

A bright sun is positioned at the top center of the frame, casting a strong, multi-pointed starburst of light across a clear blue sky. Below the sun, a vast expanse of water is covered with numerous ice floes of various sizes. The water's surface is dark blue, reflecting the intense light from the sun. A prominent rainbow-like lens flare is visible in the lower center of the image, just above the waterline. The overall scene suggests a polar or subpolar environment, likely depicting the melting of ice due to global warming.

Global Warming

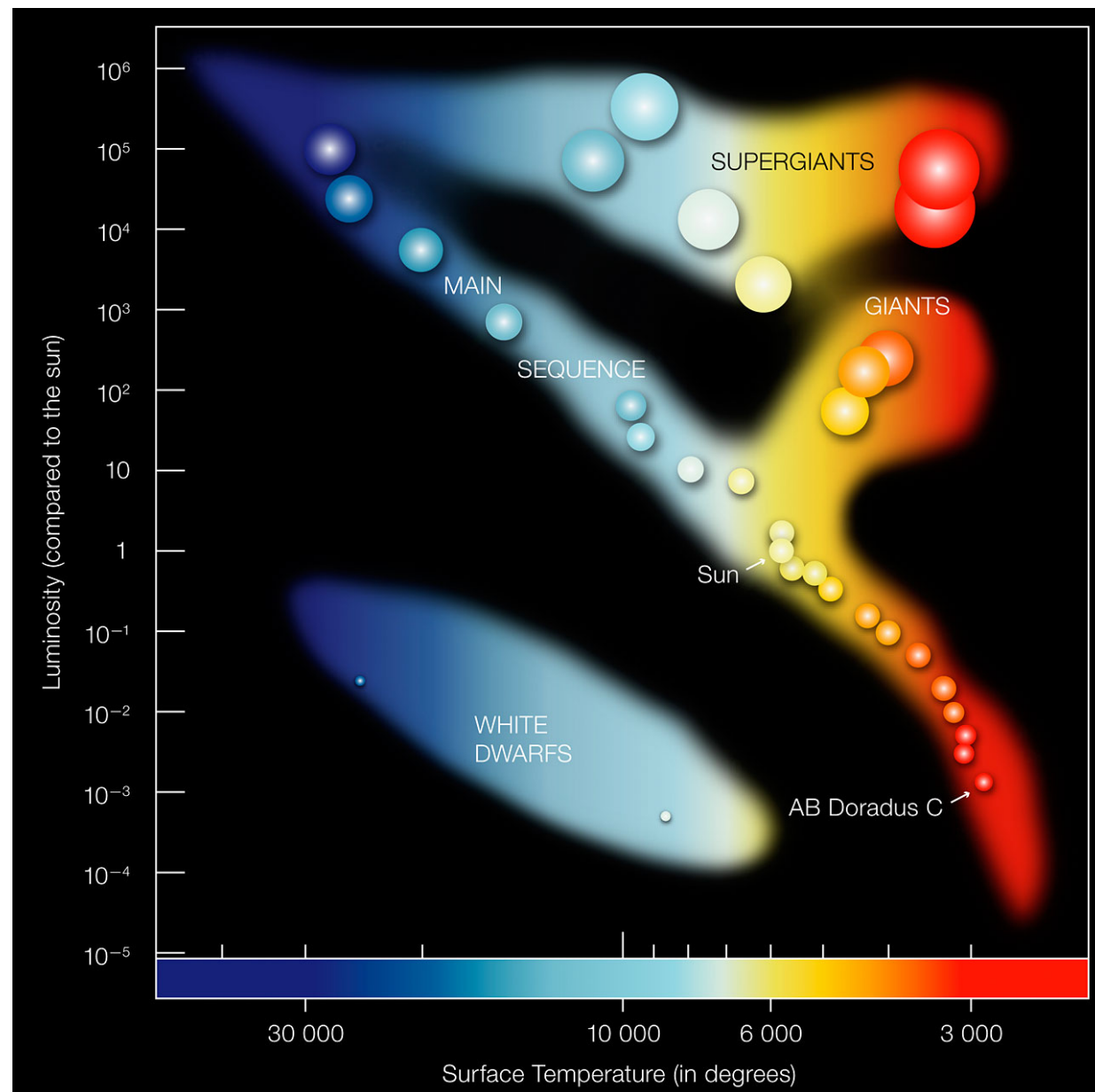
Lecture 3.2

Sunlight & Seasons

Sun*

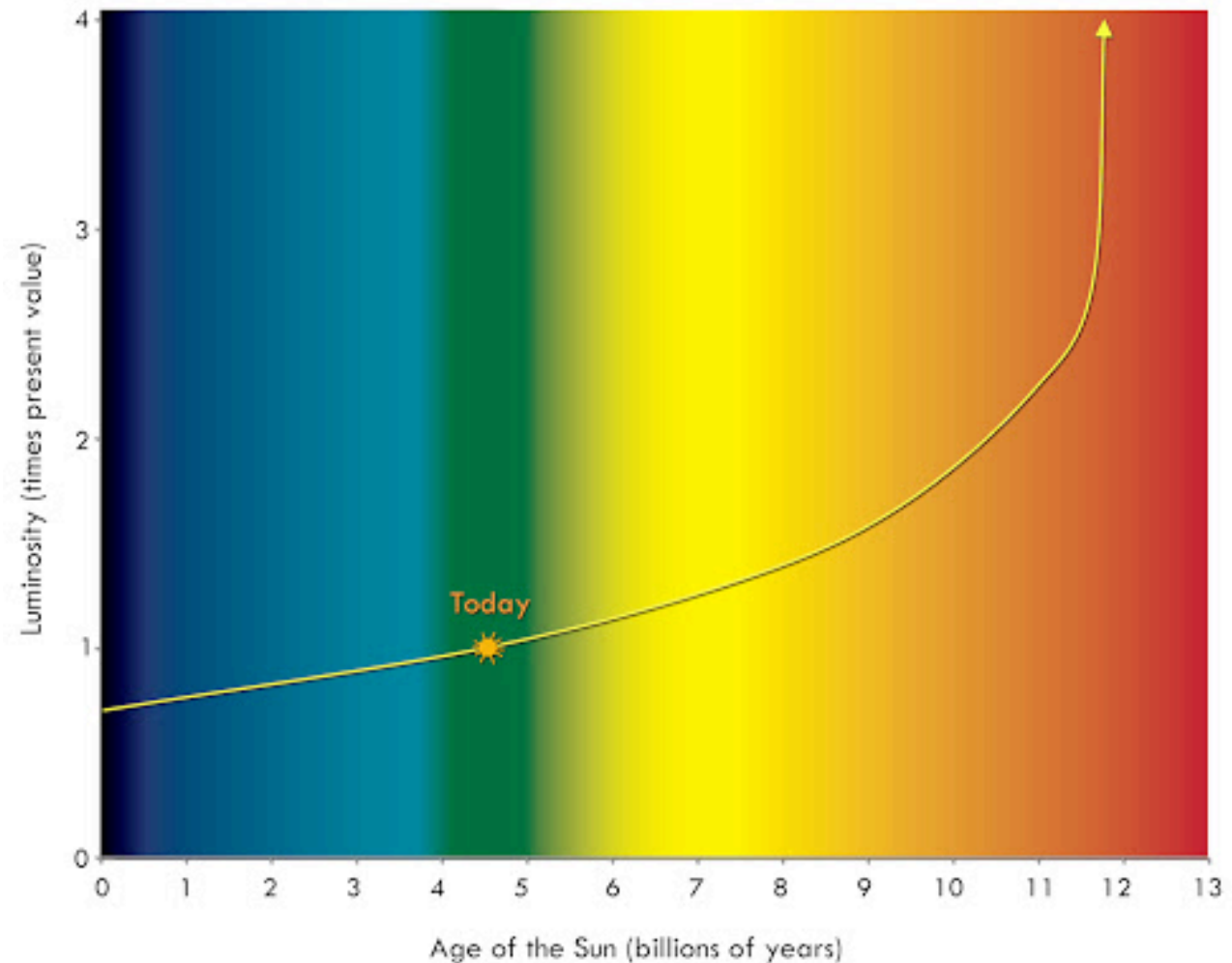
- **Sun:** Main Sequence star for 4.6B years.

Hertzprung-Russell diagram



Sun's Luminosity

- **Sun:** Main Sequence star for 4.6B years. Over that time, **its luminosity increased by 50%.**
- On the **timescales of human civilization**, the Sun's luminosity hasn't varied by much - it **cannot explain** the increase in temperature that we've observed over the past few hundred years.



Insolation

- The **insolation** is the amount of solar energy that reaches a position in space per unit area per unit time.

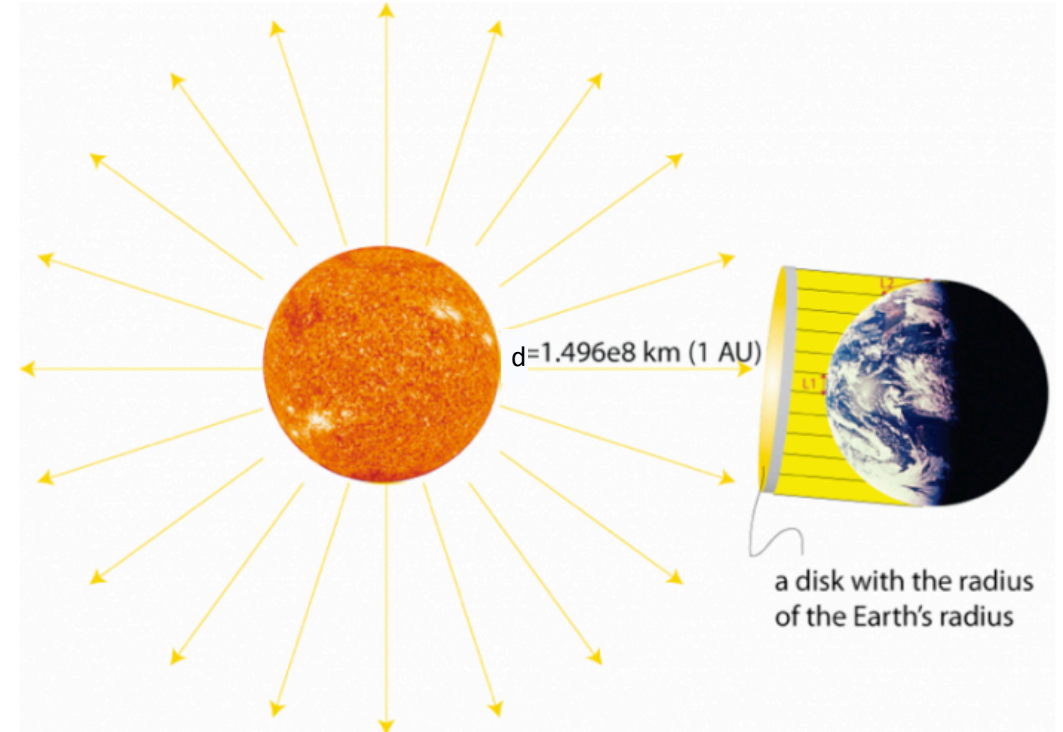
$$S_0 = \frac{L}{4\pi d^2}$$

Isolation [W/m²]
(Solar constant)

Sun's luminosity [W]

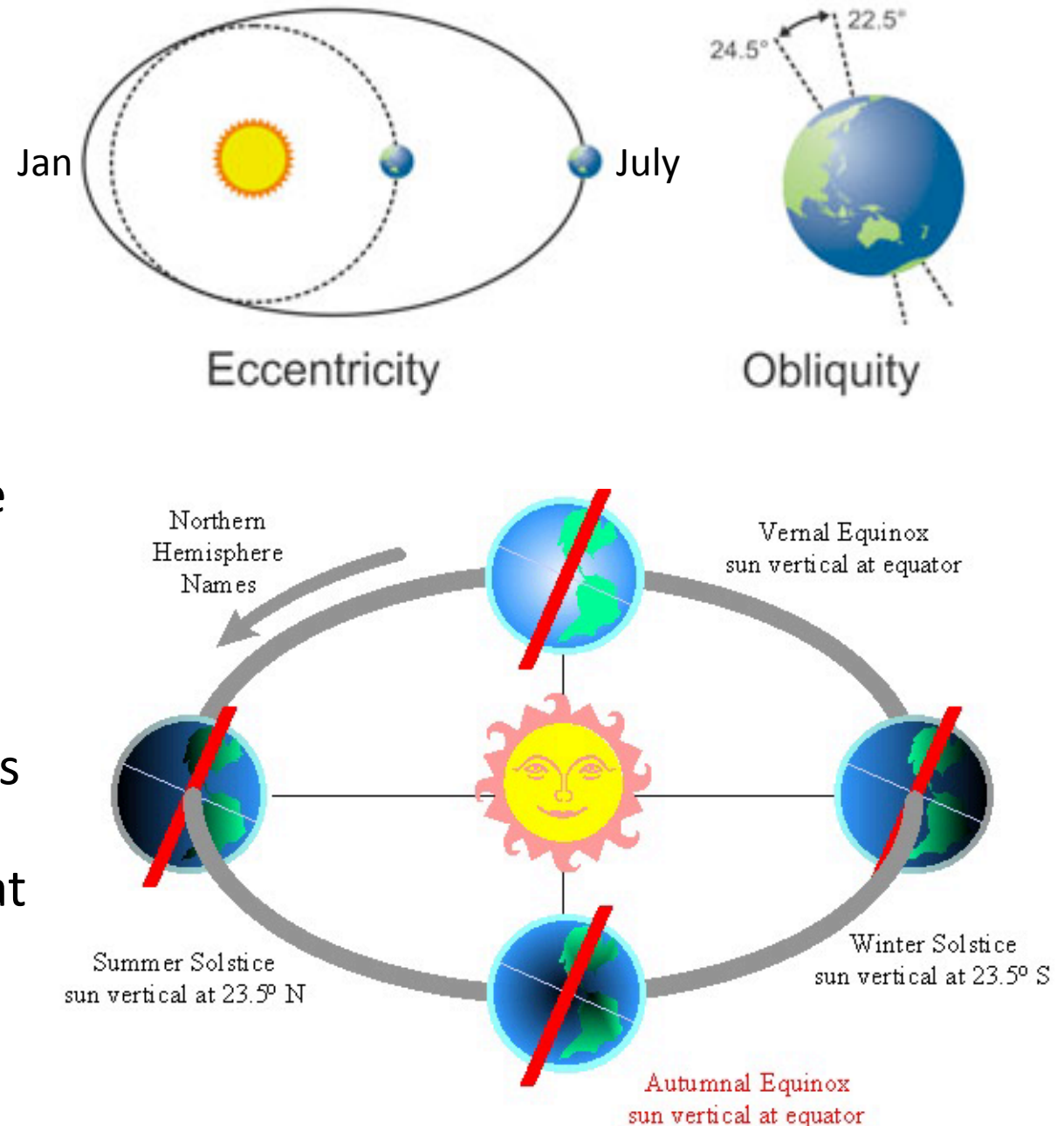
Distance to the Sun [m]

Sun-Earth distance: 1 AU (astronomical unit) = 1.5×10^{11} m



Eccentricity & Obliquity

- **Eccentricity:** Ovalness of a planet's orbit:
 - Earth's current eccentricity = 0.0167.
This leads the insolation to be about 7% larger when Earth is closest to the Sun (**January**) than when it is farthest from the Sun (**July**).
- **Obliquity:** Axial tilt
 - Summer happens in the hemisphere that is tilted toward the Sun during Earth's orbit, and winter happens in the hemisphere that is tilted away from the Sun.

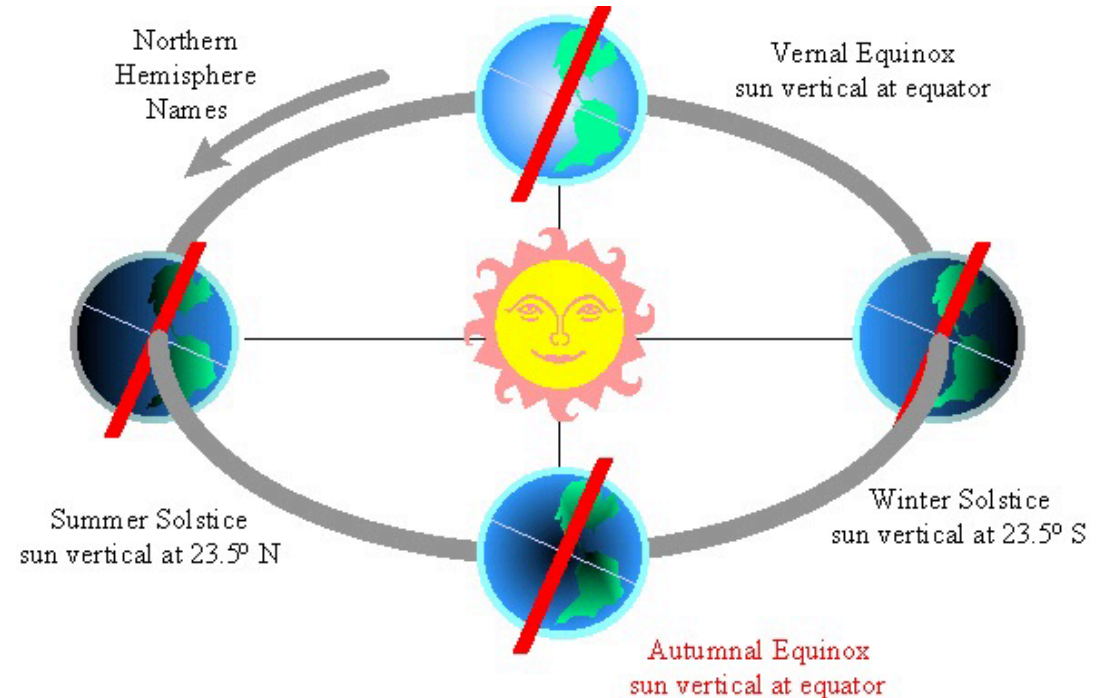
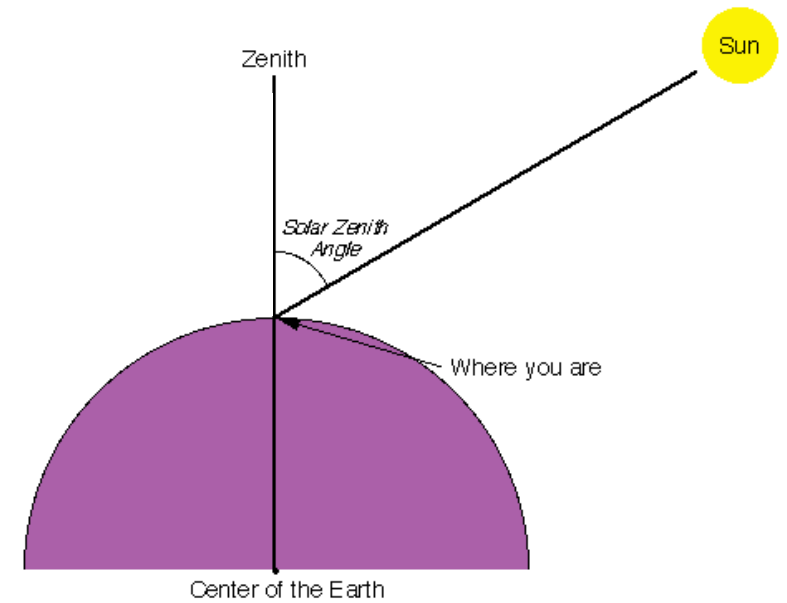


Solar Zenith Angle

- The solar zenith angle (θ_z) is the angle between the Sun and the vertical

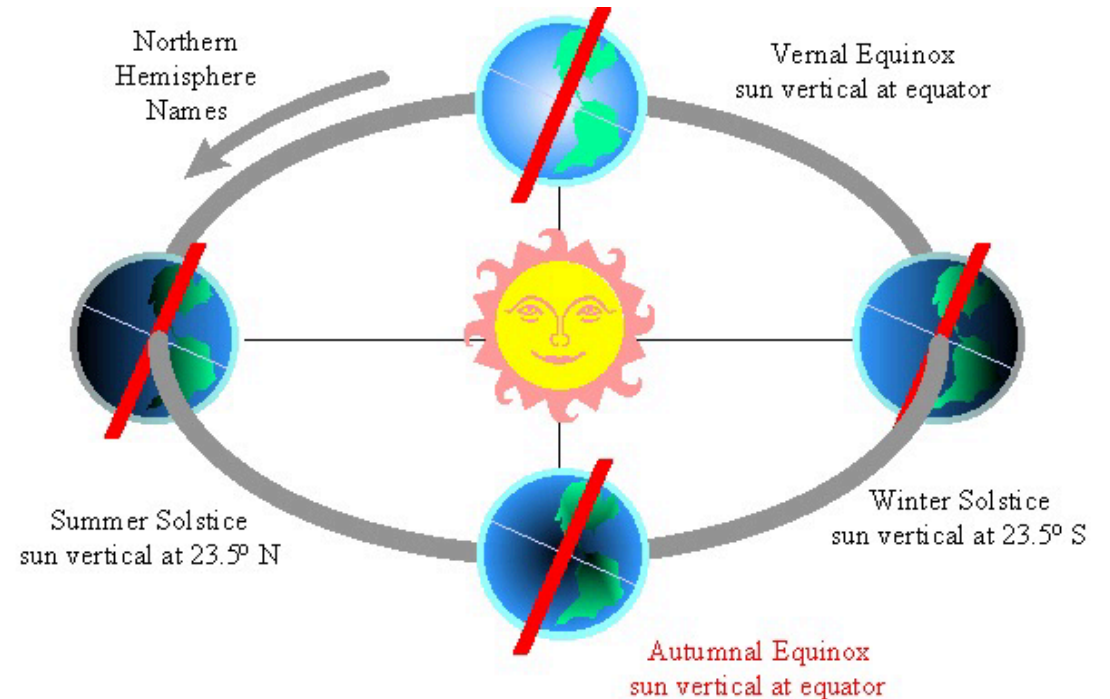
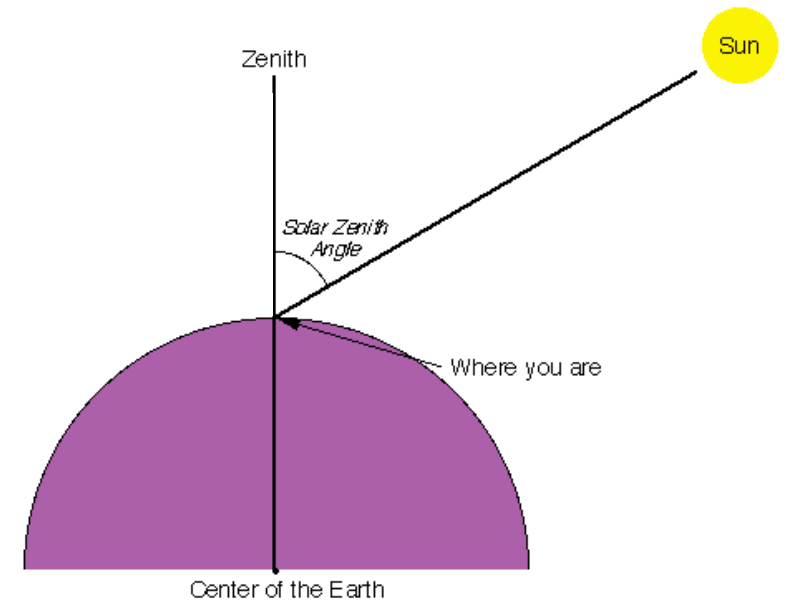
$$S = S_0 \cos \theta_z$$

- This is the reason that **it's warmer in the summer hemisphere**: the solar zenith angle in that hemisphere is smaller, so sunlight hits its surface more directly and the local insolation is higher.



Solar Zenith Angle Calculation

- **At noon:**
- Summer solstice: $\theta_z = \text{Latitude} - 23.5^\circ$
- Winter solstice: $\theta_z = \text{Latitude} + 23.5^\circ$
- Equinox: $\theta_z = \text{Latitude}$



Some video

The Arctic circle:

https://www.youtube.com/watch?v=XzTWkgKqs_Q