Radiative transfer in the environment. Weitzmann, fall 2008.

Problem set IV:

1. (based on Petty, ex. 7.2) A cloud layer has a vertical profile of the extinction coefficient ($c=0.015m^{-1}$) that is quadratic with the altitude between its base ($z_{base}=1000m$) and its top ($z_{top}=1200m$) with a maximum in the middle of the cloud and zero extinction at its base and top.

Compute the total optical path and vertical transmittance through the cloud.

2. (Petty, ex. 7.6) A particular plane parallel cloud has liquid water density $\rho_w=0.1$ g m-3 and thickness $\Delta z=100m$. At a certain wavelength, the mass extinction coefficient of the cloud droplets is $c_{water}*=150m^2/kg$, and the single scatter albedo is $\omega_{water}=1$. However, the air in which the droplets are suspended is itself absorbing at this wavelength, having an absorption coefficient $a_{air}=10km^{-1}$ and $\omega_{air}=0$.

Compute a, b, c and ω_0 for the mixture (the absorption, scattering, attenuation and single scattering albedo). Compute the total optical thinkcness of the cloud layer. If the radiation incident on top of the cloud $I_{\lambda,top}$ is at a zenith angle of sixty degrees, compute the transmitted intensity, $I_{\lambda,bot}$.

3. (Petty, ex. 7.8) A ground-based radiometer operating at $\lambda=450nm$ is used to measure the solar intensity $I_\lambda(0)$. For a solar zenith angle of $\theta=30°$, $I_\lambda(0)=1.74x10^7\ Wm^{-2}\mu m^{-1}sr^{-1}$. For $\theta=60°$, $I_\lambda(0)=1.14x10^7\ Wm^{-2}\mu m^{-1}sr^{-1}$. From this information, determine the top-of-the-atmosphere solar intensity S_λ and the atmospheric optical thickness τ_λ.

4. (Petty, ex. 7.12, using individual particle optical properties to obtain bulk properties) A certain cloud layer has geometric thickness H=0.1km and liquid water path ($L \equiv \int_{z_{bot}}^{z_{top}} \rho_w\, dz$) $L=0.01kg\ m^{-2}$. Assuming Qe~2 (the extinction efficiency of particles larger than the wavelength) and a solar zenith angle of $\theta=60°$, compute the transmittance of a direct light beam for a. $N=100cm^{-3}$ (characteristic of clean maritime environments), and b. $N=1000cm^{-3}$

(characteristic of continental environments), where N is the number of spherical drops.

5. (Continuation of problem 3 from problem set 3). Recast the problem in terms of the asymmetry parameter: $g=(T_1-R_1)/ =(T_1+R_1)$ and the single scattering albedo: $\omega_0=T_1+R_1=1-A_1$. Investigate the sensitivity of the asymptotic value of R_N to these parameter (as you did in the previous homework).

   Extra credit: in the ocean we often assume that $R_N \sim b_b/a$ {or $b_b/(b_b+a)$}. Translate this expression to g and ω_0 and investigate whether it is consistent with your findings.