Houston Galveston Bay GPS

Website: https://www.bco-dmo.org/dataset/944542
Data Type: Cruise Results
Version: 1
Version Date: 2024-11-26

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

Contributors	Affiliation	Role
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Abstract
Quantifying the direction and magnitude of CO_2 flux in estuaries is necessary to constrain the global carbon cycle, yet carbonate systems and CO_2 flux in subtropical and urbanized estuaries are not yet fully determined. To estimate the CO_2 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 pCO_2 measurements were recorded using a Shipboard Underway pCO_2 Environmental Recorder (SUPER-CO_2) system. CO_2flux was calculated for 0.025° x 0.025° latitude increments along the transect and total CO_2 flux for the Bay was estimated. Mean Bay water $pCO_2$was 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 pCO_2, water, CO_2 uptake, and high chlorophyll-a levels). CO_2 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 CO_2, with a mean air-sea CO_2 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 CO_2 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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Coverage

Location: Galveston Bay, an estuary situated adjacent to the Northwest Gulf of Mexico
Spatial Extent: **N**:30 **E**:95.5 **S**:29 **W**:94.5
Temporal Extent: 2017-10-21 - 2018-10-14

Methods & Sampling

Field Sampling

Galveston Bay is a semi-enclosed microtidal estuary located in the northwestern Gulf of Mexico (nwGOM) (Montagna et al., 2013). With an average water depth of 3 m and a surface area of 1554 km^2, Galveston Bay is the seventh largest estuary in the U.S. and the second largest on the Texas coast (Bass et al., 2018; Morse et al., 1993; Solis & Powell, 1999). The Bay receives freshwater from several rivers, including the Trinity River, San Jacinto River, Clear Creek, and smaller bayous, with the Trinity River contributing 70% of the freshwater (Bass et al., 2018; Dellapenna et al., 2020; Morse et al., 1993). The Bay is separated from the Gulf of Mexico (GOM) by the Bolivar Peninsula and Galveston Island, with water exchange occurring through Bolivar Roads, the mouth of the Bay (Glass et al., 2008).

Monthly cruises were conducted aboard the R/V Trident from October 2017 to September 2018 to examine factors regulating CO2 flux over a year following Hurricane Harvey in August 2017. Although the study began more than 45 days after the hurricane (the residence time of the Bay), salinity recovery was likely still ongoing in the inner and middle sections of the Bay (Du & Park, 2019; Du et al., 2019).

During each survey, a transect was run between five water sampling stations, extending from the Bay mouth (Station 1) to the Five Mile Marker on the Houston Ship Channel (Station 5). An additional offshore cruise in the nwGOM outside Galveston Bay was conducted in October 2018. Underway pCO_2 measurements were taken along the northwesterly transect from Stations 1 through 5 using a SUPER-CO_2 system equipped with a LI-COR® LI-840A infrared gas analyzer to collect both water and air xCO_2 after drying through a Peltier thermoelectric device (Honkanen et al., 2021). The pCO_2 data were converted at sea surface temperature, assuming 100% water vapor pressure (Jiang et al., 2008). Underway seawater was taken from a steel pipe attached to the vessel, as the ship lacked a dedicated water intake system. A diaphragm water pump fed water to the equilibrator. Sea surface temperature and salinity were measured using a SeaBird Scientific SBE45® Thermosalinograph, which was mounted parallel to the equilibrator of the SUPER-CO_2 system. Calibration of the system was done prior to and after each sampling trip using known CO_2 concentration standards (Honkanen et al., 2021; Jiang et al., 2008).

To calculate pCO_2 values for seawater and air, the mole fraction of CO_2 in seawater (xCO_2, water) and the equilibrator barometric pressure and xH_2O were first used to calculate the xCO_2 in dry air (xCO_2, air). xCO_2, air was then converted to pCO_2 using measured temperature of equilibration (Teq) and water vapor pressure of equilibration, following methods outlined by Weiss and Price (1980). Finally, pCO_2, eq was converted to pCO_2, water using sea surface temperature and Teq, according to methods in Jiang et al. (2008).

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 the sampling times was calculated and applied to the sampling period. Wind speeds were adjusted to a height of 10 m using the wind profile power law (Hsu et al., 1994):

u1/u2=(z1/z2)Pu1/u2 = (z1/z2)^Pu1/u2=(z1/z2)P

Where u2 is the wind speed at height z2 = 10 m, u1 is the wind speed at height z1, and the exponent P (0.11) for the GOM area is based on the work of Hsu et al. (1994).

United States Geological Survey (USGS) streamgages were used to obtain freshwater discharge data for the Trinity River and San Jacinto River (USGS, 2021). The stations selected were the closest gages to the mouths of the rivers and provided complete discharge data for the study period. Discharges less than or equal to 45 days prior to flux estimates (residence time of the Bay) were used (Bass et al., 2018). River endmember values for dissolved inorganic carbon (DIC) were calculated using total alkalinity (TA) and pH measurements (TCEQ, 2022), with constants from Millero (1982). Seasonally weighted averages of DIC and TA were calculated using discharge-weighted averages for each season.

Historical Data

Results from this study were compared with historical data obtained from the Surface Ocean CO_2 Atlas (SOCAT) database, which includes fCO_2, water, xCO_2, air, and other environmental variables for Galveston Bay from 2006 to 2016 (Bakker et al., 2016). SOCAT transects followed a similar route to the study's transect, starting near Station 4 and extending outward into the GOM. The fCO_2 values from SOCAT were converted to pCO_2 using the R package seacarb (Gattuso et al., 2022). SOCAT data were analyzed independently of the results of this study.

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 Eq. 3:

$F = k K_0 (pCO_{2,water} - pCO_{2,air})$ (3)

where k ($m\ d^{-1}$) is the gas transfer velocity calculated from wind speed, and K_0 ($mol\ m^{-3}\ atm^{-1}$) is the gas solubility at the measured in situ temperature and salinity (Weiss, 1974).

Gas transfer velocity (piston velocity) at a Schmidt number of 600 and referenced to wind speed at 10 m above the sea surface was calculated and compared for consistency using several methods (Raymond & Cole, 2001; Wanninkhof et al., 2009; Wanninkhof, 1992; Jiang et al., 2008). Ultimately, the equation from Jiang et al. (2008), which was meant for estuaries and allows for wind speeds up to 12 $m\ s^{-1}$, was chosen as the most appropriate for calculating gas transfer velocity within the study area (Yao & Hu, 2017):

$k = (0.314 \times u_{10}^2 - 0.436 \times u_{10} + 3.990) \times (ScSST / 600)^{-0.5}$ (4)

Where u_{10} is the wind speed referenced at 10 m above the water surface ($m\ s^{-1}$) and ScSST is the Schmidt number of CO_2 at in situ temperature, calculated for seawater according to Wanninkhof (1992).

To assess the best calculation method, air-sea CO_2 flux, sea surface pCO_2, 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. When a two-tailed Student's t-test was conducted, CO_2 flux calculations did not significantly differ between the two groupings for any of the sampling months ($p \geq 0.50$ for all sampling months). For all further analyses, CO_2 flux was calculated based on the larger 0.025° latitude increments, which simplified calculations.

Linear interpolation between adjacent months was used to quantify CO_2 flux, salinity, temperature, pCO_2, air, and pCO_2, water in sampling months where values were missing for some of the latitudinal increments (Jiang et al., 2008). Missing values for monthly atmospheric pCO_2 were also calculated based on linear interpolation. Seasonal values were determined by averaging monthly CO_2 flux estimates by season, where fall included September, October, and November; winter included December, January, and February; spring included March, April, and May; and summer included June, July, and August measurements. Resultant pCO_2, water and SSS from underway measurements were compared to pCO_2, water calculated from pH and DIC measured from discrete samples and SSS from discrete samples. pCO_2 is strongly influenced by temperature (Zeebe & Wolf-Gladrow, 2001); therefore, to allow analyses of pCO_2 changes due to other causes than temperature (e.g., photosynthesis, respiration, etc.), thermally-adjusted water pCO_2 was calculated according to equation 1 from Takahashi (2002).

Statistical Analyses

Since Galveston Bay is located immediately adjacent to the urban Houston and Galveston metroplex, local emissions may lead to high localized atmospheric CO_2 levels, which could depend on wind speed and direction. To determine the influence of wind speed (u_{10}) and direction on pCO_2, air, Pearson's correlation coefficients with p-values were calculated for each variable and pCO_2, air. Predictor variables for which Pearson's correlation p-value was < 0.05 and the absolute correlation coefficient value was > 0.7 were designated as significantly correlated to pCO_2, air.

Due to non-normality of data and non-homogeneity of variances, Kruskal-Wallis nonparametric Analysis of Variance (ANOVA) tests (Ruxton & Beauchamp, 2008) were performed in R to compare carbonate system parameters (DIC, TA, pH, and ΩAr) between seasons and stations. Further exploration of values was done via Dunn tests, which test for individual differences between each pair of groups when nonparametric data are used (Ruxton & Beauchamp, 2008).

To fully assess the influences of biogeochemistry on pCO_2, several multiple linear regression models were compared based on residuals, R^2 values, and significance. Initial possible predictor variables for the discrepancy in pCO_2 between calculated and underway measured values (calculated – measured, or ΔpCO_2) included difference in salinity between discrete and measured values, discrete salinity measurements, SST, DIC, TA, ΩAr, and pHT, of which 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

Bakker, D. C. E., Pfeil, B., Landa, C. S., Metzl, N., O'Brien, K. M., Olsen, A., Smith, K., Cosca, C., Harasawa, S., Jones, S. D., Nakaoka, S., Nojiri, Y., Schuster, U., Steinhoff, T., Sweeney, C., Takahashi, T., Tilbrook, B., Wada, C., Wanninkhof, R., Xu, S. (2016). A multi-decade record of high-quality fCO2 data in version 3 of the Surface Ocean CO2 Atlas (SOCAT). Earth System Science Data, 8(2), 383–413. https://doi.org/10.5194/essd-8-383-2016
References

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Methods

Carter, B. R., Radich, J. A., Doyle, H. L., & Dickson, A. G. (2013). An automated system for spectrophotometric seawater pH measurements. Limnology and Oceanography: Methods, 11(1), 16–27. doi:10.4319/lom.2013.11.16
Methods

Clayton, T. D., & Byrne, R. H. (1993). Spectrophotometric seawater pH measurements: total hydrogen ion concentration scale calibration of m-cresol purple and at-sea results. Deep Sea Research Part I: Oceanographic Research Papers, 40(10), 2115–2129. doi:10.1016/0967-0637(93)90048-8
Methods

Dellapenna, T. M., Hoelscher, C., Hill, L., Al Mukaimi, M. E., & Knap, A. (2020). How tropical cyclone flooding caused erosion and dispersal of mercury-contaminated sediment in an urban estuary: The impact of Hurricane Harvey on Buffalo Bayou and the San Jacinto Estuary, Galveston Bay, USA. Science of The Total Environment, 748, 141226. https://doi.org/10.1016/j.scitotenv.2020.141226
Methods

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Dickson, A. G., & Riley, J. P. (1979). The estimation of acid dissociation constants in seawater media from potentionmetric titrations with strong base. I. The ionic product of water — Kw. Marine Chemistry, 7(2), 89–99. doi:10.1016/0304-4203(79)90001-x https://doi.org/10.1016/0304-4203(79)90001-X
Methods

Dickson, A. G., Afghan, J. D., & Anderson, G. C. (2003). Reference materials for oceanic CO2 analysis: a method for the certification of total alkalinity. Marine Chemistry, 80(2), 185–197. https://doi.org/10.1016/S0304-4203(02)00133-0
Methods

Douglas, N. K., & Byrne, R. H. (2017). Achieving accurate spectrophotometric pH measurements using unpurified meta-cresol purple. Marine Chemistry, 190, 66–72. doi:10.1016/j.marchem.2017.02.004
Methods

Du, J., & Park, K. (2019). Estuarine salinity recovery from an extreme precipitation event: Hurricane Harvey in Galveston Bay. Science of The Total Environment, 670, 1049–1059. https://doi.org/10.1016/j.scitotenv.2019.03.265
Methods

Du, J., Park, K., Dellapenna, T. M., & Clay, J. M. (2019). Dramatic hydrodynamic and sedimentary responses in Galveston Bay and adjacent inner shelf to Hurricane Harvey. Science of The Total Environment, 653, 554–564. https://doi.org/10.1016/j.scitotenv.2018.10.403
Methods

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southern flounder (Paralichthys lethostigma) in the Galveston Bay Estuary, TX. Journal of Sea Research, 59(4), 259–268. https://doi.org/10.1016/j.seares.2008.02.006
Methods

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Methods

Lewis, E. R., & Wallace, D. W. R. (1998). Program Developed for CO2 System Calculations. Environmental System Science Data Infrastructure for a Virtual Ecosystem. https://doi.org/10.15485/1464255
Methods

Liu, X., Patsavas, M. C., & Byrne, R. H. (2011). Purification and Characterization of meta-Cresol Purple for Spectrophotometric Seawater pH Measurements. Environmental Science & Technology, 45(11), 4862–4868. doi:10.1021/es200665d
Methods

Montagna, P. A., Palmer, T. A., & Beseres Pollack, J. (2013). Hydrological Changes and Estuarine Dynamics. In SpringerBriefs in Environmental Science. Springer New York. https://doi.org/10.1007/978-1-4614-5833-3
Methods

Morse, J. W., Presley, B. J., Taylor, R. J., Benoit, G., & Santschi, P. (1993). Trace metal chemistry of Galveston Bay: water, sediments and biota. Marine Environmental Research, 36(1), 1–37. https://doi.org/10.1016/0141-1136(93)90087-g https://doi.org/10.1016/0141-1136(93)90087-G
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Solis, R. S., & Powell, G. L. (1999). Hydrography, mixing characteristics, and residence times of Gulf of Mexico estuaries. In T. S. Bianchi, J. R. Pennock, & R. R. Twilley (Eds.), Biogeochemistry of Gulf of Mexico estuaries (pp. 29–62). New York, NY: John Wiley & Sons.
Methods

Uppström, L. R. (1974). The boron/chlorinity ratio of deep-sea water from the Pacific Ocean. Deep Sea Research and Oceanographic Abstracts, 21(2), 161–162. doi:10.1016/0011-7471(74)90074-6
Methods

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Parameters

Parameters for this dataset have not yet been identified

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Instruments

Dataset-specific Instrument Name	AS-Alk2 alkalinity titrator (Apollo SciTech Inc.)
Generic Instrument Name	Apollo SciTech AS-ALK2 total alkalinity titrator
Dataset-specific Description	Total alkalinity was analyzed with an AS-Alk2 alkalinity titrator manufactured by Apollo SciTech, at 22.0+/-0.1 deg.C using gran titration of a 25 mL water sample with 0.1 M Hal solution (in 0.5 M NaCl), with a precision of +/-0.1%.
Generic Instrument Description	An automated acid-base titrator for use in aquatic carbon dioxide parameter analysis. The titrator provides standardisation and sample analysis, using the Gran titration procedure for alkalinity determination of seawater and brackish waters. It is designed for both shipboard and land based laboratory use. The precision of the instrument is 0.1 percent or higher, and sample volumes may range from 10-25 ml. Titration takes approximately 8 minutes per sample, and the repeatability is within plus or minus 1-2 micromoles per kg.

Dataset-specific Instrument Name	AS-C3 DIC analyzer (Apollo SciTech Inc.)
Generic Instrument Name	Apollo SciTech AS-C3 Dissolved Inorganic Carbon (DIC) analyzer
Dataset-specific Description	Dissolved inorganic carbon was analyzed with an AS-C3 DIC analyzer manufactured by Apollo SciTech Inc., by acidifying 0.5 mL water samples with 0.5 mL 10% H_3PO_4 using a 2.5 mL syringe pump, with a precision of +/-0.1%.
Generic Instrument Description	A Dissolved Inorganic Carbon (DIC) analyzer, for use in aquatic carbon dioxide parameter analysis of coastal waters, sediment pore-waters, and time-series incubation samples. The analyzer consists of a solid state infrared CO_2 detector, a mass-flow controller, and a digital pump for transferring accurate amounts of reagent and sample. The analyzer uses an electronic cooling system to keep the reactor temperature below 3 degrees Celsius, and a Nafion dry tube to reduce the water vapour and keep the analyzer drift-free and maintenance-free for longer. The analyzer can handle sample volumes from 0.1 - 1.5 milliliters, however the best results are obtained from sample volumes between 0.5 - 1 milliliters. It takes approximately 3 minutes per analysis, and measurement precision is plus or minus 2 micromoles per kilogram or higher for surface seawater. It is designed for both land based and shipboard laboratory use.

Dataset-specific Instrument Name	Benchtop salinometer (OrionStar A12, Thermo Scientific)
Generic Instrument Name	Salinometer
Dataset-specific Description	Salinity was measured with an OrionStar A12 Benchtop salinometer manufactured by Thermo Scientific.
Generic Instrument Description	A salinometer is a device designed to measure the salinity, or dissolved salt content, of a solution.

Dataset-specific Instrument Name	Spectrophotometric method
Generic Instrument Name	Spectrophotometer
Dataset-specific Description	pH was analyzed using the spectrophotometric method and purified m-cresol purple (mCP) obtained from Dr. Robert Byrne's lab (University of South Florida), analyzed on the total scale with a precision of +/-0.0004. Prior to analyses, a calibrated OrionRoss glass electrode was used to adjust the indicator to pH 7.92+/-0.01, and a 10 cm water-jacketed absorbance cell of pH was kept at 25+/-0.01 degrees C.
Generic Instrument Description	An instrument used to measure the relative absorption of electromagnetic radiation of different wavelengths in the near infra-red, visible and ultraviolet wavebands by samples.

Dataset-specific Instrument Name	Metrohm Titrando 888
Generic Instrument Name	Titrator
Dataset-specific Description	Calcium [Ca2+] concentration was measured with a Metrohm Titrando calcium-selective electrode on a titration system using automatic potentiometric titration with ethylene glycol tetra acetic acid (EGTA), with a precision of +/-0.2%.
Generic Instrument Description	Titrators are instruments that incrementally add quantified aliquots of a reagent to a sample until the end-point of a chemical reaction is reached.

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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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