Topic # 13
Atmospheric Circulation
(continued)

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

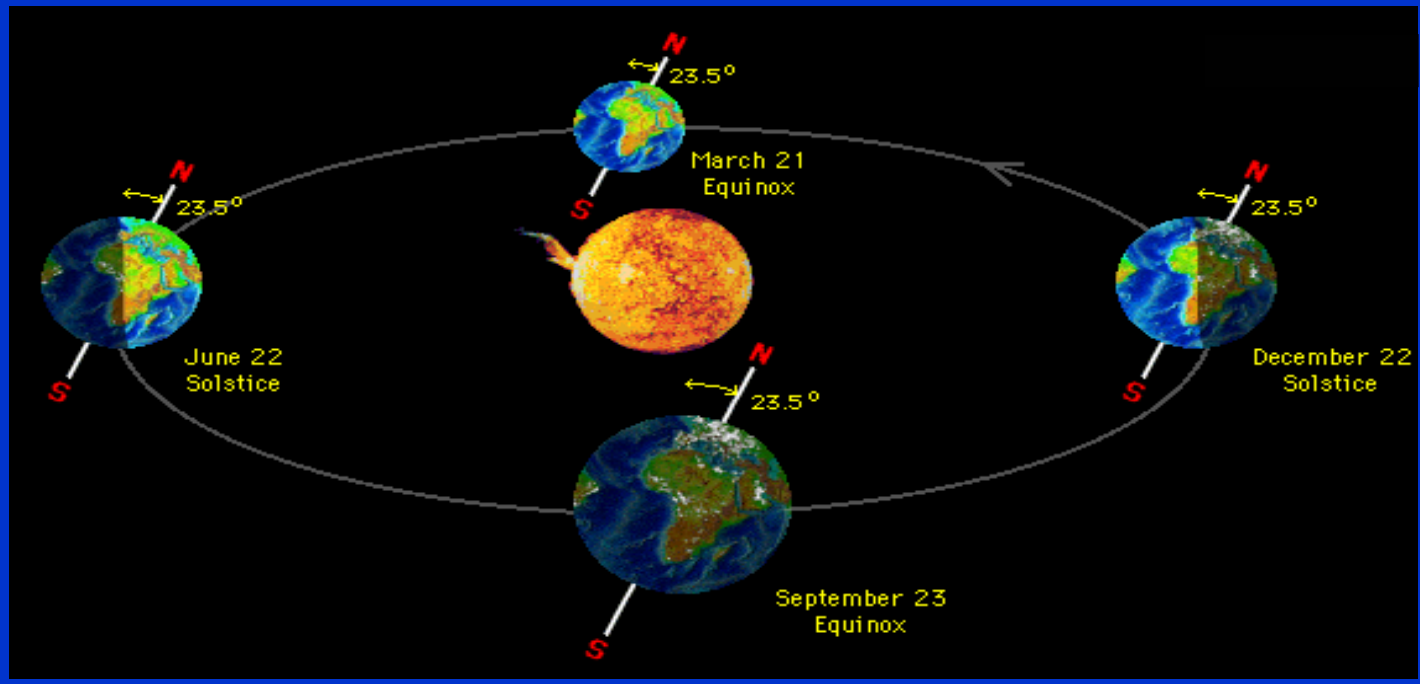
p 77-83 in Class Notes

The Earth
[as viewed from space]
. . . has the organized, self-contained look of a live creature, full of information, marvelously skilled in handling the sun.

~ Lewis Thomas

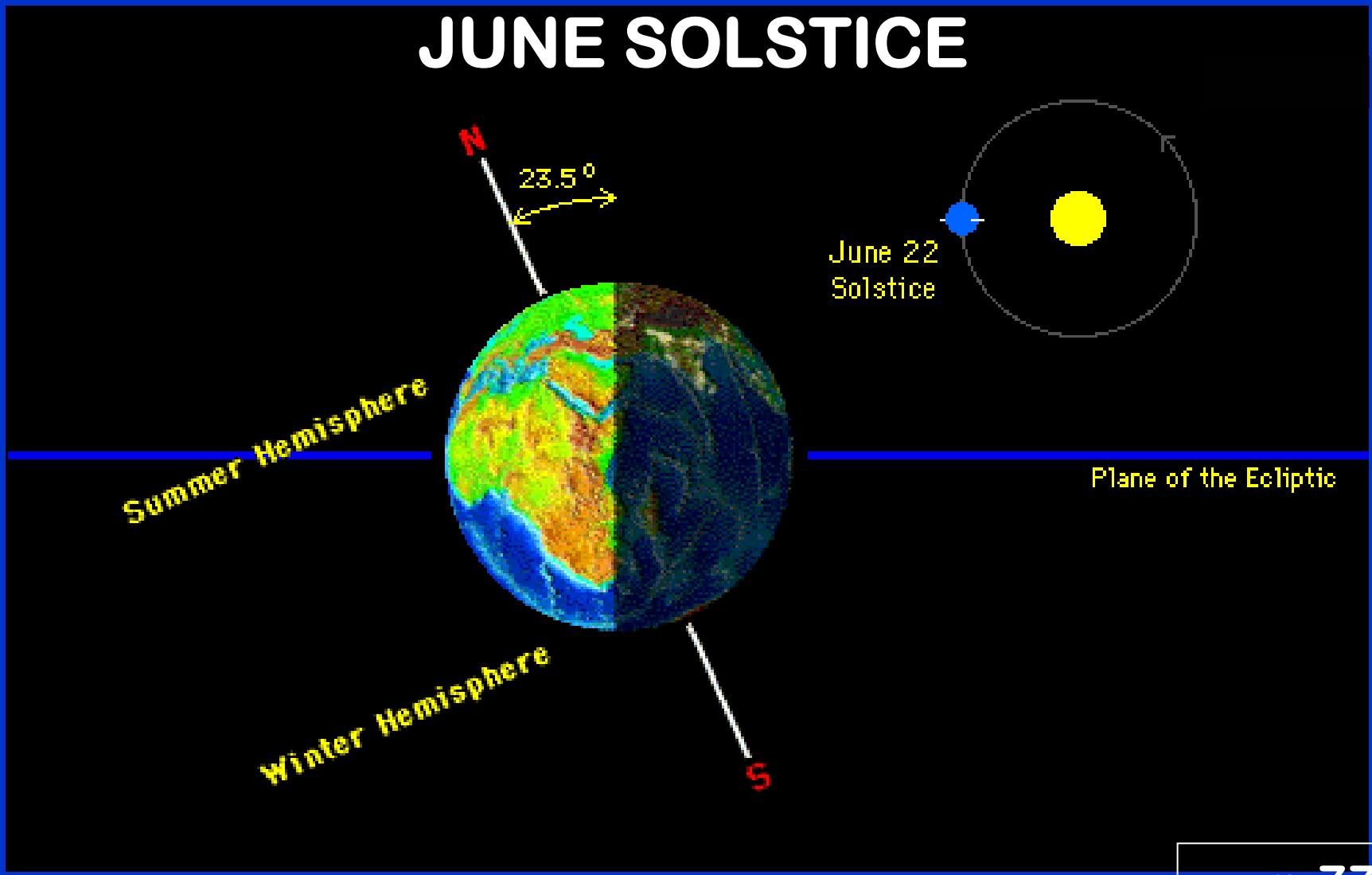
EARTH-SUN RELATIONSHIPS & The SEASONS:

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



#1 OBLIQUITY OF EARTH'S AXIS

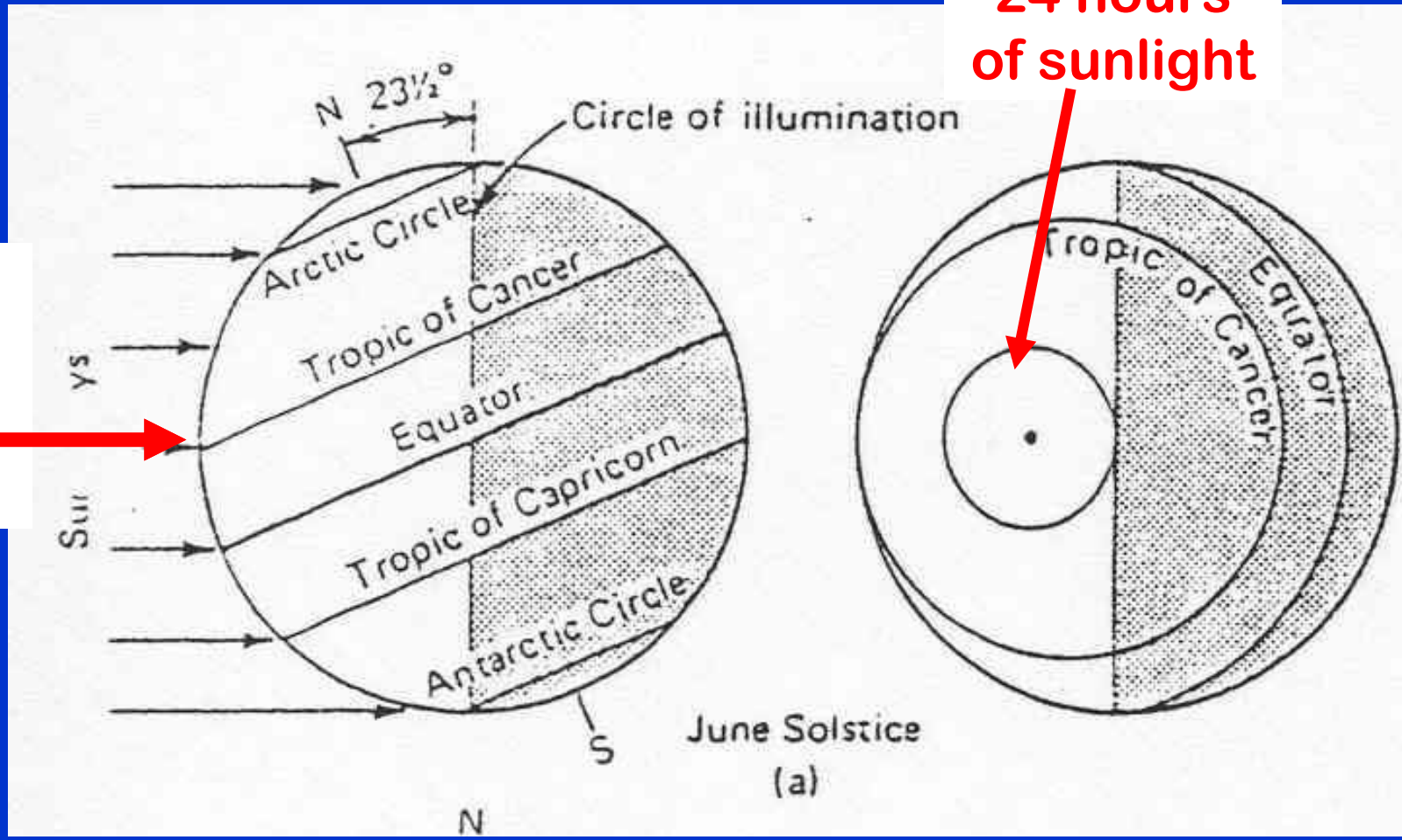
(axis "tilts" 23.5 degrees from plane of ecliptic)



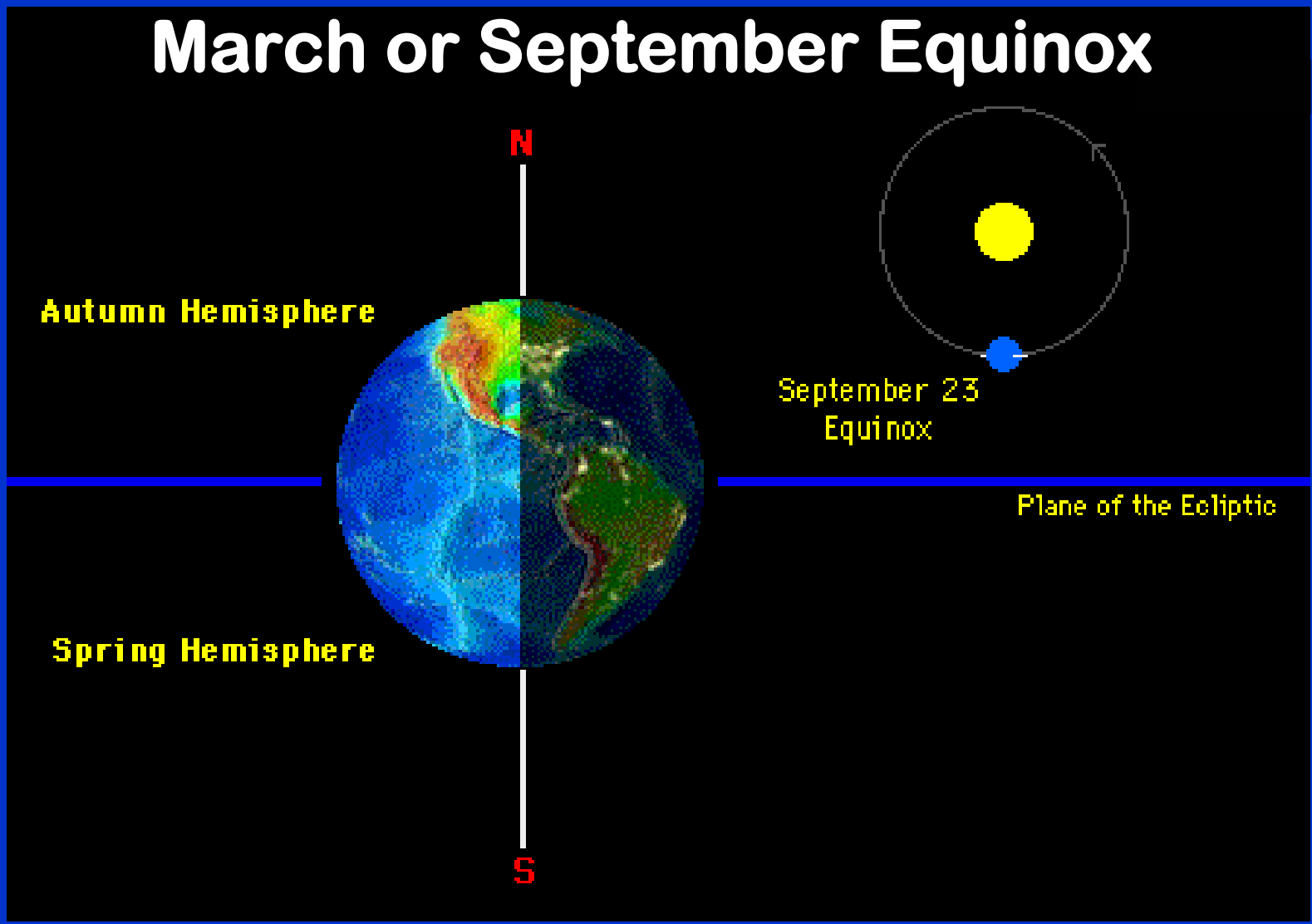
JUNE SOLSTICE

24 hours of sunlight

Most intense solar radiation



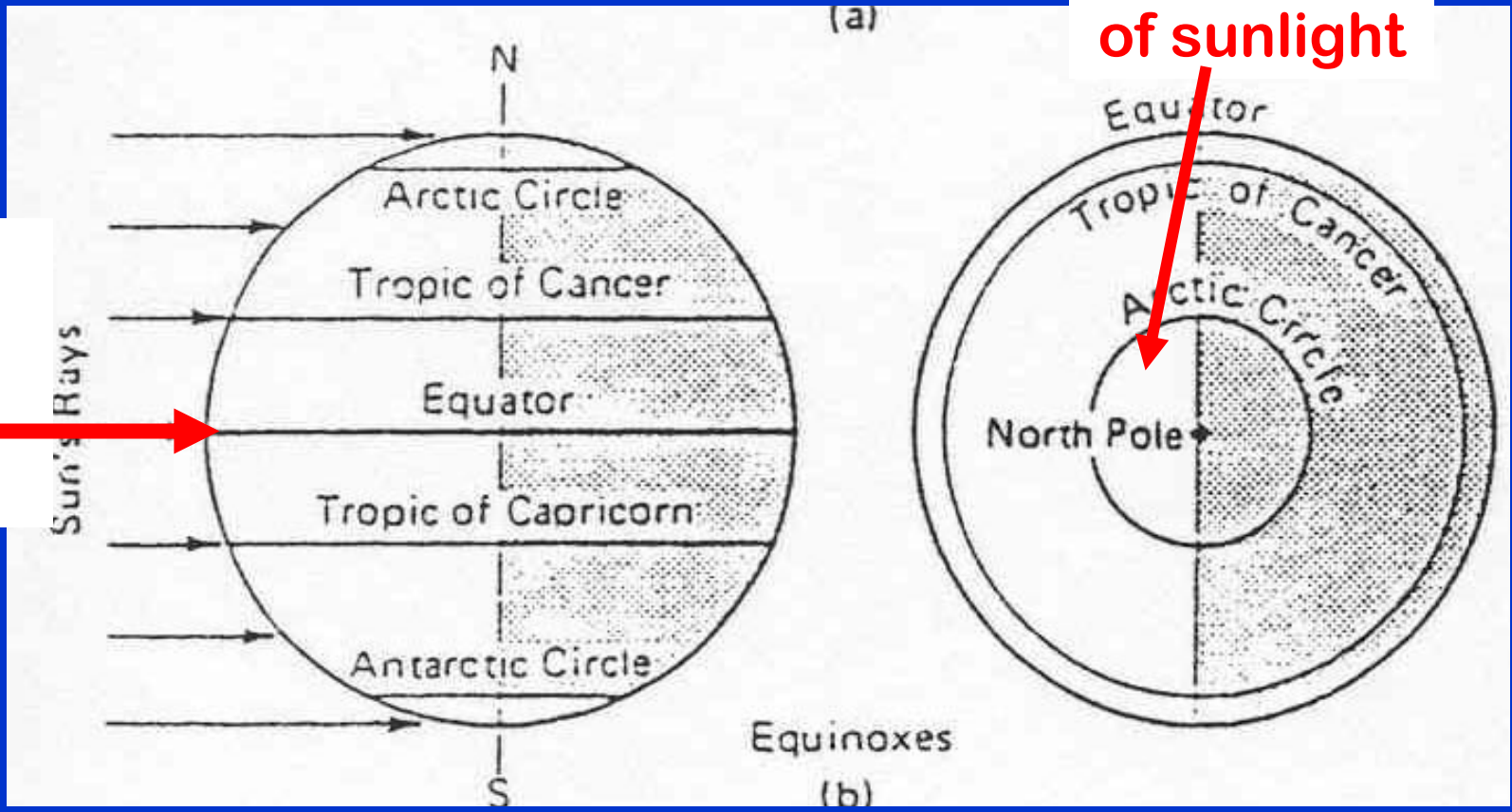
March or September Equinox



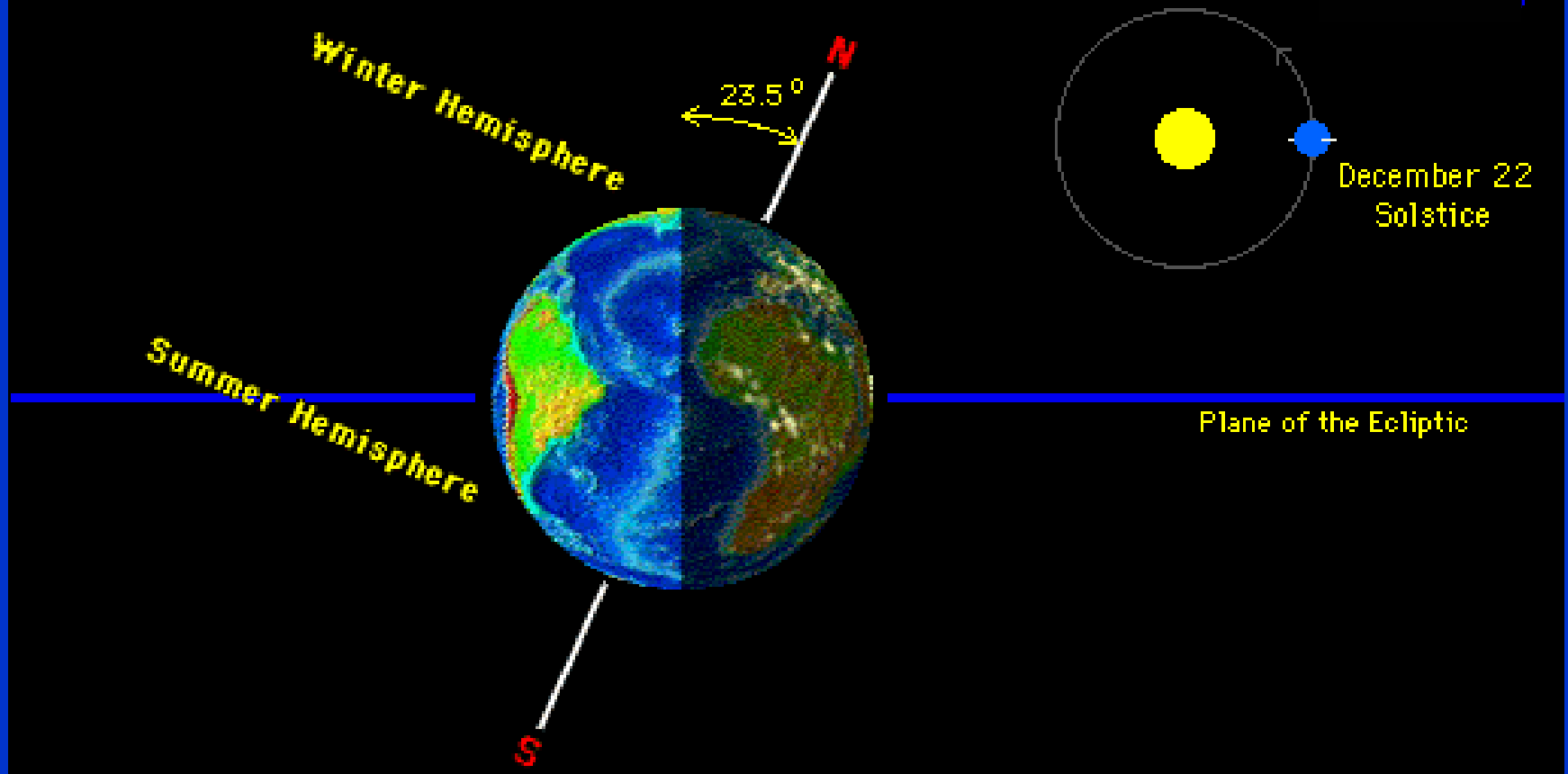
MARCH & SEPTEMEBER EQUINOXES

12 hours of sunlight

Most intense solar radiation



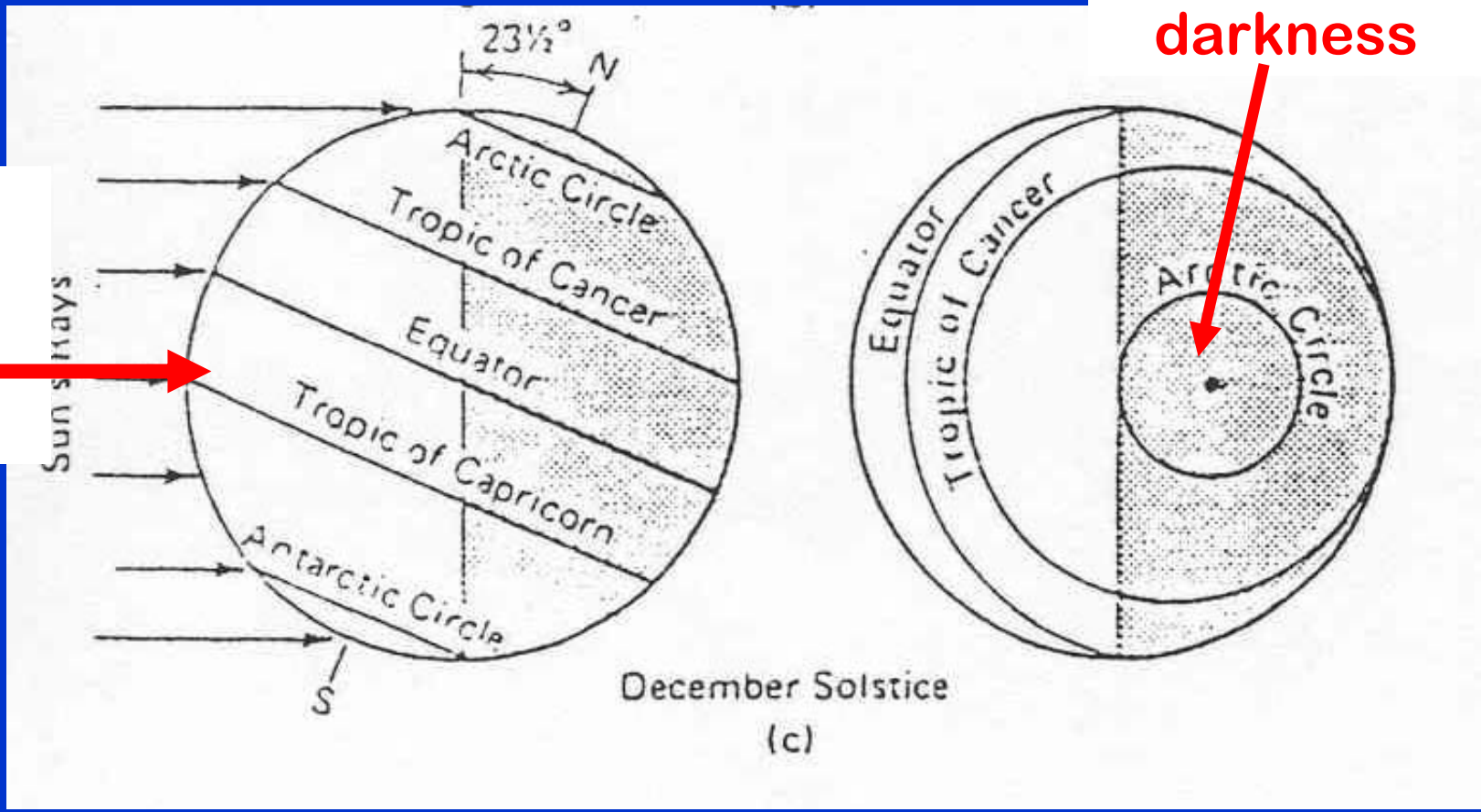
DECEMBER SOLSTICE

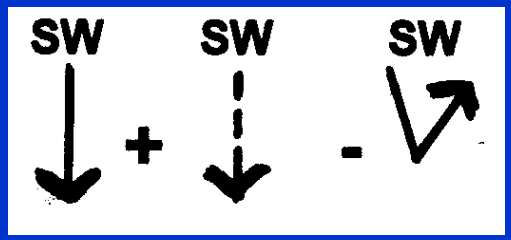


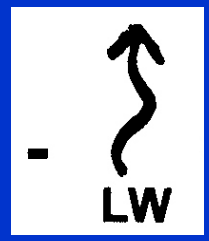
DECEMBER SOLSTICE

24 hours of darkness

Most intense solar radiation



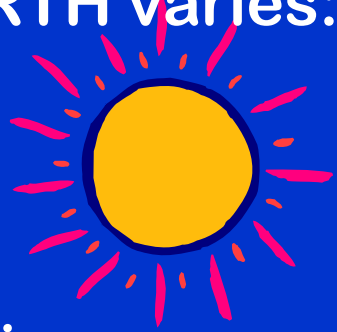




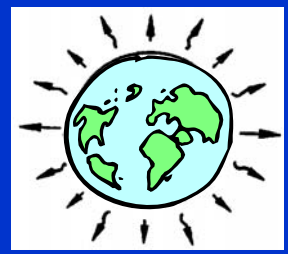
KEY CONCEPT:

The amount of SW absorbed by EARTH varies:

- by LATITUDE
- by SEASON

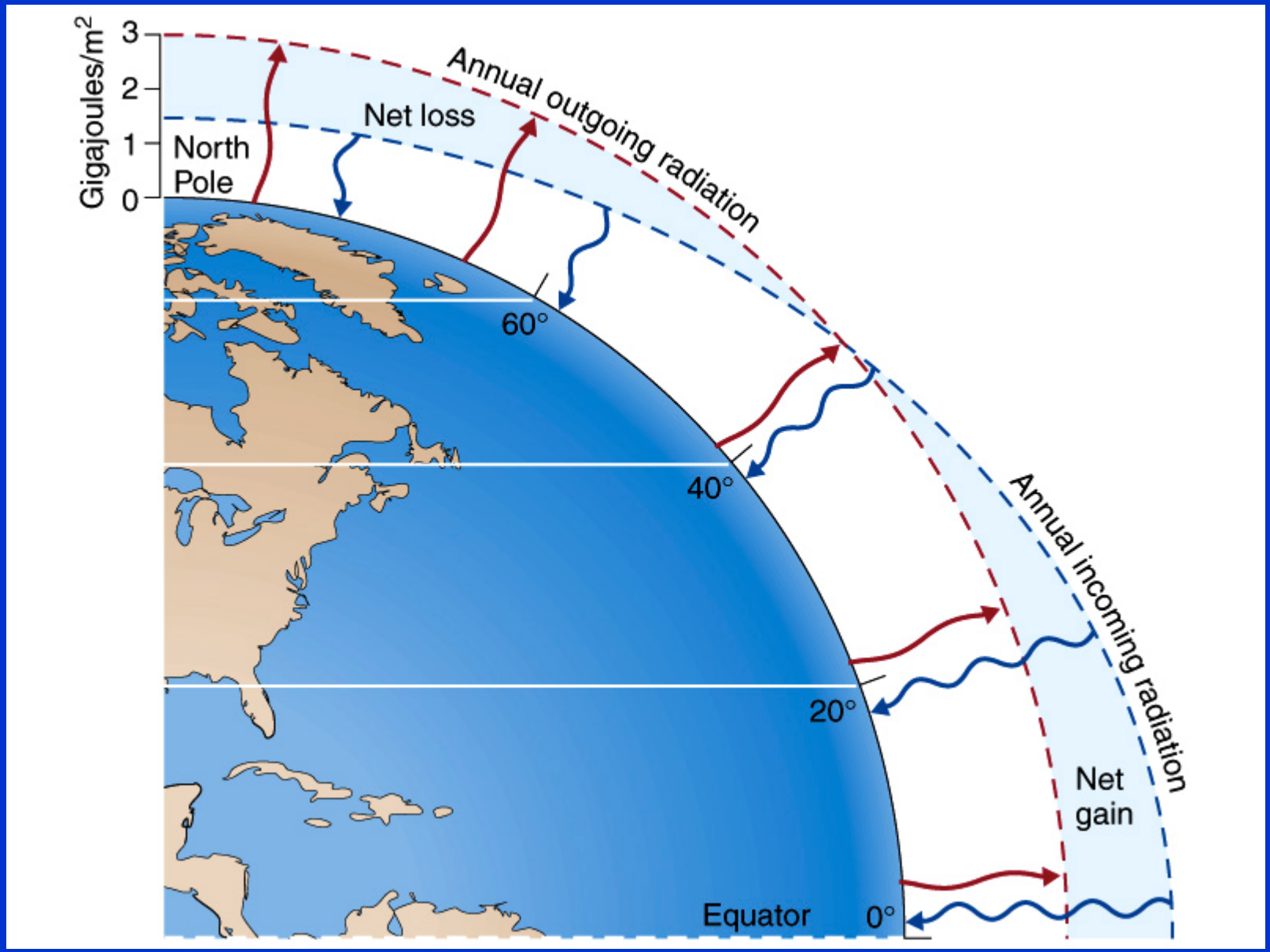


Annually, MORE is absorbed in the LOW LATITUDES (near Equator) than in the HIGH LATITUDES (near Poles)

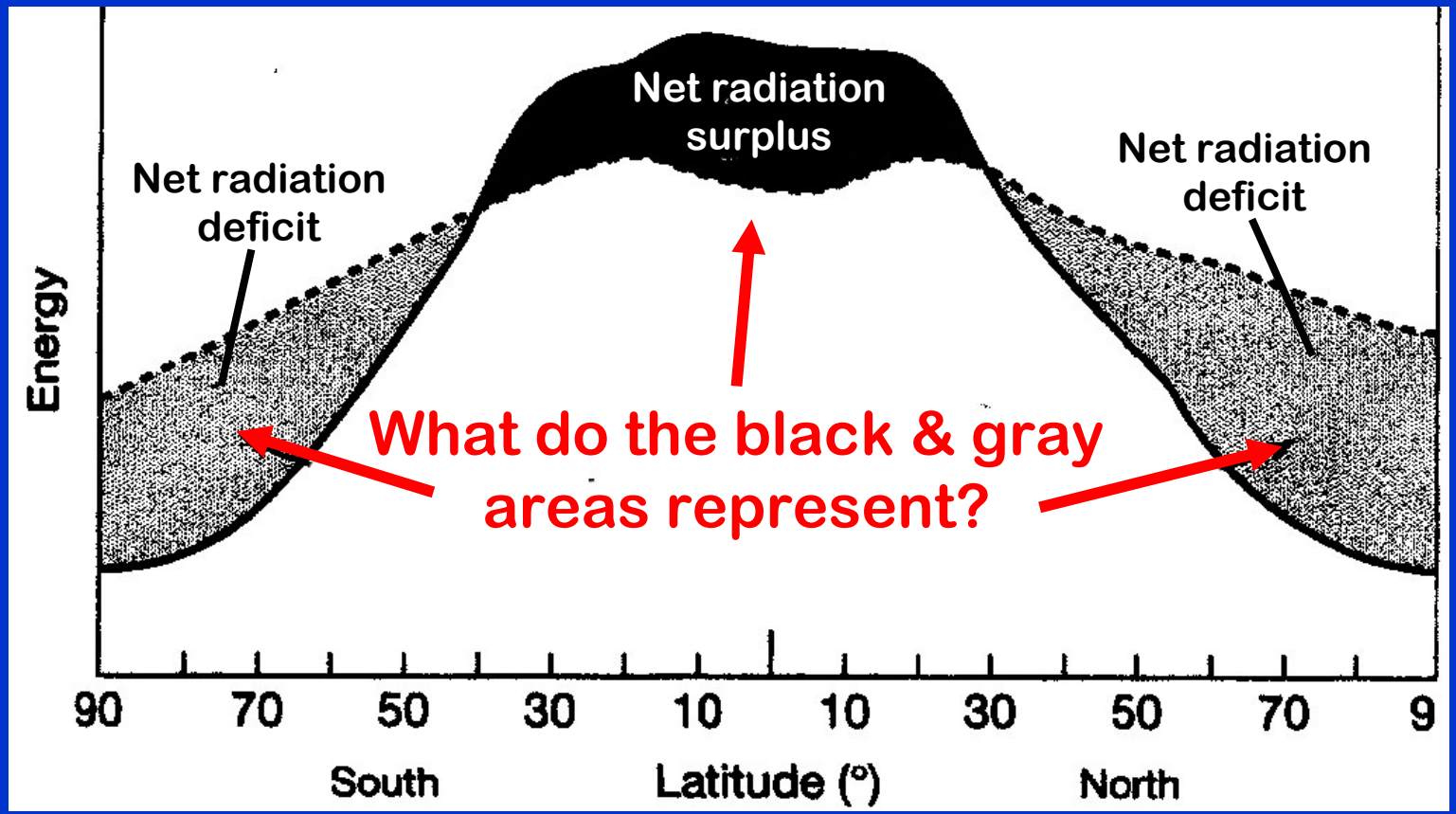


The EARTH radiates out LW fairly evenly from latitude to latitude, but MORE LW energy is radiated out in warm Equatorial latitudes & LESS in cold Polar latitudes

Remember? $E = \sigma T^4$



This Figure is on p 80



Absorbed solar energy

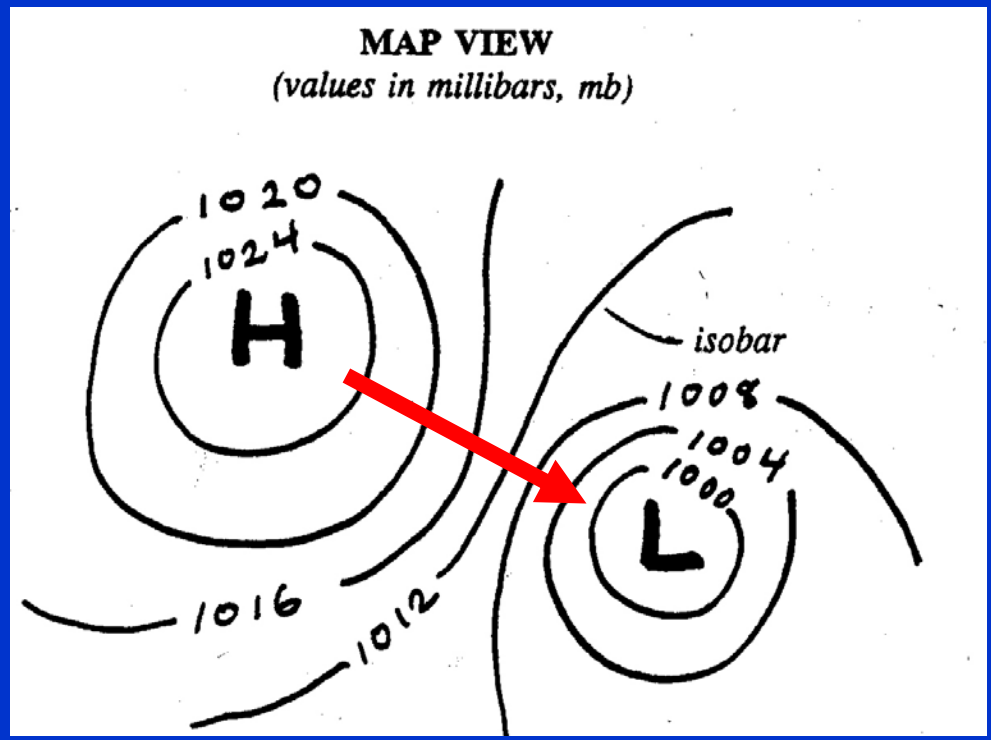
SW + SW - SW

Emitted infrared energy

(at top of atmosphere)

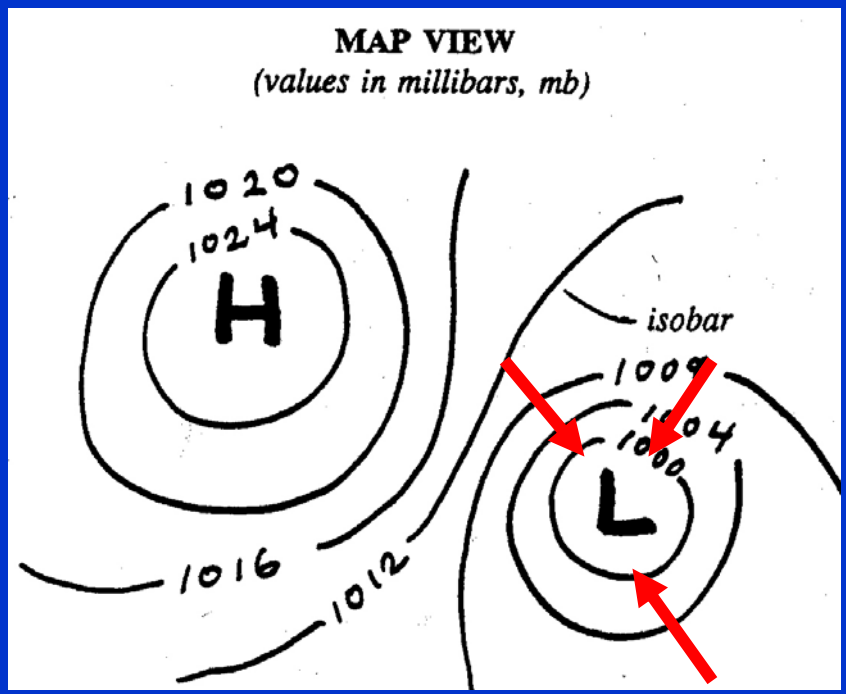
- LW

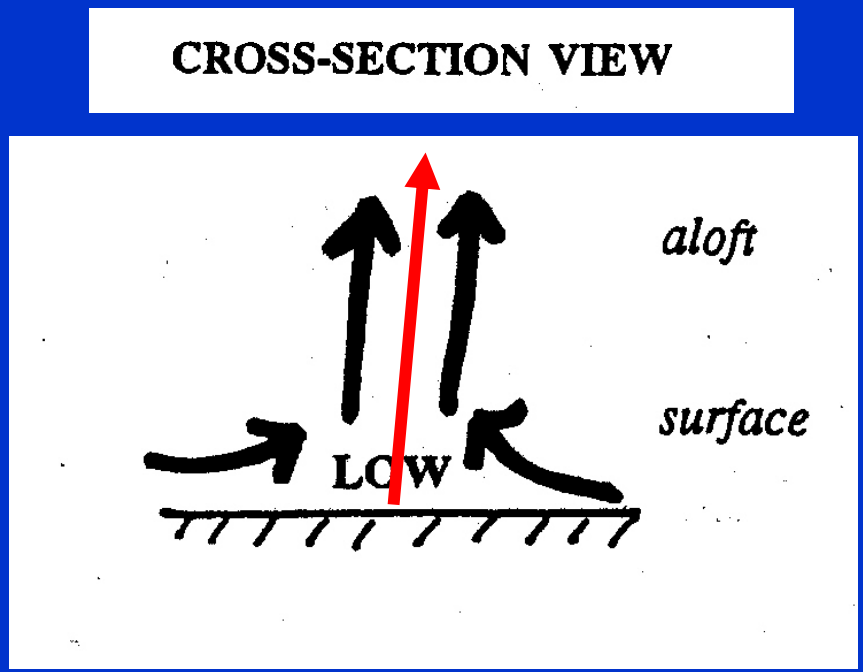
In general: Winds tend to flow from HIGH ➔ LOW Pressure areas



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

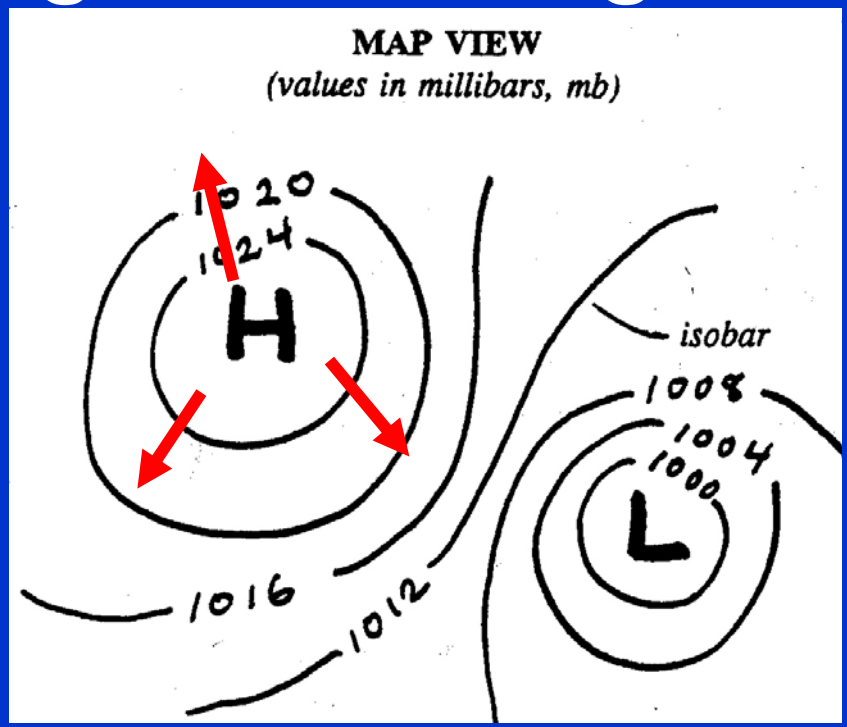
LOWS - air converges into lows and rises in the center of lows

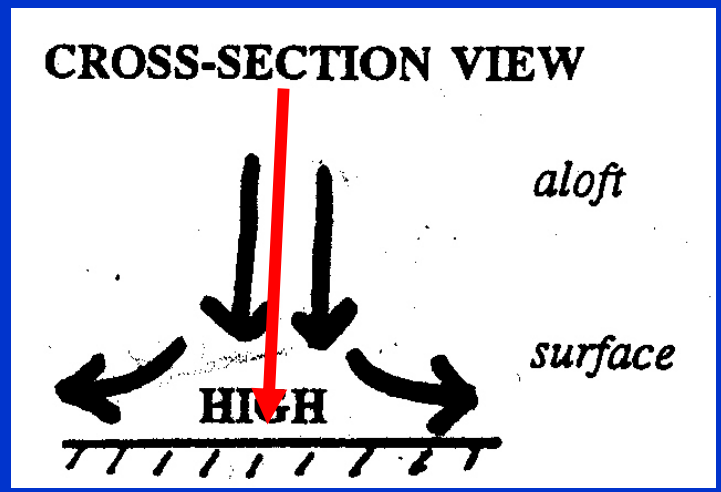




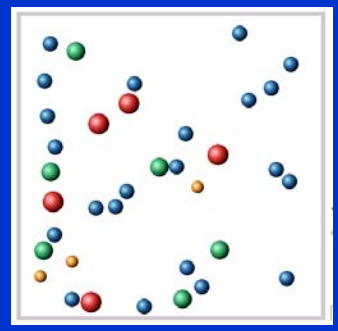
Areas or centers of high and low pressure at the Earth's surface have the following characteristics:

HIGHS - air subsides in the center of highs and diverges out of highs

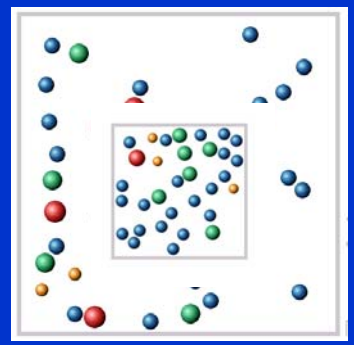


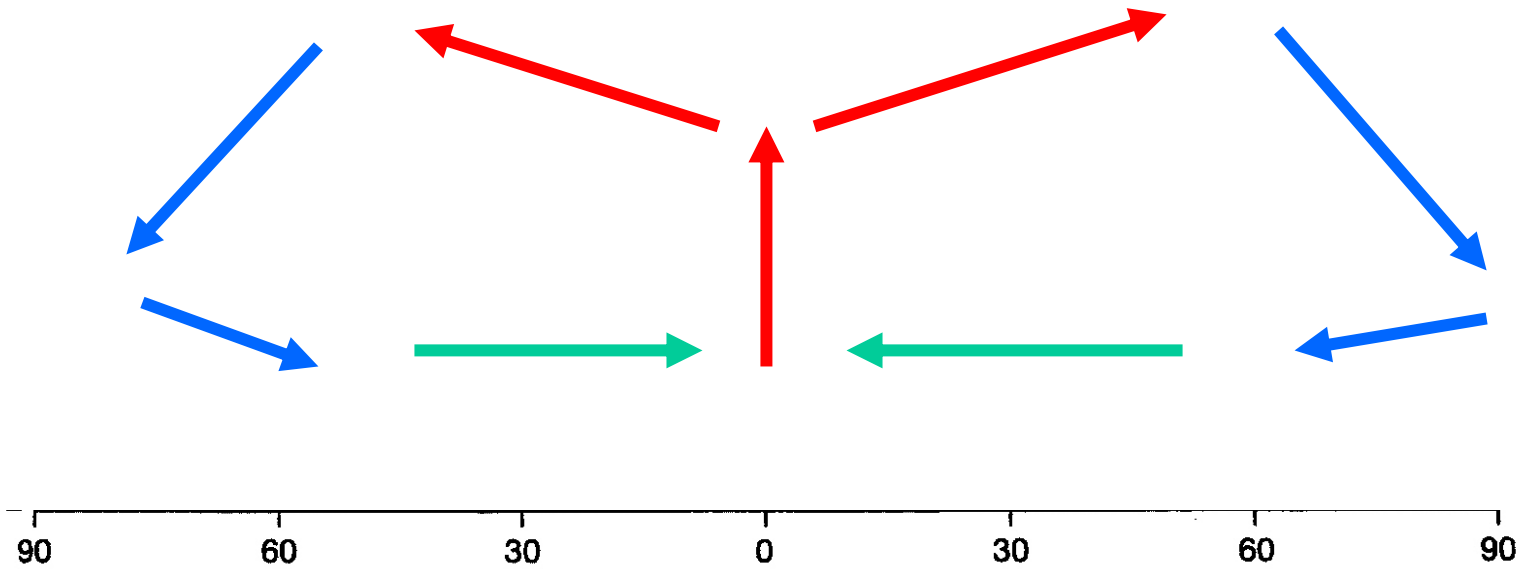


LOWS: (rising leads to **expansion and cooling** of air, and condensation of water vapor ==> clouds and possibly precipitation)



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

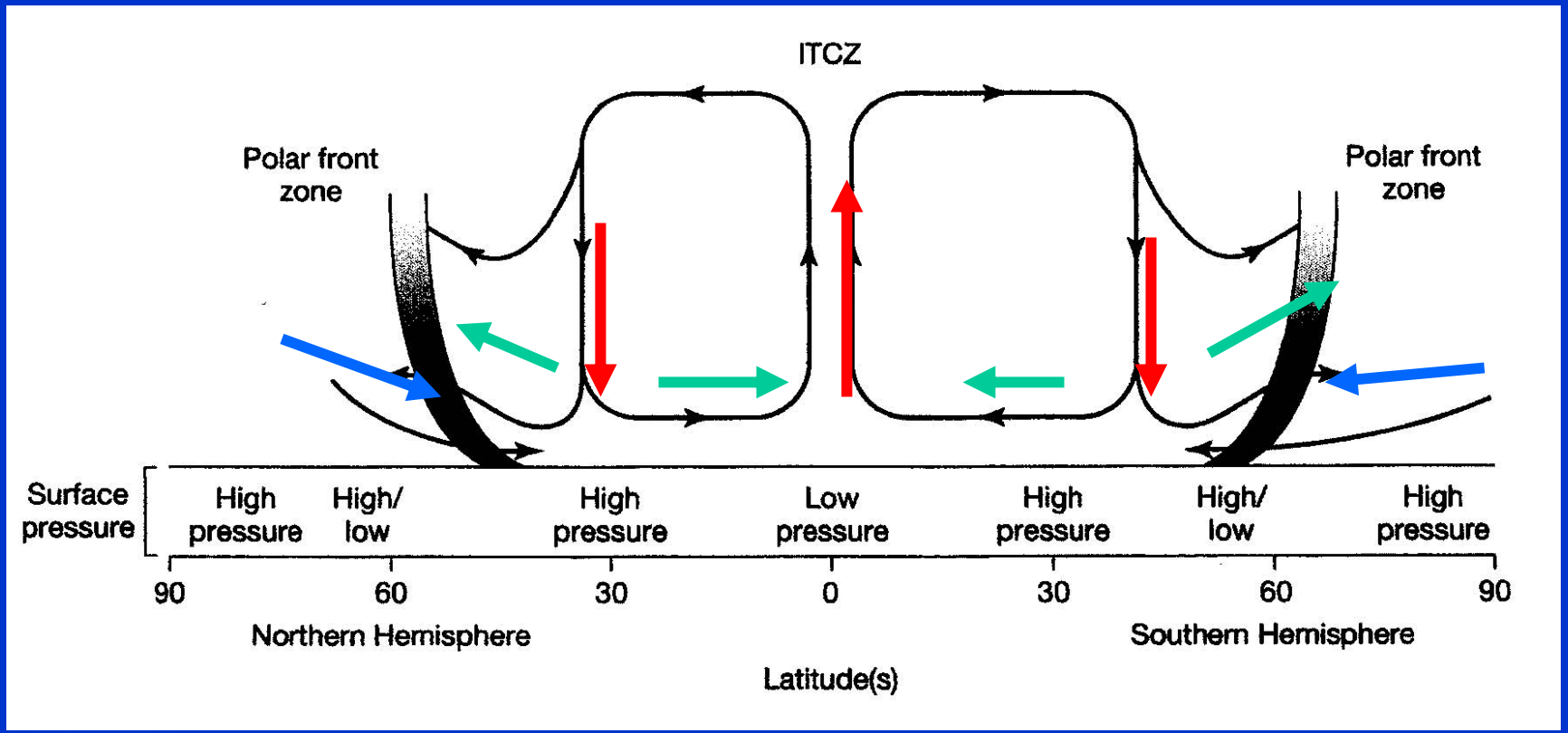




COLD POLAR REGIONS

HOT TROPICS

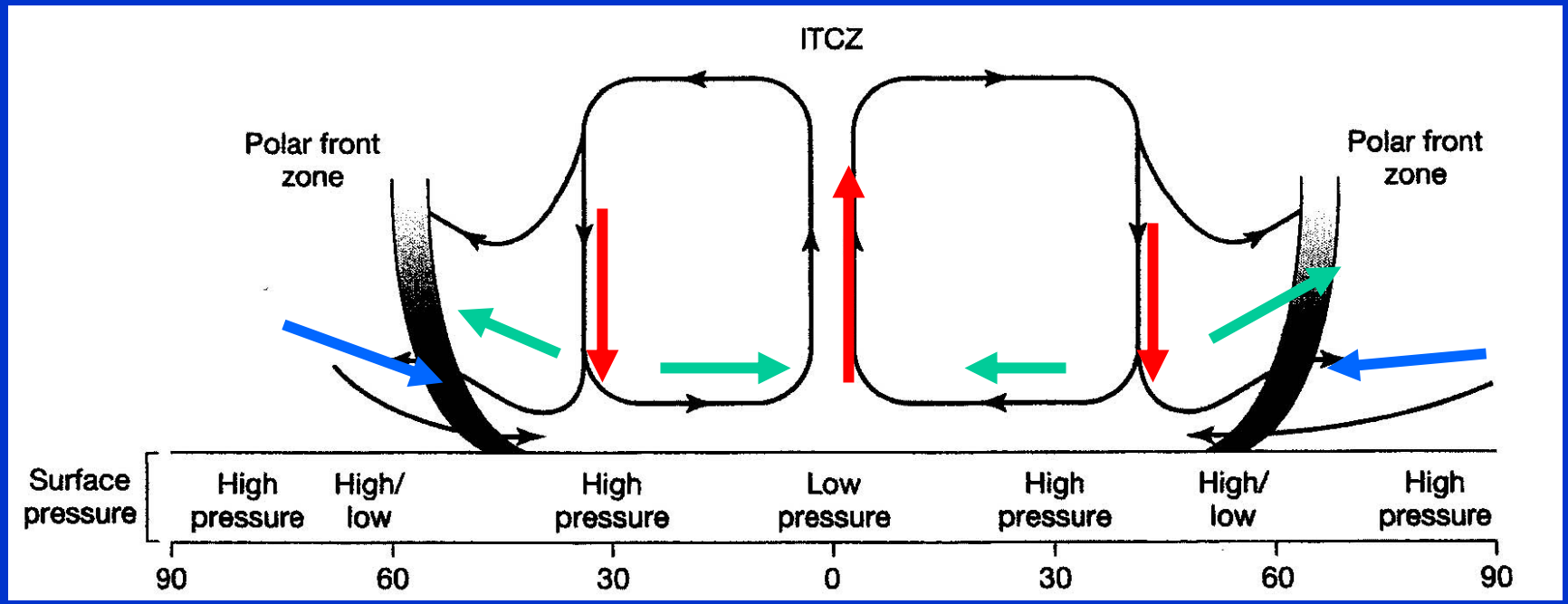
COLD POLAR REGIONS



COLD POLAR REGIONS

HOT TROPICS

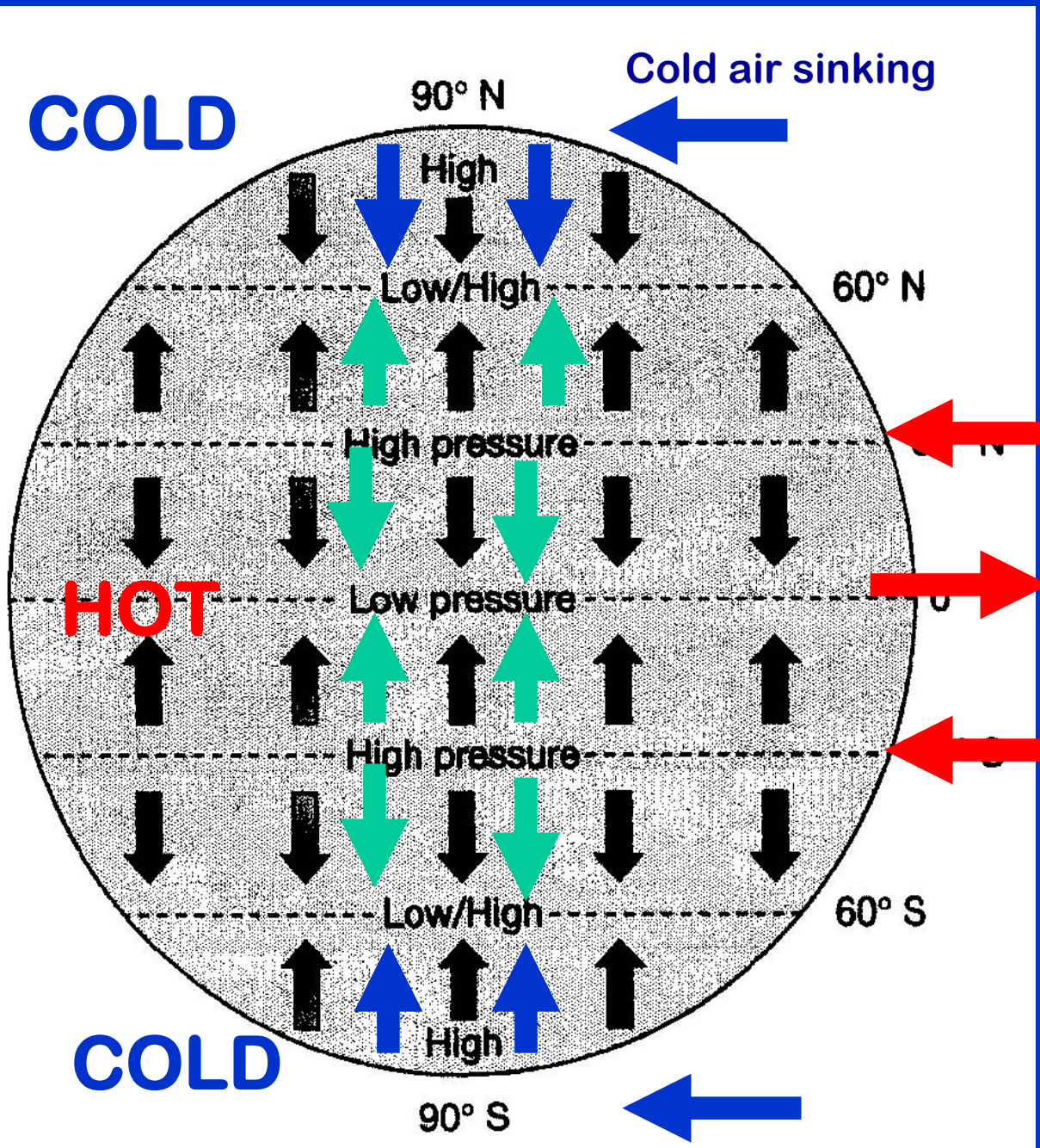
COLD POLAR REGIONS



COLD POLAR REGIONS

HOT TROPICS

COLD POLAR REGIONS


COLD
90° N
Cold air sinking
High
Low/High
60° N
High pressure
HOT
Low pressure
High pressure
Low/High
60° S
High
COLD
90° S

AIR IN MOTION: WINDS

(NOTE: recall the laws of motion)

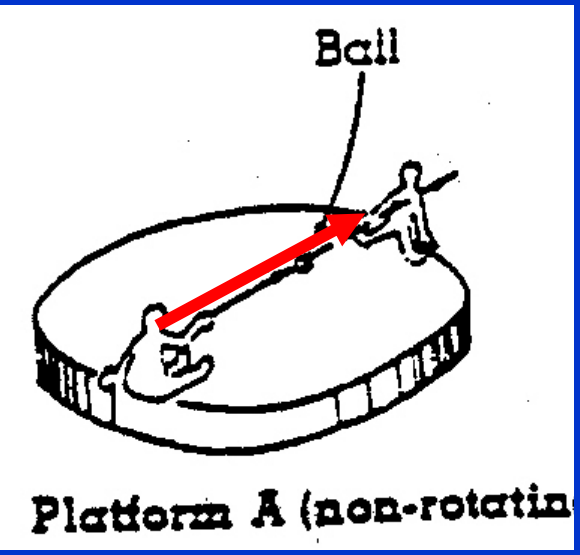
Atmospheric circulation is accomplished by air flow in the form of winds. Wind direction and strength are determined by:

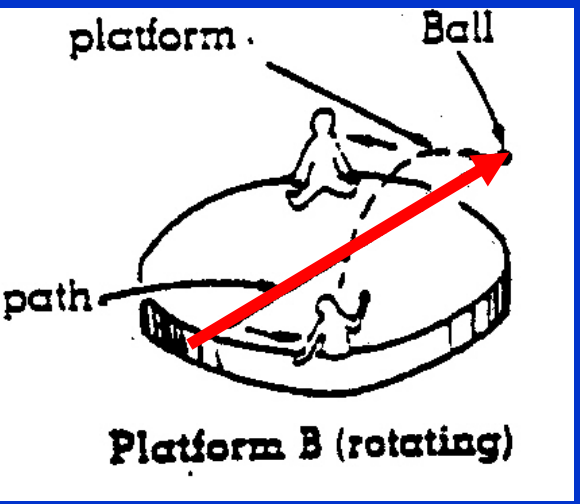
PGF Pressure Gradient Force

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 :

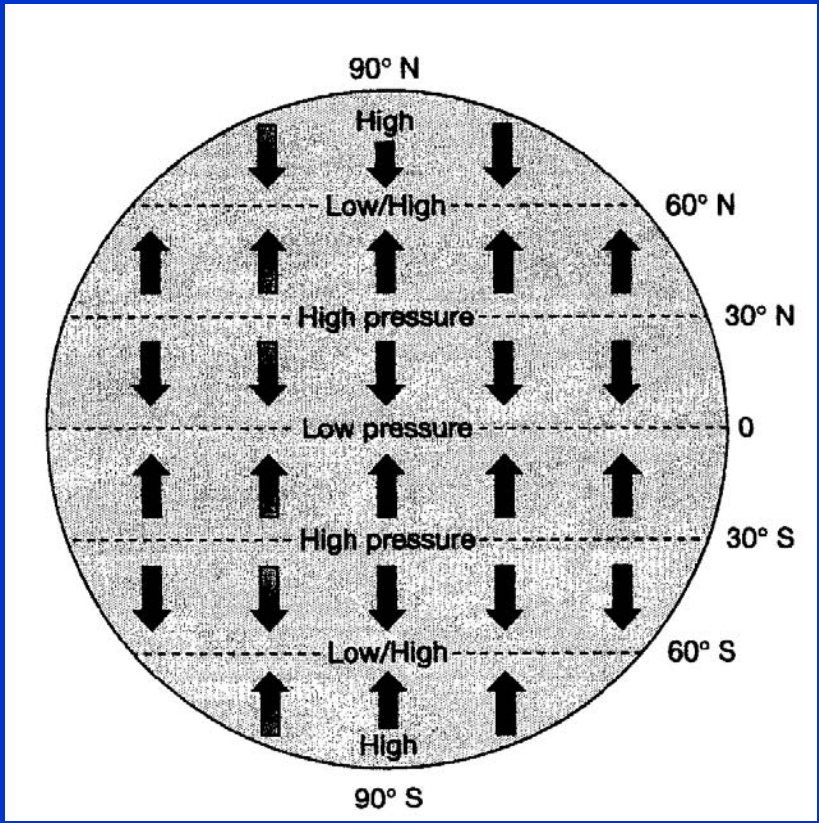
To the RIGHT in N.H.

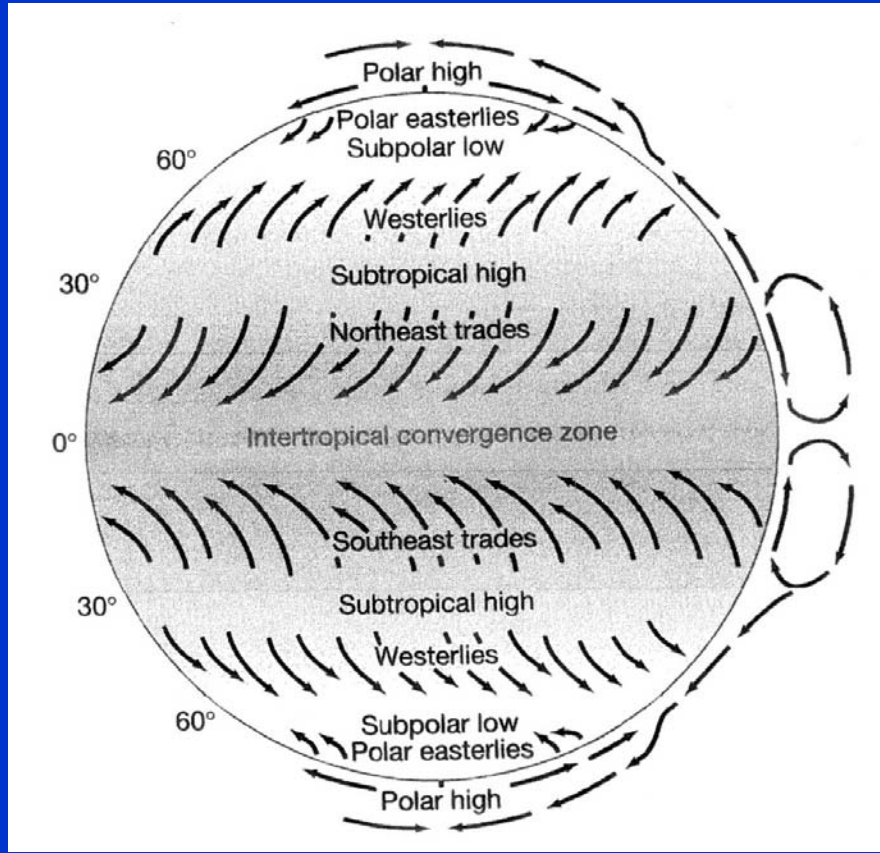
To the LEFT in S.H.

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:

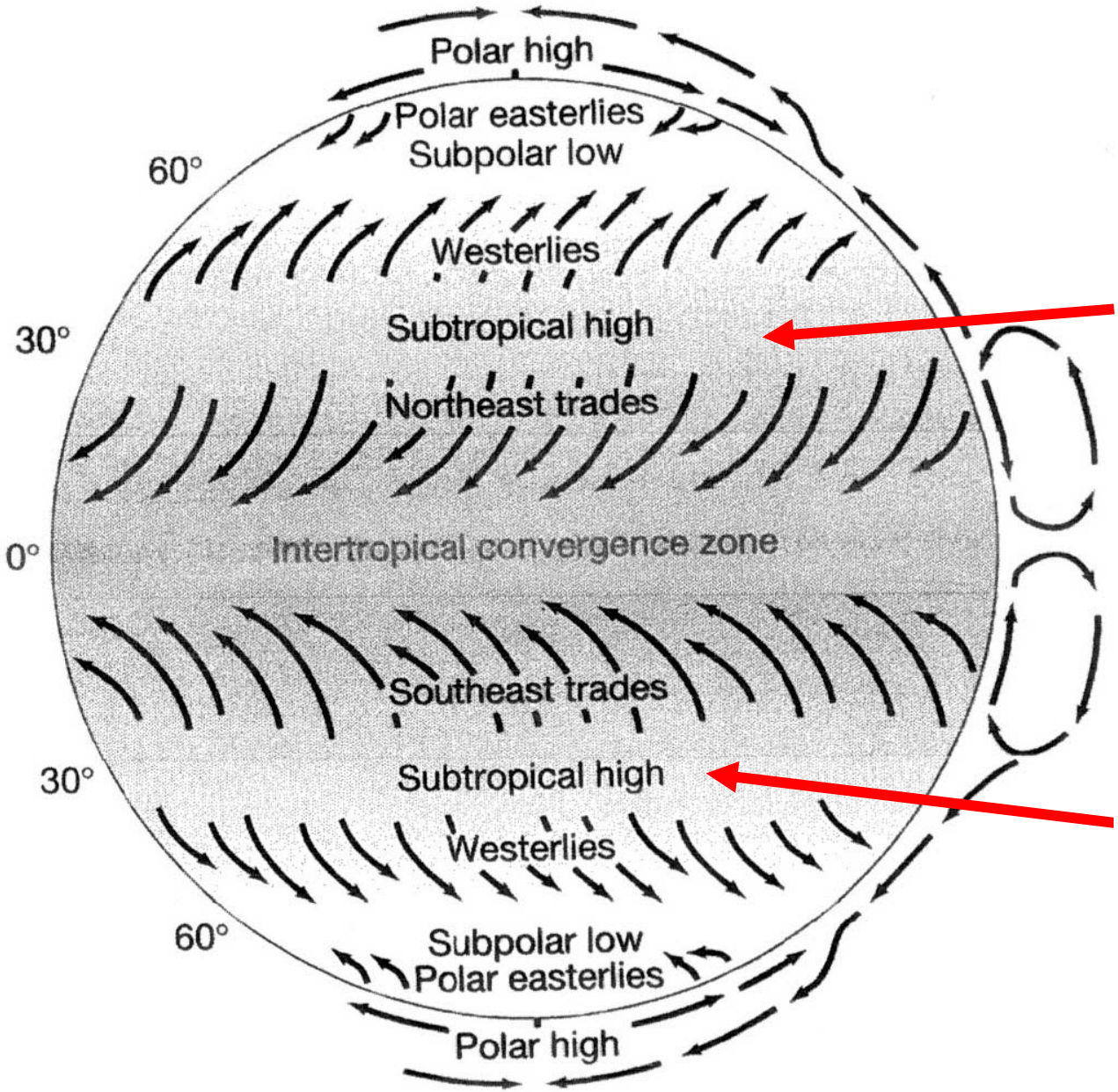
5 2 2 5





Non-rotating Globe

Rotating Globe

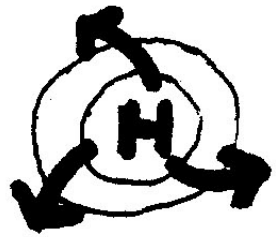


Sub-tropical HIGH PRESSURE CELLS

Northern Hemisphere:

ITCZ

Southern Hemisphere:



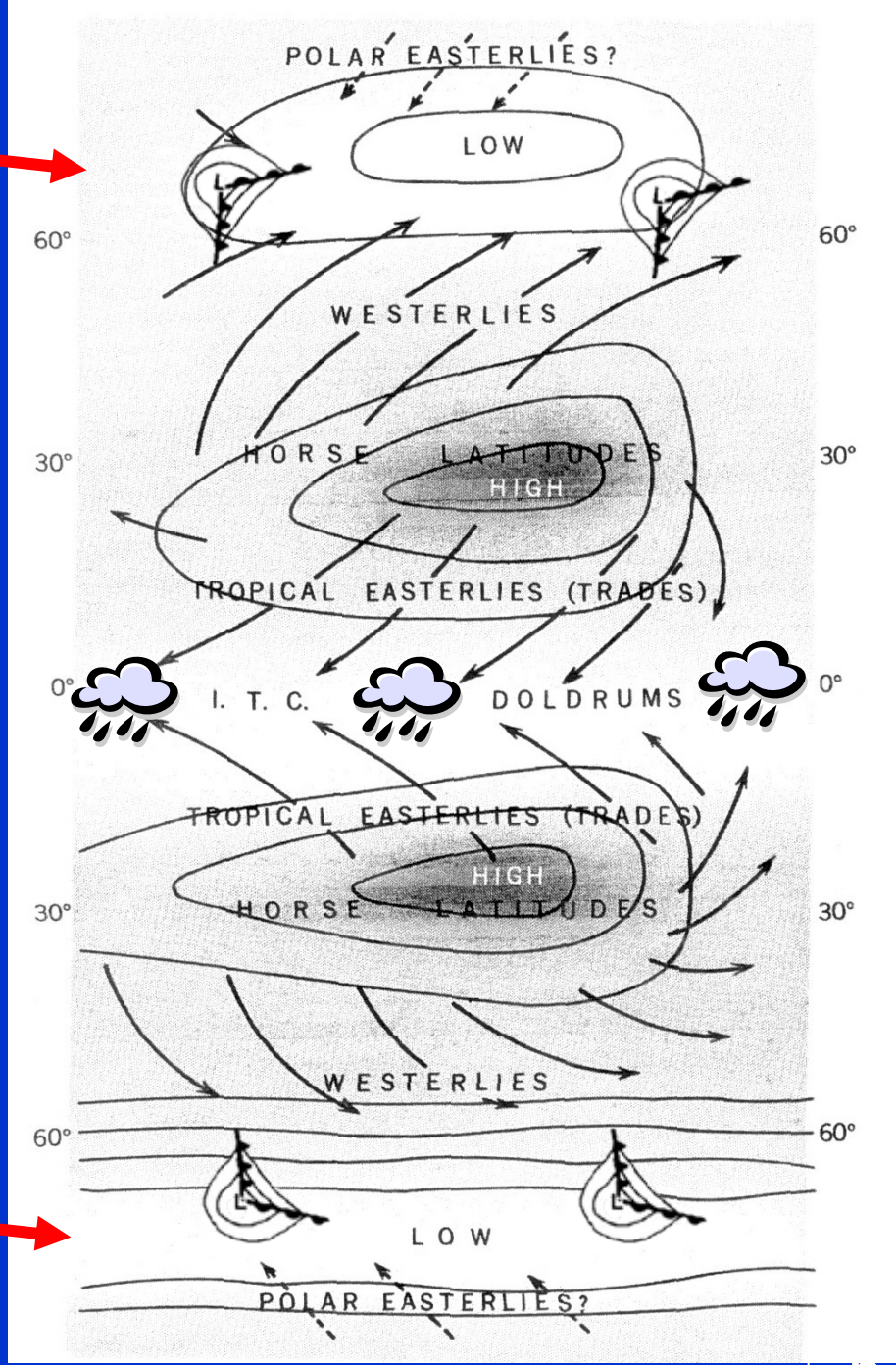
Midlatitude cyclone storms

STH
(Dry, deserts)

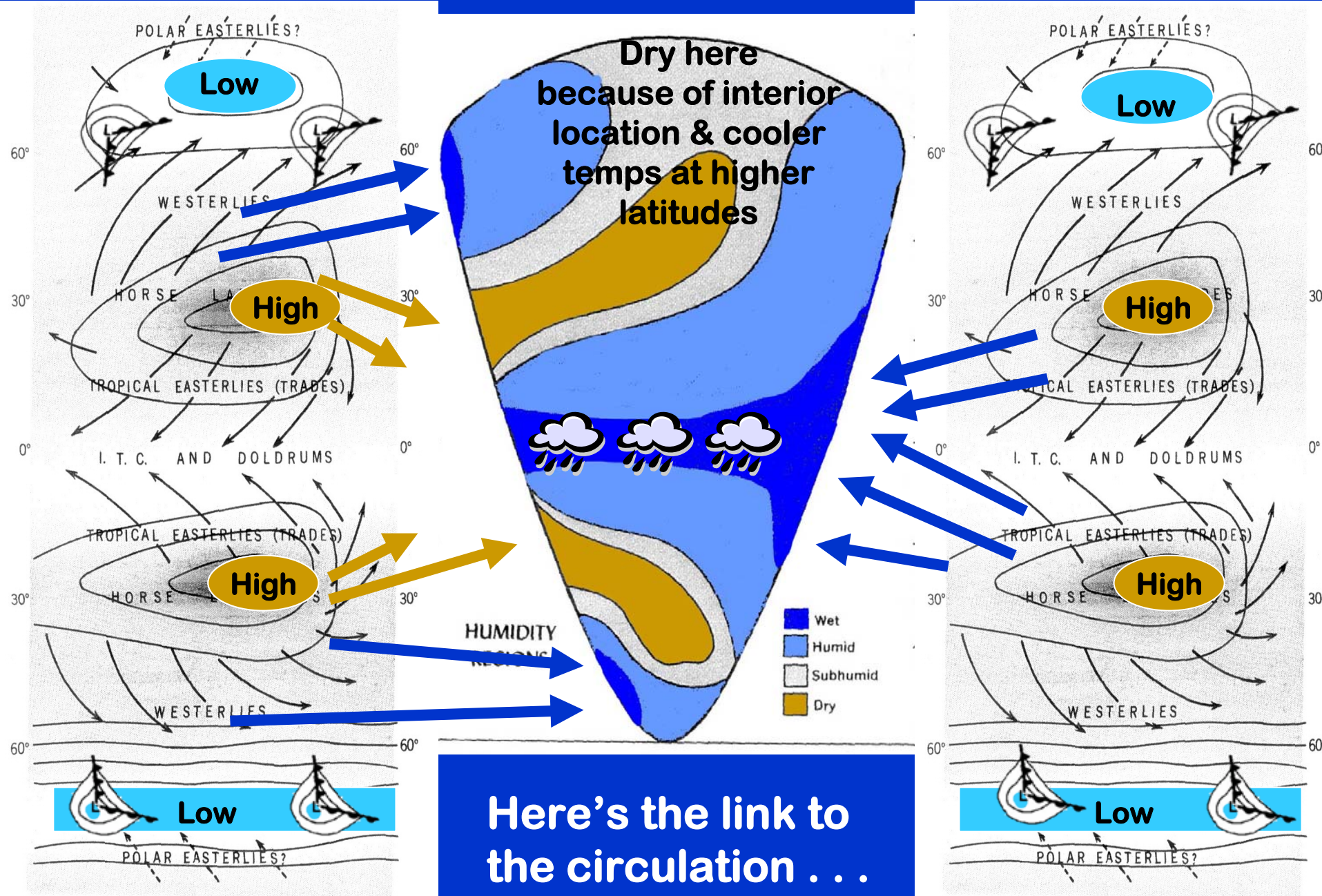
ITCZ
(tropical convection)

STH
(Dry, deserts)

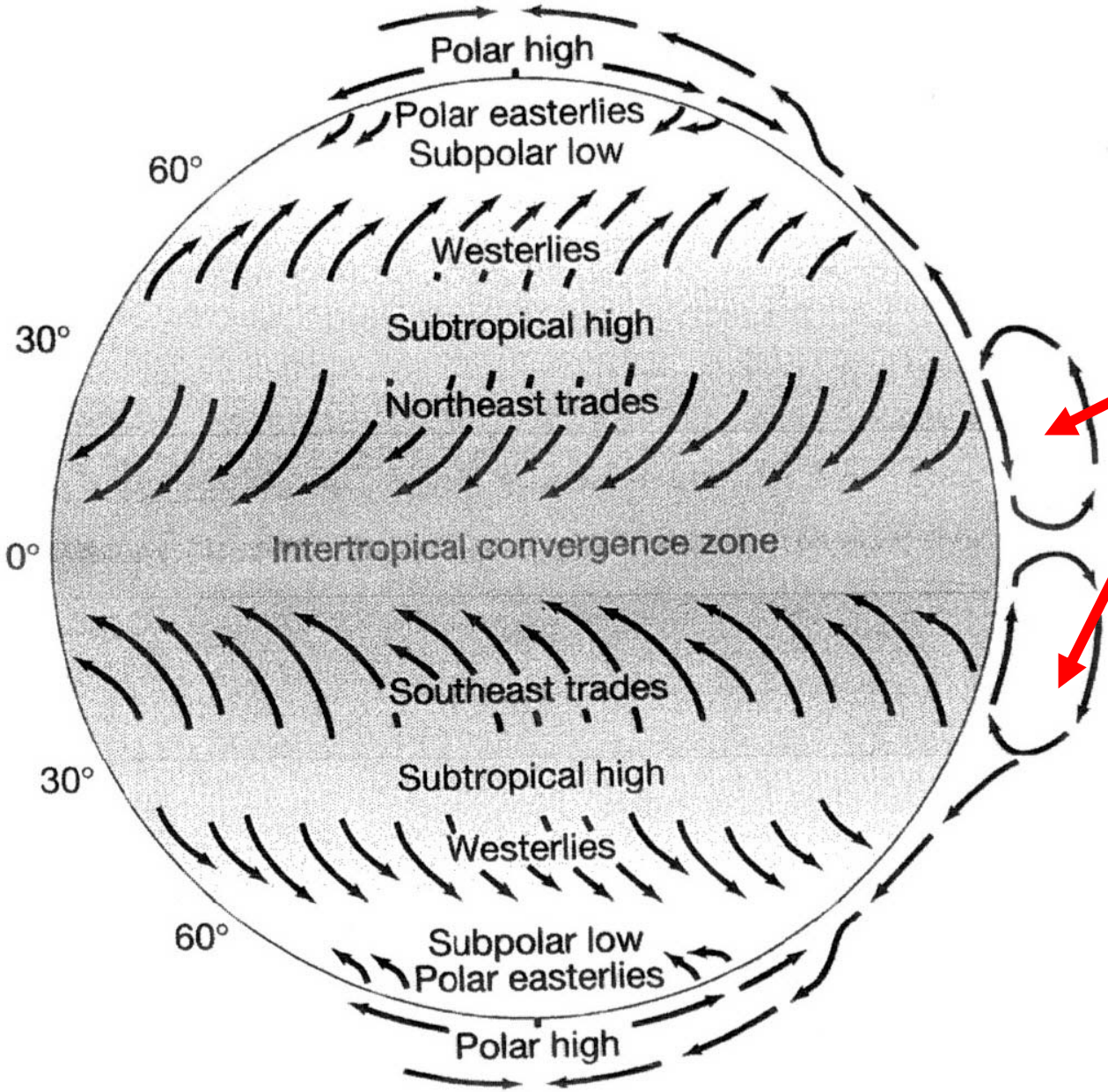
Midlatitude cyclone storms



Idealized Circulation & Hypothetical Continent



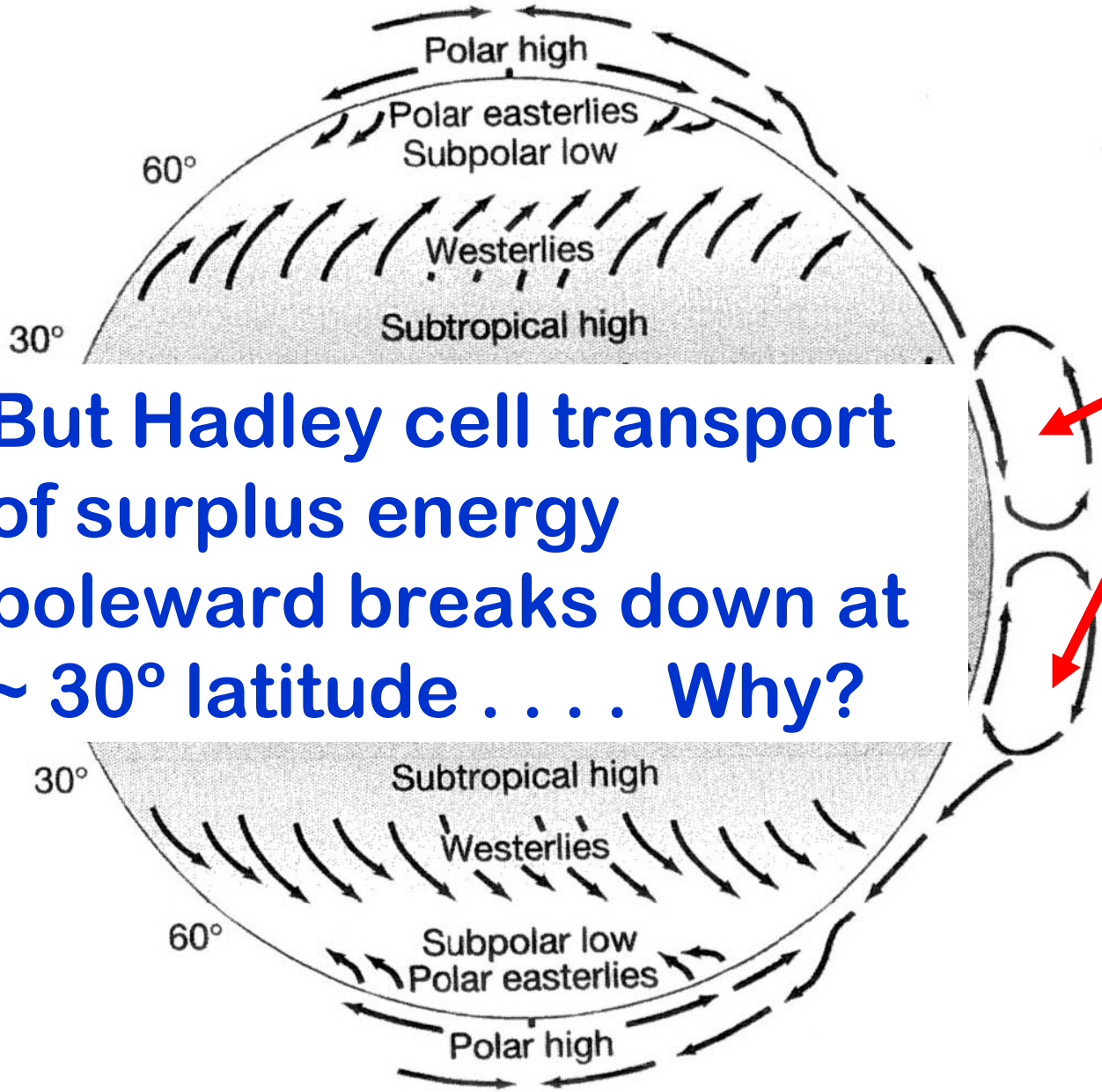
Here's the link to the circulation . . .



H

HADLEY CELLS

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

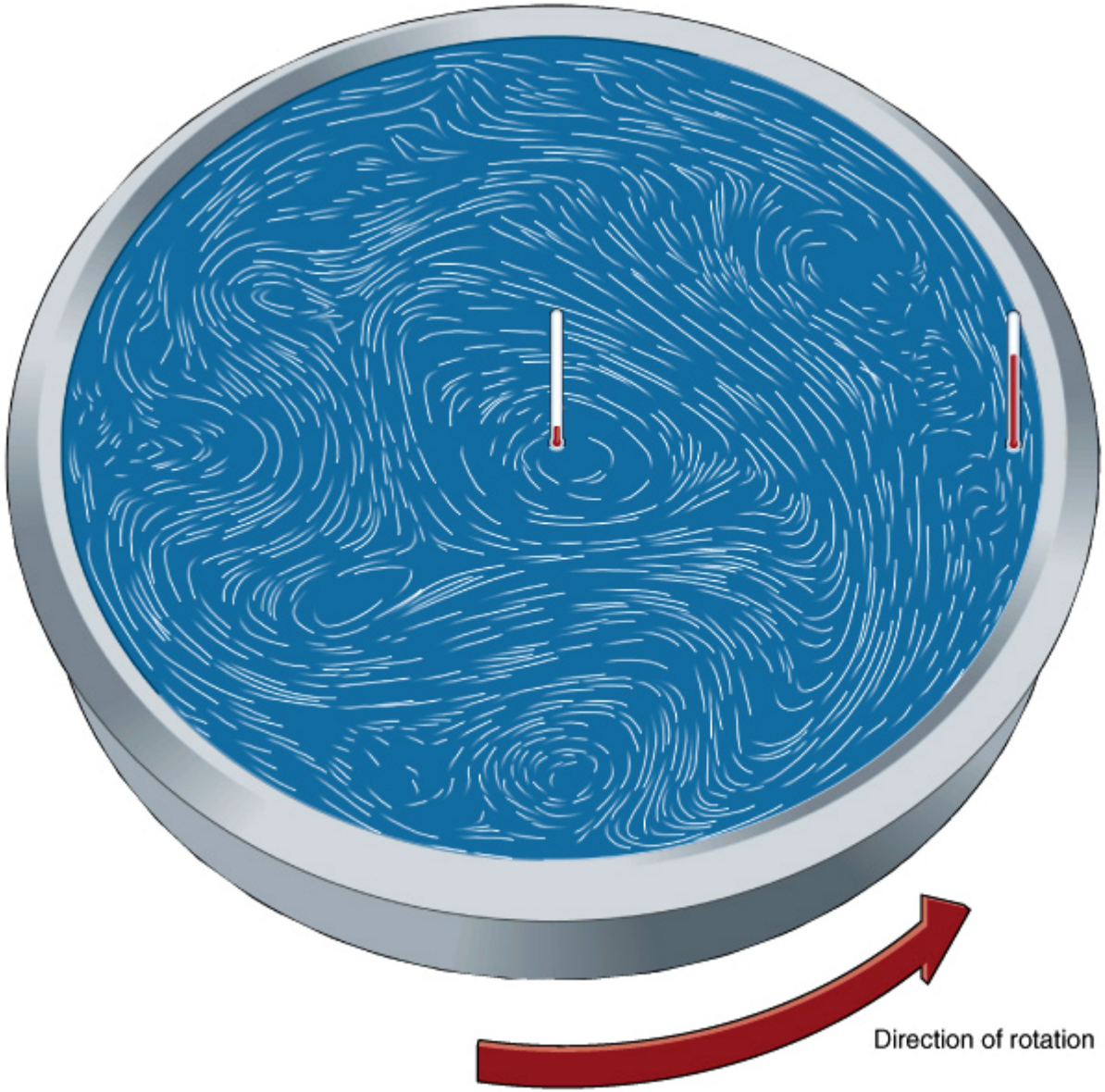


But Hadley cell transport of surplus energy poleward breaks down at ~ 30° latitude . . . . Why?

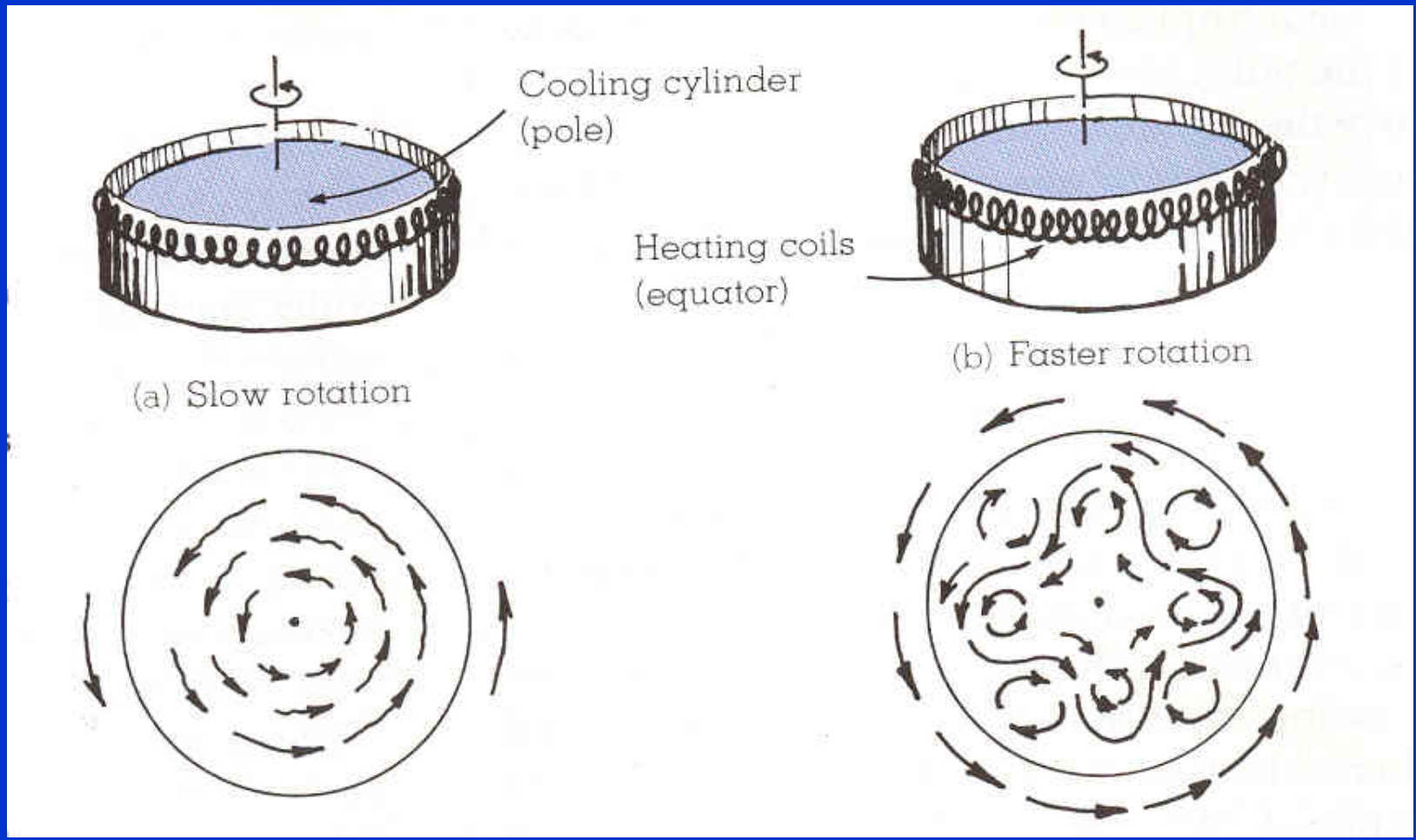
H

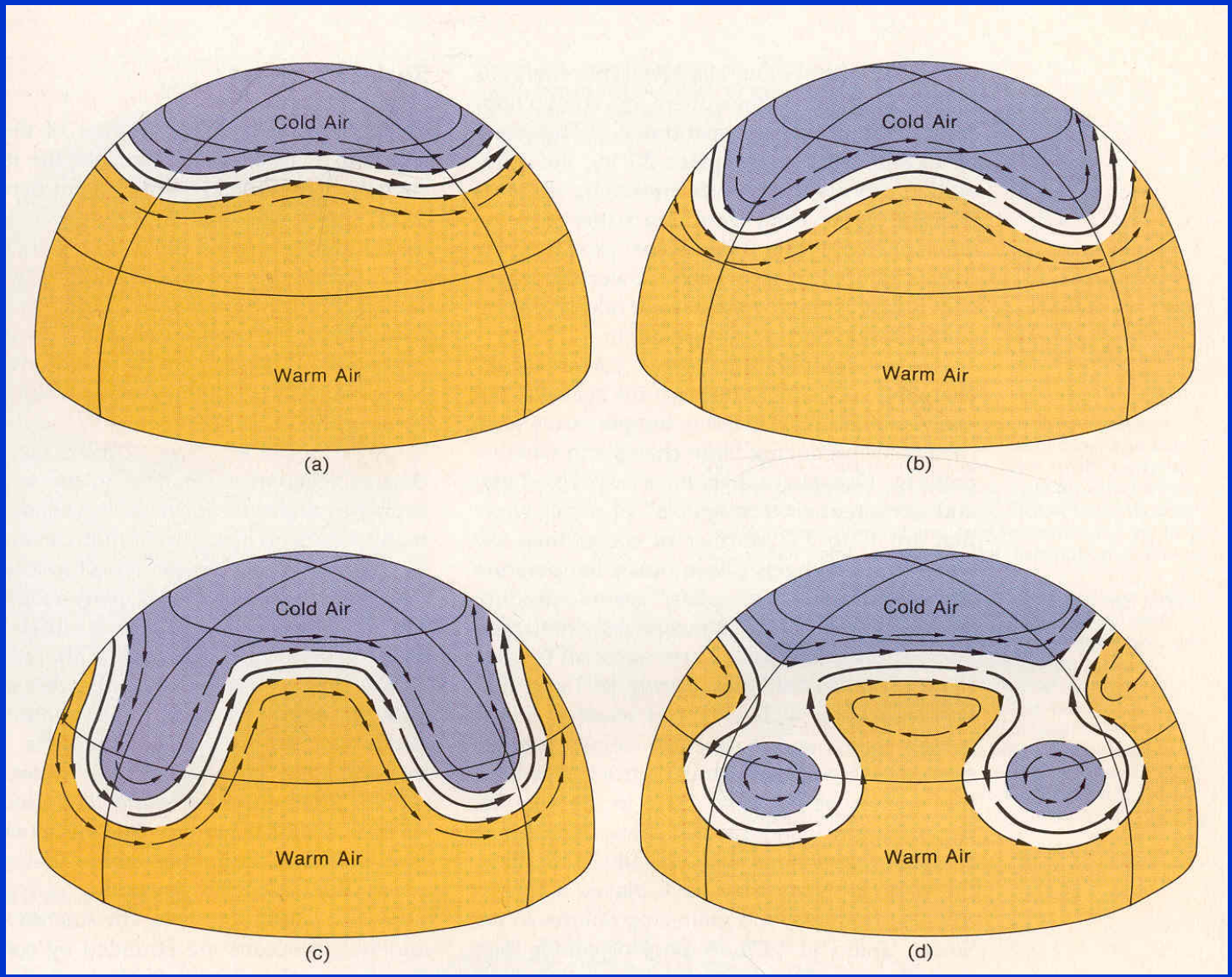
HADLEY CELLS

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


Direction of rotation

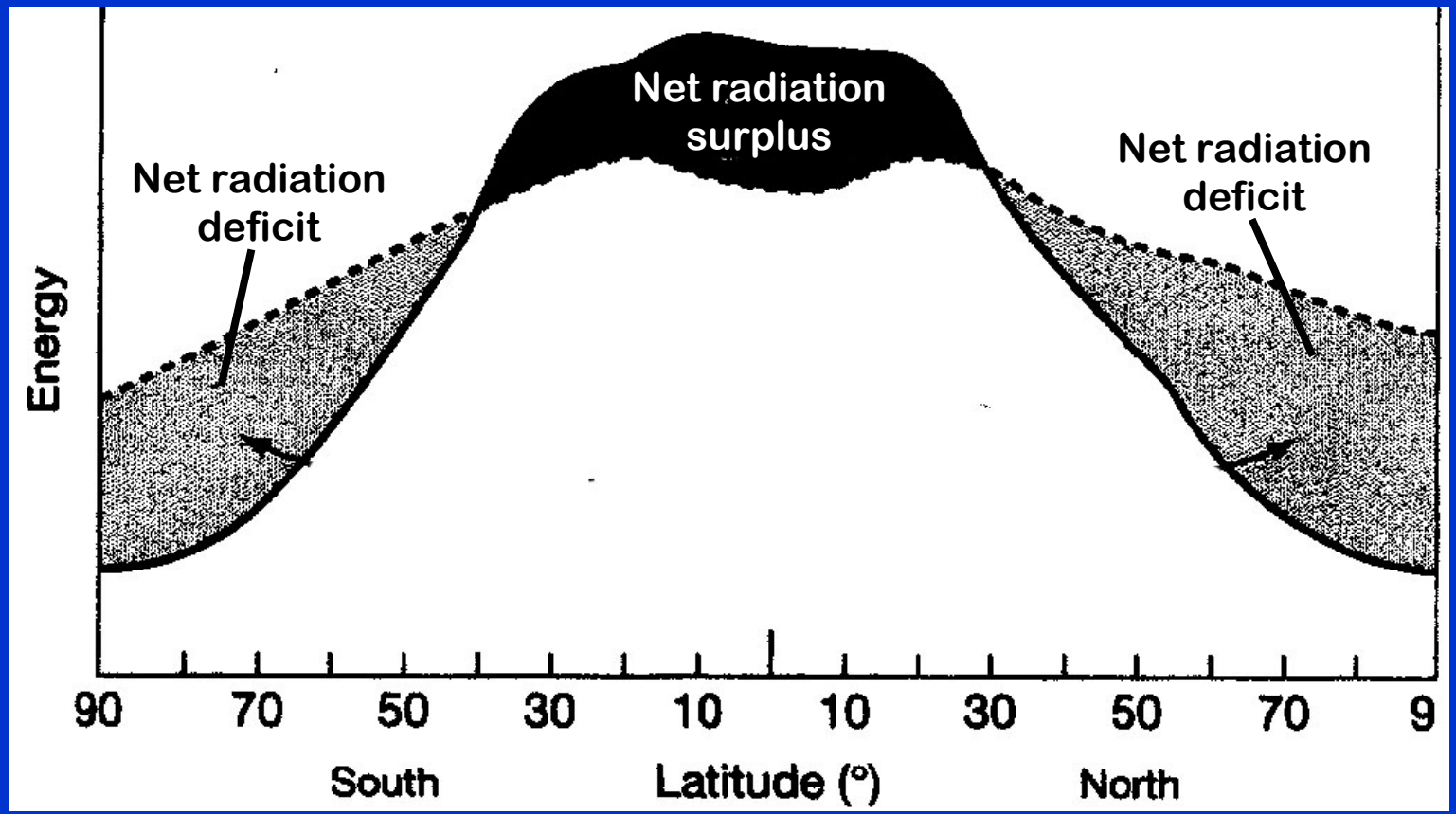
Why Hadley convective cell transport breaks down at higher latitudes:





H

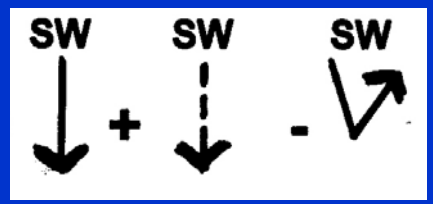
Wave transport of thermal energy instead of Hadley cell transport!

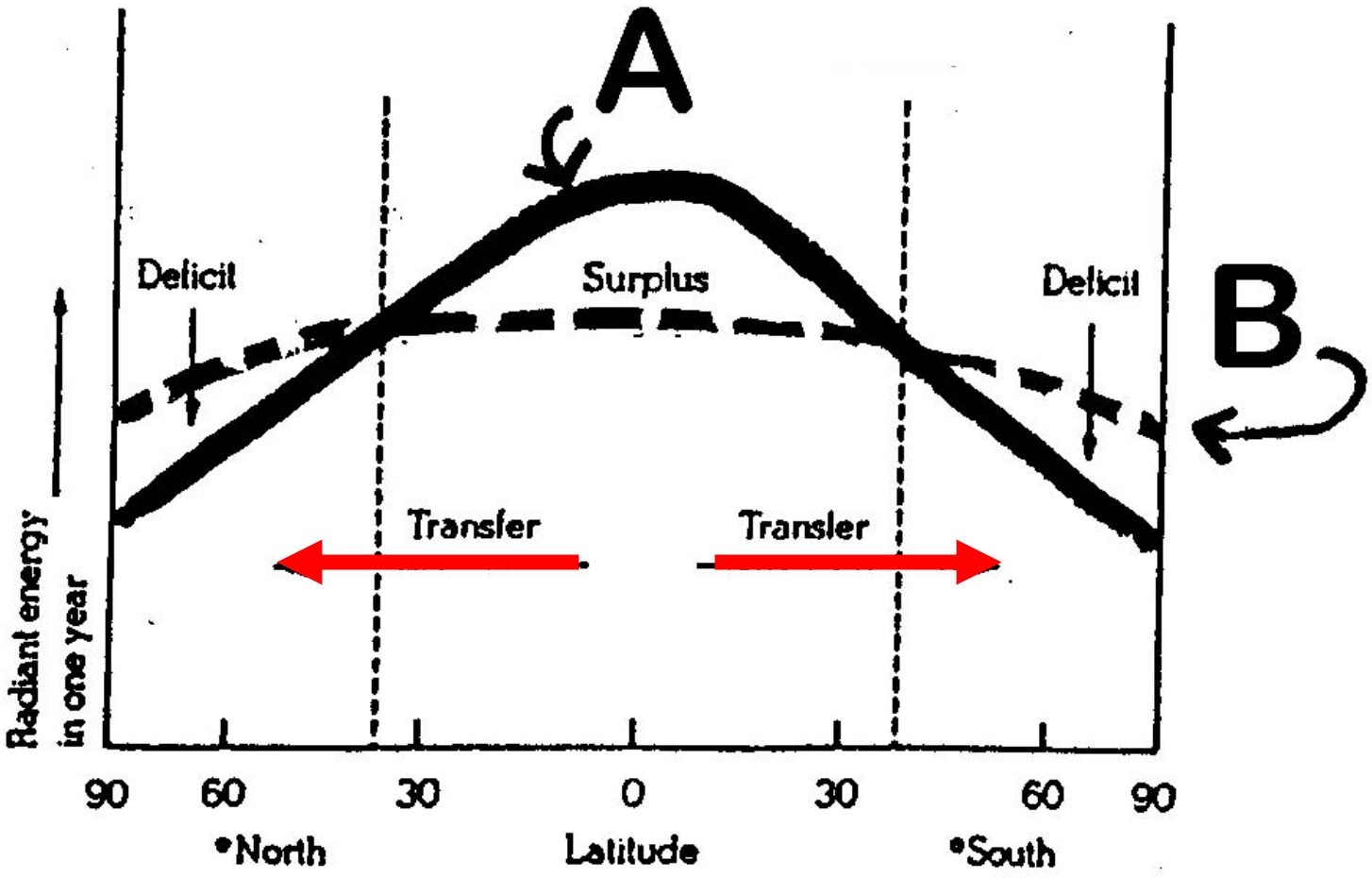


Absorbed solar energy

Emitted infrared energy

(at top of atmosphere)

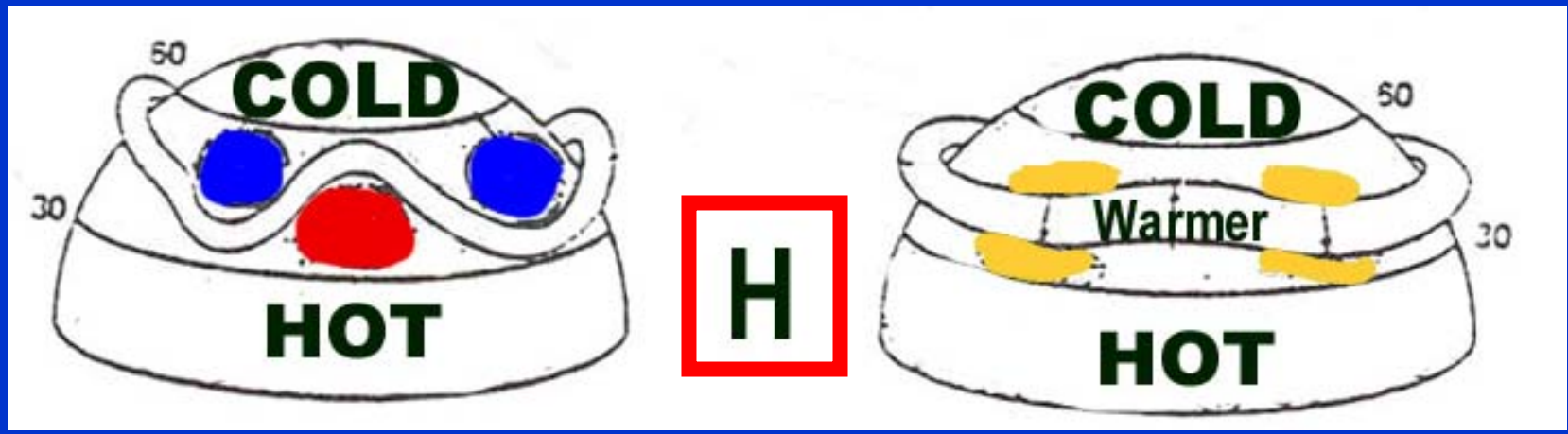


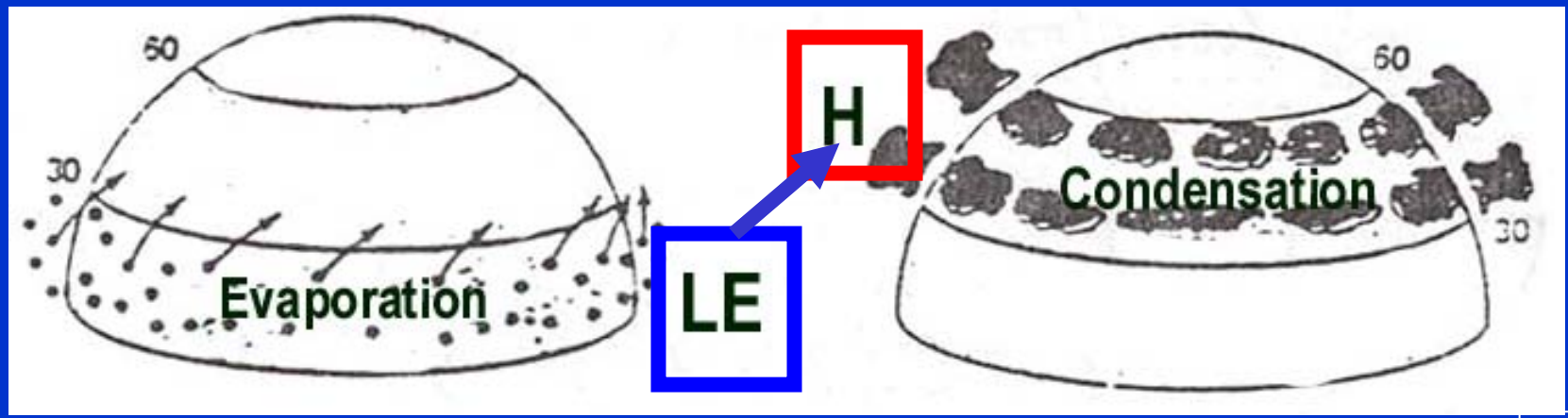


THERMAL ENERGY TRANSPORTED FROM LOW TO HIGH LATITUDES TO BALANCE OUT DEFICIT!

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

H + LE

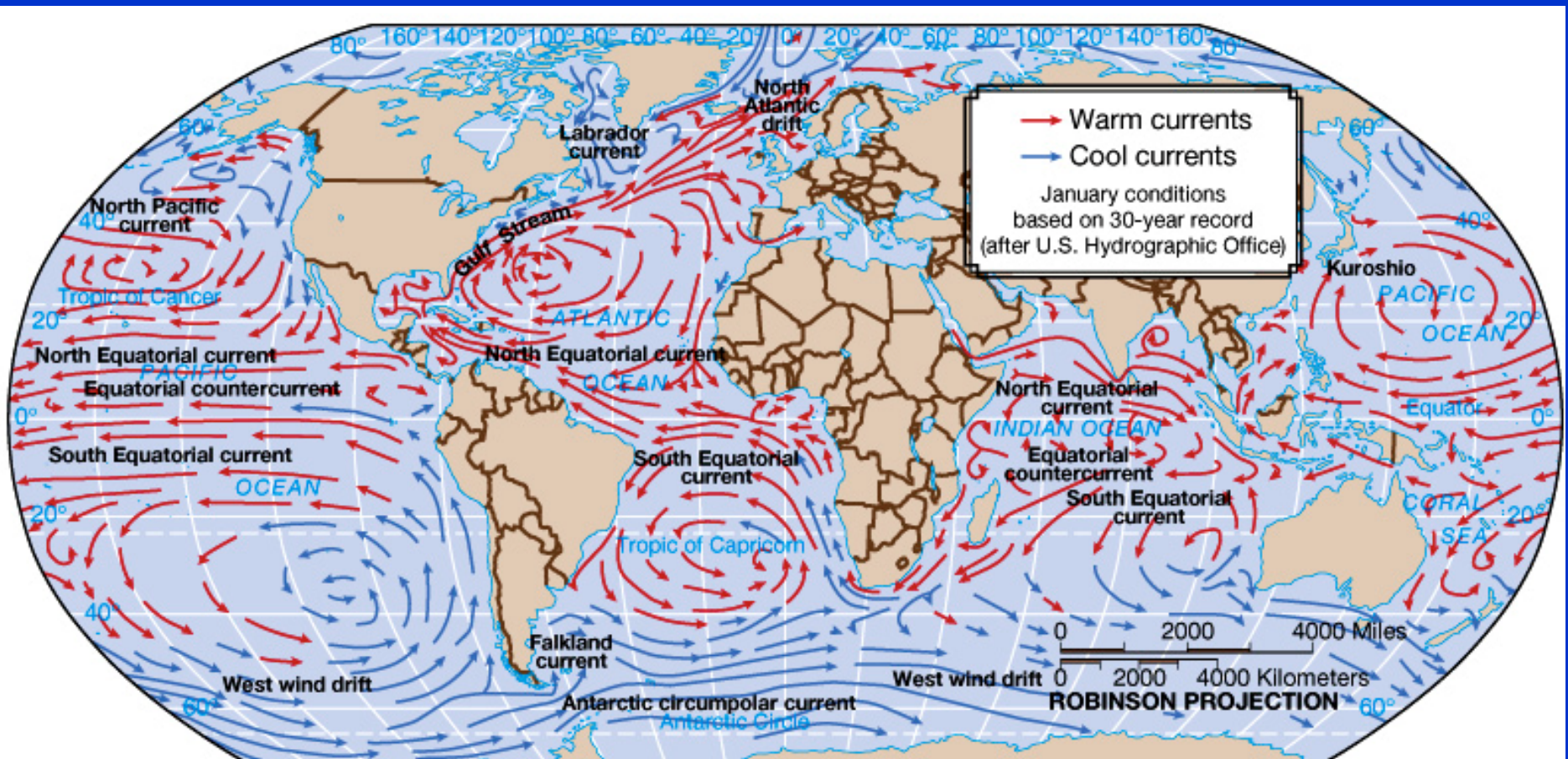




H + LE + G

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** !



GLOBAL PATTERNS OF THE CLIMATIC ELEMENTS

Climatic Elements = Variables that describe or constitute climate:

(1) **solar energy** (linked to R_n),

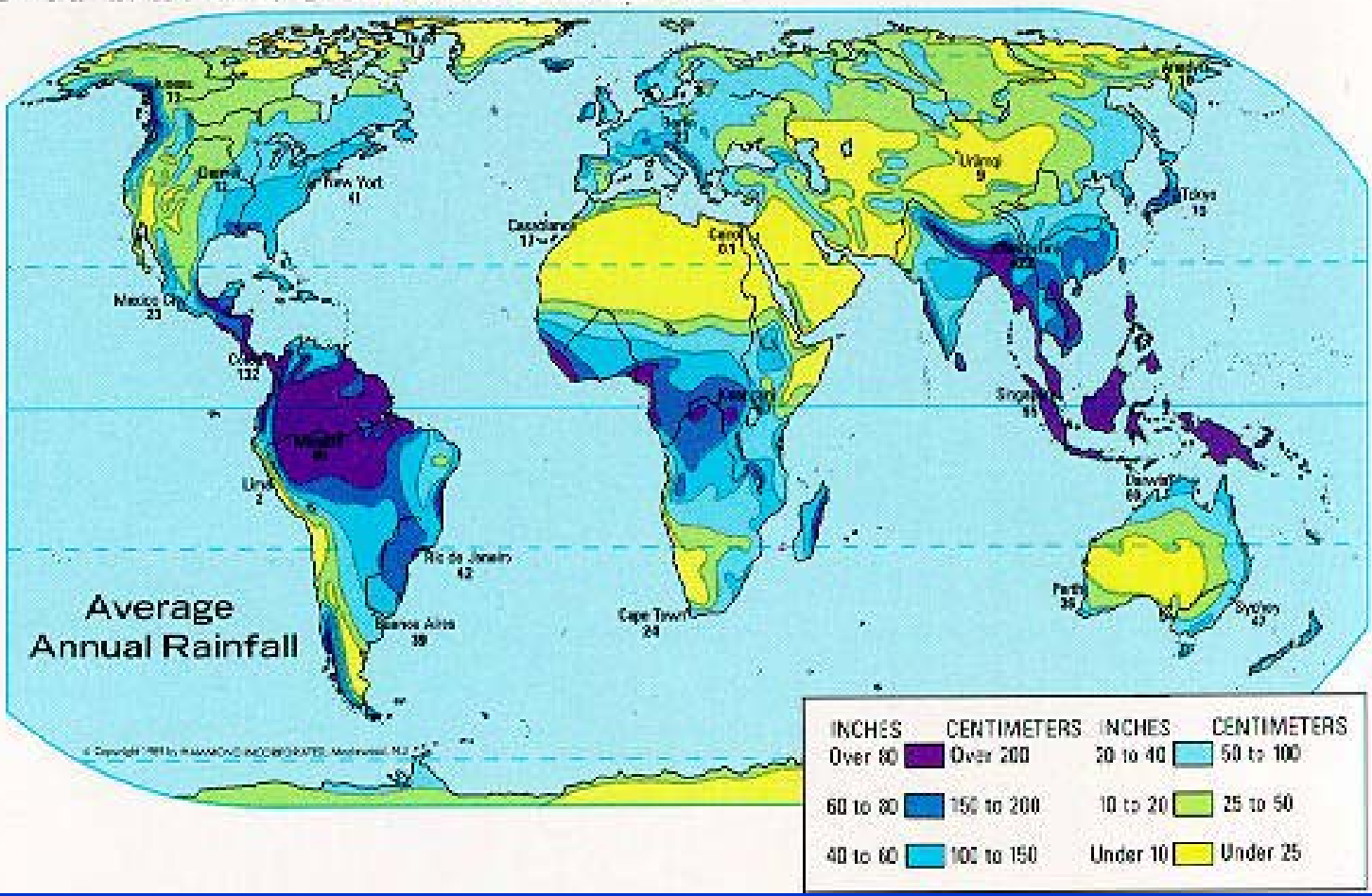
(2) **temperature** (linked to H),

(3) **moisture** (linked to LE),

(4) **pressure & winds** (circulation -- linked to latitudinal and regional imbalances in energy). ***The elements vary temporally and regionally.***

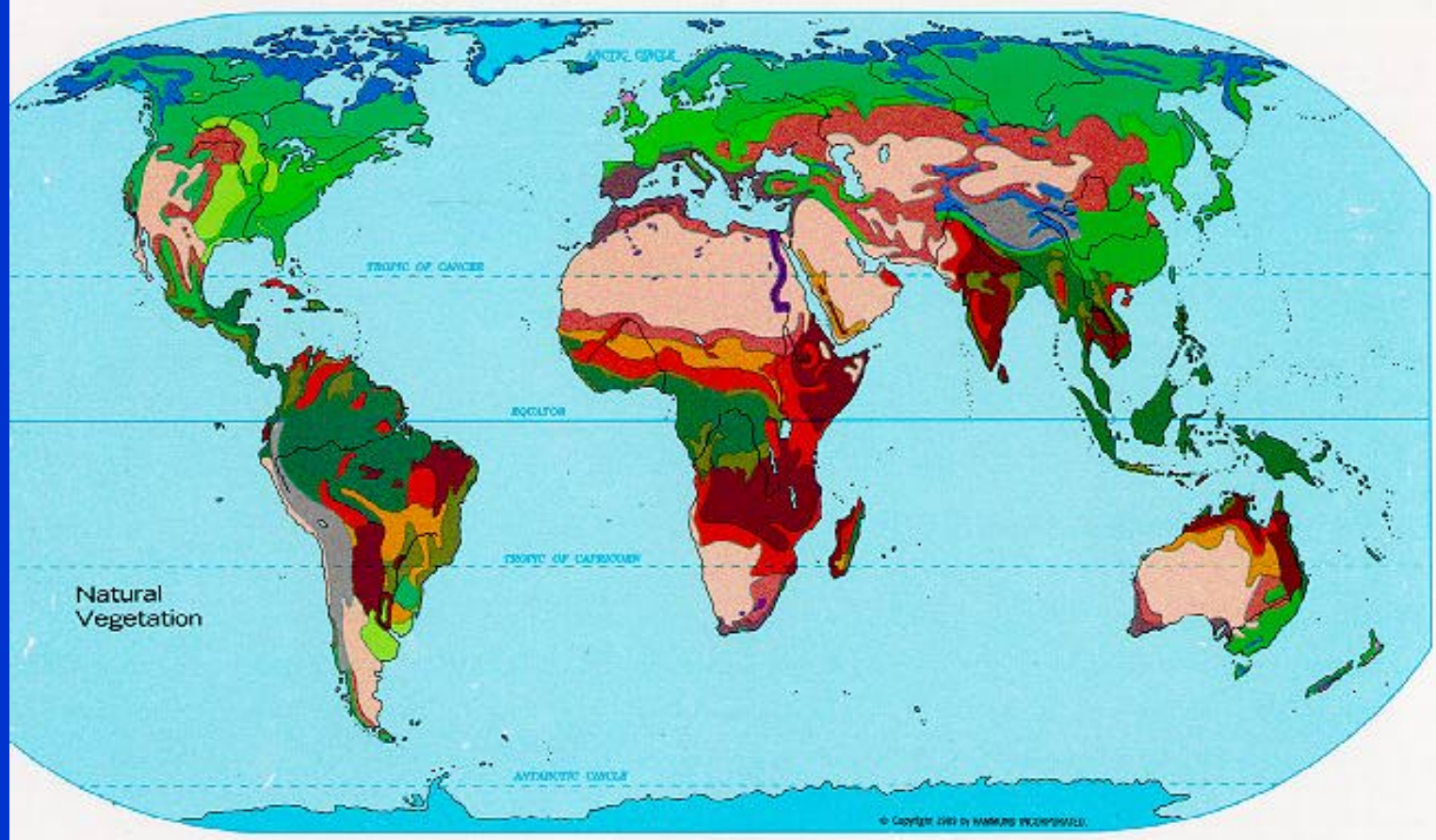
Take notes

WORLD-RAINFALL/OCEAN CURRENTS

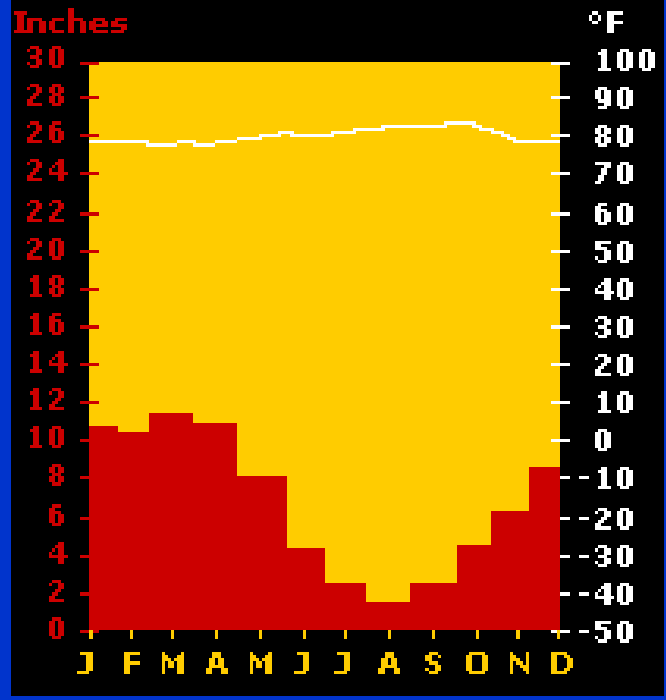


WORLD-VEGETATION

CWA 16-17



TYPE: Tropical Rainforest
PLACE: Manaus, Brazil



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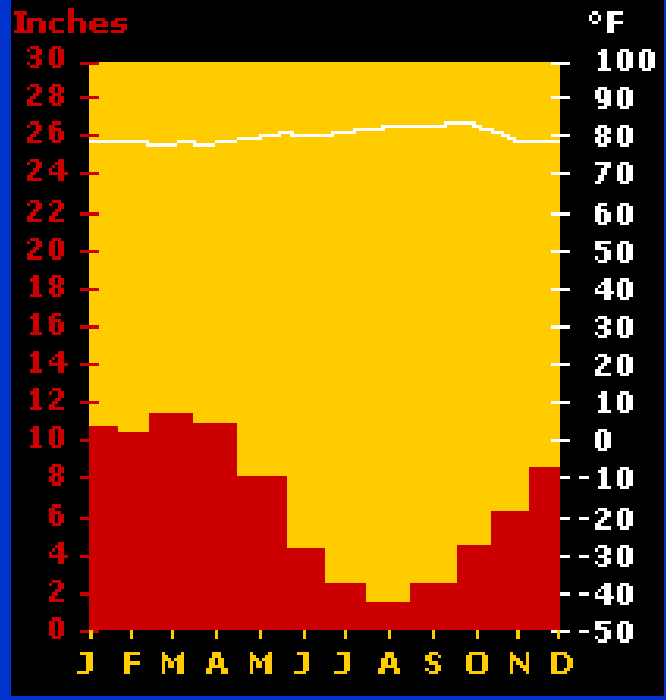
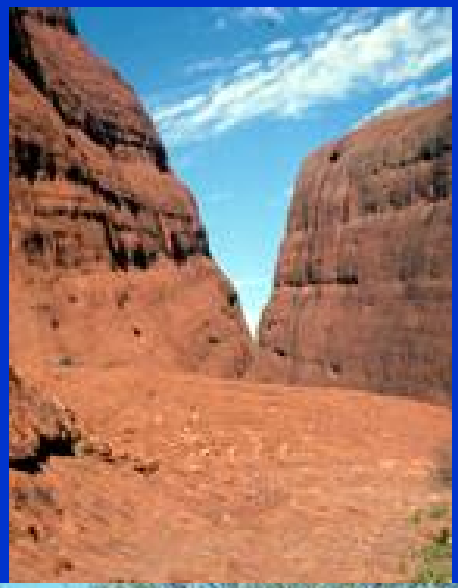
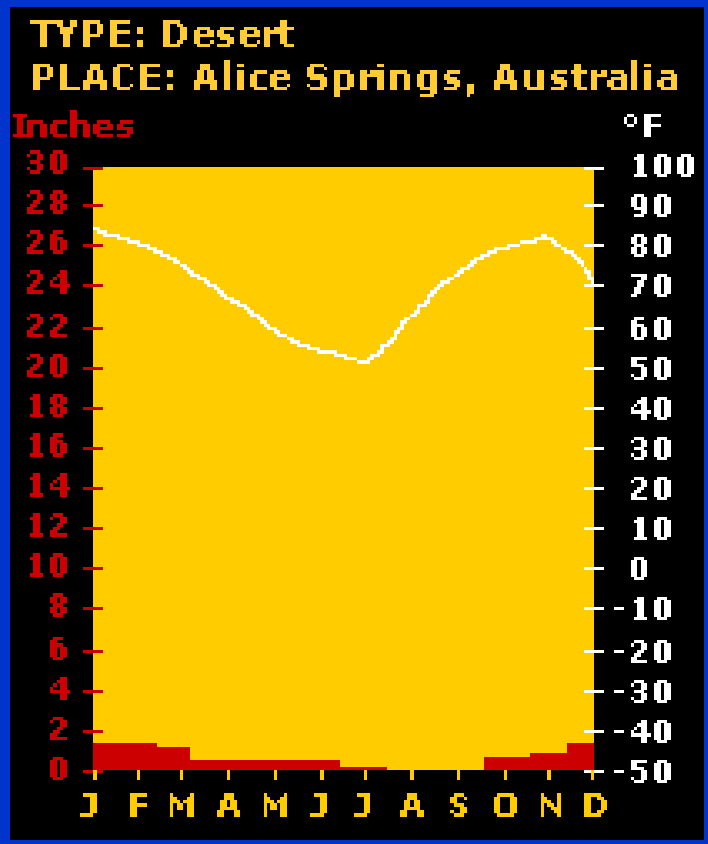
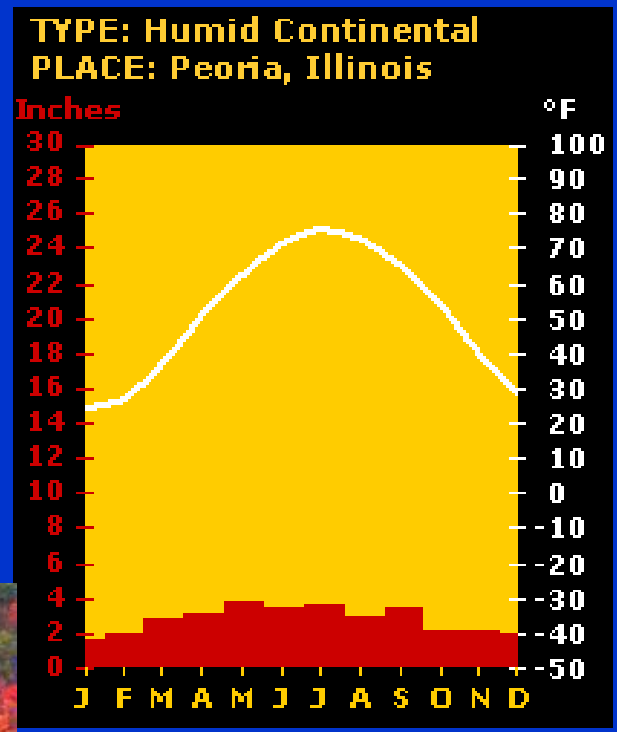
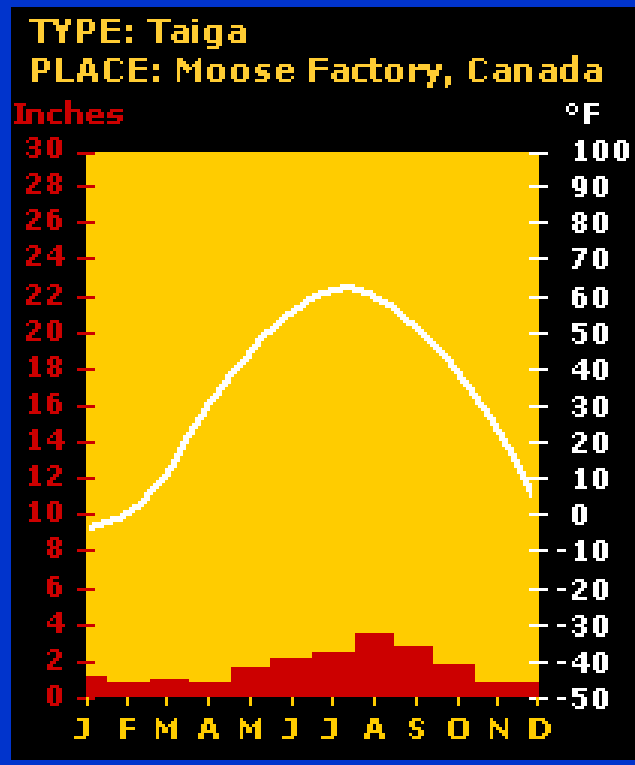


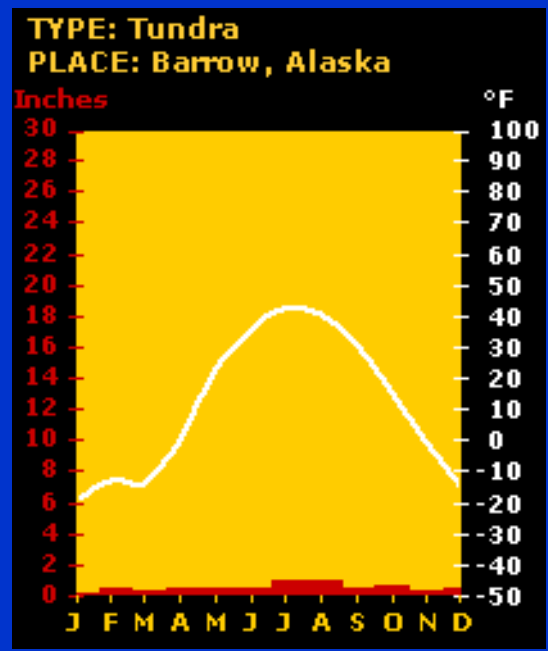



© Peter J. Unmack


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
°F
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
100
90
80
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30
20
10
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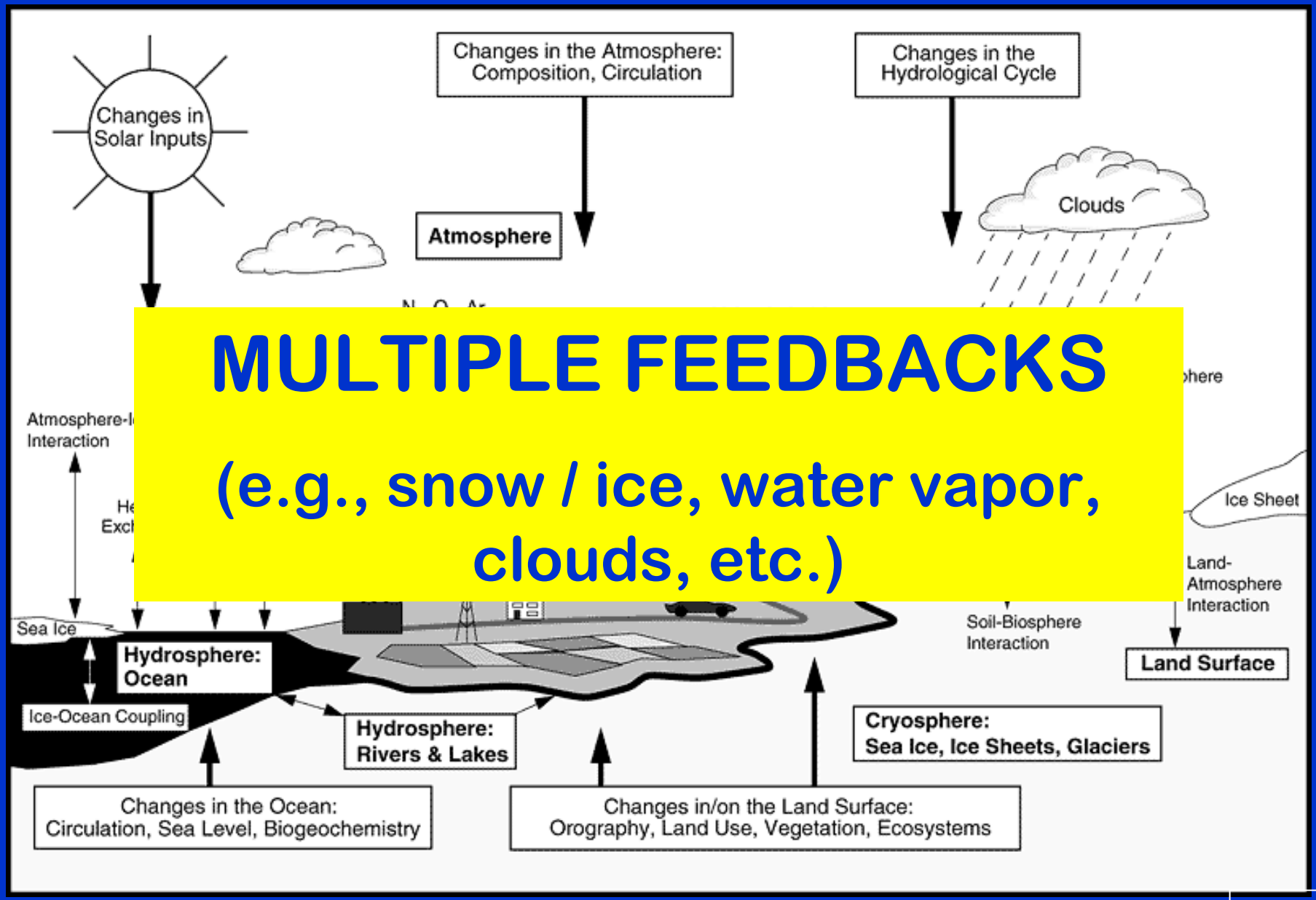
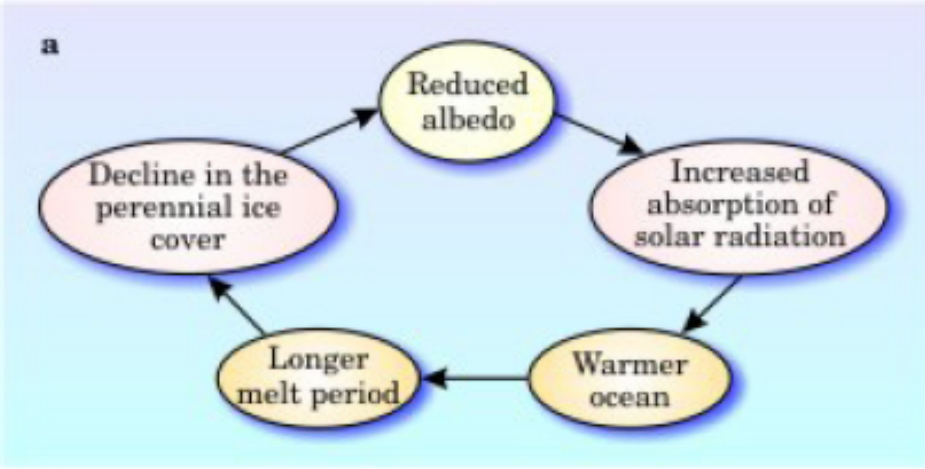
-10
-20
-30
-40
-50
J F M A M J J A S O N D

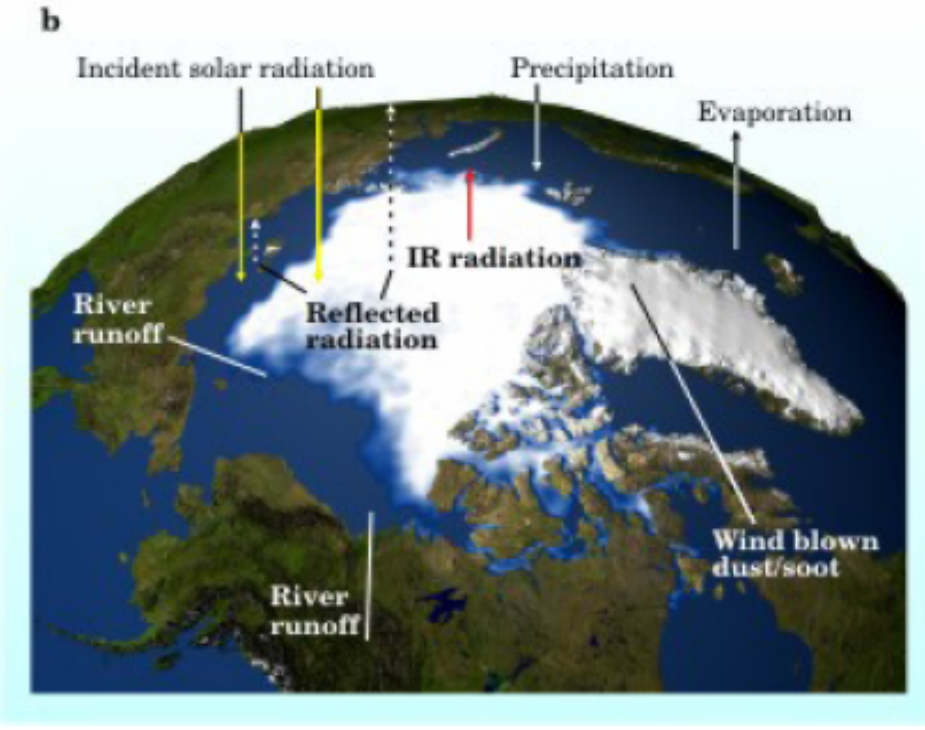

Changes in Solar Inputs
Changes in the Atmosphere: Composition, Circulation
Changes in the Hydrological Cycle
Atmosphere
Clouds
MULTIPLE FEEDBACKS
(e.g., snow / ice, water vapor, clouds, etc.)
Atmosphere-I
Interaction
Ice Sheet
Land-
Atmosphere
Interaction
Sea Ice
Hydrosphere:
Ocean
Soil-Biosphere
Interaction
Land Surface
Ice-Ocean Coupling
Hydrosphere:
Rivers & Lakes
Cryosphere:
Sea Ice, Ice Sheets, Glaciers
Changes in the Ocean:
Circulation, Sea Level, Biogeochemistry
Changes in/on the Land Surface:
Orography, Land Use, Vegetation, Ecosystems

Take home challenge to think about and try for Thursday's class:

Complete the FEEDBACK LOOP on the bottom of p 82 in CLASS NOTES . . .

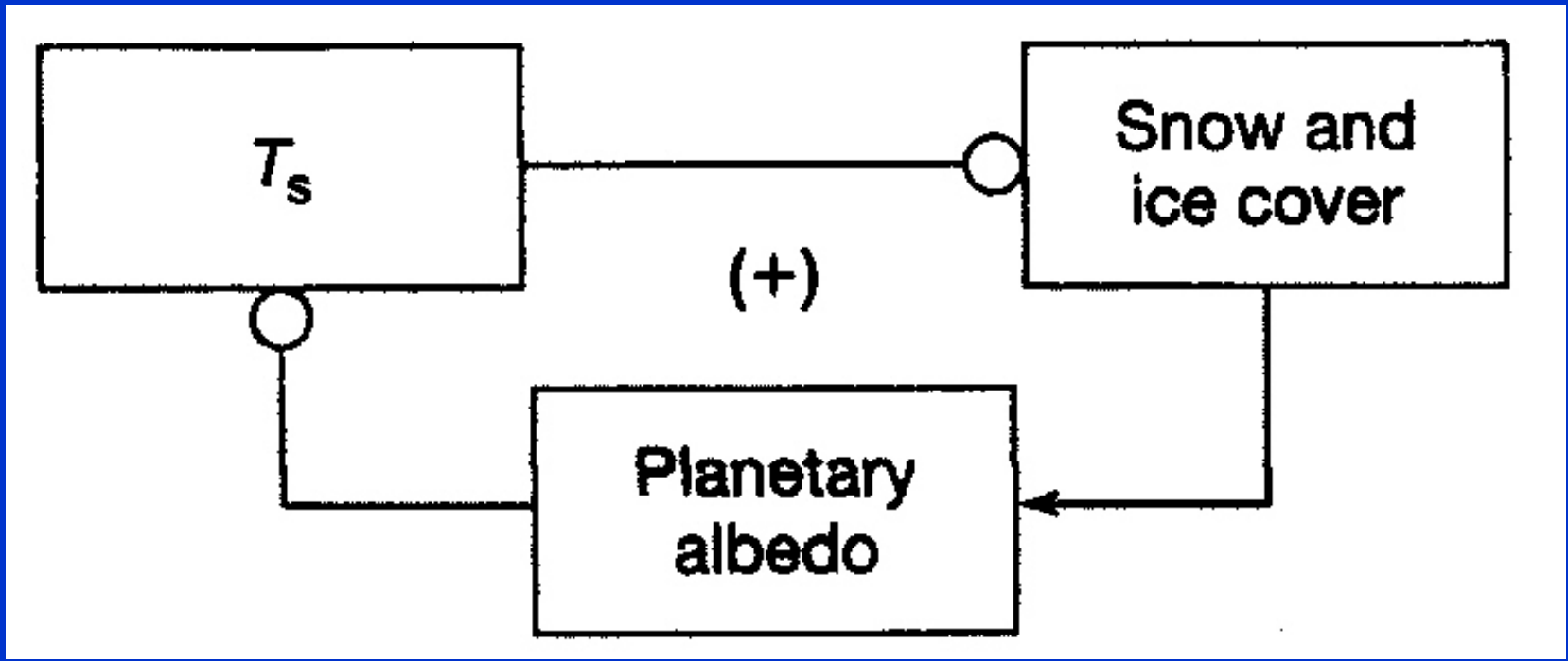
REMEMBER FEEDBACK LOOPS:
Is this one positive or negative?





Complete the feedback loop on the bottom of page 82 by linking the components with the proper coupling arrow symbols as used in the IGC text

SNOW AND ICE ALBEDO
Feedback



albedo

Extent of ice cover

SW radiation absorbed

Amount of melting

Ocean temperature