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Quantifying the climatological cloud-free direct radiative forcing of aerosol over the Red Sea

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A combination of ground-based and satellite observations are used, in conjunction with column radiative transfer modelling, to assess the climatological aerosol loading and quantify its corresponding cloud-free direct radiative forcing (DRF) over the Red Sea. While there have been campaigns designed to probe aerosol-climate interactions over much of the world, relatively little attention has been paid to this region. Because of the remoteness of the area, satellite retrievals provide a crucial tool for assessing aerosol loading over the Sea. However, agreement between aerosol properties inferred from measurements from different instruments, and even in some cases from the same measurements using different retrieval algorithms can be poor, particularly in the case of mineral dust. Ground based measurements which can be used to evaluate retrievals are thus highly desirable. Here we take advantage of ship-based sun-photometer micro-tops observations gathered from a series of cruises which took place across the Red Sea during 2011 and 2013. To our knowledge these data represent the first set of detailed aerosol measurements from the Sea. They thus provide a unique opportunity to assess the performance of satellite retrieval algorithms in this region.

Initially two aerosol optical depth (AOD) retrieval algorithms developed for the MODerate Resolution Imaging Spectroradiometer (MODIS) and Spinning Enhanced Visible and InfraRed Imager (SEVIRI) instruments are evaluated via comparison with the co-located cruise observations. These show excellent agreement, with correlations typically better than 0.9 and very small root-mean-square and bias differences. Calculations of radiative fluxes and DRF along one of the cruises using the observed aerosol and meteorological conditions also show good agreement with co-located estimates from the Geostationary Earth Radiation Budget (GERB) instrument if the aerosol asymmetry parameter is adjusted to account for the presence of large particles.

A monthly climatology of AOD over the Red Sea is then created from 5yrs of SEVIRI retrievals and shows both enhanced aerosol loading and the development of a distinct north to south gradient across the basin in the summer relative to the winter months. The climatology is used as input to radiative transfer calculations to generate corresponding estimates of the DRF at the top and bottom of the atmosphere and the atmospheric absorption due to aerosol. These estimates indicate that although longwave effects can reach 10s W m^{-2}, shortwave cooling typically dominates the net radiative effect over the basin and is particularly pronounced in the summer, exceeding 130 W m^{-2} at the surface. The spatial gradient in summer-time AOD is reflected in both the aerosol forcing at the surface and in associated differential heating by aerosol within the atmosphere above the Sea. This asymmetric forcing would be expected to exert a significant influence on the regional atmospheric and oceanic circulation and warrants further study in the context of coupled aerosol-atmosphere-ocean regional models.