Response to the Editor

While major improvements are noted, one reviewer still has some concerns. Besides, I'd question the high values of BC in Siberia in May (Fig. 10) when there are few wildfires in the region. If they are caused by fire smoke, a more in-depth investigation should be done to test the "hypothesis".

Response: We appreciate the comment from the editor and revised the manuscript as given below.

"Several typical hotspots of BC are observed throughout the year across the globe. They vary in magnitude, including many regions of South America, Africa, India, and China, with several of them coinciding with biomass-burning activities. Significantly enhanced values of BC are also found for western Canada and the USA, over Europe, and Russia, because of large fires occurring mainly during April - August. As shown in FRP maps in Figs. S11 - S13, the fire activity increases in March over Southeast Asia, north-eastern China, and some parts of southern and southeastern China. This pattern continues through May. For northern latitudes, the fire season begins in April - May. During the summer (JJA) season, the large-scale outbreak of forest fires in the boreal forests of North-America (Fauria and Johnson, 200.8) and Russia (Cheremisin et al., 2022) are reported in the literatures. In central Siberia, forest fires occur in April or at the beginning of May in southern areas, and in June in northern areas (above 60°N latitude), with peak fire activity occurring in July (Kharuk et al., 2022). This tendency is readily apparent in the distribution of FRP (Figs. S11-S13). During 2019 and 2020, the fire activity in eastern Siberia was anomalously high (Xu et al. 2022), with higher total burned-out areas (Voronova et al., 2020). For the severe fire in 2019, the seasonal distribution (May - September) of fire frequency in the Siberian Arctic was bimodal, with modes of fire frequencies occurring in June and August (Kharuk et al., 2022). The smoke aerosols emitted continuously from these forest fires initially accumulated in the southern Europe and Russia in May and spread up gradually to the northern latitudes in summer, resulting in the dispersion of the smoke plumes in the Arctic region. Apart from Siberia, during the summer (July - August) of 2019, anomalous wildfires occurred in Canada, Alaska, and Kazakhstan, as shown by the distribution of FRP and fire types. A similar pattern was also reported by Cheremisin et al. (2022). The fire activities over these regions start in April - May, contributing substantially to the aerosol emissions during spring. Noyes et al. (2022) reported that Canadian and Alaskan wildfires inject higher amounts (percent) of plumes from forest and woody fires in to the free-troposphere in May."

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Response to Reviewer 1

Even though it is second version of review, there are still many in-appropriate English (typos and inconsistencies in caption number) which may distract readers from reading this paper.

Response: We thank the reviewer for highlighting the inconsistencies as well as inappropriate sentences. We have carefully revised the manuscript taking care of the English and rectified the inconsistencies.

Response to Reviewer-2

I appreciate the author's large amount of modification work. I think most of the comments have been well responded. I suggest author further ***glorify the innovation of the algorithm based on the new references of satellite BC retrievals,*** *and to further improve the English writing before accepting it.*

Response: We sincerely thank the reviewer for the valuable comments/ suggestions and for accepting our responses to the queries. In the revised version of the manuscript, we have highlighted the innovation of the algorithm (as given below) in comparison with the recent studies of satellite BC retrievals. The English correction is also made with the help of an professional expert.

"Several new algorithms have been developed for aerosol retrieval over land (e.g., Multi-Angle Imaging Spectroradiometer (MISR) retrieval by Dinner et al. (1998), Dark Target method by Levy et al. (2007), Non-linear optimal estimation algorithm by Wurl et al. (2010), Multi-Angle Implementation of Atmospheric Correction (MAIAC) by Lyapustin et al. (2011), Deep Blue aerosol retrieval algorithm by Hsu et al. (2013), UV method by Fukuda et al. (2013), Multi-Angle and Polarization Measurements of Radiations by Dubovik et al. (2011, 2014); GOCI Yonsei Aerosol Retrieval (YAER) algorithm by Choi et al. (2016), Multi-Wavelength and -Pixel Method (MWPM) by Hashimoto and Nakajima, (2017)), but retrievals of BC from satellite-based radiation measurements have been few. Several attempts have been undertaken to identify dominant aerosol types using surface-based remote sensing of aerosols (e.g., Omar et al., 2005; Lee et al., 2010; Shin et al., 2019) and satellite-based remote sensing of aerosols (e.g., Higurashi and Nakajima, 2002; Kim et al., 2007; Lee et al., 2010; Kahn et al., 2015; Kim et al., 2018; Mao et al., 2019; Falah et al., 2022), but accurate quantification of the concentrations of various aerosol types from satellite remote sensing data persists as a challenge. Few recent studies are producing useful results for progress in this direction.

Based on Effective Medium Approximations of mixture morphology and a statistically optimized aerosol inversion algorithm, Bao et al. (2019) have reported the retrieval of surface mass concentrations of BC from Polarization and Anisotropy of Reflectance for Atmospheric Sciences Coupled with Observations from LiDAR (PARASOL) measurements. Their satellite retrieval strategy incorporates both internal and external mixing models of BC, with BC fractions limited to 5%. Among the six PARASOL channels used for the retrieval process, the results obtained at 870 nm were used because BC strongly absorb light at this wavelength than other light-absorbing species do. Overall, this algorithm demonstrated a strong capability for detecting aerosols in polluted atmospheres. In another study reported by Bao et al. (2020), MODIS Aqua Level-1B observations (MYD021KM) at three visible-infrared channels (470, 660, and 2100 nm) were used to estimate the columnar concentrations of BC aerosols based on BC and non-BC Maxwell−Garnett effective medium approximation. By incorporating wavelength-dependent refractive indexes of BC, this approach led to reliable estimation of BC. POLDER/PARASOL satellite observations were also used by Li et al. (2020) to retrieve BC and brown carbon concentrations based on an aerosol

component approach of Li et al. (2019). Apart from satellite observations, efforts have been made to retrieve BC from ground-based remote sensing data. Hara et al. (2018) reported the retrieval of BC from multi-wavelength Mie-Raman lidar observations, based on a modified algorithm reported by Nishizawa et al. (2017). Ceolato et al. (2022) reported a direct and remote technique to estimate the BC number and mass concentration from picosecond short-range elastic backscatter lidar observations.

This paper presents the regional distribution of BC over India based on satellite-based retrievals from Cloud and Aerosol-Imager-2 (CAI-2) observations made from the Greenhouse gases Observing Satellite-2 (GOSAT-2). The main purpose of CAI-2 is to derive cloud areas to improve the accuracy of greenhouse gas (GHG) retrieval from Fourier Transform Spectrometer (FTS) measurements in addition to ascertaining the concentrations of the BC mass and fine particulate matter (PM2.5). The retrieval technique of BC from CAI-2 measurements is based on fine-mode aerosol optical depth (AOD) estimates at multiple pixels, along with estimation of the volume mixing ratio of BC in fine-mode particles. The AOD and aerosol absorption properties can be retrieved simultaneously using the relation of surface reflectance and observed reflection passing through the aerosol layer at multiple pixels. Using combined information from multiple wavelengths, fine-mode and coarse-mode AOD are retrieved separately. The MWPM method reported by Hashimoto and Nakajima (2017) adopts a combination of an optimal method based on Bayesian estimation and smoothing constraint to horizontal aerosol distribution to solve the problem. In contrast to conventional pixel-by-pixel methods, it can simultaneously retrieve fine-mode and coarse-mode AOD, soot volume fraction in fine-mode aerosols, and surface reflectance over heterogeneous surfaces over multi-wavelengths and multiple pixels. Here, the soot volume fraction is assumed to be the volume mixing ratio of BC in fine-mode particles. This feature increases the accuracy of aerosol retrieval over the inhomogeneous surface, which also functions well for a homogeneous surface. Details are presented in Section 2.1.”

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