UNESCO-IOC Sub-Commission for the Western Pacific

Southeast Asian Global Ocean Observing System (SEAGOOS)

OCEAN ACIDIFICATION AND ITS IMPACT TO MARINE ECOSYSTEM (OAIME)

By Somkiat Khokiattiwong, PhD

Phuket Marine Biological Center, Phuket 83000, Thailand

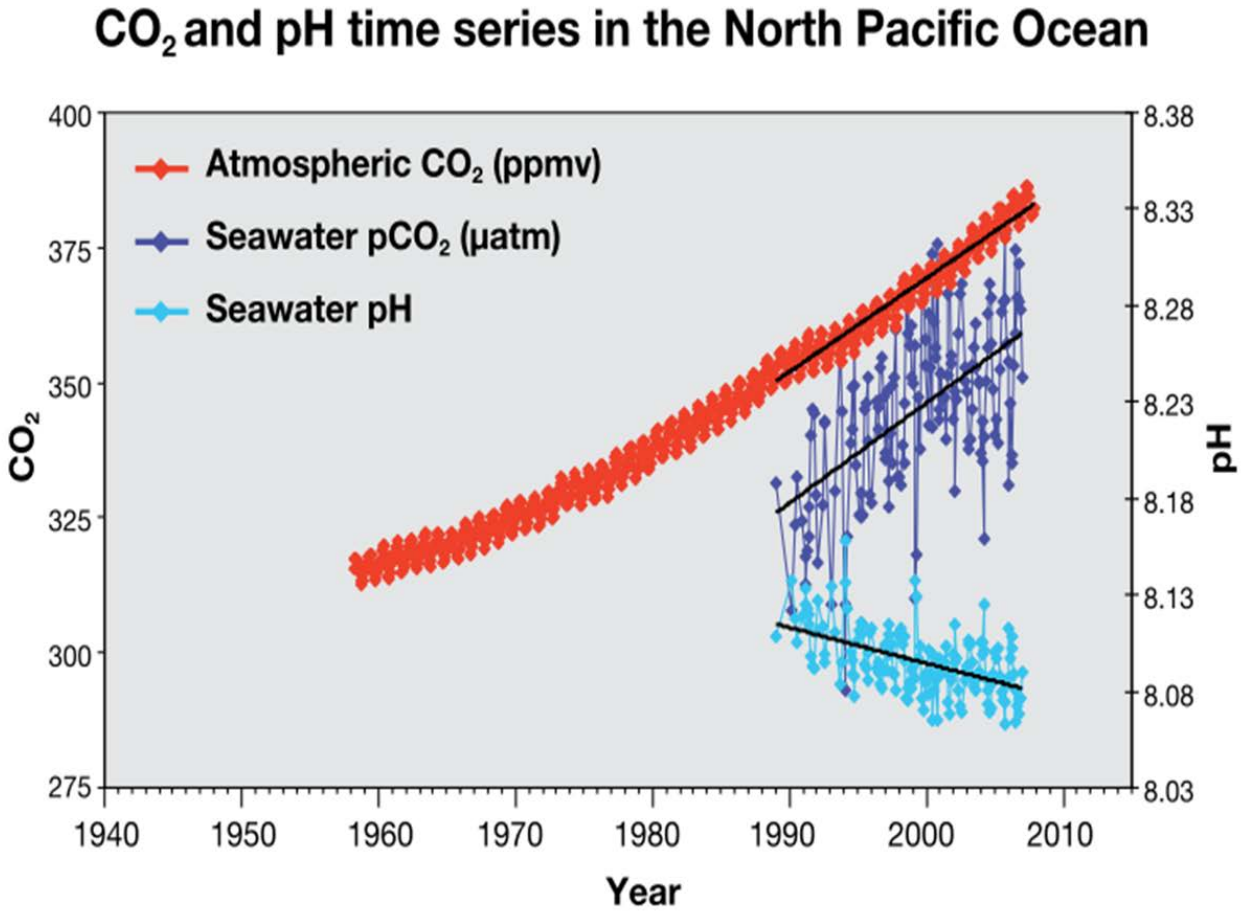
GEOOS,
11-13 January 2017,
Tokyo Japan

Development of Ocean Acidification Monitoring and Network In the WESTPAC Region

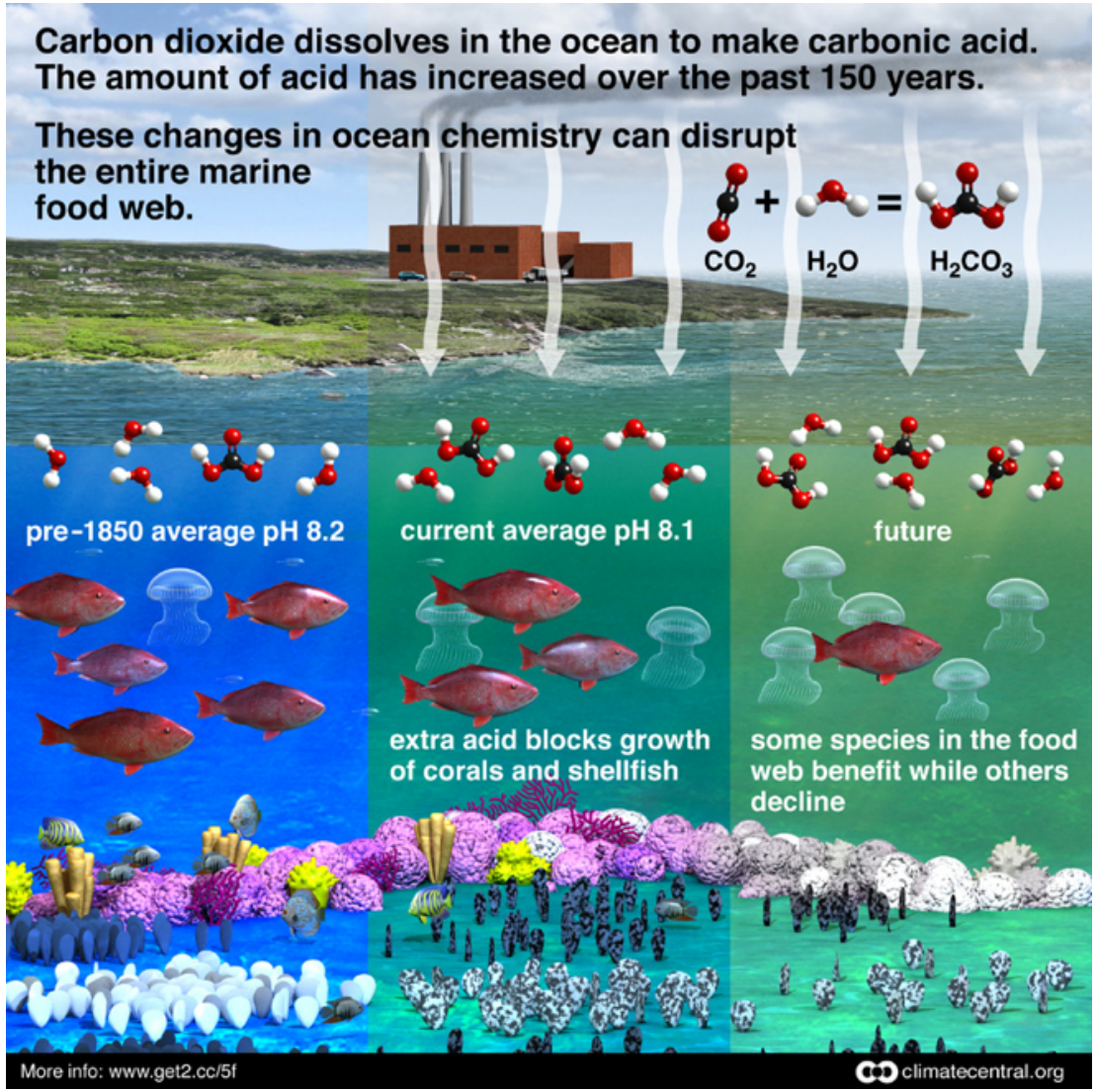
When carbon dioxide (CO2) is absorbed by seawater, chemical reactions occur that reduce seawater pH, carbonate ion concentration, and saturation states of biologically important calcium carbonate minerals.

Since the beginning of the Industrial Revolution, the pH of surface ocean waters has fallen by 0.1 pH units. Since the pH scale, like the Richter scale, is logarithmic, this change represents approximately a 30 percent increase in acidity. Future predictions indicate that the oceans will continue to absorb carbon dioxide and become even more acidic. Estimates of future carbon dioxide levels, based on business as usual emission scenarios, indicate that by the end of this century the surface waters of the ocean could be nearly 150 percent more acidic, resulting in a pH that the oceans haven't experienced for more than 20 million years

The photos below show what happens to a pteropod's shell when placed in sea water with pH and carbonate levels projected for the year 2100. The shell slowly dissolves after 45 days. Photo credit: David Liittschwager/National Geographic Stock

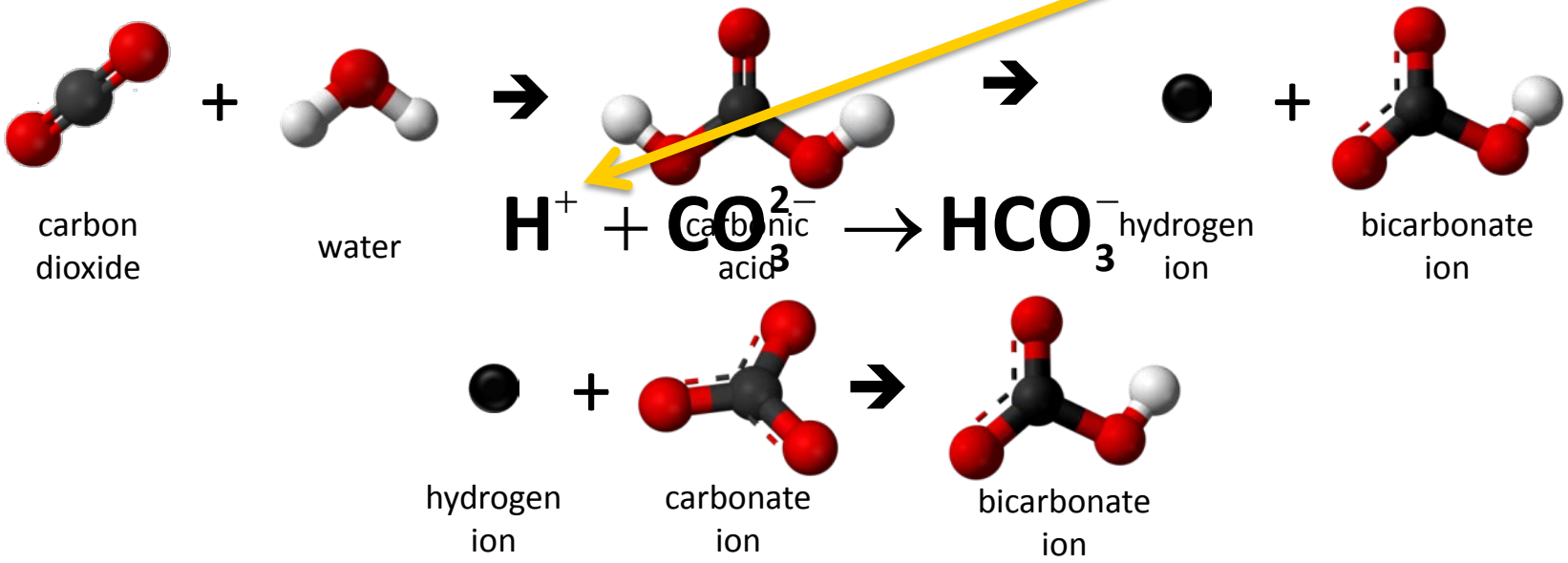


CO_2 and pH time series in the North Pacific Ocean. Adapted from Feely (2008)



Ocean Acidification: Fundamental Chemistry

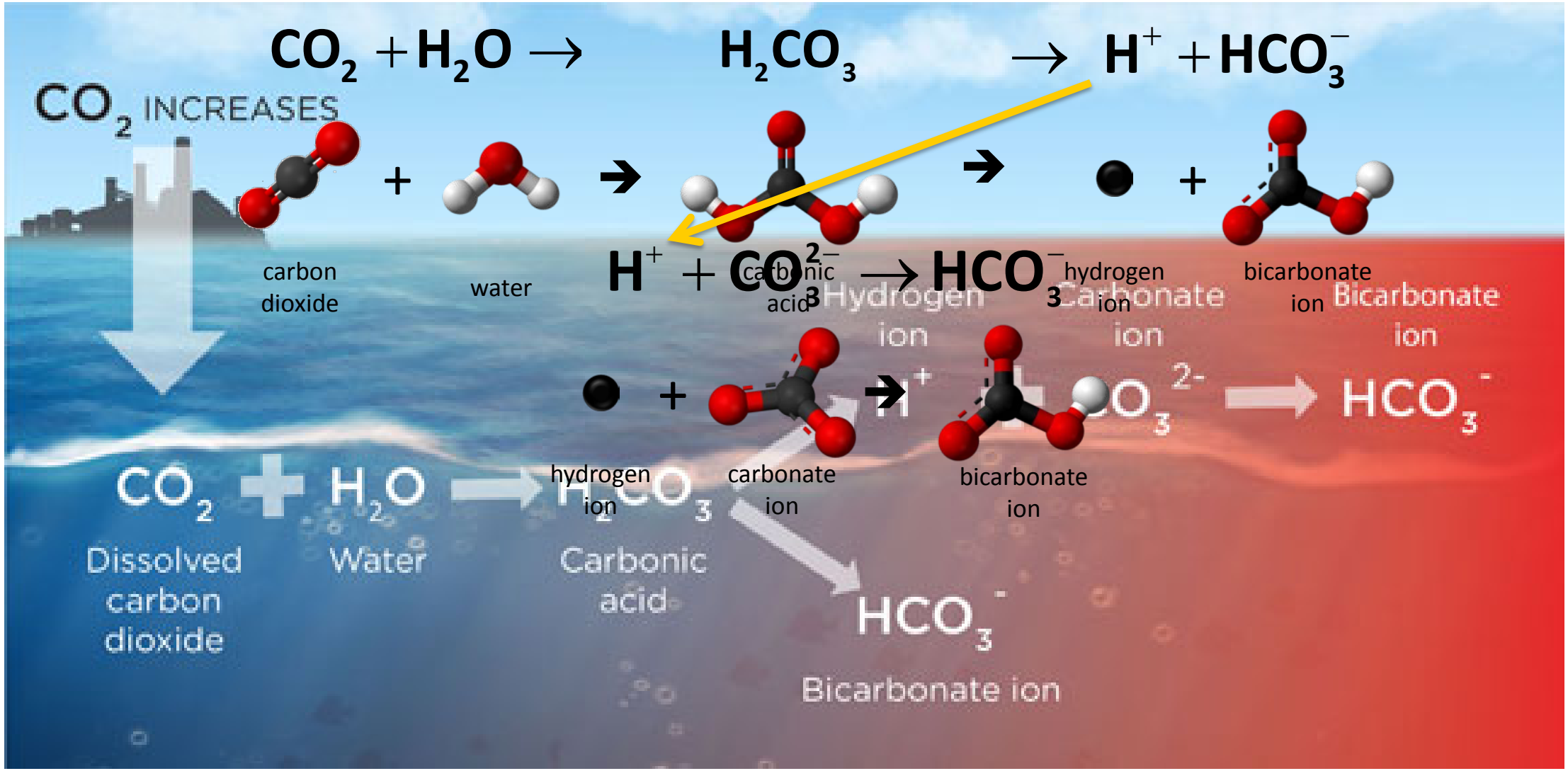
$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$



- More than 99% of the H^+ formed consume CO_3^{2-} to form HCO_3^- making it more difficult for organisms to form their shells.

CO_2 is an acid gas so the addition of 22 million tons of carbon dioxide to the ocean every day is acidifying the seawater…we call this process "ocean acidification"

By Dr. Christopher L. Sabine



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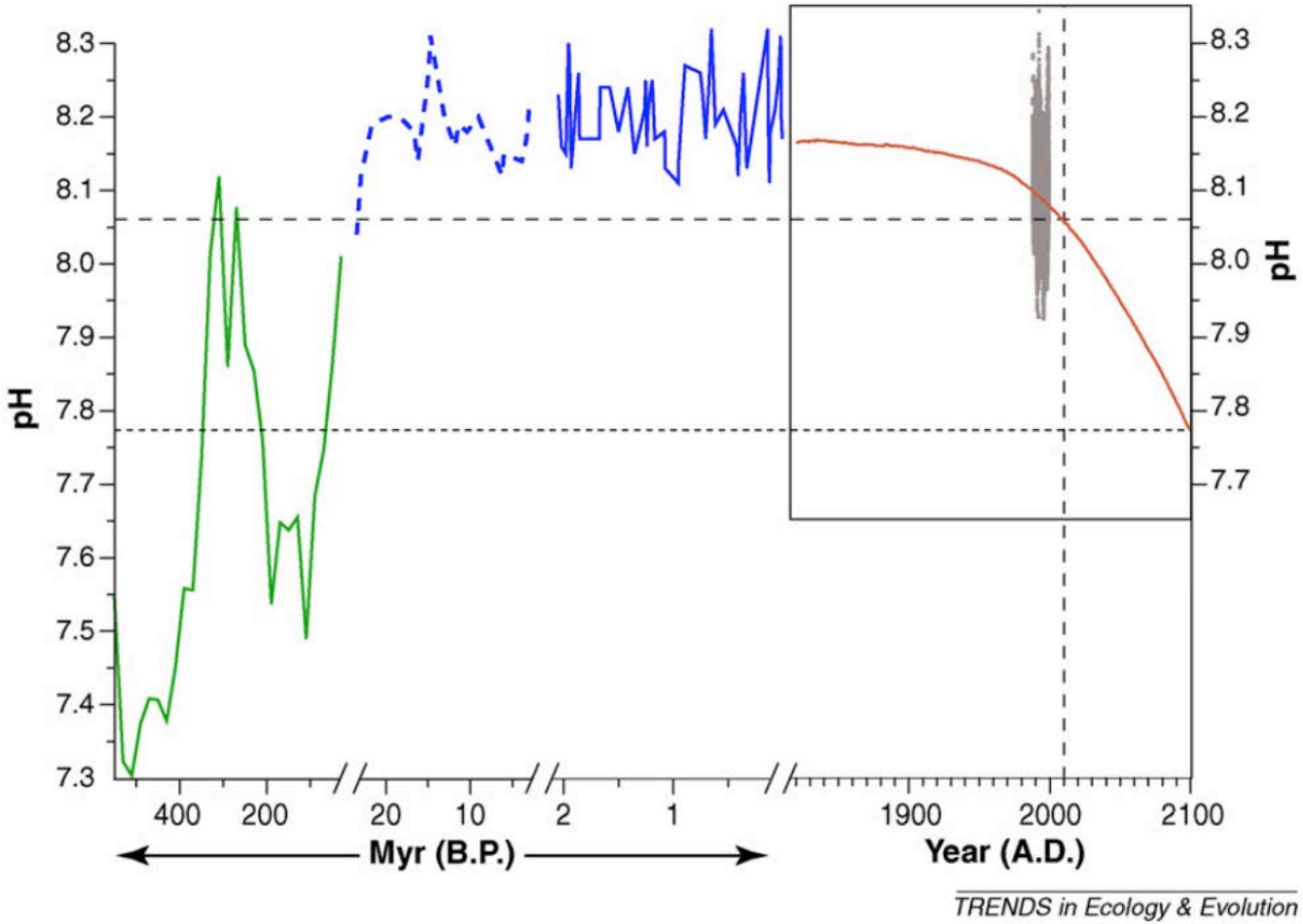
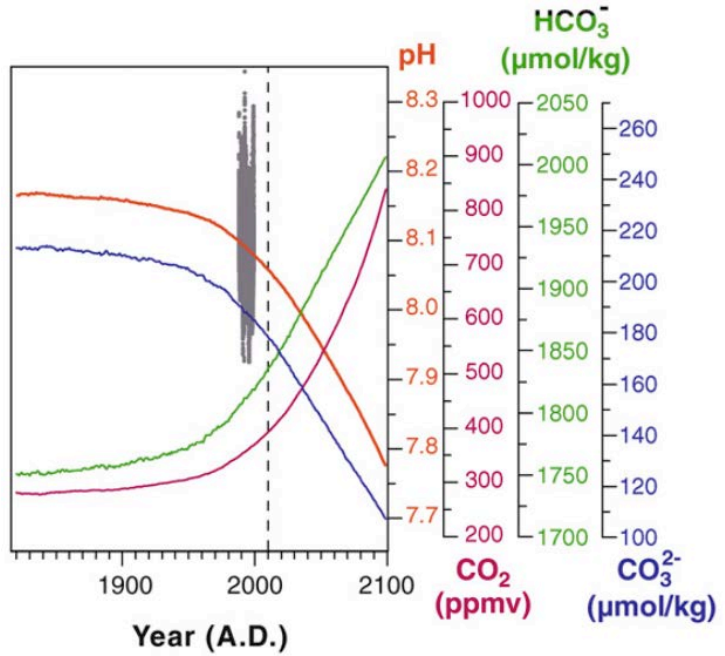
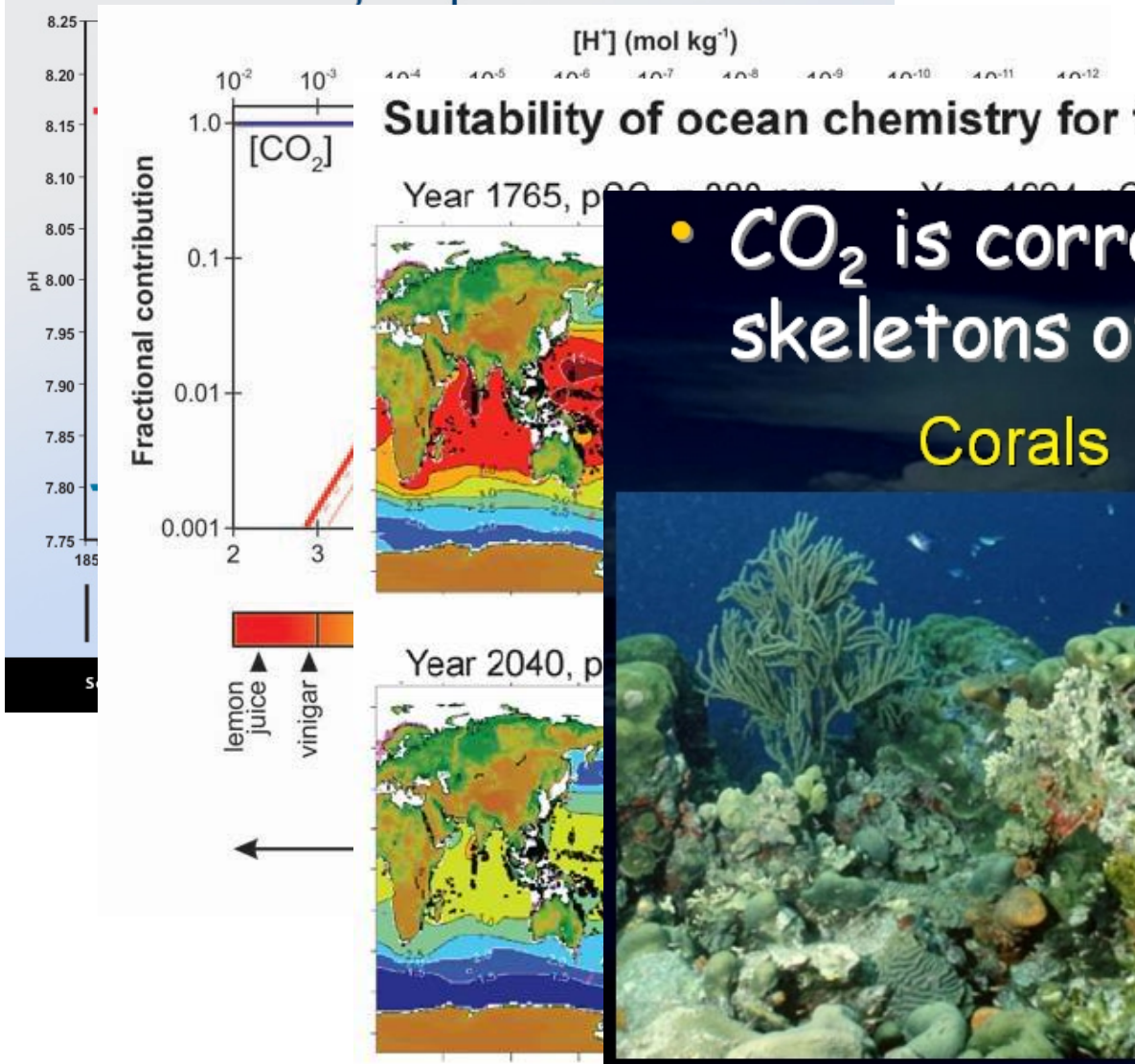


Pelejero et. al. 2010



”CO_2 is an acid gas so the addition of 22 million tons of carbon dioxide to the ocean every day is acidifying the seawater…we call this process “ocean acidification”

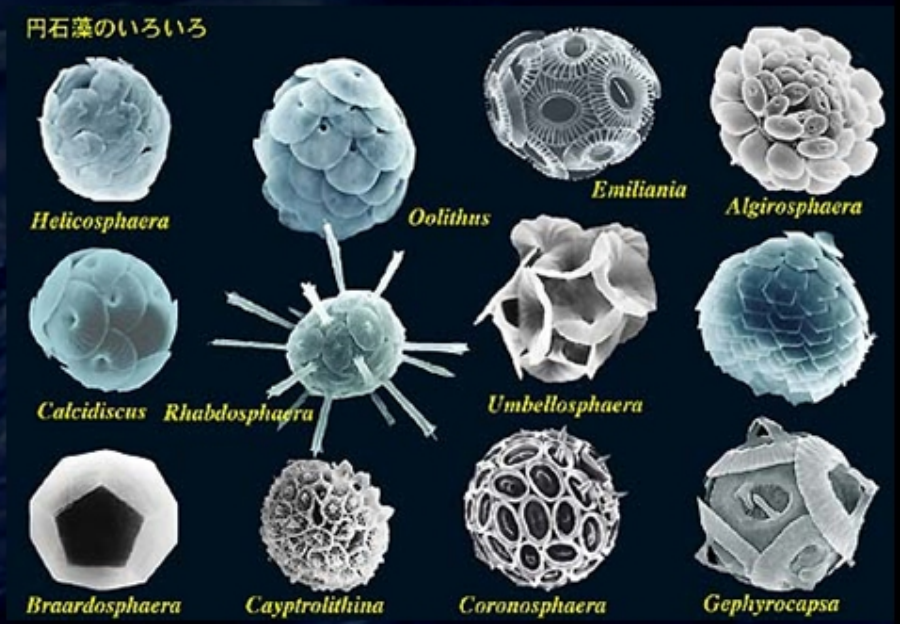
Historical & Projected pH & Dissolved CO_2



- CO_2 is corrosive to the shells and skeletons of many marine organisms

Corals

Calcareous plankton



based on Feely et al. (2006) [NOAA]

25 WESTPAC
Years of Dedication to Marine Science 1989-2014

SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD

SEAGOOS

Sustainable Development Goals

TARGETS

14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans

14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels

14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics

14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information

TARGETS

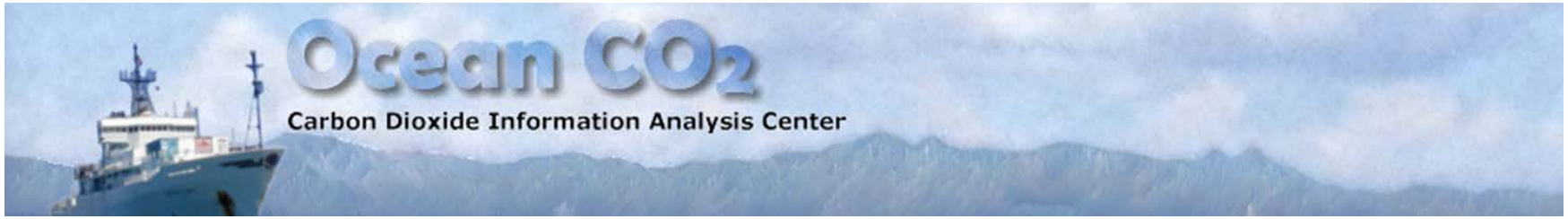
14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation

14.7 By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism

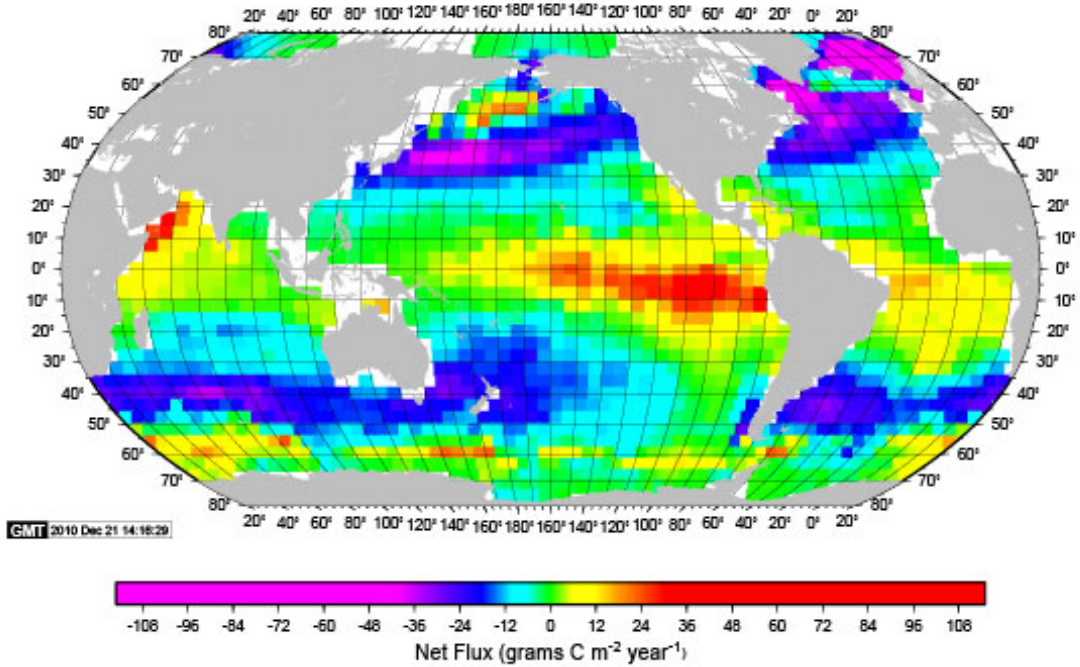
14A Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries

14B Provide access for small-scale artisanal fishers to marine resources and markets

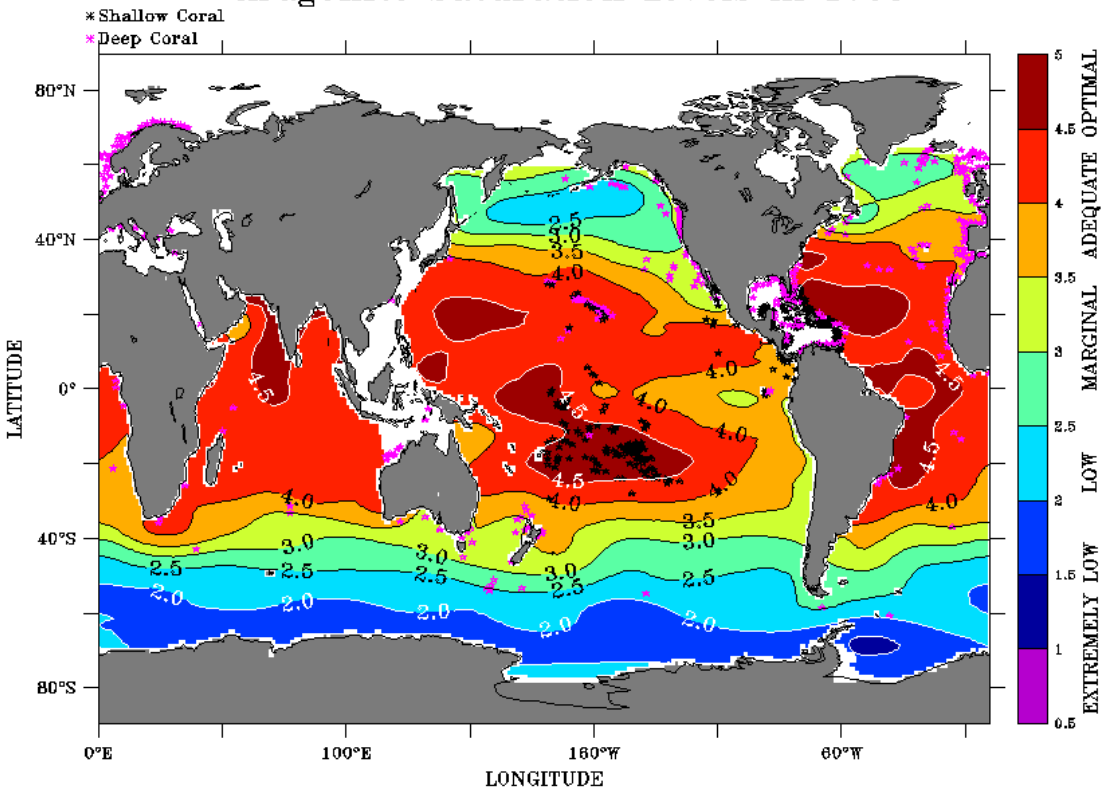
14C Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph



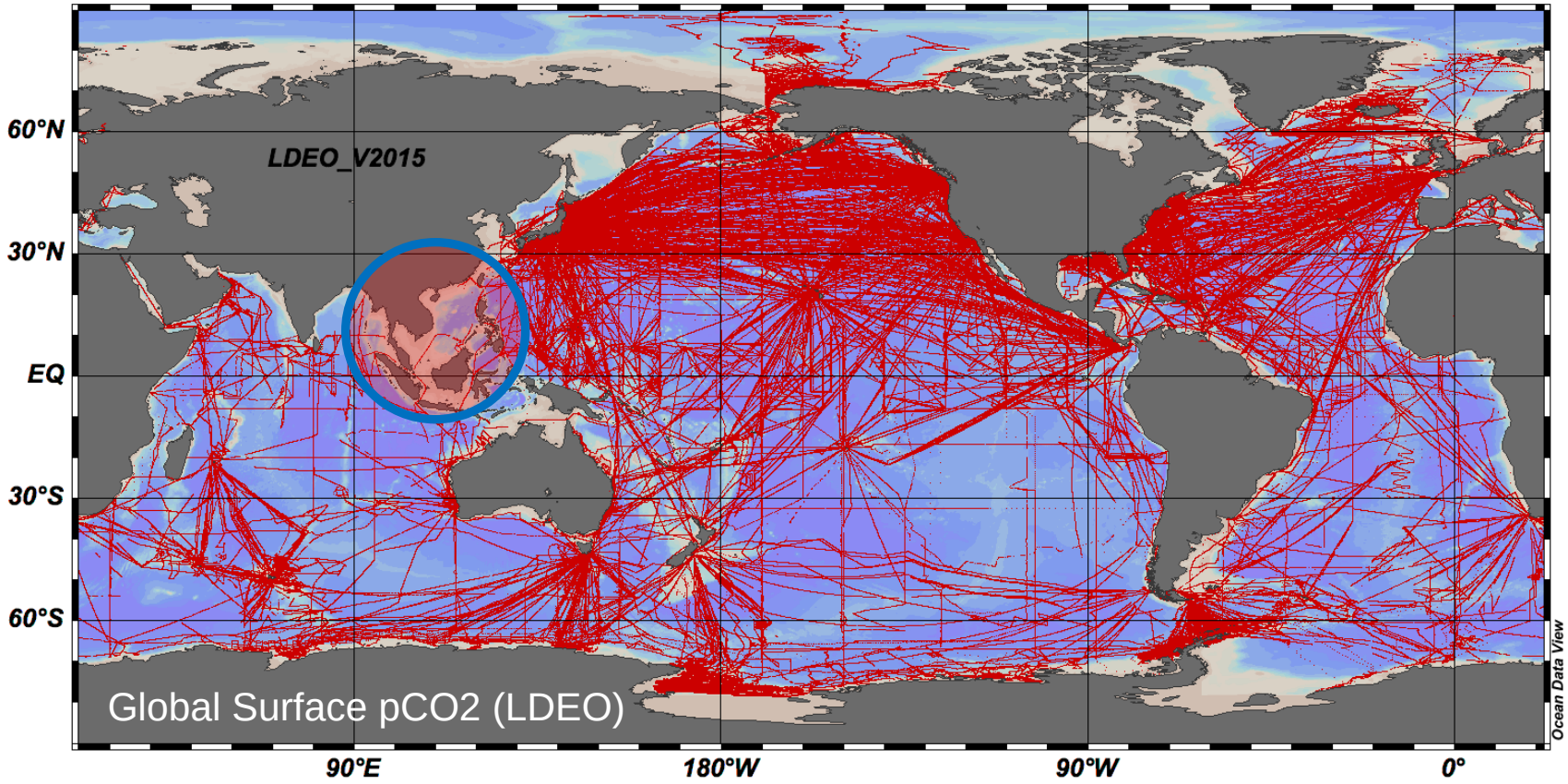
Mean Annual Air-Sea Flux for 2000 [Rev Dec 10] (NCEP II Wind, 3,040K, Γ=.26)



Aragonite Saturation Levels in 1765



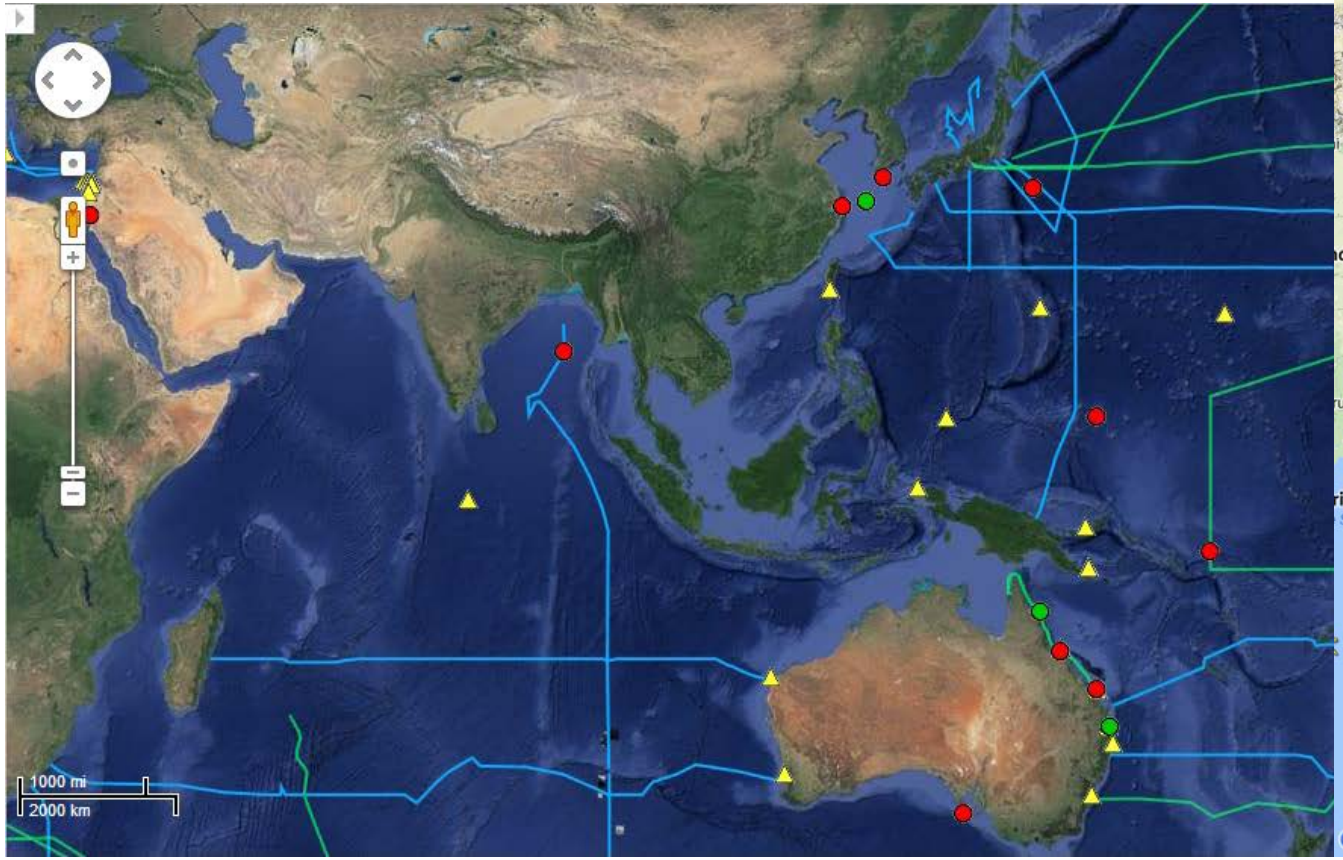
Aragonite Saturation from Orr et al 2005



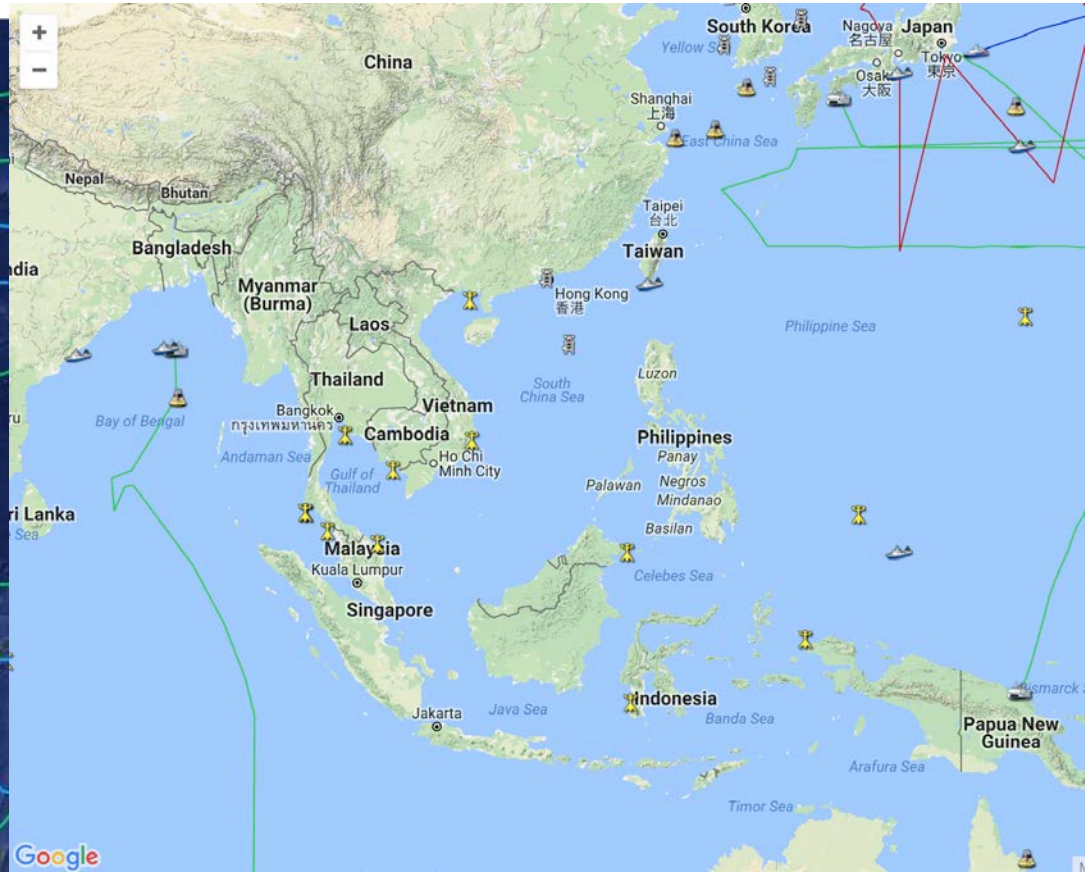
Takahashi, T., S.C. Sutherland, and A. Kozyr. 2016. Global Ocean Surface Water Partial Pressure of CO2 Database: Measurements Performed During 1957-2015 (Version 2015). ORNL/CDIAC-160, NDP-088(V2015). Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, doi: 10.3334/CDIAC/OTG.NDP088(V2015)

Ocean Acidification Monitoring

NOAA Ocean Acidification Monitoring

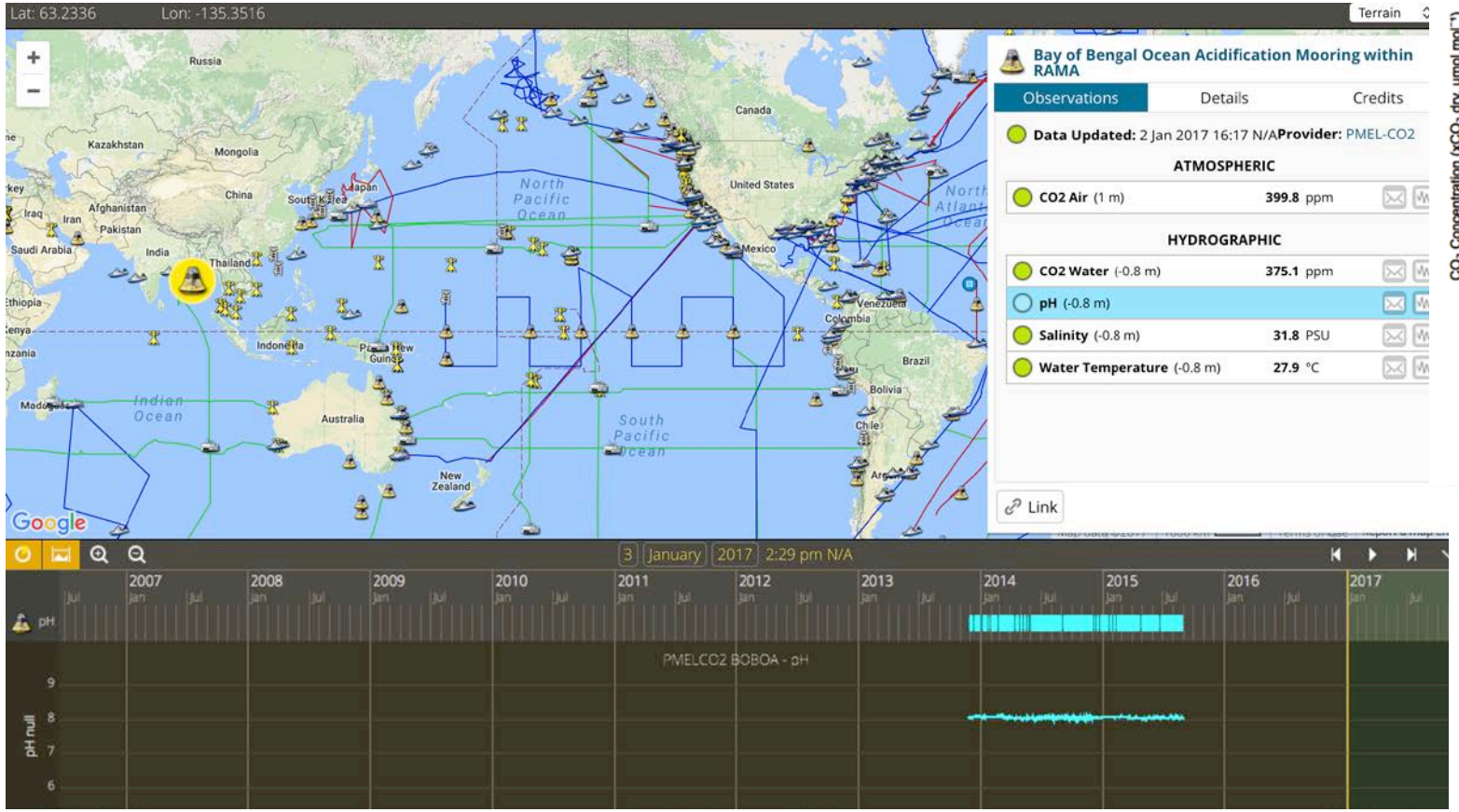


GAO-ON Net Work

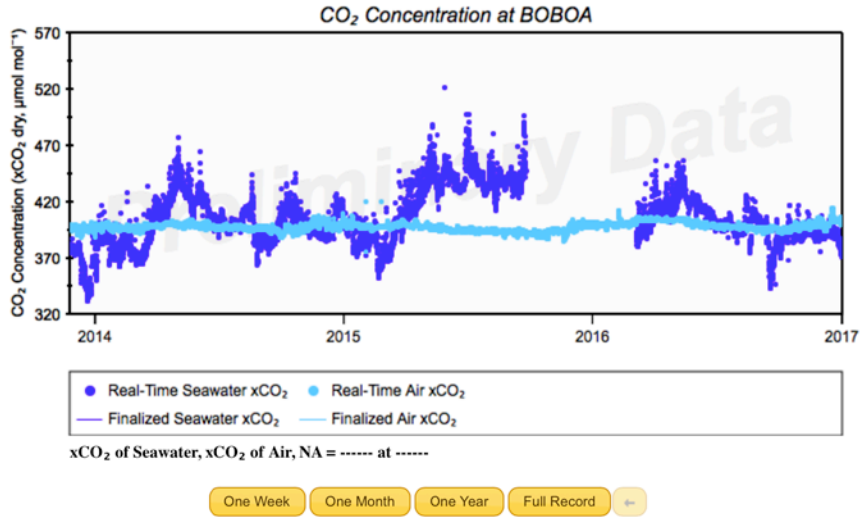


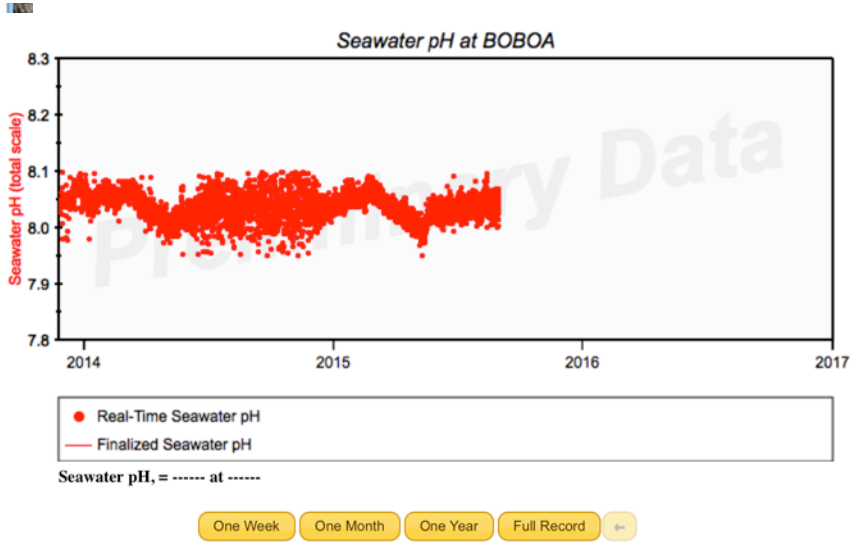
CO2 and pH Monitoring on the north of Bay of Bengal RAMA Buoy

Global Ocean Acidification Observing Network (GOA-ON)



NOAA website





WESTPAC/SEAGOOS Ocean Acidification Programme

OCEAN ACIDIFICATION AND ITS IMPACT TO MARINE ECOSYSTEM (OAIME)

PROJECT OBJECTIVES AND EXPECTED OUTCOMES:

- Improve the understanding, and develop regional capability of research and long-term monitoring on ocean acidification in the Western Pacific and its adjacent regions;
- share existing and proposed ocean acidification monitoring and research approaches, methods, and techniques;
- establish an ocean acidification monitoring and research network among scientists, institutions, and agencies in the region;
- identify challenges, gaps and explore the possibility, building on existing coral reef monitoring initiatives, of a joint long-term monitoring program on the impacts of ocean acidification on coral reefs, and of joint research on ocean acidification and its related changes/processes in seawater chemistry in the region.

Expectation of outcome:

- To establish the standard operational guideline/manual for OA monitoring in the region

- Active participate and implement the OA activities in their countries and provide sharing information in the region

- Cooperation with other partner in the member countries and international ocean acidification network such as Global Ocean Acidification Observing Network (GOA-ON) etc.

- Searching for long term support and work with partners such as NOAA, university (in and out the region), and experts

The First Workshop : Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems (19-21 January 2015, Phuket, Thailand):

- Introduction to OA:
  - ✓ Overview of OA - Overview on Ocean Acidification: what is OA and why do we care?
  - ✓ Global Ocean Acidification Observing Network (GOA-ON)
  - ✓ Why do we need to intensify research and monitoring efforts in the Western Pacific and adjacent regions?
- Country OA report:

The First Workshop : Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems (19-21 January 2015, Phuket, Thailand):

- **Approaches** and challenges:
  - ✓ Monitoring ecological impacts of ocean acidification on Indo-Pacific coral reefs;
  - ✓ Approaches/challenges to monitoring carbonate chemistry and biology impacts of coral reef ecosystems;
  - ✓ Integrating the use of ocean models into observing system design.
- **Brainstorming**: the way forward: agree in on development of OA in the WESTPAC region with appropriate methodology for Coral Reef Biodiversity (ARM) and carbonate chemistry in seawater monitoring.

The First Workshop : Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems (19-21 January 2015, Phuket, Thailand):

- 35 participants
- 4 experts from NOAA
- 1 expert from WHOI (USA)

The Second Workshop : Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems (26-28 August 2015, Phuket, Thailand):

- ✓ 30 participants
- ✓ 3 experts (NOAA), 1 expert (Scripps Institute of Oceanography)

The Second Workshop : Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems (26-28 August 2015, Phuket, Thailand):

- Technical Workshop on:
  - ✓ Biological processes on the coral reef and carbonate chemistry processes
  - ✓ Implement of Assembly of Marine Biodiversity (ARM-following NOAA method)
  - ✓ Carbonate chemistry in seawater analysis; pH by spectrophotometer and Total Alkalinity (TA) by titration method
  - ✓ How to use CO2SYS for related carbonate parameter calculation

The Second Workshop : Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems (26-28 August 2015, Phuket, Thailand):

❖ Agreement on:

- ✓ Implementation of ARM including monitoring of importance of coral reef parameters
- ✓ Monitor pH and TA base on the agreement of standard technique
- ✓ Participants propose pilot sites in the WESTPAC region
- ✓ The expert in the region agree to draft the manual for biodiversity monitoring on by ARM method and carbonate chemistry analysis method




Parameter to be Monitored

ParameterName	SamplingMethod	AnalyticalMethodology	Description	SOPLink
Fish	Transect, Stationary Point Count, etc	NCRMP Plan; CRED SOP	Fish Biological Monitoring: Abundance, size, biomass	
Benthic	Transect, Photoquad	NCRMP Plan; CRED SOP	Benthic Biological Monitoring: Includes bleaching, disease, coral recruitment (size class), macroinvertebrate	
Water_TA	Stratified Random, Diurnal Sampling		Stratified Random Sampling	
Water_pCO2	Stratified Random, Diurnal Sampling, Continuous Sensor			
Water_pH	Stratified Random, Diurnal Sampling, Continuous Sensor	Spectrophotometric pH, Electrode		
Water_DIC	Stratified Random, Diurnal Sampling			
Water_Nutrients	Stratified Random, Diurnal Sampling, Continuous Sensor			
Water_O2	Stratified Random, Diurnal Sampling, Continuous Sensor			
Temperature	Temp. Logger		Subsurface Temperature Recorders	
Salinity	SBE19?			
Carbonate Net Accretion	Calcification Accretion Unit	CAU SOP	Calcification Accretion Units (CAUs) to measure rates of production of calcium carbonate'	
Bioerosion Rate	Bioerosion Monitoring Unit	BMU SOP	Bioerosion Measurement Units (BMUs) to measure rates of bioerosion	
Cryptobiota diversity	Autonomous Reef Monitoring Structure	ARMS SOP	Autonomous Reef Monitoring Structures (ARMS) to measure crytobiota diversity	
Coral Growth Rate	Massive coral coring, bouyant weight, bands	CT scan…	Coral Cores	
Rugosity	Chain?		Rugosity	
Microbial Composition			Microbial community (patogenic or non-patogenic?) 3	

Overall IOC/WESTPAC Technical Manual Working Group

Total Alkalinity Working Group

Dr. Maria Lourdes San Diego-McGlone	**TA Lead**	**Initiate discussion on regional capacity/equipment**
Dr. Somkiat Khokiattiwong	*Co-Lead*	***Draft Procedure Ready for Testing: Dec 15, 2015.***
Dr. Adrienne Sutton		*Testing Reporting: March 2016?*
Prof. Andrew Dickson		
Dr. Muhammad Lukman		
Prof. Sayedur Rahman Chowdhury		

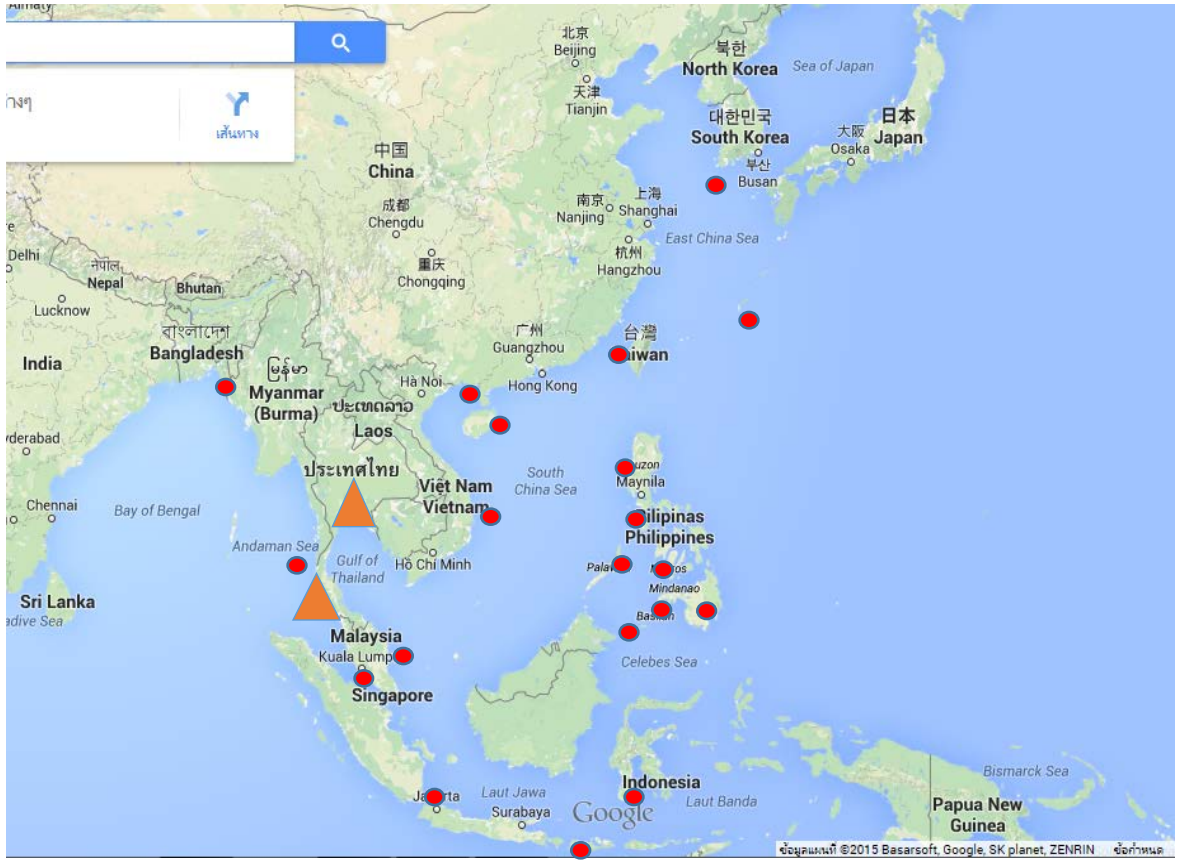
Spectrophotometric pH Working Group

Dr. Somkiat Khokiattiwong	**Spec-pH Lead**	***Draft Procedure Ready for Testing: Dec 15, 2015.***
Dr. Maria Lourdes San Diego-McGlone	*Co-Lead*	
Dr. Adrienne Sutton		
Prof. Andrew Dickson		
Dr. Muhammad Lukman		
Prof. Sayedur Rahman Chowdhury		

Biology Working Group

Dr. Suchana Apple Chavanich	**Lead**	**Finalize SOPs: Dec 15, 2015?**
Dr. Aileen Tan Shau Hwai	*Co-Lead*	
NOAA CRED		
Prof. M. Shahadat Hossain		
Dr. Patrick Cabaitan		
Dr. Vo Si Tuan		

The Second Workshop : Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems (26-28 August 2015, Phuket, Thailand):



The Third Workshop : Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems (29-31 August 2015, Phuket, Thailand):

- ✓ 30 participants
- ✓ 2 experts (NOAA), 1 expert (1 from IOC), and 2 from the region

The Third Workshop : Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems (29-31 August 2015, Phuket, Thailand):

- Technical Aspects:
  - ✓ To brief on the latest development on GOA-ON and other OA related activities;
  - ✓ To report on the progress made since the 2nd workshop by the participants on their proposed pilot sites;
  - ✓ To will review and test the draft SOPs through expert discussions, and hands on either in field or at laboratory, in order to finalize the regional SOPs for monitoring the ecological impacts of ocean acidification on coral reef ecosystems;
  - ✓ Tentative plan for the next intersessional period.

The Third Workshop : Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems (29-31 August 2015, Phuket, Thailand):

❖ **Hand on the ARM processes:**

The Third Workshop : Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems (29-31 August 2015, Phuket, Thailand):

❖ **Hand on the pH and TA measurement:**

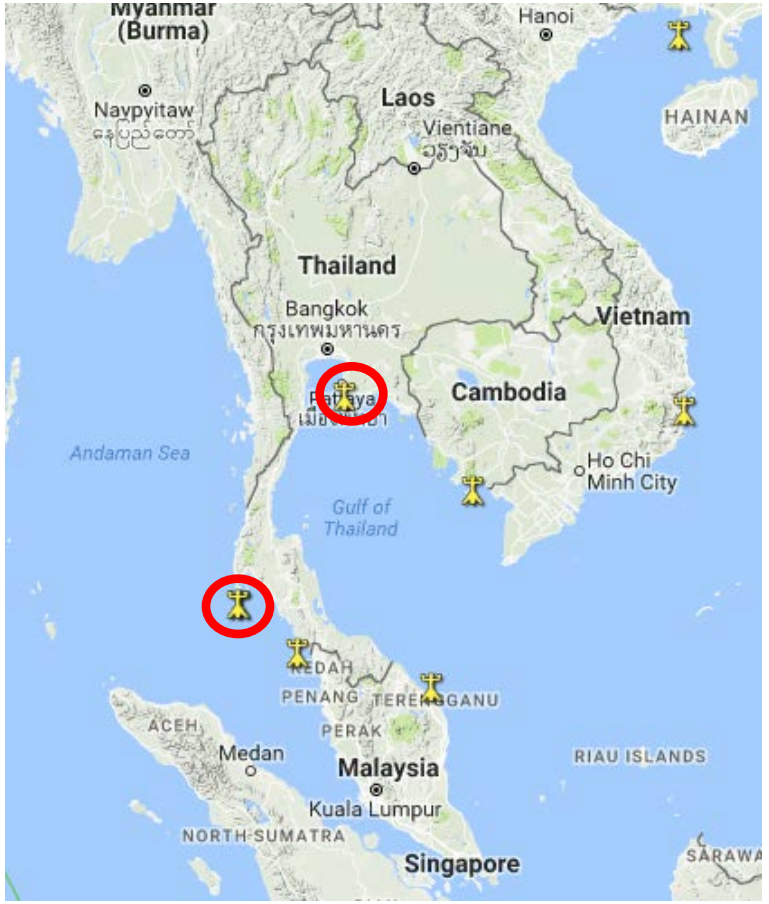
The Third Workshop : Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems (29-31 August 2015, Phuket, Thailand):

❖ **Standard Operation Procedure (SOP) for OA study of the WESPTPAC** :

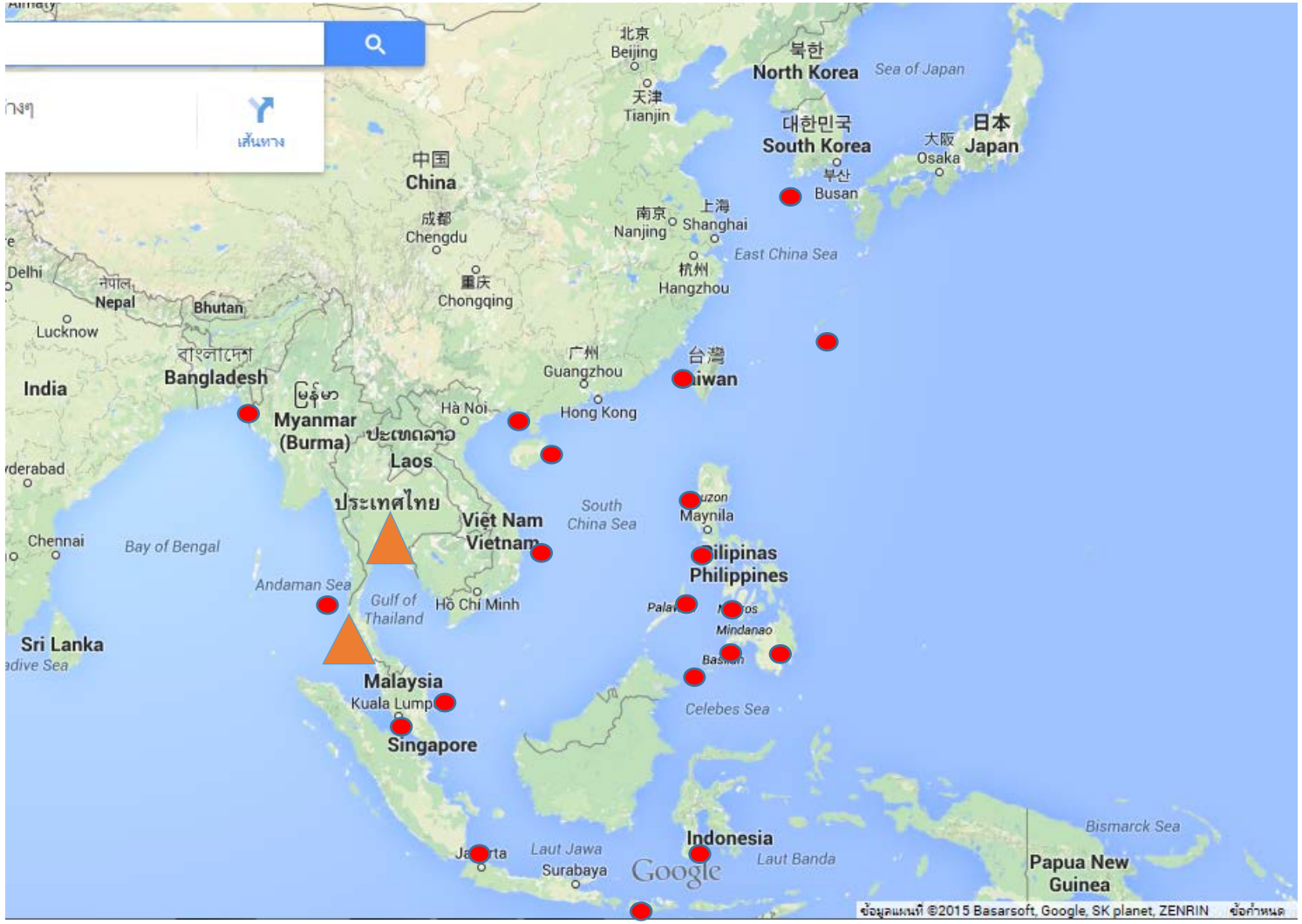
- ✓ Total Alkalinity (including method use by PMBC)
- ✓ Spectrophotometric pH (further review by expert)
- ✓ Biology Working (Further review)
- ✓ Carbonate Collection and Handling SOP (include in the pH and TA SOP)

The Third Workshop : Research and Monitoring of the Ecological Impacts of Ocean Acidification on Coral Reef Ecosystems (29-31 August 2015, Phuket, Thailand):

- Implement of OA and ARMs Monitoring in Andaman Sea and Gulf of Thailand start from January 2016 by Phuket Marine Biological Center and Chulalongkrong University, Thailand.
- There are some observations were done in Philippines and Indonesia under the cooperation with NOAA

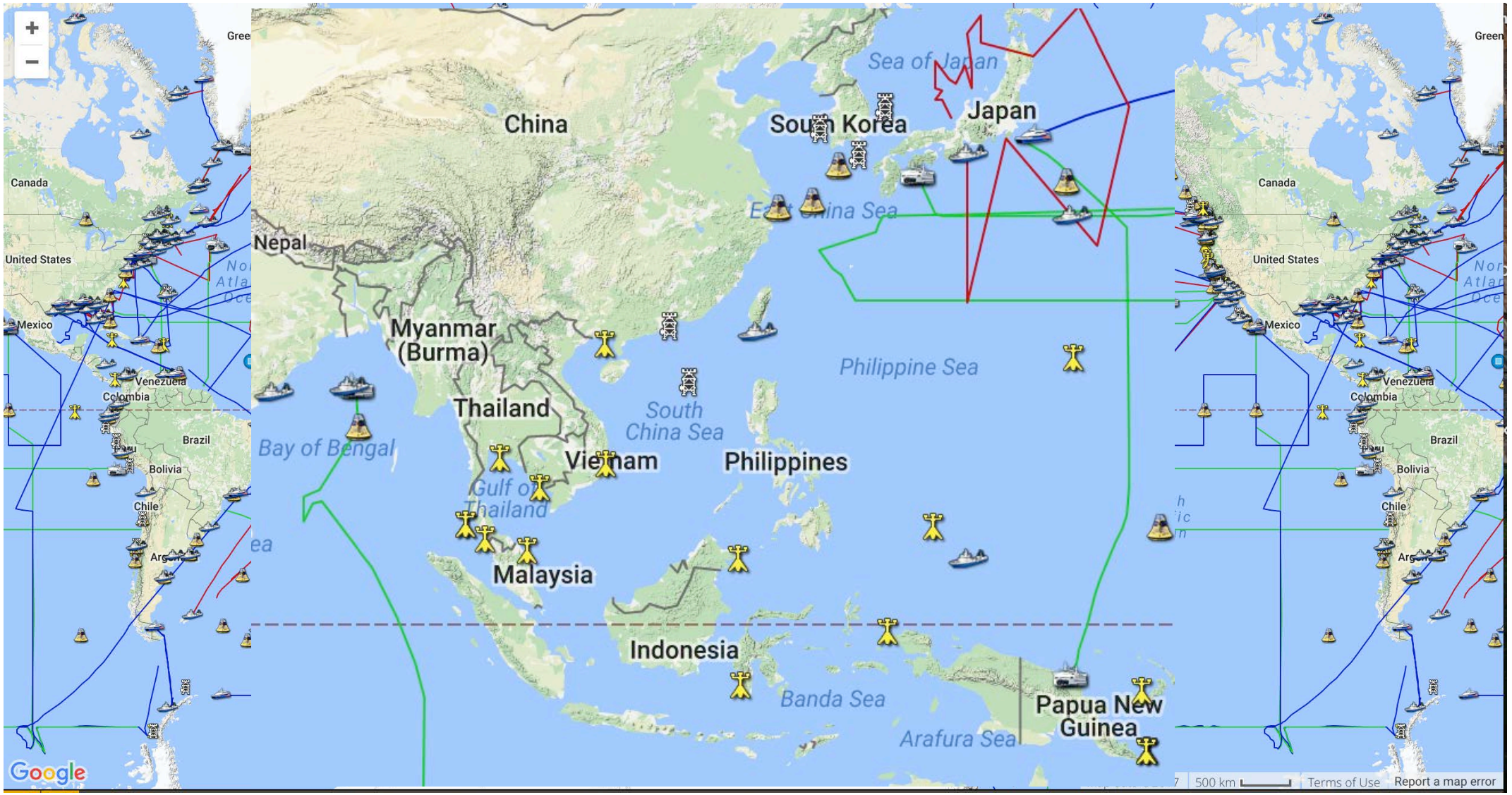


WESTPAC/SEAGOOS
Ocean Acidification Observing Network



Proposed the pilot sites for OA Observation to the WESTPAC/SEAGOOS, which some of those pilot sites have been operating since early of this year. The rest might be in the operation in near future.

Global Ocean Acidification Observing Network
GOA-ON



Thank You for Your Attention