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A study of the aerosol direct forcing using CALIPSO observation and GCM simulation

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Shortwave direct aerosol radiative forcing (DARF) is derived at the top-of the atmosphere under clear-sky, cloudy-sky, and all-sky conditions using data of space-borne CALIOP lidar and MODIS sensor. We use aerosol optical thickness (AOT), cloud optical thickness (COT), and aerosol and cloud vertical profile information in CALIPSO Lidar Level 2 Cloud and Aerosol Layer Products version 2.01. Optically thick clouds with the COT larger than about 3 completely attenuate the lidar beam; therefore, MODIS-derived COT in MYD08_M3 product is applied for the CALIOP cloud profile when aerosols exist above optically thick clouds. We investigate three scenarios for evaluating the DARF: clear-sky, the case that aerosols exist above clouds, and the case that aerosols exist below high-level clouds. The cloudy-sky DARF is estimated by the latter two scenarios. They are then compared with DARF calculated by a global aerosol model, SPRINTARS. The results show that the aerosol forcing over desert regions is positive regardless of cloud existence. The aerosol forcing off southern Africa and over East Asia and India is more than +5 Wm-2 in both CALIOP and SPRINTARS, as consistent with past studies. Annual regional averages of DARF from 60oS to 60oN under clear-sky, cloudy-sky, and all-sky are -2.81, +0.17, and -0.51 Wm-2 from CALIOP, and -3.01, +0.63, and -0.92 Wm-2 from SPRINTARS. The differences in the cloudy and all-sky conditions are mainly caused by differences in the cloud cover fraction between observation and modeling. Not only low-level cloud fraction but also high-level cloud fraction and aerosol mixing with clouds are important to estimate the reliable value of cloudy-sky and all-sky forcing.