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Comparison of modeled optical properties of Saharan mineral dust aerosols with SAMUM lidar and photometer observations

J. Gasteiger and M. Wiegner
LMU Munich, Germany (josef.gasteiger@lmu.de)

Mineral dust aerosols are relevant for weather and climate. They are quite complex ensembles of particles with different microphysical properties, that is, different sizes, shapes, and chemical compositions. Knowledge about the microphysical properties of aerosols provides the basis for quantifying the effects of the aerosols, e.g. the direct and indirect aerosol effect. Remote sensing is an important tool to gain knowledge about the aerosol properties.

This contribution aims at retrieving microphysical particle properties from simultaneous and collocated lidar and photometer observations of Saharan mineral dust aerosols. The lidar technique is an active vertically-resolving remote sensing technique. Advanced lidar systems provide several optical parameters of the aerosols. For example, the lidar system MULIS from the University of Munich provides the backscatter coefficient at $\lambda = 355$nm, $\lambda = 532$nm, and $\lambda = 1064$nm, the depolarization ratio of the backscattered light at $\lambda = 532$nm, and the extinction coefficient at $\lambda = 355$nm and $\lambda = 532$nm. Photometers are passive remote sensing instruments which provide vertically-integrated aerosol properties. Here, we consider the angular dependence of spectral radiances in the solar aureole and the spectral extinction observed by photometers. The inversion of both lidar and photometer observations provides synergistic effects because methods using data from both techniques are able to constrain the range of solutions considerably stronger than methods that rely only either on lidar or photometer alone.

The model aerosol ensembles used in this contribution are based on the desert type of the OPAC aerosol data set. Several improvements are realized: Spherical particles are replaced by irregularly-shaped particles. Furthermore, instead of assuming that all dust particles have the same refractive index, it is considered that absorbing and non-absorbing particles are mixed within the ensembles, which is in good accordance with findings from single particle analyses of Saharan dust. Each microphysical parameter of this model is varied systematically, the optical properties of each model ensemble are then calculated and compared to the lidar and photometer observations in order to find compatible ensembles. This approach may be regarded as a "manual retrieval" of the microphysical properties.

This approach is applied on Saharan dust observations from two days during the SAMUM-1 campaign (performed close to the source, Sahara), and on observations from one day during SAMUM-2 (about one thousand kilometers from the source, Sahara). The vertical aerosol columns were dominated by the dust aerosols during these observation cases, thus no type separation is required for the photometer modeling. In each case, model ensembles are found that are compatible with the observations. In order to explain the observations, the above-described extensions of OPAC with mixing of absorbing and non-absorbing irregularly-shaped particles are found to be essential. In particular, the backscattering at short wavelengths is found to be very sensitive to the presence of non-absorbing particles. Furthermore, sensitivity studies reveal that aureole radiances are well-suited for determining the cross-section-equivalent size distribution of coarse dust particles, even if their shapes and compositions are not well characterized.