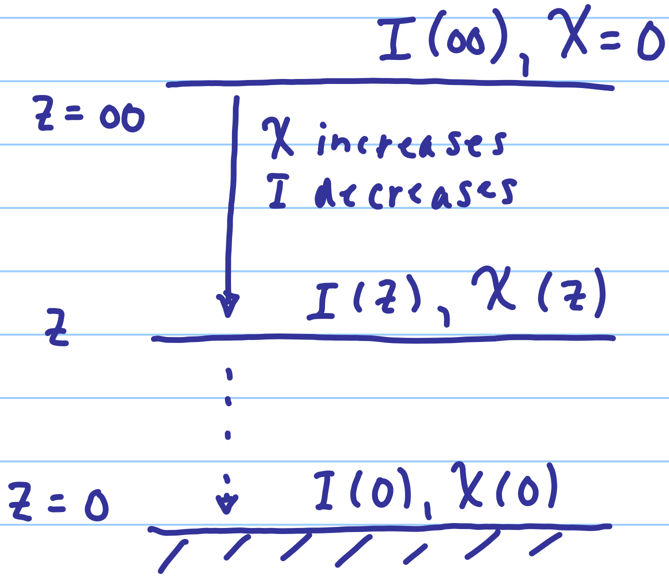
Determining the Solar Constant

We can ignore emission to good approx.

$$\frac{dI}{d\chi} = -I$$

$$\int_{I(\infty)}^{I} \frac{dI}{I} = -\int_{0}^{\chi} d\chi$$



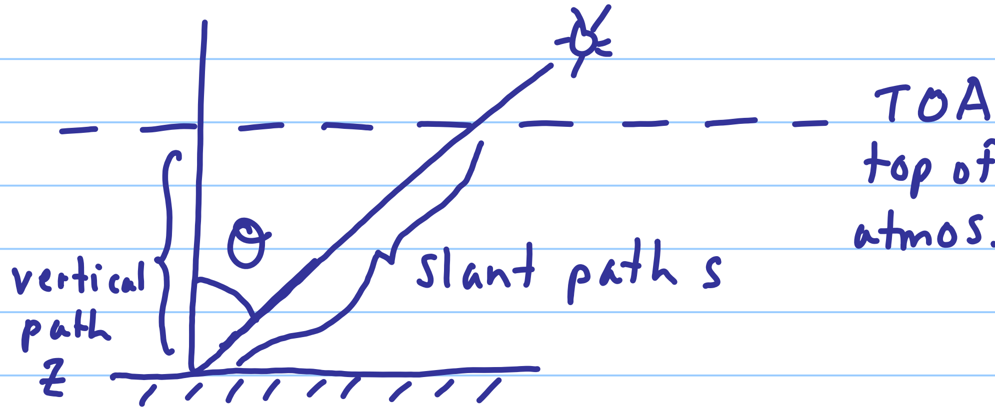
$$\ln \frac{I}{I(\infty)} = -\chi$$

$$I = \underline{\underline{I(\infty)}}\, e^{-\chi}$$

we want to find $I(\infty)$

The solar zenith angle between the Sun and the vertical changes during the day so optical depth along the path to the Sun also changes.

Plane parallel atmosphere



$\cos\theta = z/s$

$\therefore\ s = z/\cos\theta = z\sec\theta$

Assume that the atmosphere is horizontally homogeneous:

optical depth along slant path = $\chi\sec\theta$

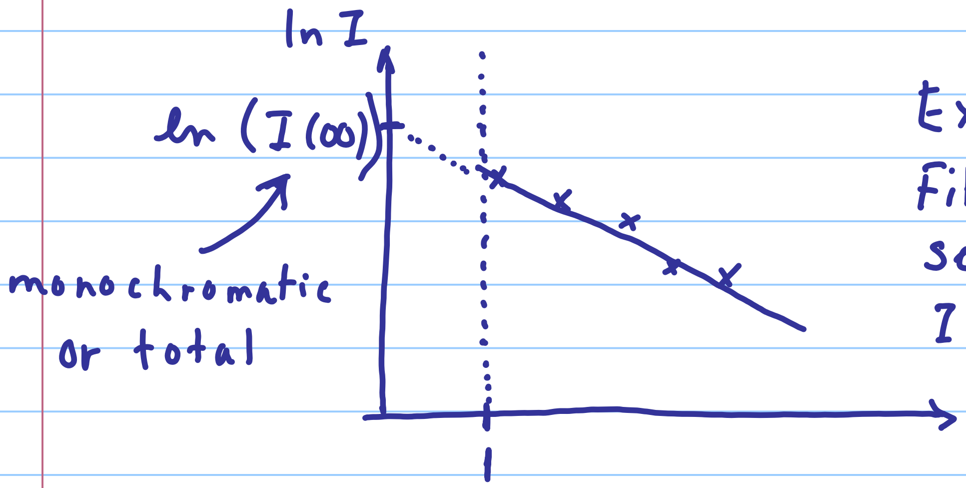
where χ = vertical optical depth

So:

$$I = I(\infty)\, e^{-\chi\sec\theta}$$

$$\ln I = \ln\left[I(\infty)\right] - \chi\sec\theta$$

The SZA θ varies during the day, allowing measurement of I vs. $\sec\theta$.



Extrapolate the fitted line back to $\sec\theta = 0$ to derive $I(\infty)$.

The total energy in the solar beam is obtained by integrating $I_\lambda(\infty)$ over all λ and multiplying by the solar solid angle $\Delta\Omega_s$.

⇒ gives total solar energy per second per unit area arriving at the top of the atmosphere ⇒ <u>the solar constant</u>

$$S \text{ or } F_s \simeq 1370 \ W/m^2$$

<u>Long method</u> for determining S.

Sources of error:

1. measurement errors, particularly for energy
2. as $\theta \uparrow$, energy $\downarrow$ and so errors increase because most instruments have a constant linear error in radiance
3. atmospheric variability → makes the extrapolation approximate
4. scattering of solar radiation out of and into the beam
5. absorption by gases which makes the atmosphere opaque in some spectral regions

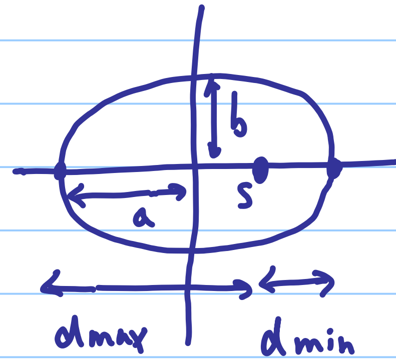
Alternative methods to obtain F_s:

- <u>short method</u> ⇒ measure additional parameters to help determine χ
- use satellite instruments

Solar Insolation

Measurements of F_s show that it varies by ~7% over the year
→ due to changing Sun-Earth distance from perihelion (closest, Dec/Jan) to aphelion (furthest, July).

eccentricity of Earth's orbit



$$e = \sqrt{1 - \left(\frac{\text{minor axis}}{\text{major axis}}\right)^2}$$

$$= \sqrt{1 - \left(\frac{b}{a}\right)^2}$$

$$= 0.017$$

$$d_{min} = (1-e)\,a = 0.983\,a$$
$$d_{max} = (1+e)\,a = 1.017\,a$$

solar radiation ∝ solid angle subtended
∝ distance^{-2}

$$\frac{\text{max flux density}}{\text{min flux density}} = \left(\frac{1.017}{0.983}\right)^2 = 1.070$$

↳ 7% variation

∴ NH receives 7% less/more solar radiation in NH summer (aphelion)/winter (perihelion) than the SH in equivalent seasons.