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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The impact of increases in South Asian anthropogenic emissions of SO_2 on sulfate loading in the upper troposphere and lower stratosphere during the monsoon season and the associated radiative impact" *by* Suvarna Fadnavis et al.

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(1) The most important conclusions of the present study (changes in ATAL and related radiative forcing both at the surface and TOA, as well as feedback processes on UTLS dynamics and clouds) are based on the model calculated distribution of sulfate aerosols following the increasing anthropogenic SO2 emissions at the surface over South Asia. This distribution is not only determined by local convective uplift, but also

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by the lower stratospheric coupling of aerosol transport and microphysics. From this point of view, the quasi-biennal oscillation (QBO) plays a major role in determining the rate of large-scale isentropic transport from the tropics to the extra-tropics. A different SO2 and SO4 lifetime in the tropical reservoir may, in turn, affect the aerosol size distribution, thus modulating the sedimentation rate and the strat-trop exchange. Nothing is said in the manuscript on how the QBO is treated in the model simulations. Internally generated? External nudging? What is the different level of sulfate export from the tropical reservoir during E/W phase years? I think the authors should clarify and produce some evidence of the model predicted variability in the horizontal gradient of the sulfate loading between tropics and extra-tropics (maybe in the supplementary material).

Reply(1):. We agree these are important points that need to be clarified. The focus of our manuscript is to understand the convective transport of Asian sulfate aerosols during the monsoon season. Therefore free simulations (10 member ensemble) were performed for the year 2011 with a one-year spin-up for the year 2010. The analysis is presented for the year 2011. These experiments are canonical in design as their aim is to understand the radiative impact of Asian sulfate aerosols. The model results do not include the influence of QBO, which has a periodicity of 22-24 months. Also, the QBO is not internally generated in the model. We now clarify this in the manuscript at L236.

We thank the reviewer for the valuable suggestion about analyzing the role of the quasi-biennial oscillation (QBO) in understanding the large-scale isentropic transport from the tropics to the extra-tropics. QBO can be generated in the model by the external nudging. To understand the influence of enhancement of sulfate aerosols on QBO, we have now performed external nudging experiments for the years 2008 - 2016 (CTRL and Ind48 simulations). Our model simulations show that the enhancement of sulfate aerosols slows down the QBO propagation (Figure 1a-b below). There is interannual variability in transport sulfate aerosols by the phases of QBO (Figure 1c). It affects the transport out of the tropics (Figure 1d). Since the focus of the present paper is to high-

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light the seasonal transport and associated radiative impacts, we plan to provide detail analysis of the interaction of QBO and sulfate aerosol in a separate paper which will focus on “Influence of sulfate aerosol on QBO: implications on Asian summer monsoon convection”.

Following the reviewer’s suggestions, we have now added a discussion about sulfate export from the tropical reservoir during E/W phase of QBO (section 6 in the manuscript).

See below the attached Figure-1

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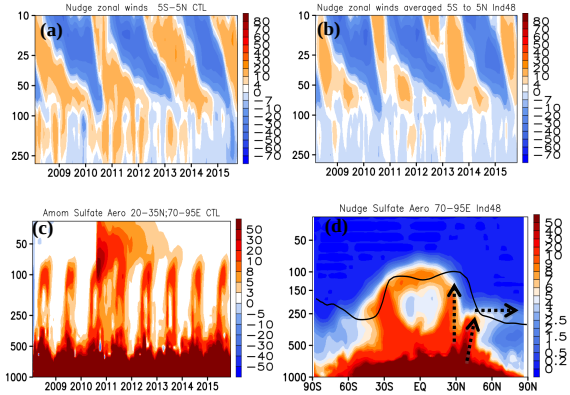

Figure-1: ECHAM6-HAMMOZ simulated vertical distribution of zonal winds (2008 - 2015) averaged for 5 ºS – 5 ºN (a) CTRL, (b) Ind48 simulations,(c) vertical distribution of anomalies of sulfate aerosols (Ind48-CTRL) over North India (70 - 95ºE; 20 - 40ºN) during 2008 – 2015, (d) anomalies of sulfate aerosols (Ind48-CTRL) averaged over 70 - 95º E for the year 2011. Arrows in Fig.1(d) indicate the transport of sulfate aerosols from North India.

Fig. 1.

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