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Variability of signals of single particle optical sensing instruments for coarse aerosols and clouds

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A practical approach to characterize elevated atmospheric particles on airborne platforms is to measure laser light scattered by individual particles. Depending on the instrument setup, the measured signal can be used for retrieving microphysical properties of the particle. Generally, detectors for the forward scattering are used to quantify the particle size, whereas backscatter detectors are expected to provide information on the particle shape and refractive index. Recently, instruments like the CAS-DPOL (DMT Inc.) became available that not only measure the intensity of the scattered light but also its polarization state, aiming to improve the characterization of measured particles.
An inherent feature of single particle sensing is that in general the signal not only depends on the particle property of interest but also on the other particle properties, which can introduce significant uncertainties. For example in case of particle sizing, the signal depends not only on the size but also on the refractive index, the shape, and, if the particle is nonspherical, on the orientation of the particle on its way through the laser beam. These dependencies together with the non-monotonic size dependence of the signal, affect particle sizing. Likewise, the determination of the shape and the refractive index is affected by the variability of the signal due to the variability of sizes and orientations.
We present an investigation on the variability of the scattering cross sections at various scattering angles (with and without azimuthal averaging) for different laser polarizations and detectors for different polarizations. We start our assessment with the setup of the CAS-DPOL which was recently operated by the “Deutsches Zentrum für Luft- und Raumfahrt” (DLR) in campaigns for dust and cloud characterization. We consider as particle shapes non-symmetric geometries imitating mineral dust and volcanic ash particles, hexagonal ice plates and columns, and water droplets. Scattering cross sections are modeled using the discrete dipole approximation for nonspherical particles and the Mie theory for spherical particles.
Our overarching aim is to investigate the expected uncertainty of single particle optical sensing instruments. Not only the characteristics of the light scattering by the particles is relevant in this context but also the characteristics of the instruments optics and electronics as well as the measurement conditions (e.g. amount of sampled particles) have to be taken into account, which however is not part of our presentation. The outcome will be useful for the optimization of instrument setups and error calculations.