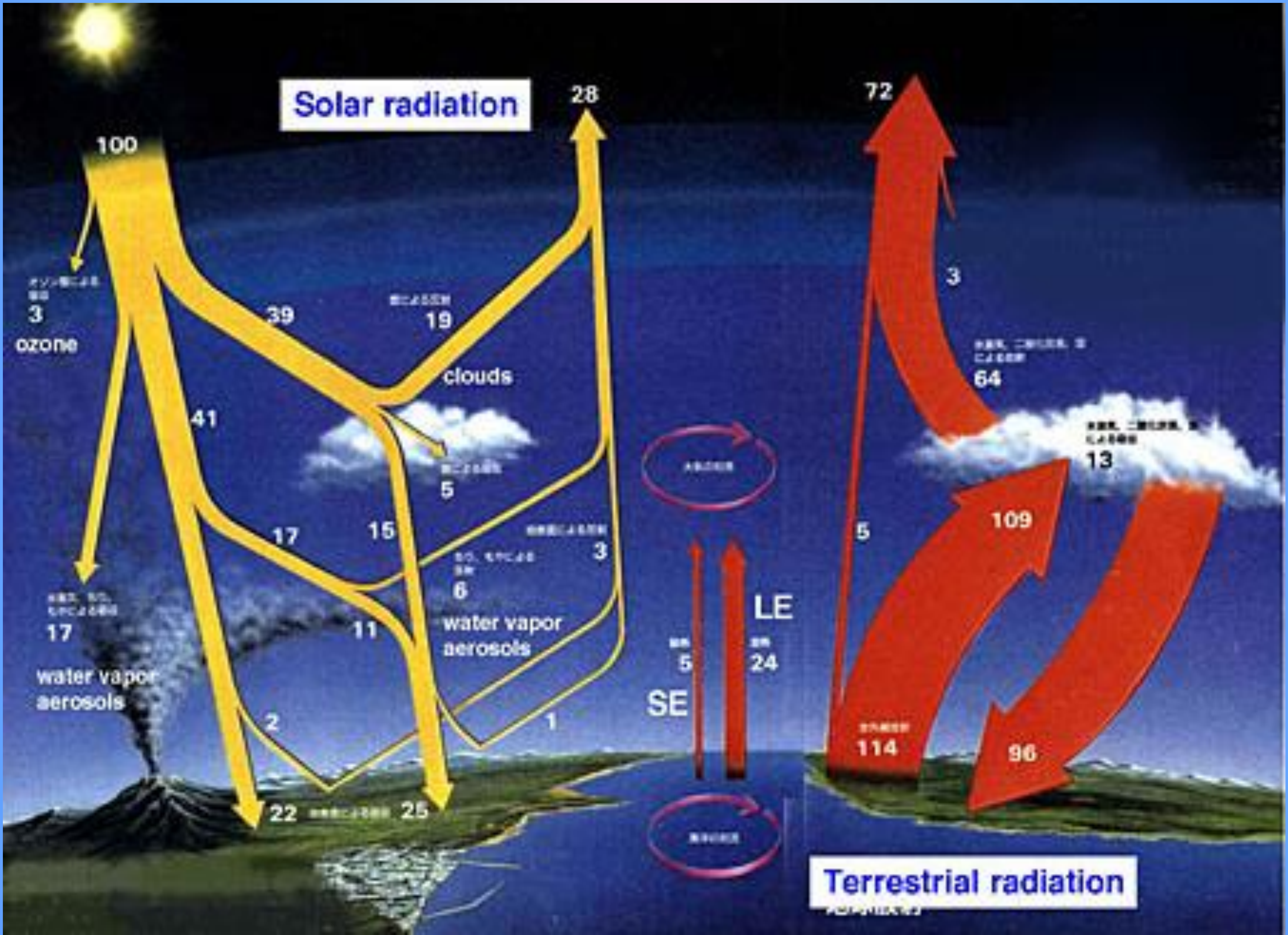
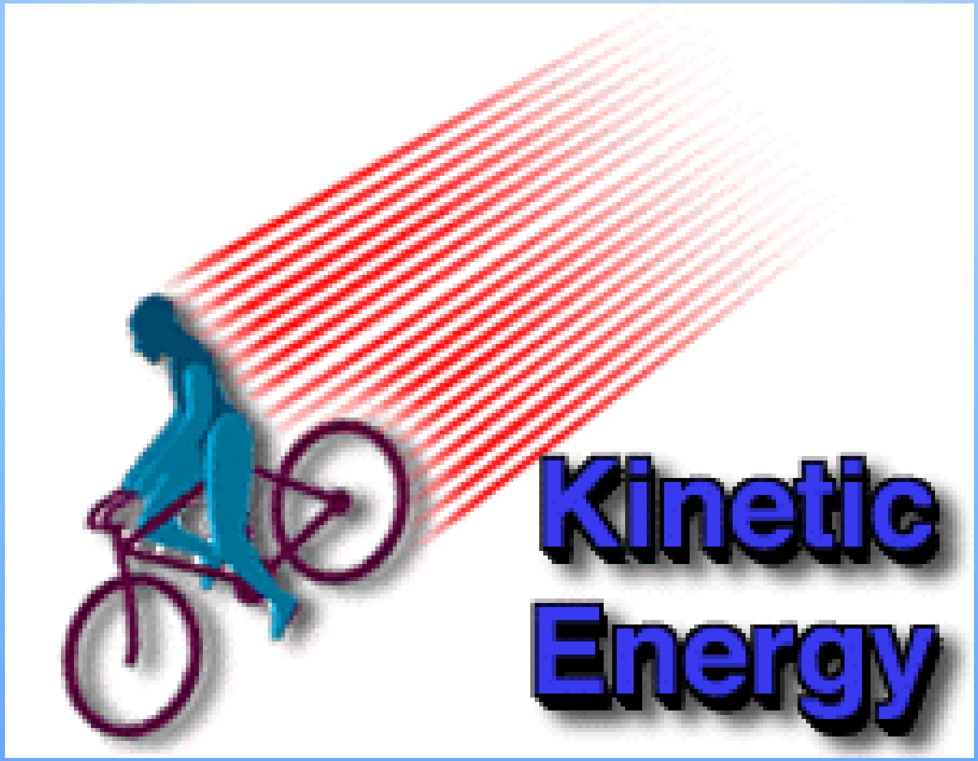
Solar and Terrestrial Radiation



Heat and Temperature

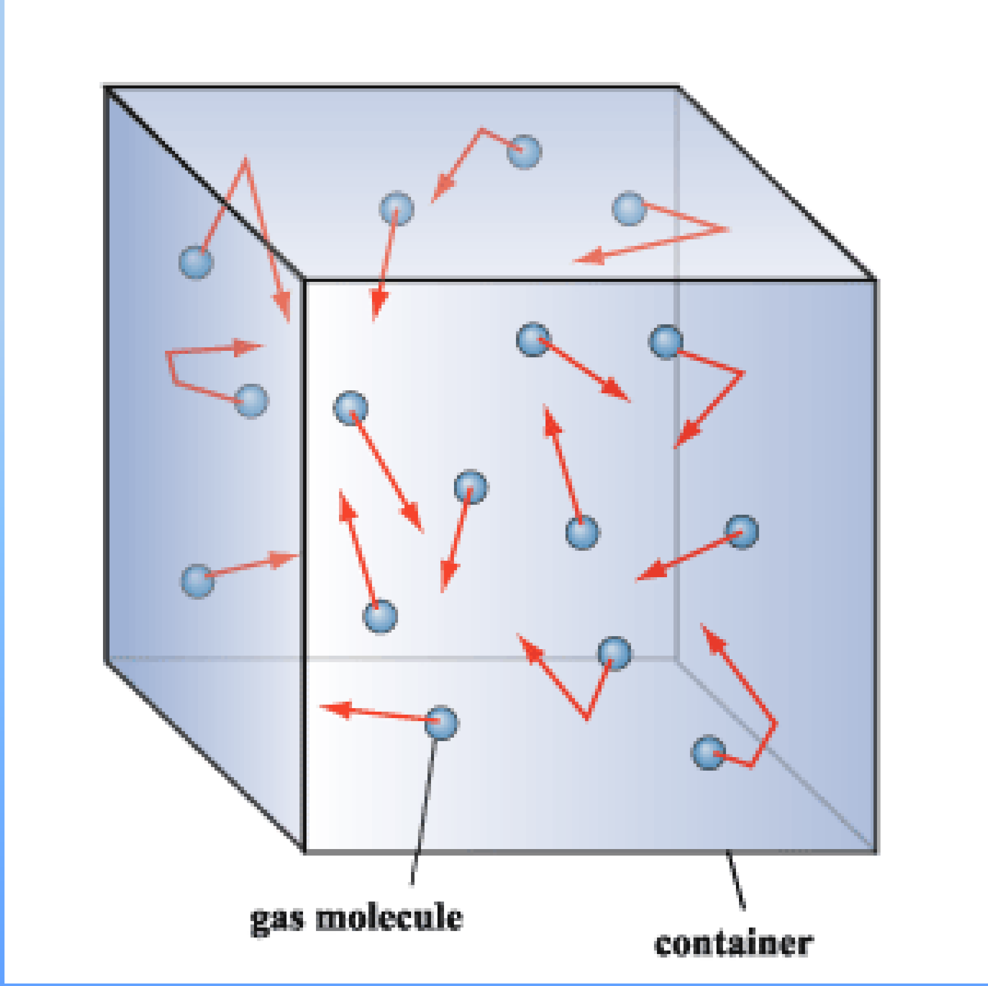
A. __Heat__

1. A form of __energy__ .

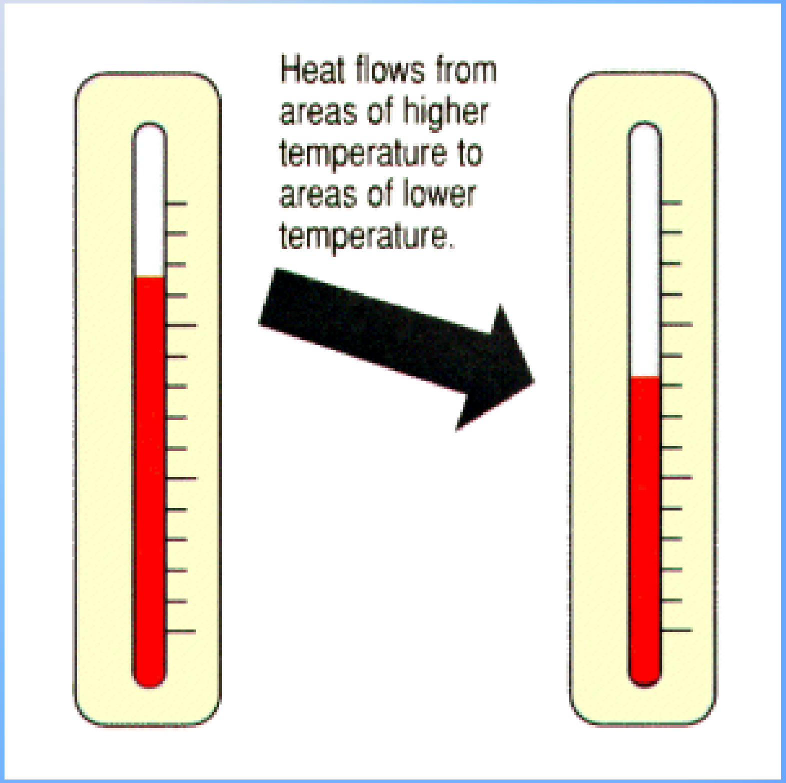


HEAT:

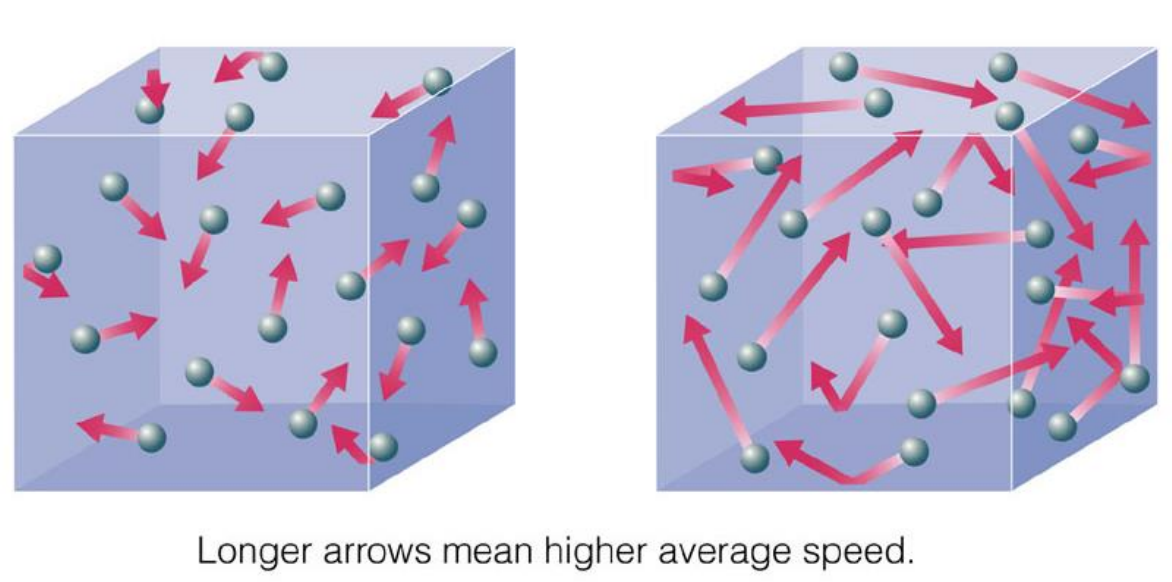
2. The *total* **kinetic energy** of all the atoms and molecules of a substance.



3. Heat always moves from a **higher** temperature body to a **lower** temperature body.



B. __Temperature__



1. The _***average** **kinetic energy***_ of the <u>individual</u> atoms or molecules in a substance

2. Addition of heat energy causes atoms to __**move faster**__ and removal causes atoms to _**slow**_ down.

3. The total amount of heat of a substance depends upon its _**mass**_.

- For example, a substance can have a ***high temperature*** and ***small amount*** of heat while another may contain a ***large amount of heat*** and have a ***low temperature***.

4. __calories__

a. A unit for measuring the quantity of heat when an object is heated or cools off.

b. Defined as the quantity of heat needed to **raise the temperature of one gram of** __**water** one degree Celsius__

c. This is the older unit but is usually used for water.

d. The newer unit is the Joule (1 calorie = 4.18 Joules)

Don’t confuse the calorie with the Calorie

- The Calorie is used for food and is actually a kilocalorie (1000 calories).

Why is the ocean water still warm in November?

5. Specific Heat

a. Defined as the quantity of heat needed to raise the temperature of __**any substance**__by one degree Celsius.

b. The __**higher**__the specific heat of a substance, the __**greater**__ the amount of heat needed to raise its temperature.

   i. Water has the __**highest**__ specific heat of all natural substances (**4.18 Joules/gram • ºC** which is 1.0 calories/gram• ºC)

   ii By comparison the only 0.84 joules are required to heat one gram of the rock basalt one degree Celsius (basalt has a specific heat of __**0.84 Joules/gram · Cº**__)

iii. Specific heats of come common natural substances are listed in the ***Earth Science Reference Tables***.

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Specific Heats of Common Materials

MATERIAL	SPECIFIC HEAT (Joules/gram • °C)
Liquid water	4.18
Solid water (ice)	2.11
Water vapor	2.00
Dry air	1.01
Basalt	0.84
Granite	0.79
Iron	0.45
Copper	0.38
Lead	0.13

Physical Setting/Earth Science

New York State Fossil

6. **Heat Loss or Gain can be expressed by the following equation.**

$$Q = m \Delta T C_p$$

Q = total heat lost or gained

m = mass in grams

ΔT= change in temperature of the substance

C_p = specific heat of the substance

Sample Problem 1

(not in notes, I will give out a worksheet)

- How much heat is need to raise the temperature of 10 grams of **basalt** from 30º C to 50º C?
- $Q = m \, \Delta T \, C_p$

$$= 10\ \cancel{g} \times 20\,\cancel{^{o}C} \times 0.84\ \frac{\text{Joules}}{\cancel{\text{gram}} \cdot \cancel{^{o}C}}$$

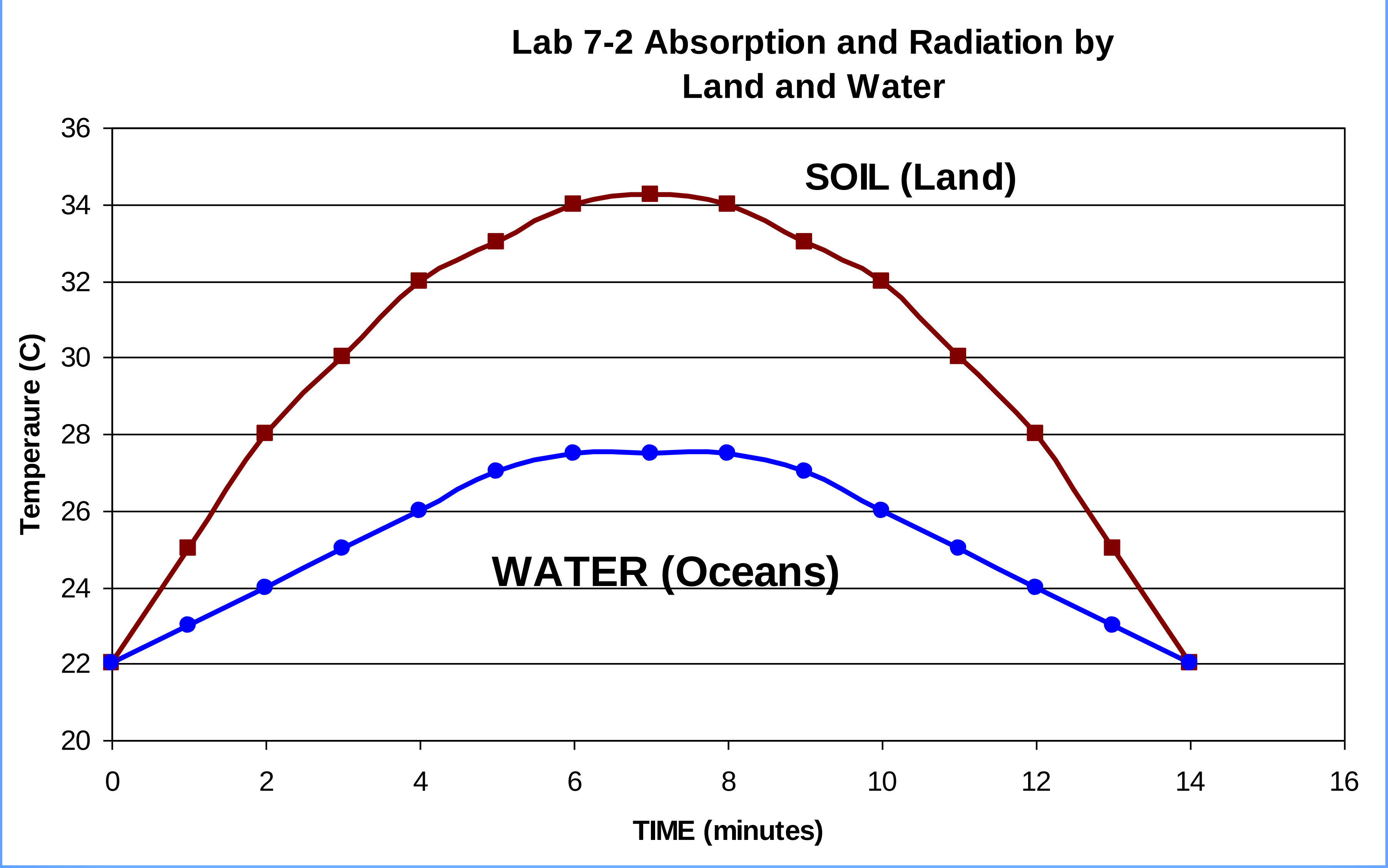
$$= 168\ \text{Joules}$$

Sample Problem 2

- How much heat is need to raise the temperature of 10 grams of **<u>water</u>** from 30º C to 50º C?
- $Q = m \, \Delta T \, C_p$

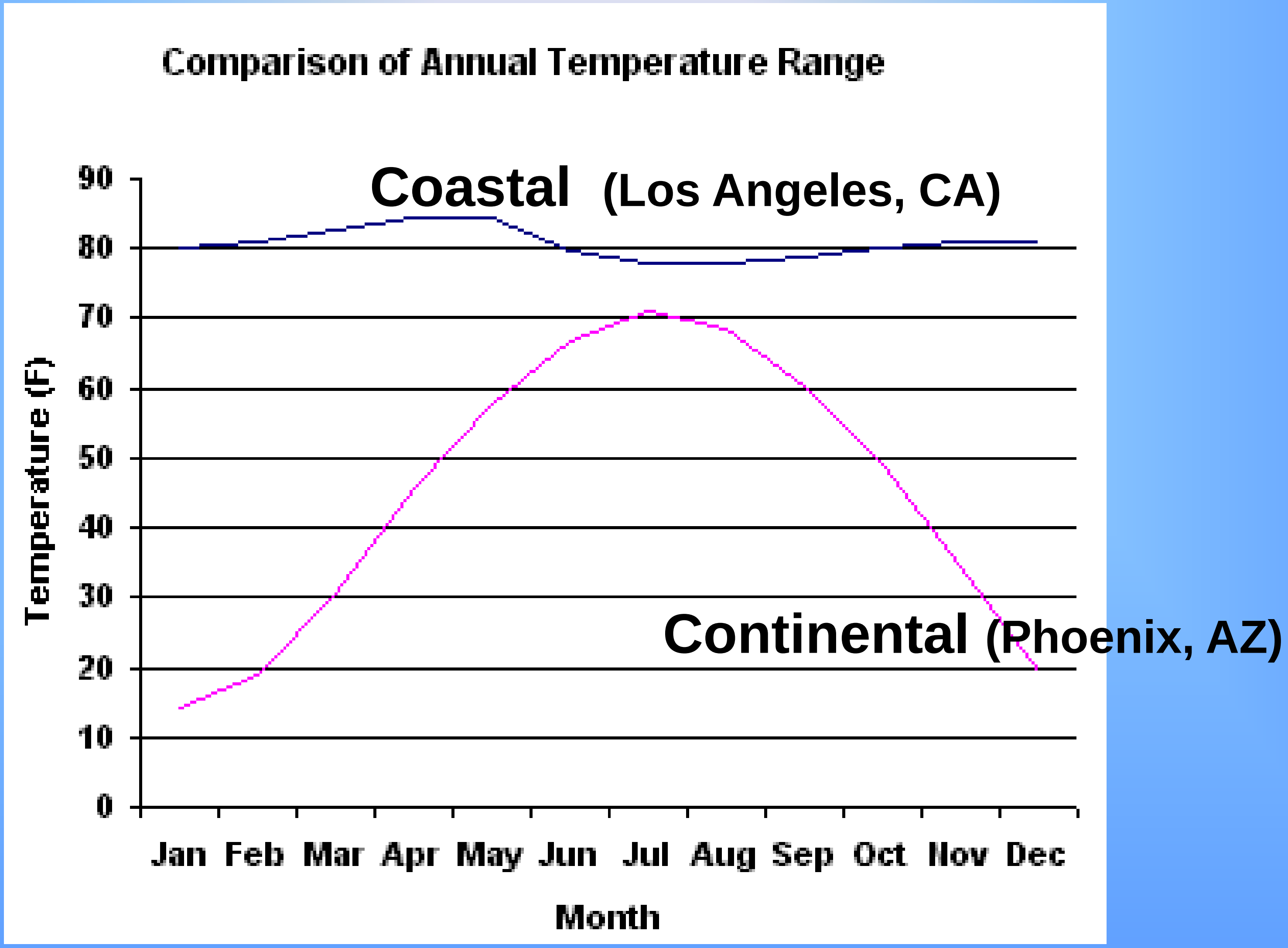
$$= 10\,\cancel{g} \times 20\,\cancel{^{o}C} \times 4.18\,\frac{\text{Joules}}{\cancel{\text{gram}} \cdot \cancel{^{o}C}}$$

$$= 836.0 \text{ Joules}$$



How does Specific Heat affect these lab results?

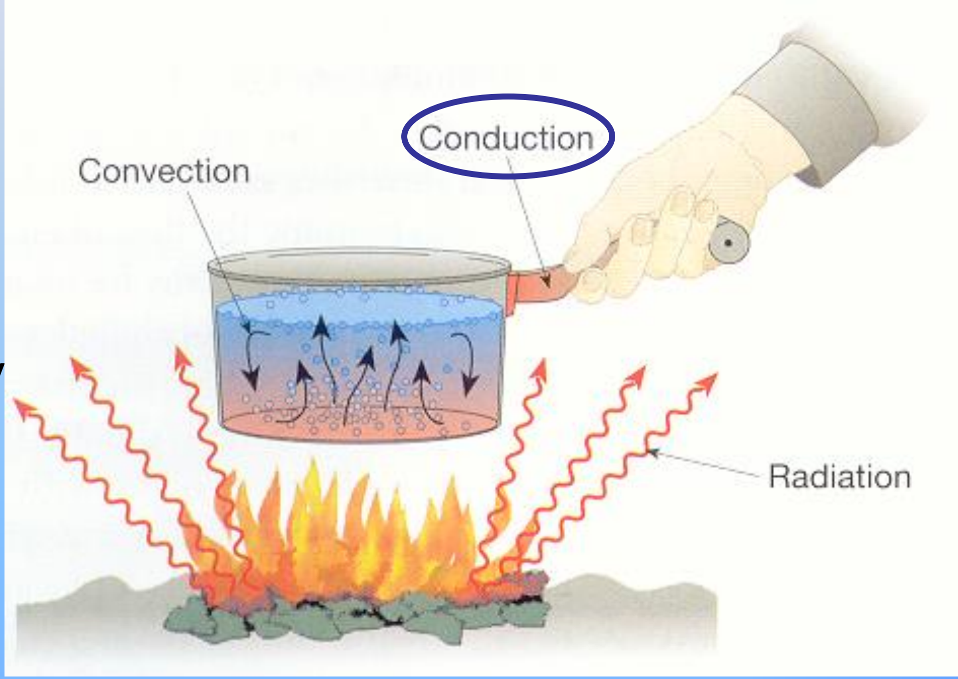
Coastal and Continental Temperature Ranges Lab 7-3



C. Methods of Heat Transfer

1. ___**Conduction**___
   a. The transfer of heat through electron and molecular ___**collisions**___ from one molecule to another.

   b. Conduction is important only between Earth's ___**atmosphere**___ and the air immediately in ___**contact**___ with the surface.

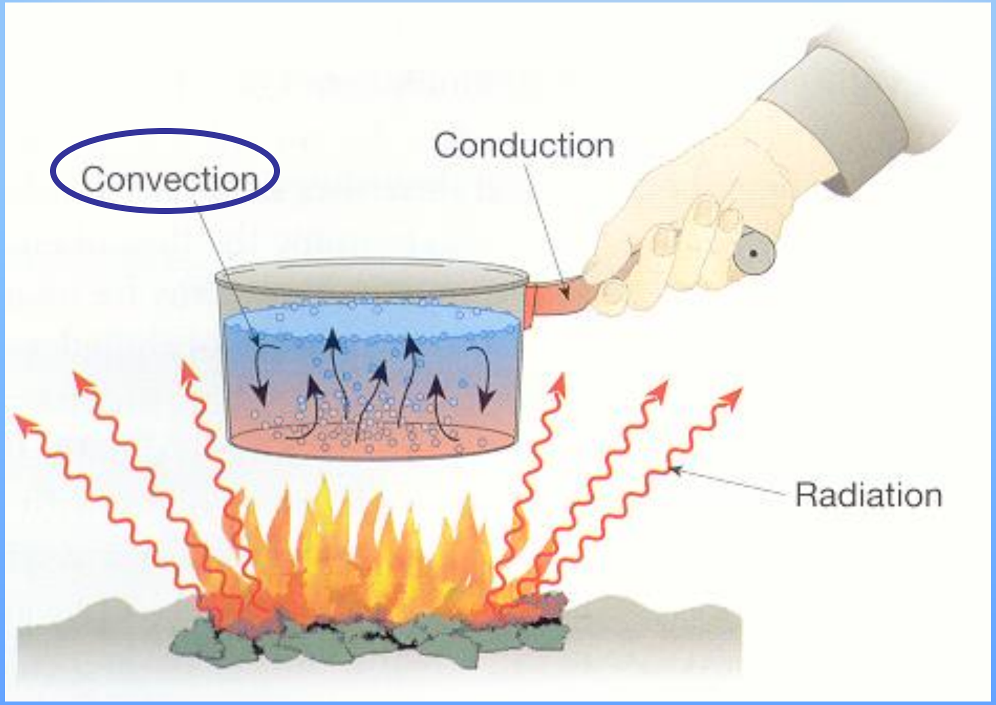


   c. As a means of heat transfer for the atmosphere as a whole, conduction is the least significant and can be disregarded when considering most meteorological phenomena.

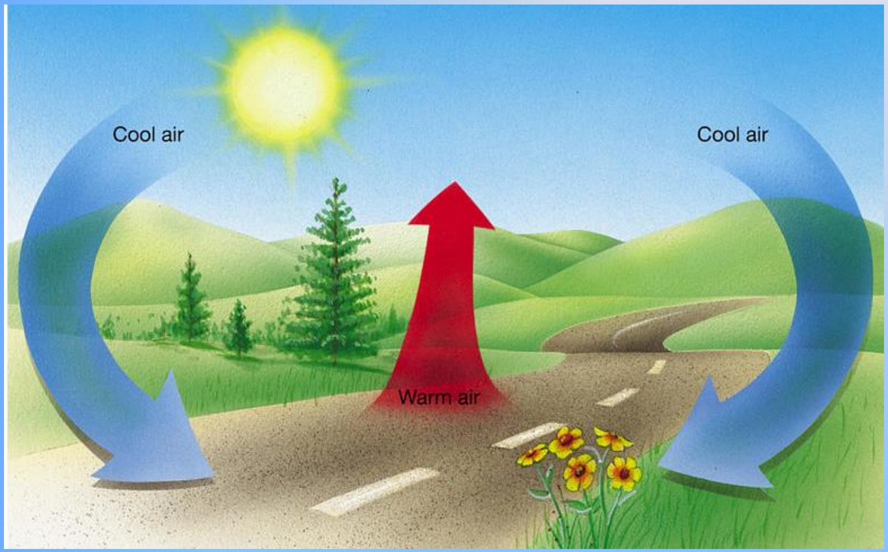
2. **Convection**

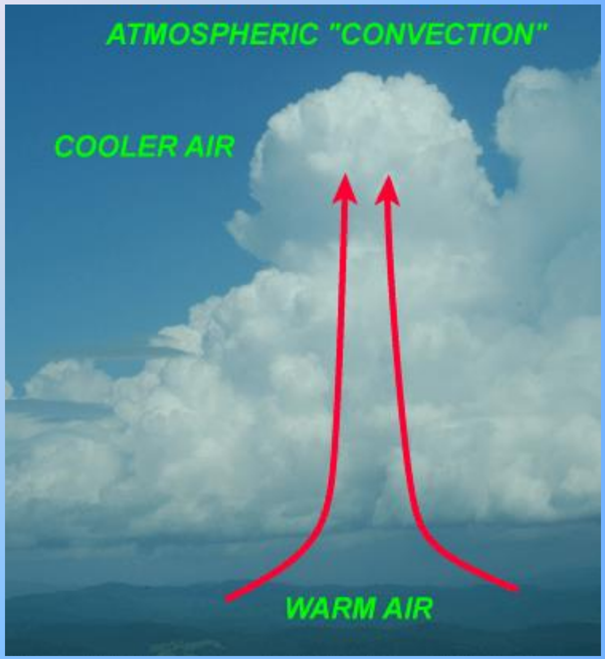
a. Heat transfer that involves movement or circulation of a substance.

b. Takes place in **fluids** where the material is able to flow.



c. Convective Circulation





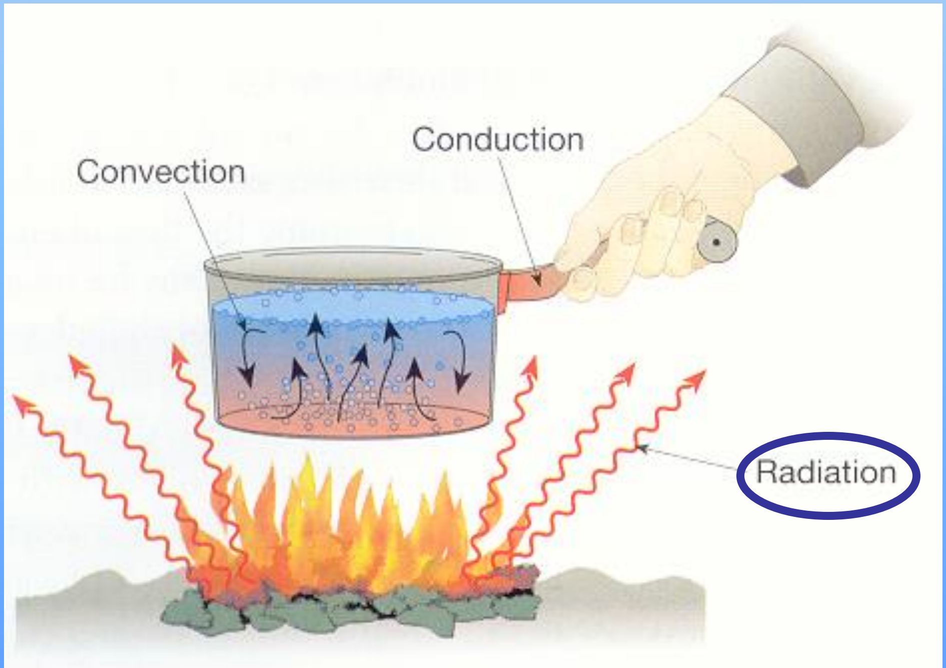
i. Takes place when the fluid near the bottom is heated and becomes less dense.
ii. It rises, cools near the top and continues to "turn over."
iii. Thermals: Air moves vertically in the atmosphere. Less dense air rises and transports heat to greater heights.

3. Radiation

a. The heat-transfer mechanism by which solar energy reaches Earth.

b. Doesn't require a medium in which to travel and can pass through the vacuum of space.

c. The Sun emits light and heat along with the rest of electromagnetic spectrum of radiation

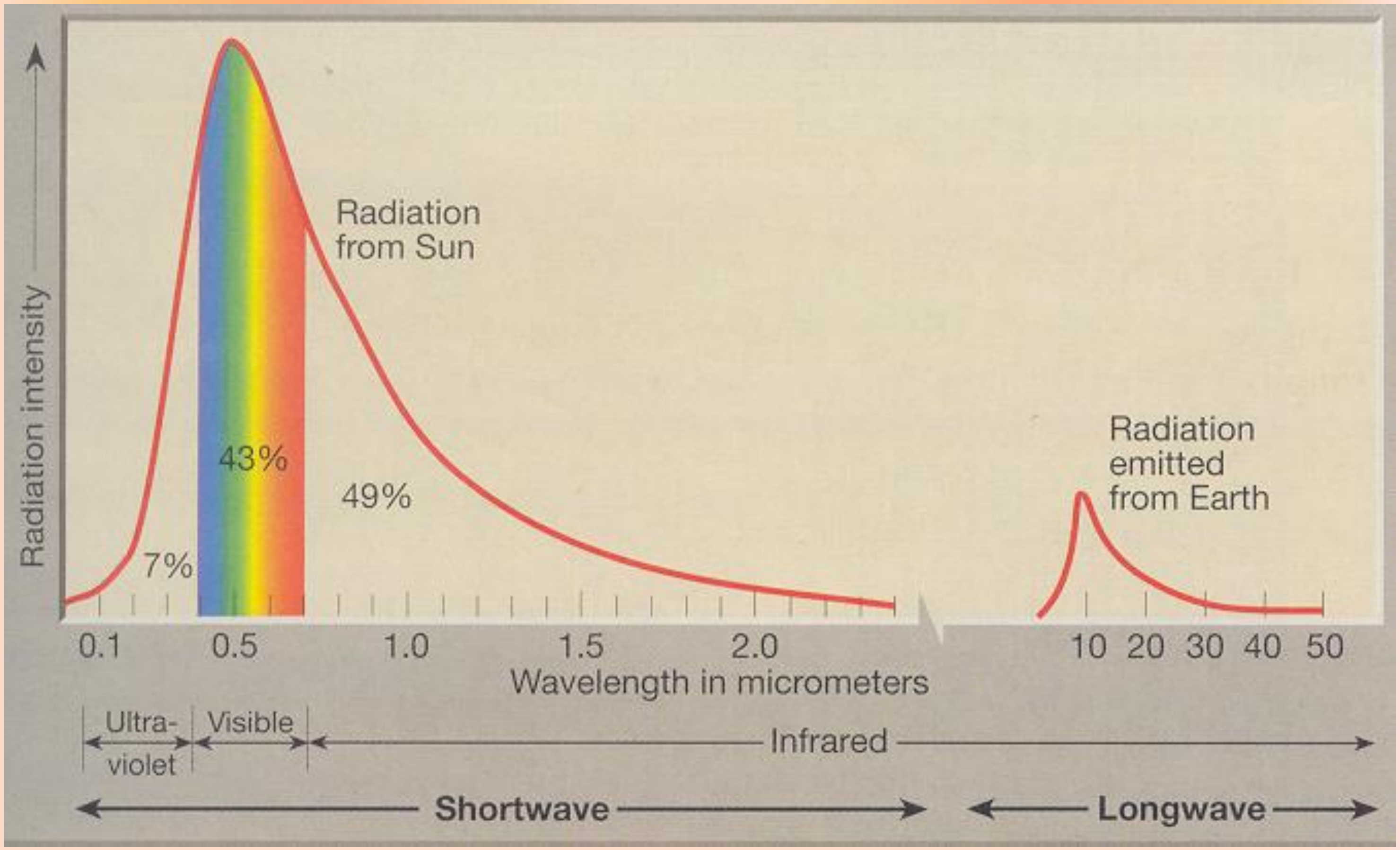


II. Insolation (Incoming Solar Radiation)

A. __Radiation__:

1. Travels out in all directions from the Sun and does travel through the __vacuum__ of space.
2. Heat transfer mechanism for __solar__ energy.

3. The Sun emits **all** wavelengths.



a. Most is concentrated in the **visible and near-visible range** (43%) See Rev. Book *Figure 8-1*, page 382.

b. Infrared to visible represents 49%

c. **Ultraviolet** represents 7%.

2. *Laws of Radiation*

a) __**All**_objects, at whatever temperature, emit radiant energy.

b) Hotter objects radiate _**more total**_ energy per unit area than colder objects

c) The hotter the radiating body, the _**shorter**_ the wavelength of maximum radiation.

d) Objects that are good absorbers of radiation are also _**good emitters of radiation**_____.

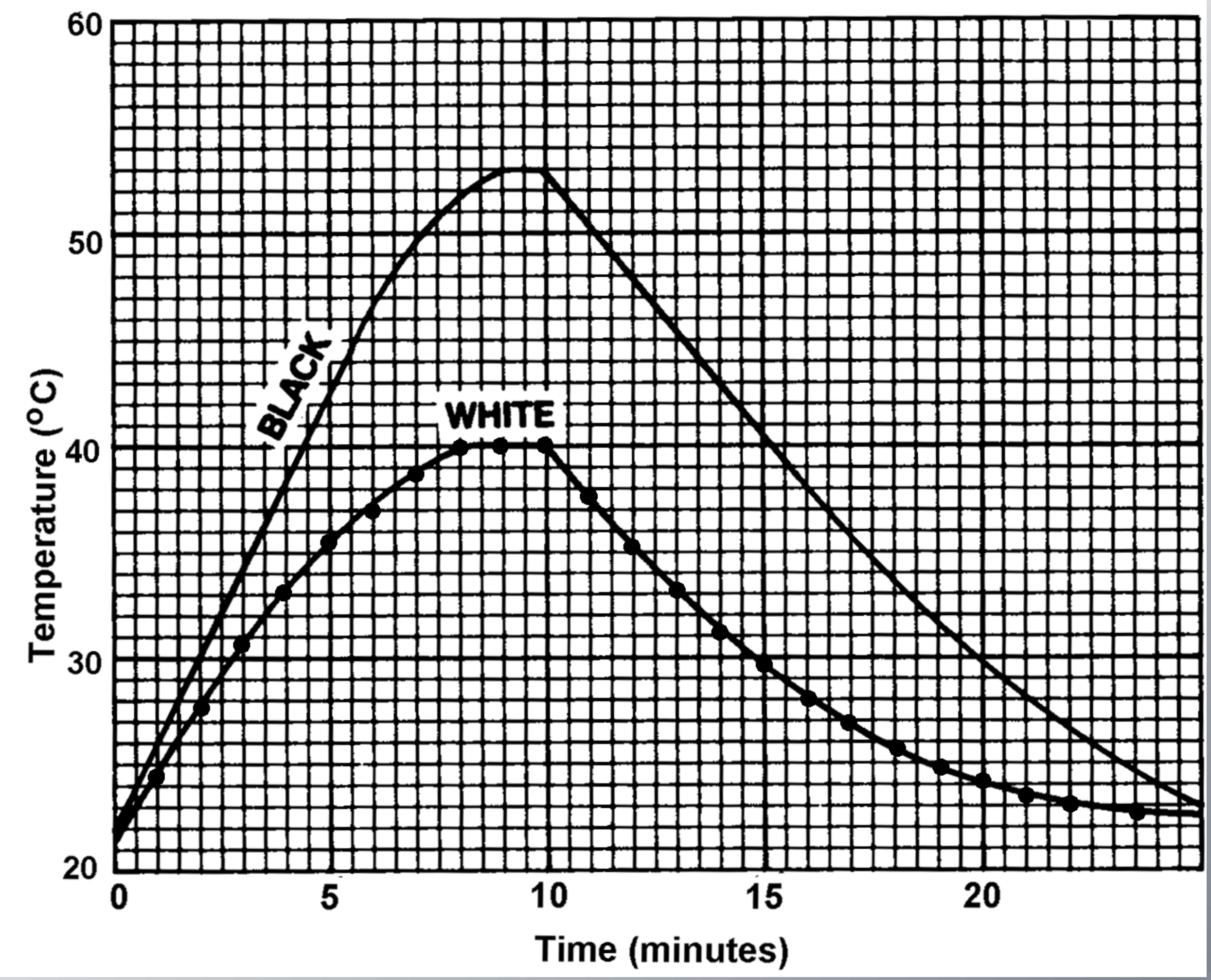
   i) A _**blackbody**___ is considered a perfect absorber and emitter. Earth's surface approaches being a blackbody because it absorbs and radiates with nearly100 percent efficiency.

ii. Surface characteristics affect absorption and emission

(1) Color

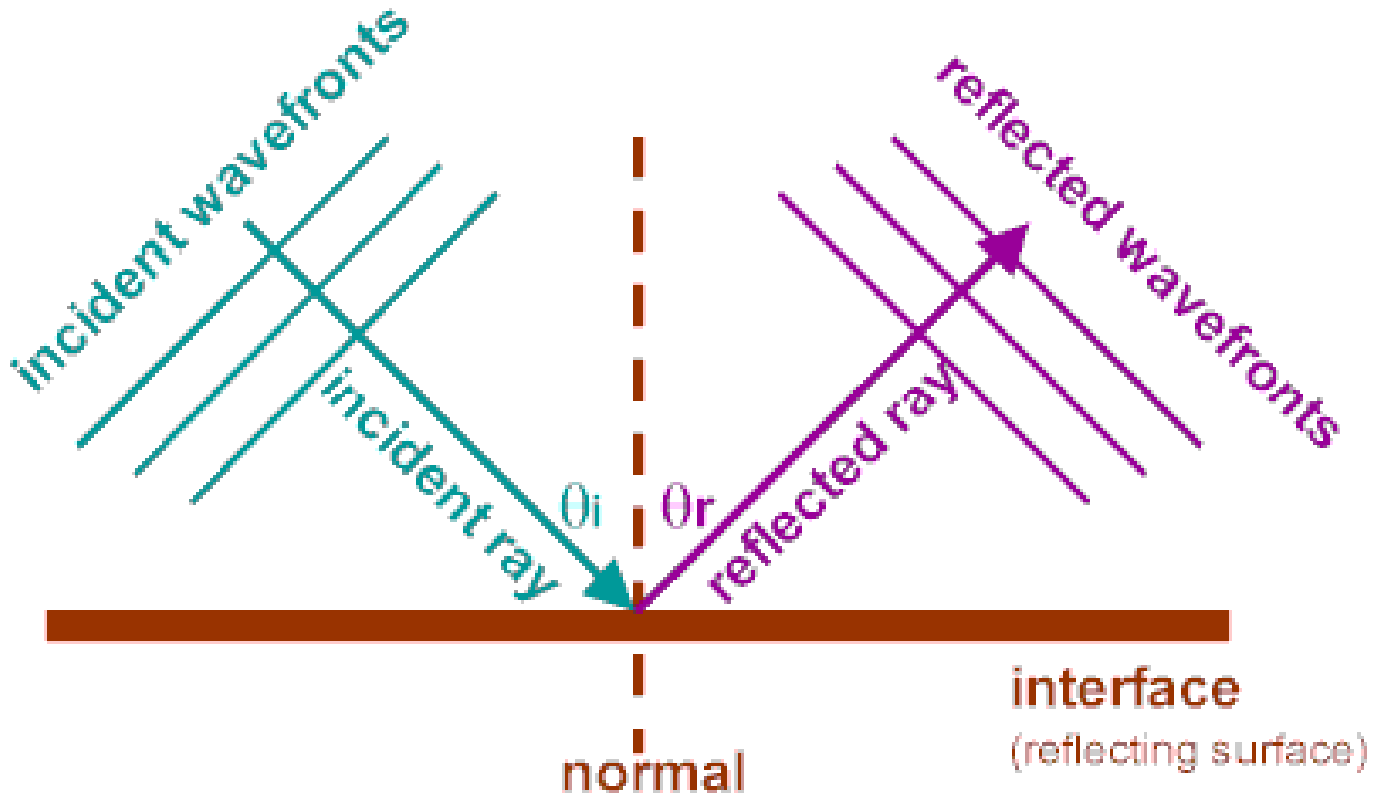
Darker colors absorb and radiate more heat than lighter colors

Temperature Vs. Color

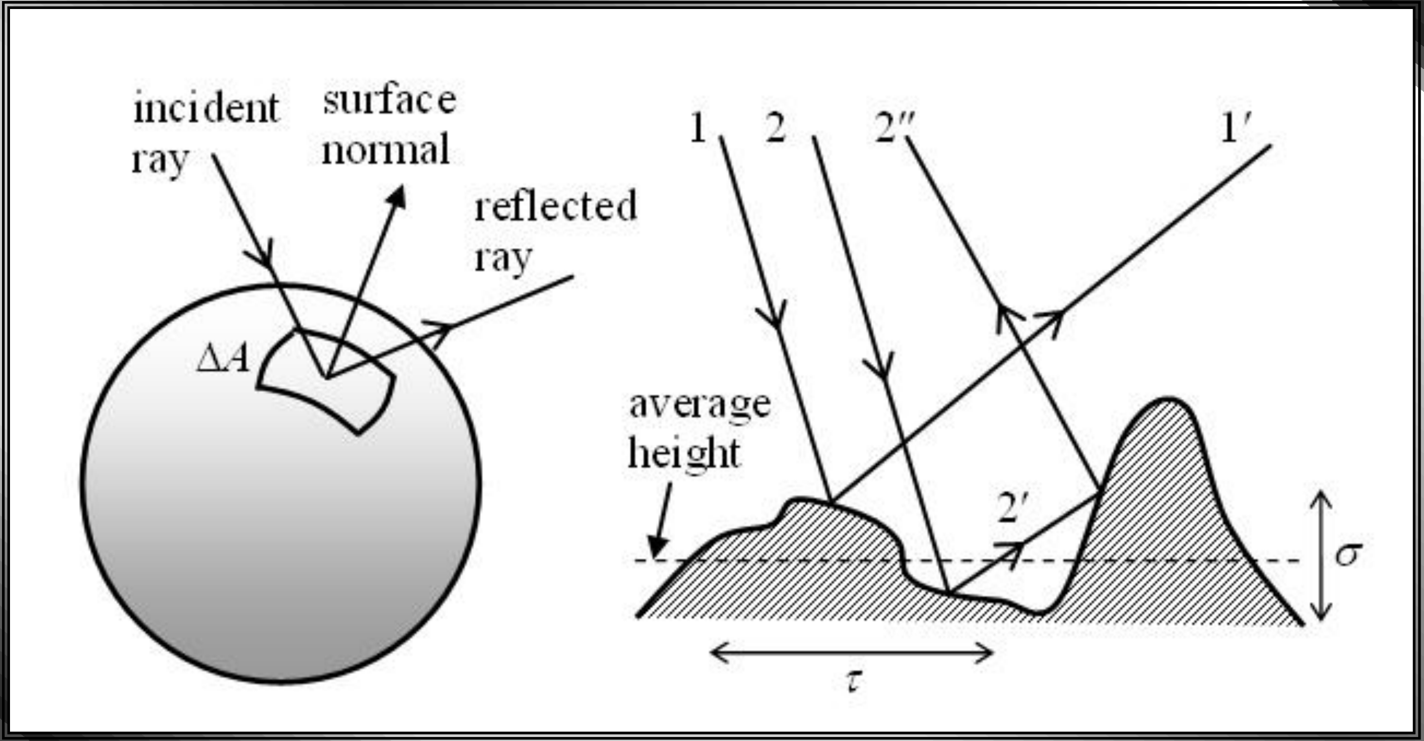


(2) Reflectivity

The greater the reflection, the less heat that is absorbed.



(3) Texture



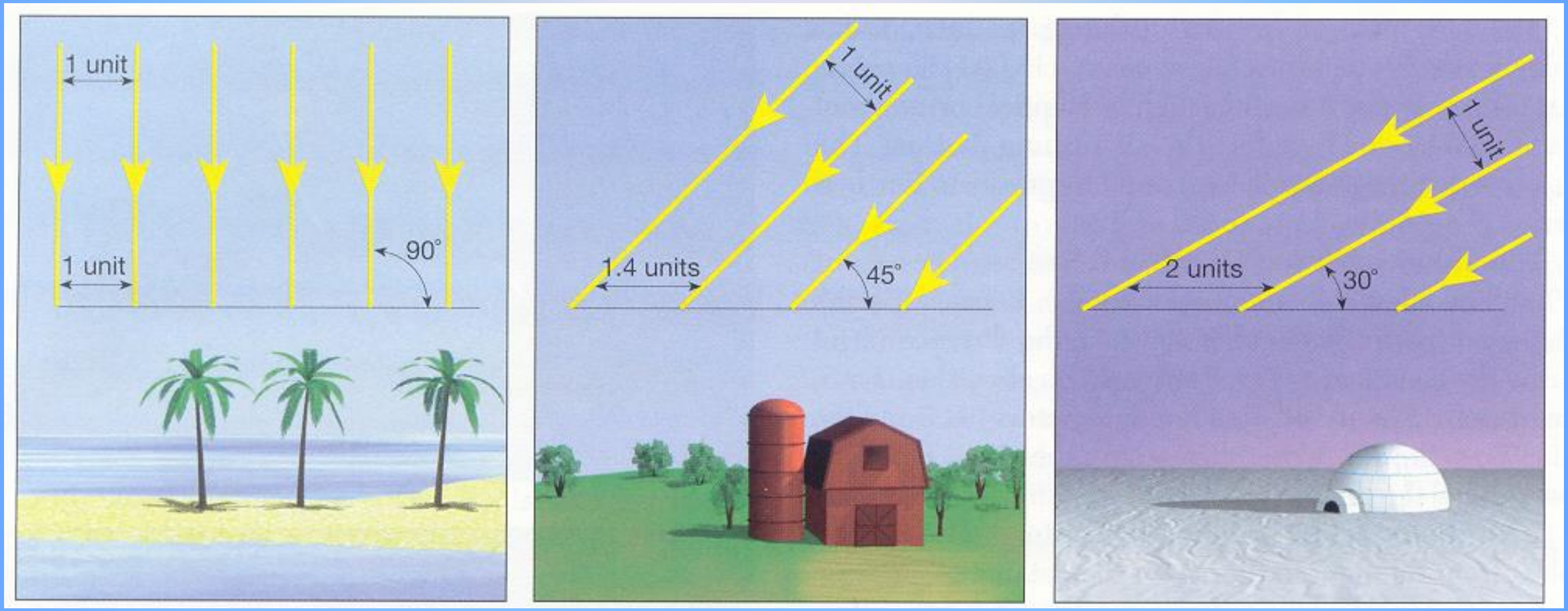
Rougher surfaces absorb more energy due to greater surface area

B. <u>Intensity of Insolation</u>

1. This is the __rate__ at which solar energy is received by a **given** __area__ **of Earth's surface per unit of** __time__ (usually calories/second/square centimeter).

Note: Atmospheric scientists will use calories instead of Joules.

2. **Angle of Insolation** ____________________: The angle at which the Sun's rays strike Earth's surface



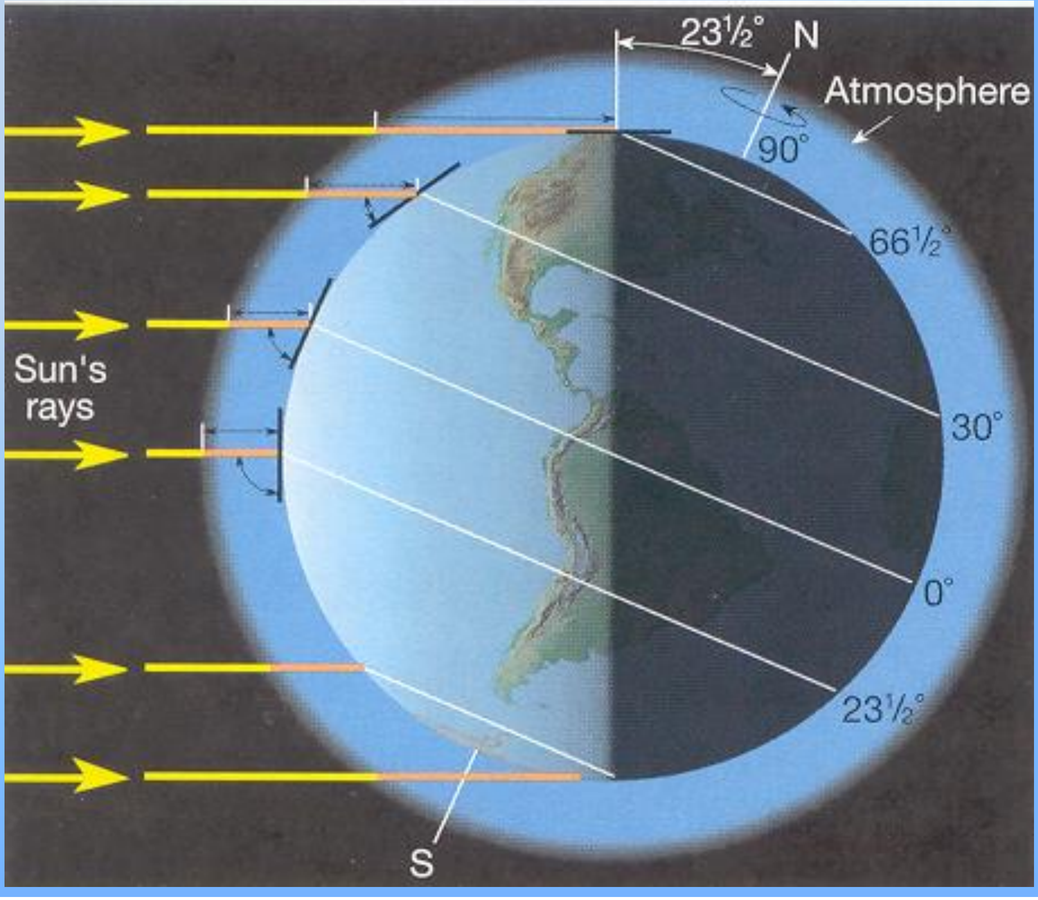
a. **Direct** ________**Rays** strike the surface at right angles. They are ___**vertical**___.

b. As the angle **decreases,** the rays become ___**less**___**direct** and insolation is spread out over a ___**greater**___**area**.

c. Therefore, the **more direct the rays** striking Earth's surface, the ___**greater**___ **the intensity of insolation.**

3. Factors Affection Angle of Insolation

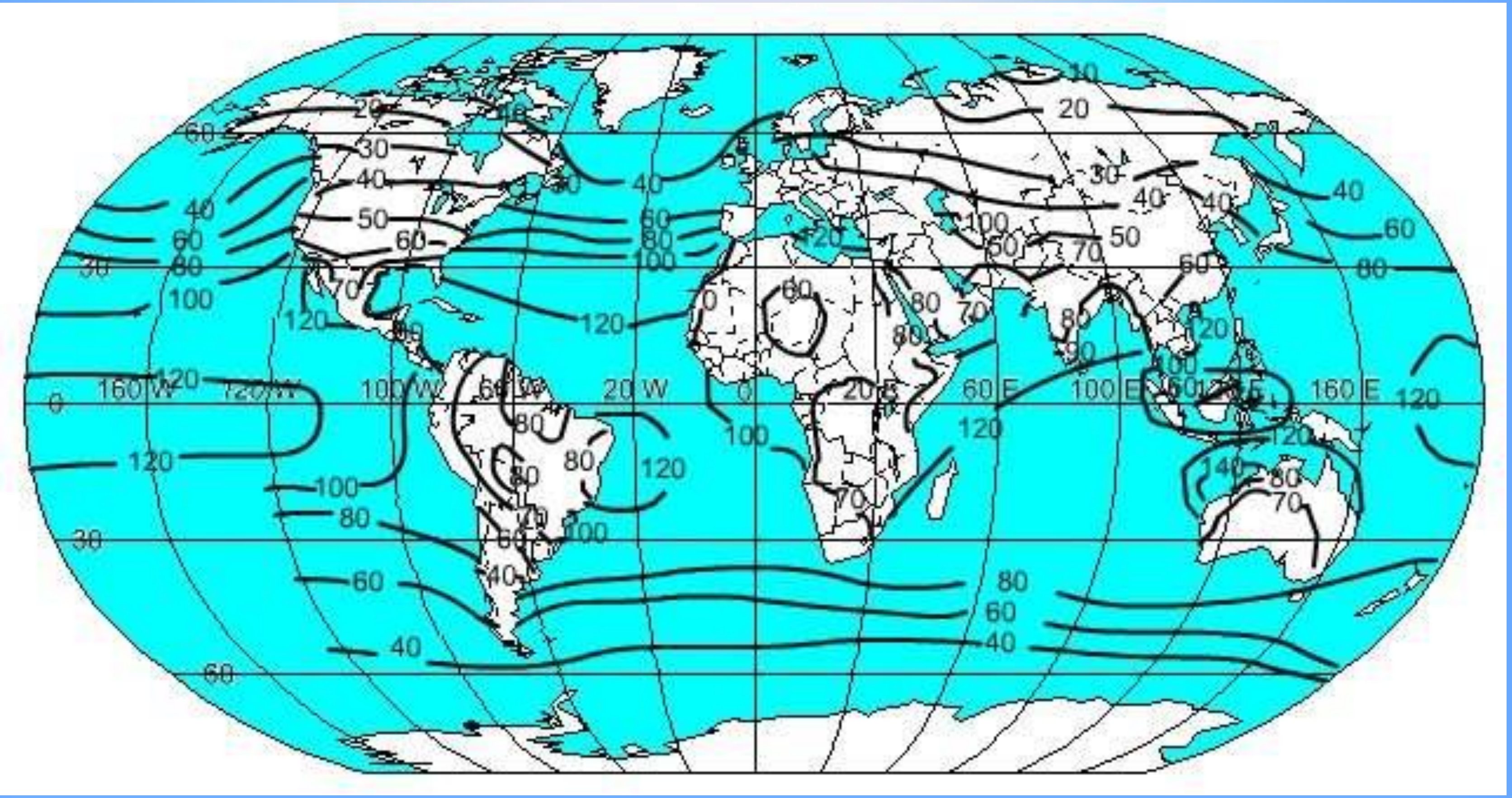
a. Latitude



***<u>Generally</u>*, **

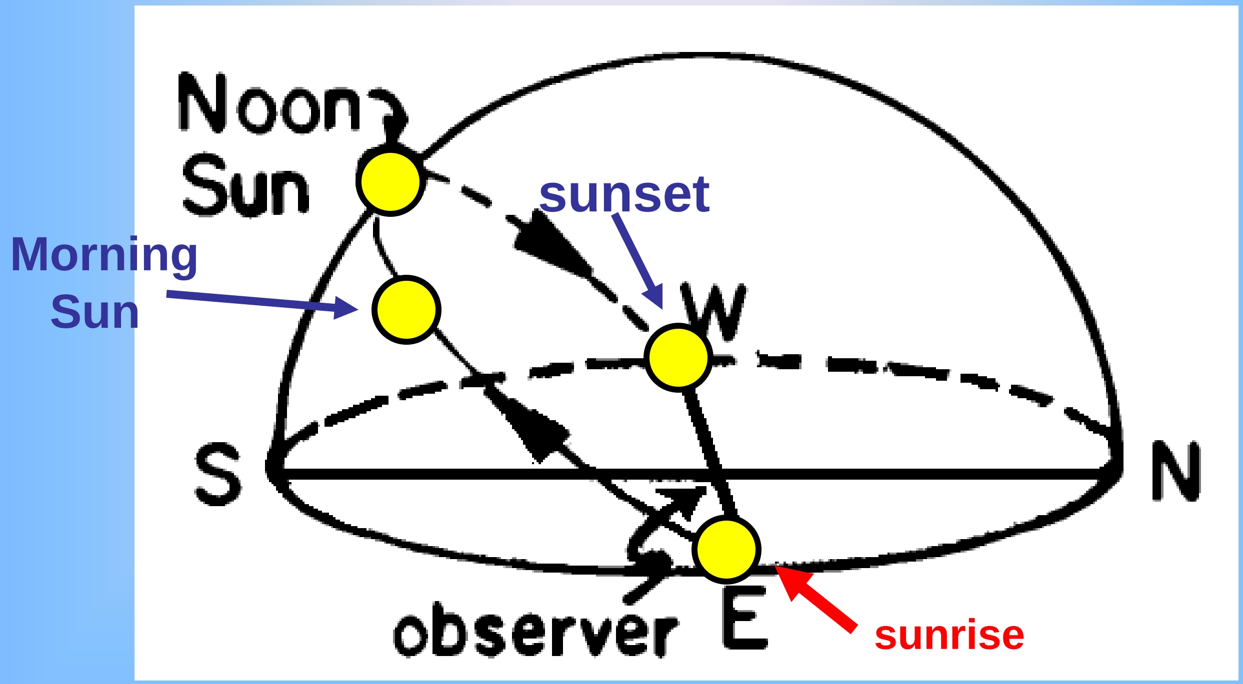
as latitude increases, angle of insolation decreases

Latitudinal Variation of the Radiation Balance



Solar Radiation in Kcal/cm^2

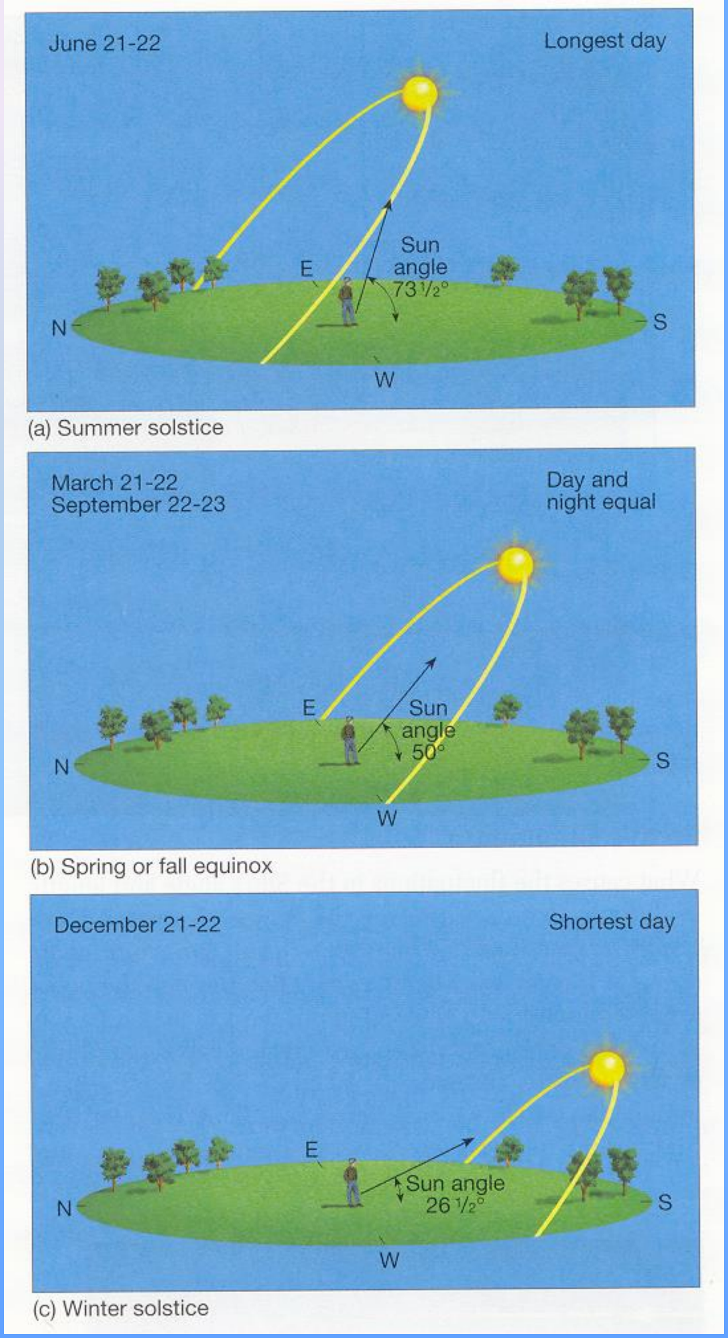
b. **Time of Day**



- The sun is highest at *solar noon.*
- This is when the angle of insolation will be greatest.
- From sunrise to solar noon the angle of insolation increases.
- From solar noon to sunset the angle of insolation decreases.

c. **Season**

- The Sun’s maximum angle of insolation is on the summer solstice.
- The minimum angle of insolation is on the winter solstice.



III. The Seasons

A. __Terrestrial__ Observations (Observed from **Earth**) See Rev. Book Figure 9-21 on page 468 and Rev. Book Table 9-3 on page 469.

1. Change in length of __daylight__.

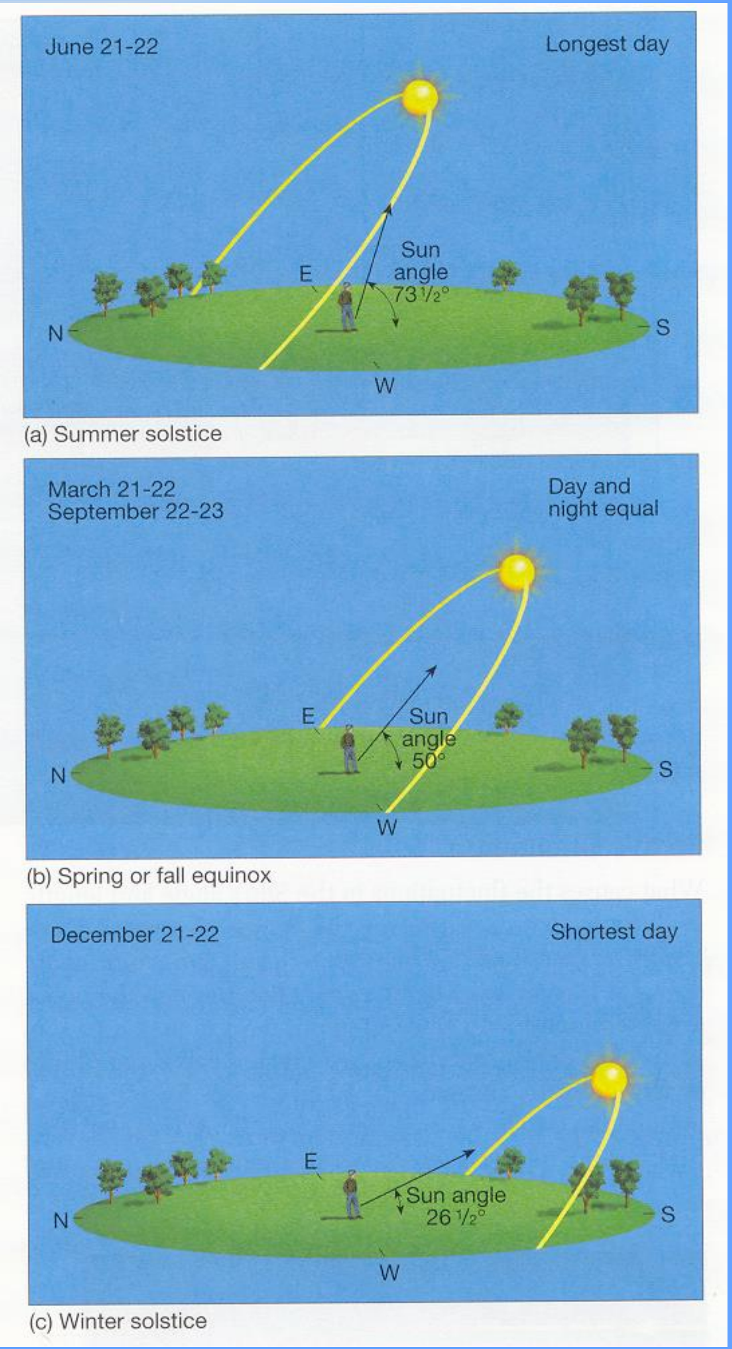
2. Change in the sun's __apparent path__ across the sky

   a) Change in __sunrise__ and __sunset__ positions

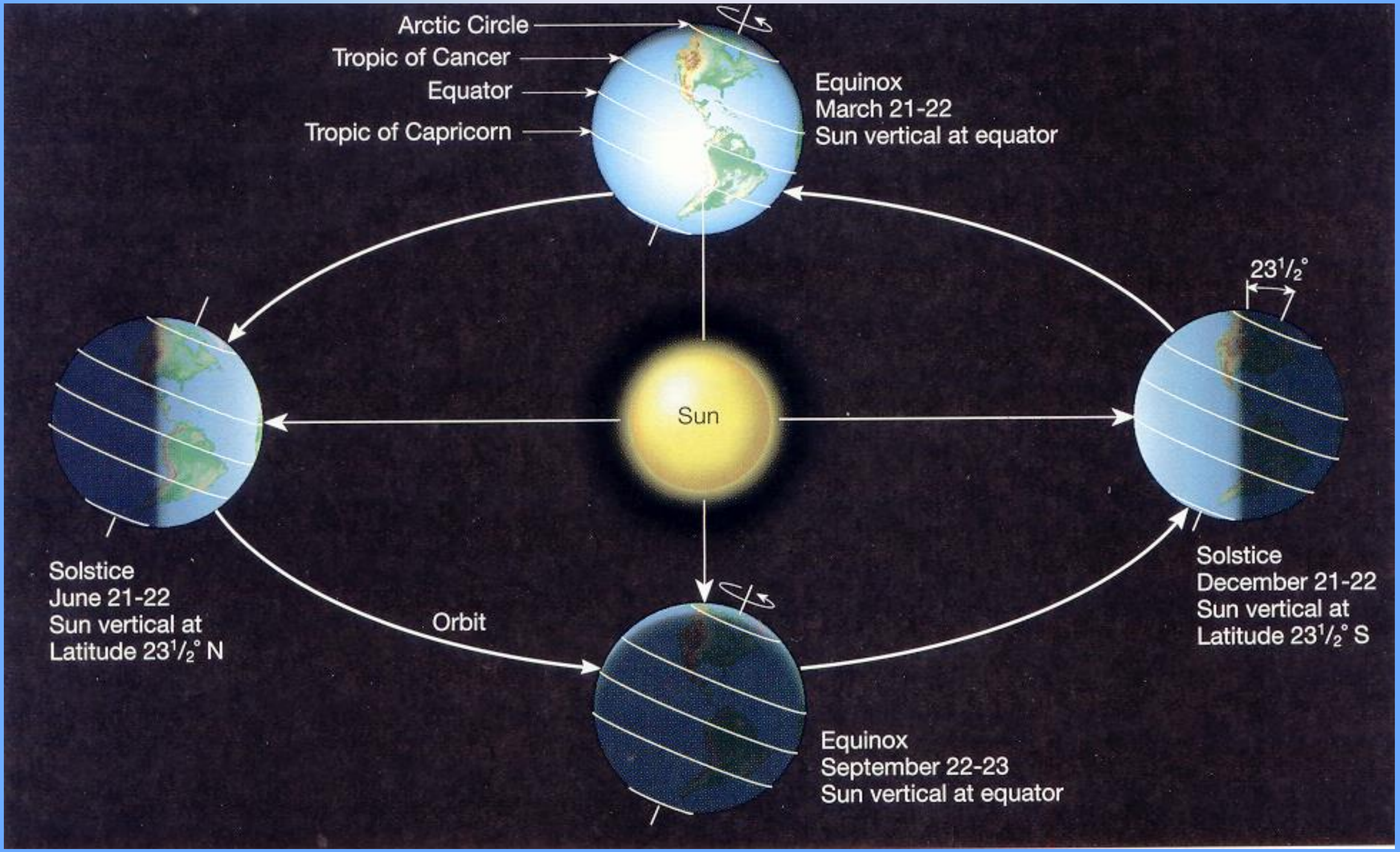
   b) Change in __noontime__ altitude (solar noon or "high" noon)

      i) Change in angle of __incidence__ of Sun's rays with Earth's surface

      ii) Change in __thickness__ of atmosphere through which the Sun's rays pass



B. Causes of changing the Sun's **noontime altitude** and **diurnal** path throughout the year



1. Earth's _**orientation**____ **to the Sun** continually changes as it __**revolves**____ around the Sun.

2. Earth's axis is inclined _**23 ½°**__ from a line perpendicular to the plane of it's orbit

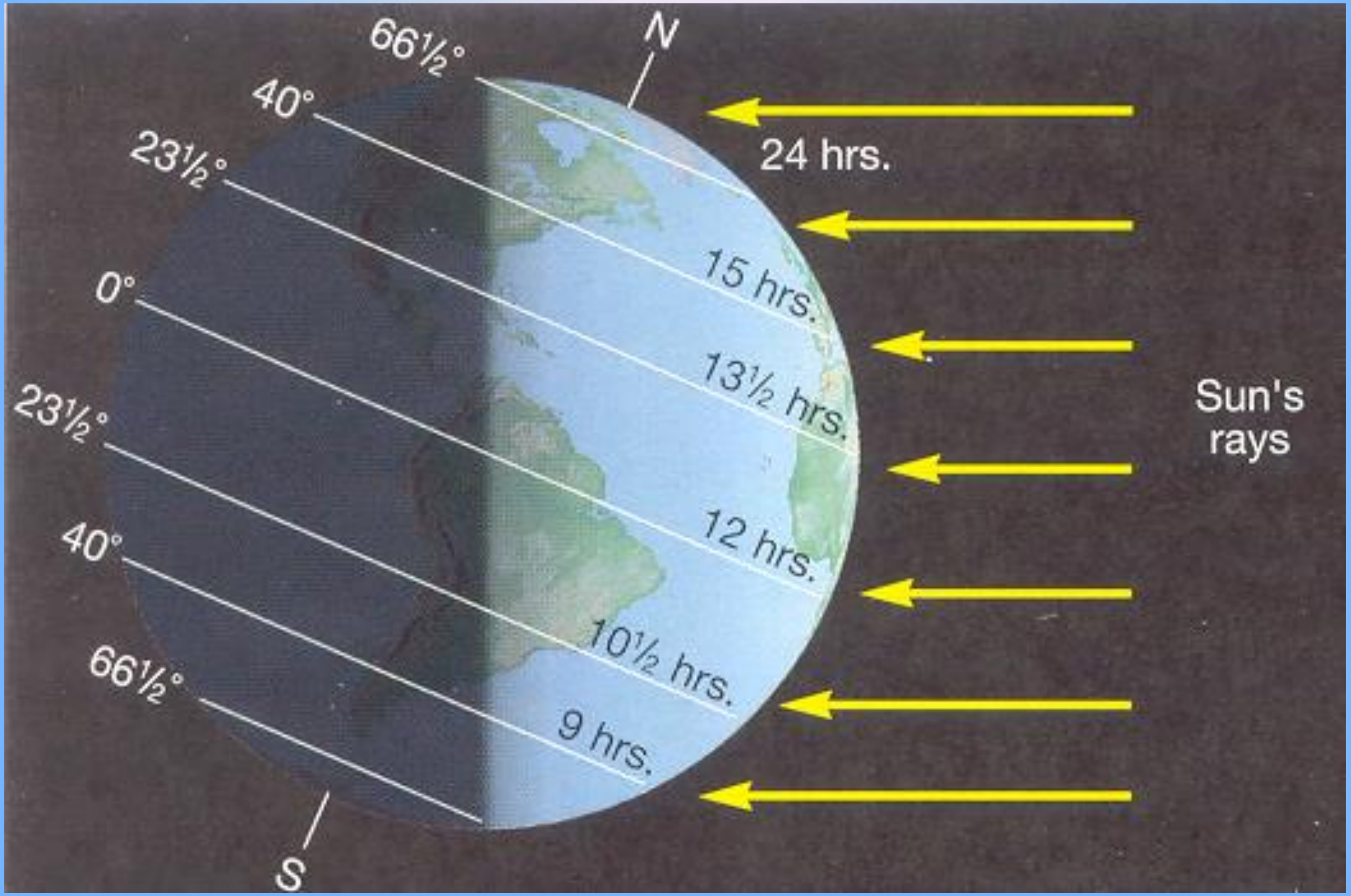
3. _**Parallelism** of Earth's axis:

   A. Earth's axis always points **in the** _**same direction**__ **in space**.

   B. The orientation of the axis is at any position in its orbit **always** _**parallel**___ **to any other position** (See Review Book *Figure 8-6*, page 386).

C. Solstices and Equinoxes

1. **Summer Solstice** (Northern Hemisphere)



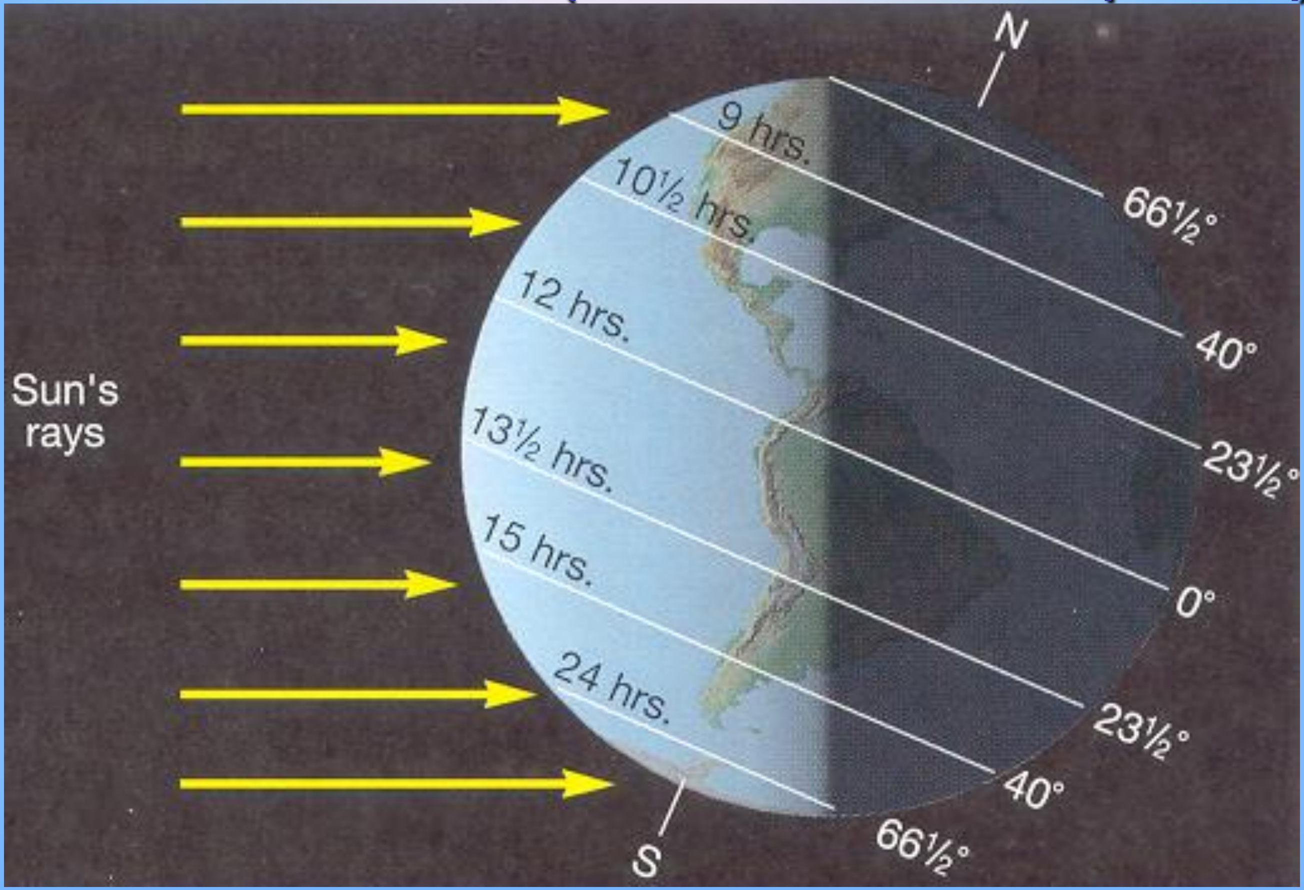
a) Northern axis tilts _**towards**_ the Sun

b) Sun's **direct rays** at _**23 ½° N**_latitude

Land of the Midnight Sun north of the Arctic Circle

Daylight on June 21st

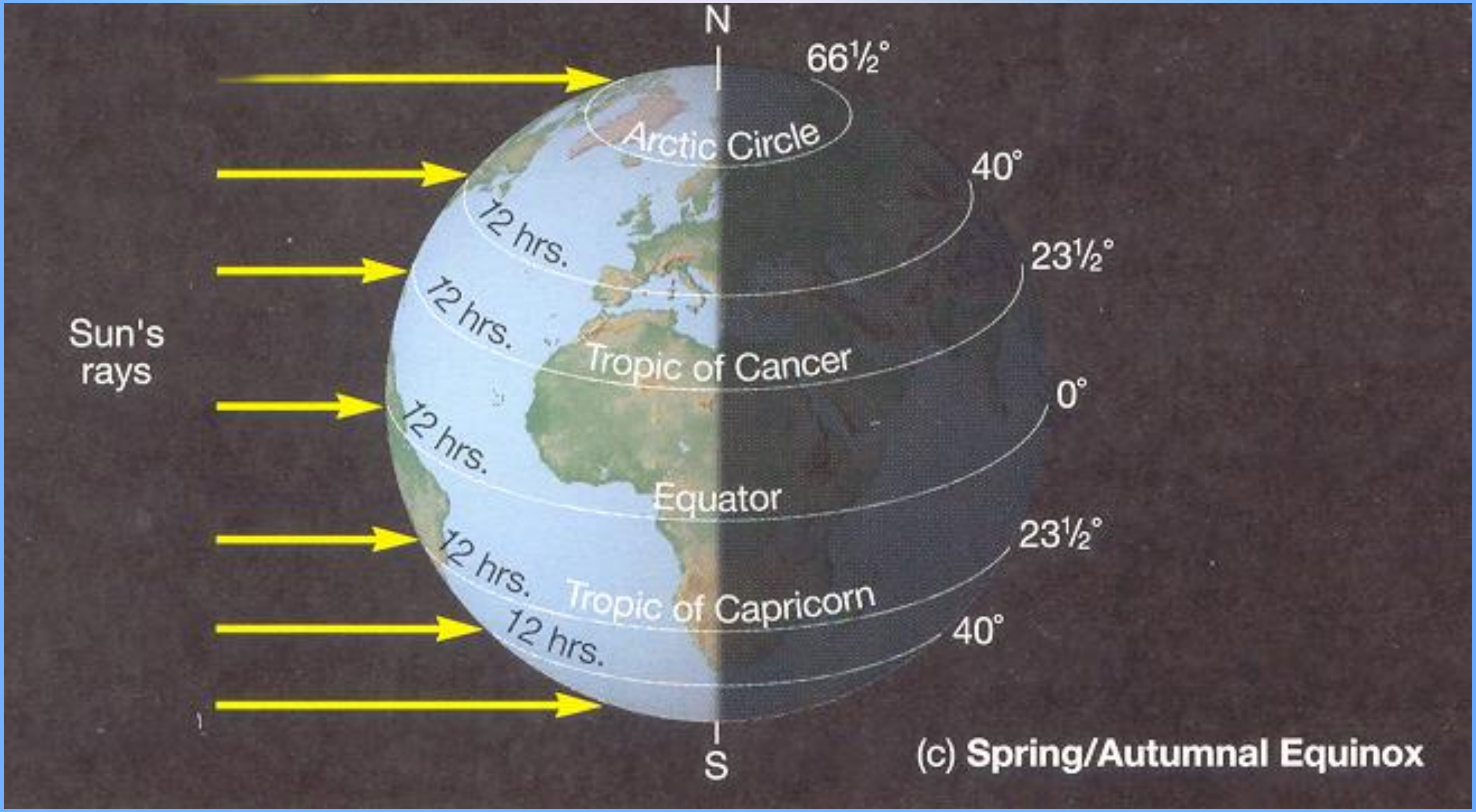
2. Winter Solstice (Northern Hemisphere)



a) Northern axis tilts __away from__ the Sun

b) Sun's **direct rays** at __23 ½º S__latitude

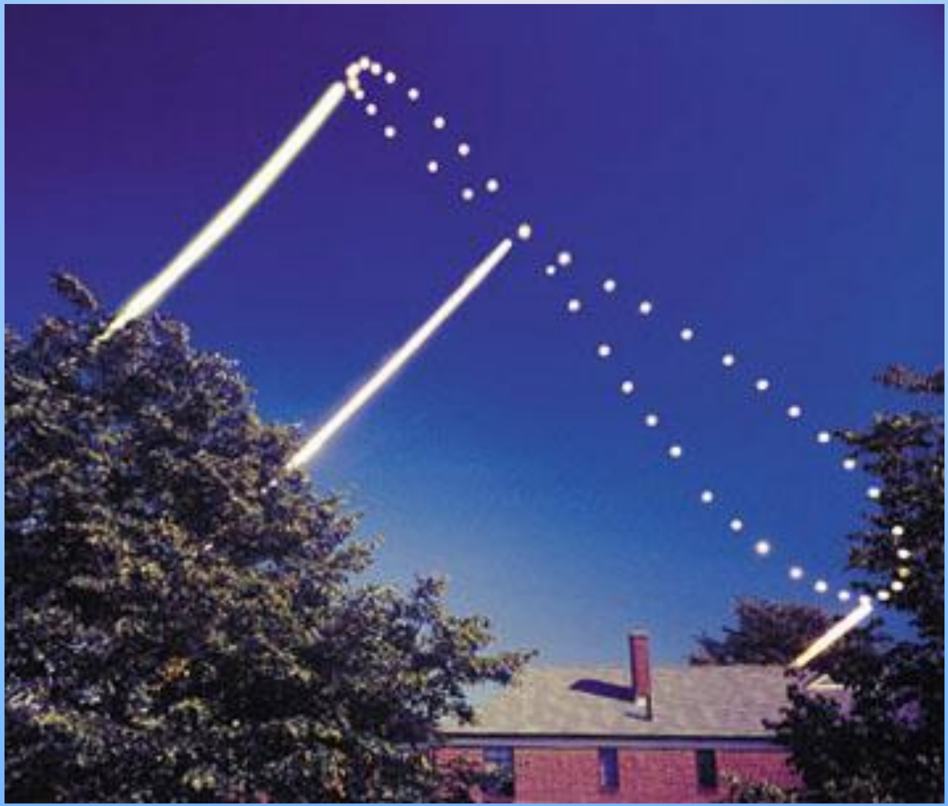
3. **Equinoxes** (Autumnal and Spring which is also called the *vernal* equinox)



a) Midway between the solstices

b) Sun's direct rays are on the equator

The Analemma



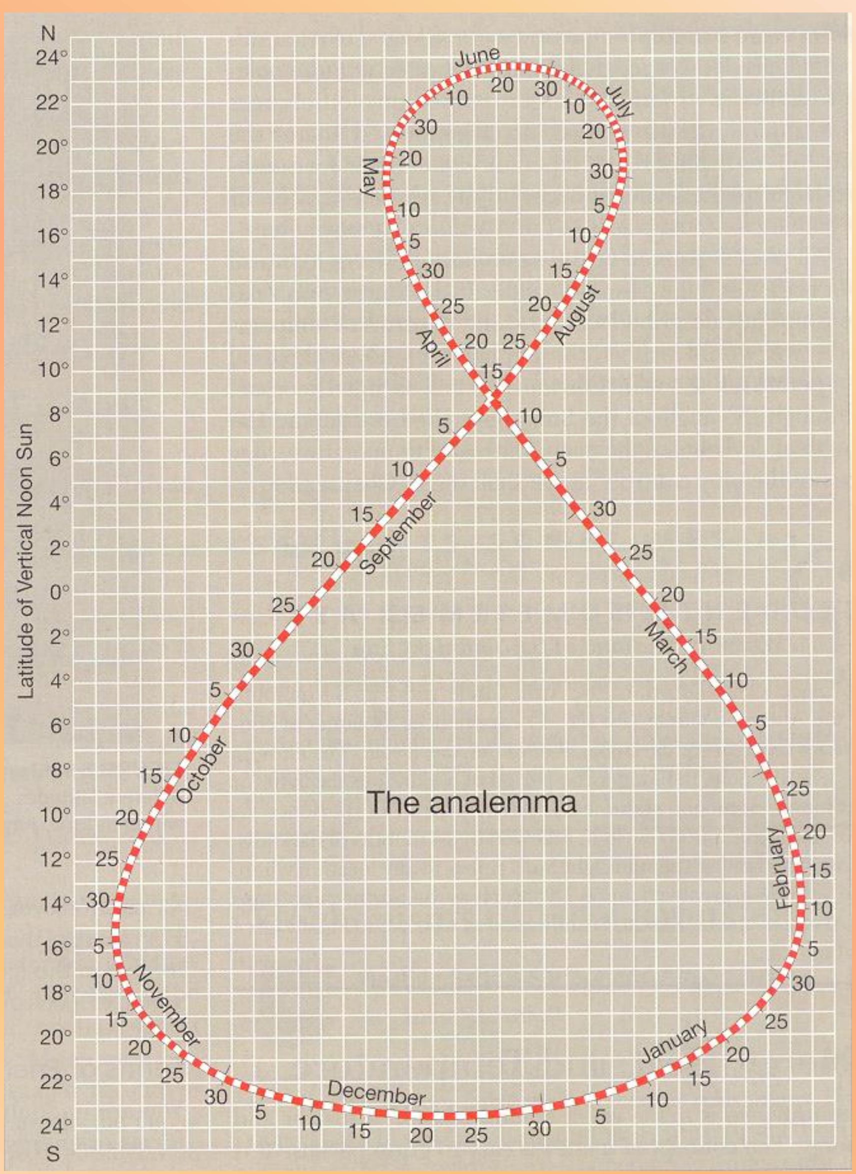
- If you could record the position of the sun in the sky at noon every day throughout the year, you would notice that the sun follows a figure-8 path.

The Shape of the Analemma

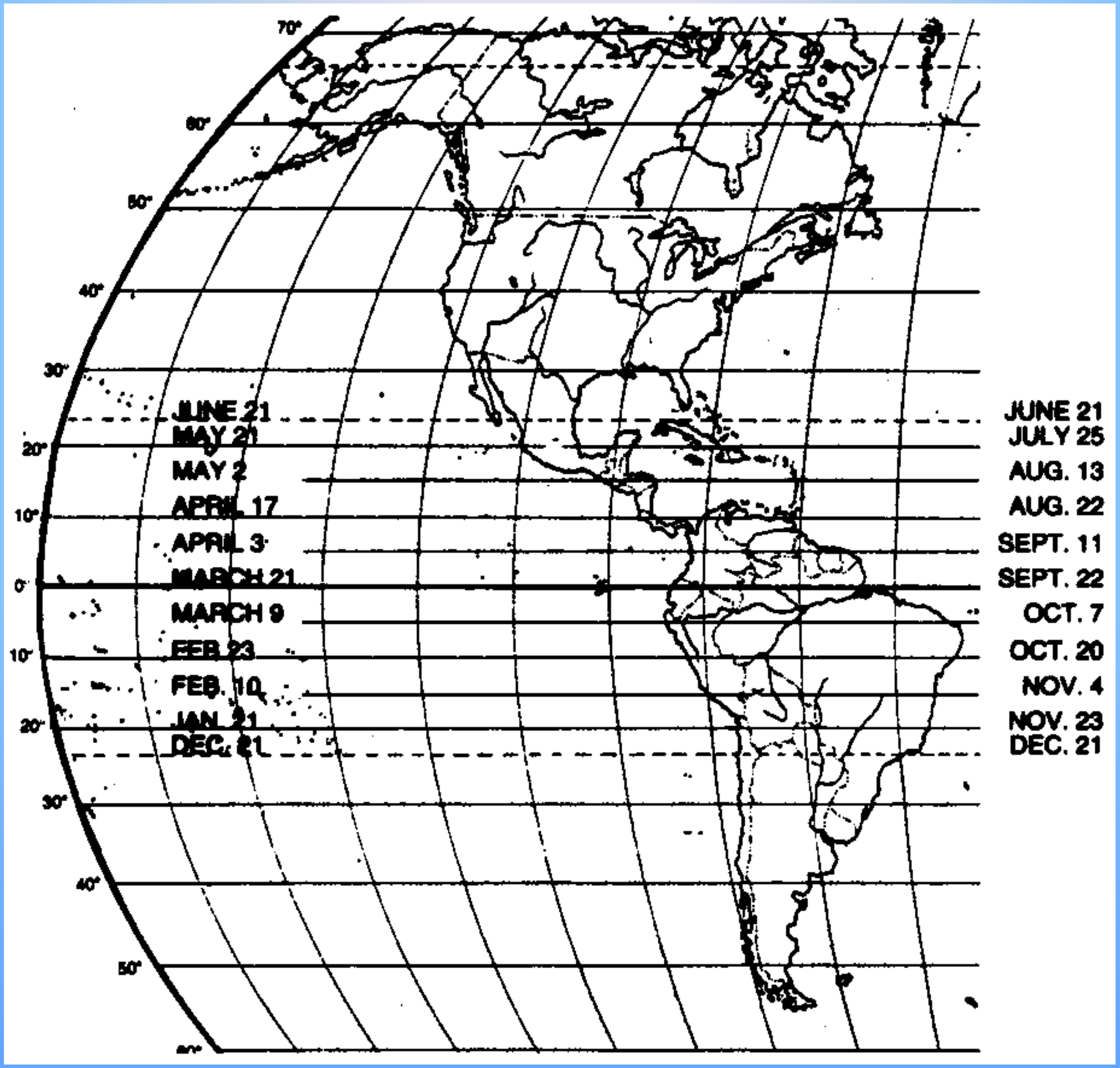
- The figure-8 pattern is distorted because of the elliptical shape of Earth's orbit.
- If Earth's orbit were perfectly circular, both loops of the figure-8 would be equal in size.

Using the Analemma

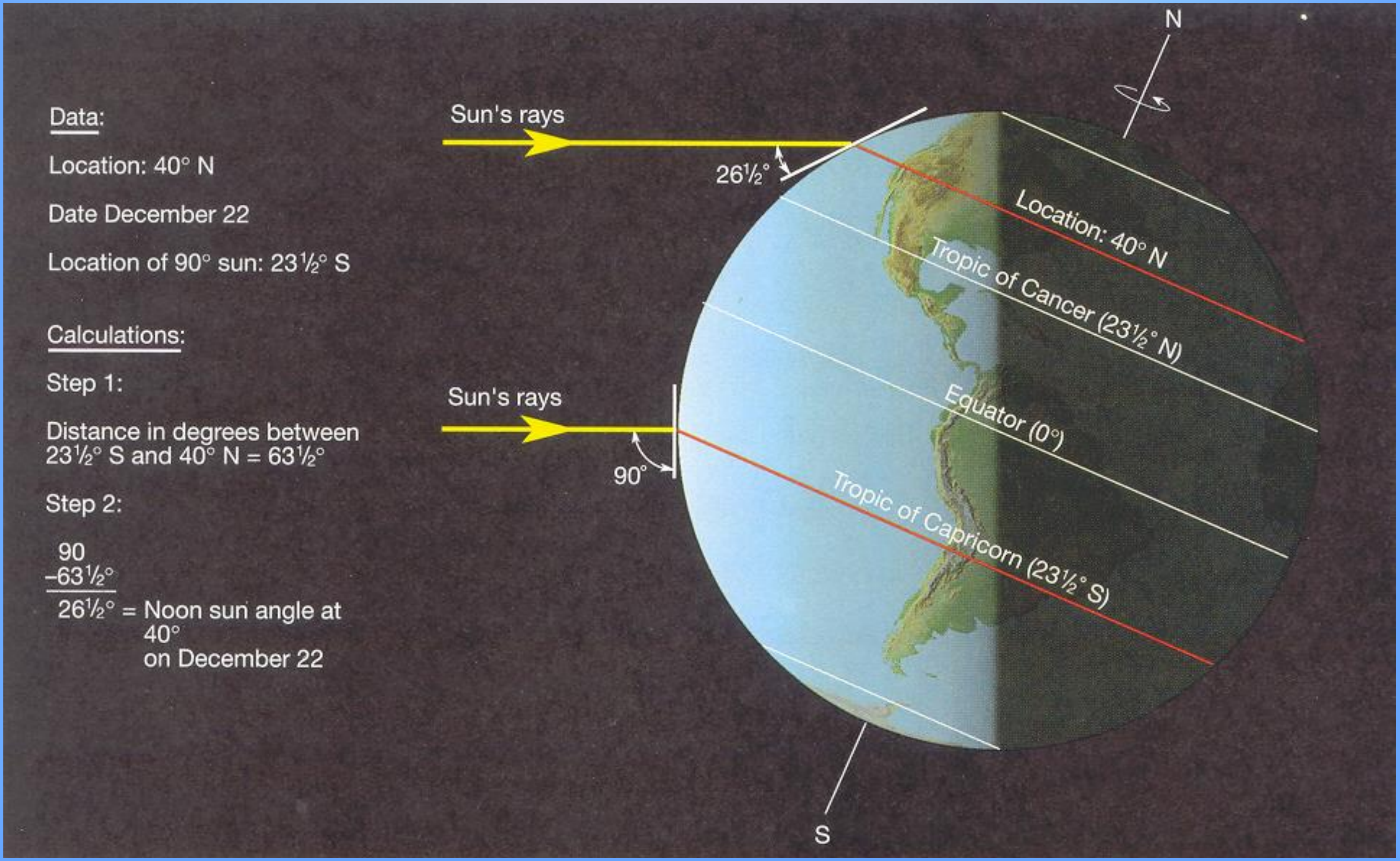
- Set the analemma curve upright, and it becomes a miniature almanac.
- The vertical coordinate of each point on it gives the sun's declination on a particular day of the year,
- The horizontal coordinate tells how much the sun is ahead of or behind clock time on that day



Vertical Rays of the Sun



Finding the Noon Sun Angle (altitude)



IV. The Atmosphere and Insolation

A. What Happens to Insolation?

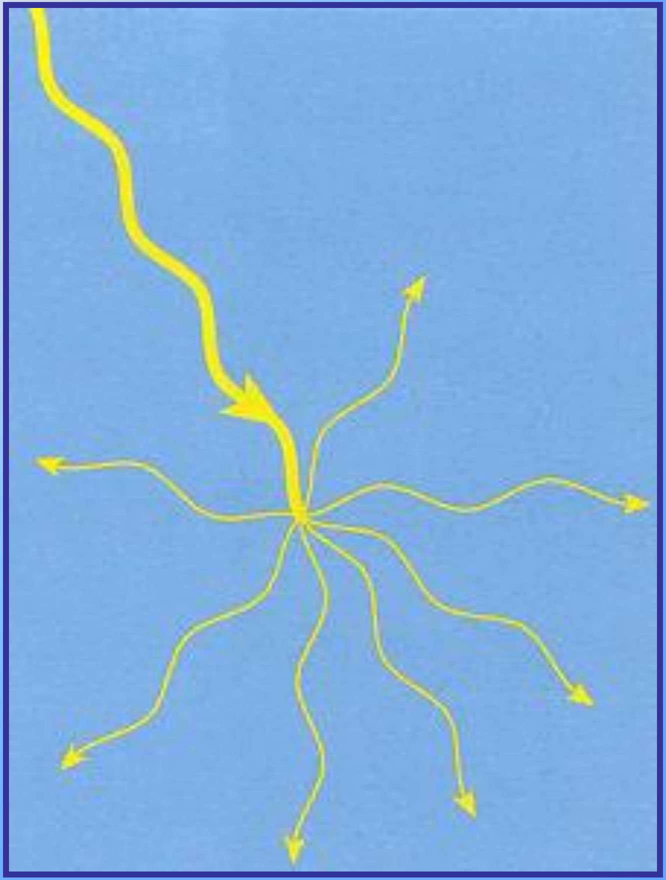
1. Scattering

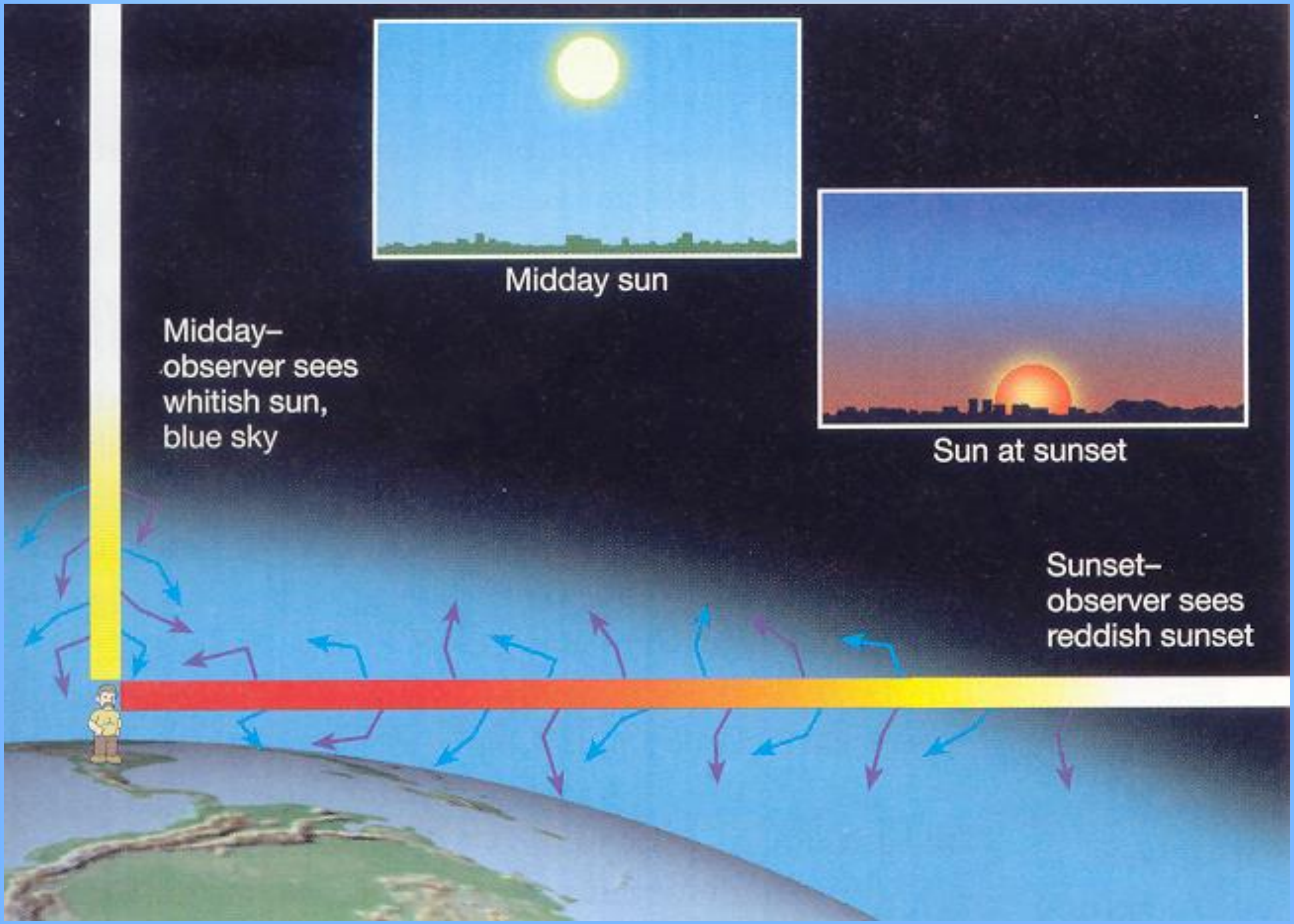
a. Insolation is redirected by gases and dust particles (**aerosols**) in the atmosphere

b. Produces **diffused** light.

i Degree of scattering depends on **the size** of particles or gas molecules

ii When light is scattered by very small particles, primarily gas molecules, it is distributed in all directions but most is scattered in the forward direction. Light lost to space is said to be **backscattered**.





iii **The blue color of the sky**:

Gas particles more readily scatter shorter wavelengths (blue and violet).

(1) During midday blue light is seen because it is most readily scattered.

(2) When the Sun is lower light travels a longer path.

(3) **A reddish or orange** color seen because most blue and violet is scattered before reaching the observer.

2. Reflection

a. Approx. 30% of insolation is reflected back into space by the outer atmosphere.

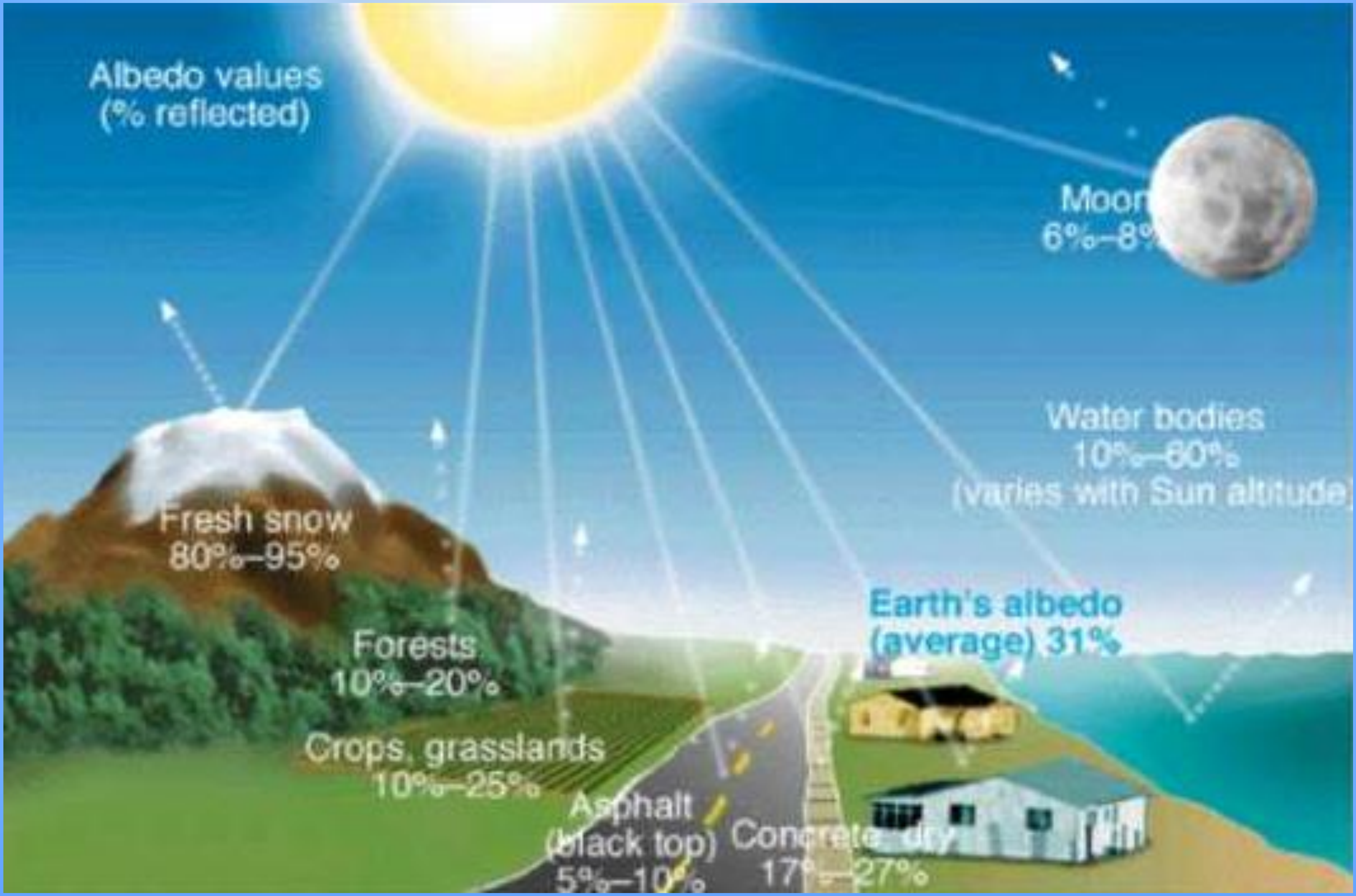
b. _Albedo_: The fraction reflected by a surface.

i. Varies with characteristics of the surface.

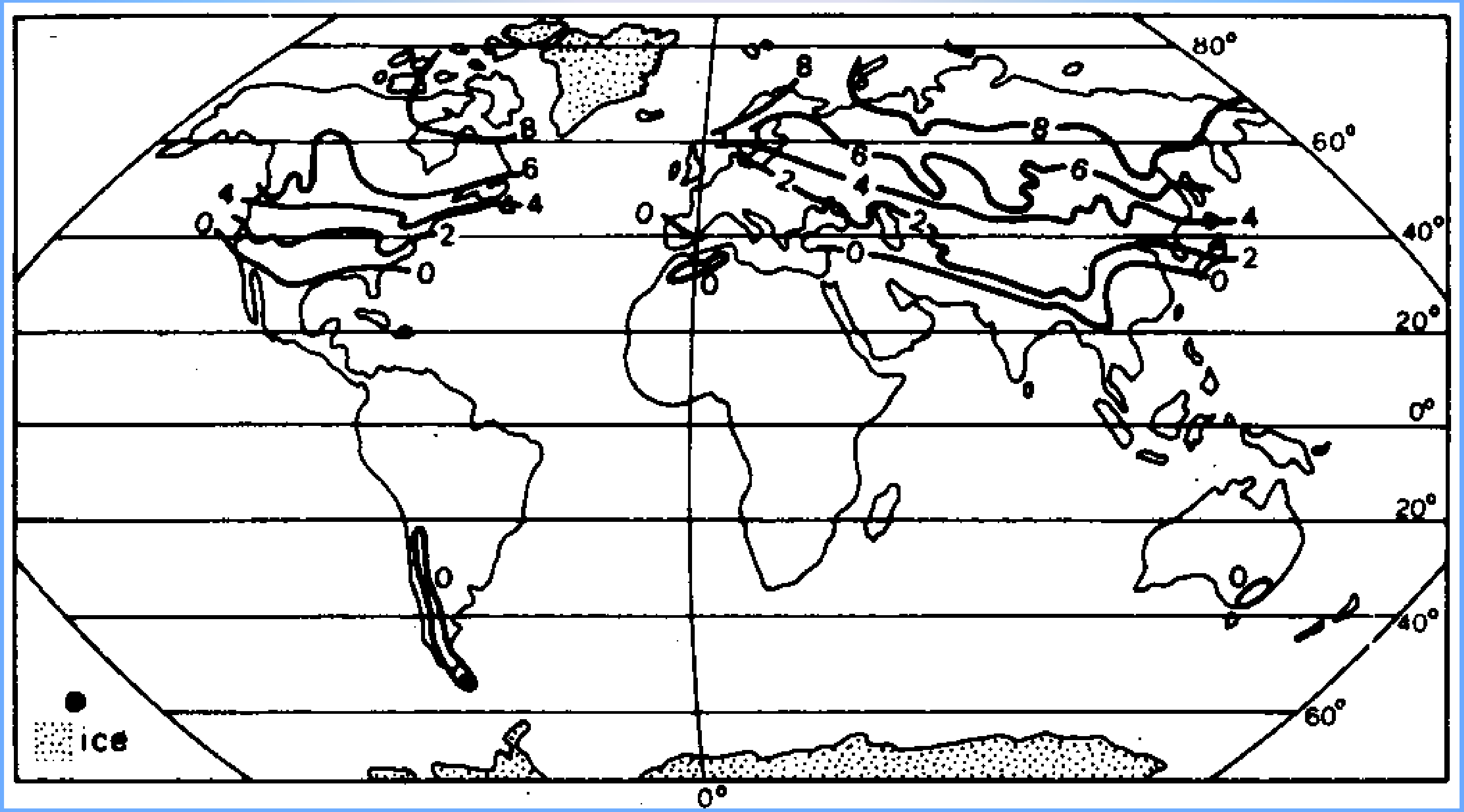
ii. Varies with weather conditions and time of day and year.

Albedo

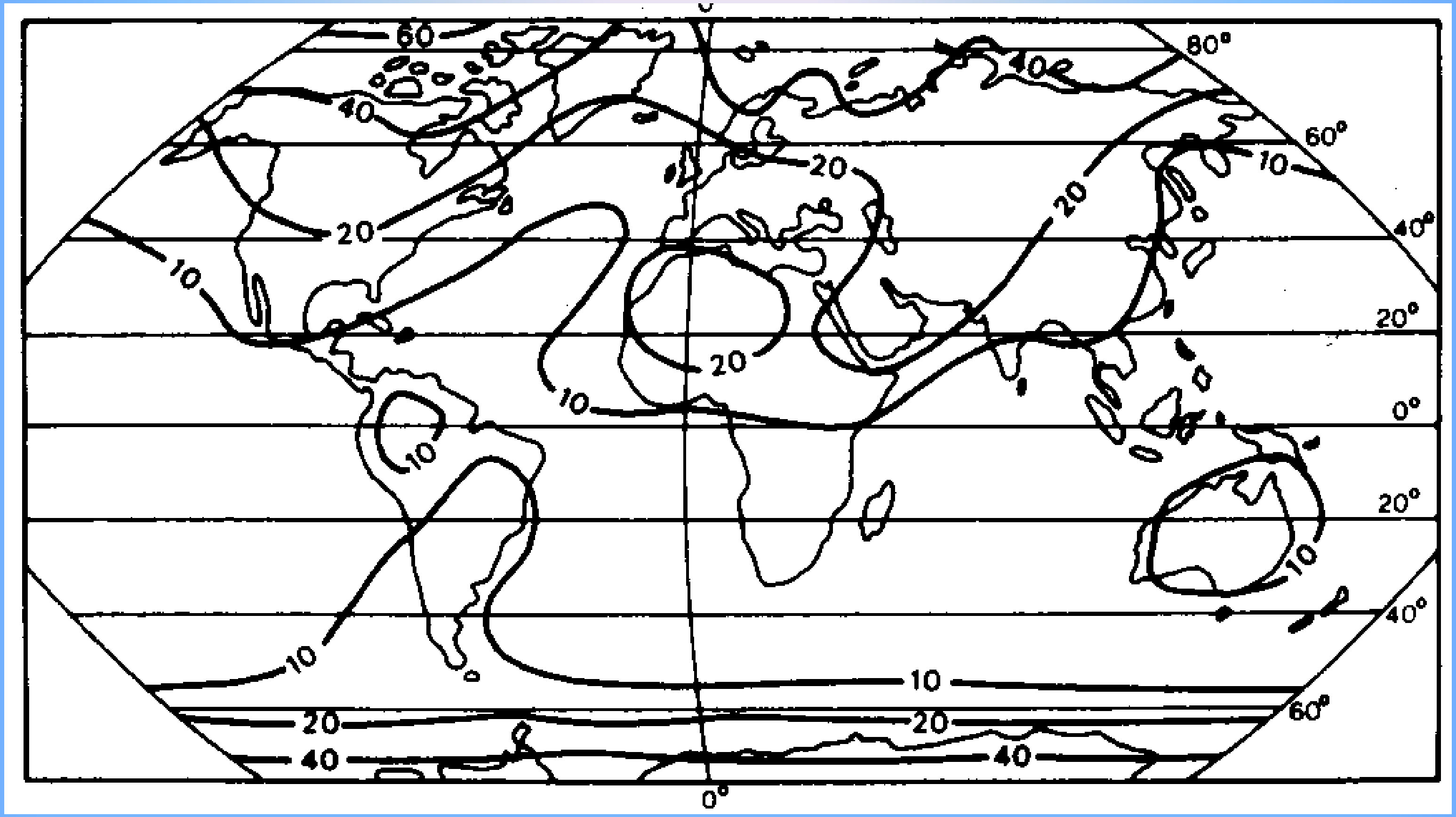
(more reflection = higher Albedo)



Average Snow Cover in Months



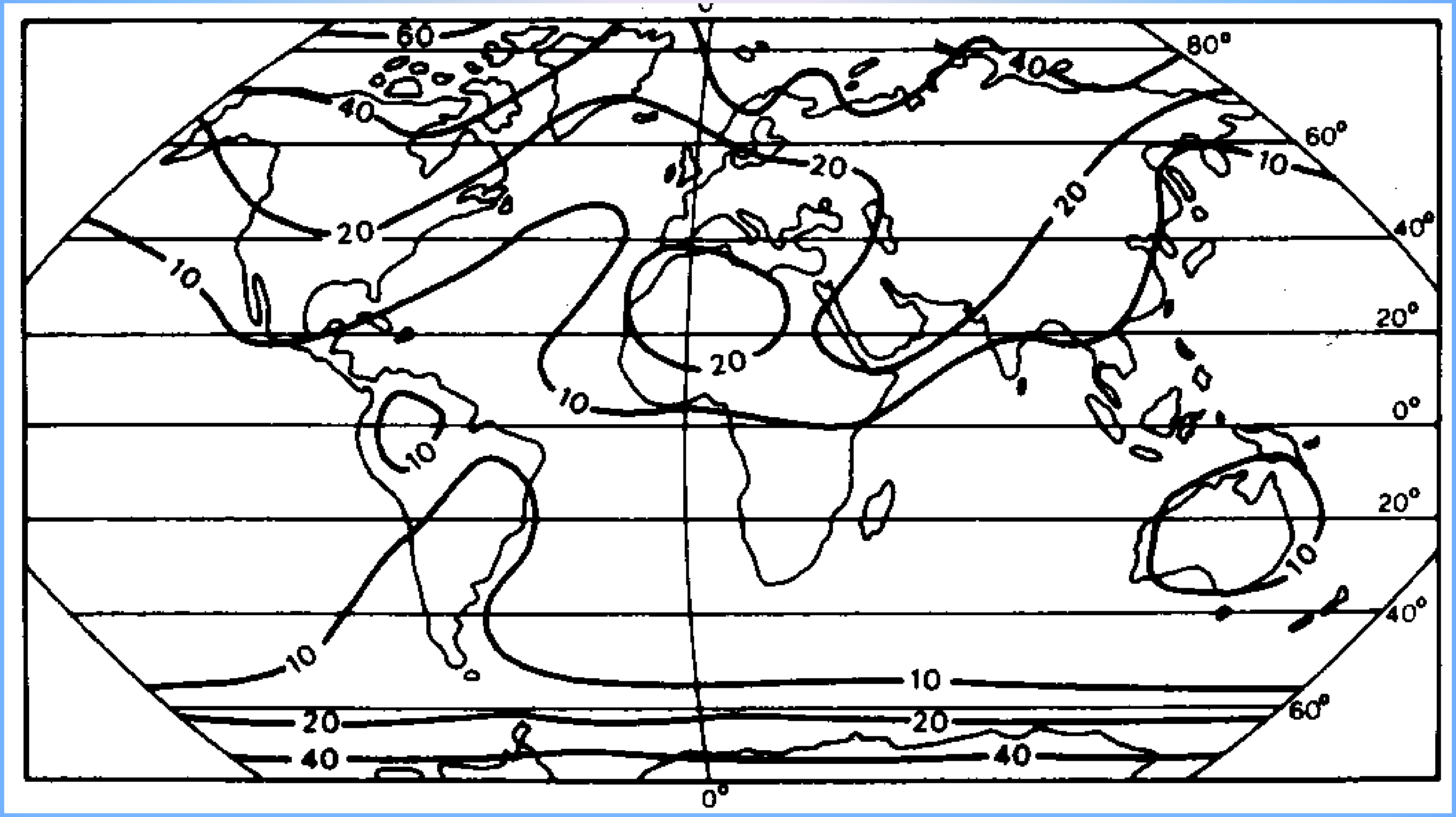
Average Annual Albedo



Why is albedo lower over tropical oceans than over high latitude oceans?

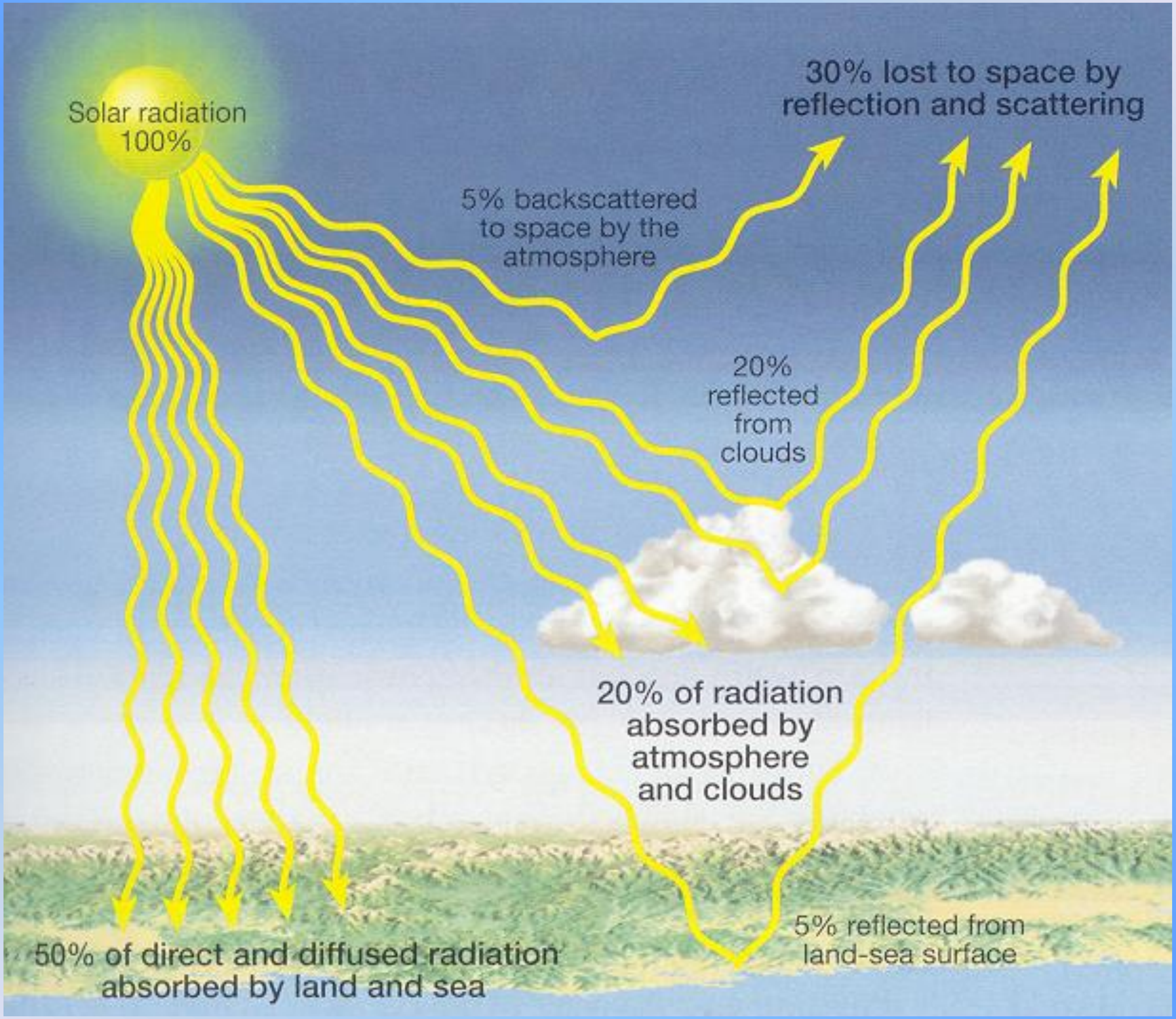
- Greater angle of insolation and less reflection

Average Annual Albedo



Why is the albedo higher in northern N. America than in northern Africa and Central Australia?

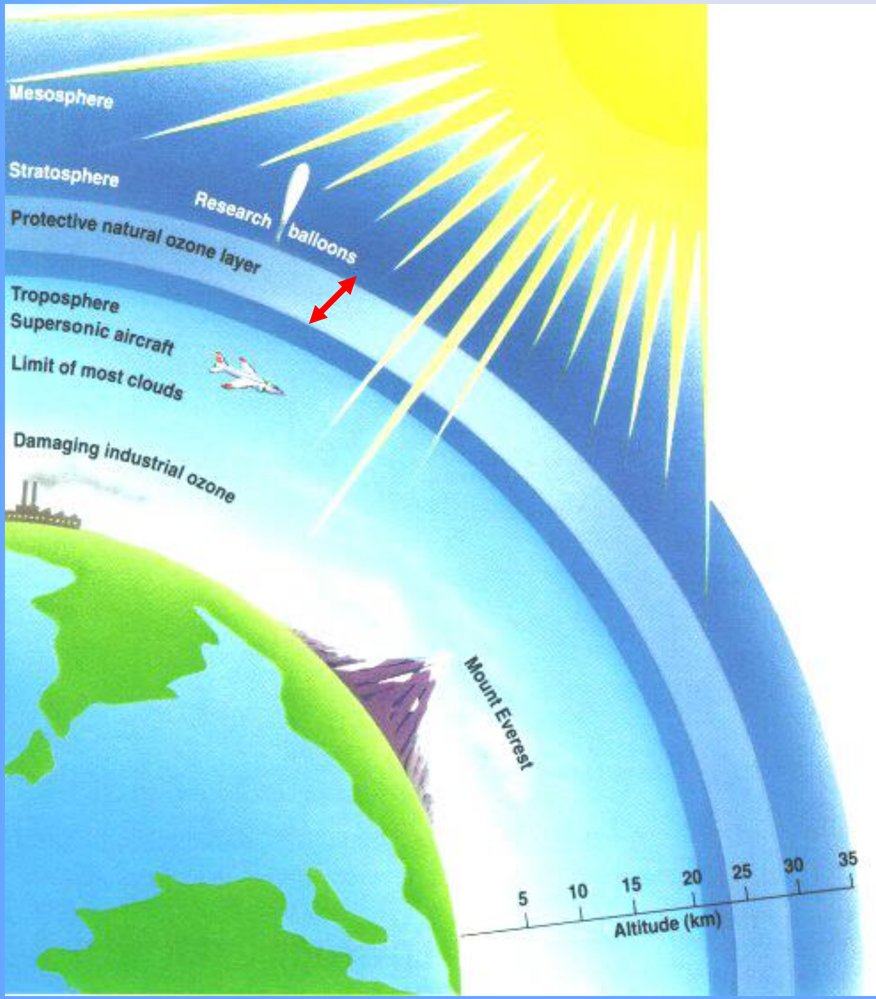
- Northern N. America is snow covered for part of the year.

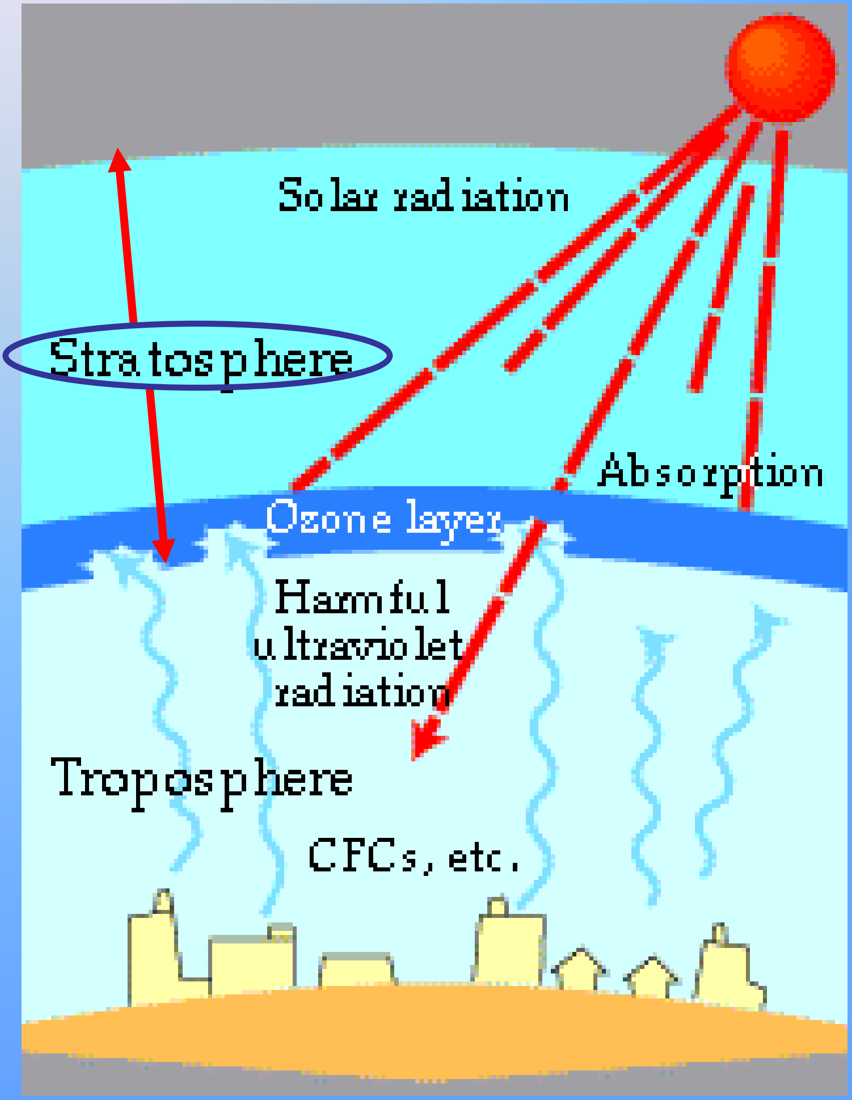

Solar radiation
100%
30% lost to space by
reflection and scattering
5% backscattered
to space by the
atmosphere
20%
reflected
from
clouds
20% of radiation
absorbed by
atmosphere
and clouds
5% reflected from
land-sea surface
50% of direct and diffused radiation
absorbed by land and sea

B. Heating the Atmosphere

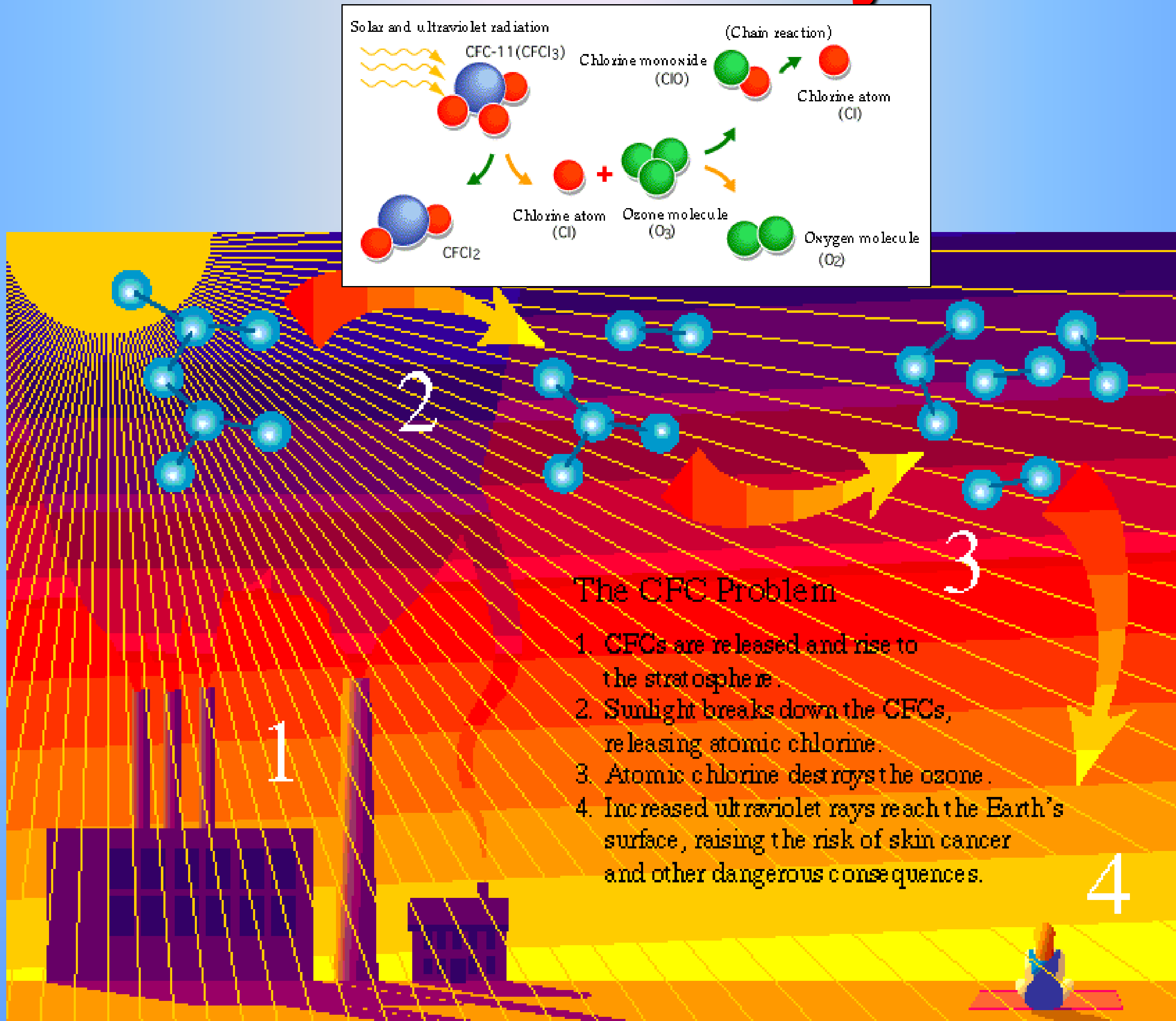
1. _**Gases**_ are the most effective absorbers of radiation and heat the atmosphere
2. The atmosphere is nearly _**transparent**__to incoming solar radiation. Direct solar energy is not an effective "heater" of Earth's Atmosphere.
3. The only significant absorbers of insolation are:
   a. **Water Vapor**_
   b. _**Oxygen**____: High energy, shortwave radiation
   c. _**Ozone**_____: High energy, shortwave radiation in the Stratosphere
4. The atmosphere is a relatively efficient absorber of long-wave (infrared) radiation.

The Stratosphere's Ozone Layer

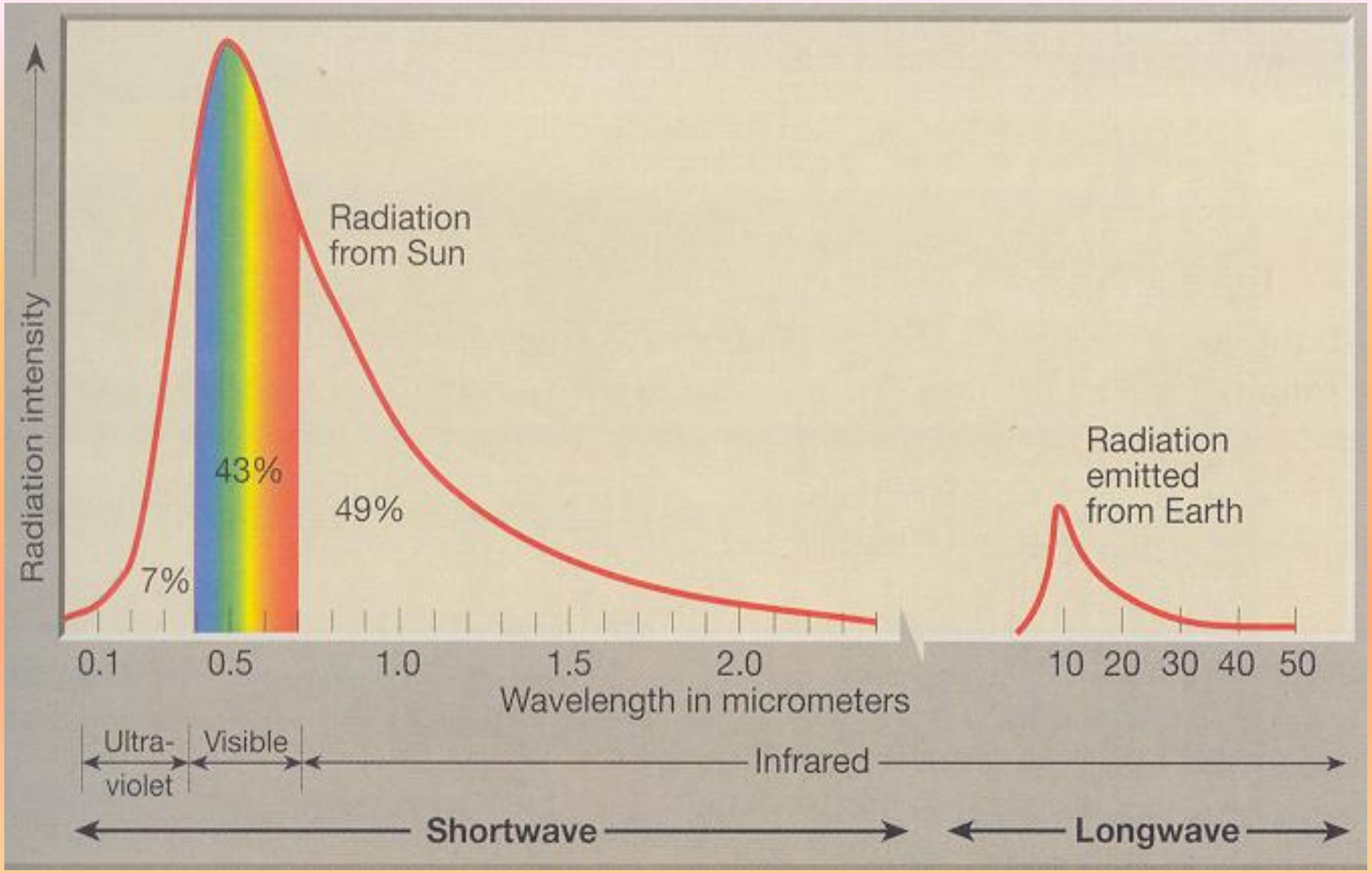




Destruction of Ozone by CFC's

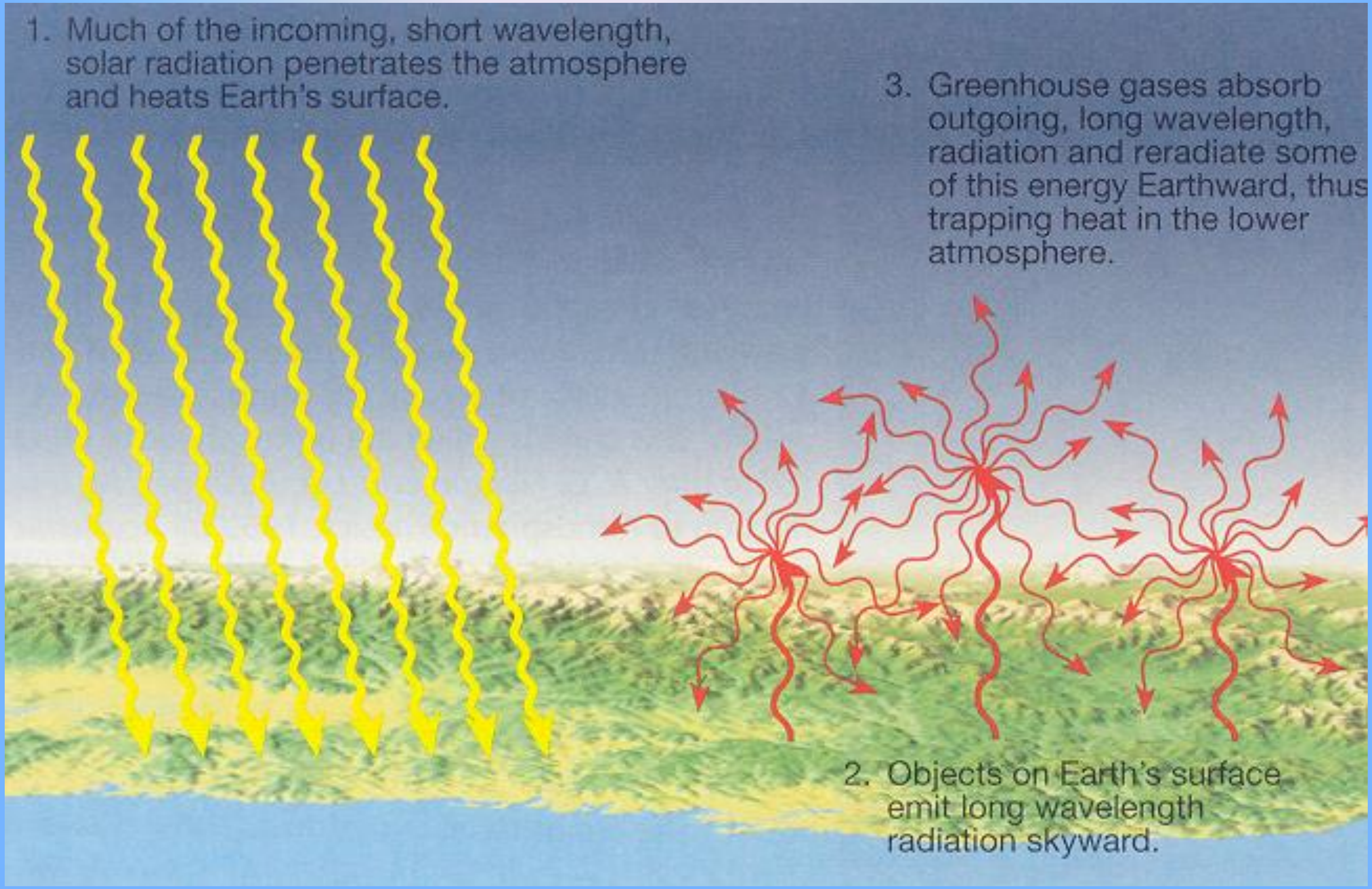


C. Terrestrial Radiation and Heating of the Atmosphere



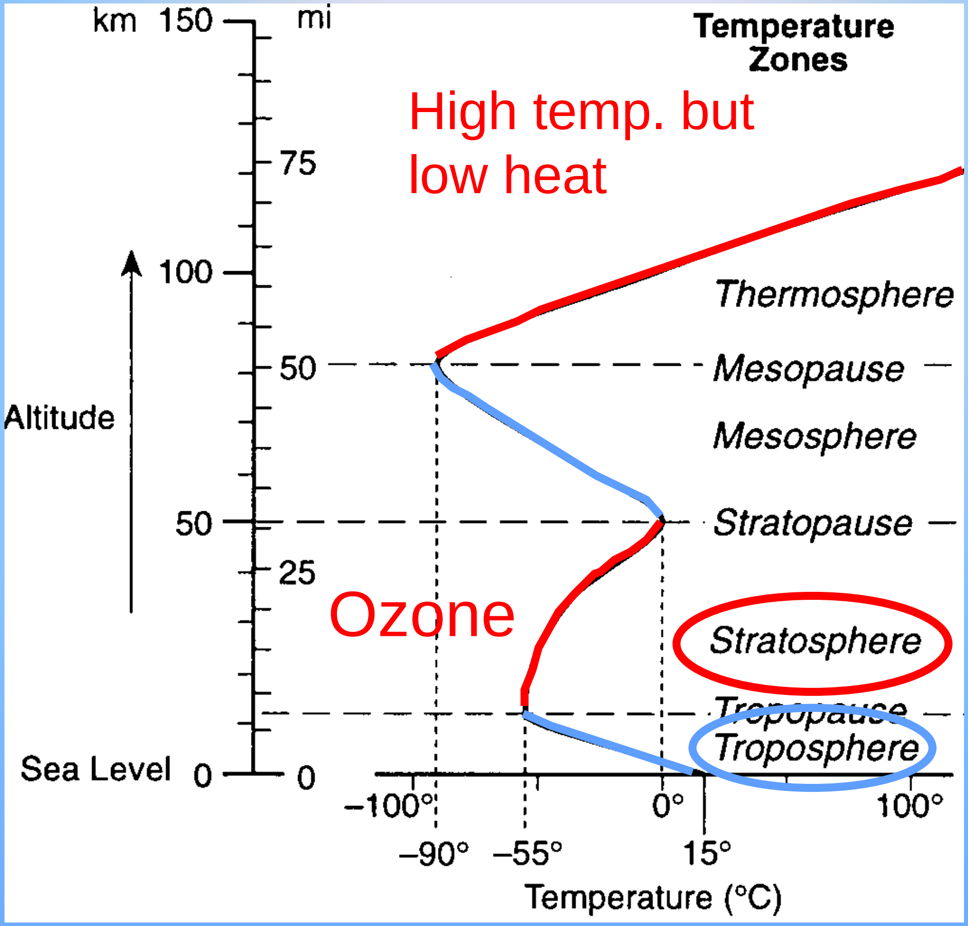
1. Emitted in __long__ wavelengths.

C. Terrestrial Radiation and Heating of the Atmosphere



2. <u>Infrared</u> range terrestrial radiation heats the atmosphere. As a result, the atmosphere heats from the ground up.

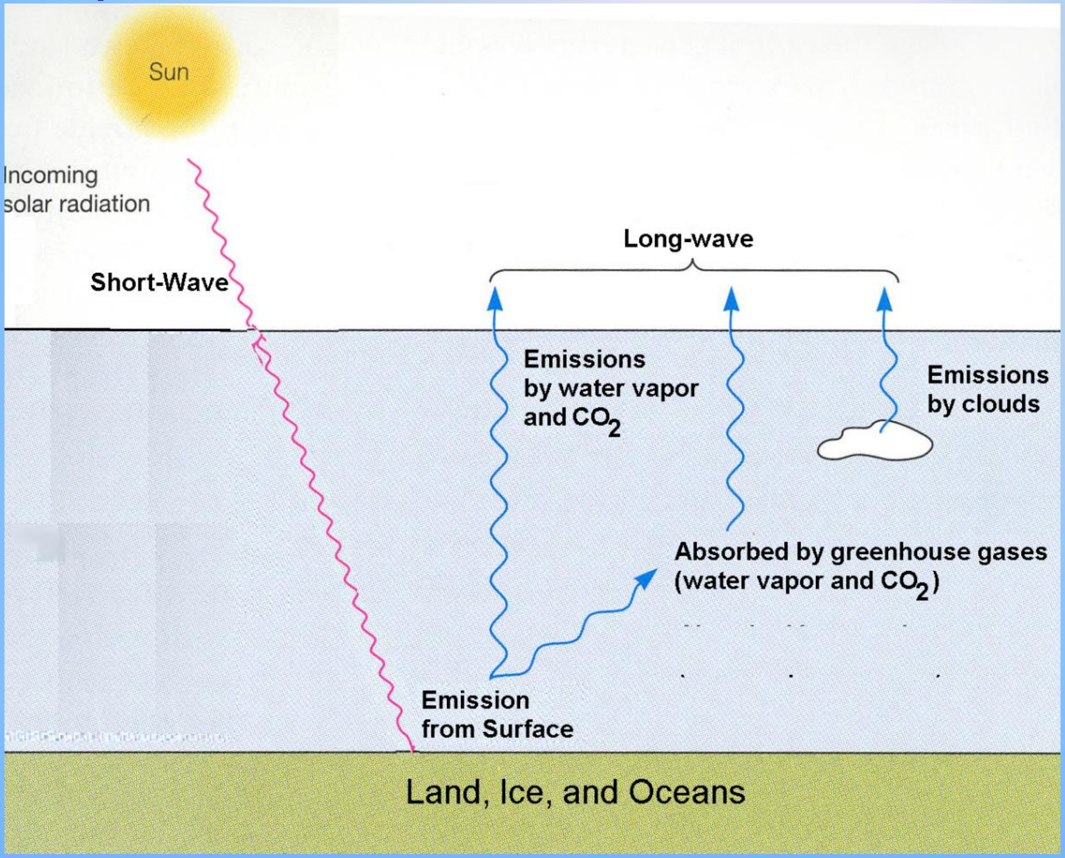
3. ***Normal Lapse Rate*: 6.5º C temperature decrease per 1000 meters of altitude. The farther from the source of heat (the ground), the cooler it gets.**



Normal Lapse Rate

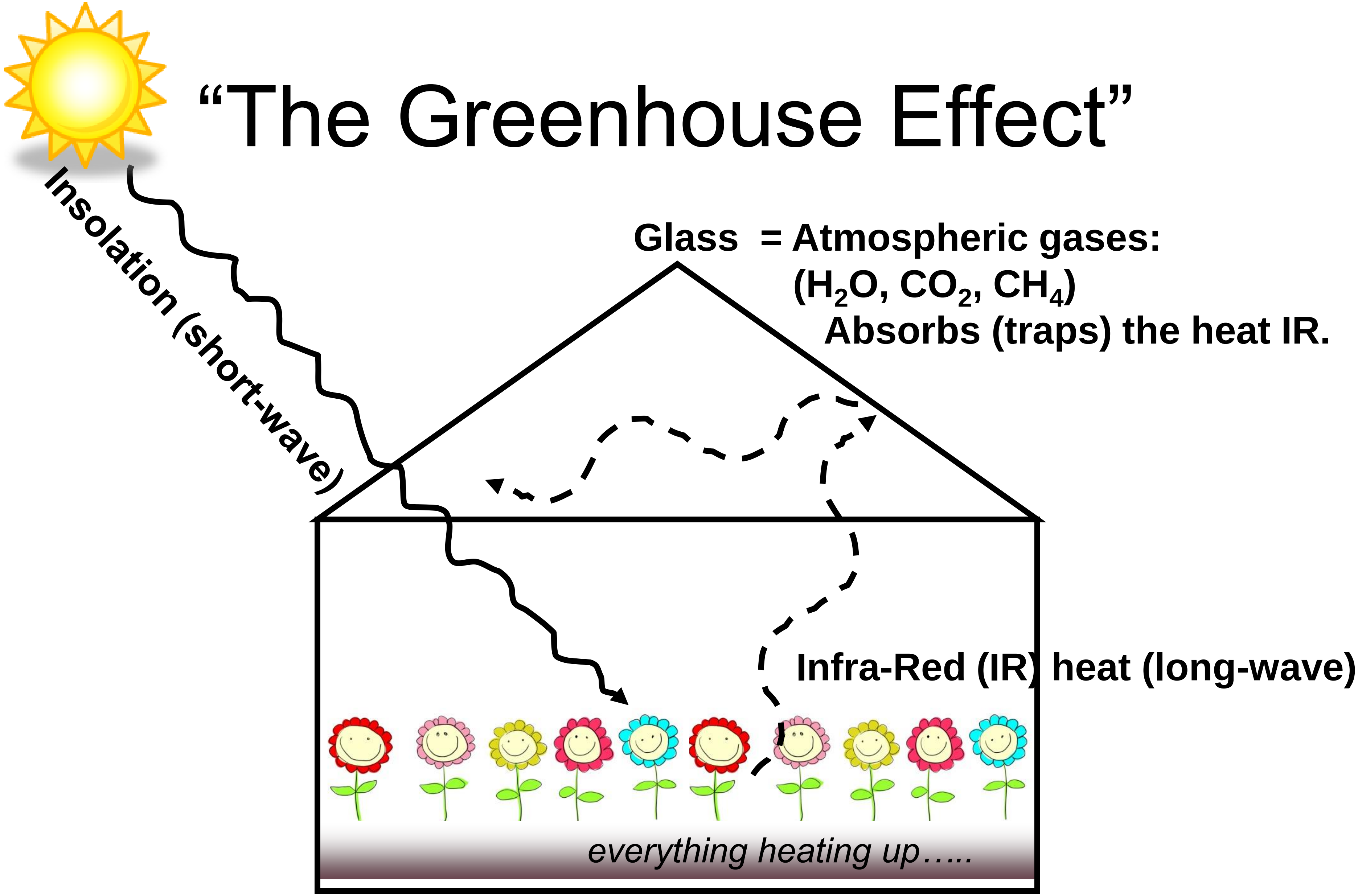
4. Carbon dioxide and water vapor are principal absorbing gases, accounting for warmer temperatures in the lower troposphere.

D. The Greenhouse Effect (Referred to by some scientists as the *Atmosphere Effect*.



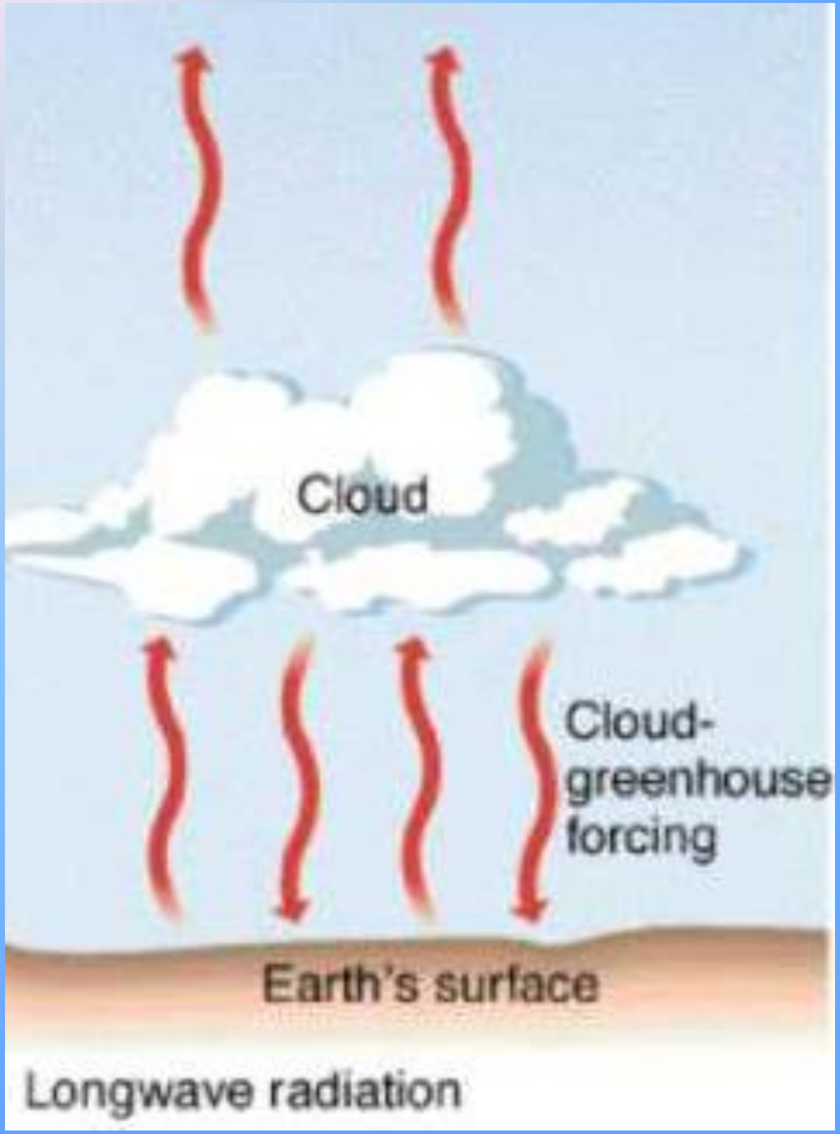
1. The transmission of **shortwave** solar radiation by the atmosphere coupled with the selective wavelengths **of longer-wave** terrestrial radiation, especially by **water vapor** and **carbon dioxide**, resulting in warming of the atmosphere.

"The Greenhouse Effect"

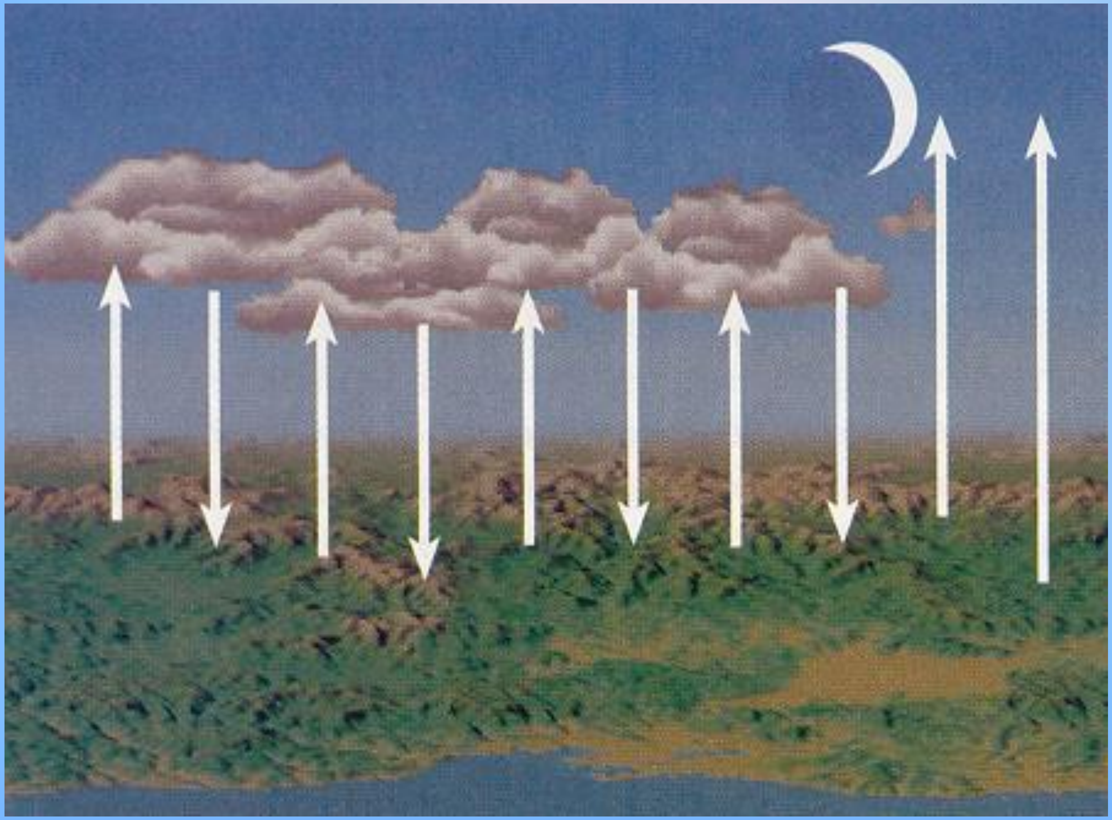


2. Effects of cloud cover:

a) <u>**Reradiates**</u>________ absorbed terrestrial radiation to the surface.

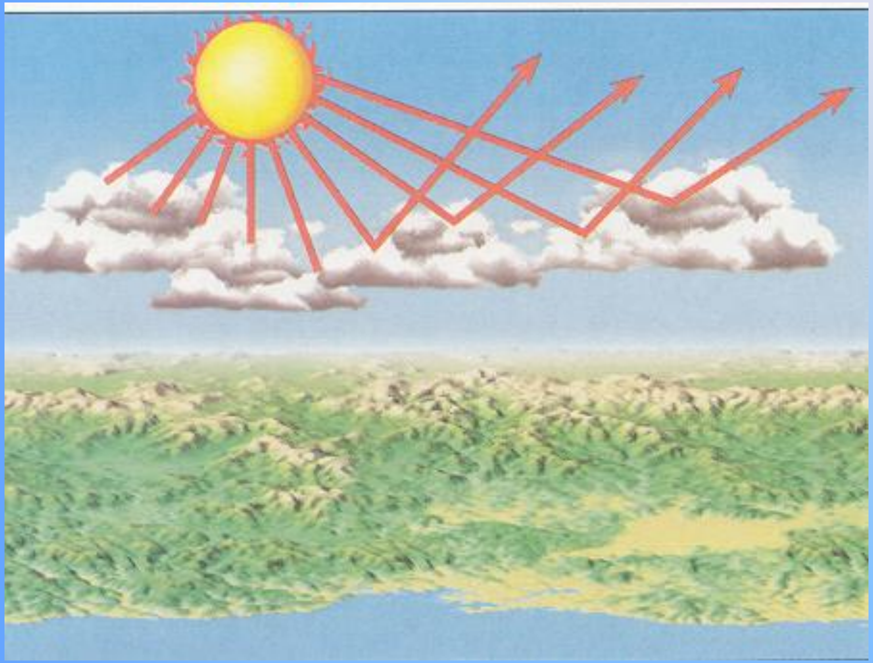


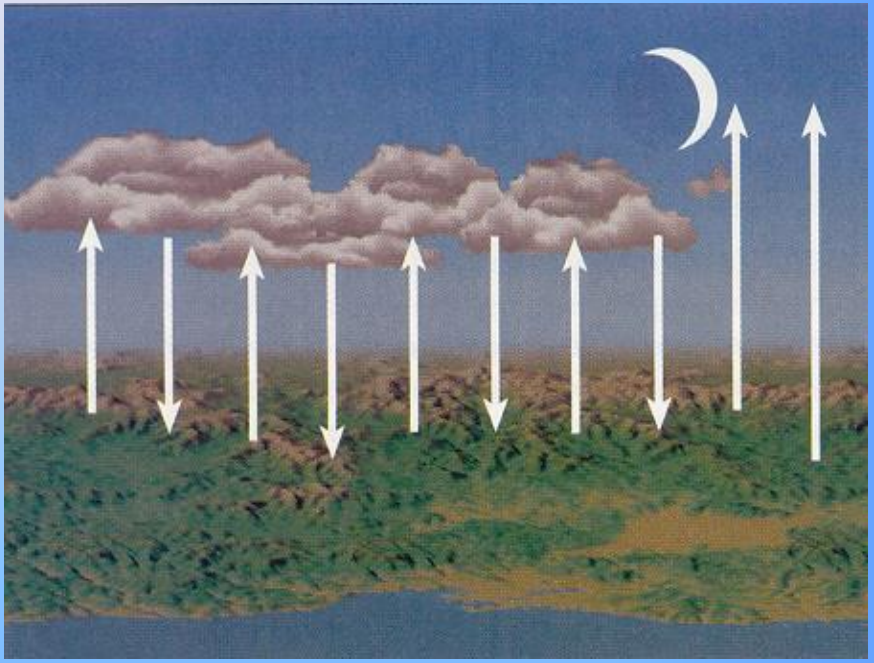
b. Clear nights vs. cloudy nights



- Terrestrial radiation is absorbed and reradiated
- Temperatures do not decrease as much as on a clear night.

Effect of Clouds on the Daily Temperature Range

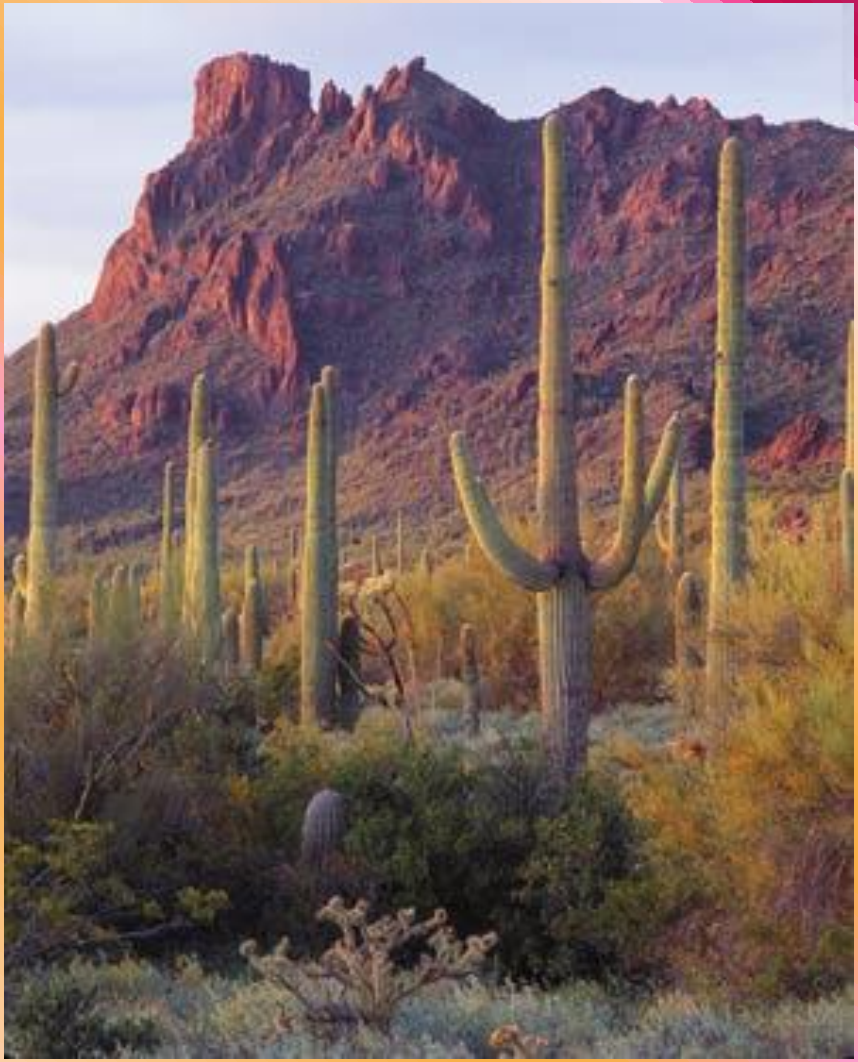




- ___Cooler___ temperatures during the day.
- ___Warmer___ temperatures at night.
- A ___smaller___ temperature range.

Daily Temperature Ranges in Deserts

c. Low cloud cover in desert regions results in ___**higher**___ daily temperature ranges.



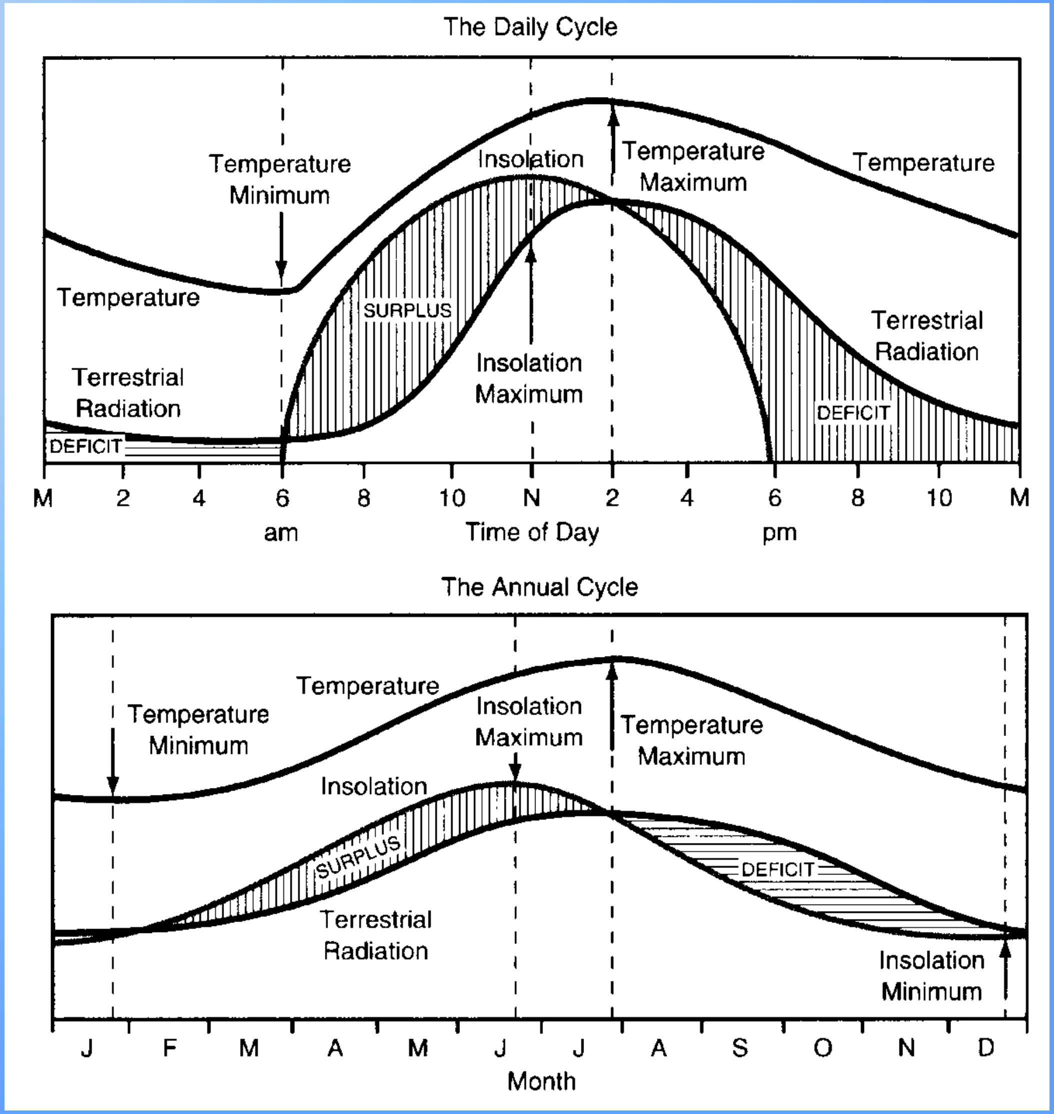
V. Earth's Heat Budget

Lab 7-4

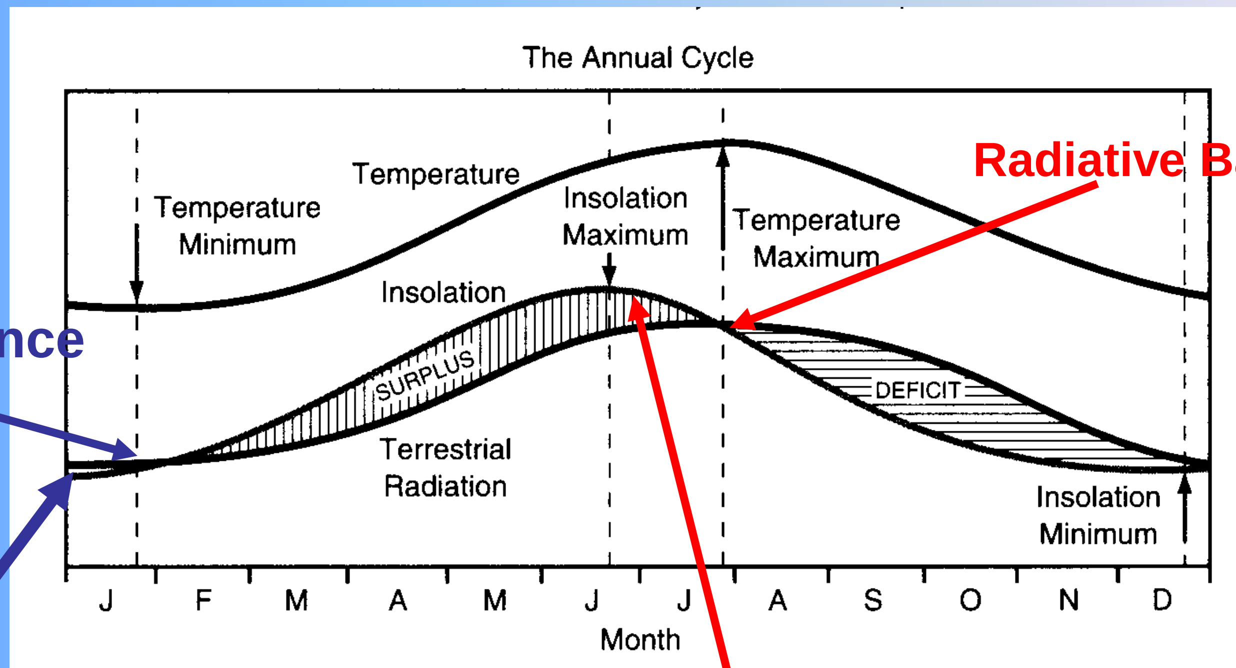
V. Earth's Heat Budget

A. Annual and Daily Balance of Incoming and Outgoing Radiation

1. Surplus
   a. Insolation is **greater** than terrestrial radiation.
   b. Temperatures **increase**.
   c. The greater the surplus the **greater** the rate of temperature increase.
2. Deficit
   a. Insolation is **less** than terrestrial radiation.
   b. Temperatures **decrease**.
   c. The greater the deficit, the **greater** the rate of temperature decrease.



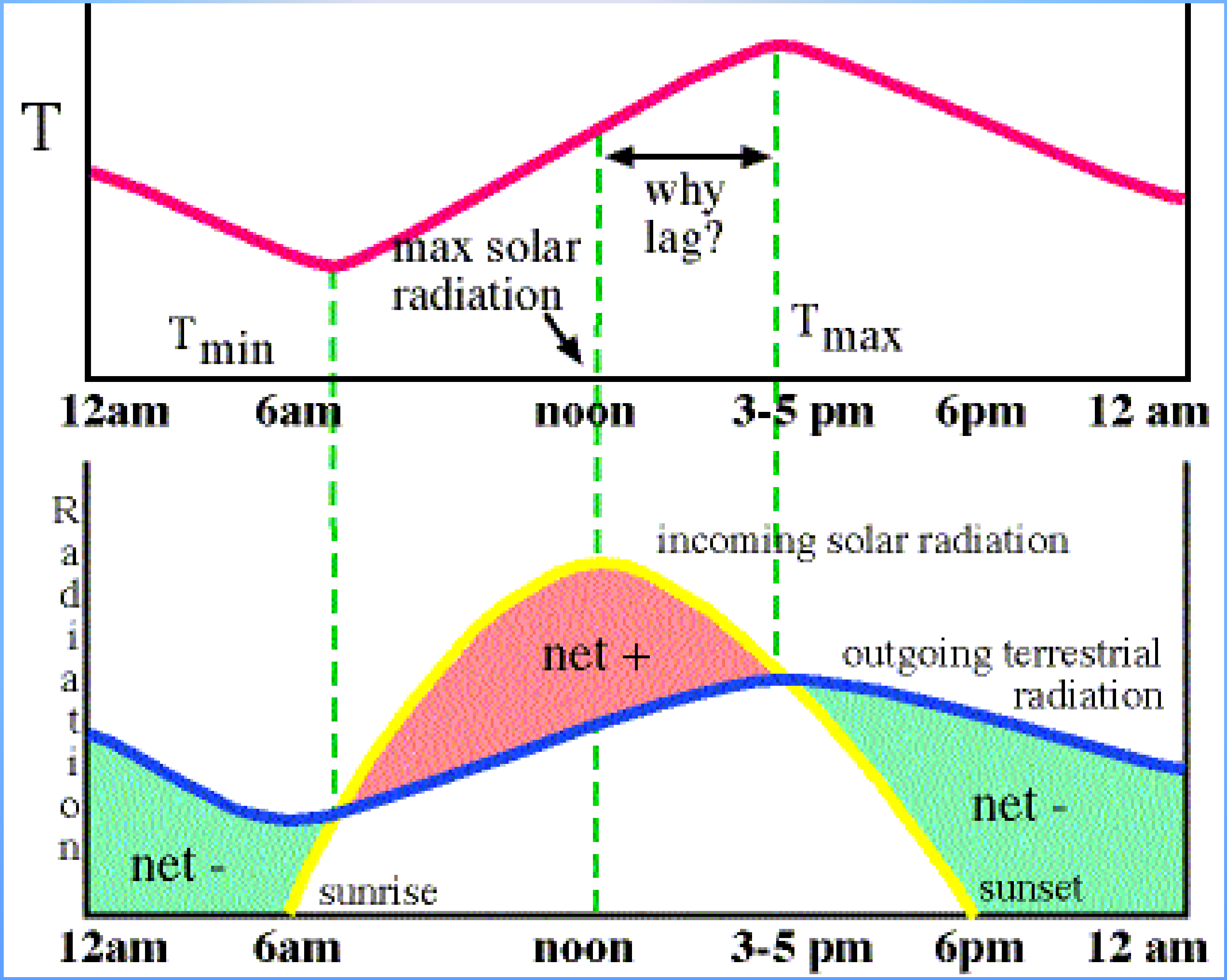
3. Time-Lag between Maximum Insolation and Maximum Temp. and between Minimum Insolation and Minimum Temperature



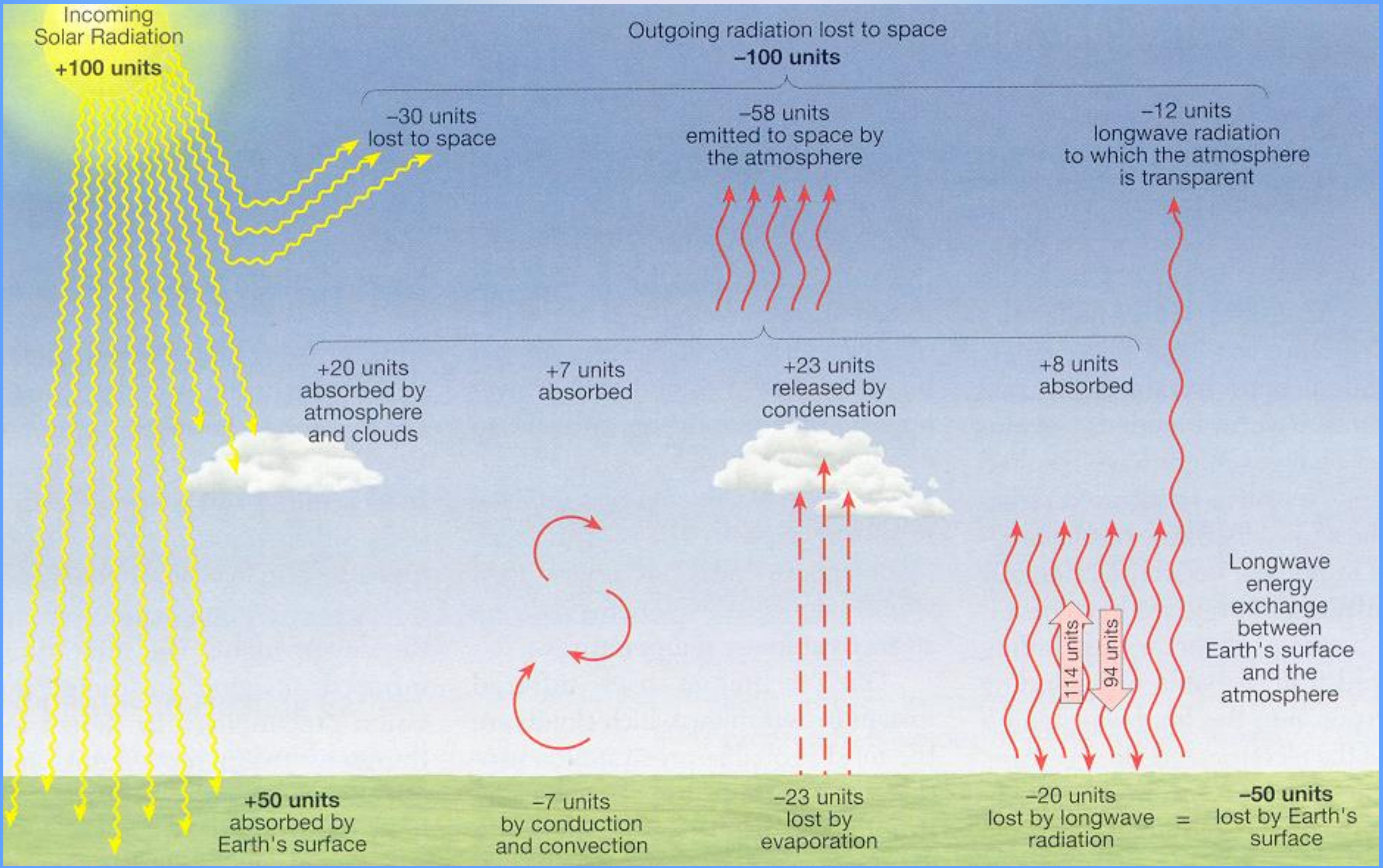
- After maximum insolation in June, insolation decreases
- Insolation is still greater than terrestrial radiation so temperatures continue to increase until radiative balance is reached.

- After minimum insolation in December, insolation increases.
- Insolation is still less than terrestrial radiation, so temperatures continue to decreases until radiative balance is reached.

Why is the hottest time of day after solar noon (why the lag time)?



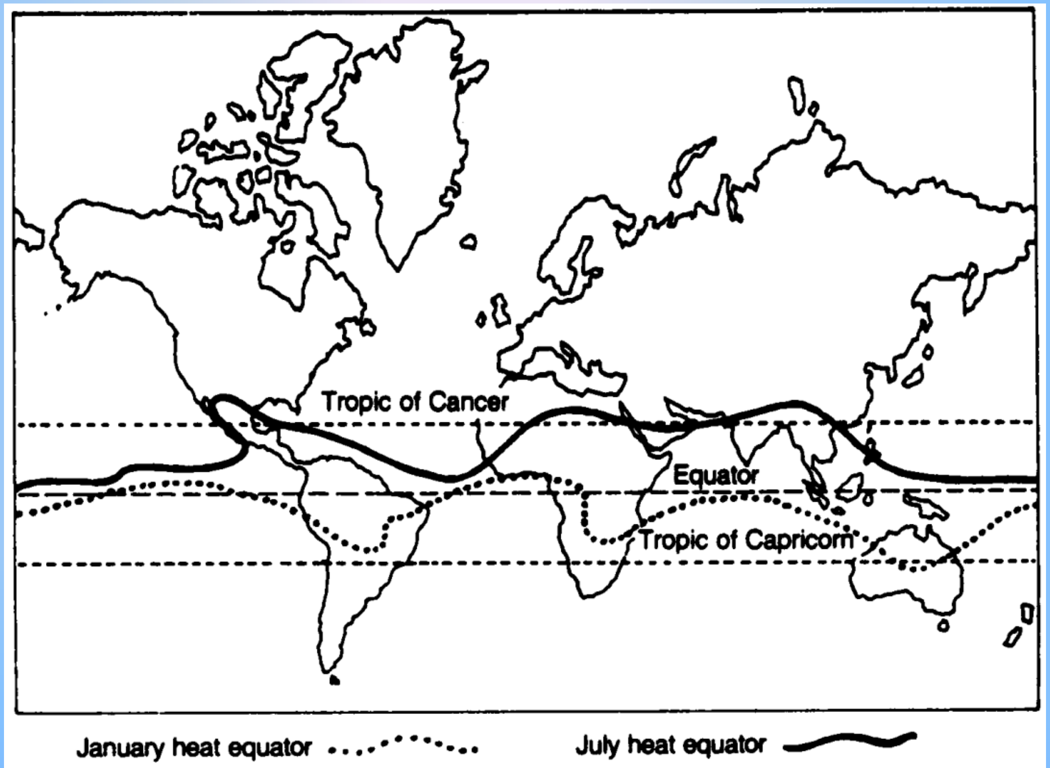
Earth's Heat Budget



Lab 7-2 Vocab.

- **Heat Equator:** The thermal equator is a belt encircling the Earth, defined by the set of locations having the highest mean annual temperature at each longitude around the globe
- **Radiative Balance:** a condition in which an object is absorbing and radiating the same amount of heat energy. Temp. will be constant.

B. ***Latitudinal Heat Balance*** (Heat Equator)

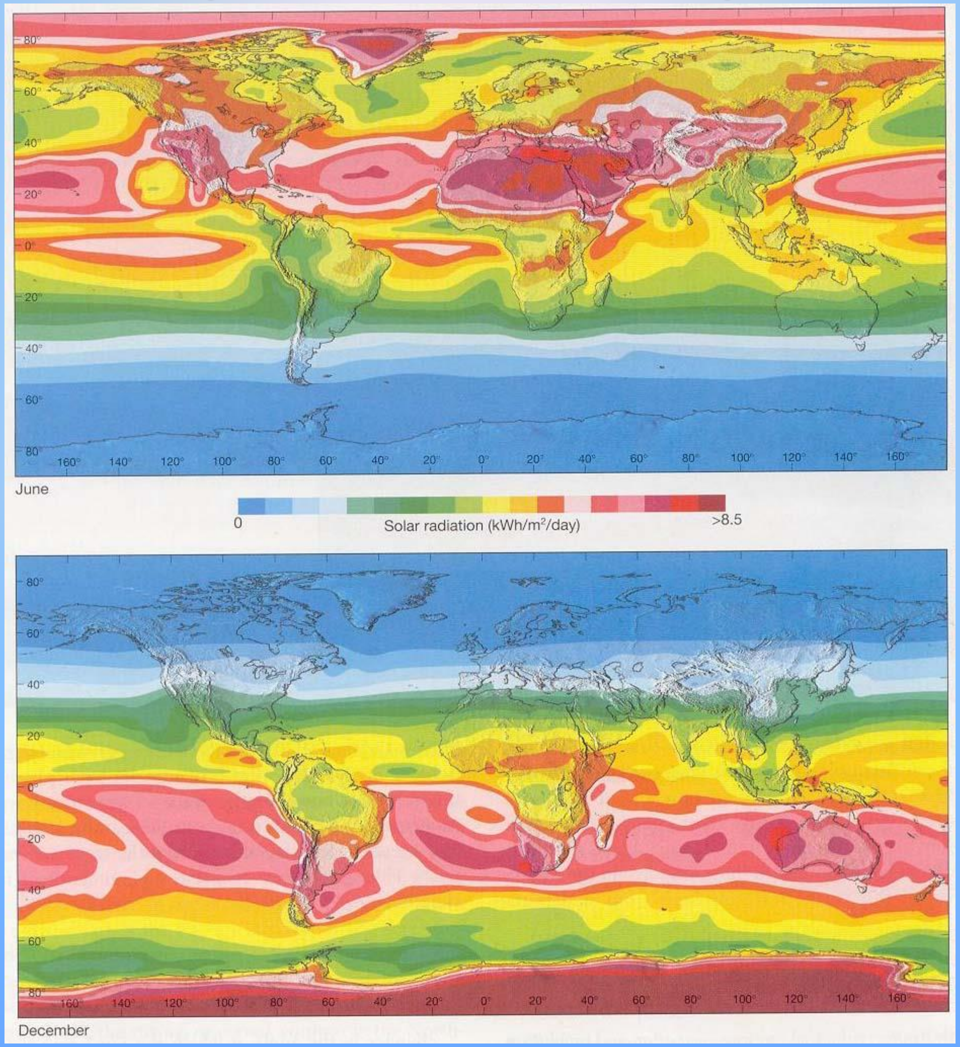


2. Observations:

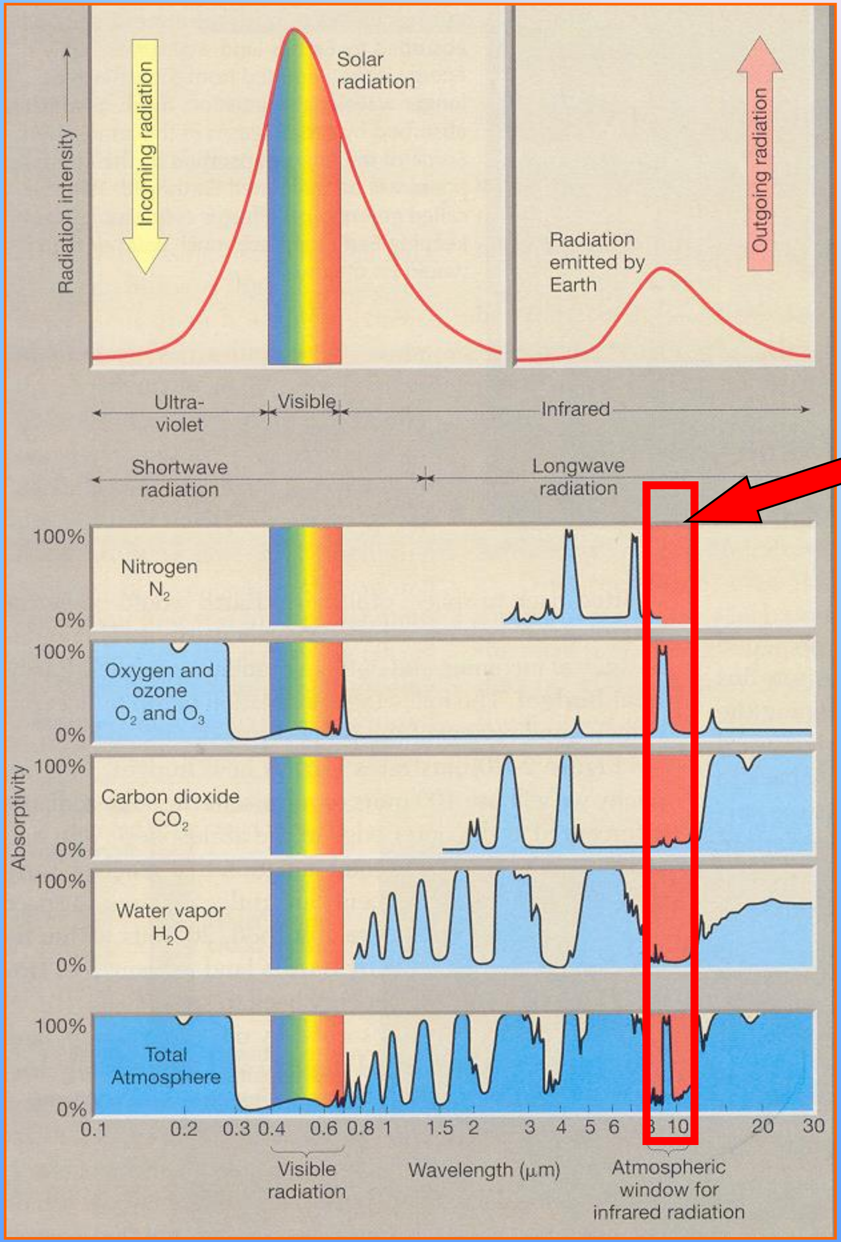
- **The Heat Equator moves higher in latitude over land.**
- **In the N. Hemisphere summer it moves higher in latitude than during the S. Hemisphere summer.**
- **This is the location of the Intertropical Convergence Zone (ITCZ)**

- The End ☺

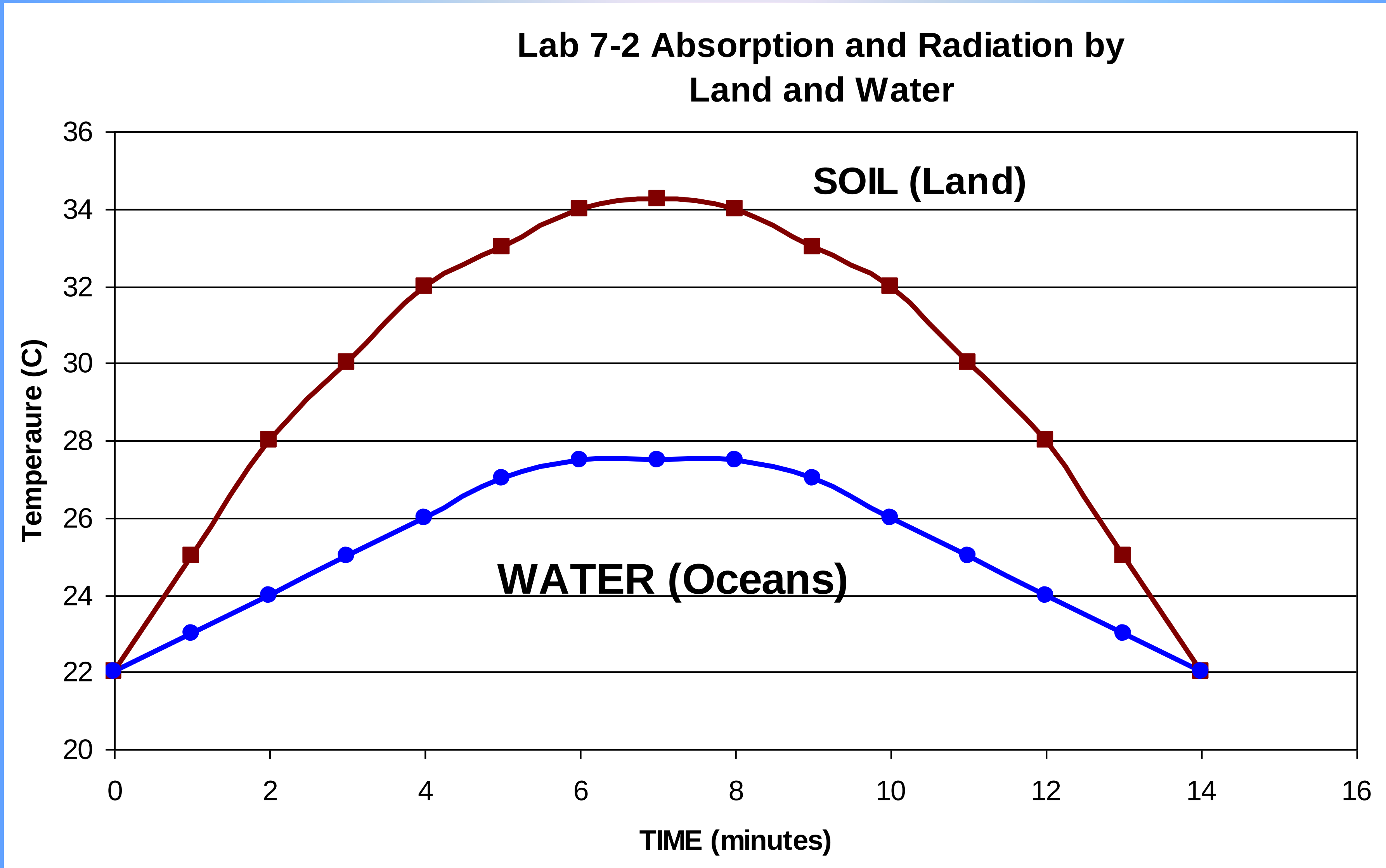
Insolation at Earth's Surface
(June and December)



Absorptivity of Select Atmospheric Gases



Atmospheric “window” for Infrared radiation.



How does Specific Heat affect these lab results?