

1. More complex radiative equilibrium profiles.

Crudely approximate atmospheric absorption of solar radiation by assuming $I_F(O_a) = I_{Fs} \exp(-b_s O_a) + I_{FL}$.

a) (12 pts) derive the general formula for $I_e(O_a)$, similar to (3.41), as a function of I_{FL} , I_{Fs} , and O_a where $b_s \geq 0$. Hint: use (3.31), (3.28), (3.33), (3.34). Also obtain the formula for $I_e(0)$.

If you would like the answer to part a on Tuesday (29 October). Turn in part a) at the start of class Tuesday.

b) (2 pts) Using your answer to part a) write down the formula for $T(O_a)$

c) (3 pts) Using the water vapor (WV) and ozone (O3) profiles given on page 3-42, write down the formula for $T(O_a)$ using the optical depth profiles of (3.44) and (3.47).

d) (7 pts) Using information in Figure caption 3.26, except where noted, find and plot the following:

i) profiles of optical depth for water vapor, ozone, and their combination vs z from $z=0$ to $z=24\text{km}$ using a 1 km interval.

ii) profiles of atmospheric temperature T from $z=0$ to $z=24\text{km}$ using a 1 km interval for optical depth due to ozone alone and due to the combination of water vapor and ozone. Let $I_{Fs} = 60 \text{ W/m}^2$, $b_s = 10 \text{ km}^{-1}$, $k_{O3} = 6 \times 10^{-4} \text{ km}^{-3}$, $H_w = 2 \text{ km}$ and also, $O_{ab} = 1.0$. Use the combined O3 + WV optical depth profile, except let $b = -0.14 \text{ km}^{-1}$. Let the albedo = 0.31.

Hint: recall that I_F is related to the solar constant $I_{Sol} = 1370$ (where $I_{FL} + I_{Fs} = (1 - A_{ld}) I_{Sol} / 4$) after the geometric correction (factor of $1/4$) and after subtracting off that which is reflected by the albedo are applied.

e) (2 pts) Comment on how temperature varies in the vertical and how that changes when water vapor is present or not.

f) (2 pts) Find and plot the profile of atmospheric temperature T from $z=0$ to $z=24\text{km}$ using a 1 km interval for optical depth due to the combination of water vapor and ozone as in part d) except now set $I_{FL} = 0$ and $I_{Fs} = (1 - A_{ld}) I_{Sol} / 4$.

g) (2 pts) Comment on how the three temperature profiles relate to the irradiance and optical depths chosen.

NOTE: all homework is to be done by you as an INDIVIDUAL: no 'group' efforts, please.

For written answers, please use a word processor, so that penmanship is not an issue.

Equations and derivations can be *neatly* hand-written.

Any plot must be completely and unambiguously labeled, including title and axes.