Response to Reviewer-2

The manuscript describes measurements of vertical profiles of size resolved number concentrations using an aerodynamic particle sizer and BC derived from a 7 channel aethalometer from three different going from west to east in the Indo Gangetic Plain (IGP). Measurements were made during an experiment named SWAAMI and the results from this experiment were discussed earlier in a couple of publications (Vaishya et al.,2018; and Govardhan et al.,2019) and probably others. There is a lack of vertical profile data of aerosols over the Indian sub-continent and in particular during the pre-monsoon season when the radiative balance over India and surrounding regions plays large role in driving the monsoon circulation. In that sense this paper is a welcome addition. However, the manuscript feels like the authors have tried to slice and dice the data in different ways but in the end doesn't seem to add anything new. It may be useful as a document of the data/analysis and I accept the paper with that view, though it often reads like a report than a research paper. The description of the dataset and the outcomes of the analysis is reasonable and there is not a lot that can be said in terms of any technical shortcomings of the arguments presented.

We thank the reviewer for the overall evaluation. We have addressed all the comments of the reviewer. Our response to each comment is shown by bold letters, below each comment.

Specific comments:

Line 462: The authors mention 'soot' emissions as of importance from thermal power plants. I generally assume this is primary fly ash and other suspended particulate matter (heavy metal containing particles). They seem to suggest there is soot and SPM and I am not sure what the distinction is?

Line 466: seems to suggest soot is BC. Are there any measurements in the power plant plumes to suggest that BC is a major emission from burning coal in power plants? I haven't come across this in discussions of power plant emissions elsewhere.

Response: Sorry for the lack of clarity. We agree with the reviewer that fly ash and SPM are major constituents in TPP emissions. Soot or BC is a major component in SPM. We have elaborated this in the revised manuscript, in addition to highlighting reported literature on BC measurements and characterization near coal burning power plants. The following has been added to the manuscript:

<u>Line nos. 505-522</u>: "In this context, we have examined the possible role of the large network of thermal power plants (TPP) over the northern part of India, which is reported to have significant contribution to regional emissions (Singh et al., 2018). These include the emissions of SO_2, NO_x, CO_2, CO, VOC, suspended particulate matter (PM2.5 and PM10, including BC and OC), and other trace metals like mercury (Guttikanda and Jawahar, 2014; Sahu et al., 2017) dispersing over large areas through stacks. Fly ash from coal-fired power plants causes severe environmental degradation in the nearby regions (5-10 km) of TPP (Tiwari et al., 2019). Over the IGP, since more than 70% of the thermal power plants are coal based, emissions of CO_2 and SO_2 hold more than 47% of the total emission share, while the relative share of PM2.5 and NOx are ~15% and 30% (GAINS, 2012). Based on in-situ measurement of BC, in fixed and transit areas, in close proximity of seven coal-fired TPP in Singrauli (located ~ 700 km north-west of BBR), Singh et al., (2018) have reported that BC concentration reached as high as 200 $\mu g.m^{-3}$ in the transit measurements. The Energy and Resources Institute, India have also reported that emission levels of the carbonaceous (soot or BC) particles are estimated to be around 0.061 gm/kWh per unit of electricity from Indian thermal power plants (Vipradas et al., 2004). Based on emission pathways and ambient PM2.5 pollution over India, Venkataraman et al., (2018) have reported that the

types of aerosols emitted from coal burning in thermal power plants and industry in eastern and peninsular India are similar to that of residential biomass combustion. These clearly indicate that TPP are major sources of BC in the atmosphere."

Figure 13: The figure shows the large fraction of the measurements with angstrom absorption exponents over values of 1 with median values of 1.3 and significant fraction near 1.5 and over. The authors say this is all fossil fuel emissions. Shouldn't these values of the angstrom absorption coefficient put these in the biomass burning and probably BrC range? Generally what fraction of the absorbing material measured using the technique used here fall in the BrC range as compared to BC?

Response: We are sorry for the lack of clarity on the discussion on Angstrom absorption exponent. We have taken care of the suggestion and revised the discussion on aerosol spectral absorption as given below:

Line nos. 550-563: "Based on laboratory studies and field investigations, it has already been shown that the higher values of α_{abs} (~ 2) are representative of BC from biomass burning emissions, while the values ~ 1 are indicative of BC from fossil fuel combustions (Kirchstetter et al., 2004). The values of α_{abs}> 1 are indicative of the presence of aerosols from biomass-burning, whose relative abundance increase with the steepness of the spectral absorption spectra, as has been reported elsewhere from the laboratory experiments [Hopkins et al., 2007].

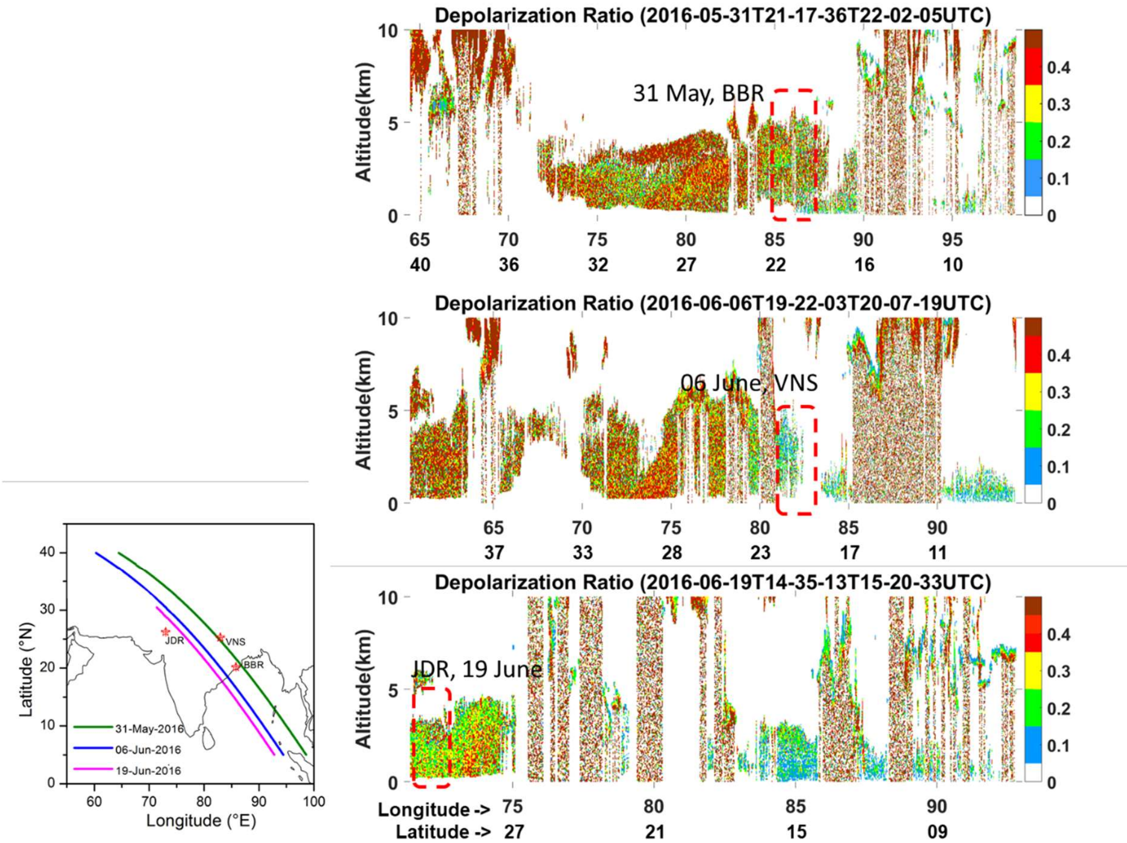
Examining Figure 14 in the above light, it emerges that significant contribution of BC from fossil fuel combustions mixed with that from biomass burning origin prevails at higher altitudes over BBR, while the association between the two decreases abruptly from ML to higher heights at VNS. Consistently higher values of BC in the column associated with the values of α_{abs} lying between 1 and 1.5 can also be due to the ageing of BC at higher heights, during which BC mixes with other species and its Angstrom exponent increases, as the spectral dependence of absorption steepens when BC (even though its source could be fossil fuel) is coated with a concentric shell of weakly absorbing material (Gogoi et al., 2017). Further investigations are needed in this direction."

Figure 11: Either labels on the figure (namely figure (a) and figure(b)) or the title of the figure is either wrong or not clear

Response: Sorry for the oversight. We have corrected the Figure caption in the revised manuscript.

Figure 9: The focus of the figure is on values less than 0.3, the scale has just one color below that. It will be better if the color scale is recalibrated and plotted with the scale going from 0 to 0.5.

Response: Complied with. We have modified the figure in the revised manuscript as shown below.



Line 290: The temperature in the western most location is said to be 40 C. This should make this location have the deepest ABL and is not consistent with the description of ABL depths in lines 238:243

Response: We are sorry for this mix-up. The value provided in the manuscript was indicative of the general surface air temperature encountered in that location. The actual values during the flight period, however, were different and this is now provided in the revised manuscript:

<u>Line nos. 210-213</u>: "The meteorological conditions across the IGP during the campaign period was generally hot (surface temperature, T ~ 34.7 ± 2.8 ^{o}C at JDR, 39 ± 1.9 ^{o}C at VNS and 32.8 ± 3.6 ^{o}C at BBR at the time of flight take off), with low to moderate relative humidity (RH) at JDR (RH ~ 40%) and VNS (RH ~ 60%)."

<u>Line nos. 254-255</u>: "The mean ABL heights are 1.3 ± 0.5 km, 2.3 ±0.5 km and1.4 ± 0.2 km for JDR, VNS, and BBR respectively (Vaishya et al., 2018) at local noon time."

References:

GAINS, Greenhouse Gas and Air Pollution Interactions and Synergies - South Asia Program. International Institute of Applied Systems Analysis, Laxenburg, Austria, 2010.

Guttikunda, S.K. and Jawahar, P.: Atmospheric emissions and pollution from the coal-fired thermal power plants in India, Atmos. Env. 92, 449-460 http://dx.doi.org/10.1016/j.atmosenv.2014.04.057, 2014.

Hopkins, R. J., Tivanski, A.V., Marten, B.D., and Gilles, M. K., Chemical bonding and structure of black carbon reference materials and individual carbonaceous atmospheric aerosols, J. Aerosol Sci. 38, 573–591, 2007.

Sahu, S.K., Ohara. T., and Beig, G.: The role of coal technology in redefining India's climate change agents and other pollutants Environ. Res. Lett. 12, 105006, https://doi.org/10.1088/1748-9326/aa814a, 2017.

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Vipradas, M., Babu, Y.D., Garud, S., and Kumar, A., Preparation of road map for mainstreaming wind energy in India, TERI project report No. 2002RT66, The Energy and Resources Institute, 2014.

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