LBA-ECO CD-06 Flux of CO2 from Amazon Mainstem Rivers, Tributaries, and Floodplains

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Revision date: March 12, 2013

Summary:

This data set provides estimates of monthly carbon dioxide (CO2) flux from the Amazon mainstem rivers, tributary stream networks, and their associated varzeas (floodplains). CO2 flux was calculated using two aggregation approaches: for defined river basins and for defined river reaches. Flux was calculated from (1) estimated surface water area by month for the Amazon mainstem rivers, associated varzeas, and tributary stream networks, (2) mean daily partial pressures of CO2 (pCO2) concentrations for the mainstem rivers, and (3) calculated mean pCO2 values for the varzea waters. Mean monthly discharge data for 11 mainstem rivers are also included.

There are five comma-delimited data files with this data set.

Amazon mainstem is a region covering the Amazon/Solimoes River mainstem from 70 degrees W to 54 degrees W. Data from the Japanese Earth Resources Satellite-1 (JERS-1) L-band synthetic aperture radar were used to estimate the areal coverage and inundation status of rivers and floodplains over 100 m in width and compiled into mosaics for periods of high and low water. For each mosaic, the study area was classified into either flooded or non-flooded areas.

Data for the seasonal and spatial distributions of pCO2 within each hydrographic region were utilized from more than 1,800 samples taken on 13 Carbon in the Amazon River Experiment (CAMREX) expeditions at different water stages throughout a 2,000 km reach of the central Amazon mainstem, tributary, and floodplain waters (Degens et al., 1991, Devol et al., 1995, Richey et al., 1988).

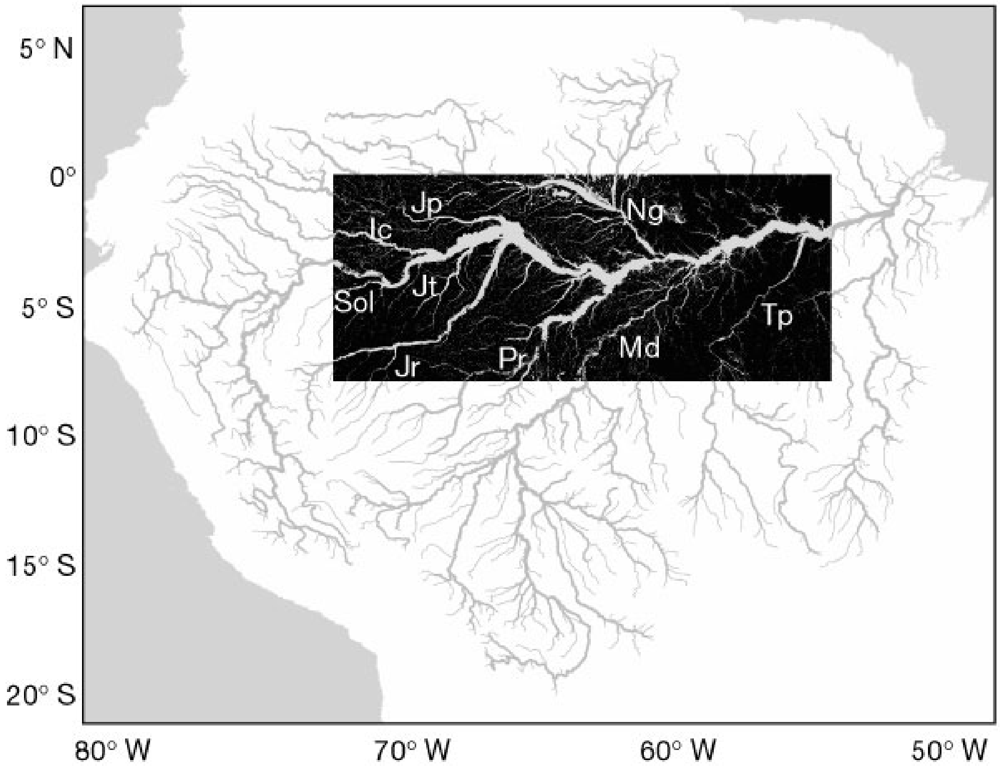

Figure 1: Flooded area of the central Amazon Basin at high water, as mapped from the Japanese Earth Resources Satellite radar data (May-June 1996). The flooded area is shown as light areas in dark inset (the study quadrant). Underlying the inundation image is a digital river network (derived from the Digital Chart of the World, the GTOPO30 digital elevation model and ancillary cartographic information). Major tributaries are labelled: Negro (Ng), Japura (Jp), Ica (Ic), Solimoes (Sol, the Amazon mainstem exiting Peru), Jutaı (Jt), Jurua (Jr), Purus (Pr), Madeira (Md), and Tapajos (Tp). Image is from Richey et al., 2002.

Data Citation:

Cite this data set as follows:

Richey, J.E., J.M. Melack, A.K. Aufdenkampe, M.V.R. Ballester and L.L. Hess. 2013. LBA-ECO CD-06 Flux of CO2 from Amazon Mainstem Rivers, Tributaries, and Floodplains. Data set. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1151

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This data set was archived in March 2013. Users who download the data between March 2013 and February 2018 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.

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 Richey, Jeffrey E. (jrichey@uwashington.edu).

LBA Data Set Inventory ID: CD06_Outgassing

This data set provides estimates of monthly carbon dioxide (CO2) flux from the Amazon mainstem rivers, tributary stream networks, and their associated varzeas (floodplains). CO2 flux was calculated using two aggregation approaches: for defined river basins and for defined river reaches. Flux was calculated from (1) estimated surface water area by month for the Amazon mainstem rivers, associated varzeas, and tributary stream networks, (2) mean daily partial pressures of CO2 (pCO2) concentrations for the mainstem rivers, and (3) calculated mean pCO2 values for the varzea waters. Mean monthly discharge data for 11 mainstem rivers are also included.

2. Data Characteristics:

Data are available in five comma separated ASCII files:

File 1: Monthly_mean_hydrograph.csv

Mean monthly flow rates for 11 mainstem river basins. Reference Figure 2 rivers.

File 2: River_area_basin_scale.csv

Calculated areas of large and small rivers for defined basins. Basins in Files #2 and #3 are the same.

File 3: Calculated_CO2_fluxes_basins.csv

CO2 flux calculated from river areas and pCO2. Basins in Files #2 and #3 are the same.

File 4: Varzea_pCO2.csv

pCO2 of river reaches as defined in Figure 2.

File 5: Calculated_CO2_fluxes_reaches.csv

CO2 flux calculated from mainstem and floodplain river areas and pCO2 for reaches as defined in Figure 2.

File 1: Monthly_mean_hydrograph.csv

Column	Heading	Units/format	Description
1	River_basin		River basin name (see Figure 2)
2	Month		Month of the year
3	Mean_monthly_dischage	m3/s	Monthly average discharge reported in meters cubed per second (m3/s)
4	Percent_max	%	Percent of maximum monthly average discharge
Missing data are indicated by -9999			

Example data records

```
River_basin,Month,Mean_monthly_discharge ,Percent_max
SPO,January,46495,73
```

```
Ica,January,5582,57
...
Japura,April,13450,67
Purus,April,18754,99
...
Xingu,December,3918,20
Tapajos,December,7198,37
```

File 2: River_area_basin_scale.csv

Column	Heading	Units/format	Description
1	Basin_name		Basin name
2	Basin_ID		Basin identification: each basin is assigned a unique numeric identifier
3	Total_basin_area	km2	Total land area in the delineated basin reported in square kilometers (km2)
4	Month		Month of the year
5	Area_large_rivers	km2	Calculated area of rivers with a width greater than or equal to 100 m reported in square kilometers (km2). These rivers were detectable in satellite images
6	Area_small_rivers	km2	Calculated area of rivers with a width less than 100 m reported in square kilometers (km2). Area was derived by a stream density function since these were too small to be detected in imagery
Missing data are indicated by -9999			

Example data records

```
Basin_name,Basin_ID,Total_basin_area,Month,Area_large_rivers,Area_small_rivers
central varzea/channel,Basin 1 ,152830,Jan,28814,-9999
central varzea/channel,Basin 1 ,152830,Feb,28149,-9999
...
Manacapura,Basin 19,13013.67,May,2383,719
Manacapura,Basin 19,13013.67,Jun,3009,907
...
Xingu,Basin 5,56195.15,Nov,353,506
Xingu,Basin 5,56195.15,Dec,464,770
```

File 3: Calculated_CO2_fluxes_basins.csv

Column	Heading	Units/format	Description
1	Basin_name		Basin name
2	Basin_ID		Basin_ID
3	Month		Month of the year
4	SA_large_rivers	km2	Surface area of large (greater than 100 m width) rivers in the basin reported in kilometers squared (km2)
5	pCO2_large_rivers	uM CO2/L	Mean pCO2 for the month from the CAMREX data reported in micromoles of CO2 per liter (uM CO2/L): where no direct measurements are available values for the nearest location were used
6	z_large_rivers	um	Surface boundary layer for the large rivers reported in microns (um)
7	CO2_flux_m2_large_rivers	umoles O2/m2/s	Evasion of CO2 from the large rivers reported in micromoles of CO2 per meter squared per second (uM CO2/m2/s)
8	CO2_flux_km2_large_rivers	mt CO2/km2/month	Evasion of CO2 from the large rivers reported in metric tons of CO2 per kilometer squared per month (mt CO2/km2/month)

9	CO2_flux_basin_large_rivers	Tg CO2/month	Evasion of CO2 from the large rivers reported in teragrams of CO2 per month for the entire basin (Tg CO2/month)
10	SA_small_rivers	km2	Surface area of small (less than 100 m width) rivers in the basin reported in square kilometers (km2)
11	pCO2_small_rivers	uM CO2/L	Mean pCO2 for the month from the CAMREX data reported in micromoles of CO2 per liter (uM CO2): where no direct measurements are available values for the nearest location were used
12	z_small_rivers	um	Surface boundary layer for the small rivers reported in microns (um)
13	CO2_flux_m2_small_rivers	umoles CO2/m2/s	Evasion of CO2 from the small rivers reported in micromoles of CO2 per meter squared per second (umol CO2/m2/s)
14	CO2_flux_km2_small_rivers	mt CO2/km2/month	Evasion of CO2 from the small rivers reported in metric tons of CO2 per kilometer squared per month (mt CO2/km2/month)
15	CO2_flux_basin_small_rivers	Tg CO2/month	Evasion of CO2 from the small rivers reported in teragrams of CO2 per month for the entire basin (Tg CO2/month)
Missing data are indicated by -9999			

Example data records

```
Basin_name,Basin_ID,Month,SA_large_rivers,pCO2_large_rivers,z_large_rivers,
CO2_flux_m2_large_rivers,CO2_flux_km2_large_rivers,CO2_flux_basin_large_rivers,
SA_small_rivers,pCO2_small_rivers,z_small_rivers,CO2_flux_m2_small_rivers,CO2_flux_km2_small_rivers,
CO2_flux_basin_small_rivers
Javari,Basin 29,Jan,2734,159,183,1.82,57,0.16,2697,159,180,1.85,58,0.16
Javari,Basin 29,Feb,2931,174,183,1.99,63,0.18,2892,174,180,2.03,64,0.18
...
Manacapura,Basin 19,Nov,790,81,183,0.93,29,0.02,238,81,180,0.95,30,0.01
Manacapura,Basin 19,Dec,783,61,183,0.7,22,0.02,222,61,180,0.71,22,0
...
Xingu,Basin 5,Nov,353,105,183,1.2,38,0.01,506,105,180,1.22,39,0.02
Xingu,Basin 5,Dec,464,81,183,0.92,29,0.01,770,81,180,0.94,30,0.02
```

File 4: Varzea_pCO2.csv

Column	Heading	Units/format	Description
1	Location		General description of the sampling location
2	Reaches		The identity of the reaches included in the general sampling location. See accompanying information for more detail about the reaches (see Figure 2)
3	Sampling_location		Description of the sample location: "surface depth" and "sides" are locations within lakes, while "all" includes all samples from lakes and paranas (side channels)
4	pCO2_mean	uM CO2/L	Partial pressure of CO2 reported in micromoles of CO2 per liter (uM CO2/L) of water
5	pCO2_Stdev	uM CO2/L	Standard deviation of the mean value of pCO2 reported in micromoles of CO2 per liter (uM CO2/L) of water
6	N		Number of samples included in the calculation of the mean and standard deviation
Missing data are indicated by -9999			

Example data records

```
Location,Reaches,Sampling_location,pCO2_mean,pCO2_Stdev,N
Upriver,1 through 10,All (surface + depth + sides + paranas),488,352,316
Upriver,1 through 10,Surface,392,269,121
...
Midriver,11 through 16,All (Off Solimoes + Off or near Madeira),339,185,49
Midriver,11 through 16,Off Solimoes ,313,180,35
...
Downstream,17 through 18,Sides,218,146,57
Downstream,17 through 18,Paranas (side channels) and tributaries,246,174,44
```

File 5: Calculated_CO2_fluxes_reaches.csv

Column	Heading	Units/format	Description
1	Reach Name		Name of mainstem river reach (see Figure 2)
2	Reach_ID		Numeric identification of river reach defining the mainstem (see Figure 2)
3	Month		Month
4	Area_mainstem	km2	Area of the mainstem river in kilometers squared (km2)
5	pCO2_mainstem	uM CO2/L	Mean monthly pCO2 concentrations for each mainstem river reach based on measured values from CAMREX cruises reported in micromoles of CO2 per liter (uM CO2/L)
6	Z_mainstem	um	Surface boundary layer for the mainstem river reported in microns (um)
7	CO2_flux_m2_mainstem	umoles CO2/m2/s	Calculated rate of CO2 outgassing from the mainstem river surface reported in micromoles of CO2 per square meter per second
8	CO2_flux_km2_mainstem	mt CO2/km2/month	Calculated rate of CO2 outgassing from the mainstem river surface reported in metric tons of CO2 per square kilometer per month (mt CO2/km2/month)
9	CO2_flux_reach_mainstem	Tg CO2/month by reach	Total amount of CO2 outgassing from the mainstem river surface reported in teragrams of CO2 per delineated reach of the river per month (Tg CO2/month)
10	Area_ varzea	km2	Area of the varzea region calculated from satellite images and reported in kilometers squared (km2)
11	pCO2_varzea	uM CO2/L	Mean pCO2 concentrations for the varzea regions based on measured values from CAMREX cruises reported in micromoles of CO2 per liter (uM CO2/L). Mean values were calculated for three regions: upriver; midriver and lower river
12	Z_varzea	um	Surface boundy layer for the varzea reported in microns (um)
13	CO2_flux_m2_varzea	micromoles CO2/m2/s	Calculated rate of CO2 outgassing from the varzea surface reported in micromoles of CO2 per square meter per second
14	CO2_flux_km2_varzea	mt CO2/km2/month	Calculated rate of CO2 outgassing from the varzea surface reported in metric tons of CO2 per square kilometer per month (mt CO2/km2/month)
15	CO2_flux_reach_varzea	Tg CO2/month by reach	Total amount of CO2 outgassing from the varzea surface reported in teragrams of CO2 per delineated reach of the river per month (Tg CO2/month)
Missing data are indicated by -9999			

Example data records

```
Reach Name,Reach_ID,Month,Area_mainstem ,pCO2_mainstem
,Z_mainstem,CO2_flux_m2_mainstem,CO2_flux_km2_mainstem,CO2_flux_reach_mainstem,
Area_ varzea,pCO2_varzea,Z_varzea,CO2_flux_m2_varzea,CO2_flux_km2_varzea,
CO2_flux_reach_varzea
Border-SPO,R0,Jan,648,69,100,1.46,46,0.03,661,488,310,3.31,104,0.07
Border-SPO,R0,Feb,648,77,100,1.61,51,0.03,825,488,310,3.31,104,0.09
...
Itapeua,R11,Sep,360,205,78,5.52,174,0.06,2010,488,310,3.31,104,0.21
Itapeua,R11,Oct,360,187,78,5.03,159,0.06,1217,488,310,3.31,104,0.13
```

```
...
Obidos,R21,Nov,1332,131,58,4.74,149,0.2,2905,217,310,1.47,46,0.13
Obidos,R21,Dec,1332,86,58,3.13,99,0.13,2714,217,310,1.47,46,0.13
```

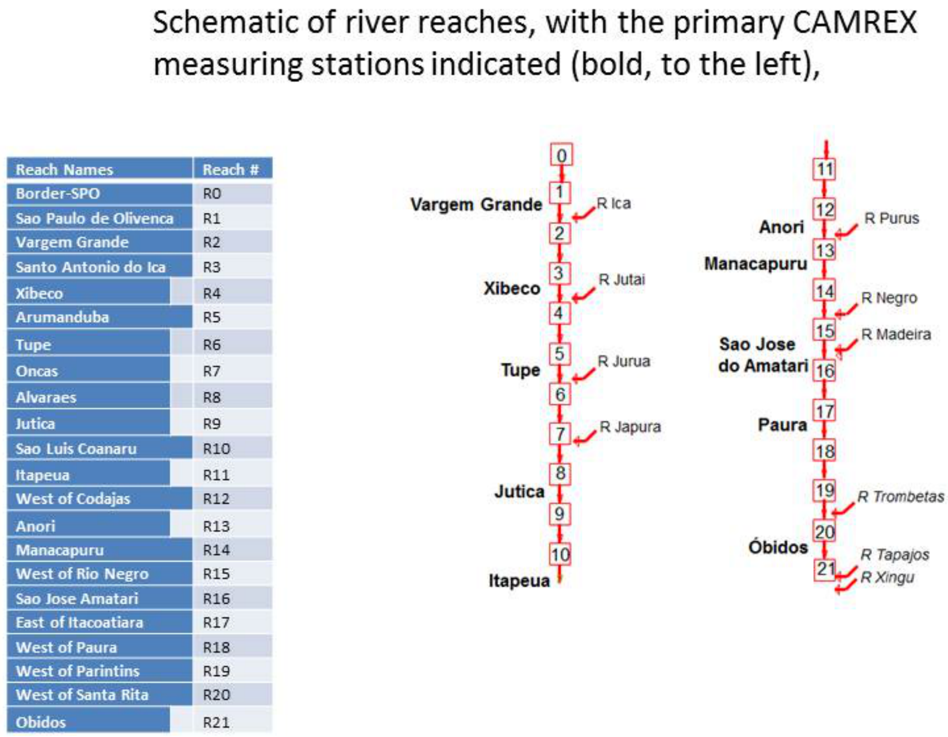

Figure 2. Amazon mainstem and tributary rivers and defined reaches for surface water area and CO_2 flux calculations as used in data files #4 and #5.

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

Site (Region)	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude	Geodetic Datum
Amazon mainstem (Amazon Basin)	-72	-52	0	-7.5	World Geodetic System, 1984 (WGS-84)

Time period: This data set covers the period: 19820401-19960630

Platform/Sensor/Parameters measured include:

- COMPUTER MODEL /ANALYSIS / CARBON DIOXIDE

3. Data Application and Derivation:

Assuming that the fluxes computed for the Amazon are representative of fluvial environments of lowland humid tropical forests in general, surface water CO_2 evasion in the tropics may help to explain an anomaly in the current balance of the global carbon cycle. Estimates that the tropics are a net carbon sink are not consistent with recent calculations from global inverse modeling, which imply that the tropics are at least in balance with the atmosphere if not a net source. Extrapolating over the global area covered by humid tropical forests with our estimate of areal evasion rates for the Amazon basin yields a flux of roughly 0.9 Gt C/yr (three times larger than previous estimates of global evasion). A return flux from water to the atmosphere of this magnitude comes closer to reconciling independent carbon budgets for the tropics (Richey et al., 2002).

4. Quality Assessment:

Area coverage and inundation: The uncertainty of the procedure was estimated using high-resolution airborne, digital videography (Hess et al., 2002) to be plus or minus 5% at high water and plus or minus 10% to 15% at low water.

pCO2 concentrations: The standard deviation ranged from 16% to 37% of mean monthly values. Annual profiles for each tributary were similarly constructed, with assumed standard deviations of 40% for each month. For regions not directly sampled, profiles were used from the nearest neighbor with data, with assumed uncertainties of 80%.

5. Data Acquisition Materials and Methods:

Delineation of Study Areas and SAR Mosaics

The central Amazon is a 1.77 million km2 quadrant covering the Amazon Basin between 0 and 8 degrees S latitude and 72 to 54 degrees W longitude. The Amazon Mainstem is a region covering the Amazon/Solimoes river mainstem from 70 degrees W to 54 degrees W..

Data from the Japanese Earth Resources Satellite-1 (JERS-1) L-band synthetic aperture radar were used to estimate the areal coverage and inundation status of rivers and floodplains over 100 m in width and compiled into mosaics for periods of high water (May through June 1996) and low water (October 1995) (Siqueira et al., 2000).

For each mosaic, the study area was classified into either flooded or non-flooded areas based on radar backscatter intensities as delineated by image segmentation (Barbosa et al., 2000), and was divided into 25 tributary sub-basins from the river network. To account for river corridors less than 100 m in width, an area density function was computed by extending a geometric series relating stream length and width to stream order from the river network for the whole basin, and applied to the study area.

Mean monthly stage data from multiyear hydrographic records within each tributary sub-basin (Richey et al., 2004) were used to estimate tributary flooding sequences by assuming a temporal correspondence between stage height and areal extent of inundation. The major tributaries are the Negro, Japura, Ica, Solimoes, Jutaı, Jurua, Purus, Madeira, and the Tapajos (Richey et al., 2002). For five sub-basins without gauging records, the normalized hydrograph for the nearest neighbor with similar climatology was used. The temporal sequence of inundation within the mainstem and its floodplain was computed from multi-year monthly composite Scanning Multichannel Microwave Radiometer (SMMR) data (Sippel et al., 1998).

CO2 Distributions

Data for the seasonal and spatial distributions of pCO2 within each hydrographic region were utilized from over 1,800 samples taken on 13 expeditions at different water stages throughout a 2,000 km reach of the central Amazon mainstem, tributary, and floodplain waters (Degens et al., 1991, Devol et al., 1995, Richey et al., 1988). A ten-year time series (Devol et al., 1995) at the Marchantaria mainstem station gave a statistically robust picture of seasonal trends in pCO2. The standard deviation ranged from 16% to 37% of mean monthly values. Annual profiles for each tributary were similarly constructed, with assumed standard deviations of 40% for each month. For regions not directly sampled, profiles were used from the nearest neighbor with data, with assumed uncertainties of 80%. Floodplain measurements exhibited no obvious seasonal trends but a pronounced gradient from higher concentrations upriver to intermediate and then lower concentrations downriver. Hence, results were aggregated by up-, mid-, and downriver sections.

CO2 Evasion

Evasion was computed from the gas transfer model, F=K(Cs-Co), where F is the evasive flux, Cs is the surface water concentration, Co is the atmospheric equilibrium, and K is the exchange coefficient (piston velocity). We determined K from direct measurements of O2 and 222Rn accumulation in free-floating chambers (Devol et al., 1987) on (1) the mainstem (K=2.3 +/- 0.9 meters/day) and (2) primary tributaries (K=1.2 +/- 0.5 meters/day) and of (3) CO2 and CH4 accumulation on the floodplain (K=0.65 +/ 0.25 meters/day).

A water temperature of 28 degrees C (Devol et al., 1987) and diffusion coefficient for CO2 in the range of 1.9 (25 C) to 2.4 (35 C) 10^-5 cm^2 sec^-1 (Jahne et al., 1987) was used in calculating the reported surface boundary layer (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

7. References:

Barbosa, C., Hess, L.,Melack, J. & Novo, E.Mapping Amazon Basin wetlands through region-growing segmentation and segmented-based classification of JERS-1 data. IX Latin Am. Symp. Remote Sensing (6 to10 November 2000) 1168 to 1176 (Universidad Nacional de Lujan, Puerto Iguazu, Argentina, 2000).

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