

Response to Reviewers of: **Mixing state of Carbonaceous Aerosol Emissions from an Ecodesign Woodstove**

October 4, 2026

To the Reviewers and Editorial Team of Aerosol Research:

We would like to thank you for your time in reviewing our manuscript: “Mixing state of Carbonaceous Aerosol Emissions from an Ecodesign Woodstove” and for providing helpful and constructive comments. Our manuscript has been strongly improved through the review process.

Our responses to each reviewer’s point-by-point comments are as attached. The reviewer comments are included in blue text with our responses in black text. Revised line numbers are bolded, and any revised text is included as red text below each response with double quotation marks, to make it easier to read the changes. The line numbers refer to the revised manuscript with all tracked changes accepted.

We look forward to your favourable response.

Best Regards,

The authors

Response to Reviewer comments

Reviewer #1

This study investigates how different operating conditions of an Ecodesign residential wood stove influence the emissions and mixing state of carbonaceous aerosols with couples of online measurements. The authors investigate the evolution of combustion phases, BC mixing state, particle size distributions, and organic aerosol composition, with the aim of understanding how user behaviour influences carbonaceous aerosol emissions from modern residential stoves. While the scope of this study is well suited to AR and the experimental dataset is comprehensive, the manuscript in its current form lacks sufficient mechanistic interpretation and discussions. In the Introduction (Lines 89–93), the authors define three scientific objectives for this study. However, these objectives are not fully addressed in the current results and discussions. Therefore, I recommend that the manuscript be reconsidered after major revision.

Many thanks for your comments on our work. We have endeavoured to address each of your comments below.

Major comment 1: Section 3.2 primarily provides a descriptive comparison of AMS mass spectra across different combustion phases. While these observations are useful, the chemical information is not sufficiently integrated into the subsequent analyses to address the mechanistic questions posed in the Introduction (Lines 89–93). Since the authors have simultaneous measurements of BC mixing state from the SP2 and organic aerosol composition from the AMS, the manuscript would benefit from examining the relationships between BC mixing state and key AMS markers, such as m/z 43, m/z 44, m/z 60 and/or m/z 202, should also be explored. Such analyses would provide further support for the proposed BC mixing

state mechanisms. For example, in Lines 510–511, the authors state that “Under low MCE, a large proportion of OM, especially PAHs, may prevent the BC particles from forming a core-shell morphology.” However, this interpretation is not supported by the current presented results. Why “especially PAH” will prevent the BC being internally mixed? Could it be the oxidization state of OM influence the BC mixing state?

Thank you for pointing out these concerns. We agree that investigating the relationship between BC mixing state and organic aerosol composition can greatly support the proposed BC mixing state mechanisms. Thus, we conducted an analysis of the relationship between BC coating bulk (D_p/D_c) and the fractions of the key AMS markers m/z 43, m/z 44, m/z 60 and m/z 202 in repeat burn cycles from the standard protocol experiments. The results are shown in Figure R1:

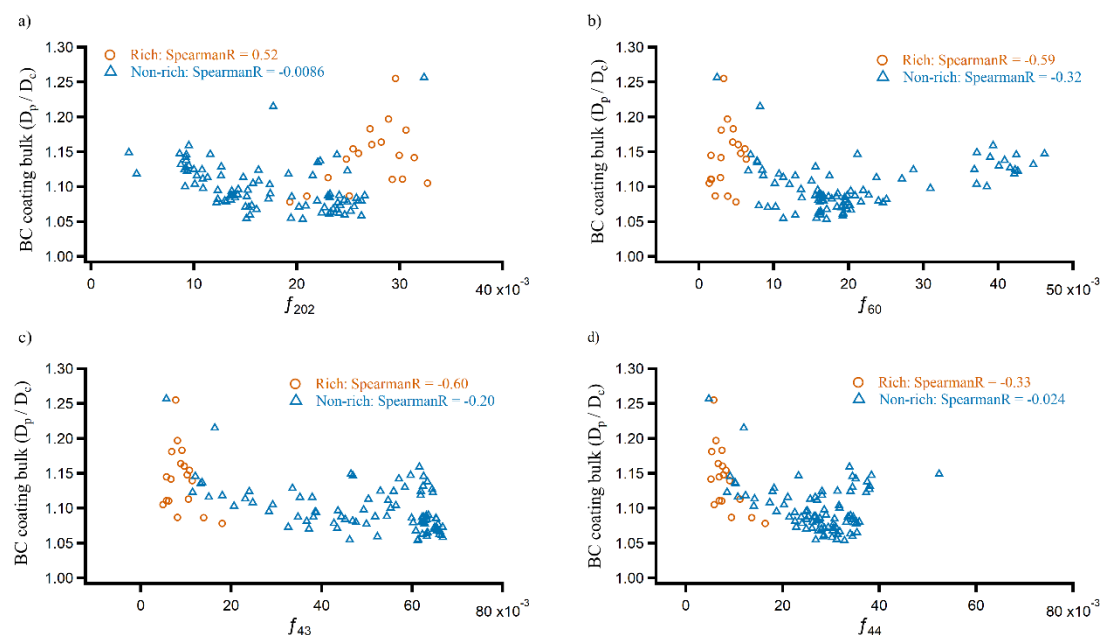


Figure R1 BC coating bulk as a function of AMS marker fractions a) f_{202} , b) f_{60} , c) f_{43} and d) f_{44} . The orange circle represents rich flaming (MCE < 0.95) while the blue triangles represent non-rich flaming (MCE > 0.95).

Spearman ranks were calculated to examine the correlations between AMS markers and BC coating bulk. During rich flaming (MCE < 0.95), BC coating bulk increased with PAH-related fractions (f_{202}) (Spearman Rank = 0.52), whereas little monotonic association was observed during non-rich flaming (Spearman Rank = -0.0086). At the same time, negative correlations between BC coating bulk and f_{60} , f_{43} and f_{44} were observed during rich flaming, with Spearman Rank = -0.59, -0.60, and -0.33, respectively.

A possible BC mixing state mechanism is that PAHs contribute to BC coatings under rich flaming. However, as the AMS measures bulk non-refractory aerosol composition rather than the chemical composition of individual BC coatings, we have avoided stating that BC coatings are composed of PAHs. During rich flaming, high OM concentrations may also contribute to the mixing state, while the PAH signals provide compositional context. Moreover, we did not attempt a quantitative mass balance between SP2 derived coatings and AMS derived PAH mass, because this would introduce the uncertainties associated with the assumed coating refractive index in the SP2 analysis and the Relative Ionization Efficiency (RIE) in the AMS analysis. Figure R1 is therefore added as supplementary figure S19. The following statements have been added from **line 560** and from **line 713**:

From **line 560 to 569**:

“The chemical composition for BC coatings is further explored by comparing coating bulk against AMS marker (m/z 43, m/z 44, m/z 60 and m/z 202) fractions. During rich flaming, BC coating bulk increased with PAH-related fractions (f_{202}) (Spearman Rank = 0.52, Figure S19a), whereas little monotonic association was observed during non-rich flaming (Spearman Rank = -0.0086, Figure S19a). At the same time, negative correlations between BC coating bulk and f_{60} , f_{43} and f_{44} were observed during rich flaming, with Spearman Rank -0.59, -0.60, -0.33, respectively (Figure S19 b-d).

A possible BC mixing state mechanism is that PAHs contribute to BC coatings under rich flaming. This observation supplemented the relationship that high coating thickness is related to low MCE (Figure 7) and provided chemical composition context for the distinct thickly coated BC particles observed during rich flaming in figure 8, specifically showing that coated BC particles coincided with higher pyrene and lower contributions from small OA fragments.”

From line 712 to 714:

“PAHs showed a positive monotonic association with BC coating bulk during rich flaming, thus a possible mechanism is that thicker BC coatings may be associated with PAHs.”

Regarding the statement that “Under low MCE, a large proportion of OM, especially PAHs, may prevent the BC particles from forming a core-shell morphology.”, we agree that the current results cannot determine individual BC particle morphology. SP2 coating thickness retrieval assumes a core-shell model and does not independently determine the actual geometry. We have removed this statement.

“...mixing state to instantaneous combustion efficiency. ~~Under low MCE, a large proportion of OM, especially PAHs, may prevent the BC particles from forming a core-shell morphology. The resulting heterogenous coating increases the scattering cross section at 1064 nm, which may lead to an overestimation of D_p .~~”

We also acknowledge that organic oxygenation could influence BC coatings. In this study, the negative correlation between BC coating and f_{44} was weak (Spearman Rank = -0.33). Although the negative correlation may suggest that thicker coatings tended to coincide with lower organic oxygenation, this correlation alone does not establish the role of organic oxygenation in determining BC coating bulk. We have added discussion from line 570 to 573:

“During rich flaming, BC coating bulk showed a weak negative monotonic association with f_{44} (Spearman Rank = -0.33), suggesting that thicker coatings tended to coincide with lower oxygenation of the organic aerosol. However, this correlation alone does not establish the role of organic oxygenation in determining BC coating bulk.”

Major comment 2: In the Introduction (Lines 62–63), the authors state that coagulation rates increase significantly under high particle concentrations, implying enhanced particle mixing. However, in the Conclusions (Lines 674–675), the authors state that the formation of thickly coated BC under high-OM conditions is “consistent with” increased external mixing. This conclusion is not sufficiently justified. Although the results are interesting and suggest that a greater BC coating thickness does not necessarily correspond to a higher degree of internal mixing, the underlying mechanism is not adequately explained. Additional analyses and discussion are needed to provide mechanistic support for this conclusion.

Thank you for the comment. We agree that the original statements are not fully explaining that a greater coating thickness does not necessarily mean high internal mixing. Coating bulk D_p/D_c characterises relative BC coating, whereas F_{in} estimates BC associated OM as a fraction of total

OM. These indicators can therefore vary in different directions when OM concentrations are high. We can see from table 2 that thick coatings can coexist with high external mixing (low F_{in}). We therefore added additional explanation after we showed the F_{in} results, and replaced “consistent with” with explanation, from **lines 630 and 714** respectively:

From **line 630 to 637**:

“Low F_{in} represents OM existed external mixing with rBC, but F_{in} is different from D_p/D_c , the latter characterises coating on BC particles. Eq. 4 expresses F_{in} as OM coated on rBC divided by the total OM, so when the mass ratio of OM to OM+rBC is large enough (for example approaching 1), a high coating bulk may coexist with a low F_{in} . For example, during standard protocol, mean F_{in} in rich flaming (0.160) was lower than non-rich flaming (0.300), but mean D_p/D_c for rich flaming (1.14) is higher than non-rich flaming (1.11) (table 2). This indicates that thickly coated BC coexisted with predominantly externally mixed OM. A possible mechanism is that organic vapours may condense onto BC, and collision with organic particles may also contribute to coating, while substantial OM remains externally mixed with rBC.”

From **line 714 to 716**:

“Low F_{in} was observed simultaneously with thickly coated BC, suggesting that greater BC coating thickness does not necessarily correspond to a higher degree of internal mixing when OM concentrations are substantially elevated.”

Major comment 3: Multiple dilution stages were applied prior to the SP2 measurements, yet the possible effects of dilution on the gas–particle partitioning of semi-volatile organics and the resulting impacts BC coating thickness are not considered. Since the proposed coating formation mechanisms rely on SP2-derived coating metrics analysis, the authors should discuss whether the observed mixing state represents the primary emissions at the stove outlet or has been modified during dilution and sampling.

Thank you for pointing this out. We understand that during dilution and transport through the sampling lines, the dilution may shift gas-particle partitioning of semi-volatile organics towards the gas-phase, causing the evaporation of coating (Lipsky and Robinson, 2006). At the same time, dilution can cool the flue, the condensation may therefore increase the coating thickness (Hytönen et al., 2009; Li et al., 2021). So, the coating thickness can be driven together by these two effects. We would like to clarify that since the location and timing of coating formation cannot be determined from our setup, the reported mixing-state metrics represent the aerosol after passing through the dilution system. Thus, we added a paragraph from **line 574 to 581**

“In addition, the BC coating thickness reported here should be interpreted as the mixing state of fresh emissions after dilution rather than initial mixing state of the flue. Dilution may decrease coating thickness through evaporation of semi-volatile organics (Lipsky and Robinson, 2006), while cooling of the flue during dilution may enhance condensation and increase particle phase organics (Hytönen et al., 2009; Li et al., 2021). The measured coating thickness therefore reflects the net effect of these processes. As the same dilution configuration was used for all burns, the comparisons of BC mixing state among different protocols and combustion phases remain informative, although the absolute coating thickness may have been modified during dilution.”

Major comment 4: The current Abstract requires substantial revision. Although the manuscript is entitled “Mixing State of Carbonaceous Aerosol Emissions”, the current abstract provides

almost no information regarding the aerosol mixing state or the key findings related to it. Instead, a large proportion of the abstract (Lines 16–30) is devoted to background information and a description of the experimental setup and instrumentation. In contrast, the main findings of the study are only briefly summarized in a few lines (Lines 30–34). The abstract should place much greater emphasis on the principal scientific results and their significance, rather than on methodological details.

Thank you for pointing out the structure and writing of the abstract. We agreed that the abstract should focus more on mixing state related findings rather than instrument setup. We then revised the abstract as below:

“Residential wood burning (RWB) has become an increasingly significant source of carbonaceous aerosols (CAs) in the UK and worldwide. Black Carbon (BC) and Organic Aerosol (OA) fractions of CAs are of particular concern due to their impacts on climate and human health. ~~Measuring the mixing state of CA is important as the mixing state can influence key aerosol properties including light absorption, hygroscopicity, cloud scavenging, atmospheric lifetime, and toxicity.~~ Mixing state of CA is important as the mixing state can influence key aerosol properties including light absorption, hygroscopicity, cloud scavenging, atmospheric lifetime, and toxicity. ~~acrosol climate and health effects.~~ While CA emissions and mixing states from traditional stoves have been previously reported and characterized, however key uncertainties remain in the influence of user behaviour on emissions and the emission characteristics from the modern ‘Ecodesign’ appliances. Recent emissions tests imply that these can emit more pollutants such as polycyclic aromatic hydrocarbons (PAHs) and BC under certain circumstances when burning dry wood and here we utilise online instrumentation to probe the mechanisms behind this and whether user behaviour has a role in impacting emissions. ~~Hardwood logs were burned in a controlled test system using a UK Ecodesign compliant woodstove under five operating protocols: standard, overload, underload, hot reload and open-door protocols. Instantaneous particle emissions were quantified using a Single Particle Soot Photometer (SP2), a Differential Mobility Sizer (DMS500) and an Aerosols Mass Spectrometer (AMS). Modified combustion efficiency (MCE) was derived from CO and CO₂ concentrations measured by a Fourier Transform Infrared (FTIR) spectrometer. Three typical combustion phases were observed: a pre-ignition phase, a flaming phase (with rich and non-rich flaming distinguished by an MCE of 0.95), and a smouldering phase. The flaming phase was further classified by modified combustion efficiency (MCE) into rich (MCE < 0.95) and non-rich (MCE > 0.95) conditions. Rich flaming was identified as a key regime driving changes in CA mixing state and chemical composition, characterized by enhanced PAH emissions and the coexistence of thinly and thickly coated BC particles. PAHs may contribute to thicker BC coating formation during rich flaming. Despite the presence of thickly coated BC, a low fraction of total OM was associated with BC, indicating that substantial externally mixed OM was present simultaneously.~~ Stove operation can affect emissions by altering particle size, leading to ultrafine particle (UFP) formation (e.g., open-door, underload and overload conditions) and also prolong the rich flaming phase (e.g., hot-reload and overload), increasing PAH emissions. The findings here demonstrate how user behaviour may increase emissions of certain pollutants from modern stoves, partially offsetting the benefits compared to older designs.”

Minor comment 1: Line 44: provide the reference.

Thanks for the comment. We have provided the reference from **line 43 to 44** as shown below:

“BC is the dominant light-absorbing component of PM_{2.5} and contributes to positive radiative forcing ([Bond et al., 2013](#)).”

Minor comment 2: Line 51 – 53: cite Riemer et al. (2019).

Thanks for pointing out this. We have cited the paper for **line 52** as shown below:

“These mixtures can be either fully internal, meaning each particle homogeneously or heterogeneously contains all species, or fully external, meaning each particle contains only one species ([Riemer et al., 2019](#); Bond and Bergstrom, 2006).”

Minor comment 3: Please unify the term “BC” and “rBC” throughout the manuscript.

Thank you for this comment. We have revised the manuscript to use BC and rBC more consistently. We use rBC when referring specifically to refractory black carbon material measured by SP2 (such as the rBC core). BC is used for more general description of black carbon aerosol or the whole BC particle including rBC core and coatings, and when discussing particle mixing state.

Minor comment 4: To what extent was BC considered to be thickly coated? The authors classify BC particles based on E_{sca} (Line 416). Including the associated D_p/D_c range or representative values would help readers better understand the degree of BC coating.

Thank you for pointing out this. We clarify that $E_{sca} > 1$ and $E_{sca} > 10$ were intended as a descriptive indication of enhanced scattering rather than a strict threshold for classifying thickly coated BC. In figure 5, effectively uncoated BC forms a broad low E_{sca} population across D_c , whereas coated BC appears as a distinct population at higher E_{sca} separating from the broad low- E_{sca} mode. Thickly coated BC classification used in this study is shown in Fig.8 based on a size dependent separation criterion. For a range of D_p/D_c , $E_{sca} = 1$ corresponds approximately to $D_p/D_c = 1$, while $E_{sca} = 10$ corresponds to 1.86 to 1.89 for D_c ranges 80 to 150 nm. For the criterion we used, thickly coated BC has corresponding D_p/D_c larger than 1.81, 1.40, 1.15, 1.01 for D_c at 80, 100, 120 and 150 nm. We have revised the manuscript as below to make the distinction and thickly coated more carefully:

From **Line 416 to 420**:

“The clearly resolved bimodal BC mixing pattern comprises (i) a broad low E_{sca} population of uncoated BC across a broad size range and (ii) a distinct higher E_{sca} population thickly coated group with $E_{sca} > 1$. E_{sca} values in the thickly coated higher E_{sca} group occasionally exceed 10. For reference, $E_{sca} = 1$ corresponds to $D_p/D_c = 1$ across the size range, while $E_{sca} = 10$ corresponds to D_p/D_c from 1.86 to 1.89 for D_c between 80 and 150 nm. These physically distinct BC types likely reflect flame heterogeneity.”

From **Line 543 to 544**:

“For reference, this dash line criterion corresponds approximately to $D_p/D_c > 1.81, 1.40$ and 1.01 for $D_c = 80, 100$ and 150 nm respectively.”

Minor comment 5: Line 429 - 430: Could BC originate from secondary sources?

Thank you for the comment. BC is considered a primary aerosol because it is formed during incomplete combustion and emitted directly from the source. Therefore, BC itself is not formed through secondary atmospheric processes, although primary BC particles can acquire secondary coatings during atmospheric aging. As the word “primary” sounds redundant here,

we have removed it from the manuscript.

Minor comment 6: Line 430, The statement “only a fraction ...” is unclear. Please specify.

Thank you for pointing this out. We mean that BC and OM are not necessarily fully internally mixed when emitted, as demonstrated by the F_{in} values in Table 2. This is especially evident during rich flaming, where enhanced OM emissions were associated with lower F_{in} , indicating a high level of external mixing. Therefore, models that assume BC and OM are fully internally mixed at emission may not represent the observed mixing state accurately. We have revised the manuscript from **line 432 to 435** accordingly:

“Our results show that only a fraction of the total emitted OM is internally mixed with rBC, while the remaining OM is externally mixed, as indicated by F_{in} (Table 2). This variable mixing state may introduce uncertainty into models that assume rBC and OM are fully internally mixed immediately after emission. ~~confirmed that only a fraction of primary BC and OM is internally mixed when emitted, and that this mixing varies by user operations, which may bias model estimation for BC radiative forcing.~~”

Minor comment 7: Line 505: Should this be "OM coagulates with BC"? Please also check similar descriptions throughout the manuscript. I think OM generally refers to particulate organic matter in the manuscript, and the term "condense" may not be appropriate.

Thanks for this comment. We agree that OM in this manuscript generally refers to particulate organic matter. We have revised the wording in **line 508** and throughout the manuscript where OM coagulation is discussed.

Minor comment 8: Line 515, in Figure 7 caption, Pearson correlation coefficient should be r ?

Thank you for pointing this out. We have revised the caption to correctly state that this is the squared Pearson correlation coefficient (r^2).

Minor comment 9: Figure 6: Are standard error bars available for all particle size distributions?

Thank you for the comment. Standard error bars are included for all particle size distributions in figure 6. However, for most distributions, the standard errors are small and therefore not clearly visible on the plotted lines.

Minor comment 10: The axis labels and tick labels in several figures (e.g., Figures 5 and 10) are too small. Please increase the font size to improve readability.

Thank you for this comment. We have increased the font size of the axis ticks and labels in figure 5 and 10. In response to the other reviewer’s comment, we have also added color bars to figure 5.

Minor comment 11: There is no clear determination of UFP size range. For example, in Line 476 - 477: When the author stated “A large UFP peak was observed during the pre-ignition

phase of single big log protocols”. What is the size range of the UFP peak?

Thank you for pointing this out. We have clarified that the UFP peak during the pre-ignition phase of the single big log protocol was centred at approximately $D_m = 18$ nm. We have also provided the peak diameter in the sentence at **line 482**.

Reviewer #2

This manuscript presents a study investigating the carbonaceous aerosol emissions from residential wood burning using a wood stove under non-ideal operating conditions. The topic of this study falls within the scope of the journal Aerosol Research. This manuscript is generally laid out well and shows its academic value. The manuscript is recommended to be published after addressing the following comments.

Thanks for the positive comments on our work. We have endeavoured to address each of your comments below.

Title: If this study focuses on non-ideal operations of a wood stove, it should be specified in the title.

Many thanks for the comment. We agree that adding “non-ideal operation” to the title makes the operating conditions investigated in this study explicit. We have therefore revised the title to: Mixing state of Carbonaceous Aerosol Emissions from an Ecodesign Woodstove under Non-Ideal Operation.

Line 60: Please double check if the term "Aiken" is a typographical error of "Aitken" and make revisions if necessary.

Thank you for this comment. We have revised the word in the manuscript.

Line 118: Please double check if the word "quantiying" is a typographical error of "quantify" and make revisions if necessary.

Thank you for pointing this out. We have revised this word in the manuscript.

Lines 131 - 133 and in general: To characterize the emissions under real-world conditions, it seems that the catalyst should be used. The removal of catalyst during the experiments of this study seems to simulate the emissions of the stove under abnormal operating conditions where the catalyst is not functioning. Please provide more detailed descriptions to clarify this step of experimental design, otherwise the emissions estimated in this study would be misleading and give the overestimated results compared with the real-world situation. If the results are used to compare with those from traditional wood stoves, the emissions from non-ideal operations of those stoves should also be used for a meaningful comparison. These should be considered and specified in the manuscript.

Thank you for this comment. We agree that the removal of catalyst may lead to deviation from real-world stove emissions. However, the purpose of removing the catalyst was to investigate the combustion generated emissions and processes occurring within the stove, because catalyst

can modify the emitted gas and particles, and may mask changes arising directly from combustion conditions and user operation. Therefore, the emissions reported in this study represent pre-catalyst emissions. We have clarified this experimental design and its limitation in the manuscript. We have also removed the quantitative comparison between traditional stoves and Ecodesign stoves where the catalyst conditions are not equivalent.

Line 131 to line 136:

“Under real-world operating conditions, the exhaust stream passes through a catalyst and is then vented via the flue. ~~To characterize the emissions, we removed the catalyst during the experiments. In this study, the catalyst was removed for all burn protocols to investigate the CA emissions, processes and mixing states within the stove without the influence of catalyst. Therefore, the reported emissions and mixing states in this study represent pre-catalyst emissions and should not be interpreted as emission levels from the appliance during normal operation with the catalyst.~~”

The following statement is removed (line 370 to 372 in original preprint):

~~“The Ecodesign stove may enhance pyrolysis because the secondary air can locally cool the firebox, which may explain lower PAH emissions observed in more traditional stoves.”~~

Lines 157 - 159: Is the catalyst removed in all these protocols? The removal of catalyst is also a deviation from the standard operating condition in the real world.

Thank you for the comment. Yes, the catalyst was removed in all protocols. As explained in our response to the previous comment, we removed the catalyst aiming to investigate emissions and processes occurring within the stove. The standard protocol therefore serves as an experimental baseline. We have added an additional explanation to avoid misunderstanding:

Line 159 to line 161:

“Non-ideal operation refers to deviations from the standard protocol, which is used as the experimental baseline, during refuelling onto an ember bed and/or subsequent burn cycle. ~~All~~ other operating variables follow the standard protocol.”

Line 159: Please double check if the word "protocols" is a typographical error of "protocol" and make revisions if necessary.

Thank you for this comment. We have revised the word to “protocol”.

Line 204: Please double check if the word "particles" is a typographical error of "particle" and make revisions if necessary.

Thank you for this comment. We have revised the word to “particle”.

Lines 215 - 216: How are the data points with $E_{sca} < 1$ treated in this study?

Thanks for the comment. Data points with $E_{sca} < 1$ were retained and treated as effectively uncoated BC particles in this study. The reasons for this are described in **lines 404 to 411**. We have revised the **line 410** as below to clarify:

“For clarity of reporting, a scattering enhancement factor less than 1 ($E_{sca} < 1$) was retained and assumed to indicate effectively uncoated BC particles.”

Line 374: Please double check if the word "has" is a typographical error of "have" and make revisions if necessary.

Thank you for this comment. We have revised the word to “have”.

Line 423: Please double check if the word "important" is a typographical error of "importance" and make revisions if necessary.

Thank you for this comment. We have revised the word to “importance”.

Figure 5: Please provide the color bar for this figure.

Thanks for the comment. We have added the color bar to figure 5.

Line 492: Why would a big log have a higher surface area to volume ratio? This statement seems counter intuitive if multiple smaller logs with a total volume equal to the volume of the big log are considered and compared.

Thank you for pointing this out. We agree that a single large log would generally have lower surface to volume ratio. What we intended to describe was the relatively large continuous contact area between the hot ember bed and the single big log. We have revised the manuscript accordingly.

Line 494 to 495:

“This may reflect both the prior release of volatiles during pre-ignition and the larger higher surface-ember contact area ~~to volume ratio~~ of the big log”

Line 683 to 684:

“We attribute the significant durational differences to wood-log geometry, specifically ~~the surface-to-volume ratio and~~ the ember contact area (Sect. 3.3.2). An ~~large surface-to-volume and~~ ember contacts area...”

Figure 8: Please provide the color bar for this figure and cite the reference for the classification criteria (Liu et al. 2019) in the caption to improve readability.

Thank you for this comment. We have added the color bar to figure 8. We also added (Liu et al., 2019) in the caption.

Line 543: Please double check if the word "absents" is a typographical error of "absent" and make revisions if necessary.

Thank you for this comment. We have revised the word to “absent”.

Figure 9: Please provide the color bar for this figure.

Thank you for the comment. We have added the color bar to figure 9.

Line 562: Please double check if the word "particel" is a typographical error of "particle" and make revisions if necessary.

Thank you for this comment. We have revised the word to “particle”.

Figure 10: Panels (a) and (b) are suggested to be added to the caption.

Thank you for the comment. We have added panel labels a) and b) to the caption to improve readability.

Lines 607 - 608: Does it mean that 20 nm is larger than 190 nm?

Thank you for pointing this out. We have corrected the sentence so that smaller particles are reported at $D_m \approx 20$ nm and the larger particles at $D_m \approx 190$ nm **from line 643 to 644**.

Table 3: Where is the second standard load cycle?

Thank you for pointing this out. The two logs in the second standard load cycle were placed close to each other, which could directly influence the duration of the pre-ignition and rich flaming phases. This cycle was retained in the other analyses because the measurements were valid for mixing state characterization and emission quantification. For the phase duration analysis, however, we excluded this cycle so that the remaining three standard burn cycles were more representative and consistent with the three cycles used for the other protocols.

References:

Hytönen, K., Yli-Pirilä, P., Tissari, J., Gröhn, A., Riipinen, I., Lehtinen, K. E. J., and Jokiniemi, J.: Gas–Particle Distribution of PAHs in Wood Combustion Emission Determined with Annular Denuders, Filter, and Polyurethane Foam Adsorbent, *Aerosol Science and Technology*, 43, 442–454, <https://doi.org/10.1080/02786820802716743>, 2009.

Li, S., Liu, D., Hu, D., Kong, S., Wu, Y., Ding, S., Cheng, Y., Qiu, H., Zheng, S., Yan, Q., Zheng, H., Hu, K., Zhang, J., Zhao, D., Liu, Q., Sheng, J., Ye, J., He, H., and Ding, D.: Evolution of Organic Aerosol From Wood Smoke Influenced by Burning Phase and Solar Radiation, *Journal of Geophysical Research: Atmospheres*, 126, e2021JD034534, <https://doi.org/10.1029/2021JD034534>, 2021.

Lipsky, E. M. and Robinson, A. L.: Effects of Dilution on Fine Particle Mass and Partitioning of Semivolatile Organics in Diesel Exhaust and Wood Smoke, *Environmental Science & Technology*, 40, 155–162, <https://doi.org/10.1021/es050319p>, 2006.