

Carbon Sources and Sinks

fossil fuel and cement from energy statistic

land use change from data and models residual land sink

Global Carbon Project

Year

1800 1850 1900 1950 2000

1750

sured atmospheric growth rate an sink from data and models

- Half the carbon from fossil fuels remains in the atmosphere
- The other half goes into land and oceans
- Land sink was unexpected is very noisy, and remains unreliable in future
- Future of carbon sinks is much harder to predict than temperatures

Where Has All the Carbon Gone?

- Into the oceans
 - Solubility pump (CO_2 very soluble in cold water, but rates are limited by slow physical mixing)
 - **Biological pump** (slow "rain" of organic debris)
- Into the land
 - CO₂ Fertilization (plants eat CO2 ... is more better?)
 - Nutrient fertilization (N-deposition and fertilizers)
 - Land-use change (forest regrowth, fire suppression, woody encroachment ... but what about Wal-Marts?)
 - Response to changing climate (e.g., Boreal warming)





Carbonate Equilibria in Solution

Three equations (equilibria) in five unknowns

Add two more constraints

 $TA = [HCO_3^{-}] + 2[CO_3^{2-}] + [B(OH)_4^{-}]$

+ $[B(OH)_4^-]$ (Titration Alkalinity) + $[NO_3^-] + [OH^-] - [H^+] \pm minor species$

 $B(OH)_3 + H_2O \leftrightarrow H^+ + B(OH)_4^-, \qquad K_b = [H^+][B(OH)_4^-]/[B(OH)_3]$

(Boric acid dissociation)

 $\Sigma B = 1.179 \times 10^{-5} S \text{ mol/kg}$ (Salinity)



Observing the Deep Ocean





















Carbon Storage & Turnover in Land Ecosystems



- Photosynthesis converts inorganic gas into living plants
- Plants die and become "litter"
- Microbes eat litter and poop soil carbon
- Soil carbon is eventually also eaten by microbes, but some lasts for many centuries



- Increasing plant growth (NPP) due to enhanced atmospheric CO₂
- Delayed increased respiration (residence time)
- + Spatial pattern follows both NPP and residence $\boldsymbol{\tau}$

Free Air Carbon Enrichment (FACE)



- Fumigation rings maintain steady levels of elevated CO₂ in canopies under changing weather conditions
- Control and replicated treatments test effects of CO₂, water, N, etc









Forest Inventory Sampling



USDA Forest Service measures hundreds of thousands of plots!



















