

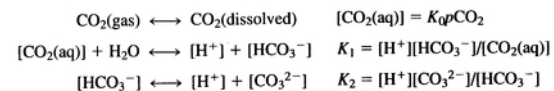
- ### Where Has All the Carbon Gone?
- Into the **oceans**
    - **Solubility pump** (CO<sub>2</sub> very soluble in cold water, but rates are limited by slow physical mixing)
    - **Biological pump** (slow "rain" of organic debris)
  - Into the **land**
    - **CO<sub>2</sub> Fertilization** (plants eat CO<sub>2</sub> ... 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)



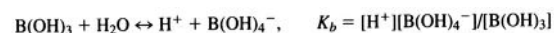
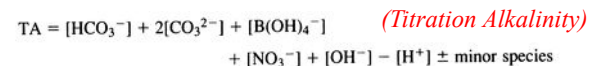


## Carbonate Equilibria in Solution

Three equations (equilibria) in five unknowns



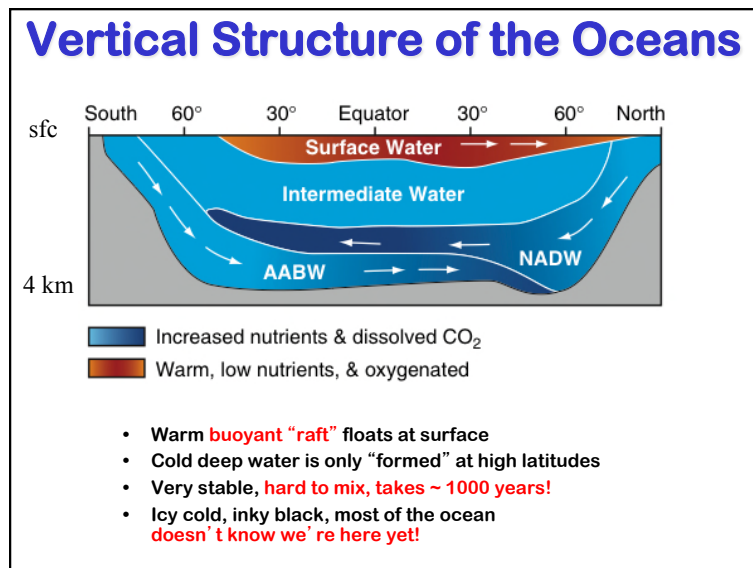
Add two more constraints



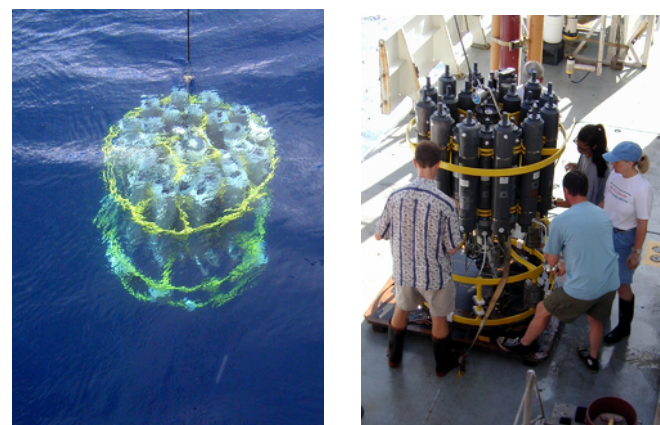
*(Boric acid dissociation)*

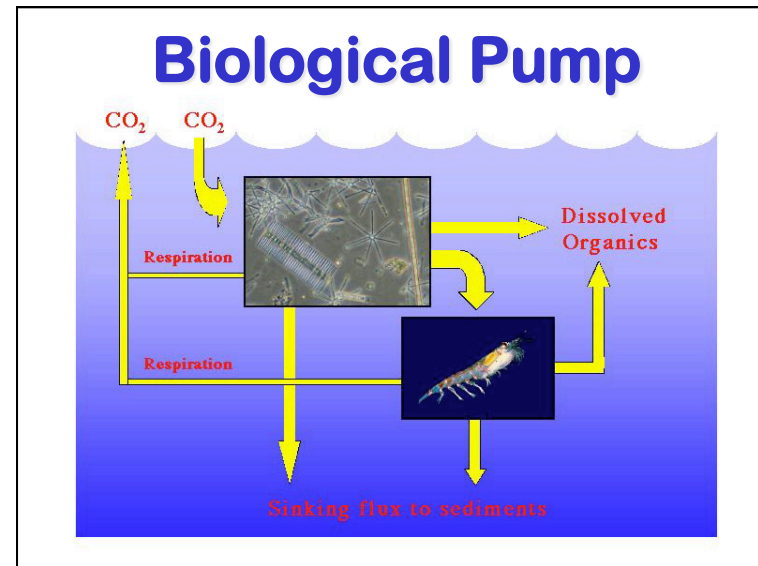
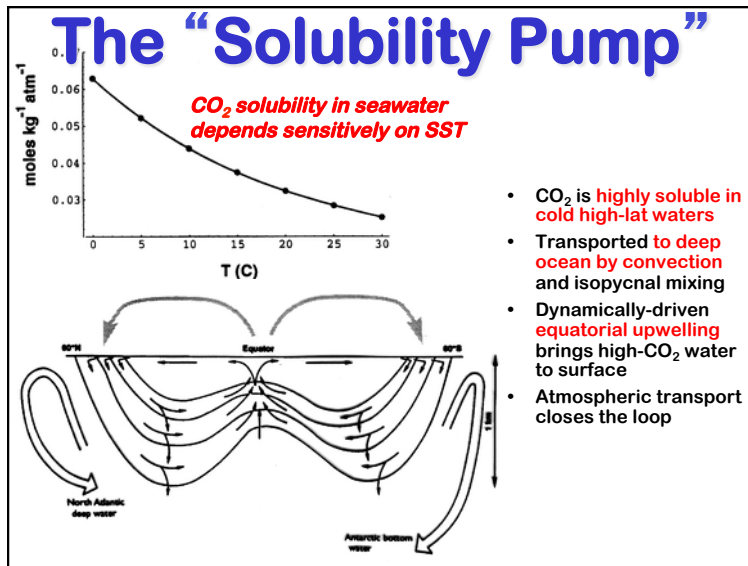
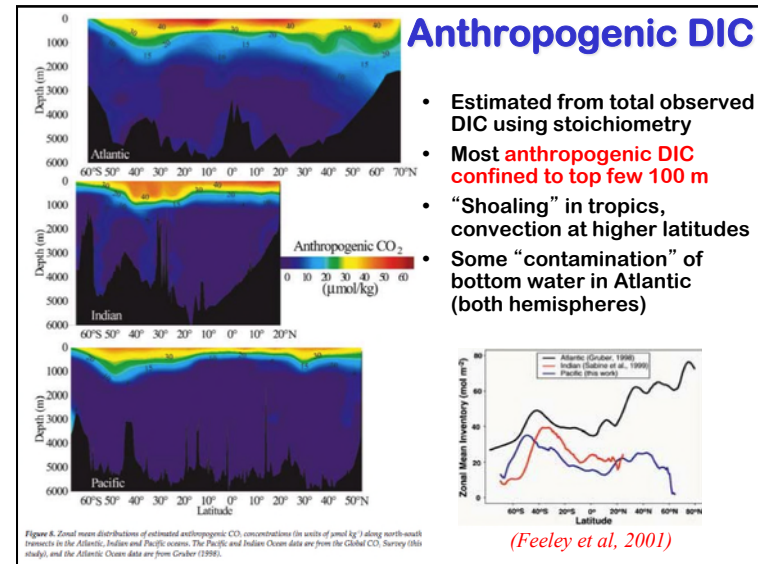
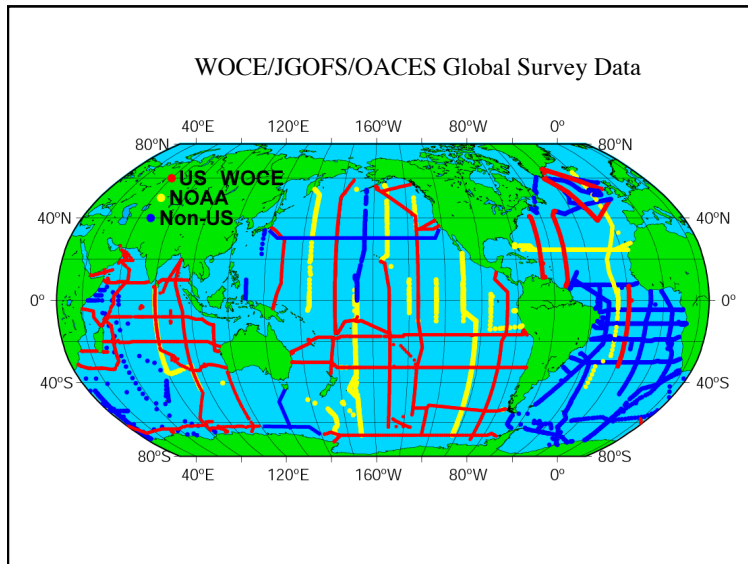
$$\Sigma B = 1.179 \times 10^{-5} \text{S mol/kg}$$

*(Salinity)*

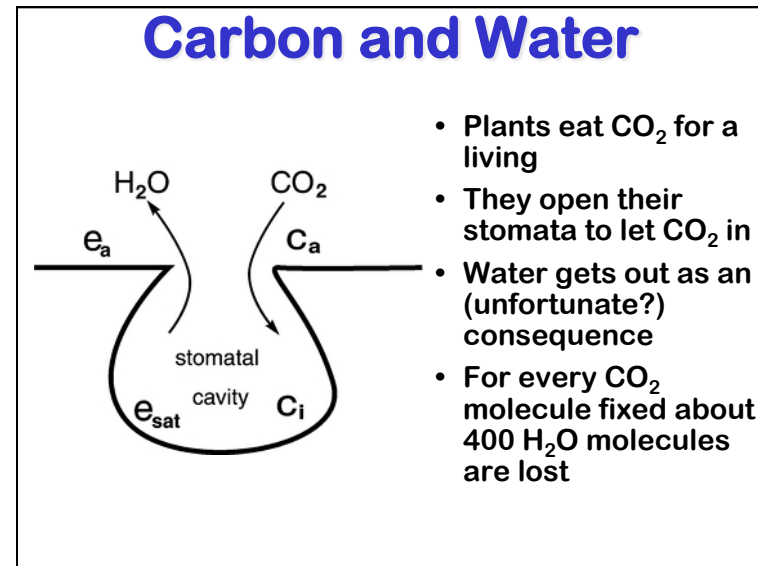
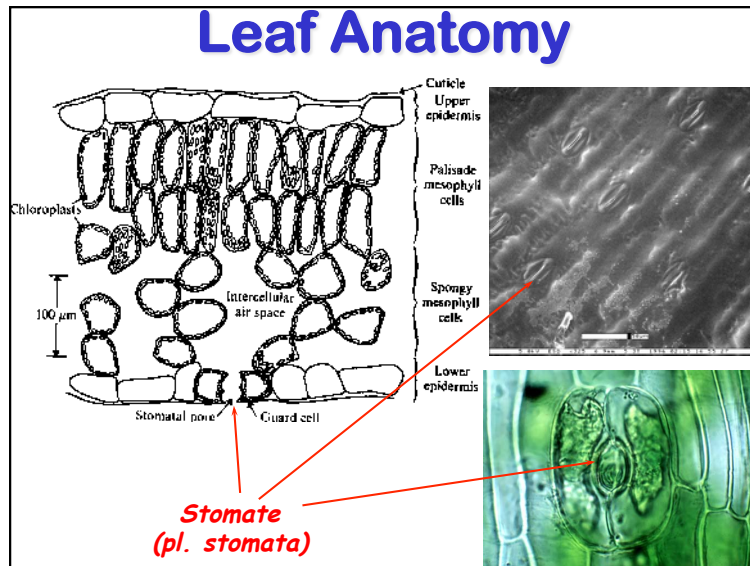
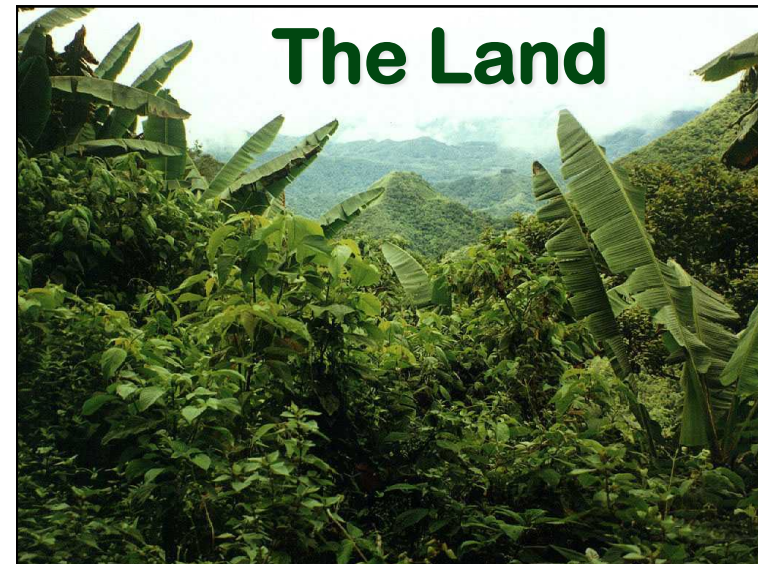
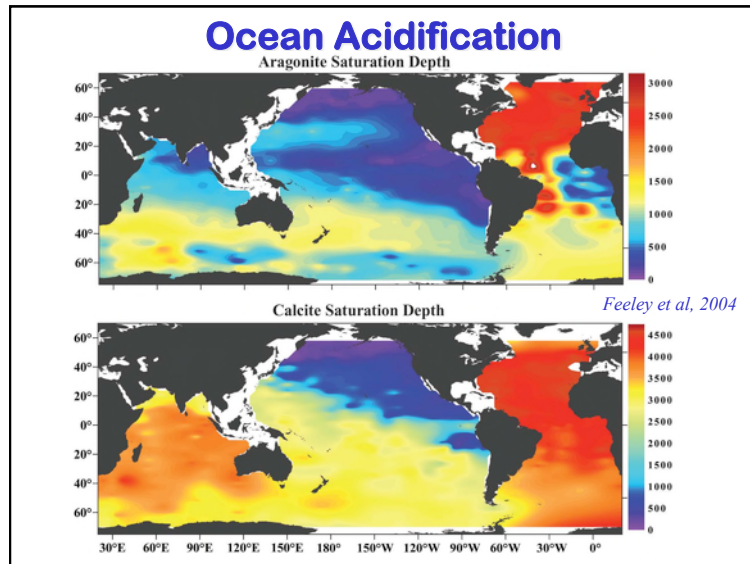


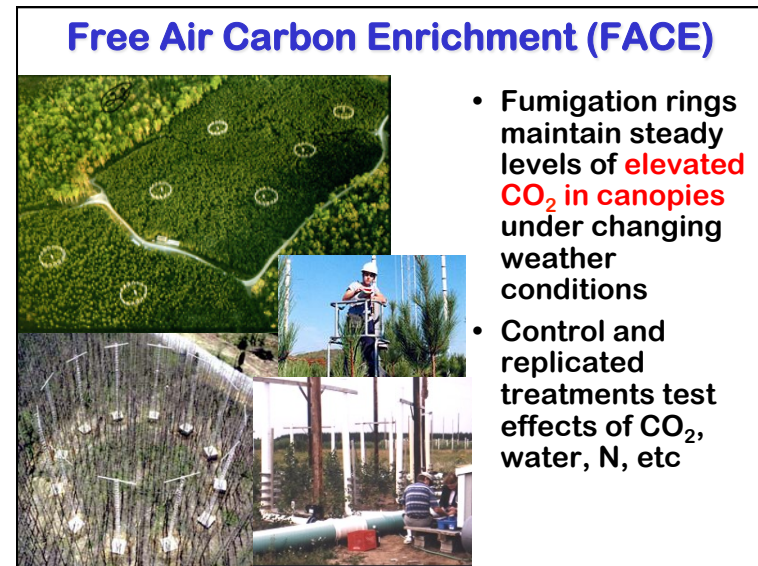
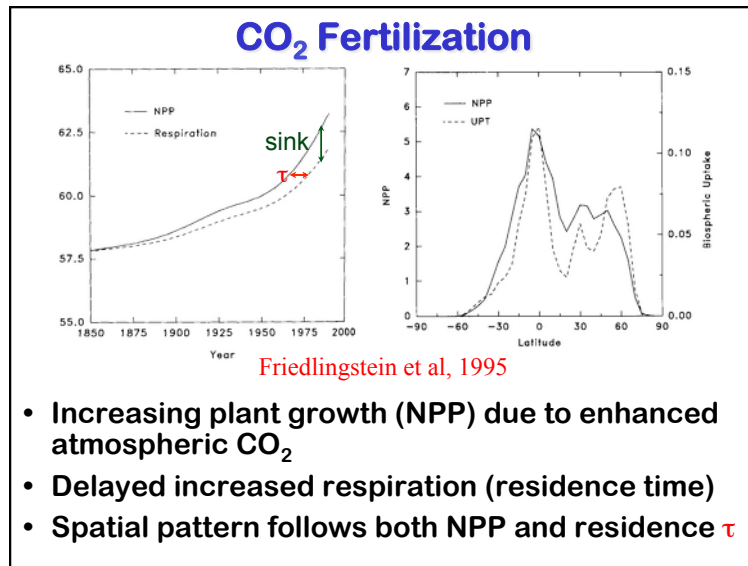
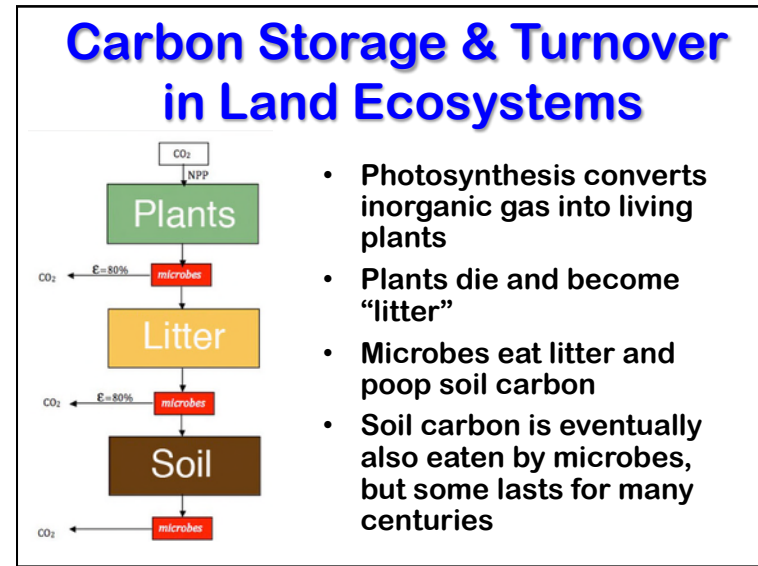
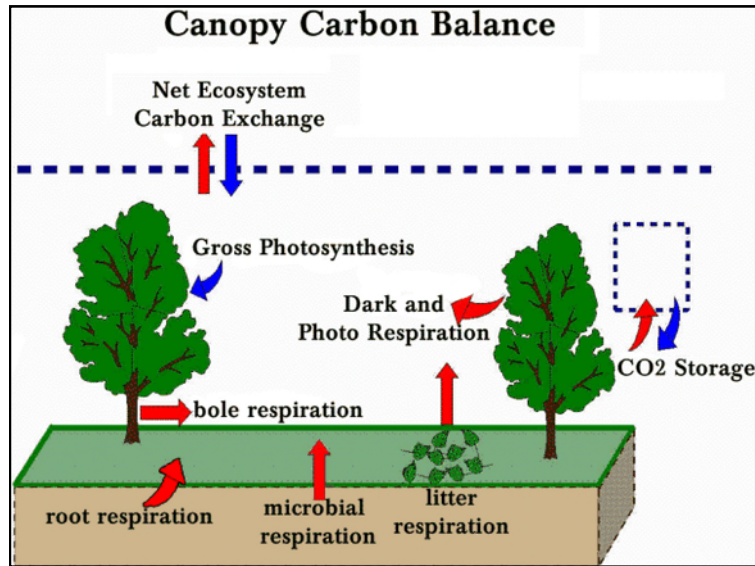
## Observing the Deep Ocean


















### Disturbance and Recovery



6-year-old

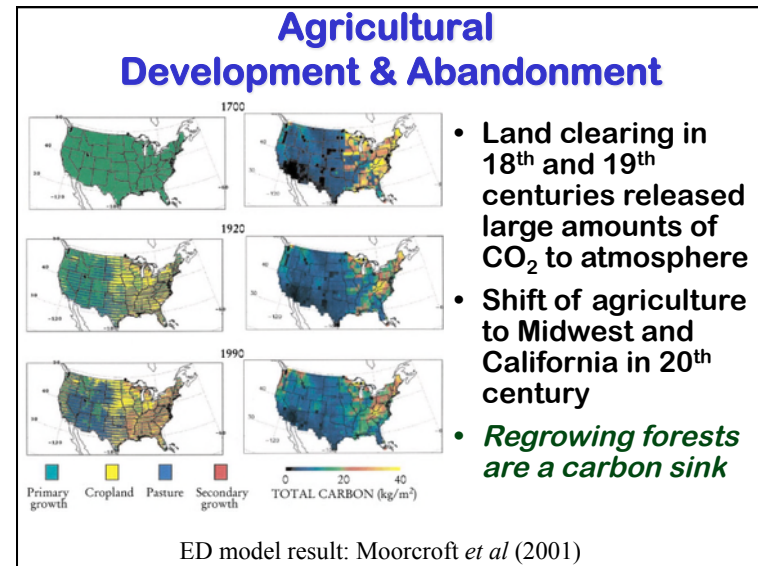
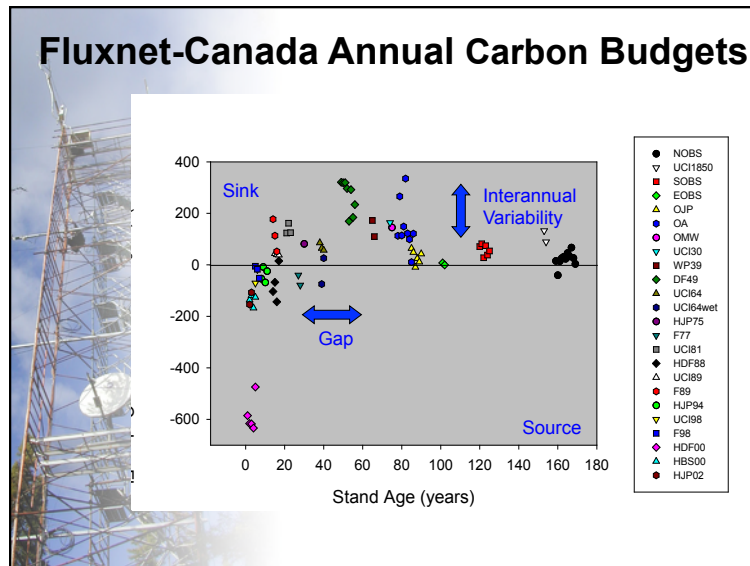


18-year-old



57-year-old

|                |      |       |
|----------------|------|-------|
| Planted 2000   | 1988 | 1949  |
| Height (m) 0.8 | 3-8  | 30-35 |

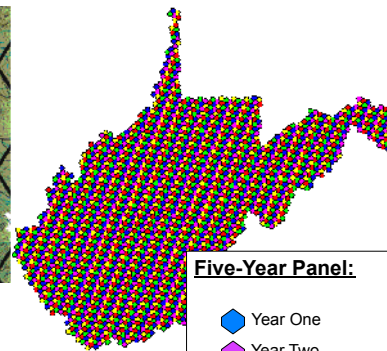
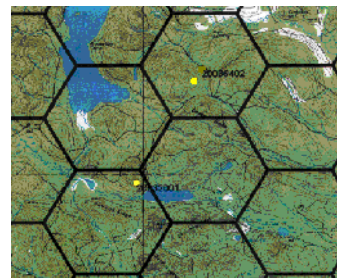


### Forest Inventory Sampling



*USDA Forest Service measures hundreds of thousands of plots!*

### USDA Forest Service FIA Plots

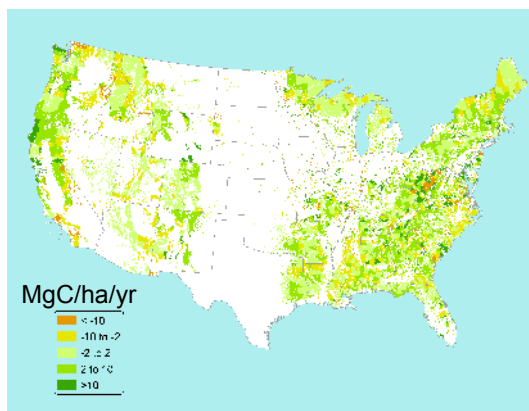


**Five-Year Panel:**

- ◆ Year One
- ◆ Year Two
- ◆ Year Three
- ◆ Year Four
- ◆ Year Five

- 6000 acre grid cells
- 1 plot per grid cell
- >800K plots
- each plot visited every 5 (east) or 10 (west) years

### Average annual live tree C stock change by county, estimated from FIA data



Courtesy of Linda Heath, USFS

# The Atmosphere



# Atmospheric CO<sub>2</sub> Observations (in-situ)

