

Optics Letters

Efficient single-scattering look-up table for lidar and polarimeter water cloud studies

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Combined lidar and polarimeter retrievals of aerosol, cloud, and ocean microphysical properties involve single-scattering cloud calculations that are time consuming. We create a look-up table to speed up these calculations for water droplets in the atmosphere. In our new Lorenz-Mie look-up table we tabulate the light scattering by an ensemble of homogeneous isotropic spheres at wavelengths starting from 0.35 μm . The look-up table covers liquid water cloud particles with radii in the range of 0.001–500 μm while gaining an increase of up to 10^4 in computational speed. The covered complex refractive indices range from 1.25 to 1.36 for the real part and from 0 to 0.001 for the imaginary part. We show that we can precisely compute inherent optical properties for the particle size distributions ranging up to 100 μm for the effective radius and up to 0.6 for the effective variance. We test wavelengths from 0.35 to 2.3 μm and find that the elements of the normalized scattering matrix as well as the asymmetry parameter, the absorption, backscatter, extinction, and scattering coefficients are precise to within 1% for 96.7%–100% of cases depending on the inherent optical property. We also provide an example of using the look-up table with *in situ* measurements to determine agreement with remote sensing. The table together with C++, Fortran, MATLAB, and Python codes to interpolate the complex refractive index and apply different particle size distributions are freely available online.

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Liquid water clouds are an important radiative constituent of the Earth-atmosphere system, but microphysical processes related to clouds remain highly uncertain and poorly represented in climate models [1]. Remote sensing observations are crucial to

improving our knowledge on cloud processes, but traditional methods are often biased especially in cases of broken or small clouds [2]. Furthermore, ignoring the temperature dependence of the refractive index may lead to biases in cloud remote sensing products [3]. The polarimetric cloudbow observations from NASA's Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission will enable retrievals of cloud-top effective radius, variance, and droplet number concentration [4–6]. In addition, lidar observations contain information on cloud optical and microphysical properties [7]. NASA's future Atmosphere Observing System (AOS) mission will likely include an imaging polarimeter and high spectral resolution lidar that will make collocated measurements further advancing cloud remote sensing capabilities. In this Letter we present a new cloud look-up table (LUT) that enables fast and precise retrievals of the microphysical properties of liquid water clouds from existing and next-generation remote sensing instruments. The LUT can also be used to compute the optical properties of clouds from airborne *in situ* droplet size distribution data. Our LUT supports a wide range of size distributions of spherical liquid water cloud droplets and derives the corresponding optical properties across the ultraviolet, visible, near-infrared, and shortwave infrared spectra.

The purpose of our LUT is to provide a fast and precise way to compute the liquid cloud inherent optical properties (IOPs) for a single-scattering case. These cases are characterized by a low value of depolarization measured by lidar and can be seen near the cloud edges [8]. The list of IOPs covered by the cloud LUT is the same as for our aerosol LUT and includes the normalized scattering matrix, the asymmetry parameter, the absorption, backscatter, extinction, and scattering coefficients [9]. Both LUTs use the same principles of work and similar unit test framework to assess the precision of estimations. Both LUTs can be used with the advanced single-instrument and combined microphysical retrievals as a part of radiative transfer model for an arbitrary lidar, spectrometer, or polarimeter wavelength. Our

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