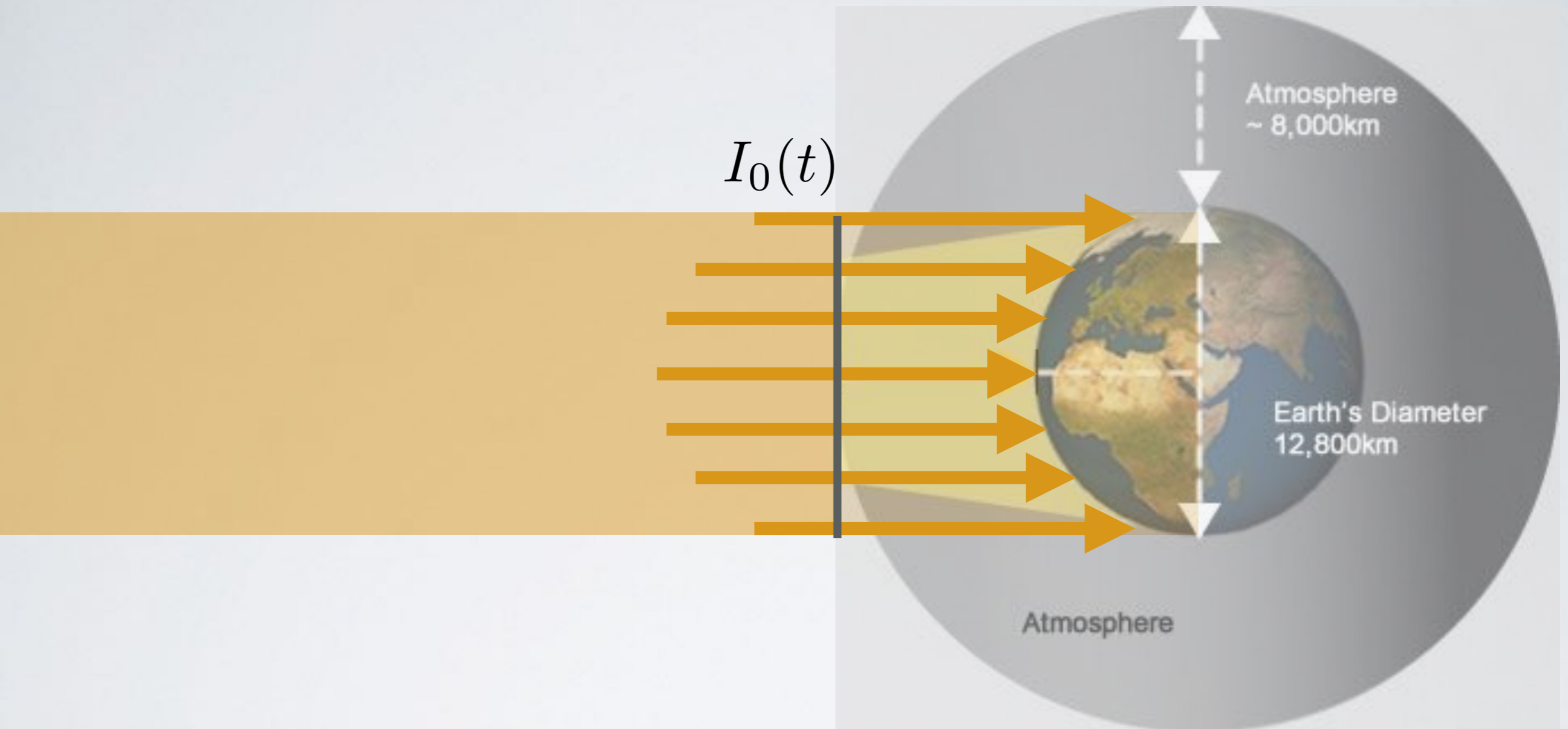


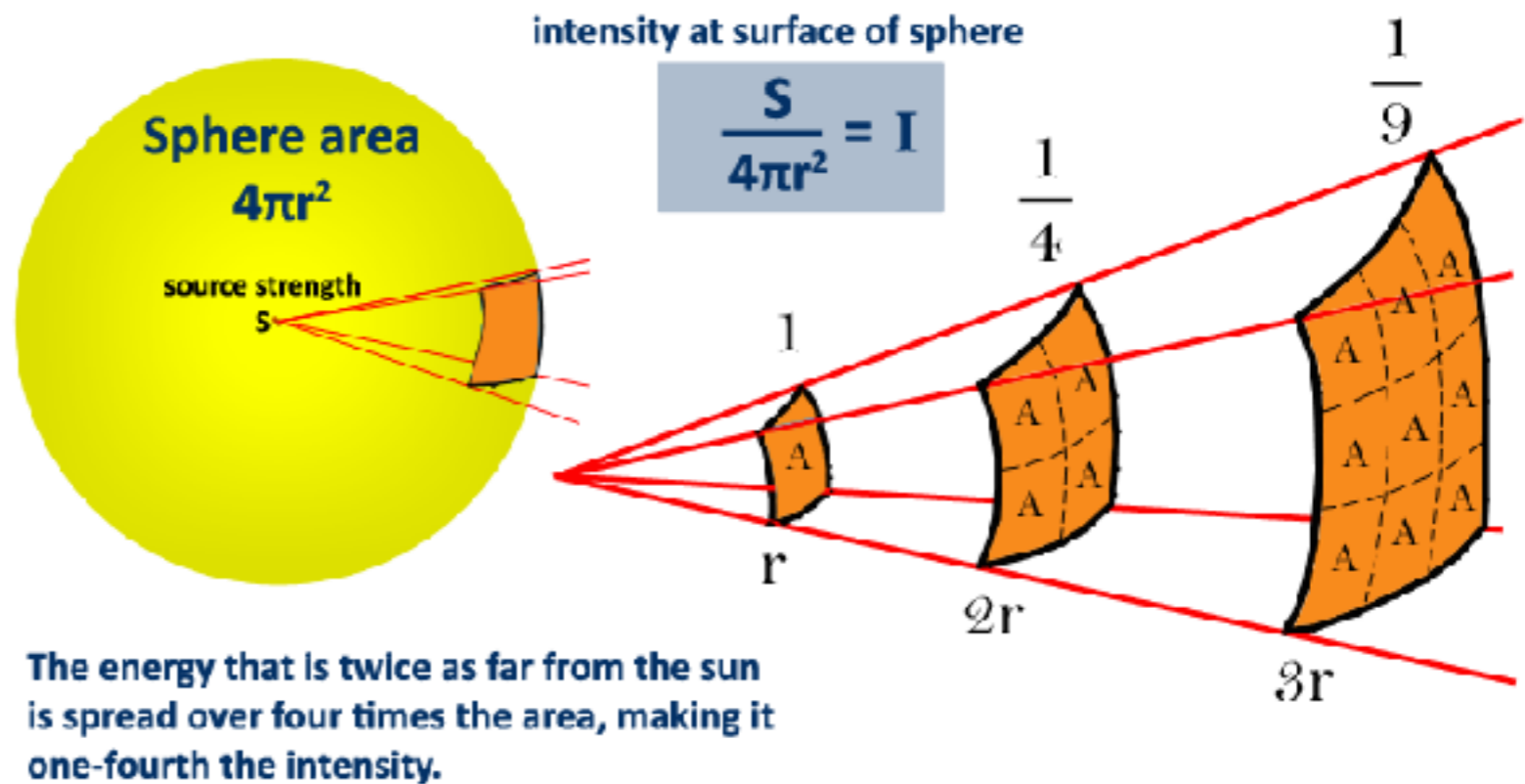


recurso solar



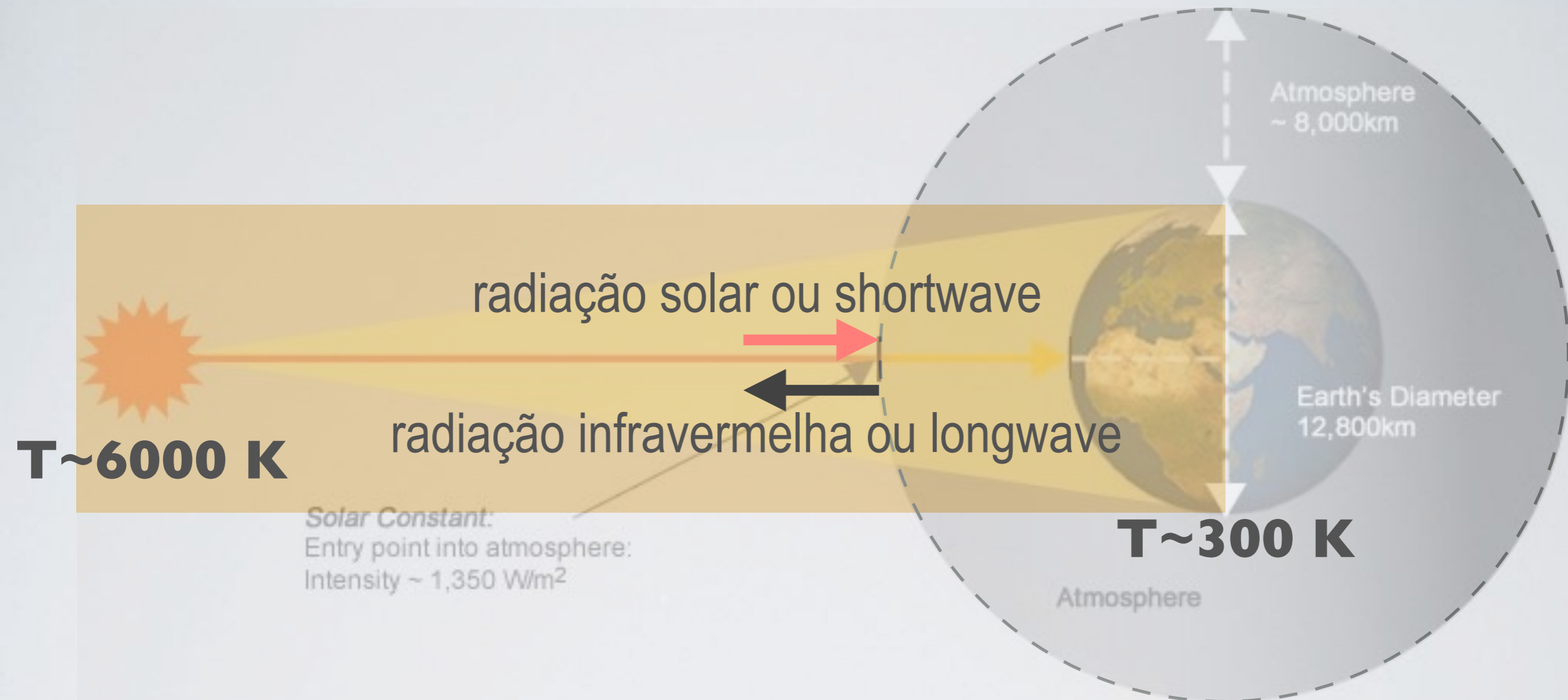
Irradiância:
fluxo de radiação solar num plano por unidade de área [W/m²]

$$I_0(t) \propto \frac{1}{[d(t)]^2}$$



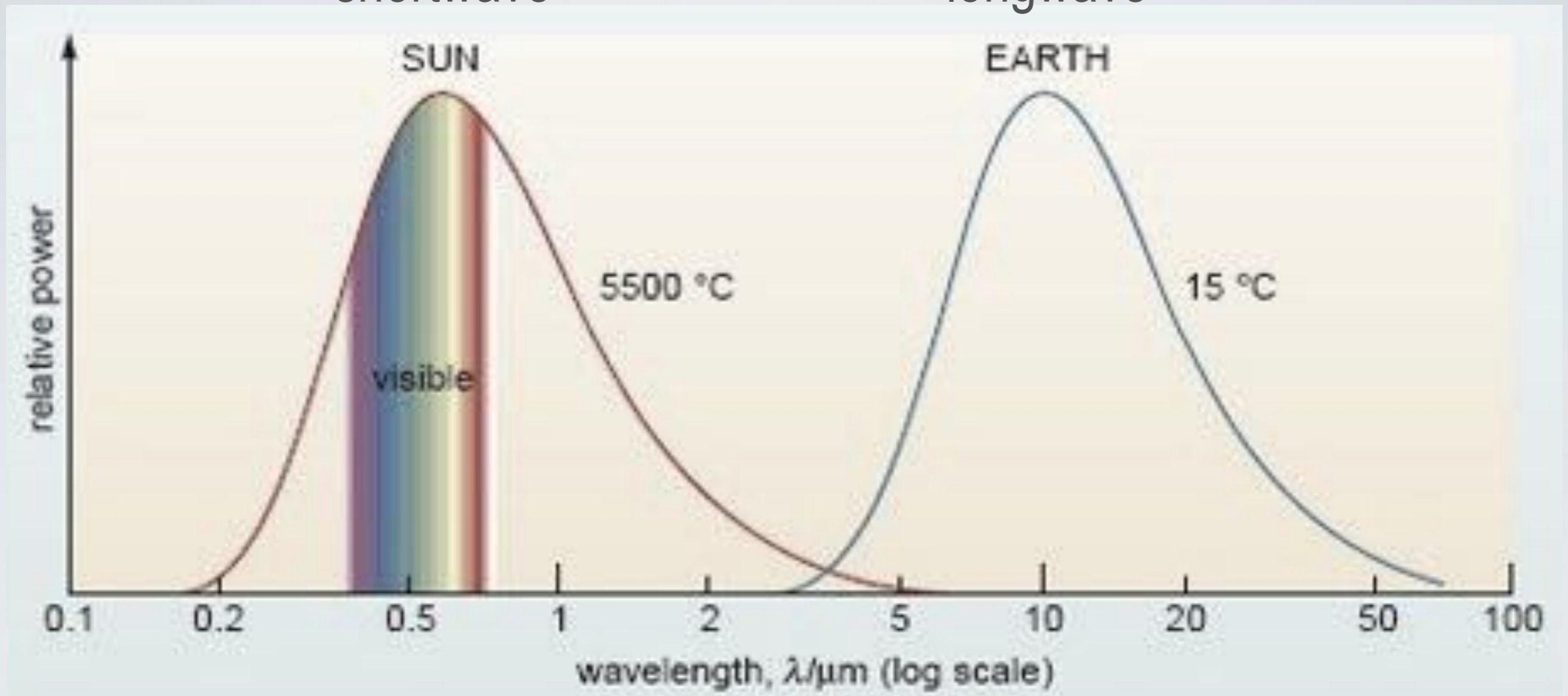
$$I_{SC} = 1366 \text{ W/m}^2$$

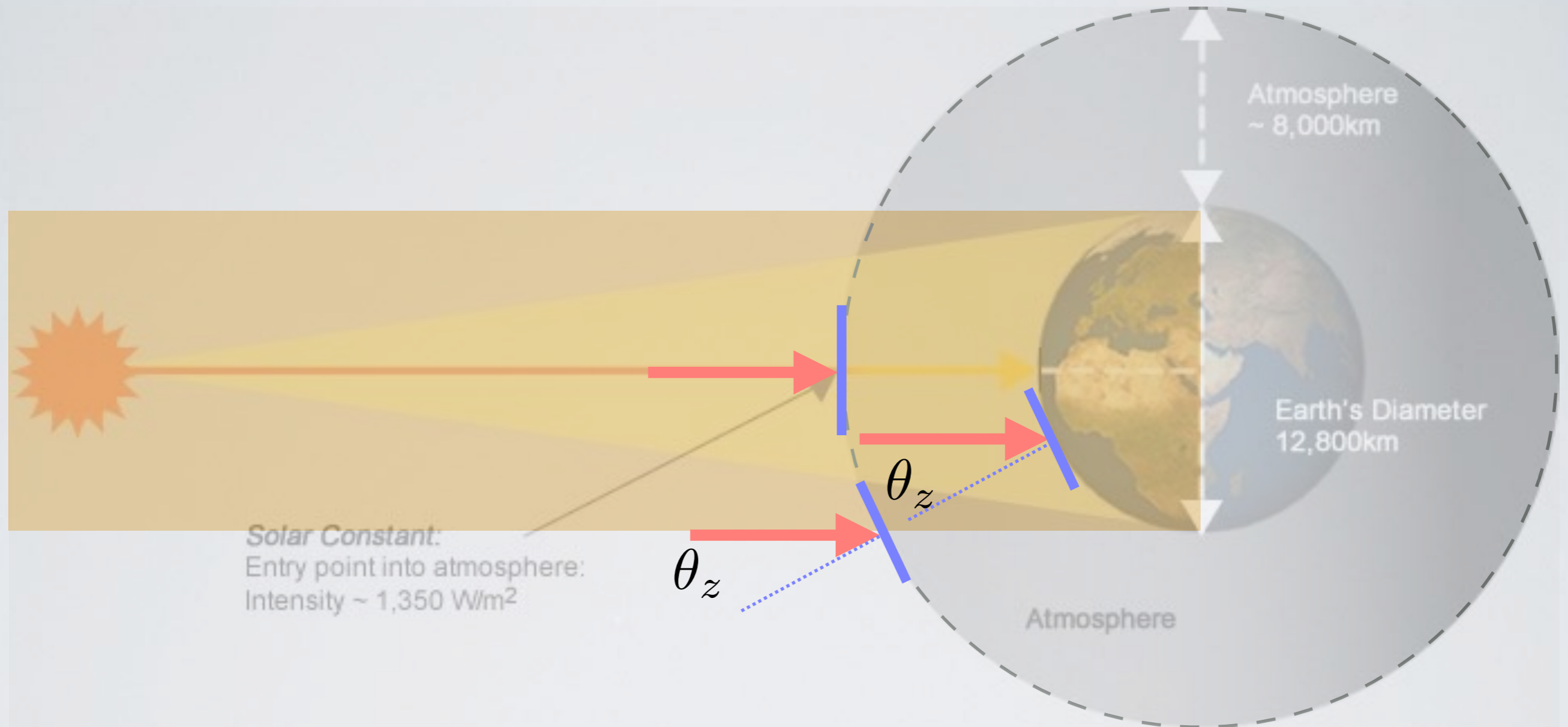
$$I_0(t) = I_{SC} \left[1 + 0.0334 \cos \left(2\pi \frac{J - 3}{365.35} \right) \right]$$

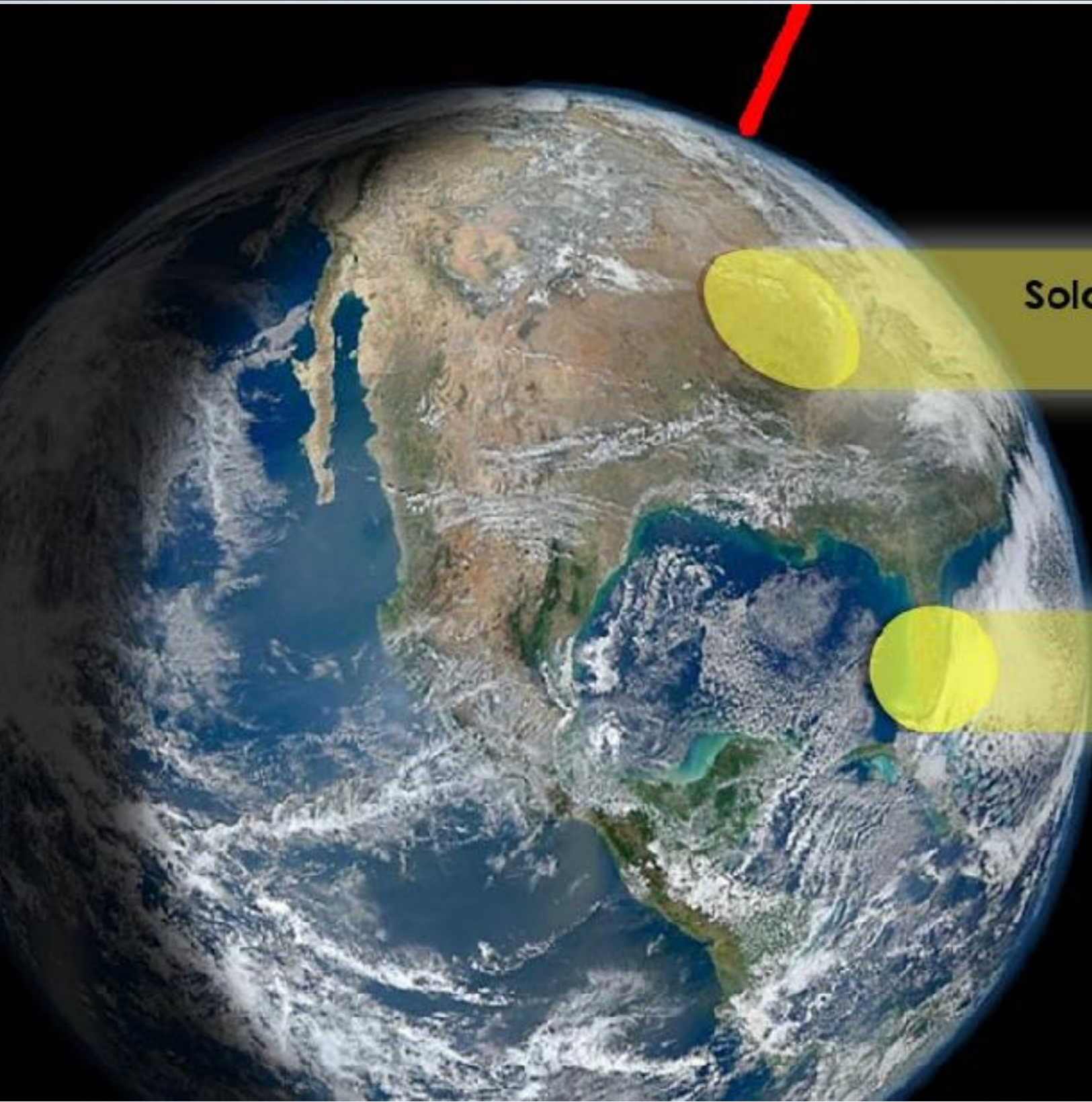


shortwave

longwave

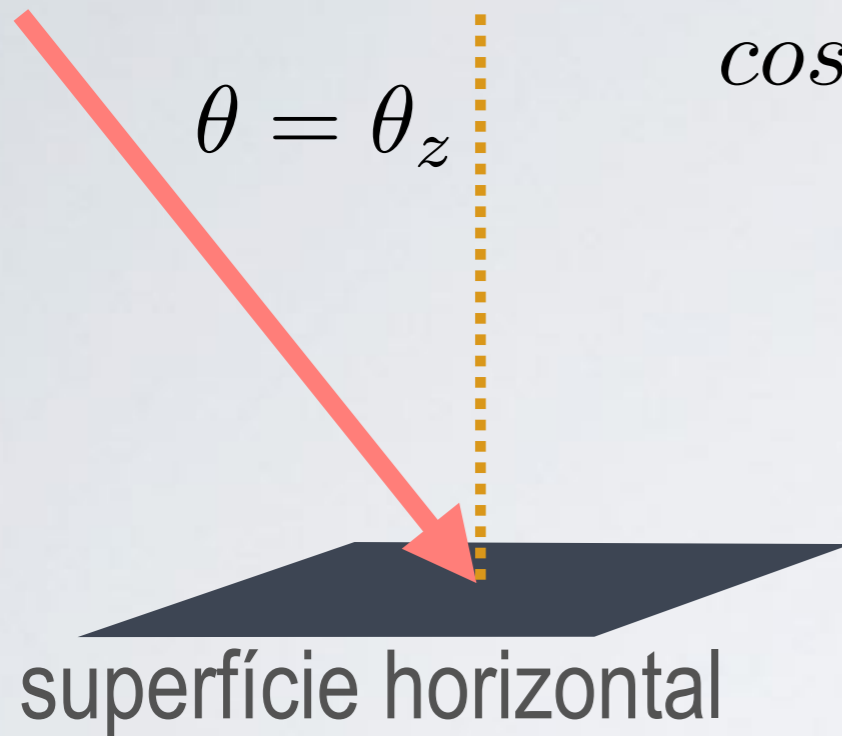






Solar radiation concentrated over a larger area

Solar radiation concentrated over a smaller area



$$\cos\theta_z = \sin\alpha = \sin\delta \sin\phi + \cos\delta \cos\phi \cos\omega$$

δ declinação solar

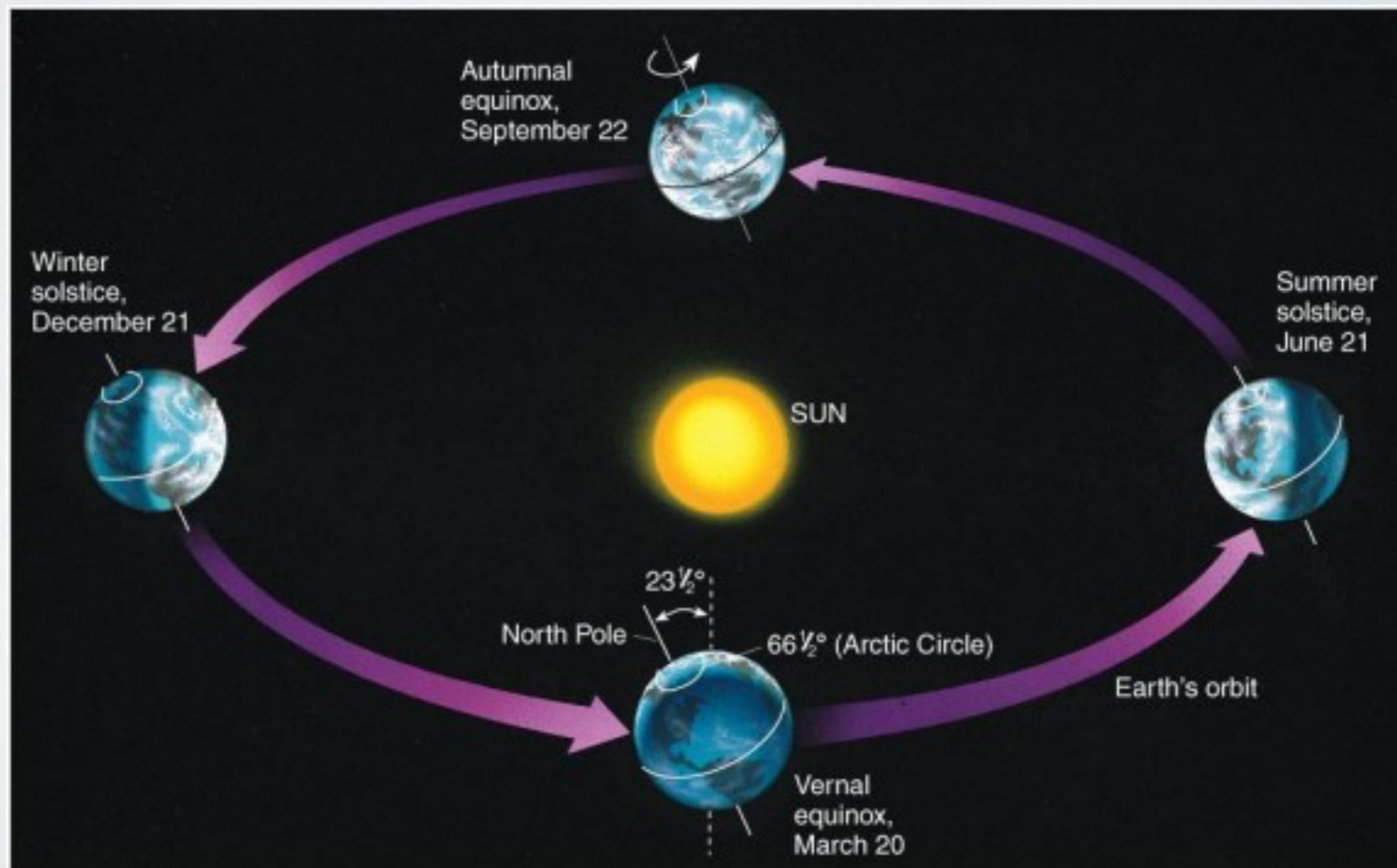
ϕ latitude

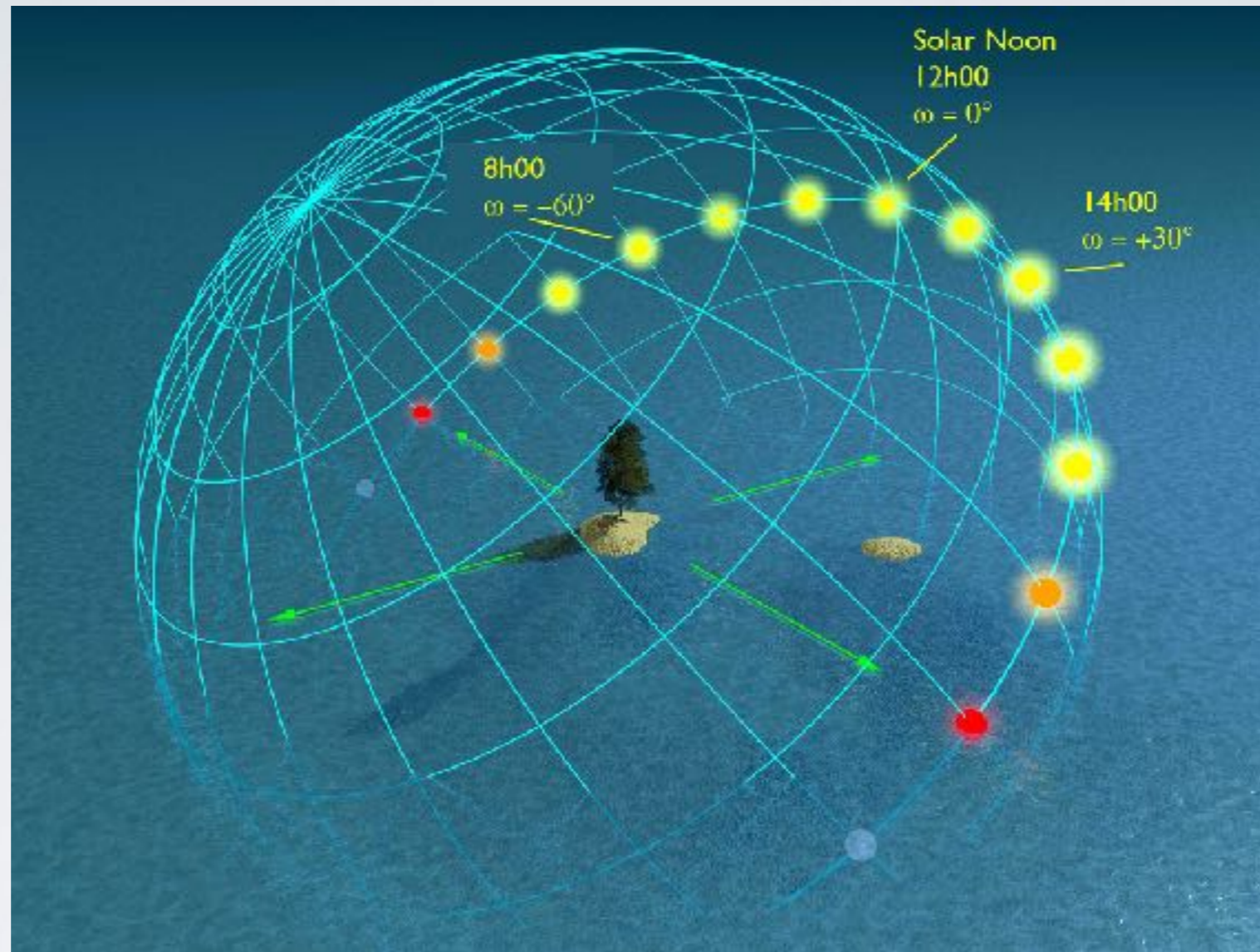
ω hora solar angular

$$\delta = 0.4093 \sin \left(2\pi \frac{284 + J}{365} \right) \text{ [rad]}$$

23.45°

Toma o valor zero nos equinócios





$$\omega = \frac{\pi}{12} (t - 12) \quad [\text{rad}]$$

15°

negativo de manhã
positivo à tarde



$$t_{local} = t_{solar} + (\lambda_{zone} - \lambda) \frac{12}{\pi} - t_{EoT} + t_{save} \text{ [hora]}$$

λ Longitude do local* [rad]

λ_{zone} Long. do meridiano que define o fuso horário* [rad]

*Positivo para este e negativo para oeste

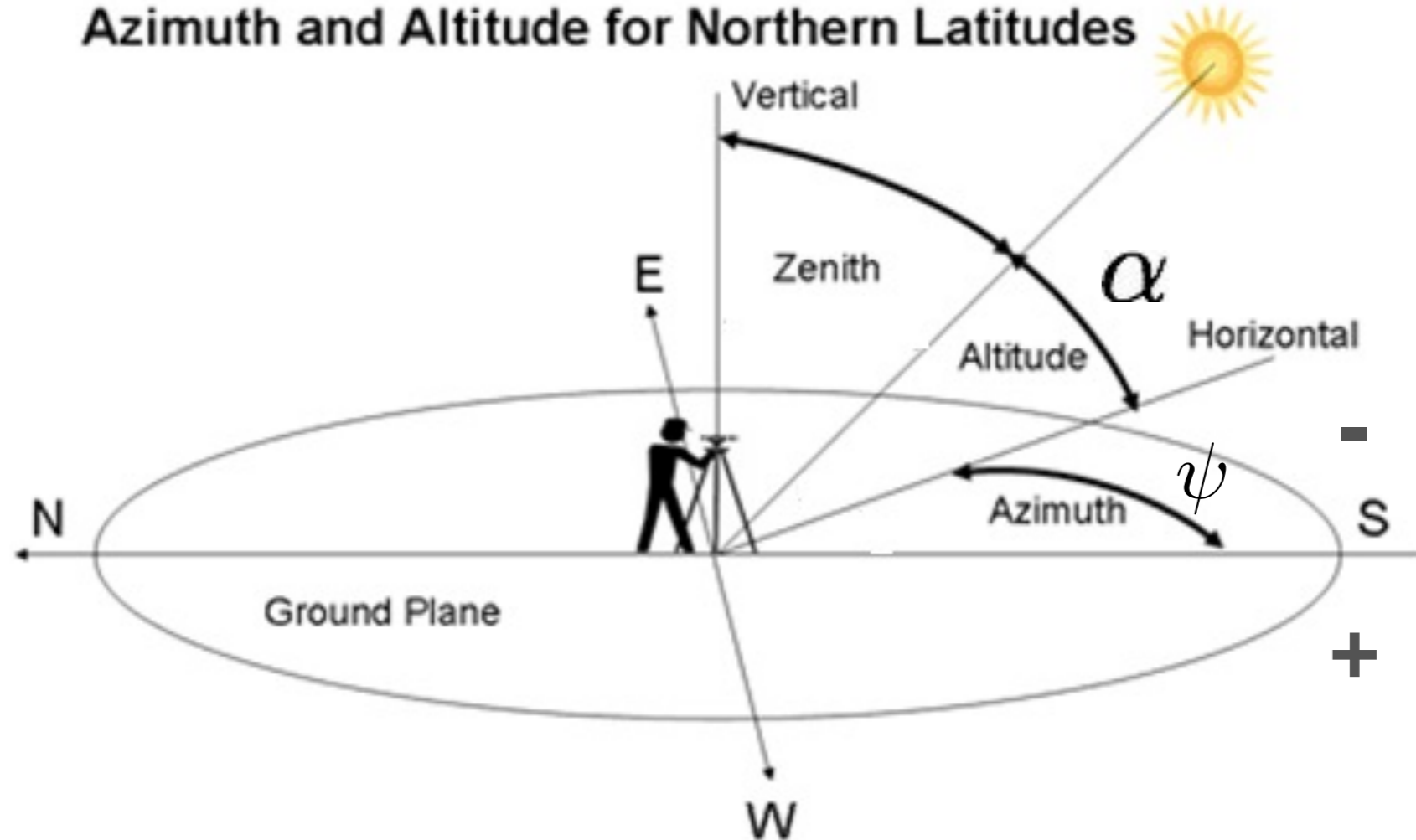
$$t_{EoT} = [9.87 \sin(4\pi J') - 7.53 \cos(2\pi J') - 1.5 \sin(2\pi J')] / 60$$

$$J' = \frac{J - 81}{364}$$

[horas]

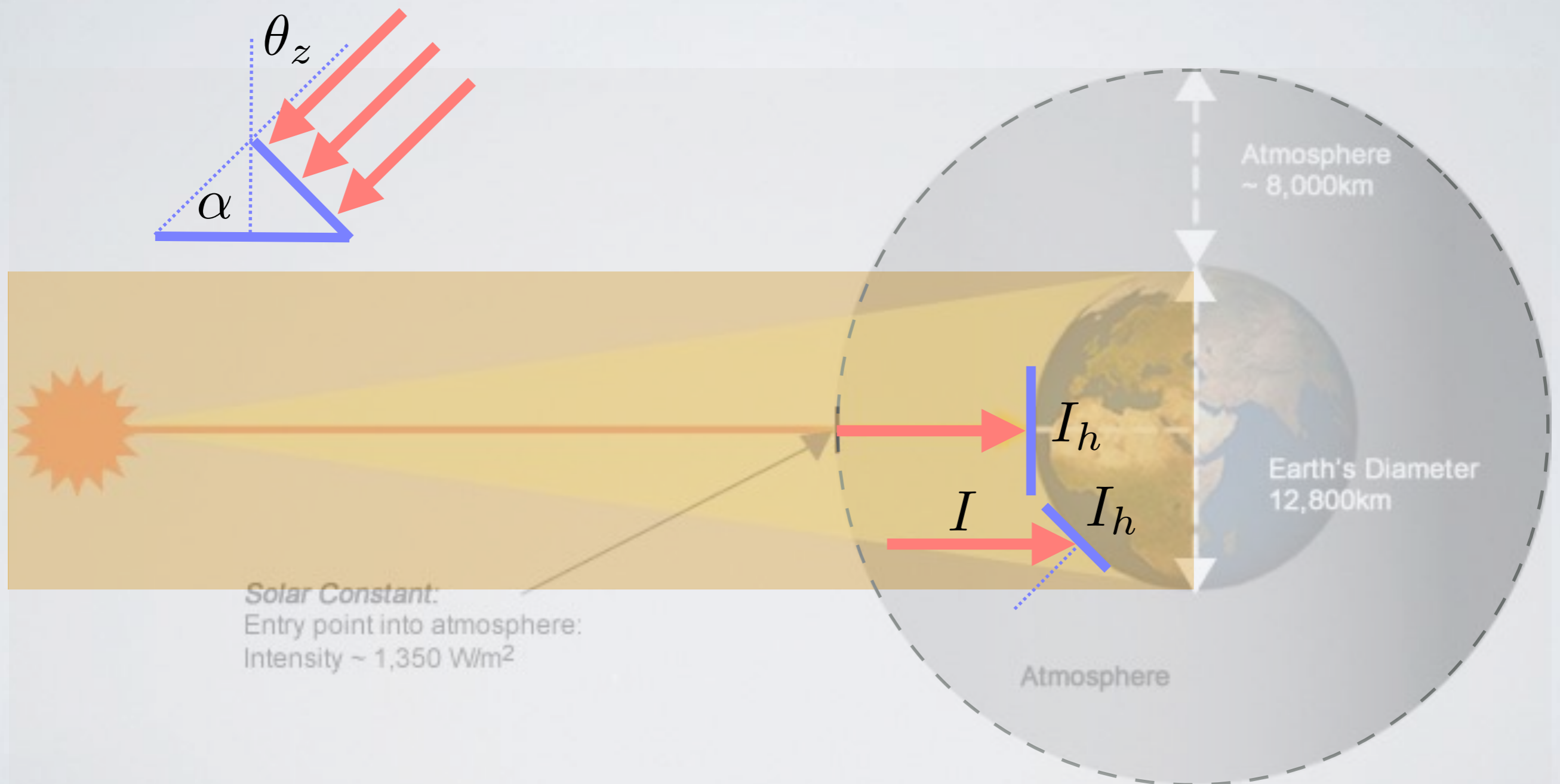
J - dia Juliano

Azimuth and Altitude for Northern Latitudes



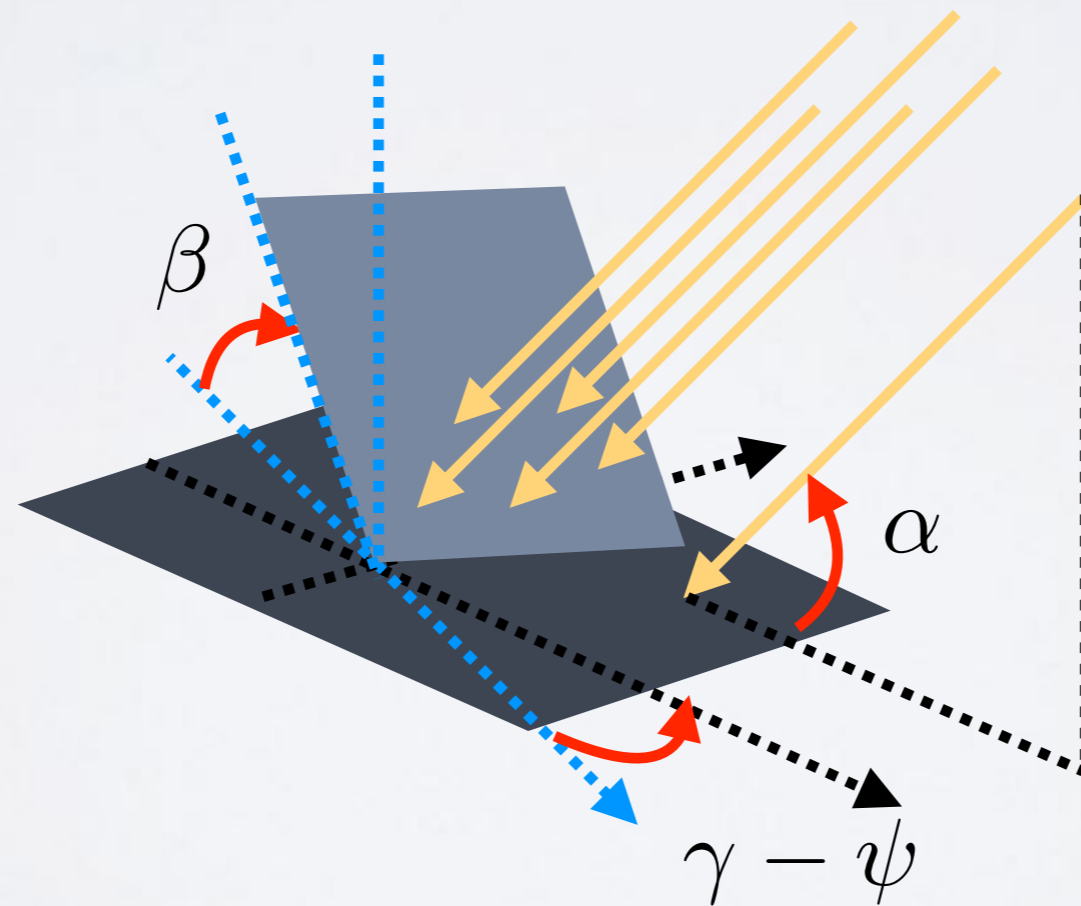
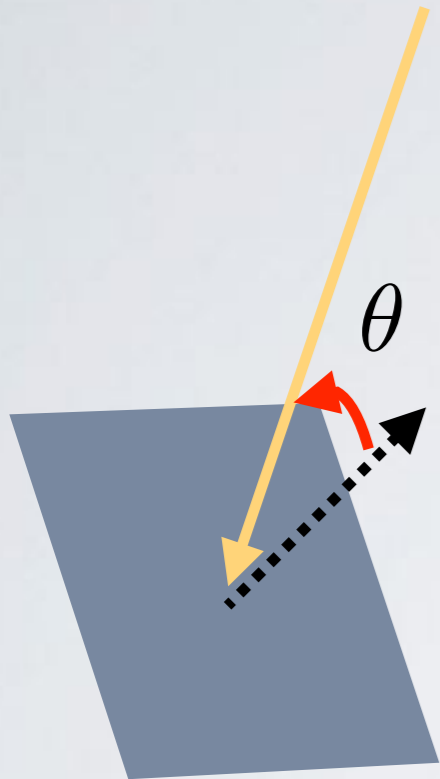
$$\sin \alpha = \cos \phi \cos \delta \cos \omega + \sin \phi \sin \delta$$

$$\cos \psi = \frac{\sin \alpha \sin \phi - \sin \delta}{\cos \alpha \cos \phi}$$



Superfície horizontal: $I_{b,h} = I_{b,n} \cos \theta_z = I_{b,n} \sin \alpha$

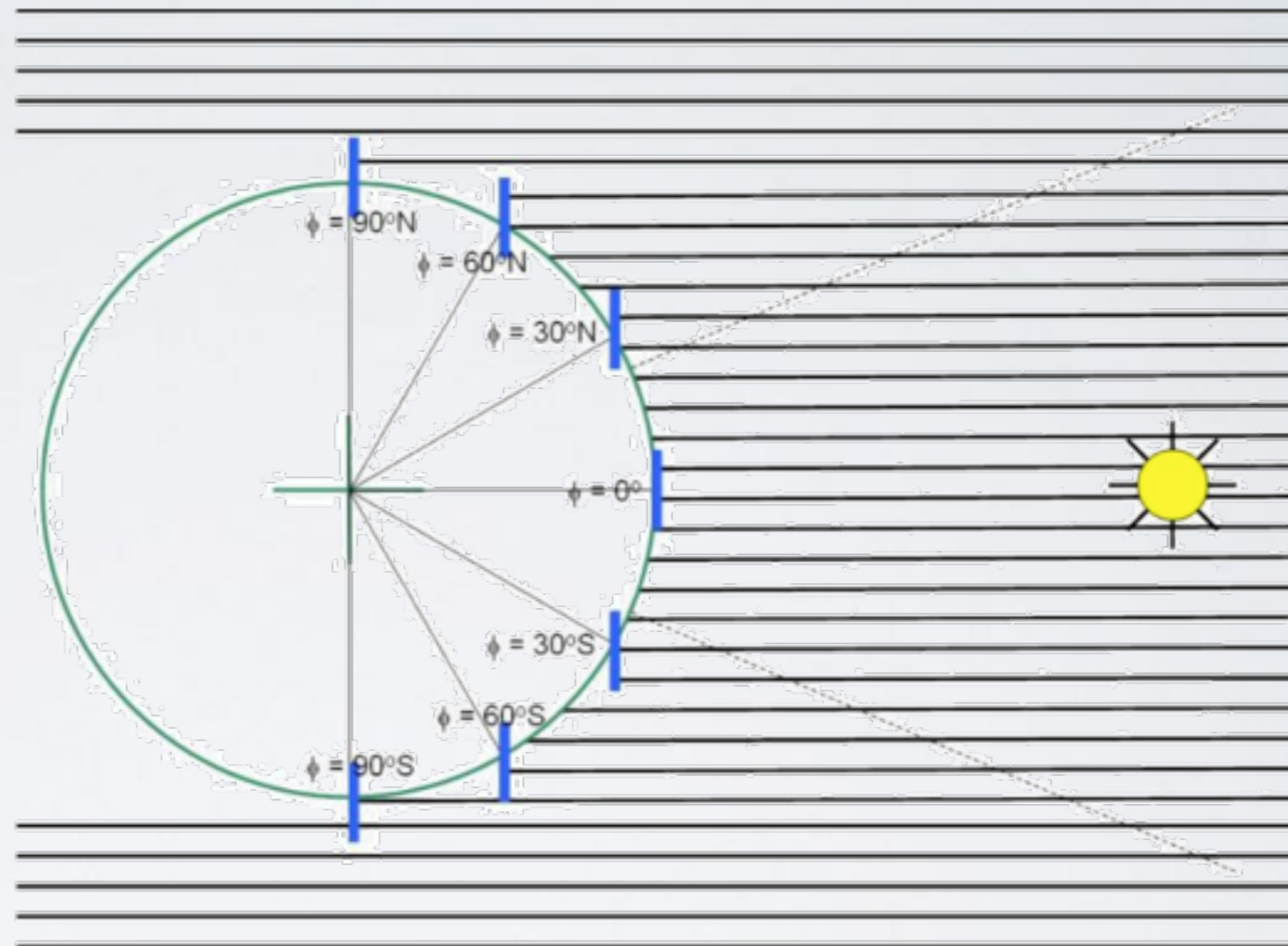
$$\cos \theta = \cos \alpha \cos(\gamma - \psi) \sin \beta + \sin \alpha \cos \beta$$



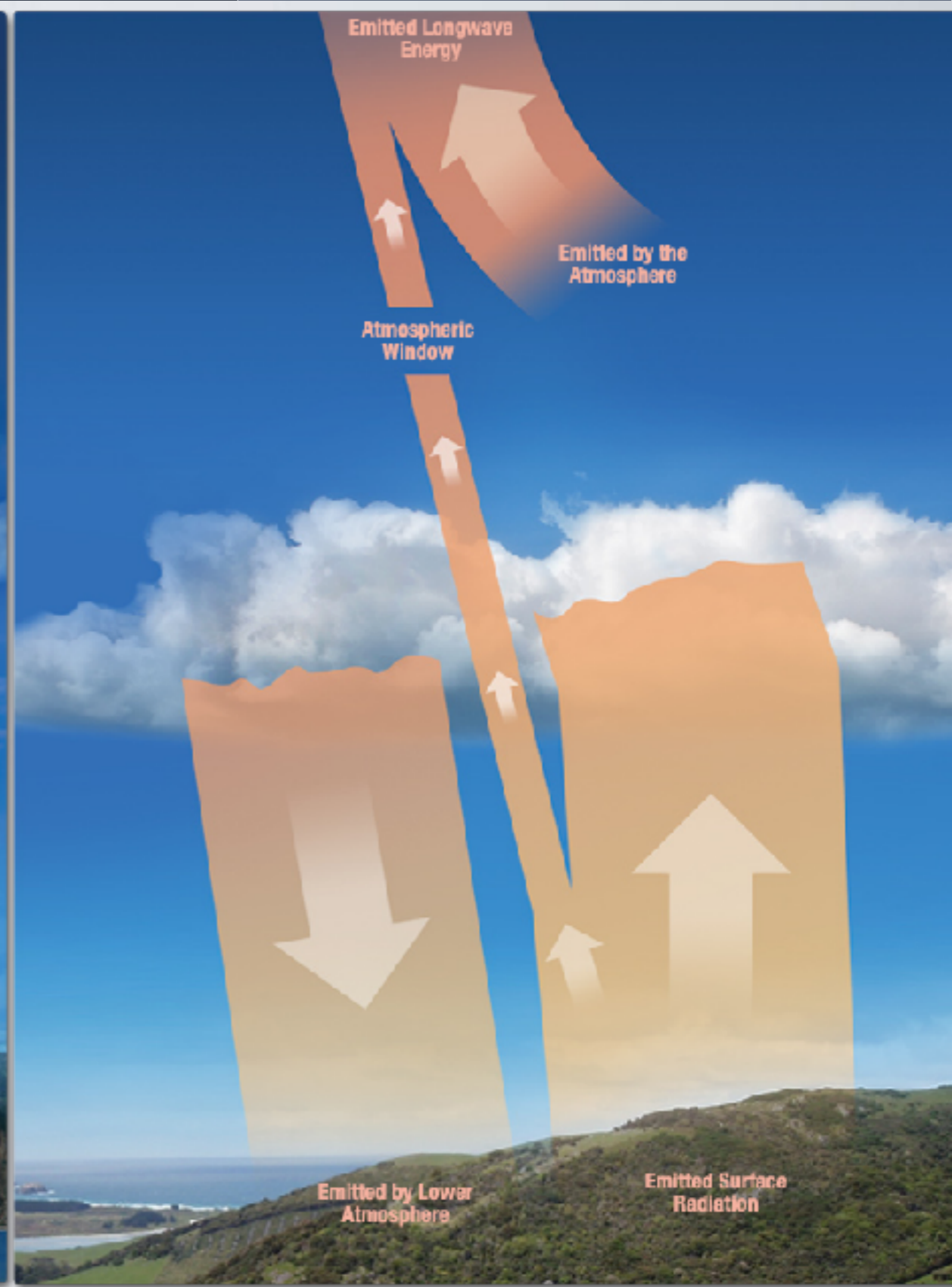
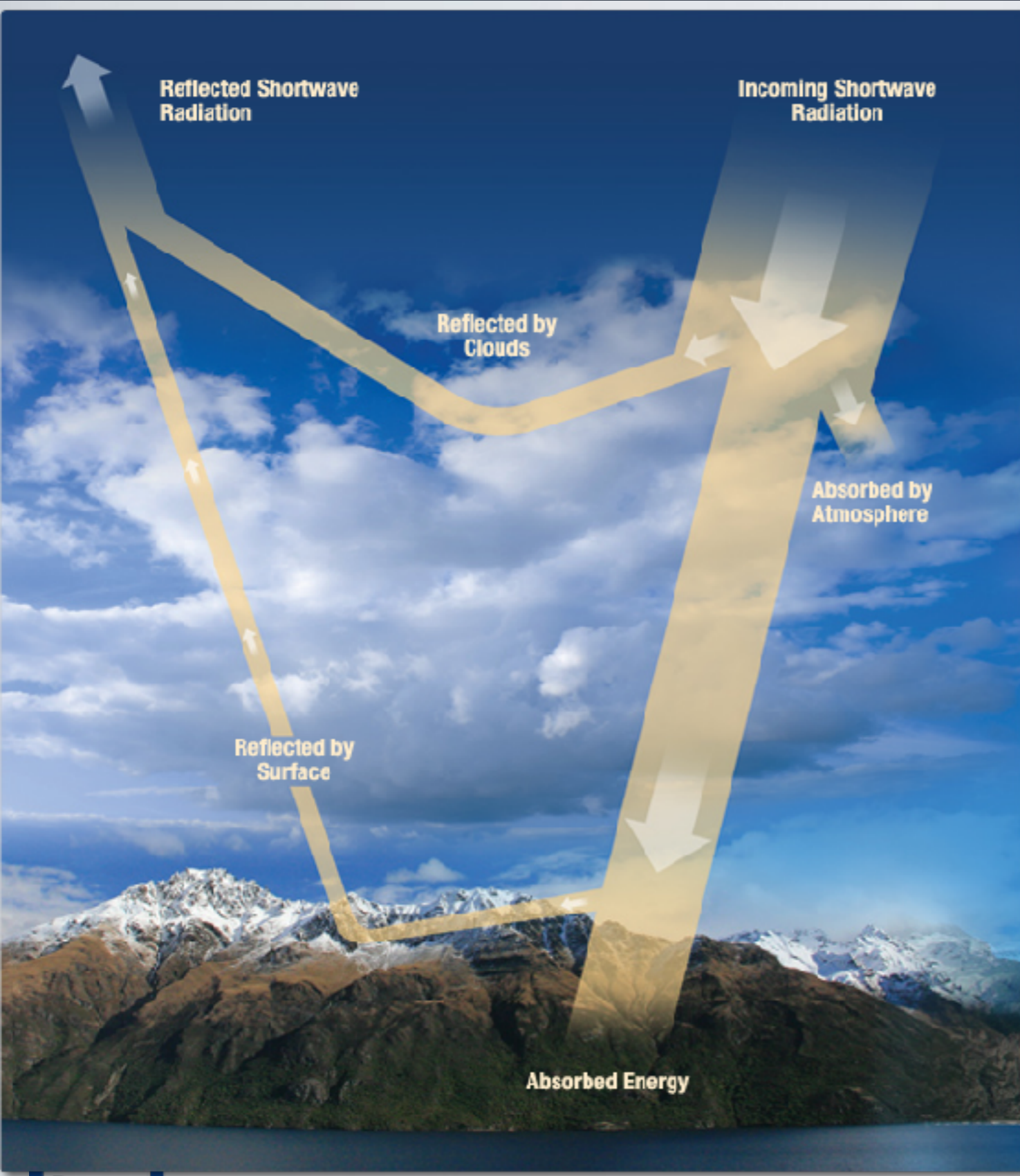
β, γ superfície
 α, ψ sol

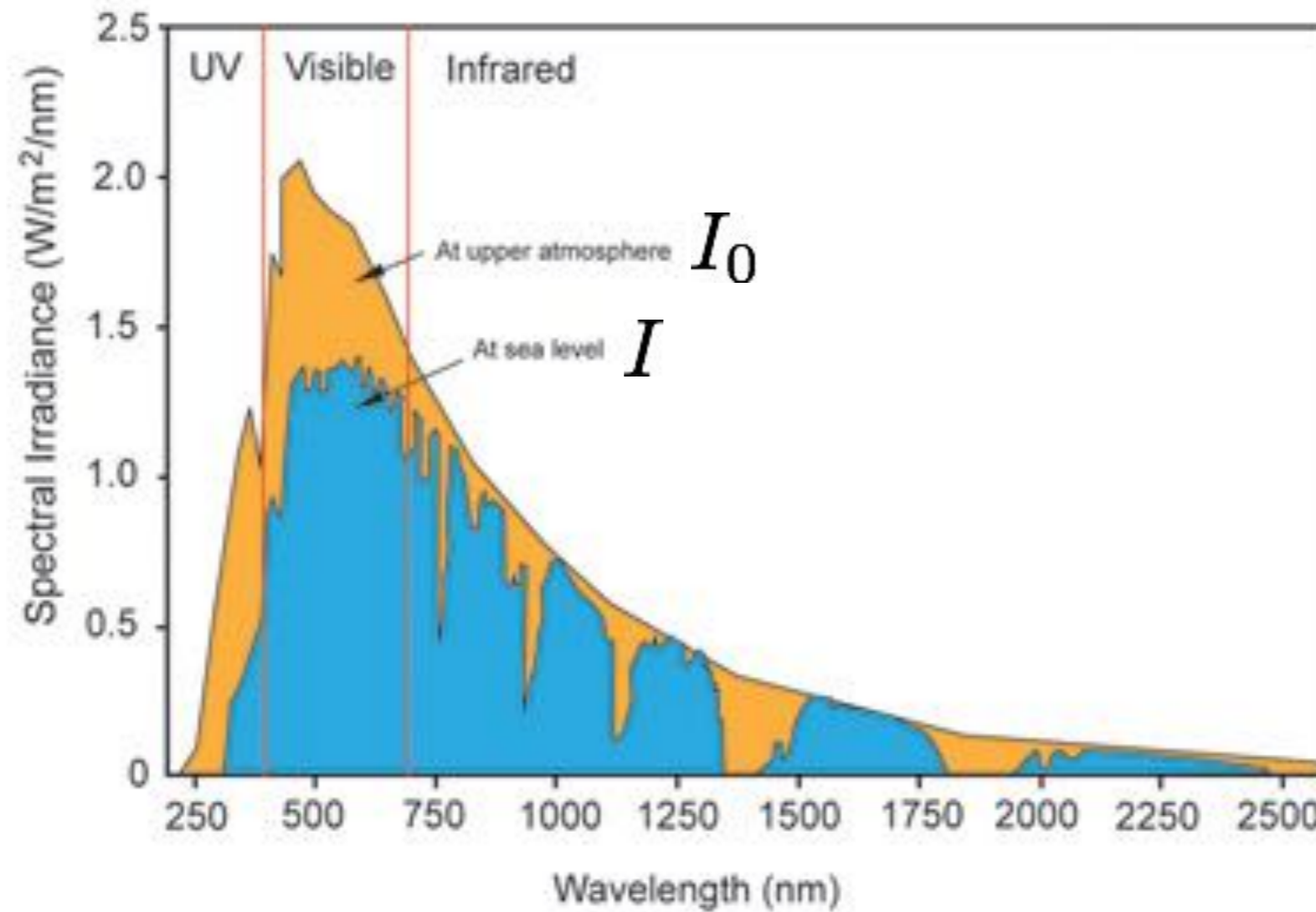
Azimute sul
(hemisfério norte)

$$\gamma = \psi$$



$$\cos \alpha \sin \beta + \sin \alpha \cos \beta = 1$$





$$I = \int I_{\lambda}(\lambda) d\lambda$$

$$I < I_0$$

Decréscimo de 30 a 70%

Modelo Hottel (1976)

$$I_{b,n} = \tau_b I_0$$

$$\tau_b = a_0 + a_1 e^{-k/\sin \alpha}$$

$$I_{d,h} = \tau_d I_0 \sin \alpha$$

$$\tau_d = 0.271 - 0.2939\tau_b$$

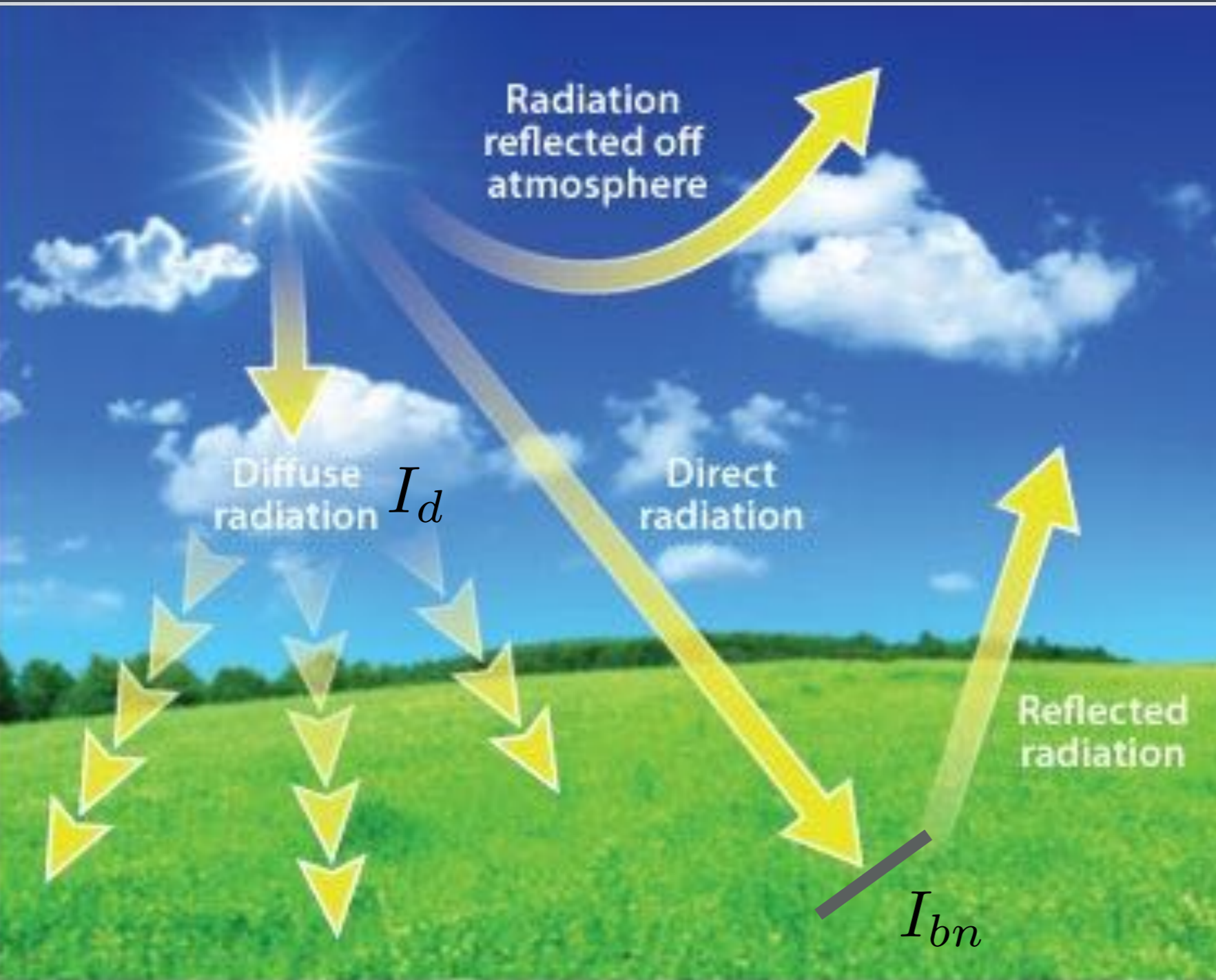
atmosfera com visibilidade

$$a_0 = 0.4237 - 0.00821(6 - A)^2$$

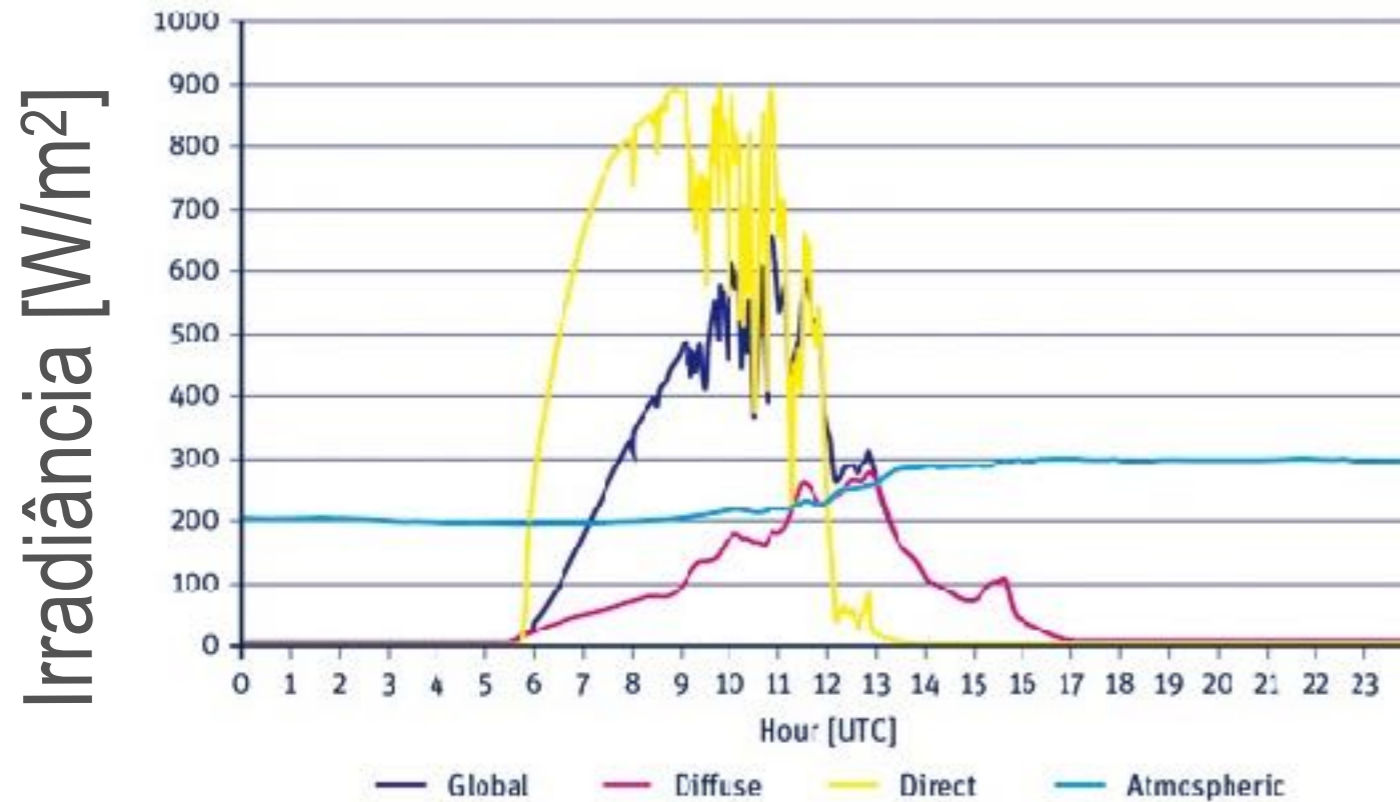
$$a_1 = 0.5055 + 0.00595(6.5 - A)^2$$

$$k = 0.2711 + 0.01858(2.5 - A)^2$$

A elevation [in km]



$$I_h = I_{bn} \sin \alpha + I_{dh}$$



Insolação diária [kWh/m²]

$$E_{day} = \int_{day} I(t) dt$$

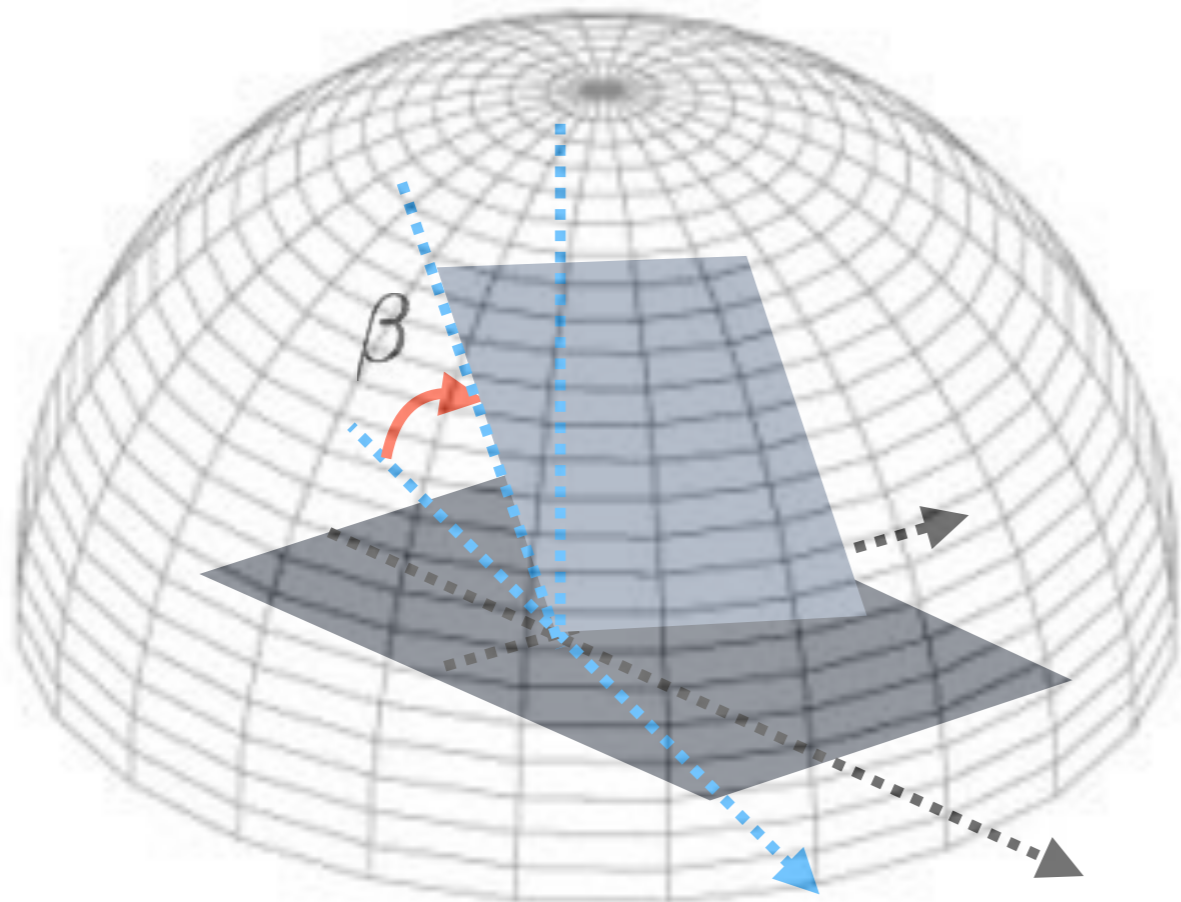
1 hora de sol = 1 kWh/m²

Insolação anual [kWh/m²]

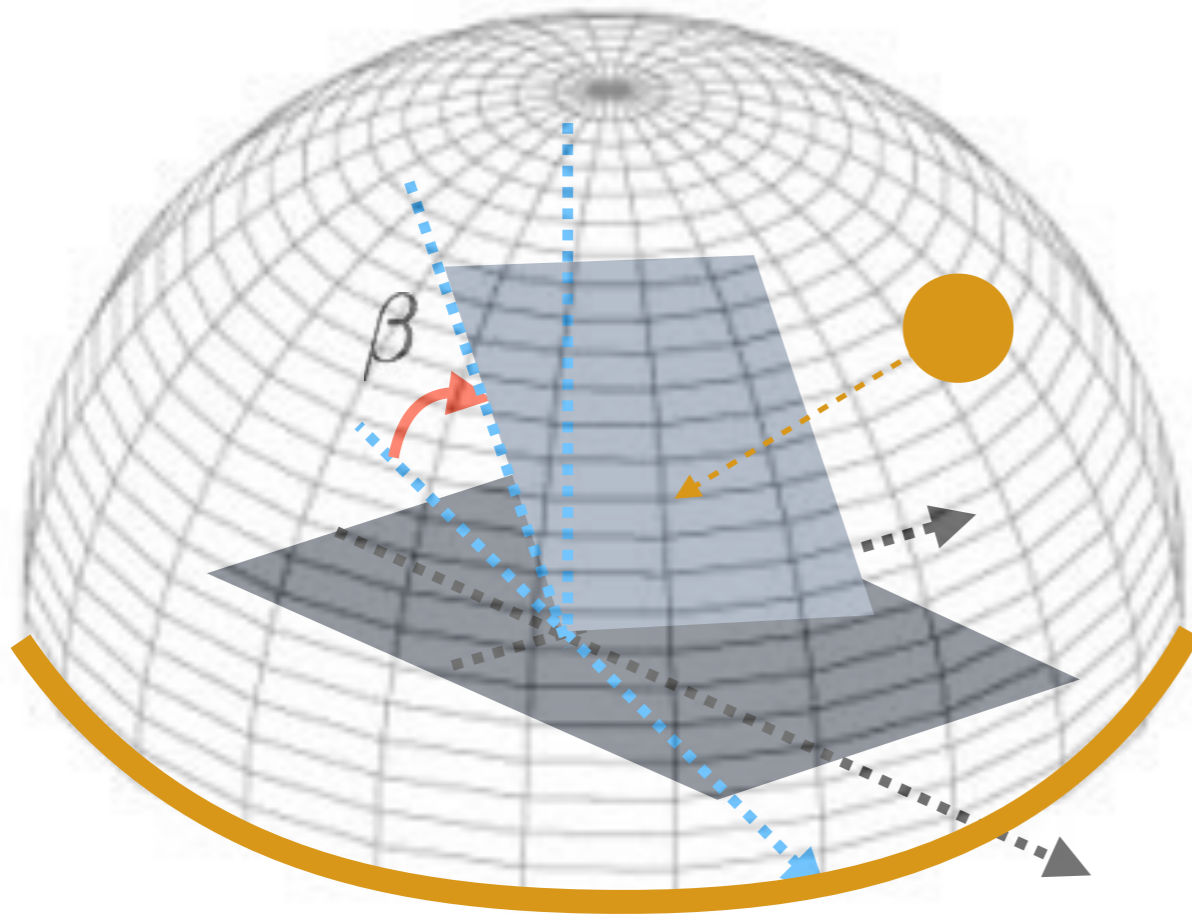
$$E_{year} = \int_{year} I(t) dt$$

Insolação média diária ou horas de pico (peak sun hours)

$$\overline{E}_{day} = \frac{\int_{year} I(t) dt}{365} \quad [\text{kWh/m}^2/\text{day}]$$



$$\frac{I_{d\beta}}{I_{dh}} = \frac{1 + \cos \beta}{2}$$



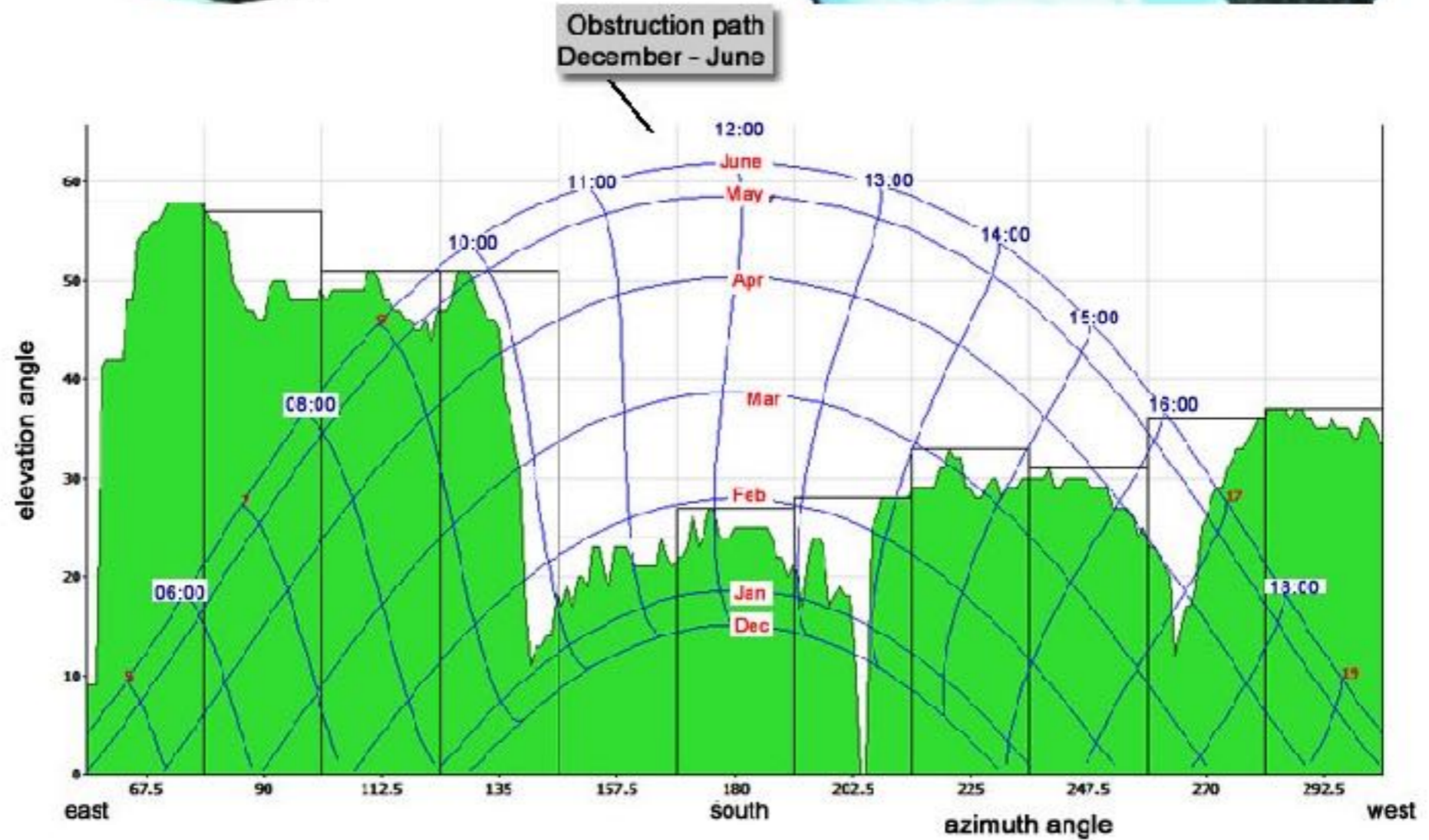
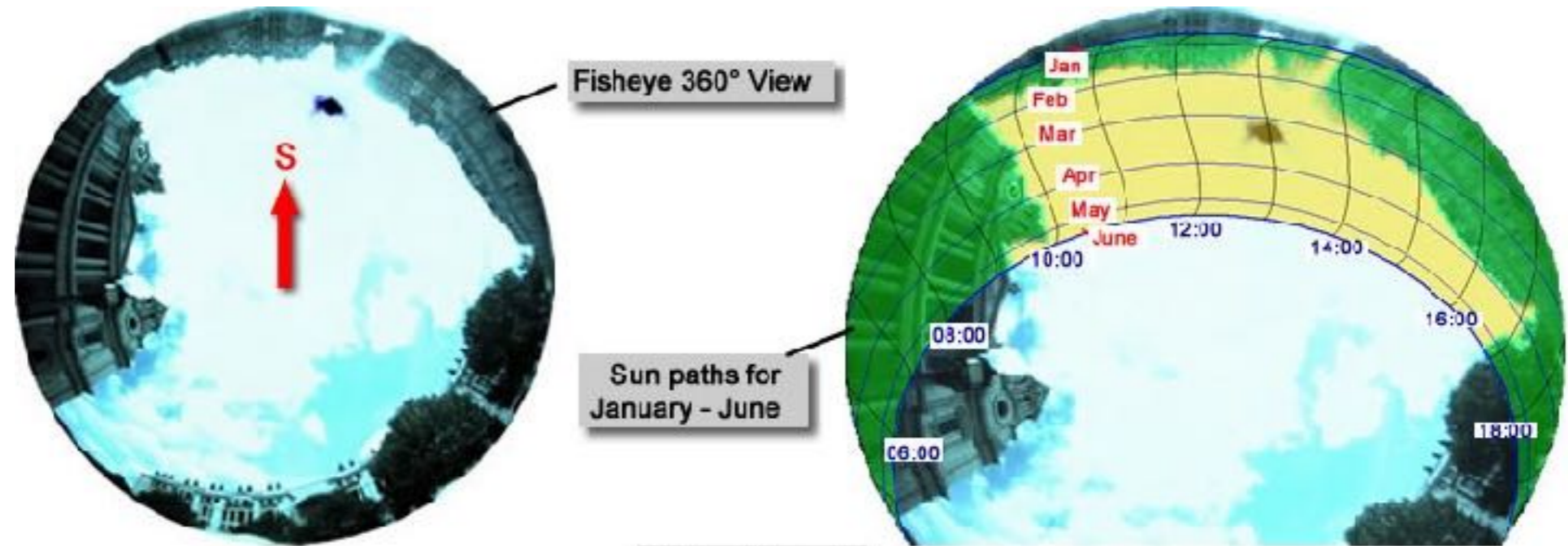
componente circumsolar F_1

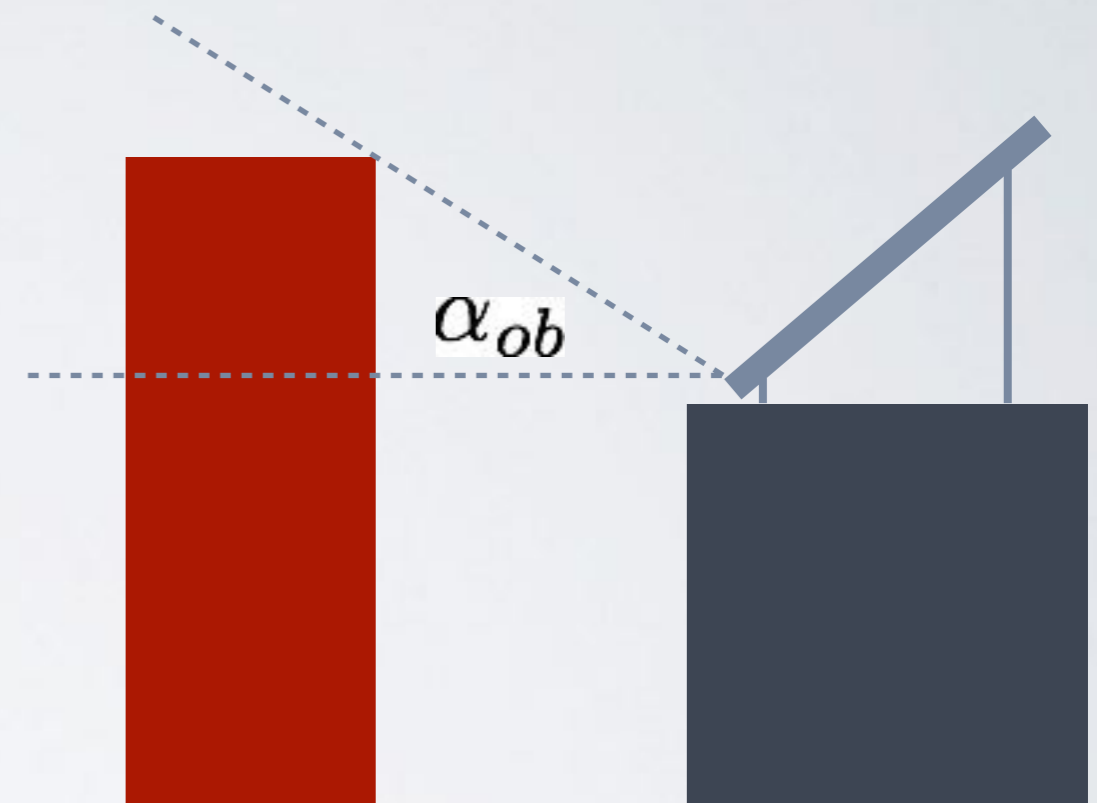
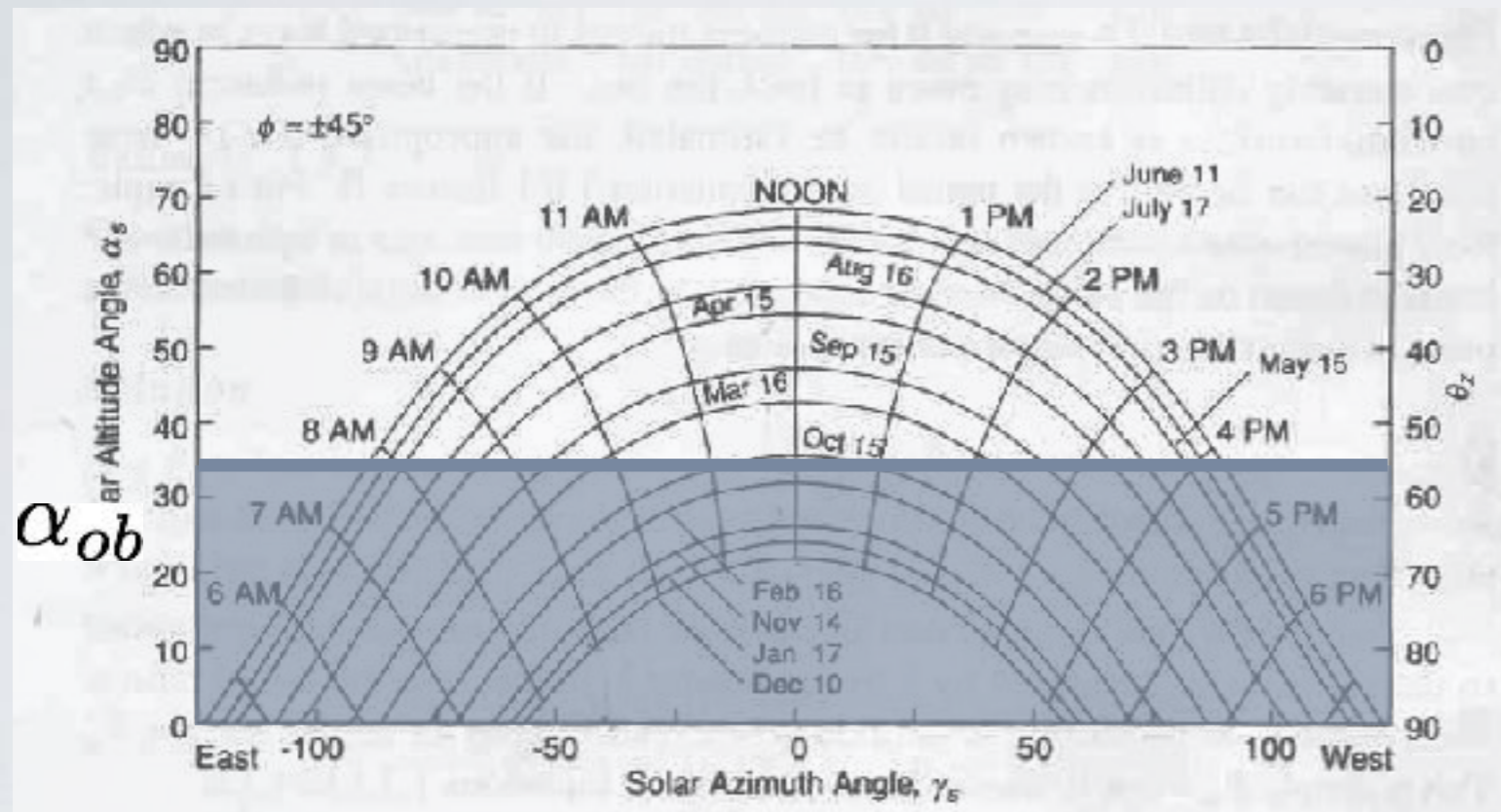
componente de horizonte F_2

$$r_D = \frac{\cos \theta}{\sin \alpha}$$

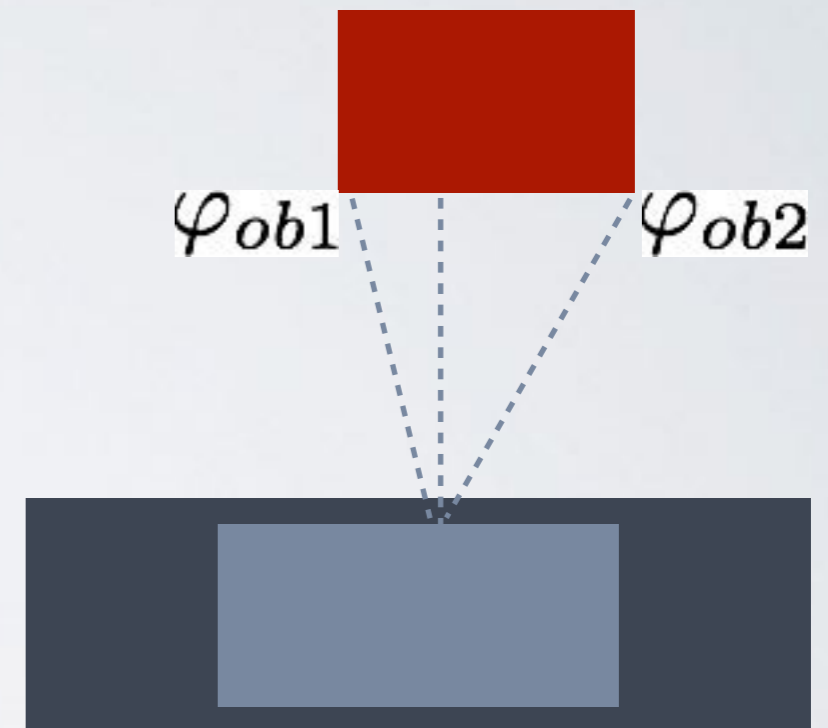
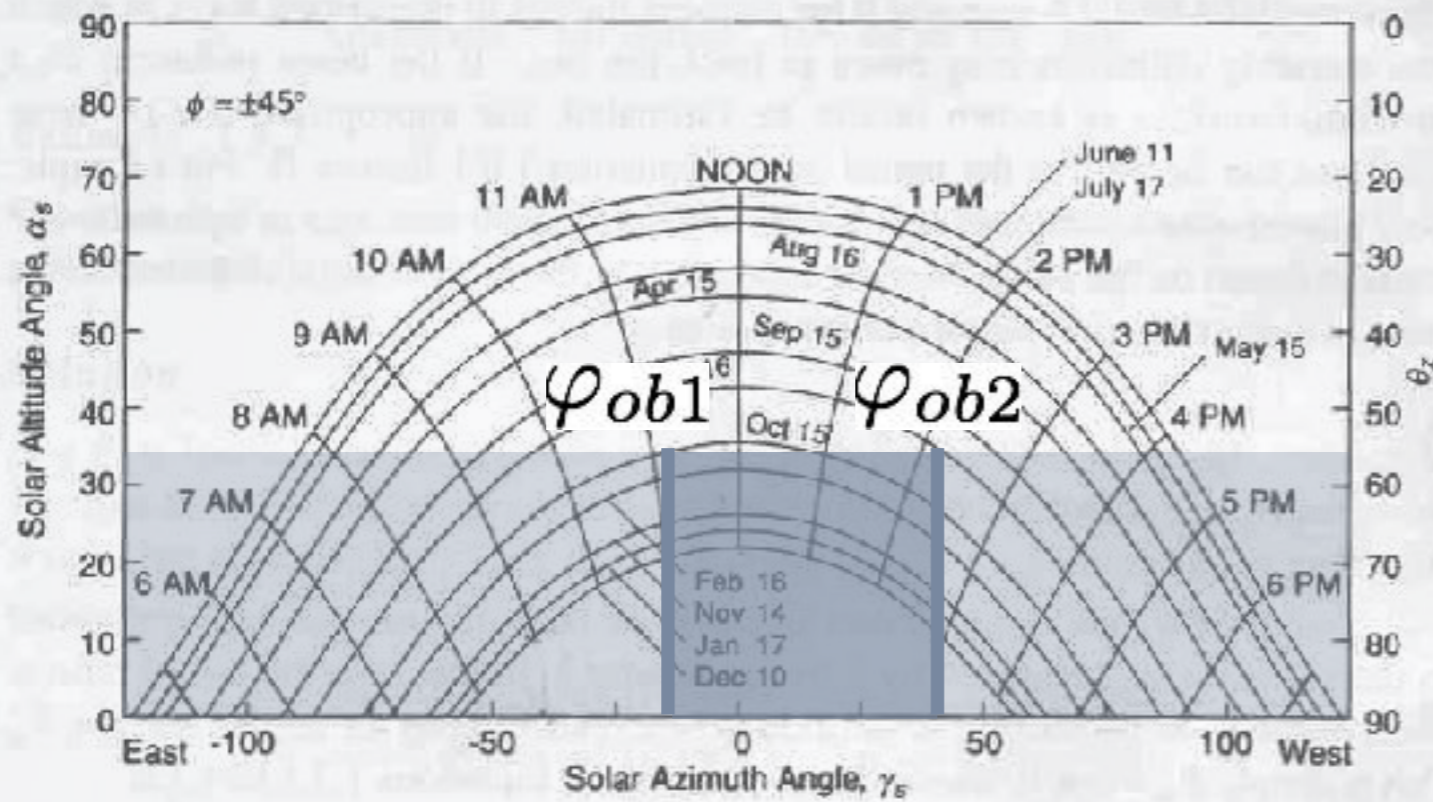
Modelo de Perez et al.

$$\Psi(I_D, I_d) = (1 - F_1) \cos^2(\beta/2) + F_1 r_D + F_2 \sin \beta$$

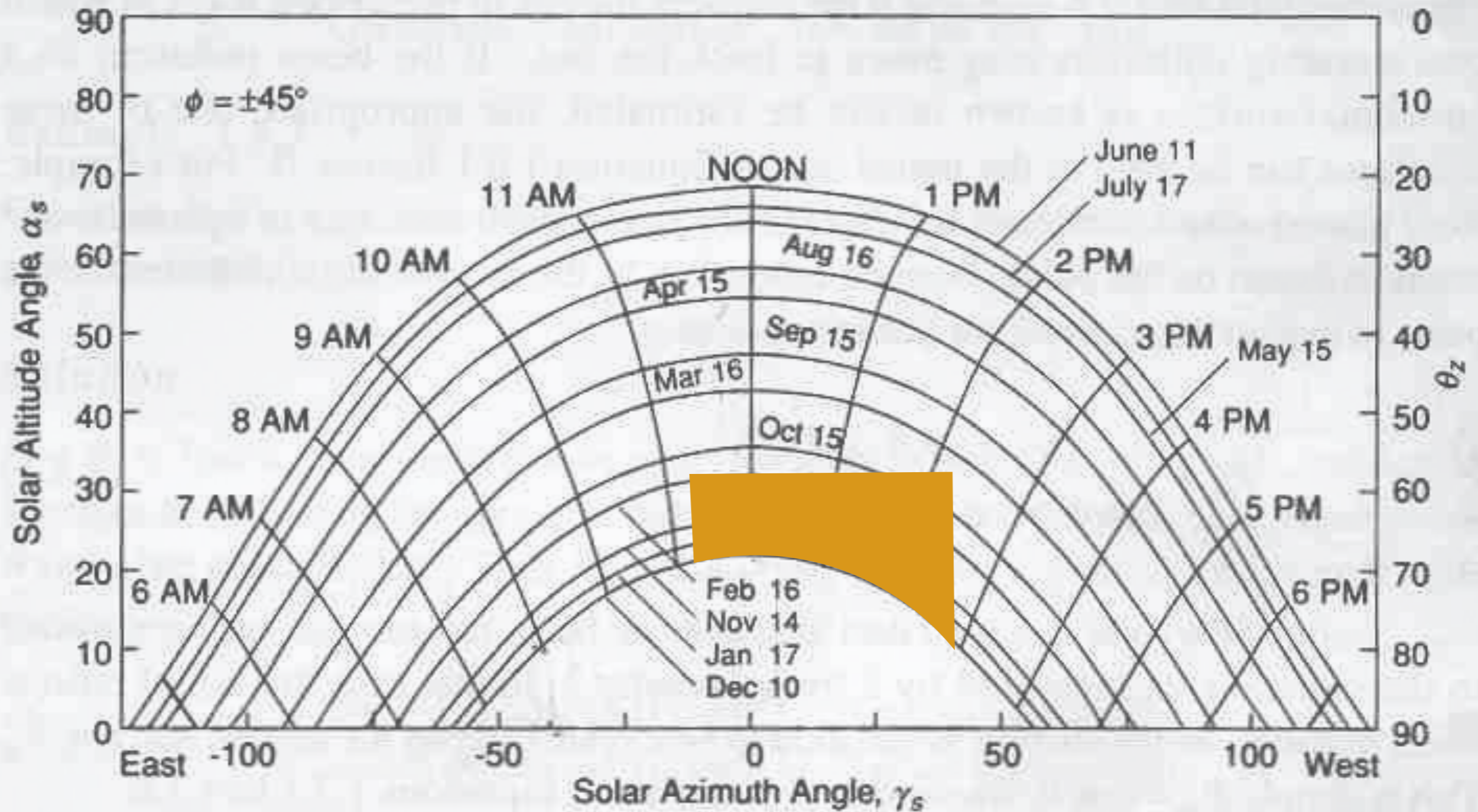




Vista em corte



vista em planta



Radiação direta é obstruída nos meses de inverno entre as 11h e as 14h (hora solar)

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Boyle, G. Renewable Energy, Power for Sustainable Future

Solar Thermal Energy (2.3)

