Temperatures in the Two-Stream Model

We can approximate $\pi B = \sigma T^4$

So the atmospheric temperature is

$$T^4 = \frac{\pi B}{\sigma} = \frac{1}{\sigma}\frac{\phi}{2}(\chi^* + 1)$$

temperature of atmosphere at any z, χ^*

$$= \frac{1}{\sigma}\frac{\sigma T_e^4}{2}(\chi^* + 1)$$

$$T^4 = \frac{T_e^4}{2}(\chi^* + 1)$$

What about T_g?

→ calculate $F^{\uparrow}$ and assume the ground is a blackbody

With χ_0^* = optical depth of whole atmosphere

the ground temperature is

$$T_g^4 = T_e^4\left(\frac{\chi_0^*}{2} + 1\right)$$

But T_a at ground level is:

$$T_a^4 = \frac{T_e^4}{2}\left(\chi_0^* + 1\right) = T_e^4\left(\frac{\chi_0^*}{2} + \frac{1}{2}\right)$$

So there is a temperature discontinuity at the ground.

The presence of an atmosphere of optical depth χ_0^* raises the ground temperature by $\left(1 + \chi_0^*/2\right)^{1/4}$

Typical numbers:

Earth $\quad T_e = 255\,K$, $T_g = 290\,K$ $\quad \chi_0^* = 1.34$, $\chi_0 = 0.81$

Two consequences:

① Translation to p or z vs. T

$$\chi^* = r k \int_z^\infty \rho \, dz = \frac{r k p}{g}$$

using Hydrostatic Equation

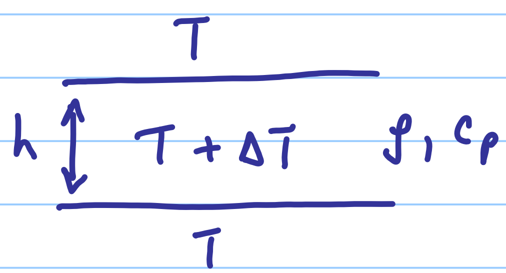
This assumes that absorption is density-related, which is not accurate for the atmosphere.

However, a more accurate calculation relating χ^* to density and pressure shows that the T profile is superadiabatic and therefore unstable to convective processes.

⇒ Radiative processes can tend to produce superadiabatic T profiles which dynamical processes try to eliminate.

② Timescales for radiative processes

Assume a simple opaque layer at $T+\Delta T$ surrounded by matter at T



Energy balance:

(rate of change of T)

$$2\sigma\left[(T+\Delta T)^4 - T^4\right] = c_p \rho h \frac{d(T+\Delta T)}{dt}$$

For small ΔT:

$$8\sigma \,\Delta T \; T^3 = -c_p \rho h \frac{d\,\Delta T}{dt}$$

Solution: $\Delta T = (\Delta T)_0 \exp\left(\frac{-t}{\tau}\right)$

where

$$\tau = \frac{c_p \rho h}{8 \sigma T^3} = 3 \times 10^5 \text{ sec} = 3.5 \text{ days}$$

when the layer is the whole troposphere

$\Rightarrow$ Terrestrial radiative transfer processes have a timescale of several days in the troposphere.