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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on “Water vapor release from biofuel combustion” *by* R. S. Parmar et al.

R. S. Parmar et al.

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We thank the reviewer for the thoughtful comments on our manuscript. Our replies to the comments shown in italics are given below. Text changes compared to the ACPD version are also indicated.

Comment 1: Page 4489, line 17: How do the E(mission)R(atio) estimates from this experiment compare to other studies ?

Response: We are not aware of similar concurring CO, CO2, and H2O gas phase emission measurements in literature we could compare to. For this reason we assumed a publication of the data to be useful. The emission ratios, however, imply fuel moisture contents which we compared to literature data (our text page 4485, middle paragraph) and found them to be consistent. This does not mean, that we expect them to fit exactly. As stated in the text, we reevaluated a data set and had no possibility to trace back to the fuel moisture contents of the combusted material when being burned. Please, see

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also reply to comment 3.

Comment 2: Page 4489, line 20: How does the storage time of the fuels affect the samples and fuel moisture content ? A short discussion may provide some insight.

Response: We have not investigated this in detail. We rely on Chuvieco et al. (2004). A decline in fuel moisture content is likely, of course. In tendency our data fit into such behavior. Savanna grass and musasa had beenwith us already for more than a year. The fuels with the fresh green needles were obtained from the forest 1 - 7 days before combustion.

Change of text: Old :The African fuels savanna grass and musasa, which had been stored for a long time, show fuel moisture contents of below 40%. Especially the fuels with fresh green needles have very high fuel moisture contents. New: The African fuels savanna grass and musasa, which had been with us already for more than a year, show fuel moisture contents of below 40%. An equilibration with ambient humidity may be assumed. In contrast, the fuels with the fresh green needles have very high fuel moisture contents, although there is a large natural variation. These fuels were obtained from the forest 1 - 7 days before combustion.

Comment 3: Page 4490, line 9: A fuel moisture content of 40% seems high for wildland fires, especially in dry climates. Maybe rephrase this statement or discuss in greater detail.

Response: We would like to clarify that the value of 40% is a quote of the work of Trentmann et al. (2006). We hope that our publication incites a discussion on whether this value is low or high. In the light of our results we understand this moisture content value as rather low as to what can be subjected to burns and what contributes to the effluents. We follow Van Wagner's statement (1977), which we had given in abbreviated form in our text on page 4485, lines 17-29, as "... foliar moisture content (FMC, his abbreviation) alone. In Canada, the conifer forests most liable to crown fire have FMC's from about 70 to 130%, lowest during the spring dip in old foliage FMC that marks the

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period of greatest crown fire hazard in northern conifers. Eucalyptus and chaparral also spend much time at FMC's of 100% or less. Aspen, birch, and maple on the other hand maintain FMC's of from about 140 to 200% after the flushing period is over." So given ignition energy (in kJ kg-1) and critical intensity (in kW m-1) of a wildland fire are high enough, fuel with a high moisture content can ultimately be ignited. Additionally, moisture in litter layers has been found to range between 200 and 300% and the F/H layer may reach more than 600% (de Ronde et al., 1990). We did not want to overload our results with so much quoting.

We extend the paragraph ending page 4490, line 10 (see also comment to reviewer 3): .. Indeed, in most of our experiments, this threshold was surpassed. (new text to follow) Much higher fuel moisture contents of 70 to 200% for instance are given by Van Wagner (1977) for crown fires, and moisture in the litter layer may exceed 200% (de Ronde et al., 1990). Combustion of such fuel indirectly will contribute to the effluents of the burns. As our reloading of fuel during the combustion session imitates a progressing fire line, higher fuel moisture contents obviously can be sustained.

de Ronde, C., J. G. Goldammer, D. D. Wade, and R. Soares. 1990. Prescribed burning in industrial pine plantations. In: Fire in the tropical biota. Ecosystem processes and global challenges (J.G. Goldammer, ed.), 216-272. Ecological Studies 84, Springer-Verlag, Berlin-Heidelberg-New York, 497 p.

Comment 4: Page 4490, line 25: Where does the 10% of carbon released in other forms come from ? Is there a reference or another study for why this percentage was chosen ?

Response: This paragraph was added to give the reader a feeling that the resulting fuel moisture content estimates remain distinctly visible, even if we missed carbon in the balance. The decrease is different depending on the assumed fuel composition. We use cellulose and lignin as borderline cases. The value of 10% missing carbon was given as an upper limit. The other forms can include gases, aerosols and ashes.

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Prominent among the gases would be methane (<1%), nonmethane hydrocarbons (<1%) and partially oxidized hydrocarbons as alcohols, carbonyl compounds and organic acids (in sum <1%, Andreae and Merlet, 2001). Both water-soluble and water-insoluble organic carbon as well as elemental carbon is found in aerosols emitted from vegetation fires (~3%, Lobert, our results: ~3%, in one case max. 5%, details see Iinuma et al., 2007). Ashes from open biomass fires usually are assumed to amount to ~10% and contain ~ 10% carbon (Lobert, 1989).

We change the text (If the fuel carbon.. , line 26) accordingly to: Even if the fuel carbon not assessed as CO and CO2 and thus escaping in other forms as gases (<3%, Andreae and Merlet, 2001), aerosols (~ 1%, Merlet and Andreae, 2001; in our experiments ~3%, Iinuma et al., 2007 for details) or ashes (~1%,Lobert, 1989) would come up to 10%, the ratio delta H2O/(delta CO+delta CO2+delta C(additional)) would still remain above unity and the estimated fuel moisture contents would be reduced by 11 to 25% depending on the assumed fuel composition, with cellulose or lignin as borderline cases.

Comment 5: Page 4491. line 13: the 60% fuel moisture calculated for the Clements et al (2006) study is much higher than what was reported by them. Comment on this difference.

Response: We thank the reviewer for pointing to that value. We checked and indeed found a transcription error. It should have read 44%. Nevertheless, our fuel moisture content was much higher. Clements et al. (2006) have used only 8% for their theoretical comparison. We should have mentioned that. Were this value experimentally derived, then it would point to a water vapor source not from within the biomass. However, this water still would have been inside the biomass burning plume, i.e., have been lofted together. Such other sources were indicated in our text on page 4491, line 7, as advection or soil moisture. The large difference makes the presence of such sources very much likely. Reviewer 3 directly reminded us of the notion of standing water. Still, we do not want to exclude completely a contribution and we have indicated on page

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4490, line 17 ff., that the fuel moisture content may be underestimated by the standard procedure to some extent.

We want to extend the text accordingly (new text): For an assumed delta CO/delta CO2 emission ratio of 8%, the amount of released water to released carbon oxides would be 1.49, resulting in a fuel moisture content of approximately 44% with cellulose as reference. The large difference to the 8% fuel moisture mentioned by Clements et al. (2006) make the influence of an additional source such as standing water and/or soil moisture very much likely. Nevertheless, this water vapor still would have been inside the biomass burning plume, i.e. have been lofted together with the combustion emissions. Returning to our arguments, we would conclude from an 8% fuel moisture content of cellulose and also 8% delta CO/delta CO2 in the emissions an increase of only 2240 ppm water vapor or 1.4 g kg-1, that is the rise would have been from 6.9 to 8.3 instead of 9.1 g kg-1. The difference would have to stem from additional sources. This estimate would hold only, of course, directly at the source. The ratio of water vapor to CO2 in ambient air is so large, that the initially diagnostic ratio of delta H2O/(delta CO+delta CO2) soon is concealed, when the mixing ratios return close to background values.

Comment 6: While plots (Figs. 1,2,3) are sufficient, they would be easier to read if they were larger in size. Maybe include more time tick marks from every 30 min to every 10 min.

Response: We have enlarged the graphs, which originally were formatted for a full view on a typical computer display. Also the number of time ticks are increased.

Changed graphs: (see additional sheets). (The graphs are with the editor and can be requested, of course).

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 4483, 2008.