

***Interactive comment on* “Field determination of biomass burning emission ratios and factors via open-path FTIR spectroscopy and fire radiative power assessment: headfire, backfire and residual smouldering combustion in African savannahs” by M. J. Wooster et al.**

M. J. Wooster et al.

martin.wooster@kcl.ac.uk

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We welcome the details and positive comments provided by the referee.

- We now mention the limitation of the near ground OP-FTIR geometry in the Introduction, as suggested.
- We have removed the suggestion that Fernández-Gómez et al. (2010) suggested use

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of OP-FTIR for biomass burning studies...and instead quote their work alongside that of earlier researchers and Burling et al (2010).

- Parameterised changed to 'initialised' and the suggestion that the fit is iteratively performed is clarified.

- Each fire lasted around 30 minutes, and for each a single ambient SB spectrum measured toward the start of the fire was subtracted from all the measured spectra of that fire. Ambient temperature changes were small during the 30 minute period - so a single ambient spectrum was considered appropriate for use. We now report this in more detail in the paper - in a new Section (3.4.3) including the ambient temperature change during the fires, and the sensitivity of the column amounts and ER values to the specifics of the ambient spectrum (i.e. a comparison of results obtained when subtracting an ambient spectrum measured toward the end of the fire rather than at the start of the fire).

- Section 3.5.1. In our ER calculations, discussed in Section 3.5.1 we don't in fact assume the pre-fire amounts of each of the gases used to define the emissions ratio are zero - this is clearly not the case since for example the ambient pathlength amount of CO₂ measured pre-fire is a significant fraction (e.g. > 10%) of the amount measured during the fire (since CO₂ has a high ambient atmosphere concentration). Rather, the approximation made is that the volumetric abundances of the target species in the pure 'unmixed' plume (p) are much greater than those in the pure ambient atmosphere (a), so that $([Xp] - [Xa]) / ([Yp] - [Ya])$ can be considered a good approximation to $[Xp] / [Ya]$ for all species [X] and [Y] tested. We now quote the fact that values of [Xp] are orders of magnitude greater than [Xa] for all four species tested - and this allows this approximation (i.e. $[Xp] / [Ya]$) to provide a very good estimate of the true emissions ratio that would have been obtained had the full equation (i.e. $([Xp] - [Xa]) / ([Yp] - [Ya])$) been used for the calculation. There is therefore no explicit dependence of the error introduced by the approximation on f, and rather the dependence is on the relative abundance of the gases in the atmosphere and in the pure plume. The maximum error

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introduced by the approximation comes for gases whose concentration in the 'pure' plume is closest to that in the ambient atmosphere. For the gases we focus on, these are CO₂ (2500x higher conc in the plume than in the dry atmosphere) and CH₄ (1800x higher in the plume than in the dry atmosphere). In this 'worst case' the error introduced by the approximation is below 0.05% (including accounting for the fact that the molar ratio of WV in the plume is greater than in the ambient atmosphere). We will make this clear in the revised manuscript. Assuming the ambient concentration of the gases (i.e. that in the non-smoke polluted air) is constant, then removing the approximation and using the full equation simply means subtracting a constant from the measured pathlength amounts of both gases; and does not change the 'shape' of the distribution of points. For this reason, the approximation used in Section 3.5.1 is not responsible for the departure of the "low pathlength amount" points in Figure 6 from the general linear trend shown by the other points.

- Yokelson et al. (1997) reference corrected.
- FRE, measured in Joules, is linearly proportional to fuel consumption. FRP, measured in Watts, is proportional to fuel consumption rate.
- We now provide estimates of the addition fuel load provided by the elephant dung, calculated somewhere between 10% and 50% (Section 4.2)
- The few minor typos' and grammatical errors, and table/reference issues identified by the reviewer have also been adjusted.
- Reference to the different products and their production in the pyrolysis/flaming/smoulding phases has been added. We will highlight the fact that we are using the definitions of Yokelson et al (1996) in the updated manuscript. Specifically, as the referee is well aware, trace gas production from biomass burning is a complex process and many gases are emitted in each fire stage, and indeed in many fires stages are occurring at the same time in different parts of the combustion zone. Nevertheless, emissions are often categorized as being "dominant" in one of the three main phases

of combustion (pyrolysis, flaming, smouldering). CO₂ is the overwhelming product of biomass burning (by mass), and is emitted most strongly in the flaming phase where a good supply of oxygen and high temperatures can result in only relatively low amounts of other species being produced (Levine, 1994; Andreae and Merlet, 2001). Whilst CO₂ is still the main product (by mass) emitted in the smouldering stage, incomplete combustion is more prevalent and reduced gas species such as CO and CH₄ are emitted in much greater relative proportions in this stage than in the flaming stage (Levine, 1994; Andreae and Merlet, 2001). In the pyrolysis phase, Lobert and Warnatz (1993) indicate that during the drying/distillation process of vegetation pyrolysis, the water and volatile contents of the fuel are driven off, including the aldehydes. Formaldehyde is one of these volatile organic compounds (VOCs). Ingemarsson et al (1998) also measure formaldehyde during a specific study into vegetation pyrolysis. However, it is true that at the low temperatures involved in the smouldering phase of biomass burning, many of the incompletely oxidized products can be similar to those seen during the process of solid phase decomposition (Lobert and Warnatz, 1993). Nevertheless, in terms of species categorisation, in the widely quoted work of Yokelson et al (1996) they give the following definition, which we follow in the current paper:

CO₂ - flaming compounds; CO and CH₄ - smouldering compounds; CH₂O - pyrolysis compounds

References Yokelson, R. J., D. W. T. Griffith, and D. E. Ward (1996), Open-path Fourier transform infrared studies of large-scale laboratory biomass fires, *J. Geophys. Res.*, 101(D15), 21,067–21,080, doi:10.1029/96JD01800.

Ingemarsson, A., Nilsson, U., Nilsson, M., Pedersen, R. and Olsson, J. (1998) Slow pyrolysis of spruce and pine samples studied with GC/MS and GC/FTIR/FID, *Chemosphere*, 36, 2879-2889.

Lobert and Warnatz (1993) in their review of the combustion products of vegetation highlight that the drying/distilling phase of pyrolysis involves the removal of the water

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and volatile contents of the fuel (including the aldehydes).

Levine, J. (1994), Biomass burning and the production of greenhouse gases, in Climate Biosphere Interaction: Biogenic Emissions and Environmental Effects of Climate Change, edited by R. G. Zepp, pp. 139–159, Wiley, New York (available at http://asd-www.larc.nasa.gov/biomass_burn/biomass.html)

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