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Polarization lidar: New ways to quantify atmospheric dust and non-dust particle properties (light extinction, mass concentration, ice nuclei concentration)

A. Ansmann (1), R. E. Mamouri (2), A. Nisantzi (2), M. Haarig (1), D. Althausen (1), H. Baars (1), and R. Engelmann (1)

(1) Leibniz Institute for Tropospheric Research, Leipzig, Germany (albert@tropos.de), (2) Cyprus University of Technology, Dep. of Civil Engineering and Geomatics, Limassol, Cyprus (rodanthi.mamouri@cut.ac.cy)

The volume linear depolarization ratio measured with polarization lidar has been used to study tropospheric and stratospheric clouds and to distinguish liquid, mixed-phase, and ice clouds since about 45 years. In contrast, a quantitative use of the polarization lidar technique in aerosol research started just 15-20 years ago. The Saharan Mineral Dust Experiments (SAMUM-1, in southern Morocco in 2006, SAMUM-2, Cape Verde in 2008) accelerated the effort to identify and quantify the amount of irregularly shaped dust particles during dust outbreak situations with well characterized and calibrated polarization lidars. Existing techniques for the separation of dust from marine, urban and smoke particles were significantly improved in the course of the SAMUM data analysis. We will provide an overview of existing and especially recently developed polarization lidar techniques and latest atmospheric applications. Meanwhile techniques are introduced that allow us to determine the fraction of fine-mode dust, coarse-mode dust, as well as residual aerosol contributions to the total particle extinction coefficient and mass concentrations. It is not only possible to quantify smoke in dust-dominated plumes, but also, vice versa, to identify and quantify traces of soil dust in smoke plumes injected by strong fires. Furthermore, methods are developed to estimate the large particle fraction LAPC (with particle radii > 250 nm) and afterwards the ice nuclei concentration INC with appropriate LAPC-to-INC parameterization schemes (developed for desert dust applictaions). After the eruption of the Icelandic volcano Eyjafjallajökull the ash mass concentration as well as the sulfate mass, which originated from the released volcanic sulfuric acid plumes, could be separately quantified by means of the polarization technique. During the SALTRACE campaign at Barbados in 2013 and 2014, for the first a three-wavelength polarization lidar was applied to monitor mixtures of dust, marine particles, and smoke. However, all these lidar methods for aerosol type separation are based on assumptions on the backscattering properties of the irregularly shaped dust particles. There are many modeling efforts to characterize the required 180° scattering properties, but almost all of these attempts are based on the an idealized spheroidal dust shape model. There is a strong need for more sophisticated, more realistic modelling efforts. We will present a list of requirements.