Assignment #3: Ocean Carbon Chemistry
Due Thursday, Nov 30

1) Use the expressions of chemical equilibria in the ocean carbonate system to calculate the partial pressure (or mole fraction) of CO_2 in the atmosphere, assuming a global average surface salinity of 34.78‰ and temperature of 16 °C:

   i) For preindustrial equilibrium with surface ocean conditions:

   - TA = 2311 μeq kg^{-1}
   - DIC = 2002 μmol kg^{-1}

   ii) For hypothetical equilibrium between the atmosphere and the deep ocean, assuming the entire ocean was mixed and warmed to 16 °C, and with:
   - TA = 2393 μeq kg^{-1}
   - DIC = 2288 μmol kg^{-1}

   For help please consult the attached article by Tans (1998) and also feel free to copy-paste from the class website (Carbonate Chemistry Toy Model).

2) An empirical relationship between air-sea fluxes and environmental conditions based on a quadratic dependence on wind speed, temperature, salinity, and the difference in pCO_2 between the air and the ocean surface (Wanninkhof, 1992) is widely used to estimate air-sea gas exchange of CO_2.

   Assume that the atmospheric CO_2 mole fraction is 400 ppmv. Using the quadratic wind-speed relationship described in the attached article, calculate the piston velocity (m s^{-1}) for air-sea gas exchange and the flux of CO_2 into the ocean (mol CO_2 m^{-2} s^{-1}) under the following conditions:

   - **Arctic ocean**: T=0 °C, wind speed = 20 m s^{-1}, sea-surface pCO_2 =375 μatm, salinity=35‰;
   - **Subtropical gyre**: T=26 °C, wind speed = 5 m s^{-1}, sea-surface pCO_2=398 μatm, salinity=35.5‰;
   - **Equatorial East Pacific**: T=21 °C, wind speed = 2 m s^{-1}, sea-surface pCO_2=425 μatm, salinity=34‰;

   The Wanninkhof article is attached, and you're welcome to copy-paste empirical values of his coefficients from the class website (3-box ocean toy model).

3) Please read the short attached article on Ocean Acidification by Feeley et al (2009).

   a) Use the values for the modern ocean in Feeley's Table 1 to estimate the pCO_2 and $[Ca^{2+}]$ for the North Pacific and the Arctic Ocean.

   b) Assuming that $[Ca^{2+}]$ remains constant, estimate the saturation states for aragonite $\mathbf{\Omega}_{ar}$ and calcite $\mathbf{\Omega}_{ca}$ if atmospheric CO_2 reaches 600 and 1000 ppm.