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# LBA-ECO TG-10 Fire Emission Factors in Mato Grosso, Para, and Amazonas, Brazil: 2004

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# Revision date: October 18, 2013

## Summary:

This data set provides derived emission factors (EFs), reported in grams of compound emitted per kilogram of dry fuel (g/kg), for PM10 (particulate matter up to 10 micrometers in size), O3, CO2, CO, NO, NO2, HONO, HCN, NH3, OCS, DMS, CH4, and up to 48 non-methane organic compounds (NMOC) from the Tropical Forest and Fire Emissions Experiment (TROFFEE). TROFFEE used laboratory measurements followed by airborne and ground based field campaigns in Mato Grosso, Para, and Amazonas, Brazil during the 2004 Amazon dry season to quantify the emissions from pristine tropical forest and several plantations as well as the emissions, fuel consumption, and fire ecology of tropical deforestation fires.

EFs were determined for 19 tropical deforestation fires in August and September, 2004. The combined output of several of these fires created a massive megaplume more than 500-km wide and covered a large area in Brazil, Bolivia, and Paraguay for about one month. For the megaplume, the EFs (reported in grams of compound emitted per kilogram of dry fuel (g/kg)) represented the effective emissions factor measured downwind from the source.

There are two comma-delimited data files (.csv) and one text file (.txt) with this data set. The text file contains information regarding the fuel/fire sources, latitude and longitudes (also provided in the data files).

## Data Citation:

**Cite this data set as follows:**

Yokelson, R.J., T. Karl, P. Artaxo, D. R. Blake, T. J. Christian, D.W.T. Griffith, A. Guenther, and W.M. Hao. 2013. LBA-ECO TG-10 Fire Emission Factors in Mato Grosso, Para, and Amazonas, Brazil: 2004. 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/1195

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This data set was archived in October of 2013. Users who download the data between October 2013 and September 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:** Trace Gas and Aerosol Fluxes

**Team ID:** TG-10 (Yokelson / Artaxo)

The investigators were Artaxo, Paulo; Yokelson, Robert James; Alvarado Celestino, Ernesto; Carvalho Jr., Joao Andrade de; Christian, Ted; Gielow, Ralf; Guenther, Alex B.; Karl, Thomas Guenther; Lincoln, Emily; Longo, Karla Maria; Miranda, Heloisa S.; Munhoz, Kelli ; Newton, Jenny and Santos, Jose Carlos. You may contact Yokelson, Robert James (bob.yokelson@umontana.edu).

**LBA Data Set Inventory ID:** TG10_TROFFEE

This data set provides derived emission factors (EFs), reported in grams of compound emitted per kilogram of dry fuel (g/kg), for PM10 (particulate matter up to 10 micrometers in size), O3, CO2, CO, NO, NO2, HONO, HCN, NH3, OCS, DMS, CH4, and up to 48 non-methane organic compounds (NMOC) from the Tropical Forest and Fire Emissions Experiment (TROFFEE). TROFFEE used laboratory measurements followed by airborne and ground based field campaigns in Mato Grosso, Para, and Amazonas, Brazil during the 2004 Amazon dry season to quantify the emissions from pristine tropical forest and several plantations as well as the emissions, fuel consumption, and fire ecology of tropical deforestation fires.

EFs were determined for 19 tropical deforestation fires in August and September, 2004. The combined output of several of these fires created a massive megaplume more than 500-km wide and covered a large area in Brazil, Bolivia, and Paraguay for about one month. For the megaplume, the EFs (reported in grams of compound emitted per kilogram of dry fuel (g/kg)) represented the effective emissions factor measured downwind from the source.

# 2. Data Characteristics:

There are two comma-separated data files (.csv), and one text file (.txt) with information regarding the fuel/fire sources, in this data set.

**File names:**

File #1:TROFFEE_AFTIR.csv: EFs derived from airborne fourier transform infrared spectrometer (AFTIR) measurement results

File #2:TROFFEE_PTRMS.csv: EFs derived from proton transfer mass spectrometer measurement results

File #3: TROFFEE_Sites.txt: Information regarding the fuel/fire sources, latitude and longitudes

Data are organized as follows:

**File #1: TROFFEE_AFTIR.csv**

| COLUMN | COLUMN HEADING | Units/format | Description |
|---|---|---|---|
| 1 | Date | YYYYMMDD | Sampling date |
| 2 | Fire_name | | Fire identification: in the case where samples from multiple individual fires were combined this is indicated by including Mean in the Fire_name |
| 3 | Latitude | decimal degrees | Fire location in decimal degrees of latitude |
| 4 | Longitude | decimal degrees | Fire location in decimal degrees of longitude |
| 5 | Obs_start | HH:MM:SS | Start time of sampling in local time |
| 6 | Obs_end | HH:MM:SS | End time of sampling in local time |
| 7 | EF_CO2 | g/kg | Initial emissions factor for carbon dioxide reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 8 | EF_CO | g/kg | Initial emissions factor for carbon monoxide reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 9 | MCE | | Modified combustion efficiency, not an emissions factor, calculated as DeltaCO2/ (DeltaCO2+ Delta CO) |
| 10 | EF_NO | g/kg | Initial emissions factor for nitric xide reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| | | | Initial emissions factor for nitrogen dioxide reported in grams of compound |

| | | | |
|---|---|---|---|
| 11 | EF_NO2 | g/kg | emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 12 | EF_NOx | g/kg | Initial emissions factor for NOx (measured as NO) reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 13 | EF_HONO | g/kg | Initial emissions factor for nitrous acid reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 14 | EF_CH4 | g/kg | Initial emissions factor for methane reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 15 | EF_C2H4 | g/kg | Initial emissions factor for ethylene reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 16 | EF_C2H2 | g/kg | Initial emissions factor for acetylene reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 17 | EF_C2H6 | g/kg | Initial emissions factor for ethane reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 18 | EF_C3H6 | g/kg | Initial emissions factor for propene reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 19 | EF_HCHO | g/kg | Initial emissions factor for formaldehyde reported ingrams of compound emitted per kilogram of dry fuel: For the megaplume this represents the effective emissions factor measured downwind from the source |
| 20 | EF_CH3OH | g/kg | Initial emissions factor for methanol reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 21 | EF_CH3COOH | g/kg | Initial emissions factor for accetic acid reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 22 | EF_HCOOH | g/kg | Initial emissions factor for formic acid reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 23 | EF_NH3 | g/kg | Initial emissions factor for ammonia reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 24 | EF_HCN | g/kg | Initial emissions factor for hydrogen cyanide reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |

Missing data are represented by -9999

**Example data records**

```
Date,Fire_name,Latitude,Longitude,Obs_start,Obs_end,EF_CO2,EF_CO,EF_MCE,EF_NO,EF_NO2,
EF_NOx,EF_HONO,EF_CH4,EF_C2H4,EF_C2H2,EF_C2H6,EF_C3H6,EF_HCHO,EF_CH3OH,
EF_CH3COOH,EF_HCOOH,EF_NH3,EF_HCN

20040829,29 Aug Fire 1,-10.27,-52.159,13:41:54,14:17:10,1638,95.72,0.916,0.238, 1.979,
1.574,0.345,4.213,0.747,0.094,0.548,0.452,1.277,2.077,3.134,0.398,
1.127,0.665
20040829,29 Aug Fire 2,-10.357,-52.019,14:30:07,14:43:30,1591,112.08,0.9,
-9999,0.93,0.606,0.167,6.916,1.238,-9999,1.137,0.728,1.912,2.874,4.172
,0.519, 1.364,0.537
...
20040907,7 Sept Fire Mean,-9999,-9999,-9999,-9999,1662,72.36,0.936,-9999,
4.12,2.687,-9999,5.324,0.454,0.62,-9999,-9999,1.409,2.165,3.704,
1.715,0.308,0.184
20040908,Mega-plume,-9999,-9999,-9999,-9999,1651,87.54,0.923,2.297,1.899,
3.535,-9999,7.636,0.378,0.085,-9999,-9999,1.004,2.55,9.242,
3.266,1.509,0.169
```

**File #2: TROFFEE_PTRMS.csv**

| COLUMN | COLUMN HEADING | Units/format | Description |
|---|---|---|---|
| 1 | Date | YYYYMMDD | Sampling date |
| 2 | Fire_name | | Fire identification: in the case where samples from multiple individual fires were combined this is indicated by including Mean in the Fire_name |
| 3 | Latitude | decimal degrees | Fire location in decimal degrees of latitude |
| 4 | Longitude | decimal degrees | Fire location in decimal degrees of longitude |
| 5 | Obs_start | HH:MM:SS | Start time of sampling in local time |
| 6 | Obs_end | HH:MM:SS | End time of sampling in local time |
| 7 | EF_Acetonitrile | g/kg | Initial emissions factor for acetonitrile reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 8 | EF_Acetaldehyde | g/kg | Initial emissions factor for acetaldehyde reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 9 | EF_Acrylonitrile | g/kg | Initial emissions factor for acrylonitrile reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 10 | EF_Acrolein | g/kg | Initial emissions factor for acrolein reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 11 | EF_Acetone | g/kg | Initial emissions factor for acetone reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 12 | EF_Propanal | g/kg | Initial emissions factor for propanal reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 13 | EF_Isoprene | g/kg | Initial emissions factor for isoprene reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 14 | EF_Furan | g/kg | Initial emissions factor for furan reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 15 | EF_Methylvinyl_ketone | g/kg | Initial emissions factor for methylvinyl ketone reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 16 | EF_Methacrolein | g/kg | Initial emissions factor for methacrolein reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 17 | EF_Crotonaldehyde | g/kg | Initial emissions factor for crotonaldehyde reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 18 | EF_Methylethyl_ketone | g/kg | Initial emissions factor for methylethyl ketone reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 19 | EF_Methyl_propanal | g/kg | Initial emissions factor for methyl propanal reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 20 | EF_Acetol_ and_Methylacetate | g/kg | Initial emissions factor for acetol plus methylacetate reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| | | | Initial emissions factor for benzene reported in grams of compound emitted |

| | | | |
|---|---|---|---|
| 21 | EF_Benzene | g/kg | per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 22 | EF_C6_Carbonyls | g/kg | Initial emissions factor for C6 carbonyls reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 23 | EF_3-Methylfuran | g/kg | Initial emissions factor for 3-methylfuran reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 24 | EF_2-Methylfuran | g/kg | Initial emissions factor for 2-methylfuran reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 25 | EF_Hexanal | g/kg | Initial emissions factor for hexanal reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 26 | EF_2_3-Butanedione | g/kg | Initial emissions factor for 2 3-butanedione reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 27 | EF_2-Pentanone | g/kg | Initial emissions factor for 2-pentanone reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 28 | EF_3-Pentanone | g/kg | Initial emissions factor for 3-pentanone reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 29 | EF_Toluene | g/kg | Initial emissions factor for toluene reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 30 | EF_Phenol | g/kg | Initial emissions factor for phenol reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 31 | EF_Other_Substituted_Furans | g/kg | Initial emissions factor for other substituted furans reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 32 | EF_Furaldehydes | g/kg | Initial emissions factor for furaldehydes reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 33 | EF_Xylenes | g/kg | Initial emissions factor for xylenes reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 34 | EF_Ethylbenzene | g/kg | Initial emissions factor for ethylbenzene reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |
| 35 | EF_PM_10 | g/kg | Initial emissions factor for PM-10 reported in grams of compound emitted per kilogram of dry fuel (g/kg): For the megaplume this represents the effective emissions factor measured downwind from the source |

Missing data are represented by -9999

**Example data records**

```
Date,Fire_name,Latitude,Longitude,Obs_start,Obs_end,EF_Acetonitrile,EF_Acetaldehyde,
EF_Acrylonitrile,EF_Acrolein,EF_Acetone,EF_Propanal,EF_Isoprene,EF_Furan,
EF_Methylvinyl_ketone,EF_Methacrolein,EF_Crotonaldehyde,EF_Methylethyl_ketone,
EF_Methyl_propanal,EF_Acetol_ and_Methylacetate,EF_Benzene,EF_C6_Carbonyls,
EF_3-Methylfuran,EF_2-Methylfuran,EF_Hexanal,EF_2_3-Butanedione,EF_2-Pentanone,
EF_3-Pentanone,EF_Toluene,EF_Phenol,EF_Other_Substituted_Furans,EF_Furaldehydes,
EF_Xylenes,EF_Ethylbenzene,EF_PM_10

20040829,29 Aug Fire 1,-10.27,-52.159,13:41:54,14:17:10,0.574,1.255,0.051,-9999,
0.429,0.067,0.236,0.207,0.166,0.066,0.1,0.229,0.081,-9999,0.189,0.98,0.252,0.036,
0.006,0.317,0.032,0.014,0.102,-9999,-9999,-9999,0.086,0.053,17.61
20040829,29 Aug Fire 2,-10.357,-52.019,14:30:07,14:43:30,0.276,1.202,-9999,-9999,
0.525,0.082,0.366,0.32,0.499,0.198,0.302,0.469,0.165,-9999,0.381,0.307,0.707,0.101,
0.017,0.79,0.085,0.038,0.109, -9999,-9999,-9999,0.092,0.084,14.43
...
20040903,3 Sept Fire Mean,-9999,-9999,-9999,-9999,0.485,3.322,-9999,
-9999,0.803,0.126,0.625,0.547,0.215,0.085,0.13,0.654,0.23,0.895,0.234,
```

```
0.241,0.668,0.095,0.016,0.995,0.106,0.047,0.399,-9999,-9999,-9999,0.322,
0.126,26.41
20040905,Planned Fire,-9.969,-56.345,14:16:42,14:51:08,0.359,1.282,-9999,
0.808,0.694,0.109,0.378,0.331,0.411,0.163,0.248,-9999,-9999,0.7,0.261,0.363,
0.511,0.073,0.012,0.634,0.066,0.029,0.135,0.406,1.095,0.255,0.137,0.078,12.53
```

**File# 3. TROFFEE_Sites.txt**

This is a text file with fire location, dates, and fuel source-types. Sample data are provided below.

```
Date          Fire_name        Latitude      Longitude
20040829      29 Aug Fire 1    -10.27        -52.159

Obs_start        Obs_end           Fuel_description          Data_reported_as
13:41:54           14:17:10          slash under partial canopy   29 Aug Fire 1

Date          Fire_name        Latitude      Longitude
20040829      29 Aug Fire 2    -10.357       -52.019

Obs_start        Obs_end           Fuel_description          Data_reported_as
14:30:07           14:43:30             pasture                    29 Aug Fire 2

Date          Fire_name        Latitude      Longitude
20040830      30 Aug Fire 1    -11.315       -54.064

Obs_start        Obs_end      Fuel_description                 Data_reported_as
12:56:51           13:00:45       grass and slash piles under partial canopy 30 Aug Fire Mean

Date          Fire_name        Latitude      Longitude
20040907      7 Sept Fire 3    -3.129        -59.056

Obs_start        Obs_end      Fuel_description               Data_reported_as
12:04:50           12:05:58       mixed forest fuels               7 Sept Fire Mean

Date          Fire_name        Latitude      Longitude
20040907      7 Sept Fire 4    -3.137        -59.147

Obs_start        Obs_end      Fuel_description               Data_reported_as
12:06:46           12:07:36       mixed forest fuels               7 Sept Fire Mean


Date
20040908      Mega-plume      not recorded      not observed          Mega-plume
```

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

| Site (Region) | Westernmost Longitude | Easternmost Longitude | Northernmost Latitude | Southernmost Latitude |
|---|---|---|---|---|
| Mato Grosso - Alta Floresta (Mato Grosso) | -54.185 | -51.798 | -9.167 | -11.491 |
| Amazonas- Manaus (Amazonas) | -59.147 | -58.93 | -3.007 | -3.137 |

**Time period:**

- The data set covers the period 2004/08/29 to 2004/09/08.
- Temporal Resolution: The measurements were obtained in two flight campaigns: Alta Floresta, Mato Grosso, from 27 August 2004 through 5 September 2004, and  Manaus, Amazonas, from 5 September 2004 through 8 September 2004.

**Platform/Sensor/Parameters measured include:**

- AIRCRAFT / PTR-MS (PROTON TRANSFER MASS SPECTROMETER) / VOLATILE ORGANIC COMPOUNDS
- AIRCRAFT / FTIR SPECTROMETER (FOURIER TRANSFORM INFRARED SPECTROMETER) / VOLATILE ORGANIC COMPOUNDS

# 3. Data Application and Derivation:

Airborne measurements of fire emission factors are needed as model input and for bottom-up emissions estimates at any scale.

# 4. Quality Assessment:

The sensitivity of the proton transfer mass spectrometer (PTR-MS) instrument during this study was typically on the order of 70 Hz/ppbv (counts per second per ppbv) for acetone and 50 Hz/ppbv for methanol at 2.3-mbar buffer gas pressure with a reaction time of 110 us and 3 to 4-MHz H3O+ ions, and thus inferred a signal to noise ratio of 60% at a concentration of 20 pptv and a 2-s integration time.

# 5. Data Acquisition Materials and Methods:

### Experiment Description

TROFFEE included airborne and field campaigns, however, this data set only includes the derived emission factors and not the measured field data. The ground-based field campaigns included measurements of biogenic emissions from pristine forest near Manaus, and fourier transform infrared spectroscopy (FTIR), and emissions measurements on initially-unlofted plumes from nine biomass fires in the vicinity of Alta Floresta, Brazil. The ground campaign fires included a planned fire in which Brazilian researchers carried out a "typical" deforestation burn under conditions where the fuel consumption and other aspects of fire ecology could be measured. The emissions from this planned fire were measured by the ground-based FTIR and in the TROFFEE airborne campaign.

### Airborne Sampling

The airborne campaign consisted of 44.5 flight hours between August 27 and September 8, 2004, on an Embraer Bandeirante operated by the Brazilian National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais (INPE)). The major instruments deployed on the aircraft included: (1) real-time ozone, condensation particle counter, and mass-calibrated nephelometry (University of Sao Paulo); (2) PTR-MS (National Center for Atmospheric Research); (3) Whole air sampling in canisters with subsequent gas chromatography (GC) analysis using flame ionization, mass selective, and electron capture detection (FID, MSD, and ECD; University of California at Irvine); and (4) airborne FTIR (University of Montana). The instruments measured CO2, CO, PM10, CH4, NOx, O3, and more than 40 non-methane organic compounds (NMOC) including the important biogenic emissions isoprene and methanol.

In phase 1, the aircraft was based in Alta Floresta, Mato Grosso, in the southern Amazon, from August 27 through September 5, where the local dry/burning season was well underway. Regional haze, due mostly to diluted biomass-burning smoke of unknown age and the nascent (minutes-old) emissions from 15 fires (mostly deforestation fires), were sampled in the states of Mato Grosso and Para within about one-hour flight time of Alta Floresta.

In phase 2, the aircraft was based in Manaus, Amazonas, from September 5 to September 8. The local dry season was just beginning and the air was much cleaner and mostly unaffected by fires, especially in the mornings. The biogenic emissions were sampled from forests, several plantations east of Manaus, and the pristine forest at the ZF-14 tower north of Manaus. In addition, four more fires were sampled around noon in the Manaus region. On September 8, from 8 to 13 degrees S, a smoke plume hundreds of km wide was sampled that contained the combined emissions from a huge number of fires. These fires represented a significant fraction of the total Amazon burning for 2004 and they generated a megaplume.

### Flight plans and sampling protocols

While based in Alta Floresta (27 August through 5 September), background air (defined here as air not within a visible biomass burning plume) was characterized at various altitudes (up to 3,352 m). These were afternoon flights conducted to search for and sample fires and most of the measurements were made below the top of the (hazy) mixed layer. While based in Manaus, cleaner background air was sampled during morning flights over a similar altitude range. The Manaus flights included both continuous-spiral and 'parking-garage'-type vertical profiles over the instrumented ZF-14 Tower, and a constant-altitude 'racetrack' pattern that sampled several regionally important ecosystems (undisturbed forest, flooded forest, and various plantations) east of Manaus (Karl et al., 2007b). Background-air sampled data are not provided with this data set.

Nearly all the fires we observed in Mato Grosso and southern Para were related to the expansion of existing, large farms or ranches. In all areas, the fires frequently occurred in clusters. TROFFEE supported a planned, deforestation fire on a farm near Alta Floresta.

To measure the initial emissions from fires in both regions, smoke, less than several minutes old, was sampled by penetrating the column of smoke 200 to 1000 m above the flame front. The AFTIR system and cans obtained grab samples in the plume (and paired background samples just outside the plume). The other instruments measured their species continuously while passing through the plume. More than a few kilometers downwind from the source, smoke plume samples are 'chemically aged' and better for probing post emission chemistry than estimating initial emissions (Hobbs et al., 2003; de Gouw et al., 2006).

### Airborne FTIR (AFTIR) and whole air sampling in canisters

The basic design and operation of the AFTIR system has been described in detail by Yokelson et al. (1999, 2003a, b). A summary description is given here followed by the details of how AFTIR was used to fill canisters:

- The AFTIR had a dedicated, halocarbon-wax, coated inlet that directed ram air through a Pyrex, multipass cell. Infrared spectra of the cell contents were acquired continuously (every 0.83 s) throughout each flight and the flow-control valves were normally open, which flushed the cell with outside air every 2 to 4 s.
- The IR spectra were later analyzed (refer to Yokelson et al., 2007 for IR spectral analysis details) to quantify the compounds responsible for all the major peaks. This accounted for most of the trace gases present in the cell above 5 to 20 ppbv (Goode et al., 1999).
- For TROFFEE, a Teflon valve was added to the AFTIR cell that connected to two options for filling evacuated canisters.
    - For a canister sample of a plume, a teflon diaphragm pump was used to pressurize the can with gas from the AFTIR cell, which already contained a grab sample of the plume. Pressurizing the cans allows more sensitive and/or a wider variety of analyses and also prevents contamination in the event of a slow leak.
    - Operationally-simpler canister samples of background air were obtained by diverting a portion of the flow through the AFTIR cell into the cans. The .635-cm outside diameter Teflon tubing connecting to the canisters had a pressure higher than the cabin pressure and attached to the can with Ultra-Torr fittings. The connecting tubing was flushed with cell air by loosening the fitting for a few minutes.
    - Once the fitting was retightened, the pre-evacuated can was opened and filled to cell pressure within seconds.
- The filling time of each can was indicated by a sharp, (logged) pressure response in the AFTIR cell.
- The canisters were later analyzed at UCI using GC/FID-MSD-ECD (Colman et al., 2001).

**PTR-MS**

- H3O+ ions are used to ionize volatile organic compounds (VOC) via proton transfer reactions. The value for E/N (E the electric field strength and N the buffer gas density) in the drift tube was kept at about 123-Townsend, which is high enough to avoid strong clustering of H3O+ ions with water and thus a humidity dependent sensitivity.
- The sensitivity of the PTR-MS instrument during this study was typically on the order of 70-Hz/ppbv (counts per second per ppbv) for acetone and 50-Hz/ppbv for methanol at 2.3-mbar buffer gas pressure, with a reaction time of 110-us and 3 to 4-MHz H3O+ ions, and thus inferred a signal to noise ratio of 60% at a concentration of 20 pptv and a 2-s integration time.
- The PTR-MS sampled air through a dedicated, rear-facing, Teflon inlet. About 17 mass channels were monitored during flight with a measurement period for each species of 1 to 20-s. Higher sampling rates were used in the plumes.

More details about the PTR-MS in this campaign are given by Karl et al. (2007a).

**Calculation of emission factors**

A widely used, derived quantity, is the normalized excess mixing ratio where DeltaX (reflects the instantaneous dilution of the plume and the instrument response time.) is compared to a simultaneously measured plume tracer such as DeltaCO or DeltaCO2. A measurement of DeltaX/DeltaCO or DeltaX/DeltaCO2 made in a nascent plume (seconds to a few minutes old) is an emission ratio (ER).

For any carbonaceous fuel, a set of ER to CO2 for the other major carbon emissions (i.e. CO, CH4, a suite of NMOC, particulate carbon) can be used to calculate emission factors (EF, g compound emitted/kg dry fuel) for all the gases quantified from the source using the carbon mass-balance method (Yokelson et al., 1996). EFs are combined with fuel consumption measurements to estimate total emissions at various scales. In this project, the primary data needed to calculate EF was provided by AFTIR measurements of CO2, CO, CH4, and many NMOC. However, the PTR-MS and canister sampling added numerous, important NMOC that were below AFTIR detection limits or not amenable to IR detection. The PM10 data allowed inclusion of particle carbon.

Fire-average, initial EF for PM10 and each observed trace gas from our fire-average initial ER was estimated using the carbon mass balance method (Ward and Radke, 1993) as described by Yokelson et al. (1999):

- We assumed that all the volatilized carbon was detected and that the fuel carbon content was known.
- For purposes of the carbon mass balance, we assumed the particles were 60% C by mass (Ferek et al., 1998).
- By ignoring unmeasured gases we were probably inflating the emission factors by 1 to 2% (Andreae and Merlet, 2001).
- We assumed in our EF calculations that all the fires burned in fuels containing 50% carbon by mass. This was in good agreement with previous studies of tropical biomass (Susott et al., 1996), but the actual fuel carbon percentage may vary by plus or minus 10% of our nominal value. (Emission factors scale linearly with assumed fuel carbon percentage).

# 6. Data Access:

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

### Data Archive Center:

E-mail: uso@daac.ornl.gov
Telephone: +1 (865) 241-3952

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