

LBA-ECO LC-07 Methane and Carbon Dioxide Emissions from Balbina Reservoir, Brazil

Summary:

This data set provides flux measurements of methane (CH₄) and carbon dioxide (CO₂) from surface waters to the atmosphere. It also provides CH₄, CO₂, and oxygen (O₂) concentrations of surface water, and concentrations measured at several depths of the Balbina Reservoir in the central Amazon Basin, Amazonas, Brazil. The Balbina Reservoir was formed by impounding the Uatuma River in 1987.

Reservoir surface water samples, bottom water samples, and gas samples from static flux enclosures were collected at 10 to 14 sites at monthly intervals between April and November of 2005, and 6 times in February, 2006. Water samples to determine the vertical profiles of temperature, dissolved O₂, CH₄, and CO₂ were collected during the rainy and dry seasons immediately above dam between September 2004 and February 2006. Water samples were collected downstream from the dam from July 2004 to November 2005 for analysis of CH₄ and CO₂ concentrations.

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

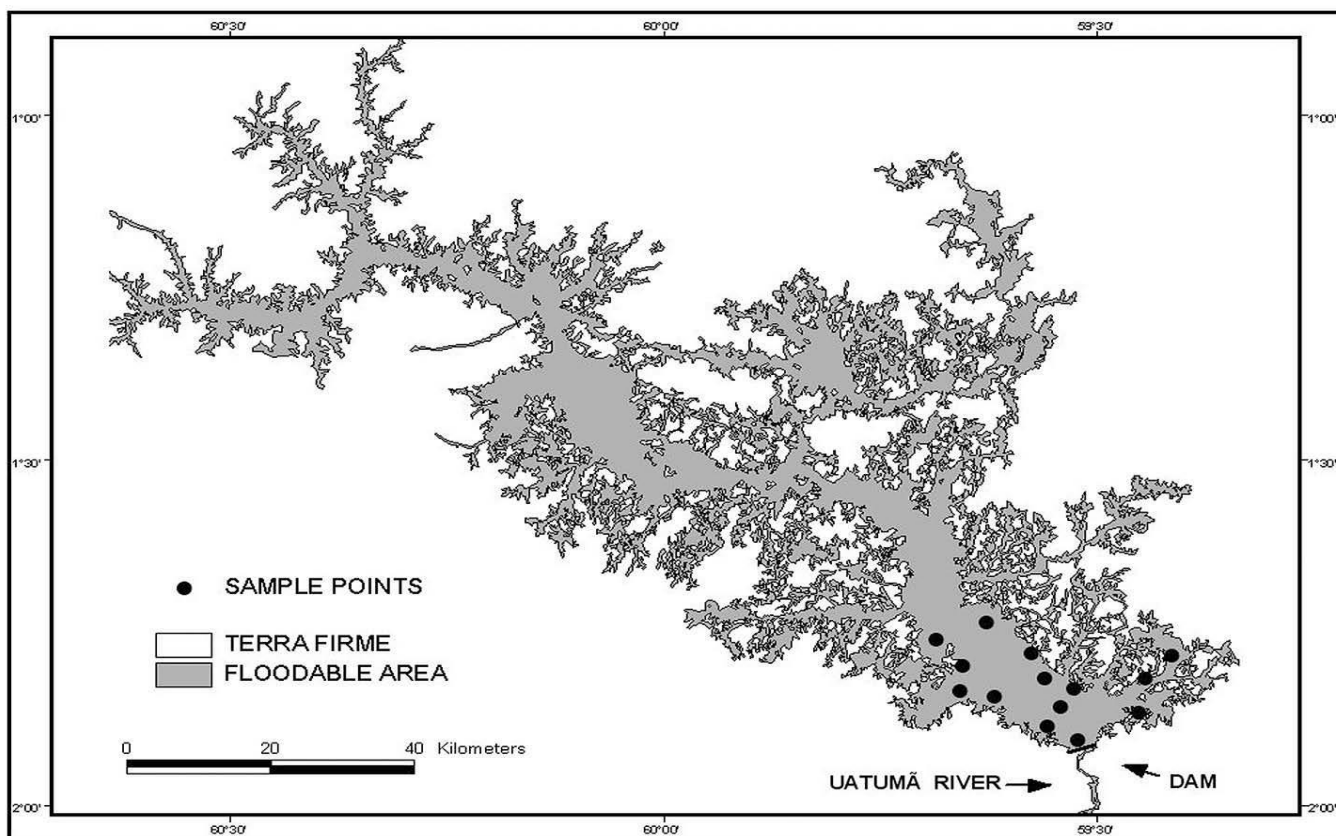


Figure 1. Balbina Reservoir showing location of the dam and reservoir sampling points (solid circles).
From Kemenes et al., 2011.

Data Citation:

Cite this data set as follows:

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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.

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1. Data Set Overview:

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

Activity: LBA-ECO

LBA Science Component: Land Use and Land Cover

Team ID: LC-07 (Melack / Novo / Forsberg)

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LBA Data Set Inventory ID: LC07_Reservoir_GHG

This data set provides flux measurements of methane (CH4) and carbon dioxide (CO2) from surface waters to the atmosphere. It also provides CH4, CO2, and oxygen (O2) concentrations of surface water, and and concentrations measured at several depths of the Balbina Reservoir in the central Amazon Basin, Amazonas, Brazil.

Reservoir surface water samples, bottom water samples, and gas samples from static flux enclosures were collected at 10 to 14 sites at monthly intervals between April and November of 2005, and 6 times in February, 2006. Water samples to determine the vertical profiles of temperature, dissolved O2, CH4, and CO2 were collected during the rainy and dry seasons immediately above dam between September of 2004 and February of 2006. Water samples were collected downstream from the dam from July 2004 to November 2005 for analysis of CH4 and CO2 concentrations.

2. Data Characteristics:

Data are available in 3 comma separated ASCII files:

File #1: LC07_Reservoir_gas_measurements.csv

- Results of analyses of reservoir surface water samples, bottom water samples, and gas samples from static flux enclosures collected at 10 to 14 sites at monthly intervals between April and November 2005, and six times in February, 2006.

File #2: LC07_Depth_profiles_gas_measurements.csv

- Results of analyses of water samples from vertical profiles for temperature, dissolved O2, CH4, and CO2 collected during the rainy and dry seasons immediately above dam between September 2004 and February 2006.

File #3: LC07_Downstream_gas_measurements.csv

- Results of analyses of water samples collected downstream from the dam from July 2004 to November 2005 for analysis of CH4 and CO2 concentrations and flux calculations.

Data are organized as follows:

File #1: LC07_Reservoir_gas_measurements.csv

Column	Heading	Units/format	Description
1	Date	YYYYMMDD	Sampling date
2	Latitude	decimal degrees S	Location of sample collection in degrees latitude south of the equator
3	Longitude	decimal	Location of sample collection in degrees longitude west of

		degrees W	the prime meridian
4	Habitat		Habitat type: AA = open water; FPI = slightly inundated dead forest; FI = moderately inundated dead forest; FMI = very inundated dead forest; FQS = nearly submerged dead forest
5	Conc_CO2_surface	mgC/m3	Concentration of carbon dioxide in the surface waters reported in milligrams of carbon per cubic meter of water
6	Conc_CH4_surface	mgC/m3	Concentration of methane in the surface waters reported in milligrams of carbon per cubic meter of water
7	Conc_CO2_bottom	mgC/m3	Concentration of carbon dioxide in the bottom waters reported in milligrams of carbon per cubic meter of water
8	Conc_CH4_bottom	mgC/m3	Concentration of methane in the bottom waters reported in milligrams of carbon per cubic meter of water
9	Flux_CH4_funnel	mgC/m2/day	Flux of methane measured using a funnel and reported in milligrams of carbon per meter squared of surface area per day
10	Flux_CO2_funnel	mgC/m2/day	Flux of carbon dioxide measured using a funnel and reported in milligrams of carbon per meter squared of surface area per day
11	Flux_CH4_total	mgC/m2/day	Total flux of methane calculated from static chamber measurements
12	Flux_CO2_total	mgC/m2/day	Total flux of carbon dioxide calculated from static chamber measurements
13	flux_CH4_diffusive	mgC/m2/day	Diffusive flux of methane calculated by subtracting measured funnel fluxes (Column 9) from the calculated total flux value (Column 11)
14	Flux_CO2_diffusive	mgC/m2/day	Diffusive flux of carbon dioxide calculated by subtracting measured funnel fluxes (Column 10) from the calculated total flux value (Column 12)
15	Conc_O2_surface	mg/L	Concentration of oxygen in surface waters reported in milligrams of oxygen per liter of water
16	Conc_O2_bottom	mg/L	Concentration of oxygen in bottom waters reported in milligrams of oxygen per liter of water
17	T_water_surface	degrees C	Water temperature at the surface reported in degrees Celsius
18	T_water_bottom	degrees C	Water temperature at the bottom reported in degrees Celsius
19	Depth_water	m	Depth to the bottom of the reservoir reported in meters
20	Transparency	m	Secchi depth transparency reported in meters

Example data for file #1:

```

Date,Latitude,Longitude,Habitat,Conc_CO2_surface,Conc_CH4_surface,Conc_CO2_bottom,Conc_CH4_bottom,
Flux_CH4_funnel,Flux_CO2_funnel,Flux_CH4_total,Flux_CO2_total,Flux_CH4_diffusive ,Flux_CO2_diffusive,
Conc_O2_surface,Conc_O2_bottom,T_water_surface,T_water_bottom,Depth_water,Transparency
20050417,-1.91094,-59.50275,AA,674.2,1,823.3,3.2,
0.02,0.01,44,1365.7,44,1365.7,
6.7,4.2,30.5,29,13,3.2
20050417,-1.88869,-59.53294,FMI,534,3.2,966.2,9.9
,0.04,0.01,124.6,2122.3,124.6,2122.3,
7.3,6.3,30.7,30,5,2.6
...

```

```

20050705,-1.7695,-59.53499,FI,1914.6,5,2150.3,8.9,
0.35,0.01,71.4,8529.9,71.1,8529.9,
4.9,3.1,30.2,29.8,12,2.4
20050705,-1.78027,-59.5681,AA,1419.9,1.7,3116.6,
78.8,0,0,8.8,5067.8,8.8,5067.8,
6.1,0.5,30.4,29.8,15,2.4
...
20060215,-1.90987,-59.49859,FQS,1093,4.6,2090.5,4.4,0.03,
0,87.6,343.3,87.6,343.3,
5.8,3.7,30,29,14,2.2
20060215,-1.91397,-59.50176,FI,1399.3,3.9,1743.1,4.8,
0,0,13.2,3584,13.2,3584,
6.5,2,30,29,11,2.8

```

File #2: LC07_Depth_profiles_gas_measurements.csv

Column	Heading	Units/format	Description
1	Date	YYYYMMDD	Sampling date
2	Depth	m	Depth in the water column at which sample was collected reported in meters (m): AR indicates a gas sample for which depth is not applicable
3	Conc_CH4	mgC/m3	Concentration of methane in water sample reported in milligrams of carbon per cubic meter
4	Conc_CO2	mgC/m3	Concentration of carbon dioxide in water sample reported in milligrams of carbon per cubic meter
5	Conc_O2	mg/L	Concentration of oxygen in water sample reported in milligrams of oxygen per liter
6	T_water	degrees C	Water temperature reported in degrees Celsius
Missing data are represented by -9999			

Example data for file #2:

```

Date,Depth,Conc_CH4,Conc_CO2 ,Conc_O2 ,T_water
0040705,0,2.7,1103.7,6.8,33
20040705,2,2.9,1157.3,6.7,33
...
20050123,6,294.2,1894.9,4.1,30
20050123,8,180.9,1742.2,4.3,30
...
20051116,32,2854.4,6515.3,2.4,30
20051116,AR,3.4,973.4,-9999,-9999

```

File #3: File name: LC07_Downstream_gas_measurements.csv

Column	Heading	Units/format	Description
1	Date	YYYYMMDD	Sampling date
2	Distance_downstream	m	Sampling location in meters downstream from the dam
3	Conc_CO2_surface	mgC/m3	Concentration of carbon dioxide in the surface water

			reported in milligrams of carbon per cubic meter
4	Conc_CH4_surface	mgC/m3	Concentration of methane in the surface water reported in milligrams of carbon per cubic meter
5	Flux_CH4	mgC/m2/hour	Flux of methane from the surface water to the atmosphere reported in milligrams of carbon per meter squared per hour
6	Flux_CO2	mgC/m2/hour	Flux of carbon dioxide from the surface water to the atmosphere reported in milligrams of carbon per meter squared per hour
7	Conc_O2_surface	mg/L	Concentration of oxygen in the surface water reported in milligrams of oxygen per liter
Missing data are represented as -9999			

Example data for file #3:

Day,Distance_downstream ,Conc_CO2_surface,Conc_CH4_surface,Flux_CH4 ,Flux_CO2,Conc_O2_surface 20040719,50,3508.6,1405.8,-9999,-9999,4.5 20040924,50,3263,1479.6,-9999,-9999,4.4 ... 20041223,2000,2483.4,936.3,129.1,362,4.8 20041223,15000,2499.5,437.9,35.6,234.7,4.9 ... 20051113,2000,1786,517.8,193.9,415.2,-9999 20051113,30000,1597.6,315.2,26.9,241,-9999
--

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

Site (Region)	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude	Geodetic Datum
Amazonas (Manaus) - Balbina (Amazonas (Manaus))	-60.74131	-59.16711	-0.85903	-1.98403	World Geodetic System, 1984 (WGS-84)

Time period:

- The data set covers the period 2004/07/05 to 2006/02/15.
- Temporal Resolution: monthly

Platform/Sensor/Parameters measured include:

- FIELD INVESTIGATION / GC (GAS CHROMATOGRAPH) / METHANE
- FIELD INVESTIGATION /GC (GAS CHROMATOGRAPH) / CARBON DIOXIDE
- FIELD INVESTIGATION /OXYGEN METERS / OXYGEN
- FIELD INVESTIGATION /TEMPERATURE PROBE / WATER TEMPERATURE

3. Data Application and Derivation:

Measured fluxes can be combined with estimates of surface area of the flooded zone as well as modeled depth of the waterways to calculate methane and carbon dioxide emissions on a monthly to yearly basis.

4. Quality Assessment:

For CO₂, standards of 335 mg per L (SD = 105) and 995 mg per L (SD = 104) were used to calibrate the analyses. The detection limit was 100 mg per L.

Chamber emissions for each deployment were estimated from the regression of CO₂ concentration against time. All regressions had $r^2 > 0.90$, indicating that emissions were predominantly diffusive.

5. Data Acquisition Materials and Methods:

Site Description

Balbina reservoir, the largest hydroelectric reservoir in the Amazon, was formed by impounding the Uatuma River in 1987. It has an average flooded area of 1,770 km² and an installed generating capacity of 250 MW (Fearnside, 1989; Kemenes, 2006). The waters are dilute (conductance varying from 6 to 10 uS per cm) and slightly acid (pH varying from 6.0 to 7.4) with a dissolved organic carbon concentration ranging from 2.7 to 7.1 mg per L. The reservoir is stratified near the dam resulting in the development of near anoxia and high concentrations of CH₄ in bottom waters through most of the year (Kemenes et al., 2007).

Sampling at the Reservoir

Reservoir surface water samples, bottom water samples, and gas emission samples were collected at 10 to 14 sites at monthly intervals between April and November 2005, and six times in February, 2006.

- Static chambers were utilized for flux measurements, and were subsampled with 60 ml polyethylene syringes at 5-minute intervals during a period of 20 minutes, after which the gas samples were transferred to 20 ml glass serum bottles with high density butyl rubber stoppers and stored until analysis. Chamber emissions in the reservoir were assumed to include both diffusive and ebullitive fluxes.
- Surface and near bottom temperatures and dissolved O₂ concentrations were measured with a YSI Model 85 m at all sites. Secchi depth transparency was determined with a 20 cm diameter white disk
- Reservoir water samples to determine the vertical profiles of CH₄, and CO₂ were collected during the rainy and dry seasons immediately above the dam between September 2004 and February 2006. Measurements of temperature and dissolved O₂ were taken with a YSI Model 85 m.
- Water samples were collected with a Ruttner sampler at the depth of the turbine inflow (approximately 30 m) and transferred to syringes. Water samples in syringes were equilibrated with atmospheric air (30 ml water: 30 ml air), and the air fraction was then transferred to a serum vial and stored until analysis.

Sampling Downstream from the Reservoir

Surface water samples below the dam were collected directly with 60 ml syringes between July 2004 and November 2005. Water samples in syringes were equilibrated with atmospheric air (30 ml water: 30 ml air), and the air fraction was then transferred to a serum vial and stored until analysis.

Methane and Carbon Dioxide Analysis

Dissolved CH₄ concentrations were estimated with the head space method (Johnson et al., 1990).

CH₄ and CO₂ concentrations in all water samples were determined using a dual column gas chromatograph (Shimadzu GC-14A) following the methodology of Hamilton et al. (1995).

Methane and Carbon Dioxide Emissions

Average areal emission rates (mg C per m² per day) were determined monthly and interpolated spatially and temporally using a digital inundation model derived from a detailed bathymetric map of the reservoir and daily stage readings.

Daily emissions for the entire reservoir were obtained by multiplying the total flooded area, estimated from the inundation model for a given day, by the average monthly areal emission rate.

Emissions of CH₄ downstream of Balbina reservoir in the central Amazon basin (Brazil) were calculated from regular measurements of degassing in the outflow of the turbines and downstream diffusive losses. Gas releases immediately below the dam were calculated as the difference between gas flux at the entrance and the outflow of the hydroelectric turbines. An inundation model derived from a bathymetric map and daily stage readings was used for spatial and temporal interpolation of reservoir emissions.

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

References

Fearnside, P. M. (1989), Brazil's Balbina Dam: Environmental versus the legacy of the Pharaohs in Amazonia, *Environ. Manage.* N. Y., 13, 401-423.

Hamilton, S. K., S. J. Sippel, and J. M. Melack (1995), Oxygen depletion, carbon dioxide and methane production in waters of Pantanal wetland of Brazil, *Biogeochemistry*, 30, 115-141.

Johnson, K. M., J. E. Hughes, P. L. Donaghay, and J. M. Sieburth (1990), Bottle-calibration static head space method for determination of methane dissolved in seawater, *Anal. Chem.*, 62, 2408-2412.

Kemenes, A., B. R. Forsberg, and J. M. Melack (2007), Methane release below a tropical hydroelectric dam, *Geophys. Res. Lett.*, 34, L12809, doi:10.1029/2007GL029479.

Kemenes, A. (2006), Emissao de metano e gas carbonico pela Hidreletrica de Balbina, Ph.D. thesis, 98 pp., Inst. Nac. de Pesqui. da Amazonia, Manaus, Brazil.

Related Publications

- Kemenes, A., B. R. Forsberg, and J. M. Melack (2011), CO₂ emissions from a tropical hydroelectric reservoir (Balbina, Brazil), *J. Geophys. Res.*, 116, G03004, doi:10.1029/2010JG001465.