Summary of Optical Depth –

As we discussed, optical depth is the product of the column mass of a component multiplied by the component's absorption crossection

Optical depth *decreases* with altitude because column mass *decreases* with altitude

The altitude where optical depth = 1 is important. For incoming shortwave radiation this is the altitude where the rate of absorption maximizes.   To rough approximation this establishes the altitude of the stratospheric ozone maximum.

For outgoing longwave radiation, and to first approximation, the altitude corresponding to optical depth = 1 is the altitude that longwave photons "leave" the Earth system unimpeded by further adsorption

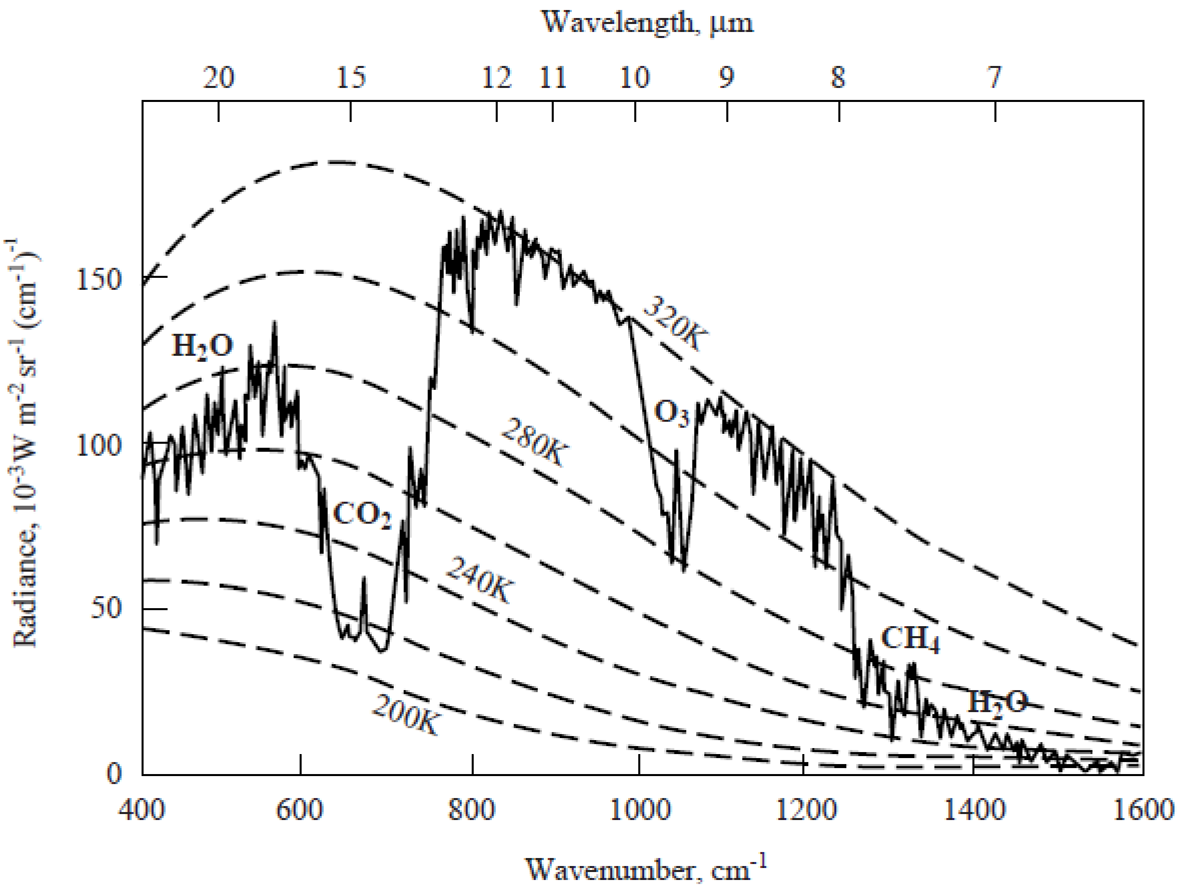

Figure 7-8 Terrestrial radiation spectrum measured from a satellite over northern Africa (Niger valley) at noon. Blackbody curves for different temperatures are included for comparison. The plot shows radiances as a function of wavenumber ($\bar{\nu} = 1/\lambda$). The radiance is the radiation energy measured by the satellite through a viewing cone normalized to unit solid angle (steradian, abbreviated sr). Radiance and $\phi_{\bar{\nu}}$ are related by a geometric factor. Major atmospheric absorbers are identified. Adapted from Hanel, R.A., et al., *J. Geophys. Res., 77,* 2629-2641, 1972.

Summary of Optical Depth – Continued

We symbolize the altitude at optical depth = 1 as z'.

$$1 = \sigma_\lambda \cdot \int_{z'}^{\infty} \rho(z) \cdot dz = \sigma_\lambda \cdot \rho(0) \cdot (-h) \cdot (\exp(-\infty / h) - \exp(-z'/h))$$

$$1 = \sigma_\lambda \cdot \rho(0) \cdot (-h) \cdot (0 - \exp(-z'/h))$$

$$1 = \sigma_\lambda \cdot \rho(0) \cdot h \cdot \exp(-z'/h)$$

(Note: above is an example of the A-F rules of integral calculus)

By algebra, we have

$$z' = h \cdot \ln(\sigma_\lambda \cdot \rho(0) \cdot h) \qquad (6)$$

Note about Equation 6: For gases with properties such that $\sigma_\lambda \cdot \rho(0) \cdot h$ is less than unity, the value of z' is negative. Gases with this property are not greenhouse gases. Gases falling into this category have a small scale height, are trace or are weak absorbers

N_2 and Argon are examples with h=H, are abundant, but are very weak absorbers. They are not greenhouse gases.

Better understanding of the greenhouse gas effect -

An increased GHG abundance implies that $\rho(0)$ is increased. E.g., the density of carbon dioxide is projected to double by the end of this century

According to Equation 6, increased GHG density implies that z' is increased

Since the longwave emission to outer space is occurring higher in the atmosphere, where it is colder, the intensity of the longwave emission is decreased

Decreased longwave emission causes a radiative imbalance. I.e., the outgoing longwave is less than the incoming shortwave

This imbalance - outgoing decreased relative to the incoming – implies that the temperature of the Earth system will increase.

Water-vapor feedback, ice-sheet feedback, and methane-clathrate feedback, are thought to be amplifiers of the projected warming