# Thursday Nov 6th SIT WITH YOUR GROUP TODAY

# Topic # 11 Natural Climatic Forcing Part II

## ANNOUNCEMENTS

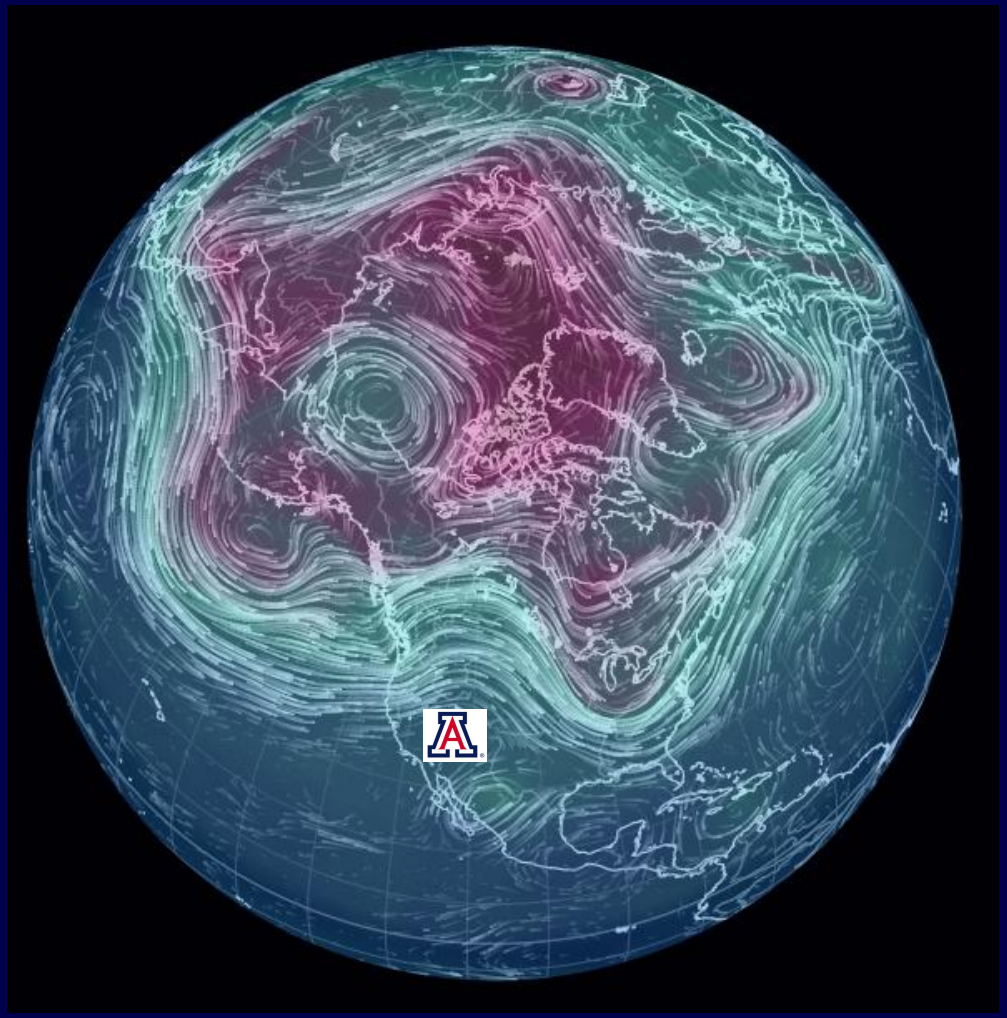
- NO CLASS next Tuesday Nov 11 (Veteran's Day) but don't forget that RQ-7 is DUE before Midnight that night!
- The G-4 Tree-Ring Wood Kit Activity must be completed by Wed Nov 12th Remaining sessions:

| | | |
|---|---|---|
| FRI | Nov 7 | 11:00 – 12 Noon |
| FRI | Nov 7 | 1:00 – 2:00 pm |
| FRI | Nov 7 | 3:00 – 4:00 pm |

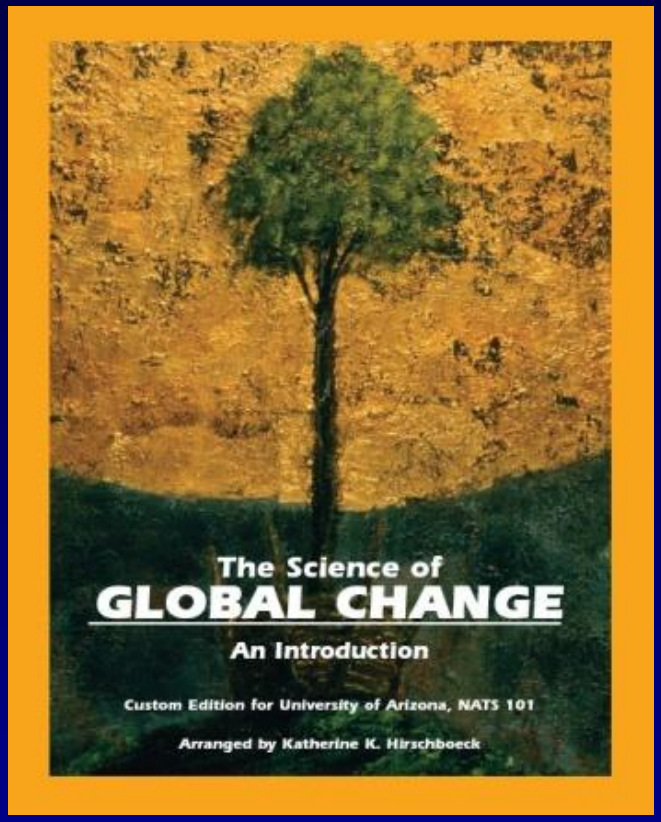
| | | |
|---|---|---|
| MON | Nov 10 | 2:00 – 3:00 pm |
| MON | Nov 10 | 3:00 – 4:00 pm |
| WED | Nov 12 | 2:00 – 3:00 pm |
| WED | Nov 12 | 3:00 – 4:00 pm |
| WED | Nov 12 | 4:00 – 5:00 pm |

- I-3 LESSON 3 on "Observable Changes" is due in the dropbox before midnight on Thur Nov 13
- Midterm Exam "Point Recovery" is due in class TODAY

# Homecoming Weather!!

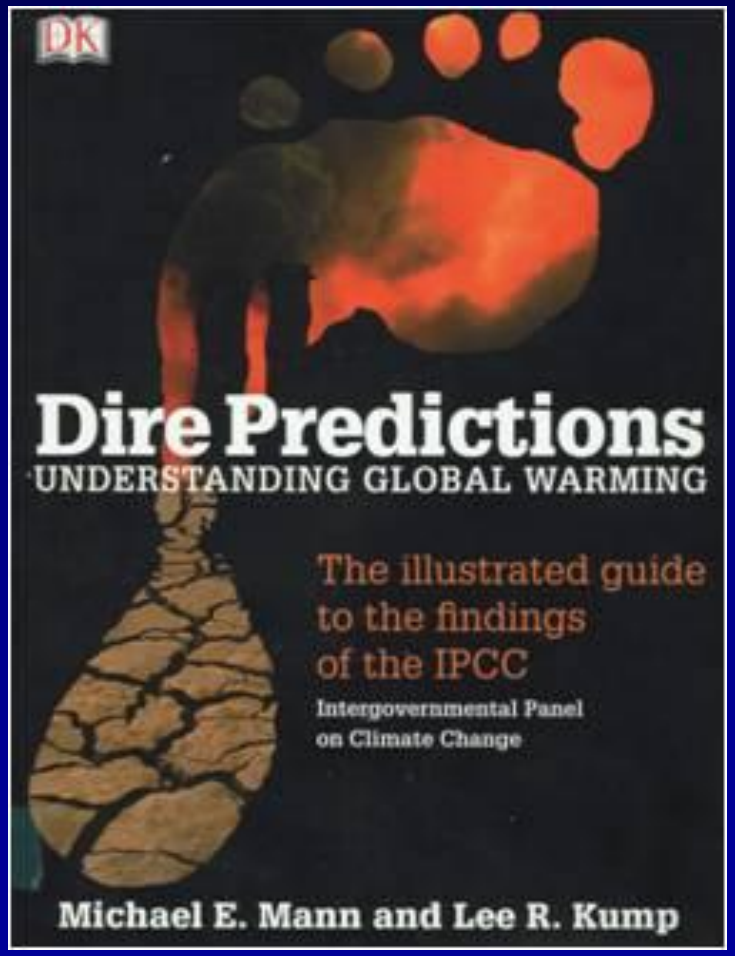



http://earth.nullschool.net/#current/wind/




"Cover" of the E-TEXT

## Cover of our other TEXTBOOK:



A SHORT VIDEO
BREAK to
Introduce

THE
LINKING-TO-LIFE
PROJECT


Discover
SCIENCE FOR THE CURIOUS

# Republican Takeover of Senate Will Spotlight Climate Denial

By Keith Kloor | November 5, 2014 7:59 am

The Washington Post

Politics

# Sen. Inhofe, denier of human role in climate change, likely to lead environment committee

In his 2012 book, "The Greatest Hoax: How the Global Warming Conspiracy Threatens Your Future," Inhofe describes himself as a lonely crusader against an environmental-liberal conspiracy. "First I stood alone in saying that anthropogenic [man-made] catastrophic global warming is a hoax," he wrote.

Shortly after becoming chairman of the committee in 2003, Inhofe took issue with the theory that increasing carbon dioxide emissions causes catastrophic disasters. "Actually," he said, "global warming can be beneficial to mankind," leading to improvements in the environment and the economy.

http://www.washingtonpost.com/politics/inhofe-an-epa-foe-likely-to-lead-senate-environment-committee/2014/11/05/d0b4221e-64f4-11e4-836c-83bc4f26eb67_story.html

# “It’s each one of us!

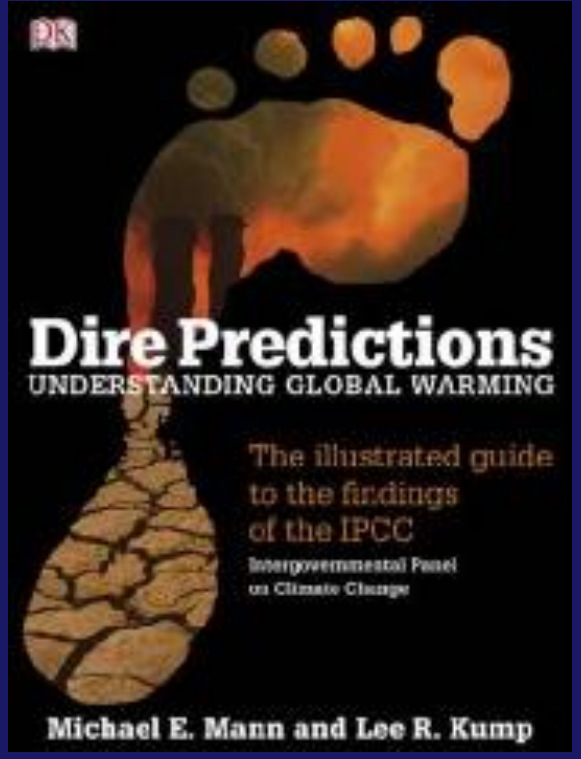
- Photographic artist Chris Jordan

## LINKING-TO-LIFE PROJECT OVERVIEW:

- Part A: Calculate your “Ecological Footprint”
- Part B: Watch a movie (or two . . . )
- Part C: Research your consumer choices about a product or activity that interests you

**GOAL: Becoming a GC Savvy Consumer!**

# CALCULATE YOUR FOOTPRINT!




## Linking-to-Life PART A: YOUR FOOTPRINT

http://www.footprintnetwork.org/en/index.php/GFN/page/calculators/

## Turn to: APPENDIX P 119

# A Tool for Quantifying Global Change Impacts: **"The Footprint" Concept**

*Examples: Ecological Footprint, Carbon Footprint, Water Footprint*

**Your Ecological Footprint = A measure of how much area of Earth's biologically productive land and water you require . . .**

(a) to produce all the **RESOURCES** you consume , and

(b) to absorb the **WASTE** you generate

. . . . using prevailing technology and resource management practices.

# The Ecological Footprint

MEASURES

How fast we consume resources and generate waste

Energy

Settlement

Timber & paper

Food & fiber

Seafood

COMPARED TO

how fast nature can absorb our waste and generate new resources

Carbon footprint

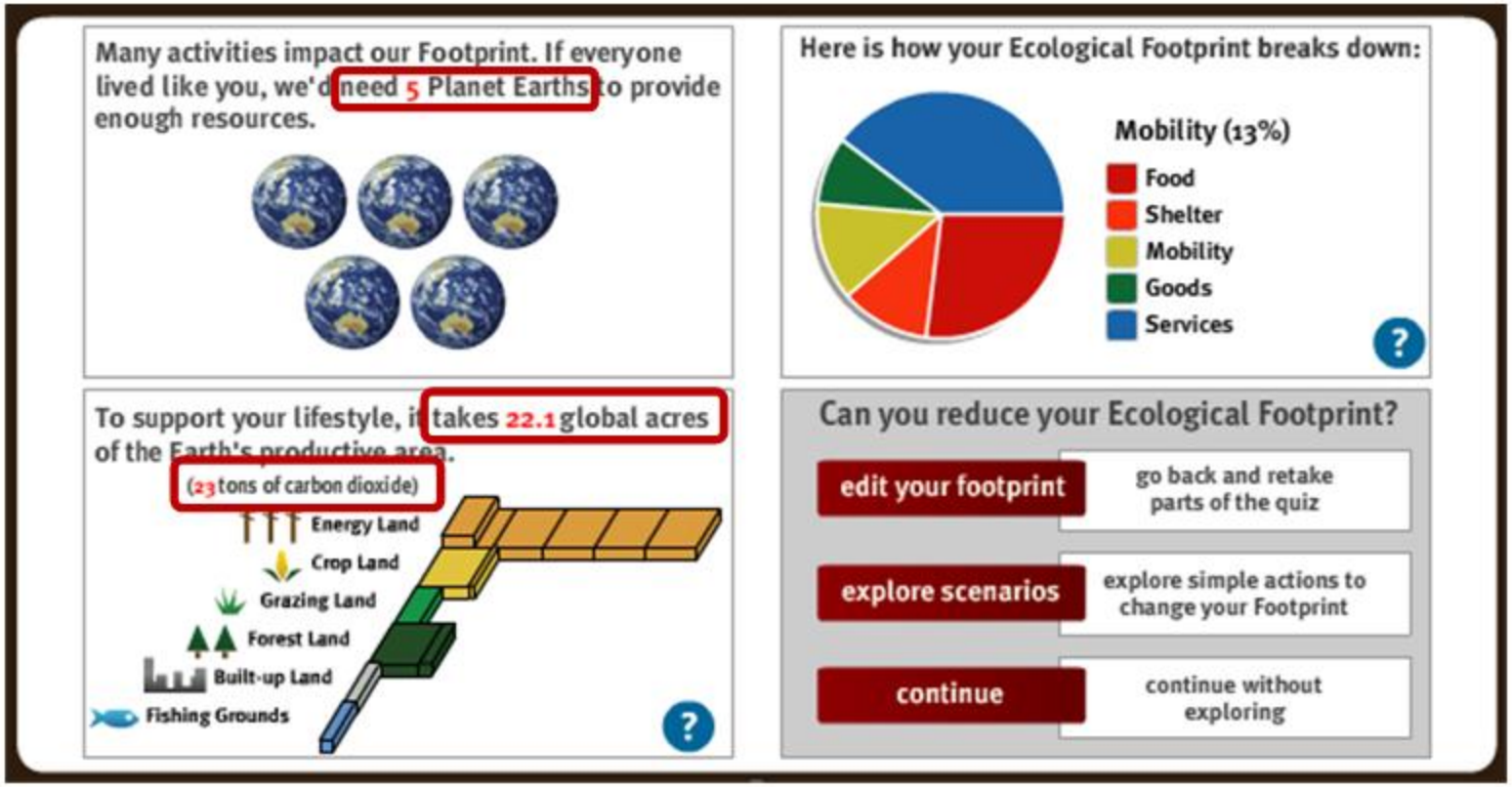
Built up Land

Forest

Cropland & pasture

Fisheries

# USA AVERAGE Ecological Footprint (based on 2008 data)




The Ecological Footprint calculator "represents the amount of land and sea area needed to provide the resources a person needs (food, shelter, etc.), and absorb the wastes they create (including carbon dioxide)"

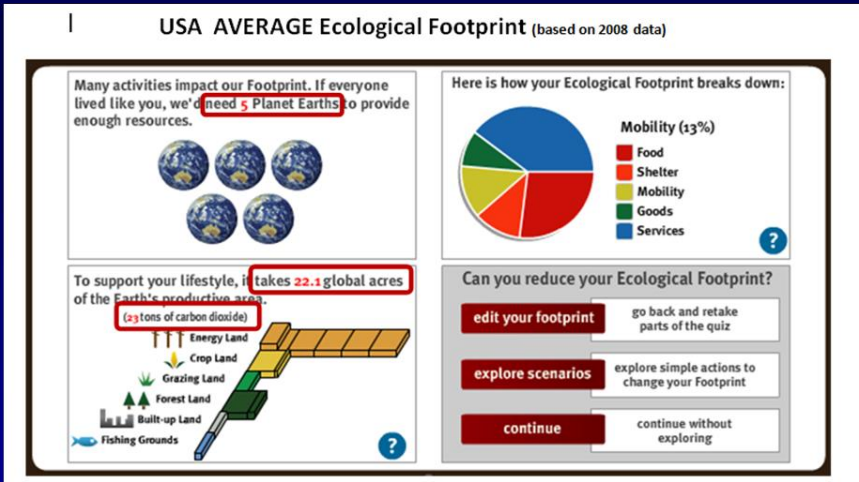
SOURCE: http://www.footprintnetwork.org/en/index.php/GFN/page/footprint_calculator_frequently_asked_questions/

# Linking-to-Life Project
# PART A:

1) Compute Your Footprint

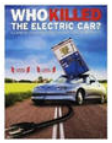
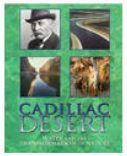
2) Save in a document

3) Write a short summary of what you noticed about what's contributing to YOUR footprint



# Linking-to-Life Project
# PART B:
# Watch a movie (or two . . .)

**FLIMS & VIDEOS for the LINKING-TO-LIFE PROJECT**

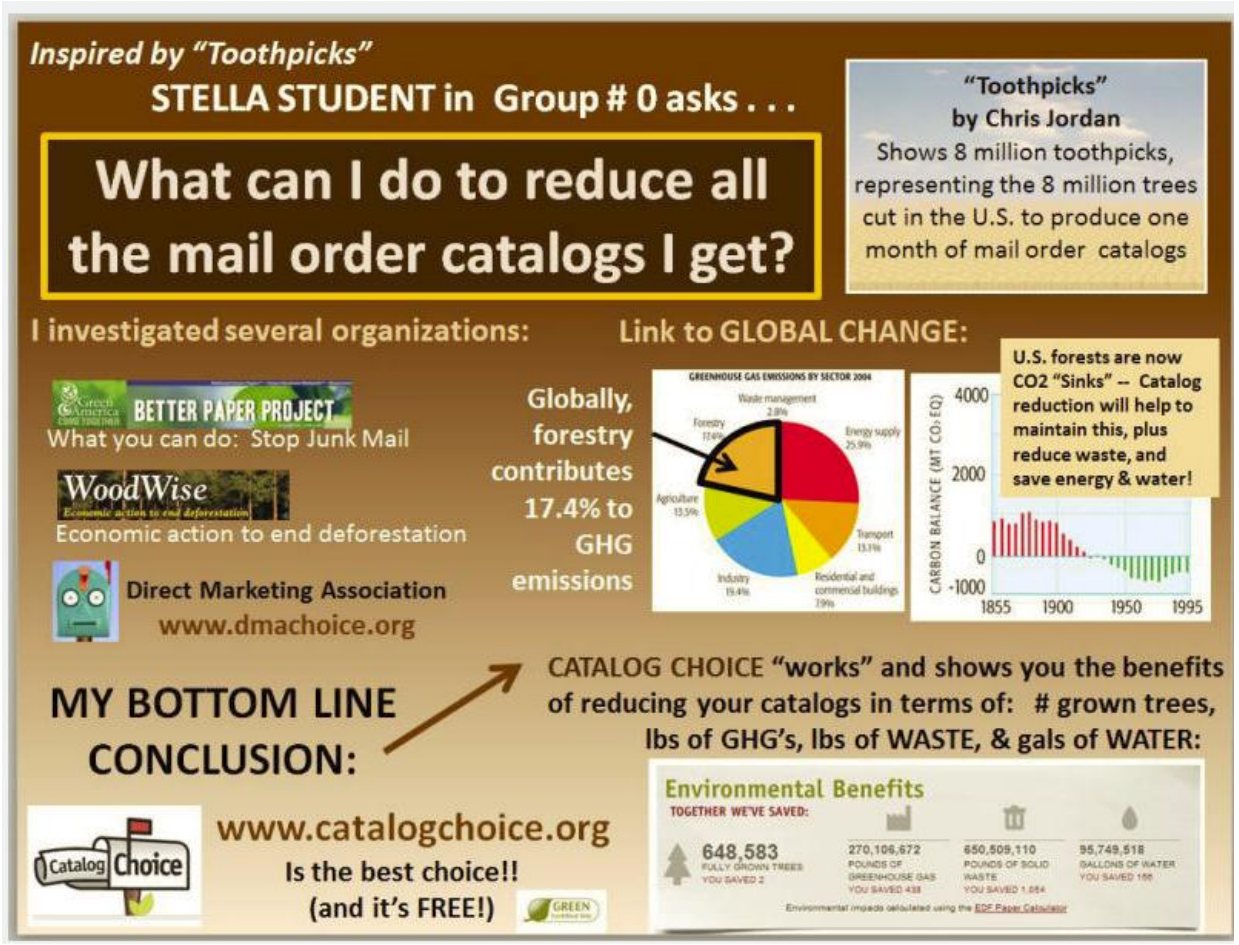
| FULL LENGTH FILMS | Click on the film's TITLE to begin streaming the video | WHAT THE FILM OR VIDEO IS ABOUT |
|---|---|---|
|   | HOME *(also available at D2L video link)* Film-related website: www.goodplanet.org *[NOTE: To watch on YouTube in another language or with closed captioning, click HERE]* | At the outset the film challenges us: *"Listen carefully to this extraordinary story, which is yours, and decide what you want to do with it."* This is a " visually astonishing portrait of the Earth as seen from mesmerizing aerial views. Home is not the first documentary to survey our planet from the air, but Arthus-Bertrand brilliantly and dreamily captures the miraculous linkage within delicate eco-systems. For viewers whose eyes glaze over at descriptions of the way Earth recycles energy and matter, Home underscores the beautiful and awesome reality of that complex process. " source |
|   | Kilowatt Ours *(available at D2L video link only)* Film-related website: www.kilowattours.org | *"Kilowatt Ours: A Plan to Re-Energize America* by Jeff Barrie is the best energy film on the market. No wonder this independent documentary has spawned a nationwide movement to conserve energy. In fact, one of the central thesis of the film is that the best possible energy choice is the conservation of energy. A brilliant, humorous, extremely accessible energy film." source [Warning: the very end of the Library's video-streamed version of the film has a tacked-on a request for donations to promote the film nationwide -- so stop the film at 55:21 . . . unless you would like to hear the solicitation!] |
|   | Who Killed the Electric Car? *(available at D2L video link only)* Film-related website: www.whokilledtheelectriccar.com | "Structured as a whodunit, this reasonably outraged documentary shuffles through a catalog of suspects in the electric car's murder, detailing the combination of forces that caused the revolutionary machine to disappear from the road mere years after first being introduced. Unsurprisingly, it's a rather long list of culprits . . ." source See what's in production . . . HERE And what's coming out now . . . HERE Concerned about car safety? Learn about the Physics of Car Crashes (see film *available at D2L video link only)* |
|   | Two separate episodes: An American Nile & Last Oasis Film-related website: Synopsis of episodes | Episodes 2 and 4 of Cadillac Desert Water and the Transformation of Nature (1997) An excellent American four-part documentary series about water, money, politics, and the transformation of nature. The American Nile tells the story of how the Colorado River became the most controlled, litigated, domesticated, regulated and over-allocated river in the history of the world. (Did you know there was once a plan to dam up the Grand Canyon? Learn about it in this film . . . and more!) The Last Oasis examines the global impact of the technologies and policies that came out of America's manipulation of water, demonstrating how they have created the need for conservation methods that will protect Earth's water for the next century. (This film is 13 years old -- have the dams it describes in India, China and elsewhere been built?) Food for Thought: the impact of climate varaibility and global warming on water sustainability are not prominently addressed in these films . . . How is climate change exacebating the future of water in the arid West -- and the world? (Note that these films are not "streamed" - instead the links take you to a series of 10-minute video segments. The quality of the videos is not great and a few seconds are lost in the transitions . . . but hang in there -- it's worth it to hear this history!) |

# Linking-to-Life Project PART C:
## Research your "GC Savvy Consumer" Choices:

**Example: Linking to Life Project "Deliverable": a single PowerPoint Slide**

**Here's Stella's example for Part C:**

**Complete directions will be posted this weekend.**



**DETAILED DIRECTIONS**
**TO BE**
**POSTED IN D2L**

**DUE the week after Thanksgiving**

# TOPIC #11
# Natural Climate Forcing
# Wrap Up

# The 3 main drivers of NATURAL CLIMATIC FORCING:

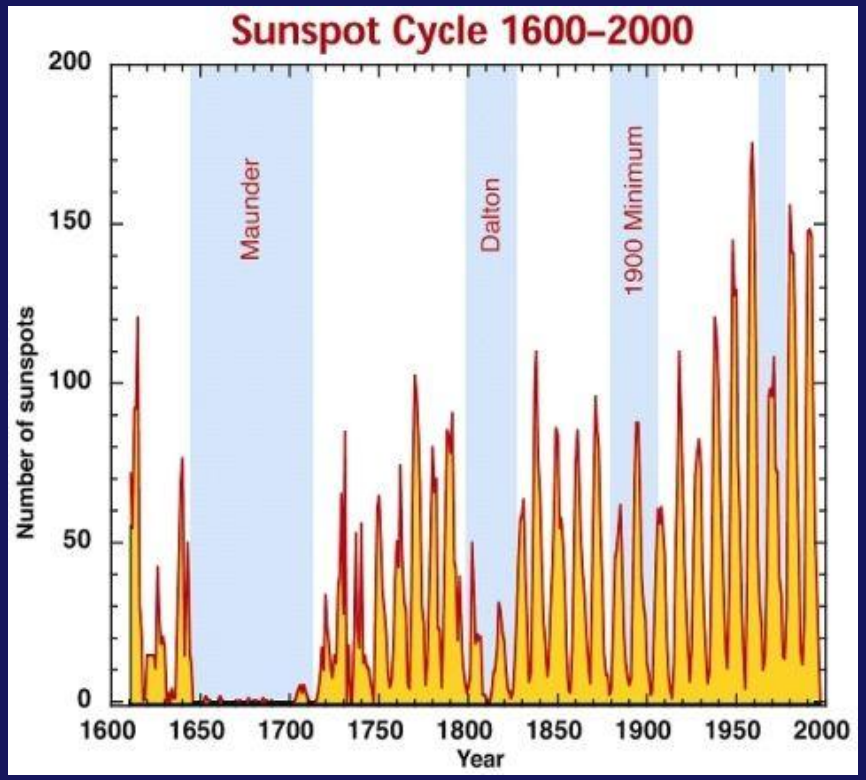
Last week

1) ASTRONOMICAL FORCING

2) SOLAR FORCING

3) VOLCANIC FORCING

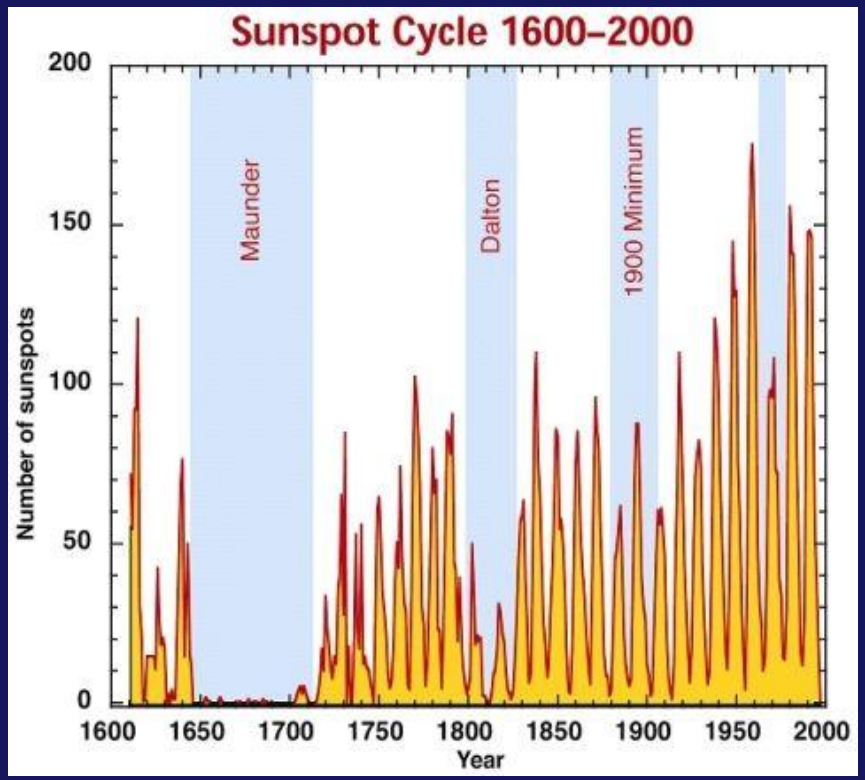
# Maunder Minimum (cooler) (1645 -1715) linked to the "Little Ice Age"



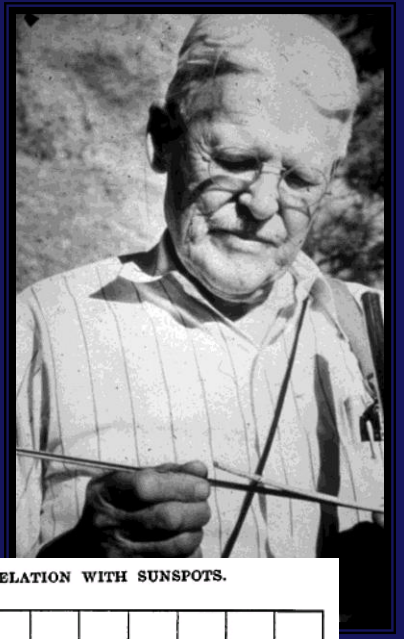
## Edward Walter Maunder (1851–1928) & Annie Scott Dill Maunder

http://en.wikipedia.org/wiki/Edward_Walter_Maunder

**Maunder Minimum**




## Andrew E. Douglass (1867 - 1962)



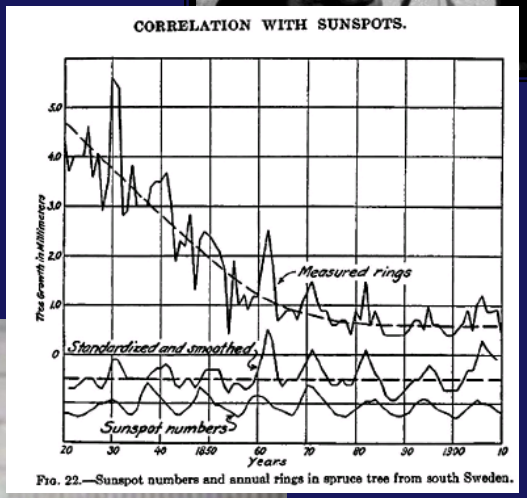
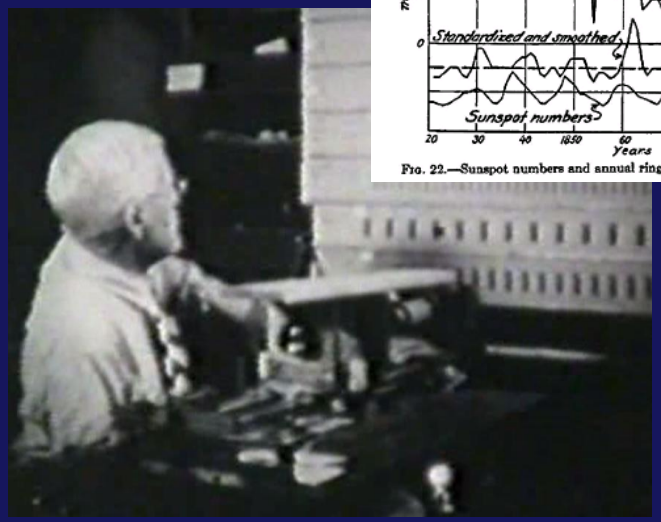


Fig. 22.—Sunspot numbers and annual rings in spruce tree from south Sweden.




# Little Ice Age

15th – 19th centuries
(1400-1800)
esp. 1600 -1800
➔ Maunder Minimum

## GLOBAL COOLING EVENT !

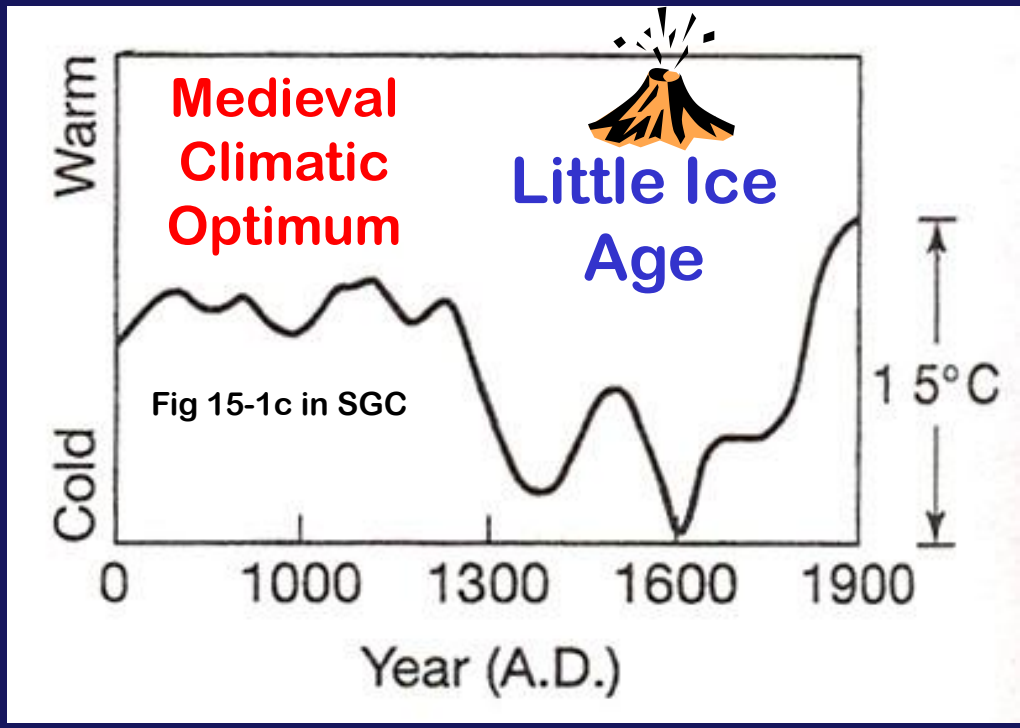
*Another DIFFERENT period:*

Medieval "Warm" Period:

## Medieval Climatic Optimum

9th-14th centuries
(800-1300)

BUT . . .
WARMING WAS REGIONAL & MOSTLY IN EUROPE



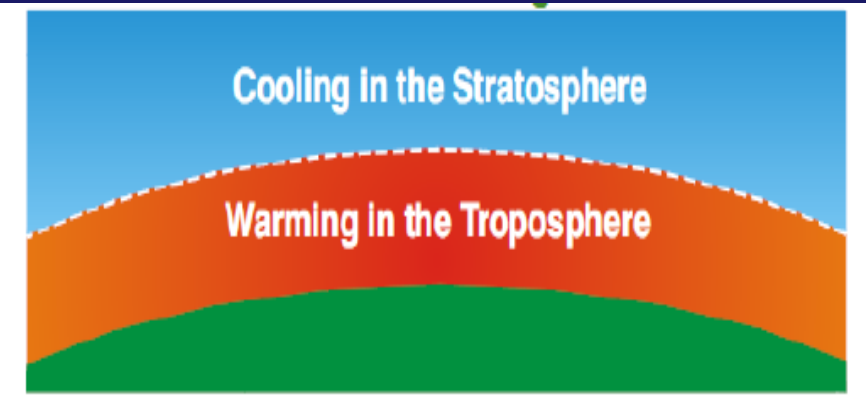
# The 3 main drivers of NATURAL CLIMATIC FORCING:

1) ASTRONOMICAL FORCING

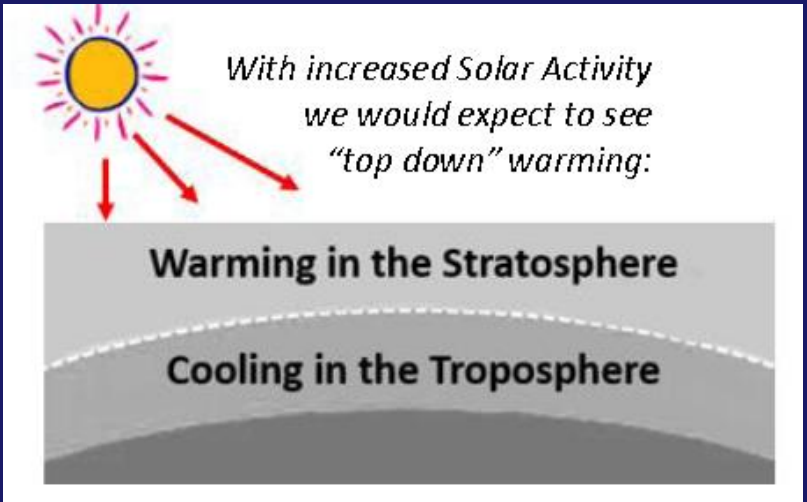
2) SOLAR FORCING

3) VOLCANIC FORCING ←

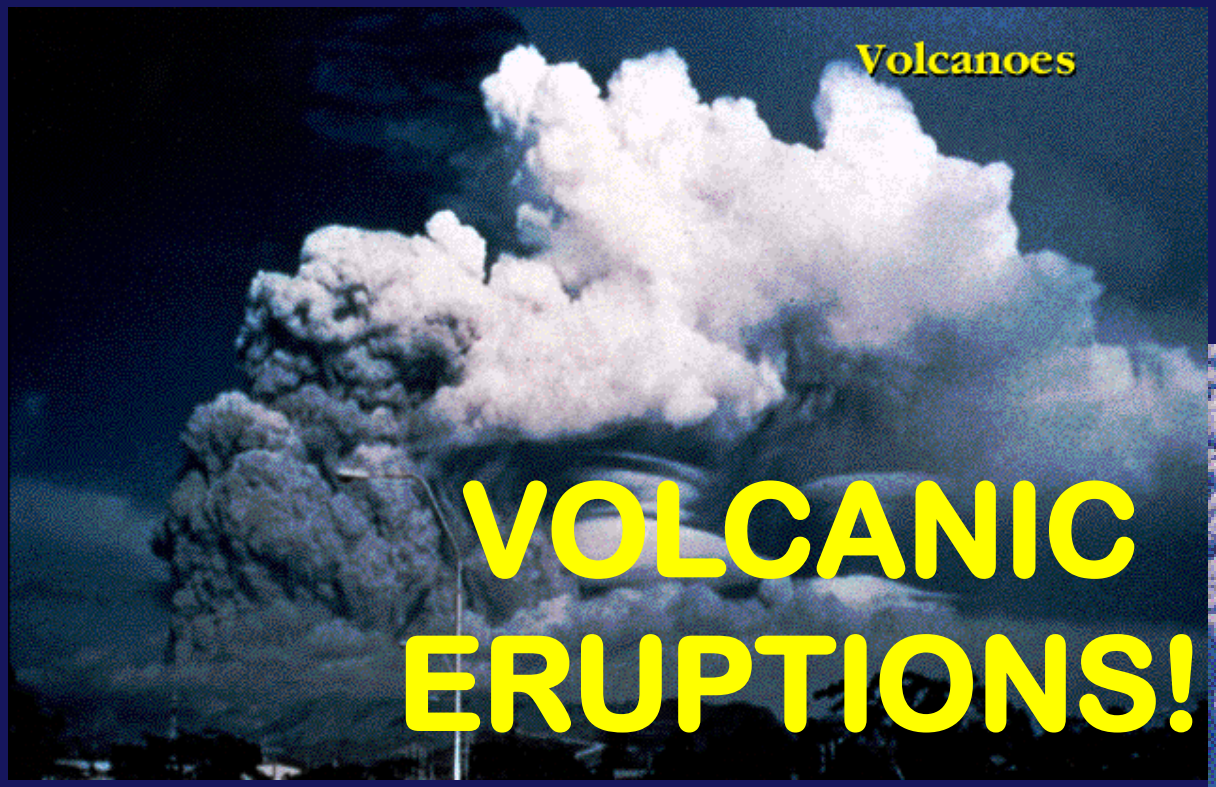
## Enhanced Greenhouse Warming Signature




## Solar Signature




## What's the "SIGNATURE" of FORCING from Volcanic Eruptions?




# VOLCANIC ERUPTIONS!

Volcanoes are one way the Earth gives birth to itself.

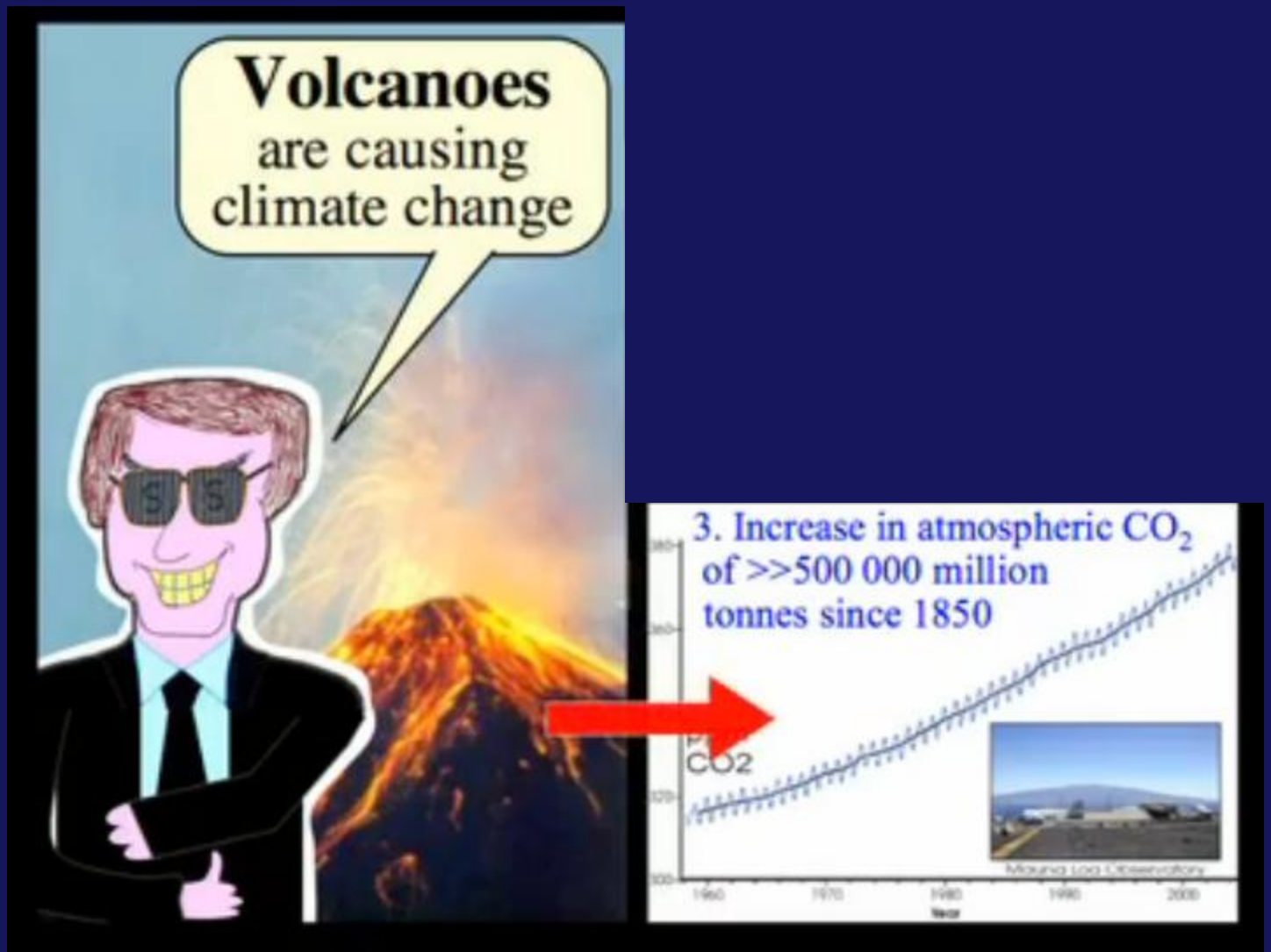
~Robert Gross

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**

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



Q1 – 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

**Q1 – Are volcanic eruptions an important cause of recent global warming?**

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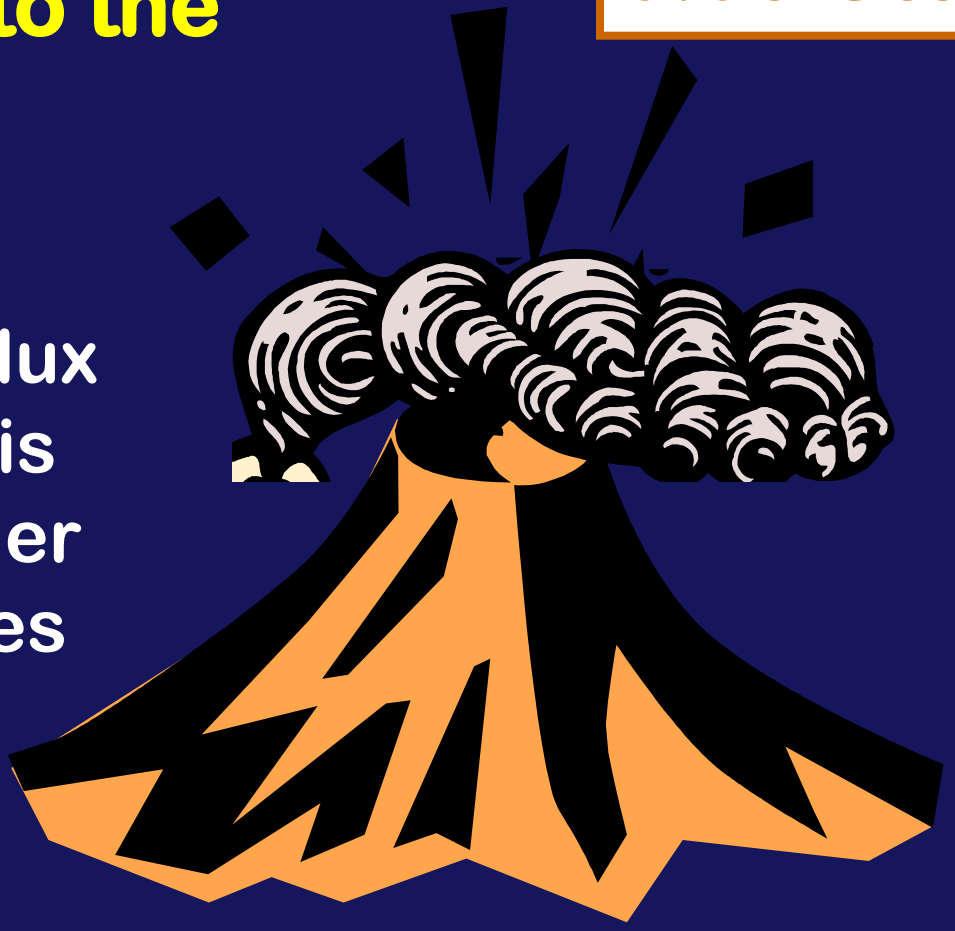
**Carbon flux from volcanic eruptions**
**What about the $CO_2$ emitted into the atmosphere?**

**Volcanic outgassing of $CO_2$ into atmosphere**

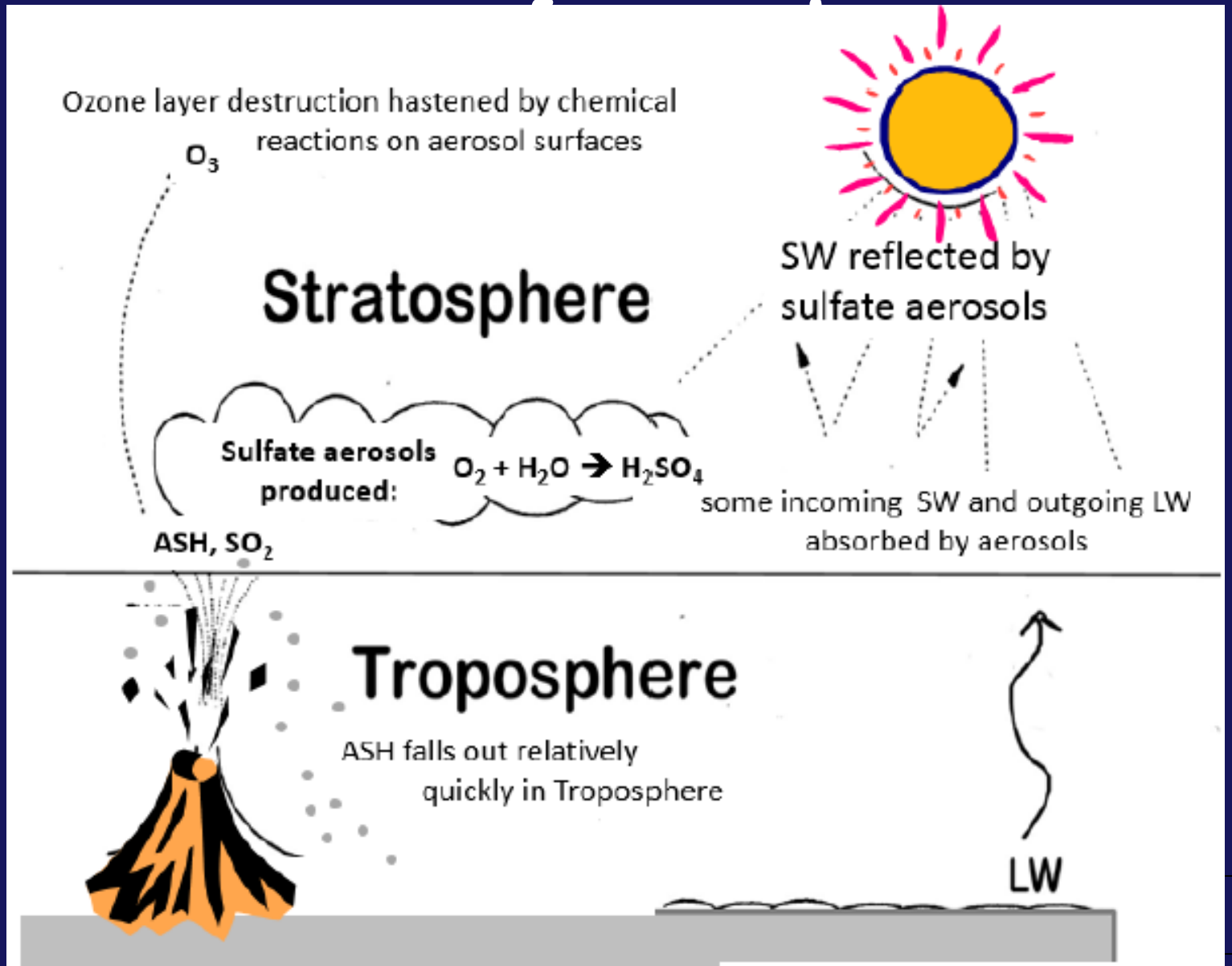
**0.06 Gtons**



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



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

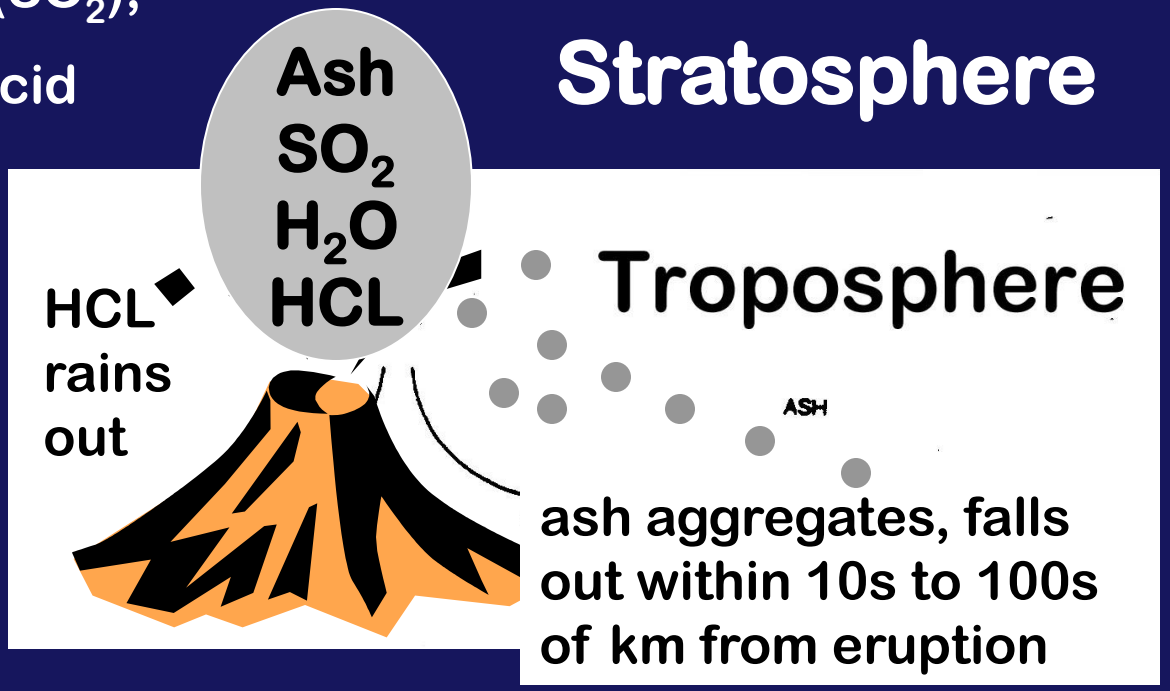
water vapor ($H_2O$)

sulfur dioxide ($SO_2$),

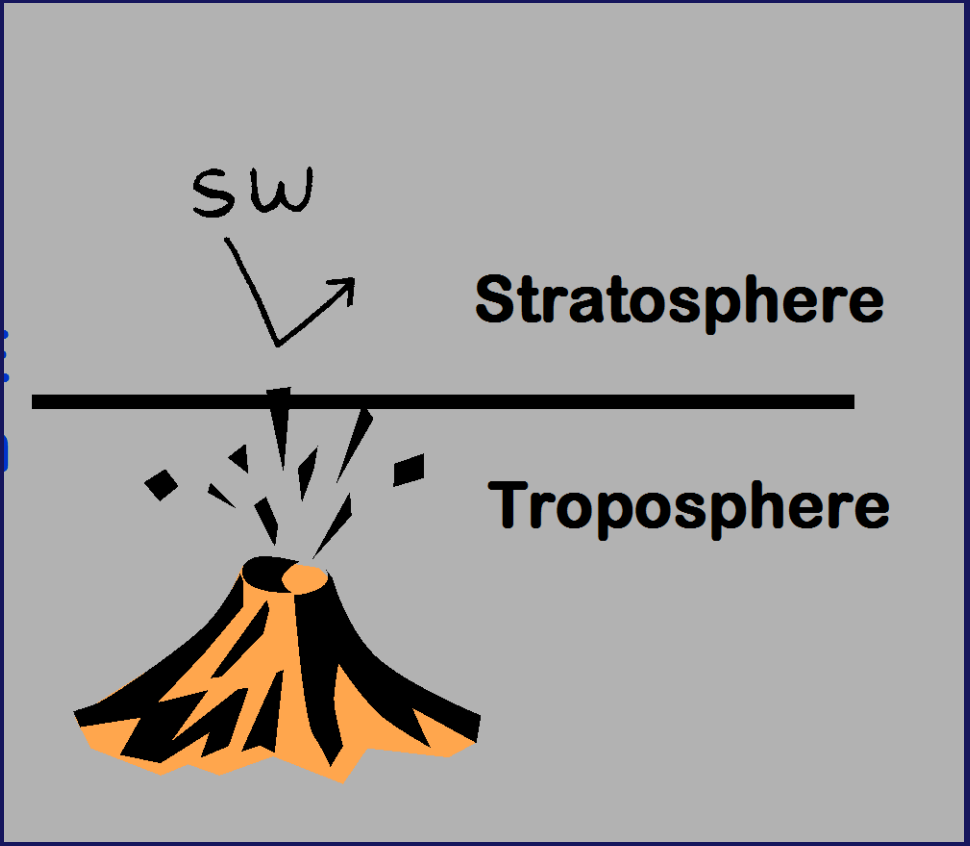
hydrochloric acid (HCl)

mineral ash

into the stratosphere

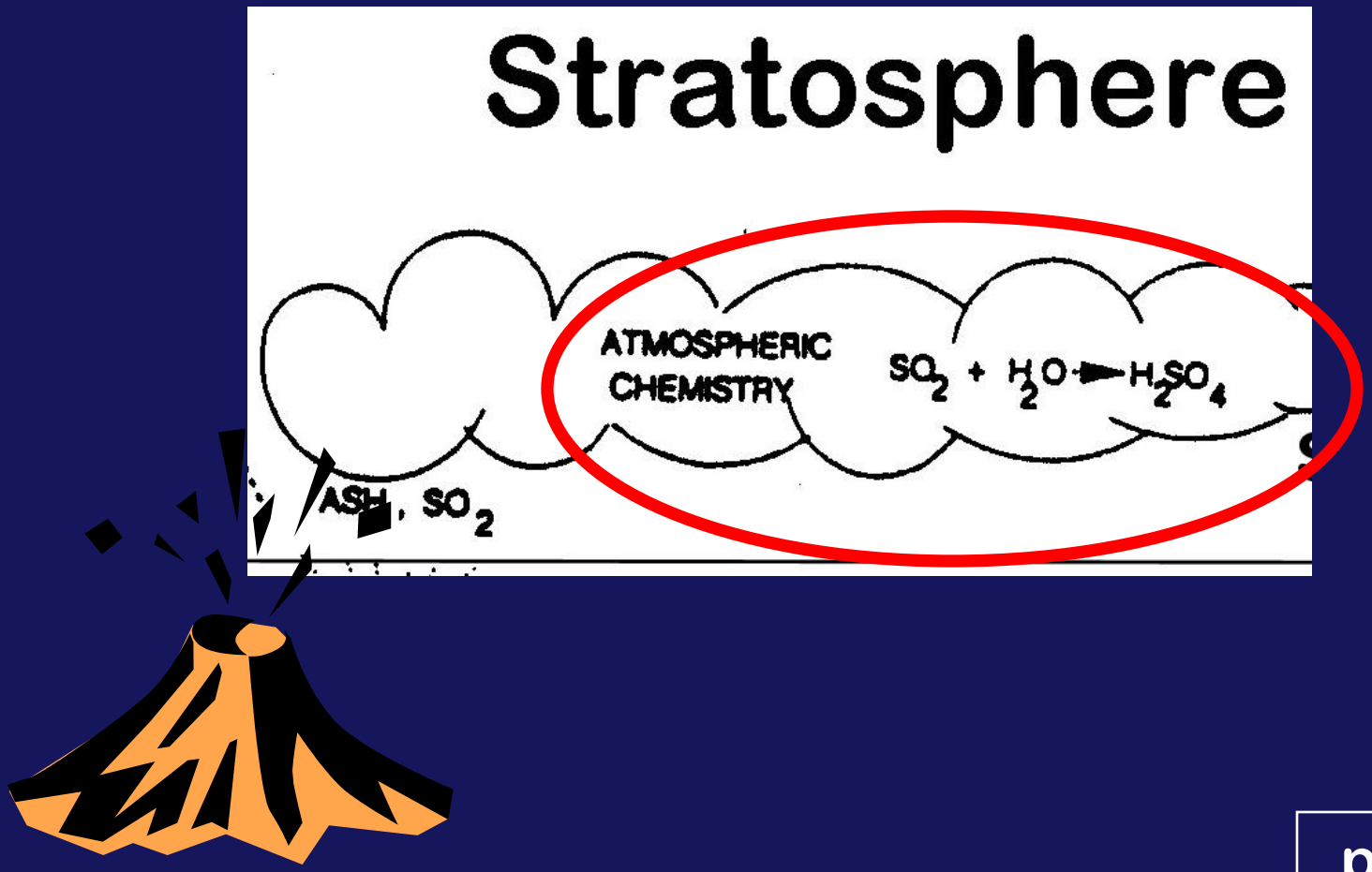


Albedo of ejected ASH in the STRATOSPHERE is *not* the reason for cooling after an eruption!
(most ash falls out early)

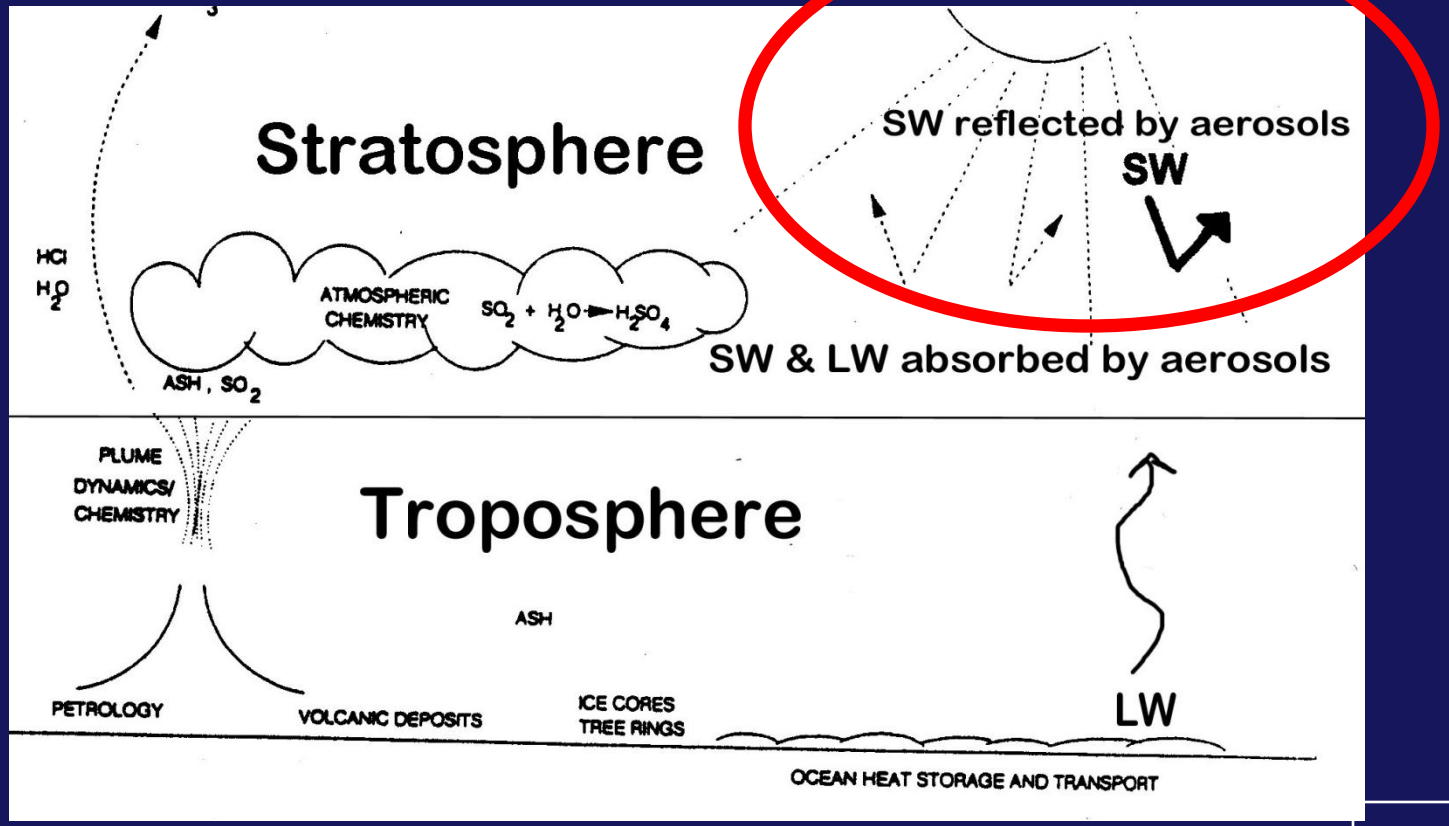



What *DOES* reflect the incoming shortwave radiation after an eruption?

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

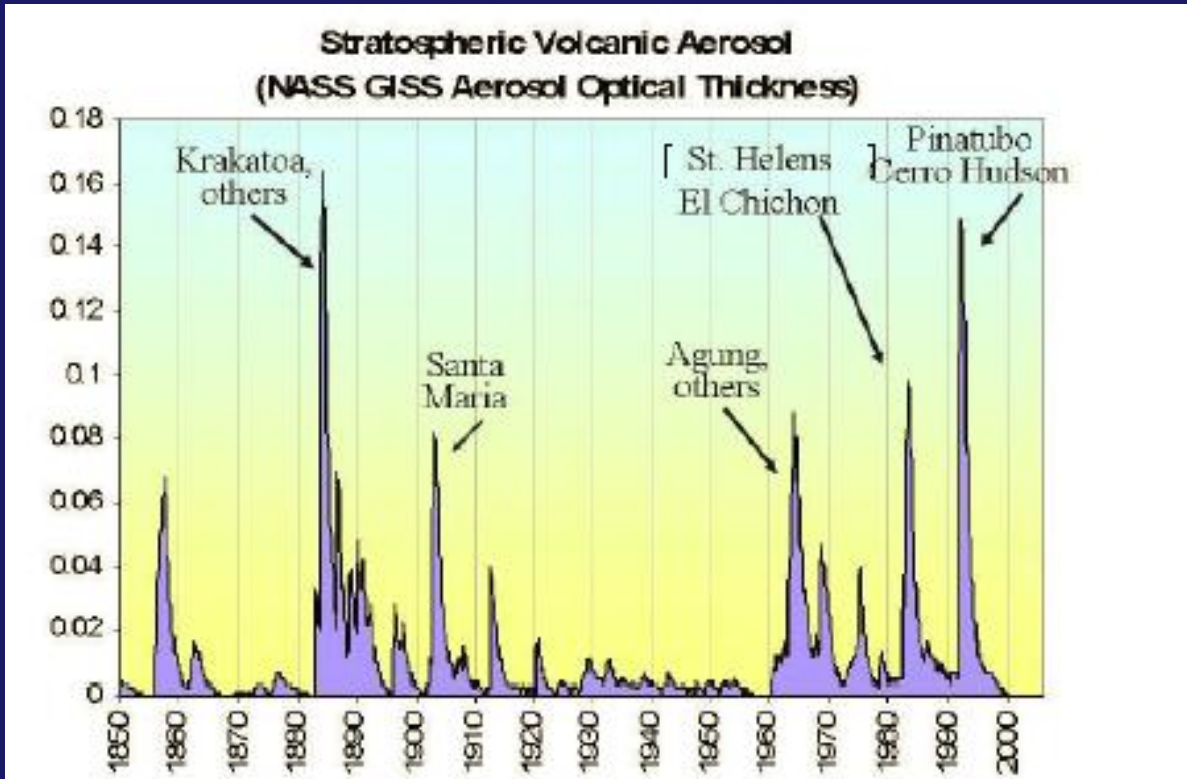


the sulfate aerosols *reflect* some of the incoming solar SW radiation back to space, cooling the troposphere below



# Volcanic aerosols in stratosphere from sulfur dioxide gases in eruption can REFLECT back incoming solar radiation → global cooling

Graph is on p 75 in Class Notes

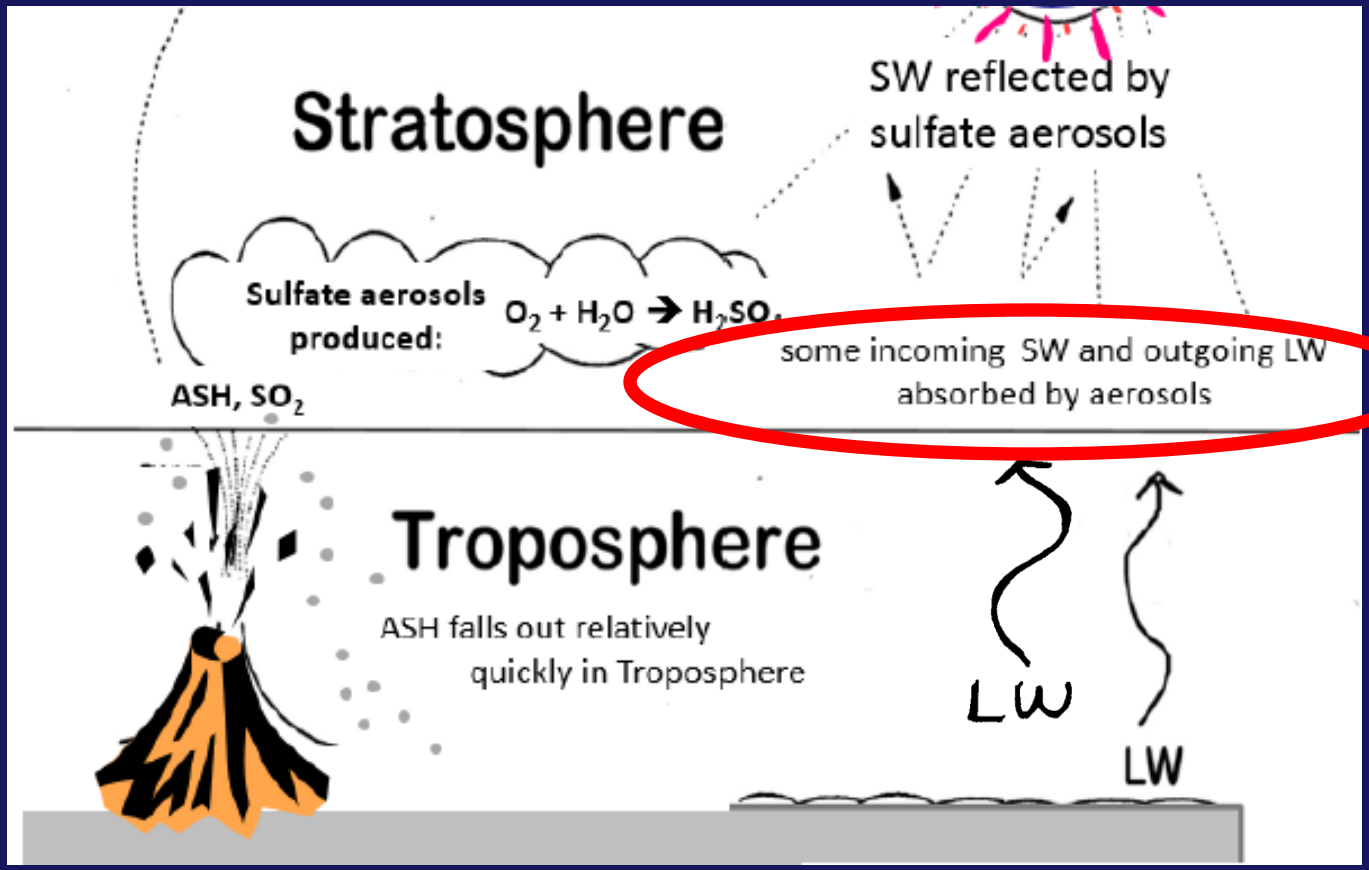



*Volcanic aerosols in the high atmosphere block solar radiation and increase cloud cover leading to widespread cooling, especially significant in summer*

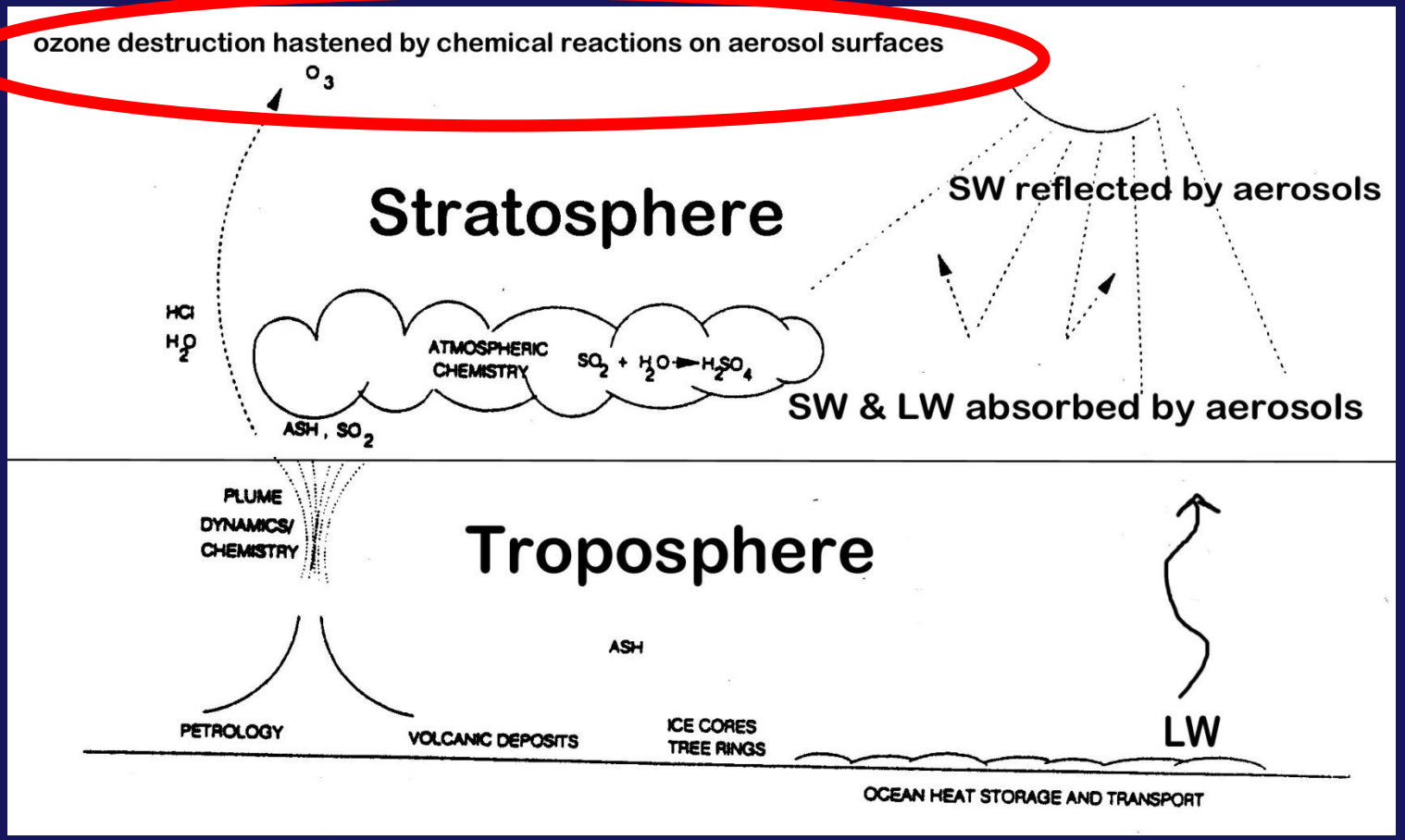
**SOME MAJOR VOLCANIC ERUPTIONS OF THE PAST 250 YEARS:**

| | |
|---|---|
| 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 |

**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)**



# Chemical effects of the sulfate aerosol cloud can also produce responses in the climate system through OZONE destruction (Topic #12)



Q2- How can an eruption in one spot on earth have a GLOBAL COOLING effect?

1- The cold air from the eruption's local cooling effect gets circulated to other locations around the globe by winds

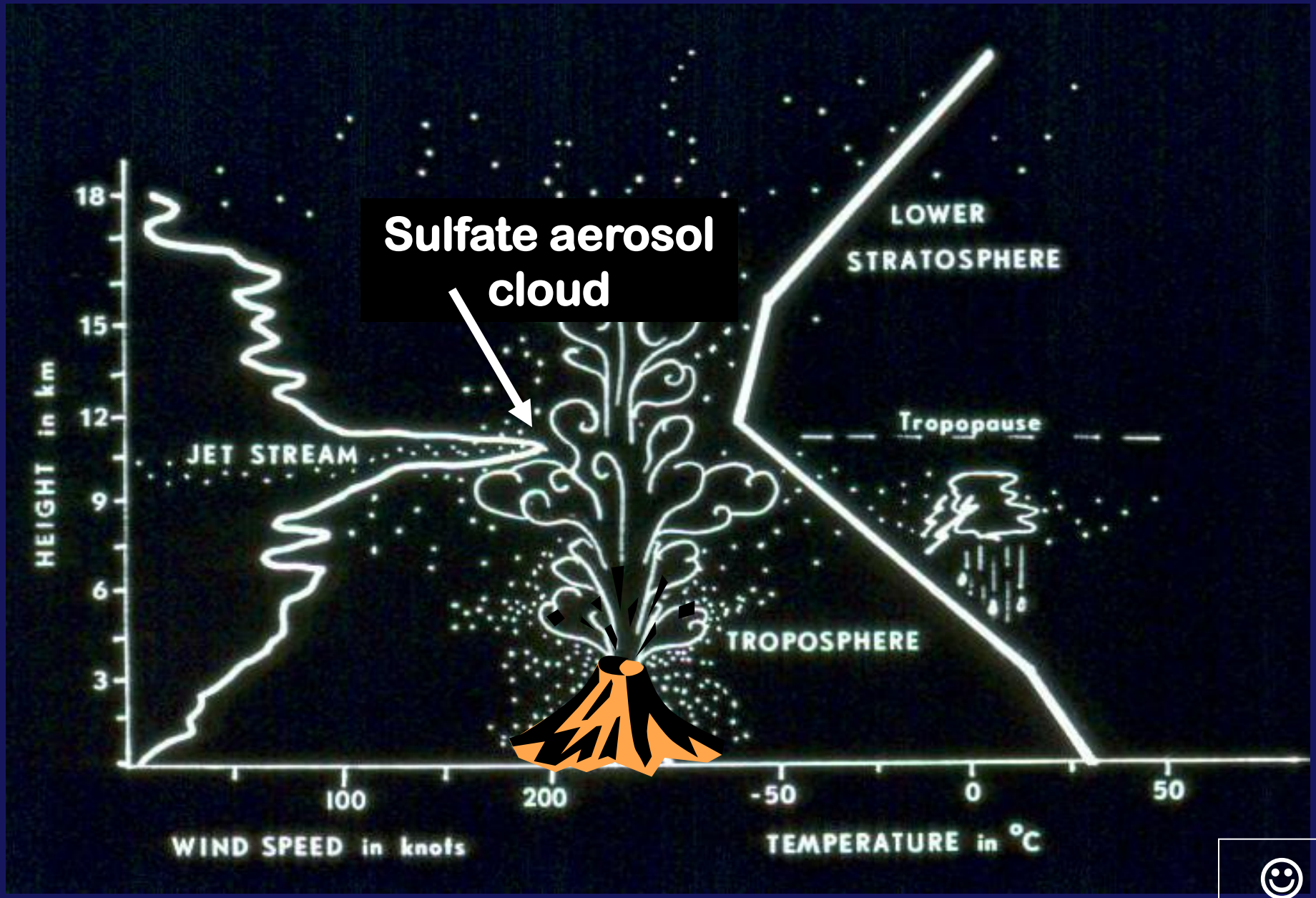
2 – The aerosols in the stratosphere get circulated around the globe by winds , which influences the radiation balance globally

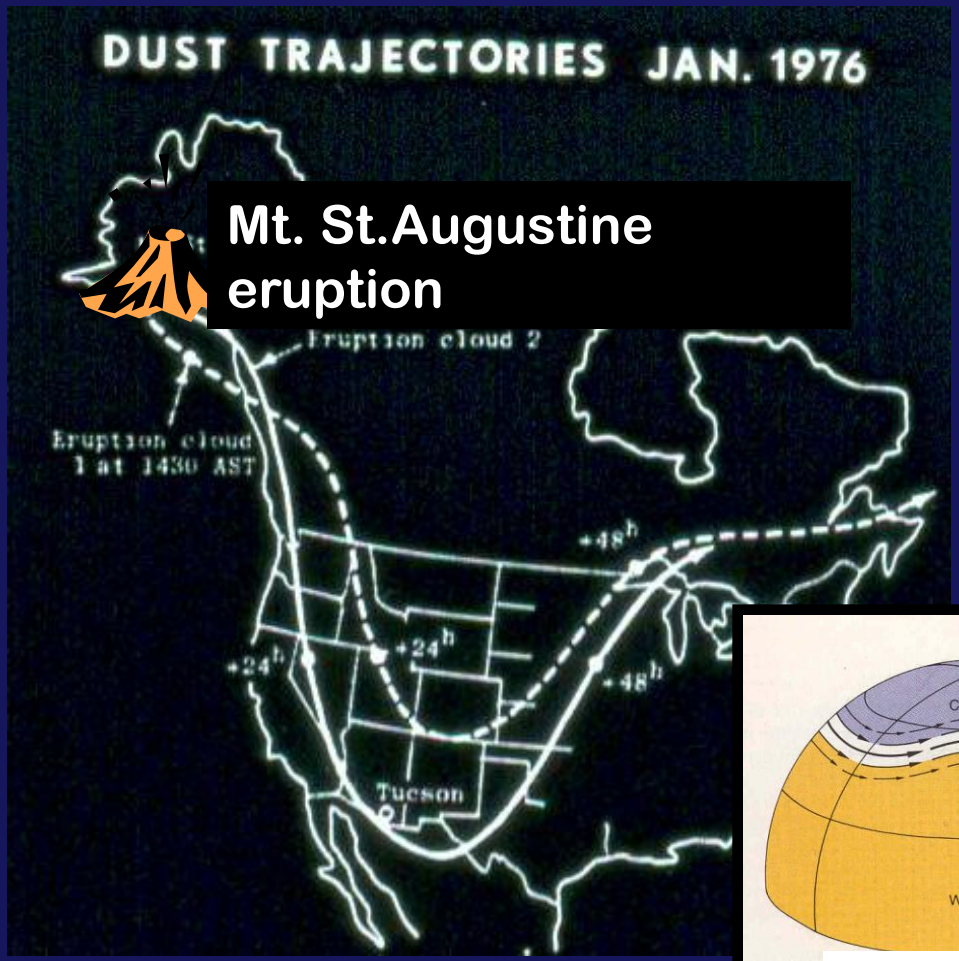
Q2 - How do you think an eruption in one spot on earth have a GLOBAL COOLING effect?

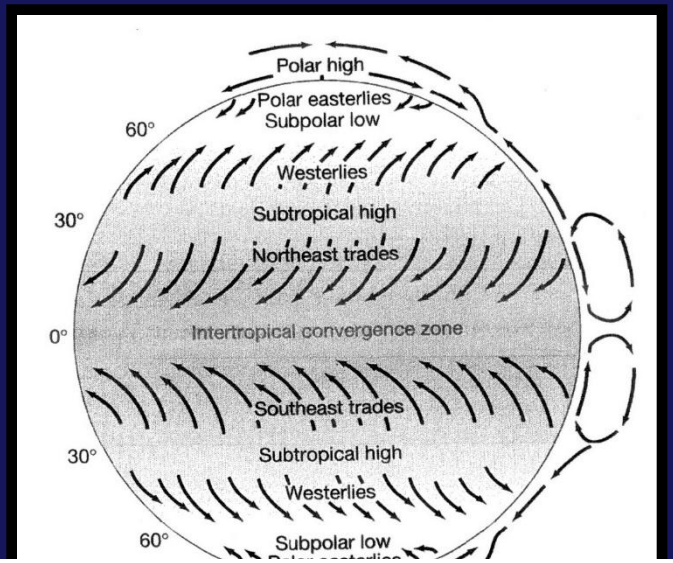
1- The cold air from the eruption's local cooling effect gets circulated to other locations around the globe by winds

2 – The aerosols in the stratosphere get circulated around the globe by winds , which influences the radiation balance globally

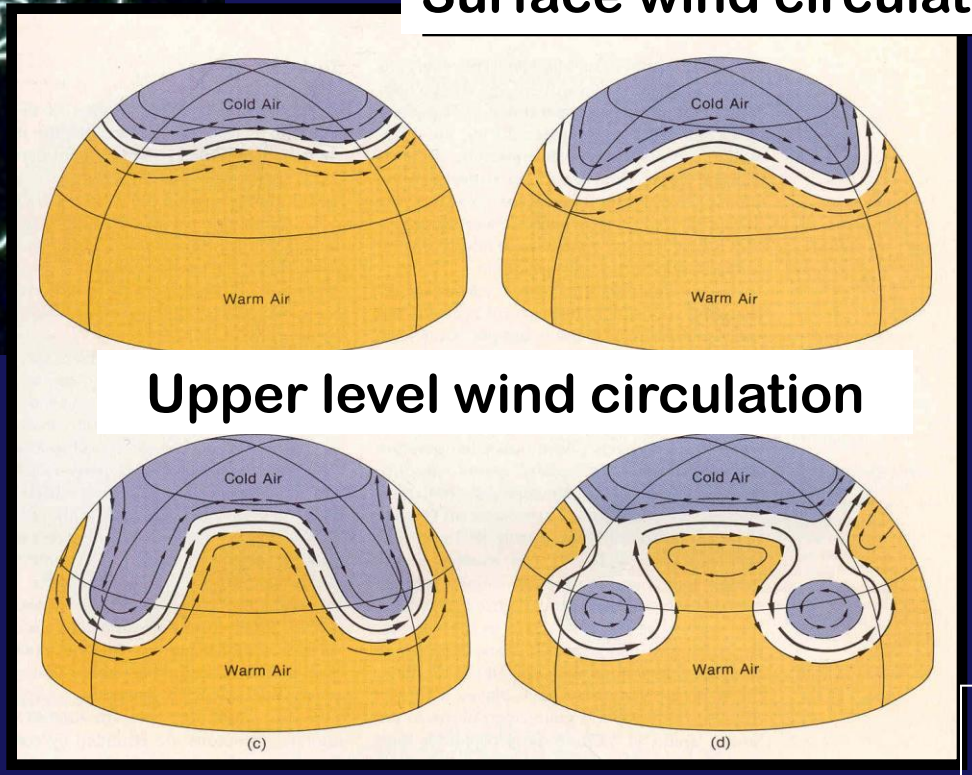
# How an eruption's effects can become GLOBAL:





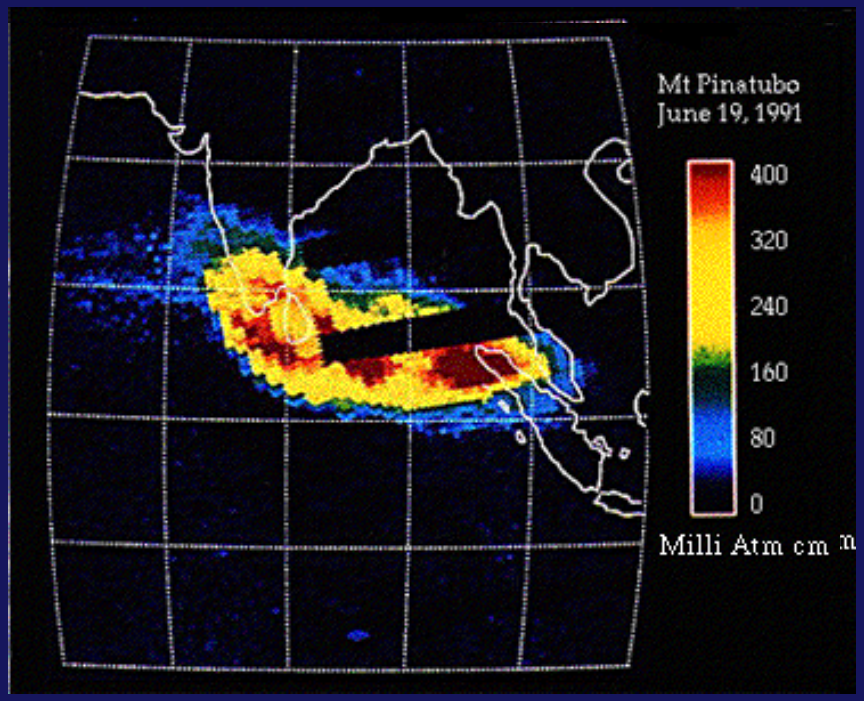




Surface wind circulation



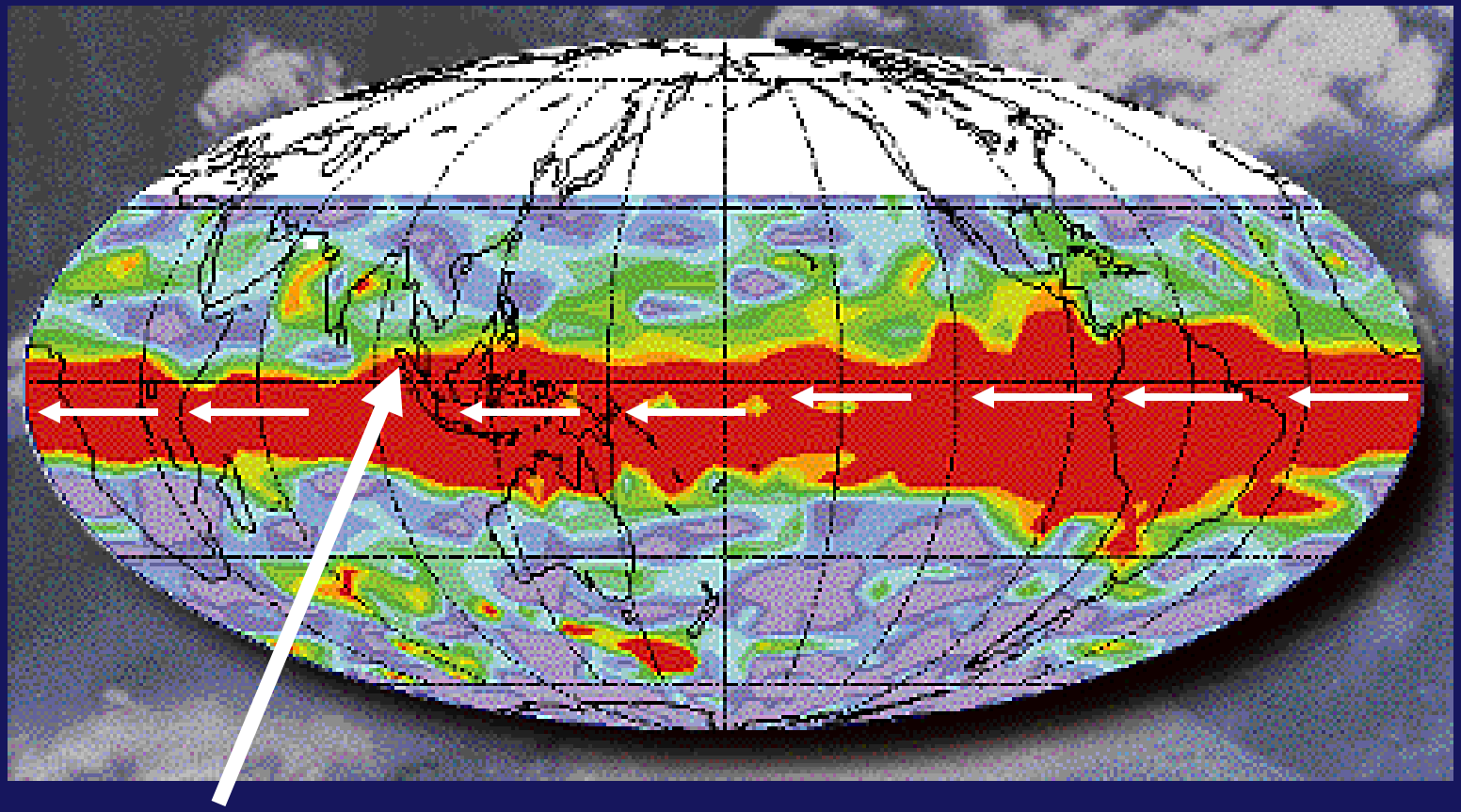

# Through the atmospheric circulation!

# Mt Pinatubo Eruption in the Philippines, June, 1991



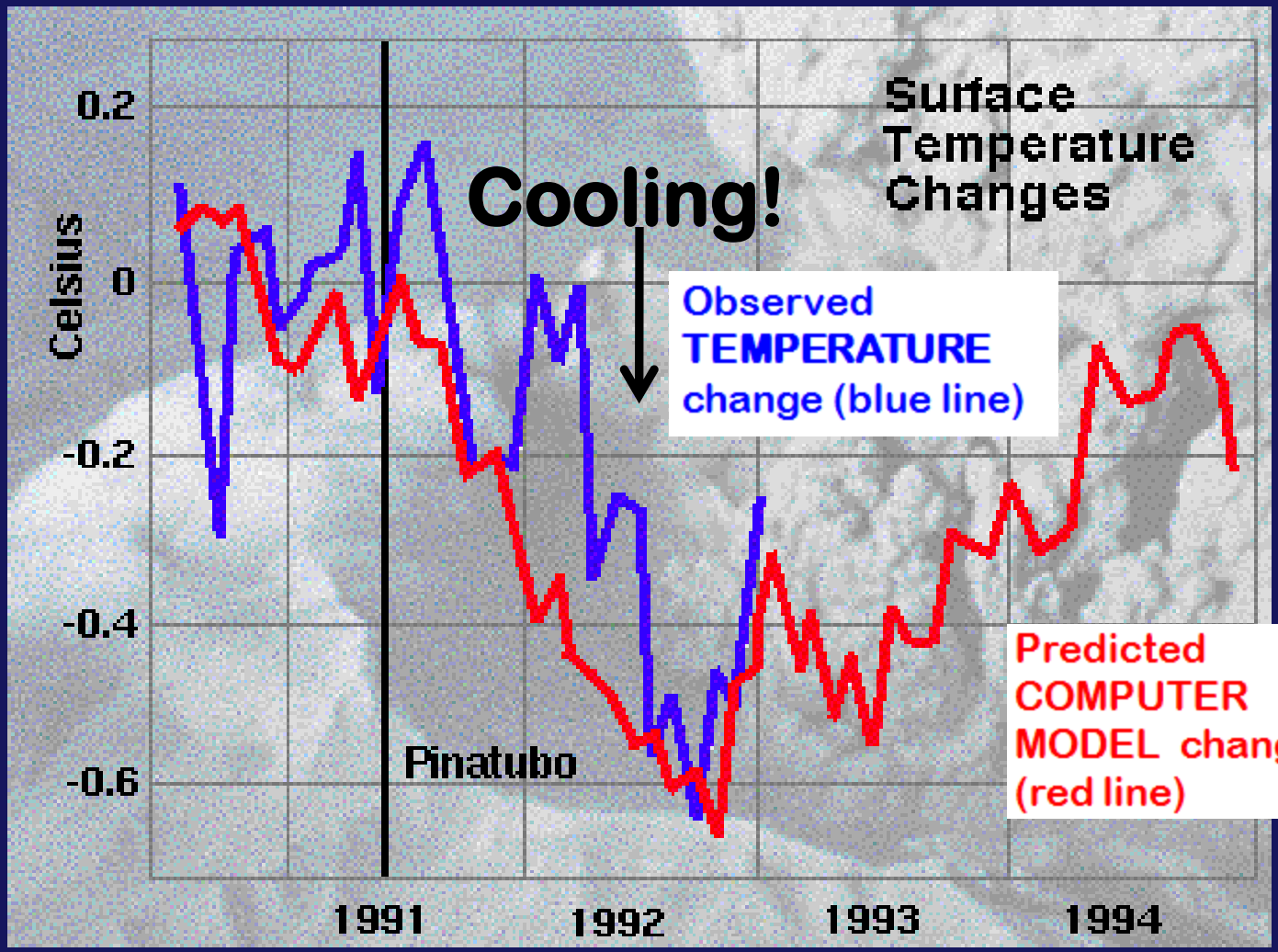

Satellite-derived image of
sulfur dioxide thickness in the atmosphere
red = higher thickness

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

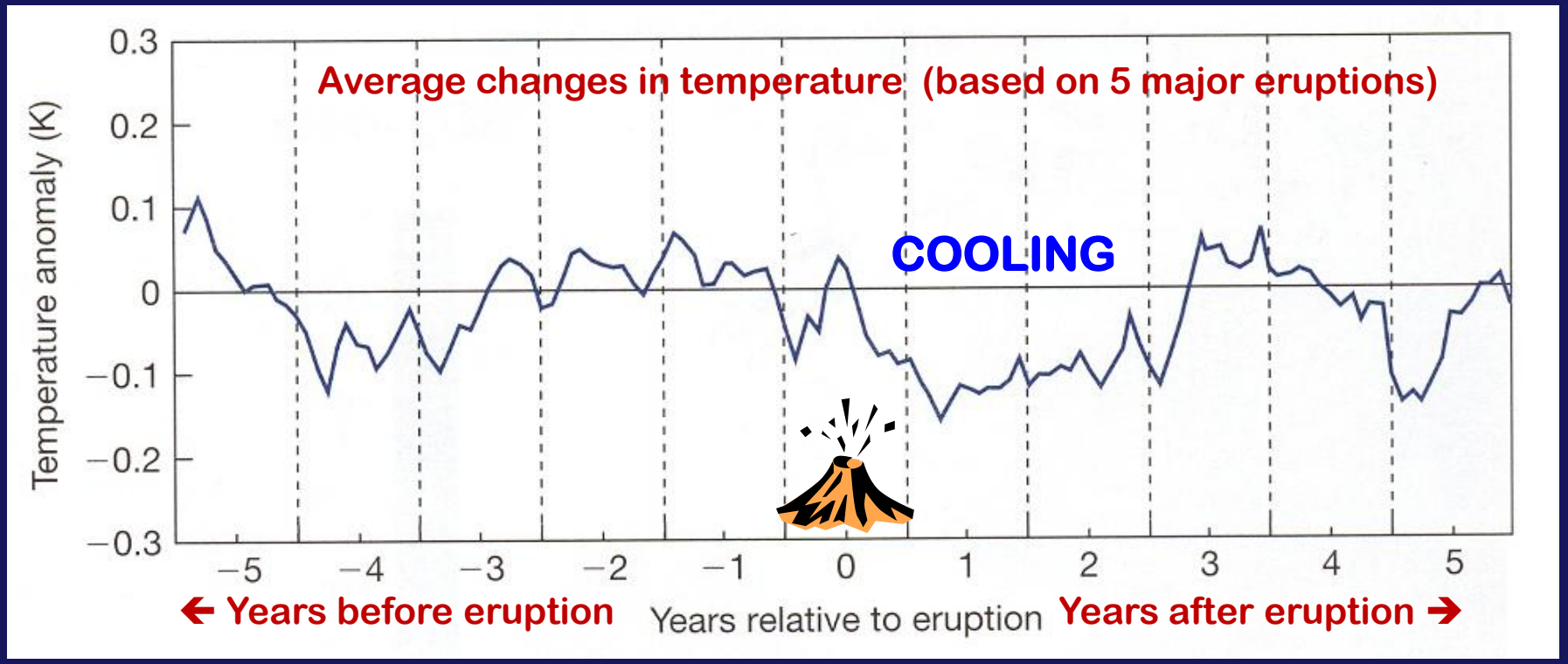


Mt Pinatubo

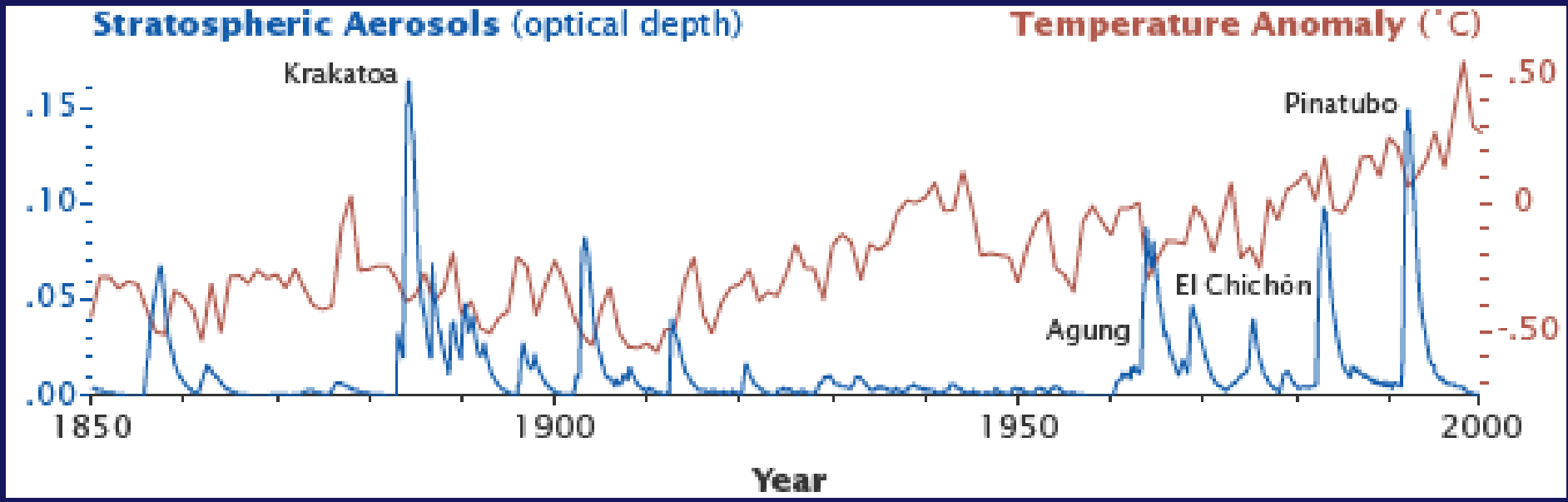
# Mt Pinatubo eruption June 1991



# 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)**



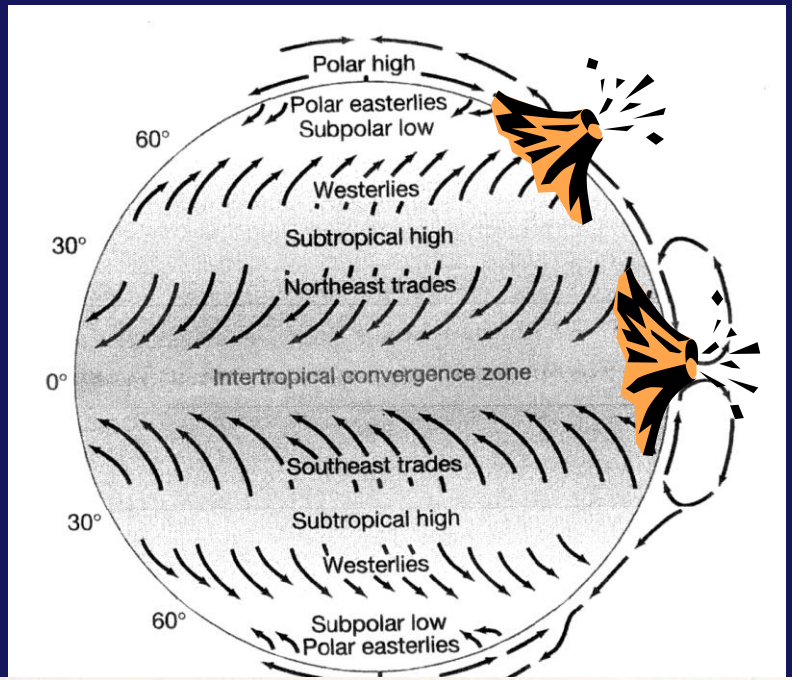

http://earthobservatory.nasa.gov/Features/Aerosols/

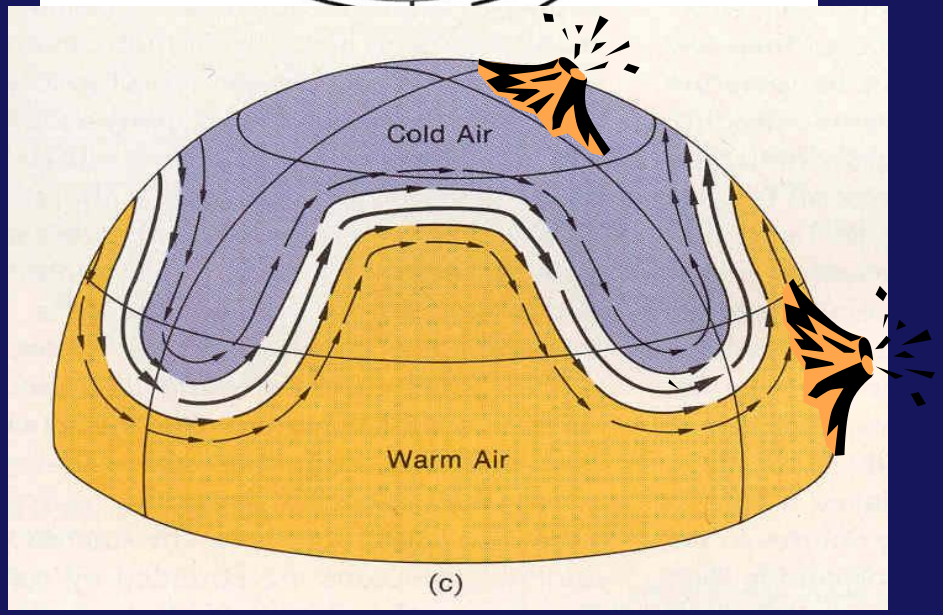
# WHICH ERUPTIONS ARE THE MOST CLIMATICALLY EFFECTIVE?

- EXPLOSIVE
- high SULFUR content in magma
- whose eruption clouds inject into the STRATOSPHERE
- Low Latitude Eruptions

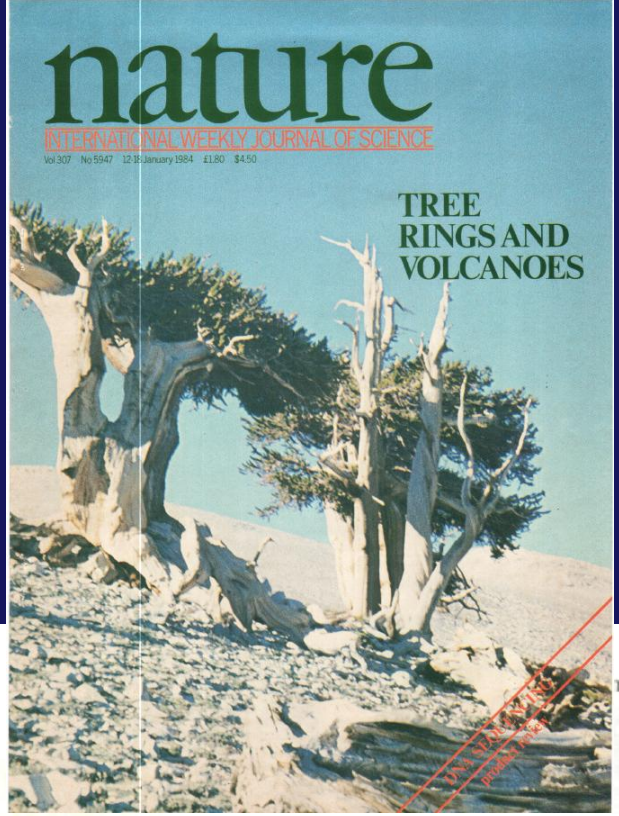
- The GEOGRAPHIC LOCATION of the erupting volcano influences the climatic effectiveness of an eruption because of the General Circulation of the Atmosphere.

- Low latitude eruption clouds get circulated more broadly & in both hemispheres



See box on p 75
for a good summary of
which eruptions are
**CLIMATICALLY EFFECTIVE**




n Nature, Vol. 307, No. 5946, pp. 121-126, 12 January, 1984

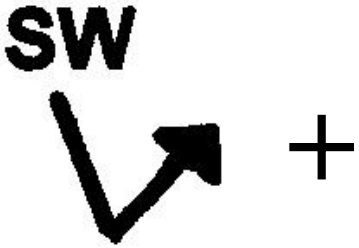

# Frost rings in trees as records of major volcanic eruptions

**Valmore C. LaMarche Jr* & Katherine K. Hirschboeck†**

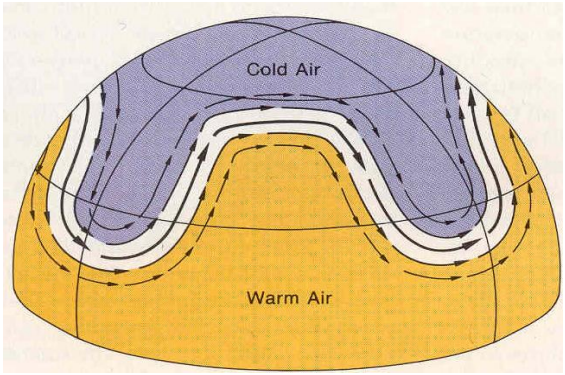
* Laboratory of Tree-Ring Research and † Department of Geosciences, University of Arizona, Tucson, Arizona 85721, USA

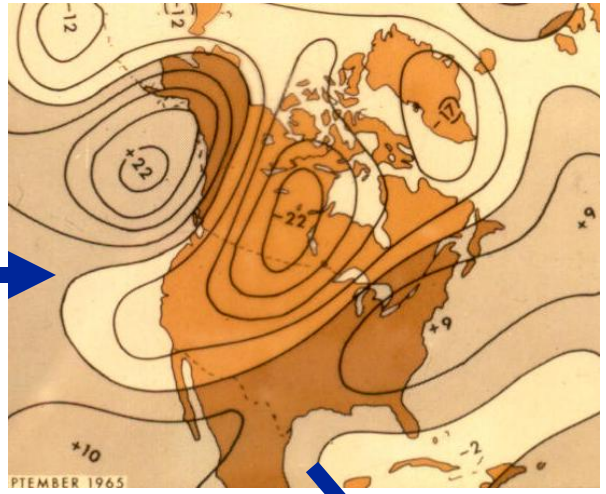
*New data about climatically-effective volcanic eruptions during the past several thousand years may be contained in frost-damage zones in the annual rings of trees. There is good agreement in the timing of frost events and recent eruptions, and the damage can be plausibly linked to climatic effects of stratospheric aerosol veils on hemispheric and global scales. The cataclysmic proto-historic eruption of Santorini (Thera), in the Aegean, is tentatively dated to 1628–26 BC from frost-ring evidence.*

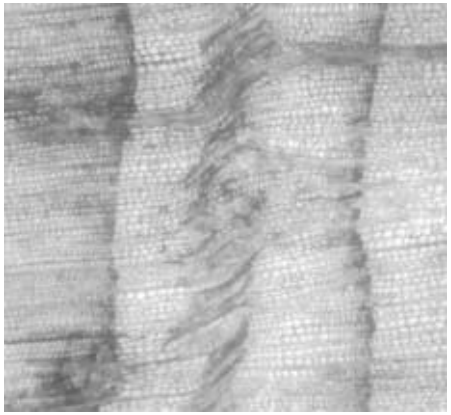
# Energy Balance Effects & Global Atmospheric Circulation




+

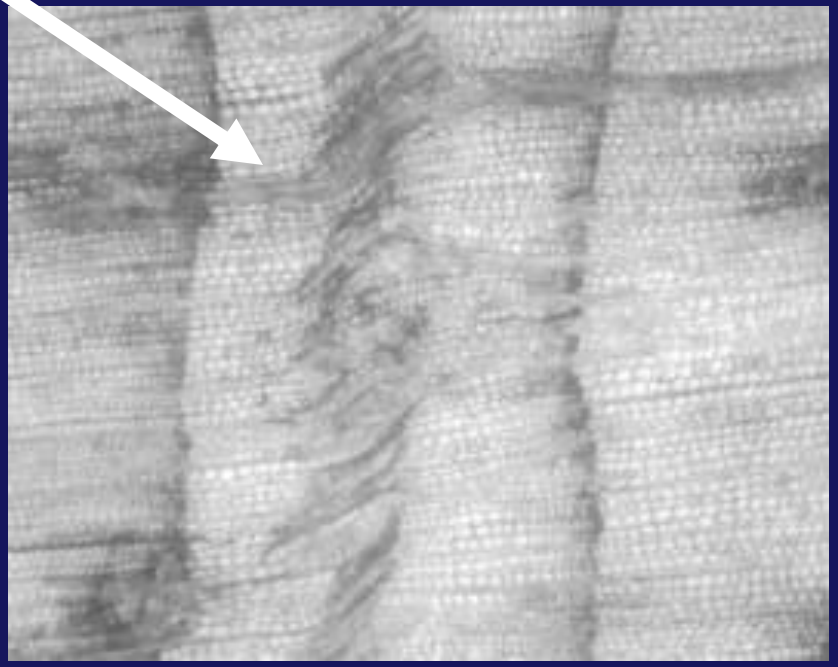


# “FROST RINGS”

Growing cells get crushed and damaged during an unseasonable FREEZE event (1 -2 days) of below freezing temperatures ➔ leaves permanent mark in the wood!



# G-5 ACTIVITY ON VOLCANISM & CLIMATE

# Comparison Table of Eruptions

Latitude

How much magma → how big an eruption

How much aerosol got into each hemisphere

Sulfur-rich if high $H_2SO_4$

Estimated N.H. temperature change °C

## COMPARISON TABLE OF ERUPTIONS

| Eruption & Latitude | Year | Amount of Magma Erupted ($km^2$) | Stratospheric Aerosol (Mt) S.H. | Stratospheric Aerosol (Mt) N.H. | $H_2SO_4$ estimate (Mt) | Estimated N.H. Temp change (°C) |
|---|---|---|---|---|---|---|
| Tambora (8°S) | 1815 | 50 | 150 | 150 | 52 | -0.4 to -0.7 |
| Krakatau (6°S) | 1883 | 10 | ~34 | 55 | 2.9 | -0.3 |
| Santa Maria (15°N) | 1902 | 9 | 22 | <20 | 0.6 | -0.4 |
| Katmai (86°N) | 1912 | 15 | 0 | <30 | 12 | -0.2 |
| Agung (8°S) | 1963 | 0.6 | 30 | 20 | 2.8 | -0.3 |
| Mt St. Helens (46°N) | 1980 | 0.3 | 0 | *no info* | 0.08 | 0 to -0.1 |
| El Chichón (17°N) | 1982 | ~ 0.3 | <8 | 12 | 0.07 | -0.2 |
| Pinatubo (15°N) | 1991 | ~ 5 | *no info* | ~25 | ~0.3 | -0.5 |
| | | *(Large eruption if lots of magma)* | *(How much got into each hemisphere)* | | *(Sulfur-rich if high)* | |

**IMPORTANT: if**
**NO INFORMATION IS AVAILABLE,**
**this does not mean the value is zero!**

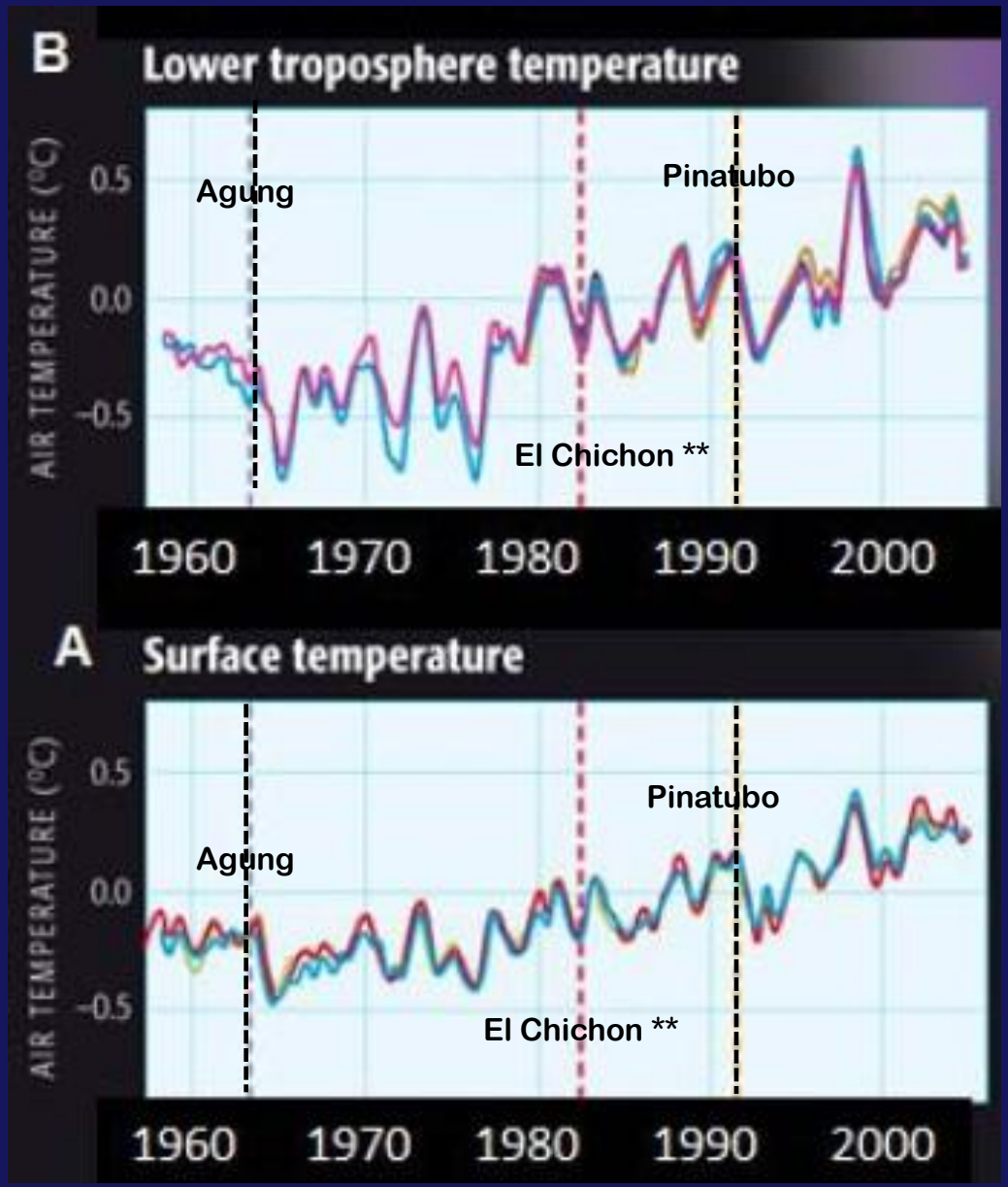
**#1. List 4 reasons why Tambora in 1815 resulted in the largest GLOBAL cooling:**

**# 2. Give at least two reasons why the eruption of Mt St. Helens was NOT a very climatically effective eruption:**

P.S. This is one of my favorite questions to ask on the FINAL EXAM!!!!

Focus on these two ERUPTIONS

Agung (1963) Pinatubo (1991)



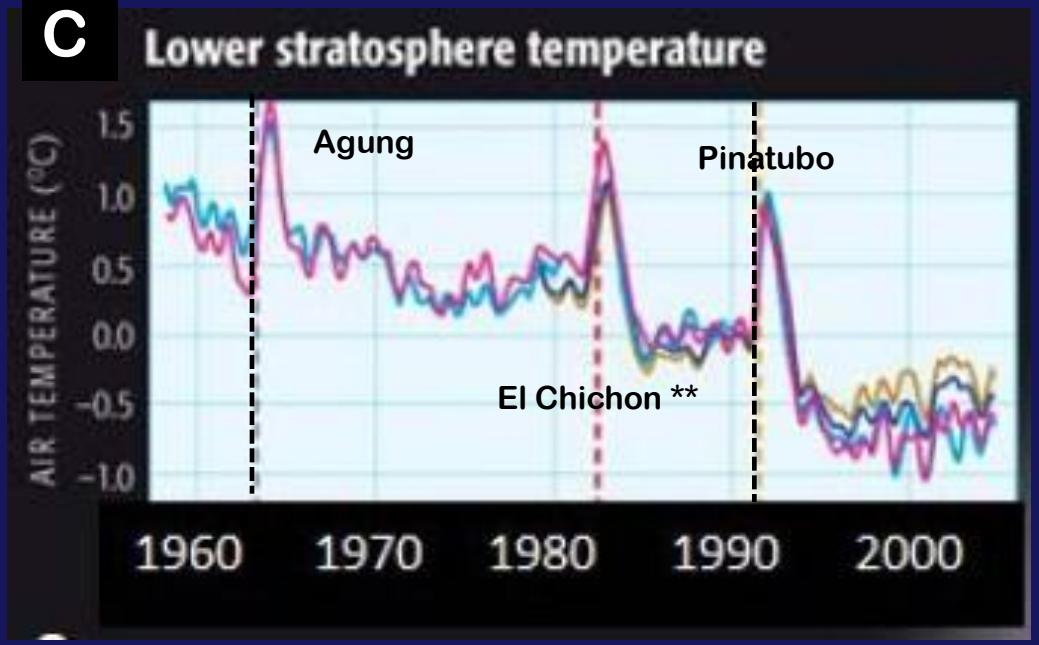

## #3. Which levels show a COOLING and which show a WARMING immediately after the eruption?

** NOTE: At the time of the El Chichon eruption, there was warming taking place due to a strong El Nino, hence the temperature change after this eruption shows a different response.

## When ANSWERING # 3 & #4 – focus on Agung & Pinatubo only

Focus on these two ERUPTIONS

Agung (1963) Pinatubo (1991)

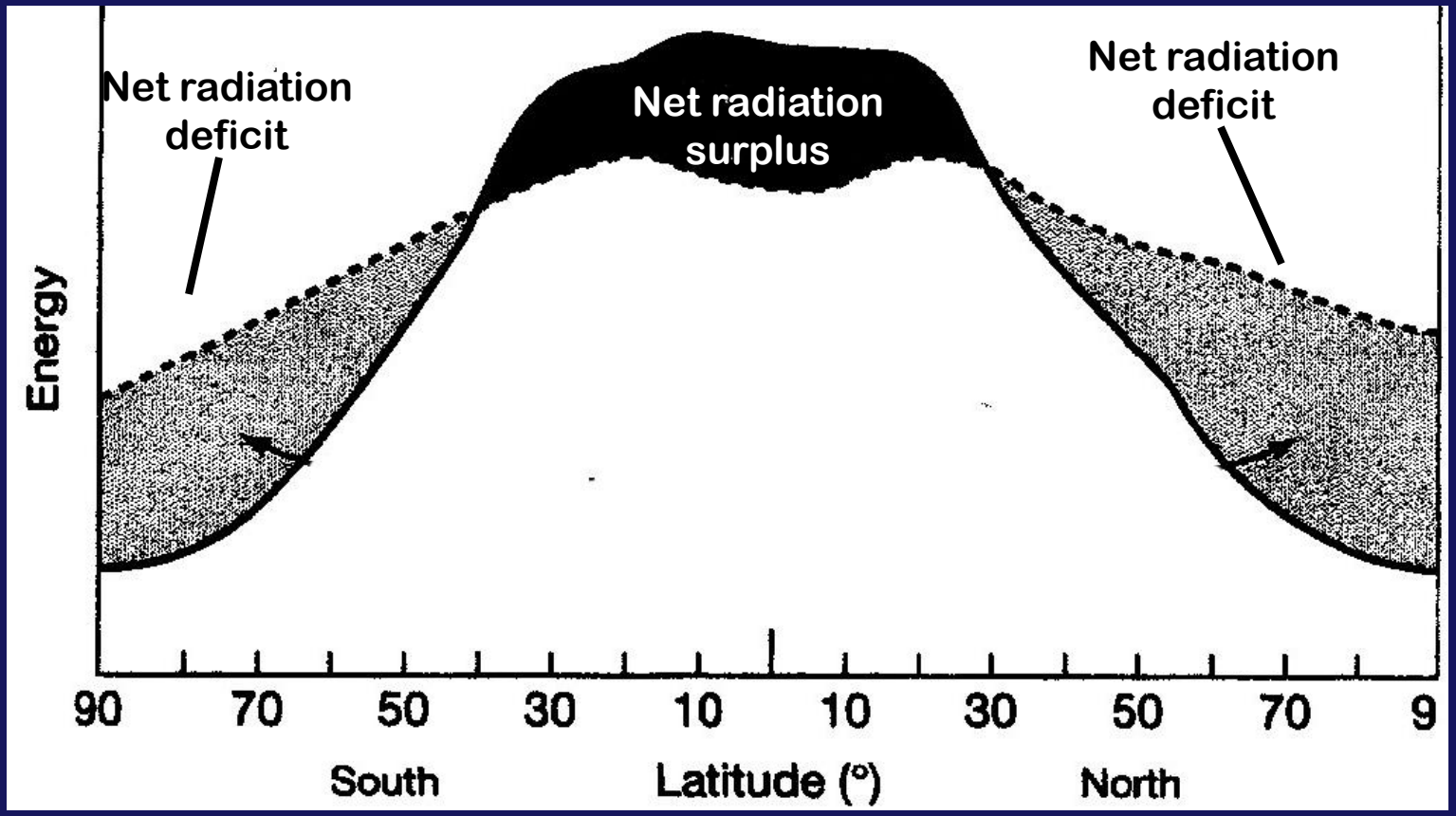



**#4. Explain WHY each level's TEMPERATURE responded as it did to the Agung & Pinatubo eruptions?**

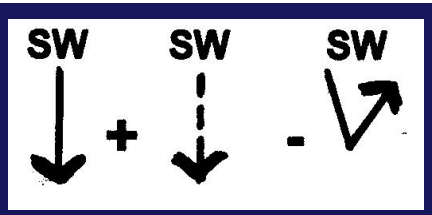
(by referring to the Radiation Balance)

**When ANSWERING # 3 & # 4 – focus on Agung & Pinatubo only**

# REMEMBER THIS IMPORTANT GRAPH?



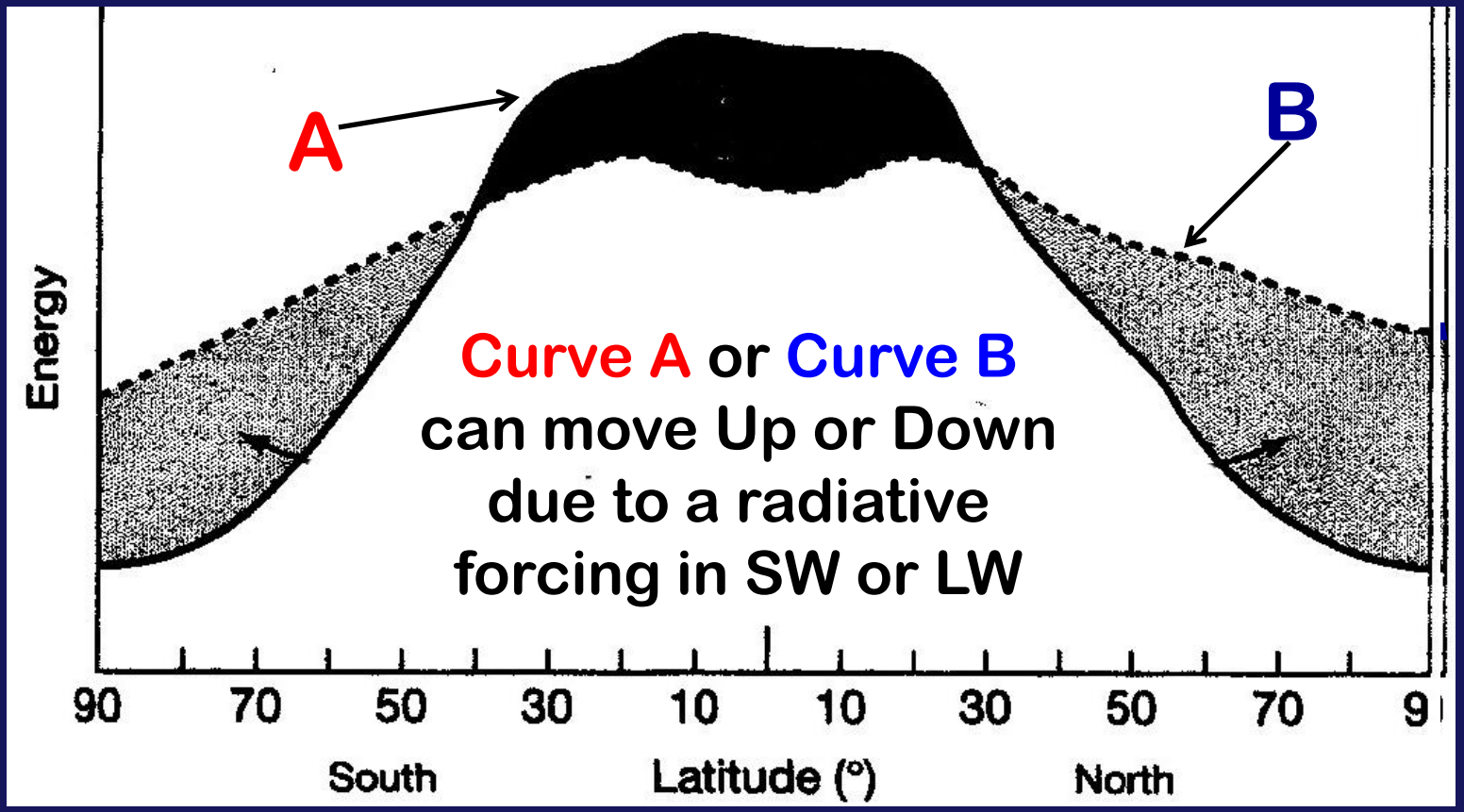

Absorbed solar energy




Emitted infrared energy

(at top of atmosphere)

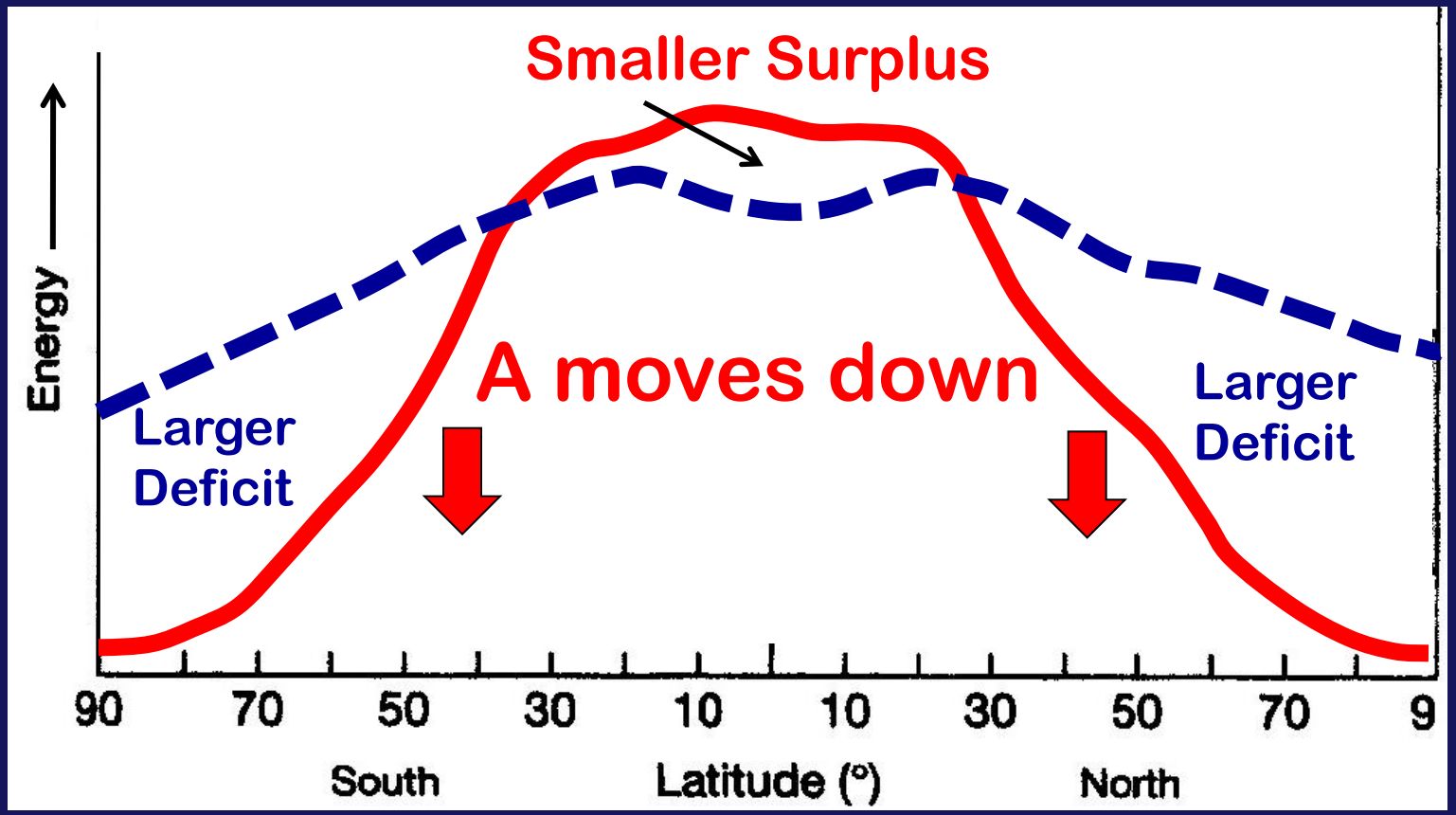
# SKETCH A NEW CURVE A OR NEW CURVE B to show how the energy balance would change if a major volcanic eruption occurred .




**CURVE A** SW + SW - SW

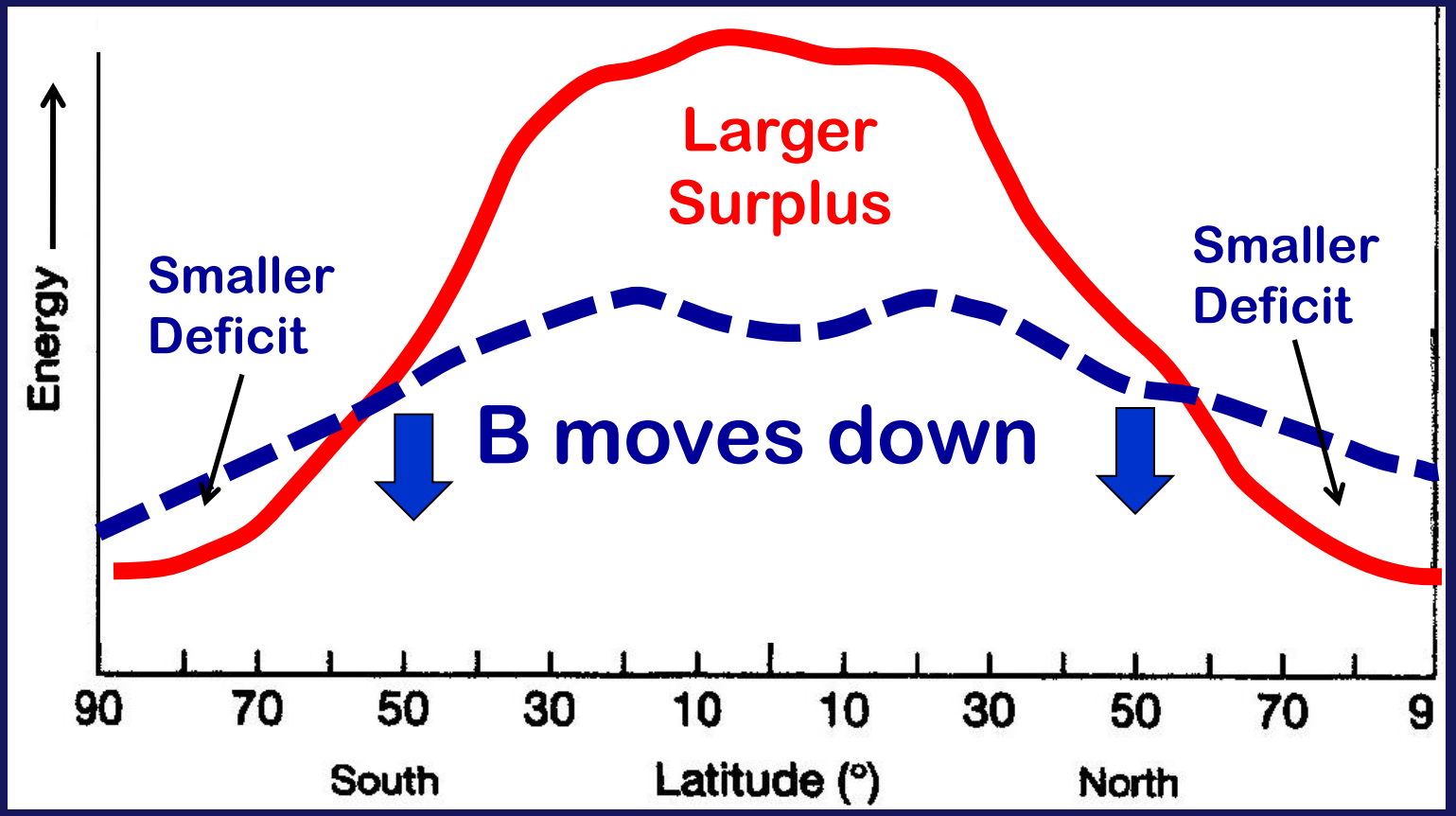
**CURVE B** LW LW

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




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

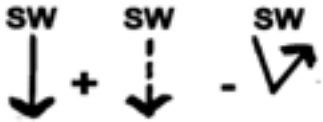
If CURVE B moves down

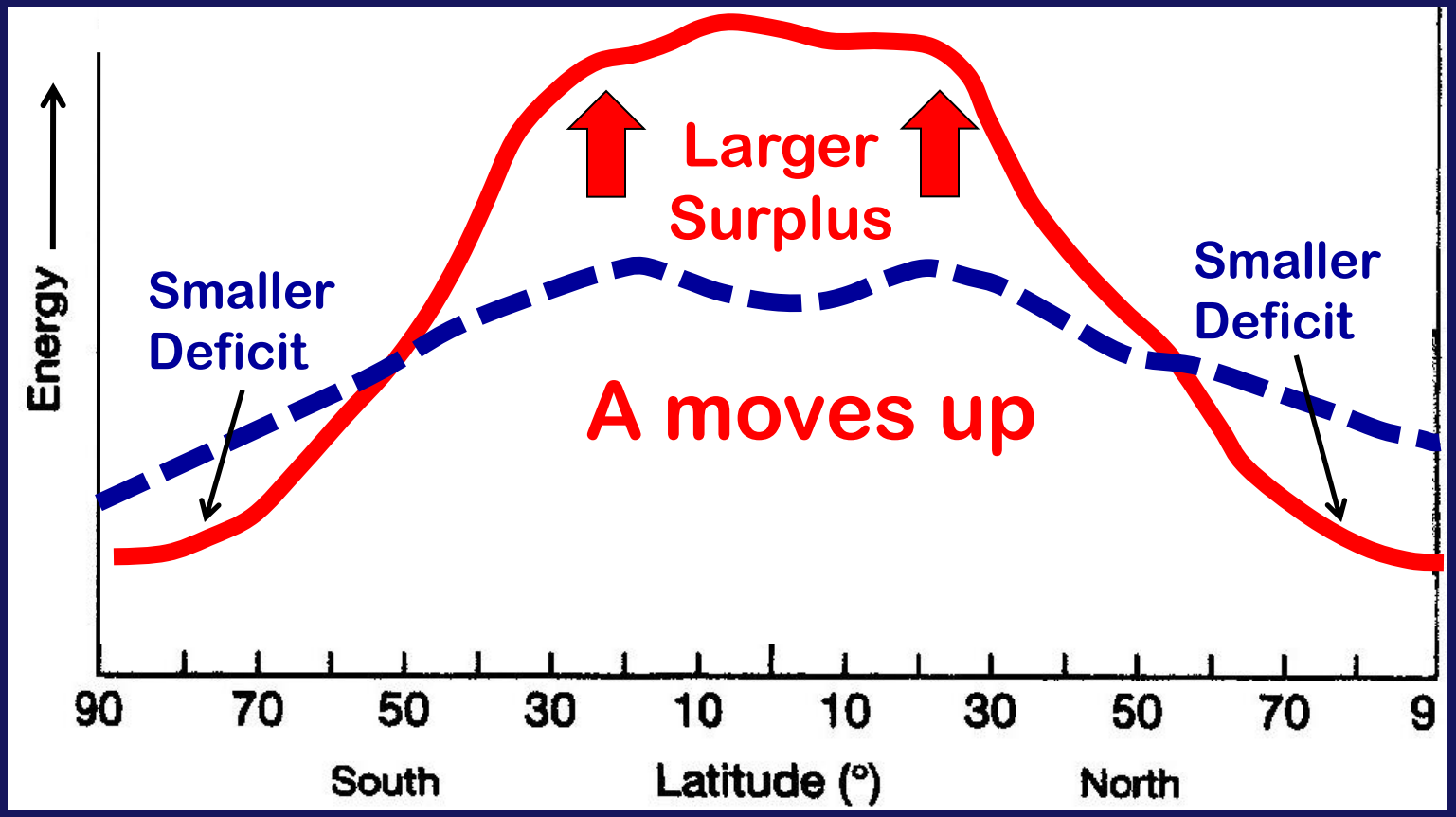


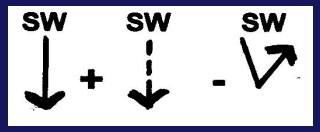

LW

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

**IF CURVE A moves up:**

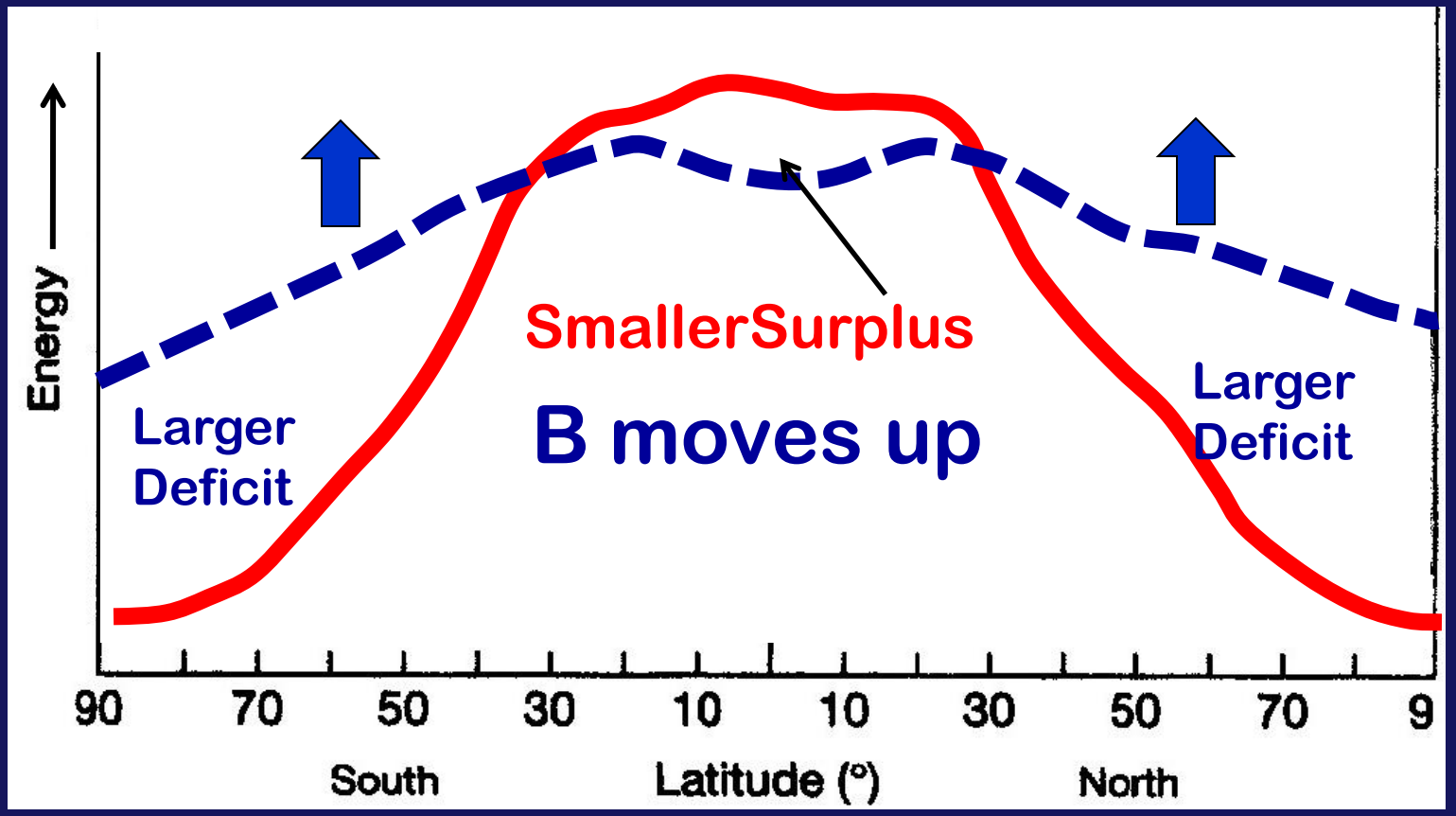



If incoming energy represented by Curve A is increased (A curve goes up)

If CURVE B moves up:



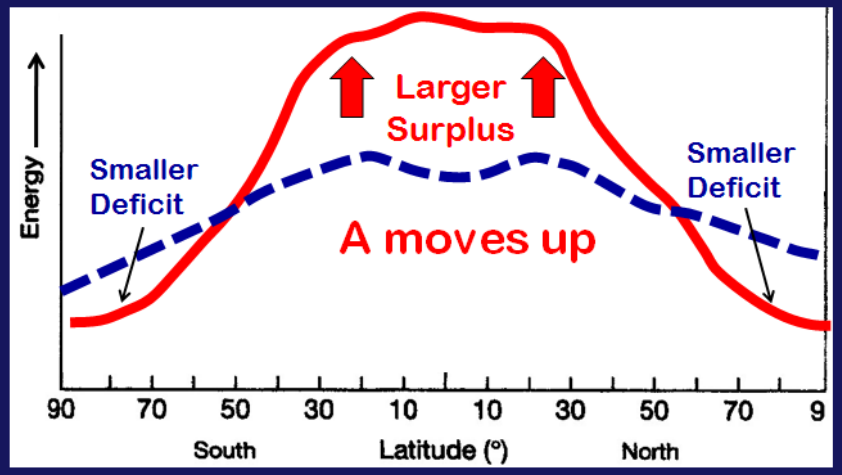
If outgoing energy represented by Curve B is increased (B curve goes up)

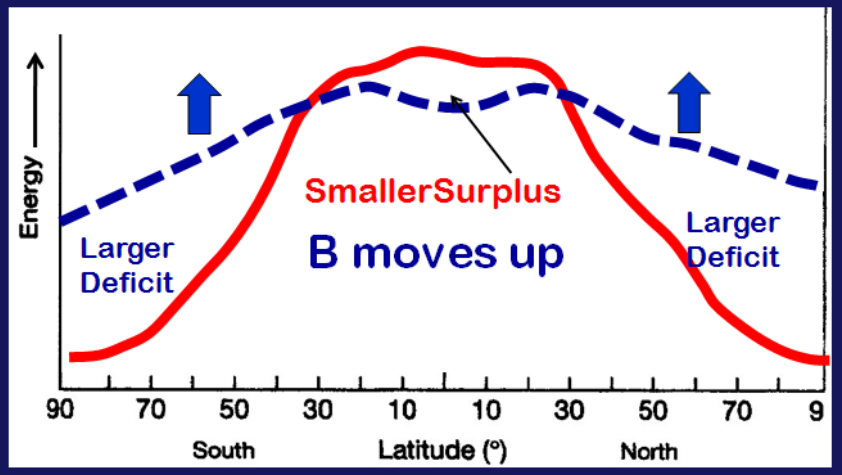
*Assume:*

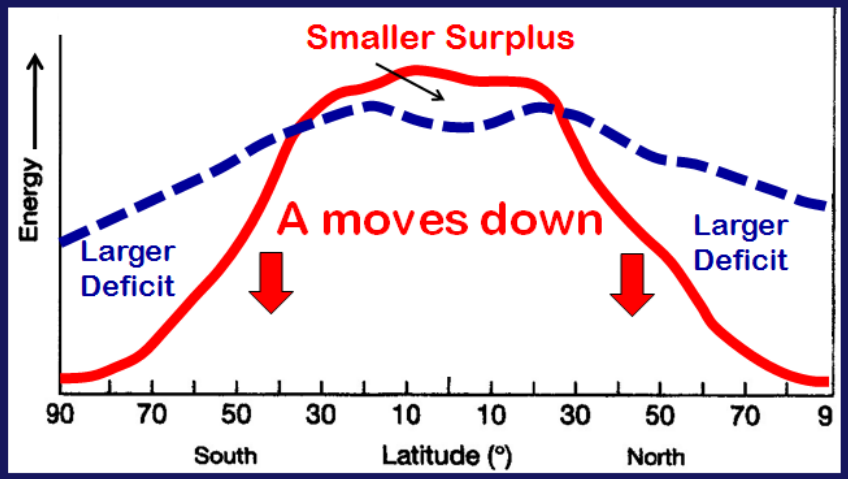
- long-lived aerosol veil in stratosphere over both hemispheres
- aerosols reflect incoming solar radiation back to space *before* solar SW enters the troposphere
- you do not need to worry about stratospheric warming for this question.

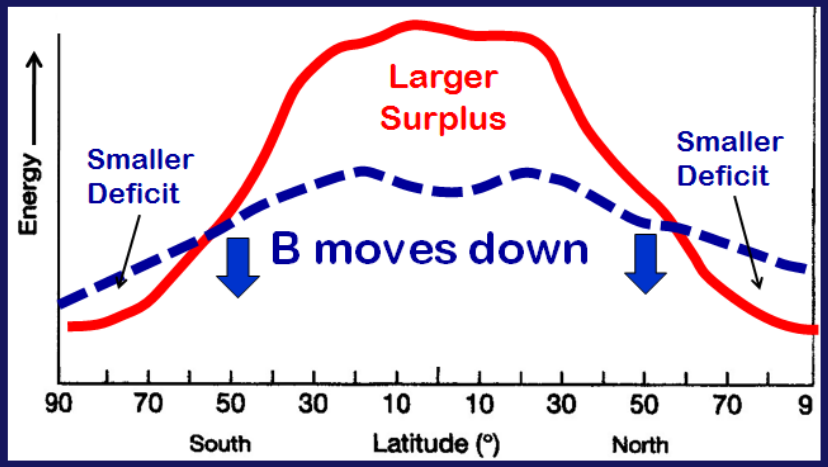
**IF CURVE A is affected:**


**If CURVE B is affected:**


**Four scenarios are possible for how you should sketch the new graph**

# IMPORTANT REMINDERS:

- NO CLASS next Tuesday Nov 11 (Veteran's Day) but don't forget that RQ-7 is DUE before Midnight that night!

- The G-4 Tree-Ring Wood Kit Activity must be completed by Wed Nov 12th Remaining sessions:

| | | |
|---|---|---|
| FRI | Nov 7 | 11:00 – 12 Noon |
| FRI | Nov 7 | 1:00 – 2:00 pm |
| FRI | Nov 7 | 3:00 – 4:00 pm |

| | | |
|---|---|---|
| MON | Nov 10 | 2:00 – 3:00 pm |
| MON | Nov 10 | 3:00 – 4:00 pm |
| WED | Nov 12 | 2:00 – 3:00 pm |
| WED | Nov 12 | 3:00 – 4:00 pm |
| WED | Nov 12 | 4:00 – 5:00 pm |

- I-3 LESSON 3 on "Observable Changes" is due in the dropbox before midnight on Thur Nov 13

- Midterm Exam "Point Recovery" is due in class TODAY

# HAPPY HOMECOMING!!

# GO CATS!