G-5 ACTIVITY ON VOLCANISM & CLIMATE

THE ANSWERS!

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

#1 Low latitude eruption → both hemispheres

#2 Large amount of eruptive material (50 sq km!)

#3 Aerosol cloud was HUGE and went into both hemispheres equally

#4 Sulfuric acid (H_2SO_4) content was very large

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

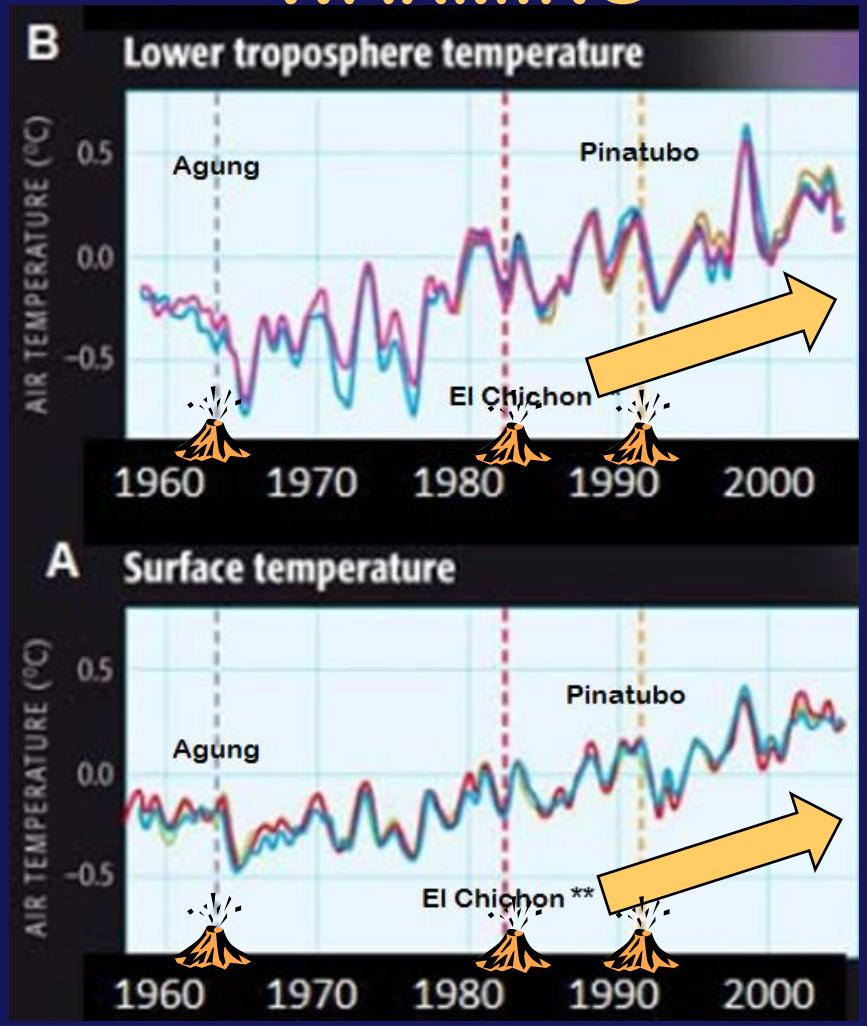
#1 High latitude – could only affect part of Northern Hemisphere

#2 Low sulfur content

(also, low volume, didn't get to S. Hemisphere, etc.)

Over Last 4 decades:

TROPOSPHERIC WARMING

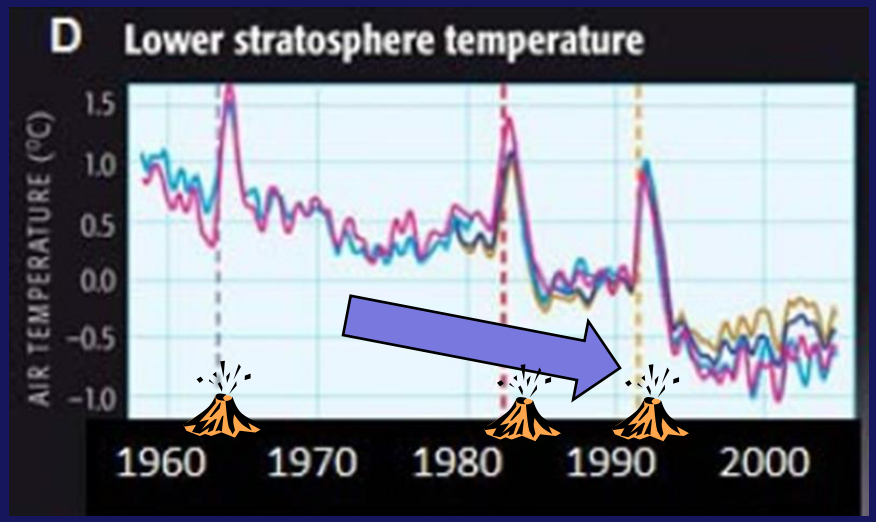


After eruptions:

TROPOSPHERIC COOLING (unless an El Niño year)

Over Last 4 decades:

STRATOSPHERIC COOLING



After eruptions:

STRATOSPHERIC WARMING

Long-term TREND is due to ANTHROPOGENIC FORCING

3 HOW did the temperature at the 3 levels respond to the Agung and Pinatubo eruptions?

#4 EXPLAIN WHY – referring to Radiation Balance?

Level A (Surface) – **Cooled**

Why? 

by sulfate aerosols in stratosphere and therefore less SW got into troposphere to be absorbed by Earth's surface

Level B (Lower Troposphere) – **Cooled**

Why? 

by stratospheric aerosols => less SW absorbed at surface and in troposphere,
ALSO: less 

radiated up into troposphere from the cooler Earth's surface

Level C (Lower Stratosphere) – **Warmed** immediately after both eruptions

Why? Sulfate aerosols in the stratosphere **absorbed** some wavelengths of incoming SW 

and heated up, they also absorbed some of the Earth's outgoing LW 

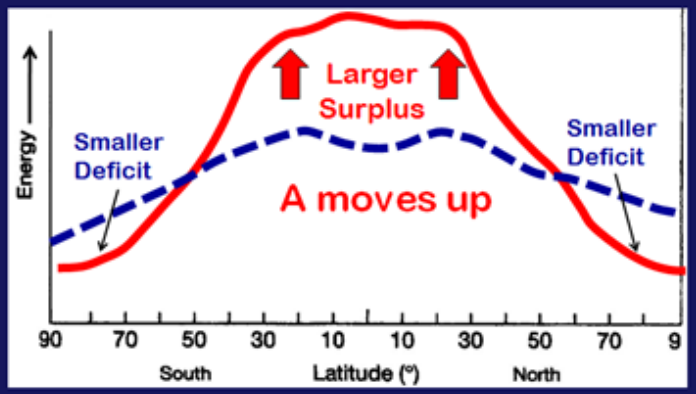
as it radiated up out of the troposphere

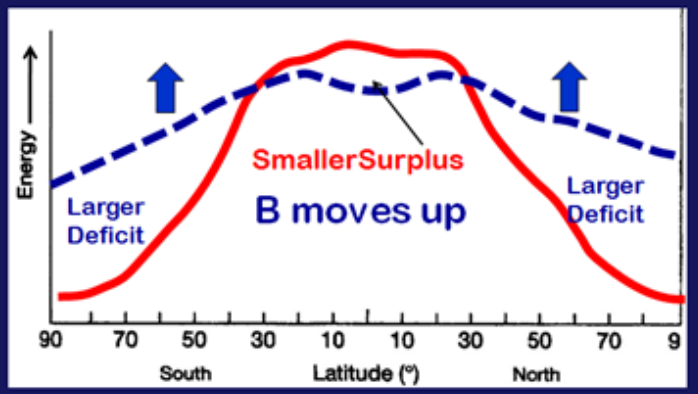
TO SUMMARIZE: 2 KEY POINTS

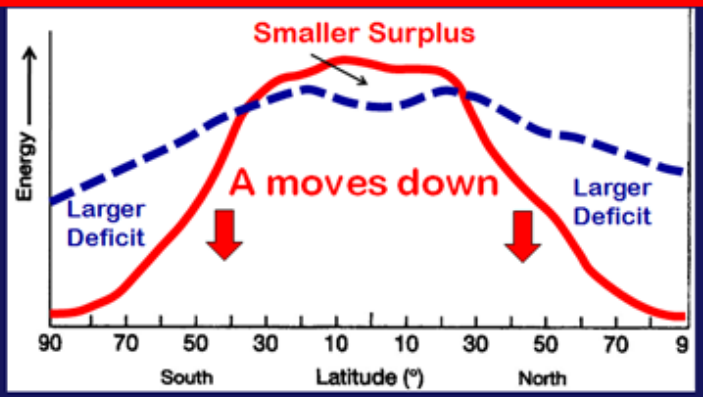
- Major eruptions with a long-lived sulfate aerosol veil REFLECT incoming solar radiation back to space BEFORE it enters the mid- & lower troposphere or gets to the Earth's surface, hence the troposphere & surface get COOLER after an eruption.

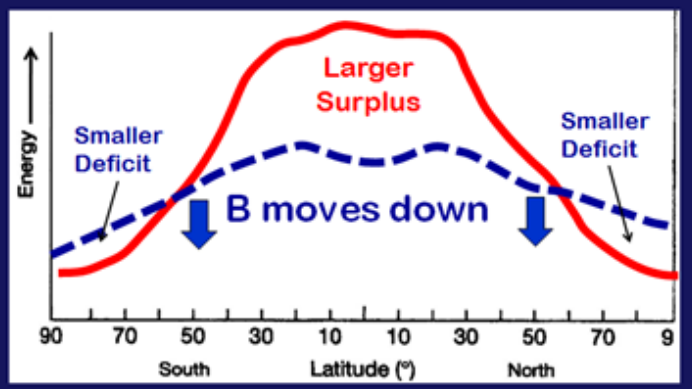
- The aerosols in the stratosphere can also ABSORB some wavelengths of incoming SW and outgoing LW, so that the stratosphere WARMS slightly after an eruption.

Show how the energy balance would change if a major volcanic eruption occurred:





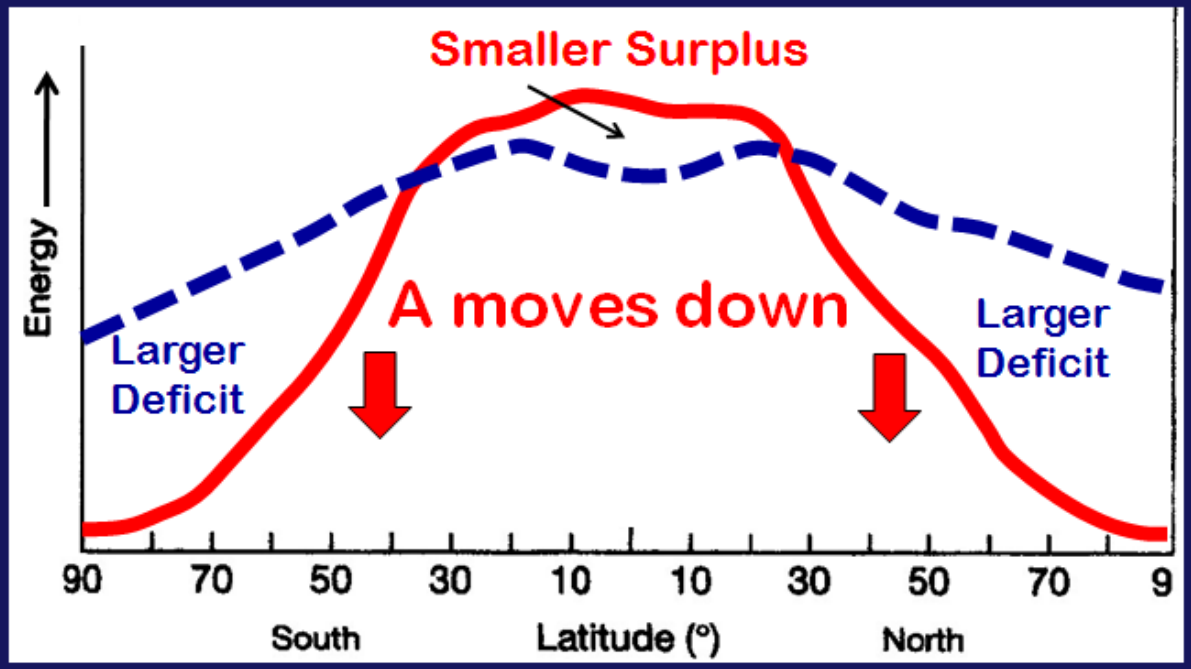




WHICH ONE IS RIGHT ?

Does the change affect CURVE A or CURVE B?

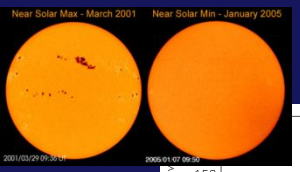
A moves down, and B stays the same . . . .

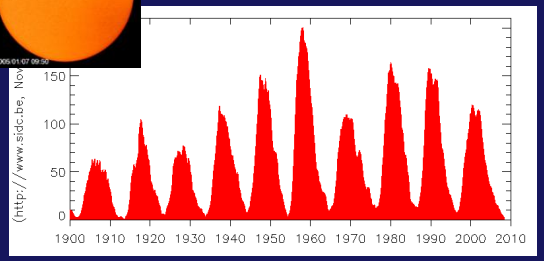


. . . but eventually B will also move down a bit due to cooler Earth temps and less outgoing LW

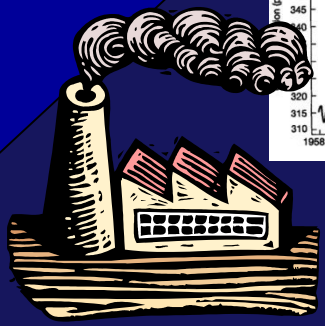
Now, continuing with ANTHROPOGENIC FORCINGS

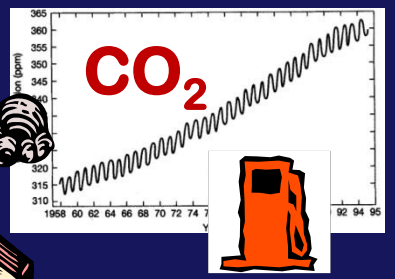
NATURAL FORCING



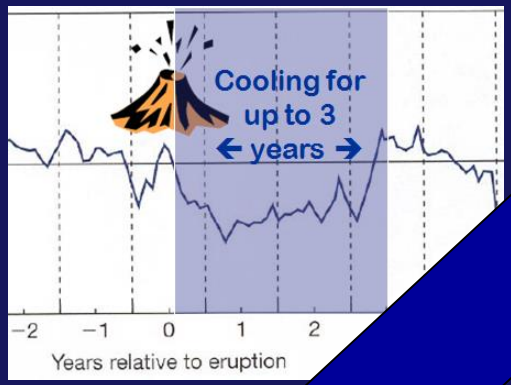


Solar output variations, sunspots



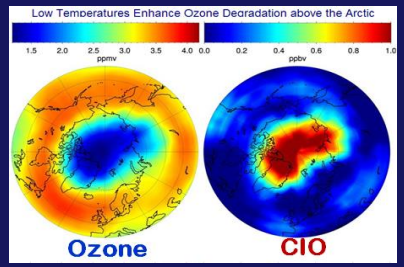


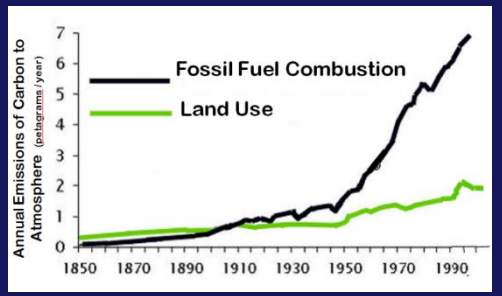
TOPIC 13
ENHANCED GHE → GLOBAL WARMING



Volcanic eruptions

TOPIC 12
Ozone Depletion





ANTHROPOGENIC FORCING

Tropospheric "dimming"

soot, SO_2

Other GREENHOUSE GASES

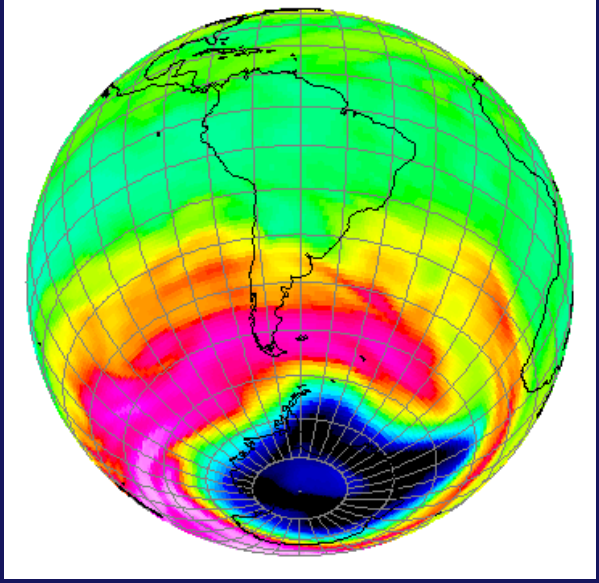
Albedo Changes

Topic # 12 Wrap Up

OZONE DEPLETION IN THE STRATOSPHERE

"A Story of Anthropogenic Disruption of a Natural Steady State"

THE DESTRUCTION OF STRATOSPHERIC OZONE

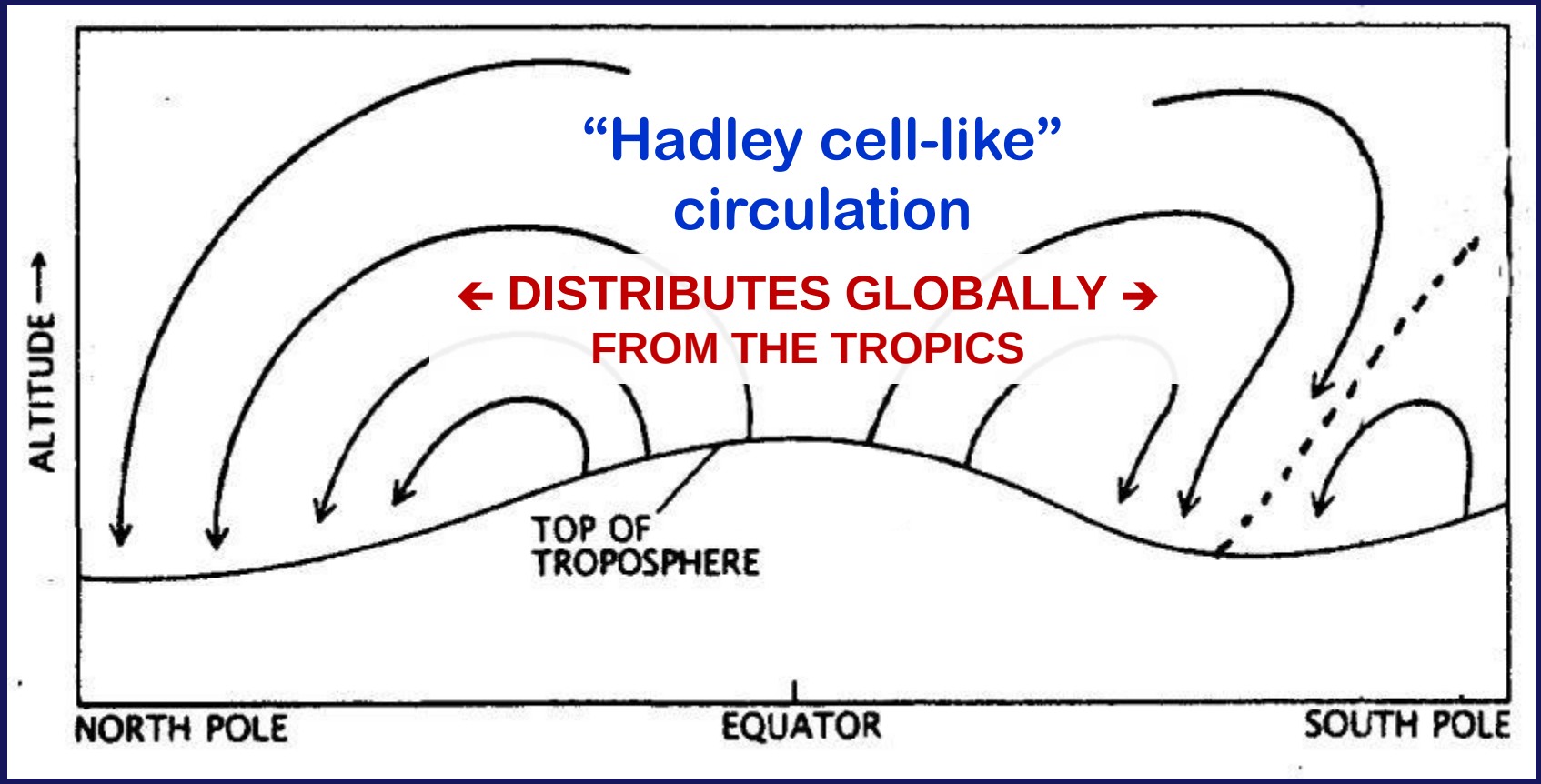


GROUP POP QUIZ!!

on Monday's topics:

El Nino
Chapman Mechanism
Ozone Depletion & "The Hole"

Stratospheric Atmospheric Circulation Determines this Distribution



Ozone production is *highest in tropics*
but stratospheric circulation distributes it poleward

GROUP CHALLENGE QUESTION:

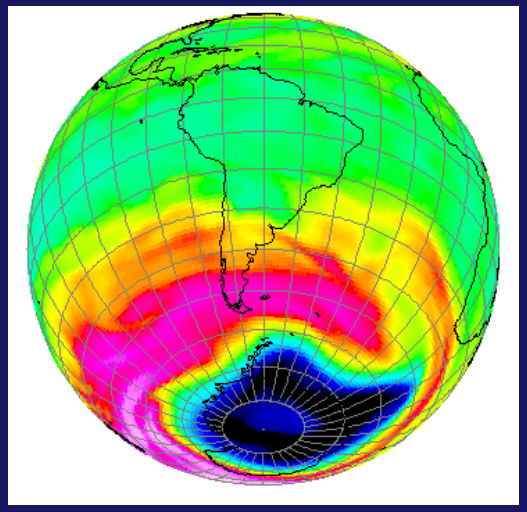
Q: Why do you think ozone production in the stratosphere is highest over the TROPICS?

Hint: Chapman Mechanism

Topic # 12 Wrap Up . . .

The STORY OF THE DISCOVERY OF THE OZONE HOLE:

"A Misadventure of Science?"



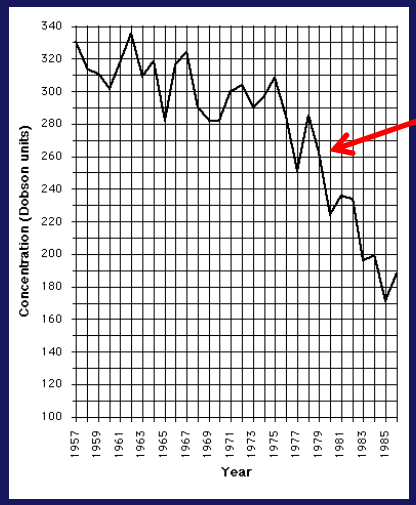
DISCOVERY OF THE OZONE HOLE:

"A Misadventure of Science?"

CHAPTER 1

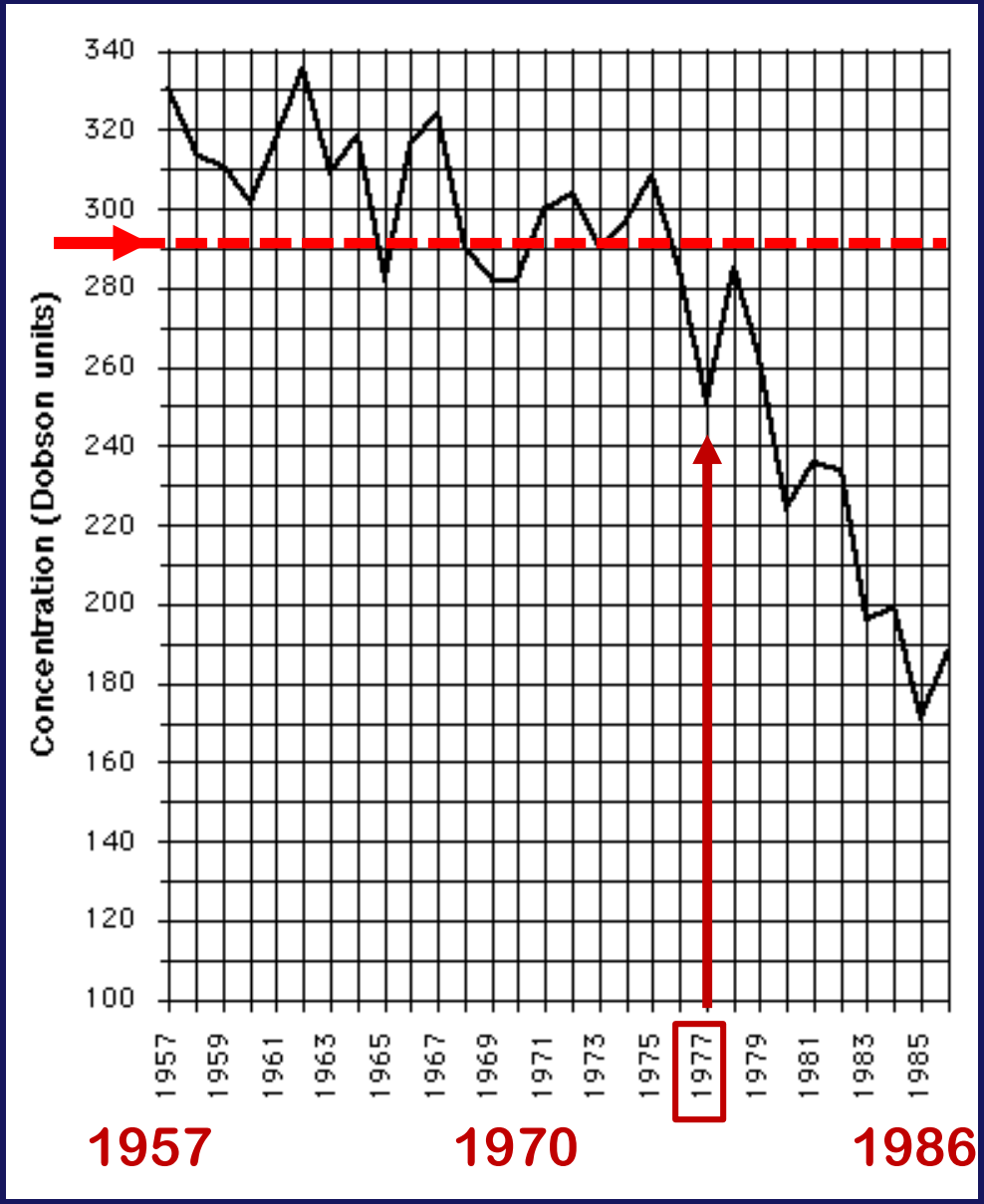
- **Ground-based** ozone measurements since **1956**. (British survey team)

- They observed a new trend of decreasing ozone concentrations **beginning in 1977**



- Didn't believe their measurements & delayed publication for several years while rechecking data & instruments.

Finally published in **1985**; greeted with skepticism!



Declining OZONE CONCENTRATIONS

(in Dobson units)

(over Antarctica)

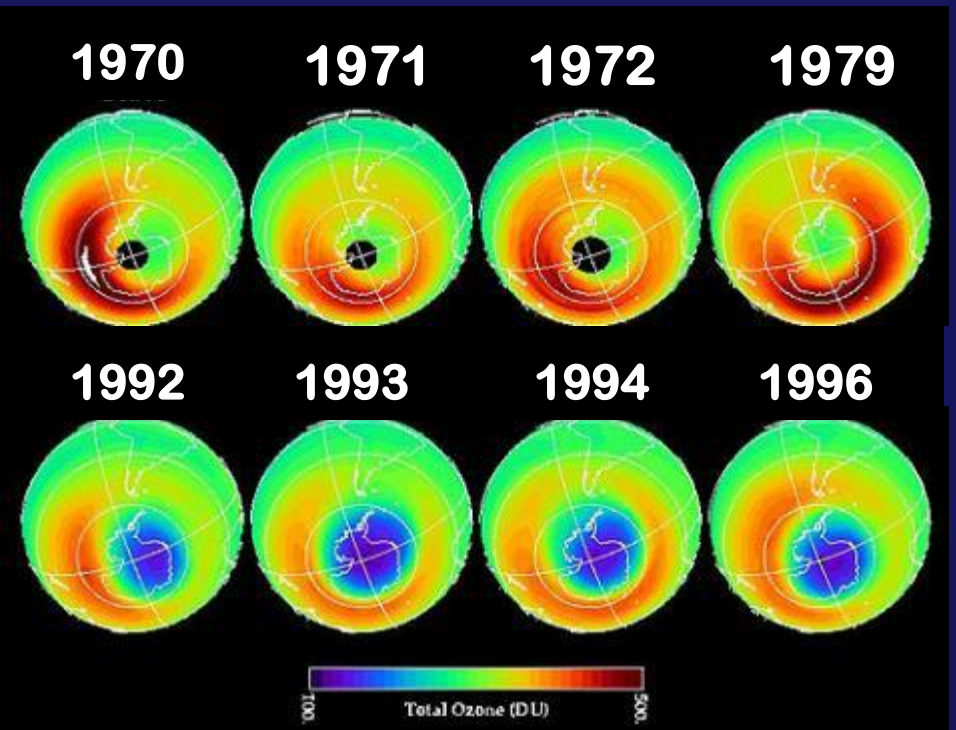
1957-1986

Early data from ground measurements of British survey team

DISCOVERY OF THE OZONE HOLE (cont.)

CHAPTER 2

- Meanwhile, satellites had been launched to observe ozone from above via the **TOMS** instrument on the satellite

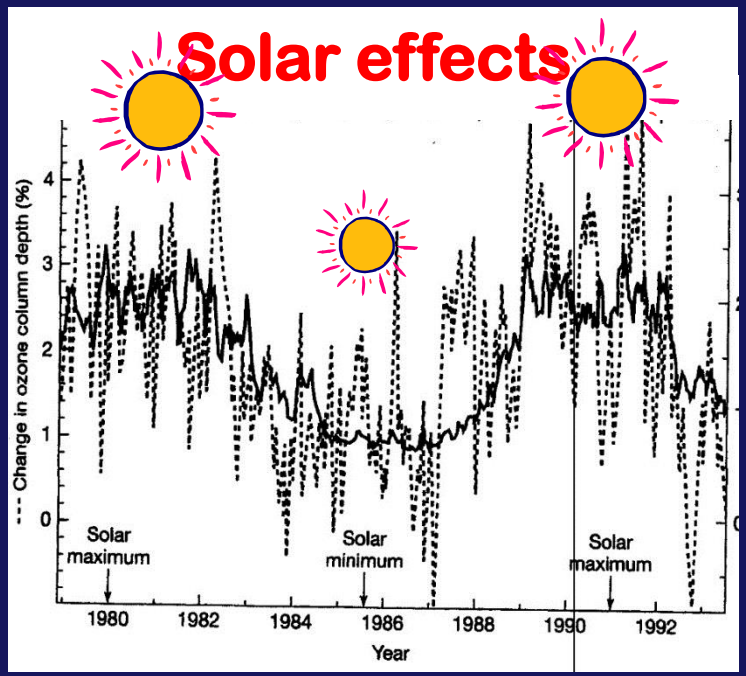


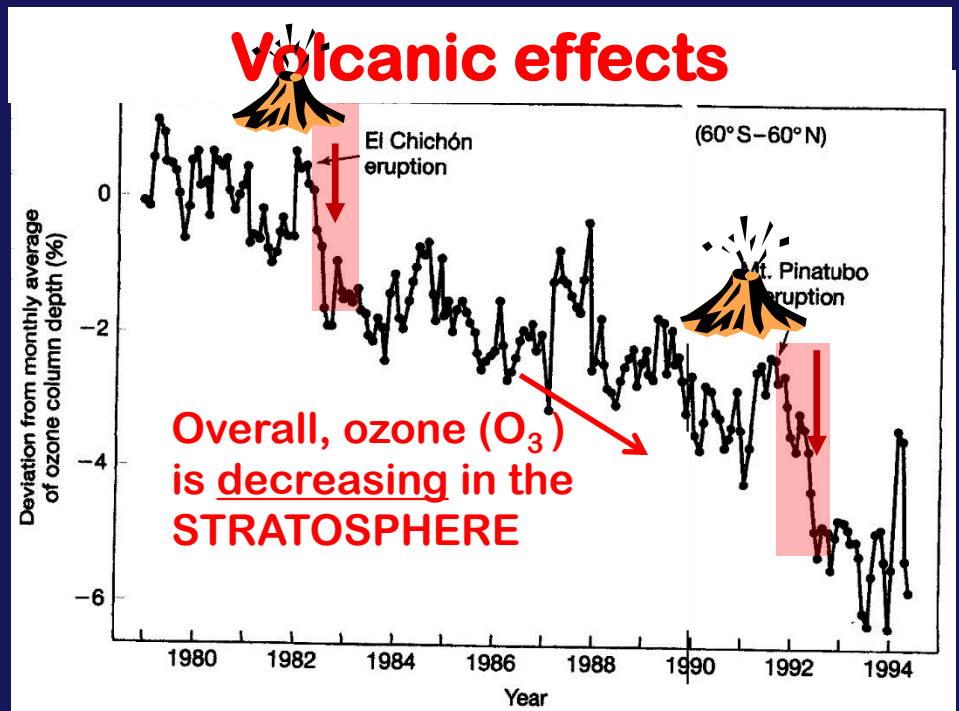
Total Ozone in October (DU)

- TOMS detected the developing hole, but the anomalously low readings were rejected as "noise" by the computer program set up to process the data !!

As realization of the hole grew, various HYPOTHESES & THEORIES were put forward to explain the hole:

- **solar variability** (sunspot cycle ➔ Chapman variations)
- **volcanic eruptions** (chemical reactions destroy O_3)





The CHEMICAL THEORY of ozone destruction by CFC's was first proposed in 1974

– but no observations existed!

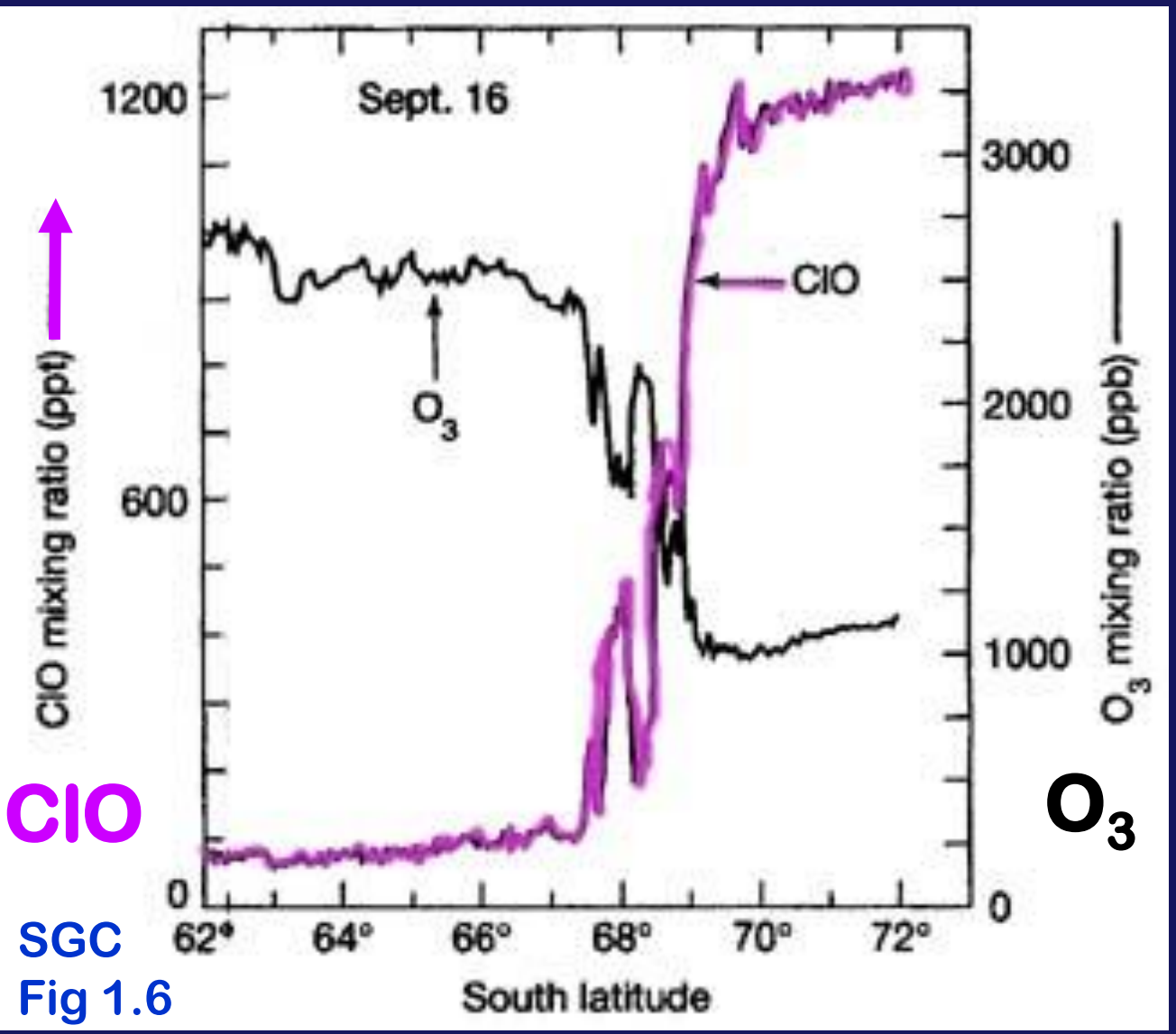
DISCOVERY OF THE OZONE HOLE

(cont.)

CHAPTER 3

- In 1986 Dr. Susan Soloman's expedition to Antarctica → identified chlorine increase

- She devised the theory that correctly explained the destruction of ozone by chlorine compounds



ClO

O_3

SGC
Fig 1.6

ClO (chlorine monoxide) from the chlorine catalytic cycle = **THE evidence of chemical reactions** occurring in hole region during time of greatest O_3 depletion (in September, spring in Southern Hemisphere)

ANTARCTIC LAND MASS

To the South Pole

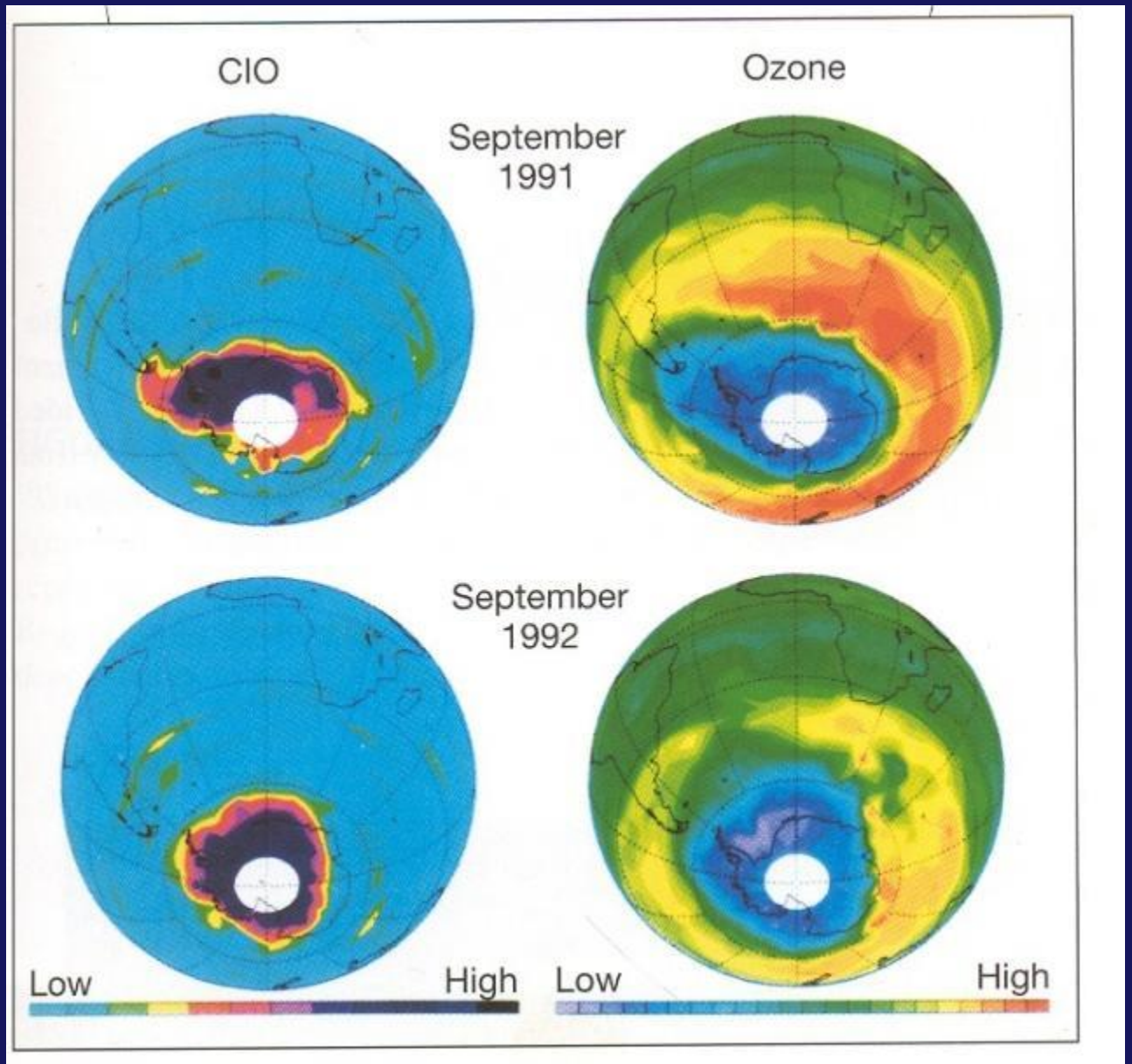
The chemical reaction theory:

Destruction "catalyzed" by chlorine (Cl) from CFCs

- Now universally accepted as conclusive
- Scientists involved were awarded the **Nobel Prize for Physics in 1995**.

Key Concept

Simultaneous measurements of ozone (O3) and chlorine monoxide (ClO)



HEALING THE HOLE . . . .

THE MONTREAL PROTOCOL

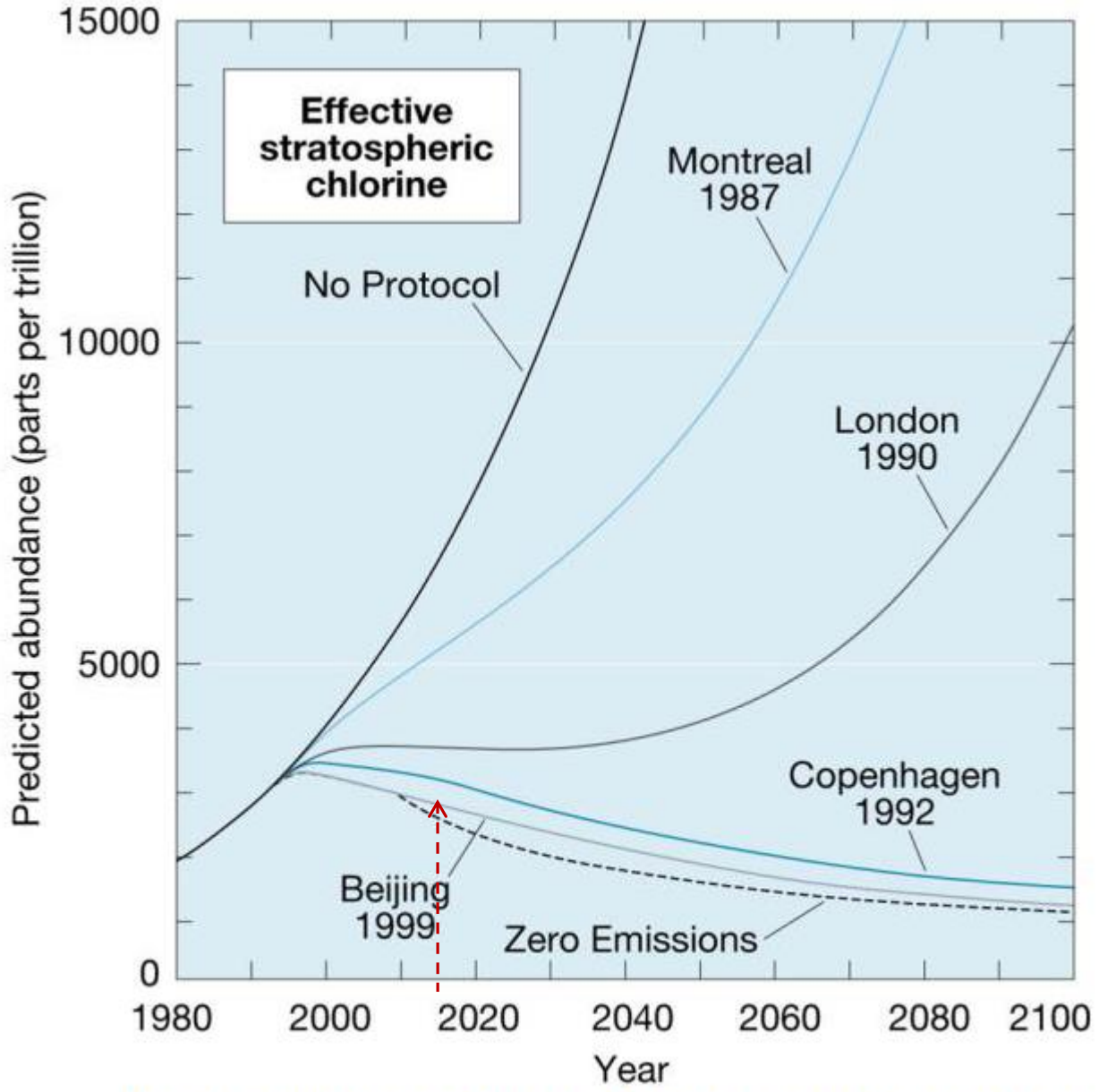
International Day for the Preservation of the Ozone Layer

SEPTEMBER 16th

The United Nations' (UN) International Day for the Preservation of the Ozone Layer is celebrated on September 16 every year. This event commemorates the date of the signing of the Montreal Protocol on Substances that Deplete the Ozone Layer in 1987.

The earth's ozone layer plays an important role in protecting human health and the environment. ©iStockphoto.com/Stephen Strathdee

http://www.timeanddate.com/holidays/un/international-ozone-layer-preservation-day



Projected atmospheric chlorine concentrations under the various international agreements

Very long residence time of Cl and CFCs!

-- The world is "making do" with freon substitutes,

-- but concern over long-term effects of substitutes remains . . .

Why can't we just ship the "bad ozone" in the troposphere up to the stratosphere to 'fill the hole'?

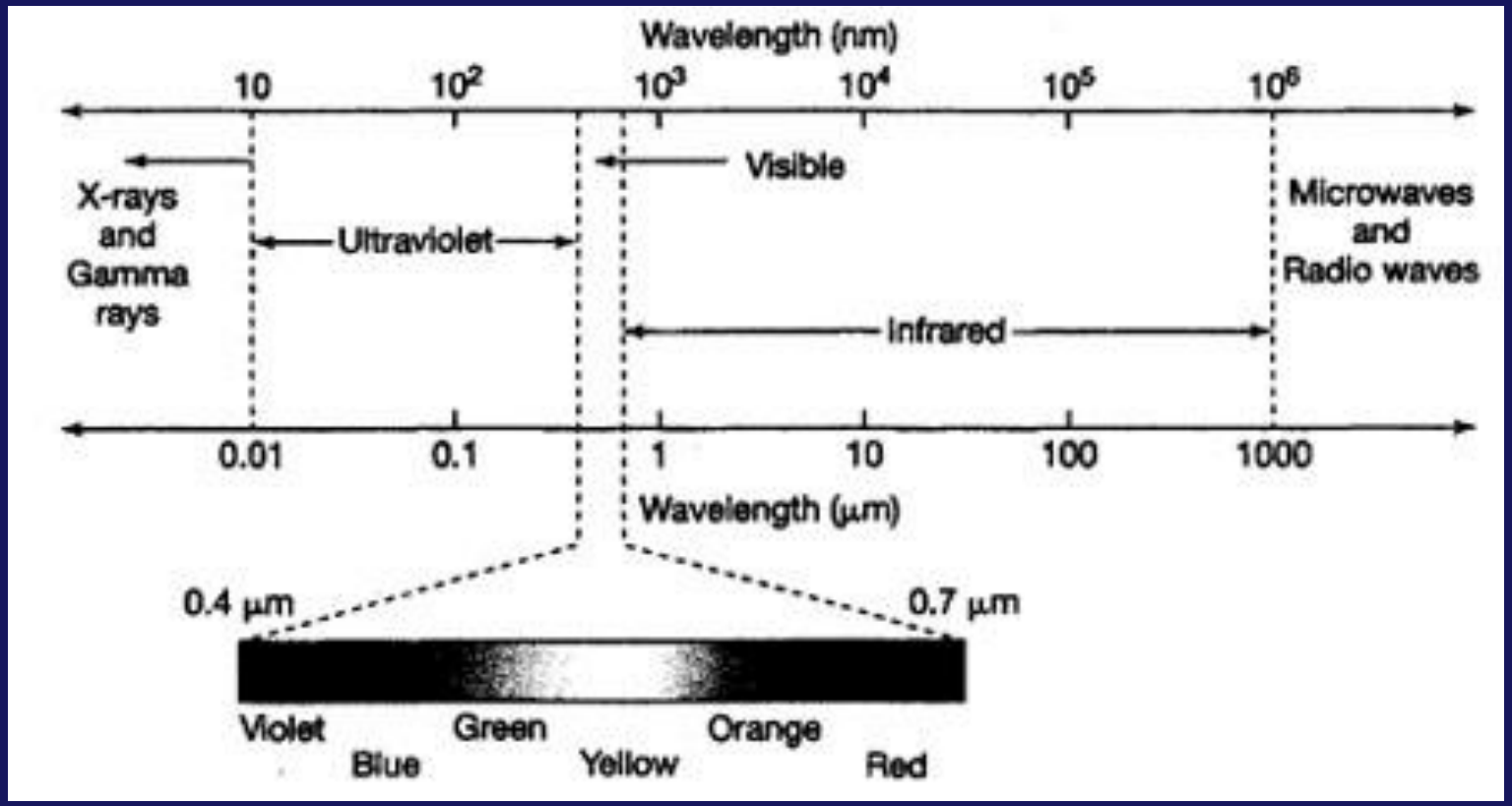
> Ozone is *increasing* in the troposphere due to car exhaust, etc ("bad ozone"), but only at the rate of about 1% per year,

> hence stratospheric levels of "good ozone" are going down at a rate faster than ozone is being added in the troposphere.

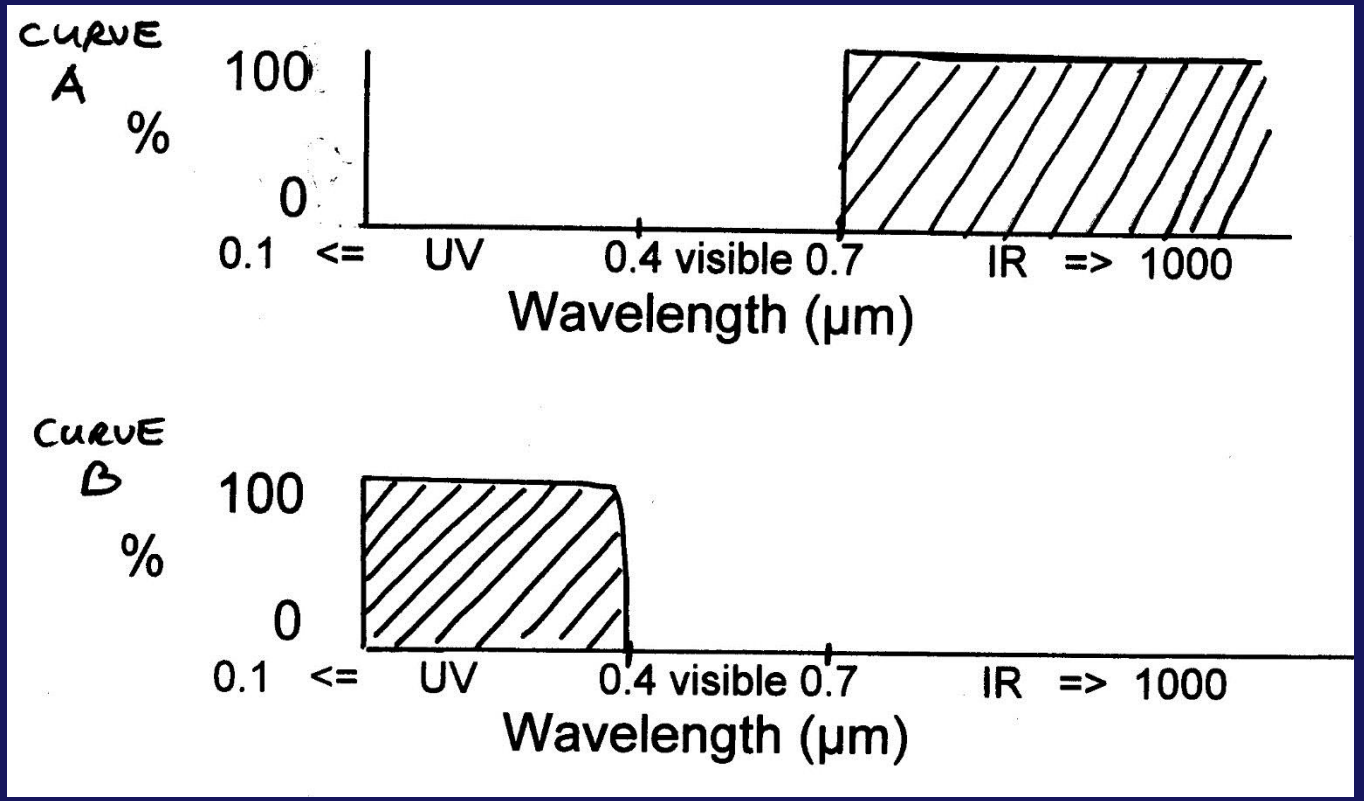
THE OZONE DEPLETION STORY TIES TOGETHER MANY OF THE CONCEPTS YOU'VE LEARNED IN THE COURSE THUS FAR:

- the nature of matter, e.g., chemical reactions and photon interaction with atoms

> the electromagnetic spectrum --especially the <u>wavelengths of UV radiation</u>

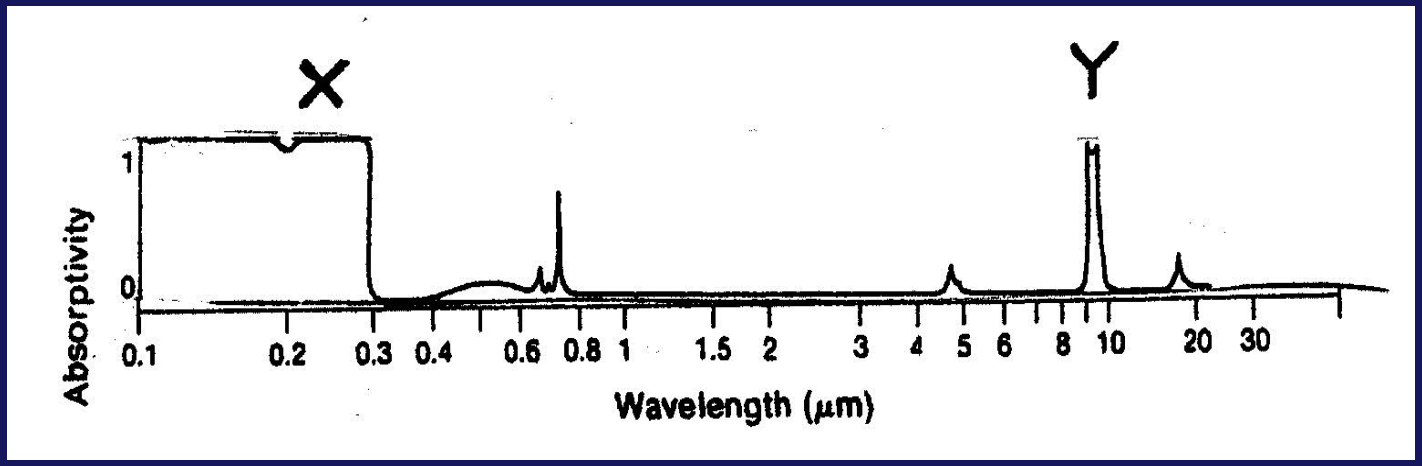


> absorption curves, especially the absorption curve for ozone

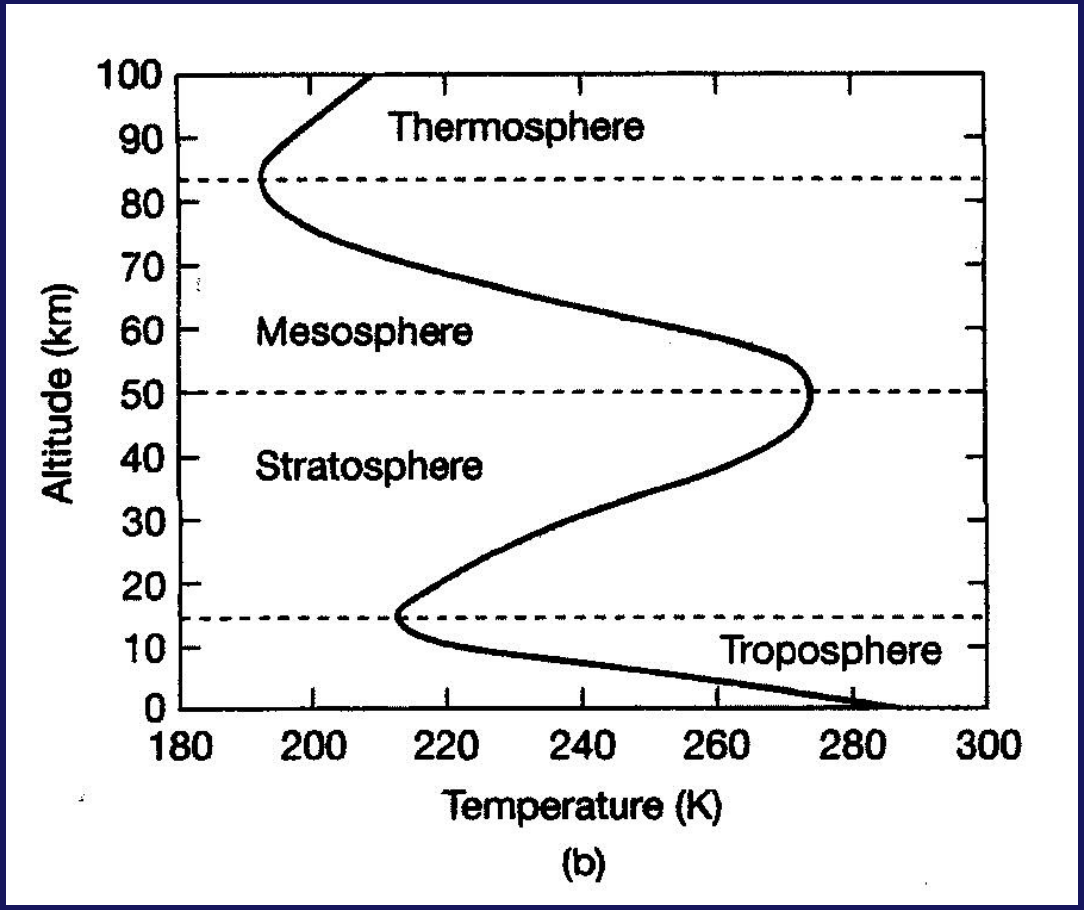


> Effect of clouds -- in this case the importance of Polar Stratospheric Clouds (PSCs)

> Greenhouse gases (ozone is also a greenhouse gas but this affects IR radiation, not UV radiation)



> the vertical structure of the atmosphere (troposphere, stratosphere)

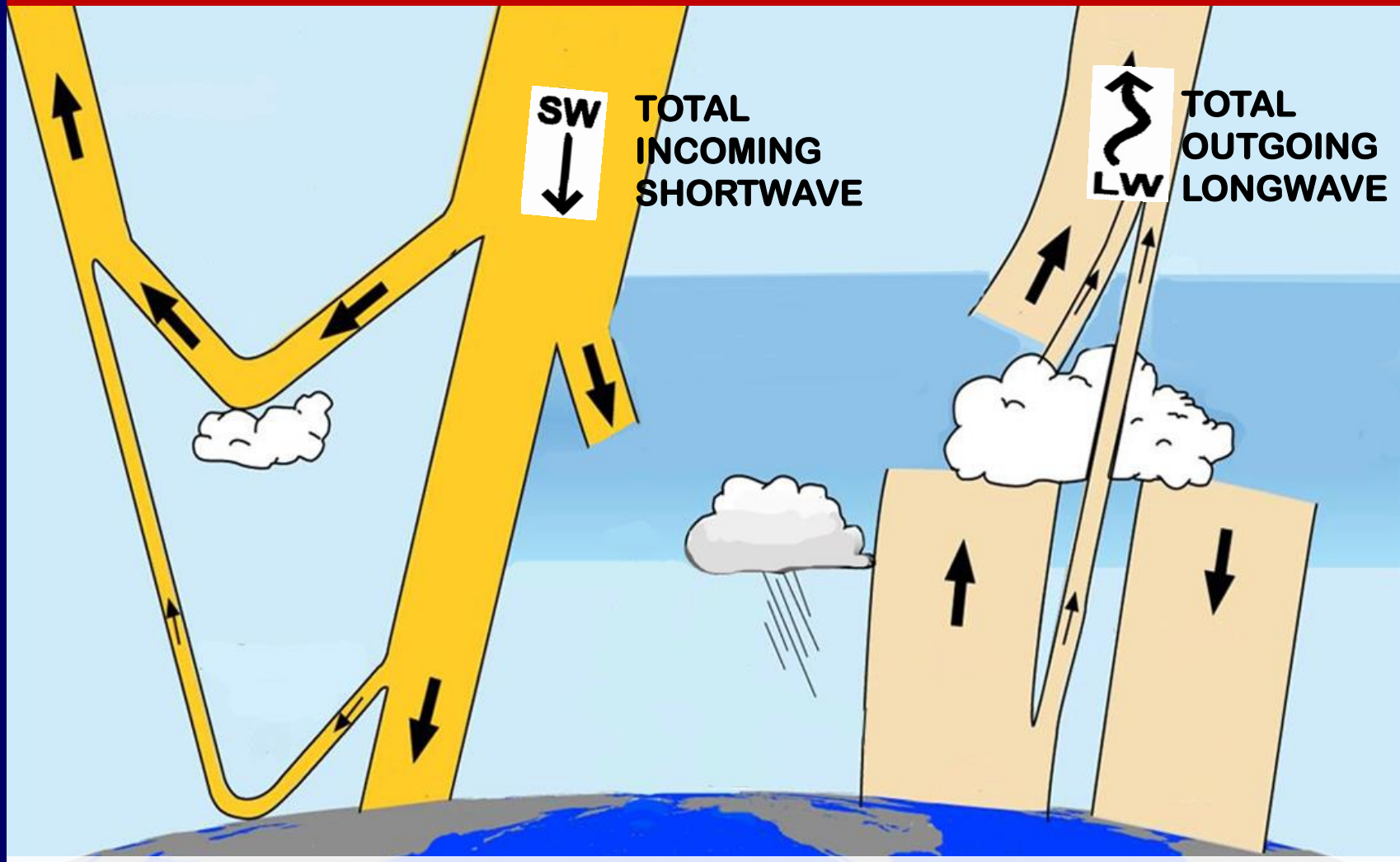


Let's wrap-up **OZONE**. . . .

CLICKER TIME!!

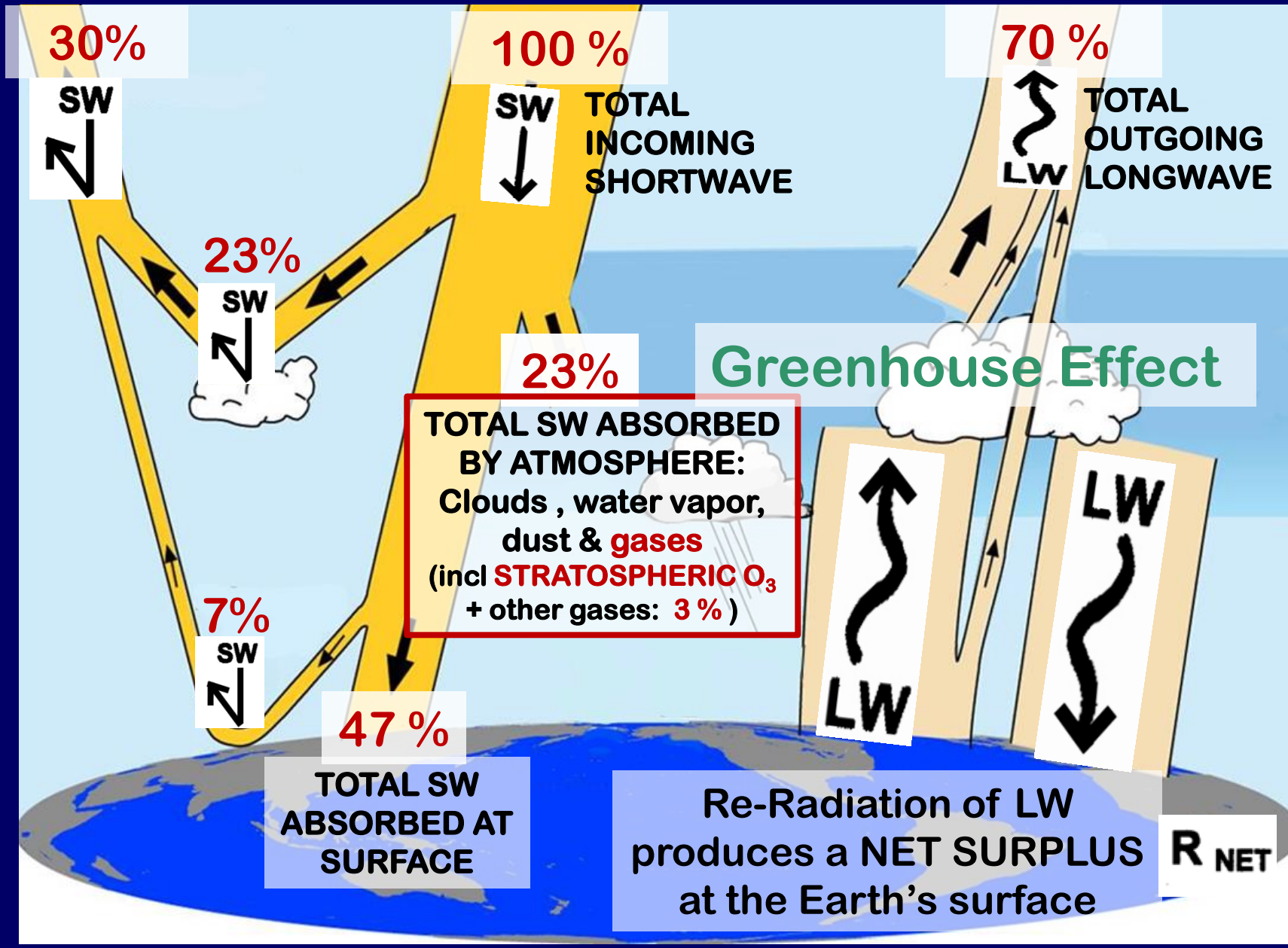
FLIP BACK TO
p 45 in CLASS NOTES

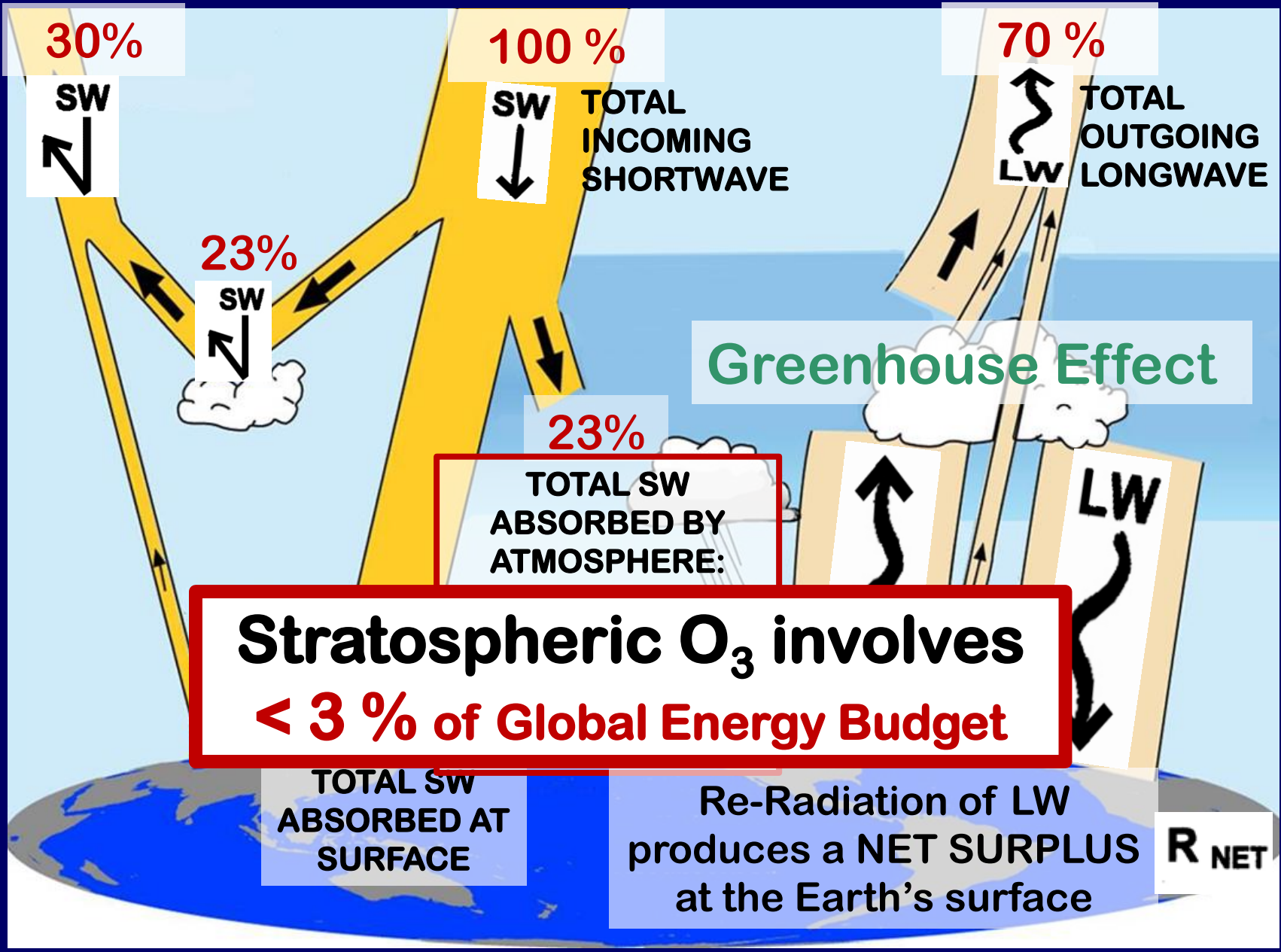
First, let's tie things back to the Energy Balance . . .



The WIDTH of the arrows represents how much energy is in each pathway

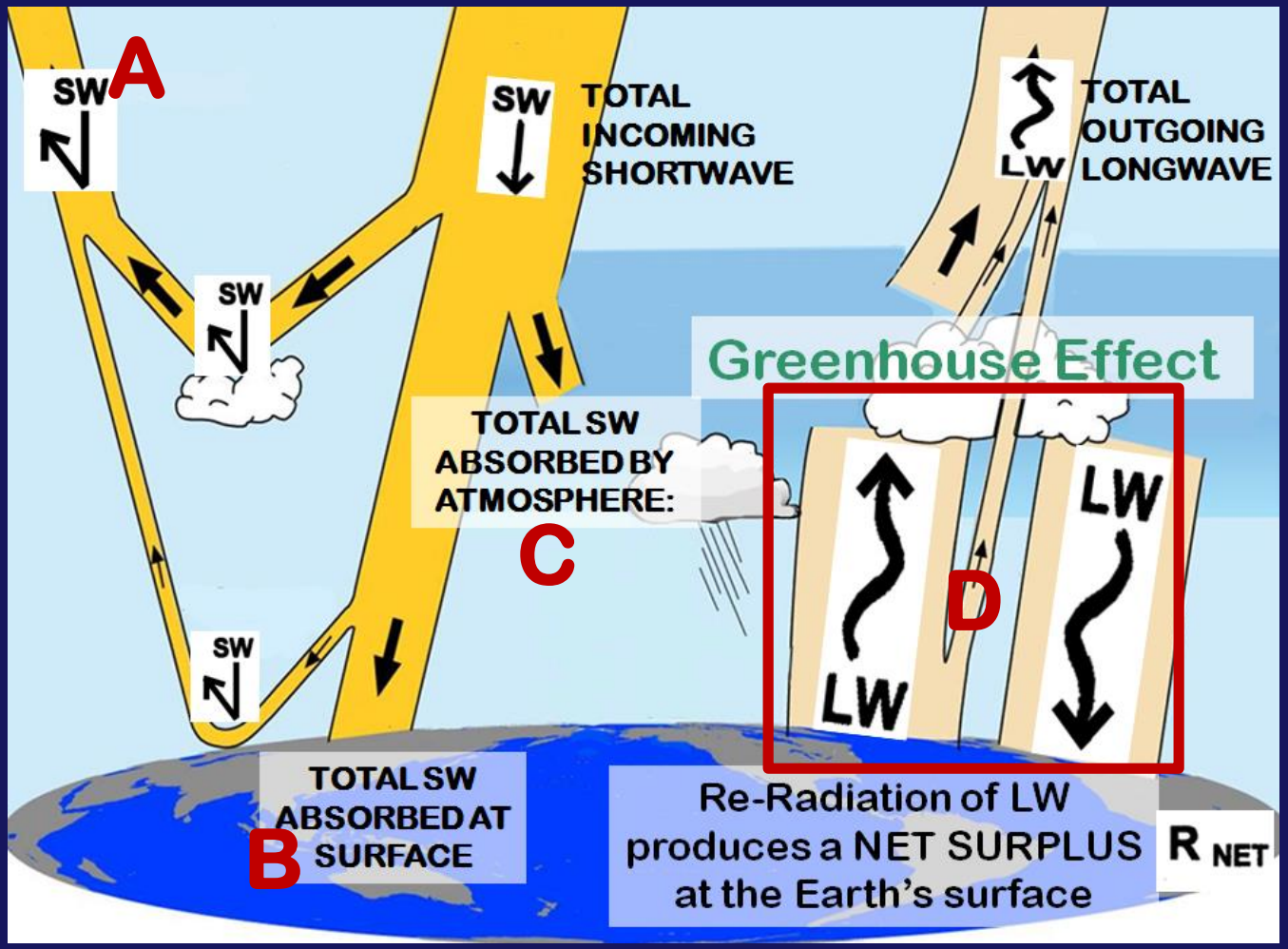
Review p 45


30%
SW
100 %
SW
TOTAL
INCOMING
SHORTWAVE
70 %
LW
TOTAL
OUTGOING
LONGWAVE
23%
SW
23%
Greenhouse Effect
TOTAL SW ABSORBED
BY ATMOSPHERE:
Clouds , water vapor,
dust & gases
(incl STRATOSPHERIC O_3
+ other gases: 3 %)
7%
SW
LW
LW
47 %
TOTAL SW
ABSORBED AT
SURFACE
Re-Radiation of LW
produces a NET SURPLUS
at the Earth's surface
R NET


30%
SW
100 %
SW
TOTAL
INCOMING
SHORTWAVE
70 %
LW
TOTAL
OUTGOING
LONGWAVE
23%
SW
Greenhouse Effect
23%
TOTAL SW
ABSORBED BY
ATMOSPHERE:
LW
Stratospheric O_3 involves
< 3 % of Global Energy Budget
TOTAL SW
ABSORBED AT
SURFACE
Re-Radiation of LW
produces a NET SURPLUS
at the Earth's surface
R NET

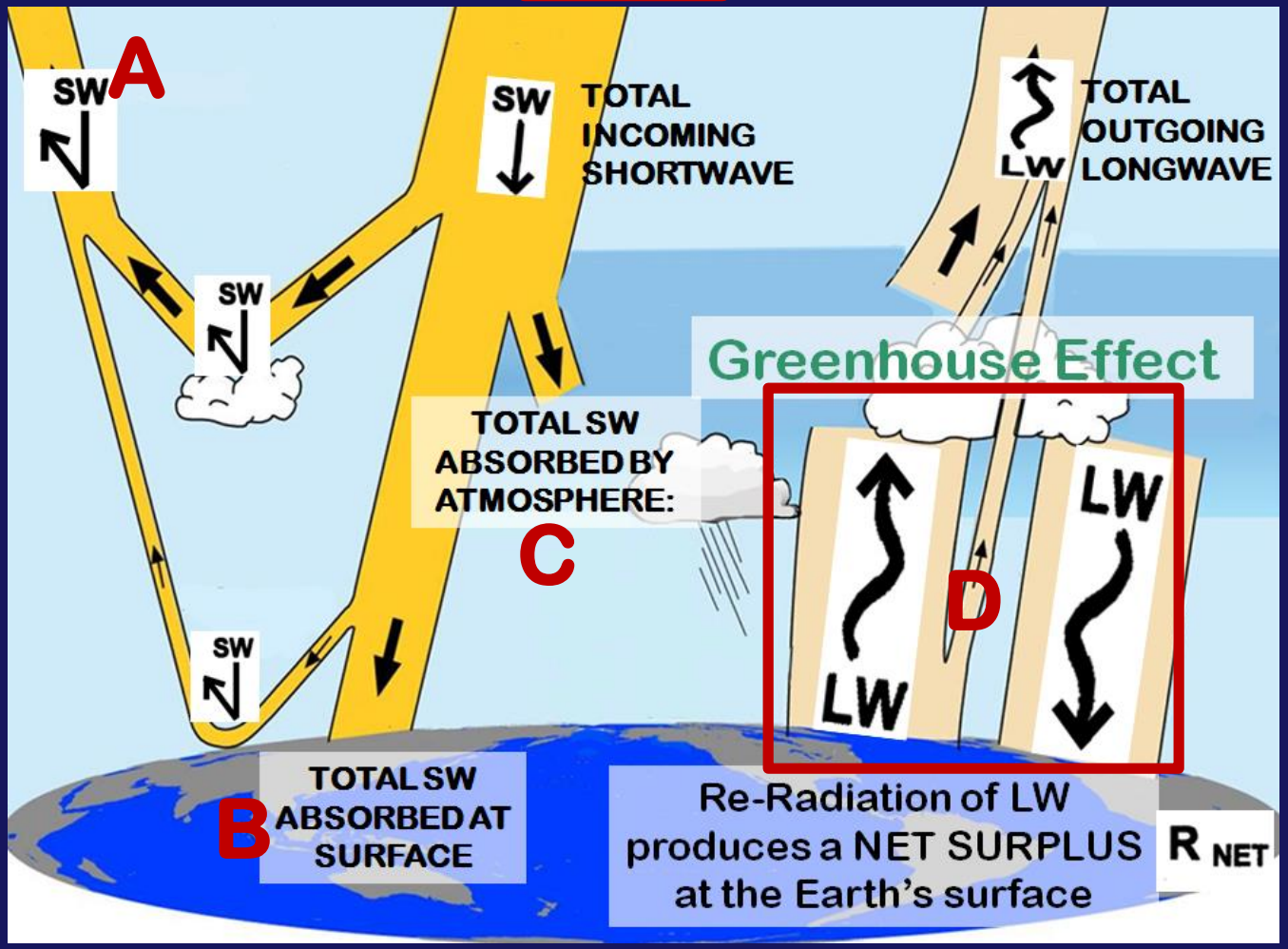
Q1. In which part of the energy balance does the main activity related to STRATOSPHERIC OZONE DEPLETION take place?

A B C D



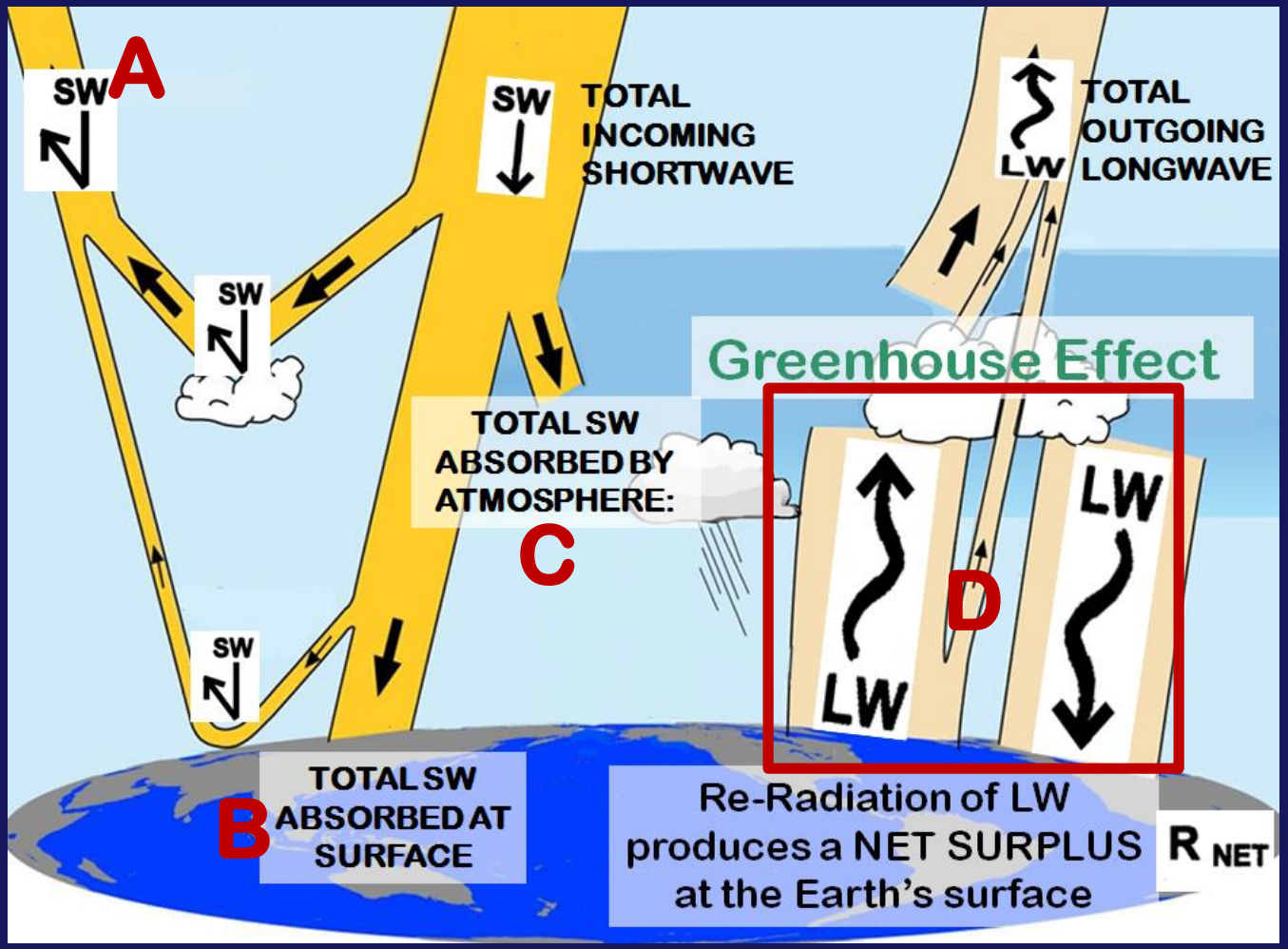
Q1. In which part of the energy balance does the main activity related to STRATOSPHERIC OZONE DEPLETION take place?

A B **C** D



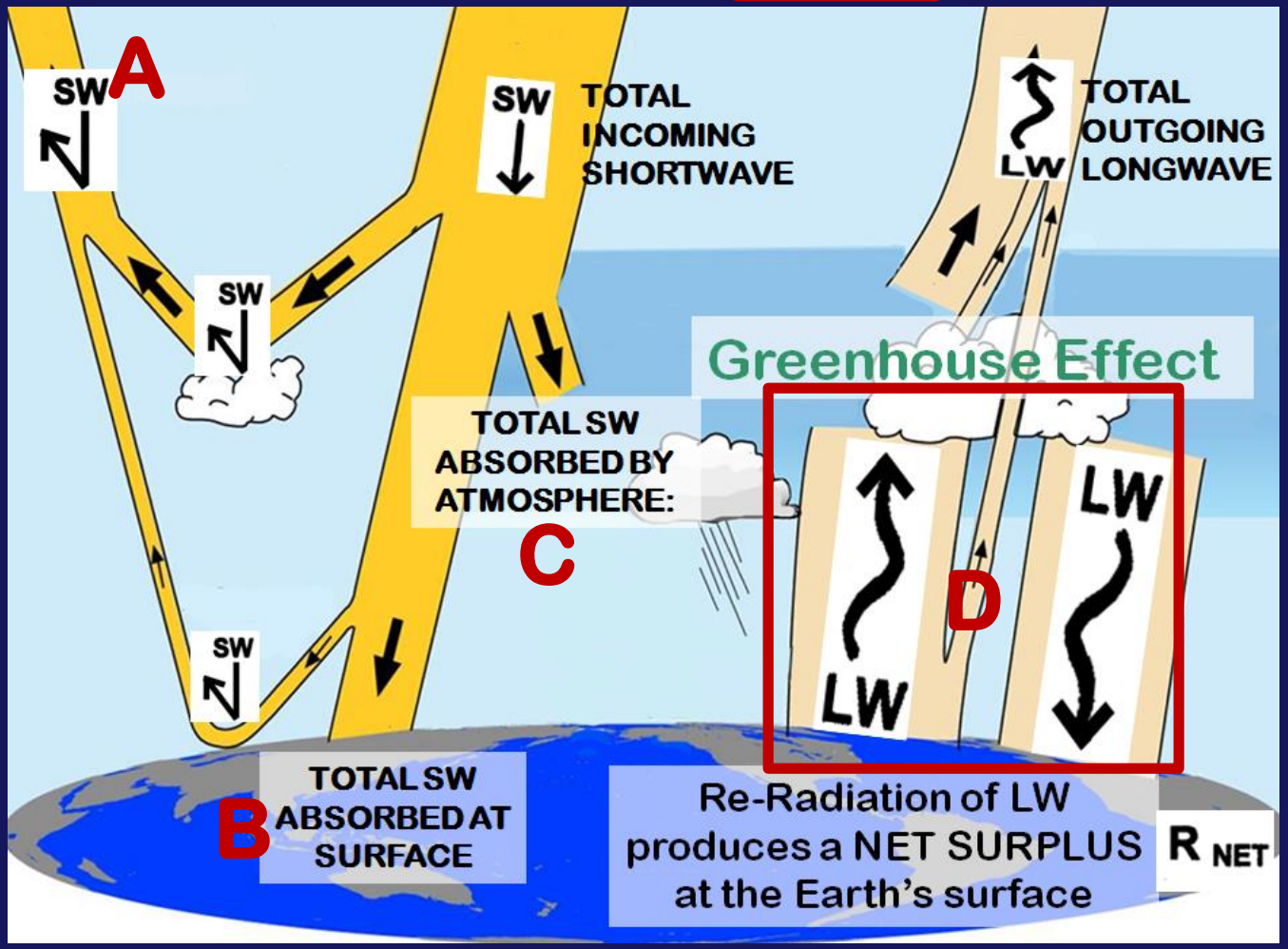
Q2. In which part of the energy balance does the activity related to GLOBAL WARMING from the enhanced GHE take place?

A B C D



Q2. In which part of the energy balance does the activity related to GLOBAL WARMING from the enhanced GHE take place?

A B C **D**



Q3 – Which is the correct statement:

1 The depletion of STRATOSPHERIC OZONE in the Ozone Hole is a critically important CAUSE of increased GLOBAL WARMING in the troposphere.

2 Increased GLOBAL WARMING in the troposphere is a newly realized important CAUSE of STRATOSPHERIC COOLING which could prolong or worsen the OZONE HOLE

3 Neither

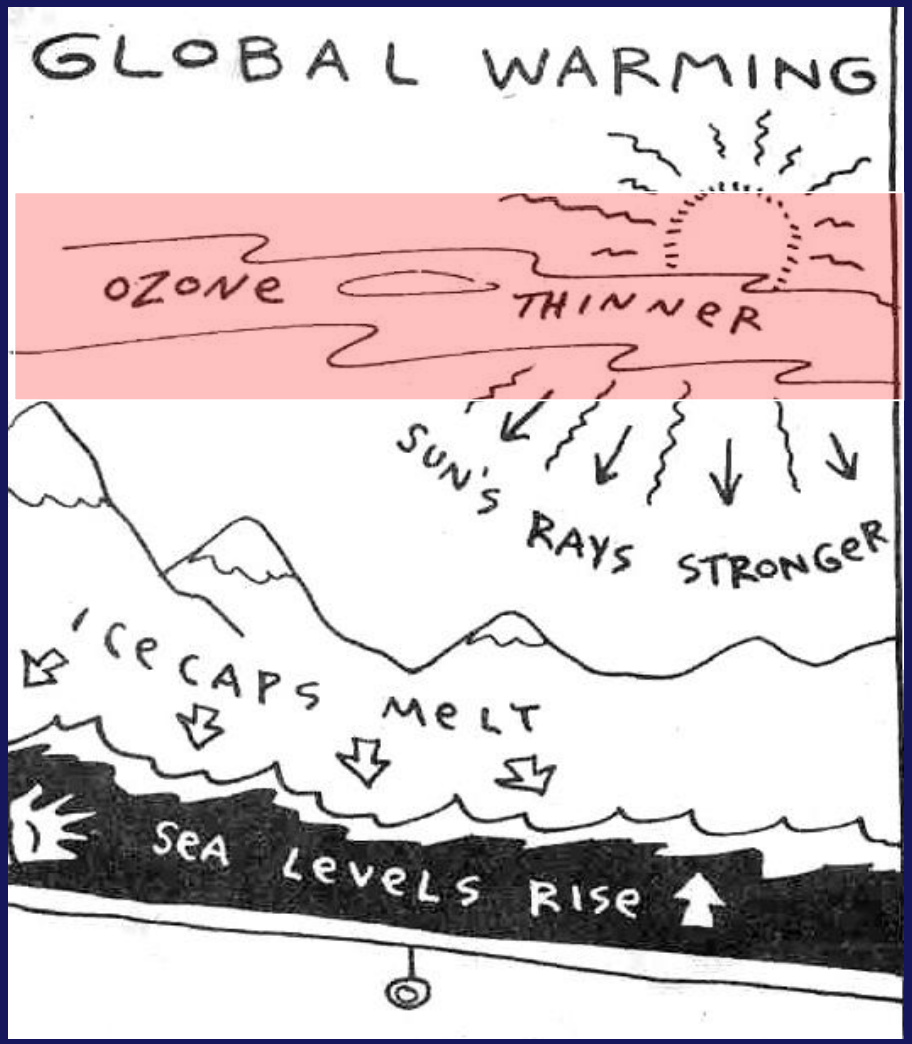
Q3 – Which is the correct statement:

1 The depletion of STRATOSPHERIC OZONE in the Ozone Hole is a critically important CAUSE of increased GLOBAL WARMING in the troposphere.

2 Increased GLOBAL WARMING in the troposphere is a newly realized important CAUSE of STRATOSPHERIC COOLING which could prolong or worsen the OZONE HOLE

3 Neither

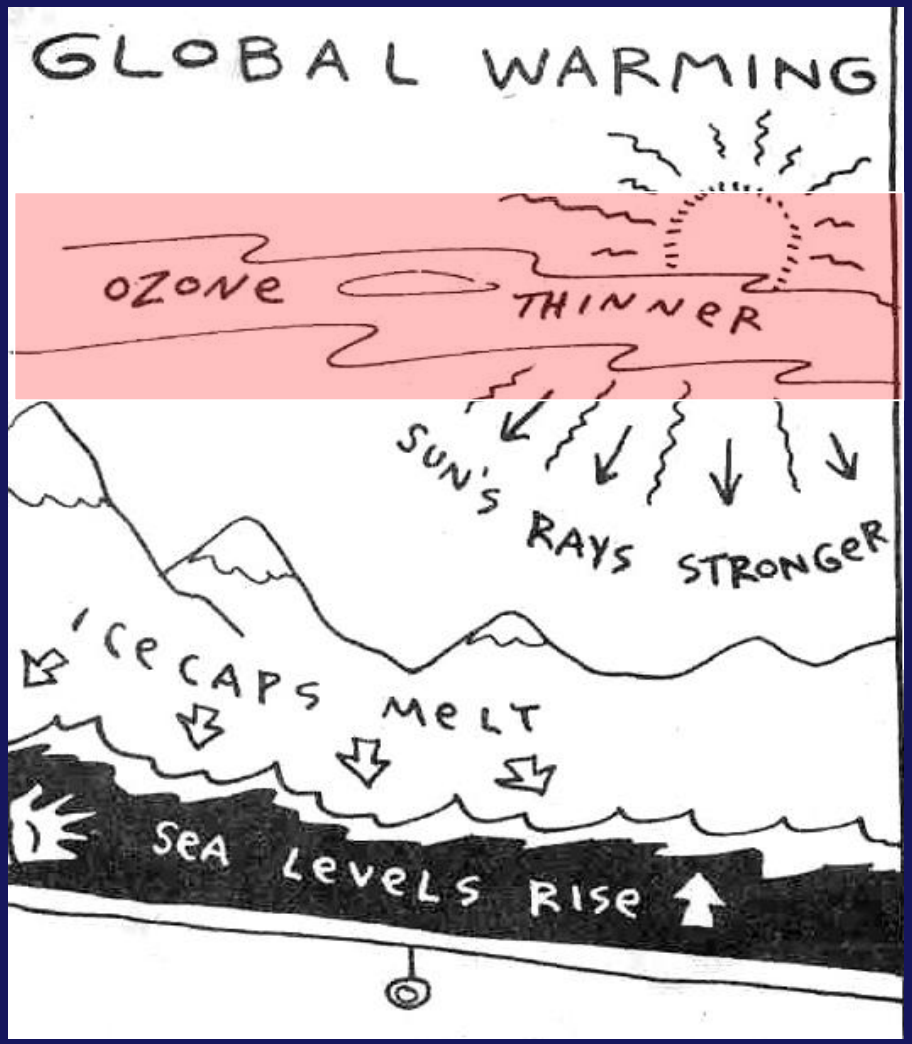
Q4. Is this explanation of the main CAUSE of GLOBAL WARMING correct?



1- YES

2 - NO

Q4. Is this explanation of the main CAUSE of GLOBAL WARMING correct?



1- YES

2 - NO

REPEAT:

"The Ozone Hole
in the Stratosphere
IS NOT
a main cause
of GLOBAL WARMING!"

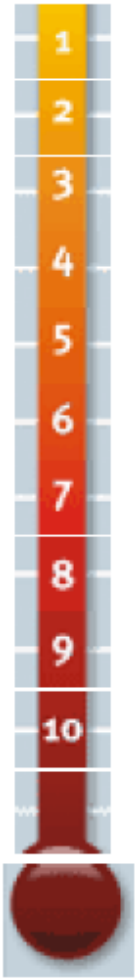
Anthropogenic
GLOBAL WARMING
occurs in the
TROPOSPHERE !!

SO WHAT IS CAUSING Global Warming ???

WHAT'S CAUSING IT?

The most used "denier" arguments about the causes and effects of climate change

From: http://www.skepticalscience.com/



1. Climate's changed before
2. It's the sun
3. It's not bad
4. There is no consensus
5. It's cooling
6. Models are unreliable
7. Temp record is unreliable
8. Animals and plants can adapt
9. It hasn't warmed since 1998
10. And so forth . . . . .

This semester we will critically examine and evaluate the most used arguments and myths about climate change!

GLOBAL WARMING
occurs in the TROPOSPHERE
and is caused by the
Enhanced Greenhouse Effect:

= the human induced
increase of GH gases
that absorb
& emit
IR radiation

TOPIC # 13
GLOBAL WARMING & ANTHROPOGENIC FORCING

Part A
CARBON RESERVOIRS & FLUXES:
Natural vs. Anthropogenically Enhanced

(or How does all that "C" get into the atmosphere??)

Class Notes pp 79

"We are playing Russian roulette with our climate . . . The Earth's climate system is an angry beast subject to unpredictable responses, and **by adding carbon dioxide to the atmosphere we may be provoking the beast.**"

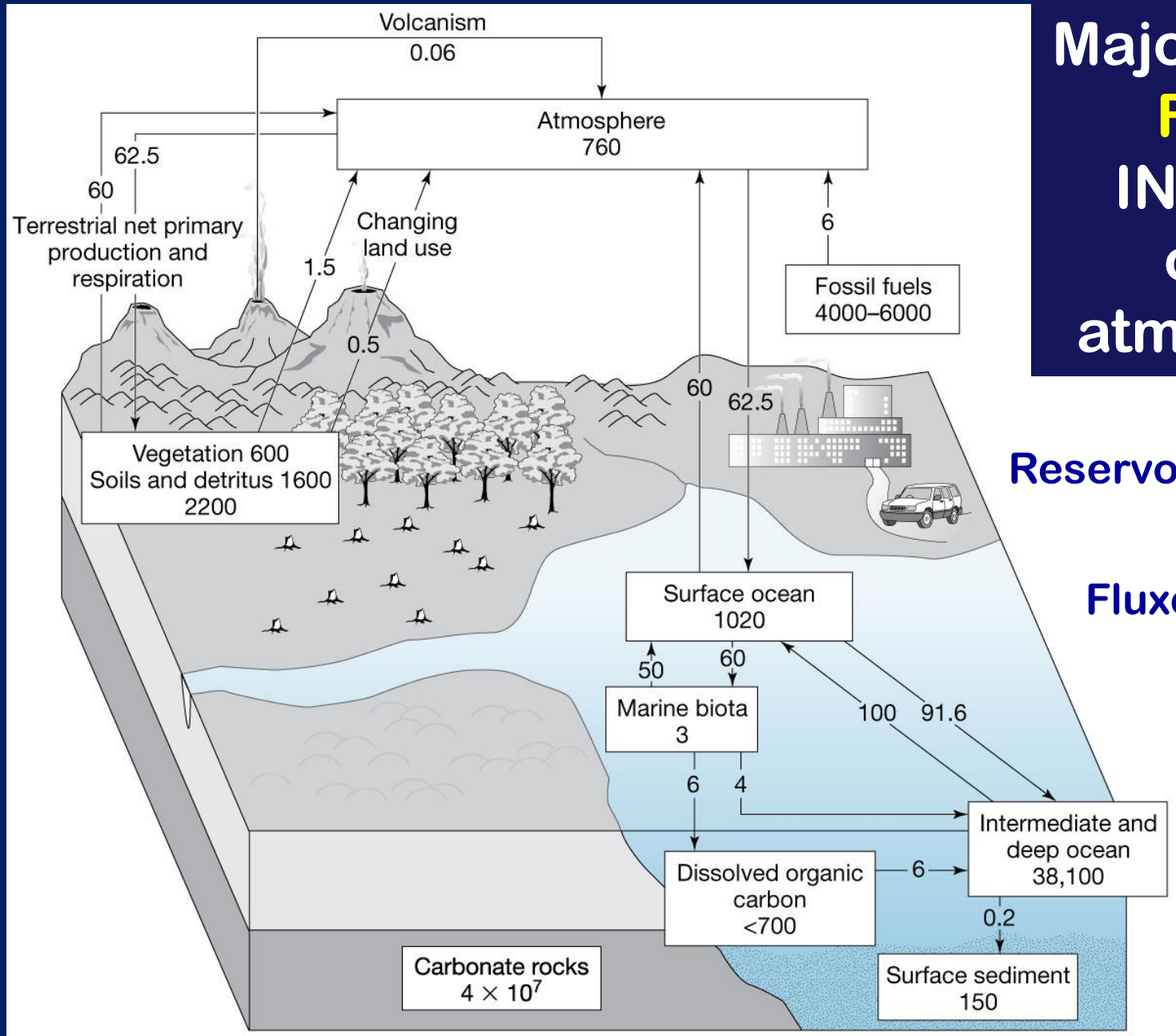
~Wally Broecker , Paleoclimatologist

CO_2 & CARBON RESERVOIRS

CO_2 in the atmosphere is one place CARBON resides in the Earth-Atmosphere system.

Where else is carbon located and how does it move (flux) from one reservoir to another?

Major Carbon Fluxes IN & OUT of the atmosphere



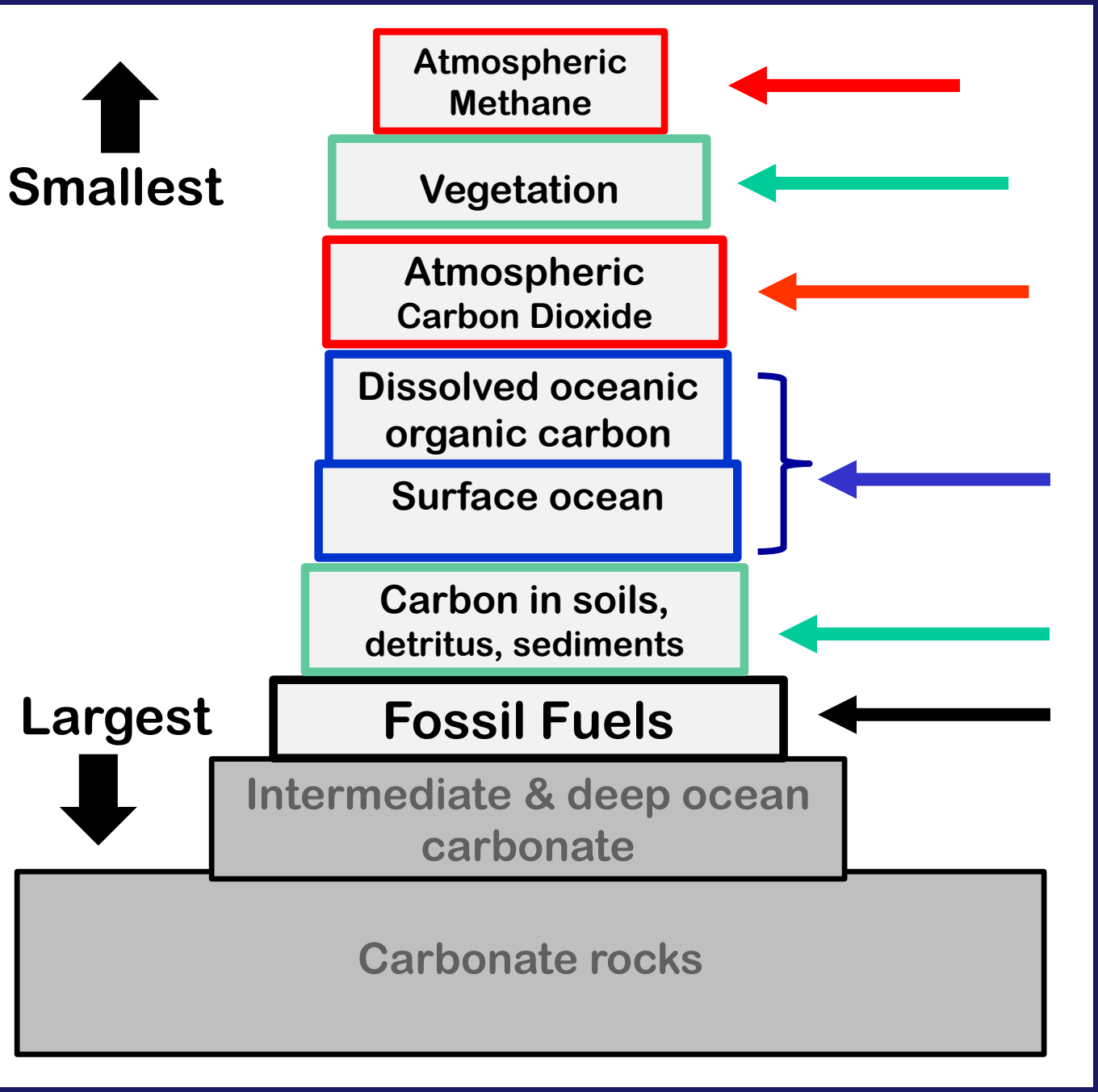
Reservoirs = 

Fluxes = 

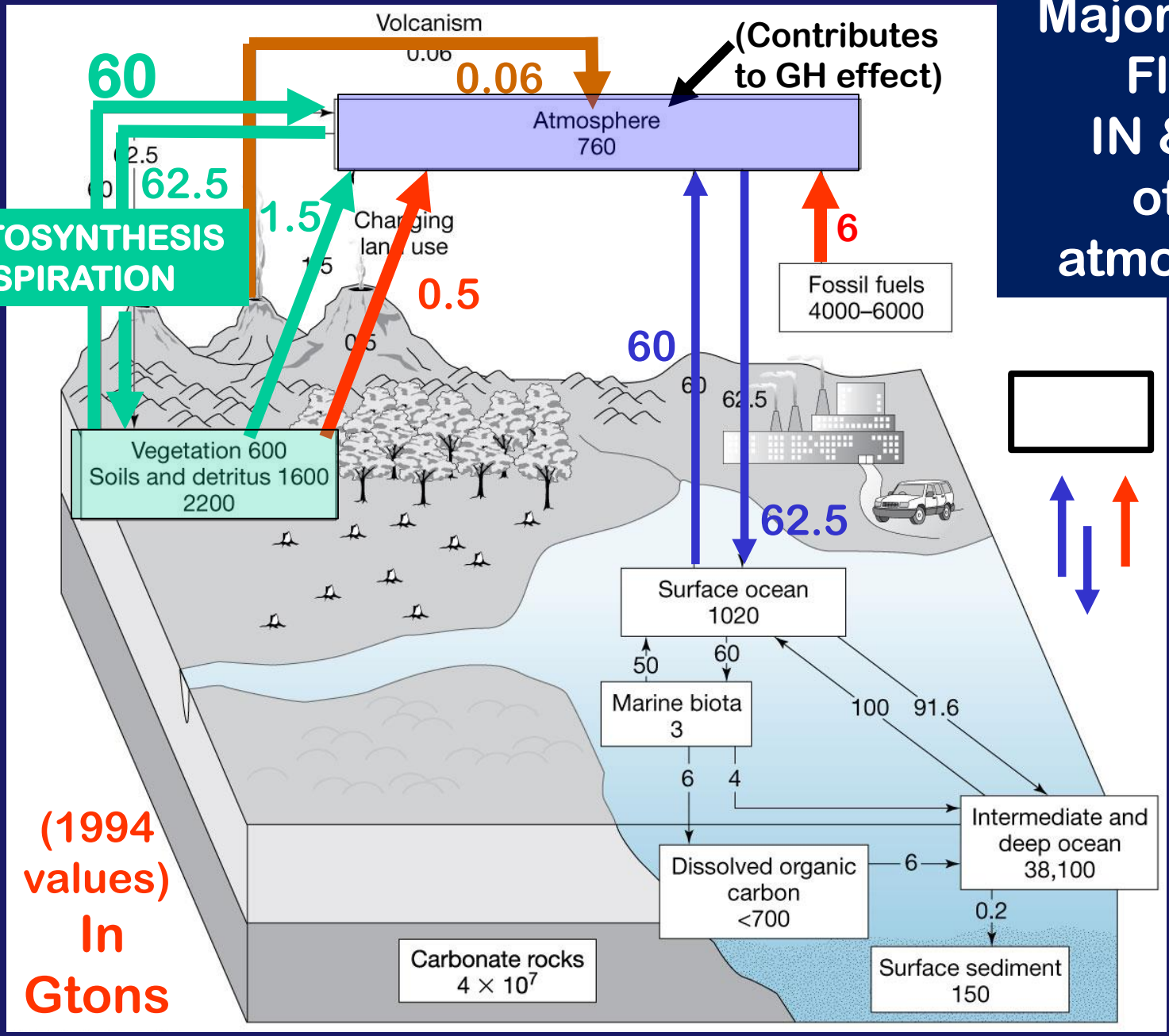
RESERVOIR (def)

a place where anything is collected or accumulated in great amount.

Carbon Reservoirs ranked by size :



Major Carbon Fluxes IN & OUT of the atmosphere



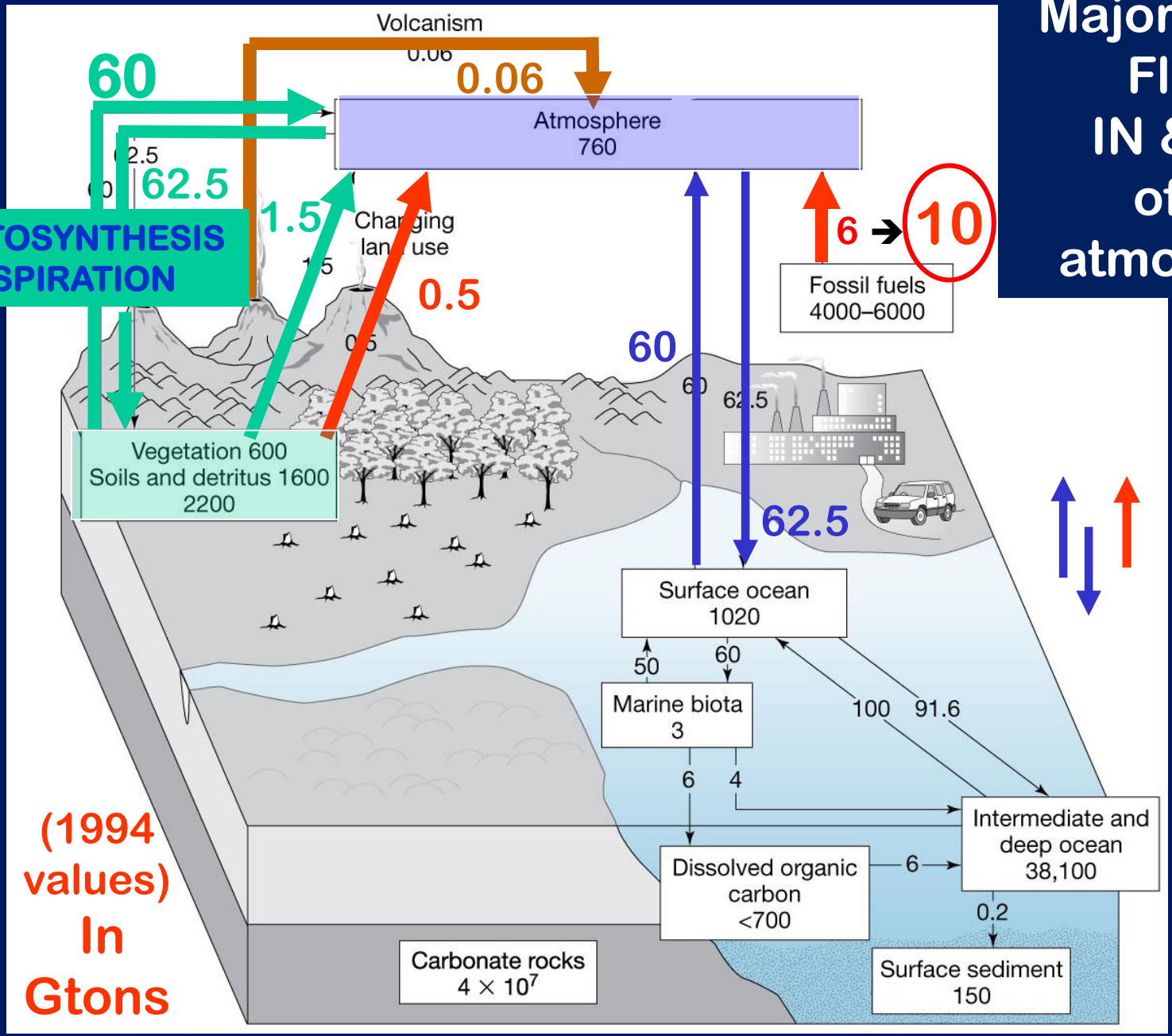
= carbon stored in a reservoir

= carbon flux from one reservoir to another

(in Gtons/yr)

1 Gton = 1 billion tons

Major Carbon Fluxes IN & OUT of the atmosphere



= carbon stored in a reservoir

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Q5.How does CARBON "flux" FROM the biosphere INTO the atmosphere?

1. Trees take in carbon dioxide during photosynthesis.

2. Trees release carbon dioxide during photosynthesis.

3. Trees release carbon dioxide into the atmosphere during respiration.

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← True in SUMMER, but doesn't answer the Q

←THIS answers the Q ! (happens primarily in winter)

NATURAL FLUXES INTO & OUT OF THE ATMOSPHERIC CARBON RESERVOIR related to BIOMASS = respiration & photosynthesis

FLUX from PLANT INTO ATMOSPHERE:

Respiration: & Decomposition (simplified)

$$CH_2O + O_2 \longrightarrow CO_2 + H_2O.$$

carbohydrate — oxygen gas — carbon dioxide — water

FLUX OUT OF ATMOSPHERE into PLANT:

Photosynthesis: (Primary Production) (simplified)

$$CO_2 + H_2O \longrightarrow CH_2O + O_2.$$

carbon dioxide — water — carbohydrate — oxygen gas

SOME DEFINITIONS:

Respiration =

biochemical process
living organisms take up O_2,
consume organic matter,
RELEASE CO_2, heat, & H_2O

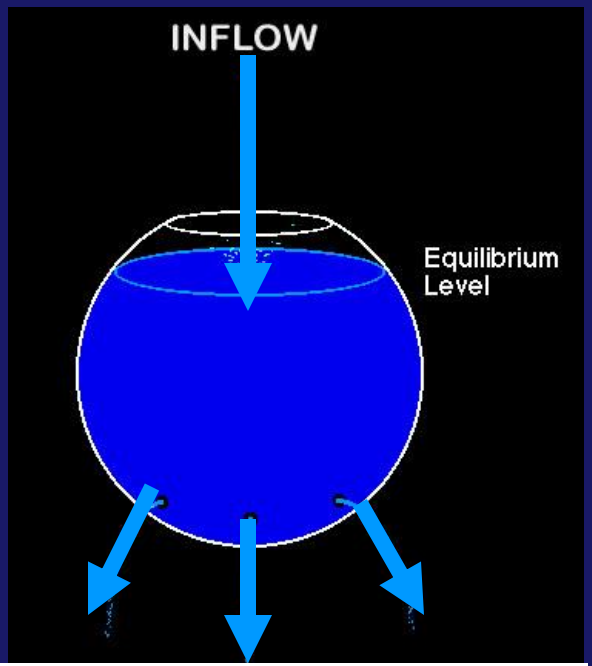
Decomposition =

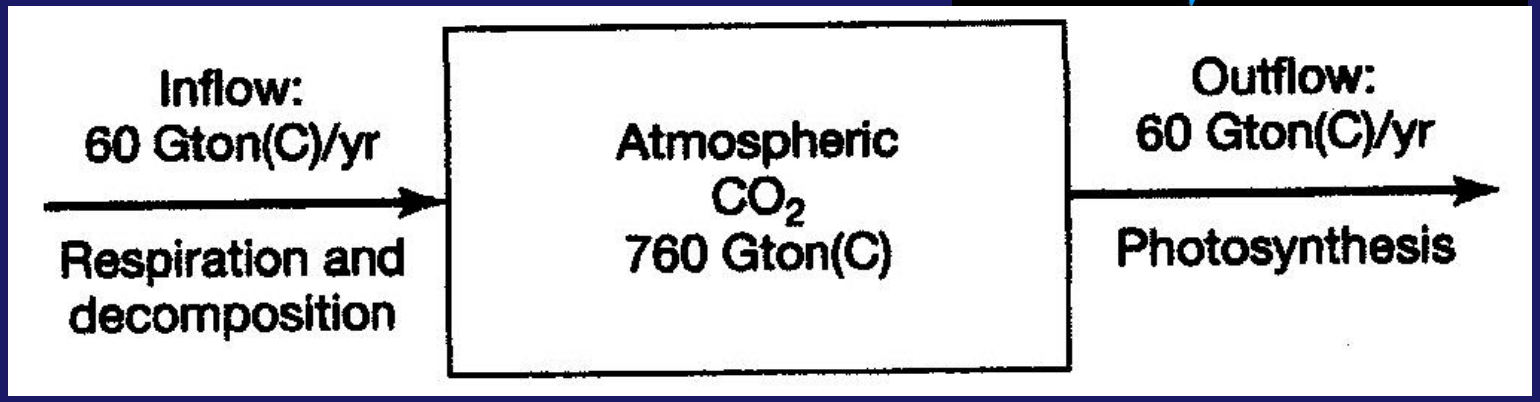
breakdown of organic matter
by bacteria and fungi,
RELEASES CO_2 to the atmosphere

Flux **IN & OUT** leads to a

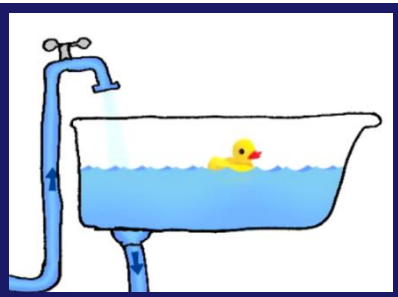
STEADY STATE

In the atmospheric CO_2 "reservoir"



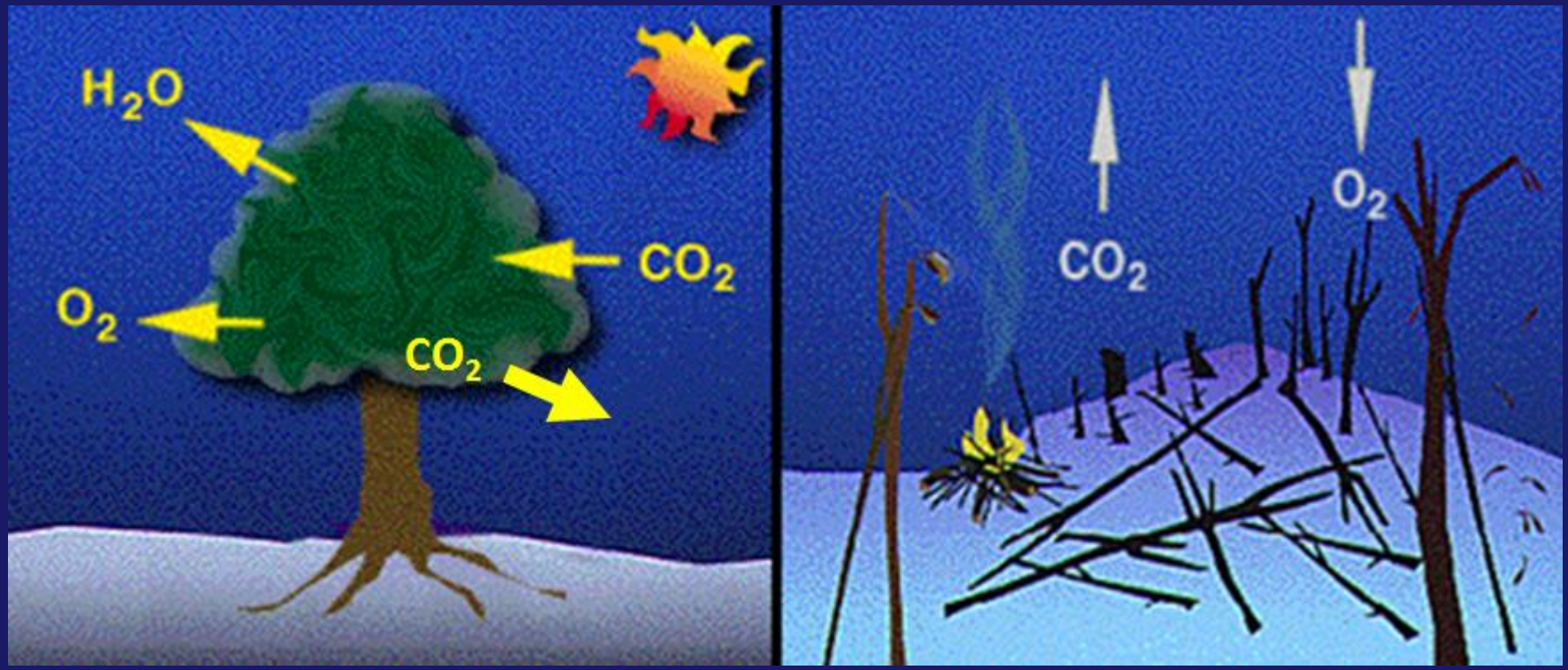


Where have we seen a STEADY STATE before?



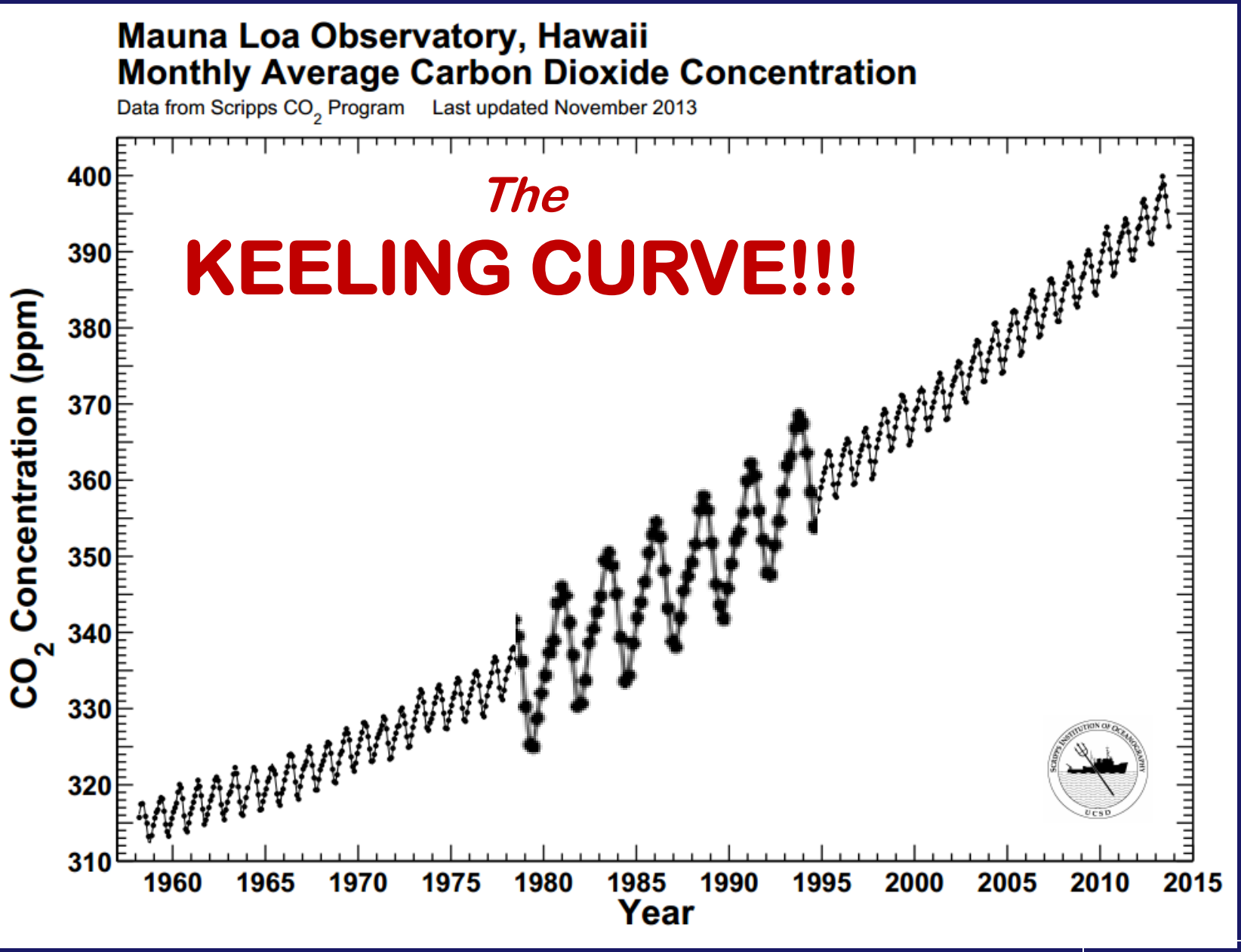
Photosynthesis & Respiration

Respiration, Burning of Biomass, & Decomposition

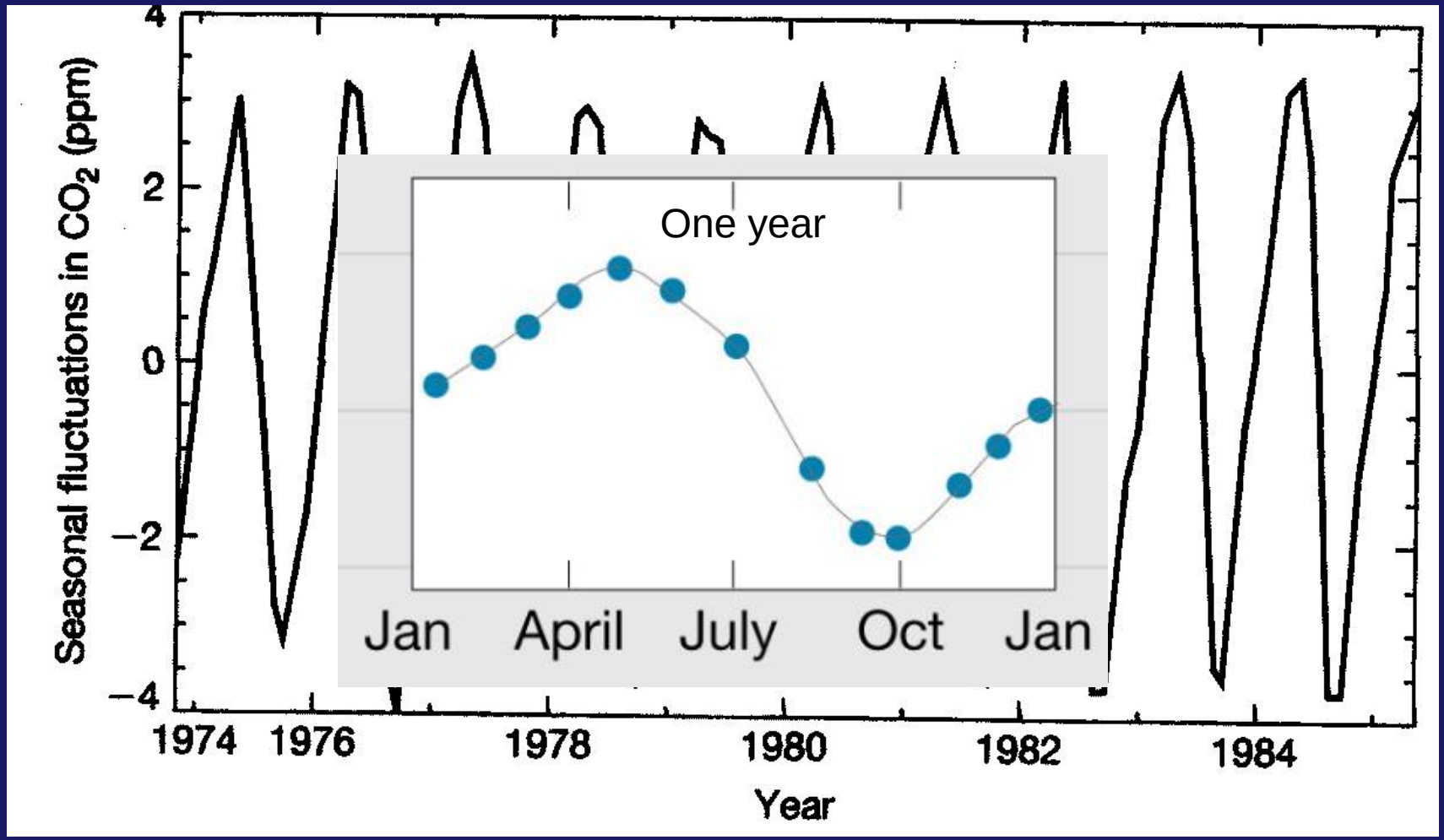


Steady State

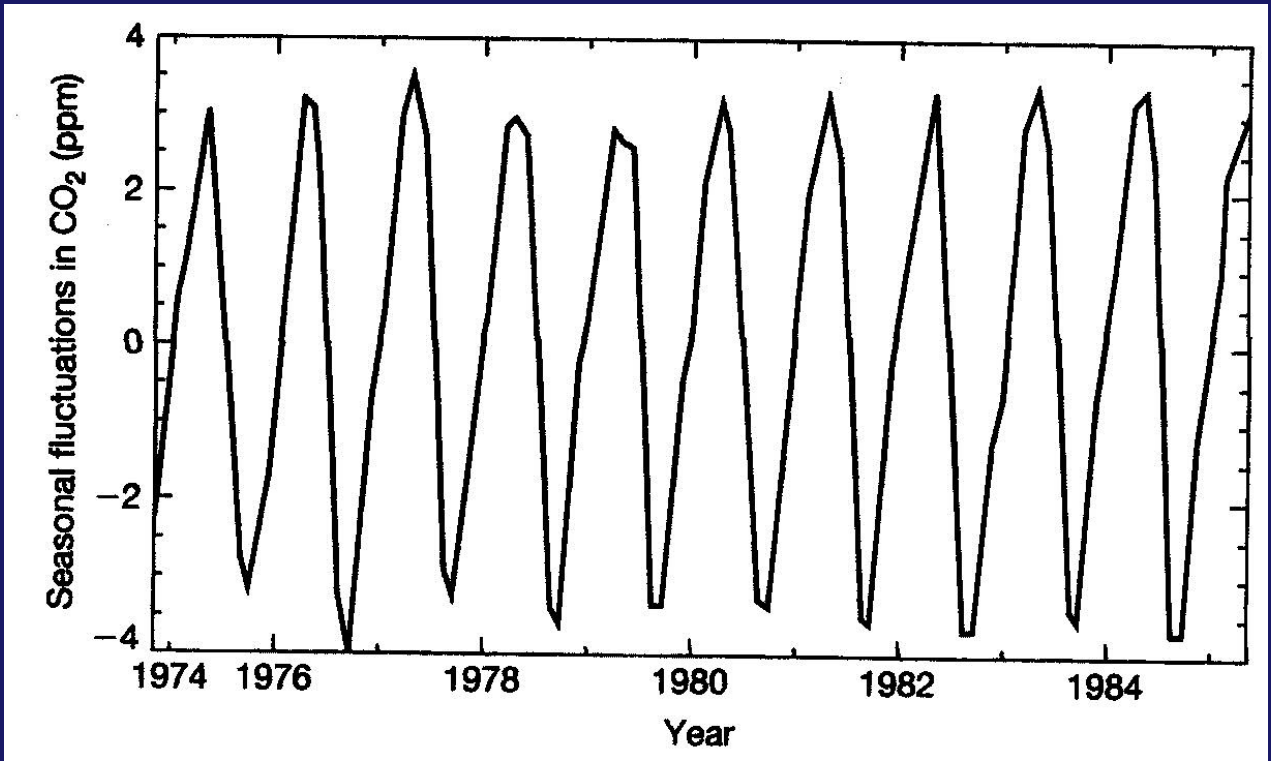
Disruption of Steady State


Mauna Loa Observatory, Hawaii
Monthly Average Carbon Dioxide Concentration
Data from Scripps CO_2 Program Last updated November 2013
The
KEELING CURVE!!!
CO_2 Concentration (ppm)
400
390
380
370
360
350
340
330
320
310
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year

CLOSE-UP VIEW:

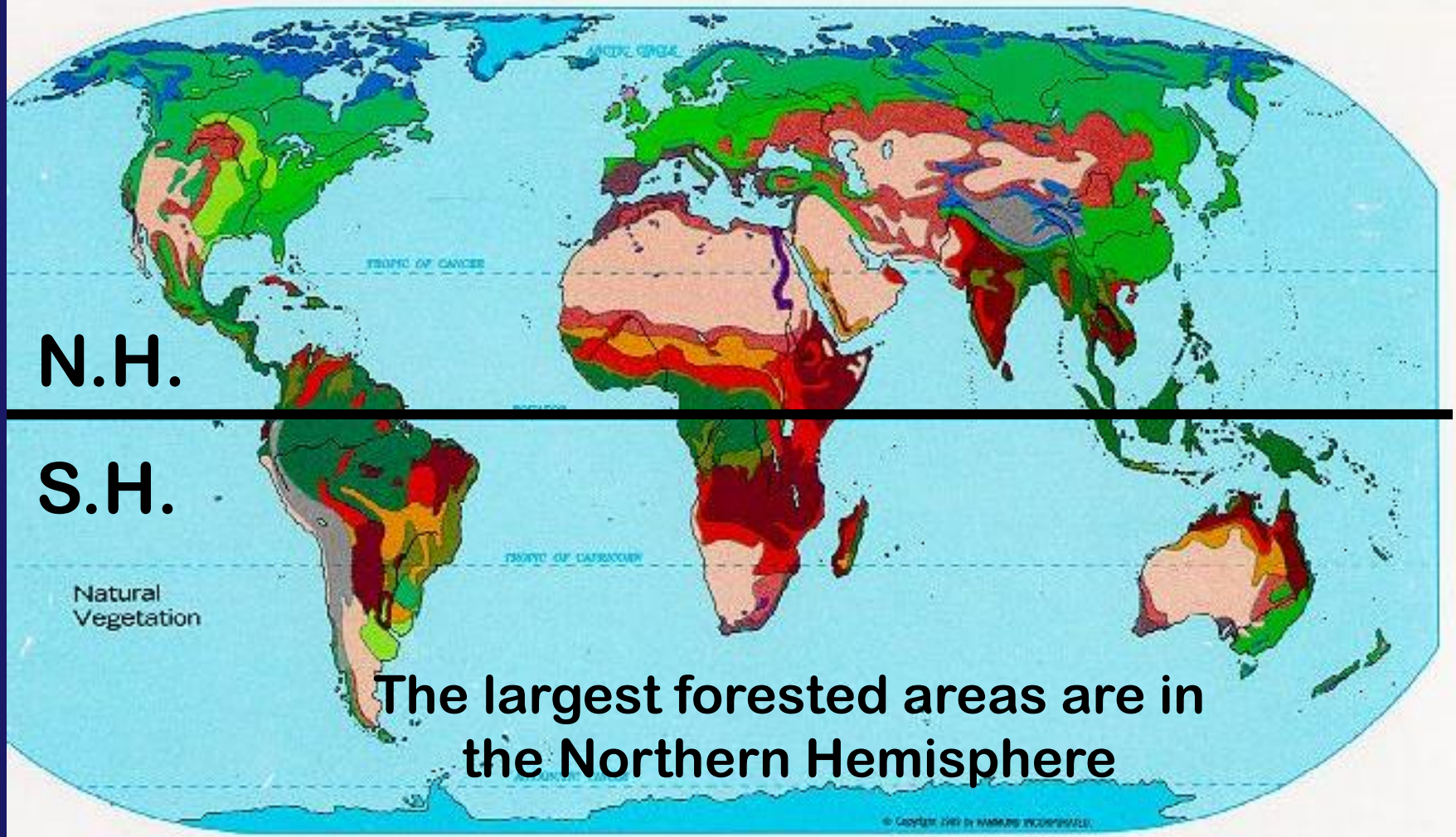


Trend due to anthropogenic increases has been removed.



Oscillations represent seasonal fluctuations driven by the balance between respiration & photosynthesis

(dominated by Northern Hemisphere forests)



The largest forested areas are in the Northern Hemisphere

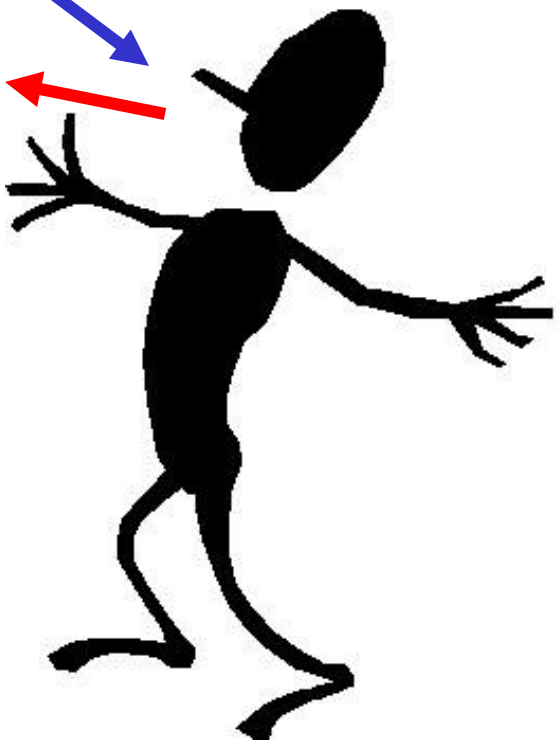
GLOBAL VEGETATION PATTERNS

"Breathing" -- ANIMALS vs. PLANTS

Respiration

O_2

CO_2

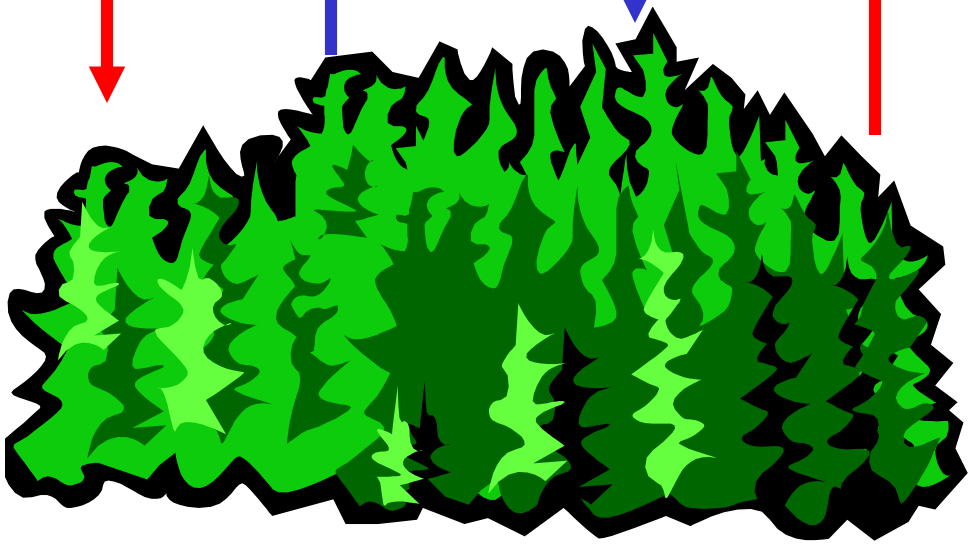


Photosynthesis

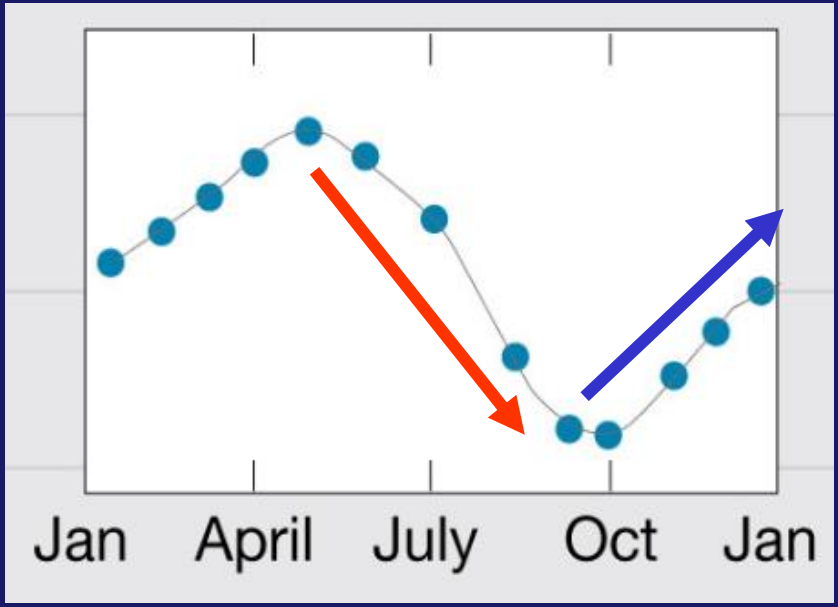
CO_2 O_2

Respiration & Decomposition

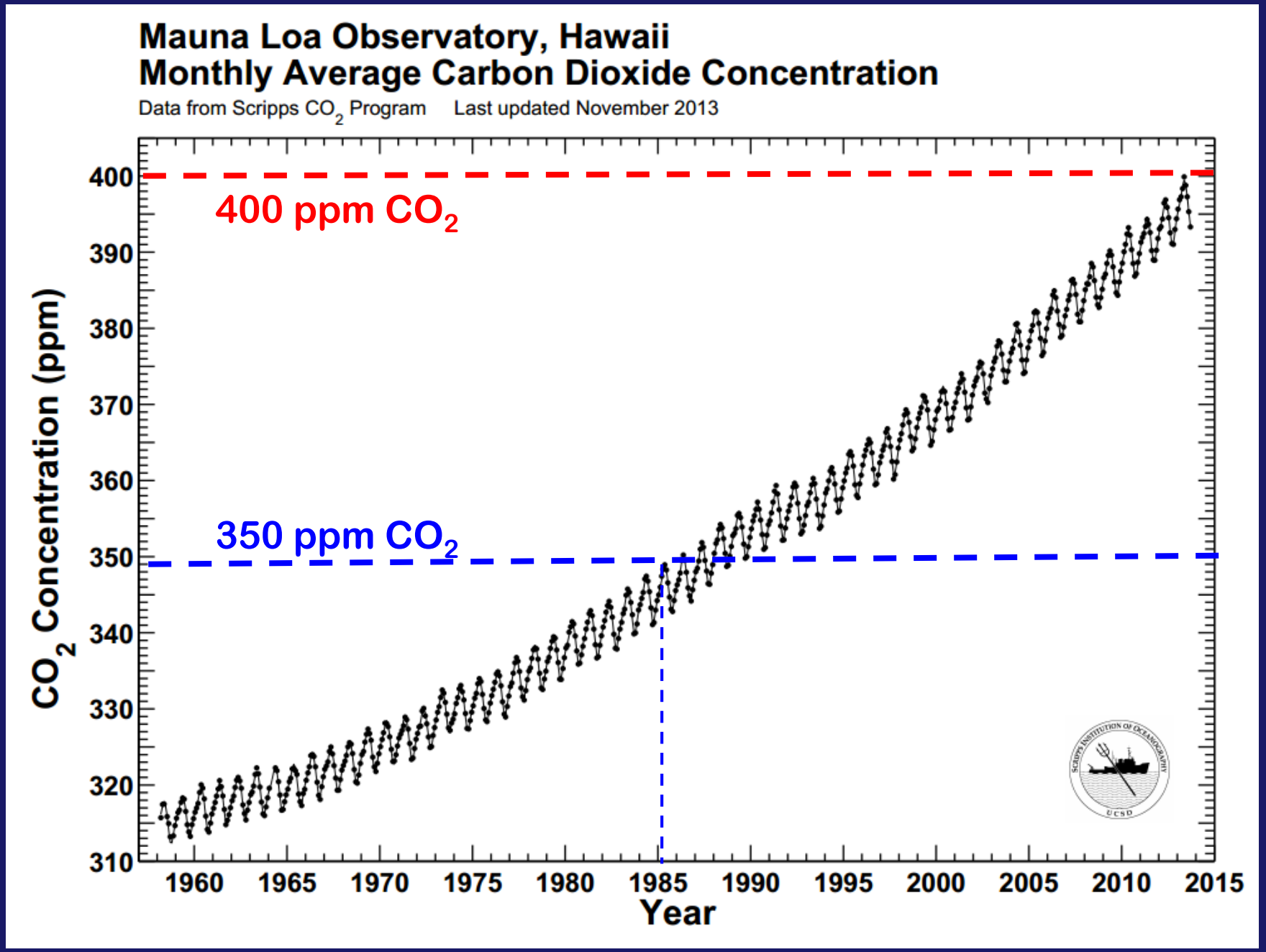
O_2 CO_2



Photosynthesis > Respiration
(CO_2 goes down in SUMMER as forests "breathe in" more CO_2)



Respiration > Photosynthesis
(CO_2 levels rise in FALL/WINTER as forests "breathe out" more CO_2)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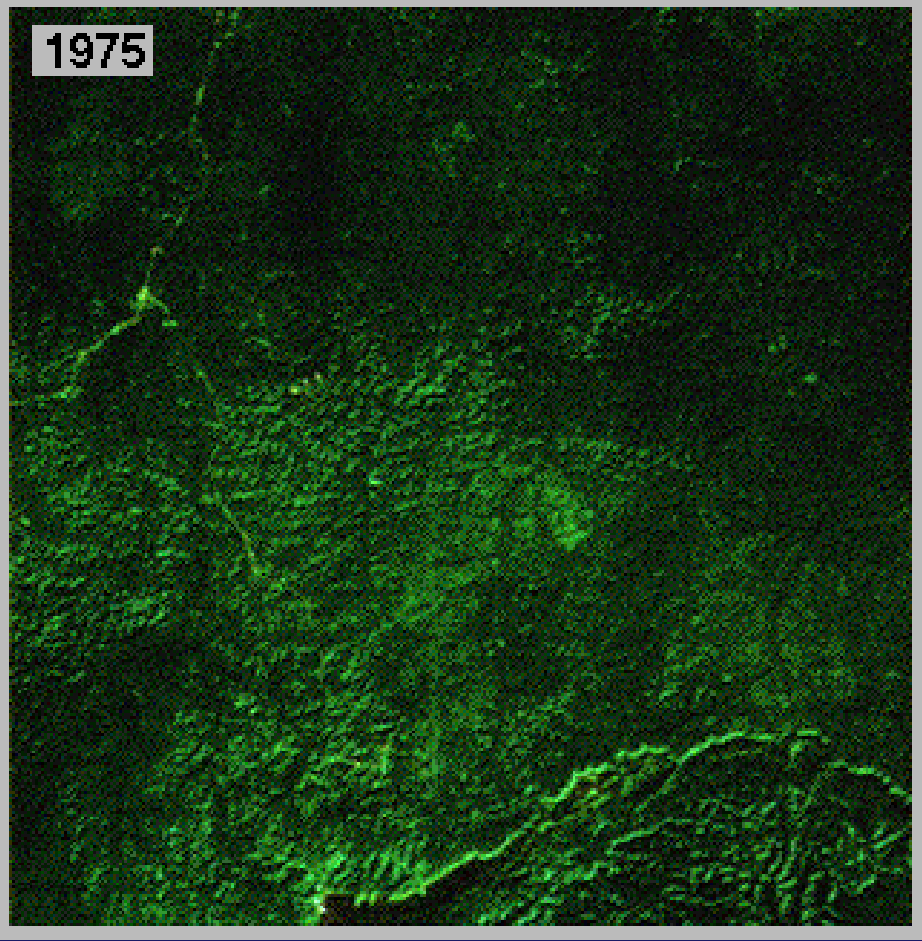
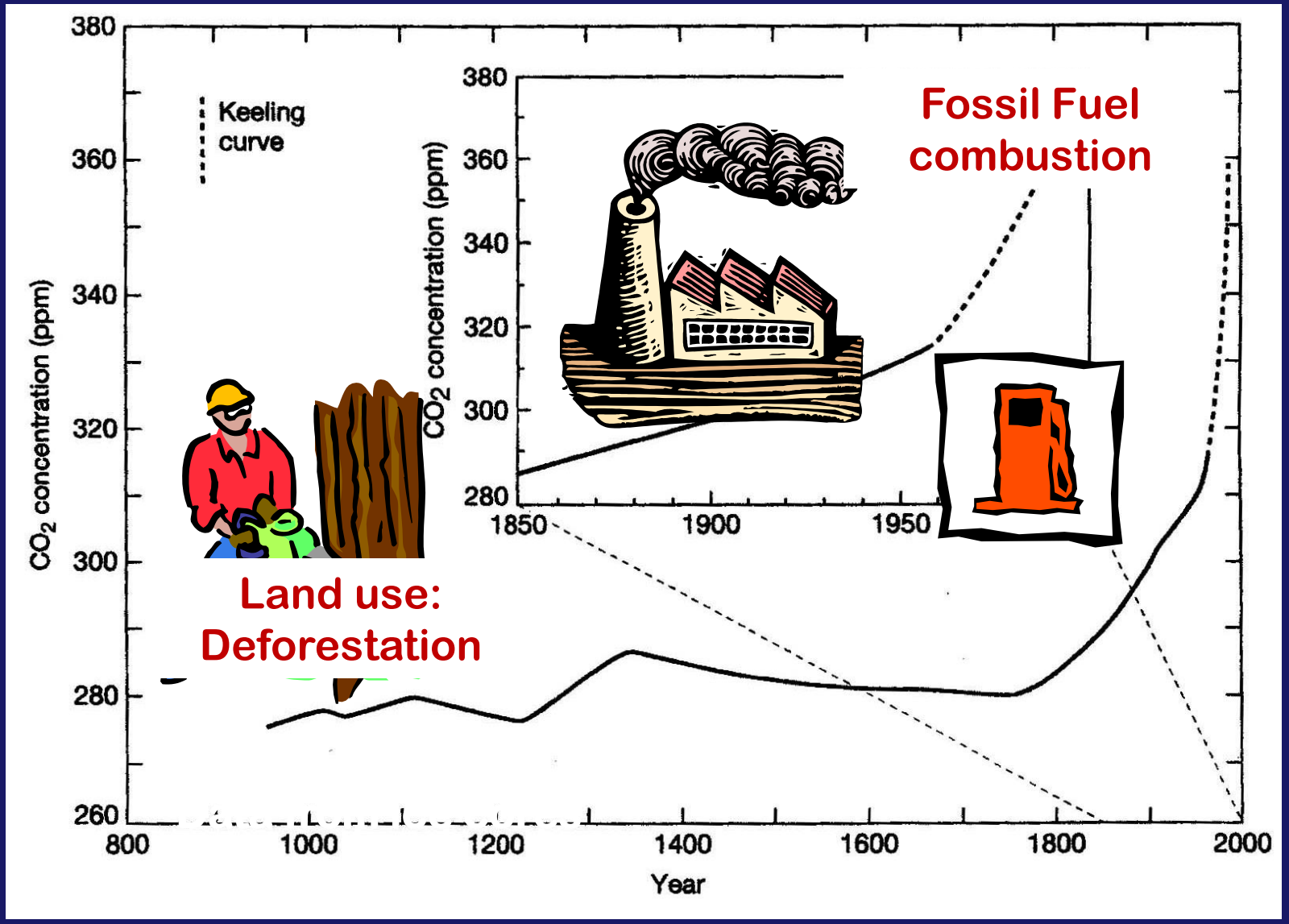
2015

LAND USE CHANGES:

Deforestation practices increase burning & decomposition of large areas of forest

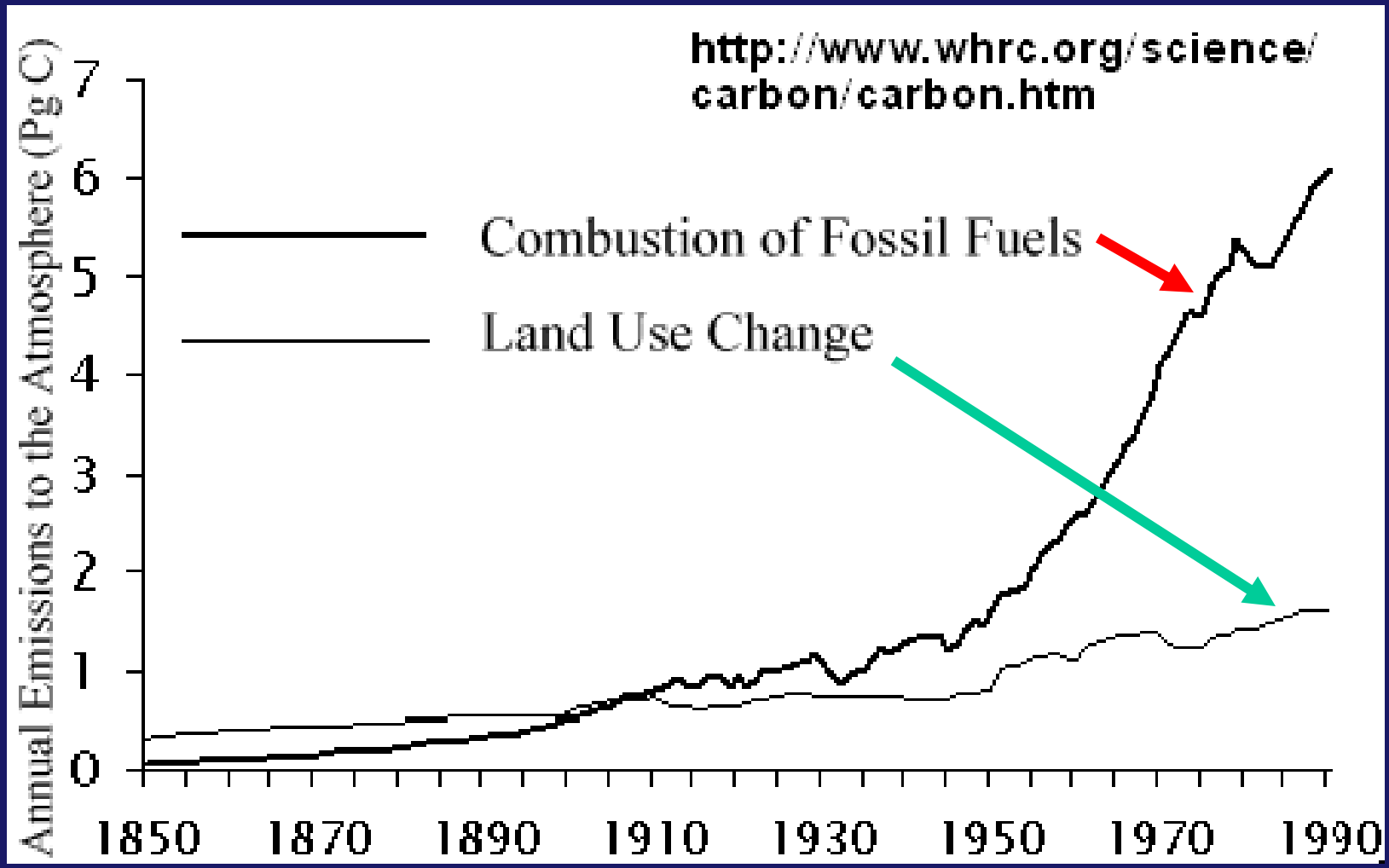


CARBON DIOXIDE: Two big sources

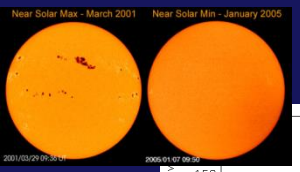


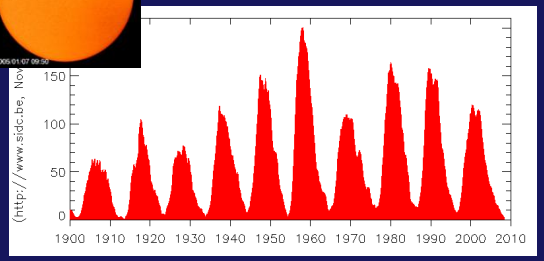
Review

Time Series Graph comparison of two ways CARBON gets into atmosphere:

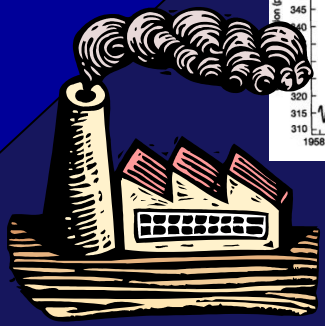


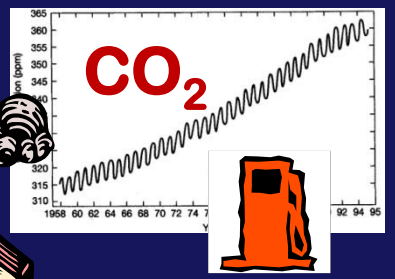
NATURAL FORCING



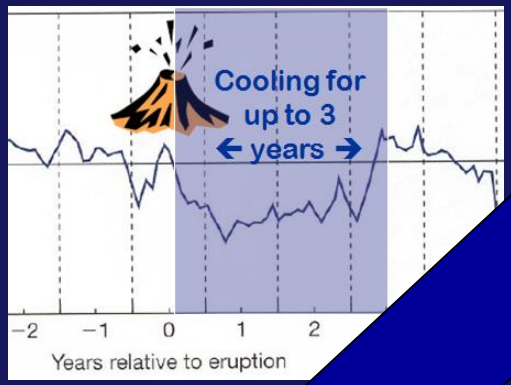


Solar output variations, sunspots



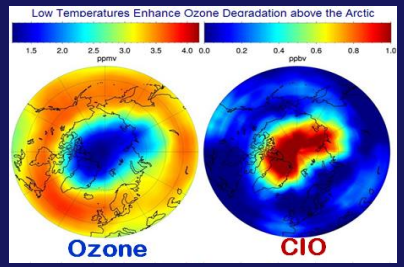


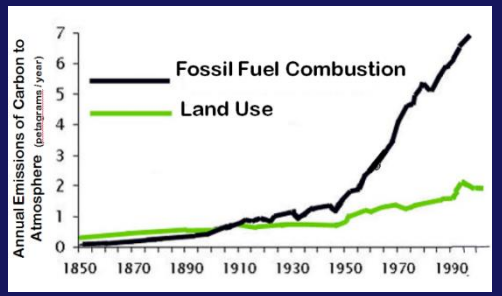
TOPIC 13
ENHANCED GHE → GLOBAL WARMING



Volcanic eruptions

TOPIC 12
Ozone Depletion





ANTHROPOGENIC FORCING

Tropospheric "dimming"

soot, SO_2

Other GREENHOUSE GASES

Albedo Changes

TO BE CONTINUED . . . .