Cloud Albedo (Reflectance) and Transmittance: Simple Model

Cloud optical depth

$$\tau = Q_{ext}\left[\frac{9\pi\ LWP^2 H}{16\ \rho^2_{BulkWater}}\ CCN\right]^{\frac{1}{3}}$$

LWP = Cloud Water Mass / Area
Q_{ext} = Cloud droplet extinction efficiency
CCN = # cloud condensation nuclei

$$\tau^* = (1-g)\ \tau$$

$$T = \frac{I_t}{I_0} = \frac{2}{2+\tau^*}\ ,\quad \frac{I_t^{direct}}{I_0} = \exp(-\tau),\quad R = \frac{I_r}{I_0} = \frac{\tau^*}{2+\tau^*}$$

n_r=1.33
λ=0.6328
D=20 um
g=0.874

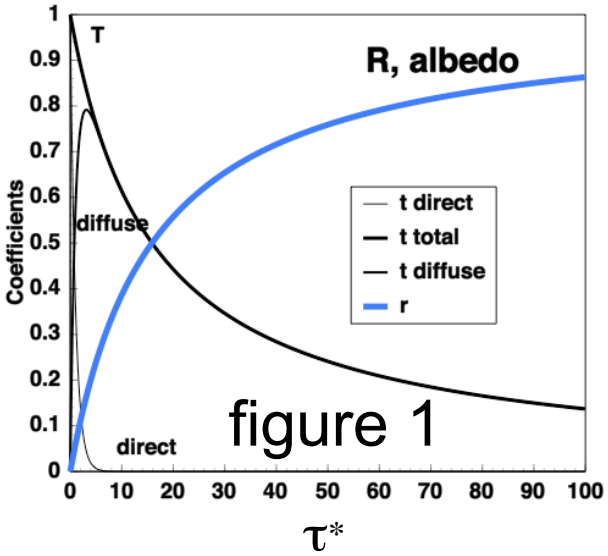
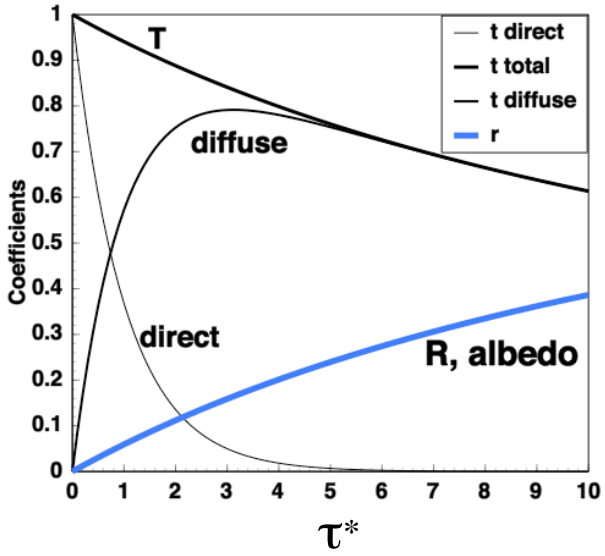
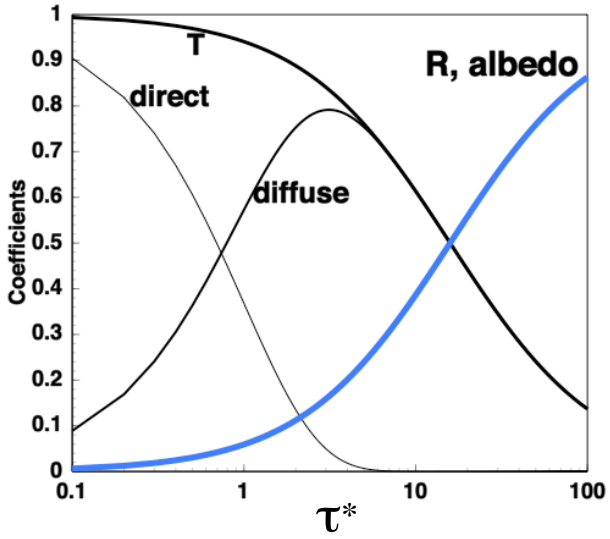


figure 1





source: http://en.wikipedia.org/wiki/Cloud_condensation_nuclei

Homework Problem #2

1. Derive the relationship between τ and *CCN* given on the previous slide.

2. Reproduce Figure 1 on the previous slide.

3. Calculate the *R* and *T* coefficients in Figure 1 for water droplets with diameters of 5 microns, and 10 microns. You will have to recalculate the asymmetry parameter.

4. Calculate the climate sensitivity to water droplet number by calculating d*R*/d*CCN*. In words, how does the cloud albedo (reflectance) change with *CCN*? Assume all of the variation in R is due to CCN; hold all other parameters fixed. Explore and explain your solution as a function of total optical depth τ. Why is this solution only an approximation of d*R*?

5. Make a plot of the asymmetry parameter *g* and the extinction efficiency Q_{ext} for cloud droplets varying in size from 1 micron to 20 microns. Explain your results.

6. Reproduce the figure on the next slide using the simple model. Interpret your results. Interpret this figure.

Cloud Liquid Water Path, Effective Radius, And Cloud Albedo

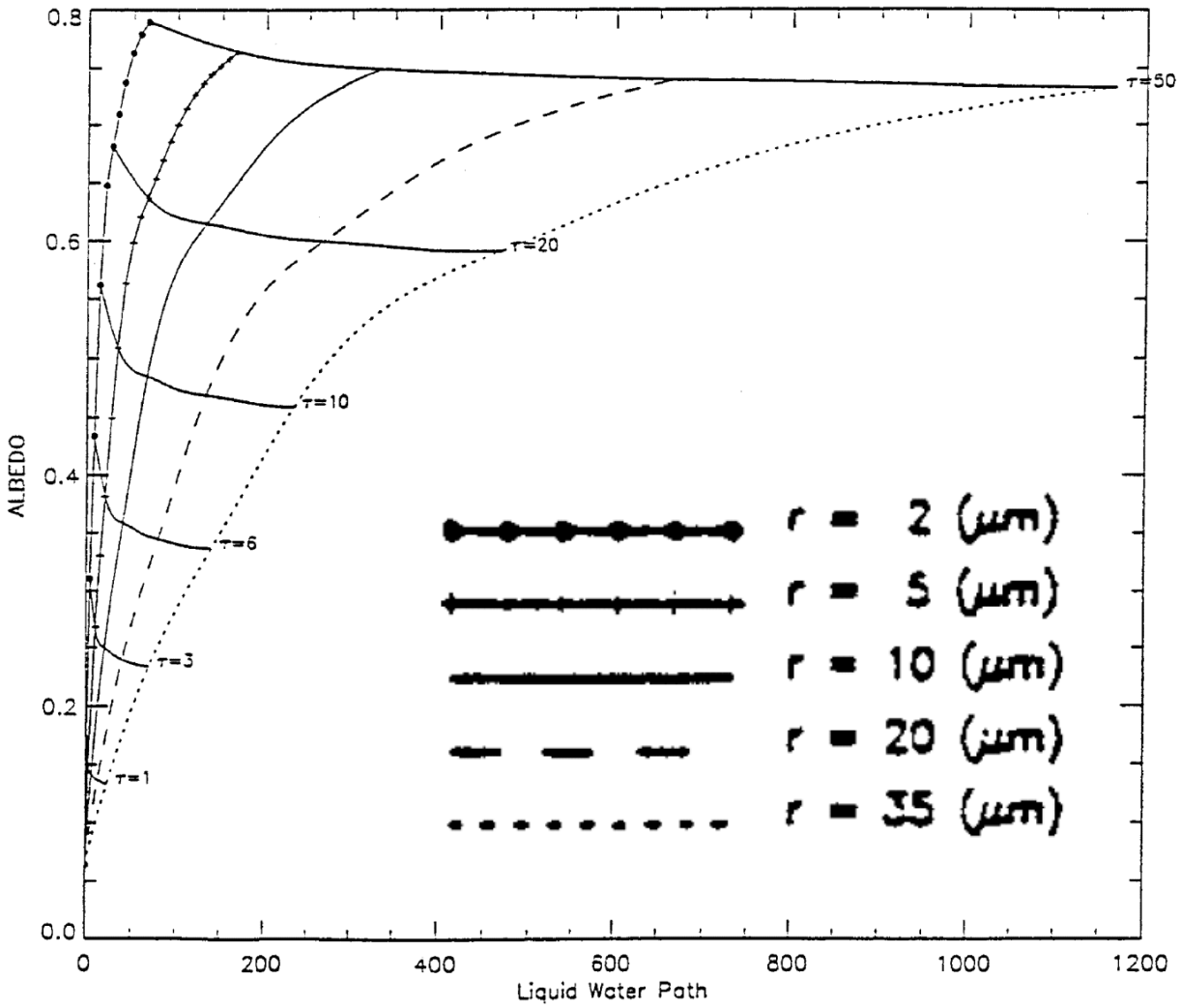


FIG. 1. Model results of cloud albedo as functions of r_e and LWP.

grams / m^2

Does this make sense? Why?

Global Survey of the Relationships of Cloud Albedo and Liquid Water Path with Droplet Size Using ISCCP.Preview By: Qingyuan Han; Rossow, William B.; Chou, Joyce; Welch, Ronald M.. Journal of Climate, 7/1/98, Vol. 11 Issue 7, p1516.