

Global Fire Emissions Database, Version 4.1 (GFEDv4)

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Documentation Revision Date: 2017-09-27

Data Set Version: 4.1

Summary

This dataset provides global estimates of monthly burned area, monthly emissions and fractional contributions of different fire types, daily or 3-hourly fields to scale the monthly emissions to higher temporal resolutions, and data for monthly biosphere fluxes. The data are at 0.25-degree latitude by 0.25-degree longitude spatial resolution and are available from June 1995 through 2016, depending on the dataset. Emissions data are available for carbon (C), dry matter (DM), carbon dioxide (CO₂), carbon monoxide (CO), methane (CH₄), hydrogen (H₂), nitrous oxide (N₂O), nitrogen oxides (NO_x), non-methane hydrocarbons (NMHC), organic carbon (OC), black carbon (BC), particulate matter less than 2.5 microns (PM_{2.5}), total particulate matter (TPM), and sulfur dioxide (SO₂) among others. These data are yearly totals by region, globally, and by fire source for each region.

This Version 4, R1 dataset includes data described as GFED4 and GFED4.1s from the data provider. GFED4 data are without small fire inputs and are in HDF format. The GFED4.1s data include small fires and are provided in HDF5 format. The mapped burned area is without small fires and this is the GFED4 burned area described in Giglio et al. (2013). The emissions fields are based on this dataset but boosted with small fires, GFED4.1s. The emissions fields also contain a layer with the fraction of emissions resulting from this boost. Additional information may be obtained from the Global Fire Data website: <http://www.globalfiredata.org/index.html>.

The dataset is divided into the following main datasets. Data products include:

1. Monthly and Daily Burned Area (GFED4 - without small fires)

- Global monthly burned area (ha) at 0.25-degree x 0.25-degree for 1997 to 2016 in HDF (.hdf) format (GFED4).
- Global daily burned area for a subset of the time series from Aug 2000 to 2015 in HDF (.hdf) format (GFED4).

2. Emissions (monthly, daily, 3-hourly) and burned area (GFED4s - with small fires)

- Annual files with monthly GFED4s burned area (including small fires), emissions, and scalars to distribute the monthly emissions over the days as well as the diurnal cycle as HDF5 (.hdf5) format (GFED4s) for the time period 1997 to 2015. These files contain fire carbon emissions ($\text{g C m}^{-2} \text{ month}^{-1}$) and dry matter emissions ($\text{kg DM m}^{-2} \text{ month}^{-1}$). In addition, fractional contributions of different fire types (grassland and savanna, woodland, deforestation and degradation, forest, agricultural waste burning, and peat fires) are provided within each file. The CASA-GFED biosphere flux sources include Net Primary Production (NPP), heterotrophic respiration (Rh), and fires (biomass burning). Rh has been updated for all years in this distribution due to a correction in only the Rh values. Available for years 2003 onward are daily / 3-hourly emissions which are scalar fields that can be used in combination with monthly emissions files to estimate emissions on a higher temporal resolution.
- Regional estimates for various trace gases and aerosol emissions are provided, in text format, that contain annual emissions (1997 - 2016) per region for totals of C and individual species from all sources, yearly lumped sources such as higher alkanes, higher alkenes, and toluenes, and from each individual fire source (forest fires, peat fires, agricultural waste burning, etc). These files are for indicative use only; they are not suitable for official reporting due to large uncertainties and the potential for aspects of information from key regions to be missing in the global approach used. There are 41 text files.
- Related files include emission factors (EF) data for individual species by biome (fire source) in comma-separated (.csv) format. There are 2 csv files.

There are a total of 5,952 files with this dataset. The data are in text, HDF5, and HDF formats as described above.

Version 4, R1 Note: This dataset is intended for use for large-scale modeling studies. It supersedes and replaces the Global Fire Emissions Database, Version 4 (GFEDv4) which was archived by the Oak Ridge National Laboratory Distributed Active Archive Center in 2015.

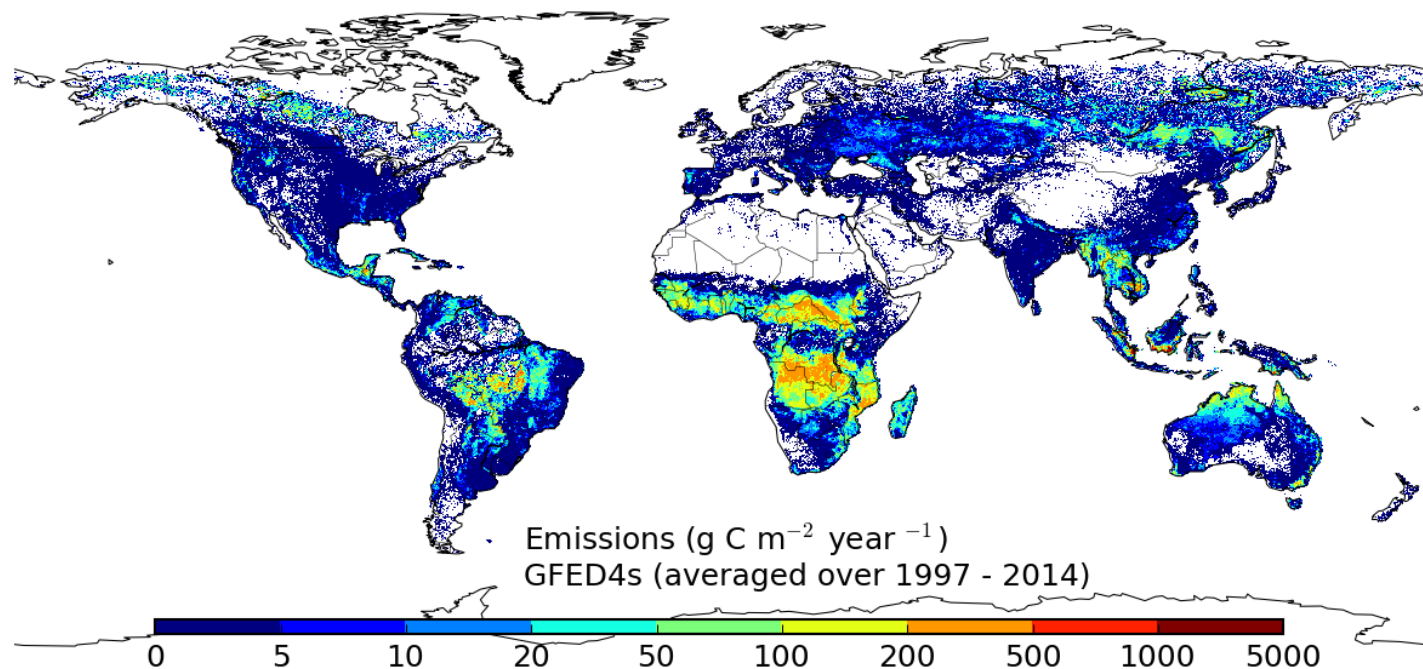


Figure 1. Annual carbon emissions from fires (as $\text{g C/m}^2/\text{year}$) averaged over 1997 to 2014.

Citation

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Table of Contents

1. [Data Set Overview](#)
2. [Data Characteristics](#)
3. [Application and Derivation](#)
4. [Quality Assessment](#)
5. [Data Acquisition, Materials, and Methods](#)
6. [Data Access](#)
7. [References](#)
8. [Data Set Revisions](#)

1. Data Set Overview

This dataset provides global estimates of burned area, monthly emissions and fractional contributions of different fire types, daily/3-hourly fields to scale the monthly emissions to higher temporal resolutions, and data for monthly biosphere fluxes. The data are at 0.25-degree latitude by 0.25-degree longitude spatial resolution and are available from July 1997 through 2016 depending on the individual dataset.

Also included with this dataset are data from small fires referred to as GFED4.1s data on the GFED website

<http://www.globalfiredata.org/index.html>. GFED4 data are without small fires in HDF format; the GFED4.1s data (data which includes small fires) are provided in HDF5 format. The mapped burned area is without small fires and this is the GFED4 burned area described in Giglio et al. (2013). The emissions fields are based on this dataset but boosted with small fires, GFED4.1s. The emissions fields also contain a layer with the fraction of emissions resulting from this boost. Additional information may be obtained from the Global Fire Data website: <http://www.globalfiredata.org/index.html>.

Emissions data are available for carbon (C), dry matter (DM), carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), hydrogen (H_2), nitrous oxide (N_2O), nitrogen oxides (NO_x), non-methane hydrocarbons (NMHC), organic carbon (OC), black carbon (BC), particulate matter less than 2.5 micron ($\text{PM}_{2.5}$), total particulate matter (TPM), and sulfur dioxide (SO_2) among others. These data are yearly totals by region, globally, and by fire source for each region.

Related datasets:

- Veraverbeke, S., B.M. Rogers, and J.T. Randerson. 2015. CARVE: Alaskan Fire Emissions Database (AKFED), 2001-2013. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAC/1282>

Release and Update Notes:

A full revision history for the GFED data is provided in section 8 of this document.

This dataset revision (Global Fire Emissions Database, Version 4 (GFEDv4), R1) includes updates to all files that are available from the GFED community. In particular, it includes monthly burned areas without small fires for 2016 and 2015-03 through 2015-12 and the daily burned areas without small fires for 2015 and 2000-2012, which were not part of the previous ORNL DAAC data distribution. Because of a small correction in respiration values, all files for emissions with small fires have been replaced for years 1997-2014 and the 2015 year has been added. Files for regional estimates for various trace gases and aerosol emissions, in text format, have been updated with a column for 2016.

2. Data Characteristics

Spatial Coverage

The study area covers the following 14 regions: Boreal, Temperate, and Central America, Northern and Southern Hemisphere South America, Europe, Middle East, Northern and Southern Hemisphere Africa, Boreal, Central, Southeast, and Equatorial Asia, Australia and New Zealand. The upper left corner of each file is centered at 179.875 W, 89.875 N and the lower right corner at 179.875 E, 89.875 S.

Spatial Resolution

The data are gridded at 0.25-degree latitude by 0.25-degree longitude.

Temporal Coverage

Annual data and emissions estimates are for the years 1997- 2016.

Monthly data for the period 1995-06 to 2016-12.

Daily/3-hourly data are available for 2000 - 2015. Daily data for year 2000 start on yearday 214 - 366. All other years have a complete record. Daily data include leap day resulting in 1 - 366 year days.

Temporal Resolution

Most data are monthly.

Study Area: (All latitude and longitude given in decimal degrees (datum: WGS84))

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude	Geodetic Datum
Global	-180	180	90	-90	WGS-84

Data File Information

Data are available from 1995 through 2016 depending on the dataset. Each data file contains 1,440 columns and 720 rows and has a 0.25-degree latitude by 0.25-degree longitude spatial resolution.

Data Dictionary

Annual Files: These files are the GFED4.1s data and include the small fire boost. The files provide data for each month, for each year, 1997-2015. There are 19 annual files in hdf5 (.hdf5) format.

The data are grouped under (1) ancillary, (2) biosphere, (3) burned area, (4) emissions, (5) latitude, and (6) longitude.

The files are named **GFED4.1s_YYYY.hdf5**

where: YYYY= 1997 to 2015.

Groups and Variables:

(1) Ancillary: provides information on the names of the 14 regions and grid cell area for the data.

(2) Biosphere: provides monthly biosphere fluxes each month of the year. Units are in g C/m²/month.

Variables: (based on the CASA-GFED4s framework):

- BB: biomass burning C emissions
- NPP: Net Primary Production (NPP)
- Rh: Heterotrophic respiration (Rh)

(3) Burned Area

Variables:

- burned_fraction: The fraction of each grid cell that burned in that month according to the GFED4 burned area data; includes an experimental small

fire estimate.

- source: Source of GFED4.1s burned area estimate; includes an experimental small fire estimate. Data are from 500-m MODIS product MCD64A1 after 2001. Before 2001, ATSR and VIRS data were used.

(4) Emissions: data files are for each month of each individual year, and daily emissions for individual species and for individual species partitioned by specific sources (grassland and savanna, woodland, deforestation & degradation, forest, agricultural waste burning, and peat fires).

Variables:

- C: Biomass burning C emissions. Units are provided in g C/m²/month.
- daily fraction: The fraction of total emissions that were emitted in the different days of the month. These data are available for 2003-2015. Data are unitless ranging from 0 to 1
- diurnal cycle: The partitioning of the daily emissions over eight three-hour windows (UTC). These data are available for 2003-2015 and based on GOES data. Data are unitless ranging from 0 to 1 and include:
UTC_XXX where XXX= 0-3h, 12-15h, 15-18h, 18-21h, 21-24h, 2-6h, 6-9h, and 9-12h.
- DM: GFED4.1s biomass burning dry matter emissions. Units are provided in kg DM/m²/month.
- partitioning: includes the contribution of fire sources to the total monthly burning carbon emissions (C_) and to monthly biomass burning dry matter emissions (DM_).
Data are grouped as **C_fire source**, as provided below, or **DM_fire source**, for the same fire sources. Data are unitless.
Fire sources include:
C_AGR1: Agricultural waste burning
C-BORF: Boreal forest fires
C_DEFO: Tropical forest fires
C_SAVA: Savanna, grassland, and shrubland fires
C_TEMF: Temperate forest fires
- small fire fraction: Fraction of total monthly GFED4.1s biomass burning emissions originating from small fire burned area. Data are unitless.

(5) lat: Latitude of data in degrees N

(6) lon: Longitude of data in degrees E

Daily Files: These files are the GFED4.0 version, without small fires. The data are estimates of burned area (BA) in hectares (ha) and for burned area uncertainty (BurnedAreaUncertainty). There are 365 hourly files for 2001 - 2015; one for each day of the year. For year 2000, the year days range from 214 - 366.

The daily files are named **GFED4.0_DQ_YYYYXXX_BA.hdf**

where: DQ=daily; YYYY= 2000 - 2015;

XXX = 001-365 (for each day of the year, 1-365. Leap year includes yearday 366);

and BA = Burned area.

Example file name: **GFED4.0_DQ_2013001_BA.hdf**

Variables:

- BurnedArea: units are in hectares (ha)
- BurnedAreaUncertainty: units are in hectares (ha)
- LandCoverDist: UMD land cover distribution of burned area; units are in percent. See the **monthly** files below for the landcover classes.
- MeanBurnDateUncertainty: units are in days
- PeatFraction: units are in percent.
- source: source of burned area estimate; unitless
- TreeCoverDist: fractional tree cover distribution of burned area; units are in percent.

Monthly Files: These files are the GFED4.0 version, without small fires. These files contain gridded, 0.25 degree x 0.25 degree, estimates for monthly burned area (BA) in hectares (ha) and for burned area uncertainty (BurnedAreaUncertainty). There are 259 monthly files in .hdf format for the period 1995-06 to 2016-12 (one file for each month).

The files are named **GFED4.0_MQ_YYYYMM_BA.hdf**

where: MQ = indicates a monthly file;

YYYY=1995 - 2016 (note: there are only seven files for 1995, June-December); and

BA = burned area.

Example file name: **GFED4.0_MQ_199506_BA.hdf**

Variables:

- BurnedArea: monthly burned area. Units are in hectares.
- BurnedAreaUncertainty: monthly burned area uncertainty. Units are in hectares.
- FirePersistence: monthly fire persistence. Units are in days.
- PeatFraction: units are in percent
- source: source of burned area estimate: data are unitless
- TreeCoverDist: fractional tree cover distribution of burned area: units are in percent
- LandCoverDist: UMD land cover distribution of burned area: units are in percent.

Land cover classes:

Class	Description
class_0	water
class_1	evergreen needleleaf forest
class_2	evergreen broadleaf forest
class_3	deciduous needleleaf forest
class_4	deciduous broadleaf forest
class_5	mixed forests
class_6	closed shrublands
class_7	open shrubland
class_8	woody savannas
class_9	savannas
class_10	grasslands
class_11	UNUSED
class_12	croplands
class_13	urban and built-up
class_14	UNUSED
class_15	UNUSED
class_16	barren or sparsely vegetated
class_17	unclassified

Feedback

Emissions Estimates

These data are GFED 4.1s data. Emissions estimates are provided for 41 species (41 .txt files) for each year for 1997-2016, for the individual regions, global, different fire types, and all fire types combined provided as text files (.txt). The units are in g species/yr, for example, g CH₄/yr.

Example file name: **GFED4.1s_CH3COCHO.txt**

Files are named **GFED4.1s_species.txt** where the **species** is one of the following:

C	H2	BC	C2H4	HCOOHC2H2	Higher alkanes
C2H6	C2H5OH	N2O	C2H4O	CH3COOH	Higher alkenes
NH3	C2H6S	NMHC	C3H6	NOX	OC (organic carbon)
C3H6O	C3H8	C6H6	C5H8	SO2	PM2.5 (Particle matter 2.5 micron emissions)
CH2O	C7H8	C8H10	C10H16	CH3COCHO	Toluene lump
HCN	CH3OH	HCOOH	CH4	HOCH2CHO	MEK (Methyl Ethyl Ketone / 2-butanone)
CO2	CO	DM	C2H2	TPC (total particulate matter)	

GFED4 Emission Factors Summary.csv

This file provides a summary of the emission factors (EF) for 39 species and lumped groups of species (g Specie per kg Dry Matter burned) by biome based on the compilations of Akagi et al., 2011, Andreae and Merlet (2001), Yokelson et al., 1997, and Christian et al., 2003.

GFED4 Emission Factors.csv

This file provides the EFs and uncertainties for the 39 species and lumped groups, EFs provided by biome, and EFs by biome from the four specific data sources listed above.

3. Application and Derivation

The GFED4 data were derived by combining 500-m MODIS burned area maps with active fire data from the Tropical Rainfall Measuring Mission (TRMM) Visible and Infrared Scanner (VIRS) and the Along-Track Scanning Radiometer (ATSR) family of sensors. Satellite information on fire activity and vegetation productivity were combined to estimate gridded monthly burned area, fire emissions and scalars that can be used to calculate higher temporal resolution emissions. Before 2001, ATSR and VIRS data were used.

This dataset is intended for use for large-scale modeling studies.

4. Quality Assessment

Annual emissions per region for totals of C and individual species from all sources, yearly lumped sources such as higher alkanes, higher alkenes, and toluene lump, and from each individual fire source (forest fires, peat fires, agricultural waste burning, etc). These files are for indicative use only; they are not suitable for official reporting due to large uncertainties and potential for key regional aspects to be missing in the global approach used.

5. Data Acquisition, Materials, and Methods

Data Sources

Satellite information on fire activity and vegetation productivity were combined to estimate gridded monthly burned area, fire emissions and scalars that can be used to calculate higher temporal resolution emissions.

Data sources used in this dataset:

- Burned area from Giglio et al. (2013)
- Burned area from small fires based on active fire detections outside the burned area maps detailed in Randerson et al. (2012)
- Carbon and dry matter emissions, revised version of van der Werf et al. (2010), manuscript currently in preparation
- Fractional contributions of various fire types to total emissions
- List of emission factors to compute trace gas and aerosol emissions based on Akagi et al. (2011) as well as Andreae and Merlet (2001) with updates provided in 2013 by M.O. Andreae

Burned Area (Monthly data files; the mapped burned area is without small fires, this is the GFED4 burned area described in Giglio et al. (2013))

GFED4 burned area data provides global monthly burned area at 0.25 degree spatial resolution from mid-1995 through the present and daily burned area for the time series extending back to August 2000. The data were derived by combining 500-m MODIS burned area maps with active fire data from the Tropical Rainfall Measuring Mission (TRMM) Visible and Infrared Scanner (VIRS) and the Along-Track Scanning Radiometer (ATSR) family of sensors. For additional information, refer to Giglio et al., 2013.

Burned area from small fires (based on active fire detections outside the burned area maps (included in the Annual data files))

Many small fires occur each year that are well below the detection limit of the current generation of global burned area products derived from moderate resolution surface reflectance imagery. Although these fires often generate thermal anomalies that can be detected by satellites, their contributions to burned area and carbon fluxes have not been systematically quantified across different regions and continents. One km thermal anomalies (active fires) and 500-m burned area observations from MODIS were combined to estimate the influence of small fires. The number of active fires inside and outside of 500-m burn scars derived from reflectance data were calculated. Small fire burned area was estimated by computing the difference normalized burn ratio (dNBR) for these two sets of active fires and then combining these observations with other information. In a final step, the Global Fire Emissions Database version 3 (GFED3) biogeochemical model was used to estimate the impact of these fires on biomass burning emissions (Randerson et al., 2012).

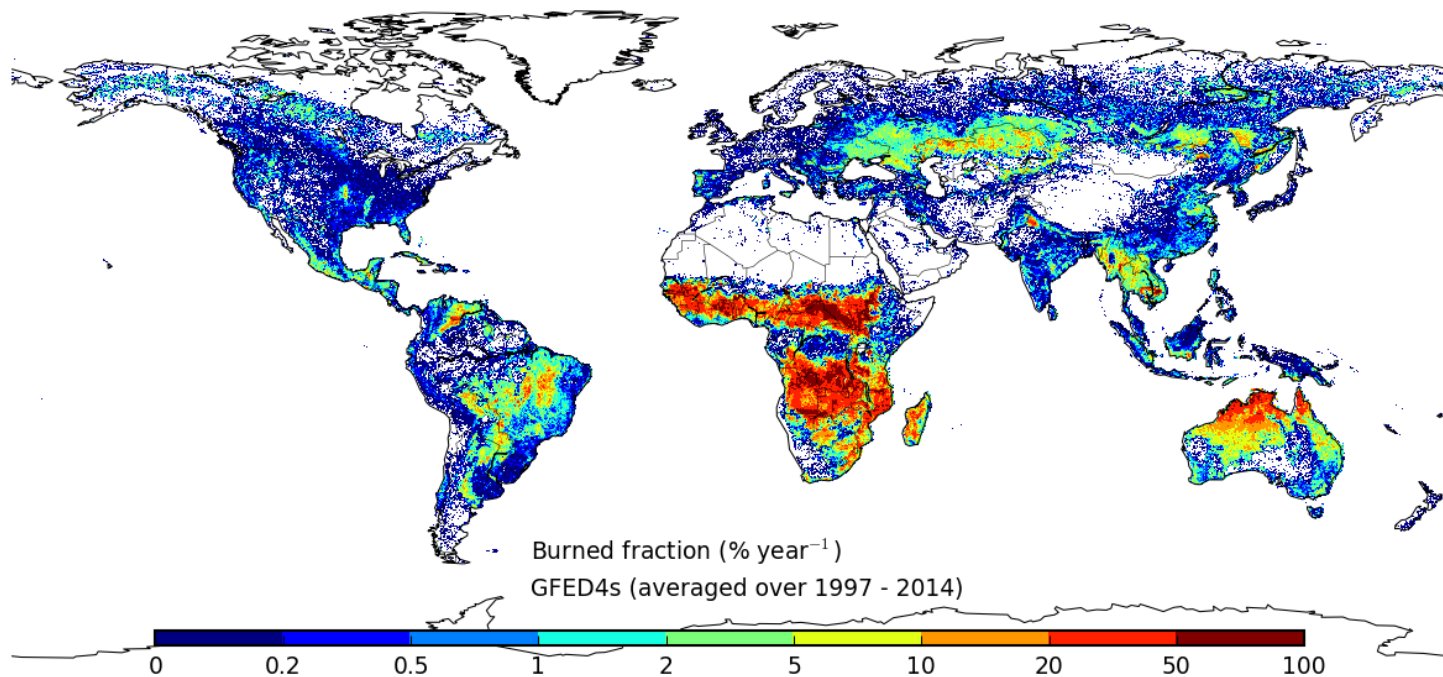


Figure 2. Annual burned area (as percentage of the area of the grid cell), averaged over 1997-2014.

Emissions-monthly, daily, 3-hourly (included in the Annual data files)

Annual files with monthly GFED4.1s burned area (including small fires), emissions, and scalars to distribute the monthly emissions over the days as well as the diurnal cycle are provided as HDF5 files. The HDF5 files include fire carbon emissions ($\text{g C m}^{-2} \text{ month}^{-1}$) and dry matter emissions ($\text{kg DM m}^{-2} \text{ month}^{-1}$). In addition, fractional contributions of different fire types can be used in combination with recommended emission factors provided ($\text{g species per kg dry matter burned}$) to calculate specific trace gas and aerosol emissions.

Emission estimates were derived by combining burned area data with a revised version of the biogeochemical model, Carnegie-Ames-Stanford Approach (CASA-GFED), that estimates fuel loads and combustion completeness for each monthly time step. For November 2000 onwards, estimates were based on burned area, active fire detections, and plant productivity. Refer to van der Werf et al., 2010 for more detailed information.

The daily and 3-hourly time series were derived by the disaggregation of the monthly MODIS data, and in parallel, mean diurnal cycles were constructed from Geostationary Operational Environmental Satellite (GOES) Wildfire Automated Biomass Burning Algorithm (WF_ABBA) active fire observations. Refer to Mu et al., 2010, for more detailed information. These scalar fields can be used in combination with monthly emissions files to estimate emissions on a higher temporal resolution. These are only available for the 2003 onwards.

Ancillary data (included in the Annual data files)

Biosphere fluxes: The CASA-GFED biosphere fluxes include NPP, Rh, and fires (BB). Units are in $\text{g C m}^{-2} \text{ month}^{-1}$. CO₂ is not included and nitrogen fertilization and is spun up to almost neutral conditions.

Annual Emissions by Country

Annual emissions per region are provided for totals of C and individual species from all sources, yearly lumped sources such as higher alkanes, higher alkenes, and toluene lump, and from each individual fire source (forest fires, peat fires, agricultural waste burning, etc.). These files are for indicative use only; they are not suitable for official reporting due to large uncertainties and potential for missing key regional aspects in the global approach used. Links to tables with annual emission estimates for the various trace gas and emissions sources identified in the basis regions (Fig. 3) are provided on the Global Fire Data website.



BONA	Boreal North America	NHAF	Northern Hemisphere Africa
TENA	Temperate North America	SHAF	Southern Hemisphere Africa
CEAM	Central America	BOAS	Boreal Asia
NHSA	Northern Hemisphere South America	CEAS	Central Asia
SHSA	Southern Hemisphere South America	SEAS	Southeast Asia
EURO	Europe	EQAS	Equatorial Asia
MIDE	Middle East	AUST	Australia and New Zealand

Figure 3. Basis regions.

For additional information such as how to read the hdf5 files, how to compute trace gas, or aerosol emissions, additional figures, etc., refer to the Global Fire Data website: <http://www.globalfiredata.org/index.html>.

6. Data Access

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

[Global Fire Emissions Database, Version 4.1 \(GFEDv4\)](#)

Contact for Data Center Access Information:

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

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8. Data Set Revisions

Updates to this dataset will be made periodically. Please contact ORNL DAAC User Services so that we can add you to our e-mail distribution list for update notices.

Date	Release and Update History	ORNL DAAC Notes
December 21, 2005	GFED Release 1	
December 21, 2005	ORNL DAAC Global Fire Emissions Database, Version 1 (GFEDv1)	Initial release archived
	GFED Release 2	
May 31, 2006	Global Fire Emissions Database, Version 2 (GFEDv2)	Superseded and replaced v1
June 23, 2006	GFED updated the burned fraction (BF), combustion completeness (CC), and fuel load (FL) files	
November 27, 2006	GFED added files for the year 2005 and added emission files with an 8 day time step for the 2001 – 2005 period	
March 30, 2007	Global Fire Emissions Database, Version 2 (GFEDv2.1)	Incorporates 2006 changes and additions and supersedes and replaces v2
September 30, 2013	Global Fire Emissions Database, Version 3 (GFEDv3.1)	Incorporates changes to spatial resolutions and data additions, and supersedes and replaces v2.1
September 2015	Global Fire Emissions Database, Version 4 (GFEDv4)	Incorporates changes to spatial resolutions and data additions, and supersedes and replaces v3.1
September 2017	Global Fire Emissions Database, Version 4.1 (GFEDv4)	Incorporates updates to temporal resolution. Addendum to the September 2015 release. All annual files have been updated with files that contain corrected Rh values.



Home

About Us

[Who We Are](#)
[Partners](#)
[User Working Group](#)
[Data Citation Policy](#)
[Workshops](#)
[News](#)

Get Data

[Complete Dataset List](#)
[Search for Data](#)
[Field Campaigns](#)
[Land Validation](#)
[Regional/Global](#)
[Model Archive](#)

Data Management

[Plan](#)
[Manage](#)
[Archive](#)
[DAAC Curation](#)
[Submit Data](#)

Tools

[MODIS](#)
[THREDDS](#)
[SDAT](#)
[Daymet](#)
[CARVE Data Viewer](#)
[Soil Moisture Visualizer](#)
[Land - Water Checker](#)

Help

[FAQs](#)

Contact Us