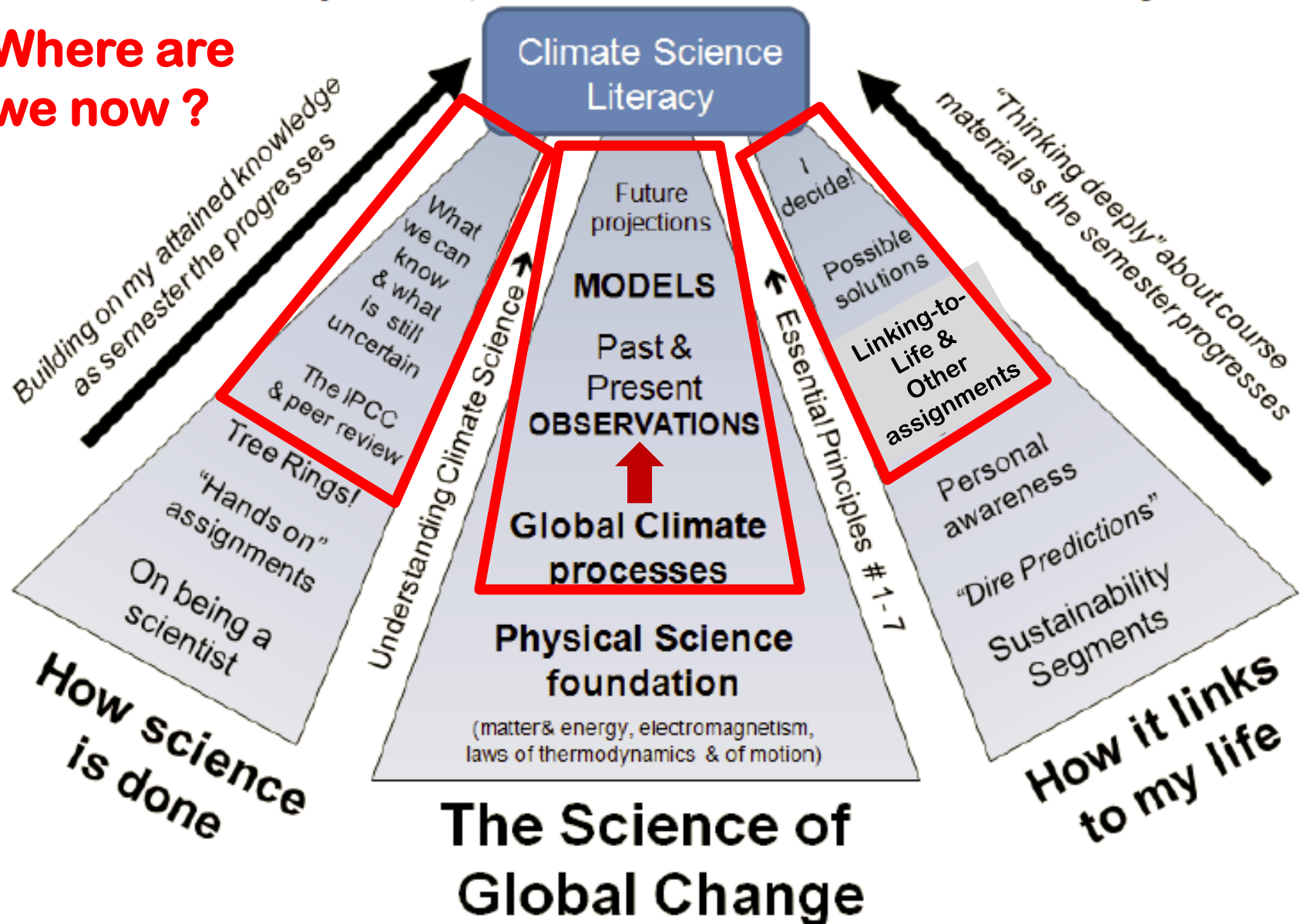


GOAL: Enhanced Understanding Of Global Change Science, How It Operates, & What It Means To Me Personally

Where are we now ?



You are almost done!

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

TESTS

1 RQ: RQ-9

1 Test: Test #4
&
the Final Exam

GROUP ASSIGNMENTS

(In-Class Activities)



G-1 Absorption Curves

Completed in class on Sep 17th



G-2 Energy Efficiency

Completed in class on Oct 3



G-3 Wood Kits

Completed in class on Oct 10



G-4 Bristlecone Pine

Completed in class on Oct 15 + 22



G-5 Applying the Energy Balance Terms

Completed in class on Oct 29+ 31



G-6 Volcanism & Climate

Completed in class on Nov 7



G-7 Climate Action Class Activity

INDIVIDUAL ASSIGNMENTS

(Short Writing Assignments)



I-1 Climate Science Basics

Lesson 1 CO₂ & the GH Effect

Past due (Oct 3)



I-2 Climate Science Basics

Lesson 2 Mother Nature's Influence

Past due (Nov 5)



I-3 Climate Science Basics

Lesson 3 Observable Changes

Past due (Nov 17)



I-4 Climate Science Basics

Lesson 4 Intro to Climate Modeling

Due Tuesday Nov 26



I-5 Climate Action Debate Preparation

Due Tuesday Dec 10

LINKING-TO-LIFE PROJECT

(Individual Term Project)

OVERVIEW OF THE TERM PROJECT

PART A: YOUR ECOLOGICAL FOOTPRINT

Past due (Sep 10)

PART B: FILM & VIDEO REVIEWS

Past due (Oct 22)

PART C: LINKING-TO-LIFE PROJECT & REPORT

Due Friday Nov 22



A few wrap-up questions
to start. . . .

CLICKER TIME!!

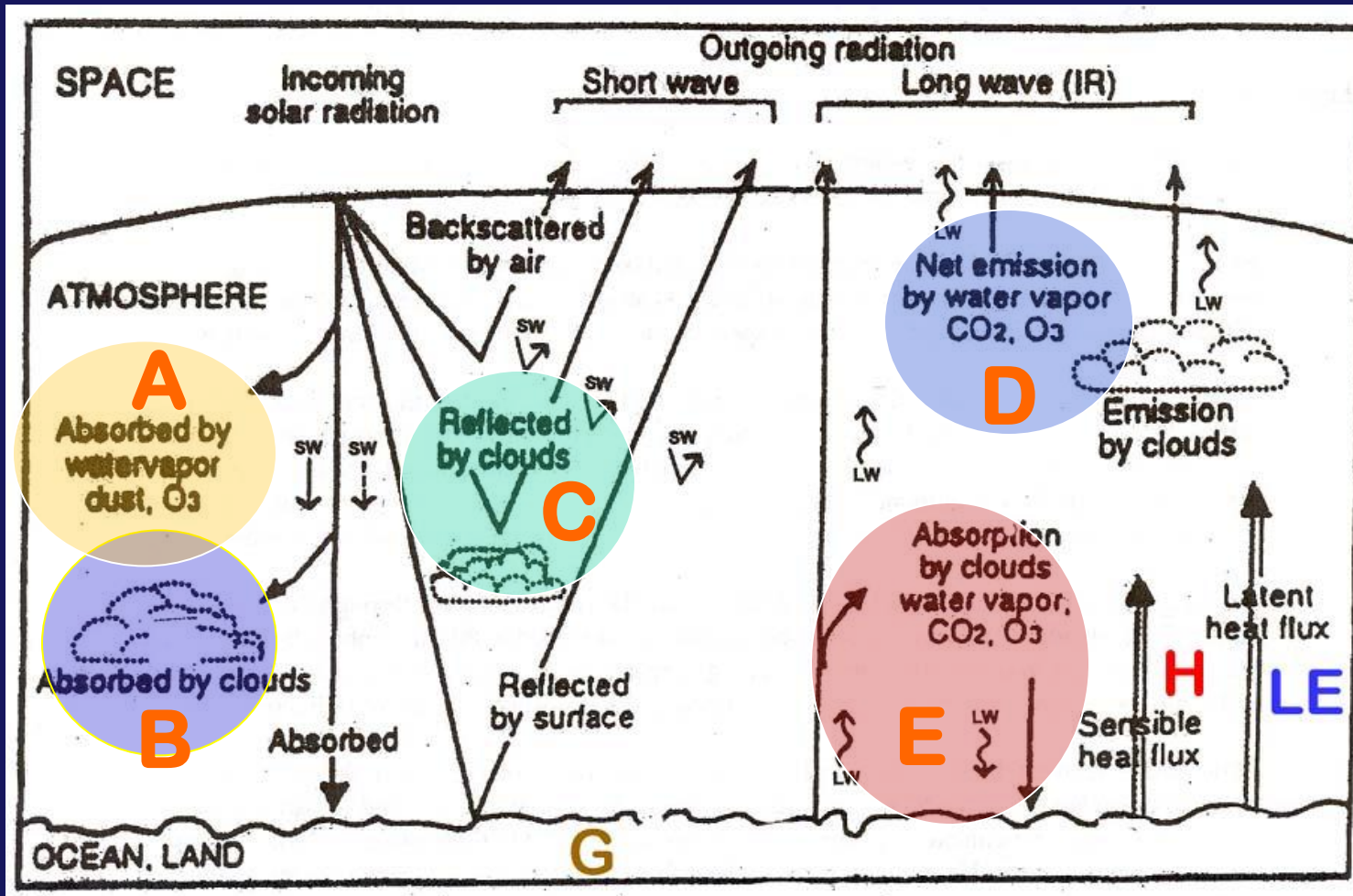
FLIP BACK TO

p 56 in CLASS NOTES

Tying things together in terms
of the Energy Balance

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

A B C D E G



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

A

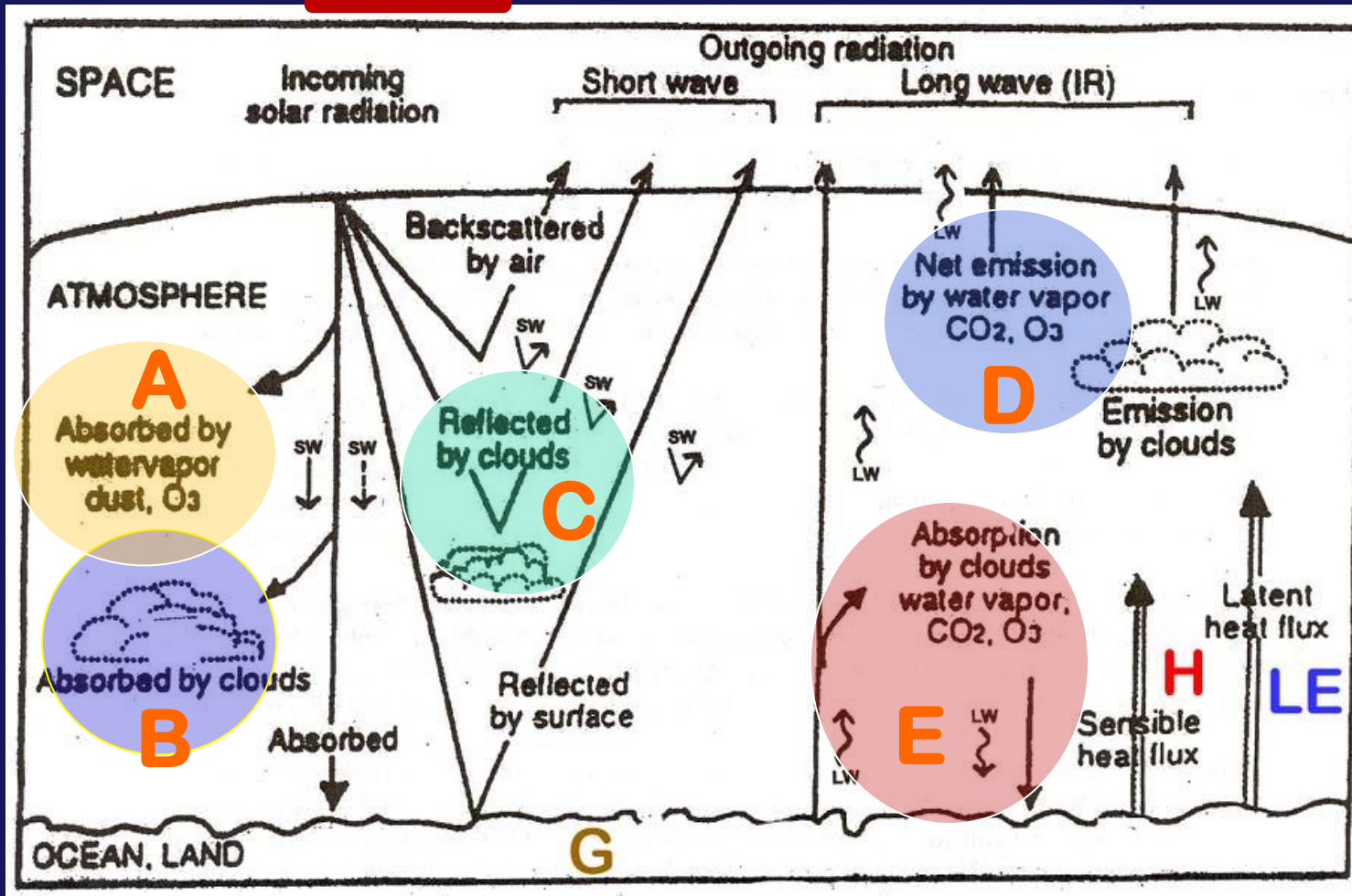
B

C

D

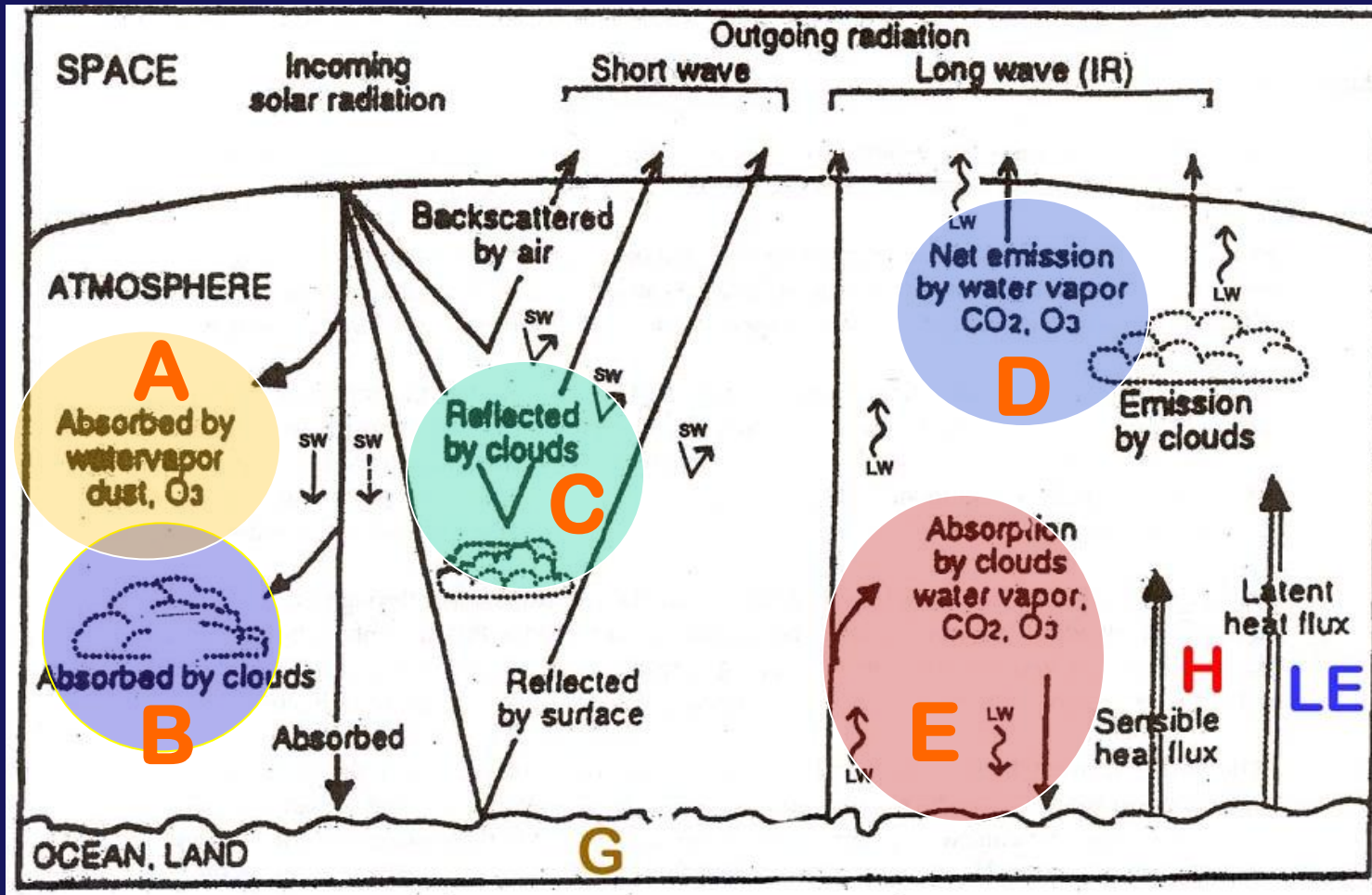
E

G



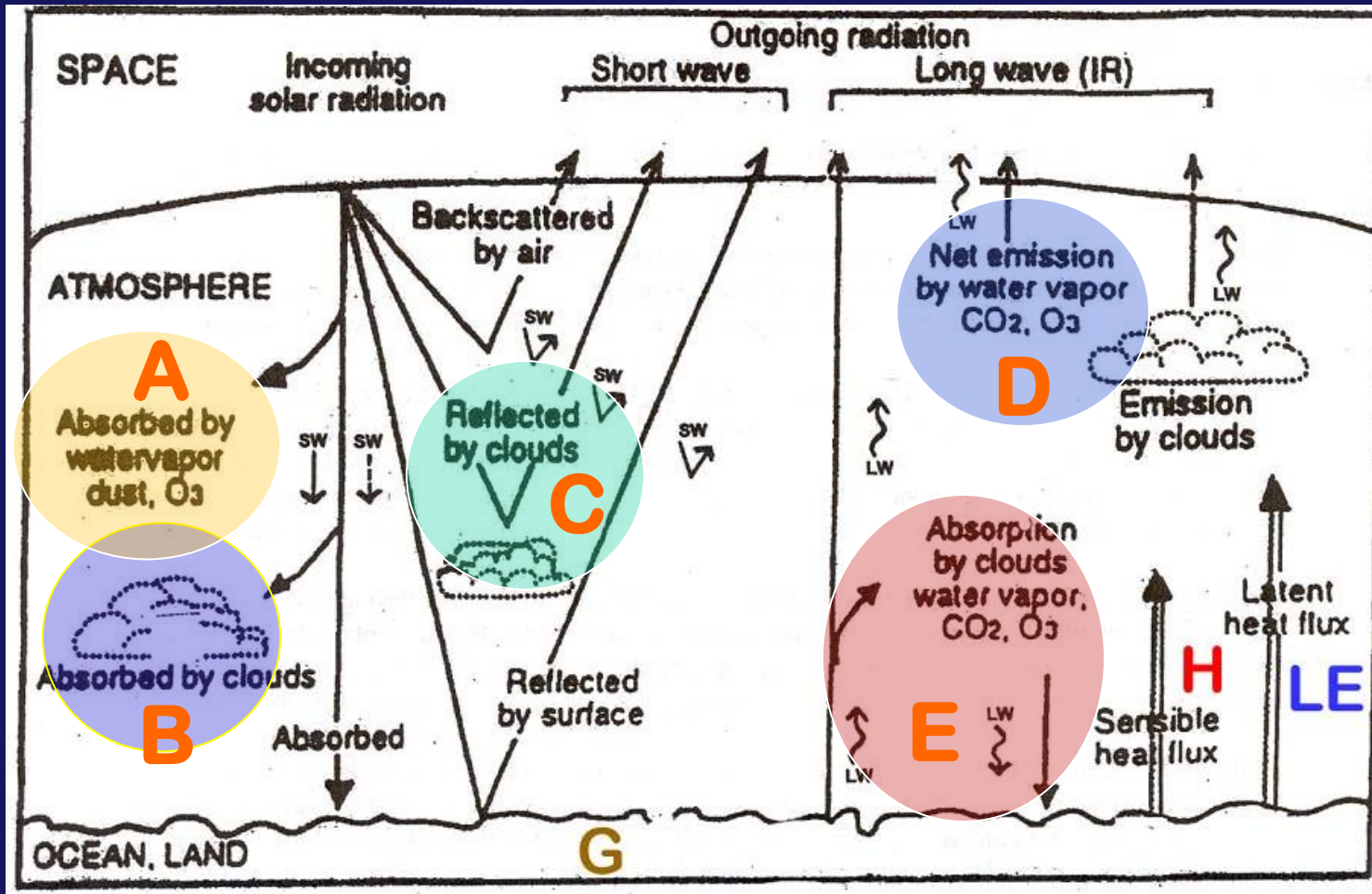
Q2. In which part of the energy balance does the activity related to GLOBAL WARMING from the enhanced GHE take place?

A B C D E G H



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 E G H



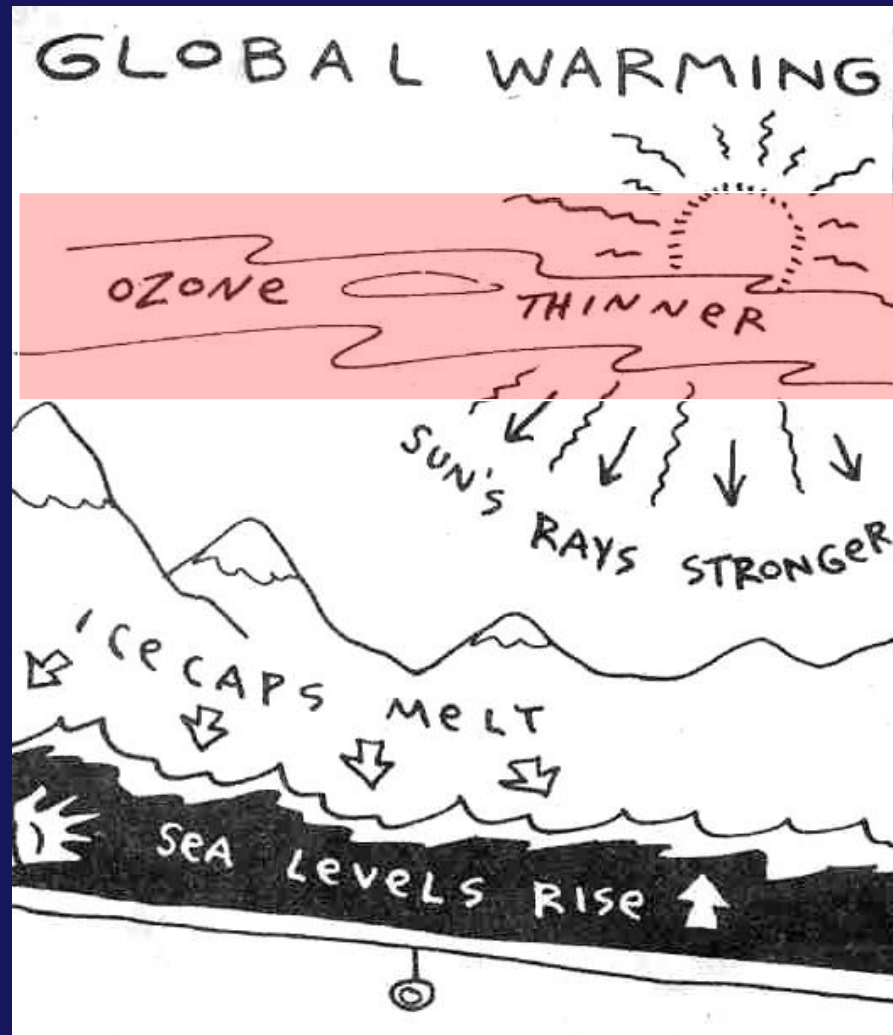
Q3 – Which is the correct statement:

- 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 critically 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 critically important CAUSE of STRATOSPHERIC COOLING which could prolong or worsen the OZONE HOLE
- 3 Neither

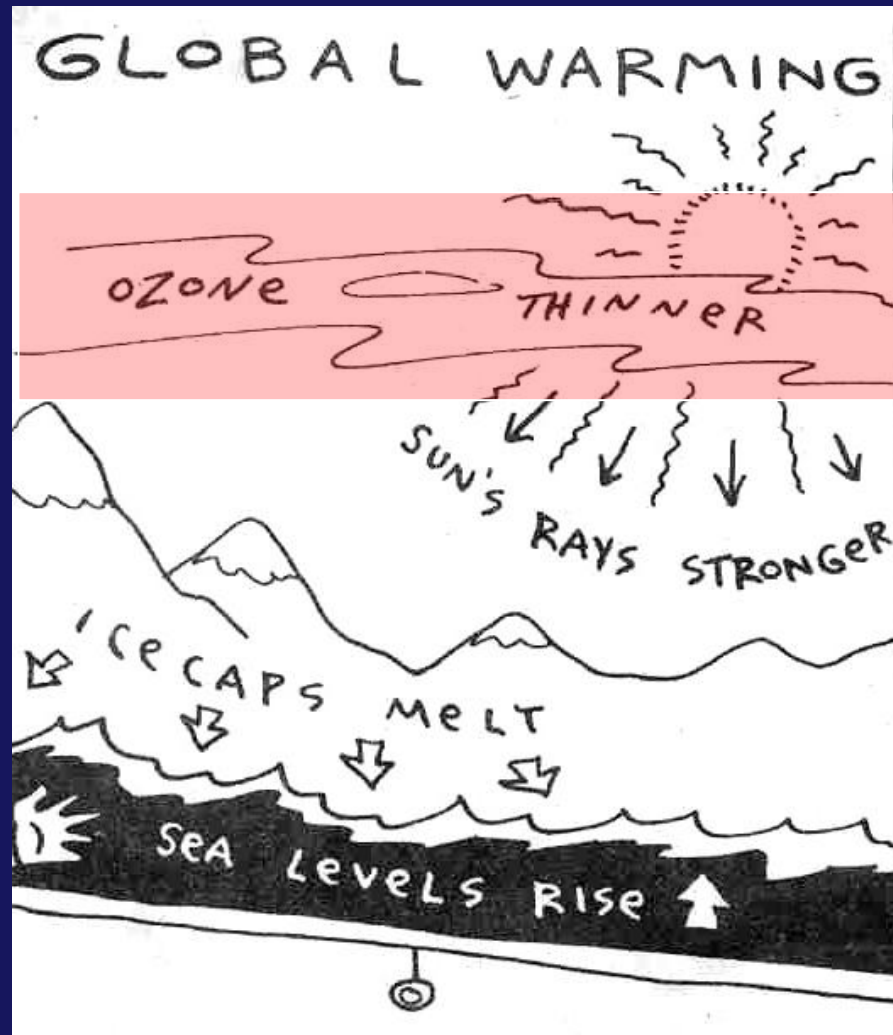
Q4. Is this explanation of the main CAUSE of GLOBAL WARMING correct?



1- YES

2- NO

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



1- YES

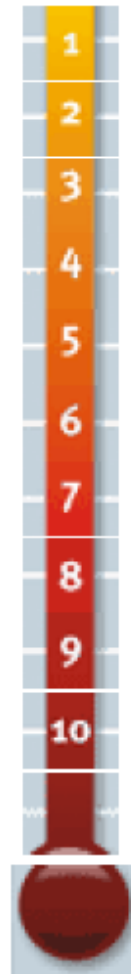
2- NO

CLIMATE CHANGE:

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**

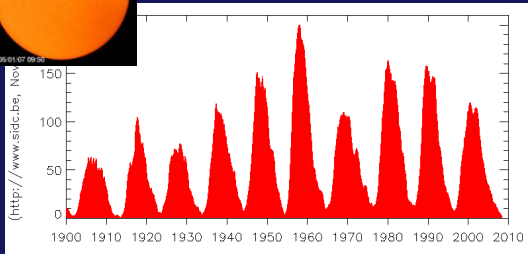
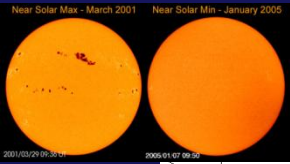
8 **Animals and plants can adapt**

9 **It hasn't warmed since 1998**

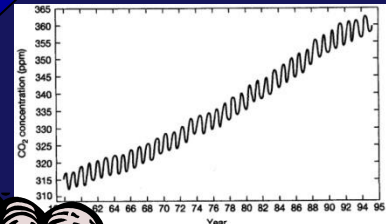
10 **And so forth**

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

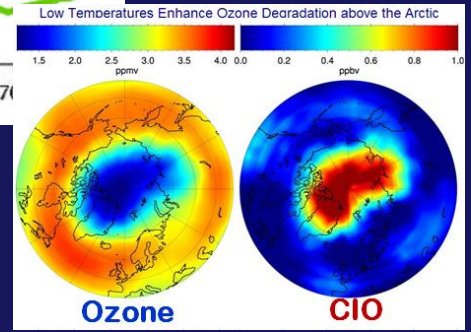
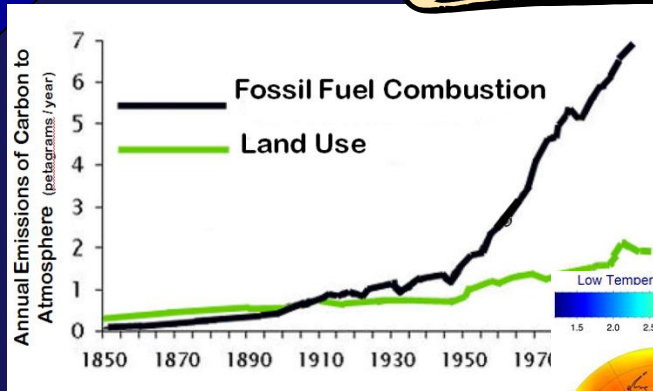
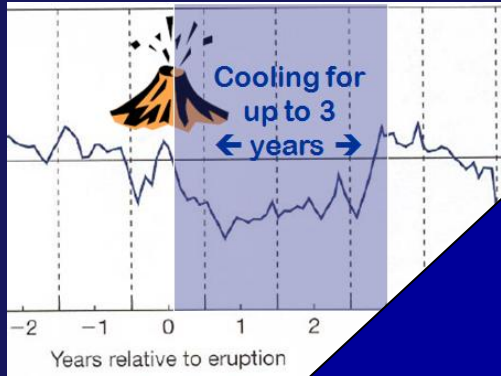
NATURAL FORCING



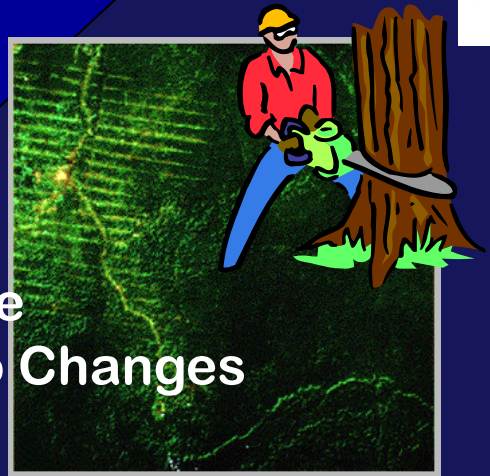
Solar output variations, sunspots



GHG's, soot, SO₂



Volcanic eruptions



Surface Albedo Changes

ANTHROPOGENIC FORCING



TOPIC # 15

GLOBAL WARMING & ANTHROPOGENIC FORCING

Part A

CARBON RESERVOIRS & FLUXES: Natural vs. Anthropogenically Enhanced

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

“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.**”

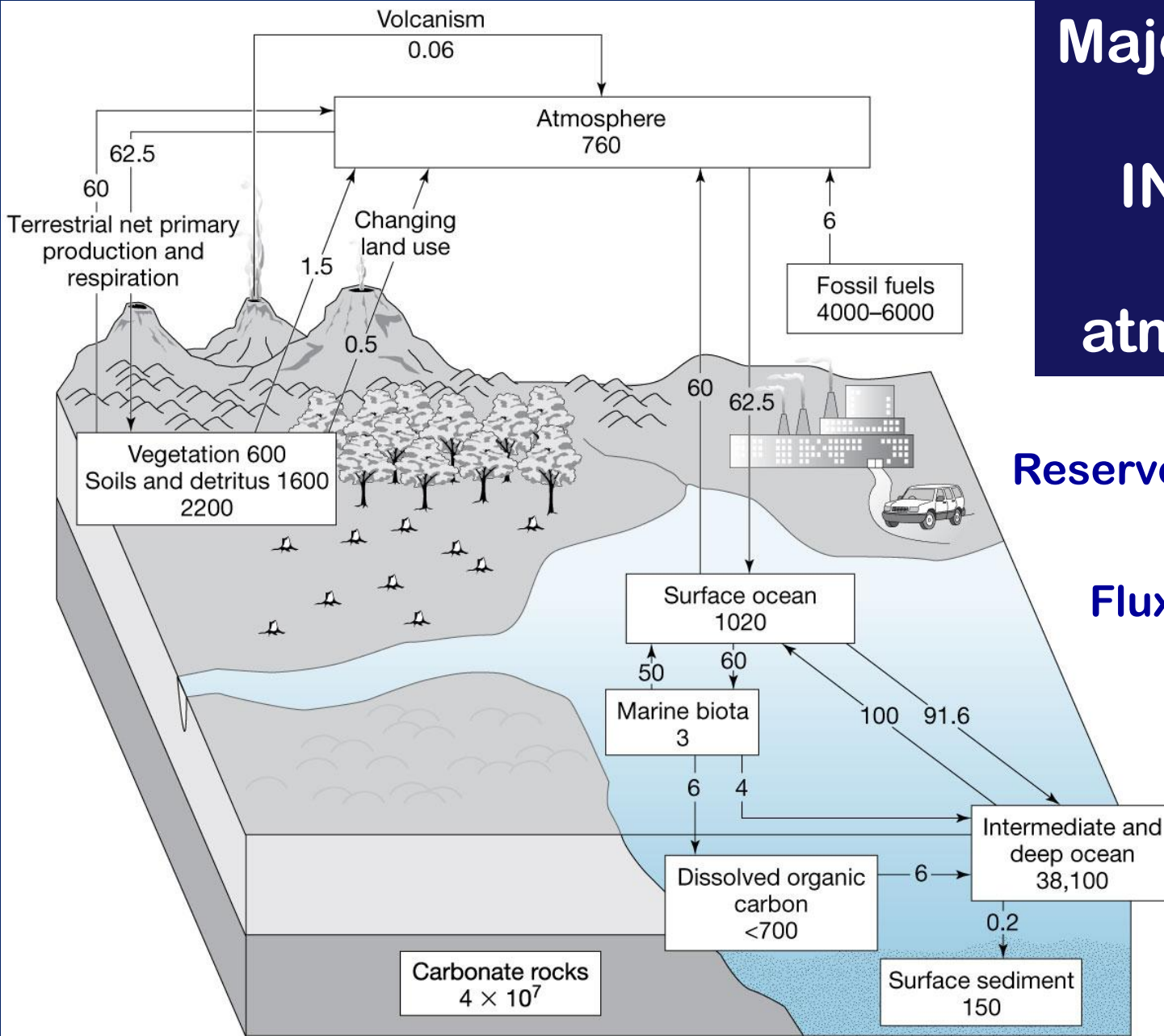
~Wally Broecker , Paleoclimatologist

CO₂ & CARBON RESERVOIRS

CO₂ 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



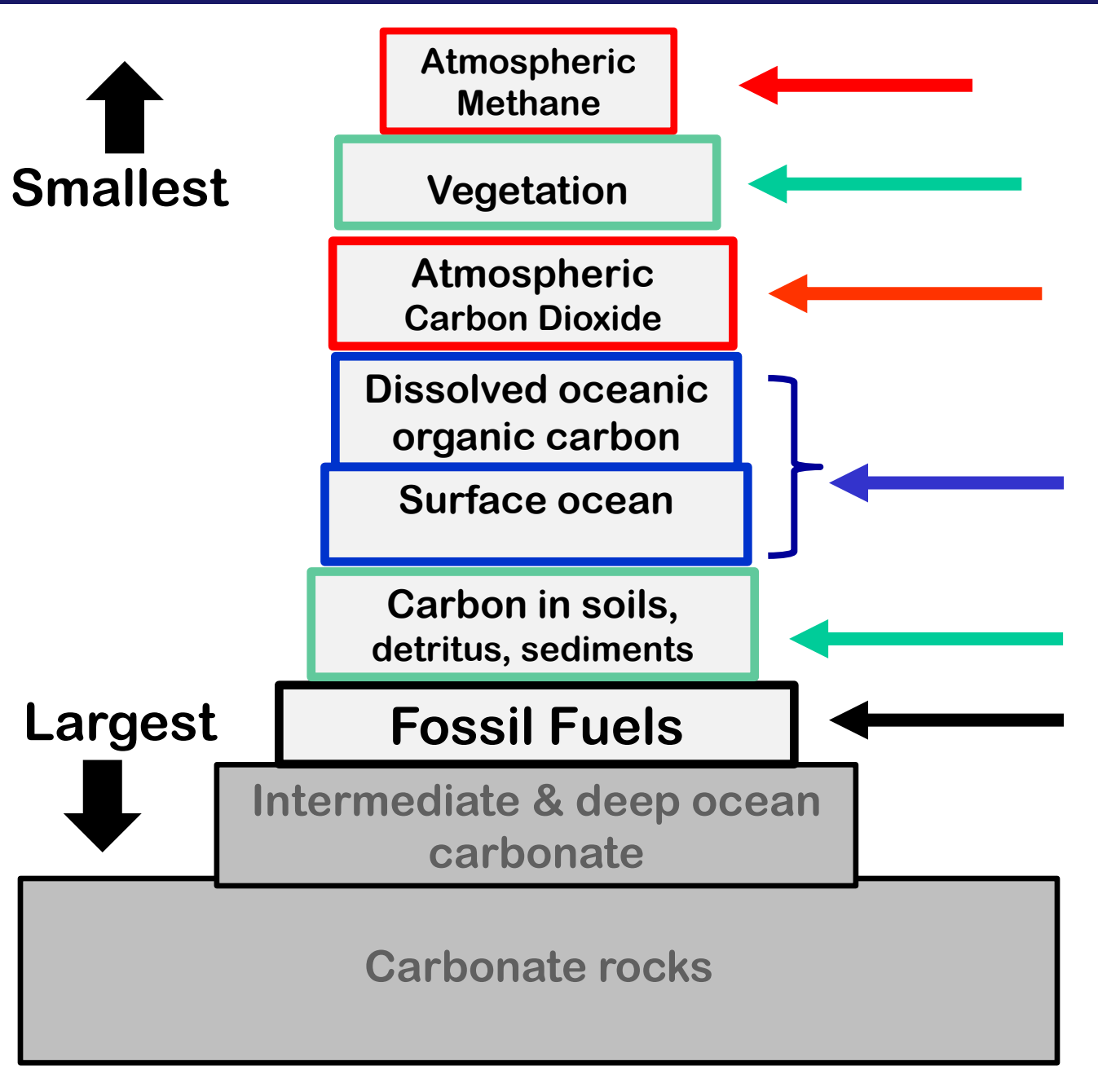
Reservoirs =

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. CO₂)



One gigaton is . . .

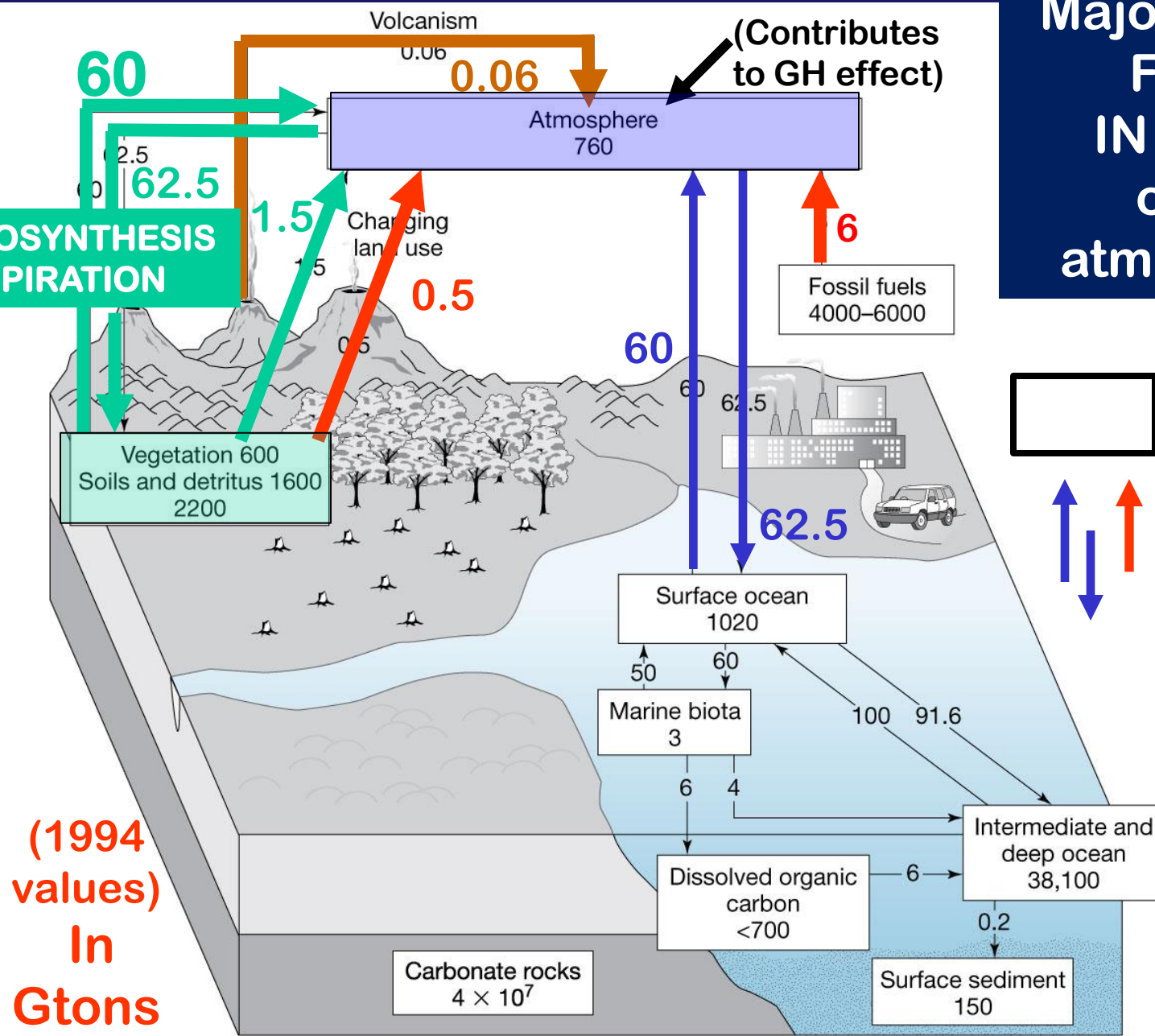


Greater than the mass
of all the humans on the planet



Major Carbon Fluxes IN & OUT of the atmosphere

PHOTOSYNTHESIS & RESPIRATION



[] = carbon stored in a reservoir

↕ = carbon flux from one reservoir to another

(in Gtons/yr)

**(1994 values)
In
Gtons**

1 Gton = 1 billion tons

But – it's now 20 years later . . .

Global carbon emissions set to reach record 36 billion tonnes in 2013

TODAY'S NEWS:



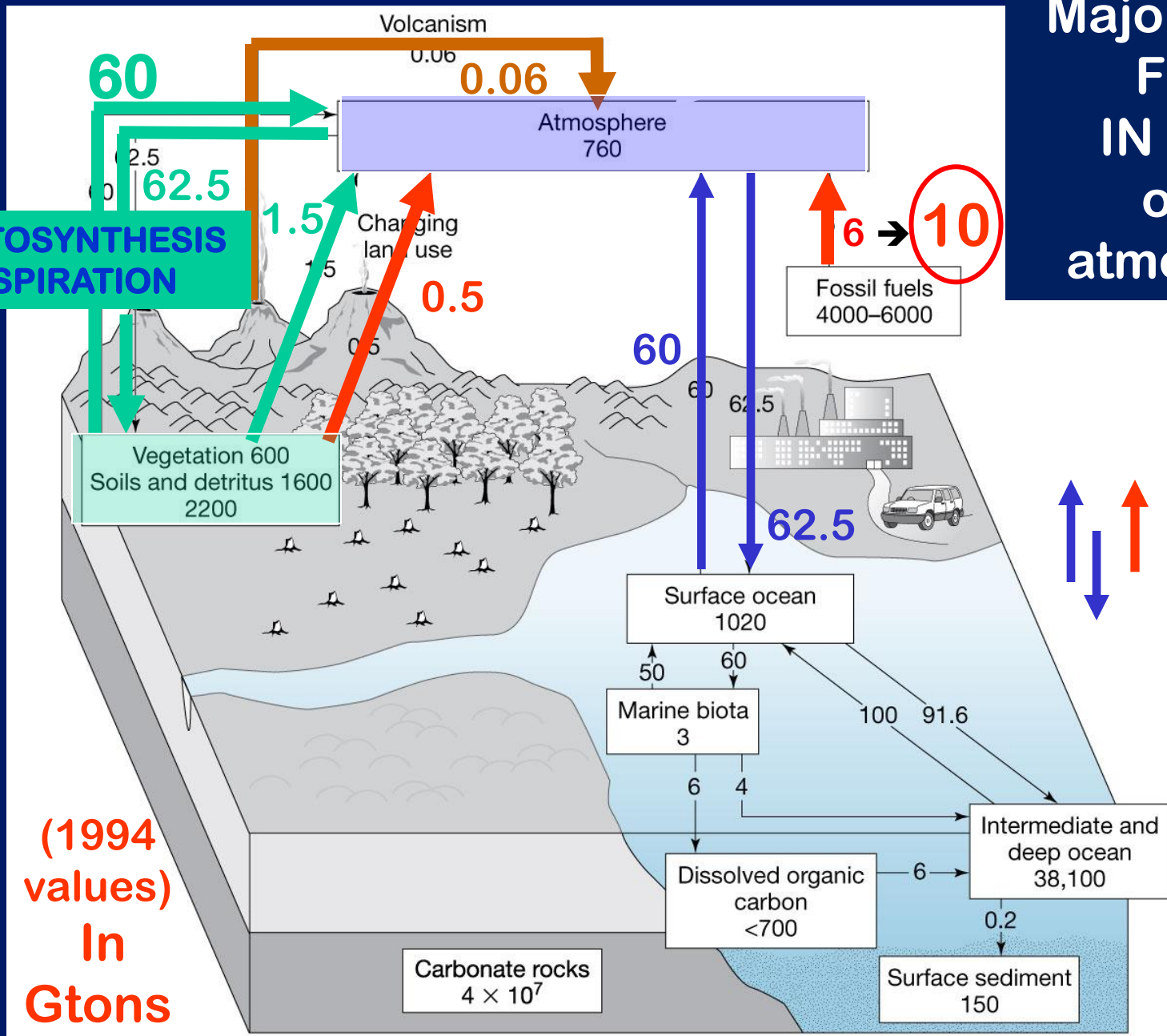
**36 Gtons
of CO₂ =
~ 10
of just the
CARBON
atoms**

Global emissions of carbon dioxide from burning fossil fuels are set to rise again in 2013, reaching a record high of 36 billion tonnes - according to new figures from the Global Carbon Project The 2.1 per cent rise projected for 2013 means global emissions from burning fossil fuel are 61 per cent above 1990 levels, the baseline year for the Kyoto Protocol.

Read more at: <http://phys.org/news/2013-11-global-carbon-emissions-billion-tonnes.html#jCp>

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 photosynthesis

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

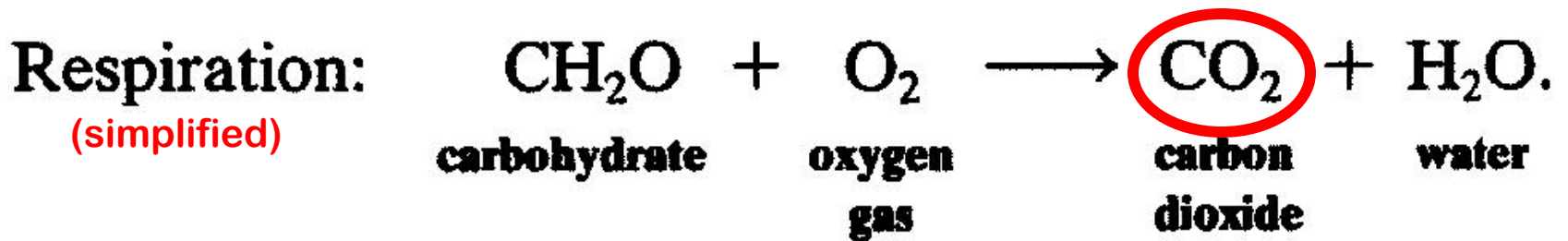
2. Trees release carbon dioxide during photosynthesis.

3. Trees release carbon dioxide into the atmosphere during respiration

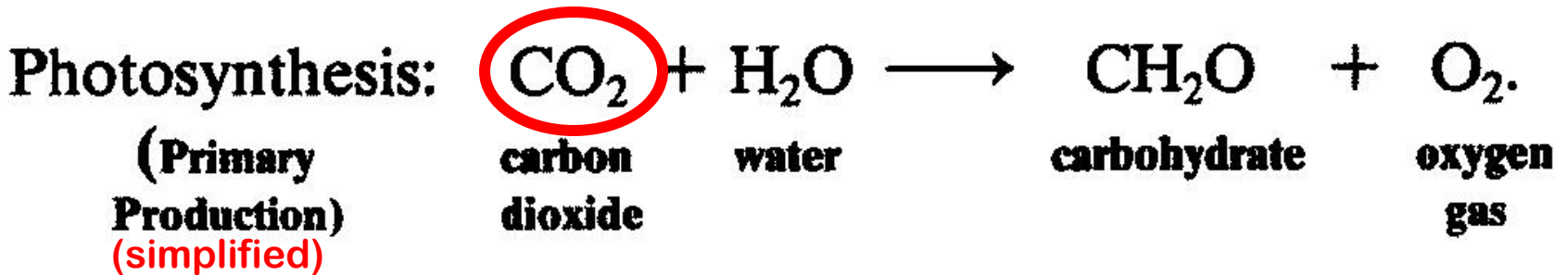
← THIS answers the Q ! (happens primarily in winter)

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

FLUX from PLANT INTO ATMOSPHERE:



FLUX OUT OF ATMOSPHERE into PLANT:



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 =

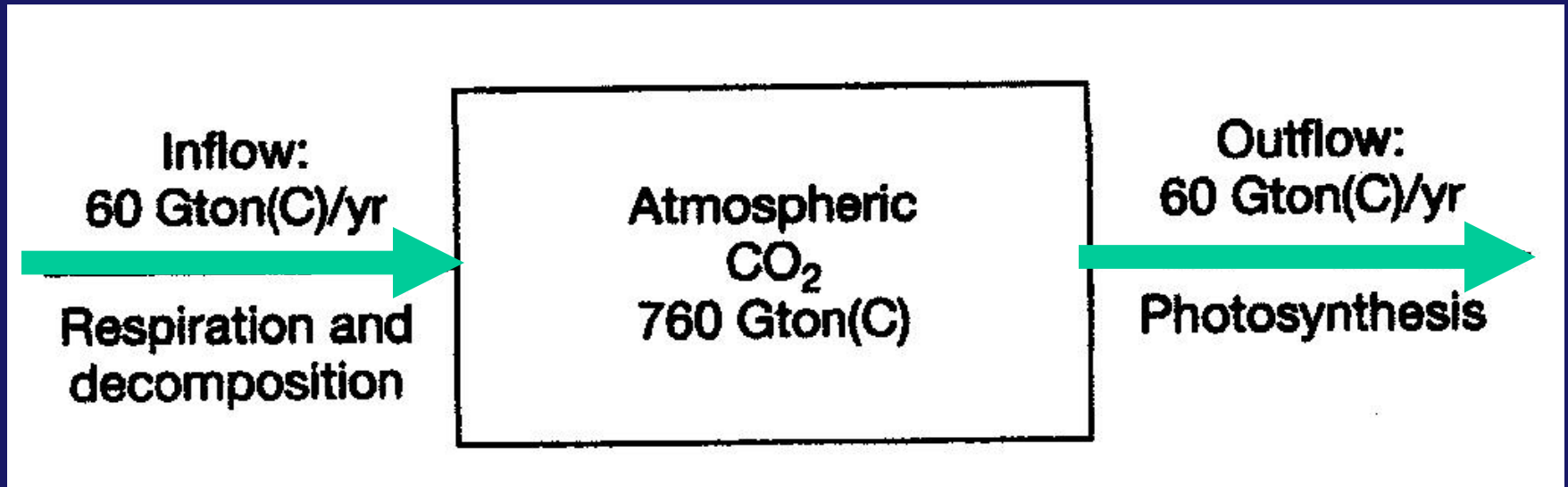
manufacture of carbohydrates & O₂
from CO₂ and H₂O
in the presence of chlorophyll
sunlight as the energy source.

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.)

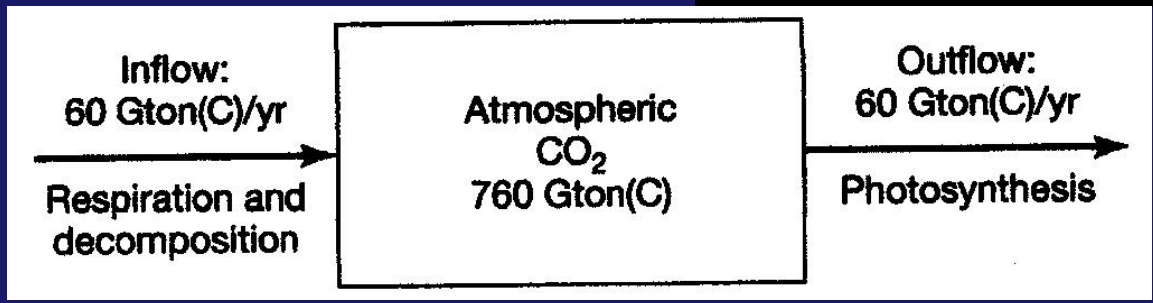
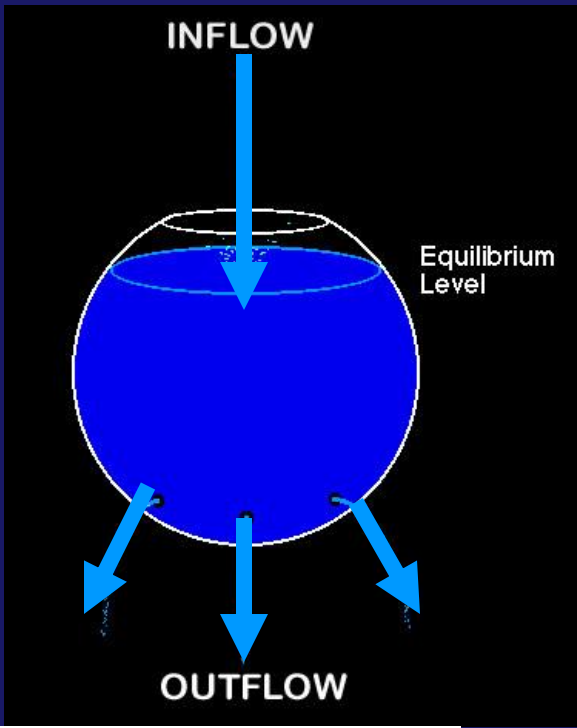
The Atmospheric Carbon Reservoir



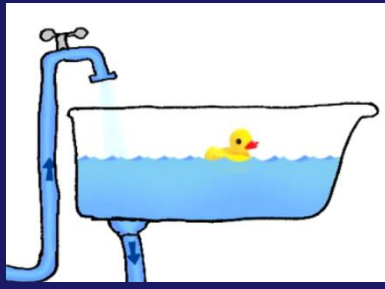
showing inflows and outflows (fluxes)

... leads to a
STEADY STATE

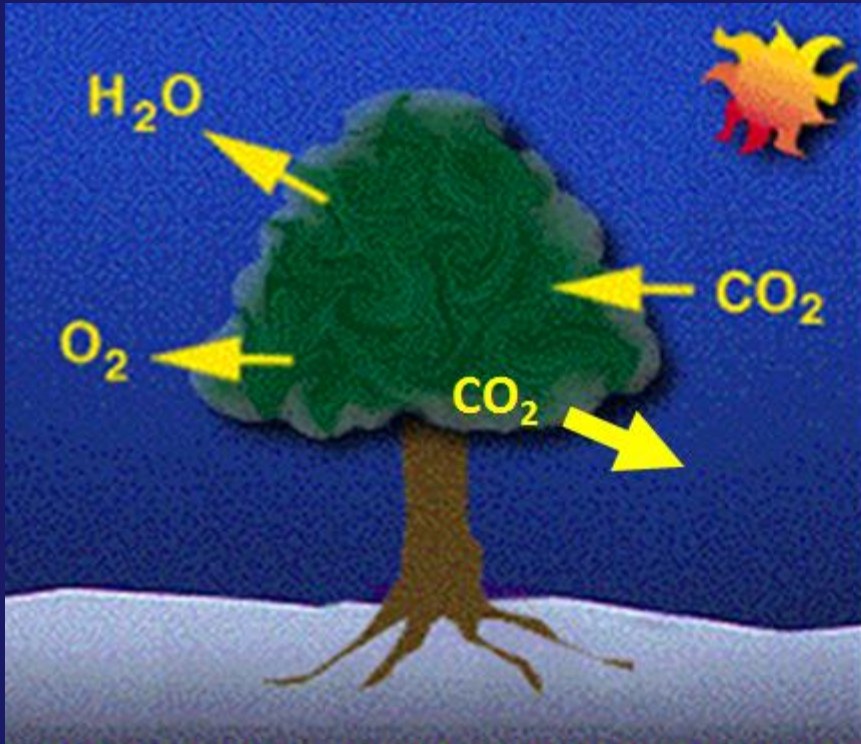
In the atmospheric
CO₂ "reservoir"



*Where have we seen a
STEADY STATE before?*

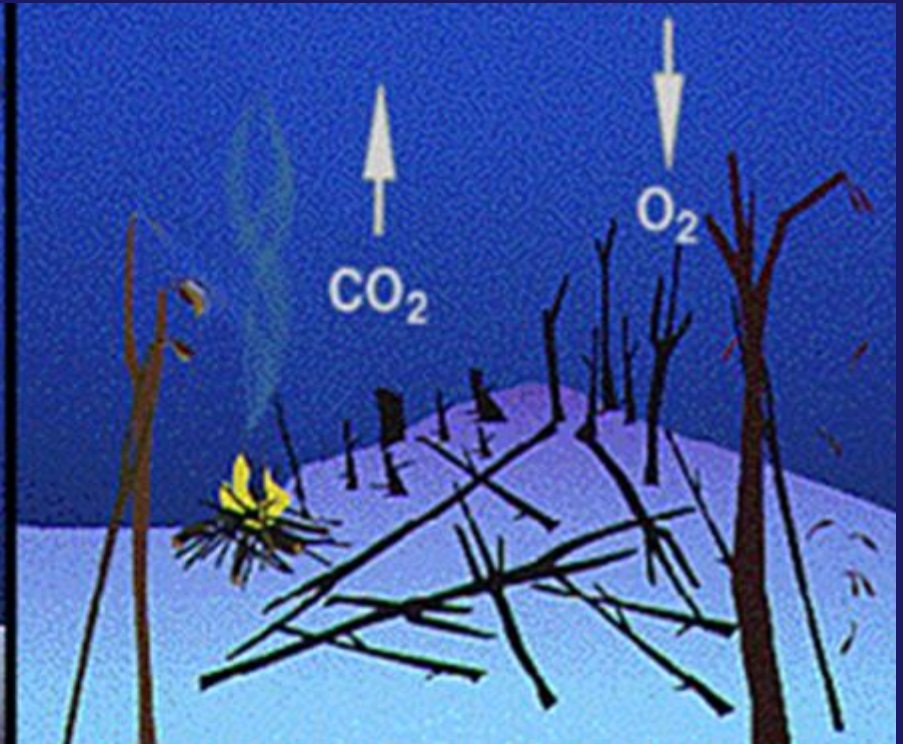


Photosynthesis & Respiration



Steady State

Respiration, Burning of Biomass, & Decomposition

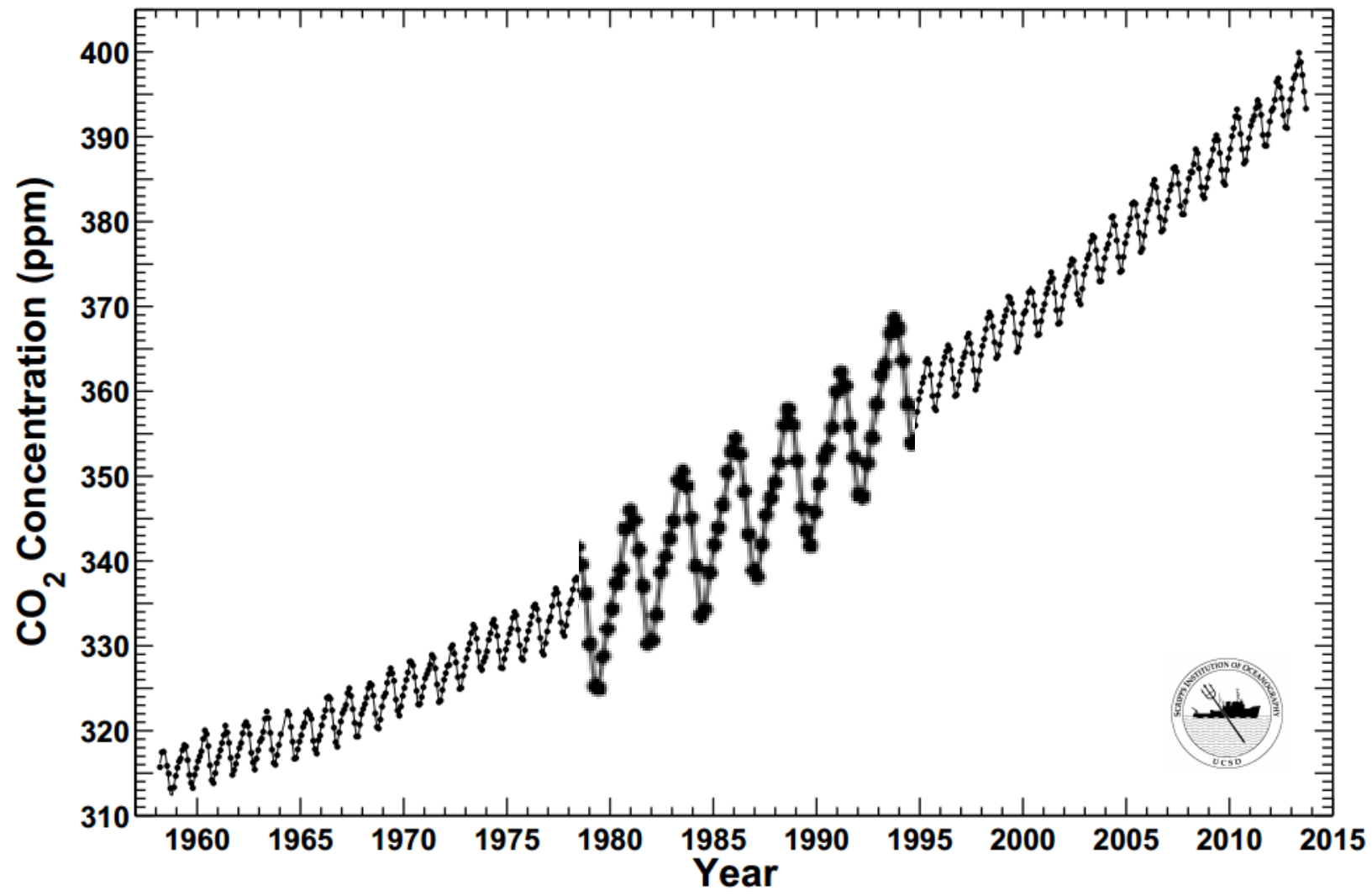


Disruption of Steady State

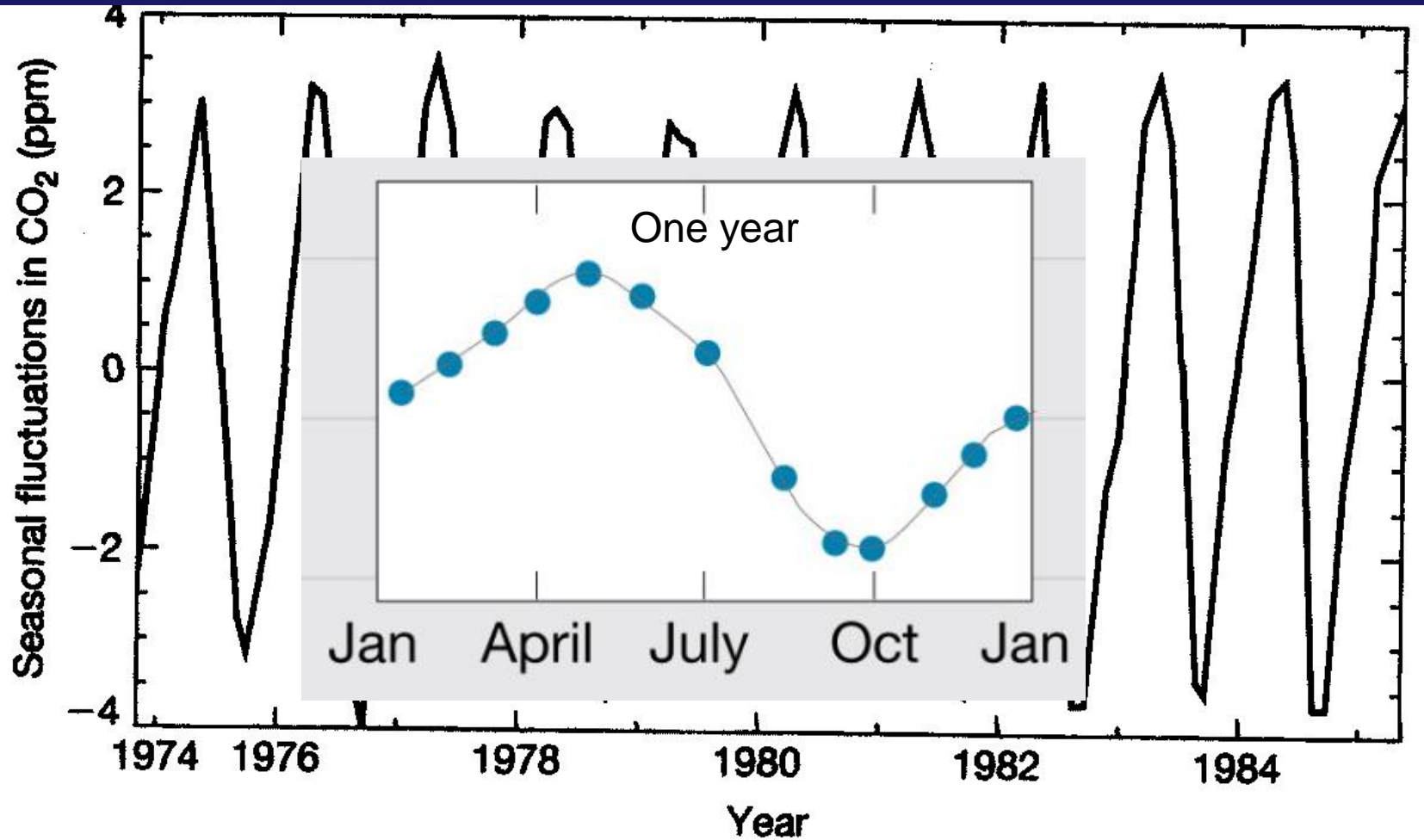
WHAT ABOUT THOSE ZIG-ZAGS IN THE KEELING CURVE?

Mauna Loa Observatory, Hawaii Monthly Average Carbon Dioxide Concentration

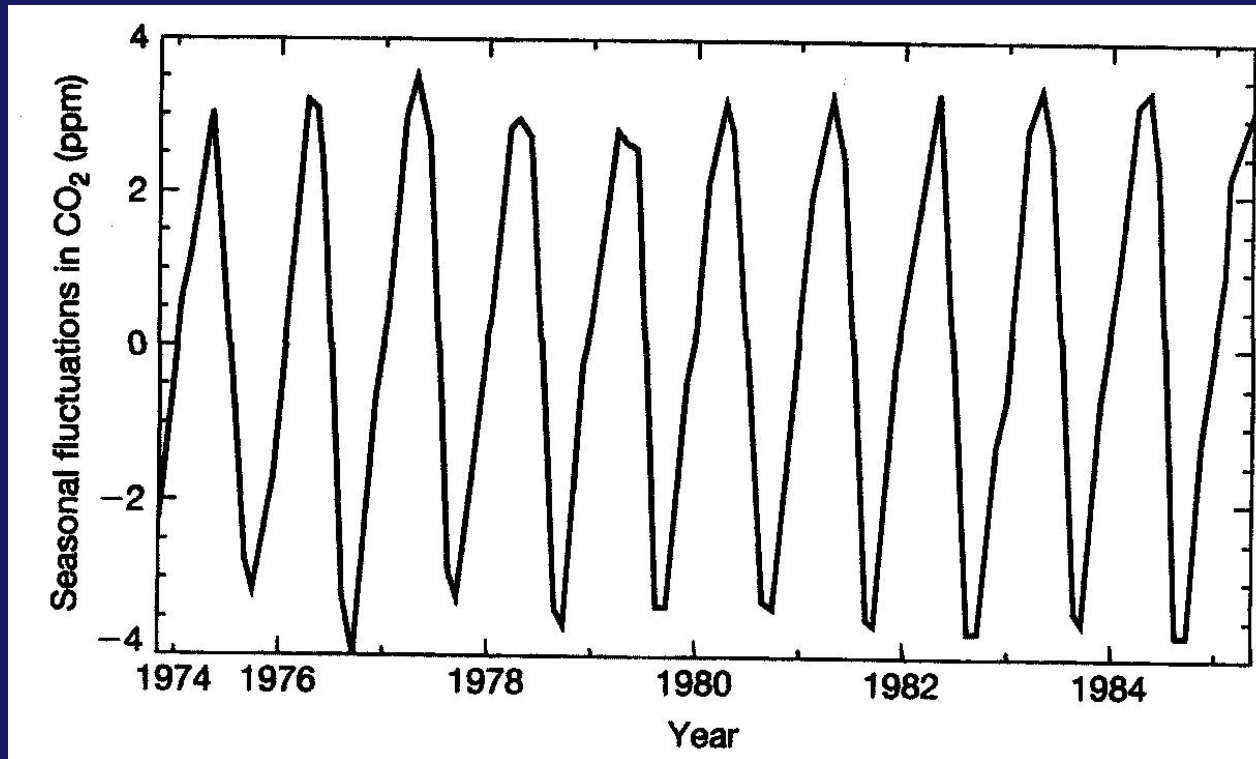
Data from Scripps CO₂ Program Last updated November 2013



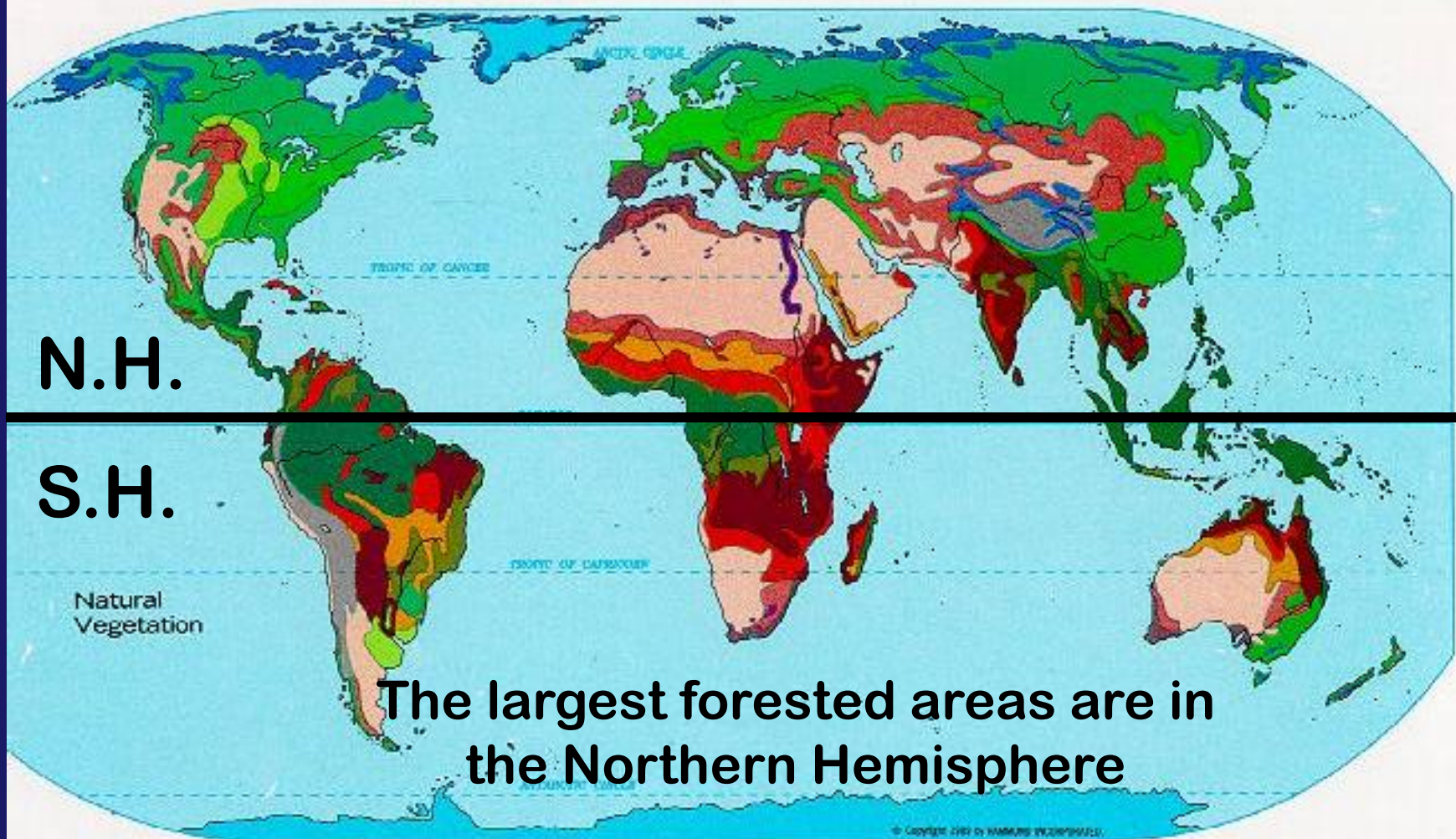
CLOSE-UP VIEW:



Trend due to anthropogenic increases has been removed.



Oscillations represent **seasonal fluctuations** driven by the balance between respiration & photosynthesis (dominated by Northern Hemisphere forests)



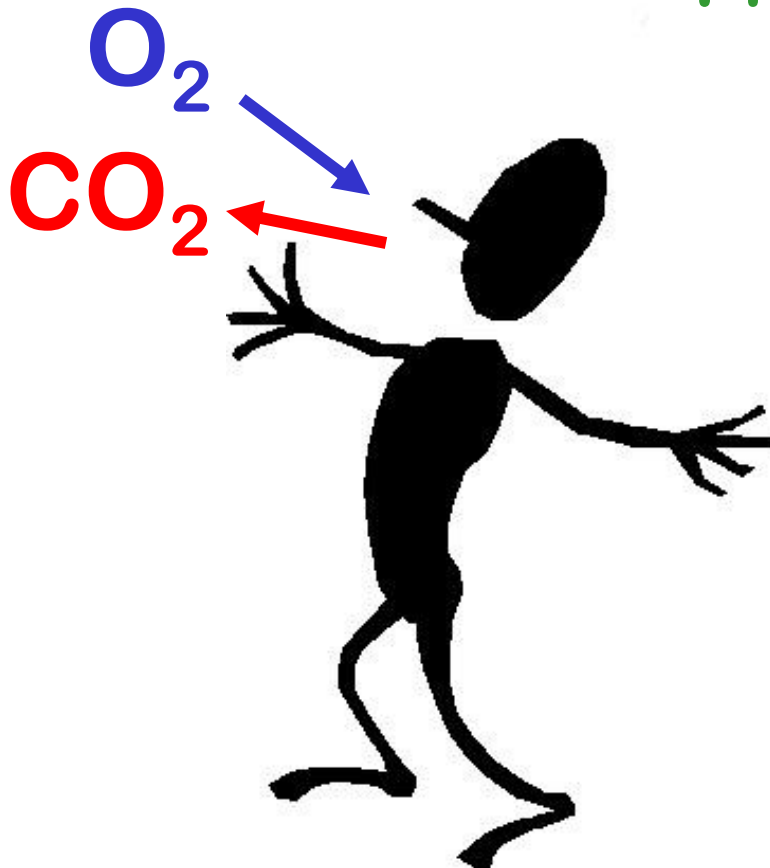
GLOBAL VEGETATION PATTERNS

Needleleaf Forest	Woodland and Shrub (Mediterranean)	River Valley and Oasis	Tropical Grassland and Shrub (Savanna)	Tropical Rain Forest
Broadleaf Forest	Short Grass (Steppe)	Desert and Desert Shrub	Tropical Woodland and Shrub	Heath and Moor
Mixed Needleleaf and Broadleaf Forest	Tall Grass (Prairie)	Wooded Savanna	Light Tropical Forest	Tundra and Alpine
Unclassified Highlands			Permanent Ice Cover	

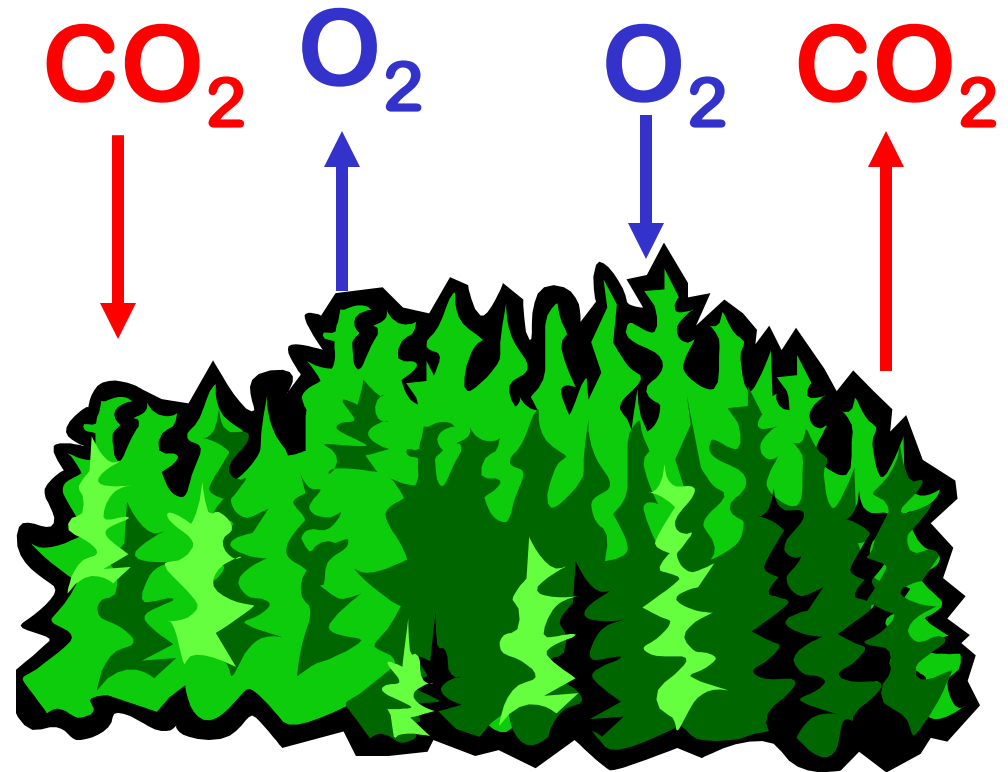


“Breathing” -- ANIMALS vs. PLANTS

Respiration



Photosynthesis



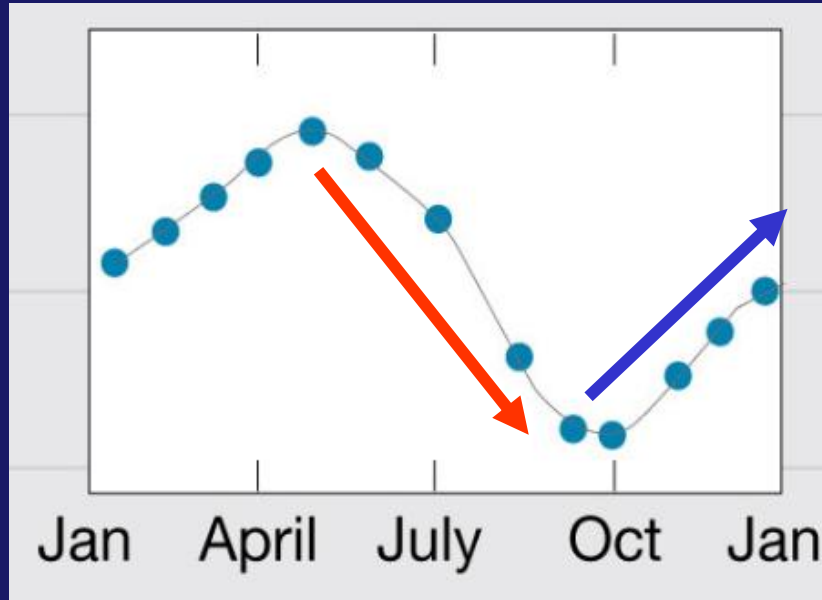
Respiration & Decomposition





Photosynthesis > Respiration

(CO₂ goes down in SUMMER as forests “breathe in” more CO₂)



Respiration > Photosynthesis

(CO₂ levels rise in FALL/WINTER as forests “breathe out” more CO₂)

Tick marks are at January of each year:

Photosynthesis > Respiration

(CO₂ goes down in SUMMER as forests “breathe in” more CO₂)

Respiration > Photosynthesis

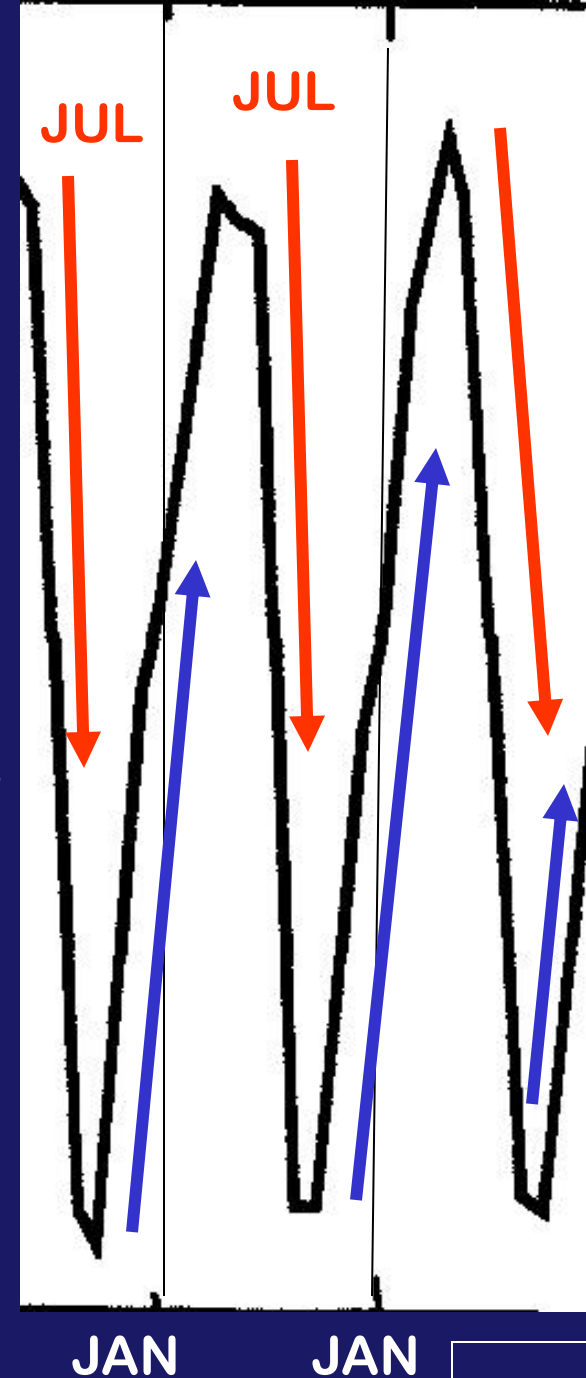
(CO₂ levels rise in FALL/WINTER as forests “breathe out” more CO₂)

Photosynthesis > Respiration

(CO₂ goes down in summer)

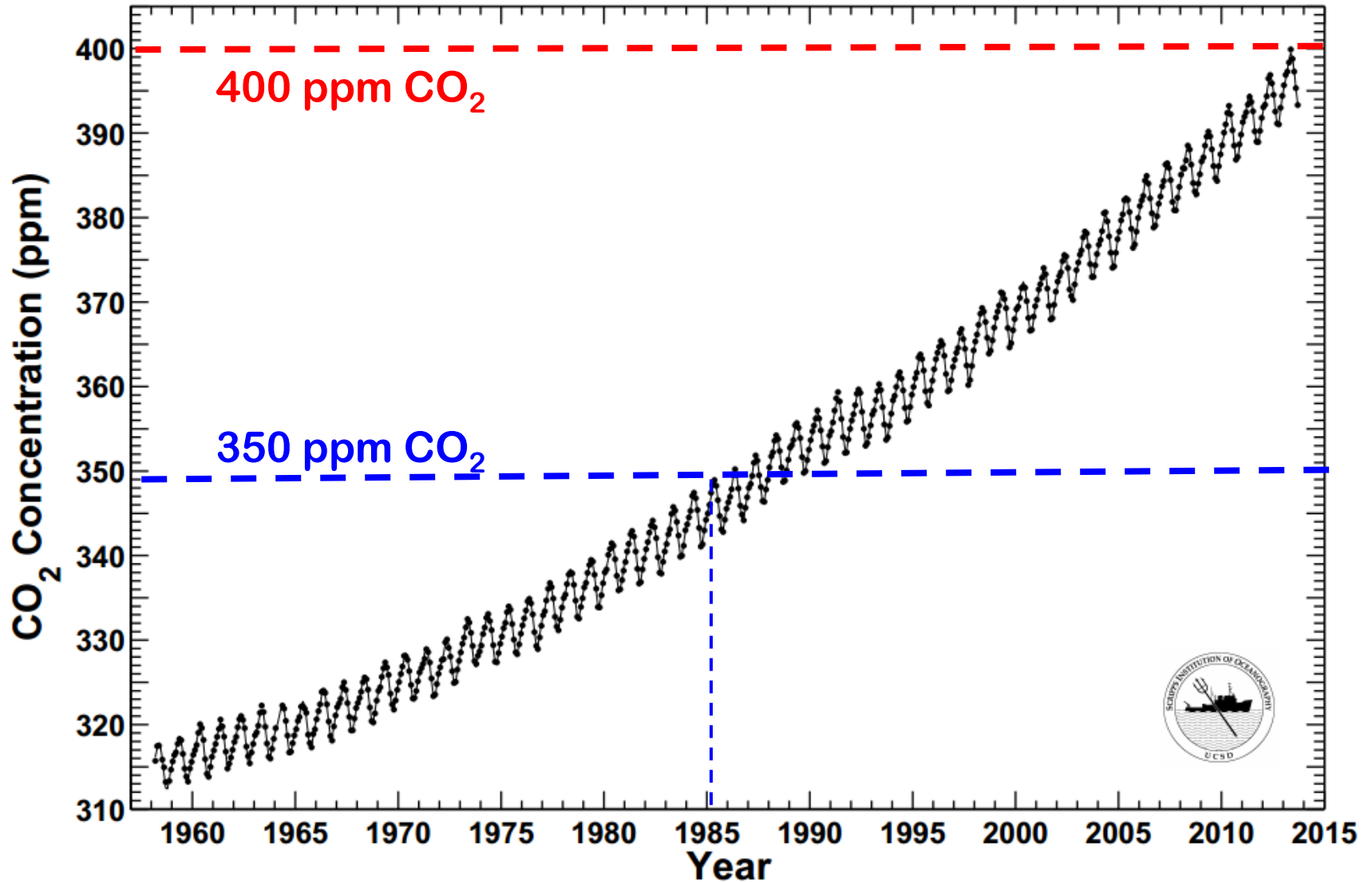
Respiration > Photosynthesis

(CO₂ levels rise in fall/winter)



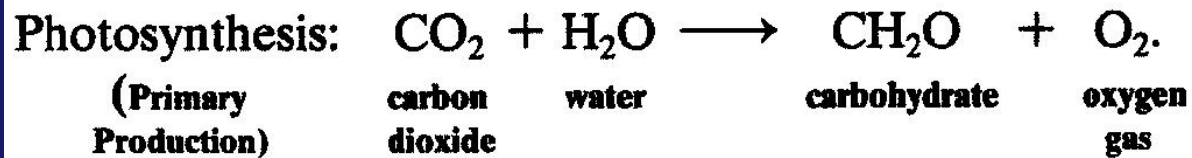
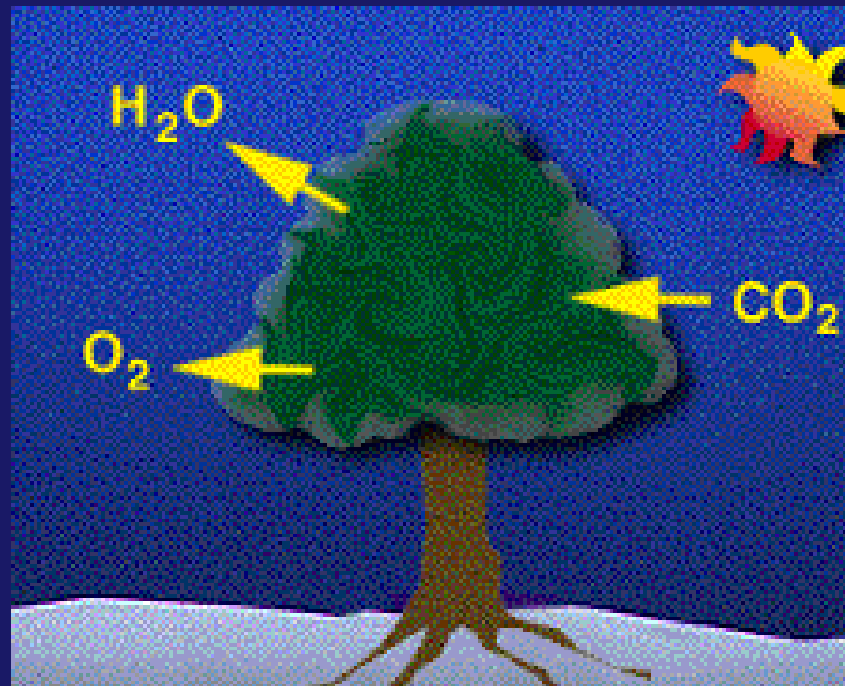
Mauna Loa Observatory, Hawaii Monthly Average Carbon Dioxide Concentration

Data from Scripps CO₂ Program Last updated November 2013



BUT IS ALL THE EXTRA CO₂
A BAD THING???

PLANTS DEPEND ON CO₂!!!



Mini-Break:

YOU TUBE!

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

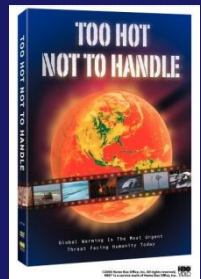


Hence with Increased CO2 :

- 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 !!



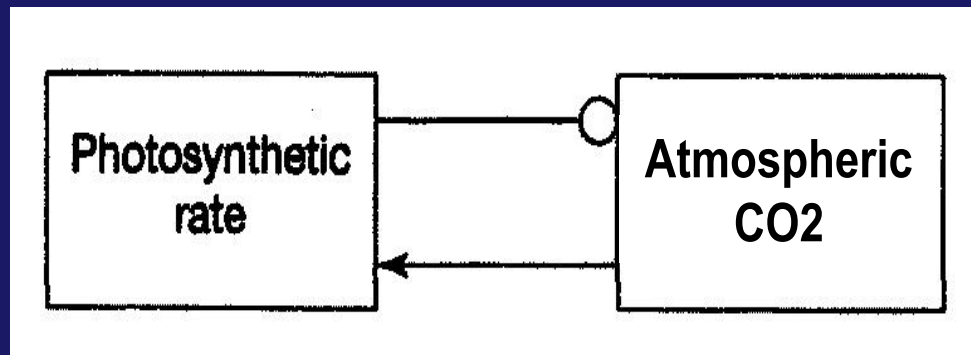
Greater atmospheric CO₂ concentration

→ **enhanced photosynthesis** (due to “CO₂ Fertilization”)

→ **more CO₂ being assimilated by plant**
and taken out of the atmosphere

→ **less atmospheric CO₂**

Wow – sounds like a FEEDBACK LOOP!



**Q6. WHAT
KIND OF
LOOP IS IT?**

- A. **Positive** and self-regulating, **stabilizing** the climate
- B. **Negative** and self-regulating, **stabilizing** the climate
- C. **Positive** and self-amplifying, adding to **global warming**
- D. **Negative** and self-amplifying, adding to **global warming**

Greater atmospheric CO₂ concentration

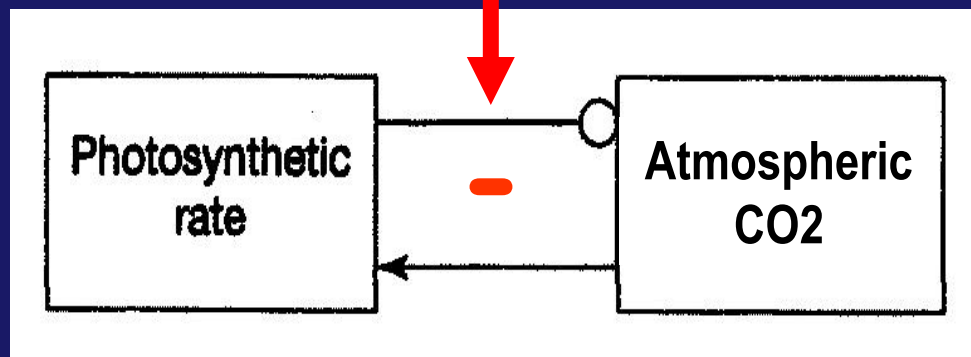
→ **enhanced photosynthesis** (due to “CO₂ Fertilization”)

→ **more CO₂ being assimilated by plant**
from the atmosphere

→ **less atmospheric CO₂**

Wow – sounds like a FEEDBACK LOOP!

What kind is it?



“B” is correct!

Negative & self-regulating!

... but ‘the jury is still out’ on how well and **how LONG** this negative feedback loop can counteract the **HUGE** anthropogenic influxes of CO₂ that continue each year!!!!

“Imagine if you took **all the cars, trucks, planes, trains and ships in the world** and added up their exhaust every year. . . .

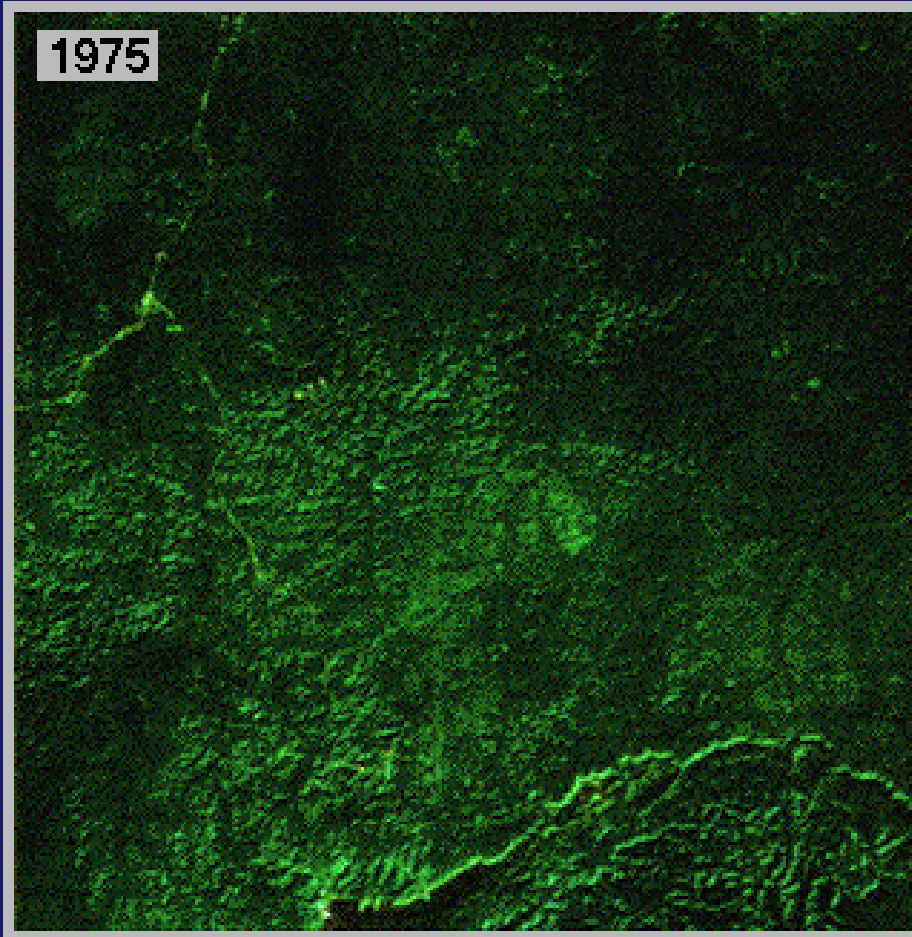
[it is] **actually LESS than the carbon emissions every year** that result from the **chopping down and clearing of tropical forests** in places like Brazil, Indonesia and the Congo. “

“We are now **losing a tropical forest the size of New York State every year**, and the carbon that releases into the atmosphere now accounts for roughly **17 percent of all global emissions contributing to climate change.** “

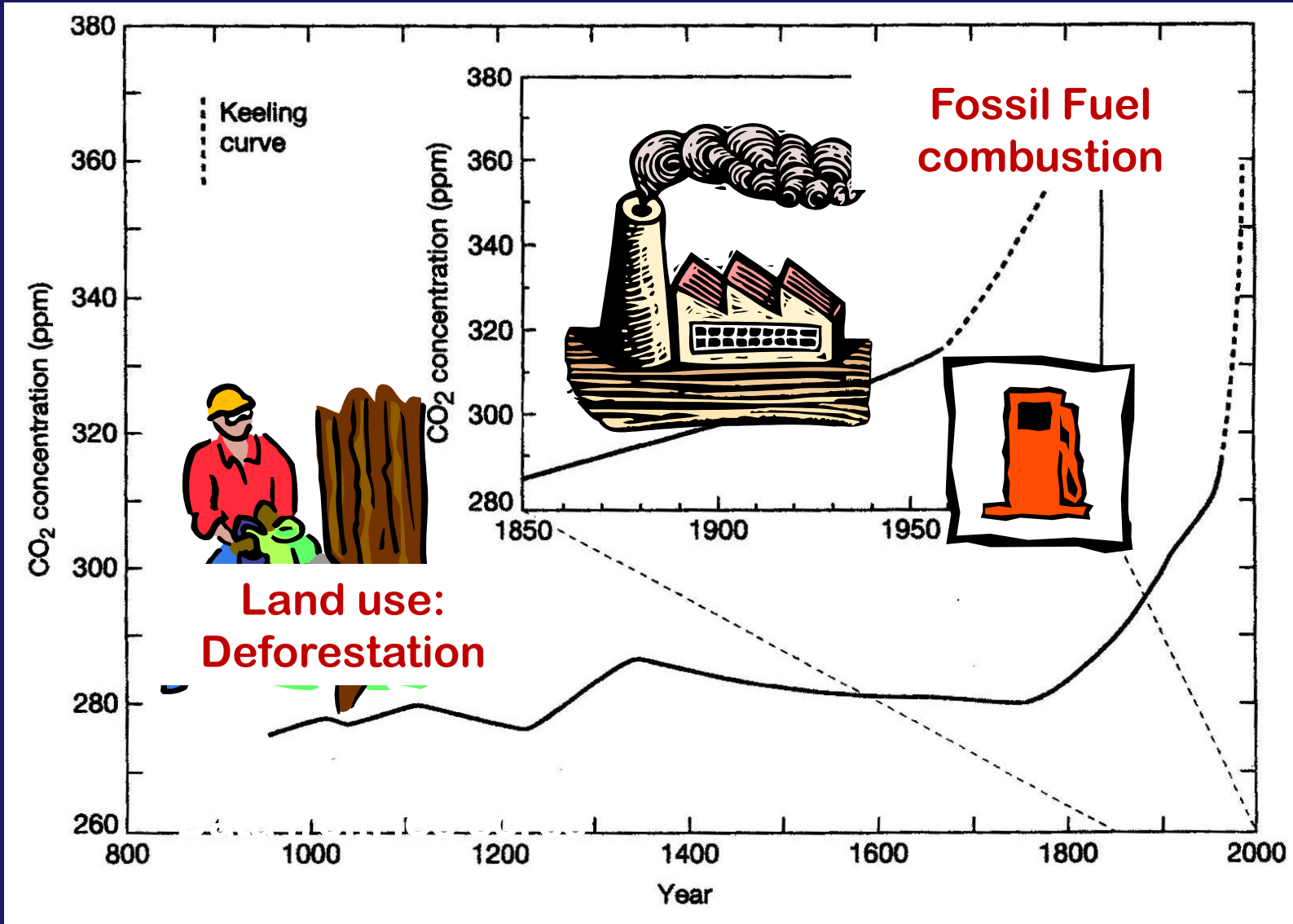


LAND USE CHANGES:

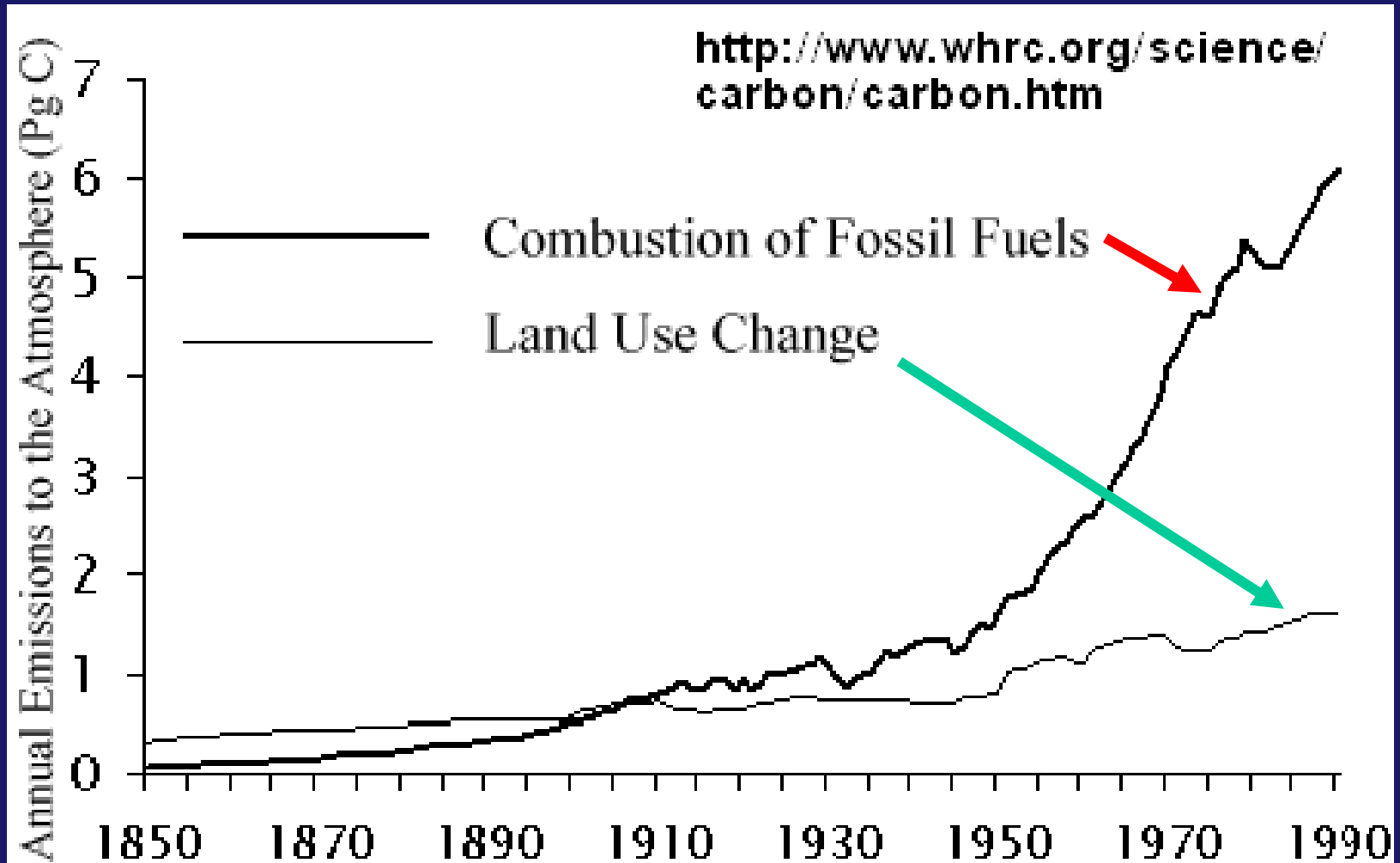
Deforestation practices increase burning & decomposition of large areas of forest



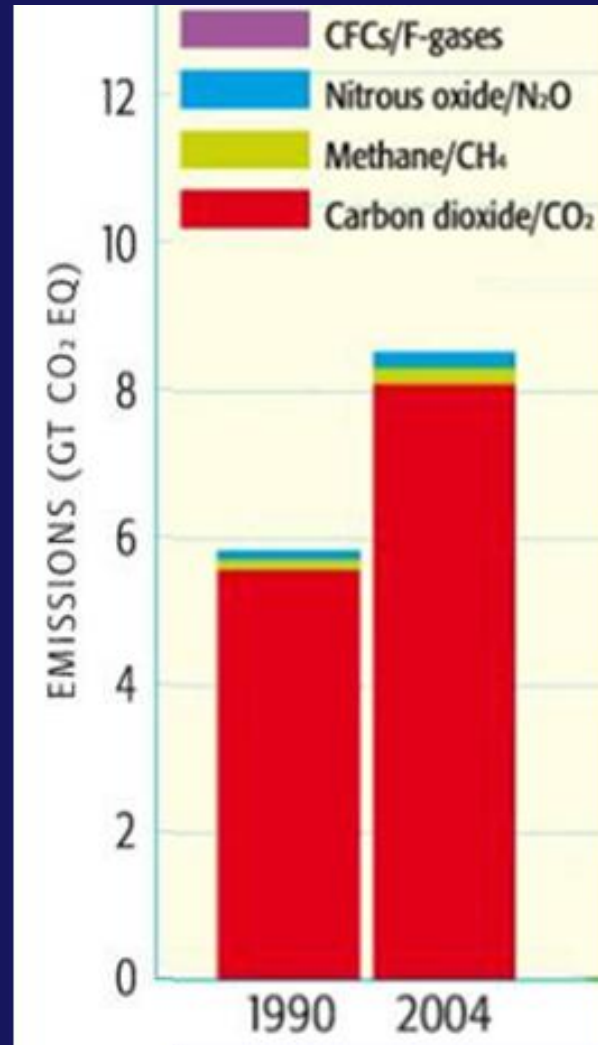
CARBON DIOXIDE: Two big sources



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

Highest rates of **DEFORESTATION** in red

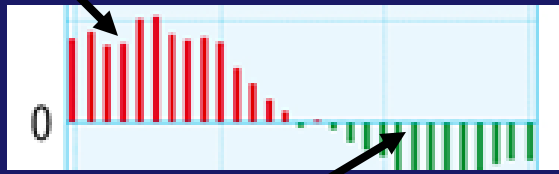
decrease  increase
< -0.5 0.5 >

NET CHANGES IN FORESTED AREA BETWEEN 2000 AND 2005 (PERCENTAGE CHANGE PER YEAR)

Figure on p 175
in *Dire Predictions*

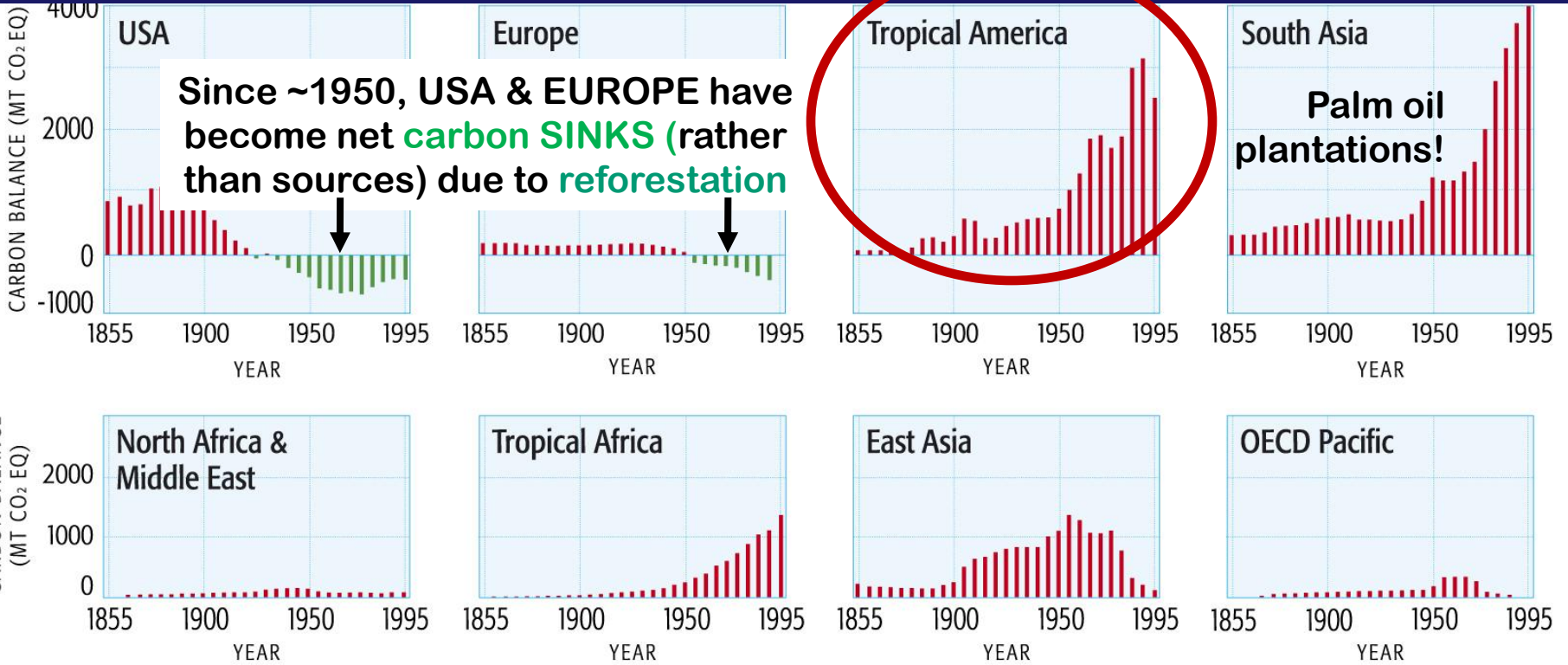
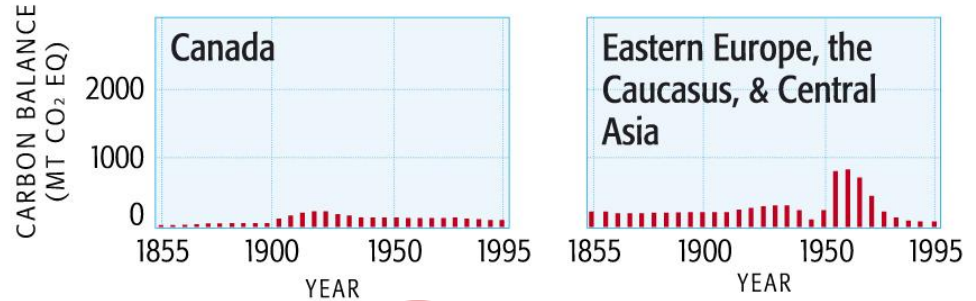
Data Source: **UN / FAO Global Forest Assessment Report**
<http://www.fao.org/forestry/fra/41555/en/>

Forest carbon emissions INTO the atmosphere (+)



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

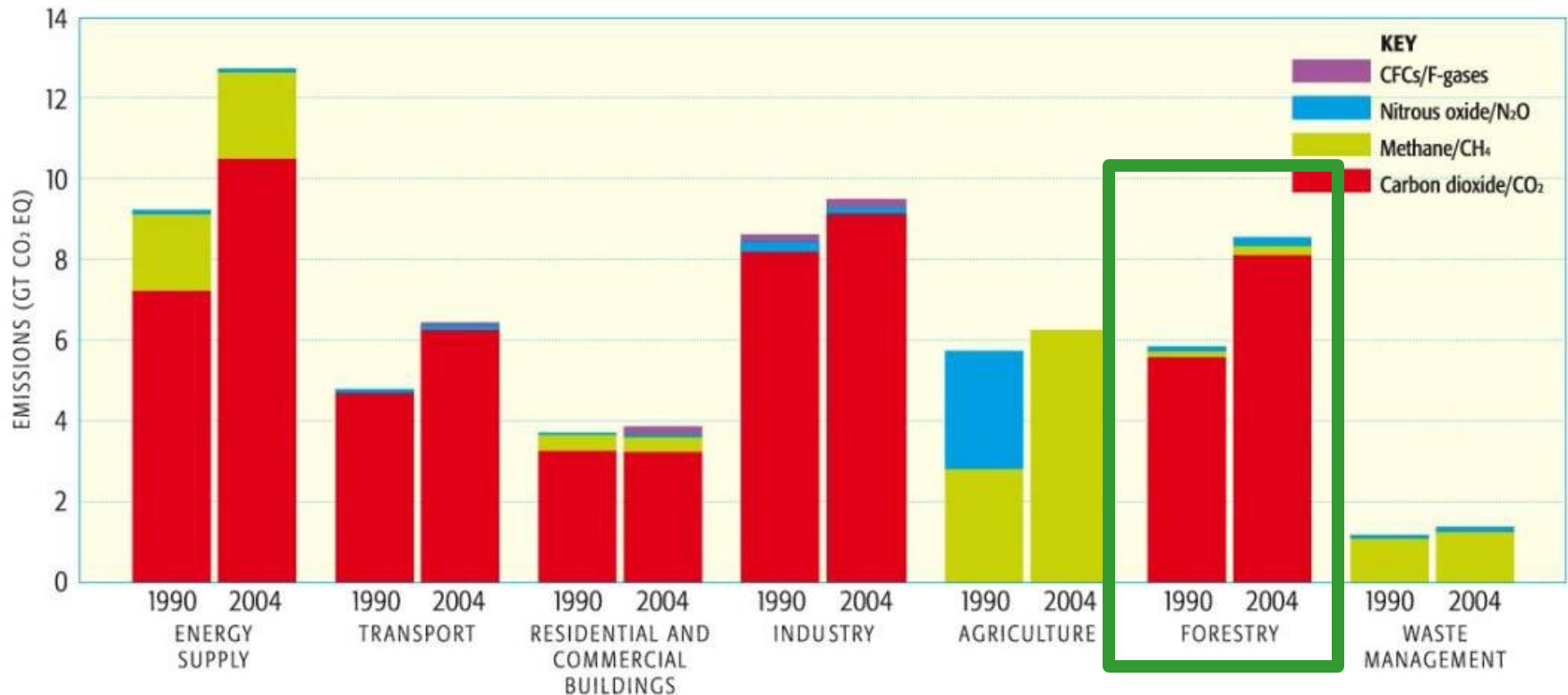
HISTORICAL TRENDS IN FOREST CARBON EMISSIONS AND UPTAKE



© 2009 Pearson Education, Inc.

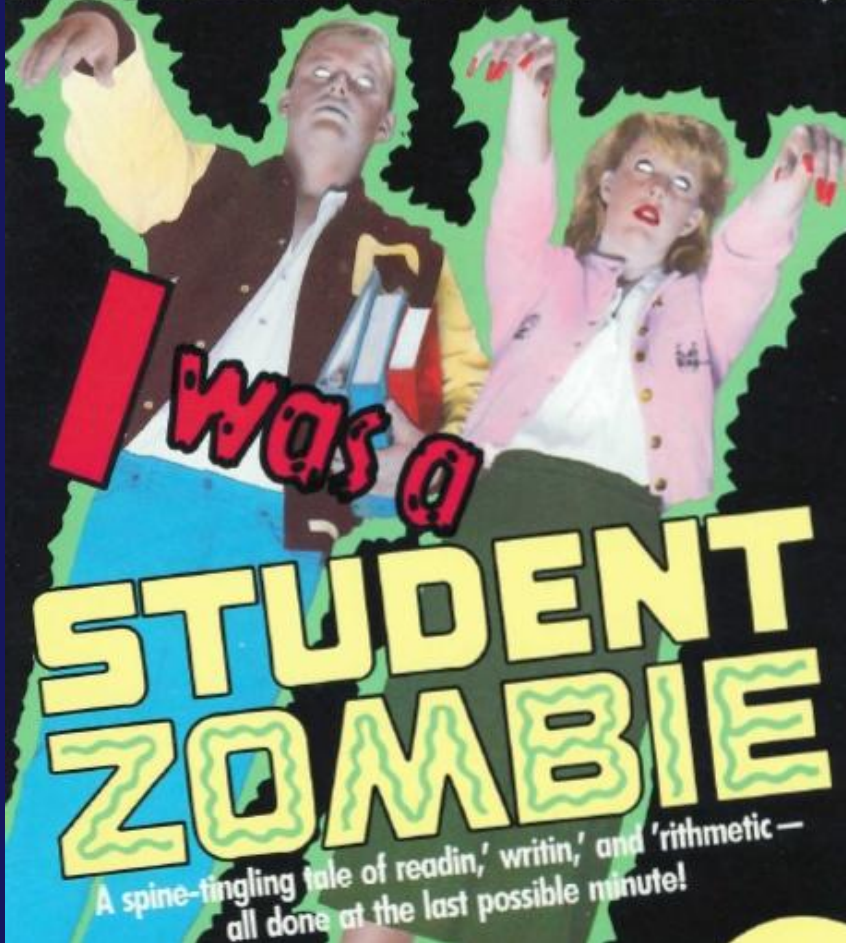
Where do all those OTHER Greenhouse Gas emissions come from?

GREENHOUSE GAS EMISSIONS BY SECTOR IN 1990 AND 2004



from p 159 in *Dire Predictions*

It's happening right now...in YOUR town...
in YOUR school...in YOUR class...in YOUR BRAIN!



ZOMBIE
BREAK !

Our new film!
MORE ON
SOLUTIONS!!!!



BONUS Q:

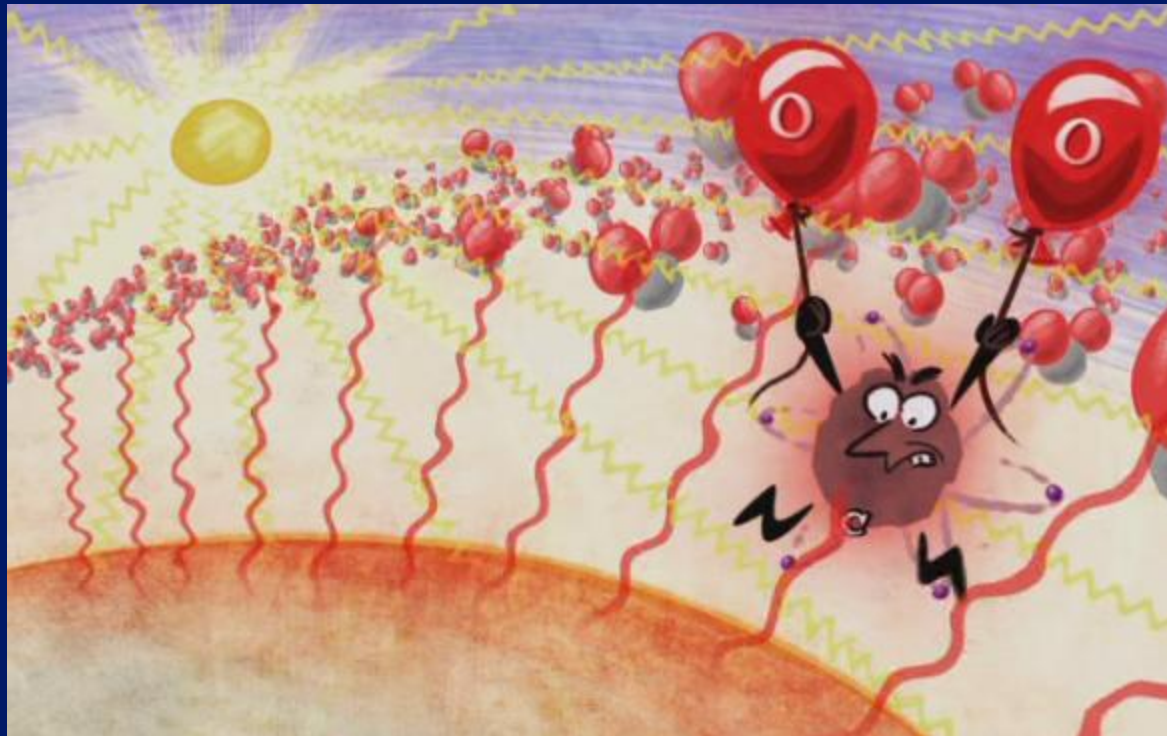
When explaining the GREENHOUSE EFFECT one of the speakers in the film describes the processes in the GHE INCORRECTLY by using the wrong words!!
(perhaps to use more familiar language for the public)

LISTEN CAREFULLY . . .

Can you identify and correct his goof?

BONUS QUESTION . . .

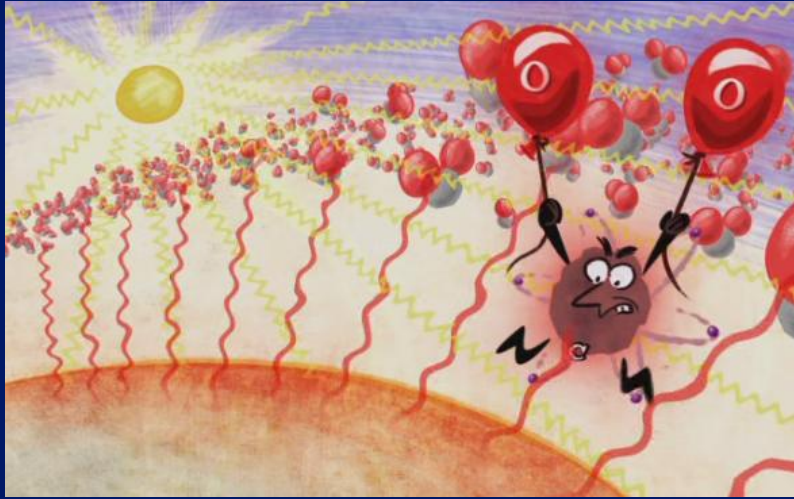
How was the
GREENHOUSE EFFECT
described **INCORRECTLY**
with the wrong words?



THE NEXT FRONTIER:



Engineering the Golden Age of Green



“The Sun’s rays pass through the carbon dioxide and hit the Earth. Some of the high-frequency sunlight is then reflected back as low-frequency infrared heat.

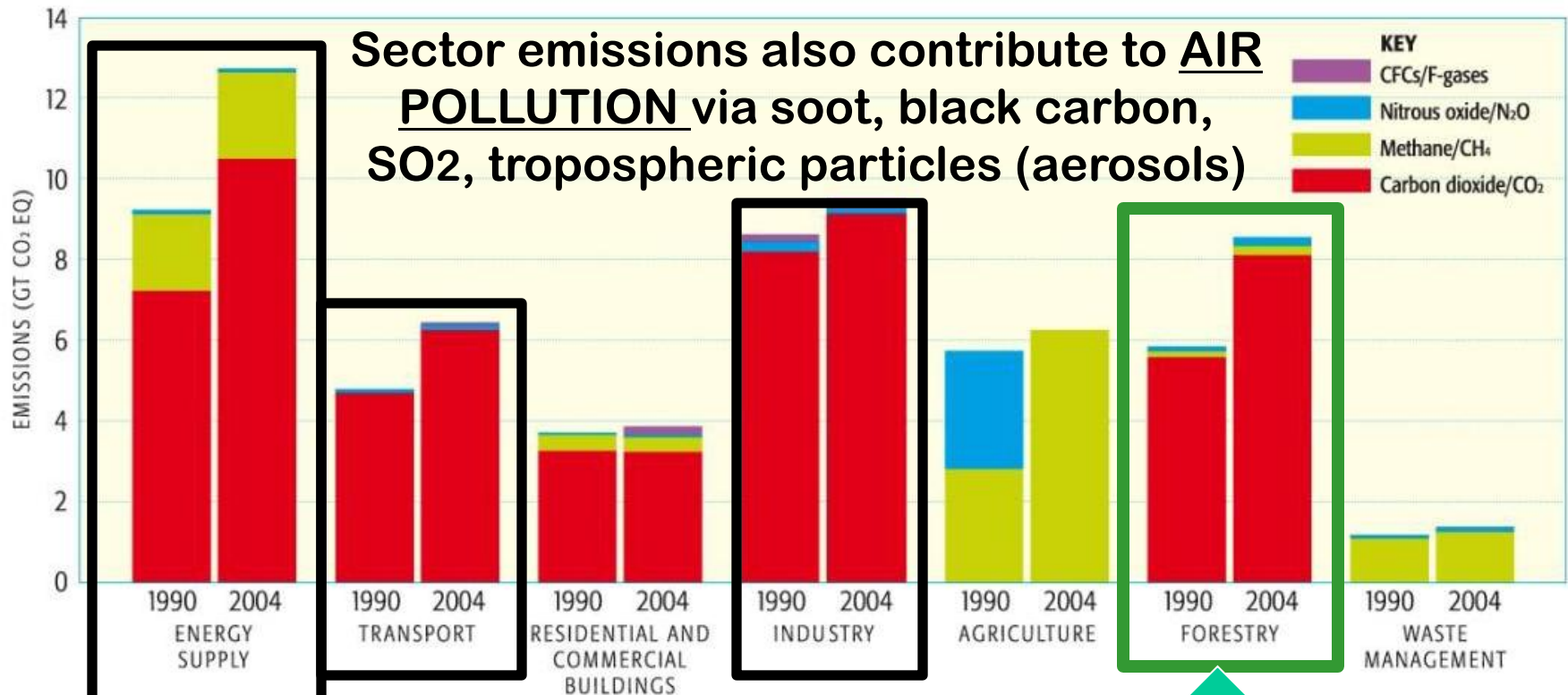
A portion of the infrared is then absorbed by carbon dioxide. There is so much more carbon dioxide in the atmosphere, more heat is being retained, warming the Earth’s atmosphere at the surface.”

“The Sun’s rays pass through the carbon dioxide and hit the Earth. Some of the high-frequency sunlight is then **RADIATED BACK** as low-frequency infrared heat.

A portion of the infrared is then absorbed by carbon dioxide. There is so much more carbon dioxide in the atmosphere, more heat is being retained, warming the Earth’s atmosphere at the surface.”

Where do all those OTHER Greenhouse Gas emissions come from?

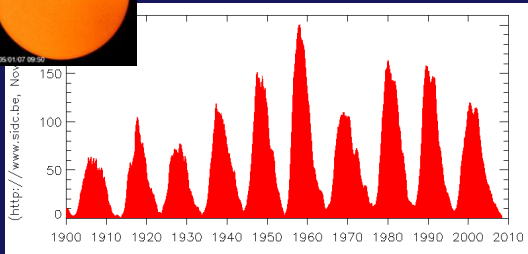
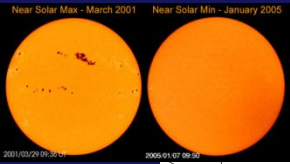
GREENHOUSE GAS EMISSIONS BY SECTOR IN 1990 AND 2004



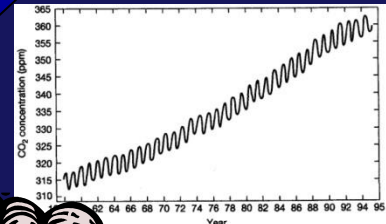
see 159
in *Dire Predictions*

**CO₂ emissions from DEFORESTATION
& BIOMASS BURNING⁸**

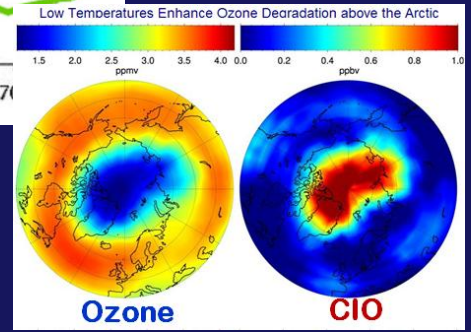
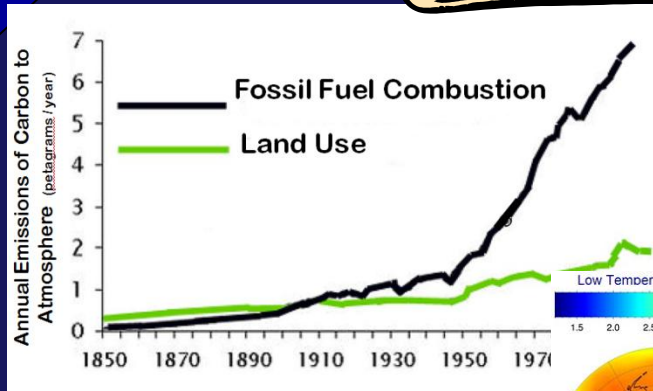
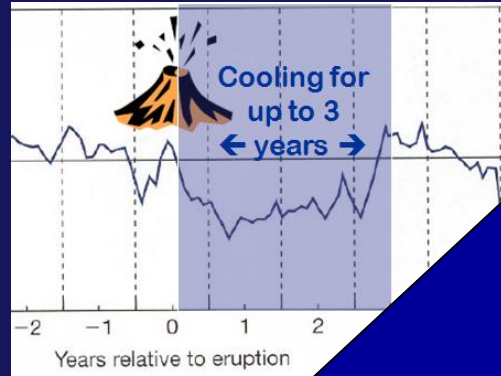
NATURAL FORCING



Solar output variations, sunspots



GHG's, soot, SO₂



Volcanic eruptions

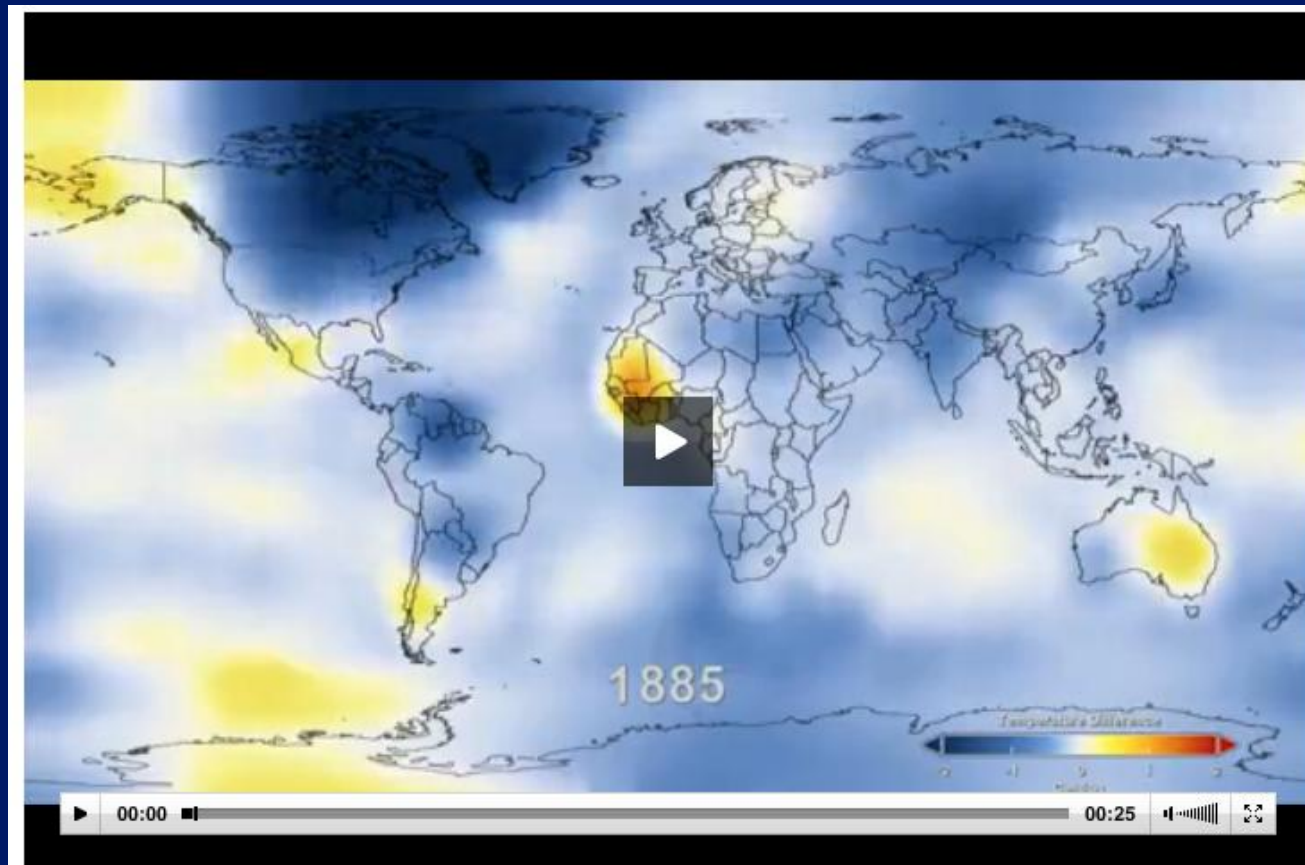


Surface Albedo Changes

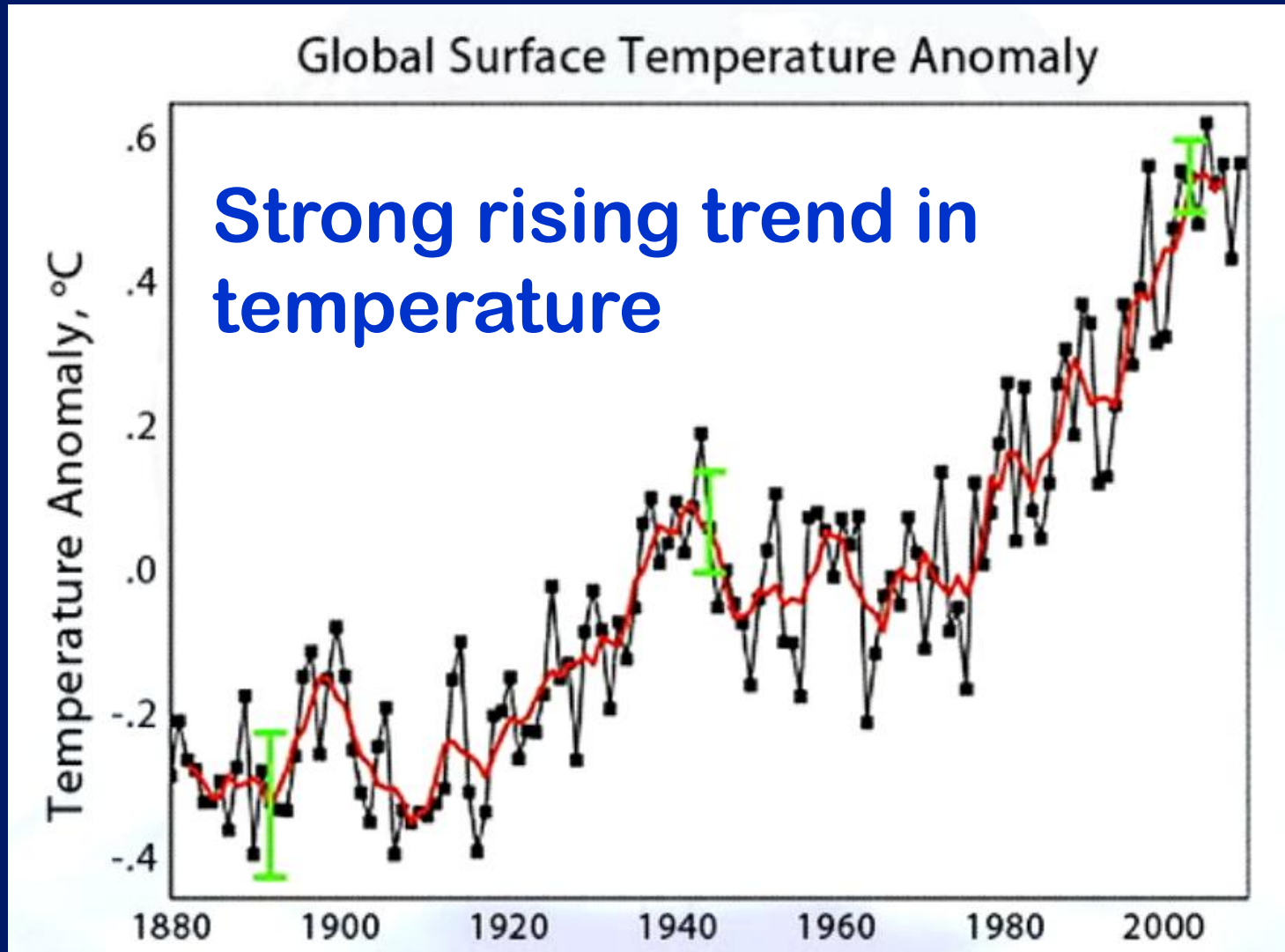
ANTHROPOGENIC FORCING



A Century of GLOBAL WARMING in 26 seconds



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



THE KEY TO IT ALL:

RADIATIVE FORCING

(linked to the Energy Balance!)

$$R_{\text{NET}} = \begin{array}{c} \text{SW} \\ \downarrow \\ \text{+} \\ \text{SW} \\ \downarrow \\ \text{-} \\ \text{SW} \\ \nearrow \\ \text{-} \\ \text{LW} \\ \uparrow \\ \text{+} \\ \text{LW} \\ \downarrow \end{array}$$

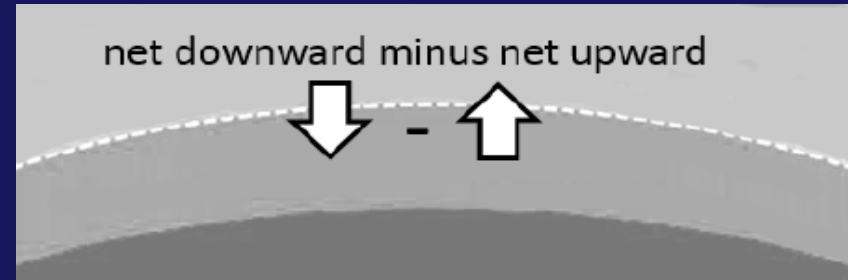
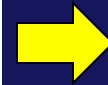
expressed in Watts per square meter (Wm^{-2}) = ENERGY!

(def) a measure of the influence a factor has in altering the balance of **incoming & outgoing energy** in the Earth-atmosphere system

... more specifically →

Radiative Forcing is based on the ENERGY BALANCE at the TROPOPAUSE!

$$R_{NET} = \begin{array}{c} \text{SW} \\ \downarrow \\ \text{SW} \\ \downarrow \\ \text{SW} \\ \searrow \\ \text{LW} \\ \uparrow \\ \text{LW} \\ \downarrow \end{array} + \begin{array}{c} \text{SW} \\ \downarrow \\ \text{LW} \\ \downarrow \end{array} - \begin{array}{c} \text{SW} \\ \searrow \\ \text{LW} \\ \uparrow \end{array} - \begin{array}{c} \text{LW} \\ \uparrow \\ \text{LW} \\ \downarrow \end{array} + \begin{array}{c} \text{LW} \\ \downarrow \end{array}$$



It's an index of the degree to which different factors (like GHG's) INCREASE or DECREASE the amount of energy that accumulates in the TROPOSPHERE!

To be continued