Thursday Oct 30th

SIT ANYWHERE TODAY – Topic #10 Wrap-Up and

Topic # 11 Natural Climatic Forcing

PLUS: A short intro to TREE RINGS for your next "hands on" activity

ANNOUNCEMENTS

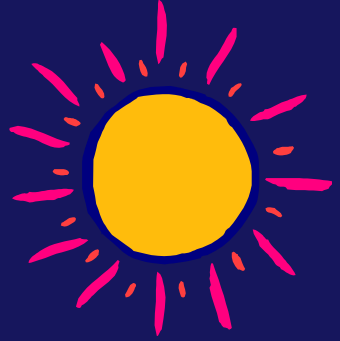
- TEST #3 is TUESDAY Nov 4th The "Top Ten" study guide will be posted TONIGHT & a Study Session will be held Monday Nov 3rd 4:30 – 5:30 pm

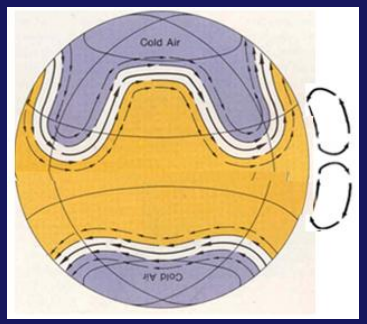
- I-2 LESSON 2 on "Mother Nature's Influence" DUE in the dropbox before midnight TONIGHT

- A Midterm Exam "Point Recovery" opportunity will be Posted in CLASS FOLLOW UP tonight

TOPIC #10 (cont.)

"HOW CLIMATE WORKS"
&
GLOBAL CLIMATE PATTERNS





SW + SW - SW - LW + LW = R_{NET} = H + LE + G

Ultimate source of energy is the SUN (SW)

LW energy is radiated in & out by EARTH & Atmosphere

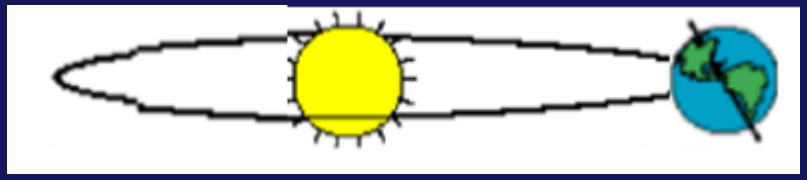
Any NET (leftover) energy

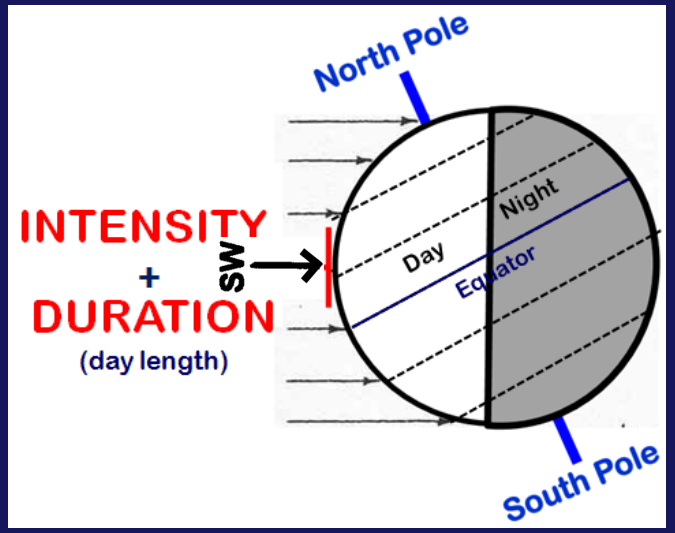
Goes into the HEAT TRANSFER processes that drive **WEATHER & CLIMATE !**

Review

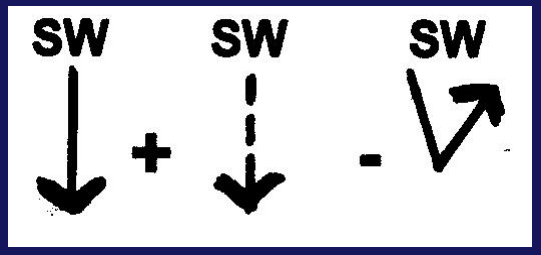
Review

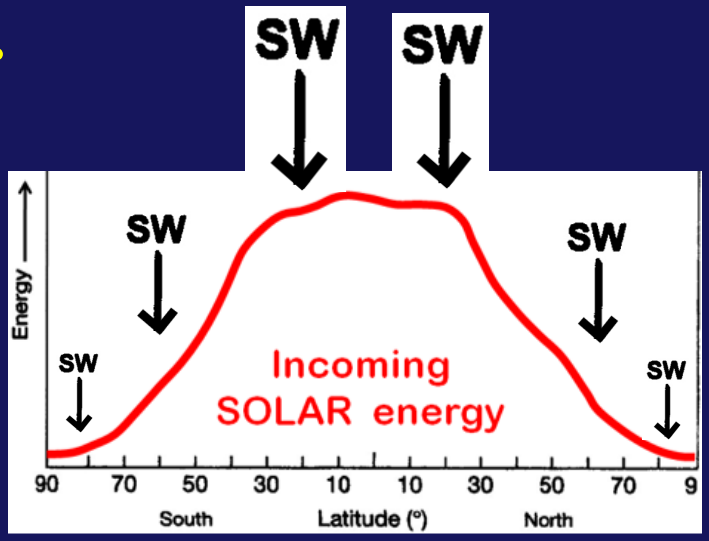
Earth-Sun Relationships (Astronomical Forcing):





This determines the **LATITUDAL & SEASONAL DIFFERENCES** of what comes **IN** from the SUN and is **absorbed** . . .

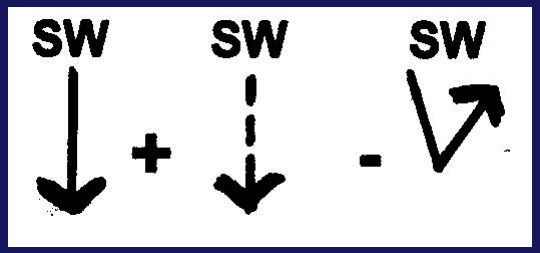


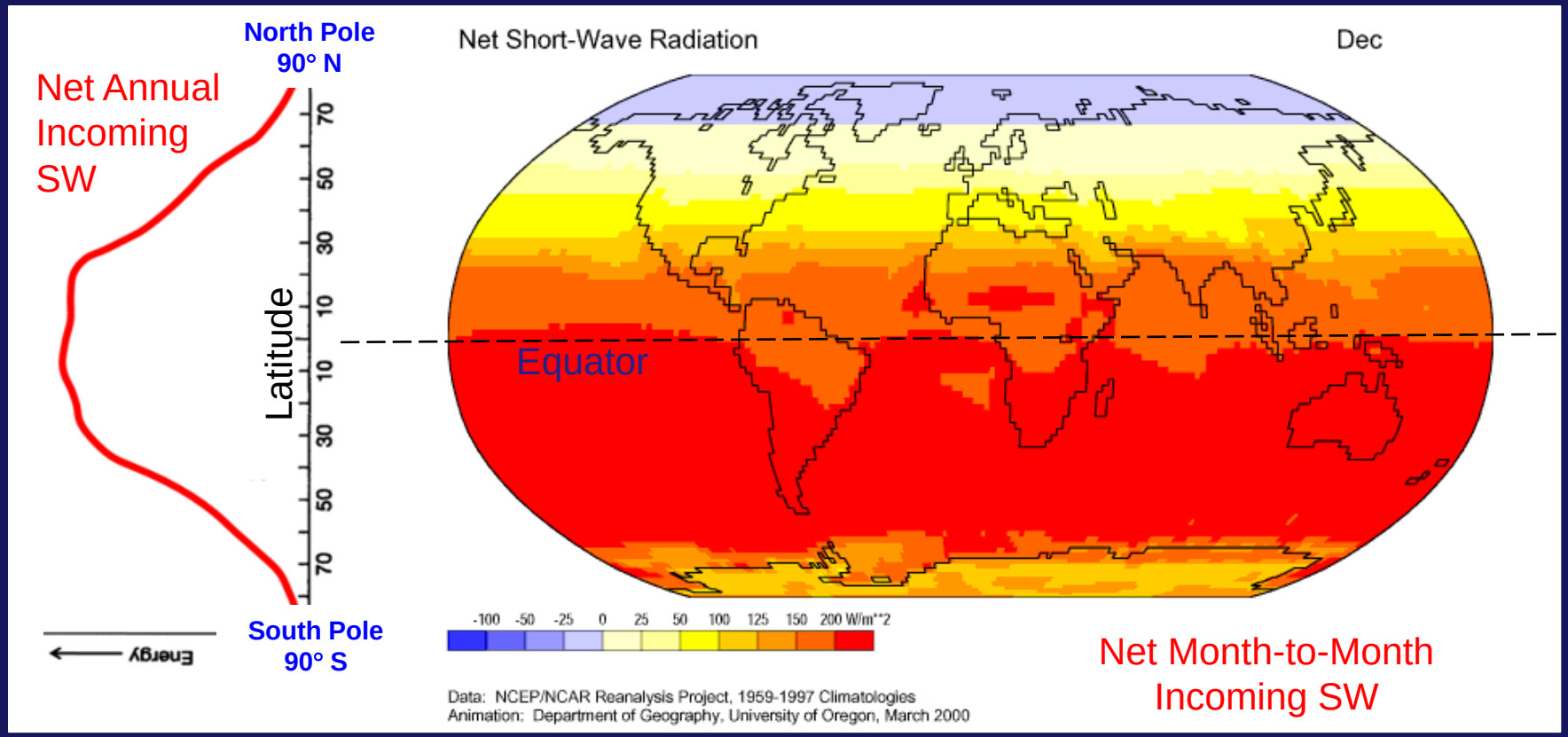


. . at each latitude

To **WARM** the Earth

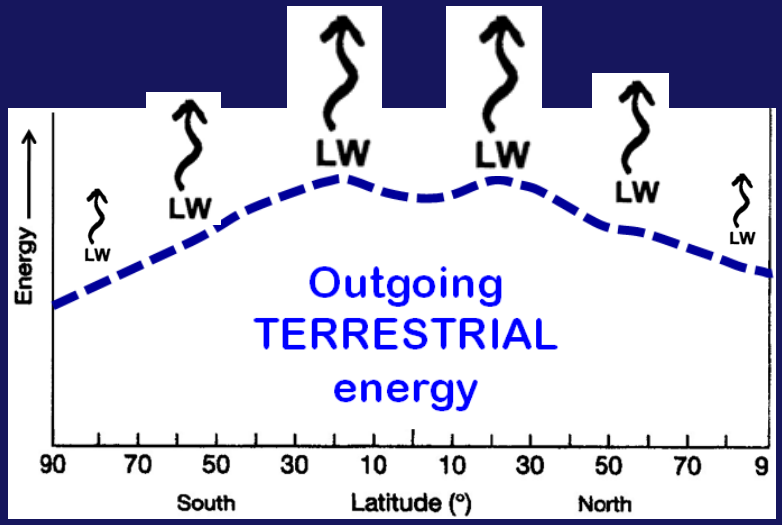
Net Incoming Shortwave Solar Radiation =





The Temperature of Earth + Atmosphere - the Greenhouse Effect

This determines the LATITUDINAL & SEASONAL DIFFERENCES of what goes OUT . . .



Radiated out to space

Minus the GH Effect: Radiated back to surface

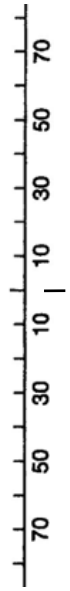
. . . at each latitude To COOL the Earth

Net Outgoing Longwave IR Radiation =

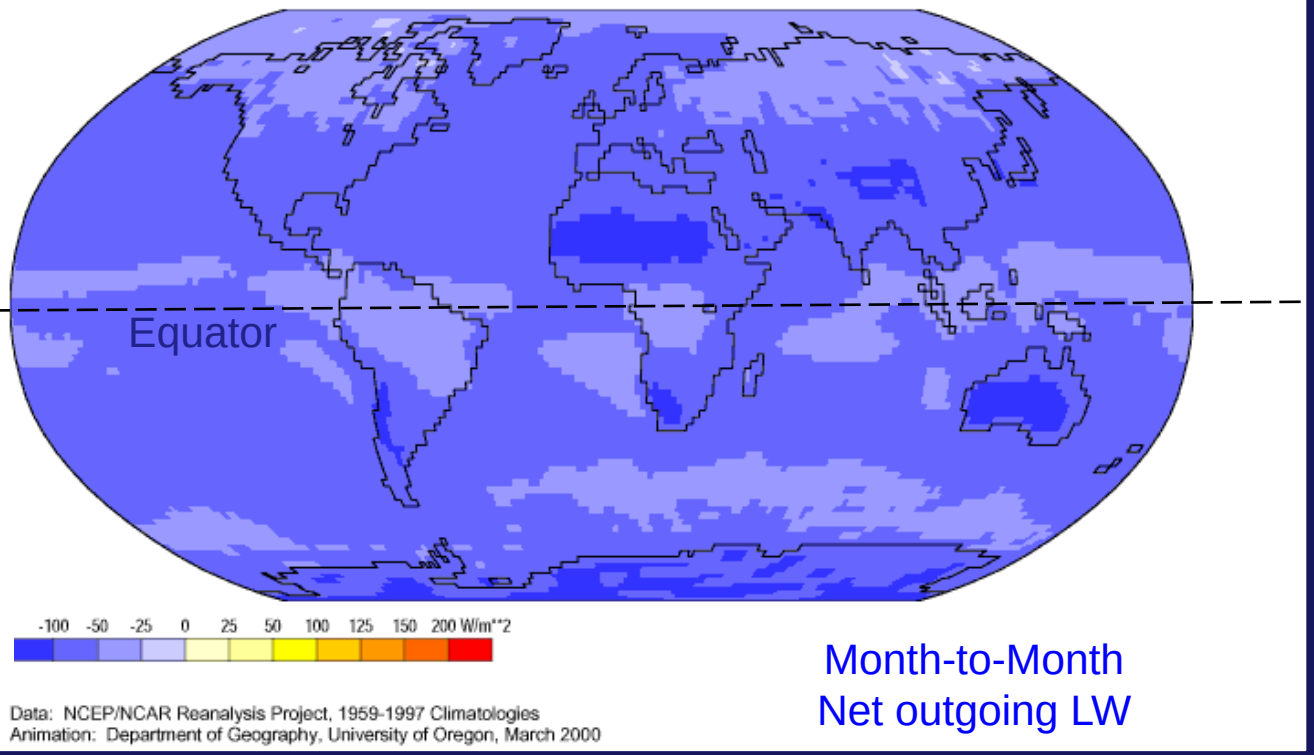
Minus the GH Effect: Radiated back to surface

Annual Net Outgoing LW

North Pole 90° N

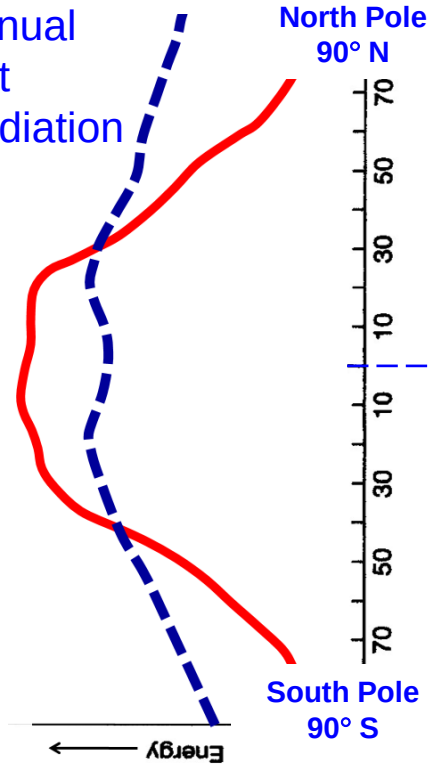


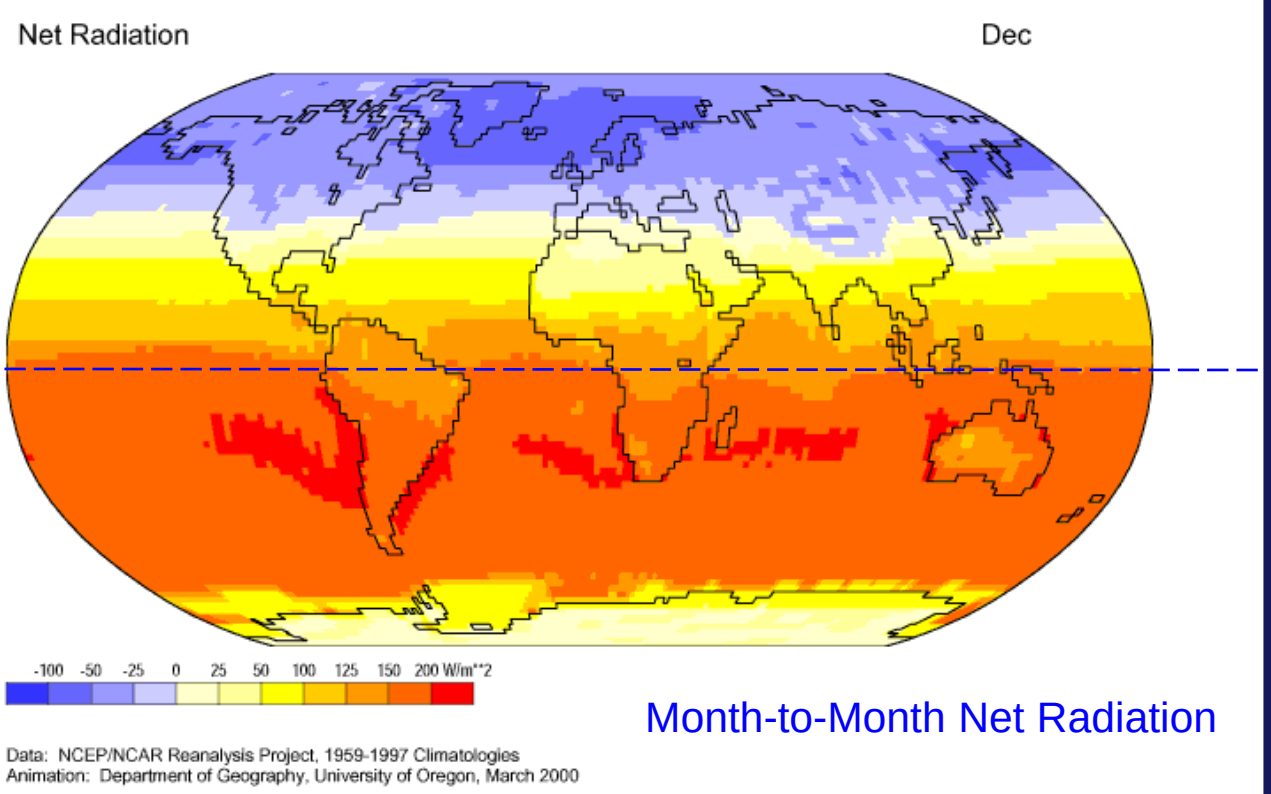
South Pole 90° S



Month-to-Month Net outgoing LW

Incoming - Outgoing radiation = Net Radiation

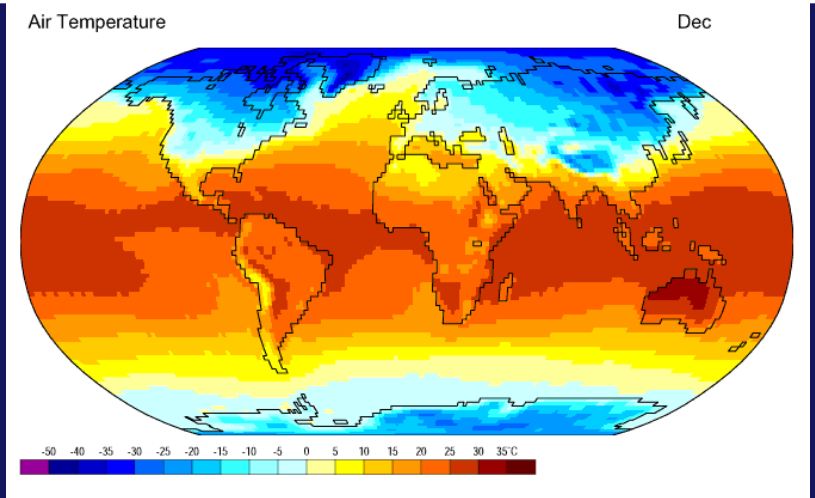




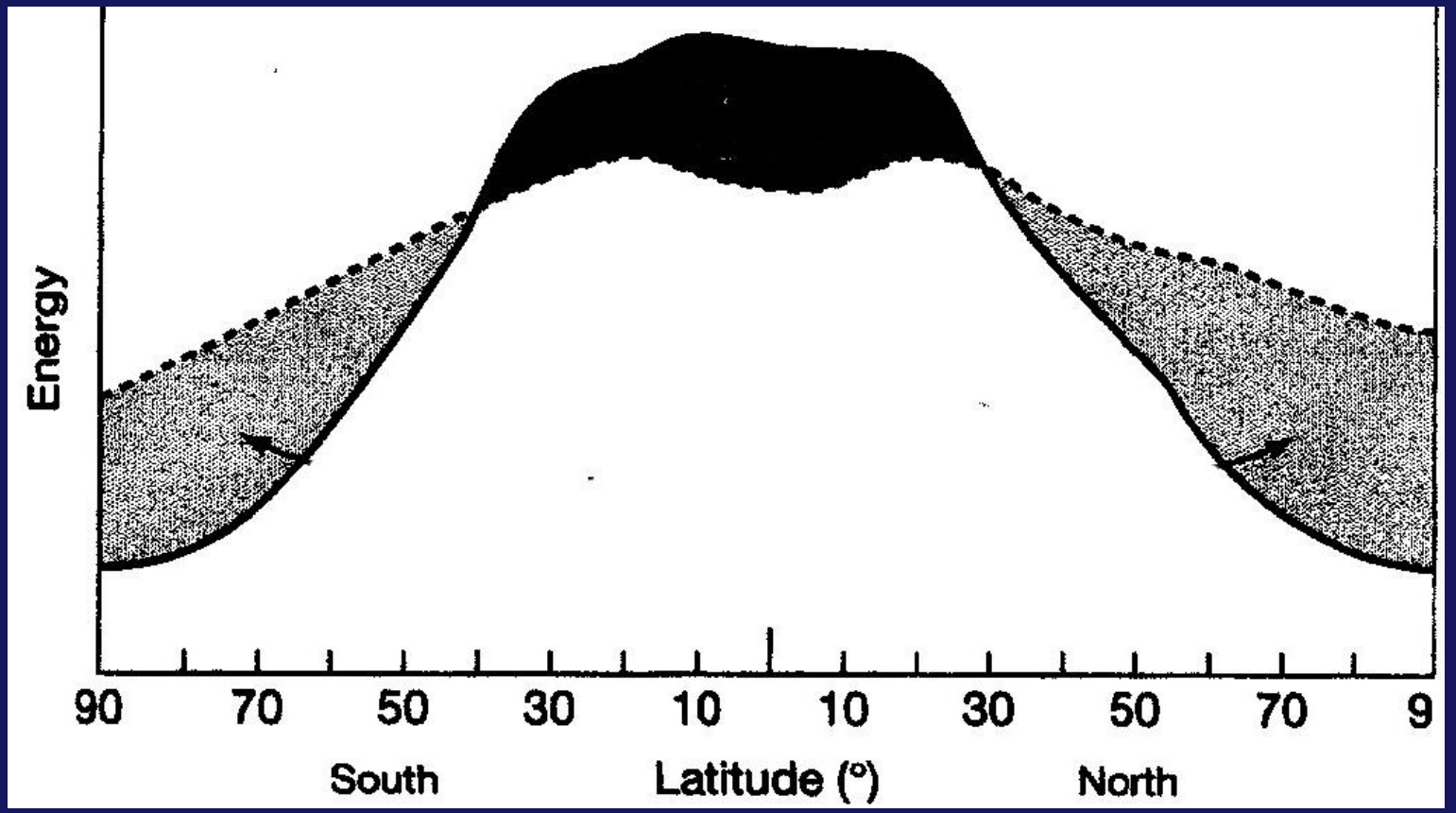
Month-to-Month Net Radiation

& Net Radiation determines:

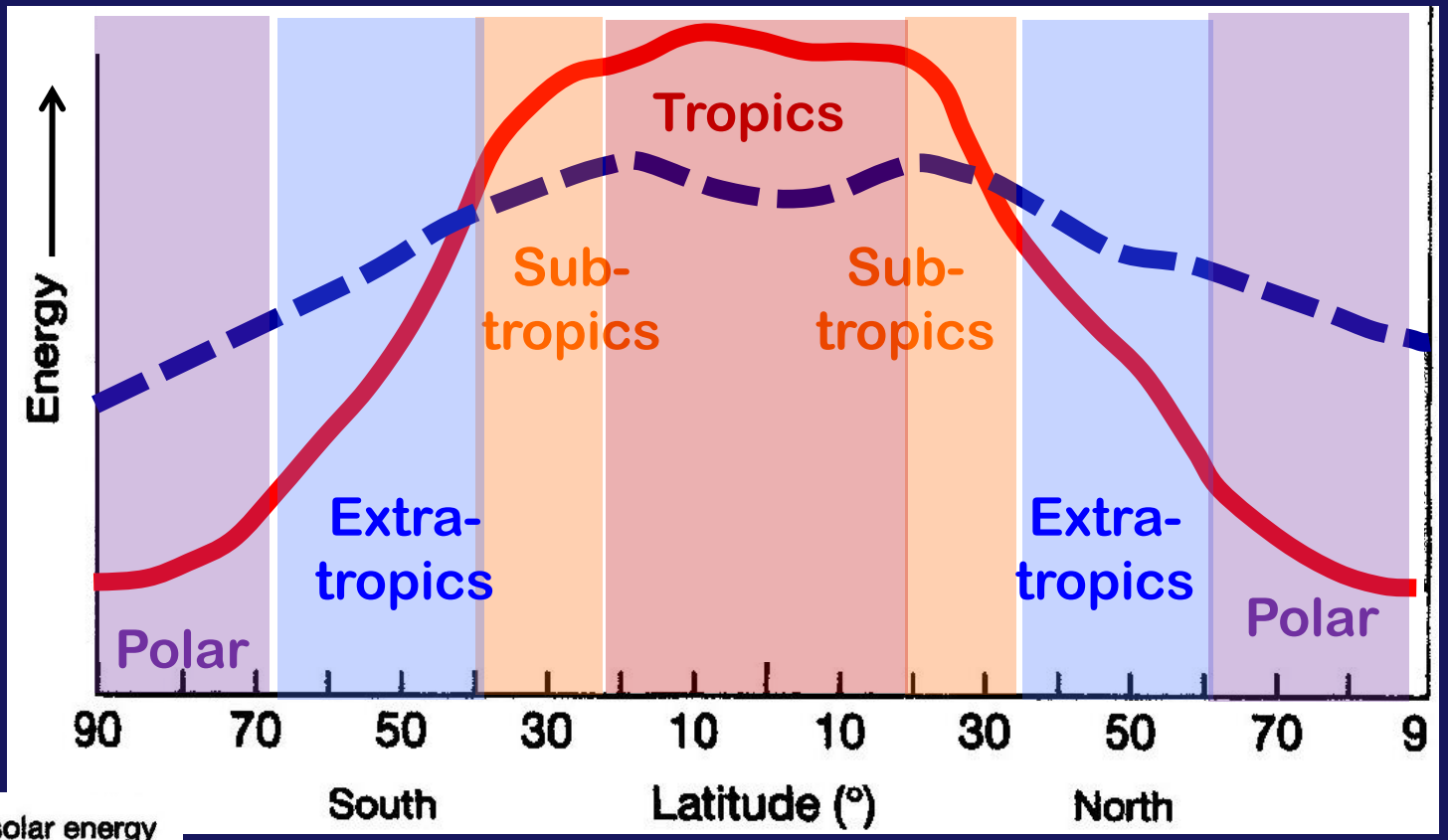
Air Temperature →



Put them together . . . .

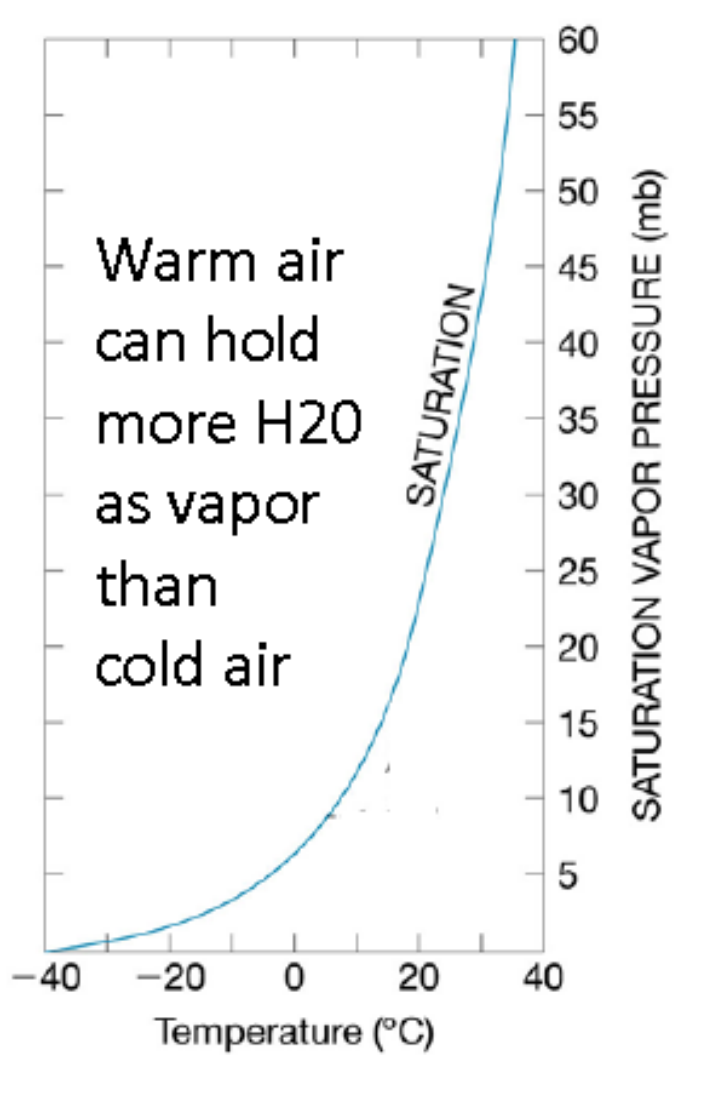


Latitude Variations → CLIMATE REGIONS

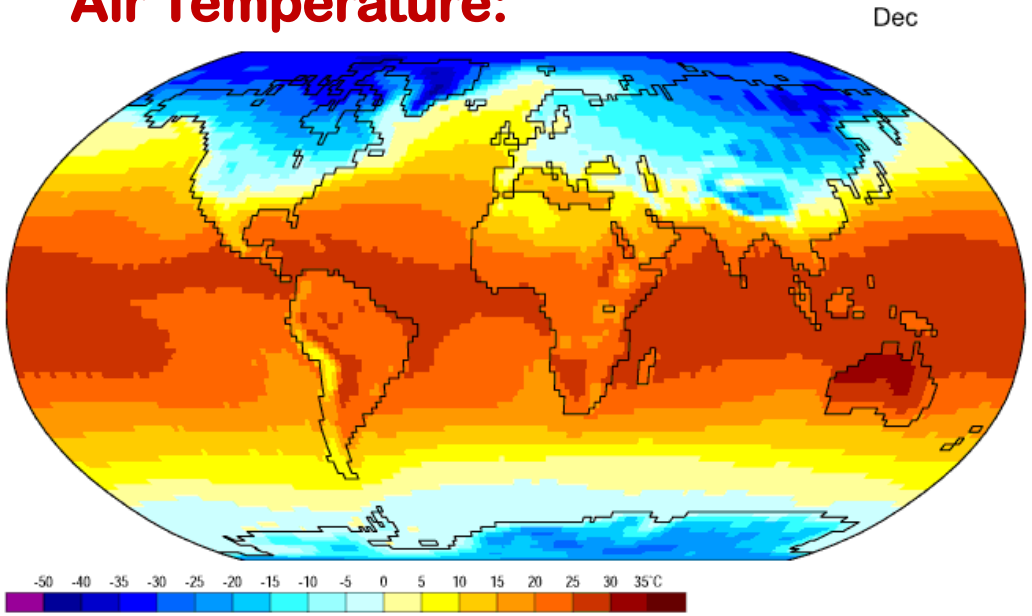


Global climate patterns are determined (in part) by regions of surplus and deficit in the ENERGY BALANCE

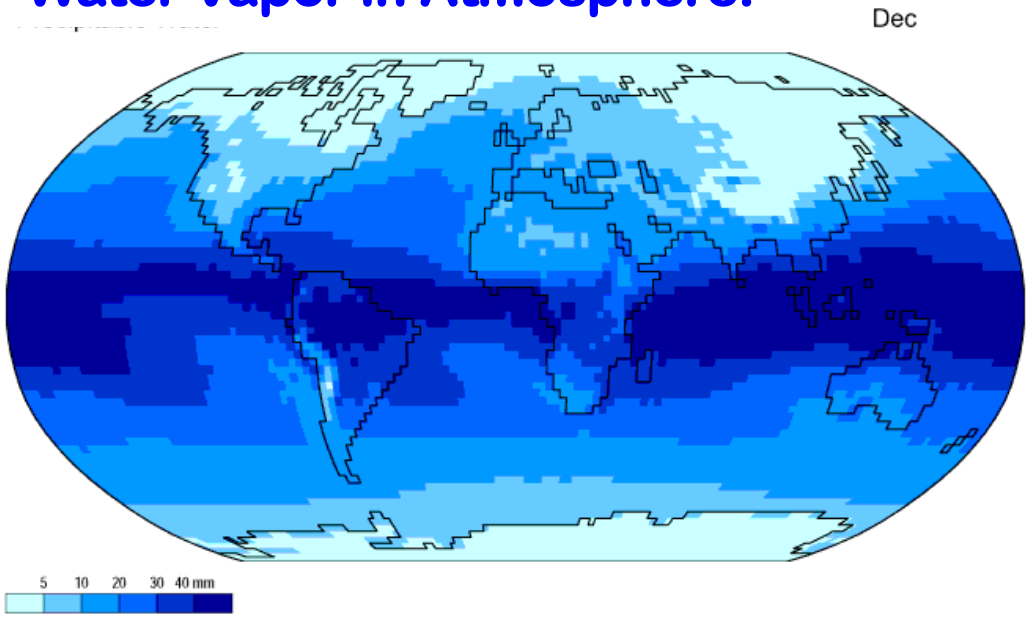
In Chapter 4 You learned that . . .



Air Temperature:

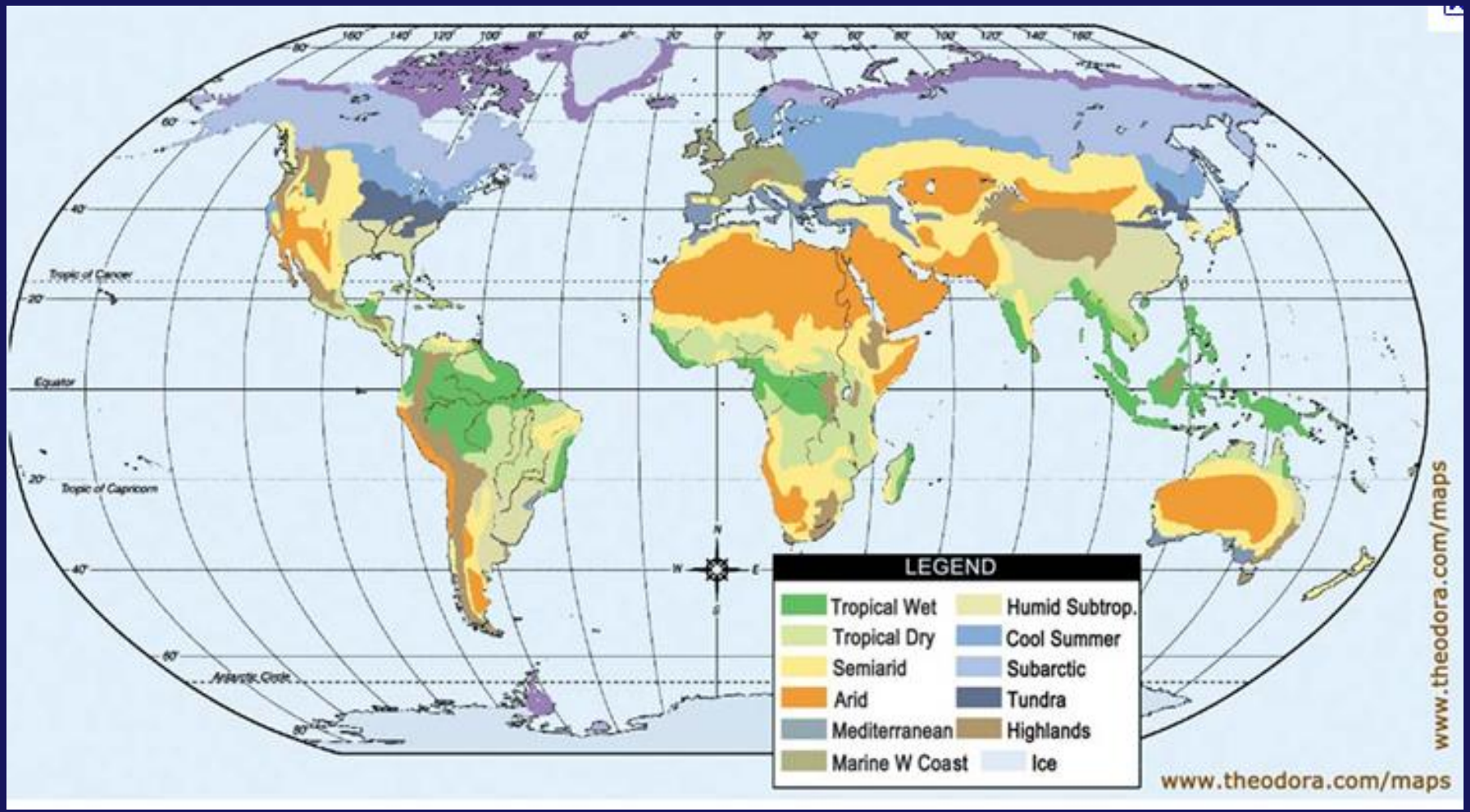


Water Vapor in Atmosphere:

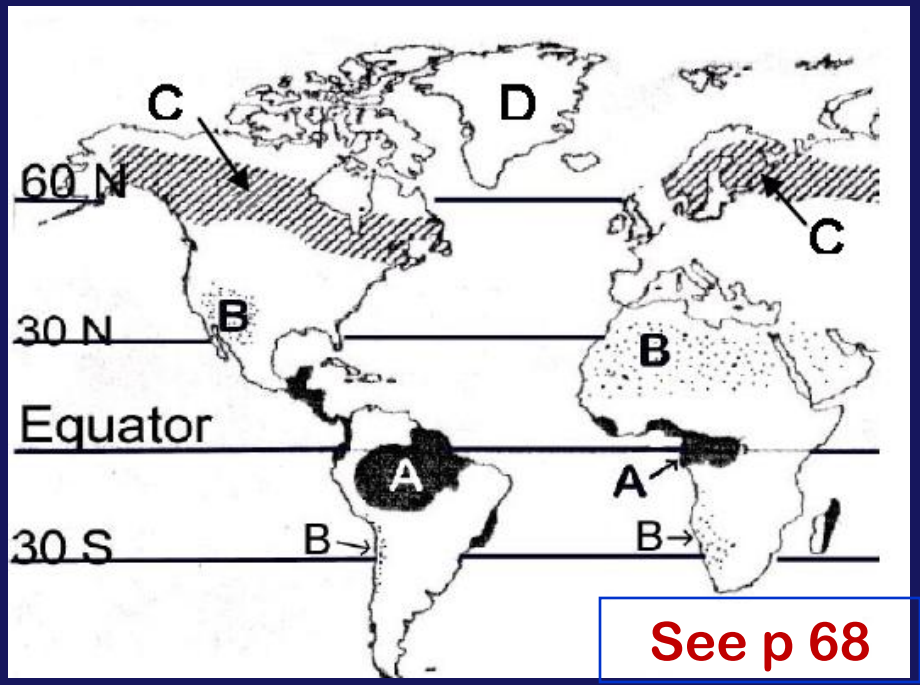


Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies
Animation: Department of Geography, University of Oregon, March 2000

Temperature & Moisture & Precipitation Patterns give us Climatic Regions



CLICKER Q1. Enter 1, 2 or 3 to indicate the climate and vegetation in the areas marked A, B , C, & D:



See p 68

CHOICE 1

A =Tropical Rain Forest
B = Cool Evergreen Conifer Forest
C = Subtropical Desert
D = Polar Snow & Ice

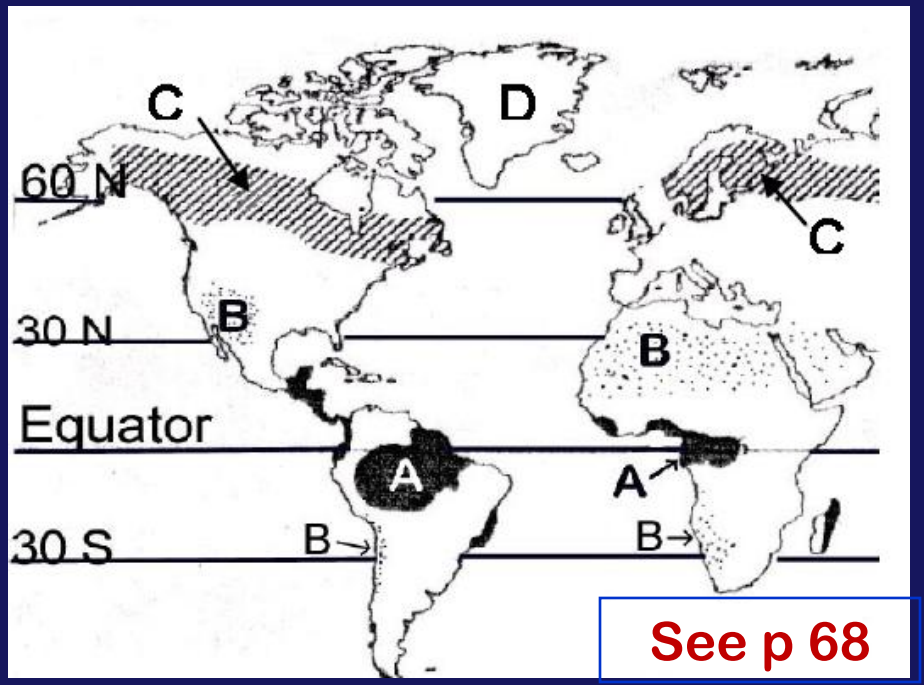
CHOICE 2

A =Tropical Rain Forest
B = Subtropical Desert
C = Cool Evergreen Conifer Forest
D = Polar Snow & Ice

CHOICE 3

A = Subtropical Desert
B = Tropical Rain Forest
C = Polar Snow & Ice
D = Cool Evergreen Conifer Forest

CLICKER Q1. Enter 1, 2 or 3 to indicate the climate and vegetation in the areas marked A, B , C, & D:



See p 68

CHOICE 1

A =Tropical Rain Forest
B = Cool Evergreen Conifer Forest
C = Warm Desert
D = Polar Snow & Ice

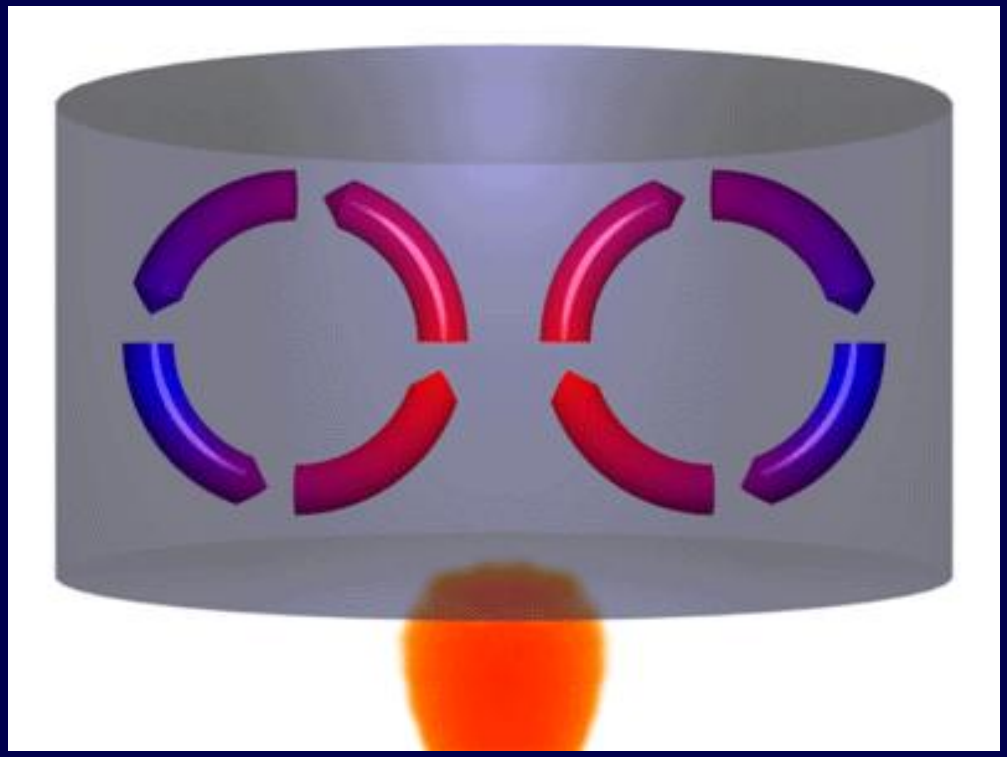
CHOICE 2

A =Tropical Rain Forest
B = Warm Desert
C = Cool Evergreen Conifer Forest
D = Polar Snow & Ice

CHOICE 3

A = Warm Desert
B = Tropical Rain Forest
C = Polar Snow & Ice
D = Cool Evergreen Conifer Forest

REMEMBER CONVECTION?

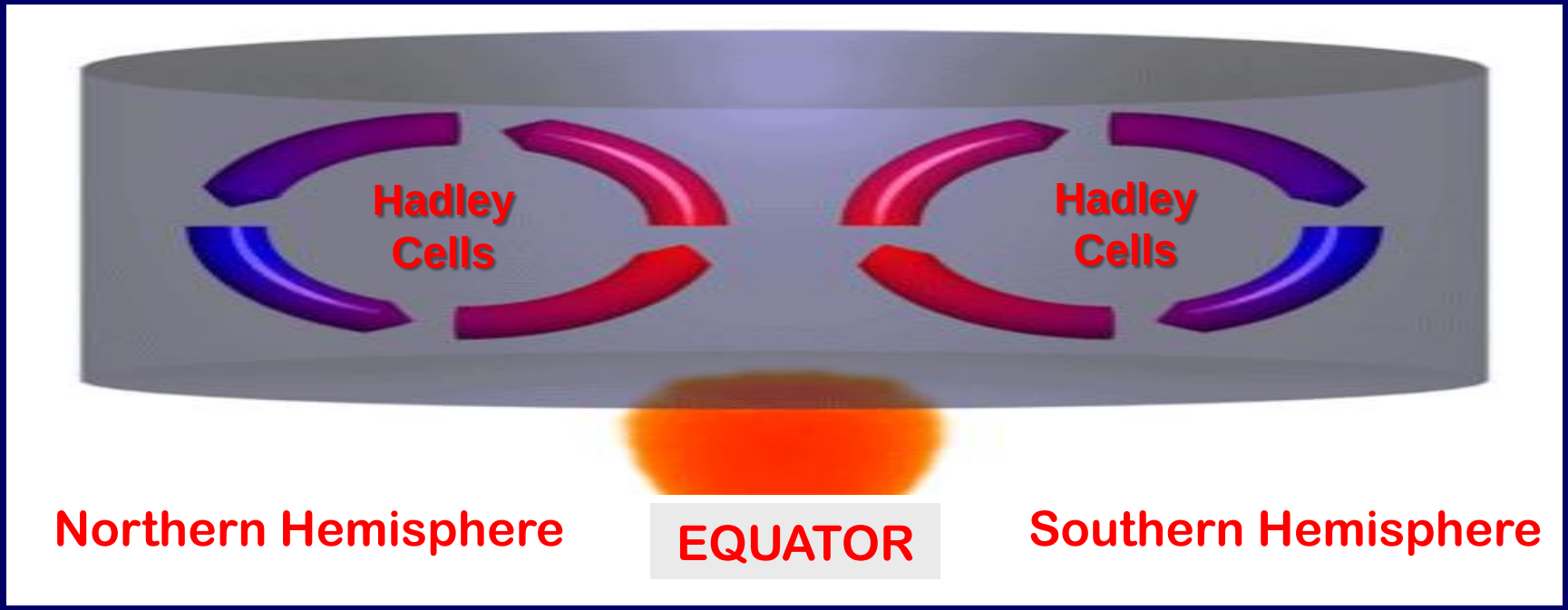


HOT

Large scale transport of
Sensible Heat (H)
(by movement of warm water or air)

Global-scale air motions are driven by thermal differences:

transfer of SENSIBLE HEAT (H) to cooler regions

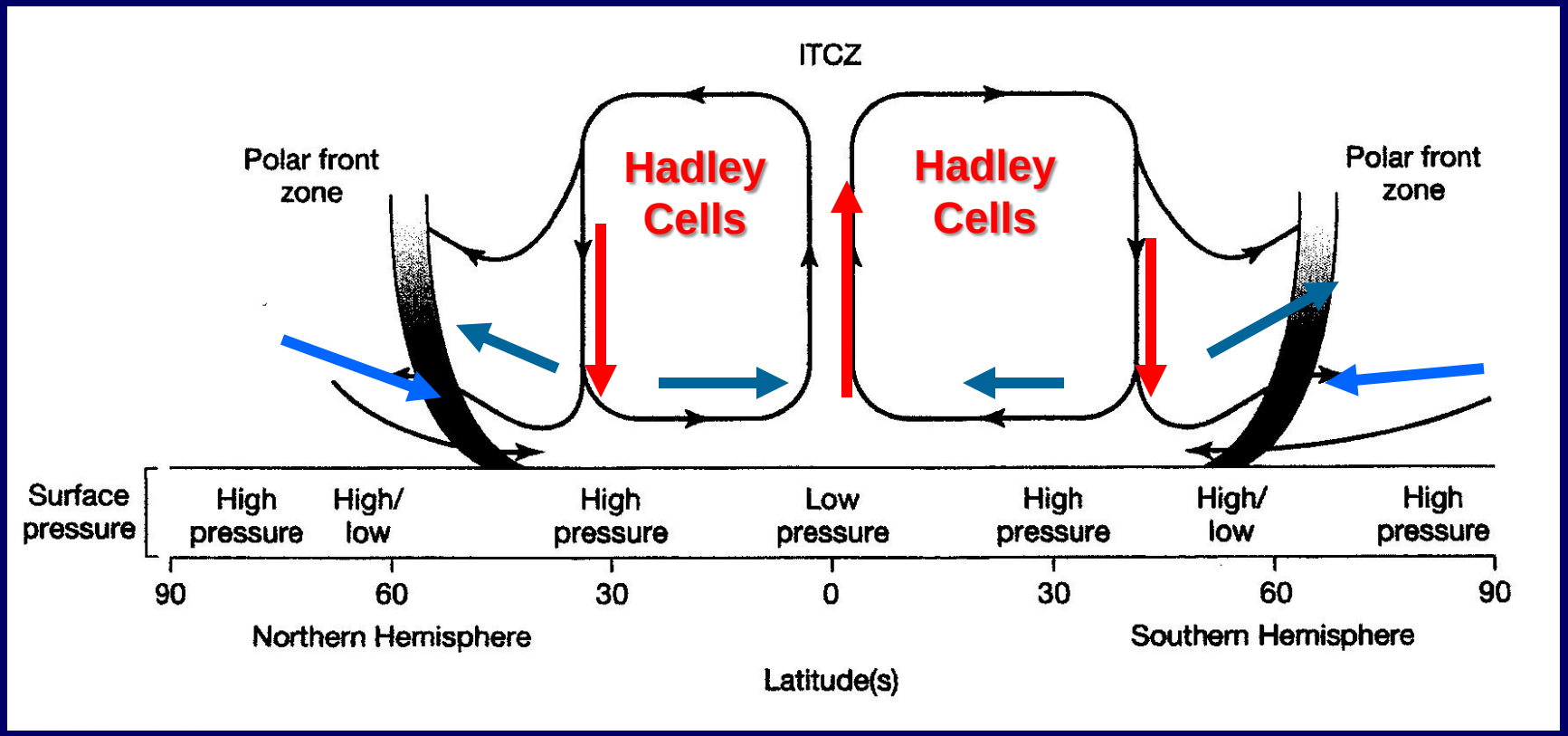


COLD POLAR REGIONS

HOT TROPICS

COLD POLAR REGIONS

← transfer of **SENSIBLE HEAT (H)** to cooler regions →



COLD POLAR REGIONS

HOT TROPICS

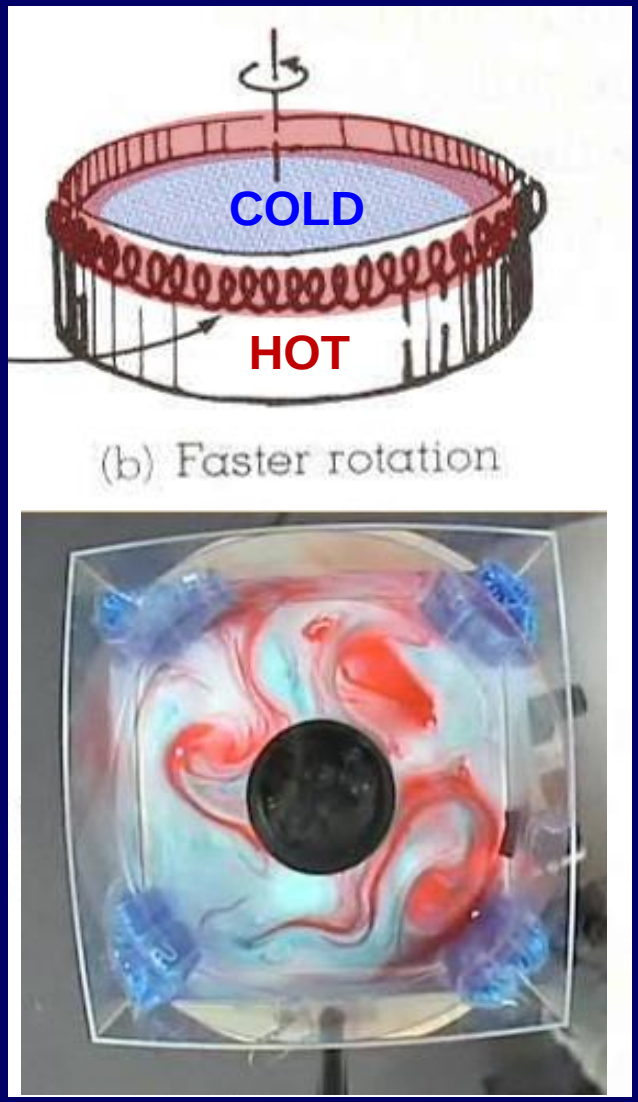
COLD POLAR REGIONS

From SGC Chapter 4

A more efficient way ➔ energy (as Sensible Heat, H) gets transported from

HOT SURPLUS areas to

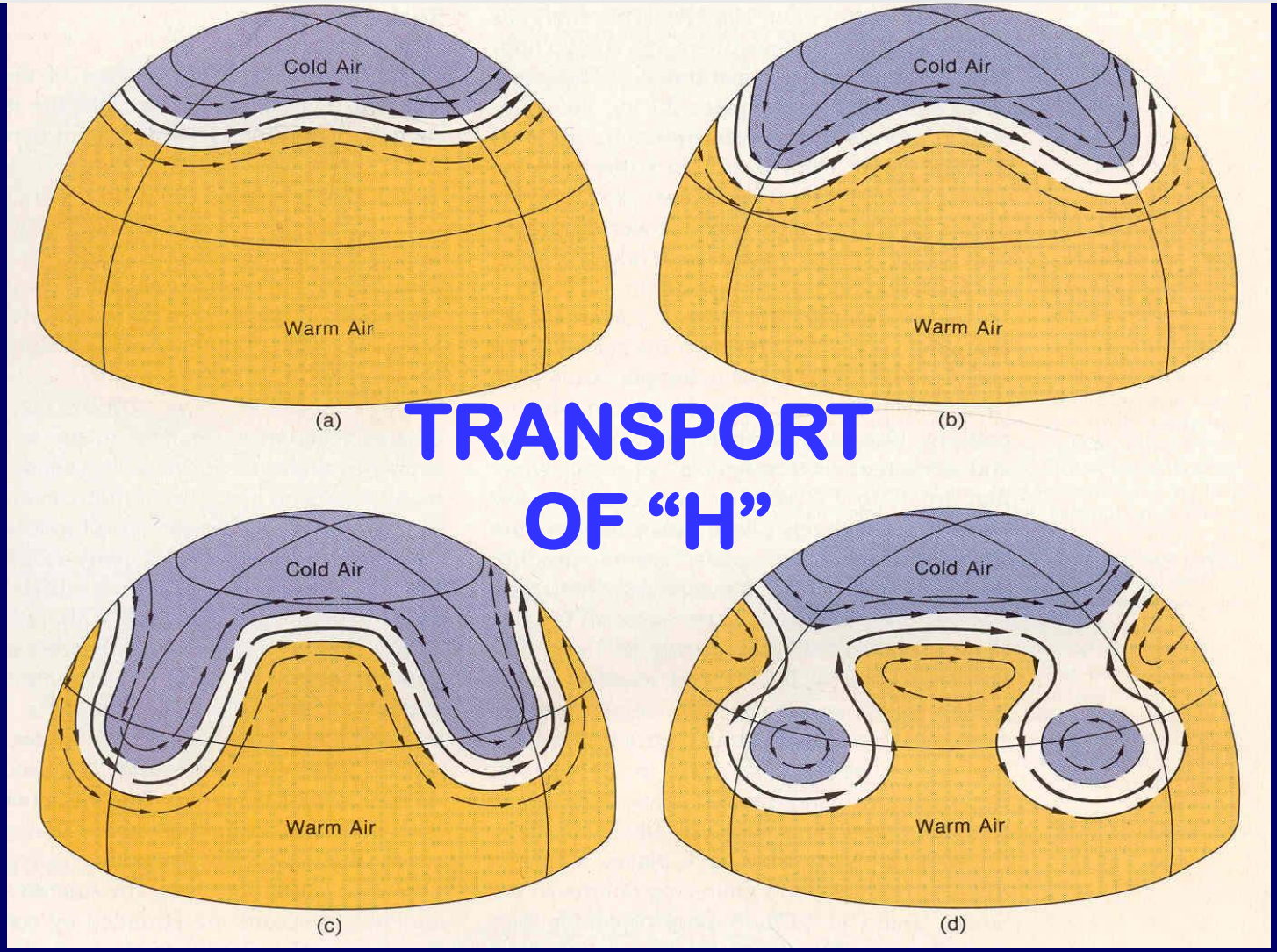
COLD DEFICIT areas



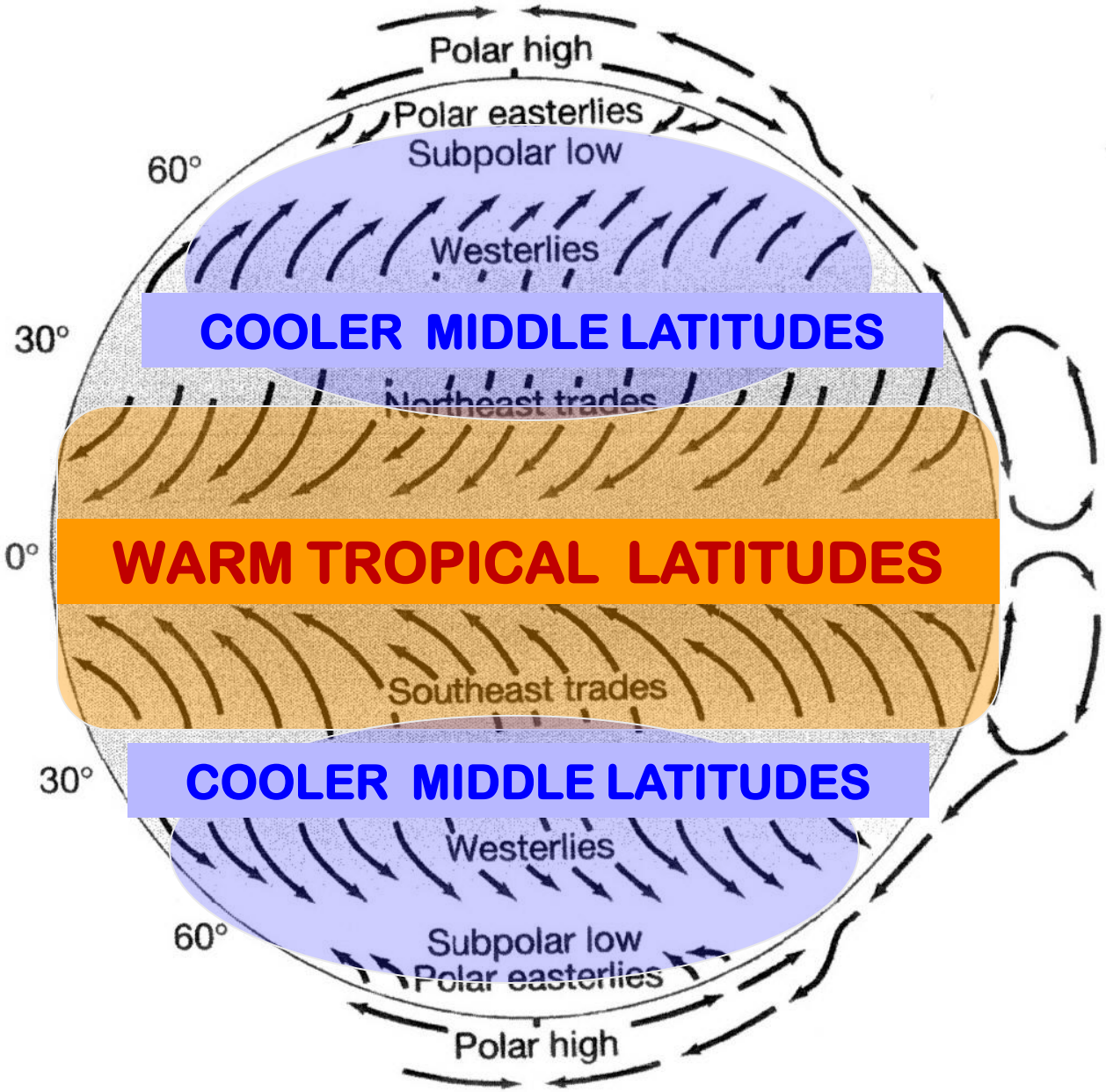
"WAVE TRANSPORT" of air or water (instead of convection cells)

"dishpan" model

UPPER LEVEL "ROSSBY WAVE" CIRCUMPOLAR WINDS !



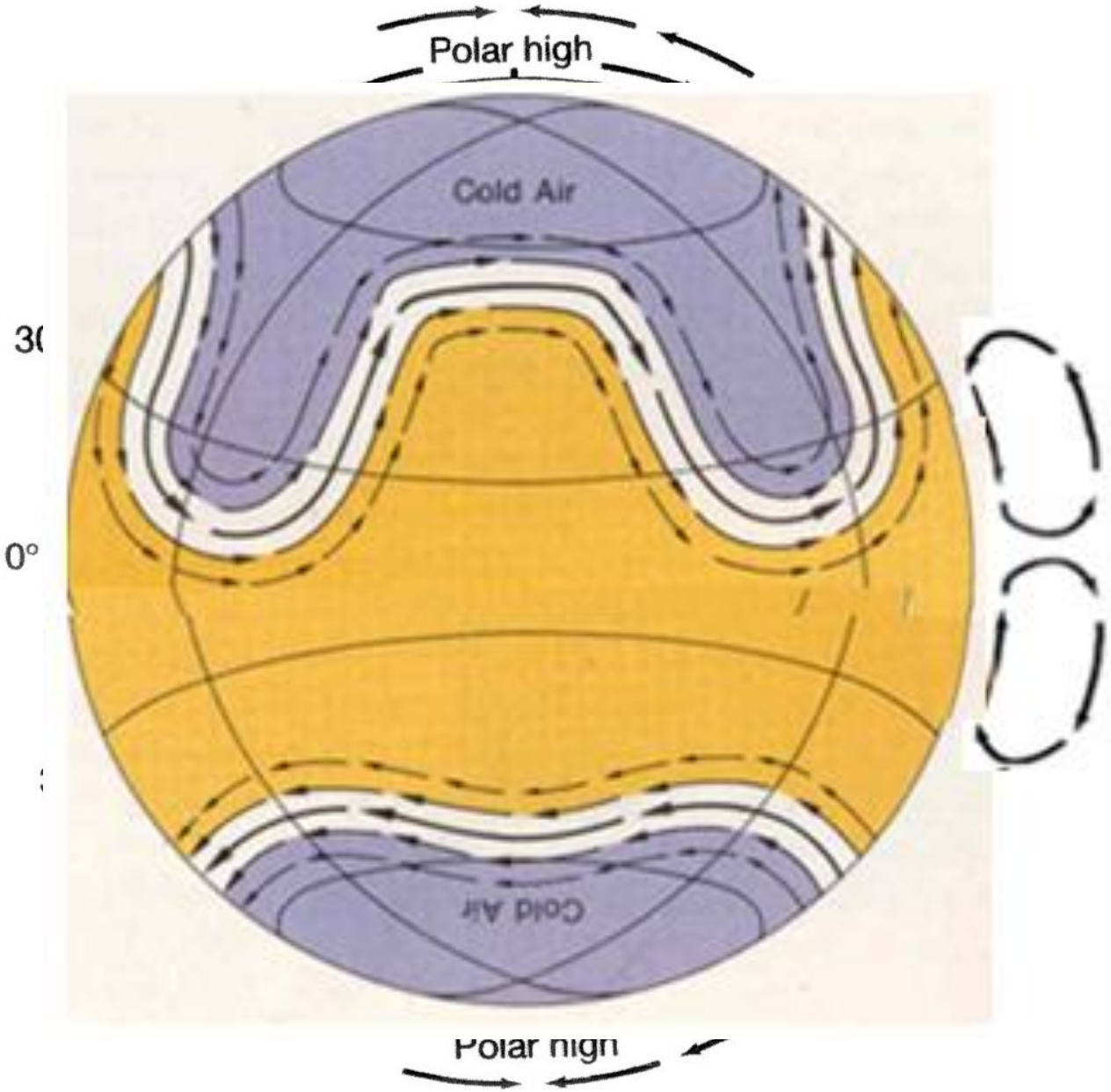
"Wave" transport of Energy as SENSIBLE HEAT
(in lobes of warm air)!



ROSSBY WAVE transport of energy

HADLEY CELL transport

ROSSBY WAVE transport of energy

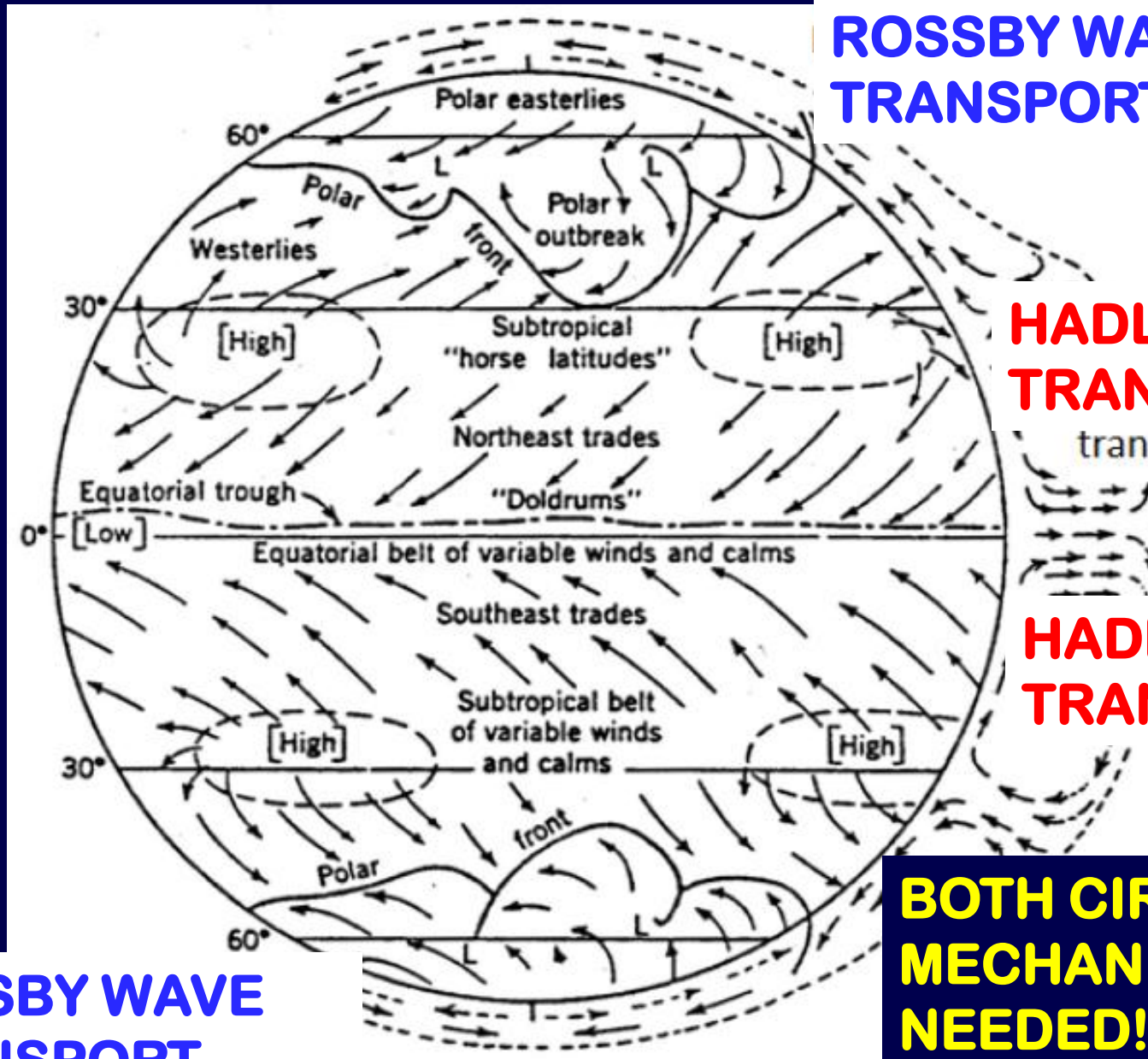


ROSSBY WAVE transport of energy

HADLEY CELL transport

ROSSBY WAVE transport of energy

The "GENERAL CIRCULATION OF THE ATMOSPHERE"



ROSSBY WAVE TRANSPORT

HADLEY CELL TRANSPORT

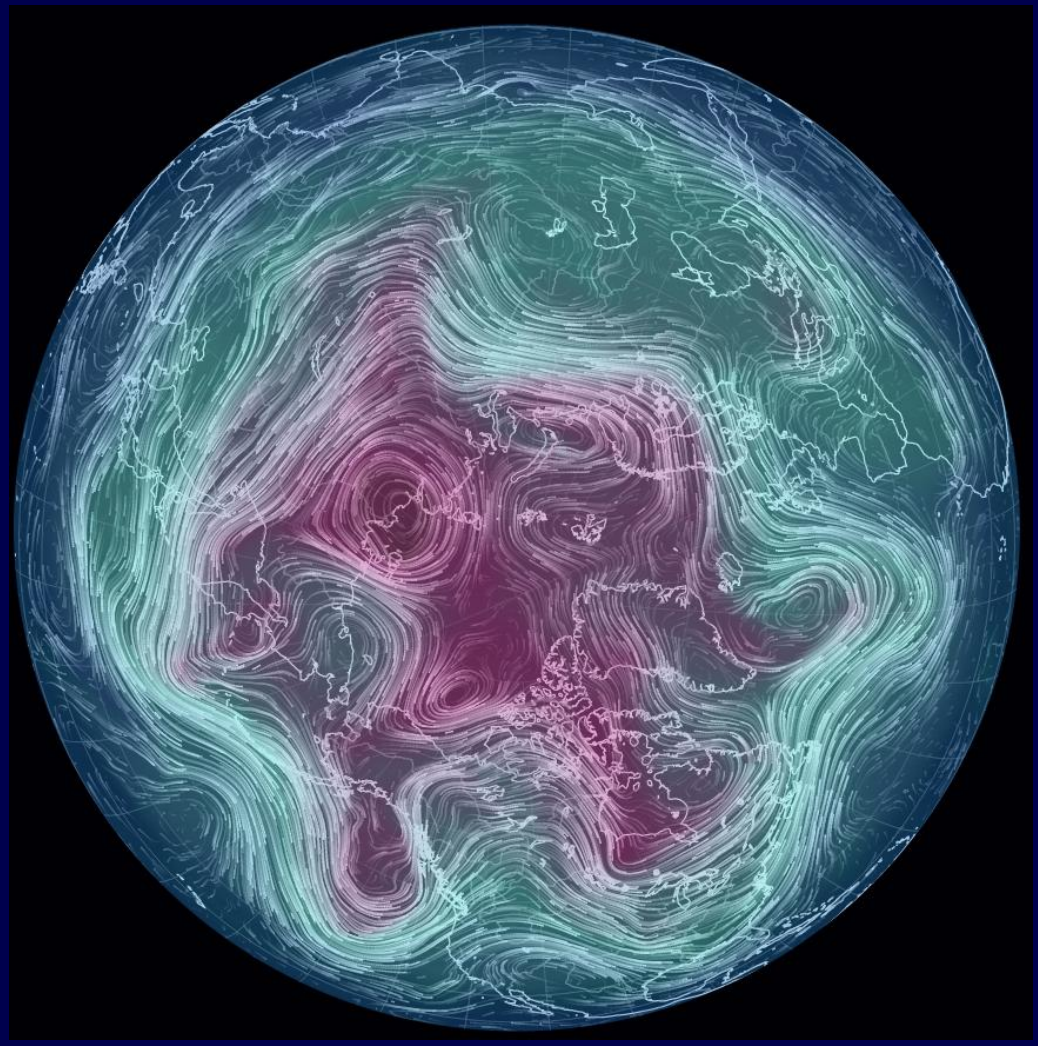
transport

HADLEY CELL TRANSPORT

BOTH CIRCULATION MECHANISMS ARE NEEDED!

ROSSBY WAVE TRANSPORT

WHAT'S HAPPENING TODAY?



Data | Wind + Temp @ 500hPa

Scale |

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

G-4 Your next “hands on”
10 pt “Group” Activity
will take place in the Tree-Ring Lab!

A Brief Intro:
TREE RINGS & DENDROCHRONOLOGY

CLASS NOTES
APPENDIX
p 99

Dendrochronology is the dating and study of annual rings in trees:

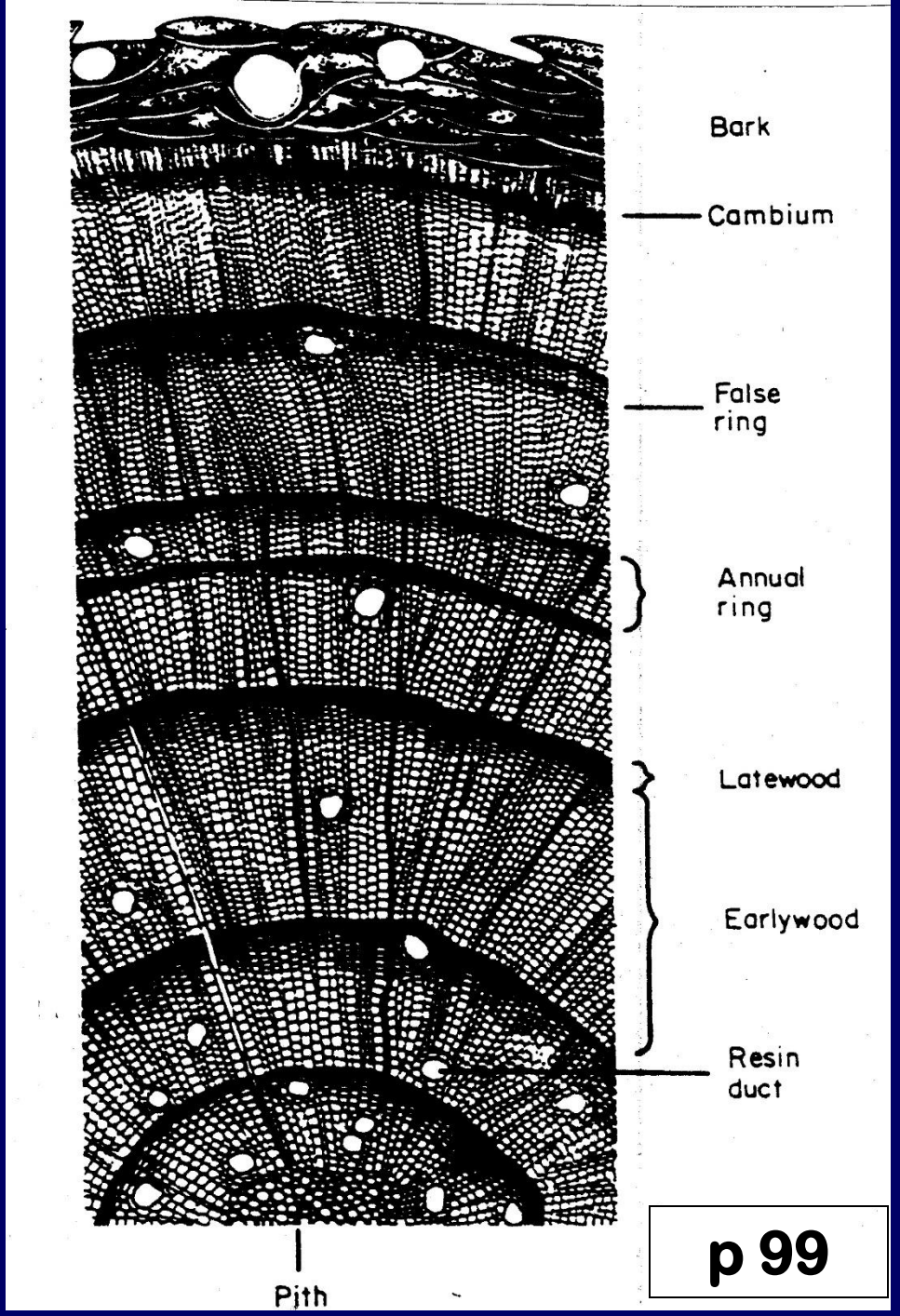
- ***dendros***: from trees, or more specifically the growth rings of trees
- ***chronos***: time, or more specifically events in past time
- ***ology***: the study of . . .

Partial cross-section of a coniferous tree

How old is it? (in complete years) count 'em!

7 years old

(now in 8th year of growth)

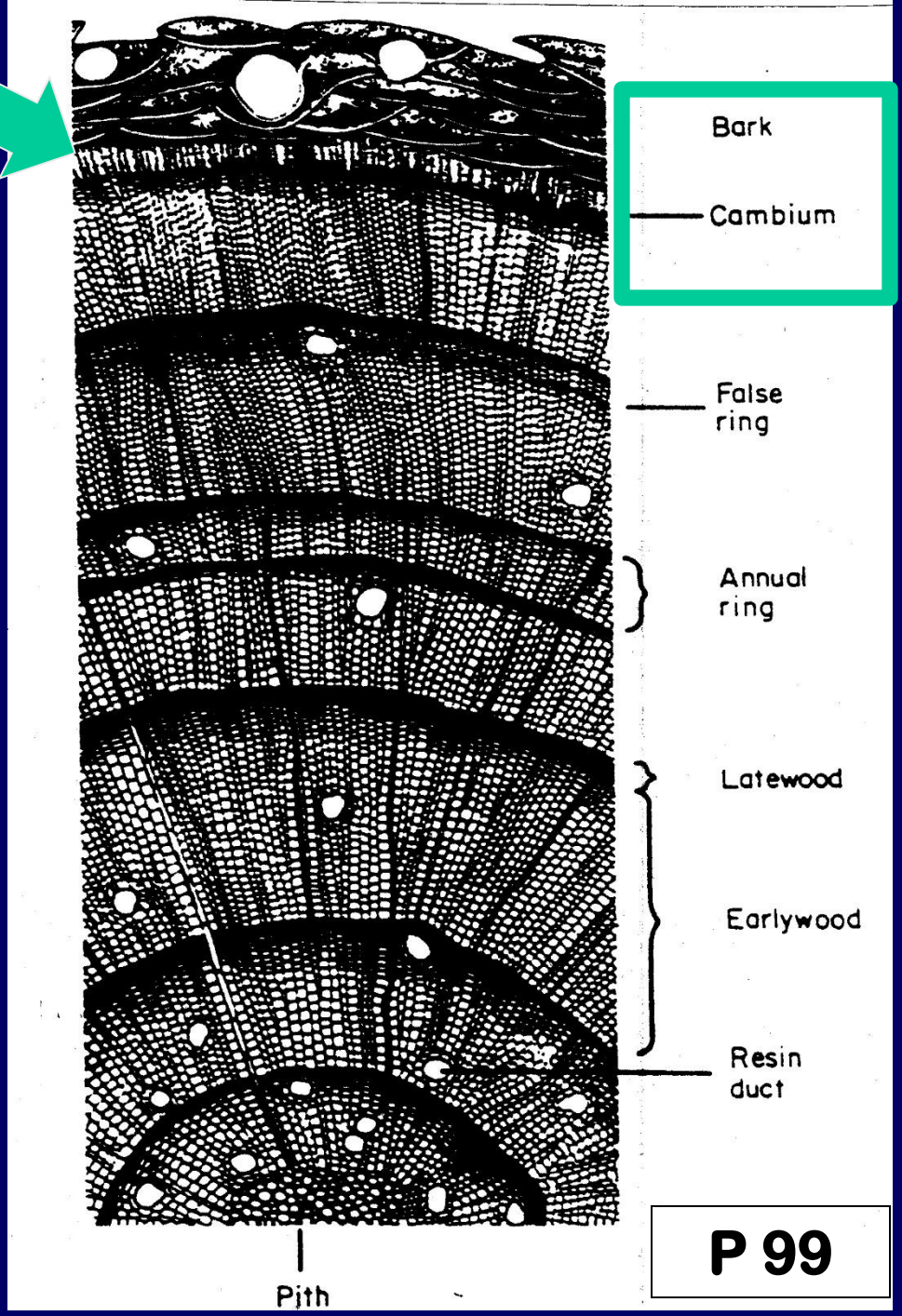


p 99

The current year's actively growing cells are just underneath the bark in the:

"Cambium"

These cells will record the climate and other environmental conditions during their growing season.

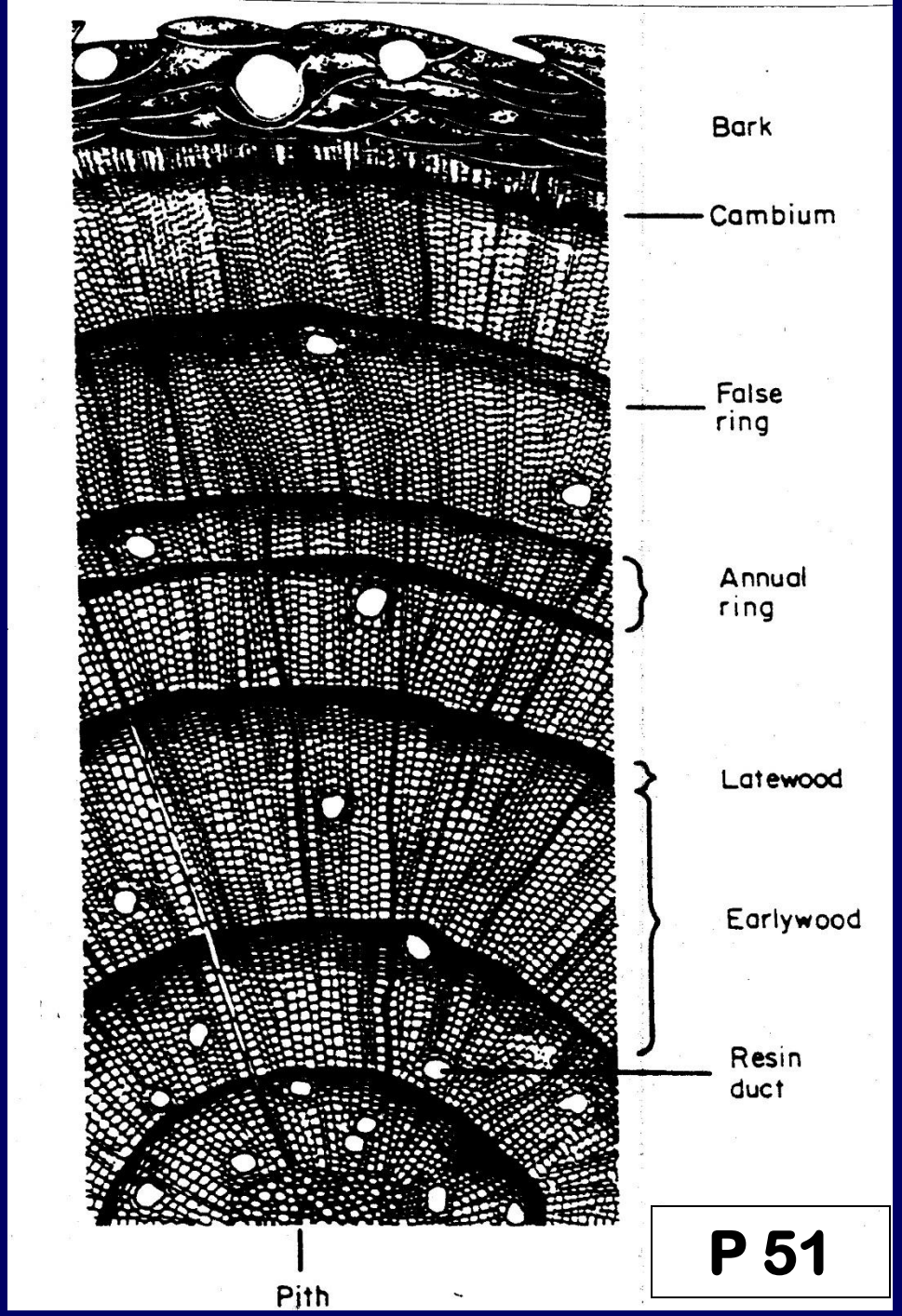


P 99

With 7 rings in the cross-section,

Is this the tree's age?

It depends on the height of the sample



P 51

“EARLYWOOD” =

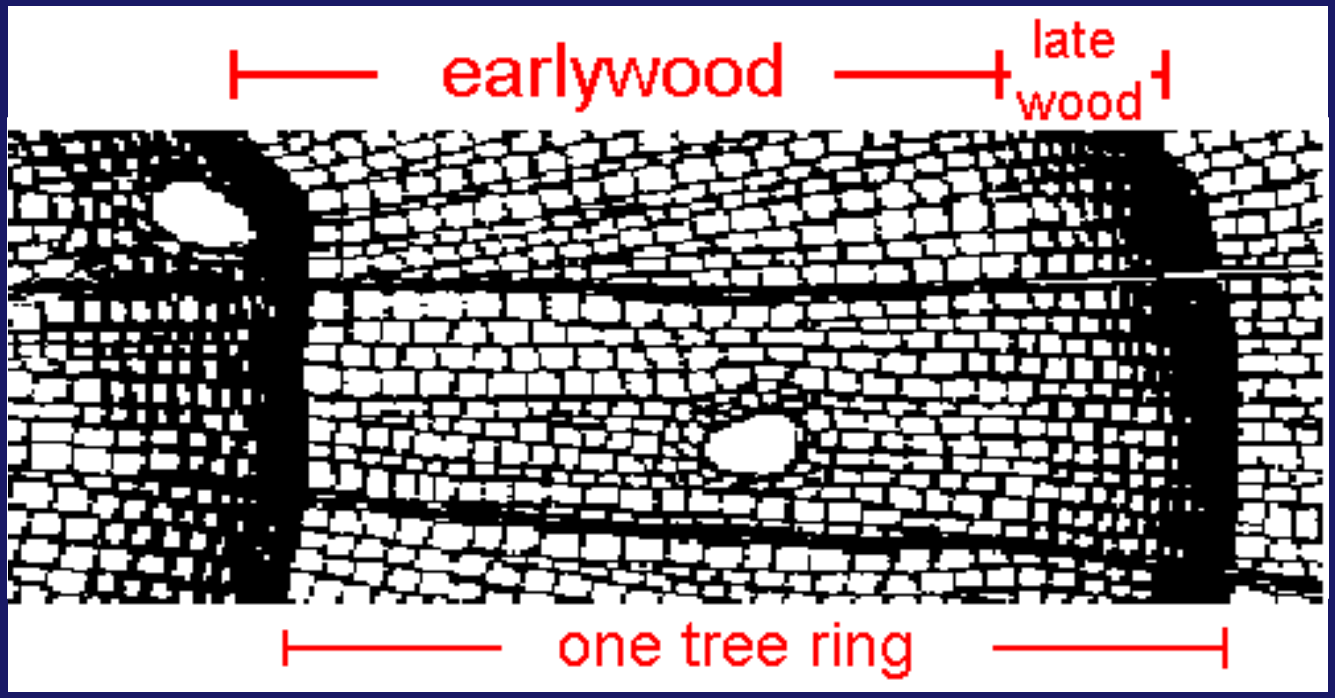
Cells are large w/ thin walls

Appear light in color

“LATEWOOD” =

Cells are small w/ thick walls

Appear dark in color



A conifer tree-ring sample with about 30 rings:

(every 10th ring is marked)

Pith ➔ Tree grows this way➔ (adding new cells) ➔

CLICKER Q2 What so you think could cause the annual rings to be narrow?

A) HOT, STRESSFUL TEMPERATURES

B) DROUGHT & REALLY DRY CONDITIONS

C) FREEZES & REALLY COLD CONDITIONS

D) INSECT ATTACKS

E) ANY OF THE ABOVE, DEPENDING ON THE TREE'S LOCATION & SPECIES

☺

A conifer tree-ring sample with about 30 rings:

(every 10th ring is marked)

Pith ➔ Tree grows this way➔ (adding new cells) ➔

CLICKER Q2 What so you think could cause the annual rings to be narrow?

A) HOT, STRESSFUL TEMPERATURES

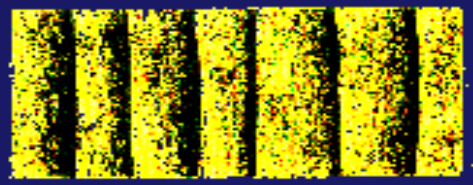
B) DROUGHT & REALLY DRY CONDITIONS

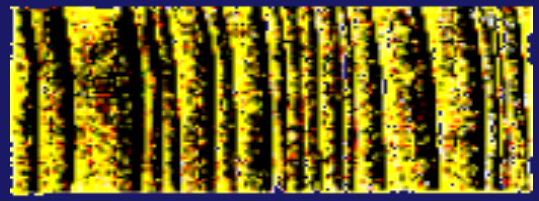
C) FREEZES & REALLY COLD CONDITIONS

D) INSECT ATTACKS

E) ANY OF THE ABOVE, DEPENDING ON THE TREE'S LOCATION & SPECIES

☺





SENSITIVE tree-ring records

tell us the **MOST** about past climate!

"Complacent"

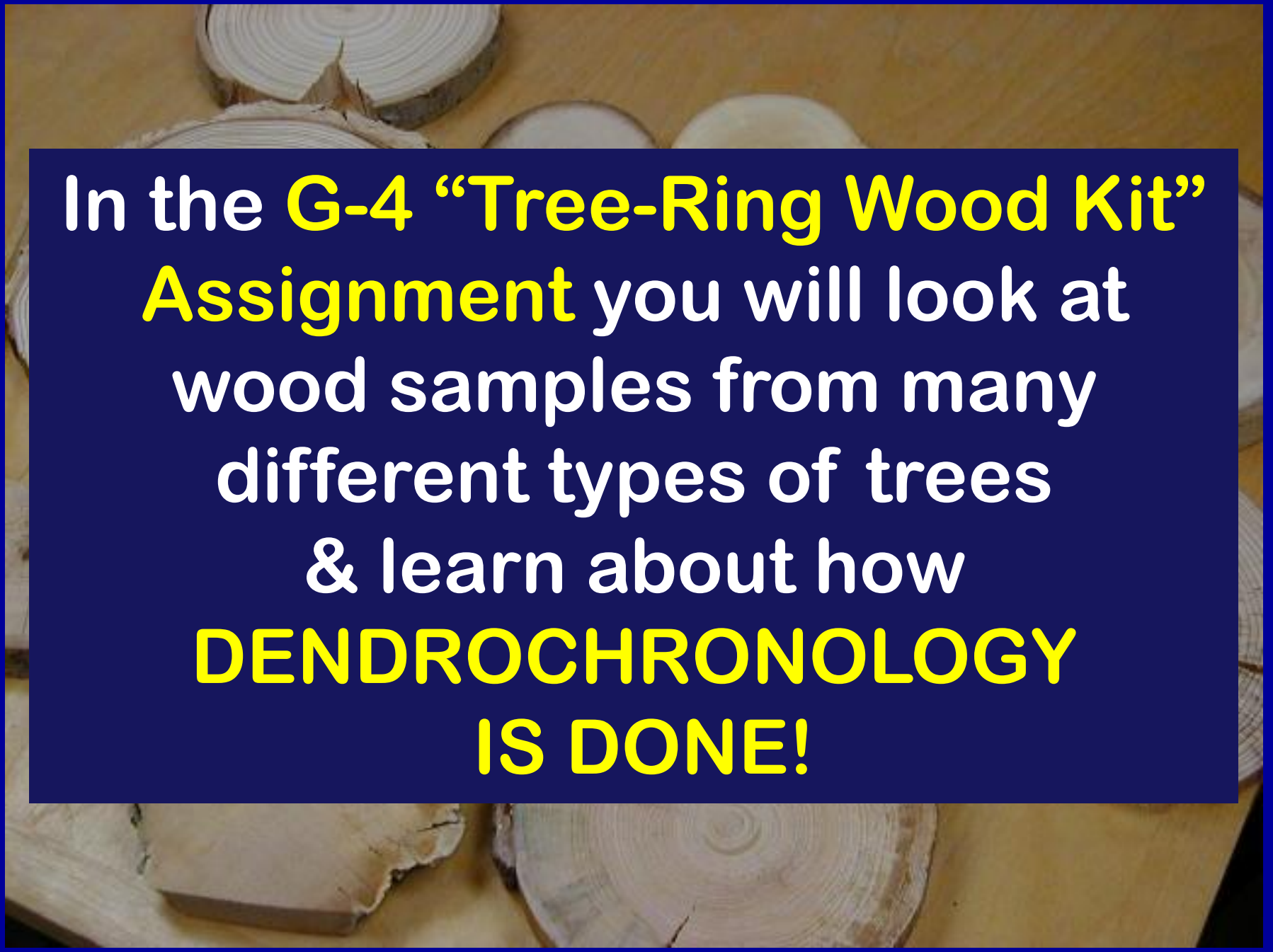
Wide, even rings with LITTLE VARIATION

Tree roots have access to moisture, not stressed out

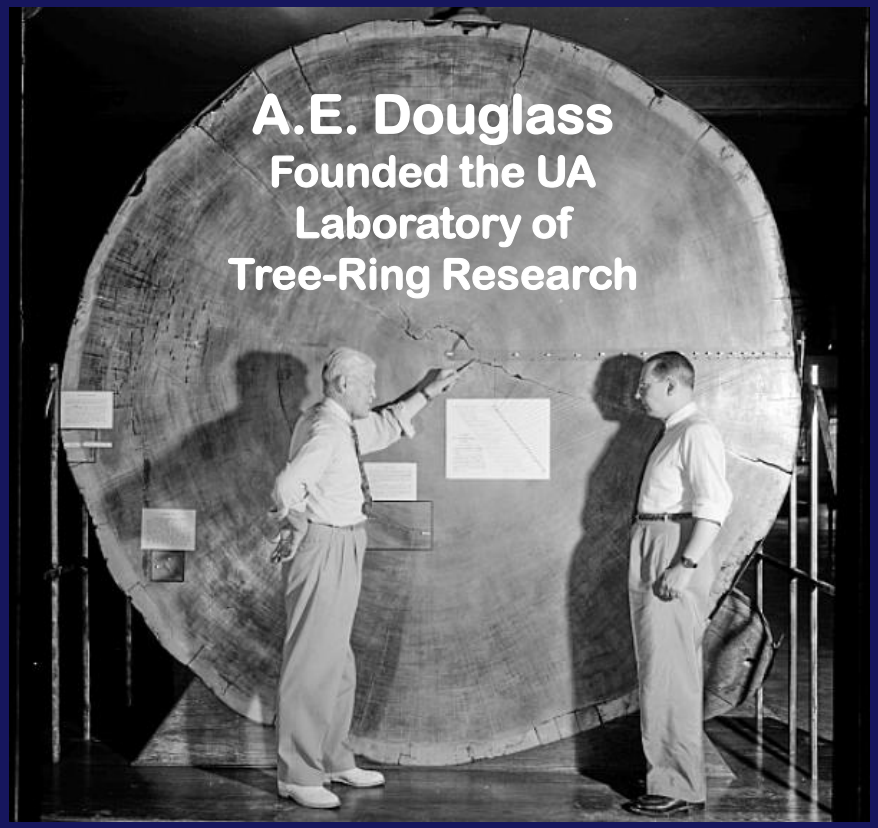
"Sensitive"

Some very narrow rings, with LOTS of VARIATION!

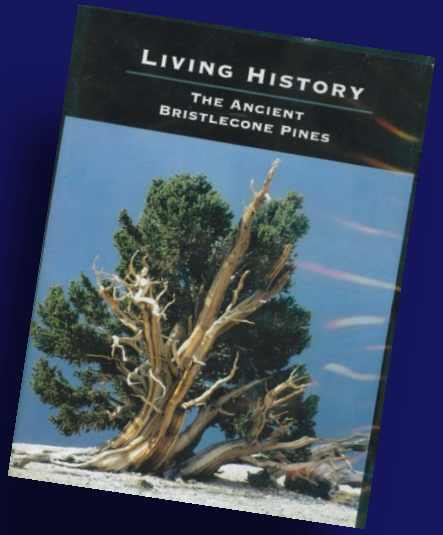
Tree growth was limited during stressful years



In the G-4 "Tree-Ring Wood Kit" Assignment you will look at wood samples from many different types of trees & learn about how DENDROCHRONOLOGY IS DONE!



Mini-Film
Break
5 minutes
from:



The G-4 Tree Ring Wood Kit Activity

begins tomorrow & is due

before MIDNIGHT on Wed Nov 12th

You will need to visit the Tree-Ring Lab at one of the posted time slots to do the activity

Want to get it done early?

The first "hands on" session is tomorrow:

Friday Oct 31 from 2- 3 pm

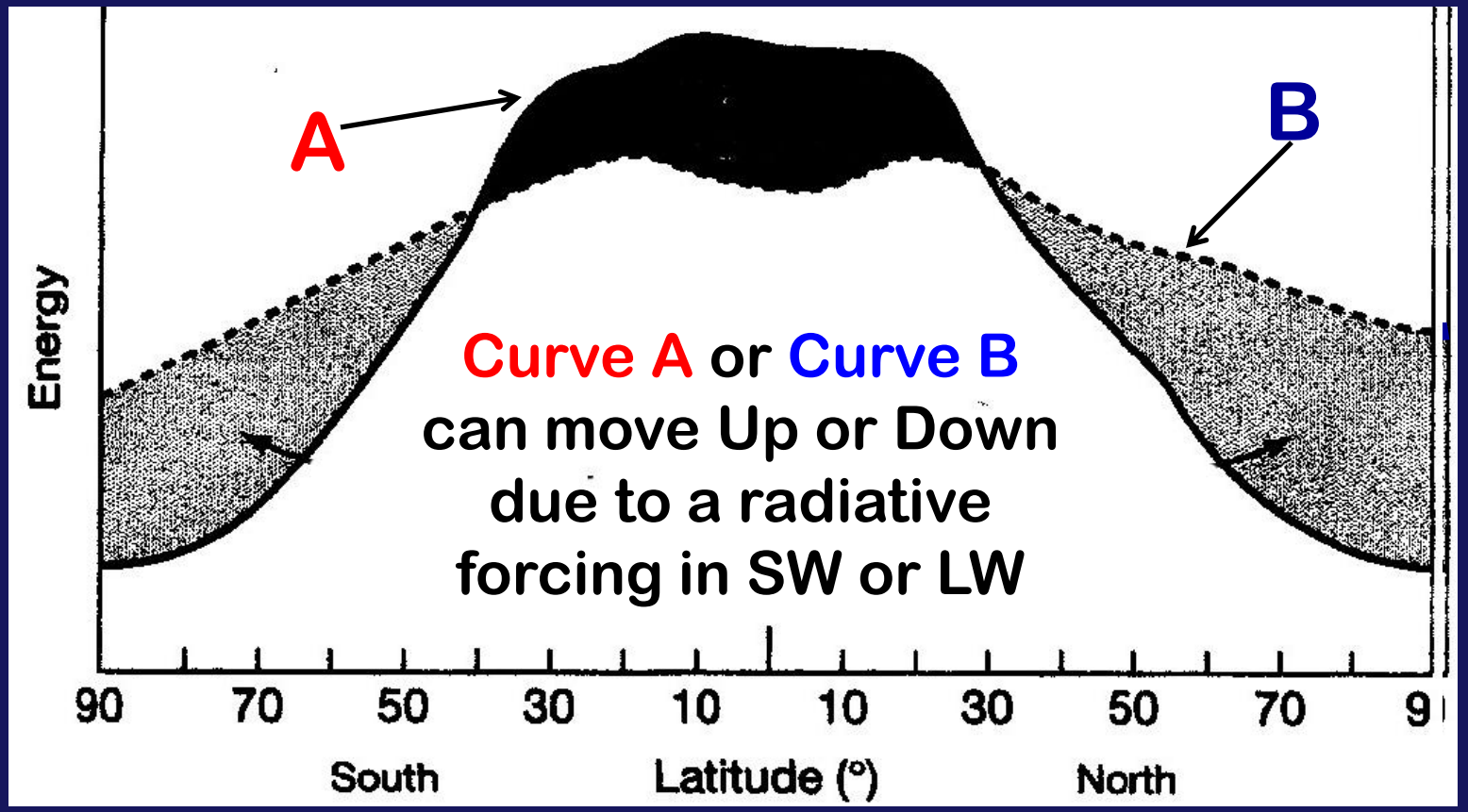
Come with your CLASS NOTES
to the LOBBY OF THE BANNISTER
TREE-RING BUILDING at 2 pm

NOTE: You don't need to be in your assigned group – come with friends from class or on your own!

TOPIC #11

NATURAL CLIMATIC FORCING

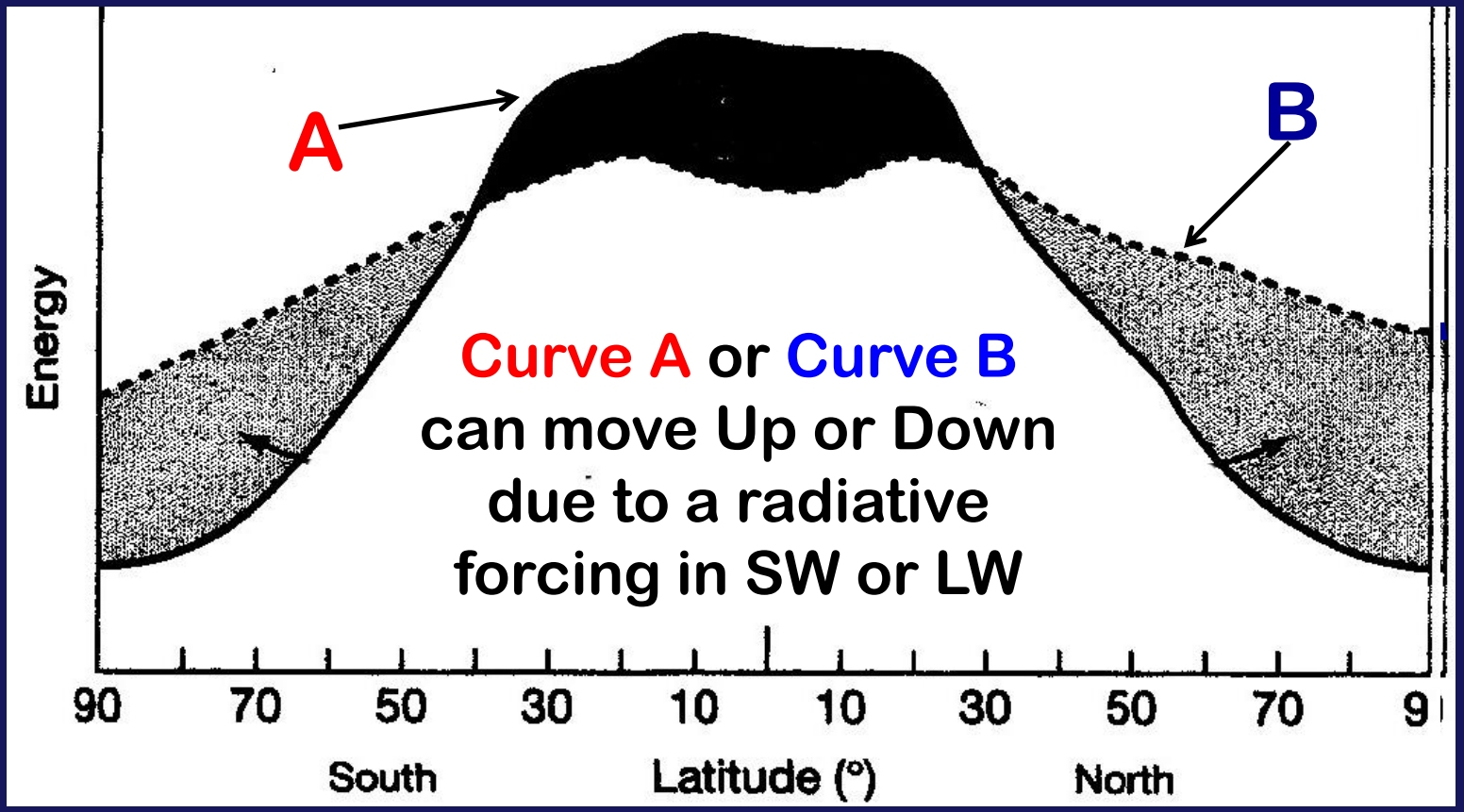
Global climate variability and change are caused by changes in the ENERGY BALANCE that are "FORCED"



CURVE A SW + SW - SW

CURVE B LW LW

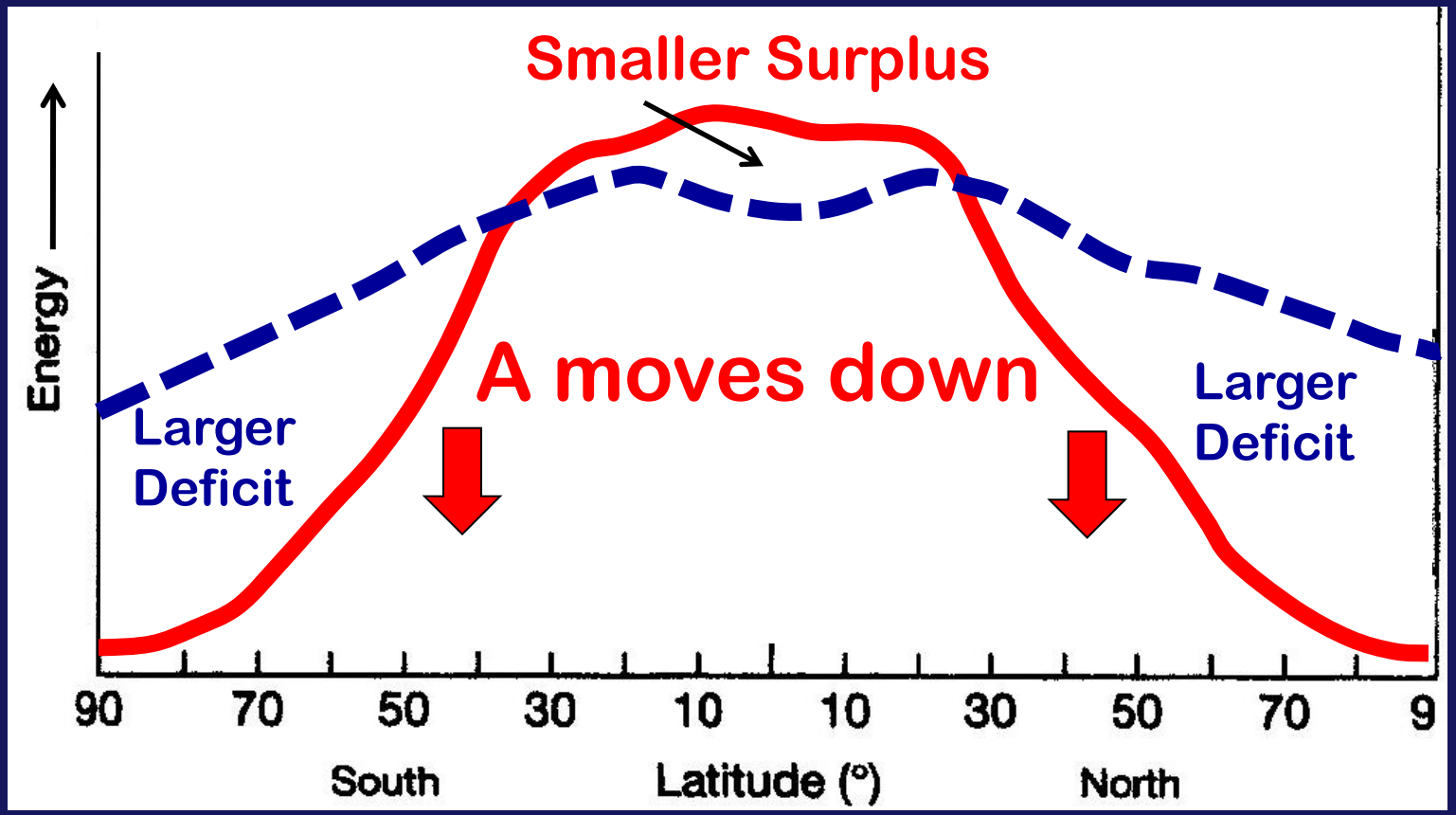
You can use this figure to conceptually "model" CLIMATE CHANGE in your mind!



CURVE A SW + SW - SW

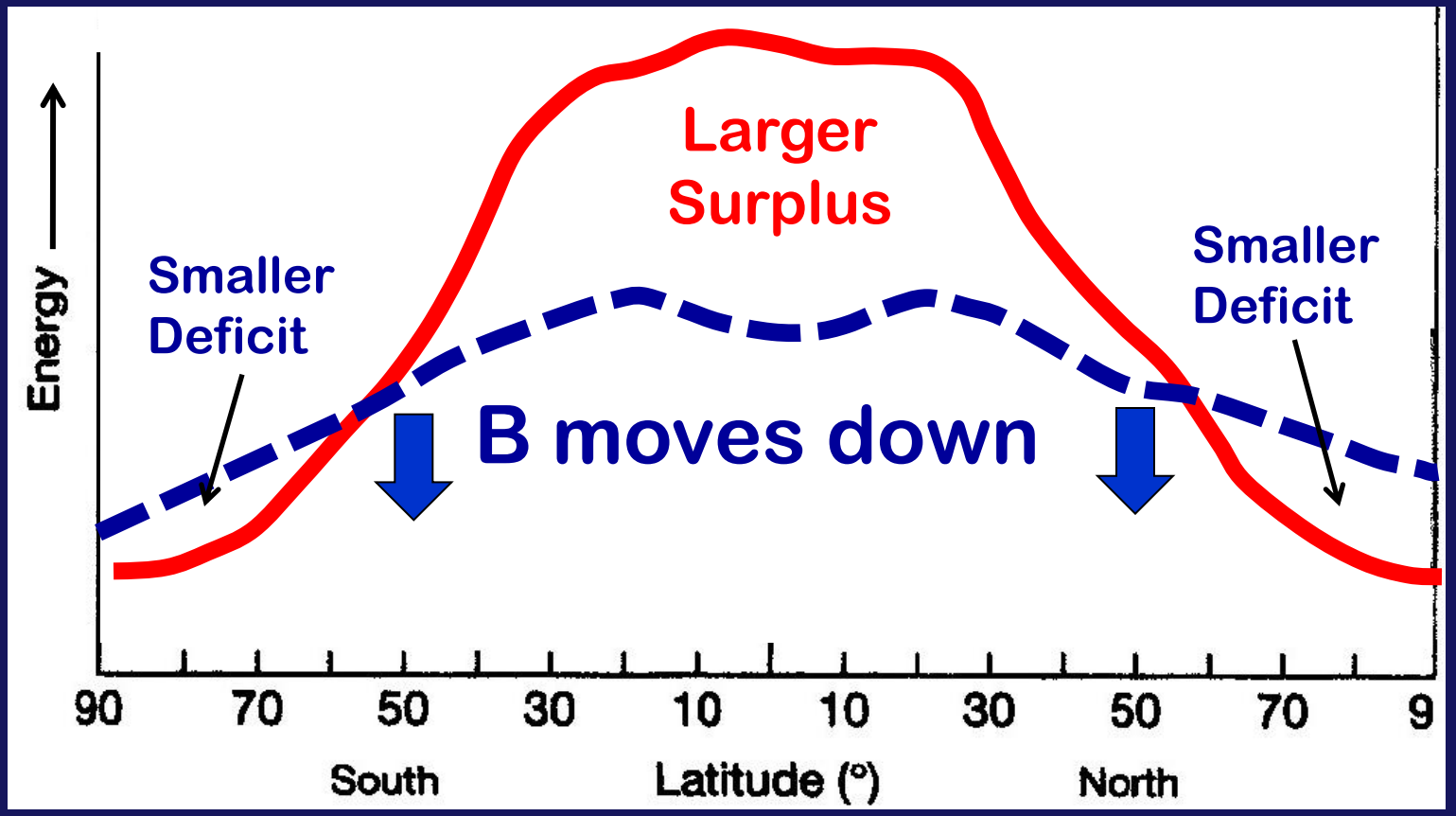
CURVE B LW LW

IF CURVE A moves down: SW ↓ + SW ⇣ - SW ↘



SW ↓ + SW ⇣ - SW ↘ If incoming energy represented by Curve A is reduced (A curve goes down)

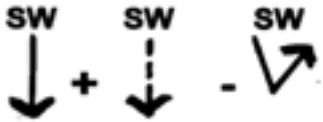
If CURVE B moves down

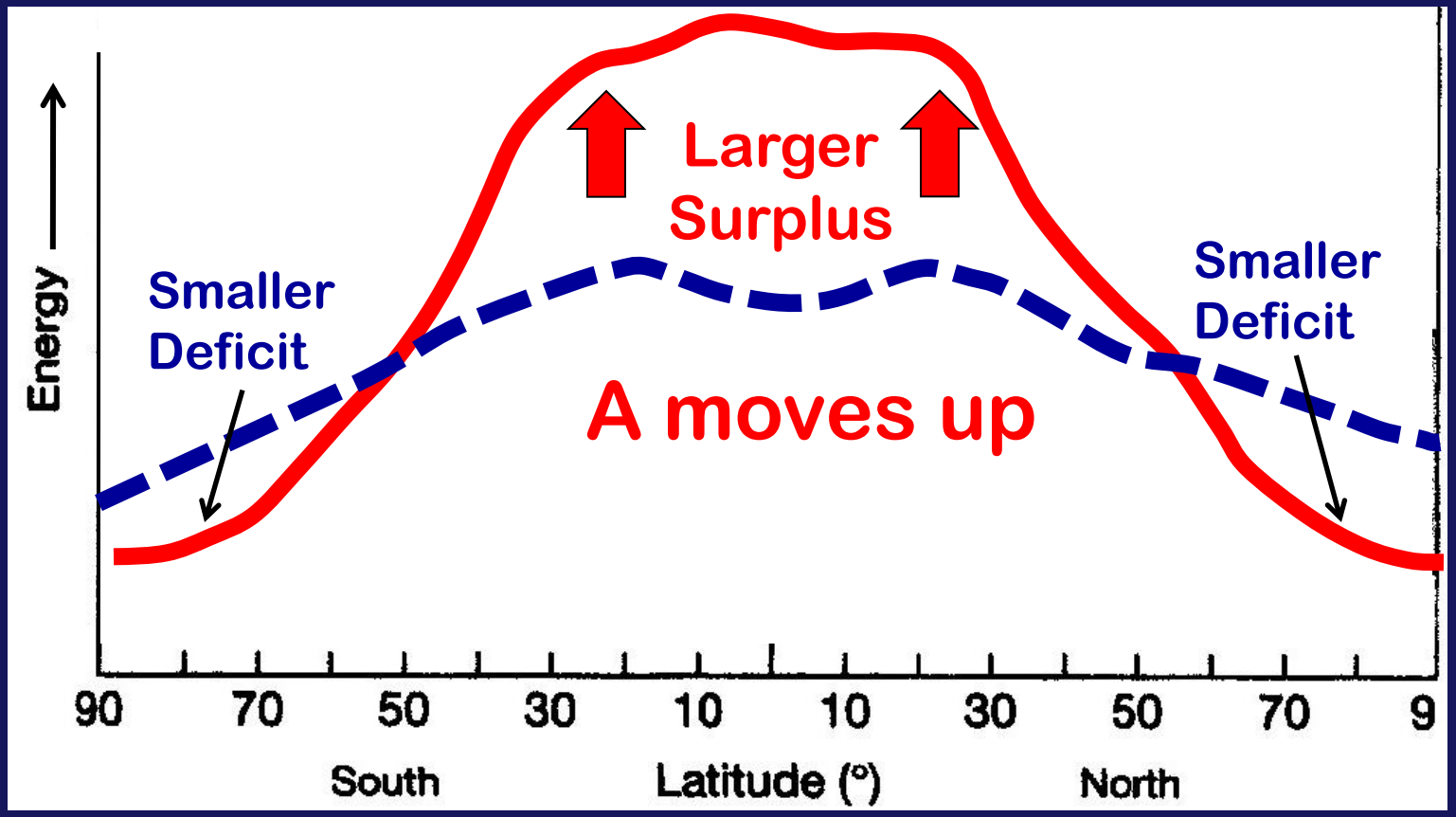


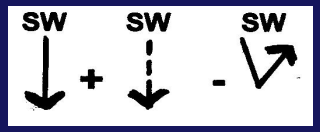
LW

If outgoing energy represented by Curve B is reduced (B curve goes down)

IF CURVE A moves up:

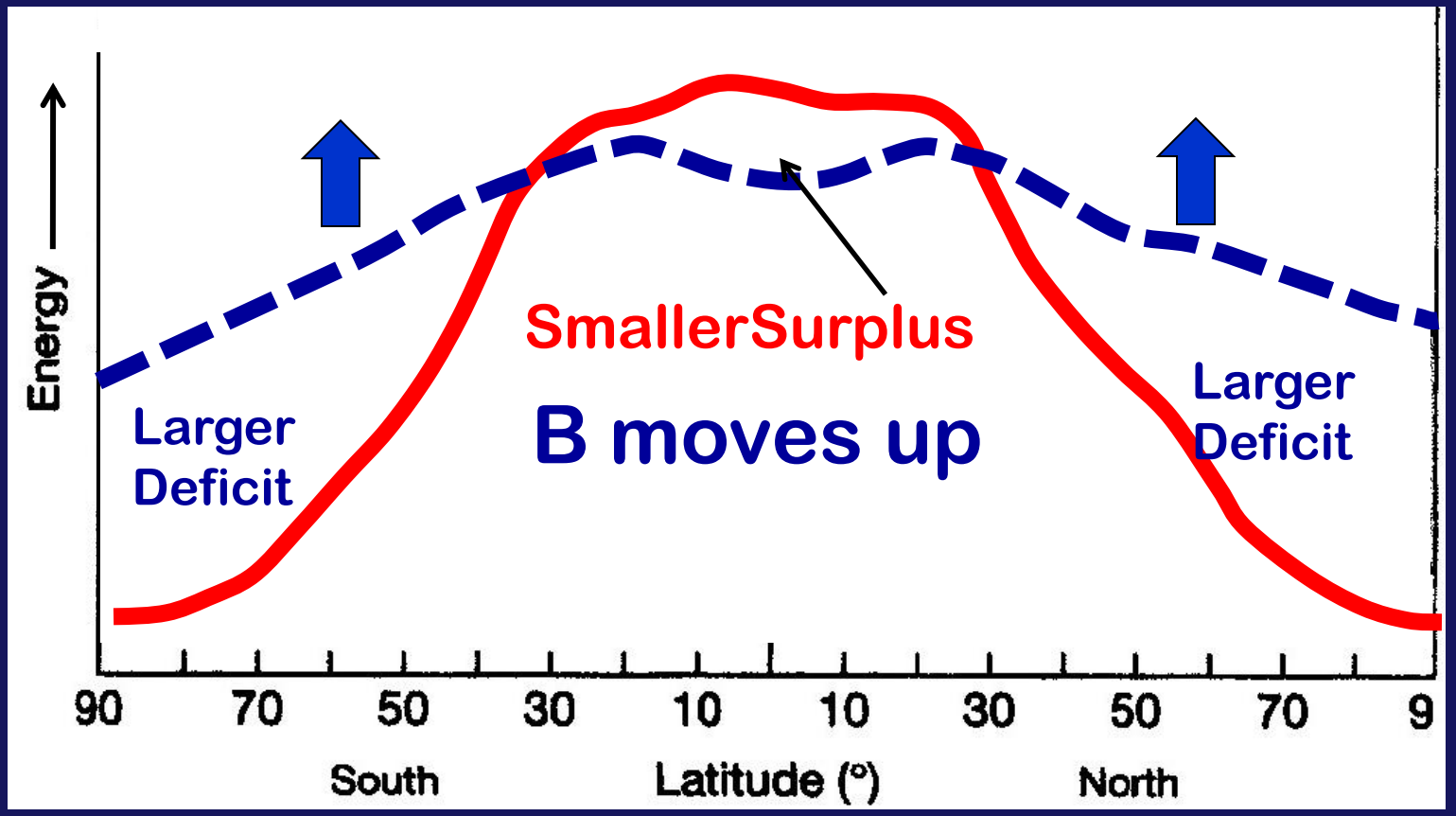






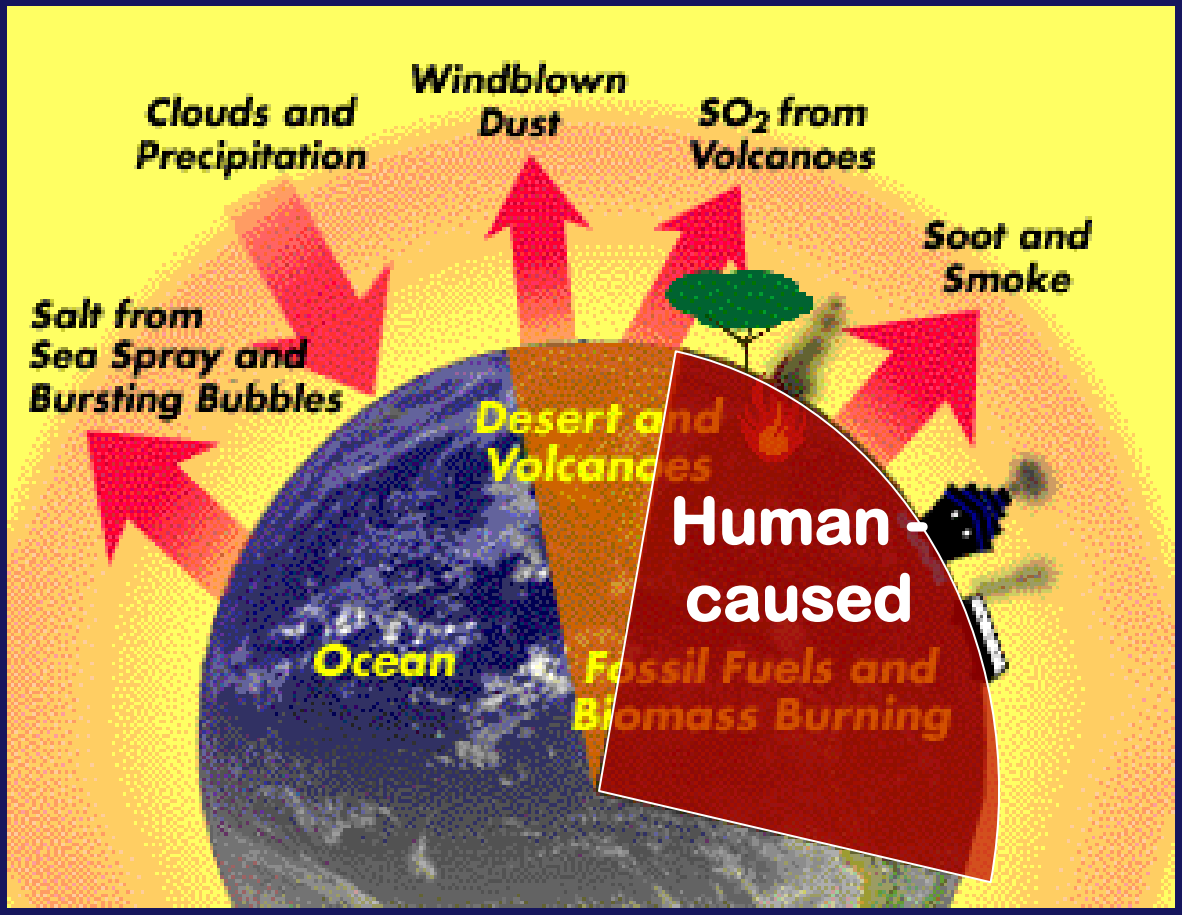
If incoming energy represented by Curve A is increased (A curve goes up)

If CURVE B moves up:



If outgoing energy represented by Curve B is increased (B curve goes up)

FORCING = a persistent disturbance of a system



(a longer term disturbance than a perturbation)

NATURAL CLIMATIC FORCING

vs.

ANTHROPOGENIC FORCING

Natural Climatic Forcing = changes due to natural earth-atmosphere-sun processes

- Earth-Sun orbital relationships
- Solar variability
- Changing land-sea distribution
  (over long time scales: due to plate tectonics)
- Volcanic eruptions

also: internal atmosphere-ocean variability (i.e., El Nino & La Nina), clouds, dust, etc

Anthropogenic Climatic Forcing = changes due to human causes or enhancement of the processes involved

- Enhanced Greenhouse Effect due to fossil fuel burning
- Land use changes due to human activity (deforestation, urbanization, etc.)
- Soot and aerosols from industry
- Chemical reactions in stratosphere involving human-made compounds (ozone depletion)

All things are connected. Whatever befalls the earth, befalls the children of the earth.

~ Chief Seattle

The 3 main drivers of NATURAL CLIMATIC FORCING:

1) ASTRONOMICAL FORCING

2) SOLAR FORCING

3) VOLCANIC FORCING

The 3 main drivers of NATURAL CLIMATIC FORCING:

1) ASTRONOMICAL FORCING ←
(Milankovitch Cycles)

1) SOLAR FORCING

2) VOLCANIC FORCING

Changes in Solar "Astronomical" Forcing have driven natural climate variability (ice ages, etc.) on LONG time scales (5,000 to 1 million years)

What has varied over time?

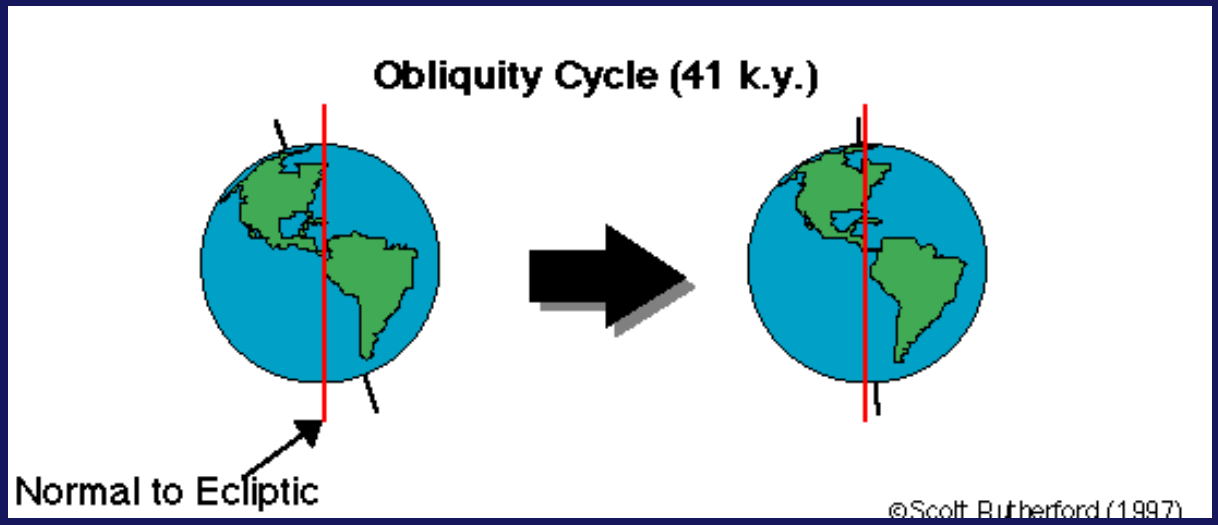
#1 OBLIQUITY OF EARTH'S AXIS

#2 ECCENTRICITY OF EARTH'S ORBIT

 # 3 Timing of Seasons in Relation to Orbit: "PRECESSION OF THE EQUINOXES"

1. OBLIQUITY OF EARTH'S AXIS

- axis "tilts" 23.5 degrees from plane of ecliptic
- causes the seasons
- has varied in the past from more "tilted" to more "vertical" (~24.5 ^{o} to ~ 22.5 ^{o})

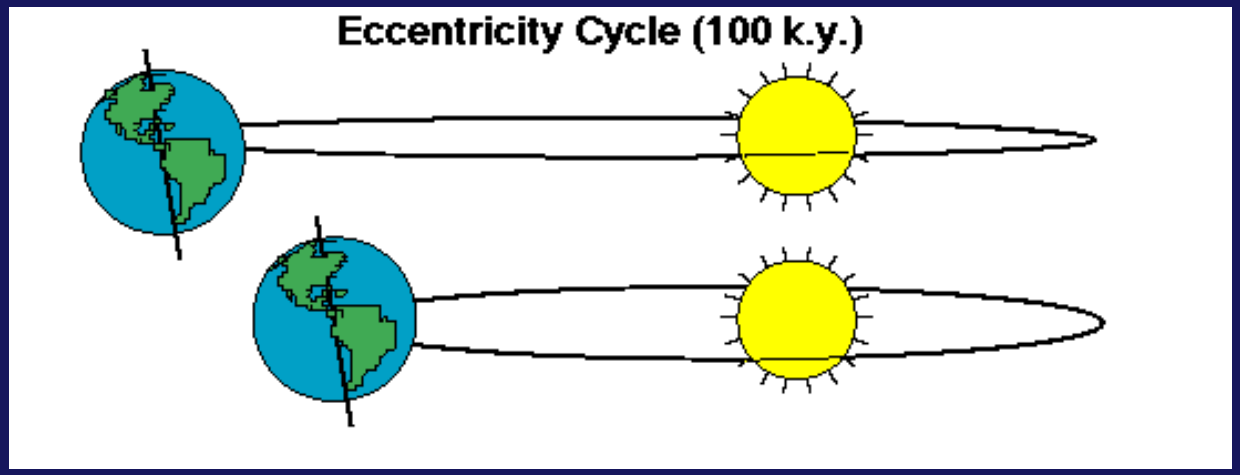


2. ECCENTRICITY OF ORBIT

- Earth's orbit around sun is not symmetrical

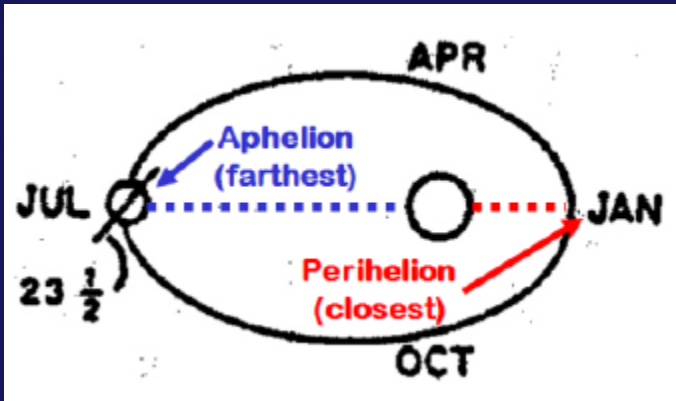
- Has varied in the past from more circular => elliptical shape

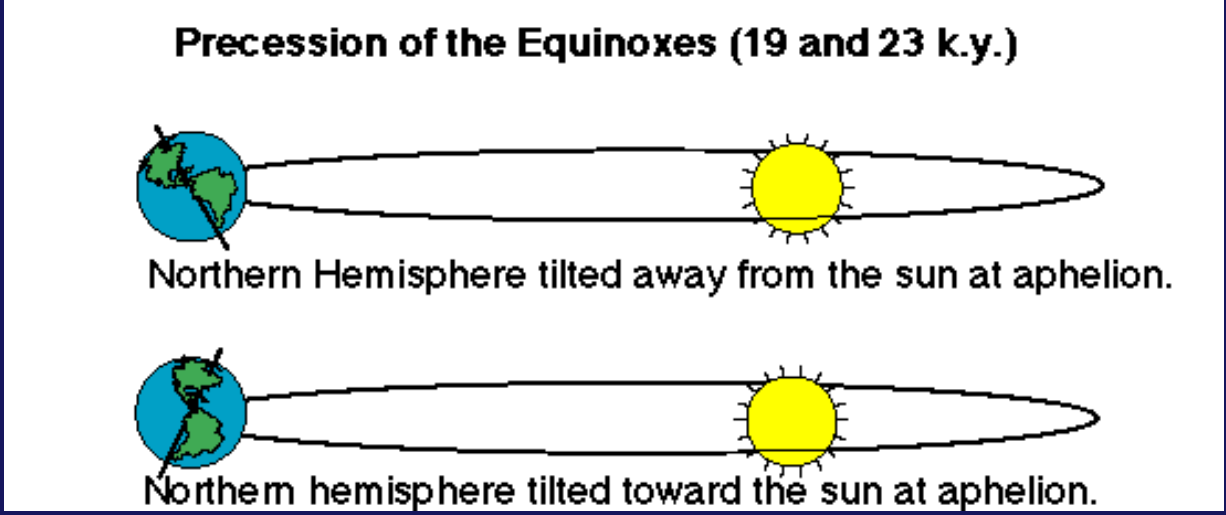
(more "eccentric!")



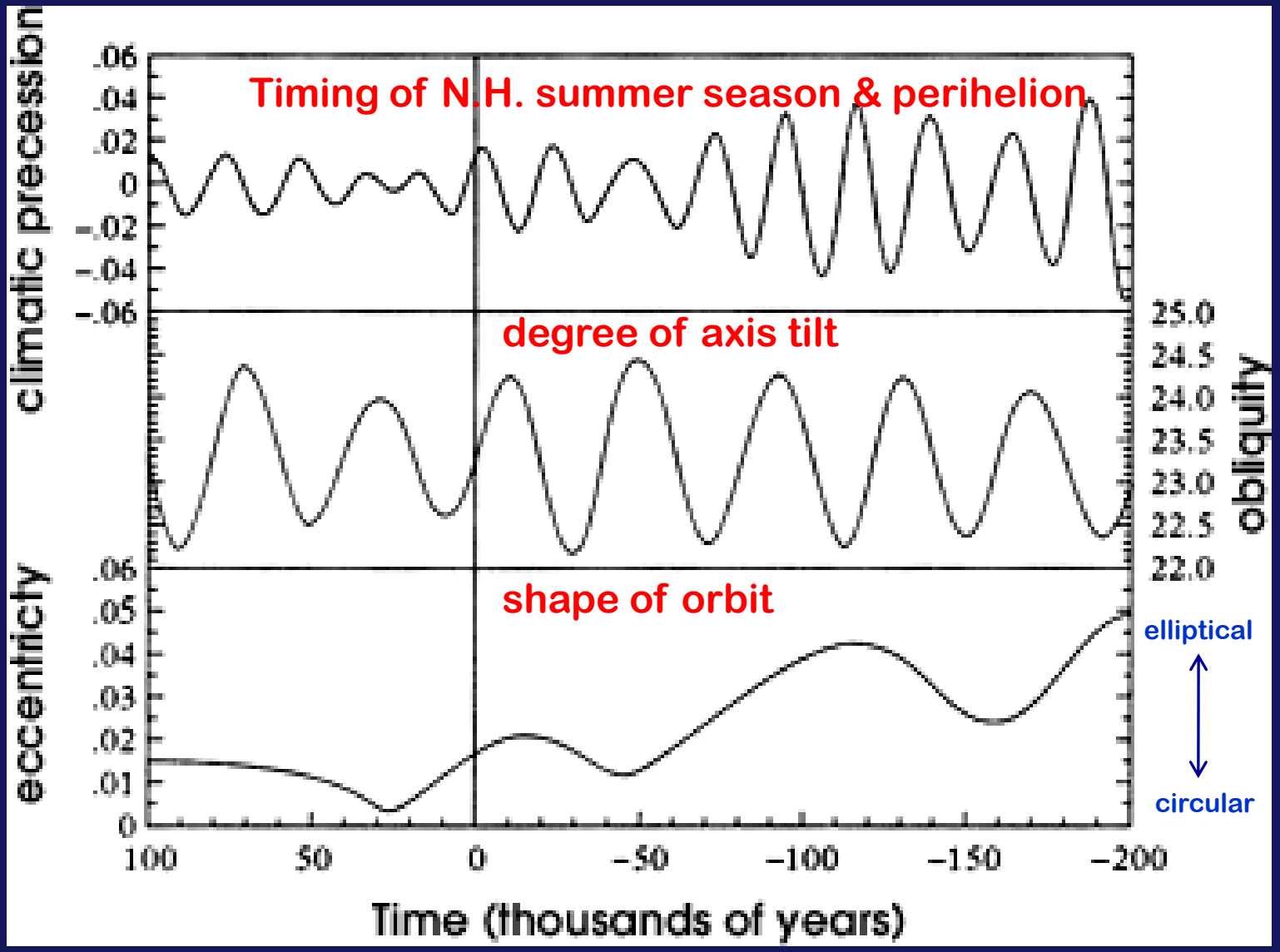
3. PRECESSION OF THE EQUINOXES
(Timing of Seasons in Relation to Orbit)

Currently the Earth is <u>closest to the Sun</u> (perihelion) in Jan & <u>farthest</u> (aphelion) in July. This has varied in the past.

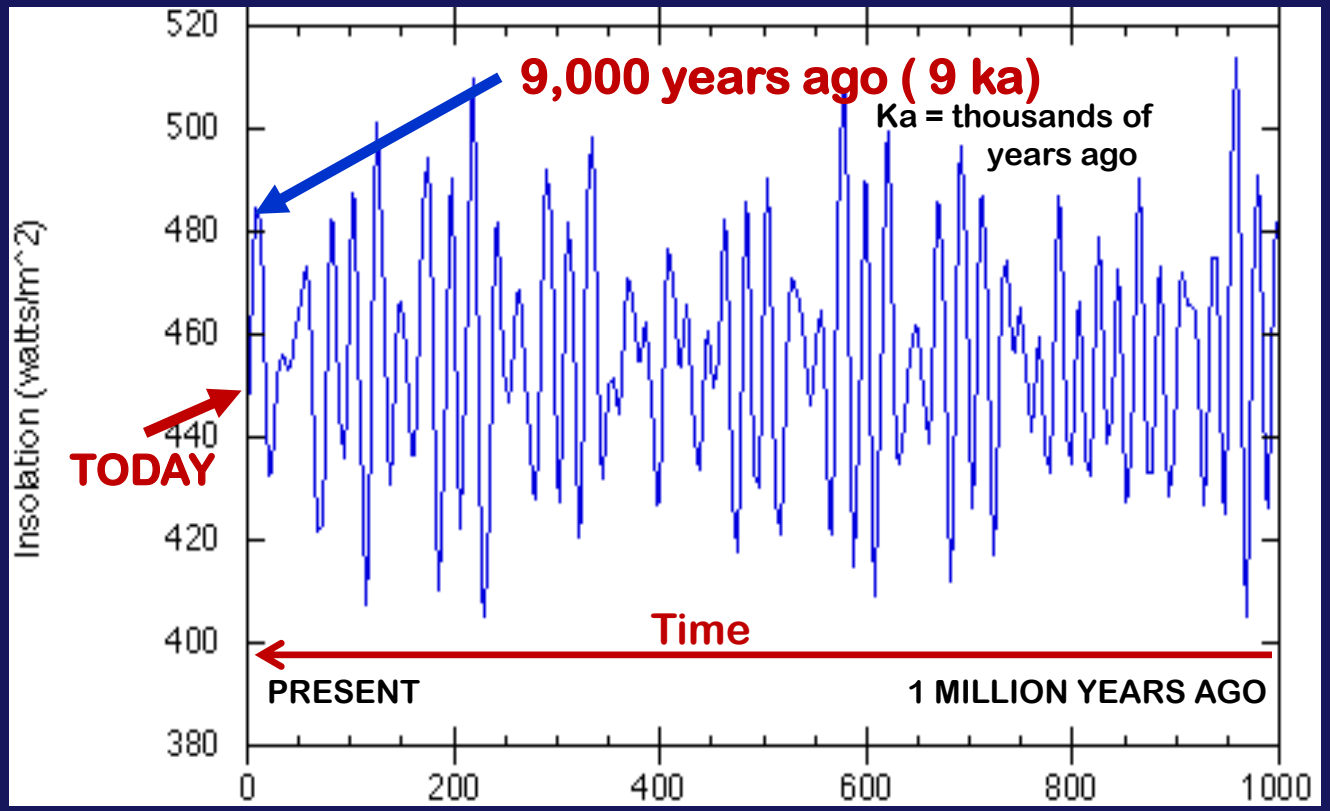




the Future ← TODAY → the Past *(in thousands of years)*



Summarizing graph of SOLAR INSOLATION calculated for 65 ° N latitude from the present to 1 million years ago based on "ASTRONOMICAL CLIMATE FORCING"



p 72

In the Northern Hemisphere, peak summer insolation occurred about 9,000 years ago when the last of the large ice sheets melted.

Since then N. H. summers have seen LESS solar radiation.

Mid-Holocene warm period
(~ 6,000 years ago)

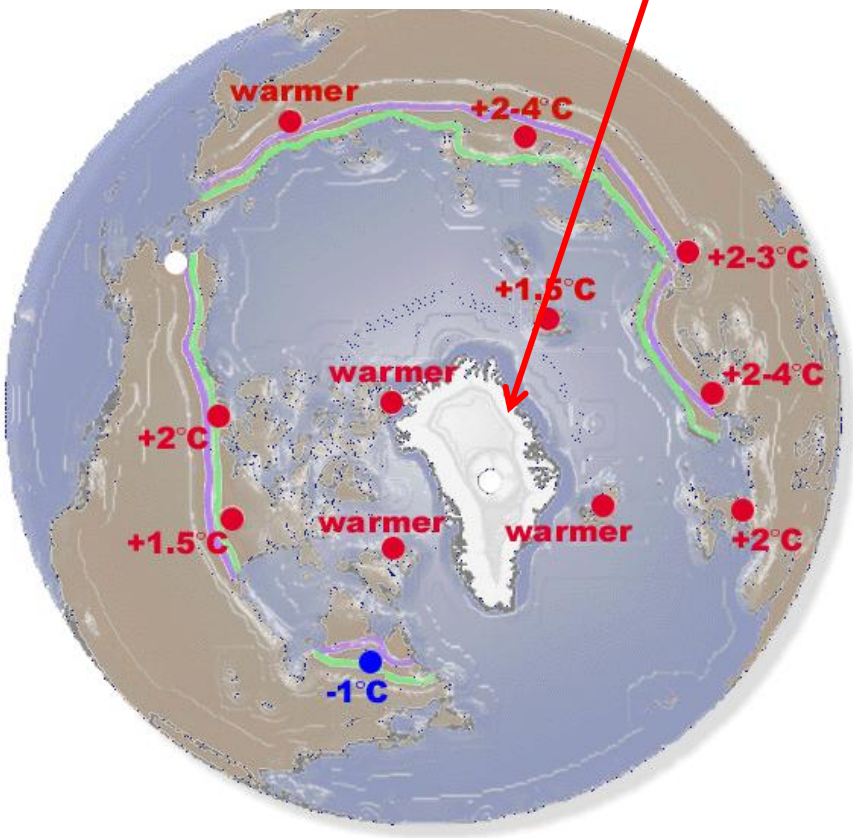
Generally warmer than today, but only in summer and only in the northern hemisphere.

Cause =

"astronomical climate forcing"

(Milankovitch Cycles)

Global warming "deniers" often point out how warm Greenland was in the past :



Top p 72

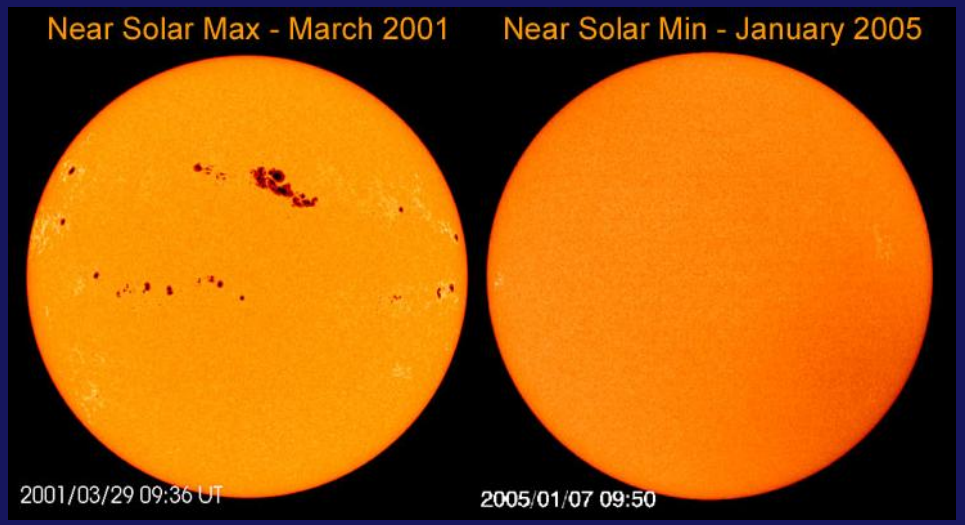
The 3 main drivers of NATURAL CLIMATIC FORCING:

1) ASTRONOMICAL FORCING

2) SOLAR FORCING ←

3) VOLCANIC FORCING

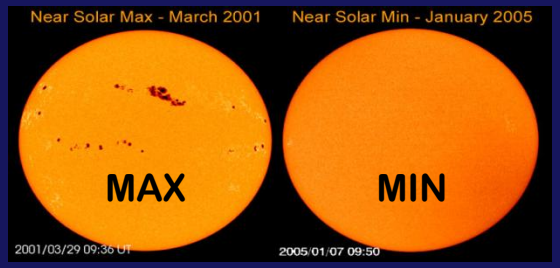
ANOTHER NATURAL FORCING:
SOLAR VARIABILITY

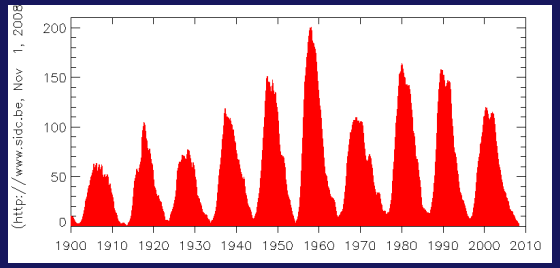


Sunspot maxima = MORE solar brightness (warmer temps)

Sunspot minima = LESS solar brightness (cooler temps)

ANOTHER NATURAL FORCING:
SOLAR VARIABILITY





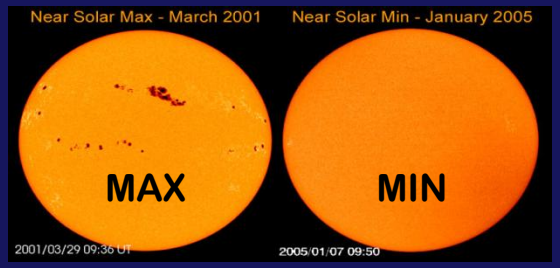
Clicker Q3 – During SUNSPOT Maximum periods:

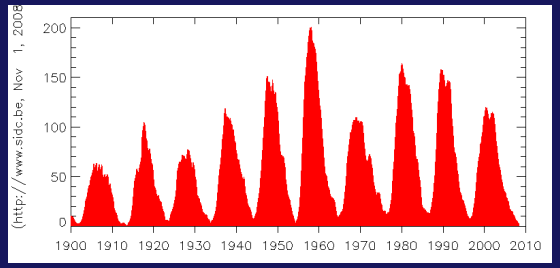
1. The sun is darker so it gives off less energy and global cooling is likely.

2. The sun sunspots indicate active solar flares and the sun gives off more energy leading to warmer periods.

3. There is no link between solar activity and global warming.

ANOTHER NATURAL FORCING:
SOLAR VARIABILITY



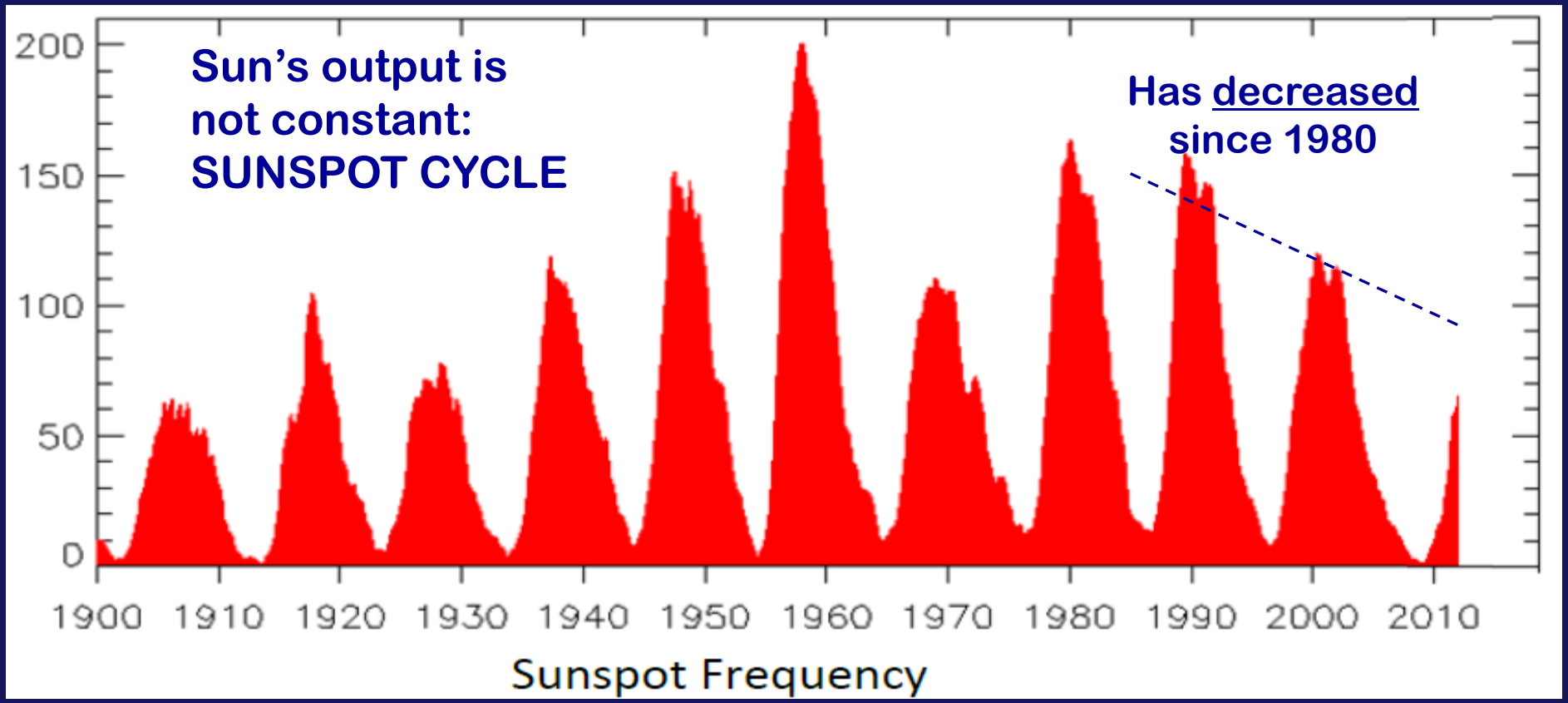


Clicker Q3 – During SUNSPOT Maximum periods:

1. The sun is darker so it gives off less energy and global cooling is likely.

2. The sun sunspots indicate active solar flares and the sun gives off more energy leading to warmer periods.

3. There is no link between solar activity and global warming.

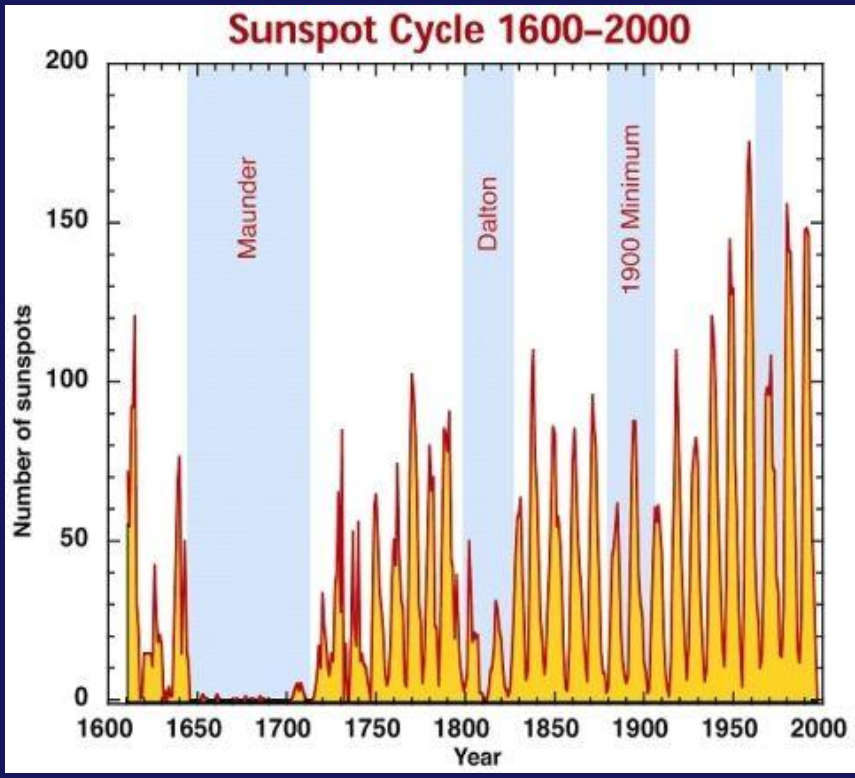


http://www.sidc.be/sunspot-index-graphics/sidc_graphics.php

Sunspot maxima = MORE solar brightness (warmer temps)

Sunspot minima = LESS solar brightness (cooler temps)

Maunder Minimum (cooler) (1645 -1715) linked to "Little Ice Age" (1600-1800)



But uncertainties remain!
What's the MECHANISM that links the Sun's drop in brightness to the lower temperatures on the Earth?

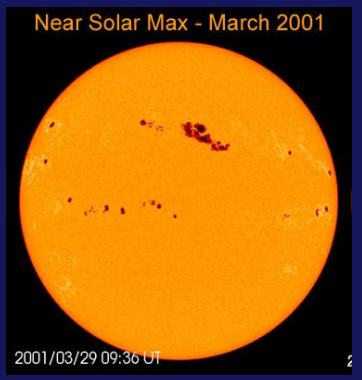
Dalton Minimum (1795 – 1825)

-- was also cooler

-- BUT, lots of large volcanic eruptions then too

Since the Dalton Minimum, the Sun has gradually brightened , e.g., "Modern Maximum" (in 2001)

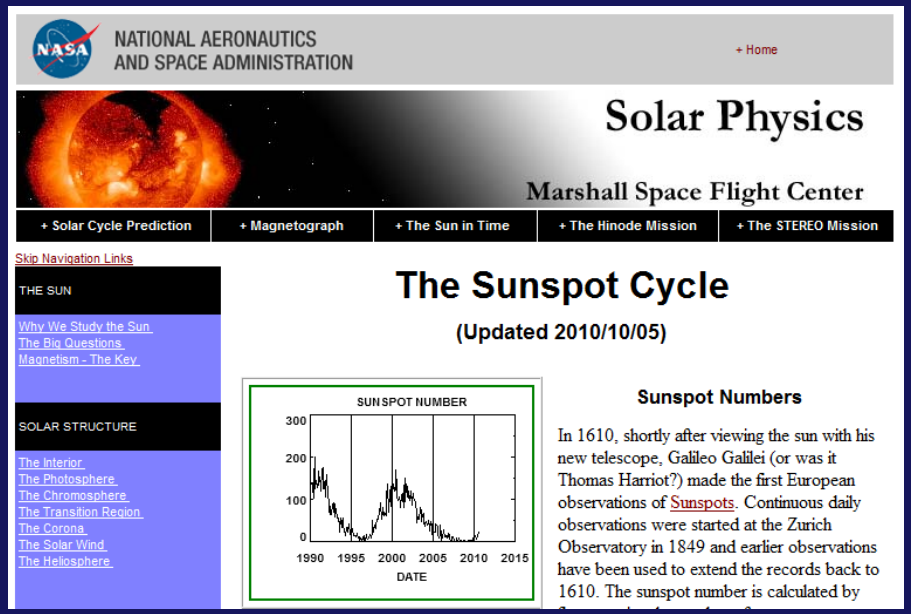
BUT . . .
The increase in solar brightness during the recent "Modern Maximum" accounted for only:



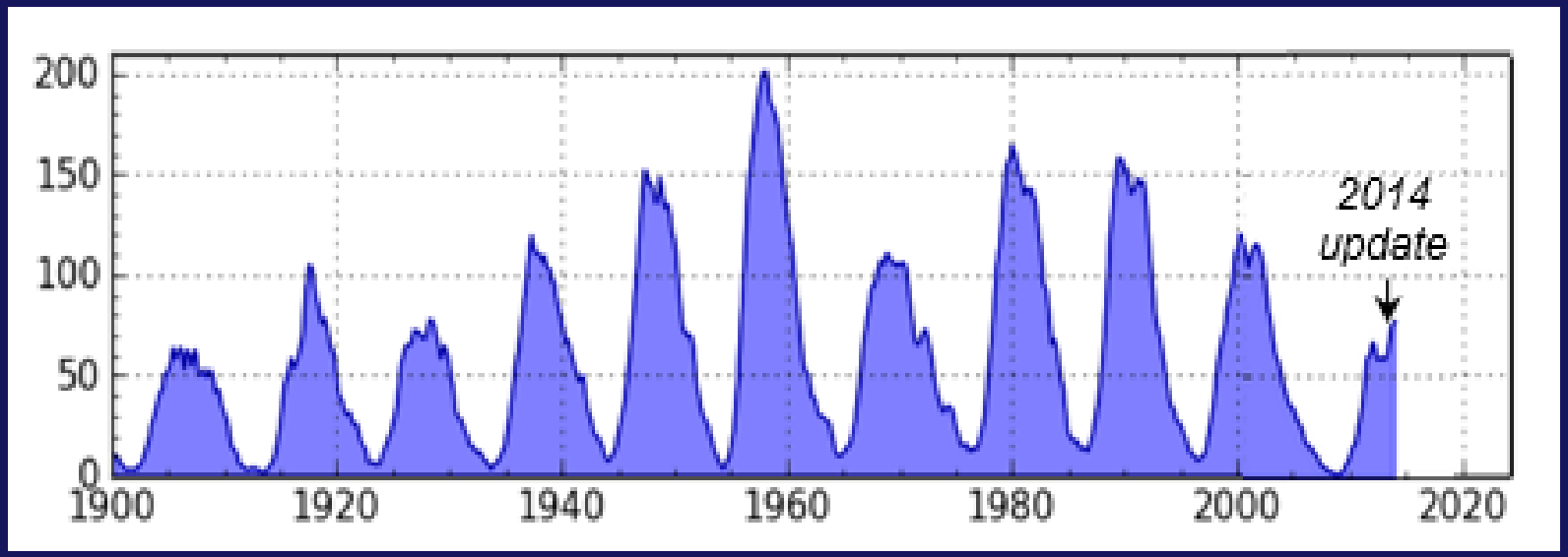
- **about ½ of the temperature increase since 1860**, and
- **less than 1/3 since 1970**

The rest is attributed to greenhouse-effect warming by most experts in solar forcing.

What is happening today?



http://solarscience.msfc.nasa.gov/SunspotCycle.shtml



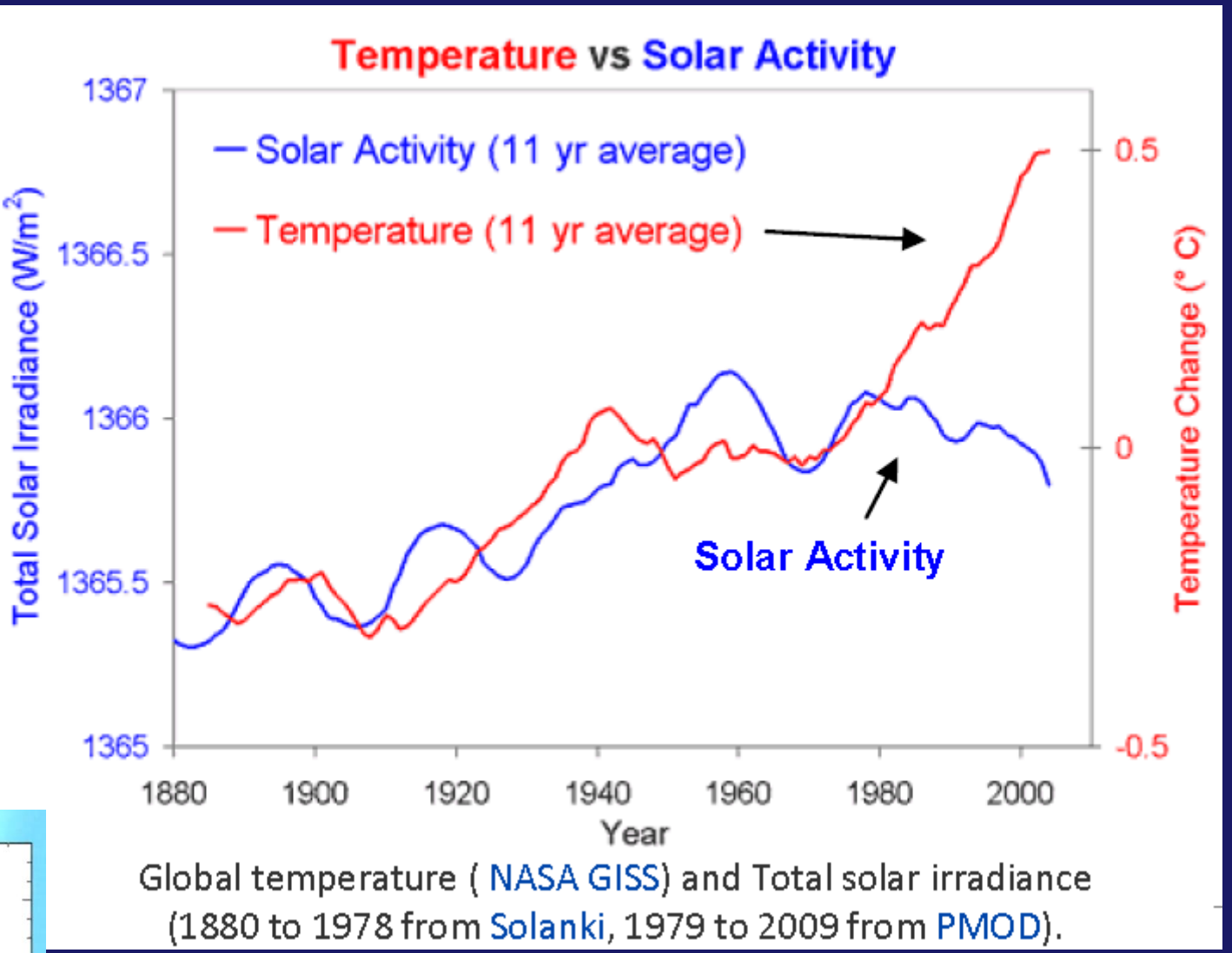
SEE ALSO: http://www.sidc.be/sunspot-index-graphics/sidc_graphics.php

Exploring Another Myth . . .

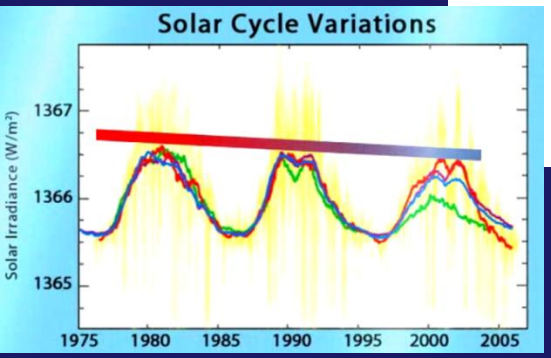
Climate Myth #2:

"It's the Sun"

(i.e., the recent warming is from natural solar variability)

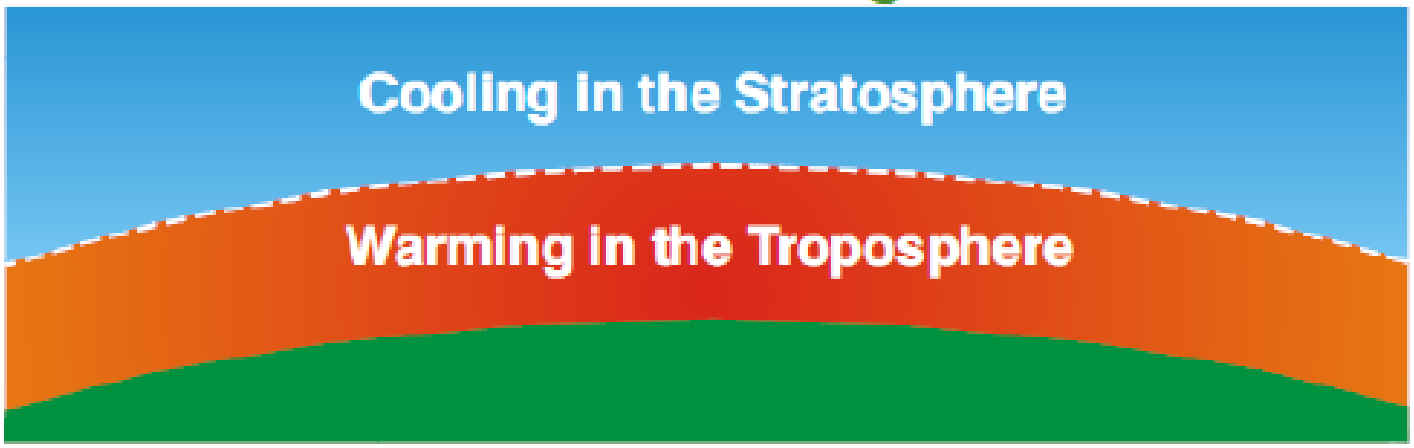


Global temperature (NASA GISS) and Total solar irradiance (1880 to 1978 from Solanki, 1979 to 2009 from PMOD).



← "Clearing the Air" in Lesson 2

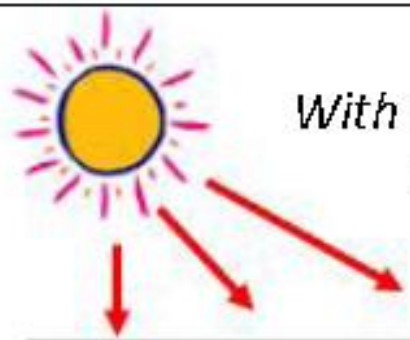
The Greenhouse Signature



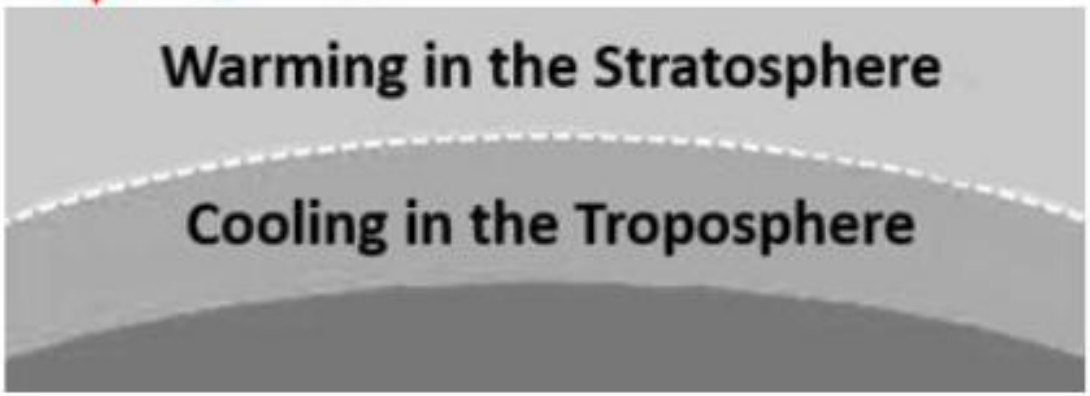
What would a SOLAR Warming Signature look like?

Review

The Solar Irradiance Signature:

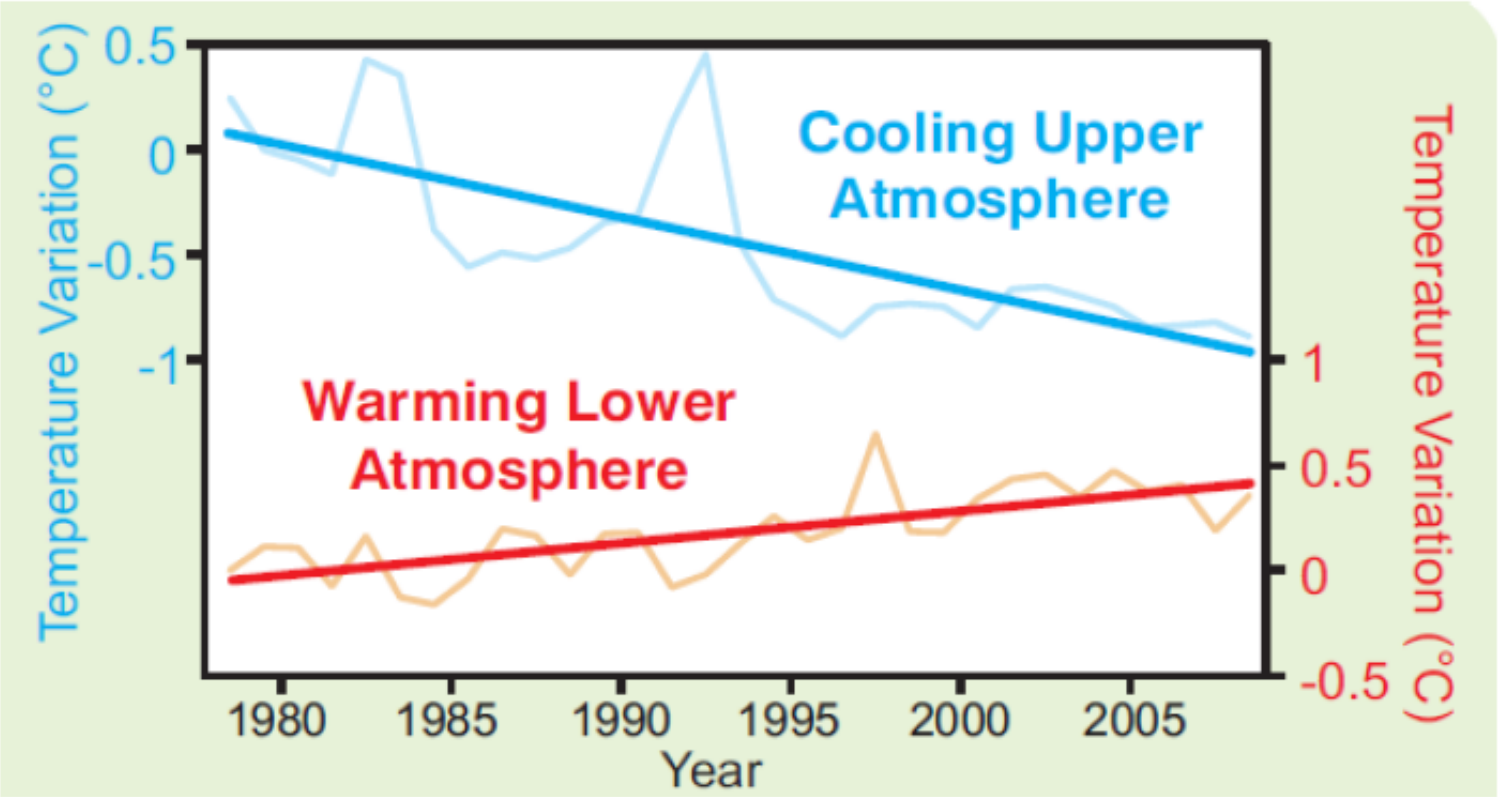


With increased Solar Activity we would expect to see "top down" warming:



Solar Signature = Warming in the upper atmosphere & cooling in the Troposphere . . .

What has been observed since 1980?



Temperature variations (degrees C) in the upper (stratosphere) and lower (troposphere) atmosphere (measured by satellites)

Topic # 11
(Volcanic Forcing)
to be continued . . . .

SEE YOU ON TUESDAY!
STUDY HARD FOR TEST #3 !!

Remember: the first Tree-Ring Wood Kit Activity Session is tomorrow afternoon @ 2 pm!!