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Supplement of

Zonal variations in the vertical distribution of atmospheric aerosols over the Indian region and the consequent radiative effects

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In the present document, the comparison of the present work with Aerosols and Chemistry Model Intercomparison Project (AerChemMIP) model simulations and Weather Research Forecasting with Chemistry (WRF-Chem) model simulations by Feng et al., (2016) are provided in sections S1 and S2, respectively.

S1: AerChemMIP simulations

A detailed comparison of our results with AerChemMIP under the Coupled Model Inter Comparison Project (CMIP6) model from Meteorological Research Institute – Earth System Model (MRI-ESM) 2.0 (Yukimoto et al., 2019) is carried out for aerosol extinction coefficient (k_{ext}) and dust AOD. The present study uses data during the time period 2006–2020, and for a comparison, the scenarios considered in AerChemMIP6 are Historical Sea Surface Temperature (HistSST; 2006-2014) and Shared Socioeconomic Pathway (SSP3-7.0; 2015-2020). These two scenarios were chosen to match the time-period between AerChemMIP6 and the present study. The rationale for using these two scenarios for comparison is that they are baseline simulations consistent with observations (Collins et al., 2017; Lund et al., 2019). A short description of the two scenarios is given below:

1) HistSST scenario (Meinshausen et al., 2017): These simulations impose changes that are consistent with observations. The model performances are evaluated against the present climate and observed climate change.
2) SSP3-7.0 scenario (O'Neill et al., 2014): These are gap-filling simulations in the CMIP5 forcing pathways and forms baseline forcing levels for several (unmitigated) scenarios.

Fig. S1 shows the AerChemMIP6 model simulation of k_{ext} for the same location and time period as in the present study (Fig. 3). They exhibit a similar zonal gradient with an increasing gradient from the west to the east, a maximum in the centre and reduction thereafter towards the east. The increase in vertical extent and magnitude of k_{ext} over the west during JJAS is also comparable. Even though the model simulations are in good agreement with the zonal gradients and the magnitudes of k_{ext} in Fig. 3 on a larger scale, our results reveal that the AerChemMIP6 simulations are underestimated over finer spatial scales. The high k_{ext} values and its vertical extent in the west (see Fig. 3) around the monsoon season was attributed to the long-range transport of dust aerosols (Banerjee et al., 2019; 2021). The dust AOD values from AerChemMIP6, shown in Fig. S2, also show high values over the west during MAM and JJAS, particularly over SR1. This agrees with our attribution of the dust influence to high k_{ext} over the Indian region (especially over the west) during JJAS and MAM seasons, as shown in Fig. 3 – 4. Our results will therefore prove useful in improving the regional climate model simulations.

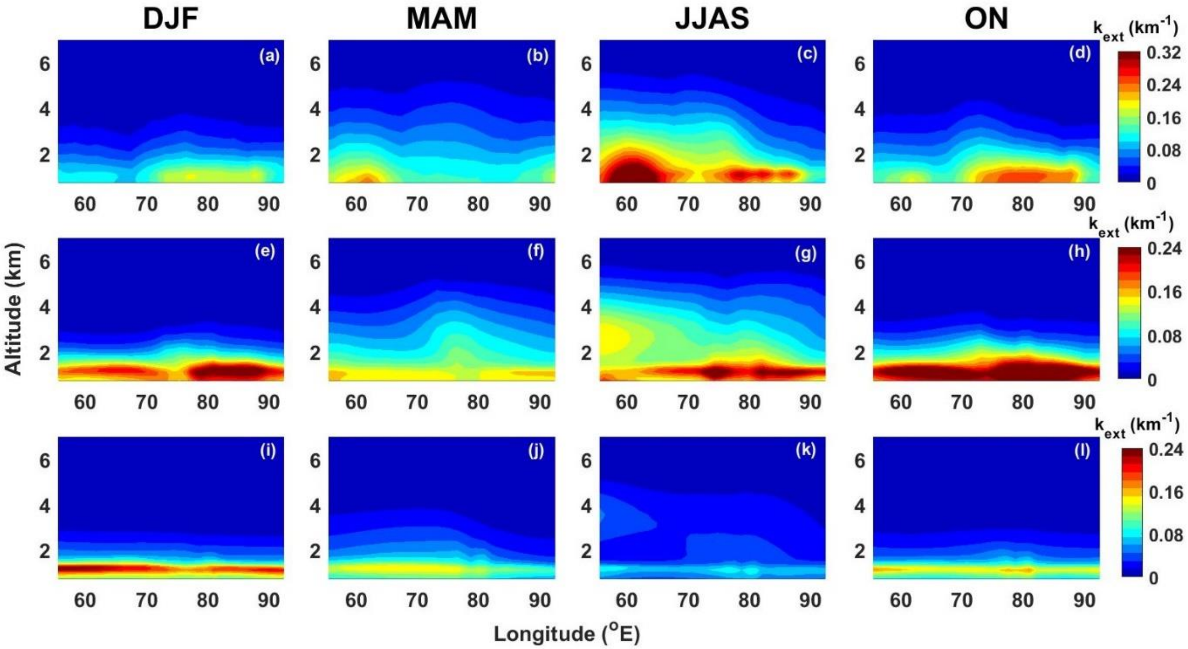

Figure S1: Zonal variation of the aerosol extinction coefficient (k_{ext}) (MRI-ESM2 model simulations) profiles for SR1 (top panel), SR2 (middle panel), and SR3 (bottom panel) sub-regions. Each column corresponds to a particular season, as marked above them.

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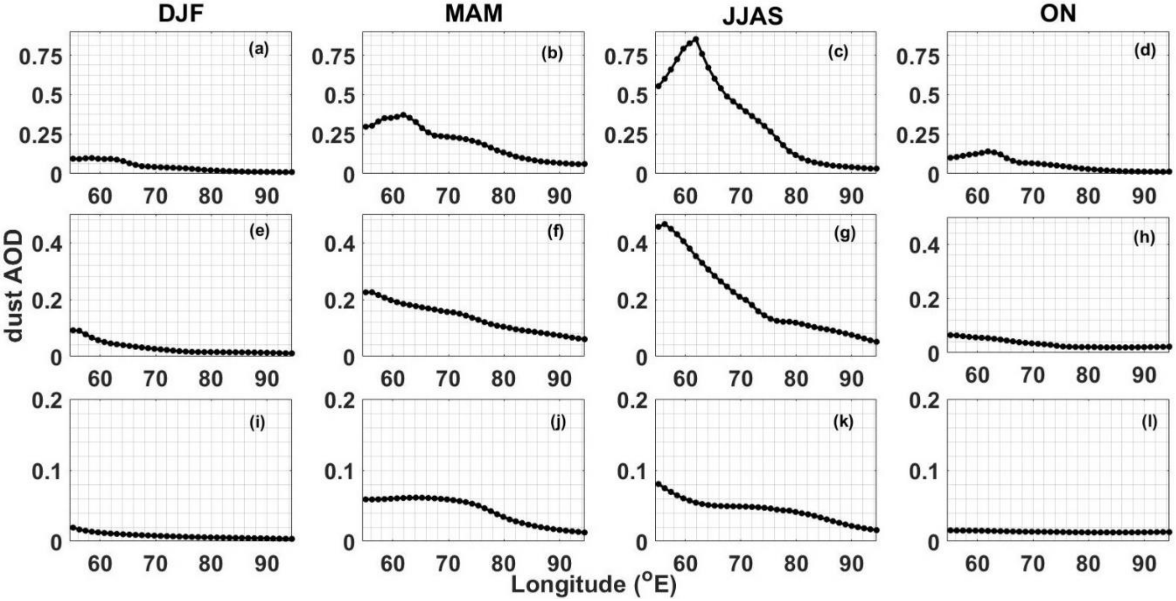

Figure S2: Zonal variation of the dust AOD (MRI-ESM2 model simulations) for SR1 (top panel), SR2 (middle panel), and SR3 (bottom panel) sub-regions. Each column corresponds to a particular season, as marked above them.

S2: Comparison with Feng et al., (2016) WRF-Chem simulations

The present work utilizes observational datasets like CALIOP aerosol extinction coefficient, Moderate Resolution Imaging Spectroradiometer (MODIS) AOD and assimilated SSA to evaluate atmospheric radiative forcing using Santa Barbara DISORT Atmospheric Radiative Transfer (SBDART) model. Feng et al., (2016) used the Rapid Radiative Transfer Model (RRTM) for radiative transfer calculations in the WRF-Chem model. For comparison, the shortwave aerosol-induced atmospheric heating rate (dT/dt) have been estimated using our data sets and SBDART for the same region and time period (55–95˚E and 0–36˚N, March 2012) as in Feng et al., (2016). These results are compared with the control runs for shortwave dT/dt simulations shown in Fig. 4a (land) and Fig. 4d (ocean) in Feng et al., (2016), and are shown in Fig. S3 below. The magnitudes of dT/dt are higher in the present work as compared to Feng et al., (2016), but the vertical variations are more or less similar. The mismatch in the magnitudes of dT/dt is understandable because of two reasons: (1) Our dT/dt calculations make use of a gamut of realistic observations as inputs while the model makes use of simulated parameters as inputs, (2) There is a large underestimation of k_{ext} in the model simulations as compared to the observations (as high as a factor of four), as can be seen in Fig. 2 of Feng et al., (2016). This comparison further elucidates the importance of our results for improving regional climate simulations.

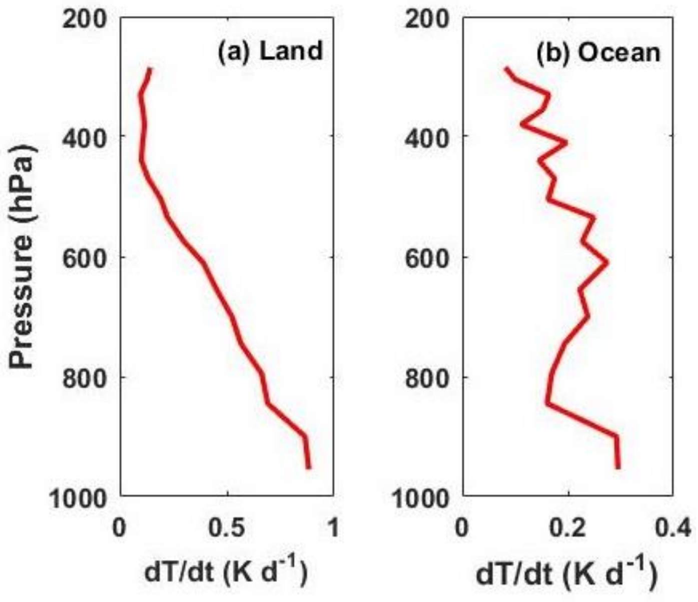

Figure S3: Vertical variation of aerosol-induced shortwave atmospheric heating rate (dT/dt) profiles over (a) Indian mainland and (b) oceanic regions.

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