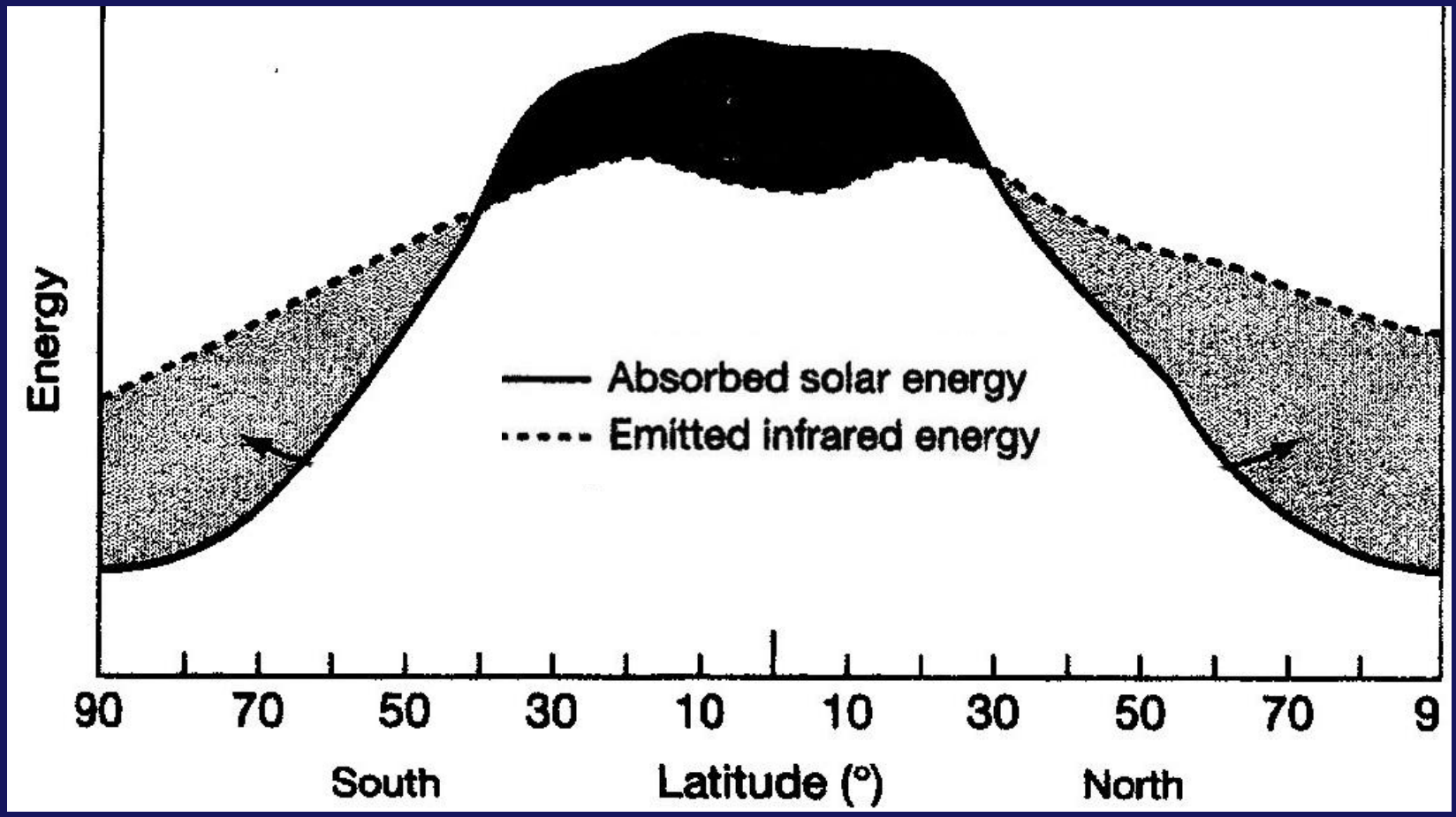
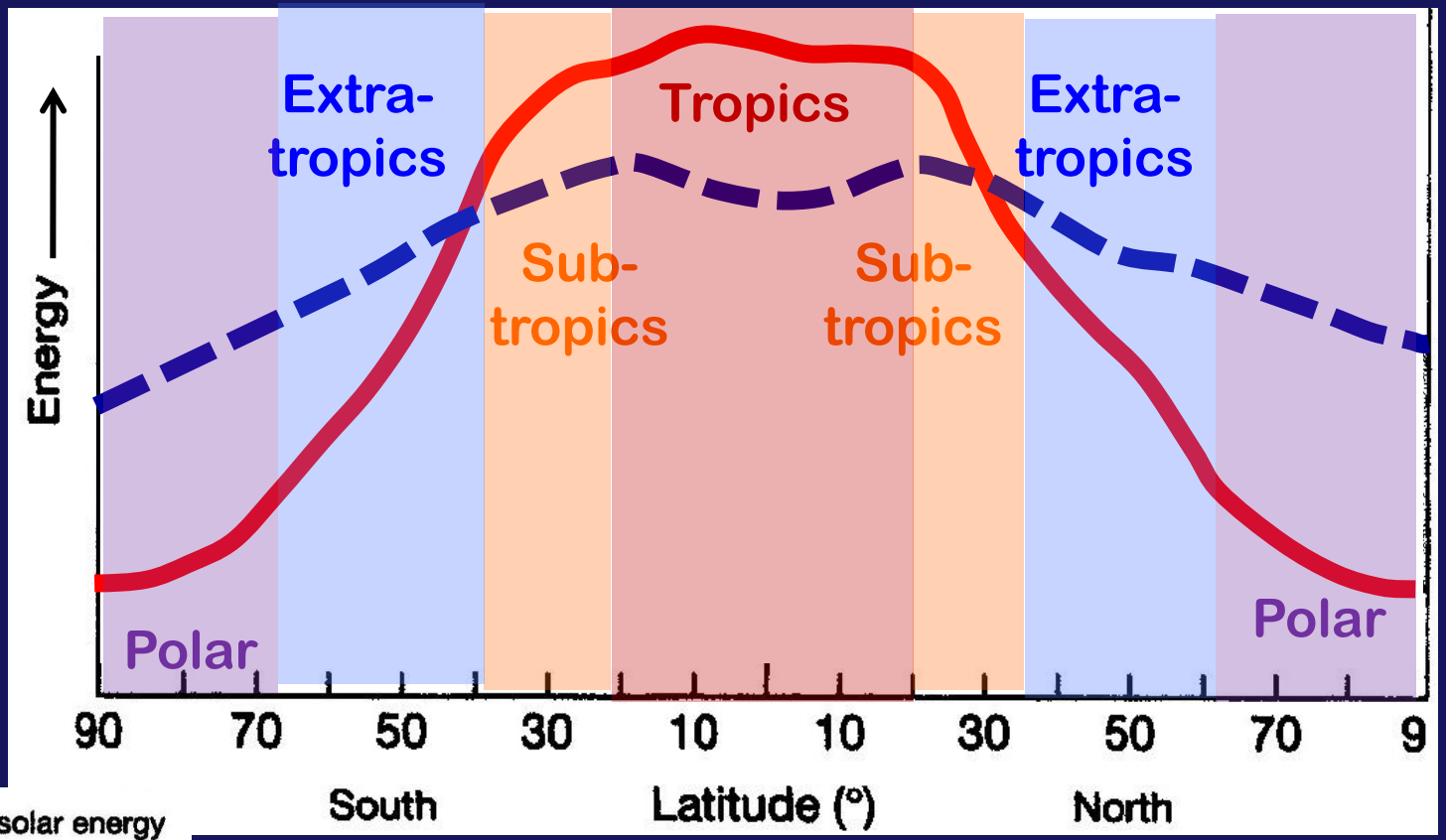
TOPIC #10

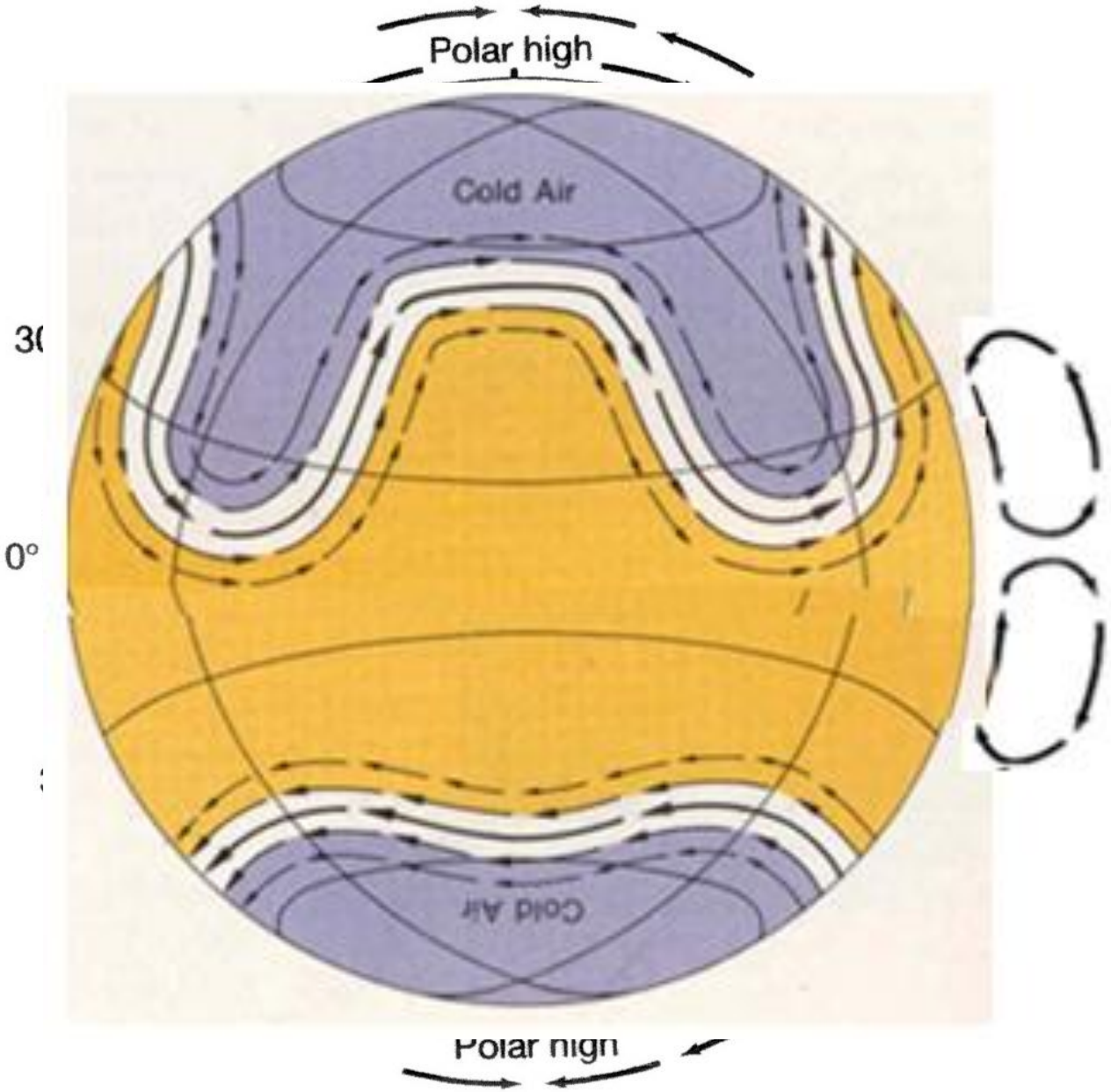
Wrap Up on GLOBAL CLIMATE PATTERNS


Energy
Absorbed solar energy
Emitted infrared energy
90
70
50
30
10
10
30
50
70
9
South
Latitude (°)
North

ENERGY BALANCE & CLIMATE REGIONS



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

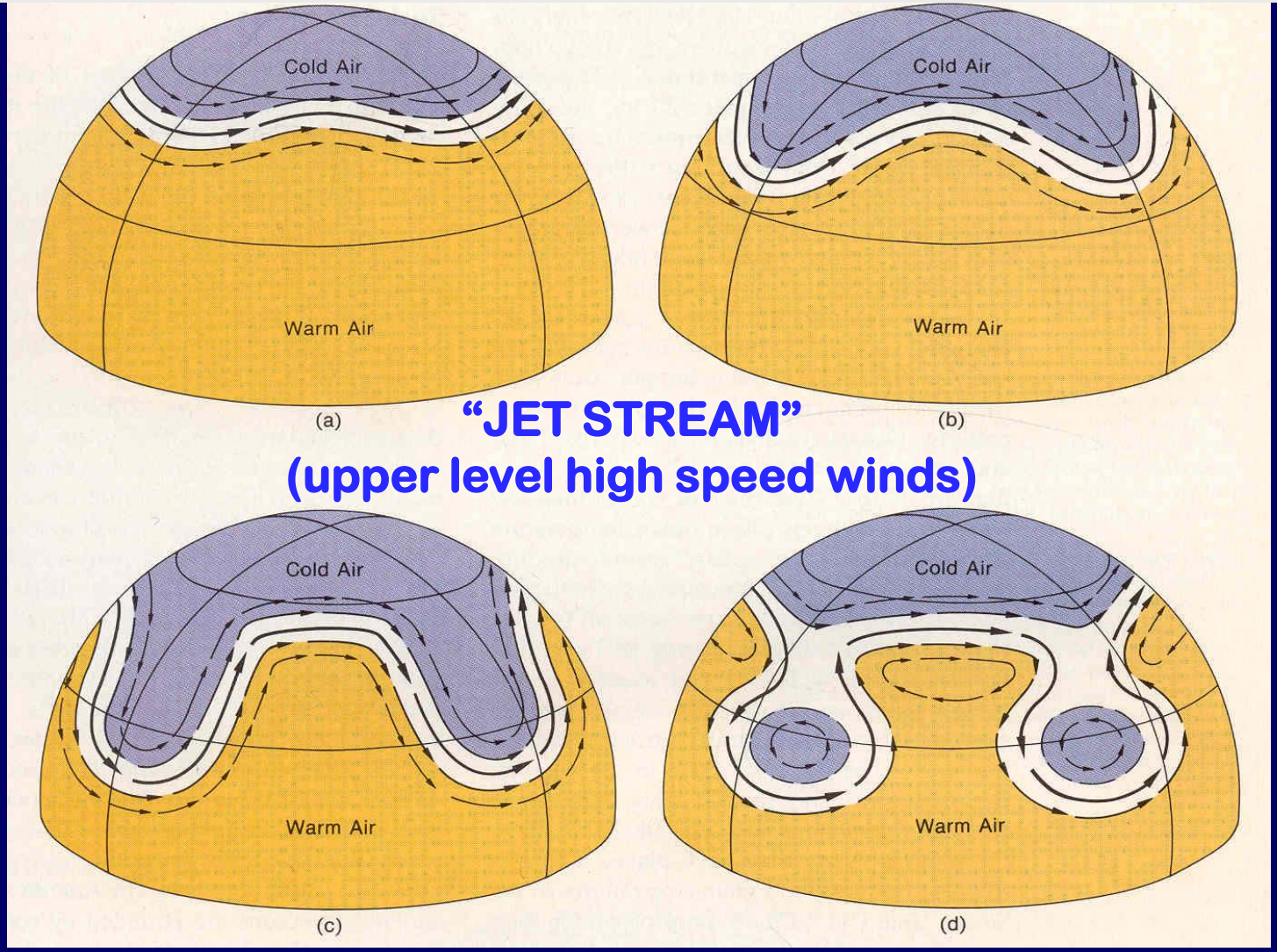


ROSSBY WAVES

HADLEY CELLS

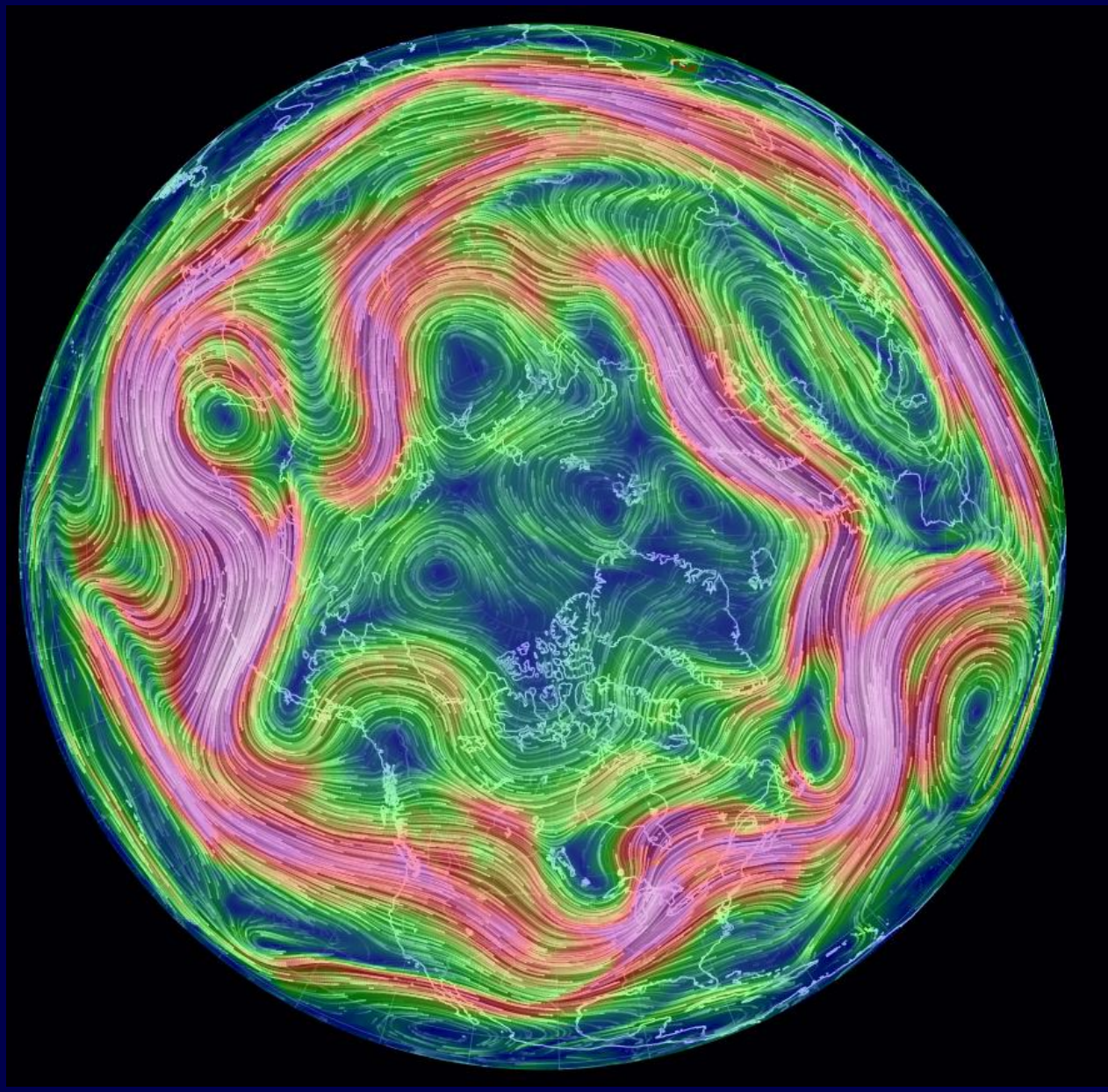
ROSSBY WAVES

UPPER LEVEL "ROSSBY WAVE" CIRCUMPOLAR WINDS !



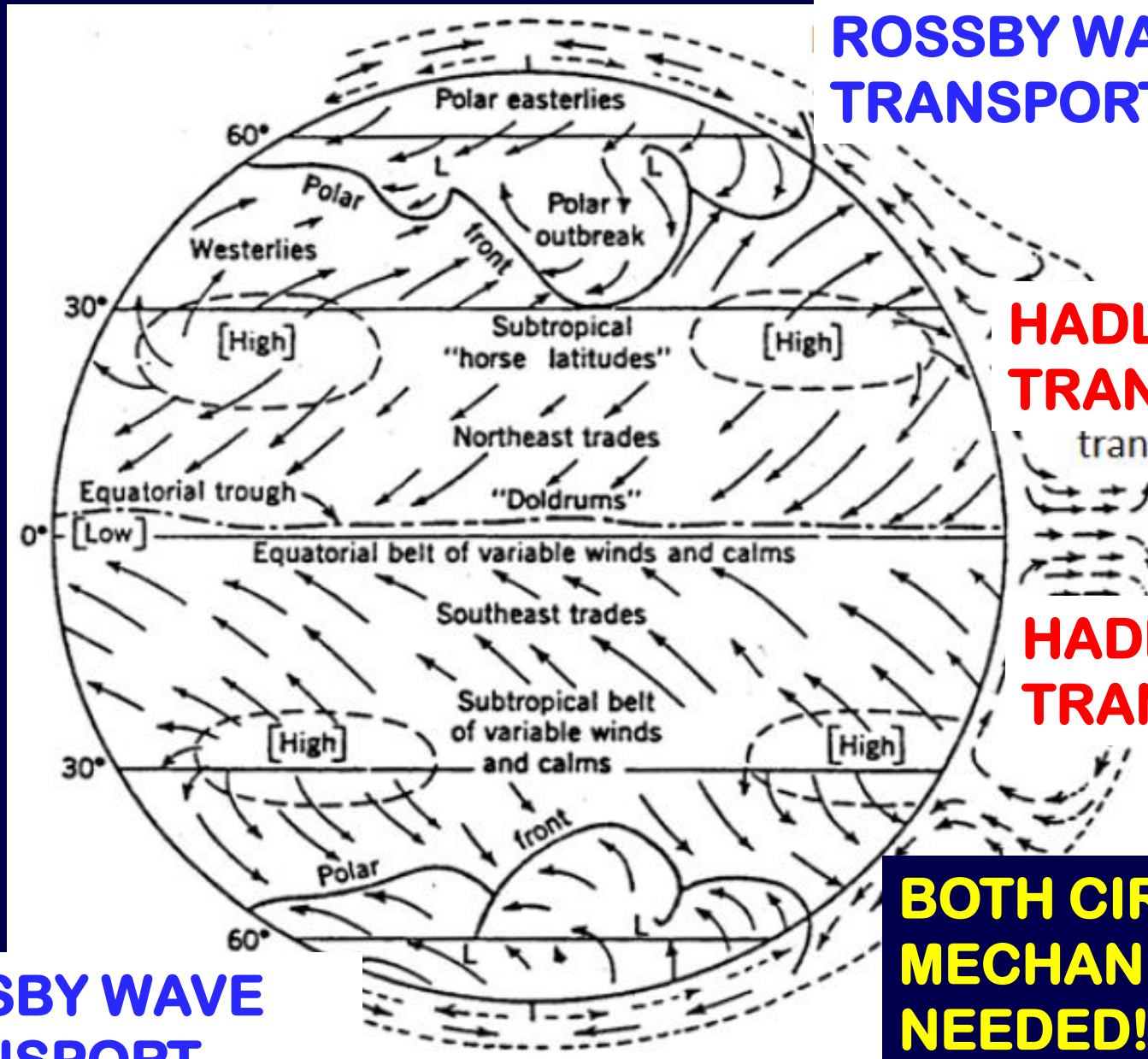
"Wave" transport of Energy as SENSIBLE HEAT
(in lobes of warm air)!

WHAT'S HAPPENING TODAY?



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

The "GENERAL CIRCULATION OF THE ATMOSPHERE"



ROSSBY WAVE TRANSPORT

HADLEY CELL TRANSPORT

transport

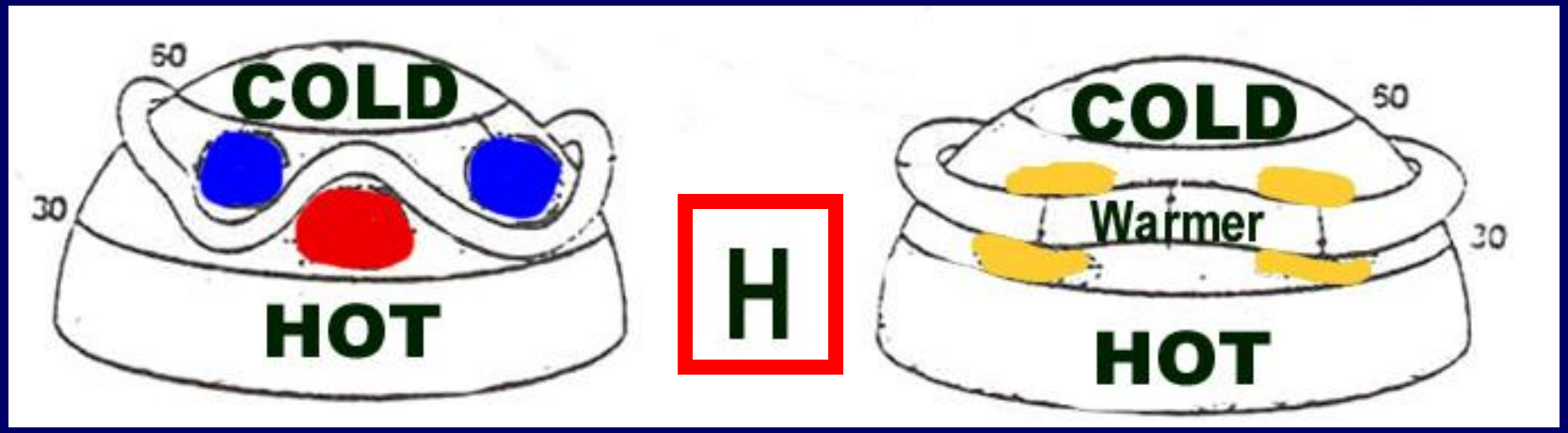
HADLEY CELL TRANSPORT

BOTH CIRCULATION MECHANISMS ARE NEEDED!

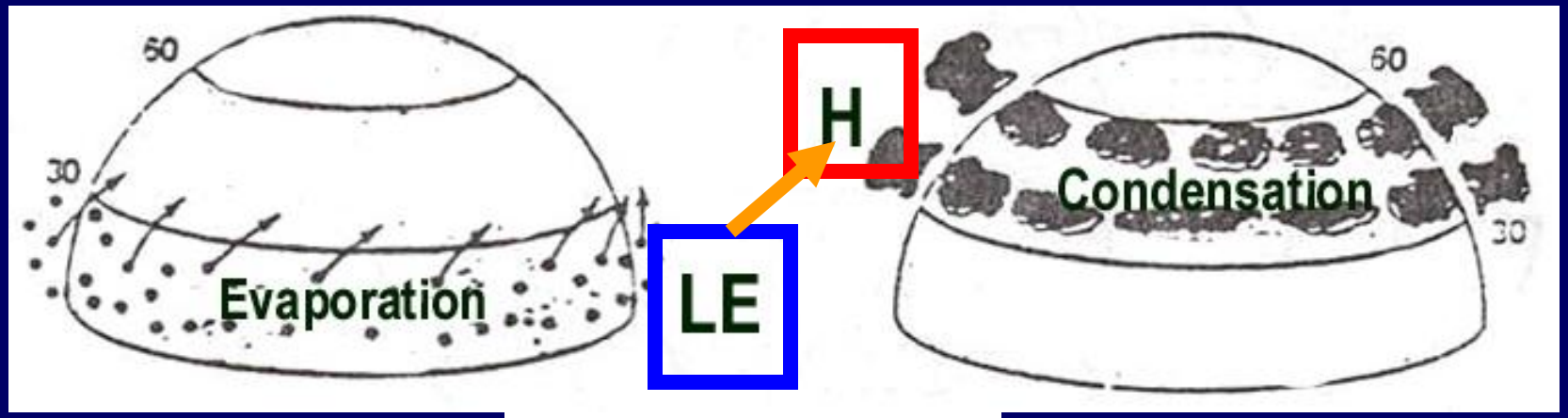
ROSSBY WAVE TRANSPORT

ENERGY is transported from areas of surplus to deficit via

Warm Air transport : H (sensible heat)



& LE (Latent Energy) transport

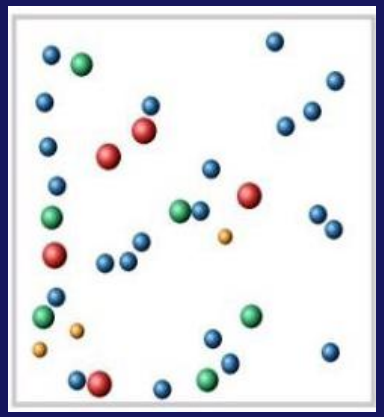


H + LE

Recap: Right Side of Energy Balance Equation:

H + LE + G

H (Sensible Heat) can be "sensed" as hot and cold temperatures due to the kinetic energy of the gas molecules →



Warm air

Cold air

Top of p 51

Recap: Right Side of Energy Balance Equation:

Phase changes ➔

H ➔ LATENT ENERGY

STORED during

EVAPORATION & TRANSPIRATION

AMAZON RAIN FOREST

theguardian

News | US | World | Sports | Comment | Culture | Business | Money

Environment › Amazon rainforest

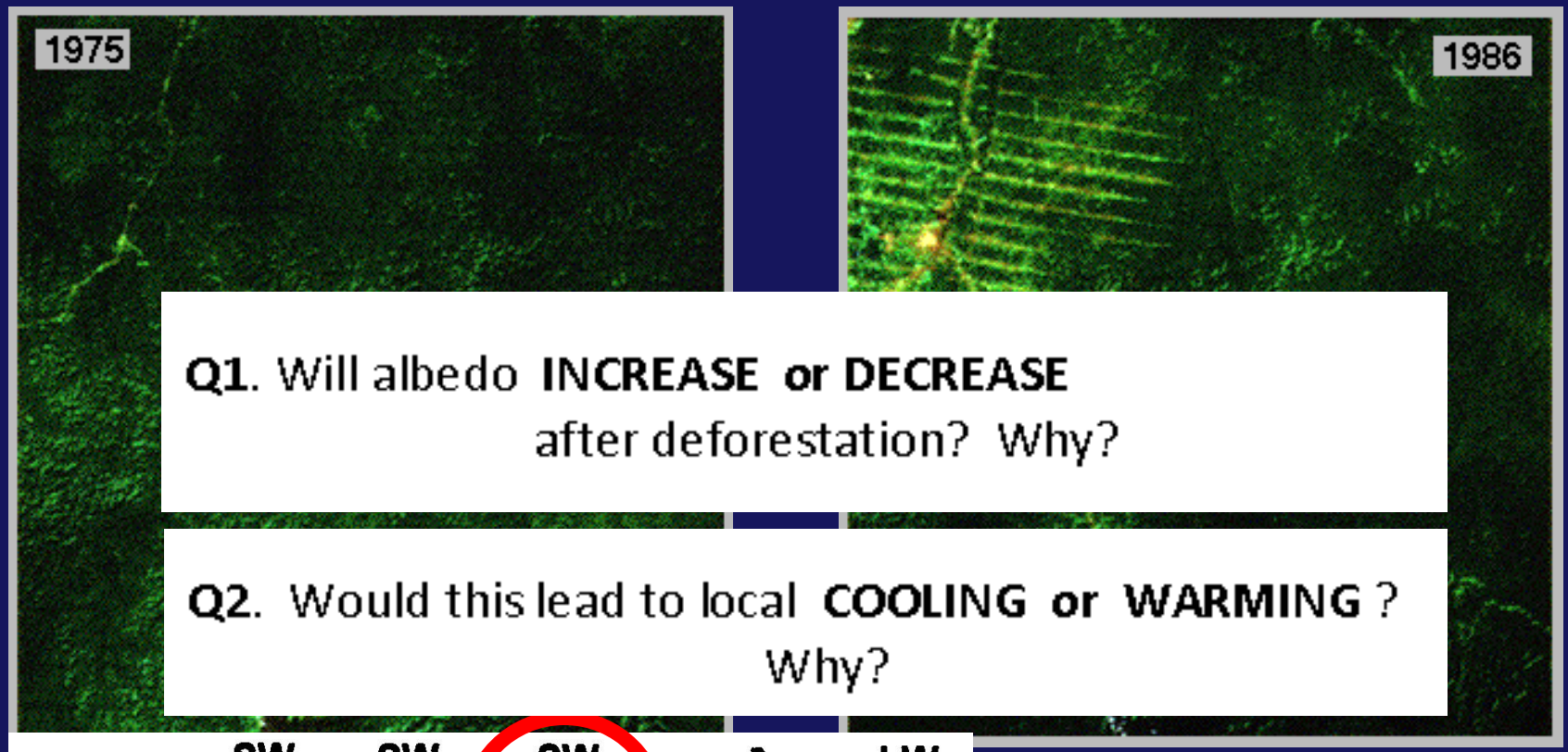
Amazon deforestation picking up pace, satellite data reveals

Data indicates 190% rise in land clearance in August and September compared with same period last year

A tree in a deforested area in the middle of the Amazon jungle. Photograph: Raphael Alves/AFP/Getty Images

http://www.theguardian.com/environment/2014/oct/19/amazon-deforestation-satellite-data-brazil

How does DEFORESTATION change the LEFT SIDE of the local energy balance???



Q1. Will albedo **INCREASE or DECREASE** after deforestation? Why?

Q2. Would this lead to local **COOLING or WARMING**? Why?

$R_{NET} = \downarrow_{SW} + \downarrow_{SW} - \nearrow_{SW} - \updownarrow_{LW} + \downarrow_{LW}$

More → cooler temperatures?

Turn back to p 50

AMAZON RAIN FOREST:

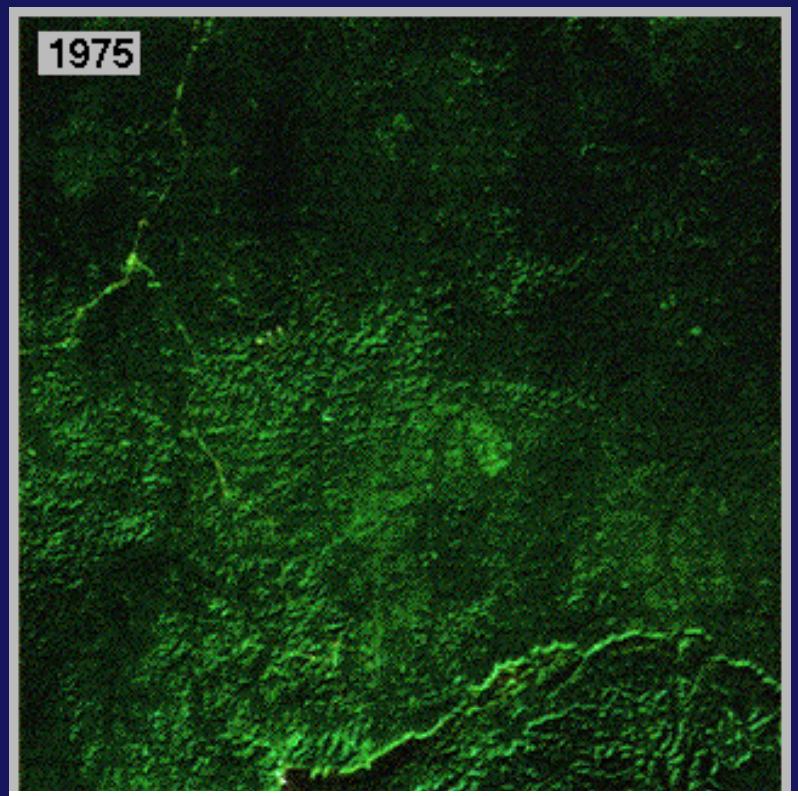
- Warm
- Rainy
- Humid
- Lush vegetation

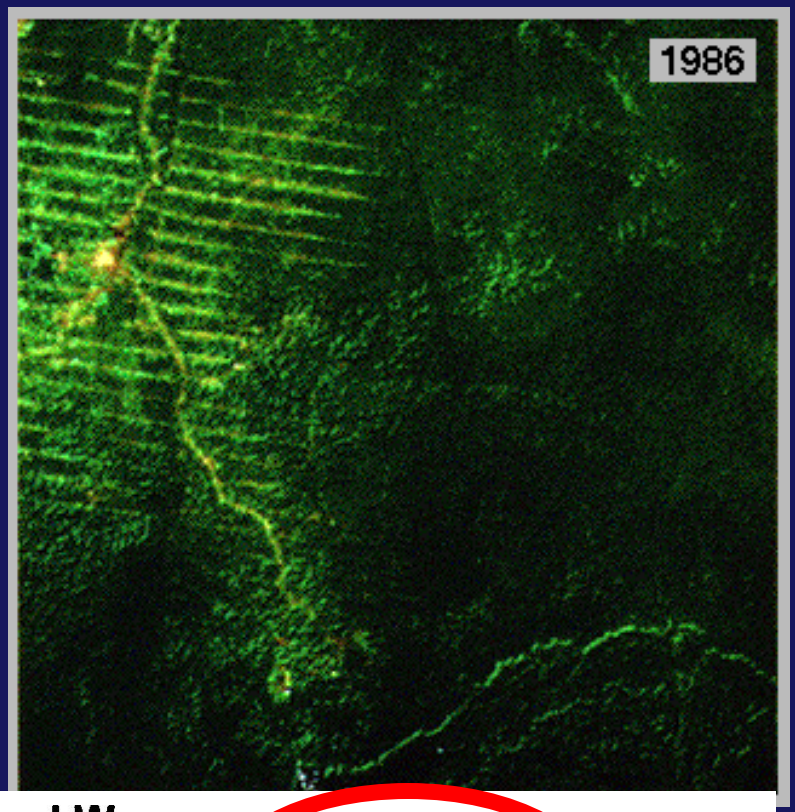
WARMTH + MOISTURE → EVAPORATION

H + water → phase change → LE + water vapor

TREES + MOISTURE → TRANSPIRATION

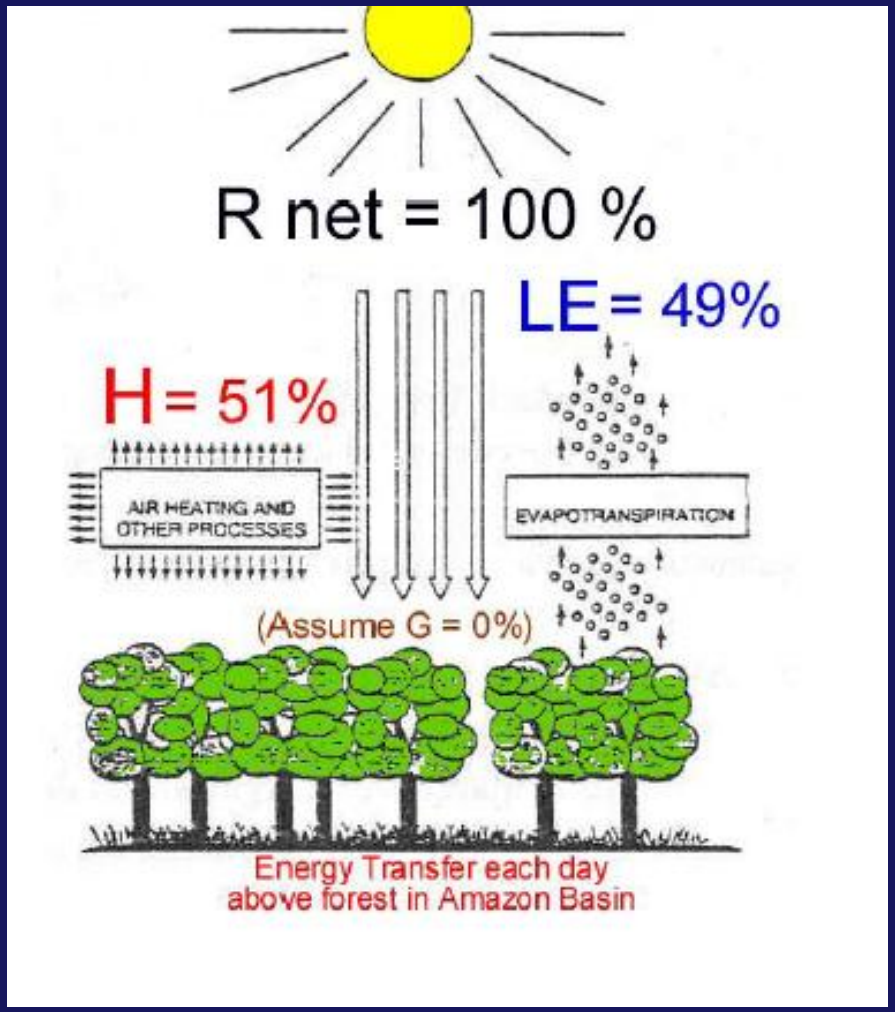
How does DEFORESTATION change the RIGHT SIDE of the local energy balance???





$$R_{NET} = \downarrow_{SW} + \downarrow_{SW} - \nearrow_{SW} - \updownarrow_{LW} + \updownarrow_{LW} = H + LE + G$$

???

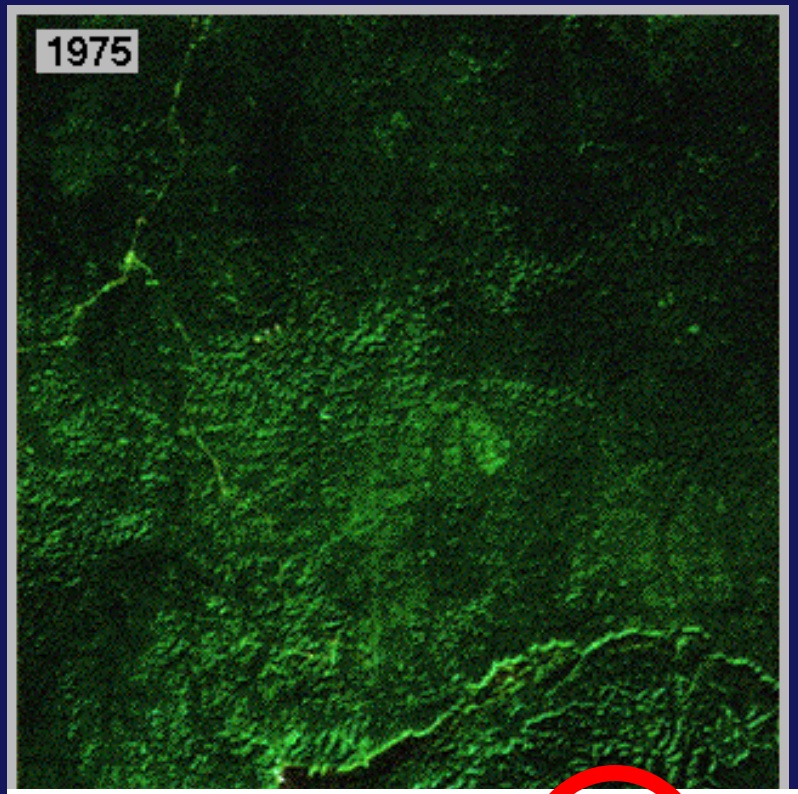


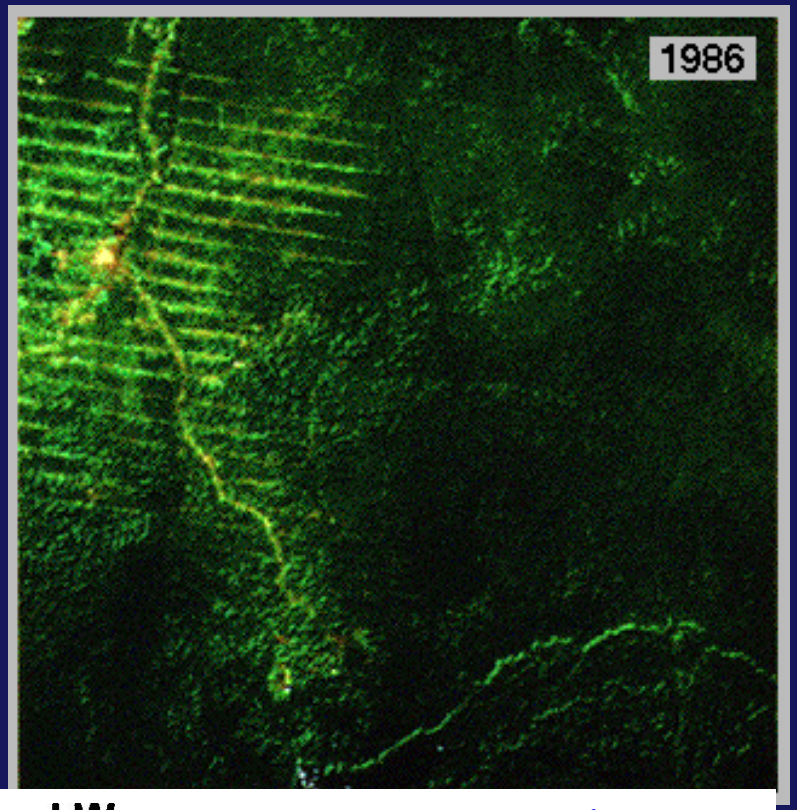
Estimates from Amazon Basin indicate that ~1/2 of its precipitation is derived from transpiration

Q3. Will the proportion of energy stored in **LE** (at the expense of H) **INCREASE** or **DECREASE** after deforestation? Why?

Q4. Would this lead to local **COOLING or WARMING**? Why?

WHICH SIDE OF THE EQUATION WILL WIN??





$$R_{NET} = SW\downarrow + SW\downarrow - SW\uparrow - LW\uparrow + LW\downarrow = H + LE + G$$

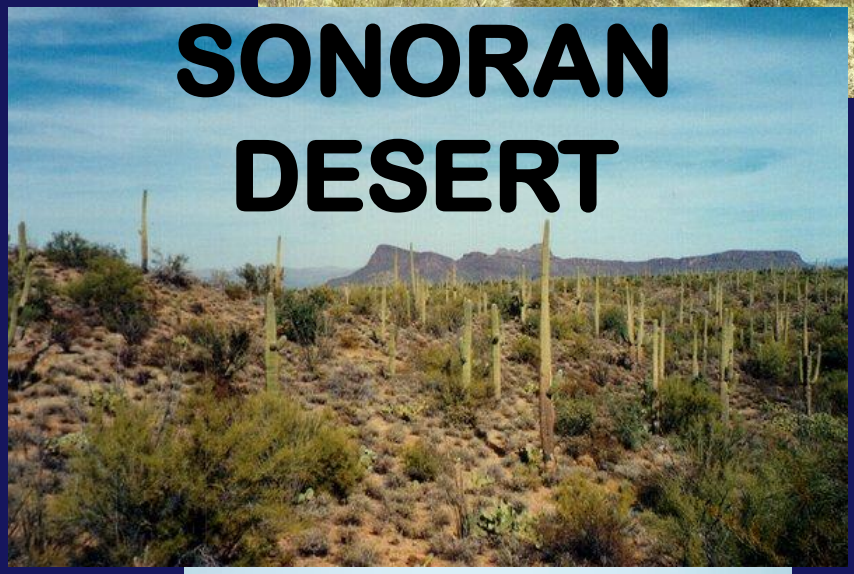
Less

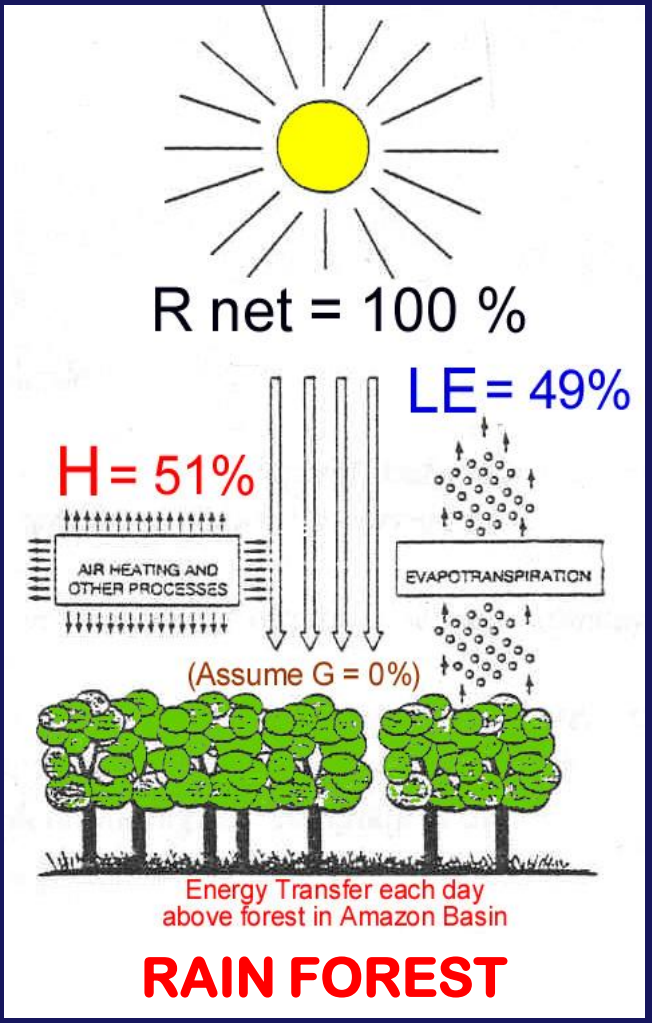
More → cooler temperatures

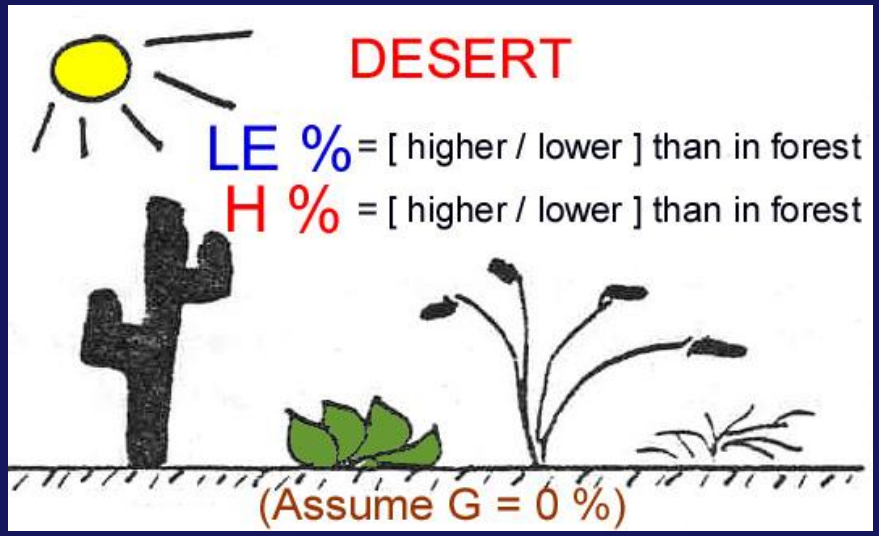
More → warmer temperatures

NOW LET'S COMPARE:

vs.







H + LE + G

How would the distribution of energy in the right side of the equation differ in the Sonoran desert vs. the Amazon rainforest?

Q5. Choose the correct response below. Why?

(a) In the desert, **LE** will be **higher** and **H** will be **lower**

(b) In the desert, **LE** will be **lower** and **H** will be **higher**

Q6. Which environment do you think can reach the **highest temperatures** during its warm season? Why?

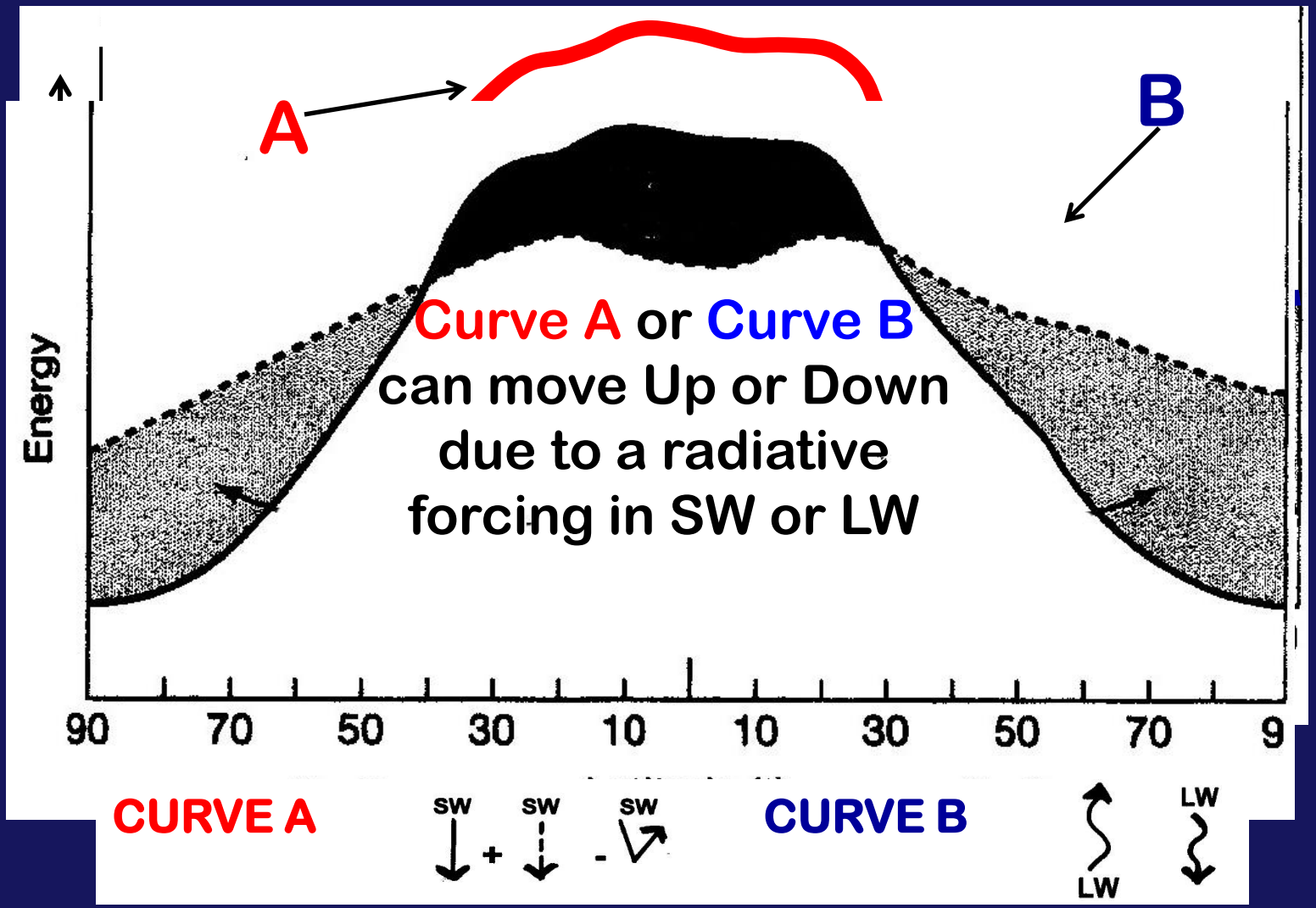
(a) The Amazon Rain Forest? (b) The Sonoran Desert?

p 50

TOPIC #11

NATURAL CLIMATIC FORCING

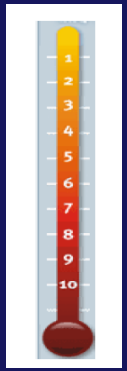
Global climate variability and change are caused by changes in the ENERGY BALANCE that are "FORCED"



NATURAL CLIMATIC FORCING

vs.

ANTHROPOGENIC FORCING



Denier Argument #1:

"Climate's changed before"

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

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

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 ←

2) SOLAR FORCING

3) VOLCANIC FORCING

Milankovitch Cycles!

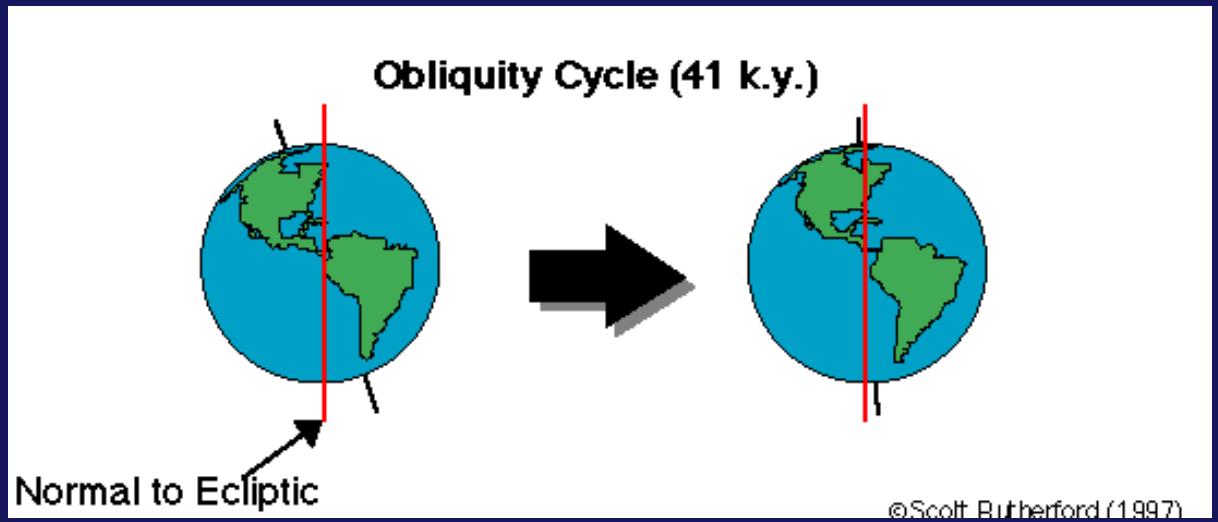
Changes in Solar "Astronomical" Forcing have driven natural climate variability (ice ages, etc.) on LONG time scales (5,000 to 1 million years)

What has varied over time?

See I-2 also p 67

1. OBLIQUITY OF EARTH'S AXIS

- has varied in the past from more "tilted" to more "vertical" (~24.5 ^{o} to ~ 22.5 ^{o})

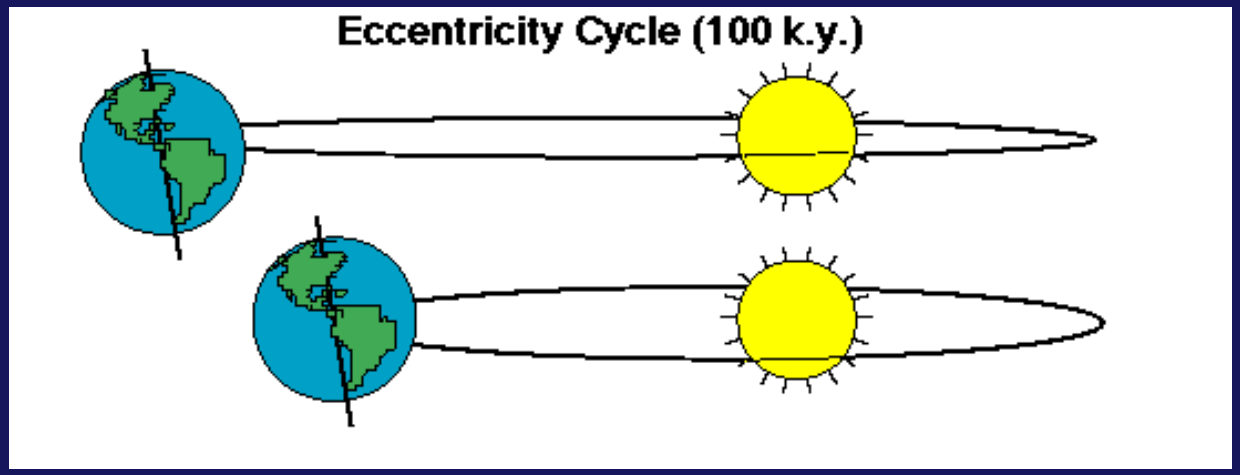


2. ECCENTRICITY OF ORBIT

- Earth's orbit around sun is not symmetrical

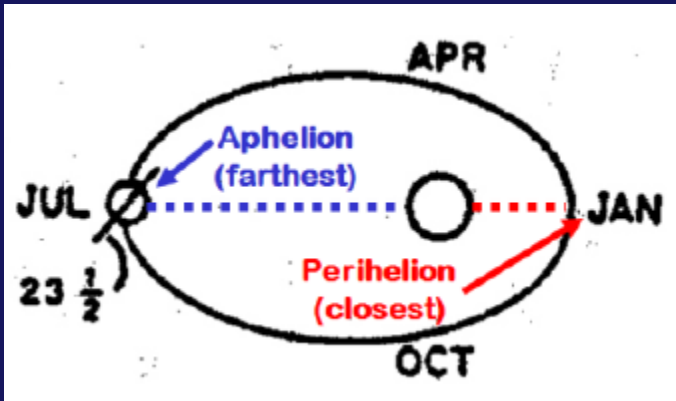
- Has varied in the past from more circular => elliptical shape

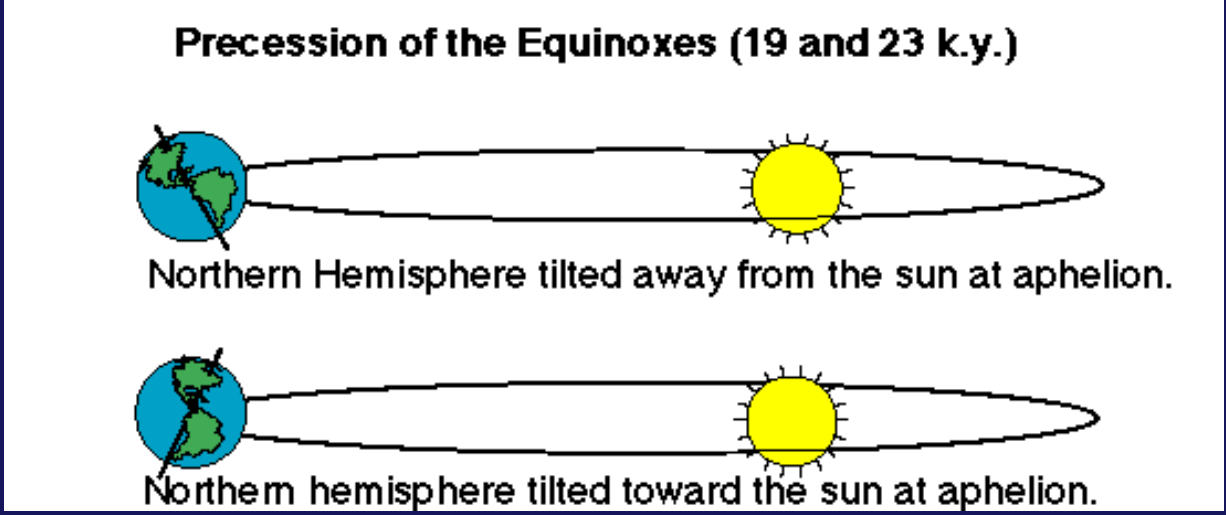
(more "eccentric!")



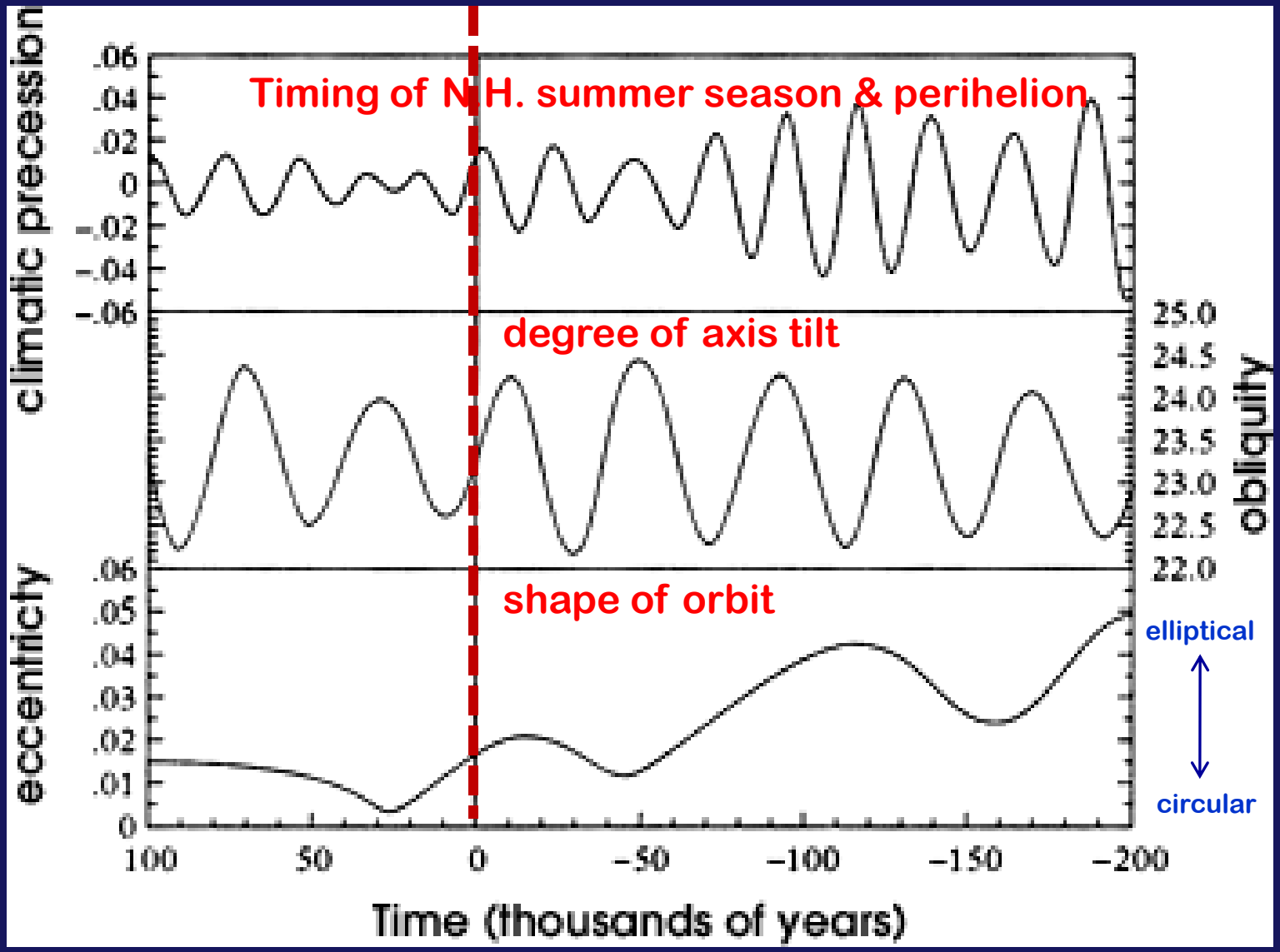
3. PRECESSION OF THE EQUINOXES
(Timing of Seasons in Relation to Orbit)

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.

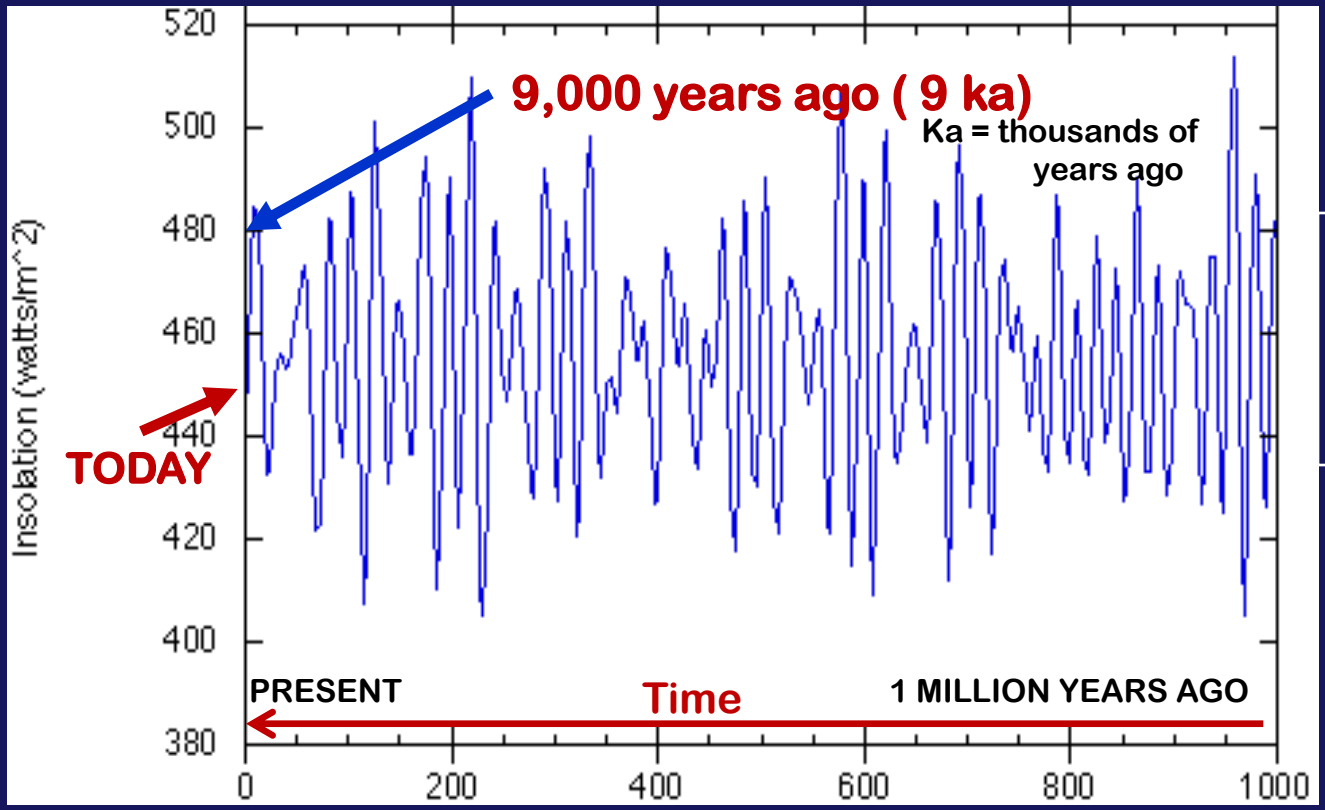




← the FUTURE ← TODAY → the PAST *(in thousands of years)*



Graph of SOLAR INSOLATION calculated for 65 ° N from today to 1 million years ago:



GRAPH TOP of p 68

In the N 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.

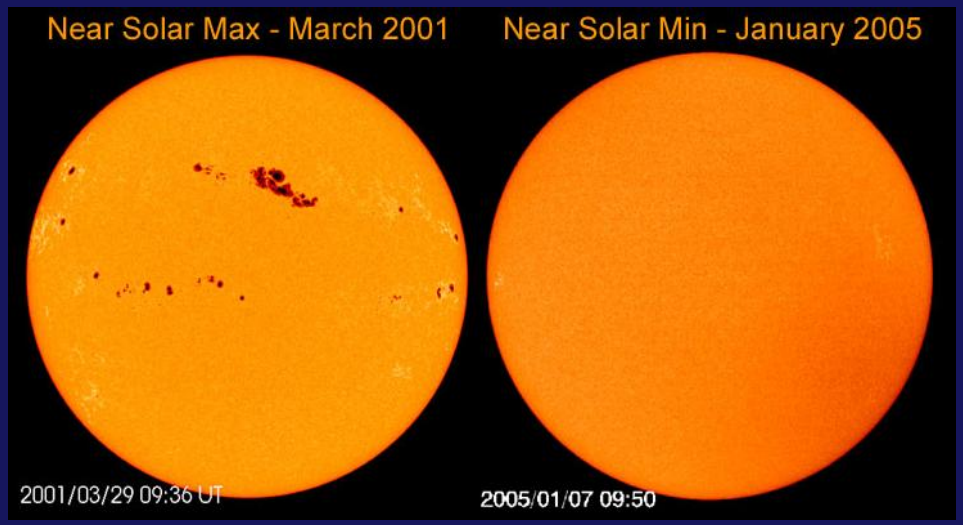
The 3 main drivers of NATURAL CLIMATIC FORCING:

1) ASTRONOMICAL FORCING

2) SOLAR FORCING ←

3) VOLCANIC FORCING

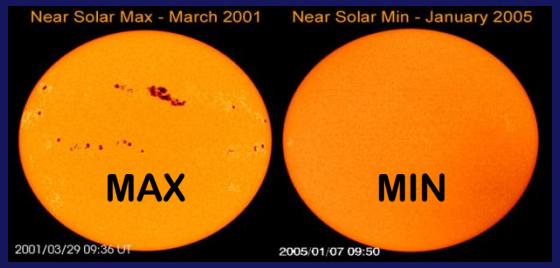
ANOTHER POSSIBLE NATURAL FORCING: SOLAR VARIABILITY

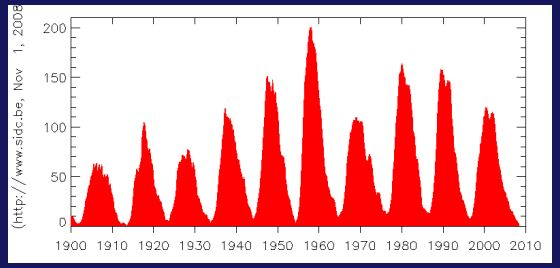


Sunspot maxima = MORE solar brightness (warmer temps)

Sunspot minima = LESS solar brightness (cooler temps)

ANOTHER POSSIBLE NATURAL FORCING: SOLAR VARIABILITY





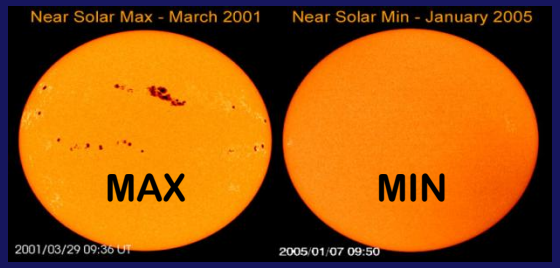
Q1 – During SUNSPOT Maximum periods:

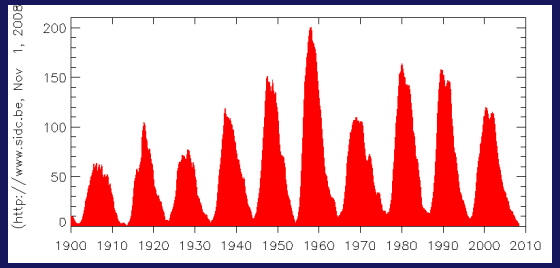
1. The sun is darker so it gives off less energy and global cooling is likely.

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 POSSIBLE NATURAL FORCING: SOLAR VARIABILITY



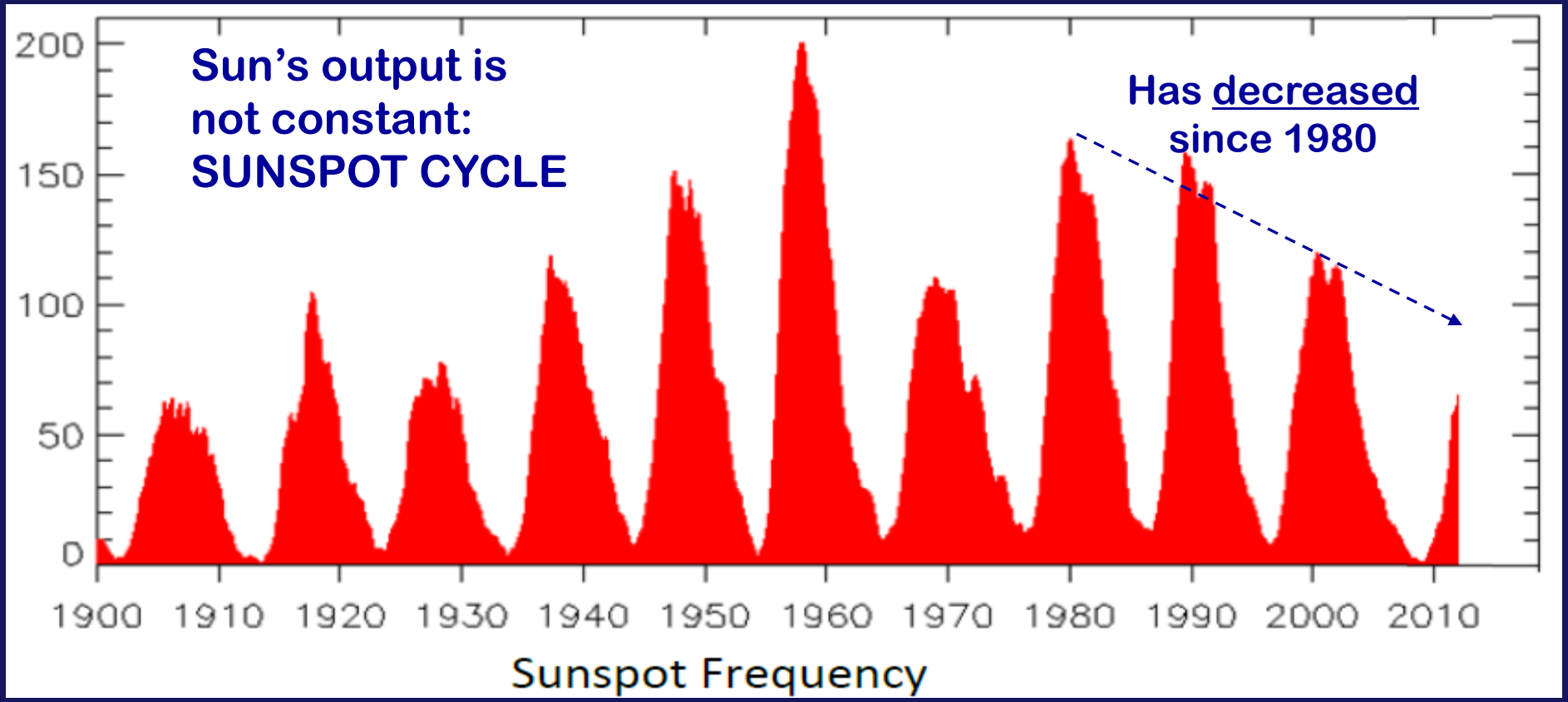


Q2 – During SUNSPOT Maximum periods:

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.

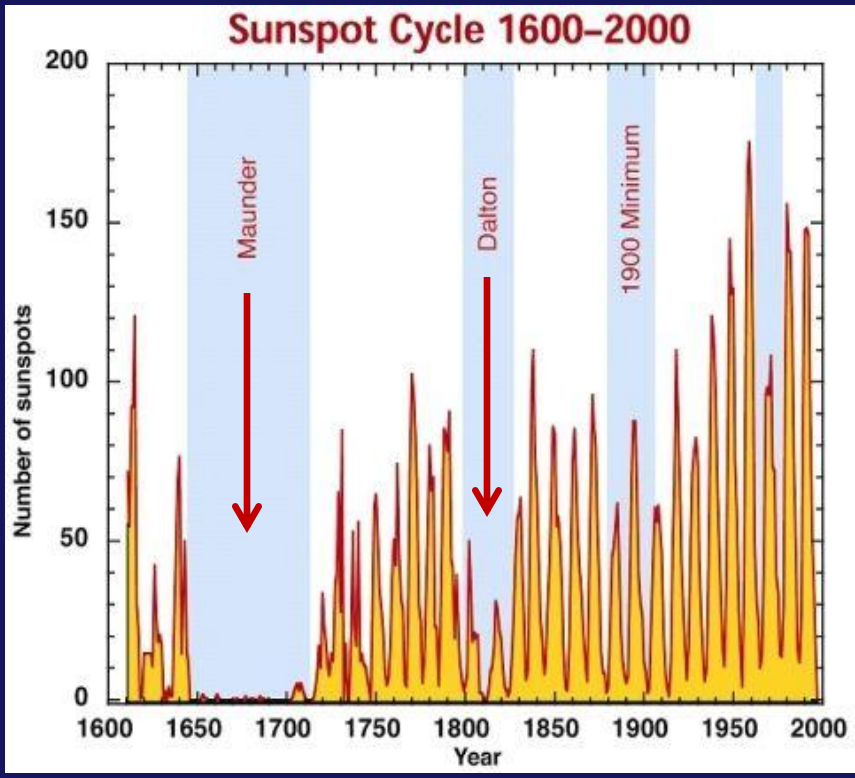


http://www.sidc.be/sunspot-index-graphics/sidc_graphics.php

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)

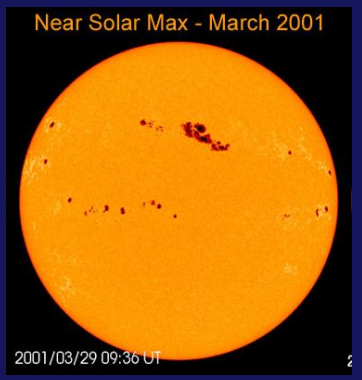


Still Q's on the MECHANISM:
what causes:
brightness DROP →
lower TEMPS on earth?

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)

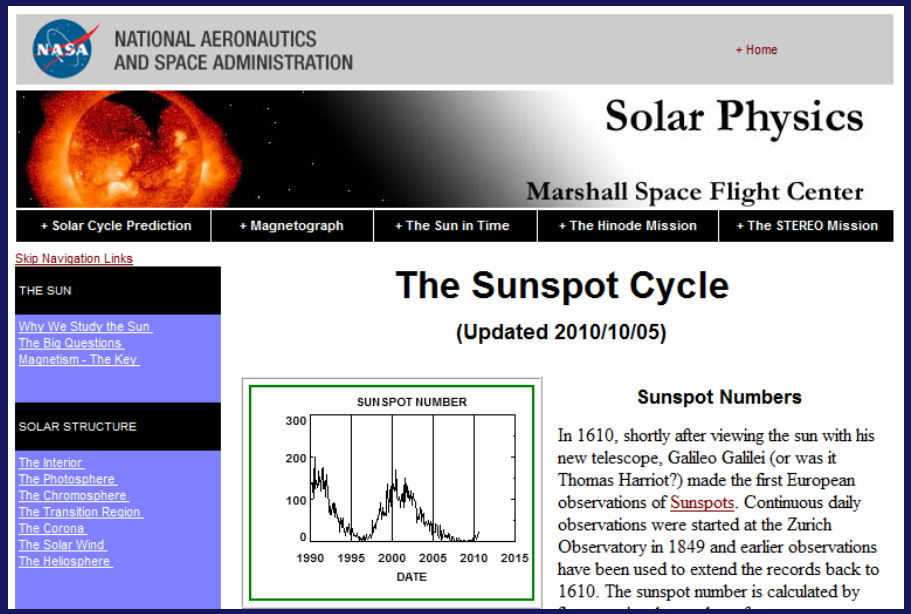
BUT . . .
The increase in solar brightness during the recent "Modern Maximum" accounted for only:



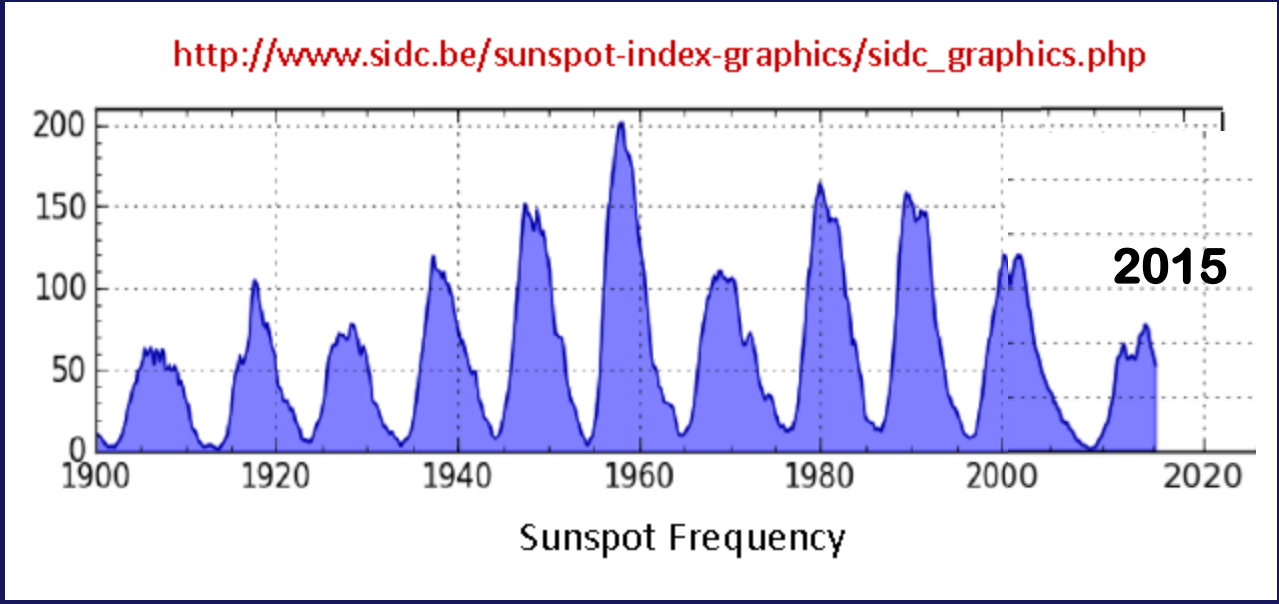
- **about ½ of the temperature increase since 1860**, and
- **less than 1/3 since 1970**

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

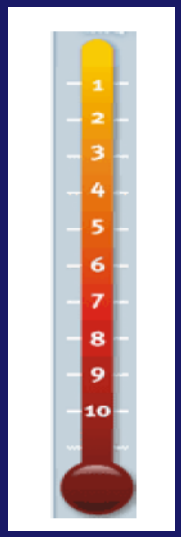
What is happening today?



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

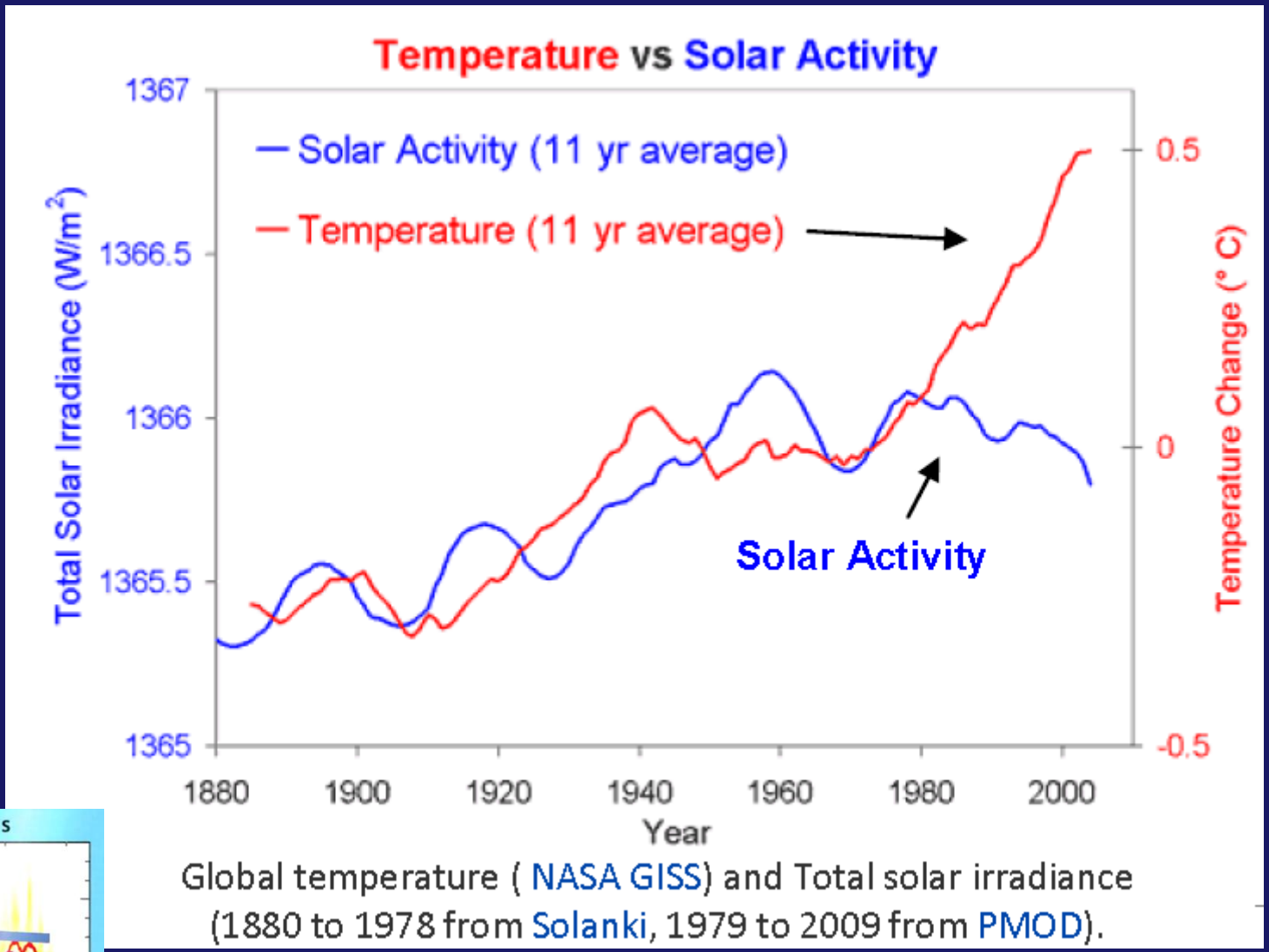


SEE ALSO: http://www.sidc.be/sunspot-index-graphics/sidc_graphics.php

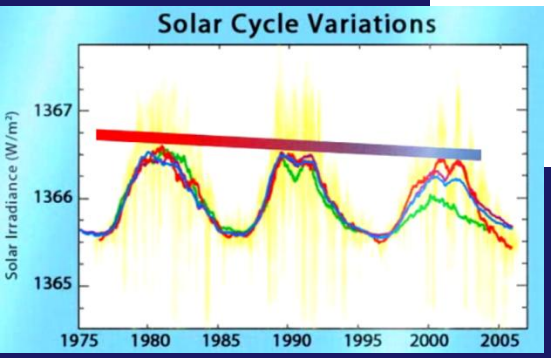


Denier Argument #2:

"It's the Sun"



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



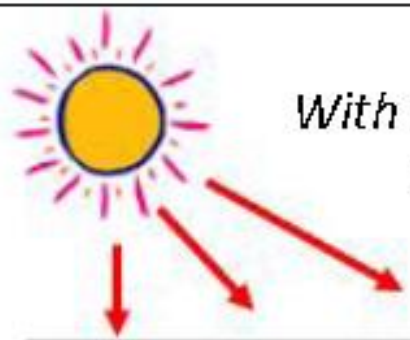
← "Clearing the Air" in I-2 Lesson 2

The Greenhouse Warming Signature:
"Increasing CO2 warms the Troposphere and cools the Stratosphere"

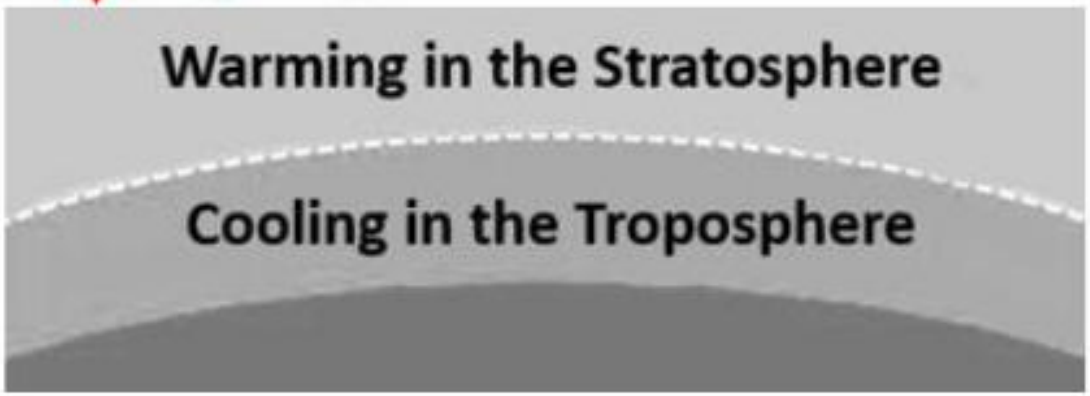
What would a SOLAR Warming Signature look like?

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

The Solar Irradiance Signature:

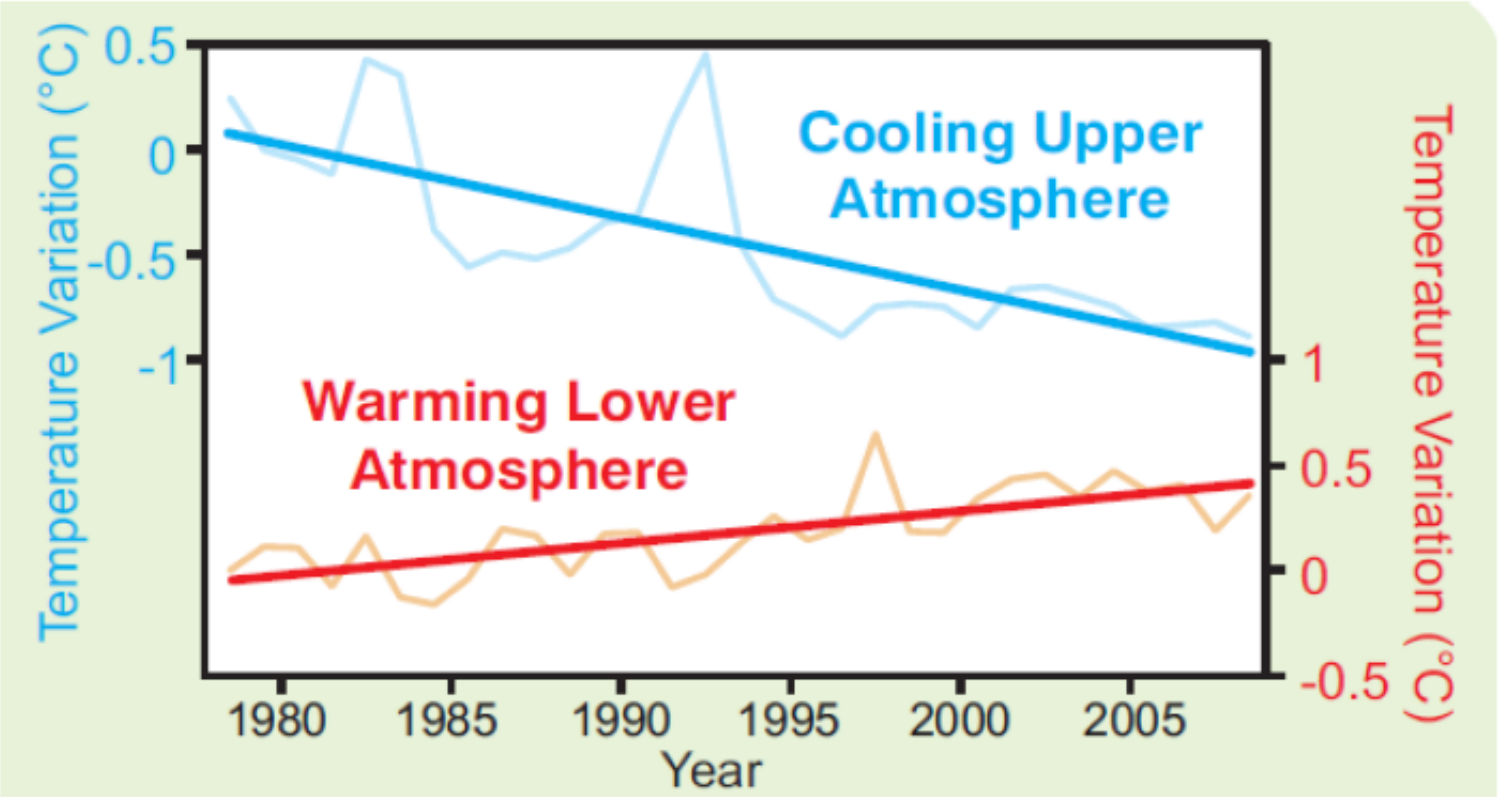


With increased Solar Activity we would expect to see "top down" warming:

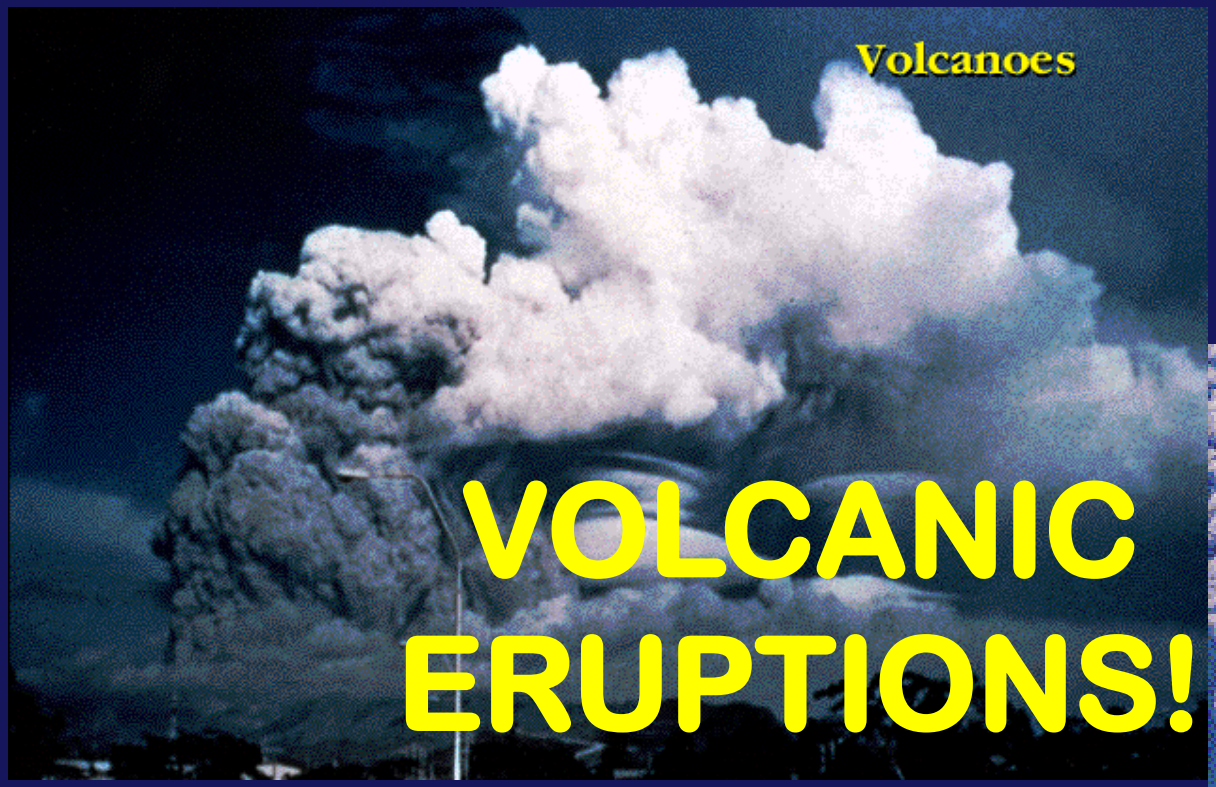


Solar Signature = Warming in the upper atmosphere & cooling in the Troposphere . . .

What has been observed since 1980?



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



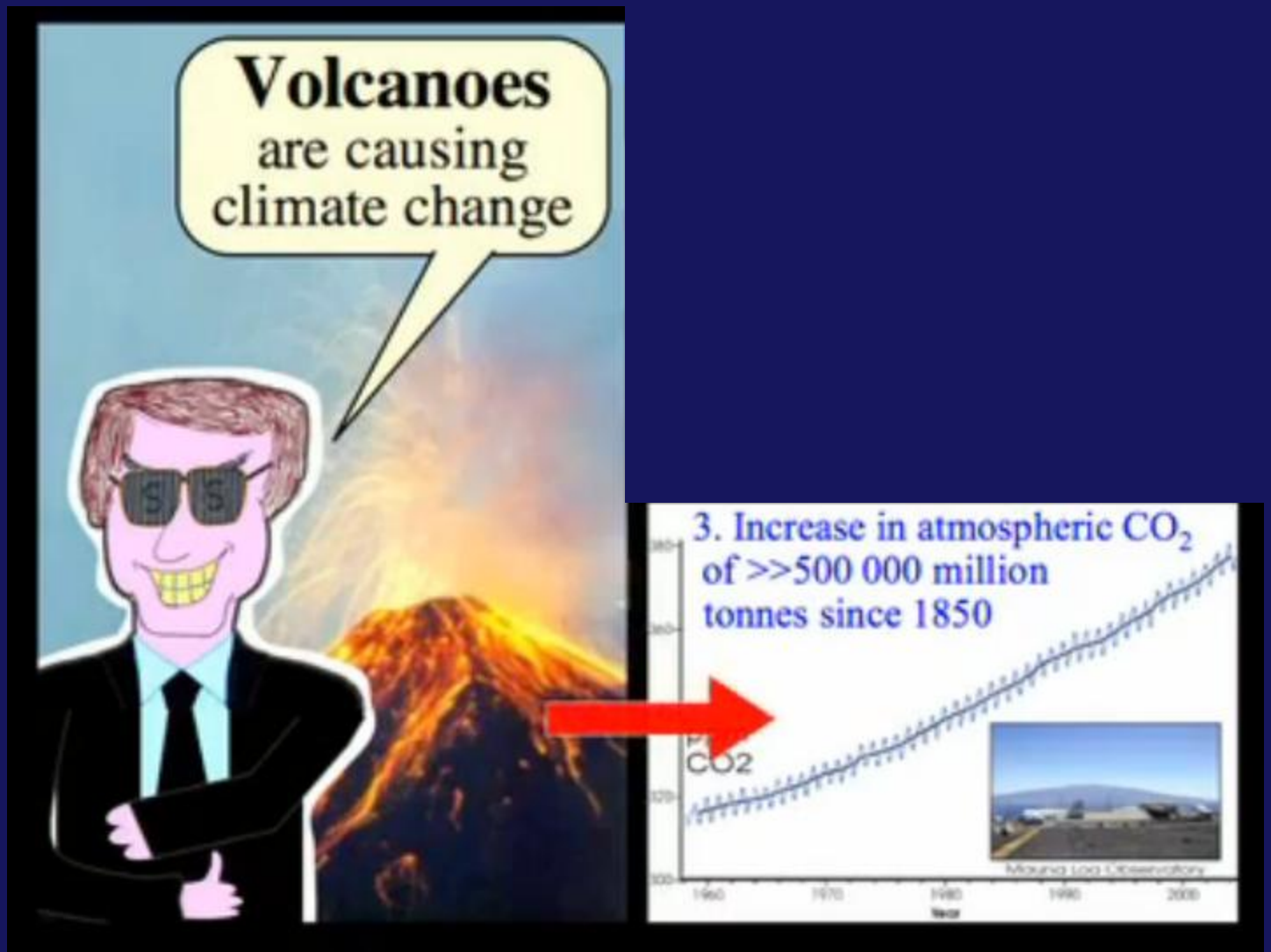
VOLCANIC ERUPTIONS!

Volcanic eruptions contribute to the **natural Greenhouse Effect** by adding CO_2 into the atmosphere:

Volcanic "outgassing" of CO_2 into atmosphere

0.06 Gtons

Is CO2 emitted by volcanoes an important natural cause of the recent global warming observed?



Q2 – Are volcanic eruptions an important cause of recent global warming?

1 – YES! The CO_2 they give off is a key cause of the enhanced GH Effect

2 – NO! It's the ash (not CO_2) that volcanic eruptions eject that is important & it causes global cooling not warming.

3- NO! The CO_2 that volcanic eruptions emit is a natural part of the carbon cycle and it balances out

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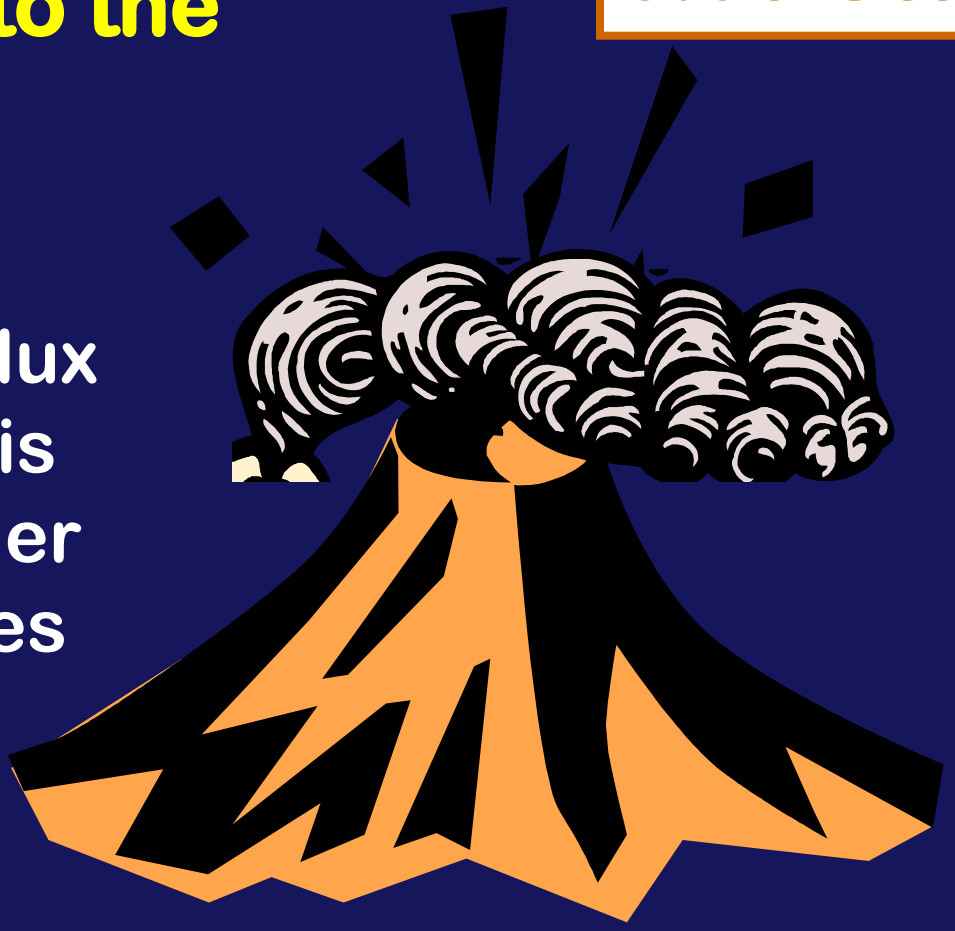
Carbon flux from volcanic eruptions
What about the CO_2 emitted into the atmosphere?

Volcanic outgassing of CO_2 into atmosphere

0.06 Gtons



Over time, this natural carbon flux balances out & is absorbed by other natural processes in the carbon cycle

But eruptions can have a more direct climatic effect under certain conditions . . .

How the Climatic Effect Occurs . . . . through the ENERGY BALANCE of course!

HOW DO YOU THINK AN ERUPTION COULD CHANGE THE ENERGY BALANCE?

SKETCH IT!!

Large volcanic eruptions inject sulfur gases, water vapor, HCL into the stratosphere:

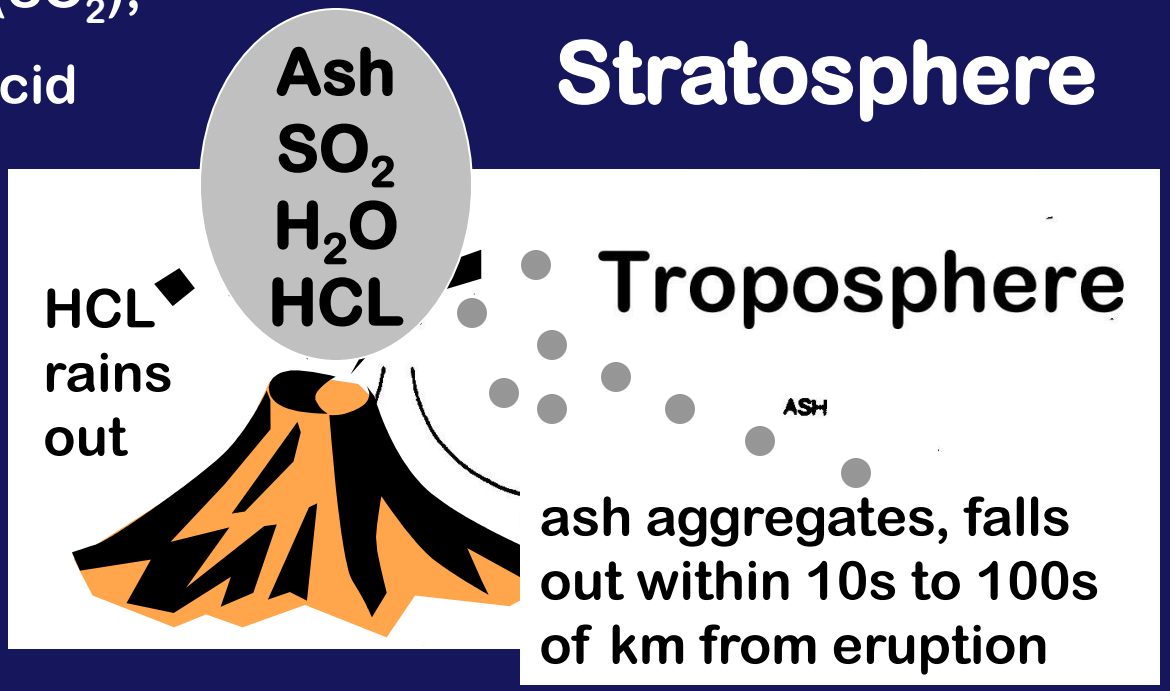
water vapor (H_2O)

sulfur dioxide (SO_2),

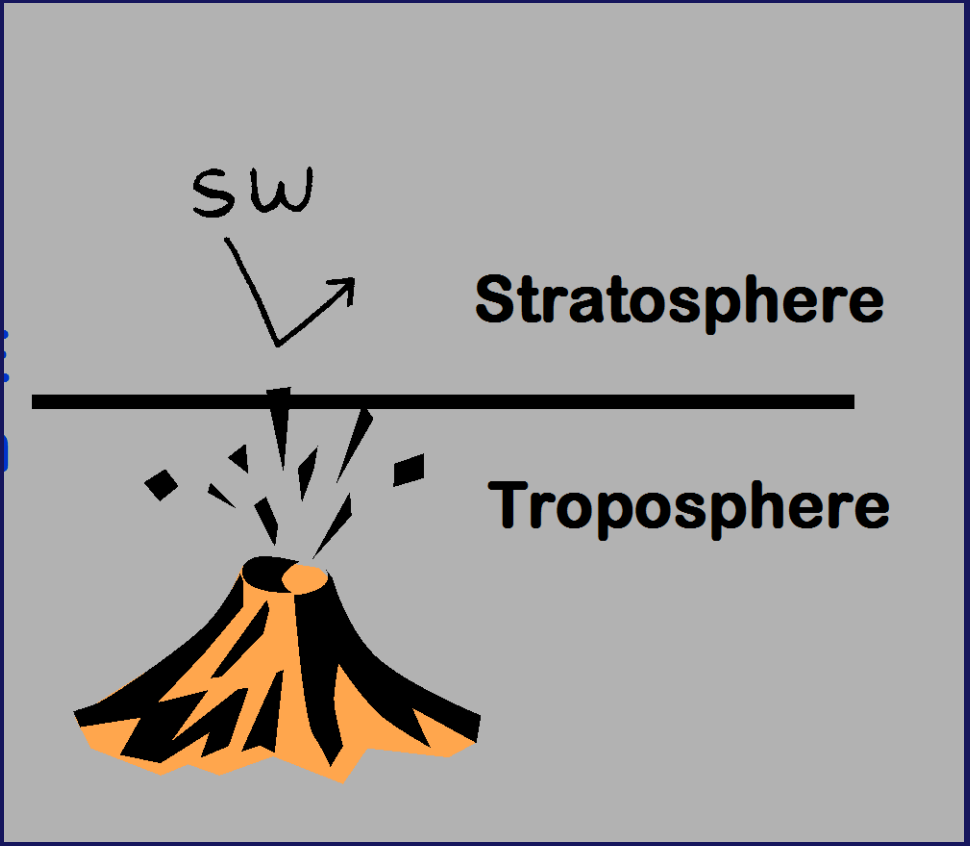
hydrochloric acid (HCl)

mineral ash

into the stratosphere

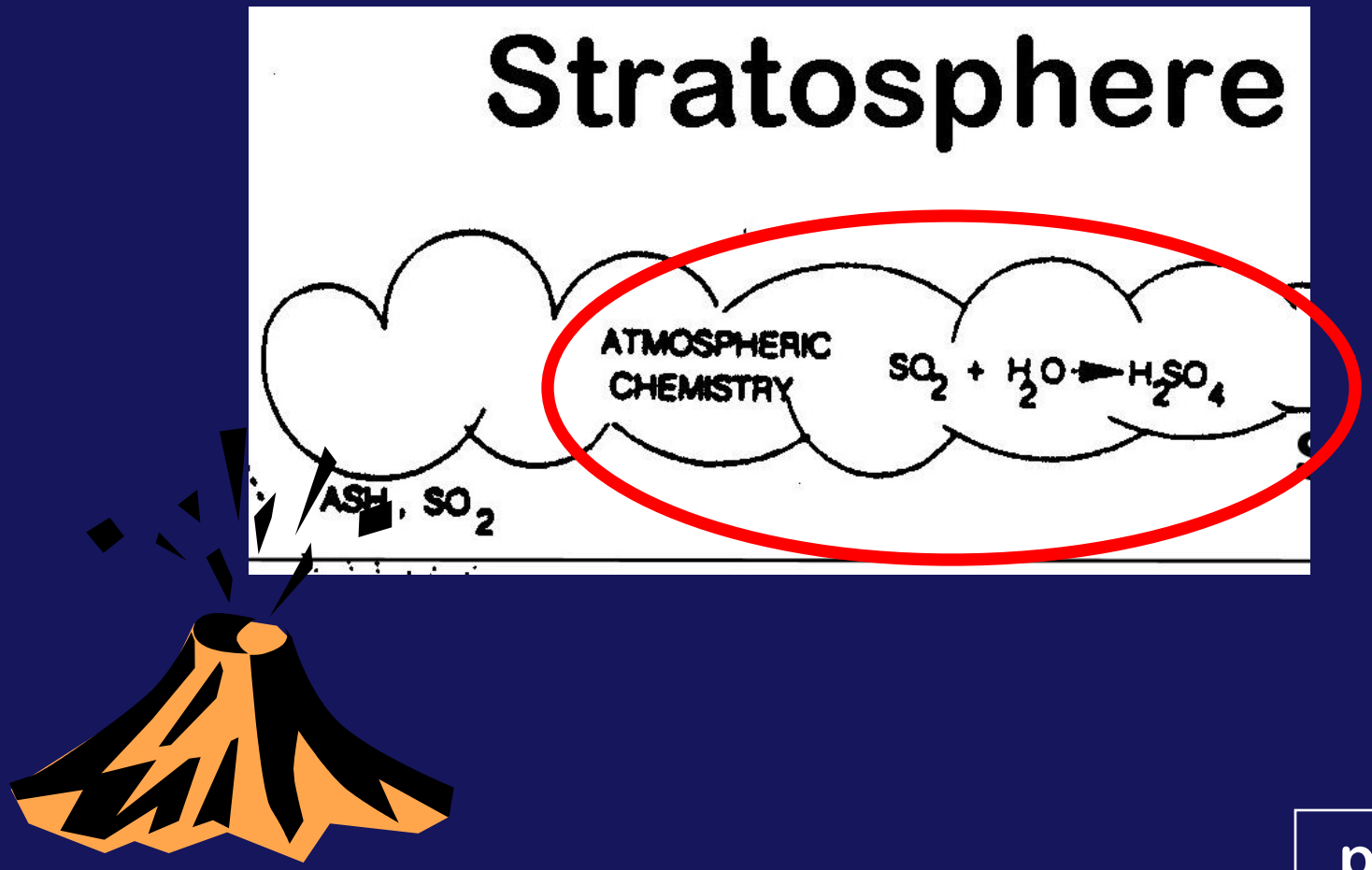


Albedo of ejected ASH in the STRATOSPHERE is *not* the reason for cooling after an eruption!
(most ash falls out early)

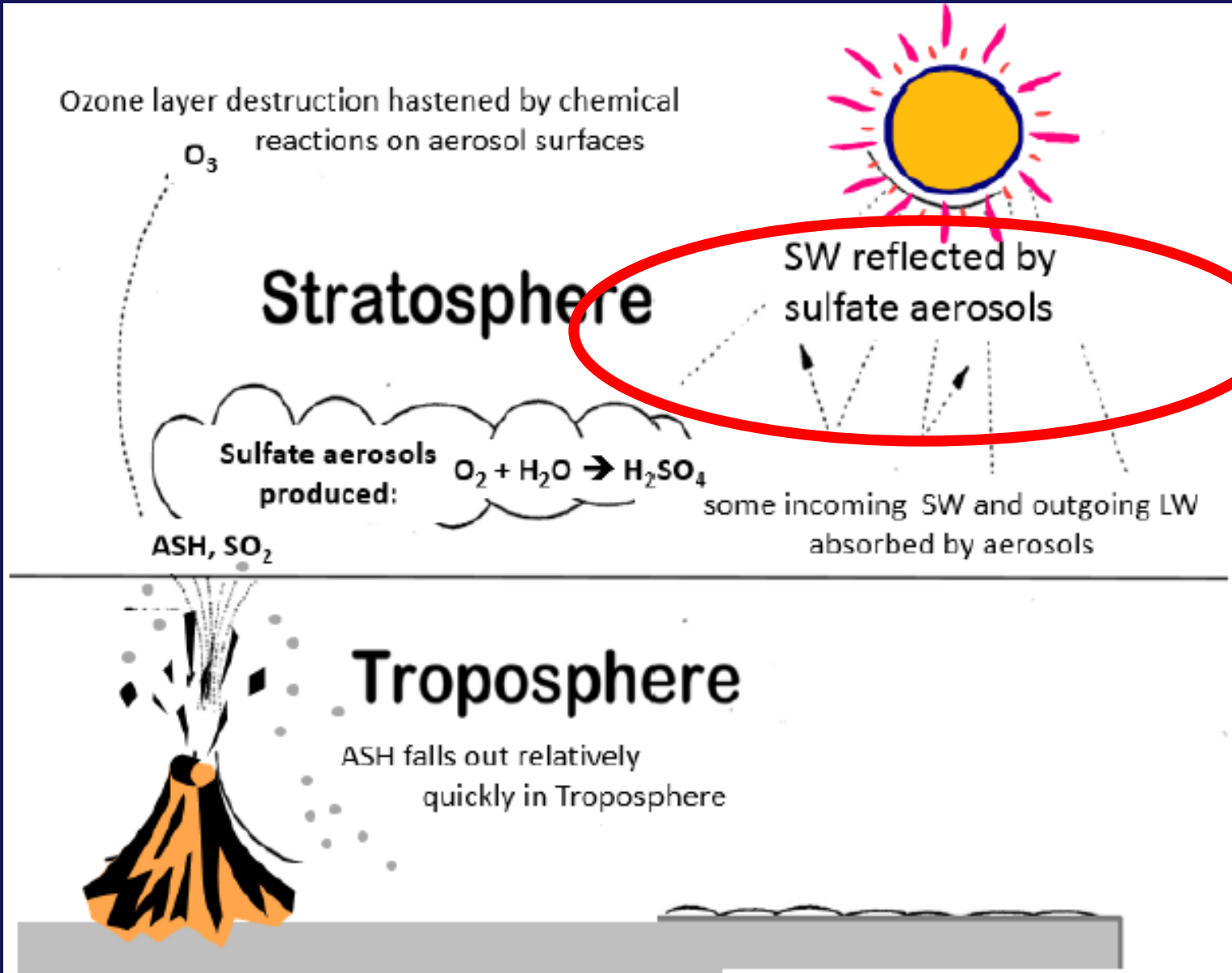


What *DOES* reflect the incoming shortwave radiation after an eruption?

SO_2 remains gaseous and is eventually converted to **sulfuric acid** (H_2SO_4) which condenses in a mist of fine particles called **sulfate aerosols.**

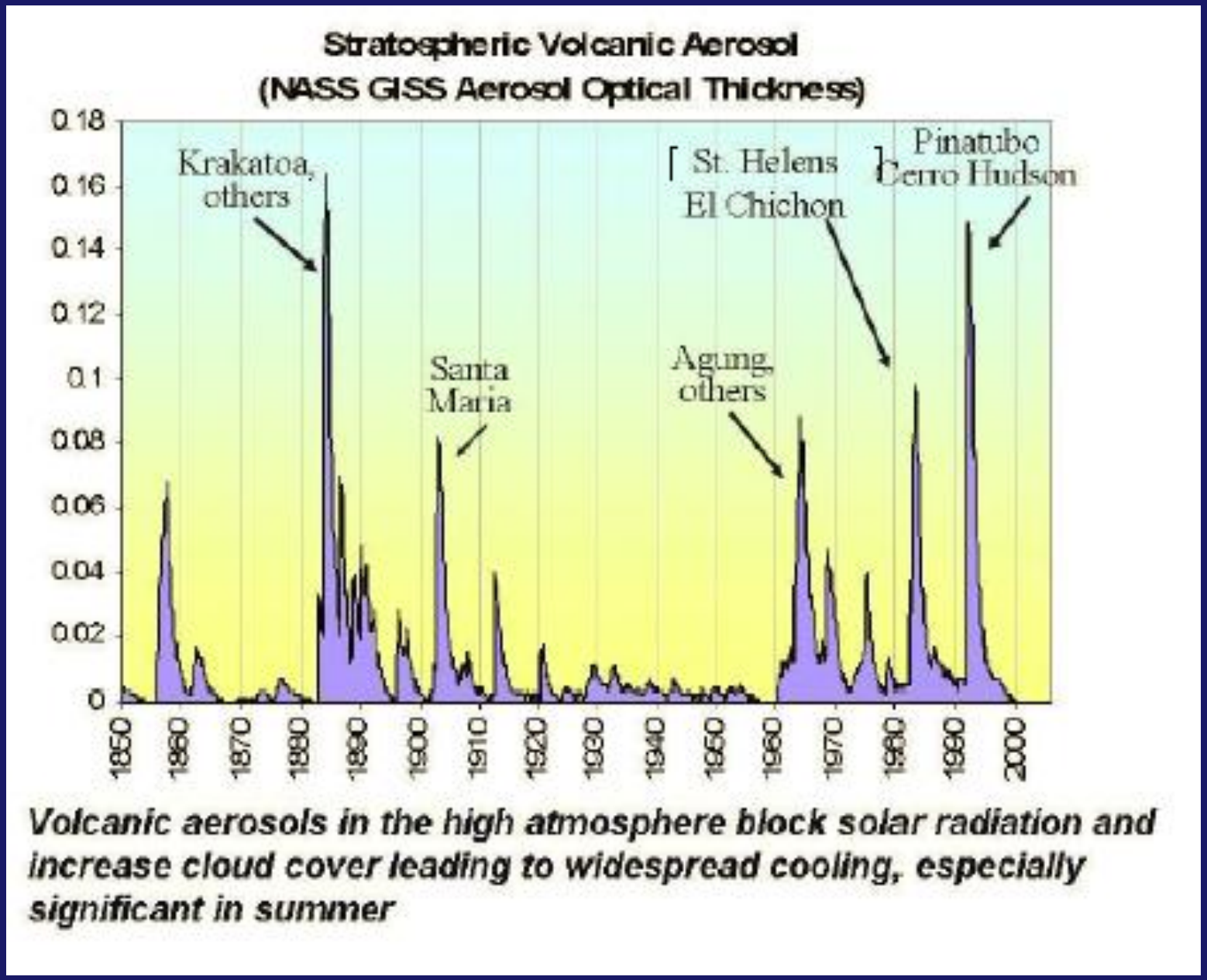


How the Climatic Effect Occurs . . . .



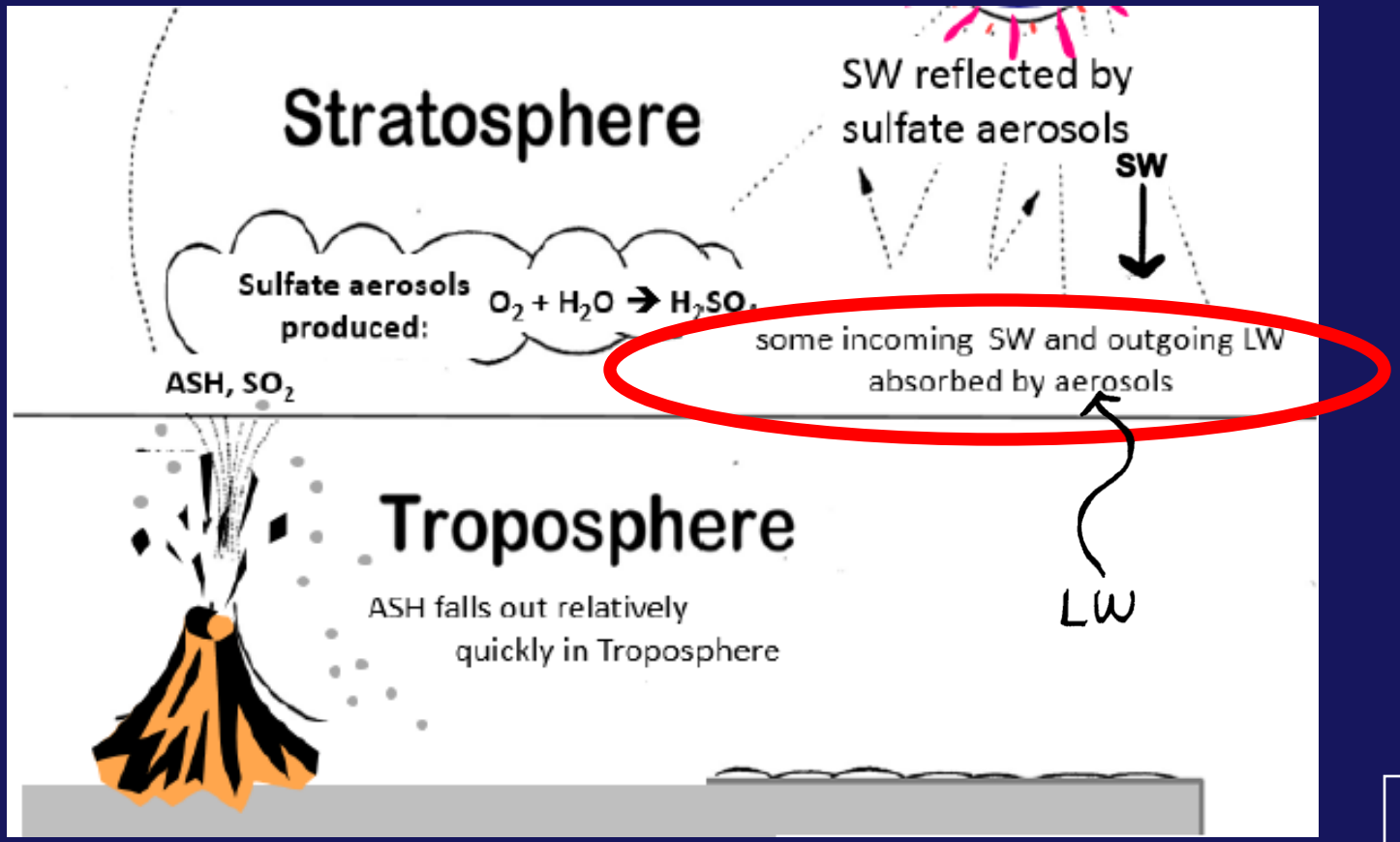
SOME MAJOR VOLCANIC ERUPTIONS OF THE PAST 250 YEARS:

Laki (Iceland)	1783
El Chichon? (Mexico)	1809
Tambora (Indonesia)	1815
Cosiguina (Nicaragua)	1835
Krakatau (Indonesia)	1883
Agung (Indonesia)	1963
El Chichon (Mexico)	1982
Mt Pinatubo (Philippines)	1991

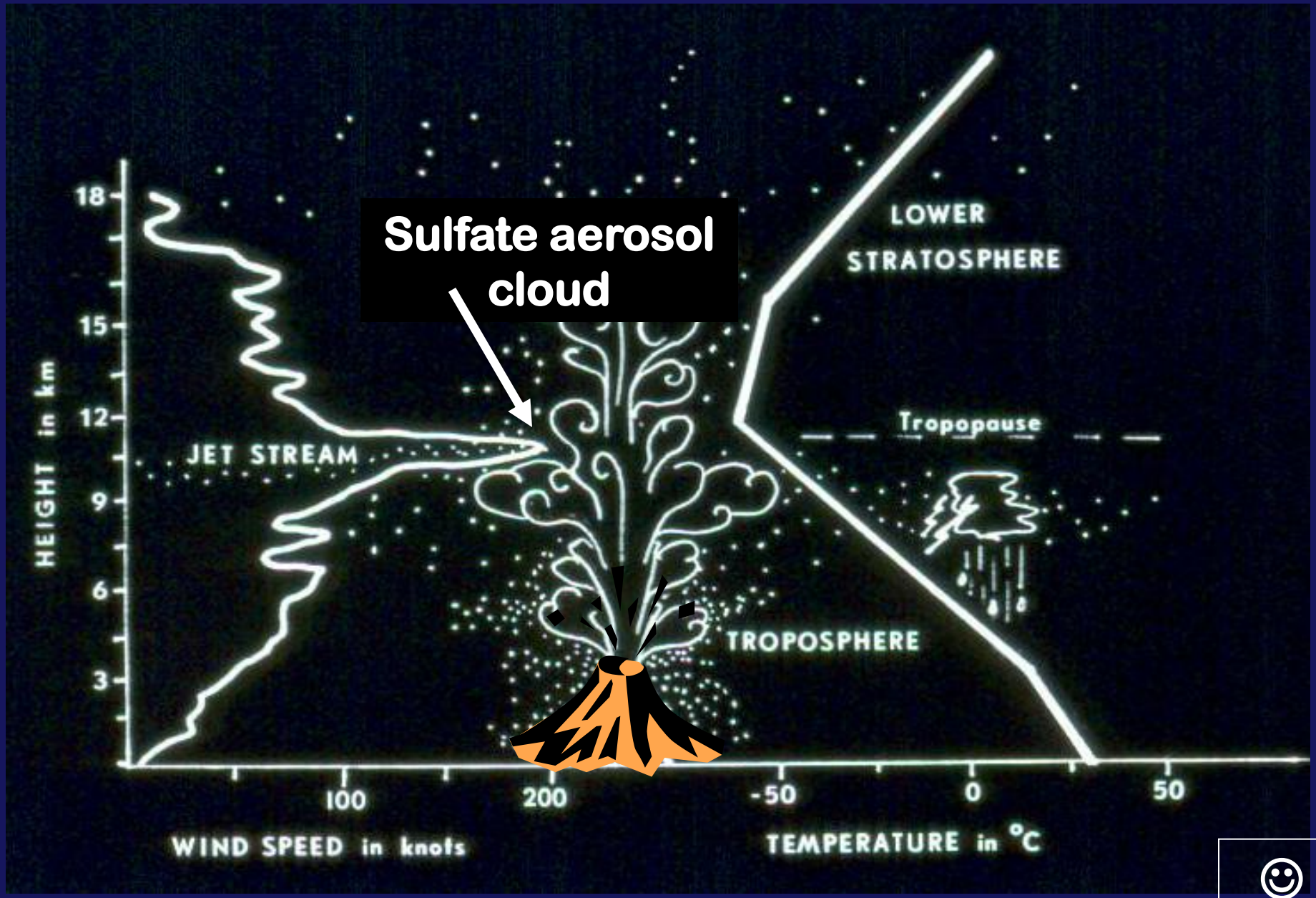


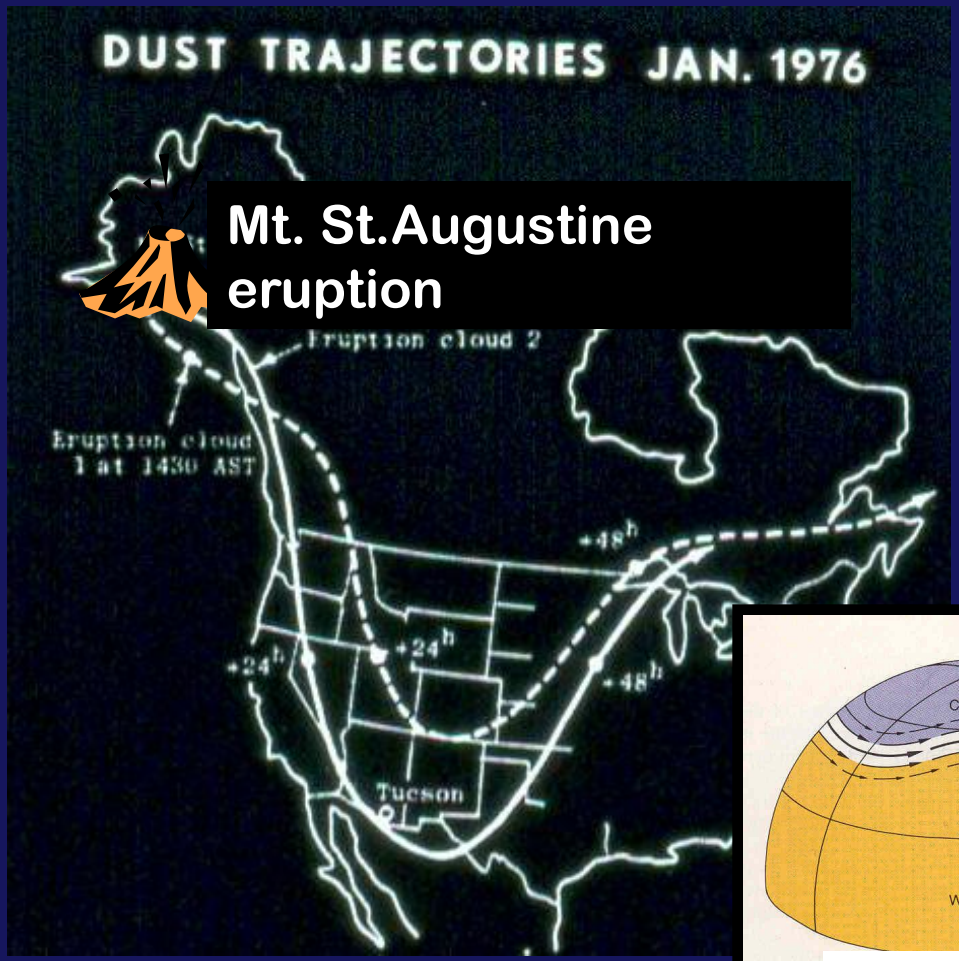
Volcanic aerosols in the high atmosphere block solar radiation and increase cloud cover leading to widespread cooling, especially significant in summer

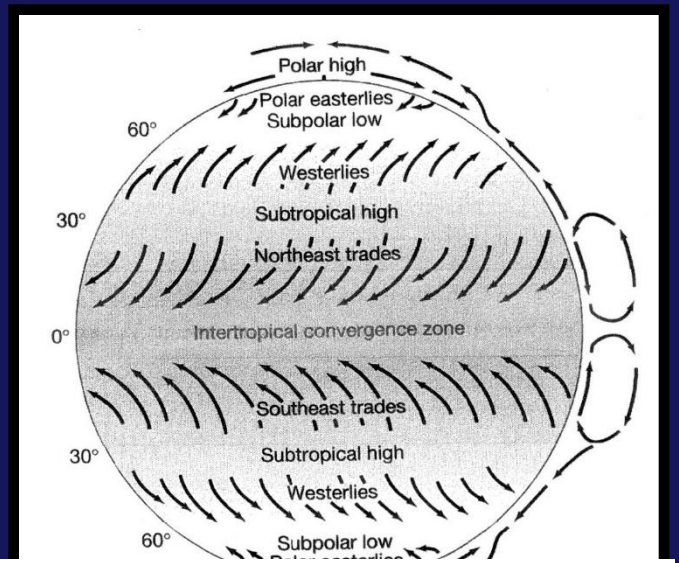
BUT - the AEROSOLS in the stratosphere also ABSORB certain wavelengths of the incoming SW radiation and some of the Earth's outgoing LW radiation, this WARMS the stratosphere (not the troposphere)



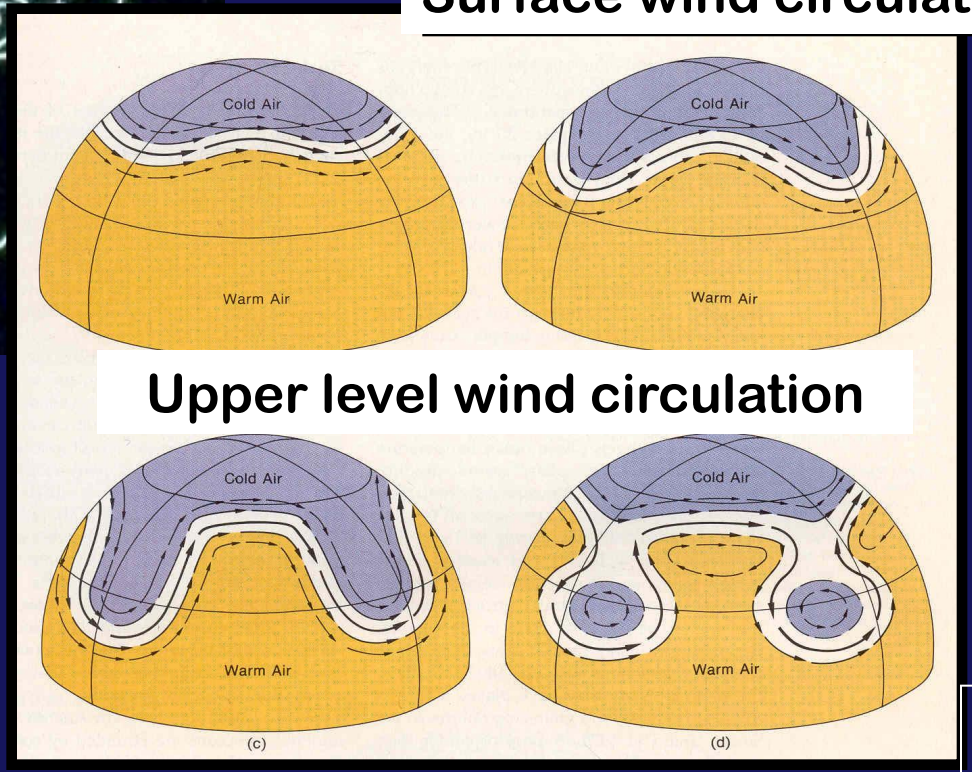
How an eruption's effects can become GLOBAL:





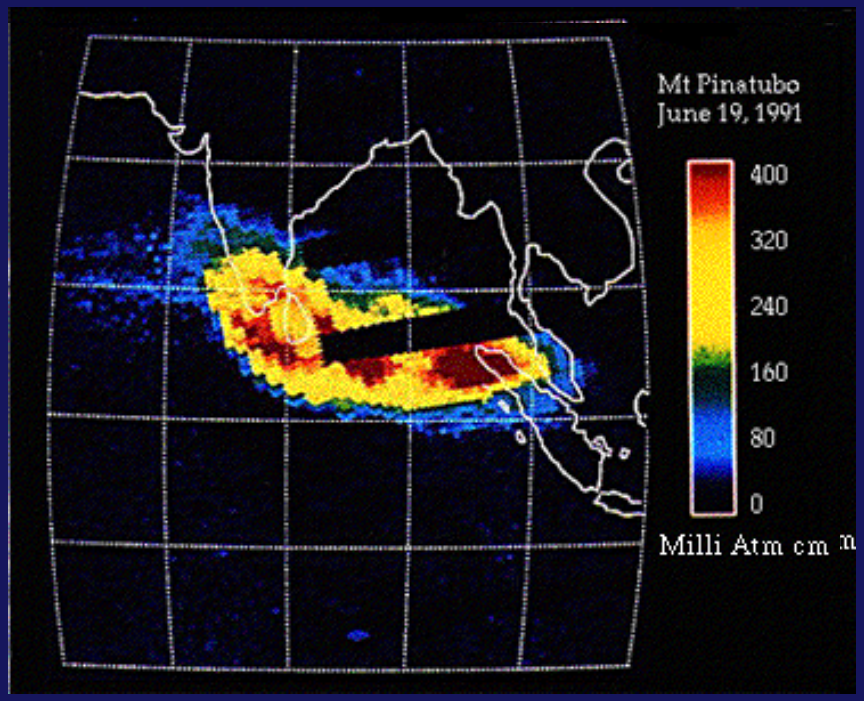


Surface wind circulation



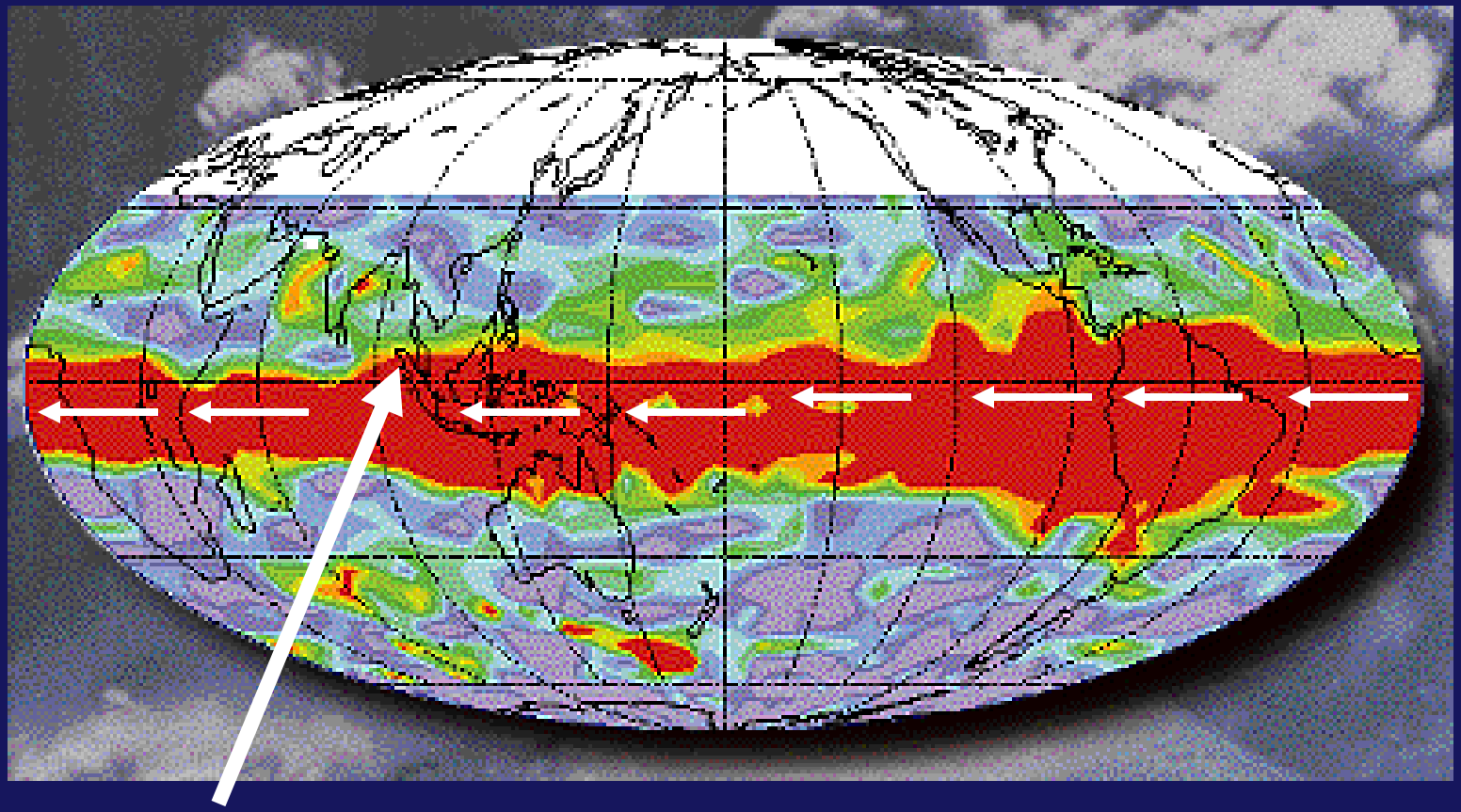
Through the atmospheric circulation!

Mt Pinatubo Eruption in the Philippines, June, 1991



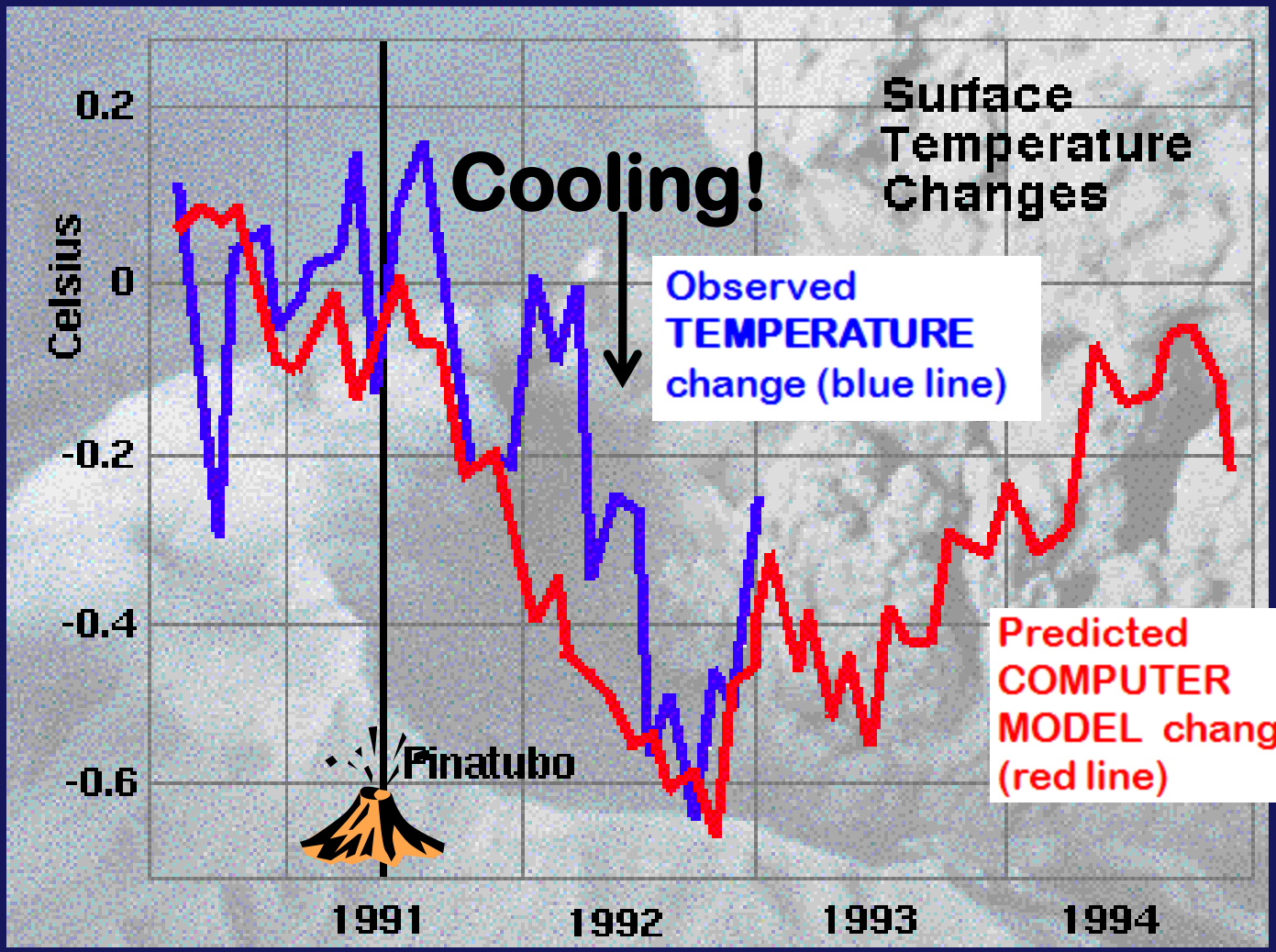
Satellite-derived image of
sulfur dioxide thickness in the atmosphere
red = higher thickness

By Sept 21, 1991 increased levels of sulfur dioxide had dispersed worldwide

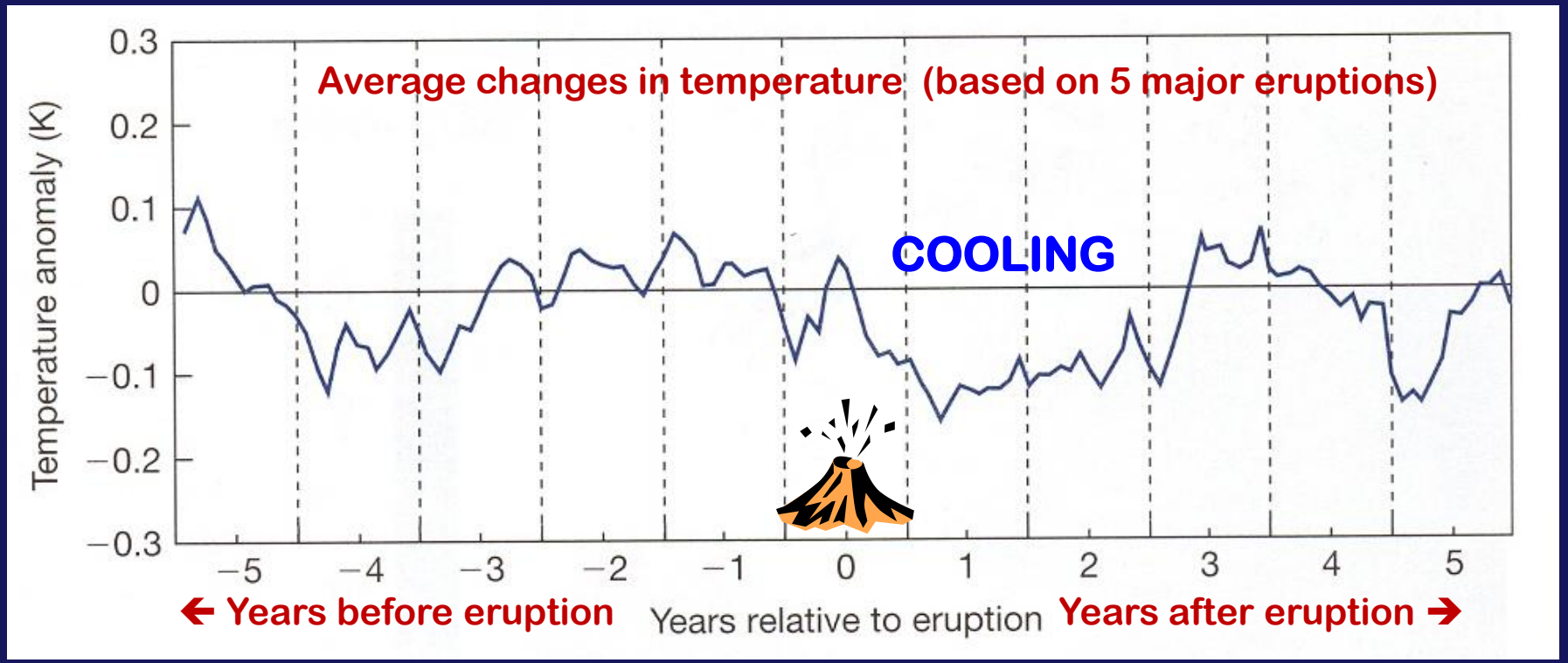


Mt Pinatubo

Mt Pinatubo eruption June 1991



Typical Global Cooling Pattern after a major explosive Volcanic Eruption



This graph shows the global mean temperature changes for years before (-) and after a large eruption (at year zero)

WHICH ERUPTIONS ARE THE MOST CLIMATICALLY EFFECTIVE?

READ THROUGH THE TABLE on p 71

THEN . . .

G-5 VOLCANISM & CLIMATE
GROUP ACTIVITY

IN YOUR FOLDERS!!

SEE YOU ON MONDAY
STUDY HARD
FOR TEST #3!