



Alaska Center for Climate Assessment and Policy

Welcome to the webinar:

Ocean Acidification: What it means to Alaska

March 23, 2010 10 AM (ADT)

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This webinar will be recorded for internal documentation.

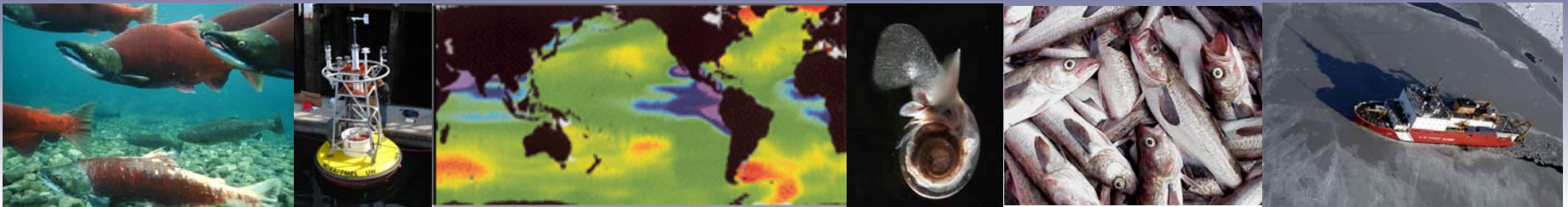
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Ocean Acidification: What It Means To Alaska

Jeremy T. Mathis

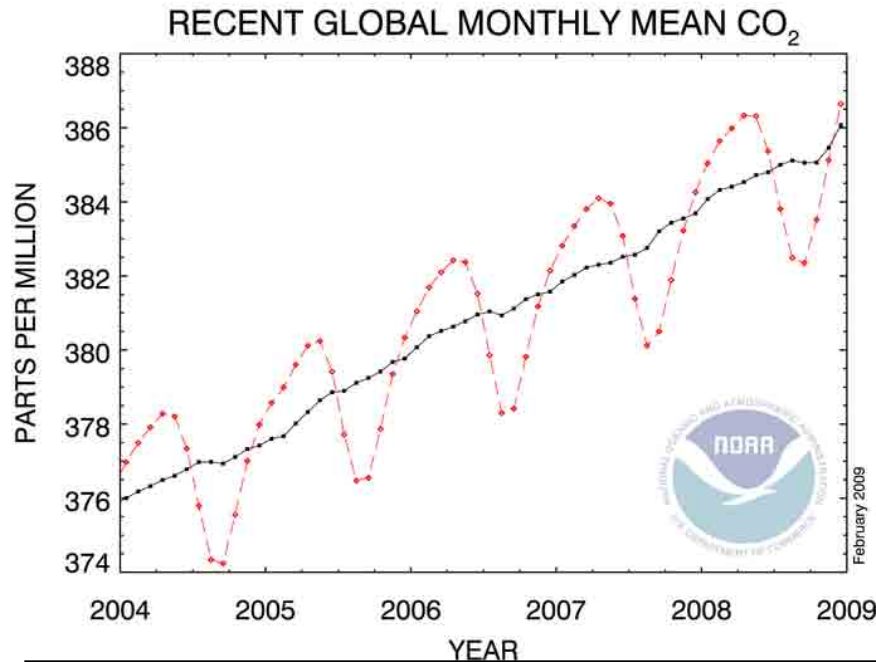
Institute of Marine Science

School of Fisheries and Ocean Sciences



- Too Much CO₂
- What is ocean acidification?
- What do we currently know?
- What are the impacts on marine organisms?
- What studies are underway in Alaskan waters?
- How could it affect Alaskan ecosystems?

Atmospheric CO₂ Concentration



Data Source: Pieter Tans and Thomas Conway, NOAA/ESRL

1970 – 1979: 1.3 ppm y⁻¹

1980 – 1989: 1.6 ppm y⁻¹

1990 – 1999: 1.5 ppm y⁻¹

2000 - 2008: 2.0 ppm y⁻¹

2008: 2.3 ppm y⁻¹

year ppm y⁻¹

2000 1.24

2001 1.85

2002 2.39

2003 2.21

2004 1.61

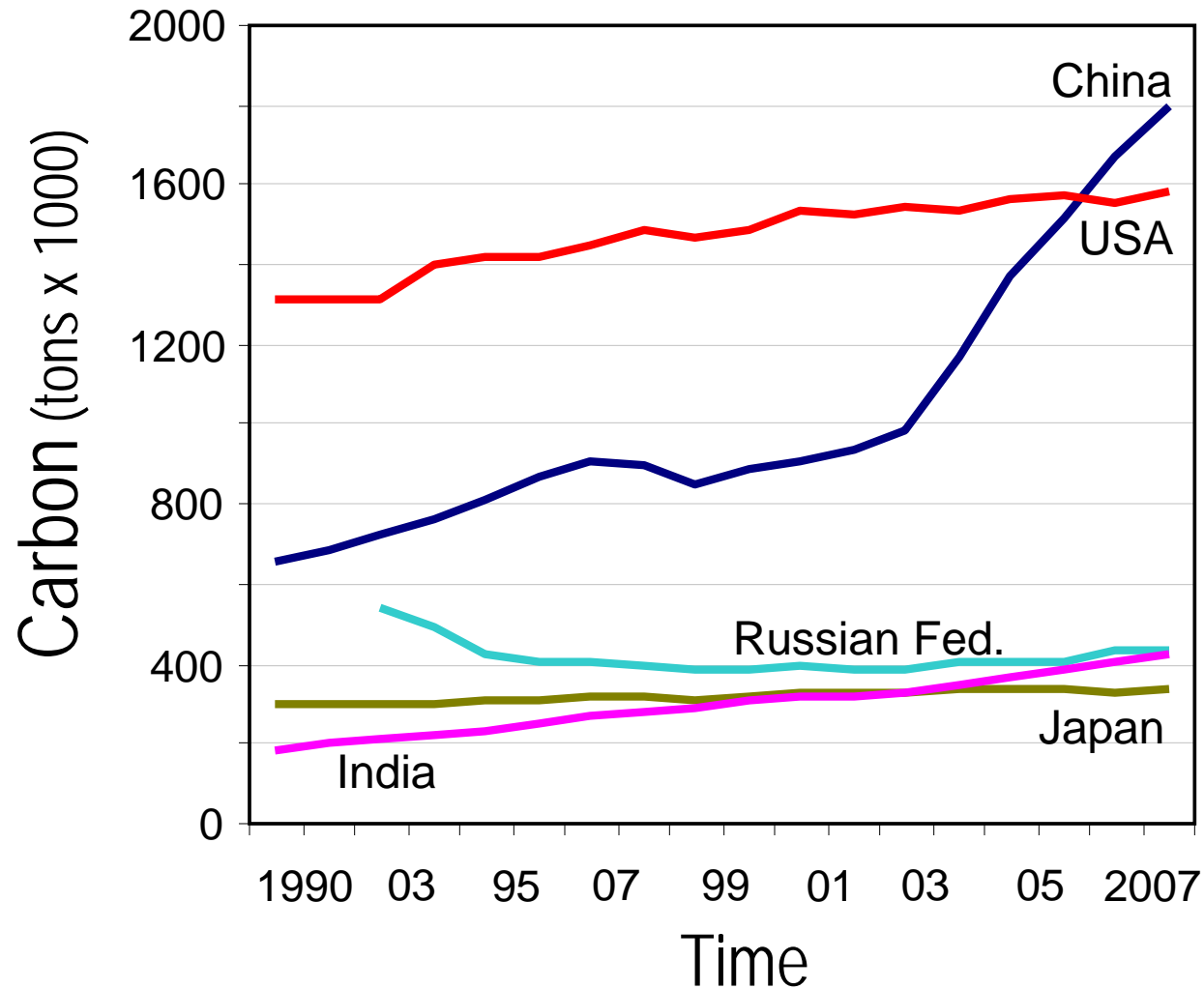
2005 2.41

2006 1.79

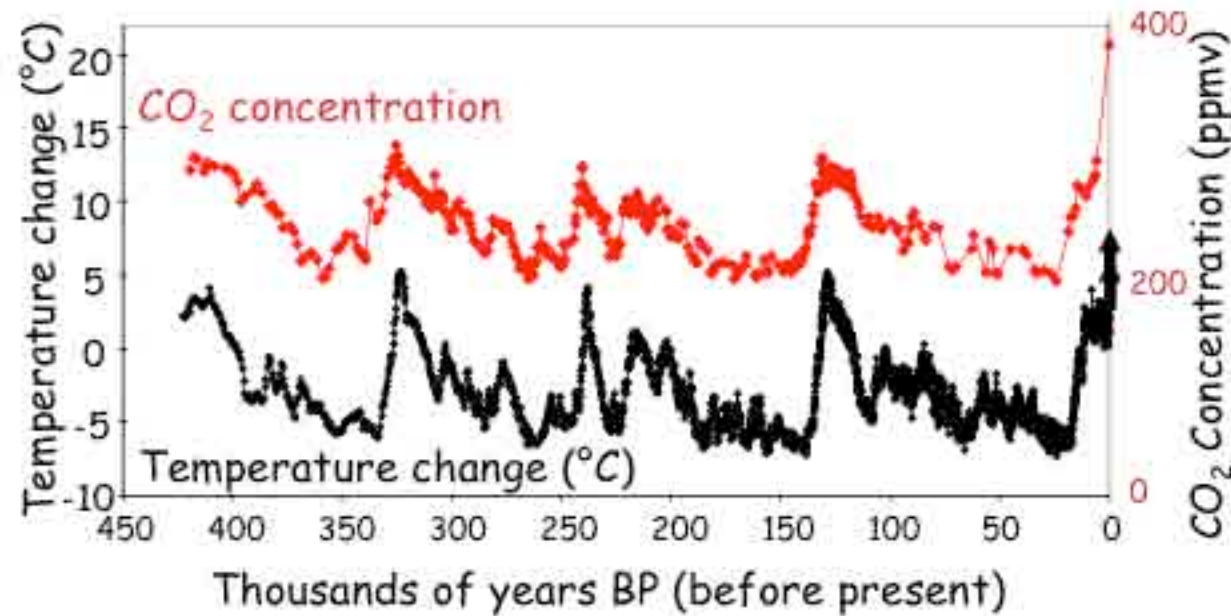
2007 2.17

2008 2.28

Fossil Fuel Emissions: Top Emitters



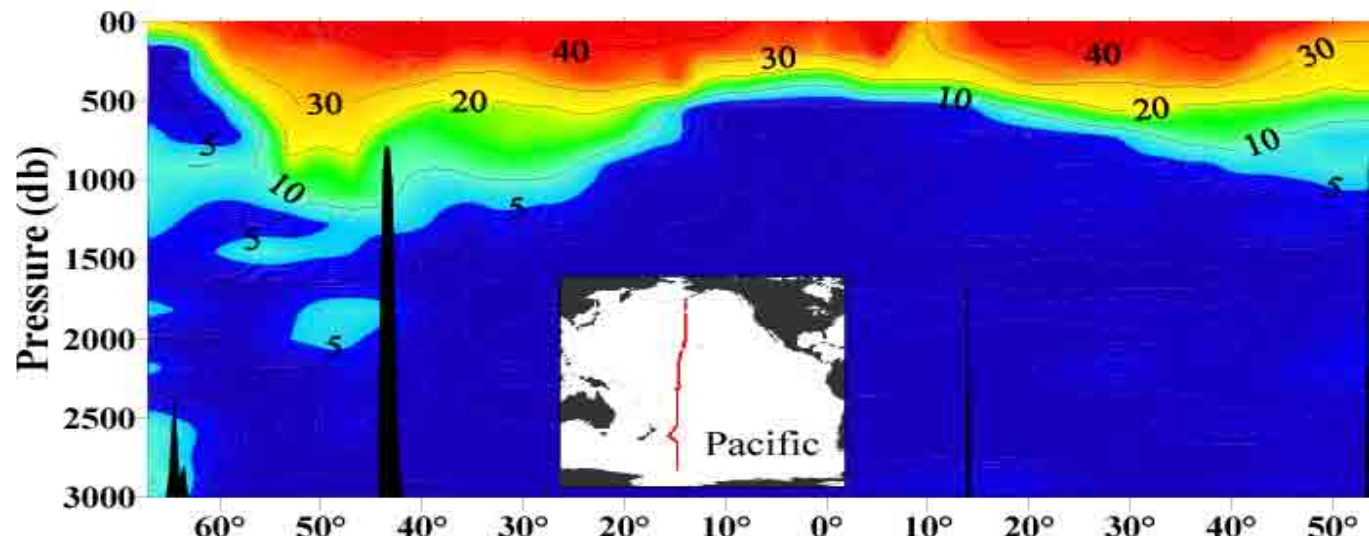
The CO₂ Problem



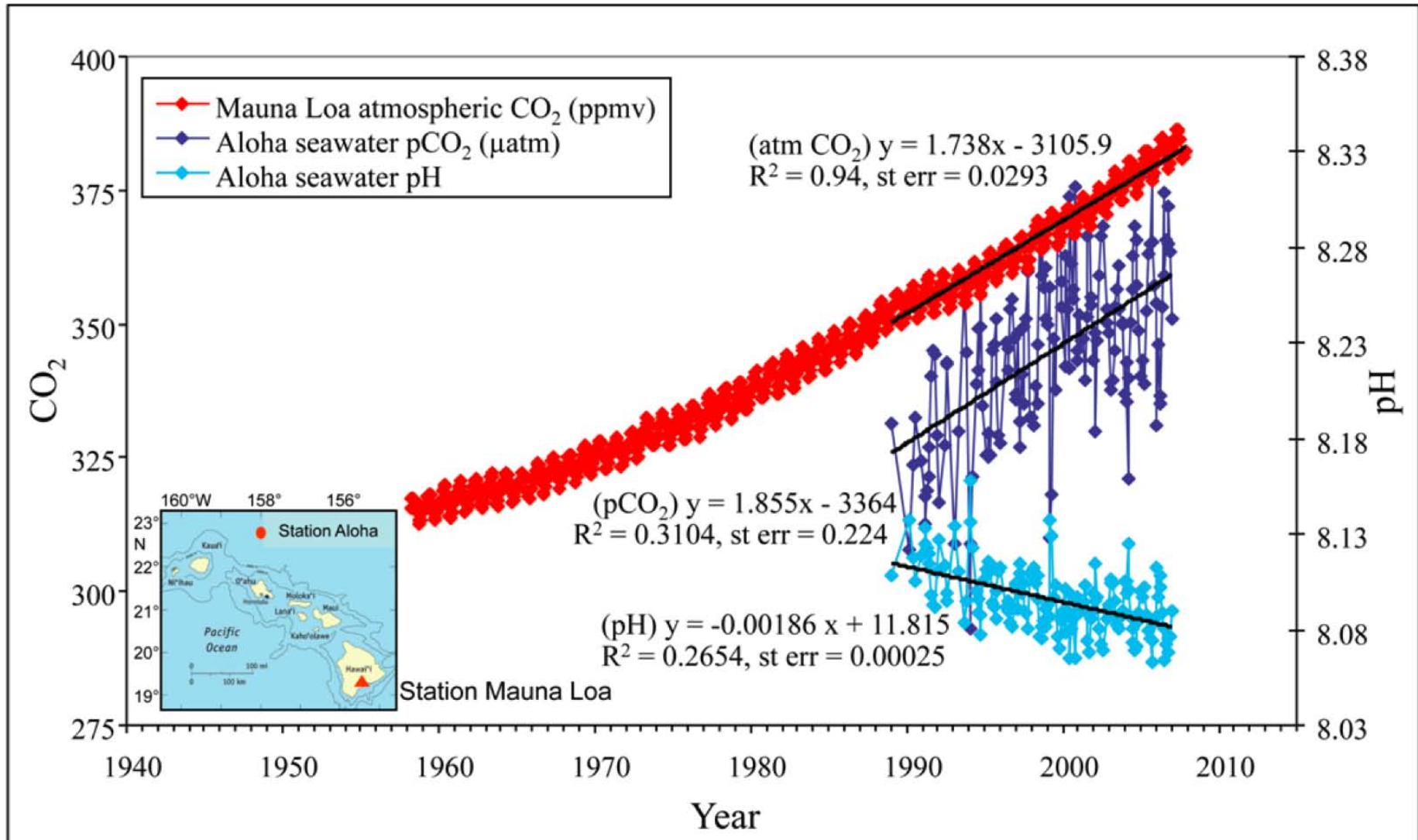
“It is very likely that [man-made] greenhouse gas increases caused most of the average temperature increase since the mid-20 century”
 - IPCC 4th Assessment Report

The ocean has taken up 1/3 to 1/2 of all anthropogenic CO₂ emissions.

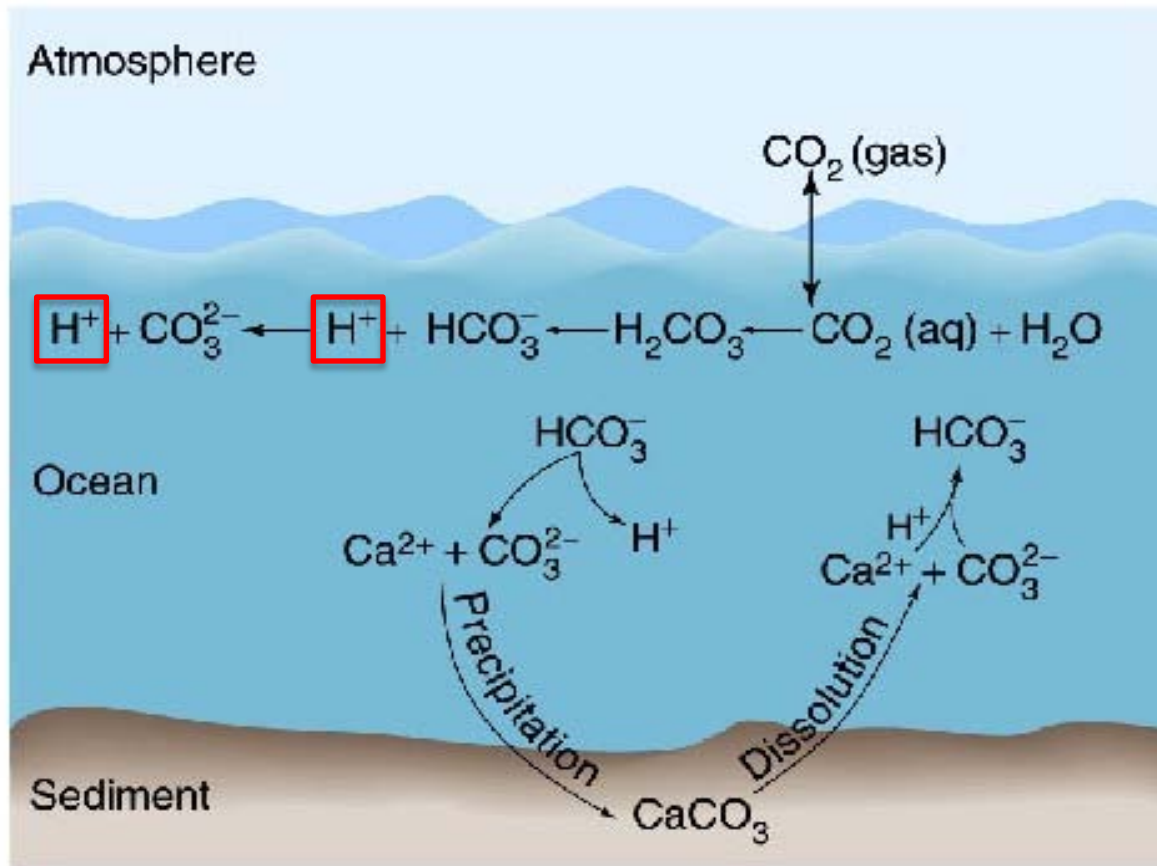
However, since the ocean mixes slowly it is concentrated in the upper 10%.



CO₂ Time Series in the North Pacific Ocean

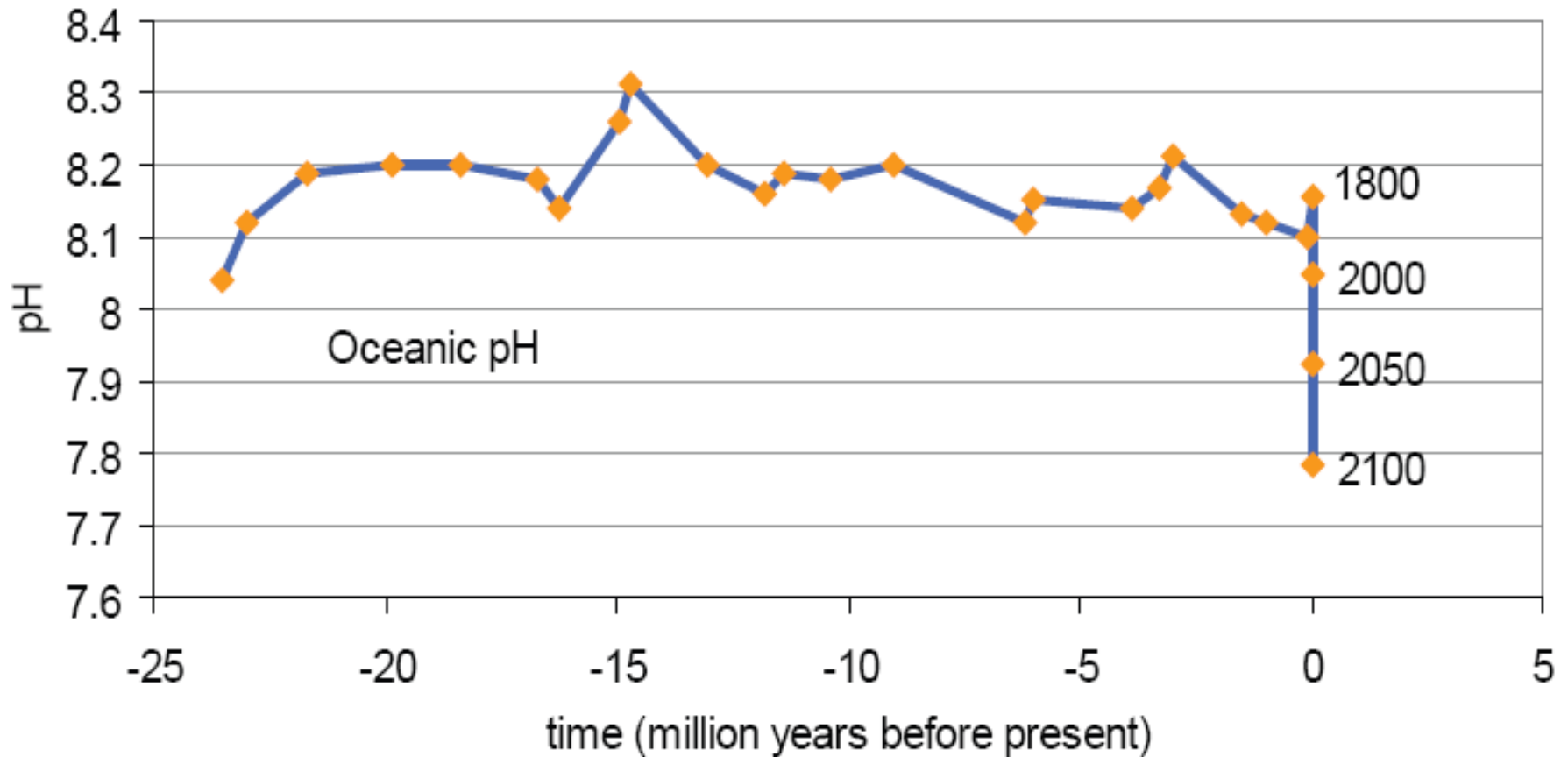


What is Ocean Acidification?



- As more CO_2 dissolves into the ocean, more H^+ ions are given off.
- As the concentrations of H^+ ions increase, the pH of the water decreases.

Creating A More Acidic Ocean



Under the “Business-As-Usual” scenario, ocean acidity will likely increase rapidly over the next 25 years.

Ocean Acidification

Since the beginning of the industrial age, the pH and CO₂ chemistry of the oceans (ocean acidification) have been changing because of the uptake of anthropogenic CO₂ by the oceans.

- These changes in pH and carbonate chemistry may have serious impacts on open ocean and coastal marine ecosystems.
- 30% increase in acidity; decrease in carbonate ion of about 16%

Photo: Missouri Botanical Gardens



Corals

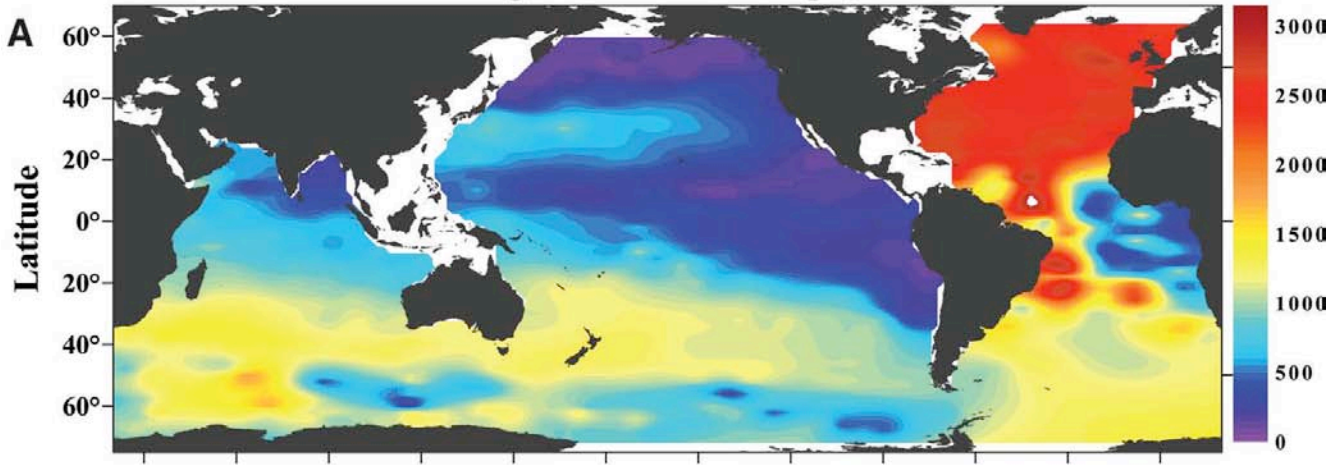


Calcareous Plankton

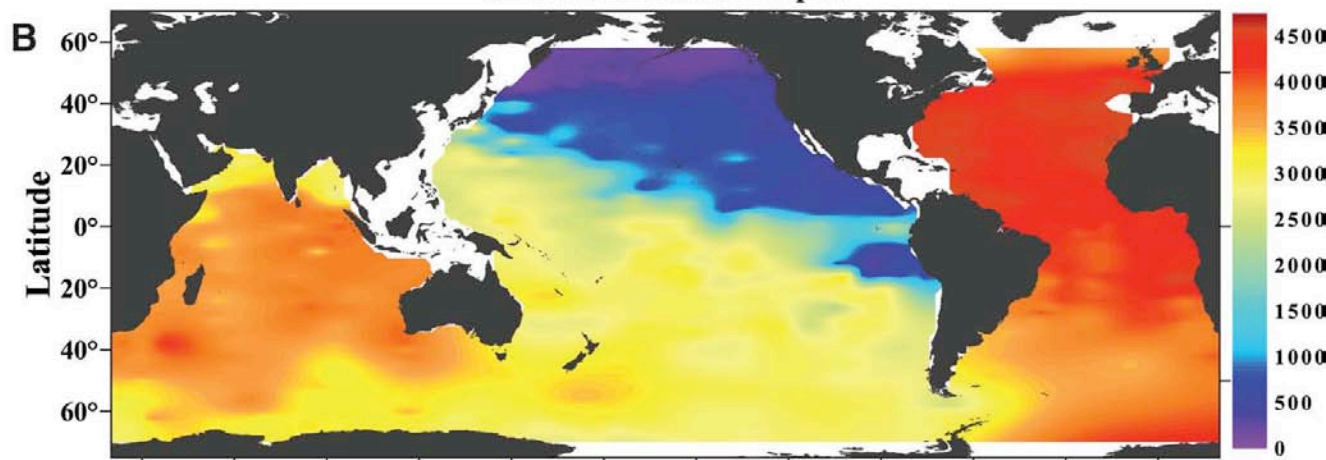
Carbonate Mineral Saturation Depth

Depth at which calcite and aragonite become undersaturated and potentially corrosive to shell building organisms

Aragonite Saturation Depth



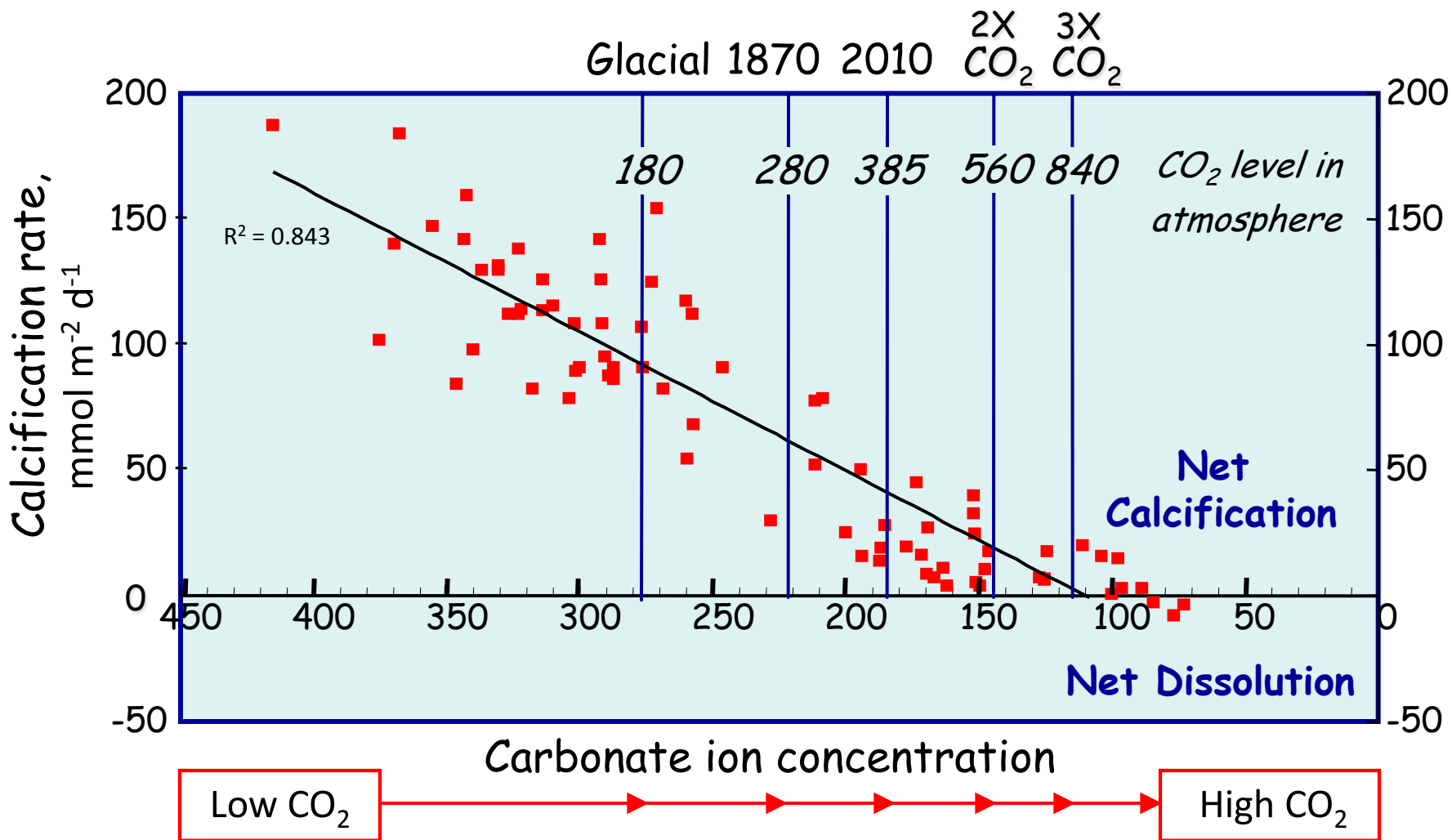
Calcite Saturation Depth



Saturation Depth:

The closer to the surface the saturation depth, the more likely organisms will be exposed to undersaturated waters

The impact of rising atmospheric CO₂ on ocean carbonate chemistry and potential impact on calcifiers



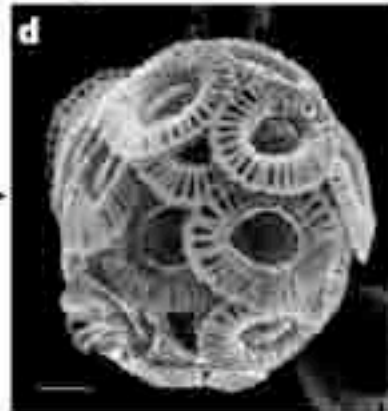
Coccolithophore (single celled algae)

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



Emiliana huxleyi

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

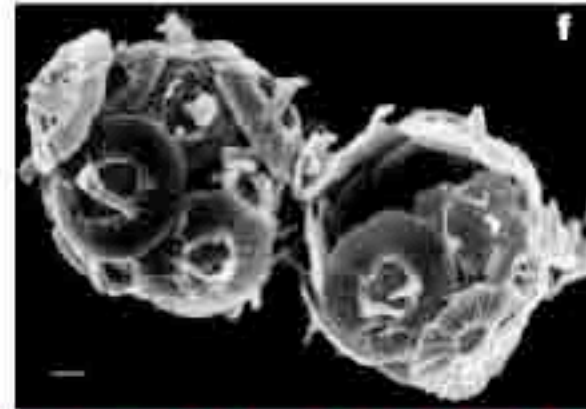


Calcification decreased

- 9 to 18%



Gephyrocapsa oceanica



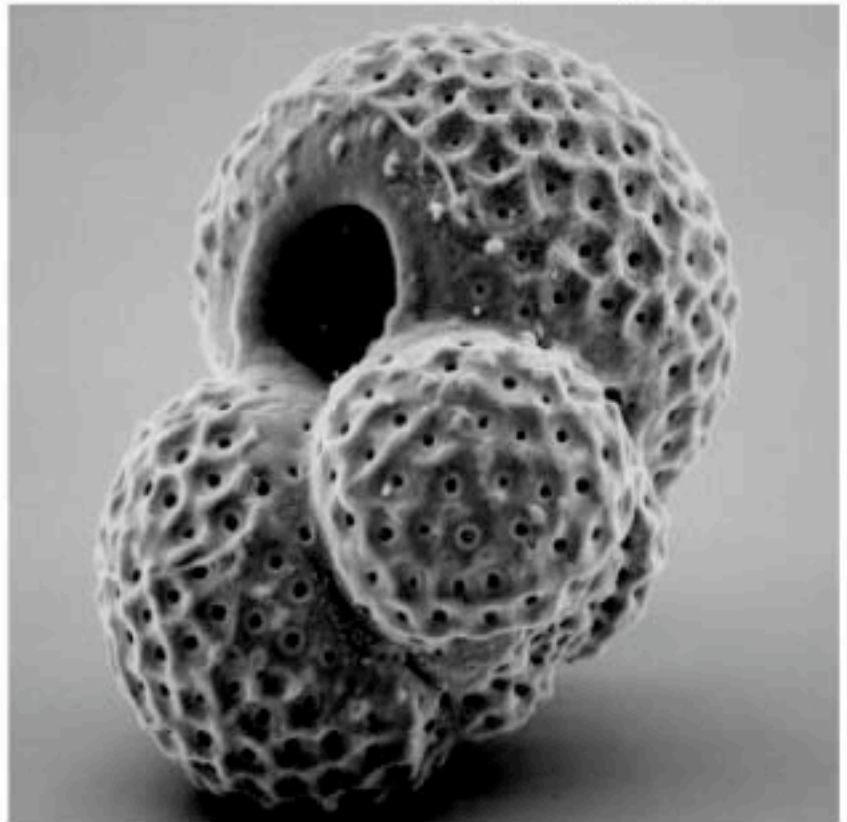
- 45%

Malformed liths at high CO_2

Manipulation of CO_2 system by addition of HCl or NaOH

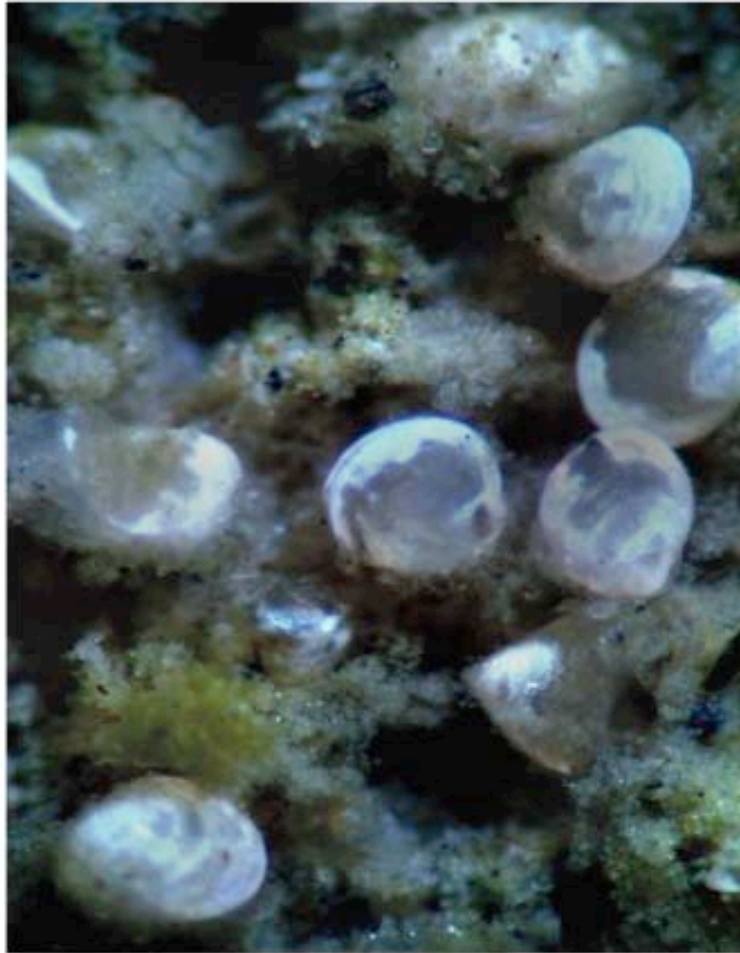
Foraminifera (single-celled protists)

Shell mass is positively correlated with $[CO_3^{2-}]$



-4 to -8% decline in calcification at $pCO_2 = 560$ ppm
-6 to -14% decline in calcification at $pCO_2 = 780$ ppm

Bivalves (e.g. clams)



Hard shell clam *Mercenaria*

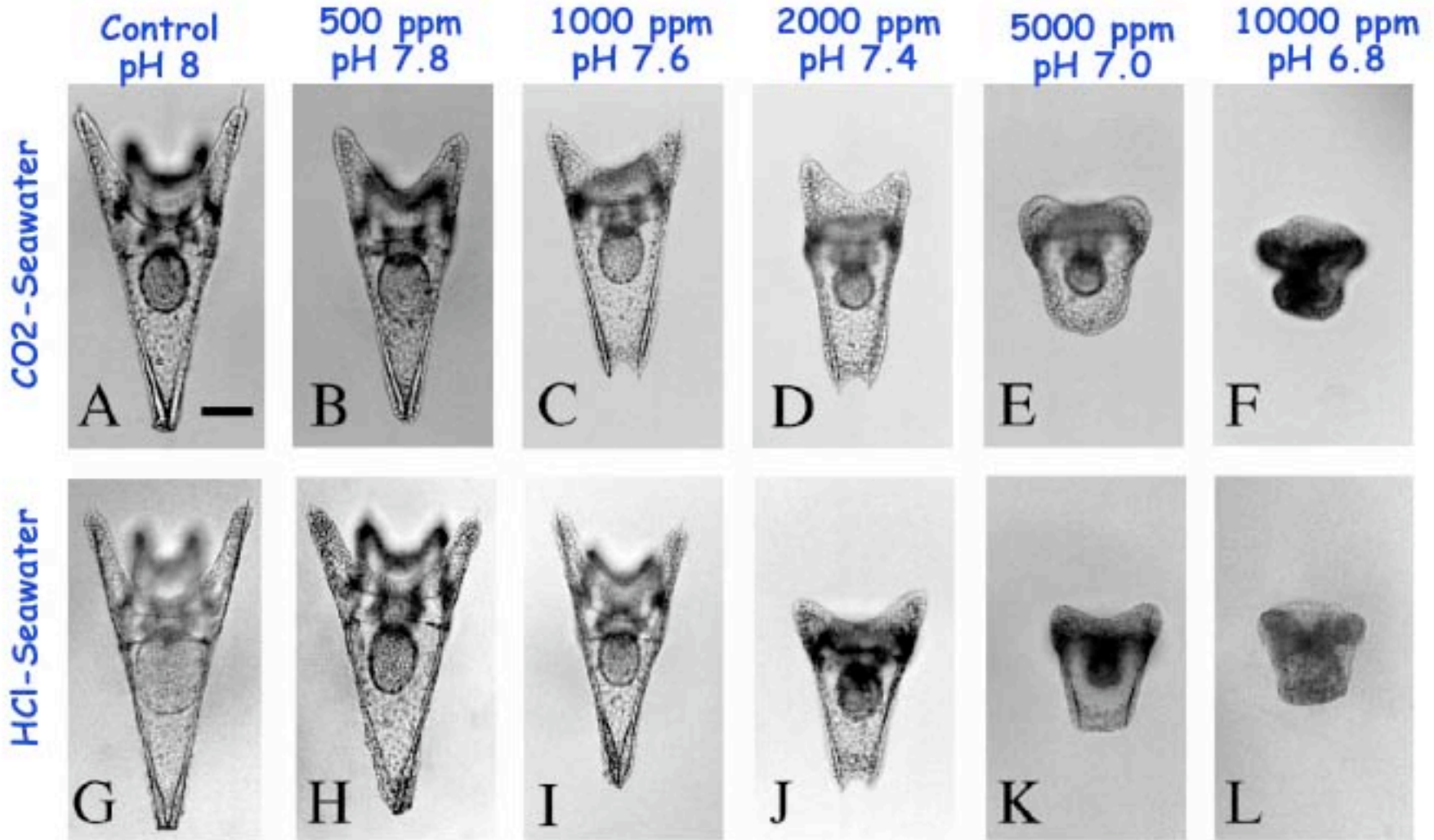
- Common in soft bottom habitats

Used newly settled clams

- Size 0.3 mm
- Massive dissolution within 24 hours in undersaturated water; shell gone within 2 weeks
- Dissolution is source of mortality in estuaries & coastal habitats

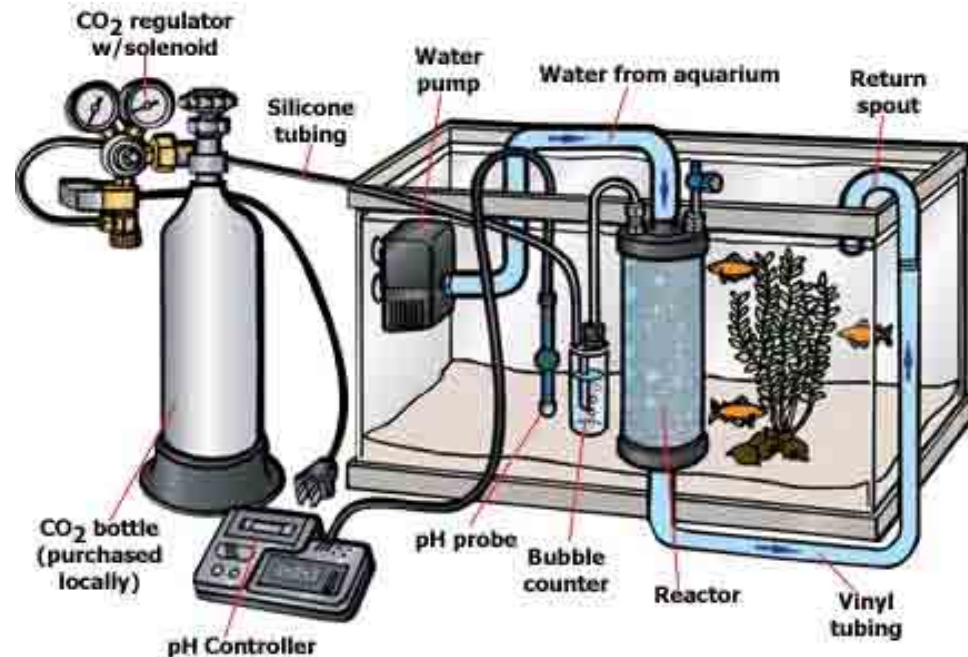
Green et al., 2004

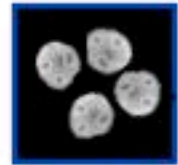
Sea Urchins



The effects of ocean acidification on age-0 and age-1 walleye Pollock physiology

- Hatching success, % mortality, growth rate, and body condition
- Metabolic enzyme activity in age-1 juveniles
- Analysis of stress hormones
- pH levels at 8.05, 7.85, 7.45, and 7.05
- Eggs hatched under these conditions





Coccolithophores



Copepods

ARCOD@ims.uaf.edu



Pteropods

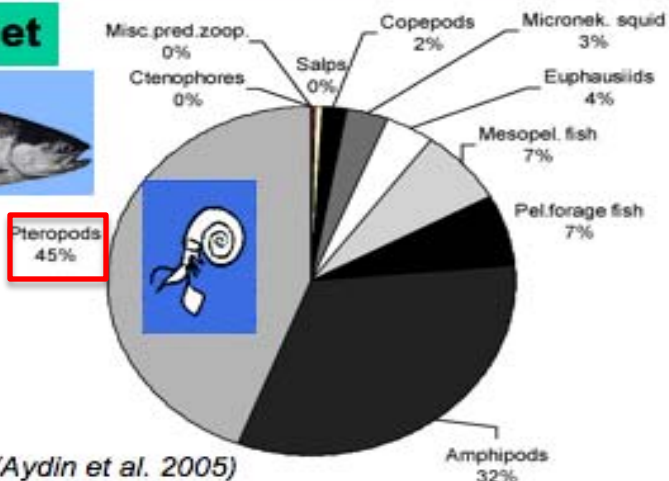


Pacific Salmon

Research on Impacts of OA on Pacific Salmon

- ▲ Western Alaskan Sockeye
- ◆ British Columbia Sockeye
- Central Alaskan Pink
- Japanese Chum

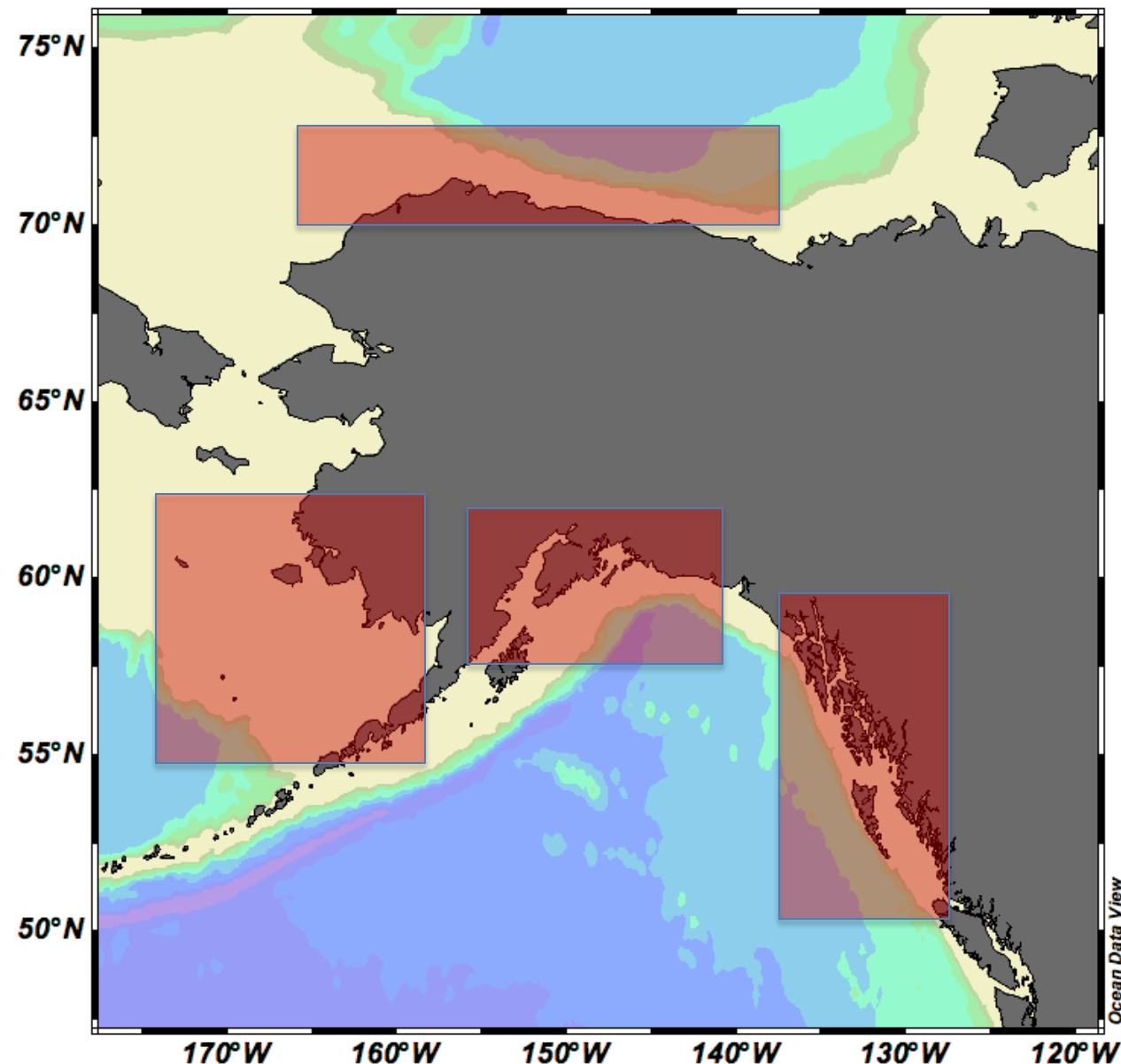
Pink salmon diet



Predicted effect of climate change on pink salmon growth:

- 10% increase in water temperature leads to 3% drop in mature salmon body weight (physiological effect).
- 10% decrease in pteropod production leads to 20% drop in mature salmon body weight (prey limitation).

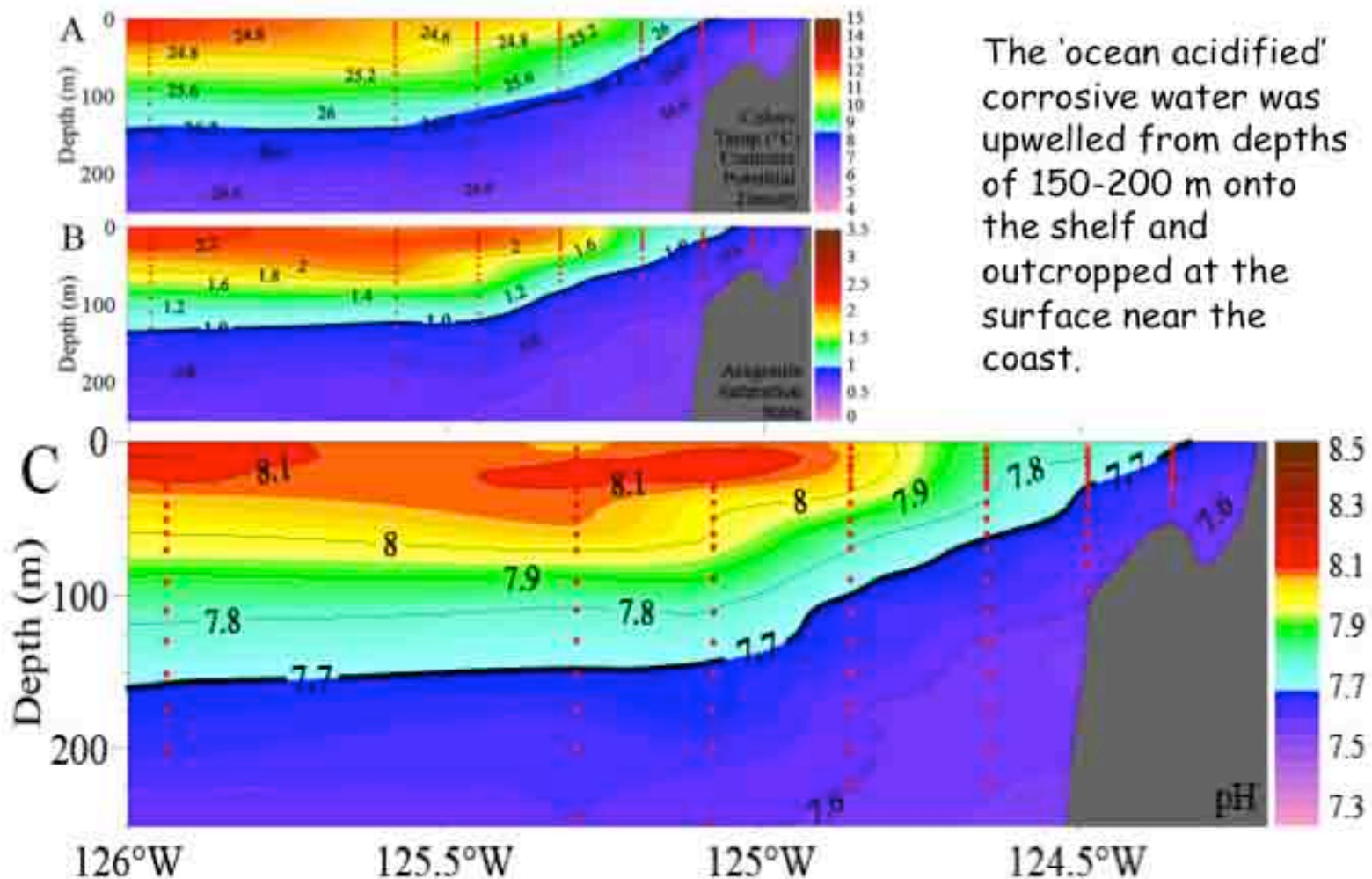
Coastal Zones At Risk From OA



- Alaskan coastal waters are cold and highly productive.
- Both of these increase the amount of CO₂ that is absorbed by the water.
- Upwelling also bring high CO₂ water to the surface
- More CO₂ = More Acidic
- Higher acidity has direct and indirect impacts on commercially important species.
 - Mineral saturations
 - Physiological response

West Coast of the US – A Proxy for SE Coastal Alaska?

NACP Coastal Survey Cruise: 11 May - 14 June 2007



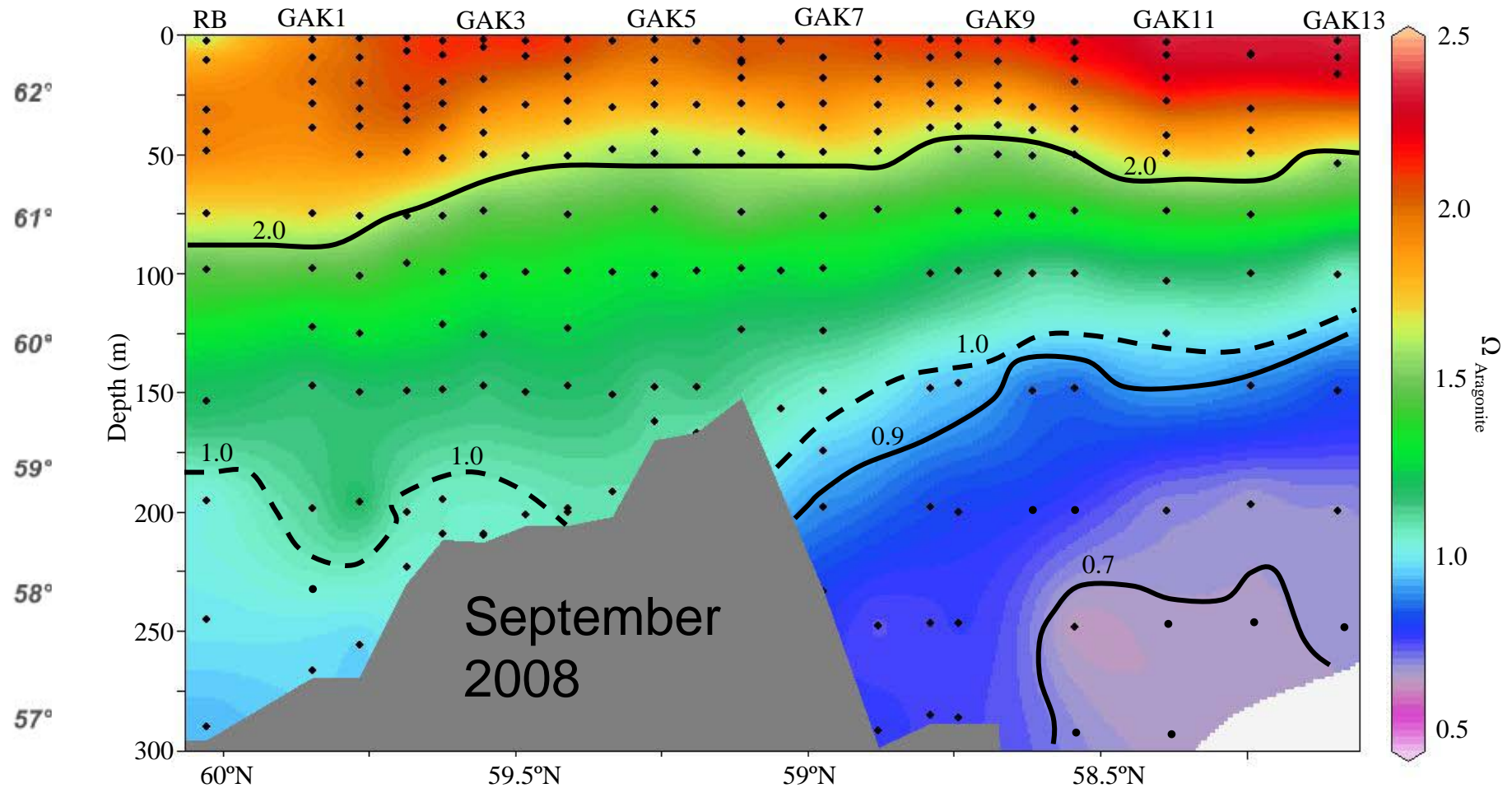
The 'ocean acidified' corrosive water was upwelled from depths of 150-200 m onto the shelf and outcropped at the surface near the coast.

Red dots represent sample locations.

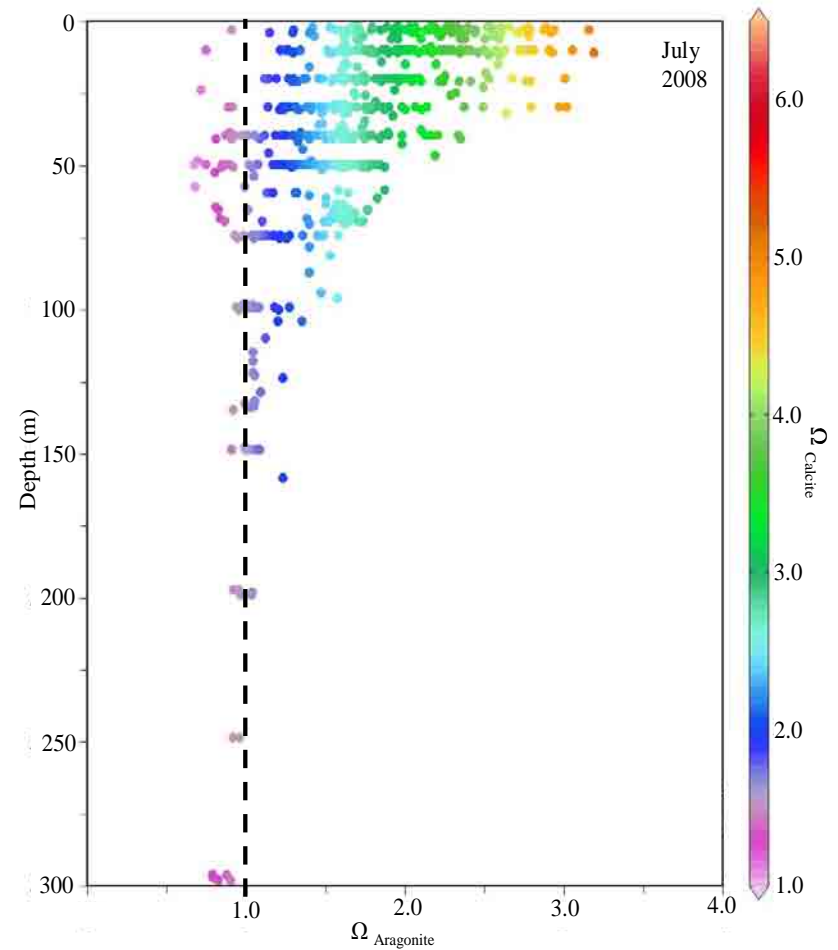
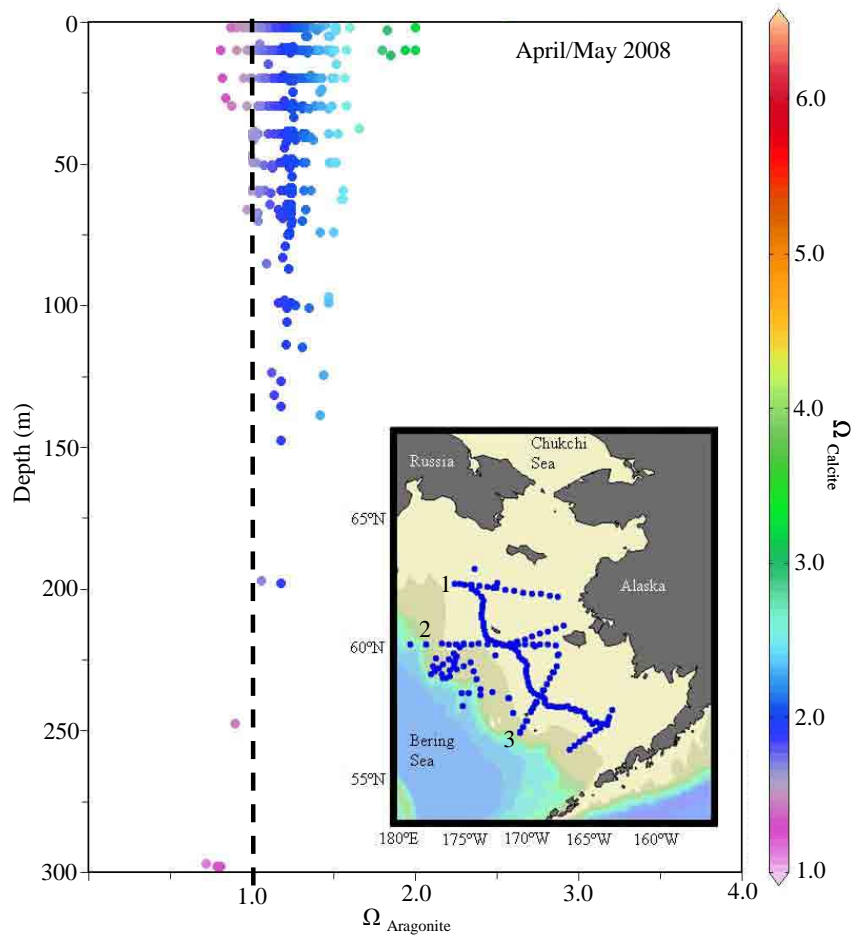
Vertical sections from Line 5 (Pt. St. George, California)

Feely et al. (2008)

OA in the GOA

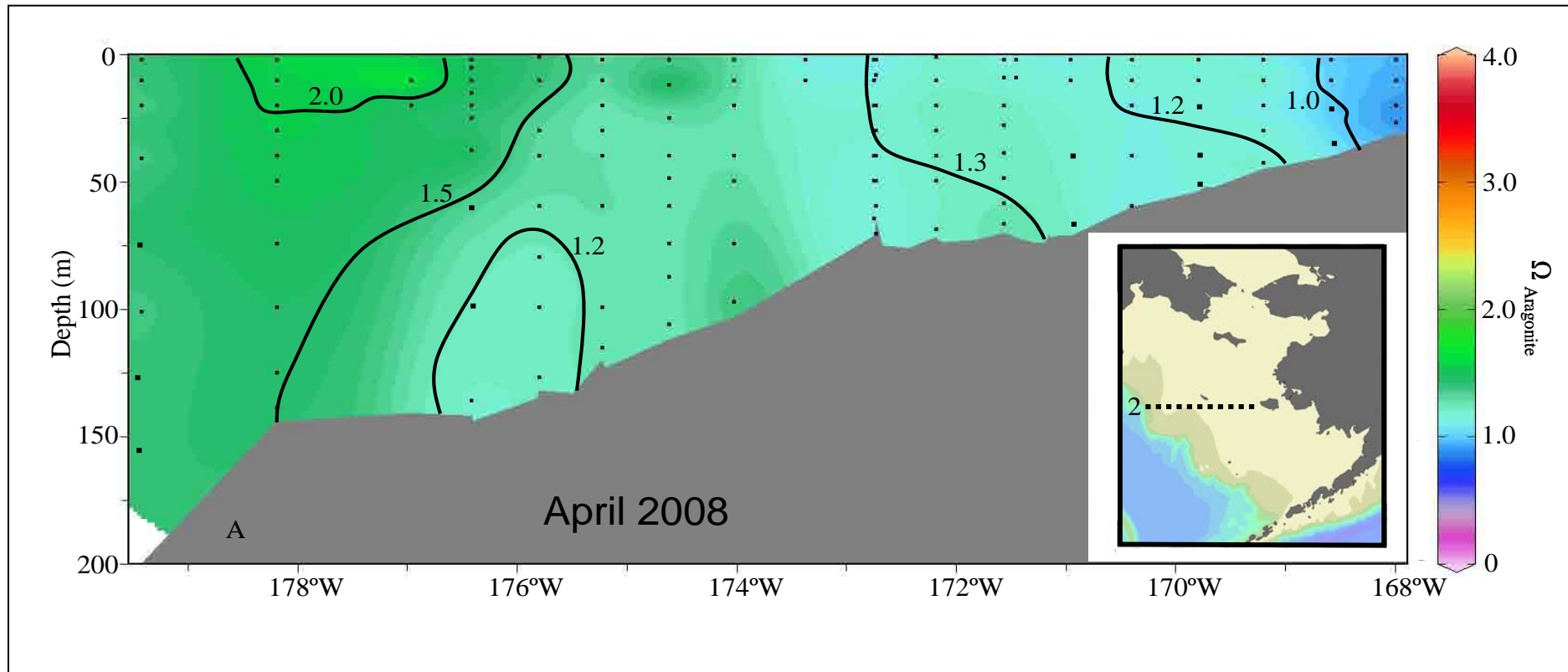


OA in the Bering Sea



OA in the Bering Sea

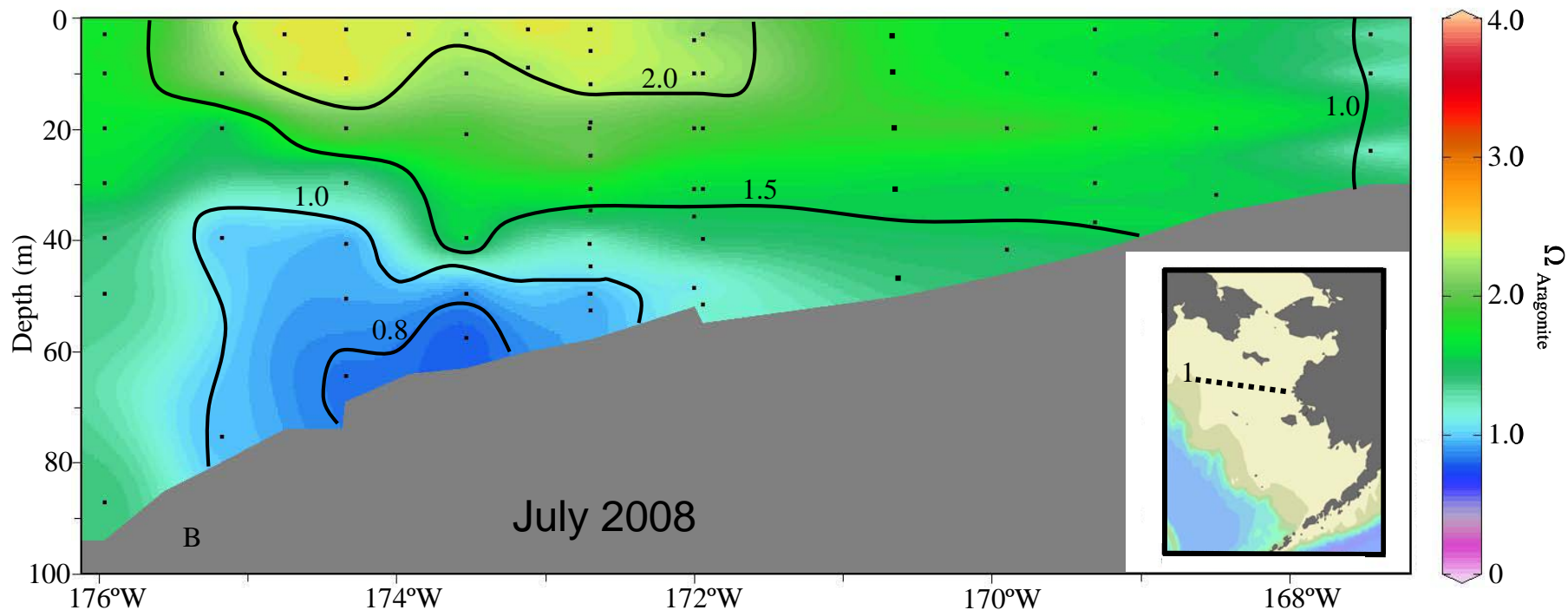
In spring, the discharge of low pH water from the Yukon and Kuskokwim Rivers causes aragonite saturation states to drop below 1.0



Mathis, J.T., Bates, N.R., Cross, J.N., Coupling Primary Production and Terrestrial Runoff to Ocean Acidification and Carbonate Mineral Suppression in the Eastern Bering Sea (*Journal of Geophysical Research-Oceans*, In Prep).

OA in the Bering Sea

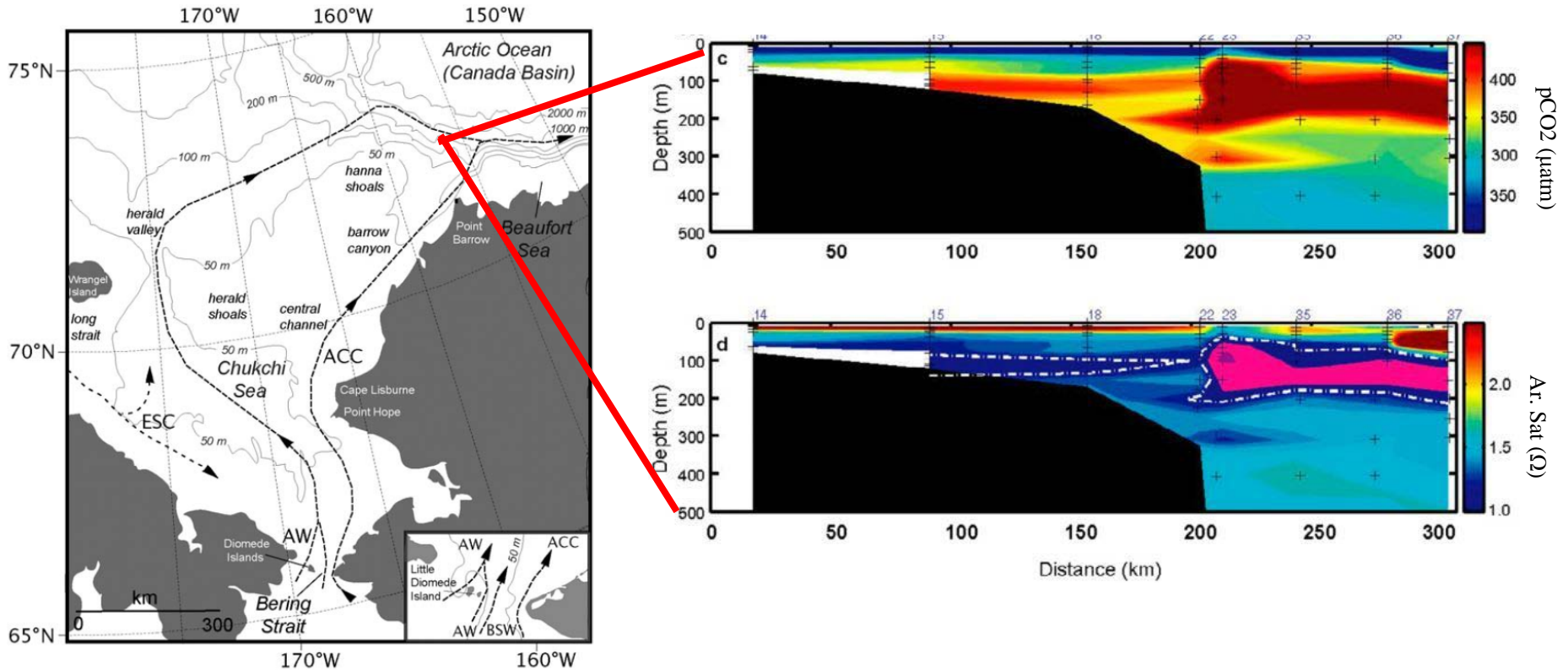
In summer, the remineralization of organic matter suppresses aragonite saturation states in the bottom waters of the shelf beneath the “green belt”.



Mathis, J.T., Bates, N.R., Cross, J.N., Coupling Primary Production and Terrestrial Runoff to Ocean Acidification and Carbonate Mineral Suppression in the Eastern Bering Sea (Journal of Geophysical Research-Oceans, In Prep).

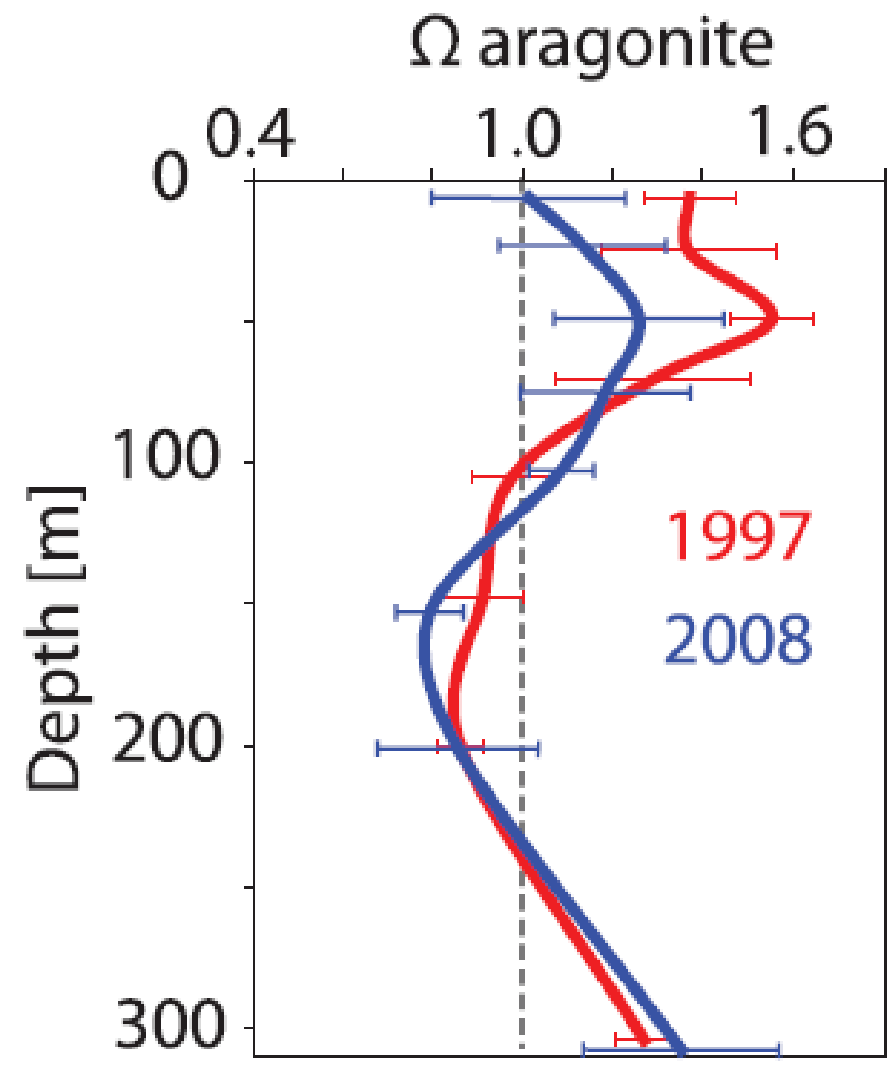
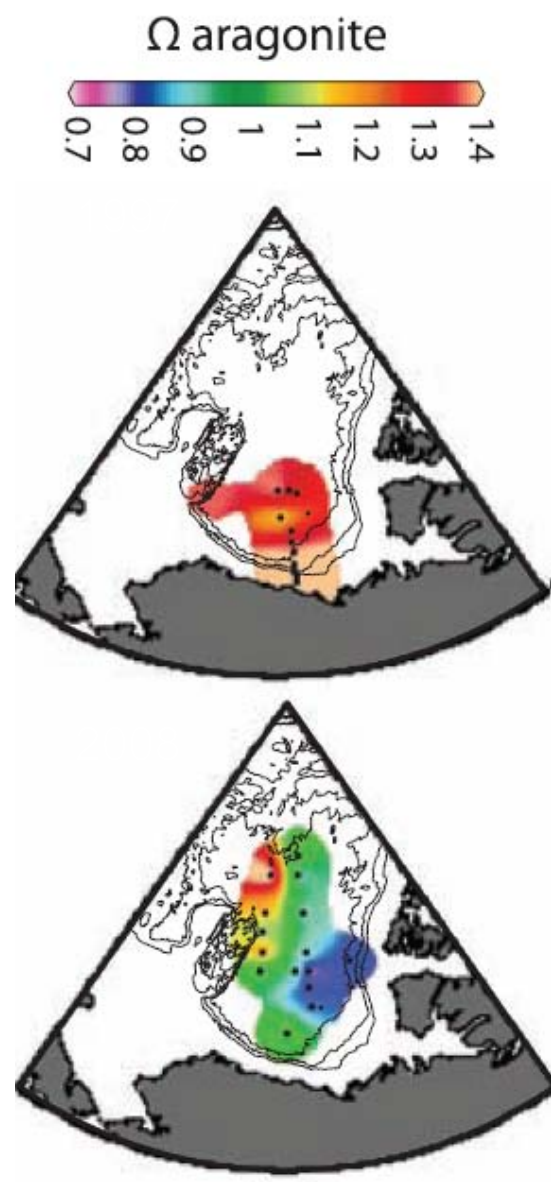
OA in the Chukchi Sea

The remineralization of exported organic matter in the bottom waters creates a high $p\text{CO}_2$ environment that suppresses saturation states. These waters then condition the halocline of the Chukchi Sea.

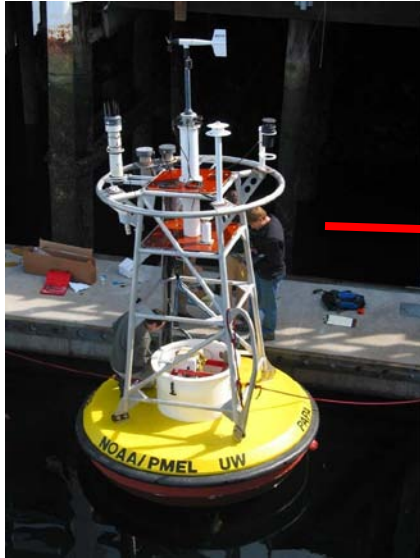


Bates, N. R., J. T. Mathis, and L. W. Cooper (2009), Ocean acidification and biologically induced seasonality of carbonate mineral saturation states in the western Arctic Ocean, *J. Geophys. Res.*, 114, C11007

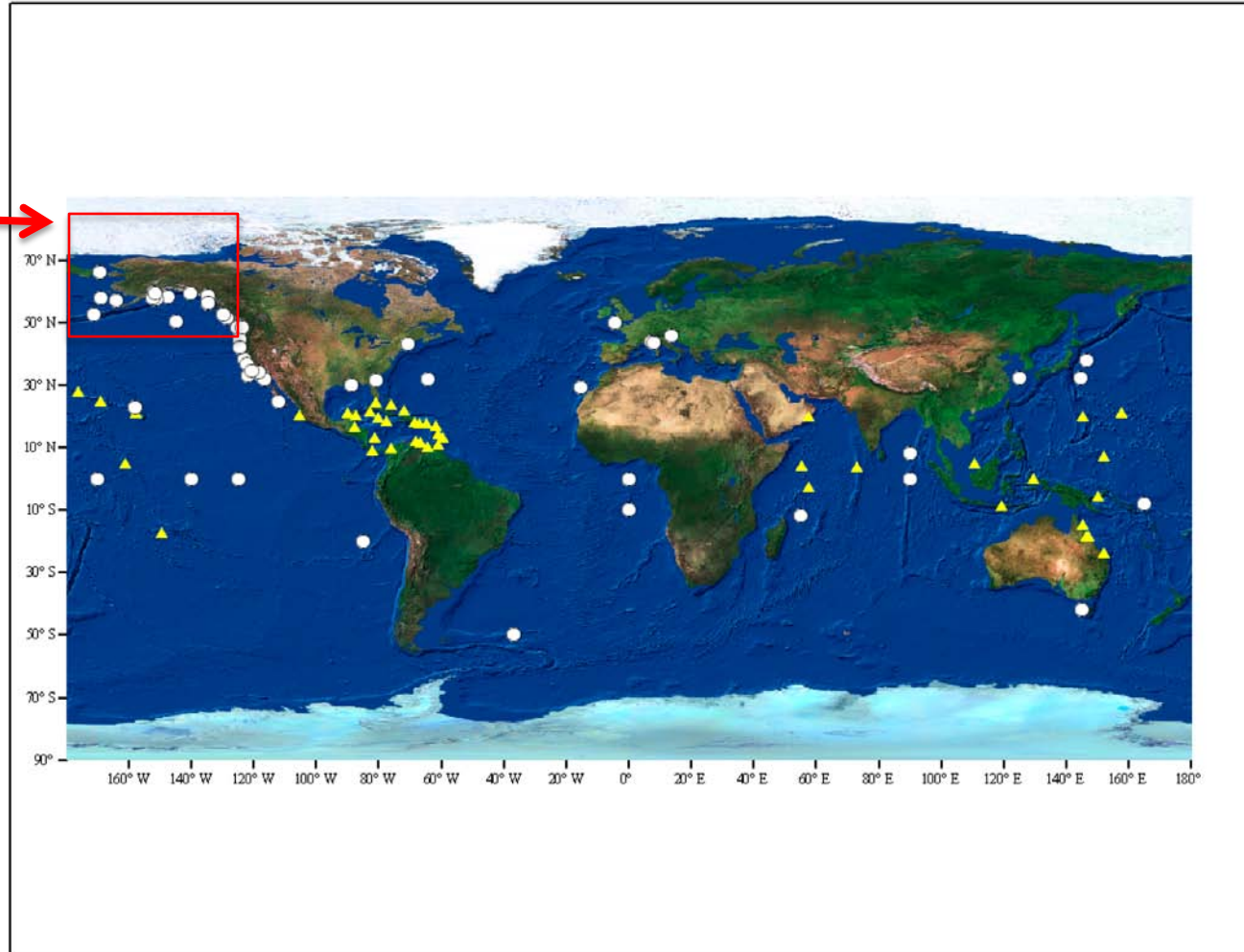
OA in the Arctic Ocean



- Impacts of ocean acidification on marine ecosystems are largely unknown.
- Calcification in many planktonic organisms is reduced at elevated CO₂, but the response is not uniform.
- Possible responses of ecosystem are speculative, but could involve changes in species composition and abundances – could affect food webs and biogeochemical cycles.
- Baseline data with sufficient resolution are lacking in some of the most sensitive regions (i.e. coastal Alaska).



A network of moorings would allow us to obtain time series data to assess real time changes in ocean pH



- The root cause of this problem is excess CO₂ emissions.
 - H.R. 2454: American Clean Energy and Security Act of 2009 (Rep. Waxman).
 - As Alaskans, let's lead the way in the push for cleaner energy sources and better conservation
- We need more data about the rates of ocean acidification and the impacts on commercially viable species.

Thanks to my staff, colleagues and SFOS