“Introduction to Carbon Cycle Science and pH in the Ocean”

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Earth2Class Workshops for Teachers

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The Importance of the Carbon Cycle

- Carbon is the key to Life as we know it—most biological molecules (carbohydrates, lipids, proteins, DNA and RNA) are carbon-based
- Biological energy – either photosynthetic or chemosynthetic—require carbon compounds
- Hydrocarbons have served as the most essential fuels during the past 150 years
- Coal and plant fuels also are carbon-based
- C is very reactive and rarely uncombined

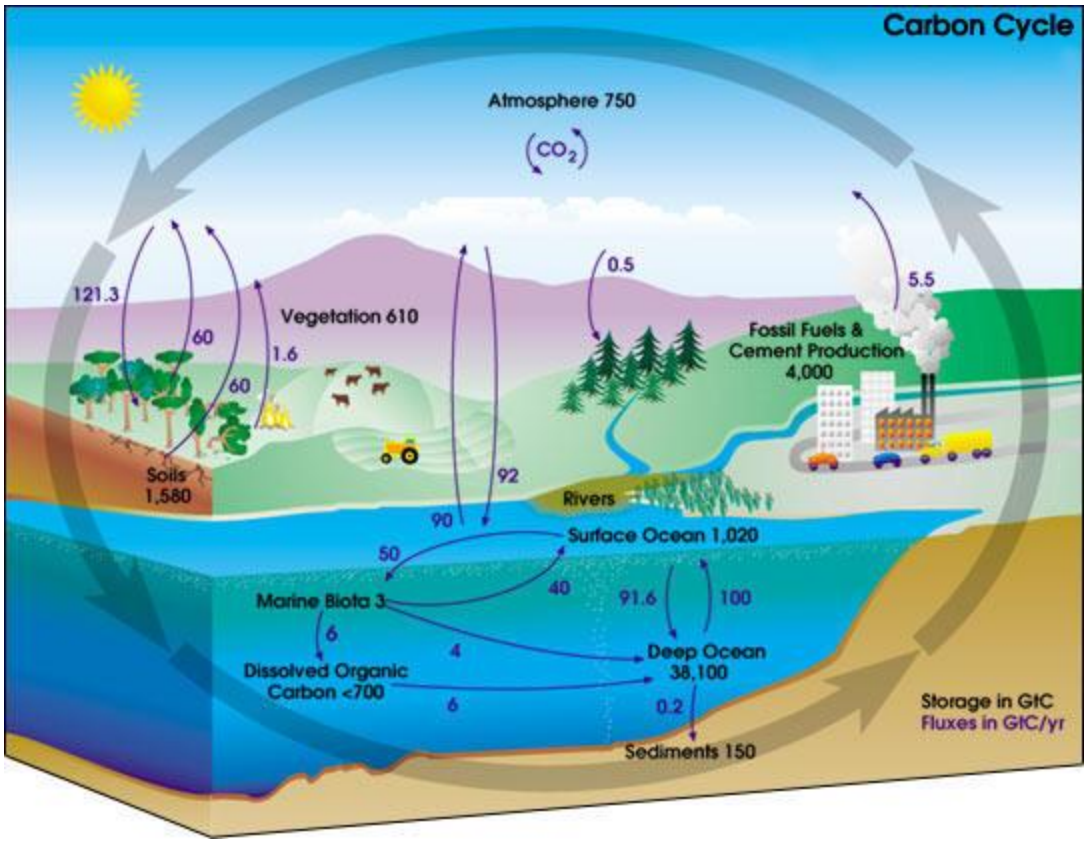
Before We Begin: Some Essential Terms

- "**Biogeochemical cycle**": model representing movement of a substance among Earth's 4 'spheres'
- "**Flux**": amount of a quantity (such as heat or CO_2) that flows through a unit area in a unit time
- "**Reservoir**": component of a system separate from other components, such as 'ocean' vs. 'air' or 'land'
- "**Sequestration**": amount of a compound 'locked away' in a reservoir so as not to be available

More Essential Terms

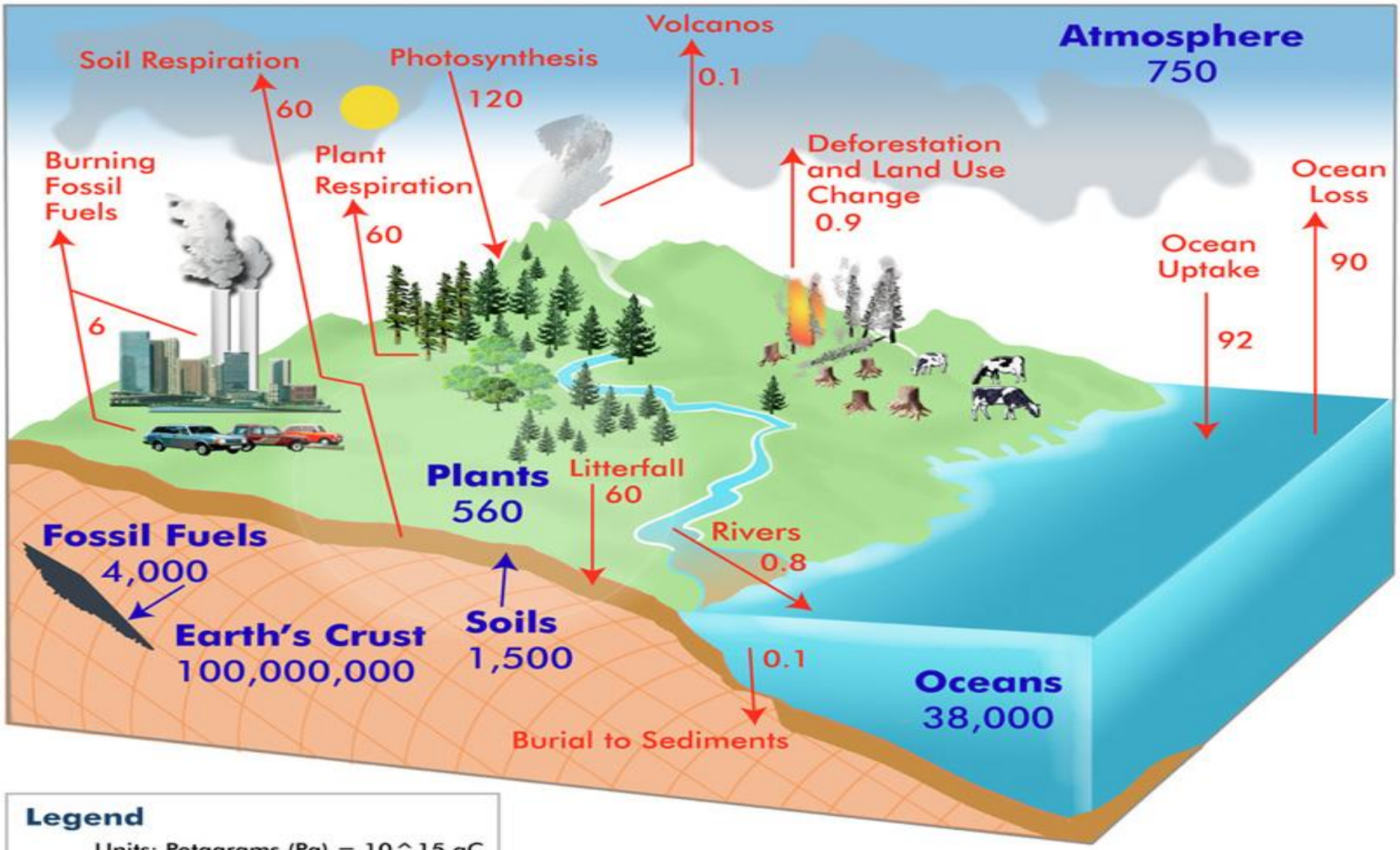
- "**Source**": where elements or compounds come from within a system, such as the atmosphere
- "**Sink**": where in a system substances finally wind up, such as in plants or rocks
- "**Anthropogenic CO_2**": CO_2 released by human activities
- "**Carbonate mineral**": compound that has "CO_3" combined with one or more elements, such as "$CaCO_3$" or "$(Ca,Mg)CO_3$"
- "**Partial Pressure**": portion of a total amount produced by one component (e.g., pCO_2)

This drawing of the Carbon cycle indicates that plants and oceans play key roles in the flow



http://earthobservatory.nasa.gov/Library/CarbonCycle/carbon_cycle4.html

Global Carbon Cycle

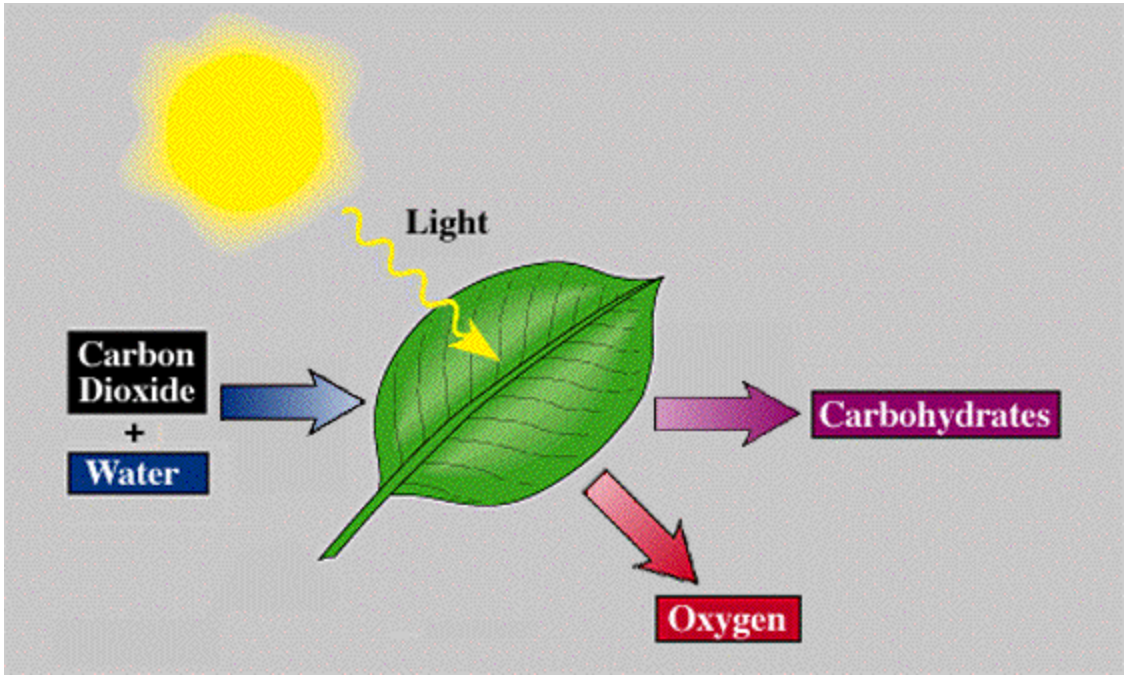


http://www.globe.gov/fsl/html/templ.cgi?carboncycleDia

Within the Carbon Cycle, the role of CO_2 has received considerable attention

- CO_2 is vital in *photosynthesis-respiration*, *combustion*, and other parts of the *C Cycle*
- CO_2 is an atmospheric *greenhouse gas*
- Research at the Mauna Loa observatory and elsewhere have identified sharply increased levels in the atmosphere
- CO_2 also occurs as one of the dissolved gases in seawater

Through photosynthesis, CO_2 and H_2O combine using solar energy to create more complex compounds that store energy



http://www.phschool.com/science/biology_place/biocoach/photosynth/overview.html

Here is another version of a photosynthesis diagram:
http://earthguide.ucsd.edu/earthguide/diagrams/photosynthesis/photosynthesis.html

Through cellular respiration, organisms gain energy and CO_2 is released form the Biosphere

In a very simplified form, **aerobic respiration** involves:

$$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{energy (ATP)}$$

Also simplified, **combustion (burning)** involves:

carbon-based fuel + $O_2 \rightarrow CO_2 + H_2O$ + heat/ light

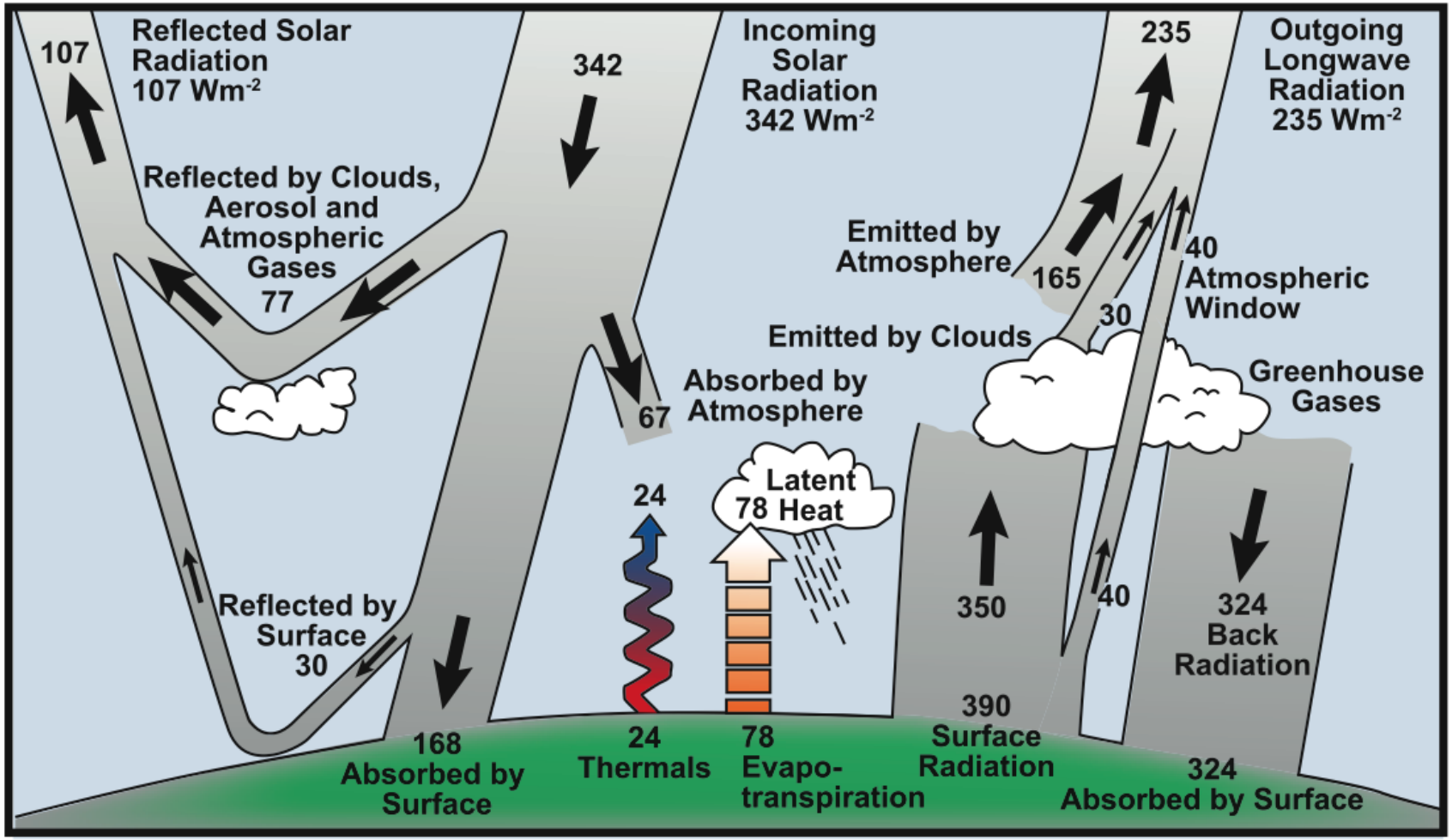
(wood, oil, gas, etc.)

What Do We Know about CO_2 and Climate, and How Do We Know It?

One of the better sources for information about current understanding of the changing Earth System is the "Intergovernmental Panel on Climate Change Working Group 1: The Physical Science Basis of Climate Change" report.

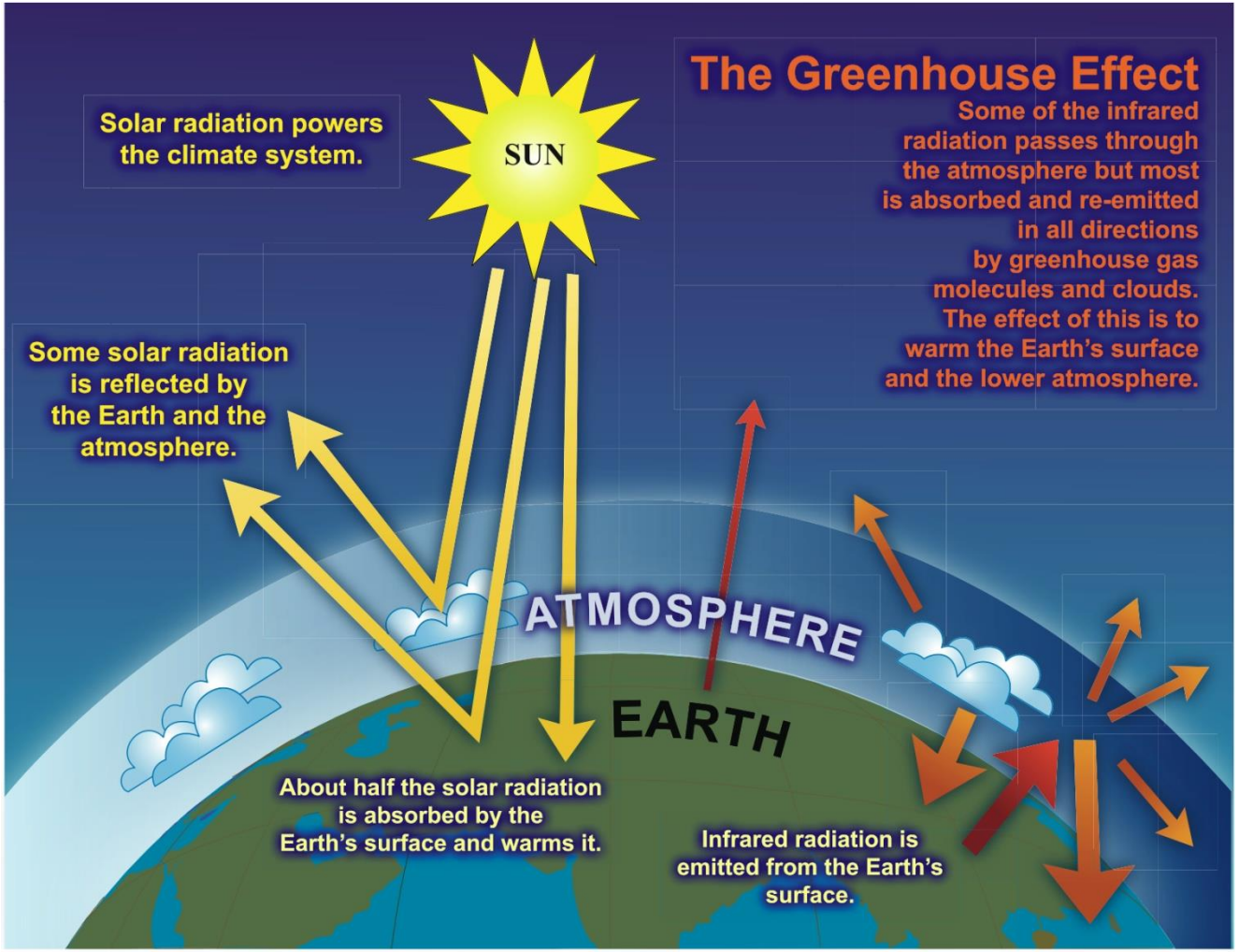
The following diagrams come from online versions of this document.

CO_2 plays a role in Earth's Energy Budget

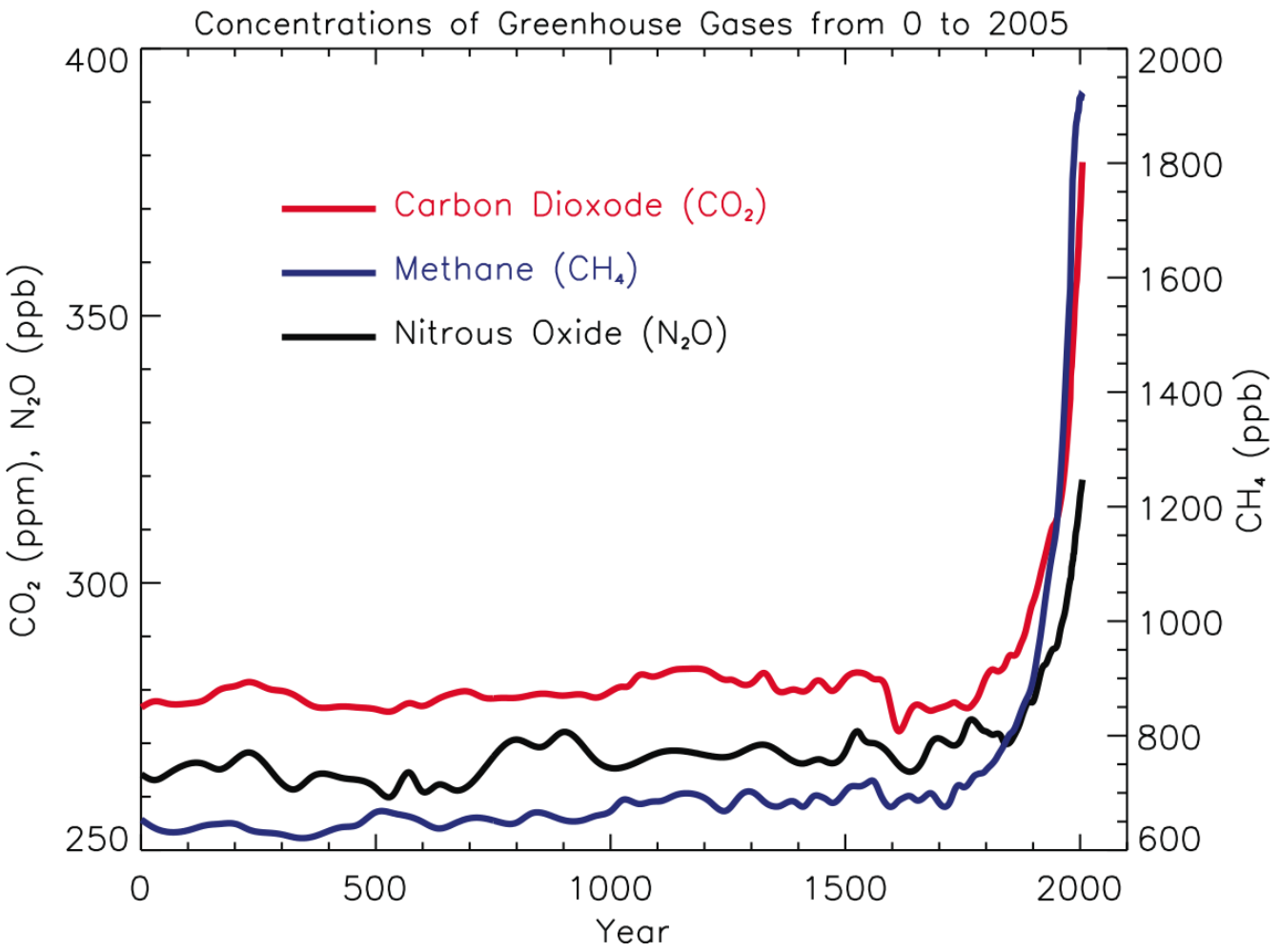


http://ipcc-wg1.ucar.edu/wg1/FAQ/wg1_faq-1.1.html

The Greenhouse Effect



http://ipcc-wg1.ucar.edu/wg1/FAQ/wg1_faq-1.3.html



http://ipcc-wg1.ucar.edu/wg1/FAQ/wg1_faq-2.1.html

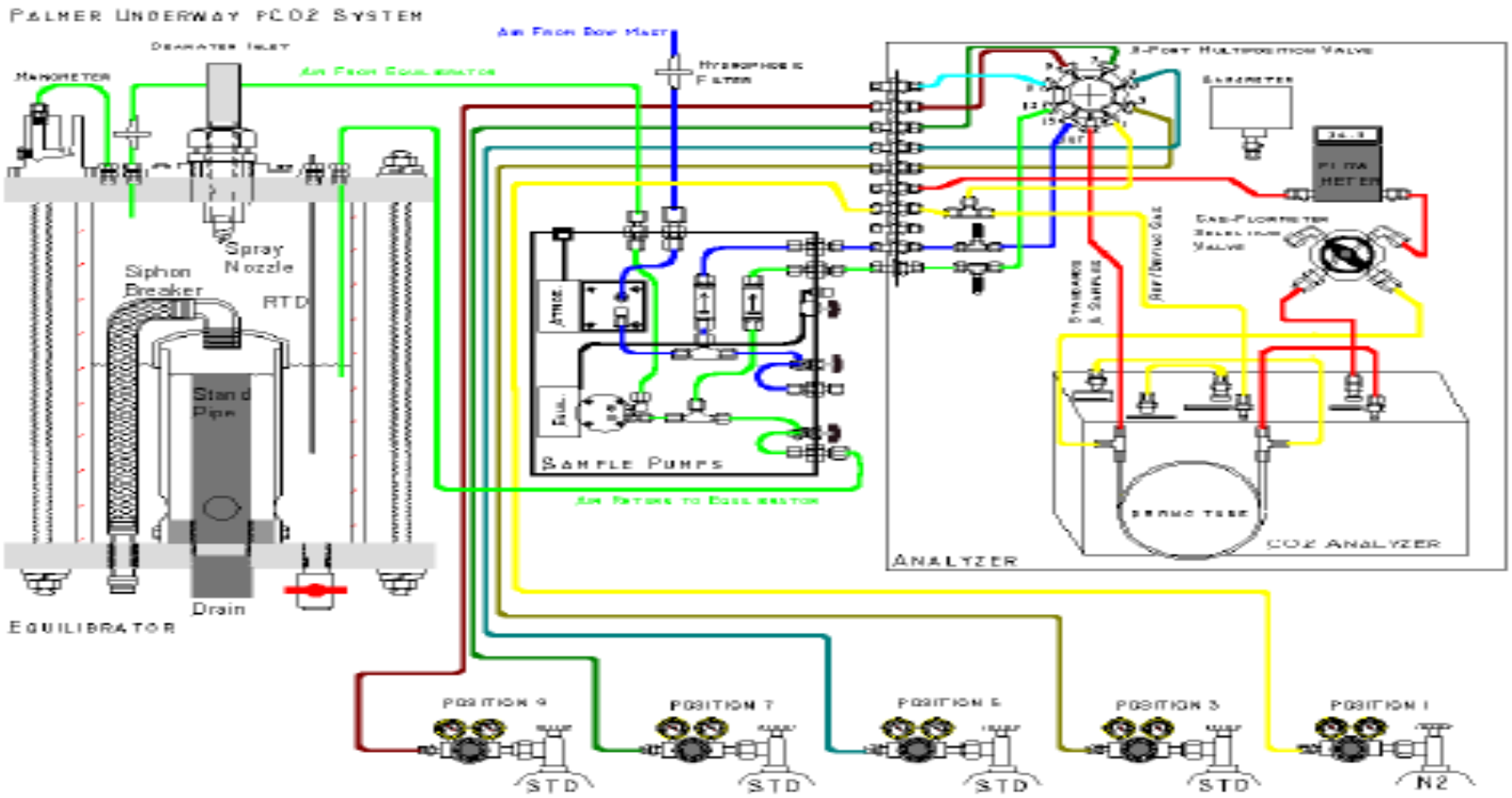
Measuring CO_2 exactly in all reservoirs and fluxes becomes critical for understanding the Earth System

- Many instruments are available to monitor CO_2 under a wide variety of conditions
- Deployment of instruments and collection of samples provide many challenges

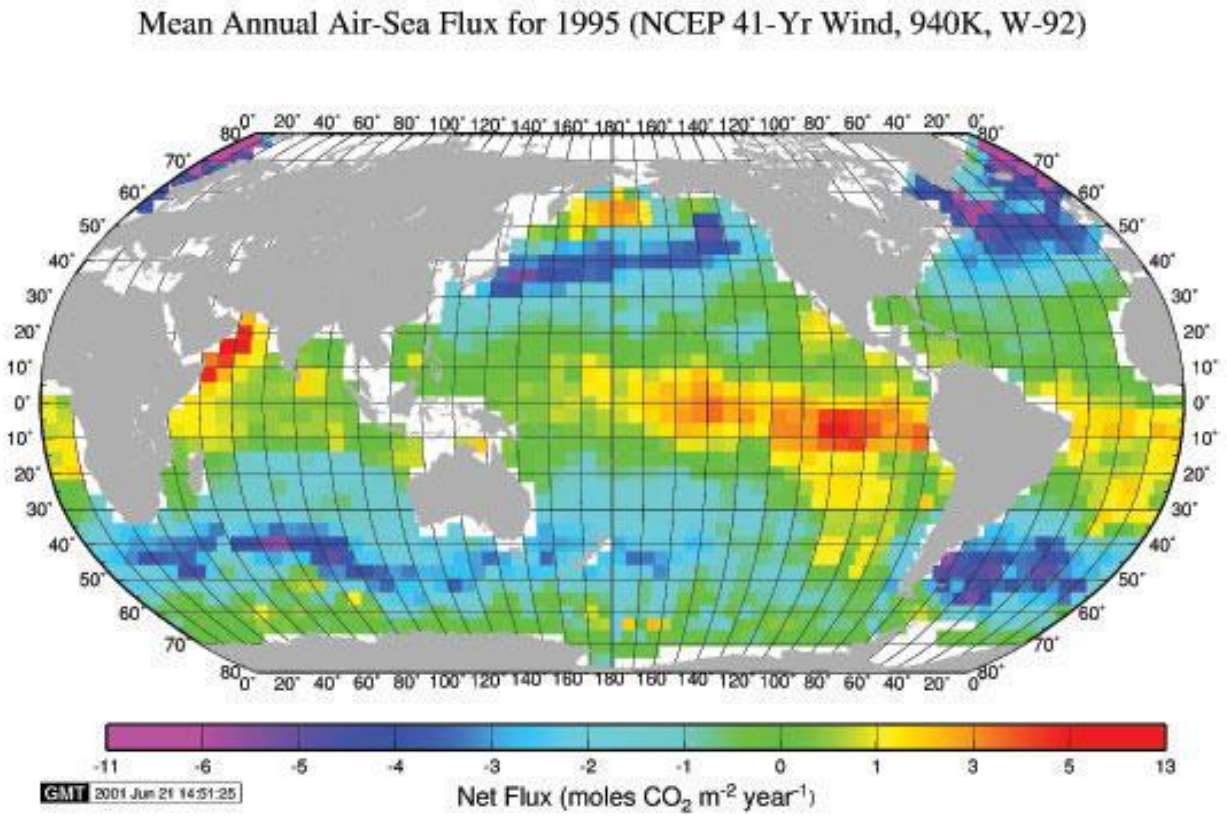




Dr. Takahashi's research focuses large on in-site measurements at sea



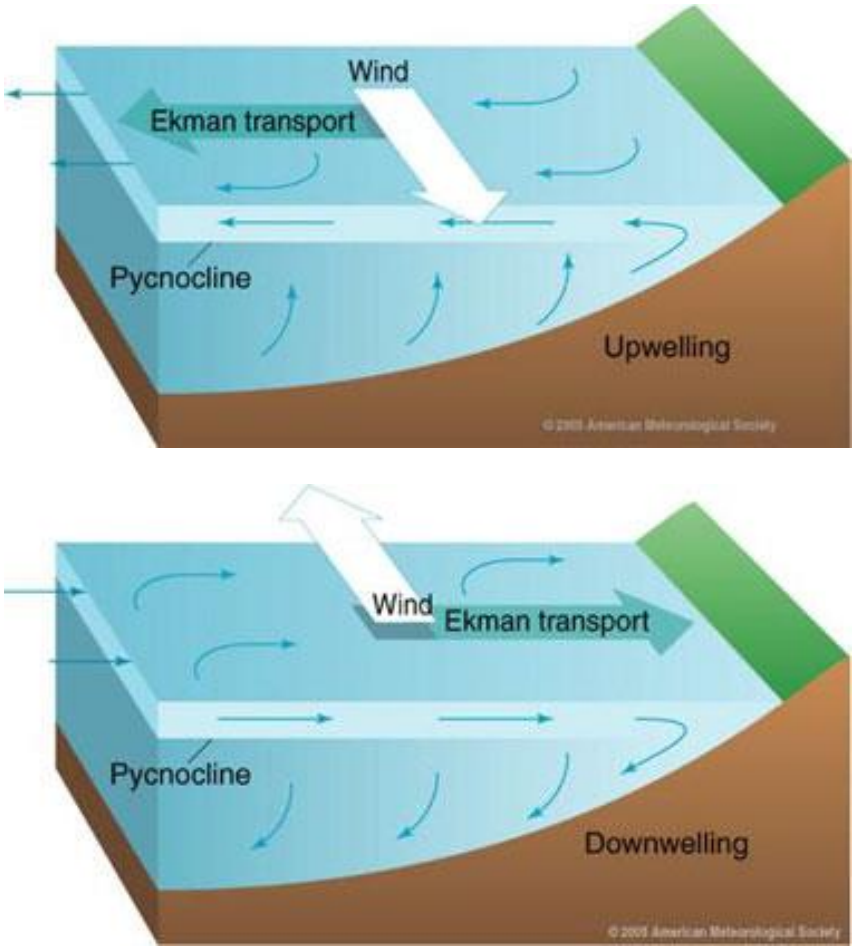
Data is often presented through color-coding to provides rapid visual comprehension



Takahashi, T. et al. (2002). Deep-Sea Res. II, 1601-1622.

In the oceans, CO_2 transport is also vertical

- Upwellings bring cooler waters (often rich in dissolved gases) to the surface
- Downwellings send surface waters into the depths and begin circulation patterns that may last for centuries



http://oceanmotion.org/html/background/upwelling-and-downwelling.htm

Factors Affecting Dissolving and Diffusing

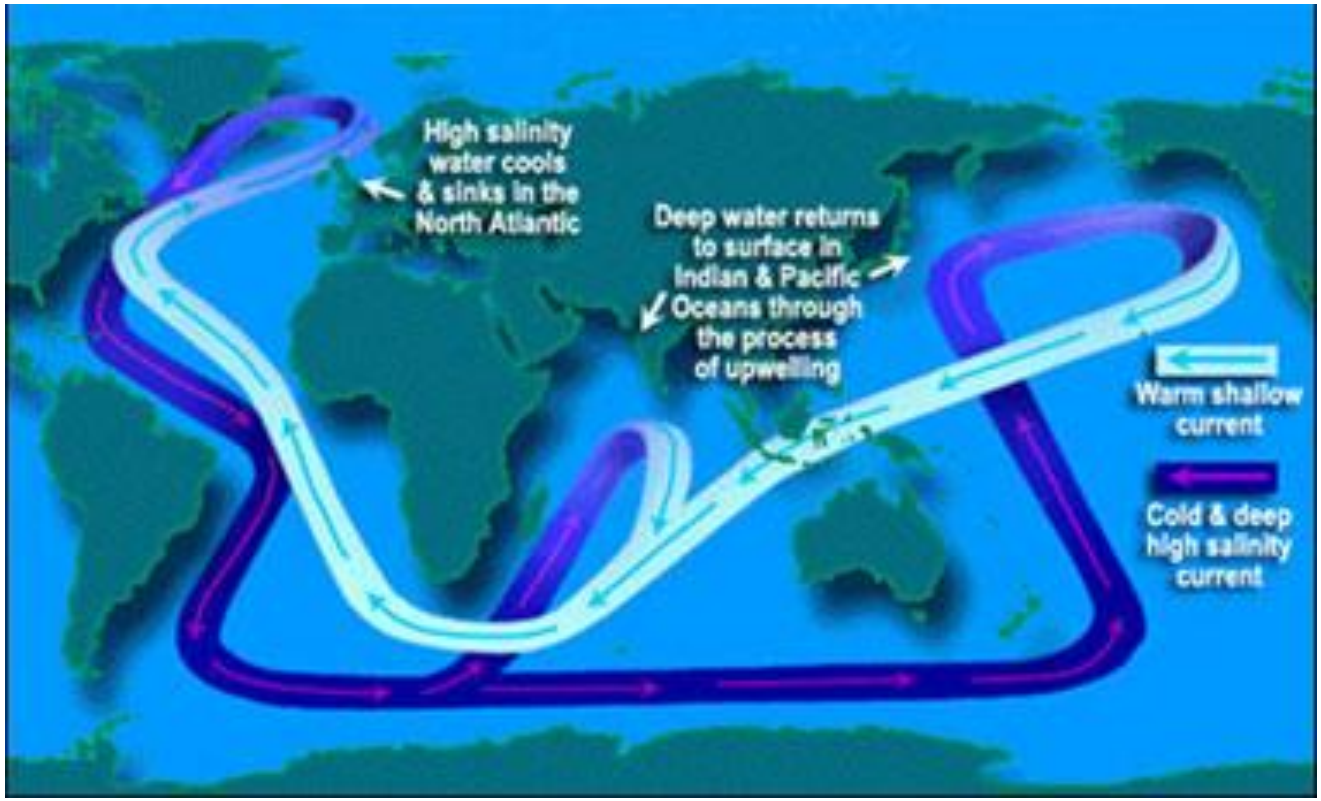
- Gases dissolve in liquids.
- How much depends in part on temperature colder = higher concentrations (think ‘soda’)
- Gas diffuse from higher concentrations to lower concentrations

More about Dissolving and Diffusing

- All of this takes place amidst biogeochemical processes
- Various factors influence the rate of diffusion at the ocean-atmosphere interface
- These include surface waves and surface films
- Wind flow over the surface also adds a factor
- Marine organisms, especially phytoplankton, also influence gas exchange rates

http://www.po.gso.uri.edu/airsea/heidel.html#airsea2

Oceanic CO_2 flow is part of the "Ocean Conveyor Belt"



http://oceanmotion.org/html/background/ocean-conveyor-belt.htm

pH

- Measure of the **acidity** or **baseness (alkalinity)** of a solution
- term derived from German “power of Hydrogen”
- generally defined as the “negative logarithm of the hydrogen ion concentration”
- Acidic: less than 7 Basic: more than 7

Neutral 7.0

pH and Marine Organisms

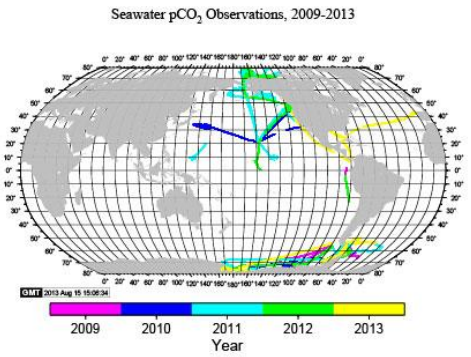
- Marine organisms live in the complex solution known collectively as “seawater”
- On the chemical scale, constant interactions among dissolved gases and solids cause a wide variation in the pH, generally from about 7.3 to more than 10
- Changes in oceanic pH can have great impacts on many marine organisms

pCO_2

- Another standard of measurement in chemical oceanography is referred to as "pCO_2"

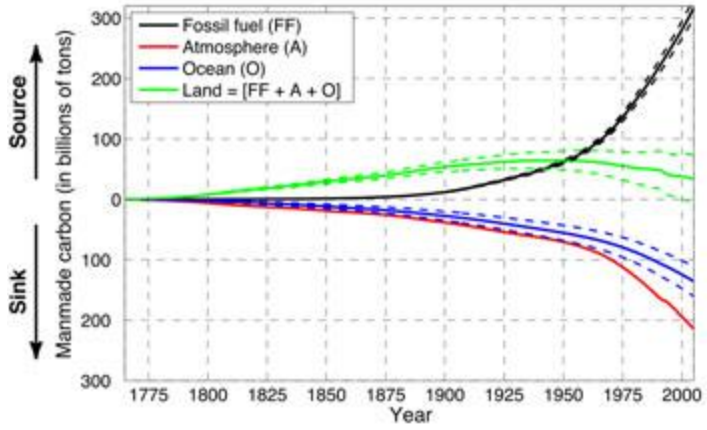
http://www.ldeo.columbia.edu/res/pi/CO2/carbondioxide/pages/pCO2data.html

Measurements are routinely collected aboard many NOAA, Navy, Coast Guard, and other research vessels.



How Fast Are Oceans Absorbing CO_2?

- This is one of the most important questions investigated by the CO_2 group http://www.ldeo.columbia.edu/news-events/oceans-uptake-manmade-carbon-may-be-slowing



A Final Key Question: When Should We Begin to Teach "Climate Literacy"?

Efforts are underway to create documents clearly identifying "Essential Principles and Concepts" in all areas of the geosciences

- "Climate Literacy: Essential Principals and Fundamental Concepts"
- Ocean Literacy
- Atmospheric Literacy

So, for us as classroom teachers…

- What should we teach about CO_2 and ocean acidification?
- When should we teach it?
- How should we teach it?
- Where can we get the necessary information?
- How good are the data and the deductions?