Tuesday Oct 28

SIT ANYWHERE TODAY

Topic # 10 How Climate Works

ANNOUNCEMENTS

- RQ-6 was due TODAY (30 min before class)
  Missed the deadline ? FAQ #22

- I-2 LESSON 2 on "Mother Nature's Influence"
  due in the dropbox before midnight on Thur Oct 30h

- EXAMS will be returned at the end of class today!

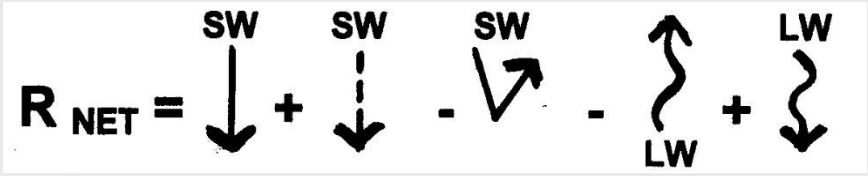
- TEST #3 is a WEEK FROM TODAY! (Tues Nov 4th)
  The Top 10 will be posted on Thursday.

WRAP UP OF TOPICS :

8 Energy Balance Intro
and
#9 Feedbacks

THE G-3
ANSWERS

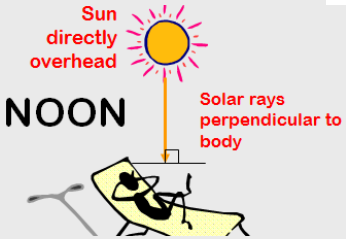
The LEFT side of the equation:

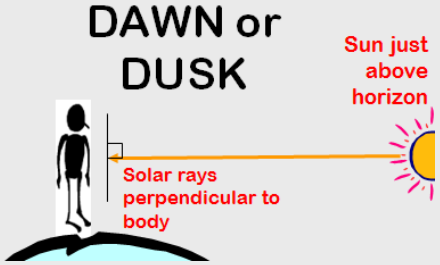


1. SW

2. SW

3. Noon: more SW & dusk: more SW





4. LW + LW together = the Greenhouse Effect

5. 

(dust, thicker atmosphere scatters longer red/orange wavelengths)

6. 

radiates day & night; camera senses IR

7. 

leads to distinct shadows, while diffuse SW 

radiation does not

8. 

All wavelengths of visible part of spectrum are scattered & transmitted in a colored spectrum by raindrops

9. Attempt to increase absorption & reduce 

into eyes and reduce glare

10. More 

is absorbed, leads to more 

which can then warm up car

The RIGHT Side of the Equation:

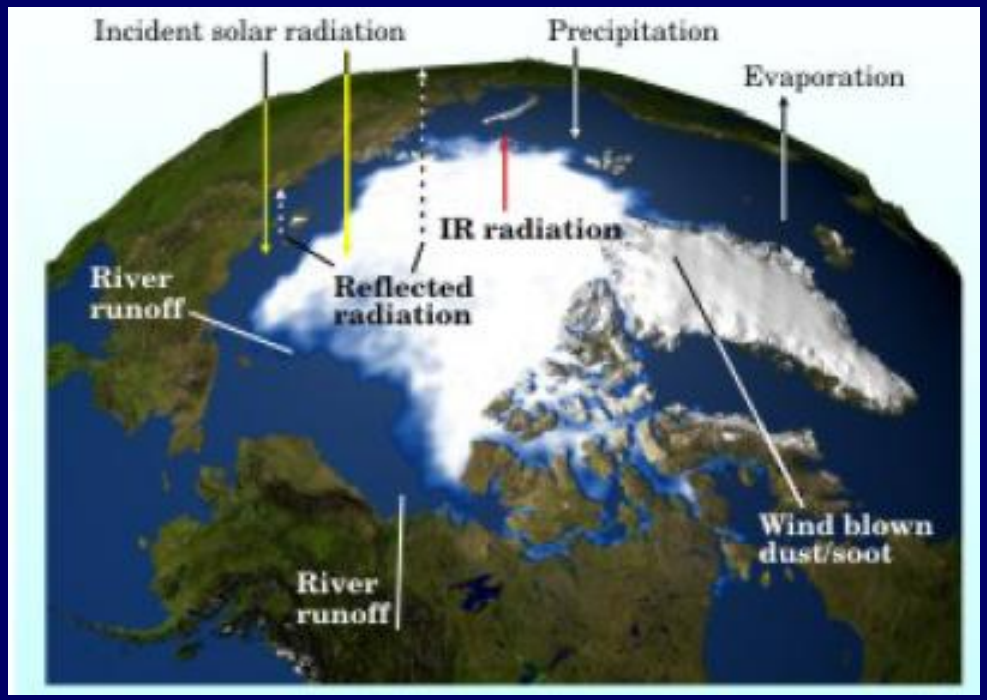
= H + LE + G

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

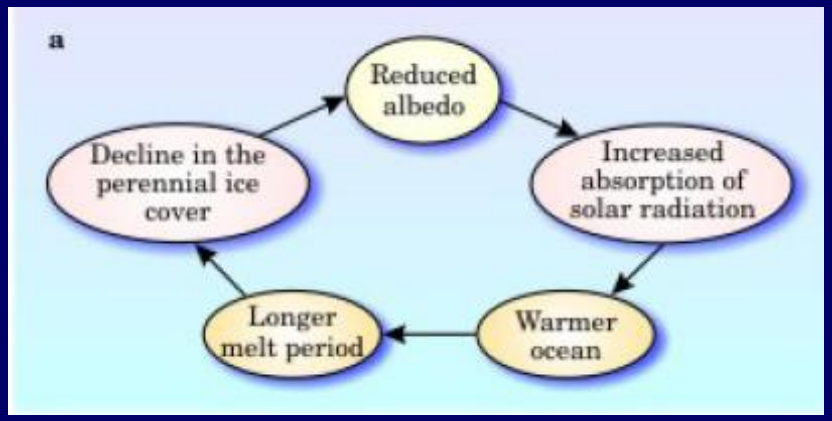
14. Wet mud evaporates from pig & cools him: LE
also heat from pig's body is conducted into soil: G

15. June is hot & dry in Tucson. Dry, hot air can "hold" more water vapor, so water in cooler pads is evaporated easily. Hence more energy goes into LE instead of H This cools the house!

TEAM & GROUP CHALLENGE QUESTION REVIEW:



One way of representing this feedback loop :



Another way:

albedo

extent of sea ice cover

SW radiation absorbed *(by ocean)*

amount sea ice of melting

ocean temperature

You can start anywhere in FEEDBACK LOOP reasoning . . . .

albedo

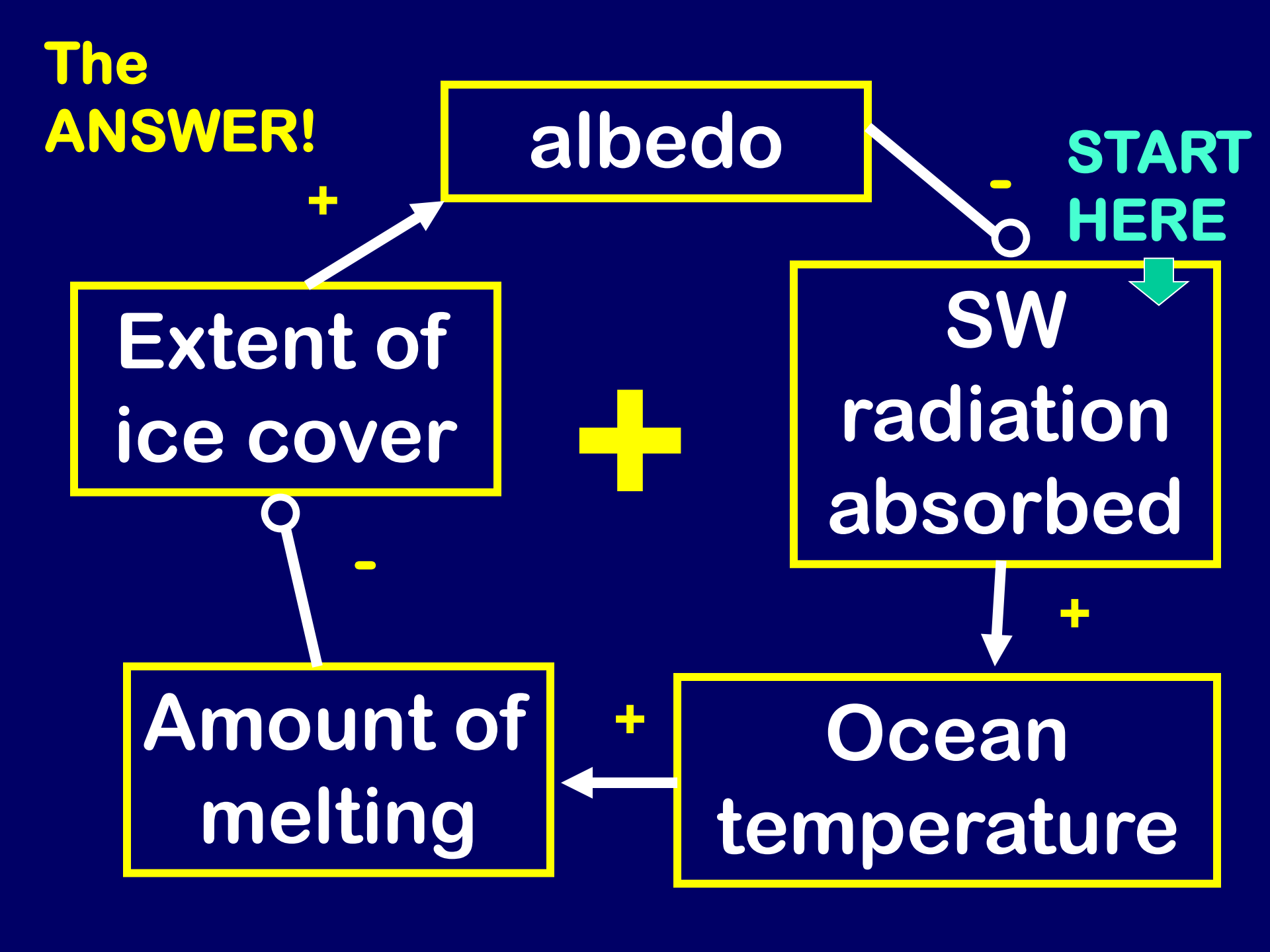
START HERE

SW radiation absorbed

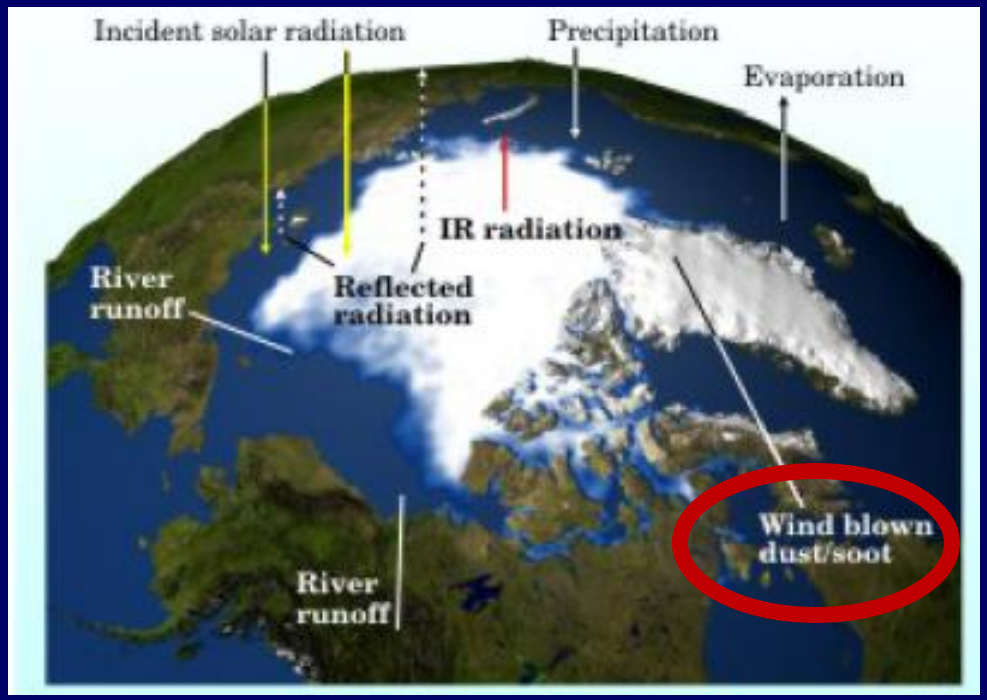
Extent of ice cover

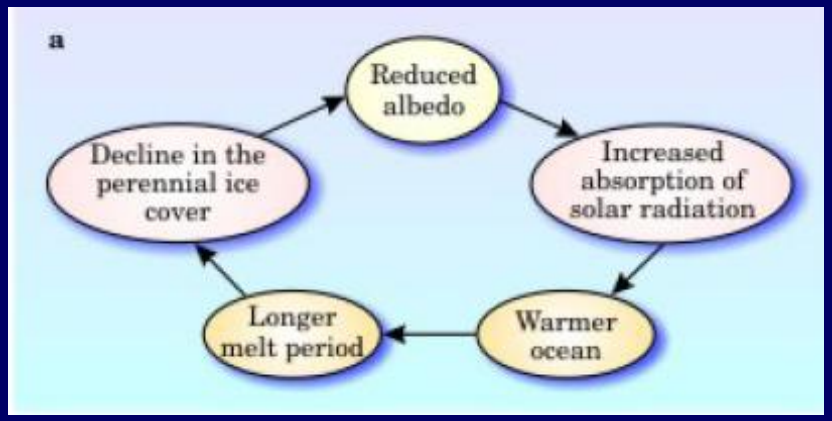
Amount of melting

Ocean temperature


The ANSWER!
albedo
+
-
START HERE
Extent of ice cover
SW radiation absorbed
+
-
+
Amount of melting
+
Ocean temperature

Sometimes a PERTURBATION or FORCING MECHANISM can START UP A FEEDBACK LOOP:





Another way:

albedo

extent of sea ice cover

SW radiation absorbed *(by ocean)*

amount sea ice of melting

ocean temperature

Do you see anything that could start up or "force" a change?

FORCING MECHANISM

Wind blows in dust and soot

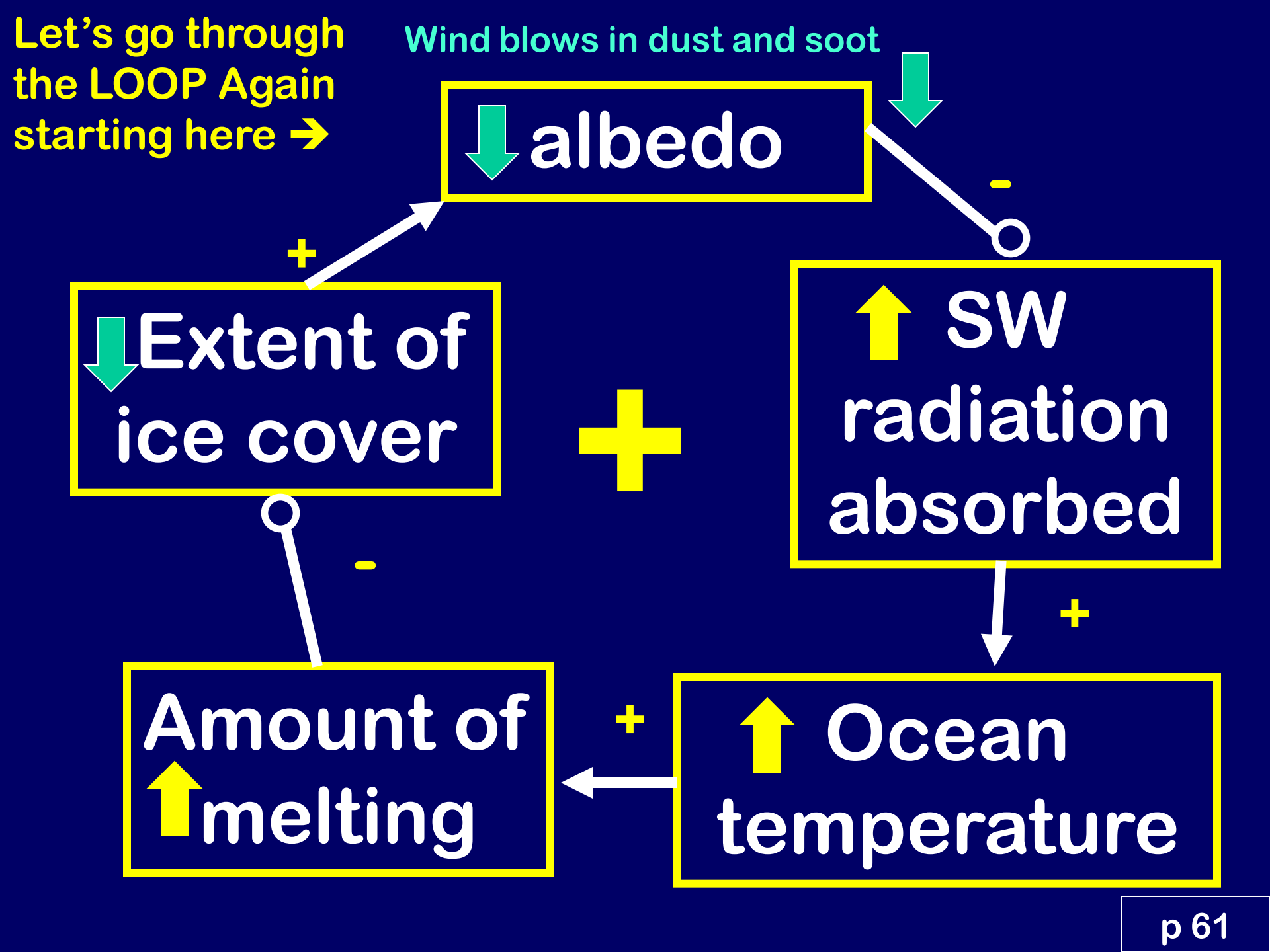
albedo

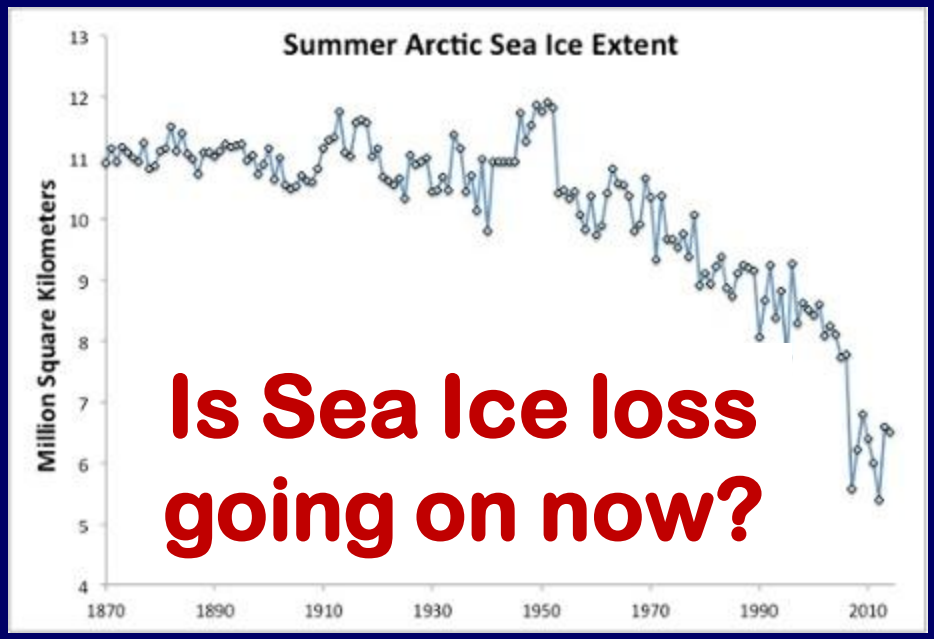
Extent of ice cover

SW radiation absorbed

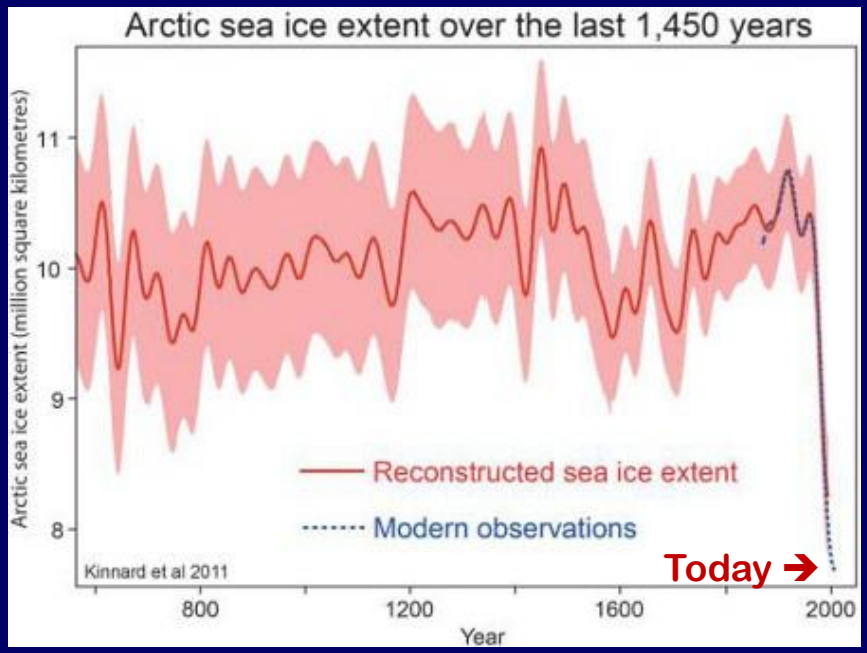
Amount of melting

Ocean temperature

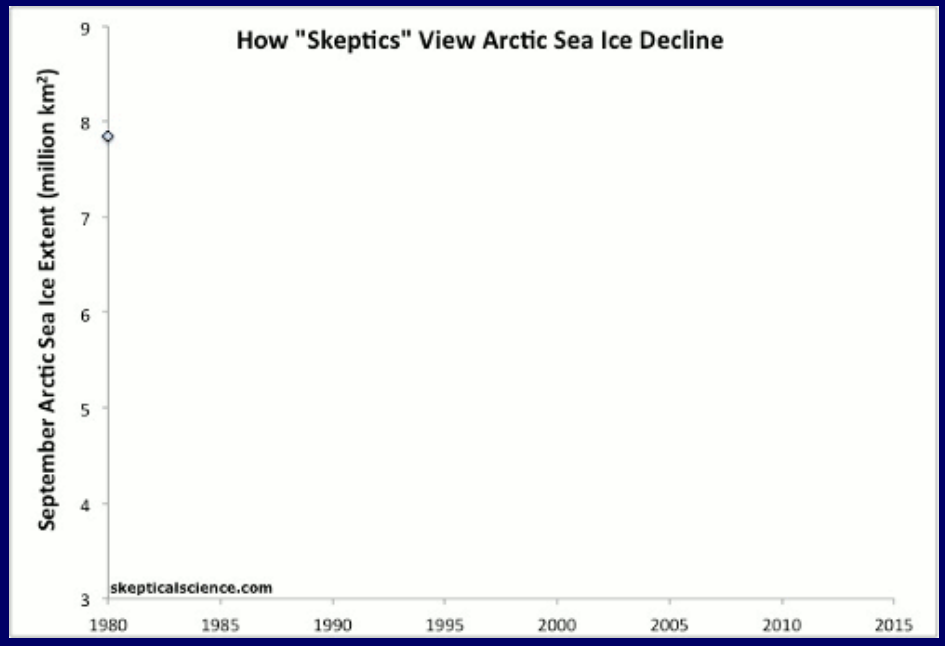

Let's go through the LOOP Again starting here →
Wind blows in dust and soot
albedo
-
+
Extent of ice cover
SW radiation absorbed
+
-
+
Amount of melting
+
Ocean temperature



Is Sea Ice loss going on now?



http://www.skepticalscience.com/2014-arctic-sea-ice-extent-6th-lowest-in-millennia.html

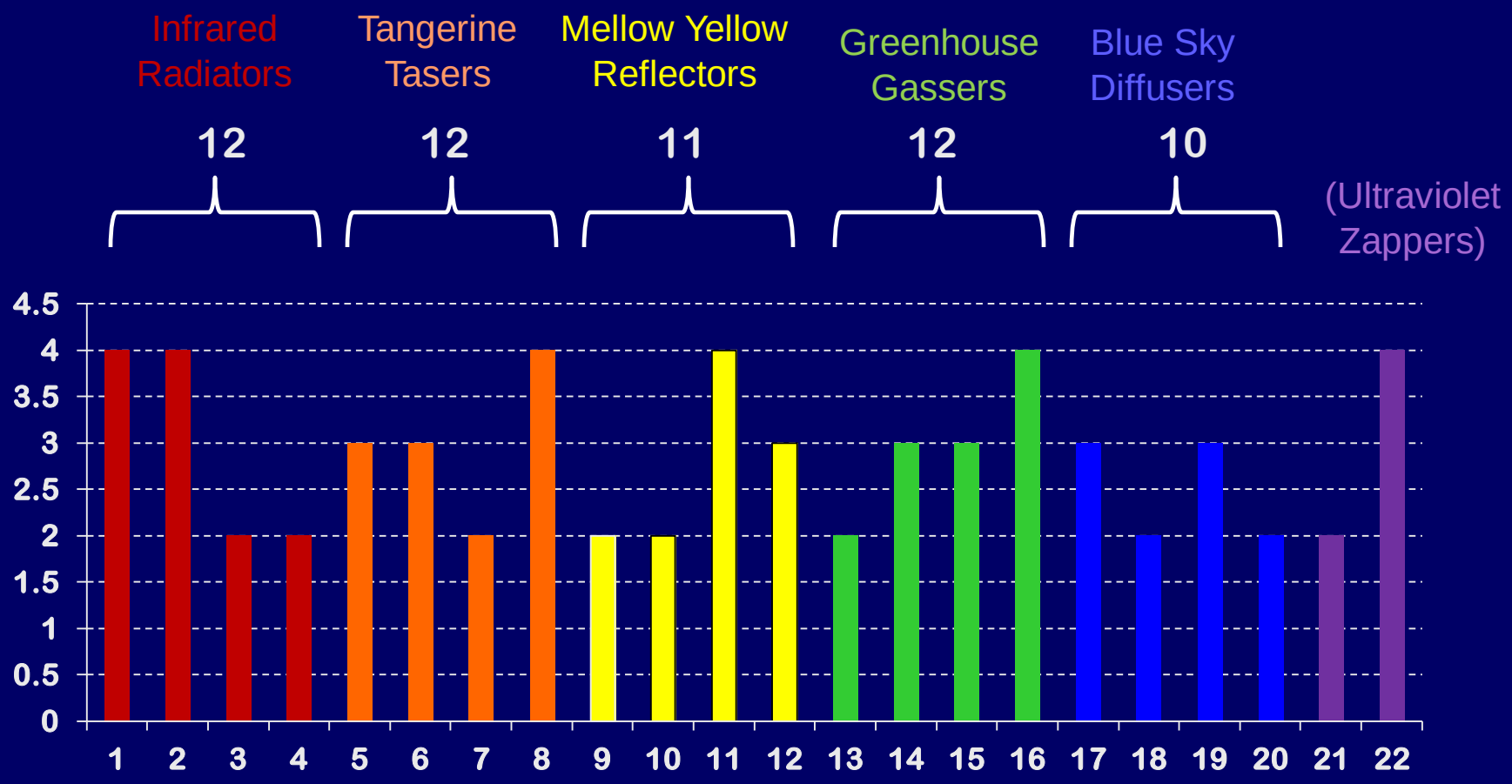


http://www.skepticalscience.com/feb-2013-sea-ice-spiral.html

But still there are skeptics . . .

← *September Arctic sea ice extent data since 1980 from the National Snow and Ice Data Center (blue diamonds). "Recovery" years, meaning years when the sea ice extent is greater than the previous year, are highlighted in red.*

TEAM & GROUP CHALLENGE STANDINGS:



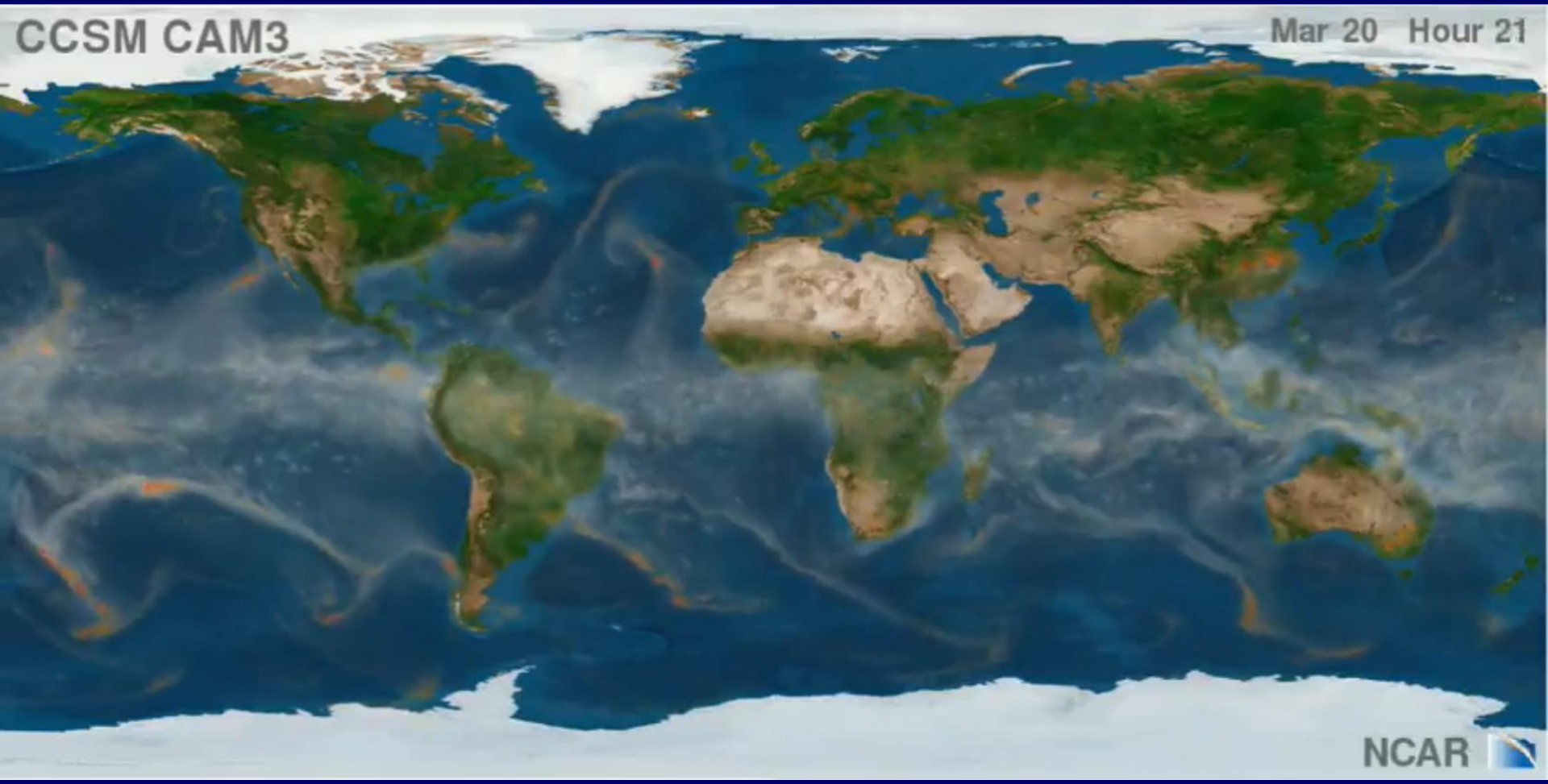
Topic # 10
HOW CLIMATE WORKS

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

How do we get energy from this . . . .

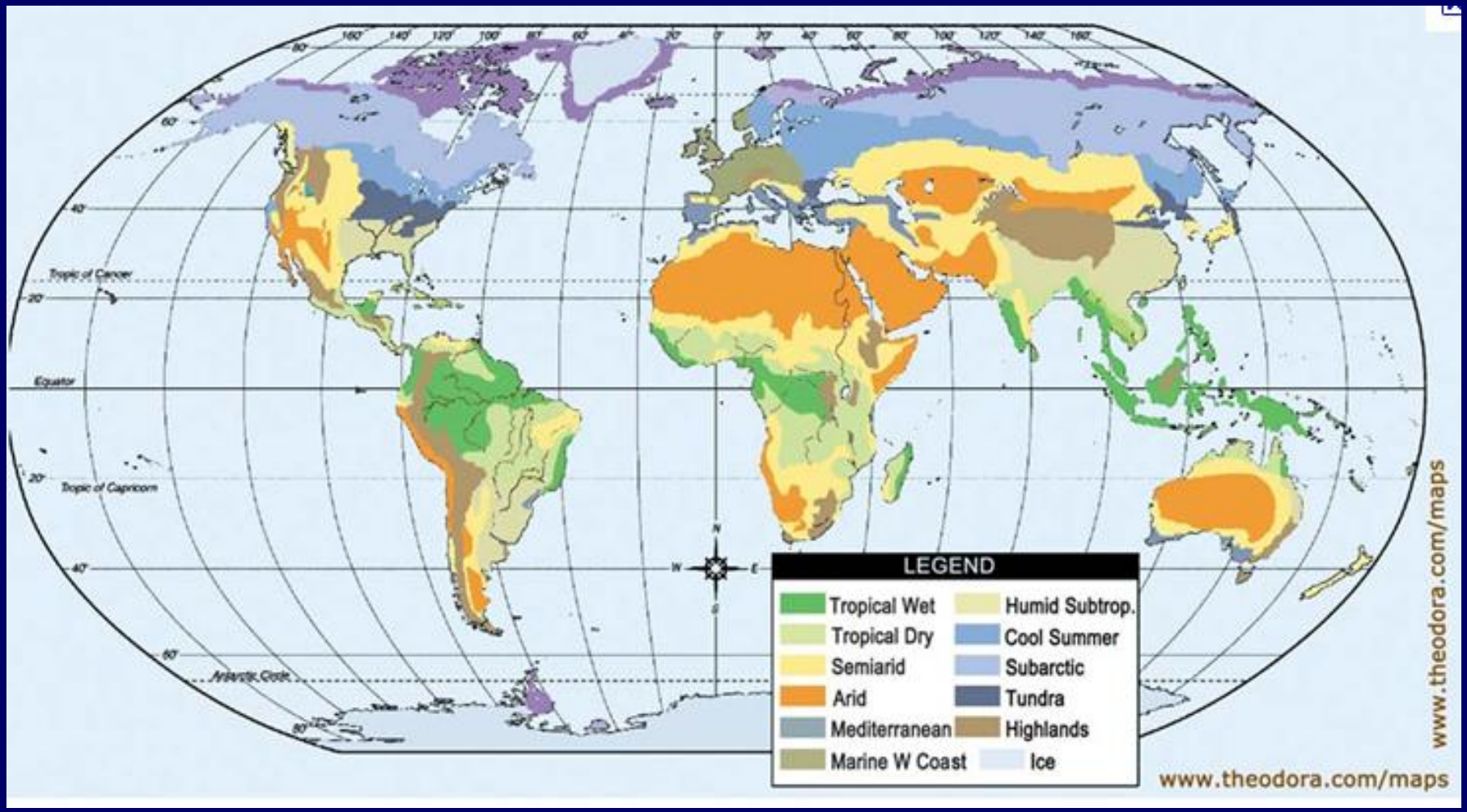
. . . . to drive this ?

. . . . or this ?



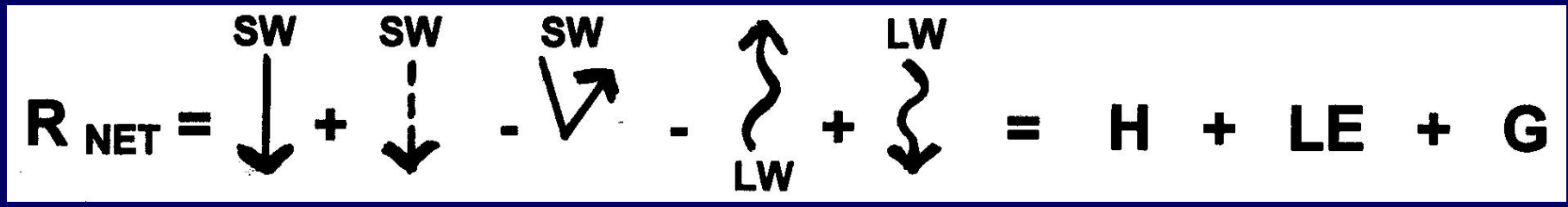
http://www.vets.ucar.edu/vg/T341/index.shtml

. . . .and end up with Global Climatic Regions:



. . . .and CHANGES in these regions!

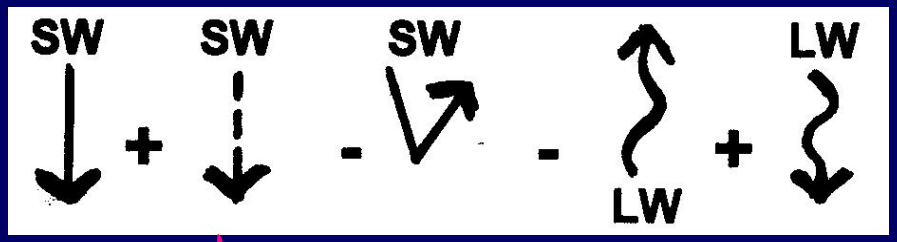
It all happens because of changes in the ENERGY BALANCE !

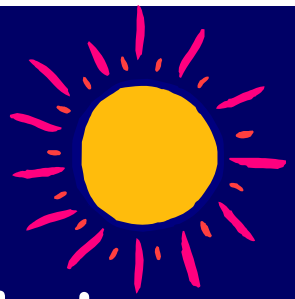


The "RADIATION" - ENERGY BALANCE:

"Radiation Balance" part

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





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. Conduction, Convection . . .**

. . . and PHASE CHANGES!

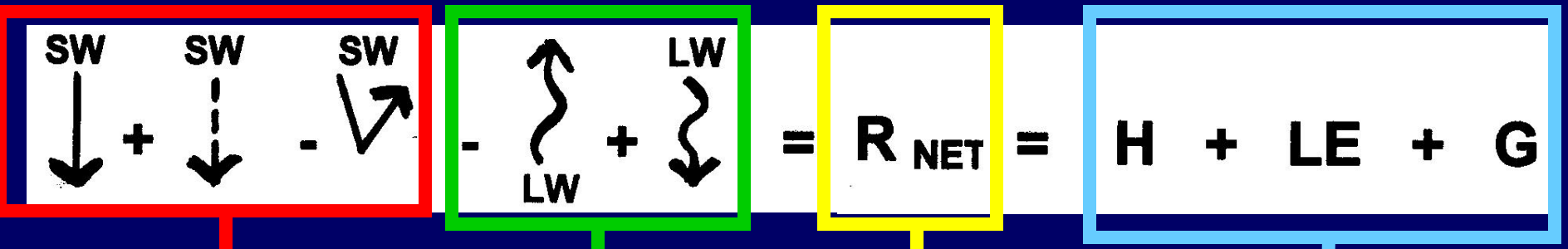
- **Sensible Heat transfer (H)**
- **Latent Heat transfer (LE)**

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.

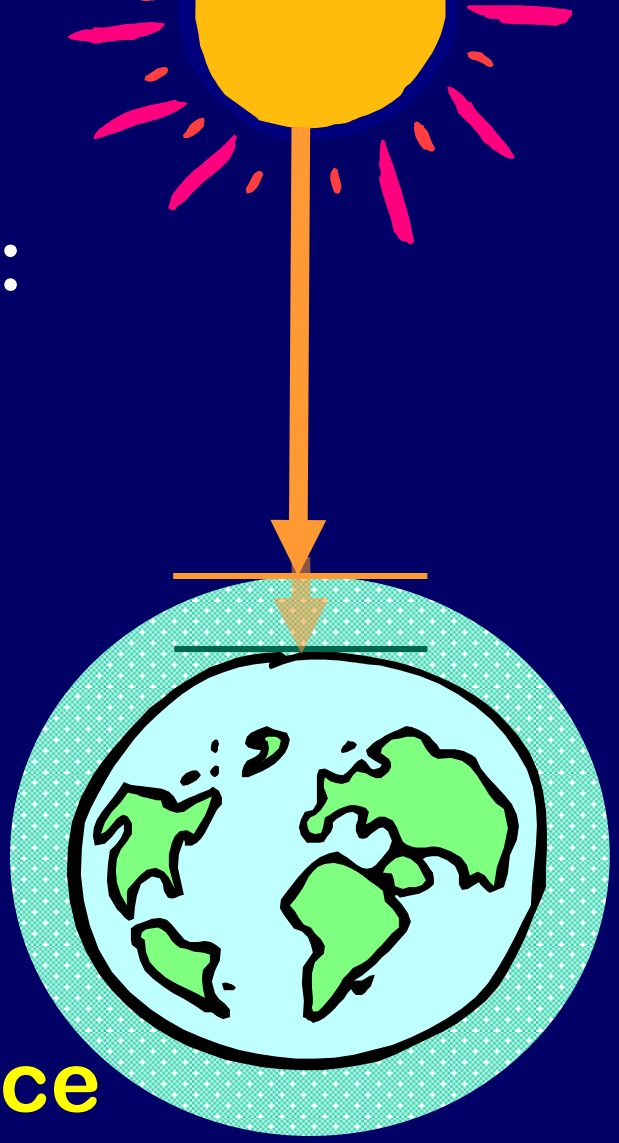
- Lewis Thomas

LINKING THE ENERGY BALANCE TO ATMOSPHERIC CIRCULATION:

We'll start with the SUN:

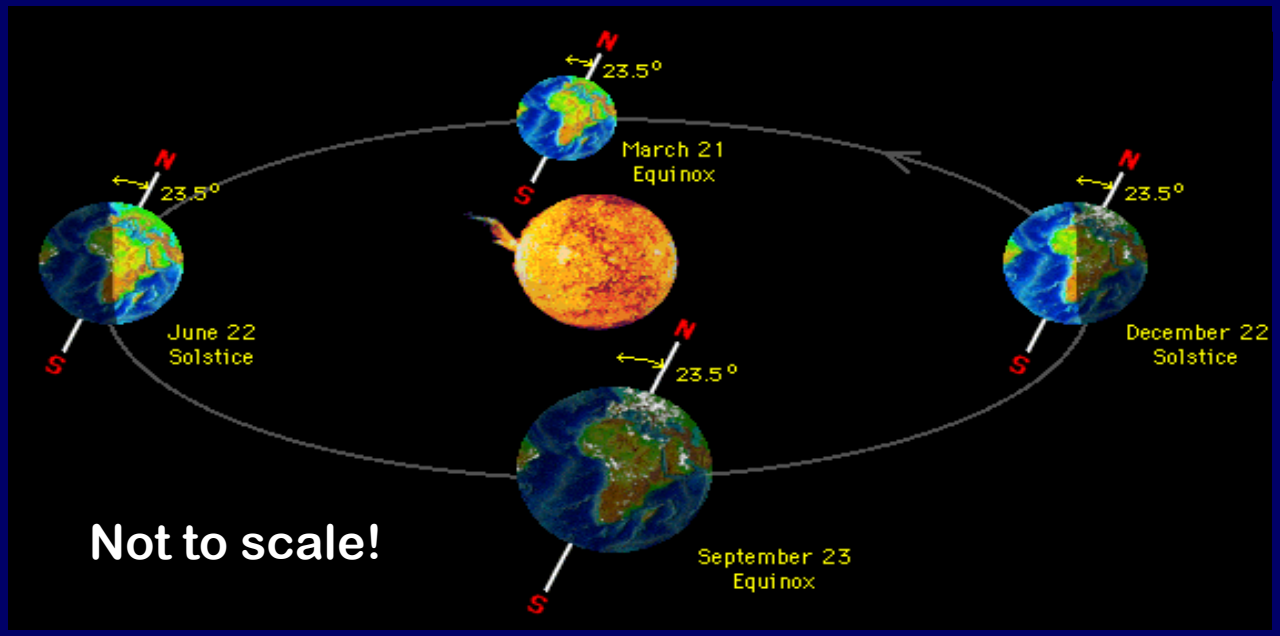
SOLAR INSOLATION

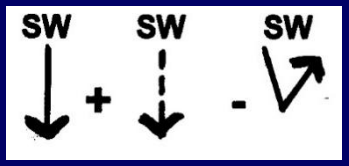
IN – SOL- ATION



= the amount of incoming solar radiation received by a horizontal surface
(e.g. at the top of the atmosphere, at the tropopause, at the Earth's surface, etc.)

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





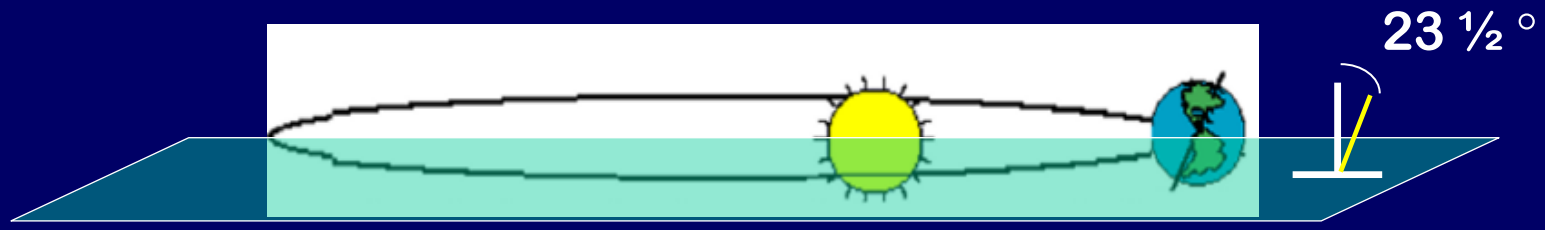
EARTH-SUN Relationships

4 Things to Know about Earth-Sun Relationships:

1) Earth orbits Sun
2) Orbit not a perfect circle
3) Orbit traces "a plane"
4) Earth's axis tilts

You can take notes on p 62

The "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"

These 4 Earth-Sun "orbital" properties lead to 2 key factors that determine the AMOUNT OF SOLAR INSOLATION at any spot on Earth as the seasons progress:

(1) INTENSITY of sun's rays
Depends on AXIS TILT and how Earth's SURFACE RECEIVES Sun's rays
[Most intense = perpendicular rays ⊥]

(2) DURATION of insolation (day length)
Depends on LATITUDE & SEASON

➔ *Intensity & Duration vary with LATITUDE & TIME OF YEAR*

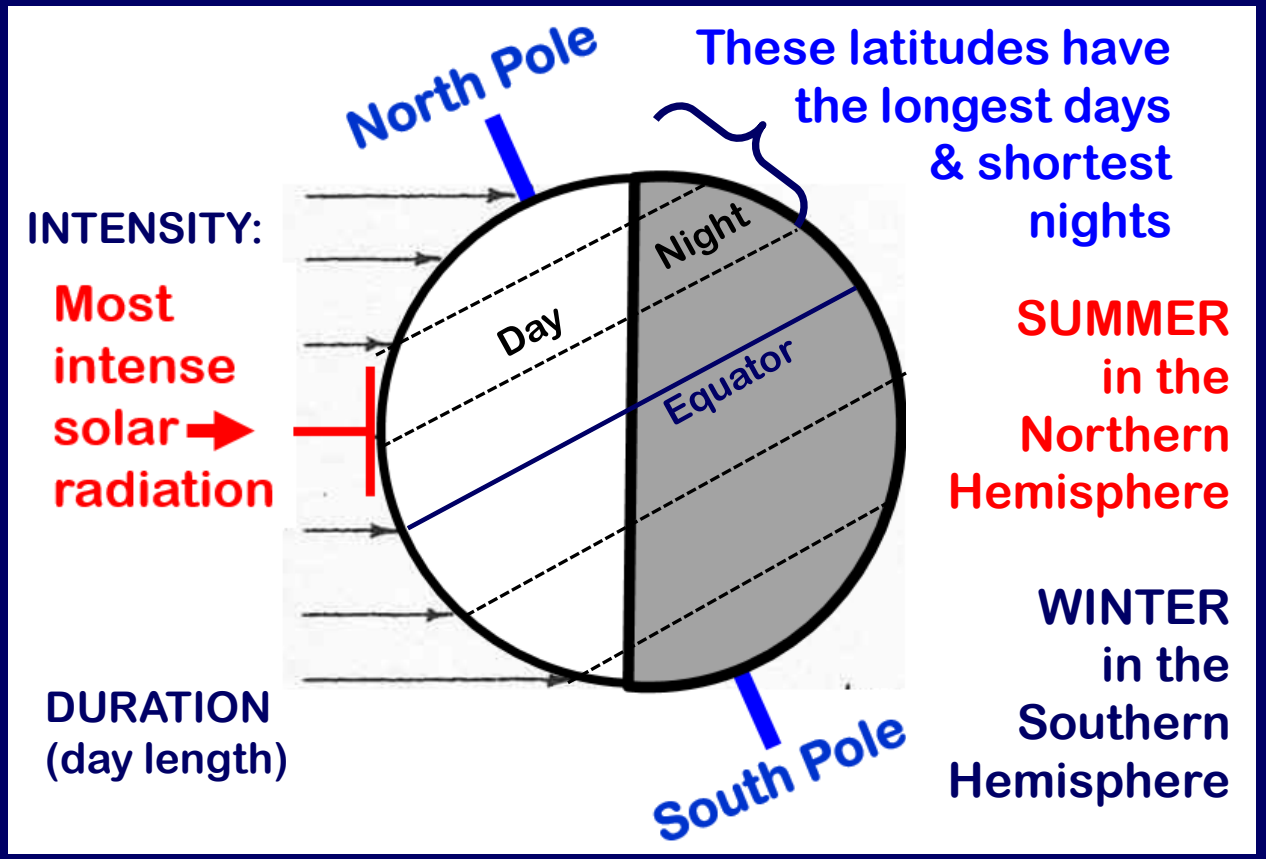
Box on p 63

INTENSITY + DURATION

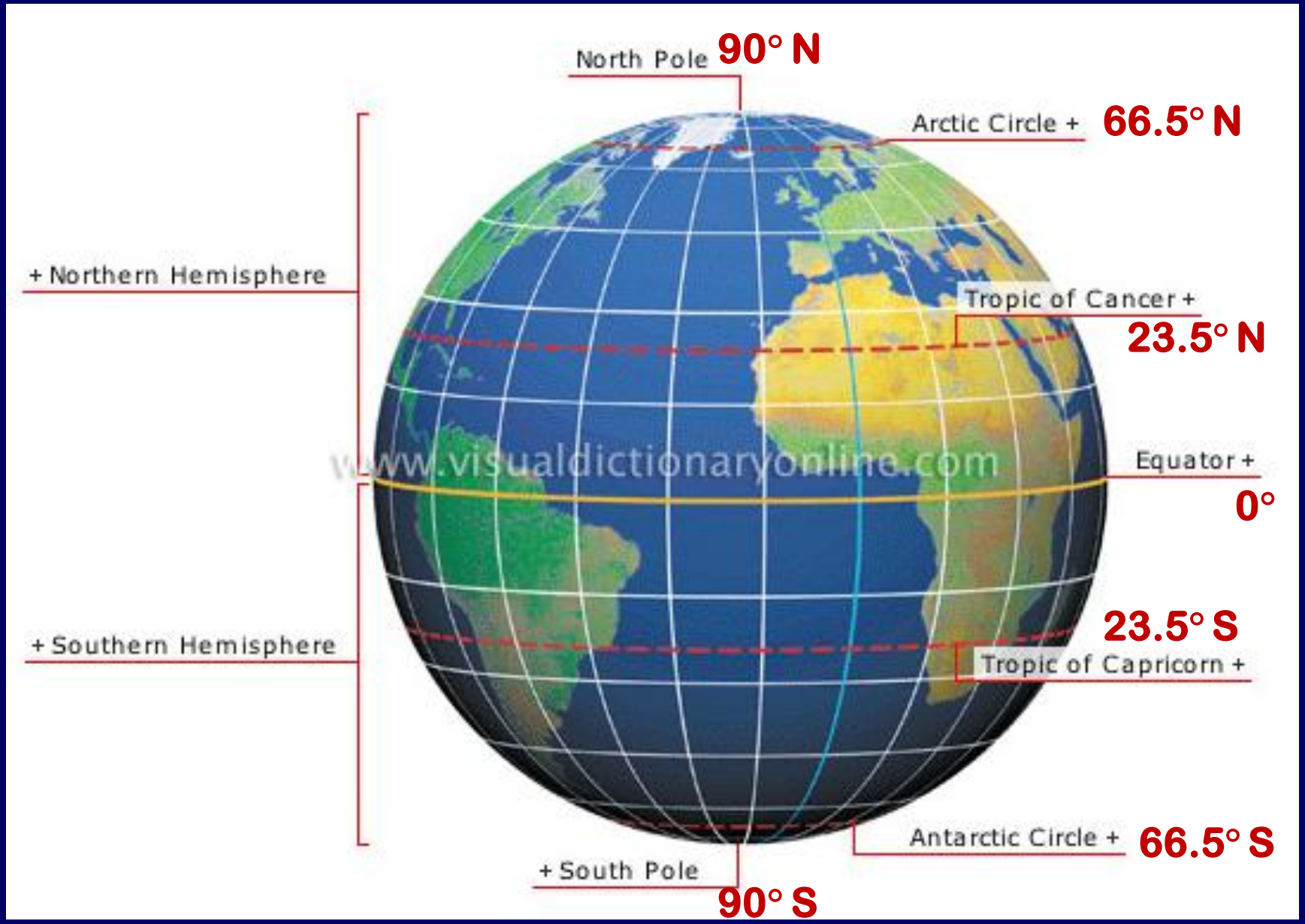
INTENSITY of sun's rays: depends on axis tilt and how earth intercepts sun's rays

DURATION of daily insolation (day length): depends on where circle of illumination intersects latitude band

Sun's rays



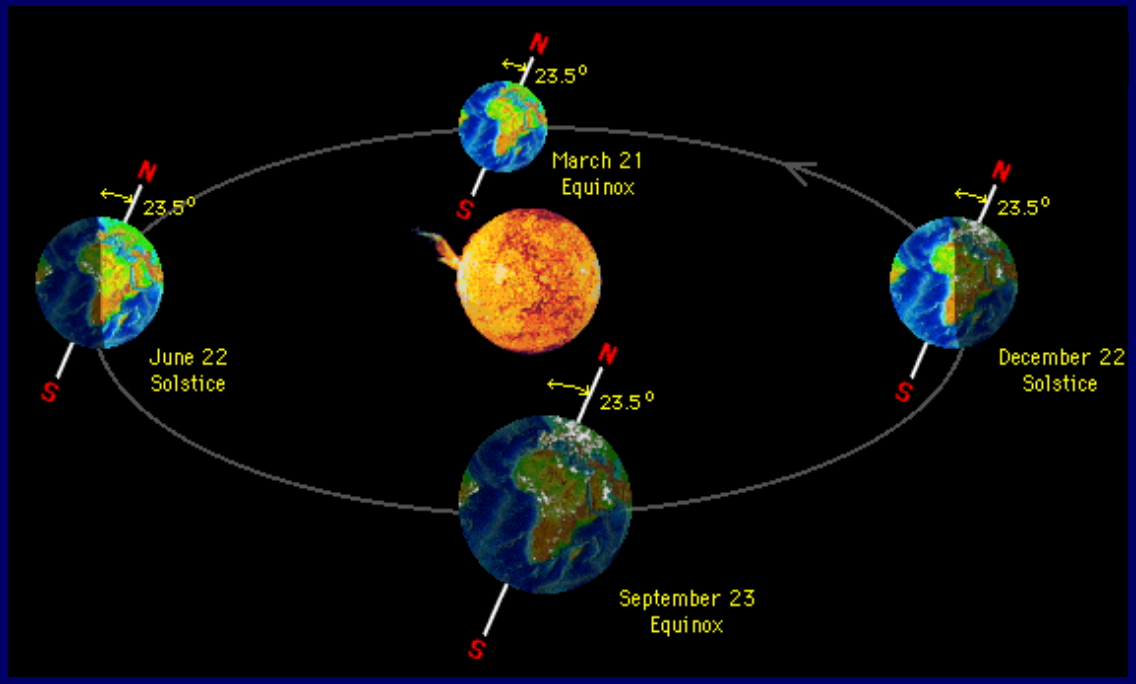
QUICKIE LATITUDE REVIEW:



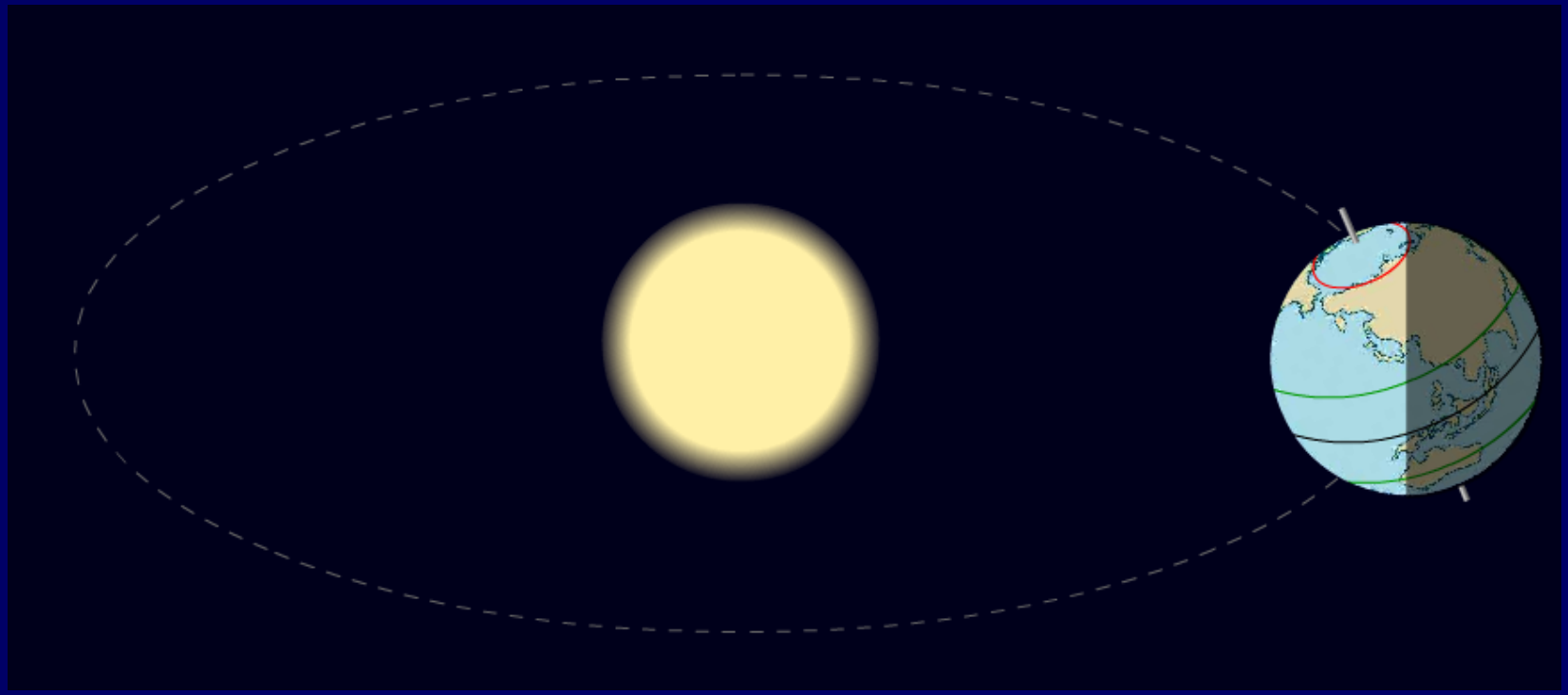
EARTH-SUN RELATIONSHIPS & The SEASONS:

VIEW THE ANIMATION:

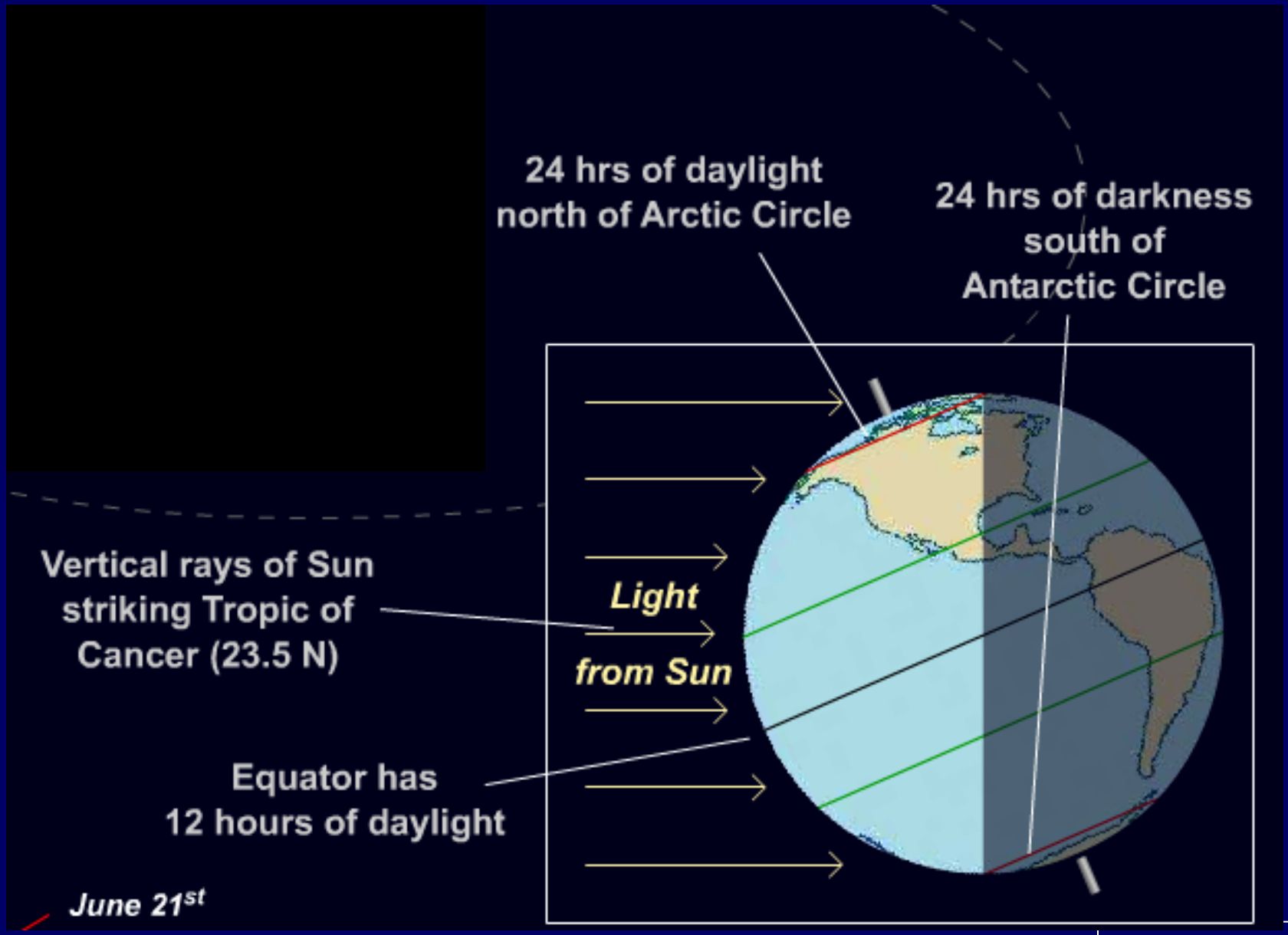
http://mesoscale.agron.iastate.edu/agron206/animations/01_EarthSun.html



JUNE SOLSTICE



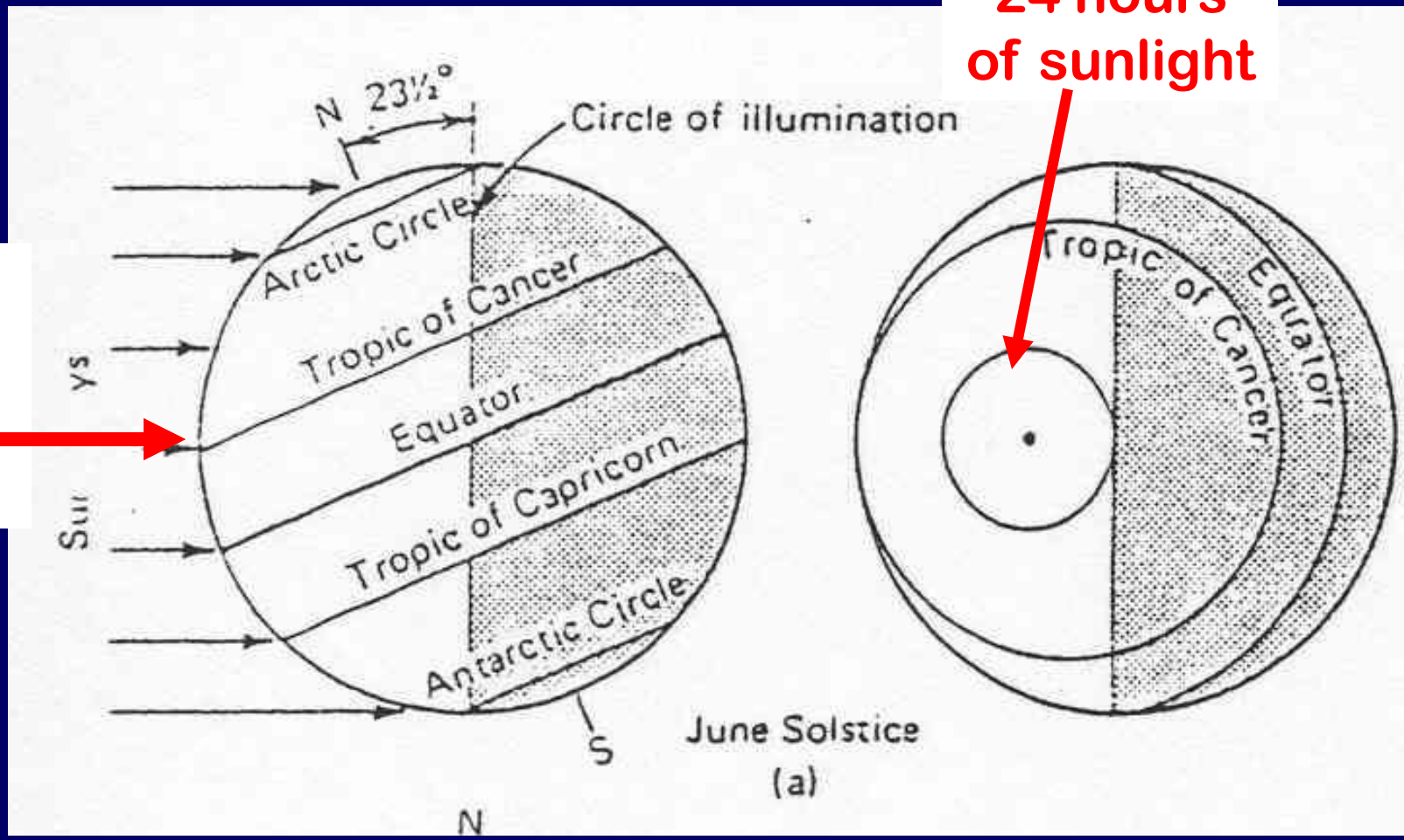
JUNE SOLSTICE



JUNE SOLSTICE

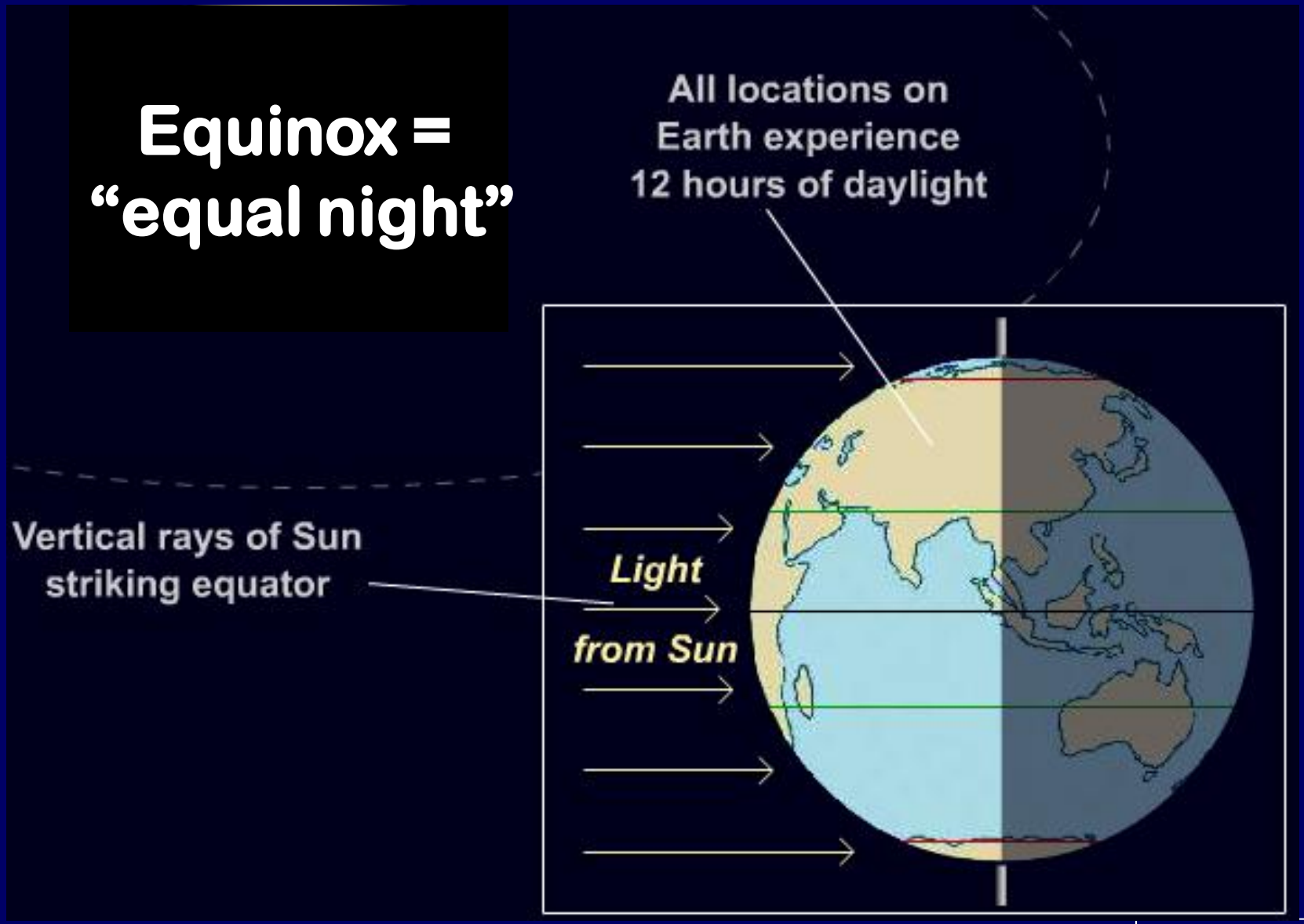
24 hours of sunlight

Most intense solar radiation



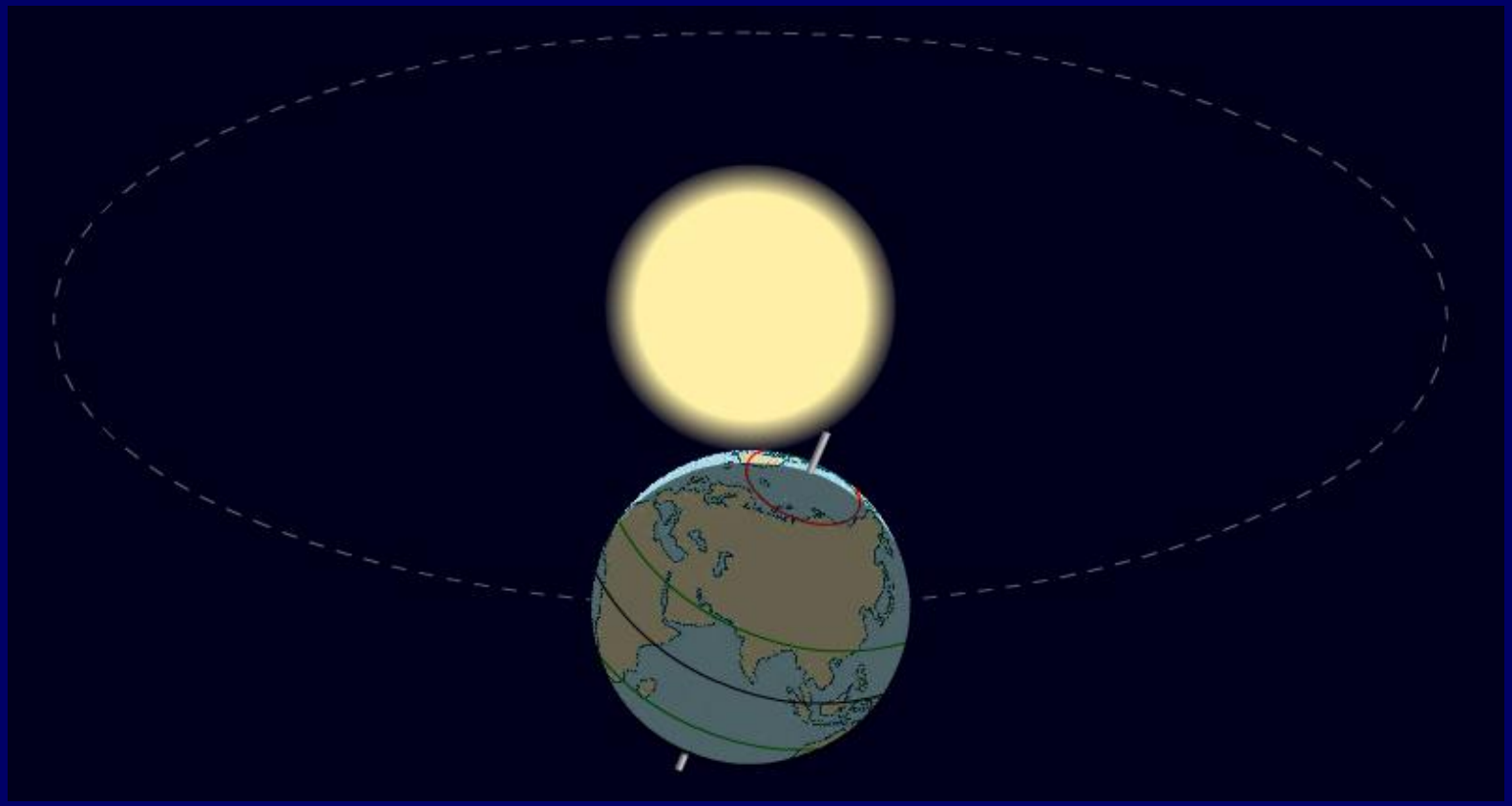
MARCH EQUINOX

Equinox = "equal night"



SEPTEMBER EQUINOX

different seasonal position in orbit . . .

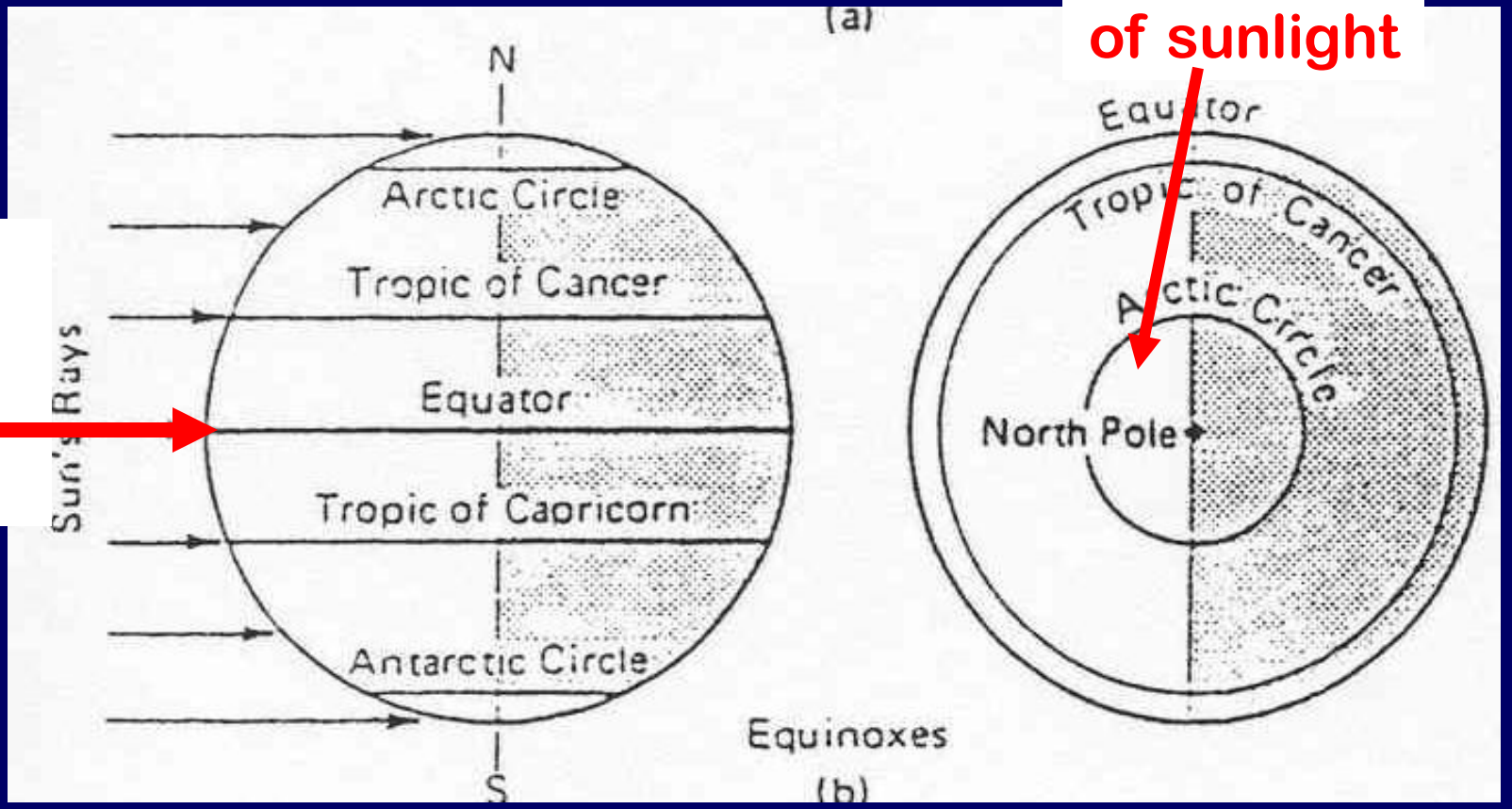


. . . but same latitudinal insolation as March Equinox

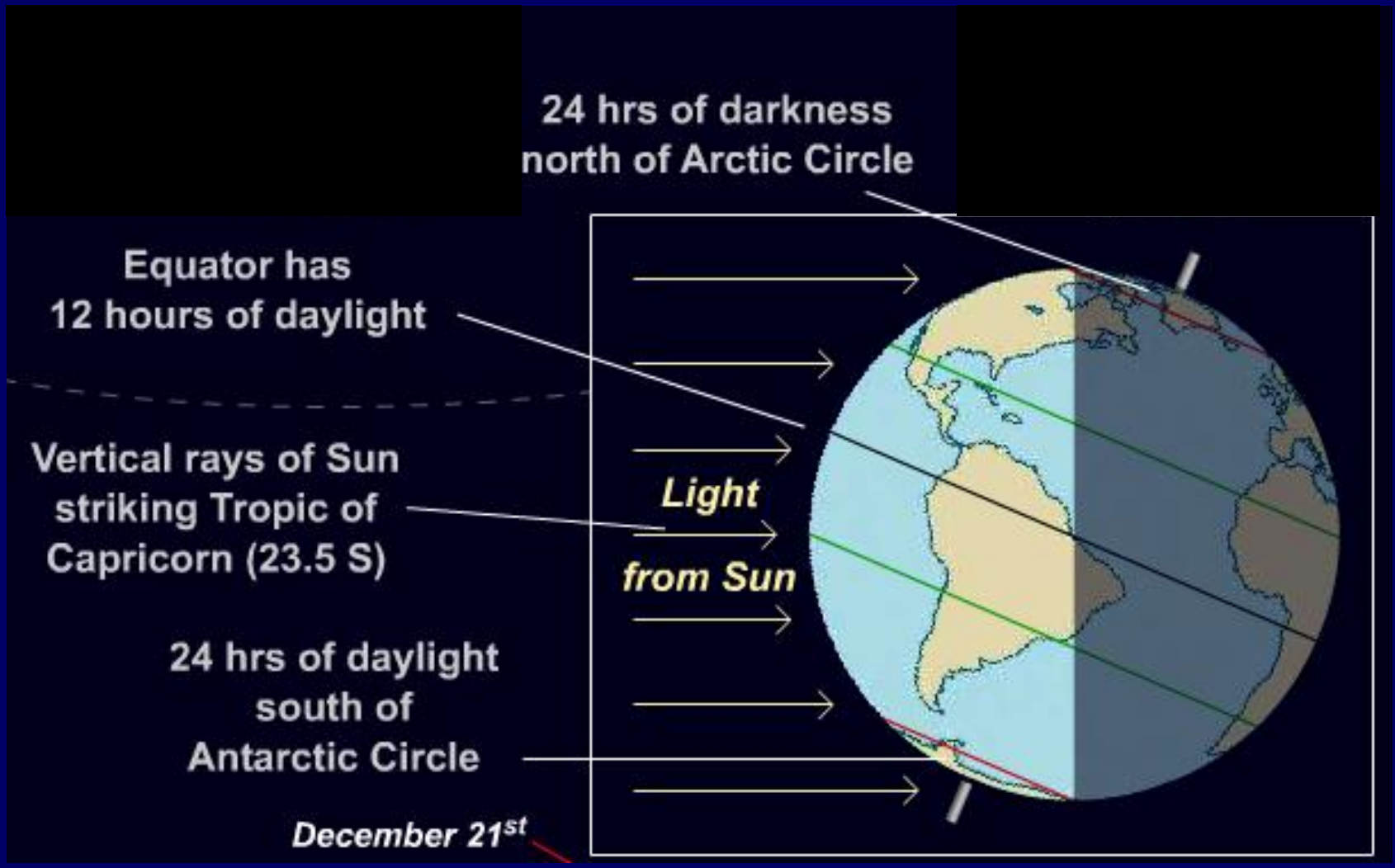
MARCH & SEPTEMBER EQUINOXES

12 hours of sunlight

Most intense solar radiation



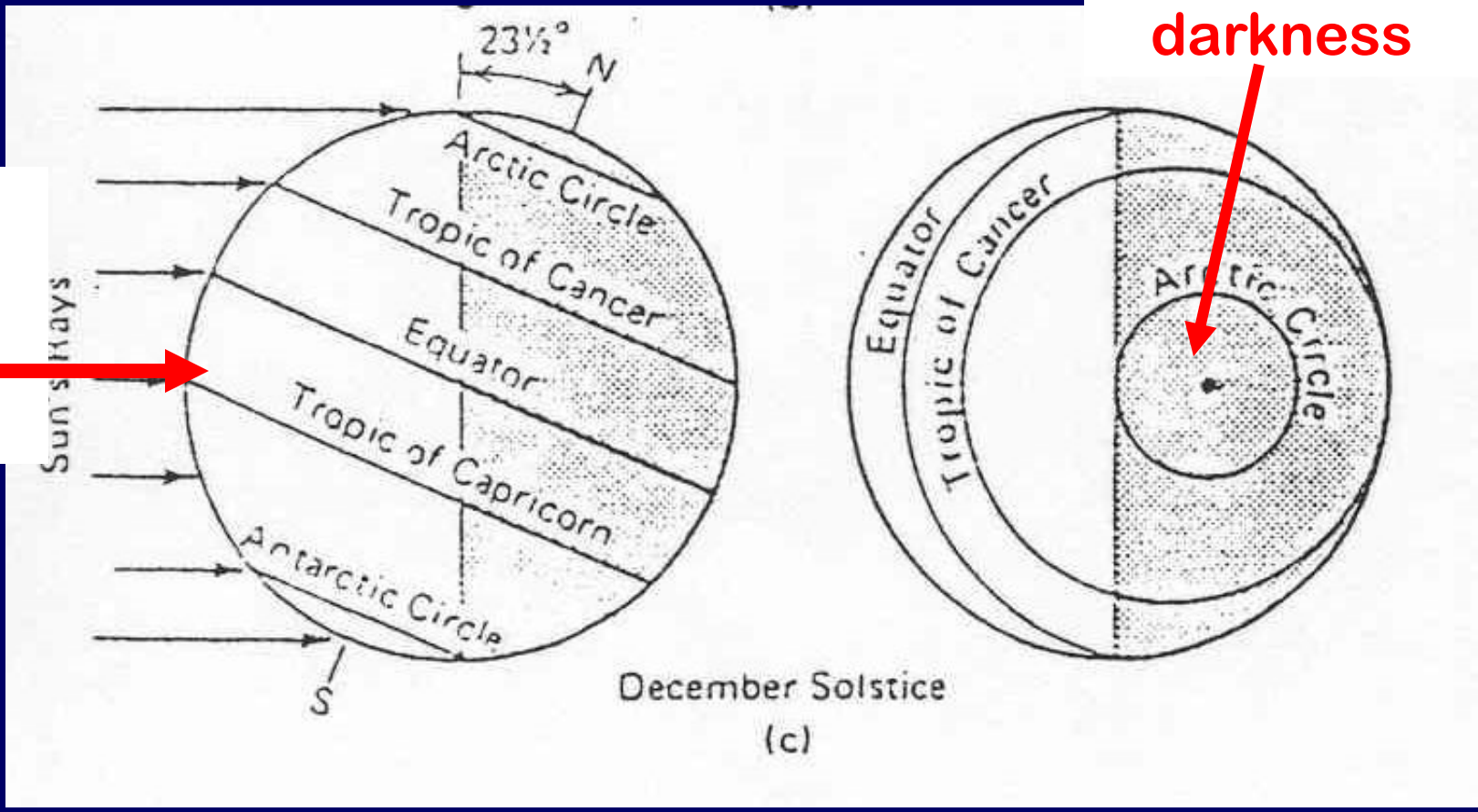
DECEMBER SOLSTICE



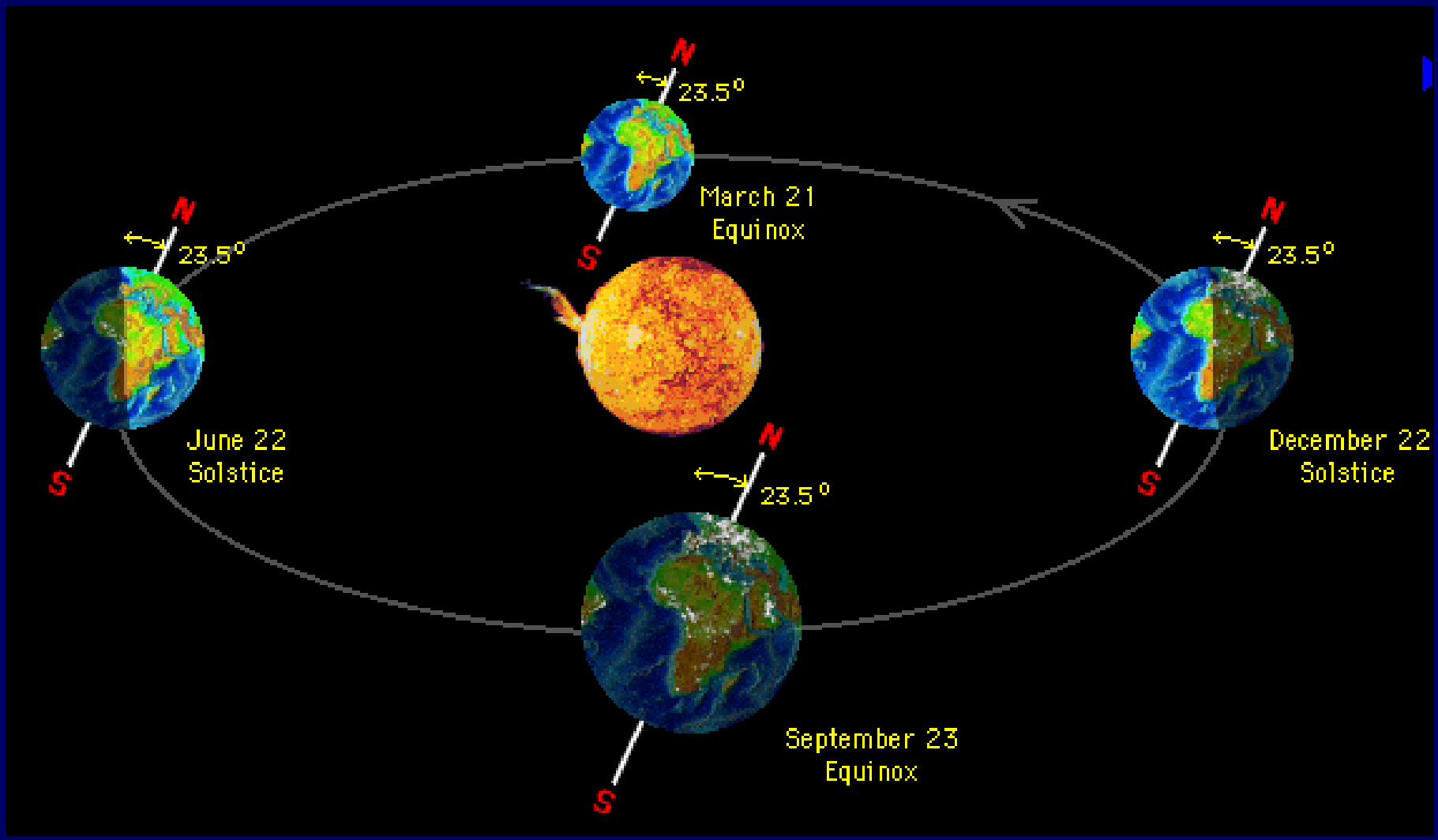
DECEMBER SOLSTICE

24 hours of darkness

Most intense solar radiation



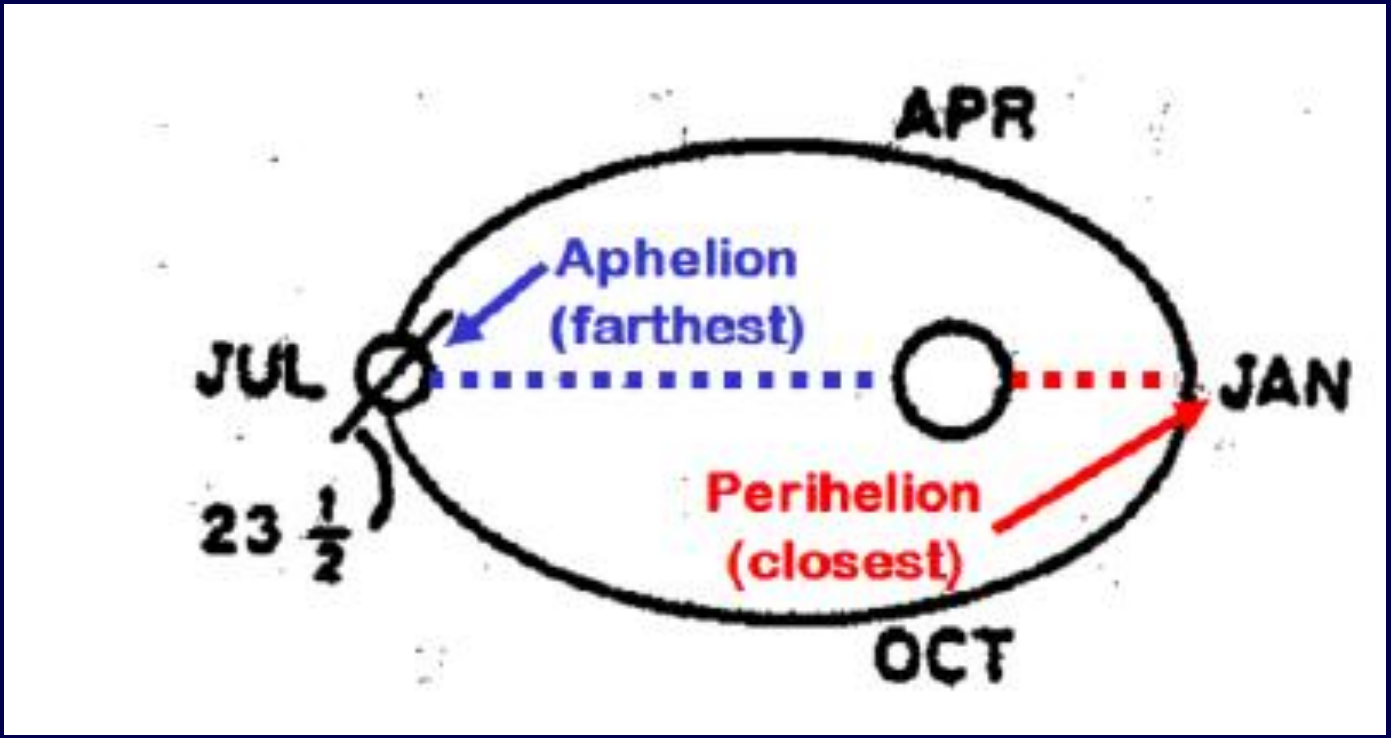
http://mesoscale.agron.iastate.edu/agron206/animations/01_EarthSun.html



Recap

Earth's Axis Tilt & Elliptical Orbit ➔

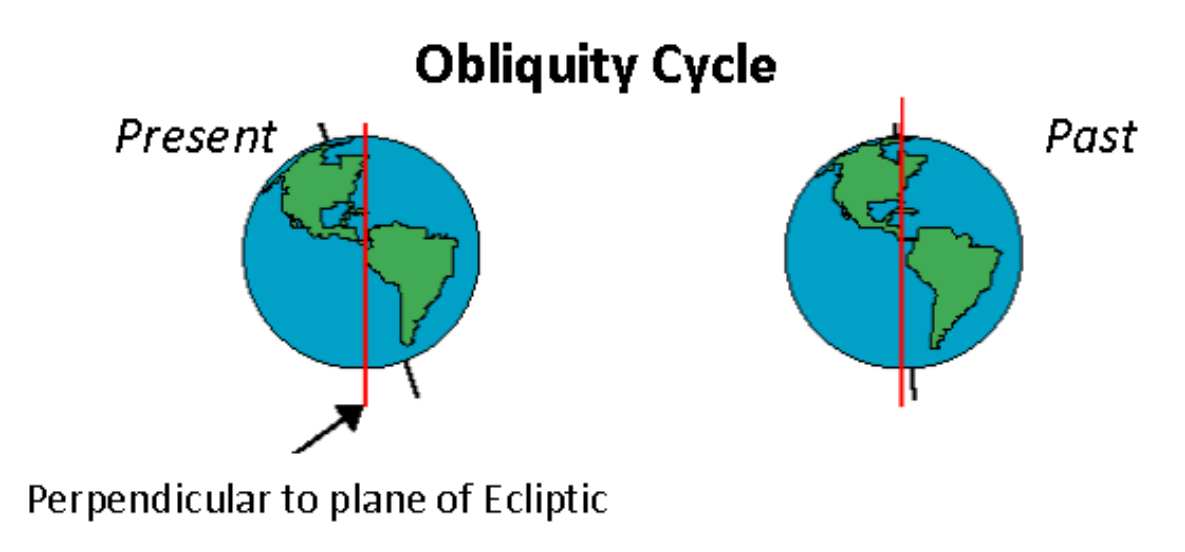
Contrast in Northern vs. Southern Hemisphere:



NATURAL CLIMATIC FORCING:
Milankovitch Cycles: (Lesson 2 tutorial)

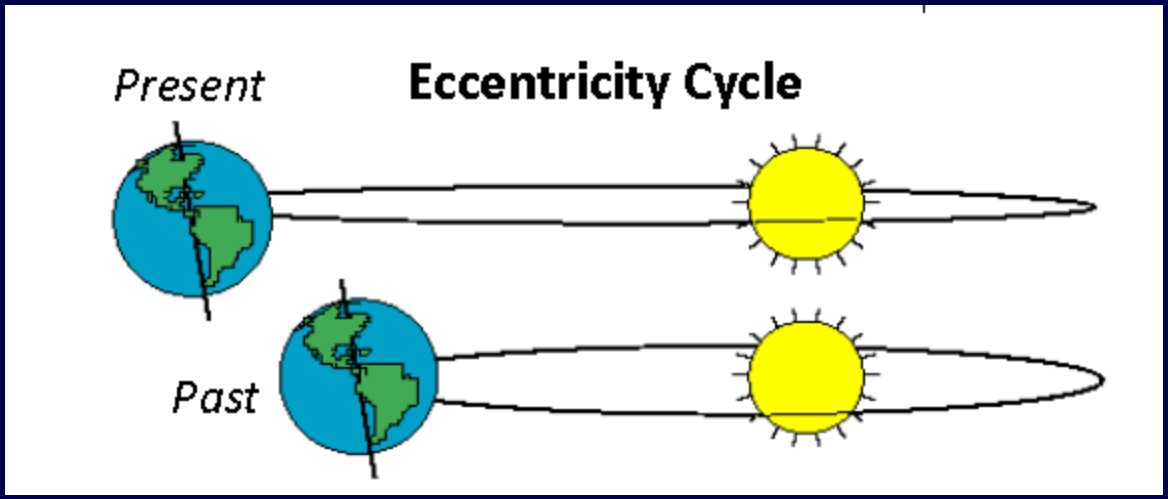
1. OBLIQUITY OF EARTH'S AXIS

Axis "tilts" 23.5 degrees from plane of ecliptic; causes the seasons; tilt angle varies over time

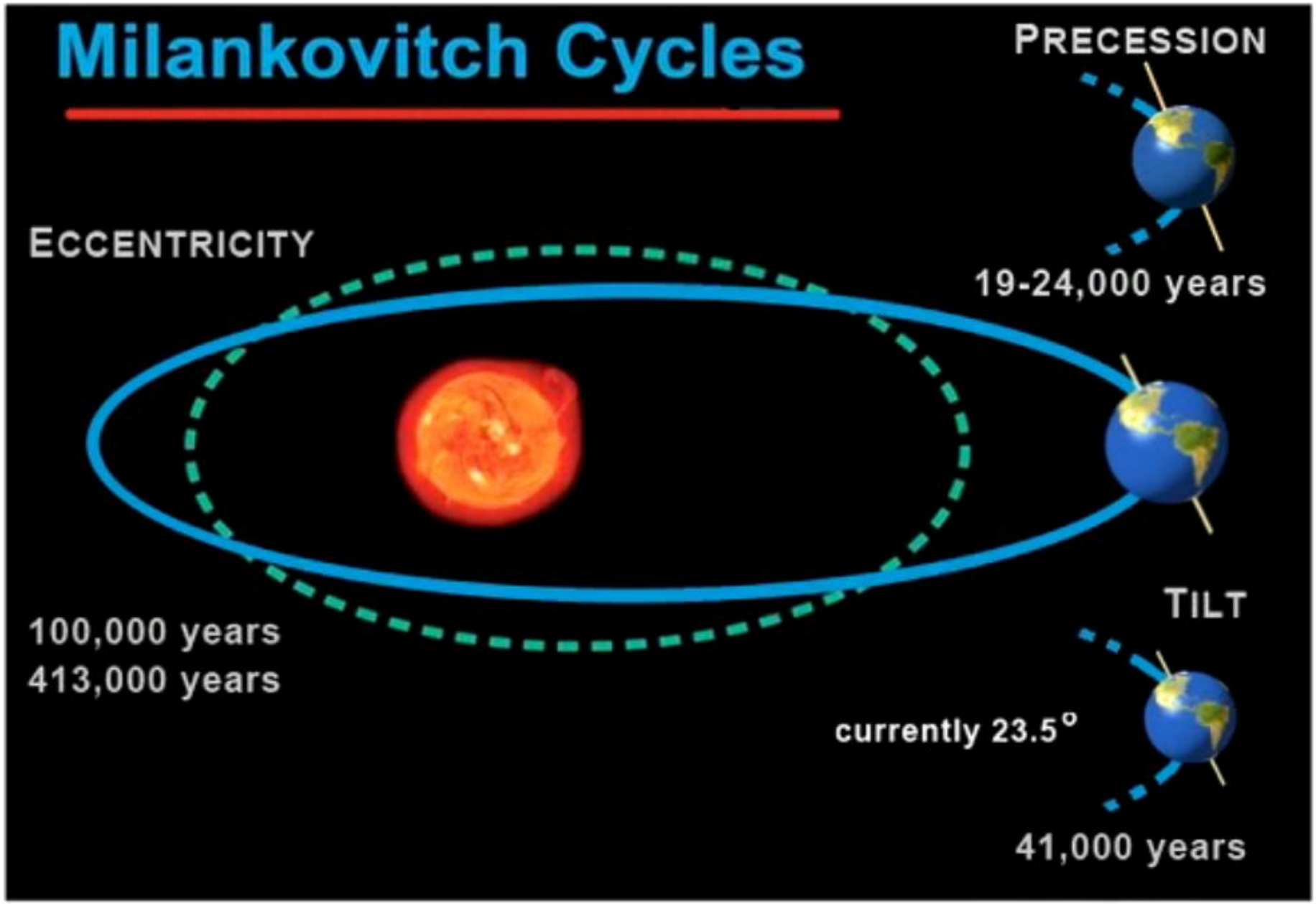


2. ECCENTRICITY OF ORBIT

Earth's orbit around sun is not symmetrical;
varies from elliptical => circular shape over time



Assignment I-2 Tutorial

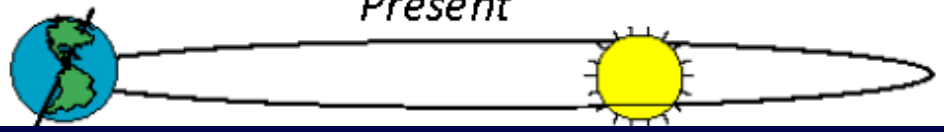


3. Timing of Seasons in Relation to Orbit:

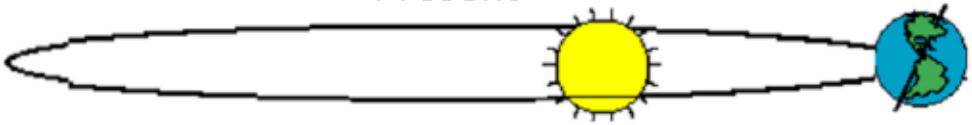
Clicker Q1 – Which diagrams represent **SUMMER** in the Southern Hemisphere?

1) A & B
2) C & D
3) B & C
4) A & D

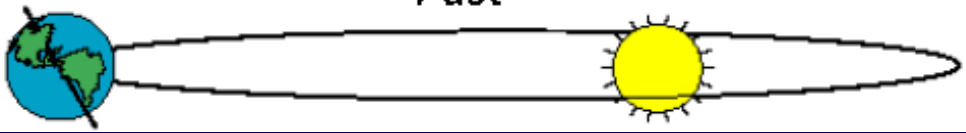
A



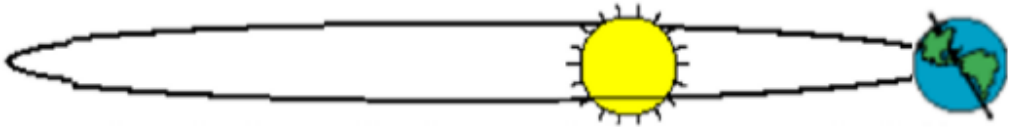
B



C



D



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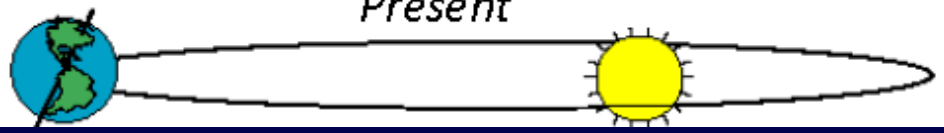
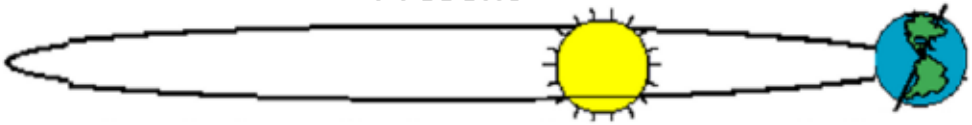
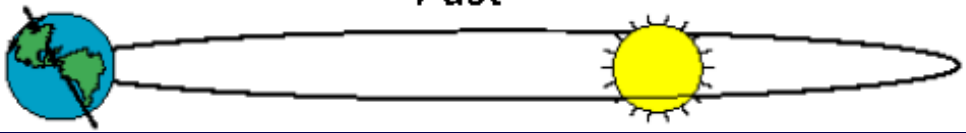
A



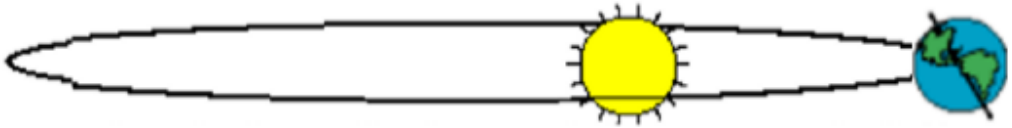
B



C



D

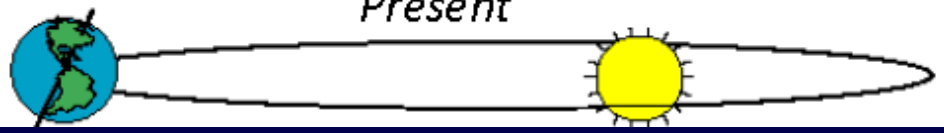


3. Timing of Seasons in Relation to Orbit:

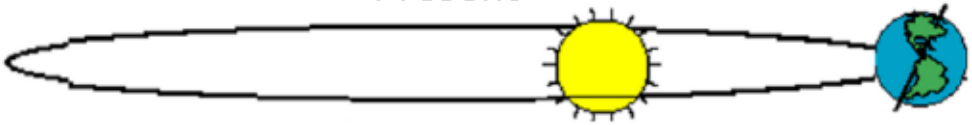
Clicker Q2 – Which diagram represents the time when the Northern Hemisphere receives the GREATEST amount of insolation?

A B C D

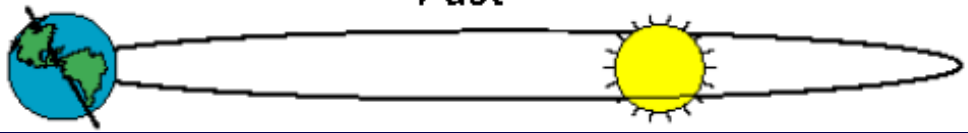
A



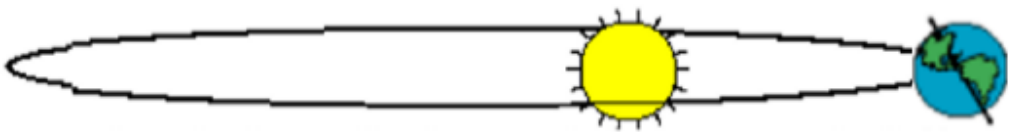
B



C



D

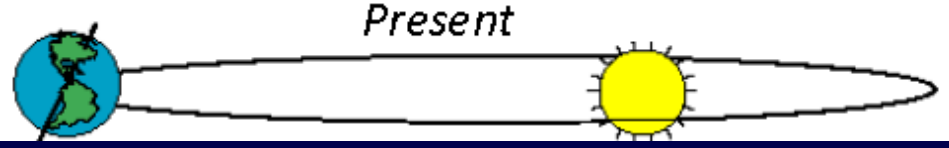


3. Timing of Seasons in Relation to Orbit:

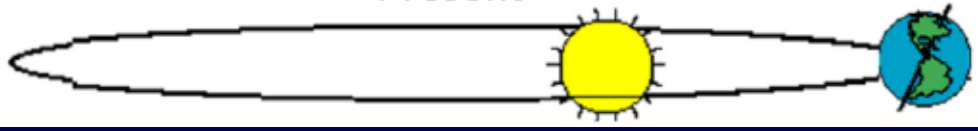
Clicker Q2 – Which diagram represents the time when the Northern Hemisphere receives the GREATEST amount of insolation?

A B C **D**

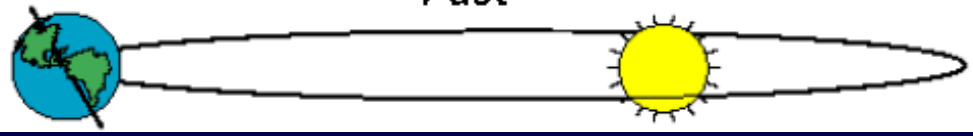
A



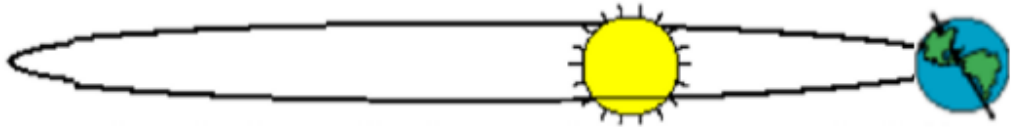
B



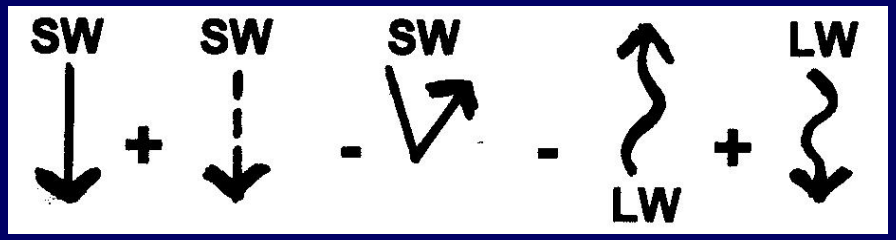
C



D

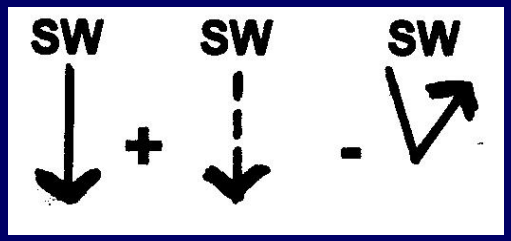


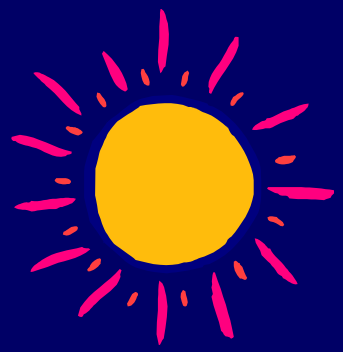
THE RADIATION BALANCE

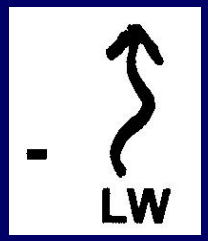


& THE GENERAL CIRCULATION OF THE ATMOSPHERE

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**

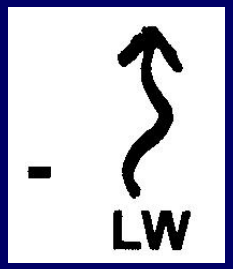
The amount of outgoing **TERRESTRIAL LW / IR** varies by latitude too --

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

HOWEVER . . .

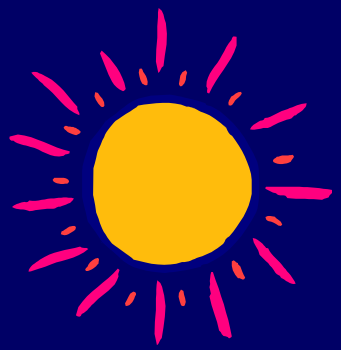
Box on p 65

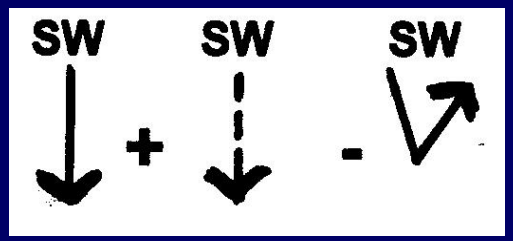
The EQUATOR-POLE DIFFERENCES of what goes OUT from the EARTH

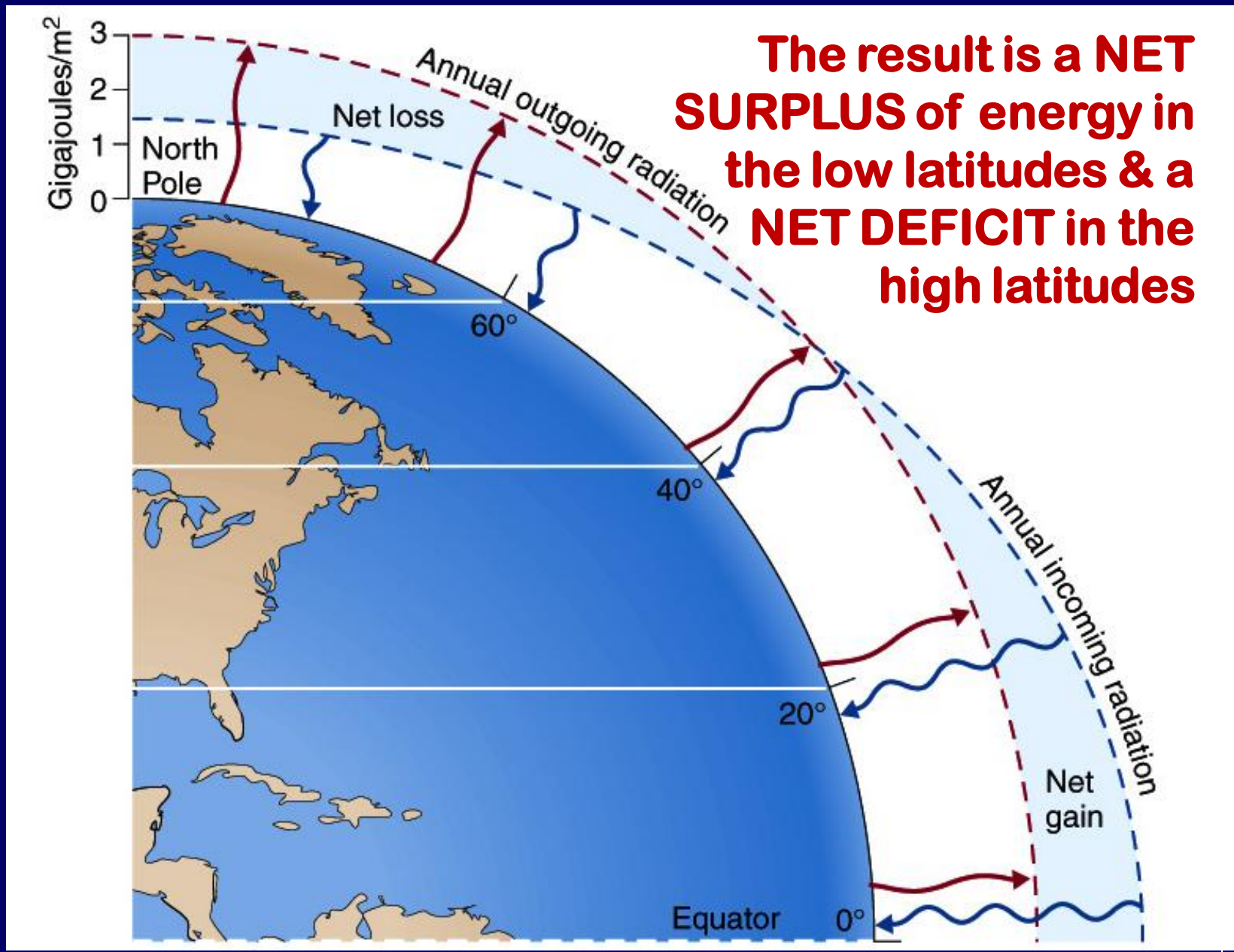


are less than the

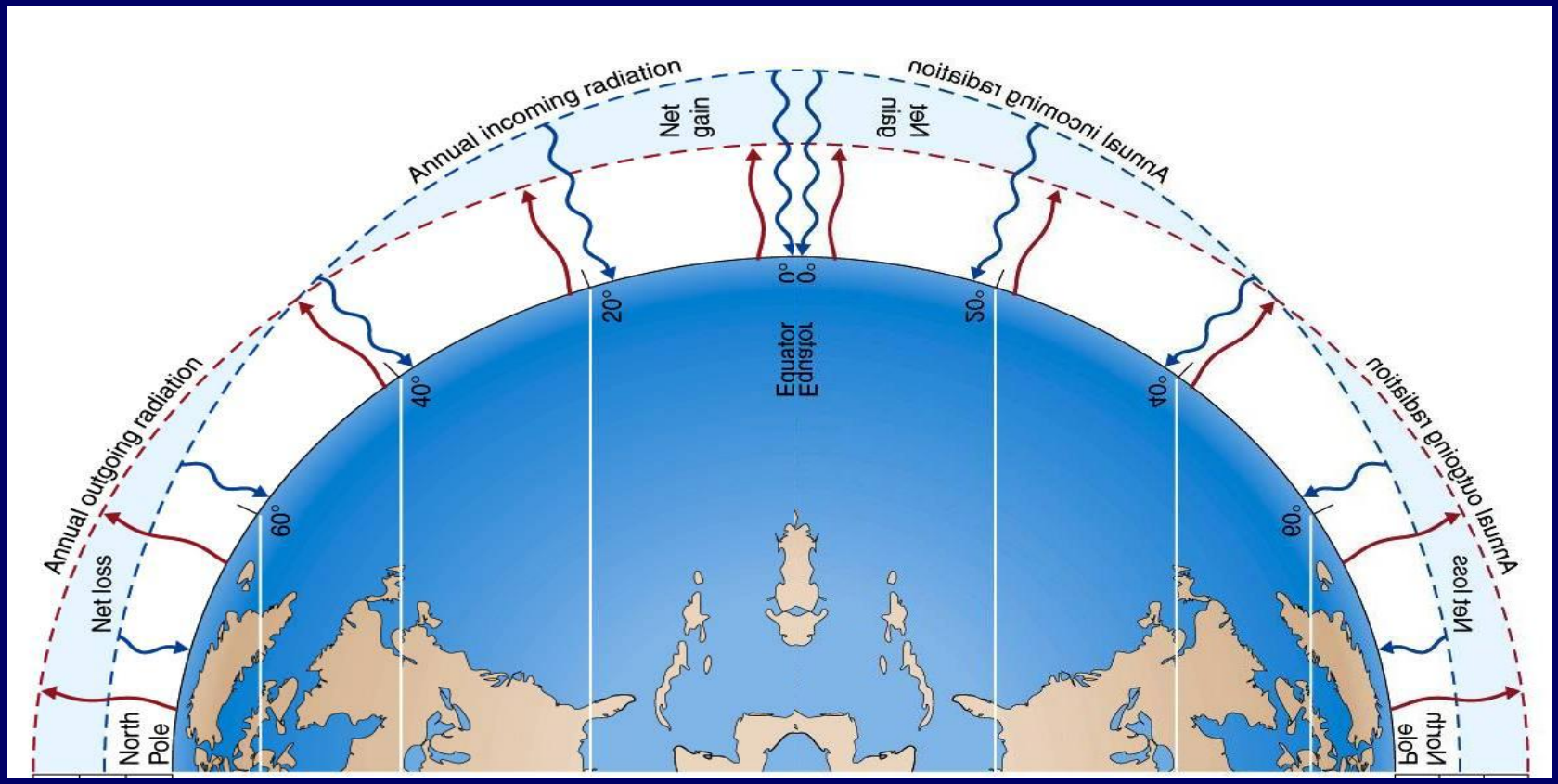
EQUATOR-POLE DIFFERENCES of what comes IN from the SUN





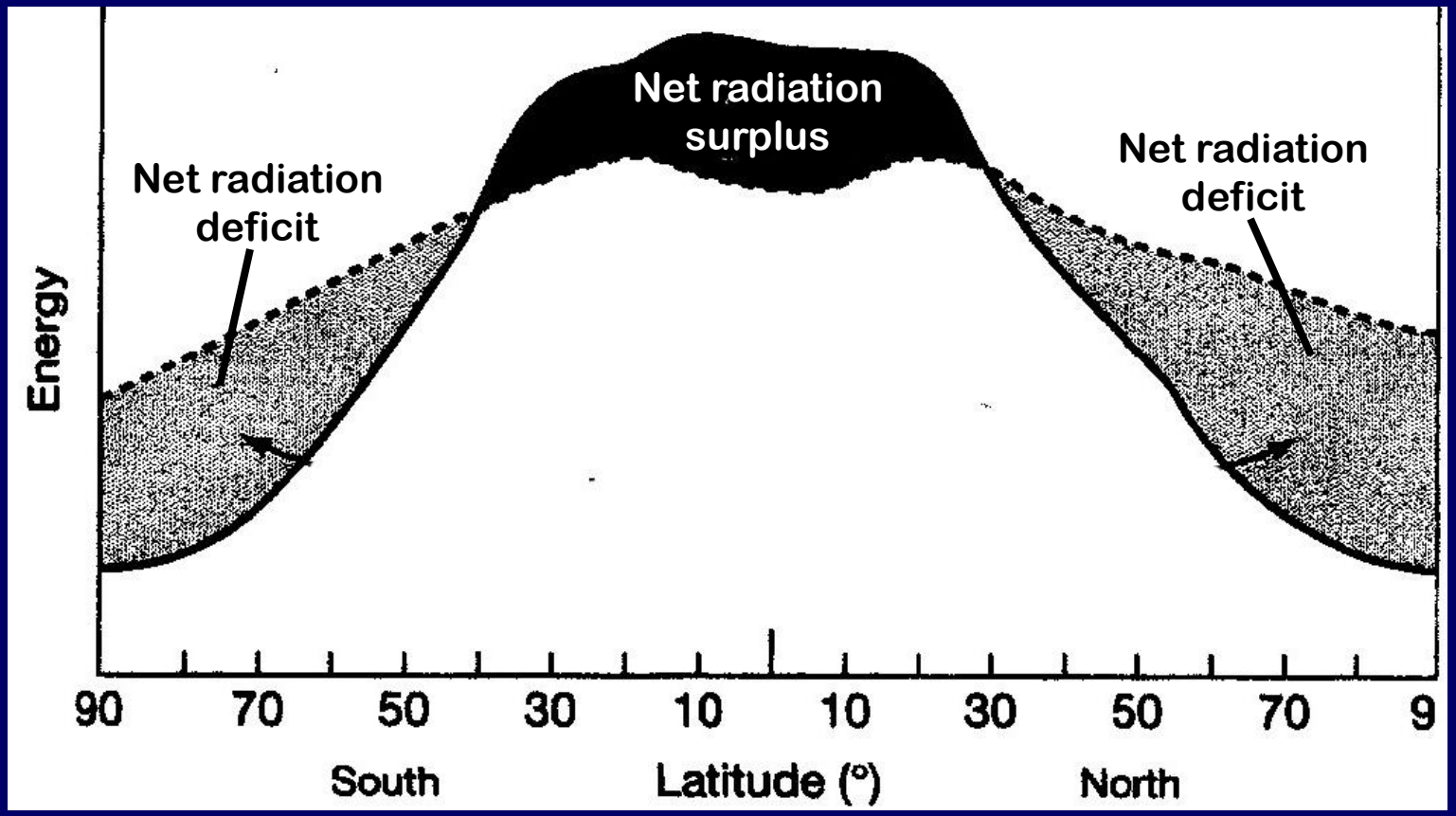


The result is a NET SURPLUS of energy in the low latitudes & a NET DEFICIT in the high latitudes



POLE **EQUATOR** **POLE**

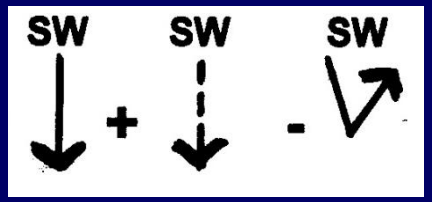
Now lets look at a Pole to Pole Transect



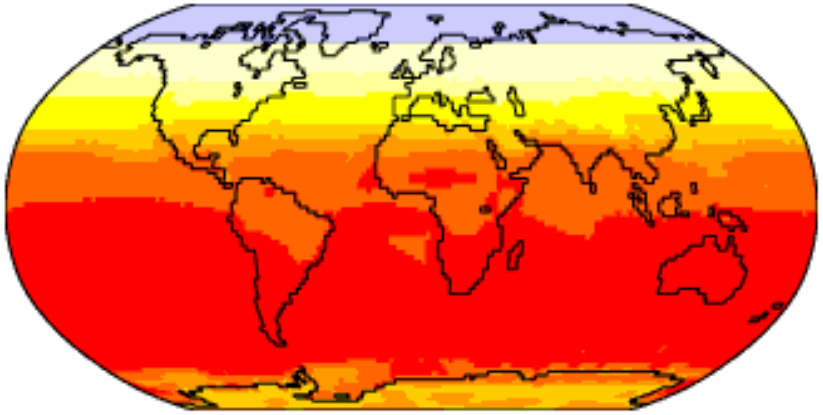
Absorbed solar energy

Emitted infrared energy

(at top of atmosphere)



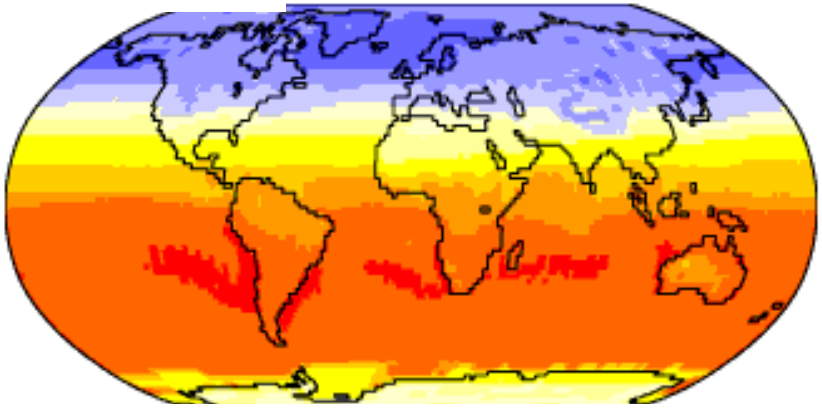
Short-Wave Radiation



Dec

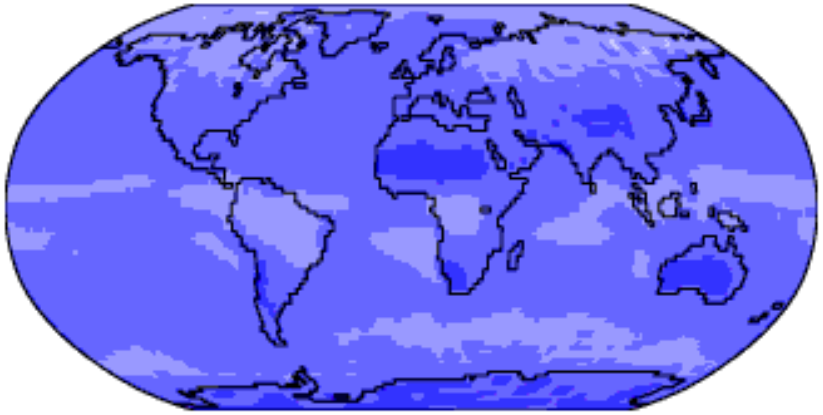
Absorbed solar energy

SW + SW - SW



Net Radiation R_{NET}

Long-Wave Radiation



- LW

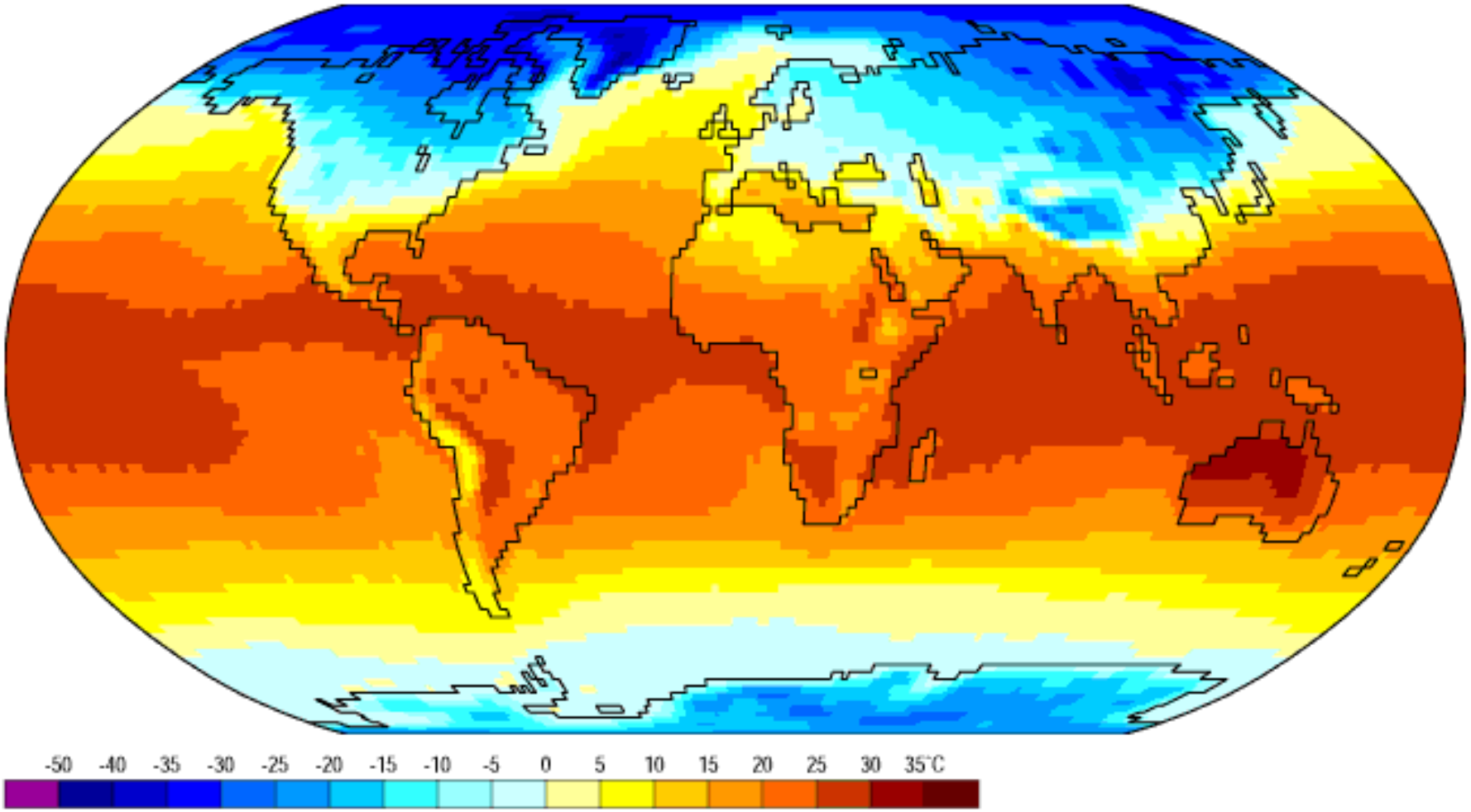
Emitted infrared energy

-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

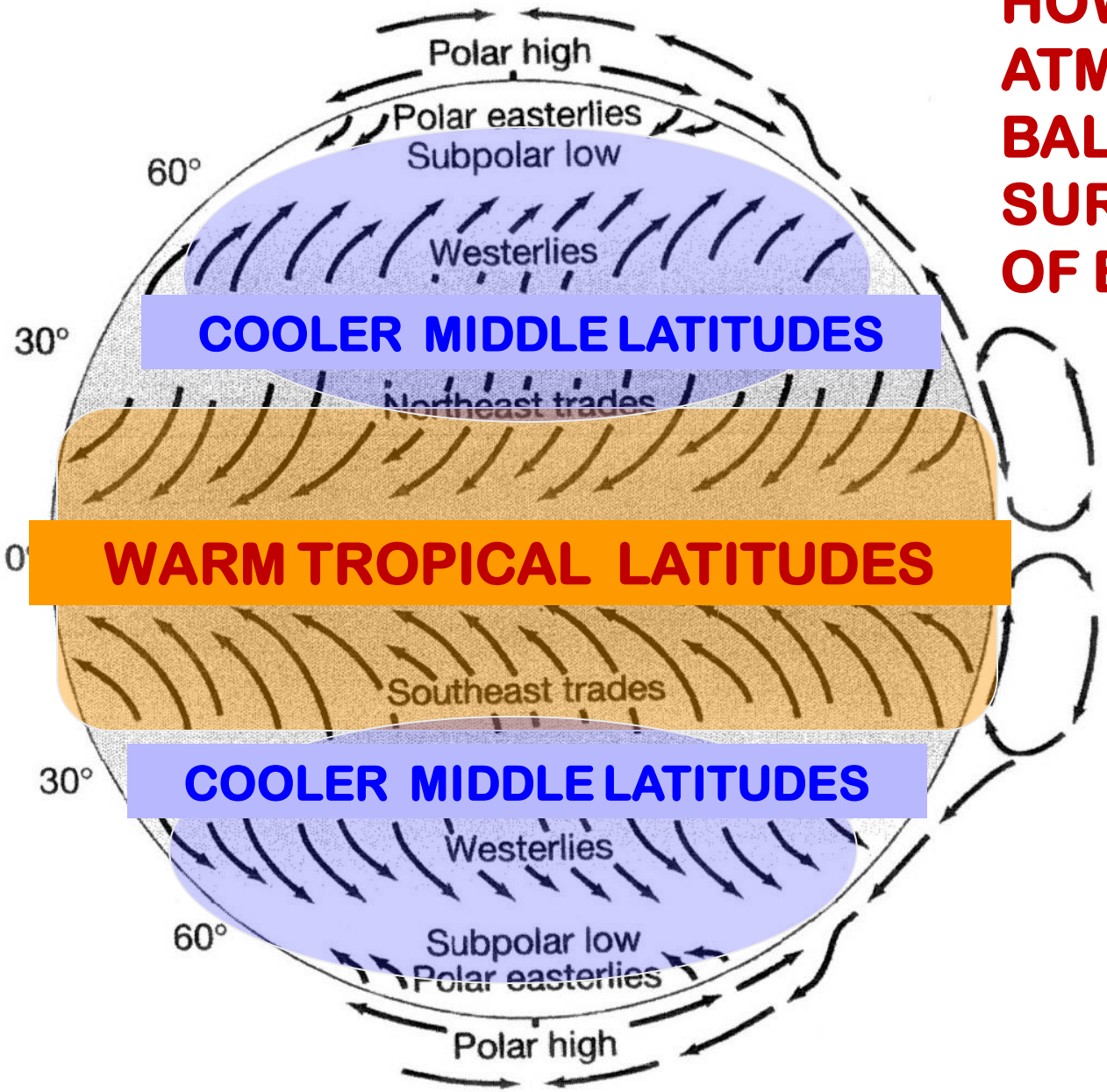
http://geography.uoregon.edu/envchange/clim_animations/

Surface Air Temperature



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

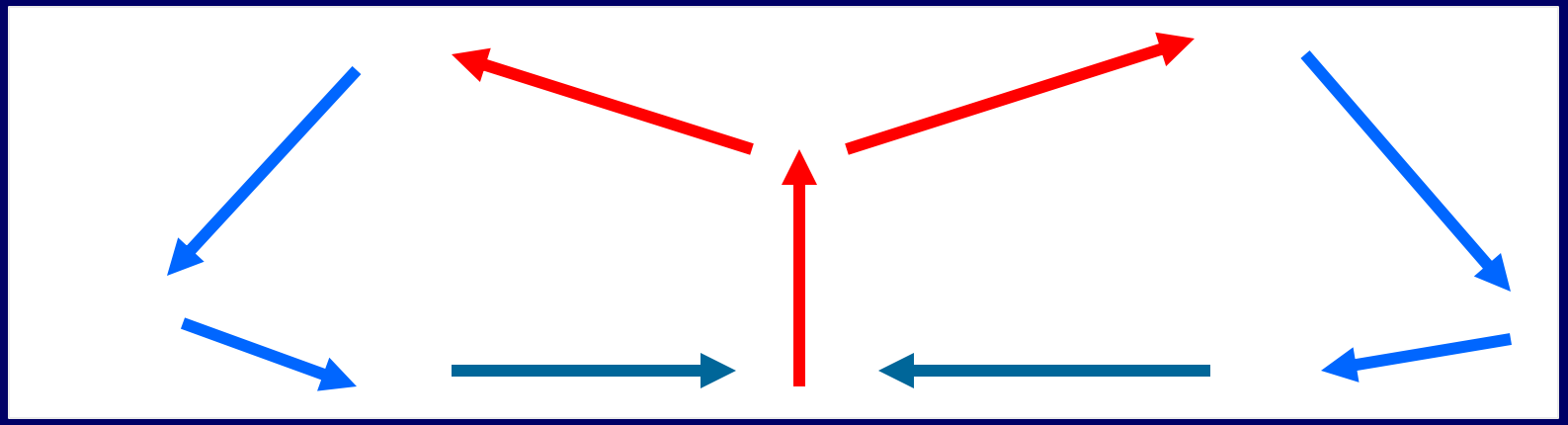
HOW DOES THE ATMOSPHERE BALANCE OUT THE SURPLUS & DEFICIT OF ENERGY??



Energy Transfer via Convection Cells

Figure from SGC E-text Chapter 4

GIANT CONVECTION CELLS
driven by thermal differences:



90 60 30 0 30 60 90

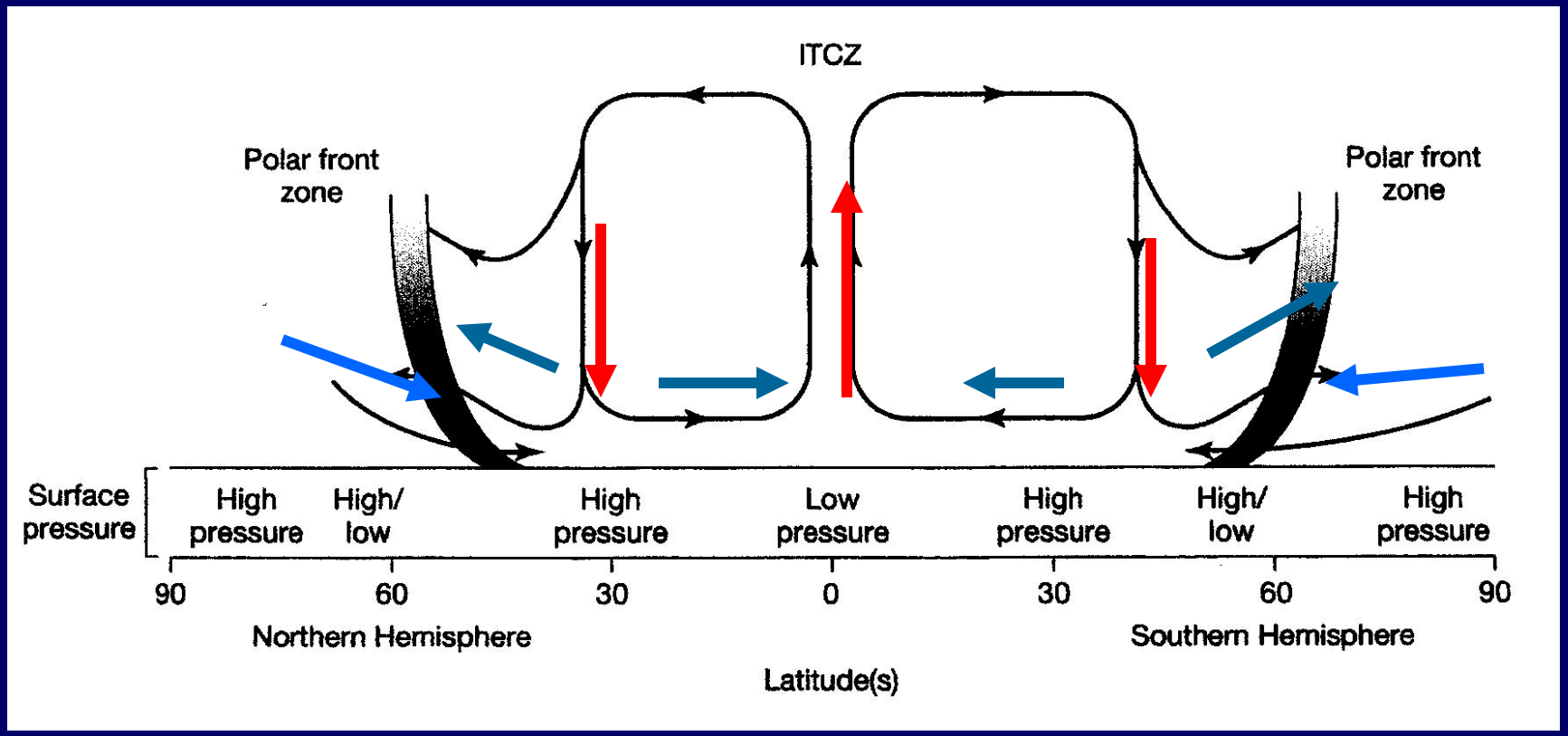
Northern Hemisphere EQUATOR Southern Hemisphere

COLD POLAR REGIONS

HOT TROPICS

COLD POLAR REGIONS

"HADLEY CELL"
← TRANSPORT →



COLD POLAR REGIONS

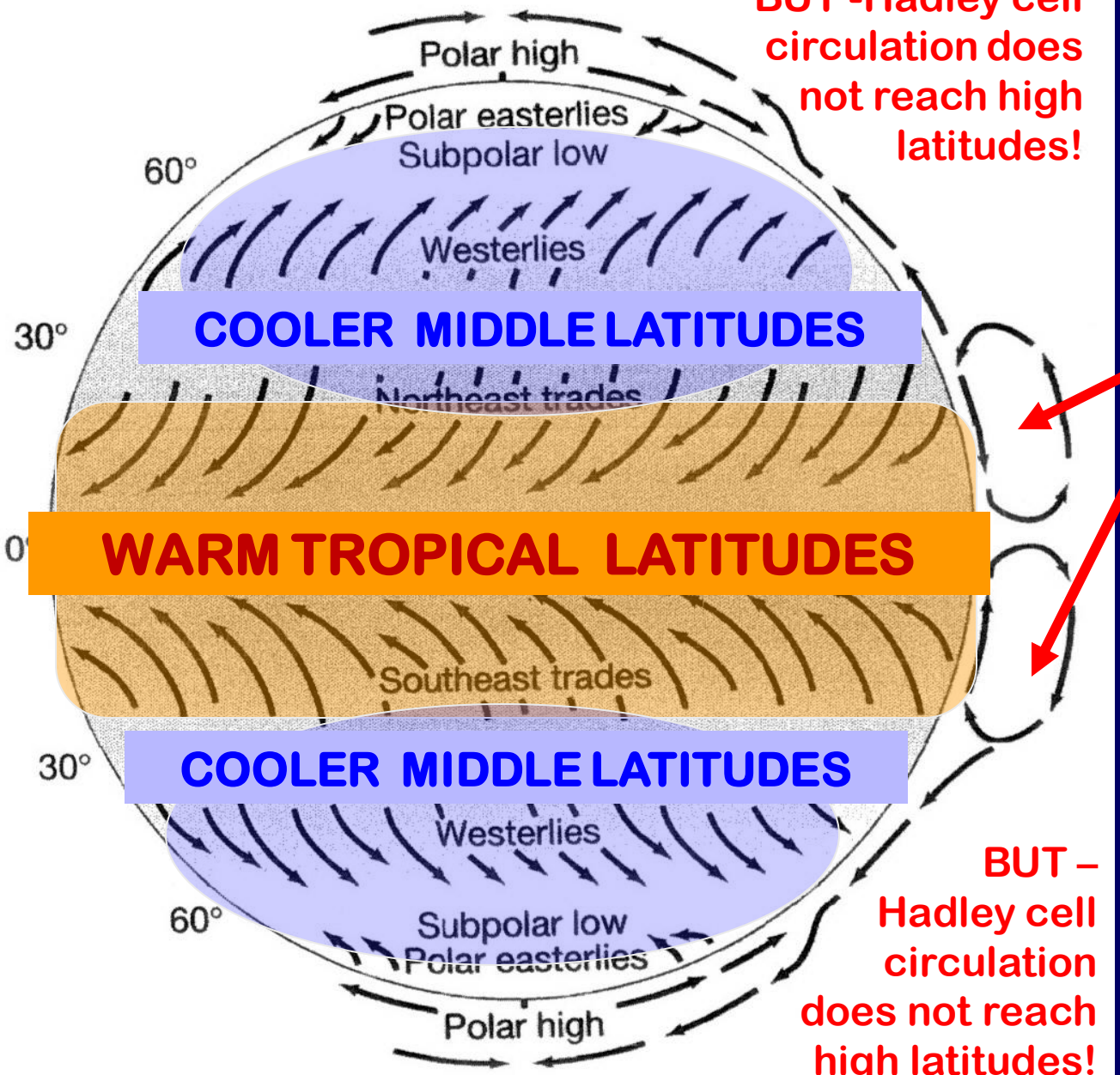
HOT TROPICS

COLD POLAR REGIONS

"HADLEY CELL"

← TRANSPORT →

From SGC Chapter 4



BUT -Hadley cell circulation does not reach high latitudes!

BUT – Hadley cell circulation does not reach high latitudes!

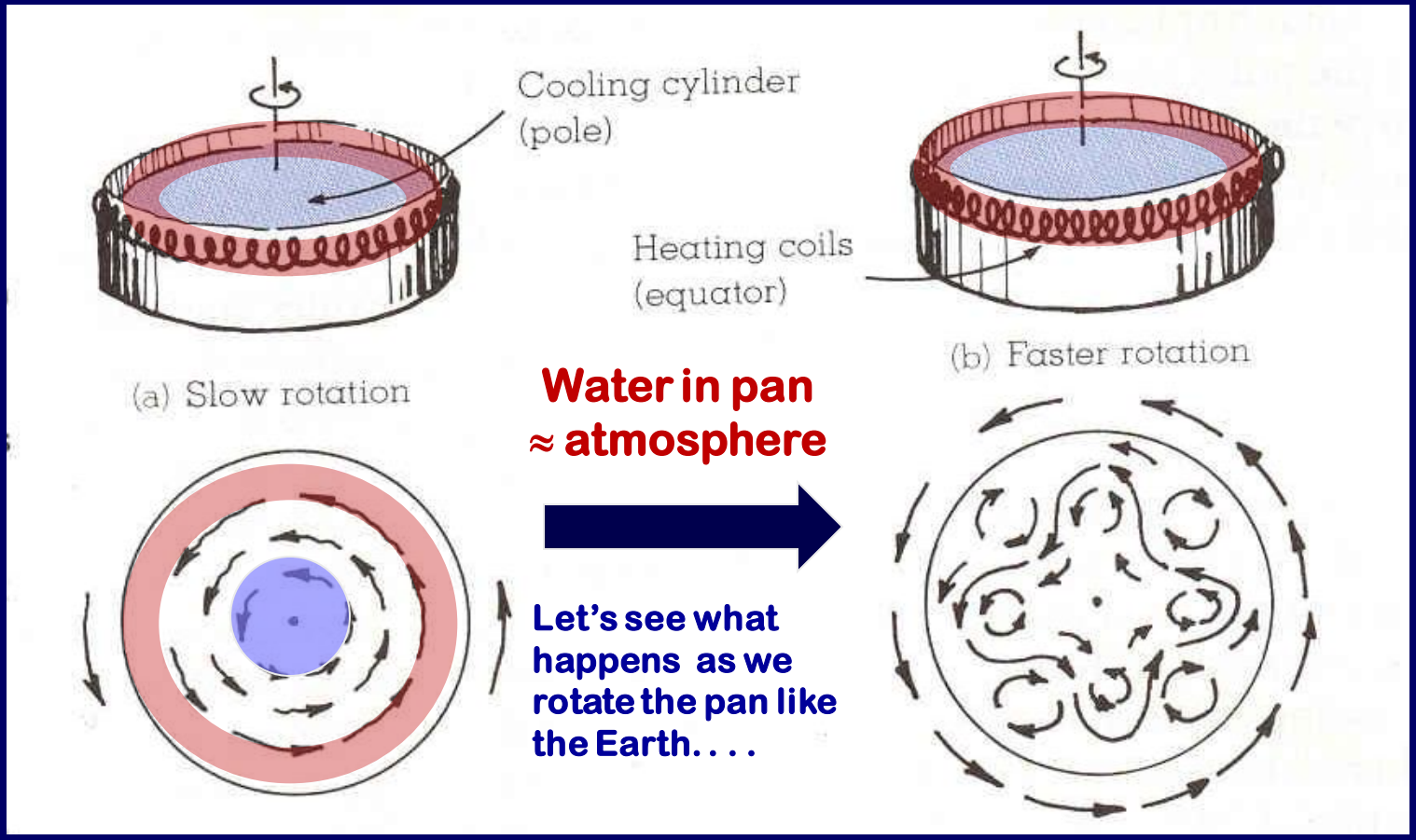
Hadley Cells transport warm air poleward as SENSIBLE HEAT

HADLEY CELLS = key drivers!

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

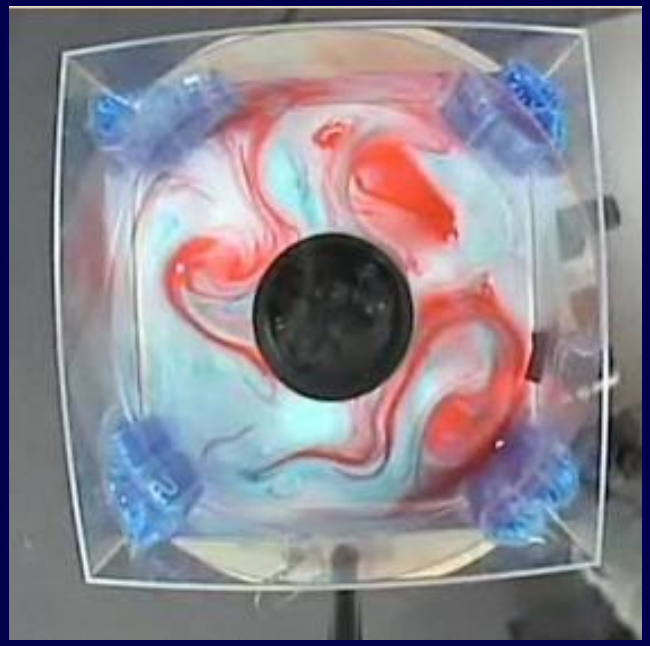
ENERGY TRANSFER BY CONVECTION

Another way energy gets transported from the hot surplus areas to the cold deficit areas:



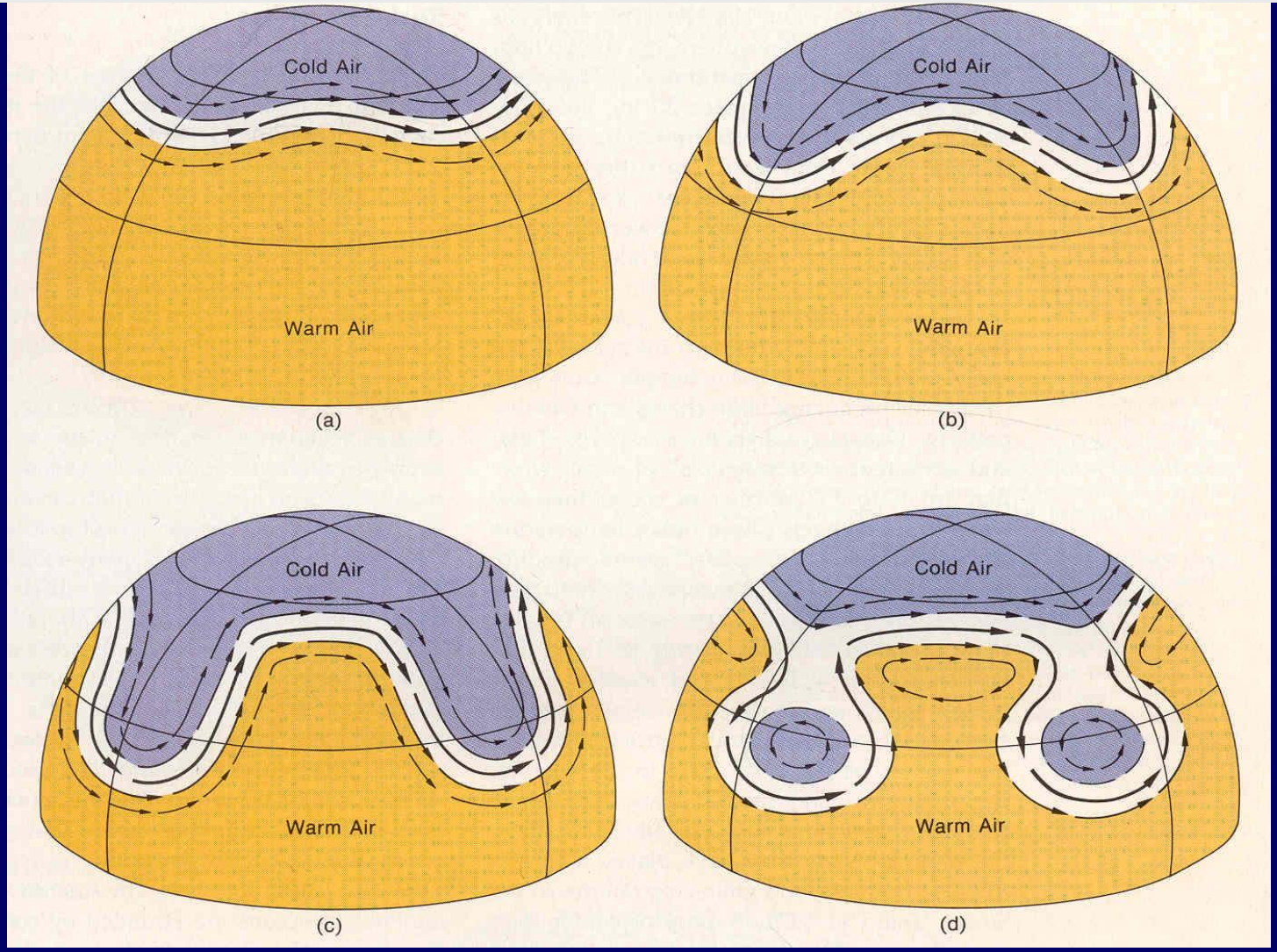
Demo of a simple "dishpan" model of atmospheric circulation

A DEMONSTRATION OF THE DISHPAN



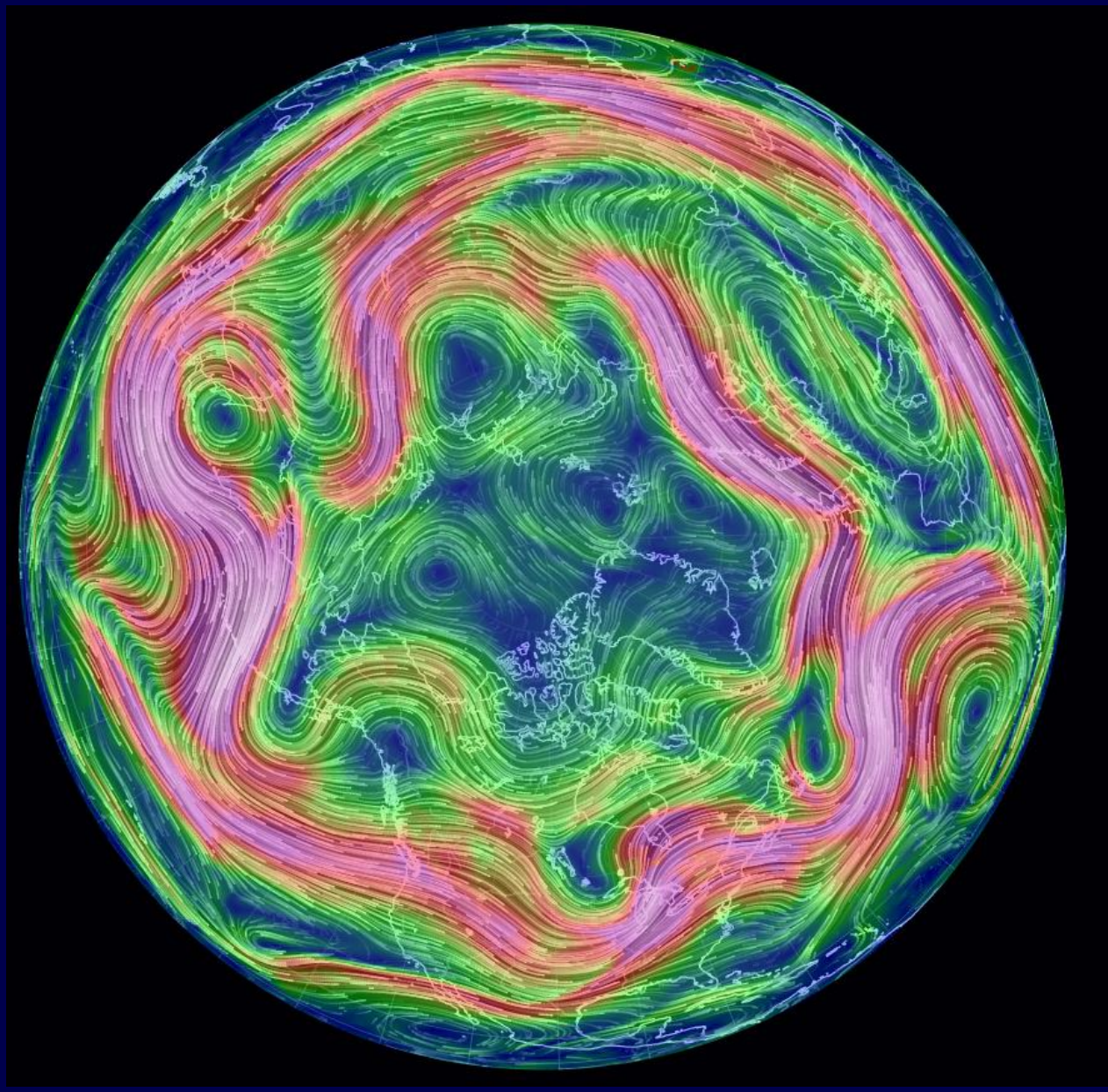
http://www.windows2universe.org/earth/Atmosphere/global_circulation_lsop_video.html

UPPER LEVEL "ROSSBY WAVE" CIRCUMPOLAR WINDS !



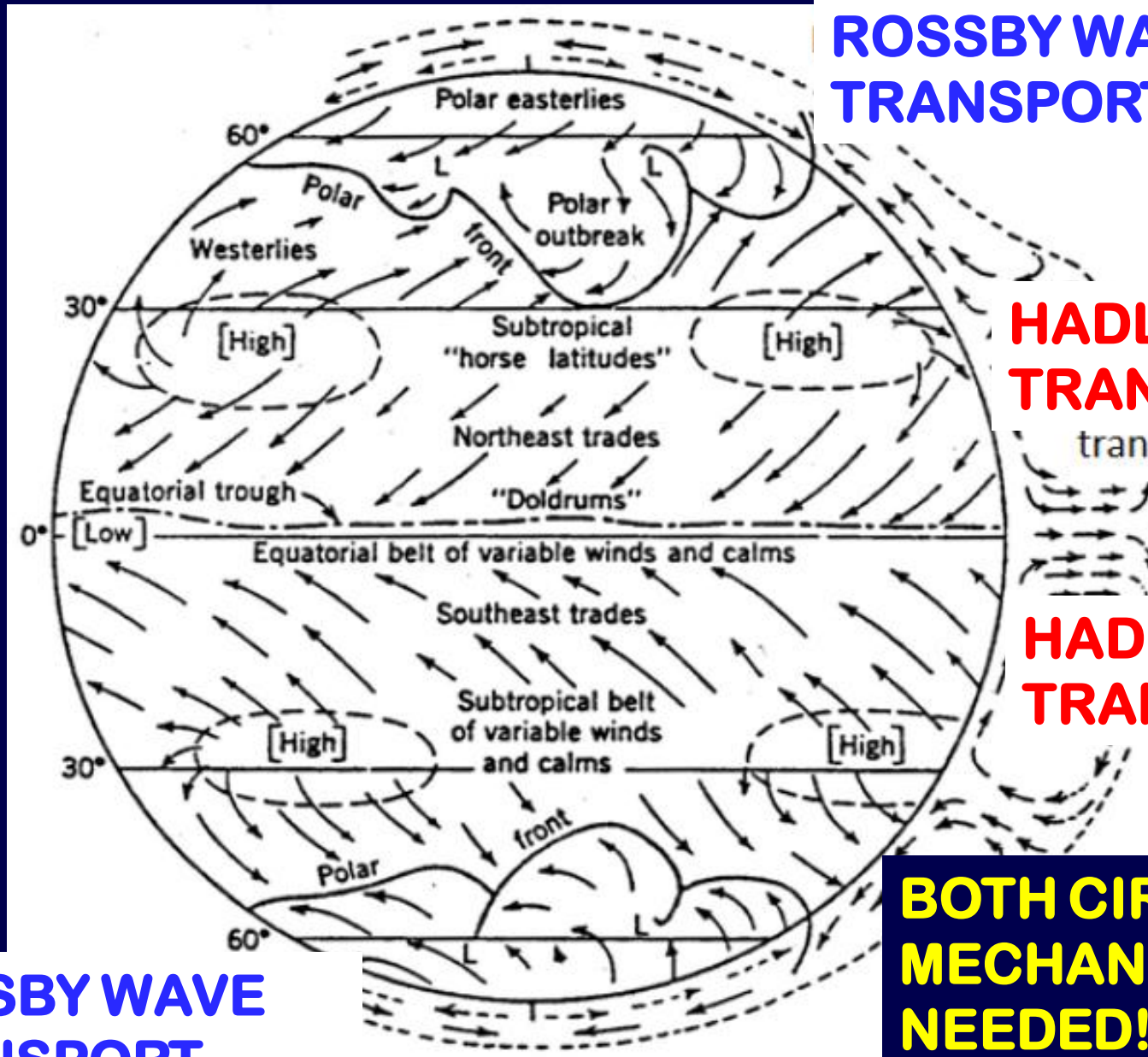
"Wave" transport of Energy as SENSIBLE HEAT (in lobes of warm air)!

WHAT'S HAPPENING TODAY?



http://earth.nullschool.net/#current/wind/

The "GENERAL CIRCULATION OF THE ATMOSPHERE"



ROSSBY WAVE TRANSPORT

HADLEY CELL TRANSPORT

transport

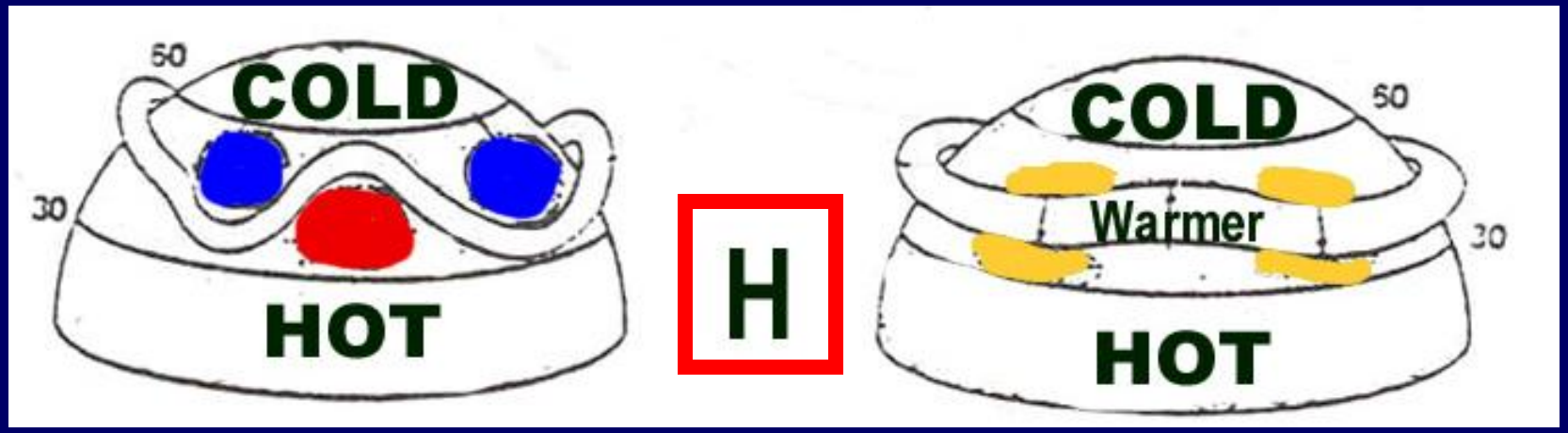
HADLEY CELL TRANSPORT

BOTH CIRCULATION MECHANISMS ARE NEEDED!

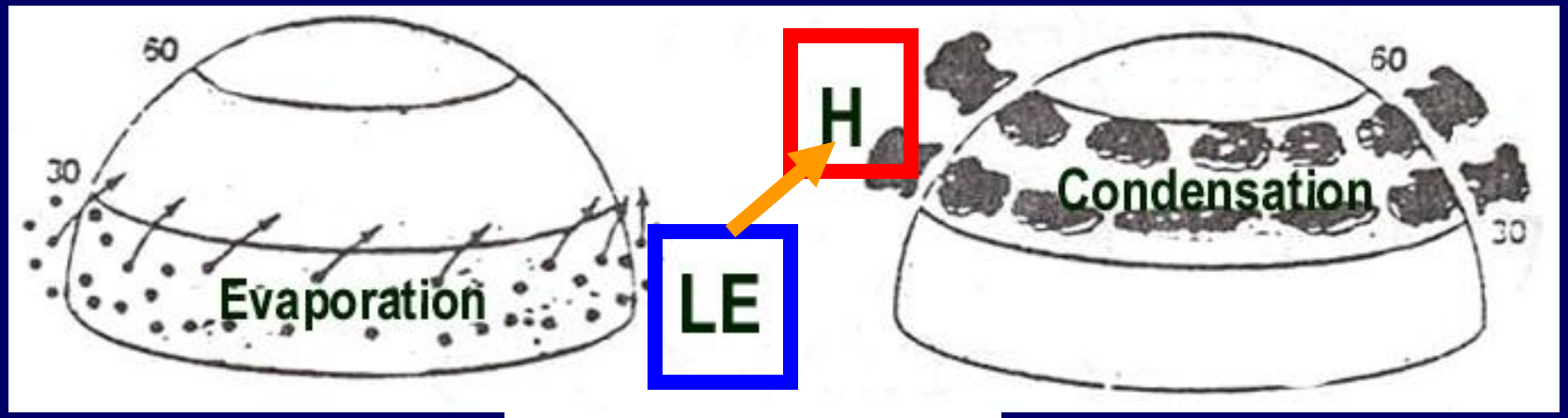
ROSSBY WAVE TRANSPORT

ENERGY is transported from areas of surplus to deficit via

Warm Air transport : H (sensible heat)



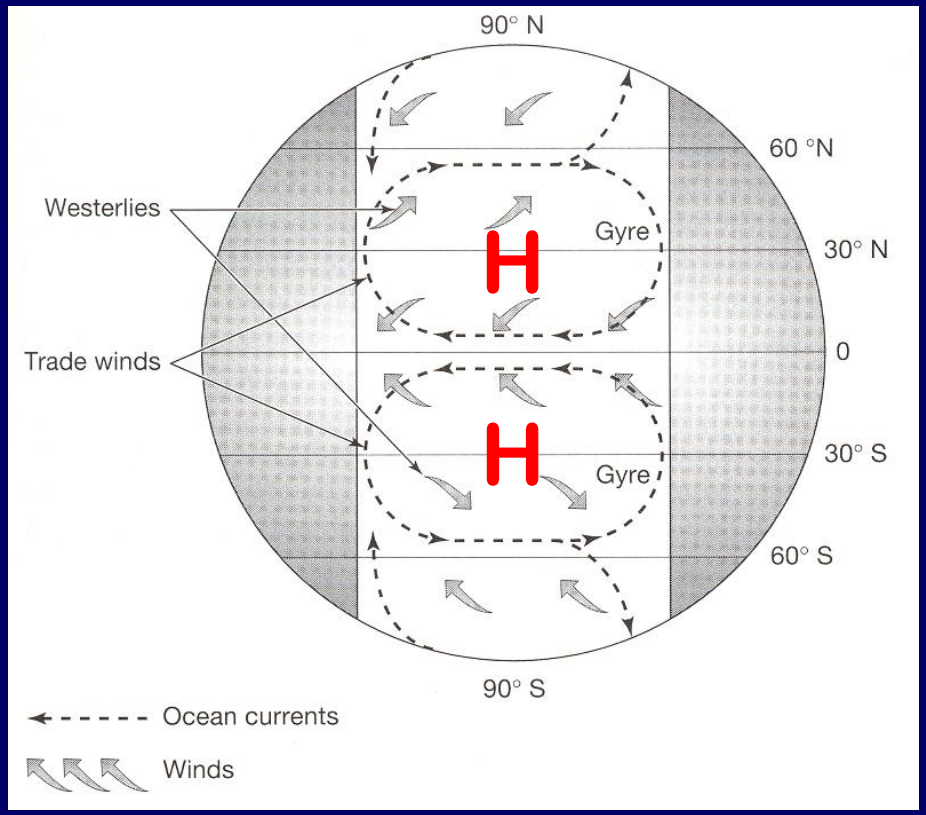
& LE (Latent Energy) transport



H + LE

WHAT ABOUT OCEAN CIRCULATION?

➔ Large OCEAN GYRES are driven by Trade Winds & Westerly Winds in Oceanic Subtropical High Pressure Cells

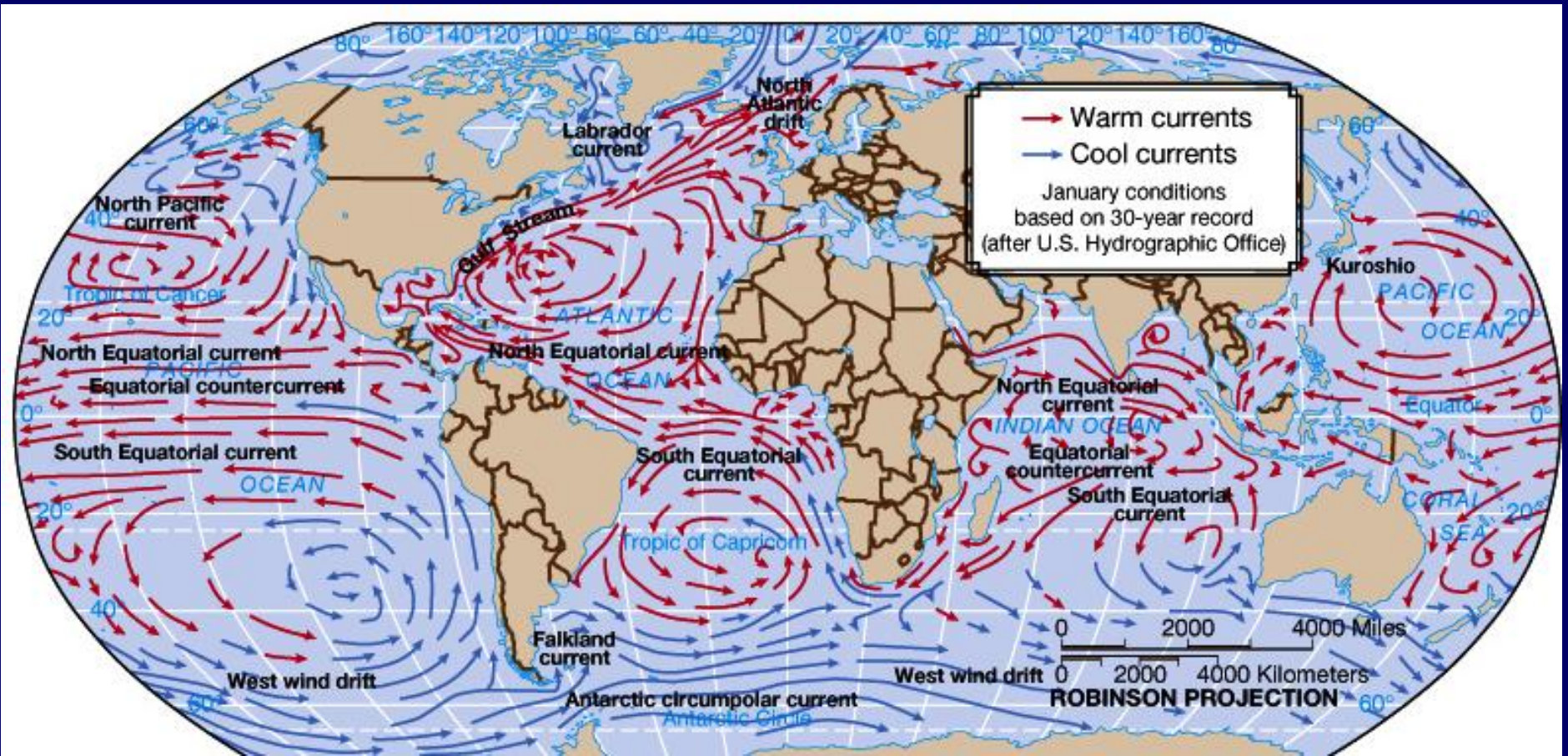


Leads to <u>SURFACE</u> ocean currents

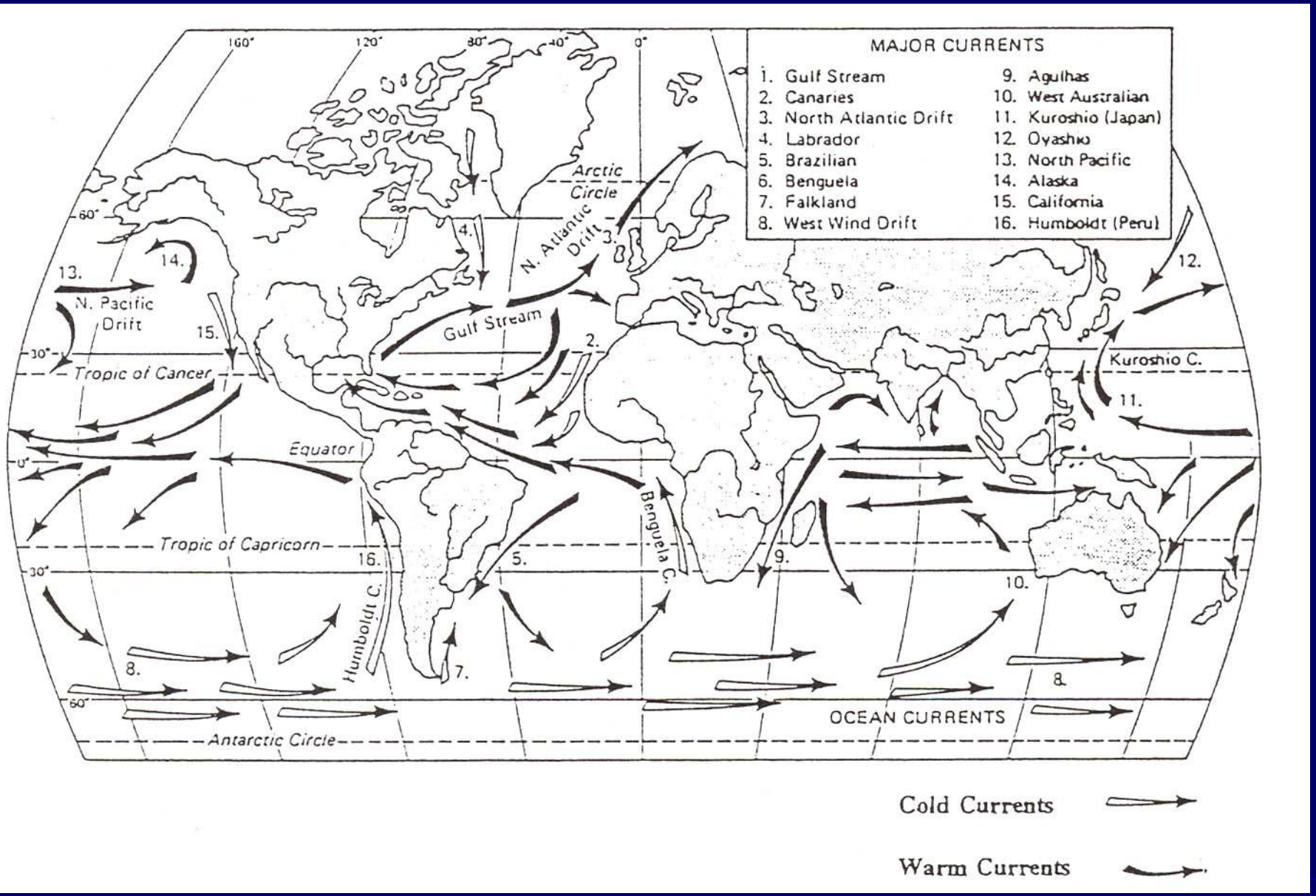
ENERGY TRANSFER IN THE OCEAN

H + LE + G

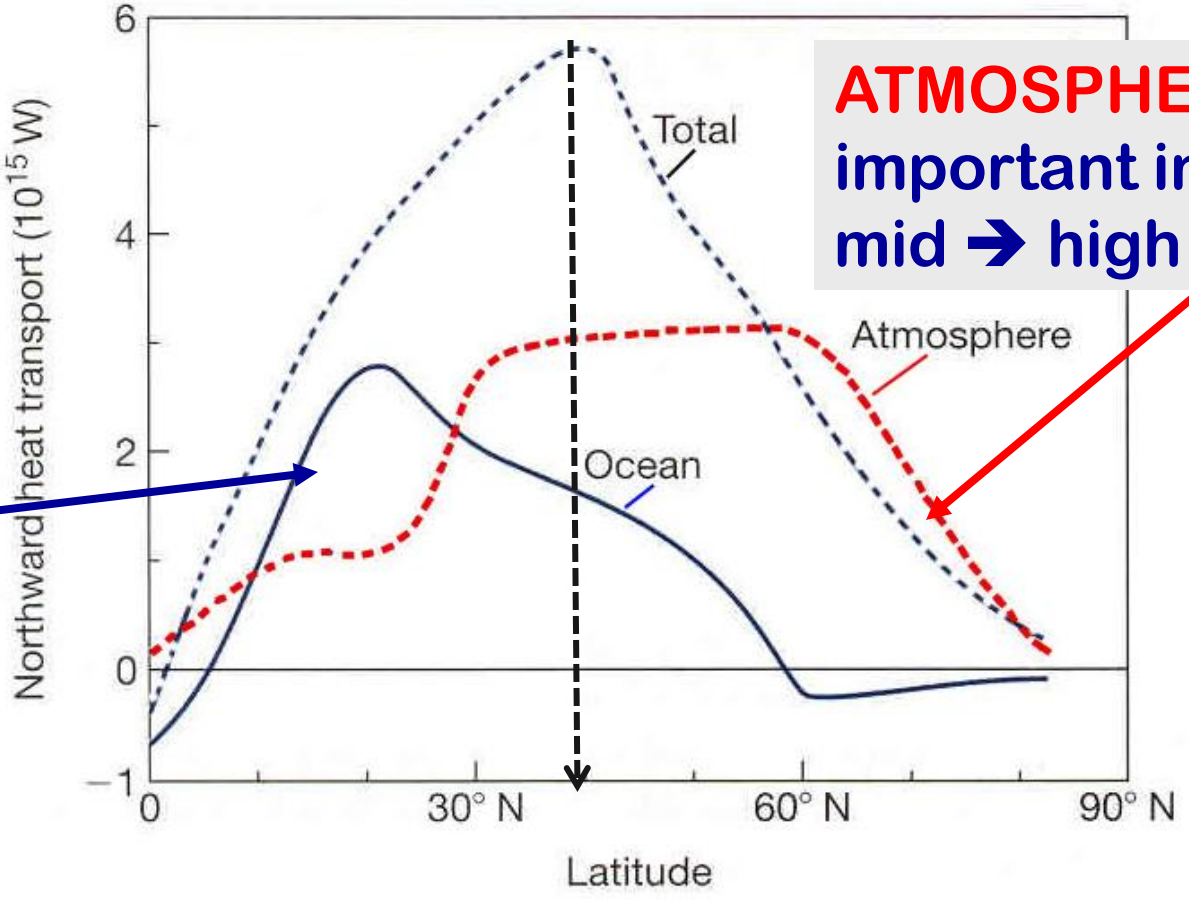
Energy stored in the OCEAN (as **G**) , can later be transported via ocean currents as **H** !



WARM & COLD SURFACE OCEAN CURRENTS:



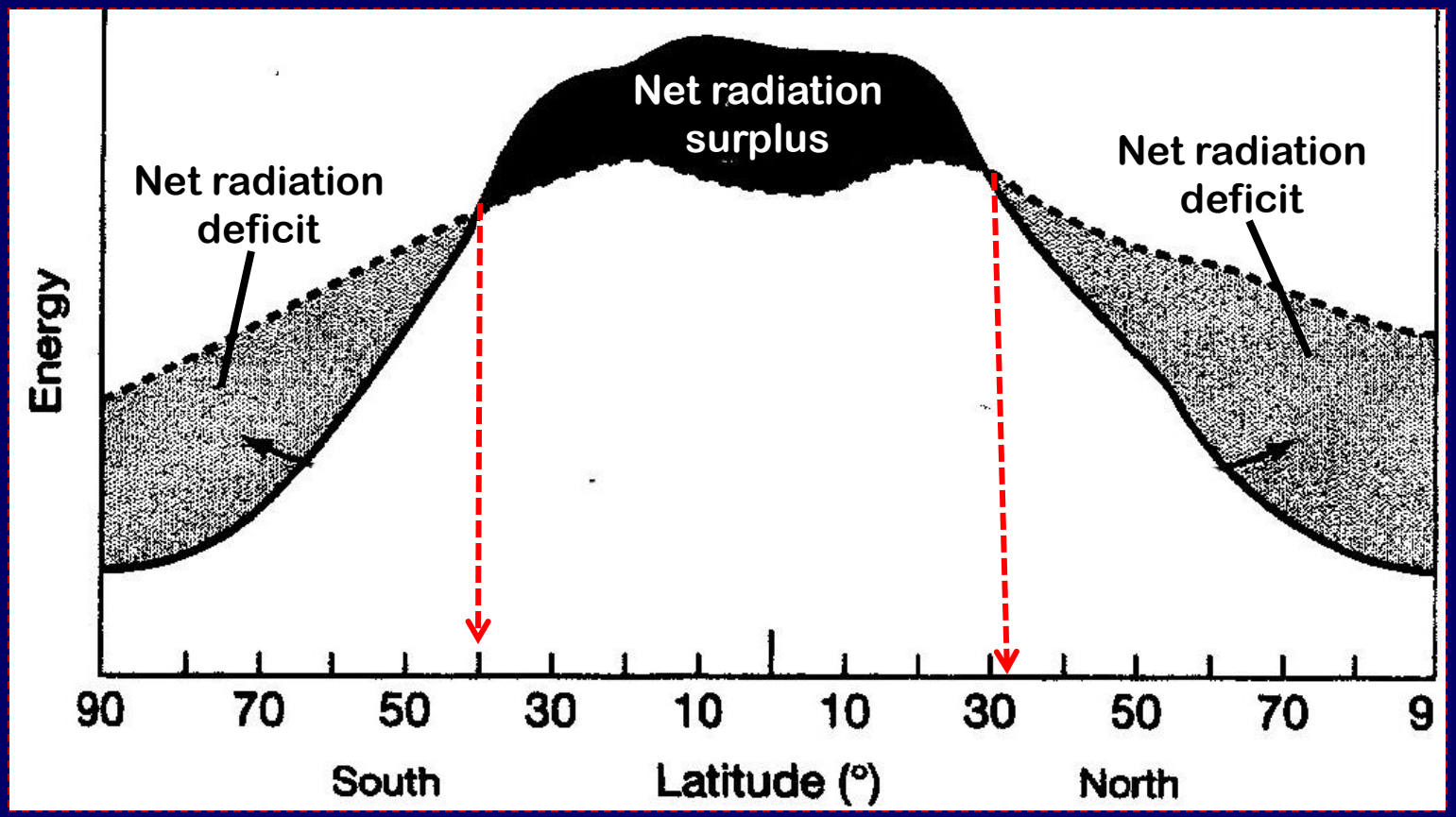
Both ATMOSPHERE & OCEAN play important roles in BALANCING OUT ENERGY SURPLUS & DEFICIT AREAS:



ATMOSPHERE more important in mid ➔ high latitudes

OCEAN transports MOST of the energy in LOW ➔ subtropical latitudes

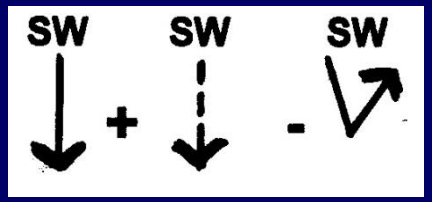
Poleward transport of energy in N.H.



Absorbed solar energy

Emitted infrared energy

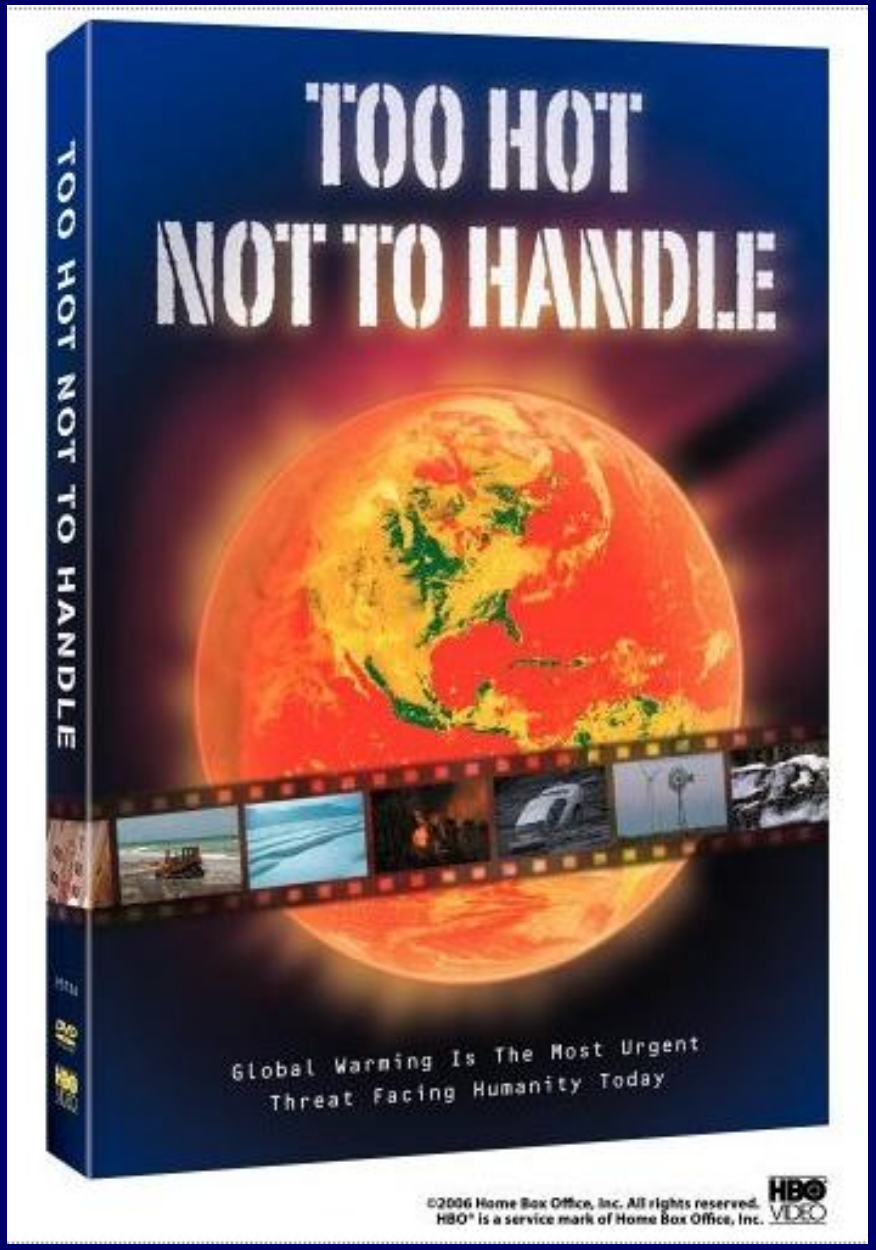
(at top of atmosphere)



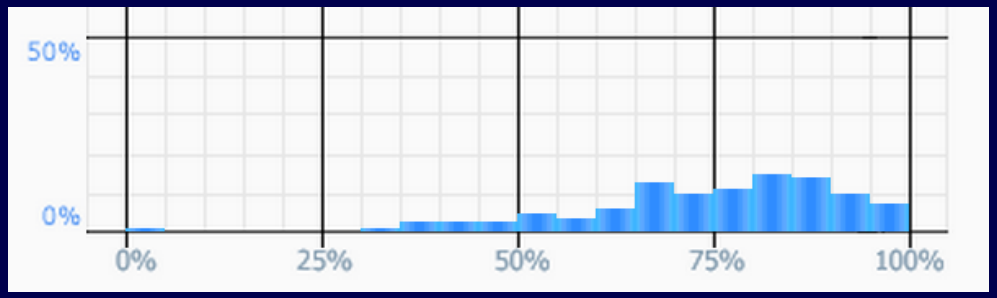
recap

INTRODUCING . . .

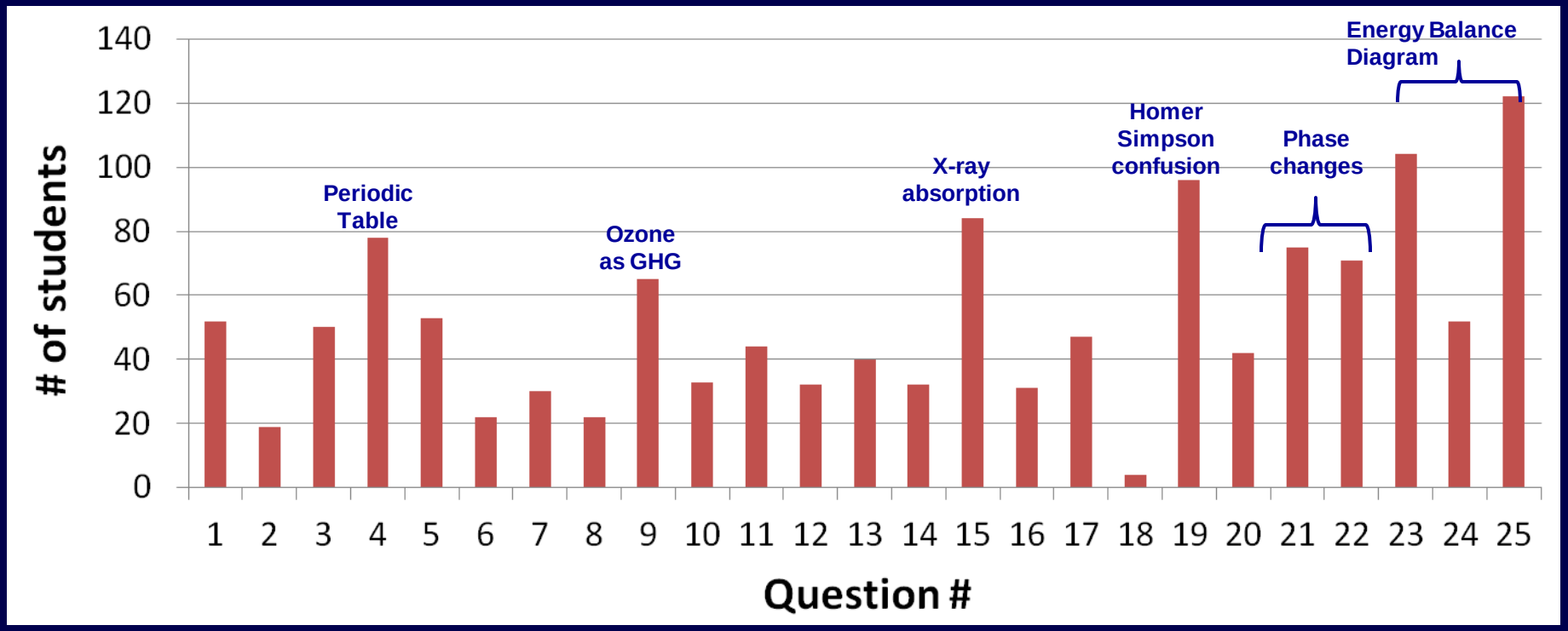
OUR NEW FILM!!!



EXAM COMMENTS



Mode: 81.5 %
Median: 77.8 %
Standard Deviation: 15.6 %



# of students who missed Q's #1 = #25 on the first try

GET YOUR EXAMS
– ORGANIZED BY GROUPS

SEE YOU THURSDAY

When I'll give you a
Midterm Recovery Point Opportunity!