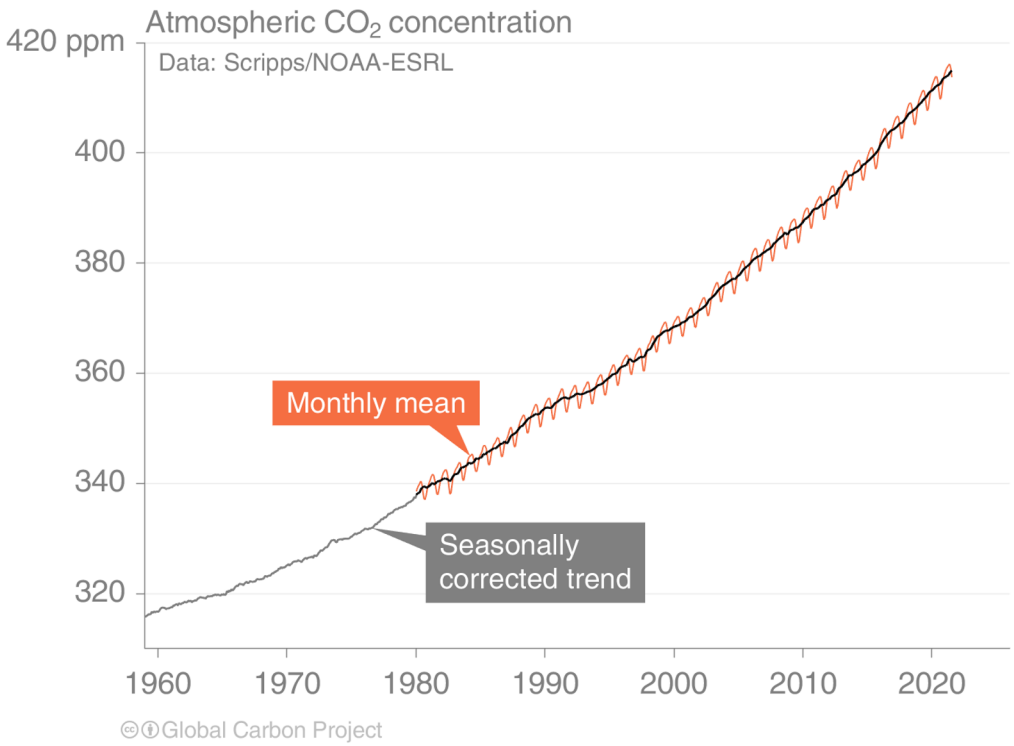
Ocean Carbon Uptake: Natural vs. Anthropogenic

Atmospheric CO_2 concentration

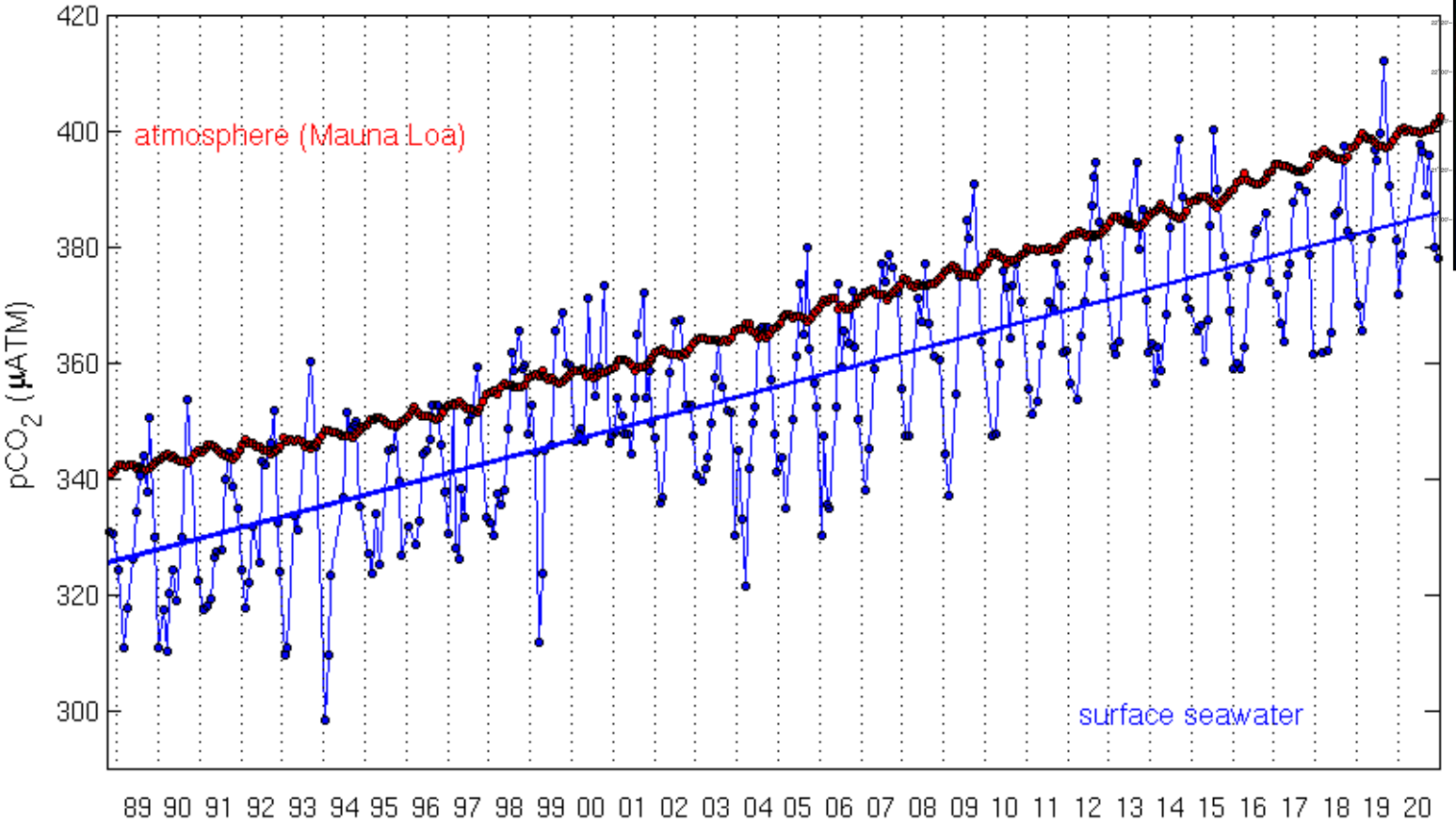
The global CO_2 concentration increased from ~277 ppm in 1750 to 415 ppm in 2021 (up 49%)

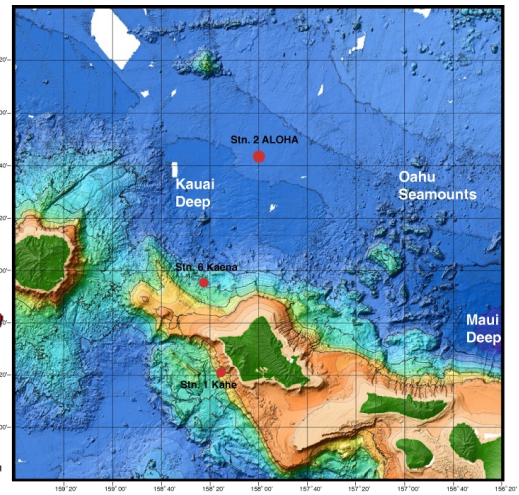


Globally averaged surface atmospheric CO_2 concentration. Data from: NOAA-ESRL after 1980; the Scripps Institution of Oceanography before 1980

Source: NOAA-ESRL; Scripps Institution of Oceanography; Friedlingstein et al 2021; Global Carbon Project 2021

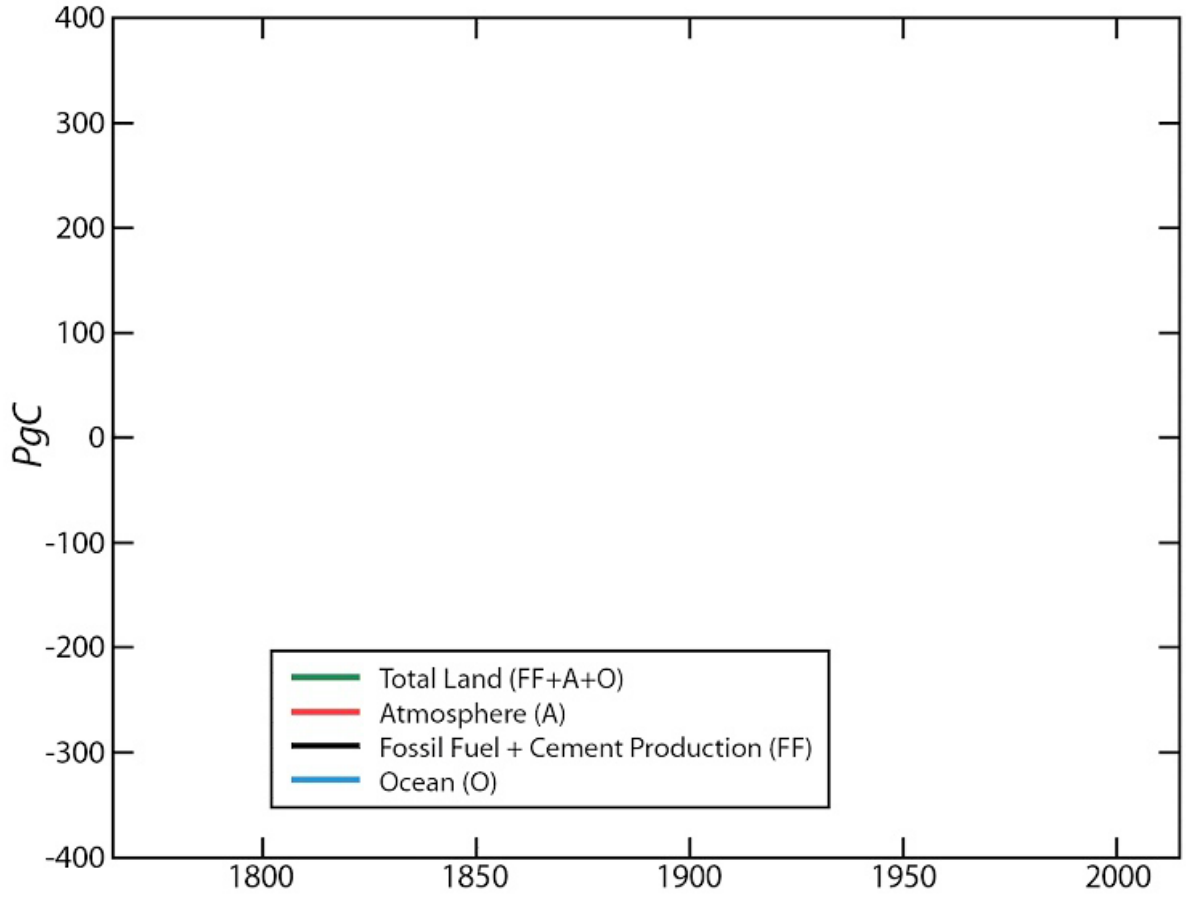
Partial Pressure of CO_2





Temporal Evolution of Carbon Accumulation

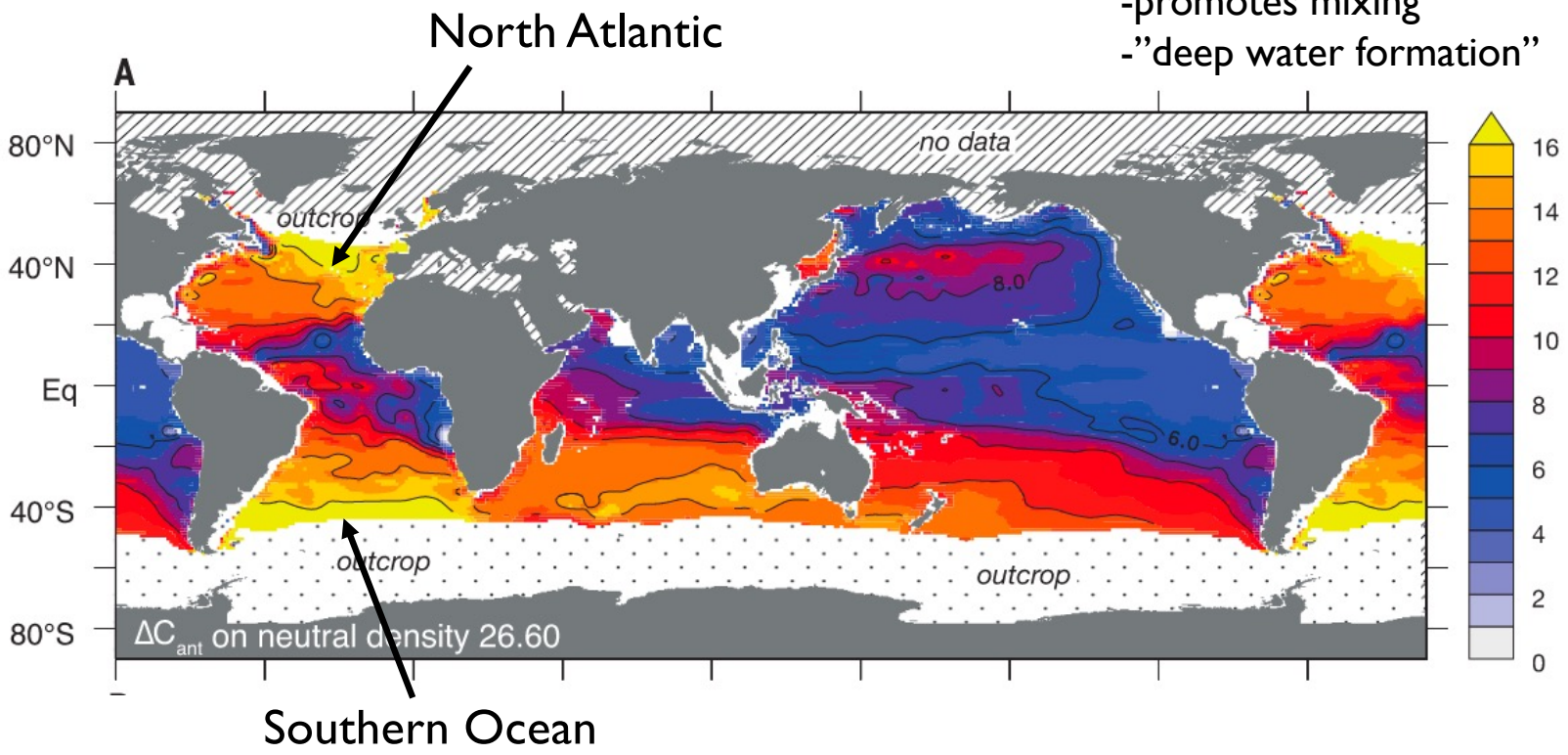
Anthropogenic Carbon Reservoirs, 1765-2011



Khatiwala et al. *Nature* (2009); *Biogeoscience* (2013)

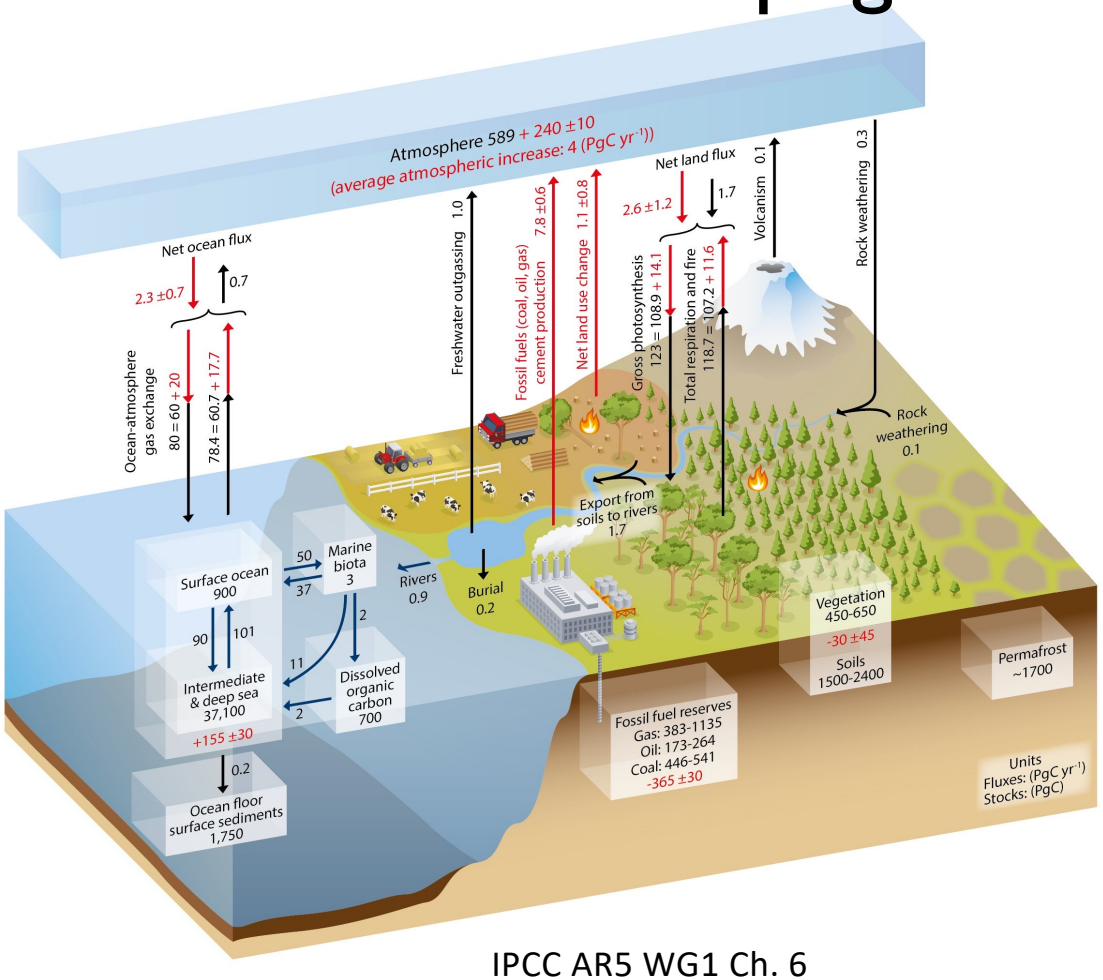
Where does anthropogenic carbon enter the ocean?

Cold, dense waters, high winds
-promotes mixing
-"deep water formation"



Gruber et al. 2019

Natural vs. Anthropogenic vs. Contemporary



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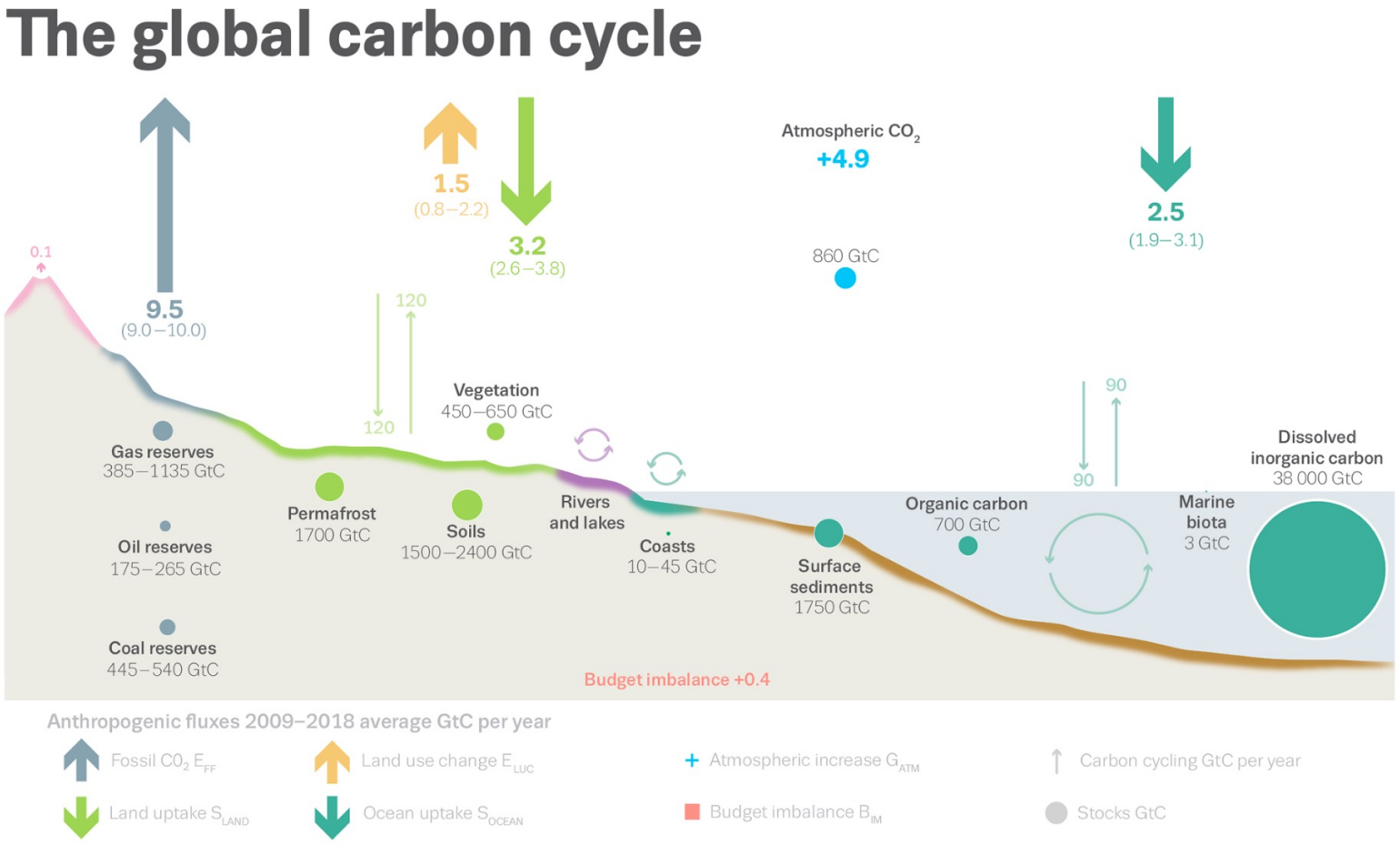
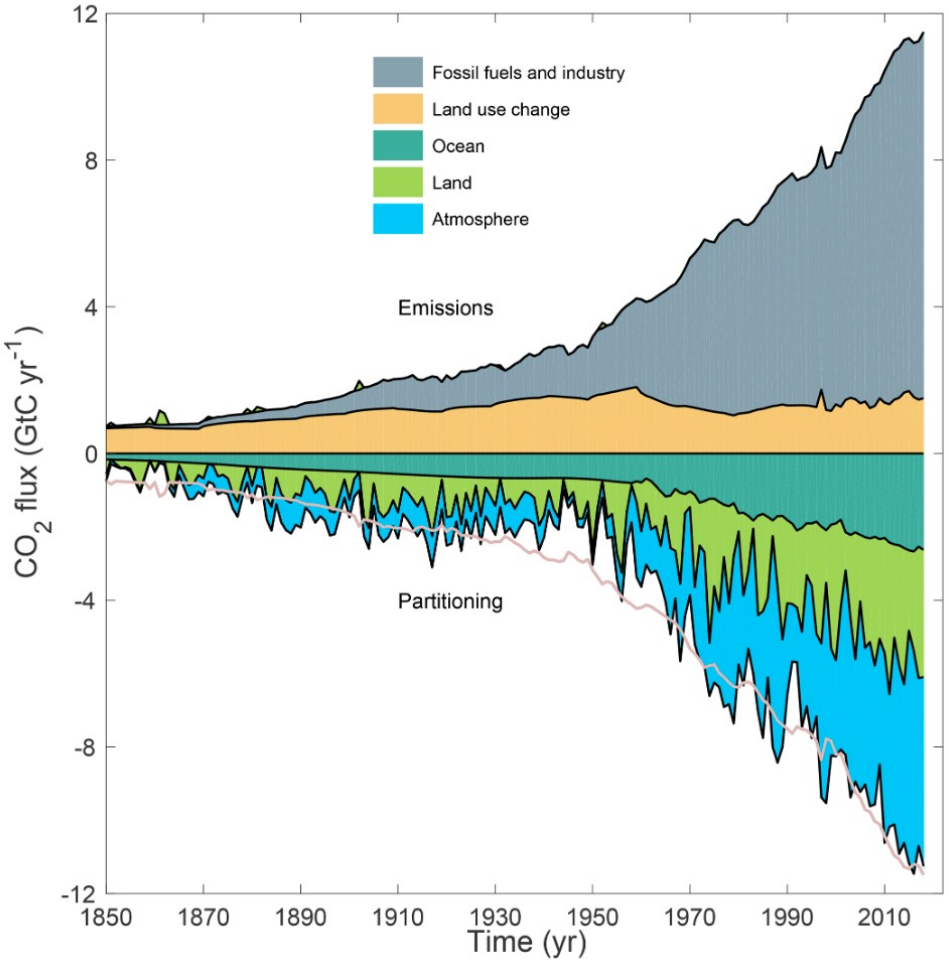
- The CO_2 uptake we see today (contemporary) is a combination of the pre-anthropogenic carbon cycle(natural) and anthropogenic changes

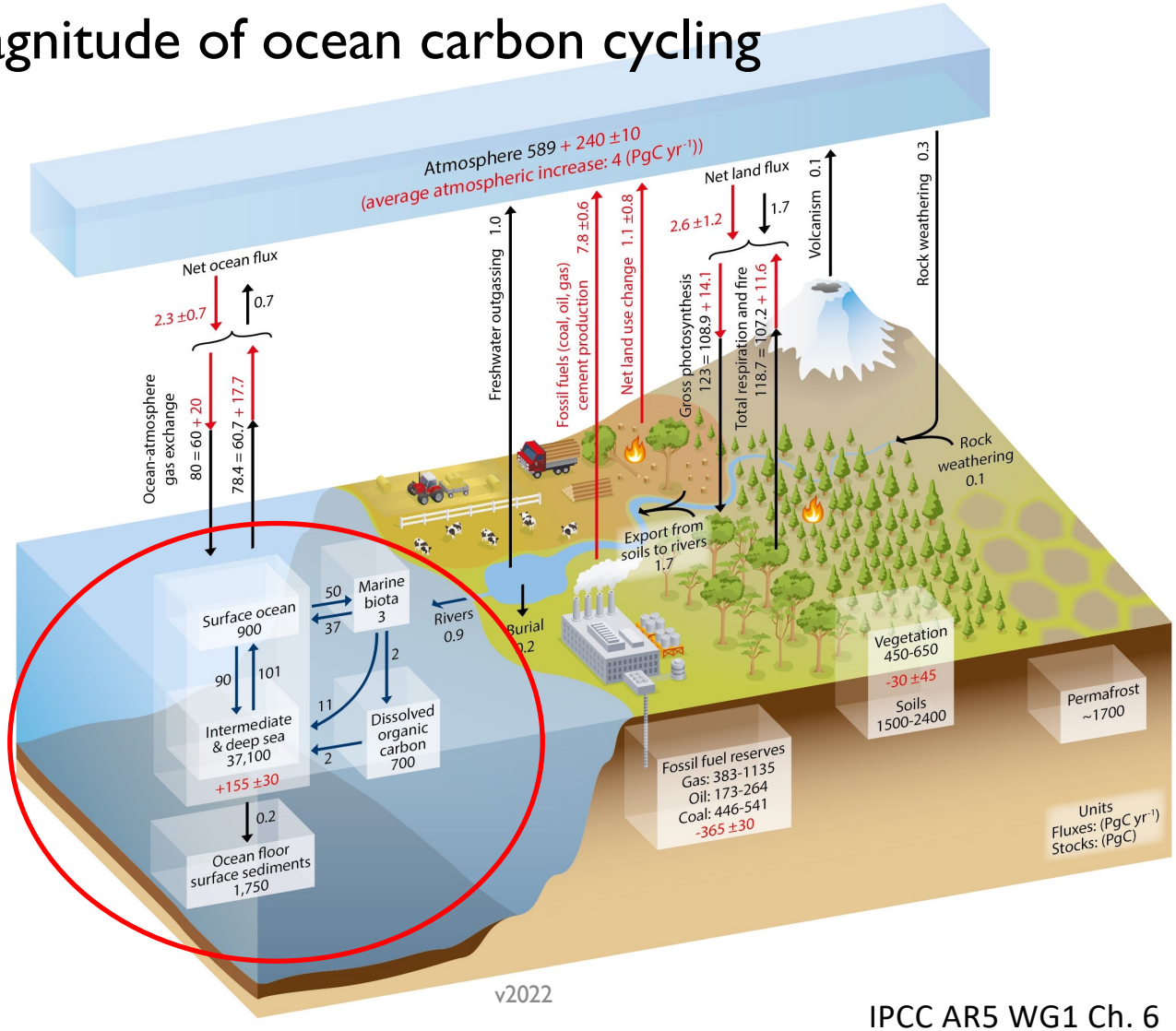

The global carbon cycle
Atmospheric CO_2
+4.9
860 GtC
9.5
(9.0–10.0)
1.5
(0.8–2.2)
3.2
(2.6–3.8)
2.5
(1.9–3.1)
0.1
120
120
90
90
Vegetation
450–650 GtC
Gas reserves
385–1135 GtC
Oil reserves
175–265 GtC
Coal reserves
445–540 GtC
Permafrost
1700 GtC
Soils
1500–2400 GtC
Rivers
and lakes
Coasts
10–45 GtC
Surface
sediments
1750 GtC
Organic carbon
700 GtC
Marine
biota
3 GtC
Dissolved
inorganic carbon
38 000 GtC
Budget imbalance +0.4
Anthropogenic fluxes 2009–2018 average GtC per year
Fossil CO_2 E_{FF}
Land use change E_{LUC}
Atmospheric increase G_{ATM}
Carbon cycling GtC per year
Land uptake S_{LAND}
Ocean uptake S_{OCEAN}
Budget imbalance B_{IM}
Stocks GtC

Ocean uptake of anthropogenic carbon:



If the ocean were not taking up CO2 and all of that carbon remained in the atmosphere, we would have over 60% more anthropogenic carbon in the atmosphere.

Magnitude of ocean carbon cycling



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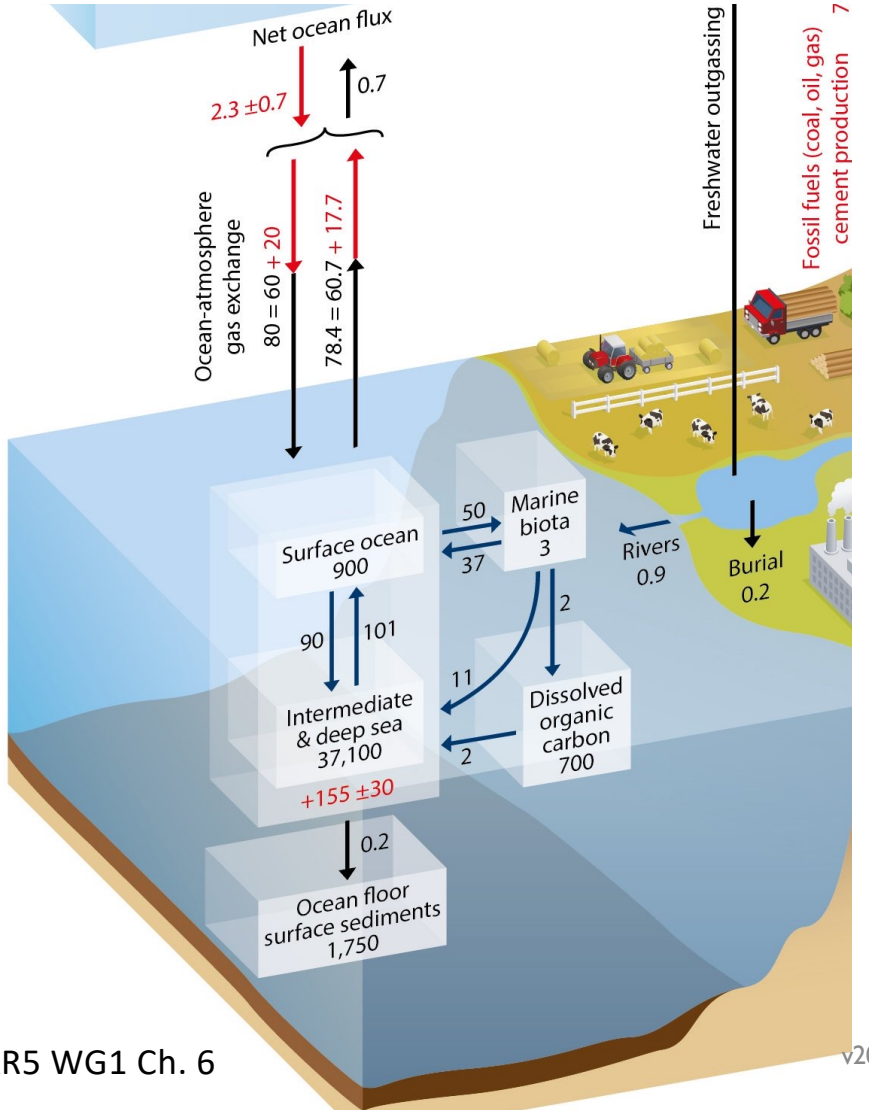

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Magnitude of ocean carbon cycling

Biological carbon export is ~10% the magnitude of the solubility pump

- Significant uncertainty in control / response to changes
- Provides an avenue for long-term burial
- Future changes are uncertain

Ocean Carbon Uptake : Key points

- As humans have put more carbon dioxide into the atmosphere, more is taken up by the ocean

- The ocean takes up the most anthropogenic CO_2 in certain areas of the ocean (cold and windy during the winter, deep mixing)

- The carbon cycle we observe today ("contemporary") is a mix of what went on before human impacts ("natural") and what we are doing now ("anthropogenic")