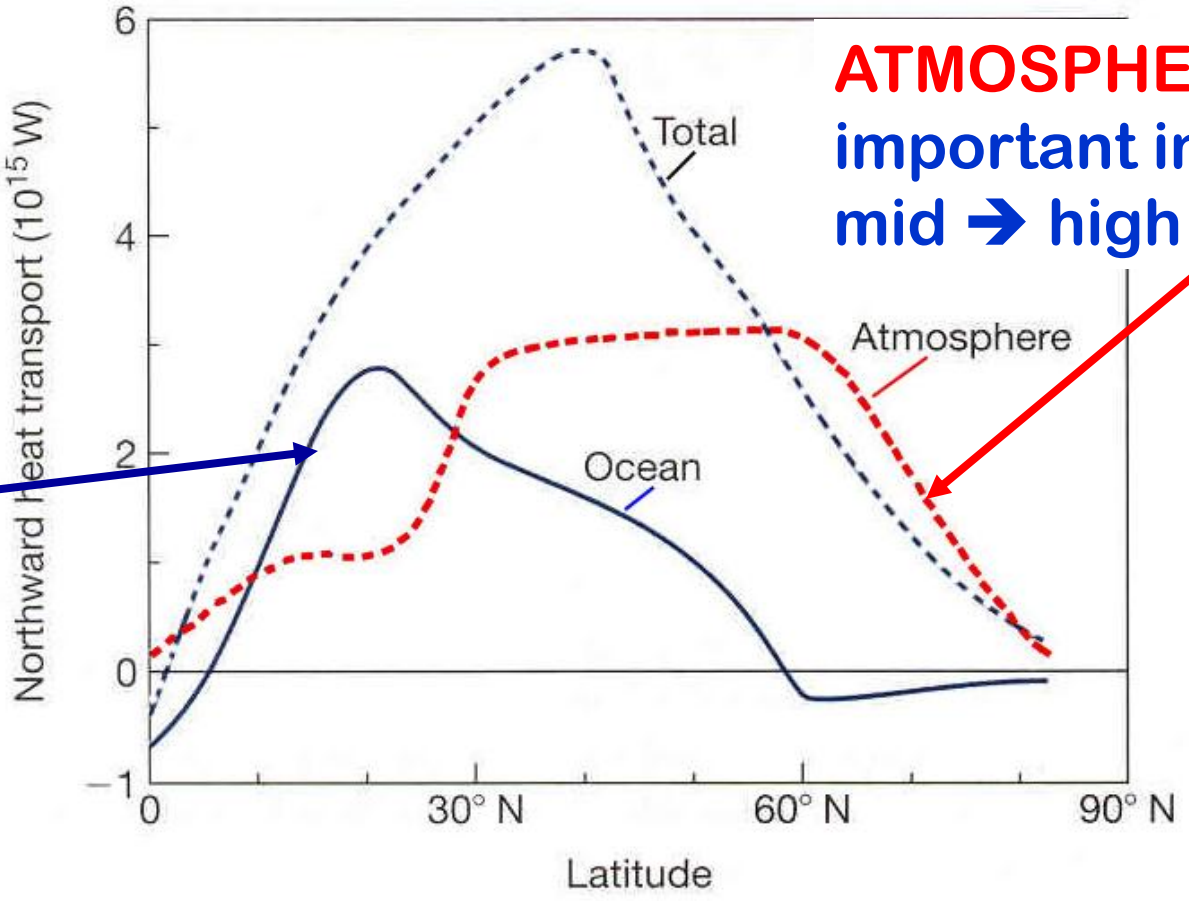
Wrap up of Topic #12 on How Climate Works: More on Ocean Circulation

pp 66-67 in Class Notes

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



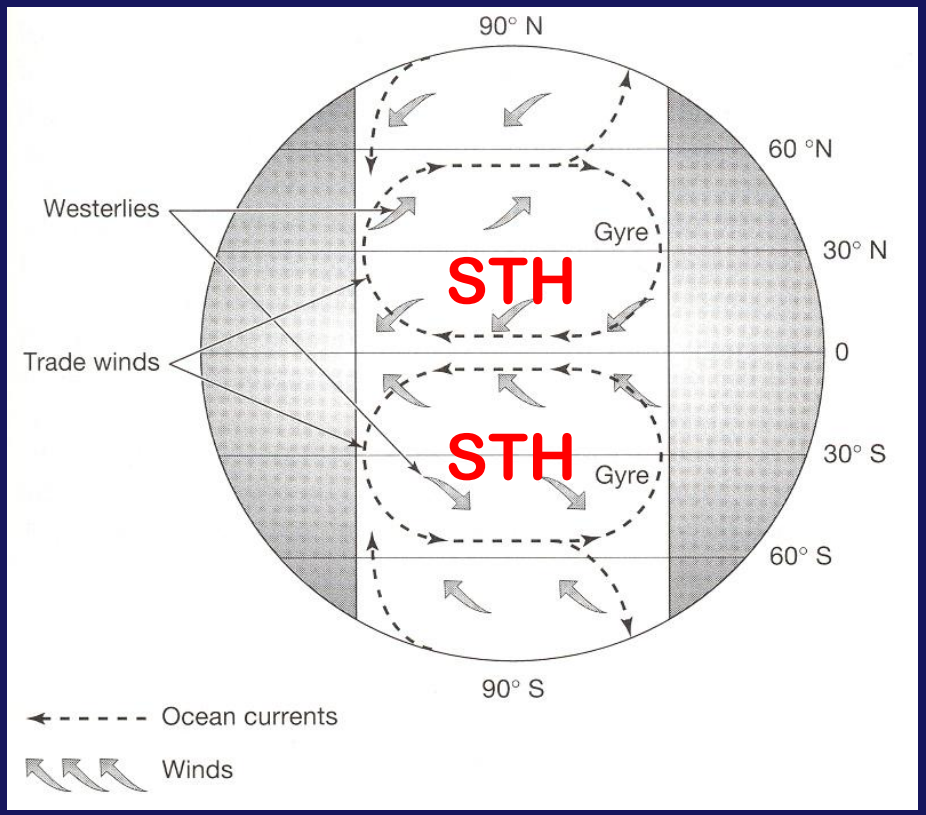
ATMOSPHERE more important in mid ➔ high latitudes

OCEAN transports MOST of the energy in LOW ➔ subtropical latitudes

Poleward transport of energy in N.H.

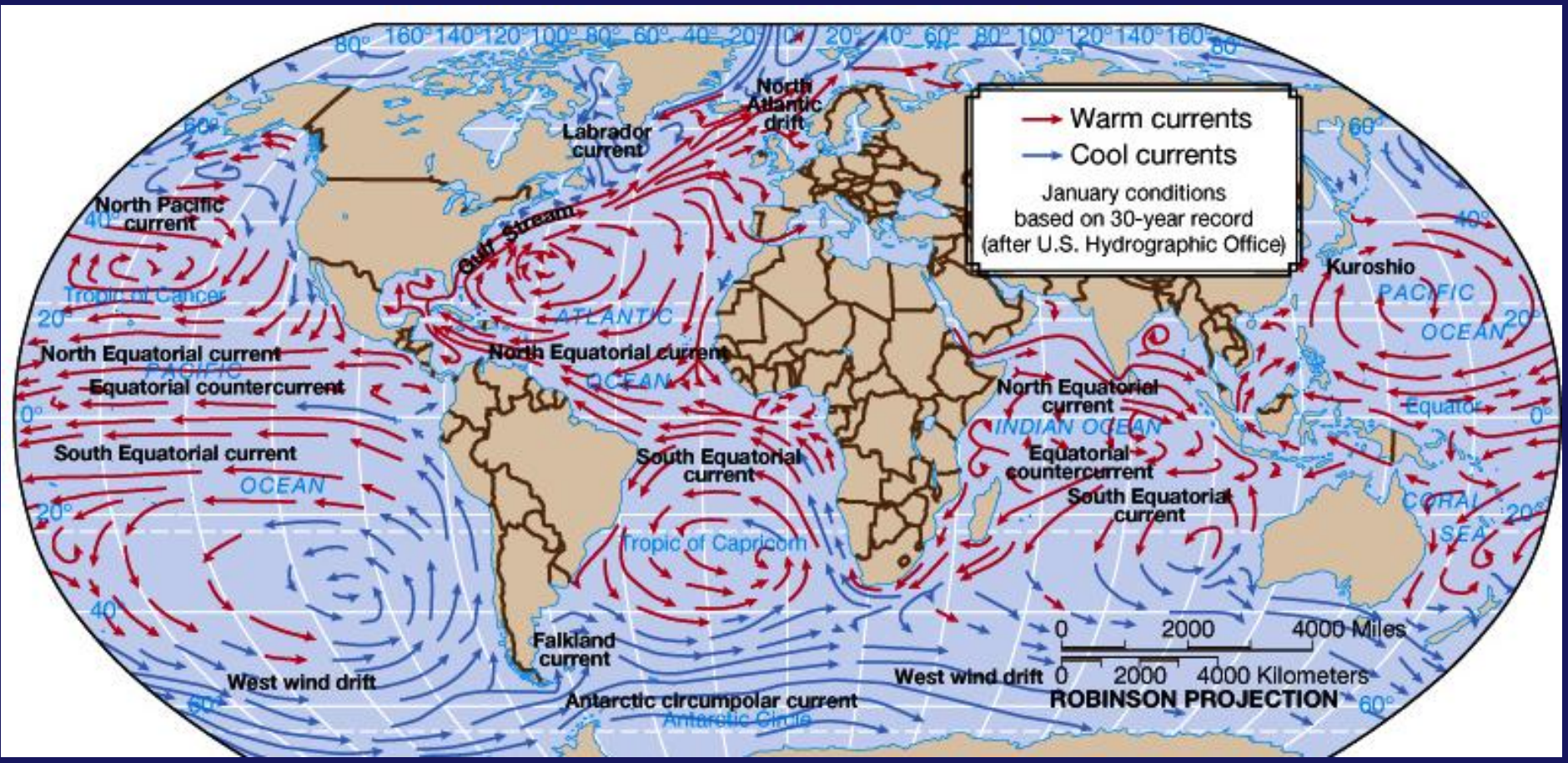
➔Large OCEAN GYRES = WIND DRIVEN

Trade Winds & Westerlies in Oceanic Subtropical HIGH PRESSURE CELLS (STH)

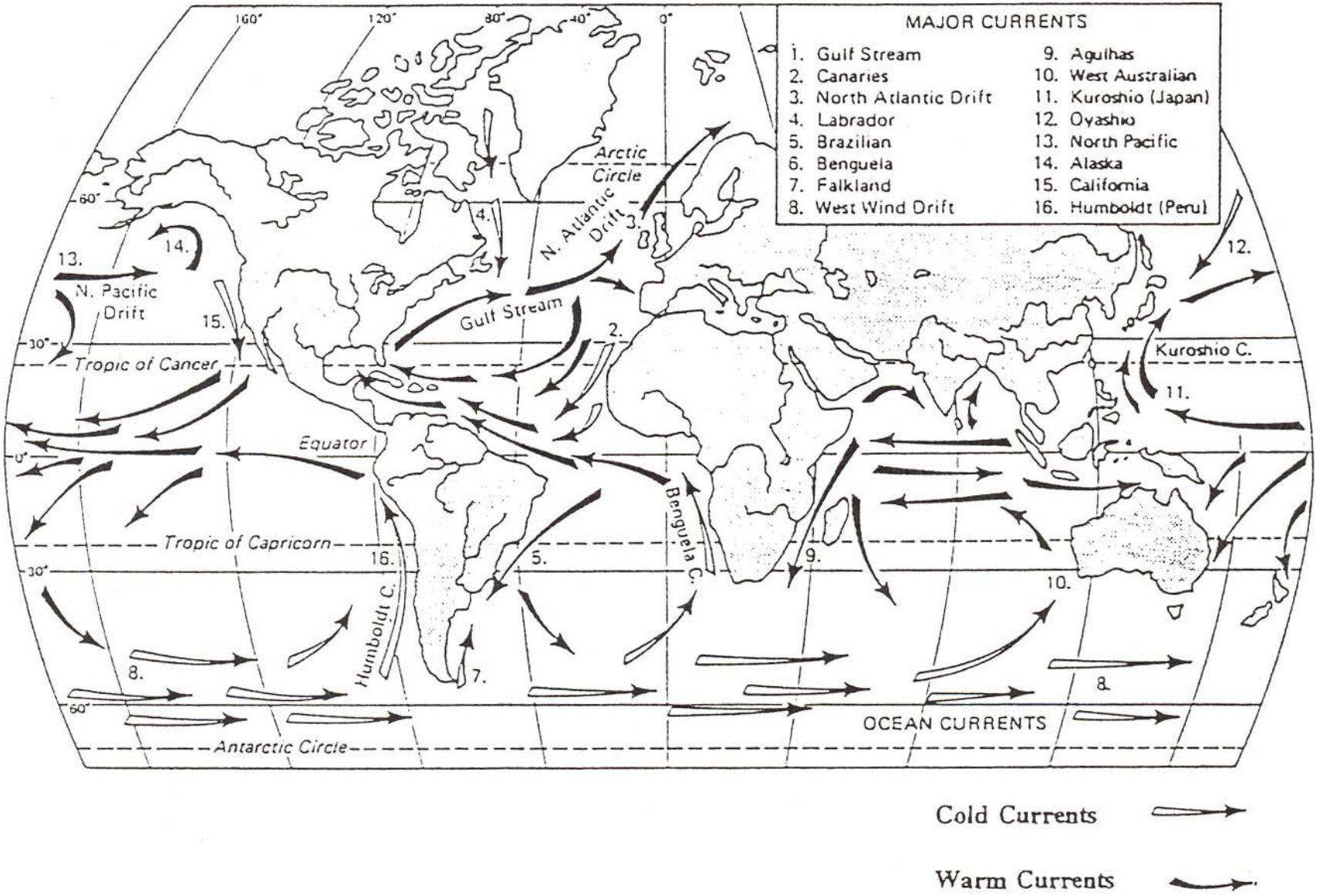


Winds drive <u>SURFACE</u> ocean currents

Energy stored in the ocean can be transferred via WARM OCEAN CURRENTS

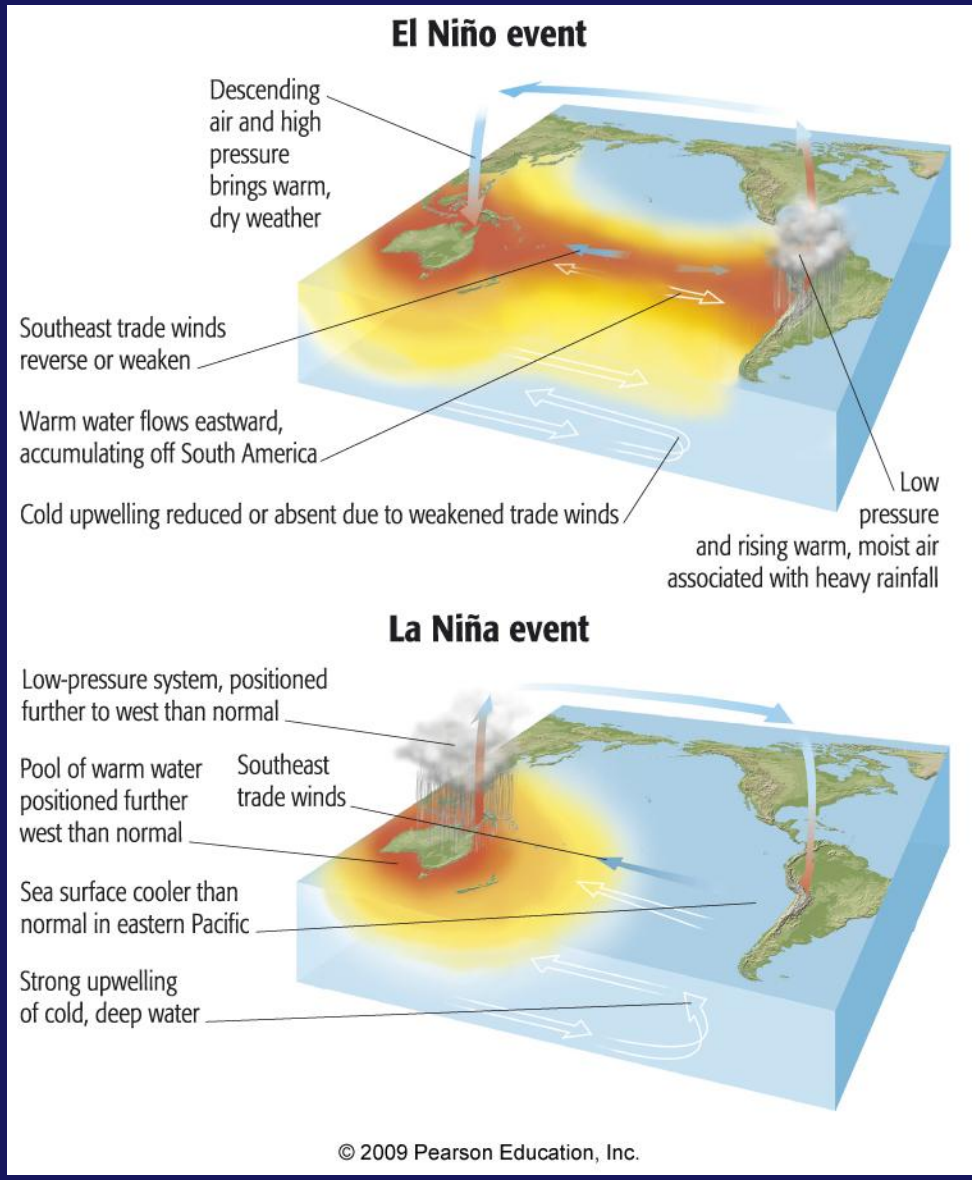


WARM & COLD SURFACE OCEAN CURRENTS:



Because of its high specific heat & heat capacity, **THE OCEAN HAS A MEMORY!**

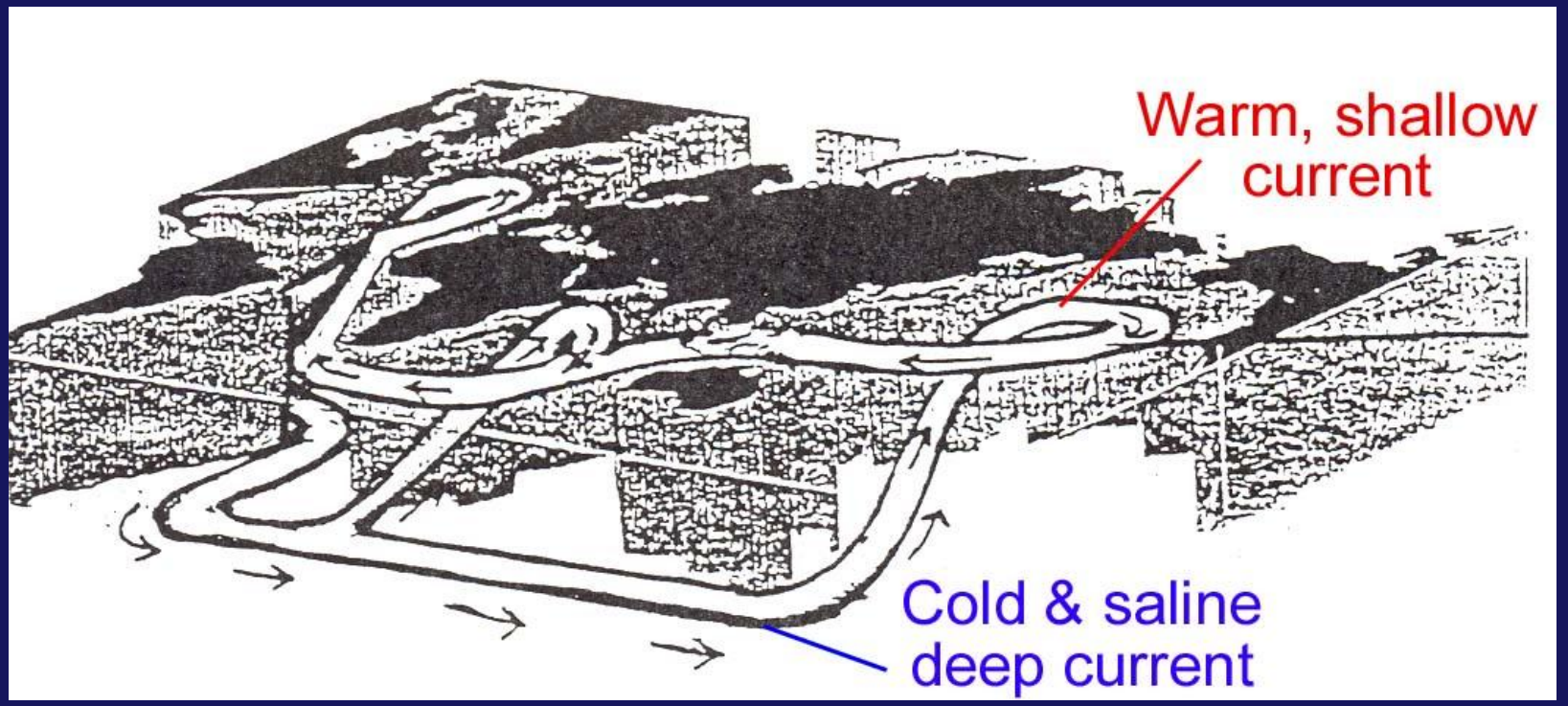
Hence **Sea Surface Temperatures** (SST's) play a key role in air-sea / sea-air interactions . . . .



El Niño & La Niña ANIMATION

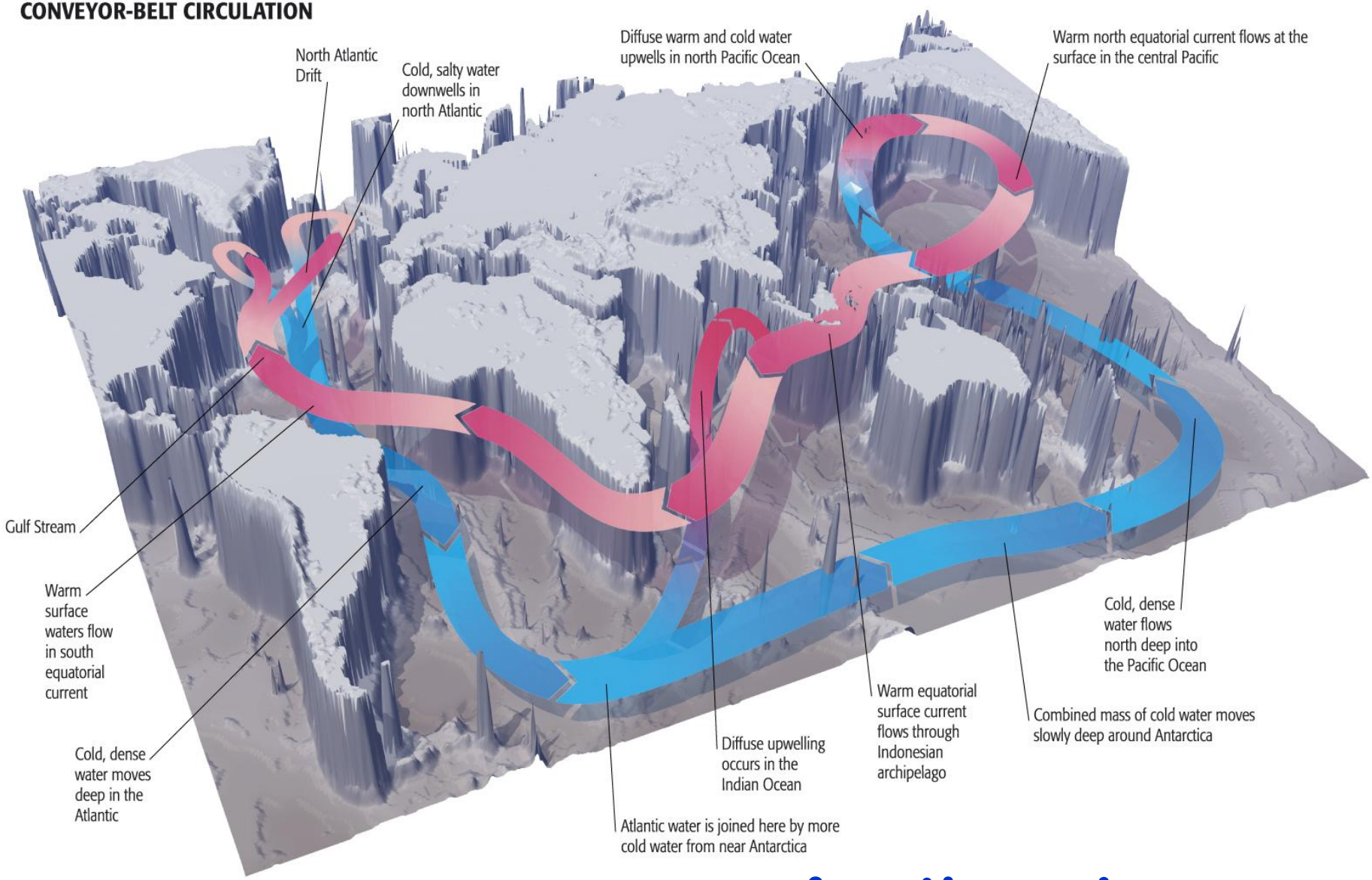
http://esminfo.prenhall.com/science/geoanimations/animations/26_NinoNina.html

There is also a DEEP OCEAN CIRCULATION – driven by thermal differences AND salinity differences: THERMOHALINE CIRCULATION - "Conveyor Belt"



- Density driven vertical circulation of the ocean

- Cold & salty waters are denser than warm & fresh waters



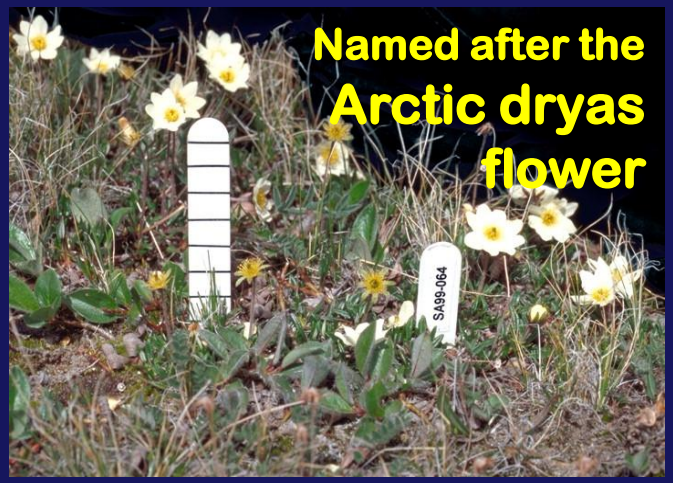
Another view

Why the Thermohaline Circulation is important . . .

At the end of the PLEISTOCENE ICE AGE, gradual warming took place between 15,000 – 10, 000 years ago (due to astronomical climate forcing) . . .

. . . until an ABRUPT END of the warming occurred ➔

➔ a ‘sudden’ COLD climate period occurred!



Arctic dryas flower is indicator of cold conditions

The “Younger Dryas”

-- interrupted a warm interval

-- was followed by the subsequent warming of the Holocene (“our” period)

An unusual “abrupt” cooling?

☺

What "forced" this cooling?

Why this "ABRUPT" shift? & HOW?

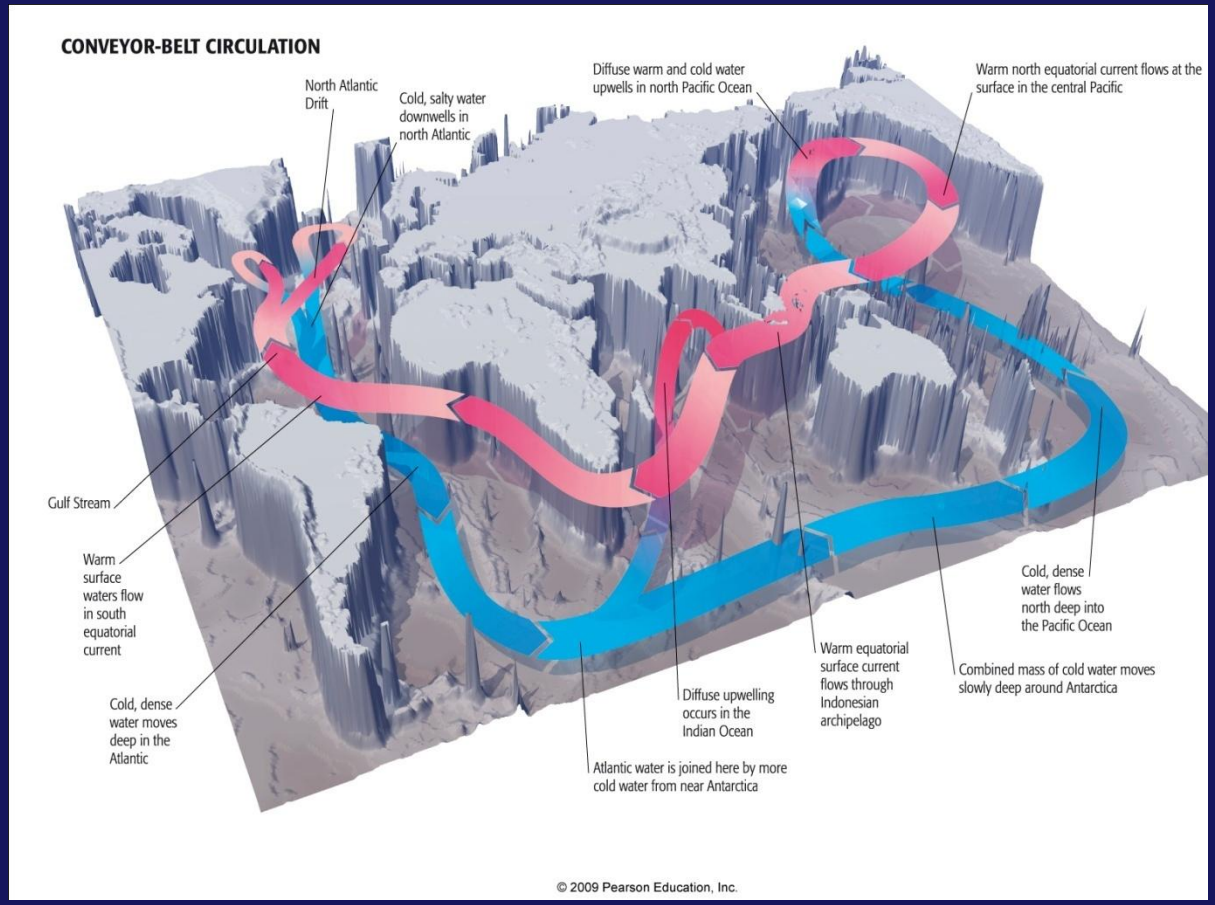
Prevailing theory = the Younger Dryas cooling was caused by . . .

- shutdown of the Gulf Stream & North Atlantic Current
- in response to a sudden influx of fresh water
- from deglaciation (rapid melting) in North America

SURFACE OCEAN CURRENTS
-- driven by winds

WARM & COLD sea surface temperatures (SST's)

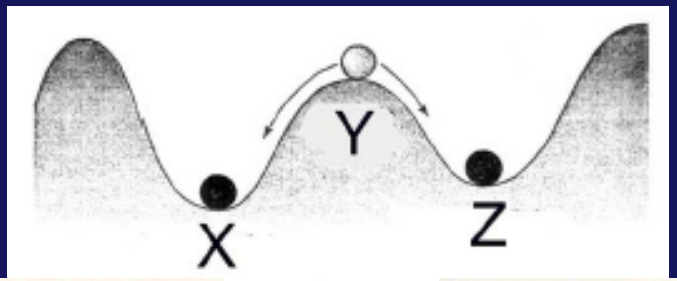
The theory says . . . **the** Thermohaline Circulation **could have been SHUT DOWN if:**



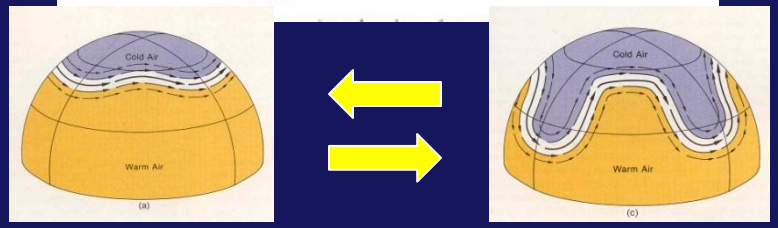
Cold & **salty** waters of N. Atlantic Current stopped sinking b/c the **salinity** was diluted by a sudden influx of **FRESH** water (from melting glaciers)

"ABRUPT" CLIMATE SURPRISES can happen!

These rapid changes appear to reflect a type of "flickering" or "switching" between preferred states of the Atmosphere - Ocean System which provides a different view of how the climate changes , e.g.



Preferred mode #1



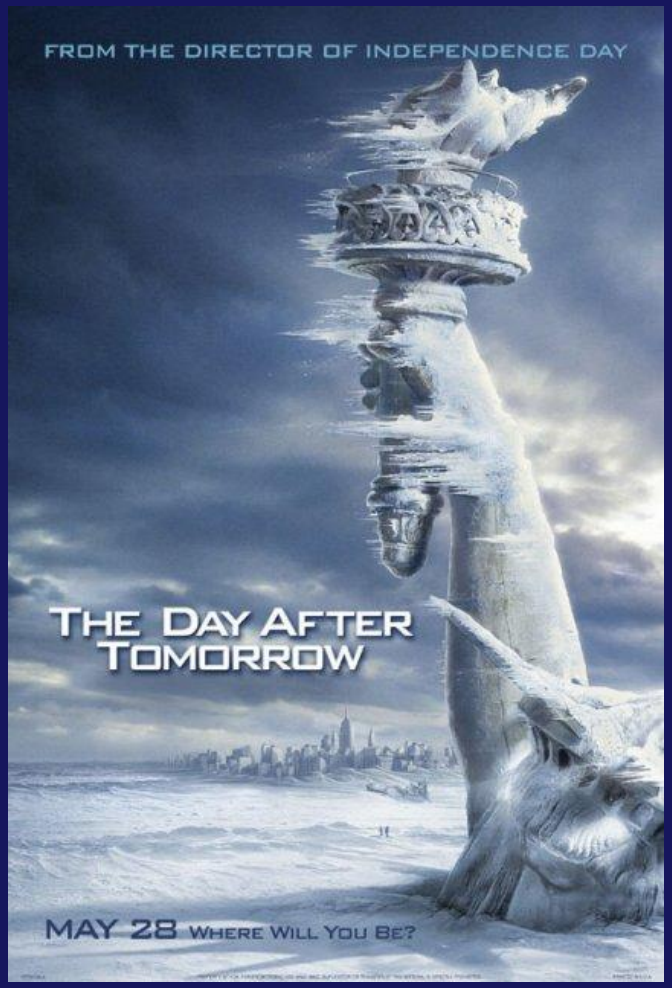
Preferred mode #2

Thus far our Holocene climates have been relatively stable and warm by comparison!

BUT could such an "ABRUPT" shift happen today?

THE DAY AFTER TOMORROW

(pure fiction based on a tiny bit of real science!)



TOPIC #13

NATURAL CLIMATIC FORCING

(& Short-Term Climatic Variability)

What natural forcings have been going on:

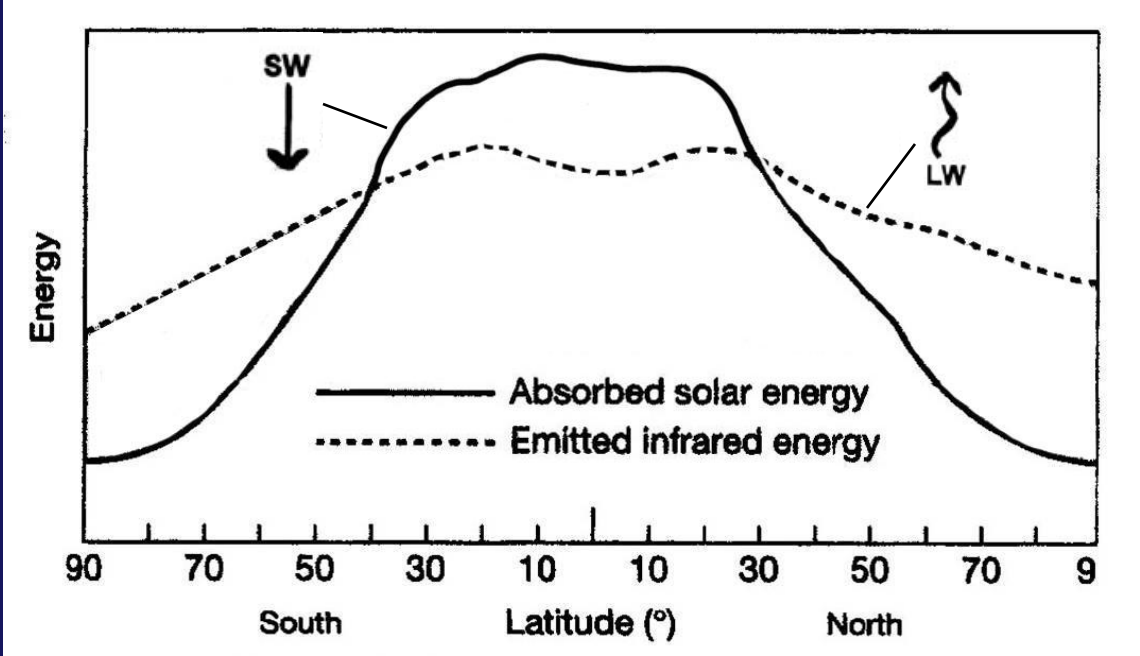
(1) in the more recent "Holocene" &
(2) over shorter time scales ?

pp 69-74 in Class Notes

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

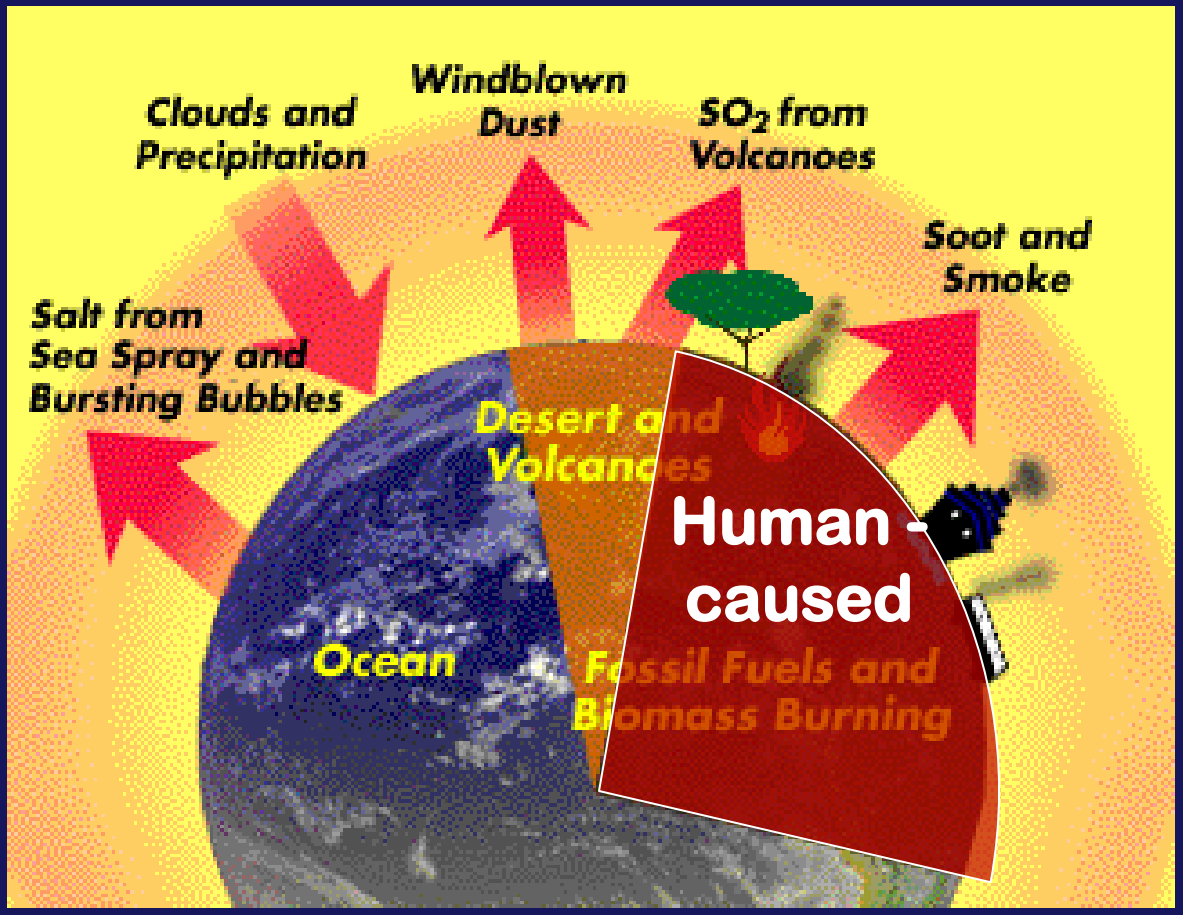
~ Chief Seattle

ENERGY BALANCE (review)



Global climate change / climate variability are due to changes in this balance that are "FORCED"

FORCING = a persistent disturbance of a system



(a longer term disturbance than a perturbation)

NATURAL CLIMATIC FORCING

Earth-Sun orbital relationships, internal atmosphere-ocean variability, solar variability, volcanic eruptions, etc.

vs.

ANTHROPOGENIC FORCING

Human-Enhanced GH Effect, due to fossil fuel burning, land use change, soot & aerosols from industry

Today we will focus on 3 main drivers of **NATURAL CLIMATIC FORCING**:

1) ASTRONOMICAL FORCING

2) SOLAR FORCING

3) VOLCANIC FORCING

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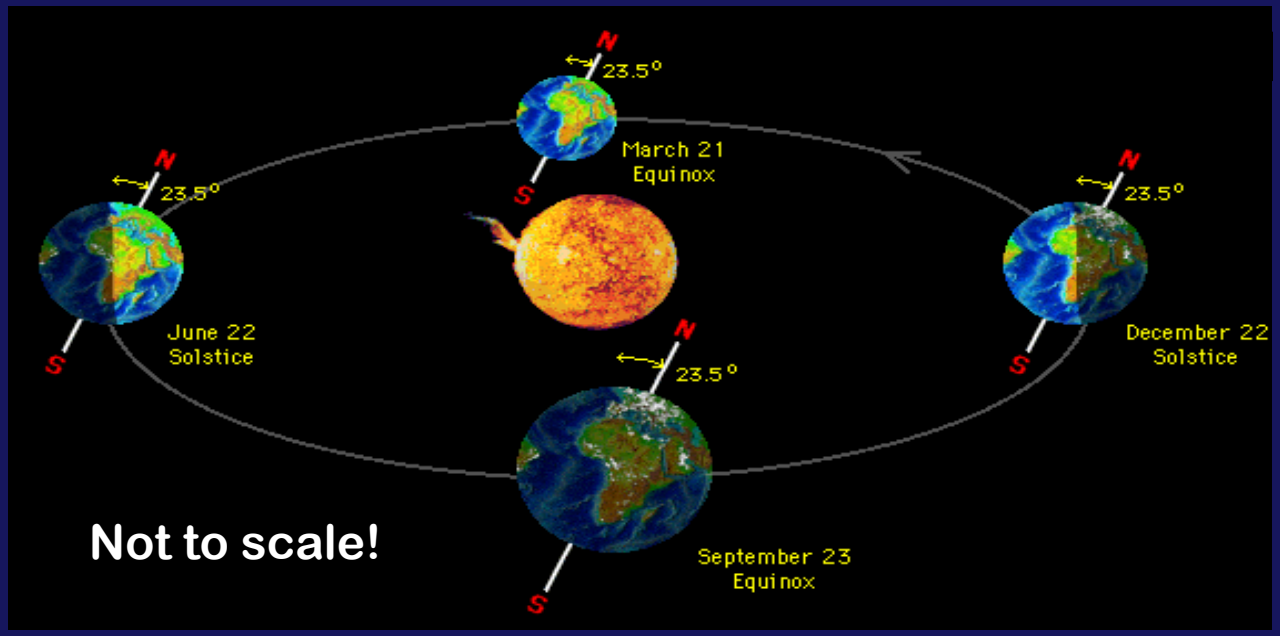
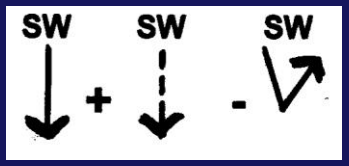
REVIEW: To drive the circulation, the initial source of energy is from the Sun:





EARTH-SUN Relationships

4 Things to Know about Earth-Sun Relationships:

1) Earth orbits Sun in one year
2) Orbit is not a perfect circle (= an ellipse)
3) Earth's orbit around Sun can be "traced" on a plane
   ("Plane of the Ecliptic" – plane passes thru the center of Sun & Earth)
4) Earth's axis tilts 23.5 ° from a ⊥ to the "Plane of The Ecliptic"

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

More on Seasonal & latitudinal variations of solar insolation:

3 Principles of EARTH-SUN RELATIONSHIPS

(They define the SEASONS in different latitudes!)

#1 OBLIQUITY OF EARTH'S AXIS

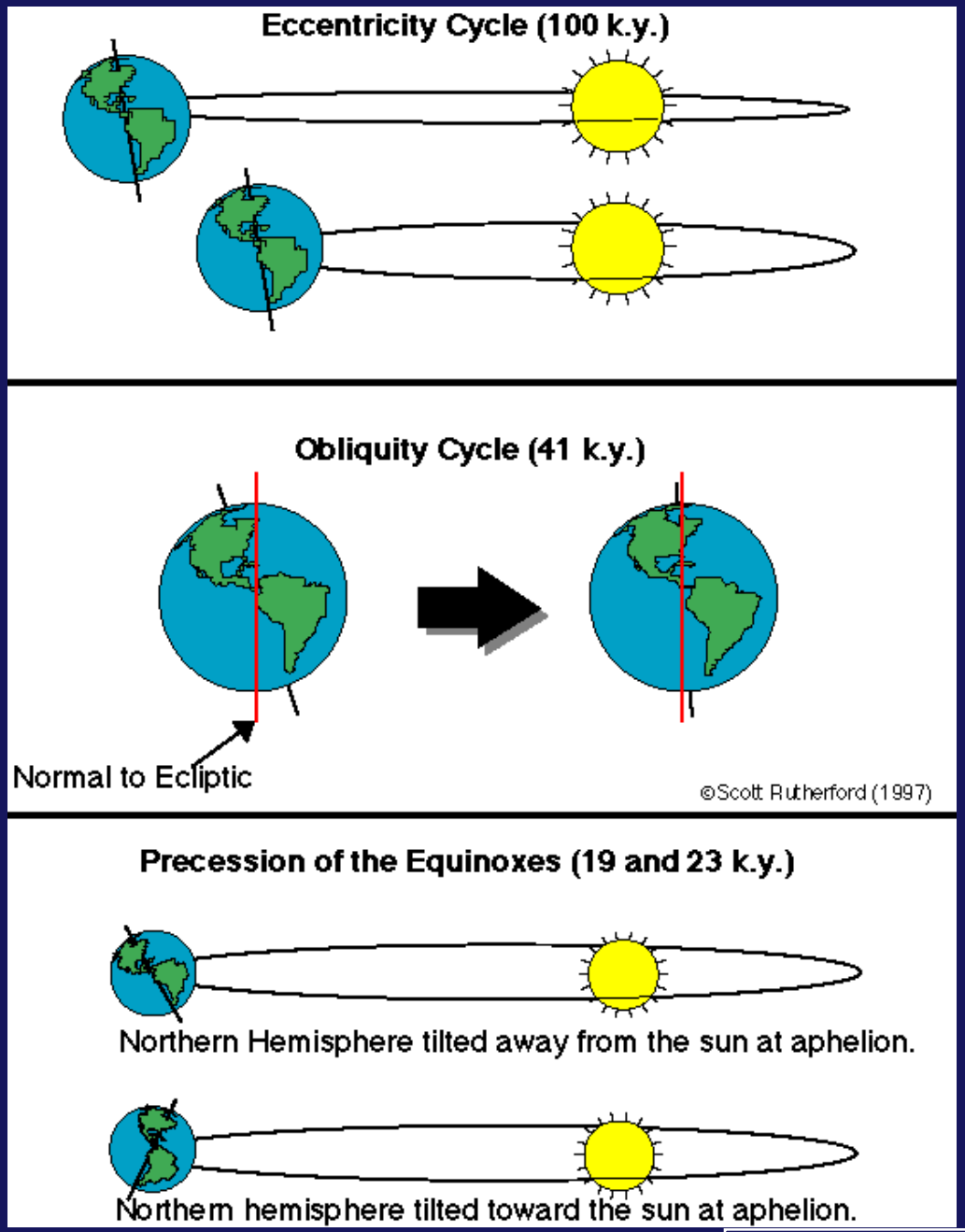
#2 ECCENTRICITY OF EARTH'S ORBIT

 # 3 Timing of Seasons in Relation to Orbit:

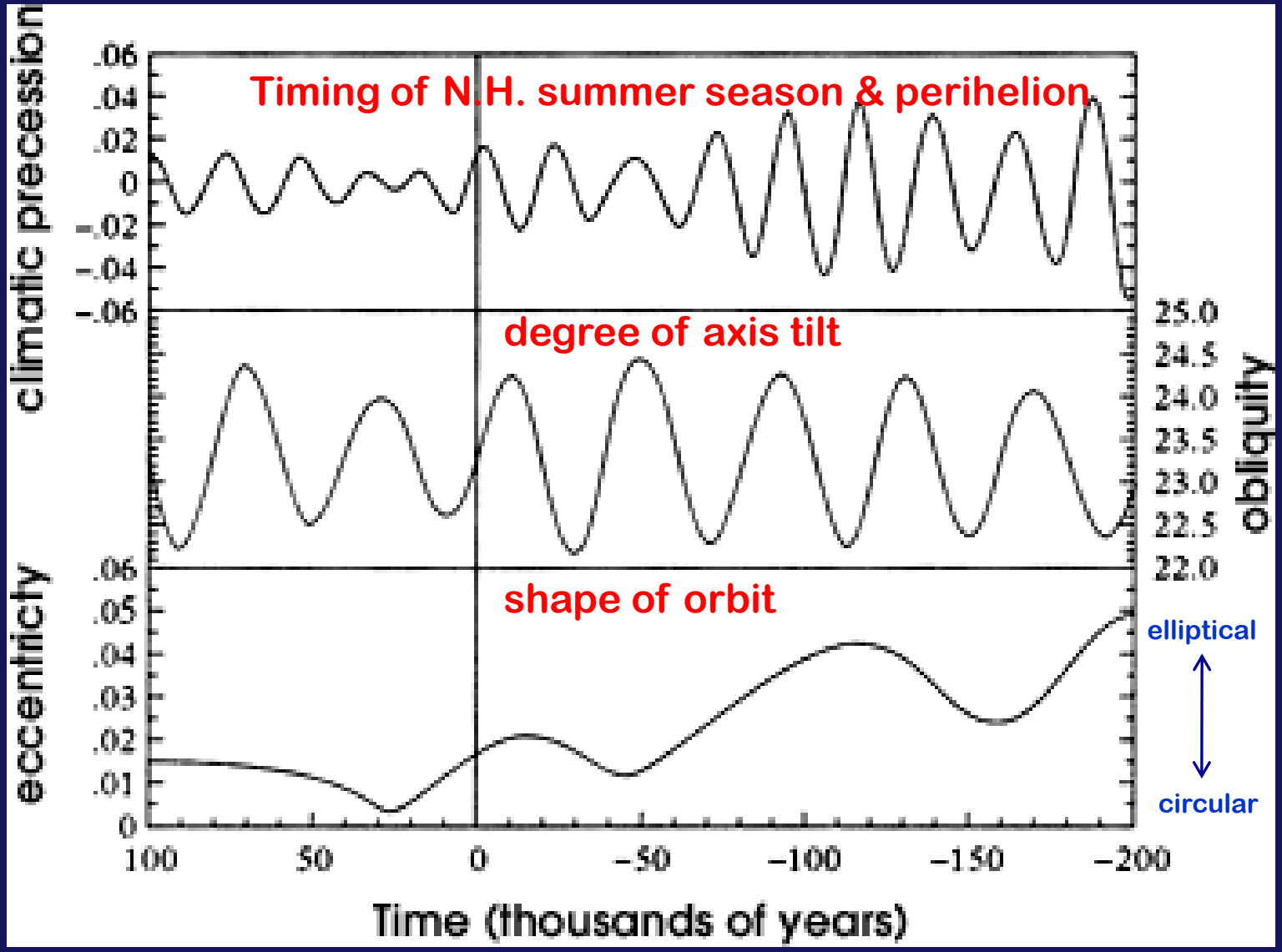
Earth-Sun Orbital Relationships

"astronomical climate forcing"

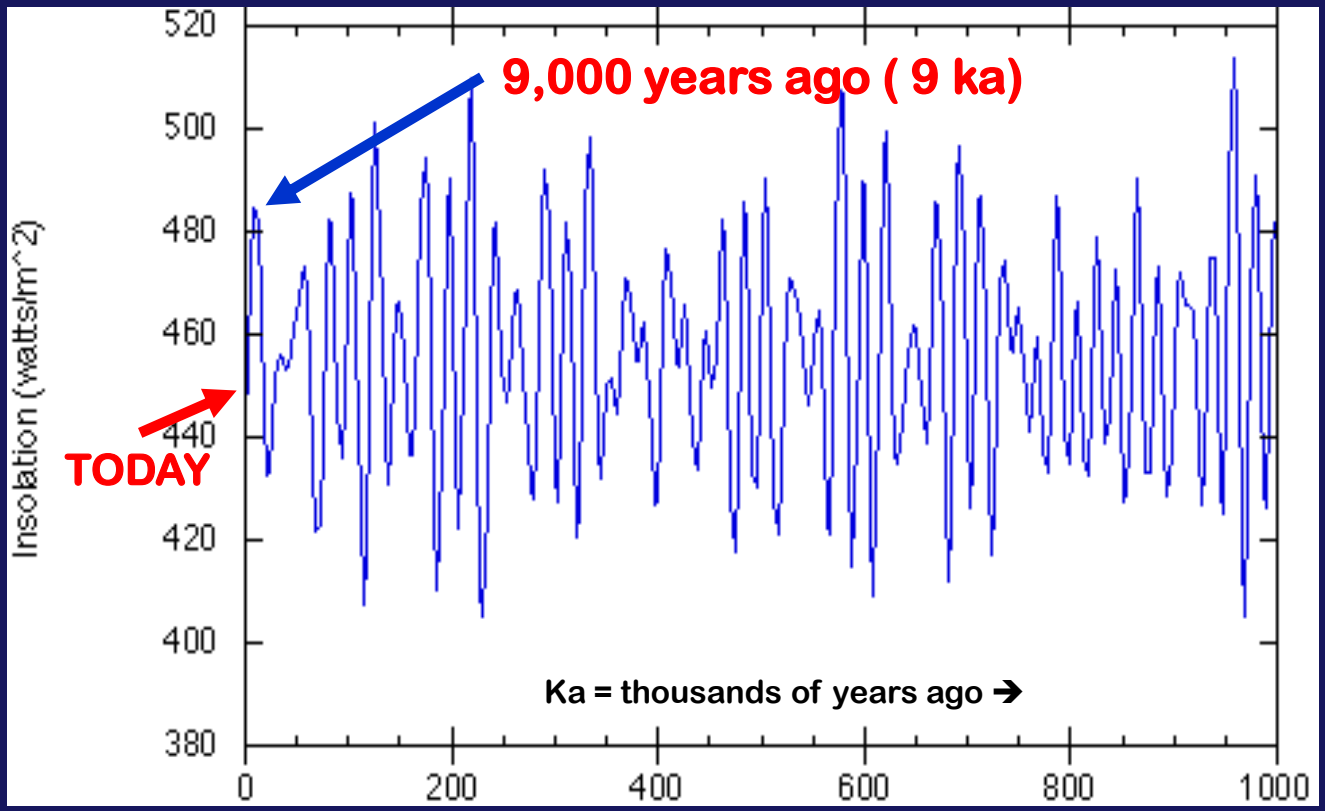
Drives natural climate variability (ice ages, etc.) on **LONG time scales** (geologic time, past 10,000 to 100,000 years, etc., etc.)



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



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



p 69

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.

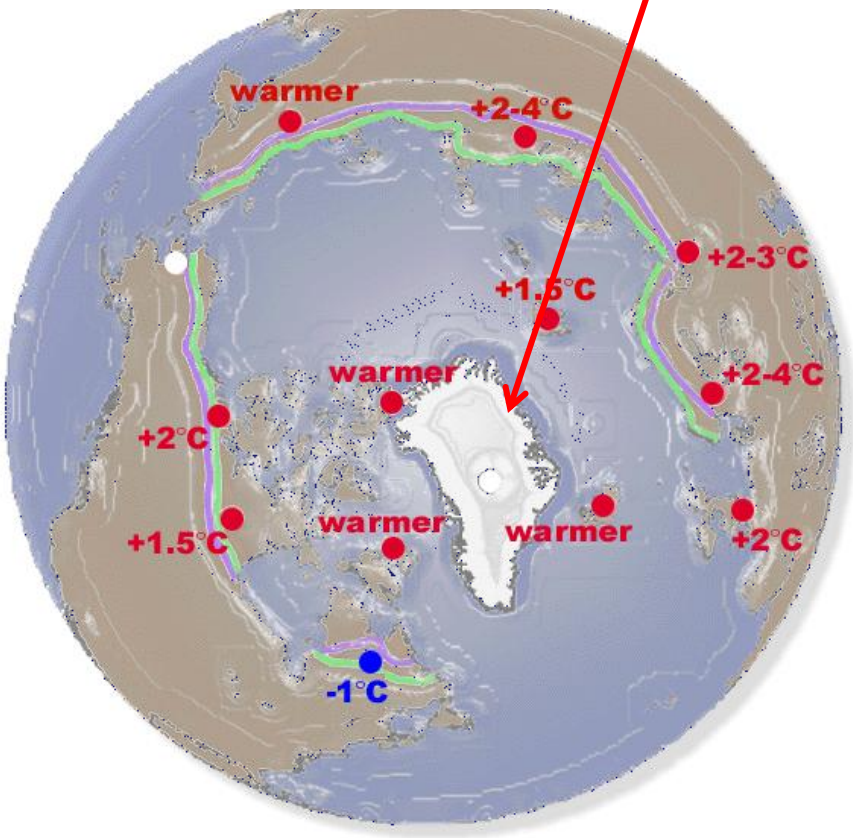
Mid-Holocene warm period
(~ 6,000 years ago)

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

Cause =

"astronomical climate forcing"

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



Other notable climate changes of the past:

"Short Term Climatic Variability"

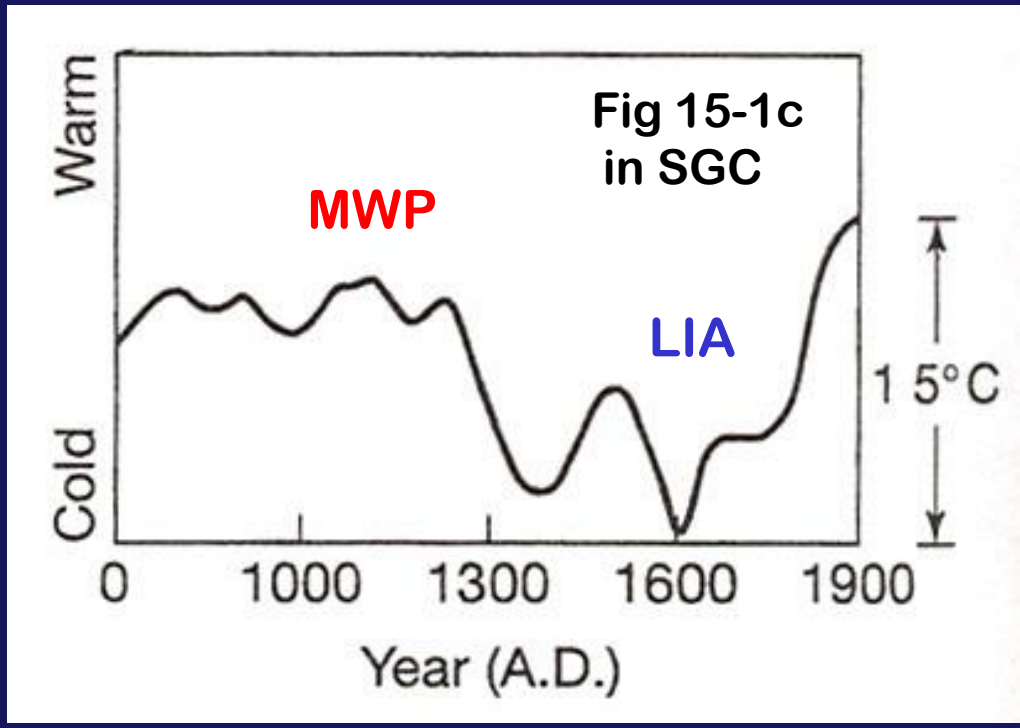
(century, decade, inter-annual time scales during the last 10,000 years)

Medieval Warm Period (MWP)

9^{th}-14^{th} centuries (800-1300)

Little Ice Age (LIA)

15^{th} – 19^{th} centuries (1400-1800) esp. 1600 -1800



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2) SOLAR FORCING ←

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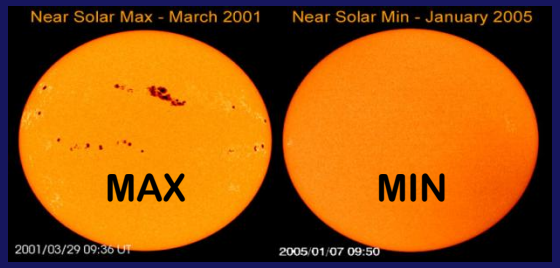
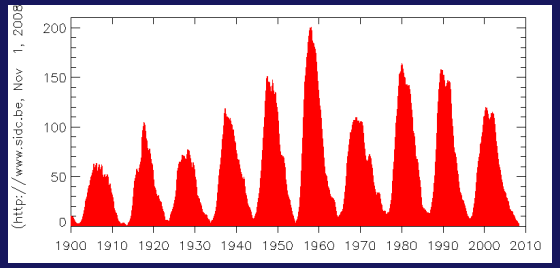
ANOTHER POSSIBLE NATURAL FORCING: SOLAR VARIABILITY





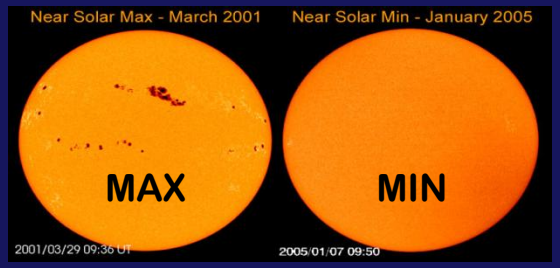
Q1 – During SUNSPOT Maximum periods:

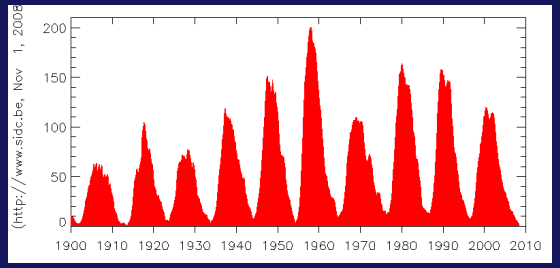
1. The sun is darker so it gives off less energy and global cooling is likely.

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





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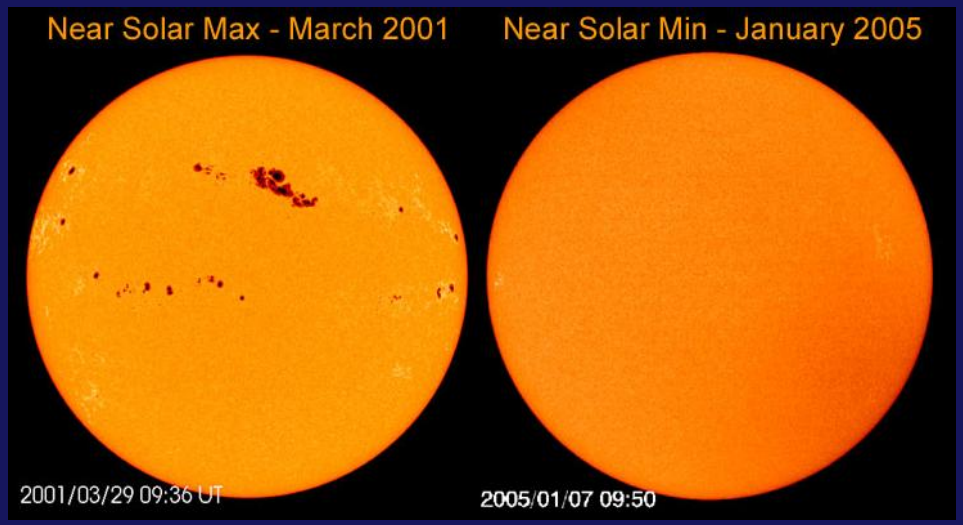
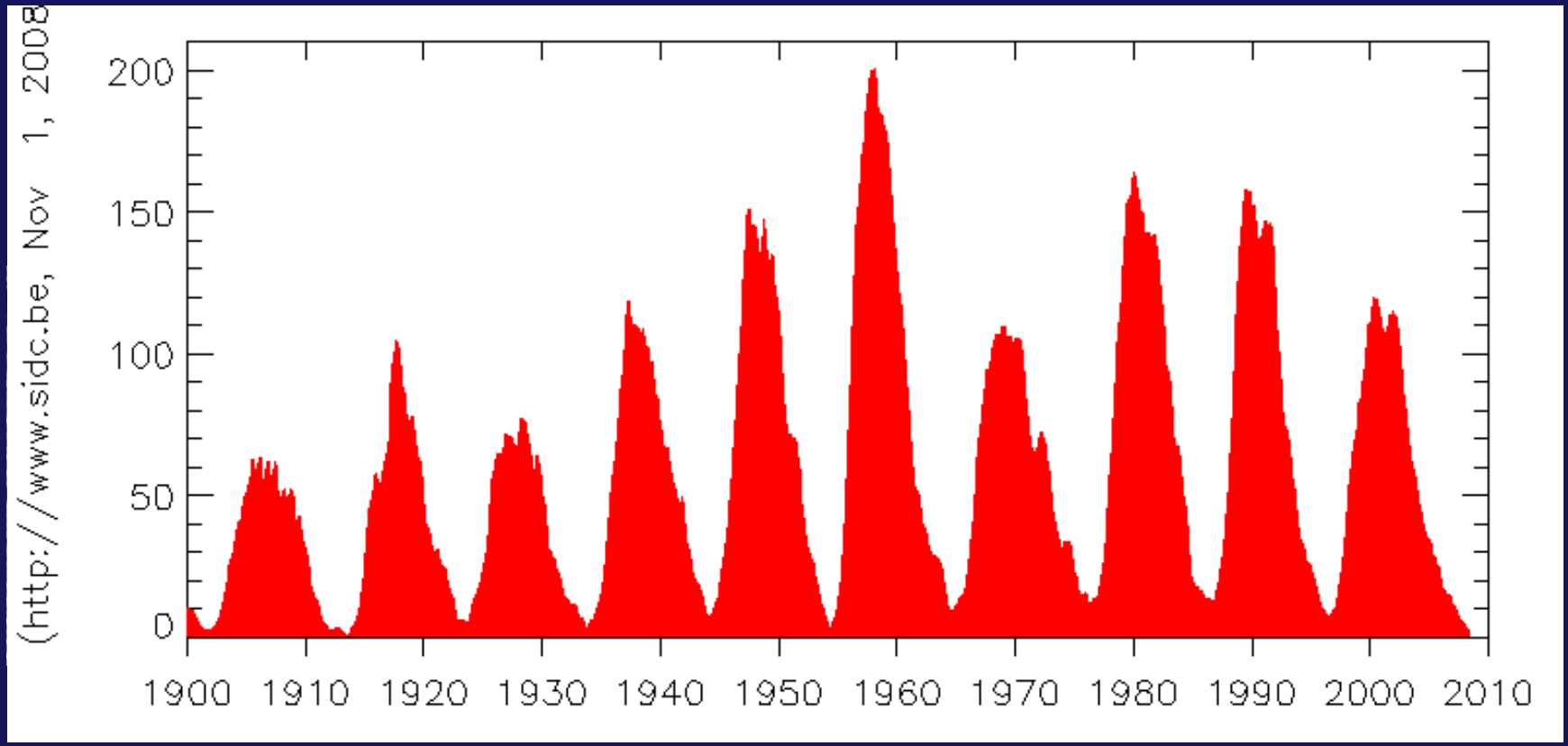


Sunspot maxima = MORE solar brightness (warmer temps)

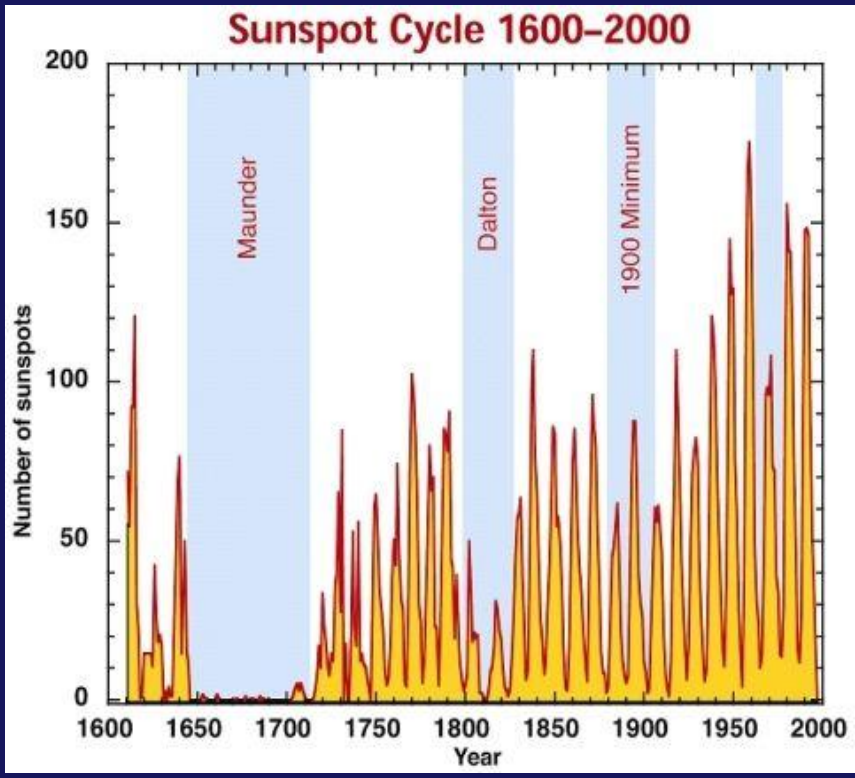
Sunspot minima = LESS solar brightness (cooler temps)



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)

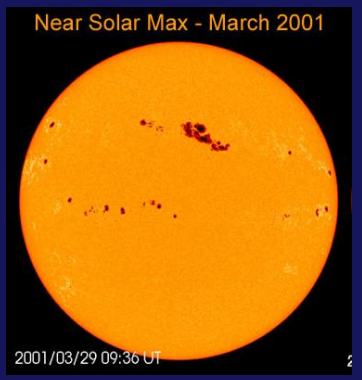


But uncertainties remain!
What MECHANISM transfers brightness drop to lower temperatures?

Dalton Minimum (1795 – 1825)
-- also cooler
-- lots of large volcanic eruptions then too

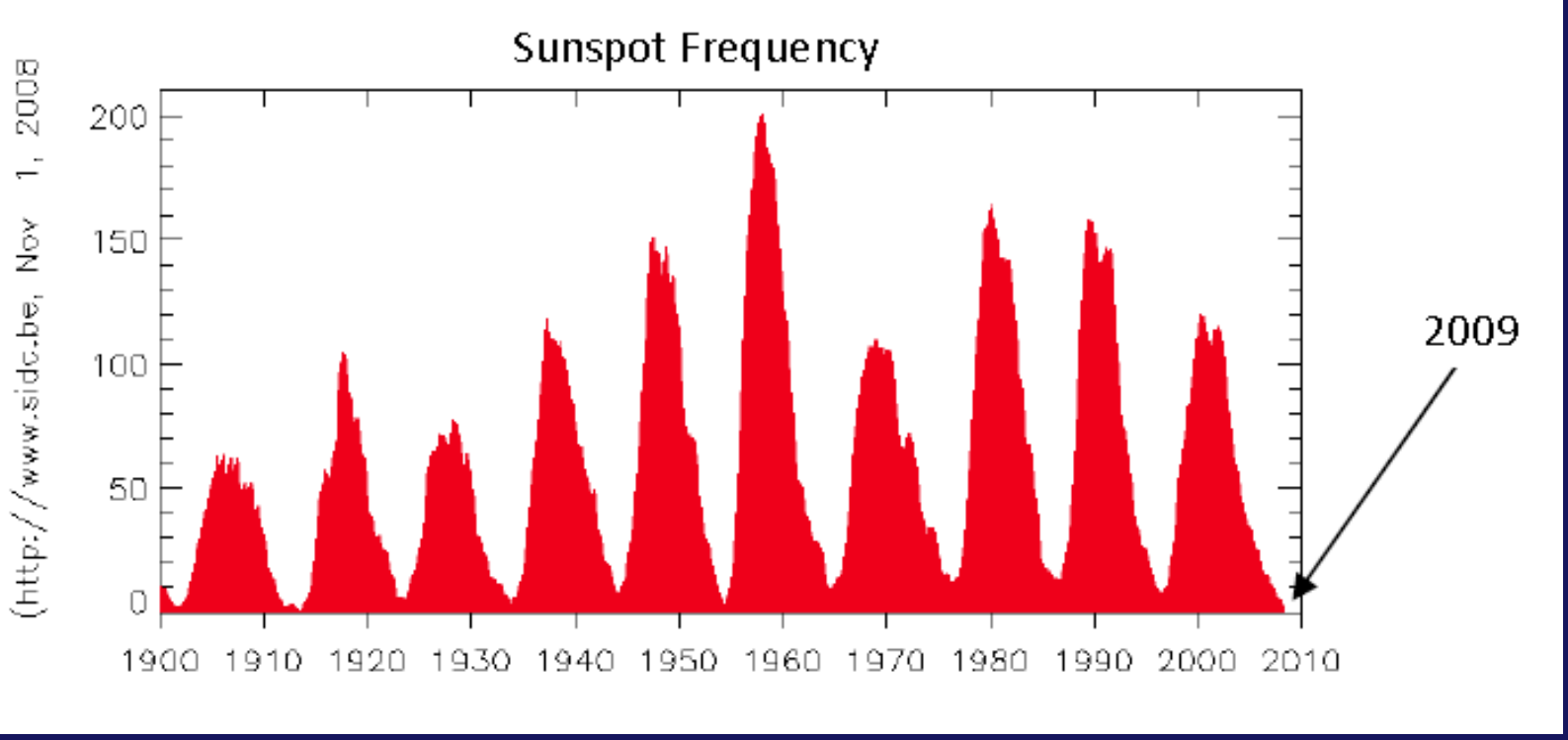
Since the Dalton Minimum, the Sun has gradually brightened – we just came out of a "Modern Maximum" (max in 2001)

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.



We are now (2010) in a SOLAR MINIMUM ***– but this caused recent (controversial) interest because:***

- minimum seemed unusually long
- number of "spotless" days has not been equaled since 1933
- the vigor of sunspots (in terms of magnetic strength and area) has greatly diminished
- Q: Are we going into another Maunder-like period? or
- Q: Will normal activity return within the year?

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Scientist Predicts Ice Age Within 10 Years

University of Mexico expert says lack of solar activity to cause significant cooling that will last over half a century

Paul Joseph Watson
Prison Planet
Tuesday, August 19, 2008

As evidence builds of the earth entering a dramatic cooling trend, another scientist has gone public with his conviction that we are about to enter a new ice age, rendering warnings about global warming fraudulent and irrelevant.

...h Of Sunspot Activity To Herald New Ice Age?

...legree drop in temperatures over next two decades

...g sun cycles for over 200 years predicts that global ... the next two decades as solar activity grinds to a halt ...ially heralding the onset of a new ice age.

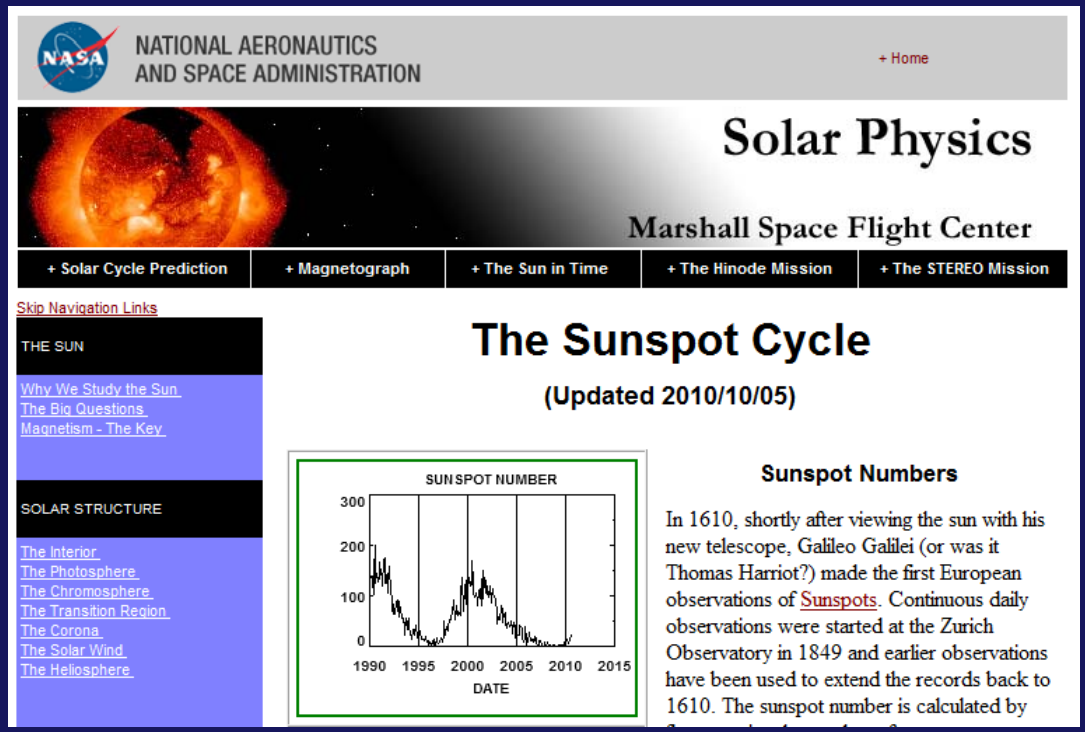
... bodies like the IPCC scaremonger about the ...d middle class pay CO2 taxes, both hard ...oints to a clear cooling trend.

...s most active period in over 11,000 years, the **last 10 years have ...cooling trend** as temperatures post-1998 leveled out and are now

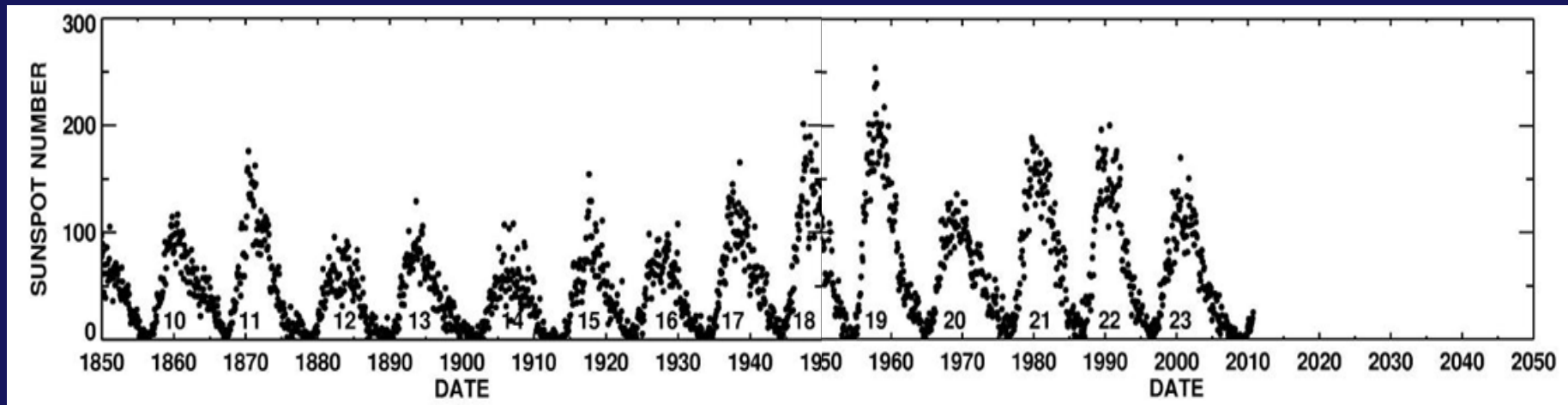
Not by Fire but by Ice

THE NEXT ICE AGE - NOW!

So what IS happening now?



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



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1) ATRONOMICAL FORCING

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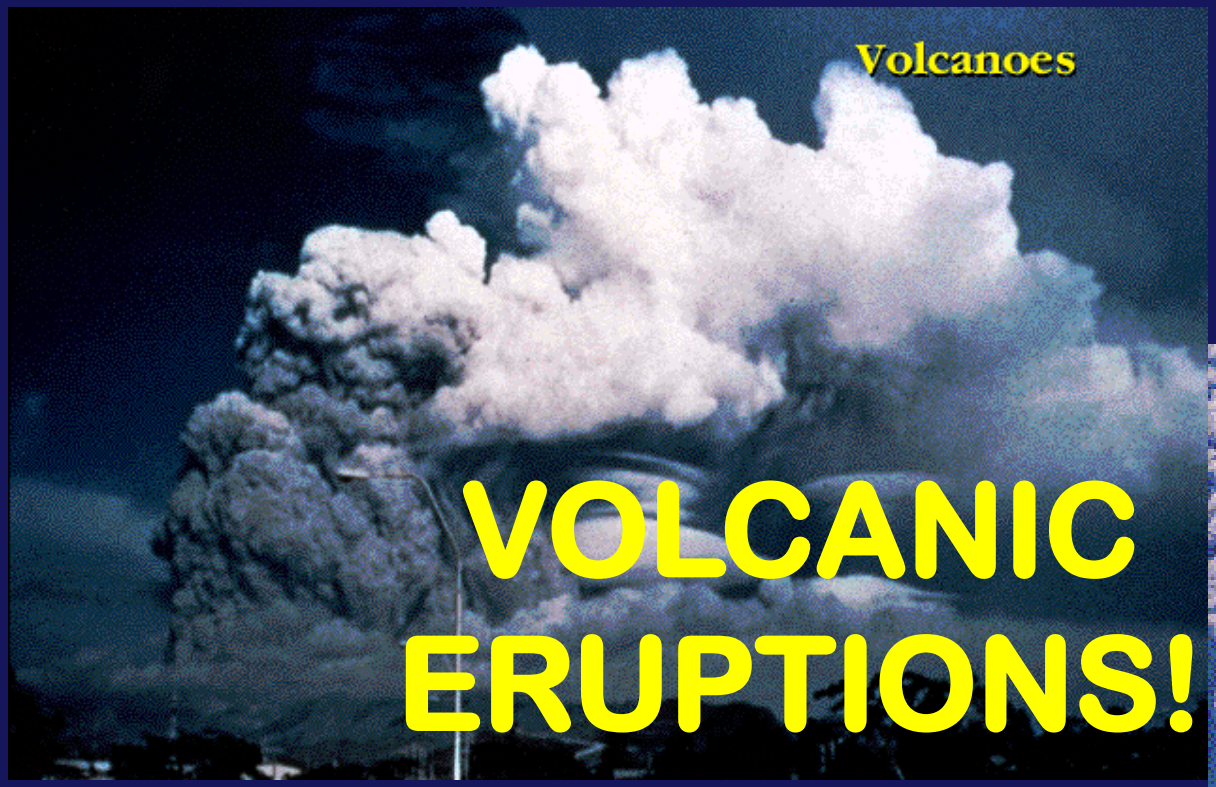


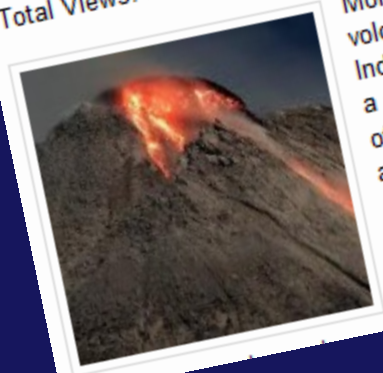
VOLCANIC ERUPTIONS!

Indonesia buried in ash after volcano Merapi eruption

Thursday, October 28th, 2010 | Posted by sayanee

Indonesia Volcano Update - Indonesia hit by Mount Merapi eruption!

Total Views: 504



More than 25 people were killed when the Mount Merapi volcano located close to the Central Java province of Indonesia erupted yesterday. The volcanic eruption came a day after a small scale tsunami hit the coastal regions of the island country. The death toll from the tsunami attack has been recorded at 113 people.

Mount Merapi is an active volcano, but is relatively quiet, report government officials in Indonesia. And that is the reason why the Volcanology Agency in the country had

r 28, 2010 13:19 PM

Malaysian Students Assist Victims Of Merapi Eruption

From Ahmad Fuad Yahya

SOLO (JAWA TENGAH), Oct 28 (Bernama) -- Malaysian medical students from two universities in Indonesia today joined volunteers in assisting victims of the Gunung Merapi eruption.

Thousands of people residing around the base of the 400,000-year-old volcano were still being accommodated at several evacuation centres to escape from the lava flow and volcanic dust emitted by the eruption.

The Malaysians from various
Negeri Surakarta
Mada, Yogyak

nprised 26 students from Universiti
re and 14 from Universiti Gadjah

28 OCT, 2010, 12.21PM IST,PTI

Ash from volcanic eruption in Mt Merapi may hit Indian region

http://www.youtube.com/watch?v=LVitigd74IM

Volcanoes are one way the Earth gives birth to itself.

~Robert Gross

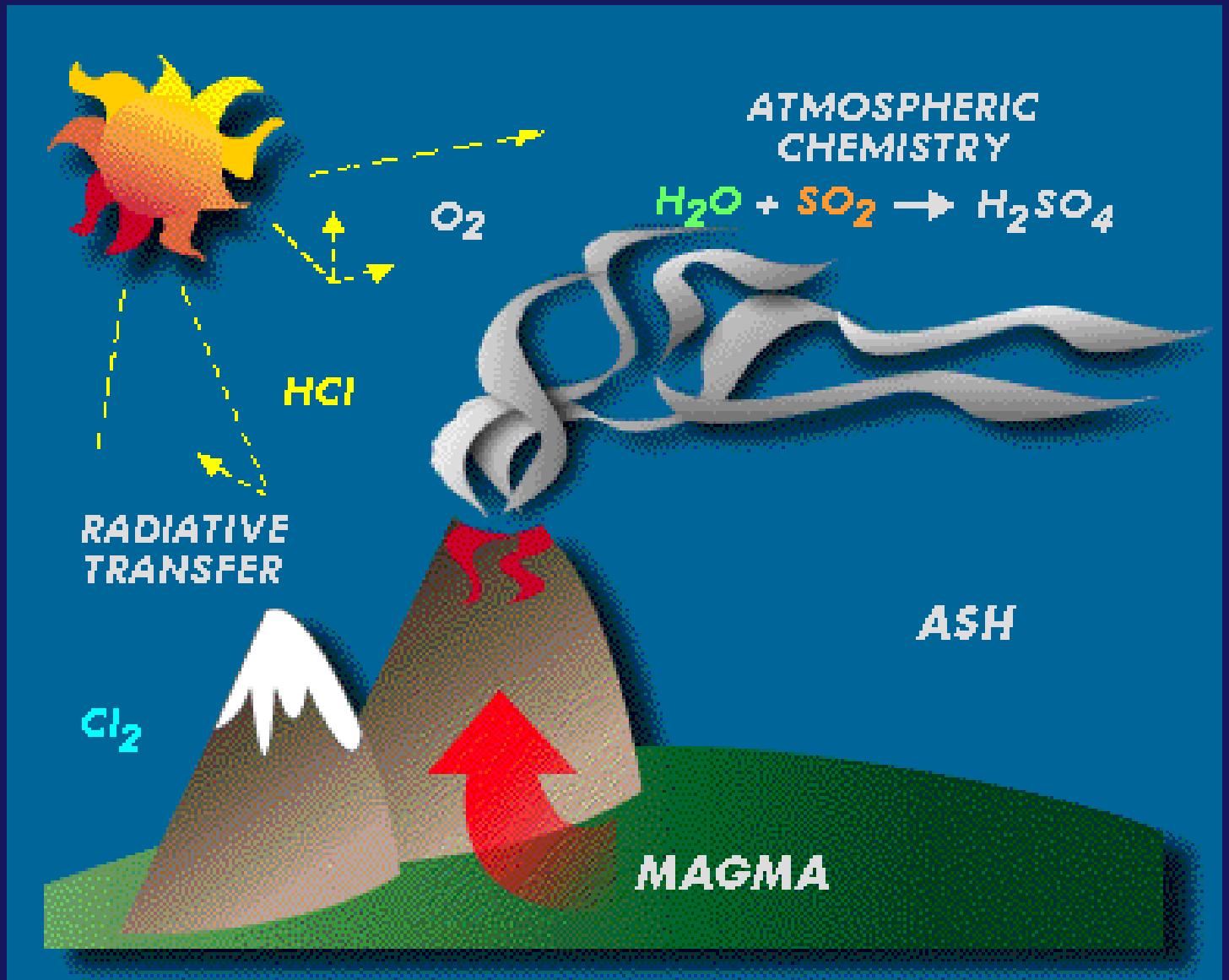
Volcanic eruptions contribute to the natural Greenhouse Effect by adding CO_2 into the atmosphere:

Volcanic outgassing of CO_2 into atmosphere

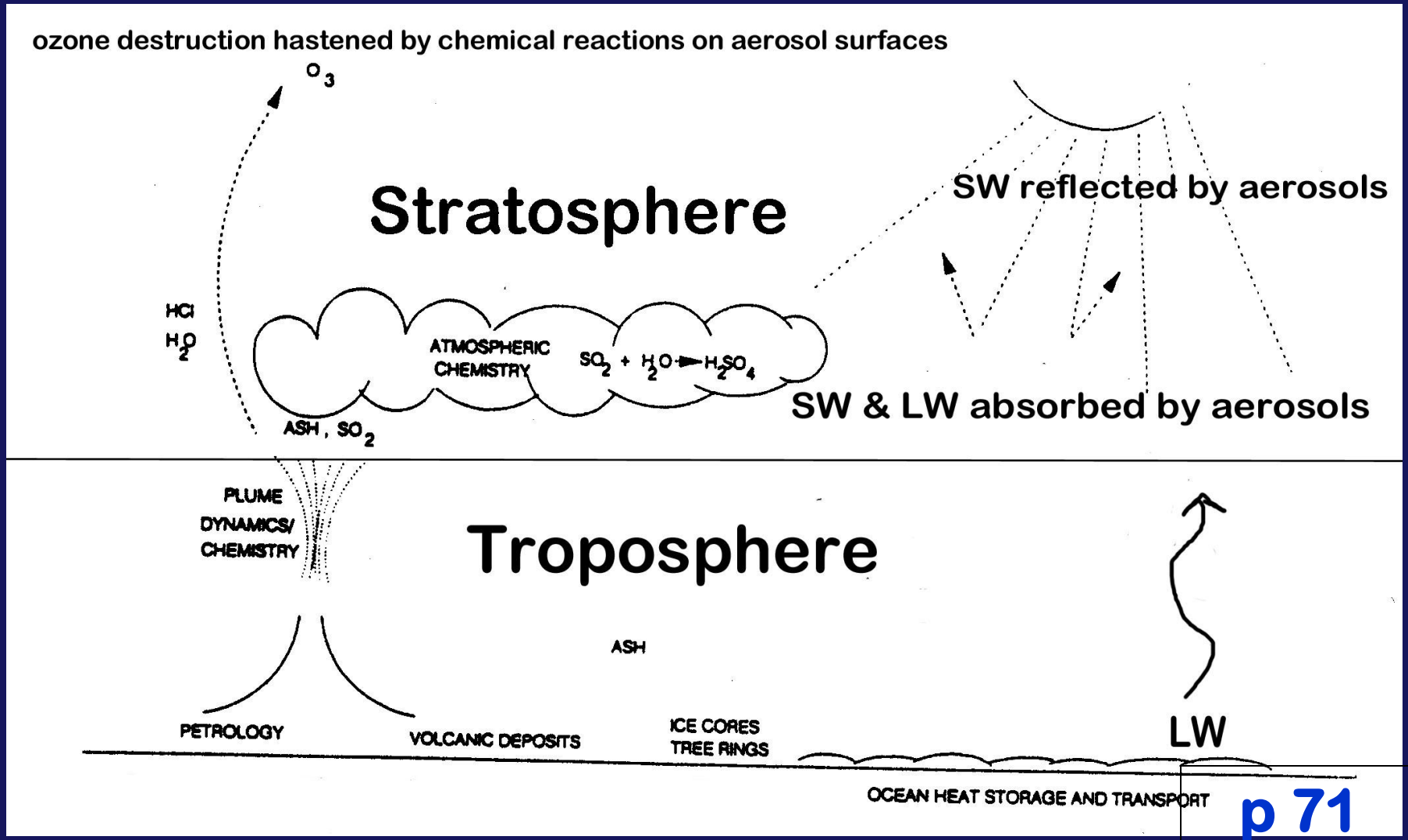
0.06 Gtons

This carbon flux is more or less <u>in balance</u> over time

Eruptions can also have a more direct climatic effect under certain conditions:



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



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

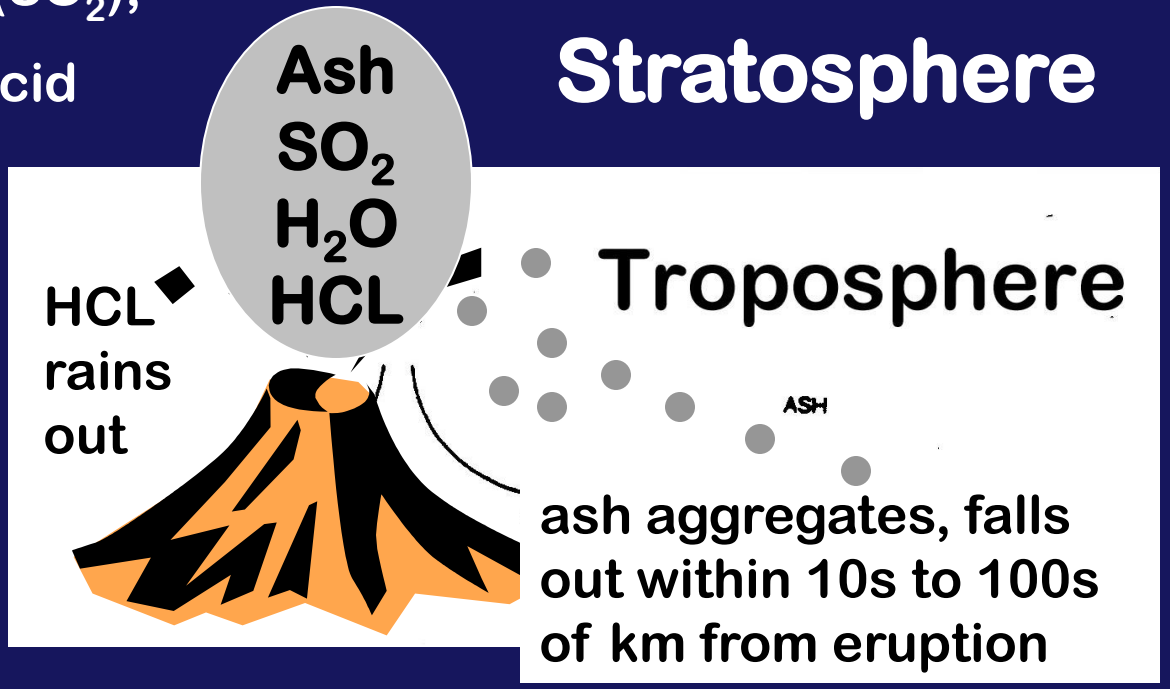
water vapor (H_2O)

sulfur dioxide (SO_2),

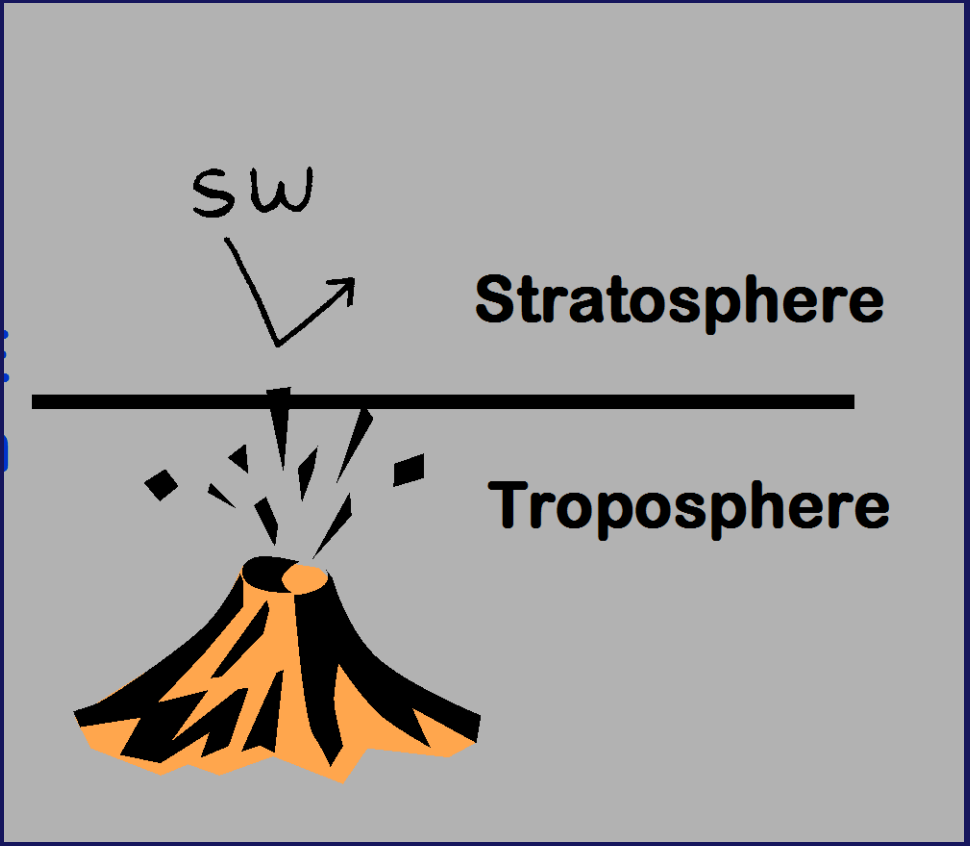
hydrochloric acid (HCl)

mineral ash

into the stratosphere

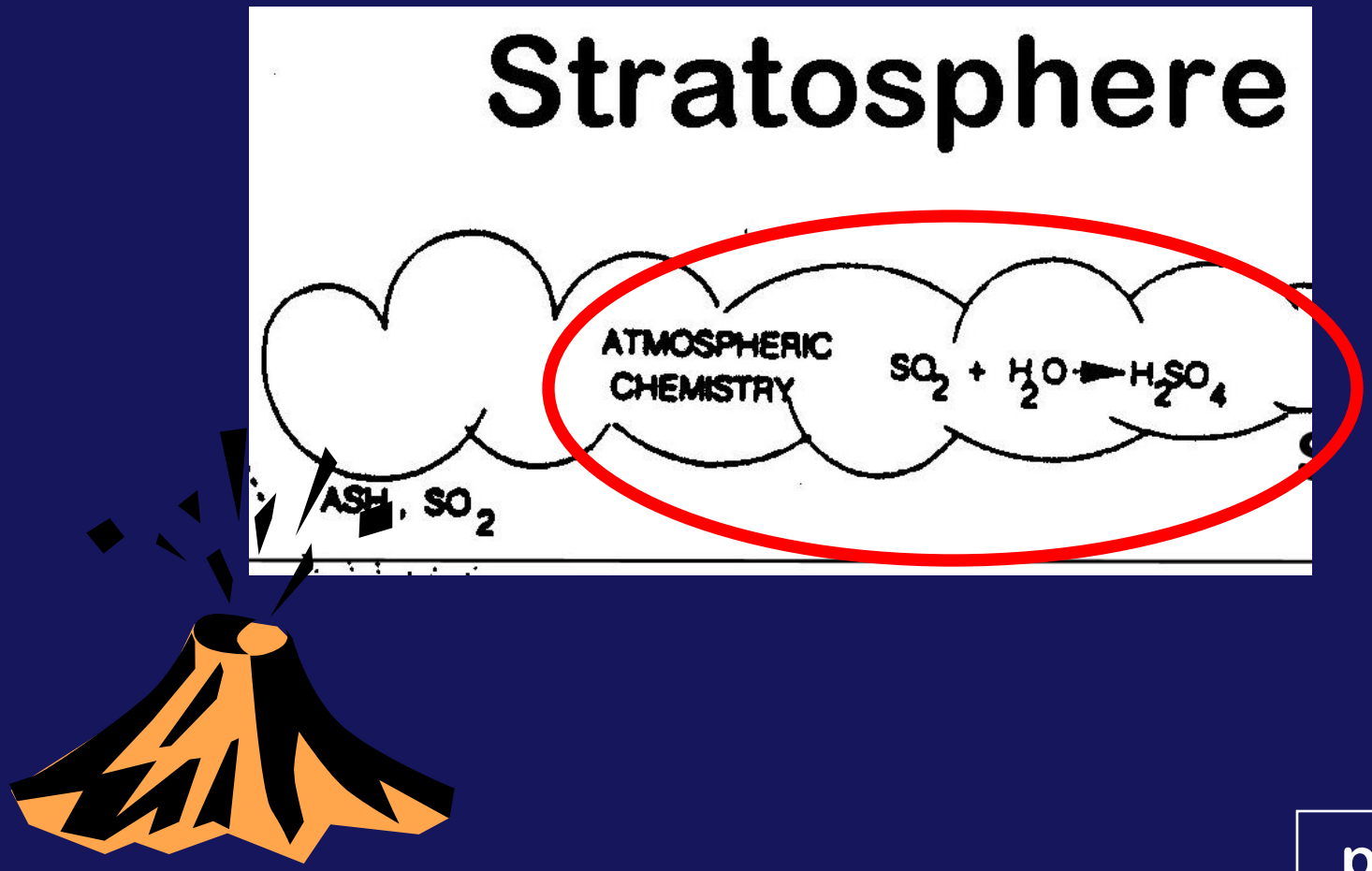


Albedo of ejected ASH in the STRATOSPHERE is *not* the reason for cooling after an eruption!
(most ash falls out early)

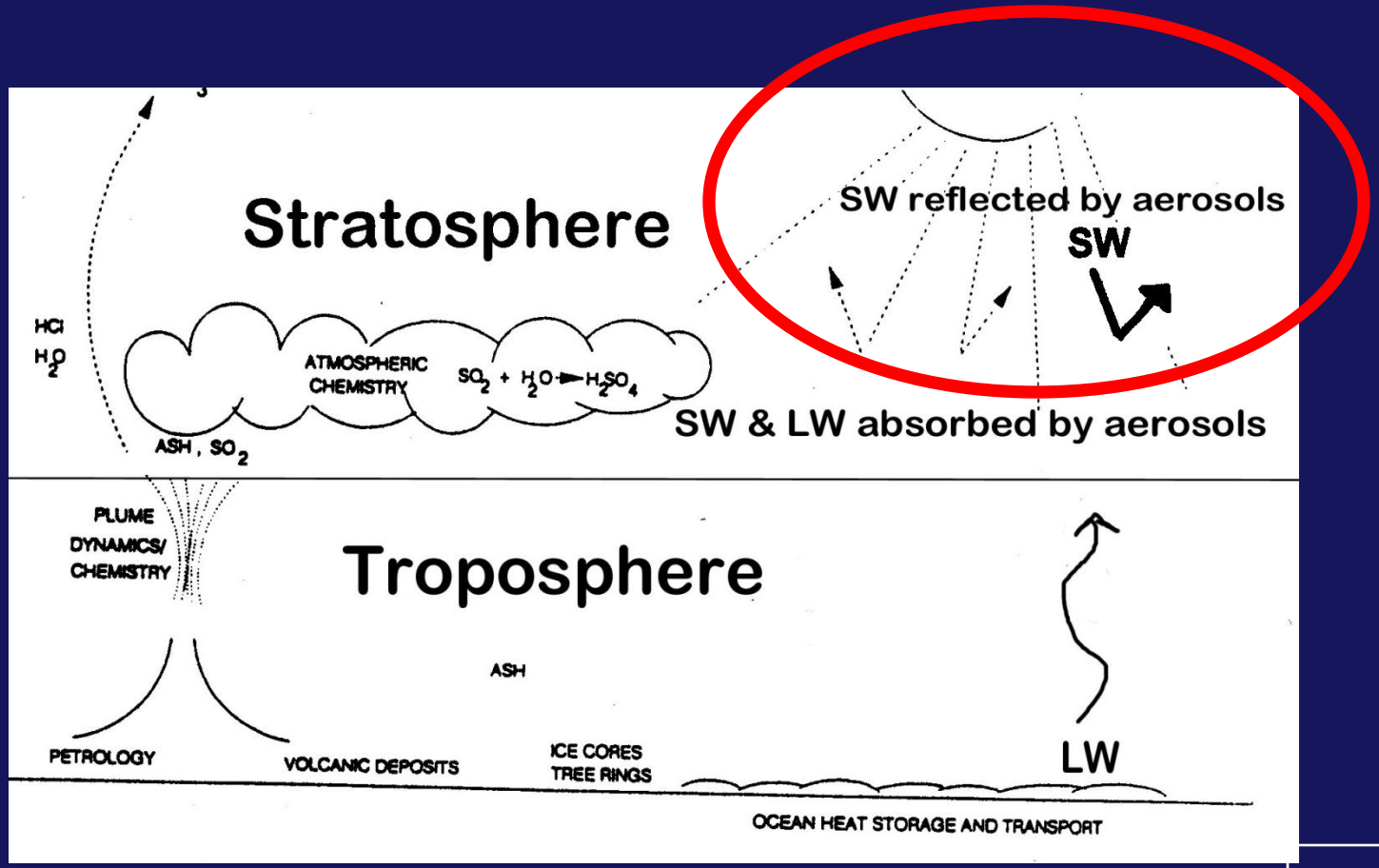


What *DOES* reflect the incoming shortwave radiation after an eruption?

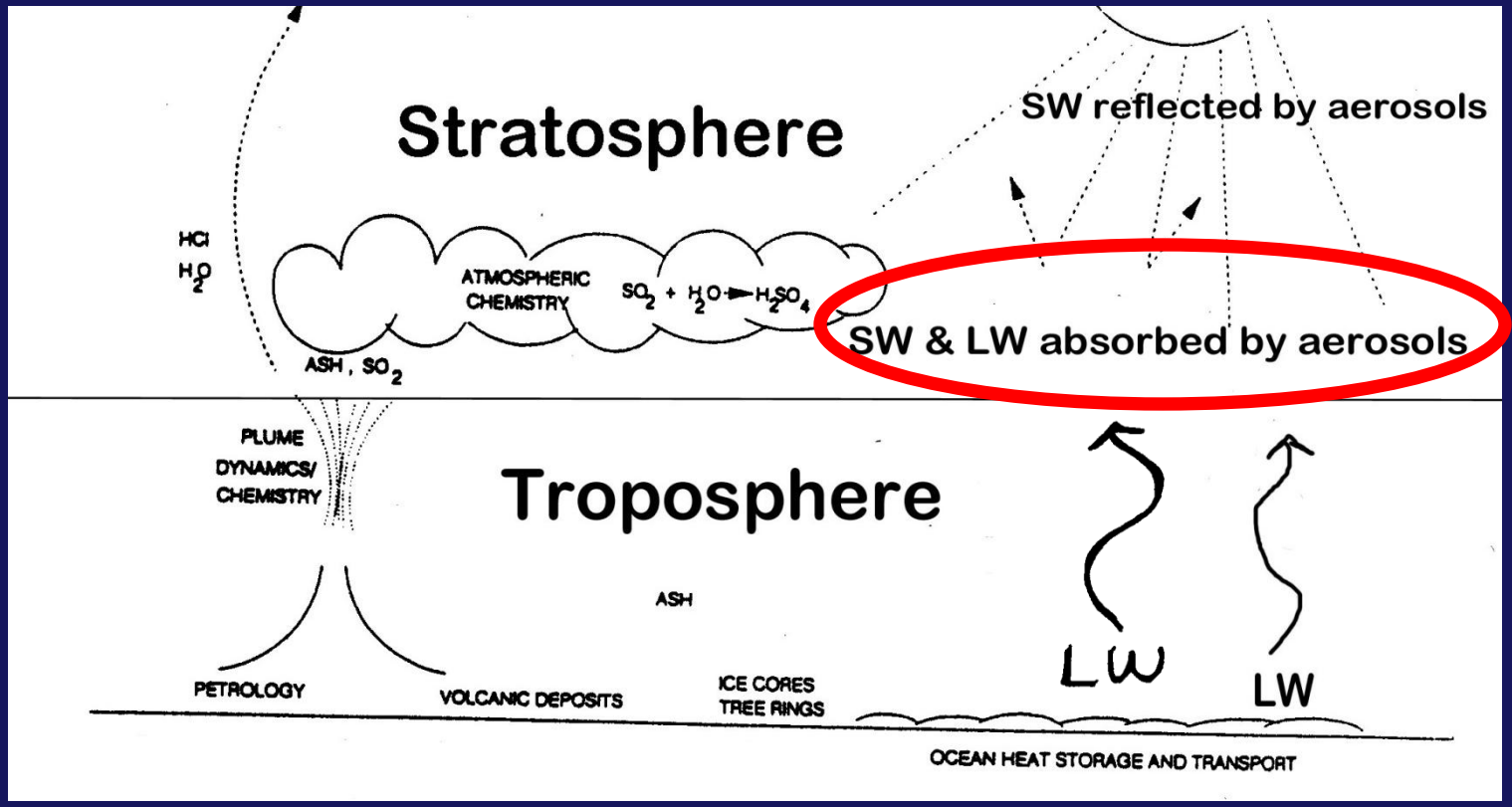
SO_2 remains gaseous and is eventually converted to **sulfuric acid** (H_2SO_4) which condenses in a mist of fine particles called **sulfate aerosols.**



the sulfate aerosols *reflect* some of the incoming solar SW radiation back to space, **cooling the troposphere below**

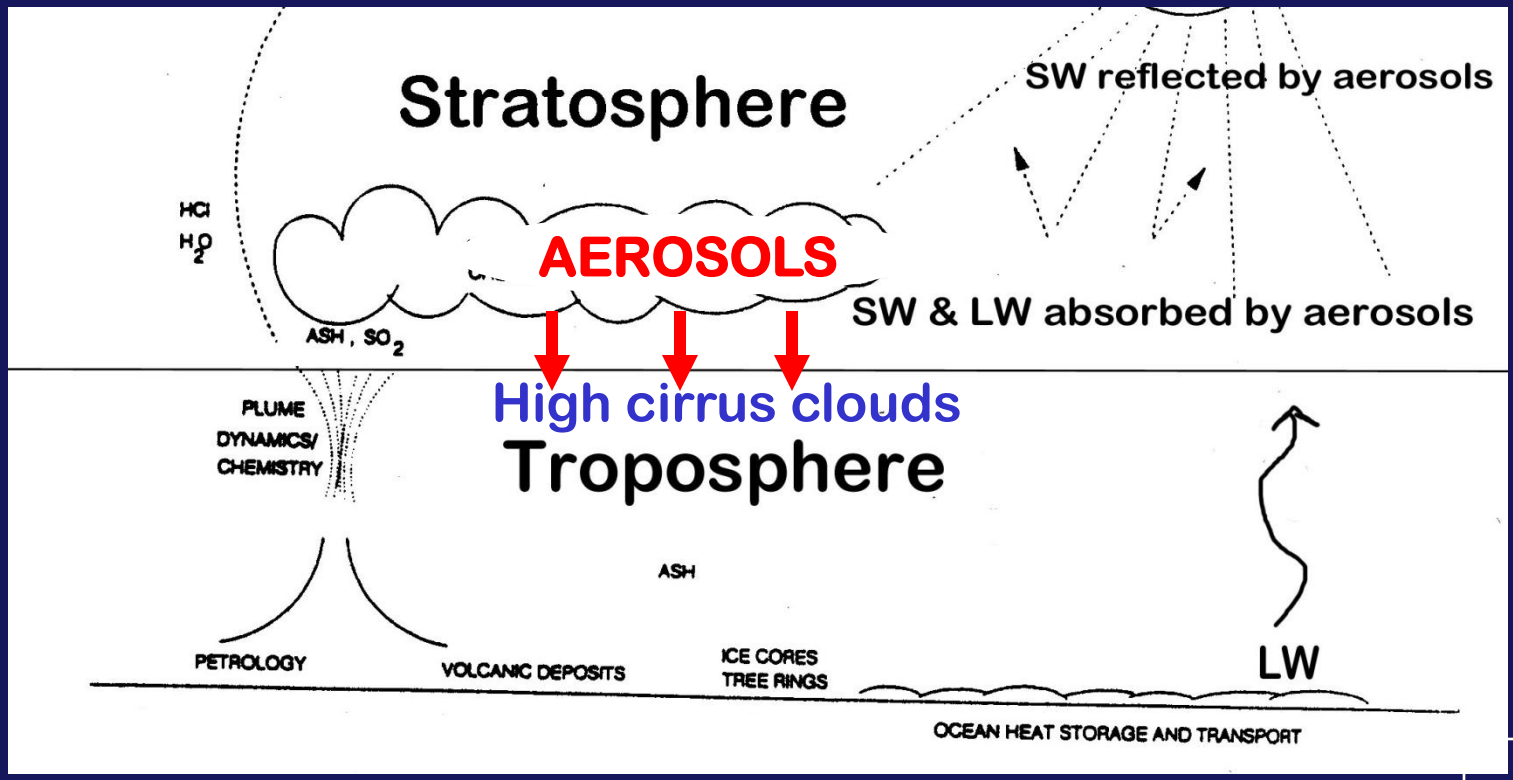


BUT - the aerosols also ABSORB certain wavelengths of the incoming SW radiation and some of the Earth's outgoing LW radiation, this warms the stratosphere (not the troposphere)

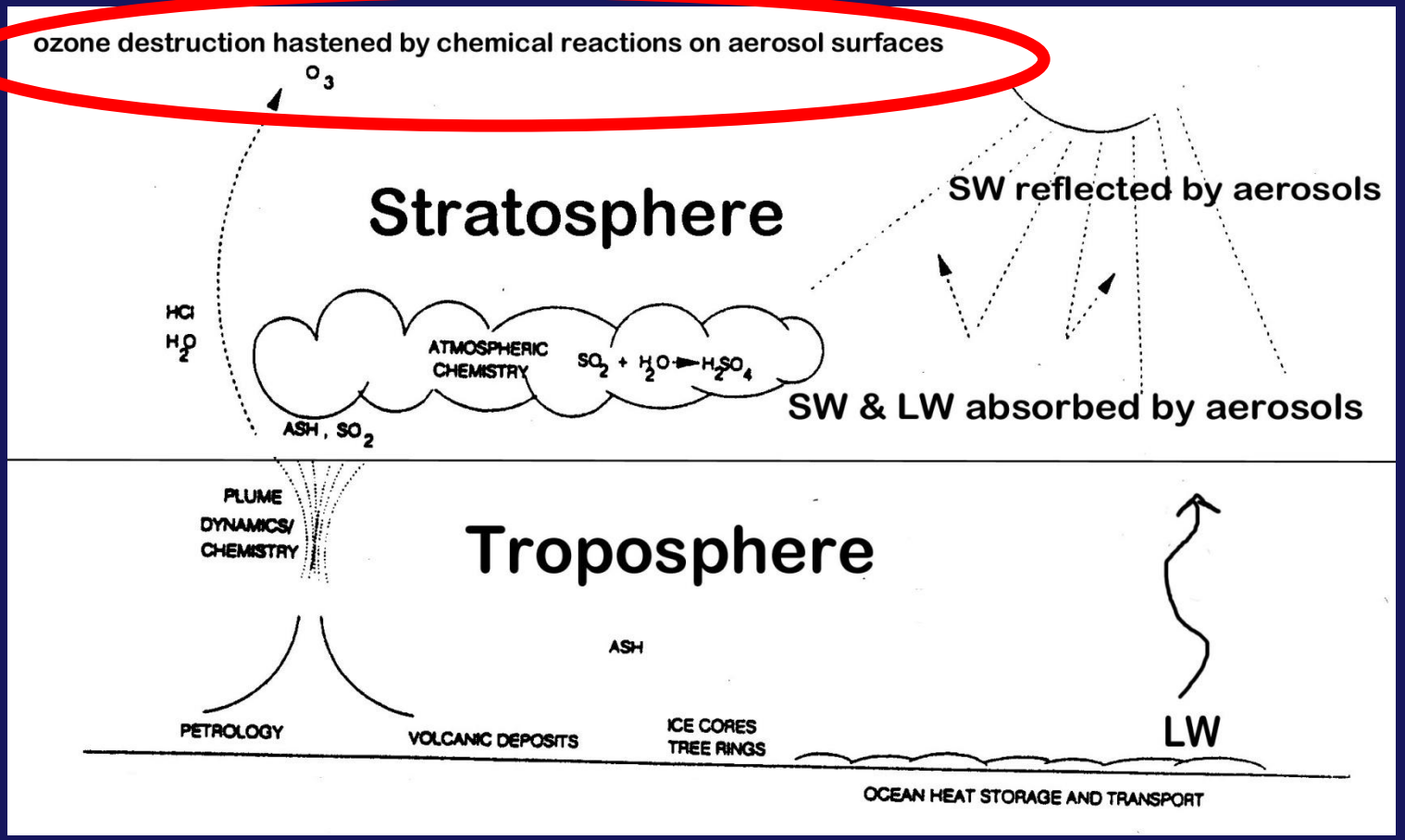


Then, as the aerosols settle into the upper troposphere, they may serve as nuclei for cirrus (high) clouds, further affecting the Earth's radiation balance *

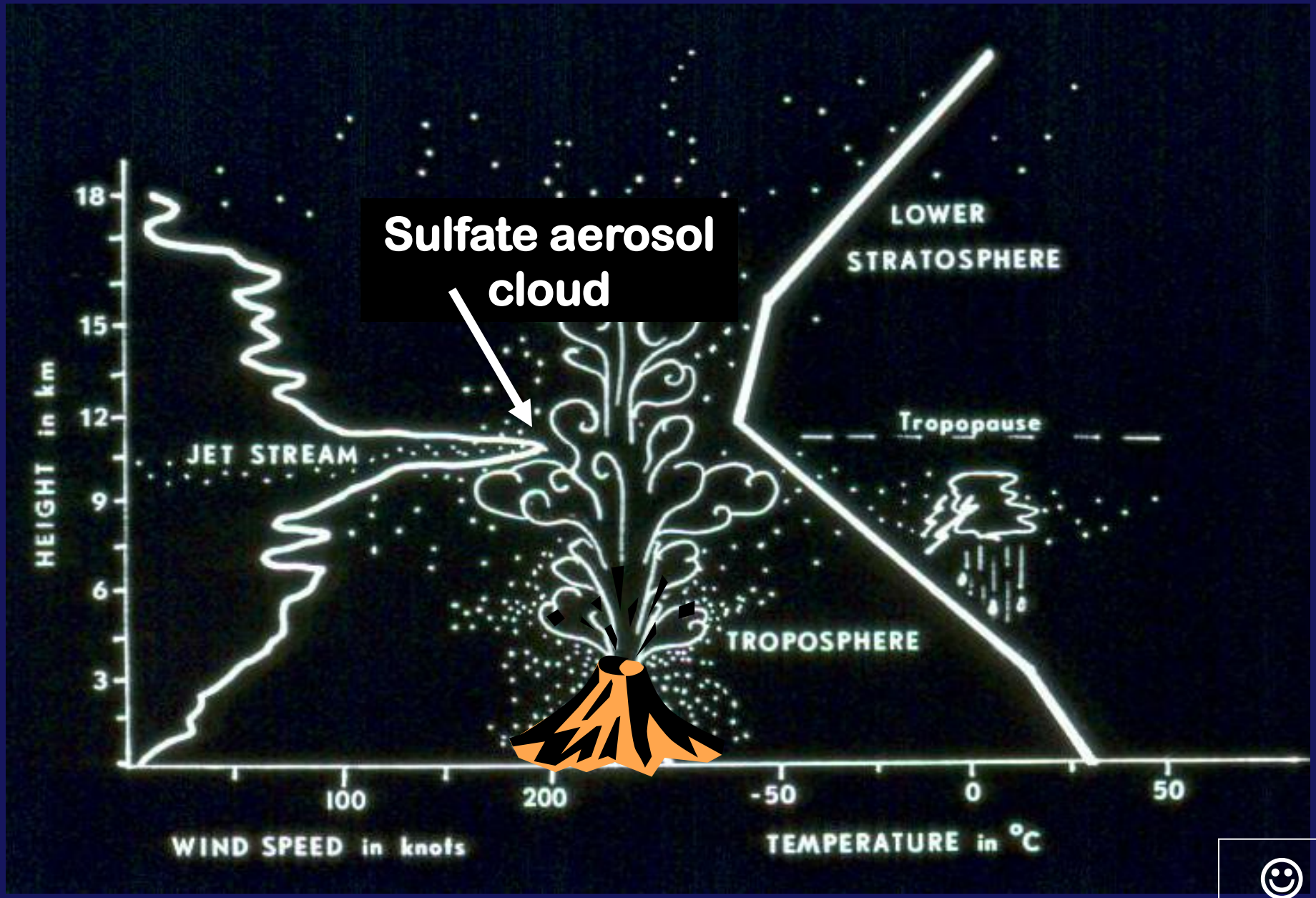
* either absorbing or reflecting, depending on the cloud's albedo and other factors

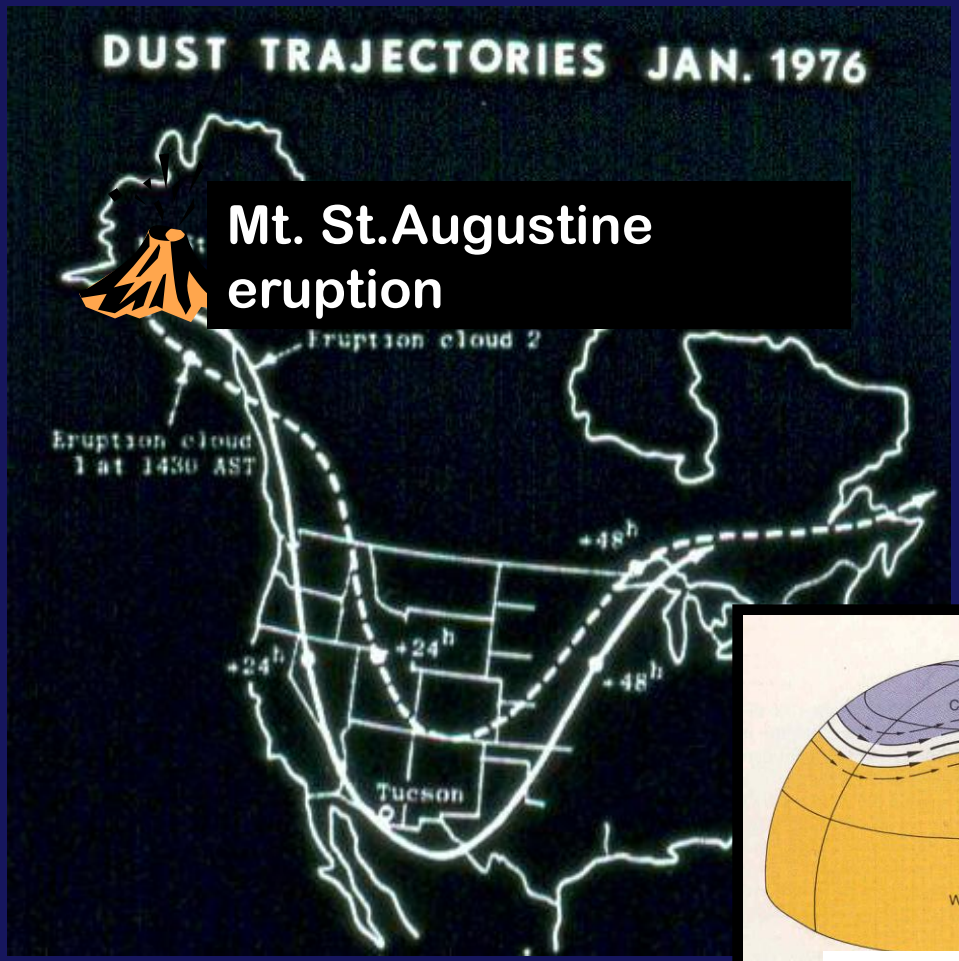


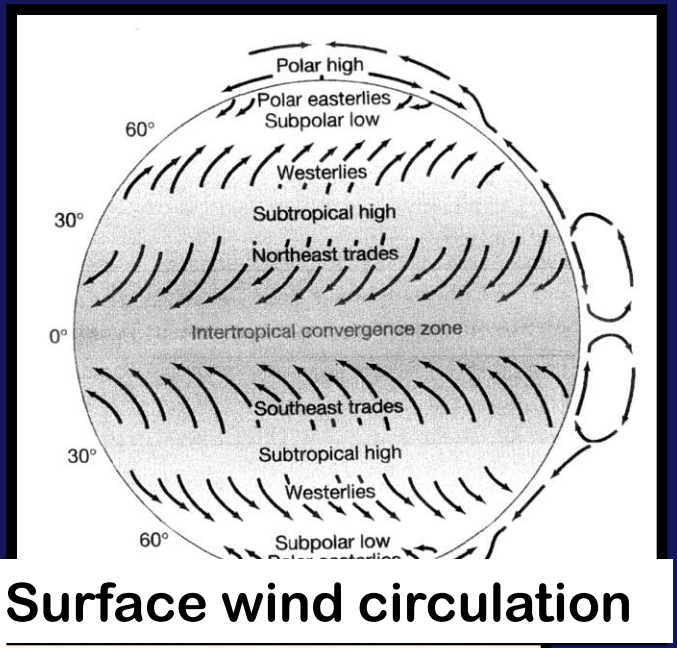
Chemical effects of the sulfate aerosol cloud can also produce responses in the climate system through OZONE destruction (Topic #15)



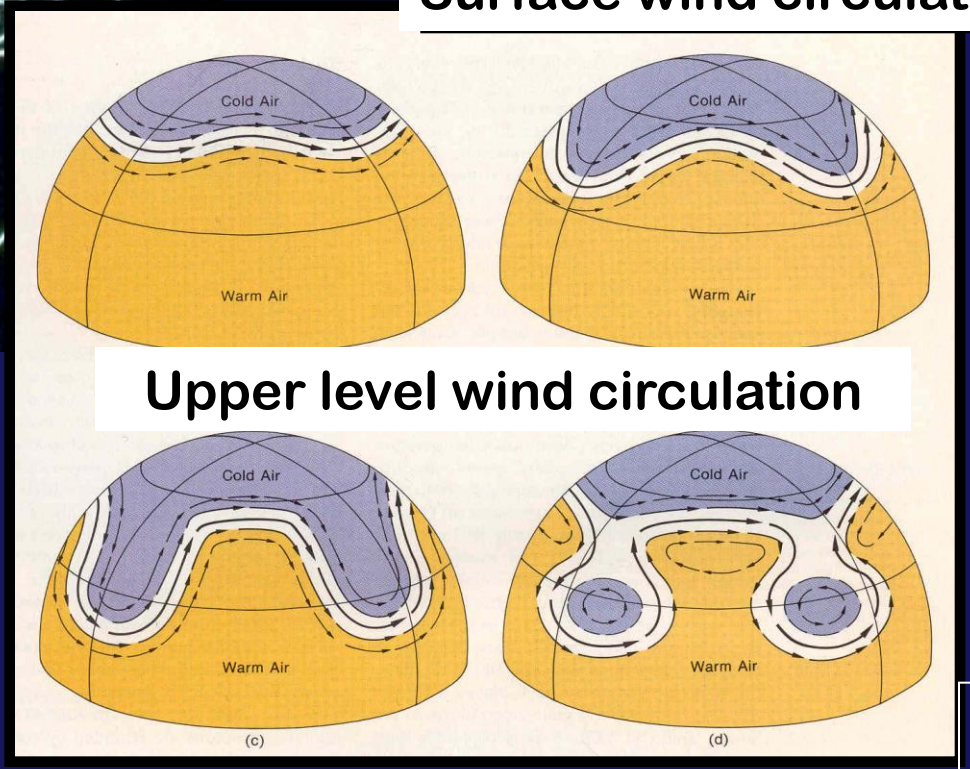
How do eruption effects become GLOBAL??





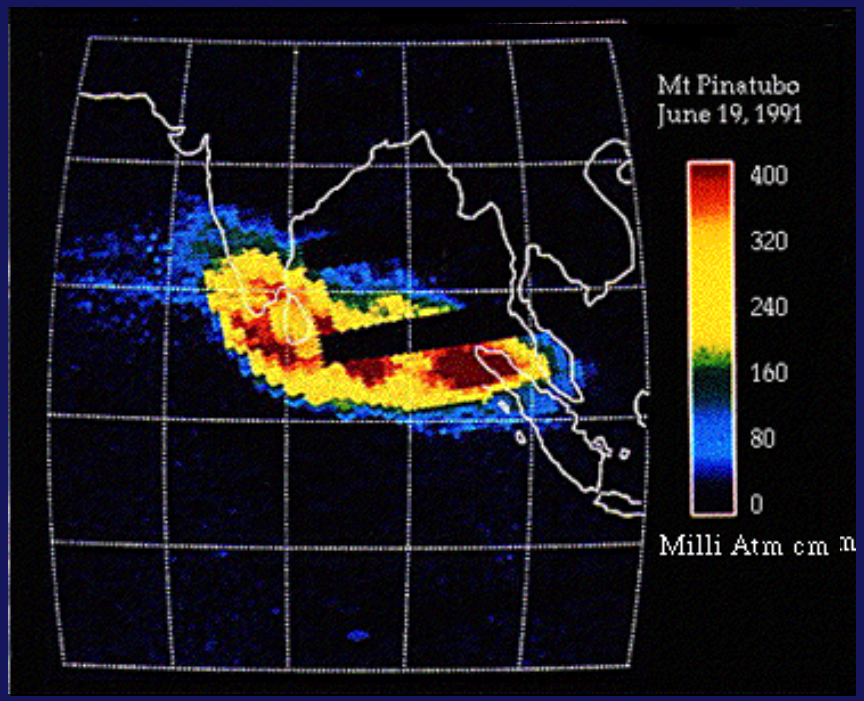


Surface wind circulation



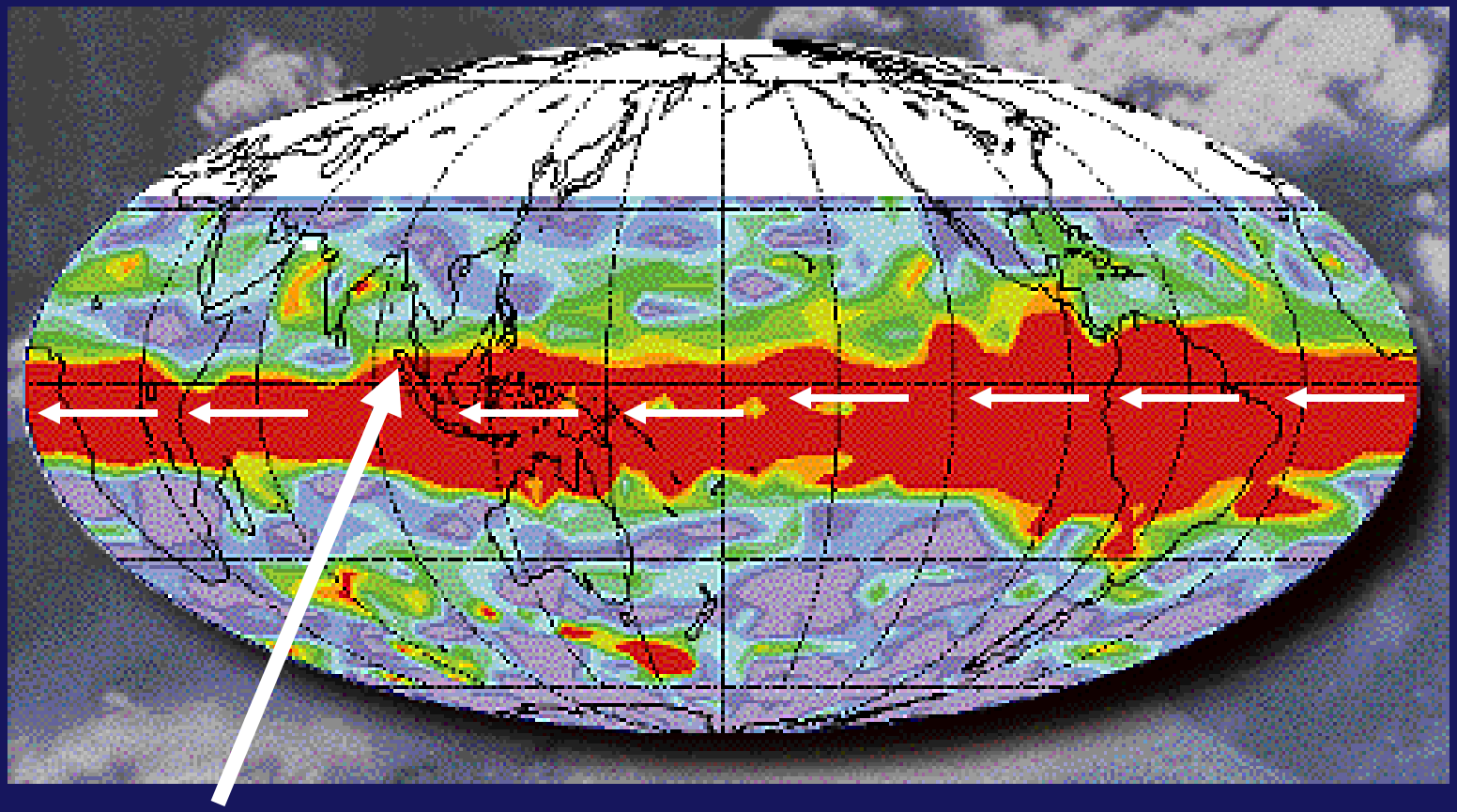
Through the atmospheric circulation!

Mt Pinatubo Eruption in the Philippines, June, 1991



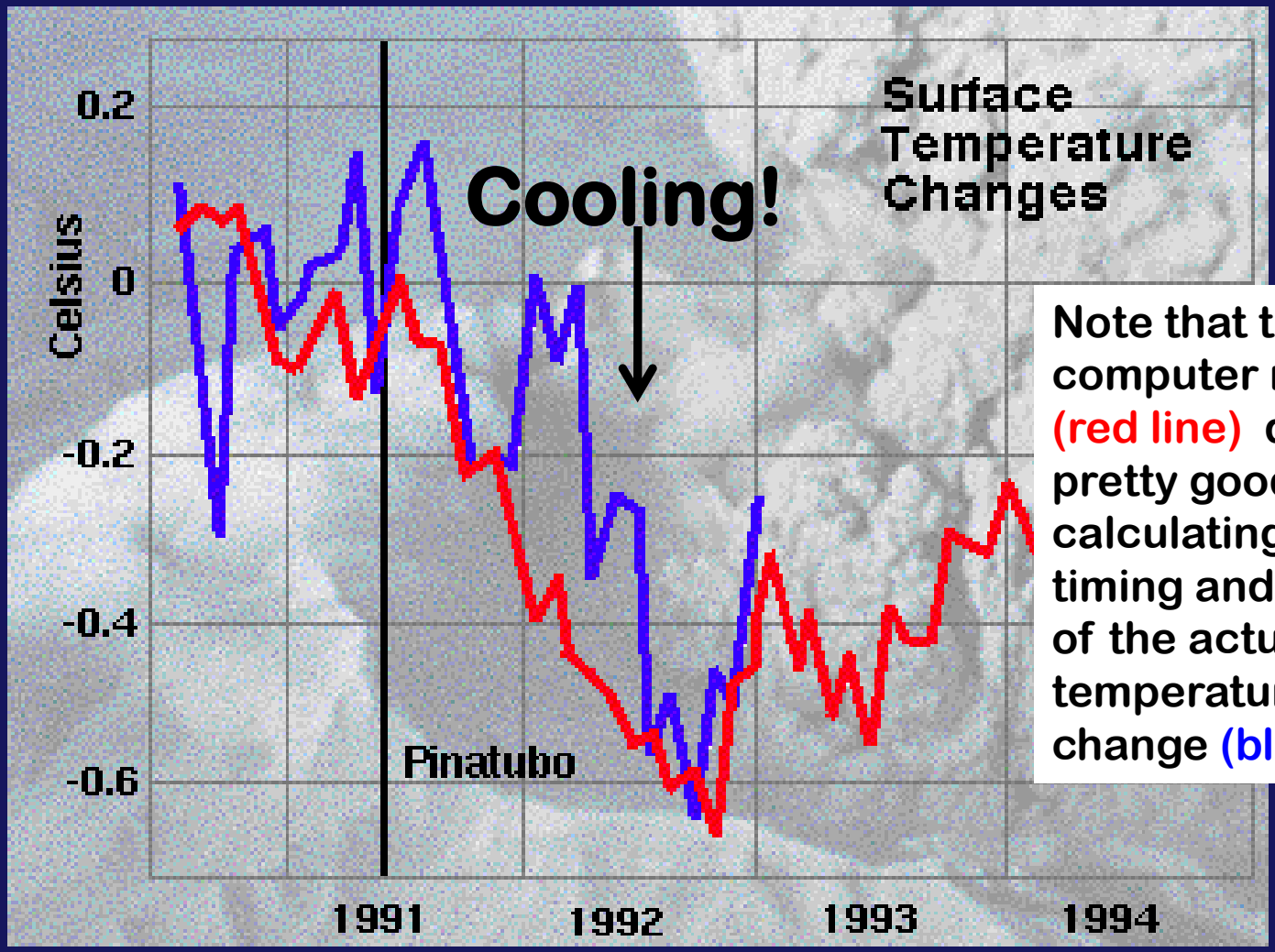
Satellite-derived image of
sulfur dioxide thickness in the atmosphere
red = higher thickness

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



Mt Pinatubo

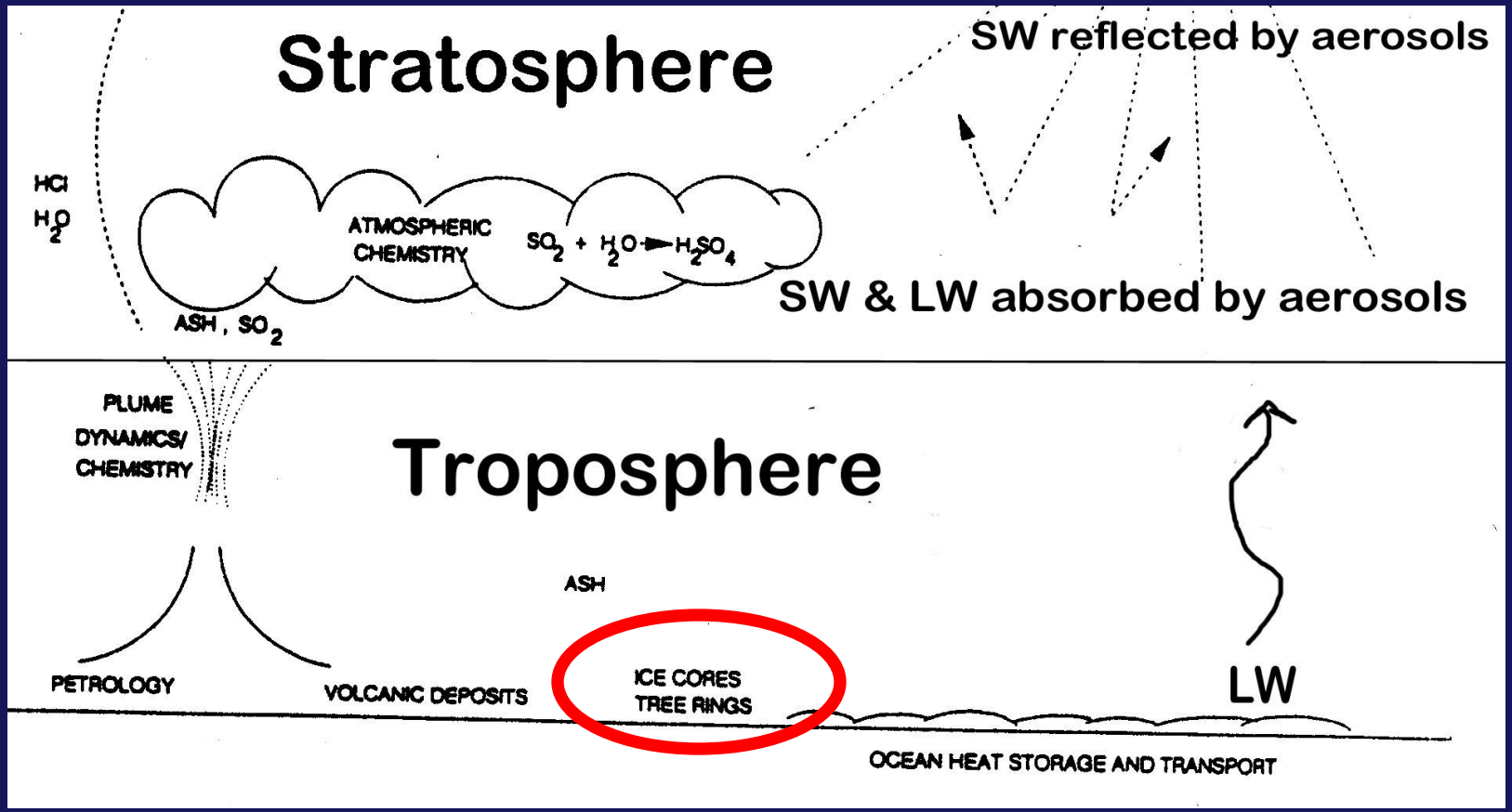
Mt Pinatubo eruption June 1991



Note that the computer model (red line) did a pretty good job of calculating the timing and amount of the actual temperature change (blue line).

Blue line = observed temperature change after eruption
Red line = modeled temperature change after eruption

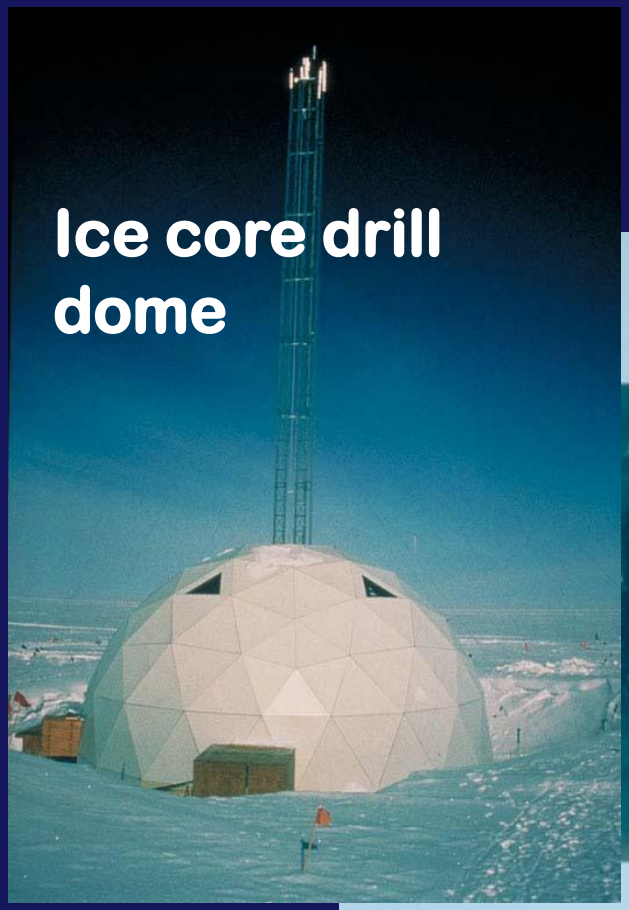
Major volcanic eruptions are infrequent events, but their climatic effects can be recorded over long time periods in ICE CORES & TREE RINGS!

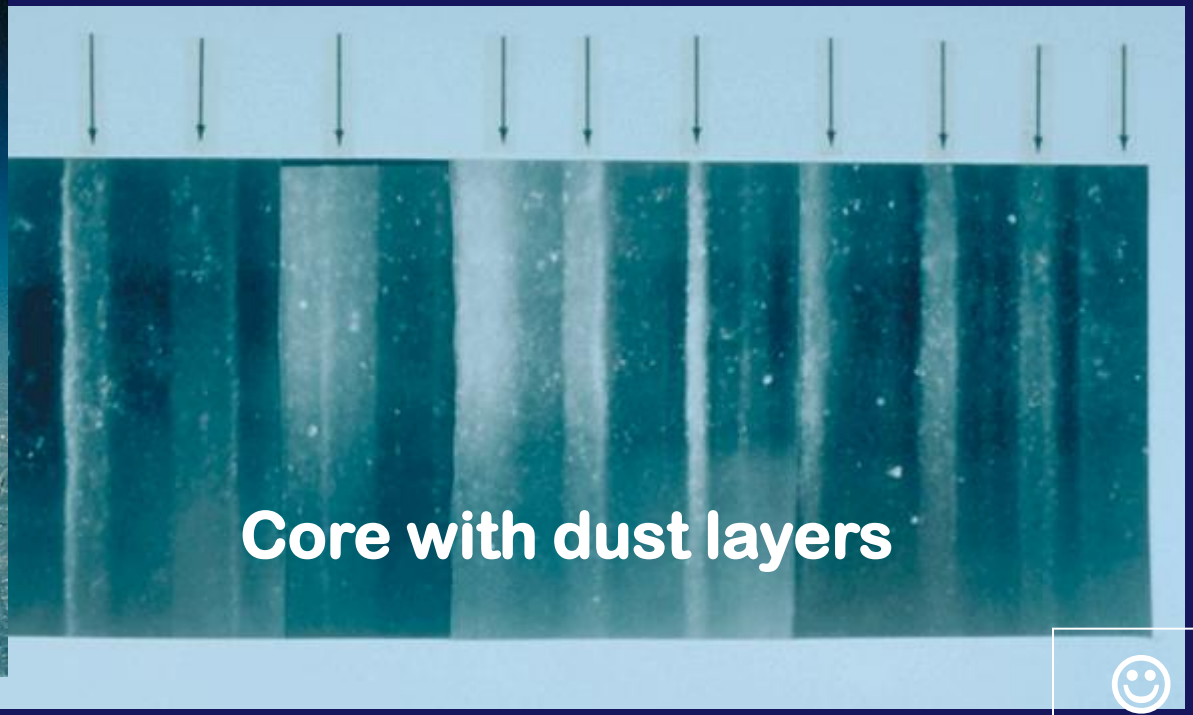


ICE CORES

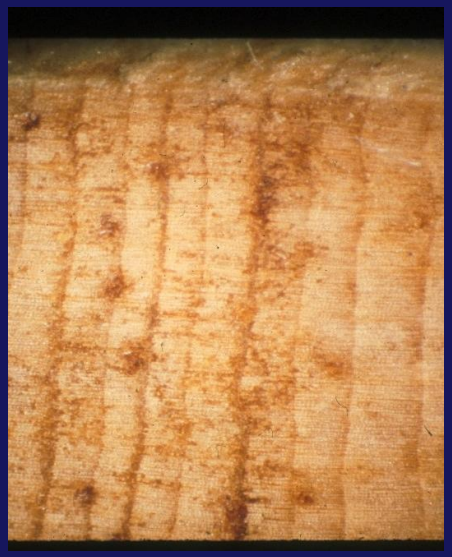

Field conditions

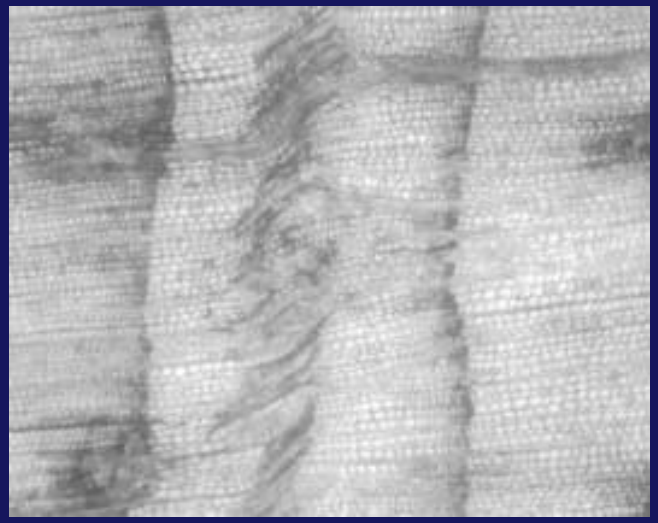

Examining core


Ice core drill dome


Core with dust layers

TREE RINGS



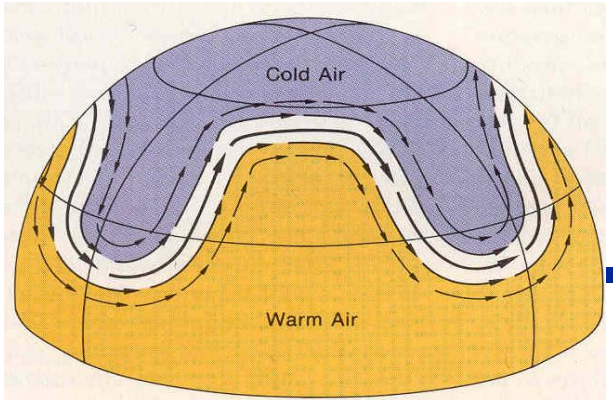


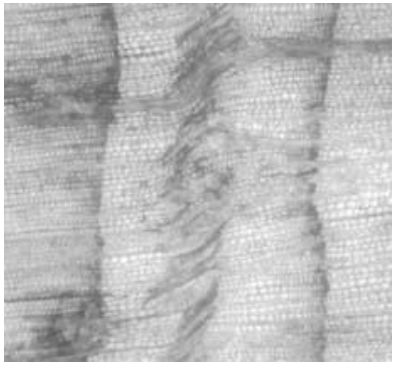
Eruption – Tree Ring Connection via FROST RINGS

Energy Balance Effects & Global Atmospheric Circulation

SW

+





BE SURE TO REVIEW THE CLASS FOLLOW-UP IF YOU WANT TO GO OVER THESE ANSWERS AGAIN . . . . .

HAPPY PUMPKIN DAY!