LBA-ECO ND-02 CO2 Flux from Soils in Forests and Pastures, Acre, Brazil: 1999-2001

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Revision date: February 28, 2012

Summary:

This data set reports soil CO2 flux and results of physical and chemical characterization of soils from pastures, secondary forests, and mature forests near Rio Branco, Acre, Brazil. CO2 flux measurements were made in the field on a monthly basis at 16 sites from June of 1999 to January 2001. In addition, a set of diel CO2 flux measurements were made at 1-hour intervals at selected pasture, mature and secondary forest sites in June and July 2000. Litter was collected monthly from 2001-2002 at each of the mature forest sites and at four of the secondary forest sites, and mean litter mass is reported. Soil samples were collected and analyzed from several land cover types at two sites during this same time period. There are six comma-delimited ASCII data files with this data set.

Data Citation:

Cite this data set as follows:

Salimon, C.I., E.A. Davidson, R.L. Victoria, and A.W.F. Melo. 2012. LBA-ECO ND-02 CO2 Flux from Soils in Forests and Pastures, Acre, Brazil: 1999-2001. 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/1066

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1. Data Set Overview:

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

Activity: LBA-ECO

LBA Science Component: Nutrient Dynamics

Team ID: ND-02 (Davidson / Carvalho / Dias-Filho / Moller / Moutinho / Sa / Vieira)

The investigators were Salimon, Cleber Ibraim; Davidson, Eric A.; Melo, Antonio Willian Flores de; Brown, Irving Foster; Victoria, Reynaldo Luiz and Pereira, and Jorcinei Widson . You may contact Salimon, Cleber Ibraim (clebsal@cena.usp.br) and Davidson, Eric A. (edavidson@whrc.org).

LBA Data Set Inventory ID: ND02_Soil_CO2_Flux

Conversion of forest to cattle pastures and subsequent abandonment of those pastures is occurring throughout the Amazon Basin, including regions with eutrophic (nutrient rich) and dystrophic (nutrient poor) soils. The objectives of this project were to determine the effects of land-use change and native soil fertility on soil respiration in pastures, secondary forests, and mature forests near Rio Branco, Acre.

2. Data Characteristics:

Data are provided in four comma-delimited ASCII files. Sampling plots were in pastures, secondary forests, and mature forest locations. File # 4 provides descriptions of the sites.

File #1: ND02_Soil_CO2_fluxes.csv

Column	Heading	Units/format	Description
1	Site		Sampling location. For additional information see file #6: ND02_CO2_Flux_Study_Site_Descriptions.csv
2	Month	mm	Month of the year in which measurements were taken (1 - 12), where 1=January, 2=February, etc.
3	Year	yyyy	Year in which measurements were taken (1999 - 2002)
4	Nutrient_class		Soil nutrient class: dystrophic=nutrient poor, eutrophic=nutrient rich
5	Land_use		Dominant land use: Pasture, Secondary forest, or Mature forest
6	Plot		Plot identification number within the Humaita and Peixoto sites (1, 2, or 3)
7	Chamber_ID		Chamber identification number (1 - 8)
8	Transect_ID		Transect identification code: where the first character indicates land use (C=Secondary forest, F=Mature forest, P=Pasture); the number in the second position indicates the research area; and the third character indicates soil nutrient class (E=eutrophic, D=dystrophic)
9	Flux_CO2	mg CO2-C per m2 per h	Flux of CO2 from the soil to the atmosphere measured in milligrams of carbon in the form of CO2 per meter squared per hour
10	Flux_CO2_std_err	mg CO2-C per m2 per h	Standard error of the CO2 flux rate calculated during the five minute sampling period
11	T_air	degrees C	Mean air temperature within the sampling chamber during the five minute sampling period reported in degrees Celsius
12	T_soil	degrees C	Soil temperature measured at 10 cm depth adjacent to the sampling chamber

Missing data represented as -9999

Example data records:

```
Site,Month,Year,Nutrient_class,Land_use,Plot,Chamber_ID,Transect_ID,CO2_flux,CO2_flux_SE,T_air,T_soil

Zoobotanical Park,6,1999,dystrophic,Secondary forest,3,1,C5D,220.96,1.96,30.5,-9999
Zoobotanical Park,6,1999,dystrophic,Secondary forest,3,2,C5D,217.99,1.26,30.53,-9999
Zoobotanical Park,6,1999,dystrophic,Secondary forest,3,3,C5D,226.99,1.79,30.6,-9999
...
Humaita,6,1999,eutrophic,Secondary forest,1,1,C1E,215.5,4.35,29.5,-9999
Humaita,6,1999,eutrophic,Secondary forest,1,2,C1E,320.24,12.91,29.3,-9999
Humaita,6,1999,eutrophic,Secondary forest,1,3,C1E,232.29,7.23,-9999,-9999
...
Peixto,1,2002,dystrophic,Mature forest,2,6,F2D,212.97,-9999,-9999,-9999
Peixto,1,2002,dystrophic,Mature forest,2,7,F2D,300.29,-9999,-9999,-9999
Peixto,1,2002,dystrophic,Mature forest,2,8,F2D,288.26,-9999,-9999,-9999
```

File #2: ND02_24hr_CO2_Flux_Acre.csv

Column	Heading	Units/format	Description
1	Land_use		Dominant land use: Pasture, Secondary forest, or Mature forest
2	Time	hour	Sampling time: Samples were taken once an hour over a 24 hour period
3	Sampling chamber		Chamber identification number (1 - 4)

4	CO2 flux	mg CO2-C per m2 per h	Flux of CO2 from the soil to the atmosphere reported in milligrams of carbon in the form of CO2 per meter squared per hour. Note for the Secondary forest site no individual chamber data are available the reported value is the mean of 4 chambers
5	SE_flux	mg CO2-C per m2 per h	Standard error of the CO2 flux rate calculated during the five minute sampling period
6	T_air	degrees	Air temperature in the sampling chamber reported in degrees Celsius

Missing data represented as -9999

Example data records:

```
Land_use,Time,Sampling chamber,CO2 flux,SE_flux,T_air
Mature Forest, 1, 1, 119.47, 1.66, 21.9
Mature Forest, 1, 2, 81.53, 0.64, 21.9
Mature Forest, 1, 3, 72.07, 2.43, 21.9
...
Pasture, 1, 1, 181.57, 2.81, 17.9
Pasture, 1, 2, 175.39, 2.71, 18.3
Pasture, 1, 3, 157.43, 3.82, 17.7
...
Secondary Forest, 22, mean, 177.24, 41.44, 24.1
Secondary Forest, 23, mean, 181.98, 37.21, 23.8
Secondary Forest, 24, mean, 185.36, 51.35, 23.5
```

File #3: ND02_Litter_2001-2002.csv

Column	Heading	Units/format	Description
1	Site		Sampling location. For additional information see file #6 ND02_CO2_Flux_Study_Site_Descriptions.csv
2	Nutrient_class		Soil nutrient class: dystropic=nutrient poor, eutropic=nutrient rich
3	Land_use		Dominant land use: Pasture, Secondary forest, or Mature forest
4	Transect_ID		Transect identification code: where the first character indicates land use (C=Secondary forest, F=Mature forest, P=Pasture); the number in the second position indicates the research area; and the third character indicates soil nutrient class (E=eutrophic, D=dystrophic)
5	Year	yyyy	Year in which measurements were collected (2001 or 2002)
6	Month	mm	Month of the year in which measurements were collected (1 - 12), where 1=January, 2=February, etc.
7	Litter_mean	g m-2	Mean litter mass from the 5 baskets at each site reported as grams of litter per meter squared per month
8	Litter_SE	g m-2	Calculated standard error of the mean litter mass

Missing values are indicated as -9999

Example data records:

```
Site,Nutrient_class,Land_use,Transect_ID,Year,Month,Litter_mean,Litter_SE
Humaita,eutrophic,Secondary forest,C1E,2001,7,121.92,16.02
Humaita,eutrophic,Secondary forest,C2E,2001,7,79.71,11.4
...
Peixoto,dystrophic,Secondary forest,C2D,2002,1,40.26,4.46
Zoobotanical Park,dystrophic,Secondary forest,C5D,2002,1,48.1,13.57
...
```

File #4: ND02_Soil_characteristics.csv

Note: Secfor means secondary forest; matfor means mature forest; numbers after the names stand for the age (i.e. Secfor 18, secondary forest with 18 years of age) (Salimon et al., 2004)

Column	Heading	Units/format	Description
1	Site		Sampling location. For additional information see file #6: ND02_CO2_Flux_Study_Site_Descriptions.csv
2	Nutrient_class		Soil nutrient class: dystrophic=nutrient poor, eutrophic=nutrient rich
3	Land_use		Dominant land use: Pasture, Secondary forest , or Mature forest
4	Transect_ID		Transect identification code: where the first character indicates land use (C=Secondary forest, F=Mature forest, P=Pasture); the number in the second position indicates the research area; and the third character indicates soil nutrient class (E=eutrophic, D=dystrophic)
5	Depth		Sampling depth class: A= 0 to 5 cm, B= 5 to 10 cm, C= 20-30 cm, and D= 50 to 60 cm depth

6	Sand	percent	Percent by weight of soil particles classified as sand (diameter greater than or equal to 2 mm)
7	Silt	percent	Percent by weight of soil particles classified as silt (diameter less than 2 mm and greater than or equal to 2 um)
8	Clay	percent	Percent by weight of soil particles classified as clay (diameter less than 2 um)
9	pH		Soil pH determined in a CaCl2 solution
10	SOM	percent	Soil organic matter reported in percent of total soil weight
11	P	mg per kg soil	Soil phosphorus concentration
12	K	cmol charge per kg soil	Soil potassium concentration
13	Ca	cmol charge per kg soil	Soil calcium concentration
14	Mg	cmol charge per kg soil	Soil magnesium concentration
15	Al	cmol charge per kg soil	Soil aluminum concentration
16	H	cmol charge per kg soil	Soil hydrogen concentration
17	Sum_of_bases	cmol charge per kg soil	Sum of bases: sum of measured calcium magnesium and potassium ion concentrations
18	CEC	cmol charge per kg soil	Cation exchange capacity: calculated as the sum of bases plus the hydrogen ion concentration
19	Base_saturation	percent	Base saturation calculated as the sum of bases divided by cation exchange capacity

Values below the detection limit are designated as -6999

The scientific community often expresses CEC of a soil as cmol/kg. This is centimoles (cmol) of charge per kilogram of soil. Many soil testing laboratories, however, express CEC as meq/100 g. This should not cause confusion since: 1 meq/100 g = 1 cmol/kg. (NOTE: 'milli' charge multiplied by 10 equals 'centi' charge and 100 g multiplied by 10 equals kg; thus, the proportions remain the same)

Example data records:

```
Site,Nutrient_class,Land_use,Transect_ID,Depth,Sand,Silt,Clay,pH,SOM,P,K,Ca,Mg,Al,H,Sum_of_bases,CEC,Base_saturation

Peixoto,dystrophic,Secondary forest,C1D,A,15,32,53,4.2,39,14,3.2,31,14,7,80,48.2,128.2,38
Peixoto,dystrophic,Secondary forest,C1D,A,12,39,49,4.2,47,12,3.2,40,13,6,109,56.2,165.2,34
Peixoto,dystrophic,Secondary forest,C1D,A,17,32,51,3.2,49,15,3.8,17,8,25,253,28.8,281.8,10
...
Humaita,eutrophic,Mature forest,F1E,C,19,41,40,3.2,13,4,1.6,1,3,33,166,5.6,171.6,3
Humaita,eutrophic,Mature forest,F1E,D,8,31,61,3.4,10,3,2.9,2,6,65,386,10.9,396.9,3
Humaita,eutrophic,Mature forest,F1E,D,12,25,63,3.1,12,3,2.5,1,4,65,477,7.5,484.5,2
...
Peixoto,dystrophic,Pasture,P1D,A,16,23,61,3.9,56,10,8.2,15,10,11,121,33.2,154.2,22
Peixoto,dystrophic,Pasture,P1D,A,22,24,54,4.4,96,17,6.4,48,19,3,88,73.4,161.4,45
Peixoto,dystrophic,Pasture,P1D,A,18,22,60,4.1,69,16,5,42,15,5,121,62,183,34
...
```

File #5: ND02_Soil_Physical_Properties.csv

Column	Heading	Units/format	Description
1	Date	YYYYMM	Sampling year and month
2	Season		Sampling was done once in the dry season and once in the wet season
3	Land_use		Dominant land use: Pasture, Secondary forest, or Mature forest
4	Site		Site identification
5	VWC	grams H2O per gram of soil	Soil volumetric water content reported in grams of water per gram of soil
6	SE_VWC	grams H2O per gram of soil	Standard error of the soil volumetric water content
7	Bulk_density	g cm-3	Soil bulk density reported in grams of soil per cubic centimeter
8	Porosity	%	Soil porosity reported in percent. Calculated as 1- (soil bulk density/ particle density (assumed to be 2.65))

9	WFPS		Water filled pore space calculated as (volumetric water content times soil bulk density) divided by soil porosity and reported as a proportion of total space
10	SE_WFPS		Standard error of the soil water filled pore space

Example data records:

```
Date, Season, Land_use, Site, VWC, SE_VWC, Bulk_density, Porosity, WFPS, SE_WFPS
200202, Wet, Mature forest, Humaita, 1, 0.3,5 0.01, 1.06, 0.6, 0.62, 0.011
200202, Wet, Secondary forest, Humaita, 1, 0.3, 0.02, 0.99, 0.63, 0.48, 0.024
200202, Wet, Pasture Humaita, 1, 0.35, 0.01, 1.24, 0.53, 0.8, 0.022
...
200106, Dry, Mature forest, Peixoto, ,1 0.16, 0, 1.06, 0.6, 0.27, 0.007
200106, Dry, Secondary forest, Peixoto, 1, 0.15, 0, 0.99, 0.63, 0.24, 0.002
200106, Dry, Pasture, Peixoto, 1, 0.23, 0.02, 1.24, 0.53, 0.53, 0.04
```

File #6: ND02_CO2_Flux_Study_Site_Descriptions.csv

Column	Heading	Units/format	Description
1	Site		Region where study was located
2	Site name		Plot locations within the sites: two secondary forests at the Zoobotanical Park (PZ) at the Federal University of Acre, Rio Branco, Acre State, and also at two government sponsored settlements: Peixoto Settlement Project and Humaita Settlement Project
3	Nutrient class		Dystrophic or Eutrophic 1, 2, or 3
4	Sampling site		Mature forest (Matfor), secondary forest (Secfor), or pasture site (Pasture). * See note below for further description
5	Transect_ID		Transect identification code: where the first character indicates land use (C=Secondary forest, F=Mature forest, P=Pasture); the number in the second position
6	Latitude	decimal degrees	Latitude (decimal degrees south) of sampling location
7	Longitude	decimal degrees	Longitude (decimal degrees west) of sampling location
8	History of site		Description of forests and pastures
9	Previous use		Description of prior land use of forest and pastures
10	Soil type		Dystrophic podzol or eutrophic podzol
11	Soil description		Nutrient poor soils where leaching is a major force in soil development

* Note: Secfor means secondary forest; matfor means mature forest; numbers after the names stand for the age (i.e. Secfor 18, secondary forest with 18 years of age) (Salimon et al., 2004)

Example data records

```
Site,Site name,Nutrient class,Sampling site,Transect_ID,Latitude,Longitude,History of site,
Previous use,Soil type,Soil description

Zoobotanical Park,Zoobotanical Park,Dystrophic 3,Secfor12(c5d),C5D,-9.95,-67.87,Secondary Forest around 12 years old,
Agriculture and pasture,Dystrophic podzol,Nutrient poor soils where leaching is a major force in soil development
Zoobotanical Park,Zoobotanical Park,Dystrophic 3,Secfor182(c6d),C6D,-9.95,-67.87,Secondary Forest around 18 years old,
Agriculture and pasture,Dystrophic podzol,Nutrient poor soils where leaching is a major force in soil development
...
Peixoto,Peixoto Settlement Project,Dystrophic 1,Matfor (f1d),F1D,-9.88,-67.08,Mature forest,
Mature forest,Dystrophic podzol,Nutrient poor soils where leaching is a major force in soil development
Peixoto,Peixoto Settlement Project,Dystrophic 2,Pasture12 (p2d),P2D,-9.94,-67.12,Pasture around 12 years old,
Mature forest,Dystrophic podzol,Nutrient poor soils where leaching is a major force in soil development
...
Humaita,Humaita Settlement Project,Eutrophic 1,Pasture14 (p1e),P1E,-9.77,-67.66,Pasture around 14 years old
Mature forest, eutrophic podzol,Nutrient poor soils where leaching is a major force in soil development
Humaita,Humaita Settlement Project,Eutrophic 2,Matfor (f1e),F1E,-9.77,-67.66,Mature forest
Mature forest, eutrophic podzol,Nutrient poor soils where leaching is a major force in soil development
```

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

Site (Region)	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude	Geodetic Datum
Acre - Parque Zoobotanico (Acre)- Secfor12 (c5d) Secfor18 (c6d)	-67.87	- 67.87	-9.95	-9.95	South-American Datum, 1969 (SAD-69)
Acre - Projeto de Assentamento Peixoto (Acre)- Pasture13 (p1d)	-67.07	- 67.07	-9.87	-9.87	South-American Datum, 1969 (SAD-69)
Acre - Projeto de Assentamento Peixoto (Acre)- Secfor11 (c1d) Matfor (f1d)	-67.07	- 67.07	-9.88	-9.88	South-American Datum, 1969 (SAD-69)
Acre - Projeto de Assentamento Peixoto (Acre)- Pasture12 (p2d) Secfor12 (c4d)	-67.12	- 67.12	-9.94	-9.94	South-American Datum, 1969 (SAD-69)
Acre - Projeto de Assentamento Peixoto (Acre) - Matfor (f2d)	-67.13	- 67.13	- 9.95	- 9.95	South-American Datum, 1969 (SAD-69)
Acre - Projeto de Assentamento Humaita (Acre)- Secfor3 (c1e) Pasture14 (p1e) Matfor (f1e) Secfor3 (c1e)	-67.66	- 67.66	- 9.77	- 9.77	South-American Datum, 1969 (SAD-69)

Time period:

- The data set covers the period 1999/06/01 to 2002/06/30
- Temporal Resolution: Monthly for the first year and then less frequently after that

Platform/Sensor/Parameters measured include:

- FIELD INVESTIGATION / IR CO2 ANALYZER / RESPIRATION
- LABORATORY /ANALYSIS / SOIL CHEMISTRY

3. Data Application and Derivation:

Carbon dioxide fluxes from pastures and forests in tropical regions are important components of the global carbon budget. These time series of soil-atmosphere gas exchange of CO2 reveal important seasonal variations in flux and provide insight to the role of soil nutrients as well as land cover in controlling CO2 fluxes from these systems.

4. Quality Assessment:

All data have been quality checked and no further changes to the data are anticipated.

5. Data Acquisition Materials and Methods:

The study areas are located in the southwestern corner of the Brazilian Amazon Basin, near the city of Rio Branco in the state of Acre, Brazil. The regional climate has a mean annual temperature of 26 degrees C; rainfall of 1,940 (plus or minus 230) mm with a well-defined dry season (with less than 50 mm per month from June through August); mean annual relative humidity of 85 percent (Duarte et al., 2000). The soils are classified as dystrophic and eutrophic Ultisols with patches of Oxisols (RADAMBRASIL, 1976). Natural vegetation is classified as Ombrophilous Open Forest (RADAMBRASIL, 1976) with patches of bamboo-dominated forest (Silveira, 1999). Where natural forests have been converted, 60 percent is now used for cattle ranching and agriculture, and almost 40 percent is in some stage of secondary succession.

Plots for this study were located in two secondary forests at the Zoobotanical Park (PZ) at the Federal University of Acre, Rio Branco, Acre State, and also at two government sponsored settlements: Peixoto Settlement Project and Humaita Settlement Project. In both settlements the main animal products are cattle and chickens and the principal crops are manioc, maize, banana, and rice. Four pasture sites were all between 12 and 15 years old, dominated by Brachiaria brizantha and had from zero to three burning events. Eight secondary forest sites were more heterogeneous in age, ranging from 3 to 18 years old, and were also diverse with respect to previous land use. Four mature forest sites had no historical sign of clear-cutting, but all had been used for rubber tapping, Brazil nut extraction, and for game hunting.

Soil sampling

In order to characterize soils at the Peixoto and Humaita sites, we sampled soils from each land cover to 60 cm depth. For this purpose, three soil pits (60 x 60 x 60 cm) were dug in each of the following sites: Peixoto: in Secfor 11, Secfor 3a, Pasture 13 and Matfor, and Humaita: in Secfor 3b, Pasture 14 and

Matfor (see file #4 for site codes and descriptions: ND02_CO2_Flux_Study_Site_Descriptions.csv).

Soil temperature was measured at 10 cm depth by inserting a temperature probe near each soil respiration chamber while each flux measurement was in progress.

CO2 flux measurements

Fluxes were measured once per month from June 1999 to July 2000 at all sites, except for October when no measurement was made. Measurements were continued through January 2001 on a less regular sampling schedule. Eight CO2 flux measurements were made at each site and date. Carbon dioxide flux from soil to atmosphere was measured using an infrared gas analyzer (IRGA), LICOR-6252, coupled to a vented dynamic chamber system (Davidson et al., 2002). Eight PVC rings (20 cm diameter and 10 cm height) were inserted 3 cm into the soil at each site. At the time of sampling, a PVC opaque chamber, with an inner diameter at the bottom just slightly larger than the outer diameter of the ring, was placed snugly over the ring, and air was circulated between this chamber (volume of the chamber with the top was 7.1 L) and the IRGA with an air pump at 0.5 L min_1. A vent (5 cm long, 2.16 mm inner diameter stainless steel tube) was installed in the chamber top through a Swaglok fitting to equalize pressure with the atmosphere. CO2 concentrations in the chamber were recorded every 12 s for 5 min and were stored in an HP 200 XL palmtop connected to the IRGA. Measurements were always conducted between nine am and two pm. In order to evaluate whether the time of sampling was representative of soil respiration during the day, we also conducted diel flux measurements at 1-hour intervals at pasture, mature and secondary forest sites in June and July 2000, with four flux measurements at each site and hour.

The flux was calculated from linear regression of the difference of CO2 concentration over time. The first few measurements during the first minute were discarded from the regression to avoid any artifact of closing the chamber, and only the data showing a linear increase in CO2 concentration (usually during a 1-5 min interval) were used to calculate fluxes (Salimon et al., 2004). The IRGA was calibrated every morning by using zero air that had been run through a soda lime scrubber and by using a White Martins certificated standard gas of 610 (plus or minus 2%) ppmv of CO2 (nitrogen as the balance gas).

Soil Analyses

Physical and chemical analyses were carried out at the Soil Laboratory at Escola Superior de Agronomia, following van Raij et al. (2001). Carbon concentration in soil was determined at the Isotopic Ecology Laboratory at the Centro de Energia Nuclear na Agricultura, University of Sao Paulo, using an Element Analyzer Carlo Erba, model 1110 CNHS.

Litterfall mass

Litter traps were constructed of 1 x 1 m squares of 5 mm nylon mesh suspended 30 cm above the soil surface. Five traps were installed in each of the mature forests and in four of the secondary forests. Litter was collected monthly, stored in paper bags, sorted for removal of coarse material with diameter 45 cm, dried at 70 degrees C for 72 h, and then weighed.

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:

Blake GR, Hartge KH (1986) Bulk density. In: Methods of Soil Analysis. Part 1: Physical and Mineralogical Methods, 2 (ed. Klute A), pp. 363-376. ASA, Madison.

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RADAMBRASIL (1976) Folha SC.19 Rio Branco. Ministerio das Minas e Energia, Departamento Nacional da Producao Mineral, Projeto RADAM BRASIL, Rio de Janeiro, RJ.

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