3rd GOA-ON Science Workshop

May 8-10, 2016
CSIRO Marine Laboratories
Hobart, Tasmania, Australia
http://www.goa-on.org/

Workshop Committee

Dr. Bronte Tilbrook, CSIRO and Antarctic Climate and Ecosystems Cooperative Research Centre, Australia
Dr. Jan Newton, University of Washington, USA
Dr. Libby Jewett, NOAA Ocean Acidification Program, USA
Prof. Fei Chai, University of Maine, USA
Prof. Minhan Dai, State Key Laboratory of Marine Environmental Science, China
Prof. Sam Dupont, University of Gothenburg, Sweden
Dr. Richard Feely, NOAA-PMEL, USA
Dr. Wajih Naqvi, CSIR-National Institute of Oceanography, India
Dr. Maciej Telszewski, International Ocean Carbon Coordination Project, SCOR and IOC-UNESCO
Dr. Phil Williamson, University of East Anglia, UK
Dr. Kirsten Isensee, UNESCO Intergovernmental Oceanographic Commission
Ms. Lina Hansson, International Atomic Energy Agency

Sponsors:

About the workshop

Goals

The 3rd Global Ocean Acidification Observing Network (GOA-ON) International Workshop will be held in Hobart, Australia, following the 4th International Symposium on the Oceans in a High CO_2 World (3-6 May 2016).

GOA-ON is guiding the development of an integrated network for the detection and attribution of ocean acidification and ecosystem response, and has engaged with over one hundred participants from 30 nations to formulate its Requirements and Governance Plan. GOA-ON has also served to focus funding bodies and international research programs to integrate within a shared vision that extends from the coastal to open ocean domains.

The 3rd GOA-ON workshop aims to further the development of the global ocean acidification observing network through the following goals:

- **Update on GOA-ON status and linkages to other global programs**
- **Build regional communities to develop hubs that will facilitate capacity building**
- **Update requirements for biology and ecosystem response measurements**
- **Discuss modeling connections, observational challenges and opportunities**
- **Present advances in technologies, data management and products**
- **Gain input on data product and information needs**
- **Gain input on regional implementation needs**
- **Launch the GOA-ON Mentorship Program**

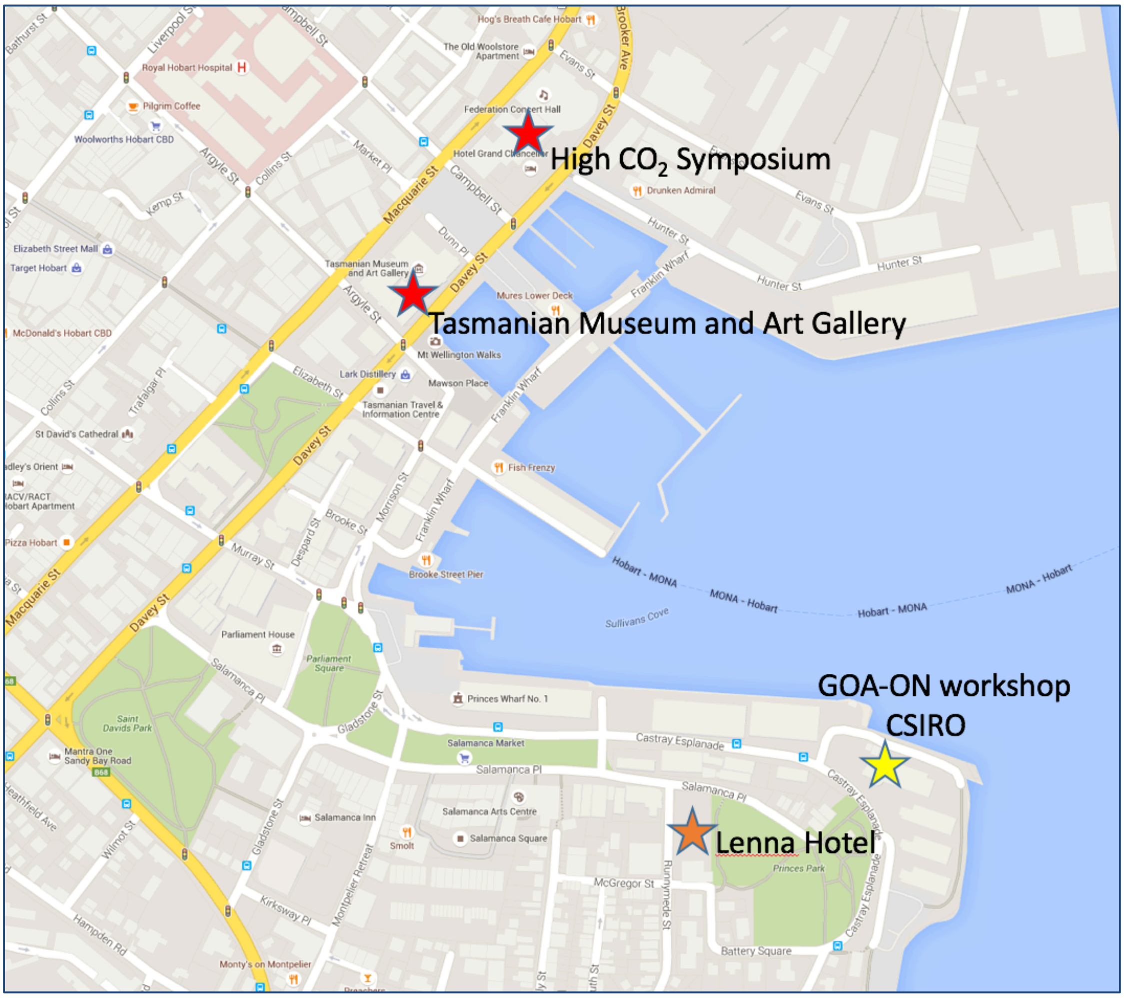
Sponsors

- Commonwealth Scientific and Industrial Research Organisation
- Integrated Marine Observing System
- International Atomic Energy Agency
- International Ocean Carbon Coordination Project
- National Oceanic and Atmospheric Administration
- The Ocean Foundation
- The U.S. Integrated Ocean Observing System
- UNESCO Intergovernmental Oceanographic Commission
- XPRIZE

Special Events

Day 1 (8 May 2016) – **Conference reception,** 1830 - 2030hrs, Tasmanian Museum and Art Gallery
Day 2 (9 May 2016) – **Showcase & Poster Session,** 1800-1930hrs, CSIRO Marine Laboratories

Location Map



Workshop Agenda

DAY 1 – SUNDAY 08 MAY 2016	
0830-0900	**<u>Workshop welcome</u>:** introductions, workshop goals ***Bronte Tilbrook,*** CSIRO and GOA-ON co-chair
0900-0930	**<u>Opening address</u>** ***David Osborn,*** Director, IAEA Environmental Laboratories
	GOA-ON implementation and importance
0930-1000	**<u>OA and GOA-ON in international and intergovernmental context:</u>** Updates from linked programs including GOOS (IOC-UNESCO), Framework for Ocean Observing, IAEA OA International Coordination Centre, Blue Planet, United Nations COP21, and IPCC ***Libby Jewett***, NOAA and GOA-ON co-chair
1000-1100	**<u>GOA-ON vision and progress:</u>** Goals, variables, data quality objectives: *Workshop 1 outcomes* ***Jan Newton***, University of Washington (20 min); Biological variables for regional ecosystems: *Workshop 2 outcomes* ***Phil Williamson***, University of East Anglia (20 min) Discussion (20 min)
1100-1130	Morning Tea & Coffee
1130-1230	**<u>Policy overview on significance of GOA-ON:</u>** Policy development from local to global scales, communication and interaction with stakeholders (e.g., industry, governments). **1) Local scale:** Impact of OA on the US shellfish industry; resulting legislation and actions taken, from the Washington state example ***Samantha Siedlecki***, University of Washington (20 min) **2) Global scale:** International treaties – Prospects to improve OA observation within UNFCCC, Sustainable Development Goals, Convention on Biological Diversity, etc. ***Carol Turley***, Plymouth Marine Laboratory (20 min); ***Kirsten Isensee***, UNESCO (5 min) Discussion (20 min)
1235-1330	Lunch
	Regional implementation of GOA-ON, opportunities for coordination, and needs for GOA-ON data and products
1330-1350	**<u>Case study</u>**: Latin America Ocean Acidification (LAOCA); issues relevant to the Latin American countries, proposed effort, regional coordination ***Cristian Vargas***, University of Concepción
1350-1410	**Regional implementation:** concept of regional hubs and current components **<u>BREAKOUT #1 CHARGE:</u>** Identify OA observing efforts within regions and potential for coordination; define region's science and policy needs for GOA-ON data and products. ***Jan Newton***, University of Washington

1410-1430	Afternoon Tea & Coffee, move to breakout rooms
1430-1700	Breakout #1: Discussion by breakout groups organized by regions
1800-2030	**Reception**, Tasmanian Museum and Art Gallery, hosted by XPRIZE

DAY 2 – MONDAY 09 MAY 2016	
0830-0835	**Day 2 objectives and summary of day 1** ***Bronte Tilbrook***, CSIRO
0835-0845	**Toward increased involvement of developing states in GOA-ON** ***Lina Hansson***, IAEA
0845-0850	**Friends of GOA-ON** ***Mark Spalding***, The Ocean Foundation
0850-0900	**Introduction of GOA-ON Mentorship Effort** ***Libby Jewett***, NOAA
0900-1030	Breakout #1 group reports and discussion
1030-1100	Morning Tea & Coffee
1100-1130	**Challenges in observing OA: distinguishing natural from anthropogenic variability** ***Richard Feely,*** NOAA
1130-1200	**Modeling requirements** for the OA observing network at local, regional, and global scale ***Fei Chai***, University of Maine
1200-1300	Lunch
	Ecological/biological component of GOA-ON
1300-1325	**GOA-ON biology working group** outcomes and recommendations on key biological variables, and theoretical framework linking physical-chemical changes to biological response ***Sam Dupont***, University of Gothenburg, ***Kirsten Isensee,*** IOC-UNESCO
1325-1350	**GOOS Biology and Ecosystems working group EOVs** ***Patricia Miloslavich***, GOOS Biology and Ecosystems Panel
1350-1405	**GOOS Biogeochemical EOVs** and links with GOA-ON requirements ***Maciej Telszewski***, IOCCP Director, SCOR and IOC-UNESCO
1405-1430	**Biological requirements:** **BREAKOUT #2 CHARGE**: Develop recommendations for biological monitoring to serve GOA-ON goals**.** Using the inputs from the three morning sessions (observing challenges, modelling requirements, biology efforts to date), identify biological monitoring system (variables and opportunities) and biological needs from chemical/physical measurements at global, regional, and local scales.

	Jan Newton, University of Washington
1430-1500	Afternoon Tea & Coffee, move to breakout rooms
1500-1730	Breakout #2: Discussions by breakout groups by scale: global, regional, local
1800-1930	**GOA-ON Showcase and poster session** including 3 min talks to provide a showcase for new GOA-ON members to highlight research and to introduce posters

DAY 3 – TUESDAY 10 MAY 2016	
0830-0835	Day 3 objectives ***Jan Newton***, University of Washington
0835-1000	Breakout #2 group reports, discussion, and consensus building
1000-1030	Morning Tea & Coffee Pier-2-Peer "meet your match"
	OA observing technology, data management and products
1030-1050	**Carbonate chemistry calculation considerations** ***Jim Orr,*** LSCE/IPSL
1050-1110	**Technological advances for observing OA** ***Adrienne Sutton***, NOAA
1110-1130	**GOA-ON Data Management and data synthesis products** ***Benjamin Pfeil***, University of Bergen
1130-1200	**Presentation of GOA-ON portal and plans** ***Emilio Mayorga***, University of Washington
1200-1230	**Capacity building needs:** **BREAKOUT #3 CHARGE:** Regional GOA-ON capacity building needs in the next 2-3 years. Define the requirements and opportunities for implementation of GOA-ON activities for: • data synthesis products in both global and regional settings • data management • training workshops and developing communities of practice • development/support of regional networks ***Bronte Tilbrook***, CSIRO
1230-1400	Working lunch for breakout #3 groups
1400-1500	Breakout #3 group reports and discussion
1500-1630	**Synthesis and consensus recommendations** to add to the GOA-ON Plan ***Jan Newton***, University of Washington
1630-1700	Meeting wrap up and thanks

Poster Presentations

(Titles and presenting author below; complete abstracts and authors follow)

Yuri Artioli, Plymouth Marine Laboratory
Sensitivity of the shelf sea ecosystems to Ocean Acidification: a model contribution to GOA-ON Goal 2

Russel Brainard, NOAA Pacific Islands Fisheries Science Center
International, Interdisciplinary, Long-term Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reefs across the Central and Western Pacific

Eugene Burger, NOAA/PMEL
Bridging the OA Data Processing Workflow Gap

Patricia Castillo-Briceno, EBIOAC/ULEAM
Building capacities and bridging gaps on Ocean Acidification research for equatorial developing countries: Ecuadorian experience

Suchana Chavanich, Chulalongkorn University
Development of a Long-term Monitoring Program on the Impacts of Ocean Acidification on Coral Reefs in the Western Pacific and its Adjacent region

Chen-Tung Arthur Chen, National Sun Yat-sen University
Deep oceans may acidify faster than anticipated due to global warming

Liqi Chen, State Oceanic Administration of China
Ocean Acidification Observation Network for the Arctic and sub-Arctic Pacific Oceans

Rachel Hale, National Oceanography Centre, Southampton
Future ocean acidification and temperature rise could alter community structure and functioning in marine benthic communities

Claudine Hauri, IARC, University of Alaska Fairbanks
Monitoring Ocean Acidification with the Northeastern Chukchi Shelf Ecosystem Observatory

Li-Qing Jiang, NOAA NCEI
Ocean Acidification Data Stewardship (OADS) Project

Rodrigo Kerr, IO/FURG
The Western South Atlantic Ocean in a High-CO_2 World: Current Measurement Capabilities and Perspectives

Katsunori Kimoto, Japan Agency for Marine-Earth Science and Technology
Shell density of Planktic Foraminifera in the North Pacific: Seasonal acidification and its ecological impacts

Atsushi Kojima, Japan Meteorological Agency
New empirical equations for total alkalinity in surface waters over the global ocean by using sea surface dynamic height

Nelson Lagos, Centro de Investigacion e Innovacion para el Cambio Climatico, Universidad Santo Tomas
Latin-American Ocean Acidification Network (LAOCA Network)

Modou Mbaye, Cheikh Anta Diop University
West Africa contribution on the global studies on ocean acidification

Fiona Murray, Heriot-Watt University
Working with industry to collect ocean acidification data

Antoine N'Yeurt, The University of the South Pacific
Initiation of Ocean Acidification Time Series in the Fiji Islands

Murugan Palanisamy, University of Madras
Influence of pH on Calcification and Biomarker enzymes of soft shell wedge clam Donax faba (Gmelin)

Juana Magdalena Santana-Casiano, Universidad de Las Palmas de Gran Canaria
The pH evolution at the ESTOC site since 1995

SM Sharifuzzaman, University of Chittagong
Ocean acidification threatens the only coral reef ecosystem of Bangladesh

Rodrigo Torres, CIEP & IDEAL - Universidad Austral de Chile
Carbonate system parameter monitoring along the coast of Chile

Cristian Vargas, Universidad de Concepcion
Riverine and corrosive upwelling waters influences on the carbonate system in the coastal upwelling area off Central Chile: Implications for coastal acidification events

(Full abstracts, arranged by presenting author (*) below)

Sensitivity of the shelf sea ecosystems to Ocean Acidification: a model contribution to GOA-ON Goal 2

Yuri Artioli

Plymouth Marine Laboratory, UK

Tracking the biological response to the physical and chemical changes related to Ocean Acidification is one of the goals of the Global Ocean Acidification – Observing Network (Goal 2). Models can contribute by interpreting observations, understanding the mechanisms underlying the biological response and upscaling local findings to the ecosystem level.

Due to the complex network of feedbacks, the attribution of observed changes to the processes responsible for those changes is not a trivial task. Similarly, change may be obscured by compensative mechanisms that are not individually measured. Finally, models can provide a platform to test hypotheses of the biological and ecological interactions that can inform the design of future experiments and the upscaling of local findings. In particular models can make a huge contribution to the efficient siting of limited monitoring platforms. We will show preliminary results describing potential ecosystem sensitivity in one of the GOA-ON stations (station L4 of the Western Channel Observatory), and highlight some of the regional heterogeneity with a view to designing efficient monitoring strategies.

International, Interdisciplinary, Long-term Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reefs Across the Central and Western Pacific

Russell E. Brainard[1]*, Thomas Oliver[1,2], Anne Cohen[3], Nichole Price[4], Richard Feely[5], Simone Alin[5], Ian Enochs[6], Libby Jewett[7], Somkiat Khokiattiwong[8], Wenxi Zhu[9], Tommy Moore[10], Maria Lourdes San Diego-McGlone[11], Zulfigar Yasin[12], Andrew Dickson[13], Christopher Meyer[14], Robert Toonen[15]

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[2] University of Hawaii Joint Institute for Marine and Atmospheric Research, Honolulu, Hawaii, 96818, USA
[3] Woods Hole Oceanographic Institute, Woods Hole, Massachusetts, 02543, USA
[4] Bigelow Laboratory for Ocean Sciences, East Boothbay, Maine, 04544, USA
[5] NOAA Pacific Marine Environmental Laboratory, Seattle, Washington, 98115, USA
[6] NOAA Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida, 33149, USA
[7] NOAA Ocean Acidification Program, Silver Spring, Maryland, 20910, USA
[8] Phuket Marine Biological Center, Phuket, 83000, Thailand
[9] U.N. Intergovernmental Oceanographic Commission-Western Pacific Subregion (IOC-WESTPAC), Bangkok, 10210, Thailand
[10] Secretariat of the Pacific Regional Environmental Programme (SPREP), Apia, Samoa
[11] Marine Science Institute, University of the Philippines, Quezon City, 1101, Philippines
[12] Institute of Oceanography and Environment, Universiti Malaysia Terengganu, Terengganu, 21030, Malaysia
[13] Scripps Institution of Oceanography, University of California San Diego, La Jolla, California, 92037, USA
[14] National Museum of Natural History, Smithsonian Institution, Washington, DC, 20560, USA
[15] Hawaii Institute of Marine Biology, University of Hawaii, Kaneohe, Hawaii, 96744, USA

Background: Ocean acidification is predicted to have significant impacts on coral reefs and the associated ecosystem services they provide to human societies over this century. To inform, validate, and improve laboratory experiments and predictive modelling efforts, scientists and managers from NOAA, IOC-WESTPAC, SPREP, and the countries of the western and central Pacific Ocean are collaborating to establish an integrated and interdisciplinary observing network to assess spatial patterns and monitor long-term temporal trends of the ecological impacts of ocean acidification on coral reef ecosystems across gradients of biogeography, oceanography, and anthropogenic stressors.

Methods: Using standardized and comparable approaches and methods, these collaborative efforts are beginning to systematically monitor: seawater carbonate chemistry using water sampling and moored instruments, benthic community structure and abundance using biological surveys and photoquadrats, indices of crytobiota diversity using autonomous reef monitoring structures, net accretion and calcification rates using calcification accretion units and coral cores, and bioerosion rates.

Findings: NOAA has established baseline observations and initiated long-term monitoring at

2 U.S.-affiliated sites in Hawaii, American Samoa, Guam, the Northern Marianas, Jarvis, Howland, and Baker Islands, and Palmyra, Kingman, Wake, and Johnston Atolls, and 2 sites in the Coral Triangle (Philippines and Timor Leste). Following two successful IOC-WESTPAC workshops, 22 additional sites are being initiated in Bangladesh (1), Cambodia (1), China (1), Indonesia (3), Malaysia (5), Philippines (7), Thailand (3), and Vietnam (1). Following two workshops and with support from New Zealand, SPREP has initiated efforts to identify multiple pilot ocean acidification monitoring sites in the Small Island Developing States of the Pacific Islands adopting similar approaches.

Conclusions: Collectively, these standardized observations of the ecological responses to ocean acidification will inform resource managers and policymakers in their efforts to implement effective management and adaptation strategies and serve as a model for the Global Ocean Acidification Observing Network (GOA-ON).

Bridging the OA Data Processing Workflow Gap

Eugene F. Burger,[1]* Kevin M. O'Brien,[2] Karl C. Smith,[2] Liqing Jiang[3]

[1]NOAA/PMEL, Seattle WA, USA
[2]University of Washington, Seattle, WA, USA
[3]NOAA/NCEI, Silver Spring, MD, USA

Effective use of data collected in support of Ocean Acidification research for analysis and synthesis product generation, it is desirable that the data are quality controlled, documented, and accessible by the applications scientists prefer to use. The processing requirements, along with increases in data volume now require a significant effort by OA scientists. Second level data processing and quality control is time-consuming, and reduces the resources available to scientists to perform their research. National data directives now require our scientific data to be documented, publicly available and archived in two years or less, further adding to the scientists' data management burden. Although procedures exist to submit data to archival centers, it is the data-workflow gap between initial data processing, known as level one processing, and data archival that has not been addressed for a significant amount of OA data.

We propose tools and processes that will streamline OA data processing and quality control. This vision suggests a solution that relies on a combination extending existing development and new development on tools that will allow users to span this data workflow gap; to streamline the processing, quality control, and archive submission of biogeochemical OA data and metadata. Workflow established by this software will reduce the data management burden for scientists while also creating data in interchangeable standards-based formats that promote easier use of the high-value data. Time savings gained by this streamlined data processing will also allow scientists to meet their obligations for data archival. This poster will present this vision and highlight the existing applications and tools that if extended, can meet the requirements at a much reduced development cost.

Building capacities and bridging gaps on Ocean Acidification research for equatorial developing countries: Ecuadorian experience

Francisco Navarrete-Mier and Patricia Castillo-Briceno*

Equatorial Biome & Ocean Acidification - EBiOAc, Facultad de Ciencias del Mar, Universidad Laica Eloy Alfaro de Manabí - ULEAM. Manta, Ecuador

Background: Equatorial populations of marine species are predicted to be among the most impacted by global warming/Ocean Acidification (OA) because their local environments are very stable, so they are adapted to a narrow range of parameters. Although OA research is growing worldwide, the most of the research is located in high-latitude areas (polar and temperate areas). Therefore, there is a strong lack of information regarding equatorial areas (which are in general developing countries).

Methods: We started the project EBiOAc with the aim to establish a permanent program of research, education and divulgation on OA and related topics. We work out this aim through conferences, meetings, seminars and workshops to involve several sectors of society including: universities, public research centres, pertinent authorities, aquaculture organizations, general society, and decision makers. We are also developing projects to evaluate the impact of OA on equatorial marine biota.

Findings: In general, there is a very open reception to attend and discuss about OA and their social, economic and biological impacts, especially from productive and conservationist sectors. Although we still found some cases of academics that were not aware of the subject and even a few that denies OA existence. Moreover, governmental dependencies are open to discuss and organize meetings, especially before COP21.

Conclusions: Climate Change receives great attention within the general society and generates publicity from governmental entities. Ocean Acidification, as part of the processes of Climate Change attracts attention and the public concern. However, between the media coverage and the financial commitment for funding research there is big gap that delays the development of projects to implement mitigation actions. We propose as strategy: to work with productive sectors, to research on emblematic species and to raise awareness on the wide public, thus to reach the effective support from decision and policy makers.

Development of a Long-term Monitoring Program on the Impacts of Ocean Acidification on Coral Reefs in the Western Pacific and its Adjacent region

Suchana Chavanich[1]*, Somkiat Khokiattiwong[2], Russell 'Rusty' E. Brainard[3], Aileen Tan Shau Hwai[4], Maria Lourdes San Diego-McGlone[5], and Wenxi Zhu[6]

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[4]School of Biological Sciences, Universiti Sains Malaysia, Penang 11800, Malaysia
[5]The Marine Science Institute, University of the Philippines, Quezon City 1101, Philippines
[6]IOC Sub-Commission for the Western Pacific (WESTPAC), Intergovernmental Oceanographic Commission of UNESCO, Bangkok 10210, Thailand

Despite the recognition that ocean acidification from increasing levels of atmospheric CO_2 represents a major global threats to coral reefs and other calcifying marine organisms, awareness of the impacts of this ‘other CO_2 problem’ has emerged only over the last decade. The Western Pacific and its adjacent regions are among the richest and most productive in the world as a home to more than 600 coral species (more than 75% of all known coral species) and ~53% of the world’s coral reefs. Most Southeast Asian coastal communities are socially and economically dependent upon coral reef ecosystems and an estimated 70-90% of fish caught in Southeast Asia are dependent on coral reefs. The ecosystem responses to ocean acidification are poorly understood in the region and more research and long-term monitoring are critically needed to develop meaningful projections on future impacts of ocean acidification on marine ecosystem, especially on coral reefs, in the region to enable resource and fisheries managers, and policy makers to develop effective long-term mitigation and adaptation strategies for the people of the region. In this context, the IOC Sub-Commission for the Western Pacific (WESTPAC) has been committed to establishing a regional research and monitoring network on ocean acidification in the Western Pacific and its adjacent regions, and to developing a regional program, as one regional component of the Global Ocean Acidification Observing Network (GOA-ON), to monitor the impacts of ocean acidification on coral reef ecosystems, mainly through a series of regional trainings and workshops, selection of pilot areas and transfer of knowledge and technology among experts within and outside the region. The first and second regional training workshops were held respectively on January 19-21, 2015 and August 26-28, 2015 with the host of the Phuket Marine Biological Center. These workshop attracted wide participation from Bangladesh, Cambodia, China, Indonesia, Japan, Republic of Korea, Malaysia, Philippines, Thailand, United States of America and Vietnam. From the workshops, several pilot sites were chosen. In addition, a consistent, comparable and cost-effective “Standard Operating Procedure (SOP)” for monitoring the ecological impacts of OA is currently being developed with the technical assistance of the National Oceanic and Atmospheric Administration (NOAA) and Global Ocean Acidification Observing Network (GOA-ON). The third regional workshop is scheduled for August 2016.

Deep oceans may acidify faster than anticipated due to global warming

Chen-Tung Arthur Chen[1]*, Hon-Kit Lui[1], Chia-Han Hsieh[1], Tetsuo Yanagi[2], Naohiro Kosugi[3], and Masao Ishii[3]

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Oceans worldwide are undergoing acidification due to the penetration of anthropogenic CO_2 from the atmosphere. The rate of acidification is generally diminished with an increasing depth. Slowing down the thermohaline circulation due to global warming could reduce the pH in the deep oceans, as more organic material would decompose with a longer residence time. To elucidate this process, time series study at a climatically sensitive region with sufficient duration and resolution are needed. Here we show with the longest, direct measured pH record that possibly due to the global warming, deep waters in the Sea of Japan are undergoing reduced ventilation, which more significantly reduces the pH of seawater than anthropogenic CO_2 does. As a result, acidification rate in the Sea of Japan is the highest near the bottom and the lowest near the surface. As a miniature ocean with its own deep and bottom water formations, the Sea of Japan provides an insight into how future global warming can alter the deep oceans acidification.

Ocean Acidification Observation Network for the Arctic and sub-Arctic Pacific Oceans

Liqi Chen

Key Lab of Global Change and Marine Atmospheric Chemistry (GCMAC), Third Institute of Oceanography (TIO), SOA, PR China

The ocean acidification (OA) in the 21st century has obviously speeded up in comparison to earlier periods. The averaged surface pH of the world ocean has decreased 0.1 units since the industrial revolution and is projected to decrease 0.3-0.4 pH units by the end of this century, equal to increasing 1-1.5 times in ocean acidity. Due to its cold water temperature, low alkalinity and rapid sea ice decline, the Arctic Ocean and subarctic Pacific Ocean (AOPO) have absorbed massive amounts of atmospheric CO_2 and changed the $CaCO_3$ system to an aragonite unsaturated state. In comparison of 1994's investigation with 2005, the unsaturated state of aragonite waters has been found from the continental shelf and slope to expend into the upper surface waters of the Canada Basin. By 2010, the unsaturated aragonite state region continued to expand northward and to shallower depths in the Arctic. This is the first time that aragonite undersaturation was observed at shallow depths (50 m) this far north (to 84°N) in the Canada Basin. OA in AOPO will be greatly changed in marine chemical environment to affect marine ecosystem. Therefore, it is important to develop an Ocean Acidification Observation Network for the Arctic and sub-Arctic Pacific Oceans (POA-ON). China will develop underway observations of parameters relative to AO during CHINARE (Chinese National Arctic Research Expedition) and promote POA-ON linked closely with GOA-ON, AMAP-AOA etc.

Future ocean acidification and temperature rise could alter community structure and functioning in marine benthic communities

Rachel Hale*, Martin Solan, Jasmin Godbold

University of Southampton, School of Ocean and Earth Science, Waterfront Campus, National Oceanography Centre, Southampton, UK

Background: Atmospheric CO_2 concentrations have risen steadily since the start of the industrial revolution, increasing global temperature and causing a drop in the pH of ocean surface water. Presently, most studies of the synergistic effects of low pH hypercapnia and temperature increase have focused on individual species in isolation and few experiments have investigated the effects of either on intact communities.

Methods: A mesocosm study was carried out to investigate the effects of the combined stressors of low pH hypercapnia and elevated temperature on macrofauna and bacterial communities in intact shelf sea sediment cores. Communities were incubated for 6 months and changes in the communities quantified. Bioturbation and bioirrigation were quantified to determine changes in community function.

Findings: Communities show significant changes in structure, diversity and function in response to the combined stressors of decreased seawater pH and increased temperature. Changes in marine biodiversity were driven by differential vulnerability within and between different taxonomical groups. Calcifying groups (molluscs and echinoderms) were the most vulnerable.

Conclusions: These studies illustrate the importance of considering both direct physiological and indirect ecological and behavioural effects that occur within multispecies assemblages when attempting to predict the consequences of ocean acidification and global warming on marine communities.

Monitoring Ocean Acidification with the Northeastern Chukchi Shelf Ecosystem Observatory

Claudine Hauri[1]*, Seth Danielson[2], Andrew McDonnell[2], Russell Hopcroft[2], Peter Winsor[2], Catherine Lalande[3], and Kate Stafford[4]

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[2]Institute of Marine Science, University of Alaska Fairbanks, USA
[3]Québec-Océan, Biology Department, Université Laval, Canada
[4]Applied Physics Laboratory, University of Washington, USA

Along with ocean acidification, the Arctic is undergoing unprecedented climate induced transformations that include warming temperatures, extensive sea-ice losses, increases in storm frequency/magnitude, enhanced wind-driven mixing, and increasing inputs of terrestrial organic matter. In an effort to capture these changes and their effects on the ecosystem we are building an ecosystem observatory on the northeastern Chukchi Sea shelf. This observatory will consist of a coordinated set of subsurface moorings recording ocean and sea ice physics, nutrient and carbonate chemistry, suspended particulate, phytoplankton, zooplankton, fisheries, and marine mammal data sets. This summer we will start measuring pH and pCO_2. Integrating pCO_2 and pH measurements with the other concurrent datasets will aid in the understanding of the controlling forces that mediate ocean acidification and carbon fluxes in the Chukchi Sea throughout the year, including the under-sampled and poorly understood seasons when sea ice inhibits ship-based sampling. The observatory site - on the southeastern flank of Hanna Shoal and northwest of the head of Barrow Canyon - is well situated to monitor the shelf's nutrient and carbon cycles and how changing wind, wave, and ice affect these biogeochemical cycles. A single mooring was deployed in September 2014 and recovered in August 2015, measuring currents, temperature, salinity, pressure, significant wave height and direction, ice thickness and keel depth, chlorophyll *a* fluorescence, beam transmission, photosynthetically available radiation, acoustic backscatter at 38/125/200/455 KHz, and particle size spectra and concentrations. The 2015 deployment consisted of three collocated moorings carrying an expanded set of instrumentation including a dissolved oxygen sensor, a colored dissolved organic matter sensor, a sediment trap, a passive acoustic recorder, and water column photography. We provide an overview of the mooring observatory objectives, design, and show highlights from the first year's worth of data returns.

NOAA Ocean Acidification Data Stewardship (OADS) Project

Li-Qing Jiang

NOAA/National Centers for Environmental Information

Funded by NOAA's Ocean Acidification Program, the National Centers for Environmental Information (NCEI) serves as the NOAA OA data management focal point under the Ocean Acidification Data Stewardship (OADS) Project by providing dedicated long-term archival, online data discovery and access for a diverse range of multi-disciplinary field observations, laboratory and experimental and model OA data for both NOAA and inter-agency OA data partners. The success of OADS lies upon two things: (a) NCEI's world class infrastructure for long term file storage, controlled vocabularies, stable data citation, and version control; and (b) OADS's autonomy in terms of ocean acidification metadata template (display format), data search portal, and submission interface, etc. A recently developed ocean acidification metadata content template enables us to document biological response OA data, as well as other commonly seen OA data, such as in-situ observation, model output, etc. with the best metadata elements in the community.

The Western South Atlantic Ocean in a High-CO_2 World: Current Measurement Capabilities and Perspectives

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Recently, the members of the Brazilian Ocean Acidification (BrOA) Network (www.broa.furg.br) met to discuss ocean acidification (OA) and concluded that identifying and evaluating the regional effects of OA in the western South Atlantic Ocean is impossible without understanding the natural variability of seawater carbonate systems in marine ecosystems through a series of long-term observations. Here, we show that the western South Atlantic Ocean (WSAO) lacks appropriate observations for determining regional OA effects, including the effects of OA on key sensitive Brazilian ecosystems in this area. The impacts of OA likely affect marine life in coastal and oceanic ecosystems, with further social and economic consequences for Brazil and neighboring countries. Thus, we present (i) the diversity of coastal and open ocean ecosystems in the WSAO and emphasize their roles in the marine carbon cycle and biodiversity and their vulnerabilities to OA effects; (ii) ongoing observational, experimental, and modeling efforts that investigate OA in the WSAO; and (iii) highlights of the knowledge gaps, infrastructure deficiencies, and OA-related issues in the WSAO. Finally, this review outlines long-term actions that should be taken to manage marine ecosystems in this vast and unexplored ocean region.

Shell density of Planktic Foraminifera in the North Pacific: Seasonal acidification and its ecological impacts

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Ocean acidification (OA) is one of the most concerning issues of recent global environmental changes. In particular, it is advancing rapidly in the western North Pacific but its biological impacts for marine calcifying organisms are still unknown. In this study, we focused on the shells of single-celled marine zooplankton (planktic foraminifers) recovered by the sediment trap mooring from the North Pacific. Sediment traps were deployed at the Station K2 (47°N, 160°E) since 2009 and successfully recovered the samples for 6 years. Planktic foraminiferal shells were handpicked from those samples and were analyzed morphology using the Microfocus X-ray Computed Tomography (MXCT) technique. We analyzed morphology of planktic foraminiferal shells in the timeseries by MXCT and found seasonal changes of shell morphology. Shell density of planktic foraminifera had decreased during the winter seasons. At the same time, shell density was remarkably related to size variations of planktic foraminifers. These variabilities looked synchronized with physicochemical variations in the mixed layer through the year. It indicates that calcification of planktic foraminifers might be related to surrounding oceanic environments.

New empirical equations for total alkalinity in surface waters over the global ocean by using sea surface dynamic height

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Improved spatial and temporal representation of total alkalinity (TA) is an important component in investigating changes in the oceanic carbon cycle and acidification over the coming decade. Takatani et al. [2012] proposed new empirical equations for TA in the Pacific surface waters by using sea surface dynamic height (SSDH) of which variability is known to be useful in describing seasonal and interannual variations in wind-driven circulation and eddies. According to the methods of Takatani et al. [2012], we propose empirical equations for TA in the global ocean surf ace waters. On the basis of the relationship between deseasonalized SSDH and salinity -normalized TA (NTA), we divided the global ocean into twelve domains. We derived the empirical equations of TA for each of twelve domains by using the variables of SSDH, salinity and temperature. The root mean square error of the fittings of these equations to the measured TA is 7.3 mol kg-1. Comparing with previous equations, the SSDH-based empirical equations are especially improved to better represent the TA distribution in the subtropical-subarctic frontal zone where NTA shows large spatio-temporal variability.

Latin-American Ocean Acidification Network (LAOCA Network)

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24 scientists from Argentina, Brazil, Colombia, Ecuador, Peru, Mexico, and Chile met at the city of Concepcion, Chile, to establish the **Latin-American Ocean Acidification Network (LAOCA Network).** First meeting addressed to document strengths and weaknesses of each country in relation to ocean acidification research, and also defining the mission and goals of LAOCA Network: (i) to synthesize the information about ocean acidification impacts in Latin-American, (ii) to encourage the implementation, maintenance, and calibration of long-term data-set of carbonate chemistry in Latin-America, (iii) training of LAOCA members in the different action lines (e.g. observation, experimentation, and modeling), (iv) to standardize chemical analytical techniques and protocols for experimentation in order to enhance data quality, (v) to establish a regional node for the articulation and communication between local, regional, and global research programs (e.g. BrOA, IMO, GOA-ON and IOCCP), (vi) to determine and evaluate local and regional scenarios of Ocean Acidification for different types of marine ecosystems (e.g. estuaries, coastal area, open ocean, etc.), (vii) to enhance student exchange and to facilitate access to infrastructure and equipment among institutions and LAOCA member countries, (viii) to design an outreach strategy for communicate the problematic of ocean acidification to society, (ix) to promote the development of cooperation projects between member countries of LAOCA, and (x) to promote the inclusion of Ocean Acidification on the political agenda of member countries, and even through the pursuit of cooperation agreements among LAOCA members.

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Working with industry to collect ocean acidification data

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Climate change is a global issue, requiring global data to understand the state of the oceans and inform policy makers. The importance of robust ocean acidification data is widely recognized with data collection, best practice analysis and sharing agreements established between research institutes, governments and international bodies through the Global Ocean Acidification Observing Network (GOA-ON, Newton et al. 2014). However, global industries, including oil and gas, have so far not been included in these networks, thus missing one of the most widespread and technically competent users of the marine environment. Joining forces with the oil and gas industry will allow us to establish a global monitoring system incorporating areas currently under-represented (e.g. African shelf) and gaining the capacity to sample water masses across depths and seasons to address key uncertainties in our understanding of this pervasive change in the marine environment.

Here we report the results of a 2014 pilot study between Heriot-Watt University, the National Oceanographic Centre Southampton, BP and Gardline to collect water samples and oceanographic CTD data for seawater carbonate chemistry analysis from their operational areas in the North Sea, off the coasts of Libya and Angola and potential extension plans to expand our 2015/16 sampling series.

Initiation of Ocean Acidification Time Series in the Fiji Islands

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The setting-up of ocean Observation Systems is of paramount importance for Small Island Developing States of the Pacific in relation to the growing threat of climate change being manifested notably in sea-level rise, coral bleaching, and Ocean Acidification. At the University of the South Pacific (USP) in Fiji pioneering efforts in this area have been undertaken to setup since 2012 a network of ocean observation systems, starting off with precise coastal sea temperature measurements with plans to add sensors to monitor pH and salinity at ten current sites within Fiji. In April 2016, the first step towards an Ocean Acidification time series was taken through the deployment by the USP (in collaboration with the Secretariat of the Pacific Community, SPC) of a state-of-the-art SEAFET pH sensor at Maui Bay, on the Coral Coast of the main island of Viti Levu in Fiji. The instrument was deployed in a coastal environment at 12 m depth, in conjunction with a RBR-duo logger for salinity measurement, and will obtain data for periods of up to 6 months at a time. This will represent the first ever precise OA time series for any South Pacific Island, and will be invaluable for climate change prediction and adaptation research in the region

Influence of pH on Calcification and Biomarker enzymes of soft shell wedge clam *Donax faba* (Gmelin)

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Ocean acidification is a direct consequence of increased carbon dioxide (CO_2) concentrations in the atmosphere. Ocean acidification may affect the biological processes of marine organisms and thereby affect their morphology and behaviour. The aim of this study is to understand the effect of lowered pH due to the global warming and ocean acidification on marine soft shell wedge clam *Donax faba* (Gmelin), which build their external skeletal material using calcium carbonate. The study revealed that the sub-lethal effect of pH has decreased the calcium level in the *D. faba* shell. At pH 8.3 the calcium content of shell was 26,280 mg.l^{-1} and it reduced to 19,030mg.l-1 at pH 6.0. Decrease in pH has significantly reduced the total protein content in the test animals. The activity of reduced Glutathione in the test animal was maximum in pH 7.0 and found to reduce towards acidic alkaline pH.

Keywords - Ocean acidification; pH effects; carbon dioxide; biomarker enzymes and *D. faba*

The pH evolution at the ESTOC site since 1995

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The accelerated rate of increase in the atmospheric carbon dioxide (CO_2) and the substantial fraction of anthropogenic CO_2 emissions absorbed by the oceans are affecting the anthropogenic properties of seawater. Long-term time series are a powerful tool for investigating any change in ocean bio-geochemistry and its effects on the carbon cycle. We have evaluated the ESTOC (European Station for Time series in the Ocean at the Canary Islands) observations of monthly measured pH (total scale at 25ºC) since 1995 by following all changes in response to increasing atmospheric carbon dioxide. The experimental values for the partial surface pressure of CO_2 were also taken into consideration. The ESTOC site has become more acidic, -0.0019±0.0003 units yr^{-1} over the first 100m, whereas the carbonate ion concentrations and $CaCO_3$ saturation states have also decreased over time. C_T at constant salinity. NC_T, increased at a rate of 1 µmol kg^{-1} yr^{-1} in the first 200 m, linked to an fCO_2 increase of 1.8±0.7 µatm yr^{-1} in both the atmosphere and the ocean. The ESTOC site is presented by way of a reference site to follow ocean acidification changes in the North Atlantic Sub-tropical gyre.

Ocean acidification threatens the only coral reef ecosystem of Bangladesh

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Historical seawater pH data, which was obtained from the National Oceanographic Data Center, was analyzed to determine the state of acidification of marine ecosystem of the northern Bay of Bengal, Bangladesh. Temporal trends indicate that the average pH value has been declining over the past few decades, i.e. a decrease is noted from 7.8 (1970-79) to 7.6 and 7.3 over the years of 1980-89 and 1990-99, respectively. The lowering pH of ocean can have large negative impacts on marine calcifying organisms, such as corals. The coral communities of Bangladesh, which are found only at the St. Martin's Island, are currently under serious threat as a result of illegal exploitation, sedimentation and pollution. Incidentally, the emerging problem of ocean acidification will further worsen the situation by hampering the calcification, reducing the growth rates and reproductive capacity, and decreasing the strength of coral reefs. Such outcomes are anticipated to affect the species abundance, composition and distribution of corals. Consequently, the structure of reef-based organisms and their habitats, i.e. spawning, feeding and nursery grounds may change. Moreover, tourism dependent business enterprises of the unique St. Martin's Island might come to cease, if reefs disappear. Most of these issues are poorly understood and virtually no science works have done in Bangladesh regarding the risks of ocean acidification and the fate of corals in a high carbon dioxide future. Therefore, adequate research studies and continuous monitoring program is essential to recognize the current and future costs of ocean acidification in Bangladesh.

Carbonate system parameter monitoring along the coast of Chile

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pH and Total Alkalinity were measure in the intertidal zone for a period of approximately two years in three stations along the coast of Chile (at 30°S, 40°S and 42°S). Two time series (30°S and 40°S) were affected by the coastal upwelling. The Station at 42°S located inside the Patagonian Archipelago was particularly affected by runoff at these rainy latitudes.

While time series at the coastal upwelling of Chile were characterized by an intense intraseasonal variability of carbonate system parameters, the main variability of carbonate system within the Patagonian Archipelago were associated to the seasonal cycle, characterized by strong summer pCO_2 undersaturation and strong winter pCO_2 supersaturation.

Riverine and corrosive upwelling waters influences on the carbonate system in the coastal upwelling area off Central Chile: Implications for coastal acidification events

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A combined data set, combining data from field campaigns and oceanographic cruises was used to ascertain the influence of both river discharges and upwelling processes, covering spatial and temporal variation in DIC and aragonite saturation state. This work was conducted in one of the most productive river-influenced upwelling area in the South Pacific coasts (36ºS). Additionally, further work was also conducted to ascertain the contribution of different DIC sources, influencing the dynamics of DIC along the land-ocean range. Six sampling campaigns were conducted across seven stations at the Biobío River basin, covering approximately 200 km. Three research cruises were undertaken simultaneously, covering the adjacent continental shelf, including 12 sampling stations for hydrographic measurements. Additionally, 6 stations were also sampled for chemical analyses, covering summer, winter and spring conditions over 2010 and 2011. Our results evidenced that seaward extent of the river plume was more evident during the winter field campaign, when highest riverine DIC fluxes were observed. The carbonate system along the river-ocean continuum was very heterogeneous varying over spatial and temporal scales. High DIC and pCO_2 were observed in river areas with larger anthropogenic effects. CO_2 supersaturation at the river plume was observed during all campaigns due to the influence of low pH river waters in winter/spring and high-pCO_2 upwelling waters in summer. δ13C DIC evidenced that main DIC sources along the river and river plume corresponded to the respiration of terrestrial organic matter. We have linked this natural process to the carbonate saturation on the adjacent river-influenced coastal area, suggesting that Ωaragonite undersaturation in surface/sub-surface waters is largely modulated by the influence of both river discharge and coastal upwelling events in this productive coastal area. Conditions of low Ωaragonite might impact negatively physiological traits for marine organisms, such as, bivalves, gastropods, and crustaceans. Therefore, local populations from river-influenced sites could be inherently more tolerant to ocean acidification than organisms living in regions with lower Ωaragonite variability.

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