Organic carbon
(terrestrial biosphere and ocean)

Last class…

- Cycle of carbon involves atmosphere, ocean, terrestrial biosphere, ocean biosphere, lithosphere
- Carbon cycles through reservoirs with differing time scales

Final answer

Until humans came along… (i.e., relative to 2008 values)

a) CO_2 was always lower than present

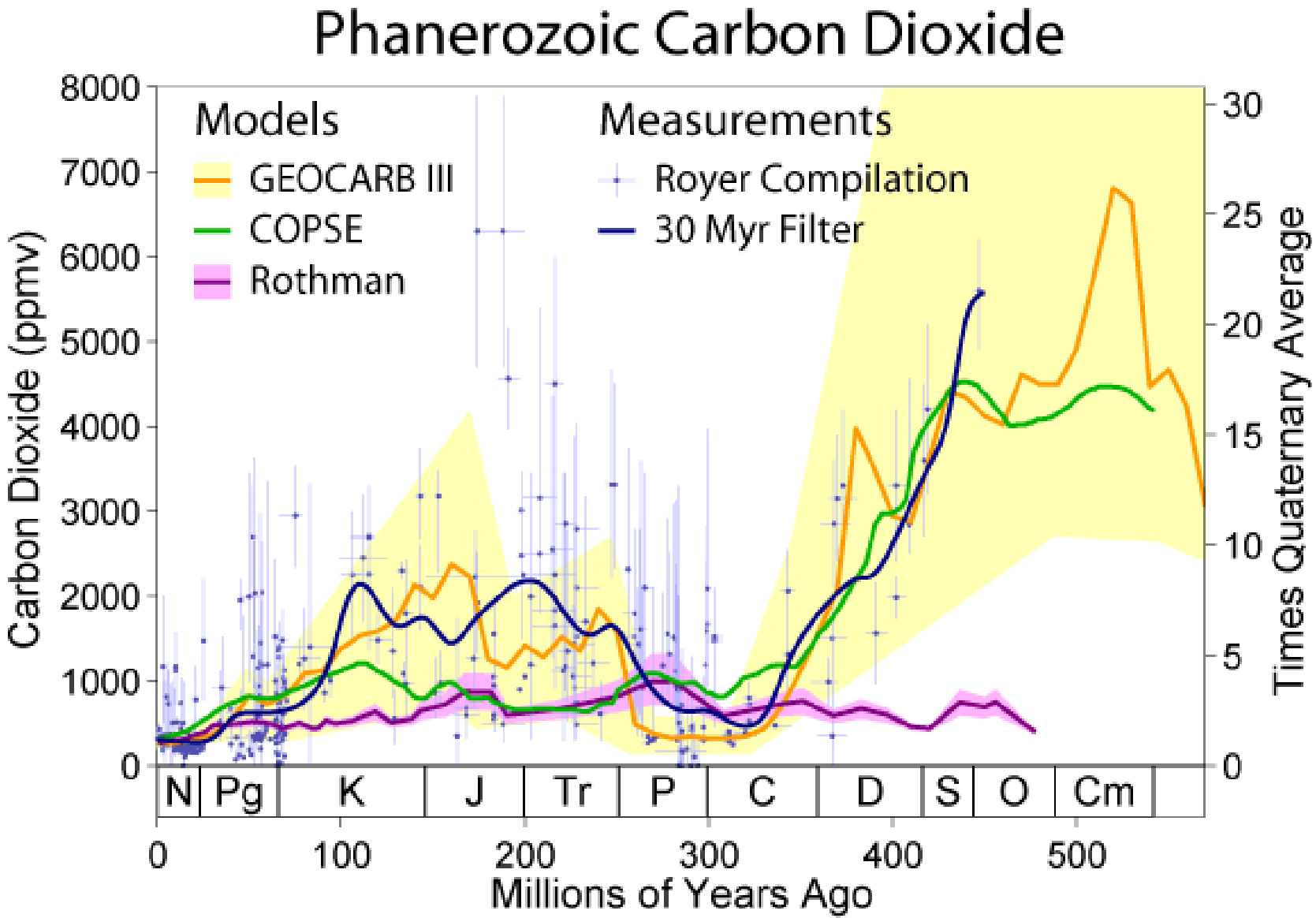
b) CO_2 was mostly lower than present

c) CO_2 was mostly higher than present

d) CO_2 was always higher than present

e) CO_2 was certainly lower and probably higher too

Changes in atmospheric CO_2



Which of the components of the Earth System influence the Carbon cycle?

A. Rice Paddies

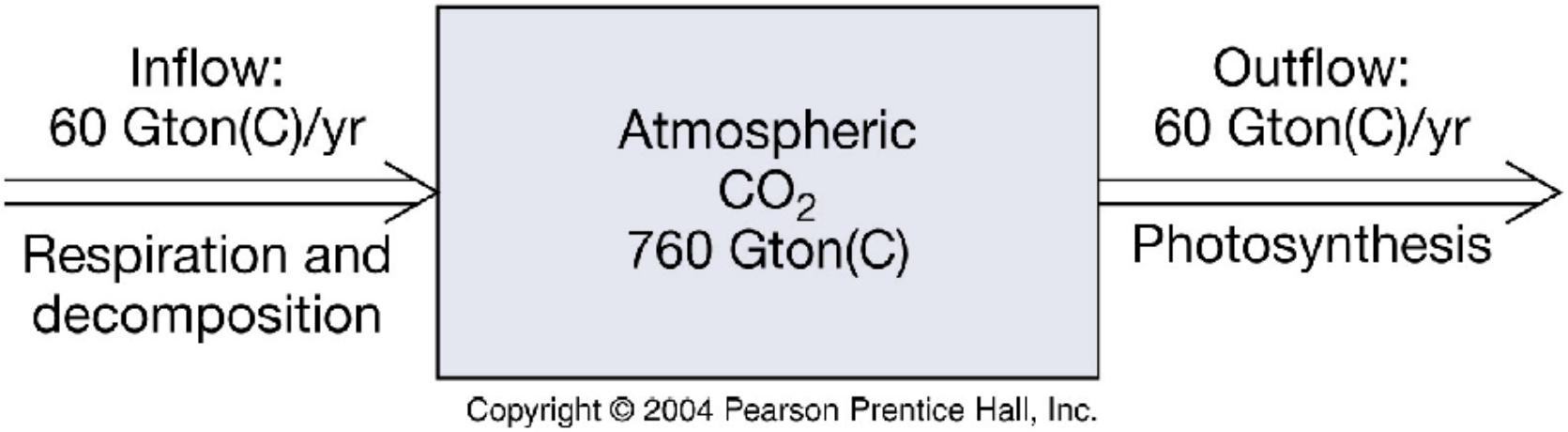
B. Cows

C. Mountain uplift

D. Oceanic phytoplankton

E. All of the

Residence time



Time scale is how long it takes for flux to refill the reservoir.

- ***Big flux***, small reservoir = short time
- Small flux, ***big reservoir*** = long time

Residence time = size of reservoir / flux

e.g., 10 gallons of ice cream, 1 gallon per day = 10 days

Or…1020 Gt C in upper ocean, 90 Gt/year flux = 11 years

Which reservoir the ***longest*** time scale for carbon cycling?

A. Atmosphere
B. Above ground terrestrial biosphere (tree trunks, leaves
C. Below ground terrestrial biosphere (soil/roots)
D. Upper ocean
E. Deep ocean

Which reservoir the ***shortest*** time scale for carbon cycling?

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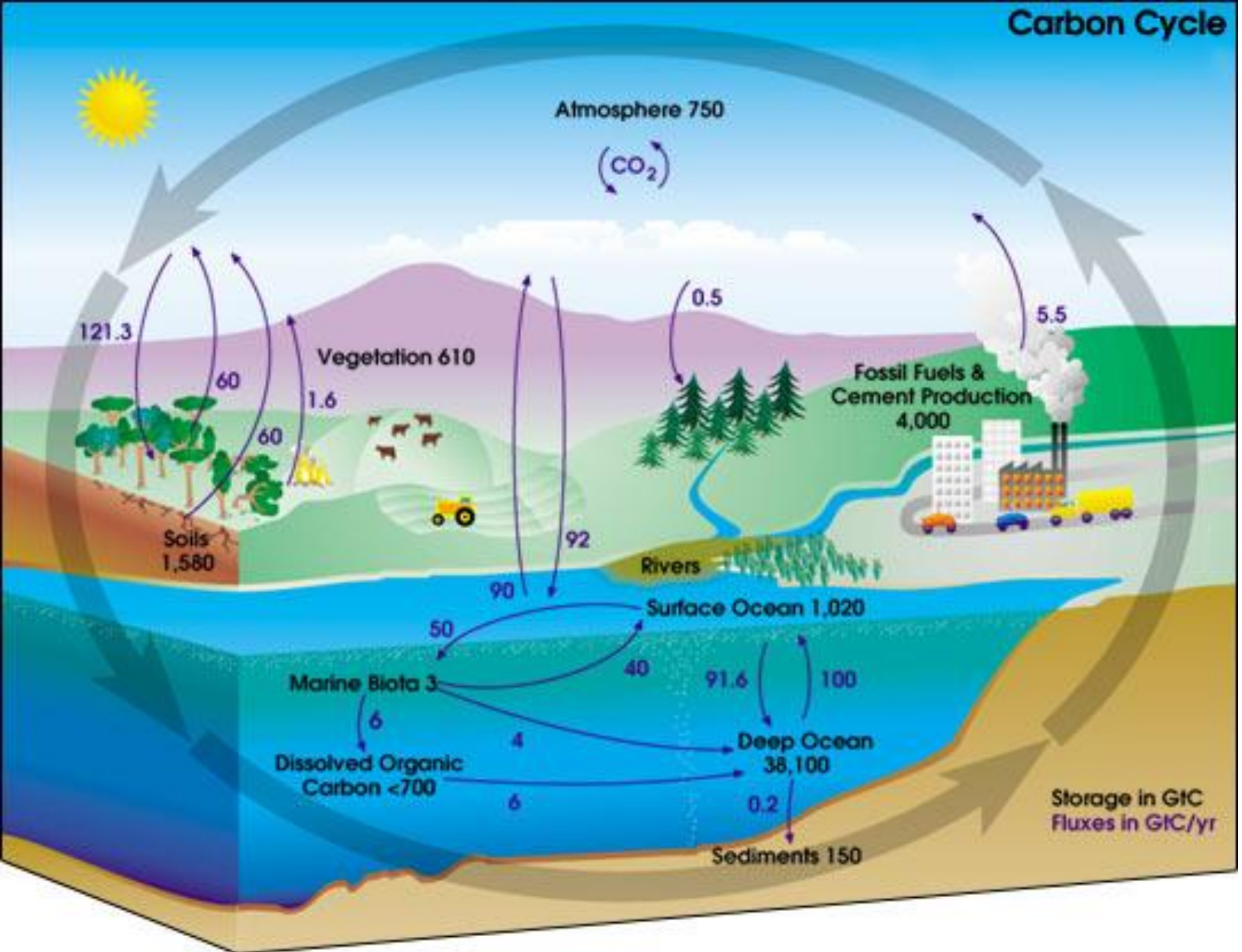
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Atmosphere 750
(CO_2)
121.3
60
60
1.6
Vegetation 610
0.5
5.5
Fossil Fuels &
Cement Production
4,000
Soils
1,580
92
90
Rivers
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91.6
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Deep Ocean
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Dissolved Organic
Carbon <700
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Storage in GtC
Fluxes in GtC/yr

Final answer

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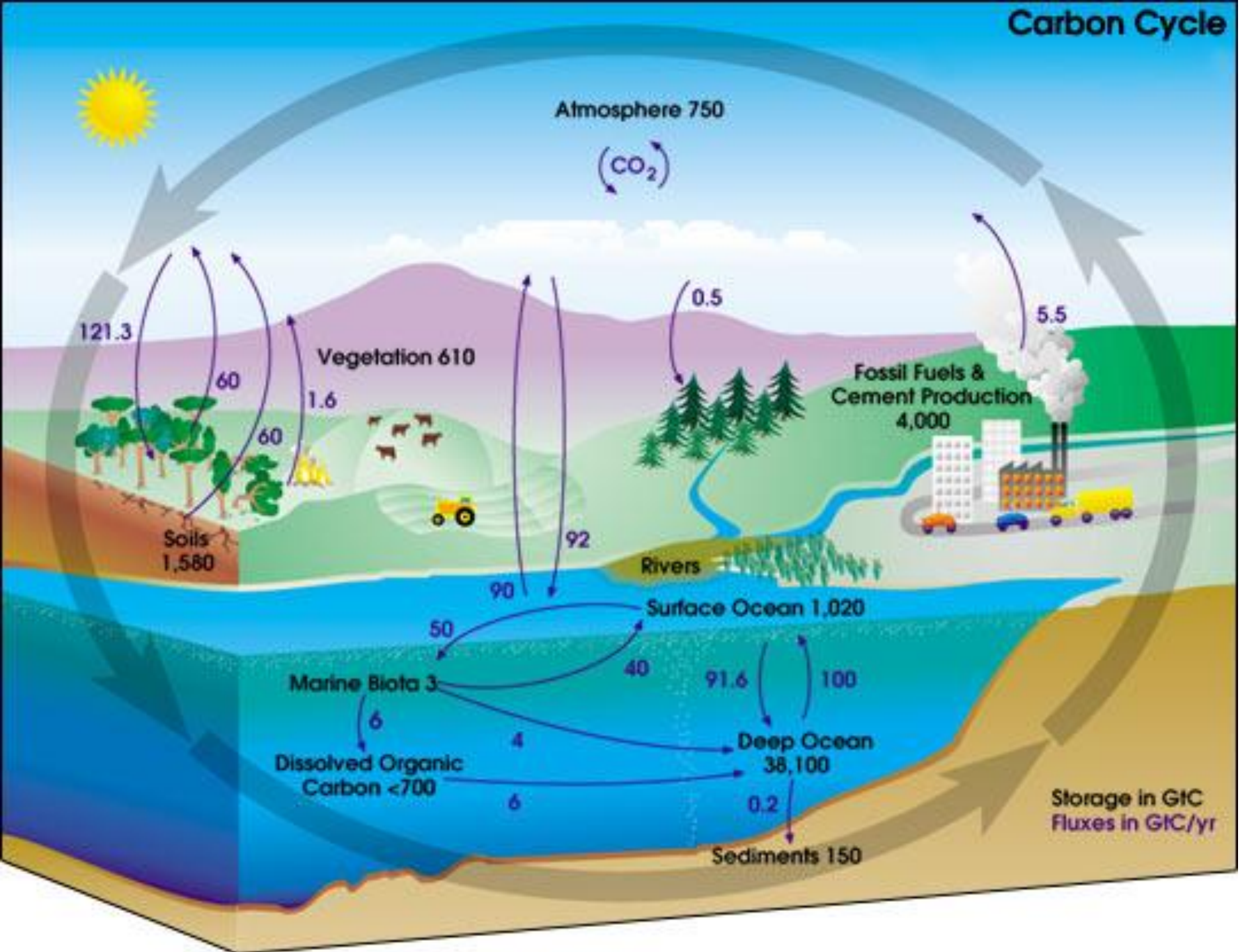
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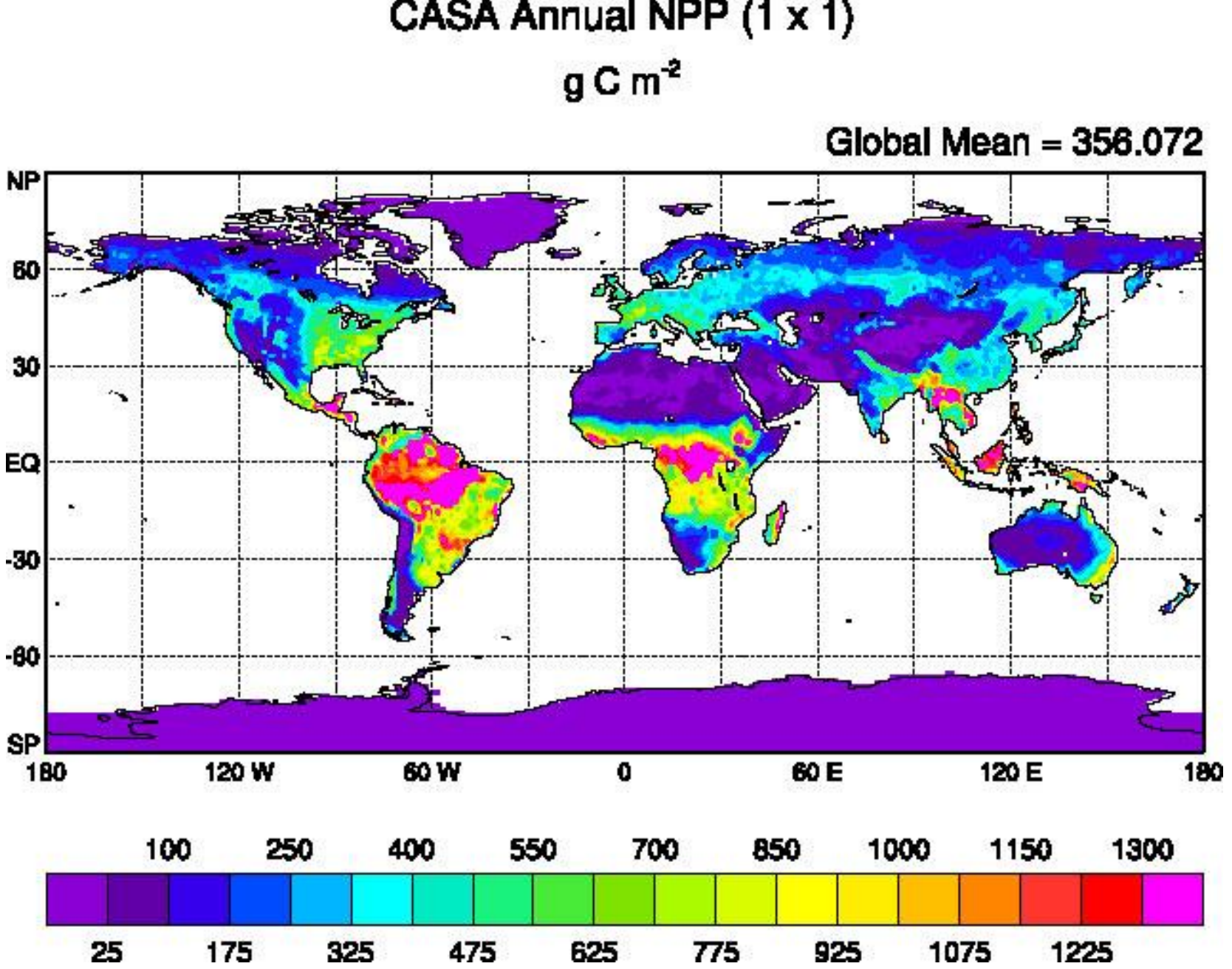
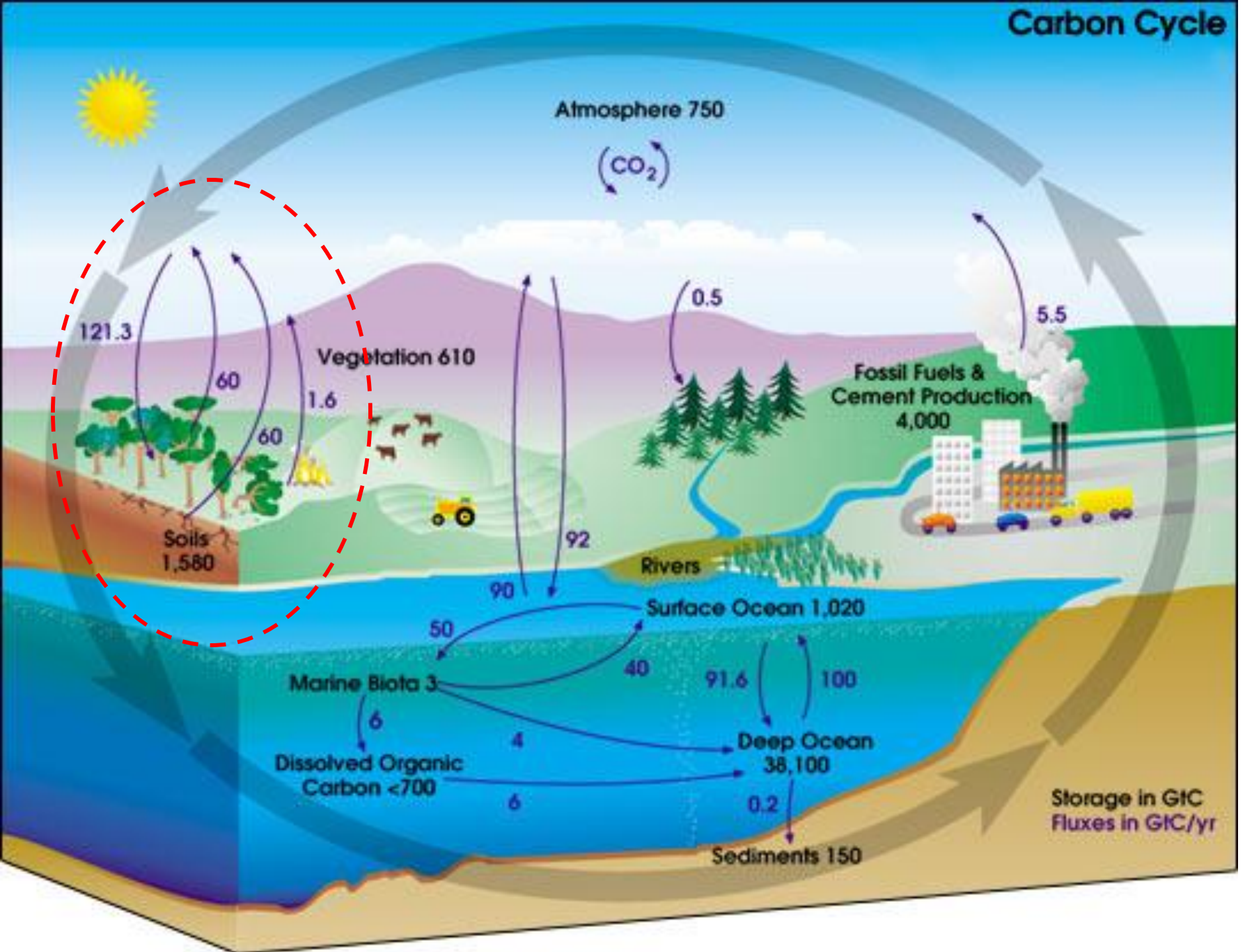


Net primary production: Carbon taken up by growing plants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Terrestrial biosphere

Growing season, photosynthesis takes up CO_2

$$CO_2 + H_2O \rightarrow CH_2O + O_2$$

Carbon dioxide + water → carbohydrate +oxygen

Requires sunlight!

Energy stored in biomass

Winter season, respiration releases CO_2

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

carbohydrate +oxygen → Carbon dioxide + water

Gives up energy

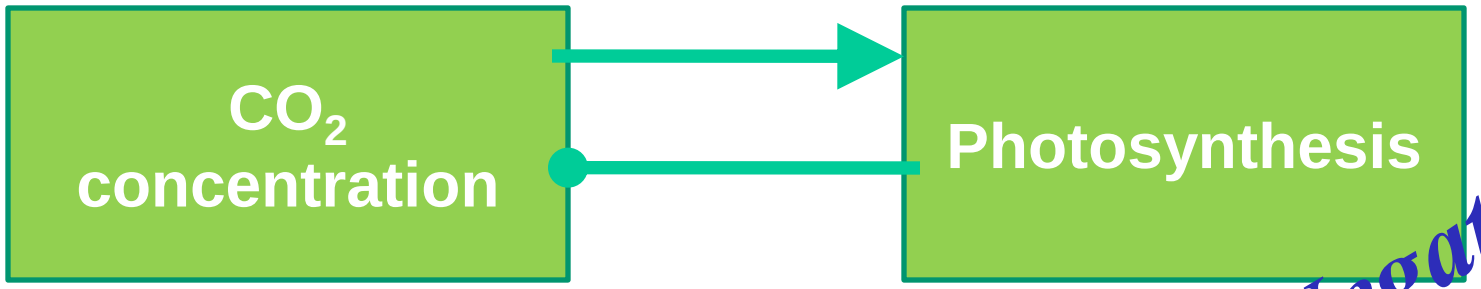
Can fuel animals, cars (bio diesel)…

Note respiration always occurs, but photosynthesis is much bigger in growing season

Can almost think of plants as solar powered batteries!

CO_2 feedbacks

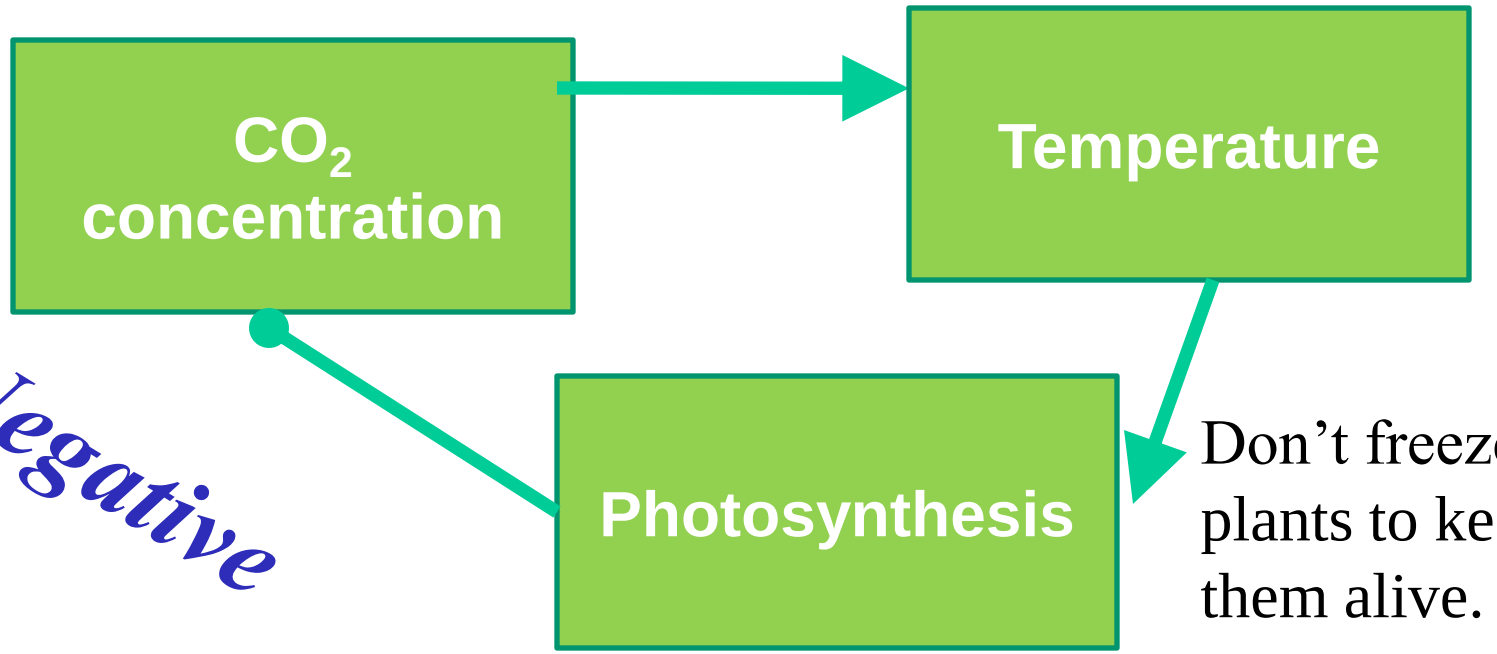
1)



Negative

Talk to your plant to make it grow

2)

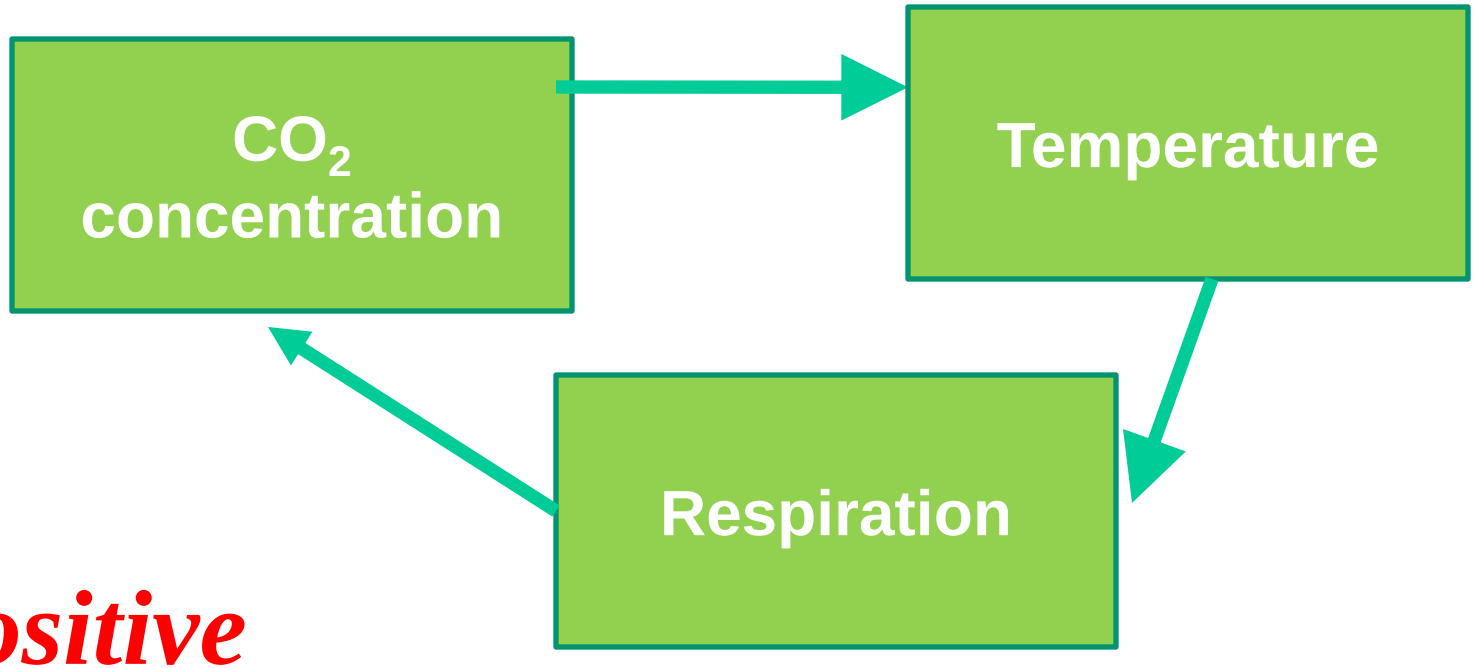


Negative

Don’t freeze plants to keep them alive.

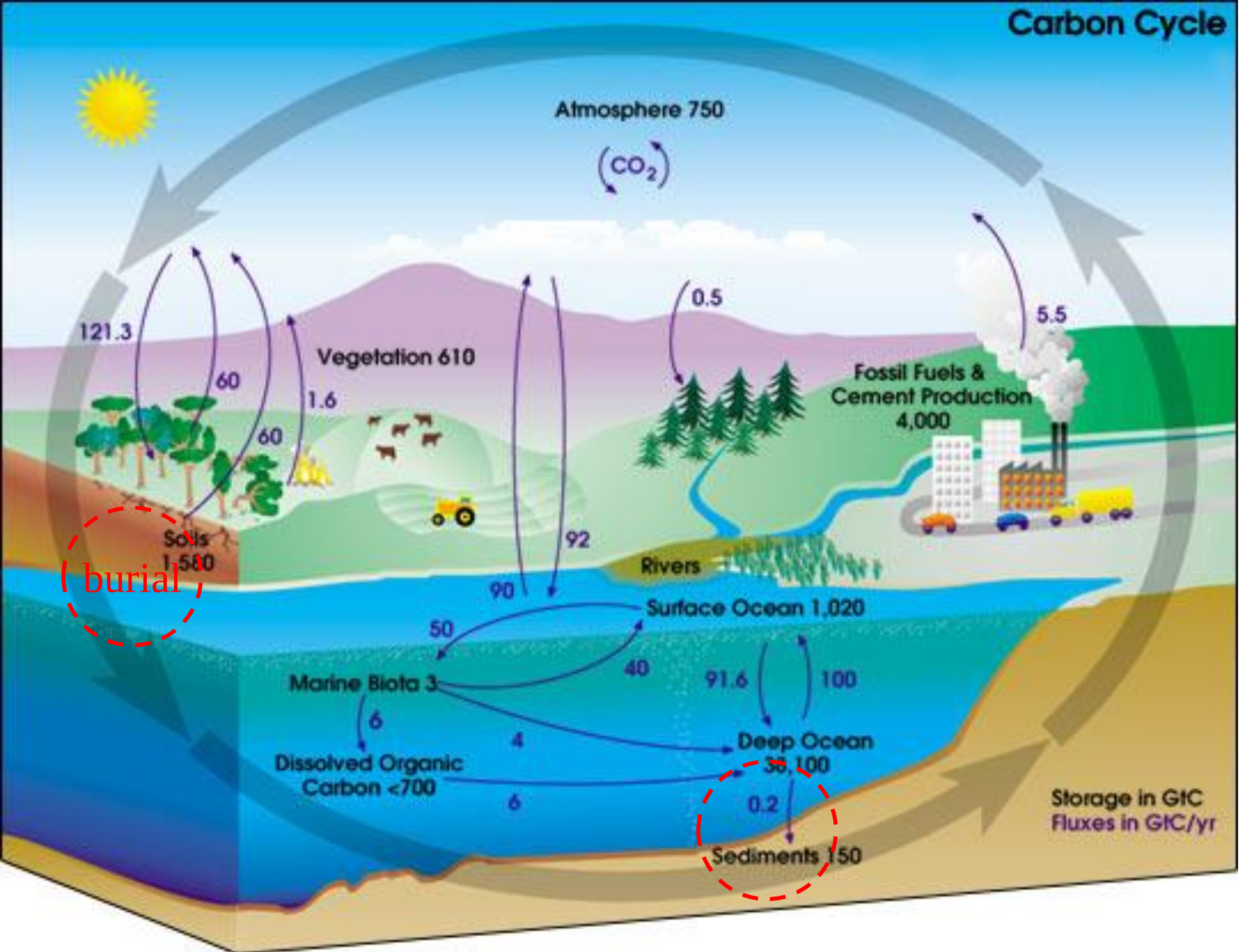
CO_2 feedbacks

3)



Positive

Any microbe will tell you, warm wet things decay faster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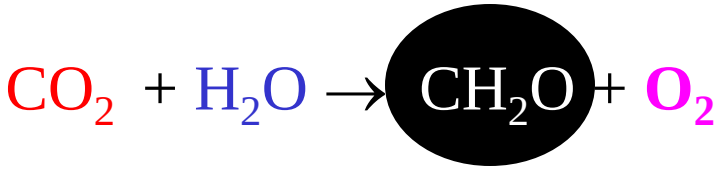
Burial of carbon

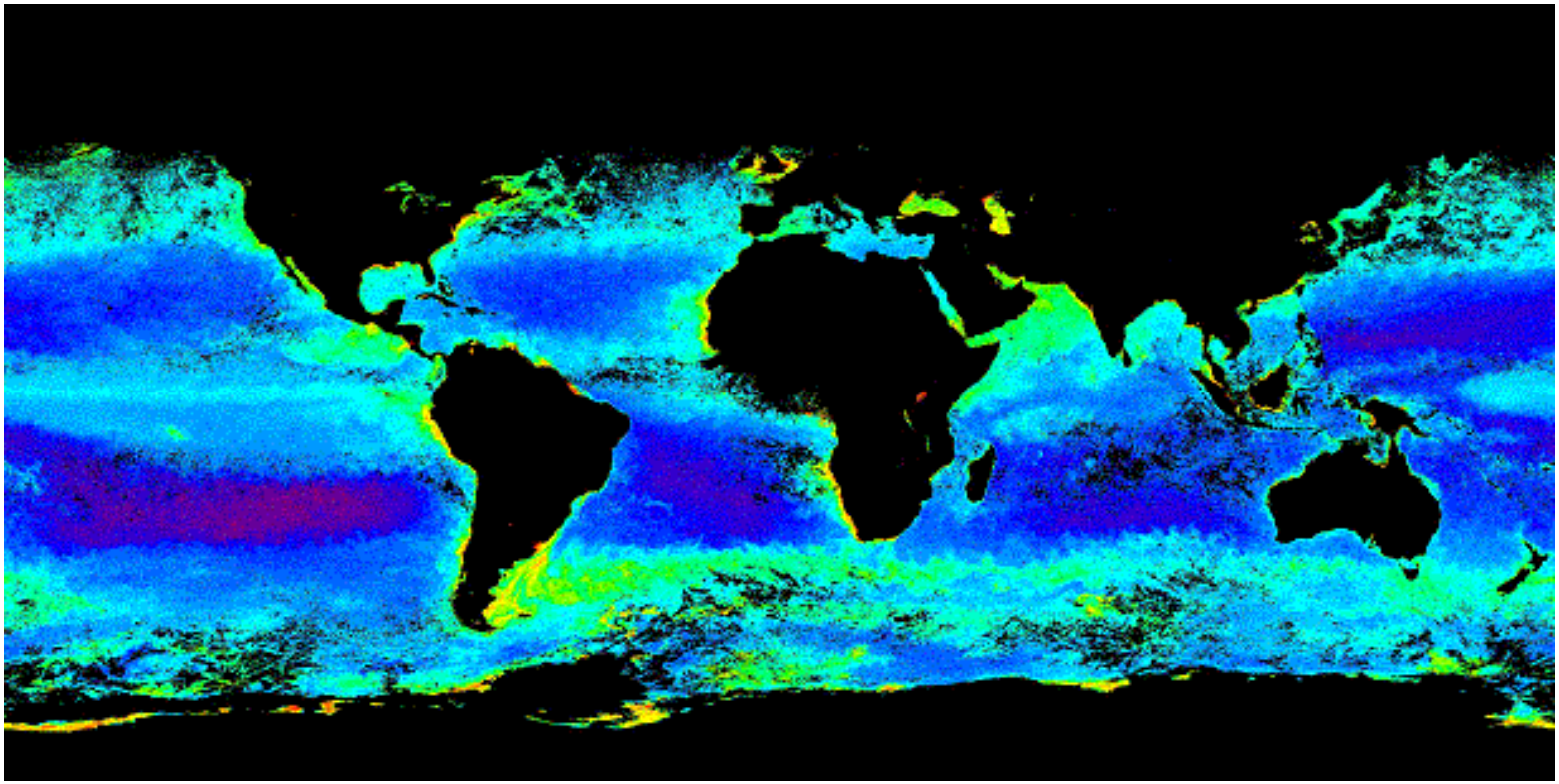
- Roots and below ground biomass can be consumed by microbes
  (when this happens without oxygen, methane is created)
- Biomass not consumed by microbes can collect in regions as sediment.
- This can turn into **coal**



- Notice burial means terrestrial biosphere is not quite in balance. More photosynthesis than respiration.
- As such, there is a net release of O_2 into the atmosphere.
- *This is balanced against chemical wreathing of rocks. Specifically oxidizing ("rusting") of rocks takes up the O_2*

Organic carbon in the ocean

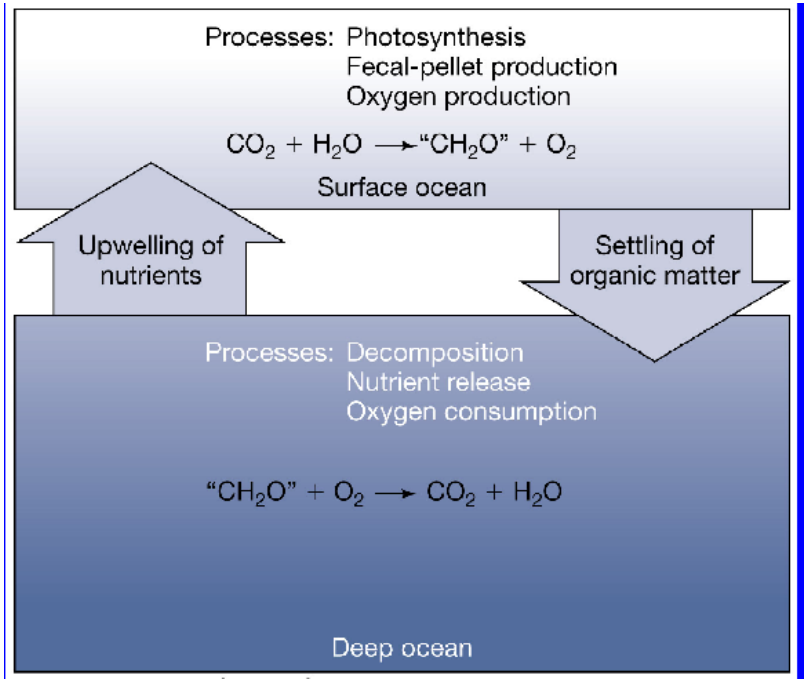
- Upper 100 meters of ocean exposed to sunlight
- Photosynthesis can occur… phytoplankton



Measured from space as amount of chlorophyll

Biological pump

- Small marine animals (zooplankton) eat phytoplankton (foraminifera, radiolaria, …)
- Fecal material falls to deeper ocean
- Mostly dissolves in deeper ocean
- This affectively moves carbon to deep ocean.
- Some very small fraction (< 1%) ends up as sediment on the sea floor.
- This can collect mixed in with mud as shale
- High concentrations can allow formation of oil.
- *(More generally organic material mixed in shales contains potential "fuel", but is such low concentration it is not economical to use… yet)*



Cycle is complete with upwelling of nutrients required to allow more biological activity

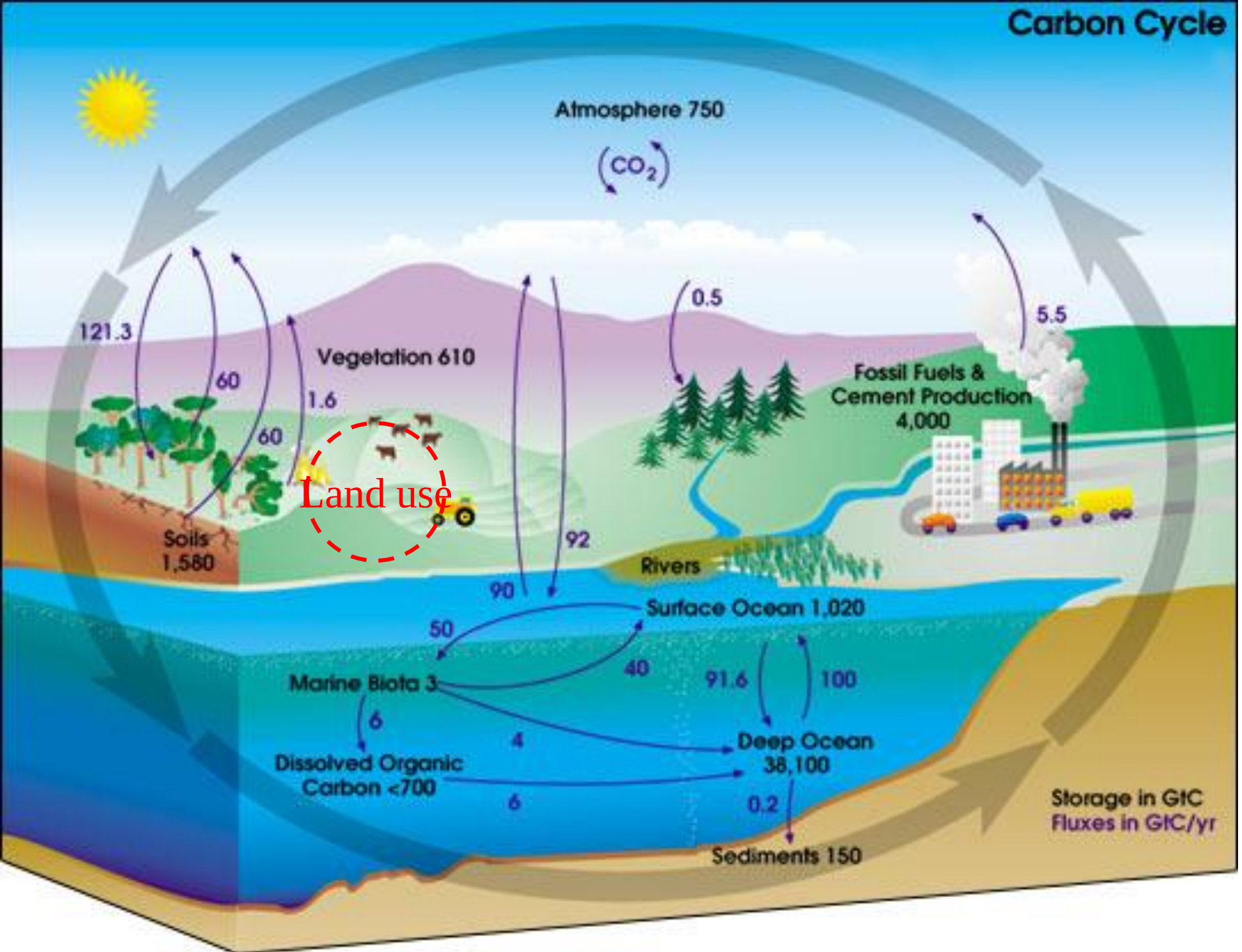
Oil shale… actually “kerogen”

Lots of it in Colorado/Wyoming/Utah Rocky Mountains

Present mining and extraction technique is experimental, and expensive give low grade of oil that results.

Also, extraction techniques presently have significant environmental impact (water waste, chemical toxins,…)

Shell Oil plant, Piceance Basin, Colorado, USA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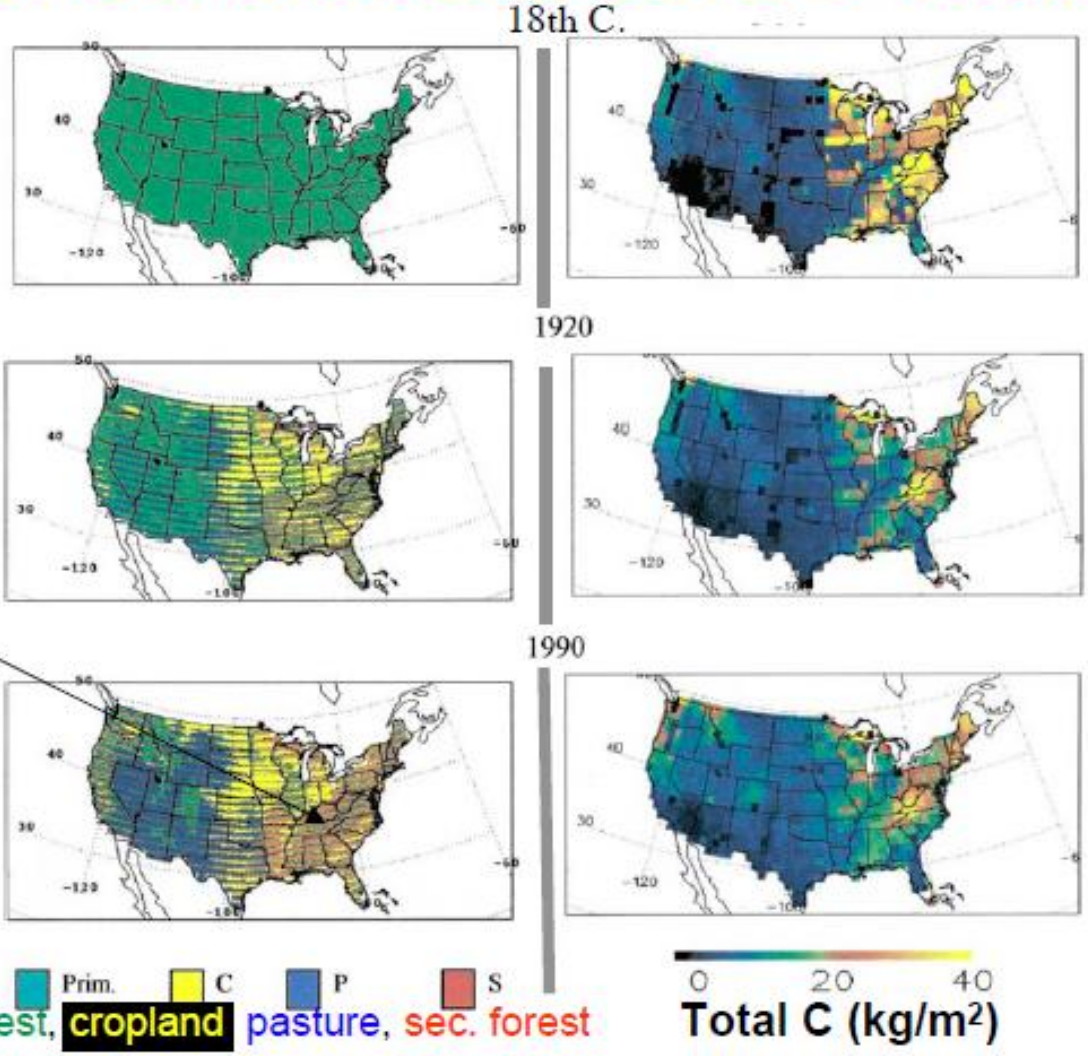
est. US land use and C change

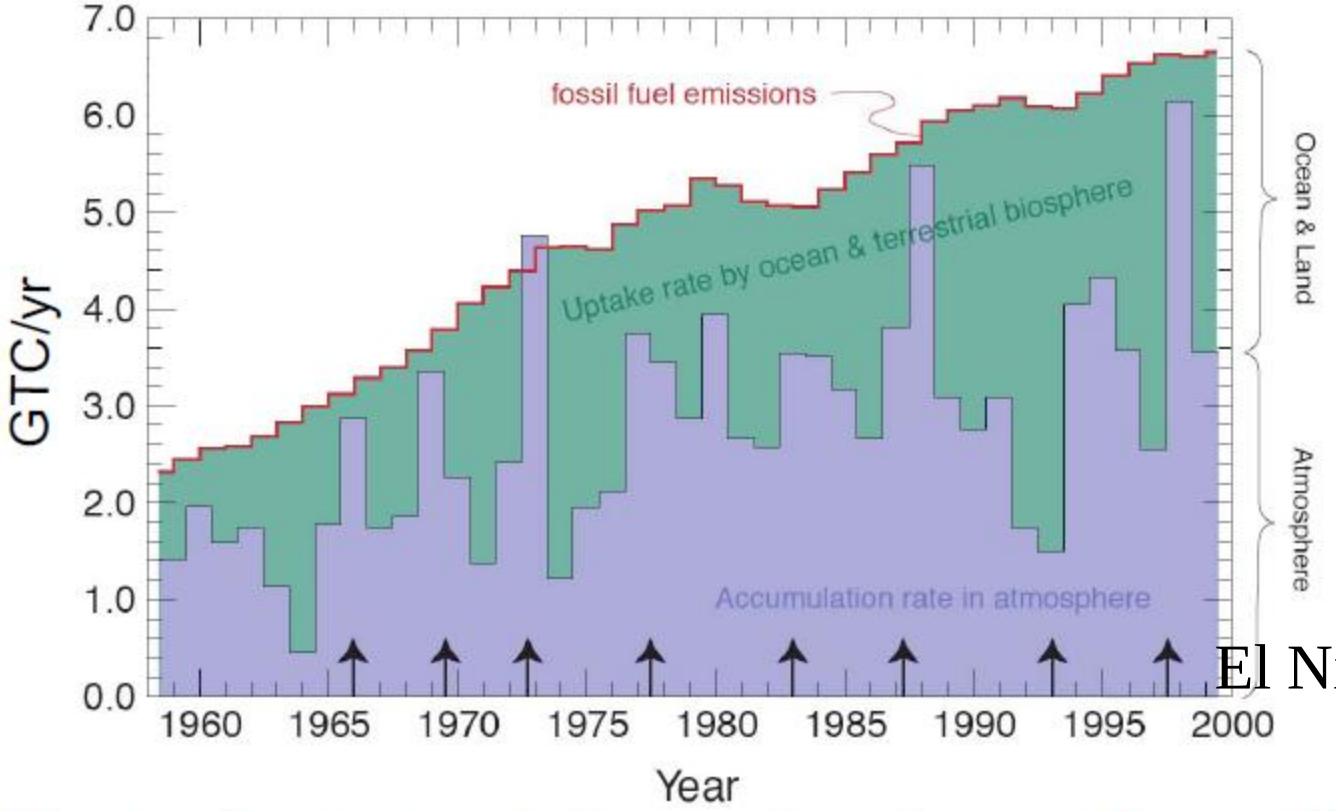


orange denotes conversion of primary to secondary forest, i.e. logging

"eastern US carbon stocks decimated by 1920....., now largely recovered" from Sarmiento & Gruber

annual changes in uptake

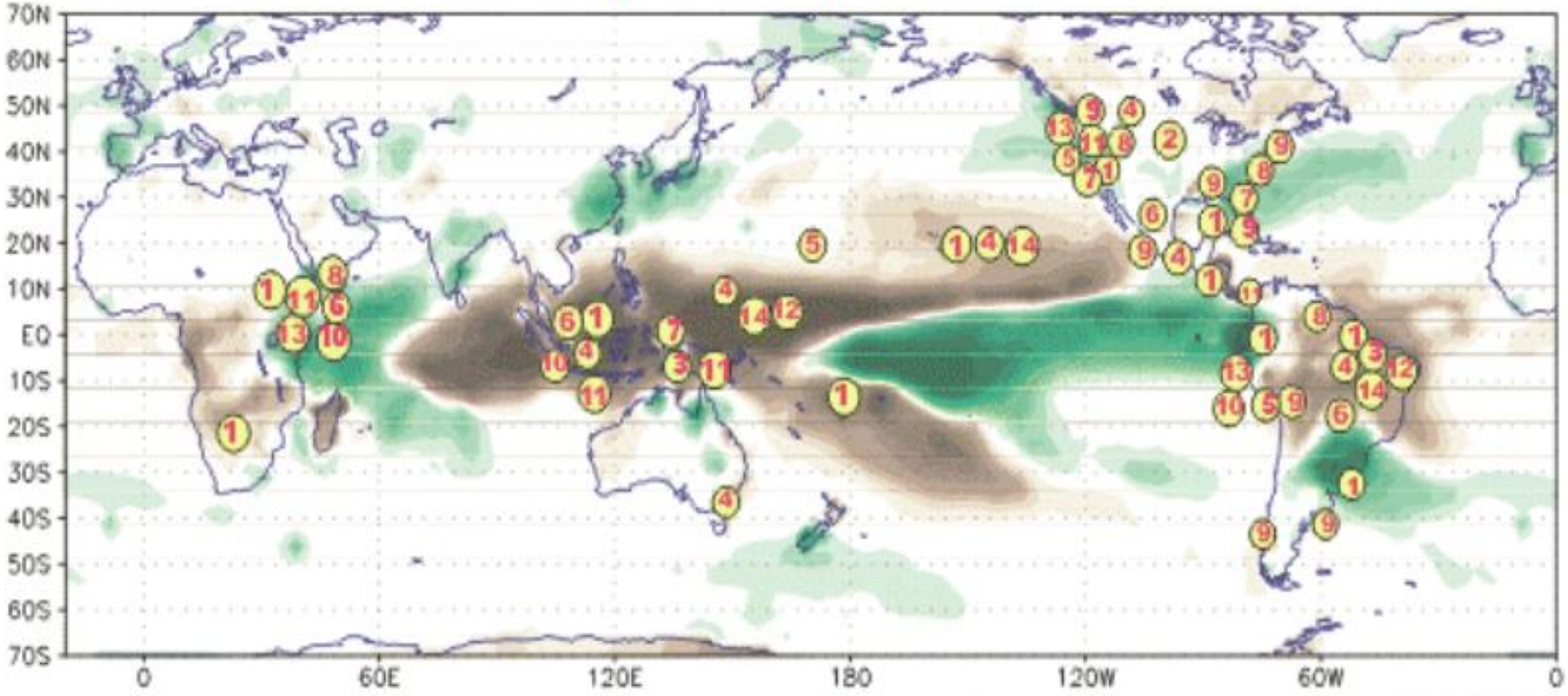
(*well constrained by atm. measurements and economic statistics*)



El Nino events

partitioning of emissions between atmosphere and ocean+land
highly variable but.....,
every year the atmospheric burden increases

recall (1997/8) El Niño



drought (brown) and rainforest burning (Amazon, Indonesia)

Wet

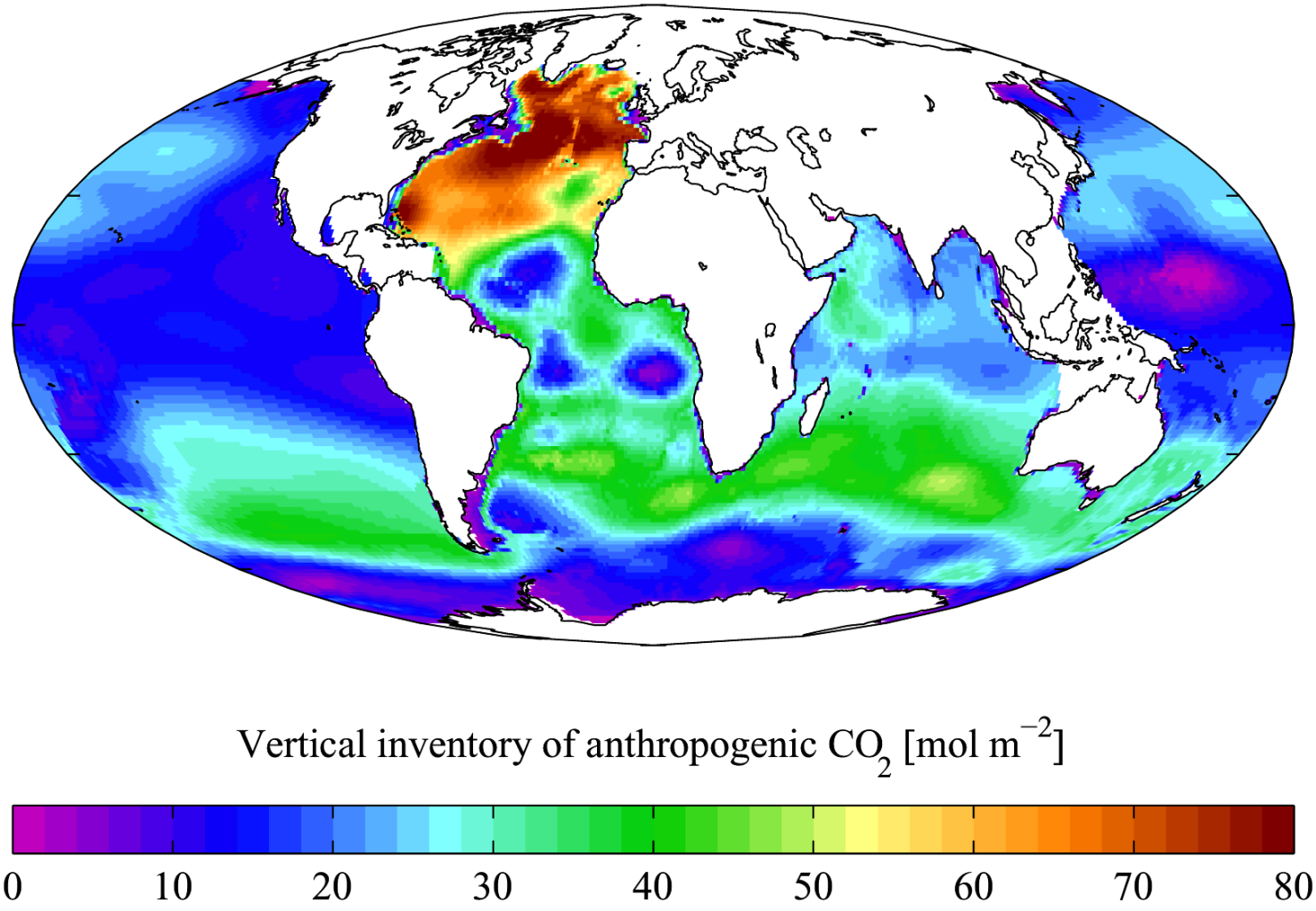
Dry

Natural fate of fossil fuels

- Weathering of rocks will ultimately allow the release of fossil fuels as CO_2
- This would normally occur over 100s of millions of years (i.e., geological time scales)

- Humans simply speed up this process by burning fossil fuels (10s of years)
- **As such, rapid burning of fossil fuels puts the carbon cycle out of balance.**

Where is the CO2 emitted from fossil fuels?



Final answer

Carbon exchanges associated with which of the following would be most likely to influence ***year to year*** variations in atmosphere $CO_{2?}$

a) Atmospheric circulation
b) Oceanic circulation
c) Changes in land vegetation
d) Changes in subduction
e) Variations in use of fossil fuels

Why is it the terrestrial biosphere that can affect year to year variations in CO_2?

- Size of fluxes, size of reservoirs.
- Fossil fuel too small to have much of a year to year change
- So must be either vegetation or ocean
- Ocean moves slow (many years to change, so unlikely to change CO2 much from year to year)
- So must be land plants.
- *Also, note large forests in the tropics are susceptible to extreme fire and drought via El Nino.*

Key points

- The terrestrial biosphere has significant year to year variations, which can influence the year to year atmospheric CO_2concentrations
- Deep ocean water stores carbon (slowly) by the biological pump (i.e., “fish poop”)
- The terrestrial biosphere leads to BOTH negative and positive feedbacks. Uncertain which dominates.
- Slow sinking and burial ultimately allows this carbon to go into the large “lithosphere” reservoir
- Sometimes are oil,
  sometimes are limestone, …