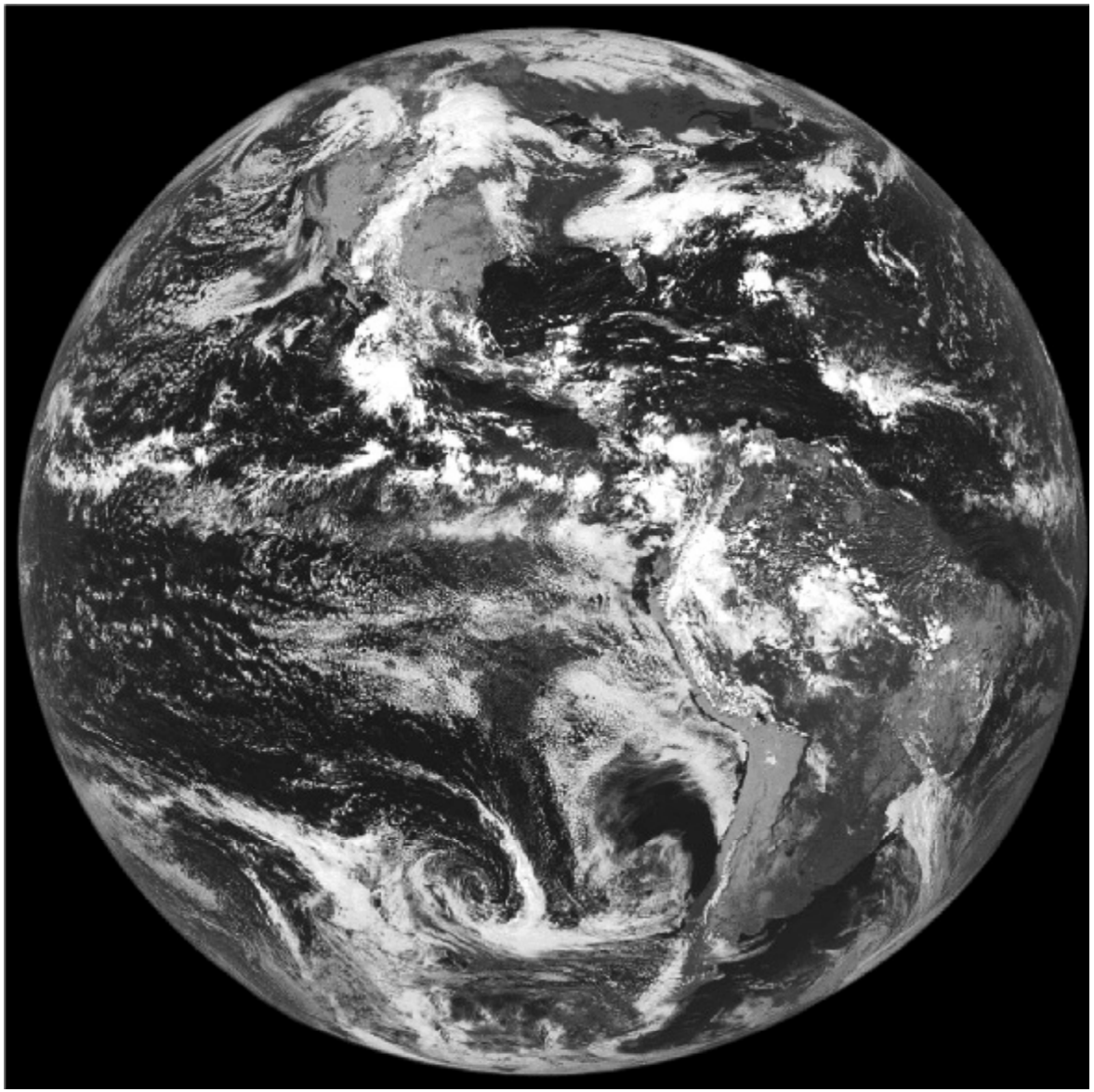
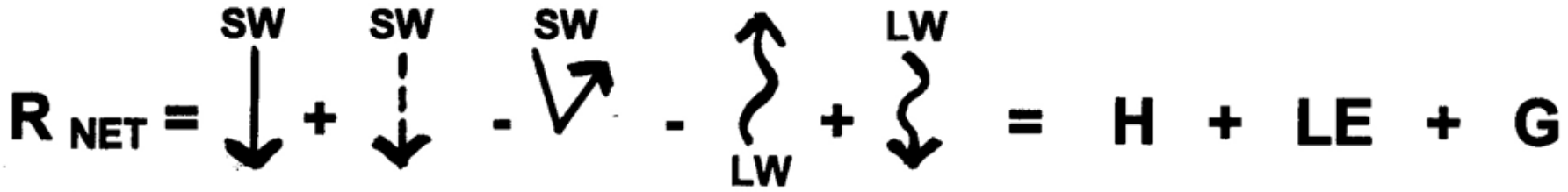
Topic # 12
Natural Climate Processes

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

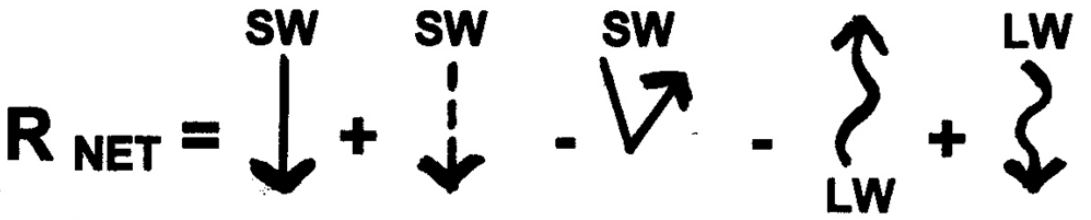
pp 63-68 in Class Notes



RADIATION / ENERGY BALANCE



"Radiation Balance" part



All components are referring to electromagnetic radiation

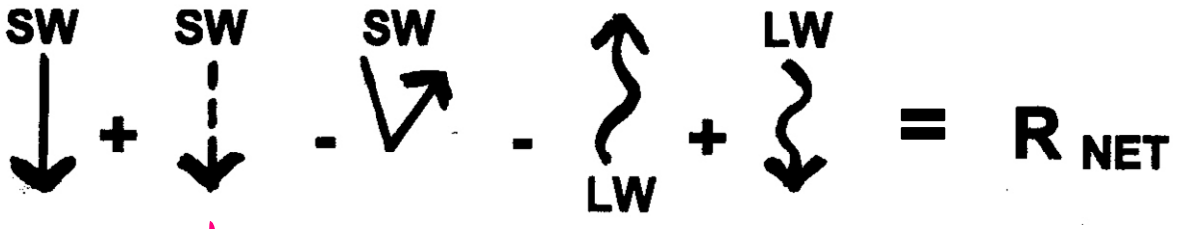
All components are referring to modes of heat energy transfer or heat energy storage <u>involving matter</u>

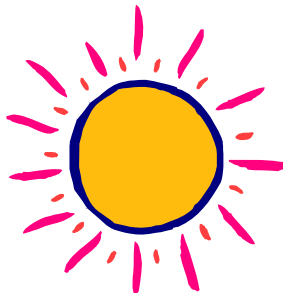
"Energy Balance" part

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

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.**

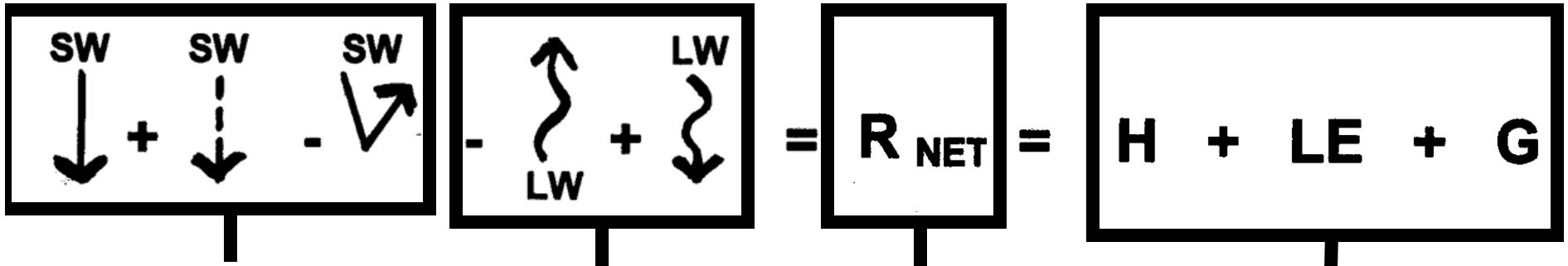
- **Sensible Heat transfer (H)**
- **Latent Heat transfer (LE)**

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

H + LE + G

Review

ENERGY IN THE EARTH-ATMOSPHERE SYSTEM

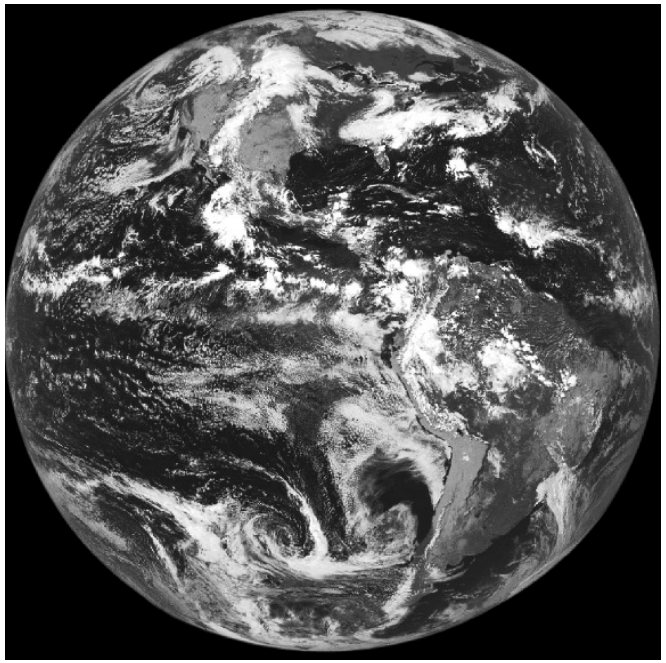


Ultimate source of energy is the SUN (SW)

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 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

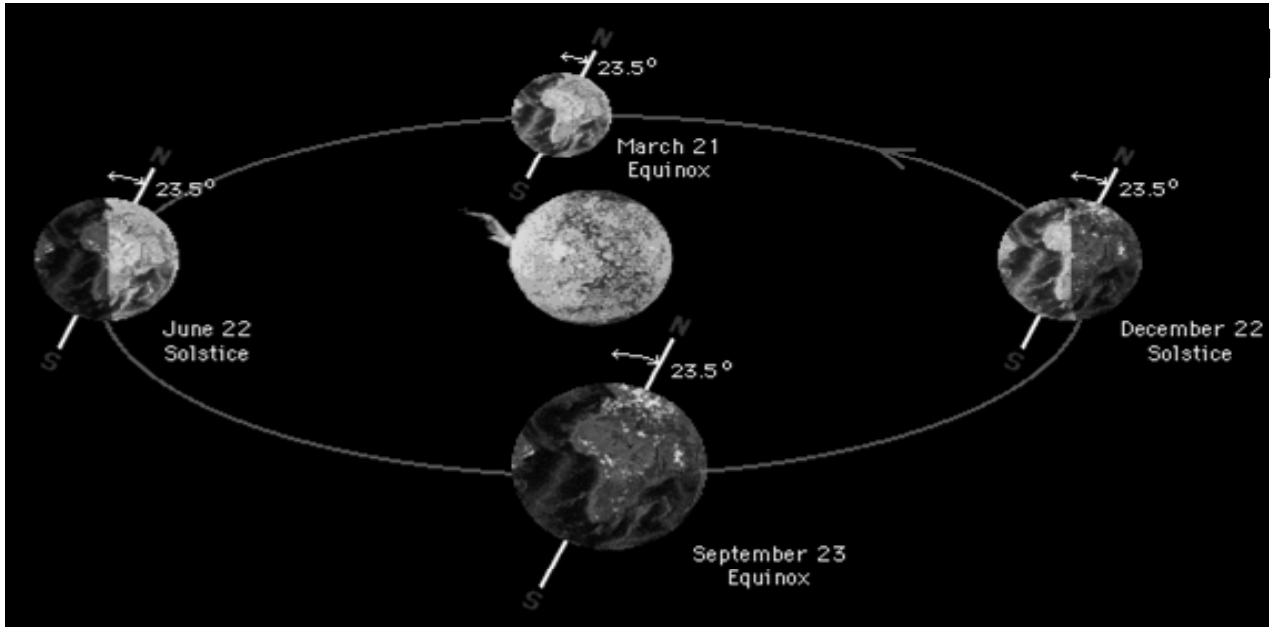
LINKING THE ENERGY BALANCE TO ATMOSPHERIC CIRCULATION . . .

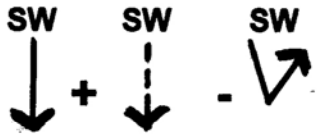
We'll start with the SUN (SOLAR INSOLATION)

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 (called the "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: Intensity + Duration

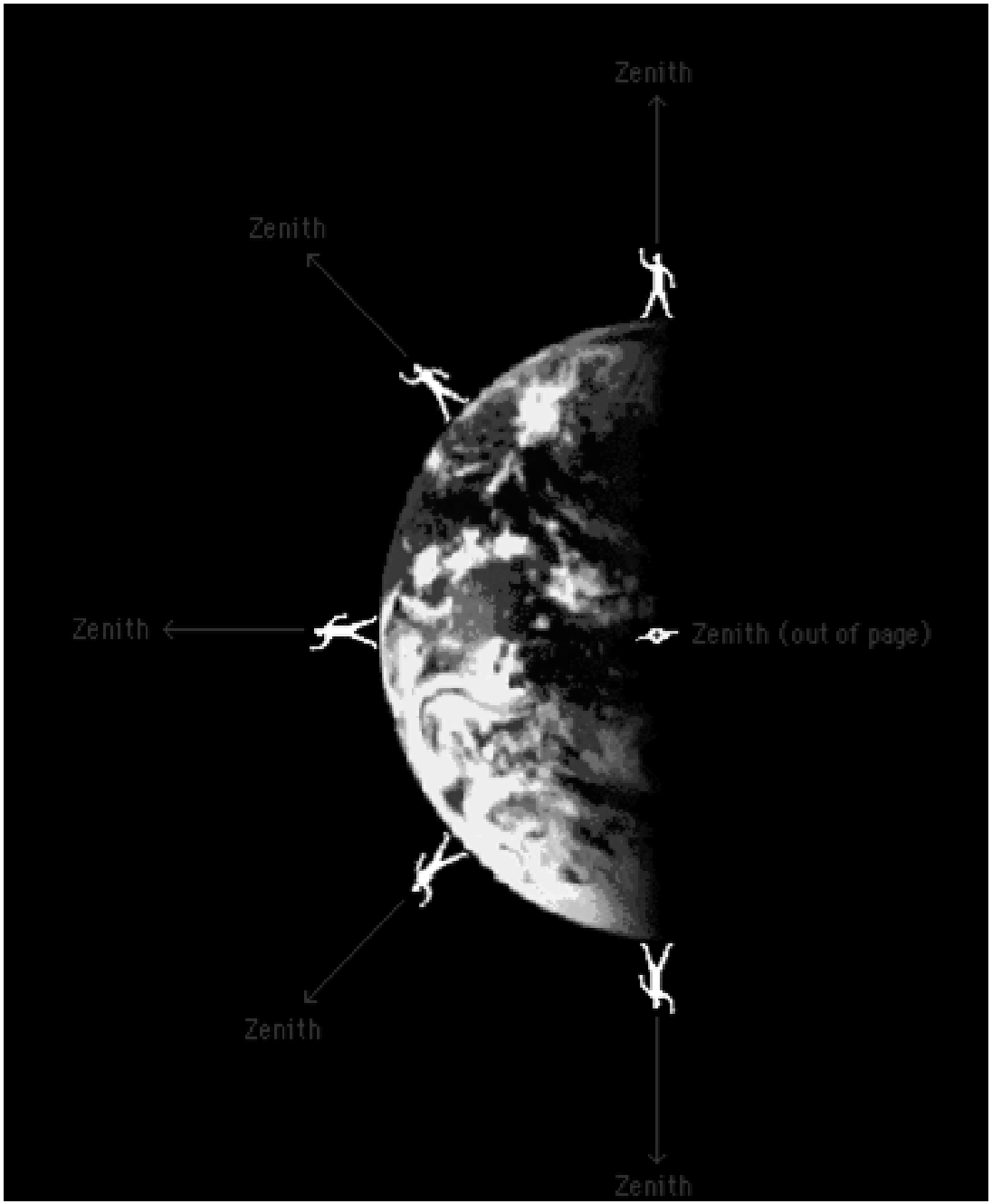
2 factors that determine the AMOUNT OF SOLAR INSOLATION *as seasons progress:*

(1) INTENSITY of sun's rays

(perpendicular to surface = more intense)

(2) DURATION of daily insolation

(longer day length = more insolation)



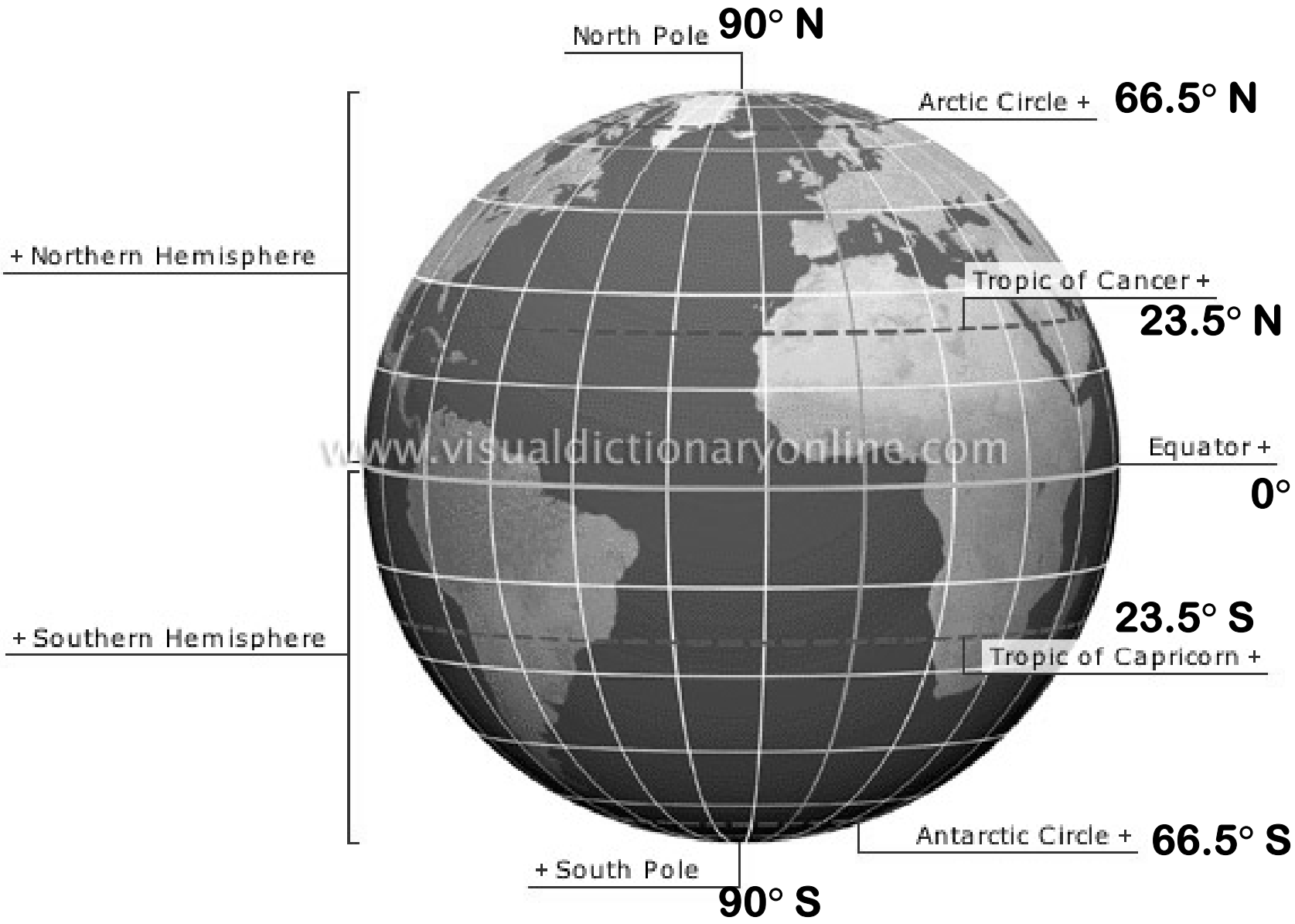
A useful term:

ZENITH = The point directly overhead

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

☺

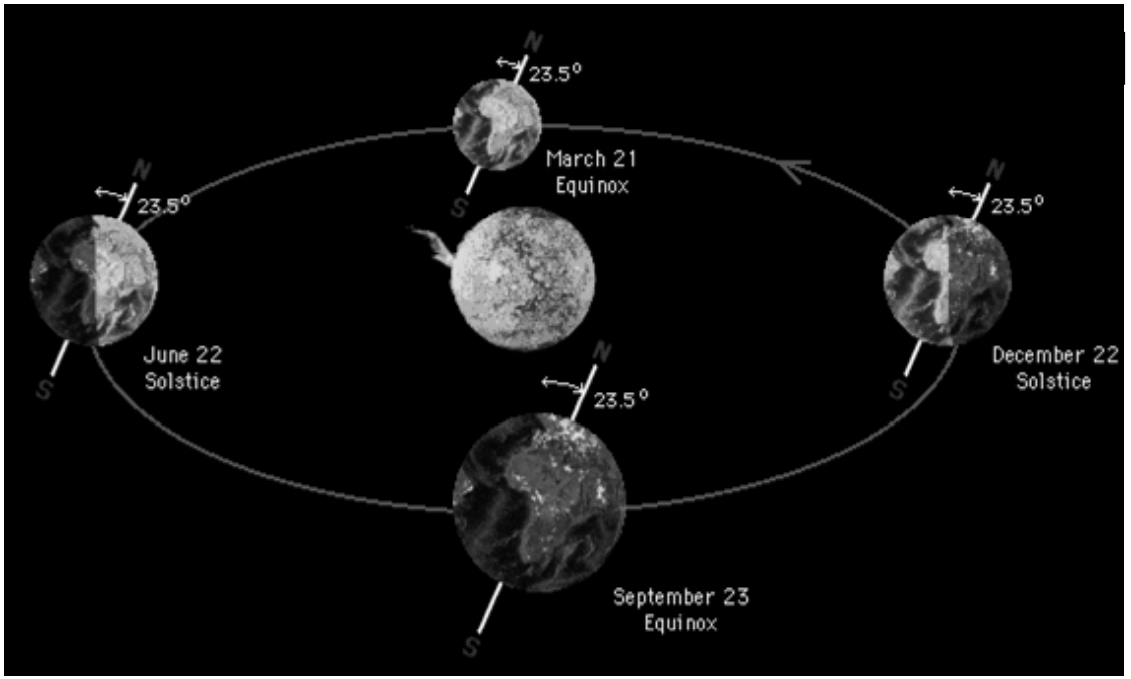
QUICKIE LATITUDE REVIEW:



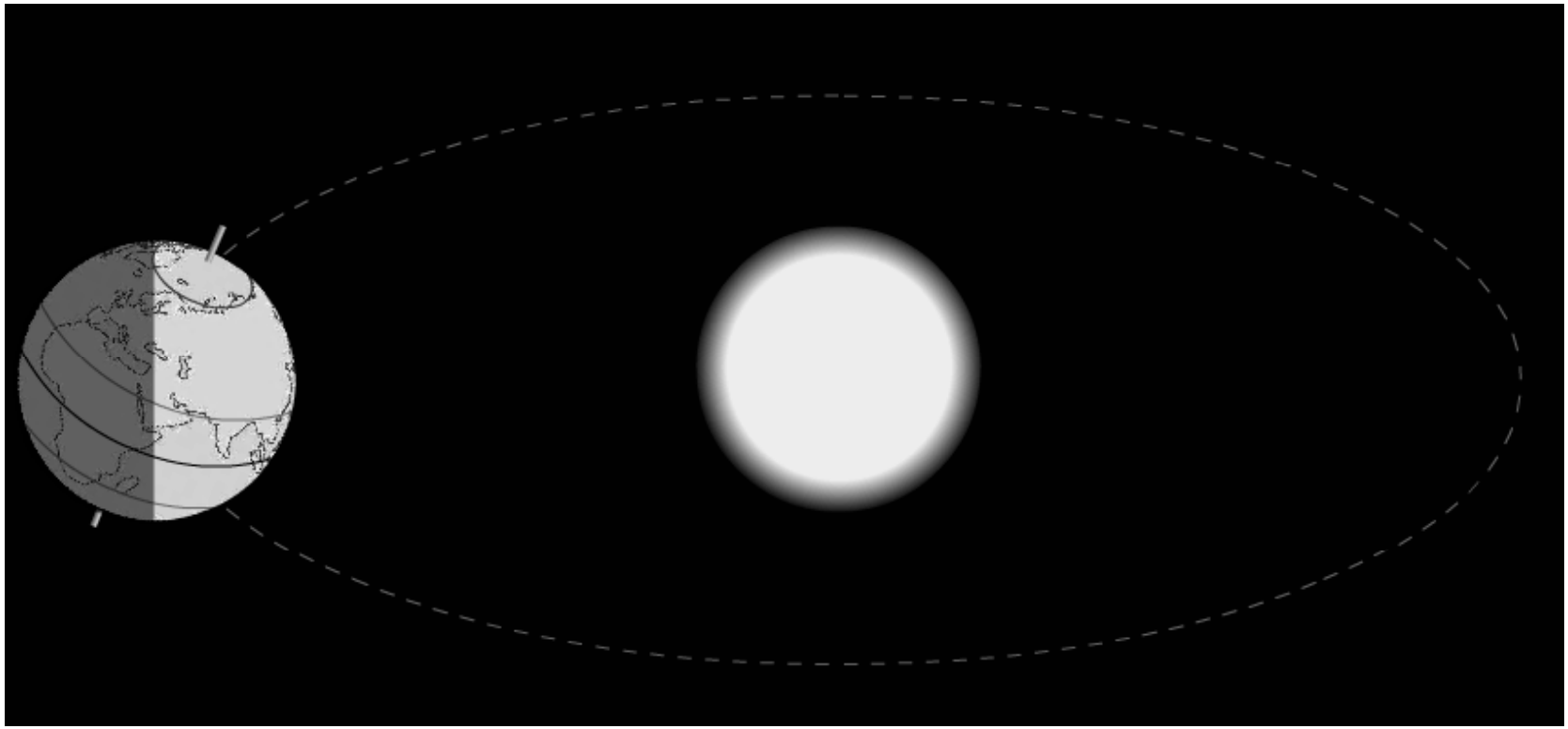
EARTH-SUN RELATIONSHIPS & The SEASONS:

VIEW THE ANIMATION:

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

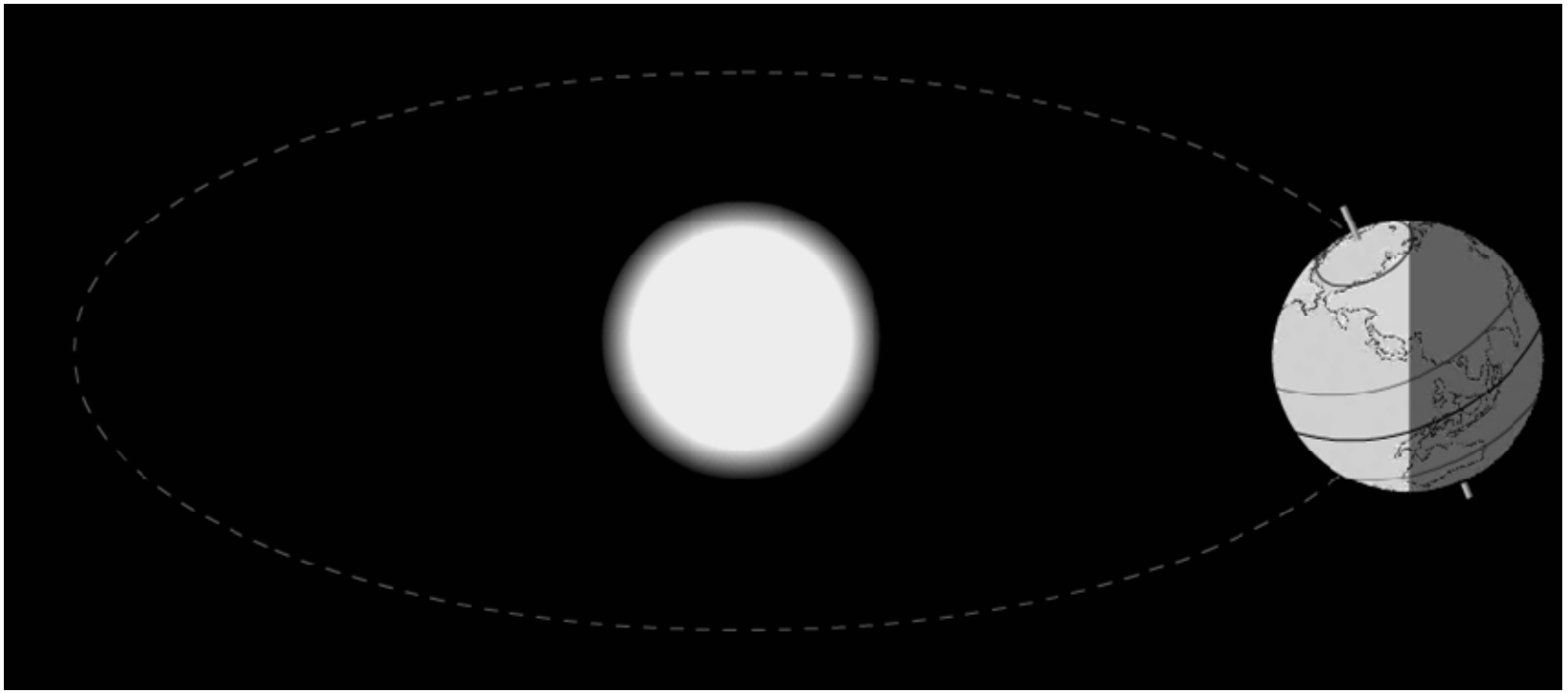


JUNE SOLSTICE



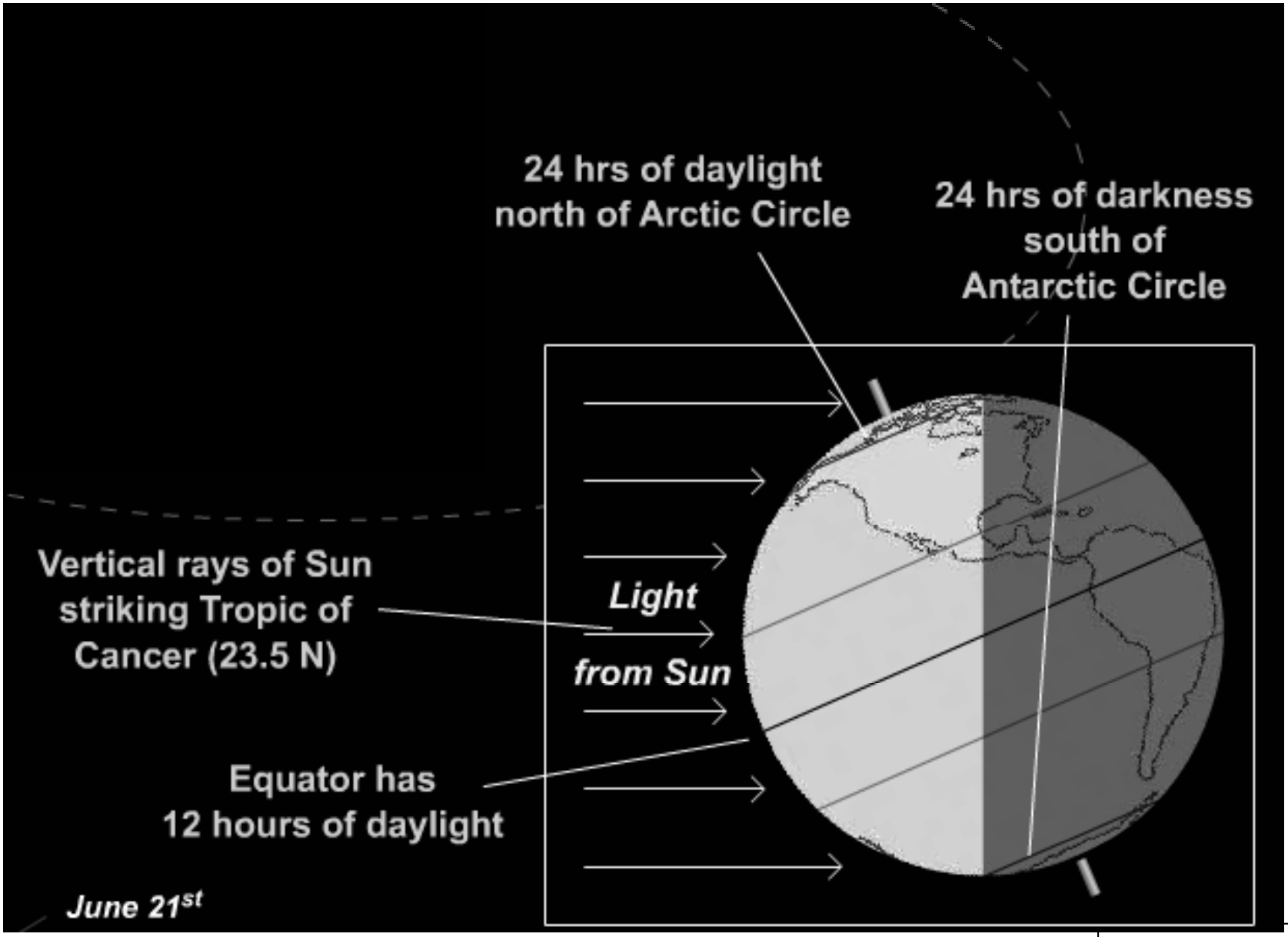
As viewed from one side of Sun

JUNE SOLSTICE



As viewed from the
<u>other</u> side of the Sun

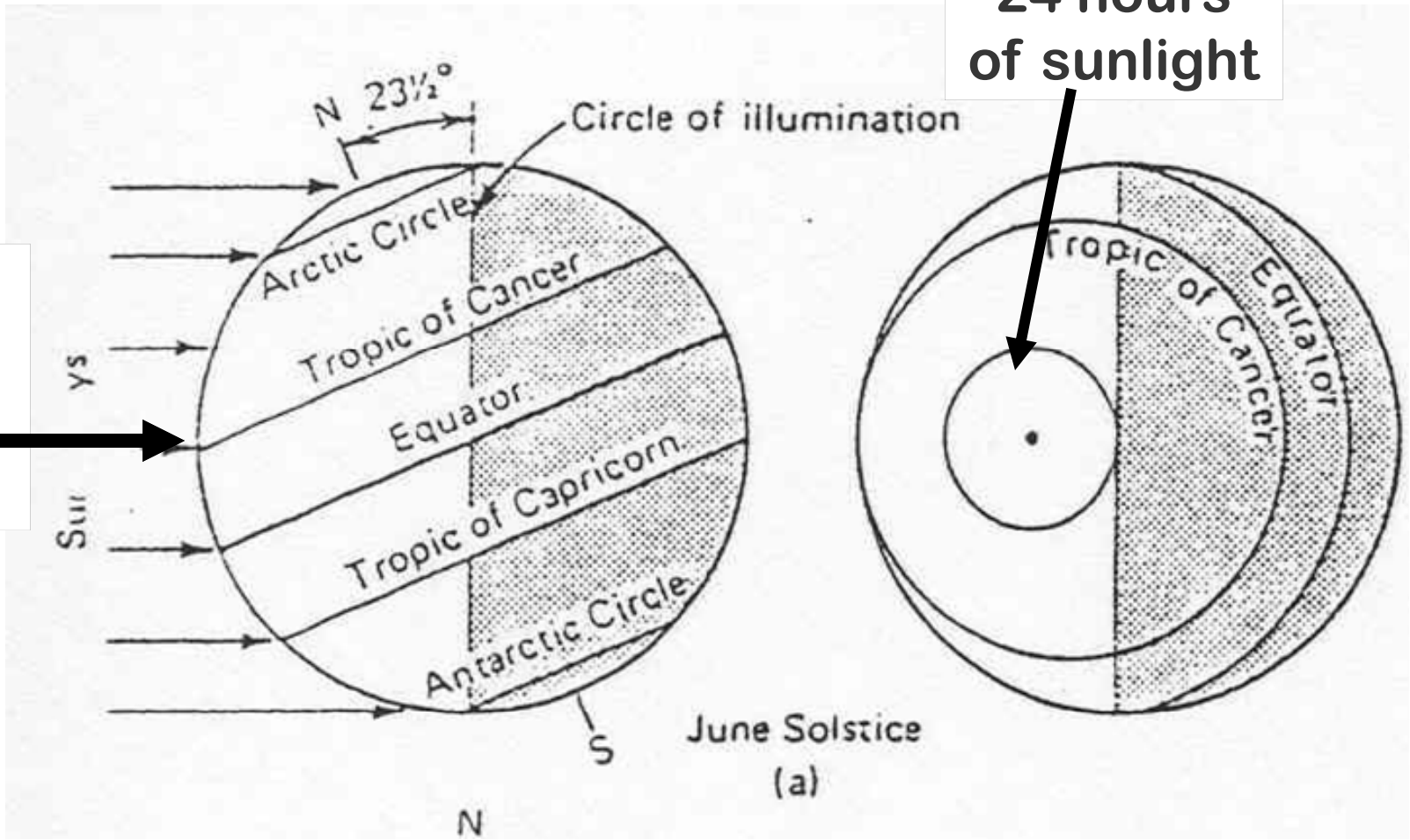
JUNE SOLSTICE



JUNE SOLSTICE

24 hours of sunlight

Most intense solar radiation



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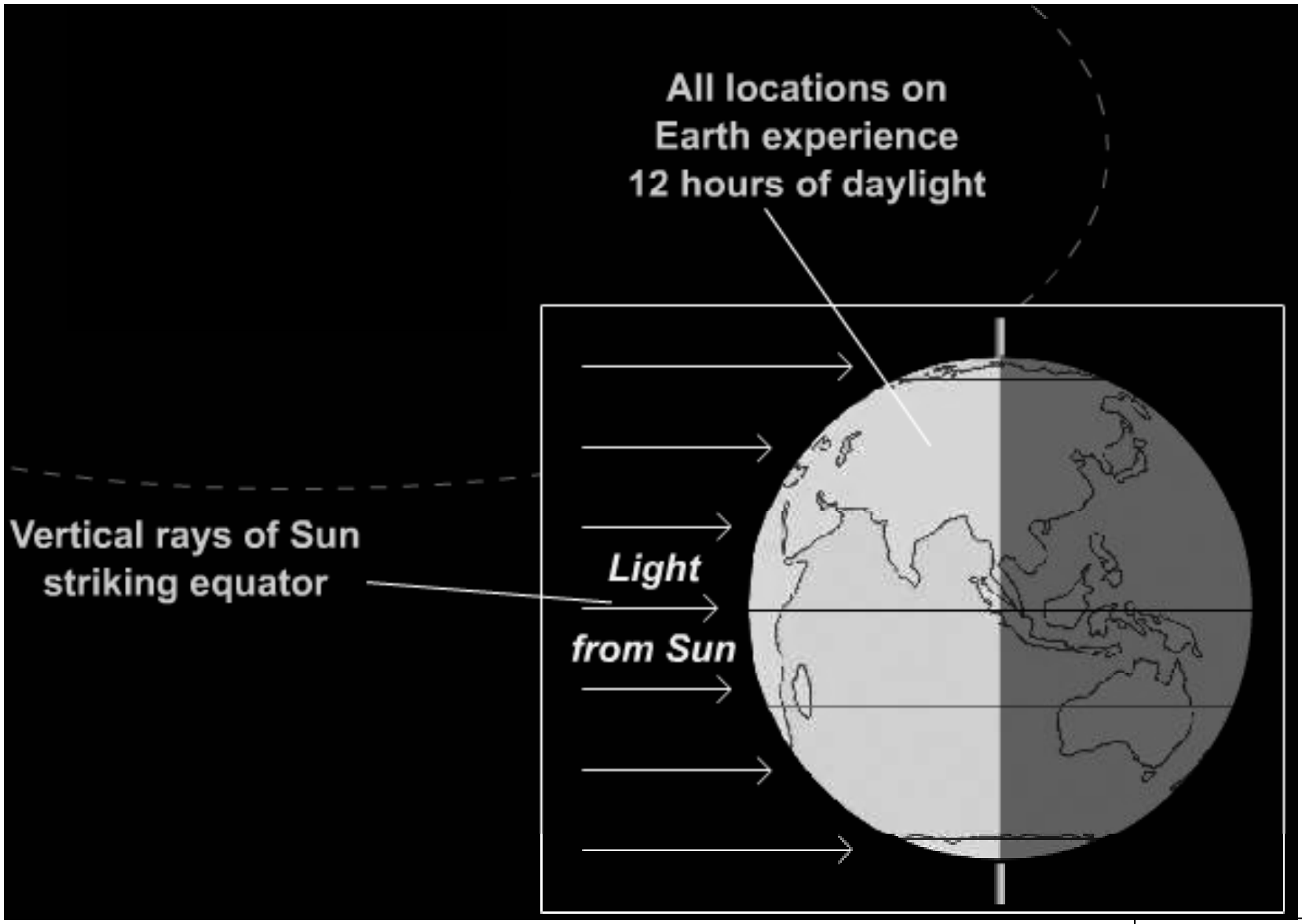
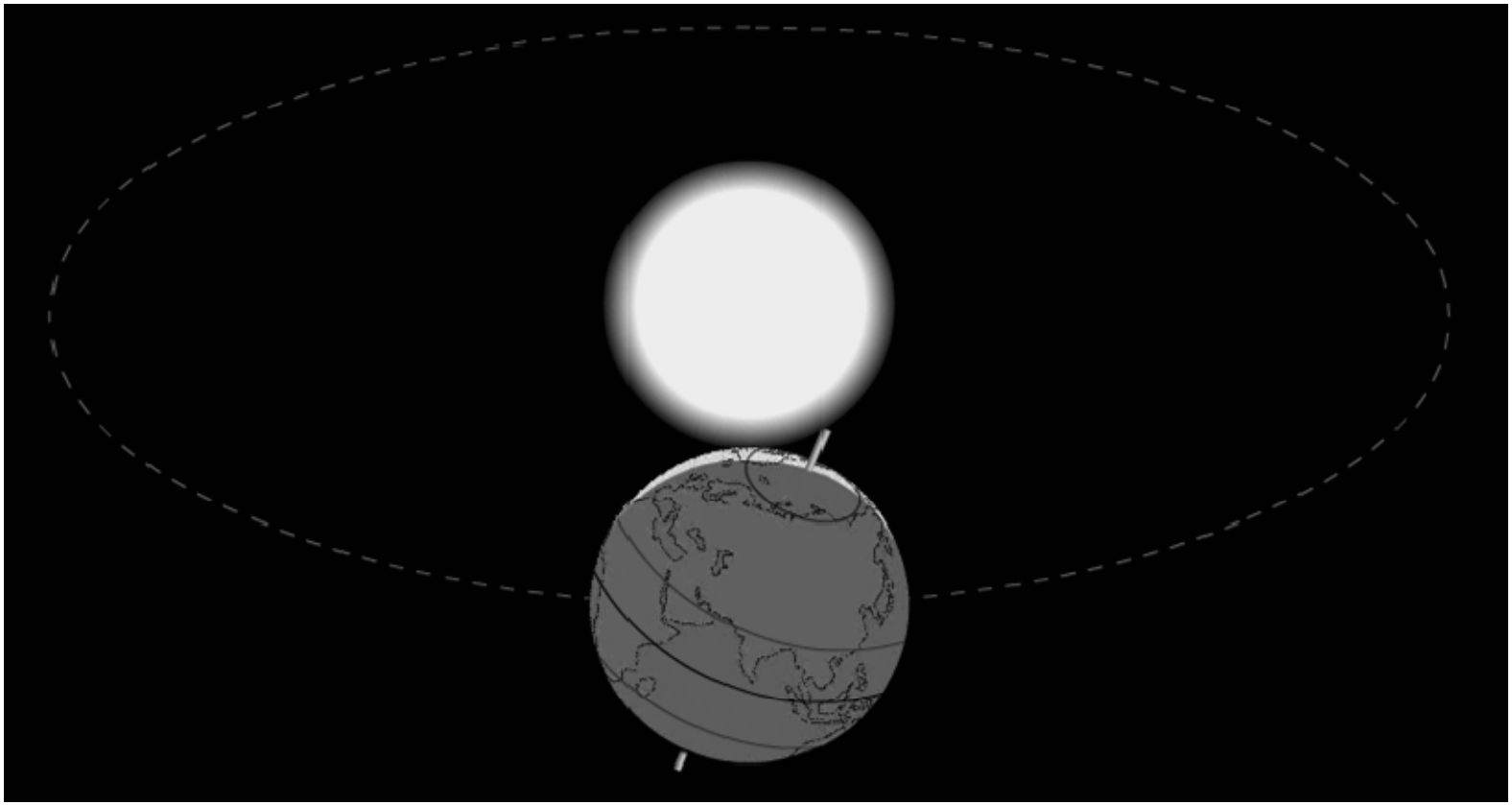
MARCH EQUINOX



SEPTEMBER EQUINOX
different seasonal position in orbit . . .

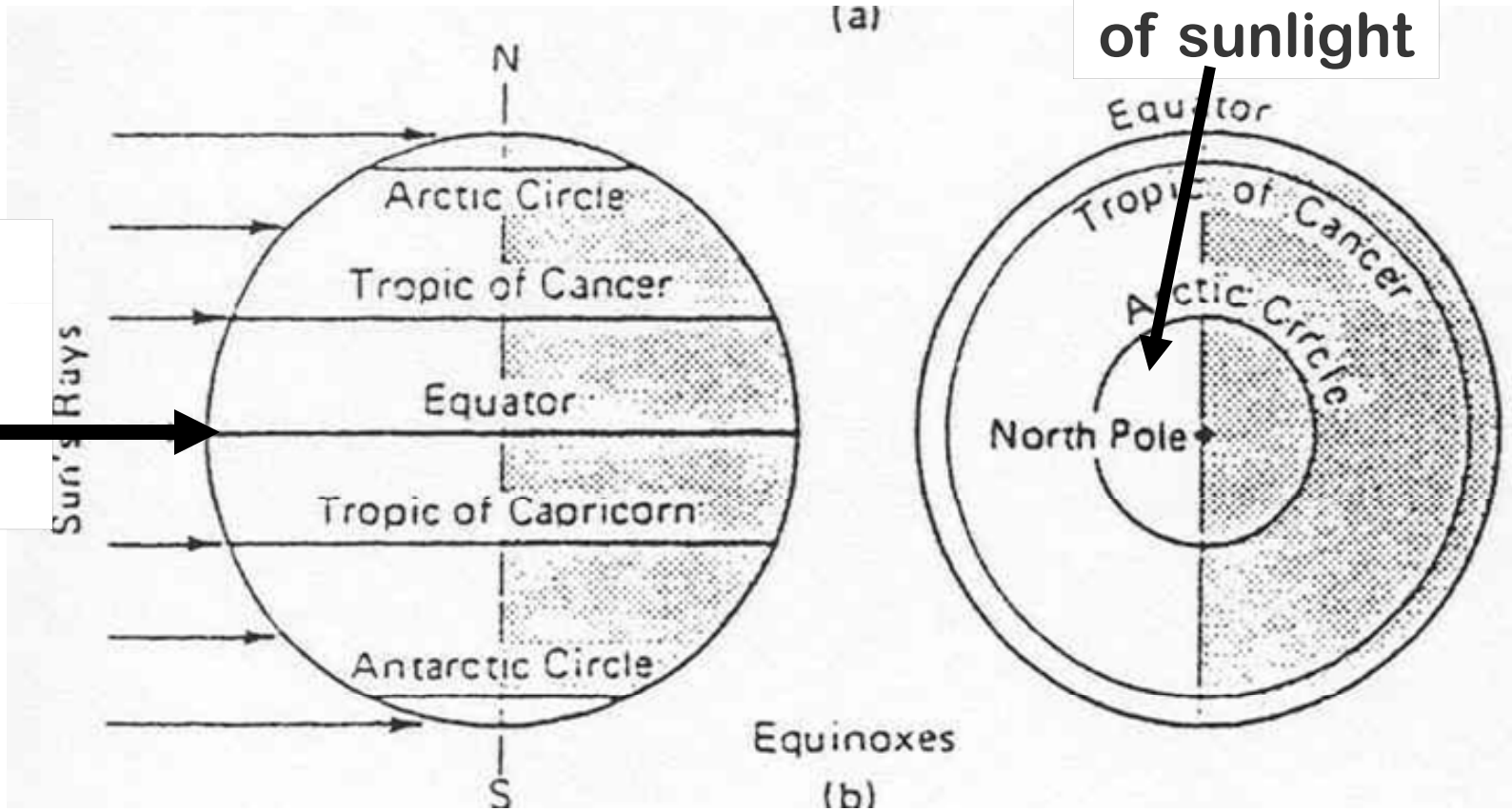


. . . but same latitudinal insolation as March Equinox

MARCH & SEPTEMBER EQUINOXES

12 hours of sunlight

Most intense solar radiation



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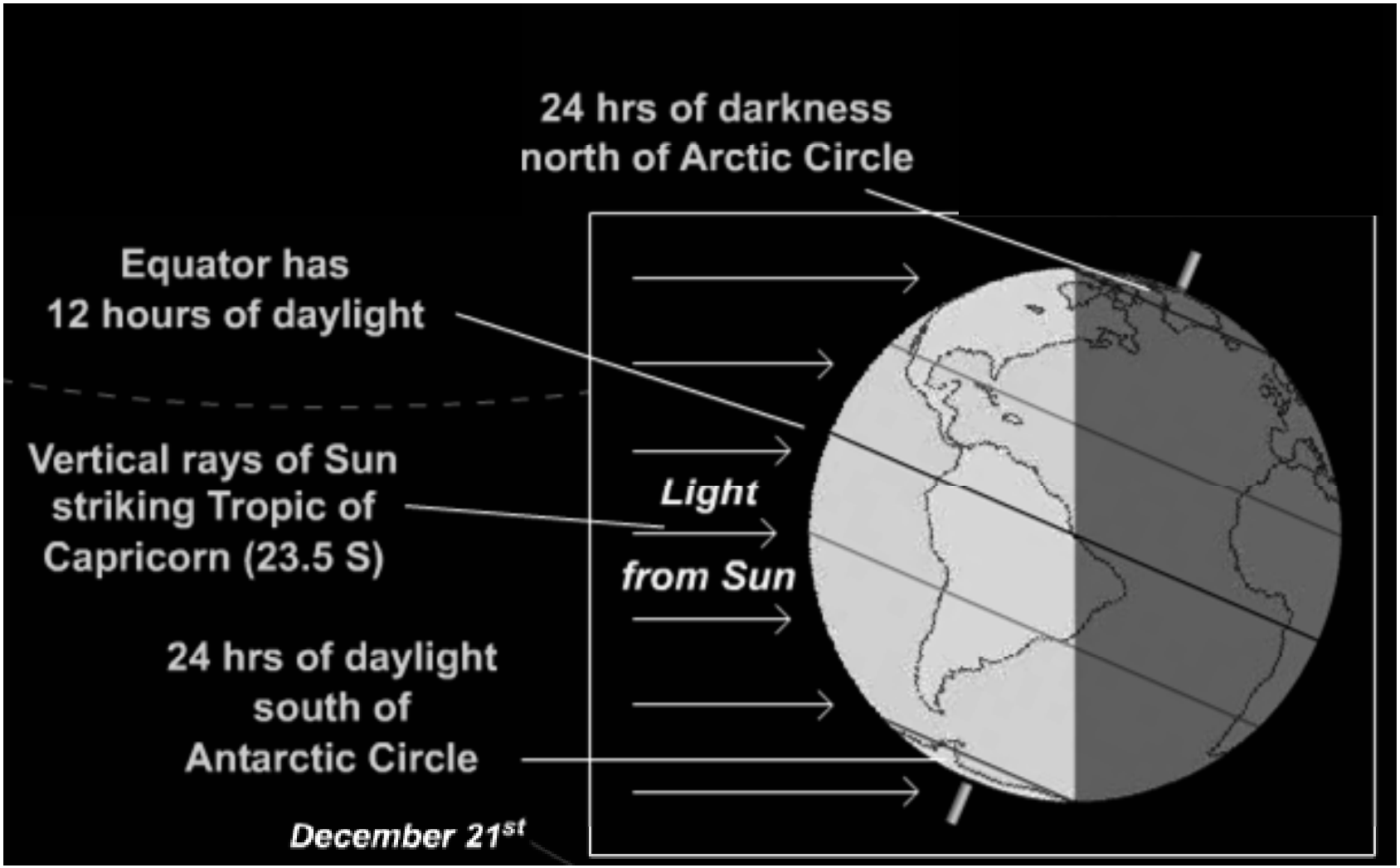
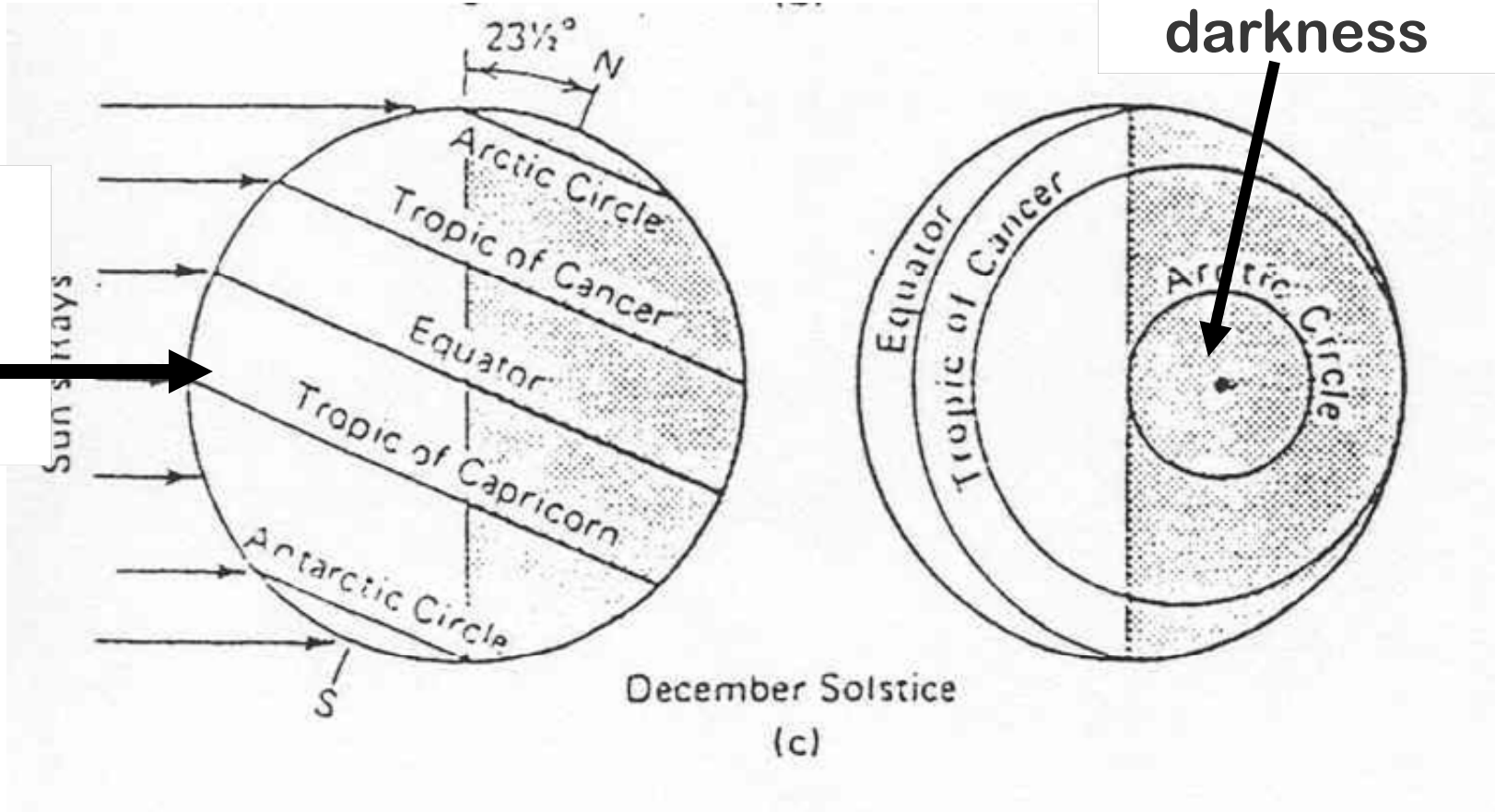
DECEMBER SOLSTICE



DECEMBER SOLSTICE

24 hours of darkness

Most intense solar radiation



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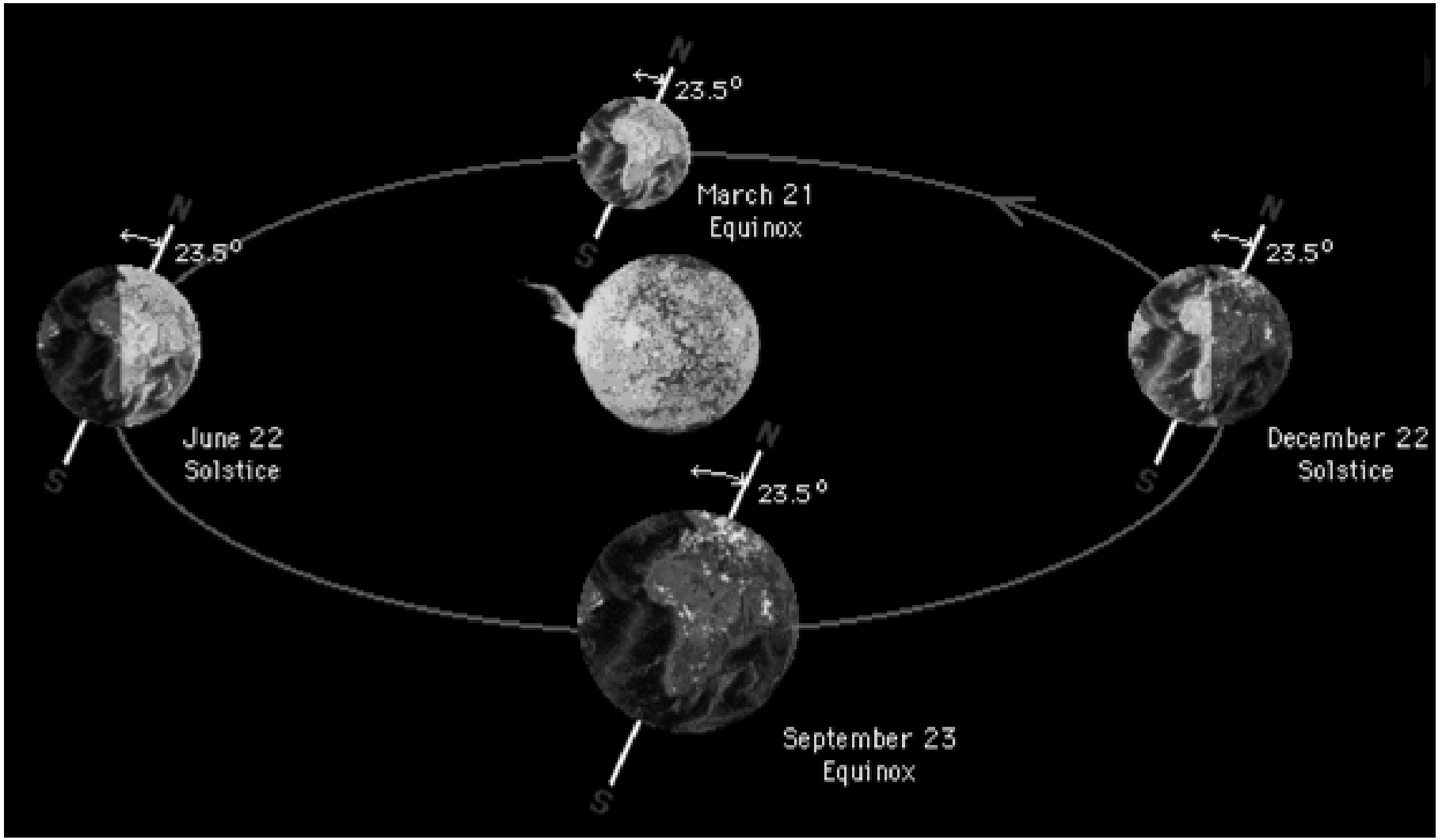
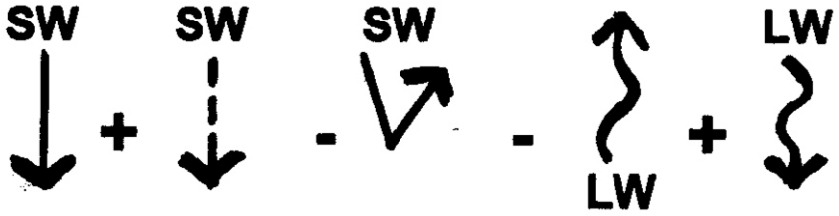
http://mesoscale.agron.iastate.edu/agron206/animations/01_EarthSun.html

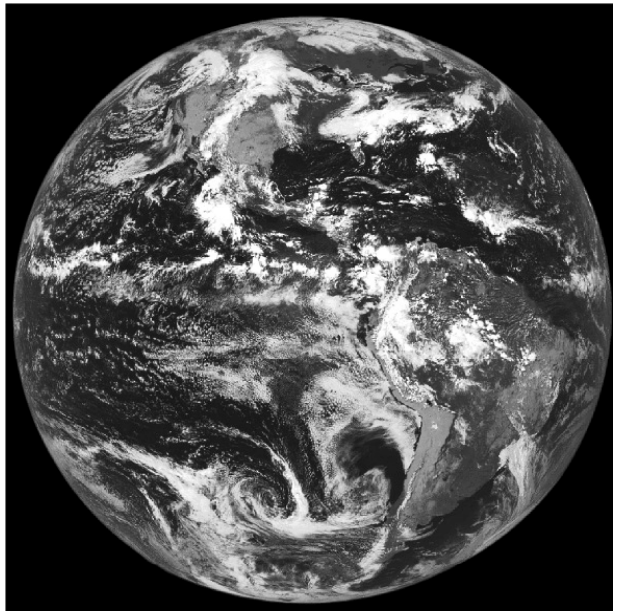


Recap

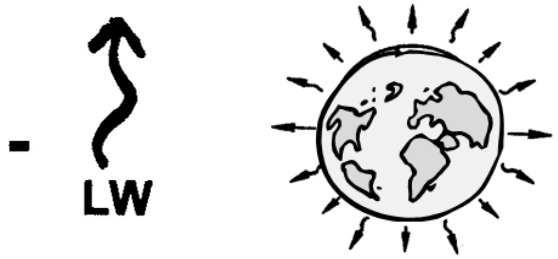
THE RADIATION BALANCE



& 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 more energy than HIGH LATITUDES

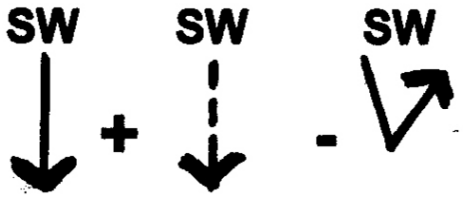
The amount of TERRESTRIAL LW / IR varies by latitude too -- MORE LW / IR is emitted at warmer TROPICAL LATITUDES, LESS in cooler HIGH LATITUDES

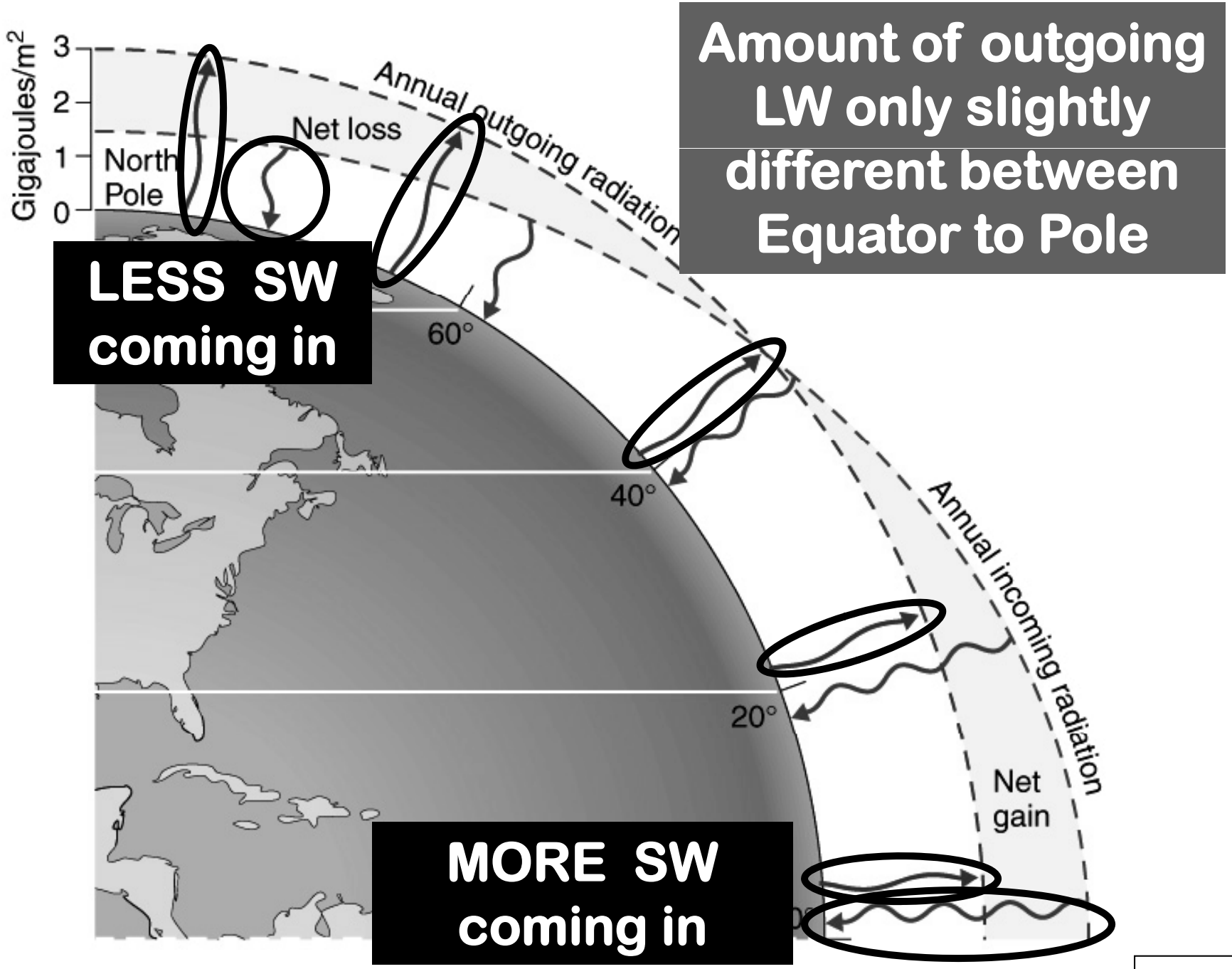
HOWEVER . . .

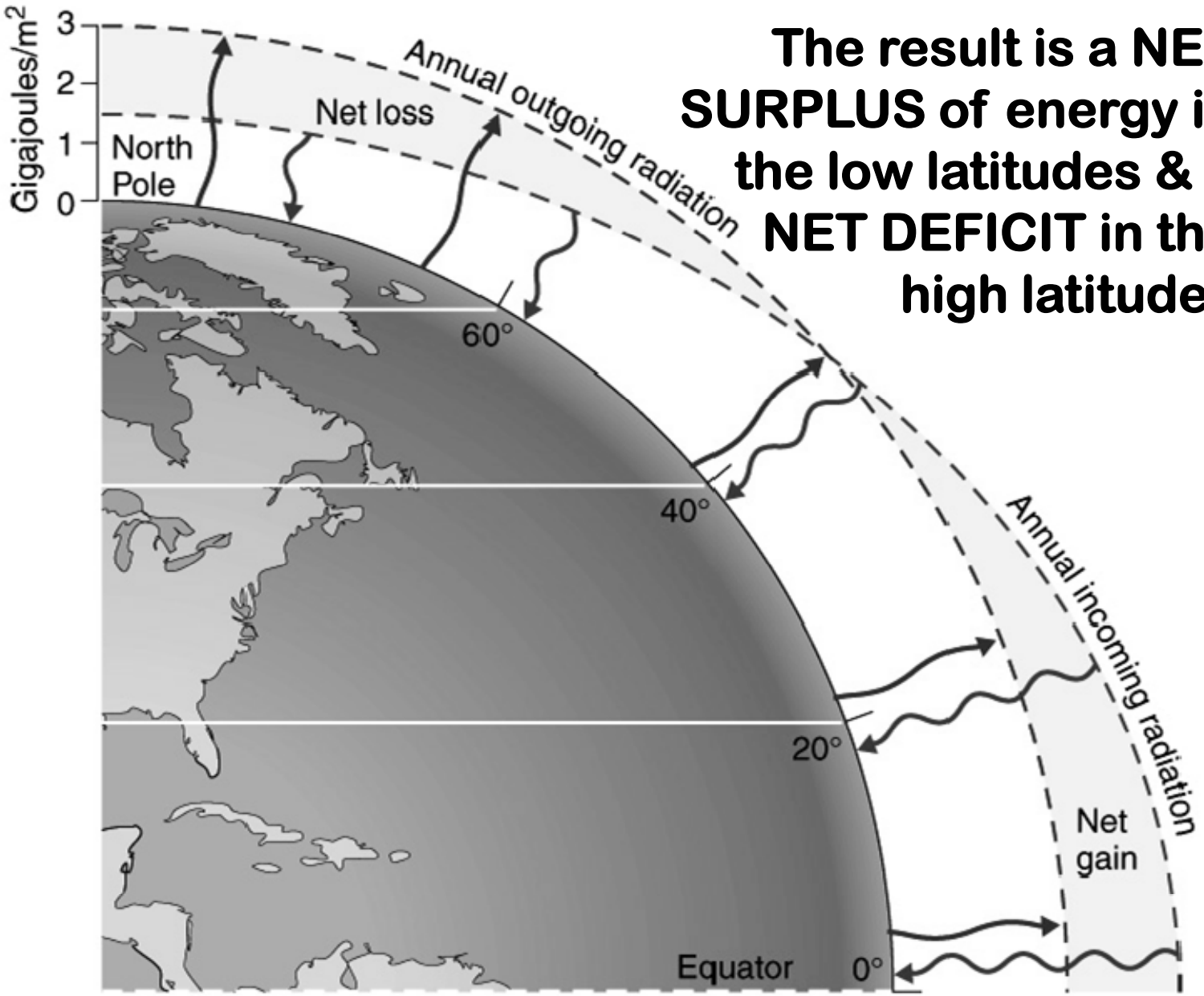
EQUATOR-POLE DIFFERENCES in what goes OUT

are less than the

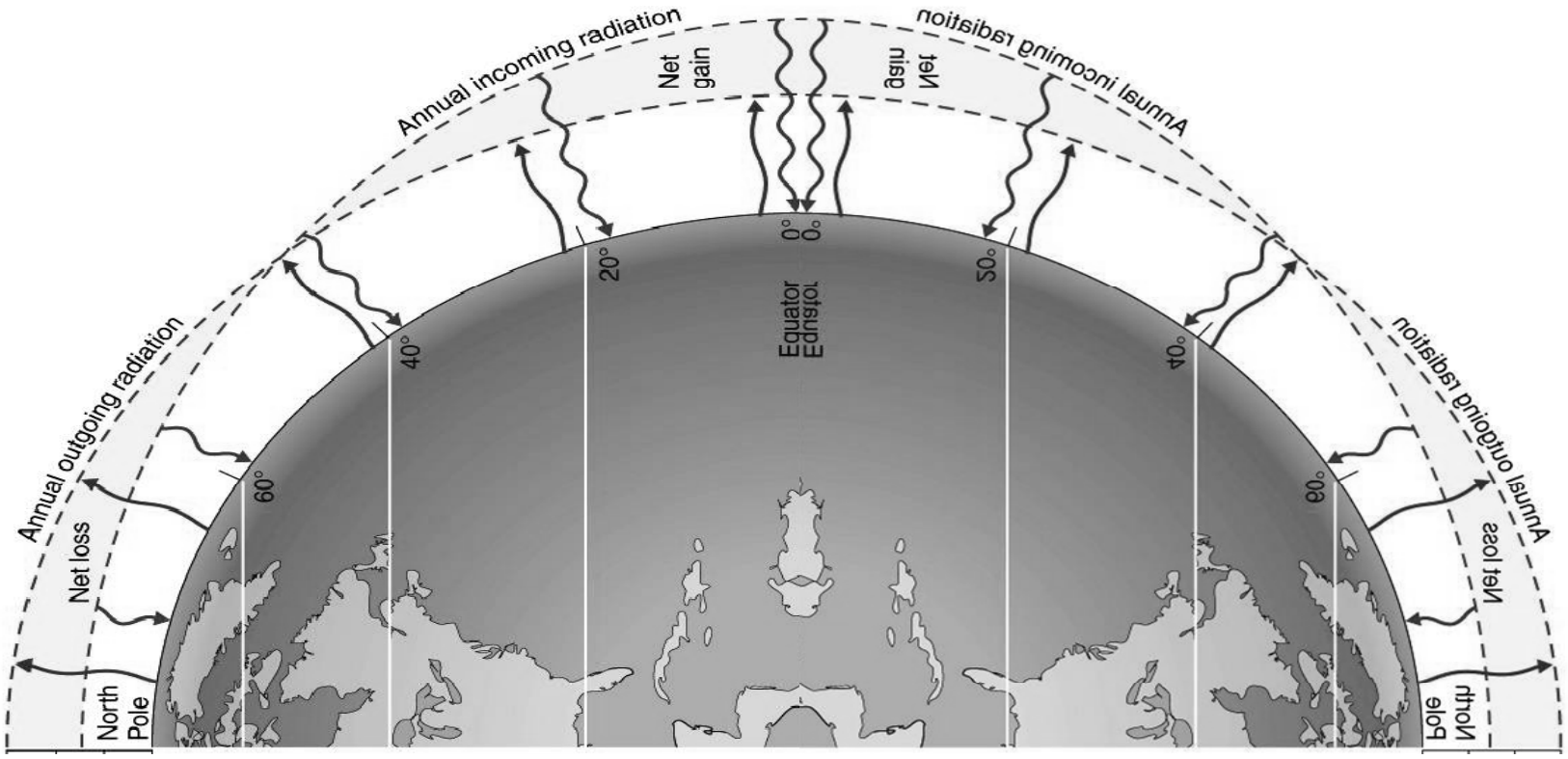
EQUATOR-POLE DIFFERENCES in what comes in




Amount of outgoing LW only slightly different between Equator to Pole
LESS SW coming in
MORE SW coming in
Gigajoules/m²
3
2
1
0
North Pole
Net loss
Annual outgoing radiation
60°
40°
20°
Annual incoming radiation
Net gain

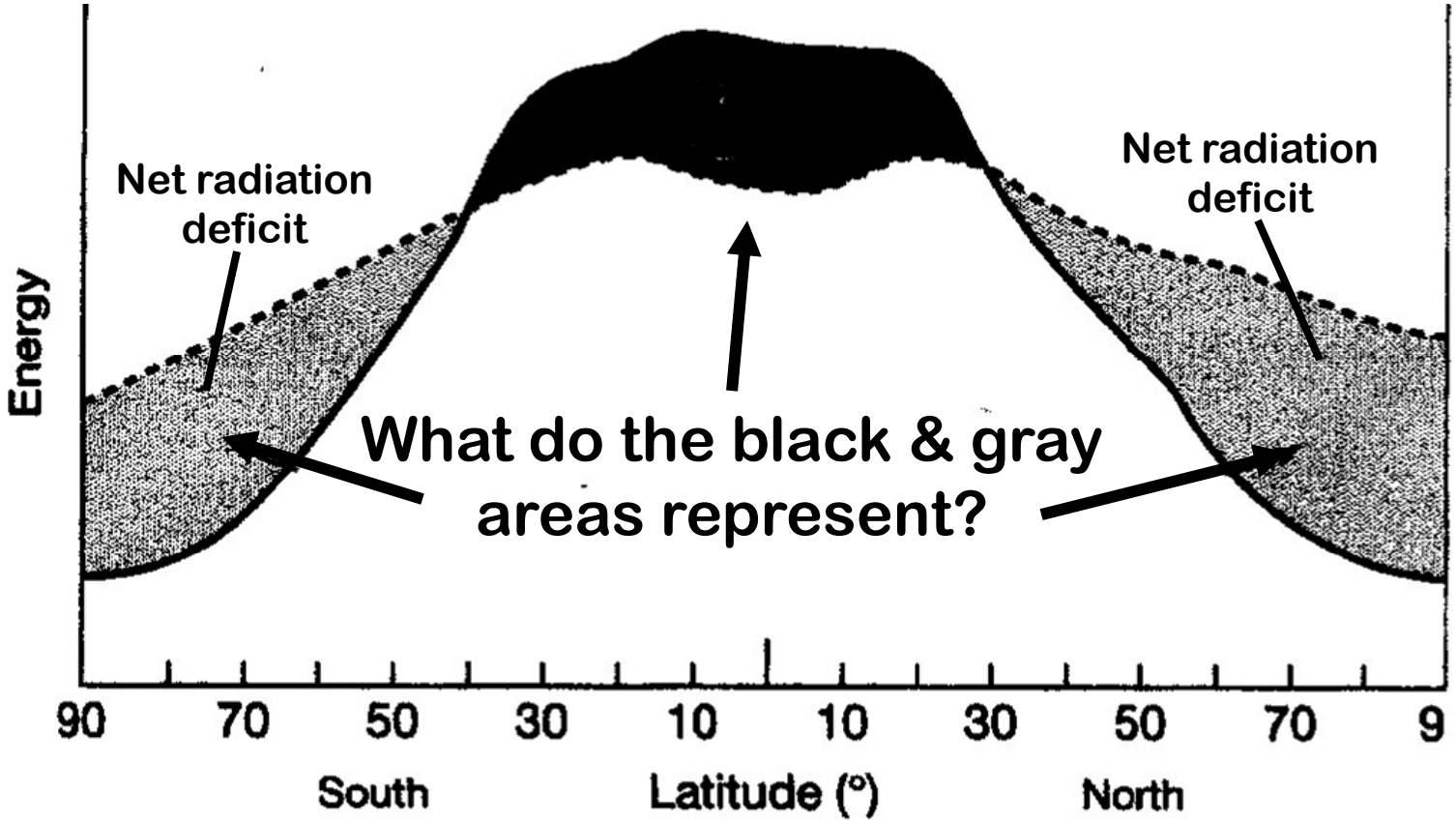


The result is a NET SURPLUS of energy in the low latitudes & a NET DEFICIT in the high latitudes



POLE **EQUATOR** **POLE**

Now lets look at a Pole to Pole Transect



Absorbed solar energy

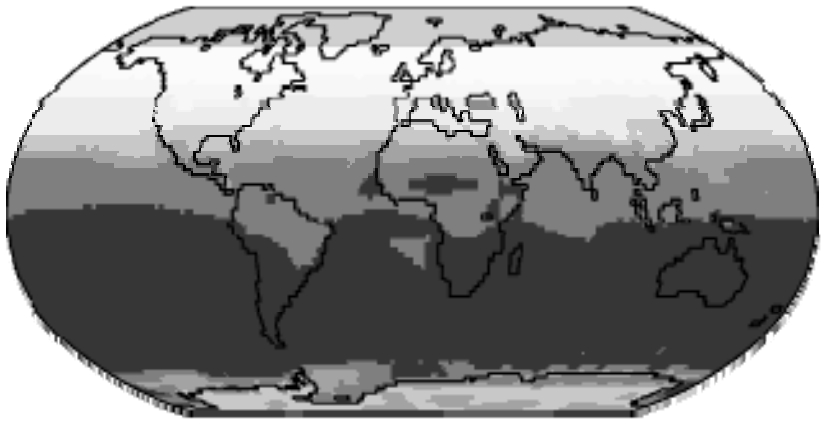
SW + SW - SW

Emitted infrared energy

(at top of atmosphere)

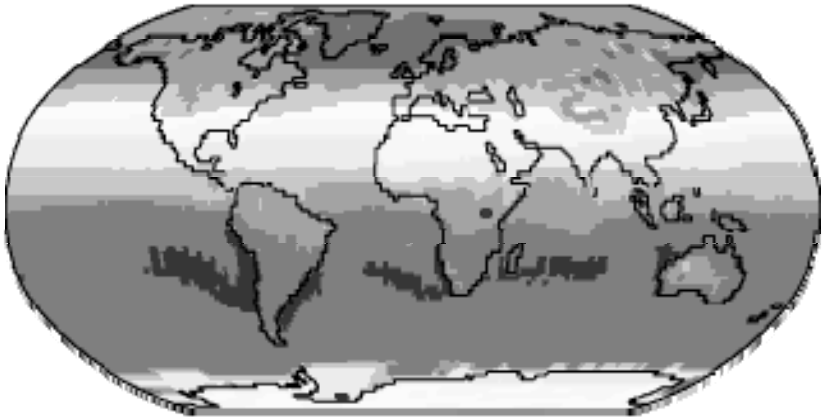
- LW

Short Wave Radiation

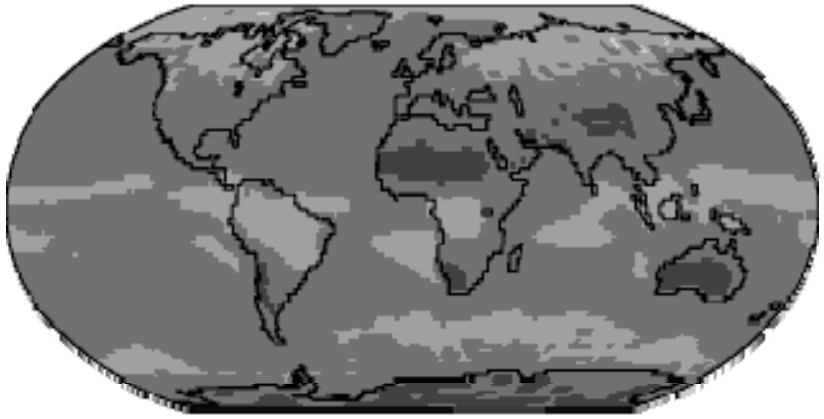


Dec

Net Radiation



Long-Wave Radiation

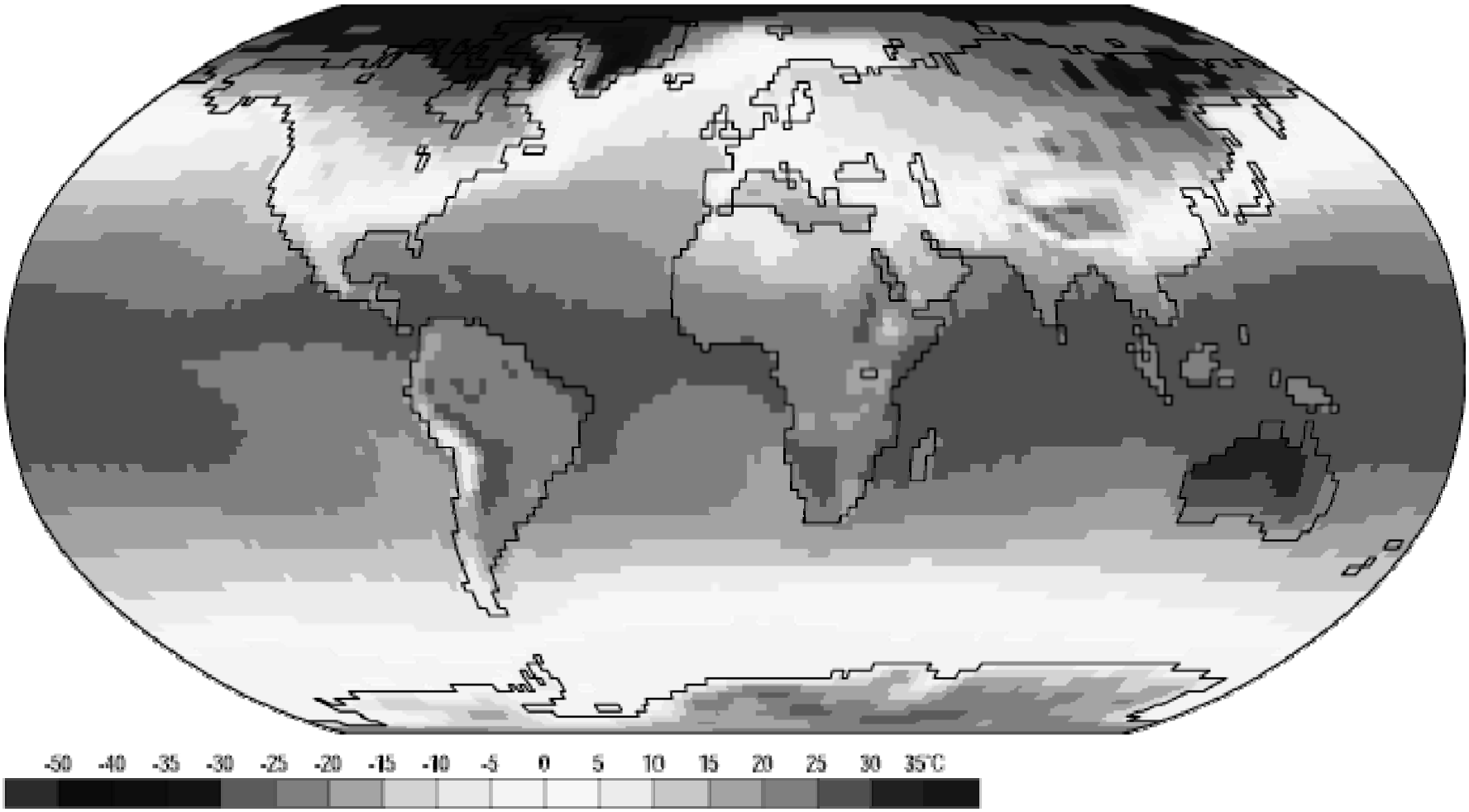


Data: NCEP/NCAR Reanalysis Project, 1958-1997 Climatologies
Animations: Department of Geography, University of Oregon, March 2000

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

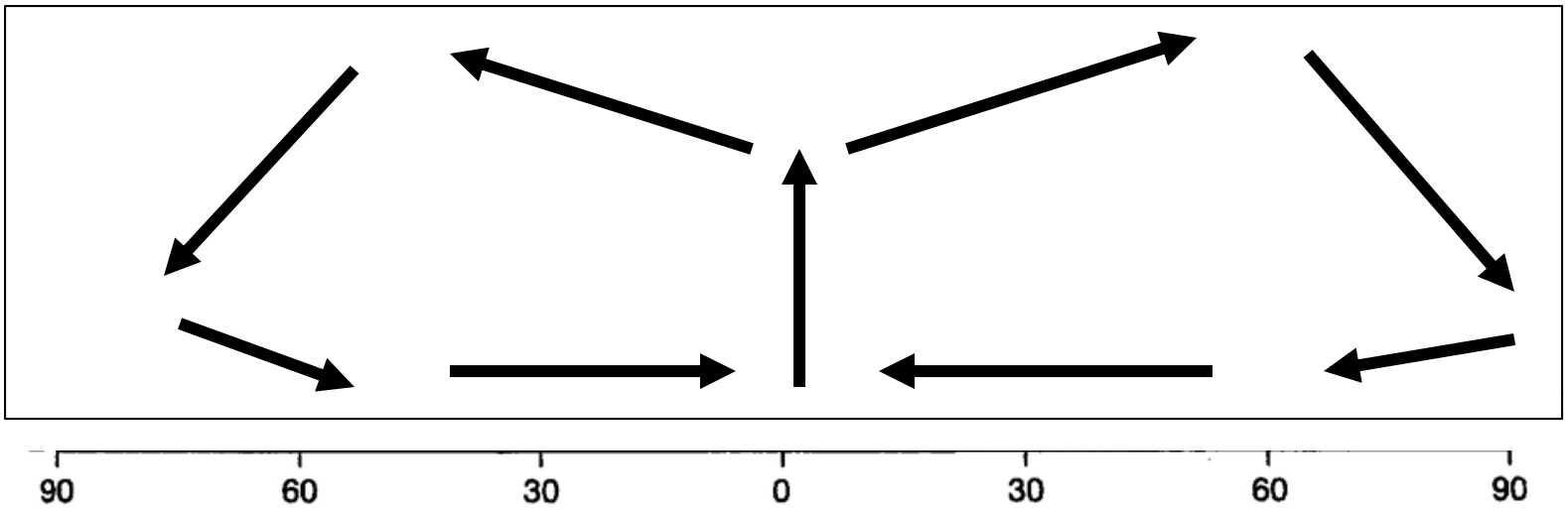
Air Temperature

Dec



Data: NCEP/NCAR Reanalysis Project, 1958-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000

Global-scale motions driven by thermal differences:



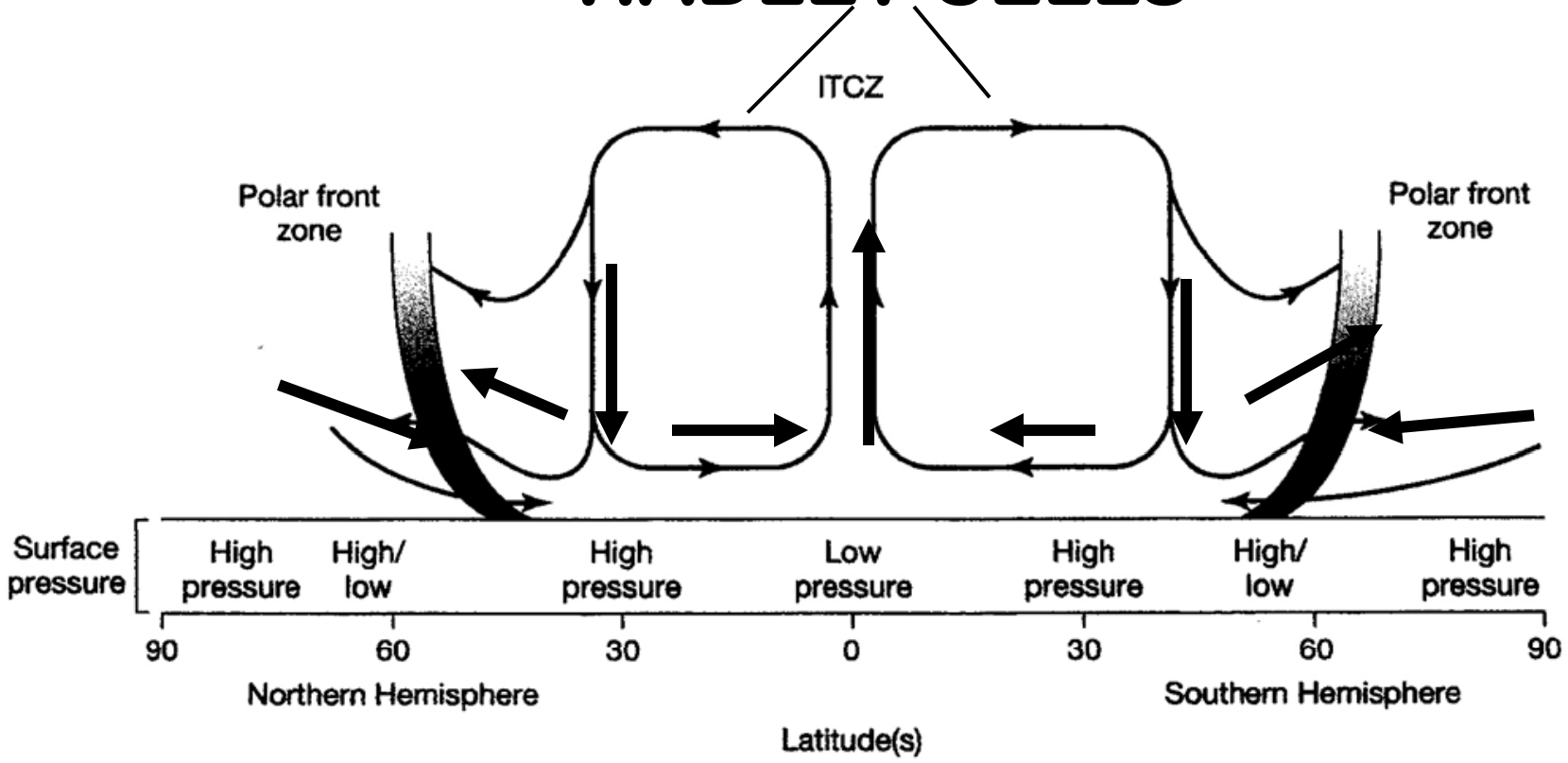
COLD POLAR REGIONS

HOT TROPICS

COLD POLAR REGIONS

☺

HADLEY CELLS



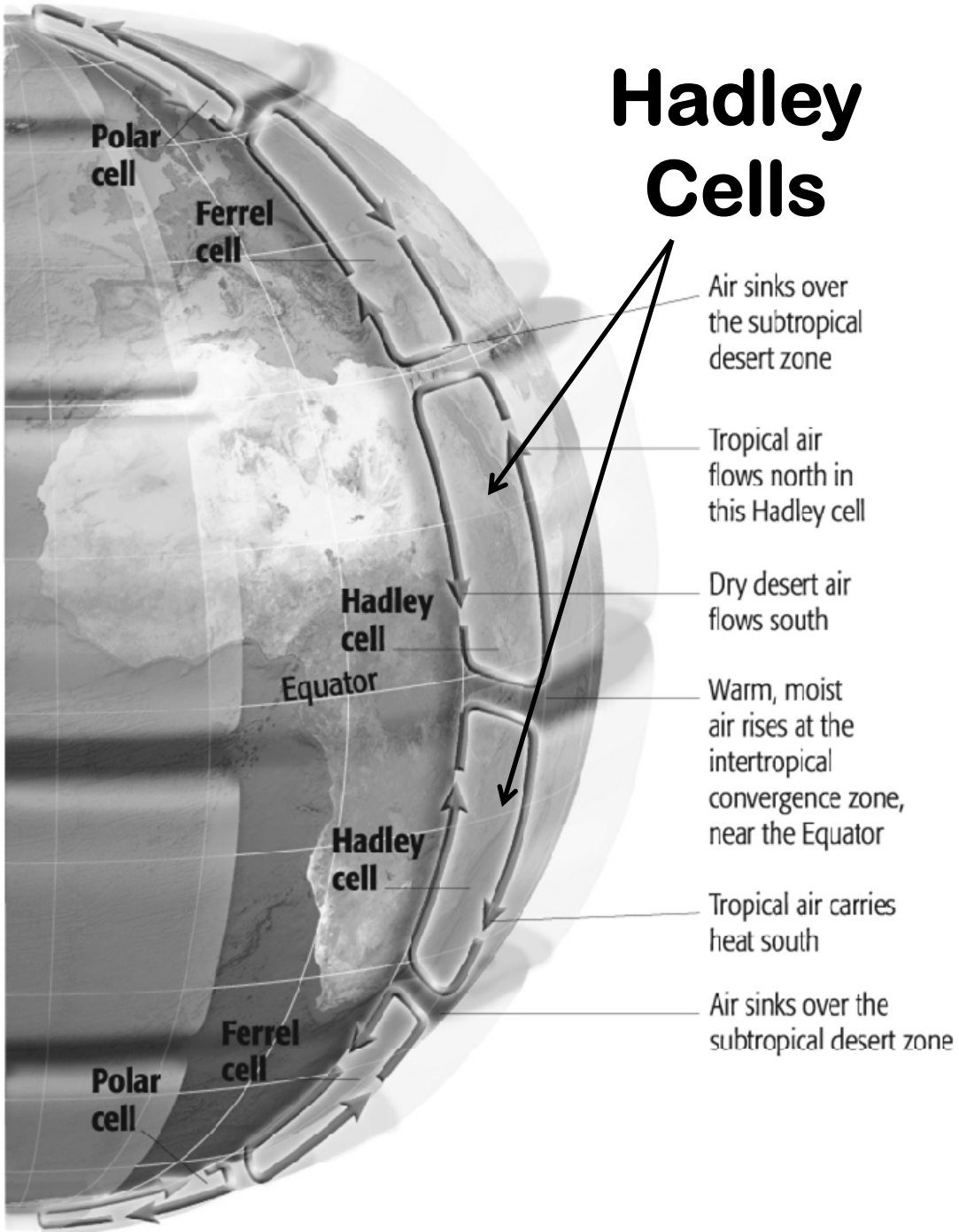
COLD POLAR REGIONS

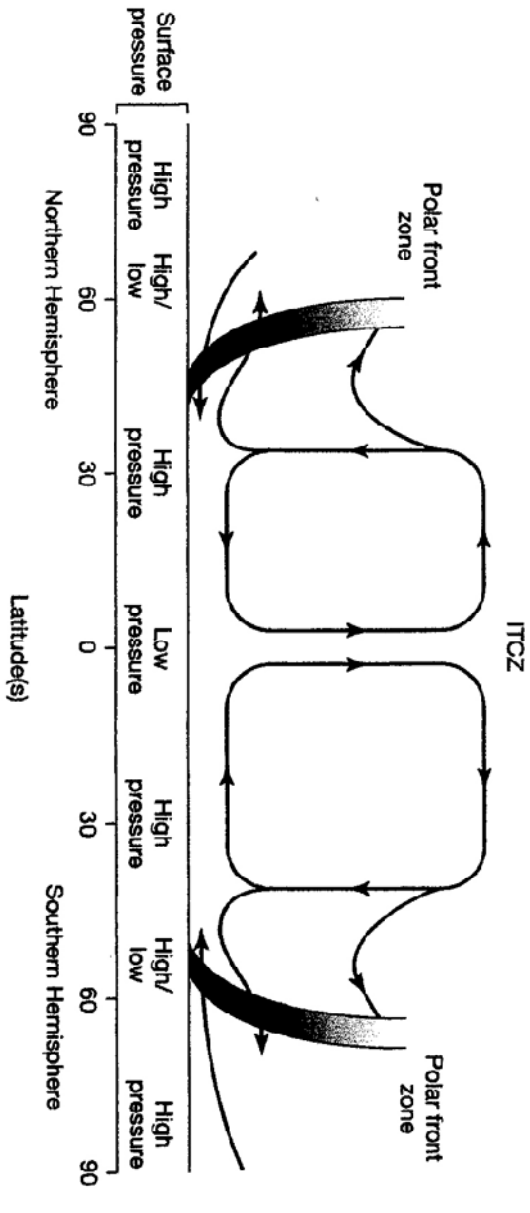
HOT TROPICS

COLD POLAR REGIONS

From SGC-I Chapter 4

Hadley Cells

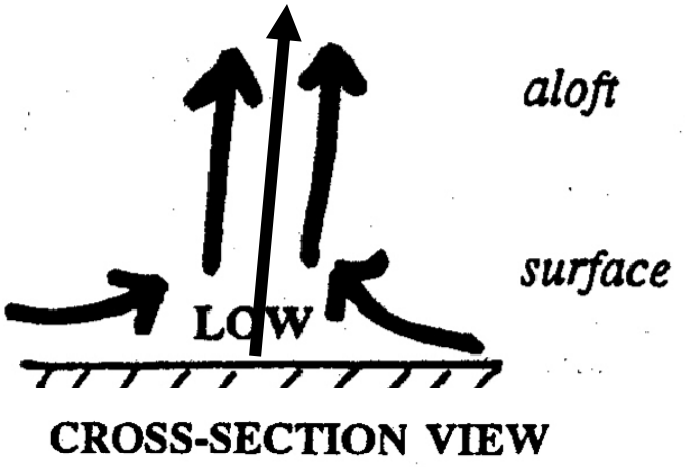




LOW PRESSURE AREAS:

Hot surface ➔ Rising air ➔ expansion and cooling of air, and condensation of water vapor ➔ clouds and possibly precipitation . . .

HUMID REGIONS



CROSS-SECTION VIEW

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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 large population of smaller drops. The large drop only forms after mixing occurs.

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

Condensation nucleus

H2O droplet

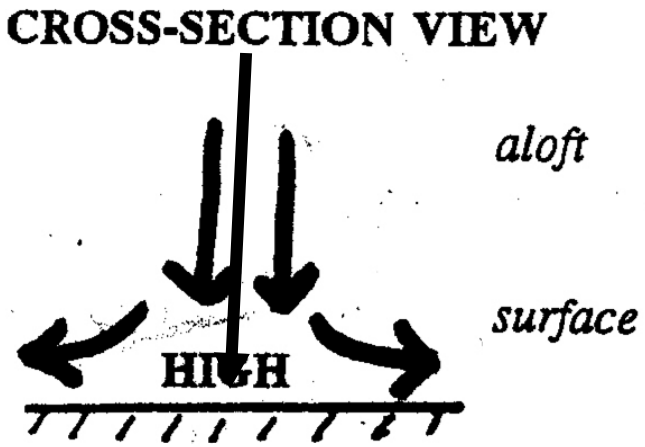
Here the women represent water molecules while the men represent cloud condensation nuclei.

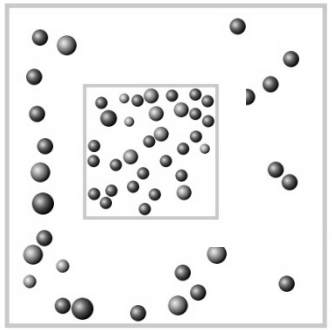
Additional women dance in a manner suggestive of mixing processes in order to create the slightly larger drop, called a collision coalescence initiator.

Through “coalescence” a single nucleus attracts all the other water droplets -- when large enough RAIN FALLS!

HIGH PRESSURE AREAS:

Forced sinking (e.g. in HADLEY CELL) leads to contraction and warming of air, and increased water vapor holding capacity → clear skies, dry air and ARID REGIONS.





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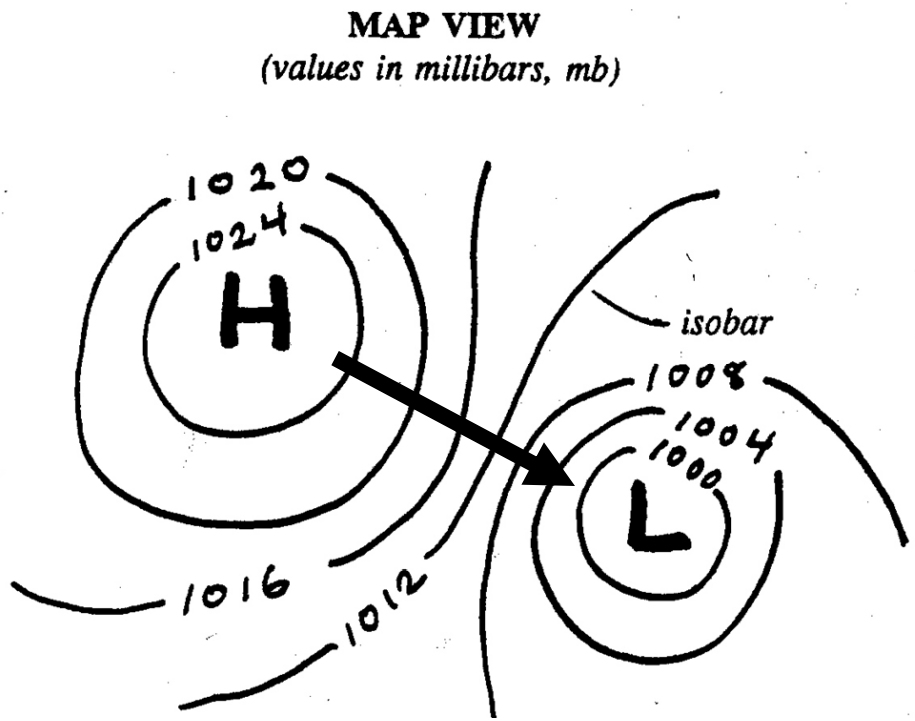
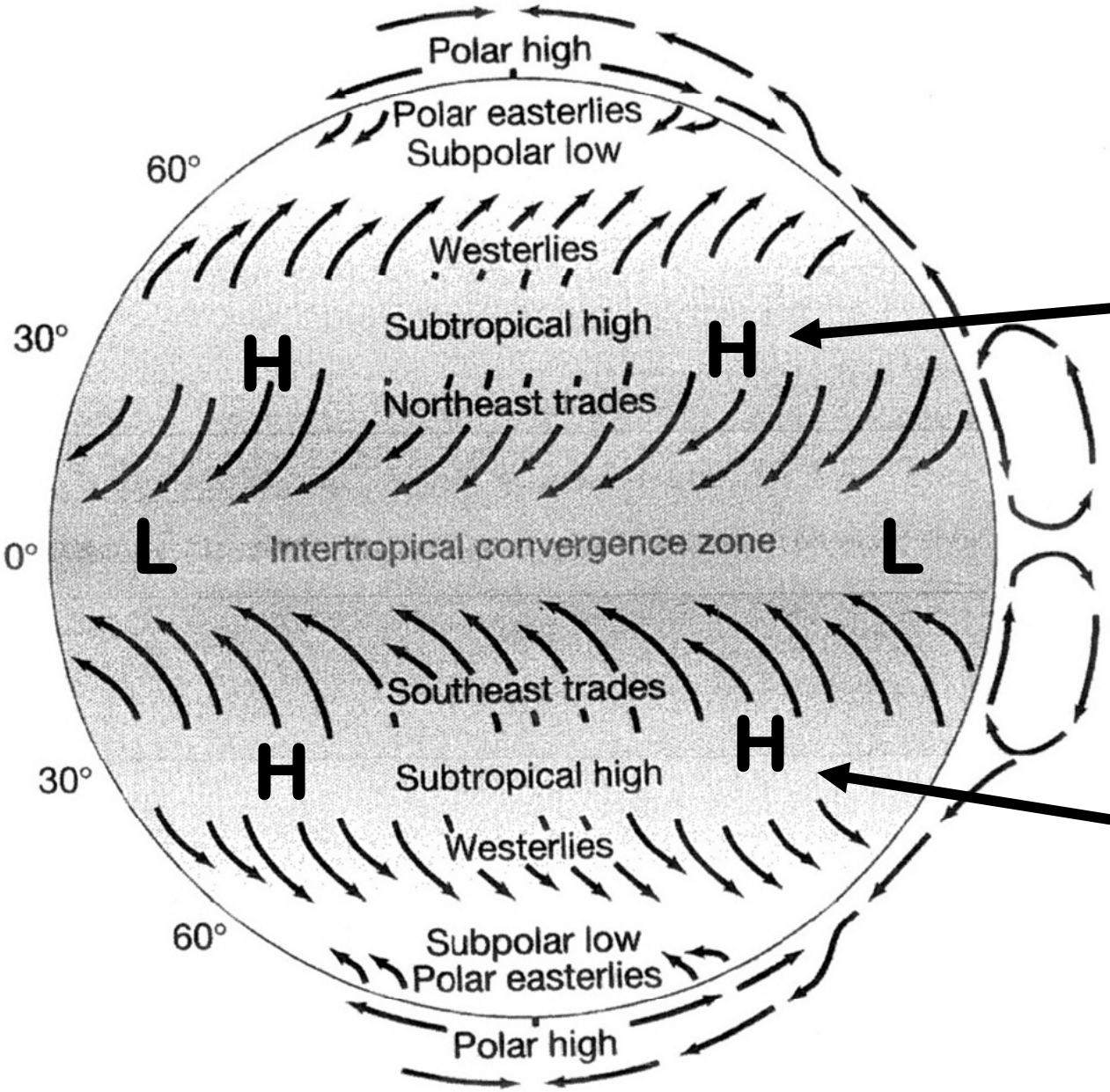
In general: Winds tend to flow from HIGH ➔ LOW Pressure areas





Sub-tropical HIGH PRESSURE

Intertropical Convergence ITCZ

Sub-tropical HIGH PRESSURE

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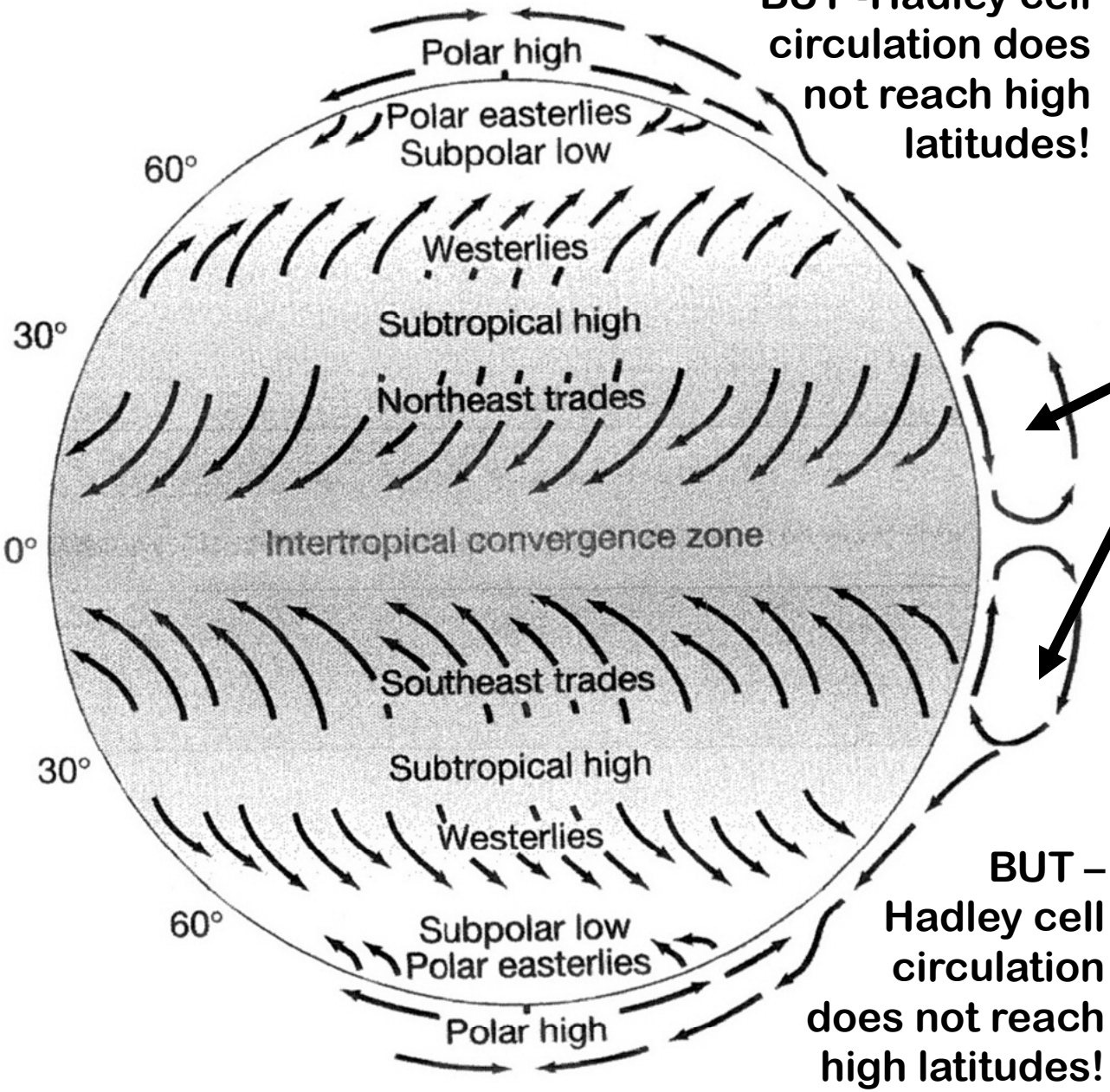

BUT -Hadley cell circulation does not reach high latitudes!

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

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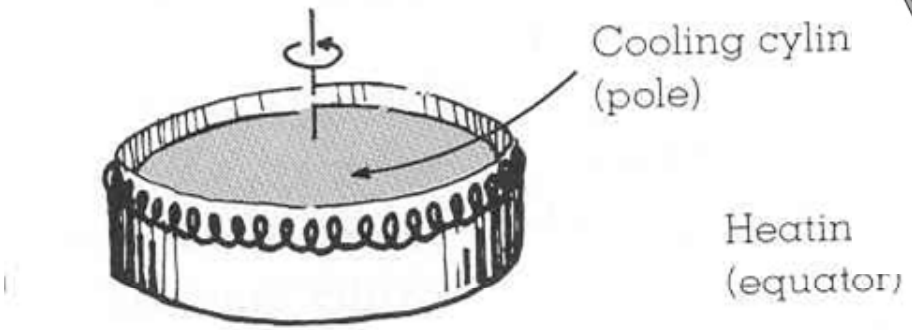
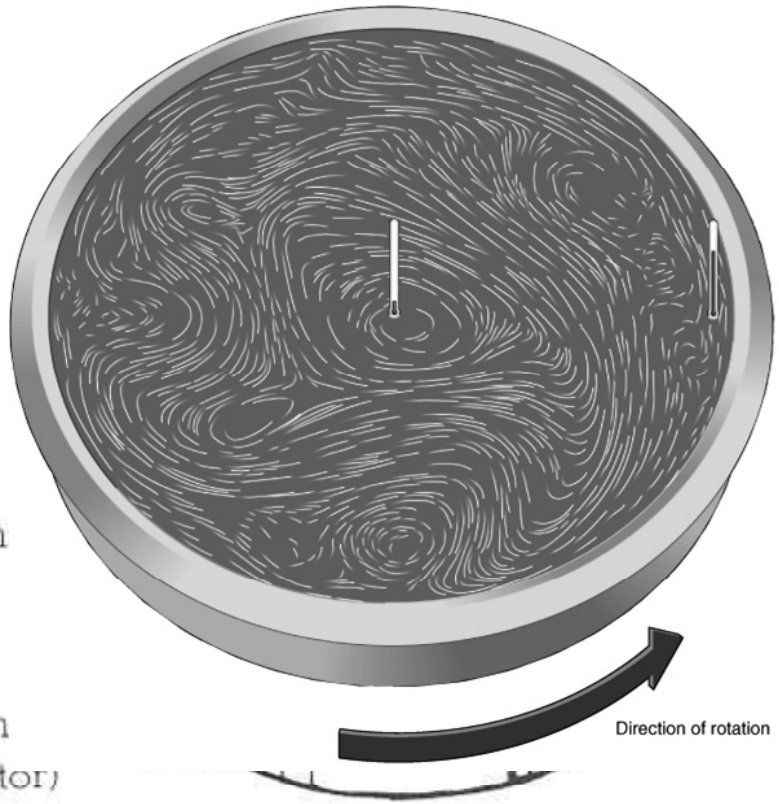
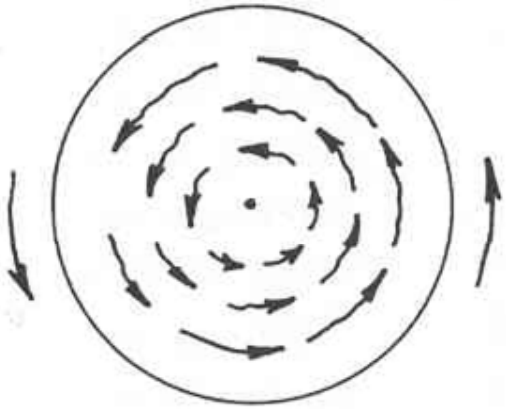
Why Hadley convective cell transport breaks down at higher latitudes:



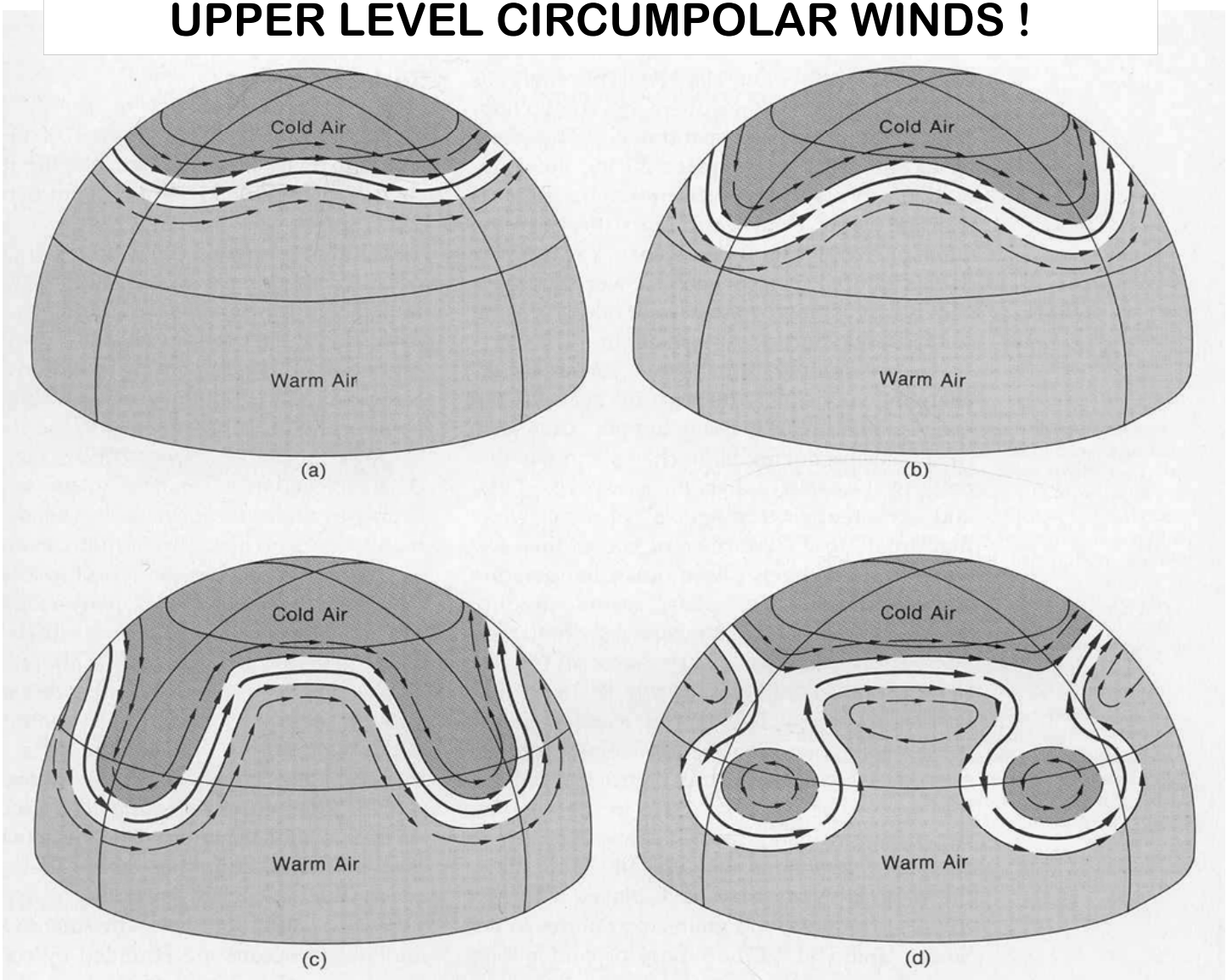
(a) Slow rotation



(b) Faster rotation



UPPER LEVEL CIRCUMPOLAR WINDS !

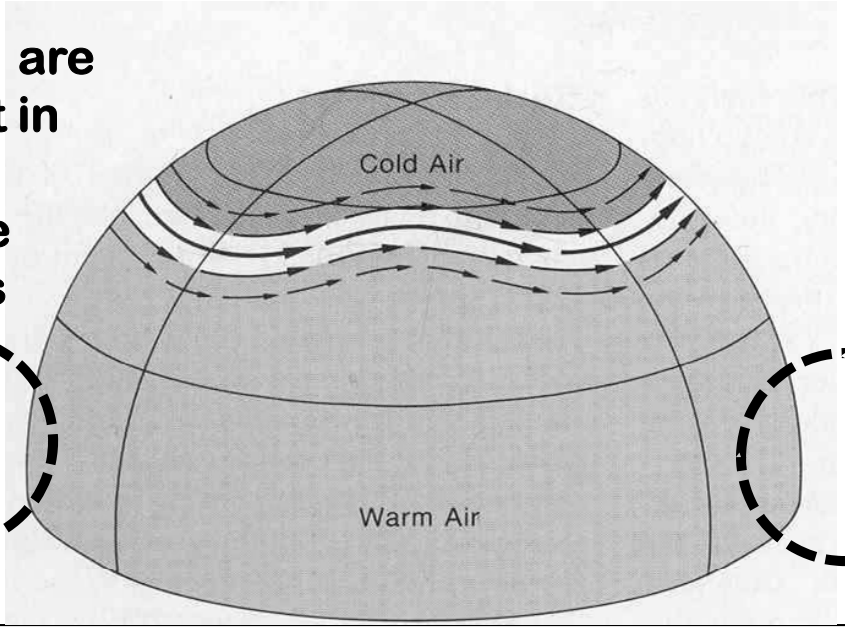


H

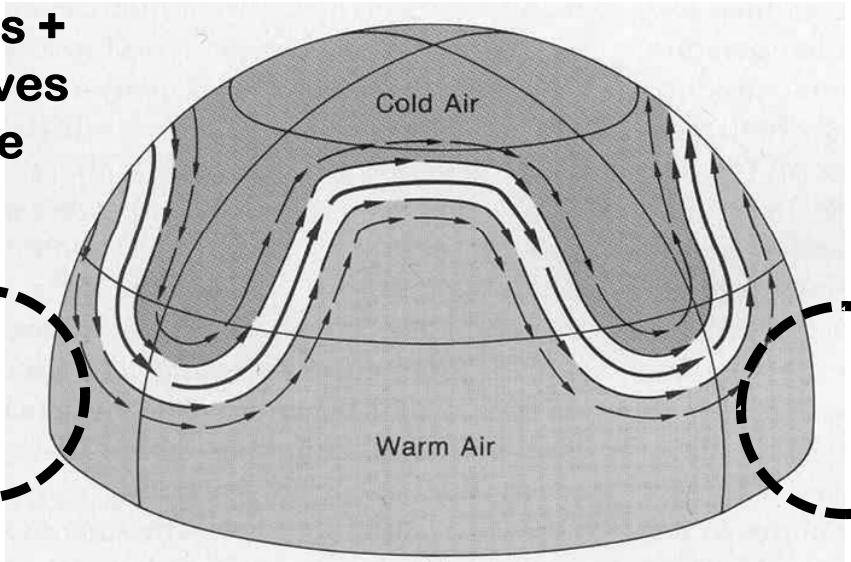
Wave transport of thermal energy instead of Hadley cell transport!

p 65

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

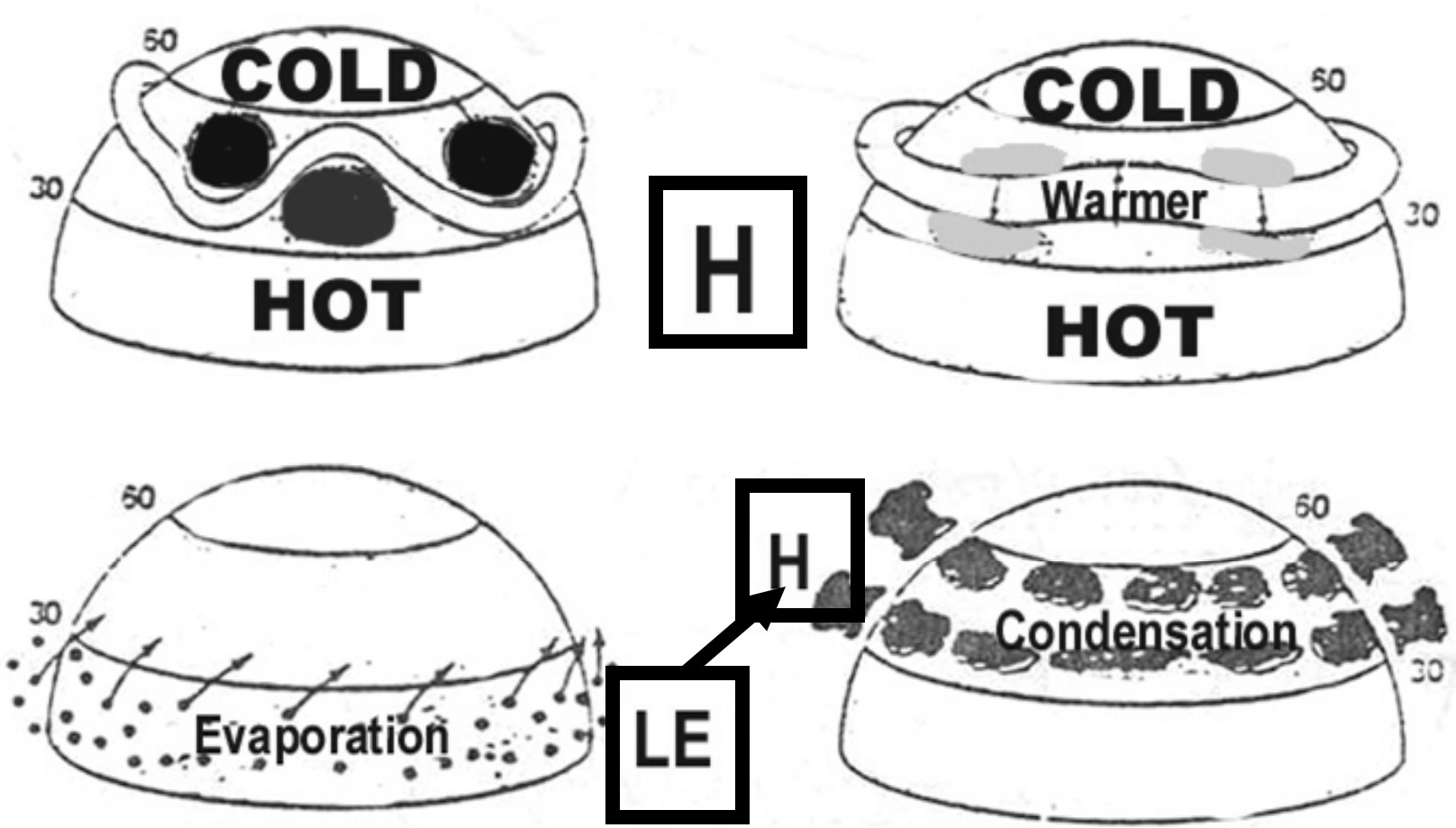


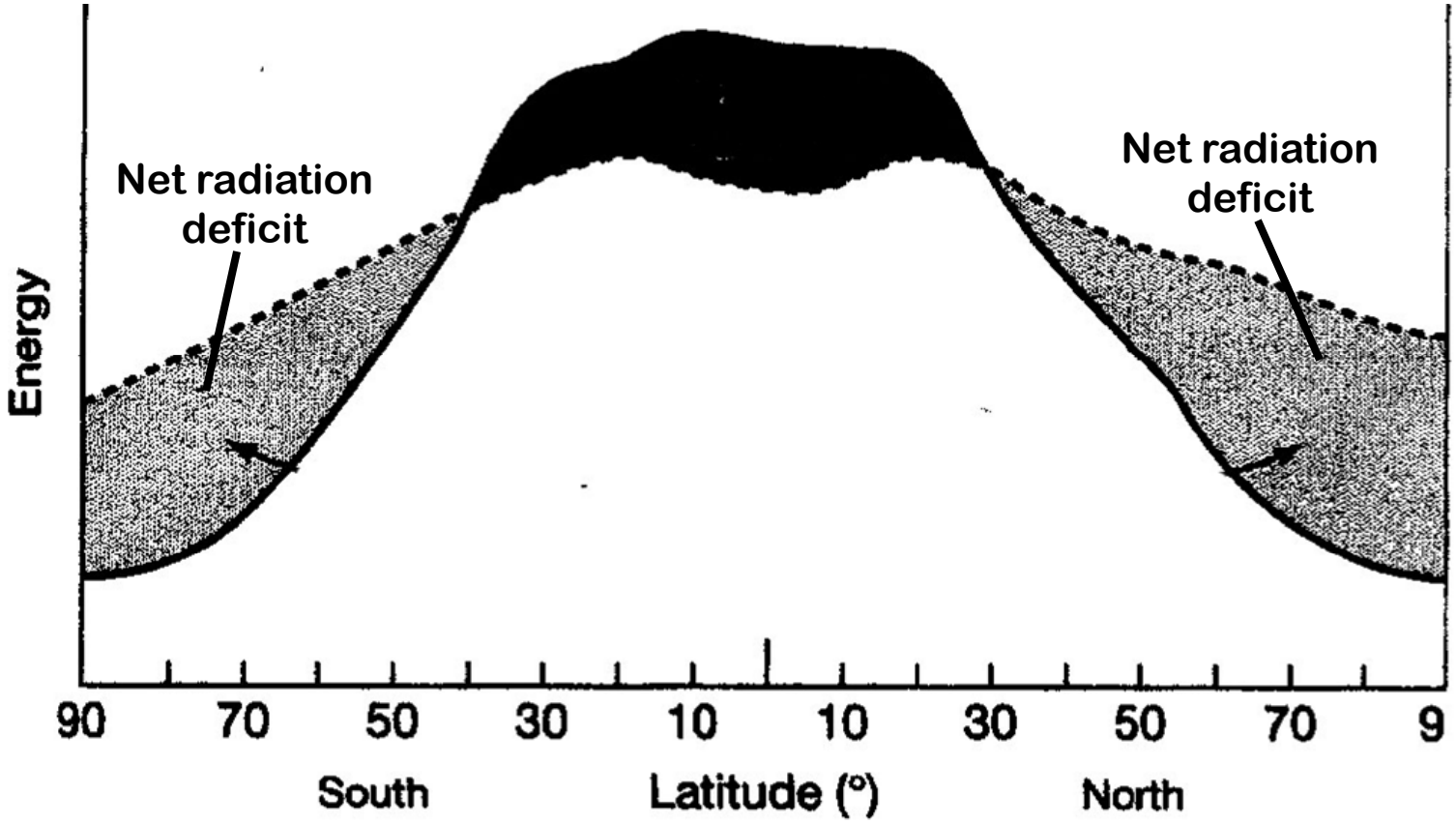
Hadley Cells + Rossby Waves together are needed!



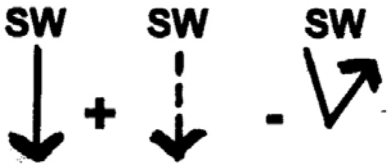
Energy is transported from areas of surplus to deficit in form of: H (sensible heat) & LE (Latent Energy)

H + LE



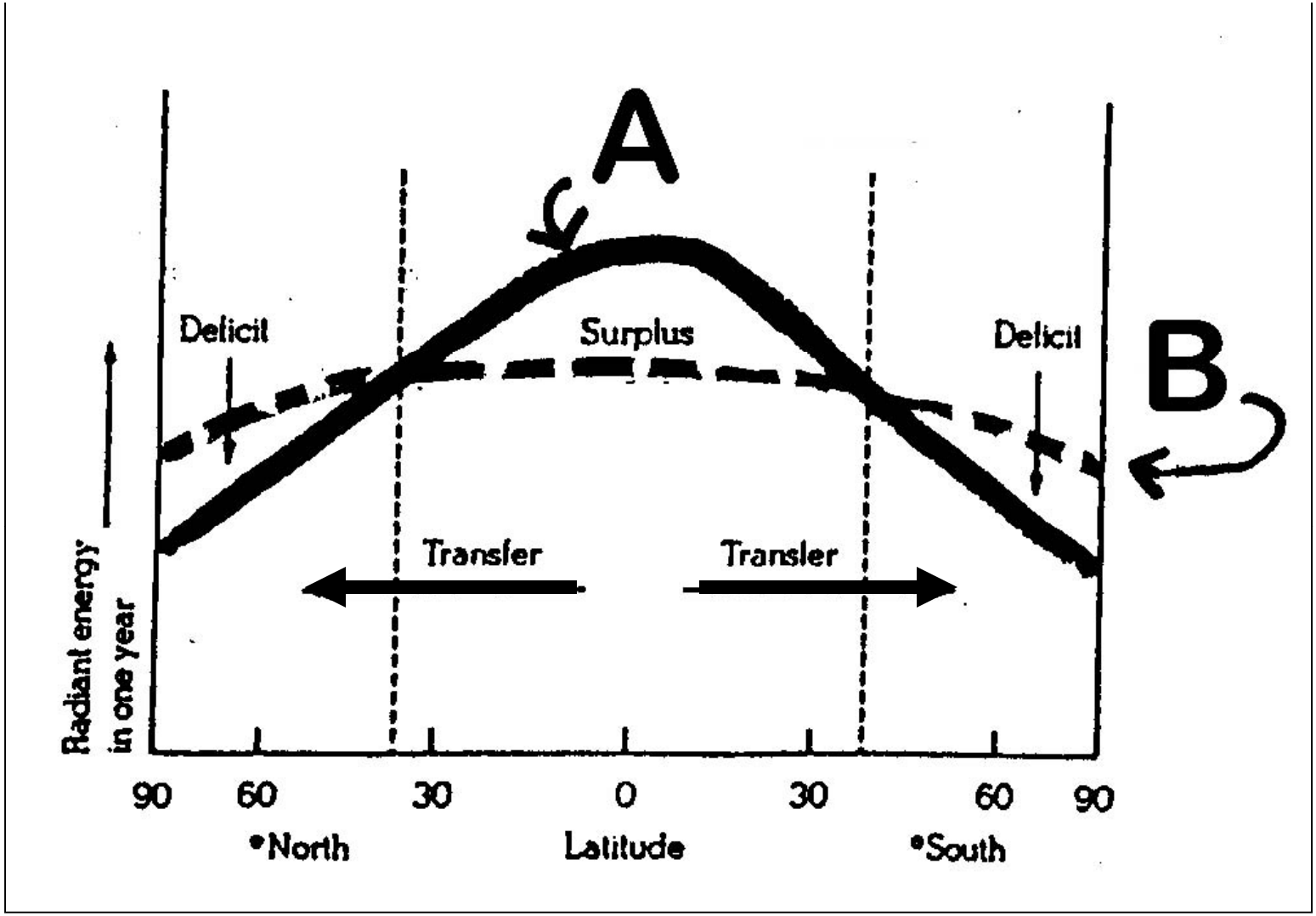


Absorbed solar energy



Emitted infrared energy

(at top of atmosphere)

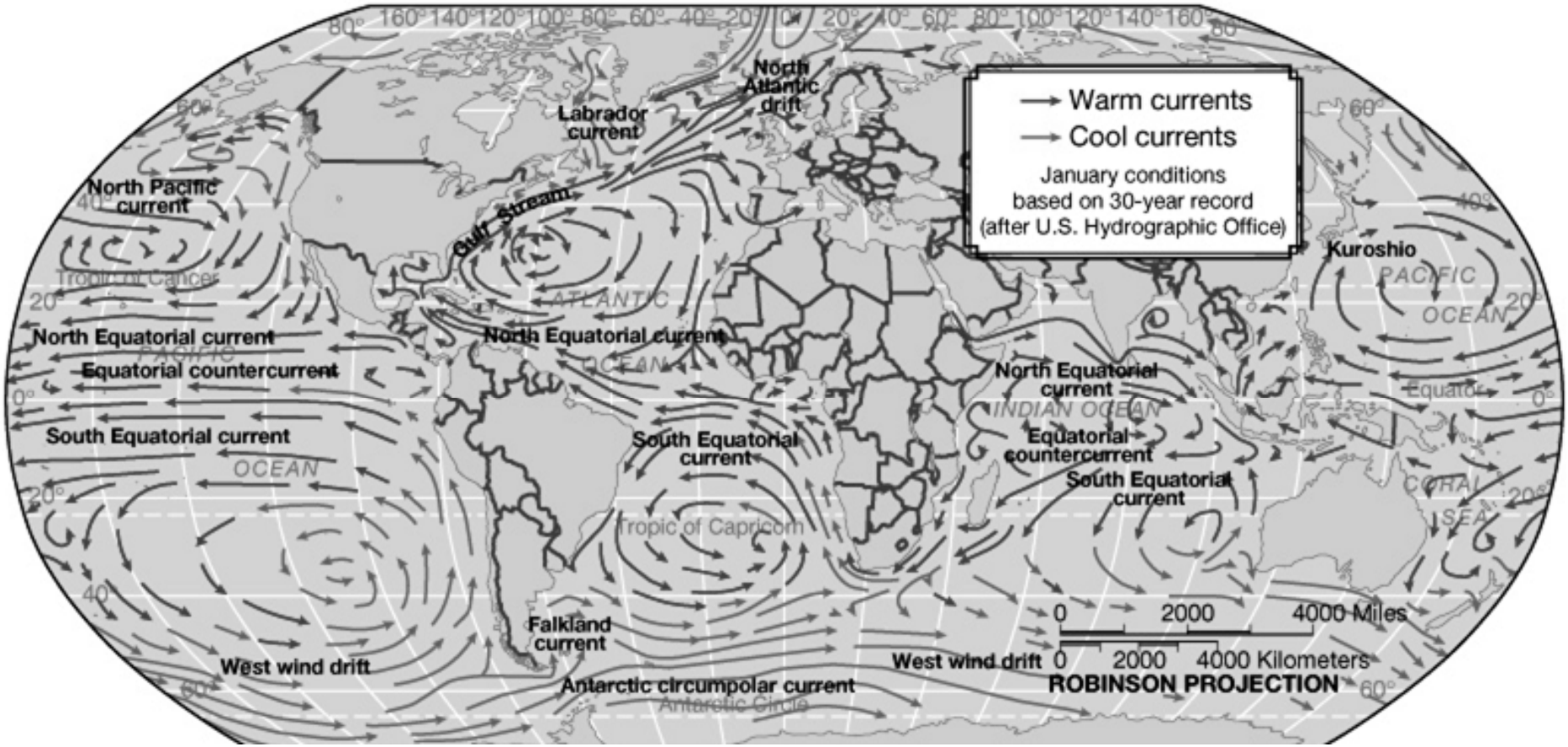


THERMAL ENERGY TRANSPORTED FROM LOW TO HIGH LATITUDES TO BALANCE OUT DEFICIT!

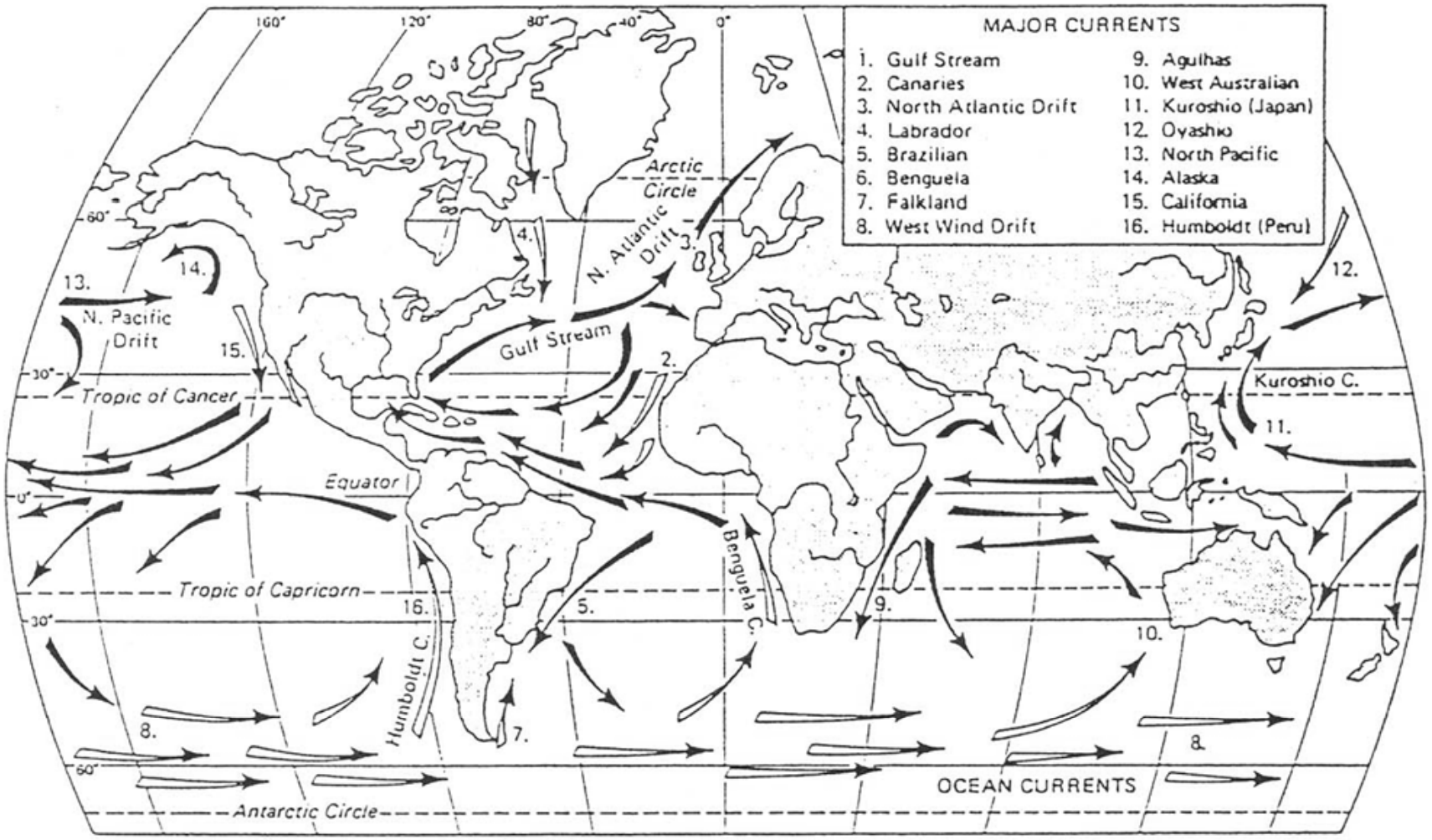
H + LE + G

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 !

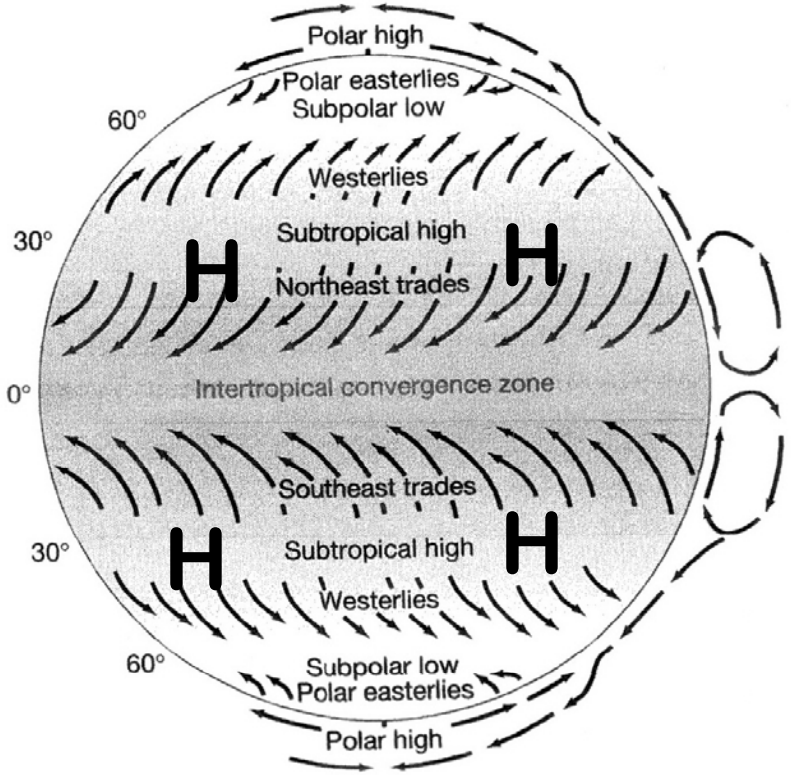


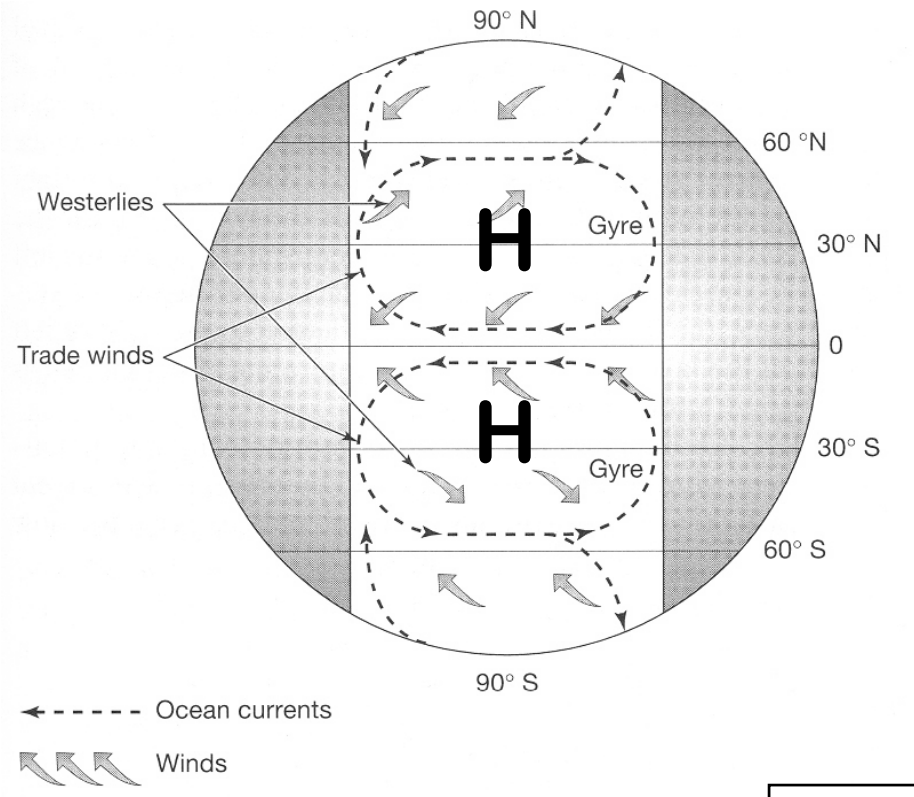
WARM & COLD SURFACE OCEAN CURRENTS:



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

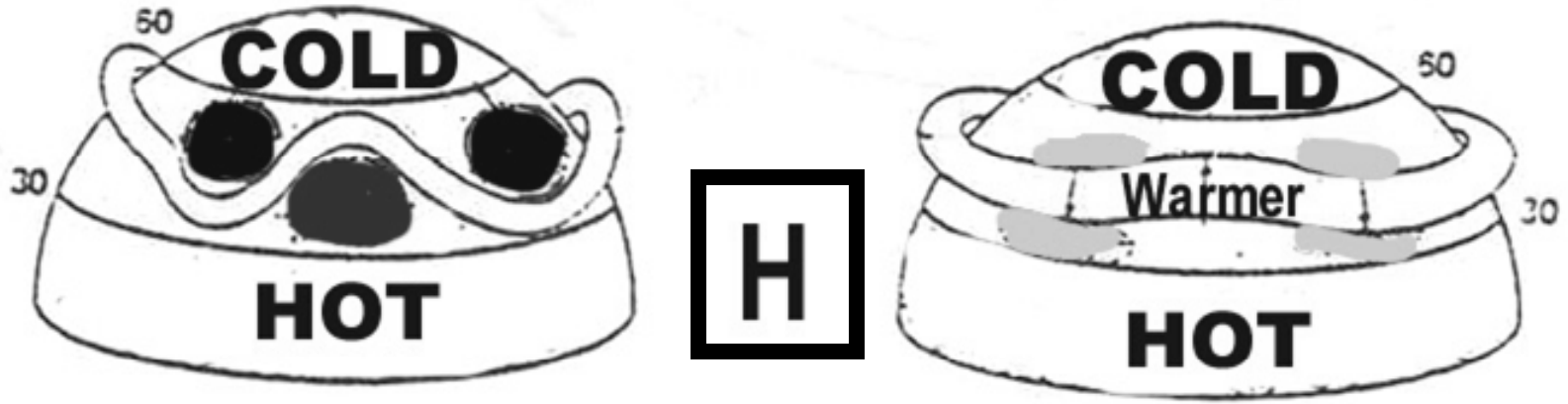
Leads to <u>SURFACE</u> ocean currents



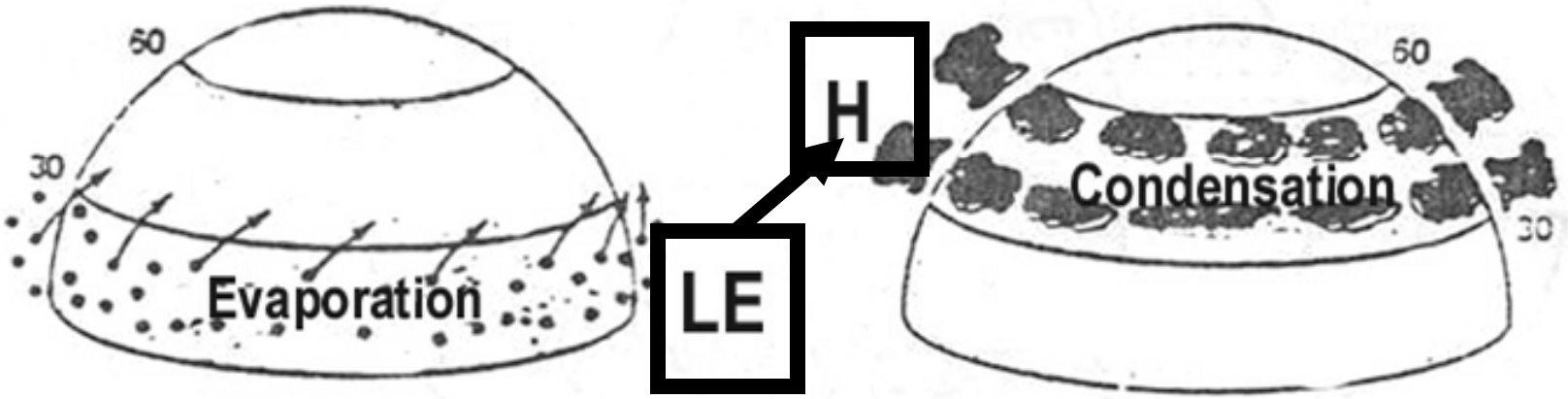


Energy is transported from areas of surplus to deficit via:

H (sensible heat)

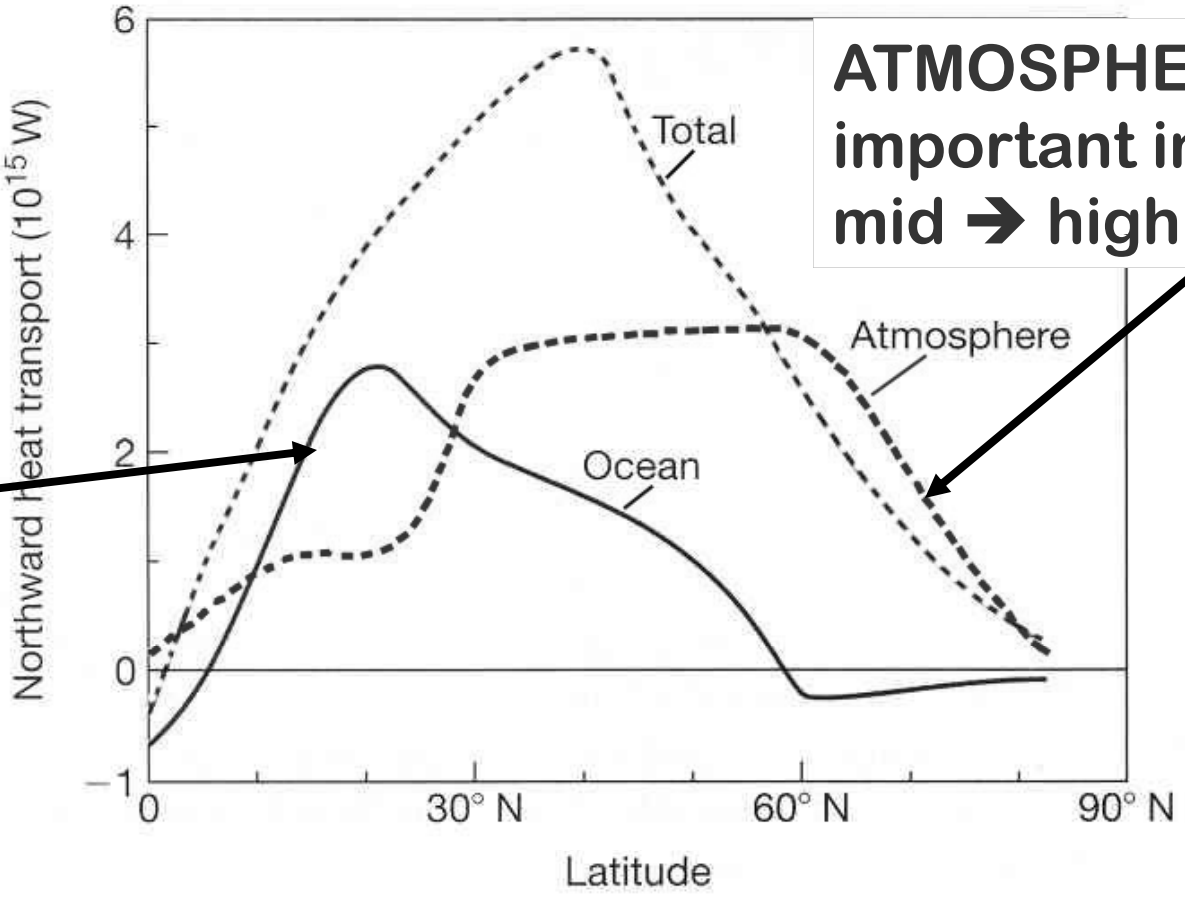


& LE (Latent Energy)



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.

P 67

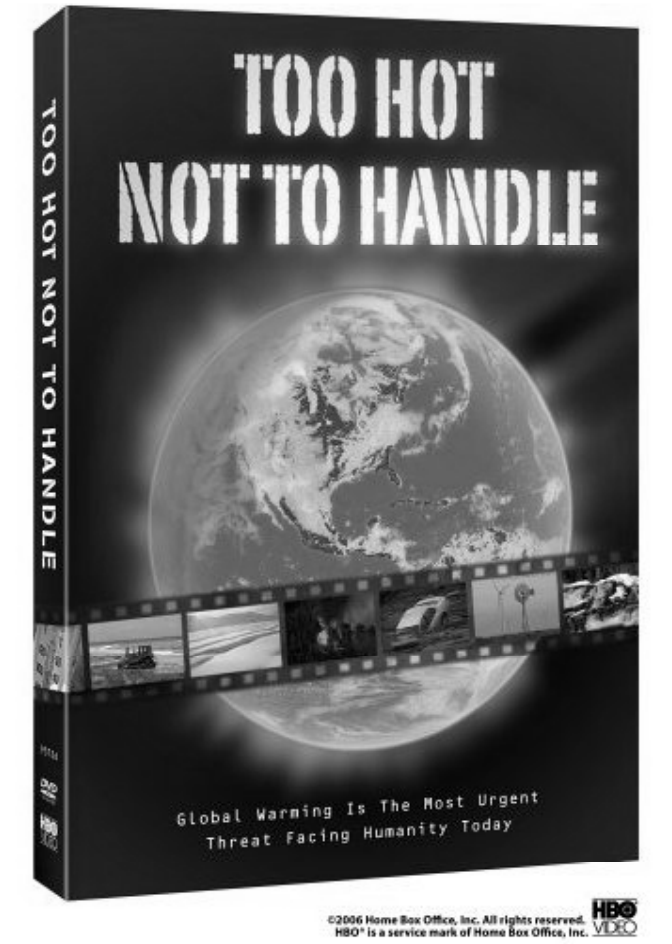
MOVIE TIME!!

GROUP BONUS POINT CHALLENGE :

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

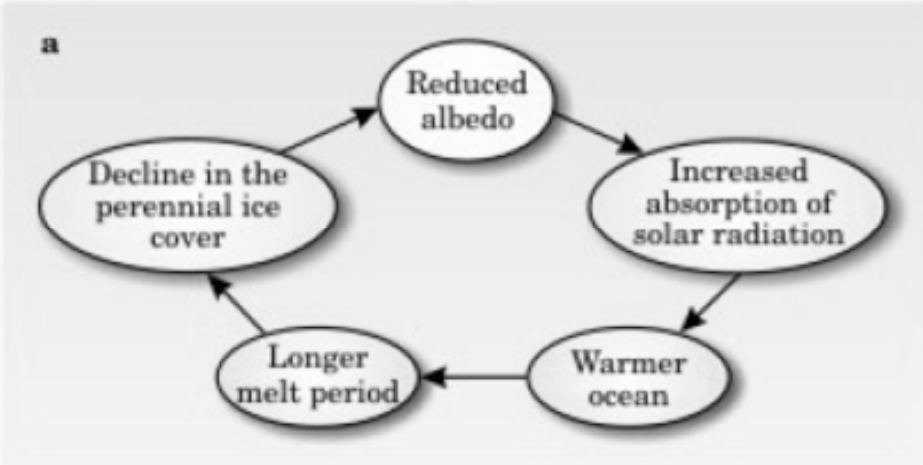
On an index card, state which feedback loop is described and sketch the diagram for it.

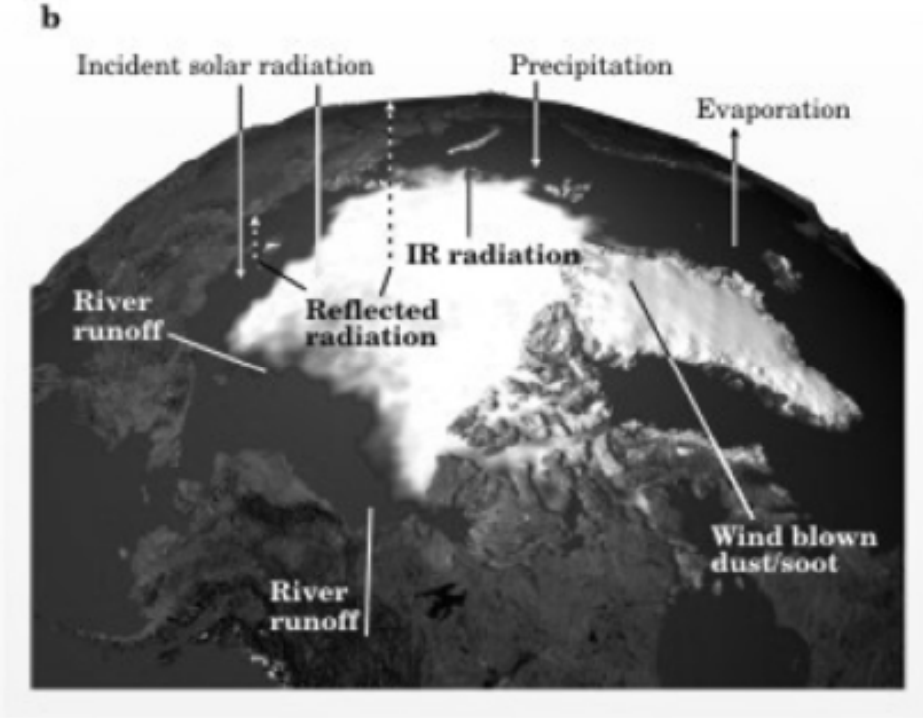
(HINT: it is one of the loops shown on p 56 in Class Notes)



NOTE: This video is posted in D2L. The part we watched was "Melting Alaska" – which starts at 19:57 min

REMEMBER FEEDBACK LOOPS:
Is this one positive or negative?





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

p 58

Here are the components from p 58:

albedo

Extent of ice cover

SW radiation absorbed

Amount of melting

Ocean temperature

The first coupling has been done to get you started!

albedo

Extent of ice cover

SW radiation absorbed

+

Amount of melting

Ocean temperature

We'll finish this and the G-3 Assignment in class on Thursday.