

Solving inverse problems of light scattering: sensitivity tendencies in remote sensing of atmospheric aerosols

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Progress in the understanding of interactions of electromagnetic radiation with small particles has stipulated the development of a new class of optical diagnostics and remote sensing applications. The necessity of data inversion, i.e., the derivation of information about properties of natural objects from the results of interactions of electromagnetic radiation with the objects, is an inherent feature of these applications. Even if the direct simulation of interactions of the light with the objects is fully known, the inversion requires additional analysis. For instance, there is a wide variety of remote sensing observations developed for monitoring properties of tropospheric aerosols. They include satellite and ground-based observations, both passive and active (lidar), spectral and multi-directional measurements, recording of only the intensity or also polarimetric properties, etc. Evidently, the scope and the accuracy of the aerosol information retrieved from these observations are very different, as are the assumptions and constraints used. This aspect always requires thorough considerations. In this study, we propose an assessment of the fundamental tendencies in sensitivities of aerosol light scattering which is expected to be of help for understanding of the full potential and limitations of aerosol remote sensing. To this end, a special “hierarchical” concept of the test evolution has been developed. The tests start from only single-scattering observations. Indeed, most of the aerosol remote sensing approaches rely on the manifestation of angular and spectral features in aerosol scattering properties determined by the aerosol scattering matrix, extinction, and absorption. Thus, if some retrieval limitations exist in the single scattering regime, then they most likely remain with some modifications in the presence of multiple scattering effects in the atmosphere. At the same time, the numerical tests only with single-scattering properties is much simpler and logistically easier than the tests with full modeling of atmospheric radiances including multiple scattering effects. Specifically, the importance of multi-angular and polarimetric observations, the possibilities to determine aerosol type and other important aspects were studied.

The tendencies established with single-scattering tests are used for the analysis of limitations of some real ground-based and satellite retrieval approaches. The conclusions are illustrated both by the numerical tests with full account of multiple scattering and by analyses of real observations. The tests use the unique retrieval algorithm GRASP (Generalized Retrieval of Aerosol and Surface Properties, see Dubovik et al. (2014)) available as an open source software (<http://www.grasp-open.com/>).