Moving Energy Around

Radiation - Requires no medium for transport, so very fast.

Advection - Horizontal transport like winds and ocean currents.

Convection - Upward vertical transport like convective storms.

Conduction - Transport through solid objects, very slow.

Latent Heat - Energy absorbed or released as water changes state.

Winds and Ocean Currents Represent Advection

Clouds Rise Because of Convection

A Hurricane Is Driven by a Combination of Advection, Convection and Release of Latent Heat

Energy, Radiation, and Atmosphere

Solar Radiation drives physical and life processes.

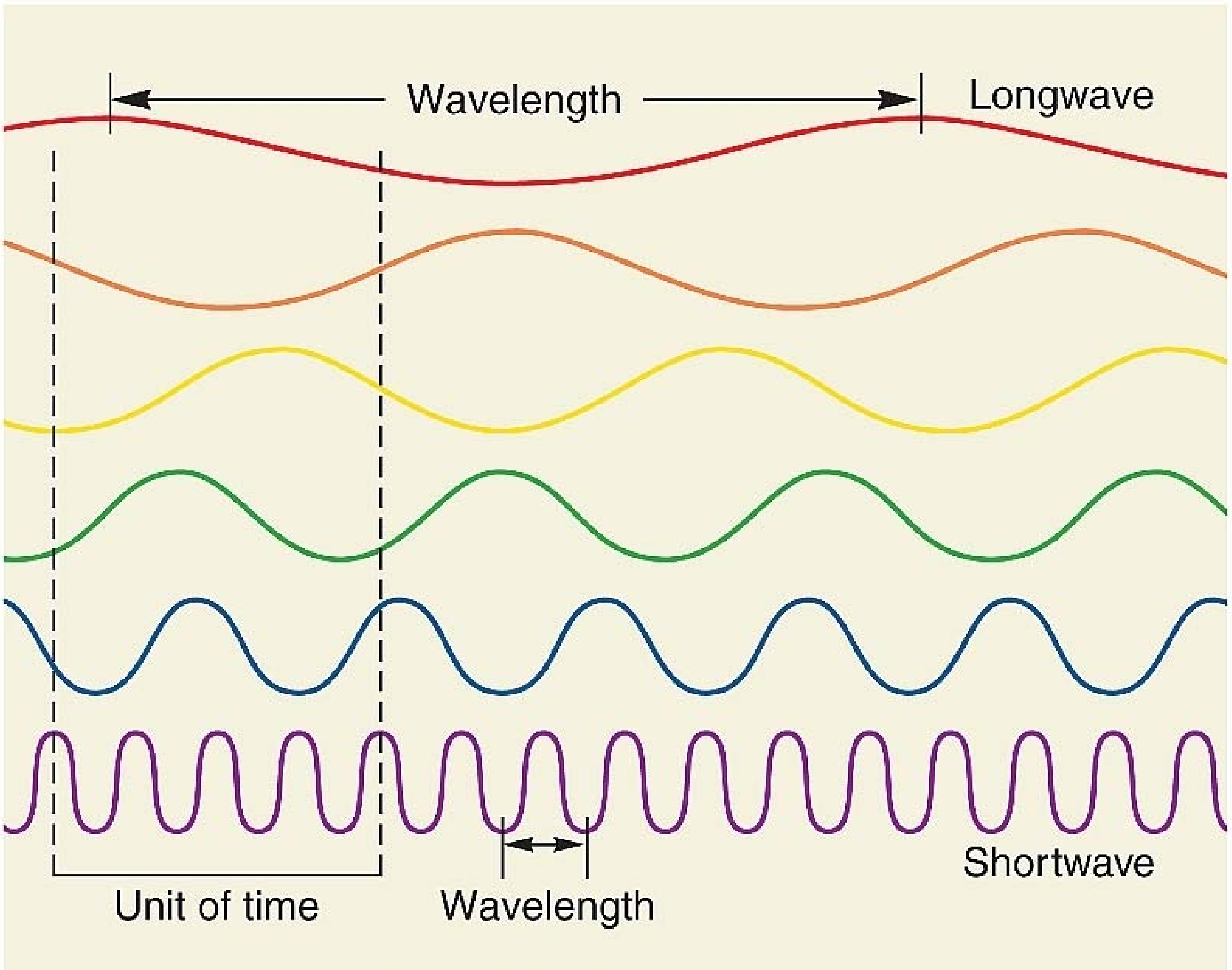
The sun produces the same amount of energy, day to day, year to year. This is the solar constant.

Solar Radiation is part of the Electromagnetic Spectrum.

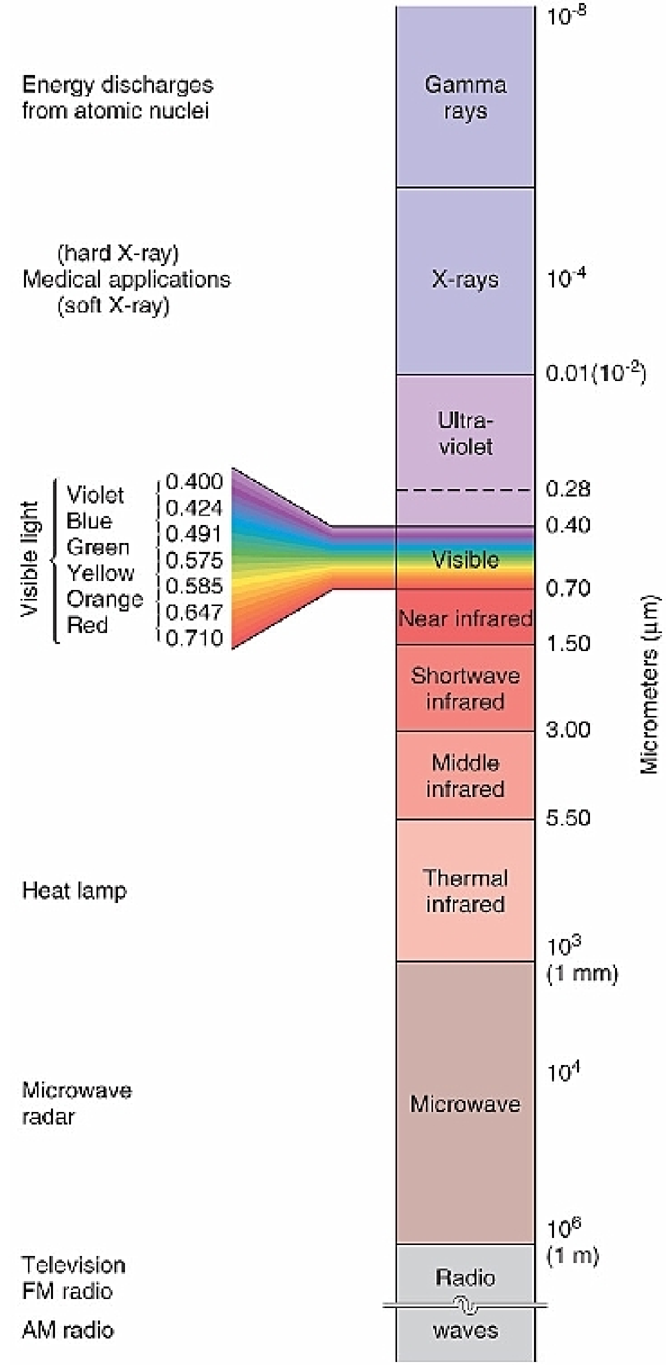
The EMS is divided into bands based on wave length.

- The hotter the object, the shorter the wave length emitted.
- The shorter the wave length, the more energy it carries.
- The sun produces short wave energy, 1/2 is light.
- The earth produces long wave energy in thermal Infrared band called “heat”.

All Electromagnetic Energy Travels at the Speed of Light. Short Wavelengths Transfer More Energy than Long Ones

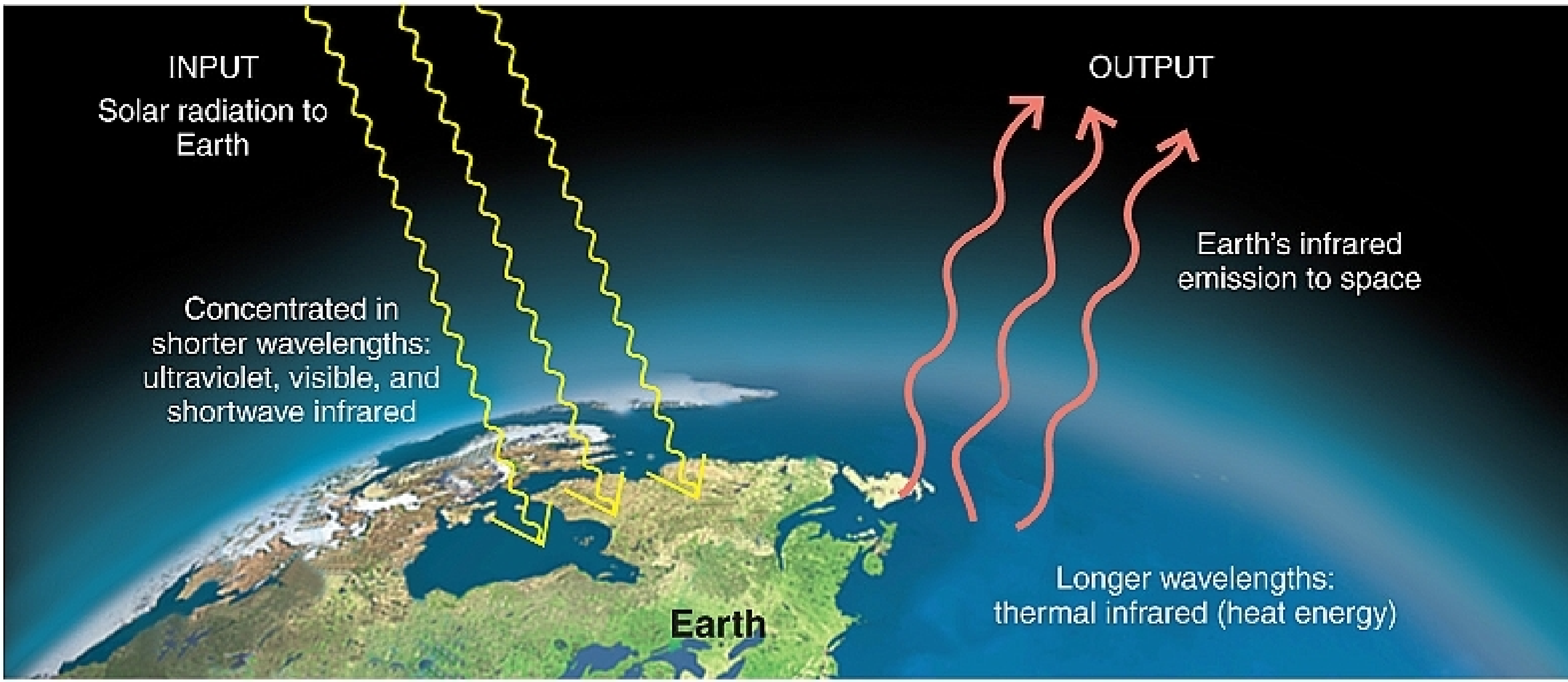


The Bands of the Electromagnetic Spectrum. Visible Light is in the Middle (Known as ROYGBIV). Bands Shorter than Light Are Dangerous

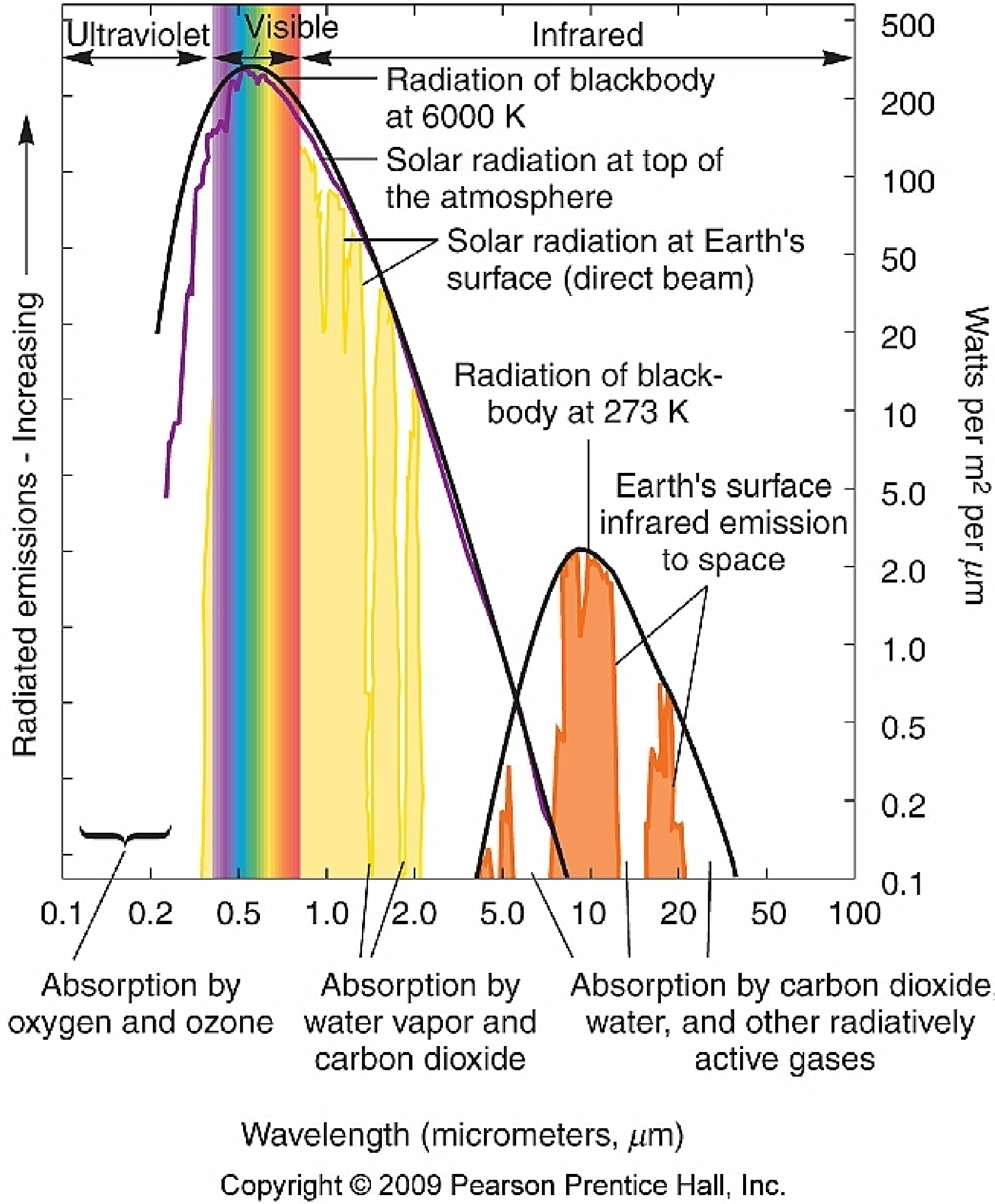


The Amount of Energy the Earth Radiates to Space Equals the Amount Received from the Sun,

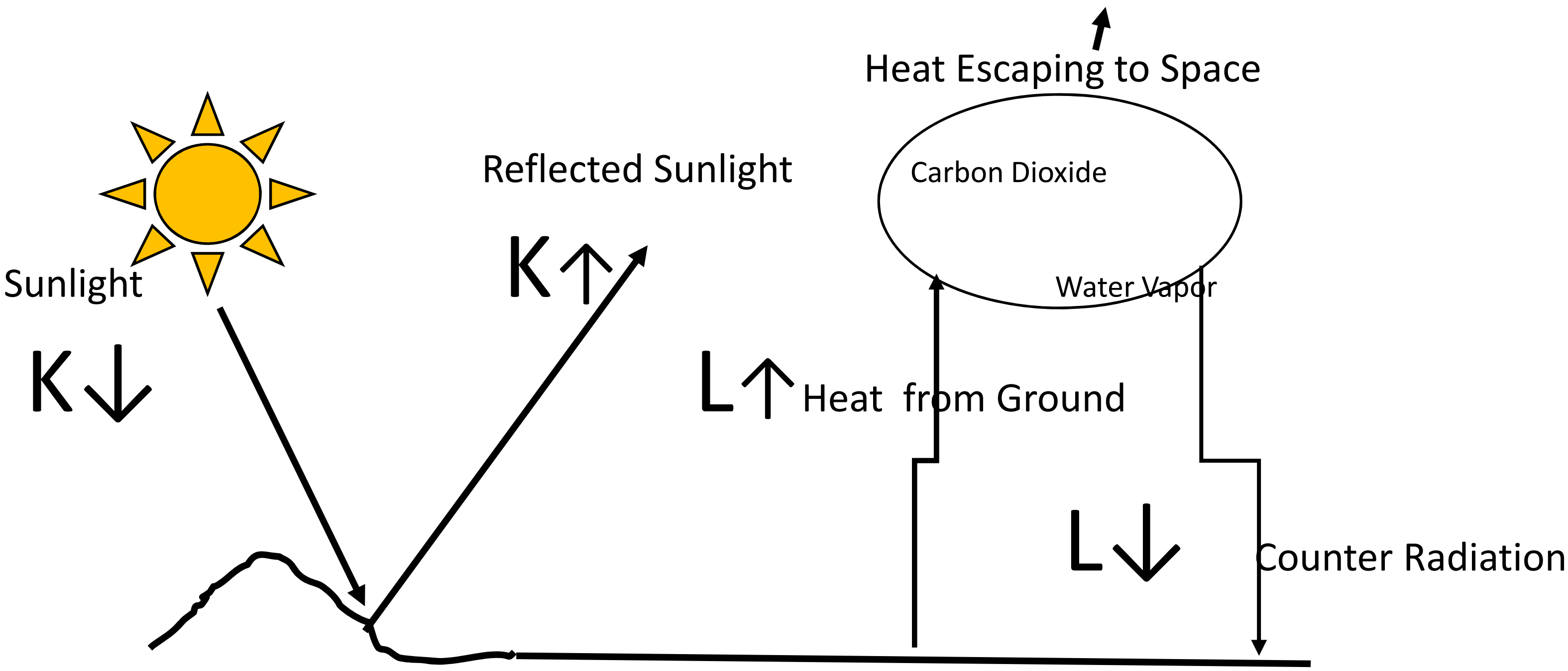
So Energy going Out Equals Energy Coming In



The Sun Produces Energy in the Ultraviolet, Visible and Near Infrared Bands Similar to a 6000° K Object. The Earth Produces Energy in the Thermal Infrared Band (Heat) Similar to a 273° Object.



The Energy Balance and Greenhouse Effect



Net radiation = Q^* = K↓ - K↑ + L↓ - L↑

Example Q^* = 800 W – 200 W + 100 W- 300W = 400 W

The Earth's atmosphere affects the transmission or cascade of solar energy to the surface. So it may be

Transmitted through air or water

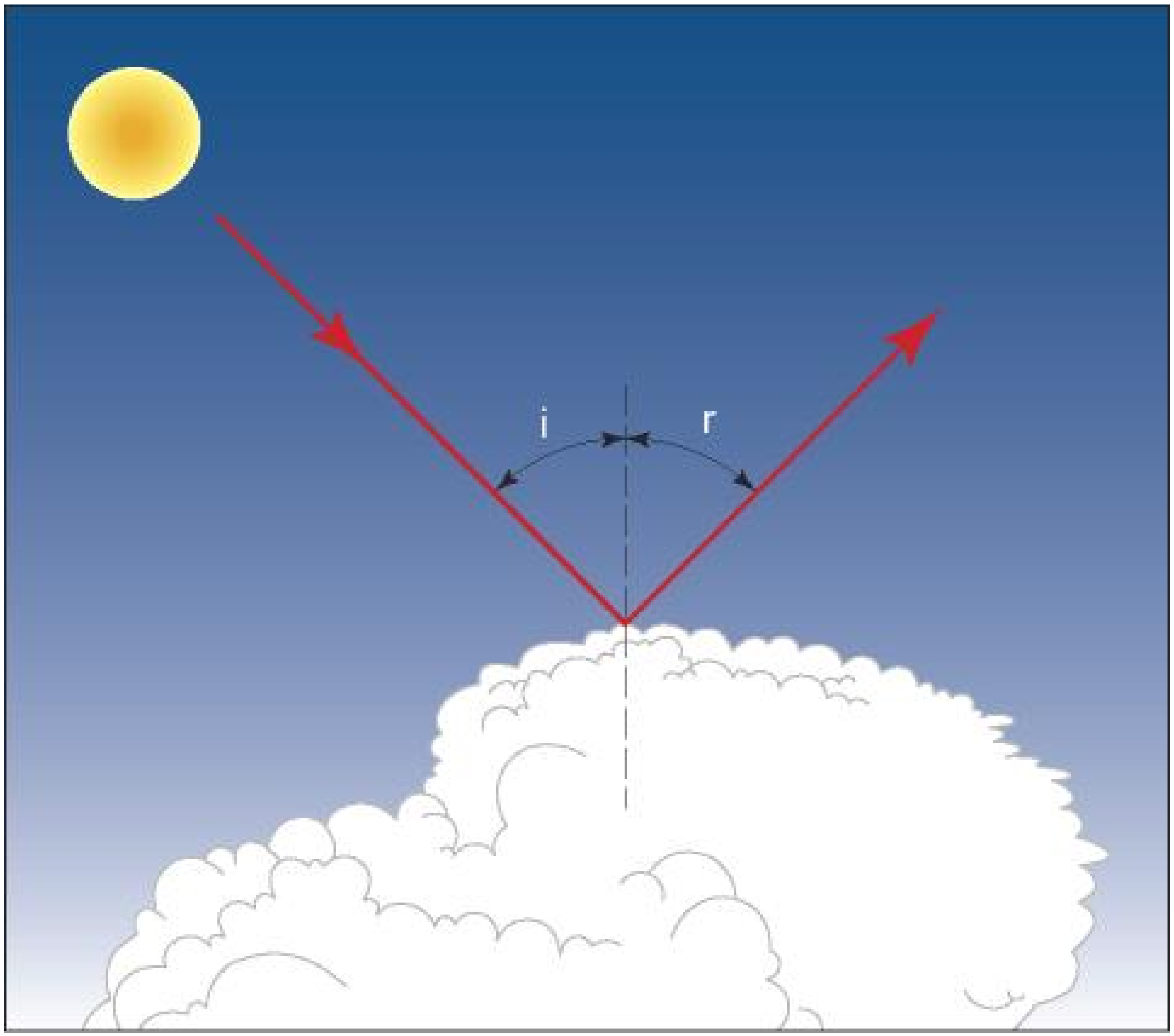
Absorbed by stuff in the air, water or at the surface.
Note: absorption of energy warms the material

.

Reflected away. The proportion of energy reflected away is determined by the materials albedo.

Albedo is important because "reflected energy does no work".

Clouds Have a High Albedo, So Reflect A lot of Sunlight

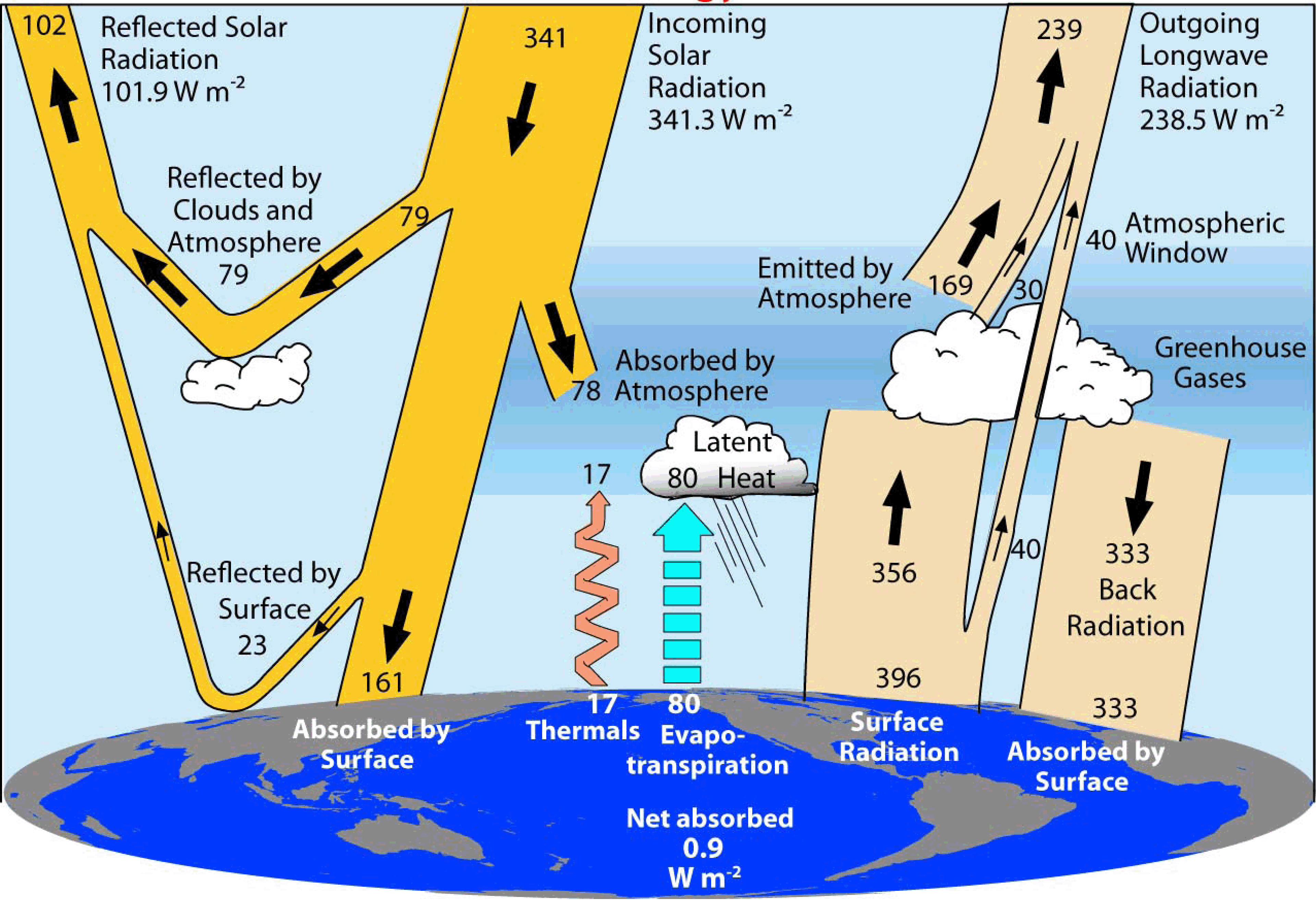


Albedo is the reflectivity of a material. Reflected energy does <u>no work</u> and is lost to the system. Clouds and snow have high albedo, vegetation has low albedo.

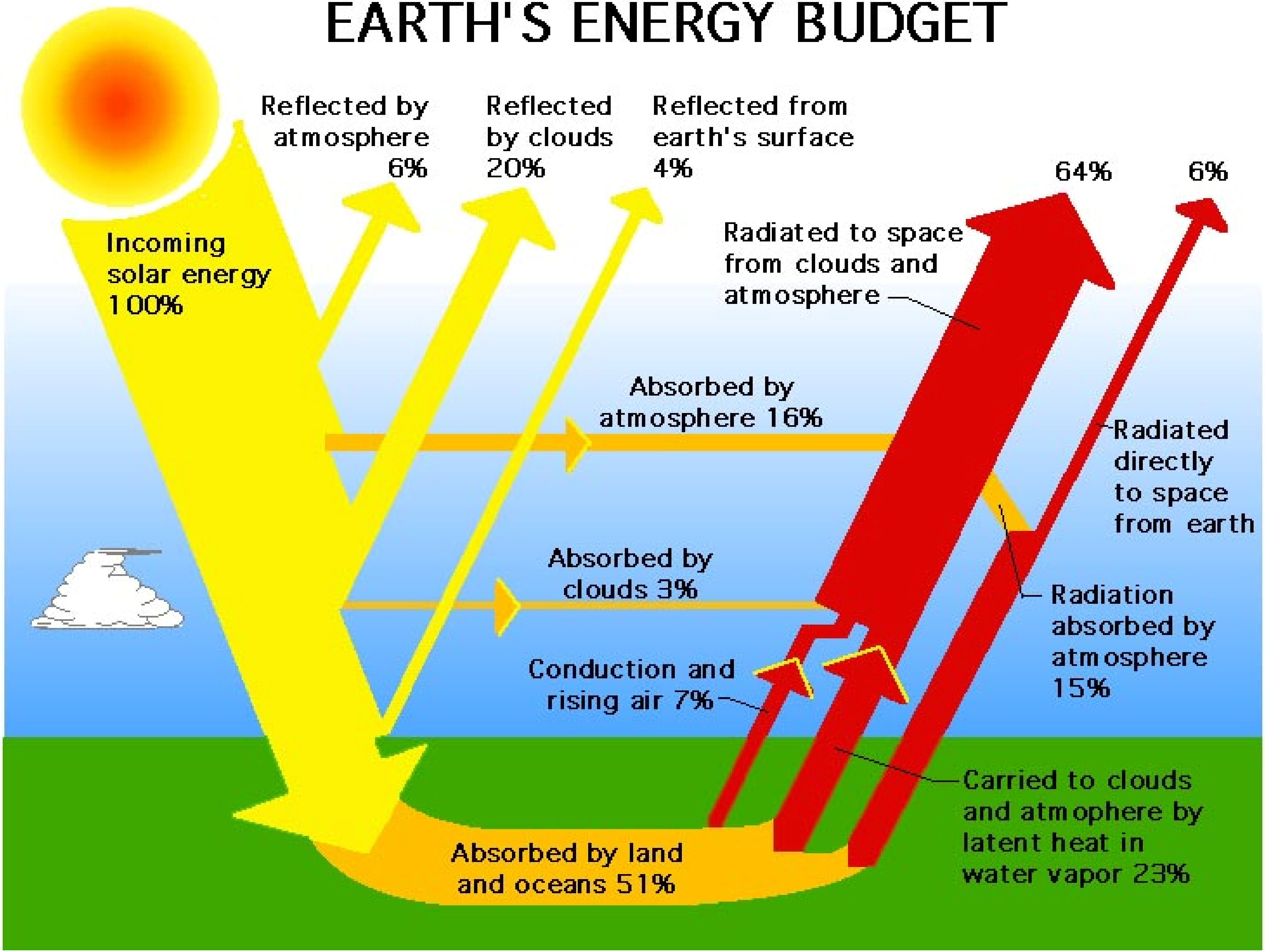
TABLE 3.1
Average Albedo (Reflectivity) of some Common Surface Types for Visible Solar Radiation

Surface	*Albedo (% reflected)*
Deciduous forest	15-18
Coniferous forest	9-15
Tropical rainforest	7-15
Tundra	15-35
Grasslands	18-25
Desert	25-30
Sand	30-35
Soil	5-30
Green crops	15-25
Sea ice	30-40
Fresh snow	75-95
Old snow	40-60
Glacial ice	20-40
Water body (high solar altitude)	3-10
Water body (low solar altitude)	10-100
Asphalt road	5-10
Urban area	14-18
Cumulonimbus cloud	90
Stratocumulus cloud	60
Cirrus cloud	40-50

Global Energy Flows W m^{-2}



EARTH'S ENERGY BUDGET



Controls on Temperature

Solar constant

Distance to sun

Angle of sun – determined by latitude, time of day, time of year

Transparency of the atmosphere

Albedo

Secondary Heating – amount of counter-radiation,
intensity of greenhouse effect

Earth – Sun Relations

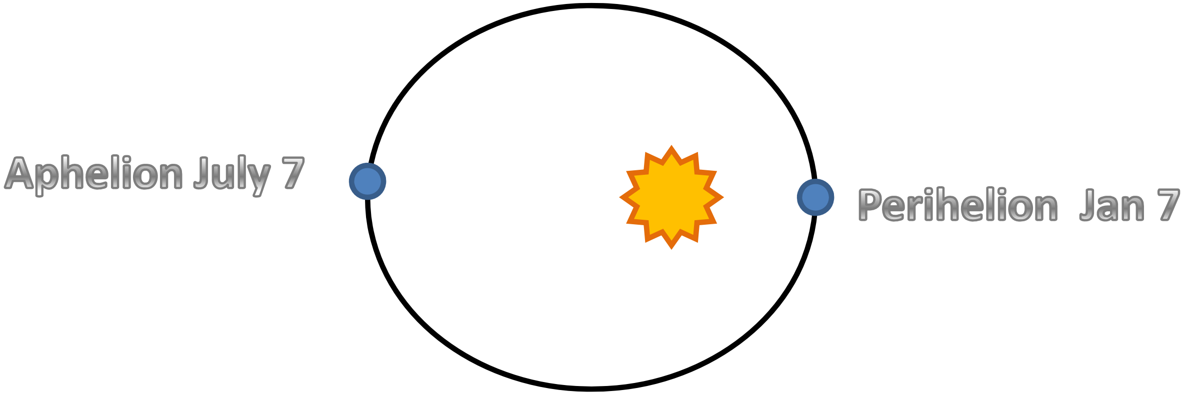
Changes in earth-sun geometry cause the seasons to change. These annual changes dramatically change the amount of energy that a given place receives from the sun. There are three principal relations:

1. **Shape** of the earth's orbit around the sun. The earth orbits the sun in almost a perfect circle, but not quite: so, the orbit is **elliptical**.

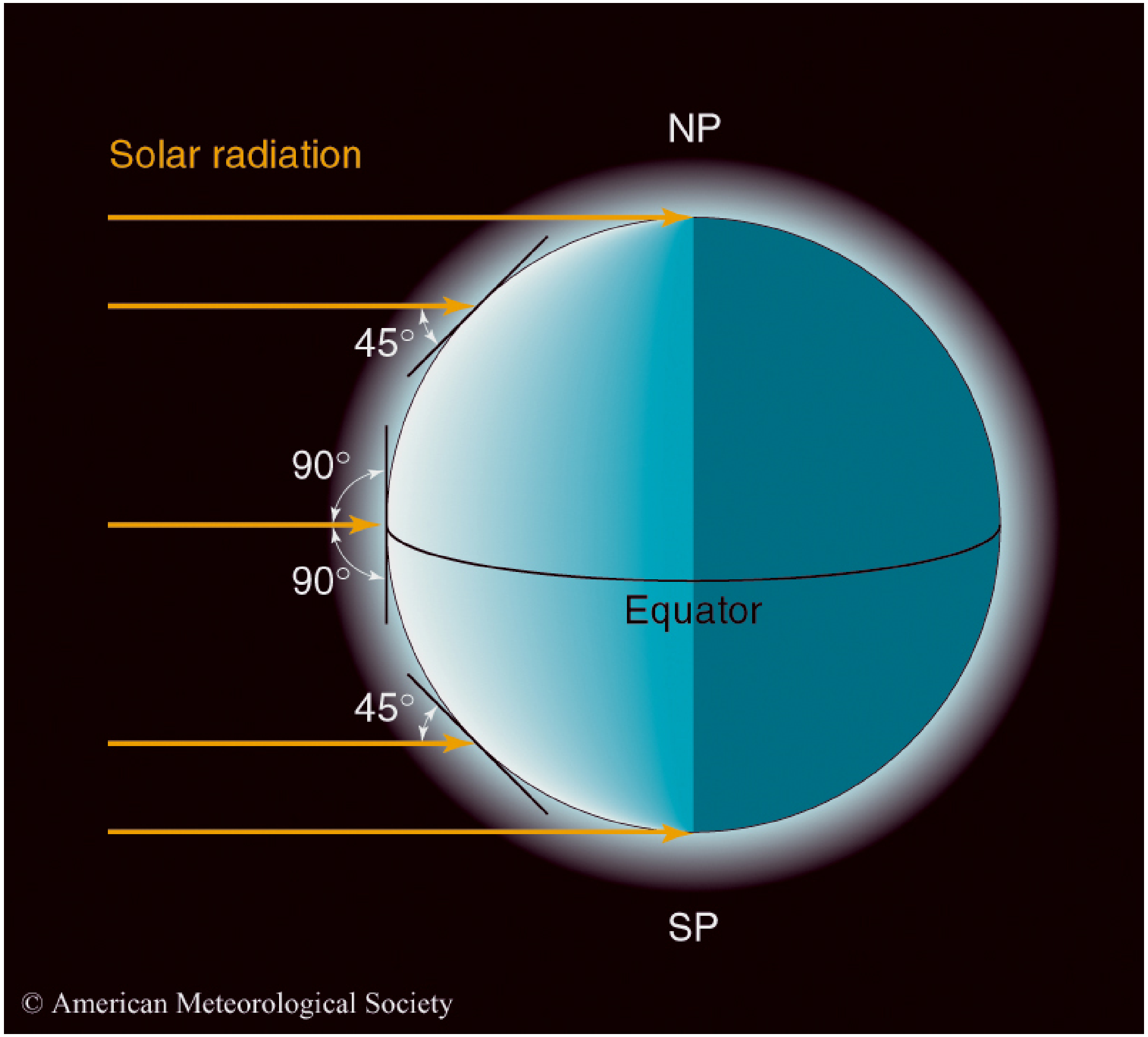
2. **Distance** from the sun to the earth. The average distance is 93 million miles, it fluctuates by about 3 million miles total. This also means that there is a time the earth is closest to the sun called **perihelion** (Jan. 7) and a time it is farthest from the sun called **aphelion** (July 7).

3. **Tilt** of the earth's axis of rotation. The 23 ½ ° tilt drives the seasons because it results in a 47° shift of the sun's position in the sky.

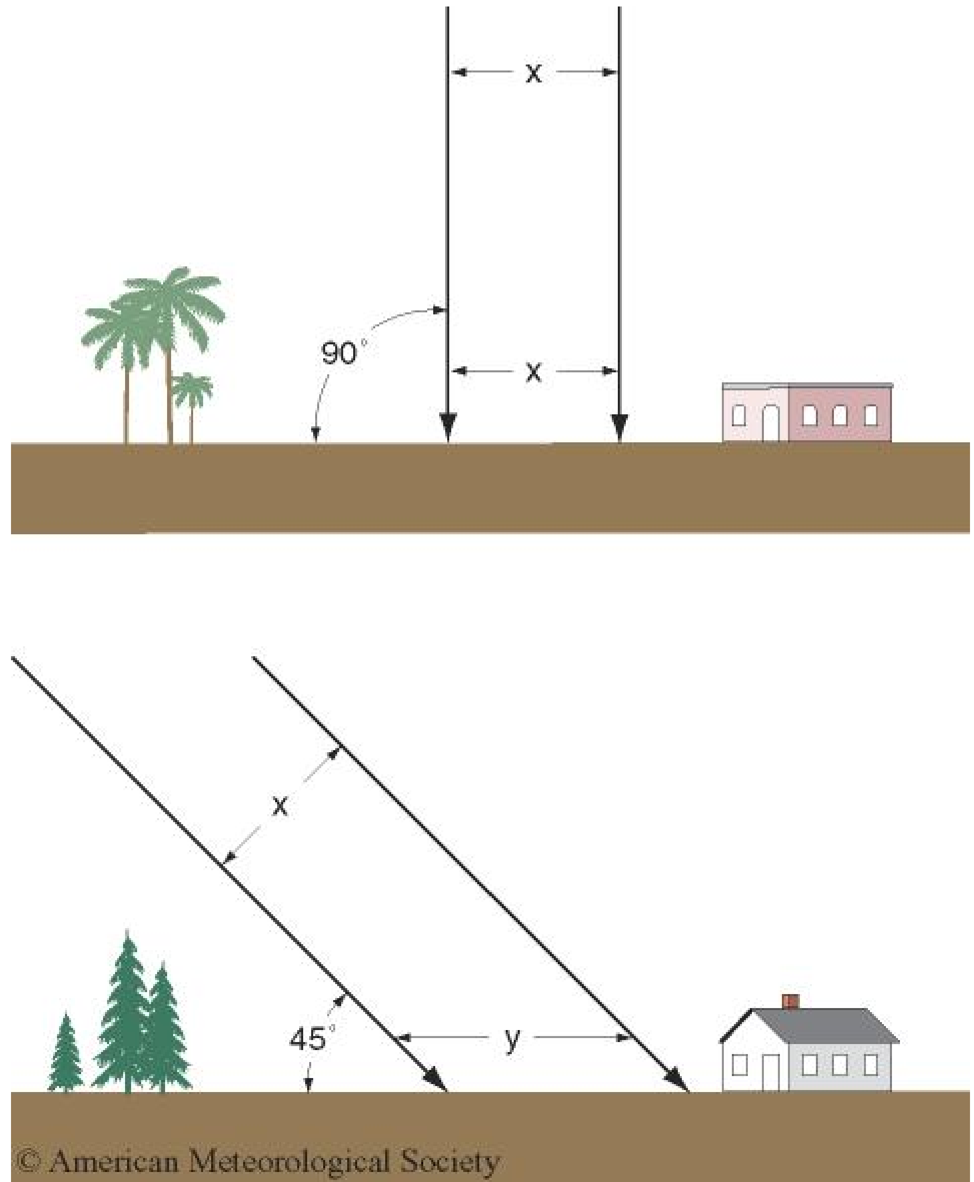
Earth's Elipitical Orbit



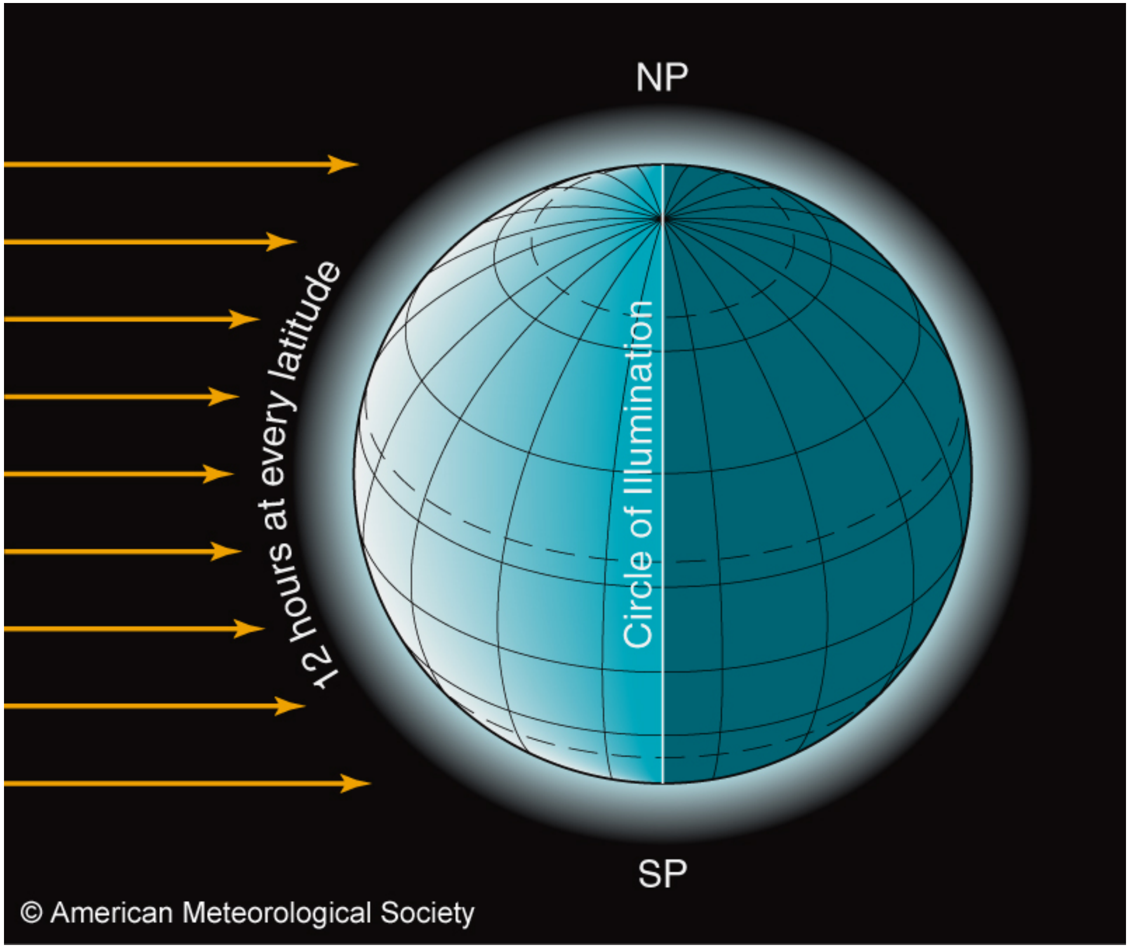
Sunlight Strikes the Earth at Different Angles Depending on Latitude



Sunlight Striking the Earth Vertically Is More Concentrated than Light Striking at a Low Angle

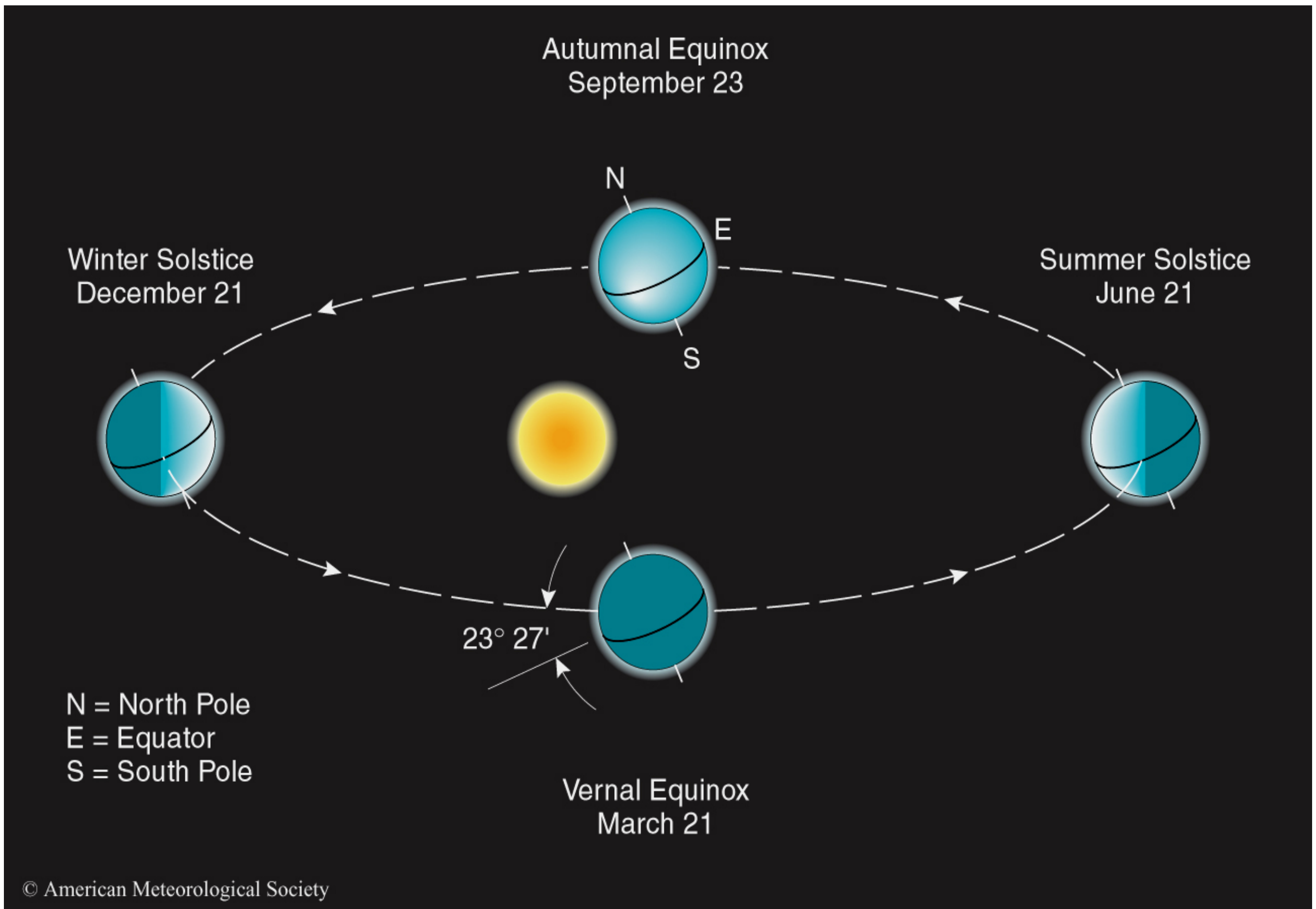


When the Circle of Illumination Passes Through the Poles on the Equinoxes, There is 12 Hours of Daylight and 12 hours of Darkness Everywhere

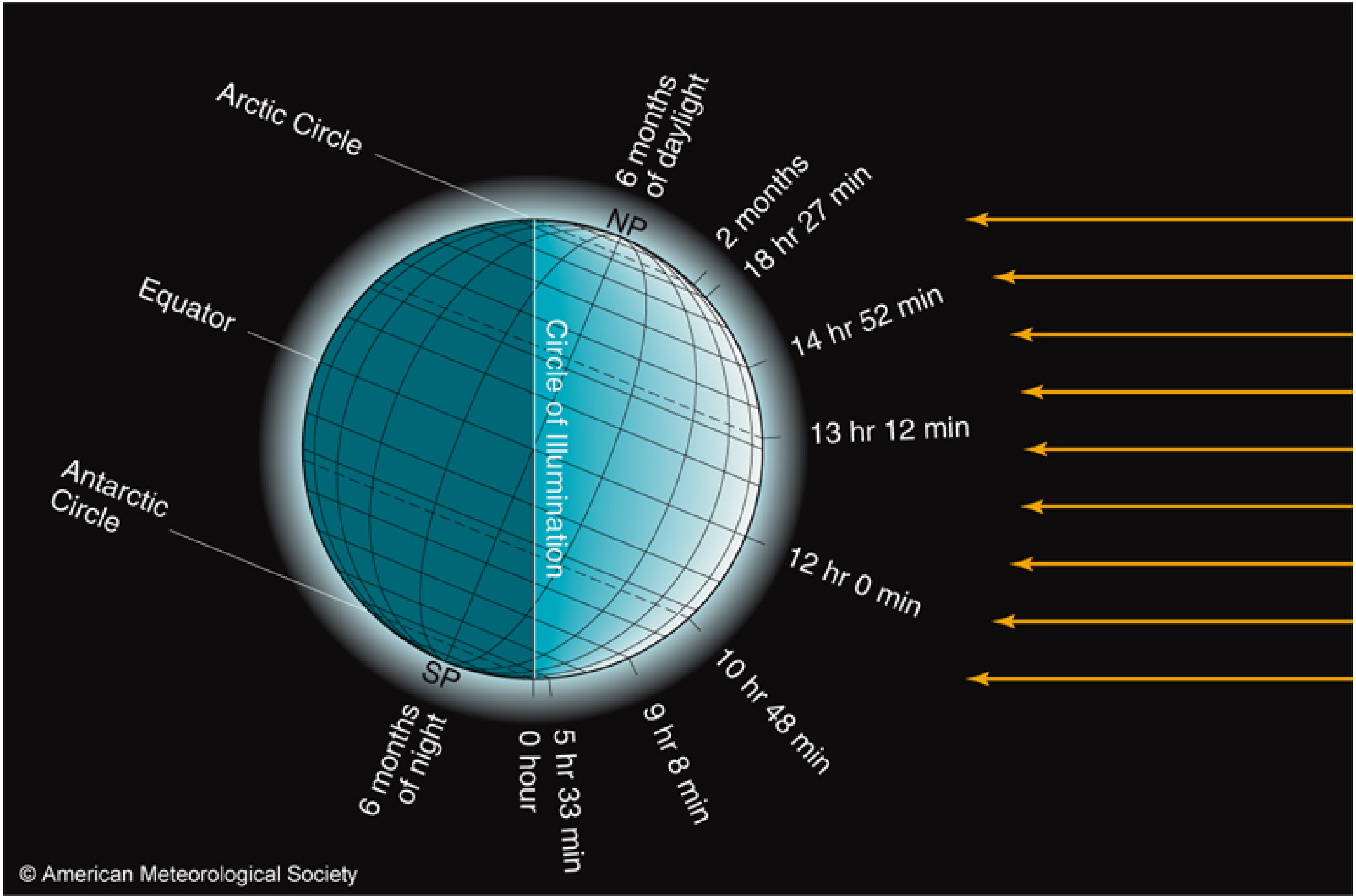


The 23.5° Tilt of the Earth's Axis Causes the Seasons.

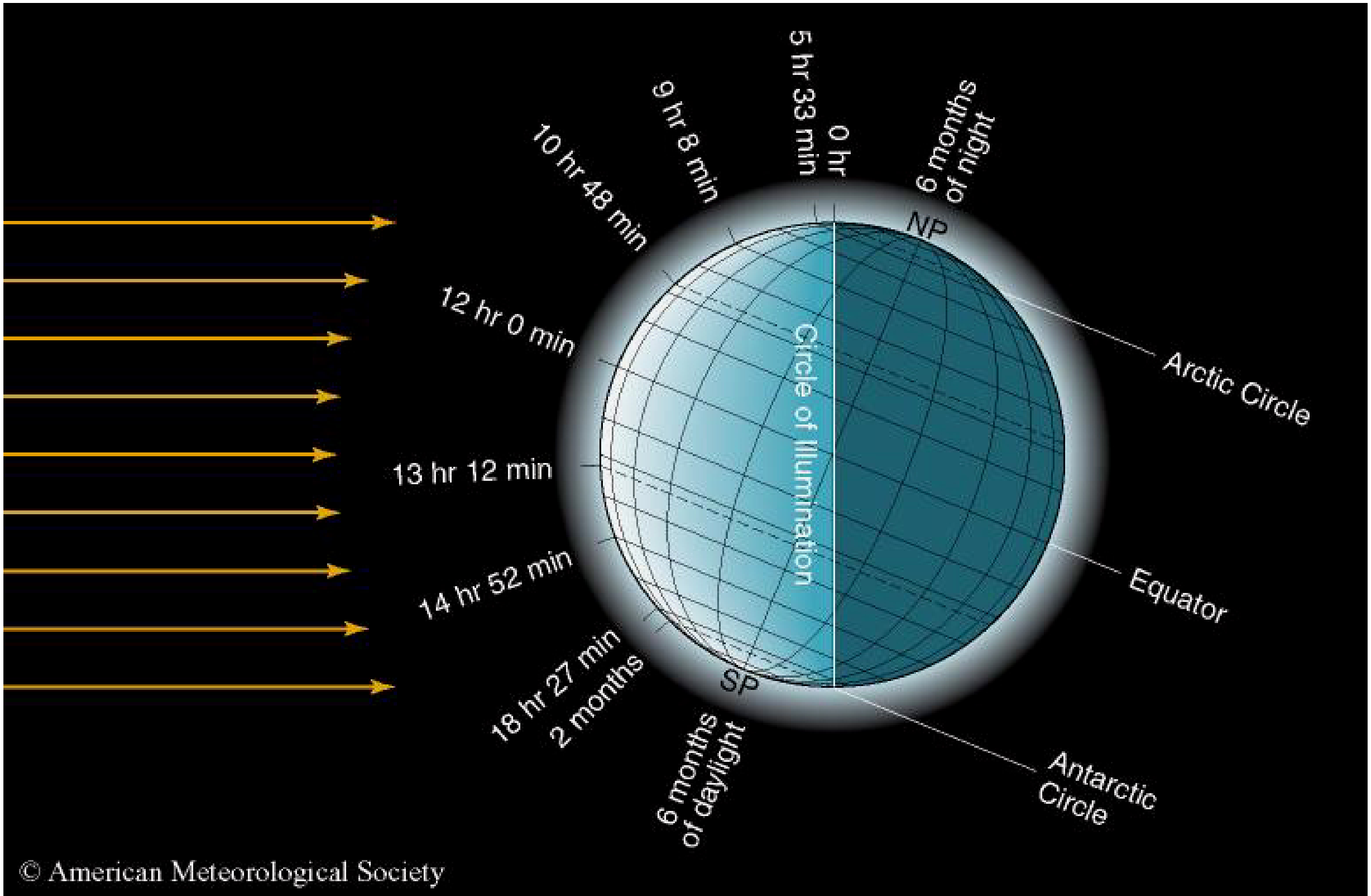
The Northern Hemisphere is Tilted into the Sun (June 21) in the Summer and Away from the Sun in the Winter (December 21). Conditions are Reversed in the Southern Hemisphere on the same dates. On the Equinoxes (March 21 and Sept. 23), both Hemispheres are Equally Illuminated



Day Length During the June 21 Solstice.
Day Length is Longer in the Northern Hemisphere



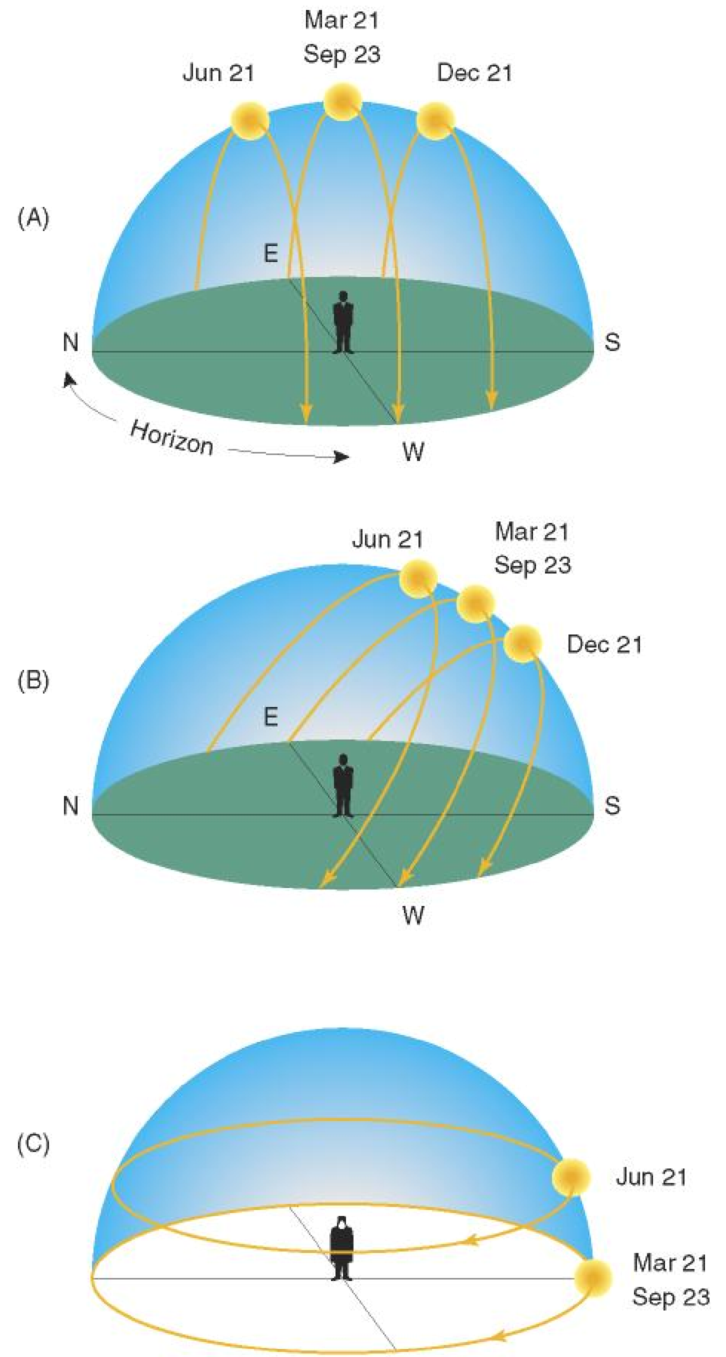
Day Length During the December 21 Solstice. Day Length is Longer in the Southern Hemisphere



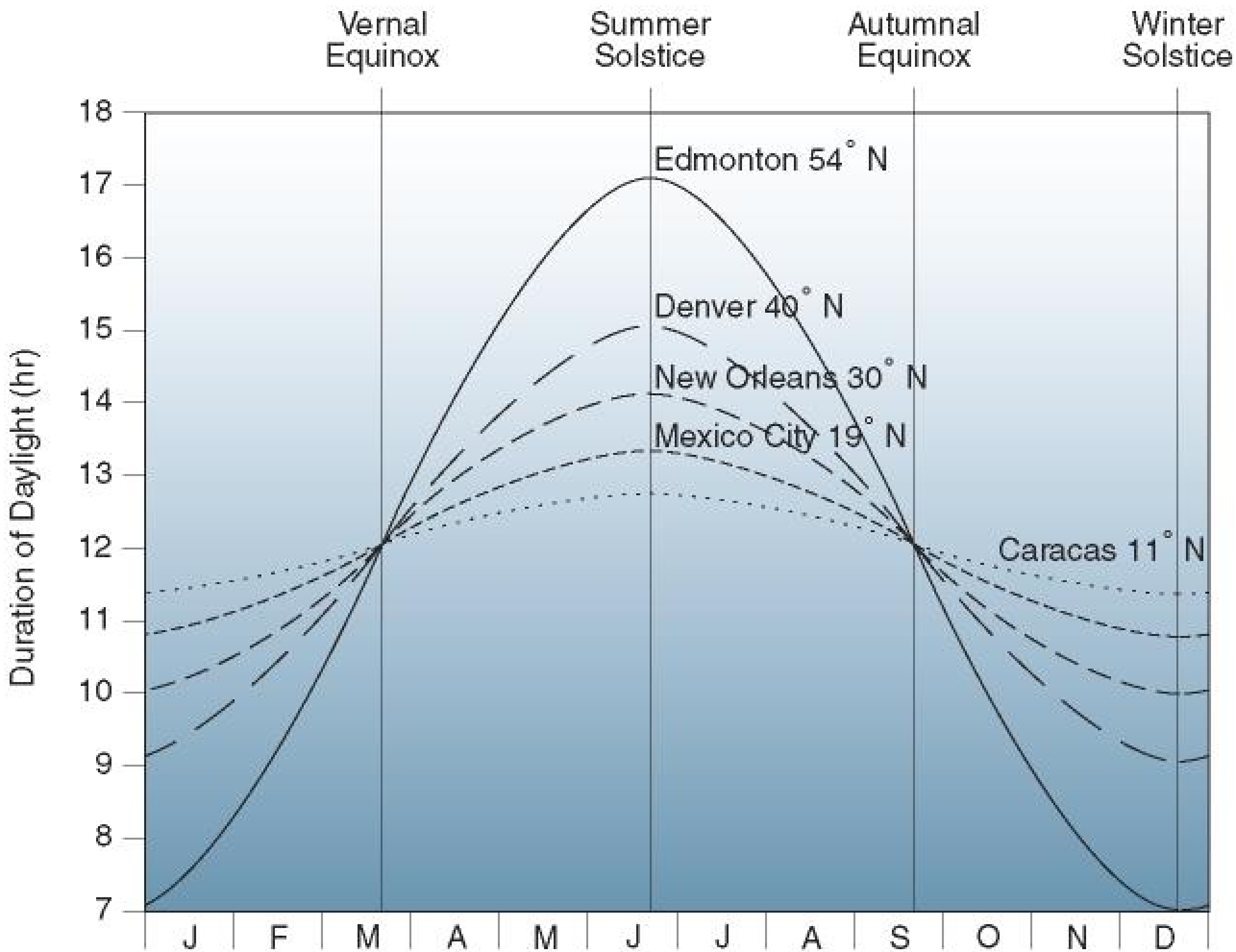
Noon Sun Position When Viewed from the Equator

Noon Sun Position When Viewed from 45° Latitude

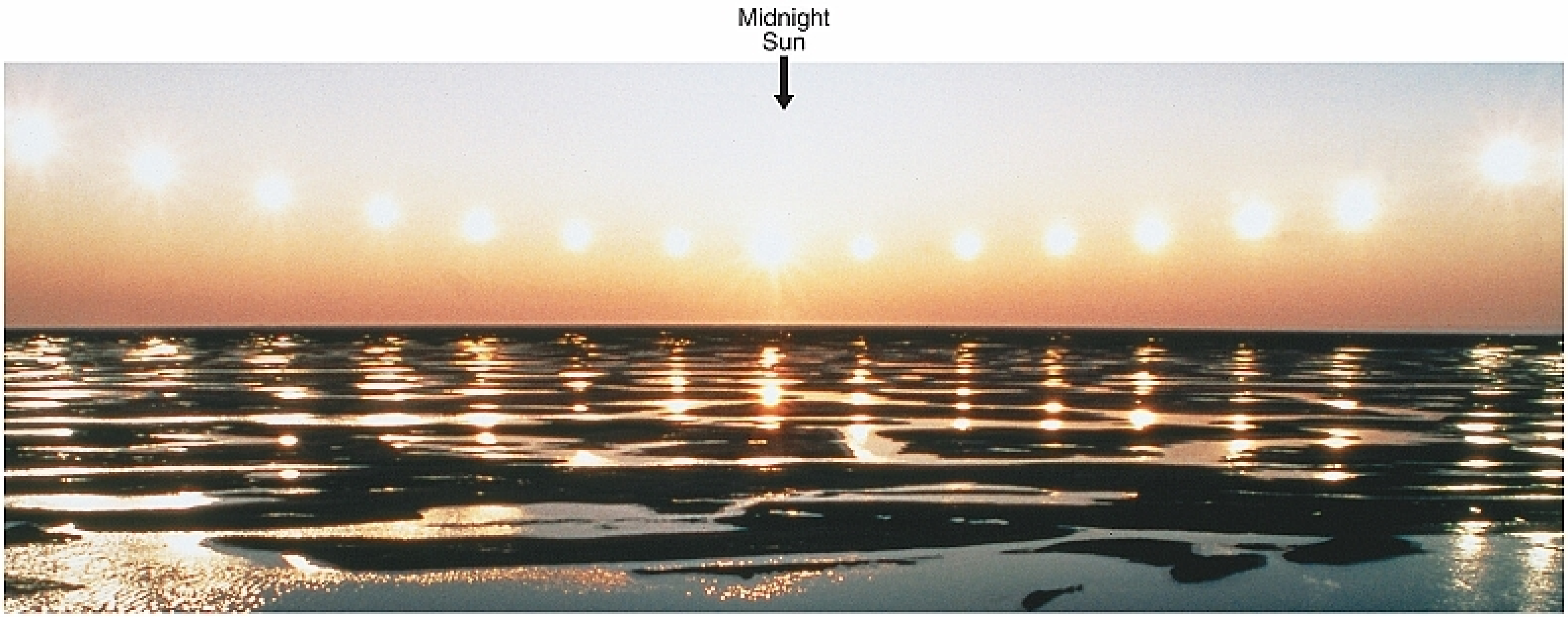
Sun Position When Viewed from North Pole



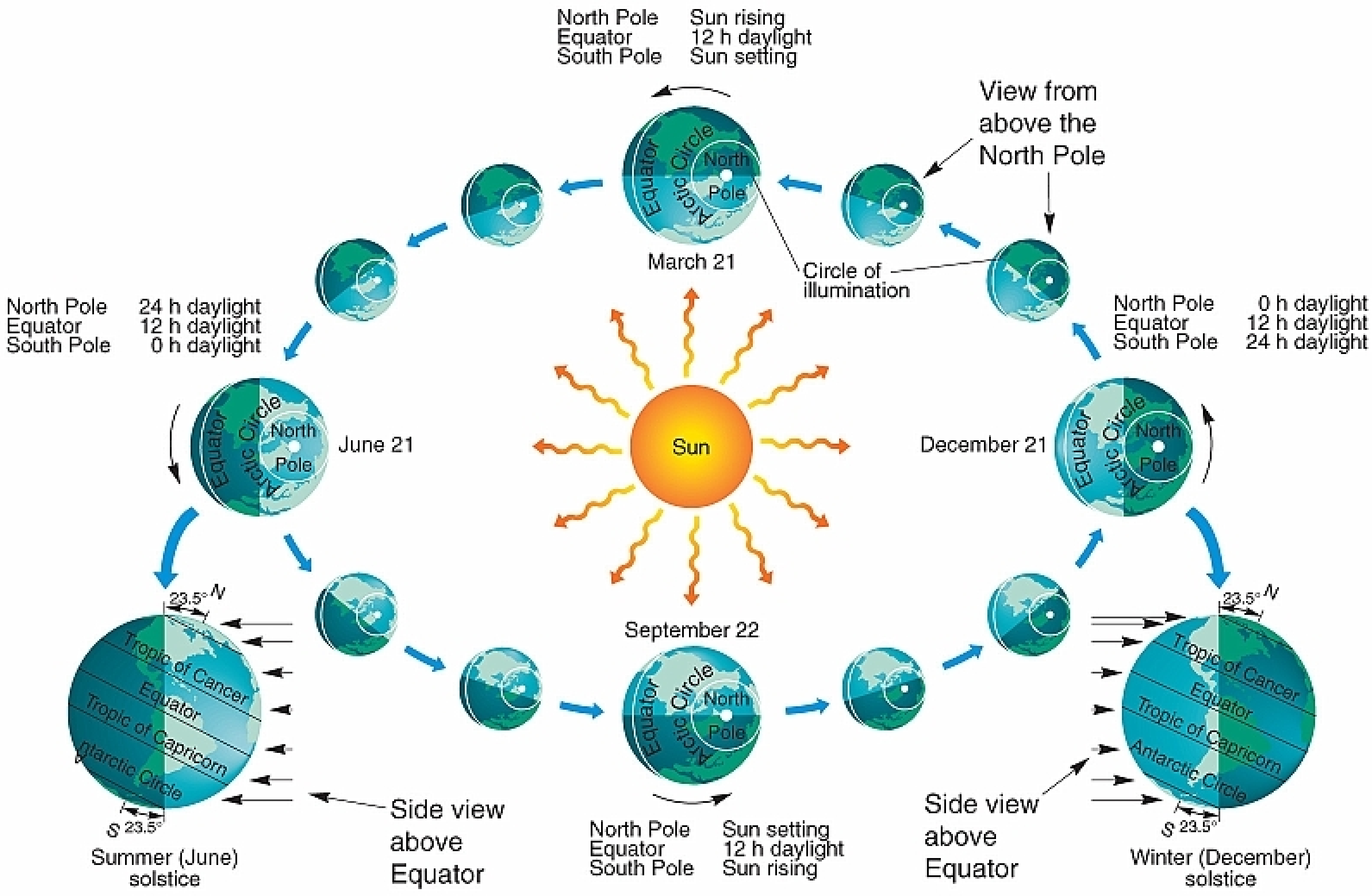
Day Length Varies with Latitude and Time of Year



Midnight Sun in the Arctic Looking Due North



Position of Earth Relative to the Sun on Solstice and Equinox Dates



Sun Rising Directly in the East on Equinox

Sun Rising in the East One Day Before Equinox

Sun Rising Slightly North of Straight East About Two Days Before Fall Equinox

Sun Rising Directly in the East on Equinox