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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Long-term Brown Carbon and Smoke Tracer Observations in Bogotá, Colombia: Association to Medium-Range Transport of Biomass Burning Plumes" *by* Juan Manuel Rincón-Riveros et al.

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Response to Anonymous Referee #3

We kindly asked to reviewer to see attached file with the response to ensure all the symbols appear correctly.

RC: This manuscript presents 3-year measurements of aerosol light absorption at multiple wavelengths over a site in the Northern South America (NSA) region. These measurements are combined with campaign-based biomass burning tracer measure-

ments, MODIS fire counts and back-trajectory analysis to examine seasonal variations and source attributions of black carbon and brown carbon. It is one of the few observational studies over NSA, and clearly demonstrates the influences of nearby biomass burning on the local air quality in densely populated areas. The long-term observations of biomass burning aerosol properties are also useful in revealing the regional and temporal variability in light absorbing aerosols. The sample collection and data postprocessing parts are well described. My major concern is about the inference of brown carbon concentration in section 2.2. First, the assumptions of FF AAE (=1) and BB AAE (=2) are subject to large uncertainty. How sensitive are the derived BC and BrC concentrations to these assumed AAEs? It would be helpful to include some sensitivity analysis by varying the AAE values.

Authors Response: We have now included a sensitivity analysis showing how the uncertainties associated to these parameters impact the calculated attribution of absorption to combustion of biomass or fossil fuels (Figure R1). We also enhanced the discussion on the sources of uncertainty. In a now expanded supplementary material, we show the impact of parameter choice on the inferred BrC concentration. After performing this analysis, we showed the estimated BrC is only slightly affected by the choice of α_BB, while it is more sensitive to α_FF. However, in any case, the correlation of BrC and MODIS fire counts remains unchanged. Figure R1 and a subsequent discussion on the sensitivity is now included in the Supplementary Material.

For our specific data set, heavily influenced by traffic emissions , the observed angstrom exponent is closer to 1 (α_(450nm-950nm)=1.025$\pm$0.2 and α_(450nm-880nm)=1.065$\pm$0.22). Therefore, the inferred BB fraction is much more sensitive to α_FF than it is to α_BB. This can be seen in the Figure R1 of this response (which has also been included in the Supplementary material for the final manuscript). This is positive for our study, as it is well known that α_BB is much more uncertain than α_FF (which is largely accepted to be close to 1). This analysis is now included in the manuscript.

RC: Furthermore, lines 156-157 indicate that BrC concentration is computed as the product of eBC (equivalent BC concentration) and f_BB (fractional contribution of biomass burning to absorption). This is confusing: isn't the product equal to BC concentrations from the BB sources? How is it related to the BrC concentration? Presumably, BB aerosols should include both BC and BrC. But the inference method of BrC in section 2.2 seems to imply that absorption in BB aerosols is due to BrC. The calculation of BrC concentrations needs clarification.

Authors Response: A section was included in the supplementary material to expand and clarify the decomposition method applied in our study. The Methods section was also expanded to improve clarity. The method we used (Sandradewi et. al. 2008) is often referred to as the "Aethalometer model". In our manuscript (section 2.2), absorption at any given wavelength is indeed considered to be due both to BB and FF at any given wavelength. The FF contribution is associated with a λ^(-1) component (typical of BC rich FF sources) and the BB component is associated with an Angstrom exponent >1 (typical of sources with light absorbing OC, such as BB). Our approach, as suggested by the manufacturer, is to use optical properties of black carbon to estimate mass. This is likely an underestimation of true BrC mass as most studies suggest its mass absorption cross sections is lower than that of BC.

RC: Another suggestion is since there are previous studies of BrC from the Amazon BB region, it'd be interesting to compare the derived BrC loadings and absorption properties over NSA with those in discussions. That would help extend the findings in this study to a larger regional context.

Authors Response: Done. We included some new references were absorption measurements of BB aerosols are made in NSA. These include (Saturno et al., ACP, 2018; Hamburguer et al, ACP, 2013). The addition now reads "Our observations are broadly consistent with other available studies of aerosol absorption in the region that have reported an increase in babs and Angstrom exponent during the dry season. Observations at the ATTO tower in central Amazonia show babs,635nm= $4.0 \pm 2.2 Mm^{-1}$ during

the dry season (Saturno et al., 2018). Other observations at Pico Espejo, in NSA show babs,525nm= $0.91 \pm 1.2 Mm^{-1}$ during dry season, corresponding to three times the mean value observed during the wet season. However, both sites correspond to locations near the source areas, while our observation site is an urban site far away from the main biomass burning areas".

Minor comments:

Line 38: the source of BrC is not limited to BB. They could also come from biofuel and biogenic sources. Suggest to revise the definition of BrC, i.e., Andreae and Gelencser, 2006

Authors Response: Point well taken. We rephrased and reorganized this section to acknowledge other sources of BrC. It now reads: "The organic material (OM) present in aerosol particles, mainly those produced in BB, biofuel combustion, and from other sources, has been recently shown to absorb light in UV and short visible wavelengths more efficiently than BC. The absorption increases proportionally to the amount of OM present in the aerosol (Yan et al., 2017; Mkoma et al.,2013). The collection of UV light-absorbing organic compounds present in aerosol particles is often termed Brown Carbon (BrC) (e.g., Kirchstetter et al., 2004; Andreae and Gelencsér, 2006; Wang et al., 2018), which is also a contributor to radiative forcing."

RC: Lines 39-40: This sentence is inaccurate. The referred paper Bond et al., 2013 suggests that BC is the second largest contributors to anthropogenic radiative forcing, not BB particles

Authors Response: This oversight is now corrected in the manuscript. We now use the reference more accurately. It now reads: "Due to its optical properties, EC is sometimes measured through light-absorption techniques, and when measured this way is referred to as equivalent Black Carbon (eBC) (Petzold et al., 2013). BC is the second largest contributor to anthropogenic radiative forcing whit open burning of forests and savannas being the largest source (Stohl et al., 2015; Bond et al., 2013)."

RC: Line 65: missing a comma after “...their work”

Authors Response: Corrected.

RC: line 66: replace “finding” with “indicating”

Authors Response: Corrected.

RC: Line 83: “Levoglucosan” doesn’t need an initial capital letter

Authors Response: Corrected.

RC:Line 92: brown carbon and black carbon do not need initial letter capitalized. This needs to be corrected in other places as well

Authors Response: This is now corrected throughout the manuscript.

RC: Section 2.4: why not make the observatory site directly as the starting point of the back-trajectories, instead of Bogota? Since they are located at different altitudes.

Authors Response: The (lat, lon) coordinates used in the calculation are indeed those of the Monserrate site. This typo is now corrected. However, it should be noted that the spatial resolution of the meteorological data (1 degree, roughly equivalent to 110 km) is too coarse to accurately represent differences in back-trajectories starting from nearby points. In a previous study, we found that due to the complex topography of the region, selecting starting points that are too close to or at the surface yields unrealistic back-trajectories. That is why we selected our arriving point at 1000 m.a.g.l, so it is not at the surface but remains within the mixing layer. This is now explicitly stated.

AC: Line 123: W doesn’t need capitalization Authors Response: Corrected.

AC:. Line 126: what is Davis Advantage Pro II?

Authors Response: This is now corrected. The Vantage-Pro2 (it was erroneously typed in the original manuscript) is the specific model of the meteorological station used for the data collection, which is made by Davis Instruments. This is now explicitly written

in the manuscript.

AC:. Figure 1 (b): suggest to add a color scale for the background map. Is it for terrain height? Authors Response: Point well taken. The figure was modified and included a more descriptive legend (See Figure R2 included in this response). The color scheme is related to land-use cover (urban area, hills, and cropland/grassland). The shading is intended to qualitatively show terrain height variations, and this is mentioned in the caption. If height contour levels are included the plot gets cluttered and then is no longer effective.

RC: Line 209: what is the spatial resolution of GDAS1 meteorology? Authors Response: This is now corrected. GDAS1 meteorology is 1° x 1°. We now explicitly mention this in the manuscript.

Please also note the supplement to this comment:
https://www.atmos-chem-phys-discuss.net/acp-2019-1124/acp-2019-1124-AC2-supplement.pdf

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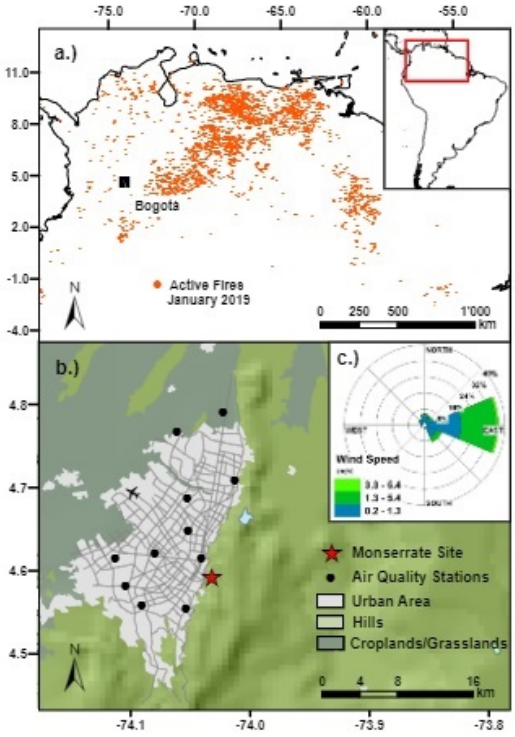

Fig. 1. Figure - R2. Modified figure including a more detailed legend