Problem Set 6
Marine Chemistry 12.742

Problem 1:
A suite of biological and geochemical constraints can be used to estimate the major terms for the upper ocean carbon budget. Shown below is a figure from Brix et al. (2004) based on data from the Hawaii Ocean Time-series (HOT) in the subtropical North Pacific.

For the calculations below, assume the following:

$$\frac{1}{pCO2}\frac{\partial pCO2}{\partial T} = 4\%/K$$

-Revelle factor $\frac{\partial pCO2}{pCO2}\frac{DIC}{\partial DIC} = 10$

-^{13}C of DIC is zero and a biological kinetic isotopic fractionation of -23 per mille

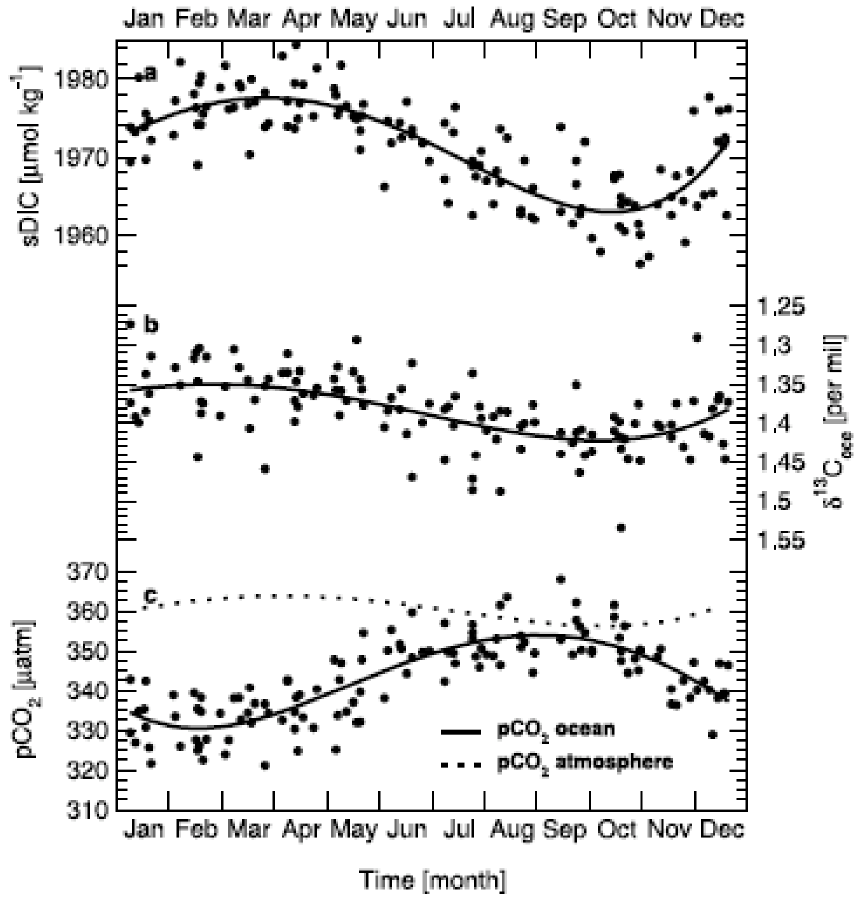
(1) Describe the major physical and biological processes controlling the seasonal cycle of mixed layer salinity normalized DIC, pCO2, and ^{13}DIC using mass balance equations and simple sketches.

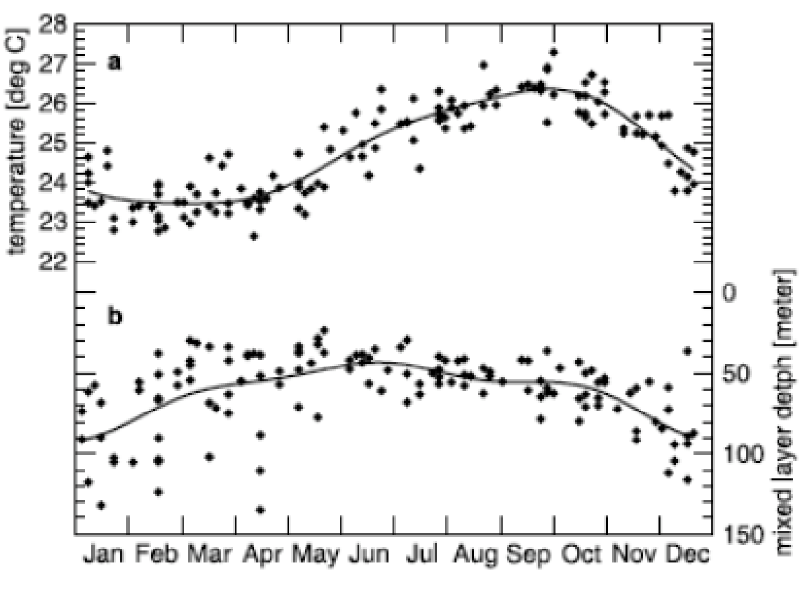
(2) Estimate quantitatively the partitioning between physical and biological impacts on the seasonal cycle of pCO2.

(3) Estimate the air-sea flux of CO2 (atmosphere pCO2 is dashed line in pCO2 panel below) given a ^{222}Rn based piston velocity estimate of 3.4 m/day, Sc (^{222}Rn)=2000, and Sc (CO2) = 660.

(4) Estimate the Net Community Production assuming a purely local balance and neglecting physical transport.

(5) Describe how could you use the ^{13}C to improve your NCP estimate in the presence of horizontal advection. Assume you knew the lateral gradients in salinity normalized DIC (-20 umol/kg/1000 km) and del^{13}C (0) but not the advection speed.


Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
sDIC [µmol kg-1]
1980
1970
1960
a
b
c
1,25
1,3
1,35
1,4
1,45
1,5
1,55
δ13Coce [per mil]
370
360
350
340
330
320
310
pCO2 [µatm]
pCO2 ocean
pCO2 atmosphere
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Time [month]


28
27
26
25
24
23
22
temperature [deg C]
a
b
0
50
100
150
mixed layer detph [meter]
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Question 2

On a cruise in the North Atlantic gyre off western Africa, you measured dissolved ^{234}Th (λ_{234} = 0.029 d^{-1}) in the upper 200m of the water column and the $C_{org}/^{234}$Th ratio in settling particles collected with a floating sediment trap deployed just below the mixed layer. You also measured "new" production in a few samples within the mixed layer using incubations with ^{15}N-labeled nitrate.

a) Estimate the particle export time-scale given a mean ^{234}Th activity in the upper 100m = 1800 dpm/m^3 and no deficit below that depth (100-200m) (the activity of ^{238}U in seawater is 2480 dpm/m^3).
b) Calculate a carbon export flux given that the material collected in the trap has a Corg/^{234}Th ratio = 4 μmol C/dpm. [Hint: The vertically integrated mass budget for ^{234}Th gives the removal flux of ^{234Th} on to particles, in atoms/m^2/time, which should balance the material caught in the trap].
c) The results from the nitrate incubation indicate a mean nitrate uptake rate of 0.3 mmolN/m^2/d. Are these results consistent with the Th based export estimates? What other physical and biogeochemical processes could lead to a disconnect between the C based and N based estimates of net cycling through the

Question 3

Imagine a hypothetical ocean with a homogeneous euphotic zone occupied by only one species of phytoplankton producing uniform spherical cells with a radius of 2μm. There are no seasonal variations, no predators and no bacteria so that the intact cells sink on their own from the euphotic zone. A sediment trap with an aperture of 0.5 m^2 is deployed for one year just below the euphotic zone and captures 91.25g of material. Assume particles sink following Stoke's Law:

$$w = \mathrm{sqrt}(16\ r\ g\ (\rho s - \rho w) / 3\ \rho w)$$

where ρs is the density of the particle; ρw is the density of water; g is the gravitational constant (9.81 m/s^2), μ is the viscosity of water (10^{-2} g/(cm s)), r is the radius of the spherical particles, and w is the terminal velocity. Take the density of water as 1g/cm^3 and that of the particles (individual and colonies) as 2g/cm^3.

a) Suppose that during that year, you filter 1 m^3 of seawater from the euphotic zone. How much material (in grams) do you expect to collect on the filter?
b) How many cells do you expect to collect on the filter?

The following year, everything stays the same but 95% of the cells start to aggregate and produce spherical colonies with a radius of 50μm, which also sink unaltered from the euphotic zone by gravitational settling.

c) By how much would the suspended matter concentration in the euphotic zone decrease compared to the previous year?

d) How many individual cells and how many colonies would you find in 1 cubic meter of water from the euphotic zone?