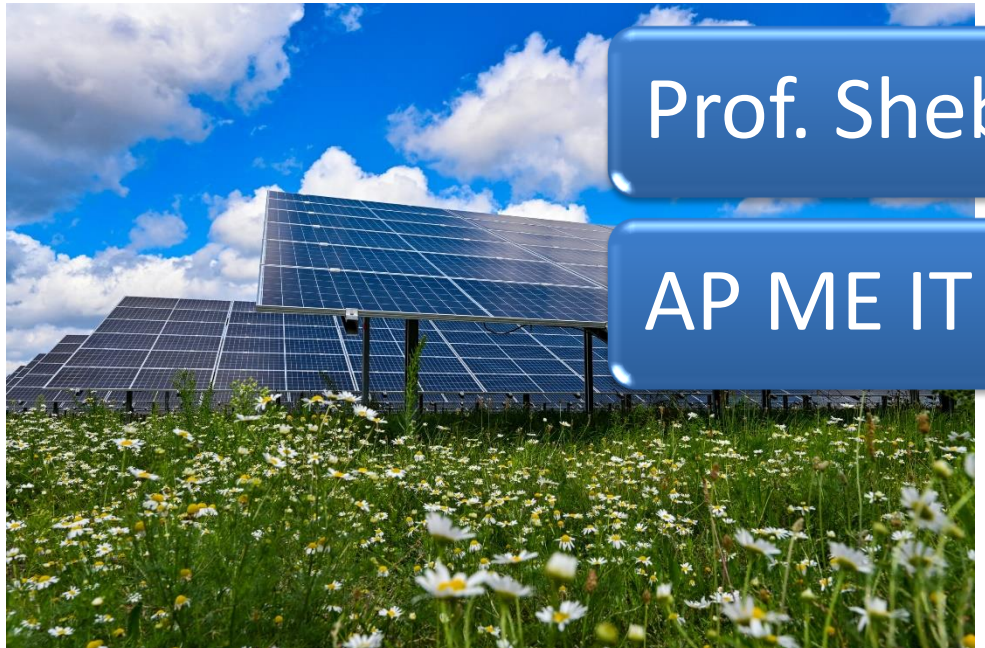
Solar energy



Prof. Shebaz Memon

AP ME IT NU

Solar energy

2. Solar Energy

Solar energy, extra-terrestrial and terrestrial radiations, radiation geometry, variation of insolation and its measurement, computation of solar radiation on horizontal and tilted surfaces,

solar flat plate collectors, their configuration, material of construction and general characteristics, concentrating collectors, receiver systems, heliostat, optical losses, types of solar energy storage, solar energy applications.

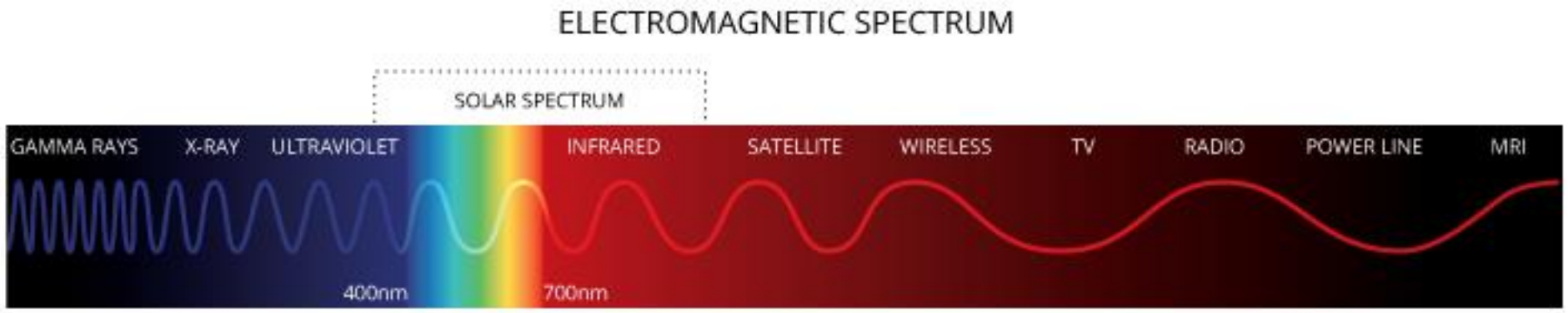
Introduction

- Very large
- Inexhaustible
- Power from the sun on the earth 1.8×10^{11}MW approximately
- Pros - Clean and free of cost
- Cons – Dilute and variation in availability

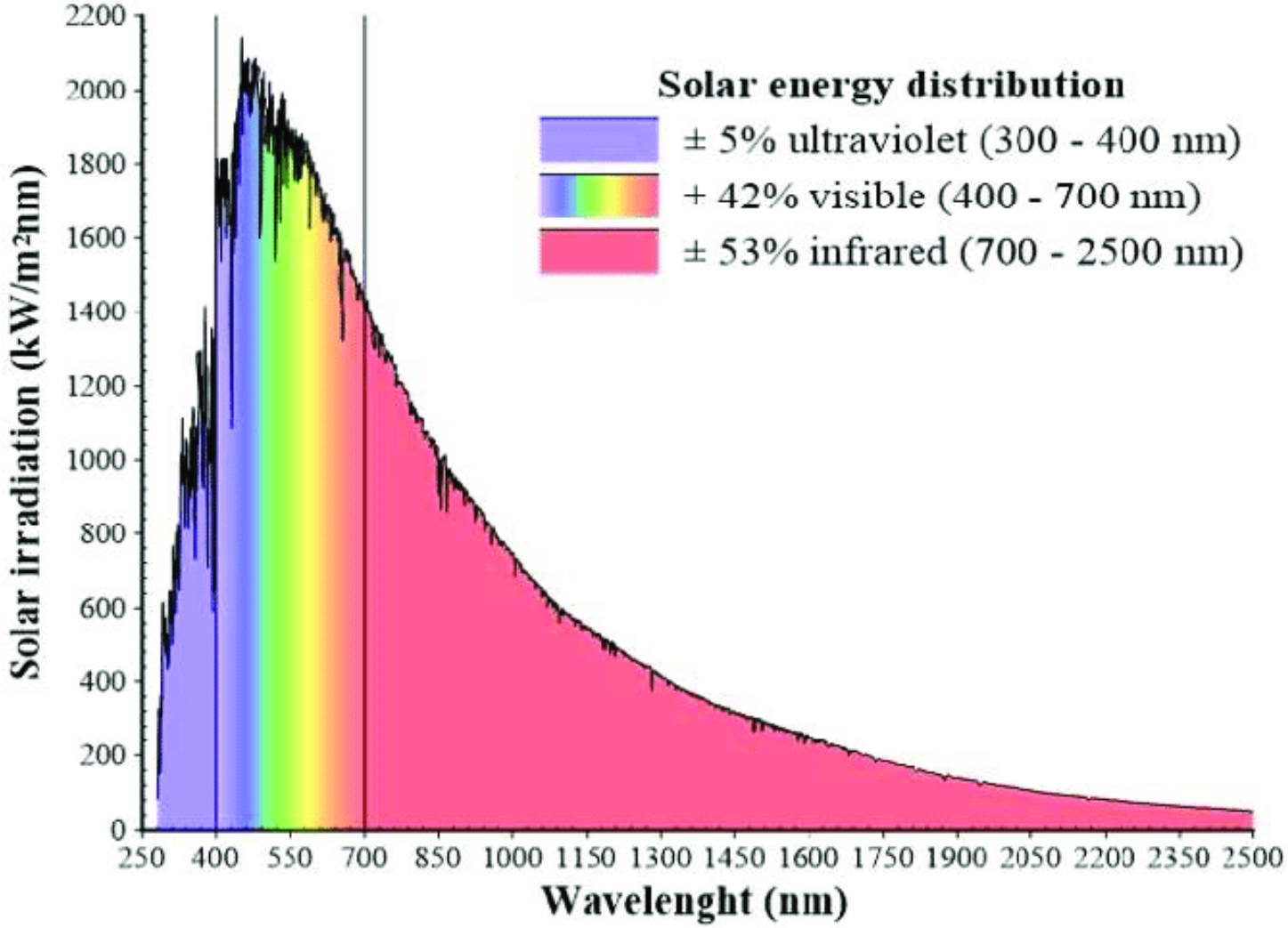
Solar energy utilisation

- Direct methods
  - ✓Thermal
  - ✓Photovoltaic
- Indirect methods
  - ✓Water power
  - ✓Wind
  - ✓Biomass
  - ✓Wave energy

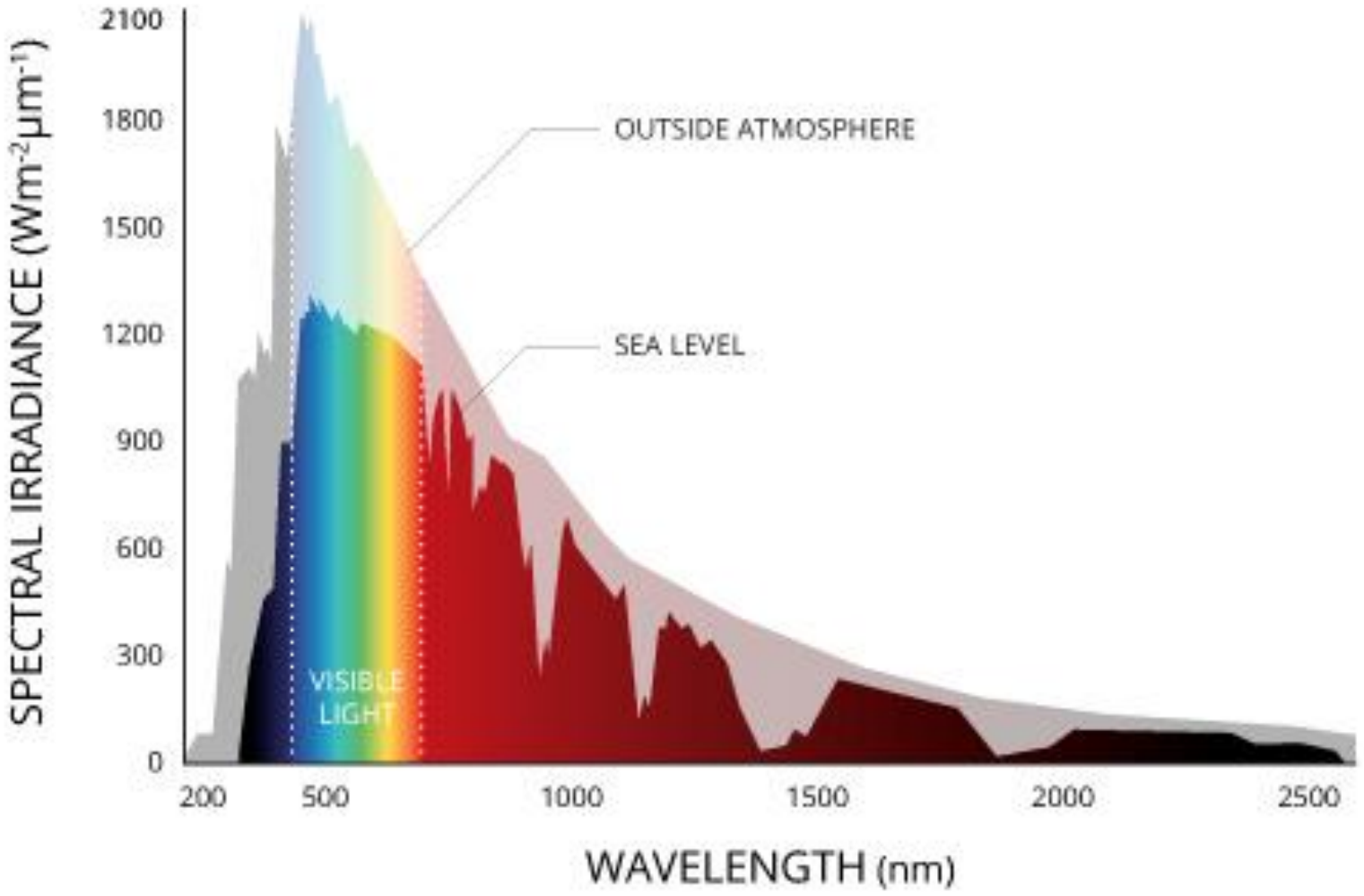
Solar Radiation



Solar Radiation

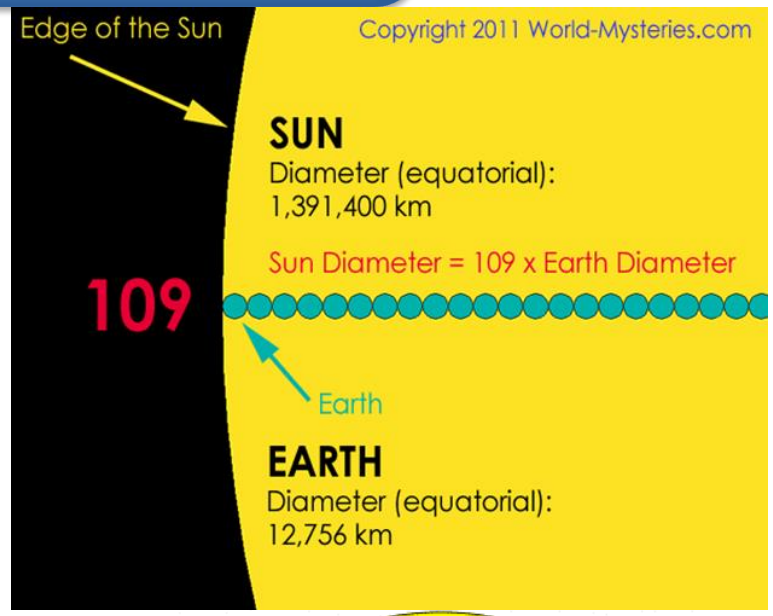


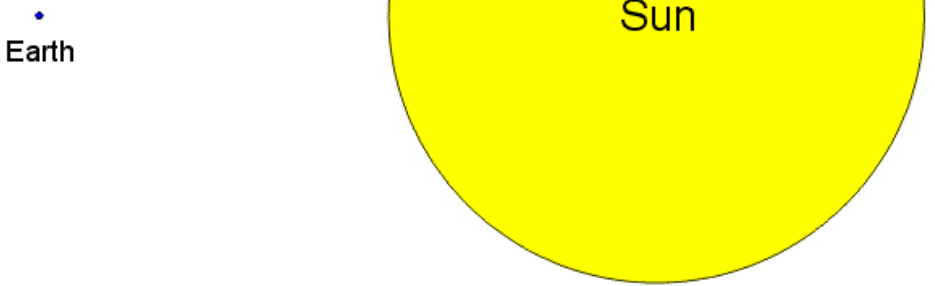
Solar Radiation



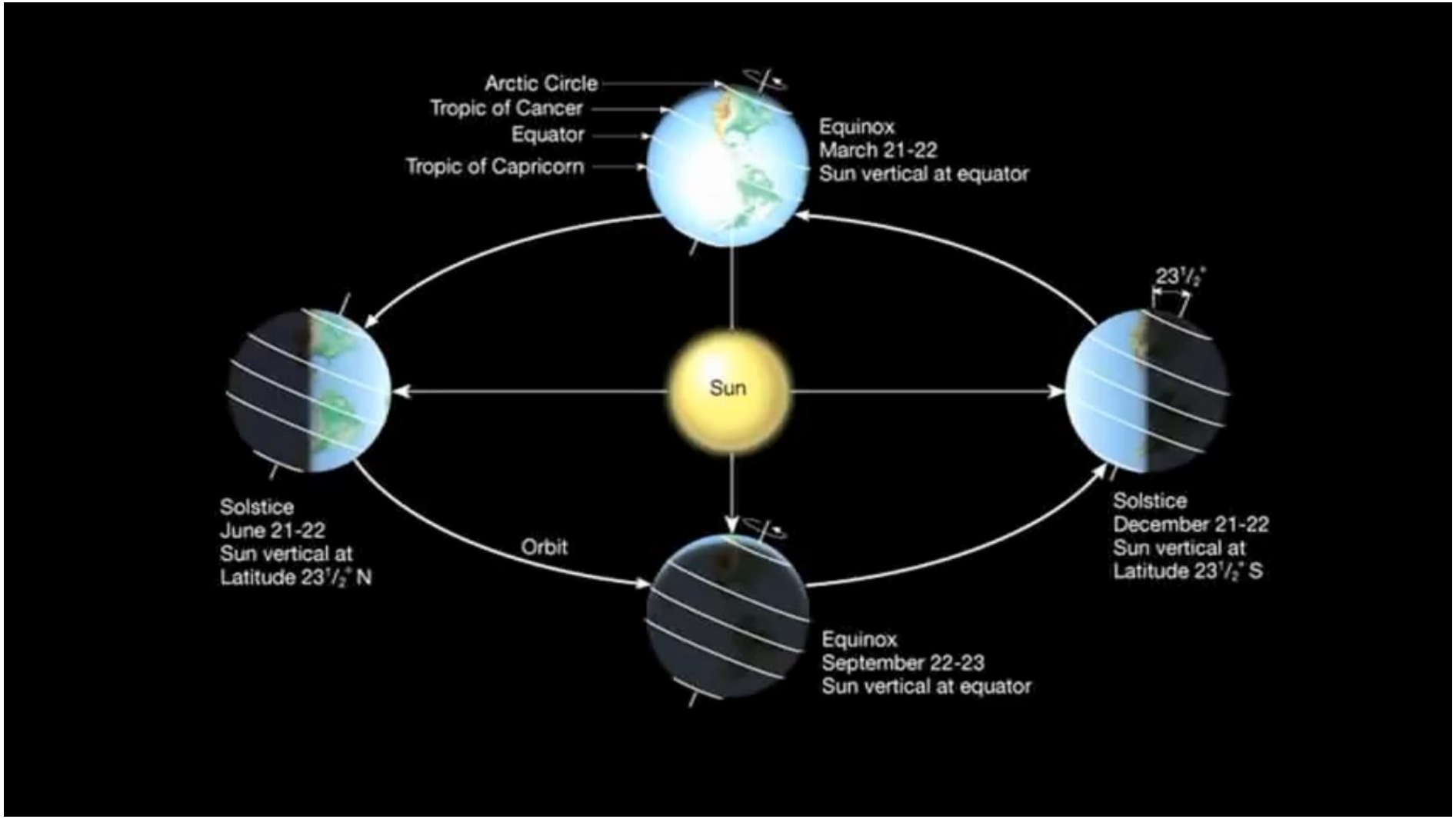
Solar Radiation

- Radius of earth is 6400 km and of sun is 7,00,000 km
- Distance b/n them is 14.96 crores km, so subtends an angle of 32 minutes
- Radiation is equivalent to black surface of 5762 K
- Solar Constant: The amount of energy received in unit time on a unit area perpendicular to the sun's direction at the mean distance of the earth from the sun
- 1353 watt per square metre (Extra-terrestrial)

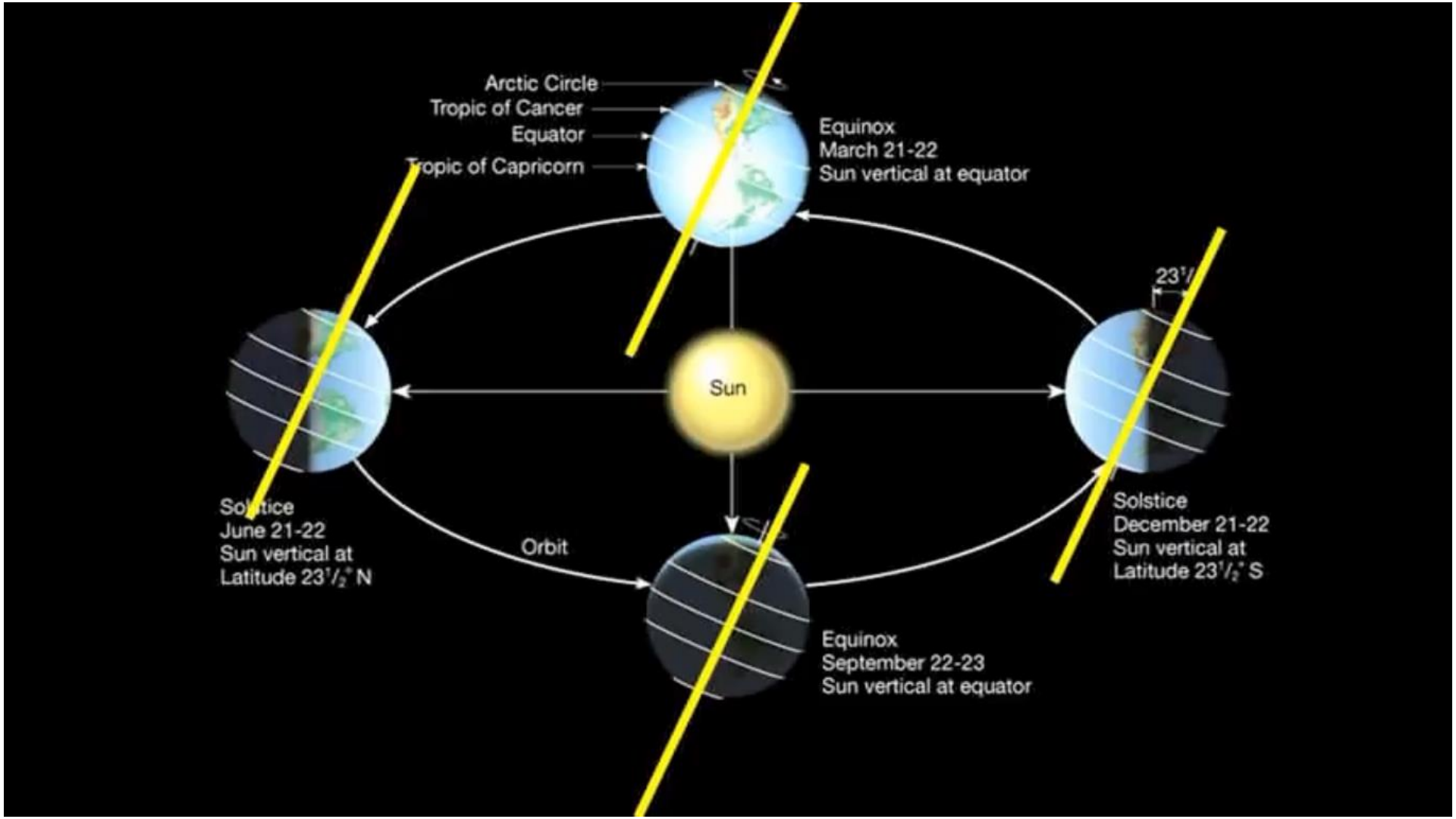




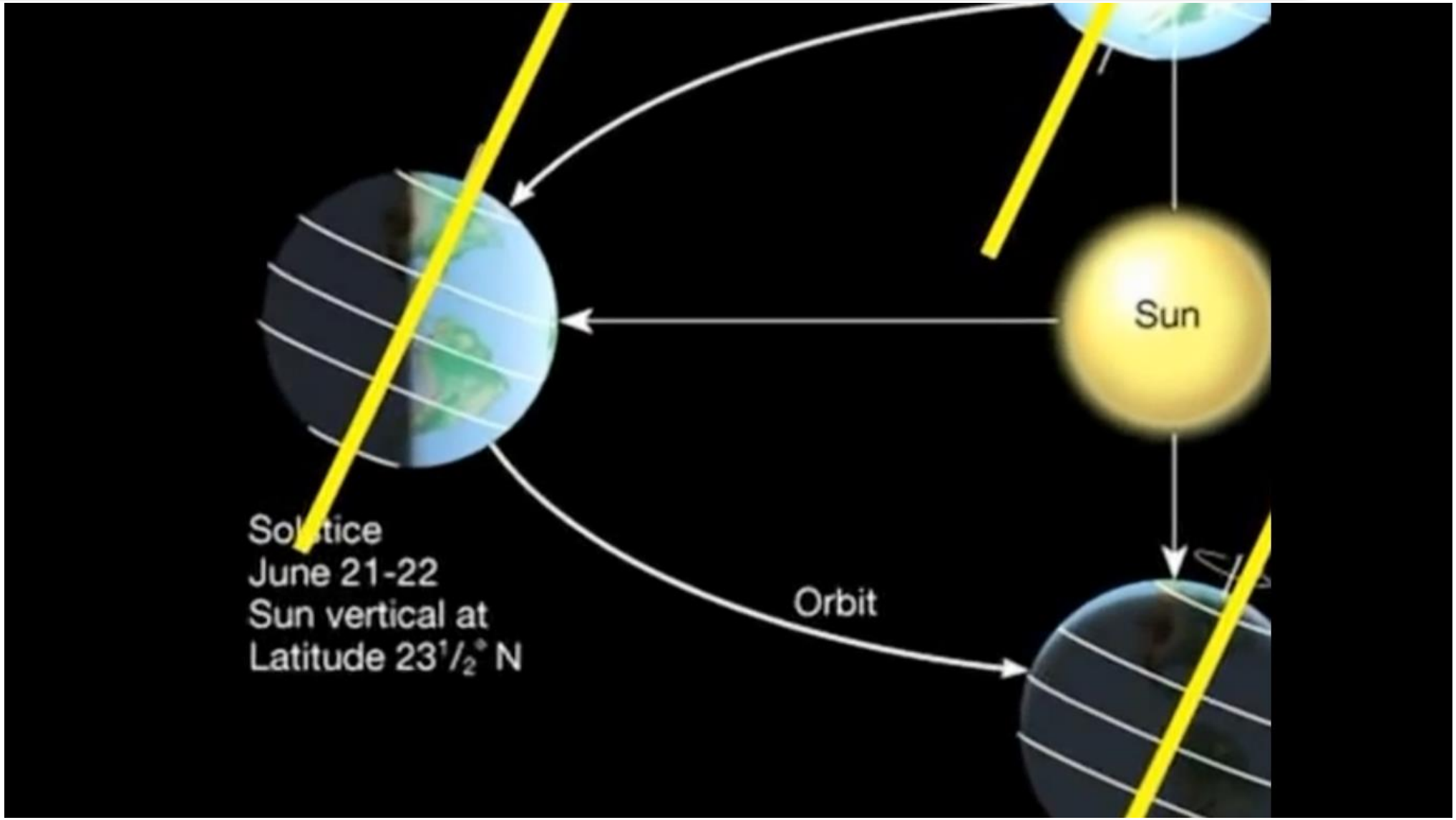
Solar Radiation



Solar Radiation



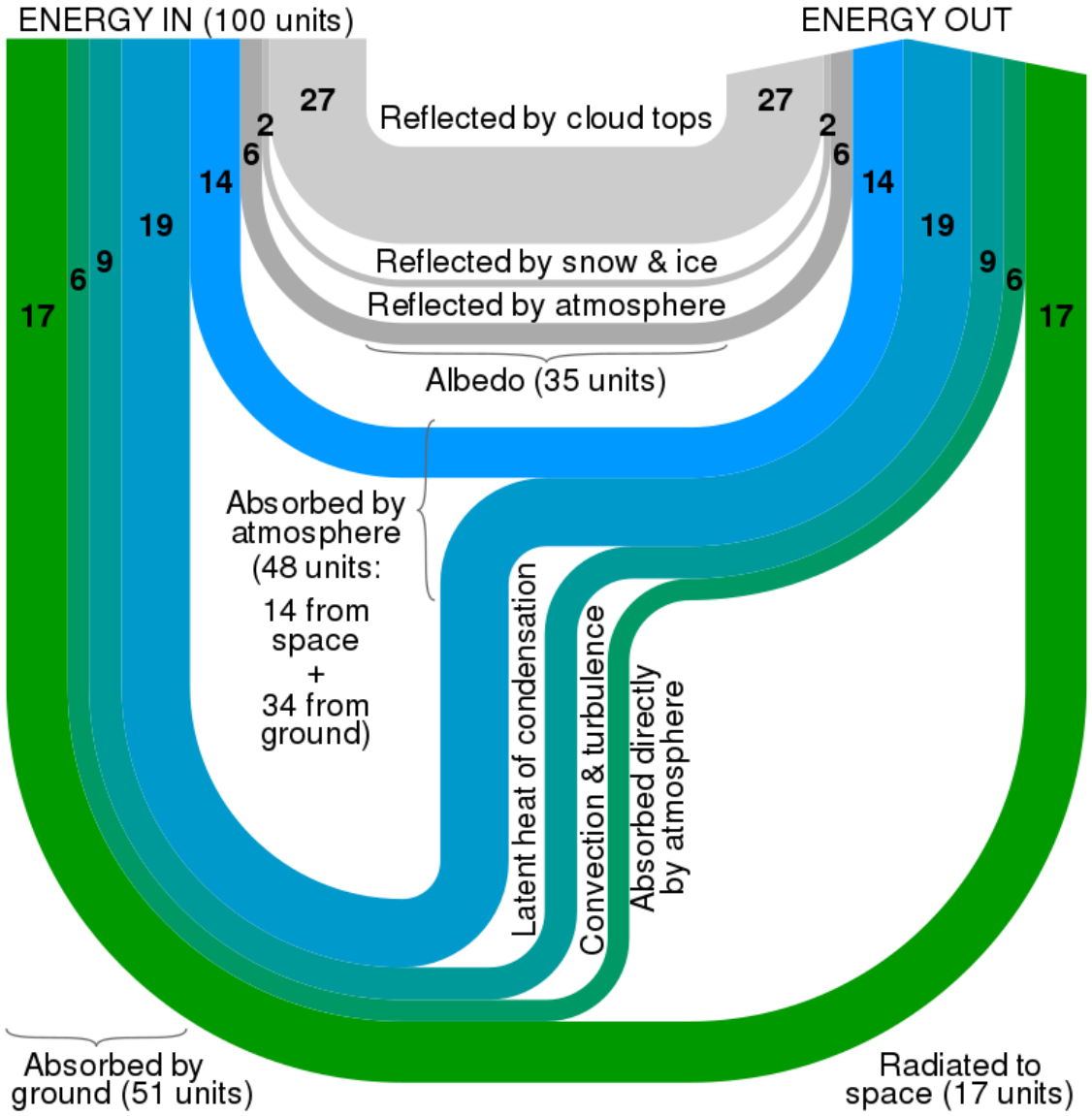
Solar Radiation

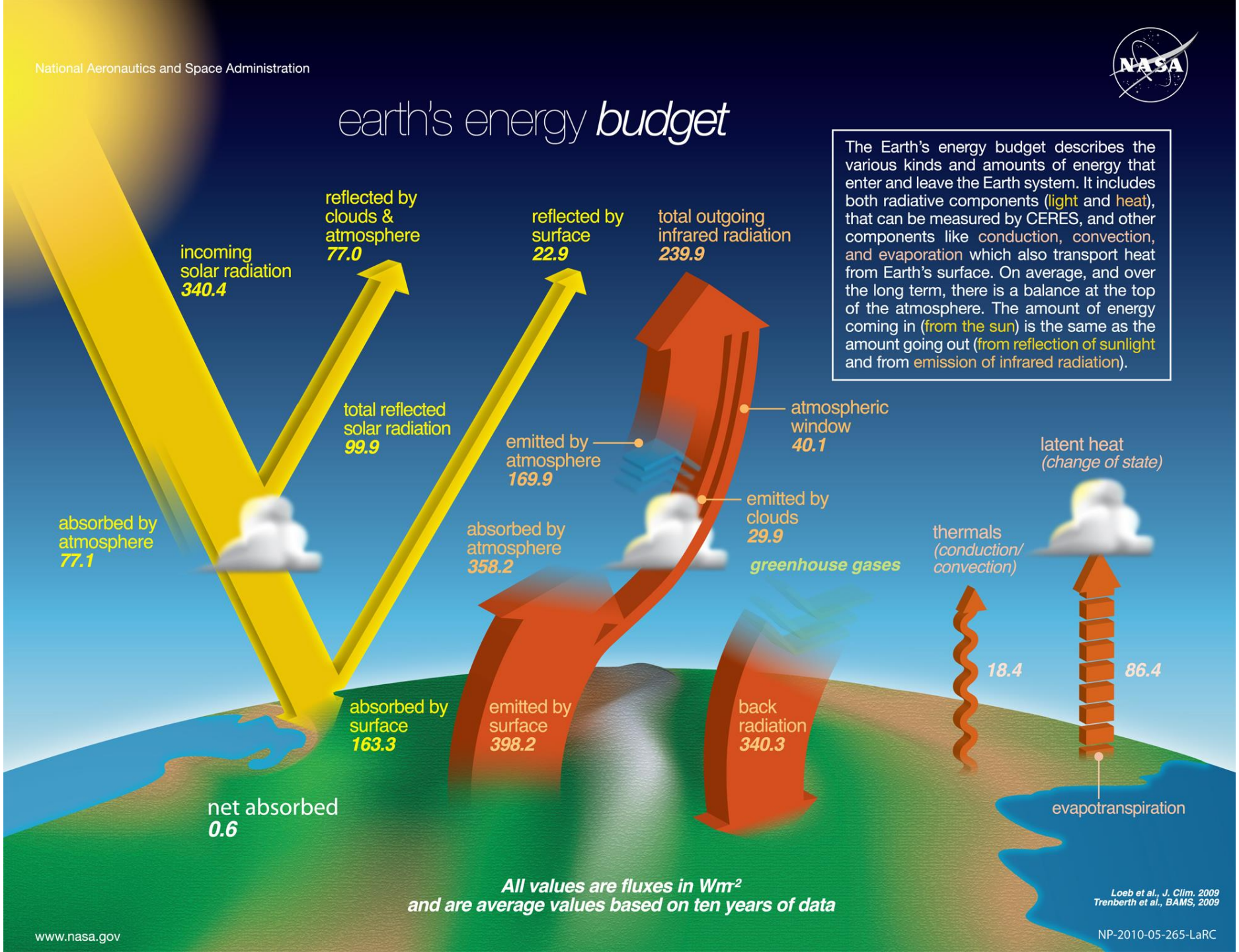


Solar Radiation

Solar Radiation

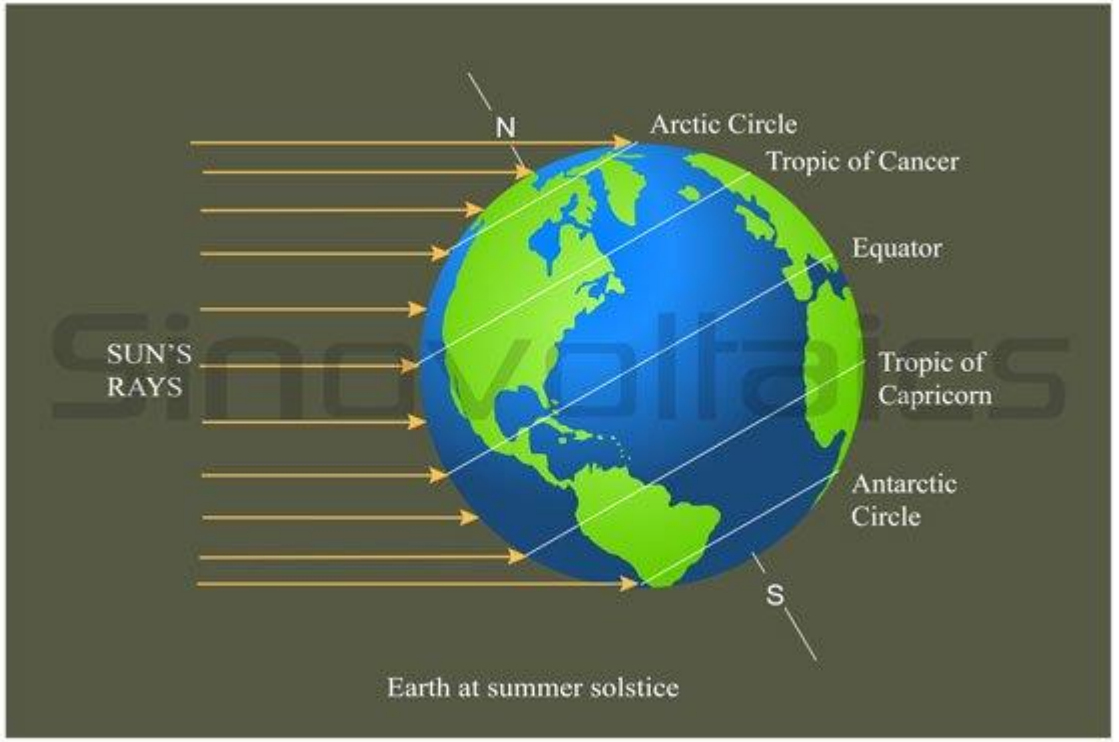
Earth's energy budget




National Aeronautics and Space Administration
NASA
earth's energy budget
The Earth's energy budget describes the various kinds and amounts of energy that enter and leave the Earth system. It includes both radiative components (light and heat), that can be measured by CERES, and other components like conduction, convection, and evaporation which also transport heat from Earth's surface. On average, and over the long term, there is a balance at the top of the atmosphere. The amount of energy coming in (from the sun) is the same as the amount going out (from reflection of sunlight and from emission of infrared radiation).
incoming solar radiation 340.4
reflected by clouds & atmosphere 77.0
reflected by surface 22.9
total outgoing infrared radiation 239.9
total reflected solar radiation 99.9
atmospheric window 40.1
emitted by atmosphere 169.9
emitted by clouds 29.9
greenhouse gases
latent heat (change of state)
thermals (conduction/ convection)
absorbed by atmosphere 77.1
absorbed by atmosphere 358.2
18.4
86.4
absorbed by surface 163.3
emitted by surface 398.2
back radiation 340.3
evapotranspiration
net absorbed 0.6
All values are fluxes in Wm-2
and are average values based on ten years of data
Loeb et al., J. Clim. 2009
Trenberth et al., BAMS, 2009
www.nasa.gov
NP-2010-05-265-LaRC

Solar Radiation

- Insolation – Total solar energy received on a horizontal surface of unit area on the ground in unit time
- Attenuation of beam radiation
    - ✓ Absorption

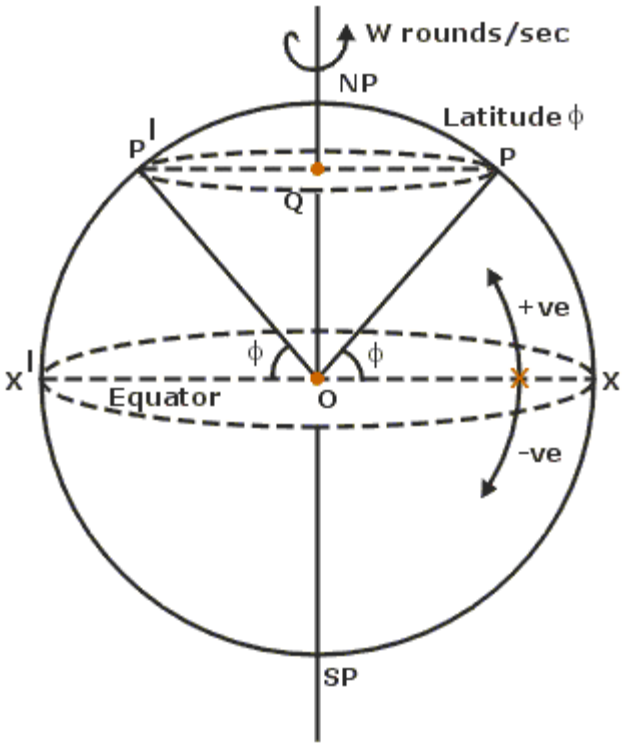


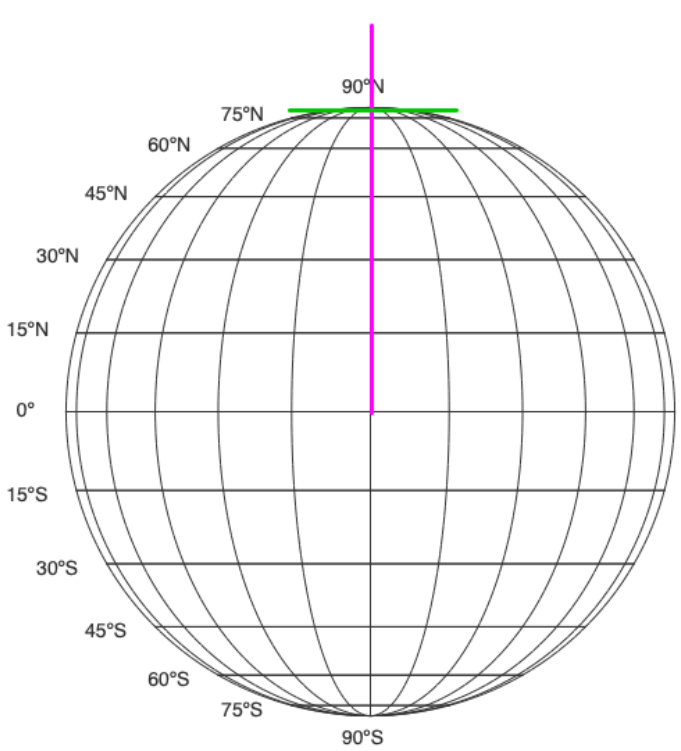
Solar radiation at surface

- Reflection from clouds
- Absorption by air molecules
  - UV by ozone
  - IR by CO2 and water vapor
- Direct Radiation (or Beam Radiation)
- Diffuse Radiation
- Insolation = Direct Radiation +Diffuse Radiation
- Zenith angle – Angle made by the sun's rays with the normal to a horizontal surface

Solar radiation geometry

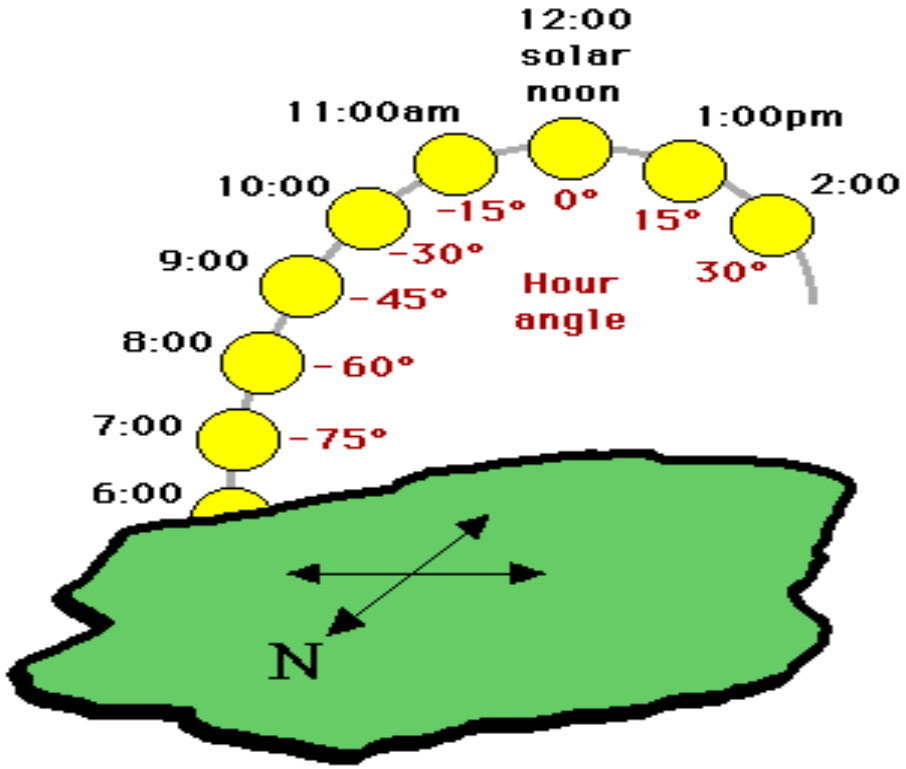
- Latitude (ϕ) => b\n line joining centre of earth with its projection on equatorial plane, positive for northern hemisphere



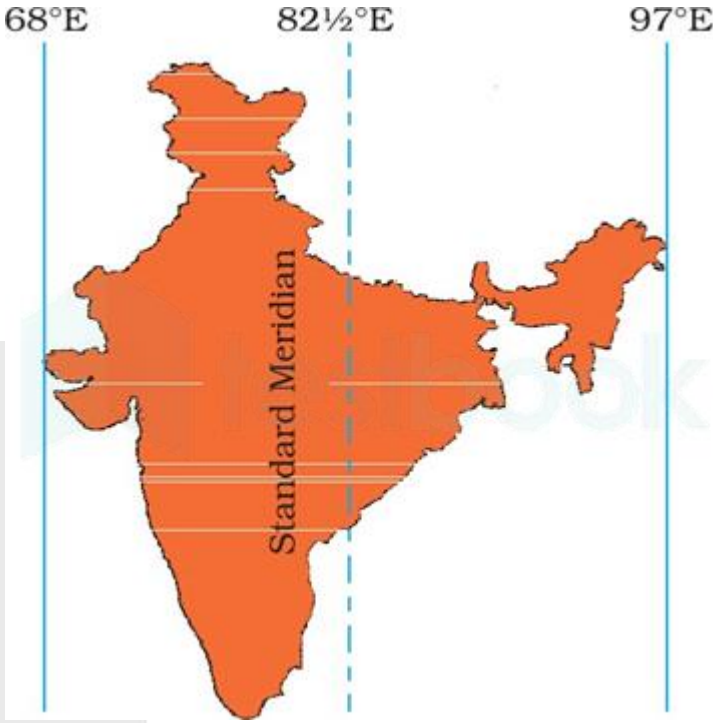


Solar radiation geometry

- Hour angle(ω)=> Angular measure of time and is equivalent to 15° per hour



Local Apparent Time



$$LST = LAT - 4\cdot(L_s - L_e) - E_t$$

- E_t → Time equation (minutes)
- $4\cdot(L_s - L_e)$ → Longitude correction

Sun apparent movement

15 degrees / hour → 4 min / degree

- L_s Standard meridian longitude
- L_e Local meridian longitude

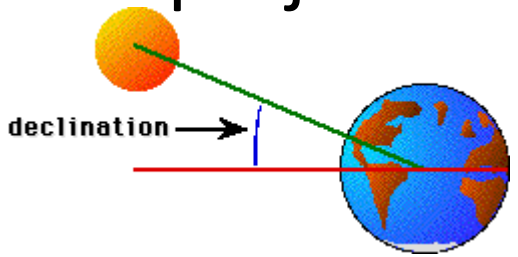
L_s, L_e
- >0 towards W
- <0 towards E

Degrees → Longitude correction in minutes

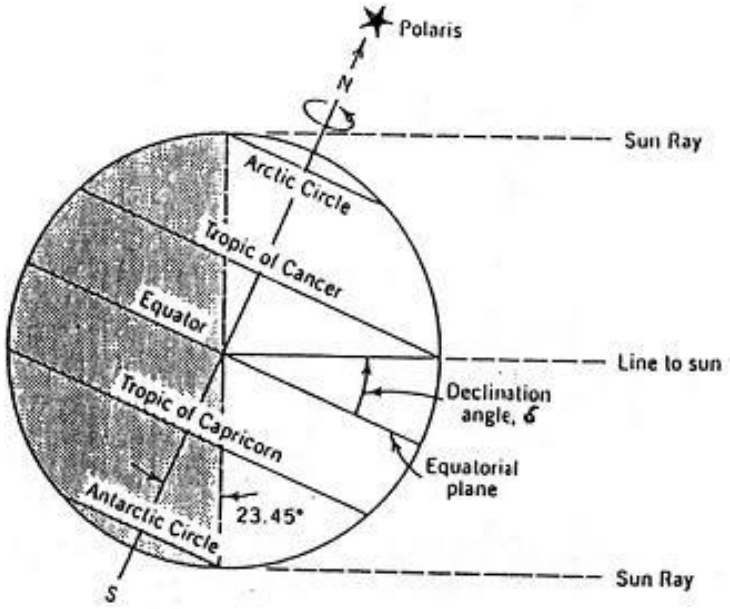
$$LAT = LST + 4\cdot(L_s - L_e) + E_t$$

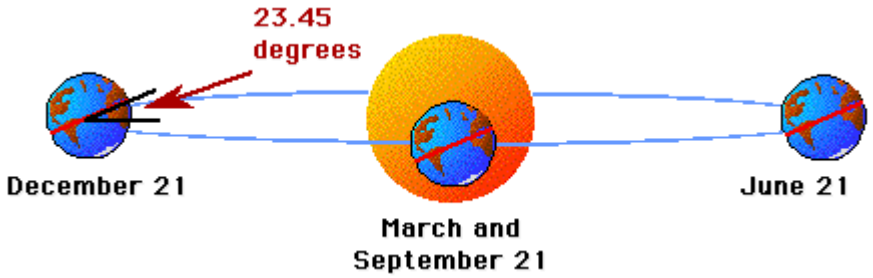
Solar radiation geometry

- Declination(δ) => b\n line joining the centre of the earth and centre of the sun with its projection on equatorial plane



$$\delta \text{ (in degrees)} = 23.45 \sin\left[\frac{360}{365}(284+n)\right]$$



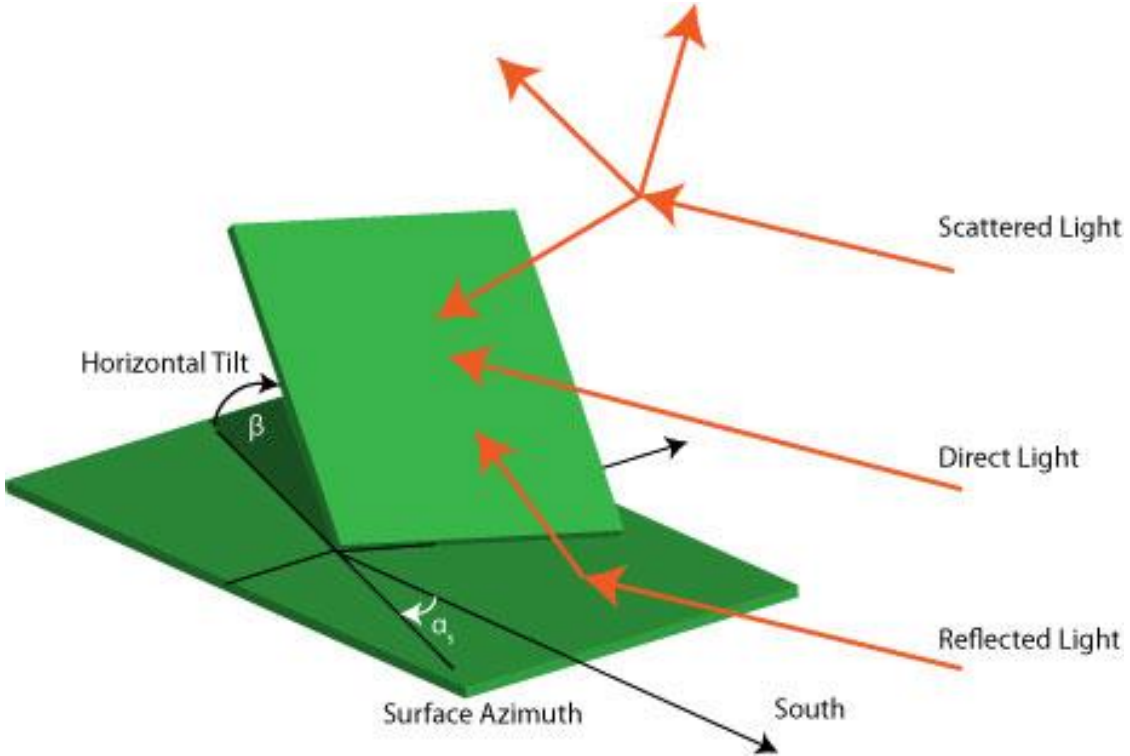


Example

- Determine the local apparent time and declination angle at Ahmedabad (Longitude 72º 40’ E, latitude 23º 00’ N) at 14:30 IST on December 15. Take Equation of time as +5’ 13”.

Solar radiation geometry

- Slope (β) => b\n plane surface and horizontal
- Surface azimuth angle(γ) => b\n horizontal line due south and projection of the normal



Solar radiation geometry

- If θ is the angle made by incident beam of flux I_{bn} and the normal to the plane, than equivalent
- It can be shown that

$$\cos\theta = \sin\emptyset\,(\sin\delta\cos\beta + \cos\delta\cos\gamma\cos\omega\sin\beta) + \cos\emptyset\,(\cos\delta\cos\omega\cos\beta - \sin\delta\cos\gamma\sin\beta) + \cos\delta\sin\gamma\sin\omega\sin\beta$$

- This can be further simplified for vertical surface β=90° OR Horizontal surface β=0°

NSRDB

DNI, DHI, GHI

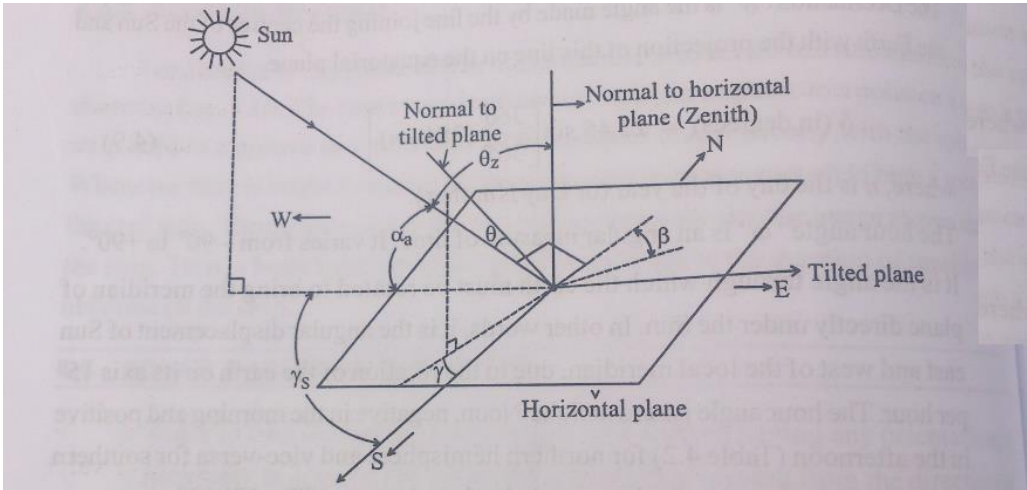


Fig. 4.11 Diagram illustrating the angle of incidance 'θ', the zenith angle 'θz', the solar altitude angle 'αa', the slope 'β', the surface azimuth angle 'γ' and the solar azimuth angle 'γs'.


Thank you!