermediate value for water surfaces) (Oke, 1988). Friction velocity was first calculated by rearranging equation (5) to solve for u_star and using the mean wind speed measured at 1.5 m as z.

6. Data Access:

This data is available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

Data Archive Center:

Contact for Data Center Access Information:
E-mail: uso@daac.ornl.gov
Telephone: +1 (865) 241-3952

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MacIntyre, S., et al. (1995), Trace gas exchange across the air-water interface in freshwater and coastal marine environments, in Biogenic Trace Gases: Measuring Emissions from Soil and Water, edited by P. A. Matson and R. C. Harriss, pp. 52-97, Blackwell Science, Oxford. Oke, T. R. (1988), Boundary Layer Climates, Routledge, Boca Raton, Fla.

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Wanninkhof, R., et al. (2009), Advances in quantifying air-sea gas exchange and environmental forcing, Annu. Rev. Marine Sci., 1, 213-244.

Related Publications

- Alin, S. R., M. F. F. L. Rasera, C. I. Salimon, J. E. Richey, G. W. Holtgrieve, A. V. Krusche, and A. Snidvongs. 2011, Physical controls on carbon dioxide transfer velocity and flux in low gradient river systems and implications for regional carbon budgets, J. Geophys. Res., 116, G01009, doi:10.1029/2010JG001398.