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Field observational experiments in Eurasia and on the African continent

Complex aerosol studies over the territory of the former USSR were carried out starting from the late-1950s. Results of these studies have been discussed in several monographs and numerous papers [8, 43, 45, 55–58, 61–63, 78, 79, 83–87] as well as in Chapter 1 of this book. Of special interest are studies on biogenic components of aerosol [10–12, 92], specific features of the structure and properties of aerosol over vast basins of Lake Baikal, the White Sea, and the Atlantic Ocean [68, 78, 79, 83], aerosols formed on the dried-up bottom of the Aral Sea [45], as well as volcanic aerosol of Kamchatka [42, 44] and the urban aerosol of Eurasia. Some works on studies of the content and chemical composition of pollutants in glacier deposits in Altai and Tien Shan have made it possible to draw conclusions about the main sources and processes of transport of the aerosol dust component and about the interannual variability of aerosol properties in the region of northern Eurasia [8, 13, 25, 33, 43, 61–63, 69, 78, 79, 82–84, 87, 92, 102]. Below we shall discuss the results of complex field experiments accomplished in a number of regions during recent years.

3.1 THE SAHARAN DUST EXPERIMENT

The first complex observational experiments aimed at aerosol–radiation studies of dust aerosol of deserts were started in the region of Ashkhabad (Turkmenistan) within the CAENEX programme in October, 1970 and then grew in scale [53–55, 58]. One of the latest stages of similar developments is connected with an accomplishment of the field experiment SHADE – taking into account the key role of the Sahara desert as the most powerful source of natural dust aerosol (DA).

Haywood et al. [38] analysed the physical and optical properties of the Saharan DA using observational data from the flying laboratory C-130 of the British Meteorological Service, obtained within the field observational experiment SHADE. Four special flights were made from the Sal Island (the Cape Verde
islands) on 21, 24, 25, and 28 September, 2000. The main sources of information were data of observations with the following instrumentation carried by C-130: (1) photometer PSAP to measure the short-wave radiation (SWR) absorption at the wavelength 0.567 μm; (2) nephelometer TSI-3563 (aerosol scattering at three wavelengths: 0.45, 0.55, and 0.70 μm); (3) spectrometer to measure the size of aerosol particles and cloud droplets in the interval of radii 1–23.5 μm; (4) broadband Eppley pyranometers for wavelength ranges 0.3–3.0 μm and 0.7–3.0 μm; (5) 16-channel filter radiometer (SAFIRE) for spectral SWR measurements; (6) and nadir-directed SWS spectrometer to measure in the intervals 0.30–0.95 μm and −0.95–1.70 μm (spectral resolution is 0.010 and 0.018 μm, respectively).

Processing of observational results has made it possible, in particular, to evaluate the aerosol optical thickness τ_aer,λ and DA-induced direct radiative forcing (RF). An analysis of observational results revealed an overestimation of the DA-induced calculated SWR absorption with the prescribed standard values of the refraction index. According to the observational data considered, the estimate of the imaginary part of the complex refraction index (0.0015i) can be considered adequate at the wavelength 0.55 μm.

Various techniques to calculate τ_aer,λ have been discussed in [38] and the respective errors have been estimated. The value of τ_aer,λ=0.55 under conditions of maximum dust loading of the atmosphere is 1.48 ± 0.05. Under these conditions, the instant value of RF is approximately −129 ± 5 W m⁻², which corresponds to an aerosol-induced increase of the surface–atmosphere system’s albedo over the ocean by a factor of 2.7 ± 0.1. A comparison of the obtained RF values with aircraft observations within the CERES programme has demonstrated an agreement to within the coefficient 1.2. The results discussed indicate that in studies of the Earth’s radiation budget, the RF due to the Saharan DA should be taken into account.

From observations with the use of the C-130 instrumentation carried out within the programme of the field observational experiment SHADE, the impact of the Saharan DA on the long-wave radiation (LWR) transfer in the atmosphere has also been studied [39]. A comparison of measurement results in the dust loaded and clean atmosphere (in clear sky) revealed, in the spectra of upward and downward LWR fluxes, a distinct signature of the DA impact on the LWR transfer. A comparison of measured and calculated spectral LWR fluxes with the required information prescribed from data of simultaneous observations enabled one to retrieve the refraction index for DA in the IR region, since the main factors affecting the radiation transfer are the refraction index, the DA content, and the height of the dust layer. The impact of aerosol size distribution is less substantial, considering the presence of particles with the radius >1 μm.

The impact of the DA layer manifested itself as a relative radiation-induced warming up to 0.5 K day⁻¹ under the layer, and a cooling (down to 0.5 K day⁻¹) above the aerosol layer. These radiative temperature changes are, by about an order of magnitude, less than the respective changes due to SWR absorption. In the field of LWR fluxes the presence of the dust layer is reflected as a decrease of the outgoing LWR (6.5 W m⁻²) at the atmospheric top level and an increase (11.4 W m⁻²) of the downward LWR flux at the surface level. The presence of dust has led to a decrease