Authors' response to Editor and Reviewers

Manuscript Number: egusphere-2024-1313

Title: Brownness of Organics in Anthropogenic Biomass Burning Aerosols over South Asia

We thank all the reviewers for careful reading of the manuscript and their constructive suggestions and comments. A point-by-point response to the comments are provided below (in blue), along with the changes incorporated in the revised manuscript (shown in *italics*).

Reviewer #1:

The manuscript "Brownness of organics in anthropogenic biomass burning aerosols over South Asia" by Chimurkar Navinya et al. measured the absorbance and its wavelength dependence of real-world brown carbon (BrC) from different biomass fuels and sources. It further connected this absorption (kBrC) and wavelength dependence (w) with the thermos-optically obtained volatility of OC, and applied the relationship between kBrC and w and OC/OA ratio to evaluate the spatial variations of kBrC and w over south Asia. The manuscript is well within the scope of the ACP journal. The ideas and methods are good, previous studies are well-referenced, and the structure of the manuscript is generally clear. However, in the Results and Discussion section, the narrations are not sufficient enough to support the authors' views and there is a lack of proper connection between subsections. Therefore, the manuscript can only be accepted for publication in ACP after addressing the following questions.
We appreciate the reviewer's kind words and helpful advice.

Specific comments:
Line 136: it's better to include the unit of each parameter
Thank you. The sentence now includes units for BrC absorption ($Mm^{-1} = 10^6\ m^{-1}$) and total OC concentration ($\mu g\ m^{-3}$).

Line 143: "the absorption" to "the absorption coefficient"?
It is corrected to "the absorption coefficient"

Line 161: solubility (Saleh, 2020).
The period has been shifted after reference (Saleh, 2020).

Line 175: why do you think you can assume a 10% uncertainty in absorption coefficient?
To account for the uncertainty in the absorption coefficient, we referred to Cheng et al. (2021) who conducted a comprehensive analysis of uncertainties in UV-visible spectrophotometry. Their study specifically highlighted a ~10% uncertainty in the methanol-extracted k_{BrC}. By combining this with a 5% uncertainty in OC concentrations, it is reasonable to approximate the overall uncertainty in the absorption coefficient to be around ~10%.

We have modified the sentence as follows (Line 190-193):
"*Cheng et al. (2021) reported an overall uncertainty of approximately 10% for methanol-soluble k_{BrC} determined through UV-vis spectrophotometry. When accounting for the 5% manufacturer-reported uncertainty in OC concentration, the corresponding uncertainty in the absorption coefficient is estimated to be around 10%.*"

Line 192: "study" to "studies"
Corrected.

Line 192: ", however," to ". However,"
Corrected.

Line 221: the usage of correlation coefficient and R2 should be unified through the text
The "R^2" has now been used throughout the manuscript.

Lines 224-226: the sentence should be restructured. What do you think is the reason for the outliers? How many samples have you measured for each fuel and source type?
Four different brown carbon classes were suggested by Saleh (2020) based on differences in magnitude of their imaginary refractive index at a particular wavelength (typically $k_{BrC,550}$) and its wavelength dependence, w, which is a surrogate for absorption Angstrom exponent. Saleh (2020) suggests that while combustion processes emit particles containing a mix of different BrC classes, smoldering biomass emissions are skewed more toward weakly absorbing BrC (W-BrC), while high-temperature biomass combustion emissions are skewed more toward moderately and strongly absorbing BrC (M-BrC and S-BrC). Saleh (2020) also observed some of the data points lying outside of these classes, possibly due to the non-uniformity of the sources that include multiple processes—smoldering and high-temperature burning—in different proportions. Our study collects multiple aerosol samples from a burning cycle of high-temperature and smoldering biomass combustion, especially in COOK and HEAT, which could be the possible reason for this deviation.

The sentence has been modified as follows (Line 239-251):
"*The range of $k_{BrC,550}$ and w observed in this study spans across three broad classes of BrC (weak, moderate and strong) suggested by Saleh (2020) for different combustion conditions. They suggest that while combustion processes emit particles containing a mix of different BrC classes, smoldering biomass emissions are skewed more toward weakly absorbing BrC (W-BrC), while high-temperature biomass combustion emissions are skewed more toward moderately and strongly absorbing BrC (M-BrC and S-BrC). In the present work, some data points, mainly from cooking and heating, exhibit greater spectral variation (larger w) than that suggested for M-BrC, while falling within its $k_{BrC,550}$ range. Changing combustion conditions were observed during several experiments, where both flaming and smoldering combustion phases occurred, while particles were collected as a time averaged filter sample. Here, the greater spectral dependence in M-BrC measurements, implies that these samples would exert stronger light absorption in the near-UV range, than typical M-BrC.*"

The number of samples collected for each fuel and source combination are now mentioned in the Table S2. These number of samples depend on availability of fuel user, seasonal availability of fuel and logistic limitations during field campaigns. For your reference modified Table S2 has shown below:

"Table S2: Source-specific summary of BrC properties at 550 nm. The BRICK activity mainly uses coal but emissions differ based on the stage of firing, hence sub category indicates the stage of burning. Values in the square brackets show the standard deviation. Here OA is 1.8 times OC and EC is treated as BC.

Source	Fuel	Samples	$MAC_{BrC,550}$	$k_{BrC,550}$	BC to OA
AGRI	Banana	3	0.11 [0.004]	0.008 [0.001]	0.030 [0.013]
AGRI	Cotton	5	0.27 [0.30]	0.018 [0.020]	0.408 [0.170]

AGRI	Pigeon Pea	2	1.25 [0.81]	0.082 [0.053]	2.054 [0.294]
AGRI	Wheat	3	0.33 [0.53]	0.022 [0.035]	0.620 [0.139]
BRICK	Initial	7	0.33 [0.55]	0.022 [0.036]	0.142 [0.065]
BRICK	Final	3	0.10 [0.04]	0.006 [0.003]	0.083 [0.026]
BRICK	Mid	4	0.15 [0.07]	0.010 [0.005]	0.182 [0.062]
COOK	Crop Residue	1	0.21 [-]	0.014 [-]	0.324 [-]
COOK	Firewood	3	0.25 [0.07]	0.016 [0.005]	0.257 [0.125]
COOK	Mix	5	0.22 [0.05]	0.014 [0.003]	0.126 [0.054]
HEAT	Crop Residue	2	0.03 [0.001]	0.002 [0.00]	0.078 [0.014]
HEAT	Dung Cake	2	0.15 [0.08]	0.010 [0.005]	0.096 [0.072]
HEAT	Firewood	8	0.20 [0.09]	0.013 [0.006]	0.172 [0.074]
HEAT	Mix	2	0.14 [0.05]	0.009 [0.003]	0.350 [0.224]

Lines 231-232: “Such relationships … .” any reference or explanation to this?

The relationship between BC, OC, and BrC, reported by Saleh et al. (2014), were used in climate model simulations to represent BrC properties (Brown et al., 2018; Neyestani and Saleh, 2022; Wang et al., 2018).

We have modified the sentence as follows (Line 256-258):

“Relationships between BC, OC and BrC properties, reported by Saleh et al. (2014), are useful in parameterizing BrC absorption in radiative and climate models (Brown et al., 2018; Neyestani and Saleh, 2022; Wang et al., 2018).”

Line 249: . However,

“However” is added

Line 255: A similar relationship between kBrC,550 and BC/OA ratio has also been…

Thank you. The sentence has now been modified as follows (Line 302-301):

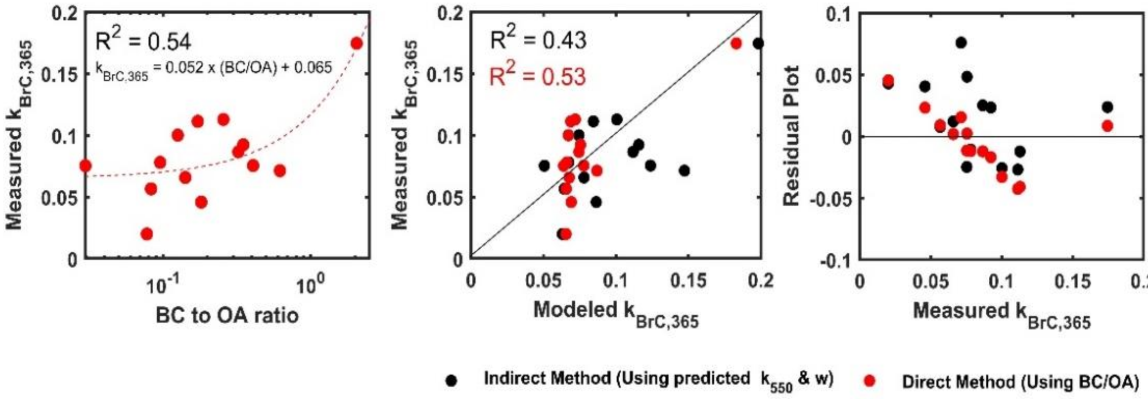
“A similar relationship between $k_{BrC,550}$ and BC to OA ratio has also been observed in other source-fuel combinations and used to parameterize $k_{BrC,550}$ and w (Figure 4).”

Lines 253-256: “In agricultural … and w (Figure 4).” Should this part be moved to the end of this subsection or section 3.3?

It has now moved to the end of this subsection.

Section 3.3 I’m interested to see the measured relationship between kBrC,365 and BC/OA ratio. It’s also interesting to see a comparison of kBrC,365 between measured and indirectly inferred from the relationships between kBrC,550 and BC/OA ratio, w and BC/OA ratio, and w and kBrC,550 ratio.

We noted the direct relationship between BC/OA ratio and $k_{BrC,365}$ has R^2 of 0.54 (see Figure below, red scatter) and the relationship between measured $k_{BrC,365}$ and indirectly (using $k_{BrC,550}$, w and BC/OA ratio) has R^2 of 0.43 (shown in black scatter markers). There is a slight difference in the R^2 between both the approaches. To maintain physical consistency, we recommend using the indirect method, despite slightly low R^2. Moreover, we observed a pattern in the residual plot when $k_{BrC,365}$ was directly estimated using BC to OA ratio (in red), which could lead to bias in k_{BrC}.



Line 318: ", while most models…"? or restructure lines 314-319.

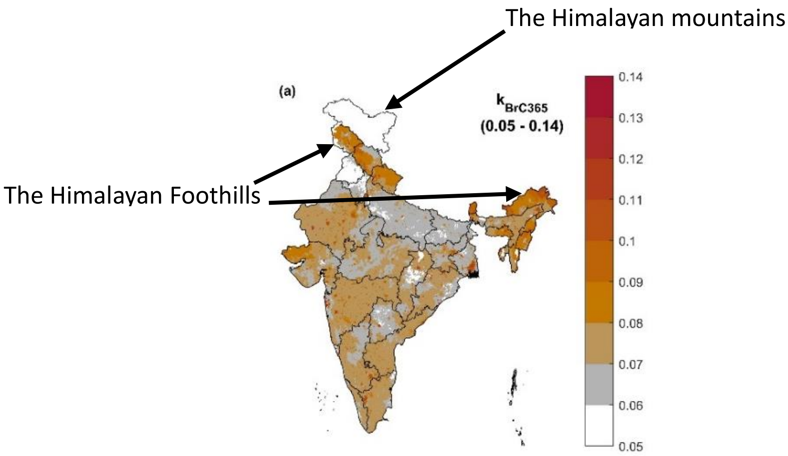
The sentence is now modified as suggested. The word "while" is added.

Lines 334-335: same to my comments to section 3.3, why do you have to estimate kBrC,365 from w and KBrC,550? Why can't you estimate kBrC,365 from the relationship between measured kBrC,365 and BC/OA ratio?

Thank you. Please kindly refer to the response to your comment on section 3.3. Briefly, we used indirectly estimated $k_{BrC,365}$ (from $k_{BrC,550}$, w, BC/OA ratio), instead of directly estimated $k_{BrC,365}$ from BC/OA ratio, due to the observed pattern in the residual plot (see above Figure), which could lead to biases.

Line 337: "shows very large kBrC", could the figure have a problem? I couldn't see very large kBrC in the northern hilly region from figure 5a or figure S6.

Thank you. We would like to clarify that the northern most part of India (The Himalayan mountains) has very low k_{BrC}, due to the low BC to OA ratio (Figure S3, S4, and S5). We would like to state that the more densely populated regions of Himalayan foothills have high k_{BrC} compared to other parts of India. In Figure S4, a high BC to OA ratio, which corresponds to high k_{BrC}, in the Himalayan foothills can be observed due to heating activities. Navinya et al. (2023) have shown that this region is dominated by extensive space heating activity.



The sentence has been modified as follows (Line 364-366):

"The Himalayan foothills show large k_{BrC} compared to other parts of India, mainly due to high BC to OA emissions from the predominant heating activity."

Lines 342-344: what I see from Figure S3 is that the absolute contribution of AGRI to kBrC in northwestern India is much lower than that of HEAT. Could you please reconsider this statement?
Thank you. The sentence has been modified as follows (Line 370-374):

"The northwestern region of India exhibits the highest OC emissions from agricultural residue burning (Figure S5), primarily from straw residue burning (Kapoor et al., 2023b), which has a relatively low BC to OA ratio. Consequently, the k_{BrC} remains lower compared to other regions, such as Maharashtra and Andhra Pradesh, where oilseed crop burning is prevalent (Kapoor et al., 2023b), resulting in higher BC to OA ratio and k_{BrC} values."

Line 350: Does "the extended time required for photobleaching" only apply to northern Idia?
Previous studies have shown a direct relationship between k_{BrC} and time required for photo-bleaching of BrC particles. Therefore, since some regions in northern India have larger k_{BrC}, BrC particles emitted in these regions are likely to take more time for photobleaching.

See the modified sentence below (Line 387-389):
"The substantial emissions of BrC across the country, coupled with the high k_{BrC} values observed in certain other regions, suggest that BrC particles may have significant radiative impacts over the region."

Lines 332-350: a detailed interpretation of the distributions of source- and/or fuel-specific contributions to w, kBrC,365, and kBrC,550 could be interesting and helpful to the explanation of other views already presented in this paragraph.
Thank you for the suggestion. We have added the following details highlighting contribution from different sources and major fuels.

Line 370-383:
"The northwestern region of India exhibits the highest OC emissions from agricultural residue burning (Figure S5), primarily from straw residue burning (Kapoor et al., 2023b), which has a relatively low BC to OA ratio. Consequently, the k_{BrC} remains lower compared to other regions, such as Maharashtra and Andhra Pradesh, where oilseed crop burning is prevalent (Kapoor et al., 2023b), resulting in higher BC to OA ratio and k_{BrC} values. Heating activities are particularly intense in the colder areas, especially in the Himalayan foothills, with a higher use of firewood in the eastern India (Navinya et al., 2023), lead to significantly higher BC to OA ratios, and elevated k_{BrC} in the northern and eastern regions (Figure S3). In the Central Indo-Gangetic Plain, particularly in Uttar Pradesh and Bihar, dung cake is more commonly used for heating (Navinya et al., 2023), which contributes to very low k_{BrC}. The variation in the BC to OA ratio across India due to cooking activities is minimal (0.075-0.125) compared to that from agricultural residue burning (0.025-0.2) and heating (0.025-0.25), resulting in substantially low spatial variation of $k_{BrC,365}$ (0.06-0.08) from cooking (Figure S3)."

Reviewer #2:

The manuscript provides important data and findings to assess the radiative forcing of BrC emissions in South Asia. The study fits well within the scope of ACP. The manuscript is well-written. It discusses the results in most cases properly and considers also relevant previous studies. The methods seem appropriate. However, the authors could discuss and elaborate the influence of the used methods on the obtained results and consider the methodological differences also when comparing the results of this study to those from previous studies (e.g. related to the methodologies used in sample collection and organic matter extraction from the collected filter samples). The results and conclusions are presented in a clear, concise, and well-structured way and the manuscript can be accepted after a minor revision, taking into account the following specific comments:
We appreciate the reviewer's valuable comments, which have greatly enhanced the quality of the manuscript.

line 19: "This leads to oversimplified model parameterization and subsequent underestimation of regional radiative forcing."

- If refractive index (RF) has uncertainty, the current estimations may either underestimate or overestimate radiative forcing? Should this rather be "subsequent uncertainty" of regional radiative forcing?

Thank you. The sentence has now been modified as follows (Line 19-20):

"This leads to oversimplified model parameterization and subsequent uncertainty in regional radiative forcing."

Lines 112 "This study leverages samples of aerosol particle emissions collected on filter substrates during the COALESCE field campaign to propose a hypothesis regarding the BrC-BC continuum in BrC optical properties."

- It remains unclear what is the hypothesis that is proposed. Please describe it.

Thank you. The sentence has now been modified as follows (Line 112-114):

"This study leverages samples of aerosol particle emissions collected on filter substrates during the COALESCE field campaign to evaluate BrC-BC light absorption continuum behavior in real-world biomass burning emissions."

Line 132: "The sampler is fully described in previous studies (Venkataraman et al., 2020; Kumari et al., 2021).

- Some basic information of the sampling system would be important. However, the link given for the reference Kumari et al. (2021) does not work and the reference Venkataraman et al., 2020 presents a project report, but the reviewer found no description for the sampling setup. Please describe how sampling was performed to acquire representative samples. Did you quantify the dilution ratio of raw exhaust gas with ambient air and the sampling temperature? Both of these influence the partitioning of organic matter and therefore the volatility fractions that are in the particulate matter during sampling. (and as the paper discusses, different volatility fractions may exhibit different BrC absorption strengths).

Thank you. A brief description of the sampling system and sampling process is now updated in the manuscript. We have updated the references and now cite Kumari et al. (2024) and Venkataraman et al. (2020). We would like to add that the manuscript of Kumari et al. (2021) (doi: https://aaarabstracts.com/2021/viewabstract.php?pid=599) is now published, the article (Kumari et al., 2024) describes measurement system in detail, which was briefly introduced in Venkataraman et al. (2020). We noted that the link to supplementary report of Venkataraman et al. (2020) is not working. However, we would be happy to provide the supplementary report of Venkataraman et al. (2024) and the accepted manuscript of Kumari et al. (2024) to editor.

Line 128-143:

"*The versatile source sampling system, as described by Kumari et al. (2024) and Venkataraman et al. (2020), consists a multi-arm inlet design adapted from Roden et al. (2006) to function as an area plume sampler, positioned 1 to 1.5 meters above the emission source (Figure S2). The system comprises eight arms that aspirate aerosols, which are then combined in a mixing plenum to ensure representative sampling of the smoke plume. Aerosols drawn through the inlet pass through a 2.5 µm cut-off cyclone, subsequently being divided into two streams: for real-time and gravimetric measurements. Aerosols in the gravimetric stream were collected on quartz filter substrates for offline laboratory analysis over the entire duration of the experiment, encompassing ignition, flaming, and smoldering phases, in order to obtain a sample representative of the complete combustion cycle. The temperatures of the emitted plumes were diluted by the surrounding air, reaching levels close to that of ambient air before entering the multi-arm sampler. This ensured that the emissions had undergone gas-to-particle partitioning, corresponding to the properties of emissions used in climate models. In this study, we utilized aerosol-laden quartz filter substrates from 14 different fuel and source combinations (Table S1) to understand soluble BrC absorption (Mm^{-1} = 106 m^{-1}) and total OC concentration (µg m^{-3}).*"

We thank the reviewer for raising this pertinent point. While we did not measure the flame temperatures, which would be necessary to quantify the dilution ratios, the average temperature of the sampled aerosol (38 ± 5) was very close the ambient temperature. Therefore, the gas-to-particle partitioning of the organic carbon aerosols would be complete, aligning with the emissions used in climate model simulations. For more clarity, we have added a following sentence (Line 138-141):

"*The temperatures of the emitted plumes were diluted by the surrounding air, reaching levels close to that of ambient air before entering the multi-arm sampler. This ensured that the emissions had undergone gas-to-particle partitioning, corresponding to the properties of emissions used in climate models.*"

Line 157: "The estimated BrC absorption could be underestimated due to excluded insoluble BrC and tarball structures, which possess high absorption strength (Corbin et al., 2019; Chakrabarty et al., 2023, 2010). The underestimation may be more pronounced within the dark-BrC region but comparatively lower in other BrC categories (figure 2), considering the inverse relationship between BrC absorption strength and solubility. (Saleh, 2020). In this study only two data points, observed marginally in the dark-BrC region, might be affected"

- It is important that this methodological limitation of excluding the methanol insoluble fraction of organic matter is mentioned here. It is also a good idea to refer to the wavelength dependency (w) vs. K_550 space presented by Saleh (2020). However, if your results indicate no low solubility organic matter in this space, but on the other hand your method excludes the analysis of methanol insoluble organic matter, is this not a circular argument? (i.e. your method restricts your data to show no insoluble organic matter in the w-k550 space.).

Thank you for the suggestion; we understand that the text may not have been clear in the previous version of the manuscript. We have rephrased the text and removed the last line to avoid the circular argument, as follows:

Line 167-169:

"The underestimation may be more pronounced as particle light absorption strength increases, i.e., closer to the dark-BrC region, since particle solubility is inversely proportional to light absorption strength (Saleh, 2020)."

- Tarball structures are often present in all kinds of open biomass burning emissions. Could you explain why they would not be present in your samples?

We agree with the reviewer that tarball-BrC may be present in the collected samples. The sentence being referred to by the reviewer has been modified.

- When comparing the results of this study to those presented by Saleh (2020), could you also discuss the methodological differences in these studies?

Saleh (2020) is a review article that compiles results from multiple studies. Hence, we have now added the sentence that includes methodological differences.

Line 169-175:
"In brief, Saleh (2020, and references therein) reviewed and categorized different BrC classes based on their volatility, using UV-vis spectrometry, optical closure (Aethalometer, Cavity Ring-Down Spectroscopy, and photoacoustic), and electron energy loss spectroscopy techniques. While UV-vis spectrometry misses out insoluble particles, optical closure techniques consider absorption by particles regardless of their solubility. However, they have uncertainties associated with separating BrC light absorption from the total aerosol light absorption."

Line 165: "Thermo-optically resolved carbon fractions (OC1, OC2, OC3, OC4, EC1, EC2, and EC3) were used after pyrolytic correction to reconstruct the total organic carbon and total elemental carbon fractions (Chow et al., 2007).

- When making the pyrolytic correction, in which fraction did you add the pyrolytic carbon (PC)? Since pyrolytic carbon is originally organic carbon that pyrolyses during the OC-phase and decomposes during EC-phase, to the reviewer's knowledge it is normally not assigned to any specific OC fractions.

We agree with the reviewer that pyrolytic carbon is not generally added to any thermal carbon fraction. However, for the purpose of representation in Figure 3, we have assigned pyrolytic carbon (PC) to OC4. While this may not be accurate, it facilitates easy understanding of the thermal fractions. Moreover, it does not affect the OC and EC calculations, as PC is included in the total OC for analysis. For additional clarity, we have revised the sentence as follows (Line 179-182):

"Thermo-optically resolved carbon fractions (OC1, OC2, OC3, OC4, EC1, EC2, and EC3) were used after pyrolytic correction to reconstruct the total organic carbon and total elemental carbon fractions (Chow et al., 2007). For the purpose of representation in Figure 3, pyrolytic carbon was assigned to OC4."

We also mentioned the same in the caption of Figure 3
"For the purpose of representation, pyrolytic carbon was assigned to OC4."

Line 179: "The imaginary refractive index of BrC (kBrC,λ) was estimated by considering the density (ρ) of freshly emitted OC to be 1.5 kg m-3"

- I assume that the density used was 1500 kg/m3? Please correct

Thank you. It has been corrected now.

Line 189: "w (AAE-1) indicates the spectral dependence of the imaginary refractive index (w)"

- Should it be "imaginary refractive index (k)" ?

Thank you. "(w)" has been removed as it has been already mentioned in Line 70.

Line 199: "Here, OA was derived by multiplying OC by a factor of 1.8"

- Is this assumption in agreement with the assumption of using 1,5 g/cm3 as the OA density? The method by Kuwata et al. (2012) could possibly be used to evaluate this.

Thank you for the suggestion. The assumption of 1.8 as a multiplication factor was just for the representation purpose to facilitate the comparison with previous studies. We tried to validate it as per Kuwata et al. (2012), and found OA density ~1.4-1.5 g cm^{-3}. Based on this, the sentence has been modified now and refer Kuwata et al. (2012) for the validation of the assumption.

Line 215-218:

"*Here, OA was derived by multiplying OC by a factor of 1.8, a methodology consistent with previous studies (Turpin et al., 2001; Chow et al., 2015; Navinya et al., 2020; Provençal et al., 2017; Kumar et al., 2023), and aligned with the considered OA density (Kuwata et al., 2012).*"

Line 227: "The thermo-optically resolved carbon fractions show a decline in the total OC fraction, mainly OC3 and OC4 (a relatively low volatile fractions) with increasing BrC absorption strength (Figure 3a).

- This result sounds somewhat confusing. If mainly OC3 and OC4 fractions (which are the low volatility and solubility fractions) decline, one would expect to see a decrease in BrC absorption strength based on the Figure 2.

Thank you for the suggestion. We modified the sentence and highlighted decrease in the OC1+OC2, high volatility, and high solubility fractions, from 50% to 20% when BrC light absorption strength increases from weak to moderate.

Line 251-253:

"*The thermo-optically resolved carbon fractions show a decline in the total OC fraction, mainly in OC1 and OC2 (relatively high volatile fractions), with increasing BrC absorption strength from weak to moderate (Figure 3a).*"

- Can you explain why specifically OC3+OC4 decline with increasing BrC absorption strength?

The sentence has now been modified, highlighting decrease in OC1+OC2 with increase in BrC light absorption strength from weak to moderate.

Line 256: "The large variation in kBrC,550 during agricultural residue burning could be due to differences in the combustion conditions and fuel properties"

- "Combustion conditions and fuel properties" is very broadly defined. It is very likely that they explain the observed variation.

The sentence has been modified as follows (Line 279-281):

"*A large variation in $k_{BrC,550}$ was observed during agricultural residue burning, with banana, which has a high moisture content (Tock et al., 2010), showing a $k_{BrC,550}$ of 0.008, and pigeon pea (an oil seed legume) having a $k_{BrC,550}$ of 0.082.*"

Line 262: "The combustion conditions during these three activities are comparatively different could be because of the very low fuel feed rate."

- If you have no data of the fuel feed rate, this sounds like unnecessary speculation and could be removed. The combustion conditions and combustion efficiencies are influenced by a large number of parameters. The fuel feed rate is not a good parameter to describe the combustion process, because of the variability in the combustion systems in this work. The air-fuel equivalence ratio would be a more precise parameter to describe the ratio of stoichiometric combustion air demand to the amount of available air in the combustion process. Moreover, distinguishing between open and closed combustion systems and reporting the fuel moisture contents could help the evaluate the data. Finally, if the measurements had included defining of the modified combustion efficiencies (by measuring CO and CO2 from the sampled gas/aerosol), it could be used to assess the differences in combustion conditions. Without any of such data I believe it will not be possible to explain the observed variation in the data.

Thank you, we agree with the reviewer that the absence of a quantitative measure of the fuel feed rate, it is difficult to support this argument with the complexities described. We have therefore removed this statement from the manuscript.

Line 271: "The values reported in our study are in the upper range of ambient MACBrC,365 (0.62-2.3) reported previously over India (Sarkar et al., 2019; Shamjad et al., 2018; Satish et al., 2020; Rastogi et al., 2021; Rana et al., 2020; Kirillova et al., 2016; Dey et al., 2021).

- Could this be because this study analysed fresh exhaust particulate matter and in ambient studies photobleaching of BrC might decrease its MAC?

We agree with reviewer and have added a line on photobleaching and a comparison with source-specific BrC. The sentence has now been modified as follows (Line 291-296):

"*The values reported in our study are in the upper range of ambient* $MAC_{BrC,365}$ *(0.62-2.3* $m^2\ g^{-1}$*) reported previously over India* (Dey et al., 2021; Kirillova et al., 2016; Rana et al., 2020; Rastogi et al., 2021; Sarkar et al., 2019; Satish et al., 2020; Shamjad et al., 2018)*, which could be due to photobleaching of ambient BrC that decreases MAC. However, our estimation of* $MAC_{BrC,365}$ *aligns well with the previously reported source-specific values (1.09-2.53)* (Debbarma et al., 2024; Pandey et al., 2020; Rathod et al., 2017)."

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