Indian Ocean Experiment: An integrated analysis of the climate forcing and effects of the great Indo-Asian haze


Abstract. Every year, from December to April, anthropogenic haze spreads over most of the North Indian Ocean, and South and Southeast Asia. The Indian Ocean Experiment (INDOEX) documented this Indo-Asian haze at scales ranging from individual particles to its contribution to the regional climate forcing. This study integrates the multiplatform observations (satellites, aircraft, ships, surface stations, and balloons) with one- and four-dimensional models to derive the regional aerosol forcing resulting from the direct, the semidirect and the two indirect effects. The haze particles consisted of several inorganic and carbonaceous species, including absorbing black carbon clusters, fly ash, and mineral dust. The most striking result was the large loading of aerosols over most of the South Asian region and the North Indian Ocean. The January to March 1999 visible optical depths were about 0.5 over most of the continent and reached values as large as 0.2 over the equatorial Indian ocean due to long-range transport. The aerosol layer extended as high as 3 km. Black carbon contributed about 14% to the fine particle mass and 11% to the visible optical depth. The single-scattering albedo estimated by several independent methods was consistently around 0.9 both inland and over the open ocean. Anthropogenic sources contributed as much as 80% (±10%) to the aerosol loading and the optical depth. The in situ data, which clearly support the existence of the first indirect effect (increased aerosol concentration producing more cloud drops with smaller effective radii), are used to develop a composite indirect effect scheme. The Indo-Asian aerosols impact the radiative forcing through a complex set of heating (positive forcing) and cooling (negative forcing) processes. Clouds and black carbon emerge as the major players. The dominant factor, however, is the large negative forcing (-20 ± 4 W m⁻²) at the surface and the comparably large atmospheric heating. Regionally, the absorbing haze decreased the surface solar radiation by an amount comparable to 50% of the total ocean heat flux and nearly doubled the lower tropospheric solar heating. We demonstrate with a general circulation model how this additional heating significantly perturbs the tropical rainfall patterns and the hydrological cycle with implications to global climate.
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