Response to Referee #2

We thank the Referee for their encouraging assessment and constructive suggestions, which improved the paper. The Referee comments are reproduced below (in black) followed by our detailed response (in blue or red). Page and line number specifications refer to the posted discussion version.

Anonymous Referee #2, 13 Jun 2022

The manuscript presented by Yokelson et al. reports on emission factors of a wide range of species obtained from multiple fires at different location in Indonesia in 2019. It is well written, the methodology is well explained, and the results are discussed in a sufficient manner. The updated emission factors that this work provides is greatly needed to address the impact of tropical peat fires on the atmospheric composition on regional and global scales. Especially the discussion on the usage of the derived dataset for fire emission inventories is very helpful and will allow to further constrain the influence of these fires on air quality and climate. I suggest the publication of this work in ACP once my comments are addressed by the authors.

Specific comments:

1. P18, L1-12: In addition to the potential impact of metals for neurodegenerative diseases, iron is important to marine biota potentially leading to biogeochemical feedbacks. Considering the exceptional strength that Indonesian peat fires can have, could you comment on the potential importance of the emitted iron on the regional ocean fertilization? Compared to other iron sources in this region, can you estimate the relative importance of these fires?

Authors response: Thank you for this very interesting comment. We briefly summarize a very large body of work. Ocean dynamics, deposition, sediments, etc. can supply Fe to the ocean's near-surface waters. Dust is the main source of total atmospheric Fe, but dust Fe has low solubility and, usually, slowly increasing solubility with aging. In contrast, pyrogenic Fe (e.g., Fe in aerosol from smelting, combustion of biomass, coal, and liquid fuels) can have high initial solubility and/or rapidly increase in solubility with aging. Thus, pyrogenic Fe has been suggested to be the major source, of deposited and then dissolved oceanic Fe over large regions including Indonesia (Fig 6 in both Conway et al., 2019 and Ito et al., 2019). Dissolved Fe can increase ocean productivity and, if some of the "extra carbon" is exported to the deep ocean, also counteract global warming. However, actual deep ocean C-sequestration in response to deposition of atmospheric Fe may have low significance in some equatorial waters compared to the effects of ocean dynamics (Winckler et al., 2016). It would require isotope data or a specialized model that includes a regionally-appropriate aging scheme to estimate the relative contribution to dissolved Fe from BB compared to other atmospheric sources, which we don't have. It seems the isotope approach of Conway et al did not estimate combustion types separately. We do agree the BB contribution is probably important in big fire years in Indonesia, which is also known as the "Maritime Continent." We agree our data could inform some of the existing models developed by others.

We added new text on page 18 at line 10 and switched the order of the two sentences following the new text to improve the flow. In the final sentence about other constituents we note their importance was already discussed in Jayarathne et al. (2018).

Previous context: "These same three metals are of interest for their major role in important neurodegenerative diseases (Ben-Shushan et al., 2021) and other studies have linked BB smoke metals to neurological hazards (Scieszka et al., 2021). Jayarathne et al. (2018) also reported field-measured values for a large suite of PAHs, alkanes, selected sugars, lignin decomposition products, and sterols. A longer list of metals and data for other $PM_{2.5}$ constituents are provided in Tab. S6 of Watson et al. (2019)."

New text in context:

"These same three metals are of interest for their major role in important neurodegenerative diseases (Ben-Shushan et al., 2021) and other studies have linked BB smoke metals to neurological hazards (Scieszka et al., 2021). Ocean fertilization via deposition of soluble aerosol Fe from dust and combustion can impact ocean productivity and in some cases may promote deep ocean C-sequestration that tends to offset GHG emissions (Coale et al., 1996; Conway et al., 2019; Ito et al., 2021; Winckler et al., 2016). Pyrogenic aerosol Fe (from smelting and BB and fossil fuel combustion, etc.) contributes to oceanic dissolved Fe depending on initial aerosol Fe concentration and oxidation state as well as co-emitted gases and aging in complex ways (Chen et al., 2012; Ito et al., 2021). Pyrogenic Fe was found to account for the large majority of deposited and dissolved Fe in Indonesia and other areas of the Southern hemisphere (Conway et al., 2019; Ito et al., 2019). Studies targeting Australia, Siberia, the Bay of Bengal, and other locations have suggested that BB alone (in particular, large fire episodes) can be a major regional source of ocean dissolved Fe (Ito et al., 2020; Ito, 2011; Bikkina and Sarin, 2013). The data we present on peat smoke iron content and co-emitted gases could inform future assessments. For instance, our measured Fe mass fraction in peat smoke aerosol (2.7×10^{-4}, Jayarathne et al., 2018) is near the low end of the range previously assumed for biomass burning ($2 \times 10^{-4} – 3.4 \times 10^{-2}$) (Ito et al., 2021) or typical BB average values ($\sim 2 \times 10^{-3}$, Luo et al., 2008; Yamasoe et al., 2000). Our data suggests that about 1.6 Gg of total Fe was emitted by Indonesian peat fires in 2015 (Jayarathne et al., 2018). It's possible that the large spatial and temporal variability in BB emissions could provide some constraints on its ocean impacts, perhaps partly via satellite-based chlorophyll retrievals (Graham et al., 2015). Data for many metals and other $PM_{2.5}$ constituents are also available for lab peat fires in Tab. S6 of Watson et al. (2019). Jayarathne et al. (2018) also reported and discussed field-measured values for a large suite of PAHs, alkanes, selected sugars, lignin decomposition products, and sterols."

References:

Chen, H., Laskin, A., Baltrusaitis, J., Gorski, C. A., Scherer, M. M., and Grassian, V. H.: Coal fly ash as a source of iron in atmospheric dust, Environ. Sci. Technol., 46, 2112–2120, 2012.

Winckler, G., Anderson, R. F., Jaccard, S. L., and Marcantonio, F.: Ocean dynamics, not dust, control equatorial Pacific productivity over the past 500 kyr, PNAS, 113, 6119-6124, 10.1073/pnas.1600616113, 2016.

Coale, K. H., Johnson, K. S., Fitzwater, S. E., Gordon, R. M., Tanner, S., Chavez, F. P., Ferioli, L., Sakamoto, C., Rogers, P., Millero, F., Steinberg, P., Nightingale, P., Cooper, D., Cochlan, W. P., Landry, M. R., Constantinou, J., Rollwagen, G., Trasvina, A., and Kudela, R.: A massive phytoplankton bloom induced by an ecosystem-scale iron fertilization experiment in the equatorial Pacific Ocean, Nature, 383, 495–501, 1996.

Conway, T. M., Hamilton, D. S., Shelley, R. U., Aguilar-Islas, A., M., Landing, W. M., Mahowald, N. M., and John, S. G.: Tracing and constraining anthropogenic aerosol iron fluxes to the North Atlantic Ocean using iron isotopes, Nat. Commun., 10, 1–10, https://doi.org/10.1038/s41467-019-10457-w, 2019.

Graham, R. M., De Boer, A. M., van Sebille, E., Kohfeld, K. E., and Schlosser, C.: Inferring source regions and supply mechanisms of iron in the Southern Ocean from satellite chlorophyll data, Deep-Sea Research I, 104, 9–25, http://dx.doi.org/10.1016/j.dsr.2015.05.007, 2015.

Bikkina, S., and Sarin, M. M.: Atmospheric dry-deposition of mineral dust and anthropogenic trace metals to the Bay of Bengal, J. Mar. Syst., 126, 56–68, 2013.

Luo, C., Mahowald, N., Bond, T., Chuang, P. Y., Artaxo, P., Siefer, R., Chen, Y., and Schauer, J.: Combustion iron distribution and deposition, Global Biogeochem. Cycles, 22, GB1012, 2008.

Ito, A.: Mega fire emissions in Siberia: potential supply of bioavailable iron from forests to the ocean, Biogeosciences, 8, 1679–1697, https://doi.org/10.5194/bg-8-1679-2011, 2011.

Ito. A., Myriokefalitakis, S., Kanakidou, M., Mahowald, N. M., Scanza, R. A., Hamilton, D. S., Baker, A. R., Jickells, T., Sarin, M., Bikkina, S., Gao, Y., Shelley, R. U., Buck, C. S., Landing, W. M., Bowie, A. R., Perron, M. M. G., Guieu, C., Meskhidze, N., Johnson, M. S., Feng, Y., Kok, J. F., Nenes, A., and Duce, R. A.: Pyrogenic iron: the missing link to high iron solubility in aerosols, Sci. Adv., 5: eaau7671, https://doi.org/10.1126/sciadv.aau7671, 2019.

Ito, A., Perron, M. M. G., Proemse, B. C., Strzelec, M., Gault-Ringold, M., Boyd, P. W., and Bowie, A. R.: Evaluation of aerosol iron solubility over Australian coastal regions based on inverse modeling: implications of bushfires on bioaccessible iron concentrations in the Southern Hemisphere, Progress in Earth and Planetary Science, 7:42, https://doi.org/10.1186/s40645-020-00357-9, 2020.

Ito, A., Ying, Y., Baldo, C., and Shi, Z.: Ocean fertilization by pyrogenic aerosol iron, Climate and Atmospheric Science, 4:30, https://doi.org/10.1038/s41612-021-00185-8, 2021.

Yamasoe, M., Artaxo, P., Miguel, A., and Allen, A.: Chemical composition of aerosol particles from direct emissions of vegetation fires in the Amazon Basin: Water-soluble species and trace elements, Atmos. Environ., 34, 1641– 1653, 2000.

2. P20, L36-37: The work of Graham et al. is currently not available yet. Please provide further information on these fires, measurements, and the methodology used. Are these findings from the same, similar, or different locations/fires? Since you refer multiple times to this work in

preparation, it would be helpful if the work of Graham et al. would be available before this work is published (at least in some sort of discussion like ACPD).

Authors response: The paper is now published and the citations and references have been updated. In summary Graham et al. (2022) describes detailed mapping of depth of burn, rate of spread, water table, precipitation, fuel moisture, etc. obtained on 6 fires in Central Kalimantan during August – September of 2015. The fires were near the fires sampled by Stockwell et al. (2016) in Oct-Nov 2015 in Central Kalimantan and similar in general nature (e.g., on disturbed sites, near canals, etc.), but were different fires. The Graham et al study was also part of our overall NASA-supported peat fire study.

Graham, L. L. B., Applegate, G. B., Thomas, A., Ryan, K. C., Saharjo, B. H., and Cochrane, M. A.: A field study of tropical peat fire behaviour and associated carbon emissions, Fire, 5, 62, https://doi.org/10.3390/fire5030062, 2022.

3. In your study, you exclude extratropical peat fire emission data. Can you draw any conclusion from your extensive dataset to also constrain extratropical peat fire emissions or provide suggestions (e.g., for other measurement campaigns) to do so?

Authors response: Good point. Unfortunately, the best we can do at this time is append to the sentence on page 12 line 16 “nor do we know of extratropical field-based emissions measurements that could help identify the best lab data for this purpose.”