CARICOOS-OCEAN ACIDIFICATION MONITORING PROGRAM

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LONG-TERM GOALS

A key CARICOOS mission is to understand and predict changes in our ocean and coasts and inform decision makers in the US Caribbean region. Ocean acidification (OA) represents one such change unfolding in direct response to increasing atmospheric carbon dioxide (CO_2) concentrations. This project works to improve our understanding of how OA impacts the coral reef ecosystem and the biogeochemical process controlling the near-reef carbonate dynamics. This is achieved using high-temporal resolution chemical monitoring, which aids NOAA's Coral Reef Monitoring Program efforts to establish baselines and track changes in both carbonate chemistry and associated ecological impacts of OA. Furthermore, this effort supports NOAA's progress towards achieving a holistic understanding of the Earth system, identified as a core objective of NOAA's Science and Technology Enterprise.

MILESTONES / OBJECTIVES

1. Provide information about the existing and foreseeable carbon chemistry conditions to help mitigate the causes and effects of OA and support adaptation to ecosystem changes.

2. Continued biweekly sampling for carbonate chemistry at selected sites along the offshore to nearshore gradient in La Parguera Marine Reserve. Data is used for validating automated collection by La Parguera MapCO2 buoy and assessing the role of nearshore ecosystems in the local carbonate chemistry.

3. Provide operational maintenance to the MAP CO2 buoy and support data management and product dissemination.

4. Quality assurance, synthesis and reporting of adquired data.

5. Provide yearly maintenance of La Parguera MapCO2 buoy.

WORK COMPLETED

- The field and analytical campaigns were successfully completed for the FY16. Sixty one (61) bi-weekly cruises to collect surface water samples and CTD profiles have been completed at LPMR, and a hundred and twenty (120) pH samples have been analyzed at CARICOOS lab. A hundred and twenty (120) DIC and a hundred and twenty seven (127) TA samples have been analyzed at UNH. Of those TA and DIC samples, eight (8)

were from samples collected in 2016, the rest were from 2015.

- Continued periodic issuance of data management and product dissemination. The MapCO2 data is retrieved and transmitted through the:

    1) IOOS Pacific Region Ocean Acidification (IPACOA) data portal: (http://www.ipacoa.org/Explorer?action=oiw:fixed_platform:PMELCO2_laparguera:observations:A1_CO2Air)

    2) CARICOOS: http://www.caricoos.org/oceans/acidification/atmospheric
    http://www.caricoos.org/oceans/acidification/seawater
    http://www.caricoos.org/oceans/observation/aragonite
    http://www.caricoos.org/ipacoa-ocean-acidification

    3) Pacific Marine Environmental Laboratories (PMEL): http://www.pmel.noaa.gov/co2/story/La+Parguera

- Discrete data was submitted to the National Centers for Environmental Information (NOAA/NCEI) on February 2016.

- Completed a 48 hrs. diurnal sampling from January 7th to January 15th of 2016 at the MapCO2 and seagrass stations using a custom made CO_2 buoy equipped with oxygen optodes, temperature and salinity recorders, fluorometer and turbidity sensors at two different depths. Twenty two (22) surface measurements of TA and DIC were collected and analyzed at UNH.

MAJOR OUTCOMES

In FY15 CARICOOS granted a subaward to J. Salisbury, U. New Hampshire (UNH) to provide support in maintaining and enhancing the autonomous and discrete observing including analytical support for DIC determinations, assisting the yearly operation and maintenance of the MAPCO2 buoy, providing required data management and supporting data product dissemination. While a core effort remains to maintain and enhance autonomous capabilities at the AOAT, progress towards addressing core science questions arising from MAPCO2 data includes the implementation of numerical analysis for the identification of the primary controls on near-reef carbonate chemistry. Also, a significant extension of the water sampling and analysis has commenced with the goal of improved understanding of the spatial variability of carbonate chemistry along the La Parguera mangrove-seagrass-coral reef-offshore gradient.

Mitigating an involuntary delay in the analysis for alkalinity at UNH, these are working on minimizing the number of discrete samples pending on analysis. Another student will be hired to help on these analyses and estimate date to finish is May 2017.

The goals of the above 48 hrs diurnal sampling effort were to characterize the OA diurnal variability at the two sites and to test the use of a low-cost sensor for the automated measurement of CO_2, calibrated for stream and estuaries, but not in coral reef areas. The results showed a significant offset between the observed MapCO2 measurements and the K30 CO2 sensor. Continued improvements of the diurnal sampling will include identifying better methods to characterize the reef and seagrass metabolic variability at site.

Meléndez is currently finishing modeling and analyzing the seawater pCO_2 and Ω_{Arg} constraints at the MapCO2 buoy. Some of her findings are explained below:

1. Seawater pCO2 at Enrique coral reef MapCO2 buoy from 2009 to Jan 2016 indicated that changes in seawater pCO2 at Enrique reef are strongly associated with both community inorganic and organic carbon production processes, but also have an interesting seasonal variability that is closely associated with the annual arrival of a fresh water mass associated with the Amazon and Orinoco Rivers. As a consequence of both community calcification and respiration processes, Enrique is a persistent source of CO_2 to the atmosphere (1.8 mmol CO_2 m^{-2} d^{-1}, S_E = 0.04) with at maximum peak during the summer and fall seasons. During the same time, carbonate mineral saturation states with respect of aragonite mineral phase (Ω_{Arg}) are generally lower along the fore-reef relative to offshore waters and dominantly controlled by short-term seawater pCO_2 dynamics primarily driven by benthic community organic matter productivity, temperature, salinity and seasonal changes. At this time, high temperatures coincide with intense local rainfall and the influx of the low-salinity Amazon and Orinoco River plumes into the eastern Caribbean.

2. The Ω_{Arg} time series showed a decrease of 0.03 % yr^{-1}. Results agreed with the trend reported by Gledhill et al. (2008) and Jiang (2015) for the Caribbean region. Although, the relatively short duration of the time series (<10 years) may not be sufficient to categorically determine whether La Parguera Ω_{Arg} has decreased over time, it sheds some light regarding the effects of climate-scale processes on local/regional coral reef ecosystems. Under a business as usual CO2 scenario, in the next 10 years LPMR will reach the low values reported as critical for coral calcification and dissolution could start playing a major role on the community metabolism processes.

3. Probability distribution function analysis of the TA-Salinity ratios between the offshore, reef and open ocean data from cruises in the Caribbean Sea showed a bimodal distribution indicating two different end members attributed to salinity differences. This data set provides for the computation of a site-specific algorithm for first order derivations of other carbonate system parameters and thus improvement and continued refinement of the current NOAA Coral Reef Watch Ocean Acidification Product Suite (OAPS, version 0.6).

In an effort to understand the hydrodynamics in the area and their influence on the local carbonate chemistry, a series of ADCP's provided by the UPRM and CARICOOS were deployed on FY16 to begin monitoring the flow dynamics across LPMR. Current profiles spanning 12 m of depth were resolved with a bottom-mounted ADCP month-long hydrodynamic assessment near a fore reef site located within 100 m of the MapCO2 buoy. Dr. Sylvia Rodriguez-Abudo showed some preliminary results at the Ocean Science Meeting this year. Results showed that under no wind conditions, dominant currents are tidally driven and aligned with the reef channel. The analysis also shows that at times surface current direction can differ from near-reef currents by as much as 200 degrees, suggesting a possible mismatch between surface and benthic carbonate chemistry.

RELATED PROJECTS

- PR SeaGrant 2016-2018 - *Natural Coastal Barriers at Risk: A First Assessment of Biogeochemical and Physical Stressors.* **PI:** Joe Salisbury **Co-PIs:** Melissa Melendez, Sylvia Rodríguez-Abudo, Julio Morell

- NOAA OAP/IOOS 2015-2018- *Tracking Ocean Alkalinity using New Carbon Measurement Technologies (TAACT).* **PI:** Joe Salisbury **Co-PIs:** Steffen Aßmann, Peer Fietzek, Carsten Frank, Jonathan Hare, William Mook, Ru Morrison, Douglas Vandemark, Christopher W. Hunt, Rik Wanninkhof

- Julio Morell, Melissa Meléndez and Joe Salisbury are part of the Puerto Rico Climate Change Council (PRCCC). We are working on the State of the Climate 2014-2017, based on the previous PRCCC publication, State of the Climate 2010-2013, where Morell and Meléndez collaborated. Melendez is the leader of two subsections on Ocean Acidification (Changes in Caribbean Climate and Puerto Rico's Climate) and Julio Morell is the leader of two subsections on Ocean Temperature.

WORK PLAN FOR UPCOMING PERFORMANCE PERIOD (Dec. 1 – May 31 2016)

- The buoy refurbishment for FY17 will be completed from January 9th to January 18th of 2017.
- UNH discrete bottle samples - to be finished by May 2017.

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Jiang, L.; Feely, R. A.; Carter, B. R.; Greeley, D. J.; Gledhill, D. K.; Arzayus, K. M. Global Biogeochemical Cycles Saturation State in the Global Oceans. 2015, 1656–1673.

PUBLICATIONS & PRODUCTS

Melissa Meléndez, Dwight K. Gledhill, Chris Langdon, Chris Sabine, Sylvia Musielewicz, Valentine Hensley, Noah Lawrence-Slavas, Derek Manzello, Jorge E. Capella, **Julio M. Morell**, **Joe Salisbury**. Sustained monitoring of near-reef carbonate chemistry at the Atlantic Ocean Acidification Test-bed, La Parguera, Puerto Rico. Manuscript in preparation.

Tyler Cyronak, Andreas J. Andersson, Chris Langdon, Rebecca Albright, Nicholas R. Bates**, Jorge E. Corredor**, Rob B. Dunbar, Bradley D. Eyre, Jean-Pierre Gattuso, Dwight Gledhill, Hajime Kayanne, David Koweek, Coulson Lantz, Derek Manzello, Ashly McMahon, **Melissa Meléndez**, Heather Page, Isaac R. Santos, Emily Shaw, Jack Silverman, Atsushi Suzuki, Lida Teneva, Atsushi Watanabe, Shoji Yamamoto. Taking the Pulse of the World's Coral Reefs. Science Advances. Submitted.

Sutton, A.J., C.L. Sabine, R.A. Feely, W.-J. Cai, M.F. Cronin, M.J. McPhaden, **J.M. Morell**, J.A. Newton, J.-H. Noh, S.R. Ólafsdóttir, J.E. Salisbury, U. Send, D. Vandemark, and R.A. Weller (2016): Using present-day observations to detect when anthropogenic change forces surface ocean carbonate chemistry outside preindustrial bounds. Biogeosciences, 13(17), 5065–5083, doi: 10.5194/bg-2016-104.

Online data set

Dissolved inorganic carbon, total alkalinity, pH, phosphate, dissolved oxygen, and other variables collected from surface discrete observations using Niksin bottle and other instruments

from R/V Sultana in the southwest coast of Puerto Rico from 2009-01-05 to 2016-02-01 (NCEI Accession 0145164) http://www.nodc.noaa.gov/oceanacidification/stewardship/data_portal.html

Strategic and policy documents

The Puerto Rico's state of the climate 2010-2013: Assessing Vulnerabilities in a changing climate. PR Coastal Zone Management Program, Department of Natural and Environmental Resources, and NOAA Ocean and Coastal Resource Management. http://www.drna.gobierno.pr/oficinas/arn/recursosvivientes/costasreservasrefugios/pmzc/prccc/prccc-2013/WG1.pdf

Talks

Meléndez M, Salisbury J, Rodriguez-Asubo S, Morell J.M. Natural Coastal Barriers at Risk: A First Assessment of Biogeochemical & Physical Stressors at La Parguera Marine Reserve, Puerto Rico. Earth Sciences Department; May 5, 2016

Morell J.M. and Meléndez M. Coastal Barriers at Risk: Ocean Acidification and Warming in the Caribbean. Coastal Ocean Observing 8th General Assembly and Stakeholders Council Meeting, Club Náutico de San Juan, Puerto Rico; April 27, 2016

Meléndez M, Salisbury J, Morell J.M. Coastal Ocean Acidification at La Parguera, Puerto Rico characterizations of the reef carbonate chemistry and the influence of metabolic processes on a coral reef. Graduate Research Conference; April 12, 2016 and at the School of Marine Science and Ocean Engineering's Graduate Research Symposium; April 21, 2016

Meléndez M, Salisbury J, Morell J.M. Coastal Ocean Acidification at La Parguera CO_2 Buoy. Puerto Rico Climate Change Council (PRCCC) Annual Meeting; April 07, 2016

Meléndez M and Salisbury J. The Other CO_2 problem. Super Stellar Friday, McAuliffe-Shepard Discovery Center, Concord, New Hampshire, USA; April 1, 2016

Meléndez M, Salisbury J, Gledhill D, Musielewicz S, Morell J.M, Manzello D. High temporal resolution characterization of the carbonate chemistry and the relative influence of community metabolic processes on controlling coral reef dynamics at La Parguera, Puerto Rico.Ocean Science Meeting, New Orleans, Louisiana, USA; February 21-26, 2016

García, E, and Morell, J.M. Organic carbon loading in tropical shelf ecosystems: the role of near-shore mangrove lagoons and channels in coastal ocean acidification. Science Meeting, New Orleans, Louisiana, USA; February 21-26, 2016

Morell J.M. Southeast Coastal Ocean Observing Regional Association (SECORA) Fisheries and Climate Workshop: Climate Variability and Fisheries Workshop: Setting Science Priorities for the Gulf of Mexico, South Atlantic, and Caribbean Regions at St. Petersburg, Florida from the 26^{th} to the 28^{th} of October 2015.

Posters

Rodriguez-Abudo S, Melendez M, Morell J.M, Padilla A, Salisbury J. Hydrodynamic observations in support of Moored Autonomous pCO2 buoy efforts at La Parguera Marine Reserve. Science Meeting, New Orleans, Louisiana, USA; February 21-26, 2016

Meléndez M, García E, Salisbury J, Morell J.M. Water Quality and Ocean Acidification in near-shore waters: an emerging challenge for coastal zones. Caribbean Regional Association for Coastal Ocean Observing, Club Náutico de San Juan, PR; March 21, 2015