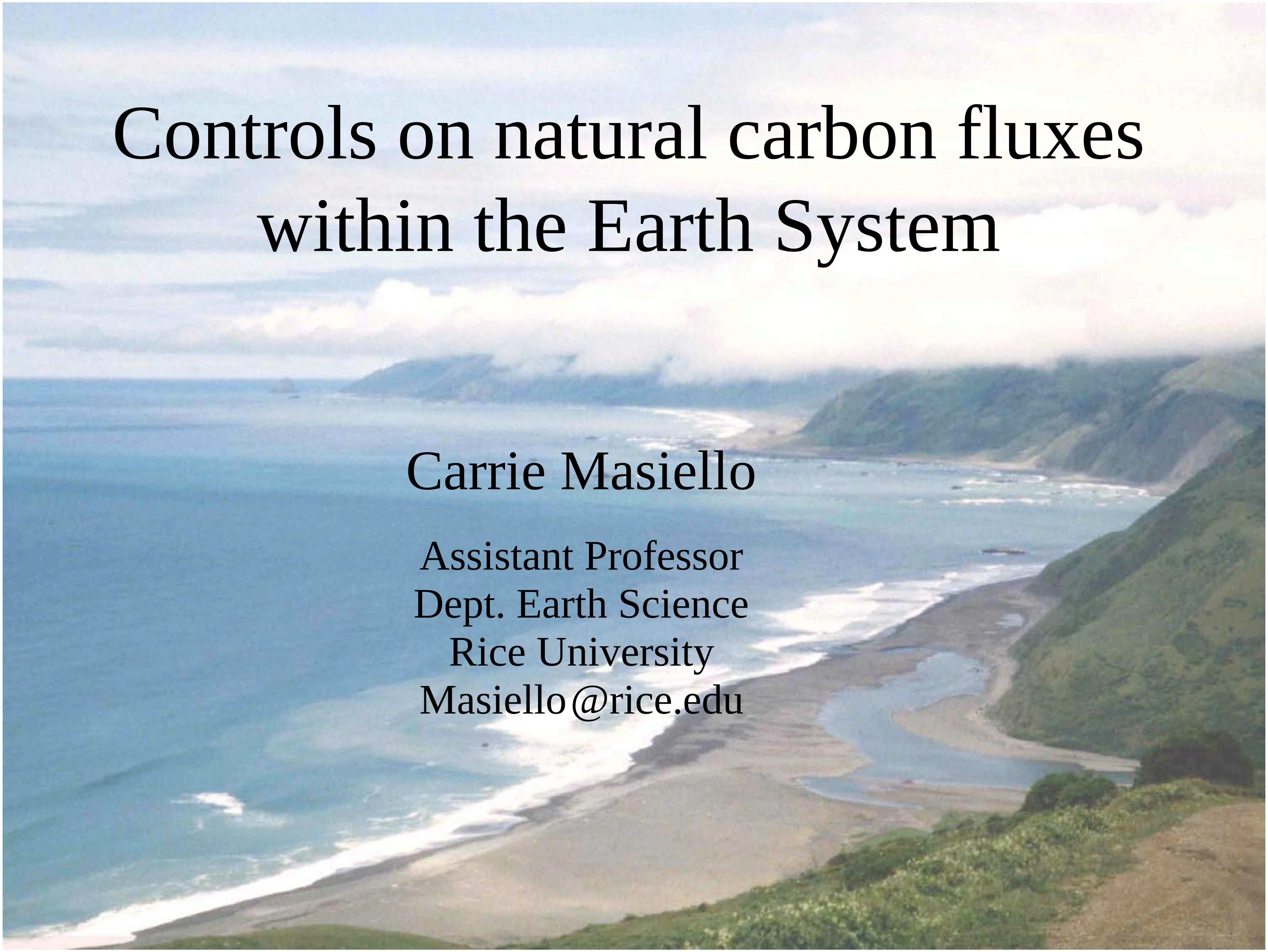

Controls on natural carbon fluxes within the Earth System

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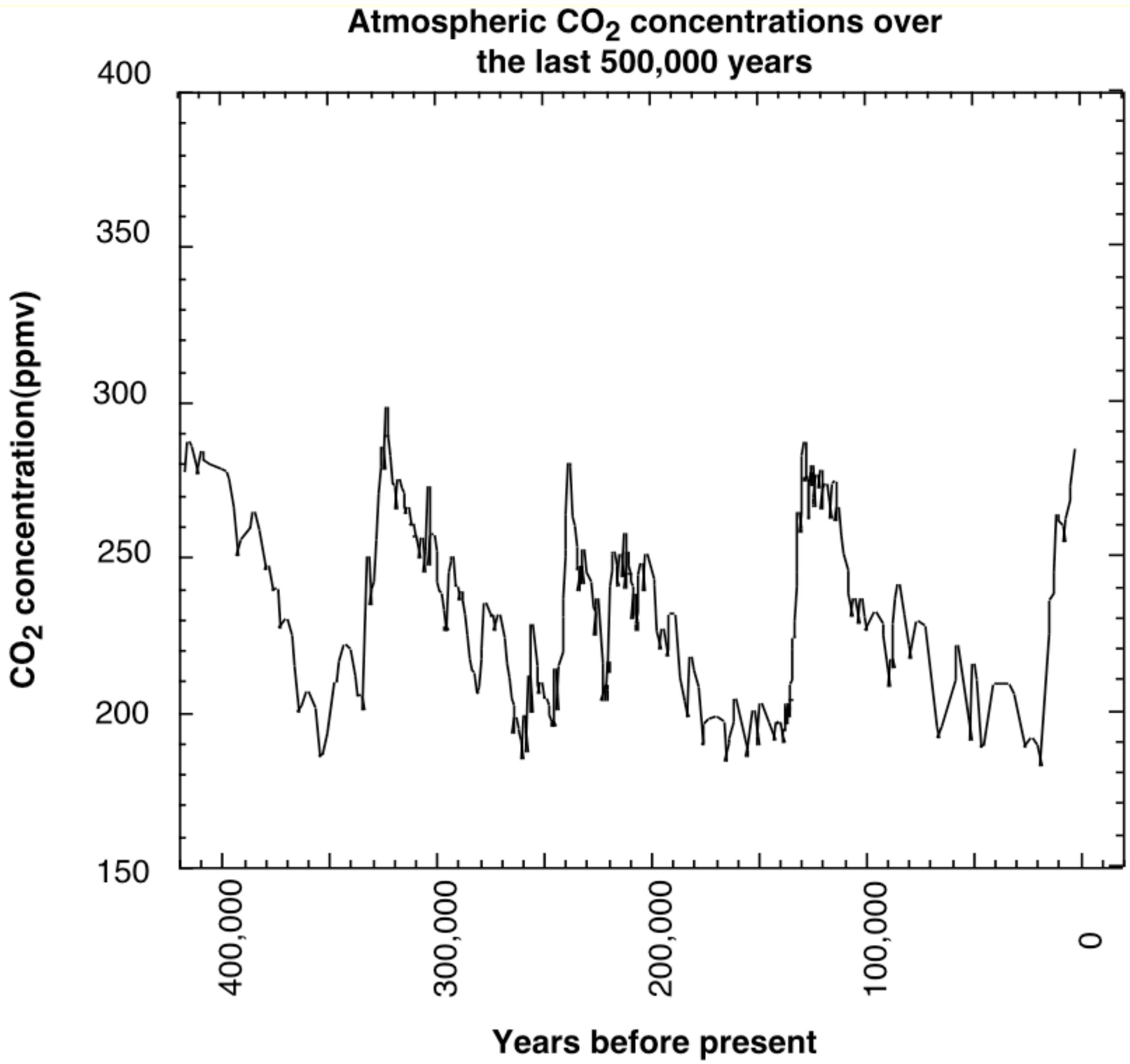
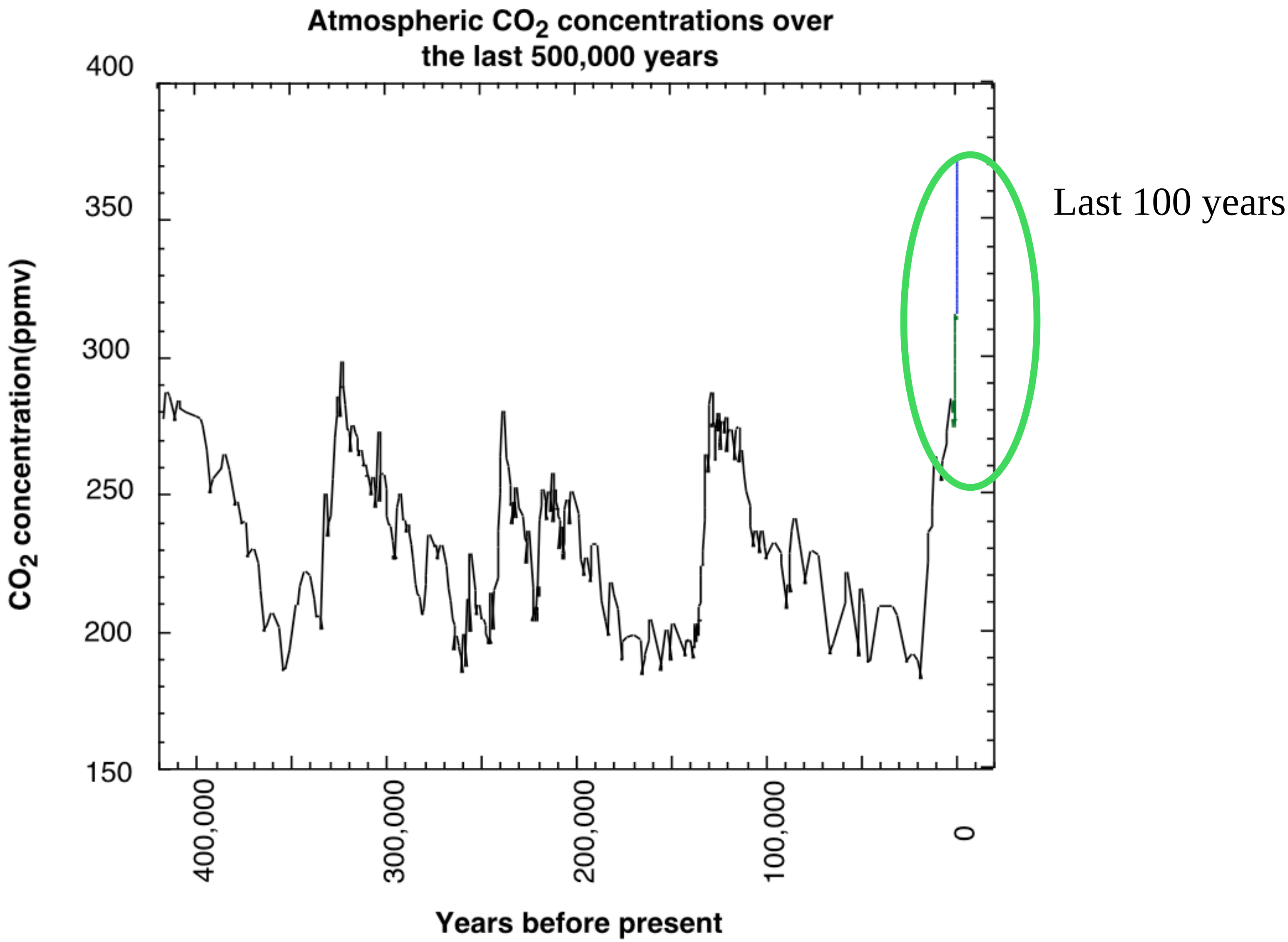


D.M. Etheridge et al. 1998. Historical CO_2 records from the Law Dome DE08, DE08-2, and DSS ice cores; Barnola, J.-M. et al. 2003. Historical CO_2 record from the Vostok ice core; Keeling, C.D. and T.P. Whorf. 2003. Atmospheric CO_2 records from sites in the SIO air sampling network.. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A



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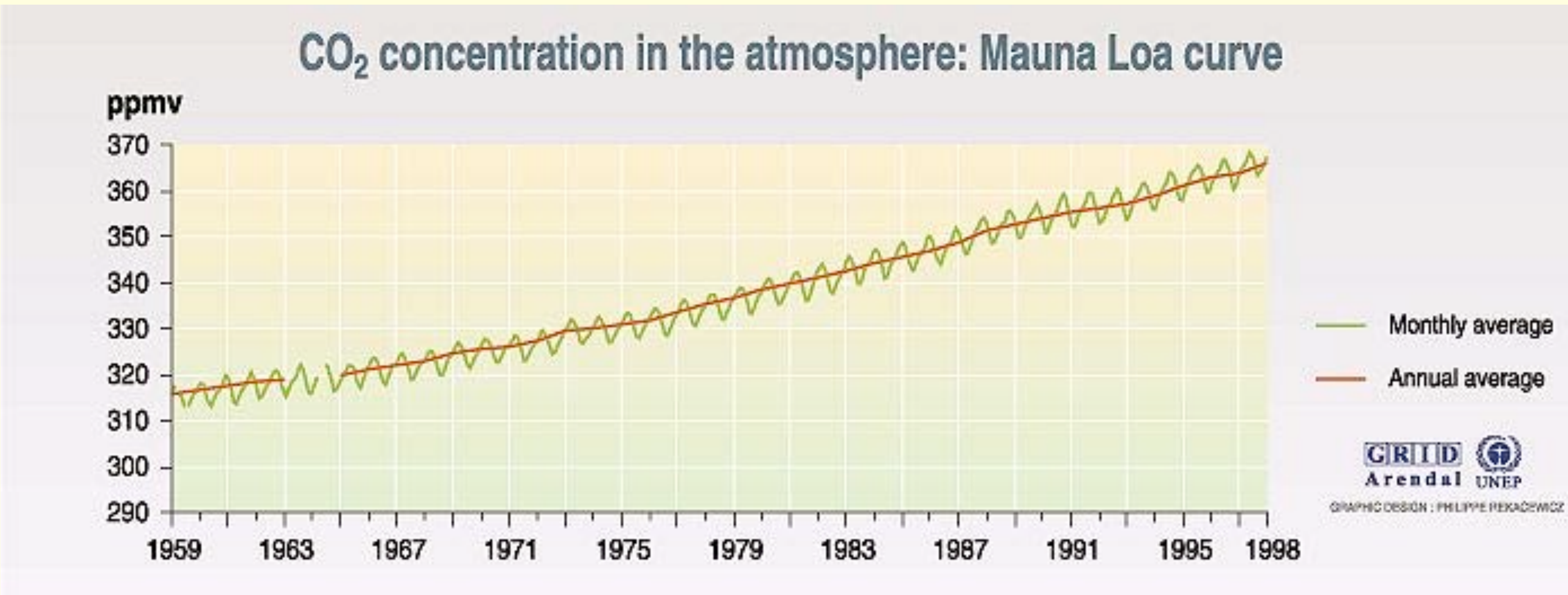
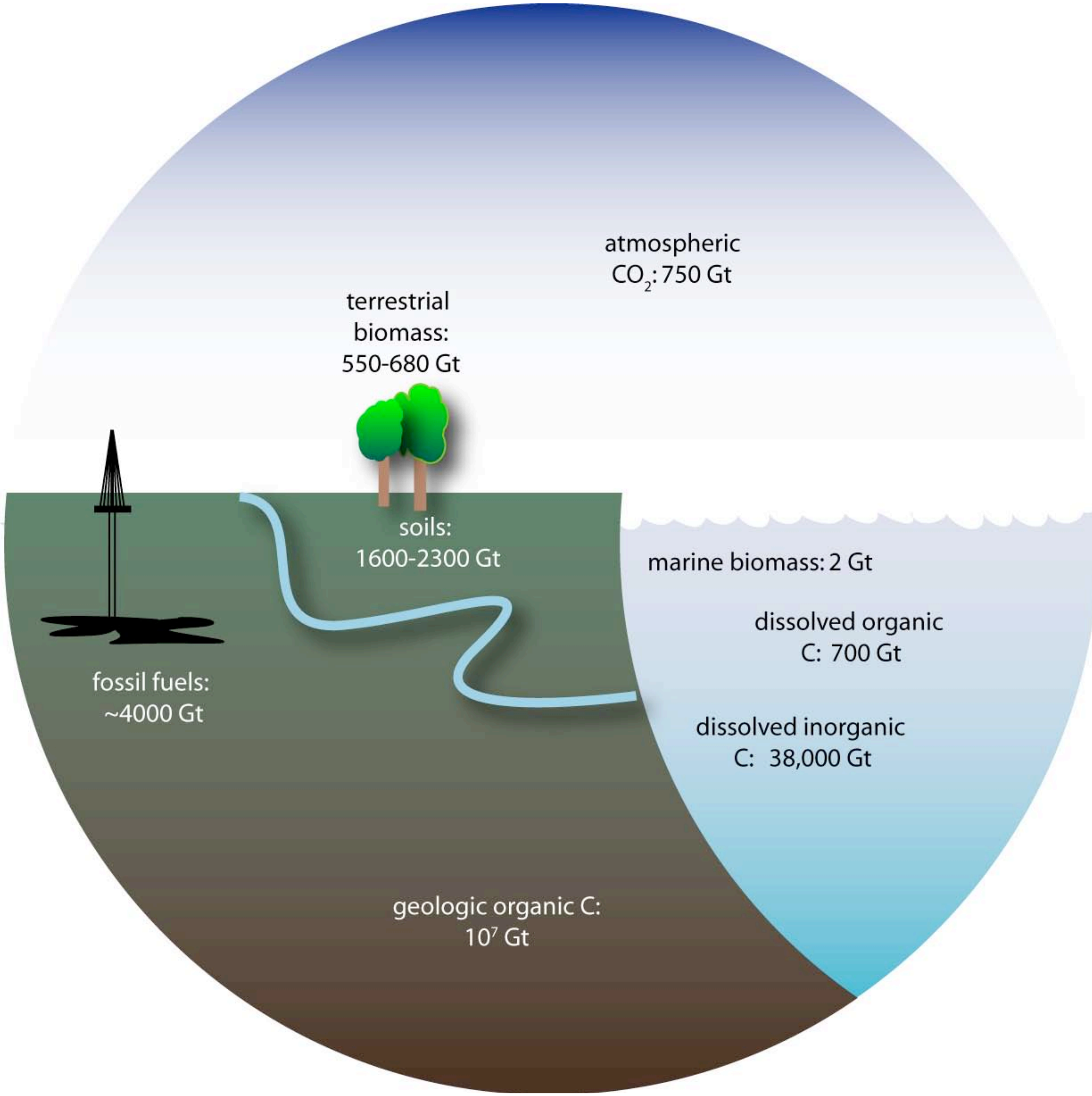
Modern atmospheric CO_2 trends

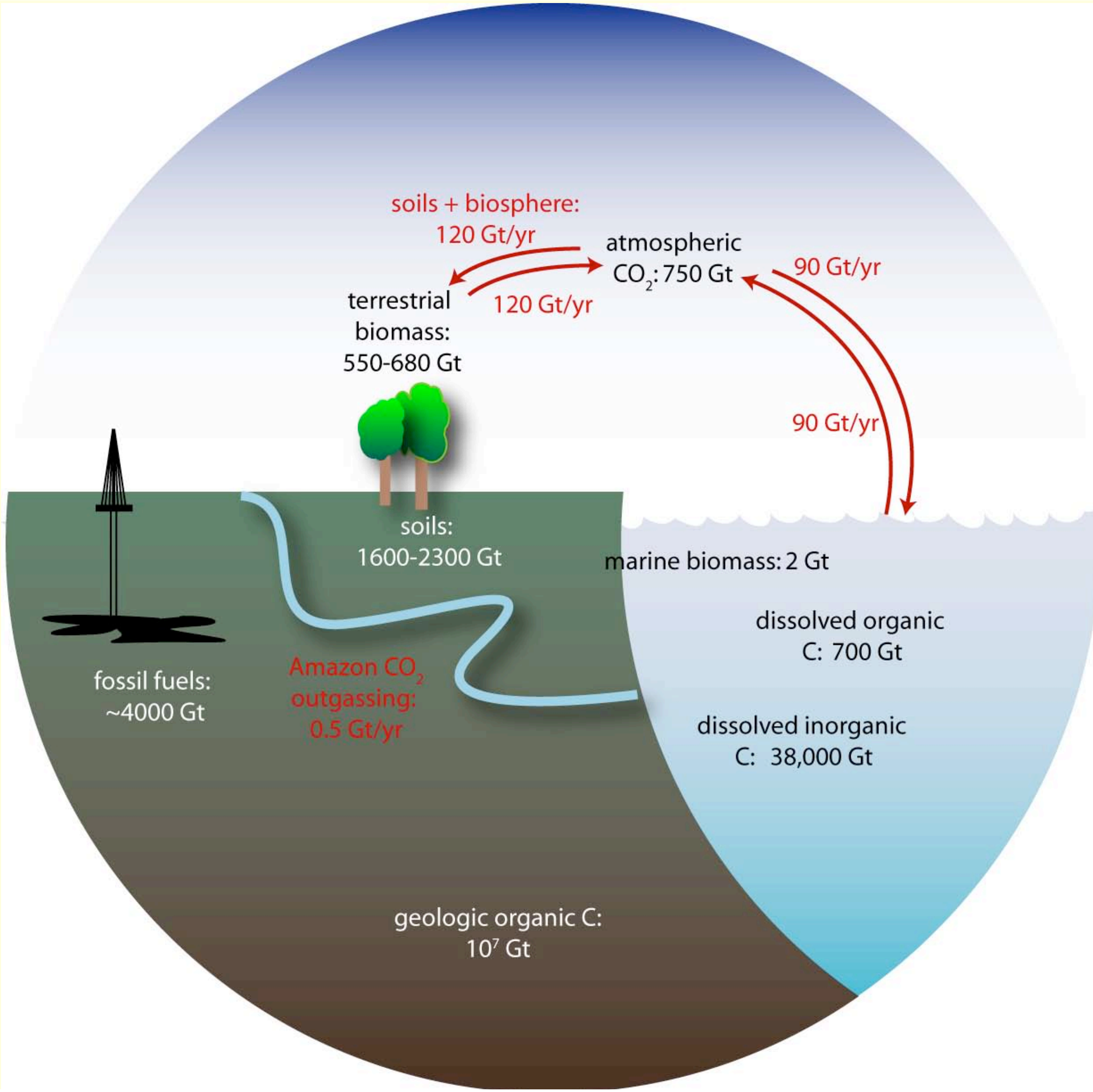


Source : Scripps institution of oceanography (SIO), University of California, 1998.

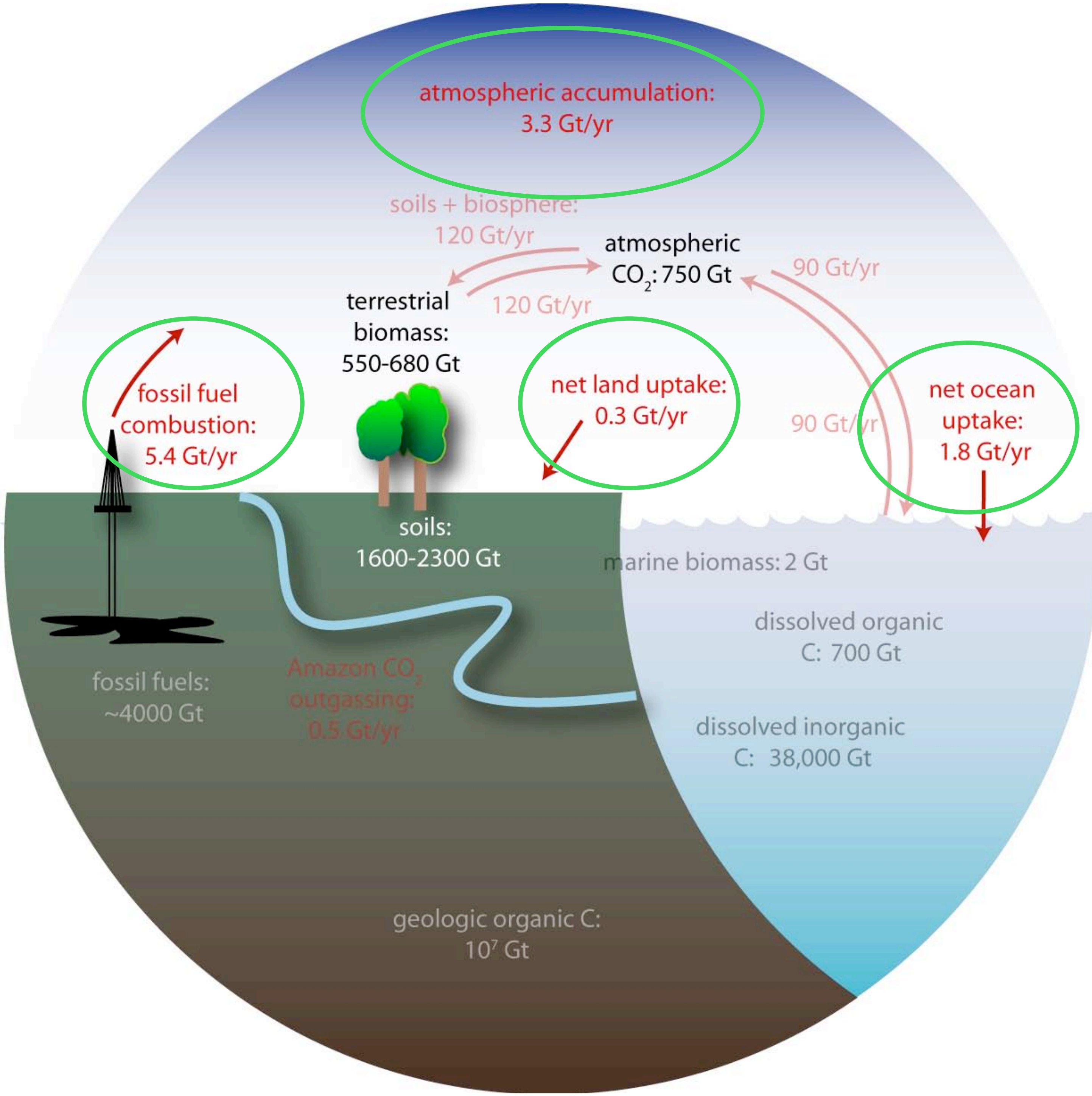
Global carbon pools



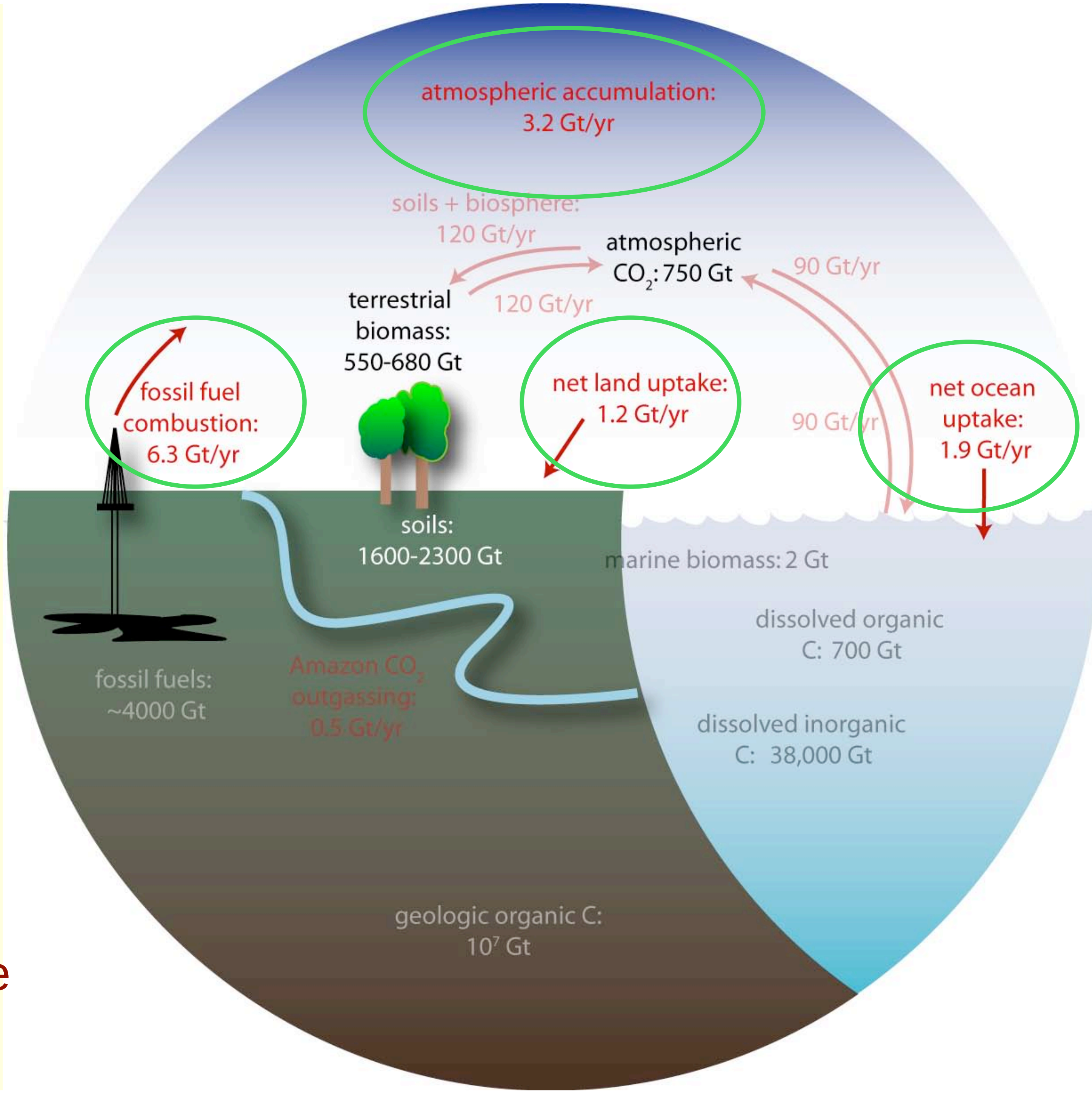
C pools and fluxes



1980s anthropogenic carbon budget



1990s anthropogenic carbon budget

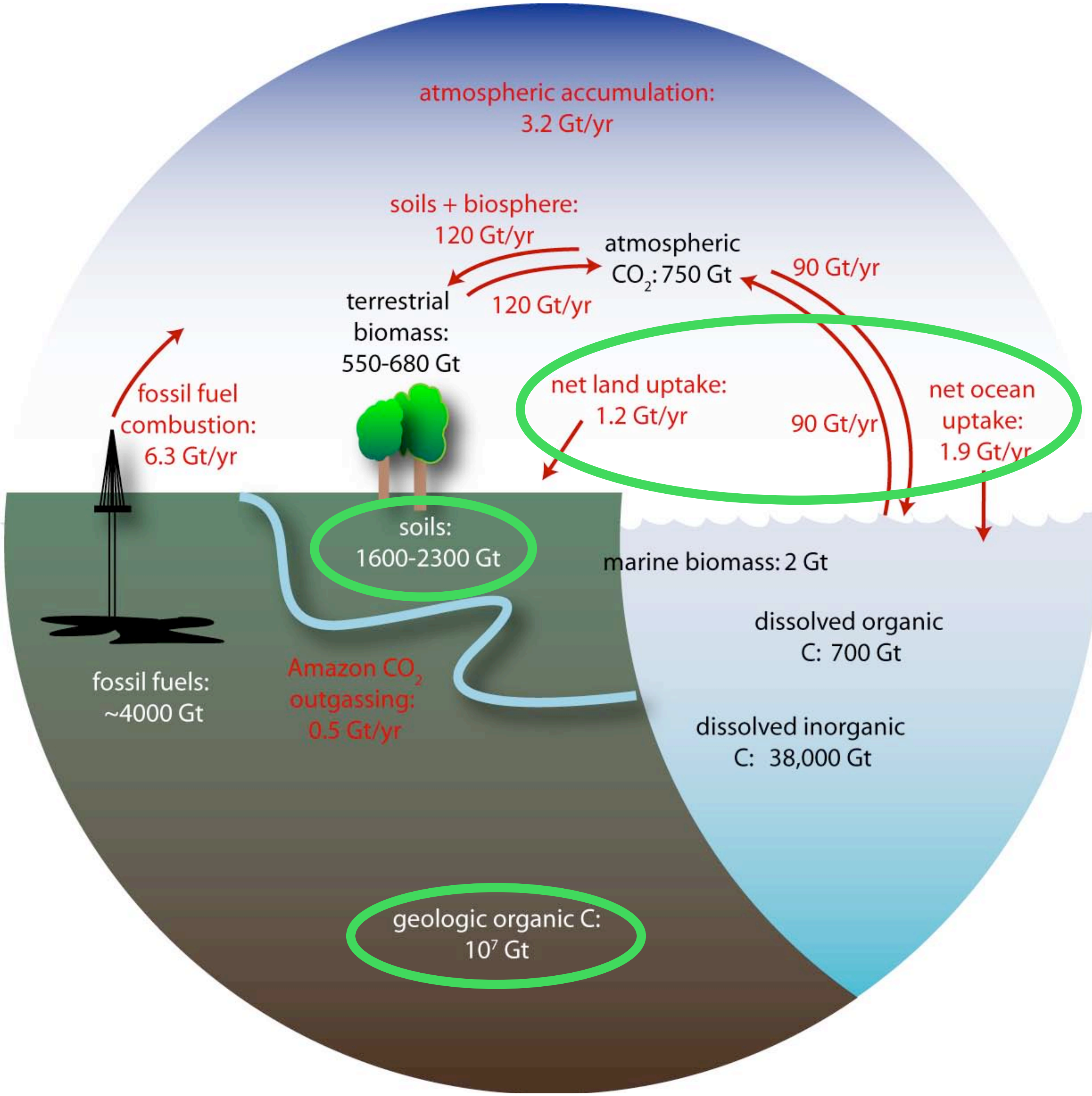


Both anthropogenic emissions and the terrestrial carbon sink are getting larger.

Global anthropogenic carbon budget

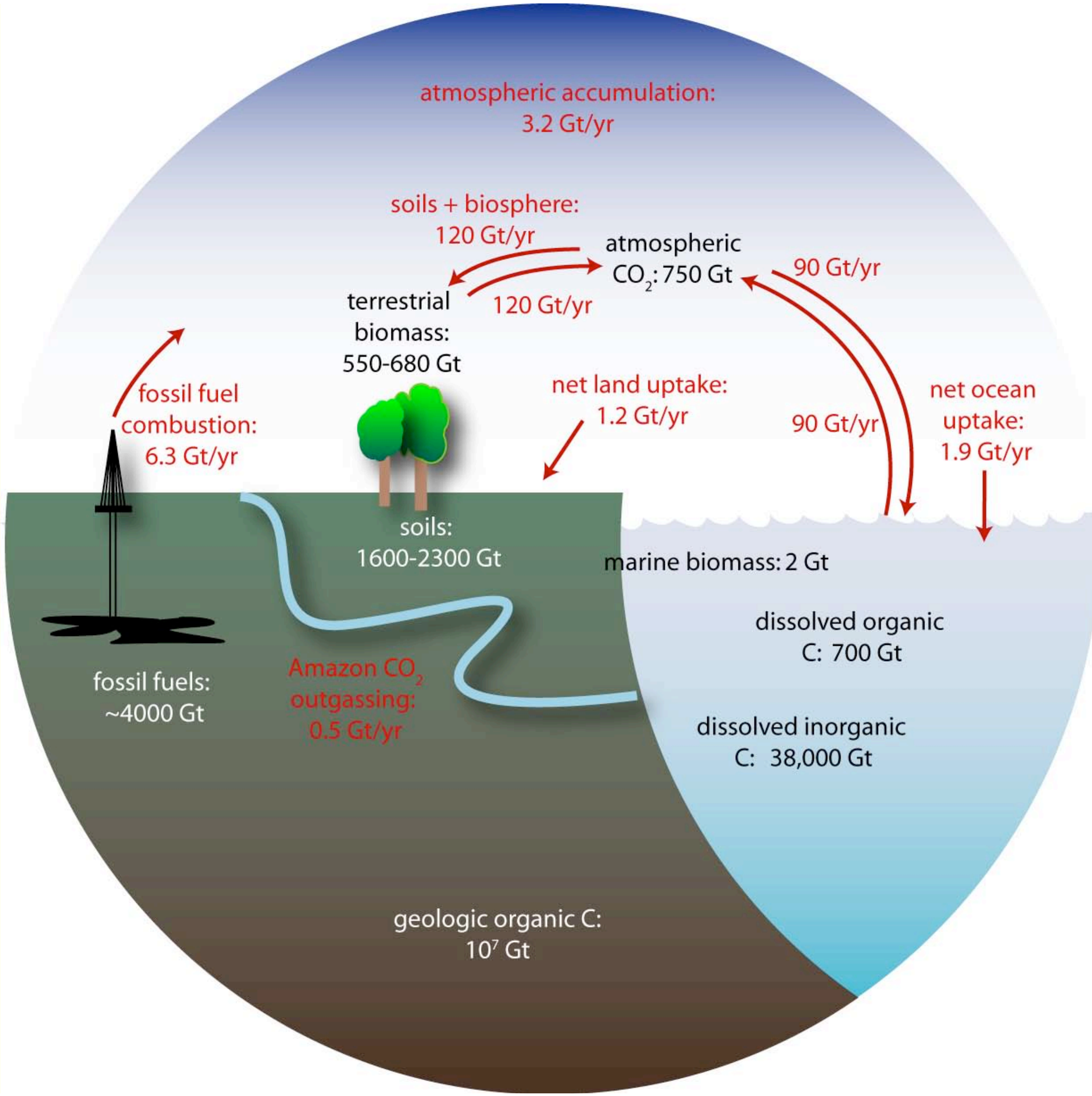
	1980s	1990s
atmospheric increase	3.3 ± 0.1	3.2 ± 0.1
total CO_2 emissions	5.4 ± 0.3	6.3 ± 0.4
flux into oceans	-1.9 ± 0.6	-1.7 ± 0.5
flux into the biosphere	-0.2 ± 0.7	-1.2 ± 0.8

- Masiello research: how do we know where carbon goes within the Earth System?



Masiello group research: oxidation state of natural carbon pools

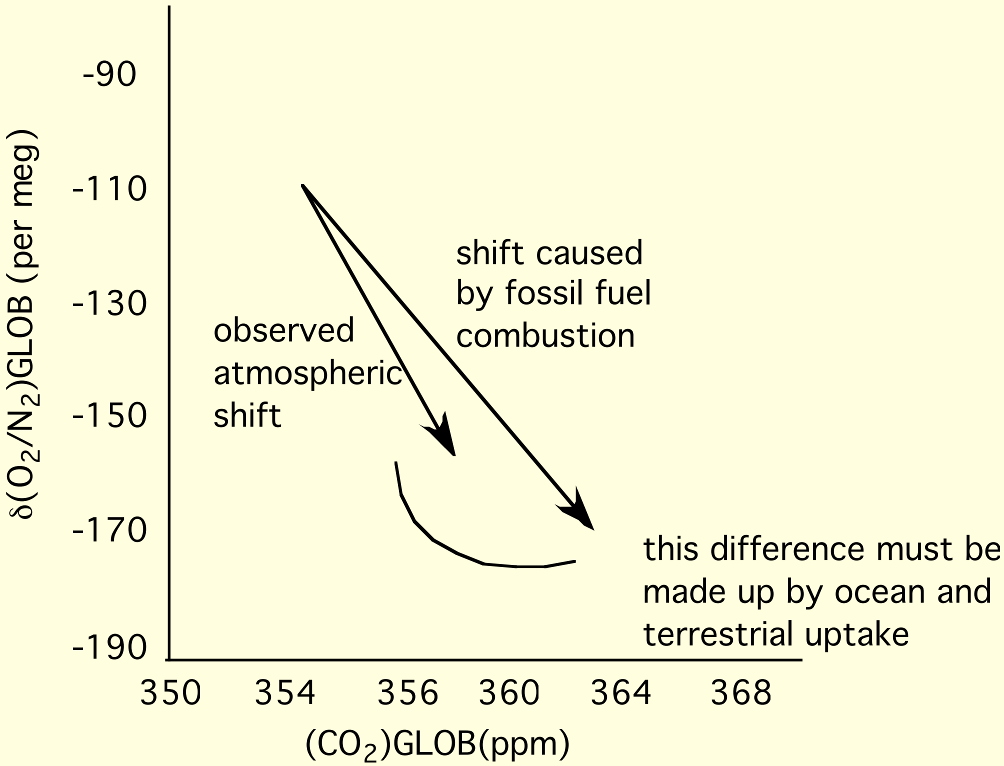
- *Application: Sink apportionment*:
  - How do we know how much anthropogenic CO_2 goes into the oceans vs into the biosphere?
    - Balancing the gas budget requires a knowledge of the oxidation state of the terrestrial biosphere's carbon
- *Basic science:*
  - What drives changes in the oxidation states of the Earth's carbon pools?
- *Production of refractory carbon*:
  - What causes some carbon to become sequestered in soils and sediments for millenia?



atmospheric accumulation:
3.2 Gt/yr
soils + biosphere:
120 Gt/yr
atmospheric
CO2: 750 Gt
90 Gt/yr
120 Gt/yr
terrestrial
biomass:
550-680 Gt
fossil fuel
combustion:
6.3 Gt/yr
net land uptake:
1.2 Gt/yr
net ocean
uptake:
1.9 Gt/yr
90 Gt/yr
soils:
1600-2300 Gt
marine biomass: 2 Gt
dissolved organic
C: 700 Gt
fossil fuels:
~4000 Gt
Amazon CO2
outgassing:
0.5 Gt/yr
dissolved inorganic
C: 38,000 Gt
geologic organic C:
10^7 Gt

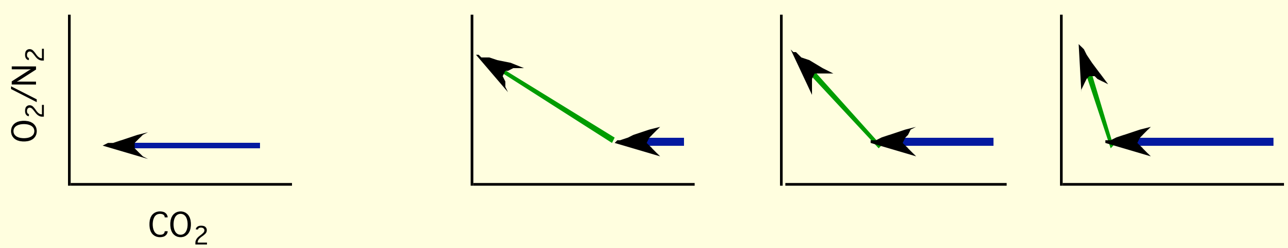
How to apportion anthropogenic CO_2:

- *Measure it in the atmosphere*:
  - Highly effective but not source or sink specific
- *Measure it in the oceans*:
  - Large error due to signal/noise
- *Measure it in the biosphere*:
  - Large error due to spatial heterogenaeity
- *Measure it by proxies*:
  - Change in atmospheric ^{13}C signature
  - Change in atmospheric O_2 and CO_2 concentrations



ocean uptake can only alter the atmospheric CO_2 concentration

The angle of the vector of terrestrial uptake determines the size of the ocean carbon sink.



adapted from Keeling et al., Nature, 1996.

Fundamental controls on the carbon oxidation state of the terrestrial biosphere?

- For the organic complex $C_xH_yO_zN_w$, where x, y, z, w are molar ratios,

$$C_{ox} = \frac{2z - y + 3w}{x}$$

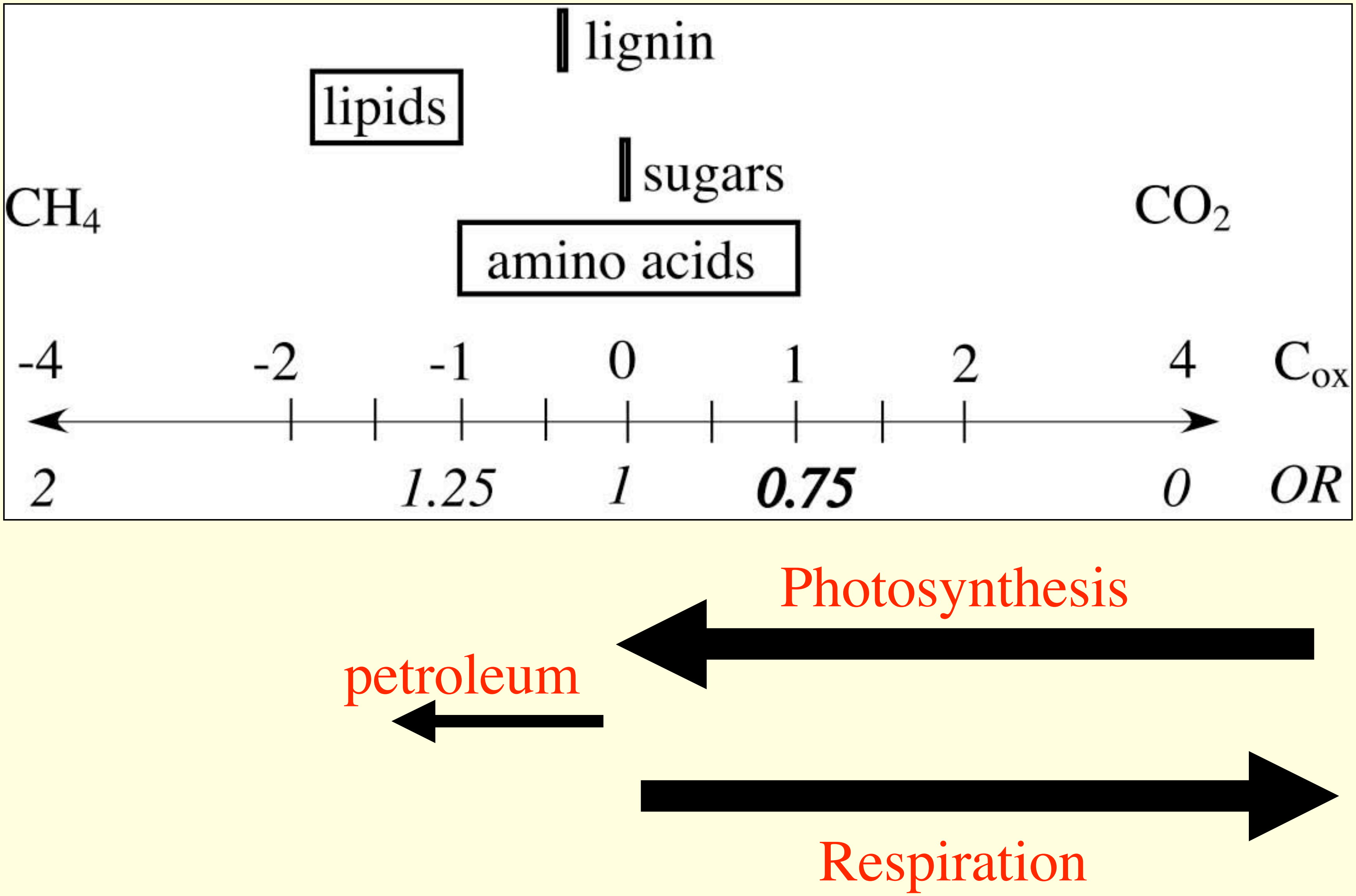
- This can be derived from:

$$xC_{ox} + yH_{ox} + zO_{ox} + wN_{ox} = 0$$

Sum of oxidation state of all elements in a species is the net charge on that species

Where $H_{ox} = 1$, $O_{ox} = -2$, and $N_{ox} = -3$

Medium/long term processes



Climate-timescale controls on Earth's organic carbon pools' C_{ox}

- Bulk terrestrial vs marine signatures
- Inter/intra-organism differences
- Long-term diagenesis
- Microbial processes:
  - Preservation of organic fractions
  - Organism choice of terminal electron acceptor

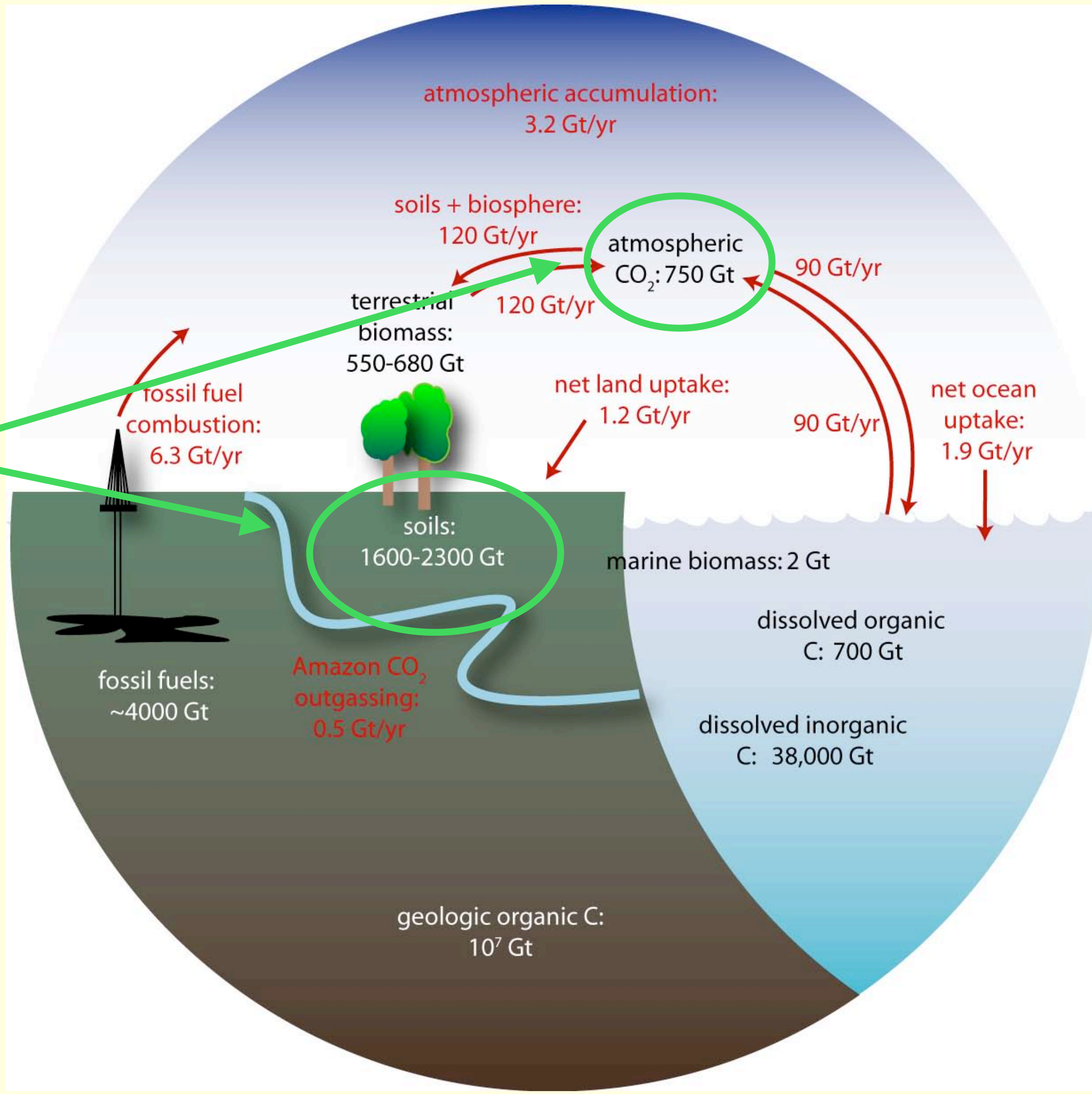
Research directions: carbon oxidation state

- Land-use drivers for C oxidation state
  - MI field site
  - Future: tropical land use change site
- Methodology for measuring C_{ox} in mineralogically complex samples
  - NMR + molecular modeling

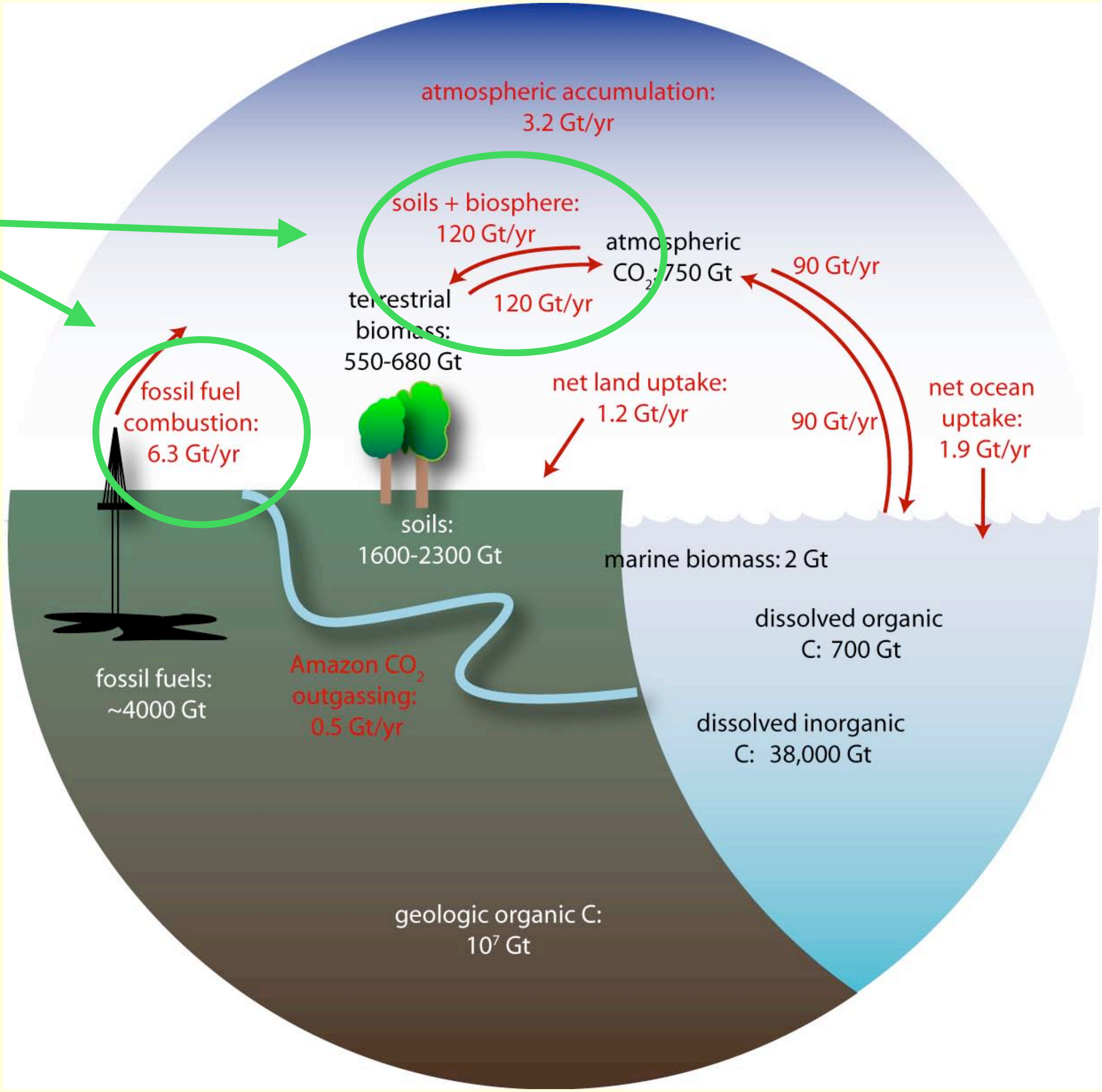
Masiello group research: carbon sequestration

- *Production of refractory carbon*:
  - Why is some soil C stored for millenia, while other C decomposes in weeks?

There is 3 times as much carbon in soils as in the atmosphere, and…



The annual flux of carbon between the atmosphere and the soil-biosphere system is 20 times greater than the fossil fuel-atmosphere flux.



How stable is the soil carbon pool?

- Will a warming Earth feed back to cause soils to release their carbon?
- Can we use current natural C sequestration mechanisms to improve soil C storage?

Soil carbon protection mechanisms

- Chemical protection: carbon is difficult to decompose due to its chemical structure, or because it is bound to minerals
  - lignin phenols, tannins
  - Black carbon (charcoal and soot)

Less vulnerable to
changes in temperature,
hydrology, or land use

Soil carbon protection mechanisms

- Climatological protection
  - Below 0°C temperatures carbon is not decomposed;
  - No O_2: anoxic conditions slow carbon decomposition

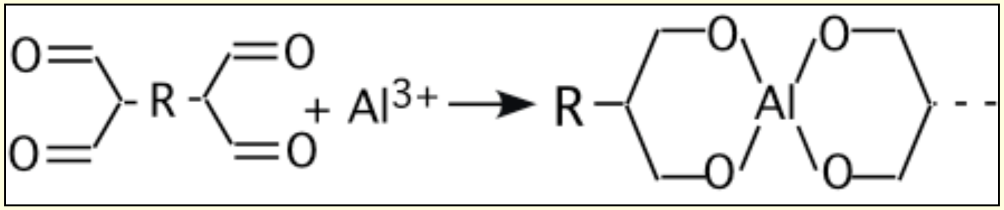
More vulnerable to changes in temperature and hydrology

- Physical protection: protected by formation of soil macrostructure

Vulnerable to changes in land use (degradation of soil macrostructure via tillage)

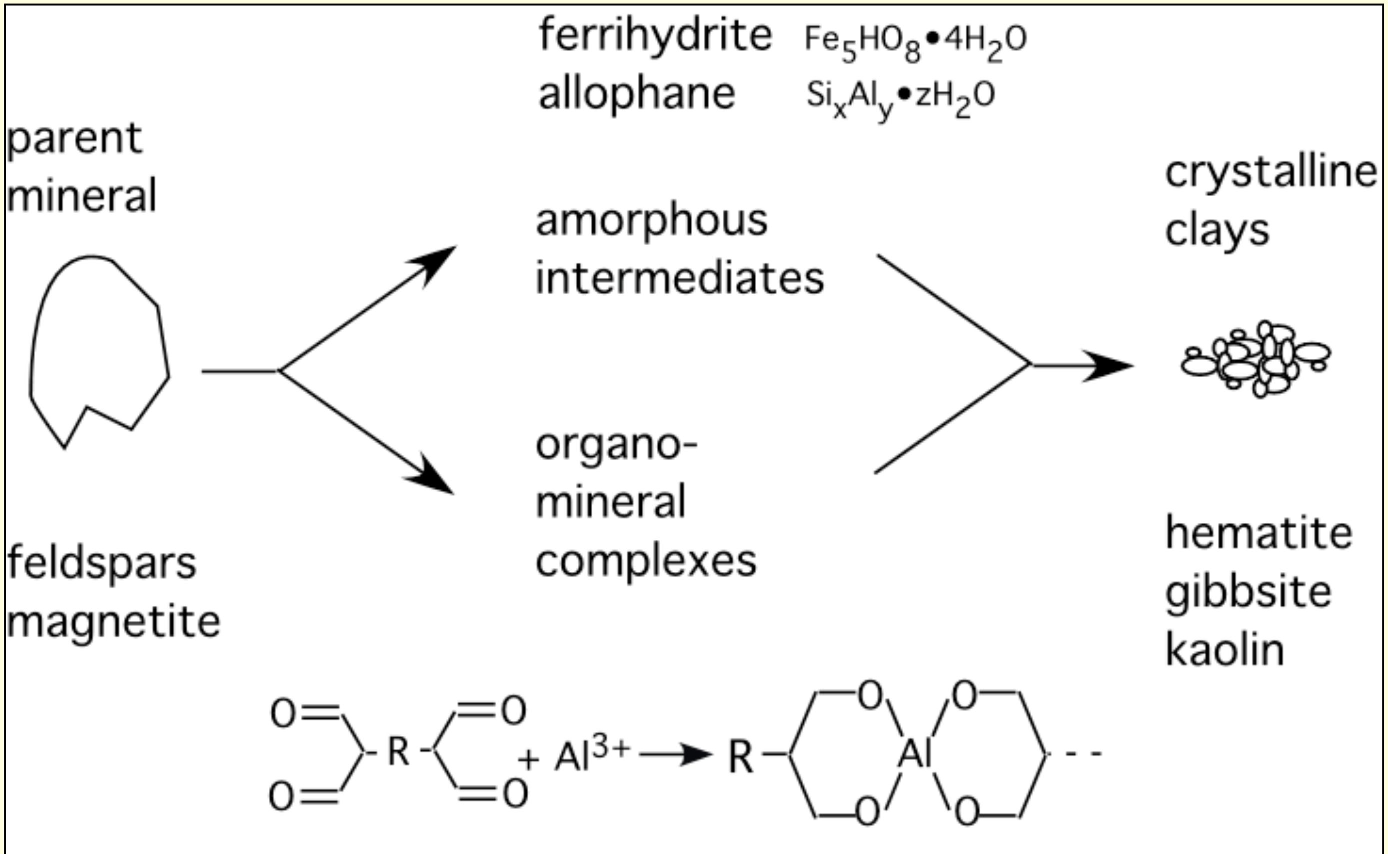
How to make chemically protected soil carbon

- Chelation:



- Reaction with other mineral surfaces
- Ped (soil macrostructure) formation

This happens naturally as part of soil weathering



Where Fe^{3+}, Mg^{2+}, Ca^{2+} can subsitute for Al^{3+}