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Interactive comment on "Contiguous United States wildland fire emission estimates during 2003–2015" *by* Shawn P. Urbanski et al.

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Referee #2 Comments and Authors' Responses

Specific comments

RC1. A large number of fuel, fire, and other sources are used when estimating fire emissions based on Eq.1. It would be helpful to provide a diagram to summary the major sources and connections.

AR1. We have added a diagram which summarizes the main steps of the inventory methodology and highlights the connections of the multiple datasets to the process. The diagram has been added as Figure 1. The text in Sect. 2.1 has been revised (Page 4, Line 14) with the insertion of the following sentence:

"The MFLEI biomass burning emission model is based on Eq. (1), given below, and the implementation and datasets are summarized in Figure 1."

Figure 1 has been included as jpg attachment with this response

RC2. Comparisons are provided between this inventory and several previous ones in the introduction section. It would be useful to briefly compare the results, especially with the previous daily inventory.

AR2. We have added a section comparing MFLEI with three other emission inventories that are mentioned in the introduction section: GFED, FINN, and WFEIS. The revised text is given below. Two figures and two tables have been added as part this revision and have been attached as jpg and pdf.

3.6 Comparison with other emission inventories Next we compare the estimated fuel consumption and PM2.5 emissions of MFLEI with three fire emissions inventories: GFED v4.1s (GFED, 2018), FINN v1.5 (FINN, 2018), and WFEIS v0.5 (WFEIS, 2018). In this comparison we have excluded fuel consumption and PM2.5 emissions associated with agricultural burning from all three inventories. Regional annual fuel consumption from the four inventories is plotted in Figure 21. Statistics comparing MFLEI regional annual fuel consumption versus the other inventories are given in Table 11. There is significant variability in the agreement between MFLEI and the other inventories. Across the west (NW, CA, SW), MFLEI annual fuel consumption is well correlated with both FINN and GFED (Table 11). MFLEI fuel consumption exceeds the mean of FINN, GFED, and WFEIS in nearly all years and is generally the highest in Northwest and Southwest regions (Fig. 21a). In the east regions (SC, SE, NO), MFLEI fuel consumption fluctuates about the FINN/GFED/WFEIS mean value (Fig. 21b). In terms of variability and mean absolute relative difference, MFLEI agrees best with GFED. Regional annual PM2.5 emissions are shown in Figure 22 and statistics comparing MFLEI PM2.5 emissions versus the other inventories are given in Table 12. As with fuel consumption, across the west (NW, CA, SW), MFLEI annual PM2.5 emissions are well correlated with both FINN and GFED, while correlation with WFEIS is weak in most regions (Table 12). In the west, MFLEI annual PM2.5 emissions are highest among the inventories in most years (Fig. 22a). The greater PM2.5 emissions of MFLEI in the west are partly attributable to the use of a larger EFPM2.5 for western forests (22.8 g kg-1, Table 9) compared with FINN (12.9 g kg-1), GFED (12.6 g kg-1), and WFEIS (11.9 g kg-1). (Because WFEIS uses combustion phase dependent EFs applied in a non-transparent manner, we have taken EFPM2.5 as the ratio of the sum of EPM2.5 to the sum of fuel consumed for all western forests.) MFLEI uses EFPM2.5 from the synthesis of Urbanski (2014) that accounts for the lower MCE measured for wildfires in western conifer forests (Urbanski, 2013). FINN and GFED use EFPM2.5 from Akagi et al (2011), with updates from May et al. (2014), which are based on emission measurements of prescribed fires, most of which occurred in the Southeast US. WFEIS employs EFPM2.5 measured for prescribed burns of logging slash. The higher EFPM2.5 used by MFLEI for wildfires in western forests is consistent with recent emission measurements of Lui et al. (2017). In a study of western US wildfires, Lui et al. (2017) reported an average EFPM1 = 26.0 g kg-1 (PM1 = particulate matter with an aerodynamic diameter < 1 μm), more than 2 times the EF for prescribed fires.

RC3. This new inventory provides daily emissions. Surface fuels at 10- and 1-hr vary at this scale. Why fuel moistures of 1000-h and 100-h rather than 10- and 1-hr fuels are used?

AC3. We estimated fuel consumption of grass, shrubs, and down dead wood using the natural fuel algorithms from the CONSUME model. These CONSUME algorithms simulate consumption completeness independent of fuel moisture for grass, shrubs, and down dead wood in the 1-h (< 1 cm diameter), 10-h (1-2.5 cm diameter), and 100-h (2.5-7.6 cm diameter) size classes. The CONSUME algorithms do use 1000-h fuel moisture and duff moisture for simulating combustion completeness for down dead wood in the 1000-h size class. Combustion completeness for litter was based on the FOFEM model, which for wildfires estimates litter consumption independent of

moisture content. We used the 100-h fuel moisture to estimate duff moisture based on Harrington (1982) (Page 13, L27 of manuscript). The duff moisture estimated from 100-h fuel moisture was used in the FOFEM duff consumption equations and in the CONSUME down dead wood equations that used duff moisture as a variable. The 1-h and 10-h fuel moistures are very important for estimating/simulating fire spread rates since fuels in these size classes, grasses, litter, and fine woody debris, are key drivers of fire spread (Albini 1976; Rothermel, 1972). Since MFLEI is a retrospective emission inventory we do not need to predict fire spread and therefore 1-h and 10-h are not used.

RC4. This inventory provides 250-m fire emissions. Fuel moisture is obtained from NFDRS station. What is the resolution of the NFDRS station and how could the resolution mismatch between the fire emission and NFDRS station affect the emission estimates?

AR4. The NFDRS stations are irregularly spaced (for current locations see https://www.wfas.net/index.php/fire-weather-stations-static-maps-43) and some stations operate/report data only during the station's regional fire season. The median distance between nearest NFDRS stations was ïĄ¿28 km.

If the fuel moisture regime was in error by one category (e.g. fuel consumption was modeled using 1000-h and duff moisture of "dry" regime, but actual conditions were "moist" regime) the error in total fuel consumption would range between +/- 2% and +/- 12%, depending on the forest type and direction of error in fuel moisture regime. For all years of the inventory, if the fuel moisture regime used was systemically one category lower (drier) than the actual moisture regime for all burned forest pixels, the overestimate in total forest fuel consumption would be ïĄ¿5%. Emission are directly proportional to fuel consumption.

RC5. It is indicated that MFLEI will be updated, with recent years, as the MTBS burned area product becomes available. MFLEI also uses other fire sources such as FOD. What would be the impacts if FOD is not updated in the future?

AR5. Dr. Karen Short, creator of FOD will be releasing an update with 2016 and 2017 at the end of this year (2018). If FOD is not updated beyond 2017, there would be a minor impact on MFLEI. We used FOD to include burned area from wildfires not captured by MTBS, GEOMAC, and MCD64. Over 2003-2015, 8% of total MFLEI burned area was attributable to FOD. In the future, if FOD is unavailable MFLEI would miss roughly 10% of wildfire burned area. MFLEI also used FOD to assign containment dates to MTBS fires and discovery dates to GEOMAC fires (recall MCD64 product provides the estimated day of burning for each pixel). Fortunately, discovery dates and containment dates are available for most MTBS and GEOMAC fires from one of five national databases (USDI Wildland Fire Management Information System, FWS Fire Management Information System, USFS Fire Statistics, USFA National Fire Incident Reporting System, and National Association of State Foresters). (In FOD, the information for ïĄ¿80% of all CONUS wildfires >10 acres was obtained from one of these five national databases (Short, 2014; Short, 2017)). If FOD is unavailable, we will extract much of the needed information from the five national fire databases listed above after consultation with Dr. Karen Short who developed FOD and is a USFS research colleague of the MFLEI team.

RC6. Subsection 3.5: The title includes “agricultural fires” but they are not discussed in this subsection. AR6. The title of subsection 3.5 has been changed to: “Prescribed fires” since agricultural fires are excluded from MFLEI and are not discussed in this section.

RC7. Section 5: It is more like a summary than conclusions.

AR7. We agree with the referee that Section 5 is largely a summary of the paper. However, we believe the content and tone is appropriate for a conclusion section of a dataset paper. We have reviewed the conclusion section of several papers published in ESSD and found ours to similar in content and tone, see for example e.g. Chuvieco et al., 2018, 10, 2015-2031. We have revised the Section 5 to mention the comparison of MFLEI with GFED, FINN, and WFEIS. The additional text is:

“A regional comparison of MFLEI with three fire emission inventories, FINN v1.5, GFED v4.1s, and WFEIS v0.5, showed MFLEI predicted significant greater PM2.5 emissions across the west, in part due to the use of a larger EFM2.5 for wildfires in forests.”

References Albini, Frank A. 1976. Estimating wildfire behavior and effects. Gen. Tech. Rep. INT-GTR-30. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 92 p. Available: https://www.fs.usda.gov/treesearch/pubs/29574

Rothermel, Richard C. 1972. A mathematical model for predicting fire spread in wildland fuels. Res. Pap. INT-115. Ogden, UT: U.S. Department of Agriculture, Intermountain Forest and Range Experiment Station. 40 p. Available: https://www.fs.usda.gov/treesearch/pubs/32533

Short, Karen C. 2017. Spatial wildfire occurrence data for the United States, 1992-2015 [FPA_FOD_20170508]. 4th Edition. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2013-0009.4

Short, K. C. 2014. A spatial database of wildfires in the United States, 1992-2011. Earth System Science Data. 6: 1-27.

Please also note the supplement to this comment:
https://www.earth-syst-sci-data-discuss.net/essd-2018-100/essd-2018-100-AC2-supplement.pdf

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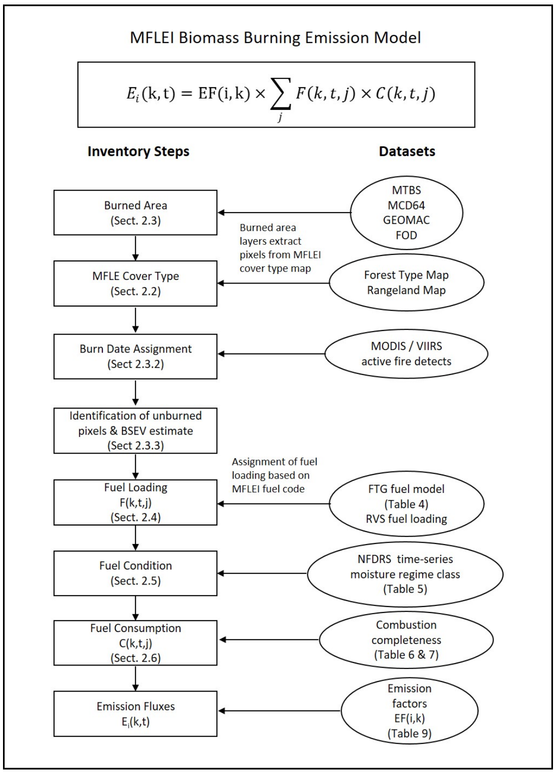
MFLEI Biomass Burning Emission Model
$$E_i(\mathrm{k,t}) = \mathrm{EF(i,k)} \times \sum_j F(k,t,j) \times C(k,t,j)$$
Inventory Steps
Datasets
Burned Area (Sect. 2.3)
MTBS
MCD64
GEOMAC
FOD
Burned area layers extract pixels from MFLEI cover type map
MFLE Cover Type (Sect. 2.2)
Forest Type Map
Rangeland Map
Burn Date Assignment (Sect 2.3.2)
MODIS / VIIRS active fire detects
Identification of unburned pixels & BSEV estimate (Sect 2.3.3)
Assignment of fuel loading based on MFLEI fuel code
Fuel Loading F(k,t,j) (Sect. 2.4)
FTG fuel model (Table 4)
RVS fuel loading
Fuel Condition (Sect. 2.5)
NFDRS time-series moisture regime class (Table 5)
Fuel Consumption C(k,t,j) (Sect. 2.6)
Combustion completeness (Table 6 & 7)
Emission Fluxes E_i(k,t)
Emission factors EF(i,k) (Table 9)

Fig. 1.

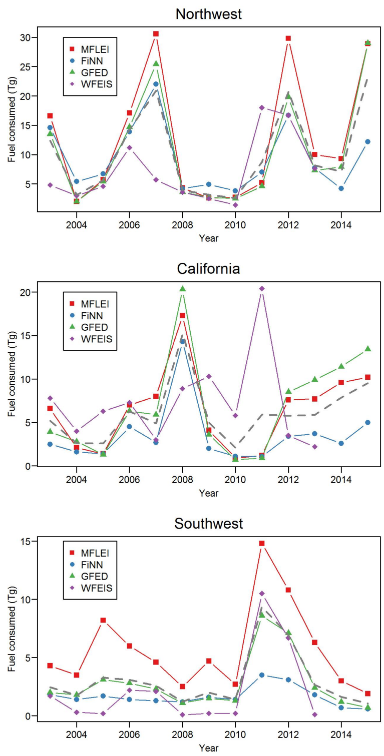
Northwest
California
Southwest
MFLEI
FiNN
GFED
WFEIS
Fuel consumed (Tg)
Year
2004
2006
2008
2010
2012
2014

Fig. 2.

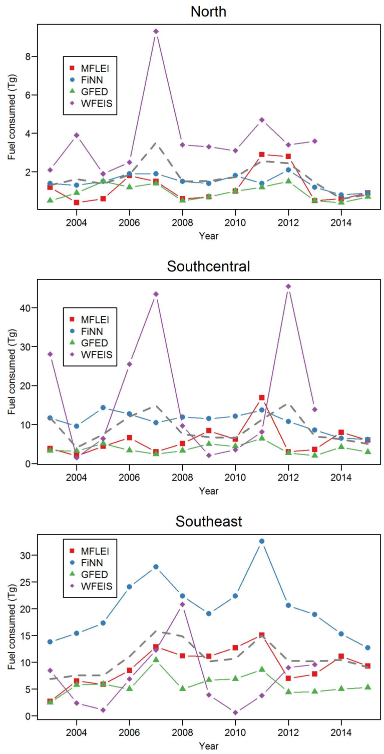
North
Fuel consumed (Tg)
MFLEI
FiNN
GFED
WFEIS
Year
Southcentral
Fuel consumed (Tg)
MFLEI
FiNN
GFED
WFEIS
Year
Southeast
Fuel consumed (Tg)
MFLEI
FiNN
GFED
WFEIS
Year

Fig. 3.

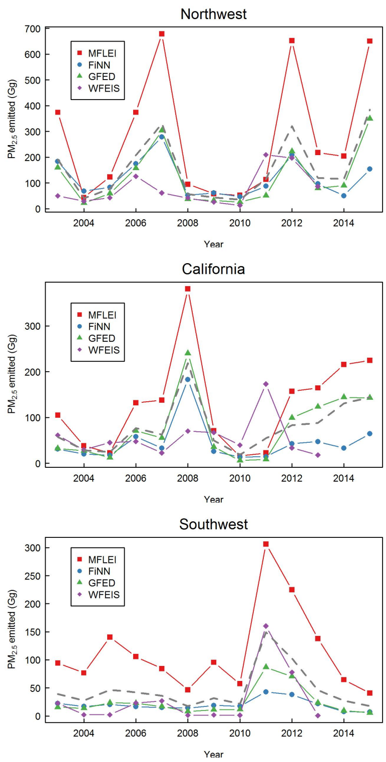
Northwest
$PM_{2.5}$ emitted (Gg)
MFLEI
FiNN
GFED
WFEIS
Year
California
$PM_{2.5}$ emitted (Gg)
MFLEI
FiNN
GFED
WFEIS
Year
Southwest
$PM_{2.5}$ emitted (Gg)
MFLEI
FiNN
GFED
WFEIS
Year

Fig. 4.

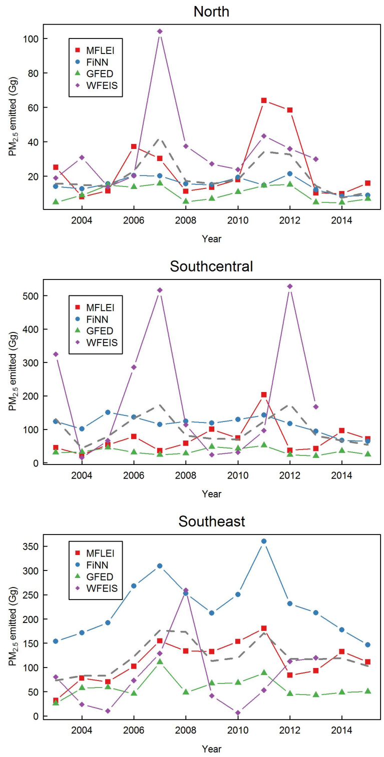
North
MFLEI
FINN
GFED
WFEIS
PM2.5 emitted (Gg)
Year
Southcentral
MFLEI
FINN
GFED
WFEIS
PM2.5 emitted (Gg)
Year
Southeast
MFLEI
FINN
GFED
WFEIS
PM2.5 emitted (Gg)
Year

Fig. 5.