The Observed Impact of Rivers on CO2 Dynamics in the Coastal Gulf of Maine

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Objectives

Goals within the OCB program include developing a robust understanding of where, when and how carbon is transported between the earth’s reservoirs and then to monitor these exchanges. Carbon fluxes at the land-ocean boundary are one area of substantial uncertainty, and our research program is focused on issues related to both optimal sampling and mechanistic understanding of CO2-air, sea-air, and ocean-atmosphere fluxes in coastal zones.

This work provides an update of our coastal observation program in the Gulf of Maine addressing several key land-ocean-atmosphere carbon transport questions by intensive monitoring of the coastal ocean’s surface carbon dioxide in space and time. These questions include:

- Does the Gulf of Maine (temperate latitude, Northeastern U.S.) act as a net atmospheric (carbon) sink?
- Which controls dominate the Gulf’s annual cycle of CO2-air exchange?
- What is the magnitude of cross and alongshore variability in the surface layer carbon pool?
- Do large episodic terrestrial inputs of freshwater, nutrients, and carbonate species alter sea-gas exchange in these coastal waters?
- What are the relevant temporal and spatial flux sampling scales for this region?

Fig 1 - Map of study region in the Western Gulf of Maine, and coastal shelf divisions (lower panel) versus depth and distance from the coastline for the coastal Wilkinson Basin transect – a single day cruise executed monthly since April 2004.

Note the addition of the UNH/PMEL CO2 time series station near WB2 starting in May 2006.

The Kennebec/Androscoggin river system is a key landward influence upon the Western Gulf waters where surface flow is predominantly North-South.

Data collection

Monthly shipboard data collected aboard UNH R/V Gulf Challenger, 2004-present

- Underway pCO2 via fast-pace Weiss-type equilibrator system, sea surface temperature and salinity
- Atmosphere pCO2 via the flow through system and underway co2 sensor (http://www.airmap.unh.edu)
- Profiles of TA and pH with depth as well a suite that include pigments, zooplankton, and nutrients
- Ancillary physical fields from the GoMPOm model as well as USGS river discharge data (for cruise data visit www.gms.usgs.gov)

Hourly/daily buoy data

- Met. & Wind speed from the NDBC and nearby coastal buoys
- Water Temp/Salinity, Chl a, currents, light field data from GoMOS buoy
- pCO2, diss. oxygen, temperature, salinity from pCO2 buoy near WB2

ApCO2 Time Series and Land- Ocean Connections

Our clear benefit of the repeated cross-shore transect is the utility in examining the seasonal and interannual cycles across a coastal ecosystem. Figures below provide a portion of our composite dataset for the period of our monthly cruises up to June 2007. Annual estimates of the CO2-air, sea-air flux are computed using the UNH cruise data and the nominal procedure for hourly mass flux estimation given as:

\[\text{flux} = (\text{mol} \cdot \text{m}^{-2} \cdot \text{day}^{-1}) = a \cdot \Delta U \cdot \alpha \cdot (\text{ApCO}_2)\]

where \(a\) is the gas solubility (a known quantity of T and S), \(U\) is the gas transfer coefficient - an unknown at sea and empirically related to wind and surface turbulence, and \(\text{ApCO}_2\) = [pCO2(seaside) - pCO2(sea)] is pCO2 being the gas’ partial pressure at 1 atm. The transfer coefficient is estimated hourly with several algorithms (e.g. Wanninkhof, 1992, Wanninkhof and McGillis, 1999) – each in terms of an hourly ‘steady’ 10m anemometer wind speed U. Whilst atmosphere CO2 measurements are typically collected aboard the Challenger we use monthly Manta Line casts for the anode level due to dramatic daily variations that can skew the mean ApCO2 estimate (Vandemark et al., 2007). Temperature, salinity and pCO2 data are interpolated from monthly values onto a 1 hour time step grid to estimate annual fluxes using Eq. 1.

Monthly sampling of CO2 vs. Buoy (2-3 hour sampling period)

As shown on the map at left, UNH now has a buoy moored just east of WB2 collecting pCO2 data using the NOAA/PMEL pCO2 system. The buoy has been deployed since 2006 and data below are being used to assess hourly to daily variations in the surface layer air and sea CO2 levels. The range of daily buoy-observed variation about our 4 year mean is significant but the general agreement with the curve is striking as well. The combined cruise and buoy data will be used to assess future sampling strategies for the wider Gulf, as well as the study of diurnal and discharge events.

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