

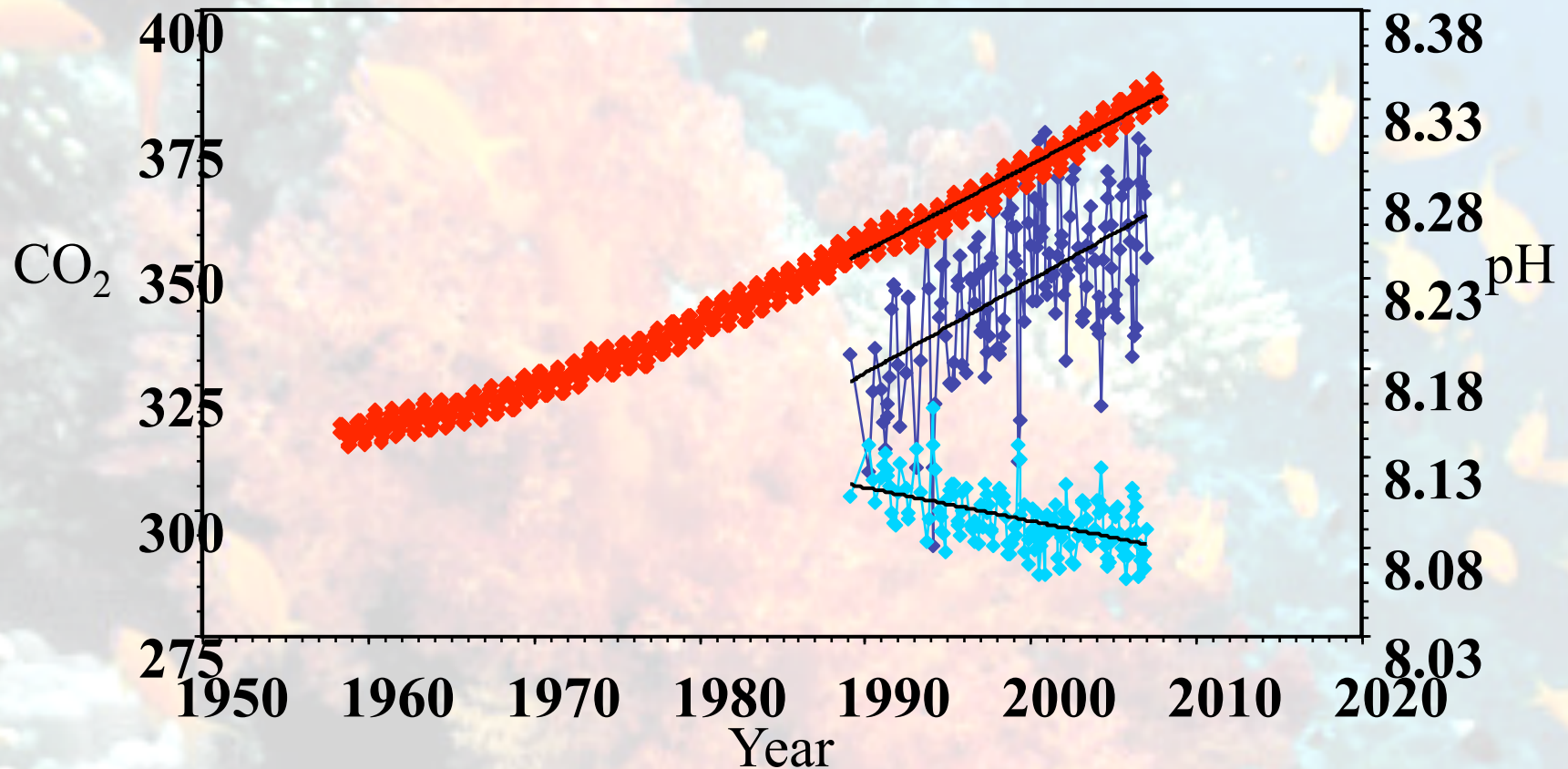
Ocean Acidification: The Other CO₂ Problem

Ocean Climate Observations Annual Review

Richard A. Feely

NOAA/Pacific Marine Environmental Laboratory,
September 3, 2008

*With special thanks to: Carol Turley, Chris Sabine,
Jim Orr, Chris Langdon*



Ocean Acidification

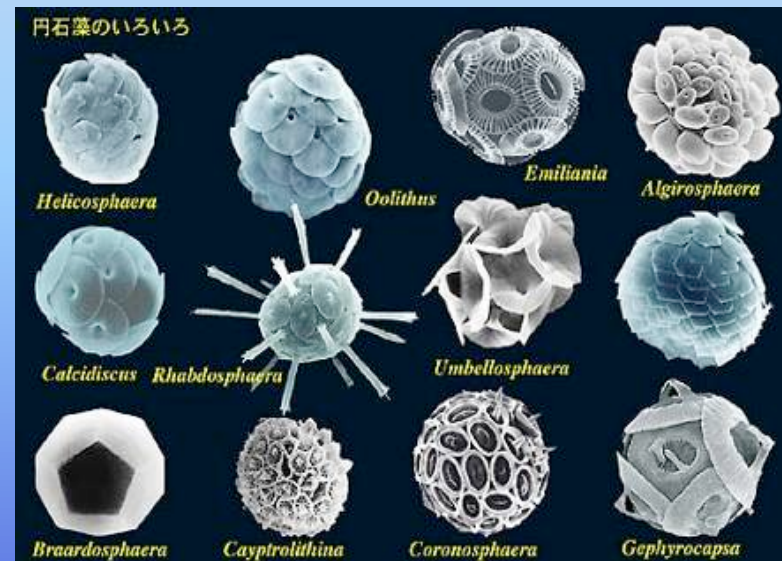
Since the beginning of the industrial age, the pH and CO_2 chemistry of the oceans (ocean acidification) have been changing because of the uptake of anthropogenic CO_2 by the oceans.

- Decrease in pH 0.1 over the last two centuries
- 30% increase in acidity; decrease in carbonate ion of about 16%

Photo: Missouri Botanical Gardens



Corals



Calcareous Plankton

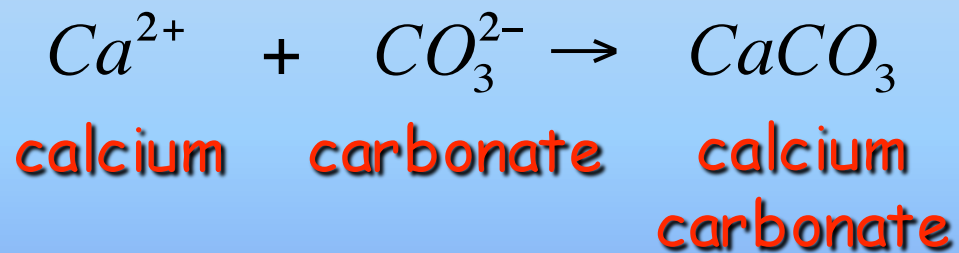
<http://www.biol.tsukuba.ac.jp/~inouye>

What we know about the ocean chemistry of
...saturation state



Saturation State

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



$\Omega > 1 =$ precipitation

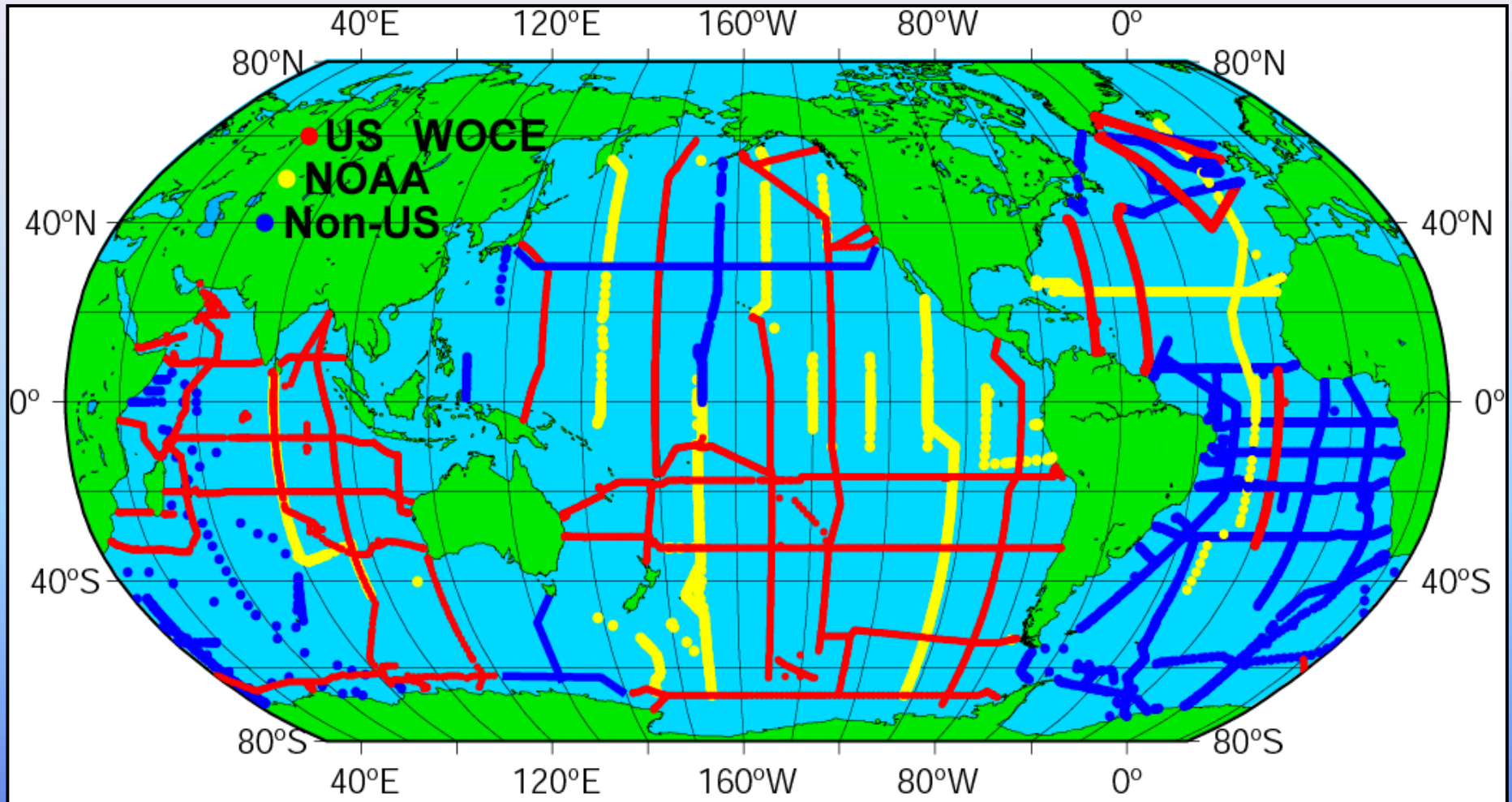
$\Omega = 1 =$ equilibrium

$\Omega < 1 =$ dissolution



What we know about ocean CO₂ chemistry

...from field observations



WOCE/JGOFS/OACES Global CO₂ Survey

~72,000 sample locations
collected in the 1990s

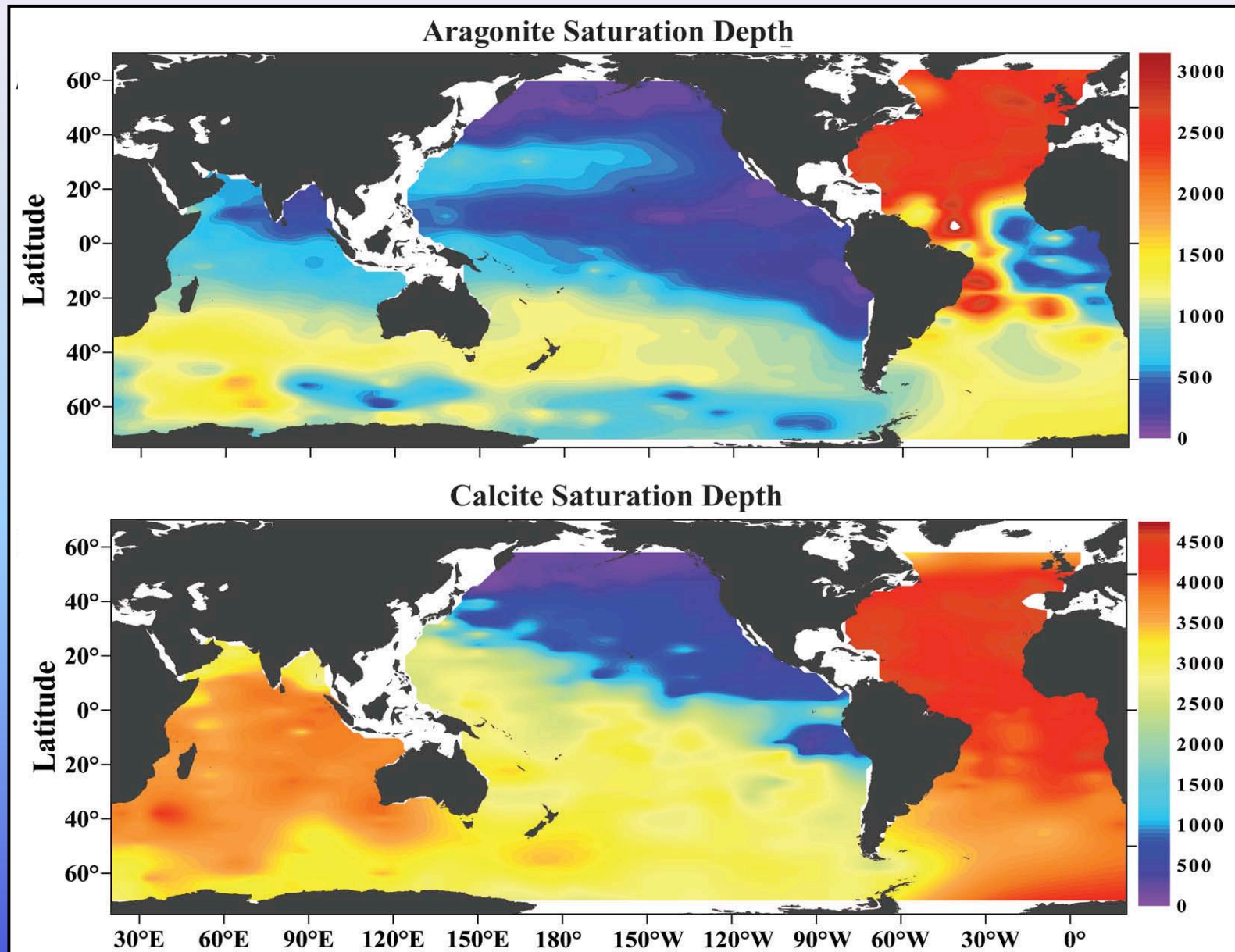
DIC $\pm 2 \mu\text{mol kg}^{-1}$

TA $\pm 4 \mu\text{mol kg}^{-1}$

Sabine et al (2004)

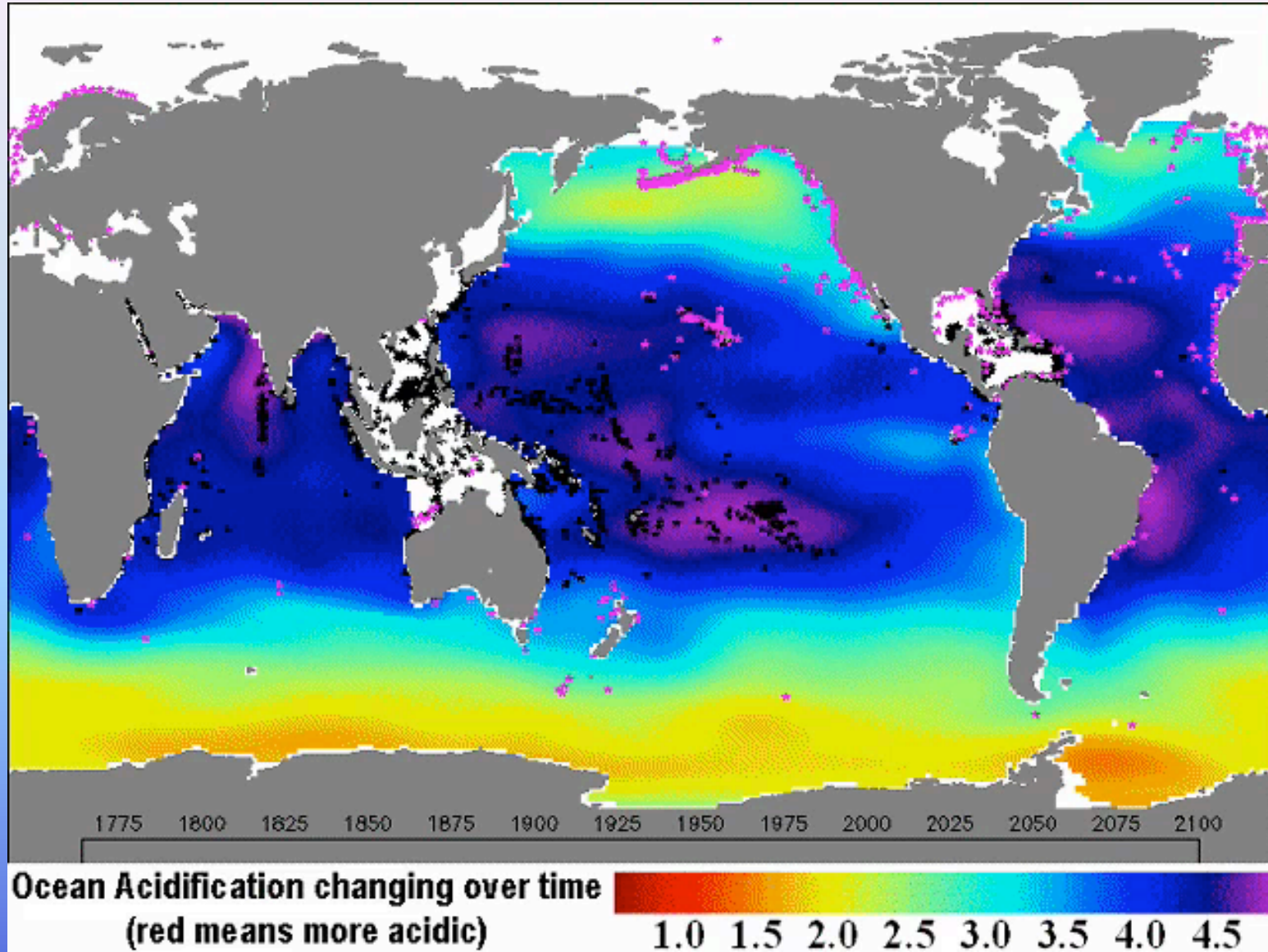
What we know about ocean CO₂ chemistry

...from observed saturation depths in the global oceans



Feely et al. (2004)

Predictions of Ocean Acidification in the Global Oceans



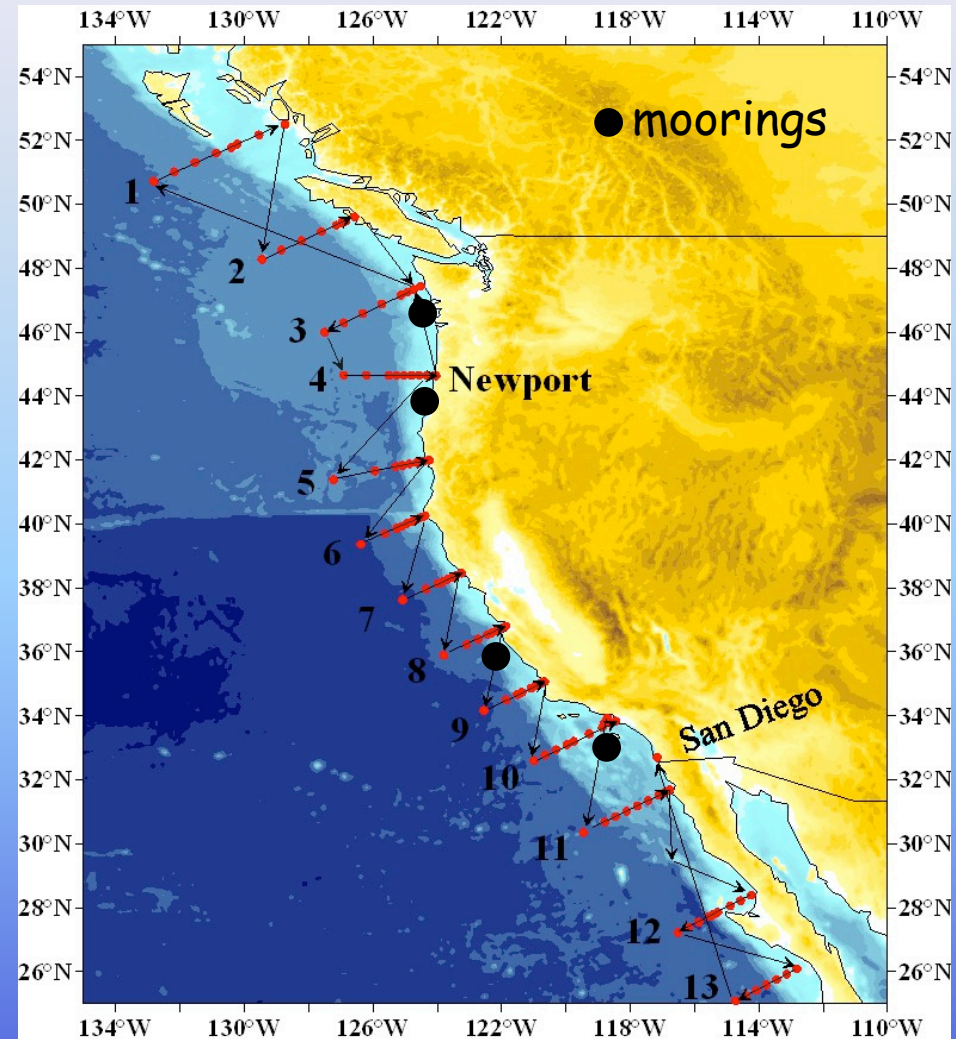
Calcification rates in the tropics may decrease by 30% over the next century

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



North American Carbon Program

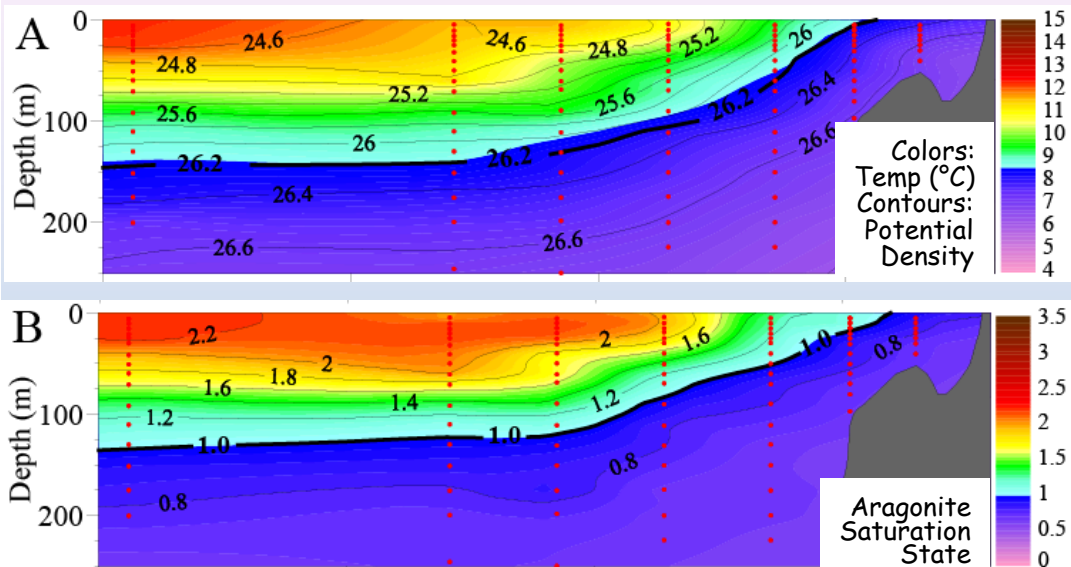
Continental Carbon Budgets, Dynamics, Processes, and Management



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

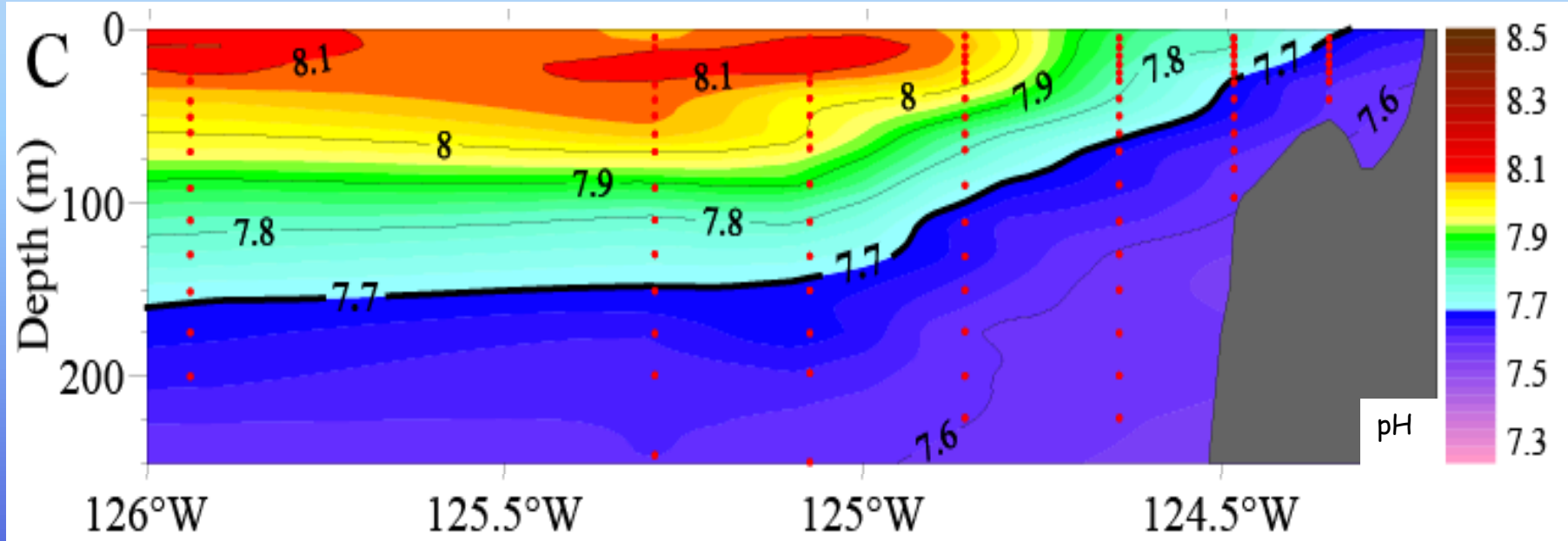
Feely et al. (2008)

NACP Coastal Survey Cruise: 11 May - 14 June 2007



Upwelling Induced Acidification of the Continental Shelf

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.

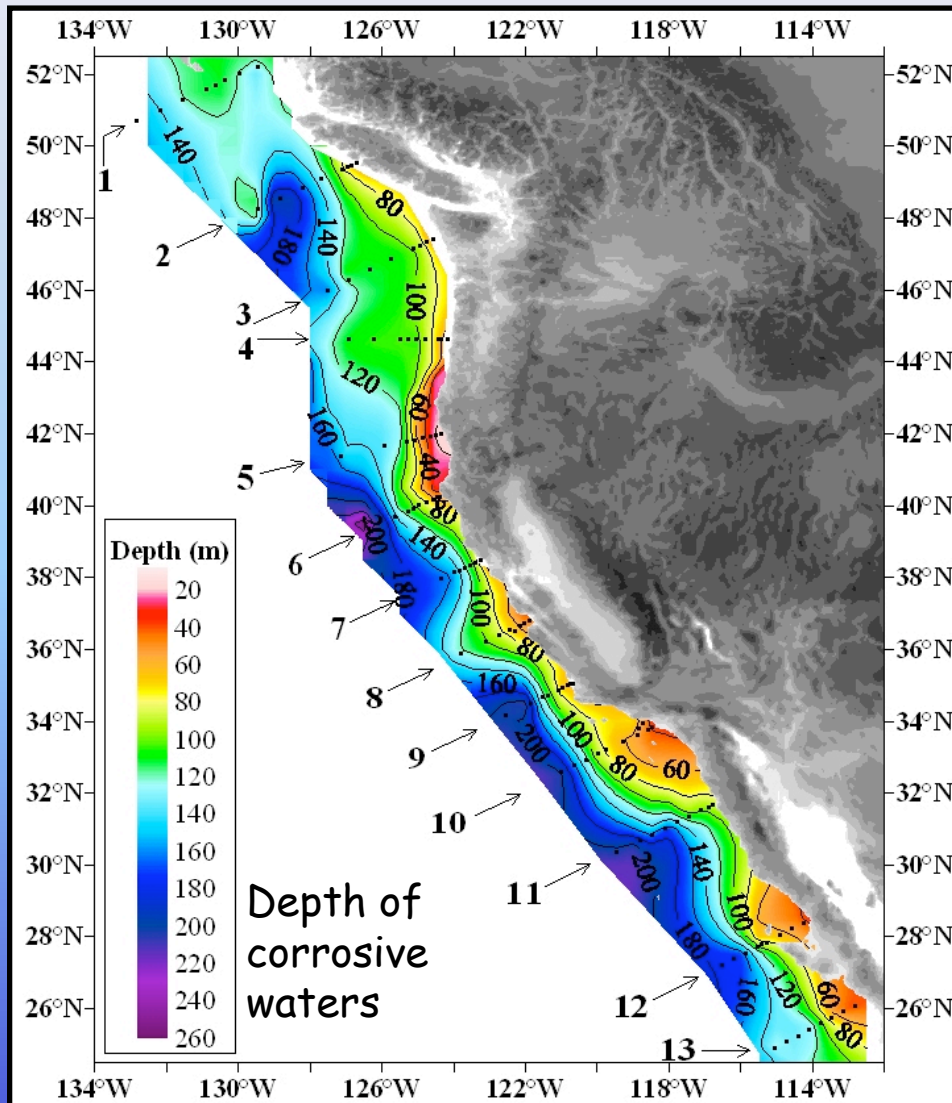
Vertical sections from Line 5 (Pt. St. George, California)

Feely et al. (2008)



North American Carbon Program

Continental Carbon Budgets, Dynamics, Processes, and Management



Feely et al. (2008)

Ocean Acidification of the North American Continental Shelf

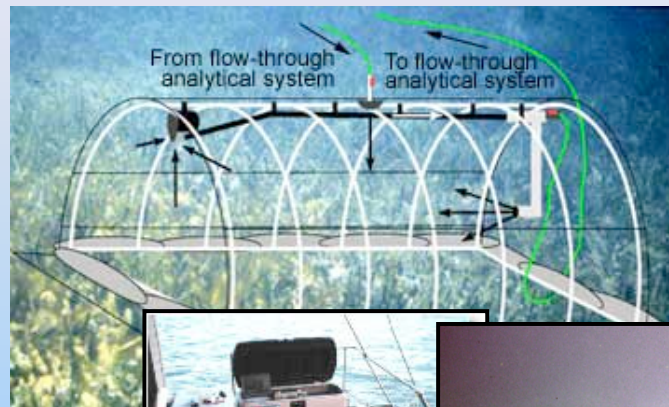
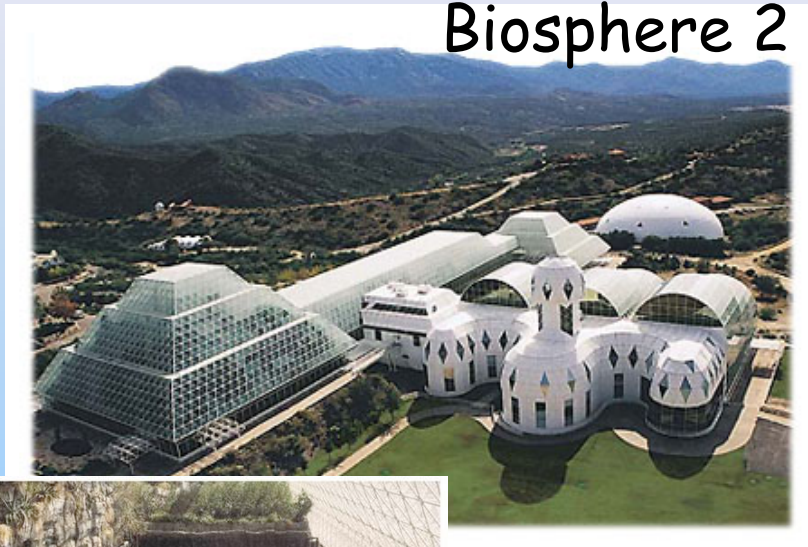
NACP Coastal Survey Cruise:
11 May - 14 June 2007

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



Provided by Mark Eakin



SHARQ
Submersible Habitat for
Analyzing Reef Quality



Aquaria and Small Mesocosms

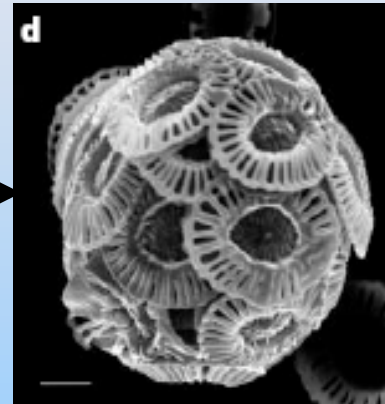
Coccolithophore (single-celled algae)

$p\text{CO}_2$ 280-380 ppmv



Emiliana huxleyi

$p\text{CO}_2$ 780-850 ppmv



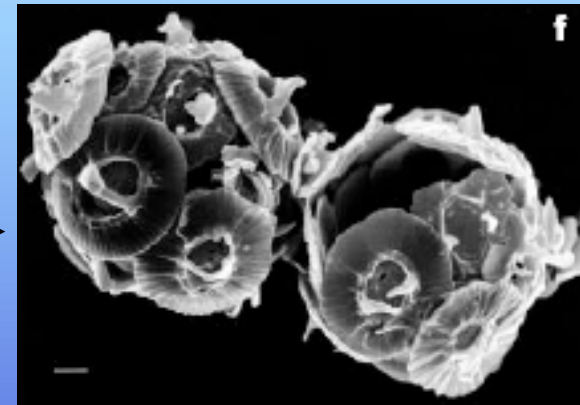
Calcification
decreased

- 9 to 18%



Gephyrocapsa oceanica

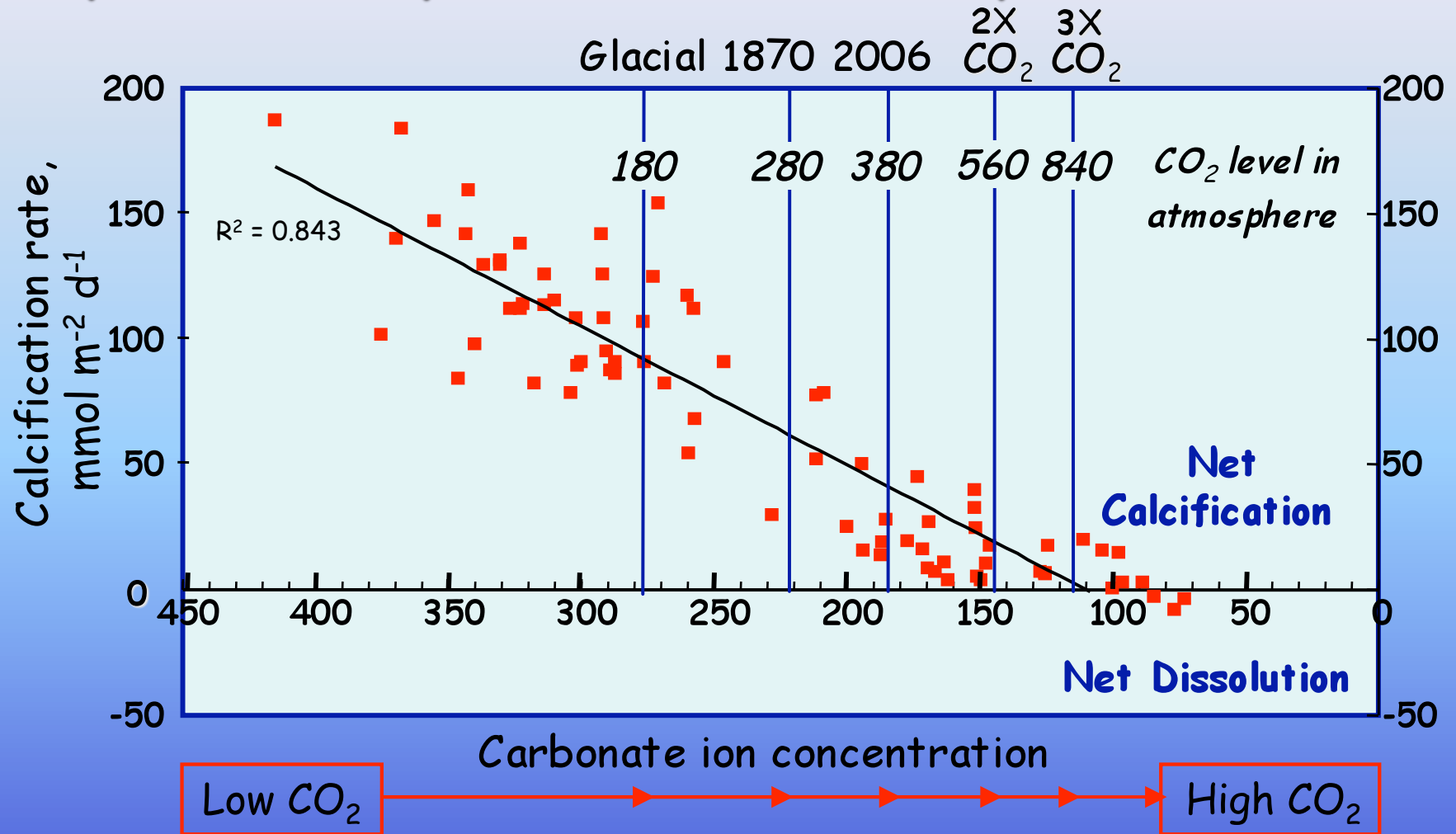
Manipulation of CO_2 system by addition of HCl or NaOH



- 45%

Malformed liths at high CO_2

The impact of rising atmospheric CO₂ on the surface ocean carbonate chemistry and its potential impact on corals - Biosphere 2 Results

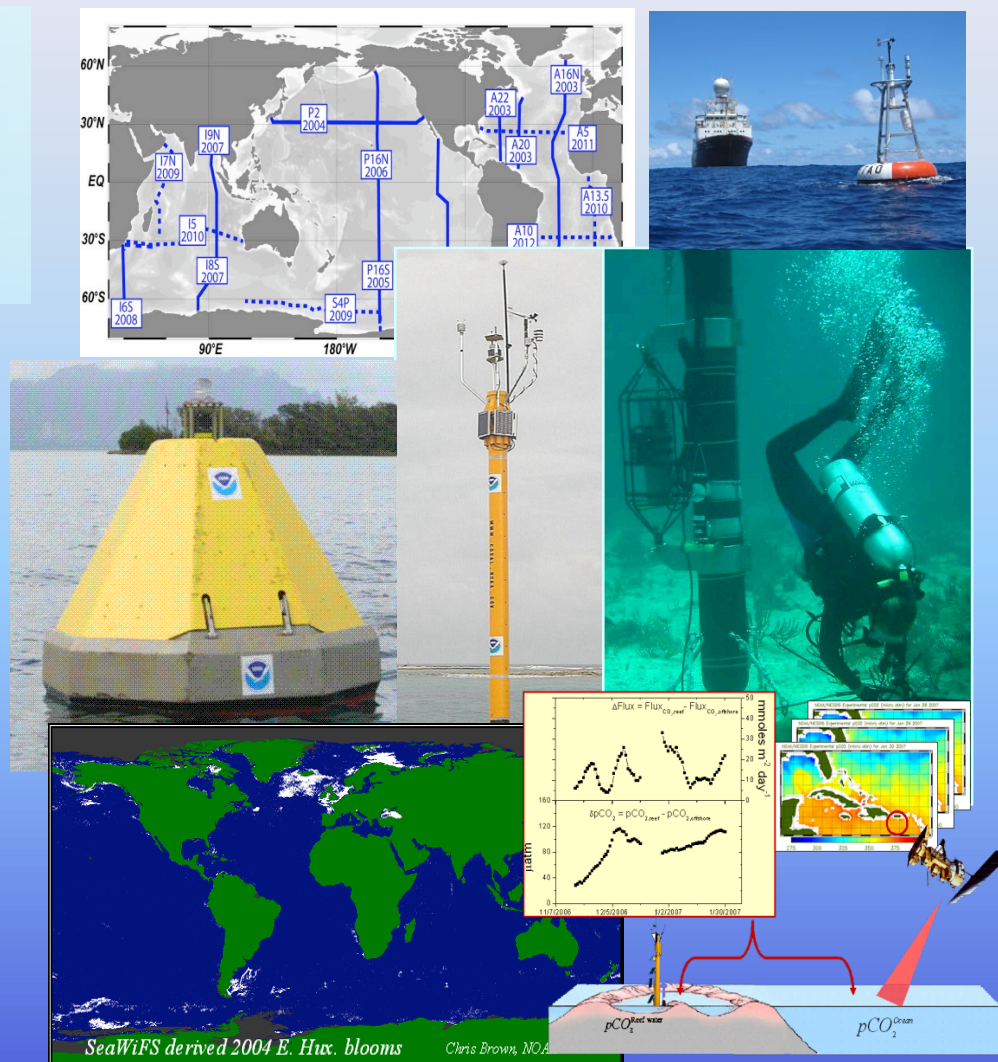


Langdon & Atkinson, (2005)

NOAA Ocean Acidification Research and Planning Activities

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

- VOS and Repeat Hydrography
- Technology Development
- Remote Sensing Applications
- CO₂ Mooring Network
- 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
- Baseline data with sufficient resolution are lacking in regions where CaCO_3 saturation states are expected to decrease <1 over in next 50-100 years.

Ocean Acidification Legislation

Senate (S. 1581) and House bills (H.R. 4174): 'Federal Ocean Acidification Research And Monitoring Act of 2007

- Introduced June and November 2007, respectively
- Senate Bill out of committee December 2007
- House Bill passed in July 2008

FORAM ACT of 2008

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.