CONUS and Global Carbon Consumption Database for Wildland Fire

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Global Connections: Fire, Smoke, Air Quality (AQ)

Fire significantly impacts both human-altered and wild landscapes on national and global scales. Though often devastating, wildland fires naturally reduce fuels, preventing larger wildfires. However, their smoke can harm human health locally and globally. To understand its impact on air quality and health, quantifying the emissions released into the atmosphere is crucial.

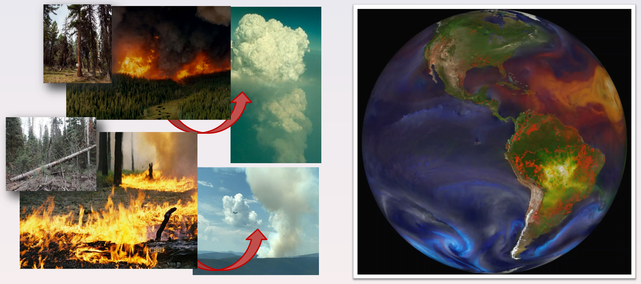


Figure 1: Fuel and fire weather are linked to fire carbon emissions and smoke plume detrainment heights. Fire emissions are transported in the atmosphere, which is linked to global processes. *Source (right): NASA SVS*

To accurately model fire emissions, understanding fuel characteristics and burning conditions is essential, as they vary with the fuelbed type and fire weather. For example, savanna fires have lower carbon loading and intensity but spread quickly, while boreal forest fires burn longer and release more carbon due to higher loading. Hotter, drier conditions increase fuel consumption and smoke plume heights. Fire weather and available fuel are key drivers of emissions.

Methodology: FIREX-AQ Proof of Concept

The Fire Influence on Regional to Global Environments and Air Quality (**FIREX-AQ**) 2019 campaign investigated the connections between: fire characteristics and emissions, chemical evolution of smoke, and downwind AQ and climate impacts. We calculated carbon emissions for each fire using daily fire weather, Fuel Characteristic Classification System (**FCCS**) fuels data, fire-detection based burned area, and GOES Fire Radiative Power to derive daily diurnal smoke emissions.

Calculating Carbon Emissions

FIREX-AQ Daily Fire Emissions Methodology

$C_t = A \times B \times F_c \times C_b$

where
A = Area Burned
B = Biomass Density
F_c = 0.5
C_b = Fraction of biomass consumed

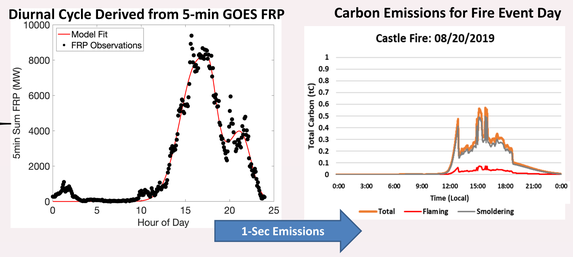


Figure 2: Emissions calculation showing the formula used (left), an example of a GOES satellite diurnal cycle used for distributing daily emissions (center), and resulting daily carbon emissions for one day sampled (right).

We calculated carbon emissions using:

A) burned area, calculated using active-fire detections (VIIRS and MODIS) for NRT estimates;

B) biomass density, derived from FCCS 30-meter fuelbeds;

Fc) biomass carbon fraction is assumed is to be 50%; and

C) the fraction of biomass consumed, is based on the fire weather maps provided by the United States Forest Service

Area Burned

Burned area was calculated using active VIIRS and MODIS fire detections, buffered to 375m or 1000m diameter, respectively, and overlaid on previous days' buffered detections.

Residual burned area: Previously burned area continuing to smolder.

New burned area: Newly ignited area burning, mostly flaming with some smoldering.

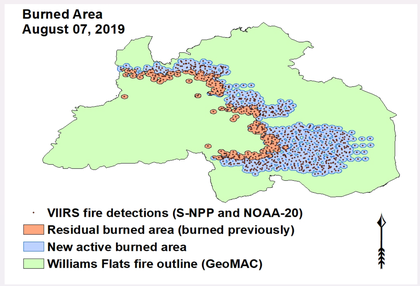


Figure 3: An example of burned area for one day of a fire (Williams Flats)

Biomass Density

The Fuel Characteristic Classification System (**FCCS**) is a 30 m resolution product with over 250 fuel types across the U.S., each fuelbed having unique biomass loading values based on canopy, wood, shrub, ground, and herbaceous biomass.

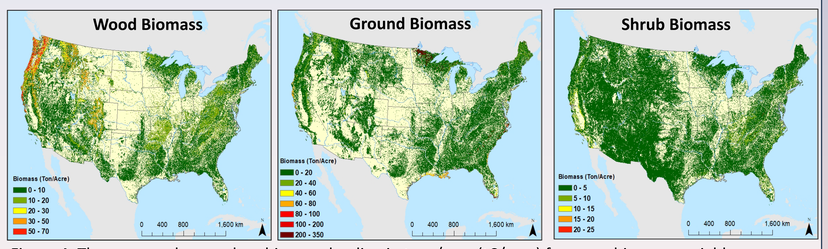


Figure 4: These maps show carbon biomass loading in tons/acre (tC/acre) for some biomass variables

Biomass Consumption

Consumption (tC/acre), for five Fire Danger categories (Low, Moderate, High, Very High, Extreme) is calculated using the following table of biomass burn percentage, for both 'new' and 'residual' burn.

Percentage of Fuel Burned in each Fire Weather Category
New (N) burned area and previously burned Residual (R) area

Variable	Extreme N/R	Very High N/R	High N/R	Moderate N/R	Low N/R
Canopy_avai_load[1]	90 / 5	80 / 5	60 / 5	10 / 0	0 / 0
Shrub_tpa_biomass[2]	100 / 0	80 / 5	60 / 5	40 / 5	20 / 5
Herb_tpa_biomass[2]	100 / 0	80 / 5	60 / 5	40 / 5	20 / 5
Wood_tpa_biomass[3]	20 / 40	10 / 20	10 / 20	10 / 10	10 / 5
LLM_tpa_biomass[4]	100 / 0	80 / 5	60 / 5	40 / 5	20 / 5
Ground_tpa_fuel[5]	20 / 40	10 / 20	10 / 20	10 / 10	10 / 5

[1] Total available canopy fuels, including tree crowns, C2/C3 snags, and ladder fuels (excluding tree boles and C1 snag wood). [2] Includes aboveground shrub/herbaceous biomass. [3] Total combustible wood, including downed wood, rotten and lightered stumps, and piled wood. [4] Litter, lichen and moss biomass. [5] Ground fuels including duff, basal accumulations and squirrel middens. Source: FCCS (Ottmar et al., 2004, Prichard et al., 2019); Soja et al., 2004; Pierce et al., 2007; Petrenko et al., 2012.

Continuous raster layers of fuel consumption potential under each fire category were created. Here we show "new" burn fuel loading. As fire danger becomes more extreme, the availability of fuel to burn increases correspondingly.

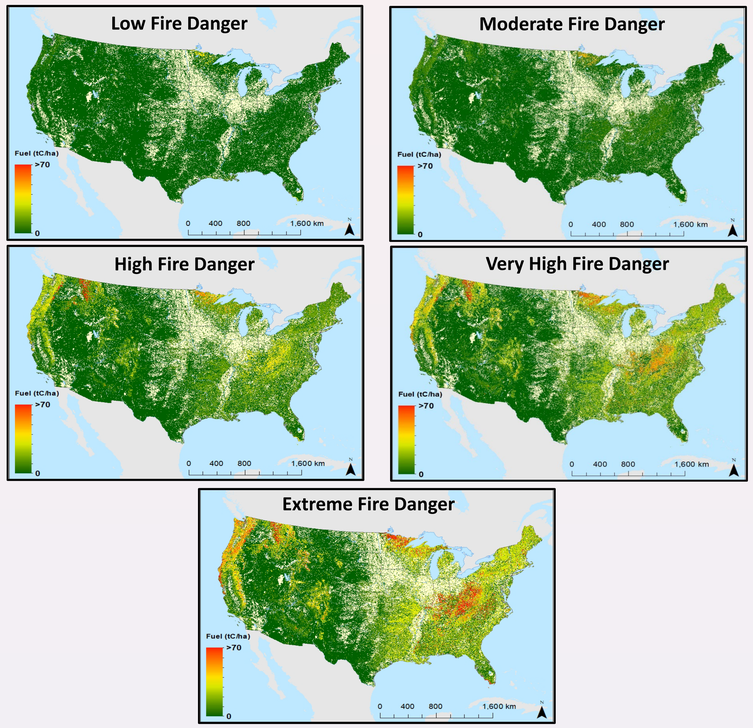


Figure 5: Resulting Fuel loading data layer for each fire danger category under 'new' burning conditions.

Emissions Comparisons

When comparing our emissions with in-situ aircraft data (daily fire average total carbon emissions rate and total particulate matter emissions rate), multiple manuscripts demonstrate our emissions have the best agreement.

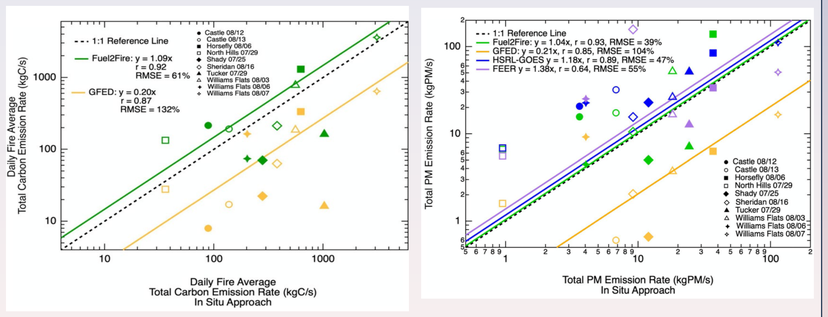


Figure 6: Total carbon emissions comparisons with in-situ aircraft data for FIREX-AQ. *Source: Wiggins et al., GRL 2020; Wiggins et al., JGR 2021; Stockwell et al., 2022*

Expanding to a Global Carbon Consumption Database

In response to the need to quantify global wildland fire emissions, we expanded our methodology to create a global consumption database linked to distinct fuels across fire danger categories, using the Pettinari (2015) Global Fuelbed database as the base for fuel loading.

Pettinari (2015) Global Fuelbed:

- a global fuel map with standardized FCCS biomass parameters
- Includes biomass variables such as total canopy, ladder fuels, shrub, duff, woody, etc
- ~300 m resolution
- 274 main fuelbeds, 359 when sub-fuelbeds considered

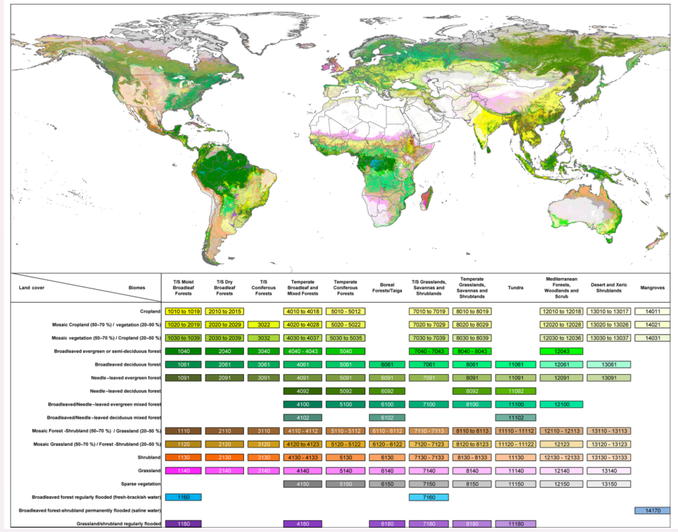


Figure 7: Pettinari & Chuvieco (2016) Global fuelbed map. The legend details the number of the fuelbeds, and the land cover biome that they represent. Source: Pettinari, M. L. and Chuvieco, E.: Generation of a global fuel data set using the Fuel Characteristic Classification System, Biogeosciences, 13, 2061–2076

- We apply the same Fuel Decision Table for allocation of New:Residual percentages for each biomass variable
- We will allocate less fuel to previously burned areas
- Final 300 m product will contain tC released under each of 5 fire danger levels and for new vs residual burning. Fire danger categories are 5 relative quintiles.
- Global product will be made publicly available

This product serves as a valuable tool when used in conjunction with burned area data to rapidly estimate the carbon consumed and released into the atmosphere.

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