Chapter 1: model with non-absorbing atmosphere

Total solar irradiance TSI $F_s = 1370\ W m^{-2}$, contained in a tube πa^2

earth has a planetary albedo $A = 0.3$

30% of incoming radiation reflected back to space. ⇒ reflects $0.3 F_s \pi a^2$ of incoming solar power.

- earth is assumed to emit as a black body. Stefan law: $P = \sigma T^4$ (σ: stef.- Boltz cst.)
  total Power emitted $4\pi a^2 \sigma T^4$ ⇒ assume all transmitted to space & none absorbed by atmosphere.
- Assume earth is in thermal equilibrium

$P_{in} = P_{out}$ $\quad (1-A) F_s \pi a^2 = 4\pi a^2 \sigma T^4 \Rightarrow A = 0.3 \Rightarrow T = 255K$ (effective temperature of the earth.)

Real value = 288K

1.3.2: adding an atmosphere

add one layer of atmosphere, temperature T_a. it transmits fraction T_{sw} incident short waves & T_{lw} incident long waves. these are called transmittances. → low transmittance means high absorbance

Assume ground at temperature T_g.

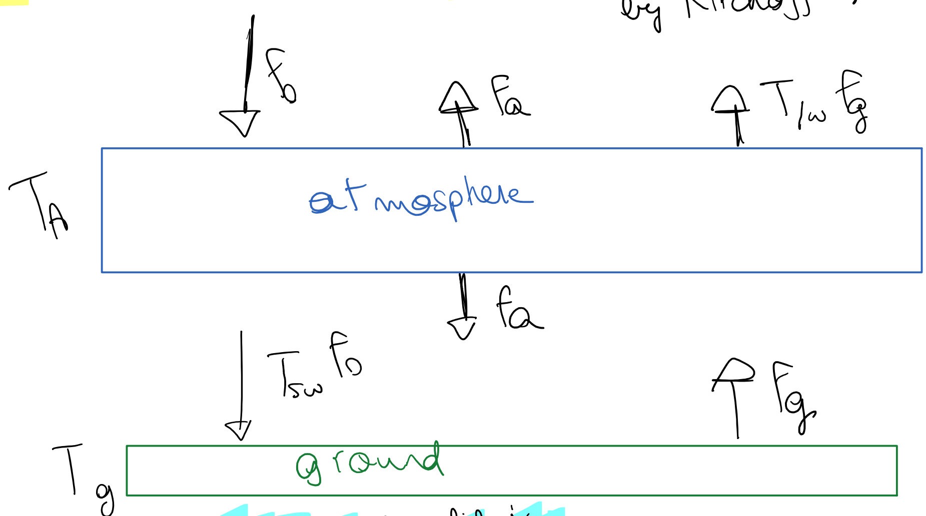
⇒ mean unreflected incoming solar irradiance at the top of the atmosphere is $F_0 = \frac{1}{4}(1-A) F_s \approx 240\ W m^{-2}$ (the $\frac{1}{4}$ due to ratio of surfaces.)

of this $T_{sw} F_0$ is absorbed by the ground & $(1-T_{sw}) F_0$ is absorbed by the atmosphere

ground emits as a black body with irradiance $F_g = \sigma T_g^4$

∘ $T_{lw} F_g$ reaches atmosphere $(1-T_{lw}) F_g$ is absorbed.

atmosphere has irradiance $F_a = \underbrace{(1-T_{wl})}_{\text{by Kirchoff's law of emittance}} \sigma T_a^4$ both up & down.



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$F_0 = F_A + T_{lw} F_g$ $\quad$ $F_g = T_{sw} F_0 + F_A$

$\Rightarrow F_g = \sigma T_g^4 = F_0 \dfrac{1 + T_{sw}}{1 + T_{lw}}$ $\quad$ rough values for earth's atmosphere $T_{sw} = 0.9$ $\quad T_{lw} = 0.2$

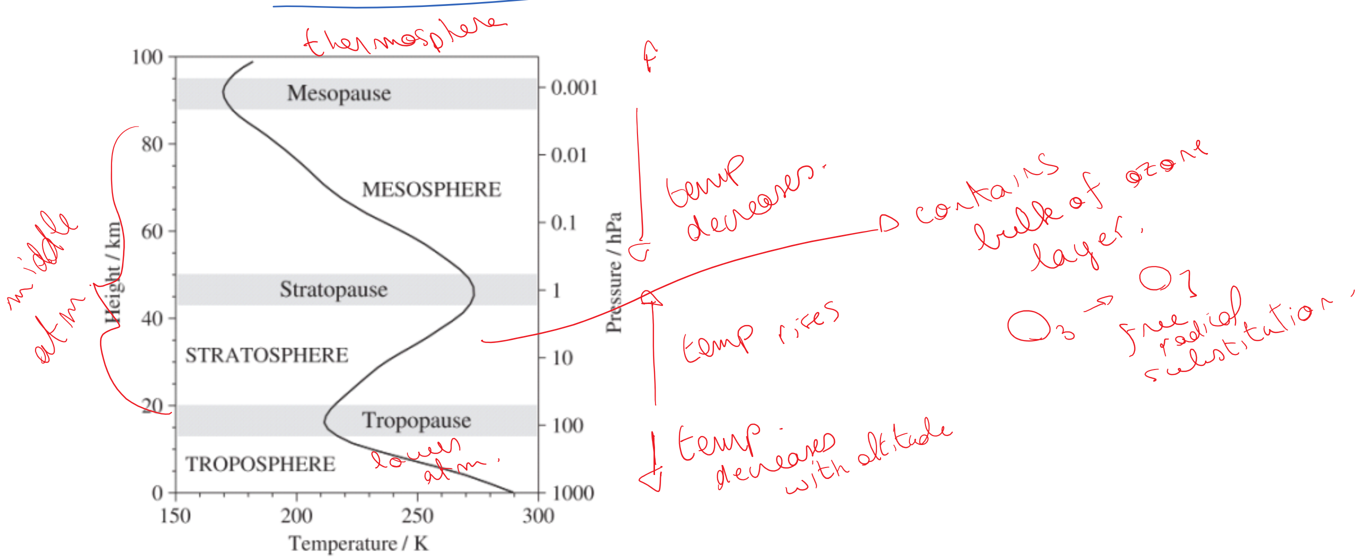
gives $T_g \approx 286$ K which is close to observed 288 K

$F_a = F_0 \dfrac{1 - T_{sw} T_{lw}}{1 + T_{lw}} \Rightarrow T_a = 245$ K

Greenhouse effect: there is less absorption for solar than thermal radiation.

Quantify the greenhouse effect of a gas: $F_g - F_0$ by which it reduces the outgoing irradiance from its surface value

so $(1 - T_{lw}) \sigma T_g^4$ (304) is absorbed by atmosphere, whereas $(1 - T_{lw}) \sigma T_a^4$ (164) is emitted upwards & the rest towards the earth.



the ozone absorbs solar UV radiation.