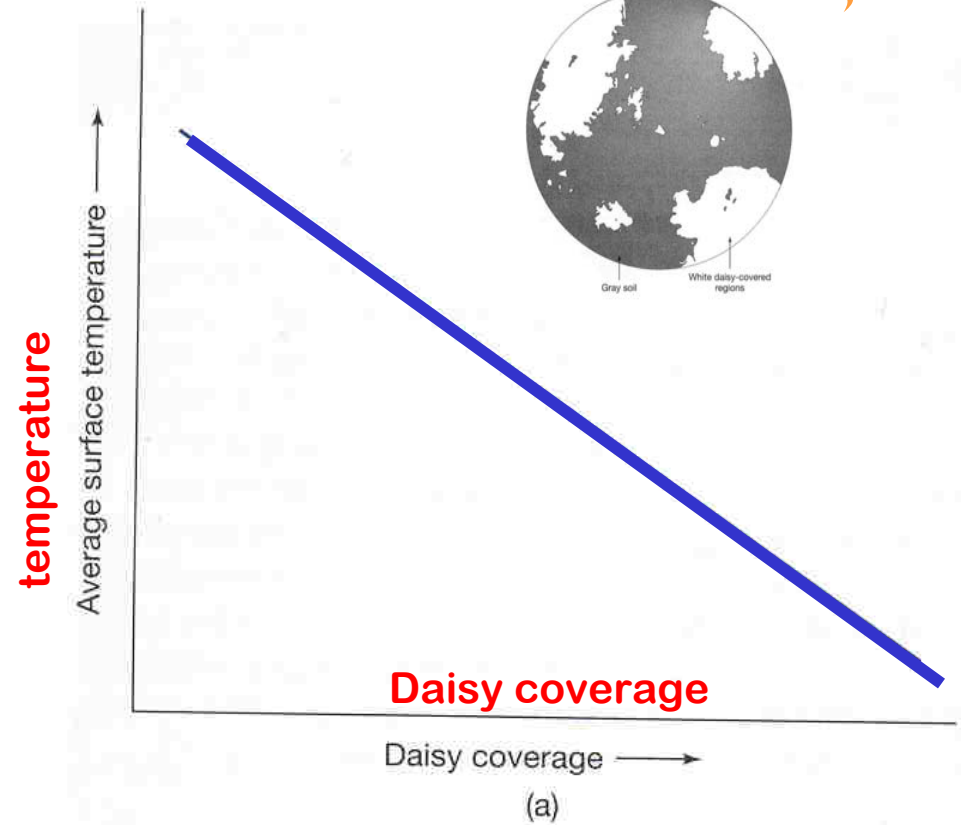
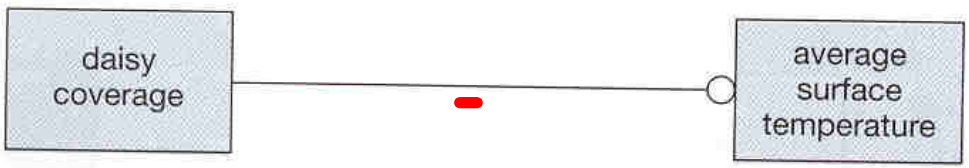
First – a recap of some Feedback Loop concepts . . .

HOW DAISY COVERAGE AFFECTS TEMPERATURE:

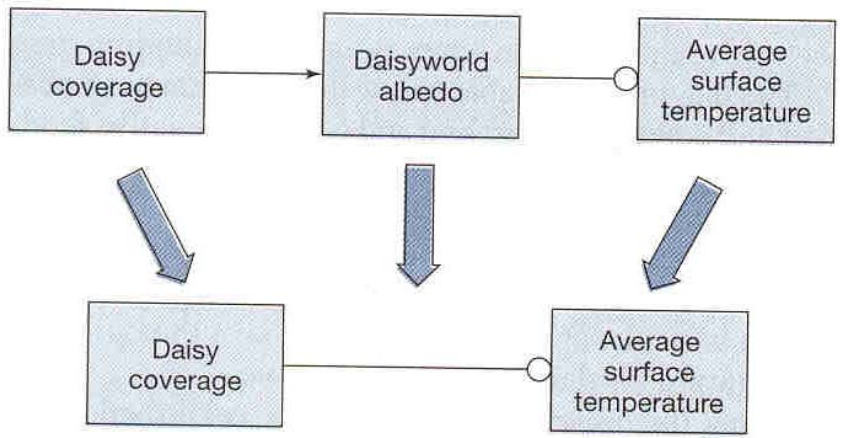
An increase in daisy coverage ➔ a decrease in surface temperature



temperature



WHY? because more sunlight is reflected back (albedo increases) ➔ less sunlight is absorbed ➔ cooler temps



p 84

RECAP/ SUMMARY

The presence of FEEDBACK LOOPS leads to the establishment of EQUILIBRIUM STATES

- **Negative feedback loops establish STABLE equilibrium states that are resistant to a range of perturbations; the system responds to modest perturbations by returning to the stable equilibrium state**

- **Positive feedback loops establish UNSTABLE equilibrium states. A system that is poised in such a state will remain there indefinitely. However, the slightest disturbance carries the system to a new state.**

Topic # 13
Atmospheric Circulation

How the Energy Balance Drives It and How It Results in Global Climate Patterns

p 87-92 in Class Notes

The RIGHT Side of the Equation:

= H + LE + G

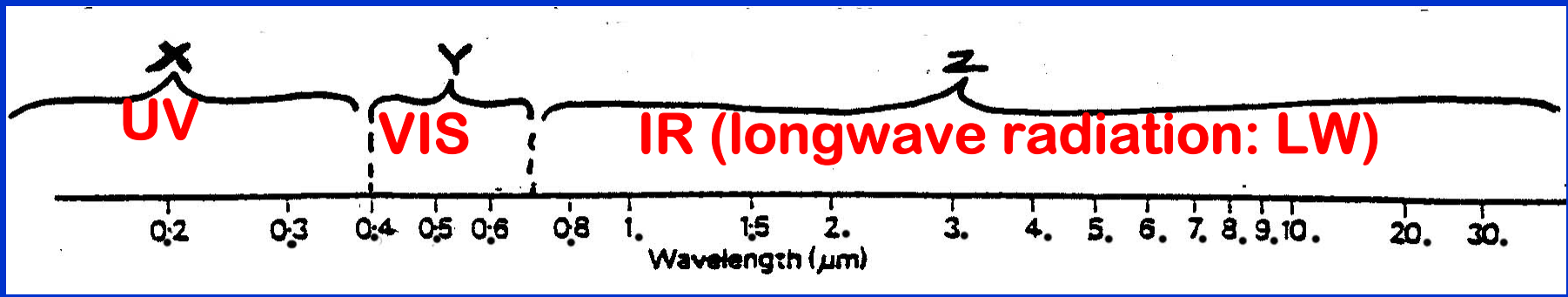
13. H Hot air (less dense than surrounding cool air) rises in a convection current & lifts balloon

14. Wet mud evaporates from pig & cools him: LE
Heat from pig's body is conducted into soil: G

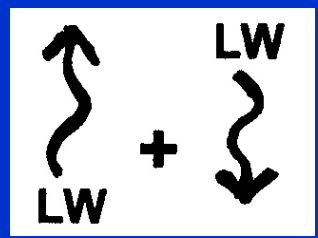
15. June is dryer, hence air can hold more water vapor, more evaporation occurs, hence more energy goes into LE instead of H

Review / Link to Electromagnetic Spectrum & RADIATION / ENERGY BALANCE

Which segment of the electromagnetic spectrum includes the wavelengths of electromagnetic energy that are involved in the atmosphere's GREENHOUSE EFFECT?

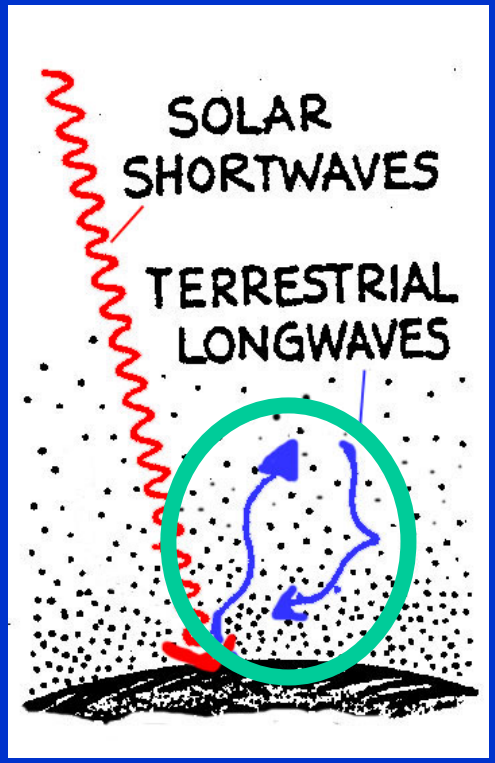


GH gas (def) = an infrared absorbing gas!!

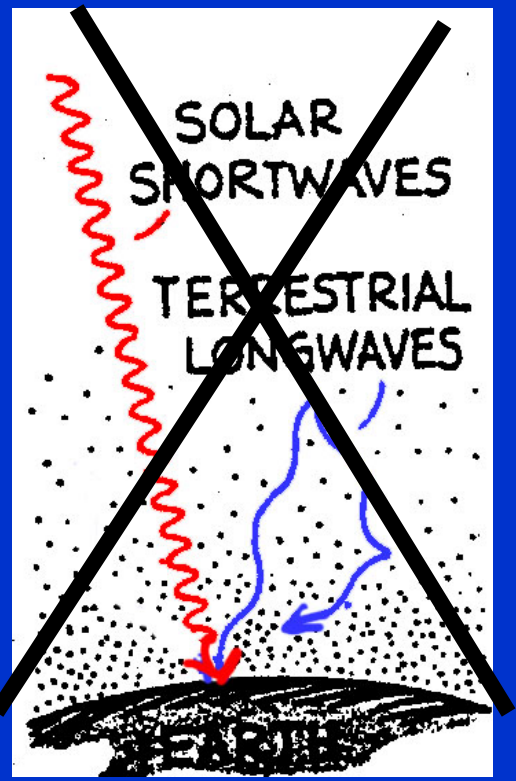


The GH Effect involves ONLY infrared (longwave) radiation

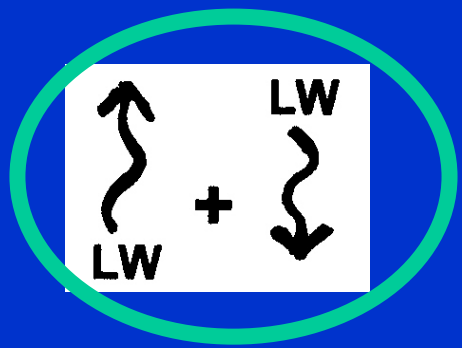
X



Y



X is better! but WHY?

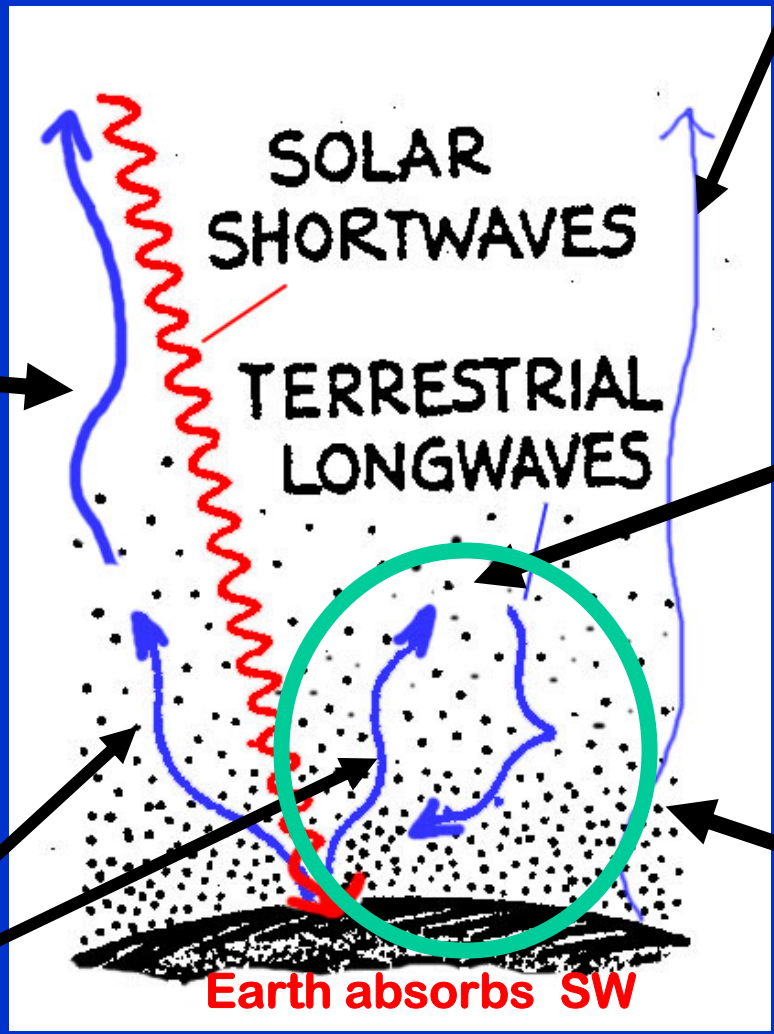


LW depicted as if it is being "bounced off" or reflected by the atmosphere – GH Effect doesn't happen like this!

Modified cartoon showing the different IR pathways:

IR radiation is emitted from the Earth's surface right out to space through "IR atmospheric window"

IR radiation absorbed in the atmosphere is emitted out to space



IR radiation is absorbed by GH gases in the atmosphere and emitted back to Earth

Earth surface emits (radiates) IR radiation "up" to atmosphere

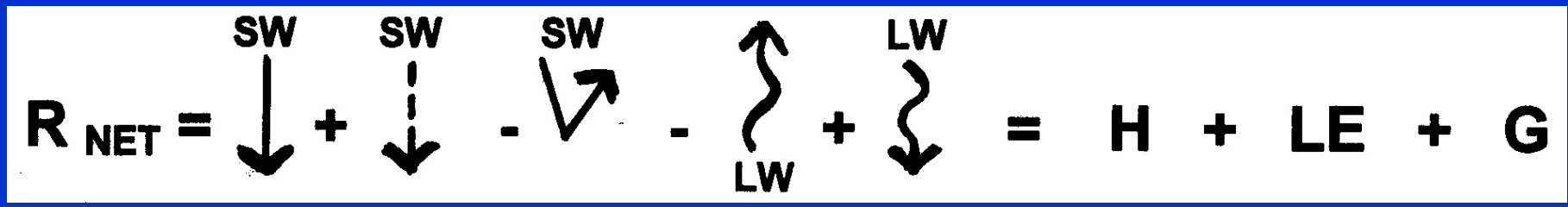
THIS PART ONLY IS THE GHE!!!

OBJECTIVES:

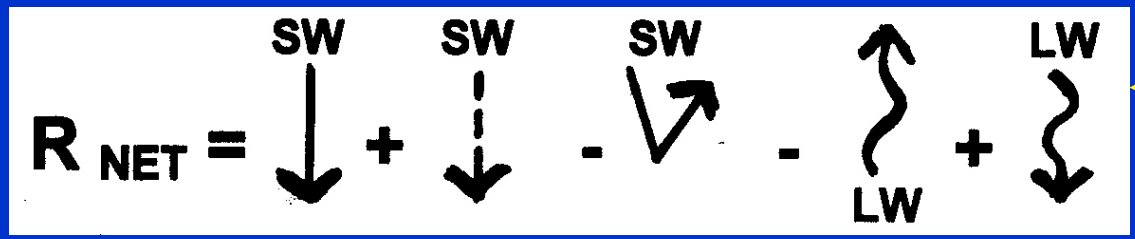
To understand how the Radiation/Energy Balance helps to drive global weather & climate

And learn a bit about how and why climates vary in different parts of the world.

RADIATION / ENERGY BALANCE



"Radiation Balance" part



All components are referring to electromagnetic radiation

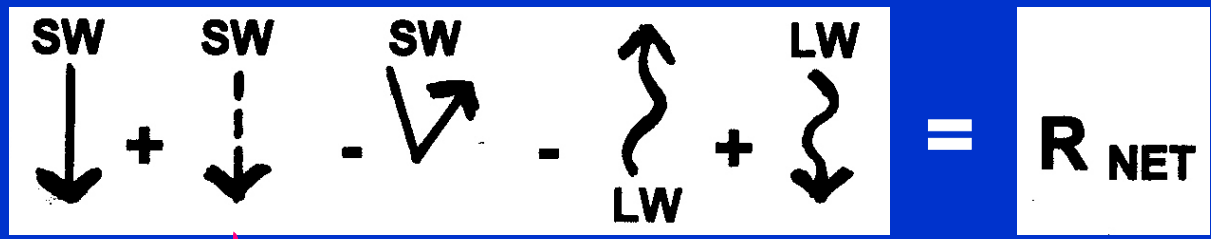
All components are referring to modes of heat energy transfer or heat energy storage <u>involving matter</u>

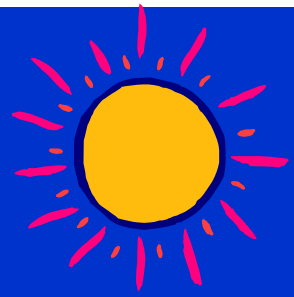
"Energy Balance" part

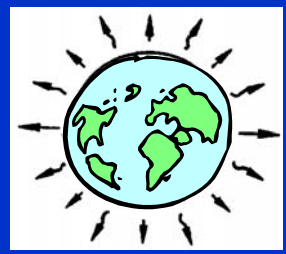
$$R_{NET} = H + LE + G$$

Start out here, with energy from the SUN radiated to Earth and so forth . . .

"Radiation Balance" part







The R_{NET} is then able to be used in thermal energy "heat transfer" processes which manifest themselves as weather & climate!

"Energy Balance" part

$$R_{NET} = H + LE + G$$

Thermal Energy Review

Heat **(def) = the thermal energy that is *transferred* from one body to another because of a temperature difference.**

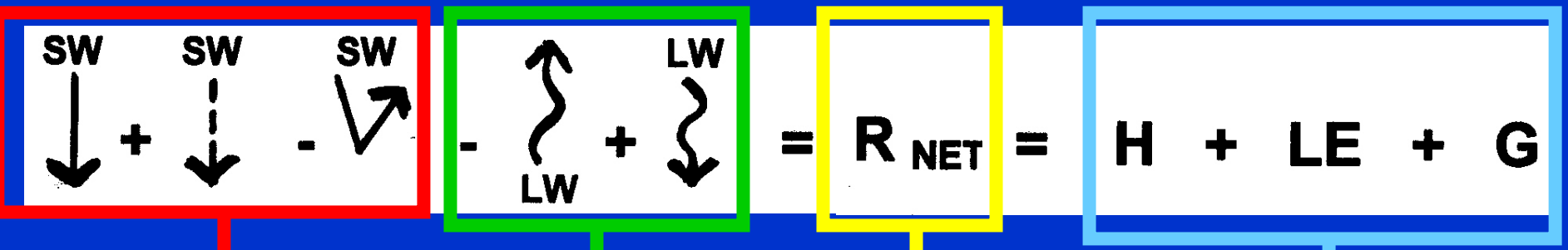
- **Sensible Heat transfer (H)**
- **Latent Heat transfer (LE)**

plus (after transfer) thermal energy can be STORED (G)

H + LE + G

Review

ENERGY IN THE EARTH-ATMOSPHERE SYSTEM



Ultimate source of energy is the SUN (SW)

After absorption of SW, LW energy is radiated in & out by EARTH & Atmosphere

Any NET (leftover) energy

Goes into the HEAT TRANSFER processes that drive climate

LINKING THE ENERGY BALANCE TO ATMOSPHERIC CIRCULATION . . .

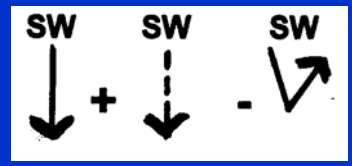
We'll start with the SUN (SOLAR INSOLATION)

IN – SOL- ATION =

Amount of incoming solar energy received by a point on Earth's surface

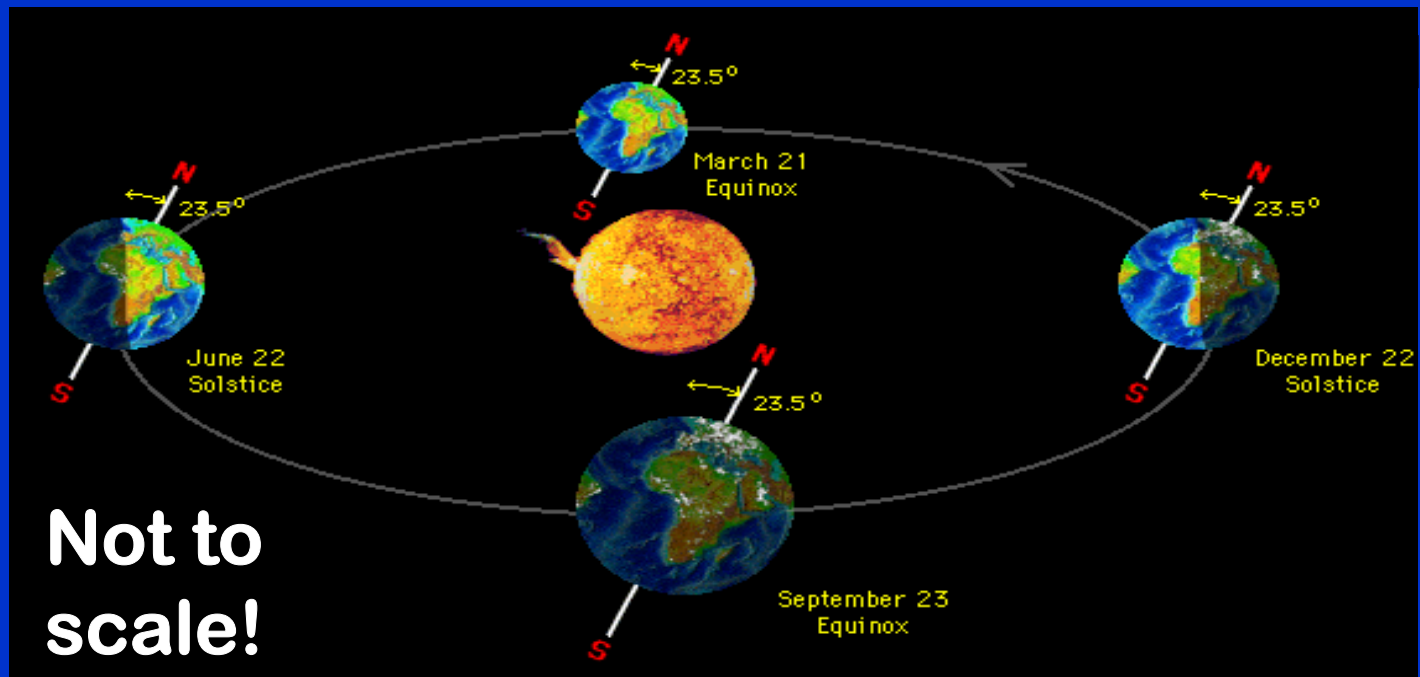
Take Notes on p 86

To drive the circulation, the initial source of energy is from the Sun:



Seasonal & latitudinal variations of solar insolation: 3 Principles →

http://mesoscale.agron.iastate.edu/agron206/animations/01_EarthSun.html



Seasonal & latitudinal variations of solar insolation:

3 Principles of EARTH-SUN RELATIONSHIPS

(They define the SEASONS in different latitudes!)

#1 OBLIQUITY OF EARTH'S AXIS

#2 ECCENTRICITY OF EARTH'S ORBIT

 # 3 Timing of Seasons in Relation to Orbit:

Take Notes on p 86

Seasonal & latitudinal variations of solar insolation:

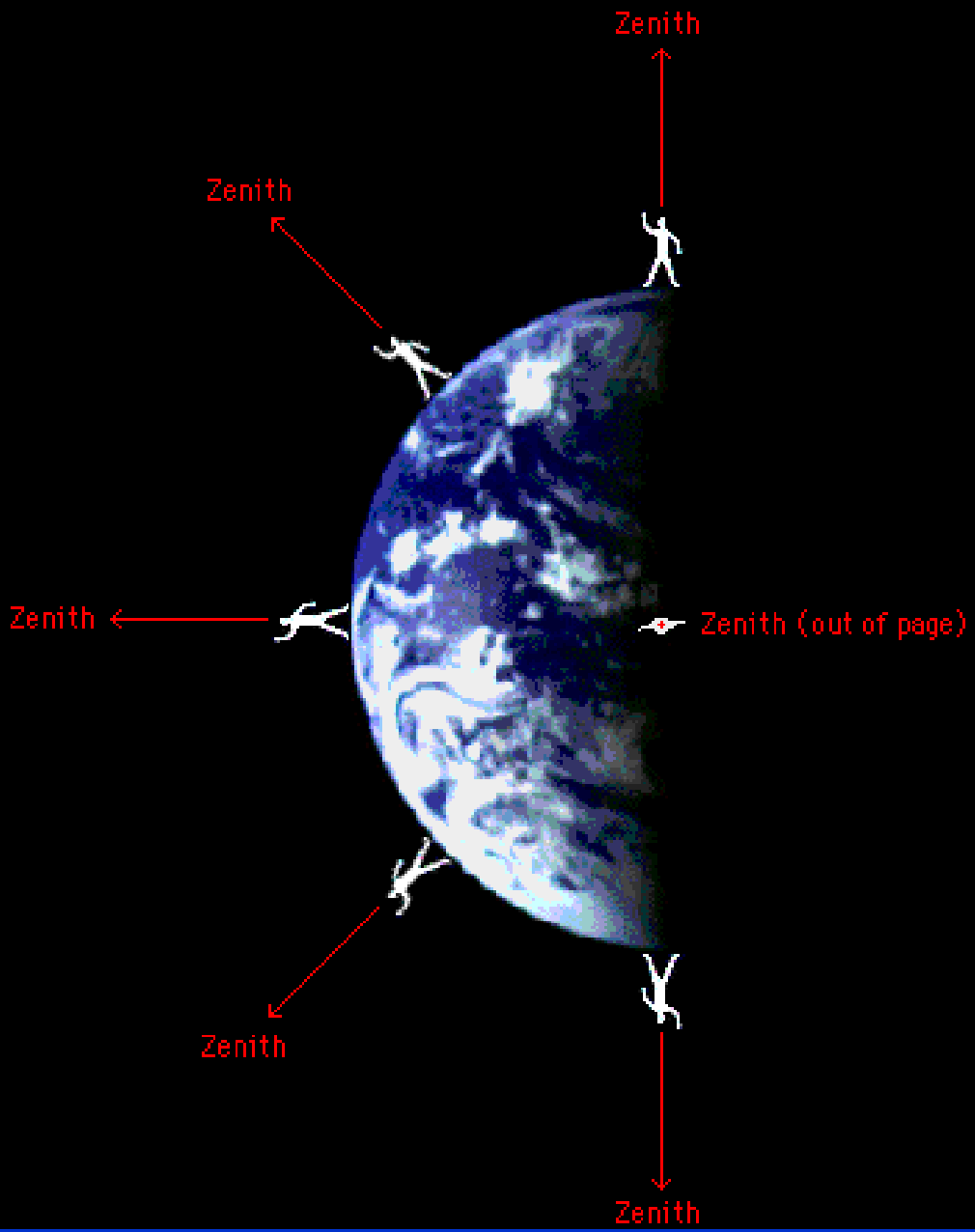
PLUS -- 2 factors that determine the AMOUNT OF SOLAR INSOLATION *as seasons progress:*

(1) **INTENSITY** of sun's rays

(perpendicular = more intense)

(2) **DURATION** of daily insolation

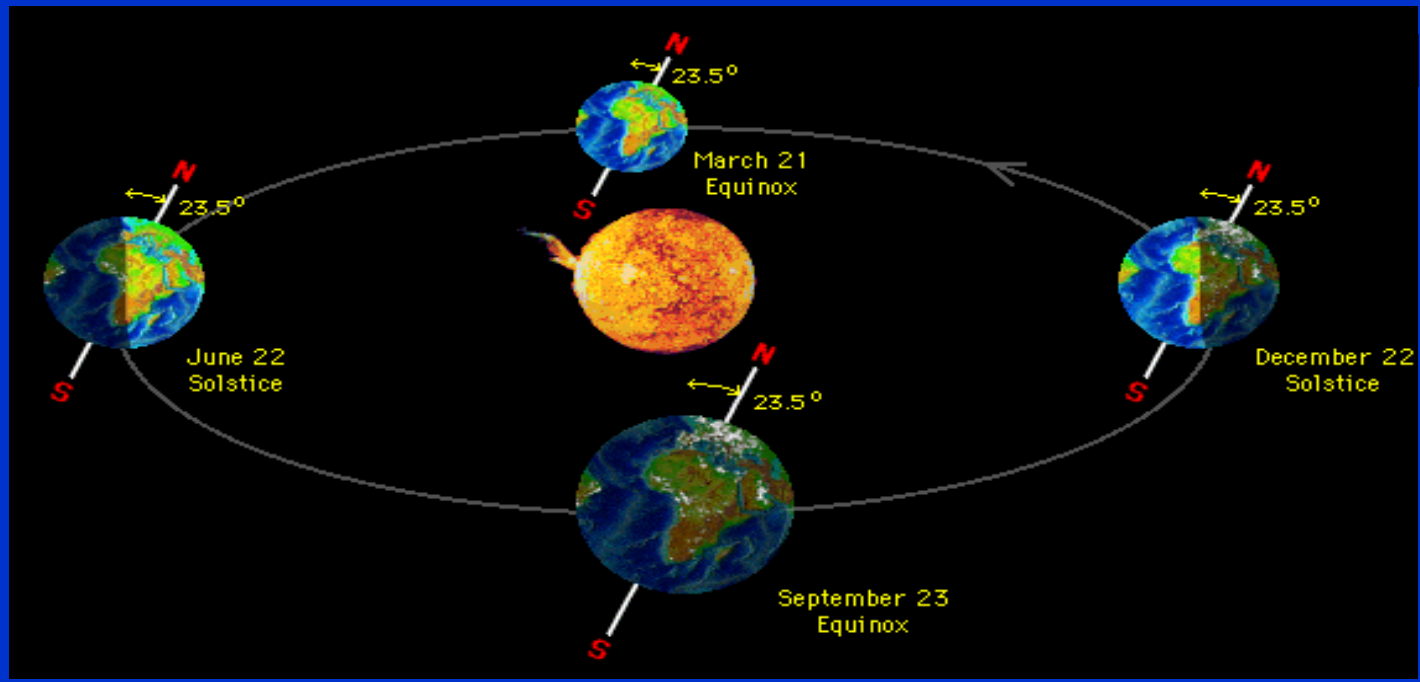
(longer day length = more insolation)



Since the zenith at any place on the earth is the point directly overhead (90° from all horizons), at each place on the earth it points in a different direction into space.

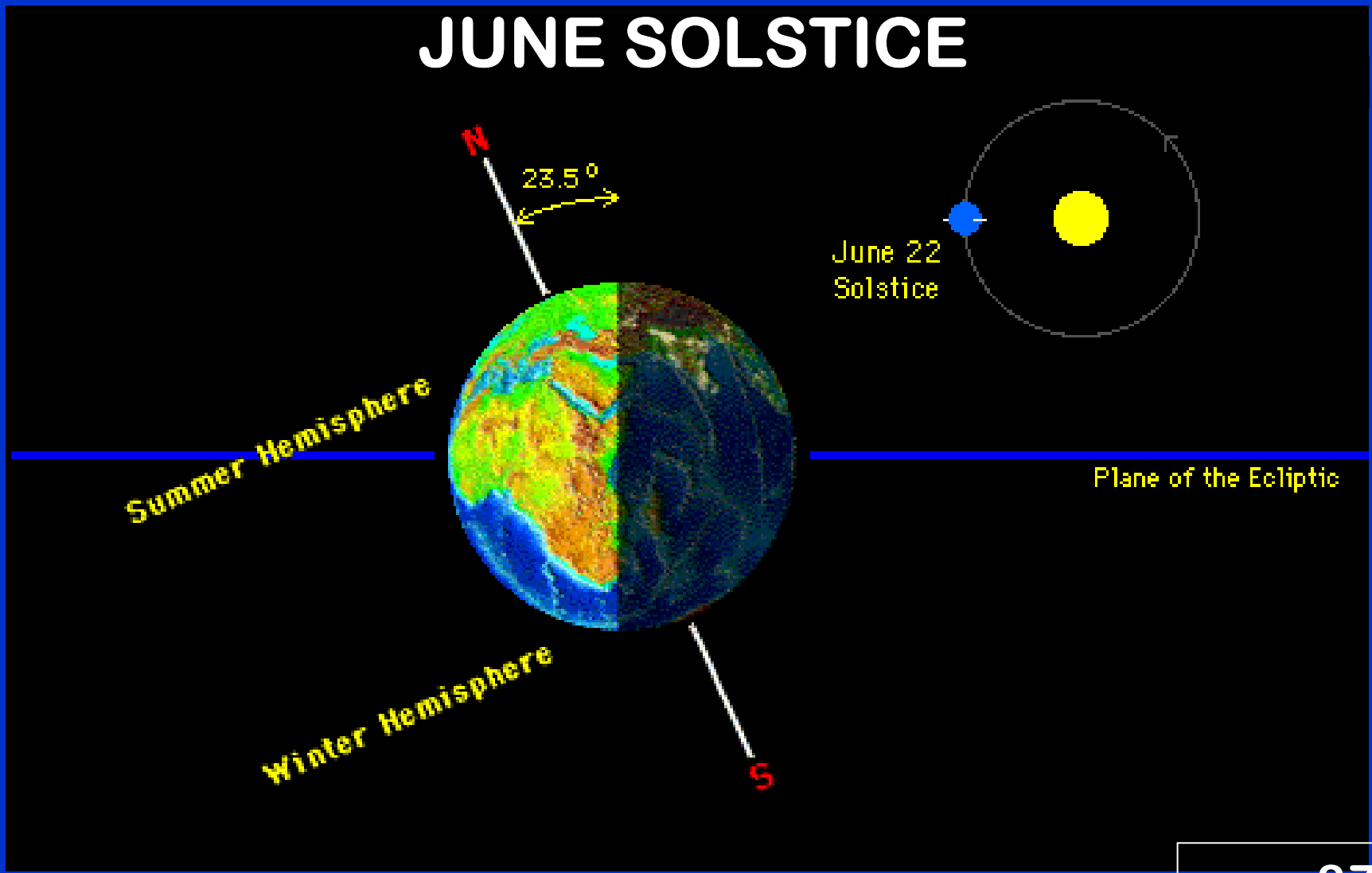
EARTH-SUN RELATIONSHIPS & The SEASONS:

http://mesoscale.agron.iastate.edu/agron206/animations/01_EarthSun.html



#1 OBLIQUITY OF EARTH'S AXIS

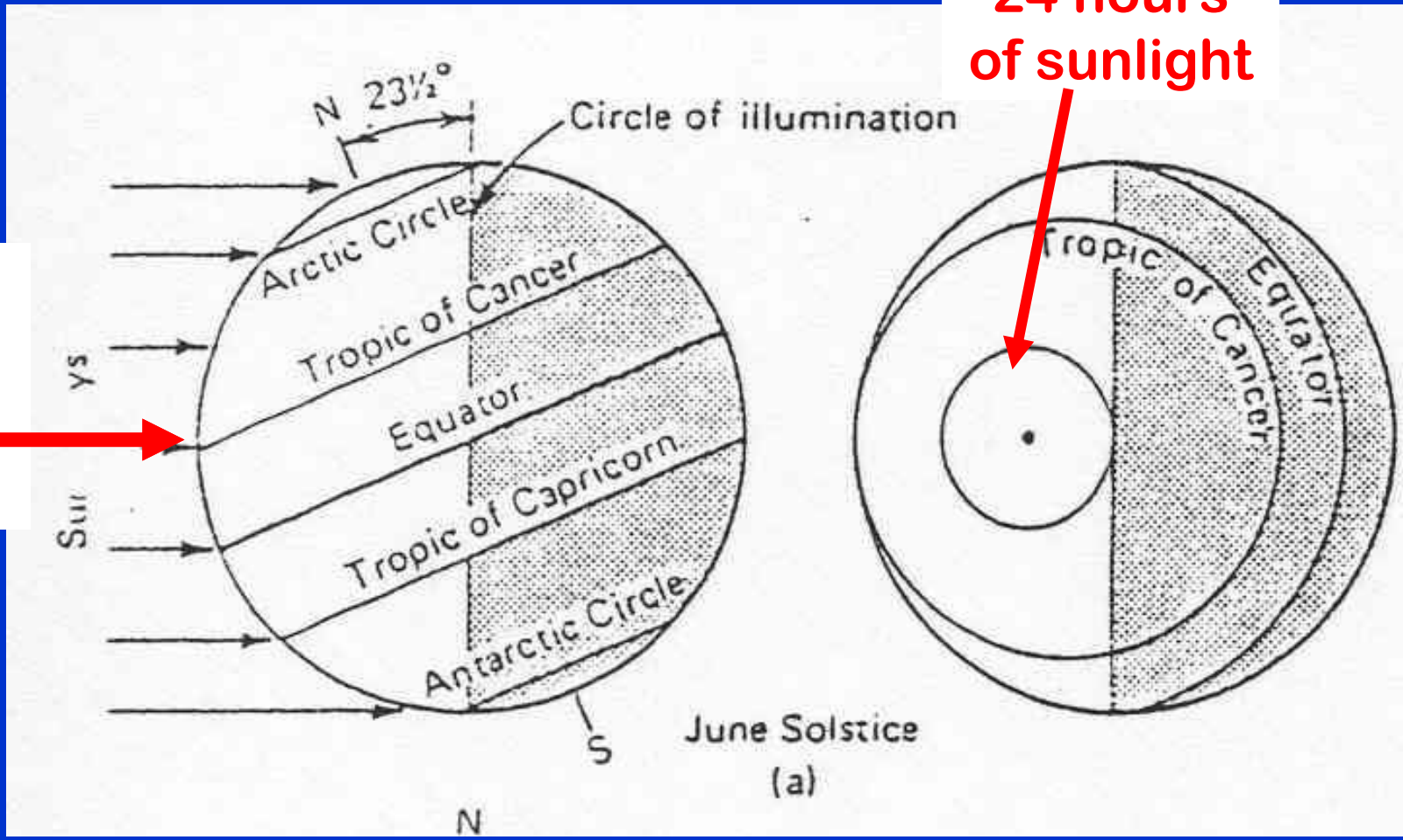
(axis "tilts" 23.5 degrees from plane of ecliptic)



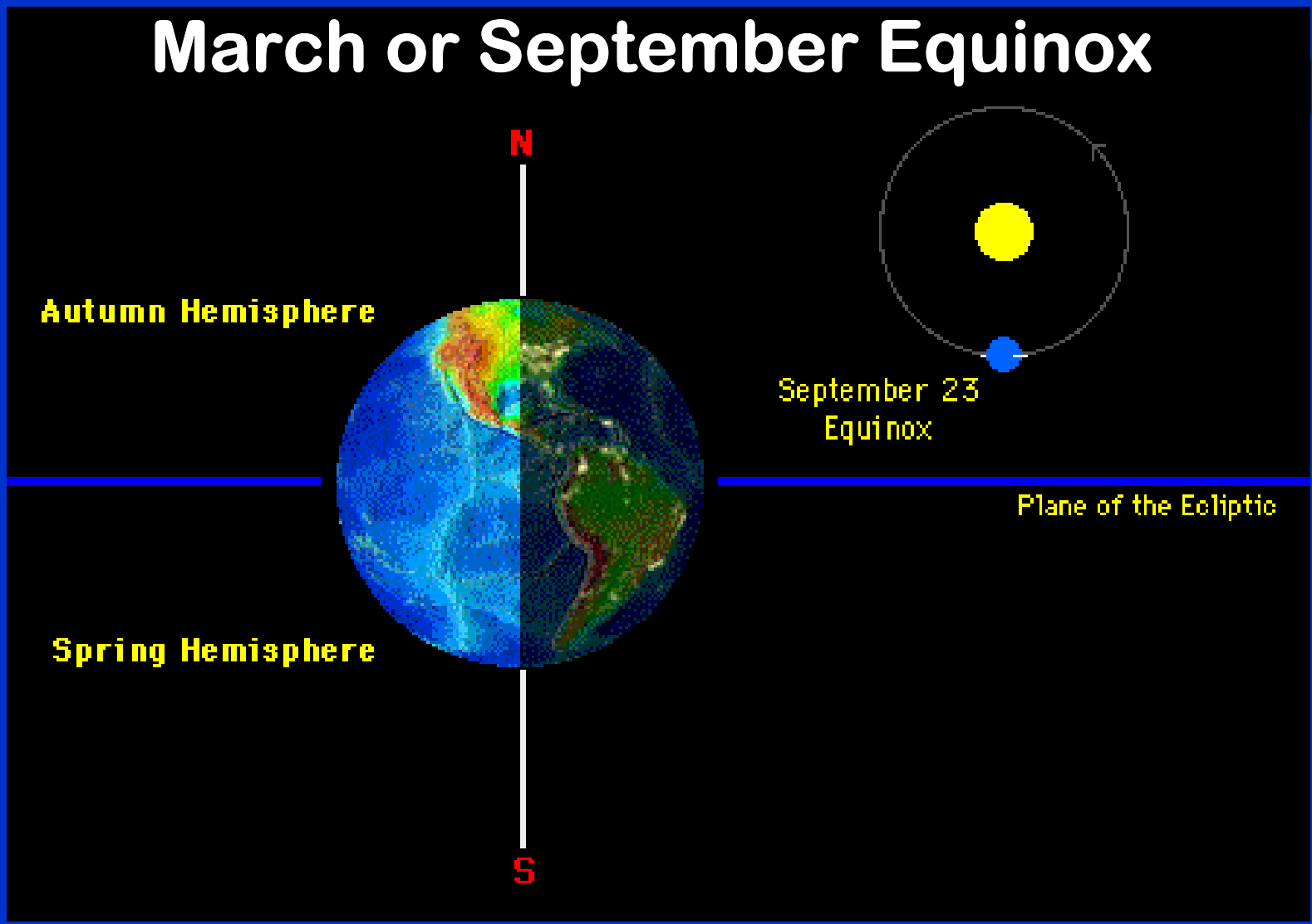
JUNE SOLSTICE

24 hours of sunlight

Most intense solar radiation



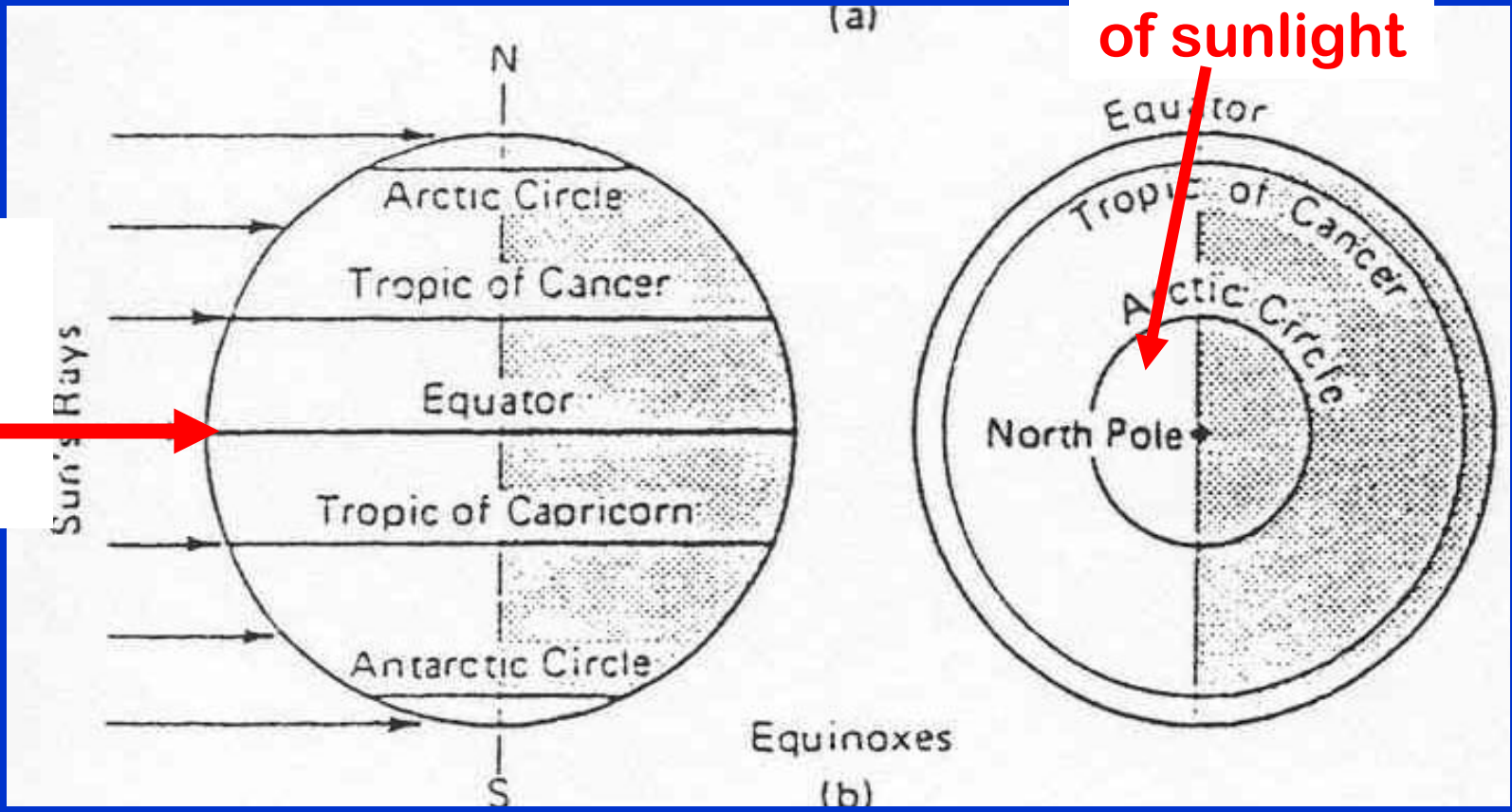
March or September Equinox



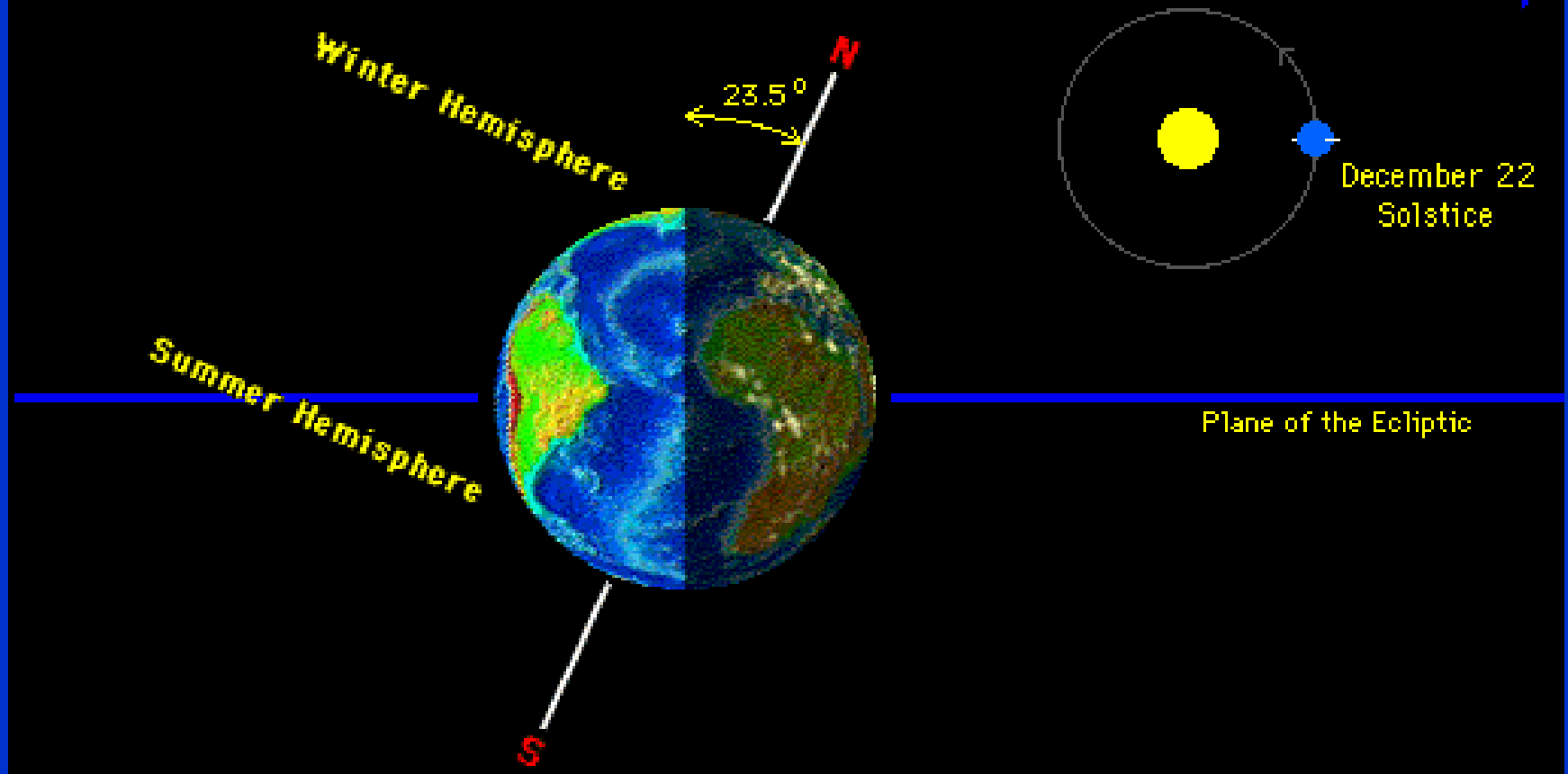
MARCH & SEPTEMEBER EQUINOXES

12 hours of sunlight

Most intense solar radiation



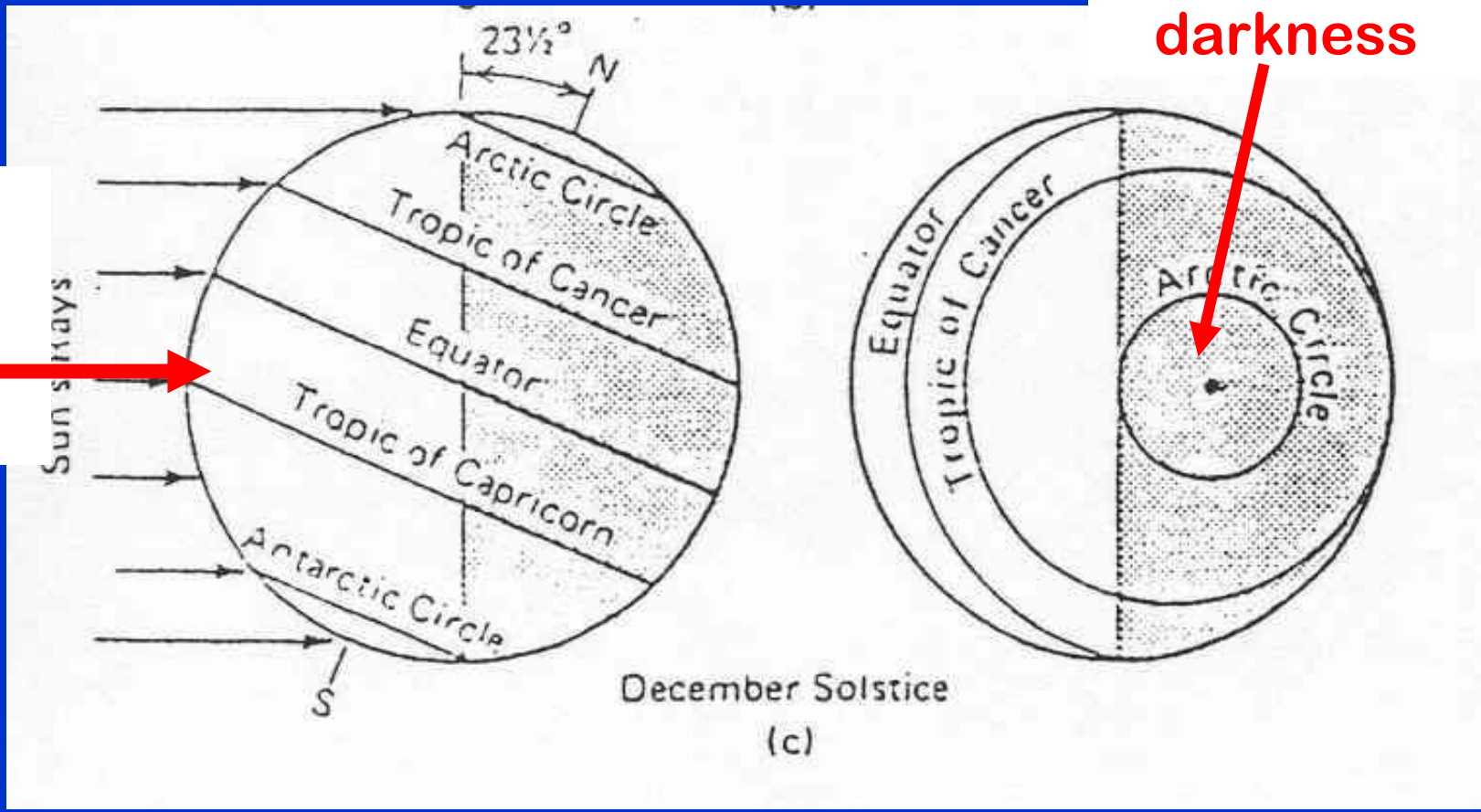
DECEMBER SOLSTICE



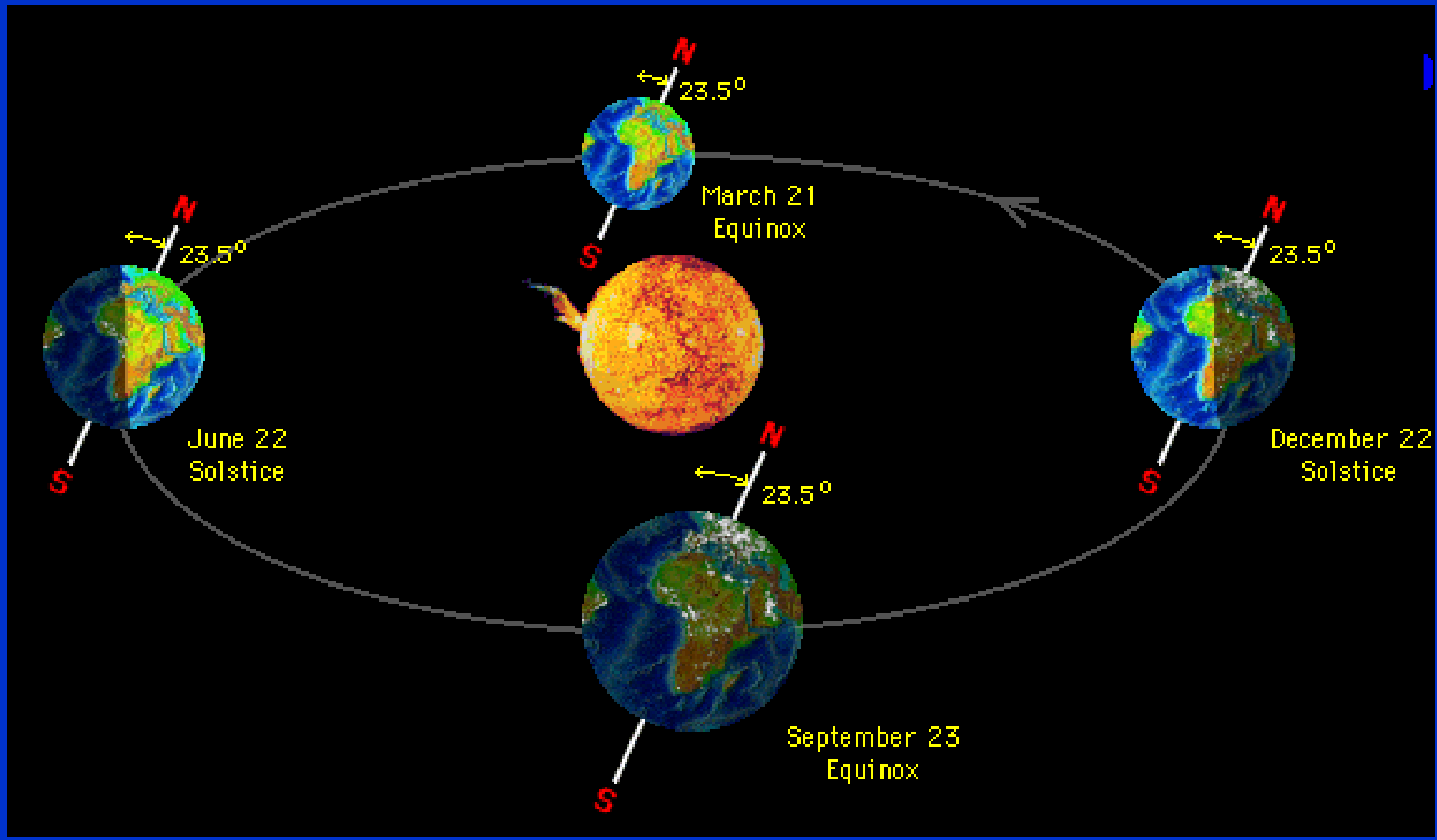
DECEMBER SOLSTICE

24 hours of darkness

Most intense solar radiation



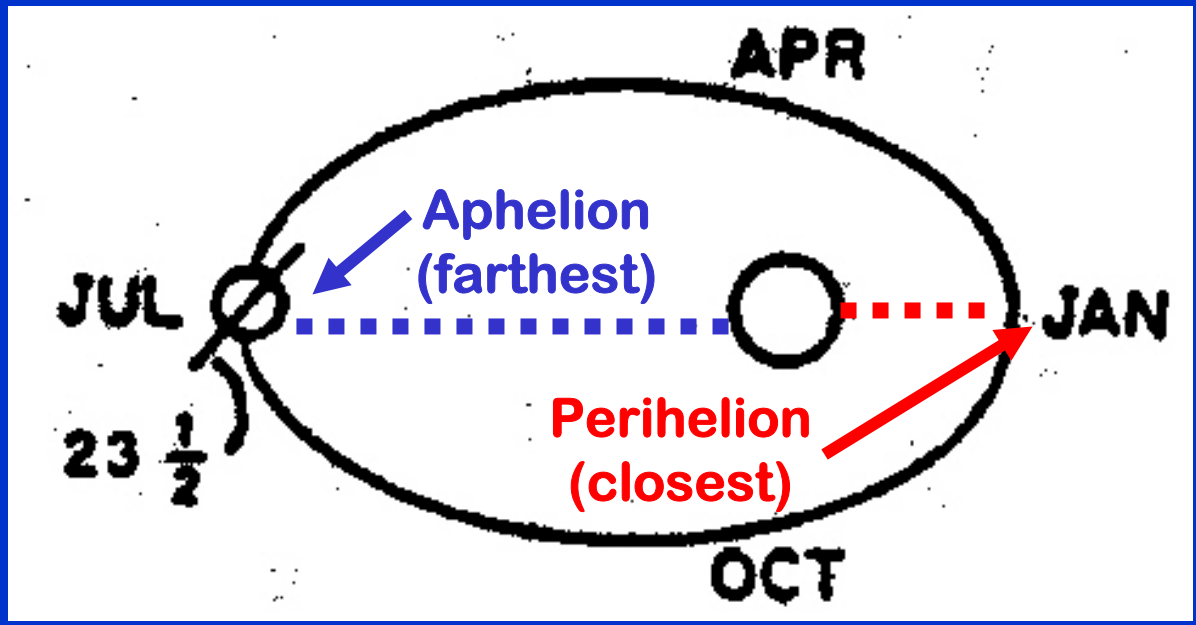
http://mesoscale.agron.iastate.edu/agron206/animations/01_EarthSun.html



Recap

#2 ECCENTRICITY OF ORBIT

Earth's orbit around sun is not symmetrical: "ellipse"



3 Timing of Seasons in Relation to Orbit: PRECESSION OF THE EQUINOXES

(Earth currently is closest to the Sun in January
– just after the Dec Solstice; but this has changed in the past)

Take Notes on p 86

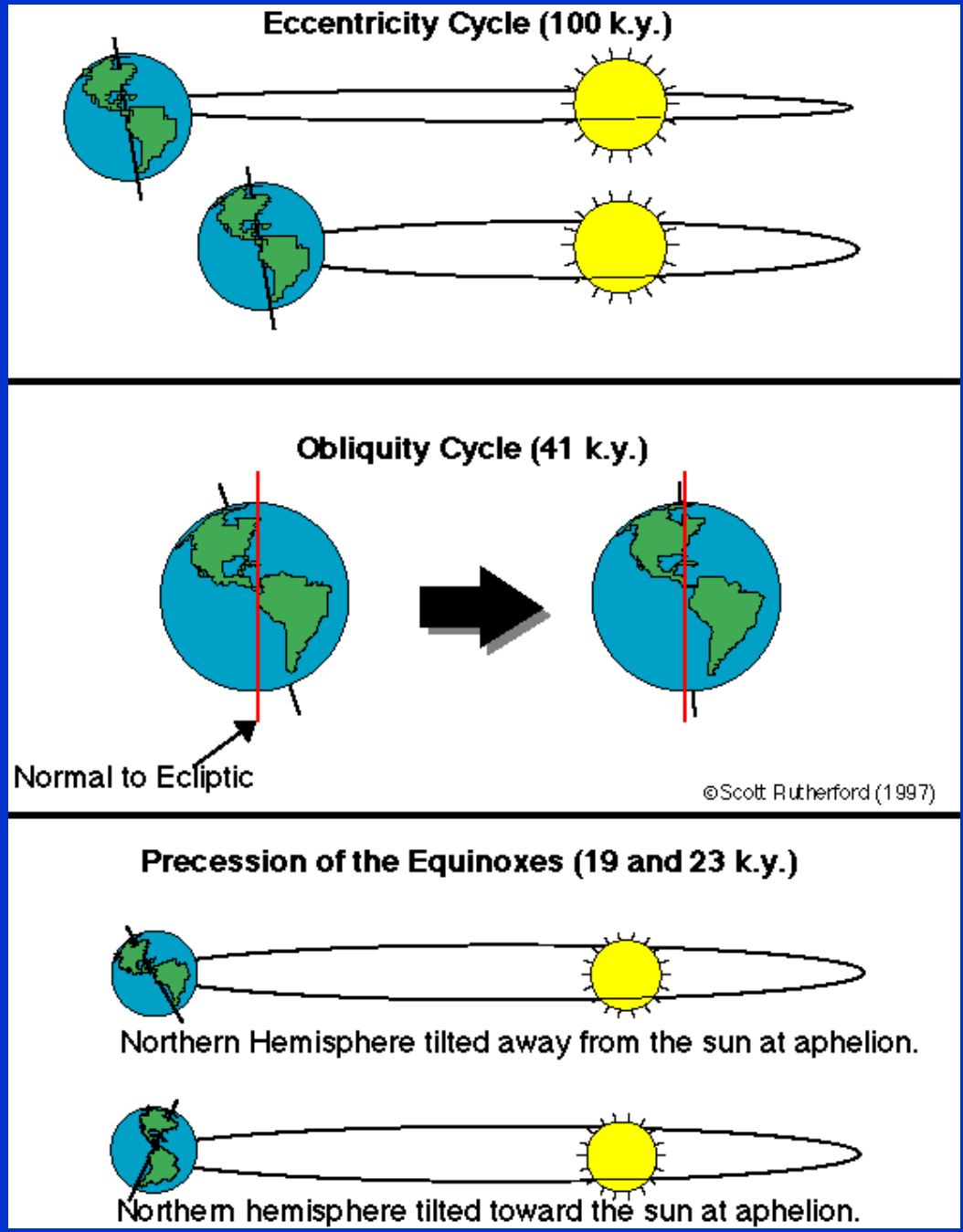
Obliquity

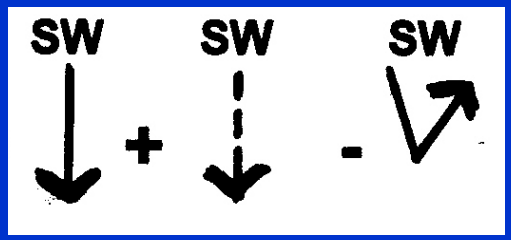
Eccentricity

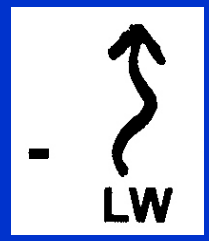
Precession

. . have all CHANGED over the past 100,000 years!!

IGC CD MODULE SELECT
➔"Weather in Motion" – Ch 16 Orbital Variations



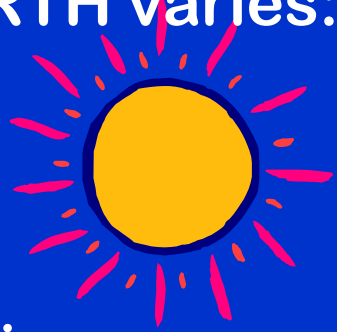




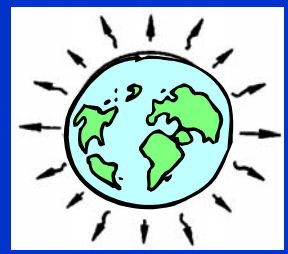
KEY CONCEPT:

The amount of SW absorbed by EARTH varies:

- by LATITUDE
- by SEASON

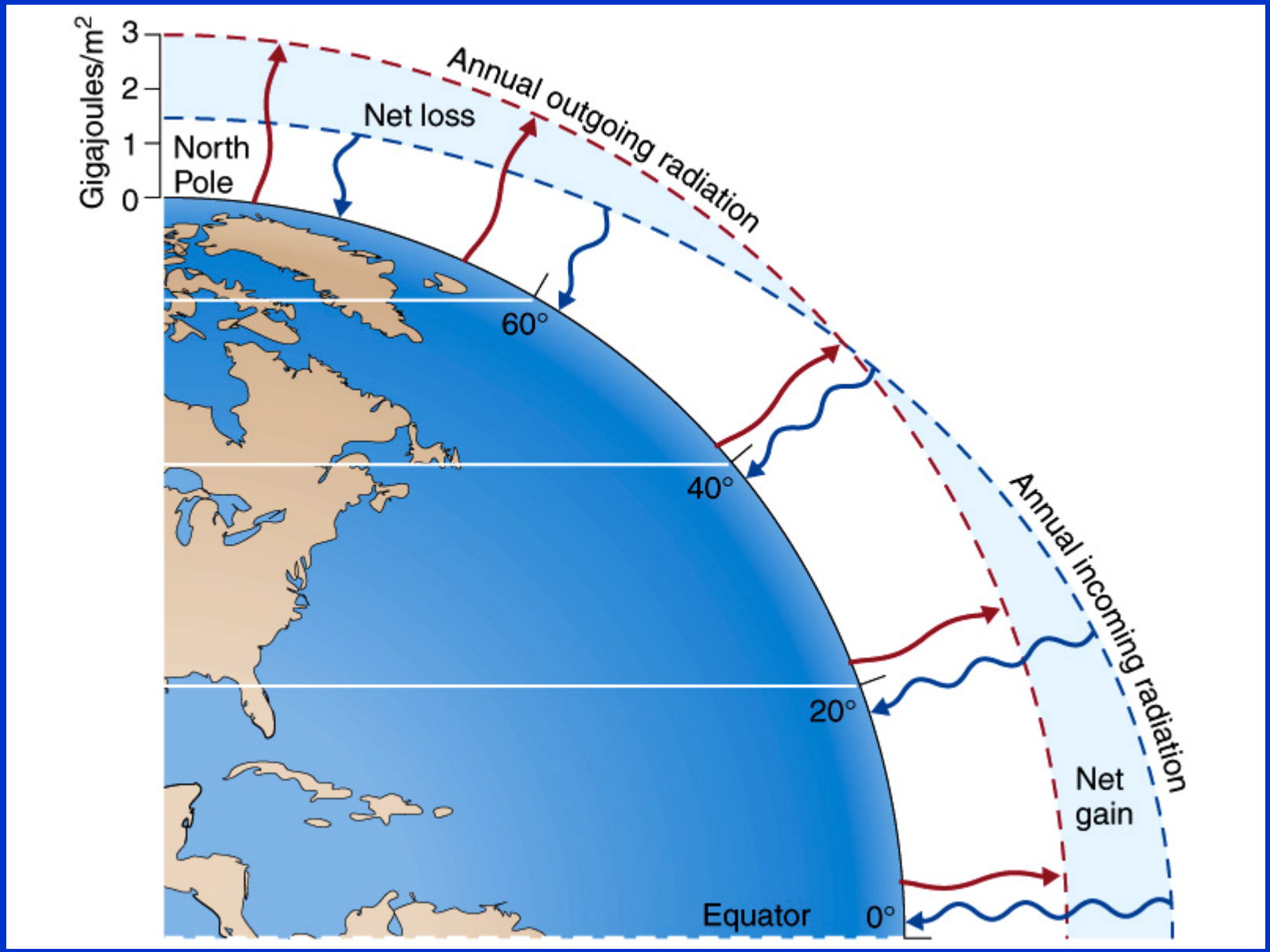


Annually, MORE is absorbed in the LOW LATITUDES (near Equator) than in the HIGH LATITUDES (near Poles)

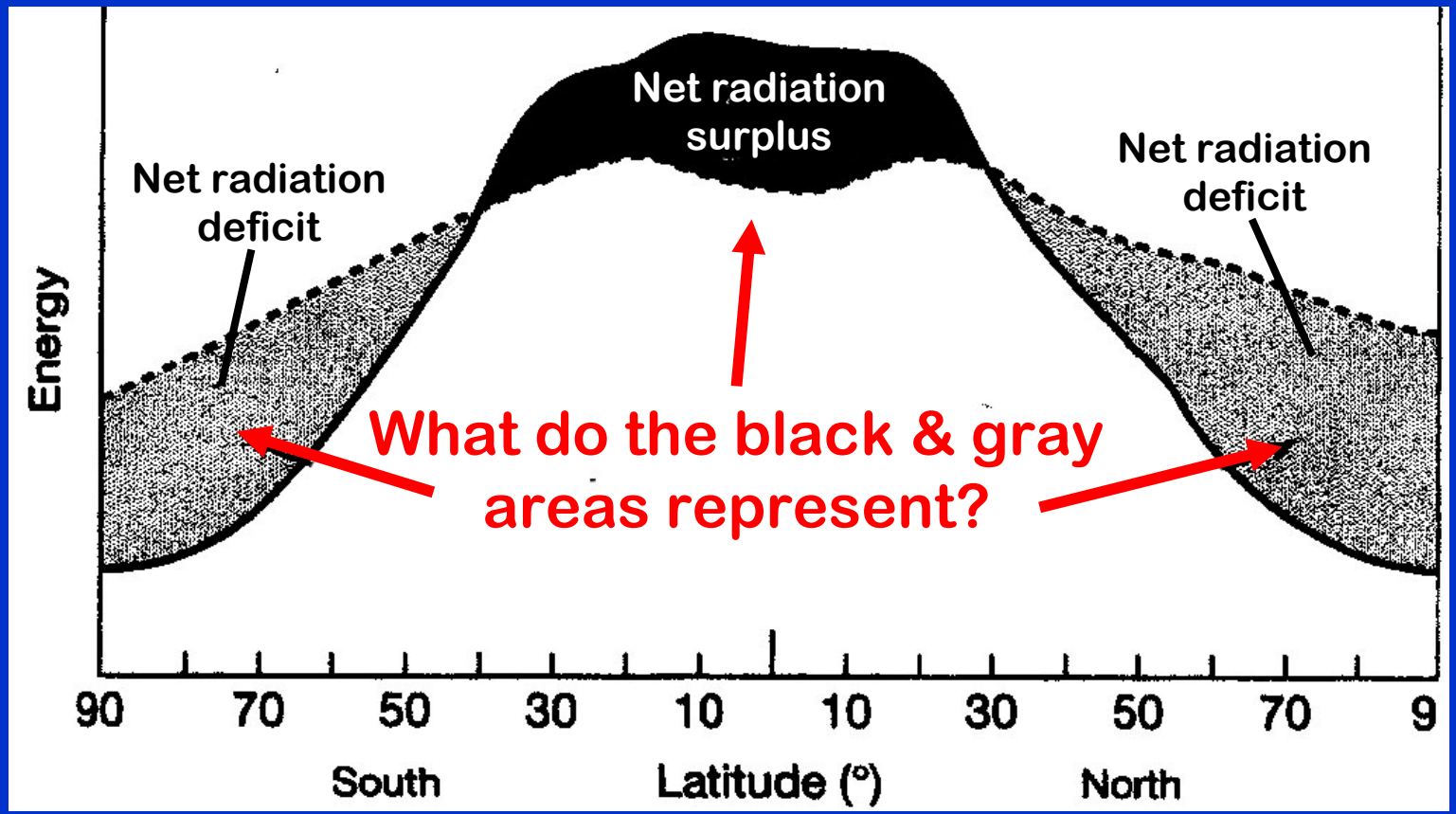


The EARTH radiates out LW fairly evenly from latitude to latitude, but MORE LW energy is radiated out in warm Equatorial latitudes & LESS in cold Polar latitudes

Remember? $E = \sigma T^4$



This Figure is on p 90



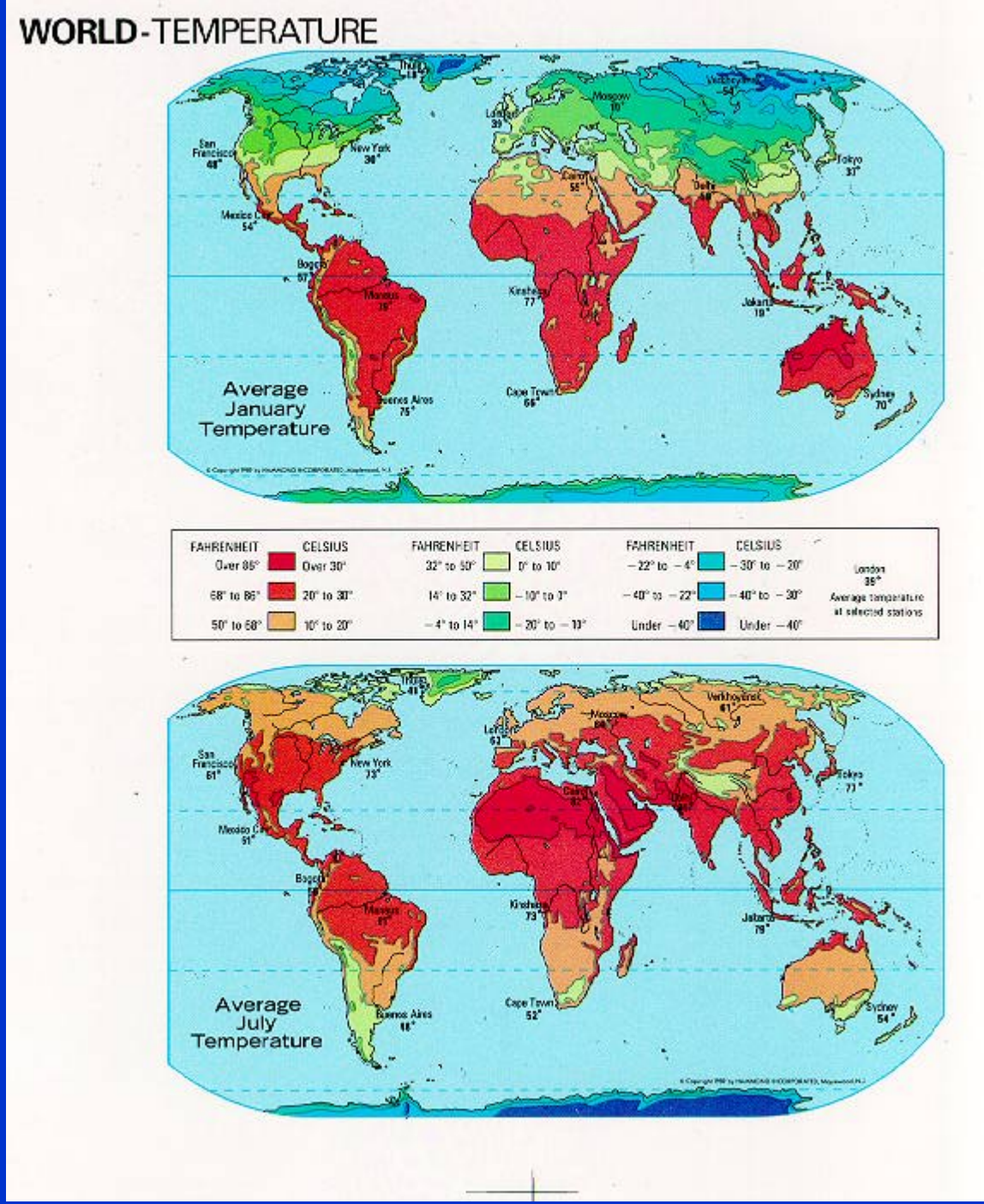
Absorbed solar energy

SW + SW - SW

Emitted infrared energy

(at top of atmosphere)

- LW

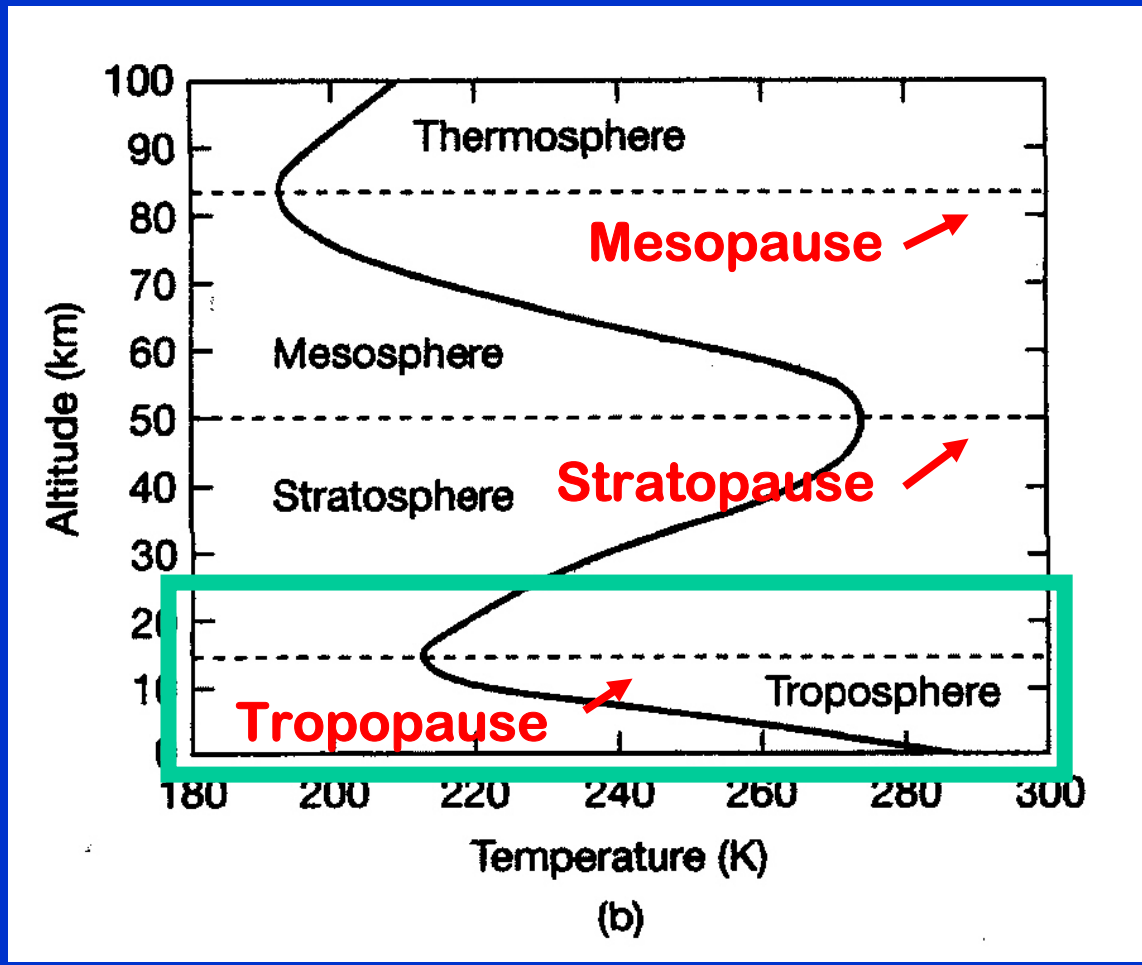


IGC CD MODULE SELECT
➔"Weather in Motion" – Ch 2 January & July 1999 Global Movie of Land & Sea Surface Temperatures & Clouds

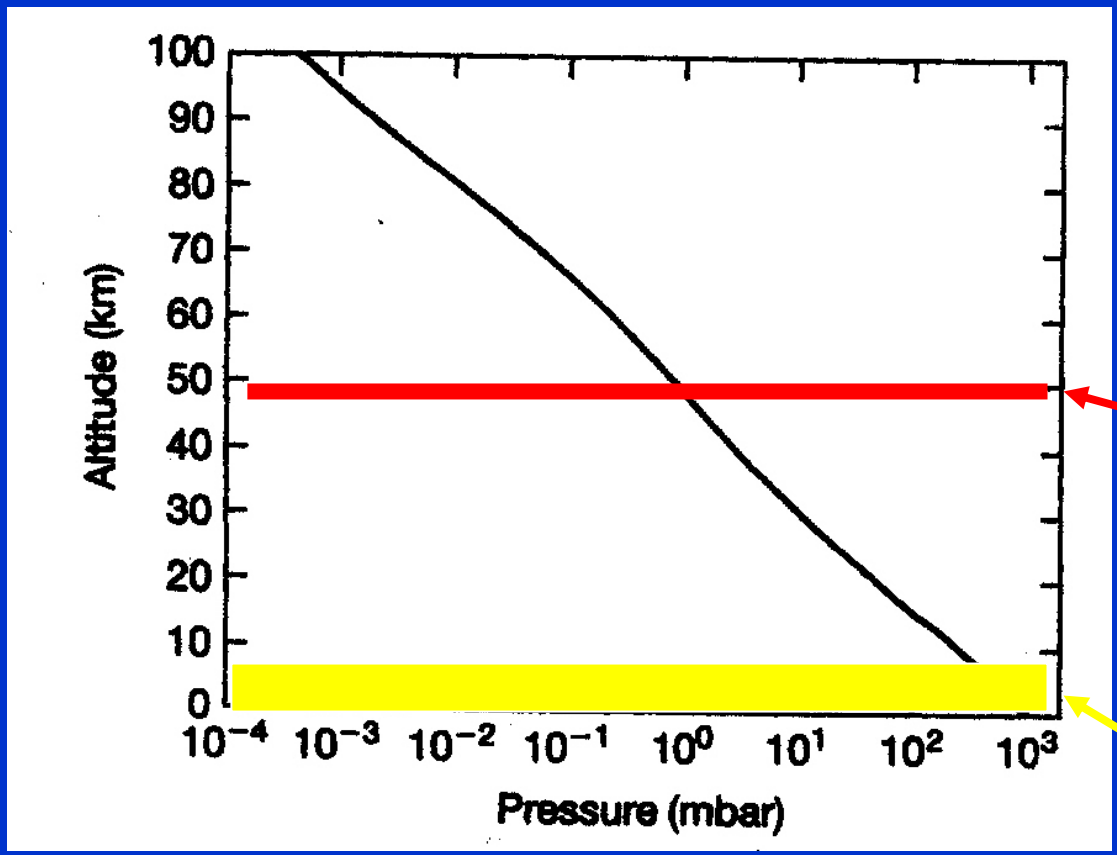
Recall: Vertical Structure of the Atmosphere

defined by ***CHANGES*** *in* ***TEMPERATURE*** *with height.*

MOST WEATHER & CLIMATE PROCESSES take place in the TROPOSPHERE (& some in Stratosphere)



ATMOSPHERIC PRESSURE



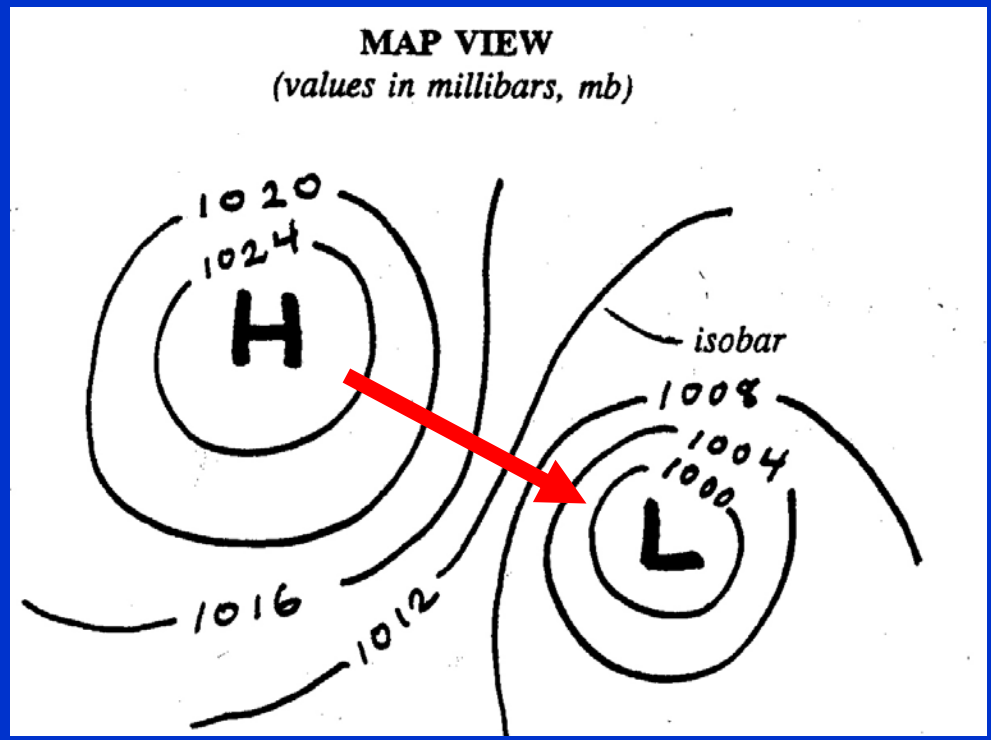
Def: the weight of the air above a given point or level.

Atmospheric Pressure & Mass Vary with Height

99% of mass lies below ~ 50 km (top of Stratosphere)

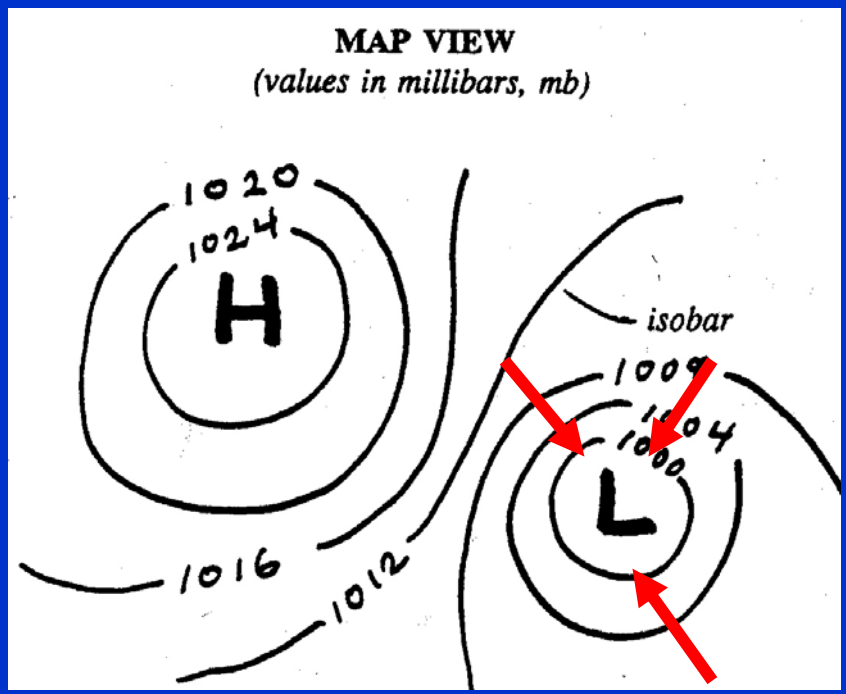
50% of mass lies below ~ 6 km (middle Troposphere)

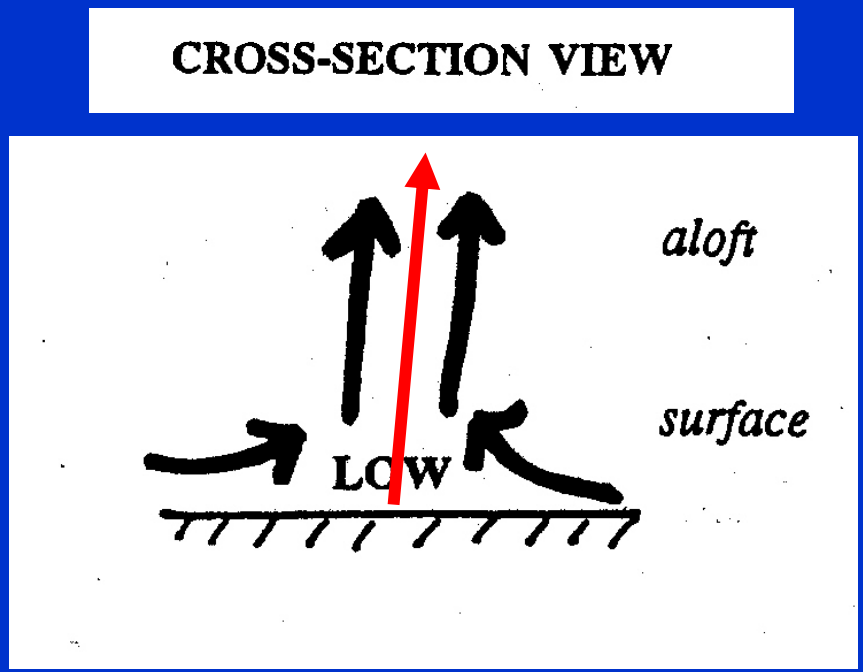
In general: Winds tend to flow from HIGH ➔ LOW Pressure areas



Areas or centers of high and low pressure at the Earth's surface have the following characteristics:

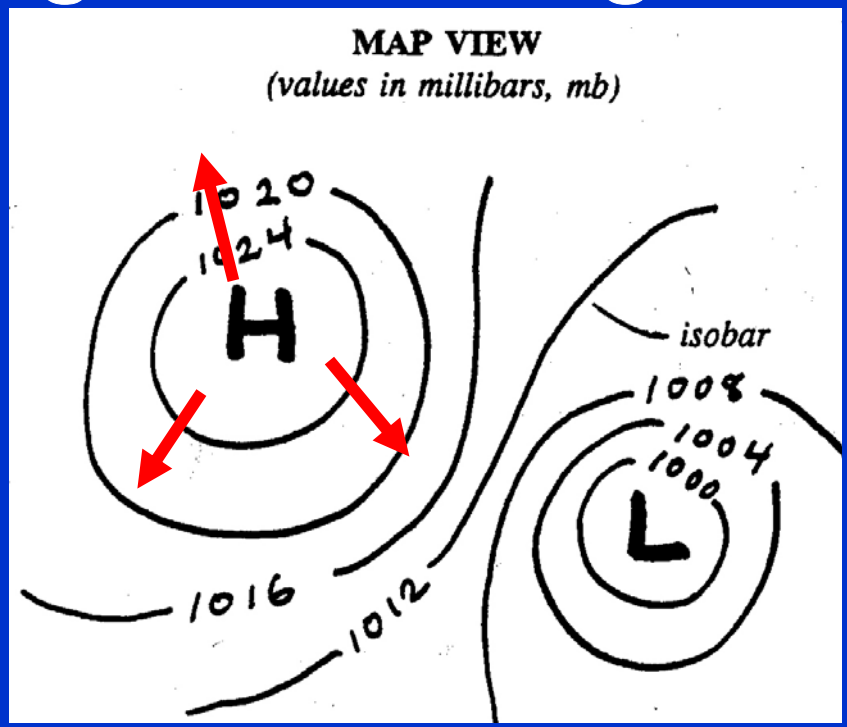
LOWS - air converges into lows and rises in the center of lows

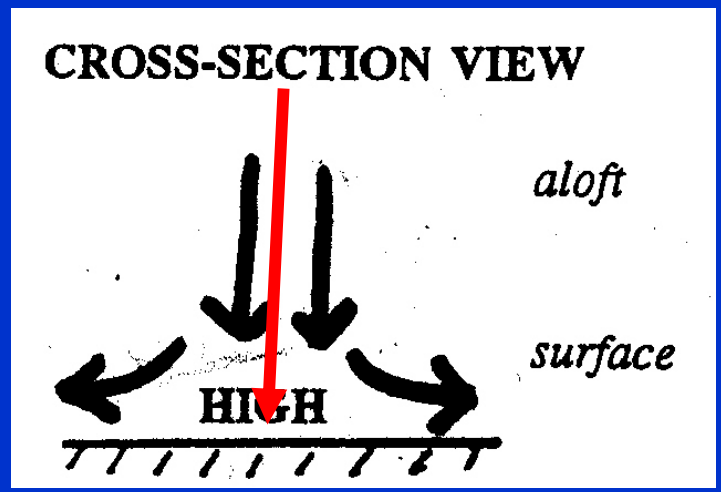




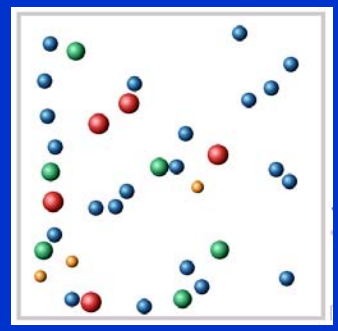
Areas or centers of high and low pressure at the Earth's surface have the following characteristics:

HIGHS - air <u>subsides</u> in the center of highs and <u>diverges</u> out of highs

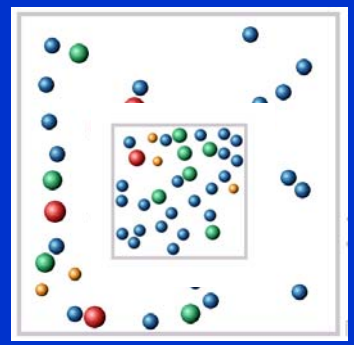


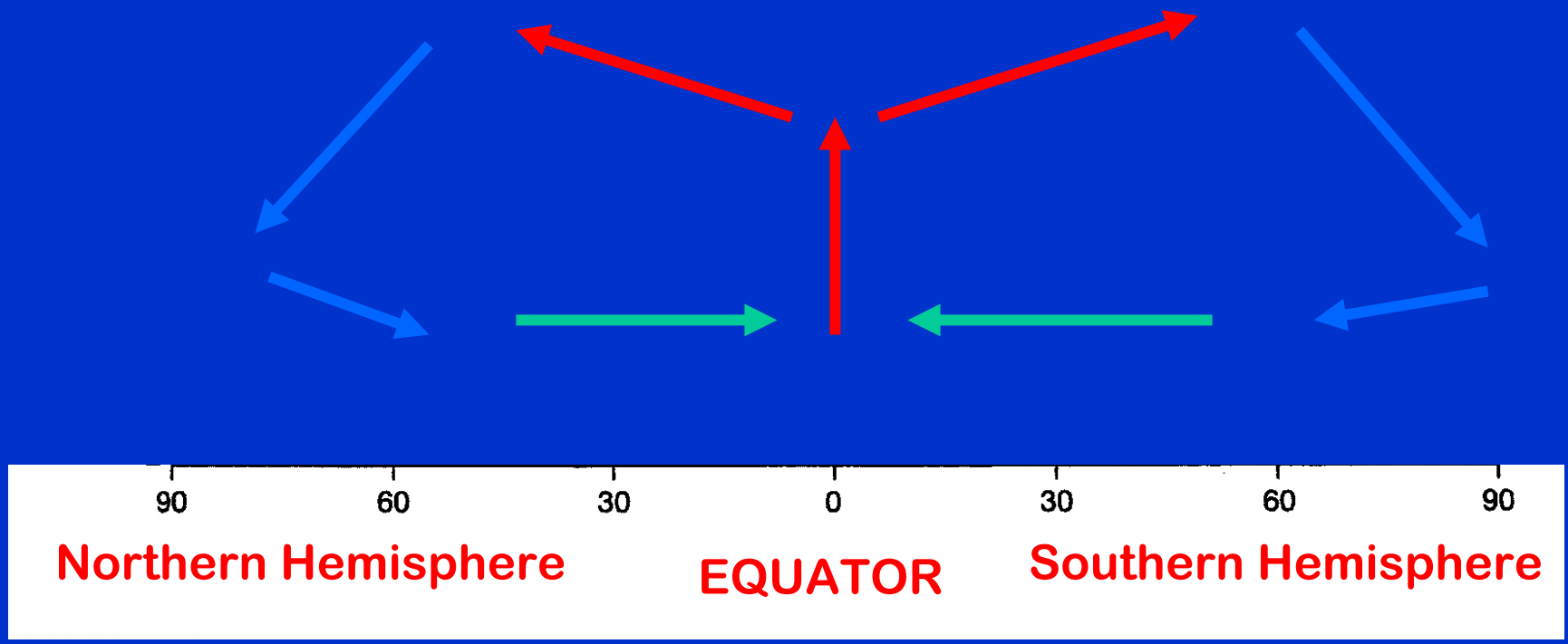


LOWS: (rising leads to **expansion and cooling** of air, and condensation of water vapor ==> clouds and possibly precipitation)



HIGHS: (sinking leads to **contraction and warming of air**, and increased water vapor holding capacity ==> clear skies, dry air)

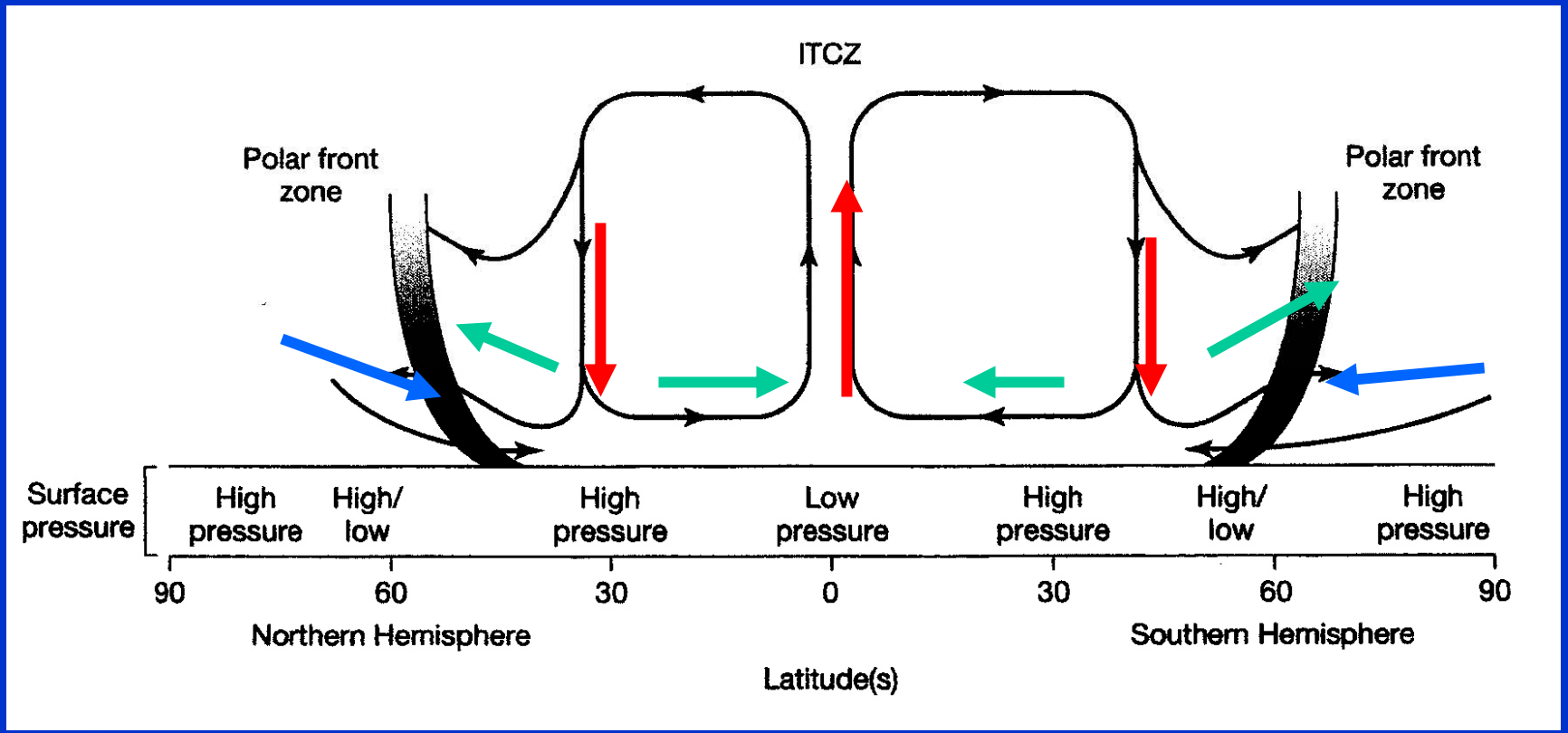




COLD POLAR REGIONS

HOT TROPICS

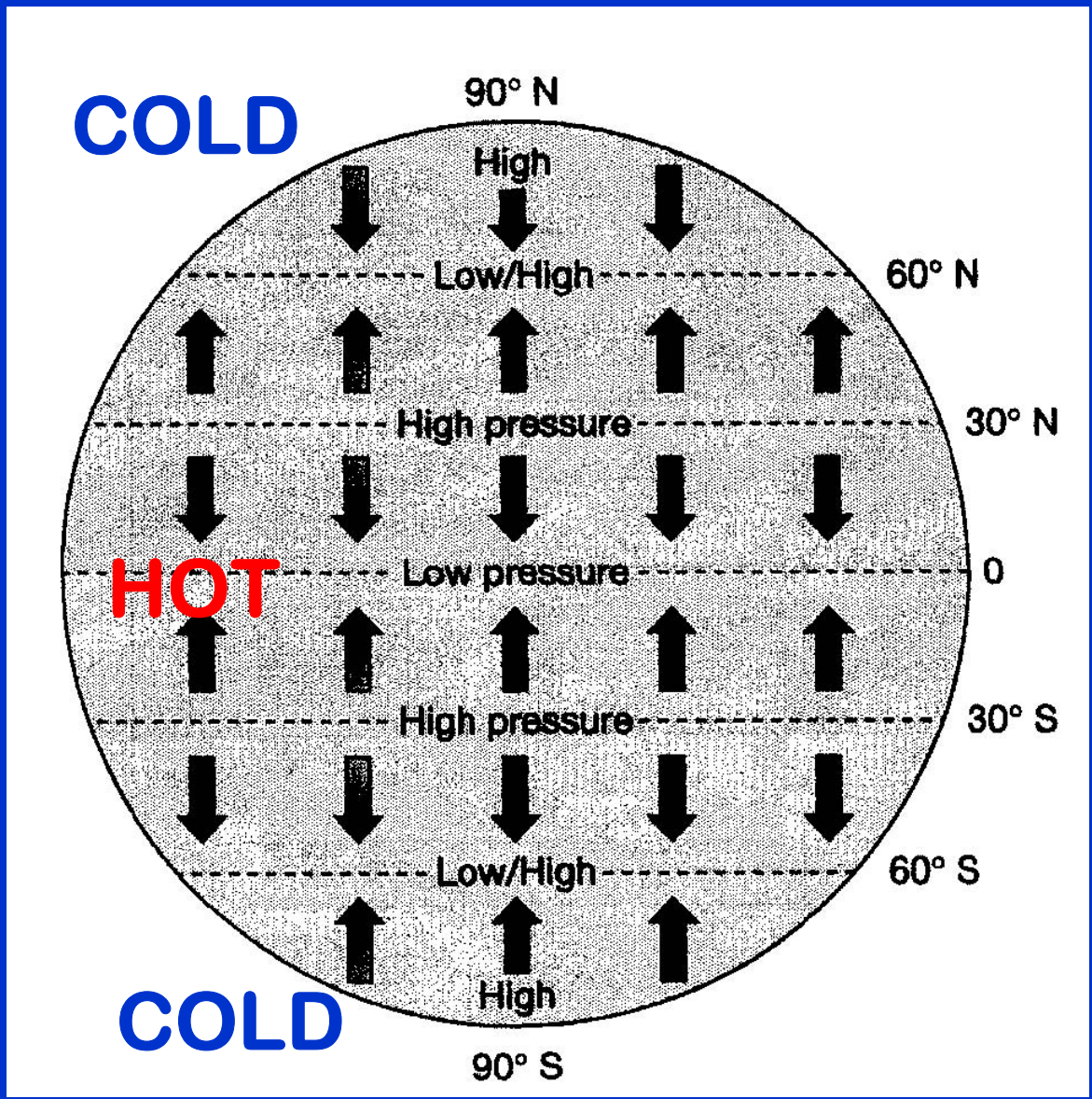
COLD POLAR REGIONS



COLD POLAR REGIONS

HOT TROPICS

COLD POLAR REGIONS


COLD
90° N
High
Low/High
60° N
High pressure
30° N
HOT
Low pressure
0
High pressure
30° S
Low/High
60° S
High
COLD
90° S

AIR IN MOTION: WINDS

(NOTE: recall the laws of motion)

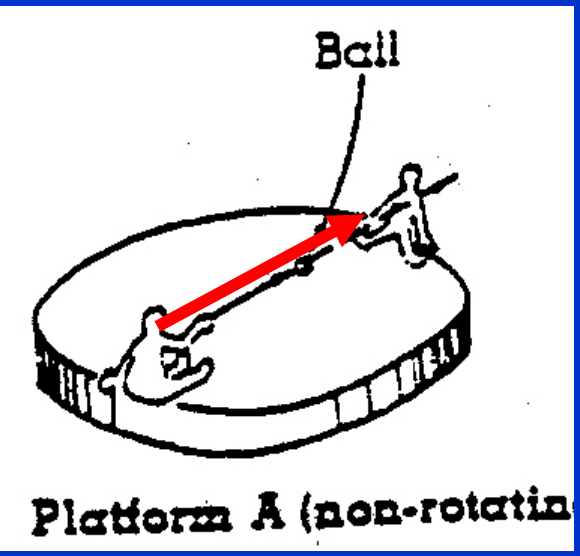
Atmospheric circulation is accomplished by air flow in the form of winds. Wind direction and strength are determined by:

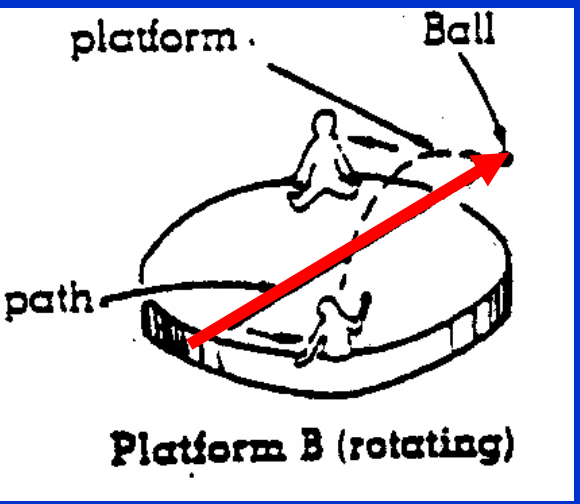
PGF Pressure Gradient Force

CF Coriolis "Force" (Effect)

FF Friction Force (near Earth's surface)

CORIOLIS EFFECT:
Recall Newton's 1st law!





Due to Earth's rotation moving objects deflected :

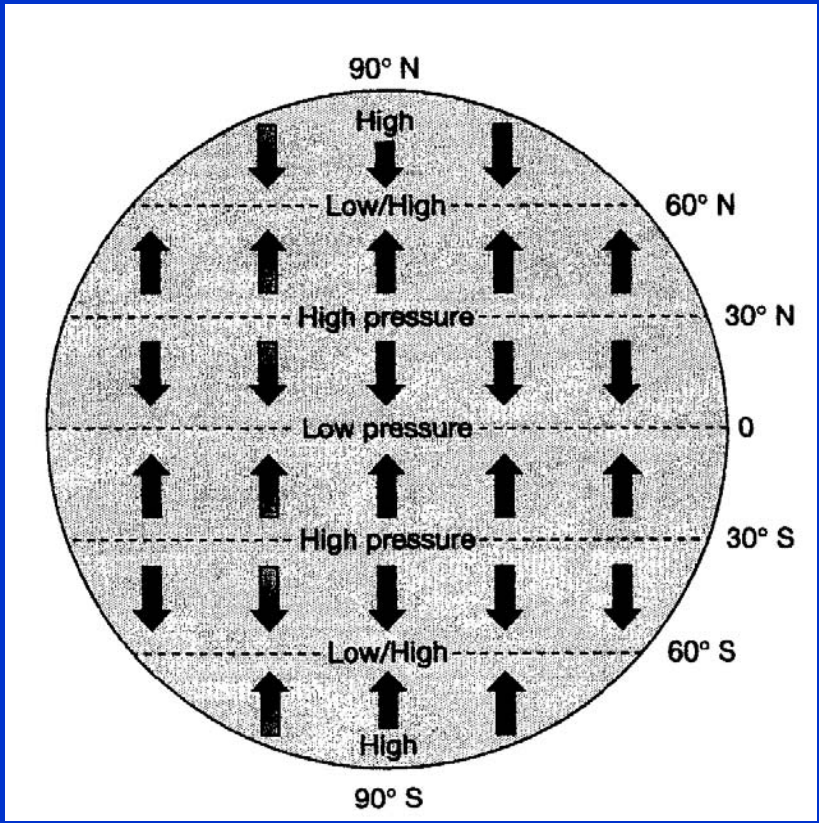
To the RIGHT in N.H.

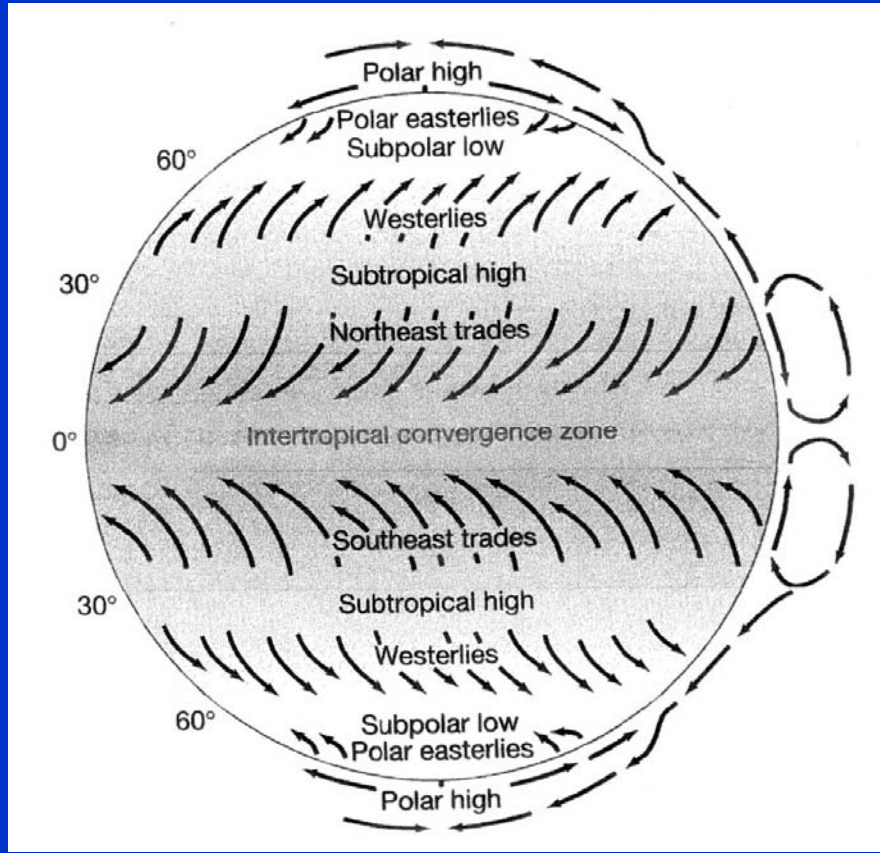
To the LEFT in S.H.

Northern & Southern Hemisphere Circulations around Highs and Lows:

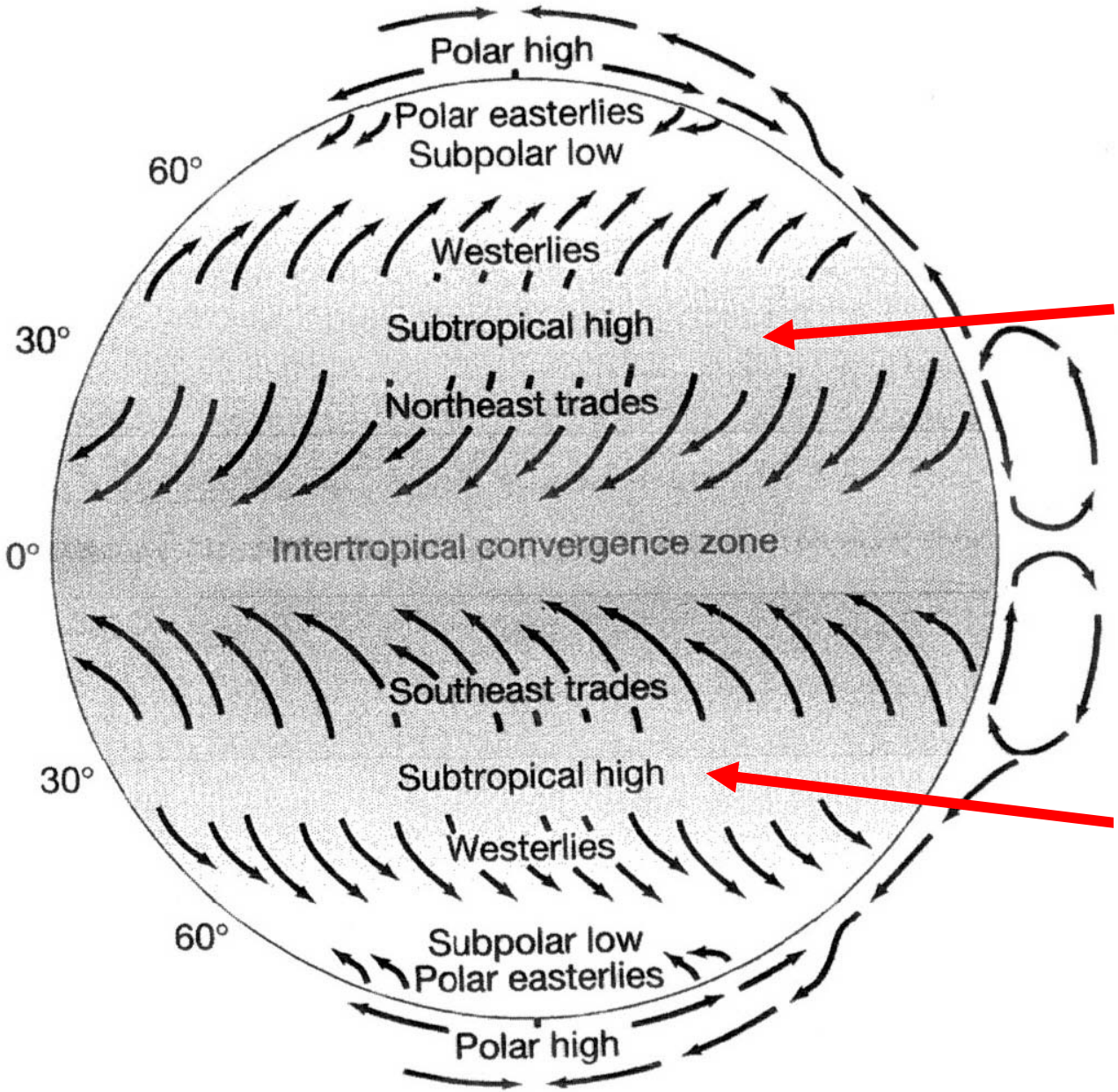
The combined PGF, CF, and FF effects result in the following patterns for surface highs and lows in the Northern and Southern hemispheres:

5 2 2 5





Non-rotating Globe **Rotating Globe**

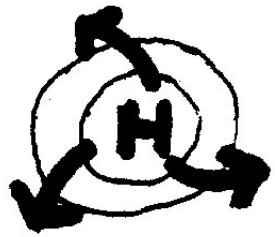


Sub-tropical HIGH PRESSURE CELLS

Northern Hemisphere:

ITCZ

Southern Hemisphere:



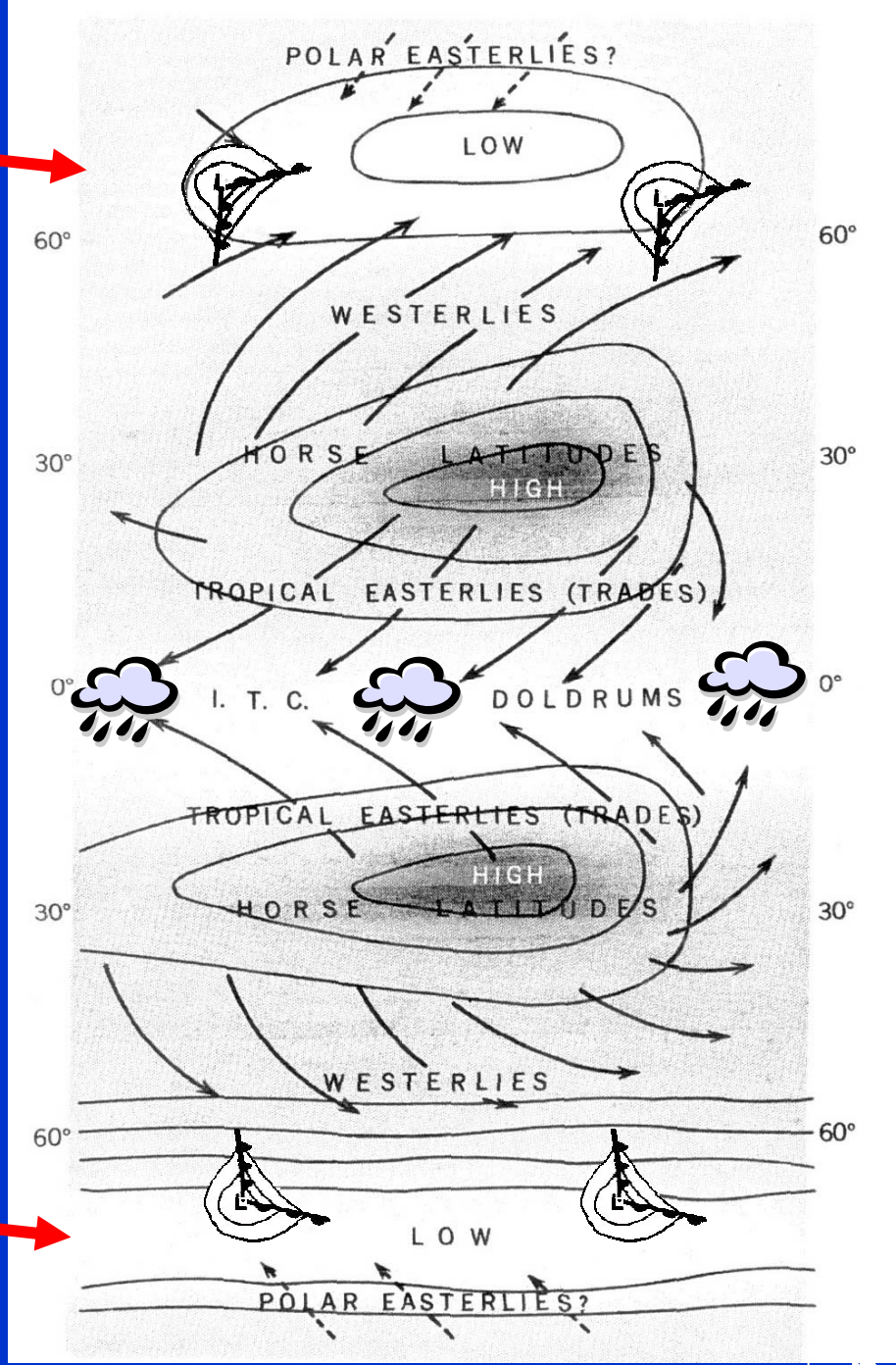
Midlatitude cyclone storms

STH
(Dry, deserts)

ITCZ
(tropical convection)

STH
(Dry, deserts)

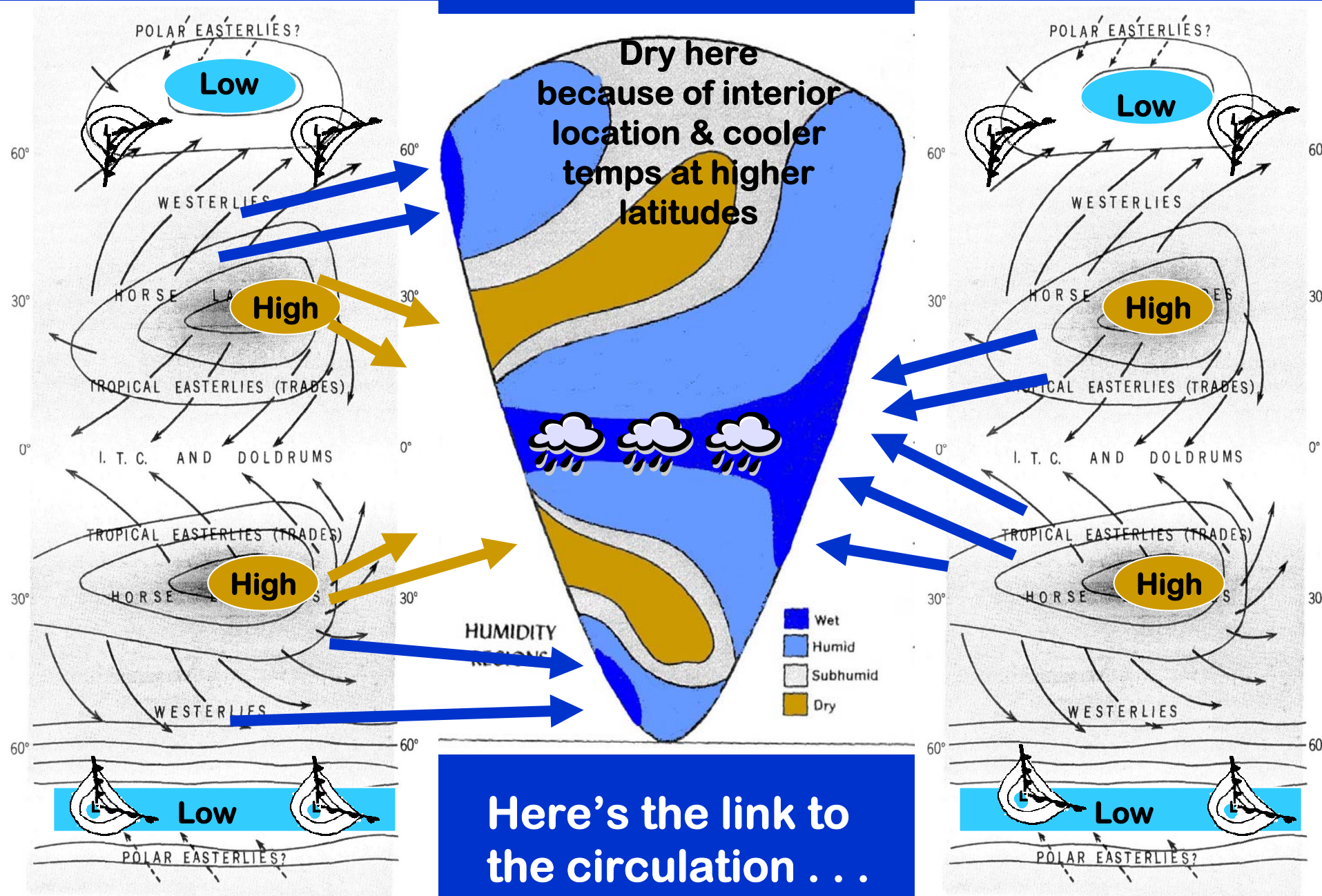
Midlatitude cyclone storms

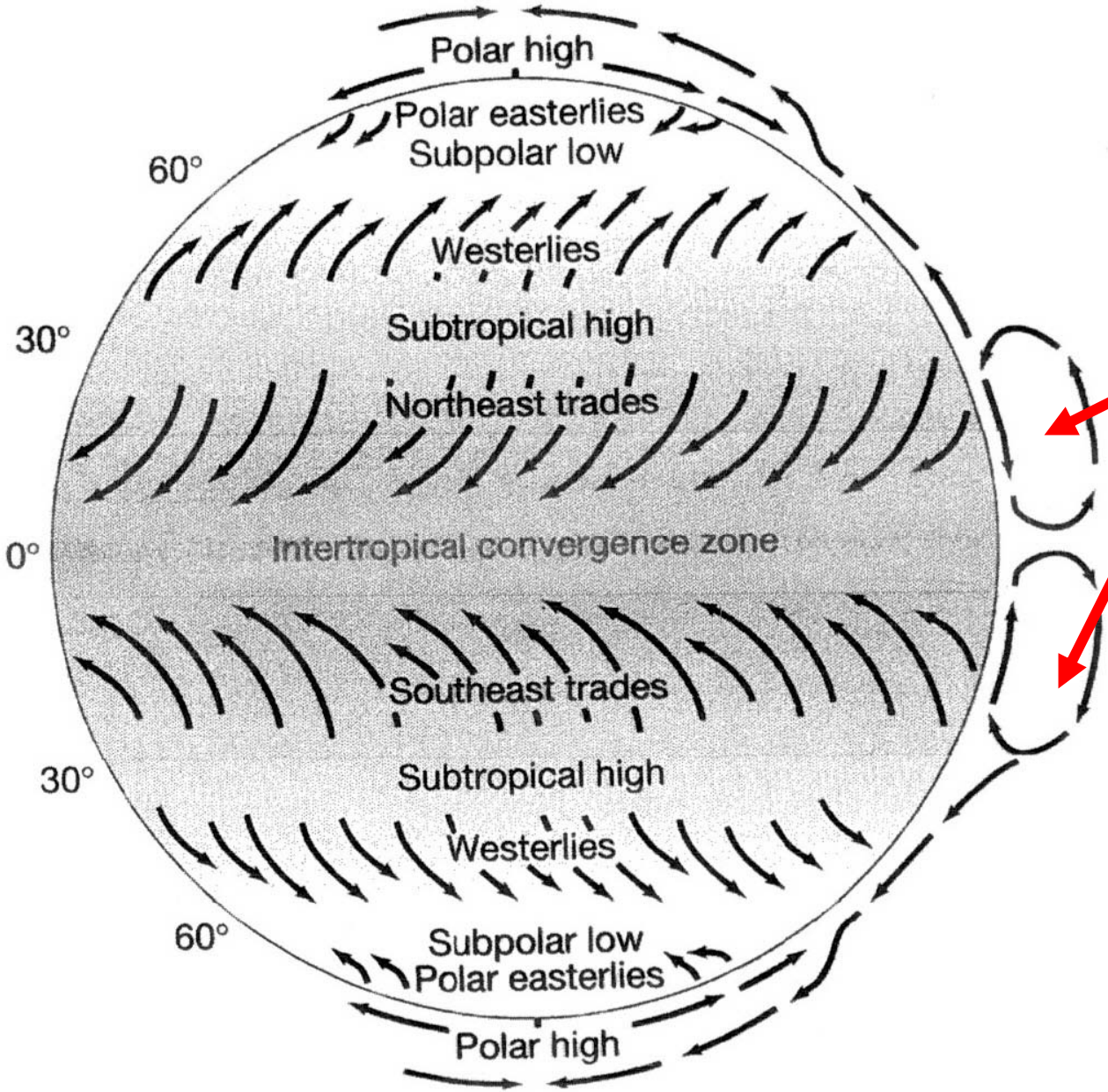


This is where we ended class.

The rest of the slides that follow will be addressed on Thursday . . . .

Idealized Circulation & Hypothetical Continent

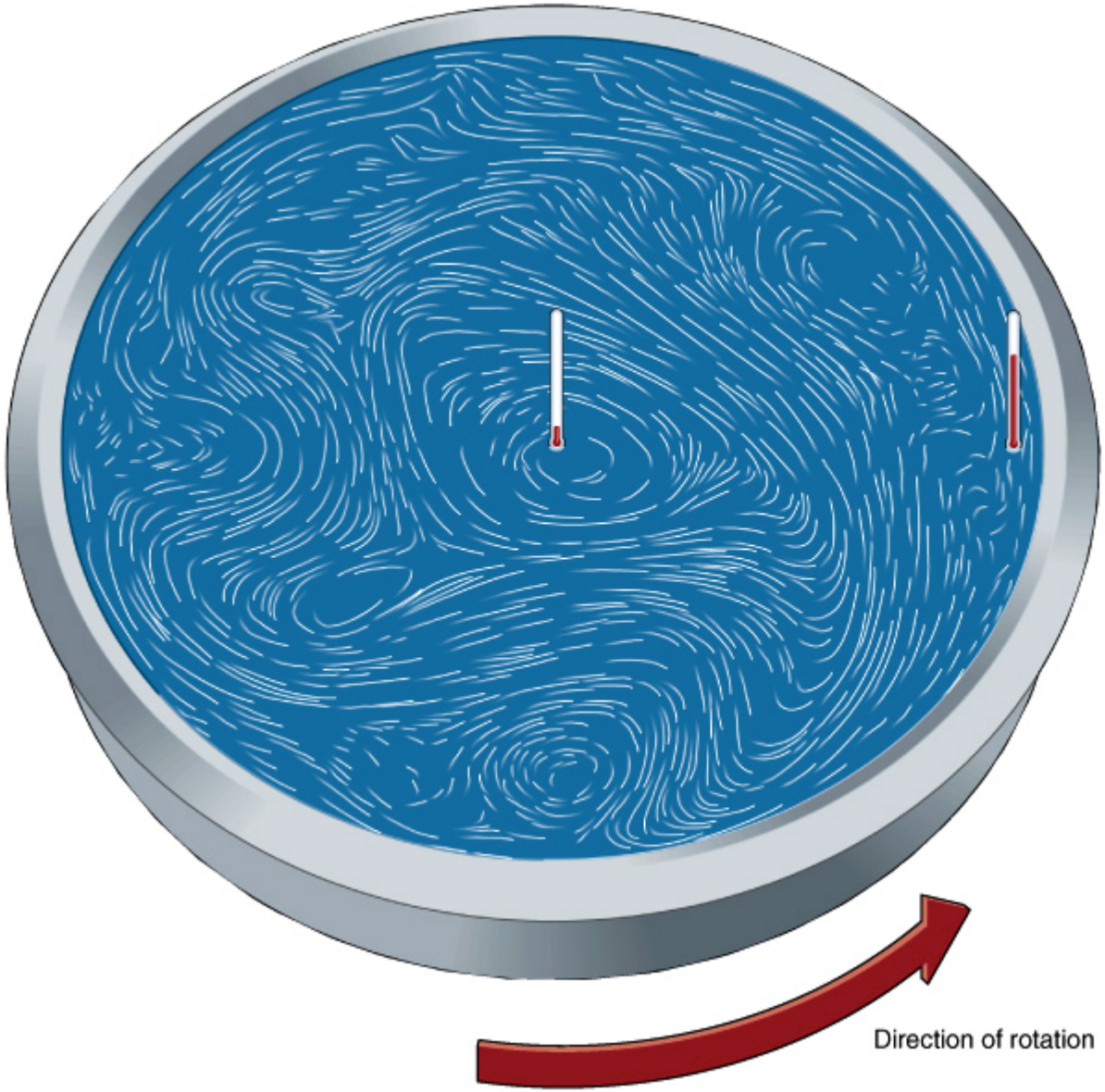




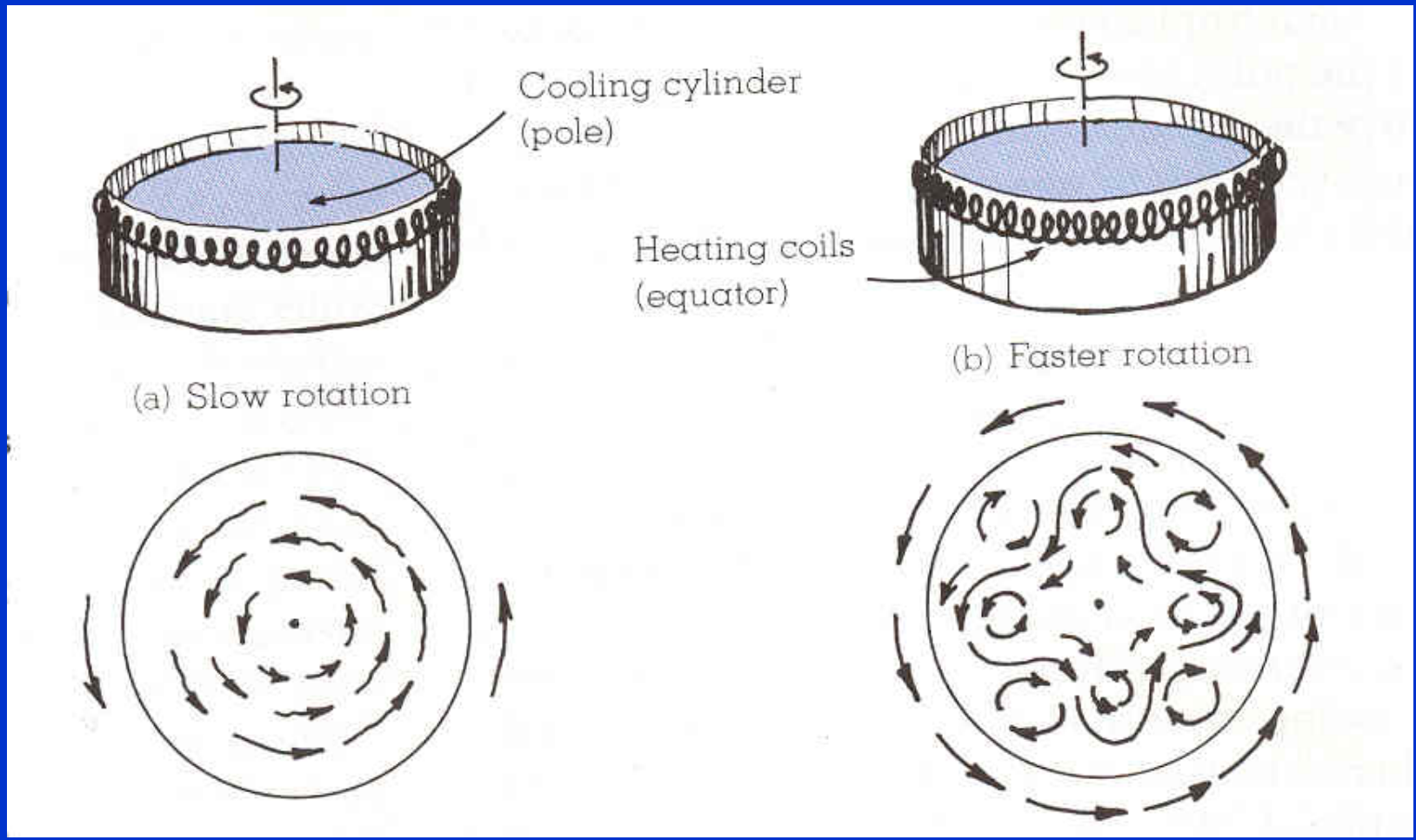
H

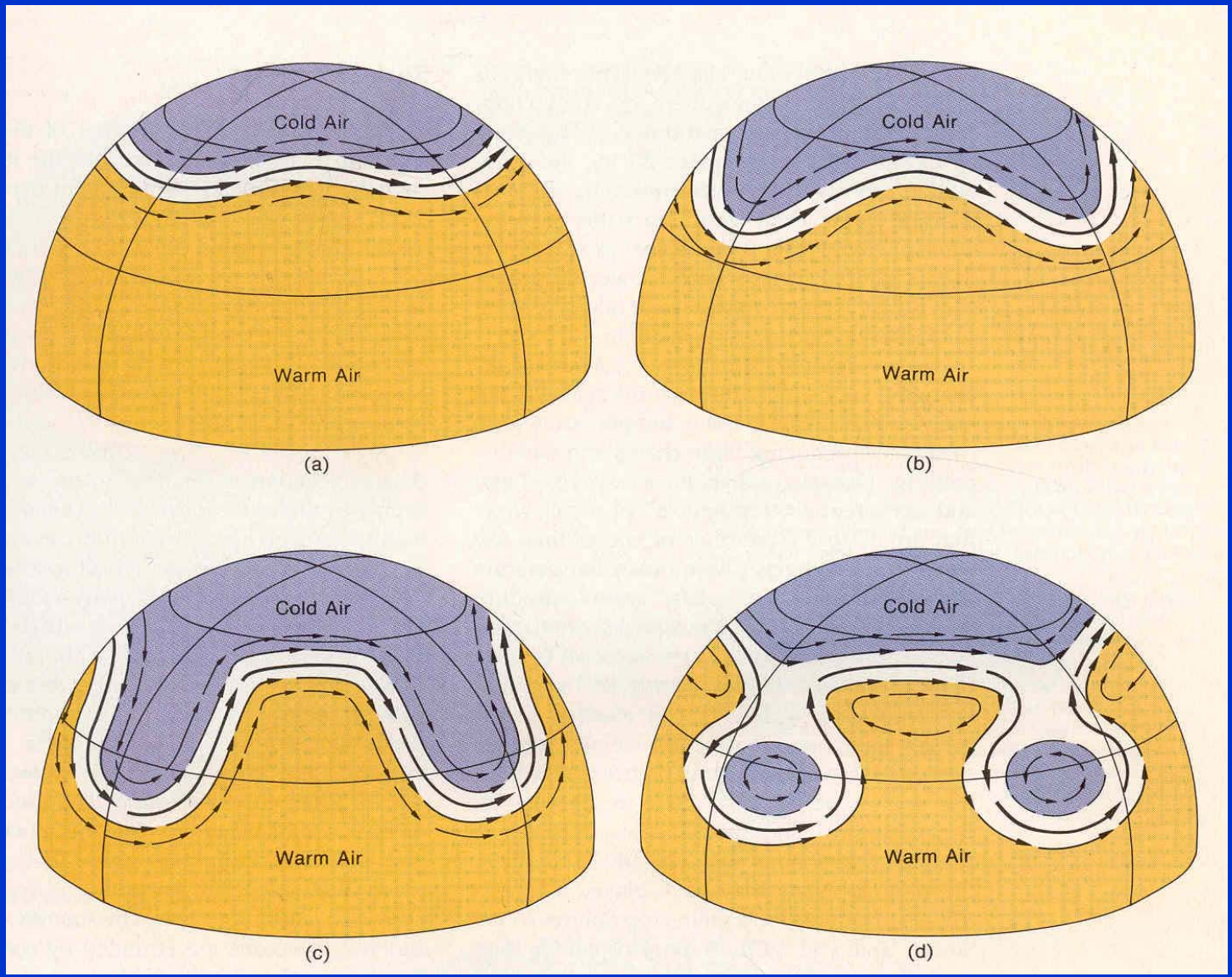
HADLEY CELLS

Convection cell transfer of thermal energy from low latitude area of energy SURPLUS to higher latitude area of energy DEFICIT


Direction of rotation

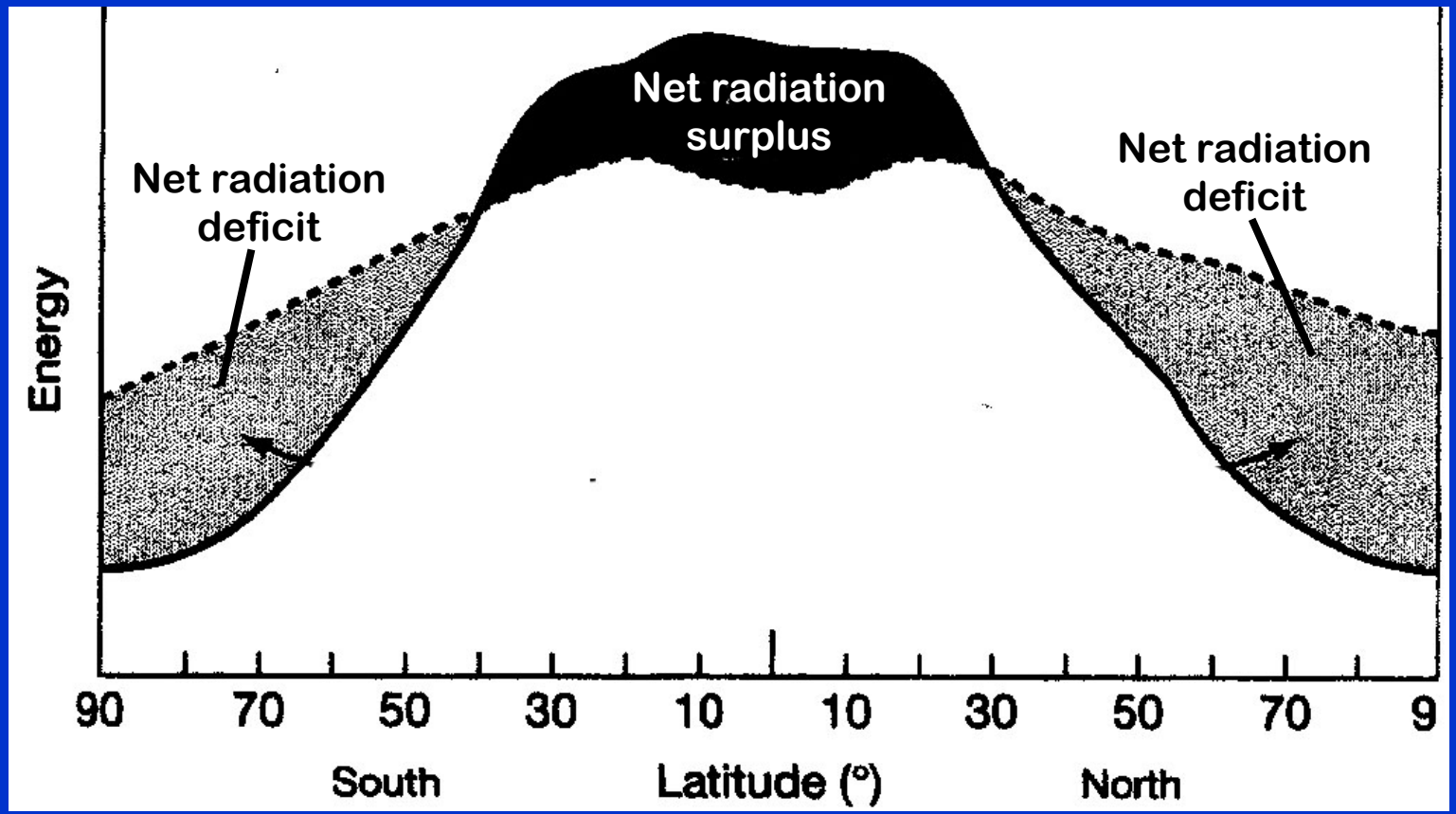
Why Hadley convective cell transport breaks down at higher latitudes:





H

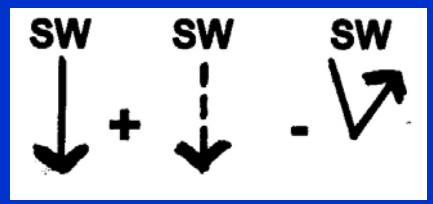
Wave transport of thermal energy instead of Hadley cell transport!

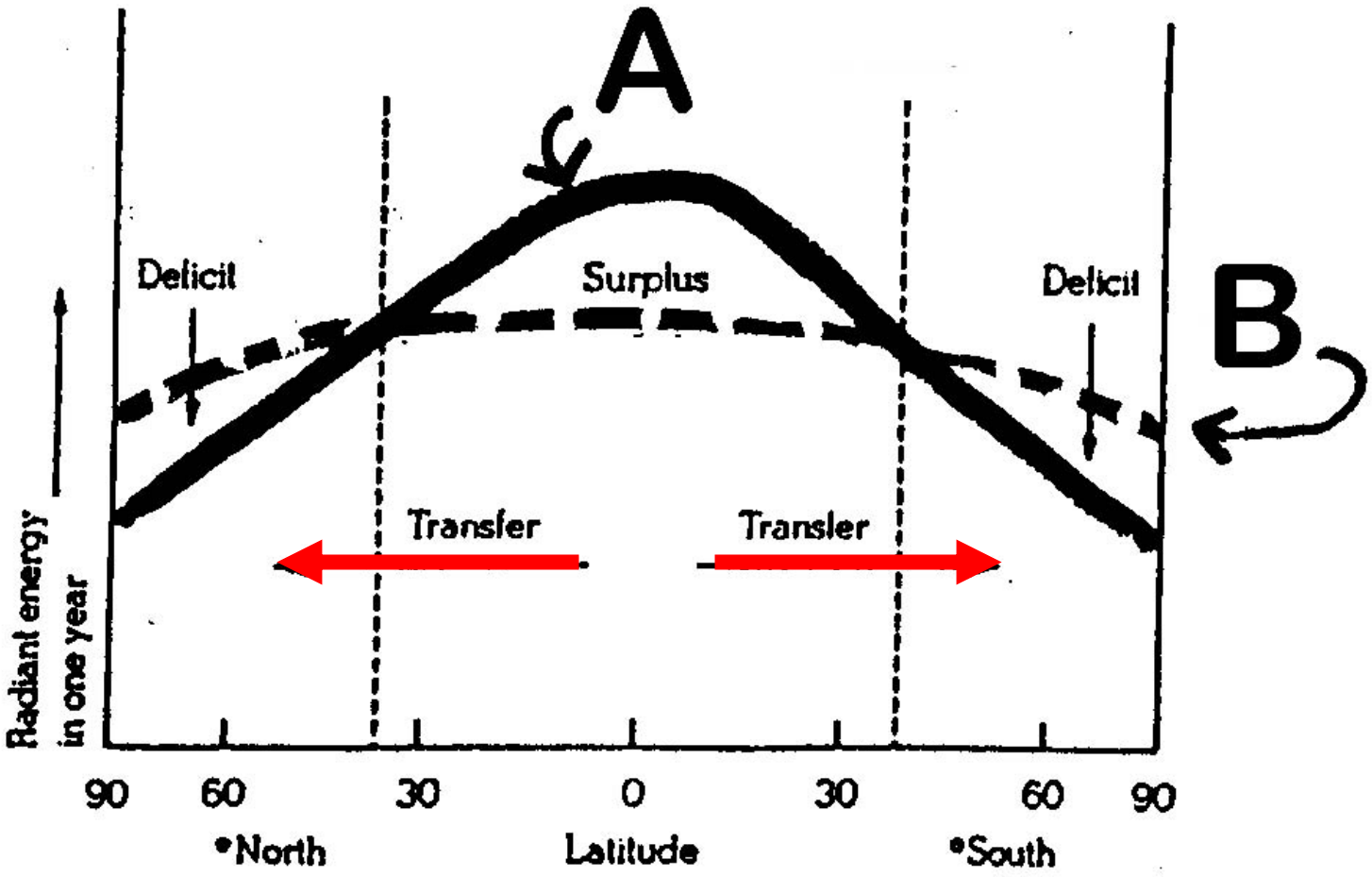


Absorbed solar energy

Emitted infrared energy

(at top of atmosphere)

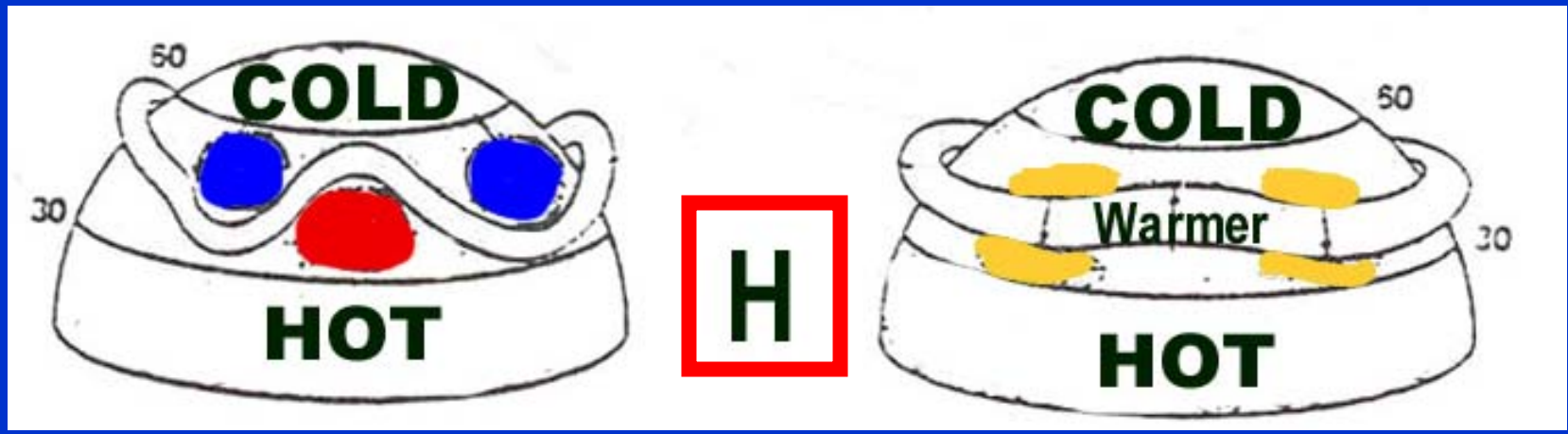


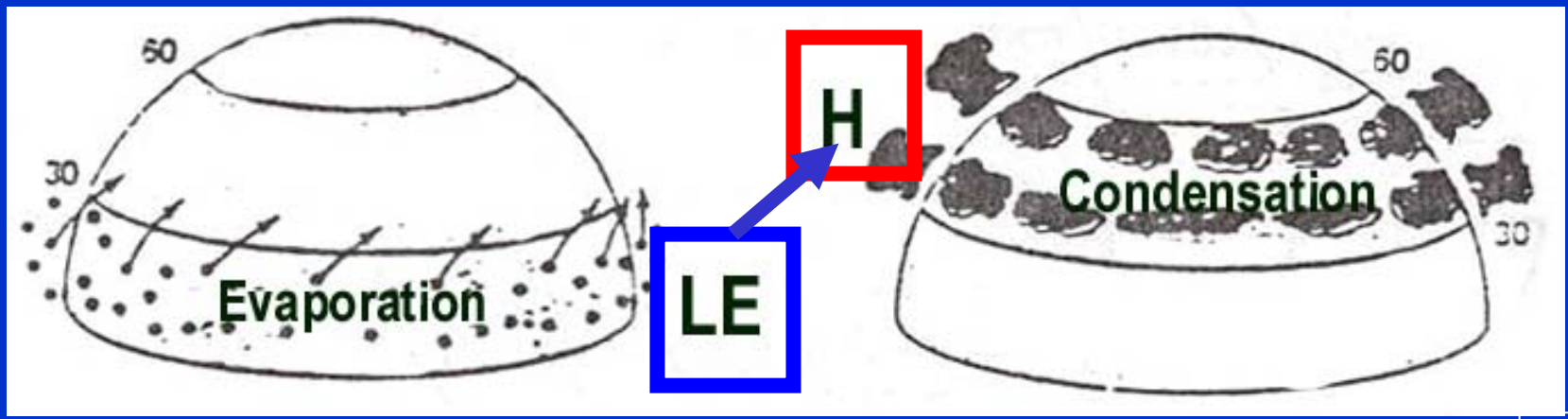


THERMAL ENERGY TRANSPORTED FROM LOW TO HIGH LATITUDES TO BALANCE OUT DEFICIT!

Energy is transported from areas of surplus to deficit in form of: H (sensible heat) & LE (Latent Energy)

H + LE

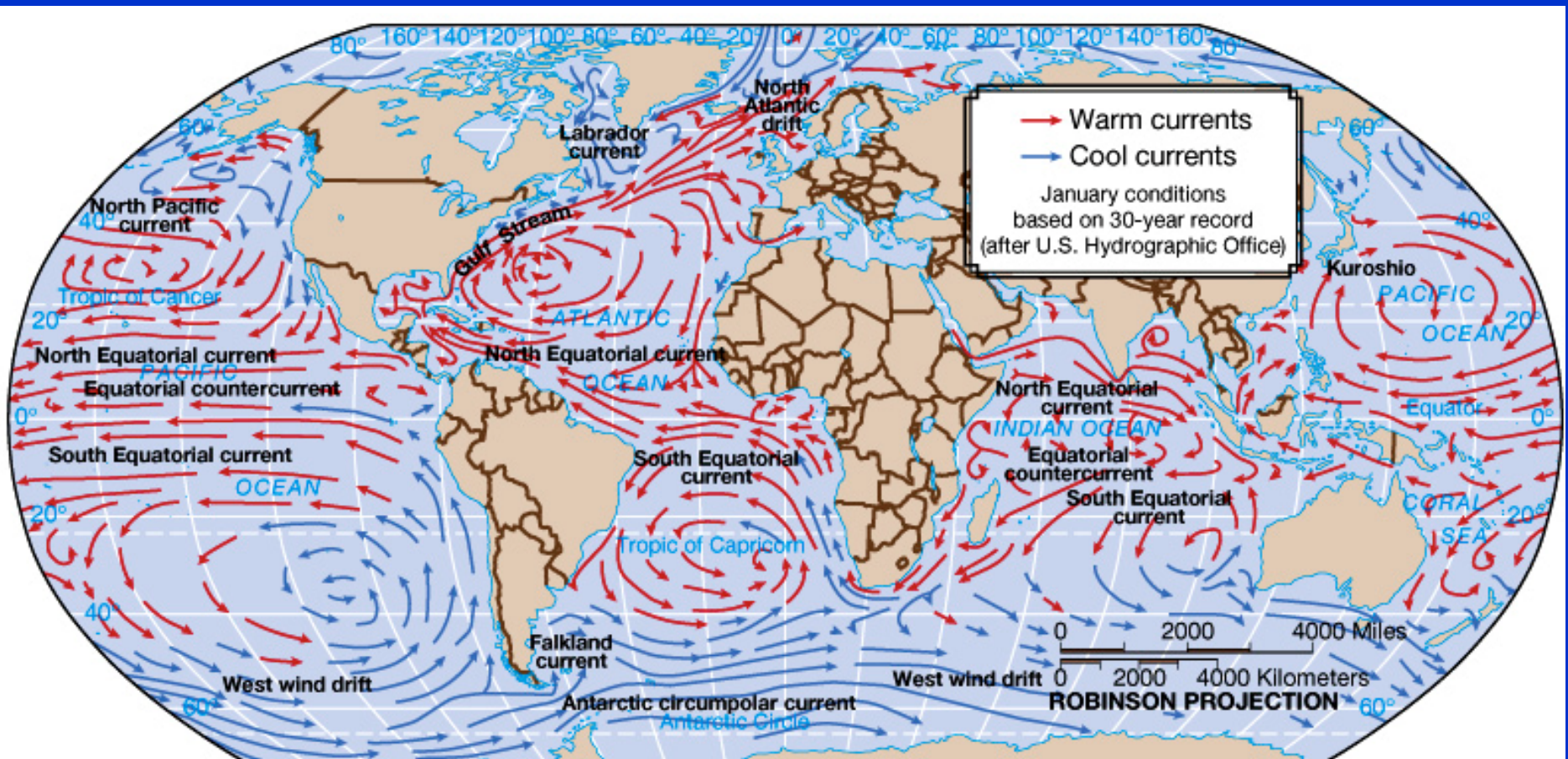




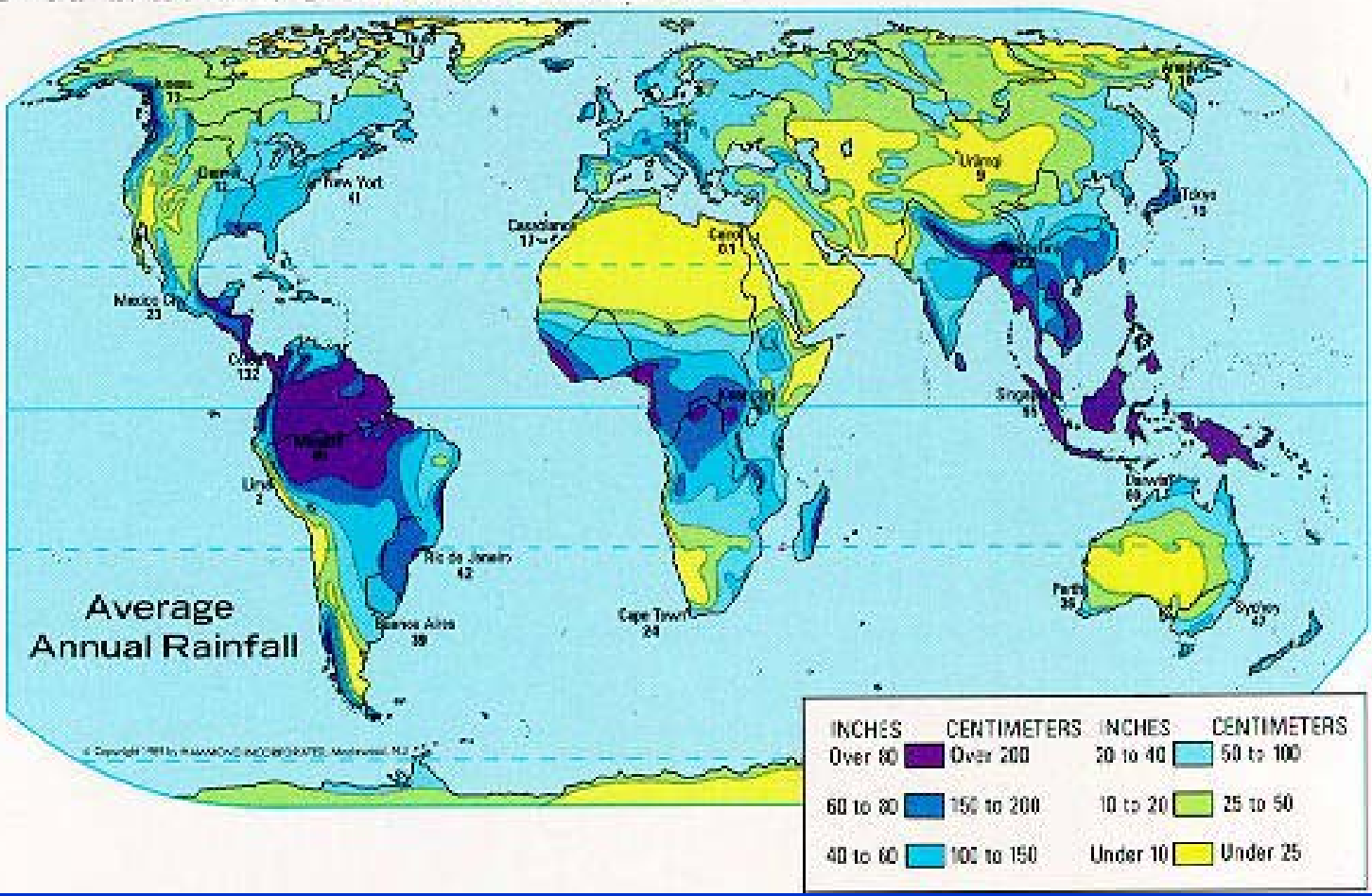
H + LE + G

BUT WHAT ABOUT G ?

G is a STORAGE component, not a transfer component BUT energy stored in the OCEAN, can later be transported via ocean currents as H !

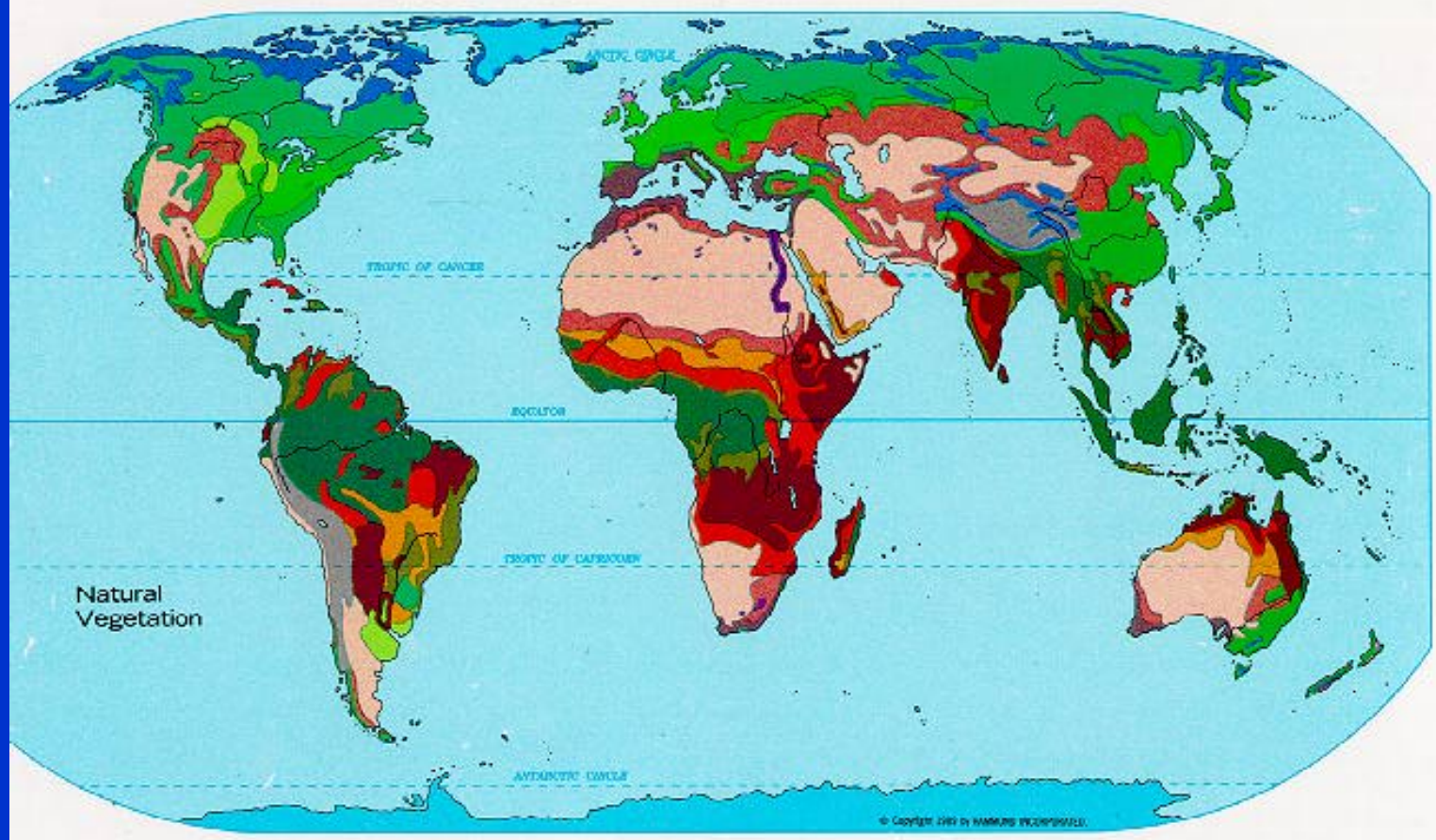


WORLD-RAINFALL/OCEAN CURRENTS



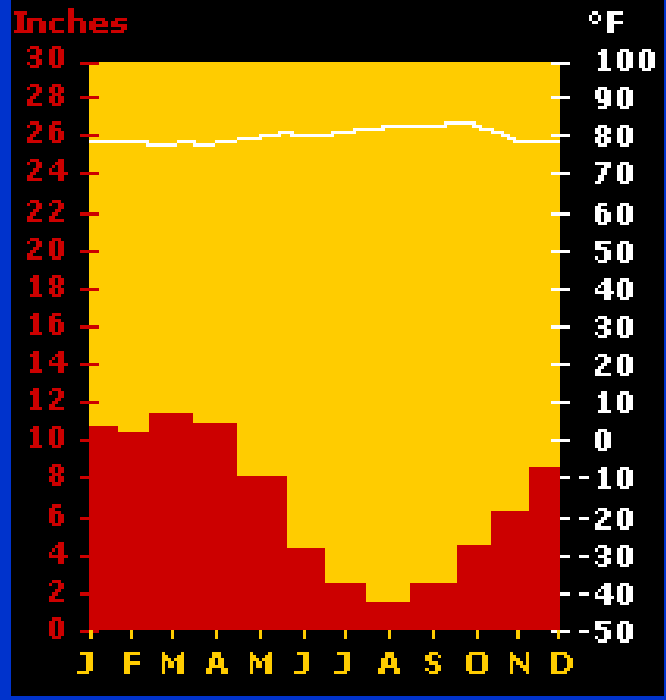
WORLD-VEGETATION

CWA 16-17

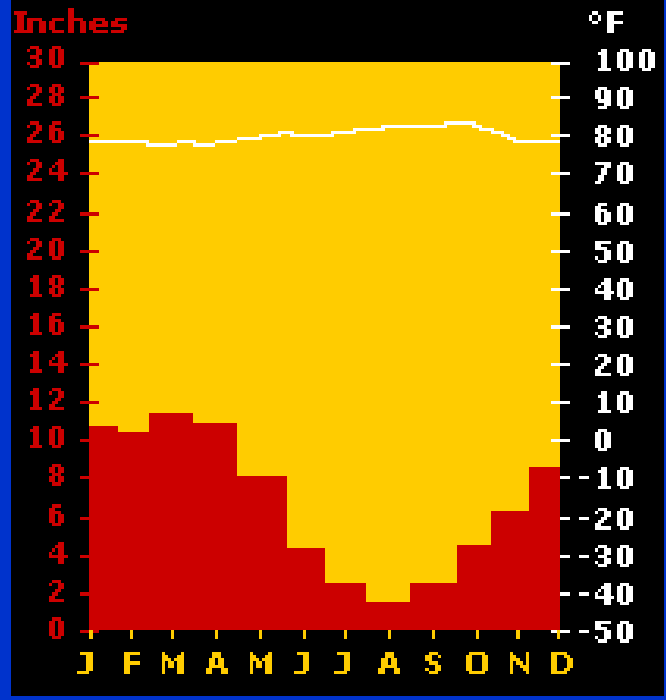


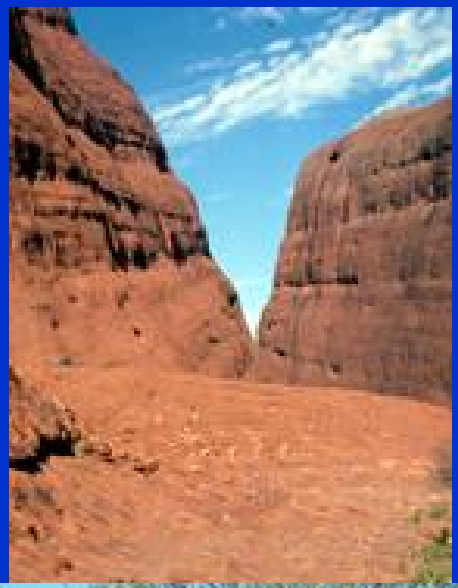
- Needleleaf Forest
- Broadleaf Forest
- Mixed Needleleaf and Broadleaf Forest
- Woodland and Shrub (Mediterranean)
- Short Grass (Steppe)
- Tall Grass (Prairie)
- Unclassified Highlands
- River Valley and Oasis
- Desert and Desert Shrub
- Wooded Savanna
- Tropical Grassland and Shrub (Savanna)
- Tropical Woodland and Shrub
- Light Tropical Forest
- Permanent Ice Cover
- Tropical Rain Forest
- Heath and Moor
- Tundra and Alpine

TYPE: Tropical Rainforest
PLACE: Manaus, Brazil

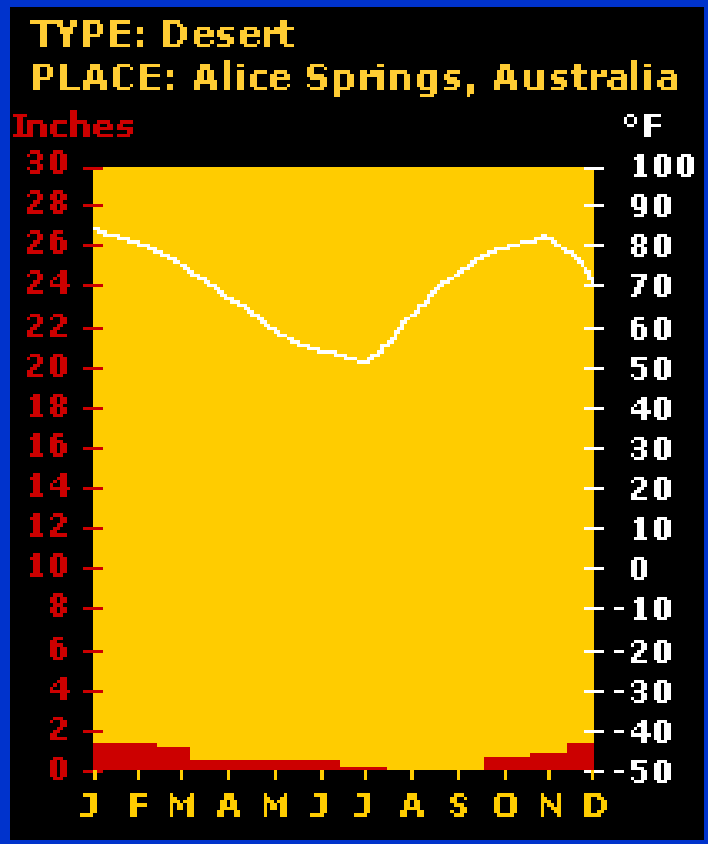


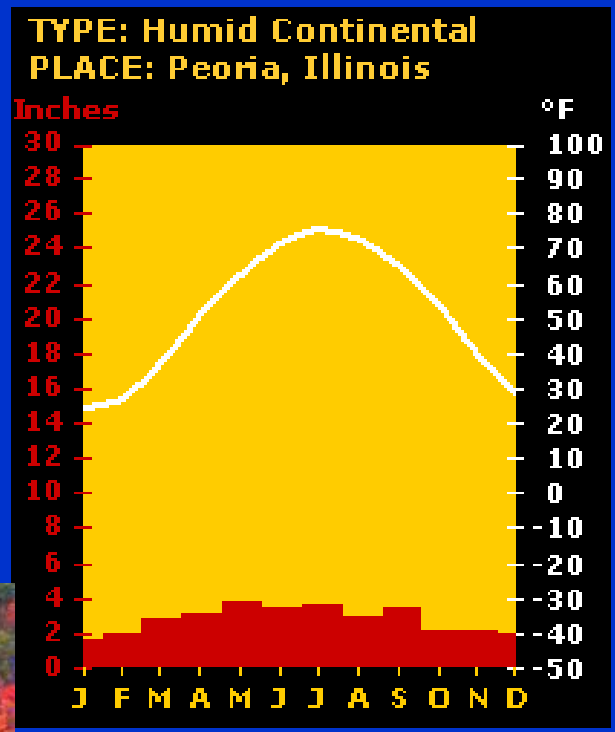
TYPE: Tropical Rainforest
PLACE: Manaus, Brazil

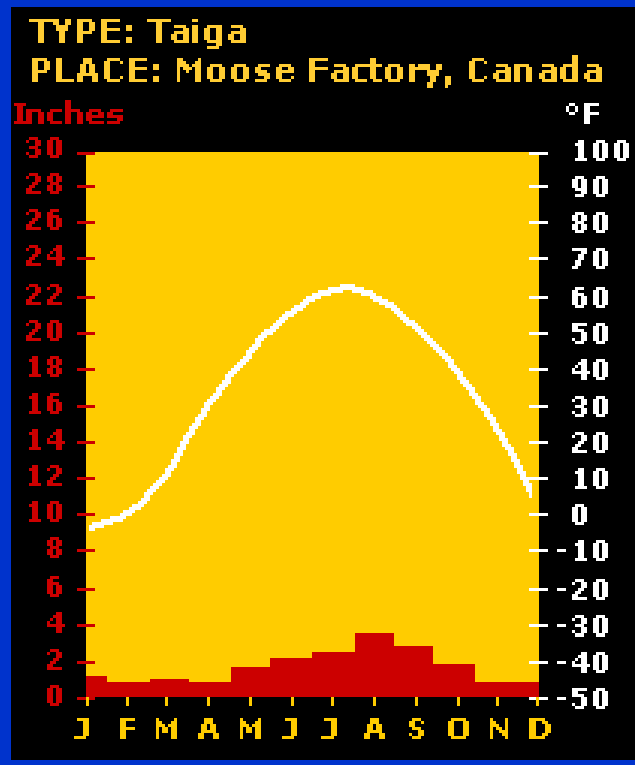


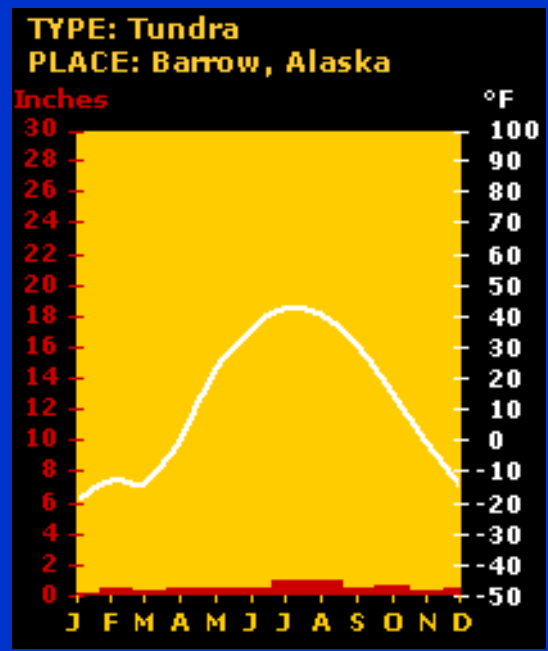



© Peter J. Unmack


TYPE: Desert
PLACE: Alice Springs, Australia
Inches
°F
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
J F M A M J J A S O N D


TYPE: Humid Continental
PLACE: Peoria, Illinois
Inches
°F
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
J F M A M J J A S O N D


TYPE: Taiga
PLACE: Moose Factory, Canada
Inches
°F
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
J F M A M J J A S O N D


TYPE: Tundra
PLACE: Barrow, Alaska
Inches
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
°F
100
90
80
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50
40
30
20
10
0
-10
-20
-30
-40
-50
J F M A M J J A S O N D