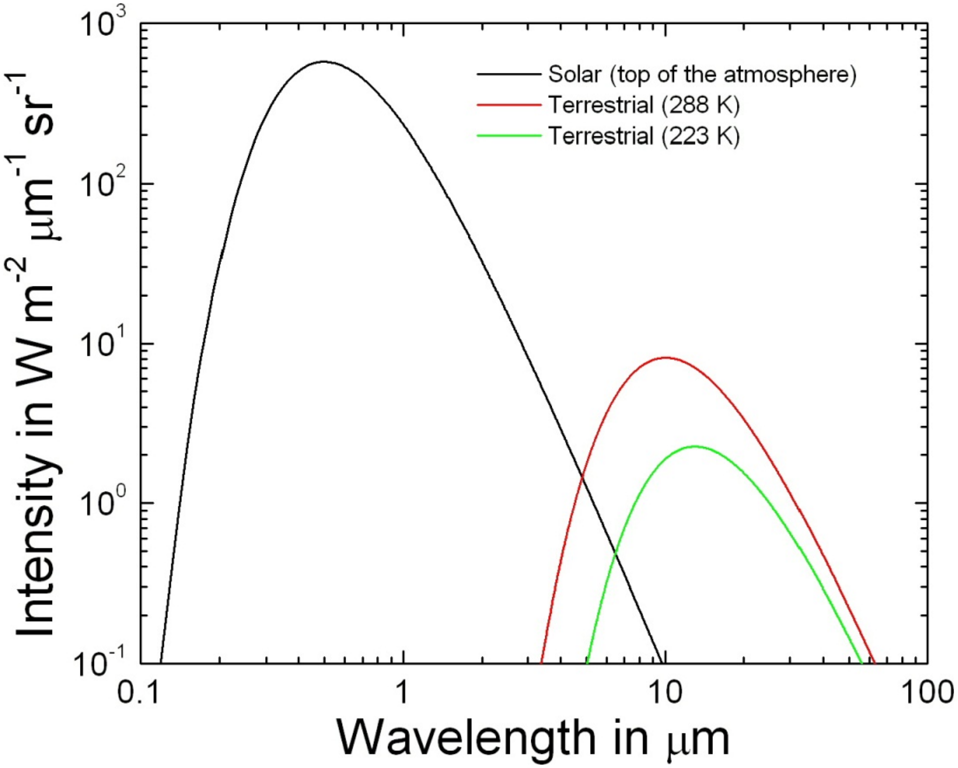
Unit 12

Shortwave and long-wave radiation

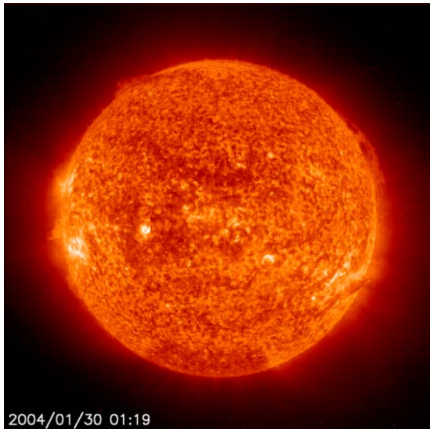
Nicole Mölders

Solar Spectrum vs. Terrestrial Spectrum

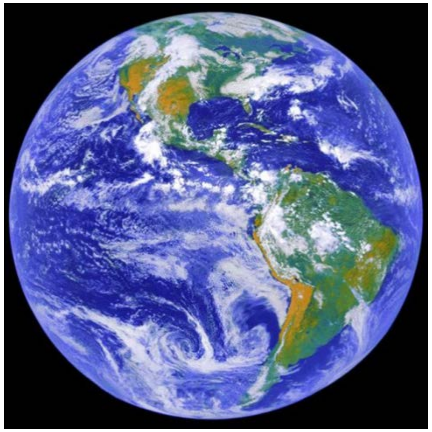
$$F = \pi \left(\frac{r_s}{r}\right)^2 \frac{F_s}{\pi} = \pi \left(\frac{r_s}{r}\right)^2 \int_0^\infty B_\lambda (T_{Sun})\, d\lambda = \pi \int_0^\infty \left(\frac{r_s}{r}\right)^2 B_\lambda (T_{Sun})\, d\lambda$$



Sun



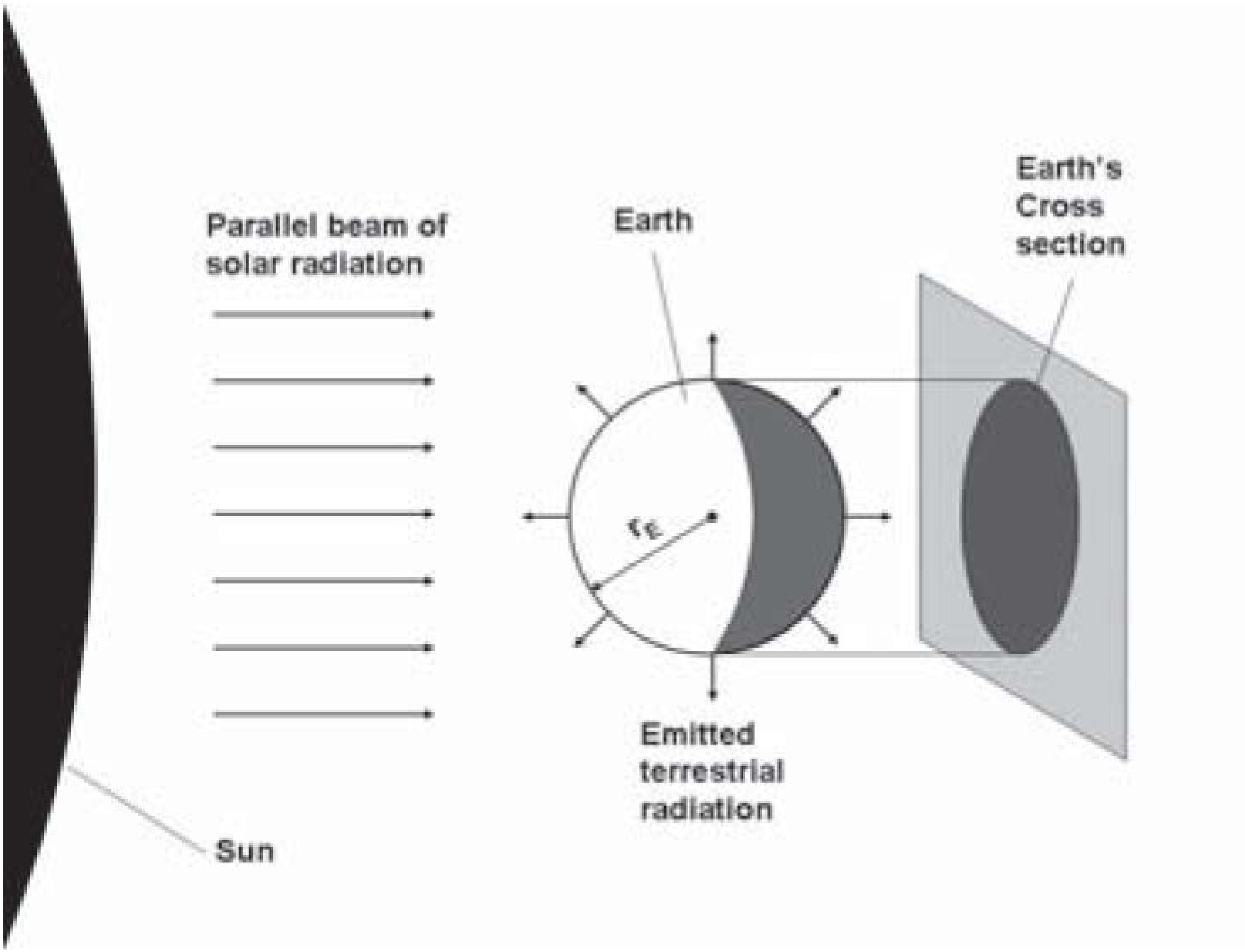
Earth



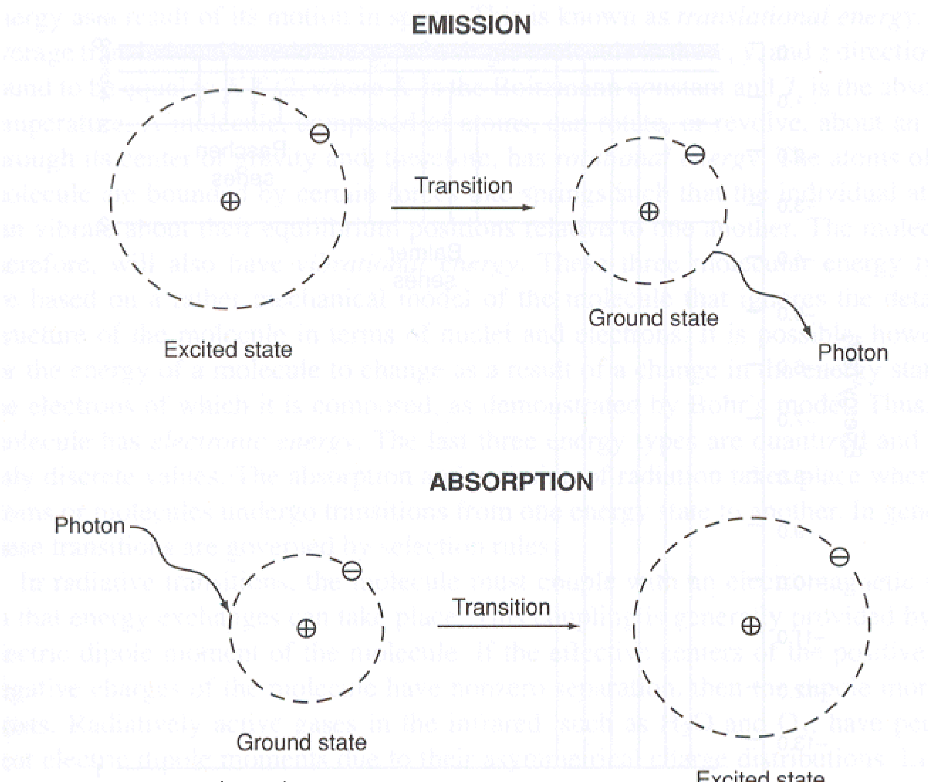
Images not to scale

$$B_{\lambda,TOA} = \left(\frac{r_s}{r}\right)^2 B_\lambda (T_{Sun})$$

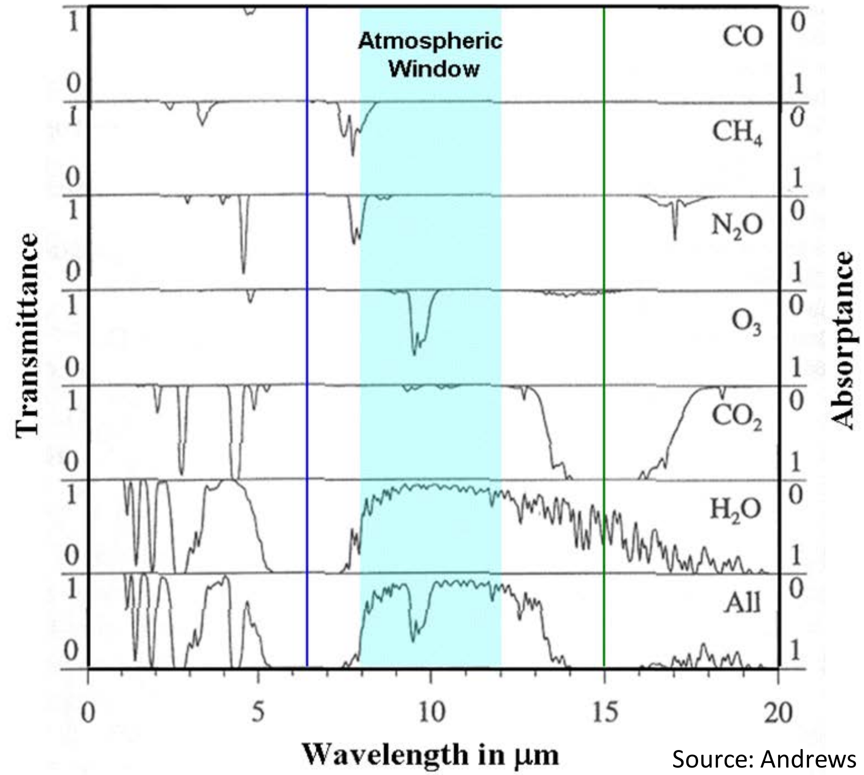
Terrestrial vs. solar radiation



Emission and absorption



From: Liou (2002)



Source: Andrews (2000)

Water vapor (H_2O)
Carbon dioxide (CO_2)
Ozone (O_3)
Methane (CH_4)
Nitrous oxide (N_2O)
Halocarbons (e.g., $CFCl_3$, CF_2Cl_2)

Vertical structure of the atmosphere

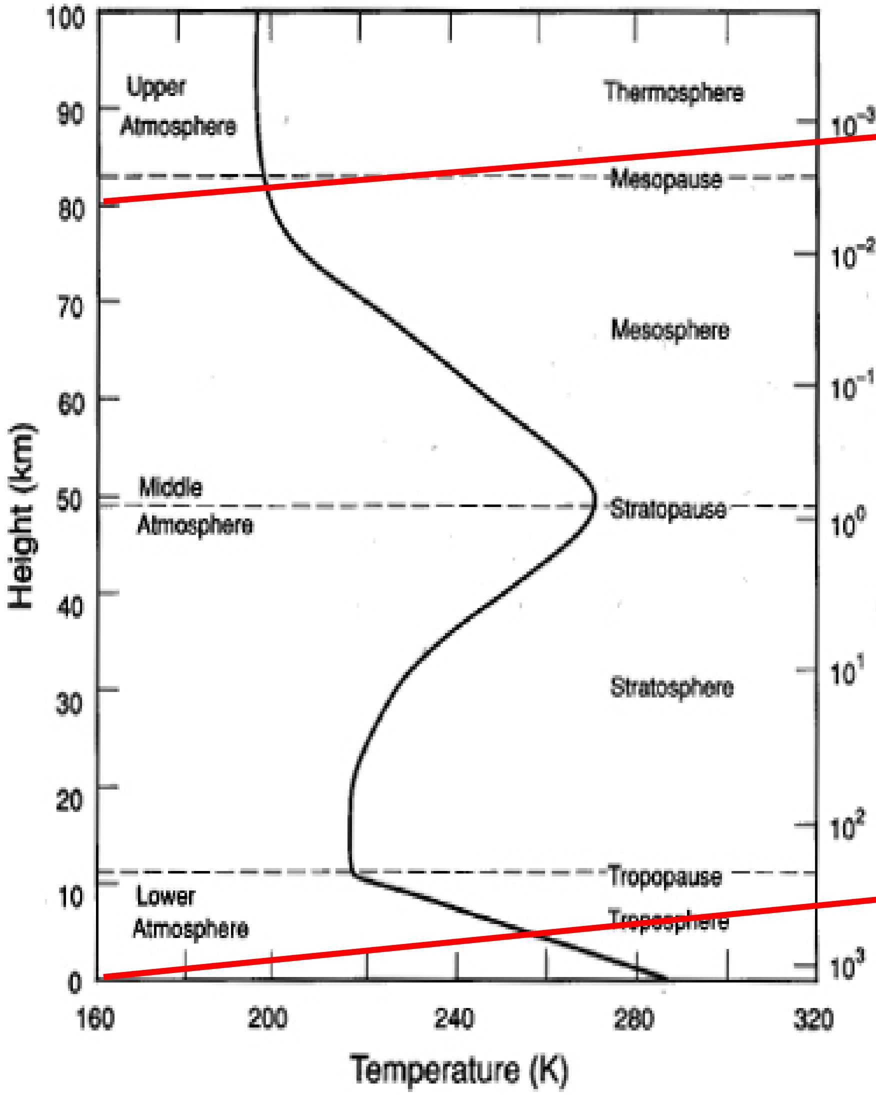


Figure 3.1 Vertical temperature profile after the U.S. Standard Atmosphere and definitions of atmospheric nomenclature.

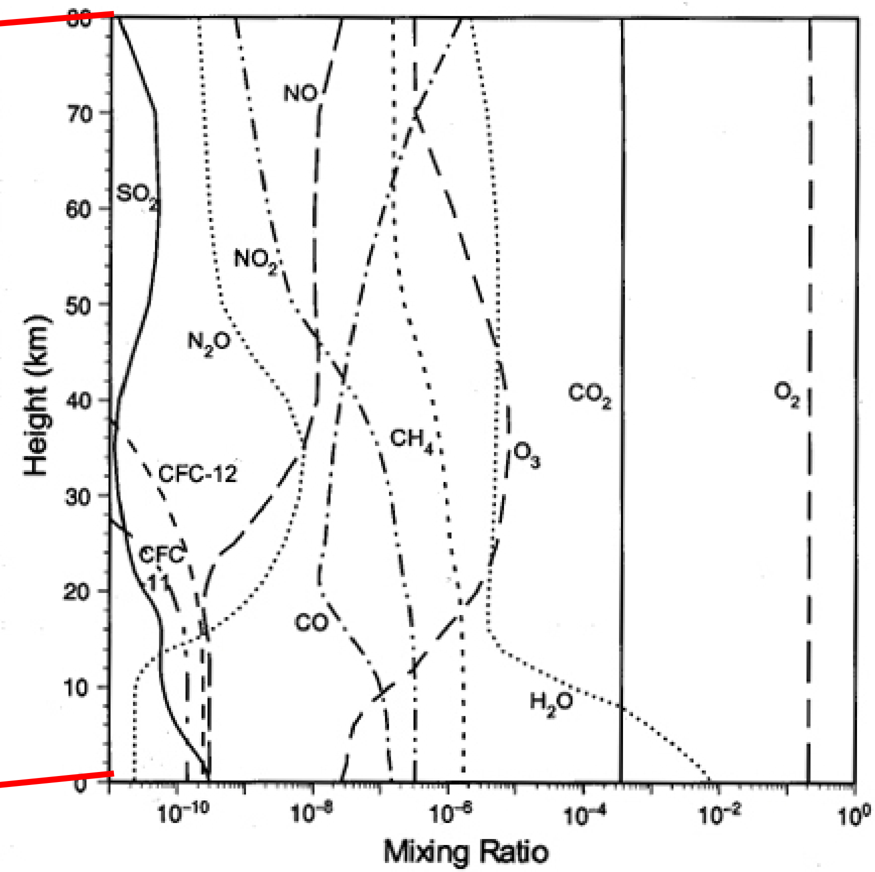
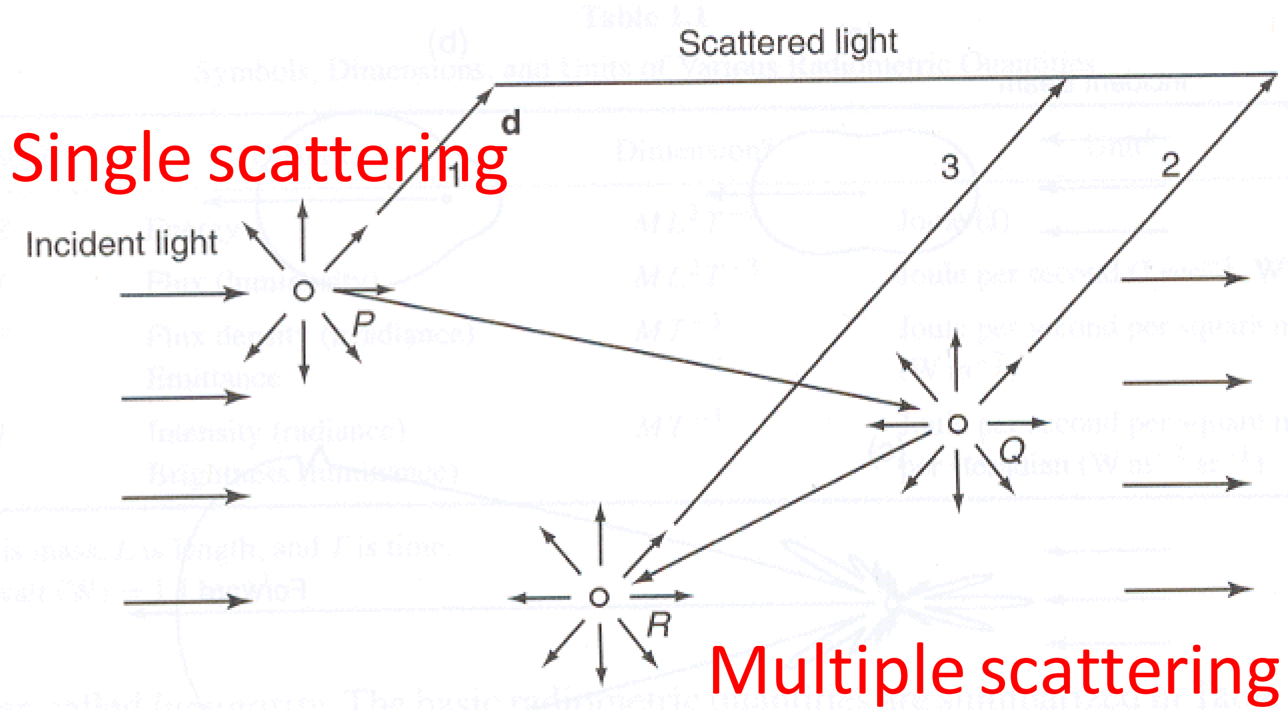


Figure 3.2 Representative vertical profiles of mixing ratios of selected species for midlatit conditions.

From: Liou (2002)

Scattering

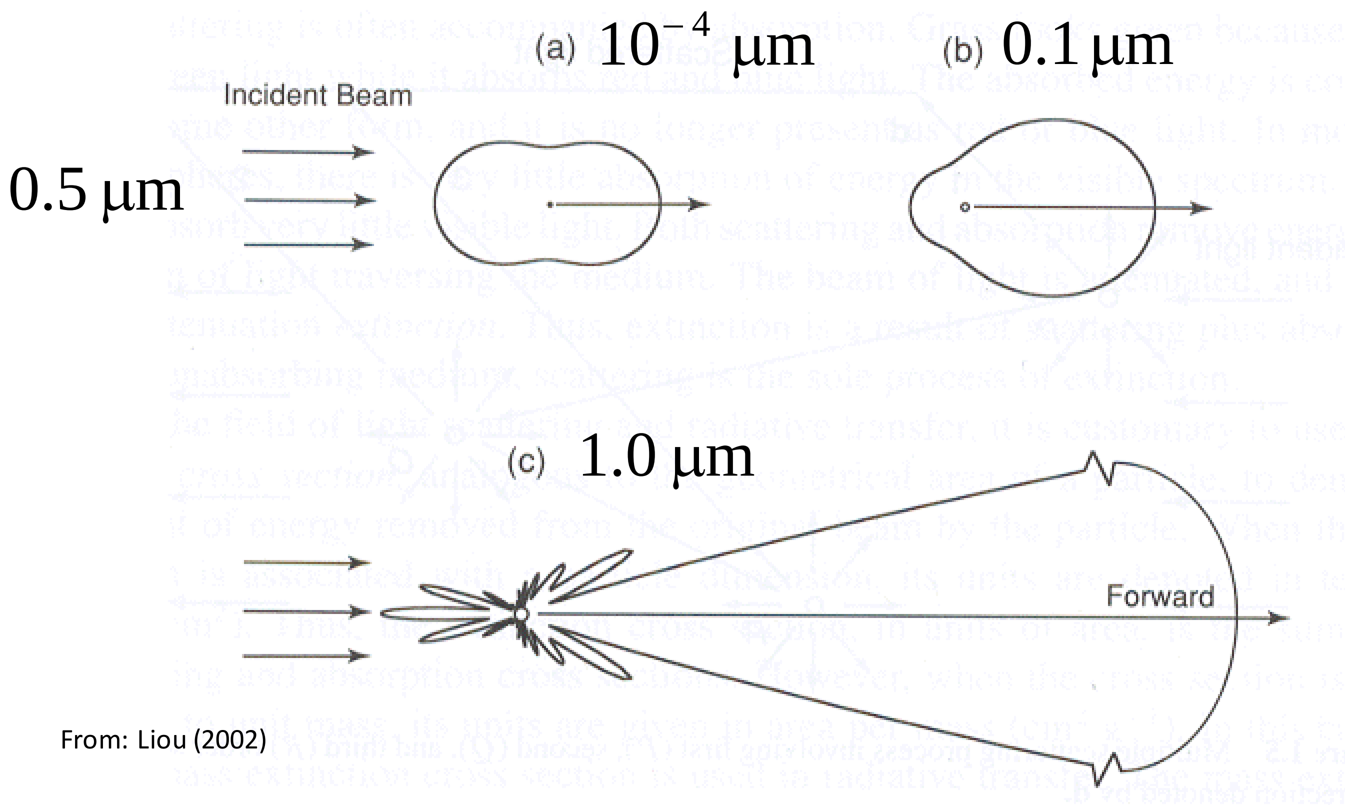
- Rayleigh scattering
- Mie scattering
- Geometrical optics



From: Liou (2002)

Scattering

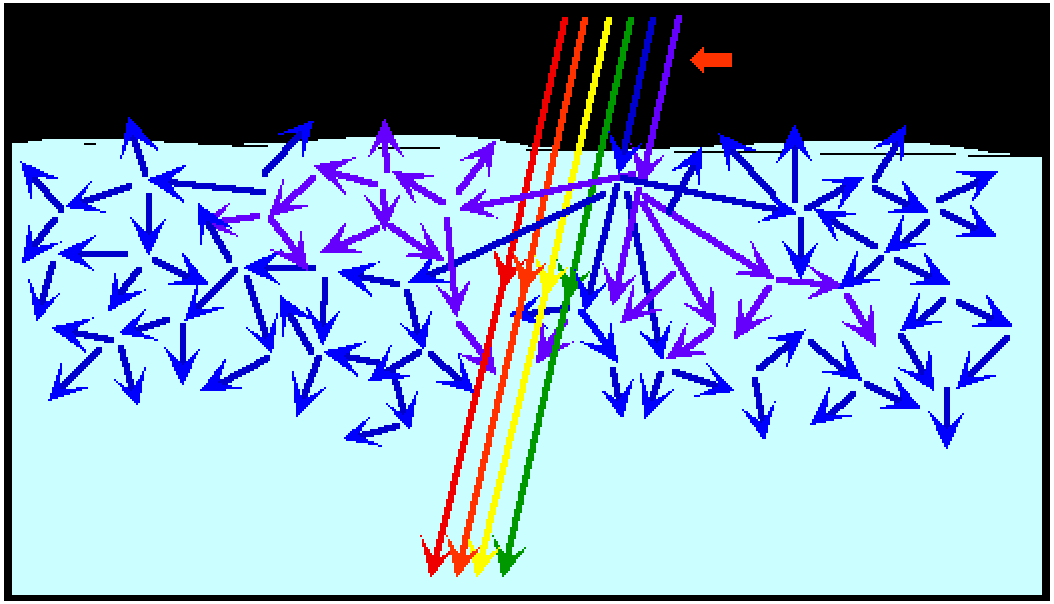
- Rayleigh scattering
- Mie scattering
- Geometrical optics



From: Liou (2002)

Scattering

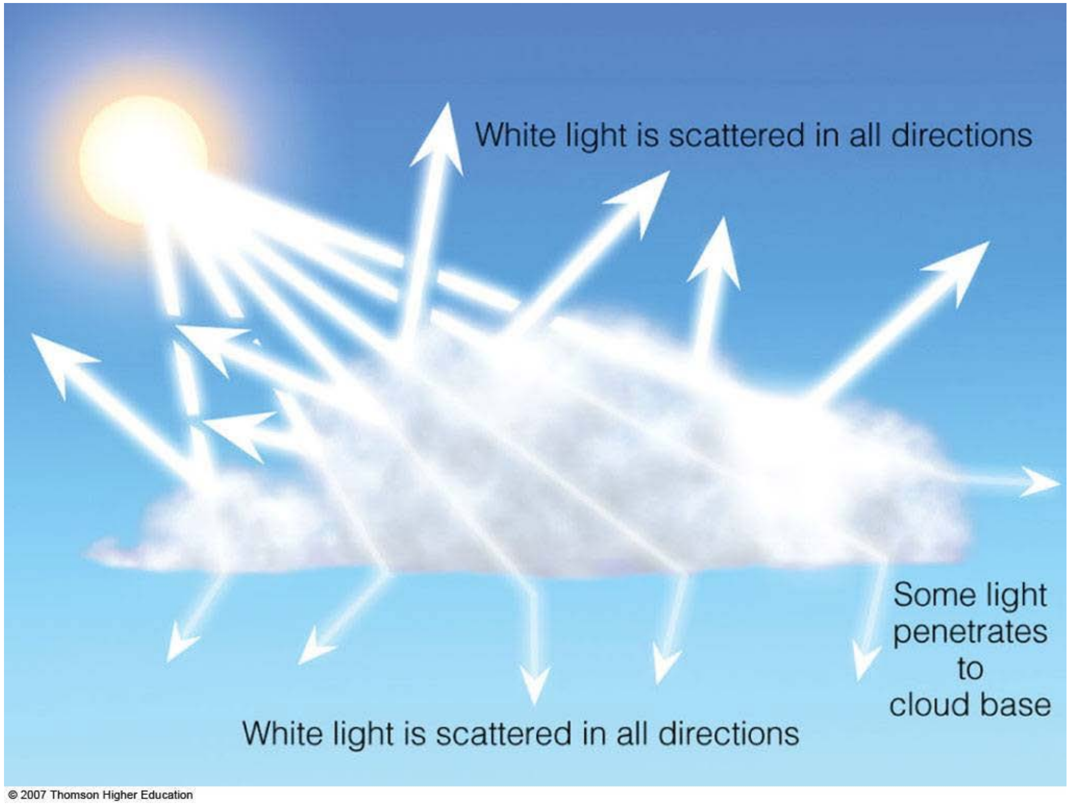
- Rayleigh scattering molecules d=$10^{-4}\mu m$
- Mie scattering
- Geometrical optics



http://home.comcast.net/~vinelandrobotics/bluesky.gif

Scattering

- Rayleigh scattering
- Mie scattering aerosols, droplets, ice crystals d~1-10μm
- Geometrical optics



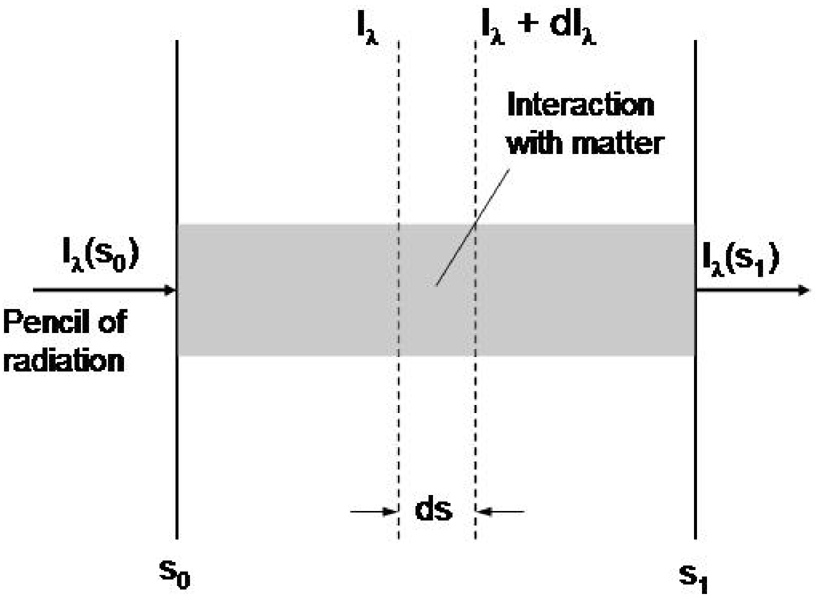
Scattering

- Rayleigh scattering
- Mie scattering
- Geometrical optics
  raindrops
  d~100μm

Radiative Transfer

Four processes can modify the beam of radiation that travels a distance, ds through the volume

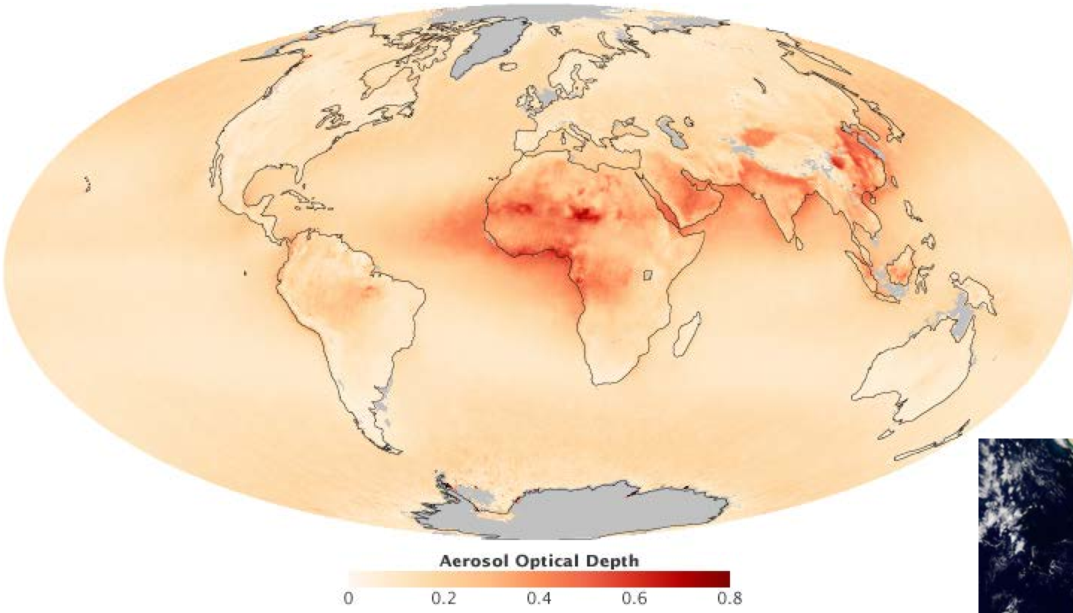
- radiation from the beam can be absorbed
- radiation can be scattered out of the volume into other directions
- radiation can be emitted
- radiation from other directions can be scattered into the beam

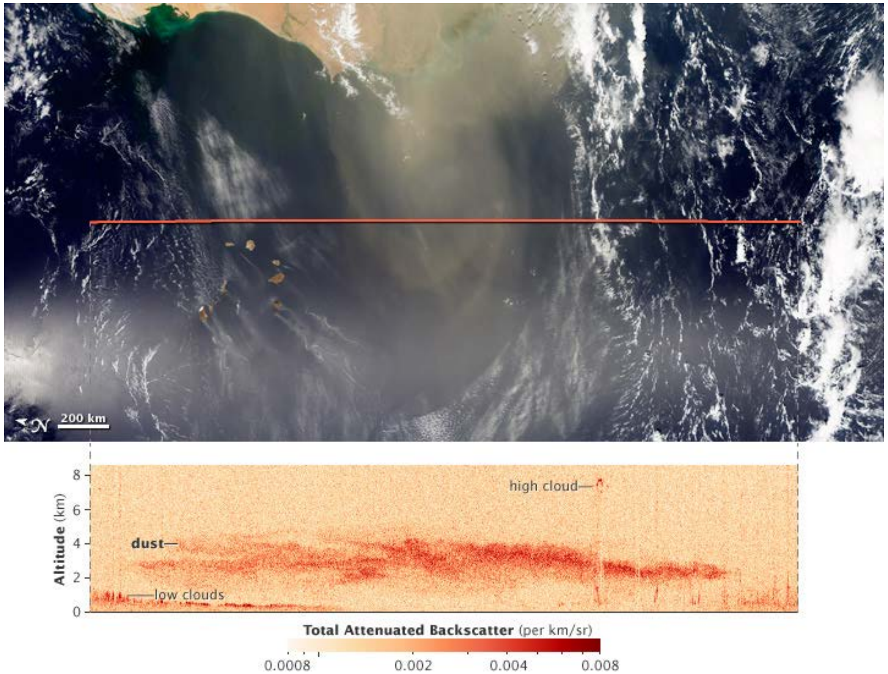


$$dI_\lambda = -\rho\,\beta_\lambda\, I_\lambda\, ds + \rho\,\beta_\lambda\, J_\lambda\, ds$$

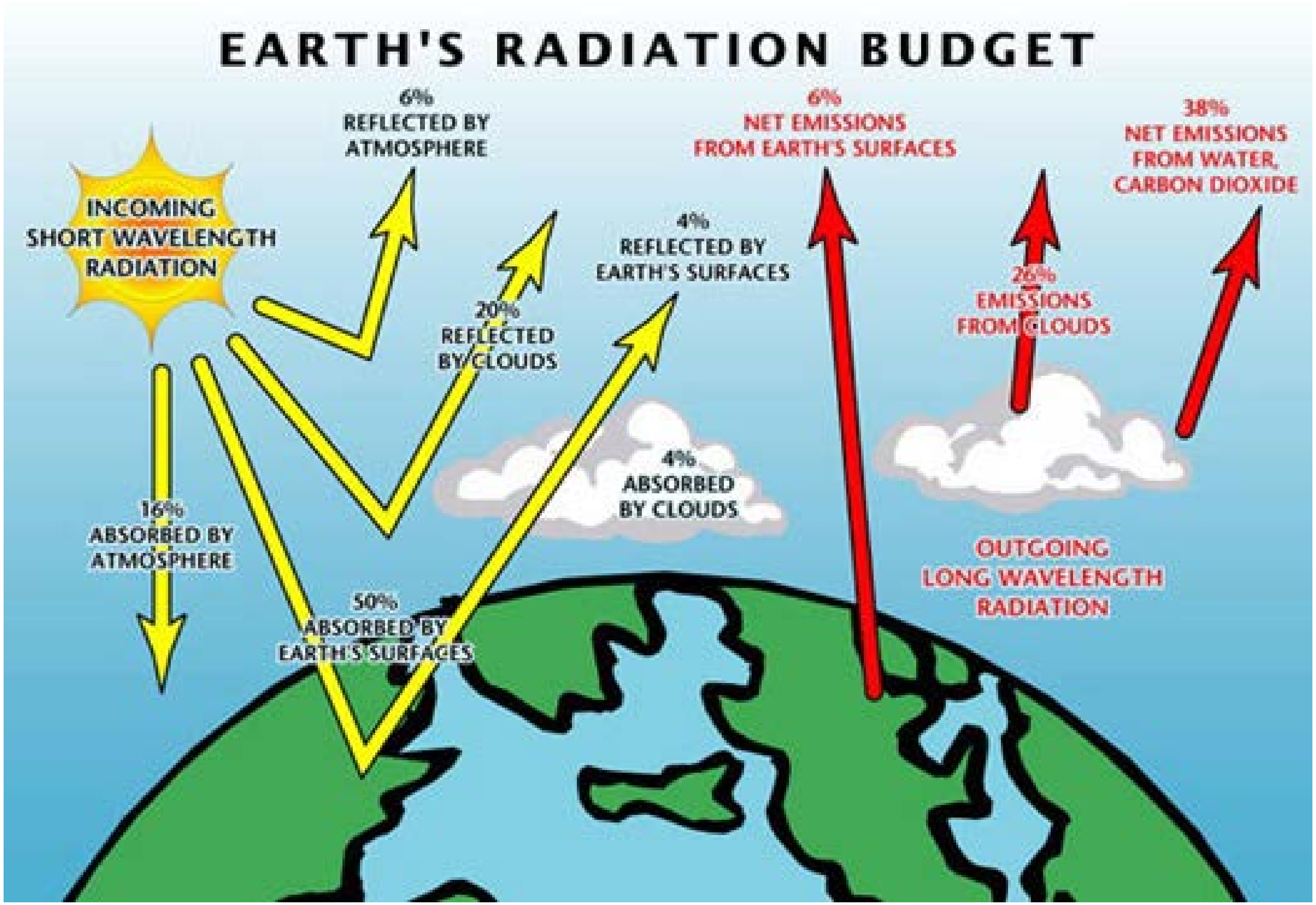
ρ = density of the material in kg/m^3
β_λ = mass extinction cross section in m^2/kg
ds = thickness of the layer in m
I_λ = monochromatic intensity in W/(m^3 sr)
J_λ = monochromatic source function (owing to emission and/or multiple scattering) in W/(m^3 sr)

Example of spatial optical depth variations





From: http://earthobservatory.nasa.gov/Features/Aerosols/images/



http://calipsooutreach.hamptonu.edu/aeroclouds-graphics/