Manuscript Review

Title: Emissions from prescribed fire in temperate forest in south-east Australia: implications for carbon accounting

General Comments

This paper presents a study that measured emission factors (EF), fuel load, and carbon content for different fuel types from a temperate forest (Eucalyptus) in south-eastern Australia. The measurements are used to estimate direct carbon emissions due to the application of prescribed fire. The carbon emission estimates derived from the studies measurements are compared to estimates based on less specific input and other methods.

Emission ratios (Table S3) and emission factors (Table 4) for the pooled species (CH_4, NMHC and PM) are dramatically at odds all of the biomass burning EF literature of the last 20-30 years!

First, the pooled species are described as the sum of CH_4, PM and non-methane hydrocarbons (NMHC), however the in the analysis used the pooled species represent all carbon containing species other than CO_2 and CO, organic compounds (volatile and semi-volatile organic compounds) and PM. In biomass smoke a significant fraction of emitted carbon is present in oxygenated organic compounds (e.g. methanol, formaldehyde, furan, …,) that are not hydrocarbons (see Akagi et al., 2013) and the authors should have described the gas portion of the pooled species as VOC or simply organic compounds.

Improper terminology aside, the pooled EF (g-C/g-C) reported in this study are for the most part far higher than that inferred from virtually all previous studies that I am familiar with (e.g. ….).

The median of the EFpooled reported in Table 4 is 0.23 g-C/g-C with maximum of 0.97 gC/g-C. The pooled emissions account for 24% of carbon emitted on average with a maximum of 43% (leaf litter – Oliver). For comparison one may use the laboratory measurements reported in Yokelson et al. (2013). This study combined multiple instruments and methods (open path FTIR spectrometer, proton-transfer-reaction mass spectrometry (MS), proton-transfer ion-trap MS, negative-ion proton-transfer chemical ionization MS, and gas chromatograpghy with MS to measure emissions of over 300 compounds for large scale laboratory burns of forest and chaparral fuels. The supplemental material for Yokelson et al. (2013) supplemental includes EF for CO_2, CO, CH_4, over 300 organic gases, and PM2.5 for 25 lab burns of forest fuels. Following conversion of these EF from units of g/kg to units g-C/g-C it may be found that the sum of the EF for PM2.5, CH_4, and all organic gases (>300 species) has a median of 0.039 g-C/g-C with a range of 0.008 to 0.139 g-C/g-C. The percent of emitted carbon contained in PM2.5, CH_4, and all organic gases averaged 3.8% with a range of 0.7% to 13.6%. The EF data from Table 4 of the manuscript and from the supplemental material of Yokelson et al. (2013) are summarized in Table 1 below.

In this manuscript the pooled EF and the fraction of emitted carbon in pooled species are far higher than observed in the comprehensive study of Yokelson et al. (2013). The Yokelson et al. (2013) is consistent with previous and subsequent EF reviews (Andreae & Merlet, 2001; Akagi et al., 2011; Urbanski 2014) and field and laboratory studies (e.g. Burling et al. 2010; Burling et al., 2011; Akagi et al. 2013). For a wide range of biomass burning, the fraction of carbon emitted in species other than CO_2 and CO is typically < 5% and rarely greater than 10%. In this manuscript the fraction of emitted carbon attributed

to species other than CO2 and CO is on average 24% (with maximum of 43%) and far exceeds what is found the previously published literature. The fact that the MCE of the burns reported in this study are relatively high (average =0.96) and therefore indicative of high efficiency burns with low PM and VOC emissions makes the pooled EF even less believable. If the authors were to conduct a similar comparison against EF data from other studies / reviews they would arrive at similar results. The authors simply made a comparison versus Hurst et al (1994b) and concluded without any justification that the discrepancies were due to PM. The authors clearly failed in their duty to seriously compare their findings to previously published work. I can only conclude that significant errors were made in the calculation of the pooled EF and this study is therefore seriously flawed and I recommend that is rejected for publication.

Table 1.				
	Average MCE	EF pooled[1] (g-C/g-C)		
		Median	Minimum	Maximum
Table 4	0.96[2]	0.24	0.00	0.97
Yokelson et al. (2013)[3]	0.935	0.039	0.008	0.139

[1]Labeled as sum of CH4, NMHC, PM in manuscript and is the sum of PMm2.5, CH4, and > 300 organic gases for Yokelson et al. (2013)
[2]MCE = $\Delta CO2/(\Delta CO + \Delta CO2)$ and was calculated from Supplemental Table 3
[3]Derived from EF reported in the Supplemental Material for 25 forest fuel burns

Additional Comments

Combustion analysis method
I find it very uncertain that the combustion analysis employed is a reasonable proxy for the following reasons:

For many of the fuel components (twigs, ground layer, understory, overstory) filling a 10 cm × 10 cm × 3 cm sample holder seems to be a great distortion of the structure and arrangement of the natural fuelbeds which should have a significant impact on the manner in which the fuel burn and the subsequent emissions.

The samples were combusted at a fixed irradiance of 25kW/m2 it is unclear how this approach replicates a natural free burning fire. It seems as though this approach could shift the combustion process towards flaming relative to natural fires.

2.3 Combustion analysis

A diagram of the combustion analysis set-up is needed.
It is stated that the mass of the samples were before burning and the mass of the residue after burning were recorded (P13817, L11-12). Was the carbon content of the fuel and residue also measured? It is unclear, but the laboratory combustion analysis should measure the mass and carbon content of fuel

prior to burning and the mass and carbon content of the post fire residue to derive $\Sigma C_{emit}/C_{fuel}$ for the carbon emission factor calculations (Eq. (1)).

2.4 Emission factors

Terminology is not consistent:
At P13818, L5 C_{fuel} is defined as "the total mass of carbon contained in fuel that is burnt", but the caption of Table 3 states: "C_{fuel} is the initial carbon content of fuel", the later which implies carbon fraction, mass C / total mass.

Specific Comments

P13811, L26-28: The authors should discuss more broadly factors that affect fuel accumulations such as disturbance history (previous land use, fire, insects, etc.), topography, and soils.

P13814, L14-15: The three fuel sampling plots at each were selected to have "similar slope and aspect". I suspect slope and aspect may have an important influence on the fuel loading as well as burning efficiency and possible fire severity. It seems that randomly locating the plots within the burn units to capture the variability of slope and aspect would have provided a better representation of the natural variability of emissions from prescribed fires in these forest types. Please comment.

P13814 – 13815: Sampling Protocol.
The ground layer and forest floor (decomposing litter, twigs, leaf litter) was sampled using destructive / disruptive methods and separate post-fire quadrants would be required to estimate fuel consumption. Please describe where the post-fire quadrants were located relative to the pre-fire quadrants. I recommend including a diagram showing the sampling design.

Please note if the "decomposing litter" included unidentifiable decomposing organic matter in the upper layer of soil that could be consumed by fire? I'm thinking of the 'duff' layer or organic soil layer typically found in Northern Hemisphere temperate and boreal forests. Is such a layer present and important in the forest examined in this study or Australian temperate forest in general? Please comment.

P13818: Define DeltaCO2, DeltaCO, etc. including units. Presumably these are molar mixing ratios as in Hurst et al. (1994b) but this must still be defined.

P13818: NMHC should be VOC (volatile organic compounds) as a significant fraction of emitted carbon is present in oxygenated organic compounds (e.g. methanol, formaldehyde, furan, …,) that are not hydrocarbons (see Akagi et al., 2013).

P13826, L11 -14: "Across the four sites, the mean proportion of fuel carbon lost to the atmosphere relative to the total amount of carbon ($\Sigma C_{emit}/C_{fuel}$) was 86 %. This is significantly less than the 97% suggested by Hurst et al. (1996). Hurst et al. (1996) based their analysis on the assumption that the carbon content of ash was constant at 6 %."

It seems that this is an invalid comparison as the Hurst et al. (1996) numbers alluded include forest fires of all types – clearing, prescribed, and wild while the current study examines only prescribed fires.

Technical Corrections

P13812, L2: Volkova and Weston (2013) reference missing from bibliography

P13812, L19: change "whether" to "demonstration that"

P13812, L23: change "shorter" to "longer"

P13812, L27 insert "that" between "burning" and "reduces"

P13815, L26-28: The sentence beginning with "sample" does not makes sense the text "and a subsample of pre-fire fraction ground" seems out of place. Insert "were" between "fraction" and "ground"?

P13862, L22: Eq. (4) predicts emissions not emission factors. Is this a typo? Should it cite Eq. (1)?

References
Andreae and Merlet (2001) Global Biogeochemical Cycles 15, 955-966
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