Global Fire Emissions Database, Version 4.1 (GFED4s)
Monthly and daily fire emissions 1997 – present

Released 3 July 2015

Updated on 26 May 2016 with:
- Data for the year 2015
- An error in the biospheric fluxes was corrected for all years, this only influenced R_h values and had no impact on the fire fluxes

Updated 17 June 2017 with:
- Data for the year 2016
- Only monthly data available, daily will follow a.s.a.p.

Updated 4 July 2017 with:
- Daily and diurnal data for 2016

Updated 12 September 2017 with:
- Reference for emissions paper

Updated 4 April 2018 with:
- Estimates for 2017 based on relations between MODIS active fire detections and GFED4s for 2003-2016. Because the underlying burned area data has been upgraded (from C5.1 to C6) we cannot maintain consistency and use this approach until GFED5 becomes available around 2019. Updates only include DM and C emissions but do include diurnal variability based on active fire distributions and diurnal cycles based on climatological data.
- A paper describing this approach is in preparation, emissions estimates based on relations between active fires and GFED4s are within 2% of the original data for continental and annual scales but early season fires are somewhat amplified.

Introduction

This fourth version of the Global Fire Emissions Database (GFED4s) provides monthly burned area, fire carbon (C) and dry matter (DM) emissions, and the contribution of different fire types to these emissions in order to calculate trace gas and aerosol emissions using emission factors. All these datasets are based on burned area boosted by small fire burned area, hence the "s" in the GFED4.1s name.

Naming convention

The files are distributed via http://www.falw.vu/~gwerf/GFED/GFED4/ as annual files named GFED4.1s_YYYY.hdf5 where YYYY is the year (1997 – 2015). The "s" denotes that these emissions are based on both the standard GFED4 burned area (Giglio et al., 2013) AND burned area derived from active fire information seen outside the burned area maps, see Randerson et al. (2012). Files are in the hdf5 (sometimes denoted with the extension .h5) format.

Resolution

The spatial resolution of the global files is 0.25 degrees, so the different fields have 720 rows and 1440 columns. The center of the upper left grid cell is located at longitude -179.875° and latitude 89.875°. The temporal resolution of the emissions files is monthly, and we provide data to distribute these over the month as well as a diurnal cycle based on Mu et al. (2011). This is only available from 2003 onwards.

Layers

Each hdf5 file contains 4 different groups: burned area, emissions, biosphere fluxes, and ancillary data.

- Within the burned_area group, there are two datasets available for each month (01, 02, .. , 12): *burned_fraction* and *burned_area_source*. The former is the fraction of each grid cell that burned in that month according to the GFED4s burned area data, the latter indicates what data was used to construct the burned area maps excluding small fires. In general, ATSR and VIRS data was used before 2001, MODIS after 2001. This solely concerns the GFED4 burned area dataset.
- The emissions group contains, for 12 months (01, 02, .. , 12), 5 datasets: *emissions* (carbon with units of g C m^{-2} $month^{-1}$ and DM with units of kg DM m^{-2} $month^{-1}$), *small_fire_fraction* (unitless), *daily fraction* (unitless), *diurnal cycle* (unitless), as well as a group *partitioning* which contains, for both C and DM, the datasets (all unitless):
    - SAVA (Savanna, grassland, and shrubland fires)
    - BORF (Boreal forest fires)
    - TEMF (Temperature forest fires)
    - DEFO (Tropical forest fires [deforestation and degradation])
    - PEAT (Peat fires)
    - AGRI (Agricultural waste burning)

  The *small fire fraction* indicates what fraction of total emissions stemmed from the small fire burned area. GFED4 emissions can be calculated by subtracting this fraction from total emissions, but we recommend using GFED4s emissions. Note that GFED4 burned area **cannot** be calculated this was for various reasons, please use the original GFED4 burned area datasets for this.

  The *daily fraction* indicates what fraction of total emissions was emitted in the different days of that month

  The *diurnal cycle* gives the partitioning of the daily emissions over 8 three-hour windows (UTC), this is uniform over the month.
- The biosphere fluxes contain monthly net primary production (NPP), heterotrophic respiration (R_h), and fire emissions (BB). All are in g C m^{-2} $month^{-1}$.
- The ancillary group contains the datasets *grid_cell_area* and *basis_regions*, with the former indicating how many m^2 each grid cell contains and the latter are the 14 basis regions we use to summarize the results throughout our papers.

The file structure is schematically shown below where <month> is 01, 02, 03, .., 12 and <source> is SAVA, BORF, TEMF, DEFO, PEAT, AGRI:

```
/burned_area
        /<month>
                /burned_fraction
                /source
/emissions
        /<month>
                /DM
                /C
                /small_fire_fraction
                /daily_fraction*
                        /day_1
                        /day_2
                        /etc. (total of n days in month)
                /diurnal_cycle*
                        /UTC_0-3
                        /UTC_3-6
                        /etc. (total of 8)
                /partitioning
                        /C_<source>
                        /DM__<source>

/biosphere
        /<month>
                /NPP
                /Rh
                /BB


/ancill
        /basis_regions
        /grid_cell_area
```

* Only for 2003 onwards

Converting DM emissions to trace gas and aerosol emissions
To convert the DM to trace gas or aerosol emissions the DM fields (kg DM m^{-2} $month^{-1}$) have to be multiplied with emission factors. These are reported as g species emitted per kilogram dry matter burned and vary between fire types. We have compiled a set of recommended emission factors based mostly on the work of Akagi et al. (2011) but also using other publications. Details can be found in the MS Excel file on http://www.falw.vu/~gwerf/GFED/GFED4/ancill/. This directory also contains a txt file with emission factors. As an example, we can calculate carbon monoxide (CO) emissions using:

$$E_{CO}(x, y, time) = \sum^{sources} EF_{CO_{source}} \times DM(x, y, time) \times contr_{source}(x, y, time)$$

Where E is emissions and EF is the emission factor, in this case for CO. Contr is the contribution of the various sources. (savanna fires etc.). This should then be summed over those sources of interest. An example script (Python) that can be used to do these calculations can be found on http://www.falw.vu/~gwerf/GFED/GFED4/ancill/ and tables with regional and annual totals for various species are on globalfiredata.org. Wolfgang Knorr (Lund University) kindly provided Matlab code to read the data as well, these are also on http://www.falw.vu/~gwerf/GFED/GFED4/ancill/

- *The conversion of carbon to dry matter is based on the emission factors of CO_2, CO, and CH_4. If you change any of these emission factors please also adjust the dry matter emissions to remain consistent.*
- *When computing total regional emissions do not forget that units are per m^2, so for total emissions these have to be multiplied with the area of the region of interest, included in the emissions files.*

Peculiarities
Some remote islands including Hawaii and Fiji have burned area but no emissions because these are not covered by the NDVI datasets we used.

Citation
Please mention you used fire emissions from the Global Fire Emissions Database version 4 (GFED4s) described in van der Werf et al. (2017). When fires are a key focus of your paper please also include a citation to the original burned area paper (Giglio et al., 2013) boosted by small fire burned area following Randerson et al. (2012). If you also use the higher temporal resolution please include a citation of Mu et al. (2011).

When focusing on GFED4 burned area please do not cite the emissions work but cite Giglio et al. (2013).

References

Akagi, S. K., Yokelson, R. J., Wiedinmyer, C., Alvarado, M. J., Reid, J. S., Karl, T., Crounse, J. D. and Wennberg, P. O.: Emission factors for open and domestic biomass burning for use in atmospheric models, Atmospheric Chemistry and Physics, 11(9), 4039–4072, doi:10.5194/acp-11-4039-2011, 2011.

Giglio, L., Randerson, J. T. and van der werf, G. R.: Analysis of daily, monthly, and annual burned area using the fourth-generation global fire emissions database (GFED4), Journal of Geophysical Research-Biogeosciences, 118(1), 317–328, doi:10.1002/jgrg.20042, 2013.

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