

MSC 409 Spring 2006 HW #4  
Answer to 1.

1. Consider solar radiation with a zenith angle of  $0^\circ$  that is incident on a layer of aerosols with a single scattering albedo  $\omega_0$  of 0.85, an asymmetry factor  $g=0.7$ , and an optical thickness  $\tau = 0.1$ , averaged over the shortwave part of the spectrum. Assume a surface albedo  $R_s$  0.15. Show the formulae you apply as well as numerical answer. This question is based on WH 4.42

a. What fraction of the solar radiation is directly transmitted through to the surface ?

Ans:  $T = e^{-\tau} = 0.9$  keep the distinction between direct and diffuse in mind.

c. What fraction of the direct solar beam is absorbed by the aerosol ?

Ans: recall the definition of  $\omega_0$ : scattering/(scattering+absorption) efficiency  
Of the amount not transmitted through the aerosol layer, 85% is scattered and 15% is absorbed. Thus:  $(1 - \omega_0)(1 - T) = 0.015$

b. What fraction of the direct solar beam is reflected back to space by the aerosol layer ?

Ans. Of the amount scattered (given by  $\omega_0$ ), the amount scattered up and down is given by  $g$ , the asymmetry parameter, but first a mapping has to be done between  $g$  and the fractional scatter. Recall  $g$  varies between -1 (for complete backscatter) to 1 (for complete forward scatter), and  $g=0$  indicates equal amounts of forward and backward scatter. If  $b$  is the backscatter fraction, you come up with  $b = (1-g)/2$ .  
=>  $b \omega_0(1 - T) = (1-g)/2 * \omega_0 * (1 - e^{-\tau}) = 0.01275$

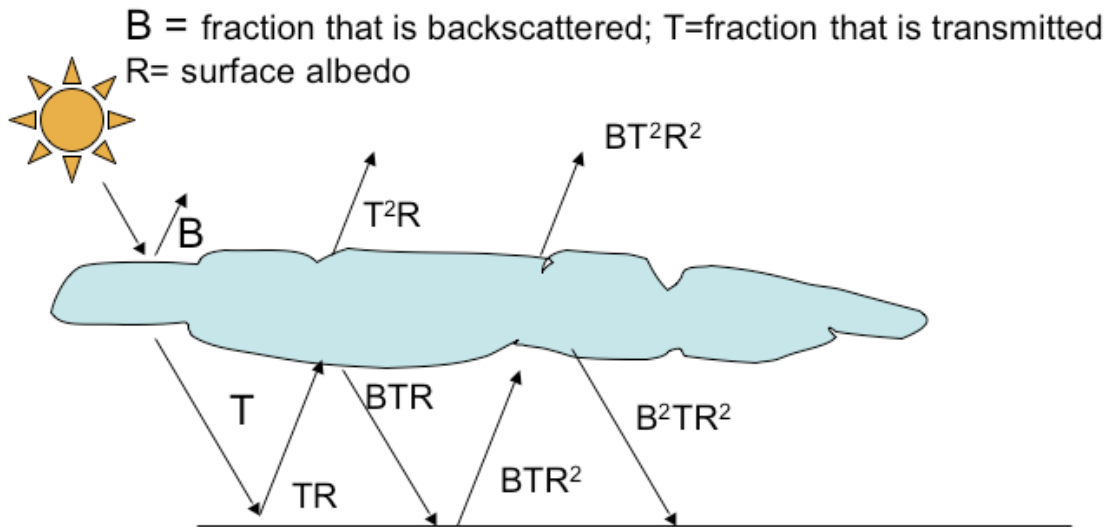
d. What fraction of the direct solar beam is reflected upward by the surface ?

$$T * R_s = (1 - e^{-\tau}) * 0.15 = 0.015 \quad (\text{similarity to ans c. is coincidence})$$

e. Of the answer to d. how much ends up getting reflected back to space ?

This is basically the amount that is able to transmit through the aerosol layer, or,  
Multiply answer to d. by T:  $0.015 * 0.9 = 0.0135$

f. Diagram the multiple scattering that occurs between the surface and aerosol layer and the portion that contributes to the total reflection back to space.



Total transmitted to surface becomes:  
 $T(1 + BR + B^2 R^2 + \dots)$

g. If instead the solar zenith angle were  $60^\circ$  how would your answers to a.-f. change ?

Ans: At a lower zenith angle, the transmission is reduced to  $T = \exp(-\tau/\cos(60)) = 0.82$ . More solar radiation is absorbed by the aerosol as a result of the longer path length, and more is also scattered. This also helps explain why aerosol is easier to detect near sunset and sunrise (along with the peak in the scattering right along and against the beam of the sun)