Seasonal variations in the shortwave aerosol direct radiative forcing over the oceanic areas around the Indian Subcontinent

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Impact of atmospheric aerosols on the radiation budget and climate of the Earth-atmosphere system is well recognized. The spatial distribution and the properties of atmospheric aerosols over the Indian subcontinent and the surrounding oceanic areas are distinctly different during the Asian dry season (November-April period) and Asian summer monsoon season (June-September). Due to this, the aerosol radiative forcing is expected to be different in these two seasons. However, a quantitative estimate of the seasonal and interannual variations in the regional distribution of the aerosol radiative forcing over this region is lacking, particularly during the Asian summer monsoon season. In the present study, we report the regional distribution of the seasonal and interannual variations of the shortwave aerosol direct radiative forcing (ADRF) at the top-of-atmosphere, within the atmosphere, and at the earth's surface over the Arabian Sea, Bay of Bengal, and tropical Indian Ocean based on a 7-year long record of satellite-derived aerosol optical depth (derived from NOAA14/16-AVHRR data) and the model estimates of the aerosol radiative forcing efficiency. Estimated values of the diurnal mean ADRF compare well with the earlier observations reported over the study region during the Asian dry season. However, during the Asian summer monsoon season, observations of ADRF efficiency is lacking over this region. The present study shows that instantaneous ADRF efficiency is a strong function of time of the day. During the Asian dry season, the diurnal mean ADRF efficiency at TOA (for unit aerosol optical depth at 550nm) is in the range of -26.5 Wm^{-2} to –29.5 Wm^{-2} during the November-April period while the corresponding value at surface is in the range of -77 to –95 $Wm^{-2}AOD^{-1}$. Corresponding ADRF efficiency at TOA during June-September period (using the Asian summer monsoon aerosol model) is in the range of –32Wm^{-2} to –34.5 Wm^{-2} and the corresponding ADRF efficiency at surface is in the range of –64 to –70 $Wm^{-2}AOD^{-1}$. During the Asian dry period, in the northern hemisphere, the diurnal mean ADRF (DM-ADRF) estimated from the spatial distribution of measured aerosol optical depth (AOD) and the estimated values of aerosol radiative forcing efficiency is in the range of -4 to -14 Wm^{-2} at TOA, -12 to -42 Wm^{-2} at the surface and 8 to 28Wm^{-2} in the atmosphere. During the Asian dry season, largest DM-ADRF is observed in the northwest Bay of Bengal followed by the southeast Arabian Sea. Throughout the Asian summer monsoon period, the magnitude of the DM-ADRF (TOA, atmosphere and surface) is high in the north Arabian

Sea and steadily decreases towards the south. However, the absolute magnitude of the DM-ADRF shows considerable month-to-month variation. The highest values of DM-ADRF at the TOA, atmosphere and surface are observed in July. The magnitude of the DM-ADRF is $>$18 Wm^{-2} at TOA, $>$24 Wm^{-2} in the atmosphere, and $>$42 Wm^{-2} at the surface over a very wide area in the north Arabian Sea in July. North of about 10˚N in the Arabian Sea, the magnitudes of the DM-ADRF are $>$9 Wm^{-2} at TOA, $>$12 Wm^{-2} in the atmosphere and $>$21 Wm^{-2} at the surface in July. The DM-ADRF (TOA, atmosphere, surface) is least in September when its magnitude is $<$12 Wm^{-2} at TOA, $<$16 Wm^{-2} in the atmosphere, and $<$29 Wm^{-2} at the surface over the entire study region.