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A synergy of MODIS-Aqua, MERRA-2 and CALIOP-CALIPSO for dust aerosols monitoring at global scale during the period 2007-2016

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Dust aerosols, emitted mainly from arid regions of the planet, are playing a crucial role in the Earth system due to their impact on climate, human health, anthropogenic activities and ecosystems. Under favorable meteorological conditions, these coarse particles of natural origin can be transported over areas situated far away from deserts and for monitoring their spatiotemporal patterns spaceborne observations have been proven a very powerful tool. Passive satellite sensors, such as MODIS, are providing columnar retrievals of high accuracy at is concerns aerosol loads in contrast to other optical properties representative of particles' size and nature, which are critical for dust identification. In order to overcome this inherent limitation, a potential solution can be the synergistic implementation of reanalysis datasets, such as MERRA-2, in which aerosols and meteorology are jointly assimilated.
The scope of the present study is to develop a global dust climatology, over the period 2007-2016, based on MODIS-Aqua Level 2 retrievals (Collection 6) in which unreliable data (cloud contamination, isolated retrievals) have been masked out. To realize, the MODIS aerosol optical depth (AOD) has been adjusted to dust optical depth (DOD), both reported at 550 nm, by utilizing the dust-to-total optical depth ratio provided by MERRA-2. The quality of the latter product has been justified via the evaluation against CALIOP-CALIPSO observations in which the contribution of pure dust to the total AOD has been computed relying on a sophisticated depolarization-based separation method, improved lidar ratios for Saharan and Asian dust and a series of quality criteria eliminating artifacts on vertical profiles.
The MODIS-derived DOD, at 0.1° x 0.1° spatial resolution, has been analyzed both at pixel-level (geographical distributions) as well as on regional scale during the study period. According to obtained results, the most active dust source of the planet is located in the Bodélé Depression exhibiting a long-term DOD average equal to 1 with weak seasonal variation. Considerably high DODs (up to 0.8) are recorded over the western Sahara and the Arabian Peninsula with maximum values during boreal summer. In Asia, the highest DODs are found in the Taklamakan Desert with regional values ranging from 0.05 (December) to 0.65 (April) throughout the year. In the southern hemisphere, the annual average DODs over the desert areas of S. America, S. Africa and Australia do not exceed 0.2. At global scale, the most pronounced dust transport pattern is observed across the tropical Atlantic Ocean revealing a strong seasonal variation in terms of intensity (maximized during boreal summer), latitudinal shift and range. The evaluation of MODIS-Aqua DOD versus AERONET observations indicates a very good agreement between the two datasets with correlation coefficient and relative bias equal to 0.85 and -7.1%, respectively, calculated from 2838 matchups collected at 260 sites. Finally, the global DOD average is equal to 0.047±0.013 while a strong contrast is evident between the northern (0.083±0.030) and the southern (0.007±0.002) hemispheres.