

NOAA Ocean Acidification Program

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January 17, 2012

Outline

- Science of Acidification
- Drivers
- Program Structure
- NOAA's research portfolio
- Other agencies: NSF, USGS, EPA, NASA, State
- Next steps

Observed Ocean Acidification

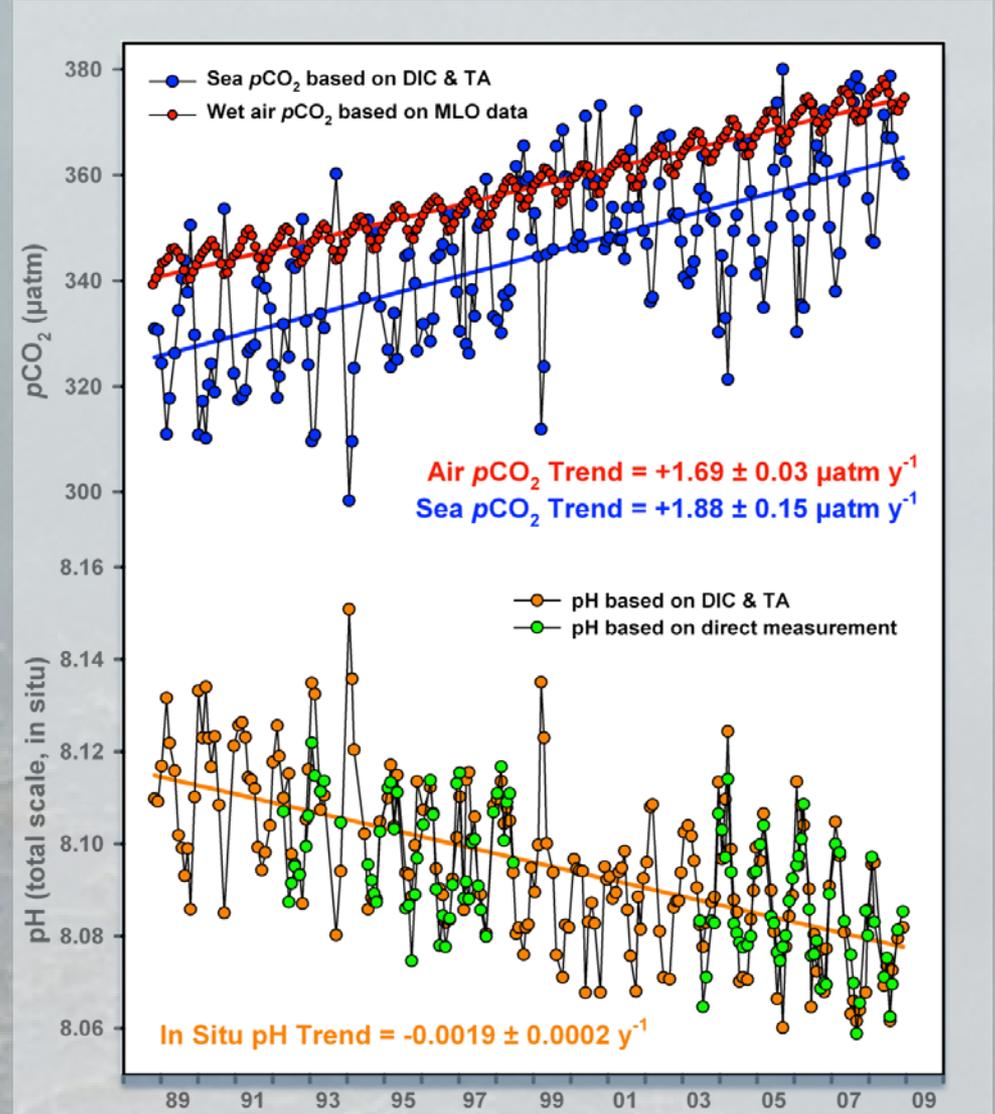
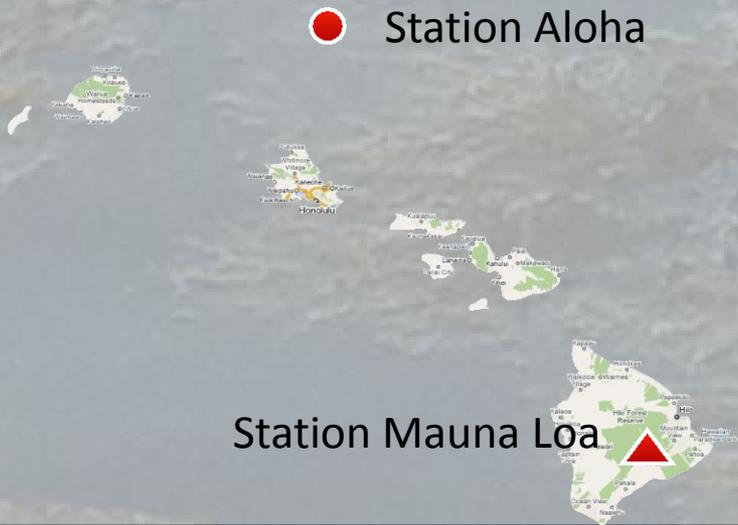
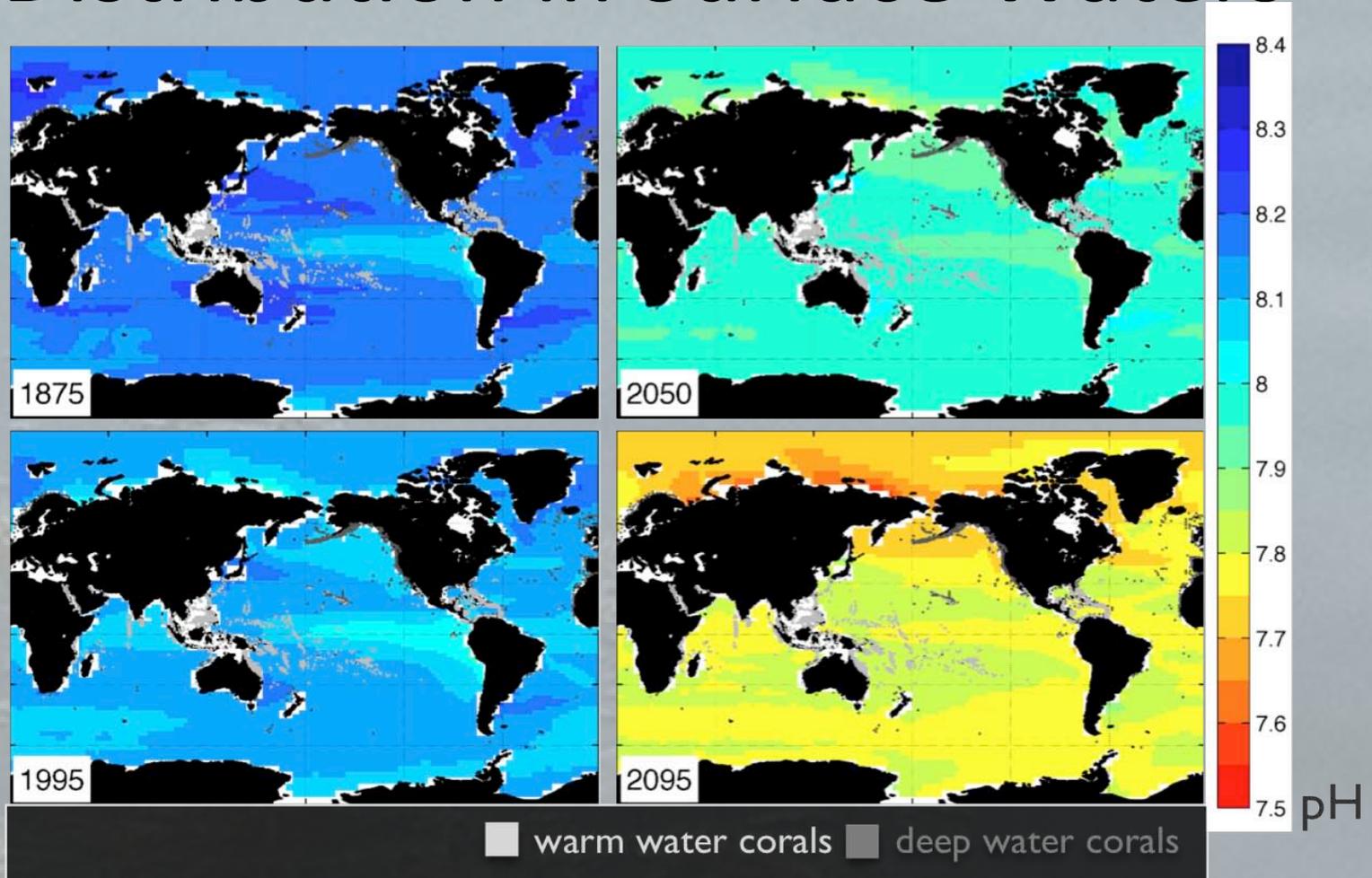


Figure modified courtesy of Richard Feely (NOAA PMEL) reproduced from Doney, *Science* (2010) and Dore et al., *PNAS* (2009)

pH Distribution in Surface Waters



Projections

from the NCAR CCSM3 model projections using the IPCC A2 CO₂ Emission Scenarios

Feely, Doney and Cooley,
Oceanography (2009)

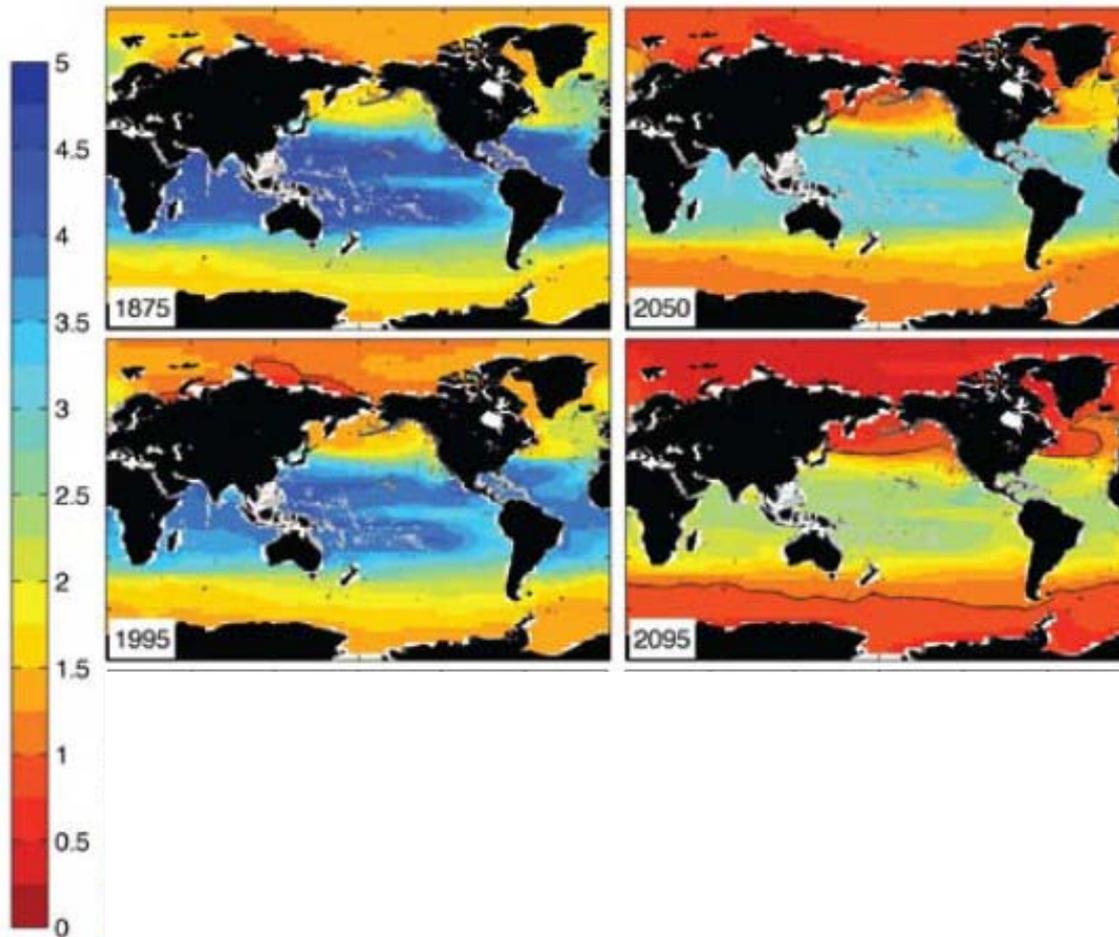
Aragonite (CaCO_3) Saturation State

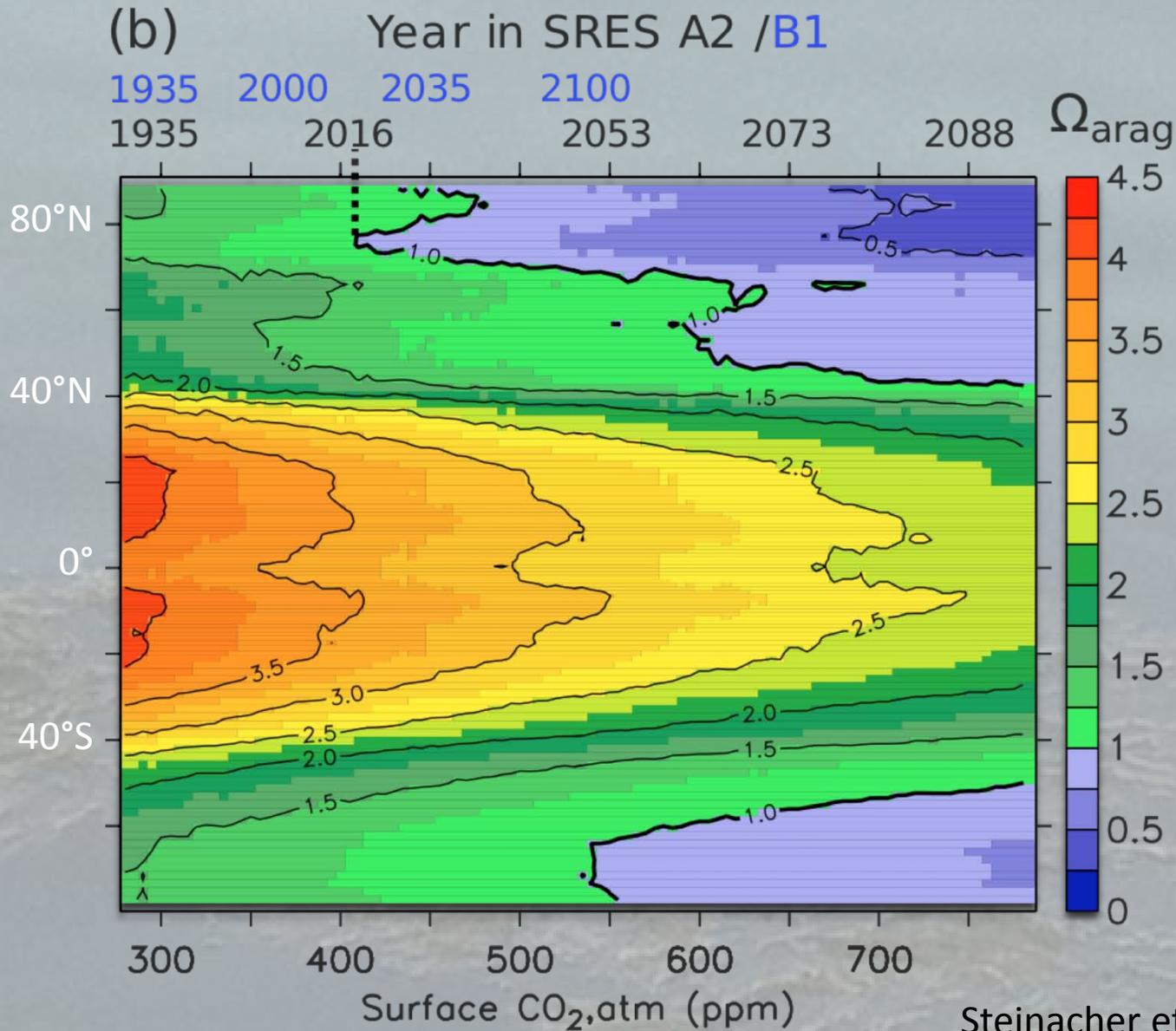
Modeled aragonite saturation state in world's oceans.

<1 = undersaturation

When saturation state drops below 1, it becomes difficult for many shelled organisms to maintain their shells.

Feely et al 2009





Change in Aragonite Saturation with CO₂

- Saturation state declines across all latitudes
- Undersaturated conditions appear for aragonite in high latitudes in next decade for A2 scenario

Complex Responses

Calcification
response
varies

Ries 2009 *Geology*

Decapod Crustacean

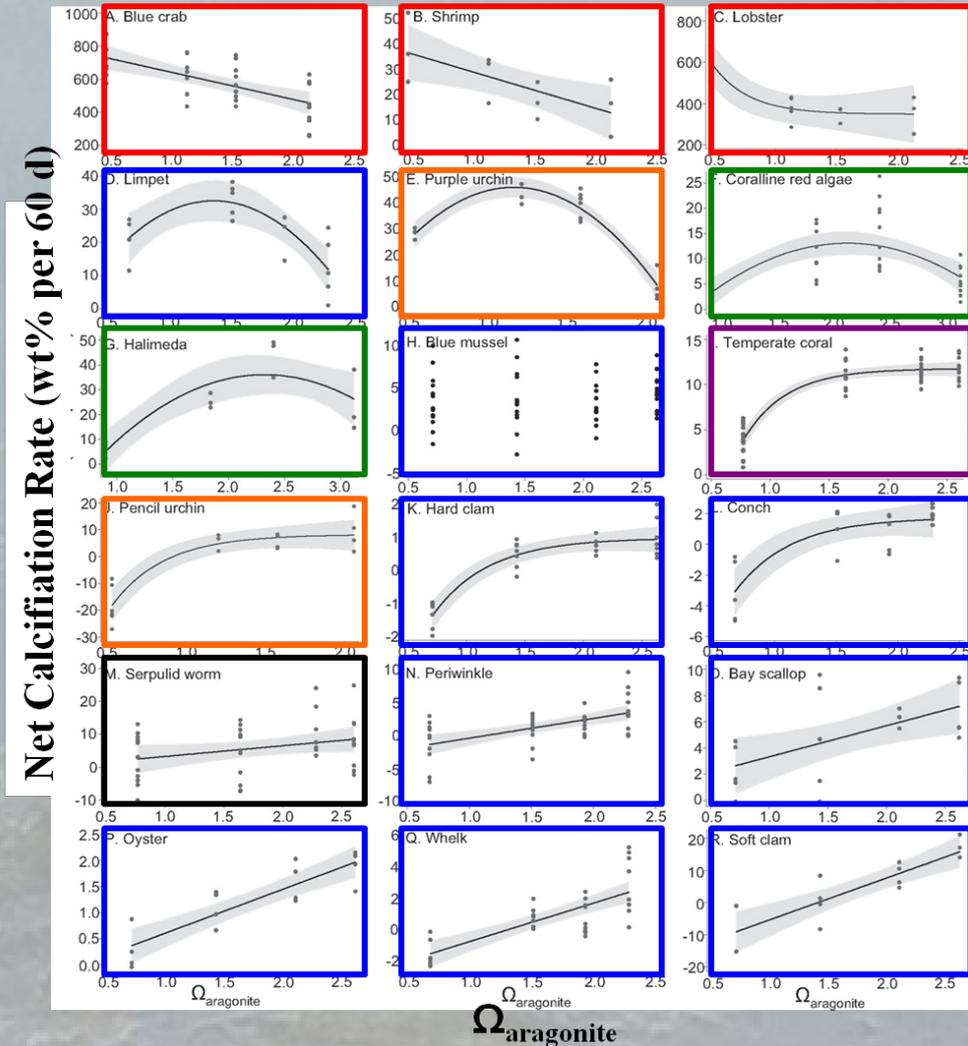
Molluscs

Algae

Temperate Coral

Echinoderms

Serpulid Worm



In terms of calcification rates, a range of sensitivities and responses to OA have been experimentally determined precluding a simple narrative

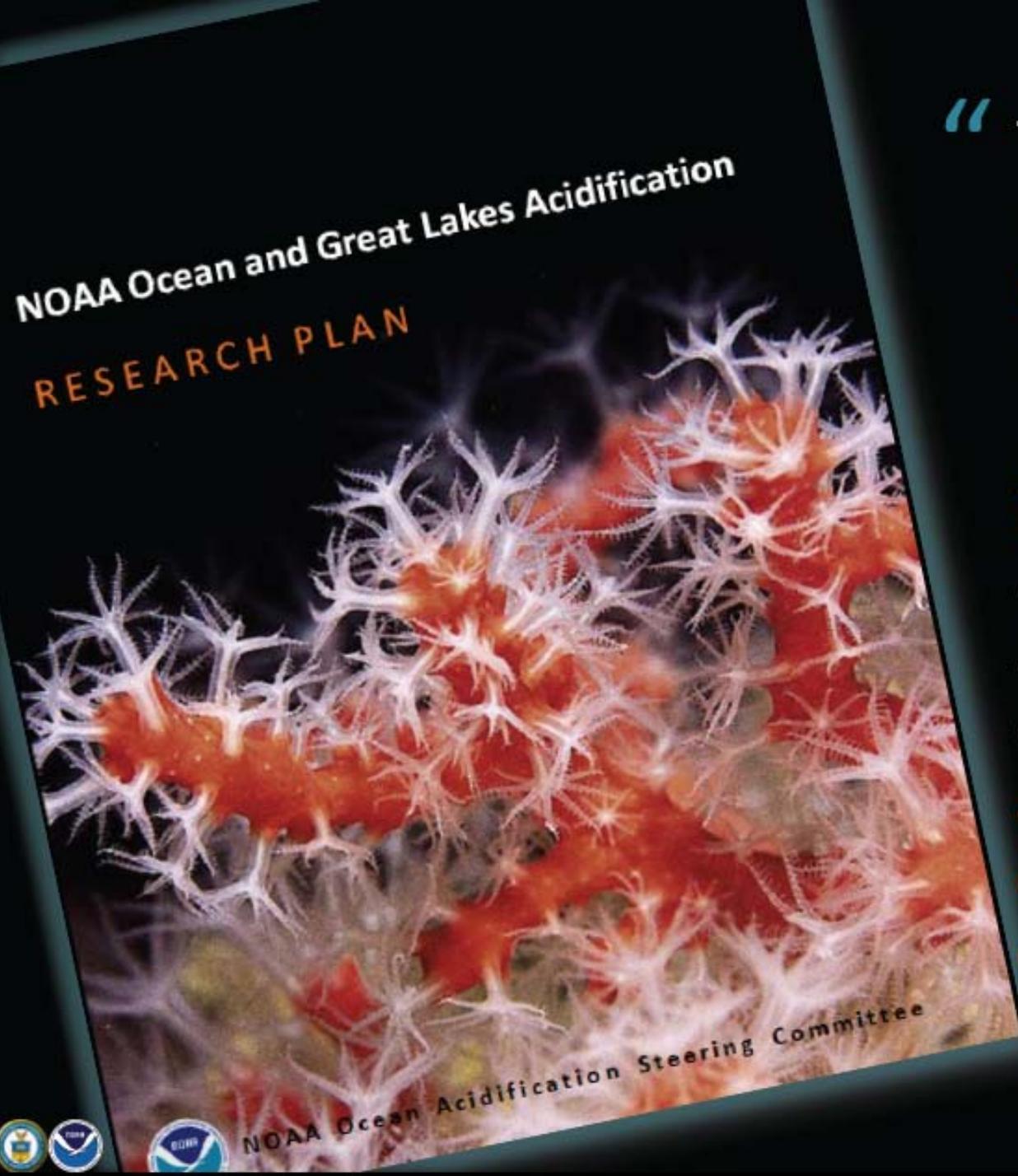
Pacific Northwest *oyster emergency*



- Failure of larval oyster recruitments in recent years
- Commercial oyster hatchery failures threatens \$100M industry (3000 Jobs)
- *Low pH “upwelled” waters a possible leading factor in failures*

Barton 2009

Update: NOAA working with Gov. Gregoire on Blue Ribbon Panel to synthesize findings and develop adaptation strategies

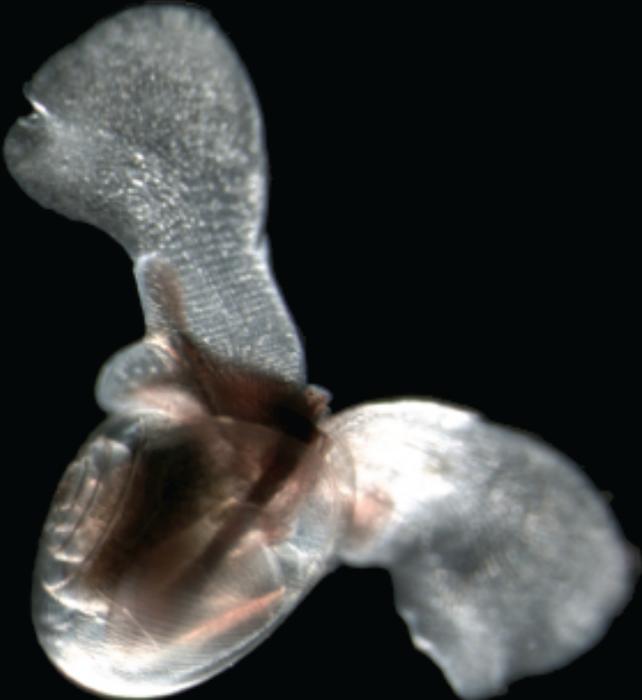


NOAA Ocean and Great Lakes Acidification
RESEARCH PLAN

NOAA Ocean Acidification Steering Committee

“ The *purpose* ... is to present a **consensus research strategy** for NOAA to advance the understanding of the **impacts** of ocean acidification and to address related challenges to **local and national ecosystems and communities**. ”

Legislative Drivers

- 
- “Development and coordination of a comprehensive interagency strategy to:
- (a) **Monitor and conduct research** on the processes and consequences of ocean acidification on marine **organisms and ecosystems**;
 - (b) Establish a **NOAA research and monitoring program** on ocean acidification;
 - (c) Establish a program at NOAA for assessment and consideration of **regional and national ecosystem and socioeconomic impacts** of increased ocean acidification research adaptation strategies and techniques for effectively conserving marine ecosystems as they cope with increased acidification.”

Federal Ocean Acidification Research and Monitoring (FOARAM) Act of 2009

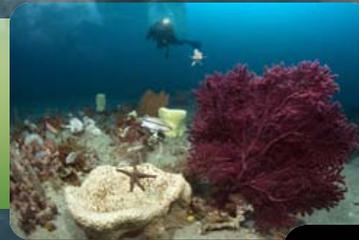


NOAA National Ocean and Great Lakes Acidification Research Plan

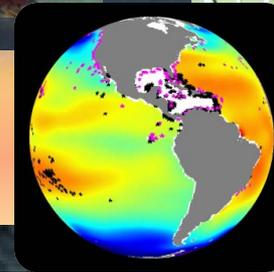
Monitor trends



Ecosystem Impacts



Model changes & responses



Develop adaptation strategies

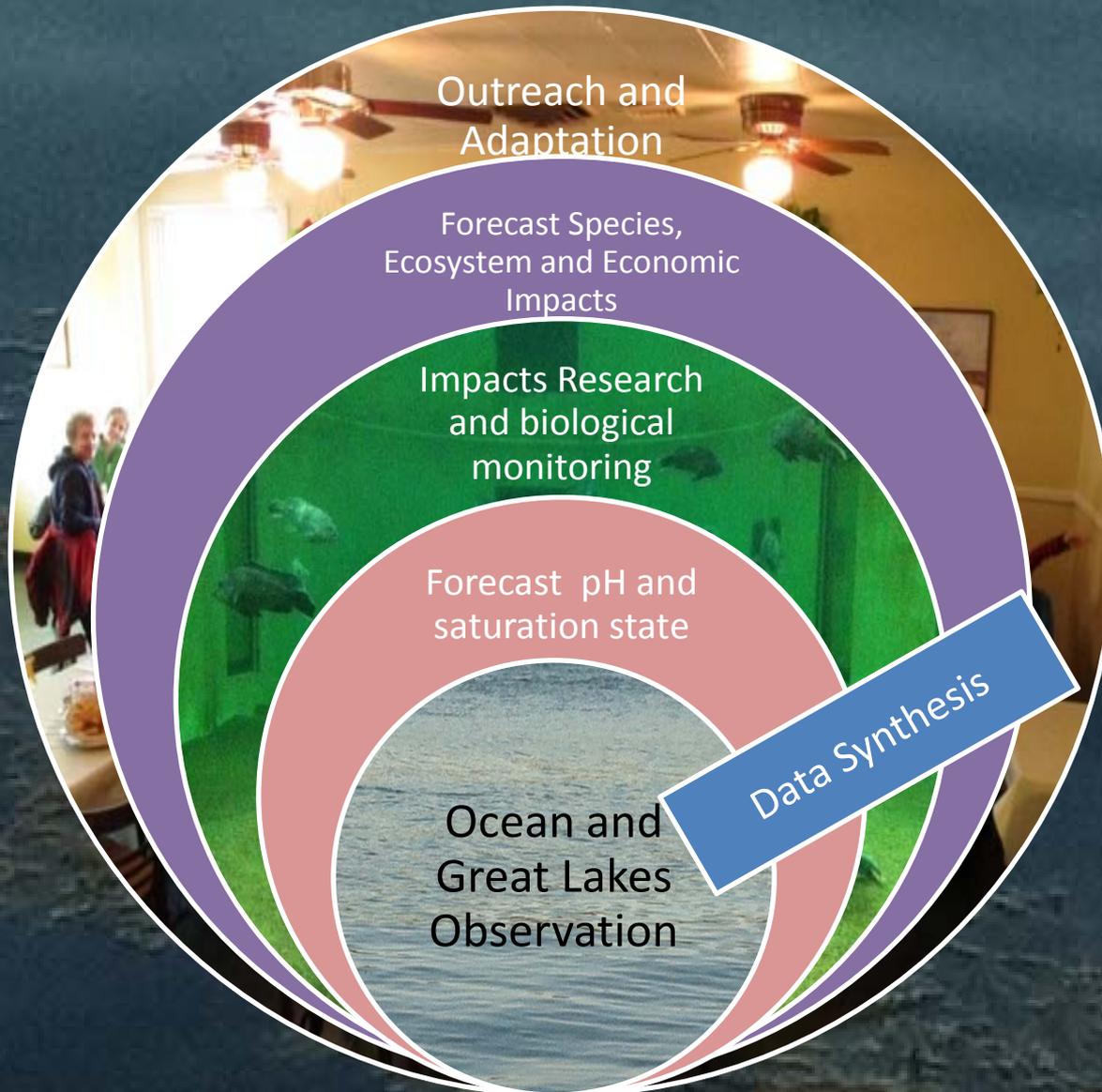


Conduct education and outreach



Data management and synthesis

NOAA Research Themes



NOAA Current and Potential Resources

- **Oceanic and Atmospheric Research (OAR)**
 - OA Program Office (HQ)
 - Observing, modeling and technology development (PMEL/AOML)
 - QA/QC for laboratories/universities (PMEL/AOML)
 - Coral reef research and monitoring (AOML)
 - National Sea Grant College Program: extramural research, communication, extension (300+ agents)
 - Climate Program Office: Office of Climate Observation and Carbon Cycle Program
 - Earth System modeling (GFDL)
 - Great Lakes Research (GLERL)
- **NOAA's Fisheries Service (NMFS)**
 - Species specific experiments on commercial or recreational fishery species or their food/prey including primary producers (NEFSC, NWFSC, AFSC)
 - Coral reef research and monitoring (PIFSC)
 - Building shared-resource mesocosm infrastructures (NEFSC, NWFSC, AFSC)
 - Fishery Impacts modeling (NEFSC, NWFSC, AFSC)
- **National Ocean Service (NOS)**
 - U.S. IOOS Program Office and Regional Associations: OA is one of the current seven HIGH priority observing foci
 - Coral Reef Conservation Program
 - Biogeochemical and Ecosystem OA Impacts Modeling– extramural program - FY 12 RFP (NCCOS)
 - NCCOS Laboratories
 - National Marine Sanctuaries: Research and outreach plans for sanctuaries
 - National Estuarine Research Reserves: Adding pH to monitoring programs
 - Arctic Program
- **National Environmental Satellite, Data, and Information Service (NESDIS)**
 - NODC: Data Archives
 - Coral Reef Watch
 - Satellite sensing of phytoplankton blooms

Ocean Acidification Working Group

Monitor Trends

OAR Laboratory; CPO Reps
CRCP Rep
National Marine Sanctuaries Rep
IOOS Rep; OER Rep

Ecosystem Responses

NMFS Laboratory Reps
NCCOS/NOS Rep
CRCP and Sea Grant Reps

Model changes

NMFS Laboratory Reps
NCCOS/NOS Rep
CRCP Rep
OAR Laboratory reps

Synthesize Data

NODC/NESDIS Rep
Data Expert
All Laboratory Reps

Adaptation Strategies

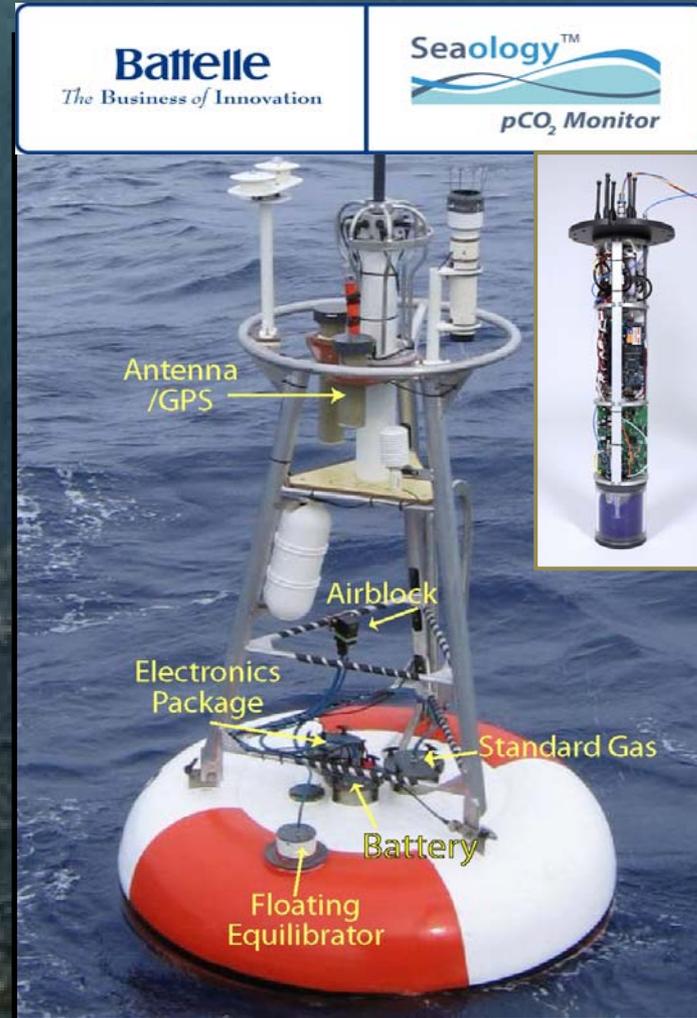
Sea Grant Rep
Climate Program Office Rep

Outreach and Education

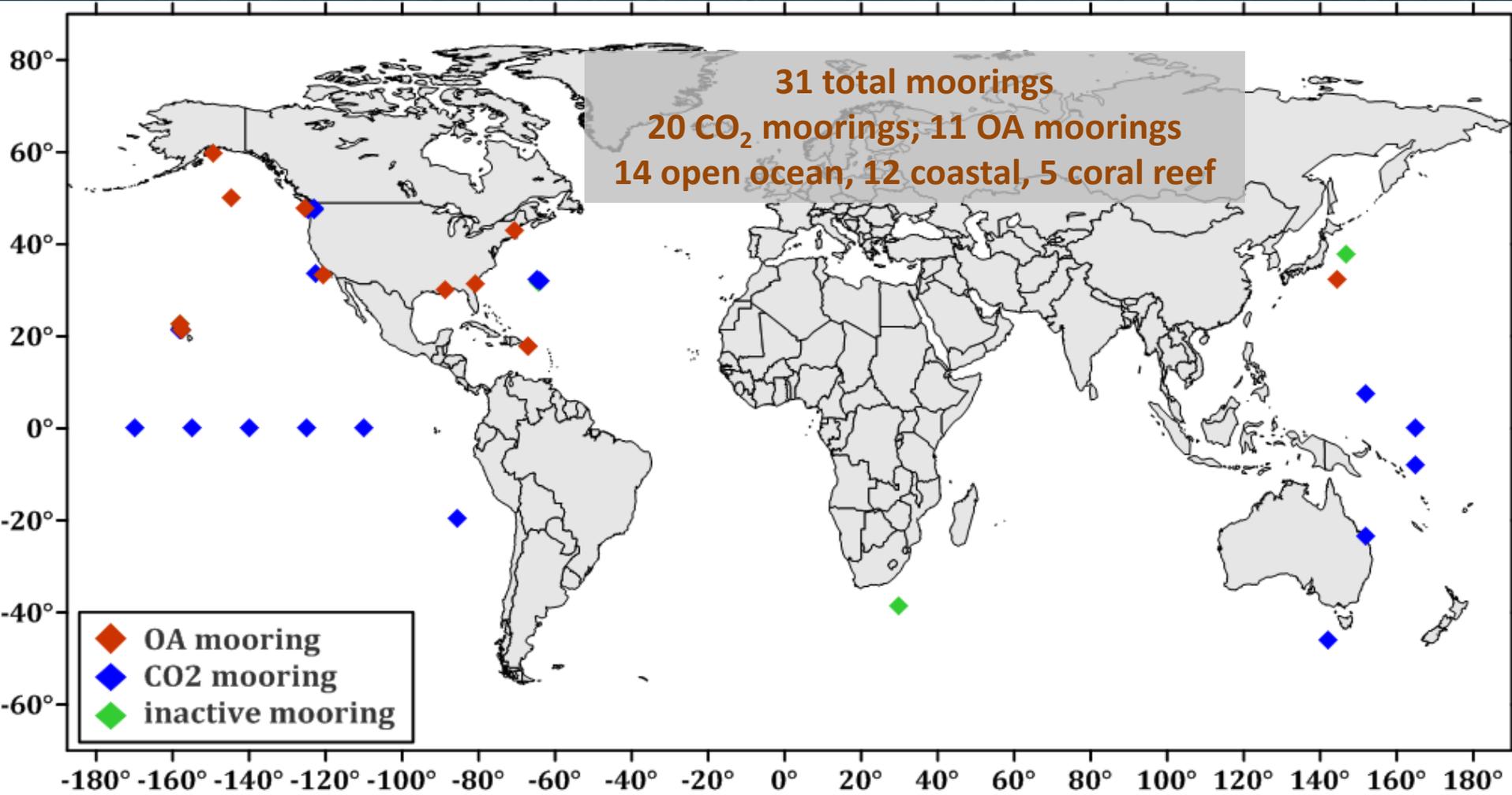
OA Program Office
Sea Grant and CRCP Rep
Internationally recognized OA expert

Ocean Acidification Observing

- Fixed site observing platforms
- Ships of opportunity
- Repeat hydrography and dedicated OA cruises
- Biogeochemical Modeling
- New technologies



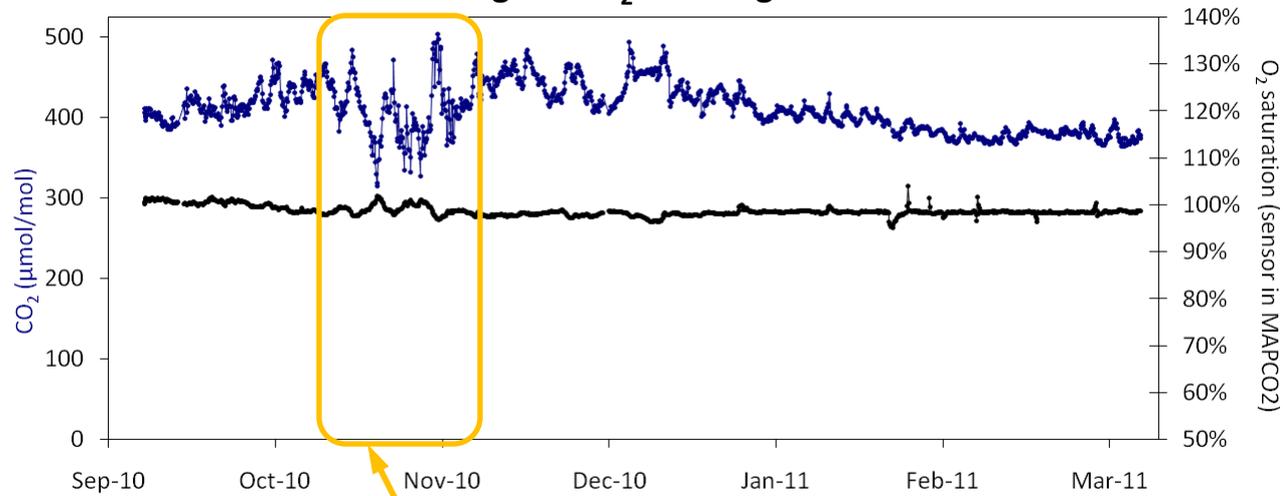
NOAA PMEL Mooring Network



Supported by NOAA's Office of Climate Observation (OCO), NOAA's Ocean Acidification Program, and a variety of partners

Gulf of Maine OA Mooring

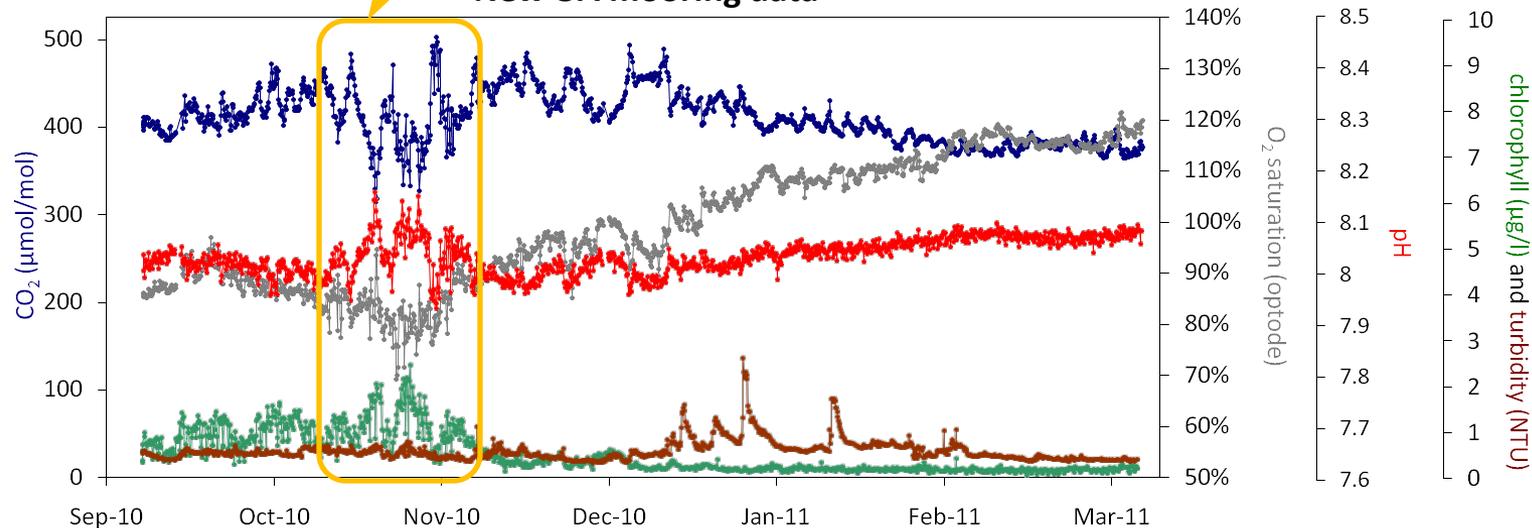
Original CO₂ mooring data



CO₂ mooring data:
CO₂
O₂ in equilibrated air

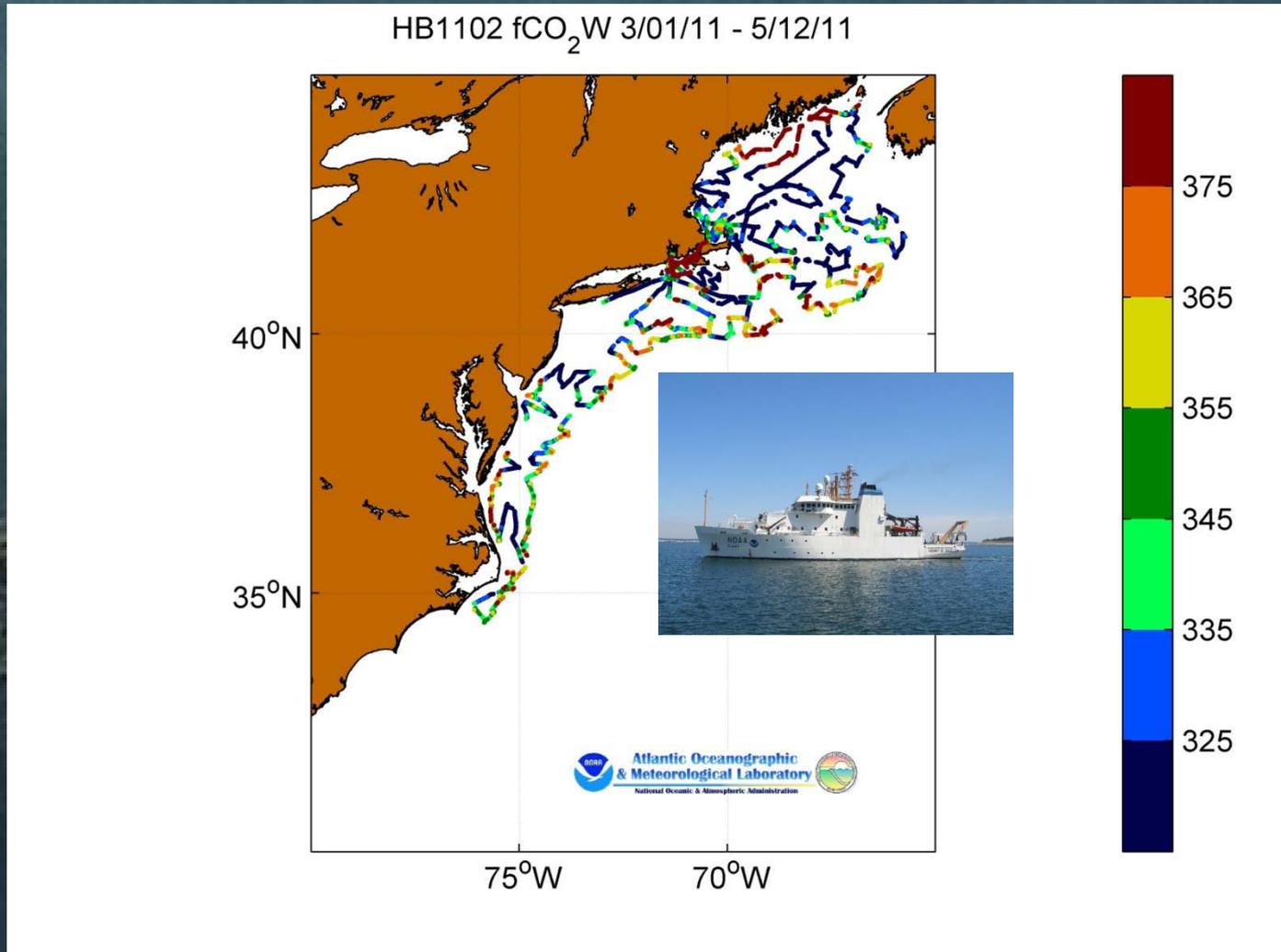
New sensors provide insights into the influence of biology on short-term variations in ocean carbon chemistry

New OA mooring data



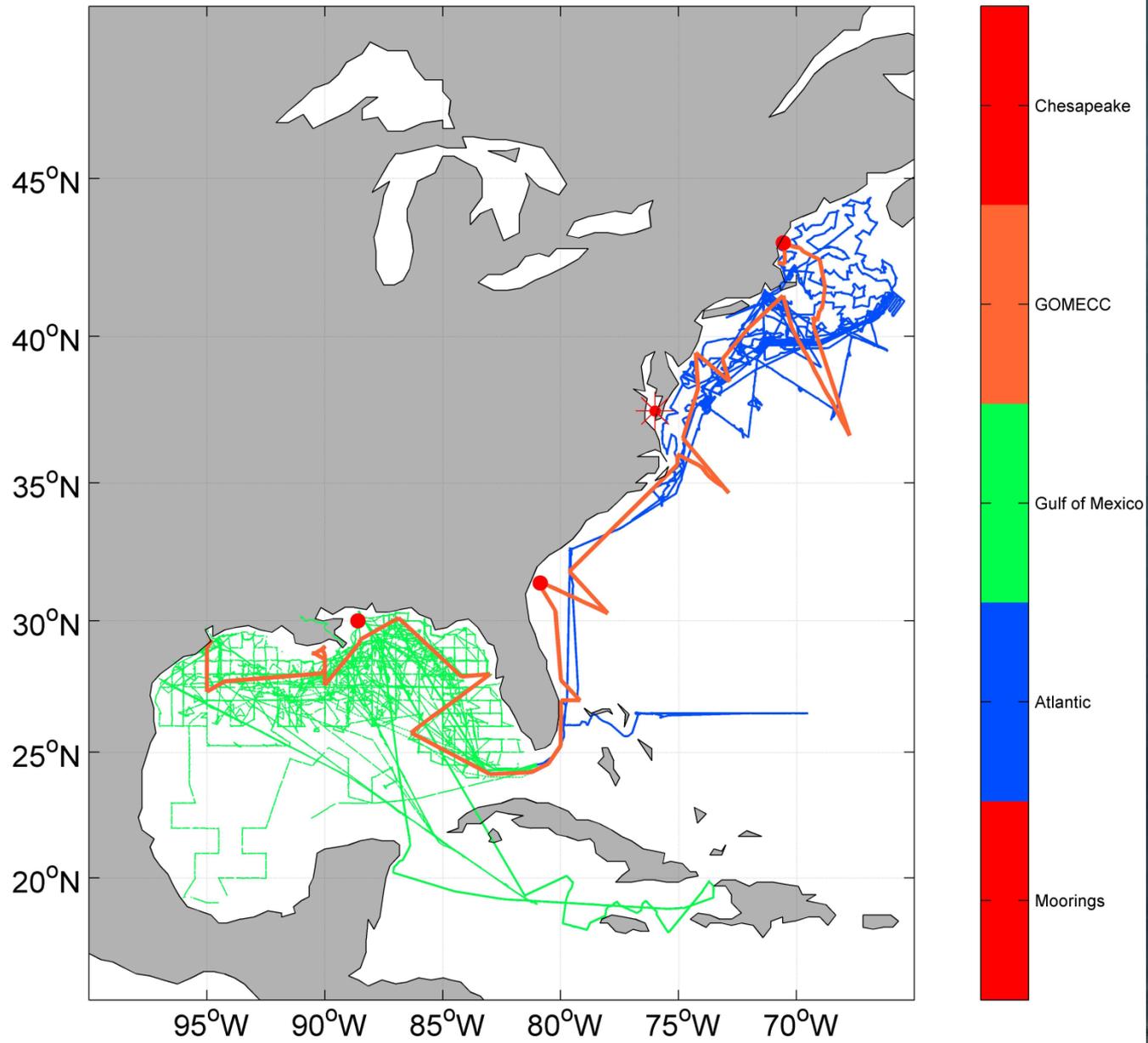
OA mooring data:
CO₂
pH
SSTC
optode O₂
fluorescence
turbidity

Ships of Opportunity



AOML and NMFS: First surface water CO₂ data from NOAA ship *Henry B. Bigelow*

Ocean Acidification Monitoring

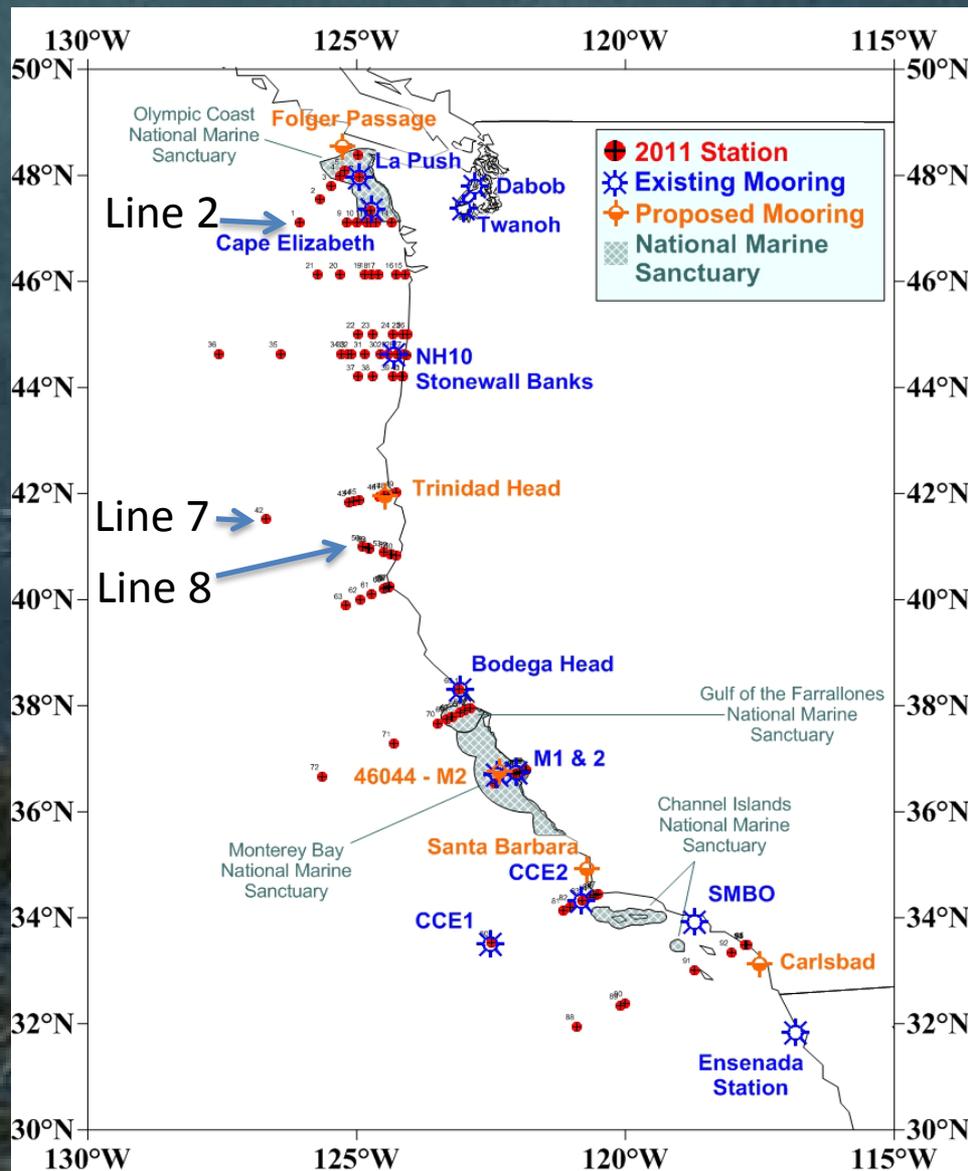




NACP/OA West Coast Survey Cruise

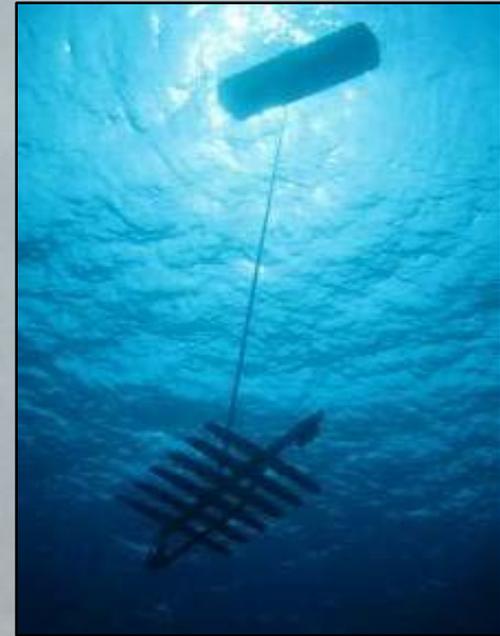
11 Aug – 3 Sept 2011

The WCOA2011 Cruise on the R/V Wecoma is designed to delineate the extent and magnitude of the exposure of West Coast ecosystems to “acidified” conditions and to study the links between acidification and hypoxia along the coast.



Carbon Wave Glider

- PMEL
- Measurements: T, S, pH, $p\text{CO}_2$
- West Coast



Impacts Research and Modeling

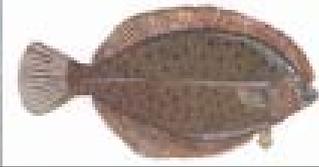
- Fishery Science Centers
- Coral Reef Monitoring and Assessment
- NCCOS/NOS Ecosystem Modeling RFP
- All involve extensive collaboration with external partners

Northeast Fishery Science Center

- Phytoplankton
- Finfish
 - Summer and Winter Flounder
 - Black Sea Bass
 - Sturgeon
 - Juvenile Scup
- Atlantic Surf Clam with WHOI
- Ecosystem Impact Modeling



Northeast Fisheries Science Center

SPECIES		SPAWNING SEASON	EGG / LARVAL HABITAT	PRIMARY VALUE
	summer flounder	autumn-winter	shelf / water column	economic
	winter flounder	winter-spring	estuaries / benthic / water column	economic
	black sea bass	summer	shelf / water column	economic
	shortnose sturgeon	spring-summer	estuaries to fresh / benthic	endangered
	Atlantic sturgeon	summer	estuaries to fresh / benthic	endangered

Northeast Fishery Science Center Howard Laboratory: Sandy Hook



Northwest Fishery Science Center

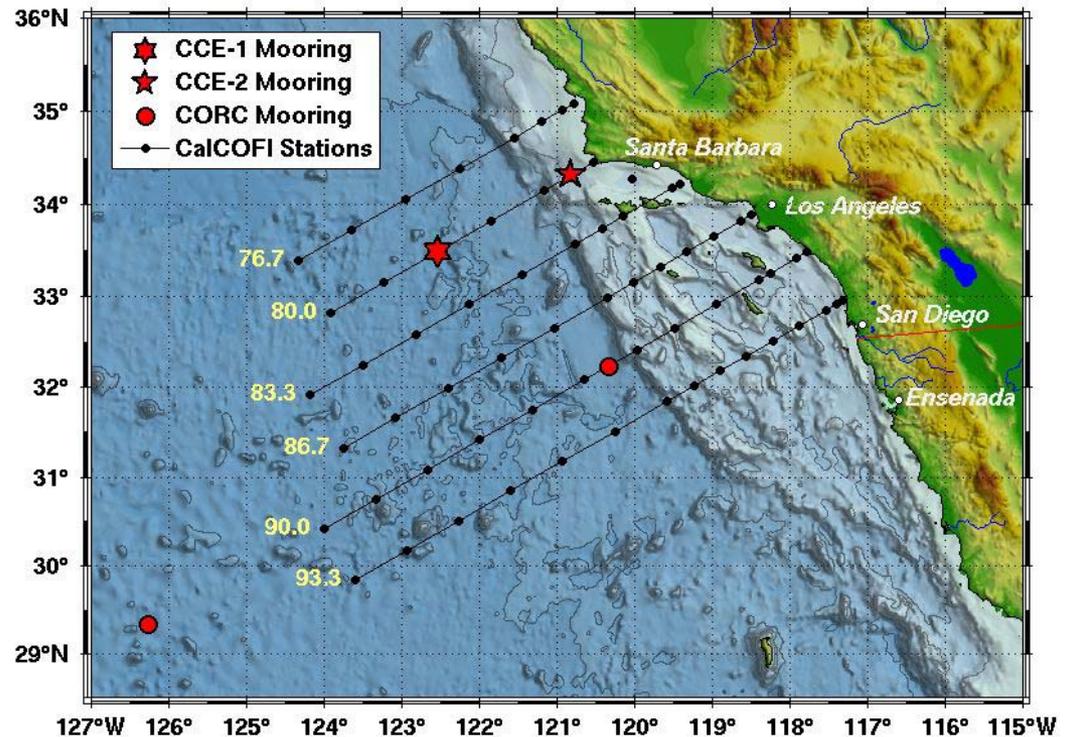
- Bivalves
 - Geoducks
 - Pacific oysters
 - Olympic oyster
 - Pinto abalone
 - Crustaceans
 - Copepods
 - Krill
 - Dungeness Crab
 - Rockfish
 - Market squid
- pH monitoring in Puget Sound as relevant to fishery species
 - Ecosystem impact modeling

System Photo



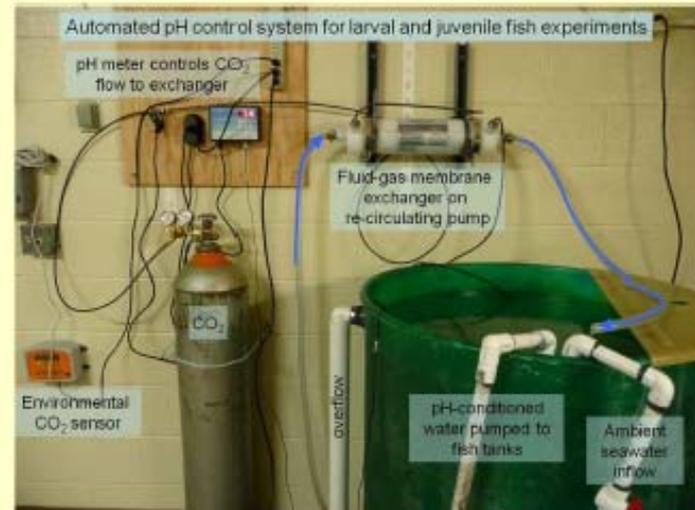
Southwest Fishery Science Center

- Retrospective analysis of the CalCOFI data
- Working closely with Scripps PIs to analyze biological data from CCE buoys off Point Concepcion



Alaska Fishery Science Center

- Managed Crab Species
 - Red, Blue and Golden King Crab
 - Tanner
 - Multiple life stages
 - Growth and survival
 - genomics
- Alaskan corals
- Fish
 - Pacific cod
 - Walleye pollock



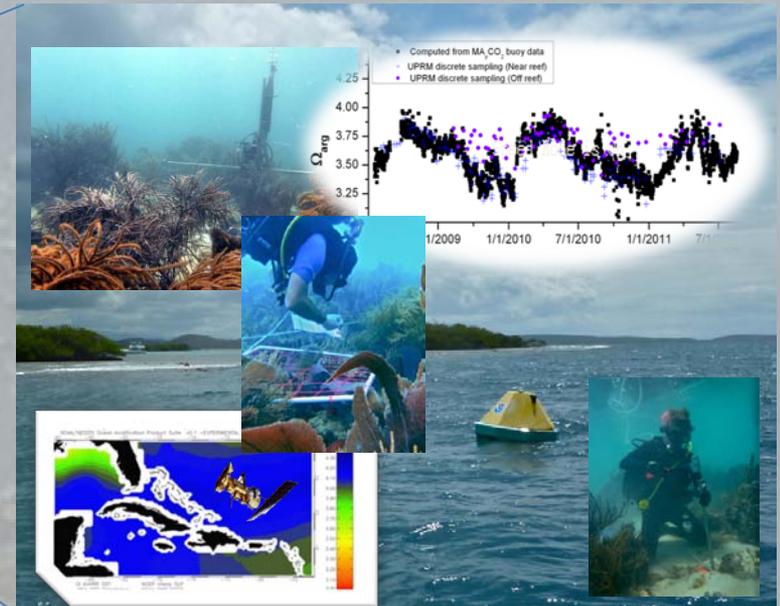
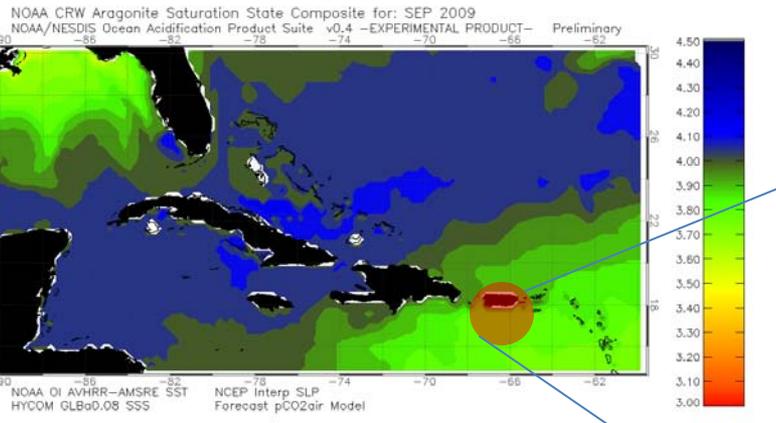
Coral Reef OA Monitoring Portfolio

- Coral Reef Conservation Program began funding OA research activities in 2007
- Ocean Acidification Program joined in 2011
- Partnering in 2012 – 2014 and beyond
- Coordinated with the National Coral Reef Monitoring Plan (NCRMP)
- Two main focus areas:
 - Atlantic Ocean Acidification Test Bed
 - Pacific Islands surveys

Atlantic Ocean Acidification Test-bed

Provide data rich observing environment uniting satellite-based regional monitoring with high-resolution *near-reef* time-series observations.

Nexus of federal and academic monitoring and research to conduct intercomparison studies and develop advanced techniques to monitor coral reef community response and feedback to OA.



Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE



AOML

Pacific Islands FSC: CRED

- Carbonate chemistry monitoring in Pacific Islands
- Autonomous Reef Monitoring (ARMs)
 - Investigate invertebrate diversity
- Calcification Acidification Units (CAUs)
 - Assess long term trends in carbonate accretion and assess spatial patterns
 - First retrievals in 2012
- Coral Coring (collaborating with Anne Cohen, WHOI)
 - Growth rate of corals

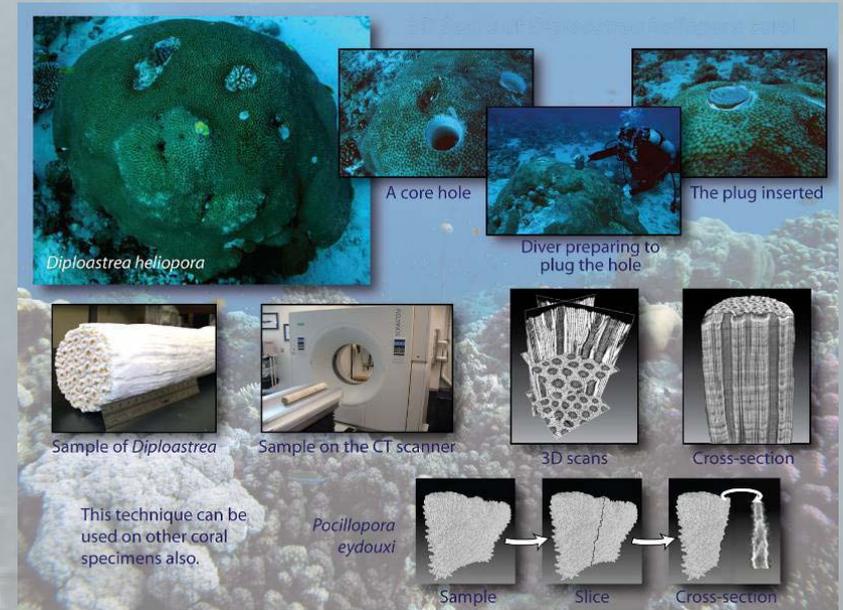


Figure 2: CAU Deployments



Autonomous Reef Monitoring

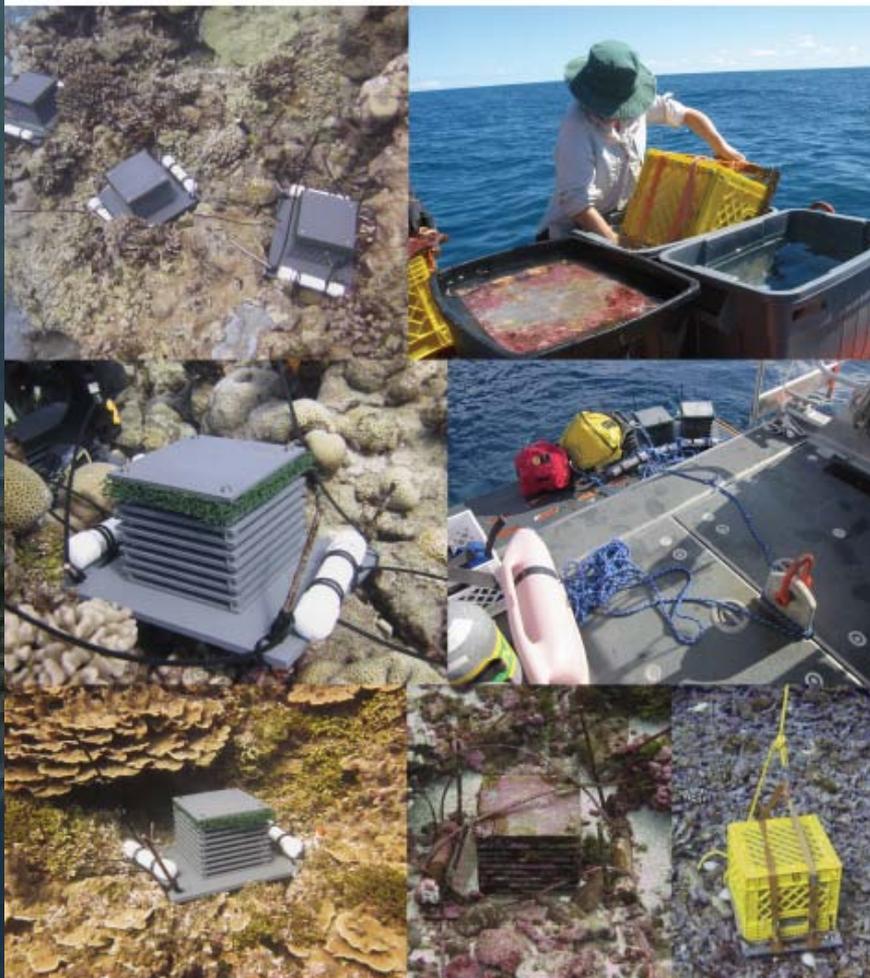


Figure 6: Ship-board ARMS processing



Federal Coordination

- Interagency Working Group on Ocean Acidification (NOAA – Lead, NSF, USGS, BOEM, EPA, DOS, DFW, NASA)
- Interagency Strategic Research Plan: In Review
- Coordinating data management and RFPs
- Participation in international efforts via the Solas-Imber OA Working Group (Dick Feely, Rik Wanninkhof)
- Department of State: Rio +20
- Participation in the Oceans in a High CO₂ World III International Symposium in Monterey, CA in Sept 2012 with Dr. Lubchenco as keynote speaker.

NSF

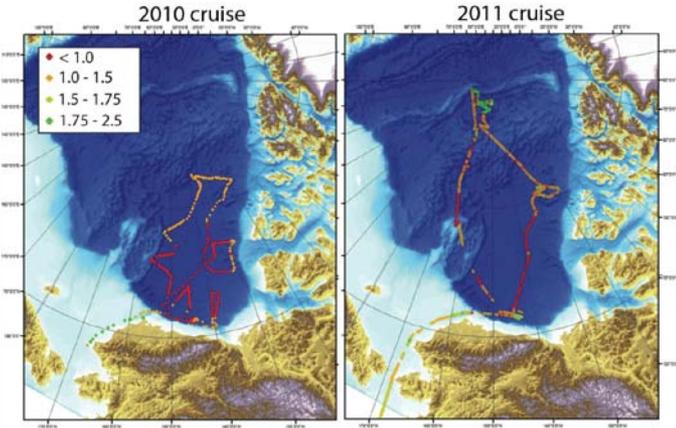
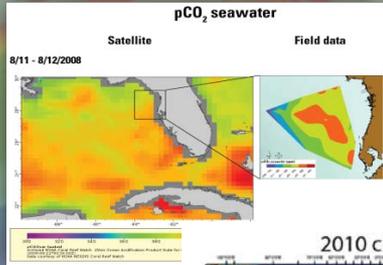
- *Integrated across 3 directorates and 5 programs*
 - *Ocean acidification interconnected to oceanic biology, chemistry, physics, and geology.*
 - *Predicting the consequences of ocean acidification on ecosystem health and function.*
 - *Interpreting the geologic record to reveal the history of climate change and the assemblages of organisms that have risen, persisted, or declined, as the earth system has evolved.*

Regional coastal saturation and pCO₂

Linked to habitat

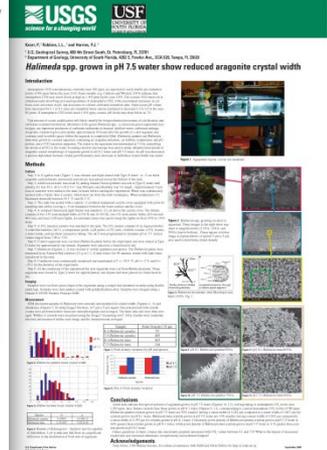
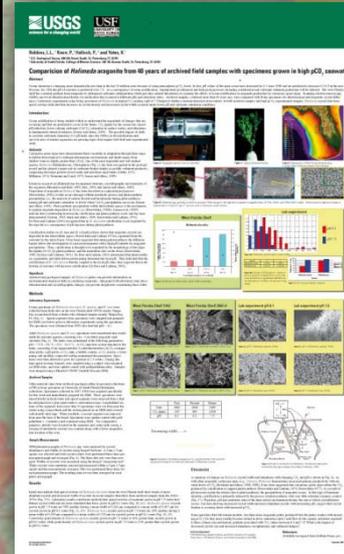
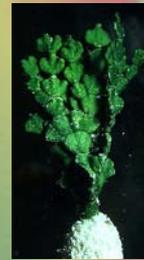
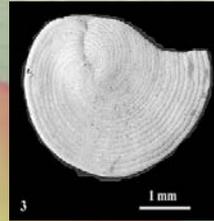
Florida & Caribbean

Arctic

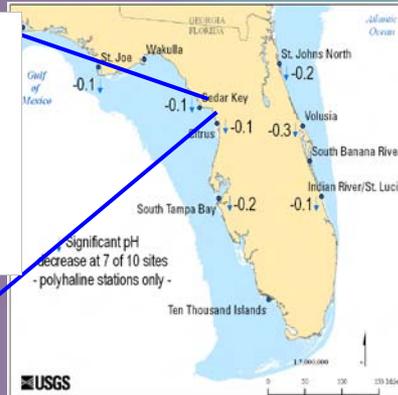
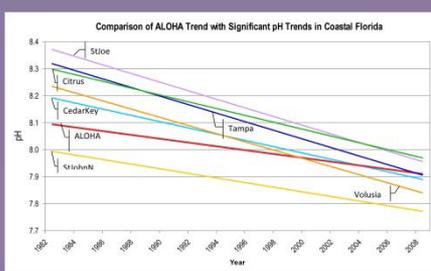


Calcifying organism response

lab and field process studies



Historic coastal pH, salinity, and temp FL Shellfish beds



Florida Department of Agriculture and Consumer Services
Division of Aquaculture



Integrated approach to understanding impacts of ocean acidification & carbon budget from estuary to shelf

Next steps for NOAA

- Build out coastal and open ocean **observing** system
- Establish Atlantic/Pacific coral reef OA **monitoring** portfolio and implementation plan
- Continue **experiments** on identified species of concern
 - Provide academic community with access to facilities
- **Model/Forecast** Species, Ecosystem and Economic Impacts
- Develop and coordinate **outreach and education** message
 - OA web page
 - Leverage skilled educators within NOAA
 - Work with NGOs
- Create standard **data** protocols and manage/serve data
- **National Program Office**: Feds and academics
 - Exploring models for this
- **International Coordination**
 - International Observing Network
 - International program office

Questions?

