Reply on RC1
Prashant Chavan et al.

Author comment on "The outflow of Asian biomass burning carbonaceous aerosol into the upper troposphere and lower stratosphere in spring: radiative effects seen in a global model" by Prashant Chavan et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-494-AC1, 2021

General comments:

The paper, basing on model simulations validated with satellite and ground observations, investigates the transport of carbonaceous BB to the Upper Troposphere – Lower Stratosphere during spring and its impact on the radiative balance. The manuscript is presented in a clear and well-structured manner, and the topic is of relevance. I therefore encourage its publication, provided some minor revisions.

Reply: We thank the reviewer for valuable suggestions and for appreciating our efforts. The suggestions made by the reviewer are incorporated in the revised manuscript. The changes are indicated in blue color in the revised manuscript and corresponding line numbers are also mentioned in the replies given below.

Specific comments:

(1) Lines 36-37: “It is one of the major sources of a large carbonaceous aerosol loading” This sentence needs to be more specific/referenced.

Reply(1): We have included a reference (Ni et al., 2019) now at L37.

(2) Lines 69-70: Are those all the references for the projects? It seems like one is missing.

Reply(2): References for all the projects are included now (L72-73).

(3) Lines 105: is there any reference for AEROCOM-ACCMIP-II?

Reply(3): A reference for AEROCOM-ACCMIP-II is now included at L116.

(4) Lines 107-108: GICC, RETRO and GFED v2: are they summed/averaged? How are they used all together?

Reply(4): Sorry for not being clear. The ACCMIP-II emissions are derived from
harmonization of data from GICC (Mieville et al. 2010), RETRO (Schultz et al., 2008), and GFED v2 (Van Der Werf et al., 2006).” However, to avoid confusion it is removed now. The text is re-written as “The anthropogenic and fire emissions were obtained from the ACCMIP-II (Emissions for Atmospheric Chemistry and Climate Model Intercomparison Project) emission inventories and are interpolated for the period 2000-2100 by using Representative Concentration Pathway 4.5 (RCP4.5) (Lamarque et al., 2010; van Vuuren et al., 2011).” (L112-116).

(5) Lines 109-110: Many inventories are representative only of averages over specific periods: is there a reason why forest and grass fires emissions are mentioned specifically in this respect?

Reply (5): We agree that many inventories are representative only of averages over specific periods. There is no need to mention forest and grass fires emissions explicitly and therefore this is removed now. The above sentence is rewritten as “The biomass burning emissions dataset represent average conditions of the decade (Tegen et al., 2019).” (L116-117)

(6) Lines 117: Is it necessary to mention sea salt and dust?

Reply (6): It is removed now.

(7) Lines 125-126: It is not clear how the setup of the simulations were made: what is meant in particular by “starting between 1 and 10 January 2012 and ending on 31 December 2013 to explore the variability due to the initial conditions.”? In which way do you vary the initial conditions? Are those variations the same between the members of the BMaerooff and the of BMaeroon?

Reply (7): Sorry for not being clear. It is re-written as “We performed two sets of emission sensitivity experiments; in one set of the simulations, the aerosol emissions from biomass burning were kept on (referred to as BMaeroon simulations) and in another set of the simulations, the aerosol emissions from biomass burning were kept off (referred to as BMaerooff simulations). We adopted an ensemble mean approach (with ten ensemble members) for the above two experiments. Ten spin-up simulations were performed from 1-10 January 2012 up to 28 February 2013 to generate stabilized initial fields for the ten ensemble members. Emissions were the same in each of the ten members during the spin-up period. In the BMaerooff simulations (ten ensemble members each), the biomass burning aerosols were switched off since 1 March 2013. The BMaerooff simulations ended on 31 December 2013. To investigate the effects of biomass burning aerosols emissions in spring (i.e., since 1 March 2013), we analyze the difference between BMaeroon and BMaerooff simulations for the spring season in 2013. (L132-144).

(8) Lines 141-143: The fire counts product is not properly presented and it remains unclear what does the mcd14d variable is representing. Where does it come from? Can the author put a summary sentence about the basics on how these values are estimated?

Reply (8): We have now explained that the variable mcd14d represents MODIS combined Terra/Aqua daily fire location data. We have now explained how fire values are estimated as below (L156-165).

In order to study spatio-temporal variations in the biomass burning activity, we analysed the Terra/Aqua combined daily active fire location data (product mcd14dl) from the Moderate Resolution Imaging Spectroradiometer (MODIS) (https://firms.modaps.eosdis.nasa.gov/download/) onboard Terra and Aqua (Earth Observing System). This MODIS collection-6, Level-2 global data are processed by NASA's Land, Atmosphere Near real-time Capability for EOS (LANCE) Fire Information for
Resource Management System (FIRMS), using swath products (MOD14/MYD14). The thermal anomaly / active fire represents the centre of a 1 km pixel that is flagged by the MODIS MOD14/MYD14 Fire and Thermal Anomalies algorithm as containing one or more fires within the pixel (Giglio et al., 2003).

(9) Lines 210-211: Is there any existing inter-comparison study that explains/show such difference between the two products?

Reply(9): Thank you for the suggestion. We have mentioned the inter-comparison study that explains the differences between MODIS and MISR as below.

The differences between MISR and MODIS may be due to differences in their calibration, algorithm assumptions, or the aerosol models in the lookup tables used in the retrieval algorithms (Addou et al., 2005; Choi et al., 2019). (L268-271)

(10) Fig 2: Is the amount of aerosol over the Himalayas indicated in the simulation expected to be a model overestimation, or can it be plausible? Why are there such low modeled values with respect to measurements in the region southerner than 10N? It seems quite a coherent pattern, is it related to any specific circulation feature?

Reply(10): The model shows overestimation of AOD over the Tibetan plateau region and underestimation over the Himalayas. Yes, there is a pattern showing underestimation to the south of 13°N and overestimation of AOD over central India. This is due to the high amount of dust emission over west Asia that is transported to India (Fig. S2). We have added related discussions in the revised manuscript at L240-255.

The simulated AOD is underestimated south of 13°N compared to MISR and MODIS (MODIS: 0.4 to 0.7, MISR: 0.4 to 0.6, model: 0.21 to 0.3) and overestimated over central India (lat: 20°-28°N lon: 75°E-88°E) compared to MODIS and MISR (MODIS:0.16 to 0.4, MISR:0.21 to 0.3, model: 0.3 to 0.5). These issues may be due to a higher amount of dust emission in the model over West Asia that is transported to India. In the past, a number of papers reported that transport of dust occurs from west Asia to the Indo-Gangetic plain and the Tibetan Plateau region during spring (Lau and Kim 2006; Fadnavis et al., 2017b, Fadnavis et al., 2021a). Simulated AOD is also overestimated over the Tibetan Plateau and East Asian region (MODIS: 0.21 to 1.0, MISR: 0.16 to 0.6, model: 0.27 to 1.2). The distribution of dust AOD also shows high amounts over these regions (See Fig. S1). This indicates that higher amounts of dust over the Tibetan Plateau and the East Asia region cause overestimation of AOD there. Tegen et al. (2019) also reported that in ECHAM6–HAMMOZ simulations the AOD is overestimated over East Asia in comparison with MISR. The model simulations underestimate the AOD over the Himalayas in comparison with MODIS (MODIS: 0.24 to 0.3, MISR: 0.1 to 0.21, model: 0.1 to 0.3).

(11) Lines 250-252: Please, justify this statement more in depth.

Reply(11): We have now elaborated it as "It shows enhanced AOD anomalies over the Indo-Gangetic plain (~0.22 to 0.8), the Tibetan Plateau and the north eastern parts of East Asia (~0.3 to 1.2). The distribution of anomalies in dust AOD shows high amounts over these regions. It indicates that dust enhancement over the Indo-Gangetic plain (~0.22 to 0.8), the Tibetan Plateau, and the northeastern parts of East Asia (0.8 to 1) (Fig. 3b) causes enhancement in AOD there. The simulated dust anomalies and circulation patterns also show transport of enhanced dust from West Asia to North India and the Indo-Gangetic plain region in the lower troposphere (Fig. 3b and Fig. S2a). Dust is also transported from Tibetan Plateau-East Asia region to North India in the mid/upper troposphere (Fig. S2b). The enhanced dust transport from west Asia and Tibetan Plateau-East Asia region to South Asia is induced by atmospheric heating generated by biomass burning carbonaceous aerosols (discussed in section 4.4). This atmospheric heating leads
to enhance dust emission over the respective desert regions. Dust being absorptive in nature contributes to a further increase of atmospheric heating. The heating led to a formation of a low-pressure zone over East India in the lower troposphere (900 hPa) (Fig. 3b) and the Bay of Bengal and Myanmar in the mid-troposphere (500 hPa) (Fig. S2b and Fig. 7b). These circulation changes further enhanced the dust transport from West Asia and the Tibetan Plateau-East Asia region to South Asia.” (L290-306).

(12) Lines 381-382: This sentence is too generically formulated

Reply(12): We show anomalies in vertical velocity to justify the above sentence. The above sentence is now re-written as: The cross tropopause transport is reinforced by enhanced vertical motion (Fig. S6a-b) produced by the heating generated by the carbonaceous aerosols. L440-442.

(12) Line 411: This is the first time in the whole manuscript that the ENSO is mentioned. A) It is worth to have a short indication of the reason why this is relevant for the presented study B) If kept, since it is the only time it is referred, the acronym has to be rewritten in full extension.

Reply(12): We have removed the abbreviation at L411. It is now referred at L147. As suggested we have given its relevance to the present study at L146-149. It is re-written as “The year 2013 was chosen for the analysis as this was a neutral year without a pronounced El Niño or Indian Ocean Dipole oscillation. Such large-scale coupled atmosphere–ocean oscillations substantially affect the transport processes to the UTLS (Fadnavis et al., 2017a, 2019).

(13) Lines 421-426: those two sentences are somehow a repetition.

Reply(13): We have avoided the repetition. It is re-written as “Our analysis shows that deep convection, which occurs over the Malay peninsula and Indonesia, transports carbonaceous aerosols from the boundary layer of the Indochina and East Asia region into the lowermost stratosphere (BC: 0.1 to 6 ng m$^{-3}$ for BC, OC: 0.2 to 10 ng m$^{-3}$).” at L480-483.

(14) Lines 454-455: It would be useful here for the reader to have a more quantitative way to understand what “counterbalanced” means. Which are the typical values of stratospheric cooling by CO2?

Reply(14): It is known that 355 ppm CO2 produces a cooling of 1 - 13.0 K day$^{-1}$ in the stratosphere that peaks at the stratopause (Clough & Iacono, 1995).” Impact of stratospheric water vapour on stratospheric temperature is complex since it may vary with latitude/altitude, e.g. Wang et al., (2020) report that increase of water vapor in tropical and subtropical lower stratosphere cause warming of the lower stratosphere, offsetting the cooling caused by doubling of CO$_2$. Maycock et al. (2013) found that a uniform doubling in stratospheric water vapor causes stratospheric cooling with a maximum amplitude of 5–6 K in the polar lower stratosphere and 2–3 K in the tropical lower stratosphere. Solomon et al. 2010 and Foster & Shine (1999) report that stratospheric water vapour radiatively cools the stratosphere. Discussion on this topic is out of the scope of the present paper. However, the impact of stratospheric water vapour on climate is certain: it causes warming of the climate (Banerjee et al., 2019; Dessler et al., 2013). Hence when reporting the climatic impact of stratospheric water vapor we have re-written above sentence as “An increase in stratospheric water vapour is important as it has an impact on stratospheric temperatures and thus indirectly on stratospheric dynamics (Maycock et al., 2013). The moistening of the stratosphere produces a positive feedback on the climate (Banerjee et al., 2019; Dessler et al., 2013). (L510-513).
References:

Wang, T. Q., Zhang, M., Kuilman, and A., Hannachi.: “Response of Stratospheric Water Vapour to CO2 Doubling in WACCM.” Clim. Dyn. 54(11–12):4877–89, 2020.

Banerjee, A., Chiodo, G., Previdi, M., Ponater, M., Conley, A. J., Polvani, L. M.: Stratospheric water vapor: an important climate feedback, Clim. Dyn, 53:1697–1710 https://doi.org/10.1007/s00382-019-04721-4, 2019.

Desslera A. E., Schoeberl, M. R., Wanga , T., Davis, S. M., and Rosenlof, K. H.: Stratospheric water vapor feedback, PNAS 110, 18087–18091, 2013.

Maycock, A. C., JoshiM. M., Shine, K. P., Scaife, A. A.: The Circulation Response to Idealized Changes in Stratospheric Water Vapor, J. Clim., 26, 545-561, DOI: 10.1175/JCLI-D-12-00155.1, 2013.

Technical comments:

(15) Fig.2 is a bit messy and non-coherent in all its panels' layout (sizes and position of panels and fonts). This is for example particularly evident when trying to compare the results of panels e and f. Also, it will be useful to specify in the title of those two panels which one is BMaeroon and which is from OSIRIS. Moreover, it will be better to have the same color scale. I would also suggest making the caption lighter, moving the information with the location of the different stations in a separated table.

Reply(15): As suggested, Figure 2 is replotted. The locations of the ten sites are shown in Fig 2c. We have used abbreviations for the locations of the ten sites in Fig 2d. The details of abbreviations and locations of the ten sites (latitude and longitude) are described in the figure caption. (Shown in attached PDF, “Figures_for_ReviewerI_and_ReviewerII”).

(16) Fig.3: Is there any specific reason why the panel b, with the DUST anomaly, is not in the same domain as the others? It would be very useful to have the same, also, since we are missing otherwise the information on the high dust aod contribution over East-China that seems to be suggested from panel c. What is the purpose of the wind arrows of figure 3b?

Reply(16): We show transport of dust from West Asia to India and its influence on AOD. Wind vectors are plotted to show the circulation pattern. Hence the domain for Fig. 3b was different than for the rest for the panels in Fig.3. As suggested, we have extended this figure over the East-China region. The discussion on transport of dust is made clear at L290-306 as below:

"It shows enhanced AOD anomalies over the Indo-Gangetic plain (~0.22 to 0.8), the Tibetan Plateau, and the northeastern parts of East Asia (~0.3 to 1.2). The distribution of anomalies in dust AOD shows high amounts over these regions. It indicates that dust enhancement over the Indo-Gangetic plain (~0.22 to 0.8), the Tibetan Plateau, and the northeastern parts of East Asia (0.8 to 1) (Fig. 3b) causes enhancement in AOD there. The simulated dust anomalies and circulation patterns also show the transport of enhanced dust from West Asia to North India and the Indo-Gangetic plain region in the lower troposphere (Fig. 3b and Fig. S2a). Dust is also transported from Tibetan Plateau-East Asia region to North India in the mid/upper troposphere (Fig. S2b). The enhanced dust transport from west Asia and Tibetan Plateau-East Asia region to South Asia is induced by atmospheric heating generated by biomass burning carbonaceous aerosols (discussed in section 4.4). This atmospheric heating leads to enhance dust emission over the respective"
desert regions. Dust being absorptive in nature contributes to a further increase of the atmospheric heating. The heating led to a formation of a low-pressure zone over East India in the lower troposphere (900 hPa) (Fig. 3b) and the Bay of Bengal and Myanmar in the mid-troposphere (500 hPa) (Fig. S2b and Fig. 7b). These circulation changes further enhanced the dust transport from West Asia and the Tibetan Plateau-East Asia region to South Asia.

(17) S1: The caption should specify that those are relative anomalies

Reply: We have defined anomalies as BMaeroon − Bmaerooff. It is mentioned in the caption of Fig. S1 which is now Fig. S3. (Shown in attached PDF, “Figures_for_ReviewerI_and_ReviewerII”) 

(18) Line 285: ..reported A radiative forcing...

Reply(18): It is corrected now at L336.

(19) Figure 5: I would strongly suggest to report panel b and panel d in the same longitude range and size, to easily individuate the regions of uplift.

Reply(19): It is correct now. (Shown in attached PDF, “Figures_for_ReviewerI_and_ReviewerII”).

(20)Figure 6: Please adjust the size of the figures, which looks vertically stretched.

Reply(20): Figure 6 is replotted. (Shown in attached PDF, “Figures_for_ReviewerI_and_ReviewerII”)

Please also note the supplement to this comment: https://acp.copernicus.org/preprints/acp-2021-494/acp-2021-494-AC1-supplement.pdf