Tuesday Nov 18th

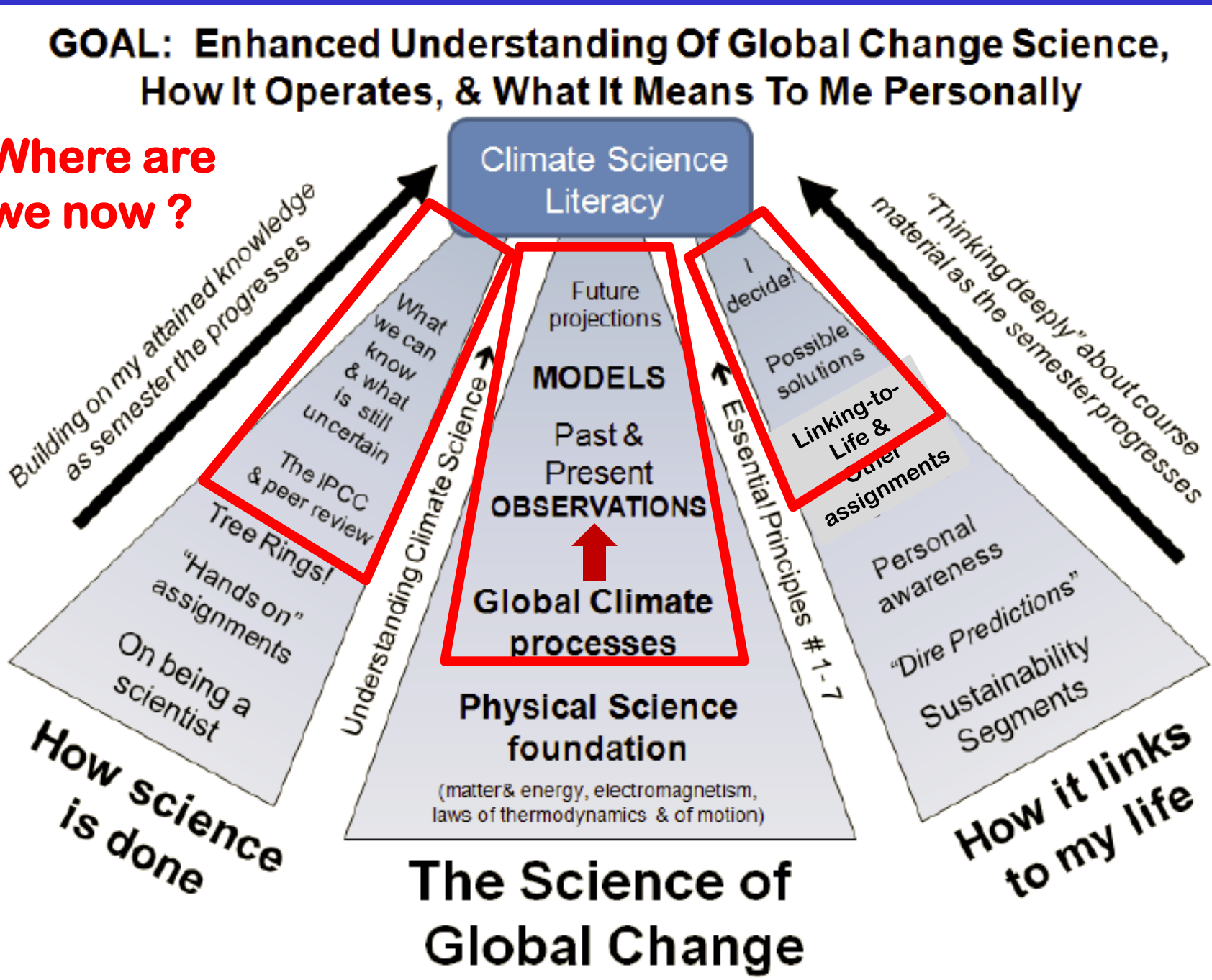
SIT ANYWHERE YOU WISH TODAY!

Topic #12 on Ozone wrap-up and . . . .

TOPIC #13 GLOBAL WARMING & ANTHROPOGENIC FORCING – Parts A+B

ANNOUNCEMENTS:

- RQ-8 was due TODAY, 30 min before class – missed? FAQ#22
- I-4 Lesson 4 is due Thursday before midnight
- TEST #4 is a week from today! Top 10 posted Thurs pm
  Study Session next Monday
- LINKING-to-LIFE Part B is posted: Movie time begins!
  Part C will be posted tonight – Read it through & questions about the assignment will be answered on Thursday


GOAL: Enhanced Understanding Of Global Change Science,
How It Operates, & What It Means To Me Personally
Where are we now ?
Climate Science Literacy
Building on my attained knowledge as semester the progresses
"Thinking deeply" about course material as the semester progresses
What we can know & what is still uncertain
The IPCC & peer review
Tree Rings!
"Hands on" assignments
On being a scientist
How science is done
Understanding Climate Science
Future projections
MODELS
Past & Present OBSERVATIONS
Global Climate processes
Physical Science foundation
(matter& energy, electromagnetism, laws of thermodynamics & of motion)
Essential Principles #1-7
I decide!
Possible solutions
Linking-to-Life &
assignments
Personal awareness
"Dire Predictions"
Sustainability Segments
How it links to my life
The Science of Global Change

You are almost done!

After this week . . . here's what's left:

TESTS

1 RQ: RQ-9
Due anytime before the FINAL EXAM

1 Test: Test #4
Next Tuesday Nov 25th

the Final Exam
On Thursday Dec 18th

GROUP ASSIGNMENTS
(In-Class Activities)

- G-1 Absorption Curves
- G-2 Energy Efficiency
- G-3 Applying the Energy Balance Terms
- G-4 Tree-Ring Wood Kit Activity — *Directions now posted*
- G-5 Volcanism & Climate
- *G-6 Bristlecone Pine Activity* (in class after Thanksgiving)

INDIVIDUAL ASSIGNMENTS
(Short Writing Assignments)

- I-1 Climate Science Basics — Lesson 1 CO_2 & the GH Effect — Past due
- I-2 Climate Science Basics — Lesson 2 Mother Nature's Influence — Past due
- I-3 Climate Science Basics — Lesson 3 Observable Changes — **Due Thur Nov13**
- I-4 Climate Science Basics — Lesson 4 Intro to Climate Modeling — **Due Thur Nov 20**

That's it!

LINKING-TO-LIFE PROJECT
(Individual Project)

PROJECT OVERVIEW
(Project Total = 130 pts)

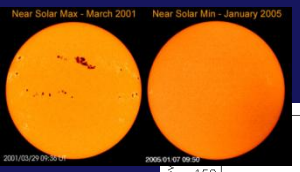
- PART A — Your Ecological Footprint (25 pts)
- PART B — Global Change Film & Video Commentary (15 pts)

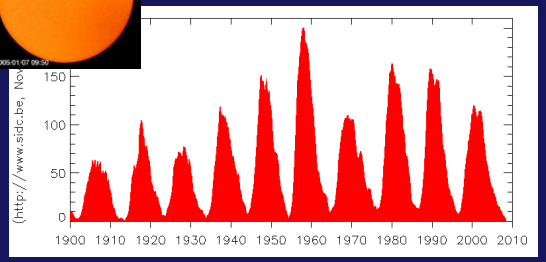
Due Tue after Thanksgiving

- PART C — Linking-to-Life Report & Slide (90 pt

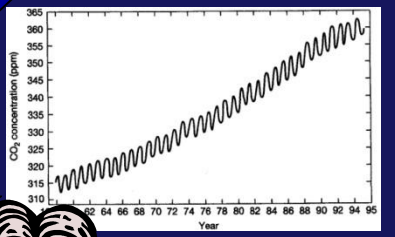
← Due last day of class, Dec 11

NATURAL FORCING

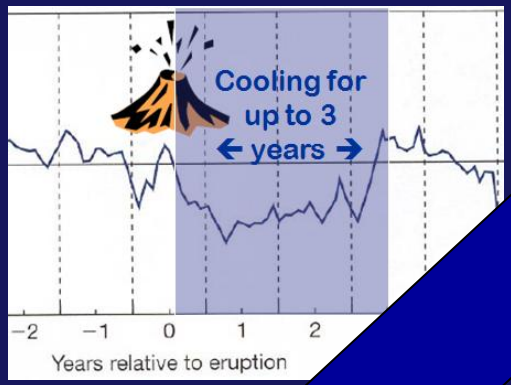




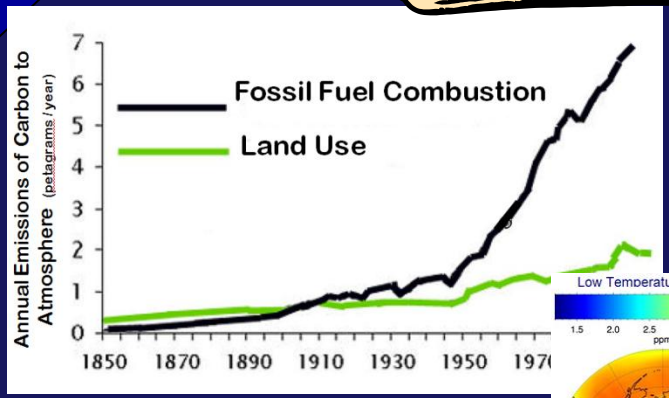
Solar output variations, sunspots

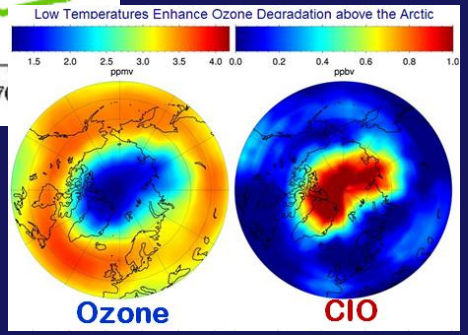


GHG's, soot, SO_2



Volcanic eruptions





Surface Albedo Changes

ANTHROPOGENIC FORCING

The STORY OF THE DISCOVERY OF THE OZONE HOLE:

"A Misadventure of Science?"

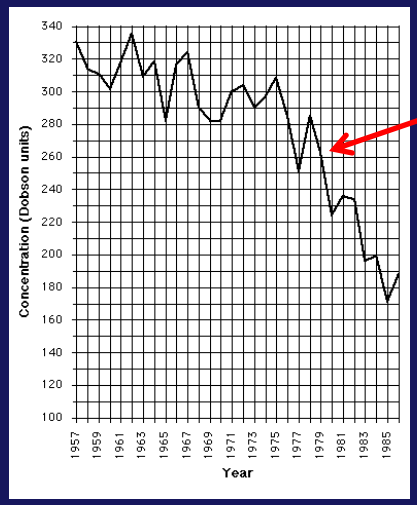
DISCOVERY OF THE OZONE HOLE:

"A Misadventure of Science?"

CHAPTER 1

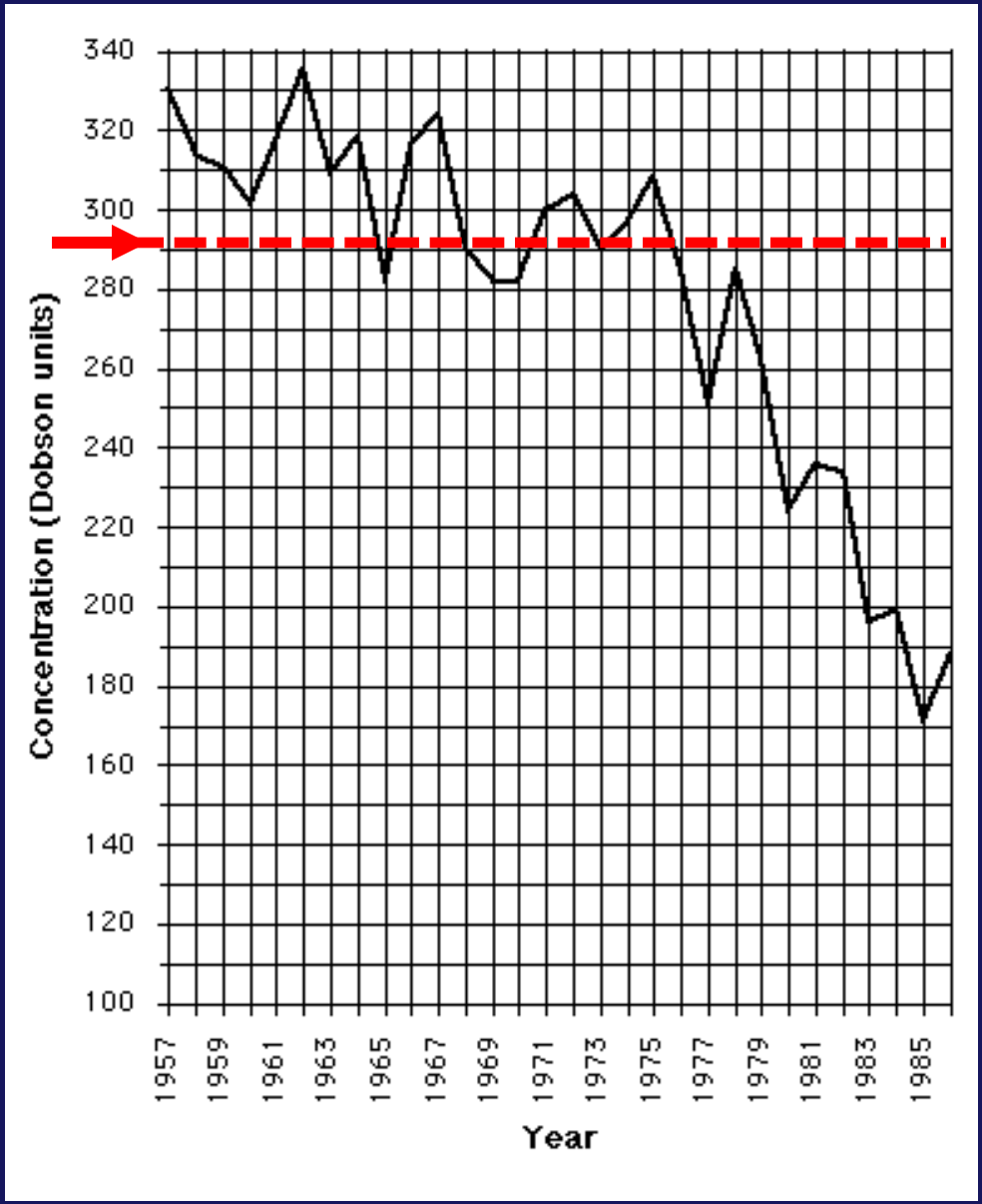
- **Ground-based** ozone measurements since **1956**. (British survey team)

- 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)

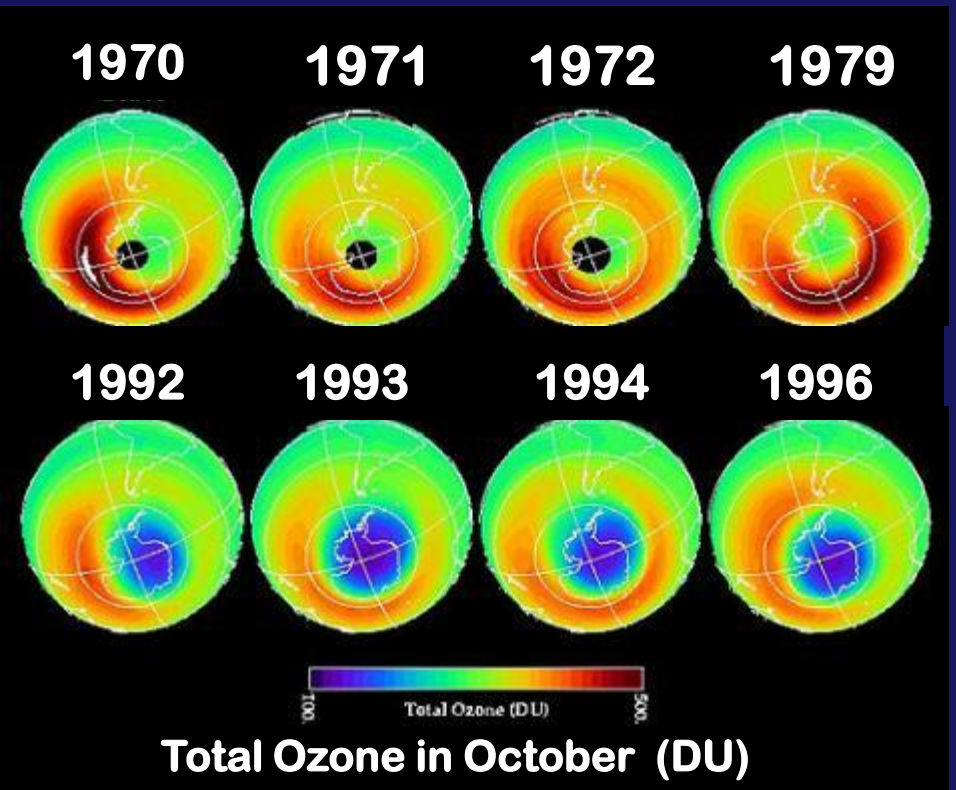
1957-1986

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

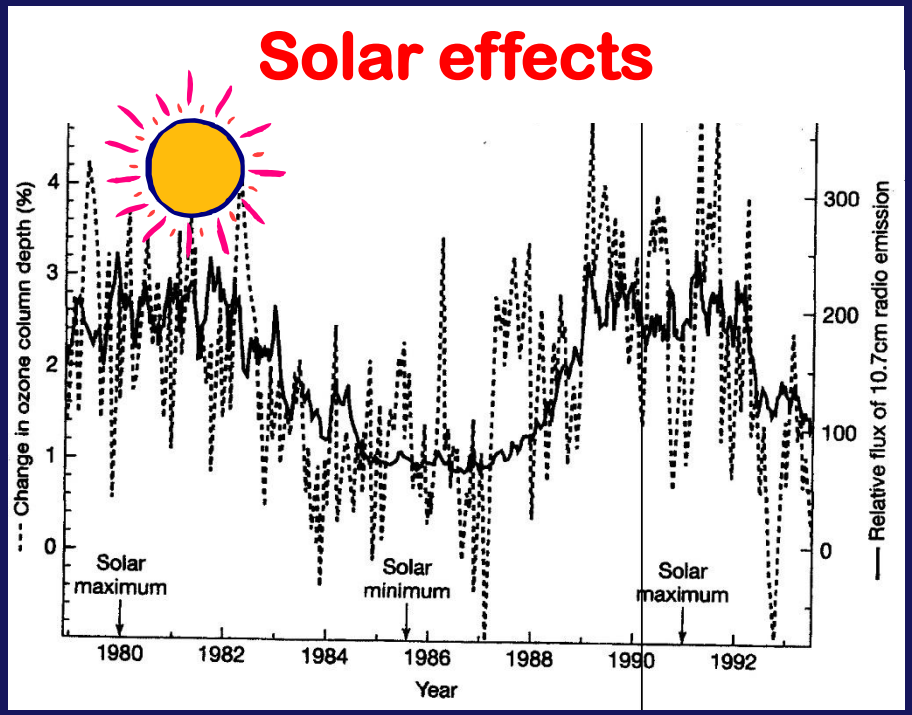


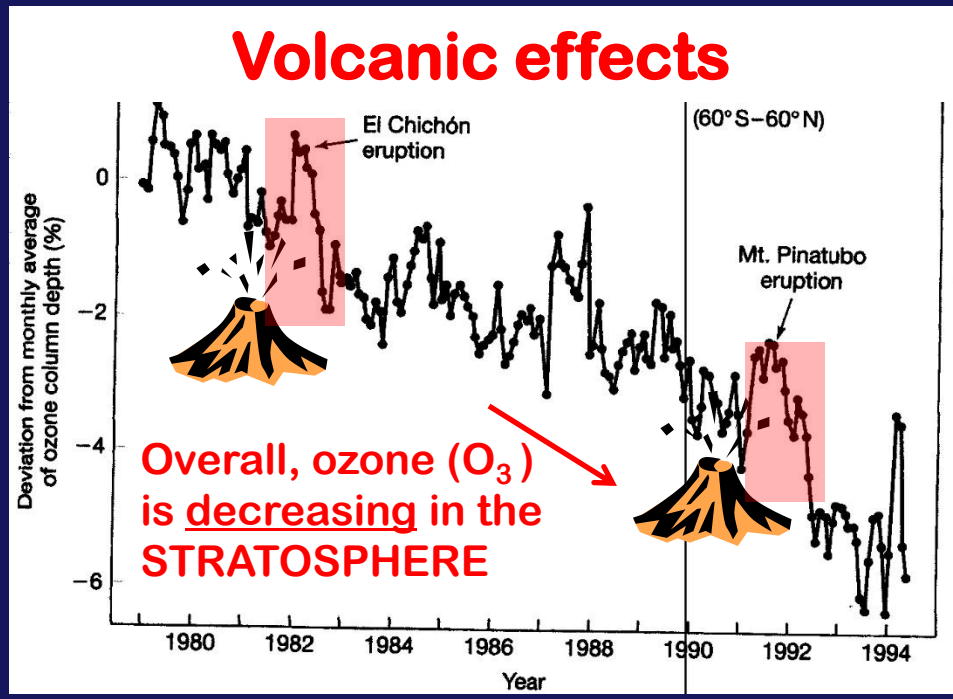
Total Ozone in October (DU)

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

Hypotheses & theories to explain the hole have included:

- **solar variability** (sunspot cycle ➔ Chapman variations)
- **dynamical air motion** (atmo circulation moves around O_3)
- **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!

(Atmospheric chemists Crutzen, Molina & Rowland were later given the Nobel prize for this theory)

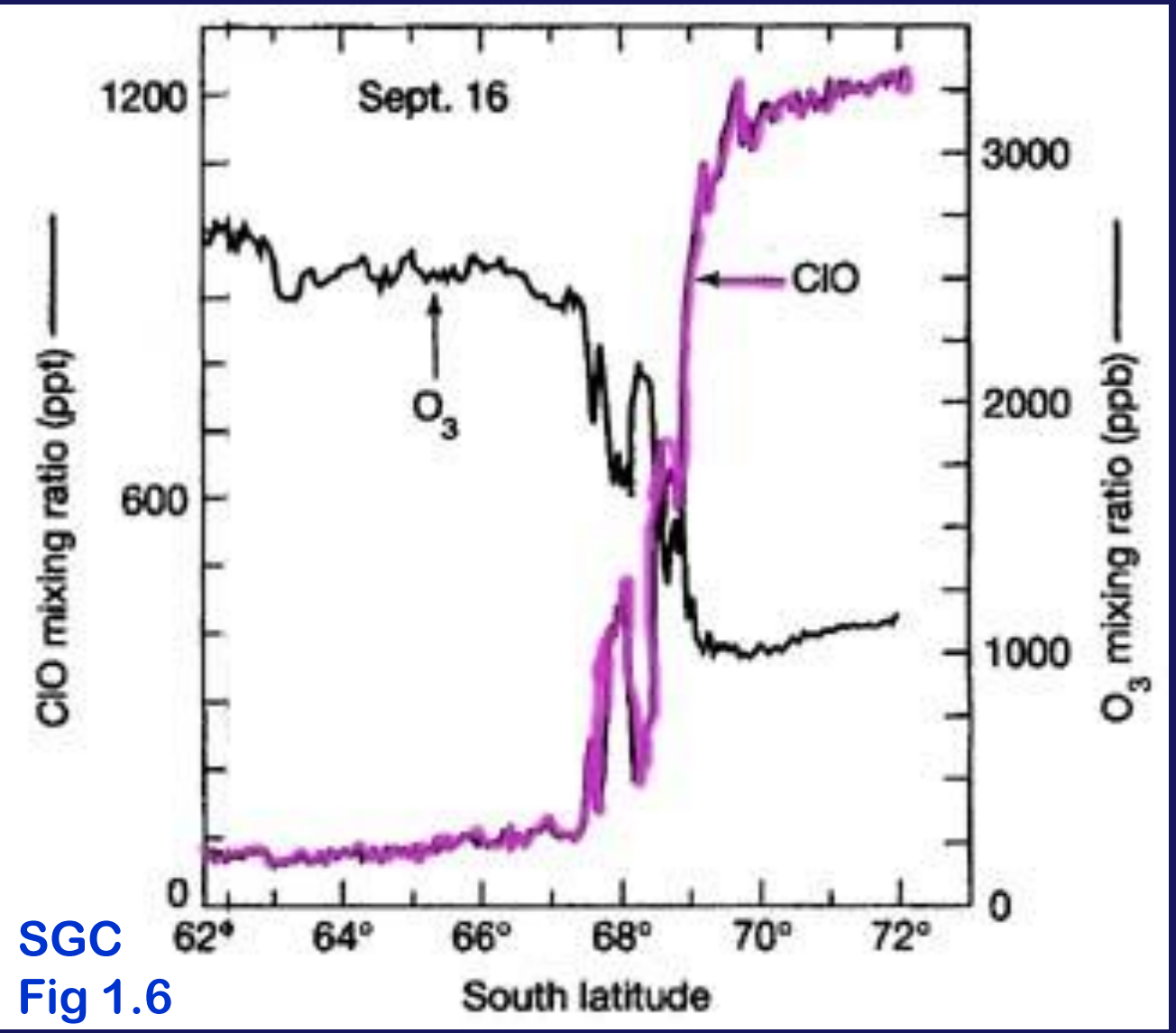
DISCOVERY OF THE OZONE HOLE

(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



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

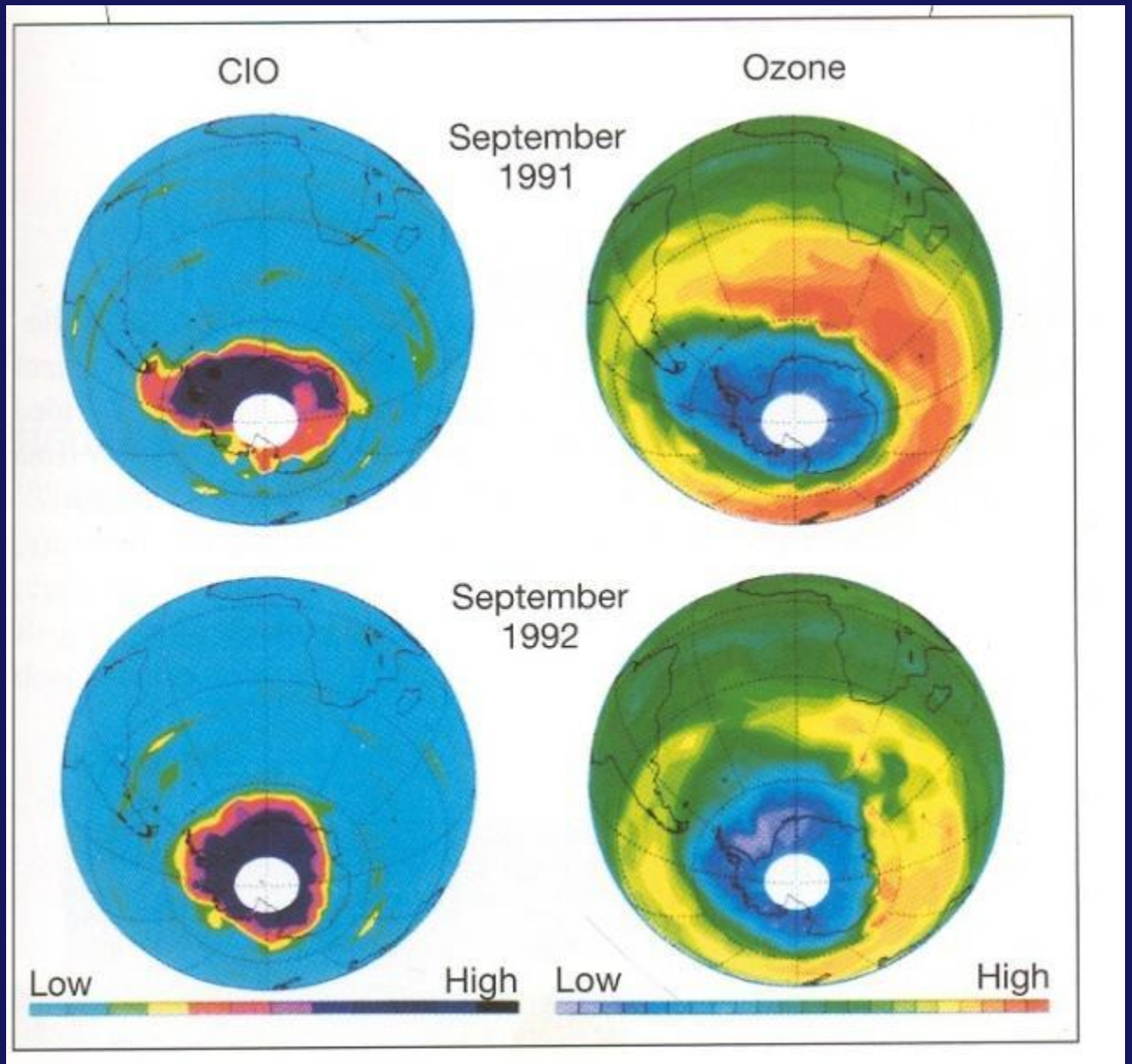
The South Pole

The chemical reaction theory – catalyzed by chlorine from CFCs -- is almost universally accepted as conclusive at present.

The prominent scientists involved in developing the chemical reaction theory were awarded the Nobel Prize for Physics in 1995.

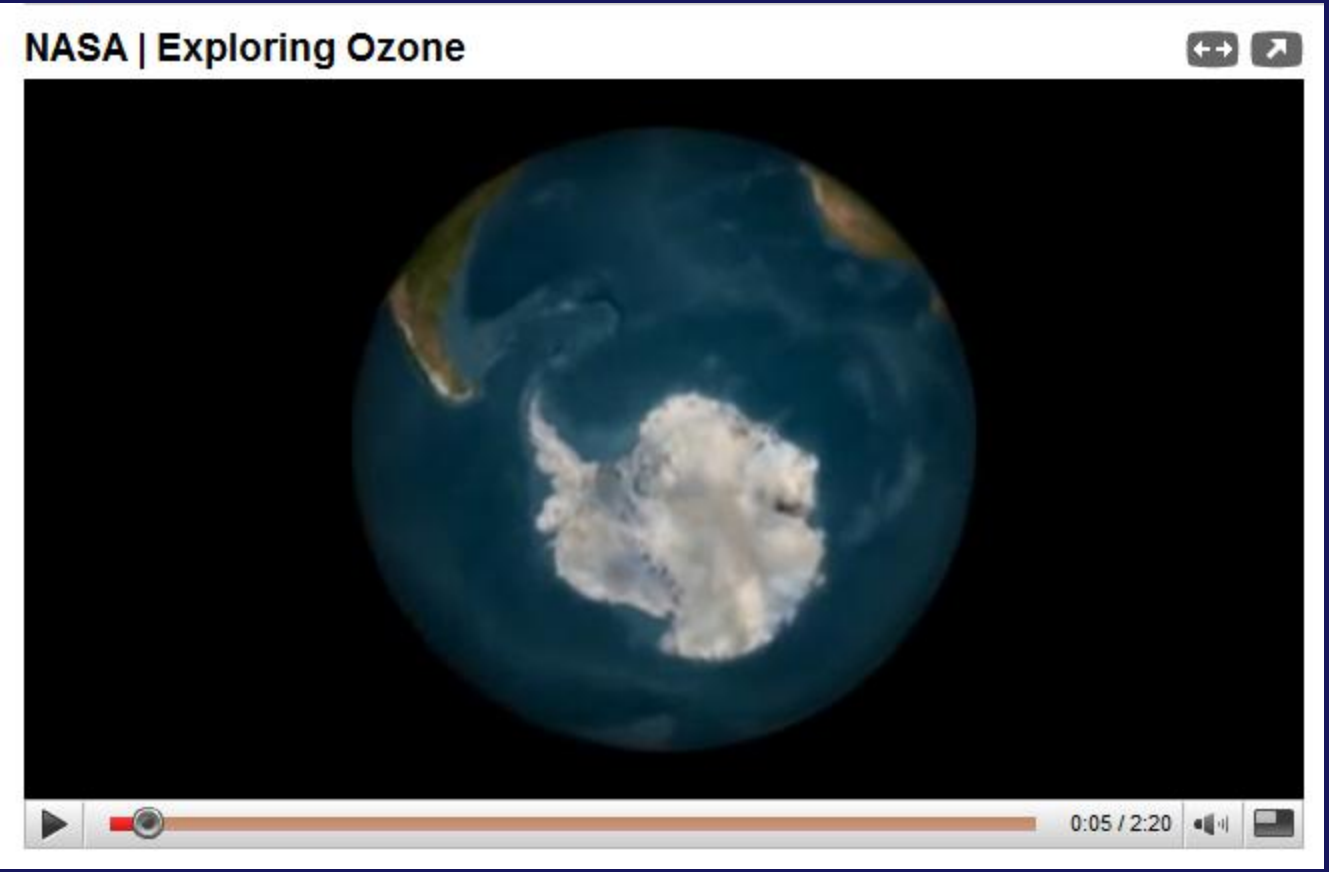
Key Concept

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



Color version of SGC Fig 1.6

Recap:



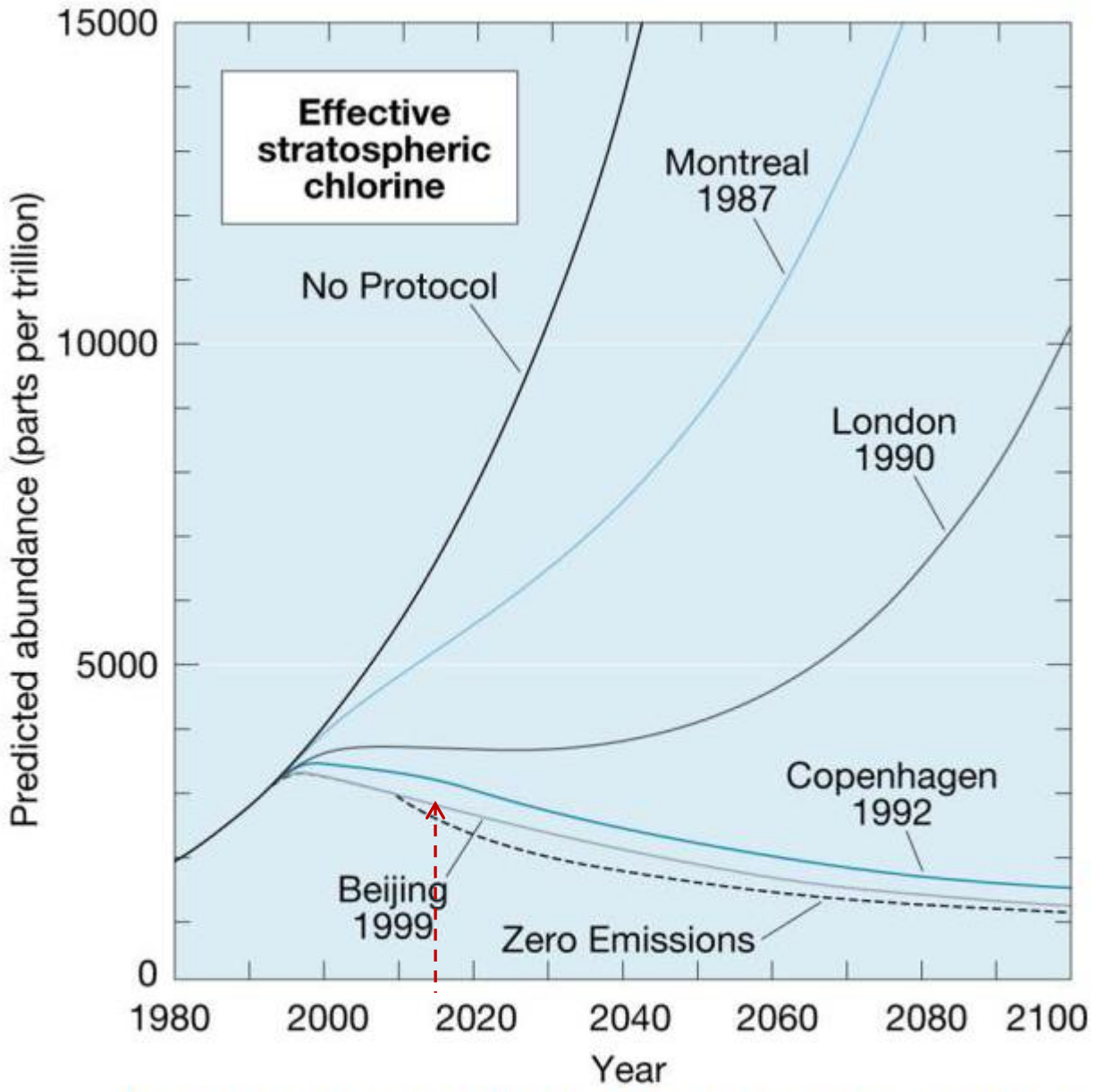
http://www.youtube.com/watch?v=qUfVMogIdr8&feature=player_embedded

HEALING THE HOLE . . . .

The OZONE & THE MONTREAL PROTOCOL

Link goes to a video projection of how and when the hole will heal . . .

http://www.youtube.com/watch?v=Dn3KvZ_Xyqs&eurl=http://www.theozonehole.com/discoverer.htm



Projected atmospheric chlorine concentrations under the various international agreements

Very long residence time of CFCs!

The world is "making do" with freon substitutes, but some concern over long-term effects of substitutes remains . . .

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

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,

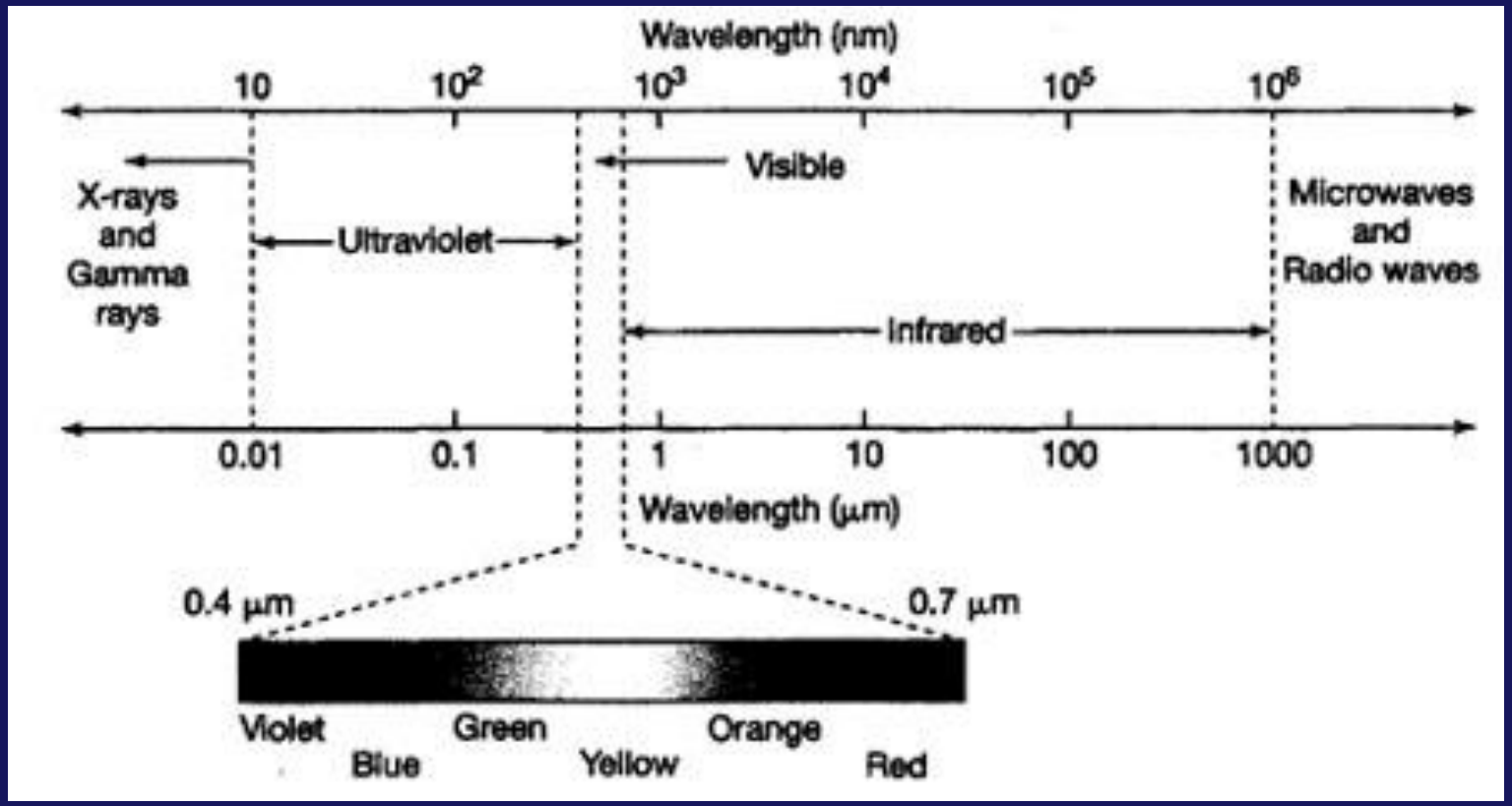
> So . . . stratospheric levels of "good ozone" are going down at a rate faster than ozone is being added in the troposphere.

Key Concept

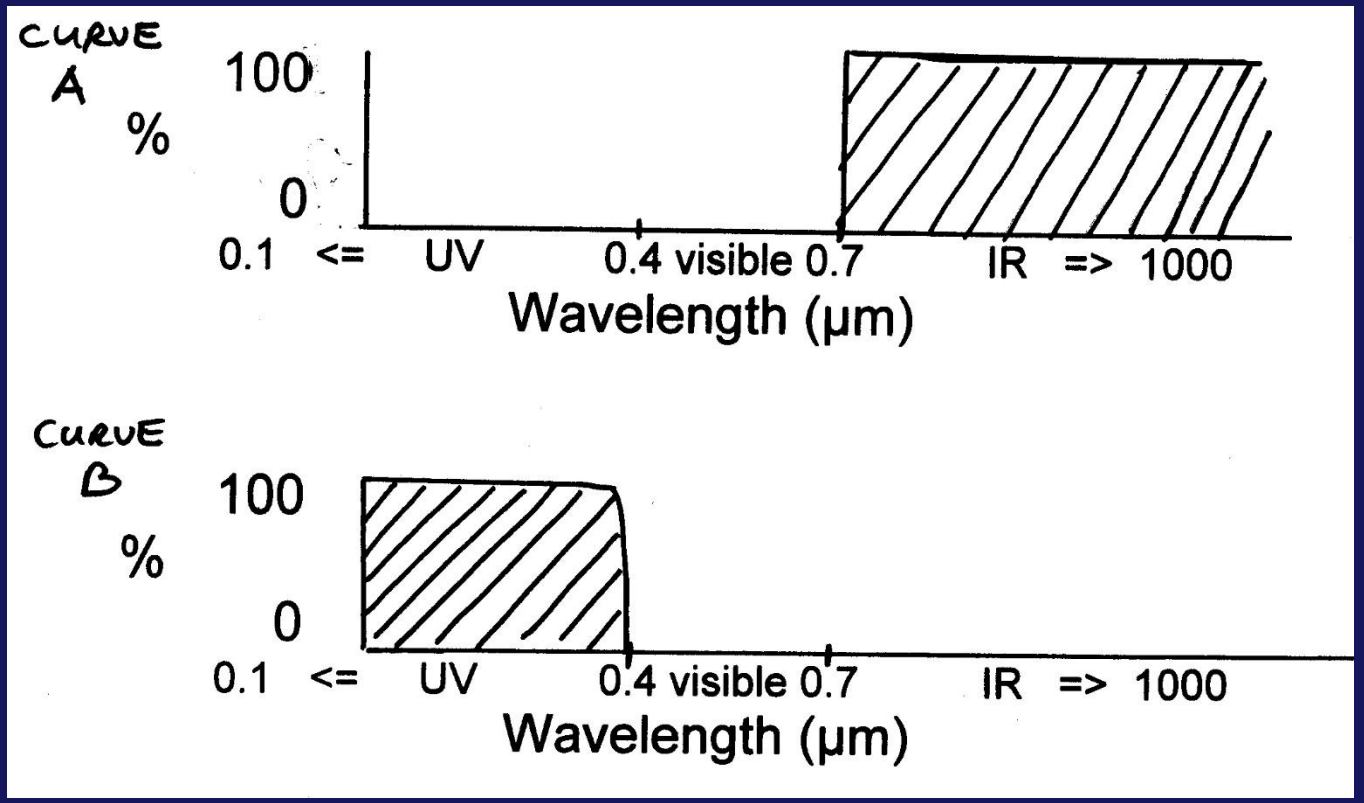
THE OZONE DEPLETION STORY TIES TOGETHER MANY OF THE CONCEPTS YOU'VE LEARNED IN THE COURSE THUS FAR:

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

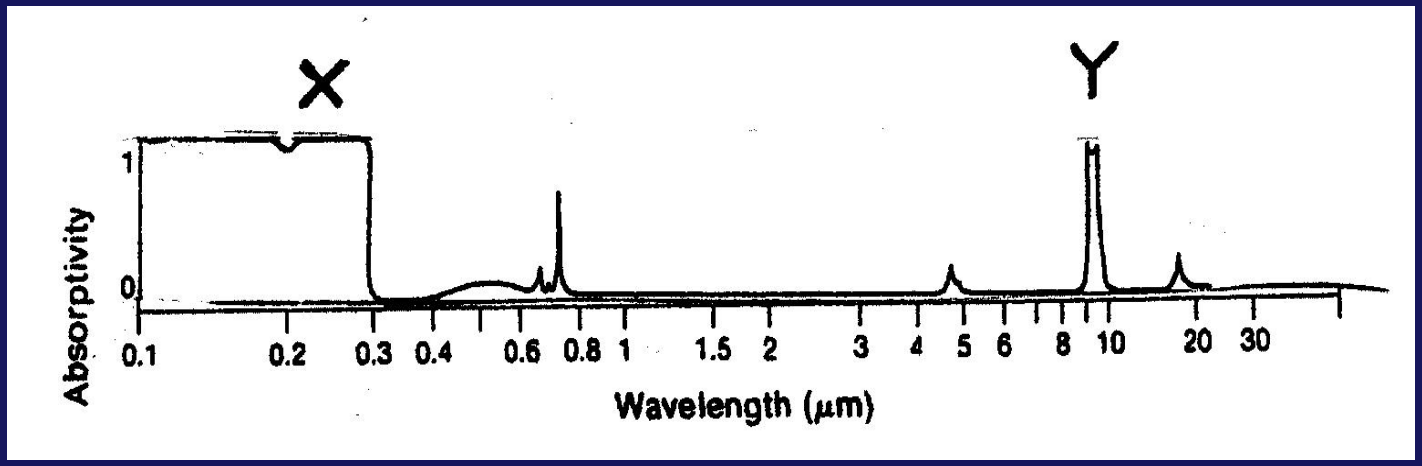
> the electromagnetic spectrum --especially the wavelengths of UV radiation



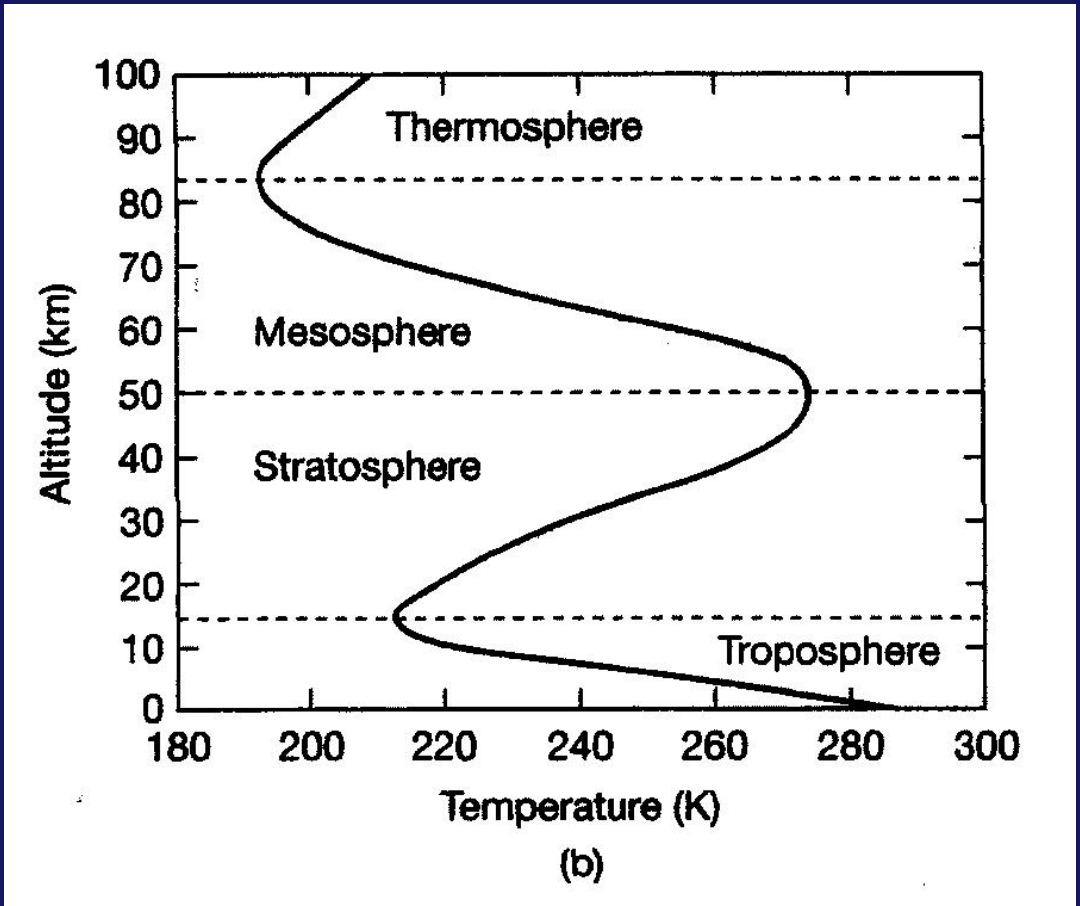
> absorption curves, especially the absorption curve for ozone



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



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



> the ever-changing nature of science; early theory right for wrong reason

> Preconceived ideas influencing one's observations

. . . and the surprise of discovery!

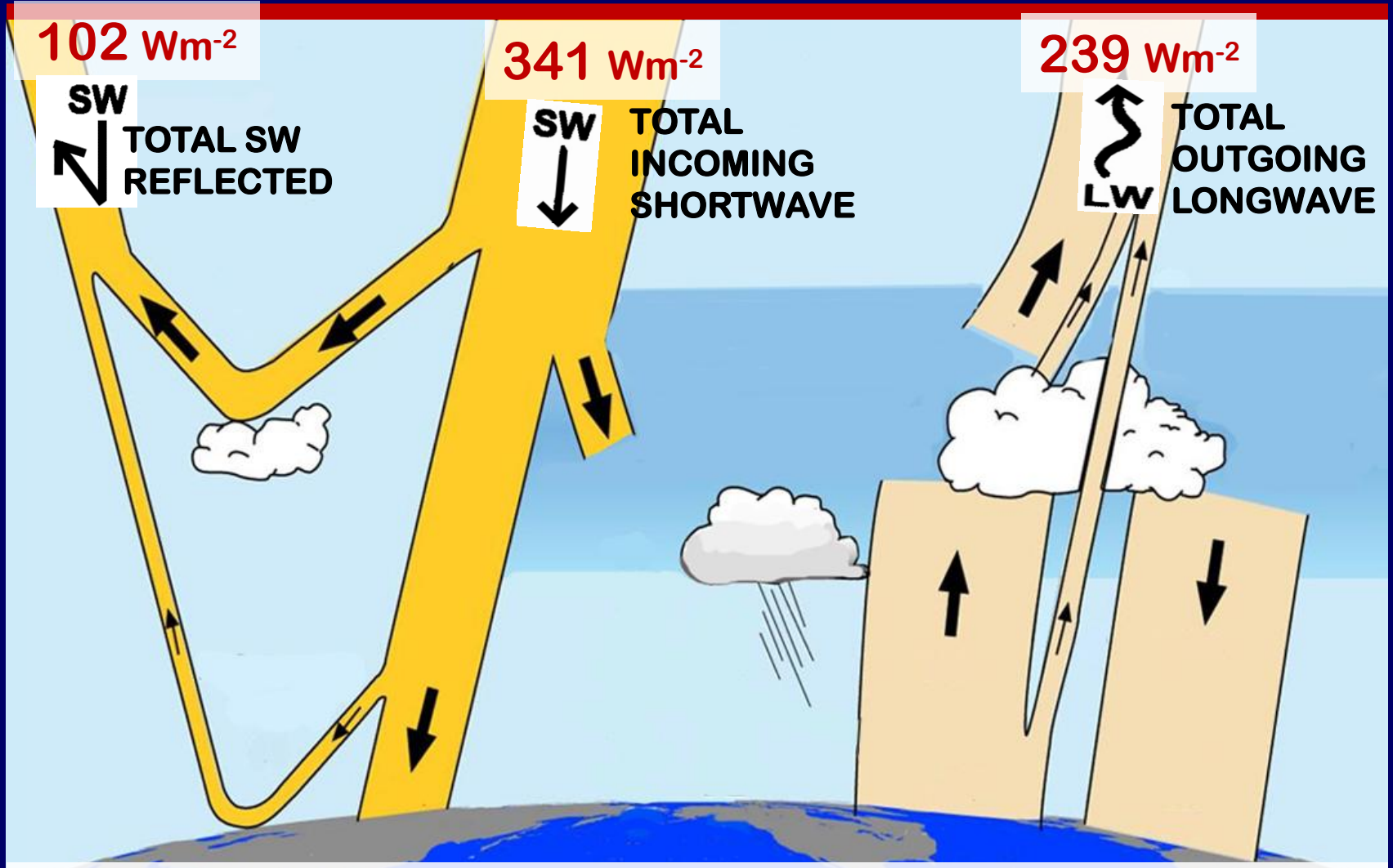
Let's wrap-up **OZONE**. . . .

CLICKER TIME!!

FLIP BACK TO
p 49 in CLASS NOTES

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

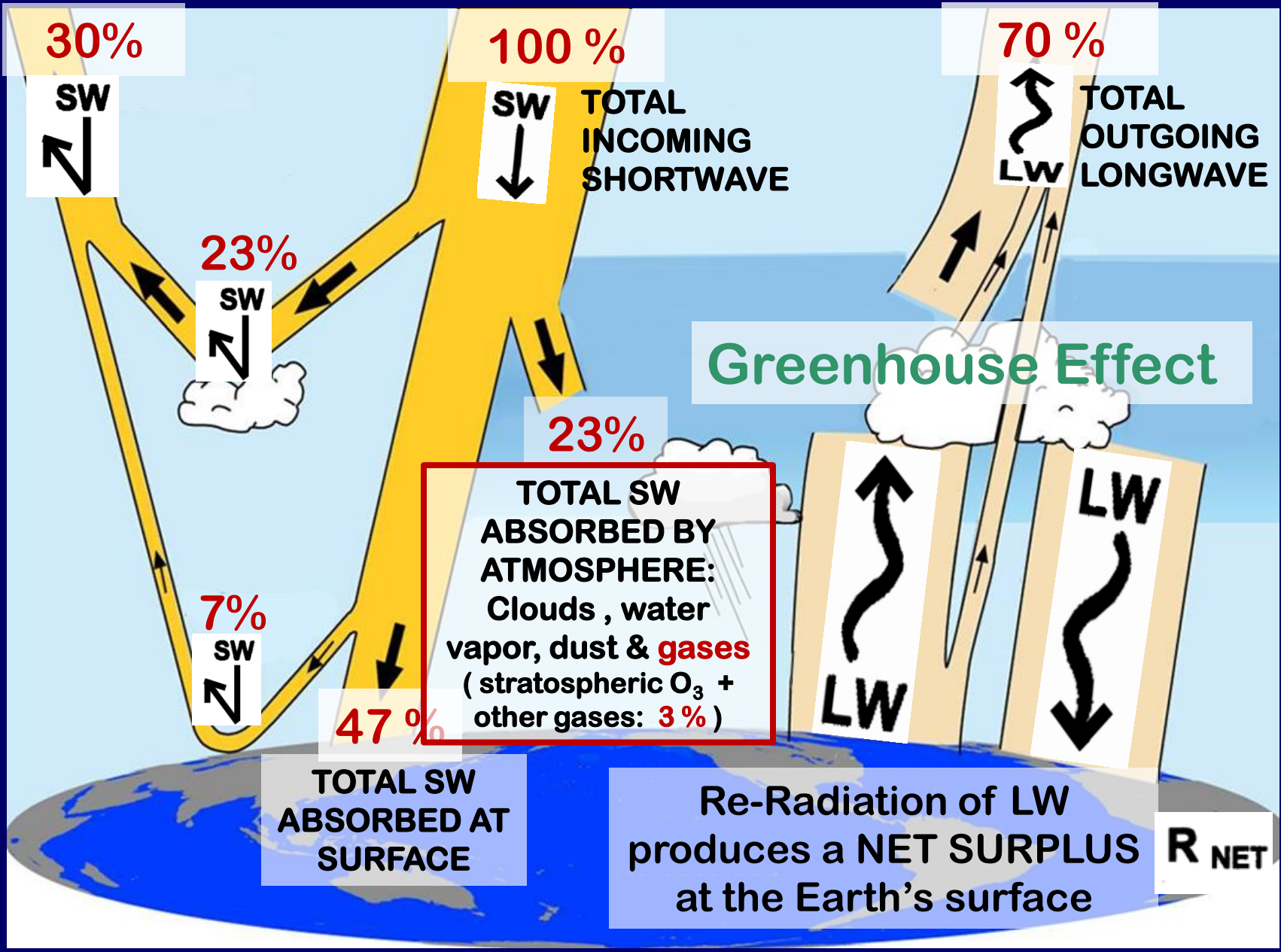
Watts / meter ^{2} measured at the "TOP" of the Atmosphere:



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

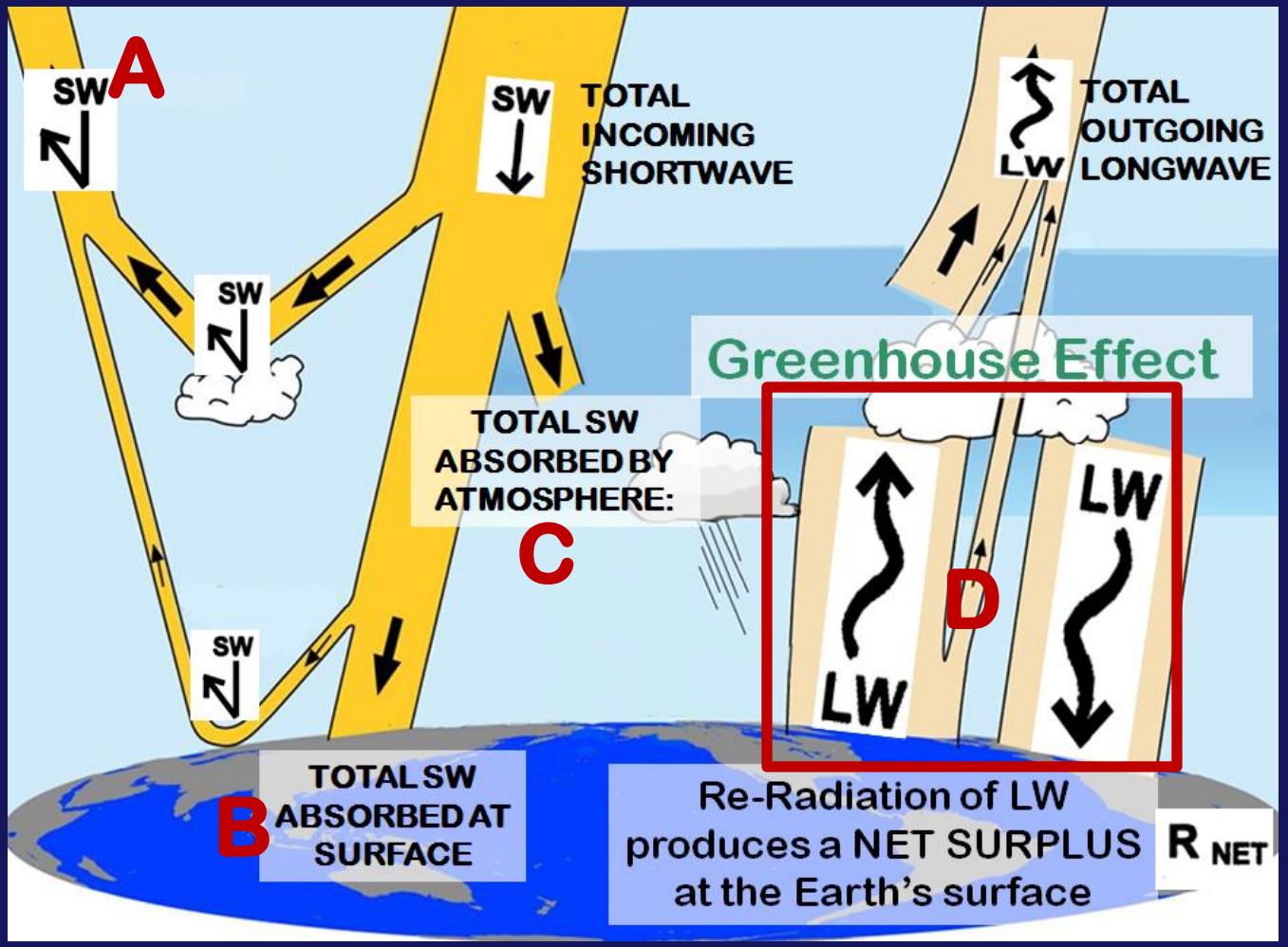
(averaged globally per year)

Review p 49


30%
SW
100 %
SW
TOTAL INCOMING SHORTWAVE
70 %
LW
TOTAL OUTGOING LONGWAVE
23%
SW
Greenhouse Effect
23%
TOTAL SW ABSORBED BY ATMOSPHERE: Clouds , water vapor, dust & gases (stratospheric O_3 + other gases: 3 %)
LW
LW
7%
SW
47 %
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



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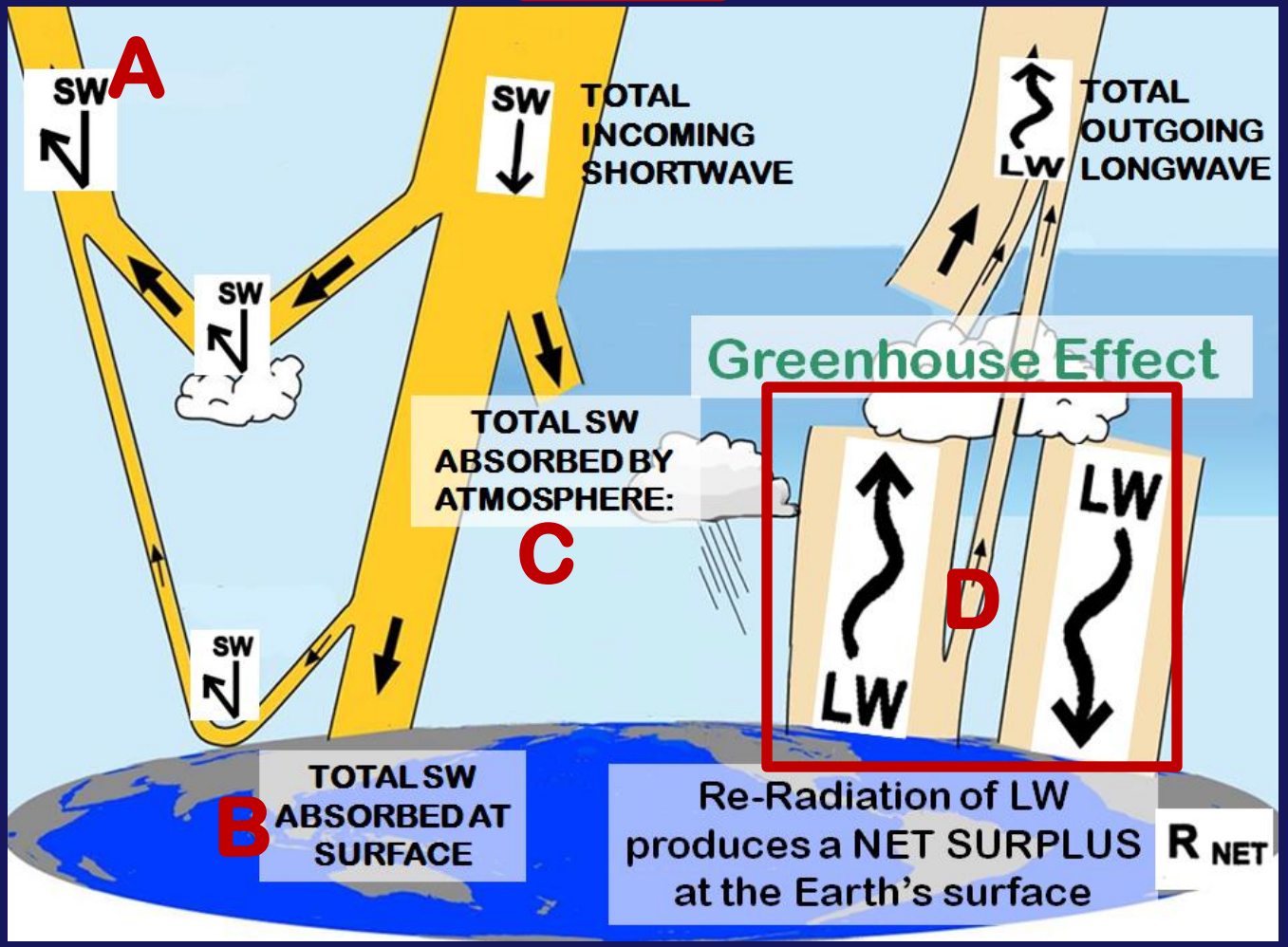
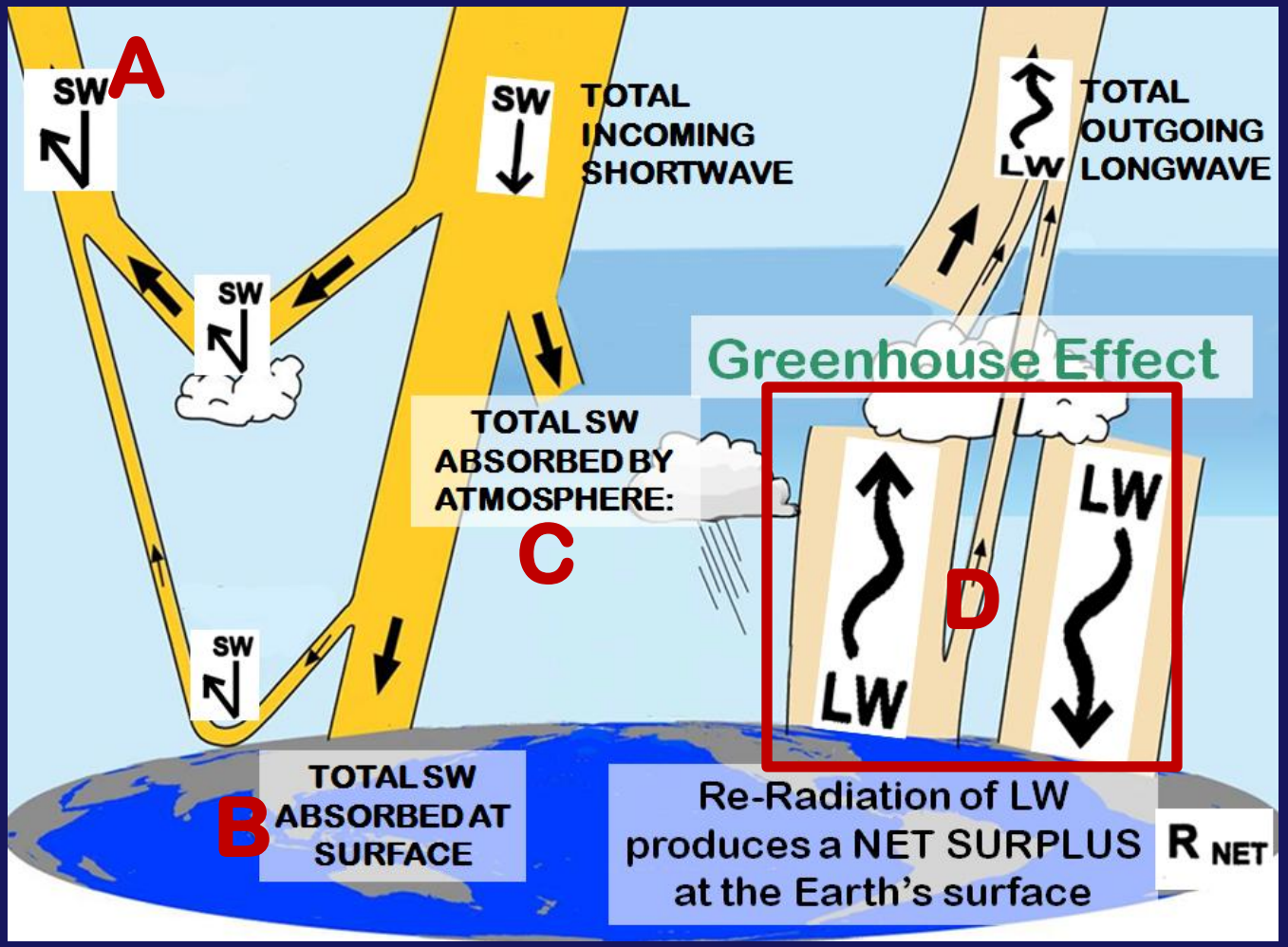
A B **C** D



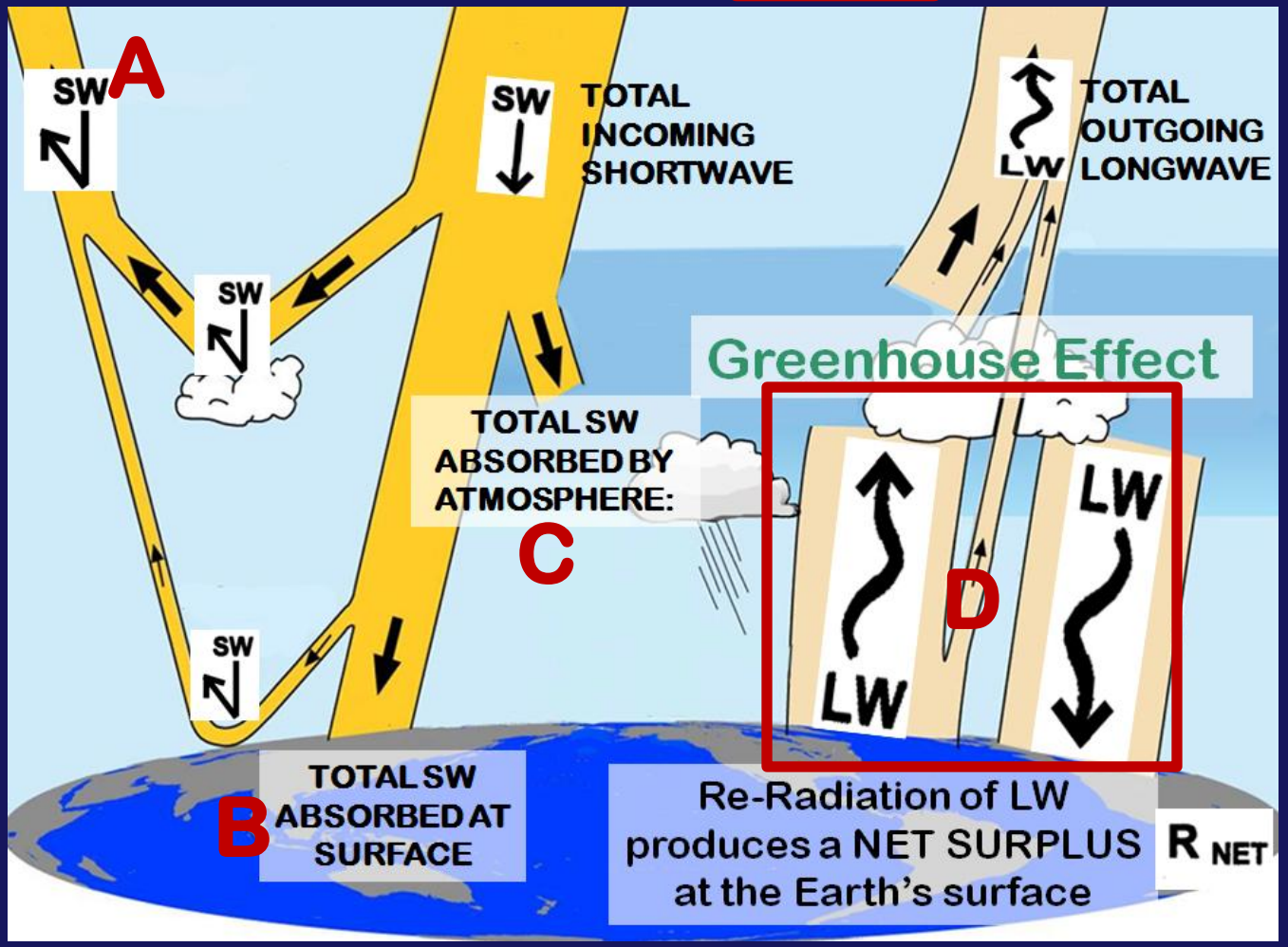
Q2. In which part of the energy balance does the activity related to GLOBAL WARMING from the enhanced GHE take place?

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

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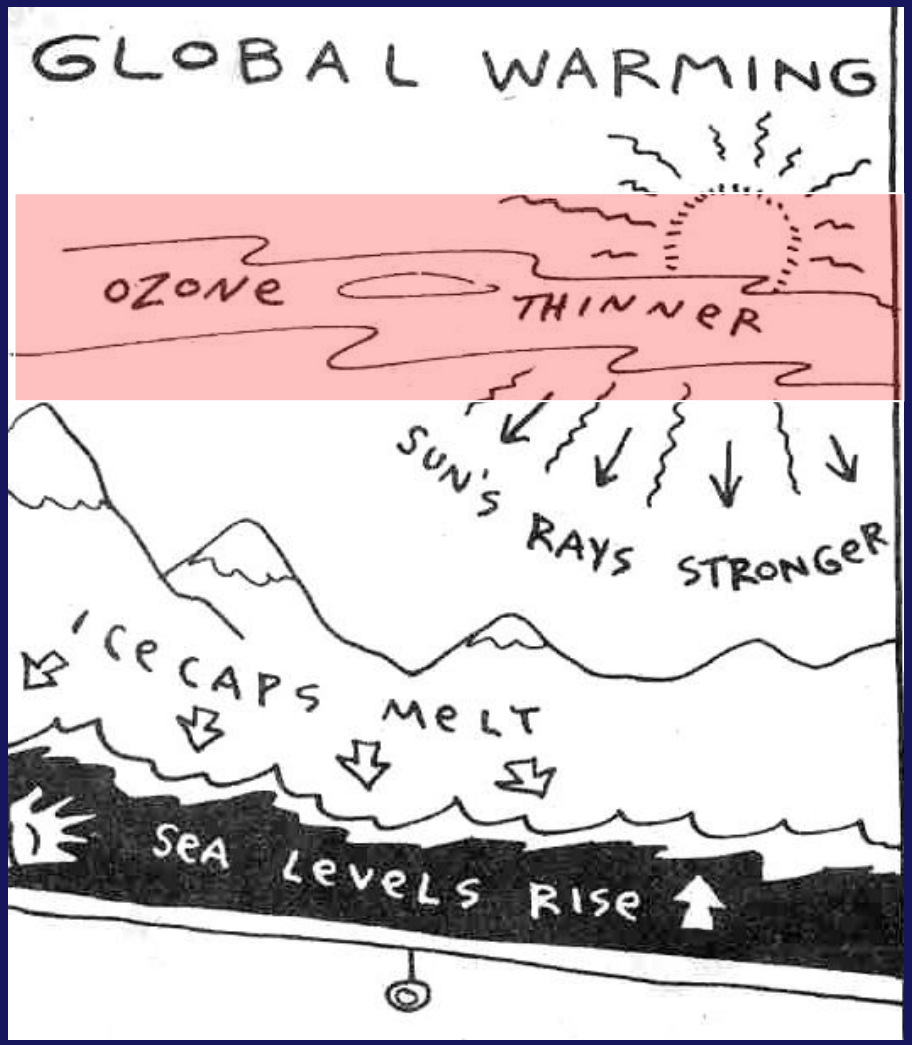
3 Neither

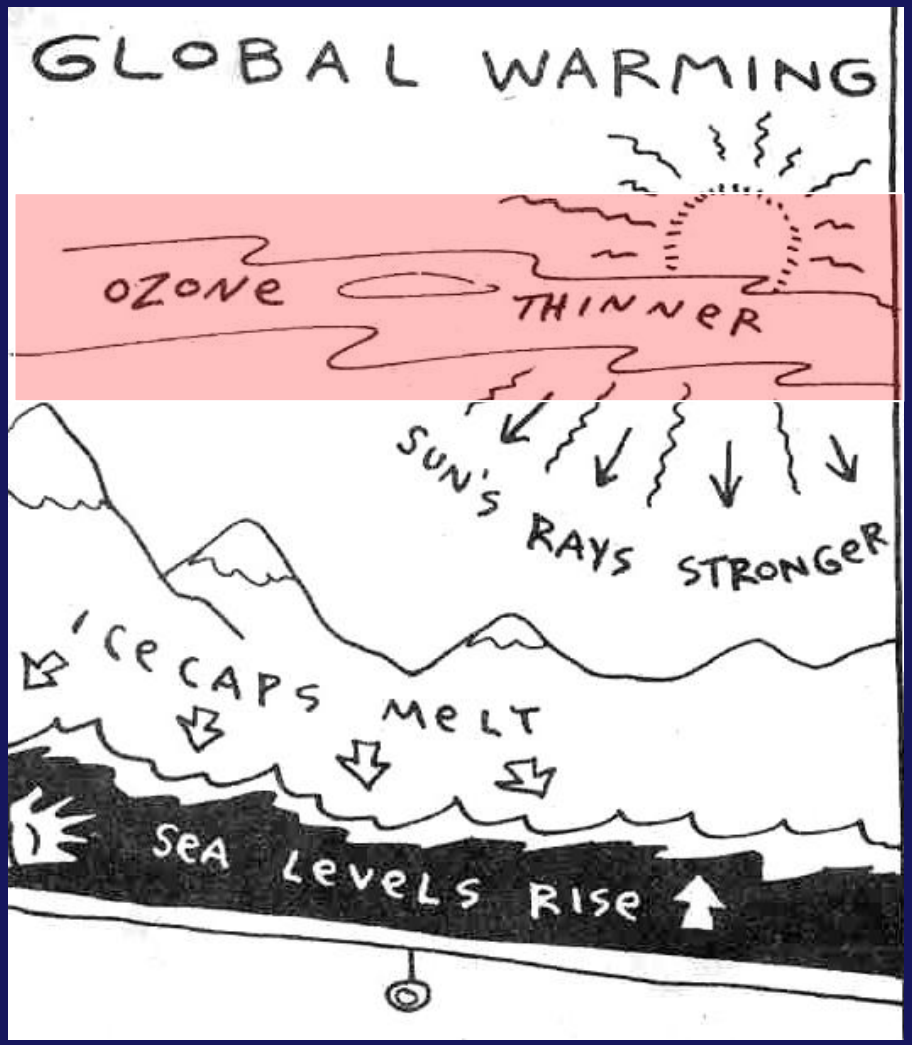
Q4. Is this explanation of the main CAUSE of GLOBAL WARMING correct?



1- YES

2 - NO

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



1- YES

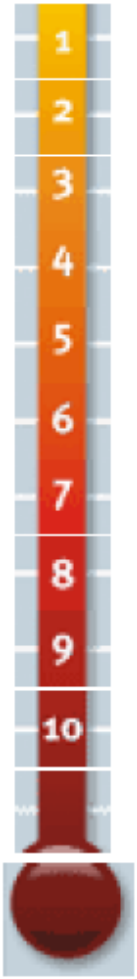
2 - NO

SO WHAT IS CAUSING the CLIMATE CHANGE & 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!

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 83

"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.**"

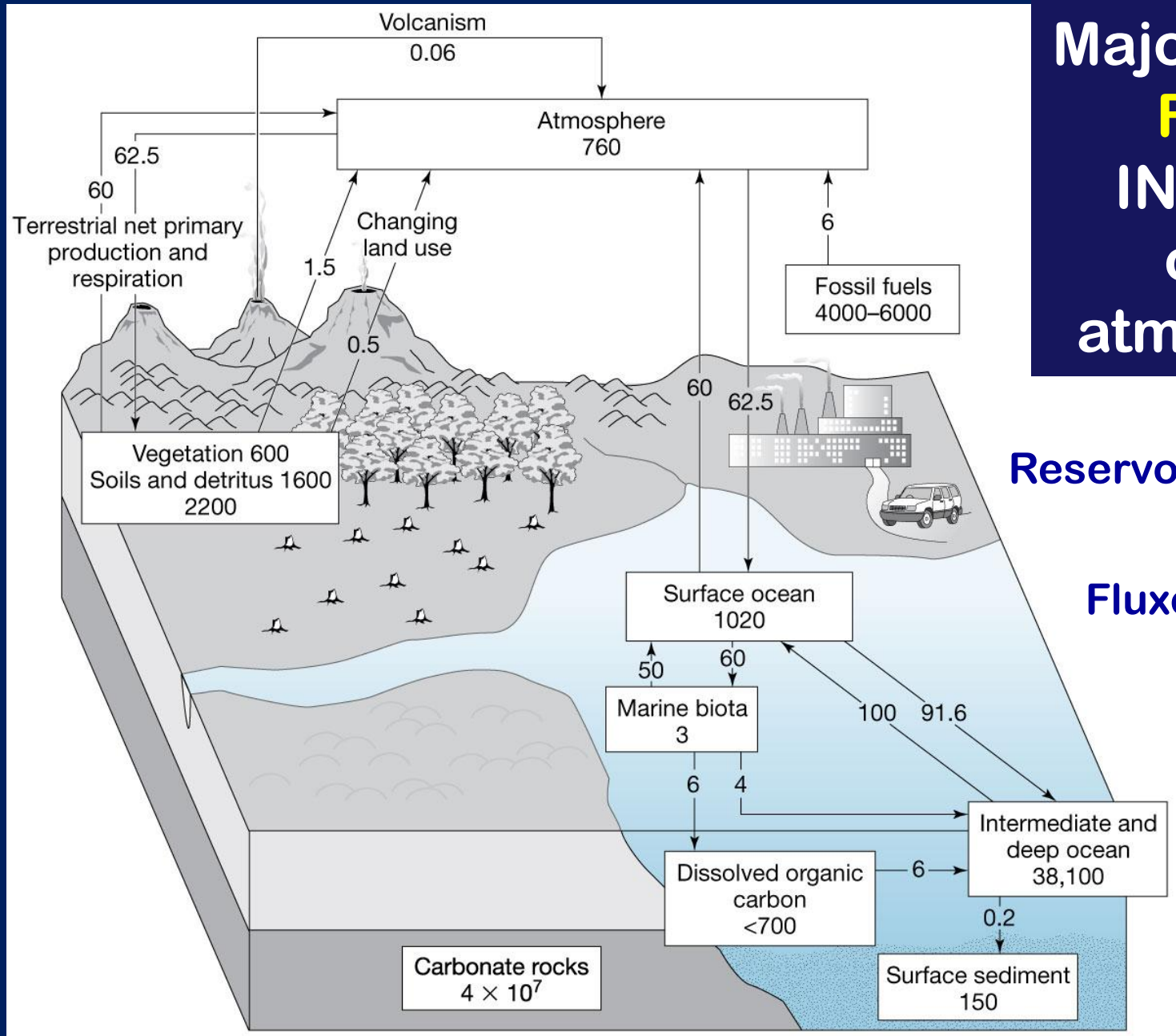
~Wally Broecker , Paleoclimatologist

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



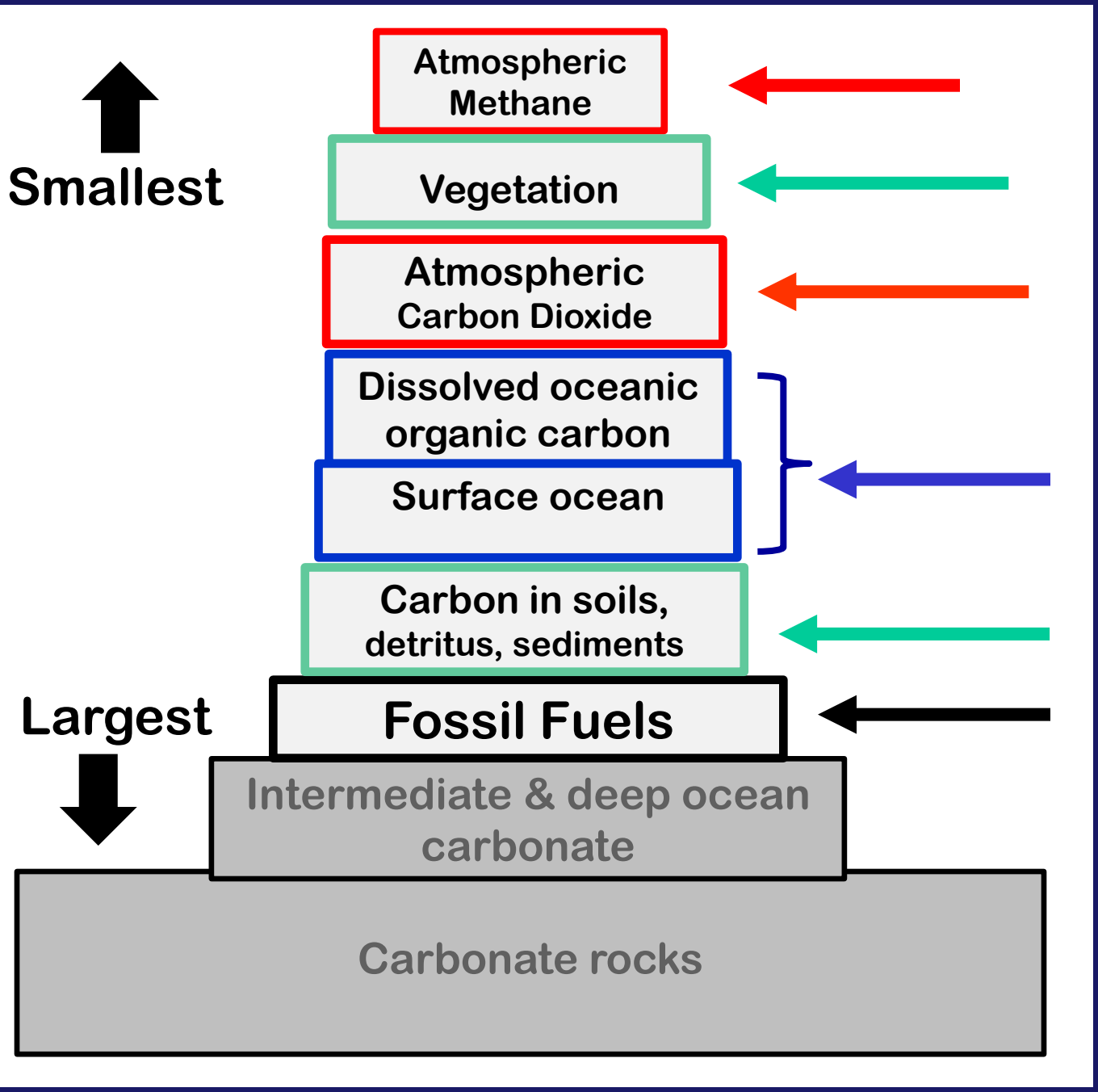
Reservoirs = 

Fluxes = 

RESERVOIR (def)

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

Carbon Reservoirs ranked by size :



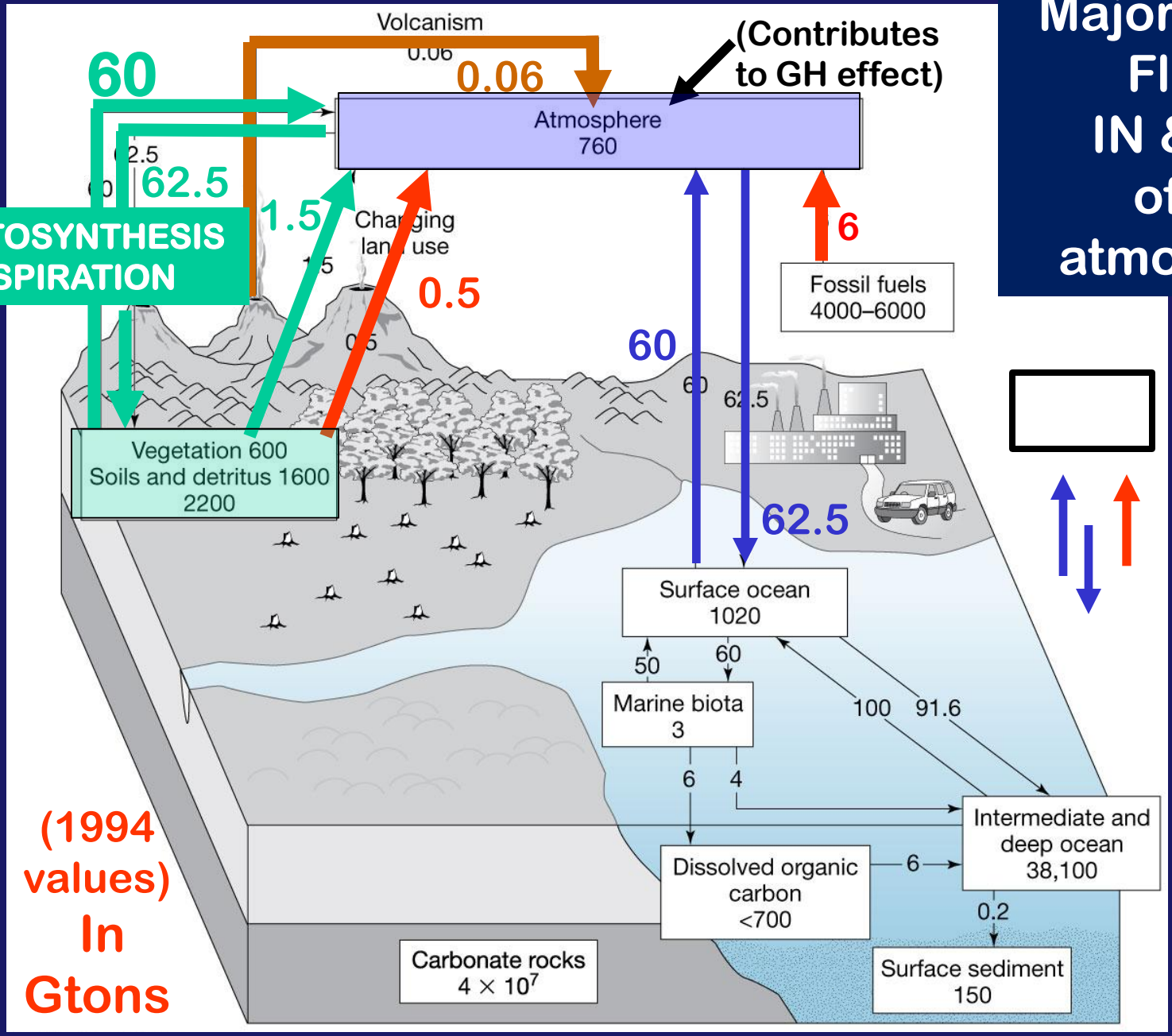
Amount of carbon is expressed in units of **Gtons (gigatons) of carbon: GT(C)**

Amounts represent the **MASS OF CARBON ATOMS ONLY**, not other atoms to which C is attached (e.g. CO_2)

One gigaton is . . .

Greater than the mass of all the humans on the planet

Major Carbon Fluxes IN & OUT of the atmosphere



(1994 values) In Gtons

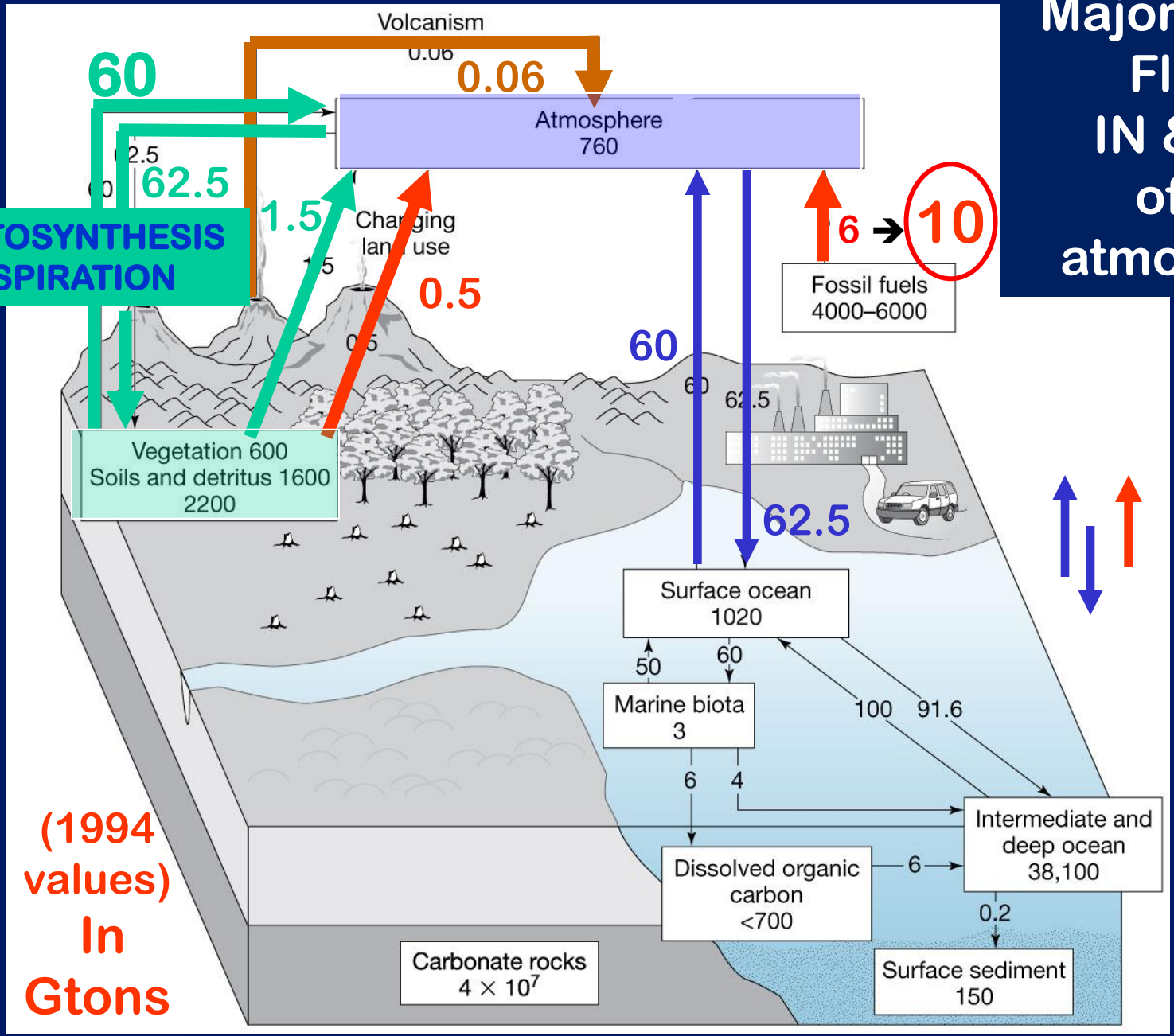
= carbon stored in a reservoir

= 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

= carbon flux from one reservoir to another

(in Gtons/yr)

1 Gton = 1 billion tonnes

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.

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

1. Trees take in carbon dioxide during photosynthes

2. Trees release carbon dioxide during photosynthesis.

3. Trees release carbon dioxide into the atmosphere during respiration

← 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: (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

Photosynthesis =

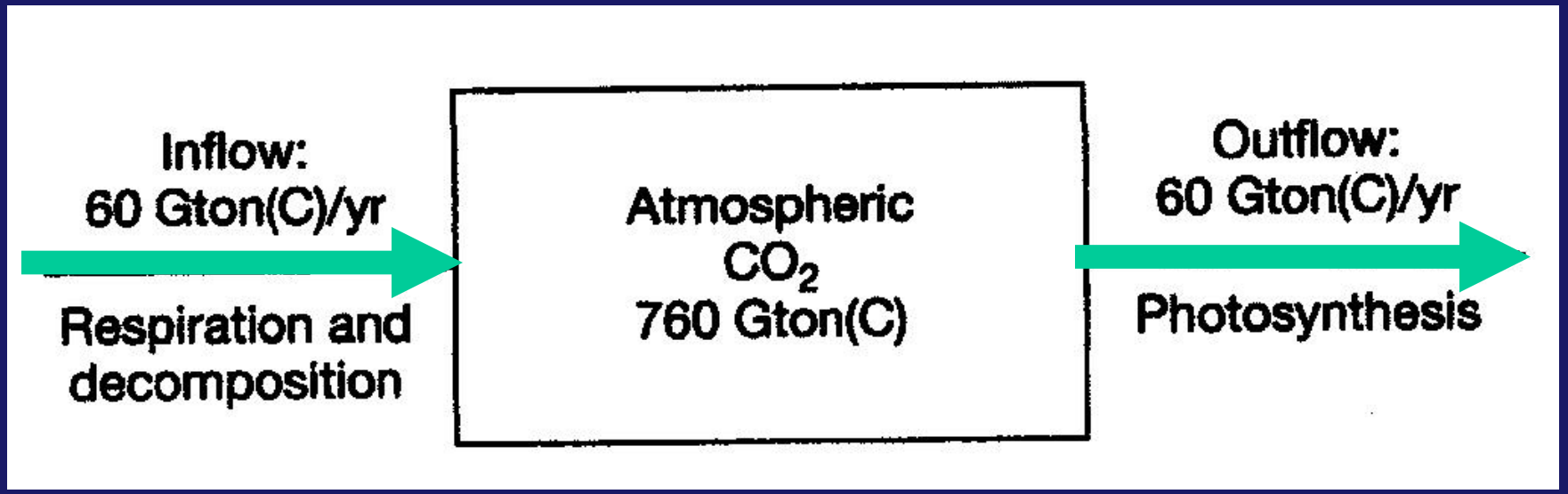
manufacture of carbohydrates & O_2
from CO_2 and H_2O
in the presence of chlorophyll
sunlight as the energy source.

Oxygen is *released* in the process.

Solar energy → chemical energy

(Part of chemical energy is stored in living tissues & used by other organisms (consumers) that cannot use solar energy directly.)

The Atmospheric Carbon Reservoir

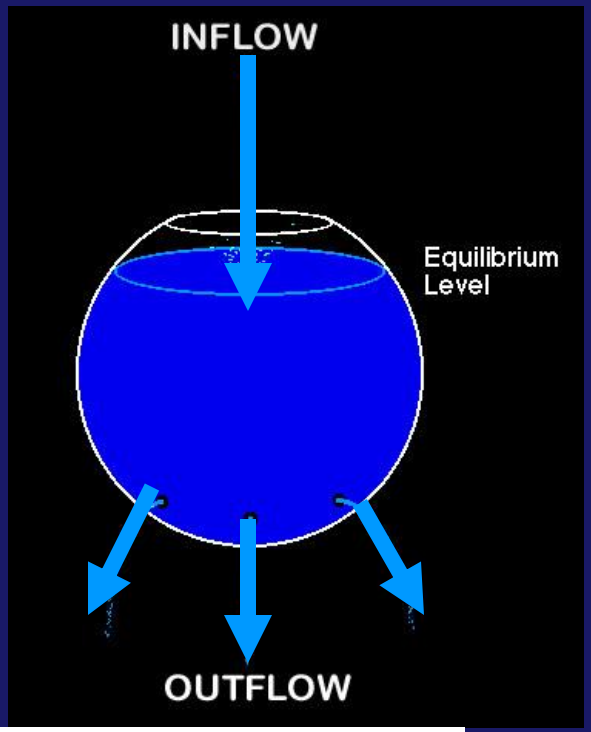


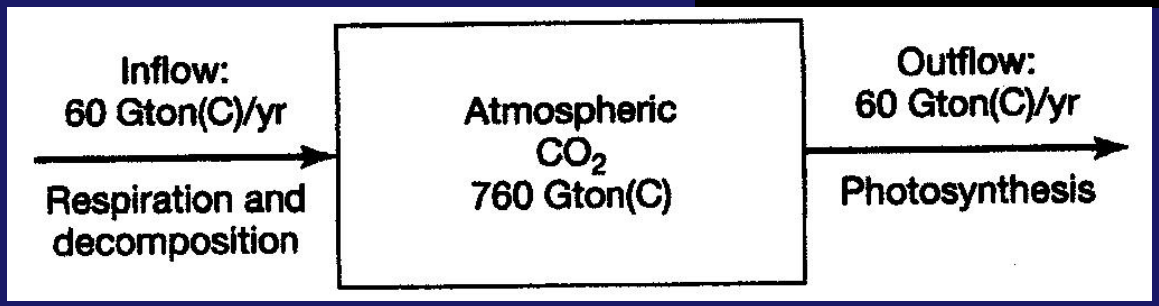
showing inflows and outflows (fluxes)

. . . leads to a

STEADY STATE

In the atmospheric CO_2 "reservoir"

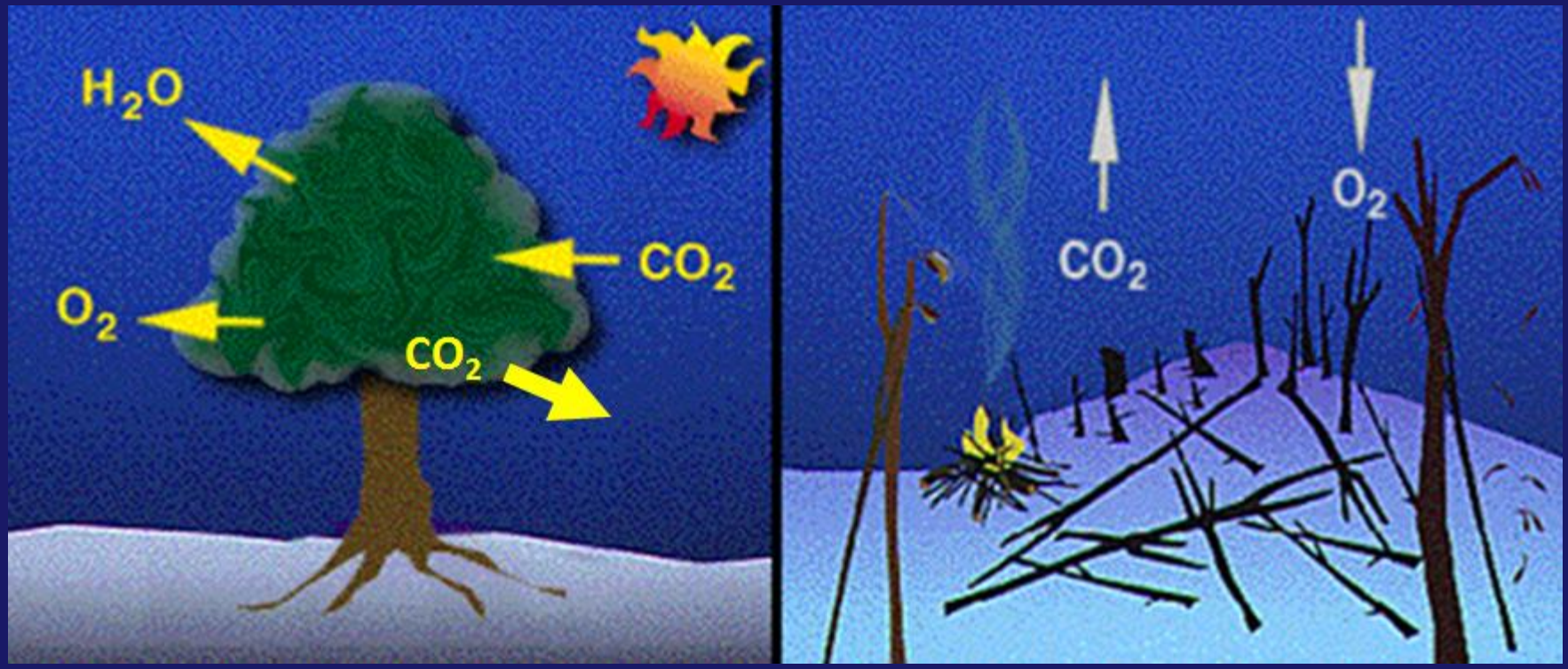




Where have we seen a STEADY STATE before?

Photosynthesis & Respiration

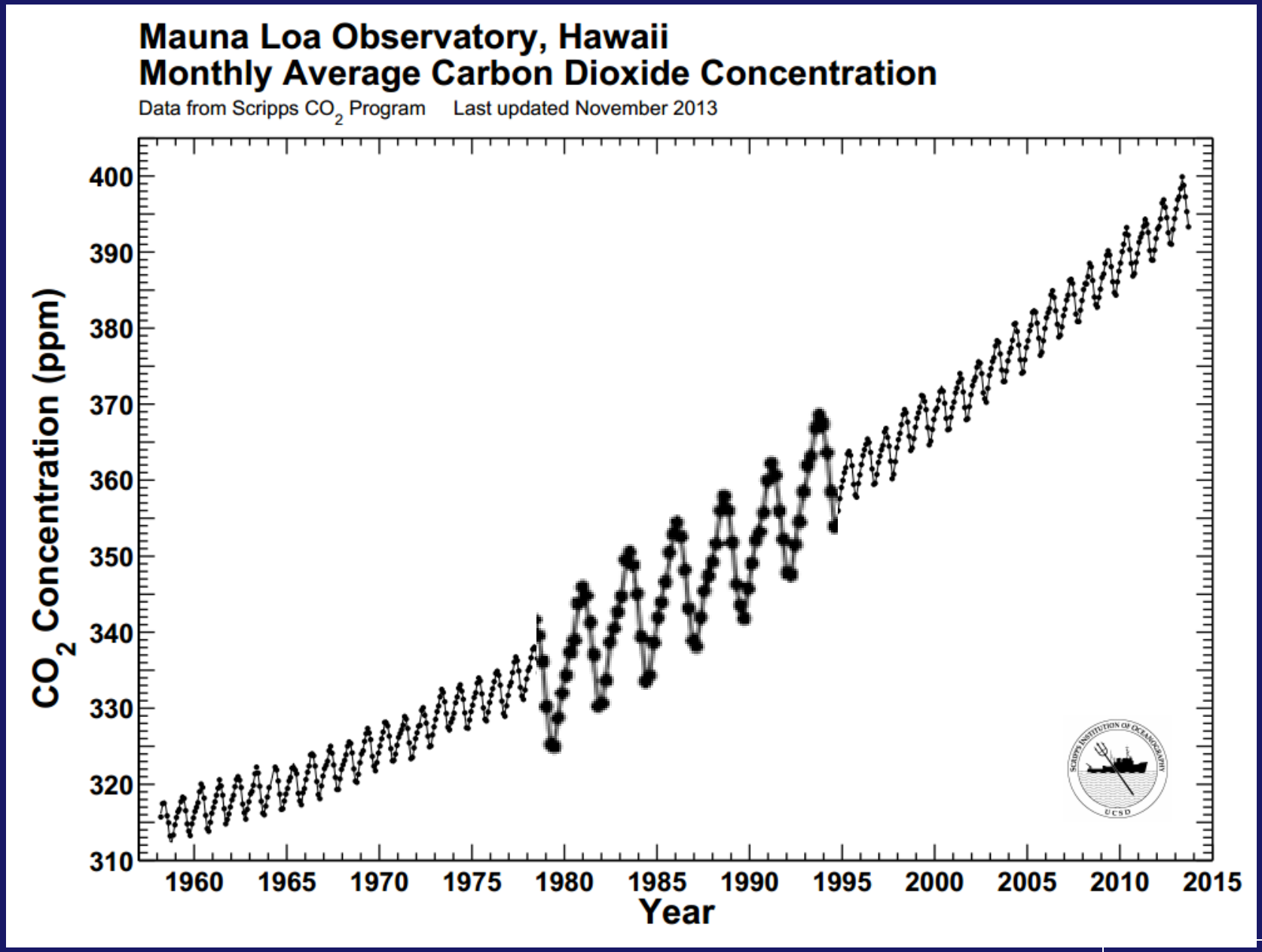
Respiration, Burning of Biomass, & Decomposition



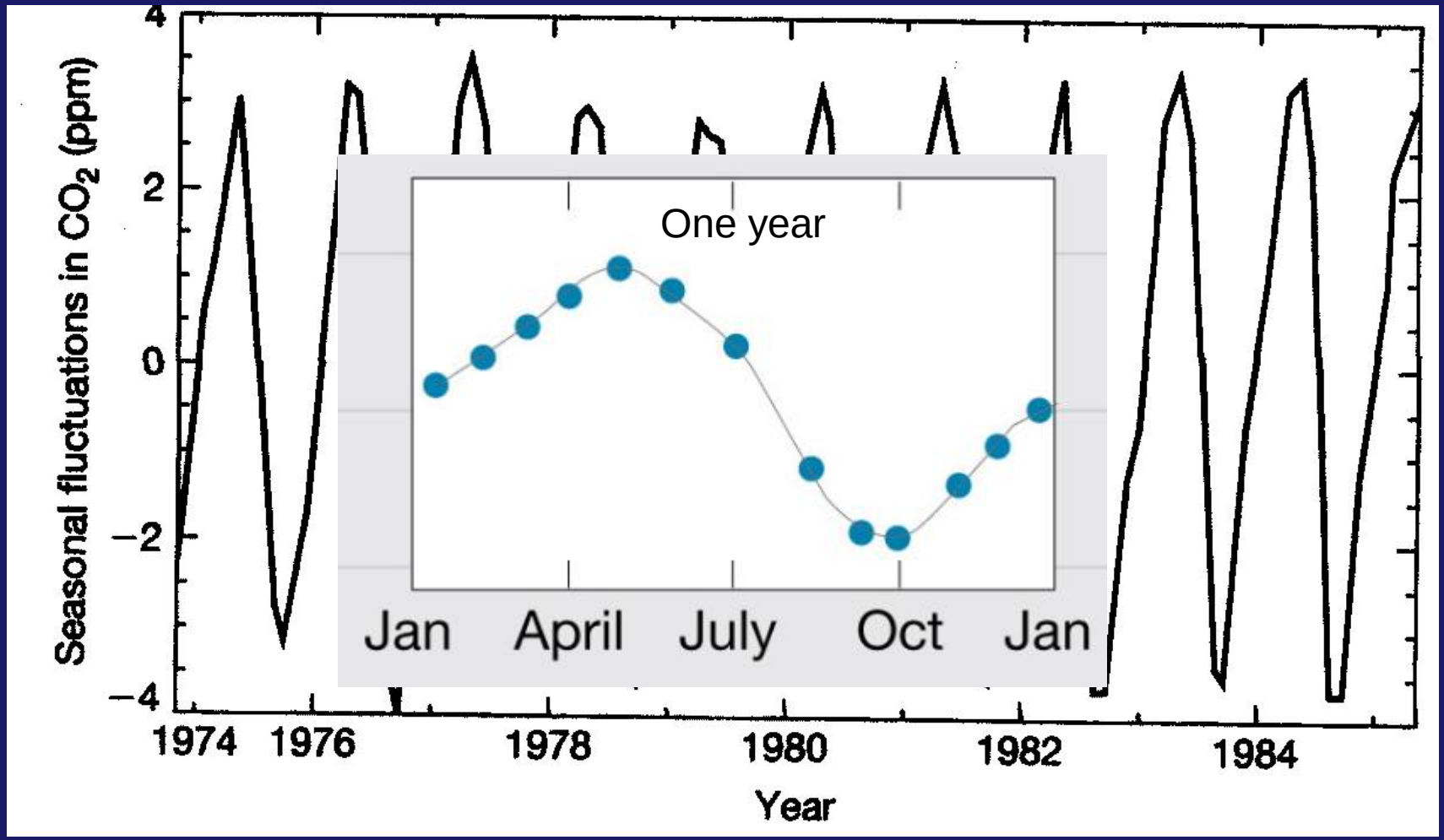
Steady State

Disruption of Steady State

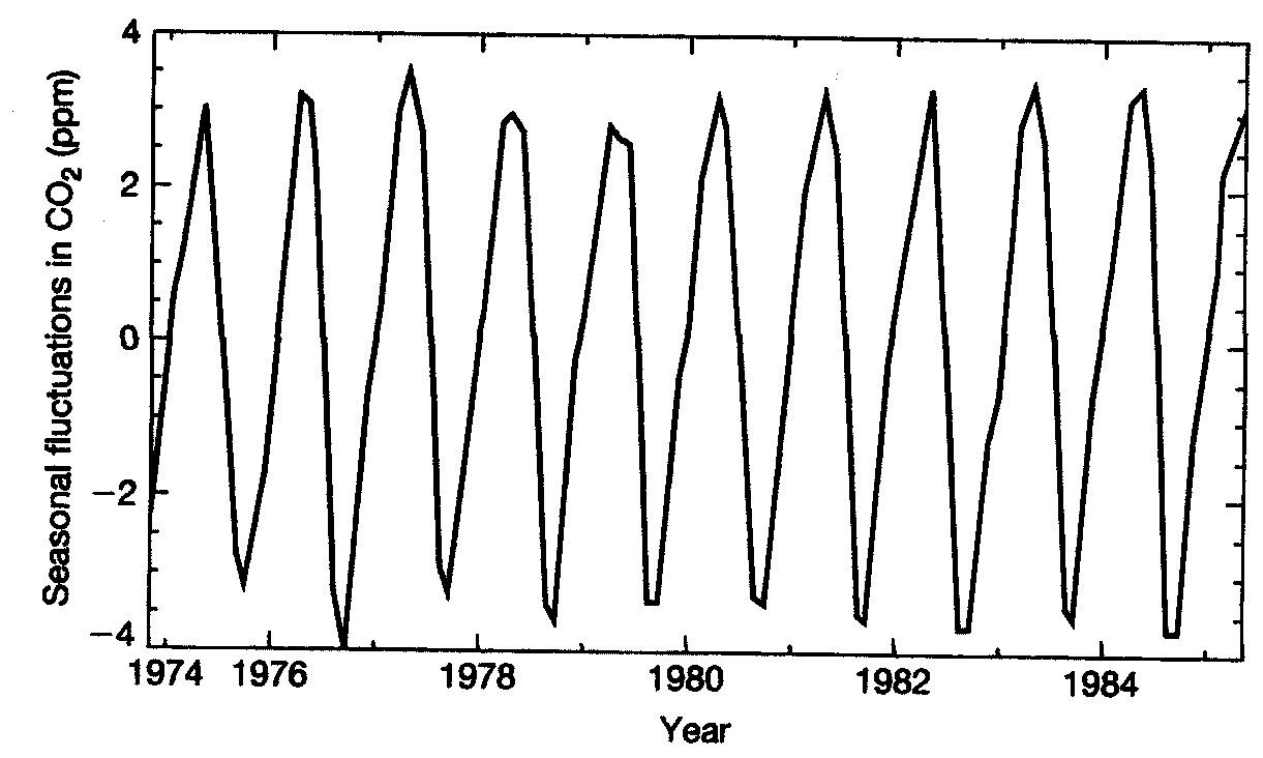
WHAT ABOUT THOSE ZIG-ZAGS IN THE KEELING CURVE?



CLOSE-UP VIEW:

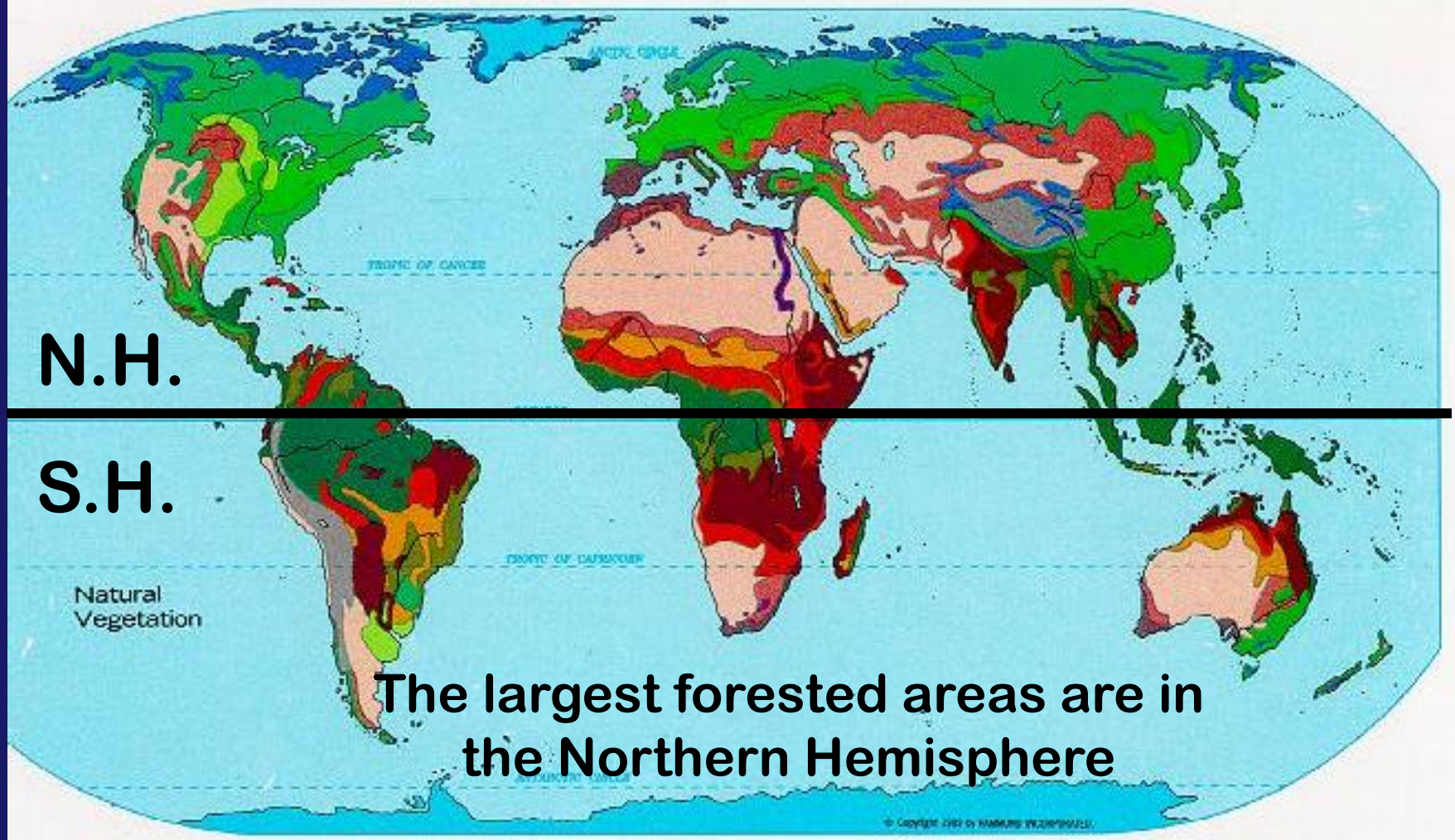


Trend due to anthropogenic increases has been removed.



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

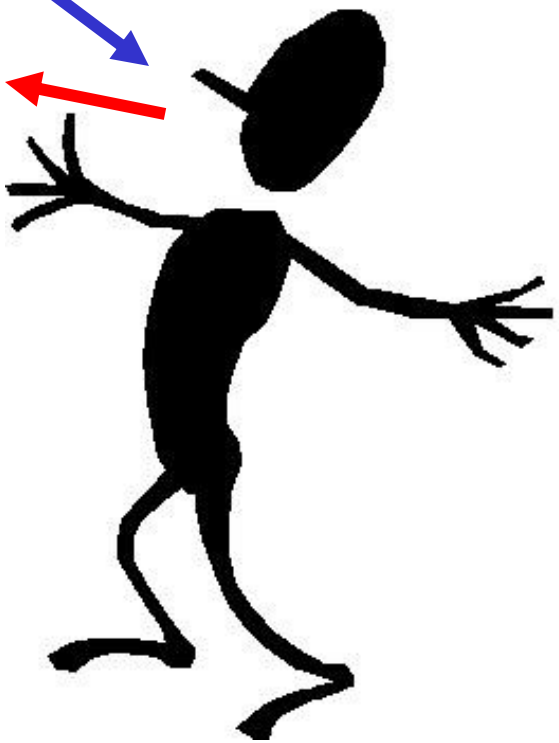
GLOBAL VEGETATION PATTERNS

"Breathing" -- ANIMALS vs. PLANTS

Respiration

O_2

CO_2

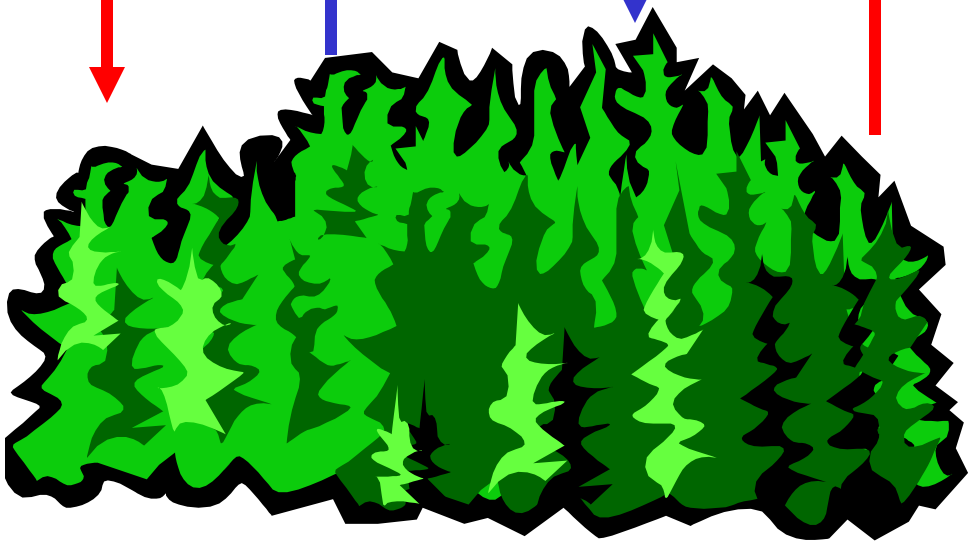


Photosynthesis

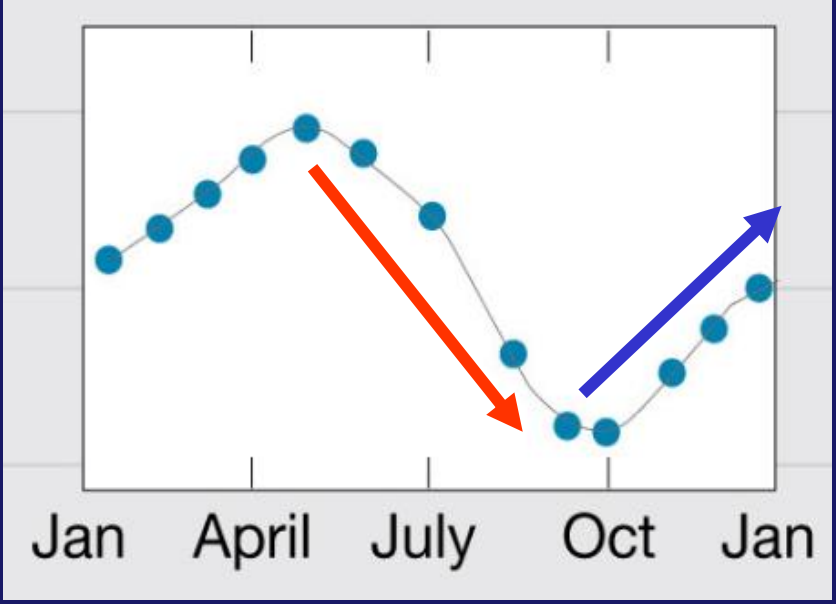
CO_2 O_2

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)

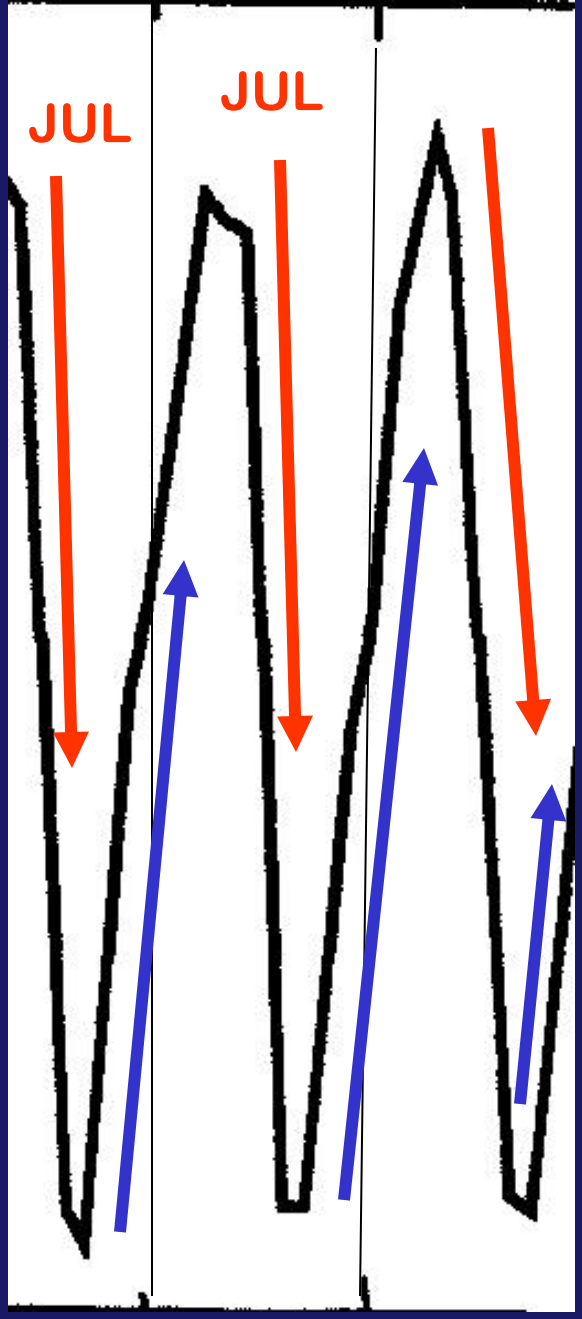
Tick marks are at January of each year:

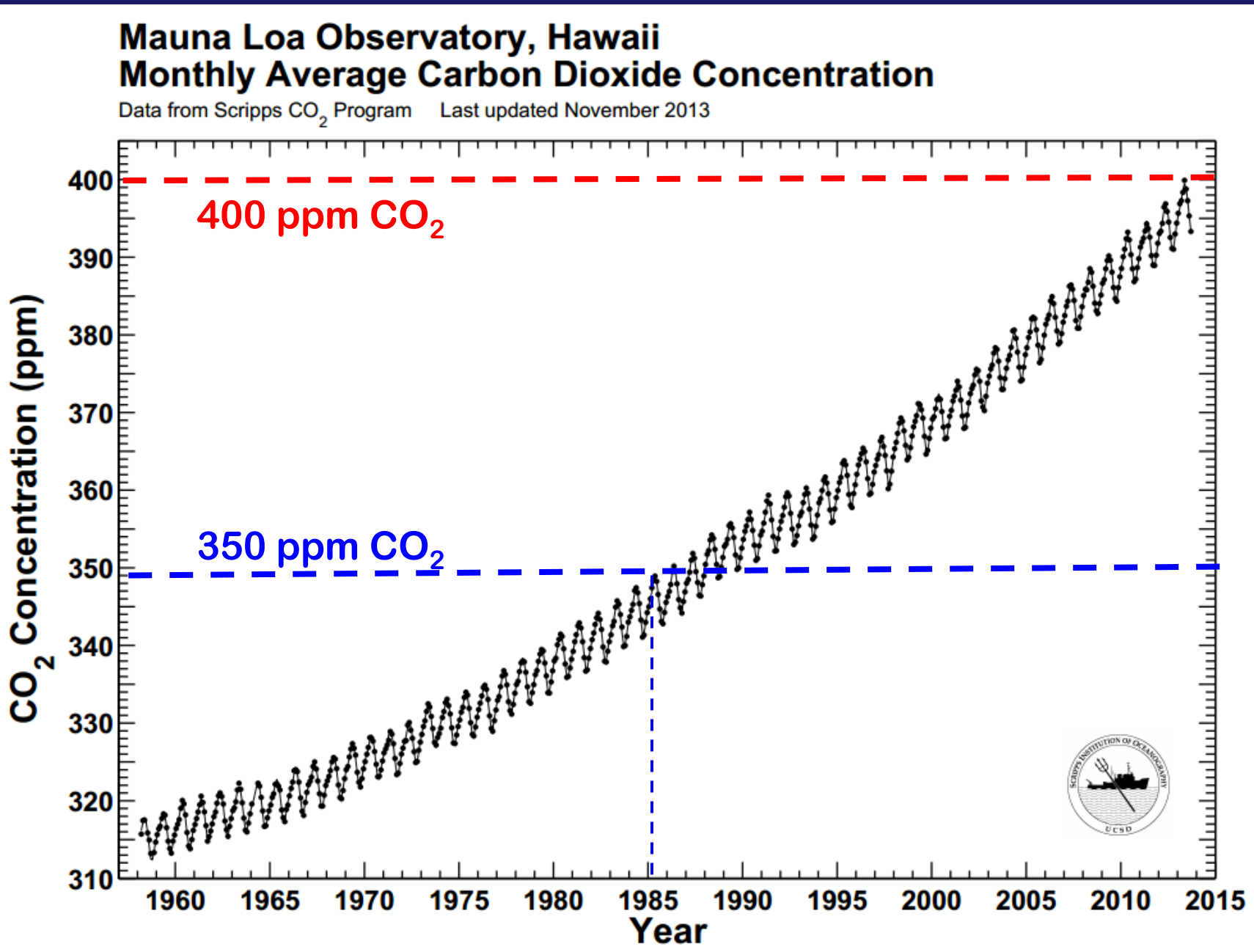
↓ **Photosynthesis > Respiration**
(CO_2 goes down in SUMMER as forests "breathe in" more CO_2)

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

↓ **Photosynthesis > Respiration**
(CO_2 goes down in summer)

↑ **Respiration > Photosynthesis**
(CO_2 levels rise in fall/winter)

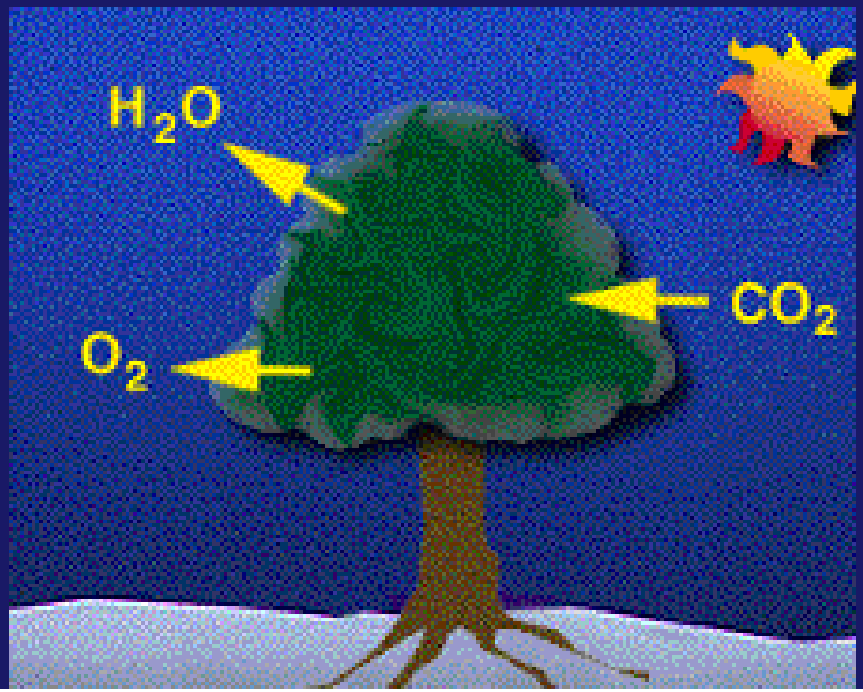



Mauna Loa Observatory, Hawaii
Monthly Average Carbon Dioxide Concentration
Data from Scripps CO2 Program Last updated November 2013
400 ppm CO2
350 ppm CO2
CO2 Concentration (ppm)
Year
400
390
380
370
360
350
340
330
320
310
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

review

BUT IS ALL THE EXTRA CO_2 A BAD THING???

PLANTS DEPEND ON CO_2!!!



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

(Primary Production) — carbon dioxide — water — carbohydrate — oxygen gas

Mini-Break:

YOU TUBE!

"Carbon Dioxide is Our Friend!"

http://www.youtube.com/watch?v=0_VmMIbWKoo

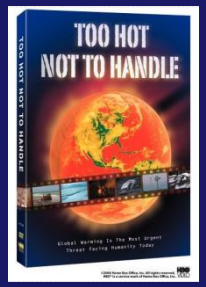
With rising CO2 levels:

- Some plant species continue to increase photosynthesis (C3) ⟷ • others do NOT (C4)

- Some plants can respond readily to higher CO2 levels ⟷ • Other plants can make only limited responses

Hence with Increased CO2 :

- some plant species will be stronger, more prolific, and may overwhelm those less able to benefit

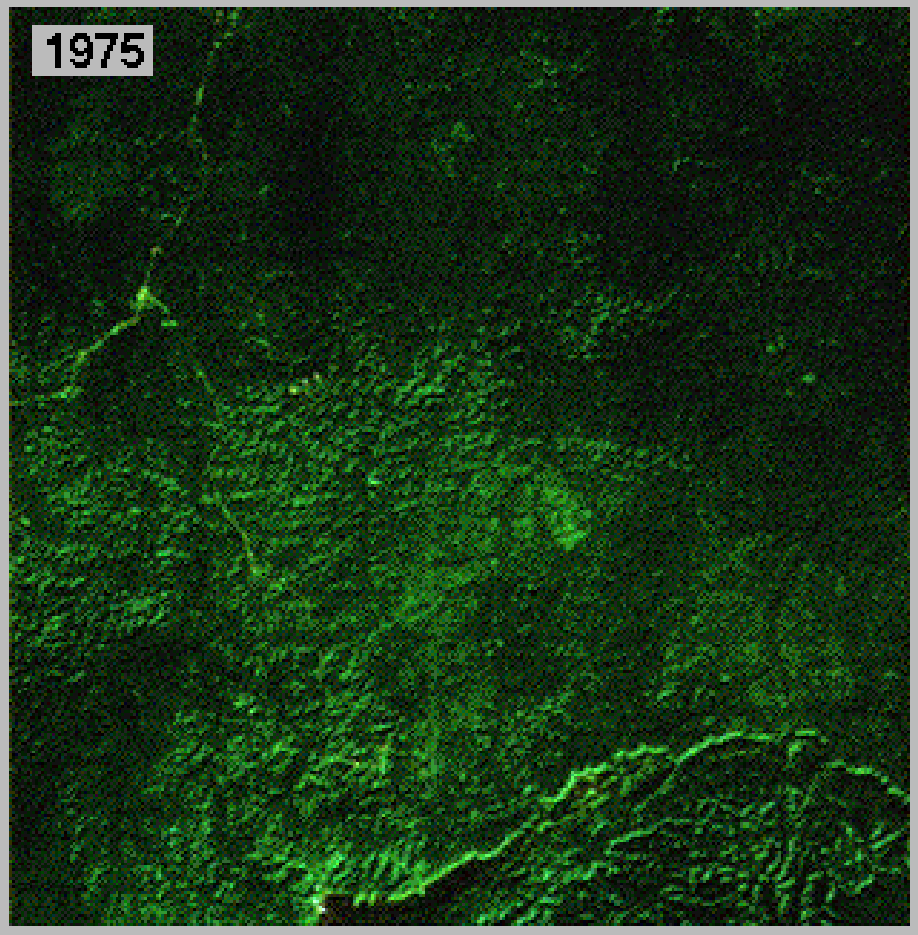


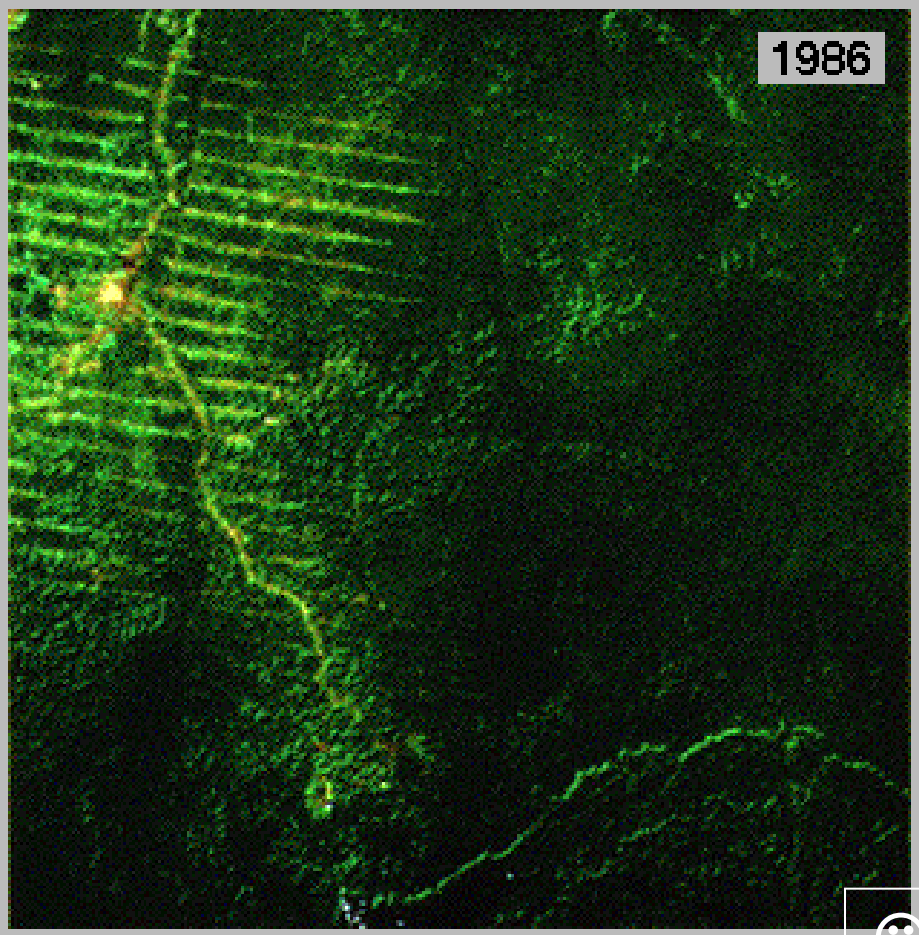
"WE ARE ALREADY SEEING POLLEN INCREASES FROM RAGWEED & OTHER PLANTS"

And . . . there may be consequences we don't yet know !!

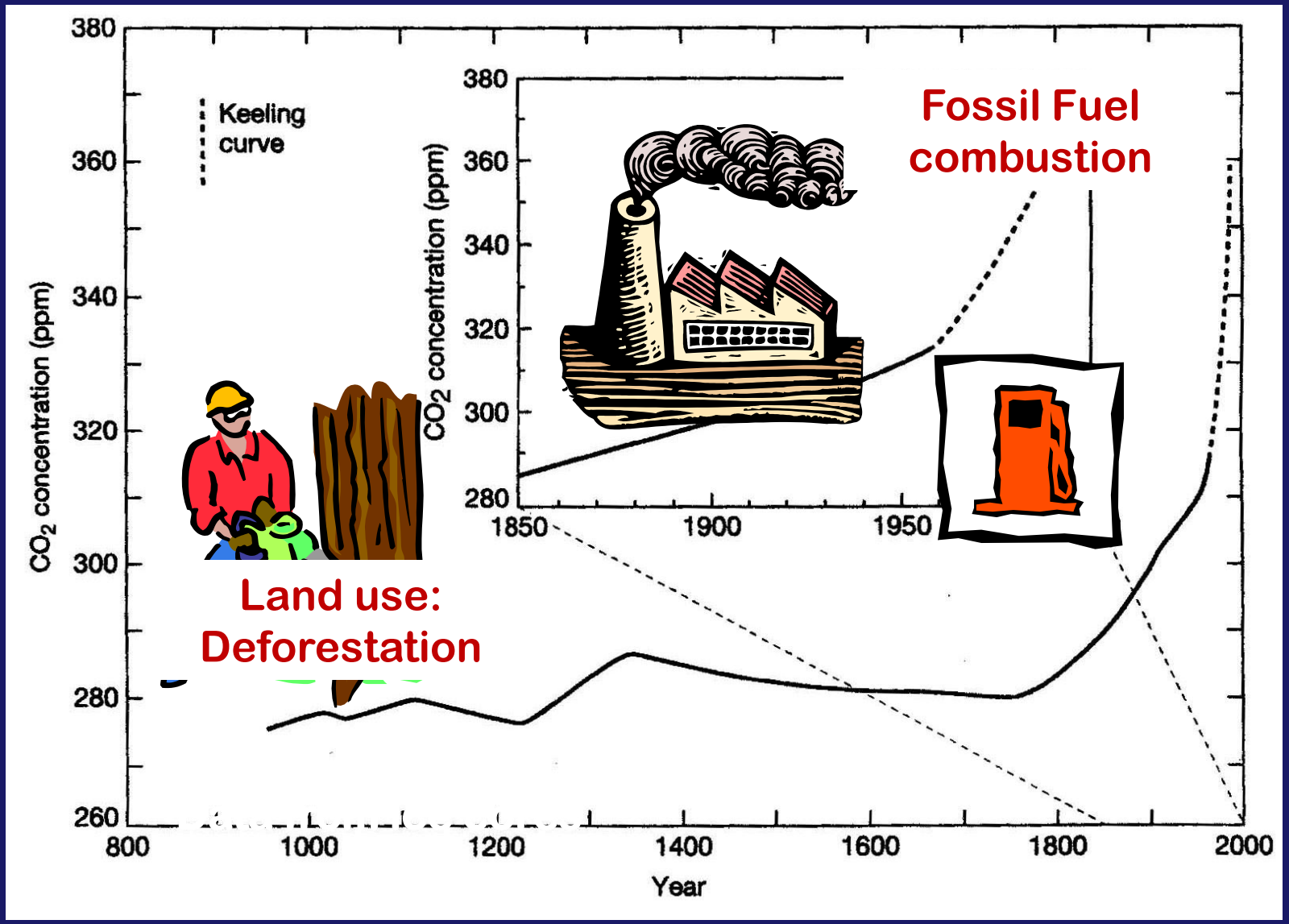
LAND USE CHANGES:

Deforestation practices increase burning & decomposition of large areas of forest



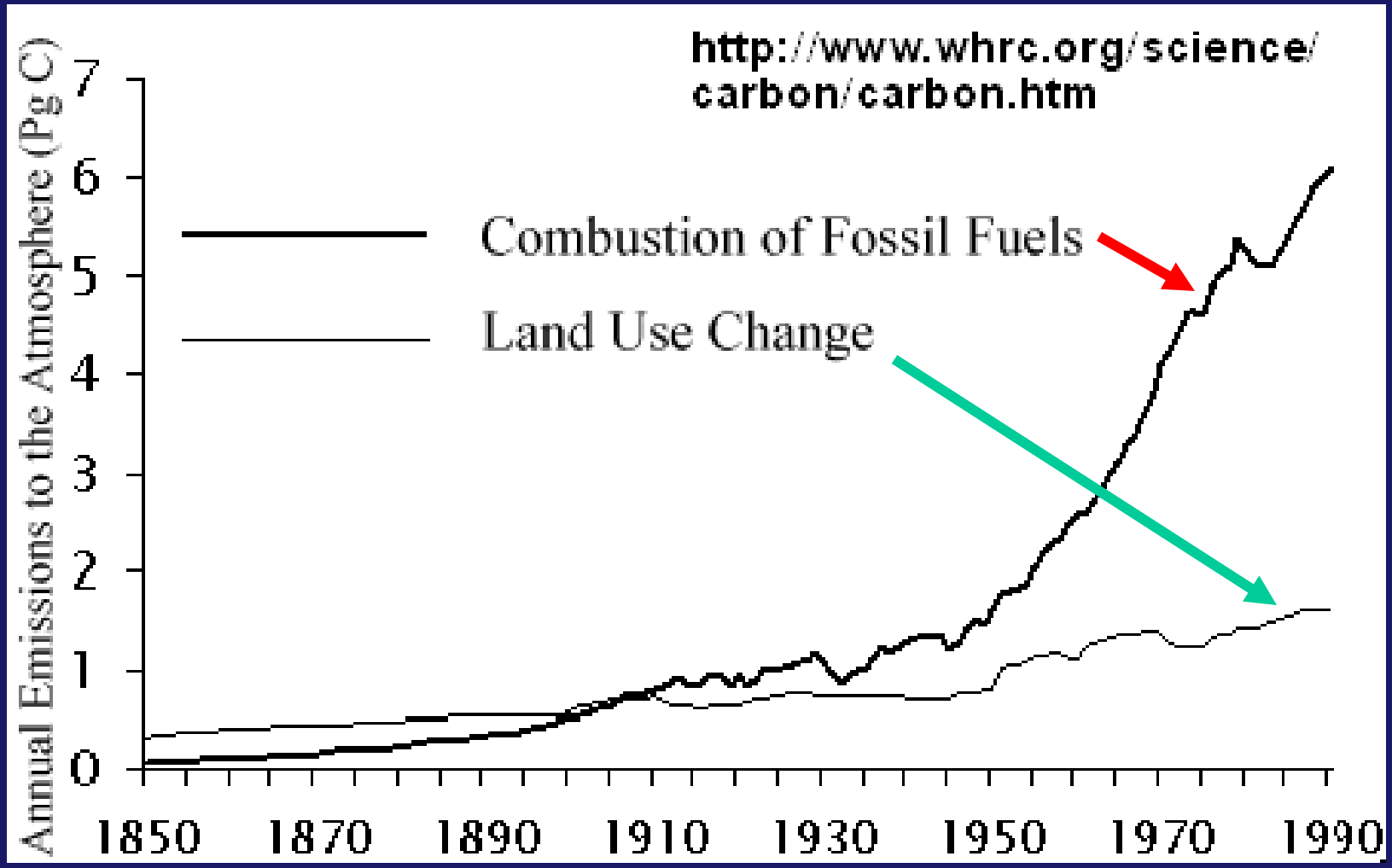


CARBON DIOXIDE: Two big sources



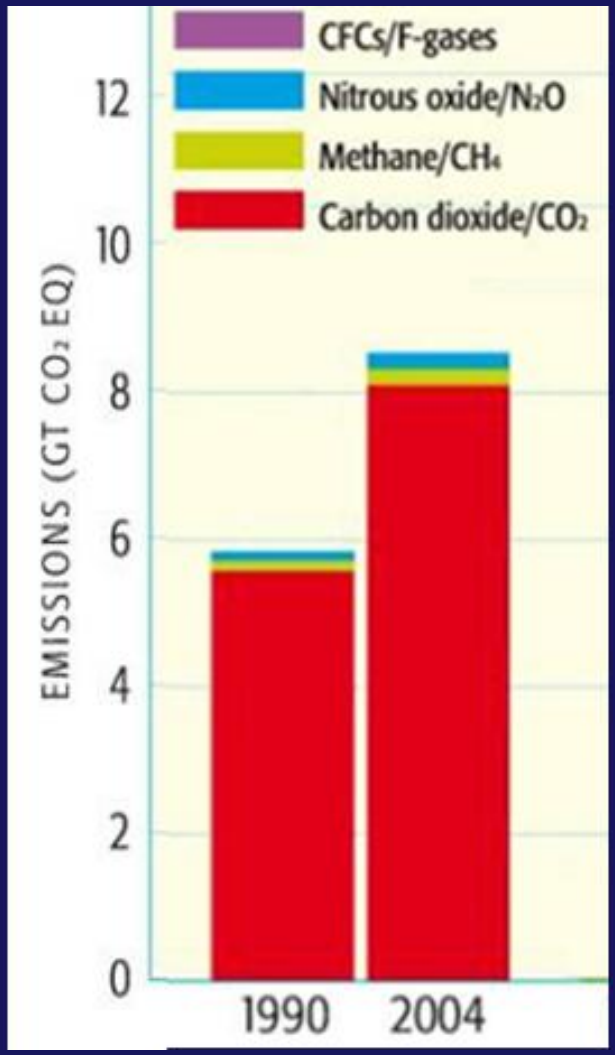
Review

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



Greenhouse Gas emissions from Forestry:

(1990 – 2004)



from p 159 in *Dire Predictions*

RATE OF CHANGE IN FORESTED AREA

Much of increase in China due to **AFFORESTATION** = planting new forests in places where preceding vegetation or land use was NOT a forest

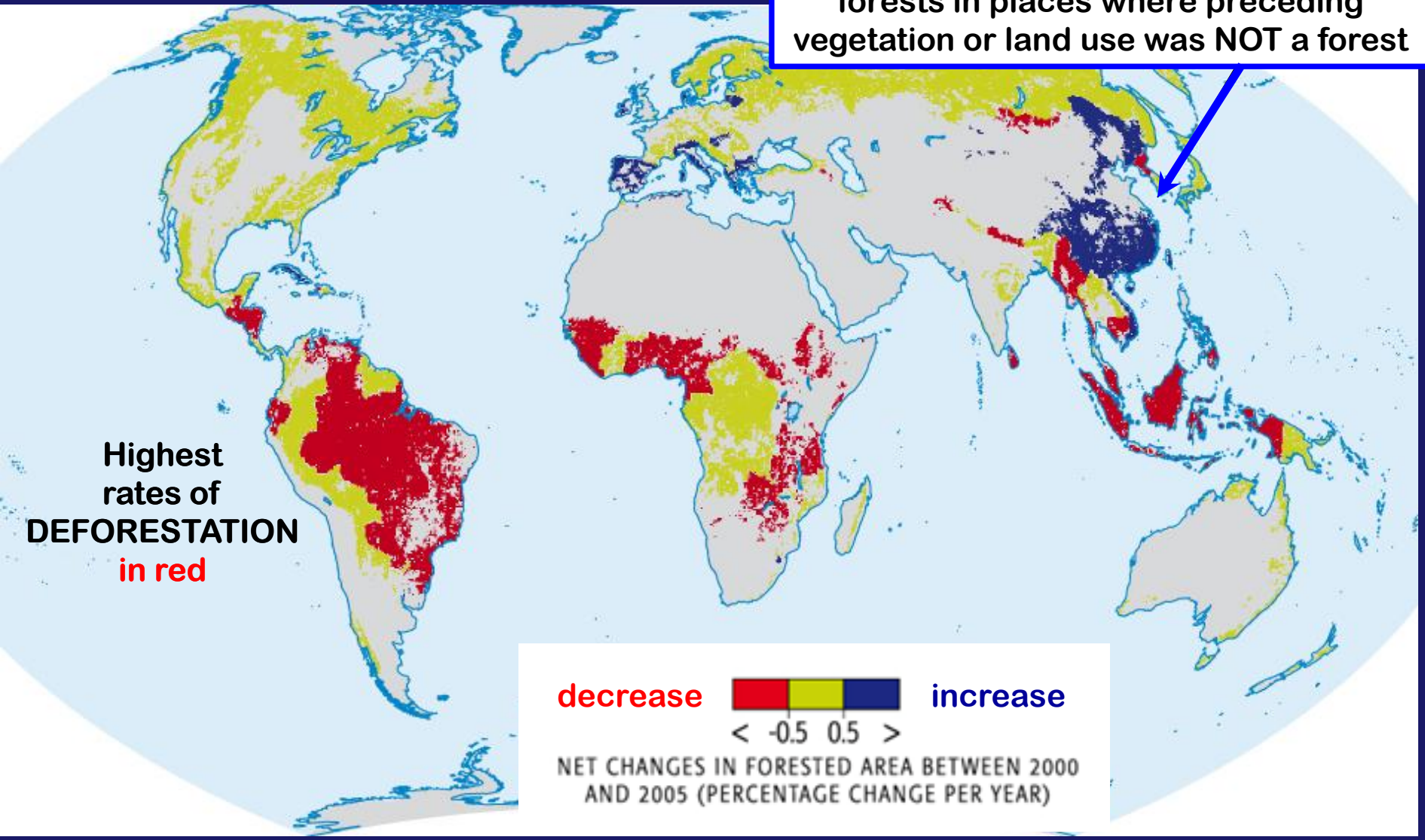
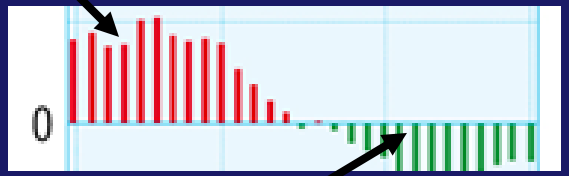


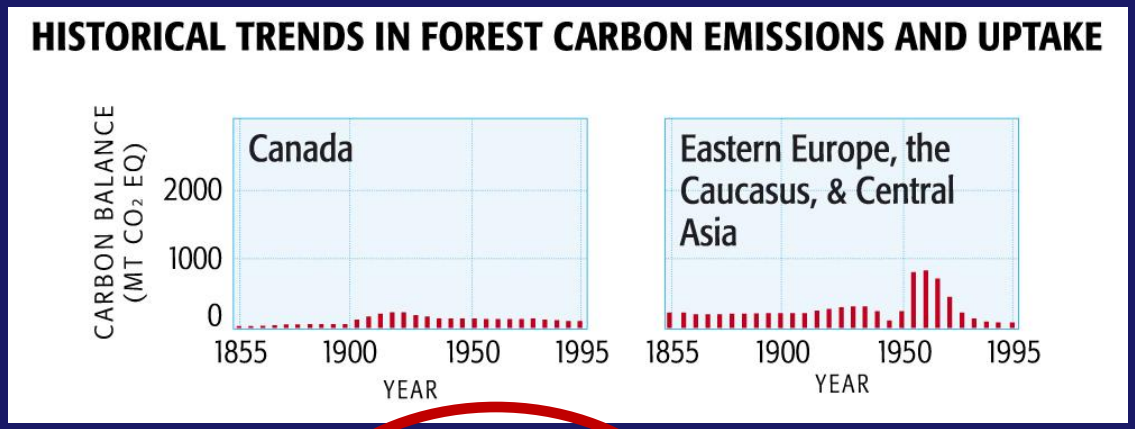
Figure on p 175 in *Dire Predictions*

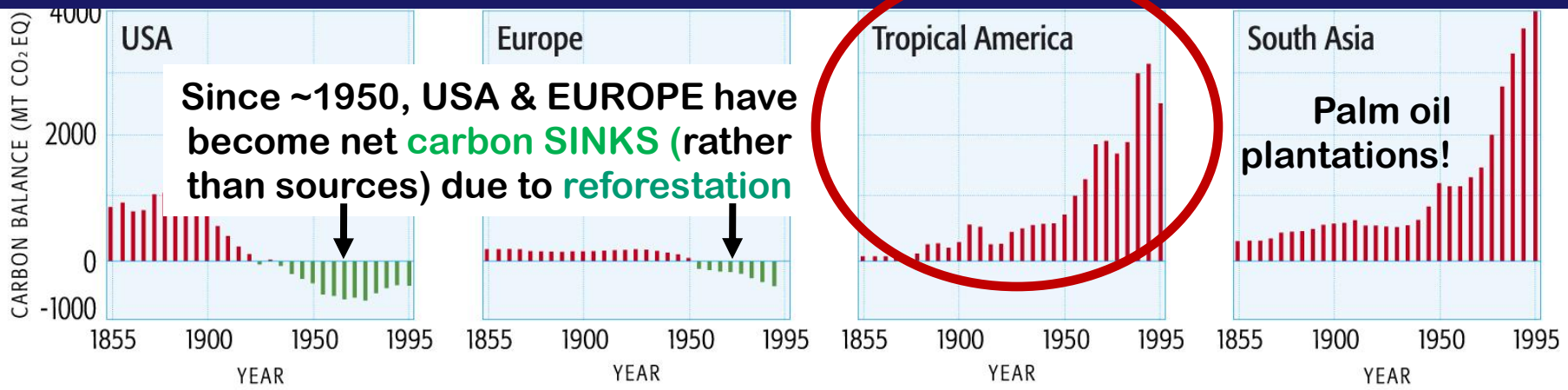
Data Source: UN / FAO Global Forest Assessment Report
http://www.fao.org/forestry/fra/41555/en/

Forest carbon emissions INTO the atmosphere (+)

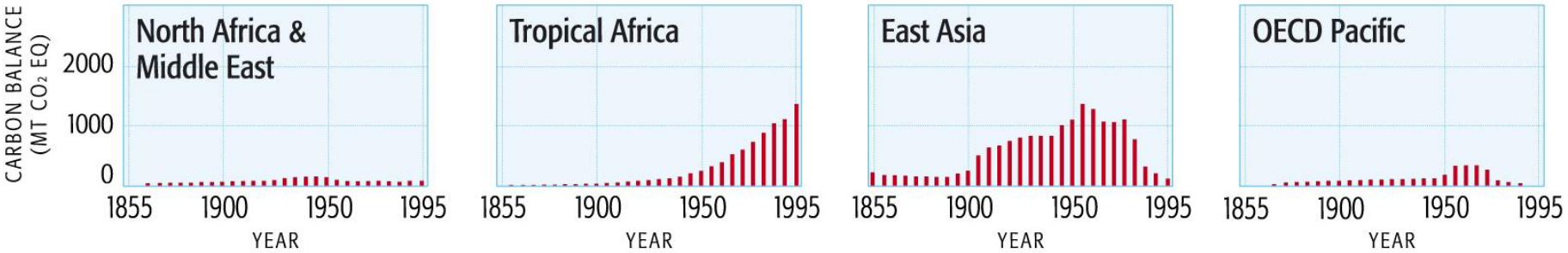


- Forest uptake of carbon OUT OF the atmosphere (-)



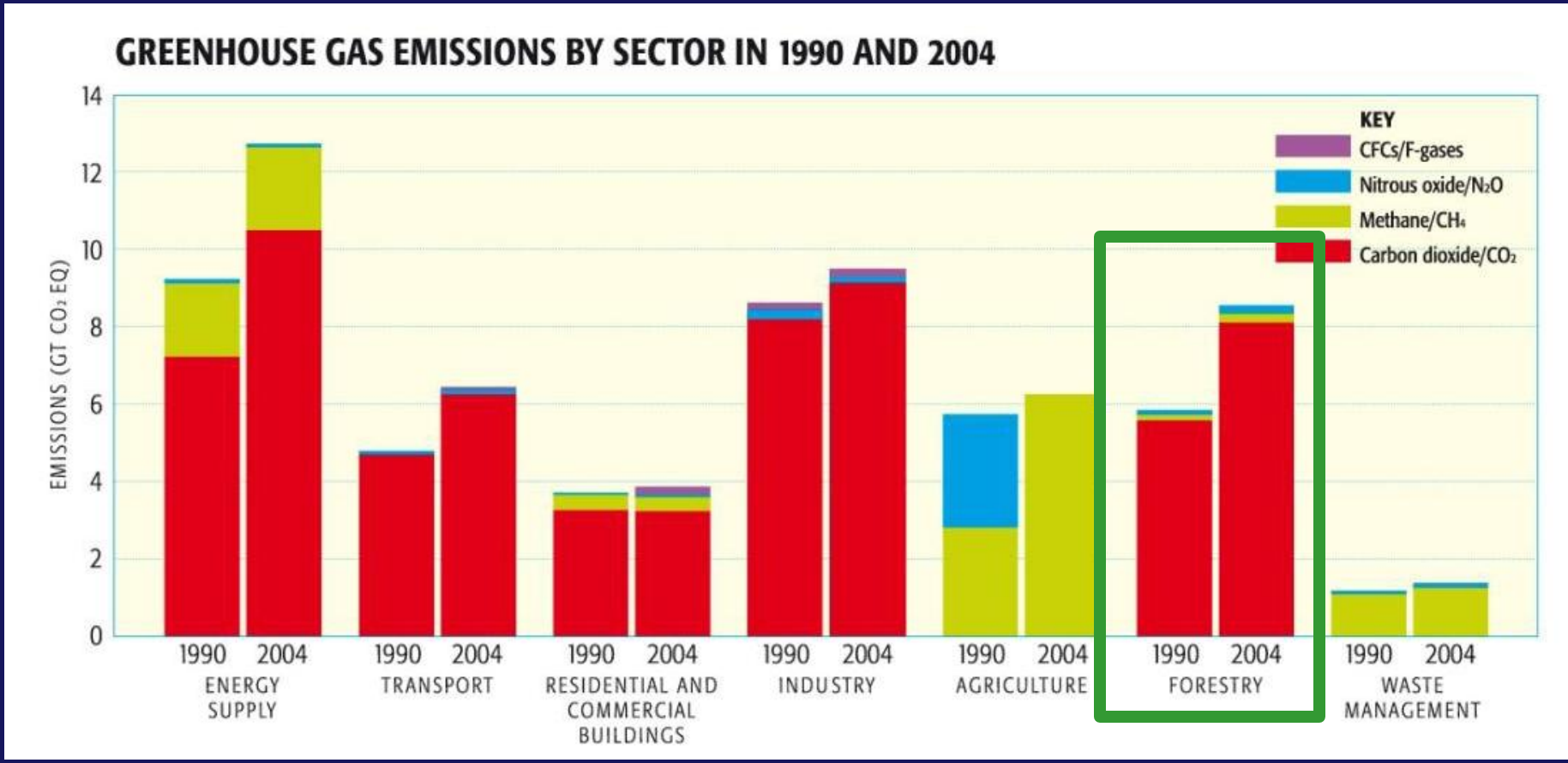


Since ~1950, USA & EUROPE have become net carbon SINKS (rather than sources) due to reforestation



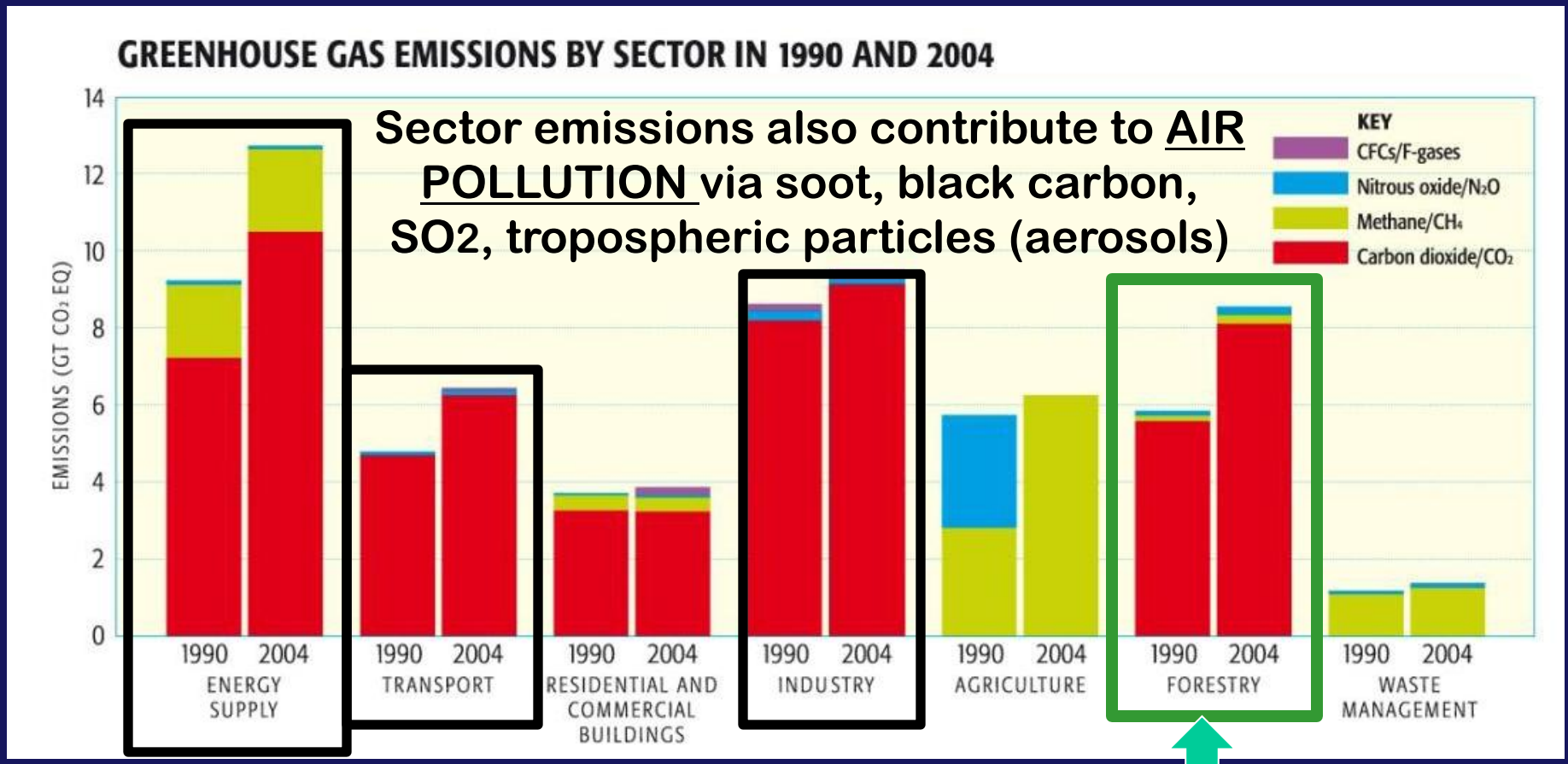
from pp 174-175 in *Dire Predictions*

Where do all those OTHER Greenhouse Gas emissions come from?



from p 159 in *Dire Predictions*

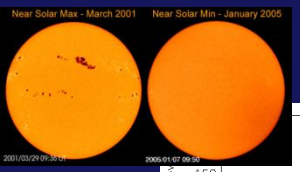
Where do all those OTHER Greenhouse Gas emissions come from?

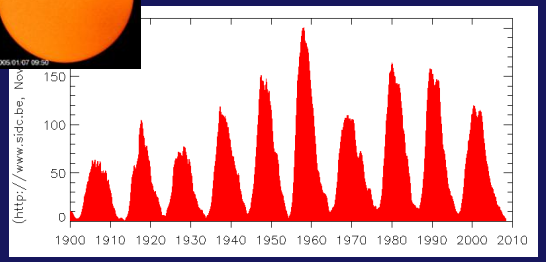


see 159
in *Dire Predictions*

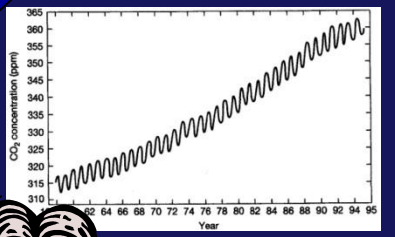
CO_2 emissions from DEFORESTATION & BIOMASS BURNING8

NATURAL FORCING

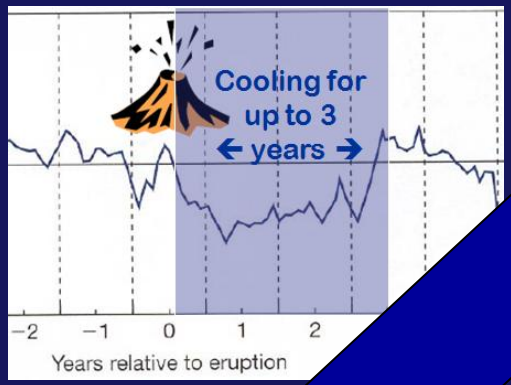




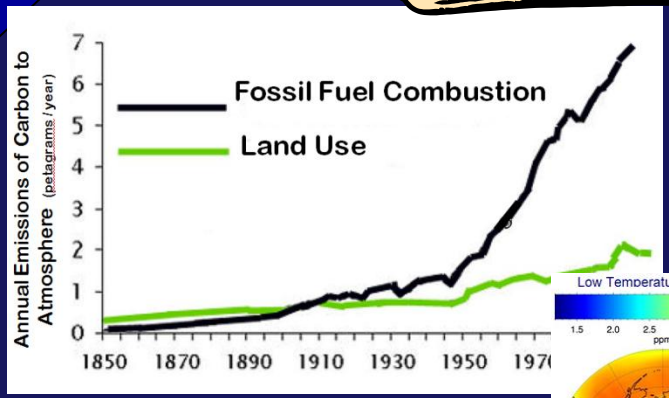
Solar output variations, sunspots

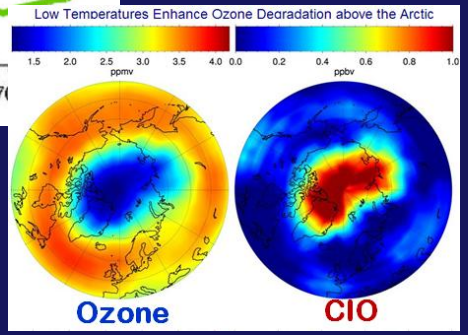


GHG's, soot, SO_2



Volcanic eruptions

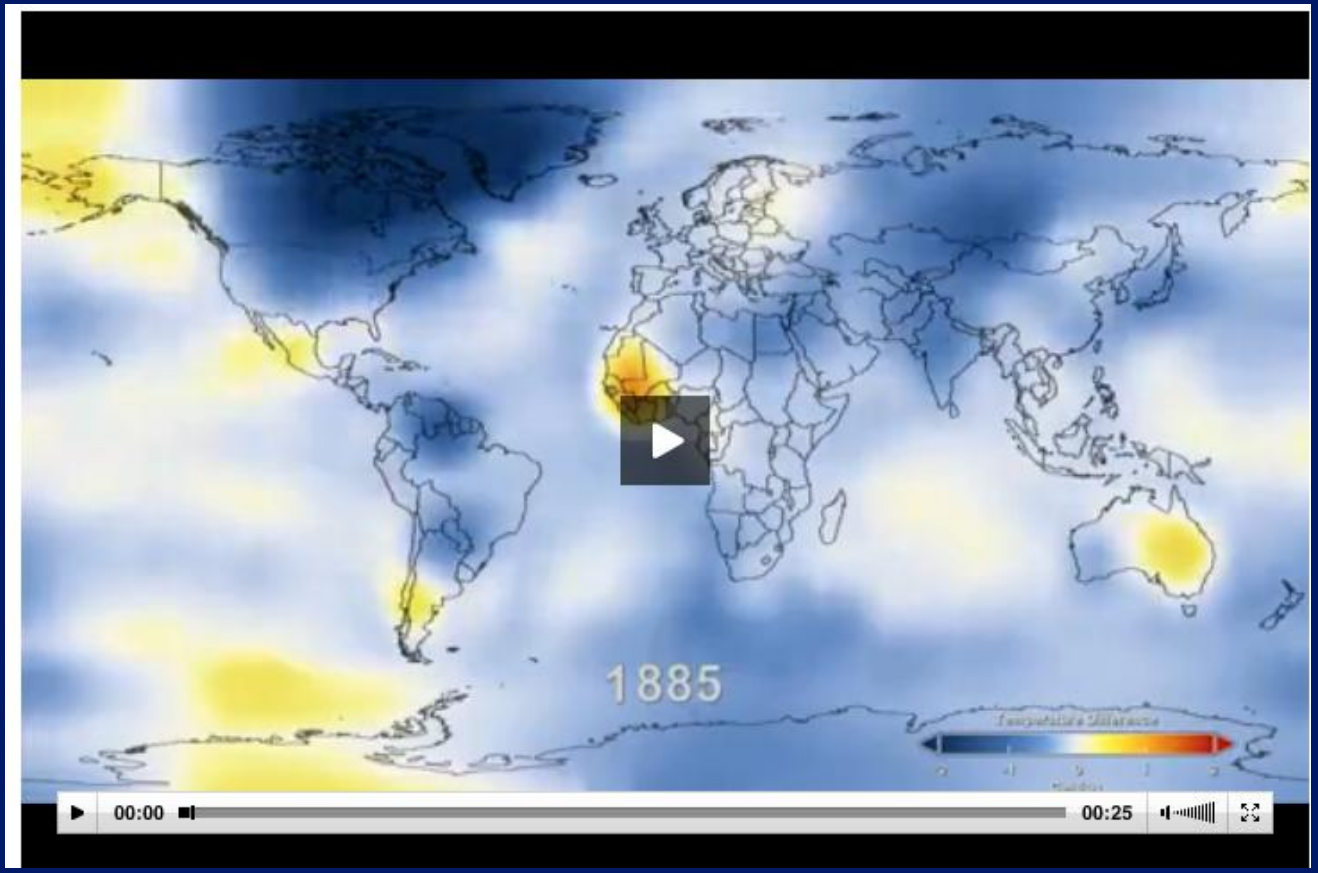




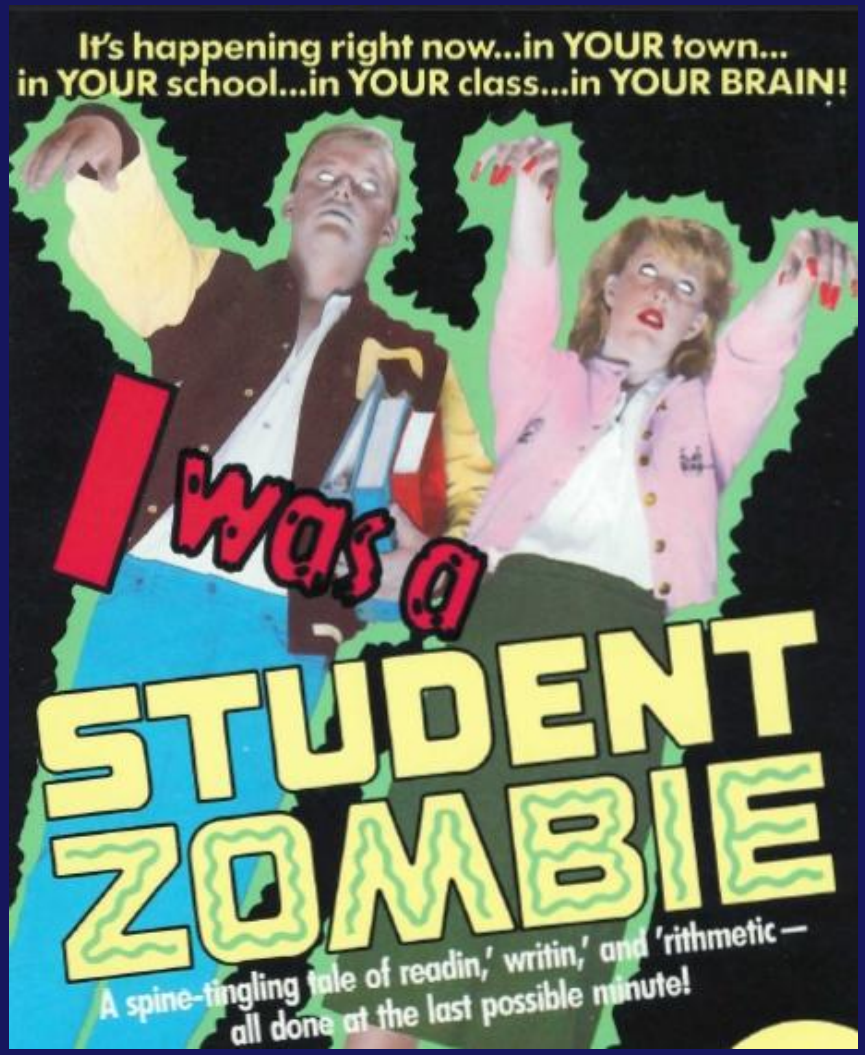
Surface Albedo Changes

ANTHROPOGENIC FORCING

A Century of GLOBAL WARMING in 26 seconds



http://www.biologicaldiversity.org/news/center/articles/2012/nasa-01-19-2012.html



ZOMBIE BREAK !