Carbon Dioxide – Oceans and the Atmosphere

OCN 623 – Chemical Oceanography

25 February 2016

Reading: Libes, Chapter 15, pp. 389 – 394

(Remainder of chapter will be used with the class "Biogenic production, carbonate saturation and sediment distributions")

Student Learning Outcomes (SLOs)

At the completion of this module, students should be able to:

1. Explain how atmospheric CO_2 increases affect the CO_2/carbonate/pH system in the upper ocean

2. Identify the regions of the surface ocean that annually take-up and release CO_2

3. Explain the regional impacts of El Niño on air-sea CO_2 exchange

Current Status of Global CO_2

- Anthropogenic CO_2 input to atmosphere is primarily from:
  - Oxidation of fossil organic matter (oil, coal and natural gas)
  - Cement production
- This CO_2 input…
  - Adds to the CO_2 inventory of the atmosphere and the oceans
  - Stimulates terrestrial biomass production
- CO_2 in the ocean is ~53x greater than in the atmosphere
- Uncertain at what rate anthropogenic CO_2 is being added to the ocean

Equations for CO_2 Speciation

The equilibrium of gaseous and aqueous CO_2:

$$CO_{2(g)} \leftrightarrow CO_{2(aq)}$$

Subsequent hydration and dissociation reactions:

$$CO_{2(aq)} + H_2O \leftrightarrow H_2CO_3 \leftrightarrow HCO_3^- + H^+$$

$$HCO_3^- \leftrightarrow CO_3^{-2} + H^+$$

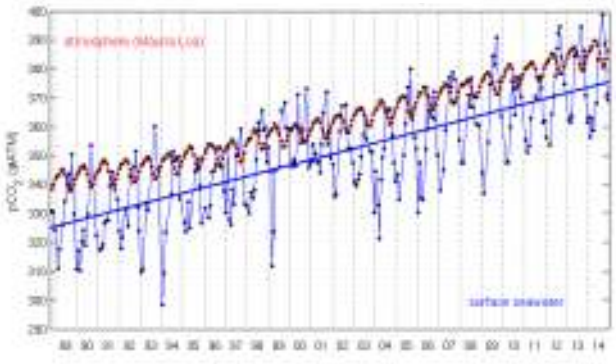
When pH is between 7.5 and 8.5:

$$CO_{2(aq)} + CO_3^{-2} + H_2O \leftrightarrow 2HCO_3^-$$

Ocean CO_2 Tracks Atmospheric Increase

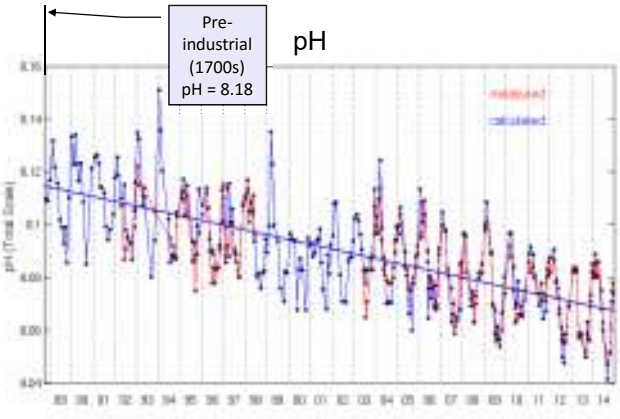
"Ocean Acidification"

CO_2 Partial Pressure



Pre-industrial (1700s) pH = 8.18

pH



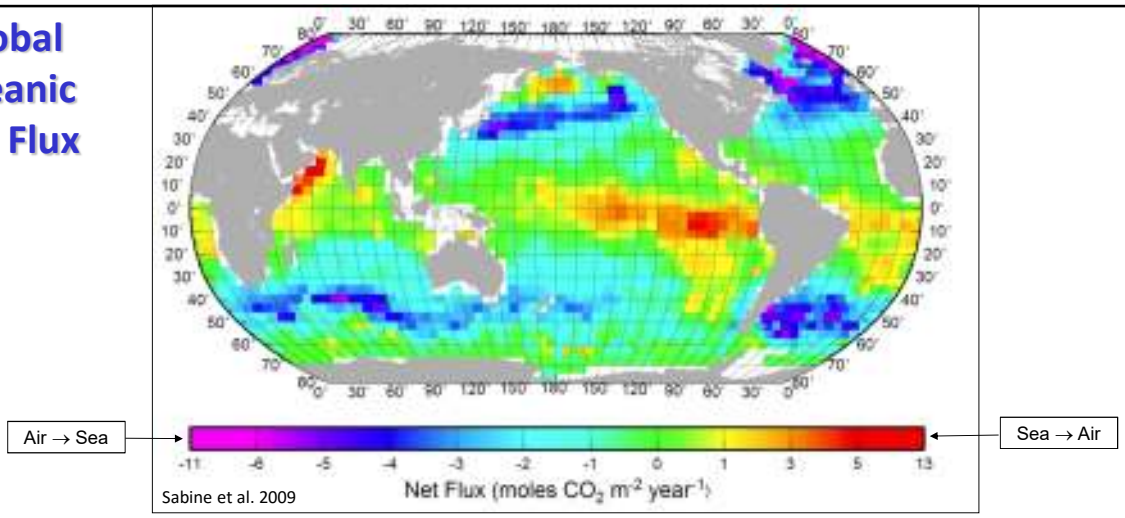
hahana.soest.hawaii.edu/hot/trends/trends.html

Watch on YouTube:
www.youtube.com/watch?v=x1SgmFa0r04

Can you identify the globally important sources and sinks, and when they are most active?

Note how the arctic "traps" large amounts of N. Hemisphere CO_2 during winter

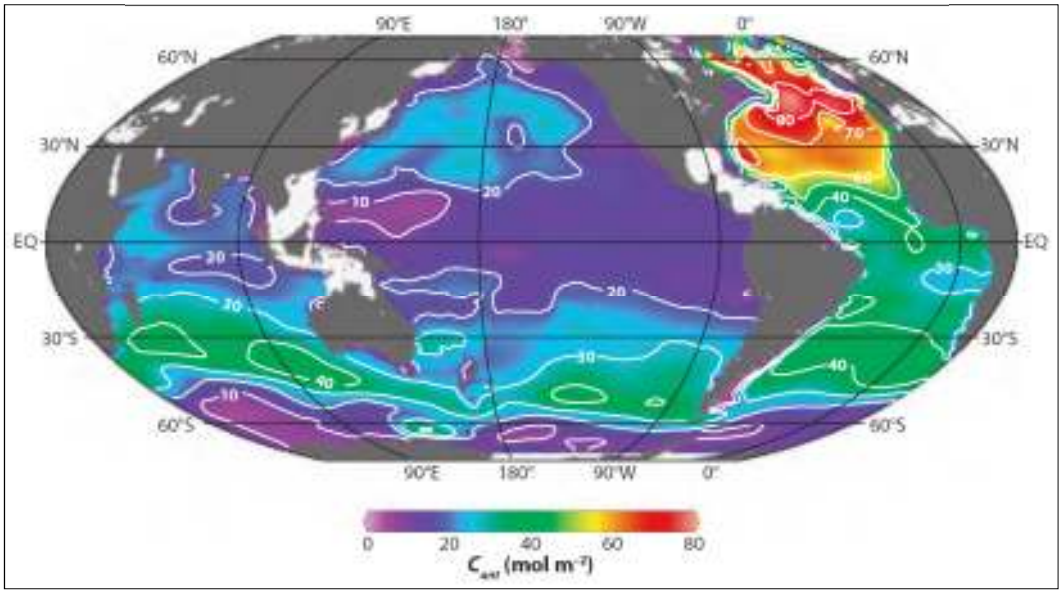
Global Oceanic CO_2 Flux



Sabine et al. 2009

- High values at equator (esp. in the Pacific) and along west coasts….from *upwelling* and subsequent *gas evasion to atmosphere*
- Low values where there is high bioproductivity
- Low values where cooling of ocean increases solubility of gas and causes *CO_2 uptake from the atm.*

Ocean Water-column Anthropogenic Carbon (C_{ant})



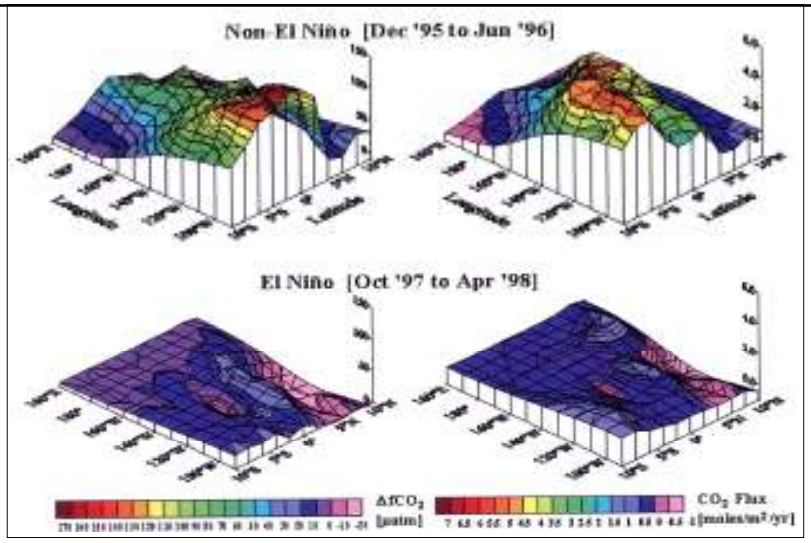
Sabine & Tanhua. 2010. Ann. Rev. Mar. Sci.

Group Task

Ocean Water-column Anthropogenic Carbon (C_{ant})

C_{ant} is highest in the North Atlantic, and lowest along the equator and offshore of Antarctica. Why is this?? (Explain each of the three cases.)

- High fluxes of CO_2 *out of the ocean* at the equator (esp. in the Pacific) and offshore of Antarctica due to upwelling of CO_2-rich deep water....which prevents C_{ant} transfer from the atmosphere
- High fluxes of CO_2 *into the ocean* in the North Atlantic, due to the high gas solubility of cold seawater, and local downwelling (deep water-mass formation)



Effects of El Niño on Pacific Ocean CO_2 Exchange

f = fugacity (the effective partial pressure)

El Niño-driven changes in CO_2 fluxes are primarily due to:

- Decreased upwelling of CO_2-enriched waters from the Equatorial Undercurrent
- Advection of CO_2-depleted waters from the western equatorial Pacific