EESC GR6922: Atmospheric Radiation, Fall 2024
Homework 4, due Dec 18

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November 21, 2024

1 Single scattering by spheres

This problem relies on the ability to do Mie calculations of single-scattering properties – extinction, scattering, and absorption efficiencies and scattering phase functions – for spheres. Scott Prahl's `miepython` package looks pretty great. It can be installed via `pip` or download from Github (`https://github.com/scottprahl/miepython`). The Github page links to thorough documentation including examples. A table of the complex index of refraction of water is bundled with the code (`data/segelstein81_index.txt`). Syl is having good luck with `https://pymiesim.readthedocs.io/en/`

1. Plot the extinction and absorption cross-sections for a drop of pure water with radius r 10 μm across the solar spectrum (0.2 - 4 μm). It may be interesting to show the size parameter $x = \frac{2\pi r}{\lambda}$ in addition to the wavelength. Make a second plot showing extinction and absorption efficiencies. Make a second set of plots for the water vapor window(8-12 µm), where the atmosphere is transparent enough that clouds can impact the surface and top-of-atmosphere radiation fields. Remember that the complex index of refraction varies with wavelength.
2. Plot the scattering phase function for a drop with radius $r = 10$ µm at wavelength $\lambda = .5$µm. Show the delta-scaled phase function on the same plot. You may but need not assume that $f = g^2$, and you'll need to make a choice of the angular width over which to replace the phase function with a delta function. Explain your choices.
3. Plot the extinction and absorption cross-sections and efficiences for droplets ranging from 4 - 20 µm for wavelength $\lambda = .5$µm. Do the same for a Gamma distribution of cloud drops with r_e varying over the same range. You can set effective variance $\nu_e \equiv 1/\alpha + 3 = 0.1$. How and why do the curves differ?

2 Two-stream solutions

Using the solutions to the two-stream equations we developed in class

1. Plot the reflectance, transmittance, and absorptance of a single layer as a function of total optical depth τ^* and single scattering albedo. Let experience guide the range of values over which you show the values.
2. Use Mie calculations to compute the single-scattering albedo and phase functions for Gamma distributions at $r_e = [2, 4, 8, 12, 16, 24]$µm at wavelengths $\lambda_{\text{vis}} = .65$µm and $\lambda_{\text{nir}} = 2.16$µm. Plot the reflectance at λ_{nir} as a function of the reflectance at λ_{vis} for $\tau^* = 4, 6, 8, 12, 16, 24, 32$. Connect lines of constant τ^* with lines; connect lines of constant r_e with lines of another type/color. Explain how measurements at these two wavelengths might be used to estimate τ^* and r_e. In what parameter range would it be possible to estimate one of these quantities from a single measurement, rather than both quantities from the two measurements?