**Ocean Acidification in the Gulf of Mexico: Drivers, Impacts, and Unknowns Supplemental Information**

Emily Osborne1\*, Xinping Hu2, Emily R. Hall3, Kimberly Yates4, Jennifer Vreeland-Dawson5, Katie Shamberger6,Leticia Barbero1,7, J. Martin Hernandez-Ayon8, Fabian A. Gomez1,9, Tacey Hicks6, Yuan-Yuan Xu1,7, Melissa R. McCutcheon2, Michael Acquafredda10, Cecilia Chapa-Balcorta11, Orion Norzagaray8, Denis Pierrot1, Alain Munoz-Caravaca12, Kerri L. Dobson10, Nancy Williams13, Nancy Rabalais14, Padmanava Dash15

1Atlantic Oceanographic and Meteorological Laboratory, National Oceanographic and Atmospheric Administration, Miami, FL, US 2Harte Research Institute for Gulf of Mexico Studies, Texas A&M University-Corpus Christi, US 3Mote Marine Laboratory, Sarasota, FL, US 4U.S. Geological Survey, St. Petersburg, FL, US 5Gulf of Mexico Coastal Ocean Observing System Regional Association, Texas A&M University-Corpus Christi, TX, US  6Department of Oceanography, Texas A&M University, College Station, TX, US 7Cooperative Institute for Marine and Atmospheric Studies, Rosenstiel School for Marine and Atmospheric Science, University of Miami, Miami, FL, US 8Autonomous University of Baja California, Mexico 9Northern Gulf Institute, Mississippi State University, MS, US 10Ocean Acidification Program, National Oceanographic and Atmospheric Administration, Silver Spring, MD, US 11Instituto de Recursos, Universidad del Mar. Puerto Angel, Oaxaca, Mexico 12Center for Environmental Studies in Cienfuegos, Cuba 13College of Marine Science, University of South Florida, Saint Petersburg, FL 14Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge, LA, US 15Department of Geosciences, Mississippi State University, Mississippi State, MS, US

\*Corresponding Author: emily.osborne@noaa.gov, 4301 Rickenbacker Causeway, Miami, FL 33149

Detailed information about the known carbonate chemistry observing efforts, both published and unpublished, across the Gulf of Mexico (GOM, Supplemental Table 1).

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| --- | --- | --- | --- | --- |
| **Dataset** | **Data Type** | **GOM Region** | **Data access** | **Source and Contact** |
| Gulf of Mexico Ecosystems and Carbon Cruise (GOMECC, 2007, 2012, 2017, 2021) | Discrete water column dissolved inorganic carbon (DIC), total alkalinity (TA), pH, partial pressure of carbon dioxide (*p*CO2), carbonate (CO3), dissolved oxygen (DO), nutrients, chlorophyll (chl) and surface *p*CO2 | Gulf wide | 1<https://www.ncei.noaa.gov/access/oads/> | U.S. National Oceanic and Atmospheric Administration (NOAA)/Atlantic Oceanographic & Meteorological Laboratory (AOML)  L. Barbero |
| Ship of Opportunity (SOOP)-Carbon Dioxide (CO2)  & SOOP-Ocean Acidification (OA) (2008-present) | Surface *p*CO2 | Gulf wide | 2<https://www.ncei.noaa.gov/access/ocean-carbon-data-system/> | U.S. NOAA/AOML  D. Pierrot |
| NOAA OA Product Suite (2014-2020) | Satellite data assimilation | Eastern GOM and Caribbean | 3<https://www.coral.noaa.gov/accrete/oaps.html> | U.S. NOAA/AOML  R. Van Hooidonk |
| Northern Gulf of Mexico (nGOMx) Acidification (2017, 2018, 2019) | Discrete water column DIC, TA, pH, DO and | Northern GOM Shelf | 4<https://doi.org/10.26008/1912/bco-dmo.831523.1> 5<https://doi.org/10.1575/1912/bco-dmo.772513.2> | U.S. University of Delaware W.-J. Cai |
| nGOMx Acidification (2017) | Surface *p*CO2 | Northern GOM Shelf | 6<https://doi.org/10.1575/1912/bco-dmo.770864.1> | US University of Delaware W.-J. Cai |
| nGOMx Bottom Water (2006-2017) | Bottom water DIC and TA | Northern GOM Shelf | 7<https://doi.org/10.26008/1912/bco-dmo.818773.1> | US University of Delaware W.-J. Cai |
| nGOMx Shelfwide Hypoxia Cruise (2010, 2011, 2012, 2013, 2014, 2015, 2016) | Discrete water column DIC, TA, pH | Northern GOM Shelf | 8<https://doi.org/10.7266/N7Z899TR>  9<https://doi.org/10.7266/N7513WM8>  10<https://doi.org/10.7266/N78913VT>  11<https://doi.org/10.7266/N7000046>  12<https://doi.org/10.7266/N73R0QXQ>  13<https://doi.org/10.7266/N77H1GM0>  14<https://doi.org/10.7266/N7GF0S2N> | US Texas A&M-Corpus Christi (CC)  X. Hu |
| Coastal Mississippi OA Mooring (2011-2017) | Surface and atmospheric CO2 and surface water pH | Northern GOM Shelf | 15<https://www.pmel.noaa.gov/co2/story/Coastal+MS> | US NOAA/Pacific Marine Environmental Laboratory (PMEL)  A. Sutton |
| Coastal Louisiana OA Mooring (2017-present) | Surface and atmospheric CO2 and surface water pH | Northern GOM Shelf | 16<https://www.pmel.noaa.gov/co2/story/Coastal+LA> | US NOAA/PMEL  A. Sutton |
| Cheeca Rocks Coral Reef OA Mooring (2011-present) | Surface and atmospheric CO2 and surface water pH | Florida Shelf (Florida Keys National Marine Sanctuary) | 17<https://www.pmel.noaa.gov/co2/story/Cheeca+Rocks> | US NOAA/PMEL  A. Sutton |
| Tampa Bay Estuary and Eastern Gulf of Mexico (2018-present) | Real time pH, surface *p*CO2, DO; discrete mid-water column TA, DIC, pH | Florida West Coast Estuary and West Florida Shelf | 18<http://tampabay.loboviz.com/>;  19<https://coastal.er.usgs.gov/data-release/doi-P91T185R/> ;  20<https://doi.org/10.5066/P9HS7ZV0>;  21<https://coastal.er.usgs.gov/data-release/doi-P9BAFC7L/> | US USGS  K. Yates |
| Texas Estuarine Acidification Sites (2016-2017) | Surface pH and *p*CO2 | Port Aransas Ship Channel, Texas, | 22<https://doi.org/10.25921/dkg3-1989> | US Texas A&M-CC  X. Hu |
| Estuarine Acidification Sites (2014-2017 & 2018-2020) | Discrete water column TA, DIC, pH | Texas Estuaries | 23<http://doi.org/10.26008/1912/bco-dmo.835227.1>  24<http://doi.org/10.1575/1912/bco-dmo.784673.1> | US Texas A&M-CC  X. Hu |
| Estuarine Acidification Sites (2015, 2016) | Discrete water column TA, DIC, pH | Texas Estuaries | 25<https://doi.org/10.1007/s12237-019-00588-0> | US Texas A&M-CC  X. Hu |
| Flower Garden Banks Seasonal Sampling (2013-2016) | Discrete water column TA, DIC, pH | Northern GOM Shelf (Flower Garden Banks) | 26<http://doi.org/10.7266/N7G15Z9M> | US Texas A&M-CC  X. Hu |
| Texas A&M University (TAMU) Galveston Bay Cruises (2017-2019) | Discrete water column TA, DIC, dissolved inorganic nutrients, DO | Estuary (Galveston Bay, Texas) | Written communication,  [June 17, 2022] | US Texas A&M  K.E.F. Shamberger,  Department of Oceanography, Texas A&M University, College Station, TX, US |
| TAMU OA Cruises (2015-2019) | Discrete water column TA, DIC, dissolved inorganic nutrients, DO | Northern GOM Shelf (Texas Shelf and Flower Garden Banks) | 27<https://www.bco-dmo.org/dataset/787575> | US Texas A&M  K.E.F. Shamberger |
| Mote Marine Lab Sampling  (2019-present) | Discrete water column TA, DIC, pH, nutrients (dissolved, particulate, total), phytoplankton community, toxins | West Florida Shelf and Estuaries | Written communication,  [June 17, 2022]  Available upon request through Fish and Wildlife Research Institute HABdata@MyFWC.com | US Mote Marine Laboratory  E. Hall,  Mote Marine Laboratory, Sarasota, FL, US |
| Southern GOM (XIXIMI) Cruises  (2010, 2011, 2013, 2015, 2016, 2017) | Discrete water column TA, DIC, pH, nutrients, phytoplankton | Open GOM and Bay of Campeche | Written communication,  [June 17, 2022] | Mexico University of Baja California  J.M. Hernández-Ayon,  Autonomous University of Baja California, Mexico |
| Mississippi Based RESTORE Act Center of Excellence (MBRACE) Sampling  (2018-present) | Discrete water column TA, DIC, pH, DO, nutrients, phytoplankton community structure, Chl-a, Phycocyanin, toxins | Northern GOM Shelf (Mississippi Sound over the natural oyster reefs) | Written communication,  [June 17, 2022] | US Mississippi State University  P. Dash,  Department of Geosciences, Mississippi State University, Mississippi State, MS, US |
| Veracruz Reef System National Park Stations (2018, 2020) | Discrete water column  temperature, salinity, pH, TA, DIC | East Mexico Shelf | Written communication,  [June 17, 2022] | Mexico Universidad del Mar/Universidad Veracruzana  C. Chapa Balcorta,  Instituto de Recursos, Universidad del Mar. Puerto Angel, Oaxaca, Mexico |
| Veracruz SeapHOX monitoring station (2019-2021) | 20 m depth temperature, salinity, oxygen, pH | East Mexico Shelf | Written communication,  [June 17, 2022] | Mexico Universidad del Mar and Universidad Veracruzana  C. Chapa Balcorta,  Instituto de Recursos, Universidad del Mar. Puerto Angel, Oaxaca, Mexico |
| Malla Fina Campaign, Gulf of Mexico Research Consortium (CIGOM) project (March and September 2016) | Discrete water column TA, DIC, pH | East and South Mexico Shelf | Written communication,  [June 17, 2022] | Mexico, University of Baja California  O. Norzagaray,  Autonomous University of Baja California, Mexico |
| Cuba OA Monitoring Stations  (2020-present) | pH and TA | Cuba Shelf | Written communication,  [June 17, 2022] | Cuba  A.Munoz-Caravaca,  Center for Environmental Studies in Cienfuegos, Cuba |

# **Supplemental Table 1.** GOM carbonate chemistry data availability. Full references for data access links are available in the Data Access Link References section and correspond to superscript numbers.

**Supplemental Text:**

The Gulf of Mexico is bordered by three countries, each having their own research programs monitoring and studying the region with varying degrees of collaboration.

**Cuba**

With the support of the Cuban National Science Program and the Technical Cooperation Department of the International Atomic Energy Agency, the Environmental Studies Center of Cienfuegos (CEAC) has implemented two ocean acidification fixed stations which have been operational since 2020. The pH and alkalinity are measured weekly at the southern station and monthly at the northern one. CEAC leads a REMARCO scientific network (www.remarco.org), involving almost all Latin-American countries with OA research groups.

**Mexico**

Mexico has conducted six oceanographic cruises covering the central and southern regions of the Exclusive Economic Zone of Mexico that were carried out in November 2010, July 2011, February–March 2013, August–September 2015, July 2016, and August-September 2017 (XIXIMI-01–XIXIMI-06, respectively) on board the R/V *Justo Sierra;* two oceanographic cruises (March and September 2016) that covered the Perdido region (~26° N) in the northwestern gulf and the Coatzacoalcos regions in Campeche Bay (CB, ~94° W) were added (Figure 1). This initiative was under the leadership the Gulf of Mexico Research Consortium (CIGoM) founded in 2015 as a consortium of scientific research and consulting services. It involved the participation of a Mexican initiative that arose from the shared ideas of a group of scientists and PEMEX personnel, due to the lack of available information to understand and act in the event of possible large-scale hydrocarbon spills in the Gulf of Mexico. As a precedent, the CIGoM was financed by the Sector Fund of the National Council of Science and Technology (Conacyt) and the Ministry of Energy (Sener Hidrocarburos).

**U.S.**

By far the biggest effort is sponsored by the United States through several programs: The NOAA Ocean Acidification Program (OAP) funds the Ship of Opportunity- OA (SOOP-OA) effort which maintains two NOAA research vessels (RV Gordon Gunter since 2008 and RV Henry Bigelow since 2011) outfitted with underway surface *p*CO2 systems (https://www.aoml.noaa.gov/ocd/ocdweb/occ.html), which also collects of discrete samples opportunistically on several vessels that are analyzed for carbonate parameters (https://www.aoml.noaa.gov/ocd/gcc/shortcruises.htm). It also produces an Ocean Acidification Product Suite which utilizes satellite data and a data-assimilative hybrid model to map the components of the carbonate system of surface water and provide monthly surface estimates of OA parameters in the eastern half of the GOM (https://www.coral.noaa.gov/accrete/oaps.html). OAP also has supported synoptic carbonate chemistry surveys (Gulf of Mexico Ecosystems and Carbon Cycle, GOMECC) conducted on ~4-5-year intervals (2007, 2012, 2017, 2021) that sample around the entire GOM region along cross shelf to deep basin transects, but with a focus on coastal regions and only a handful of stations in deep waters (Wang et al., 2013; Wanninkhof et al., 2015; Barbero et al., 2019). GOMECC-3 in 2017 increased the collaboration between the three bordering nations by including both Mexican and Cuban scientists in the cruise.

The NOAA Global Ocean Monitoring and Observing (GOMO) Program sponsors the Ship of Opportunity CO2 (SOOP-CO2) program which, although limited to surface waters, continues to provide data from underway *p*CO2 systems installed on ships that transit occasionally across the entire Gulf. SOOP-OA and SOOP-CO2 provide the vast majority of surface *p*CO2 data available in the Gulf since 2008 and has vastly built out year-round observations (Bakker et al., 2016; Kealoha et al., 2020). All those data are available through the international Surface Ocean CO2 Atlas (SOCAT) effort ([www.socat.info](http://www.socat.info/)) which provides free access to quality-controlled, surface ocean *f*CO2 observations from more than 100 international contributors across the globe, as well as gridded data products (Bakker et al., 2016). GOMO also funds several Moored Autonomous *p*CO2 (MAPCO2) buoys, two of which were deployed in the Gulf region in 2011: the first one was deployed in March of 2011 close to the coast of Mississippi, and was relocated in 2017 ashore of the coast of Louisiana (<https://www.pmel.noaa.gov/co2/story/Coastal+LA>). The second one was deployed

in December 2011 at Cheeca Rocks in the Florida Keys (<https://www.pmel.noaa.gov/co2/story/Cheeca+Rocks>). They all collect tri-hourly *p*CO2 and pH data.

The USGS has funded several cruises, data collection activities, and moored autonomous monitoring systems in Tampa Bay and the eastern Gulf of Mexico (e.g., Yates et al., 2007, 2018, 2020, 2021; Challener et al., 2015; Robbins et al. 2018; Tampa Bay LOBO, 2017). NOAA OAP, SECOORA and FWRI also fund bi-monthly cruises from the Florida Keys to north of Tampa Bay to assess Harmful Algal Bloom (HAB) conditions that since 2019 also include carbonate samples, and FWRI funds cruises along the west-central coast of Florida to assess HABs and since 2019 also include carbonate samples.

OA observing efforts include the permanent OA monitoring program on coral reefs, consisting of a SeapHOx time series (temperature, salinity, oxygen, pH) and a sampling grid inside the Veracruz Reef System National Park sampled on an annual basis. Also, calcification experiments with coral colonies of *Acropora palmata*, *Orbicella annularis*, *Pseudodiploria strigosa* were set up in this national park.

The Environmental Protection Agency (EPA) Estuaries and the National Estuary Program (NEP) began its first targeted effort to observe acidification in estuarine environments by purchasing pH and *p*CO2 sensors, several of which are in the GOM region including Tampa Bay, Florida, Aransas Bay, Texas, and Mobile Bay, Alabama. In partnership with EPA NEP, the Tampa Bay Estuary Program, and University of South Florida, USGS leads ocean and coastal acidification research and monitoring efforts with ocean acidification fixed observing assets in Tampa Bay and nearshore GOM, co-deployed on a USF Physical Oceanographic Real Time System (IPORTS) station and a Coastal Ocean Monitoring and Prediction System C12 Buoy. The Northern GOM Shelf is the most OA data rich region within the GOM, due largely to repeated observations of the seasonal hypoxic area, or “dead zone,” that develops every summer and is associated with intense bottom water acidification (Cai et al. 2011). The earliest carbonate chemistry data (TA and DIC) in the northern GOM was collected in 1998 (Cai 2003). NOAA has supported annual research cruises since 1985 to determine the spatial extent of hypoxia (Rabalais et al. 2001) and cruises that include full water column carbonate chemistry data from 2010 (Hu et al. 2017). Carbonate chemistry data have also been collected in this region on ships of opportunity cruises supported by EPA, University of Southern Mississippi as well as NSF-funded projects (e.g. Cai et al. 2011, Wang et al. 2020).

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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**Data Access Link References (see Supplemental Table 1)**

1NOAA National Center for Environmental Information, Ocean Carbon and Acidification Data Portal (NCEI-OCADS). <https://www.ncei.noaa.gov/access/oads/>.

2NOAA National Center for Environmental Information, Ocean Carbon and Acidification Data System (NCEI-OCADS). <https://www.ncei.noaa.gov/access/ocean-carbon-data-system/>.

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