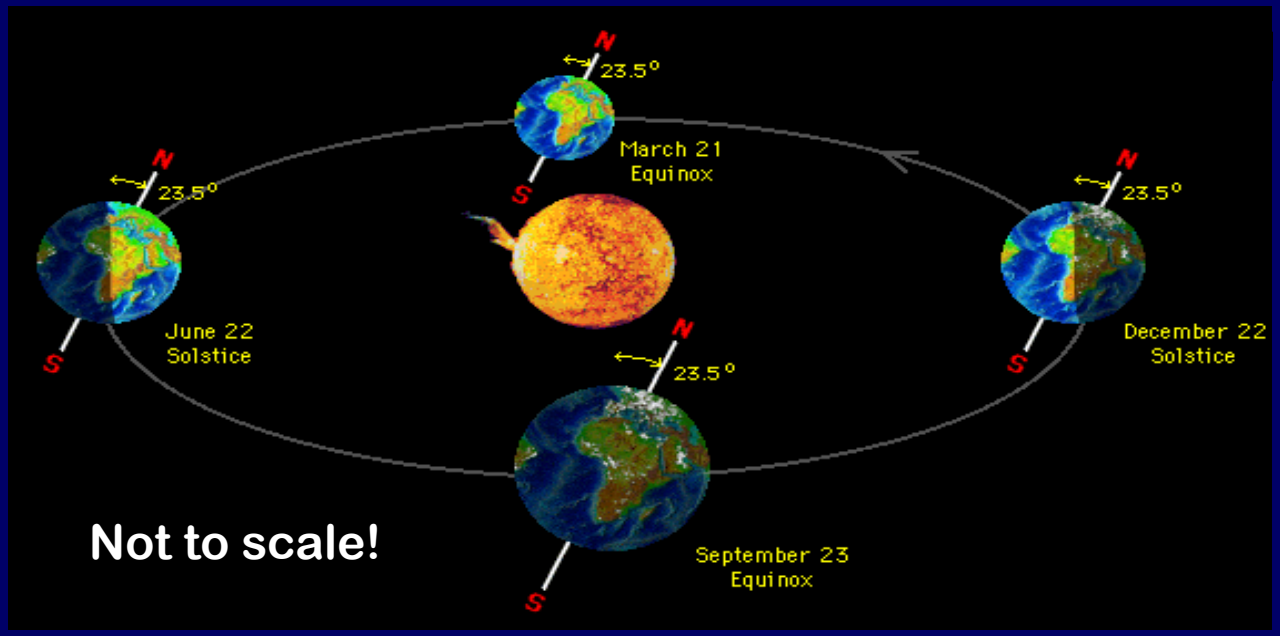
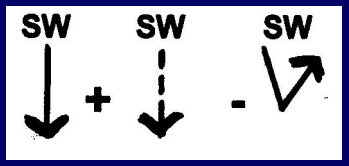
Topic # 11
HOW CLIMATE WORKS – continued (Part II)

pp 61-67 in Class Notes

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





EARTH-SUN Relationships

4 Things to Know about Earth-Sun Relationships:

REVIEW!

1) Earth orbits Sun in one year
2) Orbit is not a perfect circle (= an ellipse)
3) Earth's orbit around Sun can be "traced" on a plane
   ("Plane of the Ecliptic" – plane passes thru the center of Sun & Earth)
4) Earth's axis tilts 23.5 ° from a ⊥ to the "Plane of The Ecliptic"

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

These 4 Earth-Sun Properties lead to: the 2 factors that determine the AMOUNT OF SOLAR INSOLATION as the seasons progress:

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

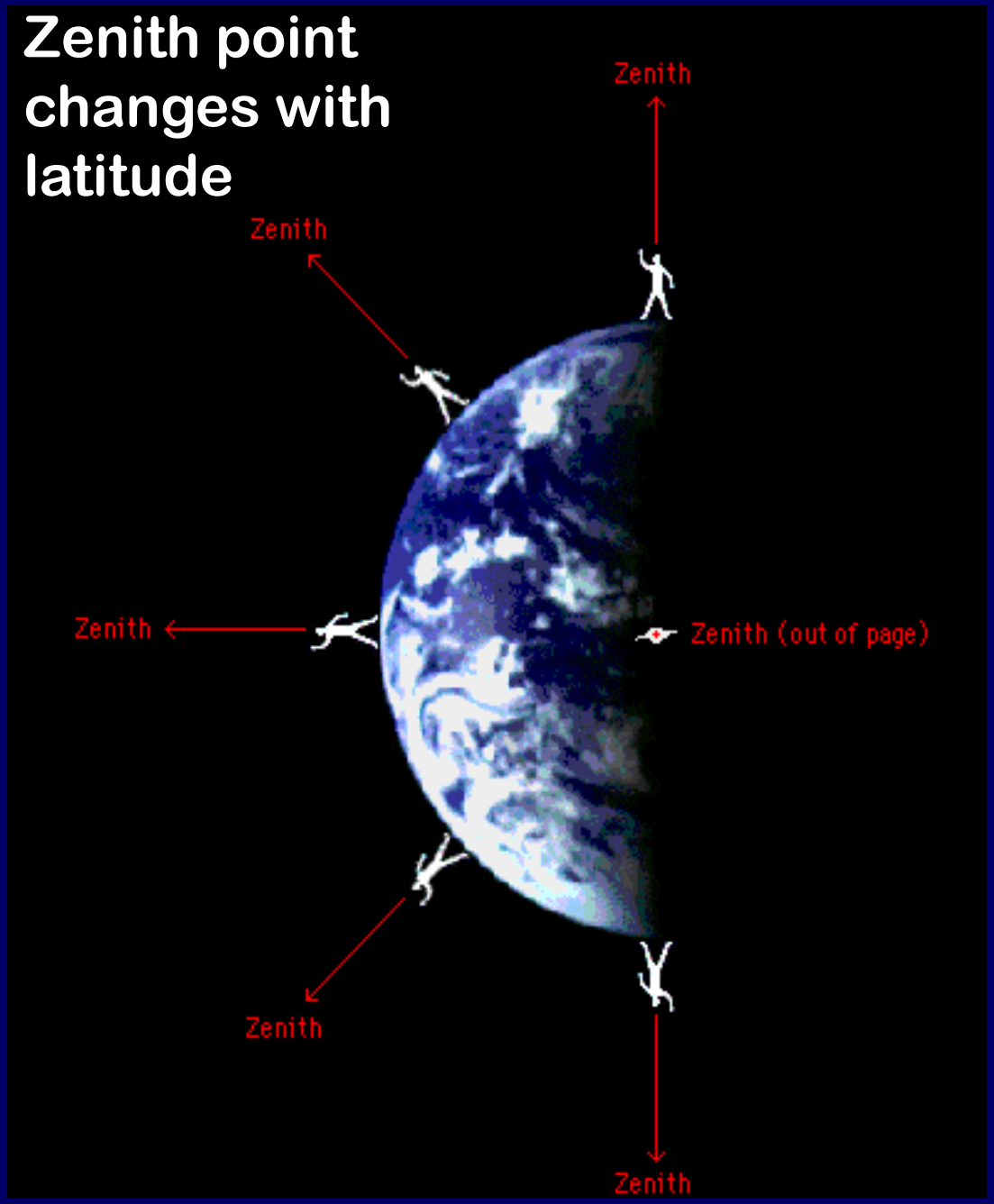
(perpendicular to surface = more intense)

(2) **DURATION** of daily insolation

(longer day length = more insolation)

REVIEW!

Zenith point changes with latitude

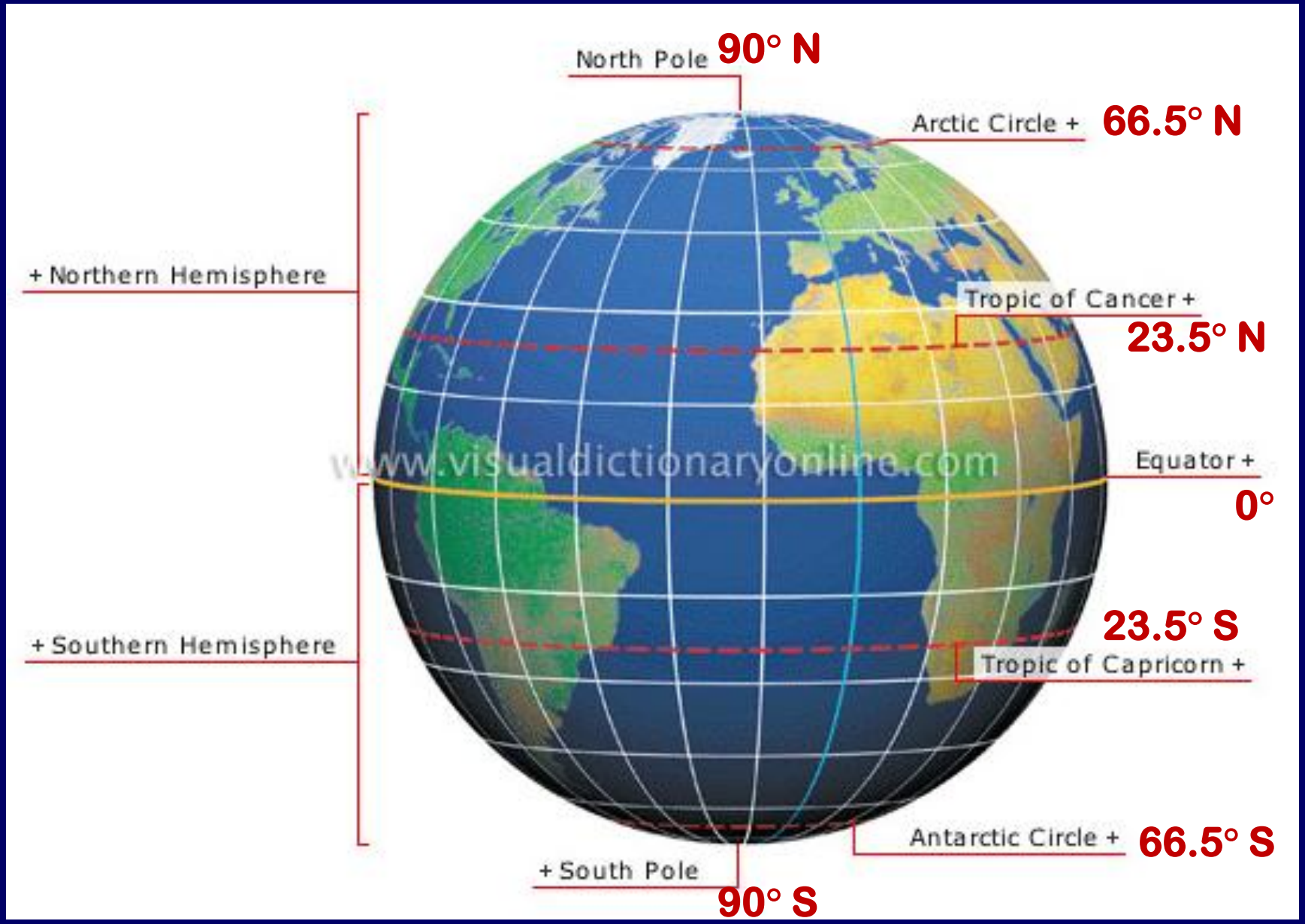


A useful term:

ZENITH =
The point directly overhead

INTENSITY is greatest at any spot on Earth when sun is closest to the ZENITH!

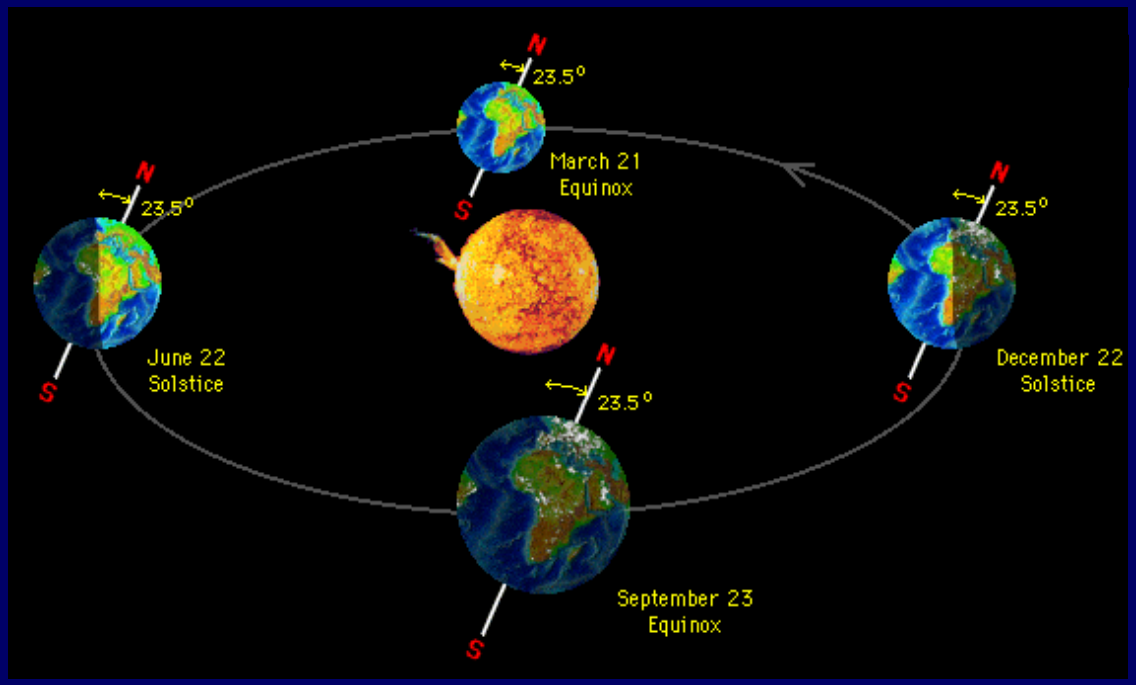
QUICKIE LATITUDE REVIEW:



EARTH-SUN RELATIONSHIPS & The SEASONS:

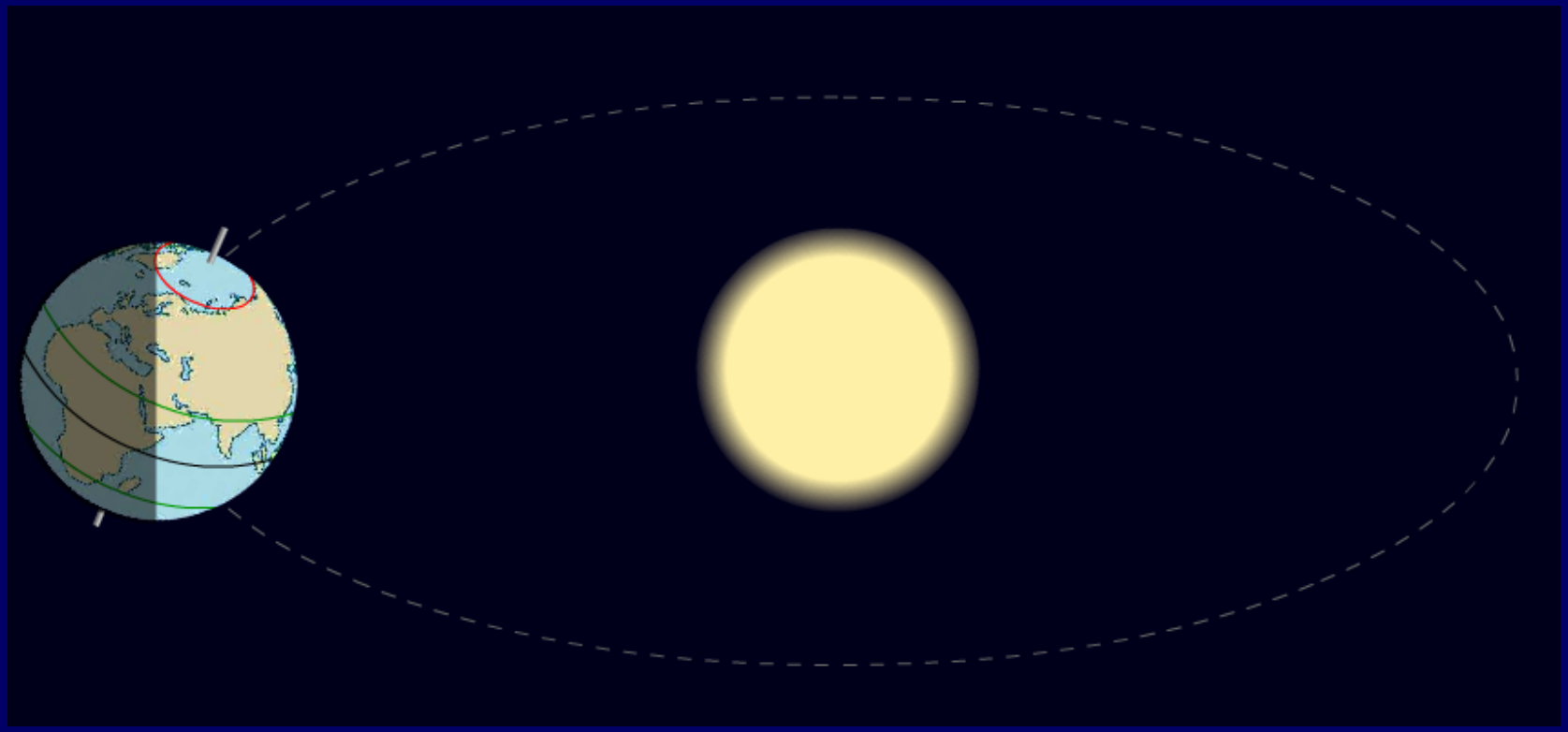
VIEW THE ANIMATION:

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



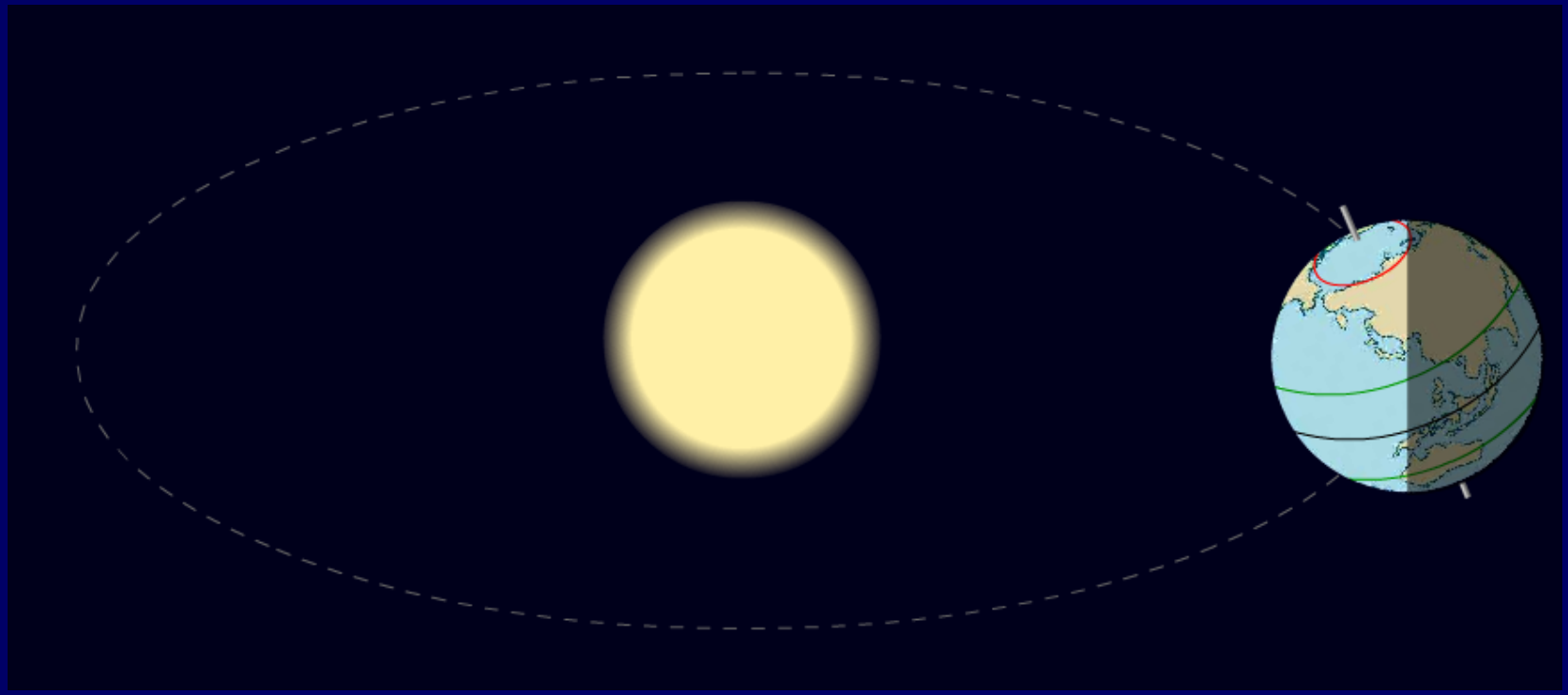
REVIEW!

JUNE SOLSTICE



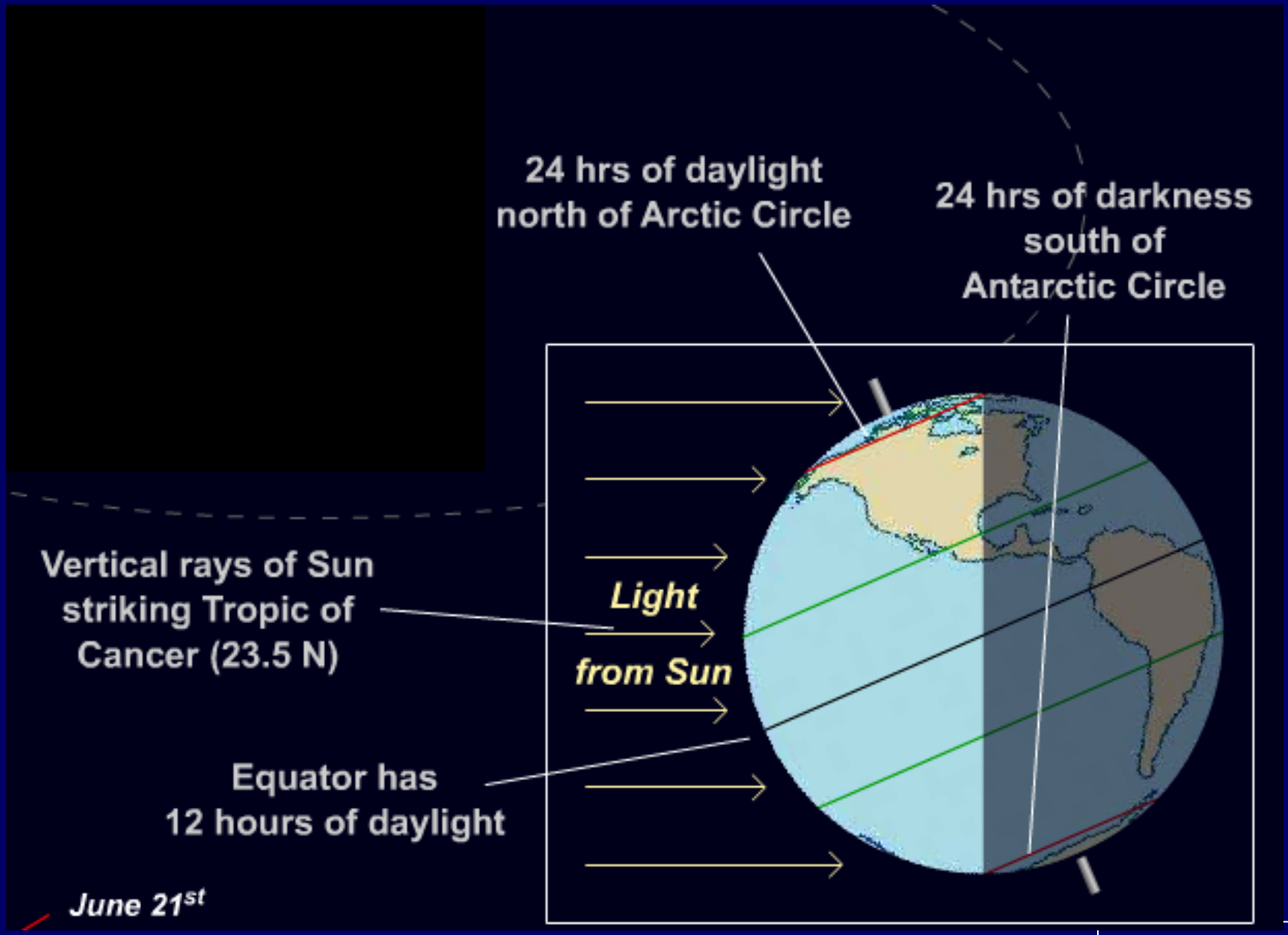
As viewed from one side of Sun

JUNE SOLSTICE



As viewed from the other side of the Sun

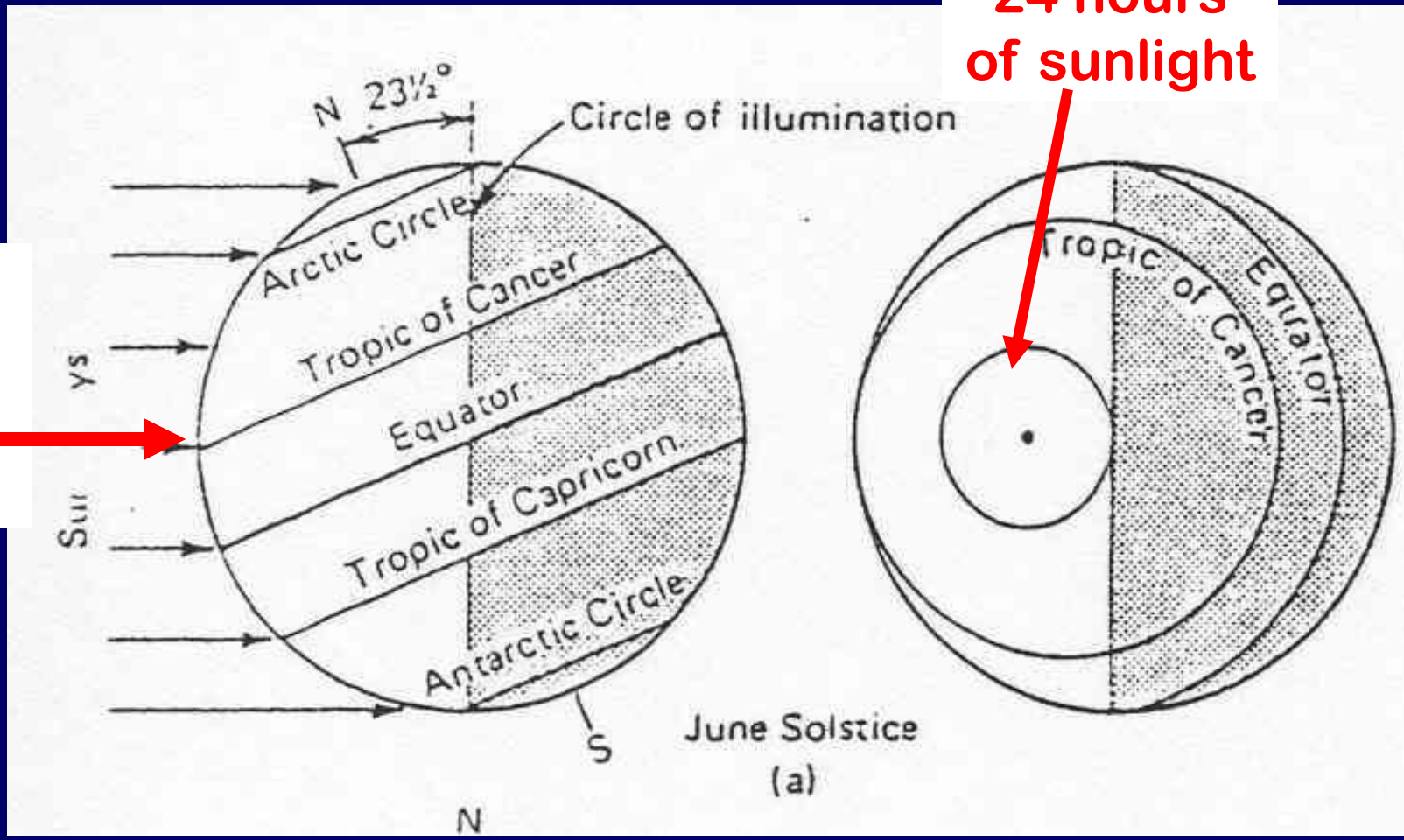
JUNE SOLSTICE



JUNE SOLSTICE

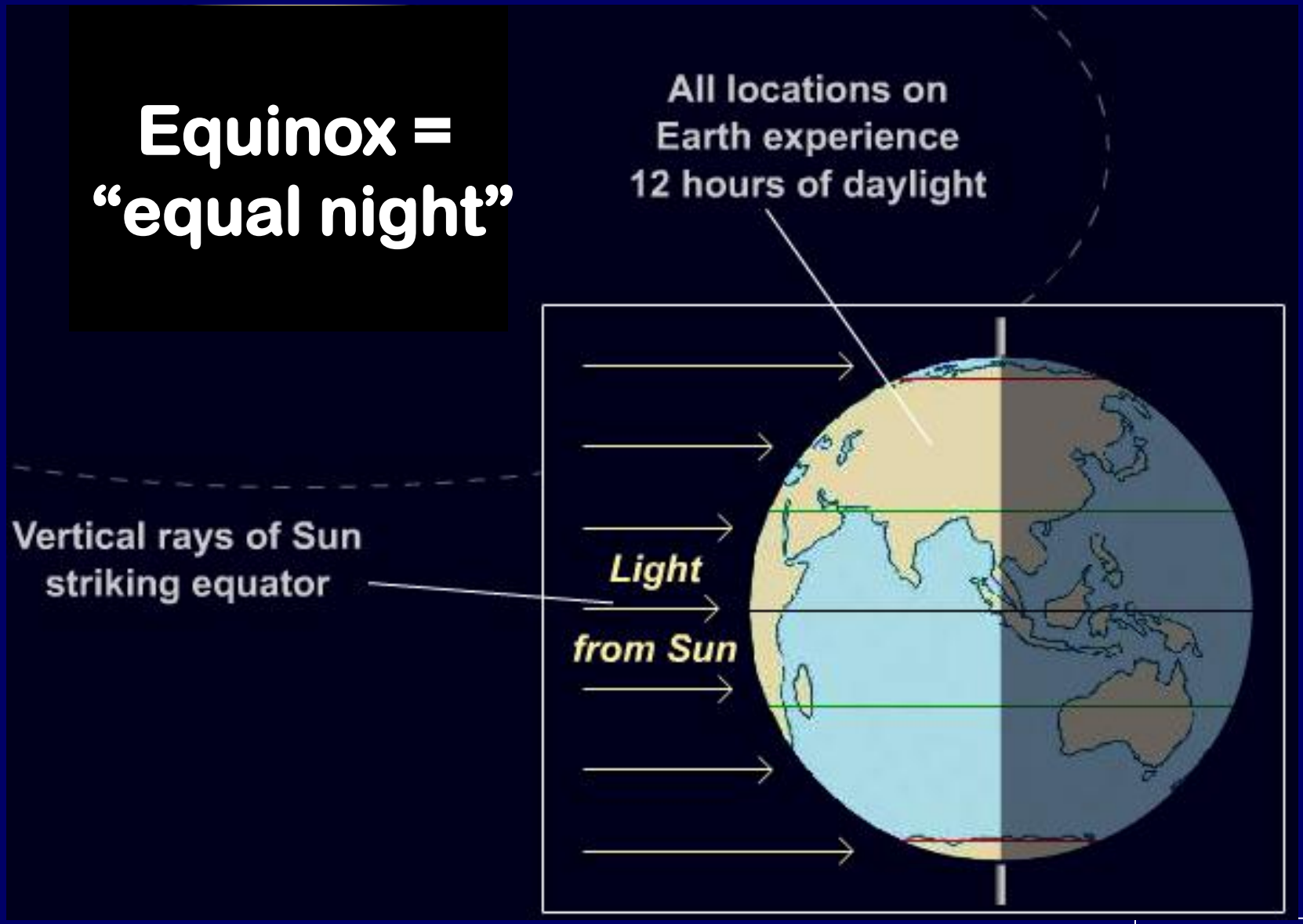
24 hours of sunlight

Most intense solar radiation



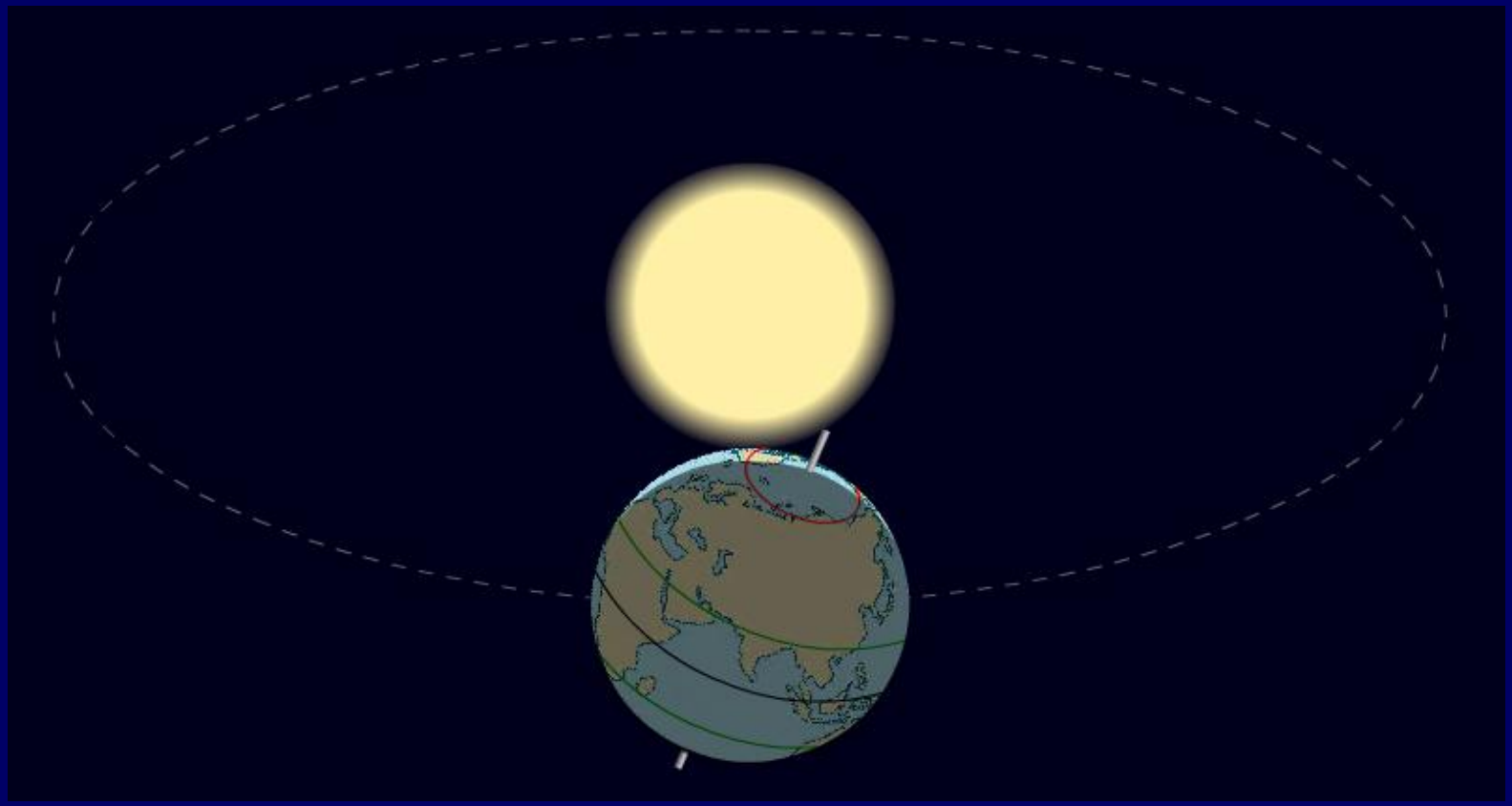
MARCH EQUINOX

Equinox = "equal night"



SEPTEMBER EQUINOX

different seasonal position in orbit . . .

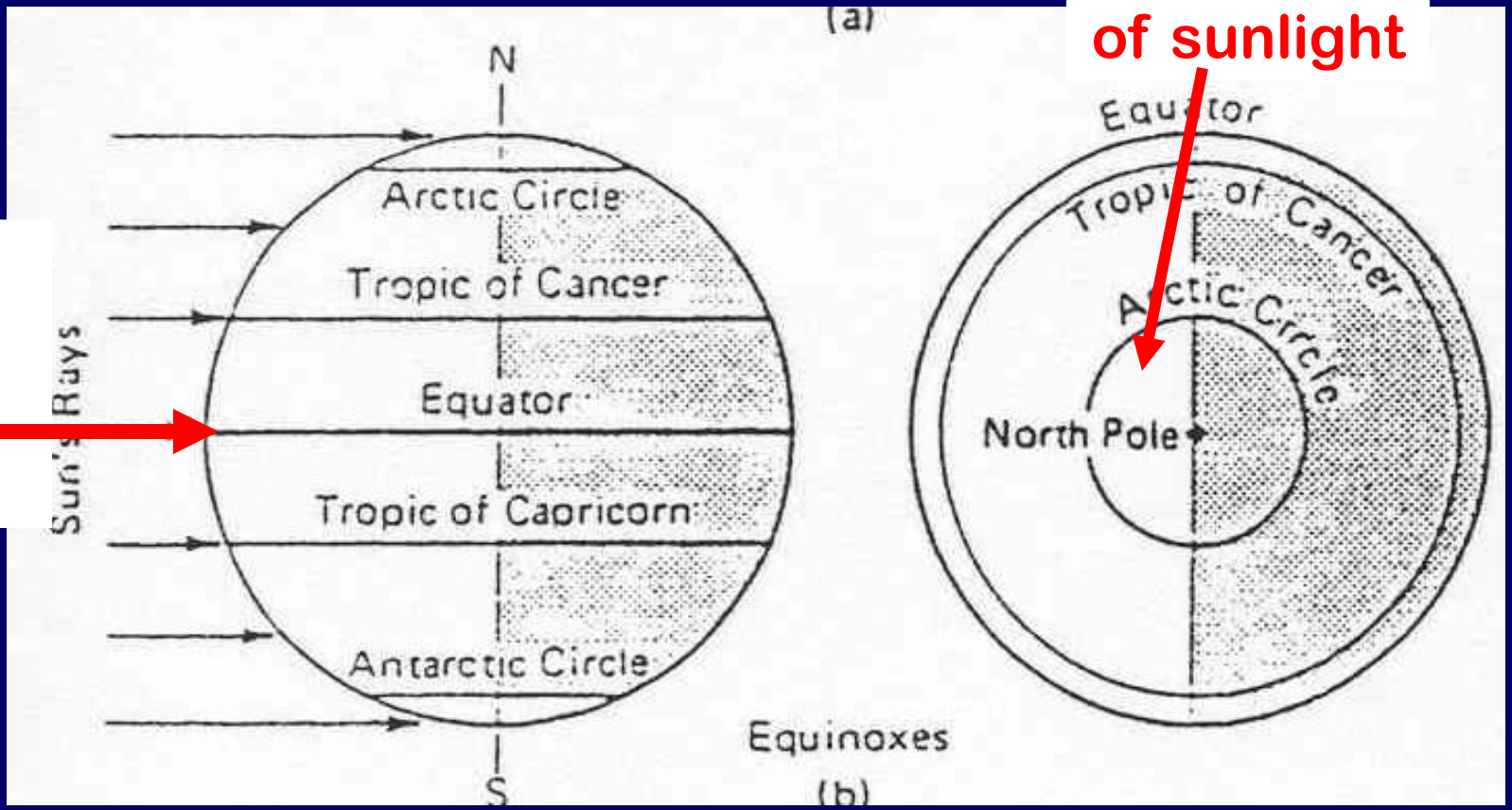


. . . but same latitudinal insolation as March Equinox

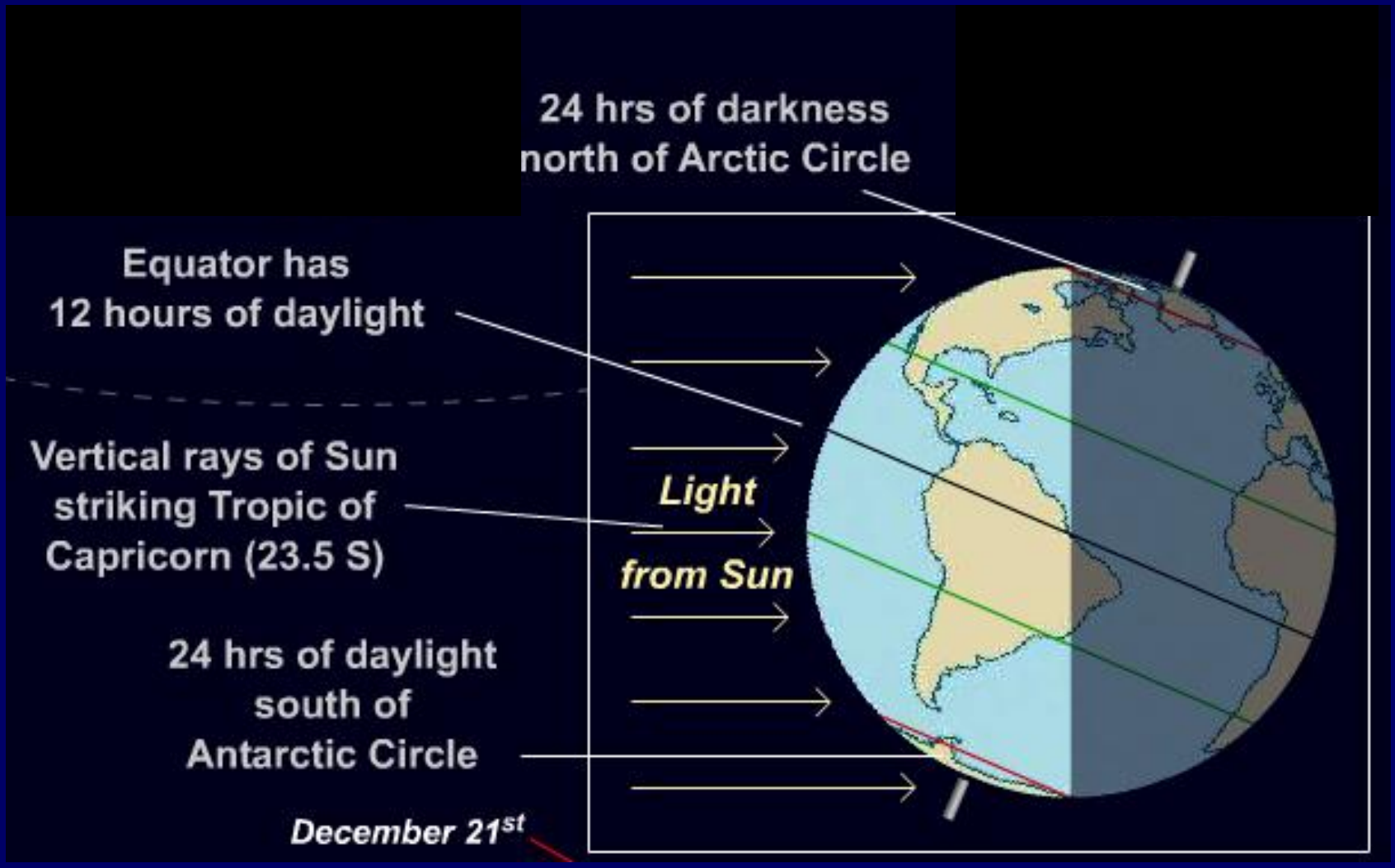
MARCH & SEPTEMBER EQUINOXES

12 hours of sunlight

Most intense solar radiation



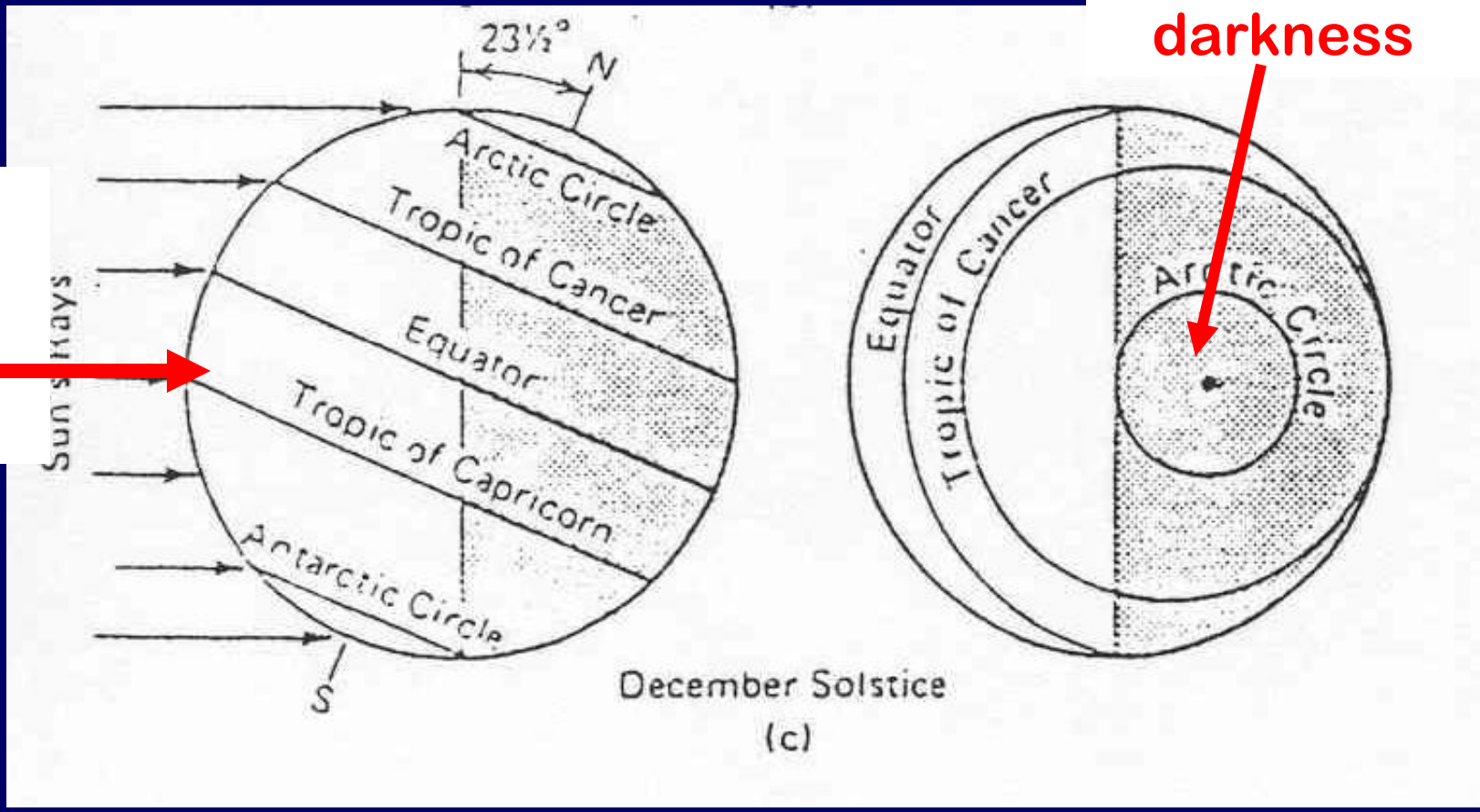
DECEMBER SOLSTICE



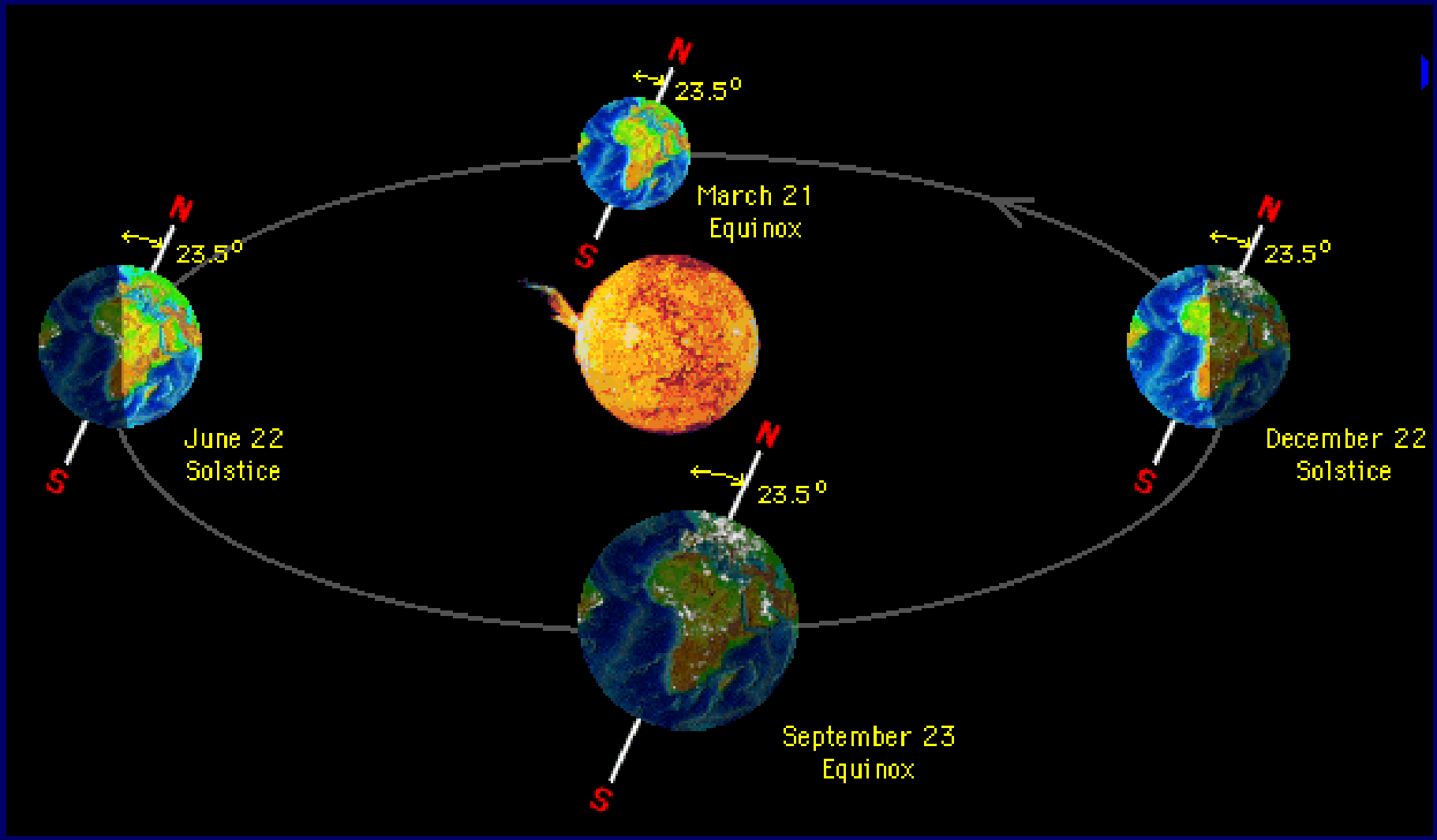
DECEMBER SOLSTICE

24 hours of darkness

Most intense solar radiation

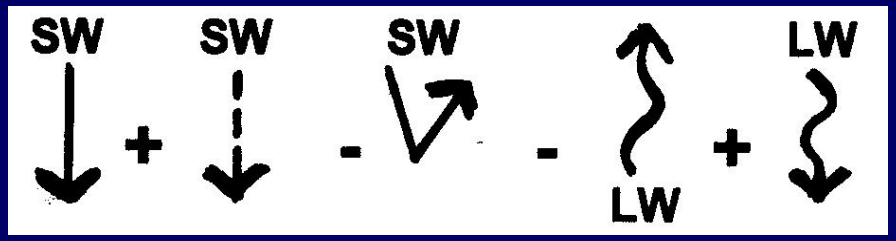


http://mesoscale.agron.iastate.edu/agron206/animations/01_EarthSun.html



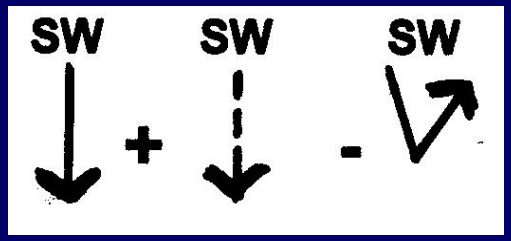
Recap

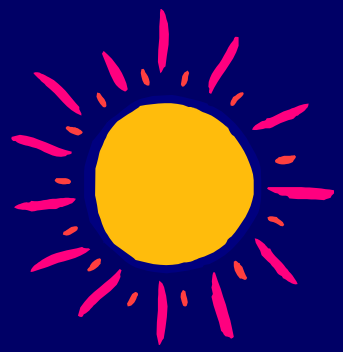
THE RADIATION BALANCE

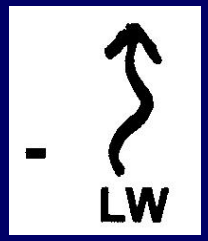


& THE GENERAL CIRCULATION OF THE ATMOSPHERE

HOW IT ALL FITS TOGETHER:







Over the course of a year . . .

The amount of **INCOMING SW** (Insolation) absorbed by EARTH **varies by LATITUDE**

(MORE comes in near the Equator, less near the Poles)

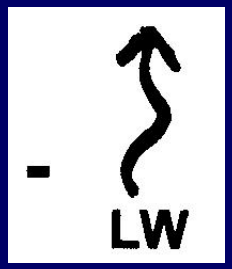
➔ **LOW LATITUDES** absorb <u>MORE</u> energy than **HIGH LATITUDES**

The amount of outgoing **TERRESTRIAL LW / IR** varies by latitude too --

<u>MORE</u> **LW / IR** is emitted at warmer **LOW LATITUDES**, <u>LESS</u> in cooler **HIGH LATITUDES**

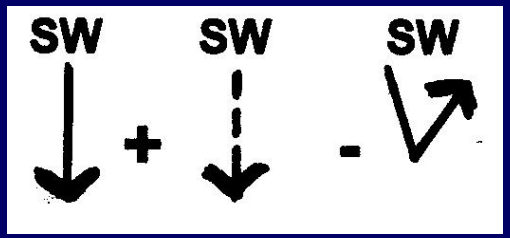
HOWEVER . . .

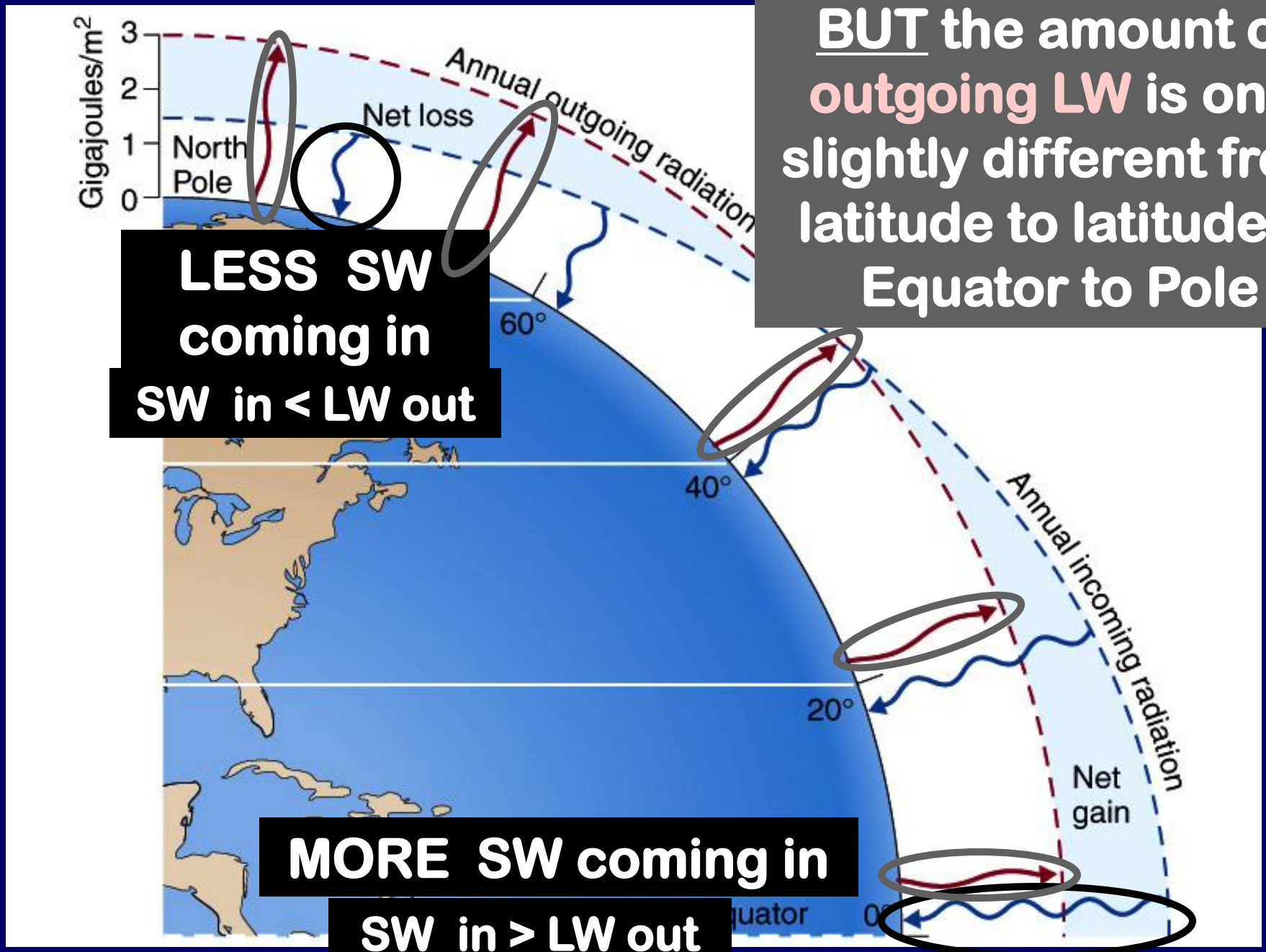
The EQUATOR-POLE DIFFERENCES of what goes OUT from the EARTH



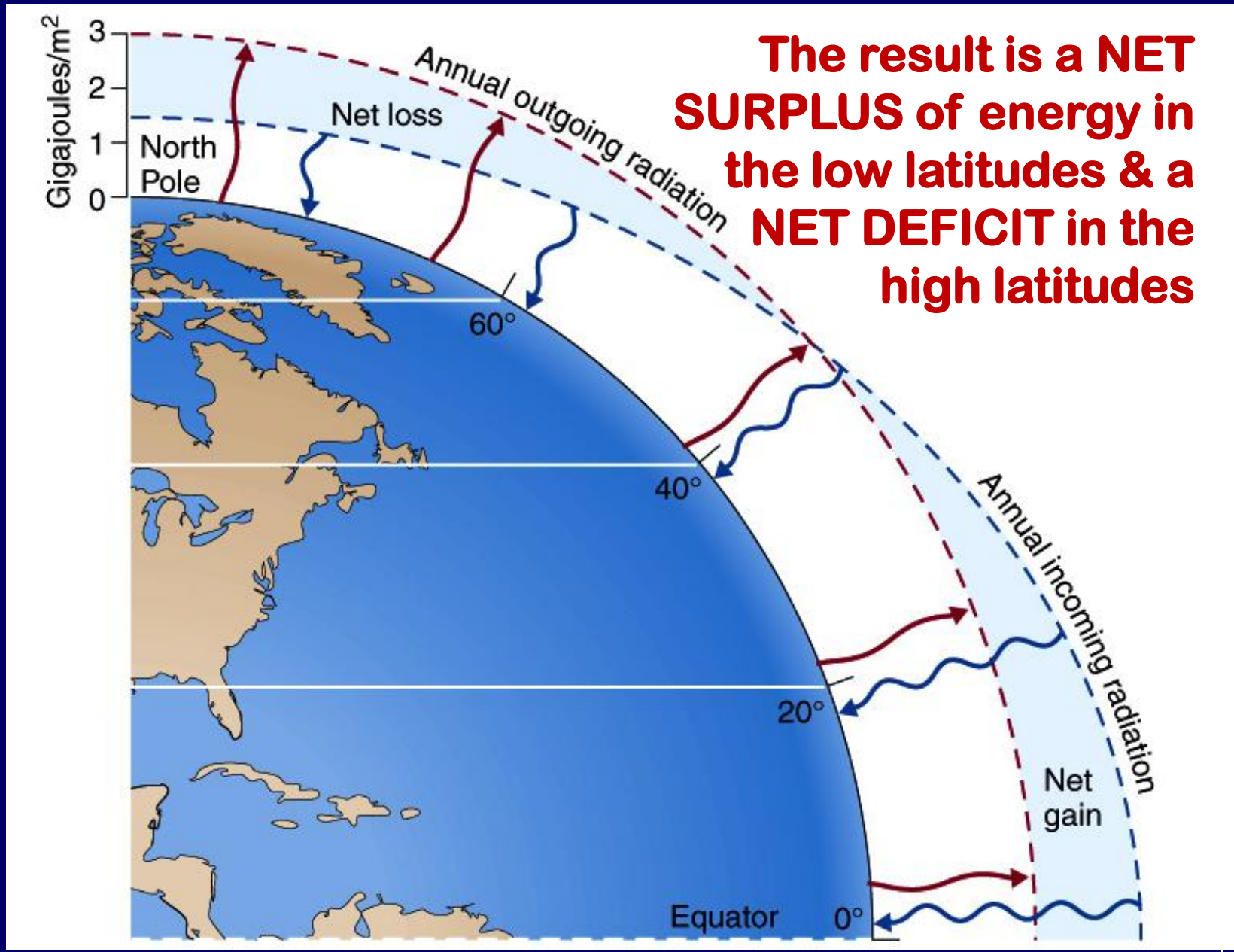
are less than the

EQUATOR-POLE DIFFERENCES of what comes IN from the SUN

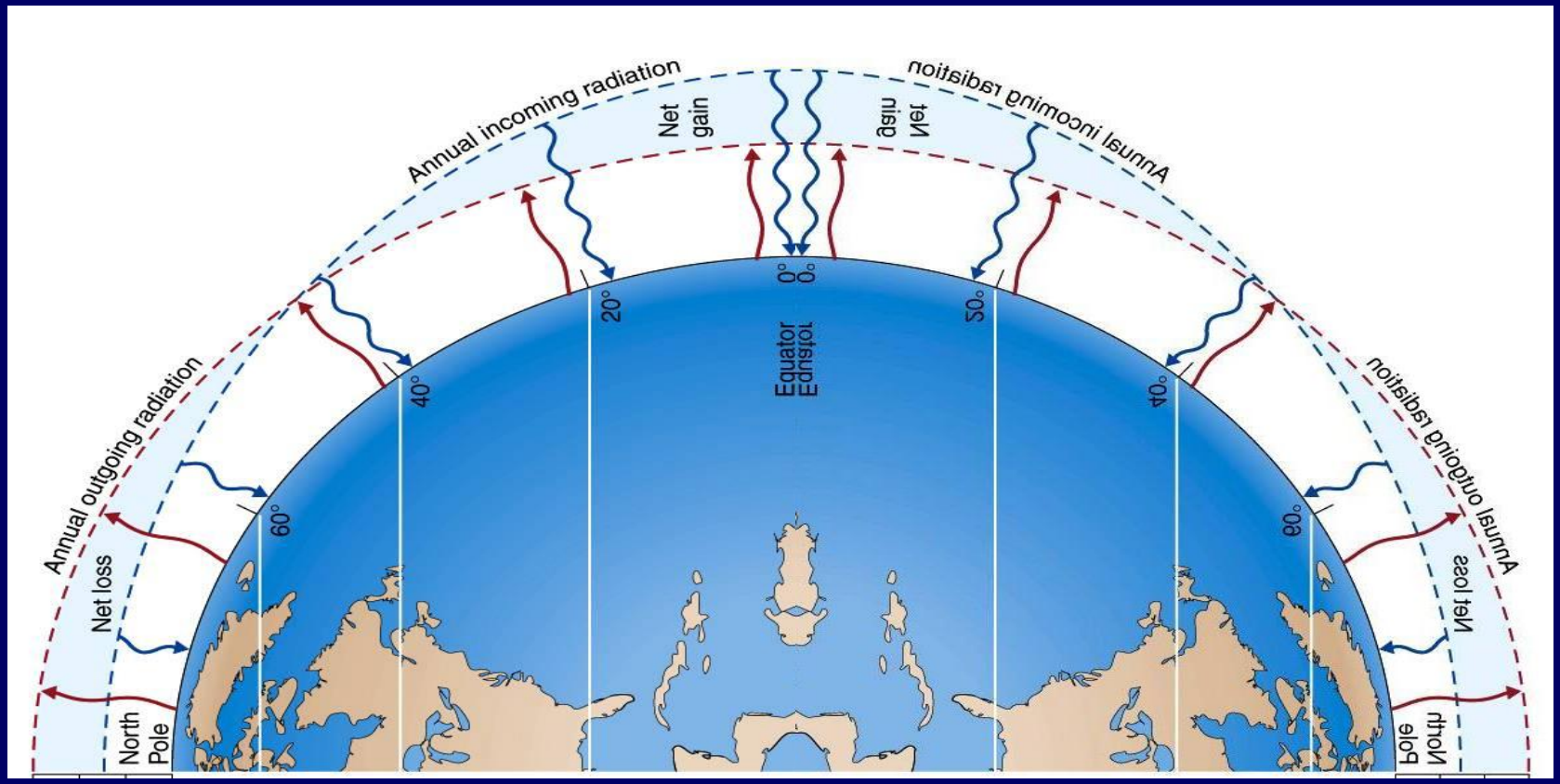




BUT the amount of outgoing LW is only slightly different from latitude to latitude & Equator to Pole

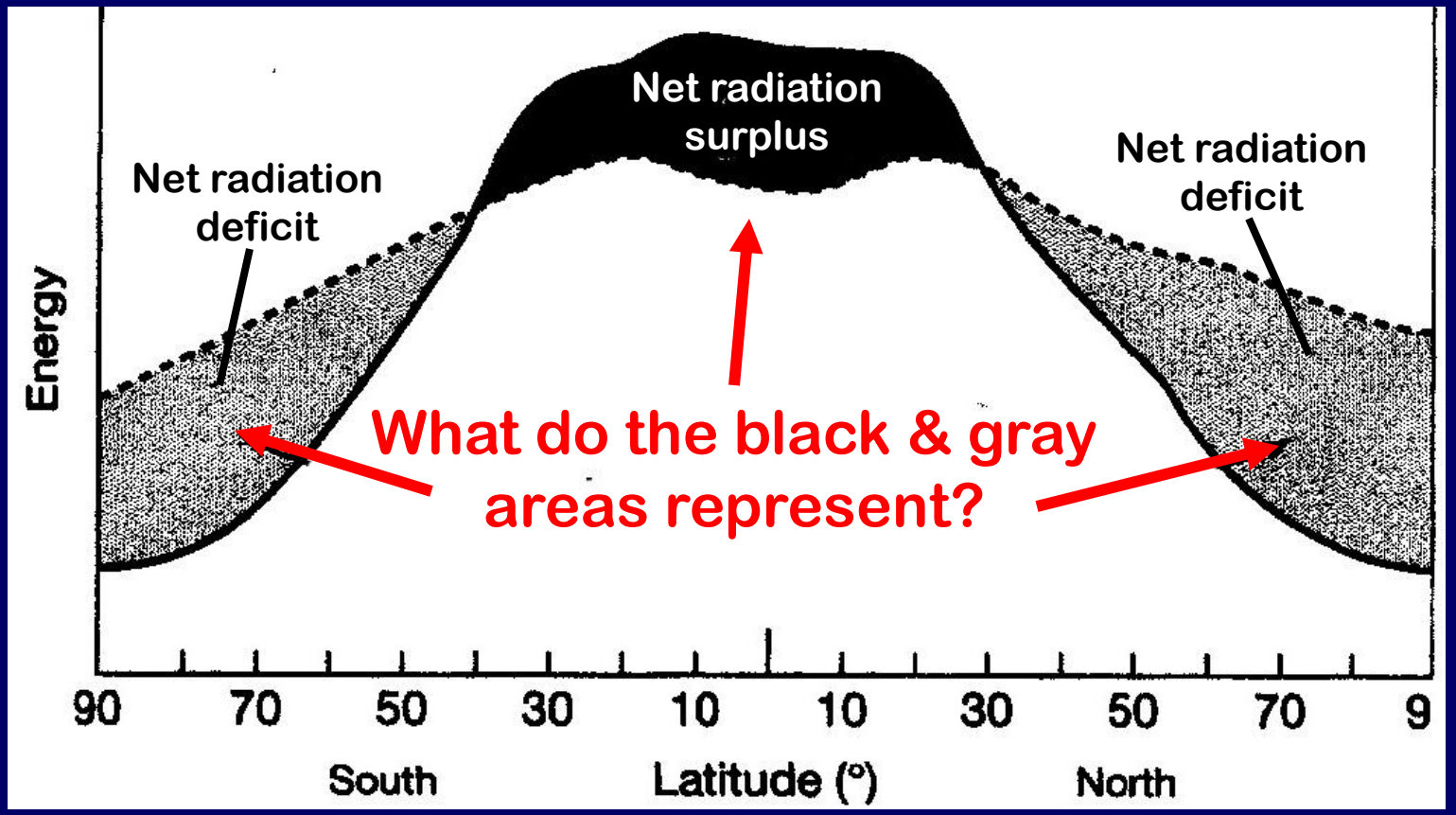


The result is a NET SURPLUS of energy in the low latitudes & a NET DEFICIT in the high latitudes



POLE **EQUATOR** **POLE**

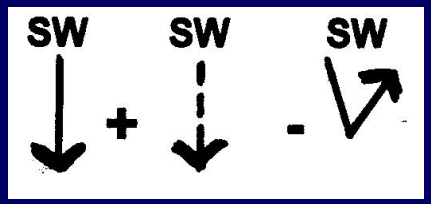
Here's the same Figure re-arranged to see it in a Pole to Pole Transect



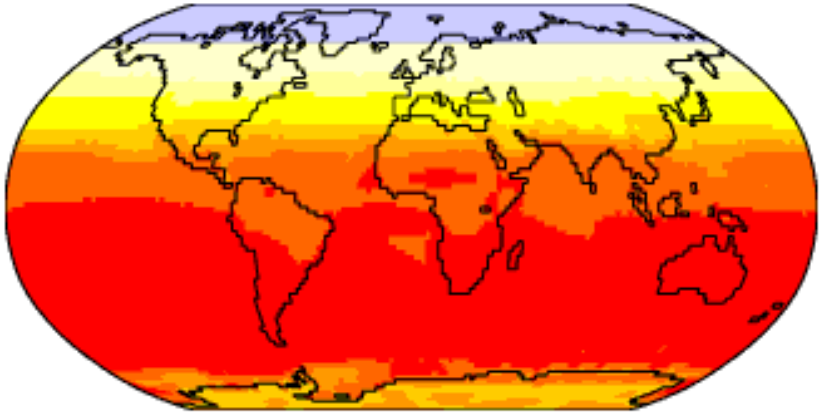
Absorbed solar energy

Emitted infrared energy

(at top of atmosphere)



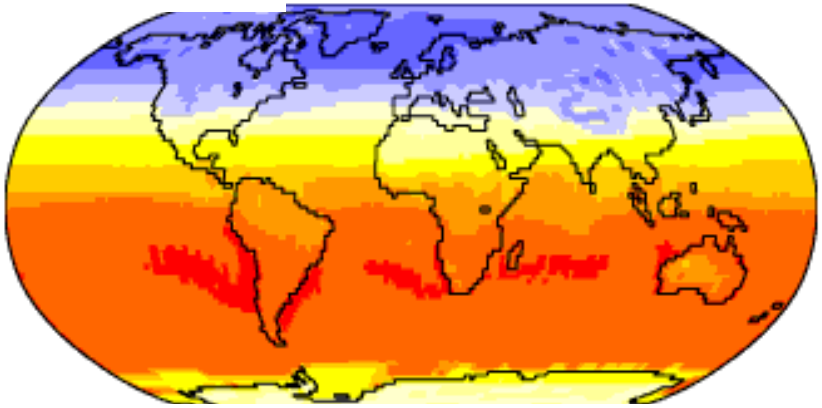
Short-Wave Radiation



Dec

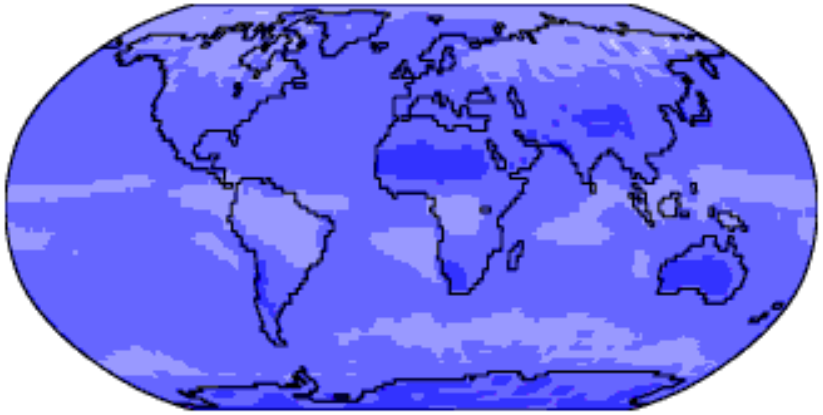
Absorbed solar energy

SW + SW - SW



Net Radiation R_{NET}

Long-Wave Radiation



\- LW

Emitted infrared energy

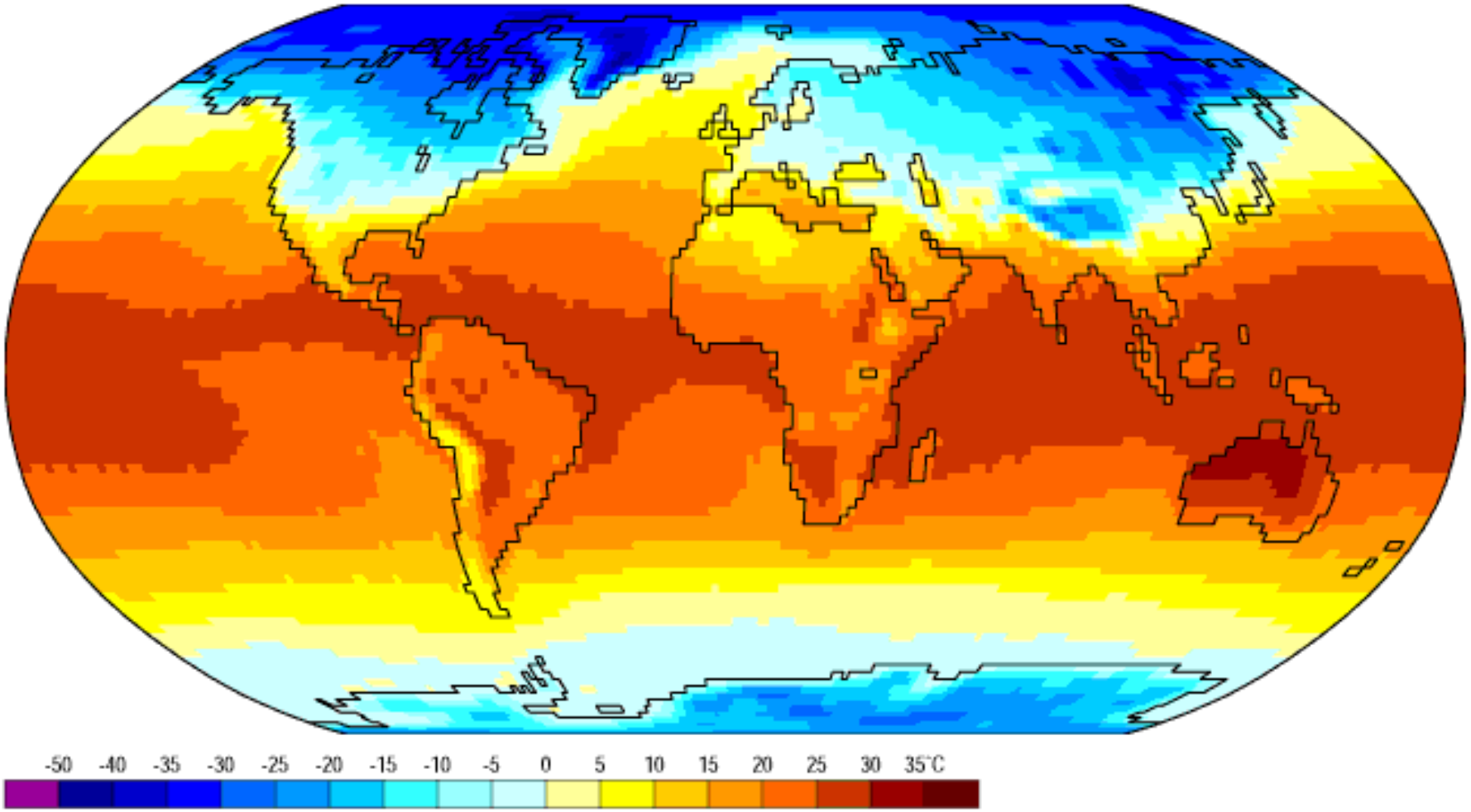
-100 -50 -25 0 25 50 100 125 150 200 W/m**2

Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000

CLICK THE LINK BELOW TO SEE MONTH-to-MONTH ANIMATIONS OF THESE MAPPED PATTERNS:

http://geography.uoregon.edu/envchange/clim_animations/

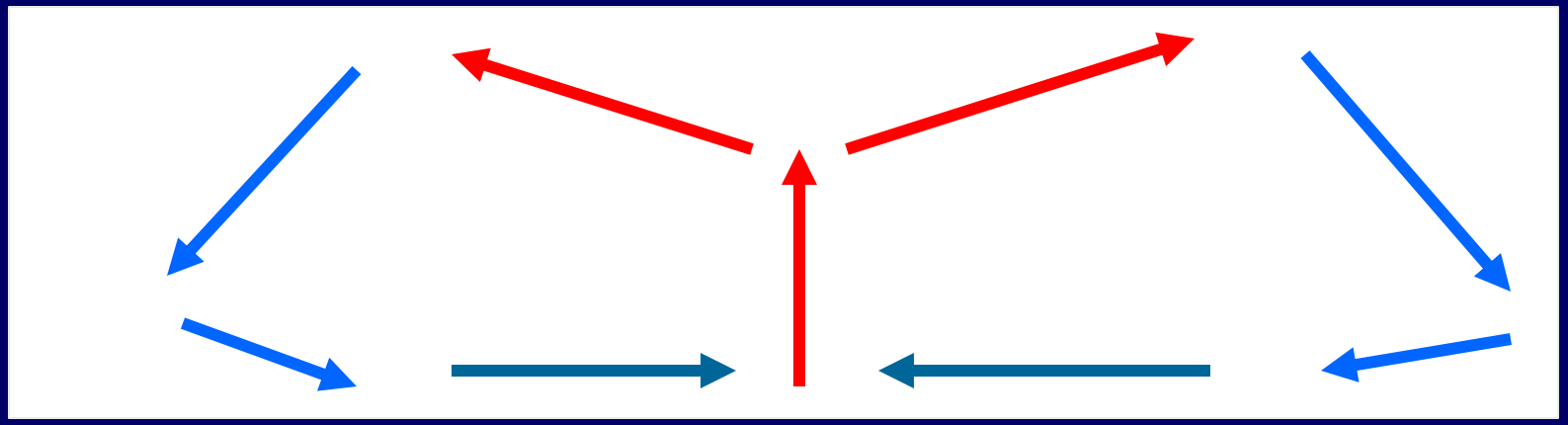
Surface Air Temperature



Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000

http://geography.uoregon.edu/envchange/clim_animations/

Global-scale air motions are driven by thermal differences:



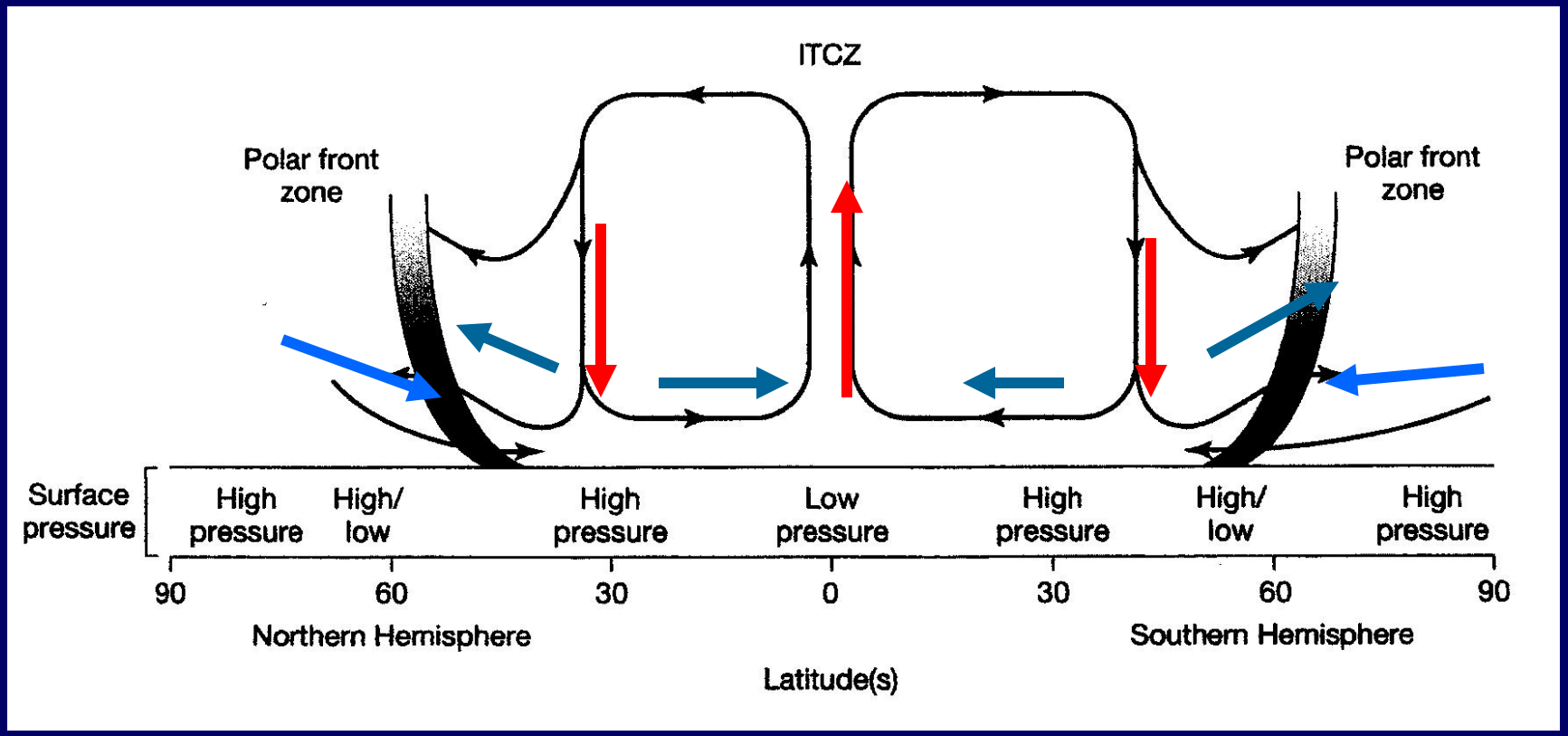
90 60 30 0 30 60 90

Northern Hemisphere | EQUATOR | Southern Hemisphere

COLD POLAR REGIONS

HOT TROPICS

COLD POLAR REGIONS



COLD POLAR REGIONS

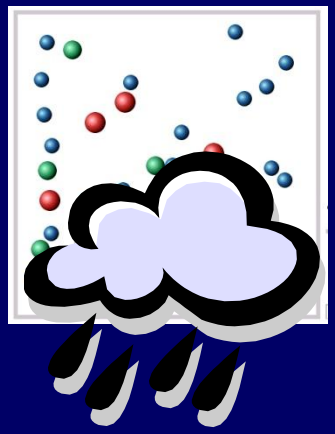
HOT TROPICS

COLD POLAR REGIONS

From SGC Chapter 4

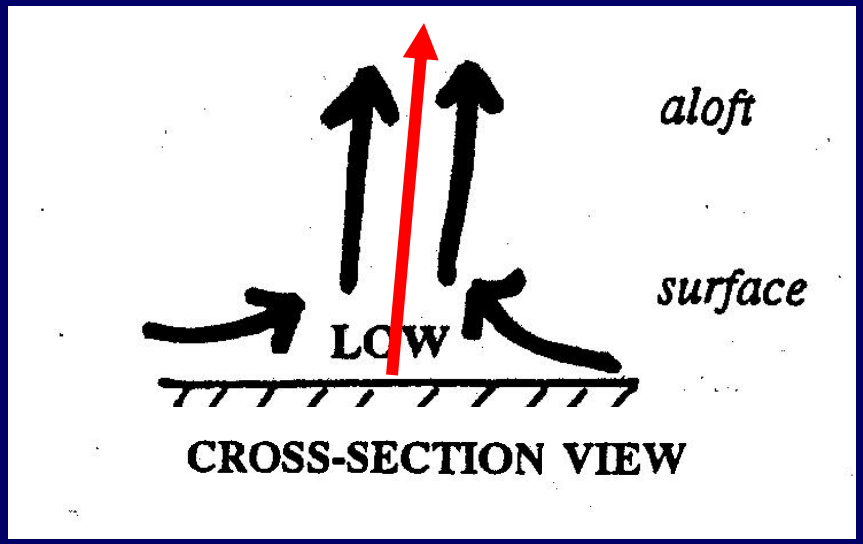
LOW PRESSURE AREAS:

Hot surface ➔ Rising air ➔ **expansion and cooling** of air, and condensation of water vapor



➔ **clouds, and possibly precipitation . . .**

HUMID REGIONS



How do H_2O droplets in warm, tropical clouds coalesce and grow so that they become heavy enough to fall as rain in the ITCZ?

Mini-Break !
Another
DANCE YOUR PH.D!

DANCE YOUR PH.D!

"Precipitation Initiation in Warm Clouds"

This dances shows **how a rain drop can form** when one SLIGHTLY LARGER RAIN DROP is present among a population of smaller drops.

In the tropics, really large drops (heavy enough to fall as rain) only form after mixing occurs.

Men are Condensation nuclei

Women are H_2O droplets

In the "mixing process" the H_2O droplets connect with "condensation nuclei partners"

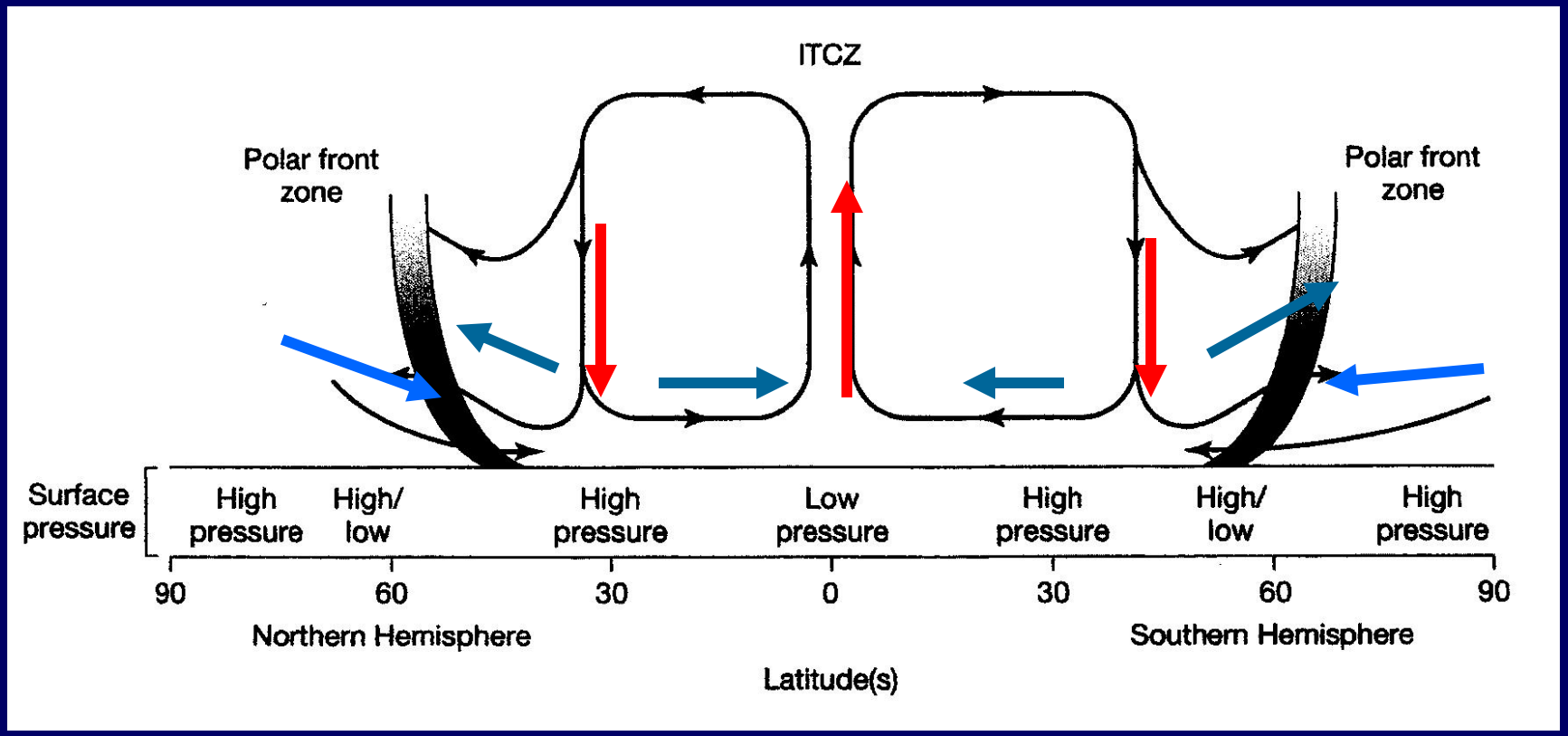
. . . but eventually some H_2O's abandon their original nuclei for a larger one!

Through "coalescence" a single nucleus attracts all the other water droplets !

When the H_2O droplet grows large enough . . .

. . . RAIN FALLS!

http://www.youtube.com/watch?v=4O7G7F_e7I0



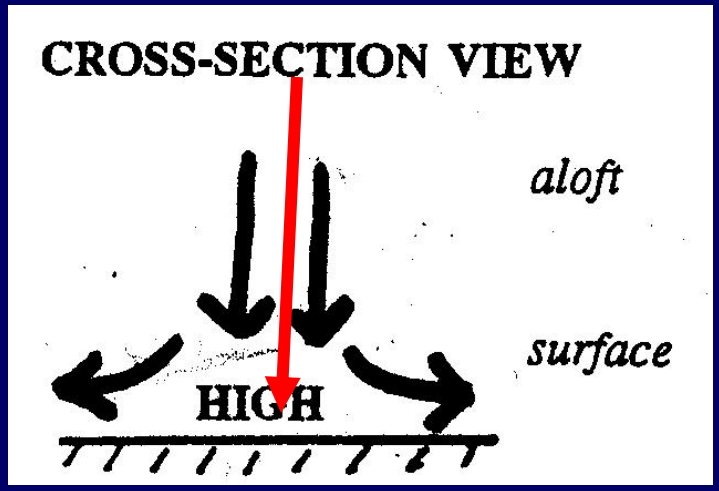
COLD POLAR REGIONS

HOT TROPICS

COLD POLAR REGIONS

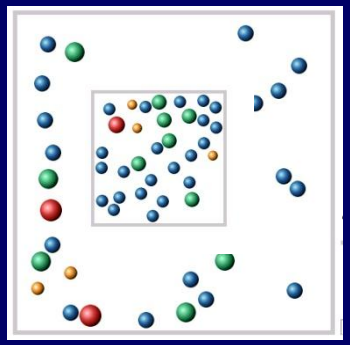
From SGC Chapter 4

The opposite of rain = subsidence (sinking air) In HIGH PRESSURE ares!



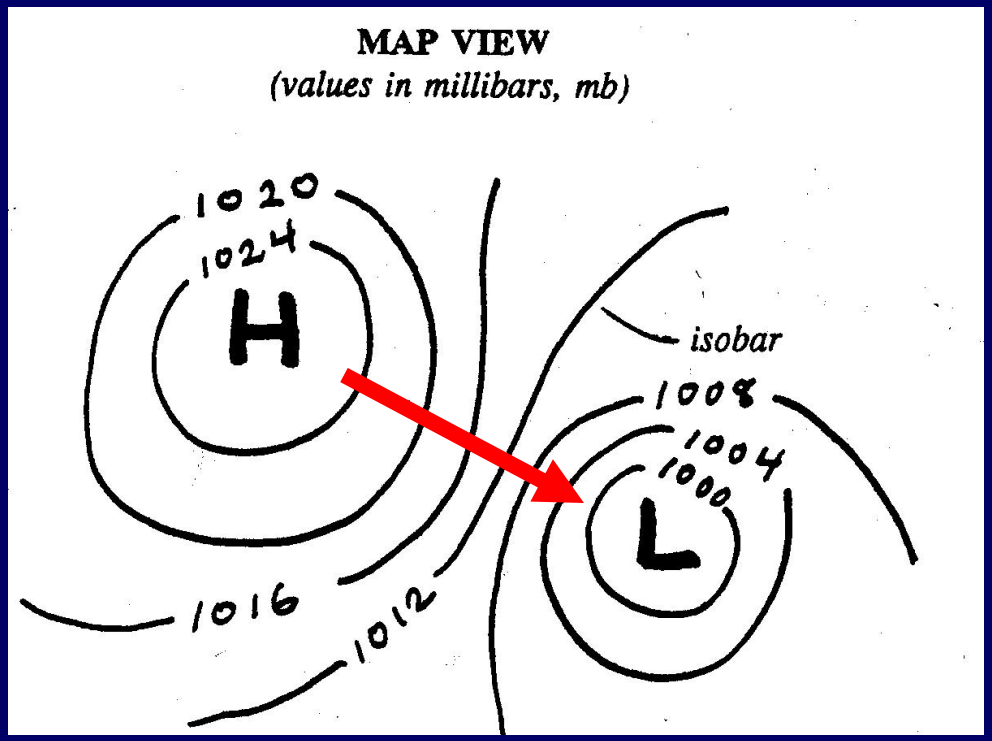
HIGH PRESSURE AREAS:

Forced sinking
(e.g. in HADLEY CELL)
leads to "**compaction" and warming of the sinking air**

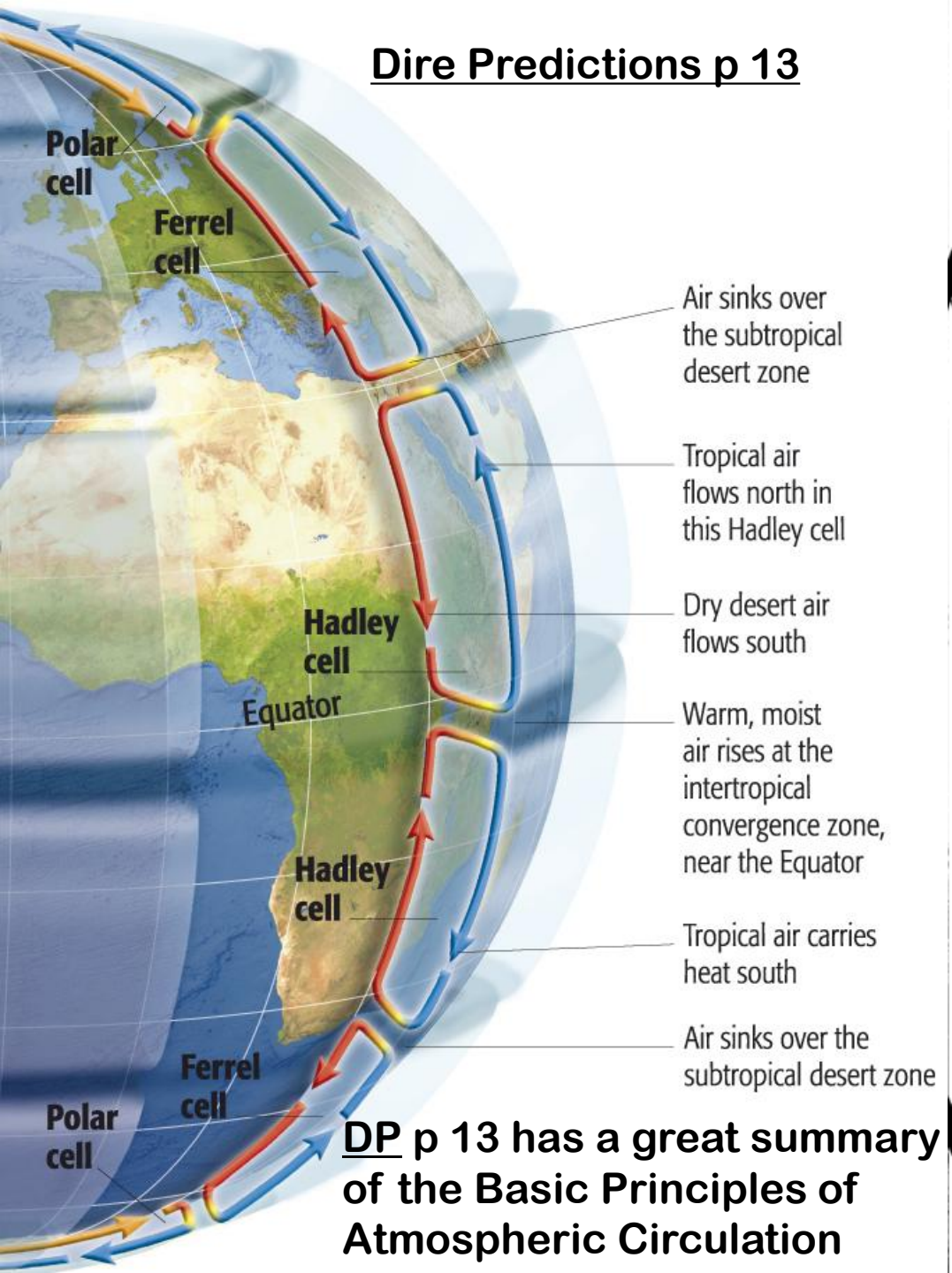


Air warms → increase in the water vapor holding capacity
→ clear skies, dry air and
ARID REGIONS / DESERTS!

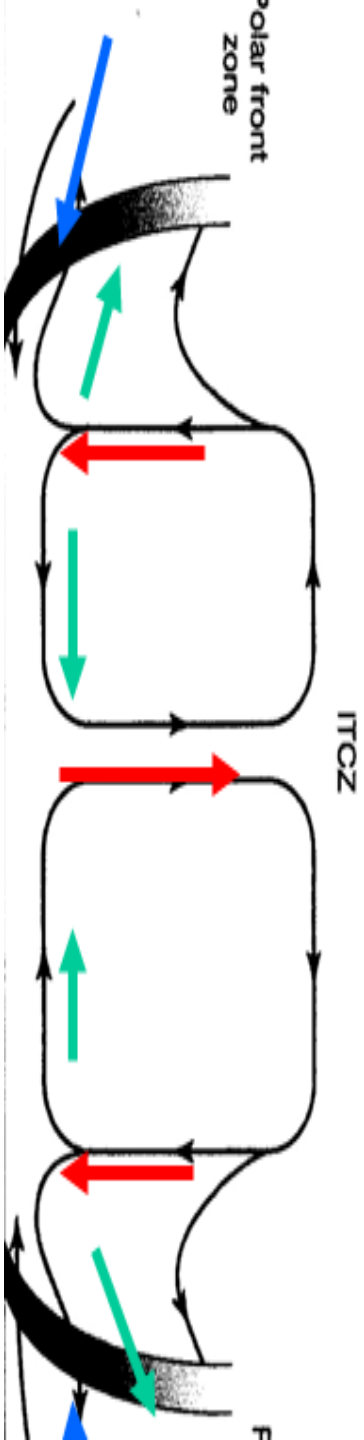
In general: **surface winds tend to flow from HIGH Pressure to LOW Pressure areas**



Dire Predictions p 13



DP p 13 has a great summary of the Basic Principles of Atmospheric Circulation

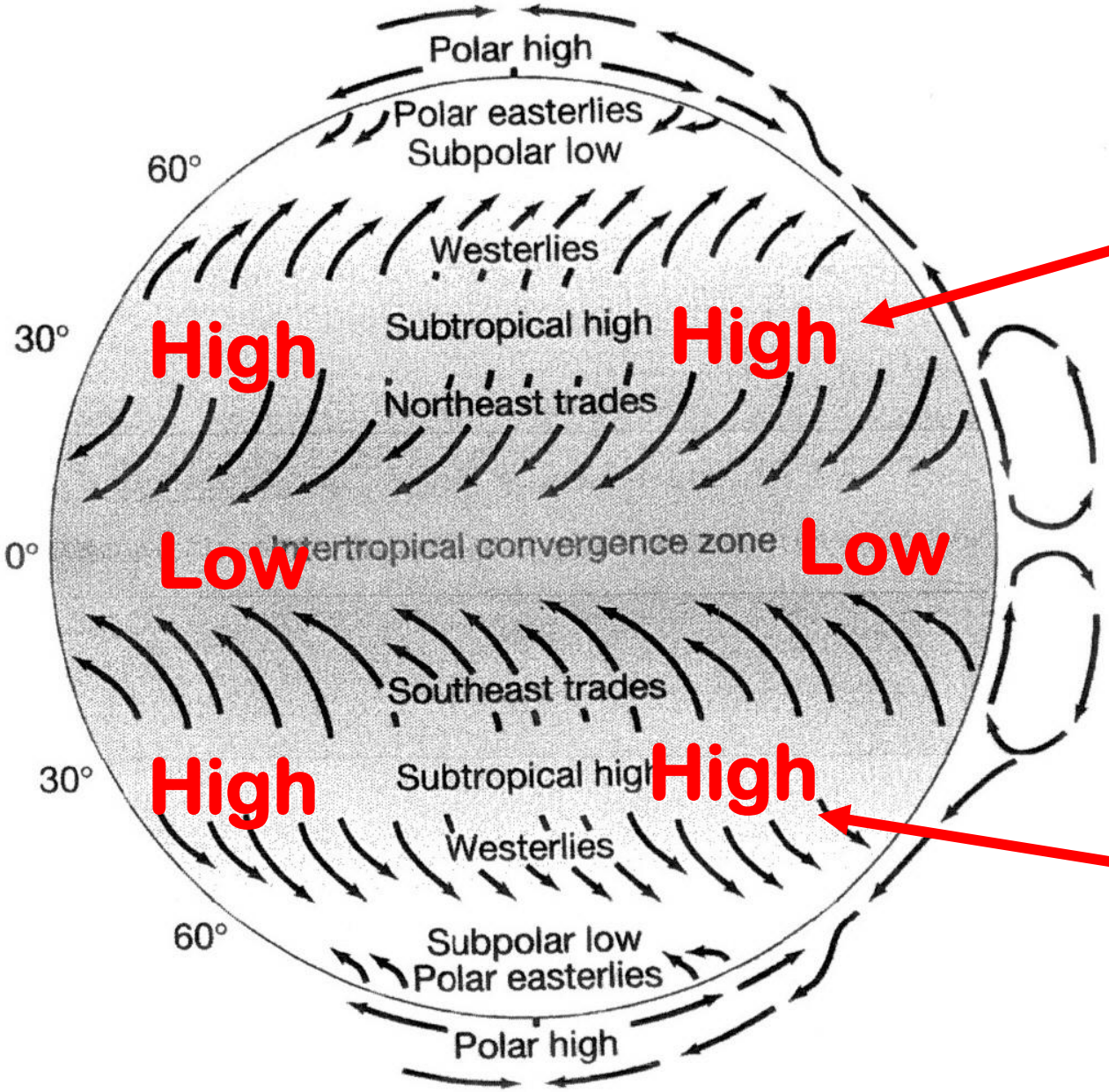


cold polar air
vs.
warm low lat air

sinking dry subtropical air

sinking dry subtropical air

warm low lat air
vs.
cold polar air

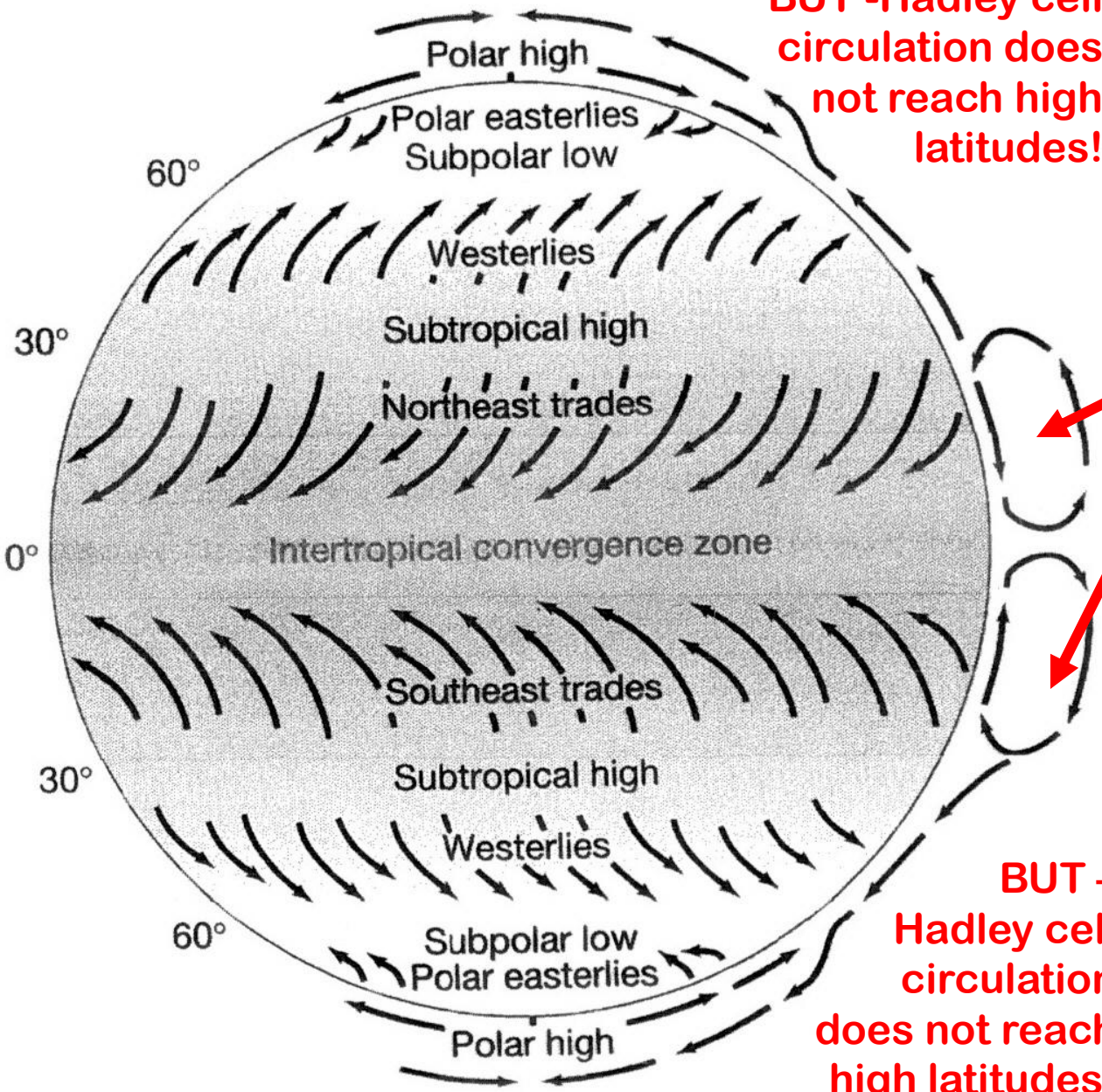


Sub-tropical HIGH PRESSURE

Intertropical Convergence ITCZ (low pressure)

Sub-tropical HIGH PRESSURE

From SGC Ch 4



BUT -Hadley cell circulation does not reach high latitudes!

BUT – Hadley cell circulation does not reach high latitudes!

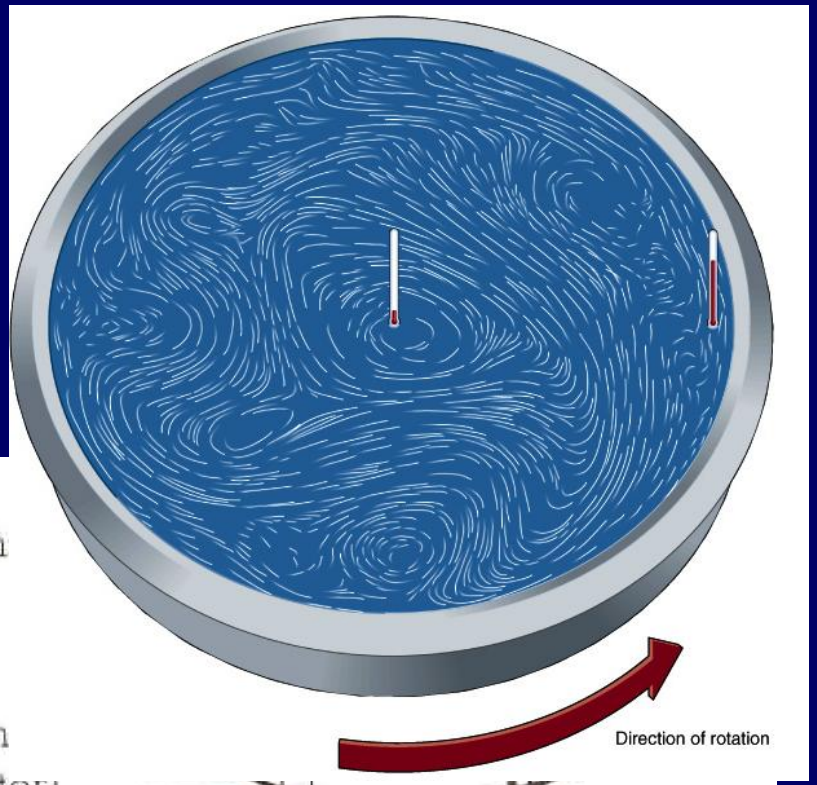
Hadley Cells transport warm air poleward as SENSIBLE HEAT

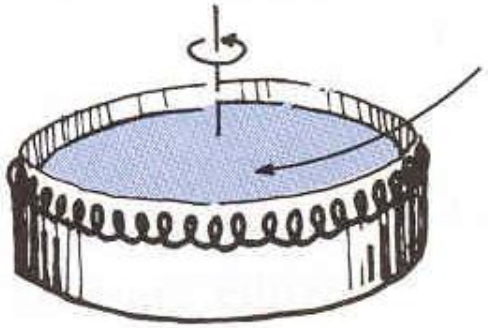
HADLEY CELLS = key drivers!

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

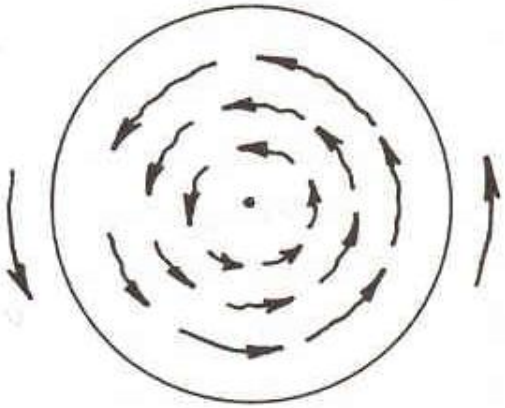
Why Hadley convective cell transport breaks down at higher latitudes:

Back to p 63



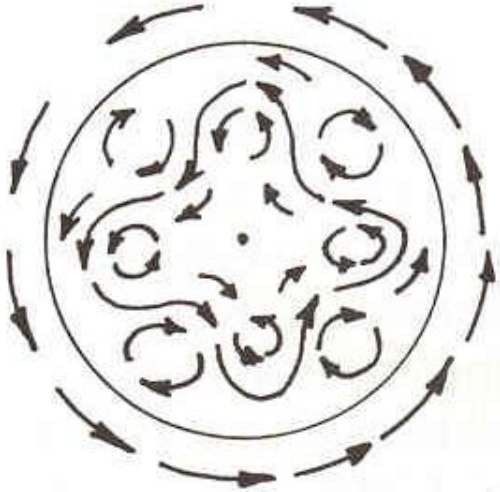


(a) Slow rotation

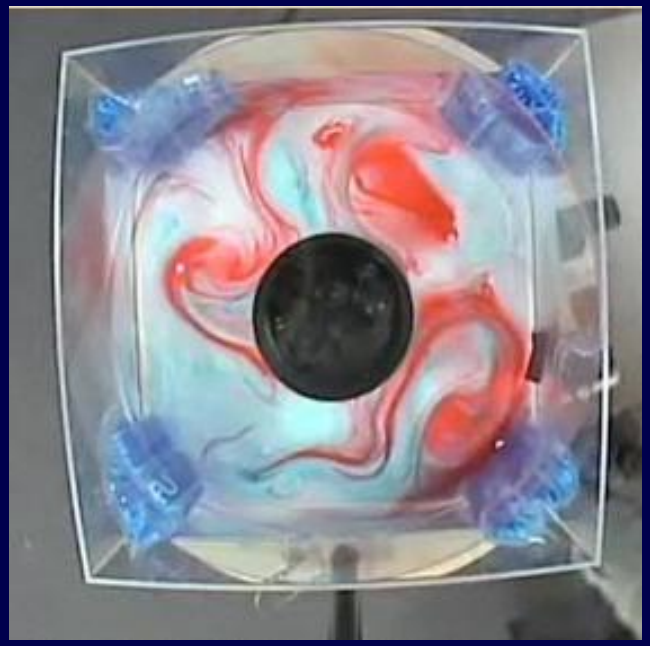


Heatin
(equator)

(b) Faster rotation

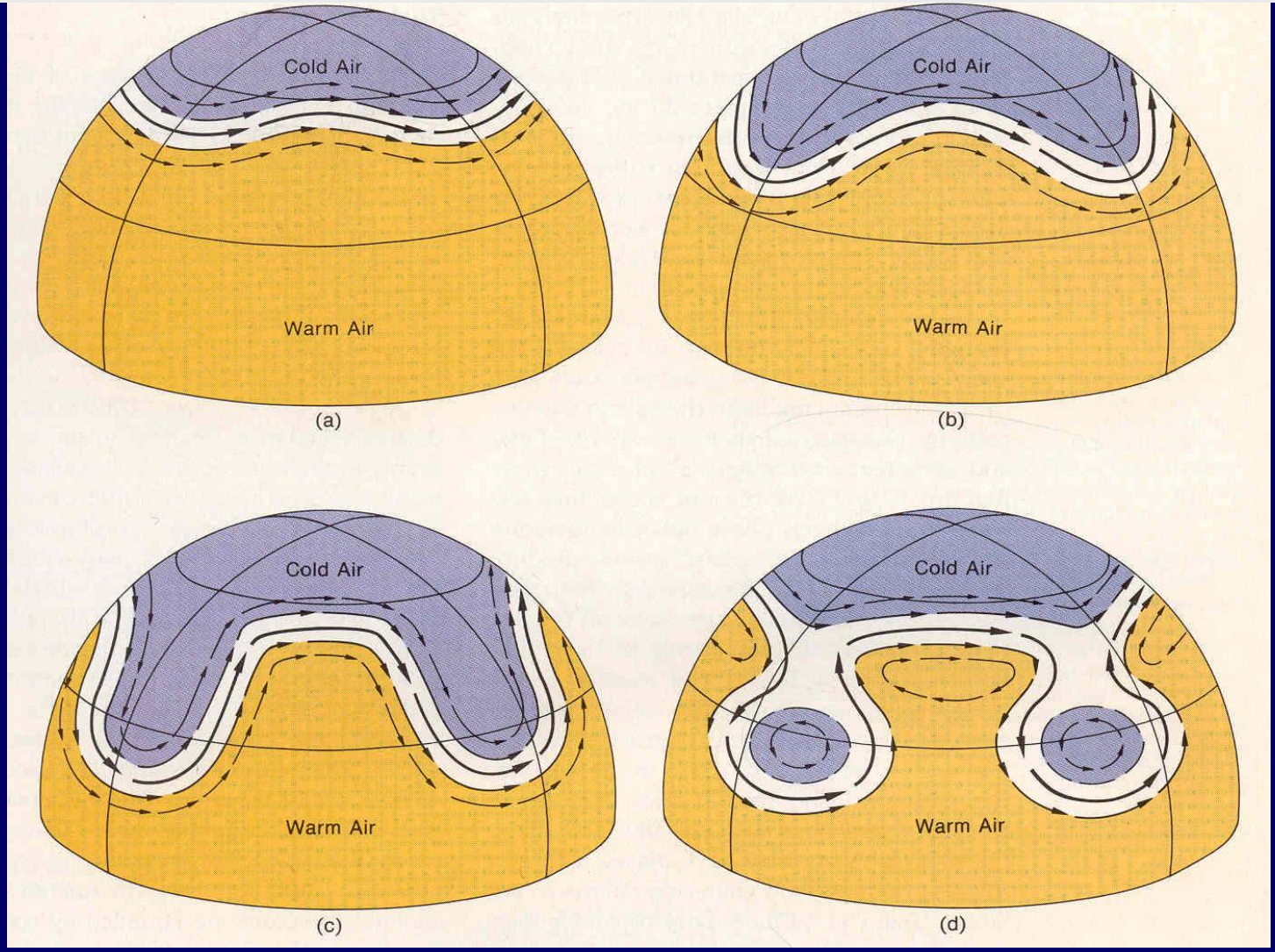


A DEMONSTRATION OF THE DISHPAN



http://www.windows2universe.org/earth/Atmosphere/global_circulation_lsop_video.html

UPPER LEVEL "ROSSBY WAVE" CIRCUMPOLAR WINDS !



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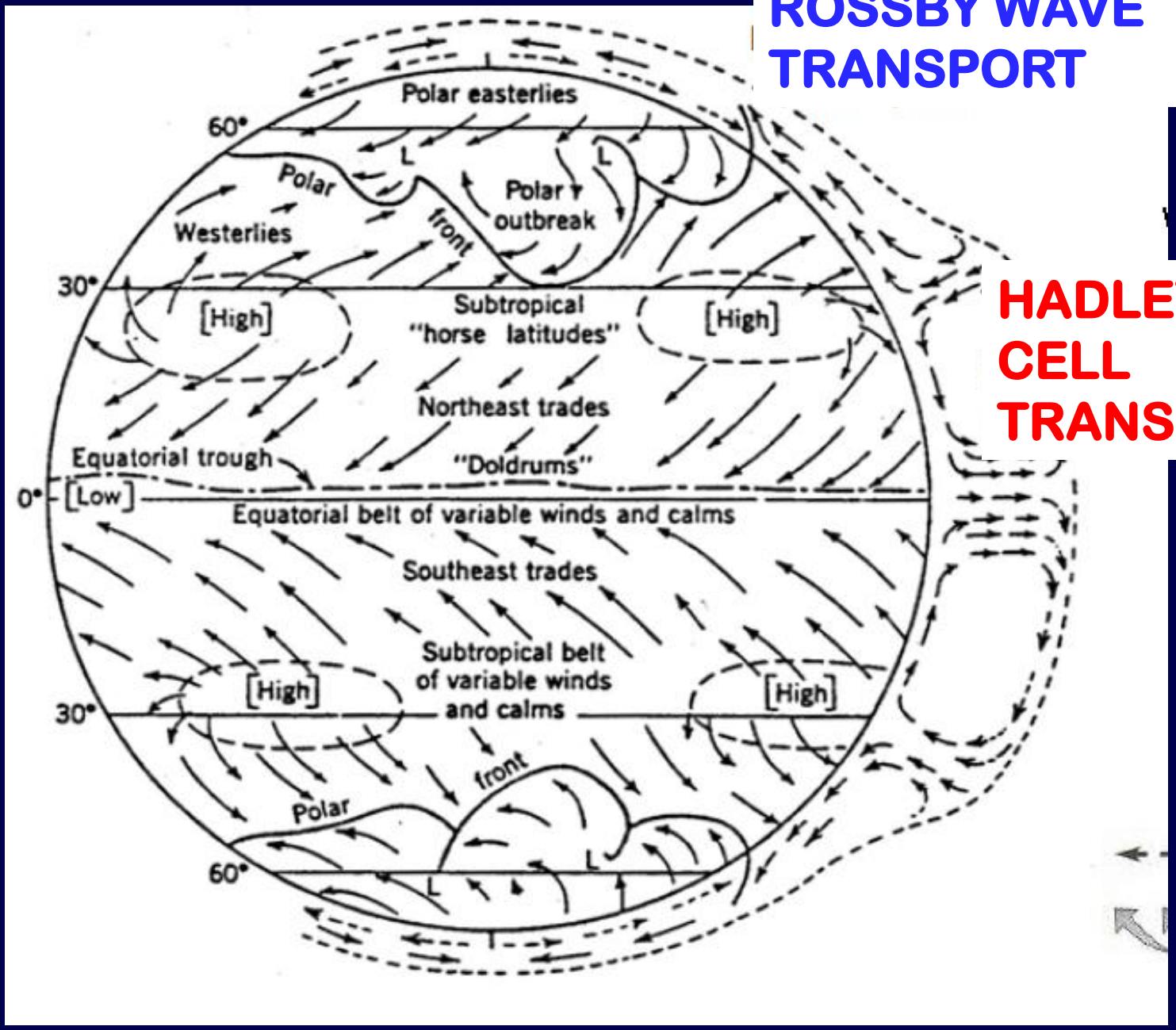
"Wave" transport of SENSIBLE HEAT (in lobes of warm air) instead of Hadley cell transport!

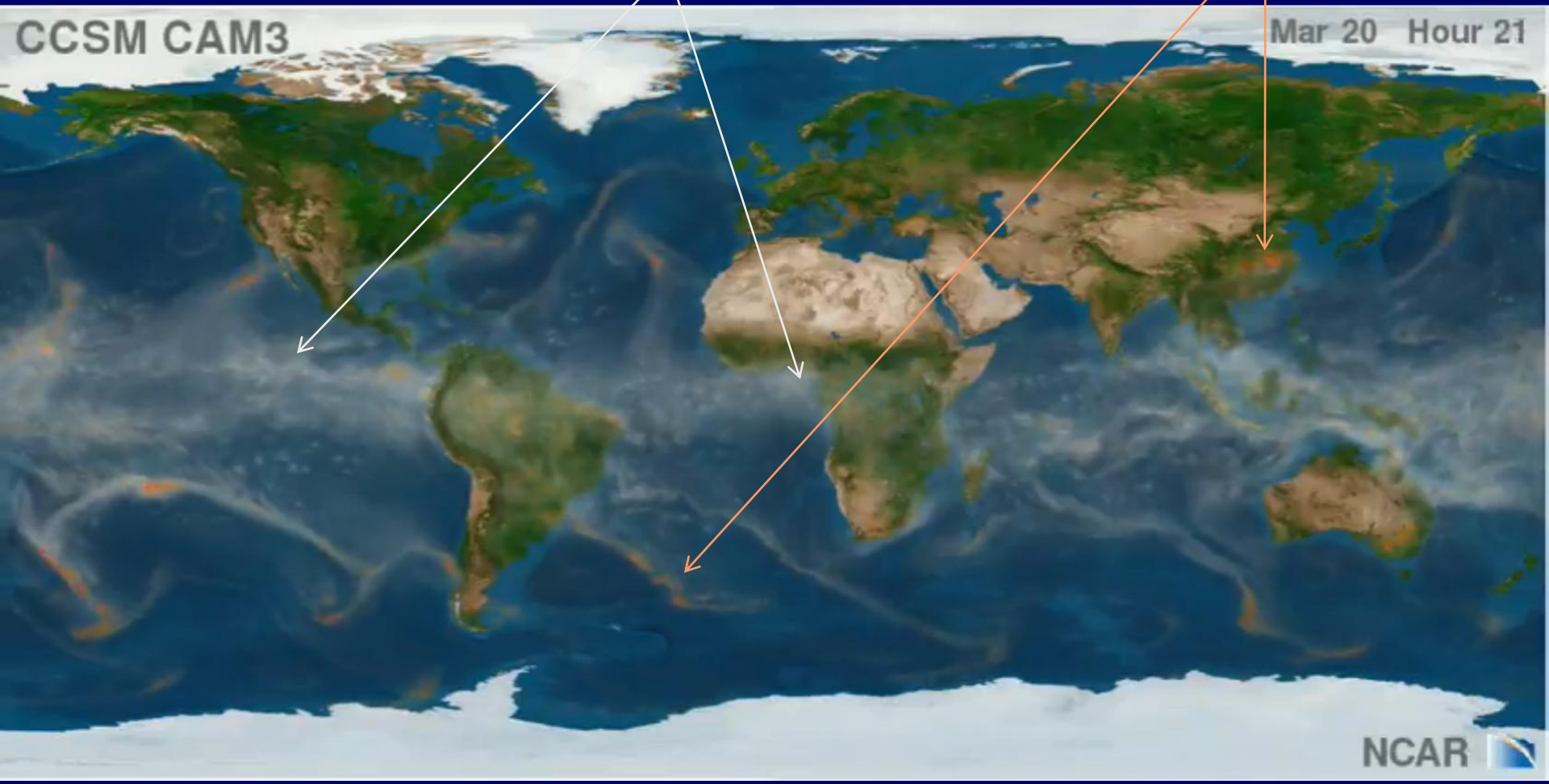
ROSSBY WAVE TRANSPORT



HADLEY CELL TRANSPORT

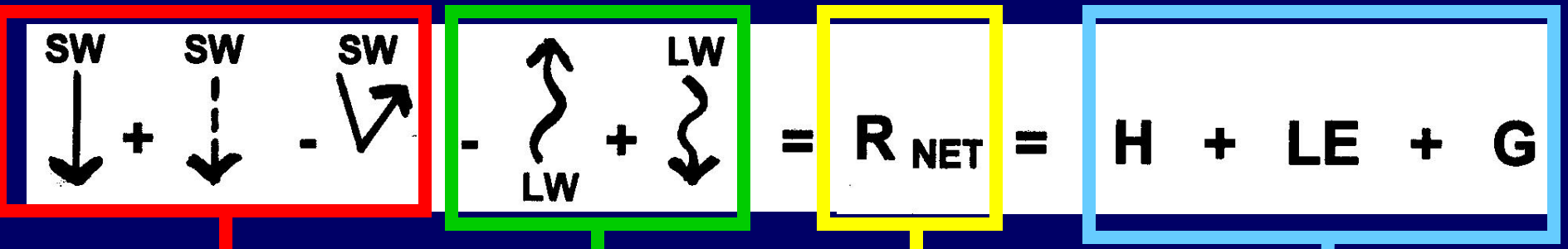
The **Community Climate System Model** (CCSM)
is a coupled climate model for simulating Earth's climate system.
It simulates the earth's atmosphere, ocean, land surface and sea-ice

water vapor = WHITE precipitation rate = ORANGE.



http://www.vets.ucar.edu/vg/T341/index.shtml

ENERGY IN THE EARTH-ATMOSPHERE SYSTEM



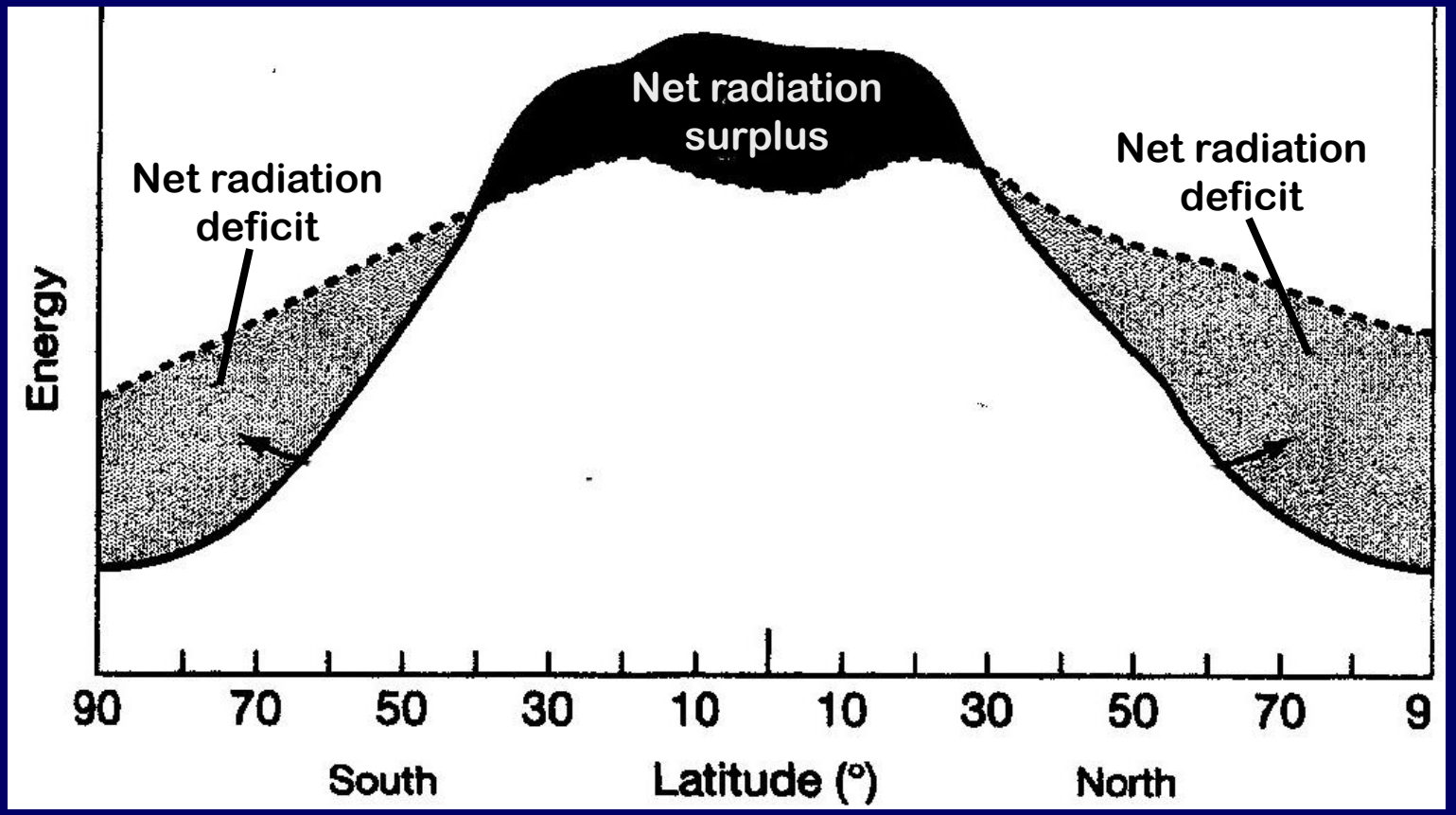
Ultimate source of energy is the SUN (SW)

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 WEATHER & CLIMATE !

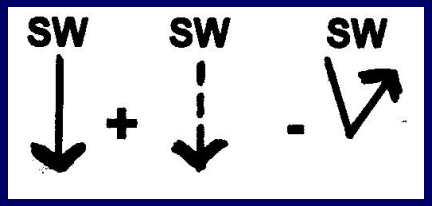
TYING IT ALL TOGETHER!!



Absorbed solar energy

Emitted infrared energy

(at top of atmosphere)



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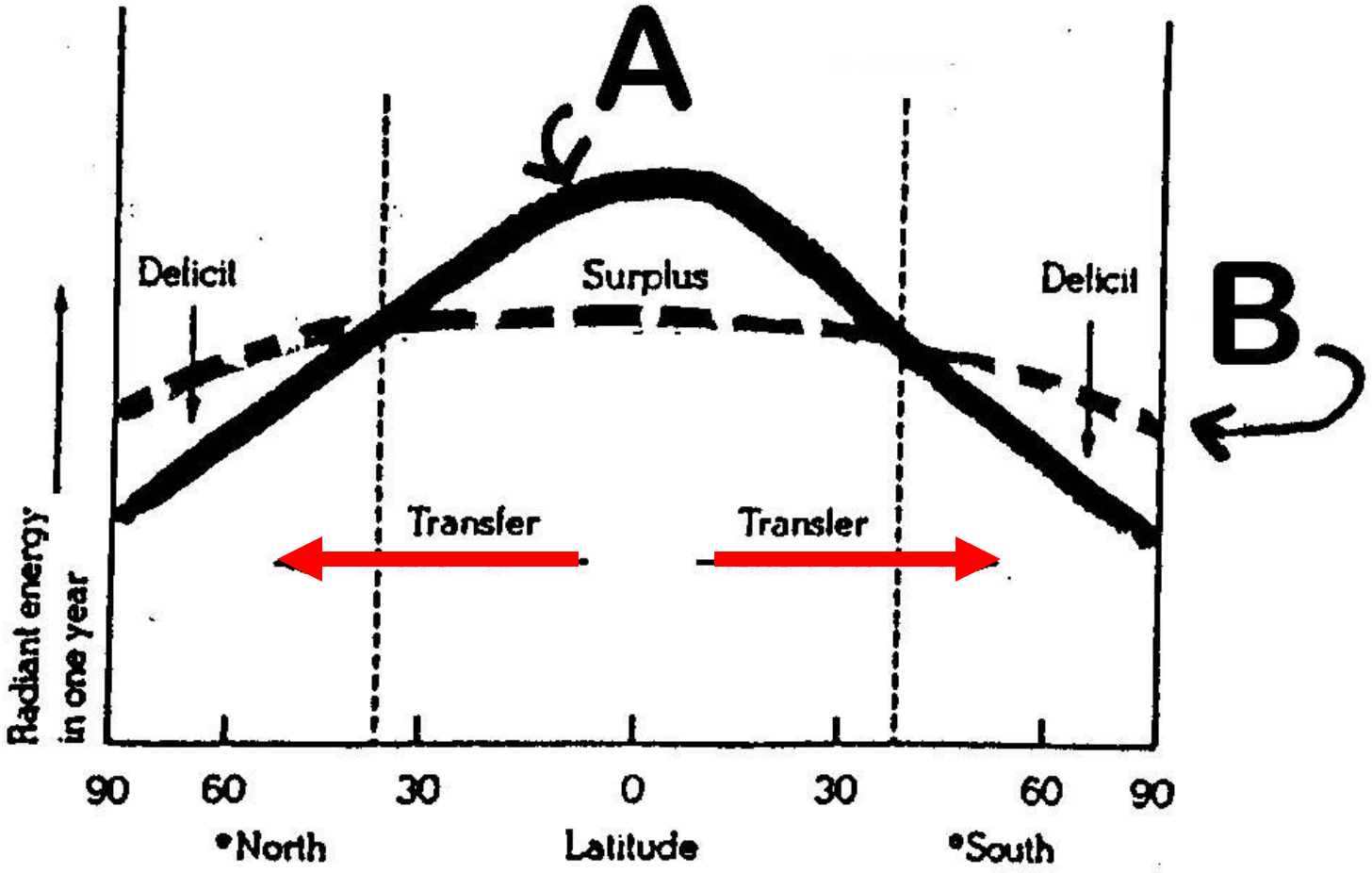
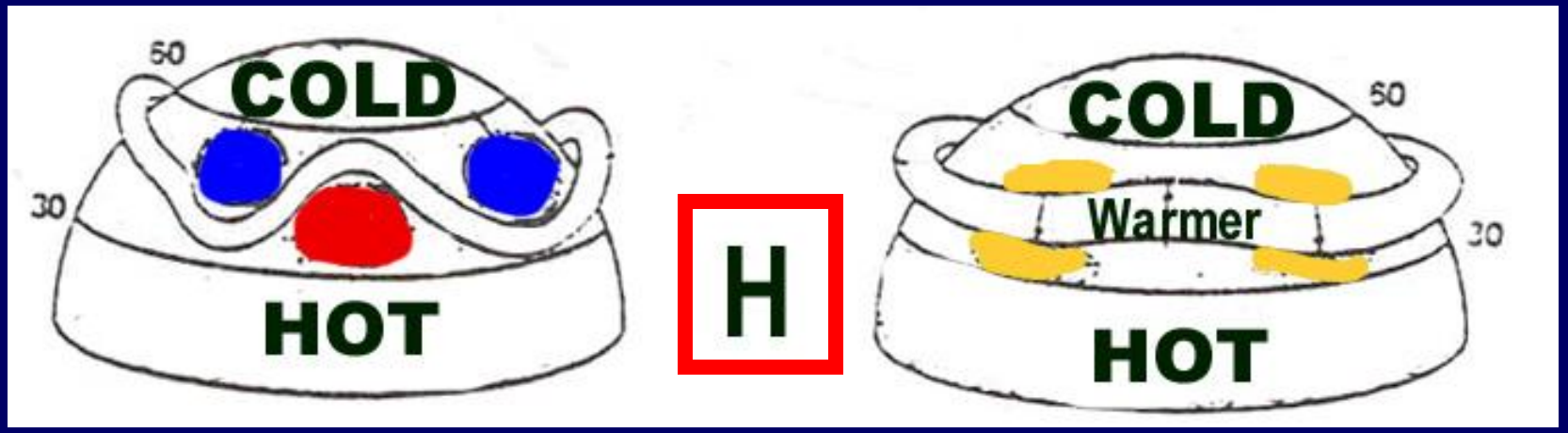


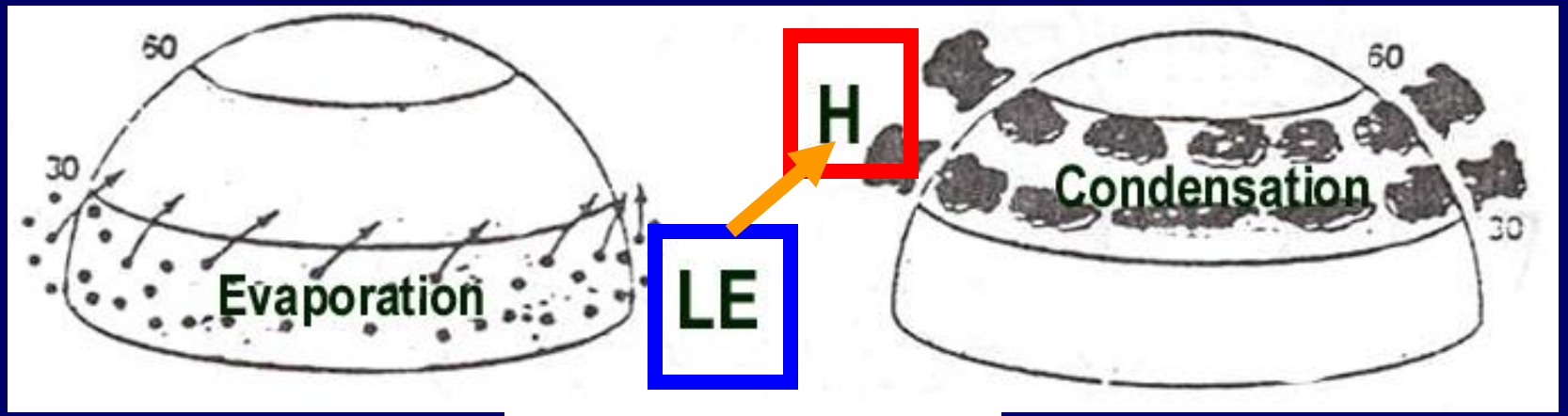
THERMAL ENERGY IS TRANSPORTED FROM LOW → TO HIGH LATITUDES TO BALANCE OUT THE DEFICIT!

Energy is transported from areas of surplus to deficit via:

H (sensible heat)



& LE (Latent Energy)



H + LE

H + LE + G

BUT WHAT ABOUT G ?

To be continued on
Wednesday . . . .