The Version 4 Global Fire Emissions Database (GFED4) Burned Area Component

Louis Giglio
Department of Geographical Sciences
University of Maryland
College Park, MD 20742
giglio@hermes.geog.umd.edu

James T. Randerson
Department of Earth System Science
University of California, Irvine
Irvine, CA 92697
jranders@uci.edu

ABSTRACT

We describe the burned area component of the version 4 Global Fire Emissions Database (GFED4), which will provide global, daily burned area and biomass burning emissions at 0.25° spatial resolution from mid-2000 through the present. Cross-calibration of fire observations from the Tropical Rainfall Measuring Mission Visible and Infrared Scanner (VIRS) and the Along-Track Scanning Radiometer (ATSR) with 500-m MODIS burned area maps allows the data set to be extended further back in time, though at a reduced temporal resolution. We include a discussion the spatially explicit uncertainty estimates accompanying our data set, and the use of these estimates within atmospheric and biogeochemical models. We then discuss plans for the integration of fire observations from the Suomi-NPP Visible-Infrared Imager-Radiometer Suite (VIIRS) into GFED to extend the data set into the future.

INTRODUCTION

Long-term, spatially- and temporally-explicit burned area information derived from satellite observations is critical for quantifying pyrogenic trace gas and aerosol emissions, which is in turn necessary to fully understand the role of biomass burning in the global carbon cycle and to discriminate natural versus anthropogenic contributions to global change. Here we describe the burned area component of the Version 4 Global Fire Emissions Database (GFED4), which provides global, multi-year, monthly and daily burned area estimates at 0.25° spatial resolution. The data set is specifically intended for use within large-scale (typically global) atmospheric and biogeochemical models.

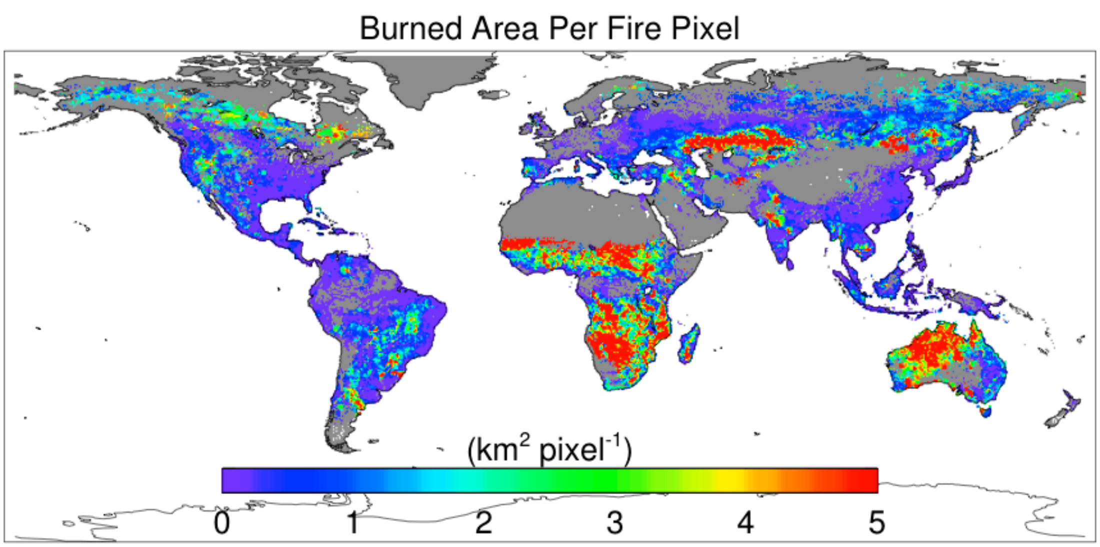
METHOD

During the MODIS-era (mid-2000 – present) the GFED4 burned area data set was derived exclusively from the 500-m MODIS direct broadcast burned area product (MCD64A1) aggregated to 0.25° spatial resolution on monthly and daily bases. During the pre-MODIS era, burned area was estimated on a monthly basis within individual 0.25° grid cells by calibrating readily available active fire data from the Tropical Rainfall Measuring Mission (TRMM) Visible and Infrared Scanner (VIRS) and the Along-Track Scanning Radiometer (ATSR) with the aggregated global MCD64A1 observations. Following the approach used by Giglio et al.[1], we use geographically weighted regression to express the monthly area burned (A) in a 0.25° grid cell at location i during month t as a nonlinear function of VIRS or ATSR monthly active fire counts $N_f(i,t)$:

$$A(i,t) = \alpha(i) N_{\mathrm{f}}(i,t)^{\beta(i)} \quad (1)$$

For illustrative purposes we show the regression coefficient α computed using Terra MODIS active fire counts for the constrained case of $\beta = 1$ in Figure 1. For this special case the constant α represents the average burned area per fire pixel. Due to the reduced sampling frequency of the VIRS and ATSR sensors, the average burned area per fire pixel for these sensors tends to be significantly higher.[2]

Figure 1. Mean burned area per Terra MODIS fire pixel for the constrained linear case of Equation (1). Note the major spatial variability of this quantity.



The MODIS Direct Broadcast Burned Area Product

The monthly MODIS direct broadcast burned area product (MCD64A1) is the basis of the GFED4 burned area component during the MODIS era. However, the product is freely available independently from GFED4 for those applications requiring higher spatial resolution. Here we briefly describe the mapping approach and product.

The direct broadcast mapping algorithm employs 500-m MODIS imagery coupled with 1-km MODIS active fire observations, processing each 10° × 10° MODIS tile[3] spanning the land surface in turn (Figure 2). The hybrid algorithm applies dynamic thresholds to composite imagery generated from a burn-sensitive vegetation index (VI) derived from MODIS short-wave infrared channels 5 and 7, and a measure of temporal texture. The VI is defined as

$$\mathrm{VI} = \frac{\rho_5 - \rho_7}{\rho_5 + \rho_7}, \tag{2}$$

where ρ_5 and ρ_7 are respectively the band 5 and band 7 atmospherically corrected surface reflectance. Cumulative active fire maps are used to guide the selection of burned and unburned training samples and to guide the specification of prior probabilities. The combined use of active-fire and reflectance data enables the algorithm to adapt regionally over a wide range of pre- and post-burn conditions and across multiple ecosystems. A complete description of the algorithm, as well as the results of a preliminary validation, is provided by Giglio et al.[4]

The mapping algorithm ultimately identifies the date of burn, to the nearest day, for 500-m grid cells within the individual 10° × 10° MODIS tile being processed. The date is encoded in a single data layer of the output product as the ordinal day of the calendar year on which the burned (range 1-366), with a value of 0 for unburned land pixels and a special value of -1 reserved for both missing data and water pixels. An example of this data layer is shown in Figure 3. The output product contains additional data layers for diagnostic purposes and to facilitate uncertainty propagation into downstream products derived from the burned area maps, such as emissions estimates.

Figure 2. MODIS sinusoidal projection tiling scheme.

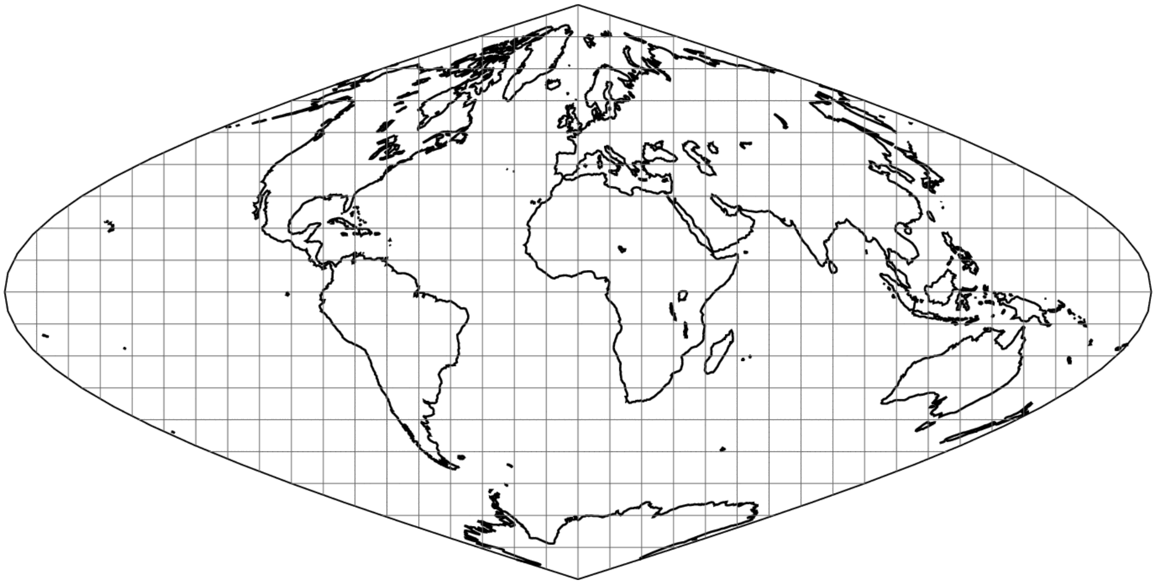
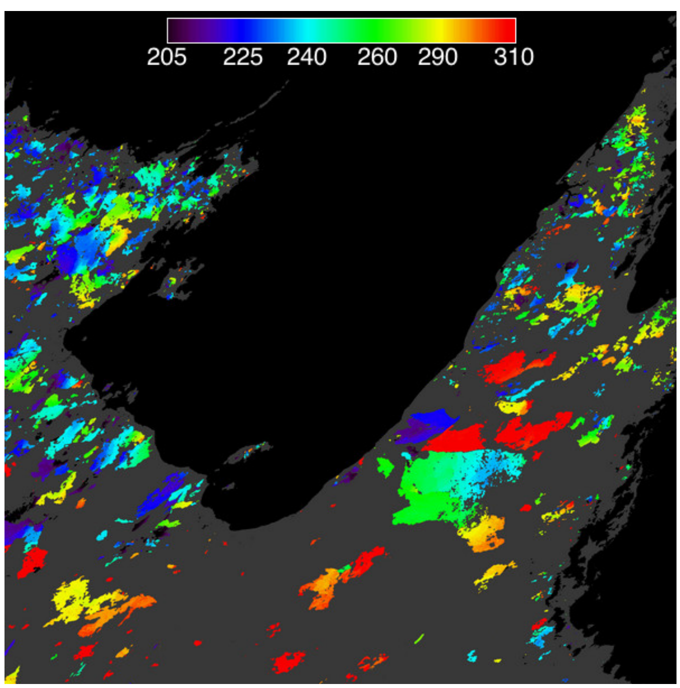


Figure 3. Final burned area mask for MODIS tile h31v10 in northern Australia, for a mapping period spanning August through October 2001. The color scale encodes the ordinal day on which an individual 500-m grid cell burned. Unburned land areas are shown in dark grey, and water is shown in black.



RESULTS

Multi-Year Burned Area Estimates

The GFED4 1997-2011 mean annual area burned and associated uncertainties are shown in Figure 4. The August 2000 – April 2012 daily time series of area burned for the entire globe and two different regions of North America are shown in Figure 5. Considerably larger daily variability is apparent in Temperate North America (corresponding roughly to the conterminous United States) compared to boreal latitudes due to the greater prevalence of different of fire types (e.g., wildfires, cropland burning, prescribed maintenance fires, etc.).

Figure 4. 1997–2011 GFED4 mean annual burned area (top) and associated one-sigma uncertainties (bottom), expressed as the fraction of each 0.25° grid cell that burns each year. One-sigma uncertainties were obtained by adding the monthly, spatially explicit uncertainty estimates (assumed to be independent and random) in quadrature.

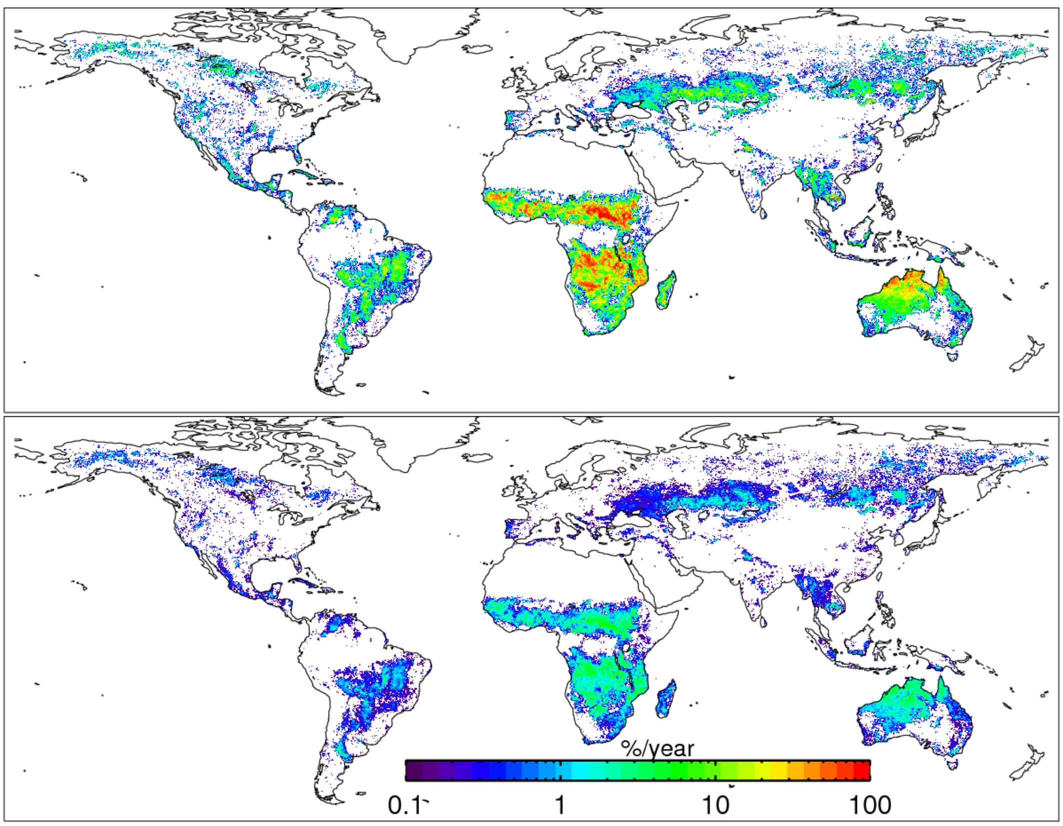
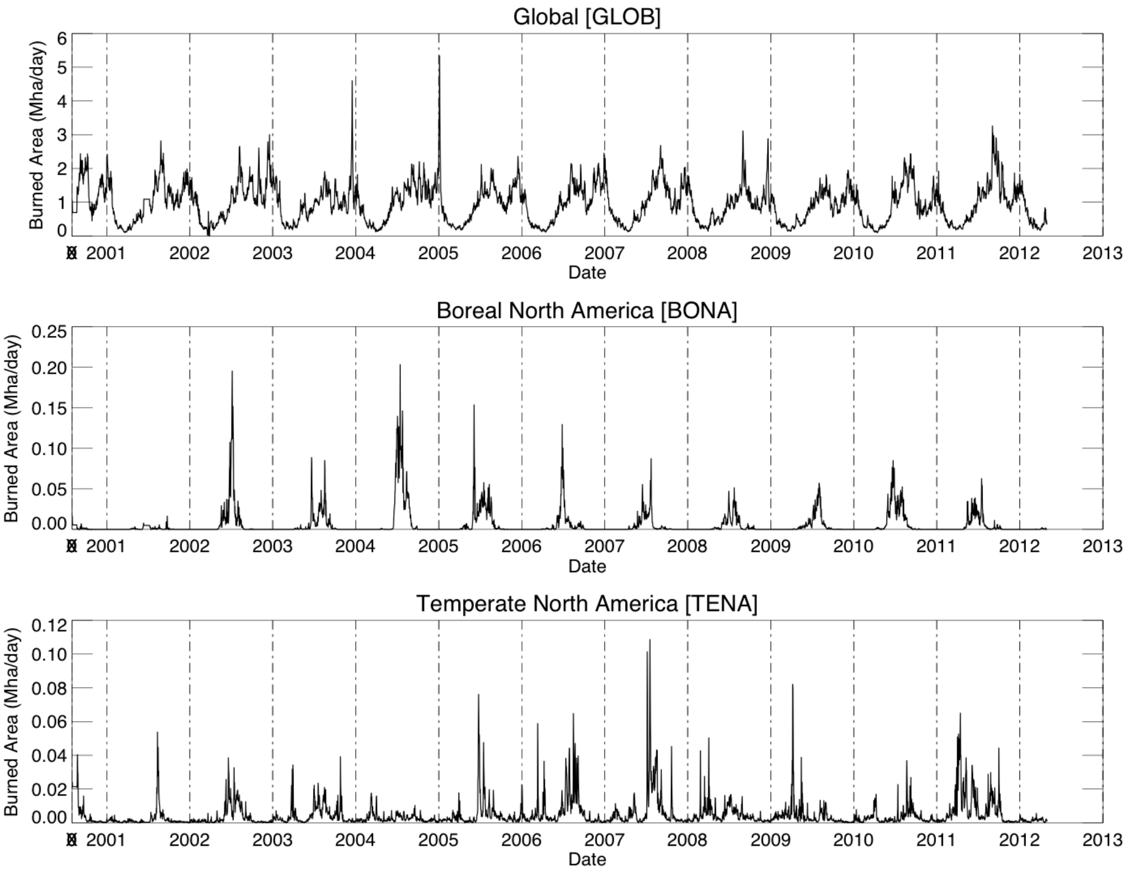


Figure 5. August 2000 – April 2011 GFED4 daily burned area time series for the entire globe and two regions of North America.



CONCLUSION

We described the burned area component of the version 4 Global Fire Emissions Database (GFED4), which will provide global, daily burned area and biomass burning emissions at 0.25° spatial resolution from mid-2000 through the present. Cross-calibration of fire observations from the Tropical Rainfall Measuring Mission Visible and Infrared Scanner (VIRS) and the Along-Track Scanning Radiometer (ATSR) with 500-m MODIS burned area maps allows the data set to be extended further back in time, though at a reduced temporal resolution. In the course of this discussion we also described the MCD64A1 direct broadcast burned area product, which maps post-fire burned areas using 500-m MODIS imagery coupled with 1-km MODIS active fire observations. The hybrid algorithm applies dynamic thresholds to composite imagery generated from a burn-sensitive vegetation index derived from MODIS short-wave infrared channels 5 and 7, and a measure of temporal texture. The direct broadcast mapping algorithm will eventually be adapted to use observations from the Visible Infrared Imaging Radiometer

Suite (VIIRS) instrument, on-board the the recently launched Suomi-NPP (National Polar-orbiting Operational Environmental Satellite System Preparatory Project) satellite. The resulting VIIRS burned area maps will be incorporated into a future version of GFED, this extending the long-term GFED data record into the future.

REFERENCES

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KEY WORDS

Fire, biomass burning, burned area, MODIS, GFED.