Geophysical Research Abstracts
Vol. 19, EGU2017-2403, 2017
EGU General Assembly 2017

Simulating Dust Regional Impact on the Middle East Climate and the Red Sea

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Dust is one of the most abundant aerosols, however, currently only a few regional climate downscalings account for dust. This study focuses on the Middle East and the Red Sea regional climate response to the dust aerosol radiative forcing. The Red Sea is located between North Africa and Arabian Peninsula, which are first and third largest source regions of dust, respectively. MODIS and SEVIRI satellite observations show extremely high dust optical depths in the region, especially over the southern Red Sea during the summer season. The significant north-to-south gradient of the dust optical depth over the Red Sea persists throughout the entire year. Modeled atmospheric radiative forcing at the surface, top of the atmosphere and absorption in the atmospheric column indicate that dust significantly perturbs radiative balance. Top of the atmosphere modeled forcing is validated against independently derived GERB satellite product.

Due to strong radiative forcing at the sea surface (daily mean forcing during summer reaches -32 Wm-2 and 10 Wm-2 in SW and LW, respectively), using uncoupled ocean model with prescribed atmospheric boundary conditions would result in an unrealistic ocean response. Therefore, here we employ the Regional Ocean Modeling system (ROMS) fully coupled with the Weather Research and Forecasting (WRF) model to study the impact of dust on the Red Sea thermal regime and circulation. The WRF was modified to interactively account for the radiative effect of dust. Daily spectral optical properties of dust are computed using Mie, T-matrix, and geometric optics approaches, and are based on the SEVIRI climatological optical depth. The WRF model parent and nested domains are configured over the Middle East and North Africa (MENA) region and over the Red Sea with 30 and 10 km resolution, respectively. The ROMS model over the Red Sea has 2 km grid spacing.

The simulations show that, in the equilibrium response, dust causes 0.3-0.5 K cooling of the Red Sea surface waters, and weakens the overturning circulation in the Red Sea. The salinity distribution, freshwater, and heat budgets are significantly perturbed. This indicates that dust plays an important role in the formation of the Red Sea energy balance and circulation regimes, and has to be thoroughly accounted for in future modeling studies.