Reply to Referee #1 and #2.

We thank both Referees for their helpful comments, which will improve the paper. Our response to each specific point made by the Referees follows. The figure that we refer to below can be found at the end of the (otherwise identical) supplement for this response.

Anonymous Referee #1

R1.1. This paper synthesizes a vast quantity of recent measurements of "fresh" biomass burning emission factors for different many species classified by vegetation and biofuel types. This paper is certainly a great resource to the community, both for a clear definition of the major terms used in discussions of biomass burning and as a compilation reference of EFs. The description of the methods is very clear, and it's extremely beneficial to have access to the original data in Supplementary Materials for further interpretation by the interested reader. The main weakness of the paper is the lack of any detailed comparison with previous literature values, in particular Andreae & Merlet and Yevich & Logan which are currently the literature standards for estimating BB and biofuel emissions. A detailed discussion of where these new estimates differ significantly from these earlier works is required to put this study in context and to inform the reader who might apply these values in their model or data analysis.

Authors Response. Referee #1 makes a good point that is reiterated by Referee #2. Thus, our response here addresses both comments R1.1 and R2.1. We point out some important caveats. (1) A comparison of 2011 values to those from 2001 or 2003 is not strictly a direct comparison, but should be seen partly as documentation of how values evolve as new information becomes available. (2) More than one averaging scheme for EFs may be adequate or appropriate since the applications of this data are diverse. (3) A large number of species are tabulated for many fire types. Measurements of a single species are often the subject of a paragraph, subsection, or whole paper. Thus, it is beyond the scope of this work to present a detailed discussion of the changes and underlying causes for those changes in all the species whose recommended values have evolved over the last ten years. (4) Our submitted paper did include detailed sections on HONO, HCN, and CH_3CN, intended to highlight some of the most significant new information. In addition, our existing NMOC section focuses on communicating the major finding that much of the NMOC mass remains unidentified.

In response to the Referees, we have added comparison of our open burning EFs with those in Andreae and Merlet (2001, hereafter AM2001), and comparison of our biofuel EFs with those in Yevich and Logan (2003) just before the existing Section 3.1. However, given the issues discussed above, we limit our comparison to AM2001 to "major" emissions whose recommended EF changed by more than 50% between 2001-3 and 2011 to keep the discussion at a reasonable length and to focus on differences outside the commonly observed variability. We loosely define major emissions as those with EF > 0.2 g kg^{-1} in our compilation. As an exception, we track the NO_x and $PM_{2.5}$ EFs even when they do not meet these two selection criteria since they are critical to so many applications. Many other major emissions differ by less than 50% and there are many trace emissions that change by more than 50% that are not discussed here. The comparison is influenced by the fact that AM2001 provided best guesses for a significant number of unmeasured species in some categories while we do not. Thus, we will also add a brief section on options for "filling in" values for unmeasured species. We feel that guidance on estimating application-specific values may be better than providing across-the-board estimates. Finally, in the spirit of both Referees' comments it seems appropriate to add a few

sentences about how the newer, high-temporal resolution, biomass-consumption inventories compare with the generally older "model year estimates" we tabulated in Table 4.

Draft of proposed new text:

P55, L12: Existing: "We begin this section with some comments on individual BB emissions that are important due to their reactivity (HONO) or use as BB tracers (HCN, CH_3CN) and for which a significant amount of new information has been recently obtained."

Change to: "We begin this section with a brief comparison to two widely used compilations of emission factors and then provide guidance on estimating EFs for individual, unmeasured species. We then discuss a few individual BB emissions that are important as a radical source (HONO) or for use as BB tracers (HCN, CH_3CN) and for which a significant amount of new information has been recently obtained."

P55, L21: Add the following sections and renumber existing sections that follow as indicated below:

3.1. Summary comparison to previous compilations

Because of the large number of compounds and fire types involved, a comprehensive comparison of the EFs presented here to all previous compilations is beyond the scope of this paper. In this section we present an overview comparison of our open burning EFs with the widely used review of Andreae and Merlet (2001, hereafter AM2001). We also compare our biofuel EFs with those in the extensive reference work of Yevich and Logan (2003). We acknowledge that a comparison of 2011 values to those from 2001 or 2003 should be seen partly as documentation of how values evolve as new information becomes available rather than as a traditional direct comparison. In addition, more than one averaging scheme may be adequate or appropriate since the applications of this data are diverse. In particular, AM2001 takes an inclusive approach while we take a highly selective approach, with each having their own strengths and weaknesses. An overly selective approach may inadvertently omit useful data while the full literature average may not reflect the ecosystem average for a large variety of reasons discussed earlier. The fact that many compounds are close in all compilations suggests some additional confidence for those species. A user may be well-advised to consider all compilations and the original work in many applications.

To keep the discussion at a reasonable length and focus it on differences outside the commonly observed variability, we limit our comparison to AM2001 to "major" emissions for which the recommended EF changed by more than 50% between 2001 and 2011. We loosely define major emissions as those with EF > 0.2 g kg^{-1} in our compilation. As an exception, we track the NO_x and $PM_{2.5}$ EFs even when they do not meet these two selection criteria since they are critical to so many applications. Many other major emissions differ by less than 50% and many minor emissions change by more than 50%, but they are not discussed here. The comparison is influenced by the fact that AM2001 provided best guesses for a significant number of unmeasured species while we do not. Instead, we discuss application-specific options for estimating values for unmeasured species separately in Section 3.2. In addition, we discuss HONO, HCN, and CH_3CN in separate sections following this overview.

We make three general points before discussing specific compounds. We provide averages for 8 fire types not found in AM2001: boreal forest, temperate forest, chaparral, cooking stoves, peat, dung, pasture maintenance, and garbage burning, with possibility for even further subdivision using the supplementary tables. For many fire types we include some new major emissions: e.g. HONO (see also Sect. 3.3), acetol, and glycolaldehyde. Our PM EFs are generally modestly higher.

We present a compact summary of the comparison with AM2001 for the more variable major EFs in Figure 1, where the black columns indicate the ratio of our EF to the AM2001 EF for each species. If a species has a blue column, this indicates that a EF was not available in AM2001 and, for the blue columns only, the height shows our actual EF in g kg^{-1} to verify that it is a major emission. For example, referring to the top panel of Figure 1 (savanna fires), we see that our EF(C_2H_6) is 2.14 times higher than the EF(C_2H_6) in AM2001. For phenol, our EF is 175 times larger than that reported in AM2001 as indicated by the number above the column. While our values are higher for most of the EFs shown, the AM2001 values are significantly higher for NH_3, HCOOH, and acetone. Our EF for NO_x is identical to that in AM2001 and our EF($PM_{2.5}$) is 33% higher. Finally, EF for glycolaldehyde and acetol are not found in AM2001 and they are now seen to be "major" emissions (EFs of 0.38 and 0.94 g kg^{-1}, respectively).

The underlying causes of all the differences depicted in Figure 1 cannot be discussed in detail here, but they can be gleaned from the original papers and careful consideration of the details of the various averaging schemes. However, for one category much of the difference with AM2001 can be summarized succinctly, which we do next. Our extratropical smoldering compounds are generally higher than AM2001, which is mostly due to two factors. (1) Our total EFs for boreal fires reflect the large component of smoldering combustion in this region and are calculated by equally weighting the ground-based and airborne averages. (2) We also weight the boreal forest fire EFs more than the temperate forest fire EFs (87:13, based on relative global fuel consumption) to generate our extratropical EF. Conversely, our EF(NO_x) for extratropical forest fires is about three times lower than EF(NO_x) for extratropical fires in AM2001. This is because the EF(NO_x) for temperate fires is higher than for boreal fires, but the temperate forest fire contribution is minimized in our extratropical average by our weighting scheme. However, our temperate forest fire EF(NO_x) is similar to the AM2001 EF(NO_x) for extratropical fires. For crop residue fires, the comparison to AM2001 is complex. The original AM2001 EFs relied on very limited data and extrapolations and AM2001 use a different averaging scheme than that applied in this work. In fact, we recommend using the EF measured specifically for mechanized or manual-harvest agriculture explicitly when possible (Sect. 2.13).

In comparison to Yevich and Logan (2003), the main difference is that they reported five major emitted species (CO_2, CO, CH_4, NO_x, and PM) whereas we include many more species (nearly all recently-measured) in this work. For species reported in both compilations most of the values are within 40% of each other, but a few changed by a factor of 2 or more. Ratios of this work to Yevich and Logan (2003) for a given EF are shown in parentheses. The large changes are: lower NO_x from charcoal burning (0.17) and dung burning (0.10); higher CH_4 (4.07) and PM (18.8) from dung burning; and higher CO, CH_4, and NO_x emissions from crop residue burned in field (2.00, 2.65, and 2.79, respectively). For the main type of biofuel burning (open wood cooking fires) the Yevich and Logan (2003) EFs are mostly very close to our EFs and all their EFs are within 48% of our updated values.

3.2. Estimating unmeasured emission factors

In general, estimating unmeasured values can improve model performance although this is not a guaranteed outcome. Our compilation does not tabulate estimates for unmeasured, individual species because the best estimation method depends on the application. The simplest estimates are obtained by using the EF values that may be available for the most similar fuel type. For example, filling in with EF values from one forest type for another, or using savanna fire EFs to estimate missing EFs for mechanized agriculture crop residue fires. To account for MCE differences between fire types, one can calculate missing EFs at the average MCE for a fire type using the relationships between EF and MCE for a similar fuel type. Or one can use the inter-compound ratios from the most similar fuel type. For example, assume compounds X and Y have both been measured for fuel type A, but only compound X has been measured for a similar fuel type B. The emissions of compound Y from fuel type B can be estimated from: $Y_B = (Y/X)_A \times X_B$. If laboratory data is used it is critical to consider how realistic the fire simulations were. In addition, lab EFs may require some mathematical processing to project EF that better reflect field burning conditions. These latter two issues are discussed in detail in Christian et al. (2003) and Yokelson et al. (2008). Another general principle is to use data relying on the most appropriate measurement technique available. For instance, in complex mixtures featuring sticky gases, some techniques may be more prone to chemical interference or positive or negative sampling artifacts. It is best to use sources where the smoke age and MCE are available in addition to the EF for the species of interest. Finally, if possible, estimates should be obtained from studies where the data for all the reported species seems reasonable. For example, BC values would be preferred from a study where all the trace gas EFs, particle size distributions, etc. are in the normal range as this indicates overall representative sampling. Sometimes a study may report a useful upper limit for a compound even though it does not report an EF. For instance, an upper limit is reported for glyoxal/acetone of 20% in OP-FTIR studies (Christian et al., 2003) or 10% in on-line, pre-separation MS studies (Karl et al., 2007; Warneke et al., 2011). In some cases, inspection of mass spectra can put an upper limit on the emissions of a compound, but it is frequently the case at high masses that many species appear at one nominal mass. Our estimates of total NMOC in Section 3.4 also provide very rough guidance for the sum of the compounds that are guessed.

P55, L21: Renumbering of the subsequent sections is shown with our voluntary changes after the point by point response to Referees:

As noted above, it also seemed appropriate based on the Referee #1's first comment to briefly compare AM2001 biomass consumption estimates to current inventories. We added a few sentences to address this:

P54, L18: Insert "The annual means for 1997-2009 from GFED3 (van der Werf et al., 2010) are about 20% lower than the widely used estimates in Andreae and Merlet (2001) for both savanna burning (2460: 3160) and total forest burning (1591:1970). The Andreae and Merlet (2001) estimate of crop residue burning is about 75% higher than GFED3, but the latter assume that they underestimate this source. Kopacz et al. (2010) suggest that GFED3 underestimates total BB in several important tropical regions. Detailed discussion and comparison of current inventories can be found in Reid et al. (2009), Kopacz et al. (2010), Wiedinmyer et al. (2010) and the references therein."

R1.2. Other more minor comments are included below.

R1.2.1. Section 3.3 is lengthy and essentially a review of previous work – I recommend trimming to keep the overall manuscript length reasonable when the comparison with previous studies is added (as per above comment).

Authors Response. We intend to trim this and also be more efficient about avoiding overlap with the conclusions and other sections.

R1.2.2. Both "emission factor" and "emission factors" are abbreviated as EF throughout the text. The later should be given as EFs

Authors Response. We have incorporated the use of "EFs" in our revisions.

R1.2.3. Page 27543, line 21: typo double brackets after TROFFEE

Authors Response. The first bracket is to close the abbreviation and the second bracket closes the parenthetical expression that the abbreviation is used in.

R1.2.4. Page 27555, line 7: why is the lower estimate of garbage burning (33 Tg/yr) not included in Table 4 and the average value for garbage burning?

Authors Response. The 33 Tg estimate was actually for incineration and not the open burning of garbage burning (GB) that we were concerned with. It is also probably far too low for global incineration (McCulloch et al., 1999) and will be removed from the paper.

McCulloh, A., Aucott, M. L., Benkovitz, C. M., Graede, T. E., Kleiman, G., Midgley, P. M., and Li, Y. F.: Global emissions of hydrogen chloride and chloromethane from coal combustion, incineration, and industrial activities: Reactive Chlorine Emissions Inventory, J. Geophys. Res., 104(D7), 8381-8403, 1999.

P55, L7: Change "ranging from 33–1000 Tg yr^{-1} (Bond et al., 2004; Christian et al., 2010 and references therein)." To "ranging up to 1000 Tg yr^{-1} (Christian et al., 2010 and references therein)."

R1.2.5. Section 3.2: The discussion of missing/unmeasured NMOC is essential, however it is misleading to include such uncertain values in your tables. It's not clear what the value of such a non-specific overall class of compound emission estimate would be given the likely range in reactivity of all the individual species included. I recommend limiting this discussion to the text and removing these values from the table.

Authors Response. It is true that the estimates of the amount of missing NMOC are very uncertain and their incorporation into models is difficult due to a lack of information on their properties. At the same time, representing unmeasured NMOC in models has improved model performance and removing them from the table risks giving a user who just consults the tables overconfidence in the degree to which we know the total NMOC. We propose to keep these entries in the tables, but flag them with a footnote and italicize to make clear that they are not the same as the measured values.

R1.2.6. Page 27560, line 26: Do your estimates differ from Andreae & Merlet because these authors did not include unmeasured NMOC as you did (scaling up by a factor of 2-3)?

Authors Response. The scaling for unidentified species that are clearly present in the mass spectra is the main factor for the difference and will be pointed out in the revised text.

P60, L25-27: Delete:

"We note that this lower value is still significantly larger than 100 Tg yr−1, which would be derived from Table 2 in Andreae and Merlet (2001) based on late 1990's data."

Replace with:

"We note that Table 2 of AM2001 estimates that about 100 Tg yr^{-1} of identified NMOC are emitted by BB when considering all the NMHC and several of the main OVOC. If the other OVOC from their Table 1 (that are not included in their Table 2) are considered, it suggests that about 150 Tg yr^{-1} of identified NMOC are emitted by BB globally. Doubling this value to account for unidentified species suggests a true global total near 300 Tg yr^{-1}, however, this has not been widely realized. The latter value is only 20-30% lower than our estimate in Table 5."

R1.2.7. Table 1 caption does not explain what values are given in brackets.

Authors Response. Thank you for pointing out our omission. The values in parentheses are our estimate of the naturally occurring variation in the EF at the "one standard deviation" level. This information will be added as the first footnote to both Tables 1 and 2.

Anonymous Referee #2

R2.1. The authors present a very detailed and comprehensive compilation of emission factor measurements for biomass burning sources for a large number of chemical species. High care has been put into acquiring and integrating results from different studies. The manuscript for this reason is lengthy and very much presents a work of reference rather than a research paper. However, this work provides essential guidance for developers and users of biomass burning emission inventories and is of high relevance to the scientific community. For this reason I recommend the paper for publication. To strengthen the value of this work I suggest, in line with reviewer 1, to include comparisons to as of now commonly used emission factors. Such a comparison would provide users with the needed information on how current emission inventories might change when these new emission factors are considered. A comparison from global emission inventories compiled with the new factors versus e.g. Andreae and Merlet (2001) would be ideal, but understand if this goes beyond the scope of this work.

Authors Response. Referee #2 reiterates Referee #1's desire for extended comparison to previously used values, while acknowledging the potentially large scope of such a discussion. Our response in A.1.1 is intended to address both of these important comments.

Additional Revisions:

In addition to changes made in response to the Referee comments, to keep the paper up to date, we added a three new studies, which required minor changes throughout the text. Also a few minor voluntary changes were made to improve readability or clarity. These changes are described in order of appearance using just the last two digits of the page numbers.

Abstract

P24, L10: change “the emission factors” to “EFs” and update EF to EFs as needed throughout.

P24, L15: move sentence “Biomass burning terminology is defined to promote consistency.” up to P24, L13 following “vegetation types.” to match order of discussion in paper.

P24, L22: change “about 4” to “almost 3”

P26, L16: To define emission factors again at first use after abstract change “EF” to “emission factors (EF or EFs, the grams of a compound emitted per kg of dry biomass burned)”

P29, L8: Change “see Section 3.3” to “see Section 3.5”

P29, L14: Change “emission factors (EF)” to “EFs”

P30, L10: add comma after “progresses”

P32, L13: Change “Section 3.2.” to “Section 3.4.”

P33, L23: Change “(PM)” to “(PM, solid or liquid particles suspended in air)”

P35, L1: Insert new paragraph: “In order to present a compilation that is as up to date as possible, we include some EF values from papers under review and a few preliminary EF values that are believed to be "final" from papers on the verge of submission. Preliminary values are clearly indicated in the supplementary tables and the reader using these values should locate the publications, check for updates, and cite those publications directly. In general we encourage the reader to examine and cite the original work that we compile and also consider modifying our averaging schemes to better suit their specific needs.”

P35, L4: Change “available EF” to “selected EF”

P35, L10: Change "GFED v. 3" to "GFED3"

P36, L17: “solid-” should be “bio” as we don’t mean coal or charcoal

P38, L23: Change “three” to “four” after adding Mexico savanna data

P38, L25: Change “two” to “three”

P39, L22: Change sentence “Finally, we group EF reported for elemental carbon (EC) or black carbon (BC) in a single “BC” category, although differences between the measurement techniques used for these species are the subject of ongoing research (Reid et al., 2005 a,b; Bond and Bergstrom, 2006; Schwarz et al., 2008).”
Change to: “Finally, we group EF reported for elemental carbon (EC) or black carbon (BC) in a single “BC” category. If there are thermal and thermal-optical measurements of EC we take the results from the latter more advanced technique. Differences between the measurement techniques used for these species are the subject of ongoing research (Reid et al., 2005 a,b; Bond and Bergstrom, 2006; Schwarz et al., 2008).”

P39, L26: Add paragraph: “We include early dry season EF measured by Yokelson et al. (2011) in Mexico that may help our average EFs (Table S1 and Table 1) better represent the full dry season. In addition, these early dry season EFs could be taken from Table S1 for an application targeted at that time of year.”

P40, L6-10: Change “For this study and all the other fires sampled by both FTIR and PTR-MS, we report only FTIR data when EF from both instruments were originally reported and more than one species could contribute to a mass peak. The synthesis of data from various instruments is described in more detail in the original papers.”

To “For this study and other studies with EFs measured by both FTIR and PTR-MS, the FTIR could sometimes quantify individual species when multiple species appeared on the same mass in the PTR-MS. In these cases, we select the FTIR data with a notable exception for acetol. The coupling and/or selection of data from various instruments is described in more detail in the original papers and by Christian et al. (2004) and Karl et al. (2007).”

P42, L24-25: Change “(I. Simpson, work in progress; Wisthaler and Mikoviny, unpublished results)” to “(Simpson et al., 2011)”

P43, L15: Add sentence to end of paragraph: “For instance, the boreal airborne average in Table S2 would likely agree well on average with airborne measurements of fresh smoke from boreal forest fires, but the overall boreal average shown in Tables 1 and S2 may better represent the true average regional fire emissions.”

P43, L19: Change “EF” to “EFs”, and add “EFs” before “retrieved”

P44, L14: Change “Yokelson et al. (2009)” to “Yokelson et al. (2009; 2011)”

P44, L15: Delete sentence: “Yokelson et al. (2009) sampled five TDF deforestation fires in the Yucatan.” Replace with: “Yokelson et al. (2011) report EFs for nine TDF deforestation fires sampled in Mexico (six of which were originally published in Yokelson et al., 2009).”

P45, L4: Delete sentence: “We include the average and standard deviation of EF from two temperate evergreen forest fires and one temperate evergreen prescribed fire measured by Radke et al. (1991), as seen in Table S4 and Table 1.” Replace with: “We include the average and standard deviation of EFs from three temperate evergreen forest fires (two wild and one prescribed) from Radke et al. (1991) and seven pine-oak forest fires sampled in remote mountain areas of Mexico by Yokelson et al. (2011), as seen in Table S4. We do not include the EFs for pine-oak forest fires measured in the Mexico City area by Yokelson et al. (2007b) as they were likely at least partially affected by nitrogen deposition from the urban area.”

P45, L6: Delete “We also include preliminary EF from two prescribed understory fires in coniferous forest in the Sierra National Forest measured during the SLOBB campaign (San Luis Obispo Biomass Burning study) (I. Burling, work in progress).”

Replace with: “We also include the average and standard deviation of the preliminary EFs from a recent study that sampled two prescribed understory fires in coniferous forest in the Sierra Nevada Mountains of California and six prescribed understory fires in coniferous forest in coastal North Carolina (I. Burling, private communication, 2011).”

P45, L14: Delete “using OP-FTIR and PTR-MS. We obtained EF(CH_3OH) by averaging data collected by both instruments since there are no interferences for methanol on the PTR-MS. For all other species we used OP-FTIR emission factors when data from both instruments was obtained”

P46, L16: Change “three” to “five”

P47, L23: Change "kg^{-1}" to "per kg" & P49, L5: Change "kg^{-1}" to "per kg"

P48, L27-28: Delete sentence "We convert their emission factors from g C kg^{-1} wood used to g X kg^{-1} charcoal produced as described above."

P51, L6: Change "1-hydroxy, 2-propanone, $C_3H_6O_2$" to "1-hydroxy-2-propanone, $C_3H_6O_2$"

P51-52: Section 2.3.13. After updating the tables there were small changes throughout this section and we adopted an improved averaging scheme. We also shortened this section. To implement this please:

1) Delete existing Section 2.3.13
2) Insert this new Section 2.3.13 (below)

Post harvest crop residue is a fine fuel that burns directly in the field and mostly by flaming in many mechanized agricultural systems. In contrast, when crops are harvested by hand the residue is often burned in large piles that may smolder for weeks. Yokelson et al. (2009) reported emission factors from airborne measurements of six crop residue fires associated with mechanized agriculture in the Yucatan, Mexico. Christian et al. (2010) made ground-based measurements of EF from mostly smoldering combustion during two similar burns in Central Mexico. Yokelson et al. (2011) made airborne measurements of the EFs for 6 additional crop residue fires associated with mechanized agriculture in central Mexico and derived overall averages that included their EFs and those from Yokelson et al. (2009) and Christian et al. (2010). We use the overall averages for mechanized agriculture from Yokelson et al. (2011) in Table S13. Christian et al. (2003) measured the mostly smoldering emissions from three laboratory fires burning manually piled Indonesian rice straw. Because of the significantly different EFs for these agricultural burning types it would be preferable to apply the specific EFs for each type of agriculture, when possible, by referring to Table S13 and the original papers. Because some users may require or prefer a global average for this category we present an estimate of this in Tables 1 and S13. In our overall average for crop residue fires, the EFs from the manual and mechanical agriculture subcategories are weighted based on the number of fires sampled, which is equivalent to assuming a 3:14 ratio of manual to mechanized harvesting on the global scale. The actual value of this ratio is not known to us and the reader can adjust the weighting if they prefer. In addition, because of the very large difference in EFs for these two types of burning, for this category only, we calculated the overall average by assuming a value of zero for the EF of ten species that were not detected from fires associated with mechanical agriculture, but very high from smoldering rice straw (see Table S13). This procedure gives a weighted EF value for these ten compounds that is more consistent with the overall average values for the other compounds.

P52, L15: Delete sentence: "Our estimate of variation is the standard deviation of the EF from the four fires measured."

P52, L21-22: Change "R. Yokelson, work in progress" to "Yokelson et al., 2011"

P53, L9: Change "determine a "combustion factor" (sometimes called "combustion completeness)" to "determine a combustion factor (sometimes called "combustion completeness)"

P53, L28: Change "GFED v. 3" to "GFED3"

P54, L11: Add "all the" before "various" and change "can be used" to "are needed"

P55, L21: Change “3.1.” to “3.3.”

P55, L22: Change “3.1.1” to “3.3.1.”

P56, L22: Change “Section 3.2” to “Section 3.5”

P57, L1: Change “3.1,2.” to “3.3.2.”

P57, L23: Change “source” to “fire type”

P57, L26: Change “has” to “can have”

P58, L1: Change “3.1.3.” to “3.3.3.”

P58, L12: change “(Wisthaler and Mikoviny, unpublished results).” to “(Simpson et al., 2011).”

P58, L15: Change “3.2.” to “3.4.”

P59, L14: Change “C. Warneke, work in progress” to “Warneke et al., 2011”

P60, L20: Change “412” to “428”, change “378” to “394”

P60, L22: change “744” to “760”

P60, L24: Change “378” to “394”

P61, L3: Change “725” to “735”

P61, L6: Replace “3.2.1.” with “3.5.”

P66, L2: Replace “3.3.” with “3.6.”

P66, L3: Replace “3.3.1.” with “3.6.1.”

P67, L2-12: Delete: “Christian et al. (2010) made some of the first detailed measurements of open GB as part of the 2007 Mega-city Impacts Local and Global Research Observations (MILAGRO) campaign based in Central Mexico. High EF(HCl) (1.65–9.8 g kg−1) were observed (Table S14) traceable to the large amounts of polyvinyl chloride (PVC) found in the landfills (Christian et al., 2010). These EF(HCl) suggest GB may be the main global source of HCl and it has long been known as the main global source of dioxins (Costner, 2005, 2006). Because GB emits large amounts of PM, HCl, and NOx (R. Yokelson, work in progress) the interaction between these species could lead to reactive products that impact O3 formation (Osthoff et al., 2008; Raff et al., 2009; Thornton et al., 2010). GB was found to emit high levels of several compounds such as levoglucosan sometimes used as tracers for BB.”

Replace with:

“Christian et al. (2010) made some of the first detailed measurements of open GB as part of the 2007 Mega-city Impacts Local and Global Research Observations (MILAGRO) campaign based in Central Mexico. High EF(HCl) (1.65–9.8 g kg^{-1}) were observed traceable to the large amounts of polyvinyl chloride (PVC) found in the landfills (Christian et al., 2010). These EF(HCl) suggest GB may be the main global source of HCl. Because GB emits large amounts of PM, HCl, and NO_x (Yokelson et al., 2011), the interaction between these species could lead to reactive products that impact O_3 formation (Osthoff et al., 2008; Raff et al., 2009; Thornton et al., 2010). GB is likely the main global source of dioxins (Costner, 2005; 2006) and the possibility of large emissions of other toxic chlorinated compounds should be investigated. GB could impact source apportionment studies because it emits high levels of several compounds such as levoglucosan sometimes used as tracers for BB (Christian et al., 2010).”

P67, L20-27:

Delete:

“So far, regional-global models have estimated air quality impacts using emission factors for temperate-region fires derived from tropical and boreal forest data, which introduces additional uncertainty to emission estimates (C. Wiedinmyer, work in progress). Recent laboratory and field campaigns have responded to this need and sampled emissions from fires in oak savanna, chaparral, pine understory, and pocosin vegetation types from California, North Carolina, and Arizona. Some of the laboratory and preliminary field results are included in this compilation and more should be forthcoming in the near future (I. Burling, private communication, 2010).”

Replace with:

“So far, regional-global models have estimated air quality impacts using emission factors for temperate-region fires derived from tropical and boreal forest data, which introduces additional uncertainty to emission estimates. Recent laboratory and field campaigns have responded to this need and sampled emissions from fires in oak savanna, chaparral, pine understory, and pocosin vegetation types from Arizona, California, and North Carolina. Some of the laboratory and preliminary field results are included in this compilation and more should be forthcoming in the near future (I. Burling, private communication, 2010). The new temperate EFs are being integrated into a new fire emissions model (Wiedinmyer et al., 2010).”

P68, L2: Replace “Finally,” with “Another major issue is that” – the reason being that “finally” incorrectly implies a complete list.

P68, L7: Replace “3.3.2.” with “3.6.2.”

P68, L8: Add comma after “major”

P69, L23: Change "GFEDv2.1-based" to "GFED2.1-based"

P70, L2: Add comma after “scale”

P70, L21: Change “profoundly” to “strongly”

P70, L25: Change: “could be addressed for the time being by increasing known NMOC by a factor of 2–3 to obtain more realistic initial emissions.” to “has been addressed for the time being by increasing known NMOC in various ways, which improved smoke model performance.”

P71, L13: add “Guido van der Werf, Thijs van Leeuwen,” after “Armin Wisthaler,”

P71, L15: add “Angelika Heil” after “Mark Carroll,”

P73, L13: Add reference “Ballhorn, U., Siegert, F., Mason, M., and Limin, S.: Derivation of burn scar depths and estimation of carbon emissions with LIDAR in Indonesian peatlands, PNAS, 106(50), 21213-21218, 2009.”

P74, L4: Update reference: “Burling, I. R., Yokelson, R. J., Griffith, D. W. T., Johnson, T. J., Veres, P., Roberts, J. M., Warneke, C., Urbanski, S. P., Reardon, J., Weise, D. R., Hao, W. M., and de Gouw, J.: Laboratory measurements of trace gas emissions from biomass burning of fuel types from the southeastern and southwestern United States, Atmos. Chem. Phys., 10, 11115-11130, 2010.”

P75, L21: Add reference: “Christian, T. J., Kleiss, B., Yokelson, R. J., Holzinger, R., Crutzen, P. J., Hao, W. M., Shirai, T., and Blake, D. R.: Comprehensive laboratory measurements of

biomass-burning emissions: 2, First intercomparison of open path FTIR, PTR-MS, GC-MS/FID/ECD, J. Geophys. Res., 109, D02311, doi:10.1029/2003JD003874, 2004.

P87, L30: Add reference: "Simpson, I. J., Akagi, S. K., Barletta, B., Blake, N. J., Choi, Y., Diskin, G. S., Fried, A., Fuelberg, H. E., Meinardi, S., Rowland, F. S., Vay, S. A., Weinheimer, A. J., Wennberg, P. O., Wisthaler, A., Yang, M., Yokelson, R. J., and Blake, D. R.: Boreal forest fire emissions in fresh Canadian smoke plumes: C_1-C_{10} volatile organic compounds (VOCs), CO_2, CO, NO_2, NO, HCN and CH_3CN, in press, Atmos. Chem. Phys. Discuss., 2011."

P90, L23: Add reference: "Warneke, C., Roberts, J. M., Veres, P., Gilman, J., Kuster, W. C., Burling, I., Yokelson, R., and de Gouw, J. A.: VOC identification and inter-comparison from laboratory biomass burning using PTR-MS and PIT-MS, Int. J. Mass Spec., in press, 2011."

P90, L25: Add reference "Wiedinmyer, C., Akagi, S. K., Yokelson, R. J., Emmons, L. K., Al-Saadi, J. A., Orlando, J. J., and Soja, A. J.: The Fire INventory from NCAR (FINN) – A high resolution global model to estimate the emissions from open burning, Geosci. Model Dev. Discuss., 3, 2439-2476, doi:10.5194/gmdd-3-2439-2010, 2010."

P91, L32: Add reference "Yokelson, R. J., Burling, I. R., Urbanski, S. P., Atlas, E. L., Adachi, K., Buseck, P. R., Wiedinmyer, C., Akagi, S. K., Toohey, D. W., and Wold, C. E.: Trace gas and particle emissions from open biomass burning in Mexico, Atmos. Chem. Phys. Discuss., 11, 7321-7374, doi:10.5194/acpd-11-7321-2011, 2011."

P93, Table 1:

Add footnote "[a]See Section 2.3 for guidance in use. Emission factors are shown with an estimate of the natural variation in parentheses, when available"

Other changes to this table are noted on the supplementary material Excel spreadsheet, "Version 2: Updated Information" tab in "Tables 1-5.xlsx"

Main changes include:

Crop Residue (Yokelson et al., 2011 added, Christian et al., 2010 removed, Yokelson et al., 2009 removed. See Table S13)

Tropical Forest (Yokelson et al., 2011 added)

Savanna (Yokelson et al., 2011 added)

Temperate Forest (Yokelson et al., 2011 added)

Boreal Forest (Simpson et al., 2011 updated, including several new species)

Extratropical Forest (recalculated given changes to boreal and temperate EFs)

P96, Table 1, footnote "a": Change "GFED v.3" to "GFED3"

P97, Table 2:

Added footnote "[a]See Section 2.3 for guidance in use. Emission factors are shown with an estimate of the natural variation in parentheses, when available"

Added footnote "[b]EFs include an assumed tropical forest overstory"

Other changes to this table are noted on the supplementary material Excel spreadsheet, "Version 2: Updated Information" tab in "Tables 1-5.xlsx"

Major changes include:

Chaparral (Burling et al., in prep updated)

Peatland (BC and OC added from Christian et al., 2003)

P99, Table 3:

Peatland category Page row, add “Peat plus overstory” to Veg specs column.

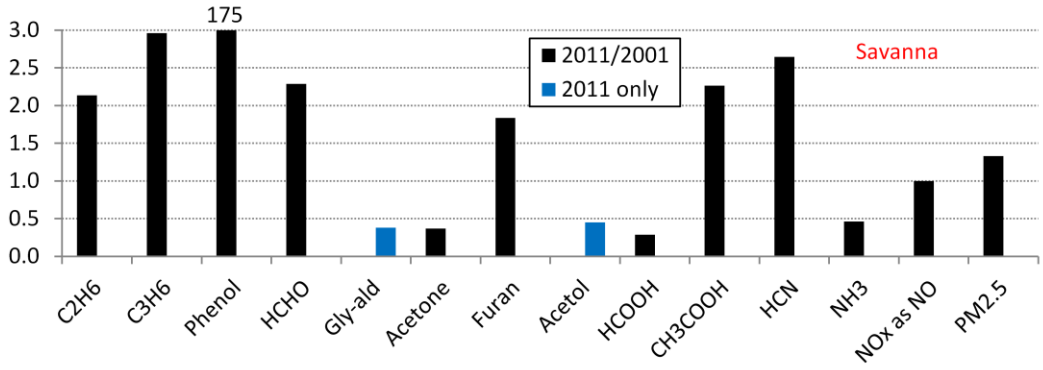
And add row for Ballhorn et al. (2009), Indonesia, Peat only, 383 Mg ha^{-1}

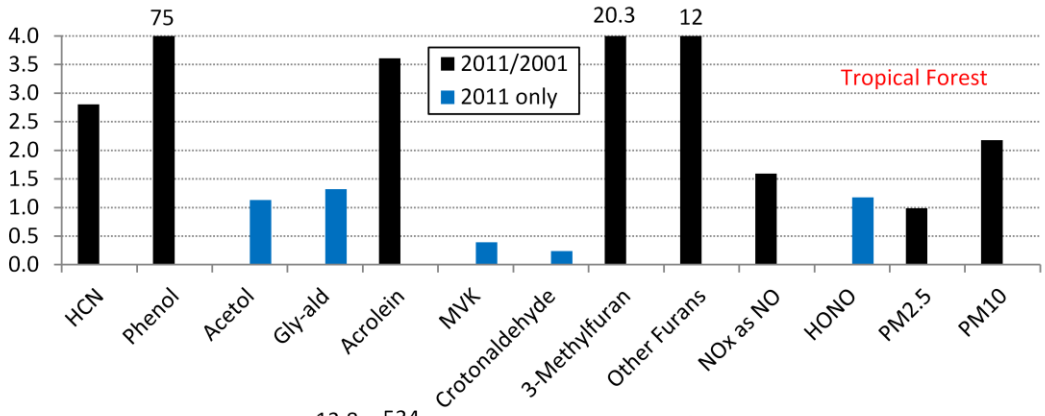
P02, L5: Table 5

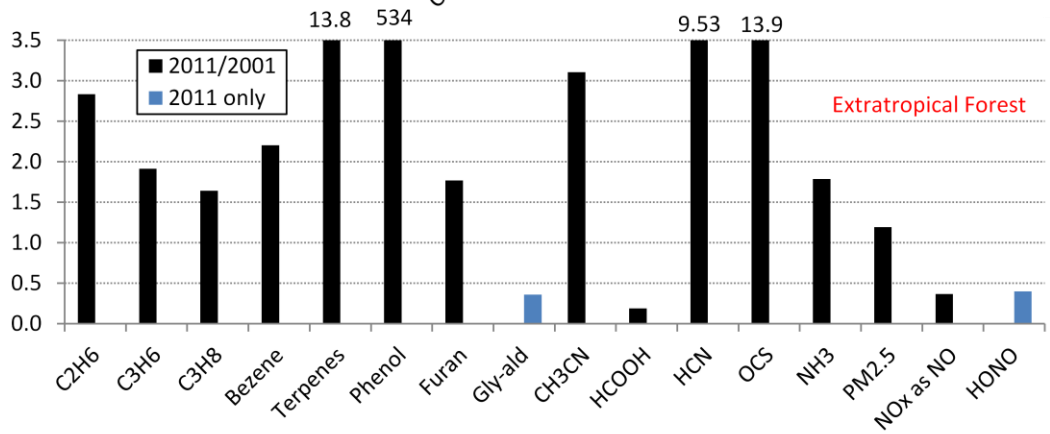
Crop residue, tropical forest, savanna, peatland, and extratropical forest rows updated.

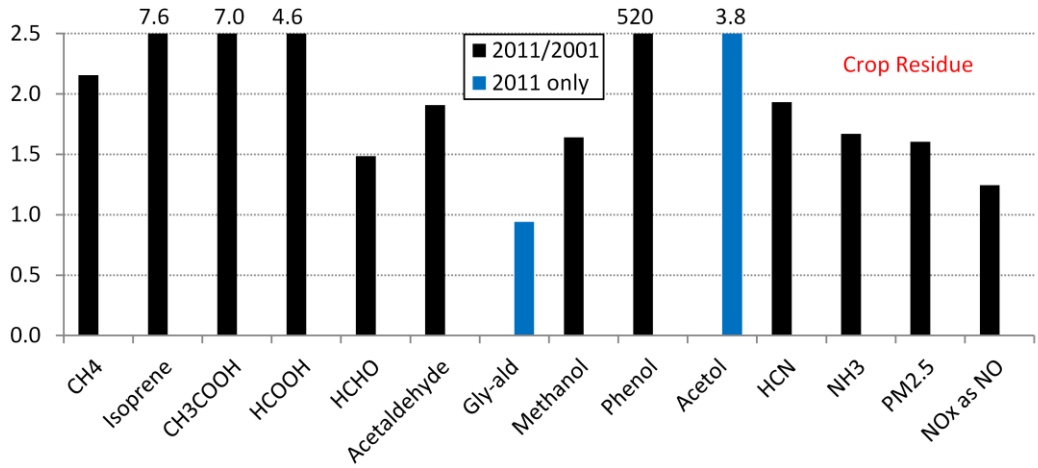
Draft Figure 1 caption: “The black columns show the EF in this work divided by the EF in Andreae and Merlet (2001) for the indicated species. The blue columns show the EF in g kg^{-1} for species not found in Andreae and Merlet (2001). “Gly-ald” and “MVK” indicate glycolaldehyde and methyl vinyl ketone, respectively. See Sect. 3.1 for discussion.”

Figure 1: see next page in supplement only.


Savanna
2011/2001
2011 only
175
3.0
2.5
2.0
1.5
1.0
0.5
0.0
C2H6
C3H6
Phenol
HCHO
Gly-ald
Acetone
Furan
Acetol
HCOOH
CH3COOH
HCN
NH3
NOx as NO
PM2.5


Tropical Forest
2011/2001
2011 only
75
20.3
12
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
HCN
Phenol
Acetol
Gly-ald
Acrolein
MVK
Crotonaldehyde
3-Methylfuran
Other Furans
NOx as NO
HONO
PM2.5
PM10


Extratropical Forest
2011/2001
2011 only
13.8
534
9.53
13.9
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
C2H6
C3H6
C3H8
Bezene
Terpenes
Phenol
Furan
Gly-ald
CH3CN
HCOOH
HCN
OCS
NH3
PM2.5
NOx as NO
HONO


Crop Residue
2011/2001
2011 only
7.6
7.0
4.6
520
3.8
2.5
2.0
1.5
1.0
0.5
0.0
CH4
Isoprene
CH3COOH
HCOOH
HCHO
Acetaldehyde
Gly-ald
Methanol
Phenol
Acetol
HCN
NH3
PM2.5
NOx as NO