Using mixtures of hexahedrals and spheroids to model dust particles, and reproduce lidar observations in Cabo Verde

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Wind-eroded desert dust is amongst the most abundant natural aerosol species, directly relevant to the Earth's weather and climate [1]. Polarization measurements, being sensitive to the aerosols' shape, may be used to disentangle the contribution of non-spherical (e.g. dust) aerosols to the total aerosol load, while in parallel entail more information to study their properties [2]. However, most remote sensing retrieval algorithms employ simplified descriptions of the highly-irregular dust particle shapes due to considerations of computational efficiency. The most widely employed shape for non-spherical particles is a spheroid [3]. Although spheroid mixtures have been shown to well reproduce the angular dependence of light scattering from dust aerosols, deviations are observed particularly for scattering angles close to backscattering [4]. These deviations result in discrepancies between simulations and field or lab-based measurements, relevant for lidar-derived intensive optical properties (particle linear depolarization ratio (d_p) and lidar ratio (S_p); [4, 5]). Recent studies employing tri-axial ellipsoids (i.e., one more degree of freedom with respect to spheroids) have shown that these shapes better reproduce the measured dust d_p but overestimate S_p [6]. Efforts have been made considering more realistic shapes based on electron microscopy images [5]. These calculations however are expensive in terms of computational power, which limits the range of possible particle microphysical properties covered, as well as their usage on an operational level.

Herein we explore a different pathway and employ mixtures of irregular hexahedrals and spheroids to simulate the observed spectral dependence of lidar-derived dust d_p and S_p. We use the TAMUdust2020 scattering database [7, 8] providing the scattering properties of irregular hexahedrals with different degrees of sphericity (Ψ: 0.695 – 0.785), in a wide range of size parameters (x: << 1 – 11800) and complex refractive index (CRI) (n: 1.37 – 1.7, k: 0.001 – 0.1). To account also for smoother particles shapes, we use the scattering properties of spheroids calculated using the MOPSMAP database [9]. The size distributions and CRIs considered, are provided by height-resolved airborne (UAV) in-situ measurements acquired during the ASKOS-ESA campaign, implemented in 2021 and 2022, in Mindelo, Cabo Verde [10]. Highly and less absorbing particle mixtures are employed to mimic the mineralogical inhomogeneity expected in the ambient dust samples. The calculated d_p and S_p for dust particles are evaluated against multi-spectral, polarization lidar data from ASKOS, lidar-derived climatological values and laboratory samples.

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