Ocean Acidification: The Other CO_2 Problem

PMEL Climate and Ecosystems

Richard A. Feely
NOAA/Pacific Marine Environmental Laboratory
May 15, 2008

With special thanks to: Carol Turley, Chris Sabine, Jim Orr, Chris Langdon, Anne Cohen, and Sylvia Barry

Outline

1. What is ocean acidification?
2. What are the impacts on marine organisms?
3. What are NOAA's program goals for ocean acidification research?
4. Conclusions

What we know about ocean CO_2 chemistry

…from cumulative carbon sources and sinks over the last two centuries

Sources

Land-use change
200 Pg C
(42%)

Fossil emission
280 Pg C
(58%)

Sinks

Atmospheric accumulation
190 Pg C
(40%)

Terrestrial sink
166 Pg C
(35%)

Ocean sink
124 Pg C
(26%)

House et al. (2002) GCB

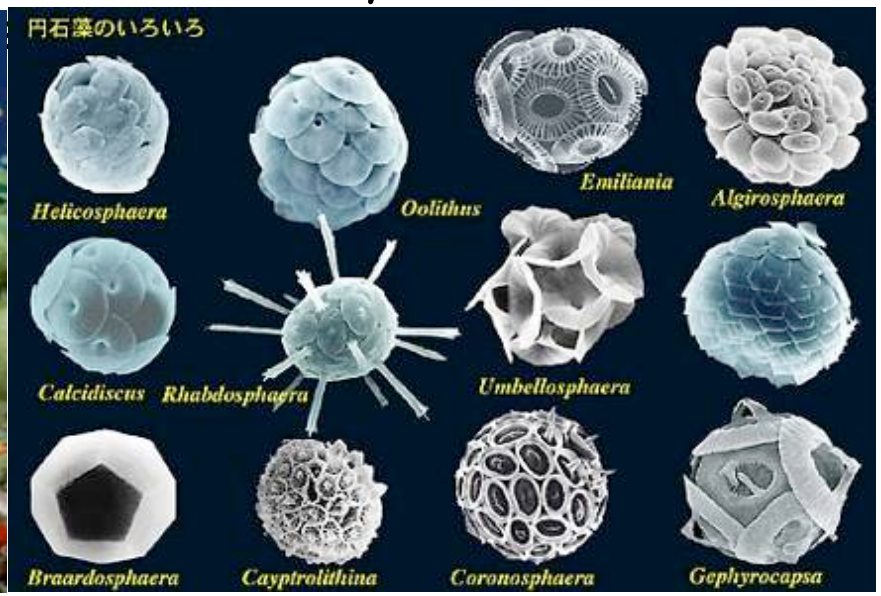
Ocean Acidification

Since the beginning of the industrial age, the pH and CO_2 chemistry of the oceans (ocean acidification) have been changing because of the uptake of anthropogenic CO_2 by the oceans.

- These changes in pH and carbonate chemistry may have serious impacts on open ocean and coastal marine ecosystems.

Photo: Missouri Botanical Gardens

Corals



http://www.biol.tsukuba.ac.jp/~inouye

Calcareous Plankton

What we know about the ocean chemistry of
…saturation state

$$CO_2 + CO_3^{2-} + H_2O \Leftrightarrow 2HCO_3^-$$

Saturation State

$$\Omega_{phase} = \frac{[Ca^{2+}][CO_3^{2-}]}{K^*_{sp,phase}}$$

$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3$$

calcium carbonate — calcium carbonate

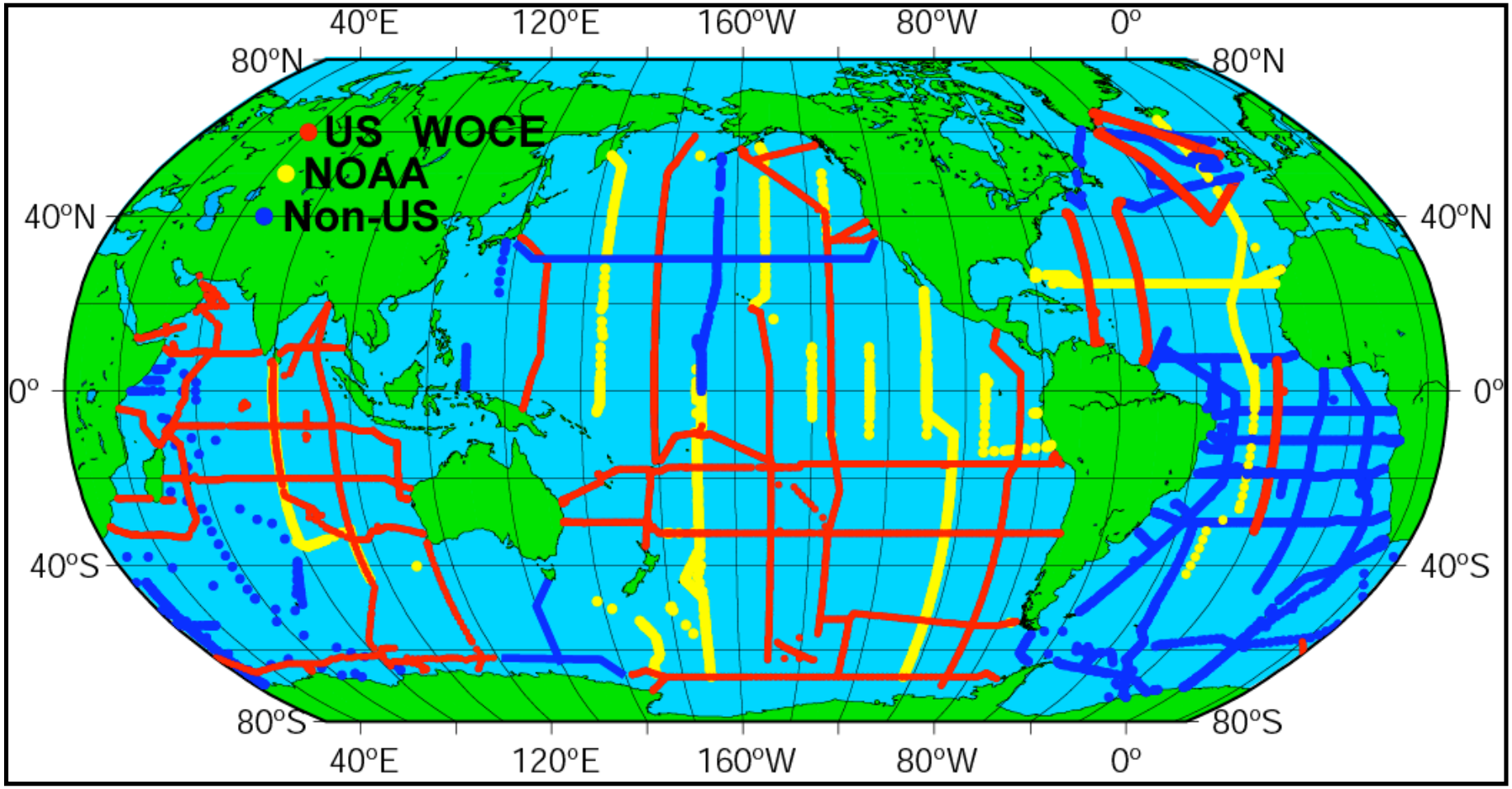
$\Omega > 1 =$ *precipitation*

$\Omega = 1 =$ *equilibrium*

$\Omega < 1 =$ *dissolution*

What we know about ocean CO_2 chemistry

…from field observations



WOCE/JGOFS/OACES Global CO_2 Survey

~72,000 sample locations collected in the 1990s

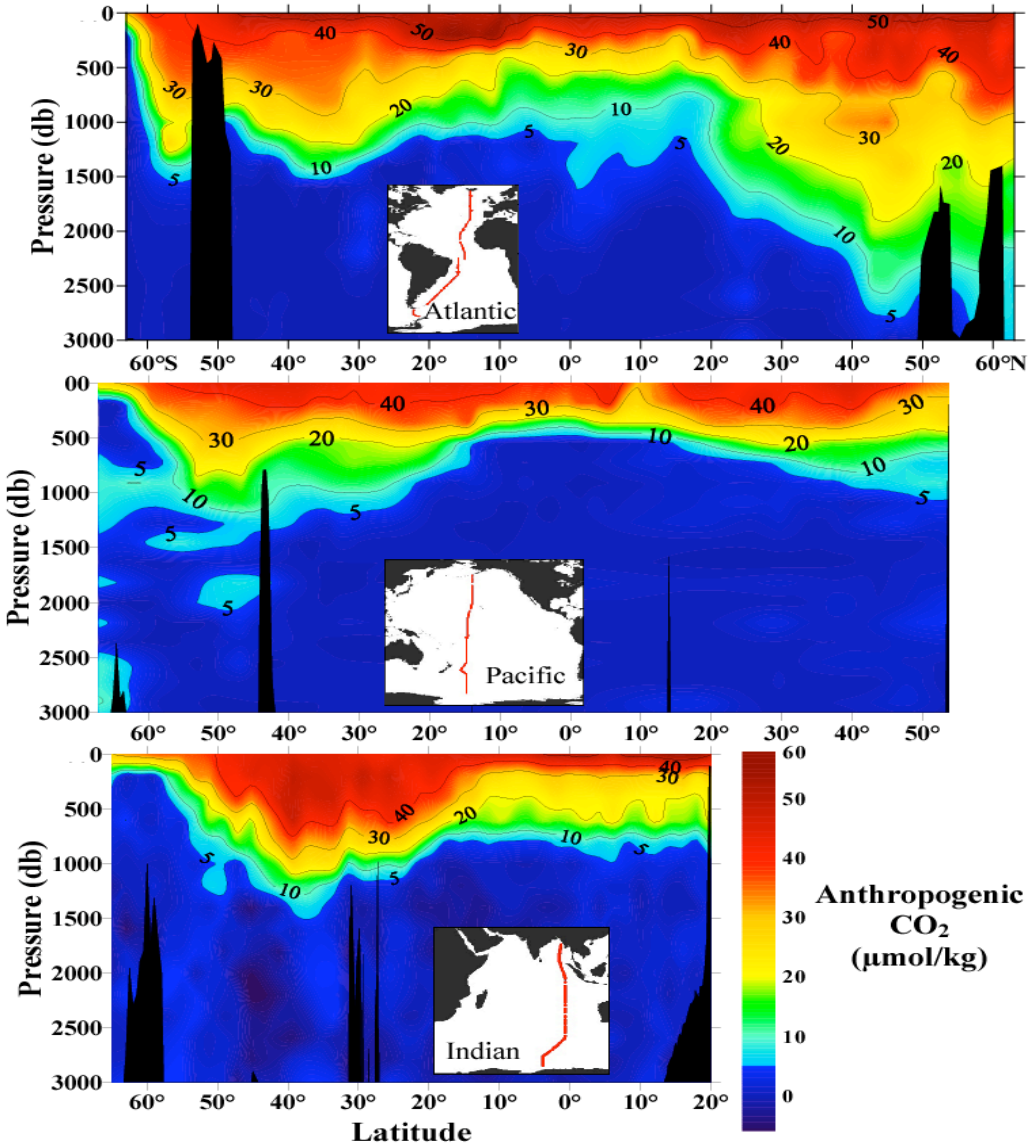
DIC ± 2 μmol kg^{-1}

TA ± 4 μmol kg^{-1}

Sabine et al (2004)

What we know about ocean CO_2 chemistry

…about human impacts on ocean CO_2 chemistry

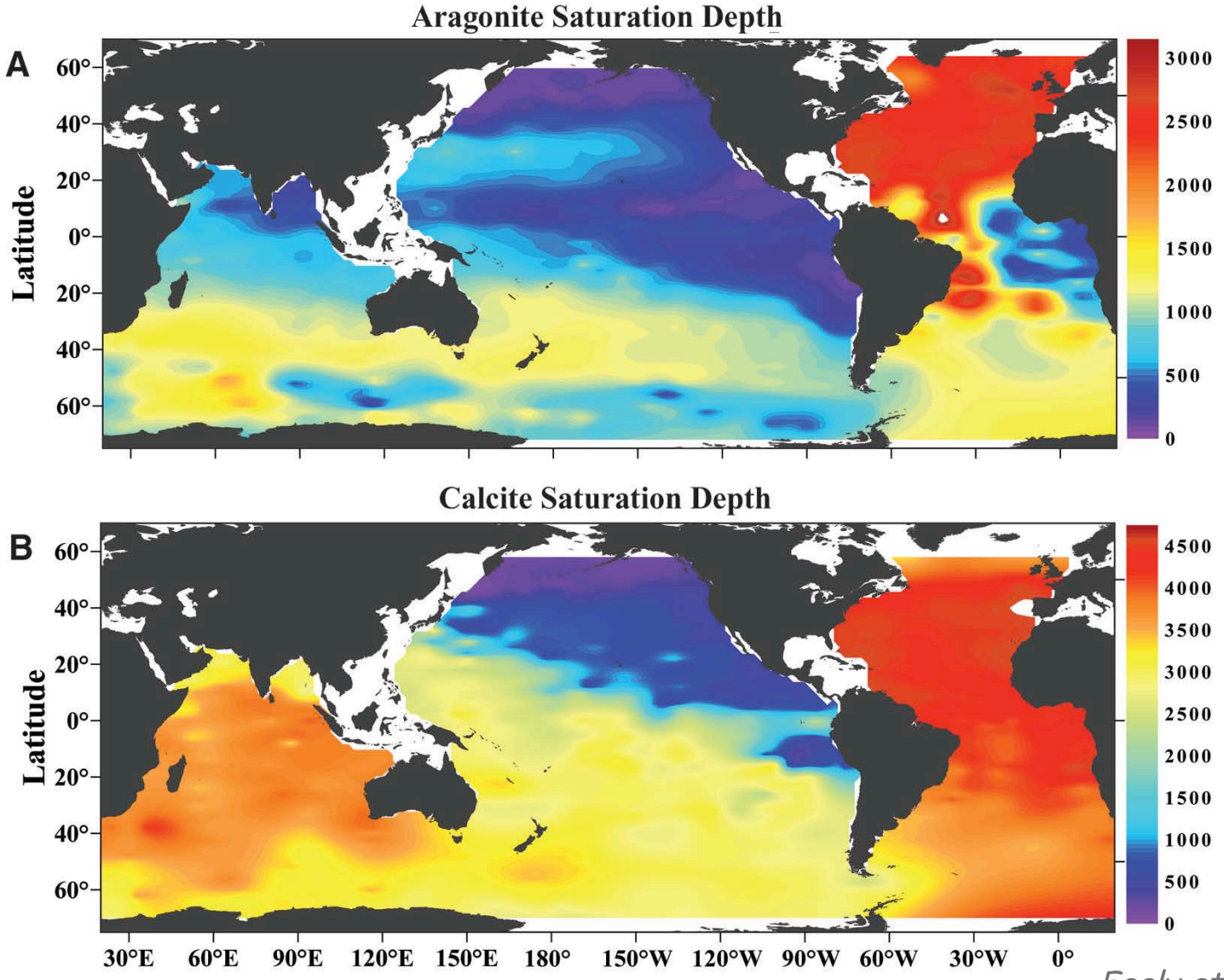


- From the WOCE/JGOFS global CO_2 survey, the observed anthropogenic CO_2 inventory through 1994 is calculated to be 118±19 Pg C.
- Because the ocean mixes slowly, half of the anthropogenic CO_2 stored in the oceans is found in the upper 10% of the ocean
- What are the impacts of increased CO_2 on marine ecosystems?

Sabine et al. Science (2004)

What we know about ocean CO_2 chemistry

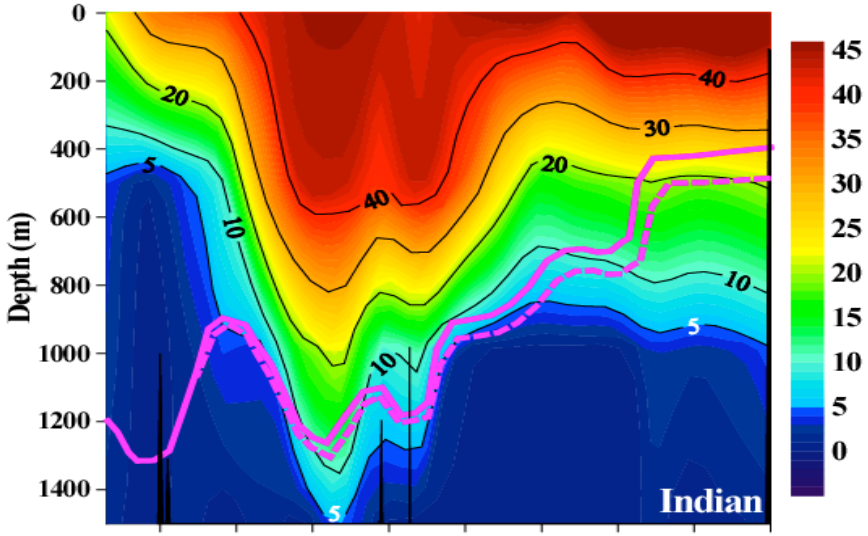
…from observed aragonite and calcite saturation depths in the global oceans

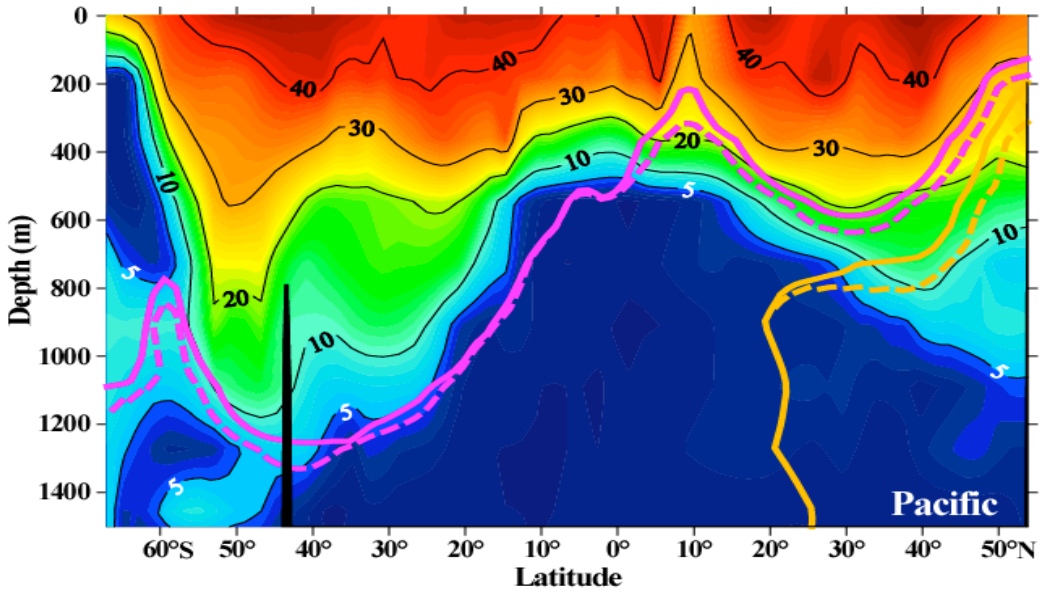


Feely et al. (2004)

What we know about ocean CO_2 chemistry

…from observed shoaling saturation horizons





Global Water-column Dissolution = 0.5 Pg C yr^{-1}

Modern Aragonite Saturation Horizon

Preindustrial Aragonite Saturation Horizon

Modern Calcite Saturation Horizon

Preindustrial Calcite Saturation Horizon

The aragonite and calcite saturation horizons have shoaled towards the surface of the oceans due to the penetration of anthropogenic CO_2 into the oceans.

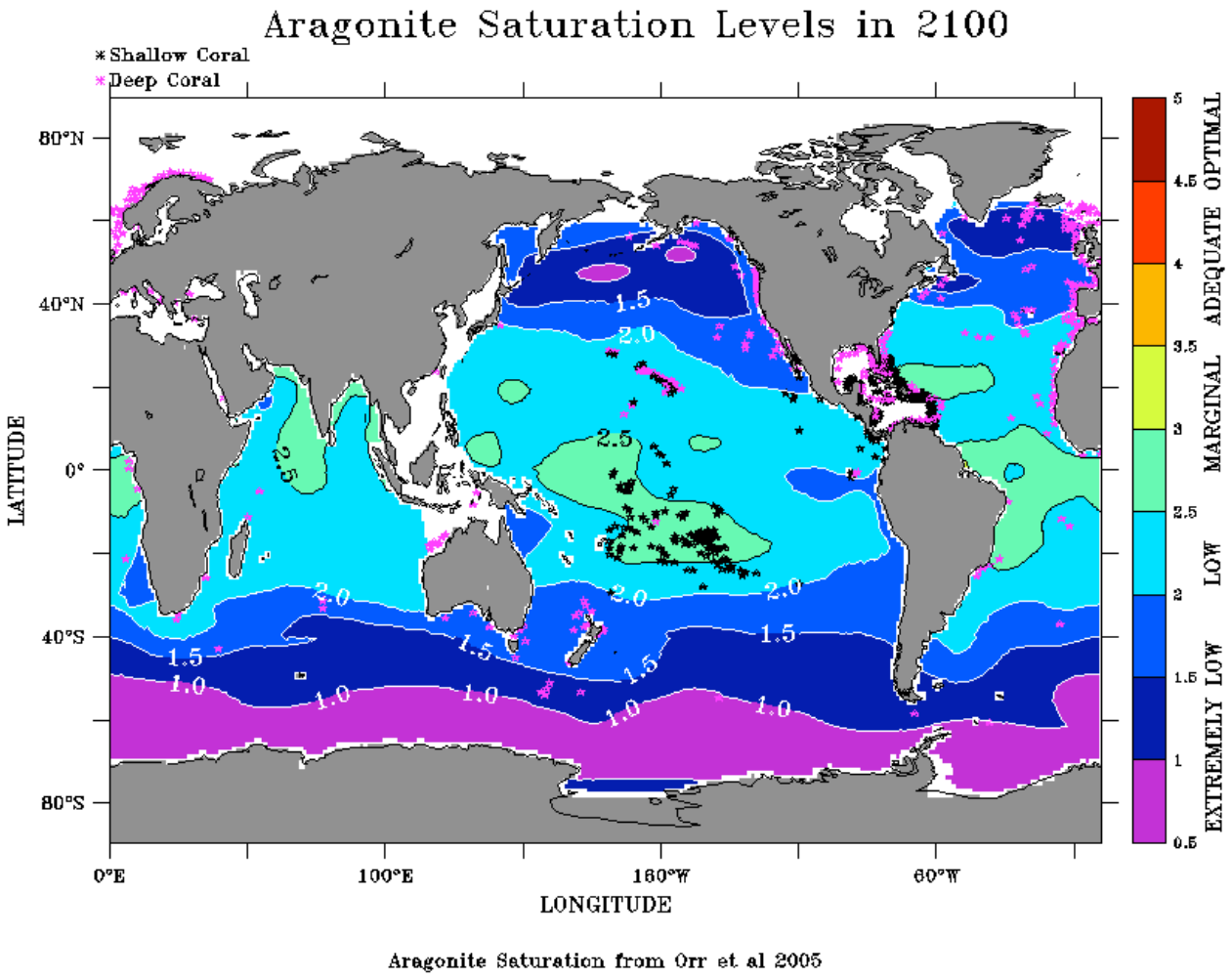
Feely et al. (2004)

Predictions of Ocean Acidification and the effects on coral reef calcification

Coral Reef calcification

- 1765 **Adequate**
- 2000 **Marginal**
- 2100 **Low**

Calcification rates in the tropics may decrease by 30% over the next century



After Feely et al (in press) with Modeled Saturation Levels from Orr et al (2005)

North American Carbon Program

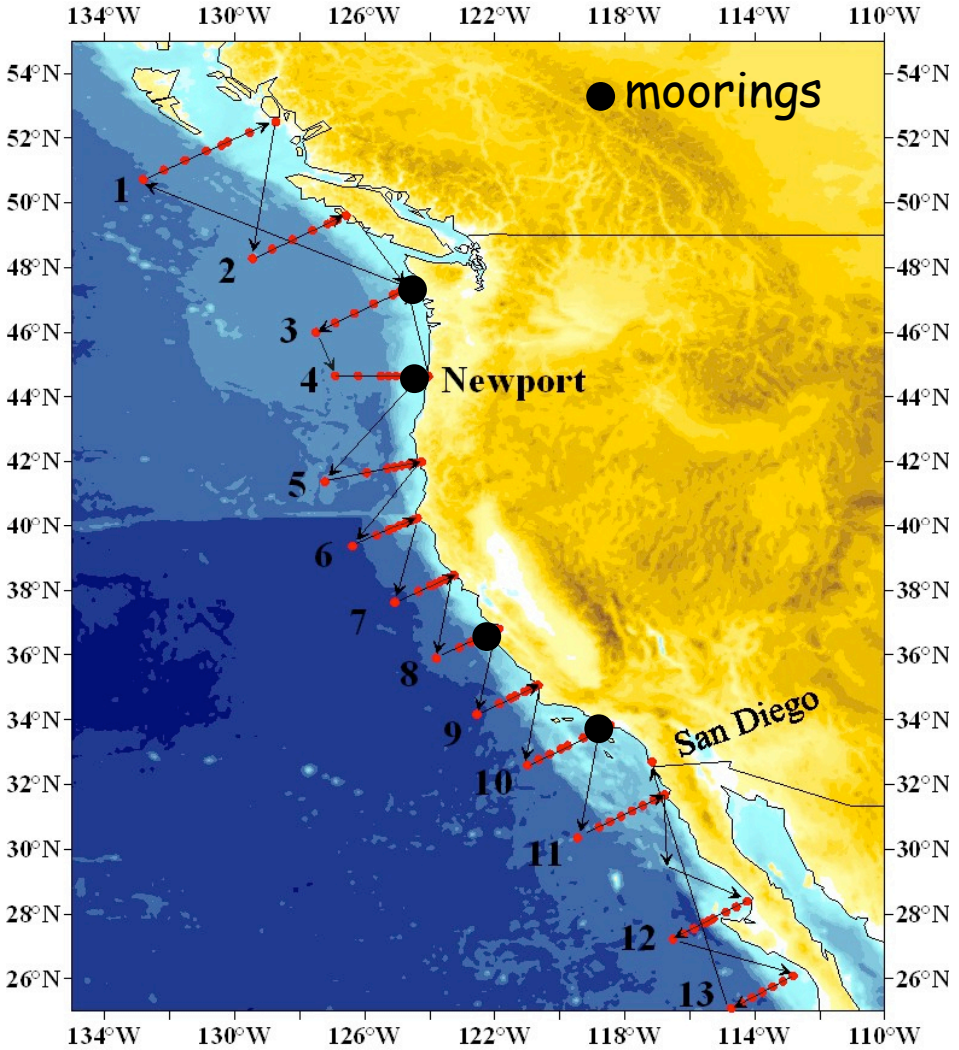
Continental Carbon Budgets, Dynamics, Processes, and Management

Newport

Aberdeen

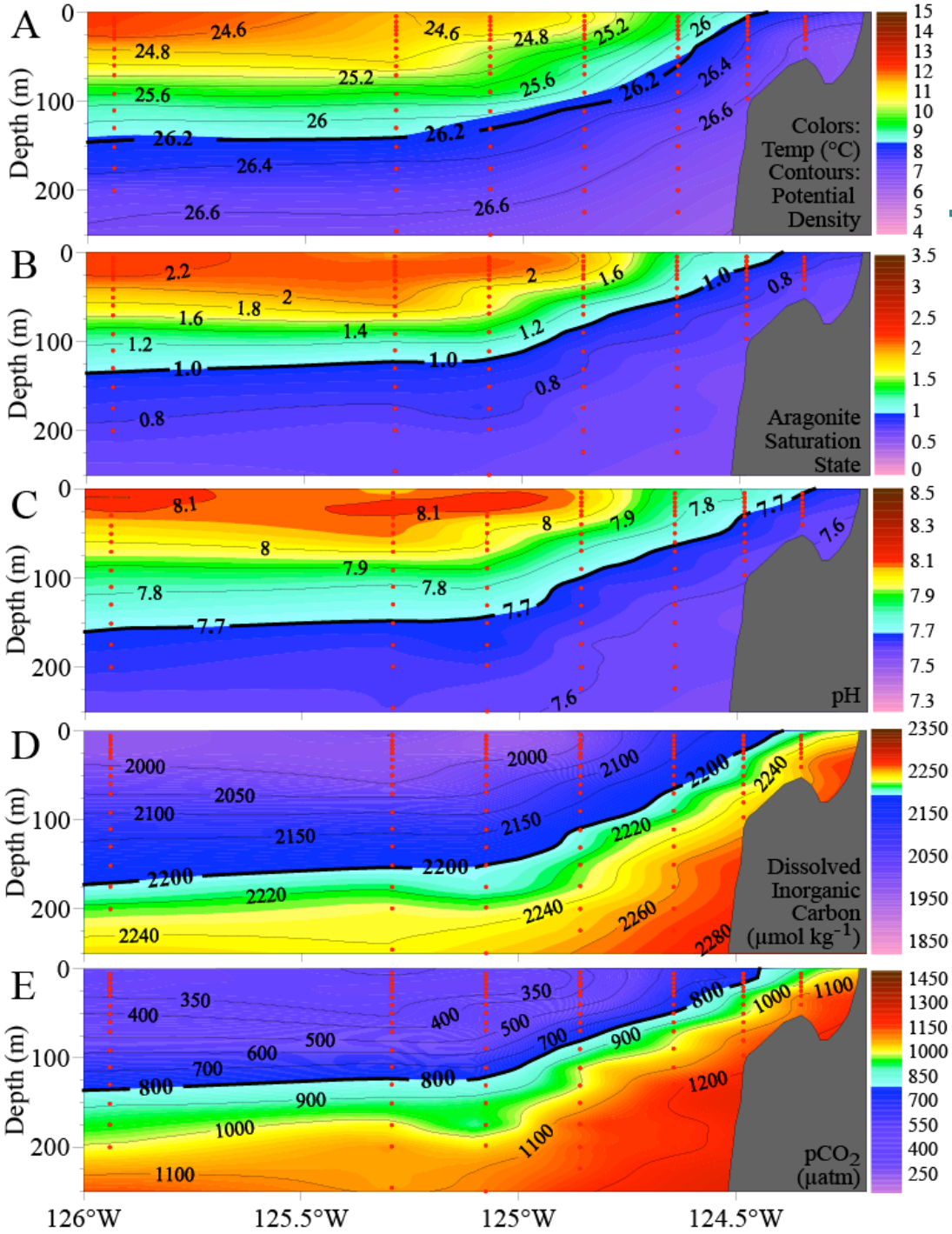
MBARI

UCLA



NACP West Coast Survey Cruise : 11 May - 14 June 2007
and mooring locations

Upwelling Induced Acidification of the Continental Shelf



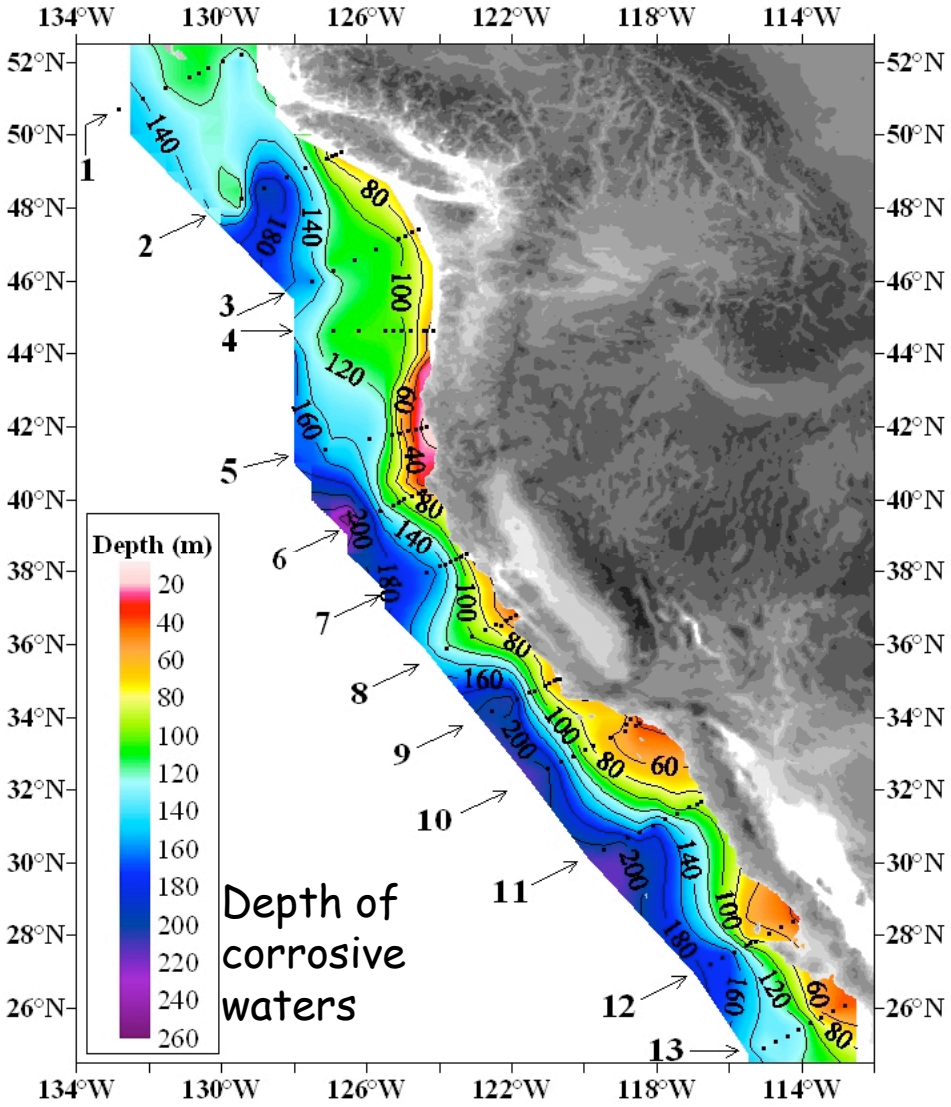
Vertical sections from Line 5 (Pt. St. George, California)

The 'ocean acidified' corrosive water was upwelled from depths of 150-200 m onto the shelf and outcropped at the surface near the coast.

Red dots represent sample locations.

North American Carbon Program

Continental Carbon Budgets, Dynamics, Processes, and Management



Ocean Acidification of the North American Continental Shelf

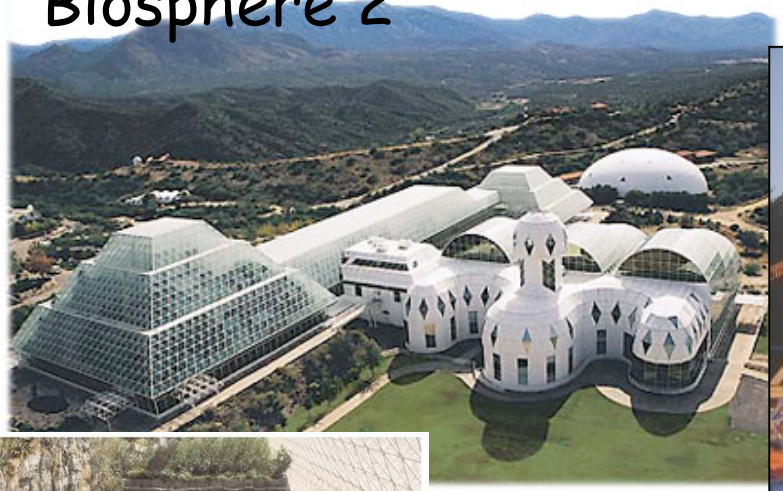
NACP Coastal Survey Cruise:
11 May - 14 June 2007

Distribution of the depths of the corrosive water (aragonite saturation < 1.0; pH < 7.75) on the continental shelf of western North America from Queen Charlotte Sound, Canada to San Gregorio Baja California Sur, Mexico.

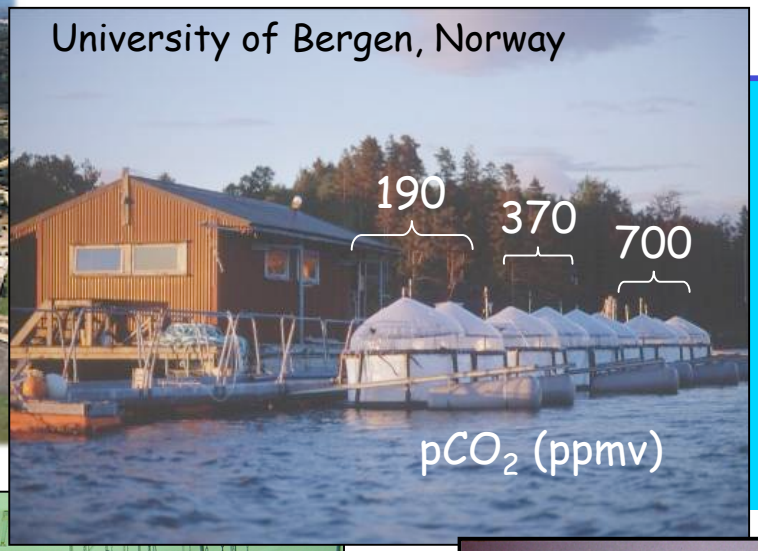
On transect lines 5 and 6 the corrosive water reaches all the way to the surface in the inshore waters near the coast.

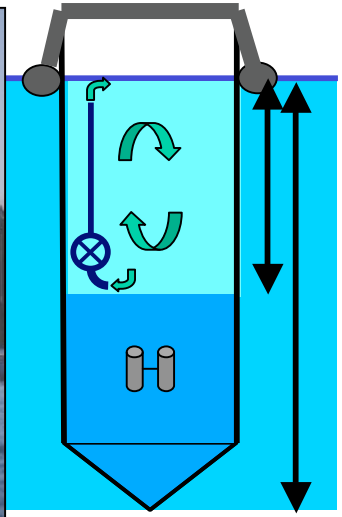
Experiments on Many Scales

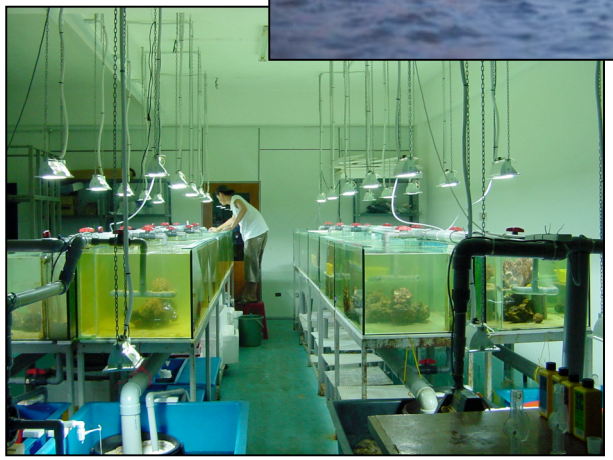
Biosphere 2



Large Scale Mesocosm Facility

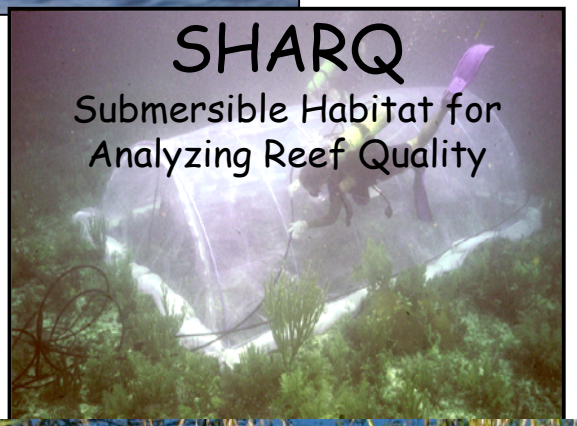






SHARQ

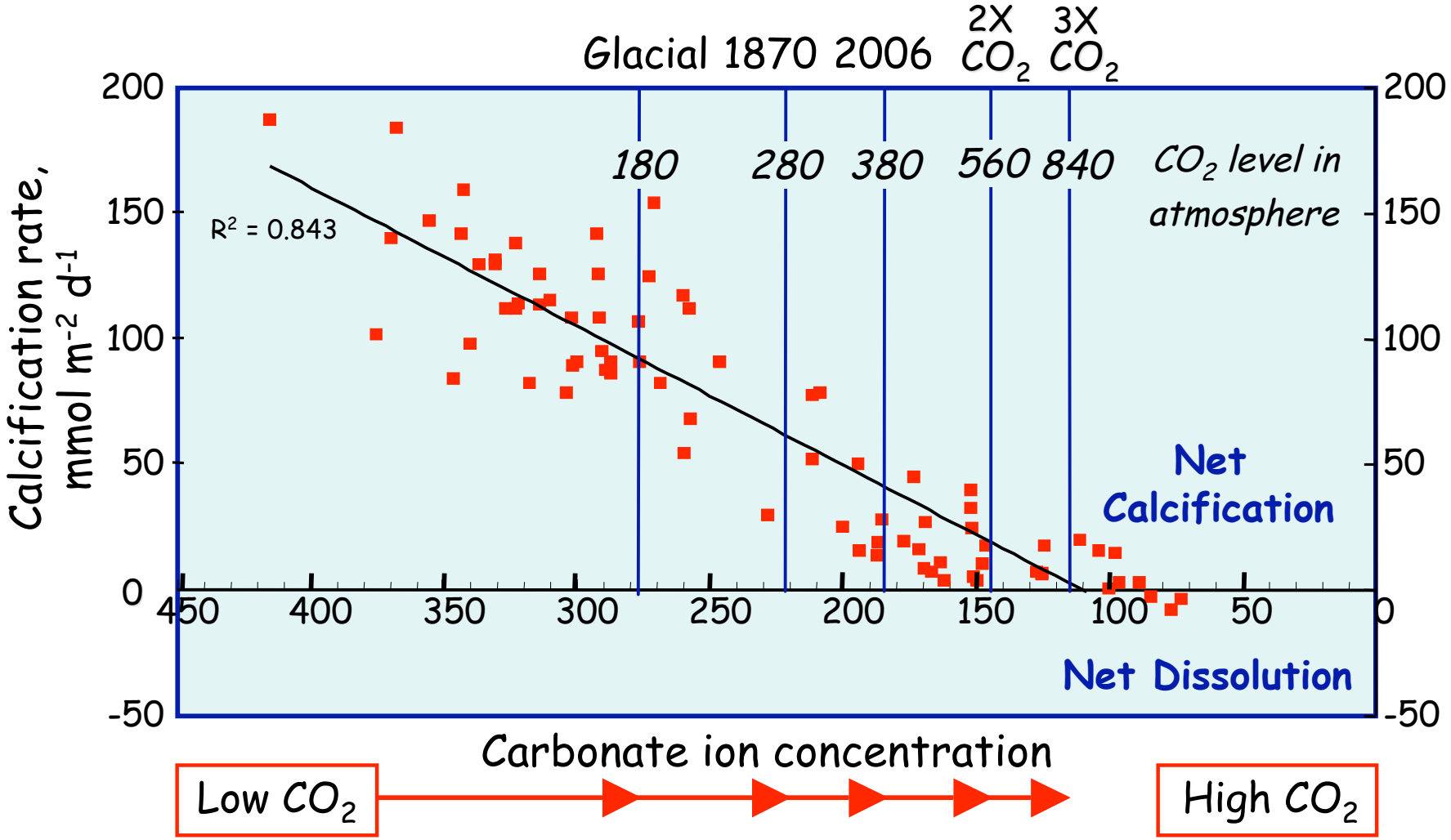
Submersible Habitat for Analyzing Reef Quality



Provided by Mark Eakin

Aquaria and Small Mesocosms

The impact of rising atmospheric CO_2 on the surface ocean carbonate chemistry and its potential impact on corals - Biosphere 2 Results



Langdon & Atkinson, (2005)

What we know about the biological impacts of ocean acidification

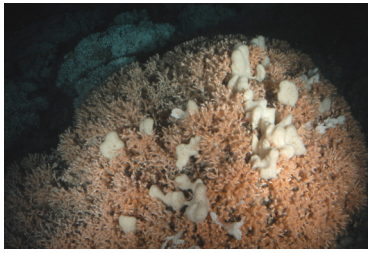
...and sensitivity to CO_2/pH perturbation

Much of our present knowledge stems from

- abrupt CO_2/pH perturbation experiments
- with single species/strains
- under short-term incubations
- with often extreme pH changes

Hence, we know little about

- responses of genetically diverse populations
- synergistic effects with other stress factors
- physiological and micro-evolutionary adaptations
- species replacements
- community to ecosystem responses
- impacts on global climate change



NOAA Perspective

- More research is needed to determine the temporal and spatial changes of the carbon system in the global oceans and their impacts on biological communities and ecosystems.

- Manipulative experiments will help us understand the impacts of high CO_2 on calcification, respiration, reproduction, settlement and remineralization.

- Long term experiments are necessary to observe if marine calcifying organisms will be able to acclimate to elevated CO_2 and/or temperature if given sufficient time.

- We need to discover how certain species are able to adapt to life in low saturation state water.

- We need to know the effects of high CO_2 on the processes that affect ecosystem responses and global carbon feedbacks.

NOAA-wide Ocean Acidification Alternative

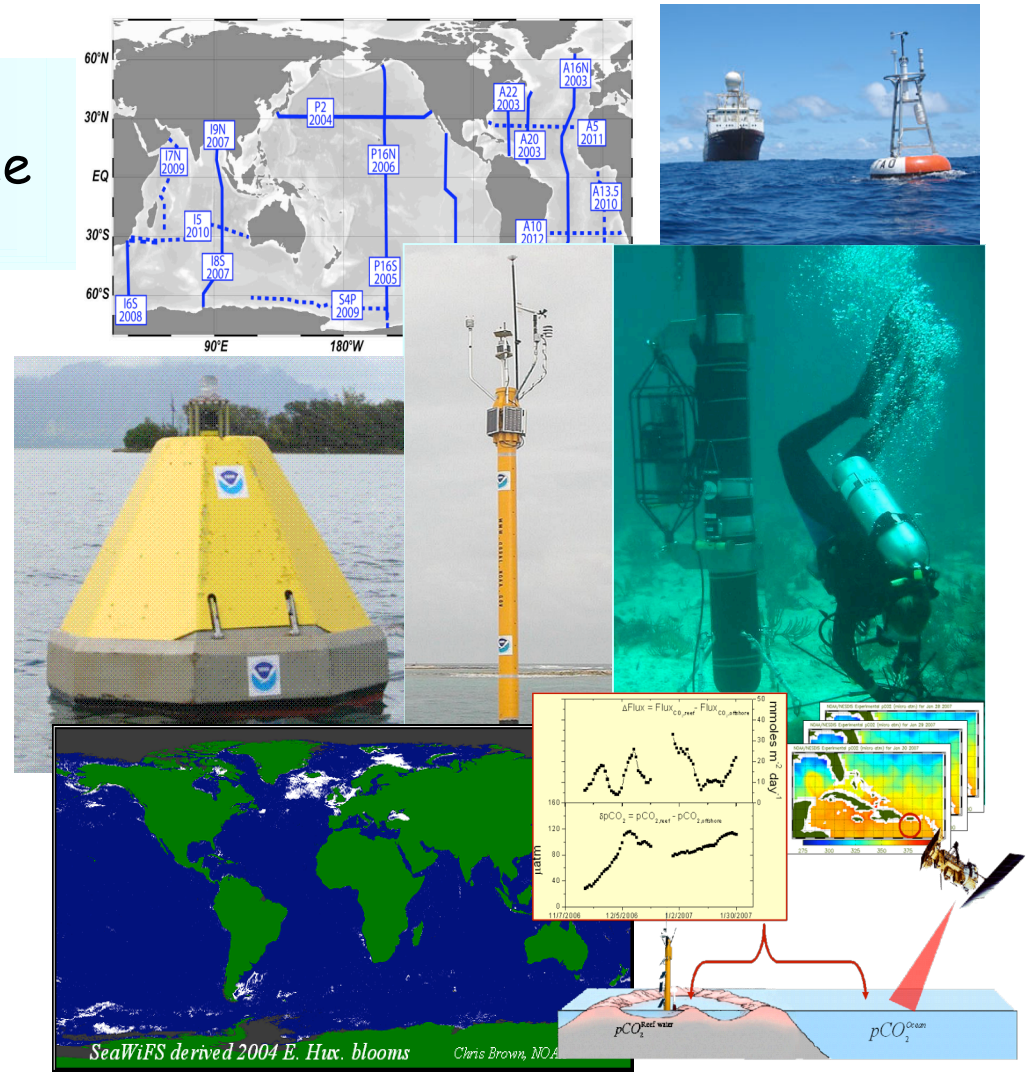
This NOAA-wide alternative will provide NOAA and its stakeholder community with the following outcomes:

- A comprehensive characterization of the threat ocean acidification poses to marine ecosystems;
- A monitoring capacity to quantify and track ocean acidification and its impacts in oceanic and coastal systems;
- An improved OA forecasting capability to provide stakeholders with the capacity to proactively and appropriately respond to ocean acidification;
- Offer adaptive management tools and requisite scientific knowledge for understanding and responding to OA in support of ecosystem-based management.

NOAA Ocean Acidification Research and Planning Activities

Existing and planned NOAA activities have important relevance to this rapidly emerging issue.

- Ocean Carbon Inventory (Repeat Hydro)
- Global Ocean CO_2 Flux (VOS)
- Technology Development
- Remote Sensing Applications
- CO_2 Mooring Network
- Coral Reef Monitoring Networks
- Environmental Modeling
- Physiological Research
- Joint Workshop's & Interagency Collaboration



Conclusions

- Impacts of ocean acidification on ecosystems are largely unknown.
- Calcification in many planktonic organisms is reduced at elevated CO_2, but the response is not uniform.
- Possible responses of ecosystems are speculative but could involve changes in species composition & abundances - could affect food webs, biogeochemical cycles.
- Satellite measurements and observational data can be integrated to provide global views of changing ecosystem dynamics and carbonate budgets.

Ocean Acidification Legislation

Senate (S. 1581) and House bills (H.R. 1474): 'Federal Ocean Acidification Research And Monitoring Act of 2007

- Introduced June and November 2007, respectively
- Senate Bill out of committee Dec 2007
- House Bill in House Resources Committee

FORAM ACT of 2007

Goal: To establish an interagency committee to develop an ocean acidification research and monitoring plan and to establish an ocean acidification program within the National Oceanic and Atmospheric Administration.