Houston Galveston Bay pCO2

Website: https://www.bco-dmo.org/dataset/949729
Data Type: Cruise Results
Version: 1
Version Date: 2025-01-27

Project
» RAPID: Capturing the Signature of Hurricane Harvey on Texas Coastal Lagoons (Hurricane Harvey Texas Lagoons)

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Abstract
Quantifying the direction and magnitude of CO2 flux in estuaries is necessary to constrain the global carbon cycle, yet carbonate systems and CO2 flux in subtropical and urbanized estuaries are not yet fully determined. To estimate the CO2 flux for Galveston Bay, a subtropical estuary located in the northwestern Gulf of Mexico proximal to the Houston-Galveston metroplex, monthly cruises were conducted along a transect extending from the Houston ship channel to the mouth of Galveston Bay and Gulf of Mexico from October 2017 to September 2018. Underway pCO2measurements were recorded using a Shipboard Underway pCO2 Environmental Recorder (SUPER-CO2) system. CO2flux was calculated for 0.025° x 0.025° latitude increments along the transect and total CO2 flux for the Bay was estimated. Mean Bay water pCO2was 384.2 ± 56.7 µatm. A large freshwater inflow event in spring was followed by a period of dilution (low salinity, TA, and DIC) and enhanced primary production (low pCO2, water, CO2 uptake, and high chlorophyll-a levels). CO2 flux exhibited large seasonal and spatial variability, likely primarily due to seasonality in photosynthesis and variability of freshwater inflow events. Overall, Galveston Bay was a sink for CO2, with a mean air-sea CO2 flux of -8.3 ± 17.3 mmol m-2 d-1, and carbonate chemistry in Galveston Bay was regulated by an interaction between hydrology and biogeochemistry. The carbonate chemistry and CO2 uptake patterns of Galveston Bay differ from those that are common in temperate estuaries, which reiterates the need for further research in subtropical estuaries.

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Methods & Sampling

Field Sampling

Galveston Bay is a semi-enclosed microtidal estuary located in the northwestern Gulf of Mexico (nwGOM) (Montagna, Palmer, & Pollack, 2013). With an average water depth of 3 m and a surface area of 1554 km², Galveston Bay is the seventh largest estuary in the U.S. and the second largest estuary on the Texas coast (Bass, Torres, Irza, Proft, Sebastian, Dawson, Bedient, 2018; Morse et al., 1993; Solis & Powell, 1999).

Galveston Bay receives freshwater from the Trinity River, San Jacinto River, Clear Creek, and smaller bayous and creeks, with the Trinity River providing 70% of the freshwater entering the Bay (Bass et al., 2018; Morse et al., 1993; Solis & Powell, 1999). The Bolivar Peninsula and Galveston Island separate Galveston Bay from the Gulf of Mexico (GOM), with exchange of water between the Bay and the GOM occurring through Bolivar Roads, the mouth of the Bay (Glass, Rooker, Kraus, & Holt, 2008).

Monthly cruises were conducted between October 2017 and September 2018 aboard the R/V *Trident*. The timing of the study allowed for examination of the factors regulating CO2 flux over the course of a year following Hurricane Harvey in late August 2017. Although the study began more than 45 days after the hurricane (the residence time of the Bay), salinity recovery of the Bay was likely still ongoing in the inner and middle sections (Du & Park, 2019; Du, Park, Dellapenna, & Clay, 2019).

During each monthly survey, a transect was run between five water sampling stations, extending northwest from the Bay mouth (Station 1) to the Five Mile Marker on the Houston Ship Channel (Station 5). One offshore cruise in the nwGOM outside Galveston Bay was conducted in October 2018. Underway pCO2 measurements were taken along a northwesterly transect from stations 1 through 5. A SUPER-CO2 System equipped with a LI-COR® LI-840A infrared gas analyzer was used to collect both water and air xCO2 after drying through a Peltier thermoelectric device. The xCO2 data, after removing residual water vapor (Honkanen et al., 2021), was converted to pCO2 at sea surface temperature assuming 100% water vapor pressure (Jiang et al., 2008). Underway seawater was taken from a steel pipe attached to the side of the research vessel, as it did not have a dedicated water intake system, and a diaphragm water pump was used to feed water to the equilibrator. In situ sea surface temperature (SST) and salinity were measured with a SeaBird Scientific SBE45® Thermosalinograph mounted parallel to the equilibrator of the SUPER-CO2 System. Prior to and following each sampling trip, the SUPER-CO2 System was calibrated using standards of known CO2 concentrations (273.3, 774.3, and 1468.7 ppm).

To calculate the pCO2 of seawater and air from measurements, the measured mole fraction of CO2 in seawater (xCO2, water) and measured equilibrator barometric pressure and xH2O were first used to calculate xCO2 in dry air (xCO2, air). This xCO2, air was then converted to pCO2 of equilibration (pCO2, eq) using measured temperature of equilibration (Teq) and water vapor pressure of equilibration, which was calculated from salinity and Teq according to methods outlined in Weiss and Price (1980). Next, SST and Teq were used to convert pCO2, eq to pCO2, water (Weiss & Price, 1980). For pCO2, air, xCO2, air was converted to pCO2, air using water vapor pressure at SST and salinity, assuming 100% humidity (Borges et al., 2004).

Meteorological Data

Three National Oceanic and Atmospheric Administration (NOAA) buoys from throughout Galveston Bay provided six-minute interval averages of continuous wind speed data (NOAA, 2022). The average wind speed for all three buoys during sampling times was calculated and applied to the timing of sampling in Galveston Bay. Prior to calculations, wind speeds were converted to a height of 10 m (u10) using the wind profile power law (Hsu, Meindl, & Gilhousen, 1994):

u1/u2 = (z1/z2)^P

where u2 is wind speed at height z2 = 10 m, u1 is the collected wind speed data at height z1, and the exponent P (0.11) around the GOM area is extracted by Hsu et al. (1994).

United States Geological Survey (USGS) streamgages for the Trinity River (gage #08066500) and San Jacinto River, east fork (SJE; gage #08070200) and west fork (SJW; gage #08068000), were used to obtain freshwater discharge (USGS, 2021). These stations were identified as the closest gages to the mouths of the rivers having complete discharge data for the period of study. Discharges of less than or equal to 45 days (residence time of the Bay) prior to flux estimates were utilized (Bass et al., 2018; Morse et al., 1993). The Texas Commission on Environmental Quality (TCEQ) performs routine water quality monitoring, and TCEQ water sampling stations were used for river endmember values from the San Jacinto (average of west fork station #11243 and east fork station #11238) and Trinity (station #10896) rivers (TCEQ, 2022). River endmember DIC was calculated from TA and pH measurements using K1 and K2 constants from Millero (1980), and pH values on the NBS scale. Seasonally weighted averages were calculated by summing the TA or DIC concentration multiplied by daily discharge values for all river measurements of that season and dividing by the sum of all discharge values for all river measurements of that season (using meteorological seasons).

Historical Data

Results from this study were compared to historical data for Galveston Bay obtained from the Surface Ocean CO2 Atlas (SOCAT) database, which provided fCO2, water and xCO2, air values, along with surface seawater salinity, temperature, and depth, with observations from 2006 and 2010 through 2016, primarily during the month of September (Bakker et al., 2016). SOCAT transects followed a similar route to our study transect, beginning near Station 4 and continuing outward into the GOM, with a side transect through the Galveston Channel, which separates Pelican Island from Galveston Island. fCO2 values were converted to pCO2 using the R package *seacarb* (Gattuso et al., 2022). SOCAT data were analyzed independently from the results of this study. As done previously with ship data, SOCAT xCO2, air was converted to pCO2, air by accounting for water vapor pressure based on SST and SSS, assuming 100% humidity (Borges et al., 2004).

Data Processing Description

Air-water CO2 Flux Calculation

Prior to calculating CO2 flux based on in situ measurements, outliers were identified graphically and removed from the final datasets. Air-water CO2 flux was calculated using the following equation:

$F = k * K0 * (pCO2,water - pCO2,air)$

Where:

- k (m d-1) is the gas transfer velocity calculated from wind speed,
- K0 (mol m-3 atm-1) is the gas solubility at the measured in situ temperature and salinity.

Gas transfer velocity (piston velocity) at a Schmidt number of 600, referenced to wind speed at 10 m above the sea surface, was calculated and compared for consistency using several methods. Ultimately, the equation from Jiang et al. (2008), which was designed for estuaries and allows for wind speeds up to 12 m/s, was chosen as the most appropriate for calculating gas transfer velocity within the study area:

$k = (0.314 * u10^2 - 0.436 * u10 + 3.990) * (ScSST/600)^{(-0.5)}$

Where:

- u10 is the wind speed at 10 m above the water surface (m/s),
- ScSST is the Schmidt number of CO2 at in situ temperature, calculated for seawater.

To assess the best calculation method, air-sea CO2 flux, sea surface pCO2, temperature, salinity, wind speed, and atmospheric pressure were averaged over 0.01° and 0.025° latitude increments, and values were used to calculate flux in two separate analyses. A two-tailed Student’s t-test showed that CO2 flux calculations did not significantly differ between the two groupings for any of the sampling months ($p \geq 0.50$ for all months). For all further analyses, CO2 flux was calculated based on the larger 0.025° latitude increments to simplify calculations.

Linear interpolation between adjacent months was used to estimate CO2 flux, salinity, temperature, pCO2, air, and pCO2, water during months where values were missing for some of the latitudinal increments. Missing values for monthly atmospheric pCO2 were also calculated using linear interpolation. Seasonal values were determined by averaging monthly CO2 flux estimates by season, with fall including September, October, and November; winter including December, January, and February; spring including March, April, and May; and summer including June, July, and August measurements.

Resulting pCO2, water and sea surface salinity (SSS) from underway measurements were compared to pCO2, water calculated from pH and DIC measured from discrete samples and SSS from discrete samples. Since pCO2 is strongly influenced by temperature, thermally-adjusted water pCO2 was calculated according to the equation from Takahashi [79] to assess changes in pCO2 due to factors other than temperature (e.g., photosynthesis, respiration).

Statistical Analyses

Galveston Bay, located adjacent to the urban Houston and Galveston metroplex, may experience high localized atmospheric CO2 levels due to local emissions, which could depend on wind speed and direction. To determine the influence of wind speed (u10) and direction on pCO2, air, Pearson’s correlation coefficients with p-values were calculated for each variable and pCO2, air. Predictor variables with a Pearson’s correlation p-value <0.05 and an absolute correlation coefficient value >0.7 were designated as significantly correlated to pCO2, air.

Due to non-normality of data and non-homogeneity of variances, Kruskal-Wallis nonparametric Analysis of

Variance (ANOVA) tests were performed in R to compare carbonate system parameters (DIC, TA, pH, and ΩAr) across seasons and stations. Further exploration of values was conducted using Dunn tests, which assess individual differences between each pair of groups when nonparametric data are used.

To fully assess the influences of biogeochemistry on pCO2, several multiple linear regression models were compared based on residuals, R^2 values, and significance. Initial potential predictor variables for the discrepancy in pCO2 between calculated and underway measured values (calculated – measured, or dpCO2) included the difference in salinity between discrete and measured values, discrete salinity measurements, SST, DIC, TA, ΩAr, and pHT. All but salinity difference and SST remained in the final chosen model.

Problem Description

Gaps in sampling were filled with linear interpolation.

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Related Publications

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Methods

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Parameters

Parameters for this dataset have not yet been identified

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Instruments

Dataset-specific Instrument Name	SUPER-CO2 System
Generic Instrument Name	CO2 Analyzer
Dataset-specific Description	A SUPER-CO2 System equipped with a LI-COR LI-840A infrared gas analyzer was used to analyze both water and air xCO2 after drying through a Peltier thermoelectric device.
Generic Instrument Description	Measures atmospheric carbon dioxide (CO2) concentration.

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Deployments

Galveston_Bay_Cruises

Website	https://www.bco-dmo.org/deployment/949750
Platform	R/V Trident
Start Date	2017-10-21
End Date	2018-10-14

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Project Information

RAPID: Capturing the Signature of Hurricane Harvey on Texas Coastal Lagoons (Hurricane Harvey Texas Lagoons)

Coverage: Northwest Gulf of Mexico estuaries on Texas Coast

NSF Award Abstract:
Hurricane Harvey made landfall Friday 25 August 2017 about 30 miles northeast of Corpus Christi, Texas as a Category 4 hurricane with winds up to 130 mph. This is the strongest hurricane to hit the middle Texas coast since Carla in 1961. After the wind storm and storm surge, coastal flooding occurred due to the storm lingering over Texas for four more days, dumping as much as 50 inches of rain near Houston. This will produce one of the largest floods ever to hit the Texas coast, and it is estimated that the flood will be a one in a thousand year event. The Texas coast is characterized by lagoons behind barrier islands, and their ecology and biogeochemistry are strongly influenced by coastal hydrology. Because this coastline is dominated by open water systems and productivity is driven by the amount of freshwater inflow, Hurricane Harvey represents a massive inflow event that will likely cause tremendous changes to the coastal environments. Therefore, questions arise regarding how biogeochemical cycles of carbon, nutrients, and oxygen will be altered, whether massive phytoplankton blooms will occur, whether estuarine species will die when these systems turn into lakes, and how long recovery will take? The investigators are uniquely situated to mount this study not only because of their location, just south of the path of the storm, but most importantly because the lead investigator has conducted sampling of these bays regularly for the past thirty years, providing a tremendous context in which to interpret the new data gathered. The knowledge gained from this study will provide a broader understanding of the effects of similar high intensity rainfall events, which are expected to increase in frequency and/or intensity in the future.

The primary research hypothesis is that: Increased inflows to estuaries will cause increased loads of inorganic and organic matter, which will in turn drive primary production and biological responses, and at the same time significantly enhance respiration of coastal blue carbon. A secondary hypothesis is that: The large change in salinity and dissolved oxygen deficits will kill or stress many estuarine and marine organisms. To test these hypotheses it is necessary to measure the temporal change in key indicators of biogeochemical processes, and biodiversity shifts. Thus, changes to the carbon, nitrogen and oxygen cycles, and the diversity of benthic organisms will be measured and compared to existing baselines. The PIs propose to sample the Lavaca-Colorado, Guadalupe, Nueces, and Laguna Madre estuaries as follows: 1) continuous sampling (via autonomous instruments) of salinity, temperature, pH, dissolved oxygen, and depth (i.e. tidal elevation); 2) bi-weekly to monthly sampling for dissolved and total organic carbon and organic nitrogen, carbonate system parameters, nutrients, and phytoplankton community composition; 3) quarterly measurements of sediment characteristics and benthic infauna. The project will support two graduate students. The PIs will communicate results to the public and to state agencies through existing collaborations.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1760006

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