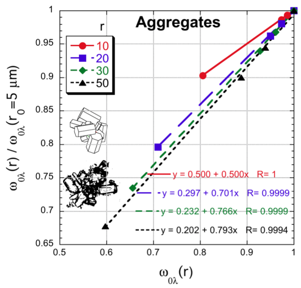
Spectral Invariant Properties of Single-Scattering Albedo for Water Droplets and Ice Crystals

Research Highlight

This paper addresses a fundamental question of the relationship between two single-scattering albedo spectra for water droplets (and ice crystals) at weakly absorbing wavelengths. The single-scattering albedo in atmospheric radiative transfer is the ratio of the scattering coefficient to the total extinction coefficient. It is equal to unity if all extinction is due to only scattering (e.g., Rayleigh molecular scattering); conversely, it is equal to zero if all extinction is due to only absorption (e.g., gaseous absorption). For cloud water droplets, both the scattering and absorption coefficients, thus the single-scattering albedo, are functions of wavelength and droplet size.

The paper shows that for water droplets at weakly absorbing wavelengths, the ratio of two single scattering albedo spectra, $\omega_{0\lambda}(r)$ and $\omega_{0\lambda}(r_0)$, is a linear function of $\omega_{0\lambda}(r)$. This ratio does not vary with wavelengths; thus the term "spectrally invariant". The slope and intercept of the linear function are wavelength-independent and sum to unity. This relationship allows for a representation of any single-scattering albedo $\omega_{0\lambda}(r)$ via one known spectrum $\omega_{0\lambda}(r_0)$.

The paper provides a simple physical explanation of the discovered relationship. In addition to water droplets, similar linear relationships were found for the single-scattering albedo of non-spherical ice crystals. These "spectrally invariant relationships" help us to better understand the physics of atmospheric radiative transfer and might substantially simplify remote sensing algorithms.



The ratio of $\omega_{0\lambda}(r)/\omega_{0\lambda}(r_0)$ plotted against $\omega_{0\lambda}(r)$ for four wavelengths, #=0.86, 1.65, 2.13 and 3.75 um. An example for the aggregates ice crystal habits is shown (see Yang et al. 2000. "Parameterization of the scattering and absorption properties of individual ice crystals." Journal of Geophysical Research 105: 4699–4718). Ice crystal effective radius r=10, 20, 30, and 50 um; r_0=5 um.

Reference(s)

Marshak A, Y Knyazikhin, JC Chiu, and WJ Wiscombe. 2012. "On spectral invariance of single scattering albedo for water droplets and ice crystals at weakly absorbing wavelengths." Journal of Quantitative Spectroscopy & Radiative Transfer, 113, 715-720.

Contributors

Alexander Marshak, *NASA Goddard Space Flight Center*

Working Group(s)

Cloud-Aerosol-Precipitation Interactions