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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Combustion efficiency and emission factors for US wildfires" *by* S. P. Urbanski

Anonymous Referee #3

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The manuscript presents so far unpublished high-quality aircraft measurements of CO2, CO and CH4 from three large wildfires and one prescribed fire in mixed conifer forests of the northwestern United States. From these measurements, the author calculates emission factors (EF) for these species and analyses the relationship between observed modified combustion efficiency (MCE) and EFCH4. The author uses fuel consumption and MCE measurement data from 18 prescribed fires described in literature to statistically explore the linear relationship between the ratio of heavy fuels consumption and MCE. By combining the average MCE measured in this study with linear EF-MCE relationships found for temperate conifer-dominated forests in other studies, wildfire EF for 14 additional species are estimated. The author concludes that fuel composition is an important driver of variability in MCE and EF, and that wildfires, due to a higher fraction of large diameter fuels consumed, predominantly burn with

lower MCE than prescribed fires. The author further concludes that the application of EF from prescribed fires for estimating emissions from wildfires will lead to significant underestimates of emissions typical for smoldering combustion (low MCE fires), such as PM2.5 and NMOC.

The emission characteristics of wildfires in temperate forests and the differences to prescribed burns are still poorly described in literature. The manuscript provides valuable information to improve emission inventories from these fires. The manuscript fits well into the scope of the journal and I recommend it for publication in ACP provided that it is substantially revised.

First of all, I agree with the comments on this manuscript by the reviewers #1 and #2 that the interpretation and discussion misses a well-defined scope and clear statements on the uncertainty and transferability of the measured factors for estimating temperate wildfire emissions in general. Suggestions already made by the reviewers #1 and #2 will not be repeated here.

Secondly, the presentation and discussion section of the new CRDS measurement data, which I consider of key value for this paper, is much too sparse. Thirdly, the structure of the manuscript is not well-arranged and needs to be improved.

A fourth aspect addressing the quality of writing: In my opinion, it must not be the task of the reviewers assigned by ACPD (which mostly – so also me –are not native English speakers) to correct for the numerous punctuation and grammatical errors contained in this manuscript (some examples: P41L21: "Frequent, in-flight, calibrations" (superfluous commas); P42L18: "throughout the perimeter interior" (correct: perimeter's interior); P43L9: "emission factors for the each compound" (correct: emission factors for each compound); P43L12: "while, the second approach (Eq. 2) used" (superfluous comma); P43L22: "therefore our neglect other carbon-containing species" (correct: our neglect of other); P57L17: "and in the case of one fire, a previous burn." (missing comma before "in case"); P5712: "An examination of results [. . .] show a clear

trend" (correct: shows); P57L24: "This observation suggests the comparatively low MCE [...] from" (missing "that" after "suggests"). Please ensure that native speaking internal reviewer (e.g. one of your colleagues at your institute) reads carefully through your manuscript before resubmitting.

1 General aspects

–> The abstract is too lengthy containing detailed introductory remarks and a detailed presentation/interpretation of results. Please restrict the abstract to the key information. Please add a sentence defining the aim of the study.

–> Two key hypotheses of this paper are that emission characteristics of prescribed burns differ from those of wildfires in temperate conifer-dominated forests of western US and that prescribed fires, due to the lower fraction of large diameter fuels consumed, are expected to burn with more flaming combustion than wildfires and therefore have lower EF values for species characteristic for smoldering combustions, such as CH4. It is confusing that the hypotheses are somewhat subverted by the measurement results, namely in that the measured emission characteristics of the prescribed fire shows no distinct differences to the three wildfires. In fact, the prescribed fire exhibits the lowest MCE and the highest EFCH4 of all nine fire-day averages in Tab. 2, contradicting the second hypothesis postulated in this paper. The author argues that the prescribed fire was burning during the wildfire season and can therefore be treated as wildfire. This implies that only prescribed fires burning outside the wildfire season exhibit emission characteristics different to wildfires. Wouldn't it then make sense to rather discriminate between temperate fires during and outside the wildfire season? The author compares and discusses the wildfire result to measurements of prescribed temperate fires without addressing their timing. It is very important that these aspects are clarified in detail.

–> In the beginning of the introduction, a clear definition of both fire type categories (prescribed fires and wildfires) is missing. Please explain in more detail the differences

between them, e.g. in terms of temporal and spatial patterns (e.g. what a fraction occurs during the wildfire season), fire size, fuel and combustion characteristics (e.g. loading, arrangement and moisture of fuels, fire intensity). The emission factors presented in this study are of high value for those working on establishing regional to global scale biomass burning inventories. Please provide some guidance on how to discriminate between wildfires and prescribed temperate fires on these spatial scales and how to best apply the emission factors derived in this study.

–> Principally, I find the structure of this manuscript hard to read as the individual sections (introduction, methods, results/discussion) are somewhat mixed up. Please put some effort to improve the clearness of the manuscript.

2 Detailed/technical aspects

–> P36L15: Please consider rephrasing (e.g. "the individual contribution of wildfires or prescribed fires") since the contribution of prescribed fires to O3 related air quality degradation is as difficult to quantify as of wildfires.

–> P38L27: Please explain the reason why you introduced fire-days (sample number for statistics).

–> P39/40 (Methodology: Site descriptions): Please provide detailed statistics what fuels burned in each site (fraction grassland, tree species, including a best-guess estimate of the fraction of large diameter fuels burned), preferably in a supplementary table or chart. Please integrate the specific fire weather/fuel moisture situation at each site (Table 1) into the text. How did the sites differ in terms of all these parameters? Please also provide approximate coordinates for each site. To improve the structure of the paper, please move the description of the Saddle Complex Fire (P45L13-21, including Fig. 1) into this section.

–> P41L4: Since the results of the H2O measurements are not presented or discussed in this study, there is no point of mentioning them.

–> P42/43 (Methodology: Airborne sampling): Please explain in detail how you defined a sample run. Please also add more information on the airborne sampling procedure and conditions for each fire/fire-day (wind conditions, plume height, transect characteristics). To improve the structure of the paper, please move the description of the sampling of smoke from the Saddle Complex Fire (P45L21-P55L2) into this section.

–> P43L7: Please specify if EMR refers to the volume or mass mixing ratio.

–> P44L4 (Equation 2): The differences in the results using Equation 2 compared to Equation 1 are addressed in a single sentence only (P46L9/10). In my opinion, there is no point of presenting Equation 2 without presenting the individual results. Please consider showing the individual results of both equations or removing Equation 2 and modifying P46L9/10 into e.g. “The fire-day average EF (Eq. 1) agreed within 10% with the EF that were calculated from zero-forced linear regression of the emission ratios of the 2 s data points”.

–> P44L5-P55L10: This section primarily contains a more general reasoning on the differences between flaming and smoldering emission characteristics and of the usability of MCE to differentiate between both combustion modes. It should thus be partly moved to the introduction section.

–> P45/46 (Results and discussion: Emission measurements): Please describe and discuss the results of the emission measurements individually for each fire/fire-day and in comparison to each other. Please also incorporate the individual fire characteristics (Tab. 1) into the discussion. Please also address the observed variability in the measurement data, e.g. EFCO spans from 89 to 173 g kg-1. How do you explain this large variability?

–> P46L3: According to Tab.2, SC2402 has a smaller number of individual measurement points (namely n=55) than actually shown in Fig. 2 (namely n=63). Please explain this difference. More principally: How robust is your analysis in respect to your definition of a sample run?

–> P50L4-P51L10: This section provides information on the methodology used to derive EF for species not measured in this study. Please consider moving this section to the methodology section.

–> P53-P56: This is a nice literature analysis on the relation between CWD, fuel moisture and MCE (or EF). While it is well readable, it is a bit lengthy – please try to condense this section.

–> P69 (Table 1): The line arrangement in the table is not correct. Is it typographical error that the daily burned area growth rate of the Hammer Creek fire on Aug. 22 is 0 ha? The description of the fire activity is much too casual and needs some refinement.

–> P70-71 (Table 2): In this table, you provide the study average of the individual fire-day averages and the fire day averages calculated from the average of the sampling run averages. I would also like to see the summary statistics of the individual 2s data. Please display the study average EFCO value with one decimal number.

–> P72 (Table 3): Why are the average EF values for CO2 and CH4 different to the study average values in Table 2 (EFCO2=1600 g kg-1 in Table 3 but 1596 g kg-1 in Table 2)?

–> P73 (Table A1): Please add, if possible, information on the fire season and the fuel moisture.

–> P74 (Figure 1): please specify to what date the MODIS Burn Scars and Hotspots refer to.

–> P75 (Figure 2): Helpful would be to see the MCE as additional variable.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 33, 2013.