Topic # 12
How Climate Works

A "Primer" on
How the Energy Balance Drives Atmospheric & Oceanic Circulation, Natural Climatic Processes

pp 63-68 in Class Notes

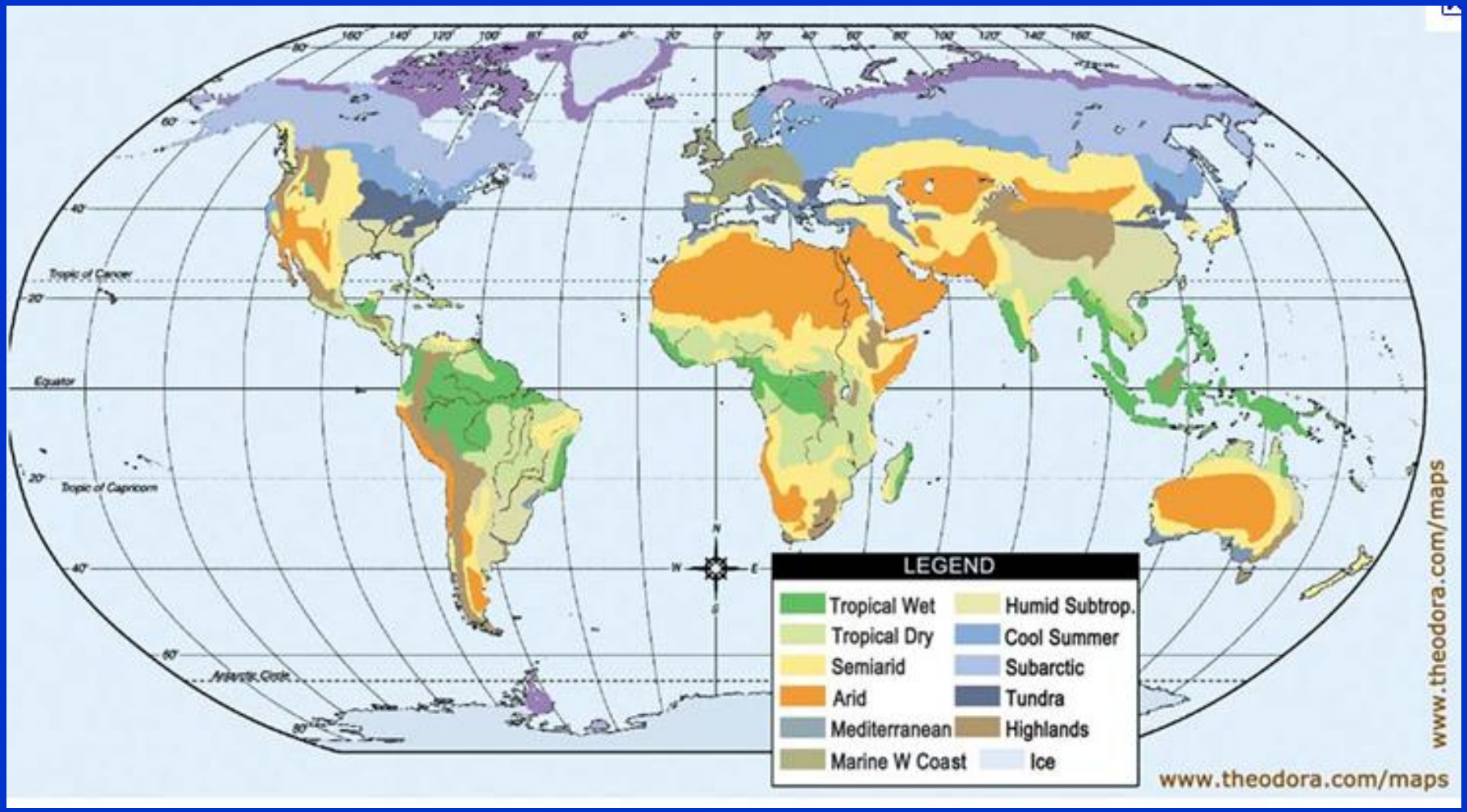
How do we get energy from this . . . .

. . . . to drive this ?

. . . . or this ?

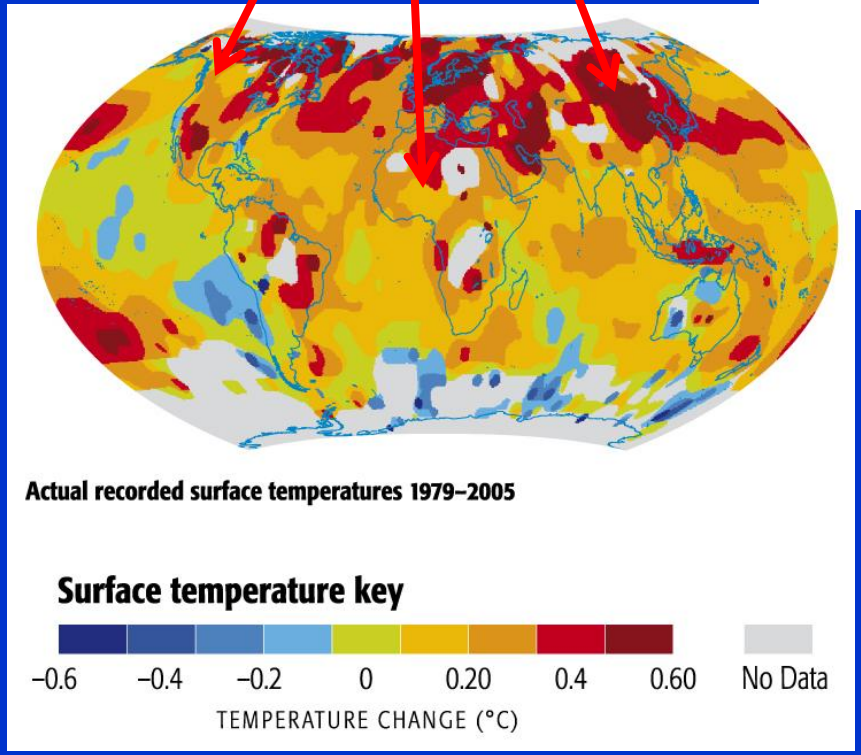
http://www.vets.ucar.edu/vg/T341/index.shtml

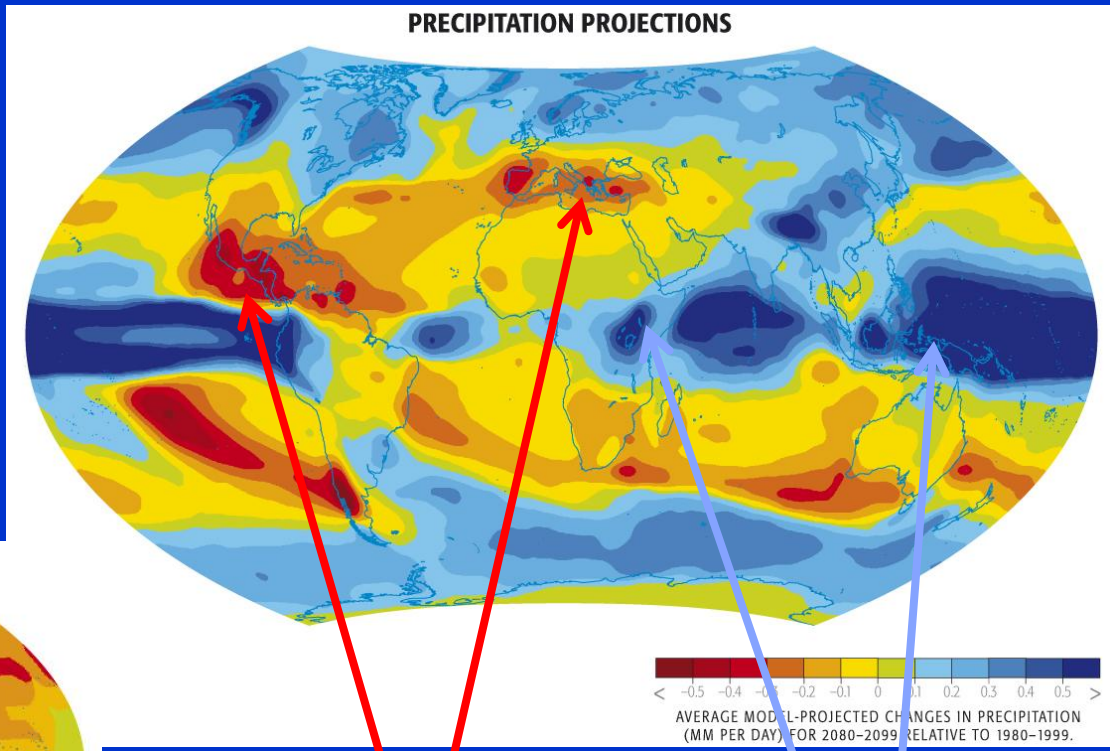
. . . .which leads to Global Climatic Regions:



. . . .and CHANGES in these regions!

Hotter!



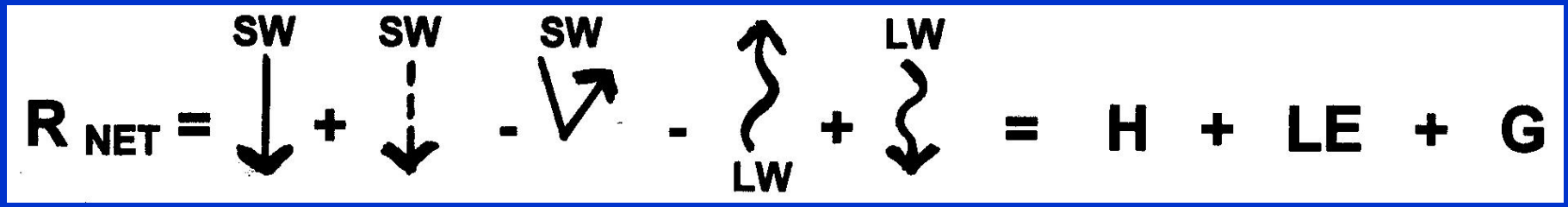


Drier!

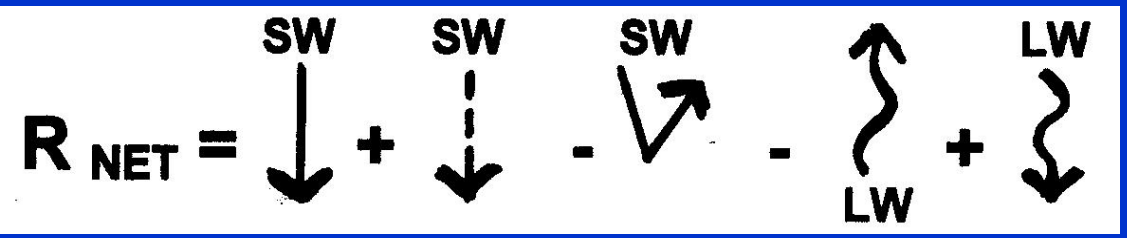
Wetter!

from *Dire Predictions* text

It all happens because of changes in the RADIATION / ENERGY BALANCE !



"Radiation Balance" part



All components are referring to electromagnetic radiation

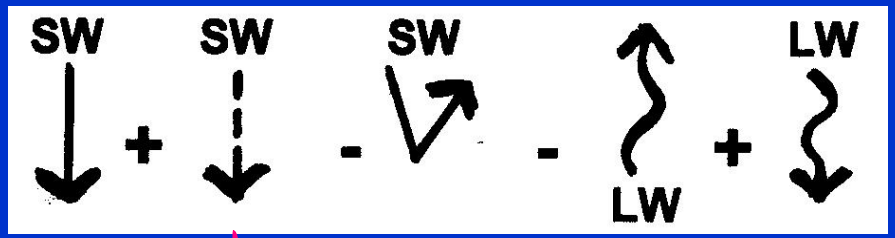
All components are referring to modes of heat energy transfer or heat energy storage involving matter

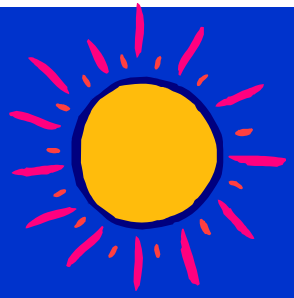
"Energy Balance" part

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

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.**

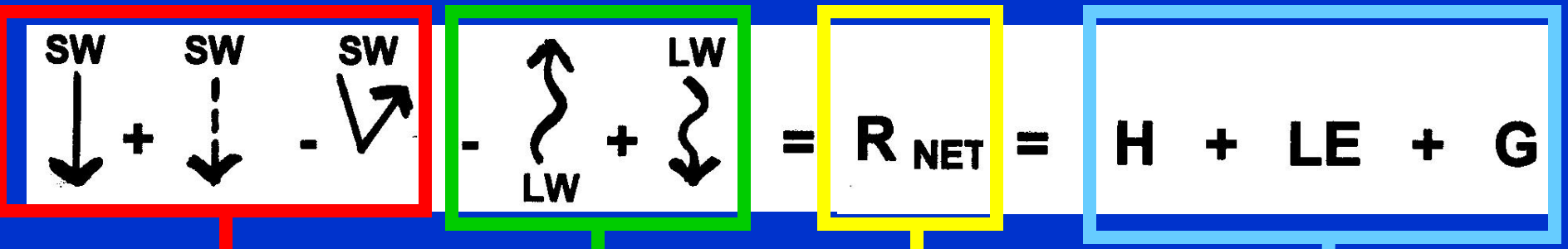
- **Sensible Heat transfer (H)**
- **Latent Heat transfer (LE)**

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 **WEATHER & CLIMATE !**

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

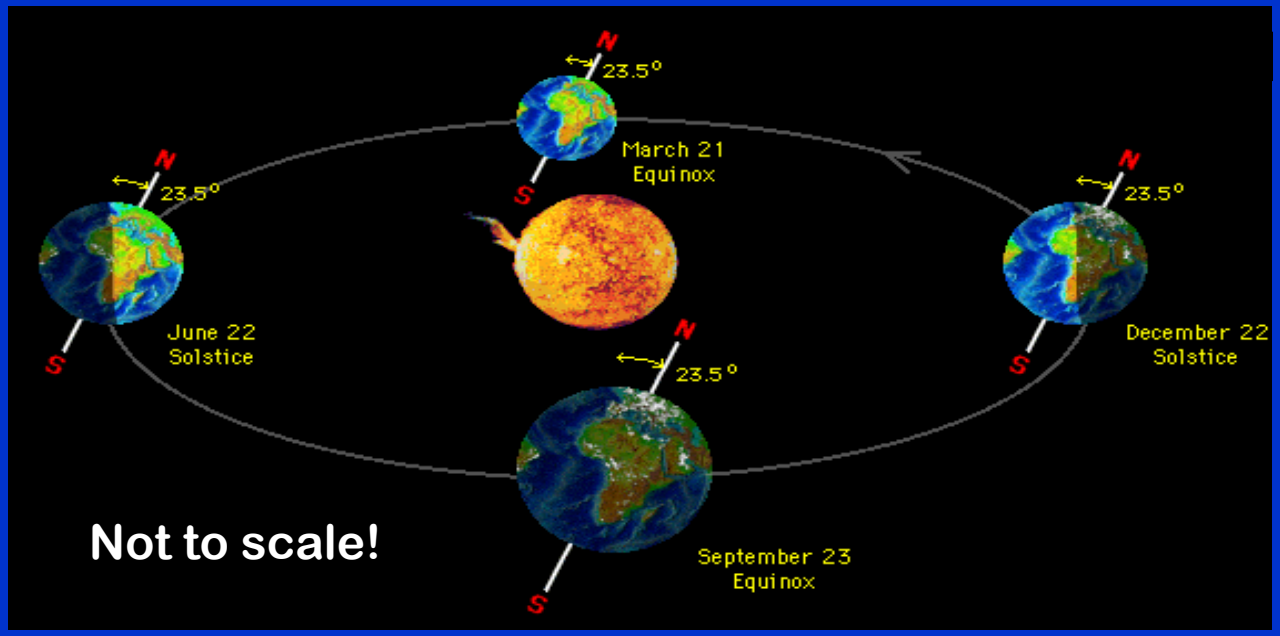
LINKING THE ENERGY BALANCE TO ATMOSPHERIC CIRCULATION . . .

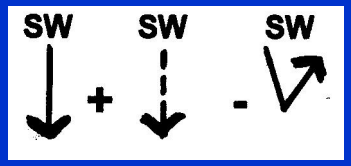
We'll start with the SUN (SOLAR INSOLATION)

IN – SOL- ATION =

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

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





EARTH-SUN Relationships

4 Things to Know about Earth-Sun Relationships:

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:

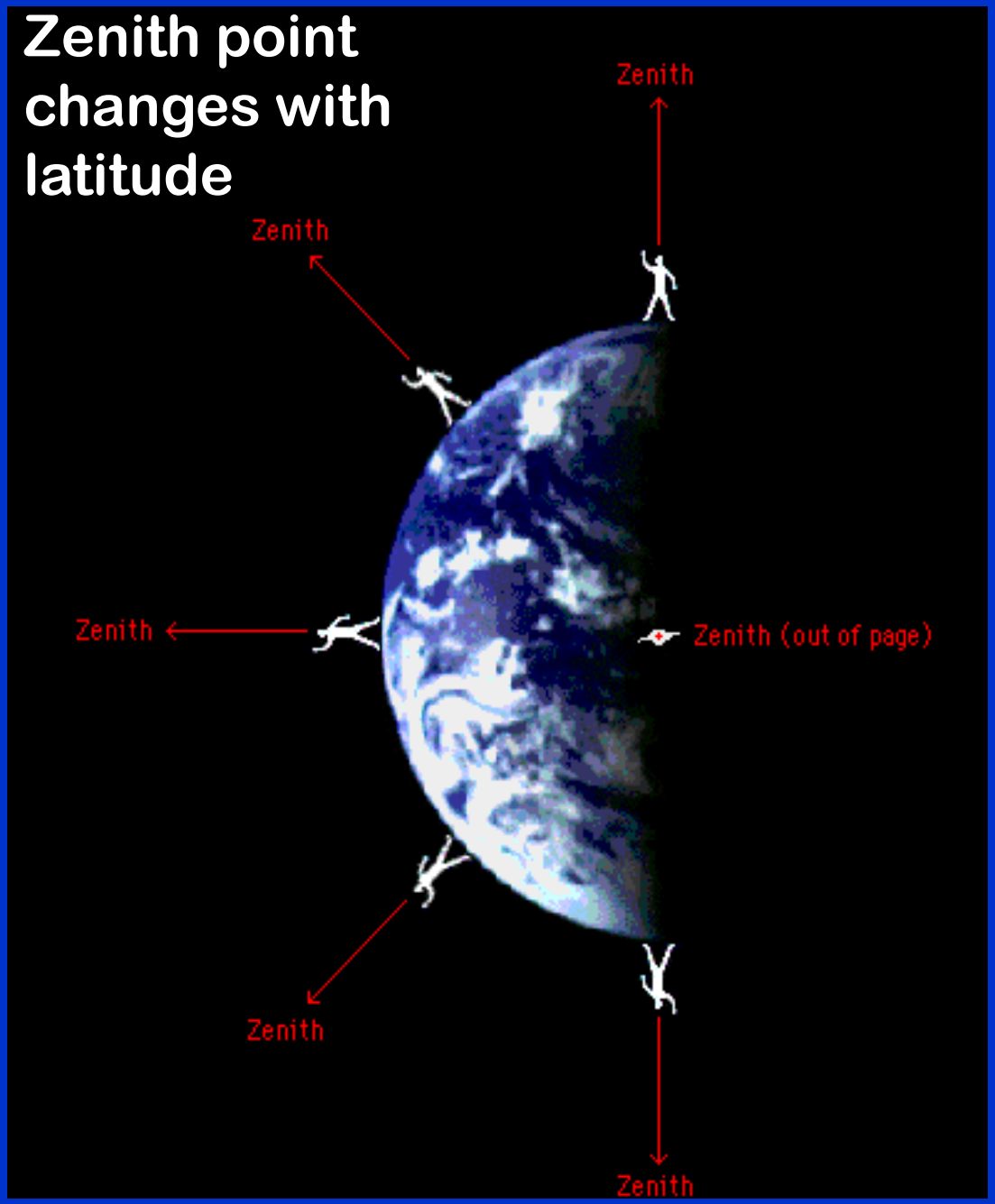
(1) **INTENSITY** of sun's rays

(perpendicular to surface = more intense)

(2) **DURATION** of daily insolation

(longer day length = more insolation)

Zenith point changes with latitude

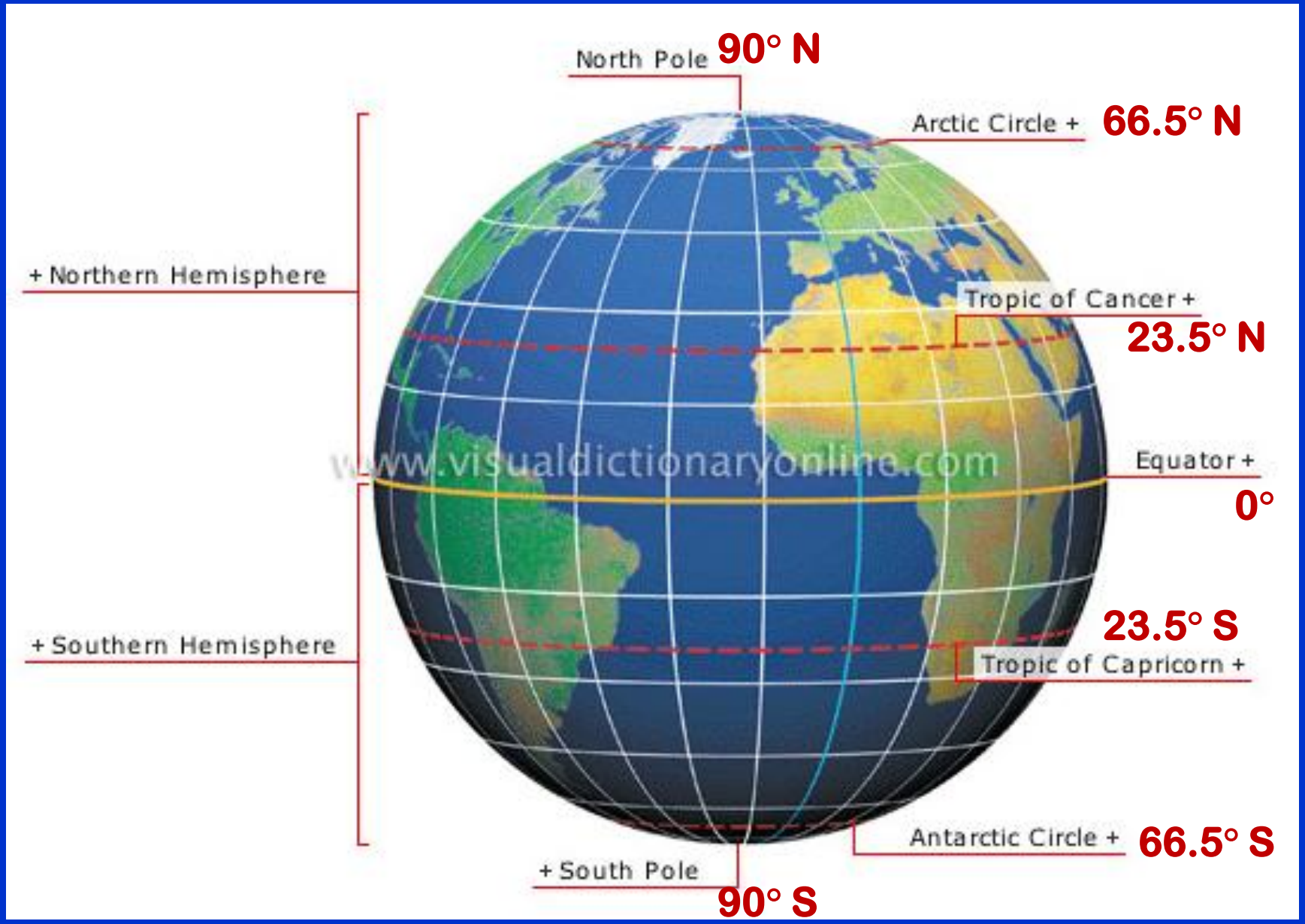


A useful term:

ZENITH = The point directly overhead

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

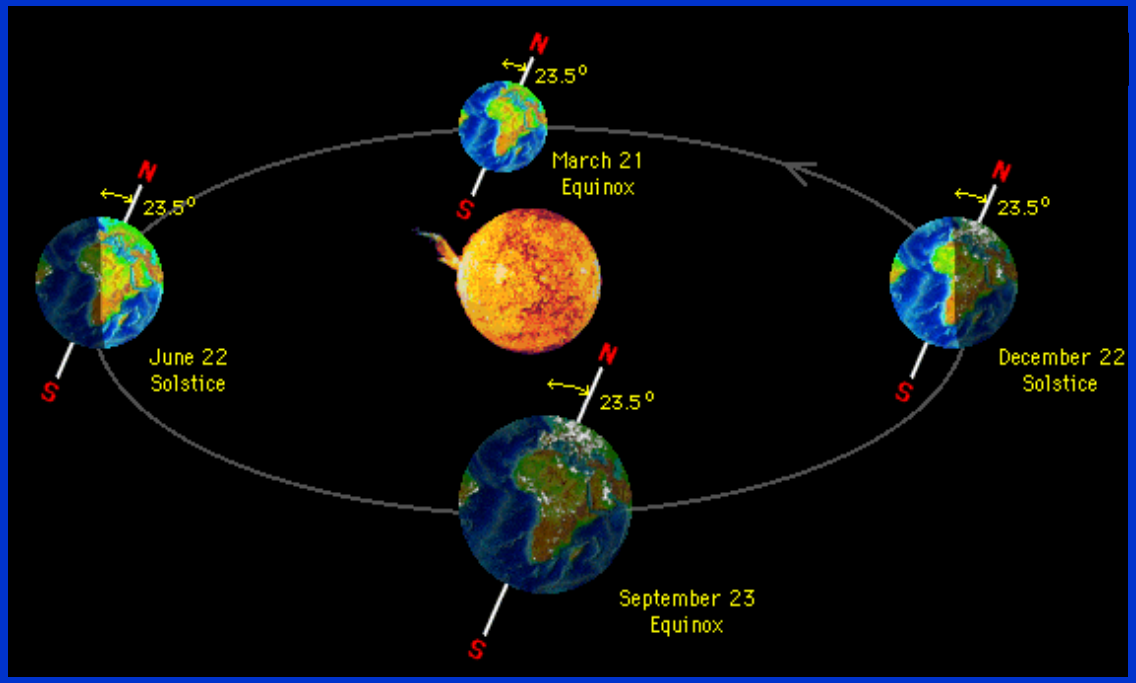
QUICKIE LATITUDE REVIEW:



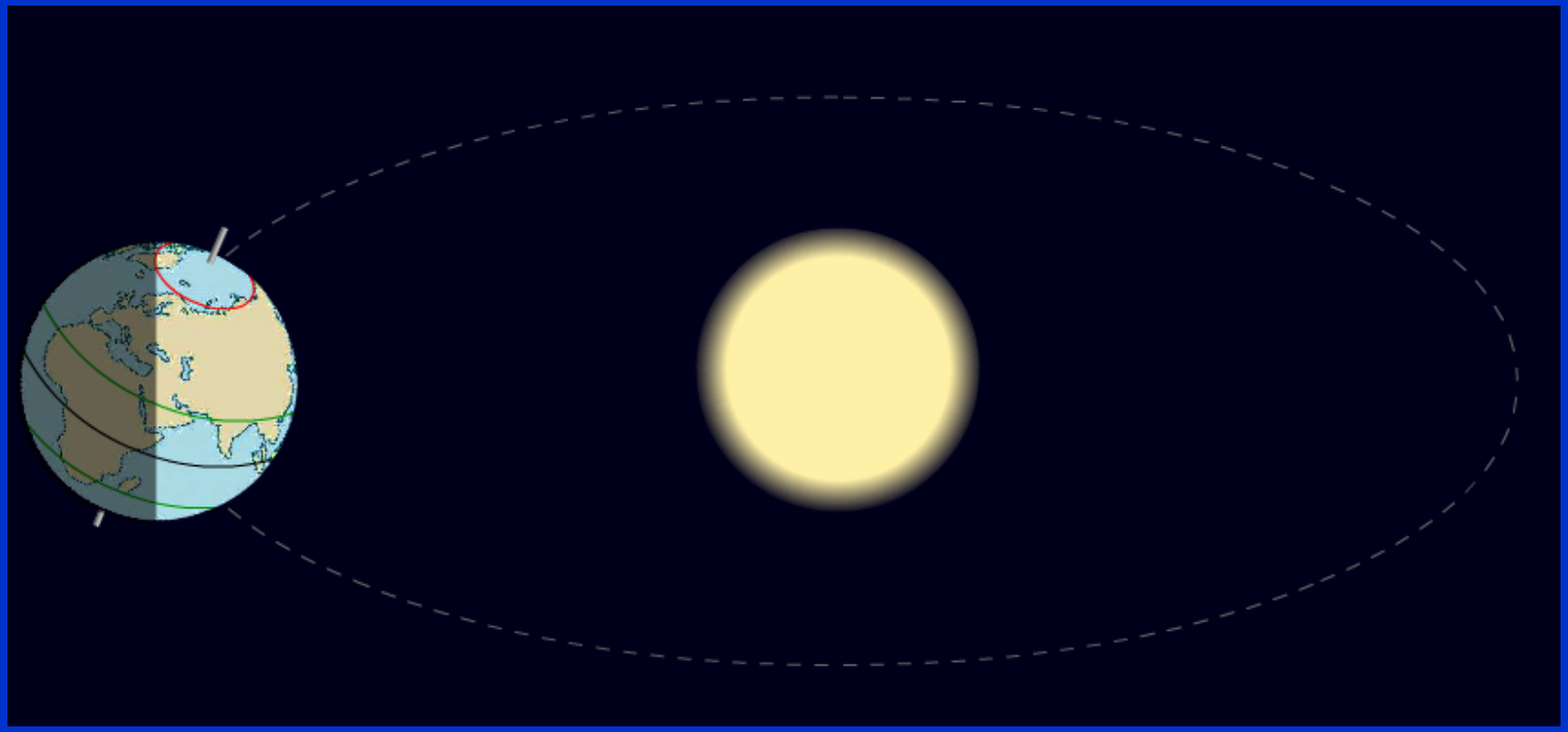
EARTH-SUN RELATIONSHIPS & The SEASONS:

VIEW THE ANIMATION:

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

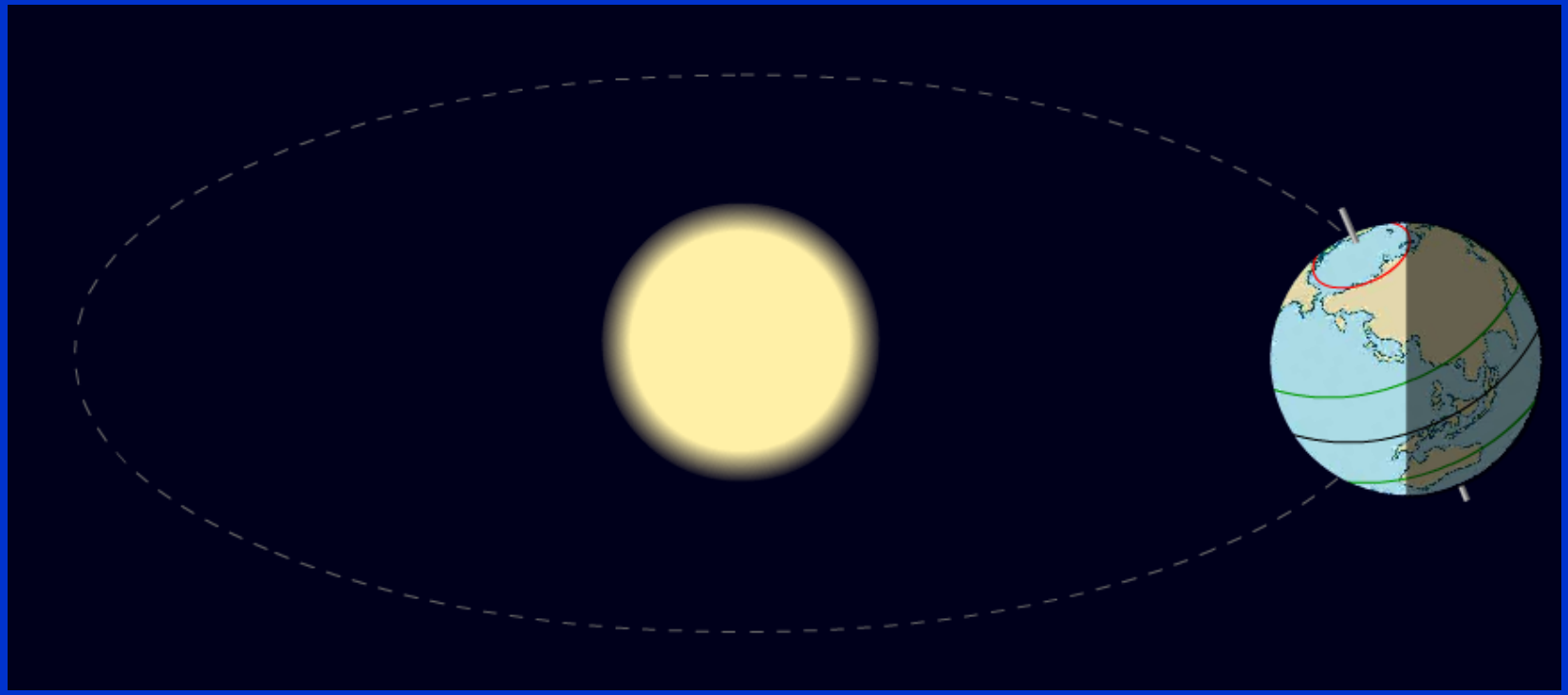


JUNE SOLSTICE



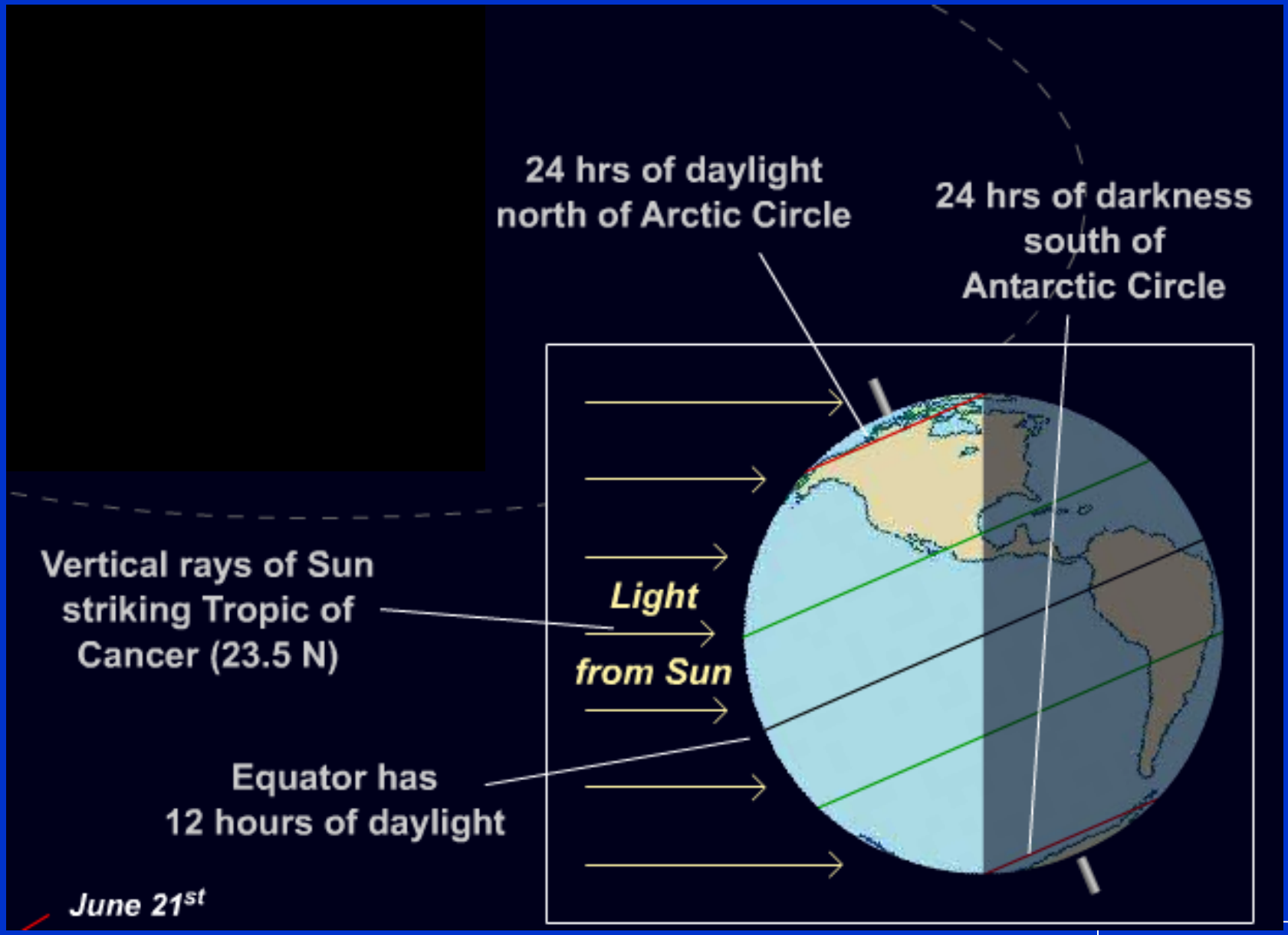
As viewed from one side of Sun

JUNE SOLSTICE



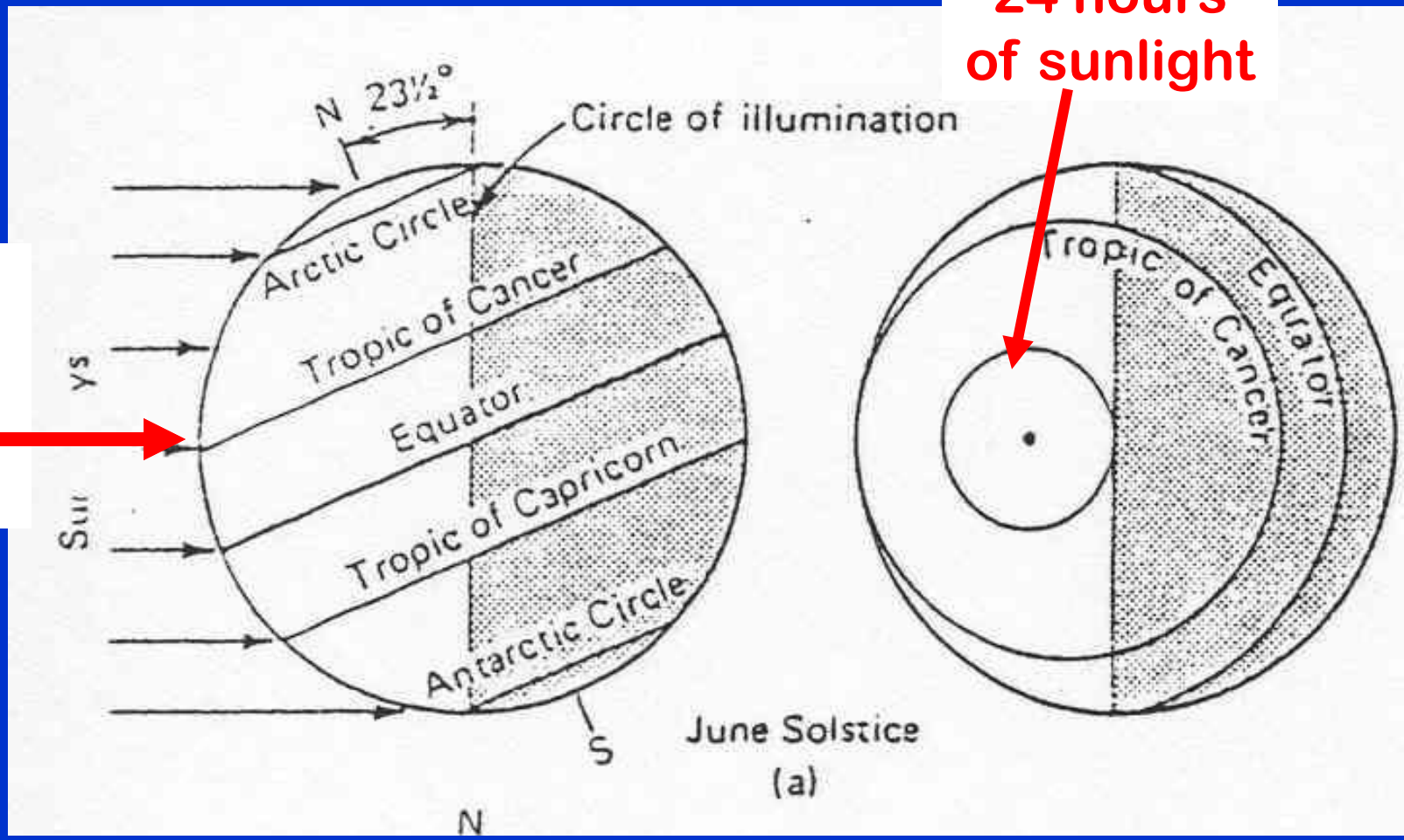
As viewed from the other side of the Sun

JUNE SOLSTICE



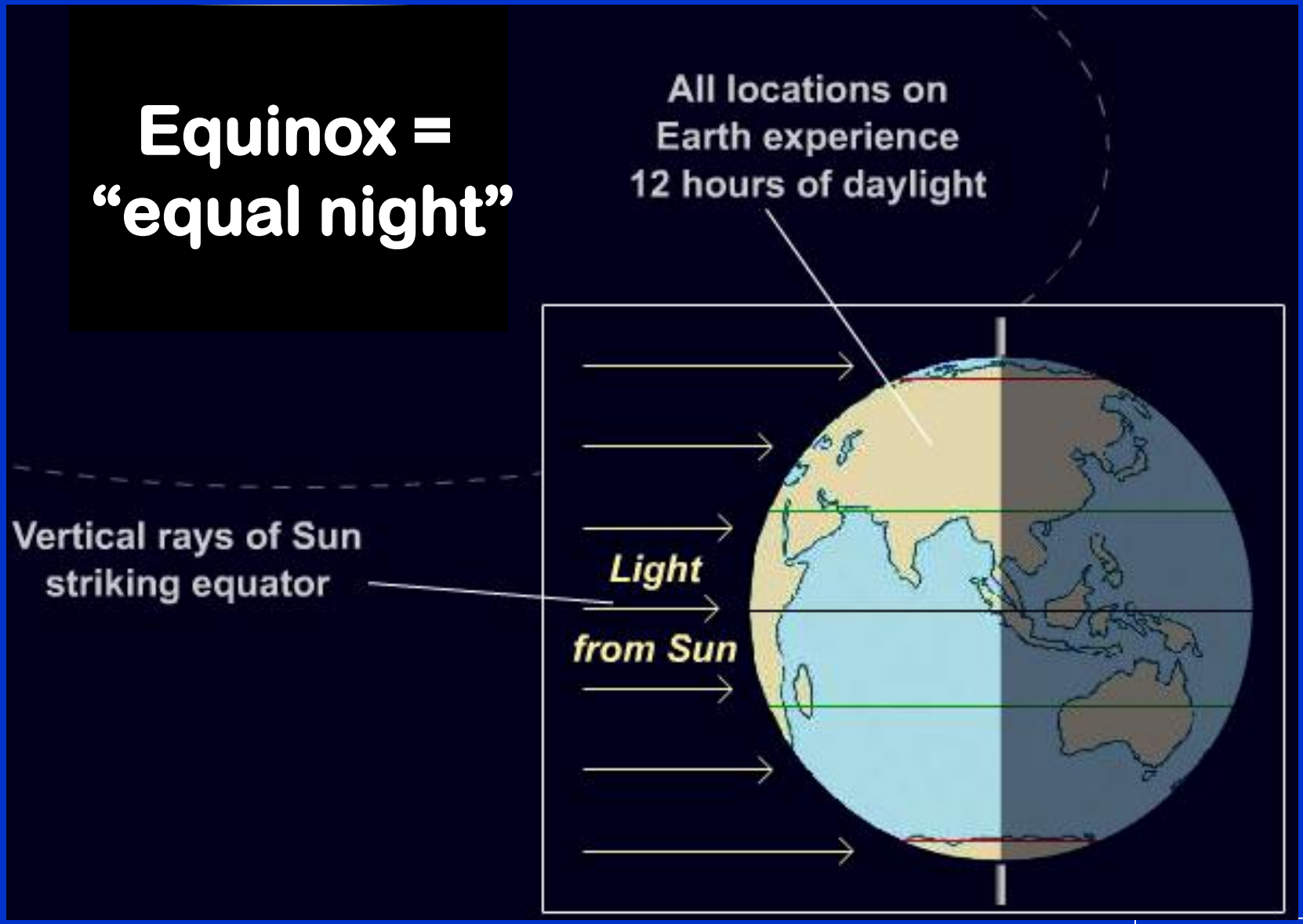
JUNE SOLSTICE

Most intense solar radiation



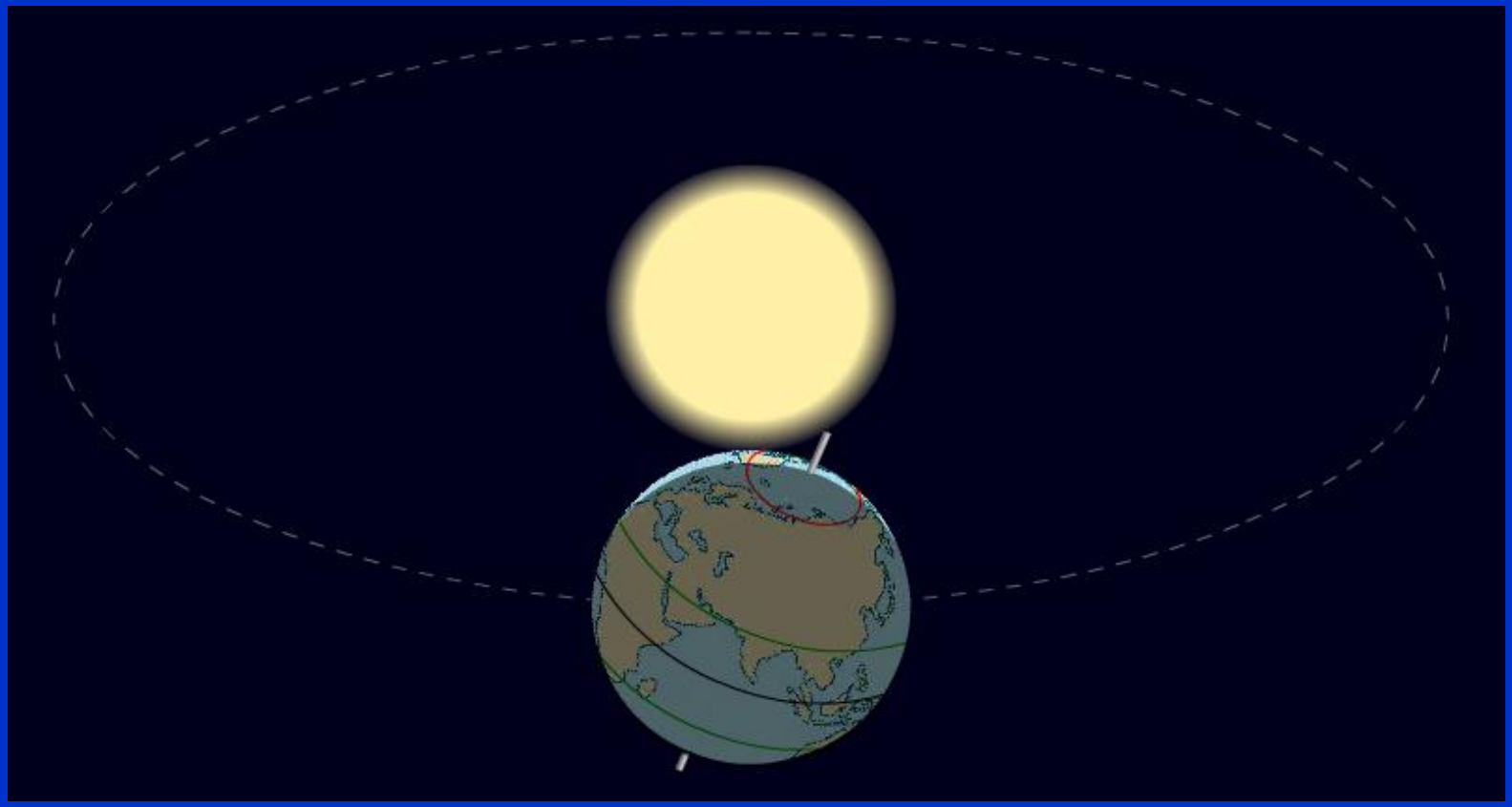
MARCH EQUINOX

Equinox = "equal night"



SEPTEMBER EQUINOX

different seasonal position in orbit . . .

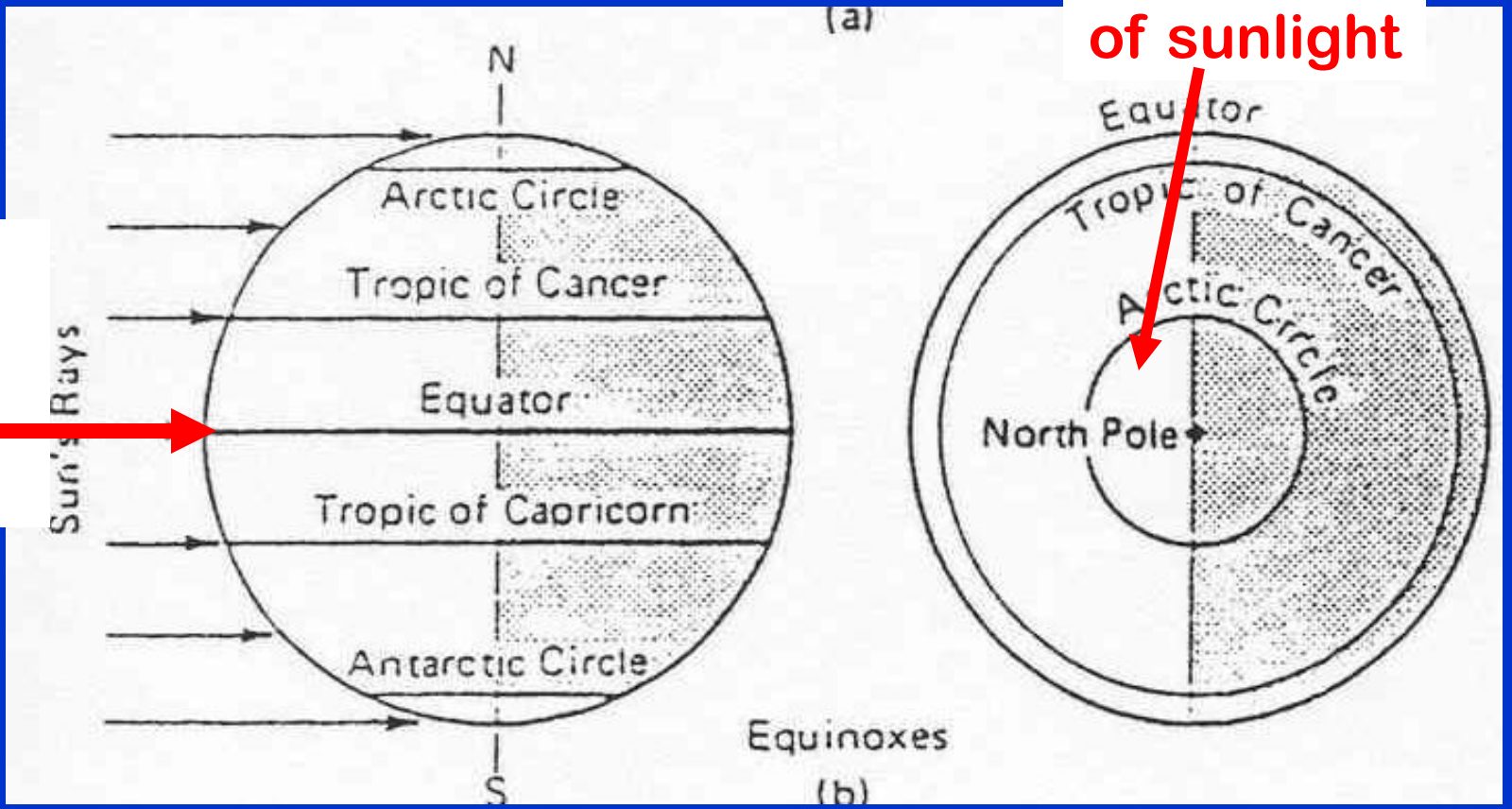


. . . but same latitudinal insolation as March Equinox

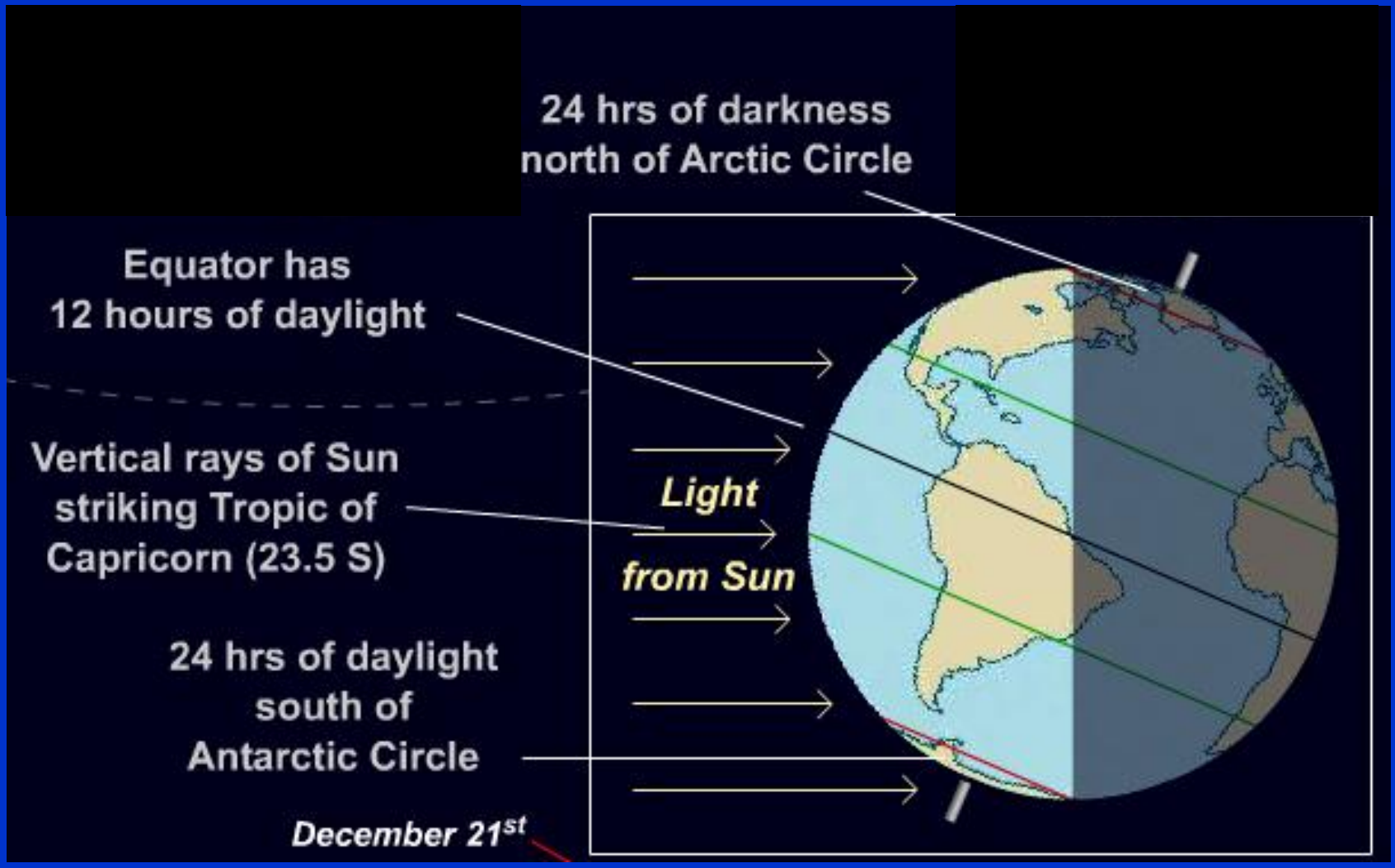
MARCH & SEPTEMBER EQUINOXES

12 hours of sunlight

Most intense solar radiation



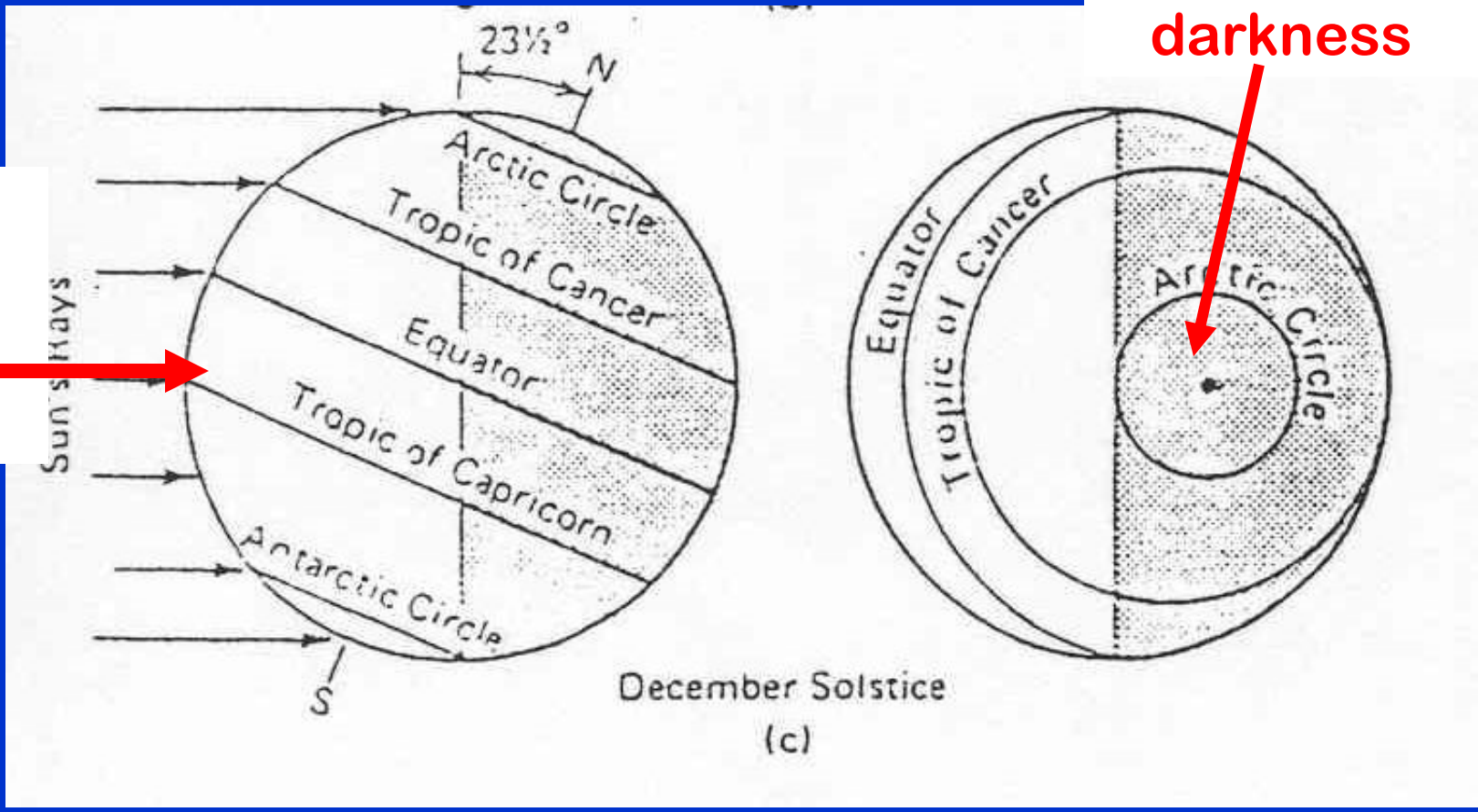
DECEMBER SOLSTICE



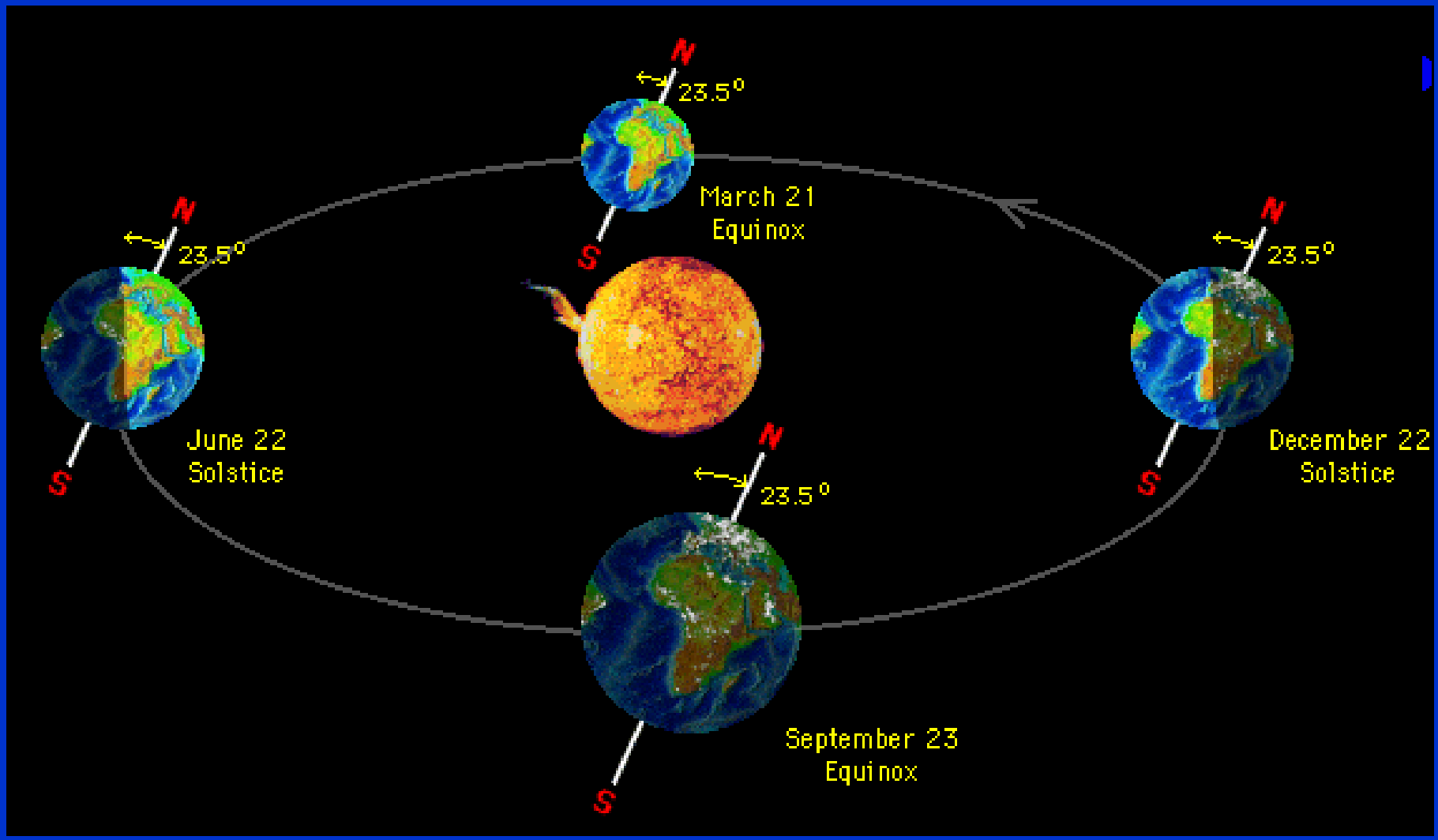
DECEMBER SOLSTICE

24 hours of darkness

Most intense solar radiation

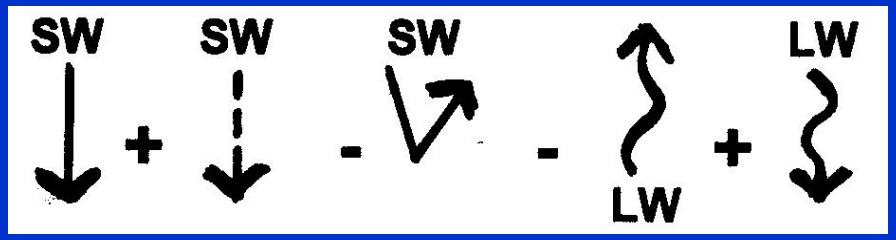


http://mesoscale.agron.iastate.edu/agron206/animations/01_EarthSun.html



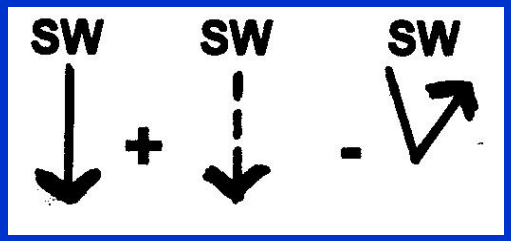
Recap

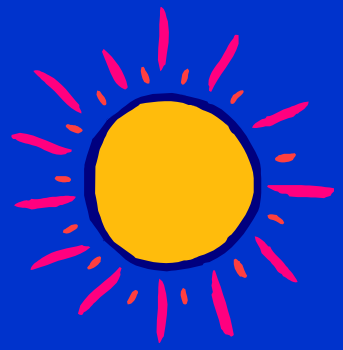
THE RADIATION BALANCE

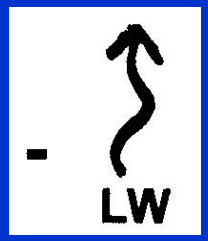


& THE GENERAL CIRCULATION OF THE ATMOSPHERE

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)

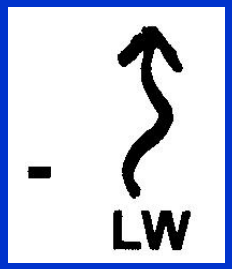
➔ **LOW LATITUDES** absorb <u>MORE</u> energy than HIGH LATITUDES

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

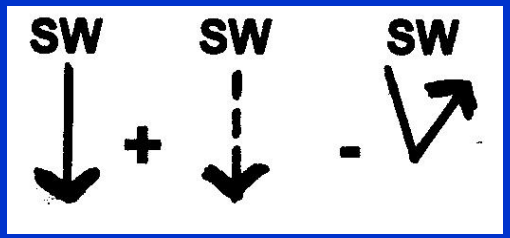
HOWEVER . . .

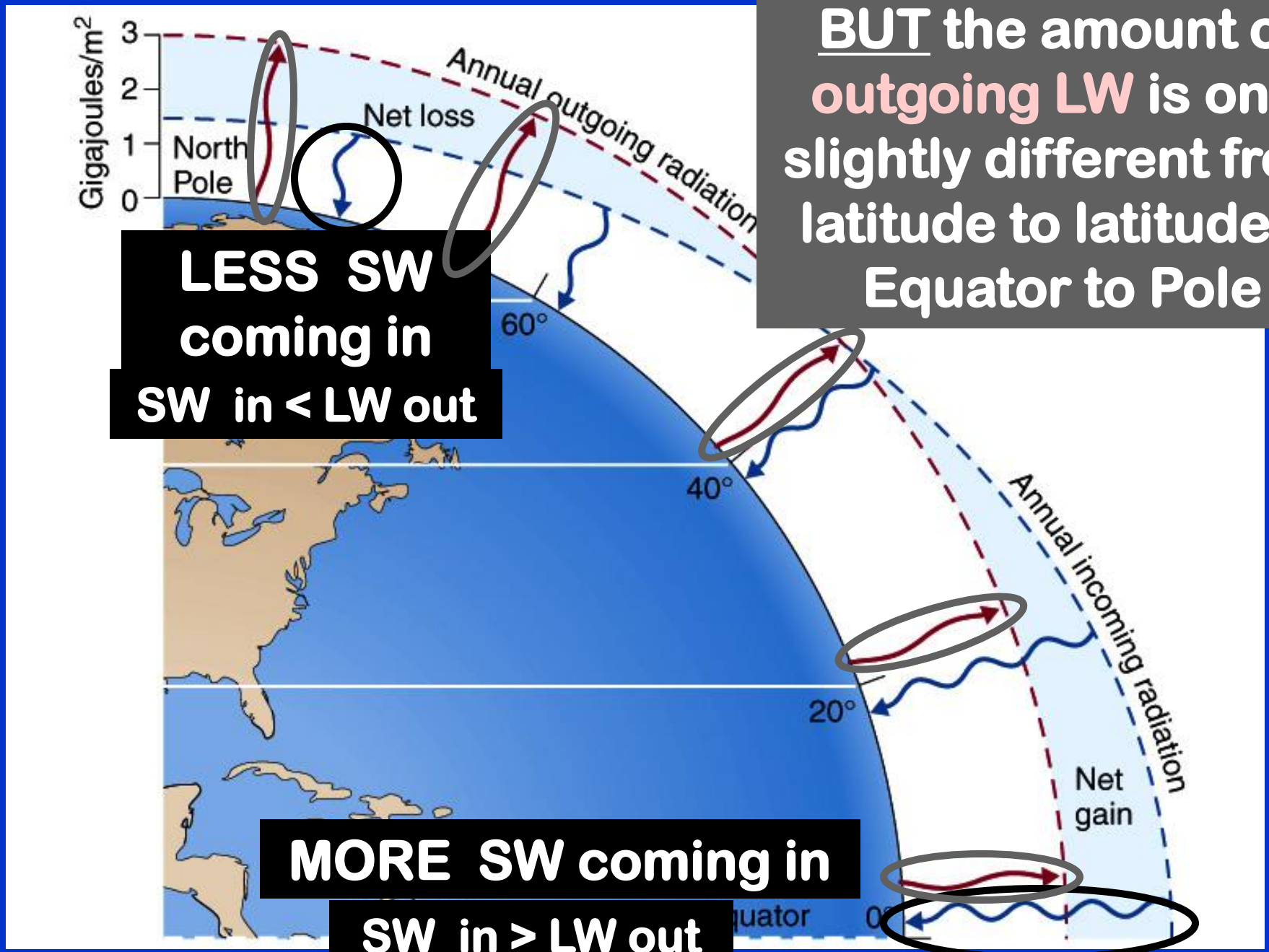
The EQUATOR-POLE DIFFERENCES of what goes OUT from the EARTH



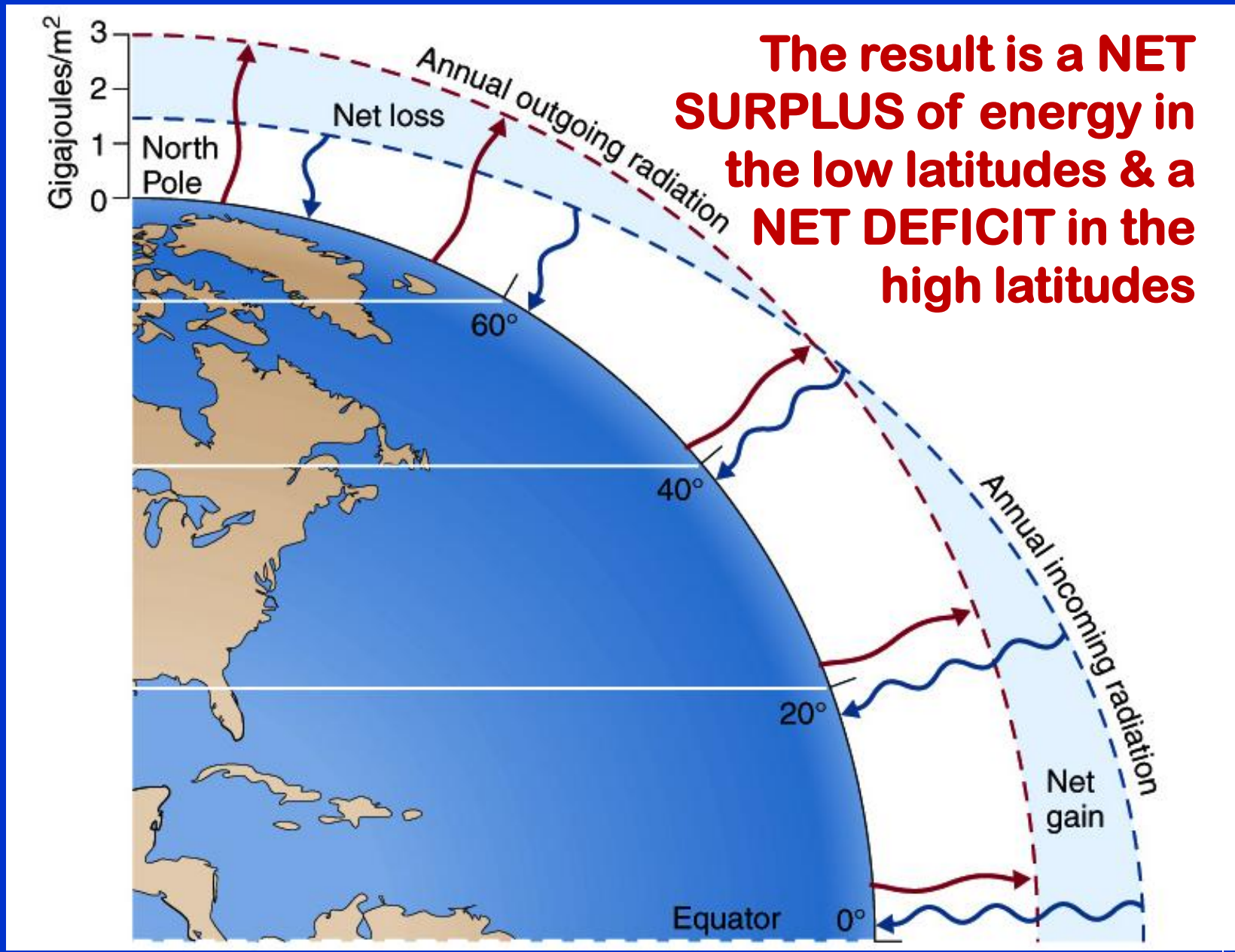
are less than the

EQUATOR-POLE DIFFERENCES of what comes IN from the SUN

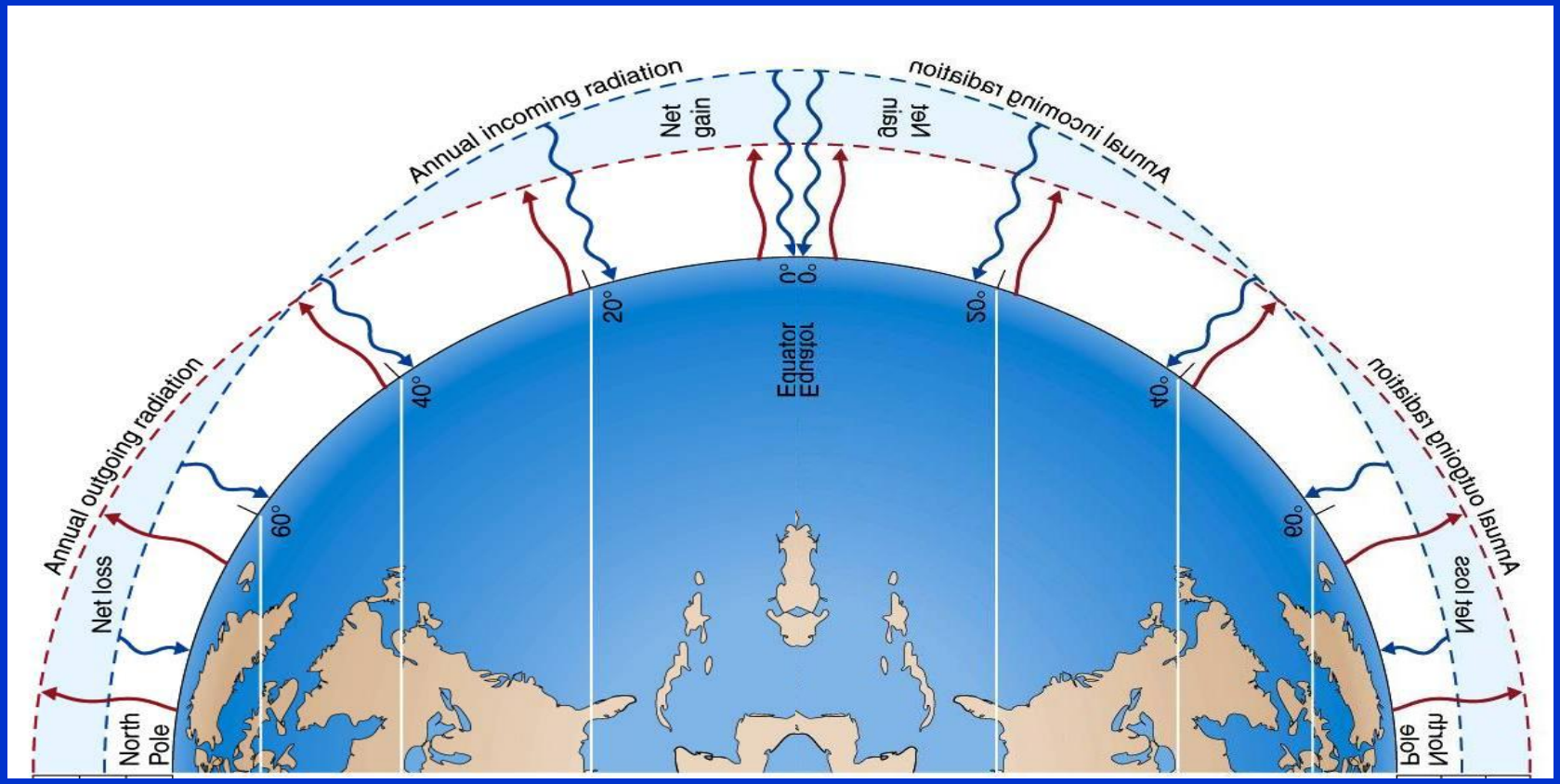




BUT the amount of **outgoing LW** is only slightly different from latitude to latitude & Equator to Pole

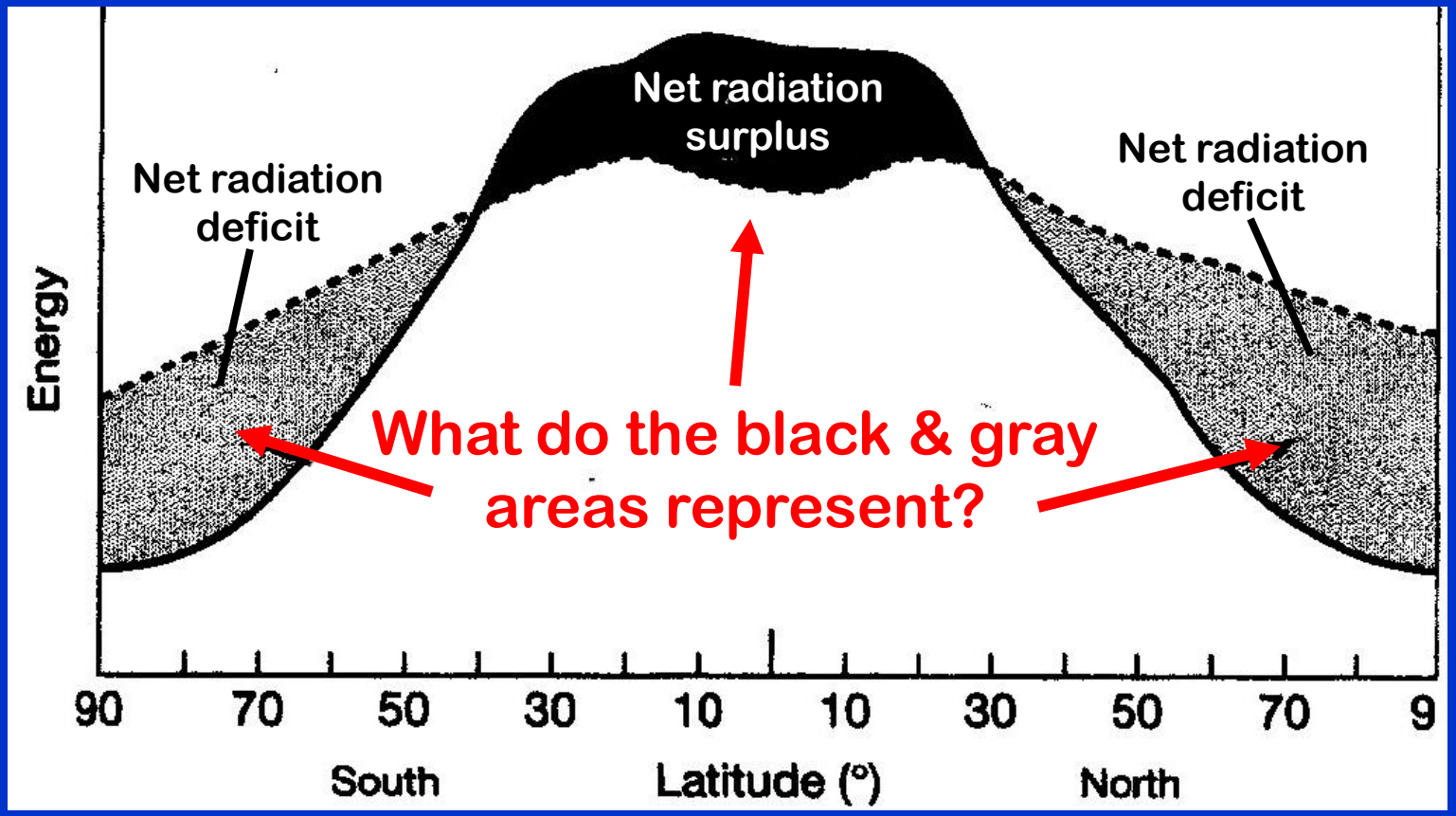


The result is a NET SURPLUS of energy in the low latitudes & a NET DEFICIT in the high latitudes

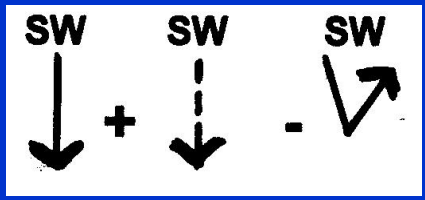


POLE **EQUATOR** **POLE**

Now lets look at a Pole to Pole Transect



Absorbed solar energy

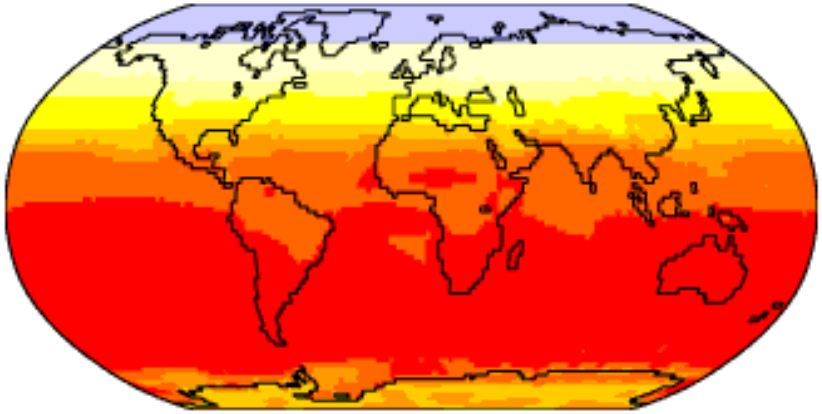


Emitted infrared energy

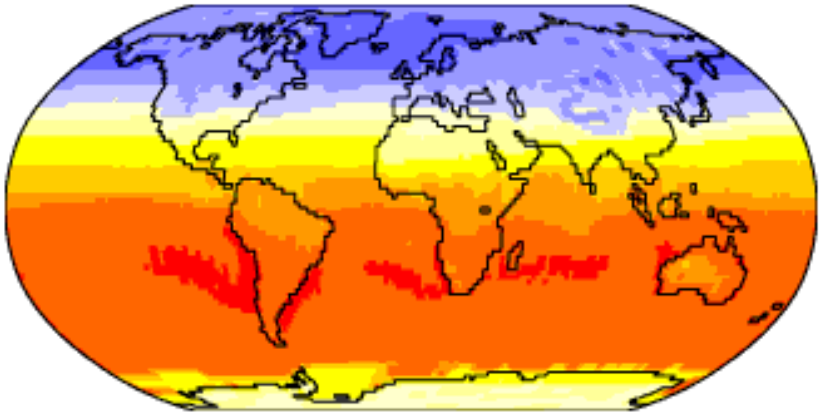
(at top of atmosphere)

Short-Wave Radiation

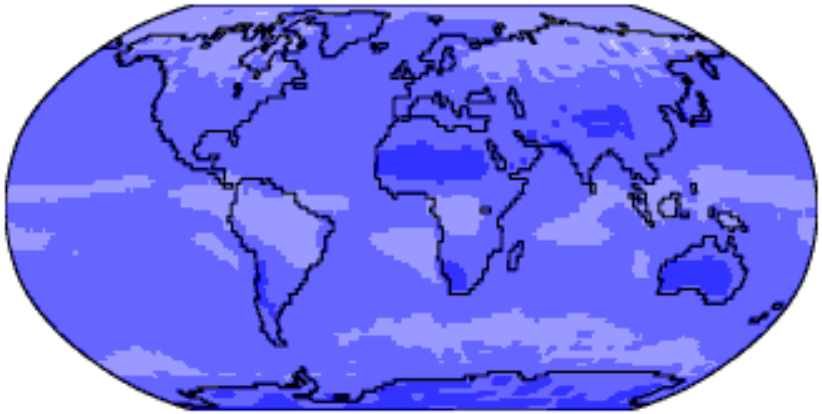
Dec

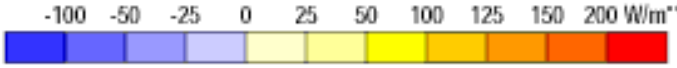


Net Radiation



Long-Wave Radiation



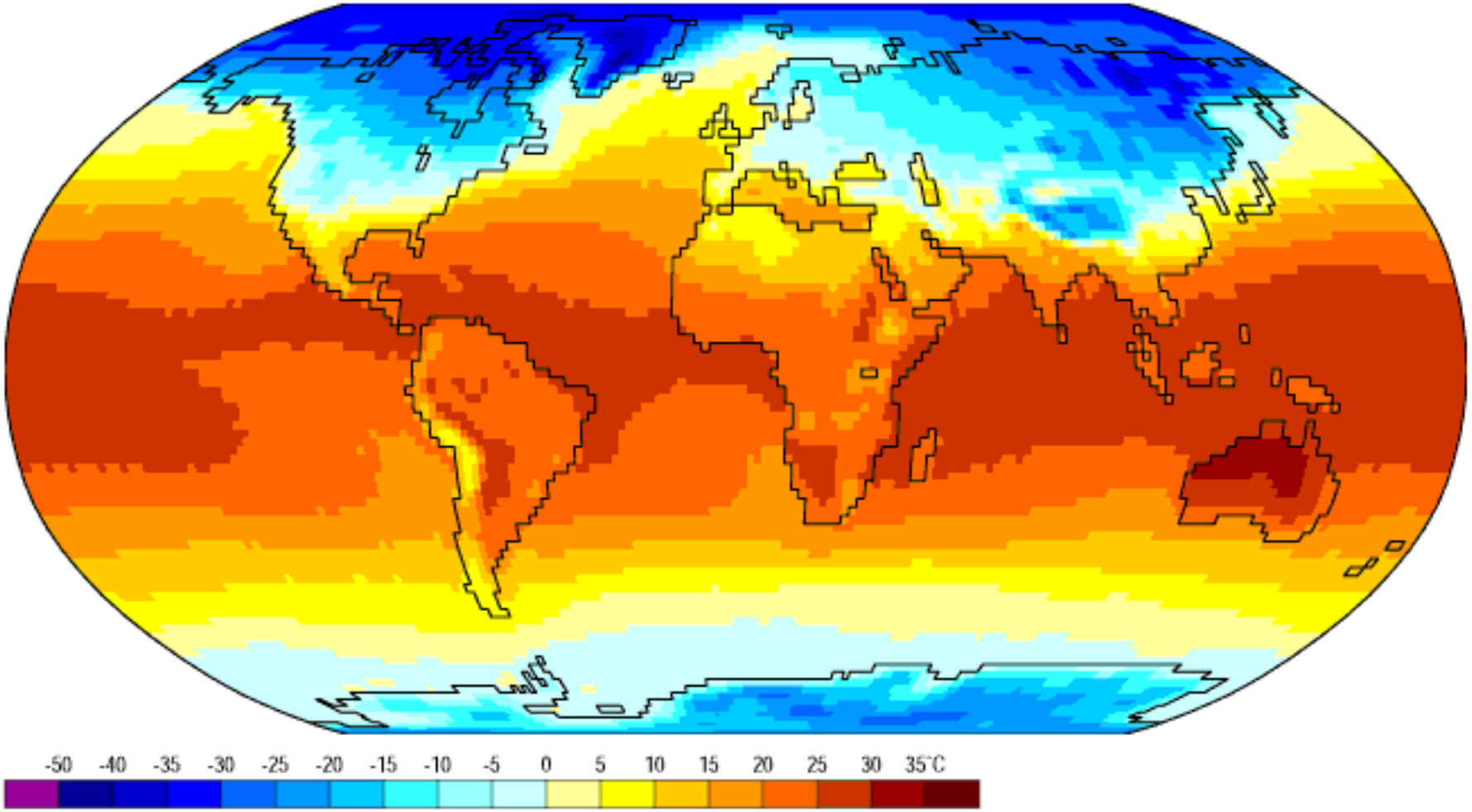


Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000

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

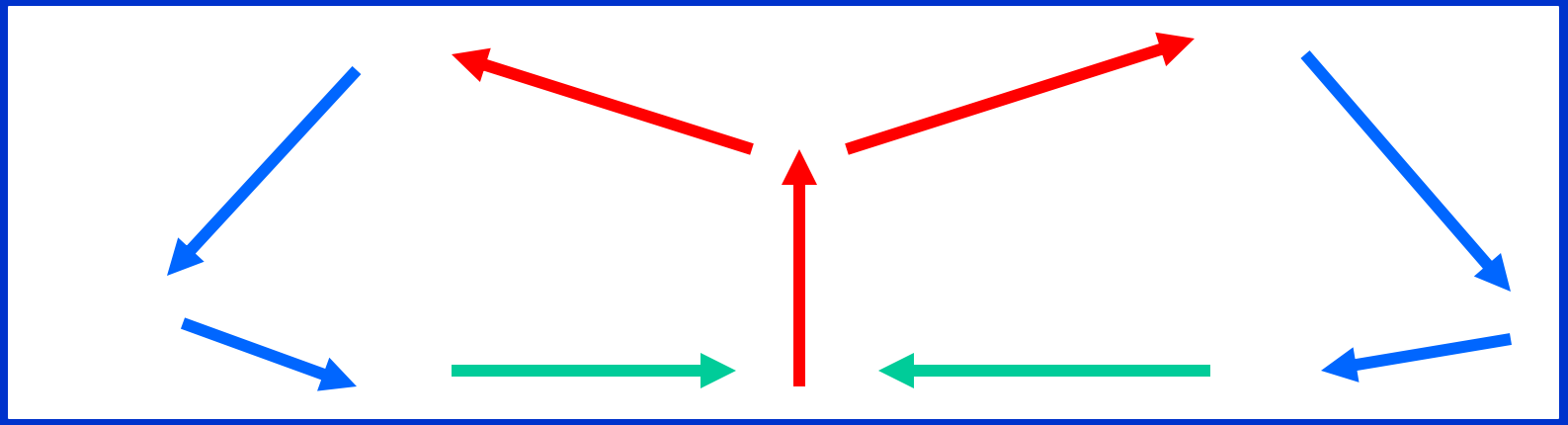
Air Temperature

Dec



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

Global-scale air motions are driven by thermal differences:



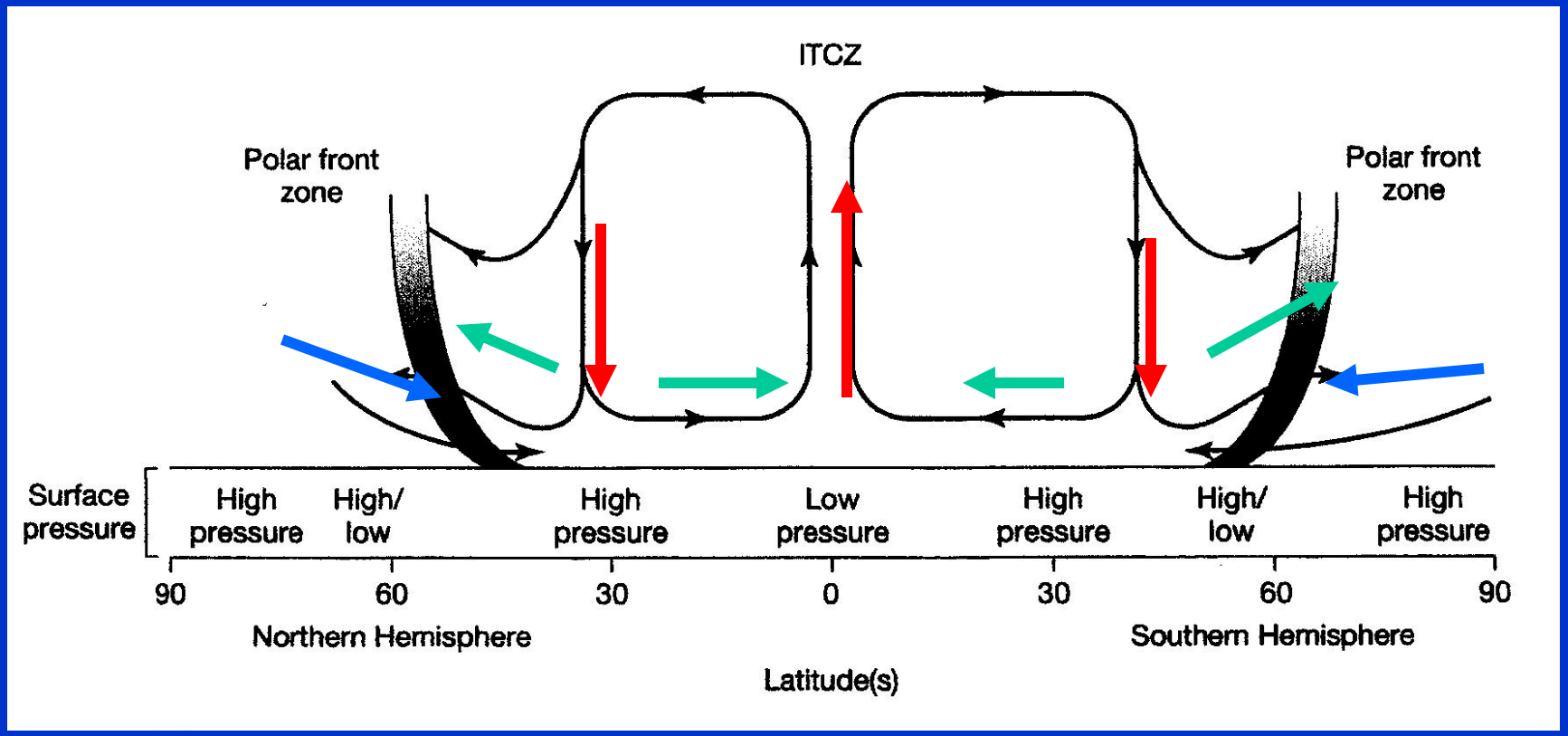
90 60 30 0 30 60 90

Northern Hemisphere EQUATOR Southern Hemisphere

COLD POLAR REGIONS

HOT TROPICS

COLD POLAR REGIONS

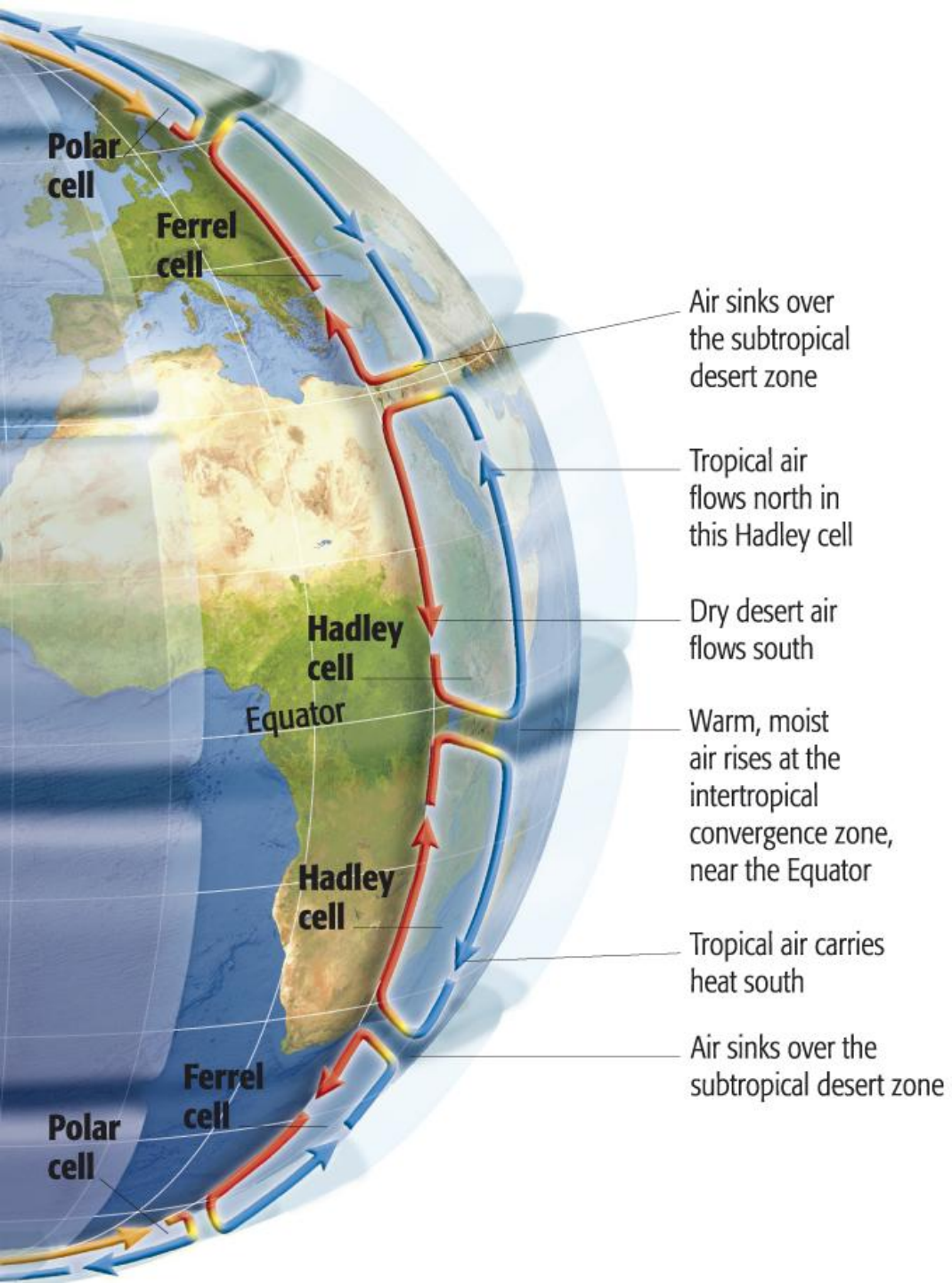


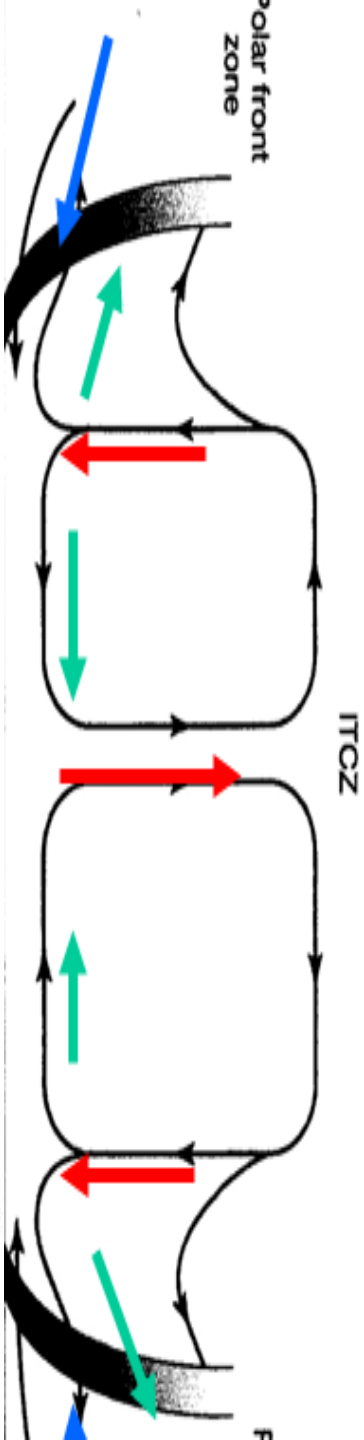
COLD POLAR REGIONS

HOT TROPICS

COLD POLAR REGIONS

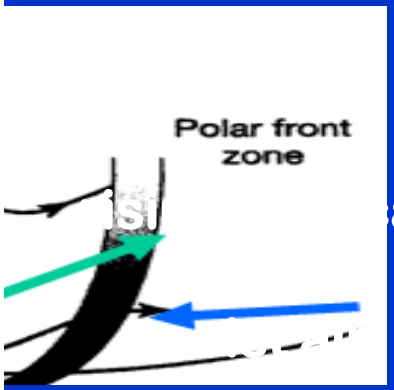
From SGC-I Chapter 4





cold polar air
vs.
warm low lat air

sinking dry subtropical air



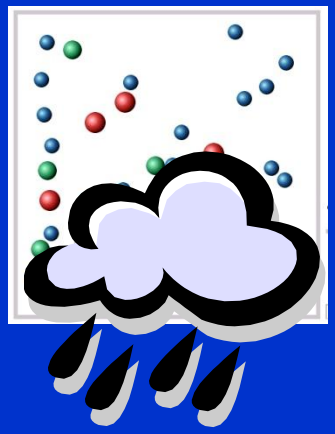
al

sinking dry subtropical air

warm low lat air
vs.
cold polar air

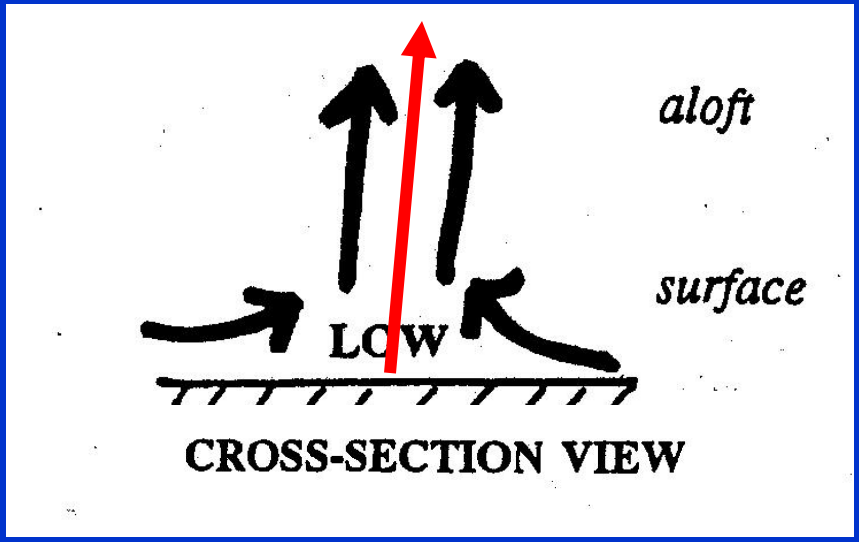
LOW PRESSURE AREAS:

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

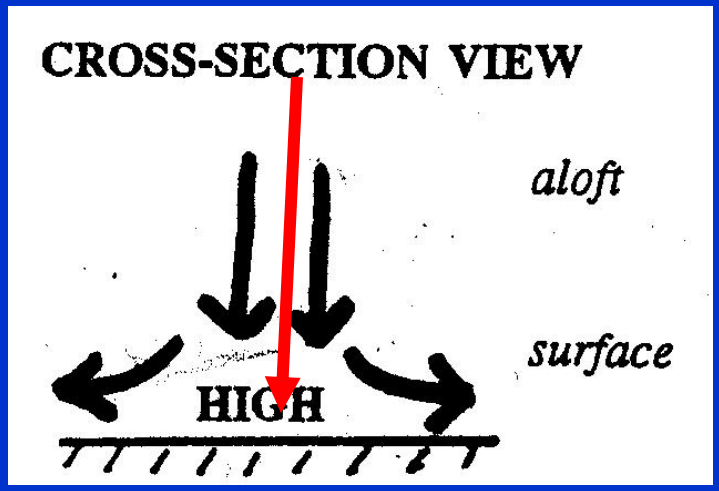


➔ clouds, and possibly precipitation . . .

HUMID REGIONS

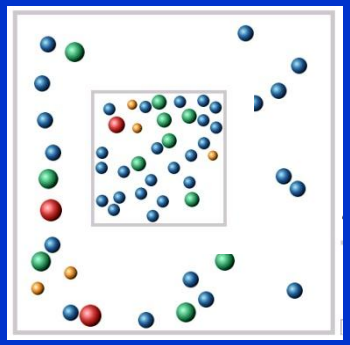


The opposite of rain = subsidence (sinking air) In HIGH PRESSURE ares!



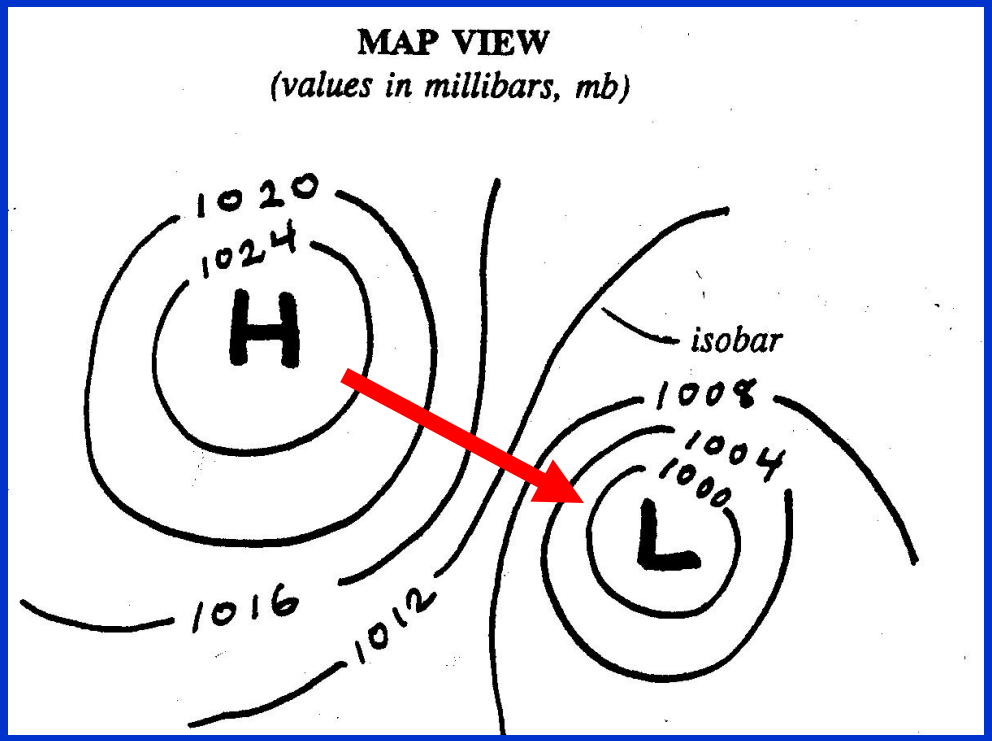
HIGH PRESSURE AREAS:

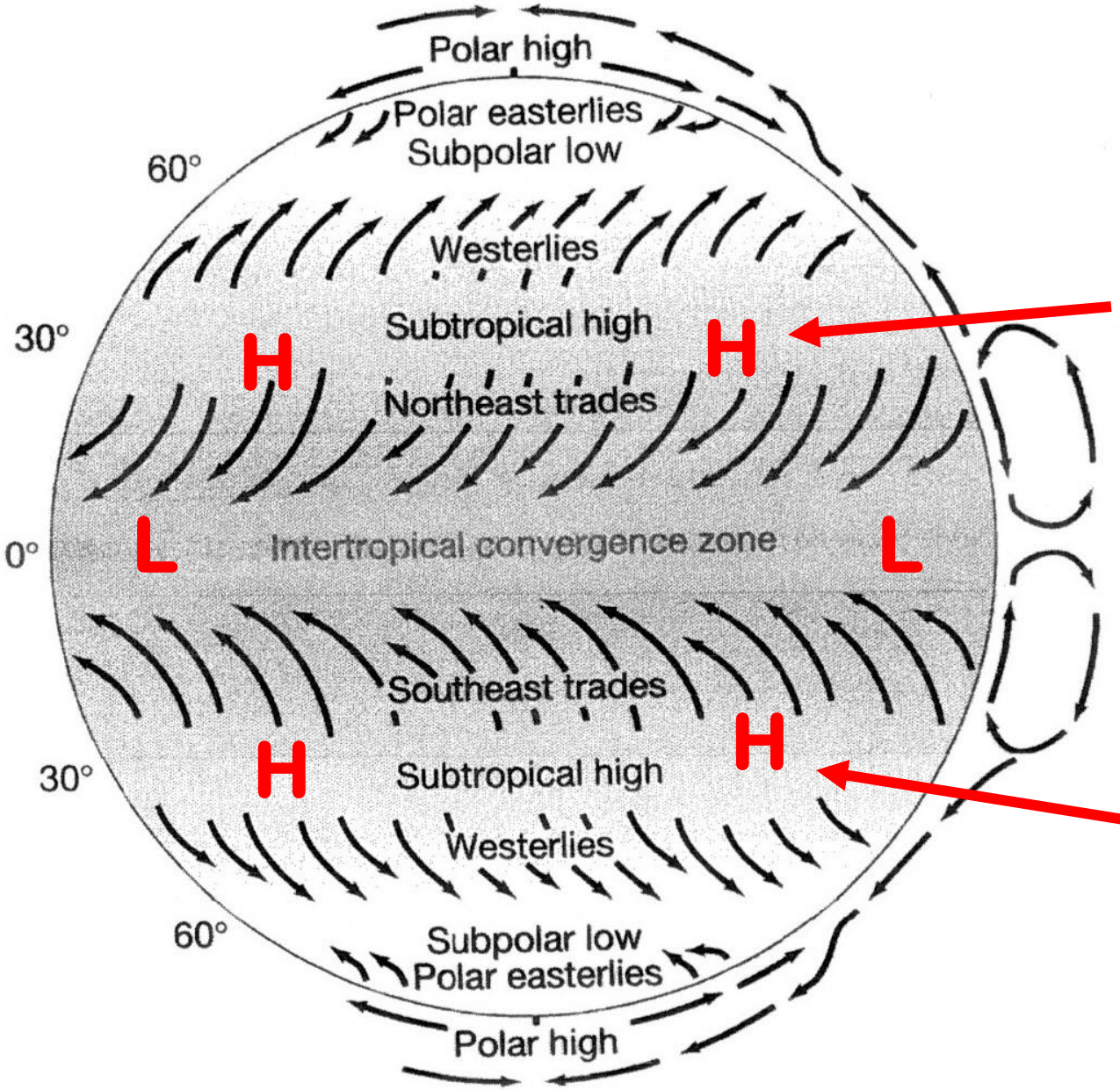
Forced sinking
(e.g. in HADLEY CELL)
leads to "**compaction" and warming of the sinking air**



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

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

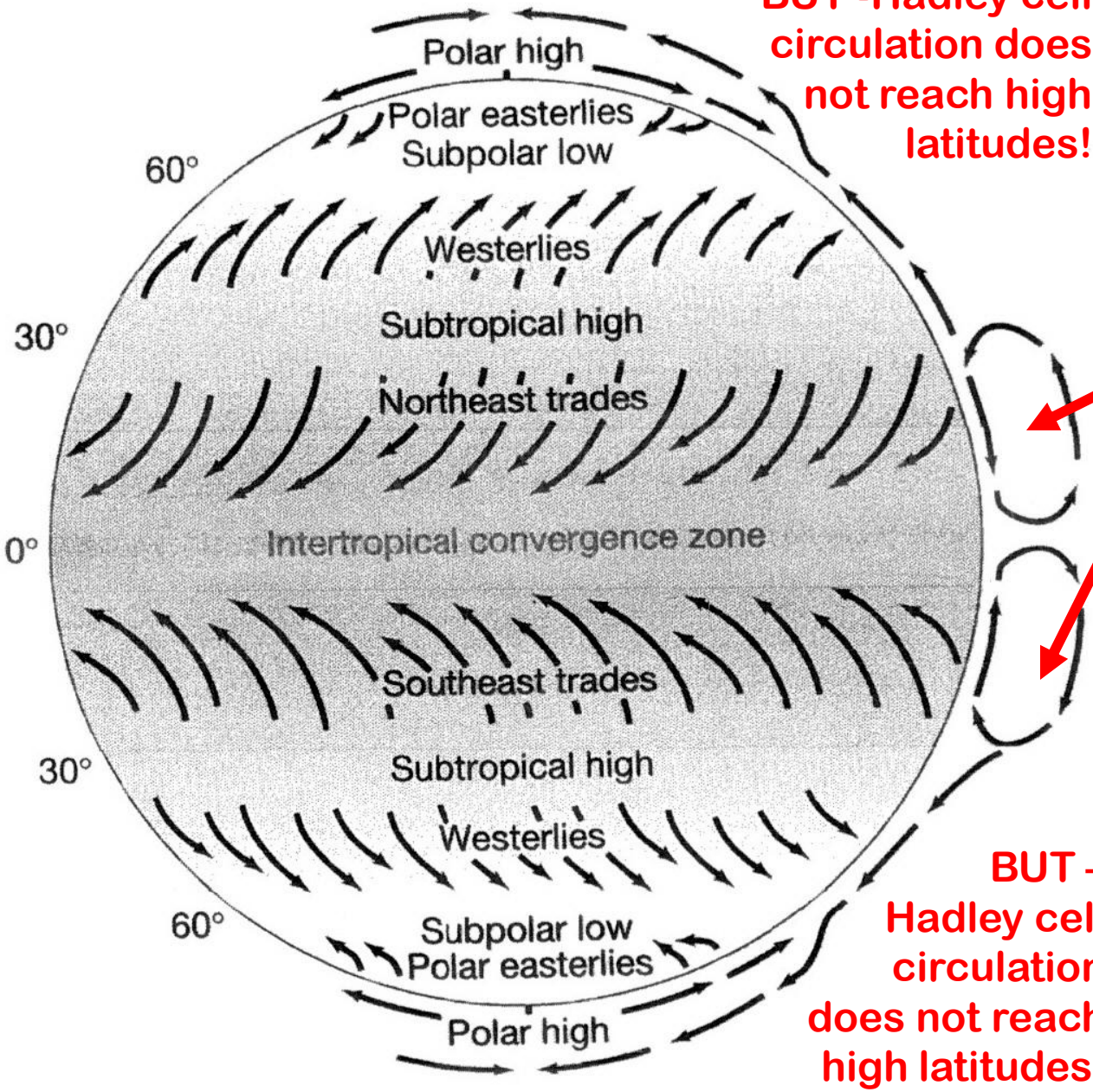




Sub-tropical HIGH PRESSURE

Intertropical Convergence ITCZ

Sub-tropical HIGH PRESSURE



BUT -Hadley cell circulation does not reach high latitudes!

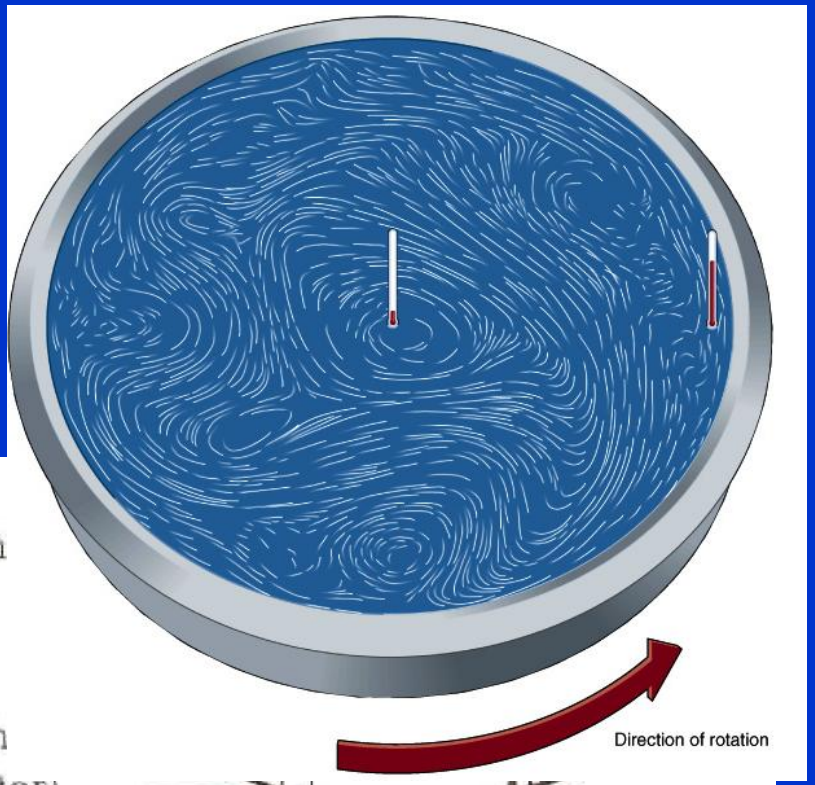
BUT – Hadley cell circulation does not reach high latitudes!

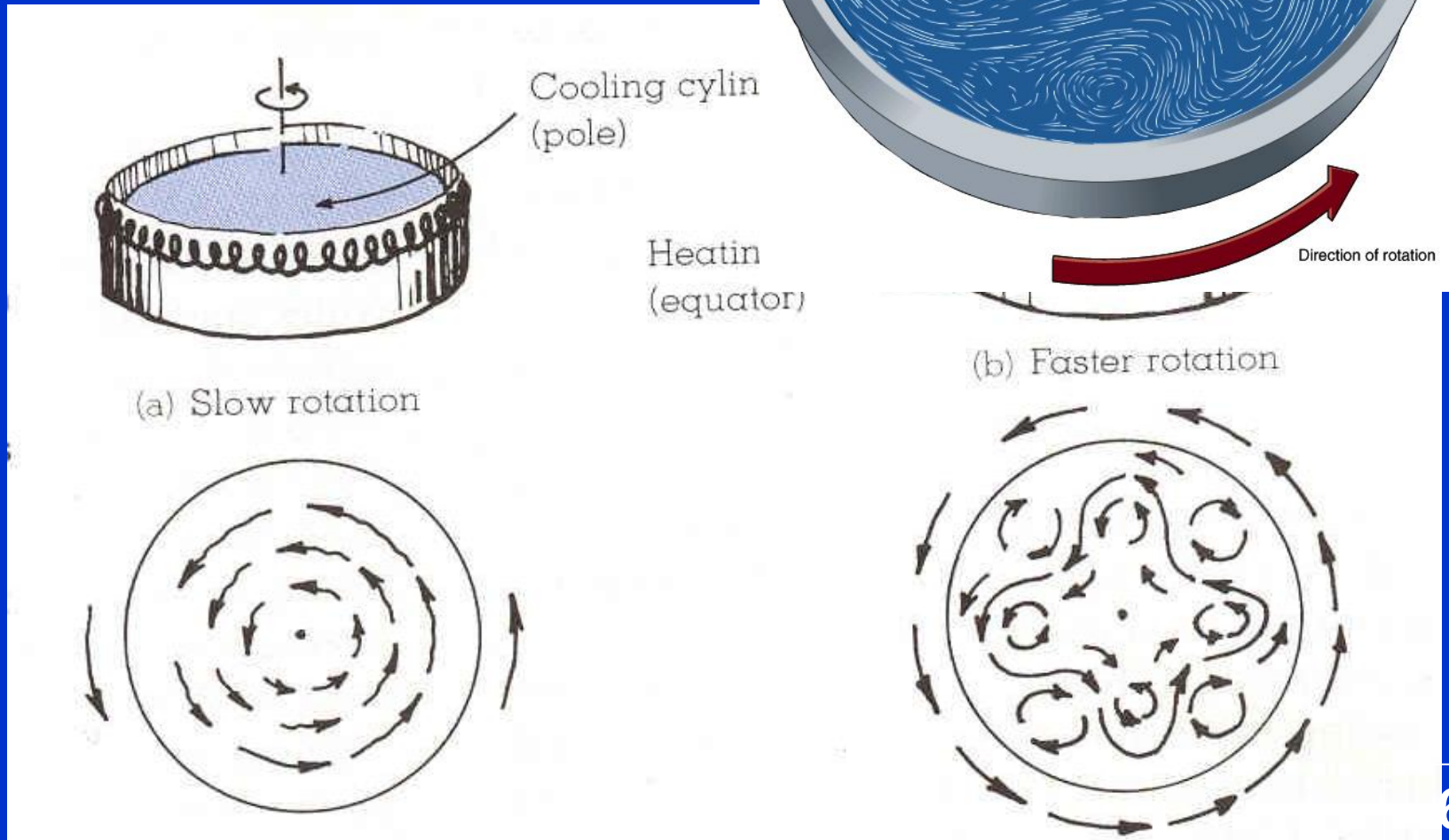
H

HADLEY CELLS = key drivers!

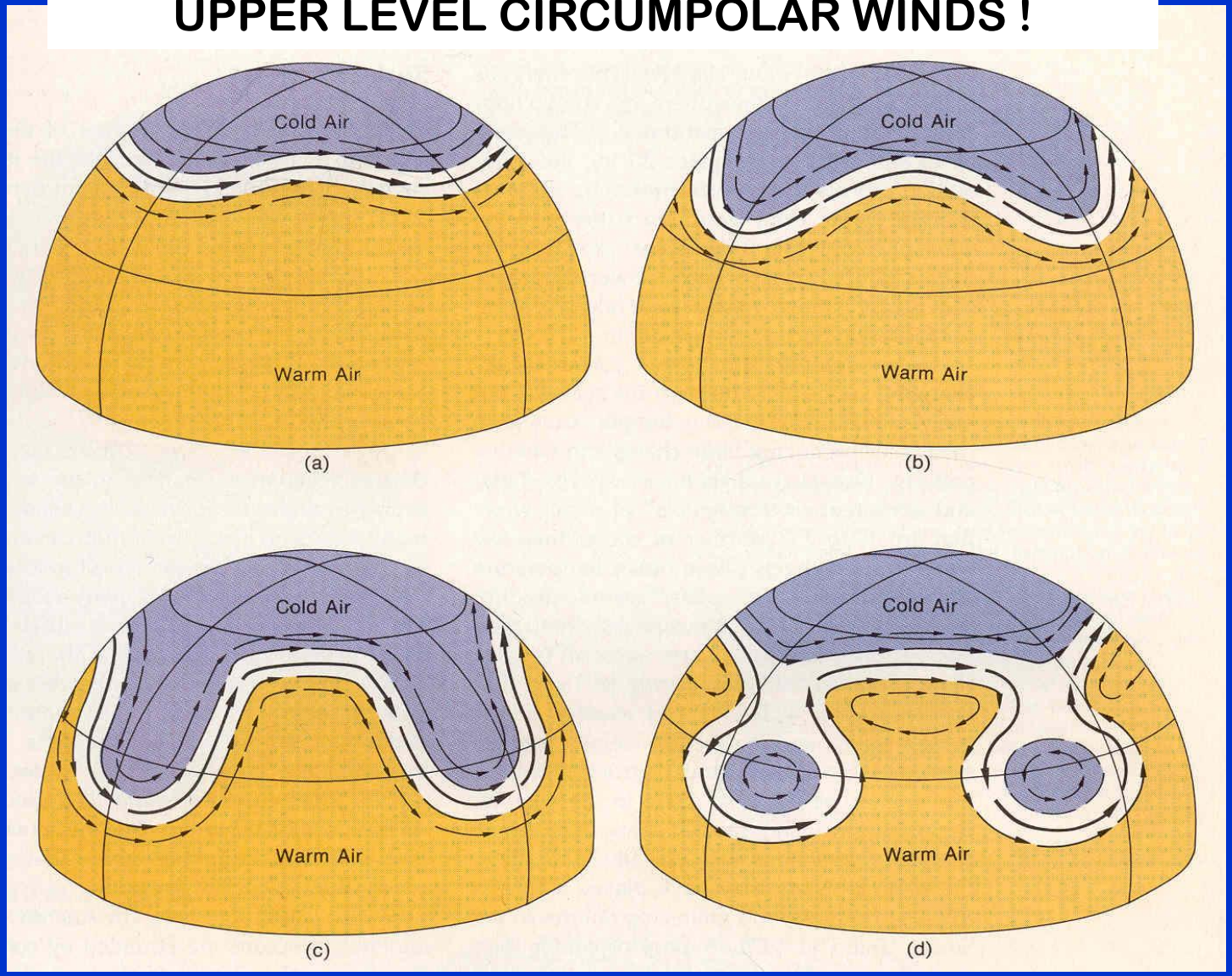
Convection cell transfer of thermal energy from low latitude area of energy SURPLUS to higher latitude area of energy DEFICIT

Why Hadley convective cell transport breaks down at higher latitudes:





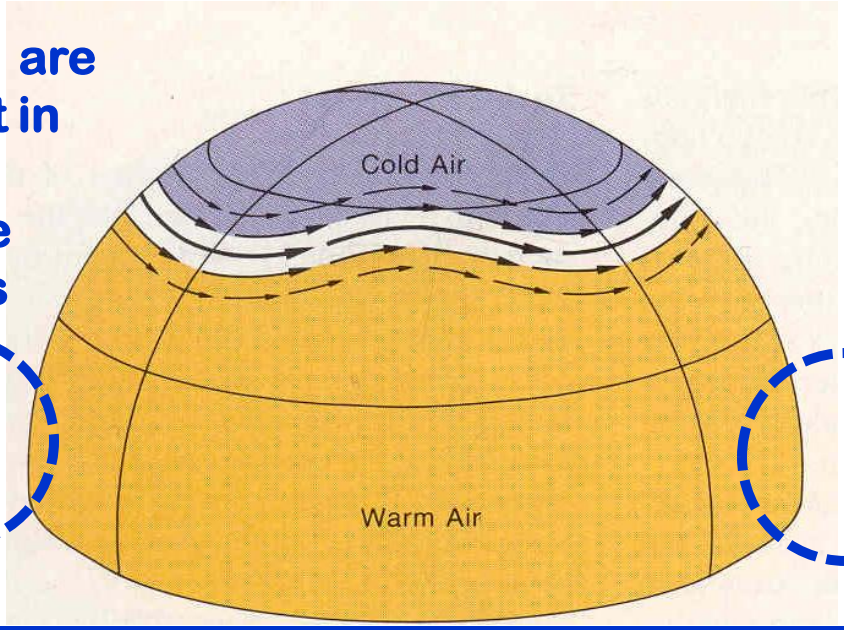
UPPER LEVEL CIRCUMPOLAR WINDS !



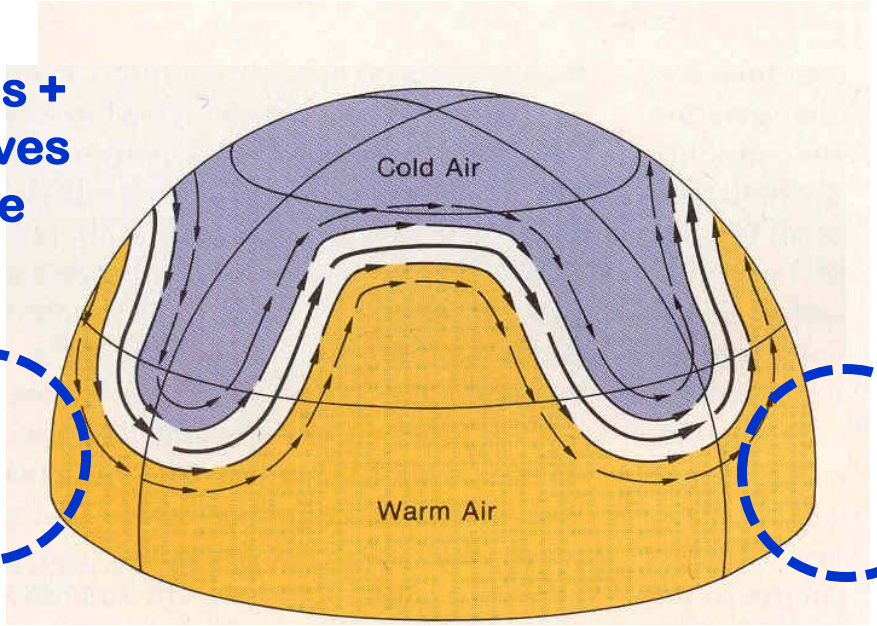
H

"Wave" transport of thermal energy instead of Hadley cell transport!

Hadley Cells are only efficient in transporting energy to the mid-latitudes



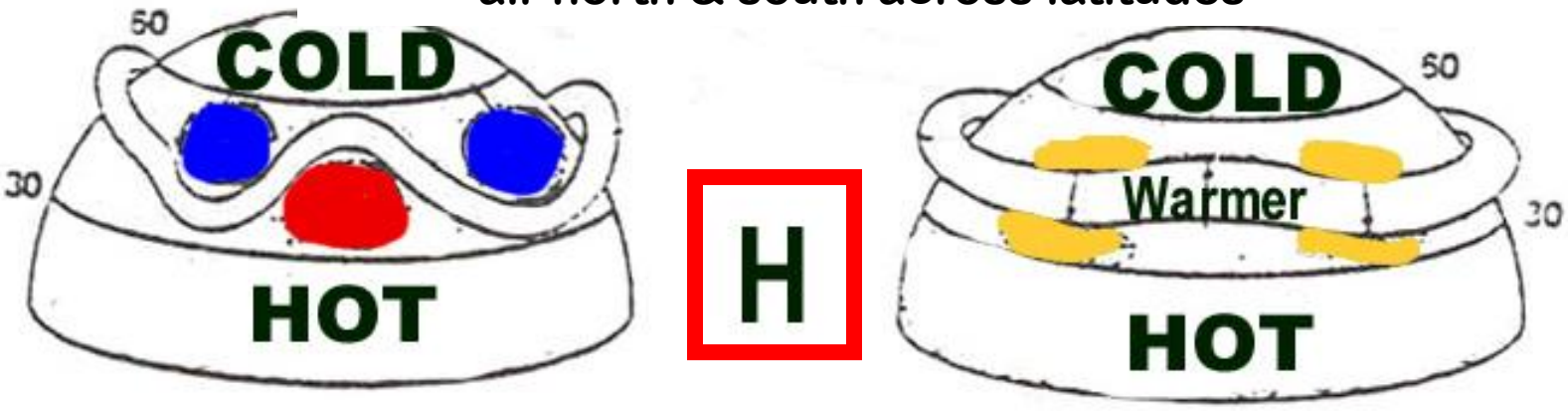
Hadley Cells + Rossby Waves together are needed!



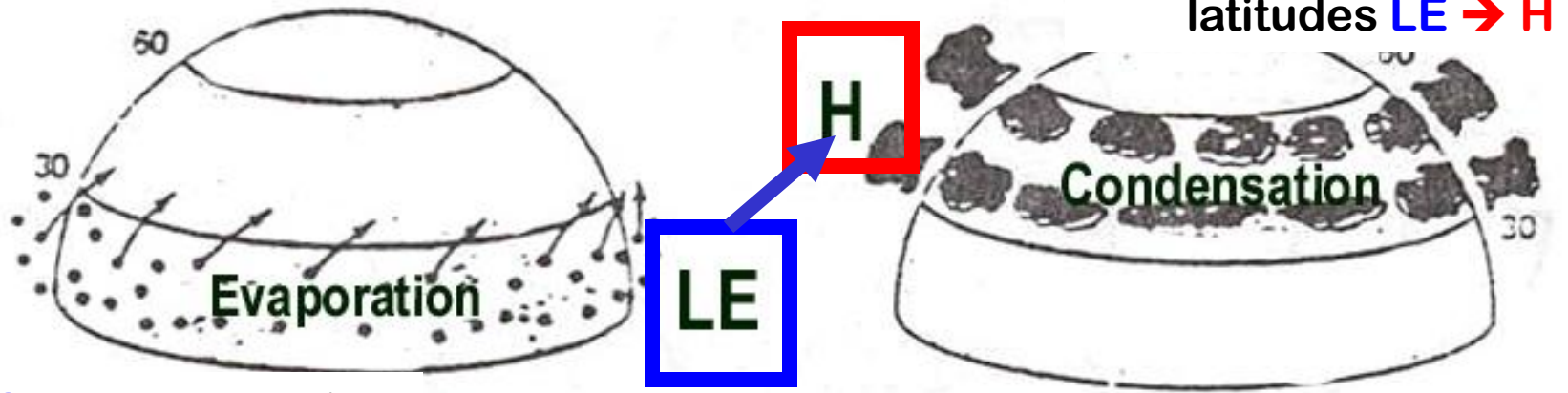
Energy is transported from areas of surplus to deficit in form of: **H** (sensible heat) & **LE** (latent energy)

IN TWO MAIN WAYS:

Atmospheric circulation moves warm & cold air north & south across latitudes



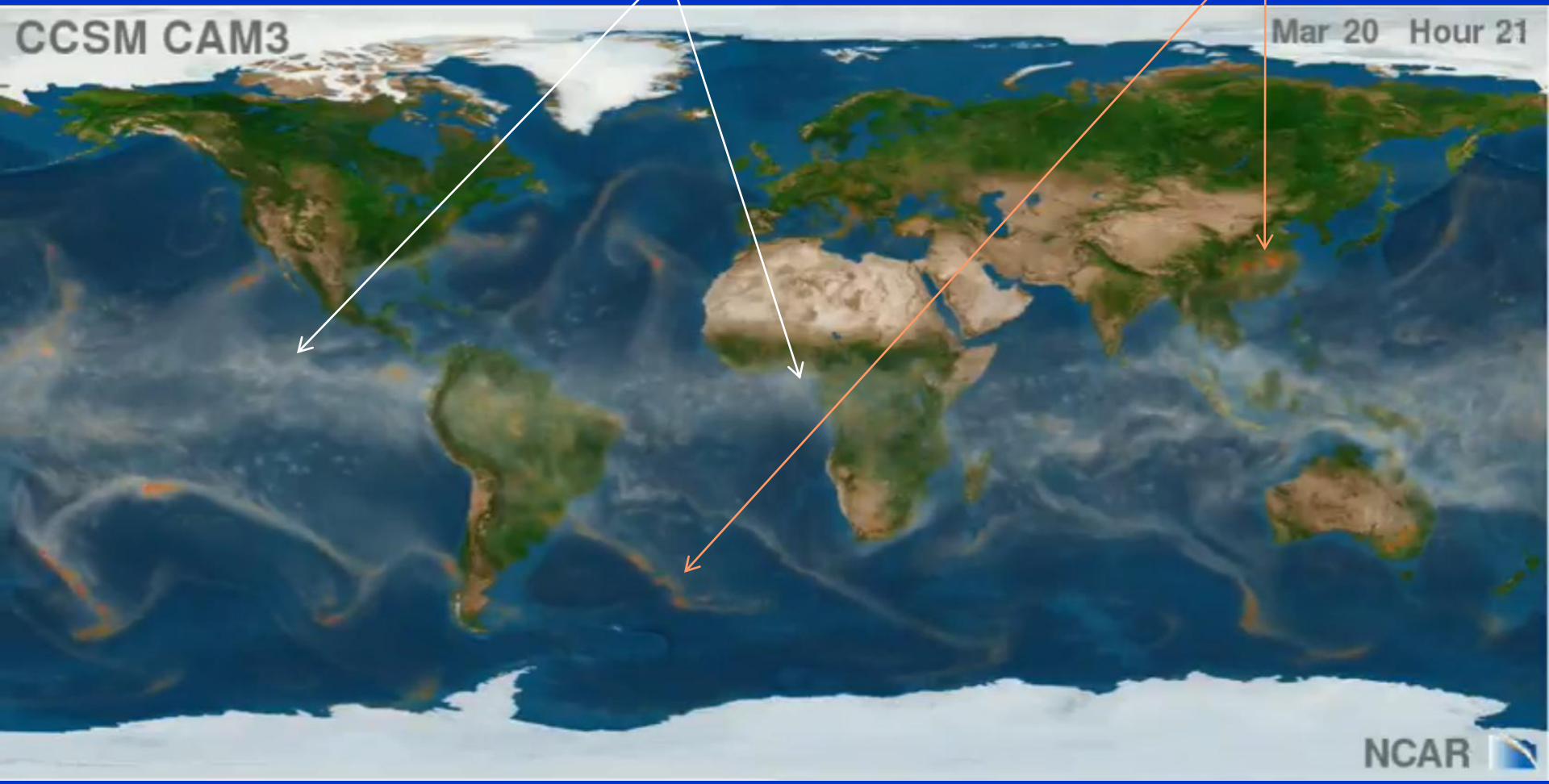
H_2O condenses in high latitudes LE → H



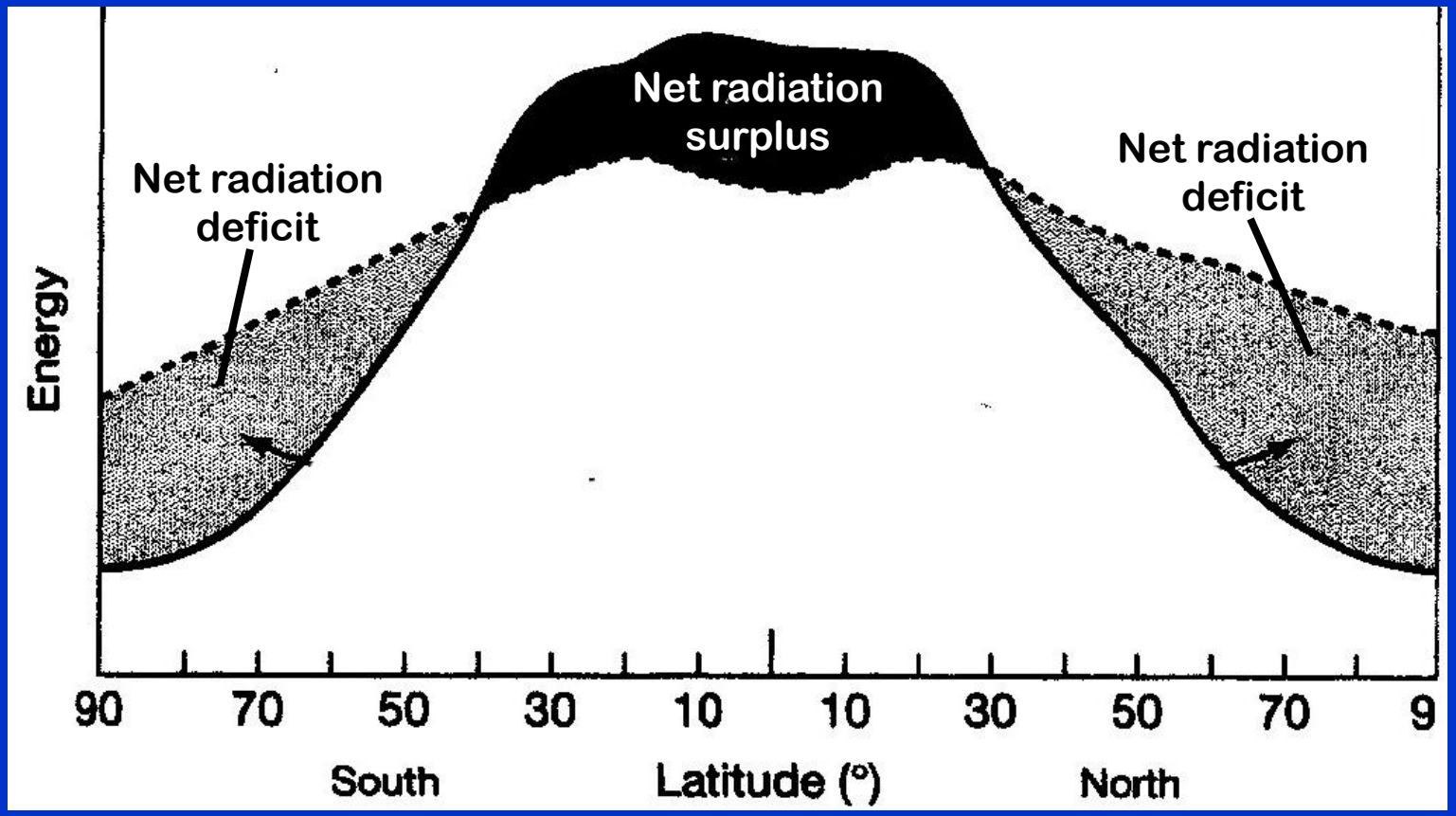
H_2O is evaporated in low latitudes H → LE

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.



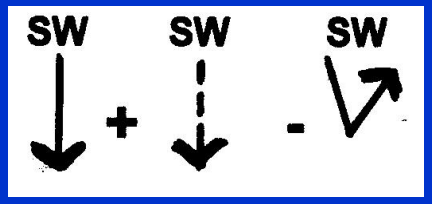
http://www.vets.ucar.edu/vg/T341/index.shtml

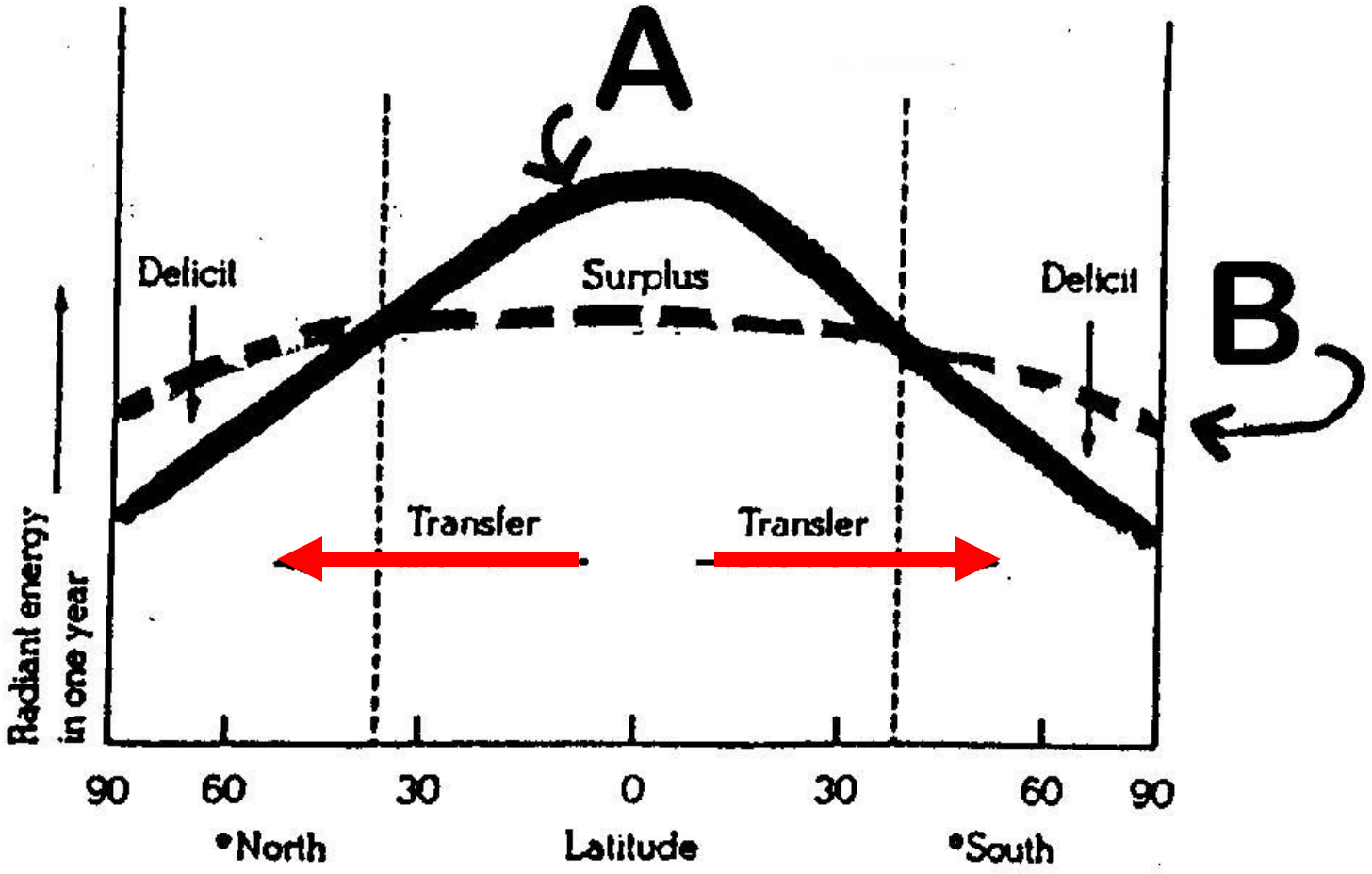


Absorbed solar energy

Emitted infrared energy

(at top of atmosphere)



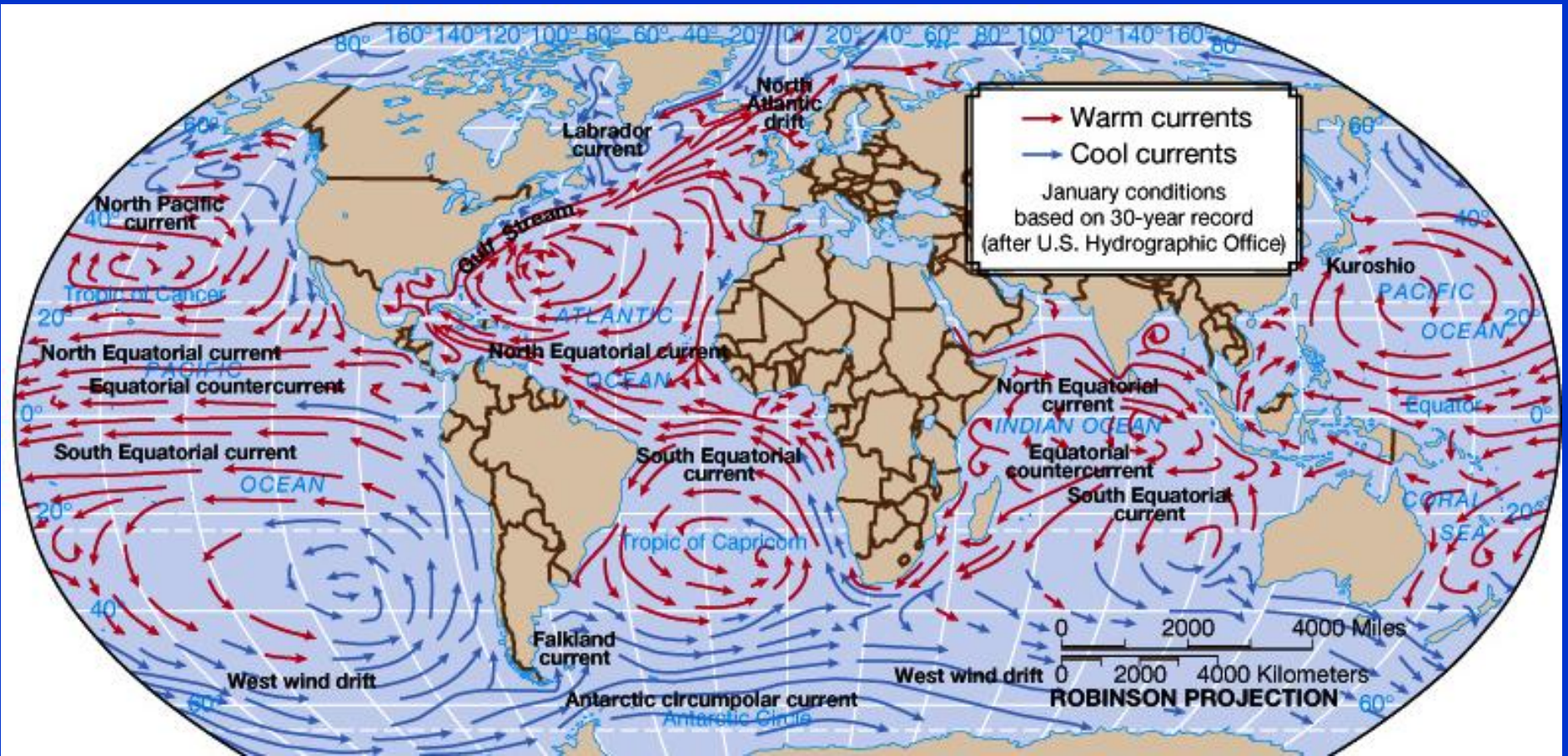


THERMAL ENERGY IS TRANSPORTED FROM LOW → TO HIGH LATITUDES TO BALANCE OUT THE DEFICIT!

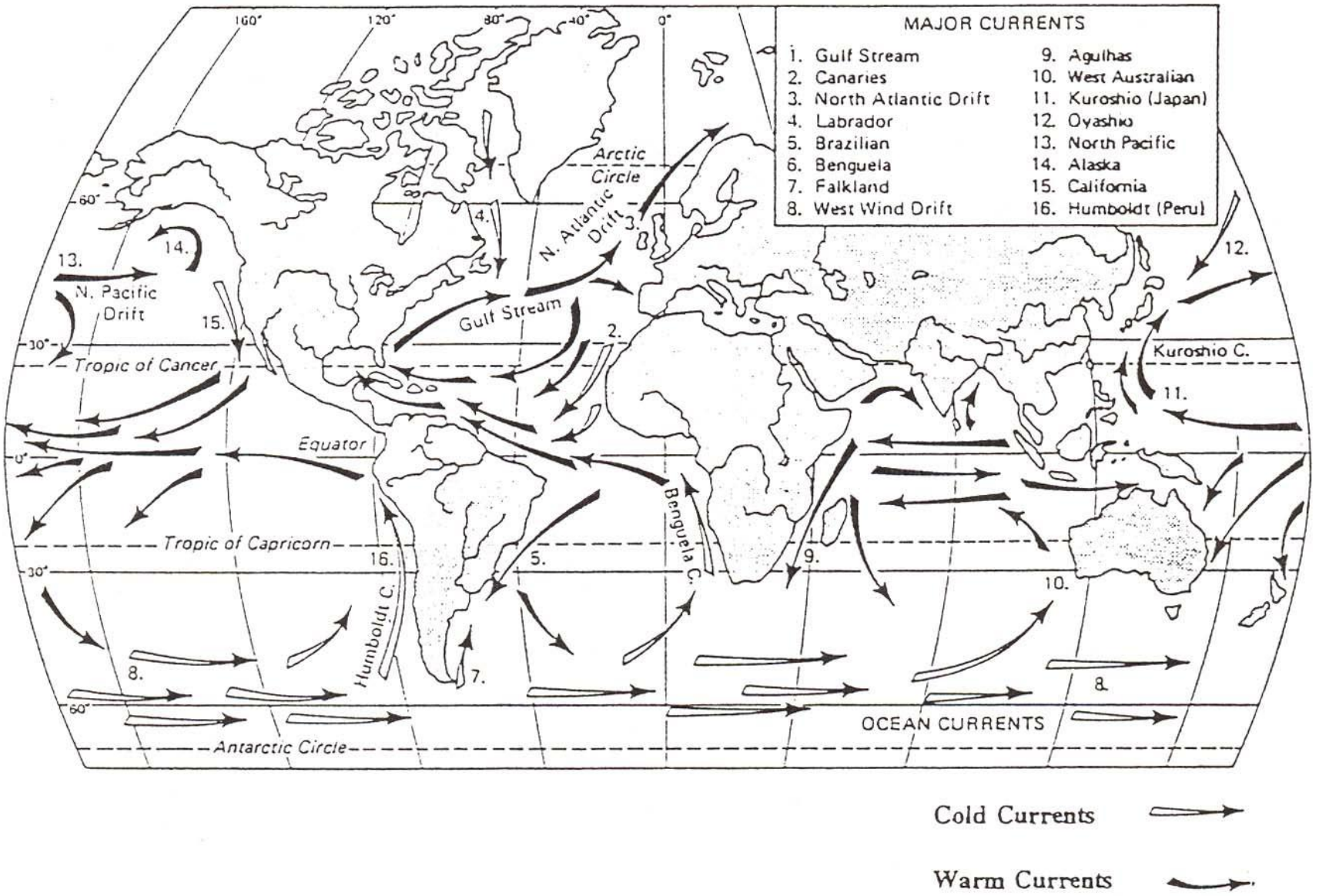
H + LE + G

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** !

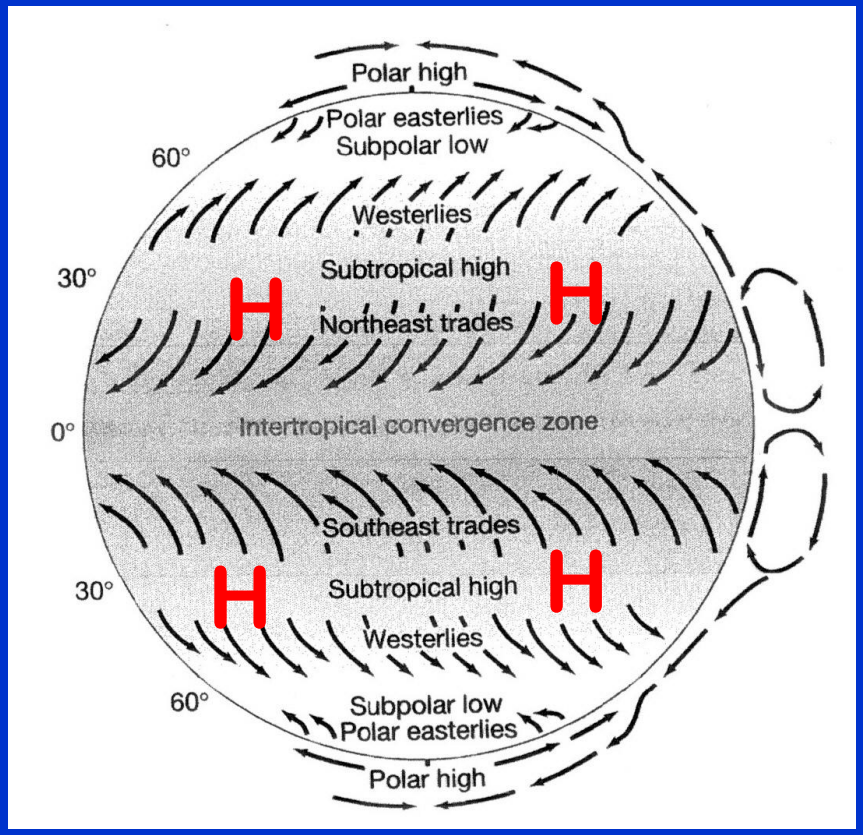


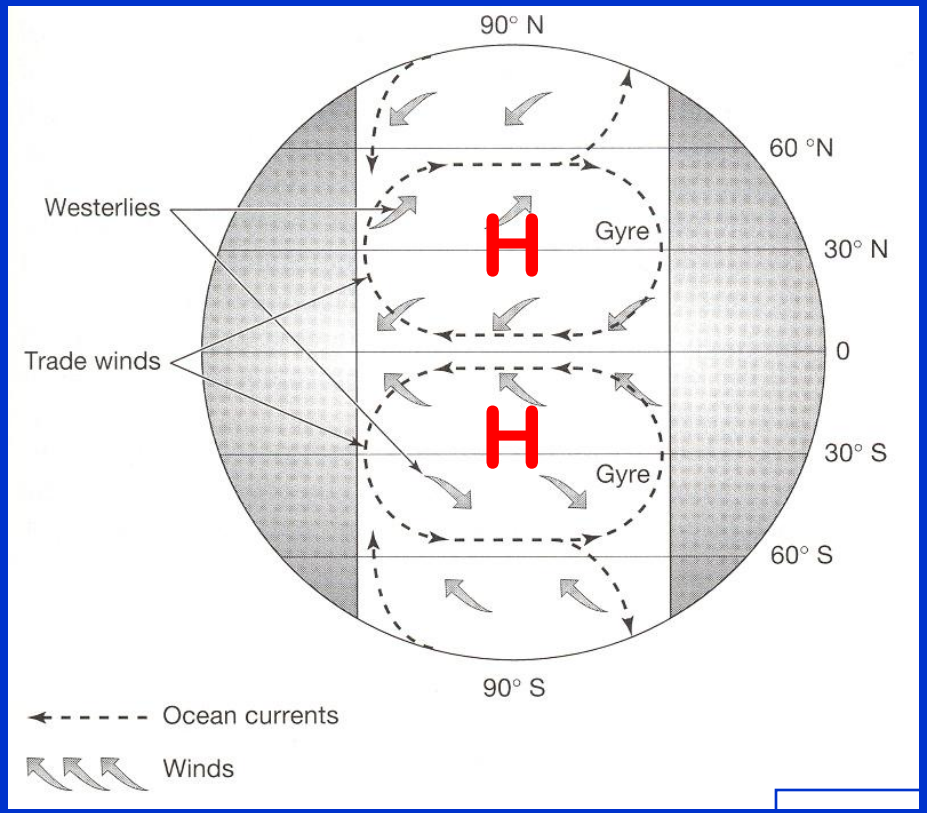
WARM & COLD SURFACE OCEAN CURRENTS:



➔ Large OCEAN GYRES -- driven by Trade Winds & Westerlies in Oceanic Subtropical HIGH PRESSURE CELLS (STH)

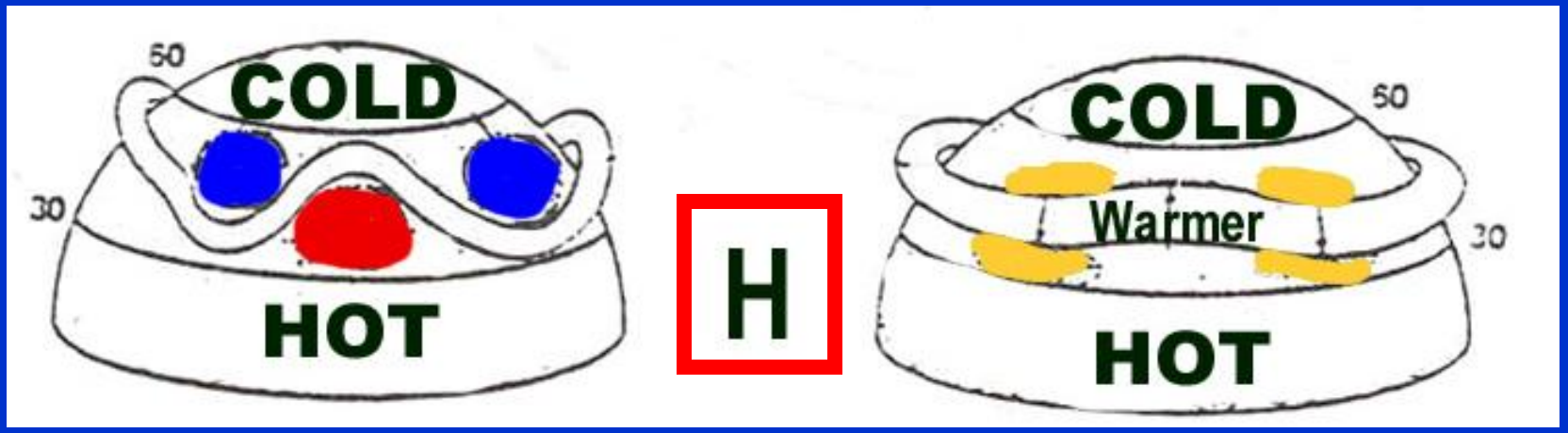
Leads to SURFACE ocean currents



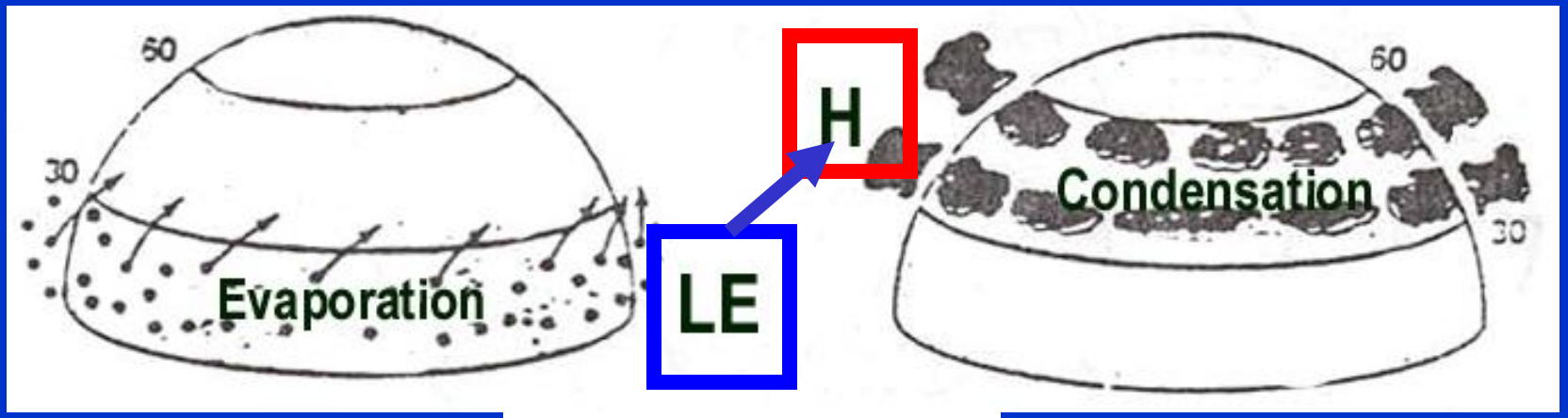


Energy is transported from areas of surplus to deficit via:

H (sensible heat)

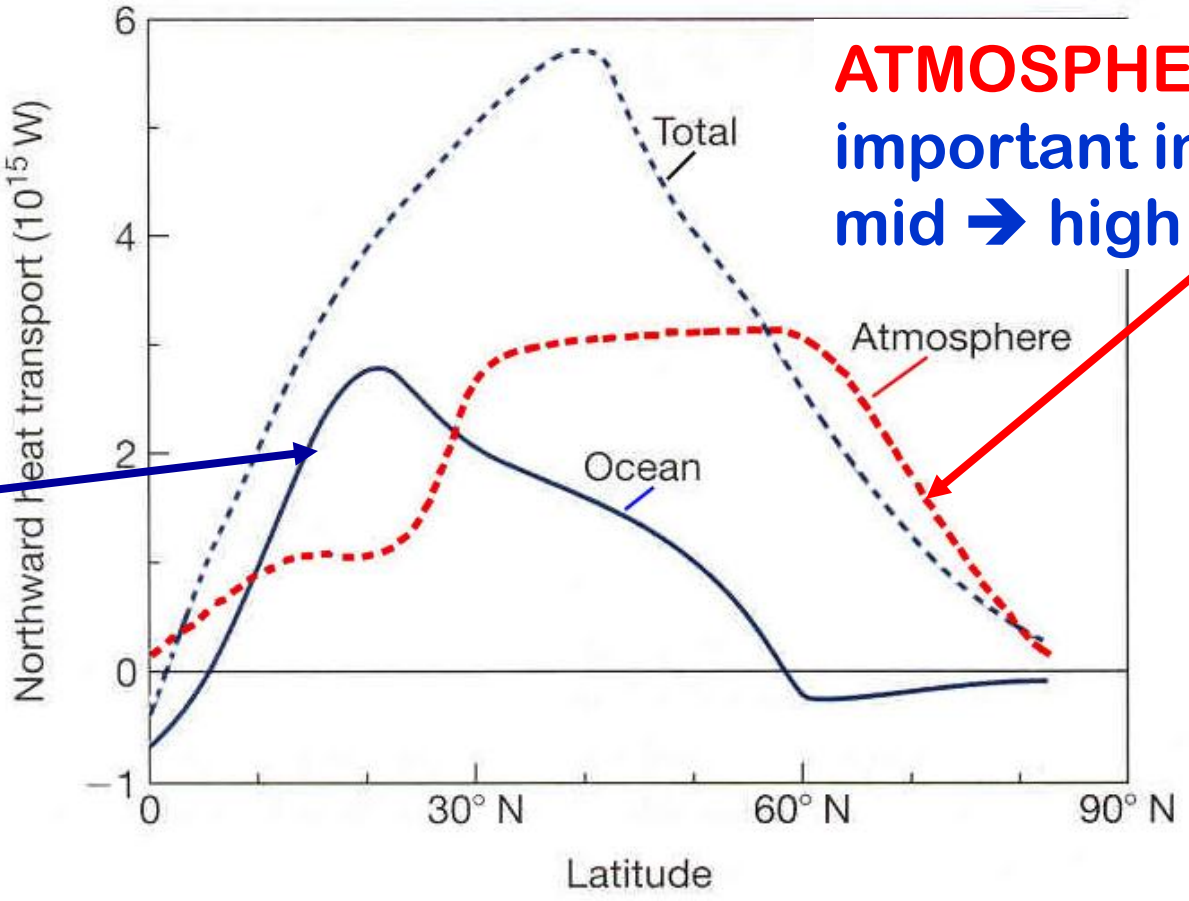


& LE (Latent Energy)



H + LE

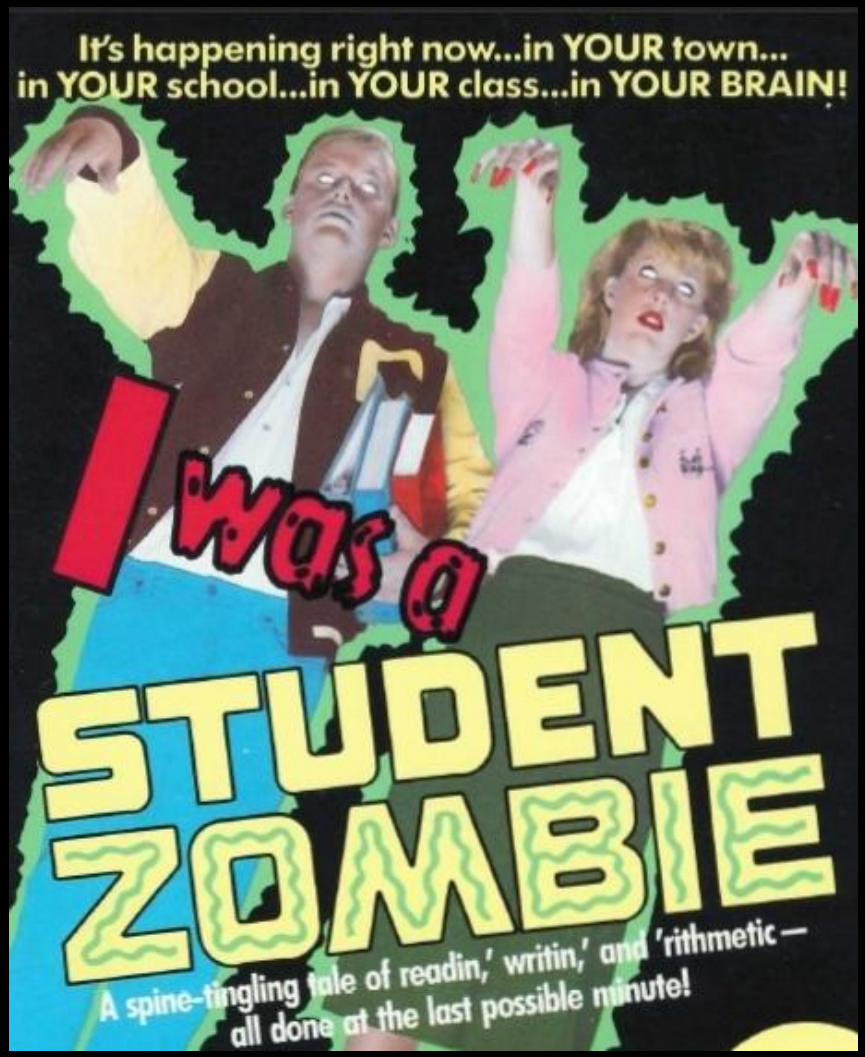
Both ATMOSPHERE & OCEAN play important roles in BALANCING OUT ENERGY SURPLUS & DEFICIT AREAS:



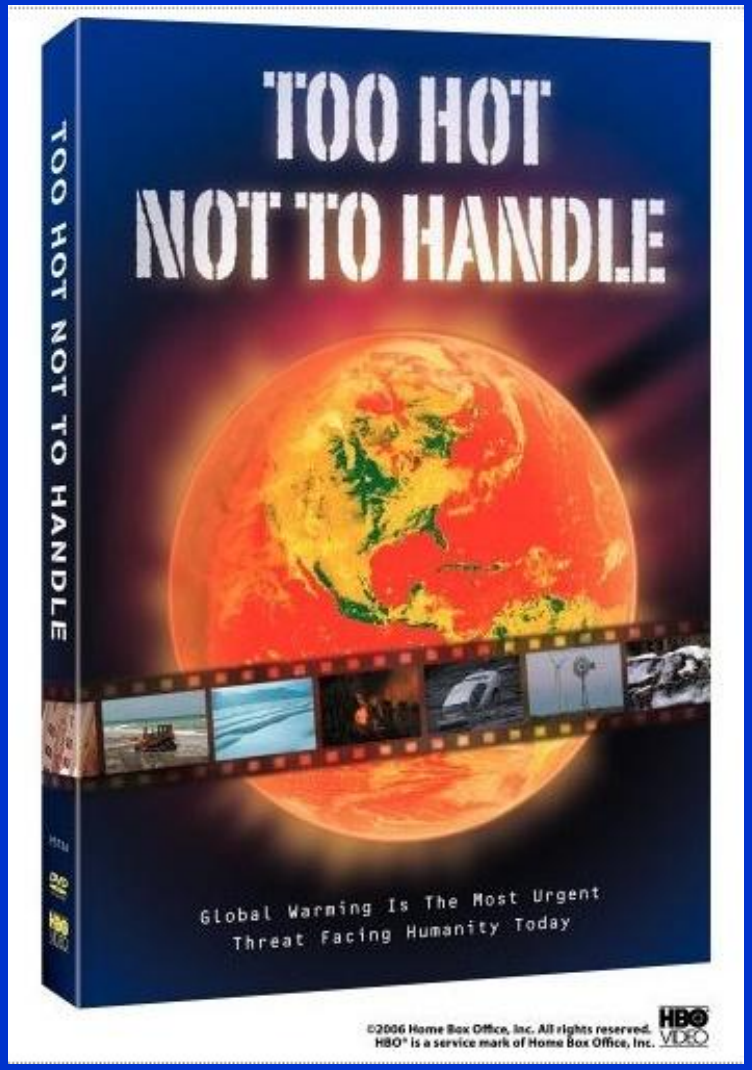
ATMOSPHERE more important in mid ➔ high latitudes

OCEAN transports MOST of the energy in LOW ➔ subtropical latitudes

Poleward transport of energy in N.H.



ZOMBIE BREAK !



Turn to Page 30

in Class Notes . . . .

As you watch the segments of this film . . . .

Check off the changes on p 30 in CLASS NOTES :

Checklist of Direct Observations of Recent Climate Change:

Checklist of Direct Observations of Recent Climate Change

TEMPERATURE: [daytime ____ nighttime ____ heat waves ____ # cold days/ frosts ____]

PRECIPITATION: [water vapor ____ drought ____ heavy rains ____]

etc., etc.

HYDROLOGY: [streamflow ____ snowmelt ___ floods ____ reservoirs /dams____ water supply ____]

CRYOSPHERE: [snowpack ____ mt glaciers ____ sea ice____ ice caps ____ frozen ground ____]

OCEAN: [sea level ____ sea surface temps ____ salinity _____ corals ____ fisheries ____]

BIOSPHERE: [plant / animal ranges _____ phenology_____ crop dates _____ disease _____]

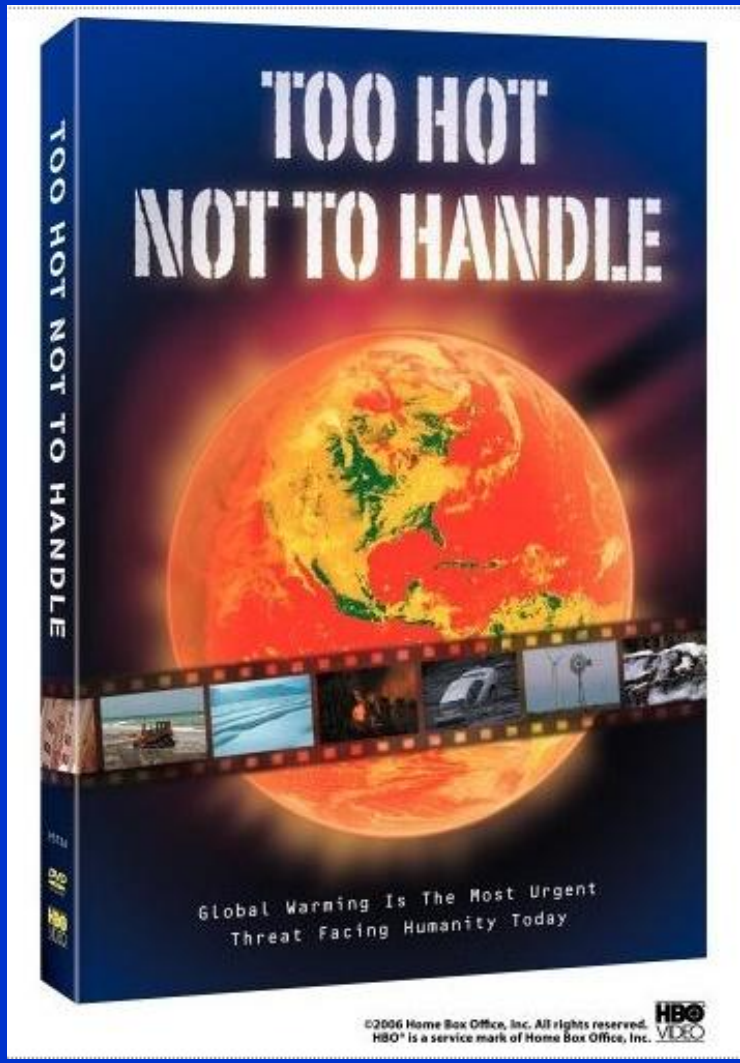
OTHER: [atmospheric circulation ____ wind belts / storm tracks _____ hurricanes _____]

Watch the video carefully – at some point a **feedback loop** process is described.

Can you recognize it ???

(HINT: it is one of the loops shown on p 56 in Class Notes)

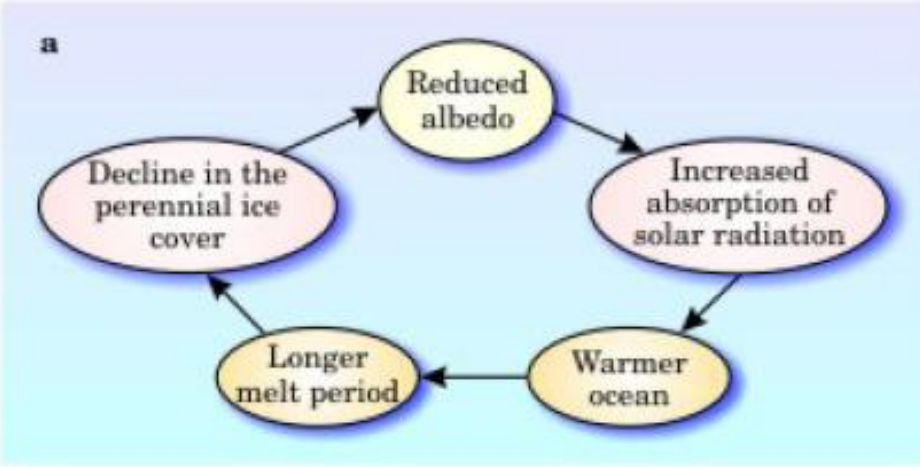
Make a note of it . . . . .

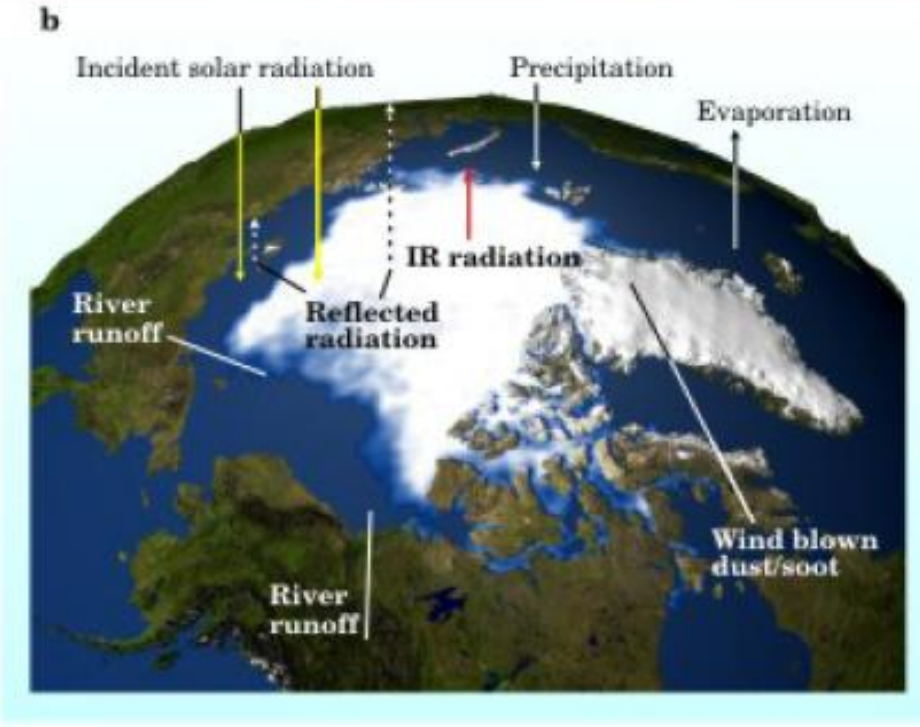


AFTER THE FILM: GROUP BONUS POINT CHALLENGE - PART 1:

State which feedback loop was described in the film and sketch the FEEDBACK DIAGRAM for it on one side of the INDEX CARD provided.

REMEMBER FEEDBACK LOOPS:
Is this one positive or negative?





GROUP BONUS POINT CHALLENGE - PART 2:

NOW – on the back of the index card, as a group, complete the feedback loop on the bottom of page 58 by linking the components with the proper coupling arrow symbols as used in the SGC text

p 58

albedo

Extent of ice cover

SW radiation absorbed

Amount of melting

Ocean temperature