

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 and shapes. 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 where ice is melting, a visual metaphor for global warming.

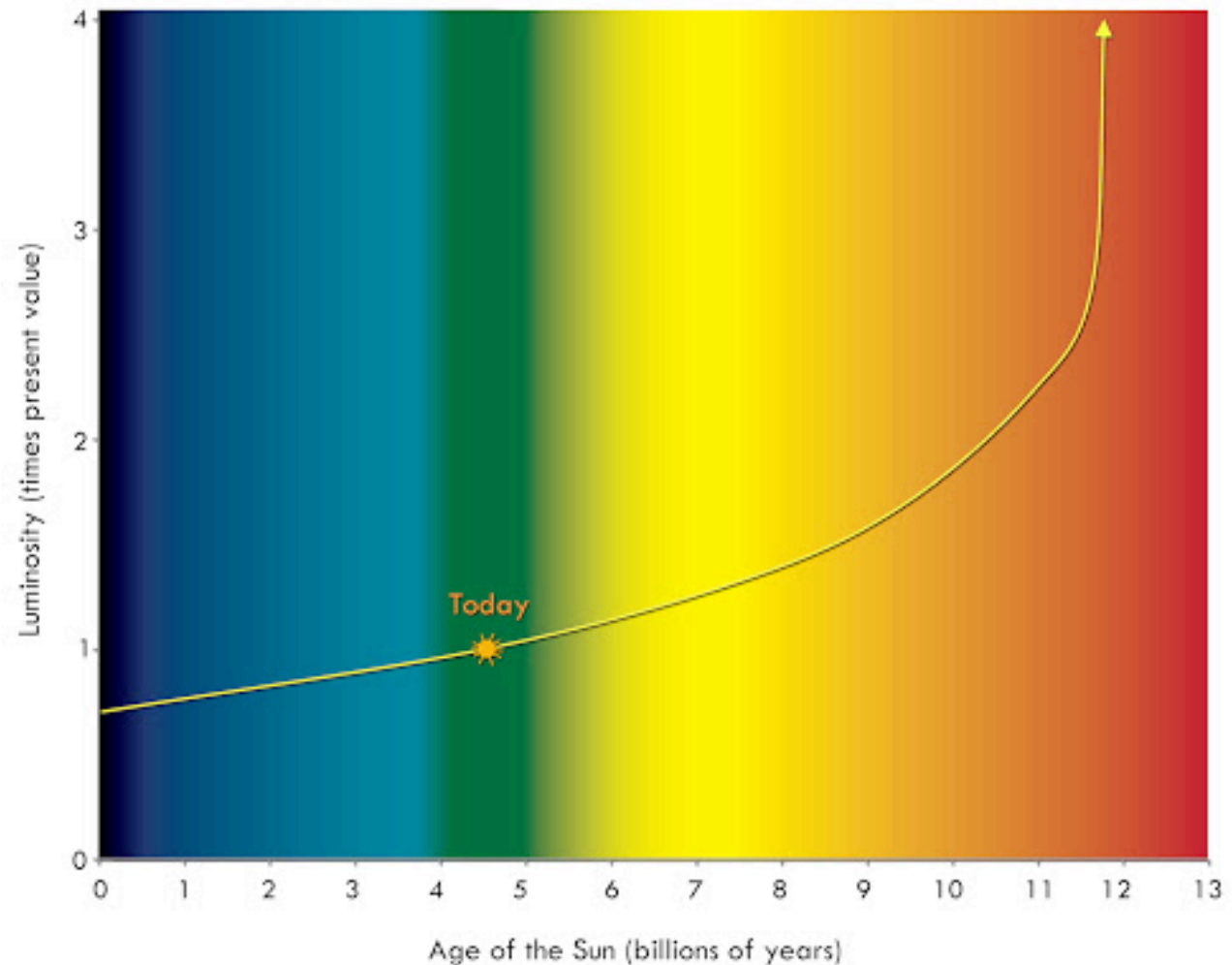
# Global Warming

## Lecture 3.2

### Sunlight & Seasons

# 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.

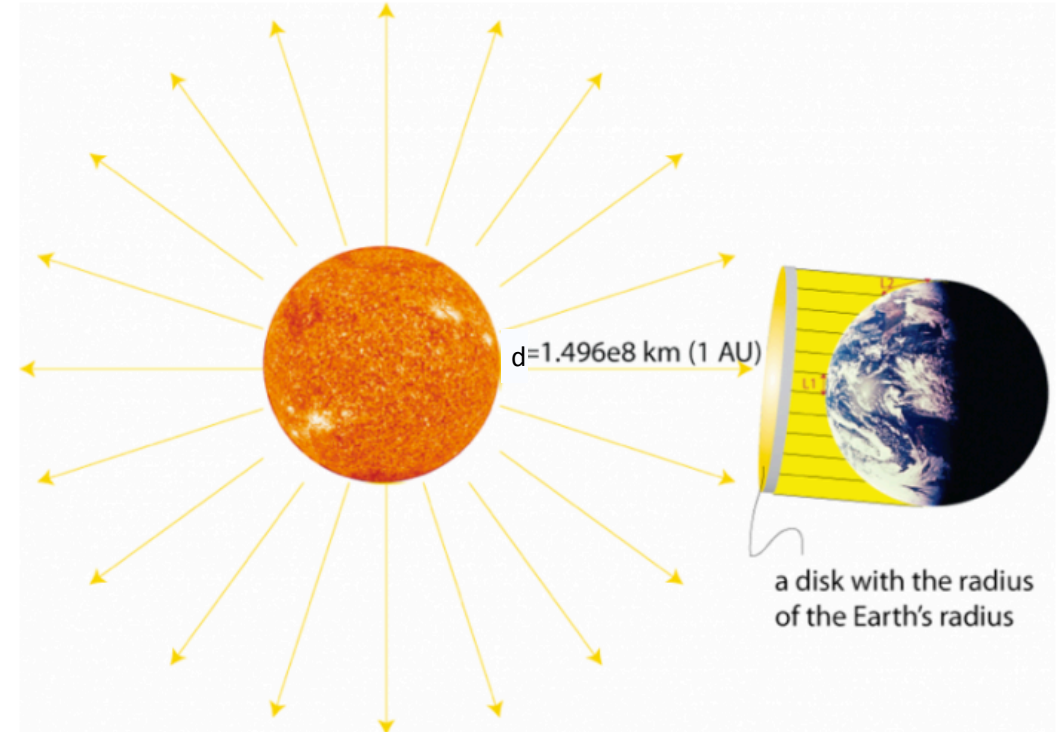
$$S_0 = \frac{L}{4\pi d^2}$$

Isolation [W/m<sup>2</sup>]  
(Solar constant)

Sun's luminosity [W]

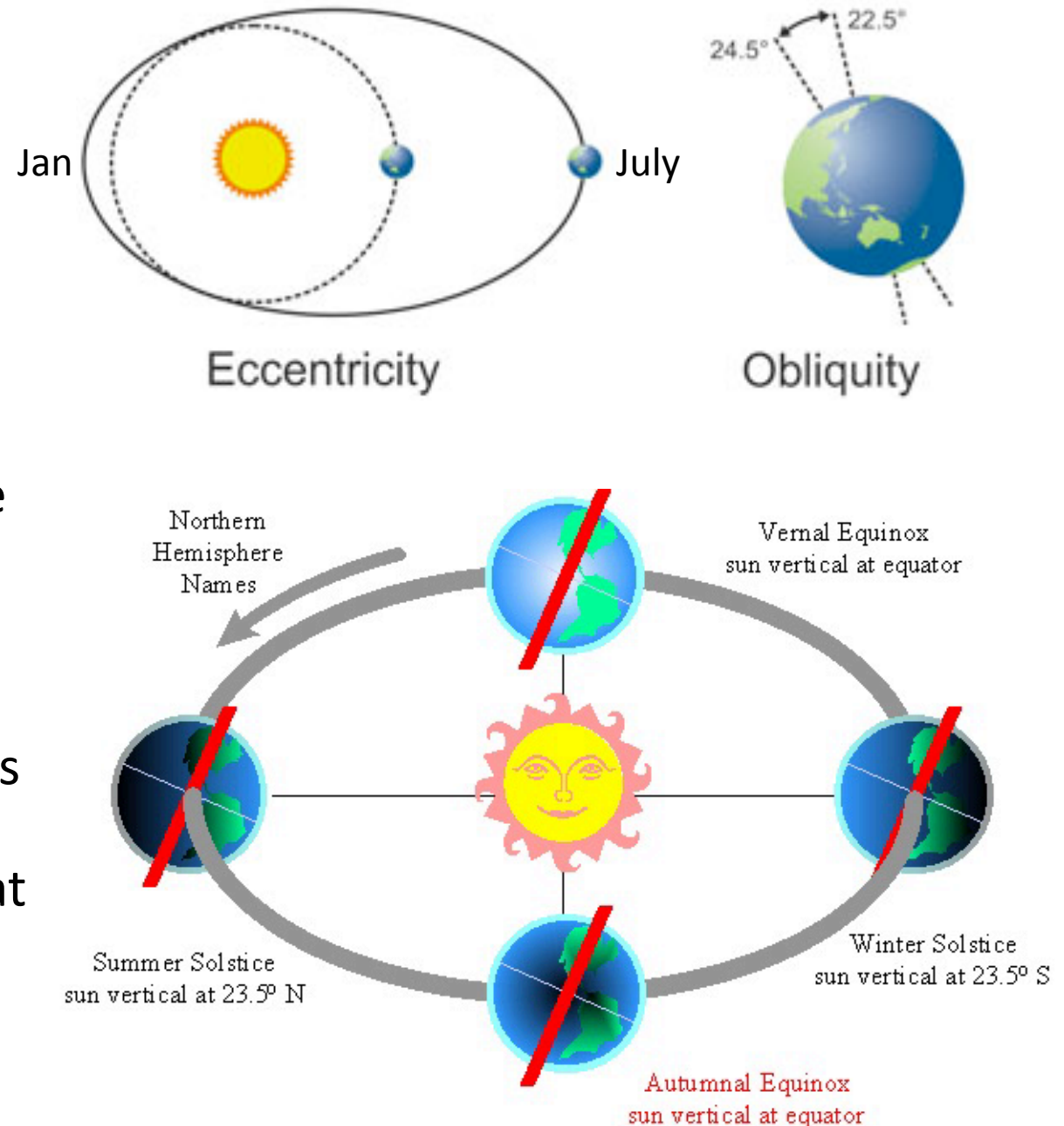
Distance to the Sun [m]

The diagram shows the formula for insolation,  $S_0 = \frac{L}{4\pi d^2}$ . The variable  $S_0$  is labeled as 'Isolation [W/m<sup>2</sup>] (Solar constant)'. The variable  $L$  is labeled as 'Sun's luminosity [W]'. The variable  $d$  is labeled as 'Distance to the Sun [m]'. The  $d^2$  term in the denominator is circled in red.



# 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.

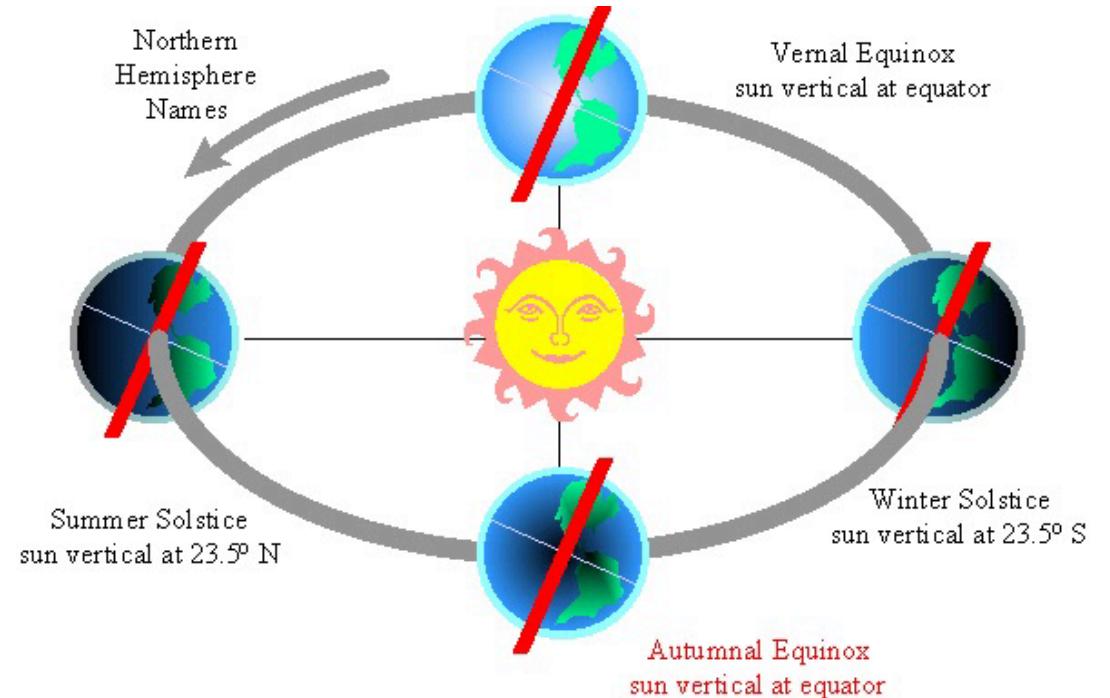
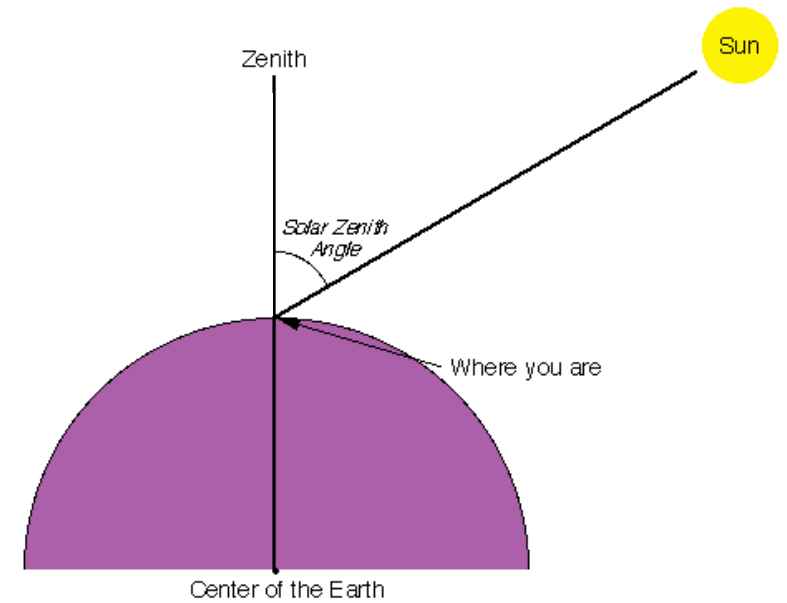


# Solar Zenith Angle

- The solar zenith angle ( $\theta_z$ ) 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:  $\theta_z = \text{Latitude}$

