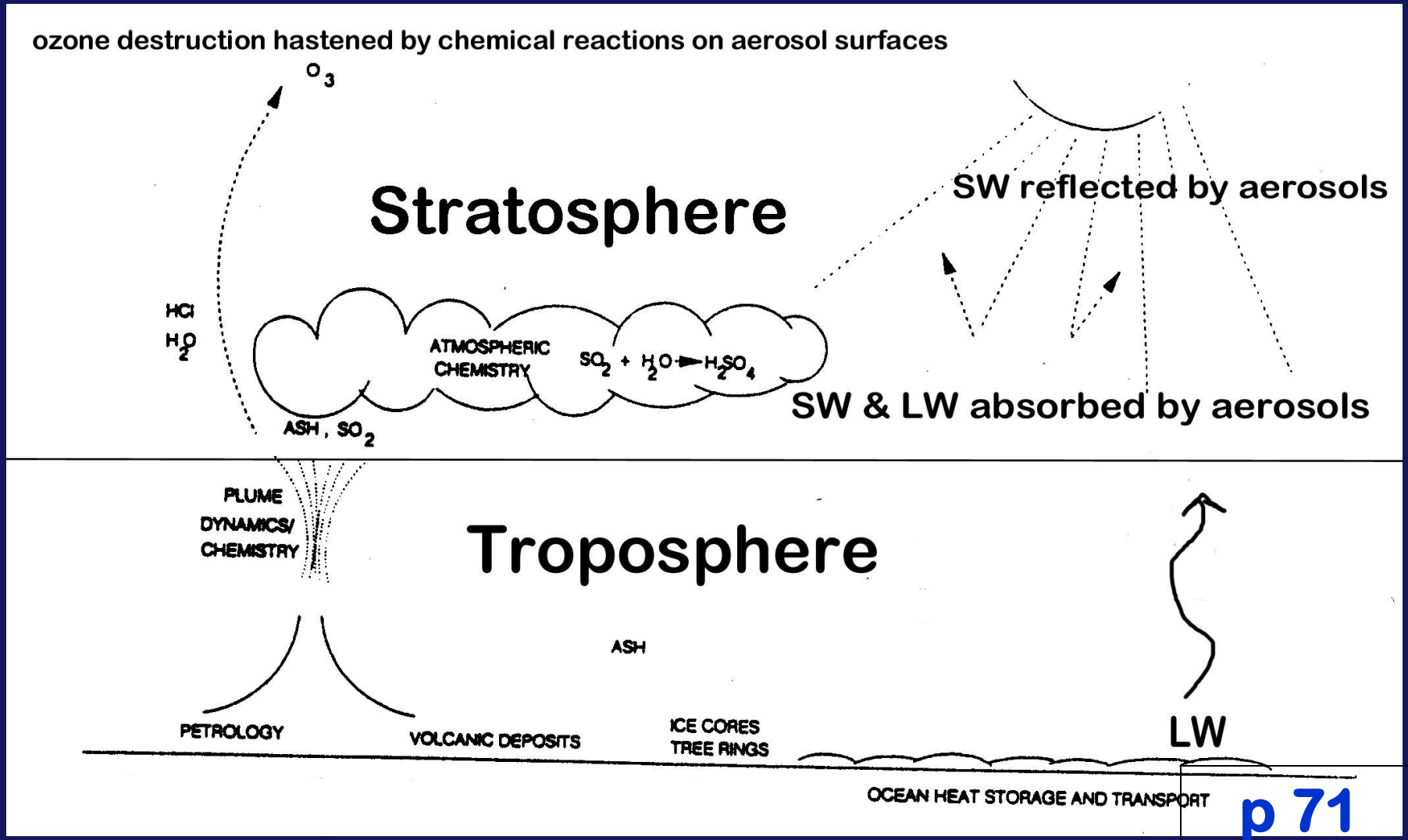
Wrap up of TOPIC # 13 NATURAL CLIMATIC FORCING:

Volcanic Eruptions

(pp 71-74)

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



Mt Merapi

Latitude: 7°32'30"S

Villages escape as Mount Merapi erupts near Deles village, Klaten, Indonesia, 01 November 2010. Indonesia's Mount Merapi volcano erupted again on the morning of 01 November, sending a plume of ash and smoke about 3,500 metres into the air. EPA/ADI WEDA

"Indonesia's Mount Merapi erupted with renewed strength on Wednesday, the fourth eruption in eight days, forcing authorities to move refugee shelters further away from the volcano, a vulcanology official said.

The volcano, near Yogyakarta on Java island, spewed **clouds of ash and gas 5 km (3 miles)** into the sky for more than an hour on Wednesday, its biggest eruption so far in the past 10 days.

How CLIMATICALLY EFFECTIVE will this eruption be??

Q2 - Will it get into the stratosphere?

1 – YES
2 - NO, Probably not

Hint: See p 39

WHICH ERUPTIONS ARE THE MOST CLIMATICALLY EFFECTIVE?

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

Q3 Why do you think Low Latitude eruptions are more climatically effective and have more of a effect?

1. Because the temperature is warmer in tropical latitudes and hot air rises.

2. Because the Hadley Cell circulation can distribute the volcanic aerosols into both hemispheres if the eruption occurs near the equator.

3. Because the tropopause is lower over Low Latitudes and hence its easier for aerosols to get injected into the stratosphere where they will not be rained out.

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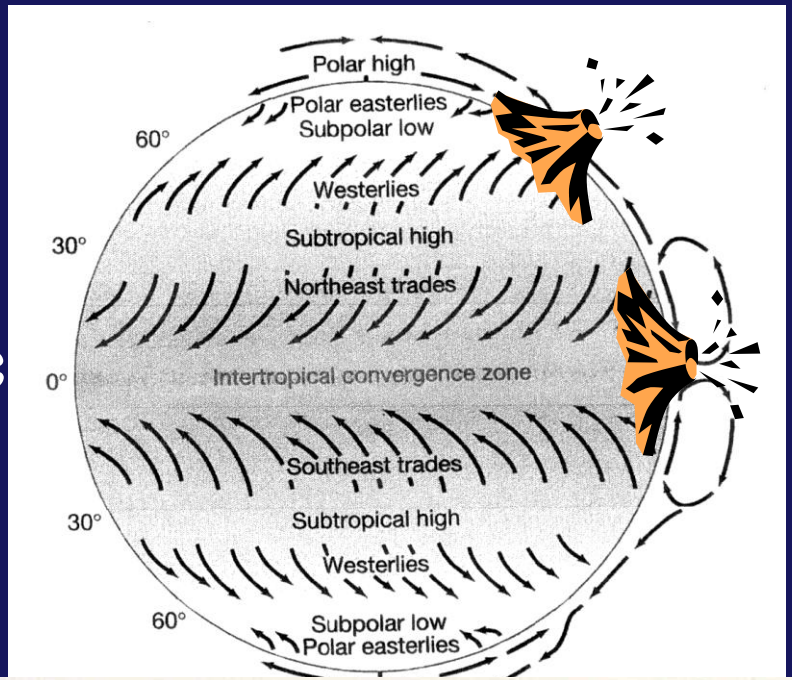
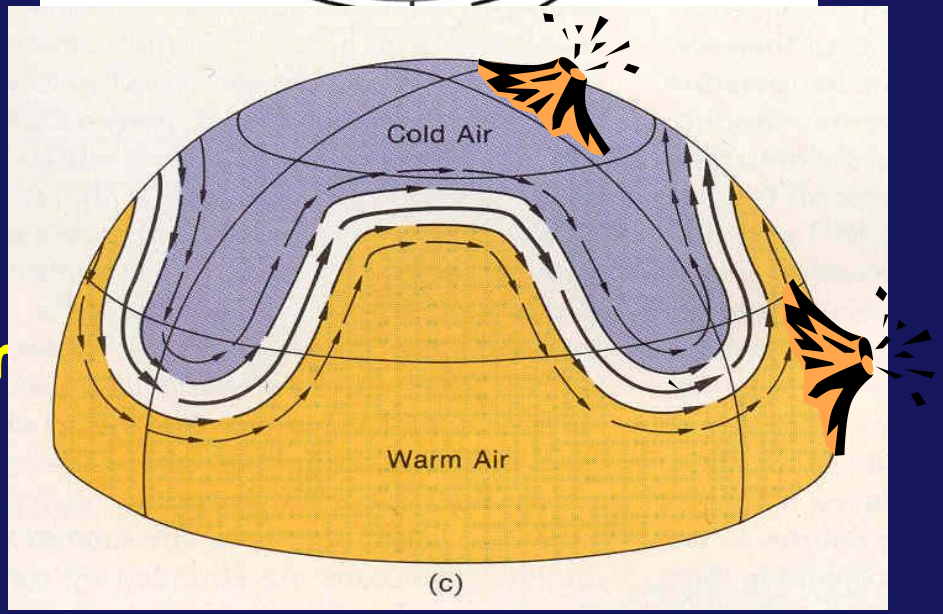
- The GEOGRAPHIC LOCATION of the erupting volcano influences the climatic effectiveness of an eruption because of the General Circulation of the Atmosphere.

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





HOW DO REGIONAL CLIMATES RESPOND TO AN EXPLOSIVE ERUPTION?

In general, explosive eruptions warm the stratosphere and cool the troposphere, especially during the summer season.

Major tropical eruption:

- Stratospheric heating is larger in the tropics → enhanced pole-to-equator temperature gradient, esp. in winter.

N.H. winter → enhanced gradient produces a stronger polar vortex → stationary wave pattern of tropospheric circulation resulting in winter warming of NH continents.

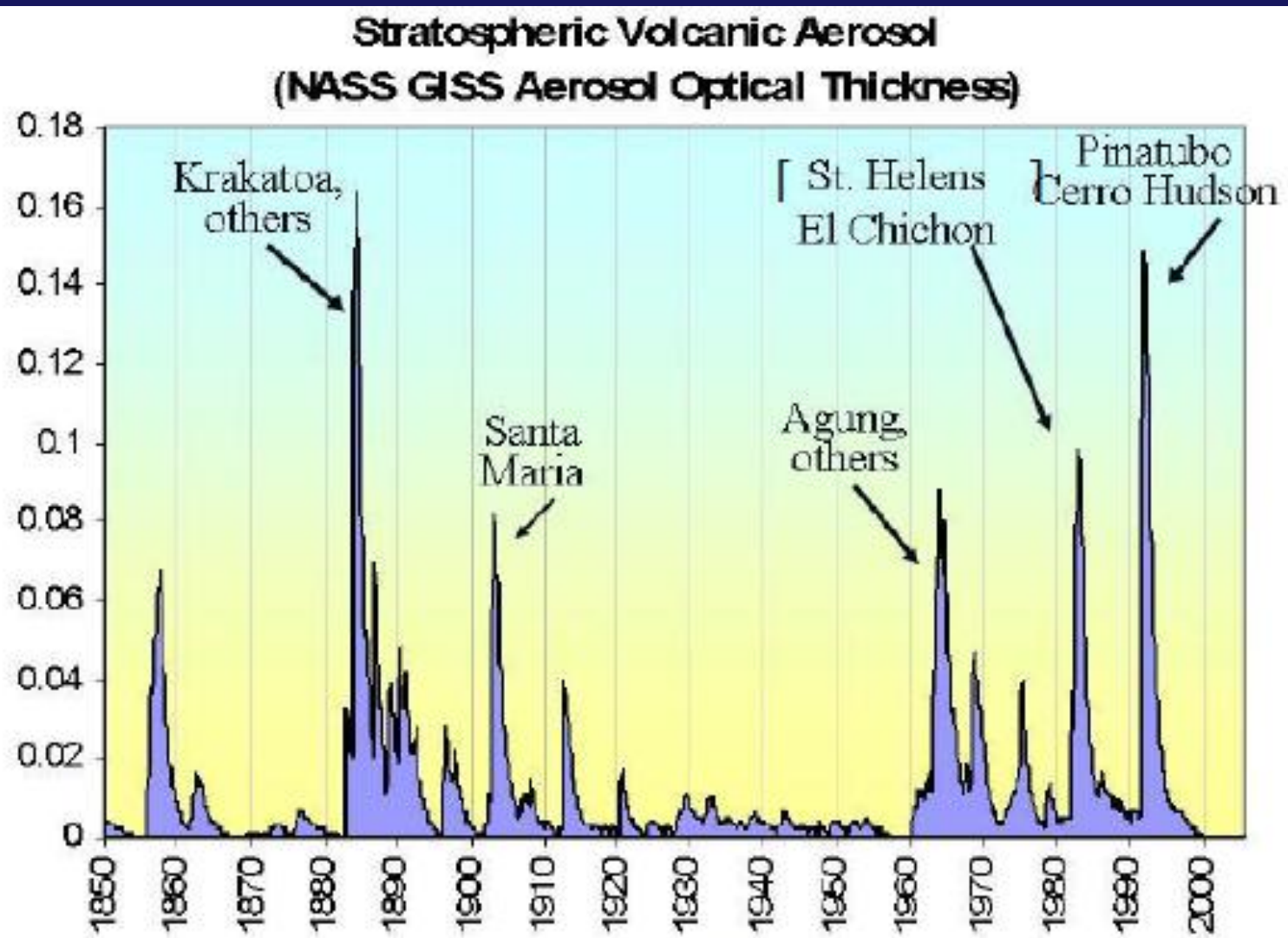
HOW MUCH TROPOSPHERIC COOLING CAN OCCUR AND HOW LONG DOES IT LAST?

- Individual large eruptions can result in a 1-to-3 year cooling of average surface temperatures of 0.3 to 0.7° C.

Tambora in 1815
Krakatau in 1883
Agung in 1963
El Chichon in 1982

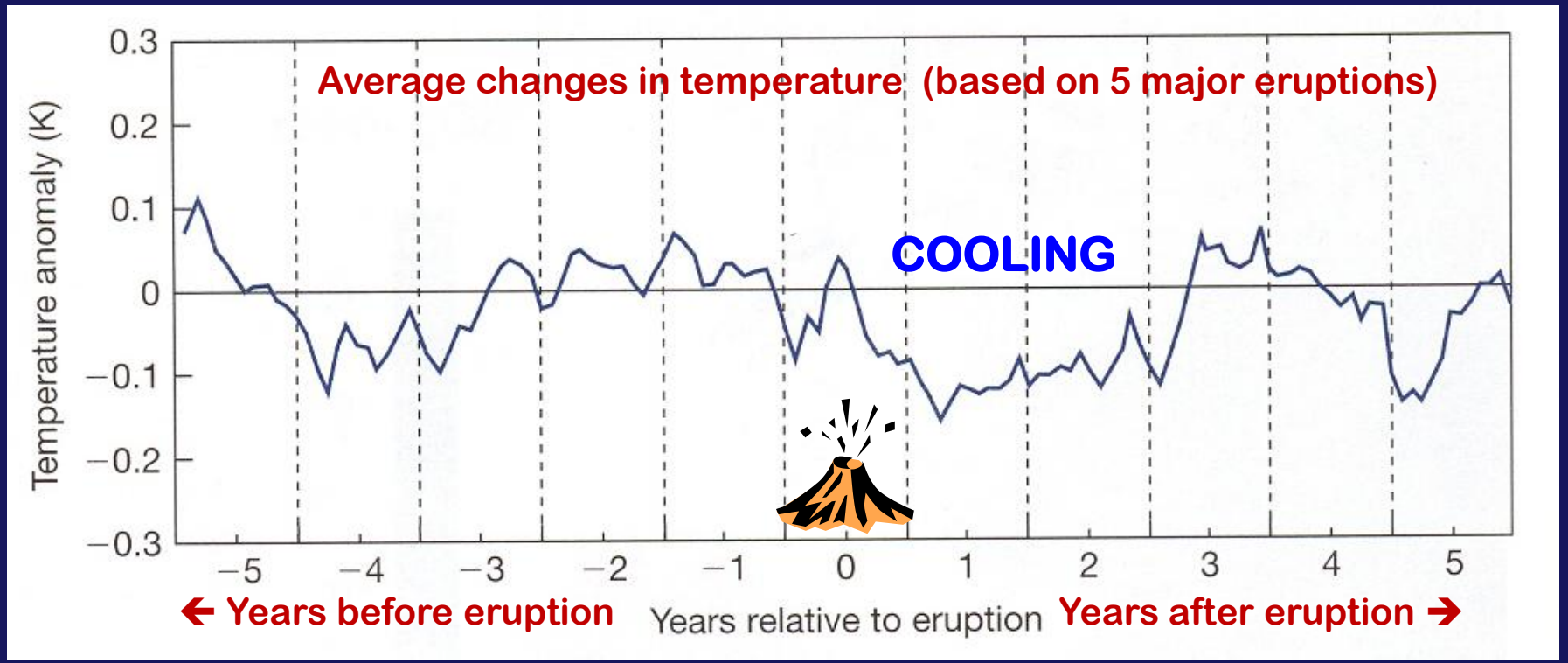
HOW IMPORTANT IS EXPLOSIVE VOLCANISM AS A FORCING MECHANISM FOR PAST AND FUTURE CLIMATE CHANGES?

- interdecadal climate change ("Little Ice Age")
- Individual years, such as 1816, the "Year without a Summer" after the eruption of Tambora in 1815
- Link not always conclusive – e.g., El Nino at same time, etc.



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

Typical Global Cooling Pattern after a Volcanic Eruption



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

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)*	

G-4 ACTIVITY ON VOLCANISM & CLIMATE

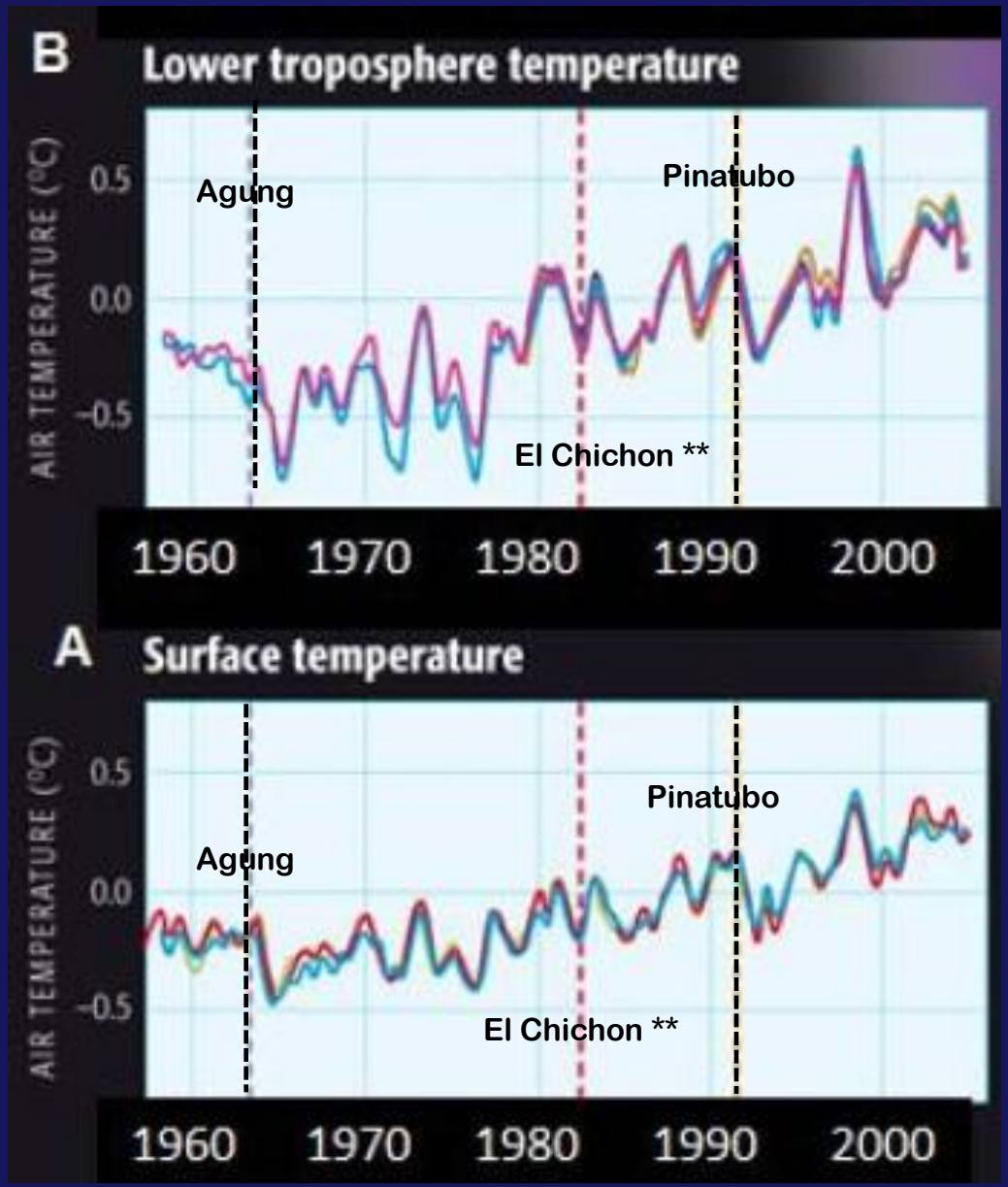
P.S. This is one of my favorite questions to ask on the FINAL EXAM!!!!

#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:

Write in the ERUPTIONS at top of page

Agung (1963) Pinatubo (1991)



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

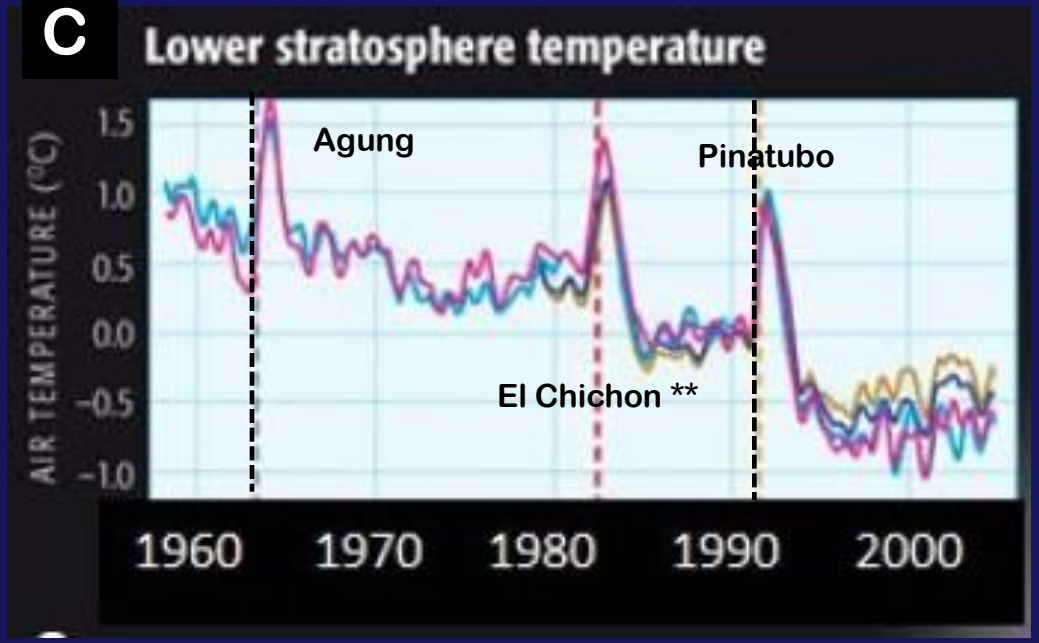
** NOTE: At the time of the El Chichon eruption, there was warming taking place due to a strong El Nino, hence the temperature change after this eruption shows a different response.

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

Write in the ERUPTIONS at top of page

Agung (1963) Pinatubo (1991)

C

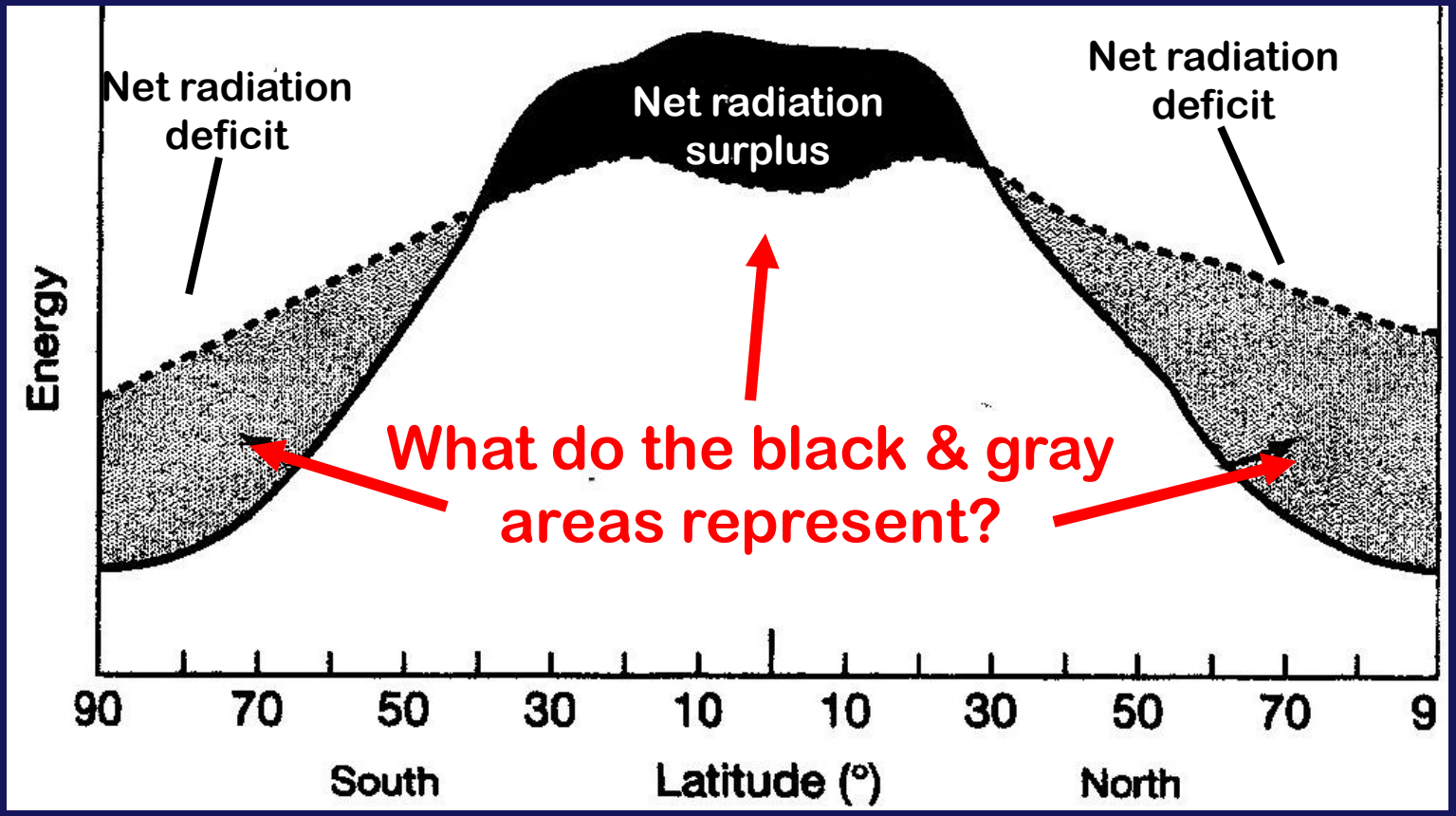


#4. Explain WHY each level's TEMPERATURE responded as it did to the Agung & Pinatubo eruptions?

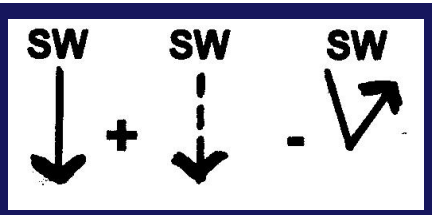
(by referring to the Radiation Balance)

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

REMEMBER THIS IMPORTANT GRAPH?



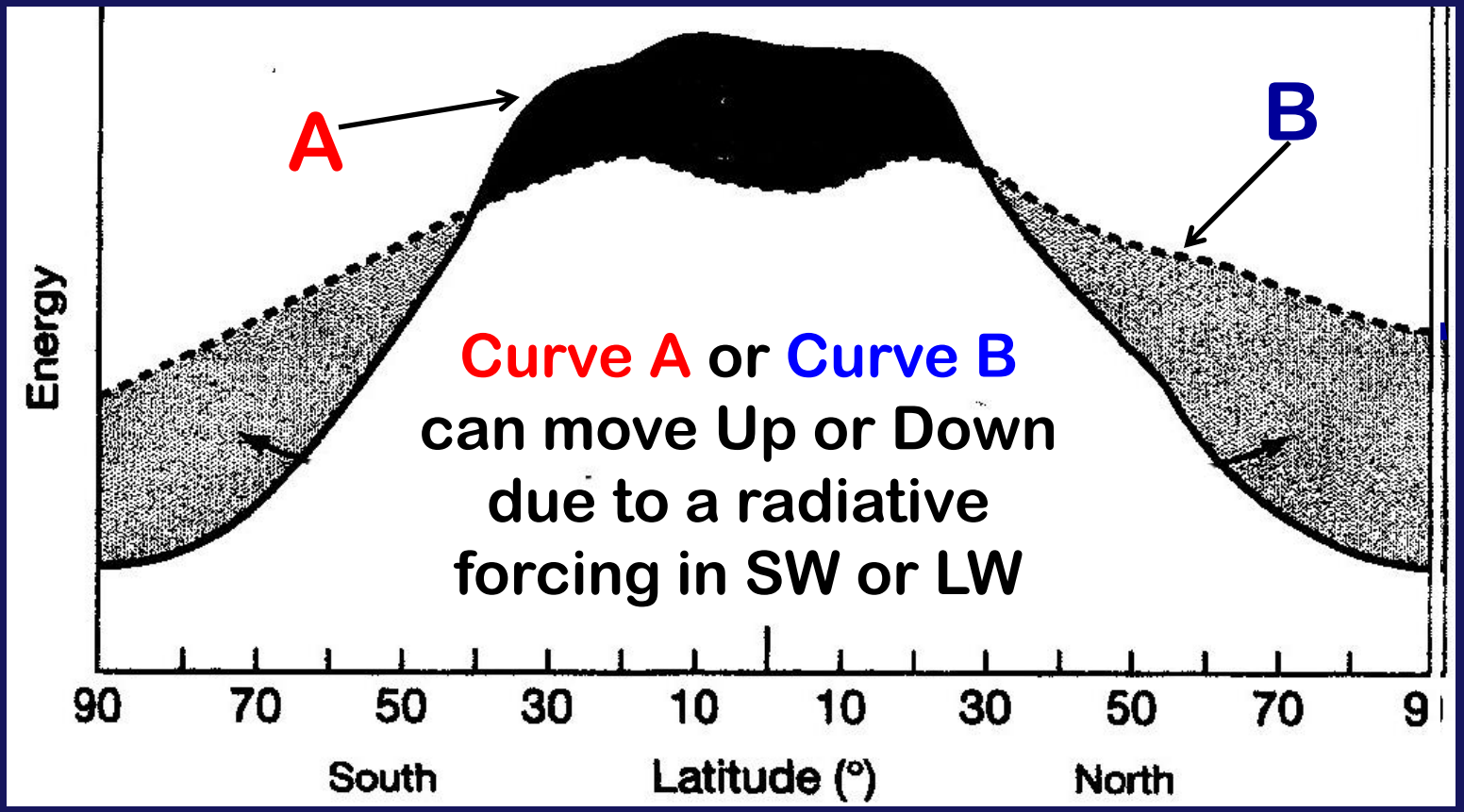
Absorbed solar energy



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

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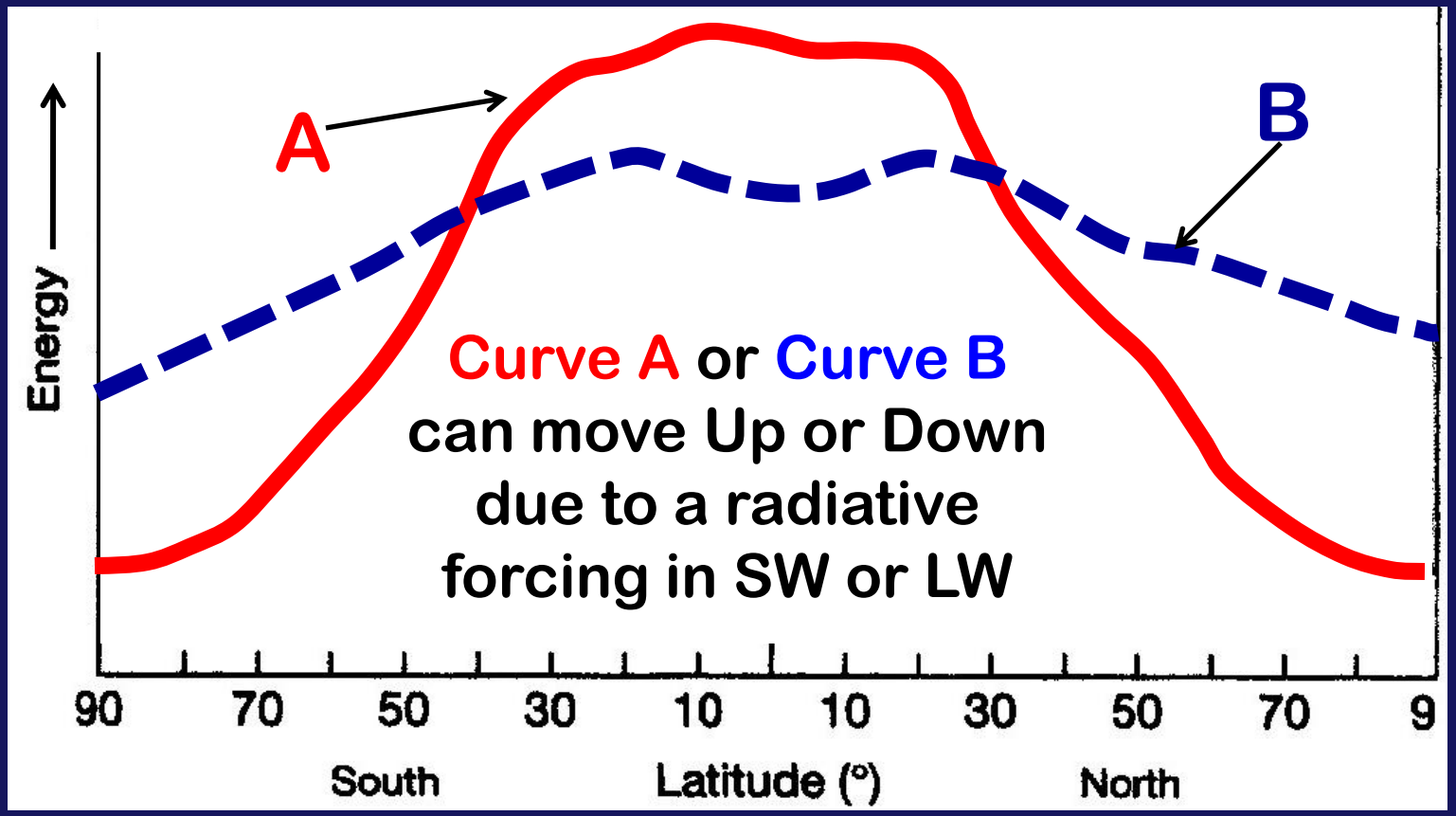
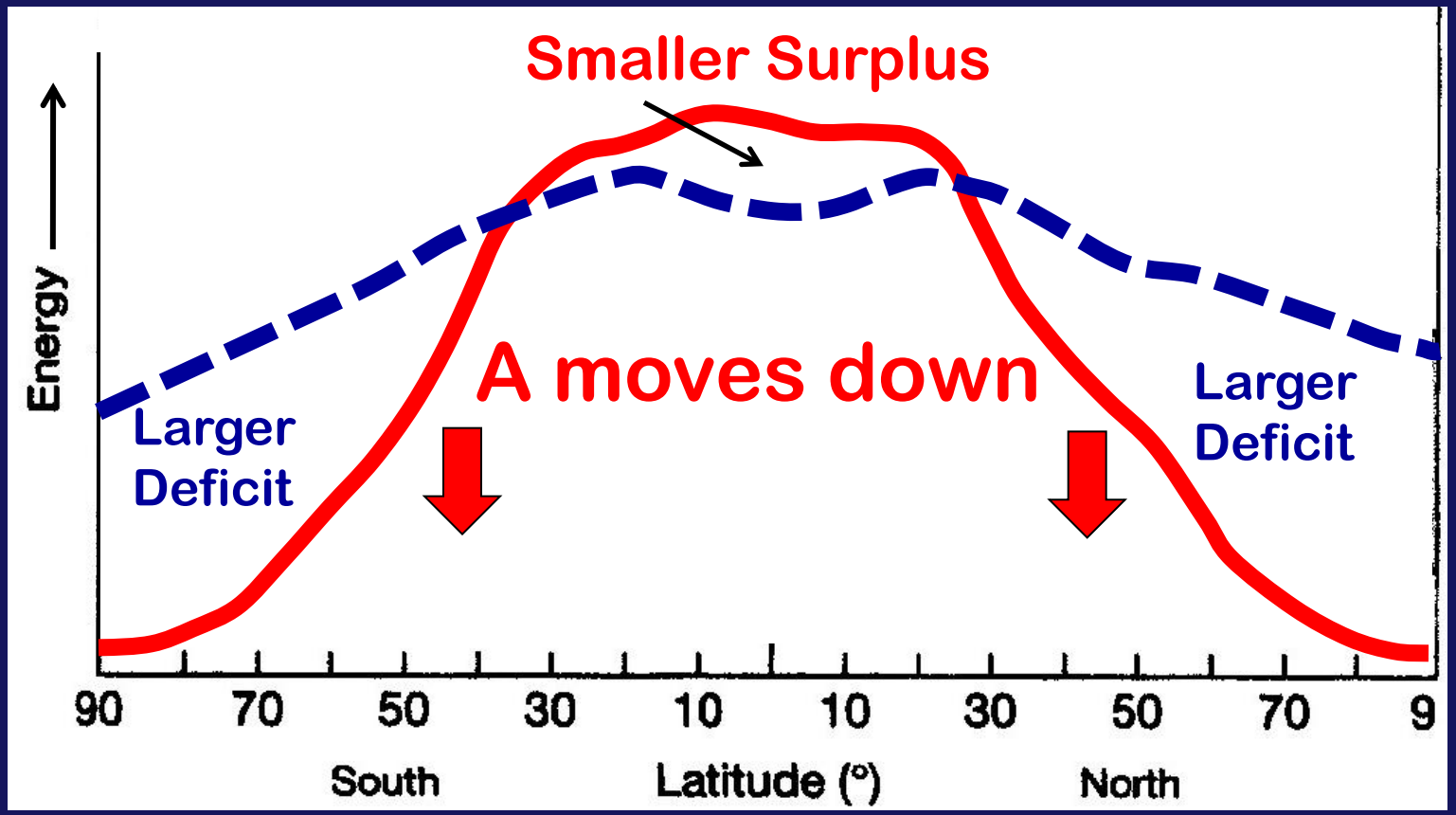


CURVE A SW + SW - SW

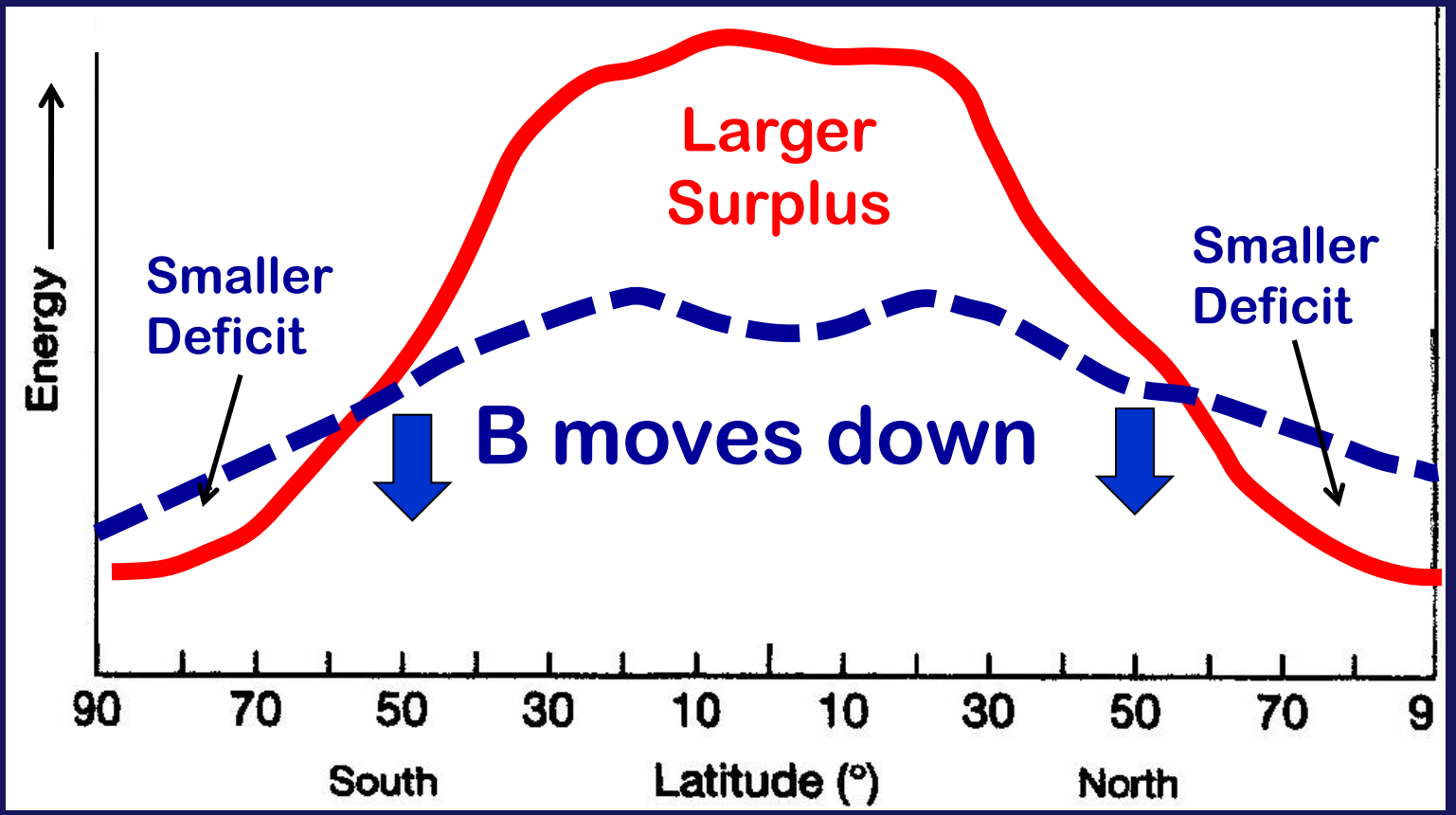
CURVE B LW LW

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



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

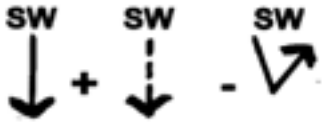
If CURVE B moves down

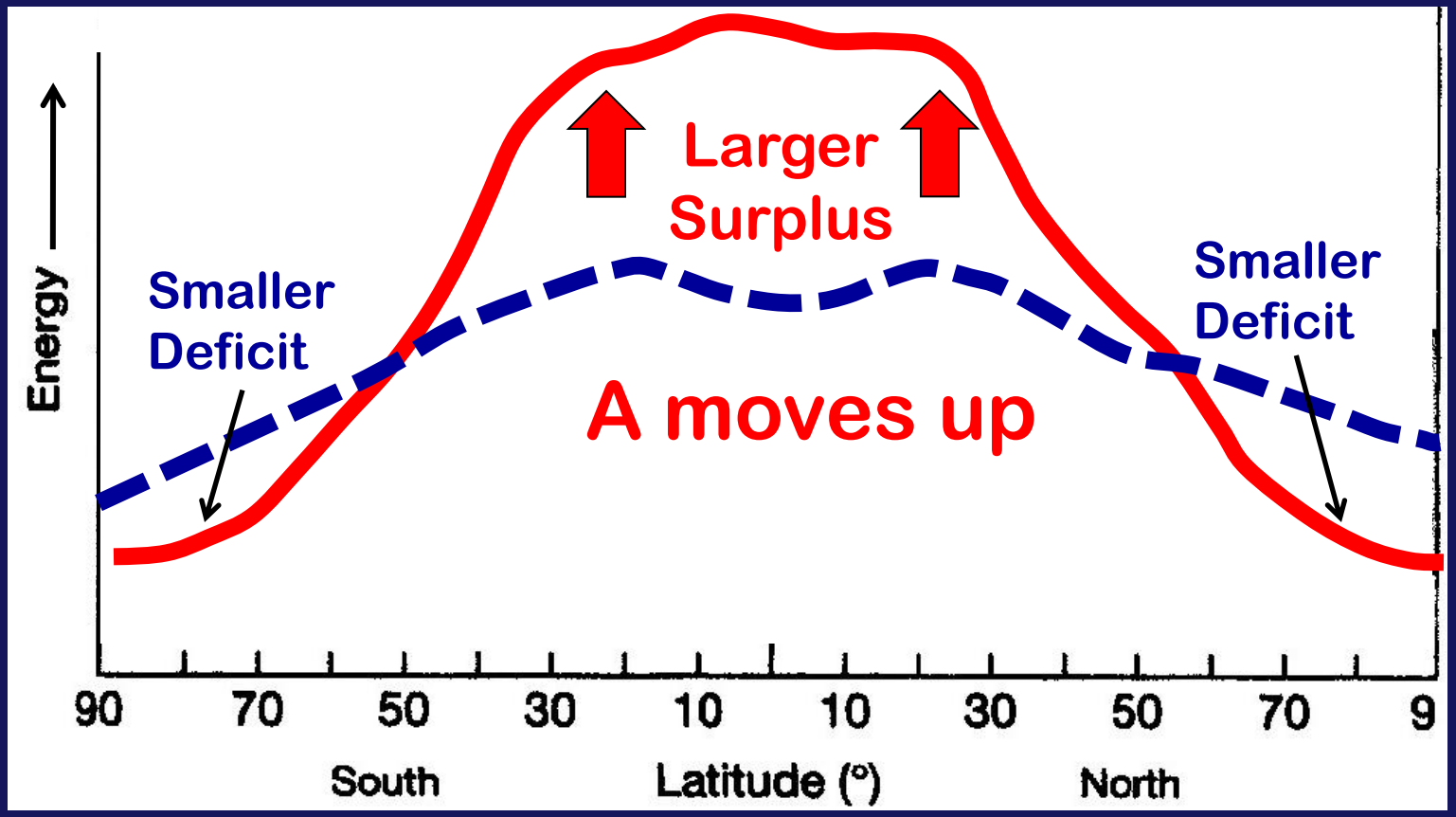


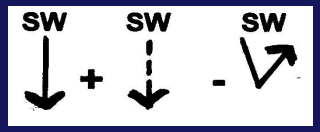
LW

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

IF CURVE A moves up:

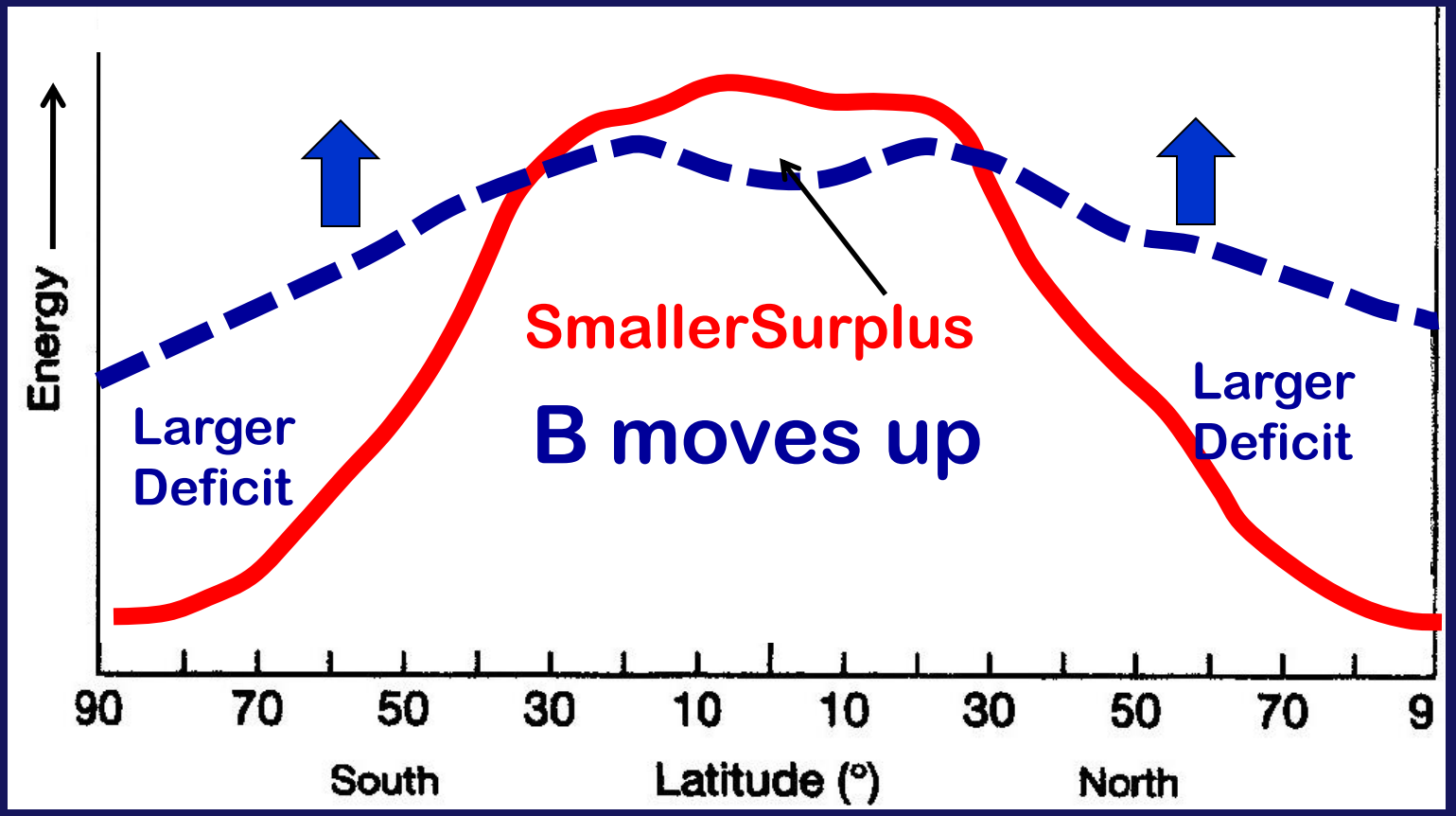






If incoming energy represented by Curve A is increased (A curve goes up)

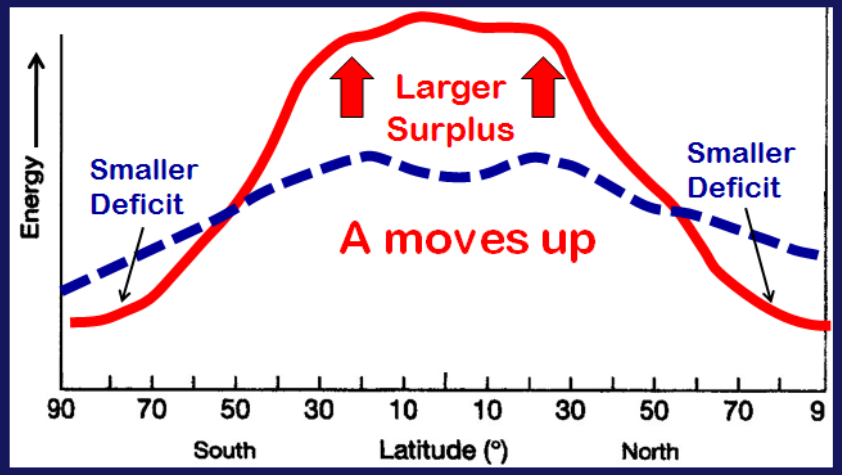
If CURVE B moves up:

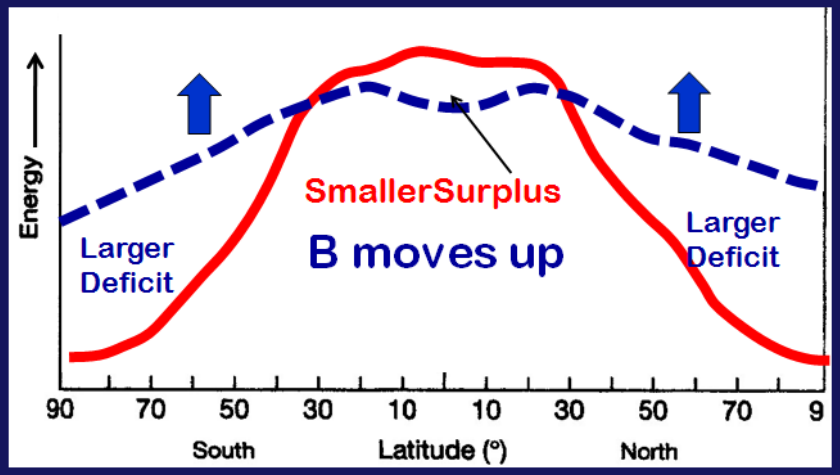


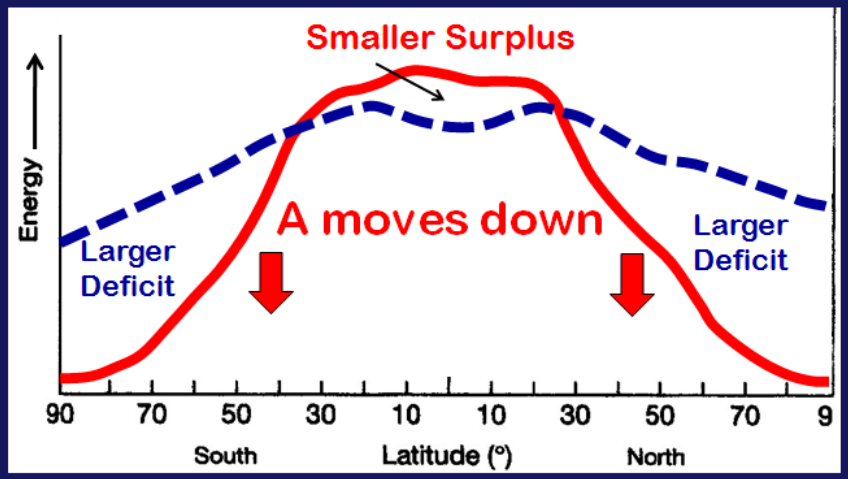
If outgoing energy represented by Curve B is increased (B curve goes up)

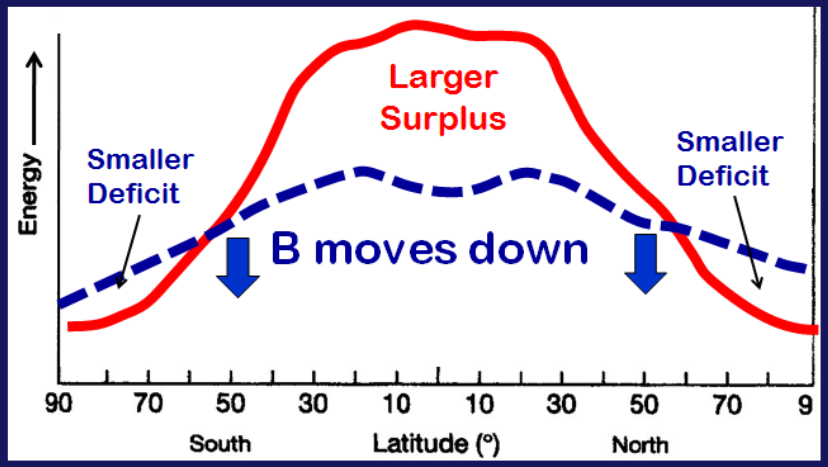
IF CURVE A is affected:

If CURVE B is affected:









Four scenario's are possible for how you should sketch the new graph

Assume:

- that the eruption produces a long-lived aerosol veil in the stratosphere over both hemispheres

- that this veil reflects large amounts of incoming solar radiation back to space *before* it enters the troposphere's earth-atmosphere system shown in the graph.

- *Hint: you do not need to worry about stratospheric warming for this question.*