

19 May 2026

Dear Professor Qiang Zhang,

Thank you very much for handling our manuscript submitted to ACP for the consideration of publication (manuscript number: egosphere-2025-4058; title: Residential burning is a significant source of soluble iron to the ocean).

We submitted our revised manuscript on 18 December 2025, and it was reviewed by three referees. [Two referees \(#2 and #3\) recommended that the manuscript should be accepted as it is, and referee #1 recommended that it should be accepted subject to minor revisions.](#) In the second round of revision, we have addressed comments ref #1 had, and revised the manuscript according. [Below we summarize our changes, and more details can be found in our response to ref#1 and our revised manuscript and supplement.](#)

In this revision, we have added a third and final emission inventory: 'central'. While this addition has no impact on previous results or conclusions presented, it addresses the referee's comments on uncertainties in BC emission themselves in two ways to be as complete as we can in assessing Fe emissions from our observational component of the study: first, this inventory follows CMIP6 sector definitions as closely as possible; second, this update includes a new separation of the 'waste' emission sources. The resulting global Fe budget for the 'central' inventory is 4.9 Gg/a, with waste contributing only 0.9 Gg /a (0.04% of the total Fe budget).

The three anthropogenic Fe emissions inventories presented here, high-, central-high, and central-, each increase in their respective source grouping complexity to evaluate key uncertainties in the representation of Fe emissions from residential combustion in global inventories. Despite differences across inventories, the model simulations are all very similar in terms of observational comparisons, reinforcing our conclusions that observations have historically not been representative of residential burning plumes and that a two order of magnitude uncertainty exists in their emission magnitude (previously one order).

We have also addressed the concern regarding biofuel source classification. We now explicitly state our solubility parameter assumptions and remove discrete labeling of

'residential biofuel' where applicable, clarifying that biofuel sources span multiple sectors rather than residential sources alone.

We believe that the revised manuscript can be accepted for publication, and highly appreciate these comments which have helped us further improve our work. We would like to take this opportunity to thank you and the three referees for all the inputs. Please feel free to contact us if you need further information.

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Comments by referees are in blue.

Our replies are in black.

Changes to the manuscript are highlighted in red both here and in the revised manuscript.

Reply to referee #1

The authors show the Fe emissions in Tables S8 and S9, which elucidate the misclassification of source and fuel types. Although the focus of this paper is solubility, the method of scaling “COAL” sources and applying “WOOD” sources in the Rathod dataset should be corrected. At least, the name for source and fuel types should be corrected.

Reply: To clarify methodological approach succinctly we have replaced Table S8 with a methodological flow chart for each inventory in Figures S4a–4b (supplement) and Figure 1 (main text).

For the ‘central’ and ‘central-high’ inventories, ‘WOOD’ sources of Fe (labeled in this study as ‘BIOF’ to encompass all biofuels) were distinguished from CMIP Sector #4 using the Bond et al. (2004) BC emissions inventory: <https://doi.org/10.1029/2003JD003697>

Major comments

By scaling high case (460 Gg/a), the authors estimate “low-residential” emission for coal (16 Gg), which is reasonable, considering the uncertainty in PM emission estimates. However, if not considering the uncertainty in PM emission estimates, by distributing anthropogenic “COAL” Fe into industrial and residential sources, Fe content of 0.5 mg/g (3.9 Gg/a) in Rathod et al. (2020) is scaled to 2.1 mg/g (16 Gg/a) and 59 mg/g (460 Gg/a) for low and high cases in this study. These estimates are higher than the range of the measurements (0.025-0.101 mg/g) listed in Table 2. Thus, “low” case would mislead the reader, because Fe content for the “low-residential” estimate (2.1 mg/g) is comparable to the maximum of the measurements (1.7 mg/g) listed in Table S6. At least, low and high cases should be renamed, as “low-residential” Fe emission of 16 Gg/a is actually high, compared to Rathod “Central” case Fe emission of 3.9 Gg/a.

Reply: As the referee suggested, we have renamed this inventory to ‘central-high’ (16 Gg/a) to be relative to the Rathod ‘central’ case (3.6 Gg/a) reported in Rathod et al. (2020) (<https://doi.org/10.1029/2019JD032114>). We ran an additional set of model sensitivity simulations using what we have now deemed as the ‘central’ case in this work, which resulted in an annual emission of 4.9 Gg/a Fe from residential coal burning.

Our methodology is not directly comparable to Rathod et al. (2020, 2024), as we have chosen to use Fe:BC ratios in our study to be able to produce future Fe emissions following CMIP6 emission dataset projections. That would not be possible following Rathod’s methodology of Fe:PM ratios.

An assessment of the uncertainty range in BC:PM therefore also needs to be considered before the values the referee presented can be used as direct comparisons. That would need to account for each fuel class in CMIP6 as uncertainties will differ between sources. Such an assessment of BC emission uncertainties is beyond the scope of our present study.

To address the referees comments on uncertainties, and to be as complete in this as we can for our study, we conducted a third and final set of simulations. Here we added a previously unaccounted for CMIP6 emission class ‘waste’ (accounting for only 0.04% of total Fe emissions, but included for completeness on uncertainty quantification following our method

to track CMIP sector groupings as closely as possible). We also tested how our choice of classification of different CMIP6 sources affected Fe:BC ratios. This produced a new emission inventory with an emission estimate very similar to Rathod et al. (2020) (4.9 Gg/a herein, vs. 3.6 Gg/a in Rathod et al.).

This allows us to make the qualitative assessment that if BC:PM is linear we now span 2 order of magnitude uncertainty in the fuel Fe content. This is larger than the uncertainty between values within and across simulations conducted in our work and that by Rathod et al. (2020, 2024). We therefore believe that we have captured the full extent of the uncertainty that residential sources add to current understandings of Fe emissions from anthropogenic sources.

Most importantly, however, is that there is no measurable difference in model-observation comparisons found across all simulations spanning all combinations of emissions inventories and solubility parameterizations for combustion sources. That means this emission source (residential coal burning) is largely unconstrainable at present due to a combination of lack of measurements downwind of residential sources (a key outcome for future research) and a lack of process understanding in this fuel category itself.

Table S8 shows that the residential Fe emission for wood is 7.15 Gg/a, but Table S9 indicates that “Residential Biofuel” Fe emission is 70 Gg/a. “Residential Biofuel” sources probably include all the wood fuel types including industry. Please elucidate the sector and fuel types in 70 Gg/a of the “Residential Biofuel” Fe emission to check whether you include industrial wood of 58.9 Gg/a in the “Residential Biofuel” sources of 70 Gg/a.

Reply: All wood burning from industrial, energy, residential, and commercial sectors, as reported in Rathod et al. (2020), was classified as ‘BIOF’ to align with CMIP6 Sector #4 emissions groupings. This classification was necessary to project Fe emissions changes under the SSP scenarios. In the absence of direct measurements for Fe solubility and soluble Fe content in industrial and energy sector wood burning, we applied the solubility parameters derived from residential wood burning to all BIOF sources.

We have revised ‘residential biofuel’ to ‘biofuel’ throughout when referring directly to the emissions inventory, and explicitly stated this solubility assumption for industrial and energy wood burning sources within the BIOF category.

In the revised manuscript (page 32) we have added the following sentence to provide further explanation: “Biofuel Fe emissions are not limited to residential sources in our Fe inventory. However, lacking updated measurements for industrial biofuel combustion sources, the newly derived solubility parameter (56%) was applied uniformly within the “BIOF” grouping.”

If the authors use “WOOD” sources in the Rathod dataset for residential emission for biofuel (70 Gg) but the residential Fe emission for wood is 7.15 Gg/a, Fe content of 0.580 mg/g (7.15 Gg/a) in Rathod et al. (2020) is scaled to 5.7 mg/g (70 Gg/a) in this study. This estimate is higher than the range of the measurements (0.002-0.101 mg/g) listed in Table 2. At least, “Residential Biofuel” emission should be renamed to “Biofuel” emission.

Reply: We have revised ‘residential biofuel’ to ‘biofuel’ throughout when referring directly to the emissions inventory, and explicitly stated this solubility assumption for industrial and energy wood burning sources within the BIOF category.

In the revised manuscript (page 32) we have added the following sentence to provide further explanation: “Biofuel Fe emissions are not limited to residential sources in our Fe inventory. However, lacking updated measurements for industrial biofuel combustion sources,

the newly derived solubility parameter (56%) was applied uniformly within the “BIOF” grouping.”

Specific comments

I.262 and Table S8: A scaling factor of 0.035 is used to redistribute the emission but the low-residential emission for coal (16 Gg/a) is higher than that of Rathod “Central”-case Fe emissions listed in Table S8 (3.9 Gg/a), mainly because of different “industry” categories for Fe and BC. Actually, the solid biofuel emission at each grid and month can be calculated from the CMIP6 supplemental SOLID-BIOFUEL anthropogenic emission dataset of Hoesly et al. (2018) and thus the BC emissions for biofuel and the other fuels separately. Please replace n.d. in Table S8.

Reply: We agree that the SOLID-BIOFUEL dataset could have been one approach to distinguish biofuels from residential coal within Sector #4 CMIP data. However, we elected to utilize the source-specific Bond et al. (2004) BC dataset instead to achieve the same separation. This workflow is now described in our final third emissions inventory (‘central’), as detailed in Figure 1 in our revised manuscript ([page 15](#)).

I.365, Table S8 and Table S9: Table S8 shows that the residential Fe emission for wood is 7.15 Gg/a, but Table S9 indicates that “Residential Biofuel” Fe emission is 70 Gg/a. “Residential Biofuel” sources probably include all the wood fuel types including industry. Please correct or justify this.

Reply: We have revised ‘residential biofuel’ to ‘biofuel’ throughout when referring directly to the emissions inventory, and explicitly stated this solubility assumption for industrial and energy wood burning sources within the BIOF category. We have replaced Table S8 with Figure 1 (main text) and Figures S4a-4b (supplement) for methodological clarification.

In the revised manuscript ([page 32](#)) we have added the following sentence to provide further explanation: “Biofuel Fe emissions are not limited to residential sources in our Fe inventory. However, lacking updated measurements for industrial biofuel combustion sources, the newly derived solubility parameter (56%) was applied uniformly within the “BIOF” grouping.”

Table S8 indicates that BC emission in residential sector is adjusted to 762, but Table S9 indicates 2160 and 1330 for coal and biofuel in low case. These should be replaced by the actual CMIP6 emission data.

Reply: We agree that the methodology presented a challenge to follow through the table alone (e.g., 762 is 35% of 2160, which is the fraction of the Bond et al 2004 residential BC that could be attributed to coal). Therefore, in the revised manuscript we have replaced Table S8 with Figure 1 (main text) and Figures S4a-4b (supplement) for methodological clarification and ease of interpretation of what is being done at each step of our process.

Table S8 indicates that Fe emission for coal in industrial sector is 254, but Table S9 indicates 750 and 310 for low and high cases. Table S9 indicates 750, but the anthropogenic coal Fe in low case is calculated to be 766, so this should be 754. Please correct these.

Reply: In the revised manuscript we have replaced Table 8 with flow charts (Figures 1, S4a and S4b); moreover, Table S9 has also been updated. Discrepancies between inventories arose from differences in global budgets for Fe sourced from coal-burning reported in Rathod

et al. (2020) and Rathod et al. (2024). Table S8 reported values from Rathod et al. (2020), which varied by ~15 Gg/a within Rathod et al. (2024), as the referee pointed out. To overcome this variation, we applied ratios from Rathod et al. (2020) to separate industrial from residential sources of coal, which are now reflected in our ‘central’ emissions inventory.

1.456: By distributing anthropogenic coal Fe into industrial and residential sources, Fe content of 0.5 mg/g (3.9 Gg/a) in Rathod et al. (2020) is scaled to 2.1 mg/g (16 Gg/a) and 59 mg/g (460 Gg/a) for low and high cases in this study. These estimates are higher than the maximum of the measurements (1.7 mg/g) listed in Table S6. Please correct or justify this, showing the uncertainty in PM emission estimates for coal Fe in residential sector. My suggestion is that “high-residential” case should be replaced by the “Central” case Fe emission of 3.9 Gg/a, because the “high-residential” Fe emission of 460 Gg/a is significantly higher than that of Rathod “Central” case Fe emission of 3.9 Gg/a.

Reply: See overall response above regarding inconsistencies with comparing Fe:BC and Fe:PM. Our new case aligns with Rathod’s values, and we now bound 2 orders of uncertainty in residential Fe sources. We have relabeled the cases to be relative to the Rathod 2020 naming conventions, with our cases being “high” (460 Gg/a), “central-high” (16 Gg/a), and “central” (4.9 Gg/a).