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Interactive Comment

Interactive comment on "The Wildland Fire Emission Inventory: emission estimates and an evaluation of uncertainty" *by* S. P. Urbanski et al.

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The Wildland Fire Emission Inventory: emission estimates and an evaluation of uncertainty S. P. Urbanski, W. M. Hao , and B. Nordgren

Response to comments by Anonymous Referee #1

We thank Referee #1 for the helpful comments. The referee's comments have helped improve our manuscript. We describe our response to Referee #1 and propose specific changes to manuscript.

In the following text "R" refers to referee comments and "A" refers to the authors' response.

General Comments:

R1. PM2.5 and CO emissions are useful; however, why wasn't the emissions of other important compounds calculated? Are these available?

A1. We present emissions for CO and PM2.5 as one or both of these are common to other published biomass burning emission inventories. They are also useful for analyses involving remote sensing, e.g. CO from MOPPIT / AIRS and AOD from MODIS. We are waiting on the publication of a large dataset of wildfire EF before we expand our inventory. We have decided to wait based on reasons regarding NMOC – MCE relationships as discussed in Section 4.5. Once the published data is available for wildfire EFs we will expand our inventory and it will be made publicly available through the U.S. Forest Service National Data Archive: (http://www.fs.usda.gov/rds/archive/).

R2. The authors present a robust analysis of the uncertainties in the wildfire emissions estimates. The analysis of these uncertainties across temporal and spatial scales is particularly valuable. If one is to apply this model or emissions, is there a recommended set of model combinations (e.g., fuel loadings and consumption models) that the authors suggest, or is a user to run the ensemble of options and use the mean values? It is not entirely clear what is to be used in air quality applications. As a follow to that, in the tables that present the annual results by state (Tables 2-5), are these the annual mean values?

A2. We use the mean of the model combinations of fuel loadings and consumption models as the best estimate of the true fuel loading consumed, as stated at 23367-9: "At each element of the $g_{\Delta x,\Delta t}(k,t)$ we aggregated base resolution FLC data (500 m and 1 day) and used the mean of the four predictions as the best estimate of FLC (μFLC, Table 1)."

We believe modelers using the data are best able to select the resolution most appropriate for their application. The horizontal aggregation scales used in this study were selected based on a survey of published atmospheric chemistry studies. We se-

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lected dx of 10 km and 25 km based on guidance of the U.S. EPA which for air quality modeling recommends a horizontal grid resolution of $\leq$ 12 km for ozone and PM2.5 National Ambient Air Quality Standards and of 36 km for Regional Haze (U.S. Environmental Protection Agency, Guidance on the use of models and other analyses for demonstrating attainment of air quality goals for ozone, PM2.5, and Regional Haze, EPA-454/B-07-002, 2007).

The state level data in Tables 2 – 5 are annual sums. The text in Sect. 3.1 describes the Tables 2-5 at 23370-6 as: "The annual sums and uncertainties of A, FC, ECO, and EPM2.5 for each of the 11 states are provided in Tables 2 through 5."

We have modified the descriptions of Tables 2-5 to clearly identify the data as such. In the description of each Table 2-5 we have inserted the text "Annual sums of" before "state level".

R3. Although this emissions model is applied to the western U.S. only for this particular study, the authors also state that this model can be used elsewhere. However, I understand that FOFEM and CONSUME are constrained for use with fuel maps that have been specifically developed for the U.S. (as are the maps of fuel loadings applied here). Can the authors comment on how this can be applied in other regions?

A3. The reviewer is correct that CONSUME & FOFEM were developed for use with fuels found in the US. Further, the fuel maps that were used in this study, FCCS & FLM, are only mapped for the US. In this study we applied the model to the western US, however it could be easily expanded to cover all of CONUS and Alaska as FLM & FCCS maps are available for all of the US. The FCCS fuel models for Alaska & the northern lower 48 could be applied to Canada by cross walking Canadian fuel or vegetation maps to the FCCS fuel types. But this is not trivial. We do believe that the uncertainty/sensitivity analysis presented in our study may be applicable to BB EI globally. We have modified the text to reflect the reviewer's concern:

23354-26: Changed: "However, the algorithm and uncertainty/sensitivity analysis pre-

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sented here are applicable to BB EI for different regions of the globe." To: "However, the uncertainty/sensitivity analysis presented here may be applicable to BB EI for different regions of the globe."

R4. How consistent are the fuels maps used in CONSUME and FOFEM?

A4. The fuel consumption models CONSUME and FOFEM each used both the FCCS and FLM maps. We did not conduct a spatial comparison of the FCCS / FLM maps, however we discuss the variability of the fuel load consumed (FLC) combinations at the annual, domain wide scale in Sect. 3.2.1. This discussion and the accompanying Fig. 9 provide a measure of the consistency between the mapped fuel loads. Comparison of the results produced by the same fuel consumption model using the two different mapped fuel loads (FCCS, FLM) provides a measure of the consistency between the fuel maps (technically the mapped fuel loads): 23373-7 "For both fuel consumption models, the FCCS predicted FLC was always greatest and exceeded the FLM predictions by 37% to 189%."

R5. Why were only measurements from field studies used for the emission factors, and not laboratory studies? This study developed best estimates for emission factors of CO and PM2.5 from forested and non-forested landscapes. What were these? It would be interesting to see the PDF for the EFs that were applied in the uncertainty analysis.

A5. This study focused on emissions of CO and PM2.5. The EF for CO is highly dependent on the relative fractions of flaming and smoldering emissions, often quantified with the modified combustion efficiency (MCE). Fires conducted in laboratory experiments often burn with a different average MCE than fires burning in the natural environment (Akagi et al., 2011). Therefore, we chose to use only EFCO from field measurements from the burning of forest and non-forest fuels in the natural environment in CONUS. We note that laboratory measurements of EFX vs MCE can be used to estimate the emissions of many gas phase compounds in the natural environment if the typical fire average MCE of the natural fire is known. Using laboratory based MCE – EFX is

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extremely useful when appropriate field measurements of a compound x are not available, but field measurements of MCE are. When we expand WFEI to include additional compounds, in particular NMOC, this approach will be used. Akagi et al. (2011) noted that dilution/cooling regime of laboratory fires may be very different from that for fires in the natural environment. They postulate that such differences may lead to different rates of secondary particle formation, and hence different EFPM2.5, between lab and field plume as they are injected into the atmosphere. We have therefore chosen to use only field measurements for EFPM2.5 in this study.

We used the mean (μ) of the pdfs derived from the literature dataset as our best estimates of EFCO and EFPM2.5 for forest and non-forest cover types. This is stated in Sect. 2.2.5 Emission factor uncertainty, but we should have stated this in Sect. 2.1.5 when the EFs are first discussed. We have corrected this mistake by modifying the text as follows at 23362-10: "The statistical variability of each EF (CO or PM2.5, forest or non-forest) was determined by fitting log-normal and normal distributions to the source data. For each EF, the μ from the fitted distribution was taken as the best estimate of EF. The best estimates for EFs are given as the μ of the pdfs in Table 1."

Given the length of the manuscript we decided to only include the pdf types and fitted parameters (Table 1) in the paper. We agree that the EF datasets used to derive the pdfs in this study should be made available. We plan to make the emission inventory and EF datasets publicly available. We are waiting on the publication of a large dataset of wildfire EF so we expand our inventory to include additional species. Once the published data is available for wildfire EFs we will expand our inventory and it will be made publicly available through the U.S. Forest Service National Data Archive: (http://www.fs.usda.gov/rds/archive/).

Specific Comments:

R6. Page 23356, lines 29-31: How much difference does it make to have the contextual filter for the burn scar detection changed to 3km and 5 days (from 5km and 10 days)?

A6. The bias in the improved algorithm used in this study was 7% (23365, lines11-14) compared to 36% in the original algorithm. We have modified the text as follows at 23357-3: We have changed: “These improvements were proposed in Urbanski et al. (2009a) and their implementation has eliminated the overestimation of burned area in the original mapping scheme.” To : “These improvements were proposed in Urbanski et al. (2009a) and their implementation has largely eliminated the overestimation of burned area in the original mapping scheme. The previous algorithm has a bias of 36% (Urbanski et al., 2009a) while the bias of the improved algorithm used in this study has a bias of 7% (Sect. 2.2.3).”

R7. Page 23366, Equation 2: How was this relationship developed? Is it defined within one of the references cited?

A7. The development of Equation 2 is described in Appendix A. The form of Equation (2) was based on Giglio et al. (2010) and the parameterization and evaluation of the equation’s goodness of fit followed the approach used by Urbanski et al. (2009a). We have added the following text at 23366-14: “The development of Eq. 2 is described in Appendix A.”

R8. Page 23367, line 9: How were the data aggregated to the different scales?

A8. The FLC data were aggregated by summing each of the four FLCi,j at each grid cell and time step and then taking the average of the four sums. At 23367-9 we have modified the text to read as follows: “At each element of the gΔx,Δt(k,t) we aggregated base resolution FLC data (500 m and 1 day) by summing each of the four FLCi,j at each grid cell and time step and then used the mean of the four predictions as the best estimate of FLC (μFLC, Table 1).”

R9. Page 23373, line 17: What is FLM 011?

A9. As discussed in Sect. 2.1.2, the FLM were developed based on the anticipated fire effects (fuel consumption, emissions, and soil heating) of the fuels and are not based

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on vegetation type. Therefore, the FLMs cannot be easily described in terms of a vegetation type, e.g. Ponderosa-pine forest. FLM011 is a fuel model that has minimal litter and fine woody debris and median duff and coarse woody debris loadings of approximately zero. Due to the low fuel loading FLM011 produces little emissions and minimal soil heating (Lutes et al., 2009).

R10. Discussion section 4.1: in this section, are you discussing a particular scenario, or the mean of the all of the simulations?

A10. We used only one emission scenario, but we aggregated the emissions at different spatial and temporal scales to evaluate the variability and uncertainties.

R11. Page 23377, line17: Change to “inventories (BB EI) that cover”

A11. We have changed text at 23377-17 to: “inventories (BB EI) that cover”

R12. Page 23382, line 25: Remove the extra “in” and change “this” to “these”

A12. We have changed the text accordingly.

References Akagi, SK, Yokelson, RJ, Wiedinmyer, C, Alvarado, MJ, Reid, JS, Karl, T, Crounse, JD, and Wennberg, PO, Emission factors for open and domestic biomass burning for use in atmospheric models, Atmos. Chem. Phys., 11, 4039-4072, 2011.

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