TOPIC # 14
GLOBAL WARMING & ANTHROPOGENIC FORCING

Part A: The Key Cause = CARBON

(Human factor = Deforestation / Fossil Fuels)

Part B: Evidence from Natural Archives

(One way to sort out Natural vs Human contributions)

Part C: Computer Model Evidence

(Another way to sort out Natural vs Human contributions)

Parts D+ E: Early Warning Signs of Human Influence ("Fingerprints")

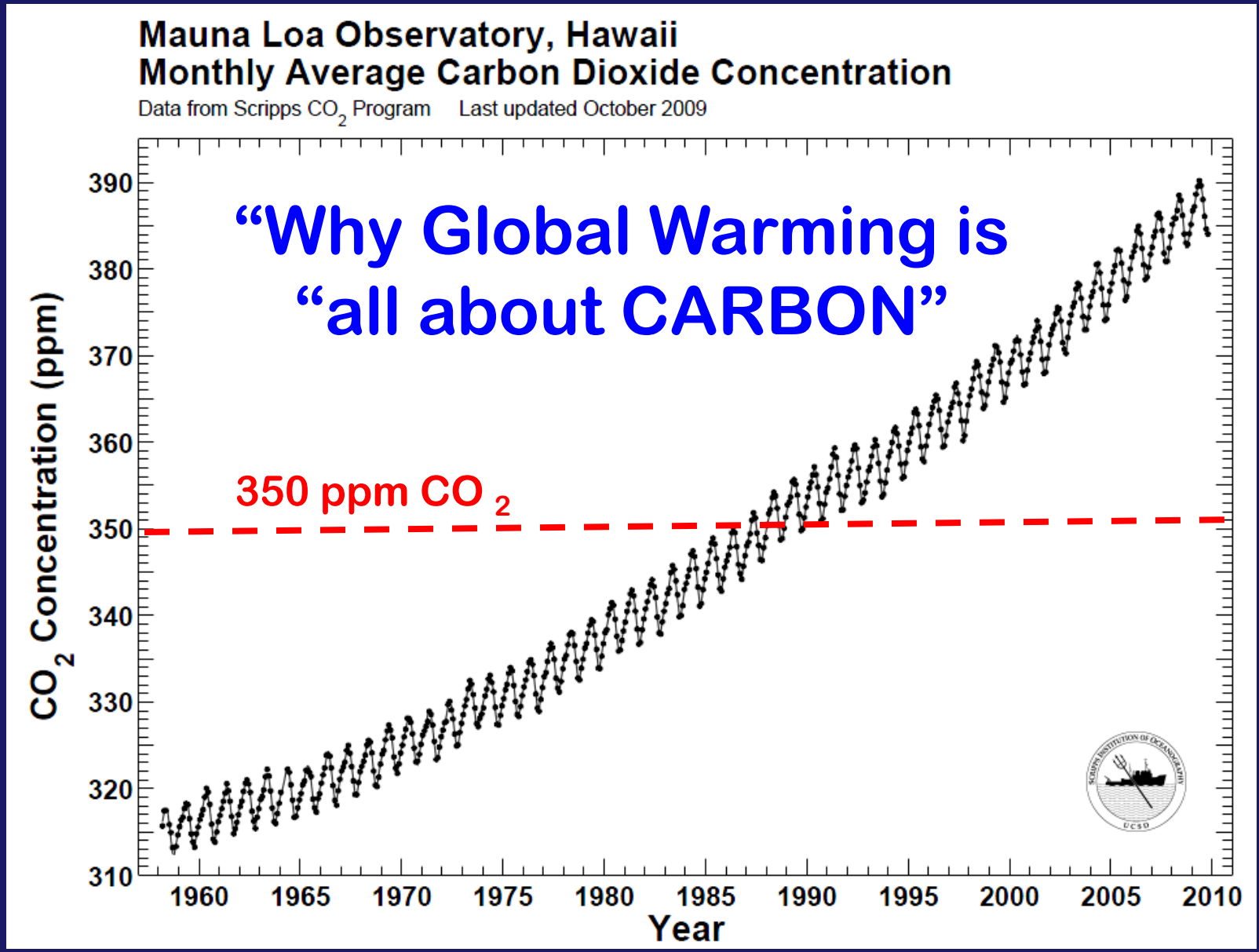
(Do observations match the model predictions?)

Starting with . . . .

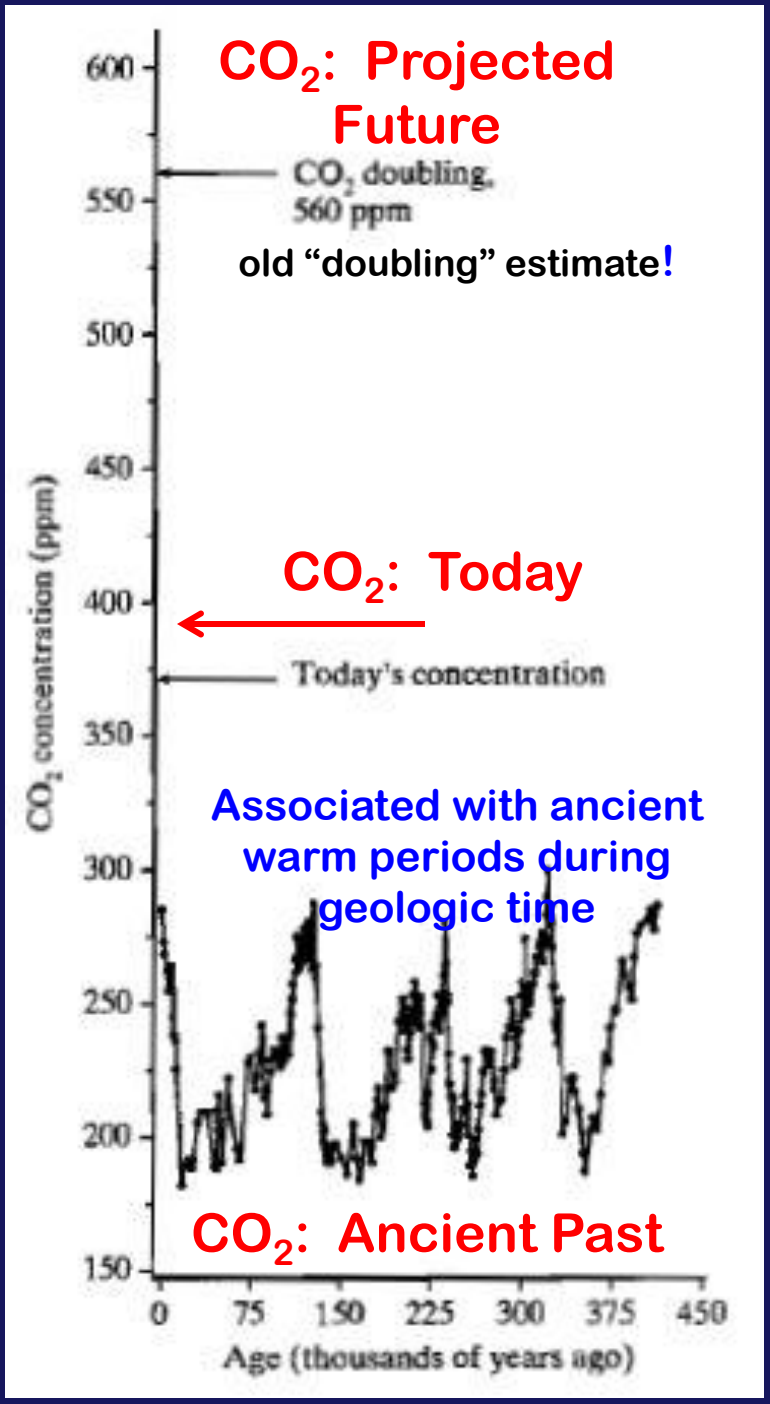
Part A - CARBON RESERVOIRS & FLUXES: Natural vs. Anthropogenically Enhanced

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

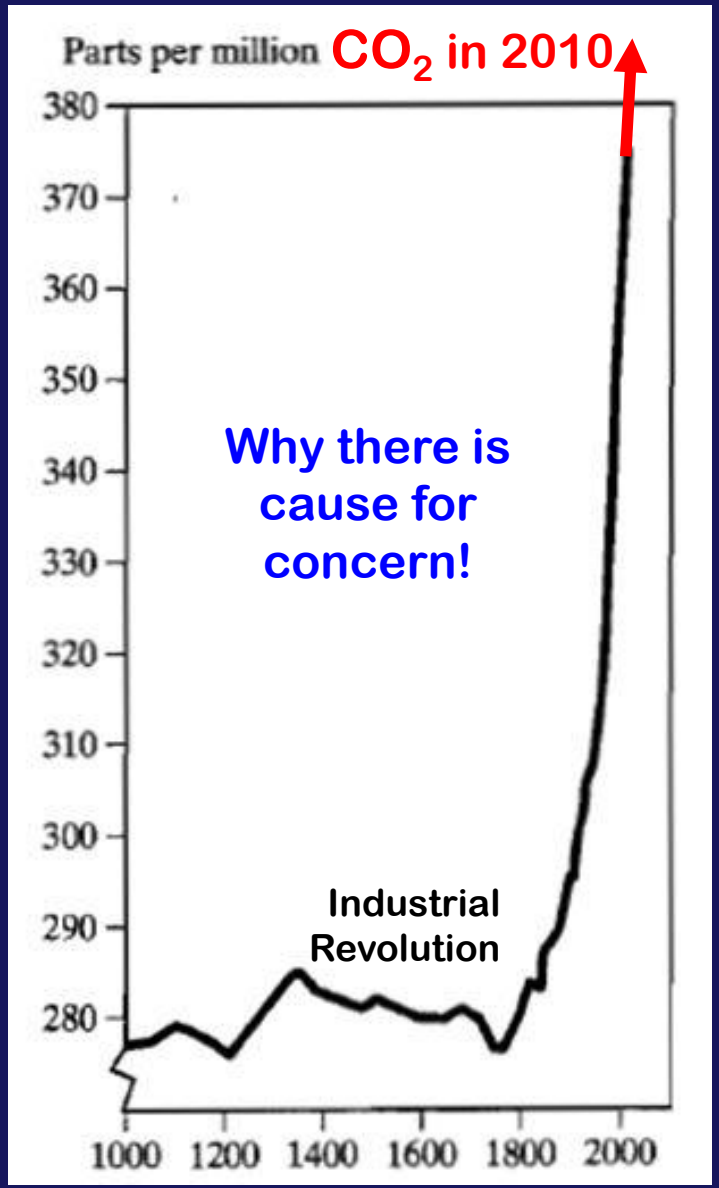
Class Notes pp 75


Mauna Loa Observatory, Hawaii
Monthly Average Carbon Dioxide Concentration
Data from Scripps CO2 Program Last updated October 2009
"Why Global Warming is
"all about CARBON"
350 ppm CO 2
CO2 Concentration (ppm)
390
380
370
360
350
340
330
320
310
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

CO_2 Concentration (ppm)



390 ppm



From SGC-Hobson Ch. 9

"I'm extremely concerned that the Earth has a chronic disease, and

that chronic disease is CO_2 syndrome,

it's something that's creeping on us.

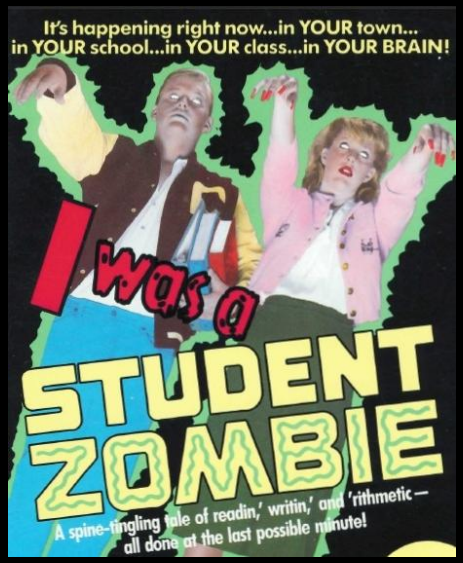
We have plenty of fossil fuel so it's going to continue to get worse, and it's going to affect every aspect of life on the planet,

-- from food production
-- to drinking water
-- to coastlines
-- to the plight of the poor in the tropics,

and so forth."

~Wally Broecker , Paleoclimatologist

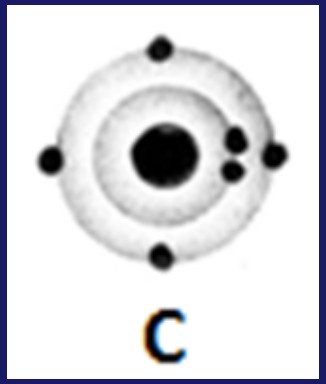
Lots of Mini-Zombie Breaks TODAY!



Episode 1: It's All About Carbon

http://www.npr.org/templates/story/story.php?storyId=9943298&ps=rs

CO_2 & CARBON RESERVOIRS



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

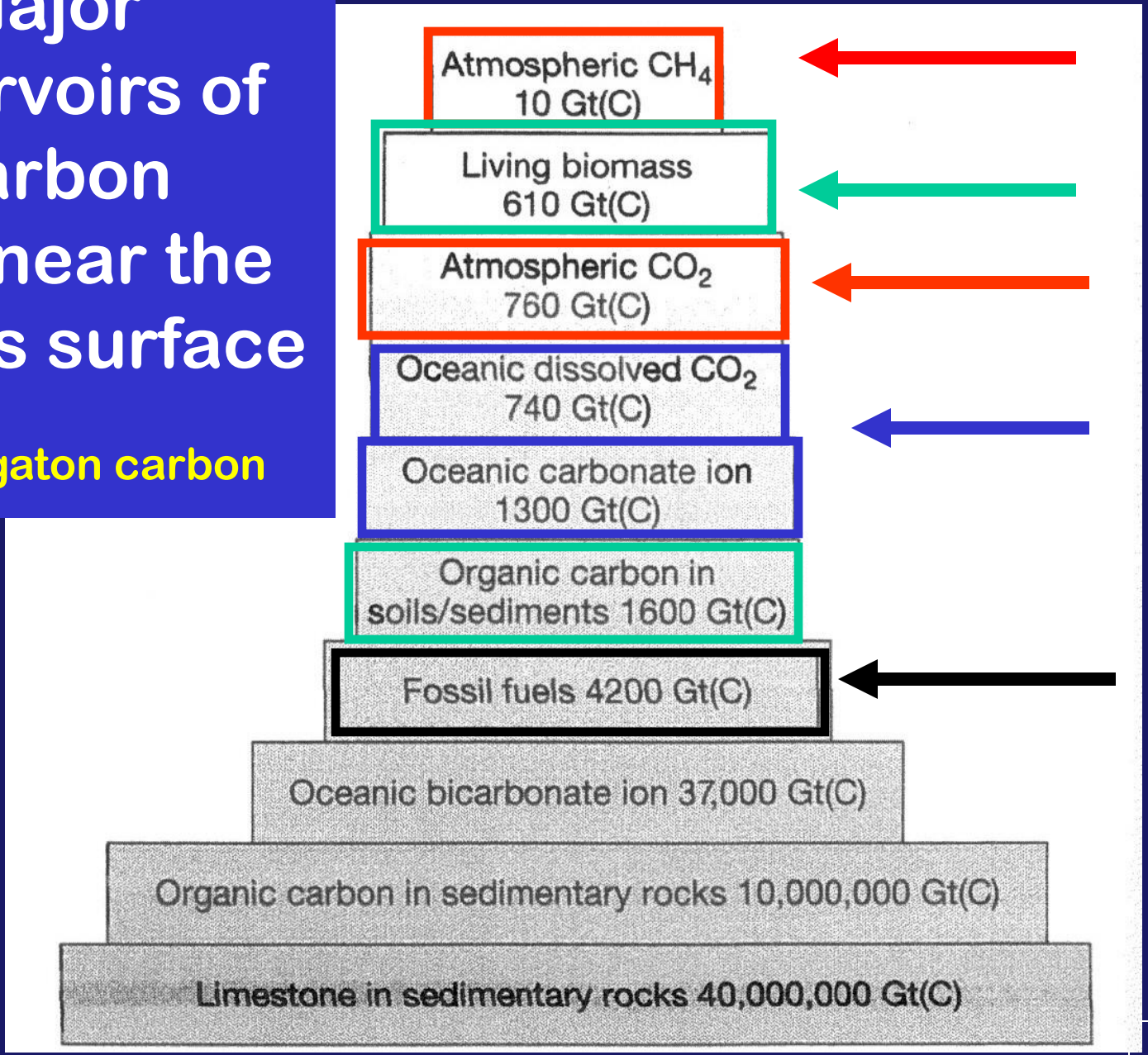
Where else is carbon located and how does it move (flux) from one reservoir to another?

Episode 2: Carbon's Special Knack for Bonding

http://www.npr.org/templates/story/story.php?storyId=11027169&ps=rs

Major Reservoirs of Carbon at or near the Earth's surface

Gt (C) = gigaton carbon



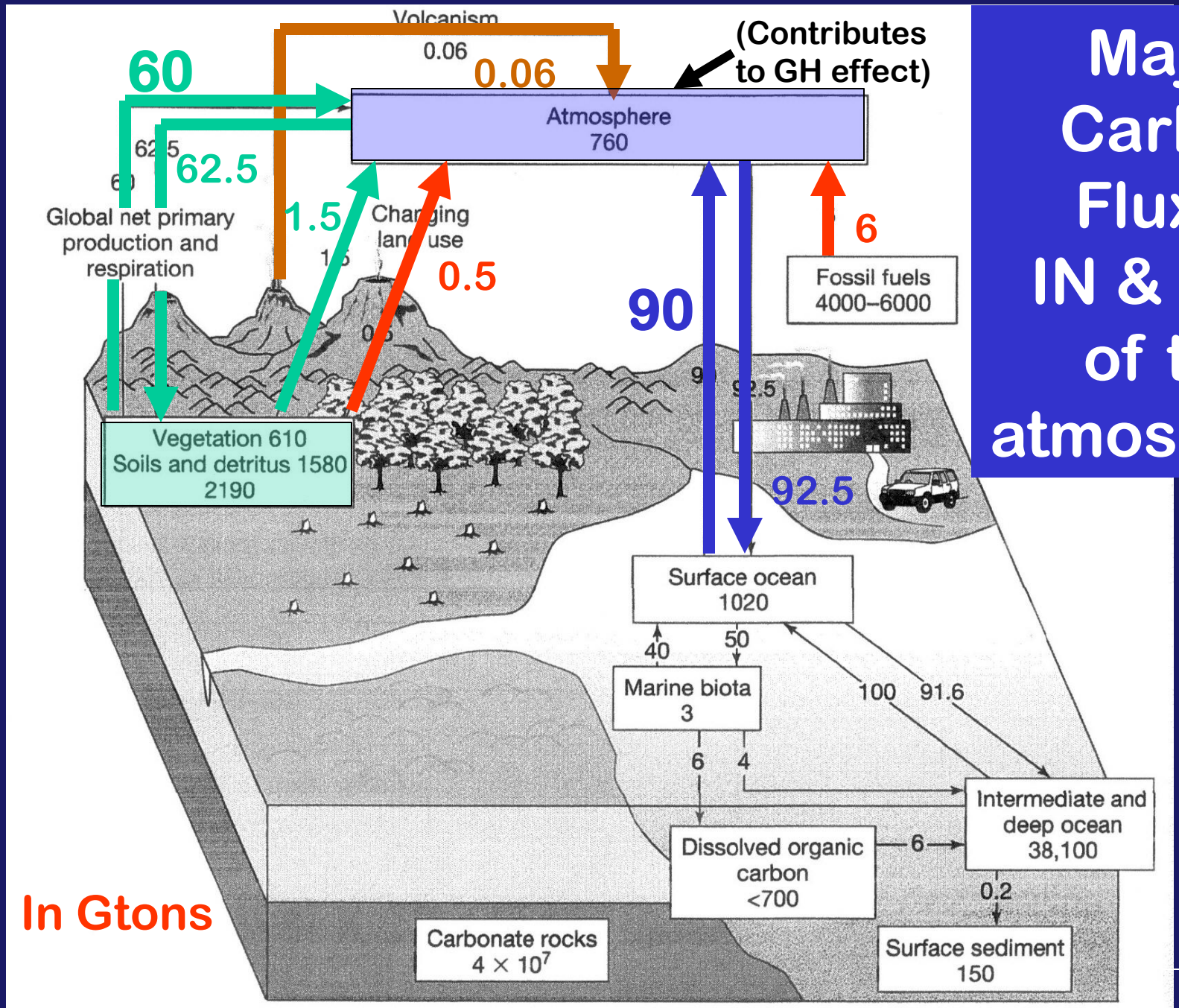
Amount of carbon is expressed in units of **Gtons (gigatons) of carbon: GT(C)**

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

Episode 3: Break a Carbon Bond and — Presto! — Civilization

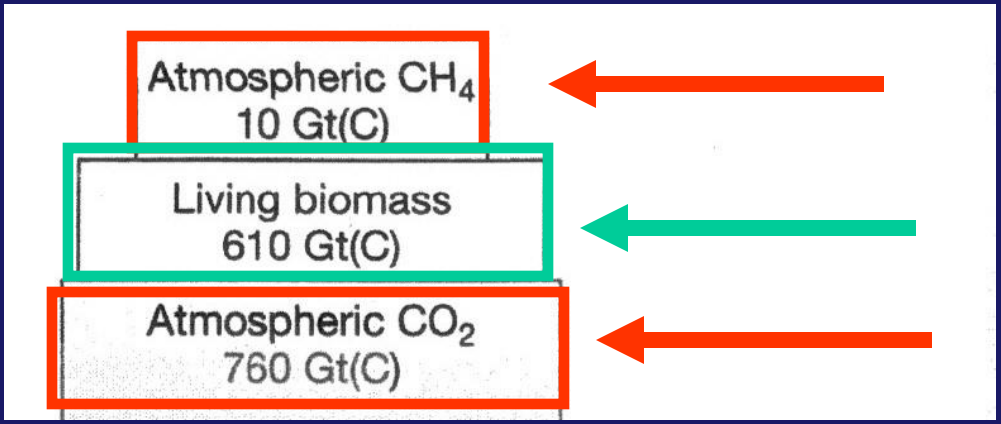
http://www.npr.org/templates/story/story.php?storyId=11366031&ps=rs

Major Carbon Fluxes IN & OUT of the atmosphere



Biomass = the total mass of organic matter in living organisms in a particular reservoir.

(Definition on p 76)



The total amount of carbon in **LIVING BIOMASS** = 610 Gt

The total amount of carbon in the **ATMOSPHERIC CARBON RESERVOIR** = 770 Gt (760 Gt is in CO_2 gas)

Q1: 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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NATURAL FLUXES INTO & OUT OF THE ATMOSPHERIC CARBON RESERVOIR related to **BIOMASS** = respiration & photosynthesis

FLUX from PLANT INTO ATMOSPHERE:

Respiration: CH_2O + O_2 ⟶ CO_2 + H_2O.

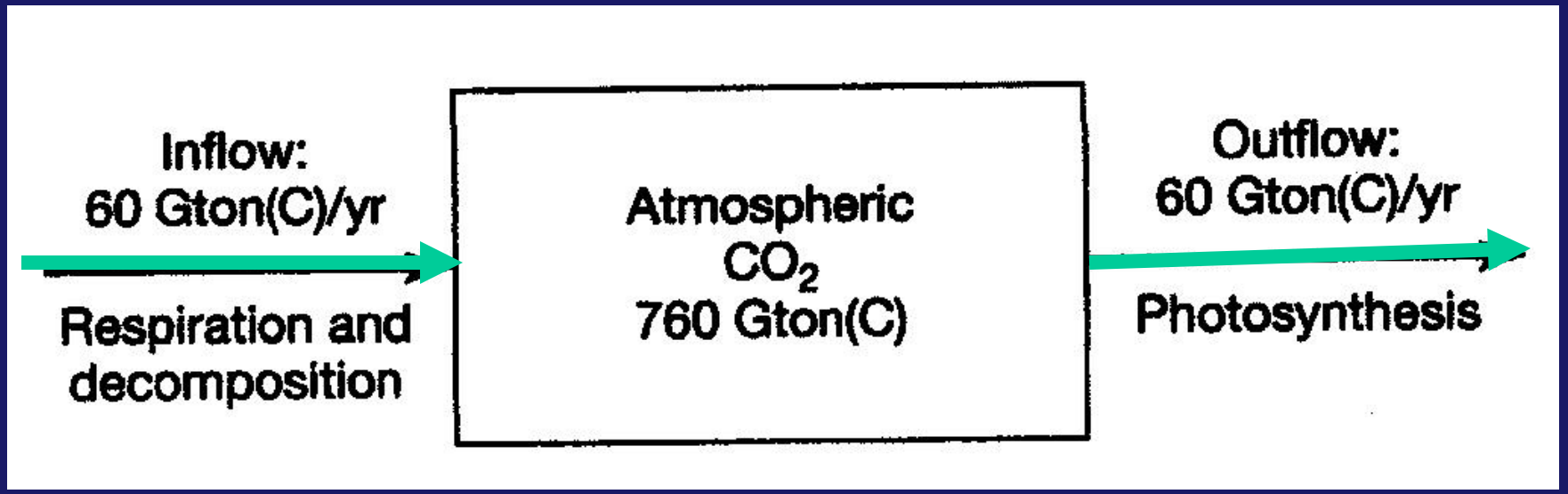
carbohydrate | oxygen gas | carbon dioxide | water

FLUX <u>OUT OF ATMOSPHERE</u> into PLANT:

Photosynthesis: CO_2 + H_2O ⟶ CH_2O + O_2.

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

The Atmospheric Carbon Reservoir

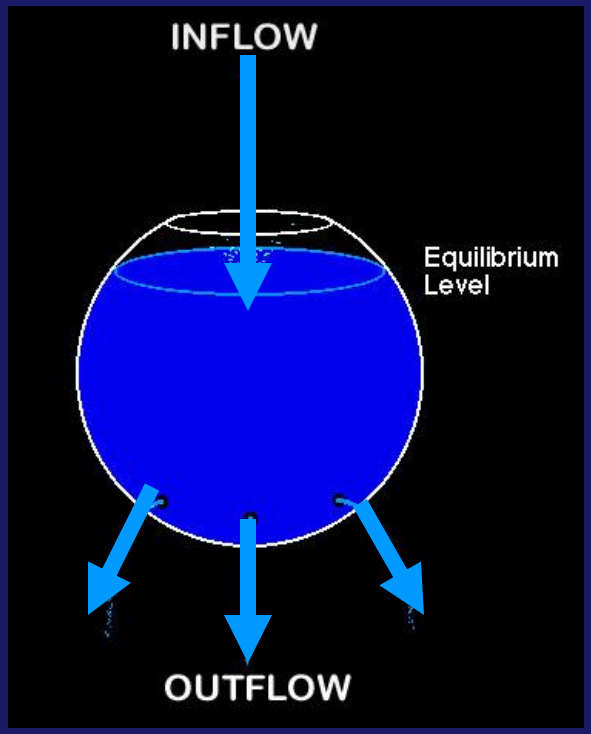


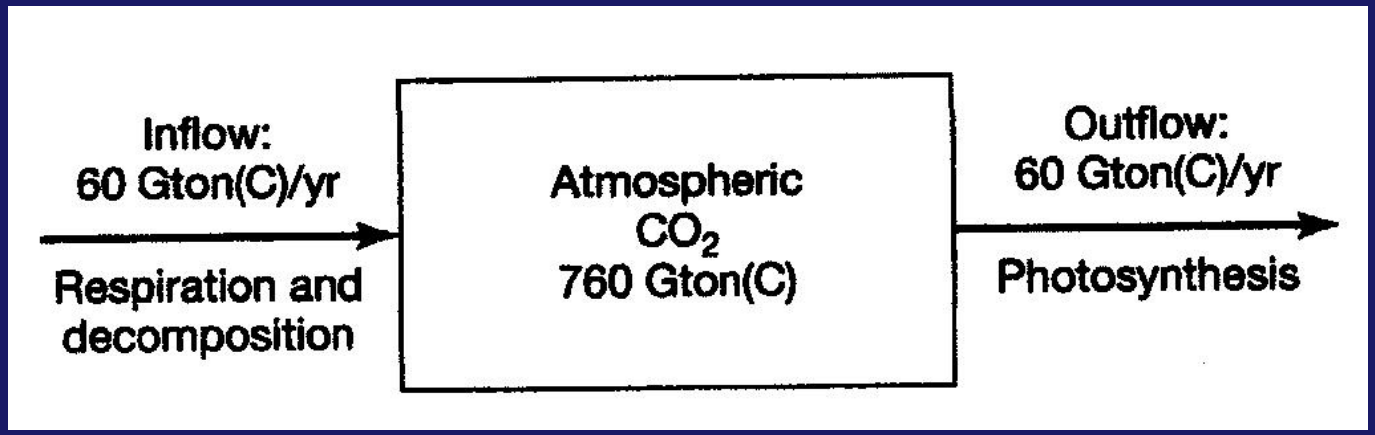
showing inflows and outflows (fluxes)

. . . leads to a

STEADY STATE

In the atmospheric CO_2 "reservoir"





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

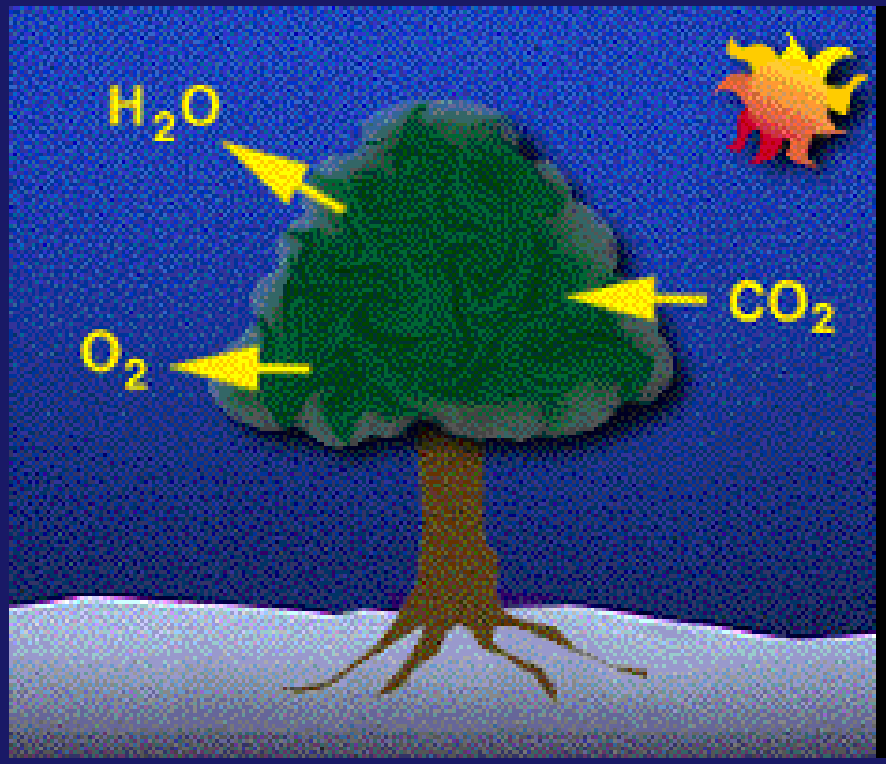
Photosynthesis =

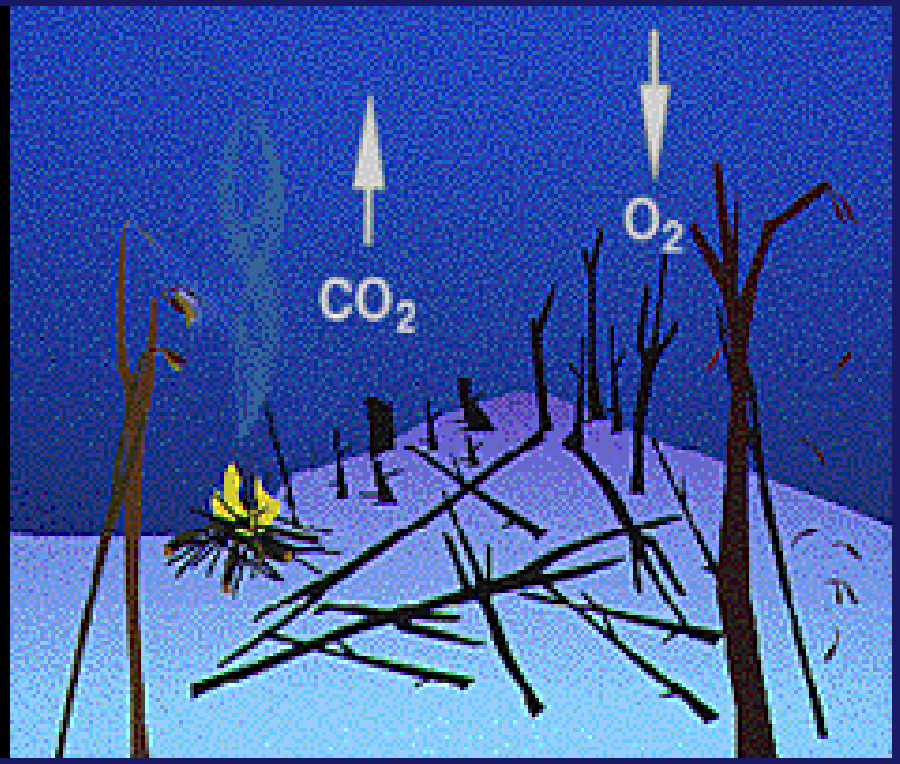
manufacture of carbohydrates & O_2
from CO_2 and H_2O
in the presence of chlorophyll
sunlight as the energy source.

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.)

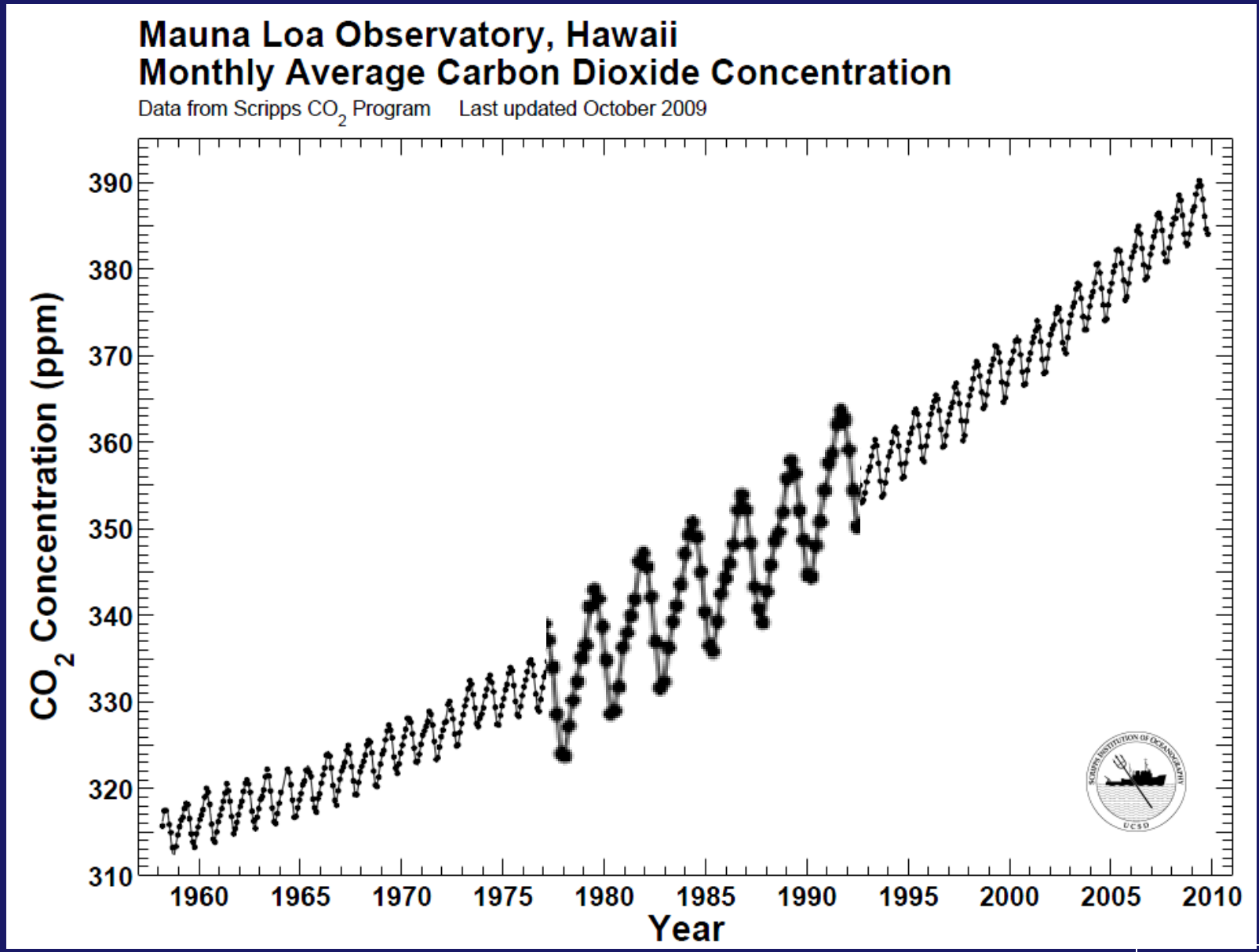




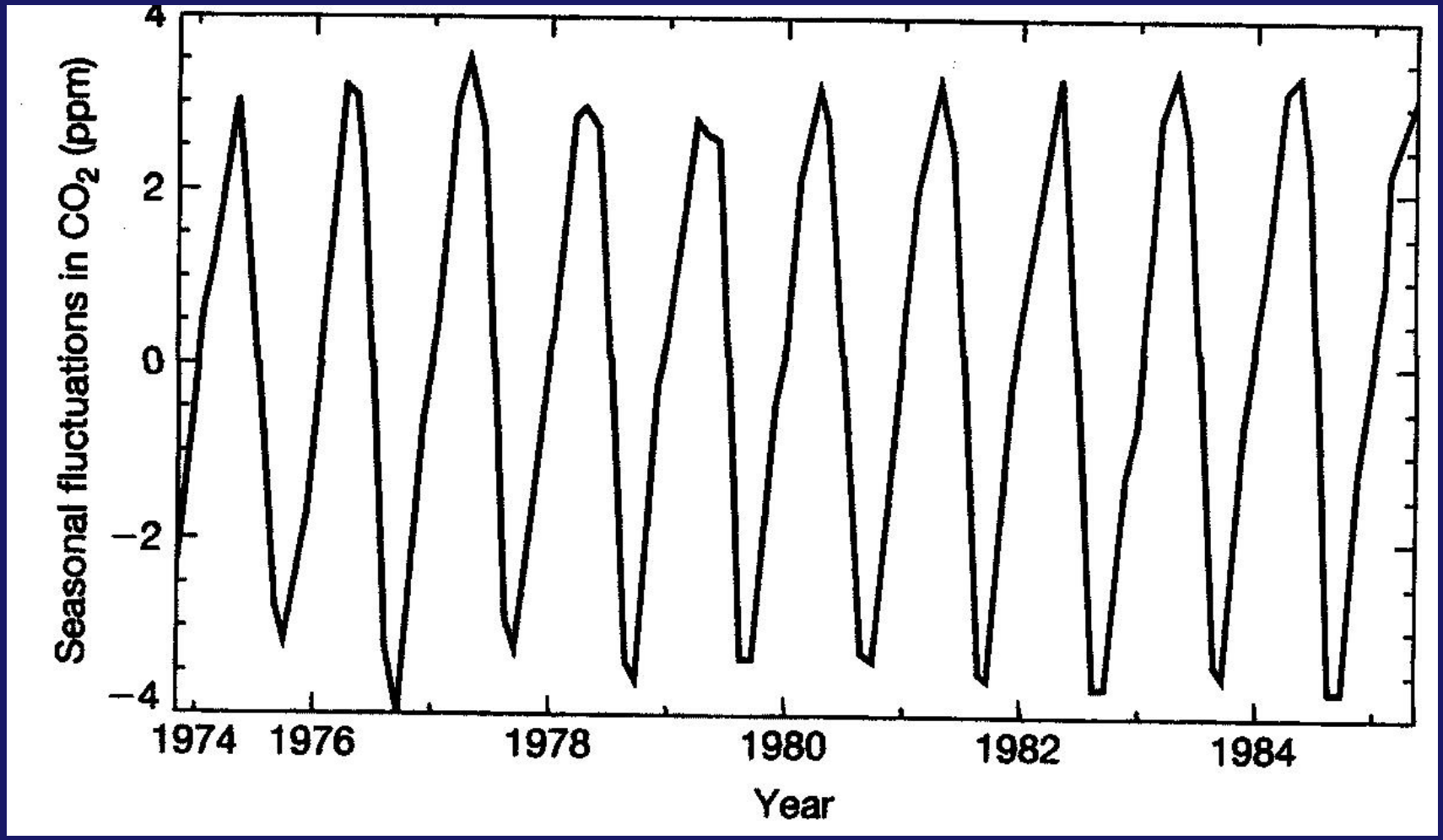
Photosynthesis

Respiration, Burning of Biomass, & Decomposition

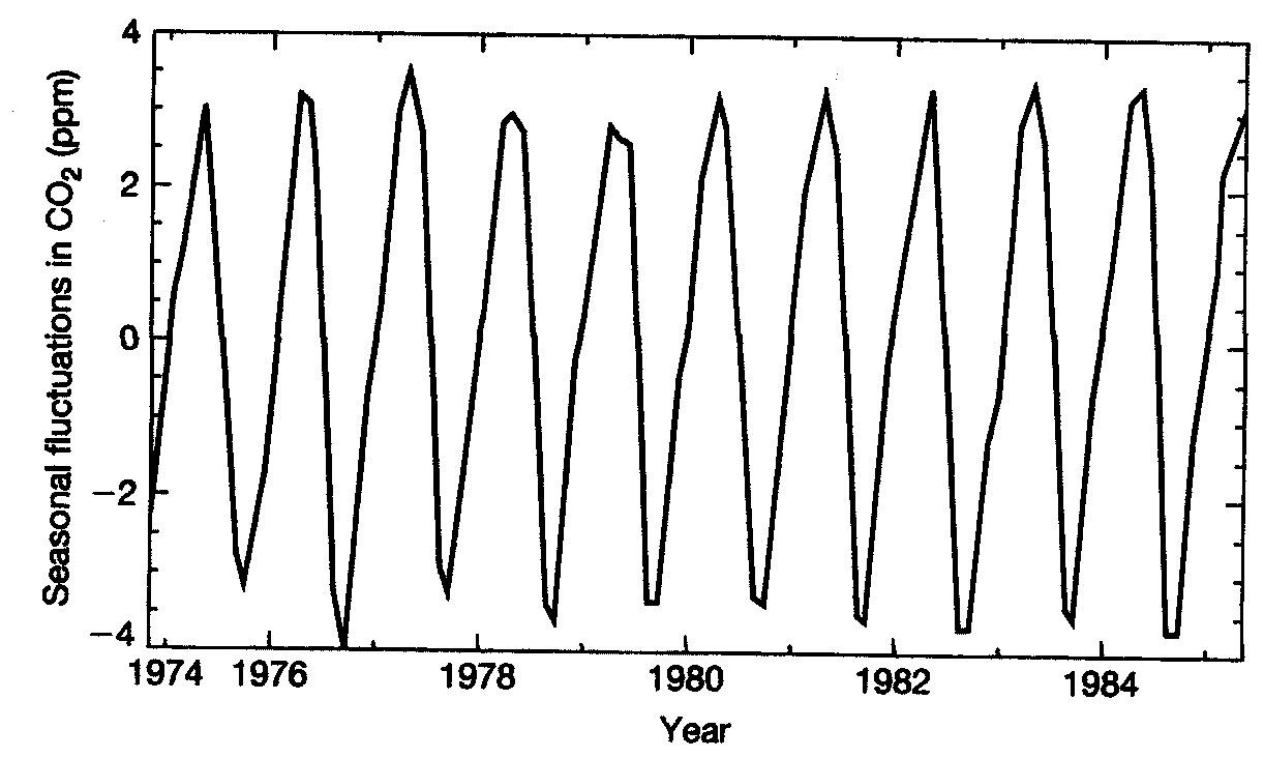
WHAT ABOUT THOSE ZIG-ZAGS IN THE KEELING CURVE?



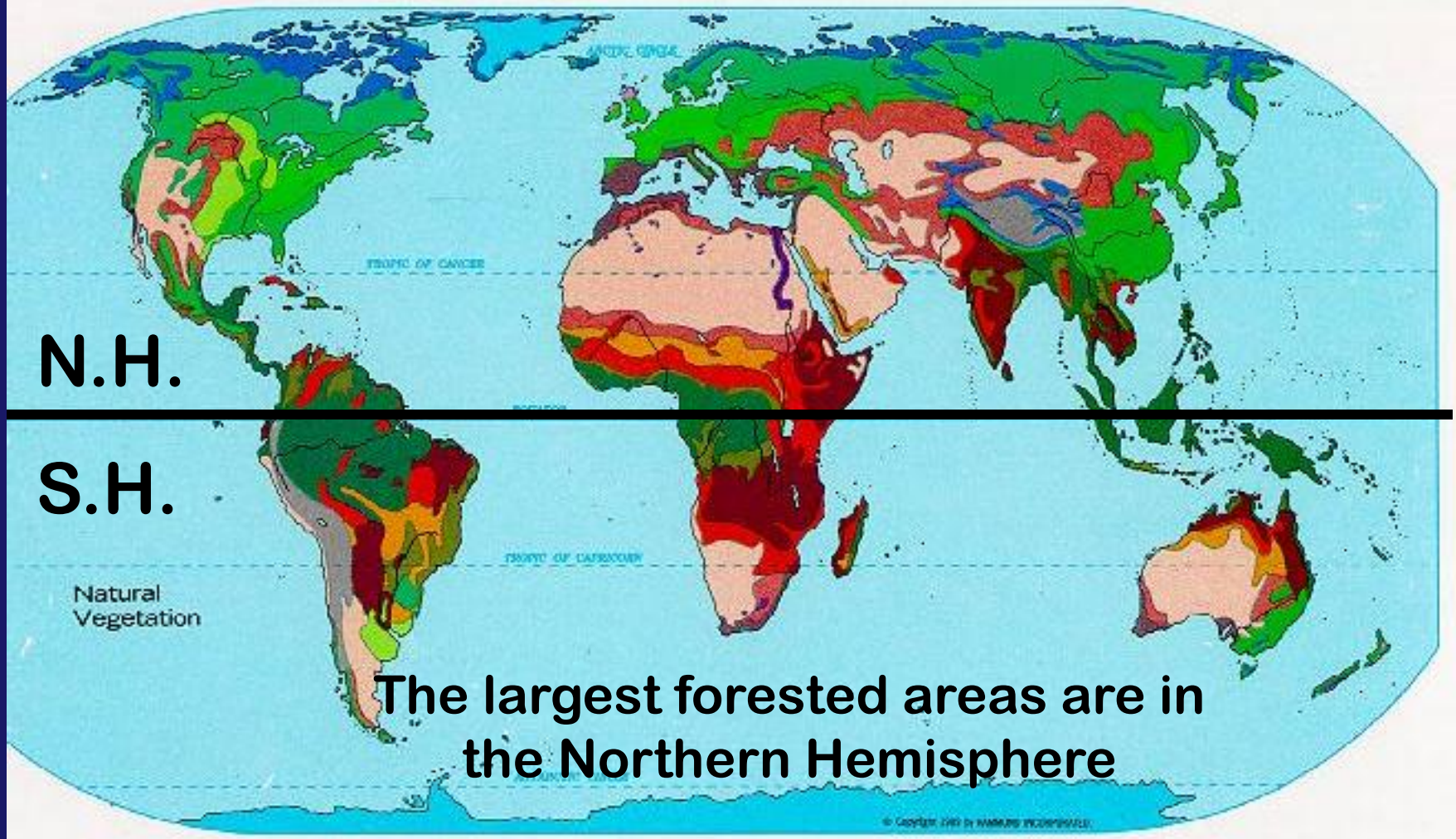
CLOSE-UP VIEW:



Trend due to anthropogenic increases has been removed.



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



GLOBAL VEGETATION PATTERNS

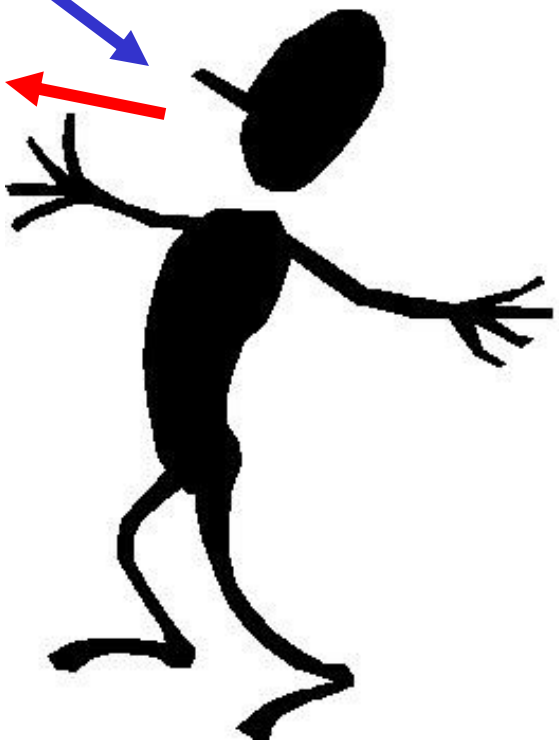
- Needleleaf Forest
- Broadleaf Forest
- Mixed Needleleaf and Broadleaf Forest
- Woodland and Shrub (Mediterranean)
- Short Grass (Steppe)
- Tall Grass (Prairie)
- Unclassified Highlands
- River Valley and Oasis
- Desert and Desert Shrub
- Wooded Savanna
- Tropical Grassland and Shrub (Savanna)
- Tropical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

"Breathing" -- ANIMALS vs. PLANTS

Respiration

O_2

CO_2

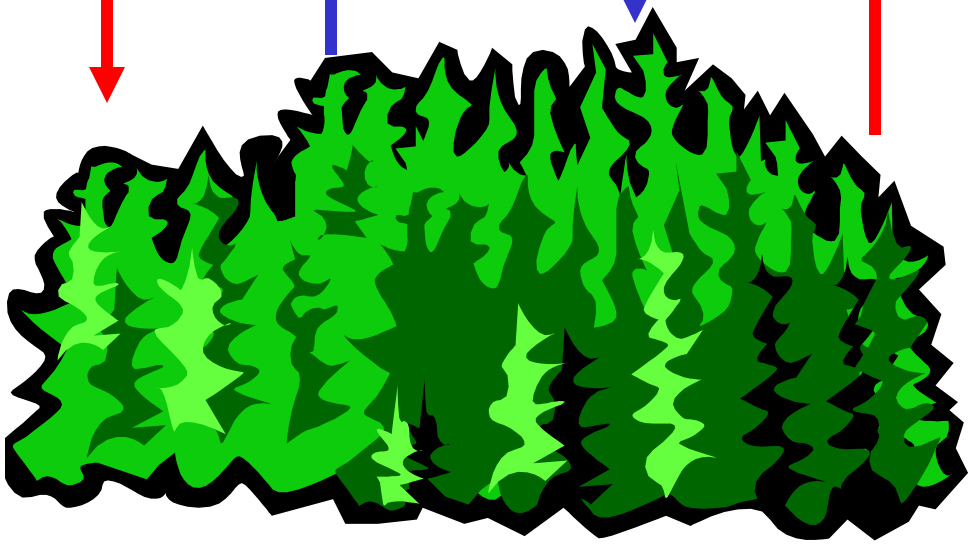


Photosynthesis

CO_2 O_2

Respiration & Decomposition

O_2 CO_2



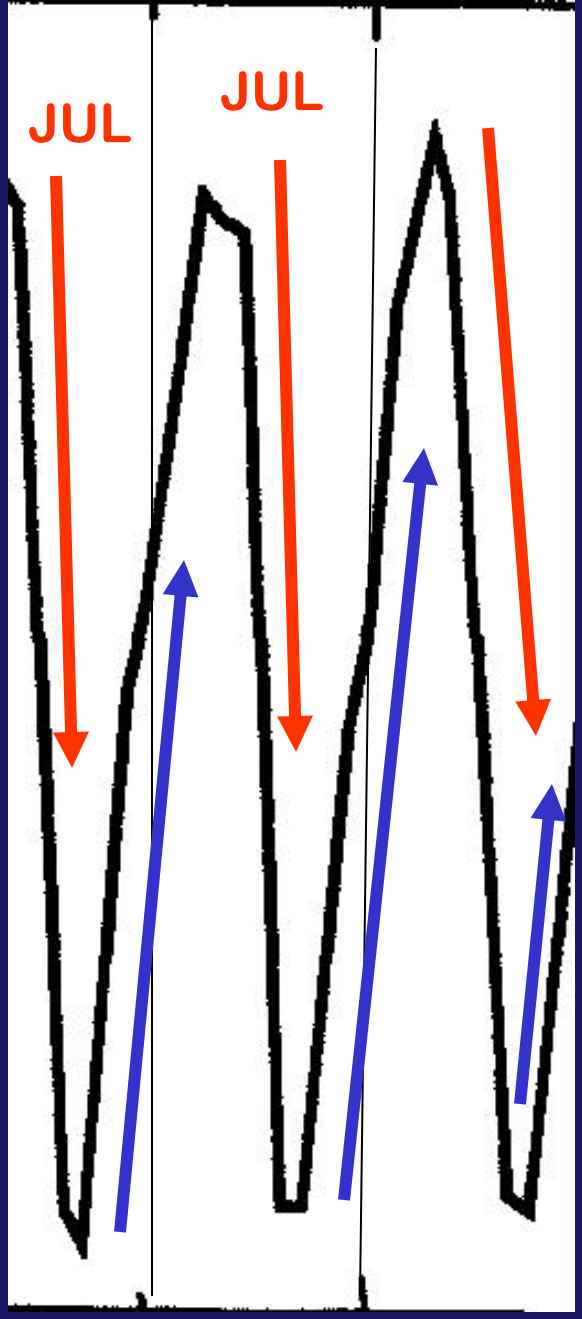
Tick marks are at January of each year:

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)

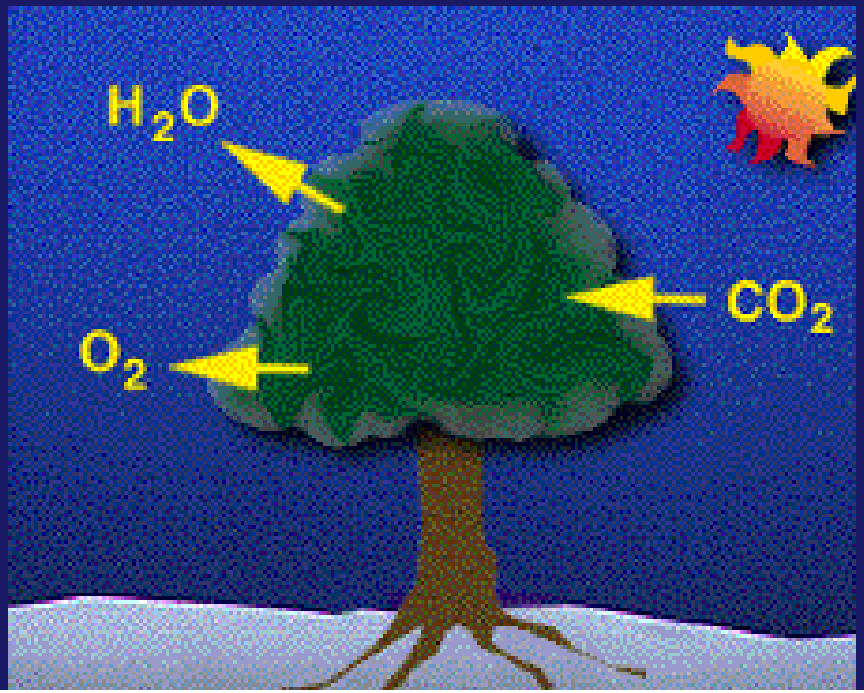
Photosynthesis > Respiration
(CO_2 goes down in summer)

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



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

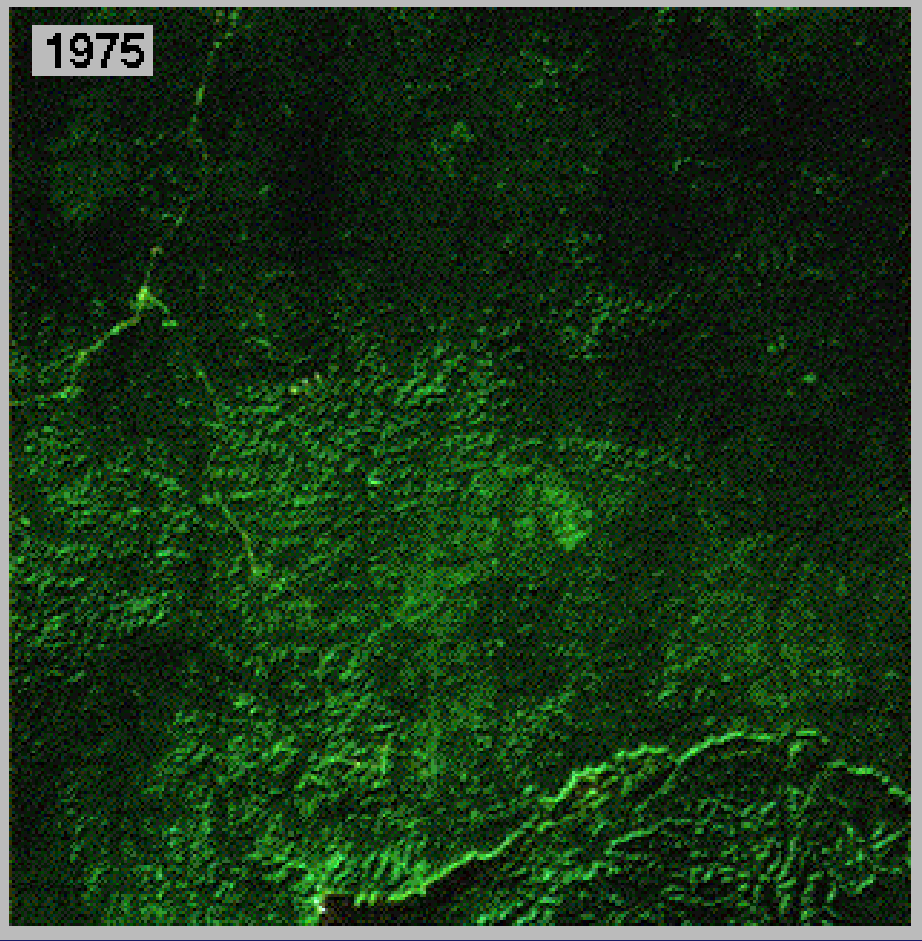
Mini- Zombie Break:

YOU TUBE!

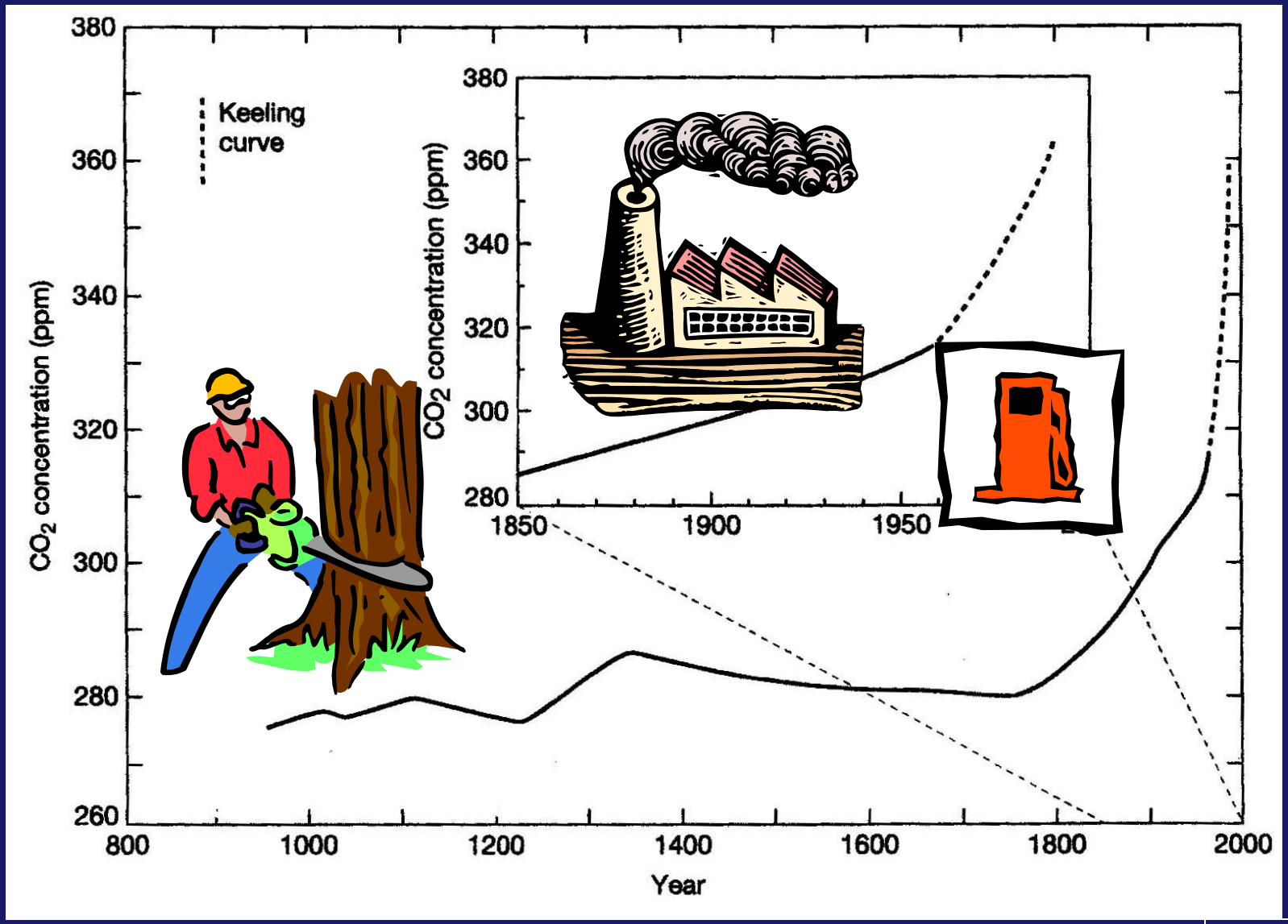
http://www.youtube.com/watch?v=0_VmMIbWKoo

LAND USE CHANGES:

Deforestation practices increase burning & decomposition of large areas of forest

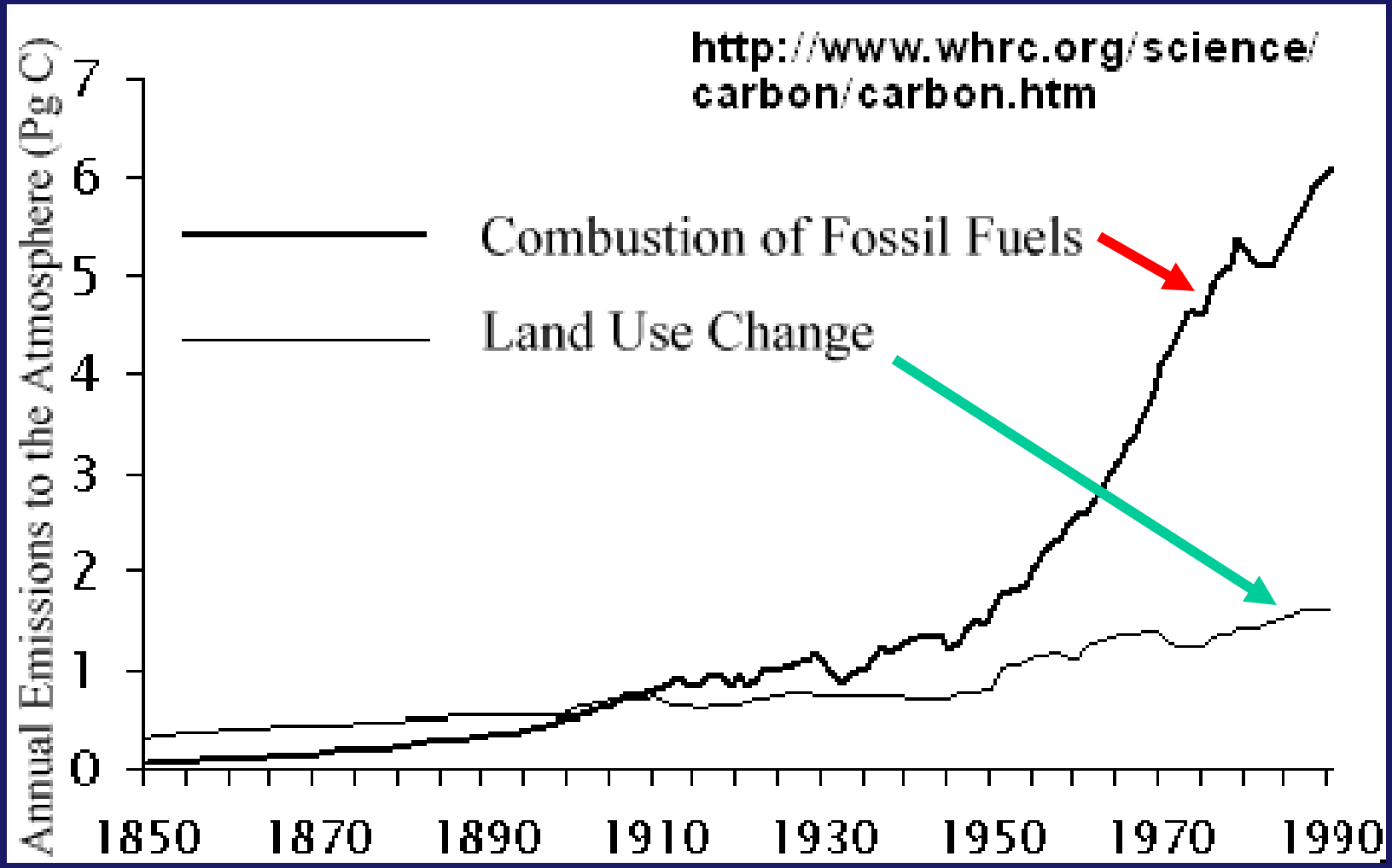


CARBON DIOXIDE: Trends



Review

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

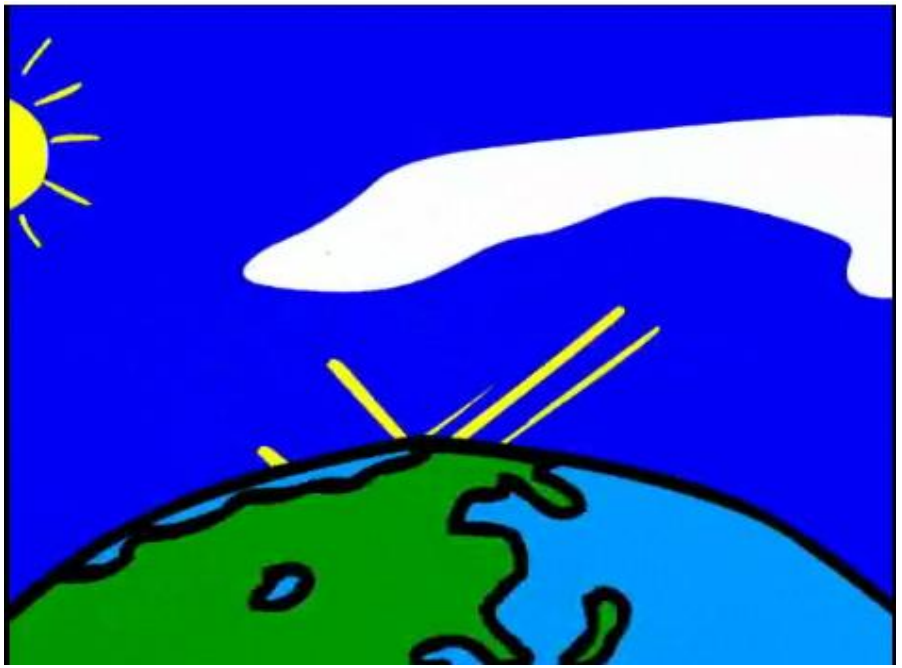


Episode 4: When Carbon Falls in Love, the World Heats Up

http://www.npr.org/templates/story/story.php?storyId=11662978&ps=rs

Greenhouse Effect explanation . . .

YIKES!!



Sunlight does not BOUNCE off Earth and bump INTO and HIT the CO_2 . . .

Q2: What DOES the energy in the Solar radiation do to get into the CO_2?

1. It is reflected into the atmosphere as **INFRARED radiation**, which the CO2 then absorbs.

2. It is absorbed directly by the CO2 and then **re-radiated as INFRARED** radiation.

3. It is absorbed by the Earth's surface and then radiated into the atmosphere as INFRARED radiation, which the CO2 then absorbs

Q2: What DOES the energy in the Solar radiation do to get into the CO_2?

1. It is reflected into the atmosphere as **INFRARED radiation**, which the CO2 then absorbs.

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RATE OF CHANGE IN FORESTED AREA

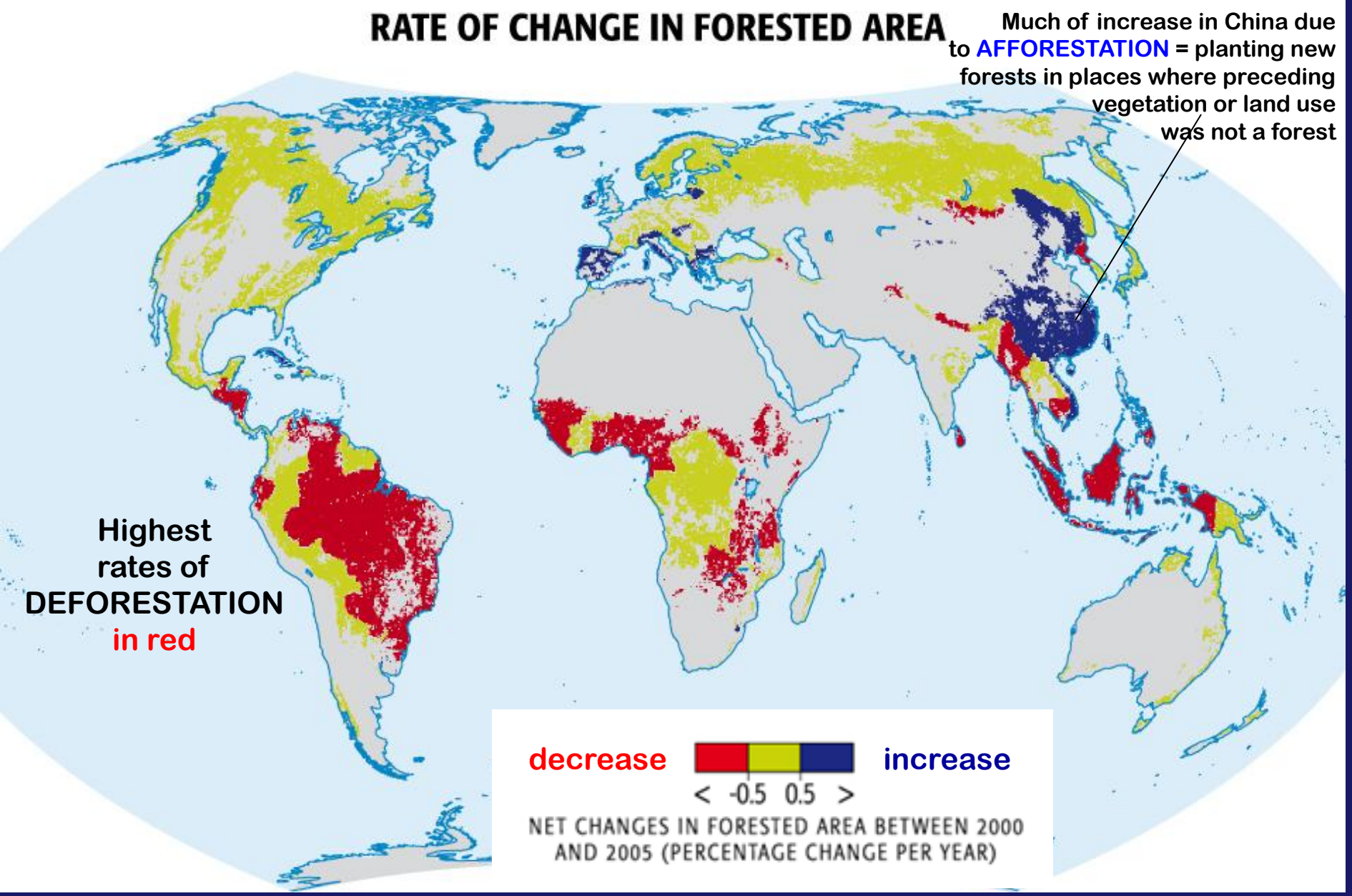
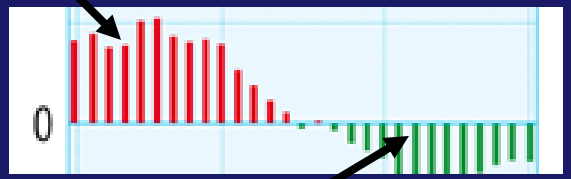


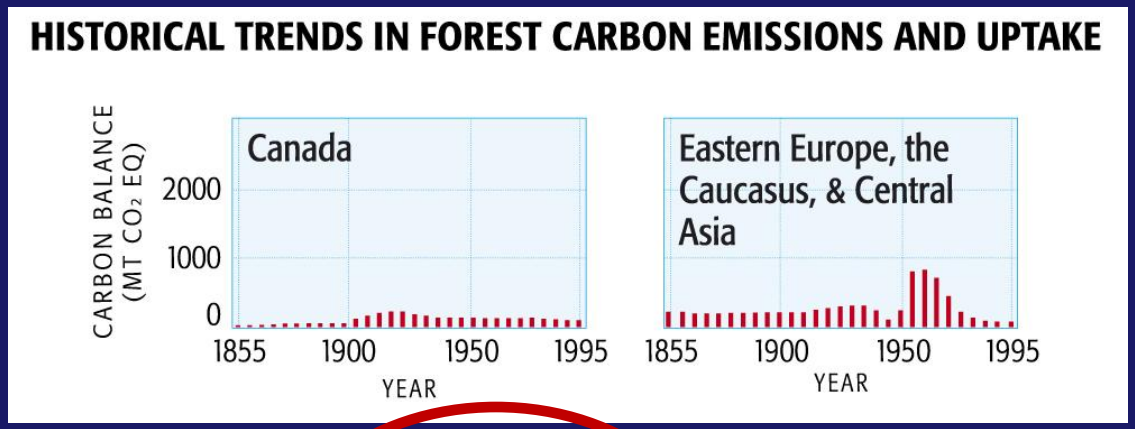
Figure on p 175 in *Dire Predictions*

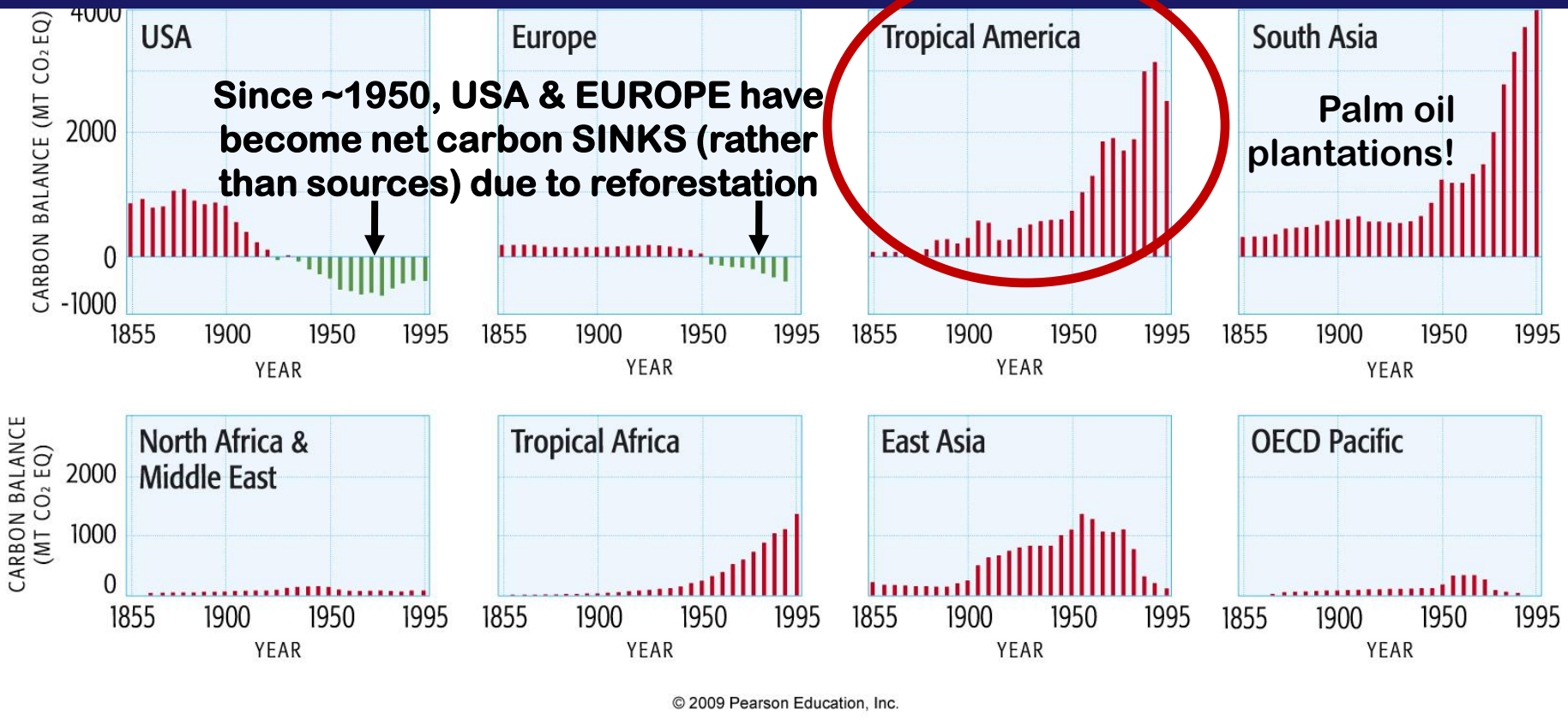
Data Source: UN / FAO Global Forest Assessment Report
http://www.fao.org/forestry/fra/41555/en/

Forest carbon emissions INTO the atmosphere (+)

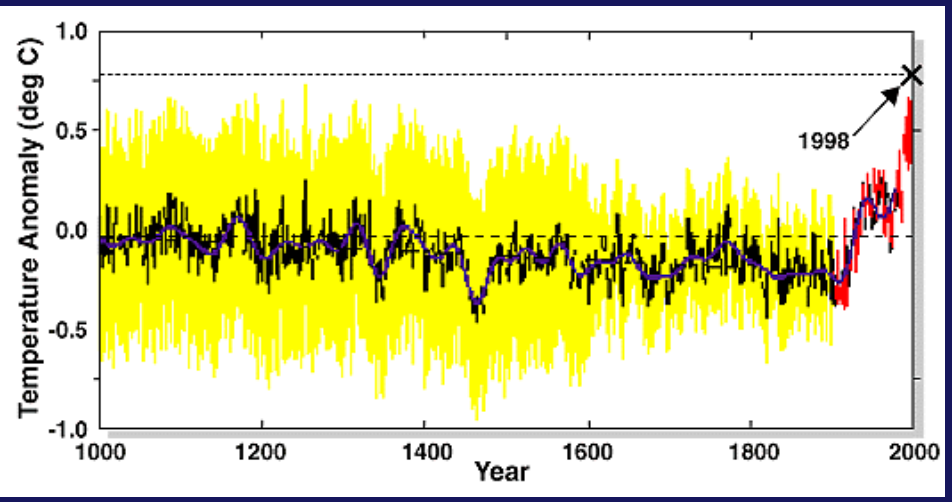


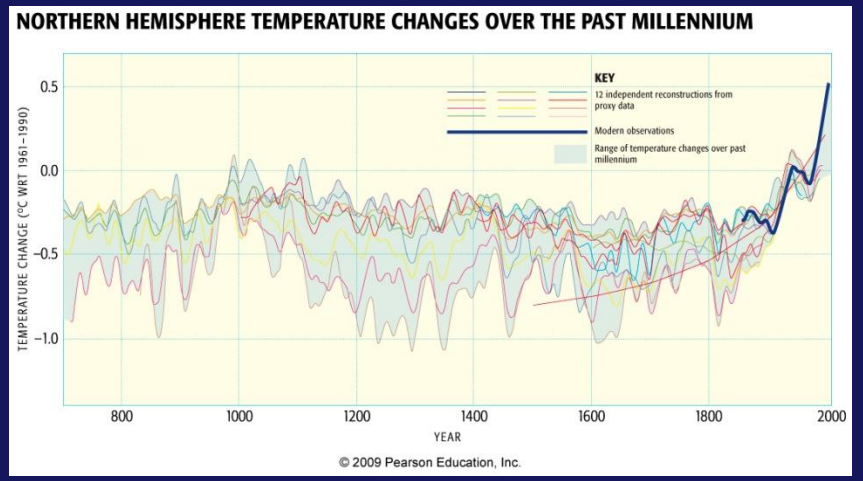
- Forest uptake of carbon OUT OF the atmosphere (-)





TOPIC # 14, PART B:
Evidence from Natural Archives

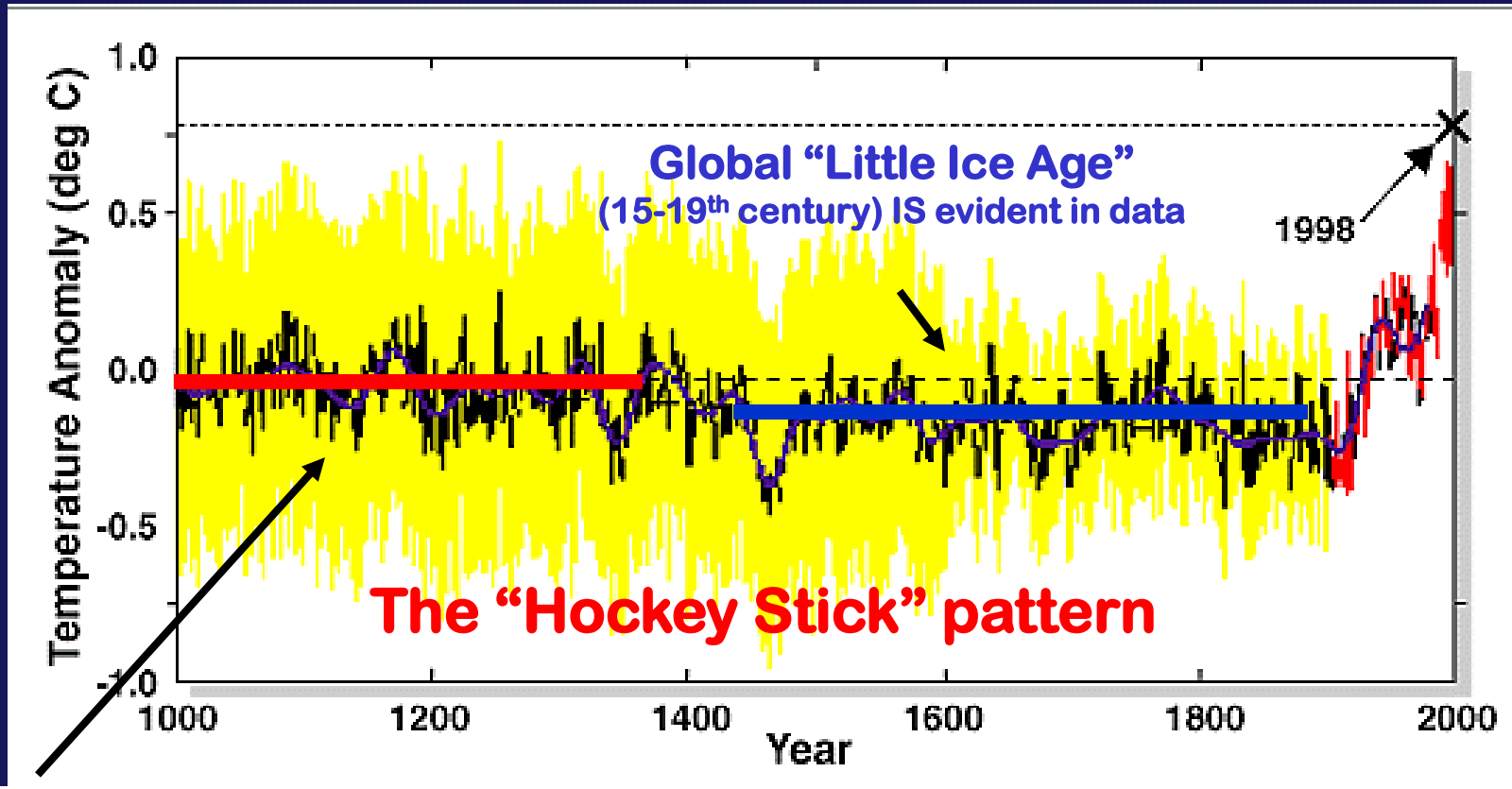




Class Notes pp 78

KEY GRAPH! Temperature change over the last 1000 years from multi-proxy records: shows there is NO period of global or hemispheric temperatures warmer than the 20th century

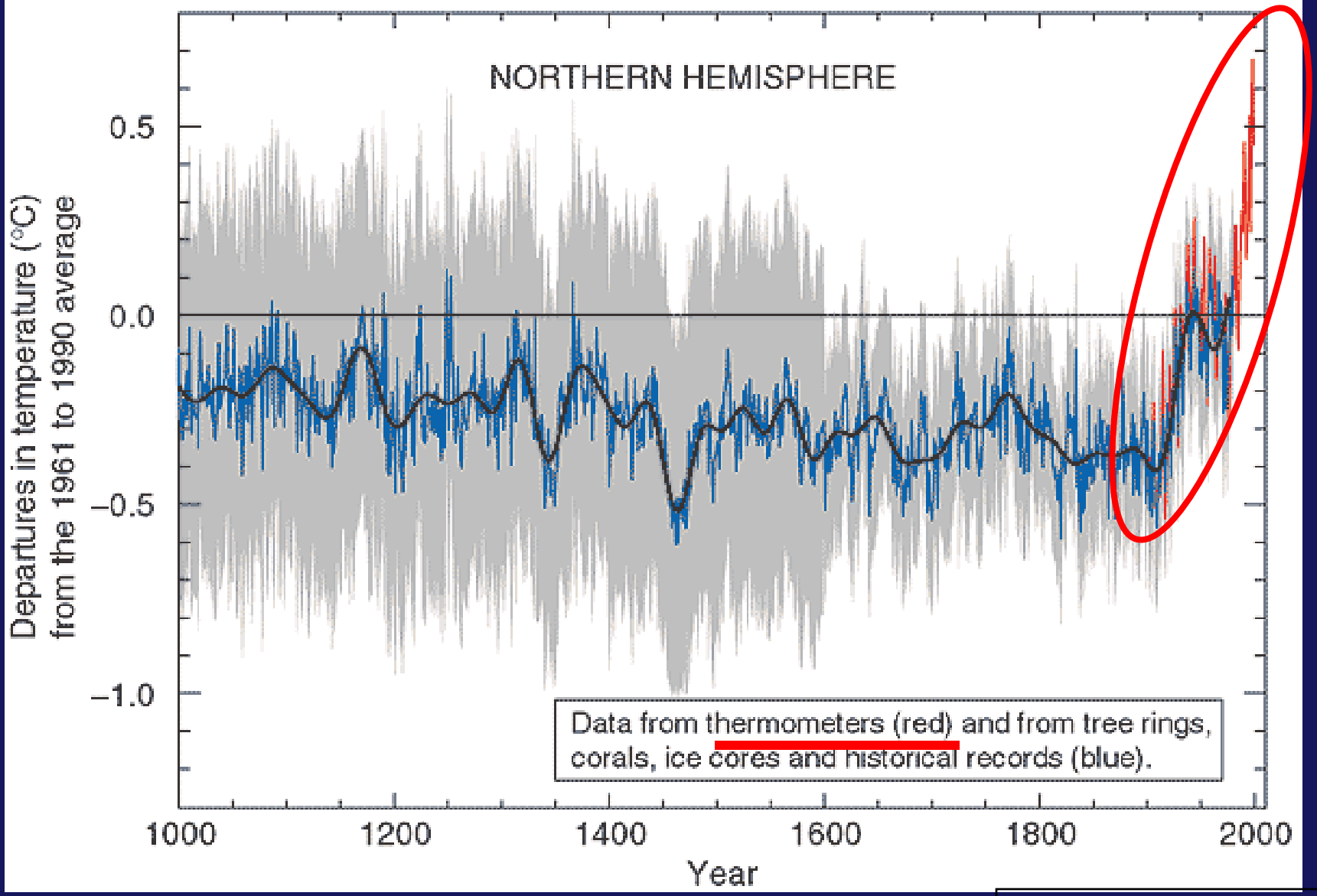
1902 -80 global mean



"Medieval Warm Period" (9-14th century) is a regional phenomenon only -- not globally warmer than 20th century!

Another view of the "HOCKEY STICK" GRAPH

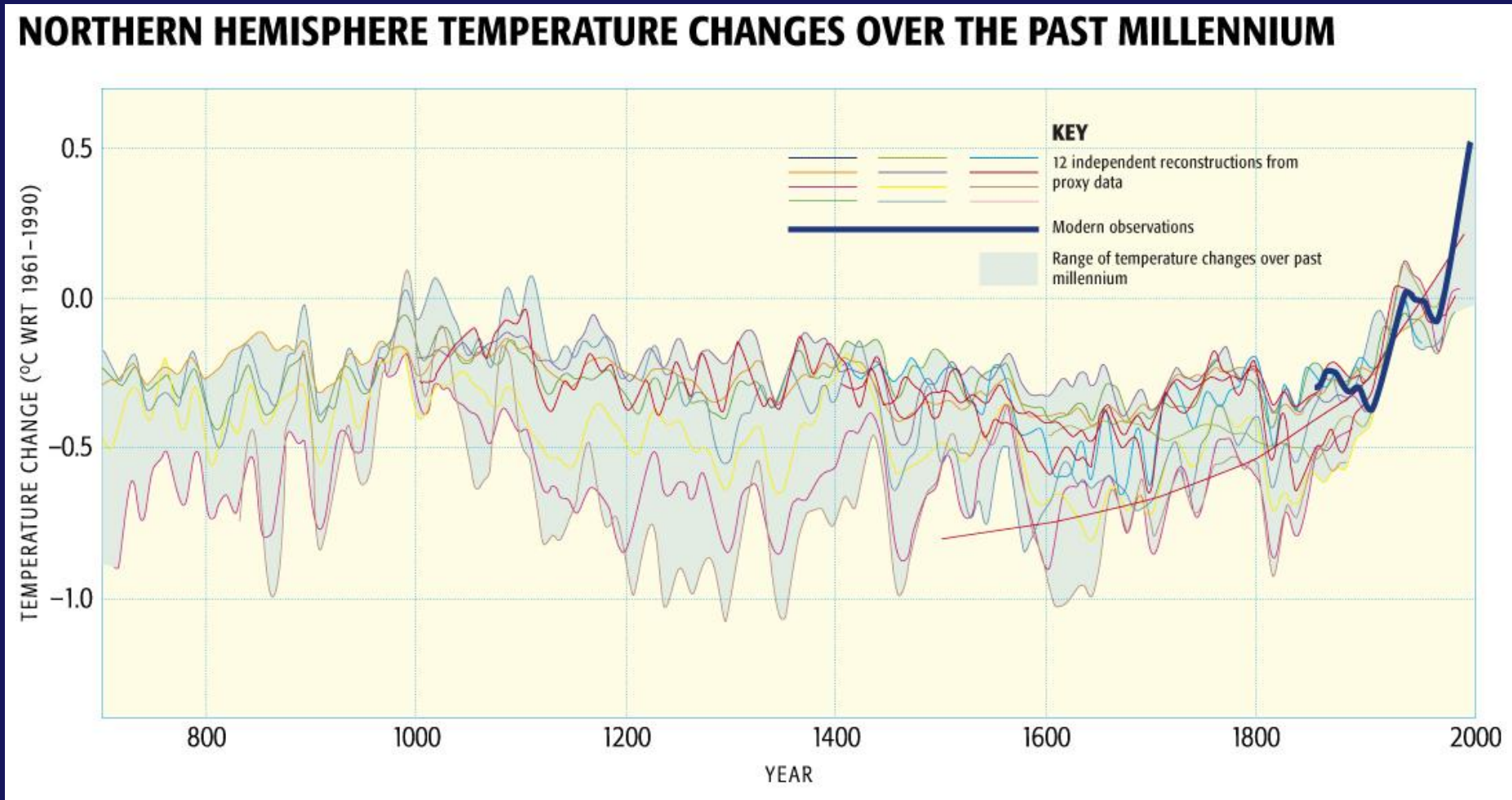
"proxy" data added to thermometer records



Like p 78

Has stood the test of time, despite intense scrutiny and debunking attempts:

Converging evidence of basic shape based on 12 independent reconstructions:



SEE YOU NEXT TUESDAY!

Watch one of the Personal Project Films this week with your “time off”!

DON’T FORGET RQ-8