General Meteorology

Lecture 4

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Electromagnetic Radiation

$$E = h\nu = \frac{hc}{\lambda}$$

Planck's function

$$E_{\lambda}(\mathrm{T}) = \frac{2\pi h c^{2}}{\lambda^{5}\left(e^{hc/\lambda k \mathrm{T}} - 1\right)}$$

Stefan-Boltzmann Law

$$\mathbf{E = \sigma T^4}$$

Wien's Displacement Law

$$\lambda_{\text{peak}} = \mathbf{b / T}$$

Kirchhoff's Law

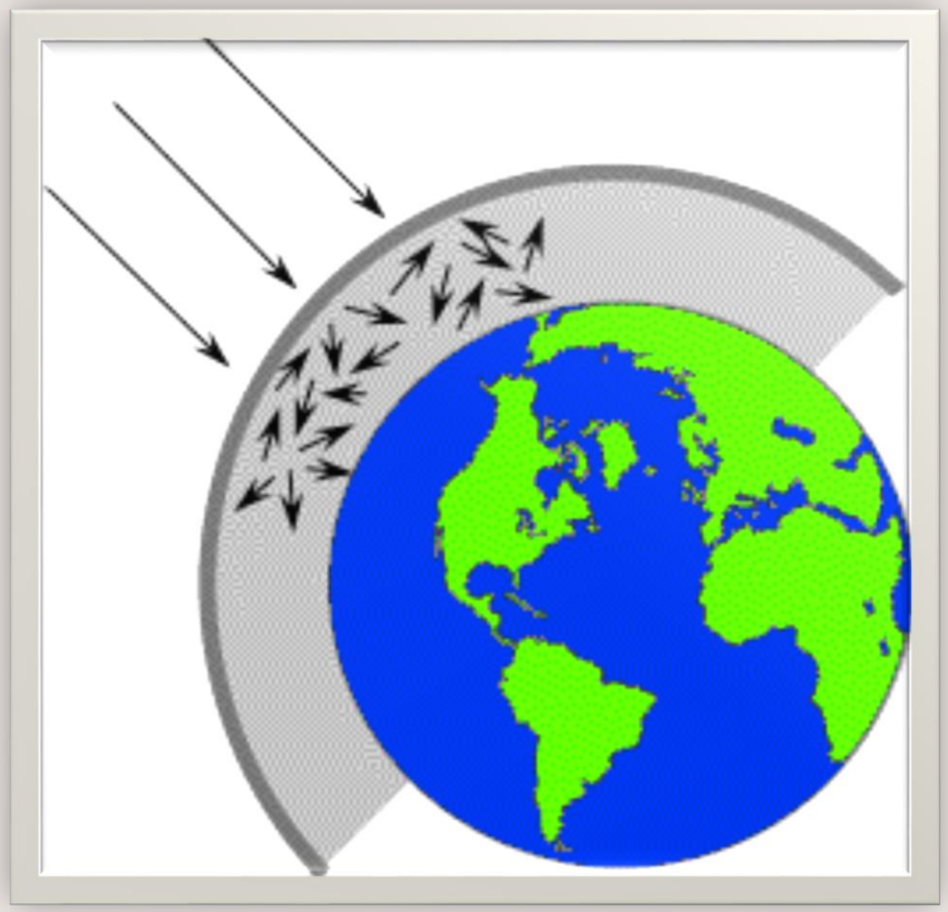
$$\frac{F_{\lambda}}{F_{B}} = a_{\lambda}$$

Solar Constant

The **solar constant** is the rate at which solar radiation (i.e. the irradiance) passes through an area perpendicular to the direction that the electromagnetic waves are traveling at the top of the Earth's atmosphere.

The **solar constant** is **1367 W m^{-2}**.

The Influence of Atmosphere



Rayleigh scattering

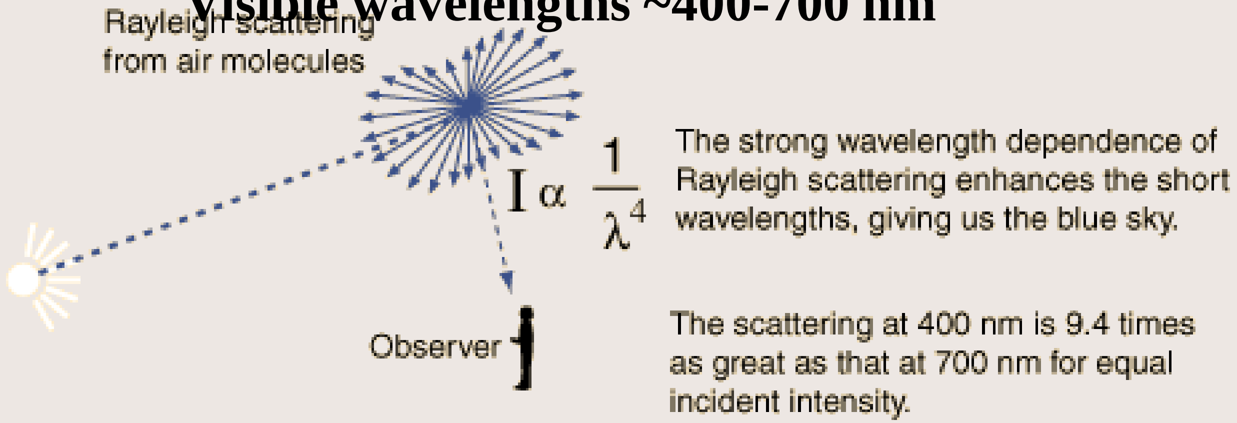
Atmospheric composition: N_2 (78%), O_2 (21%), Ar (1%)

Size of N_2 molecule: 0.31 nm

Size of O_2 molecule: 0.29 nm

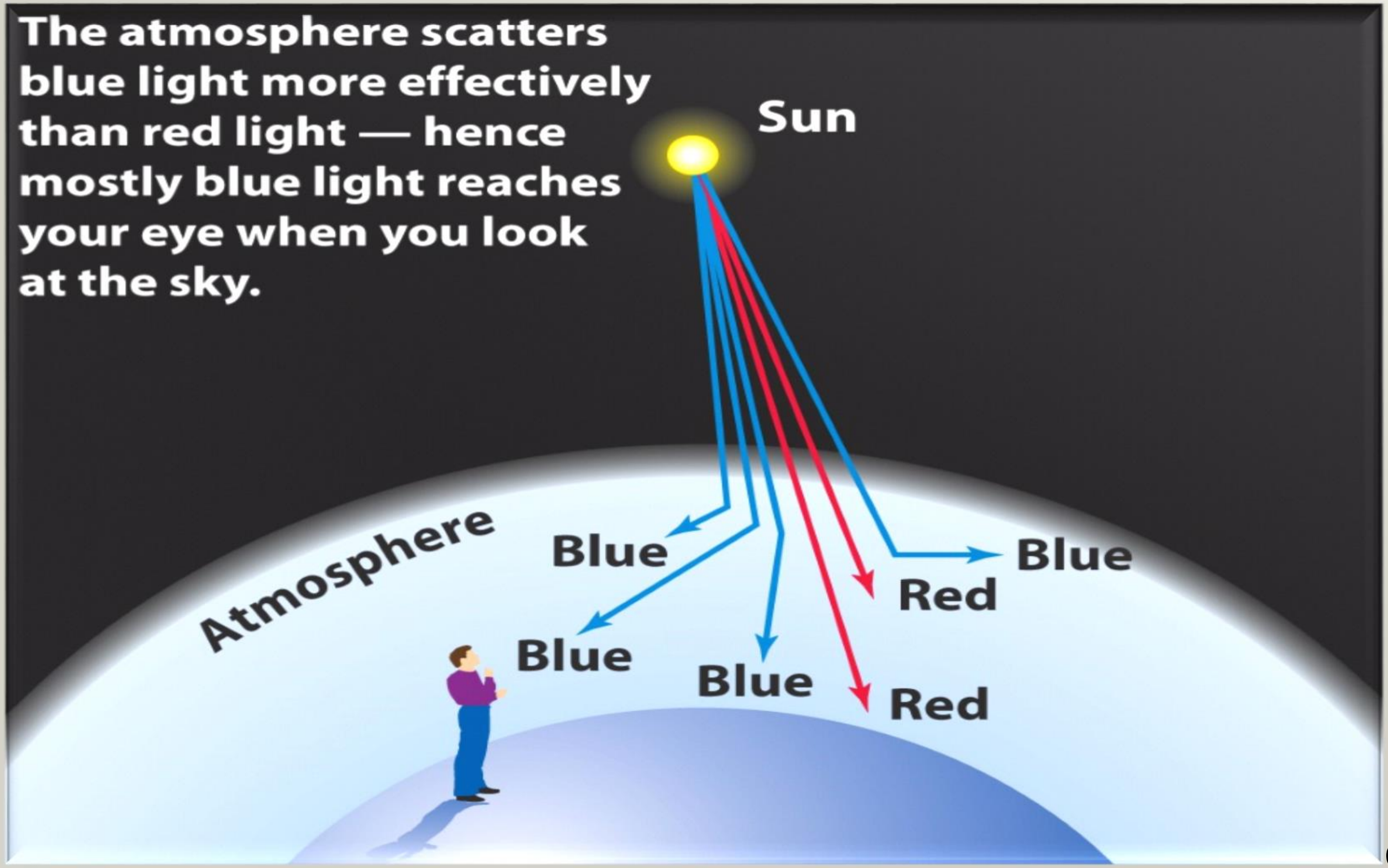
Size of Ar molecule: 0.3 nm

Visible wavelengths ~400-700 nm



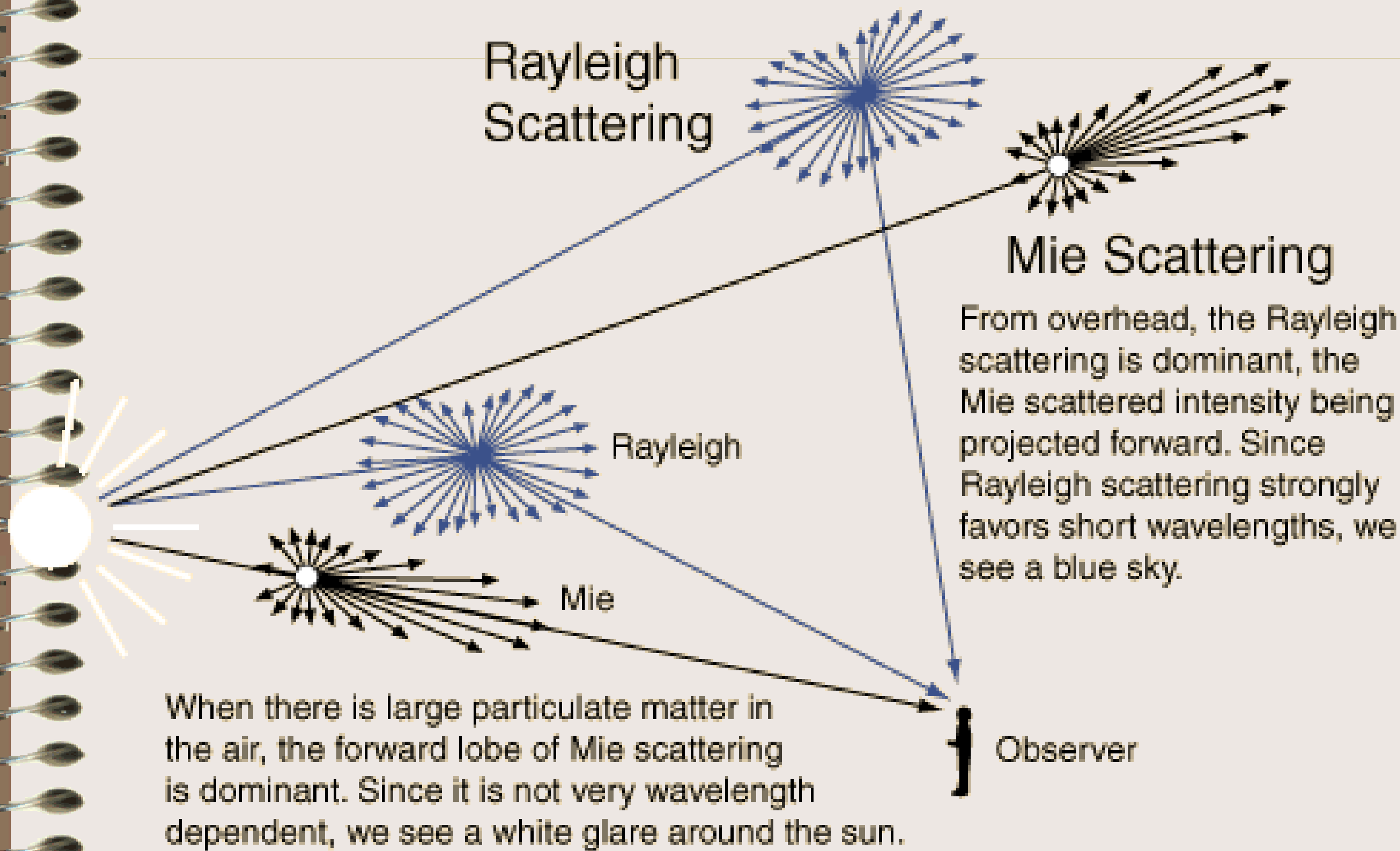
- Scattering of light off air molecules is called Rayleigh Scattering
- Involves particles much smaller than the wavelength of incident light
- Responsible for the blue color of clear sky

SCATTERING



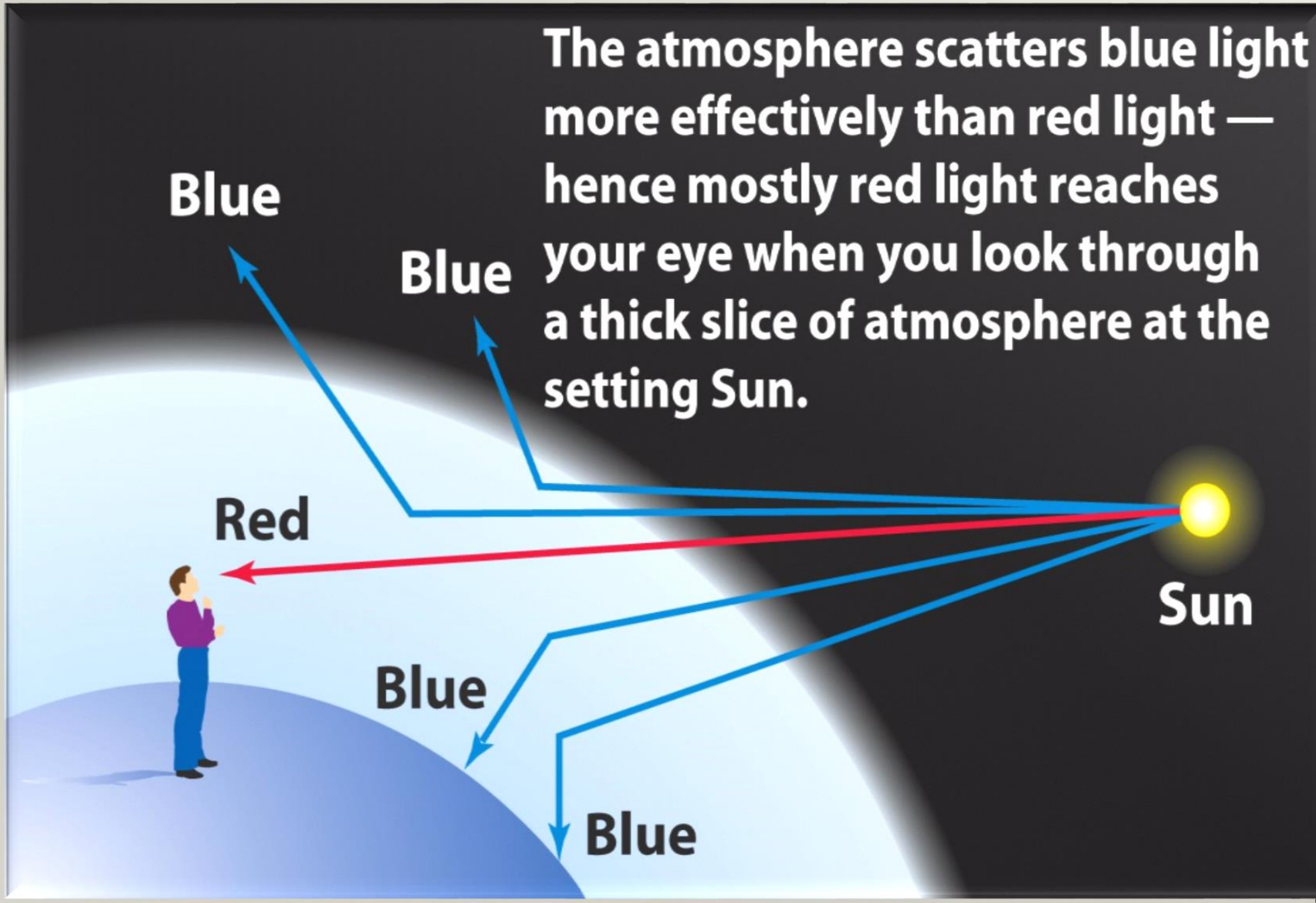
The atmosphere scatters blue light more effectively than red light — hence mostly blue light reaches your eye when you look at the sky.
Sun
Atmosphere
Blue
Blue
Blue
Blue
Red
Red

Rayleigh and Mie scattering



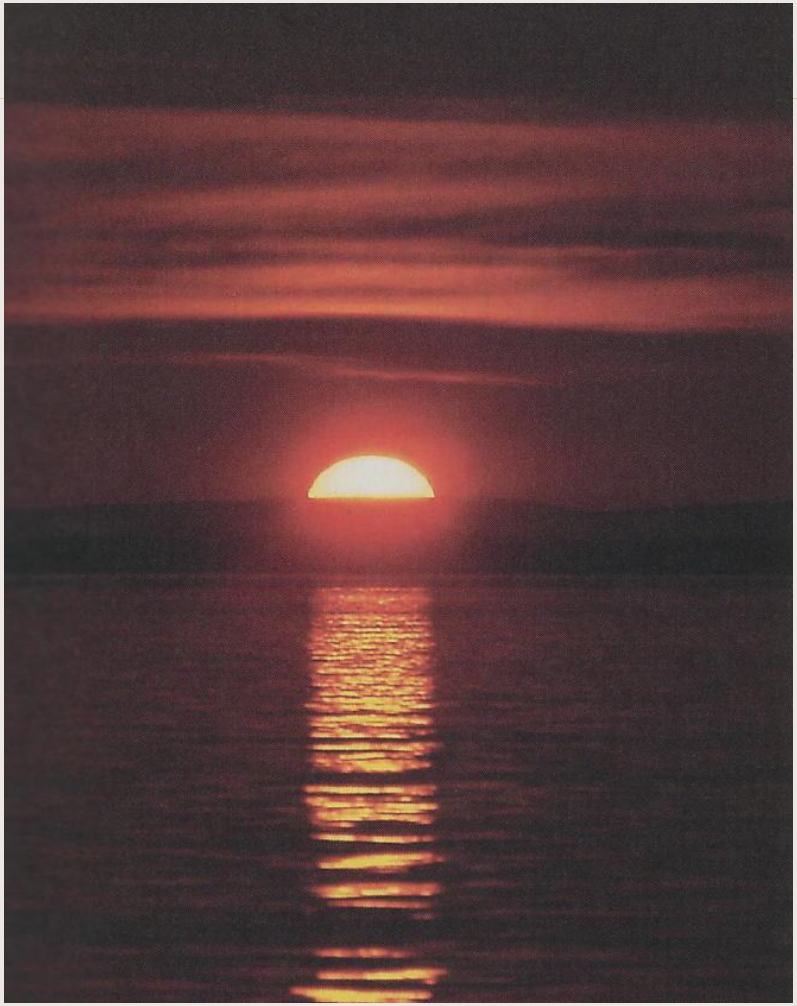
Scattering determines the brightness and color of the sky

SCATTERING

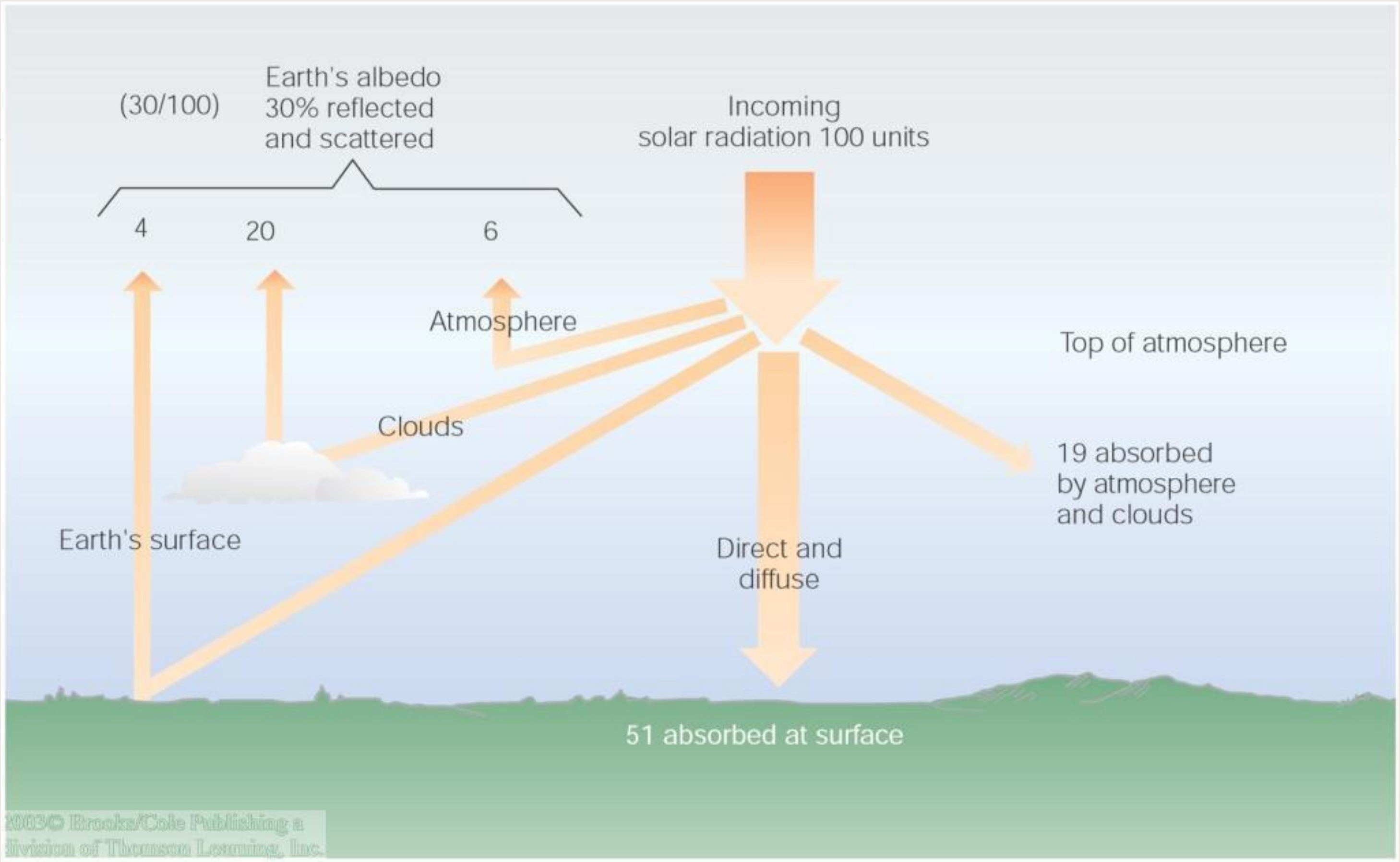

The atmosphere scatters blue light more effectively than red light — hence mostly red light reaches your eye when you look through a thick slice of atmosphere at the setting Sun.
Blue
Blue
Red
Sun
Blue
Blue

Why are sunsets red?

- The sun appears fairly white when it's high in the sky
- Near the horizon, sunlight must penetrate a much greater atmospheric path
  – More scattering
- Scattering by gases removes short visible λ's from the line-of-sight
  – Sun appears orange/yellow because only longer wavelengths make it through
- When particle concentrations are high, the slightly longer yellow λ's are also scattered
  - Sun appears red/orange



Incoming Solar Radiation



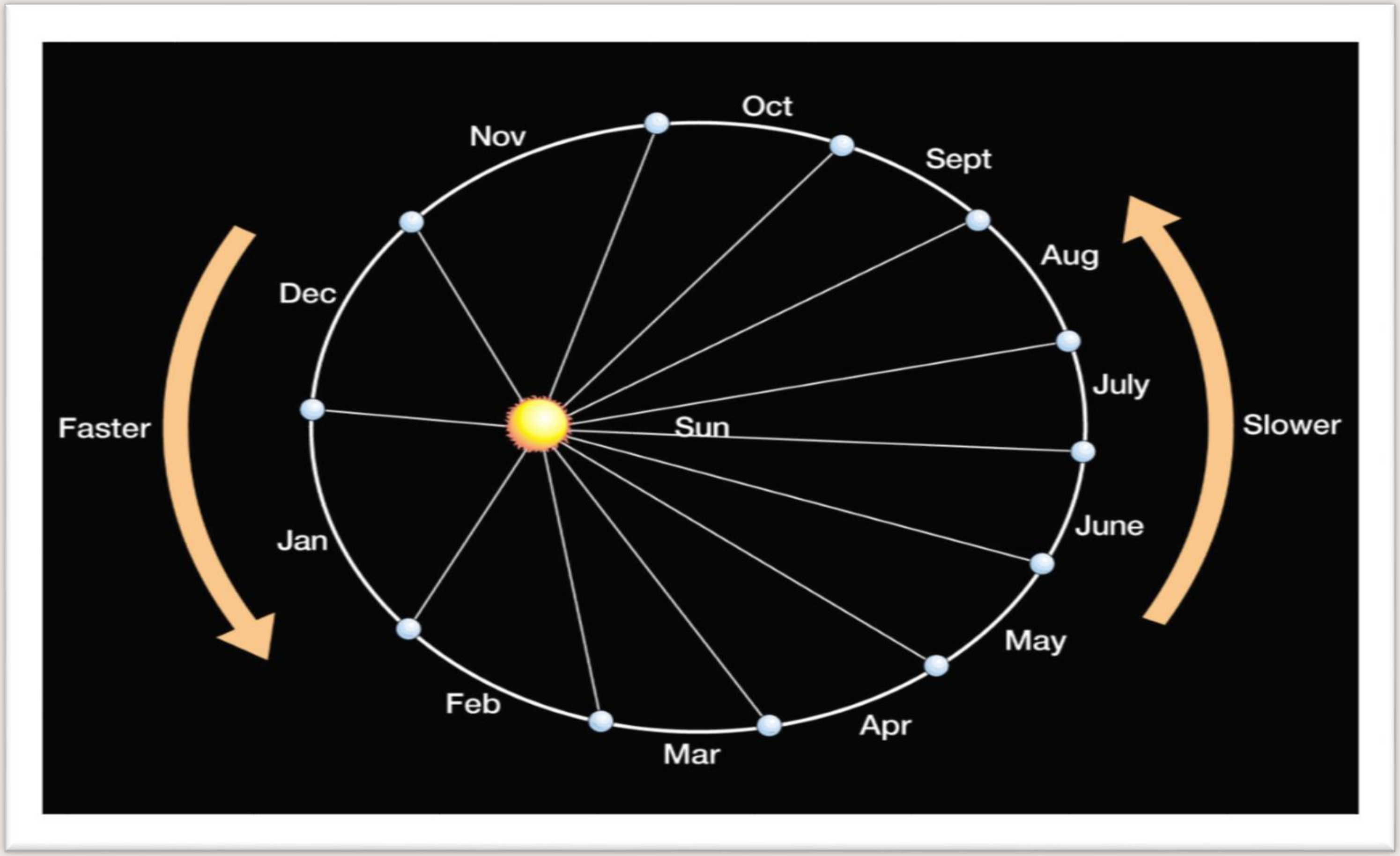
Solar radiation is scattered and reflected by the atmosphere, clouds, and earth's surface, creating an average albedo of 30%.

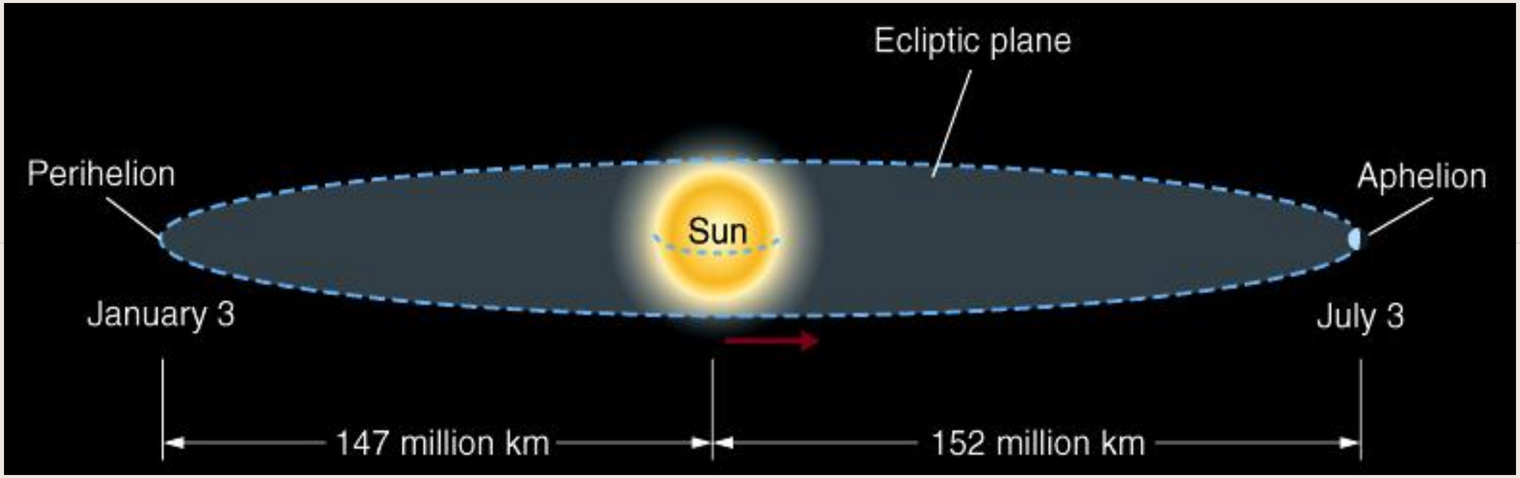
Atmospheric gases and clouds absorb another 19 units, leaving 51 units of shortwave absorbed by the earth's surface.

Earth motions

- Two primary motions
  - Rotation
    - Turning, or spinning, of a body on its axis

Kepler’s law of equal areas





complete revolution = 365.25 days (1 year)

orbit is elliptical → distance from sun varies

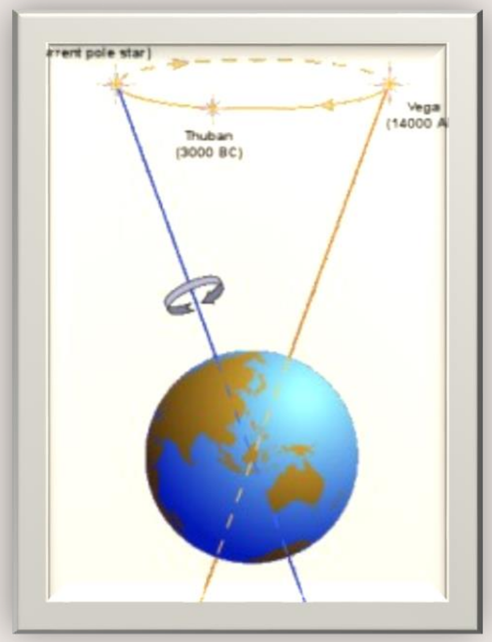
perihelion: near sun (Jan. 3), 147 million km

apehelion: furthest away (July 3), 152 million km

NOT responsible for seasons determines the length of the year and duration the seasons

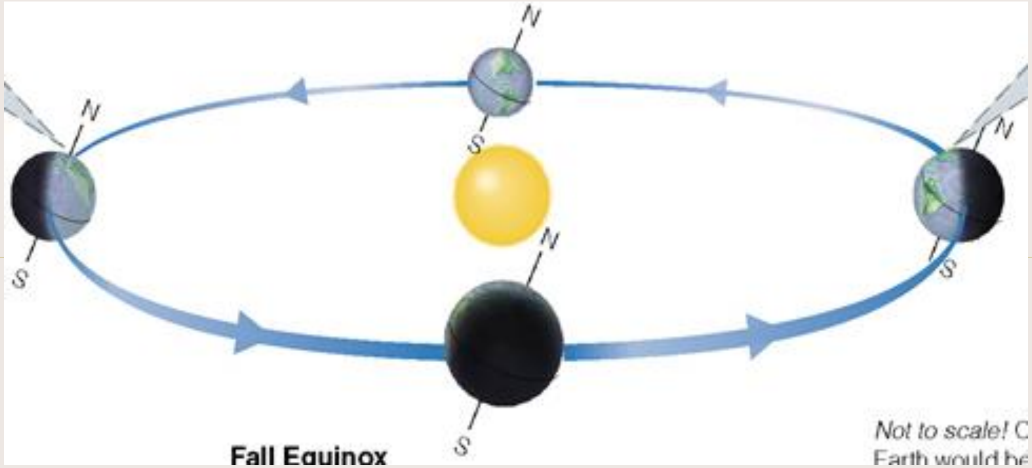
Earth precession

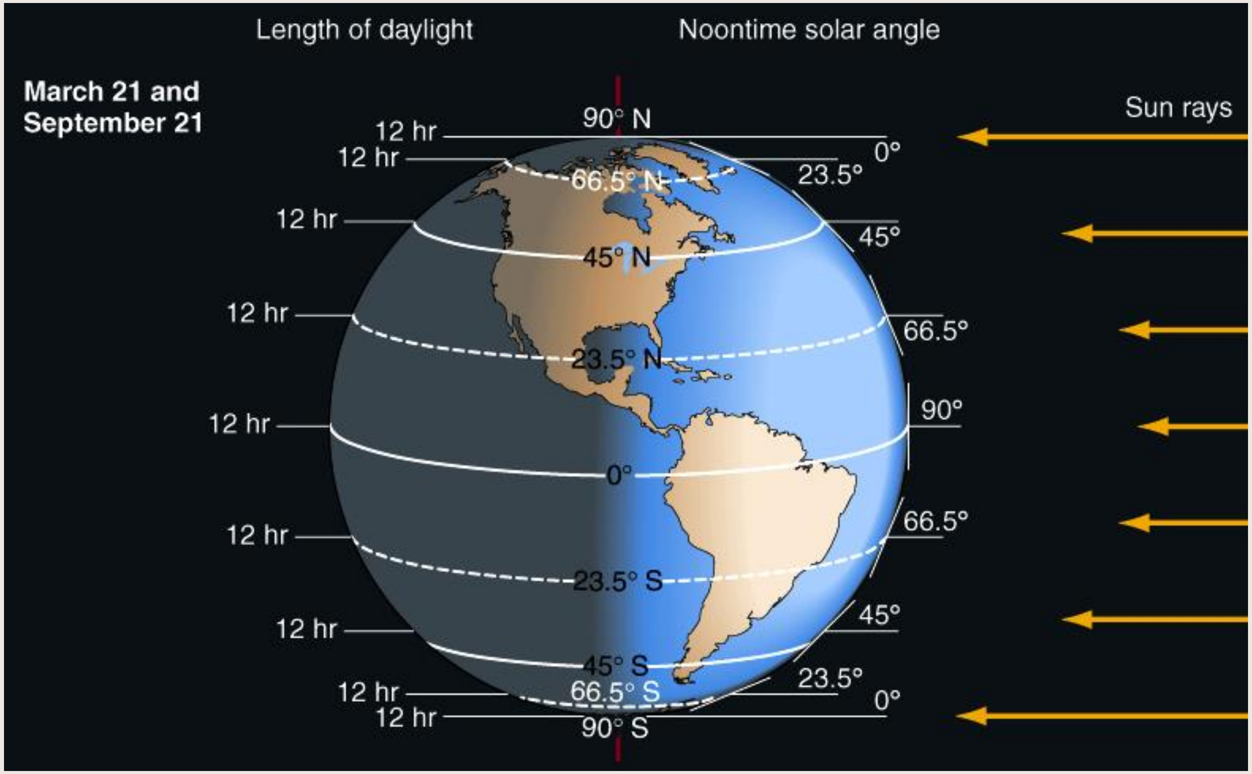
The Earth's rotation axis is not fixed in space. Like a rotating toy top, the direction of the rotation axis executes a slow precession with a period of 26,000 years (see following figure).



Reasons for the Seasons

Earth's Orbit and Orientation


N
S
Fall Equinox
Not to scale! C
Earth would be


Length of daylight
Noontime solar angle
March 21 and
September 21
Sun rays
12 hr
90° N
0°
66.5° N
23.5°
45° N
45°
66.5°
23.5° N
90°
0°
23.5° S
45° S
66.5° S
90° S

The Reasons for the Seasons on Earth

The seasons *on Earth* are caused by the 23.5° tilt of its rotation axis, and its revolution around the Sun.

Although the distance of the Earth to the Sun changes slightly as it orbits around the Sun, its effect is not big enough to cause the four seasons.

The seasons for other planets may be due to the changing

distance to the Sun, not the tilt of their rotation axis…For example, the orbit of Pluto has a very large eccentricity.

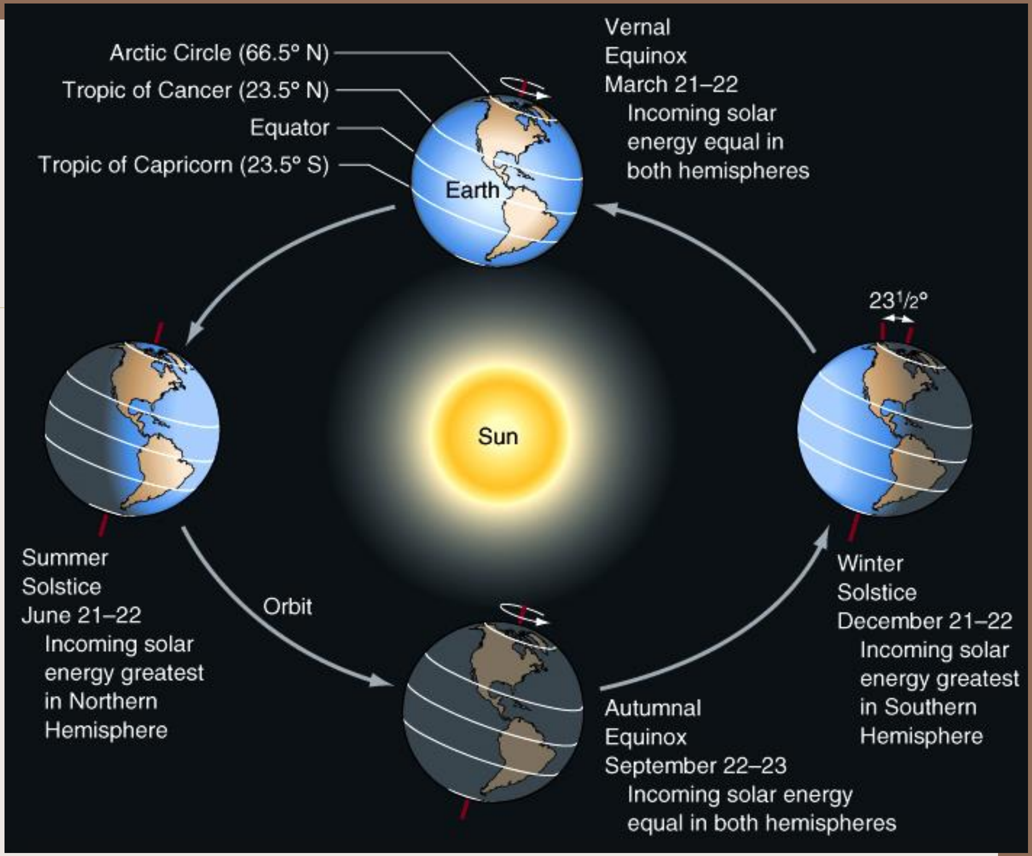
Four Cardinal Dates

Orientation

rotation → spins on its axis

determines day length

axis tilted 23.5° (constant)



REASON FOR SEASONS

w/o tilt no seasonal change →

constant Spring/Fall conditions with

equal days/nights everywhere

How does Day Length influence energy receipt?

June 21st

Arctic Circle – N. pole → 24 hrs light

Antarctic Circle – S. pole → dark

high northern latitudes longer days

high southern lat. shorter days

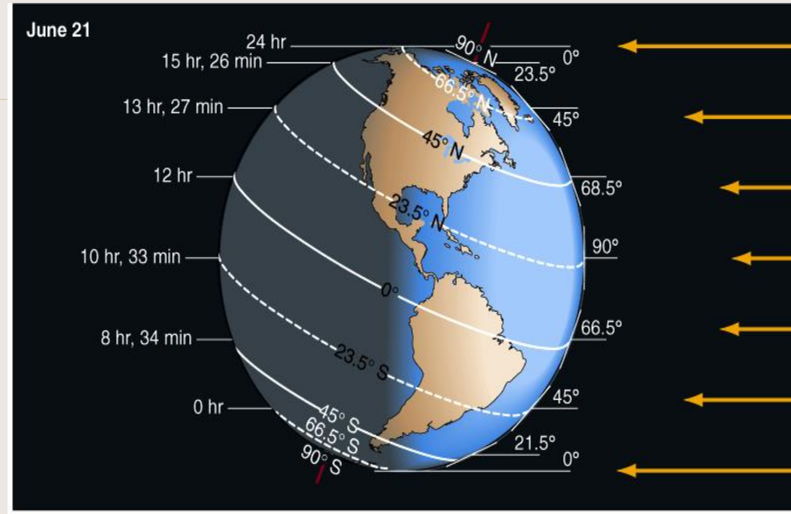
December 21st

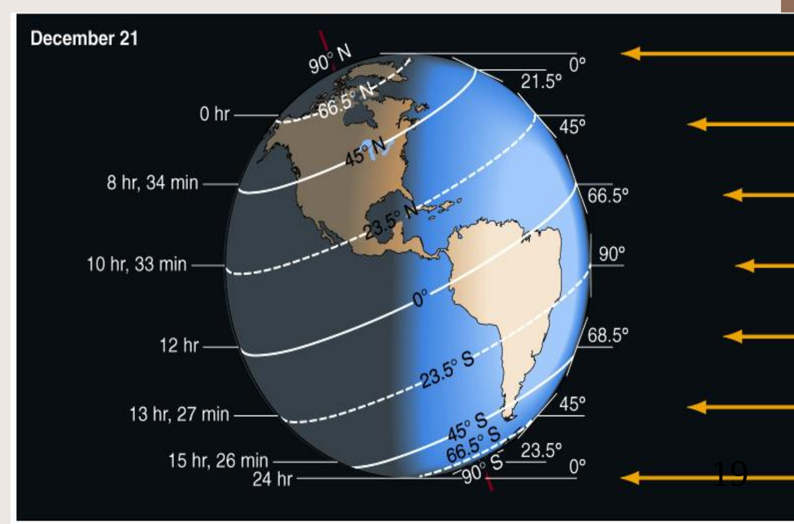
Arctic Circle – N. pole → dark

Antarctic Circle – S. pole→24 hrs light

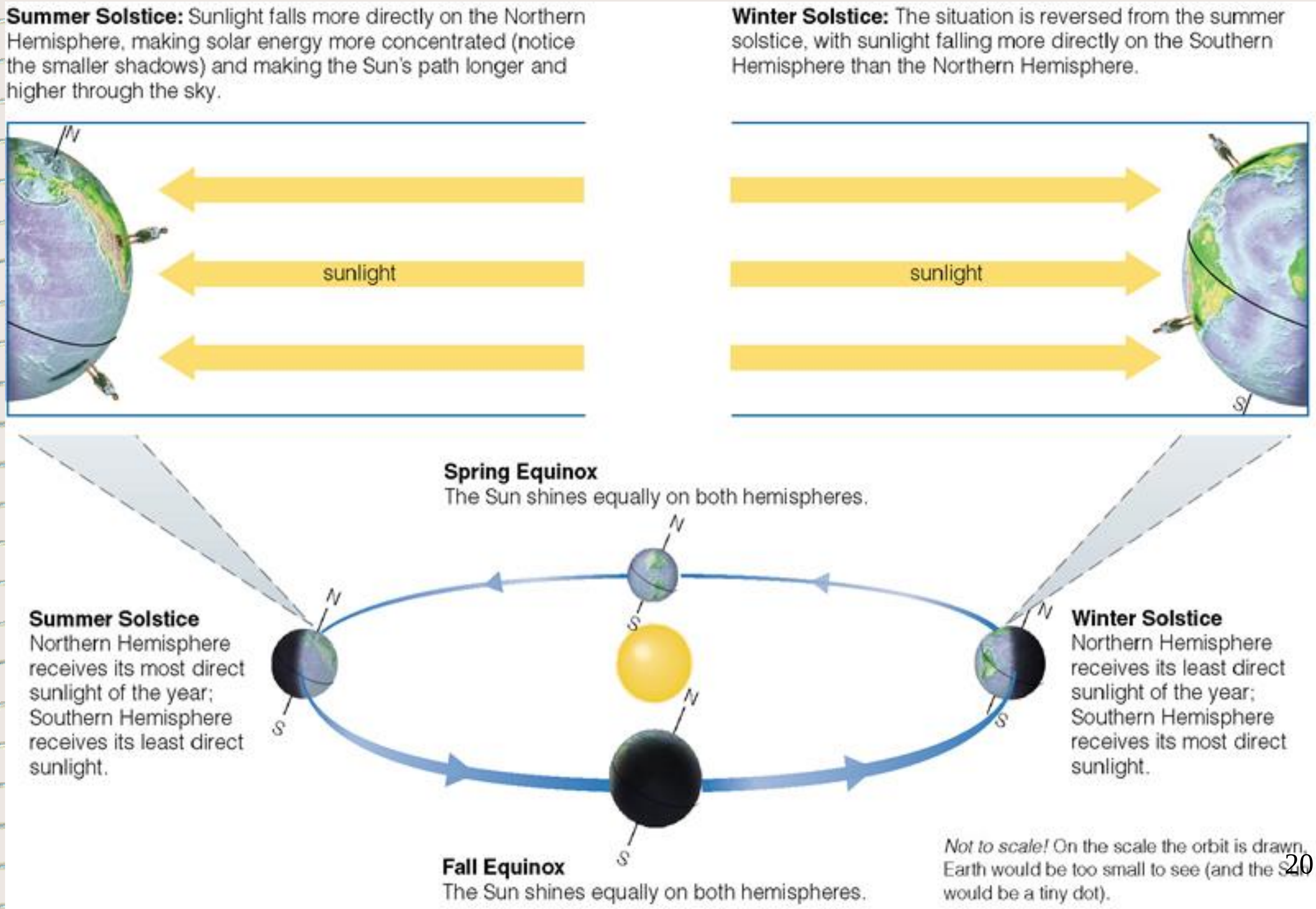
high northern latitudes short days

high southern lat. long days



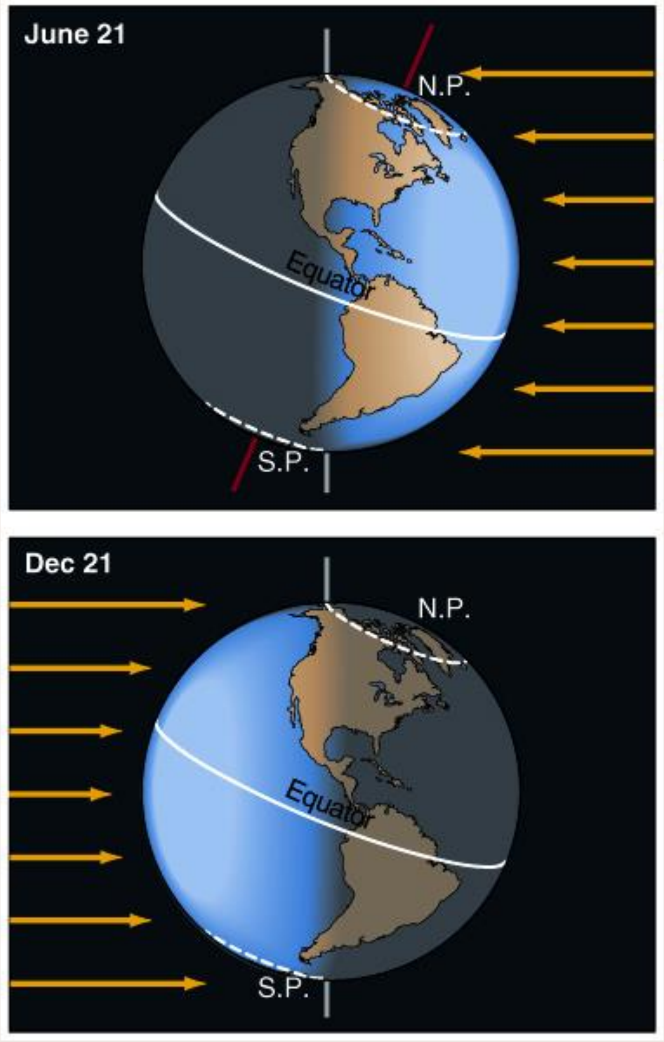


The Four Seasons: The Effect of the Tilt of Earth's Rotation Axis

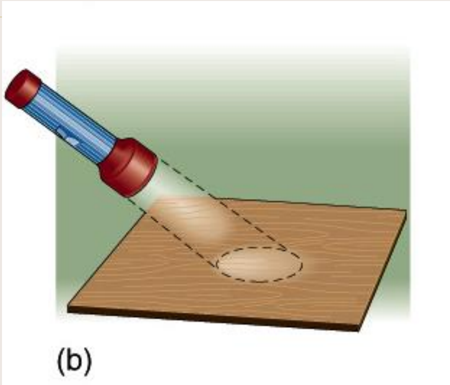


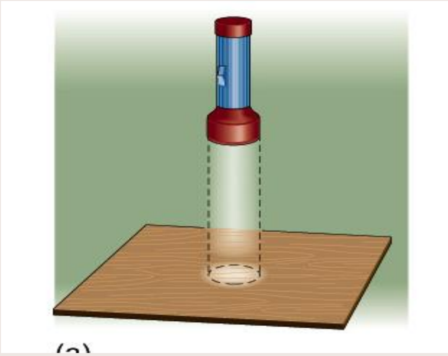
The tilt of Earth's axis affects solar rad'nreceipt in 3 ways:

1) **Length of daylight**
2) **Solar angle**
3) **Beam depletion**



How does Solar Angle influence heating?





related to beam spreading

smaller the solar angle, greater surface area rad’n spread

decreases intensity

beam spreading limited in summer

major role in causing seasons → not precise

How Does Beam Depletion Influence Energy Receipt?