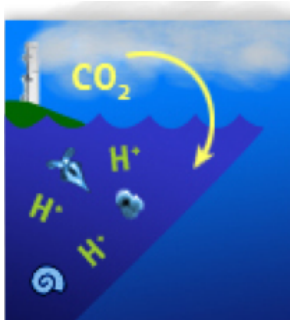
Observations & Monitoring Ocean Acidification

Synthesis of Projects

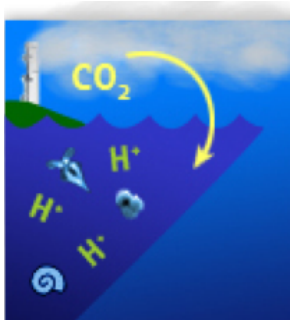
Lisa Robbins

USGS



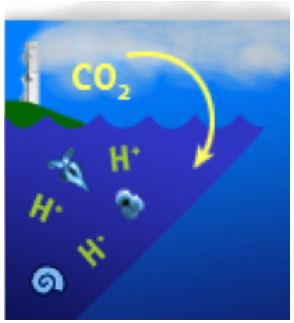
Observation & Monitoring: Funding - Coral Reefs

- **Andreas Andersson**: NSF BEACON Burmuda ocean acidification and coral reef investigation
- **Derek Manzello**: NOAA Assessing carbonate budgets of coral reef communities across natural CO2 gradients on the Florida Reef Tract.
- **Rusty Brainard:** NOAA: Pacific Reef Assessment and Monitoring Program
- **Chris Langdon:** NSF Application of a novel geochemical approach to the alkalinity anomaly method of estimating coral reef calcification: implications of ocean acidification
  - NSF: Climate change and coral reefs: integrating calcification, photosynthesis and symbiosis flexibility into species survival trajectories for Caribbean reef corals.
  - NOAA: Small boat CO2 equilibrator and gradient flux measurements of calcification
- **Kim Yates:** USGS: Coral Reef community calcification and metabolism
  - USGS: Diurnal variation in coastal carbonate system parameters.



Monitoring: East Coast & Gulf of Mexico

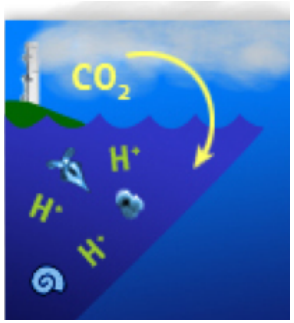
- **Wei –Jun Cai**: NOAA: " Grays Reef OA monitoring Program"
  - NSF Satellite assessment of CO2 distribution, variability and flux and understanding of control mechanism in a river dominated ocean margin
- **Aleck Wang**: Distributions of the Marine CO2 System along the U.S. Atlantic and Gulf of Mexico Coast
- **Lisa Robbins**: USGS: Response of Florida shelf ecosystems to climate change
- **Rik Wanninkhof:** NOAA: GOMECC cruises Gulf of Mexico and East Coast
- **Dan McCorkle**: field studies of the controls on carbonate chemistry of estuaries and coastal ocean, emphasizing shellfish and coral reefs.
- **Gareth Lawson:** NSF: Distribution, abundance, species composition, shell condition and vertical migratory behavior of pteropods in NW Atlantic and NE Pacific
- **Denise Breitburg** (Smithsonian): NOAA funding: Shallow water hypoxia-tipping the balance for individual, populations and ecosystems. Chesapeake Bay



Monitoring: Funding West Coast

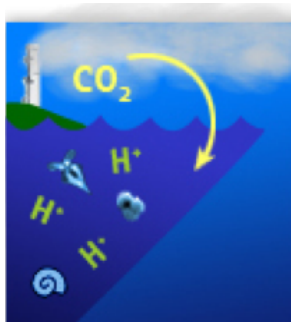
- **Adrienne Sutton** NOAA: High resolution OA time series in the surface ocean
- **Dick Feely**: NOAA: Combined impacts of OA and hypoxia along Cascadia Margin between Canada and Mexico
- **Chris Sabine**: NOAA:NOAA Ocean Acidification Monitoring Project
- **Simone Alin:** NOAA: predictive relationships for hindcasting and forecasting OA conditions along the West coast
- **Paul McElhany:** NOAA:
- **Francis Chan: NSF:** "EAGER: Initiation of a pH/pCO2-sensing mooring platform on the Oregon coast." co-PIs B. Menge)
  - Gordon and Betty Moore Foundation: Microbial diversity and activity in the seasonal hypoxic waters off Central Oregon and Chile: A comparative study.
  - NSF: Acclimation and adaptation to ocean acidification of key ecosystem components in the California Current System. PIs: B. A. Menge, et al.)
- **Francisco Chavez:** OMEGAS team proposed research
- **Lisa Levin**: NSF Macrophyte- induced variability in coastal ocean pH and consequences for invertebrate larvae

  - NSF: Development of geochemical proxies to evaluate larval ph-exposure history



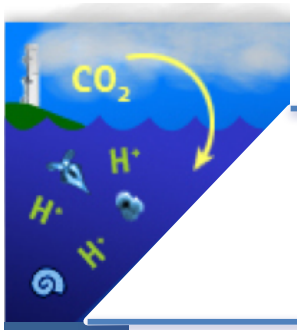
Monitoring: Funding High Latitudes

- **Wei-Jun:** NSF: Controls on sea surface pCO2 variability and CO2 uptake in the western Arctic ocean margins
- **Kris Holderied**: NOAA: Spatial and temporal variability of OA in estuary Kachemak Bay
- **Lisa Robbins:** USGS : Arctic research related to OA using ship of opportunity to collect carbonate system parameters in Canada Basin and northward
- **Sergio Signorini**: NASA: Assessment and impact of carbon variability in Nordic Seas.
- **Jeremy Mathis:** NSF: Observation and prediction of OA in the western Arctic Ocean- impacts of physical and biogeochemical processes on carbonate mineral states
  - NSF: An interdisciplinary monitoring mooring in the western arctic boundary current: climatic forcing and ecosystem response)
  - BOEMR: Biogeochemical assessment of the north Aleutian Basin ecosystem
  - Alaska Ocean observing system (AOOS): measure carbon parameters along time series- May- Sept in northern Gulf of Alaska. Includes mooring with OA sensors at surface and near bottom.
  - NPS: impacts of glacial discharge on OA and saturation states
- **Gretchen Hofmann**: NSF: Characterizing response of larval sea urchin to OA and warming.
  - NSF: Effects of OA on fertilization kinetics embryos and larvae of Antarctic echinoderms

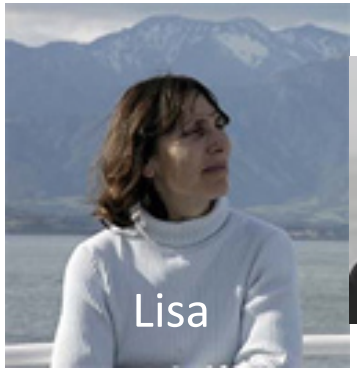


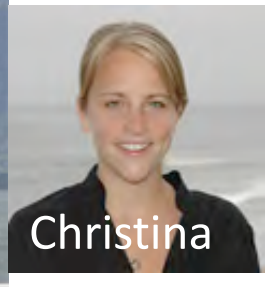
Monitoring: Funding Others

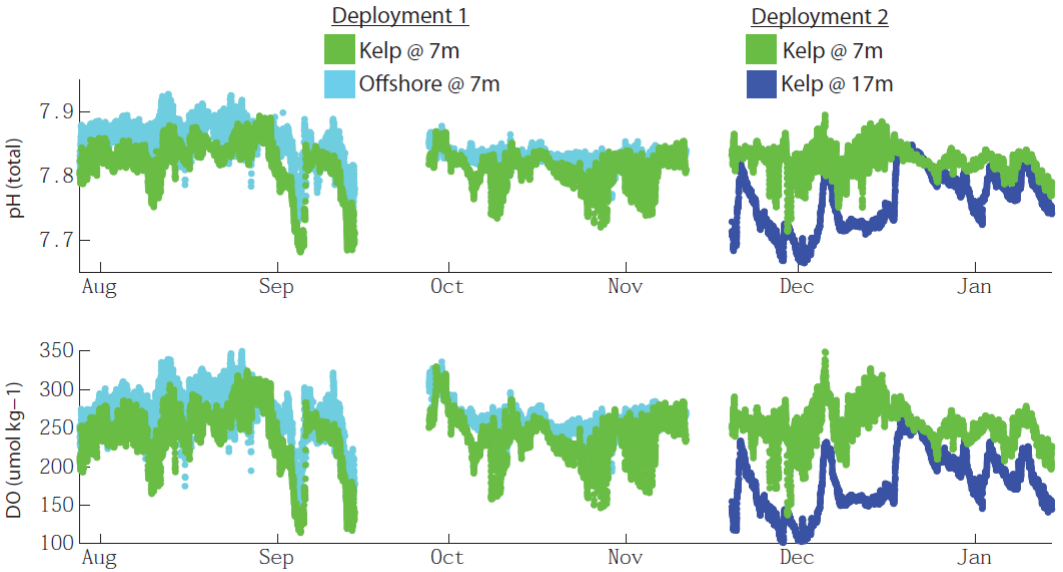
- Julie Reichert EPA: Identifying and tracking OA related monitoring and research efforts that could be useful for states for future OA related impairments.
- Tim Wootton : What is Driving Rapid pH Decline?
- Taro Takahashi: NSF :Climatological Mean Distribution of pH and CO3= in Global Ocean Waters in the Unified pH Scale
- John Joseph: Naval Posgrad School- Measurement analysis and modeling prediction of sound propagation in spatially and temporally varying ocean media.

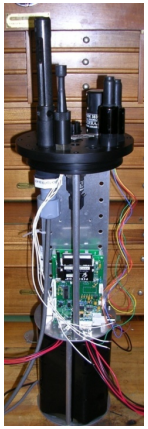


OBSERVATIONS & MONITORING

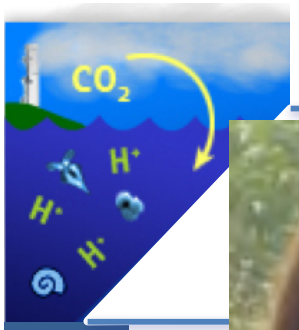








To address the interplay between anthropogenically driven pH changes and the inherently variable coastal ocean, and directly test the implications for invertebrate larvae

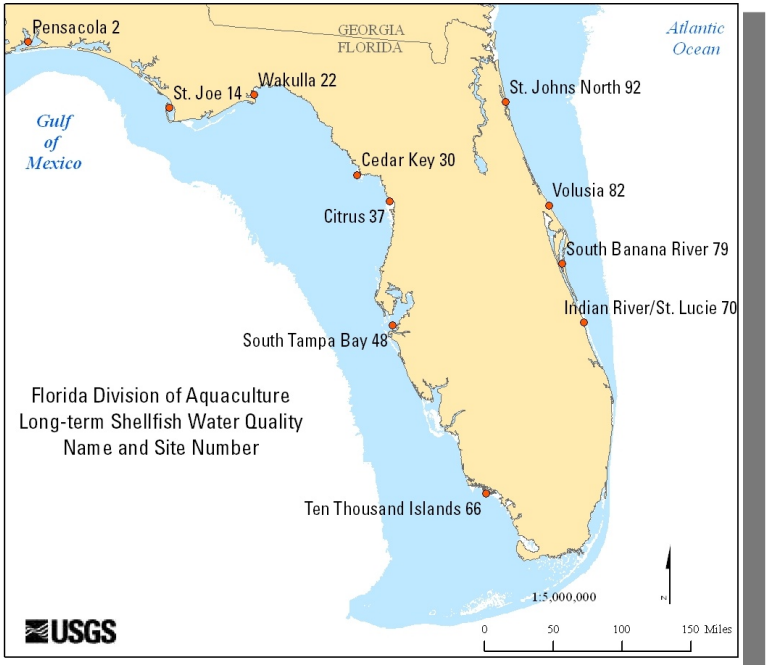


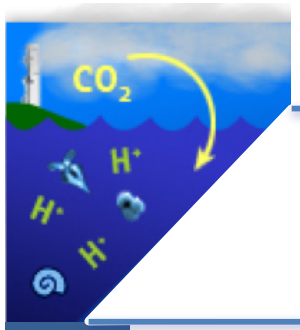
OBSERVATIONS & MONITORING

Identifying and evaluating techniques that can determine past and present pH levels for 303(d) listing.

Collaborating with other programs to create a National database that is searchable by State, monitoring program, and parameter (e.g., pH), with easy data access options.

Why? Such a database would help improve States' efforts to locate and solicit external OA-related data for assessment and 303(d) listing purposes.

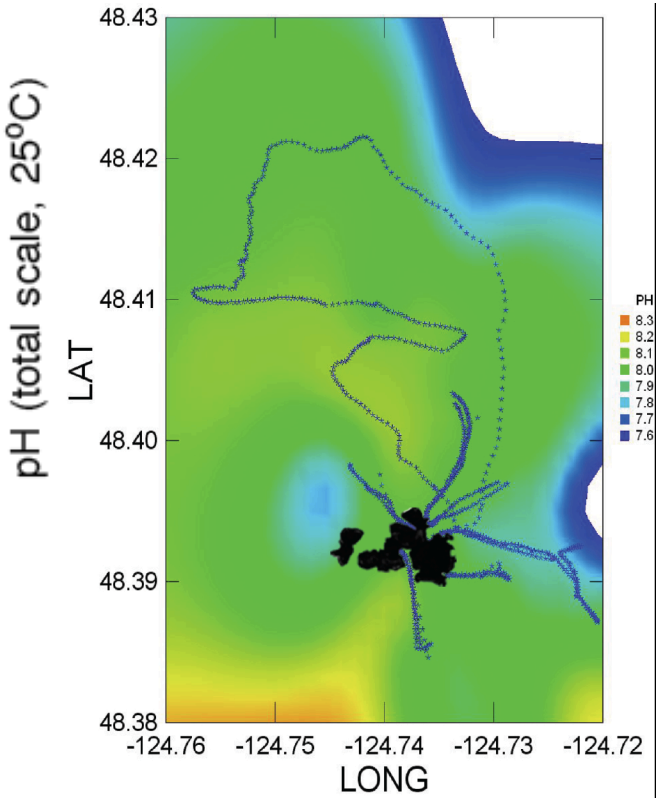


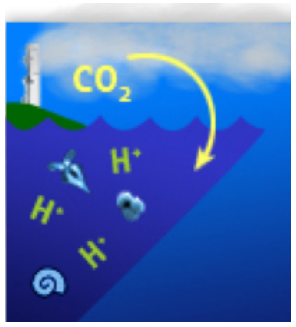


OBSERVATIONS & MONITORING

Ecological Dynamics in an Experimentally-Tractable Natural Ecosystem

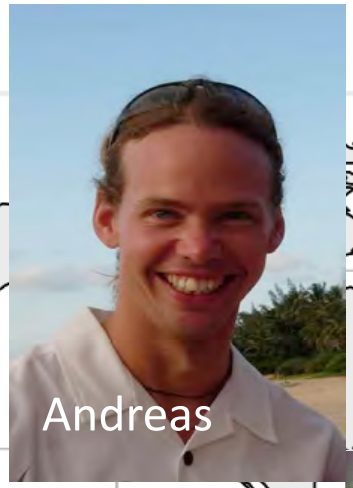
✓Monitor ocean conditions w/Hydrolab probe (>50,000 measures over 11 yr)

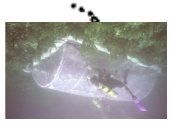




Observations:

Coral Reefs





90°N
60°N
30°N
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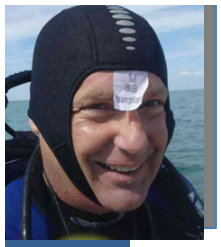
30°S
60°S
180°W
90°W
0°
90°E
180°E



Dr. Chris Langdon

J. Corredor, M. Degrandpre, K. Yates,
D. Gledhill, W. McGillis, B. Loose

Rosenstiel School of Marine and Atmospheric Sciences

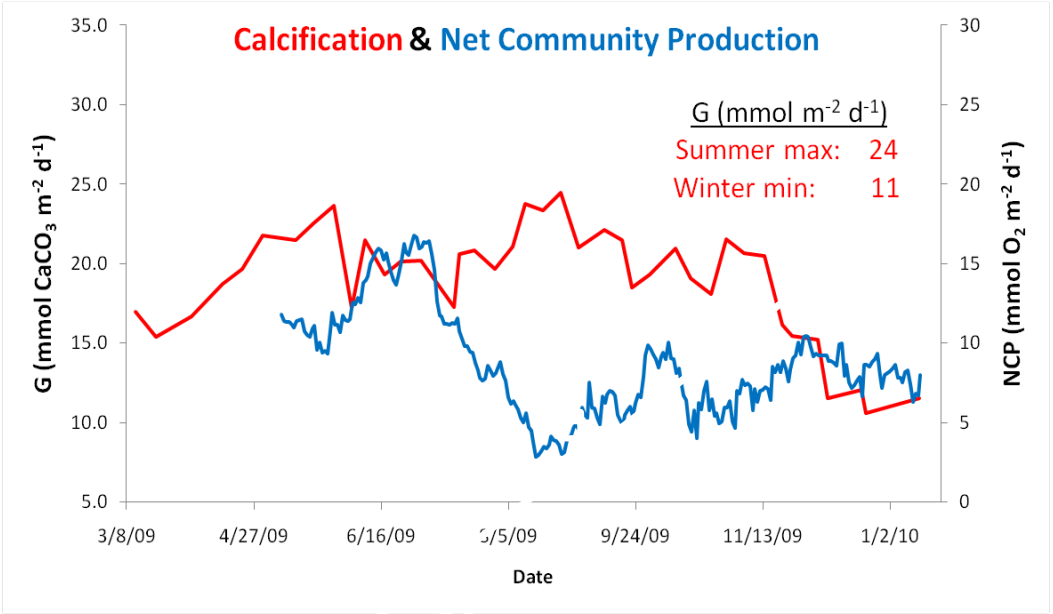
University of Miami

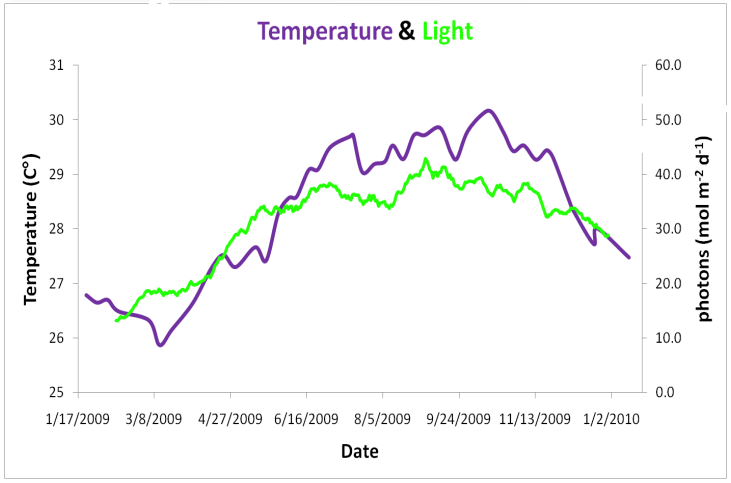
Year-Long Time Series of Coral Reef Calcification based on the Eulerian Method – Establishing a Baseline

OBSERVATIONS & MONITORING

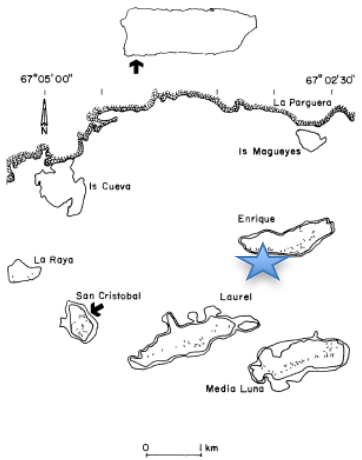
Measurements

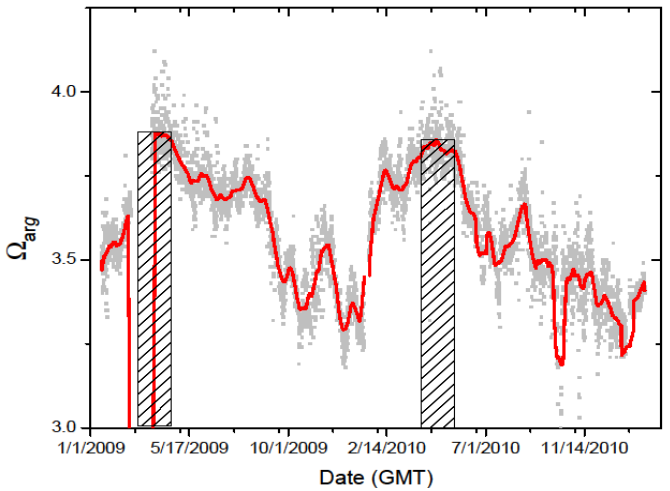
- TA & pH – *weekly*
- Current Speed – *every 6 min.*
- MAP pCO_2 – *every 3 hrs.*
- Temp & Salinity – *every 3 hrs.*
- ICON light – *hourly*

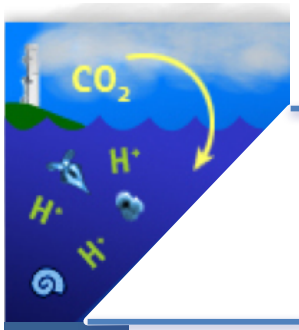




La Parguera, PR

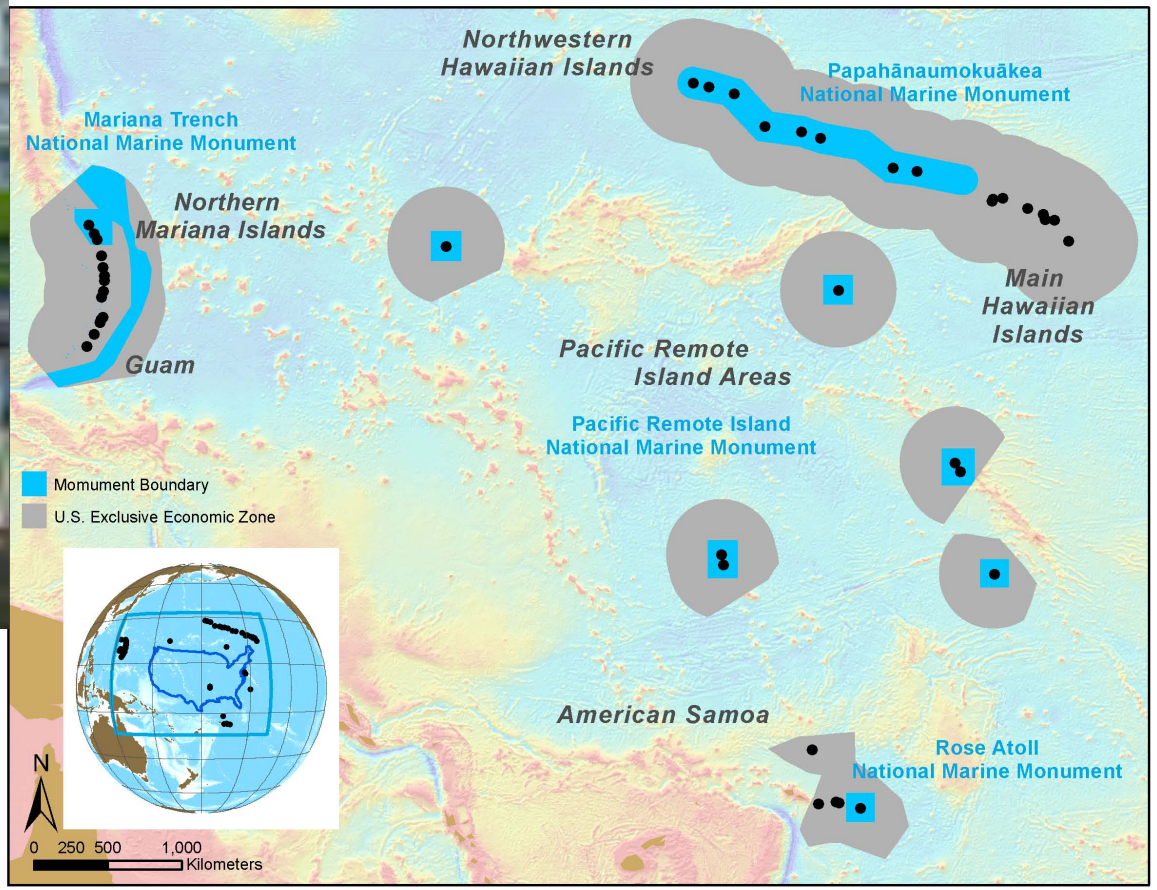


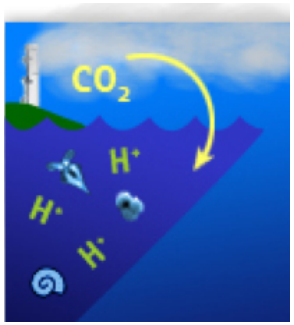




Pacific Reef Assessment and Monitoring Program Pacific

OBSERVATIONS & MONITORING





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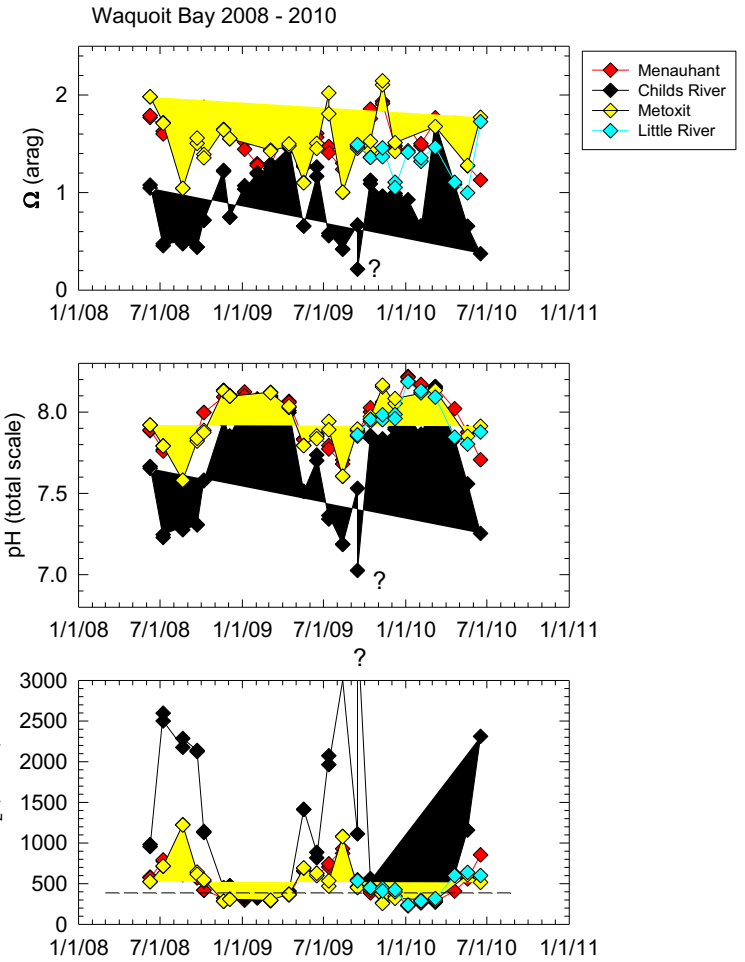
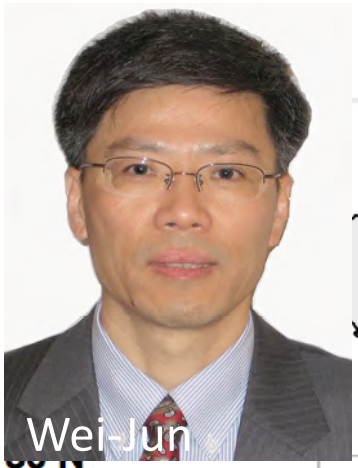
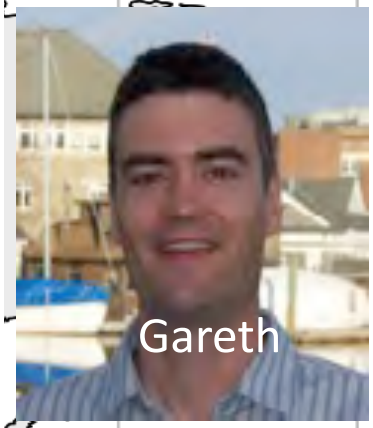
East Coas







60°S

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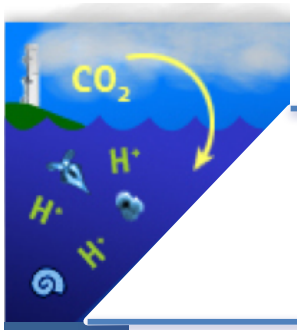
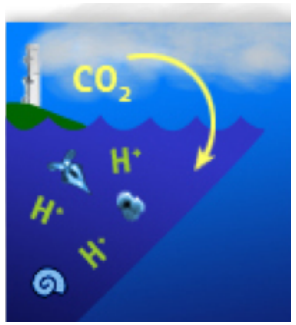


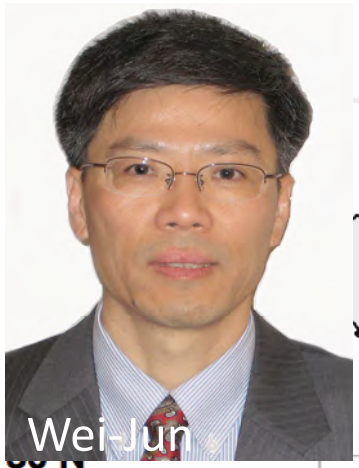
OBSERVATIONS & MONITORING

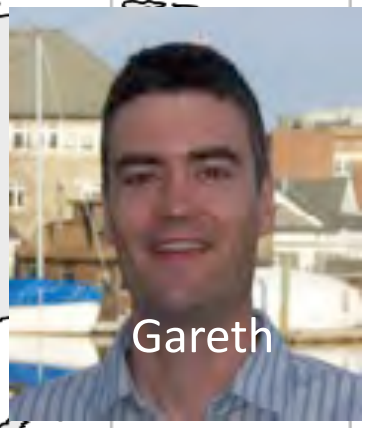
- NW Atlantic and NE Pacific Time Series
- Distribution, abundance, species composition, shell condition, and vertical migratory behavior of **oceanic pteropods**
- correlate these quantities to hydrography and measurements of carbonate chemistry, including vertical and horizontal distributions of aragonite saturation state.

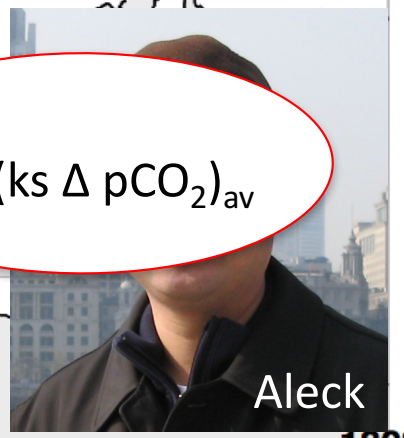


Observations:

East Coast and Gulf of Mexico







$F = (ks\ \Delta\ pCO_2)_{av}$

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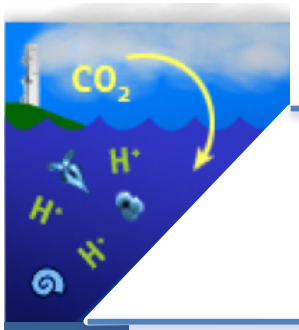
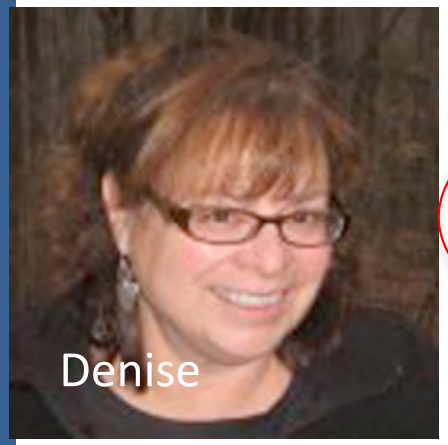


Exploring shallow water diel-cycling hypoxia in the Chesapeake

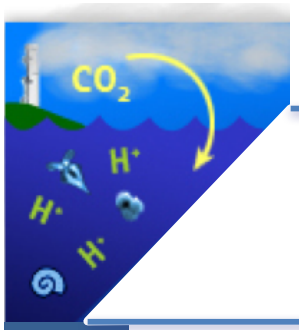
OBSERVATIONS & MONITORING



1) determine the quantitative relationship between diel-cycling hypoxia and diel-cycling pH in shallow water habitats in Chesapeake Bay

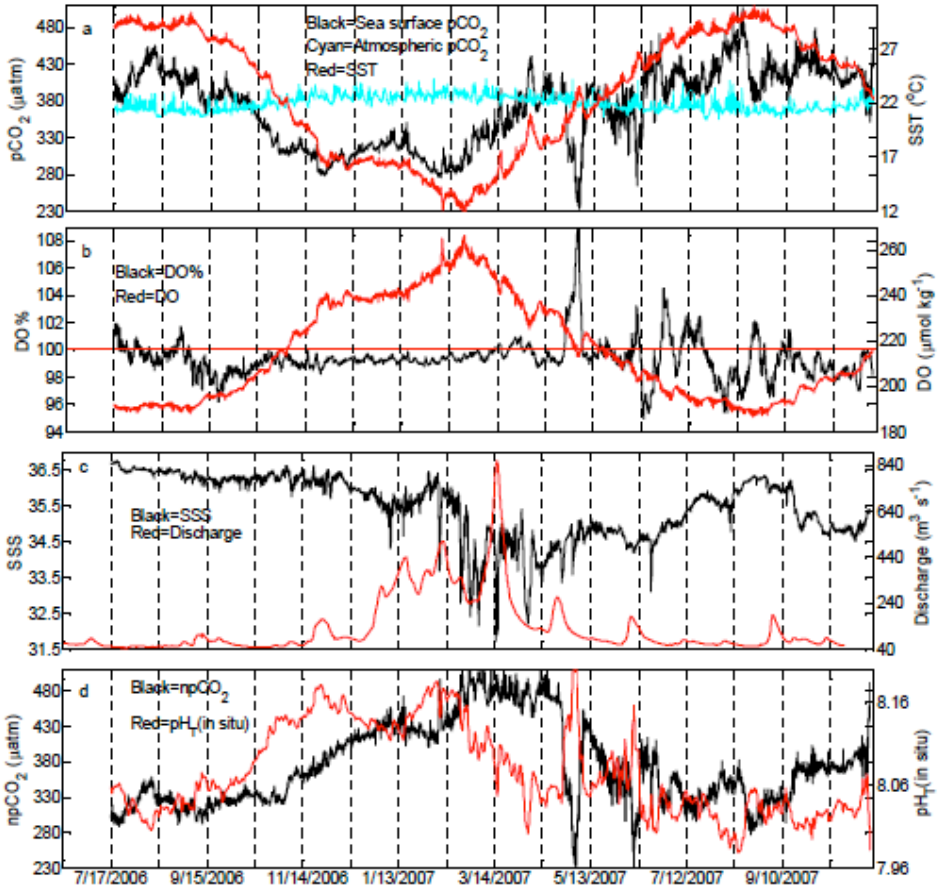
2) determine the behavioral responses of fish to diel-cycling hypoxia and co-occurring low pH in the field

3) conduct lab experiments
to test the individual and interactive effects of diel-cycling hypoxia and diel-cycling pH on juvenile growth, mortality and reproduction of finfish and oysters, and on the acquisition and progression of P. marinus
infections in oysters



OBSERVATIONS & MONITORING

Collect and interpret high resolution pCO_2 and pH data at NOAA buoy 41008



Jason Grear and Janet Nye

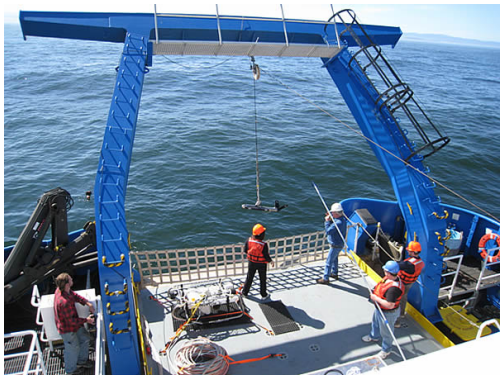
US EPA

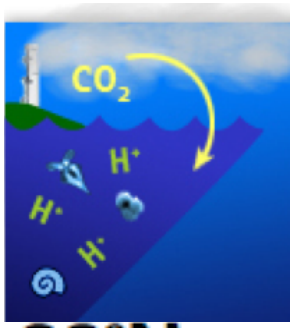
OBSERVATIONS & MONITORING

Coastal surveys of pCO2, total alkalinity, and dissolved inorganic carbon

We are assessing current and needed equipment with an emphasis on supporting current OA research in Narragansett Bay (see slides by J. Grear and J. Nye).

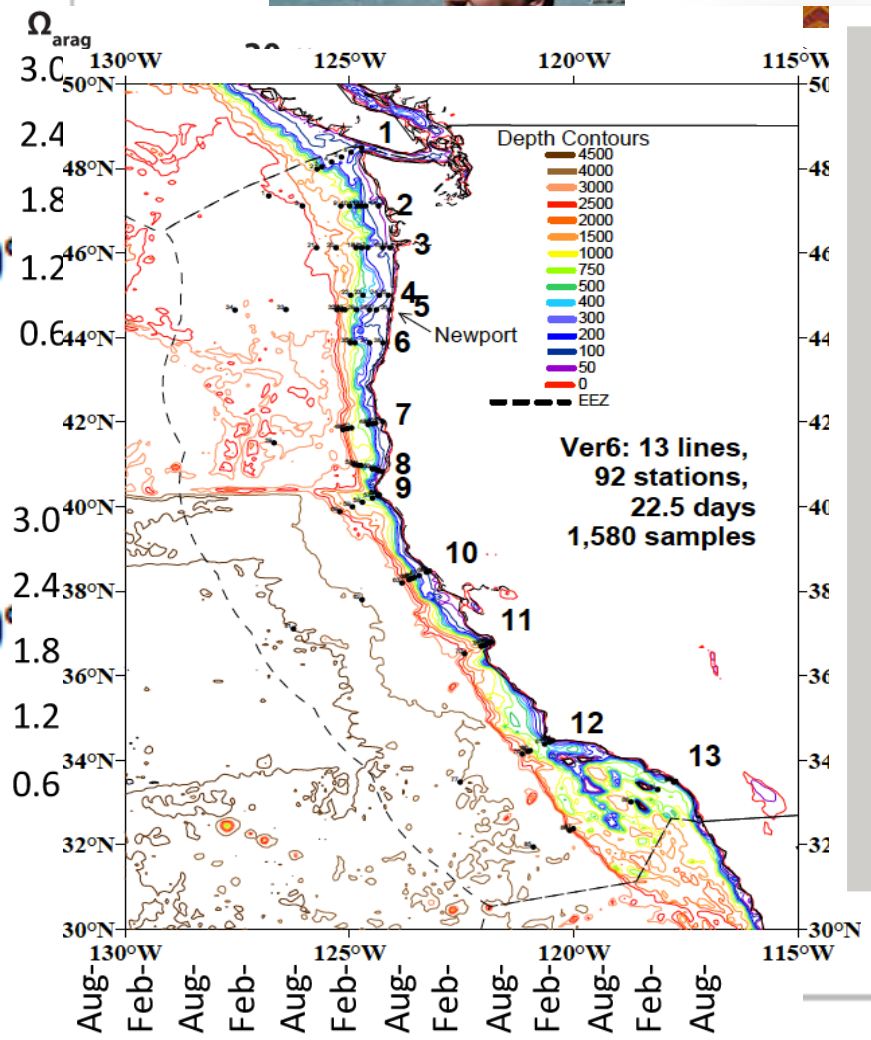
- ✓ TOC analyzer for DIC
- ✓ Auto titrator for TA
- Considering pCO2 system for alternating deployment on survey vessels (e.g., O.S.V. Bold) and our laboratory seawater intake.
- Coordinating with NOAA
- Broader regional survey needs?

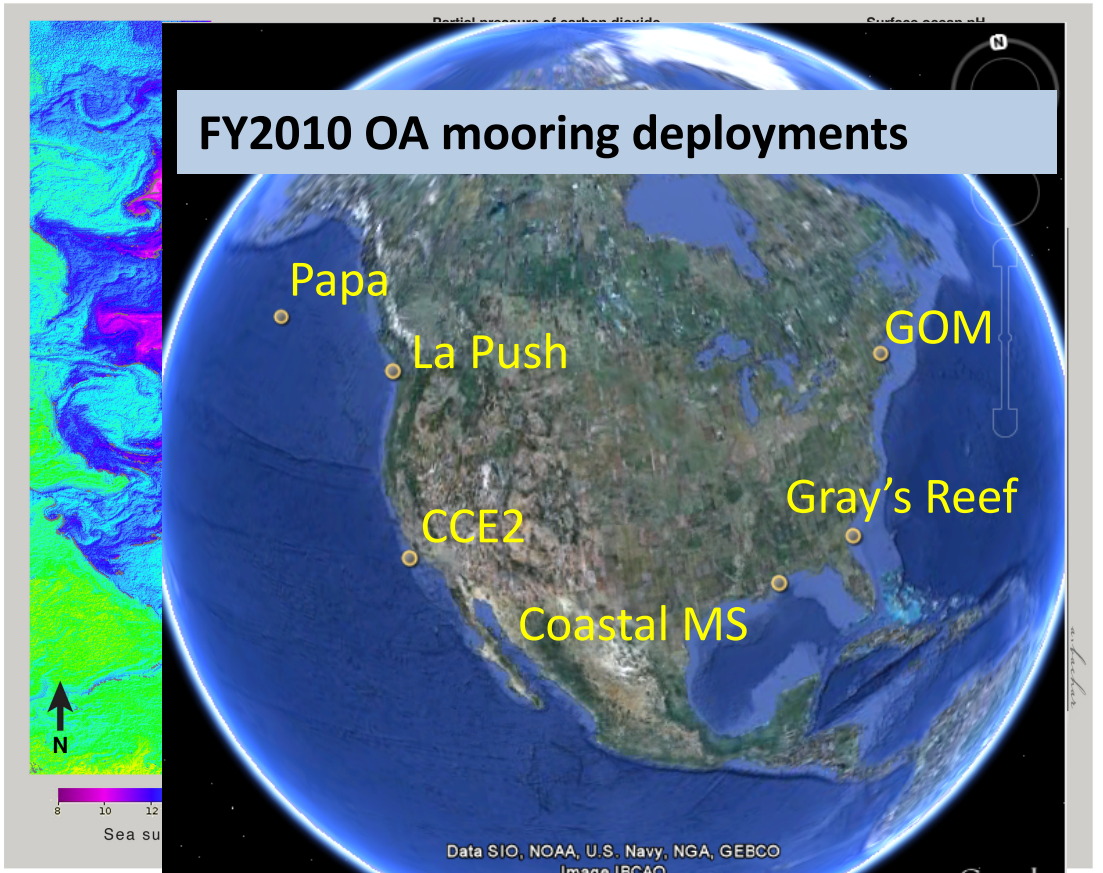


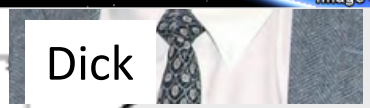


Observations:

West Coast







Dick

Francis Chan

Bruce Menge

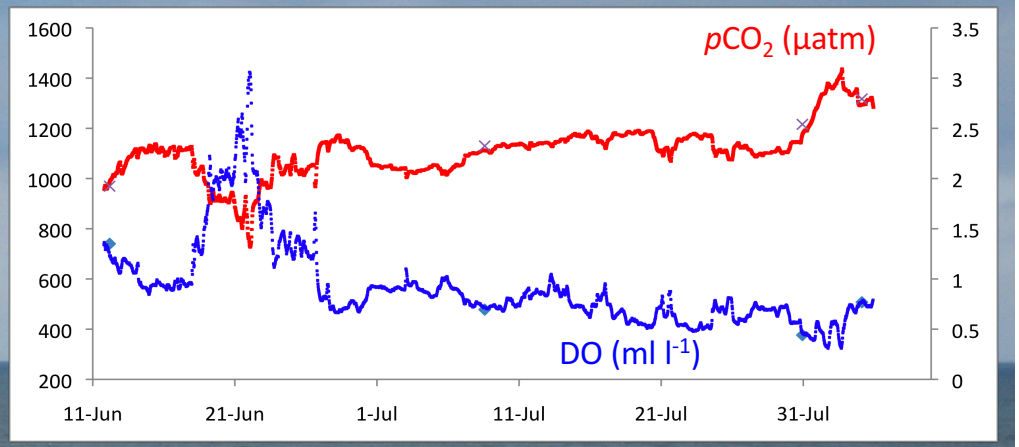
Oregon State University

August 2009

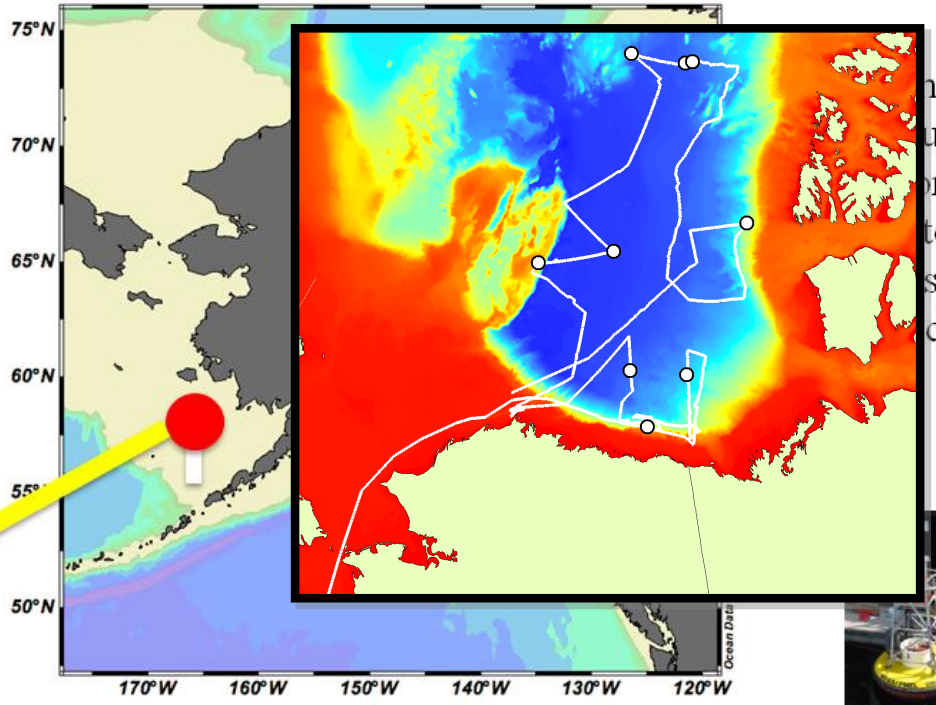
EAGER: Initiation of a pH/pCO_2-sensing mooring platform on the Oregon coast

OBSERVATIONS & MONITORING

- Evaluate the feasibility of maintaining continuous pH and pCO2 time-series
- Examine the scales of variability in OA stress and its coupling to low-oxygen stress in an upwelling shelf



PISCO
Partnership for Interdisciplinary Studies of Coastal Oceans



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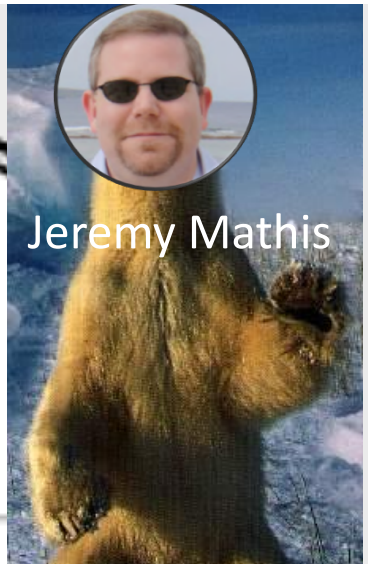
- Seasonal surface pCO_2 and pH, nitrate, DO, florescence and turbidity
- Continuous bottom pCO_2, pH, nitrate, DO, florescence and turbidity

- Continuous surface and bottom pCO_2, pH, nitrate, DO, florescence and turbidity

30°N



Jeremy T. Mathis

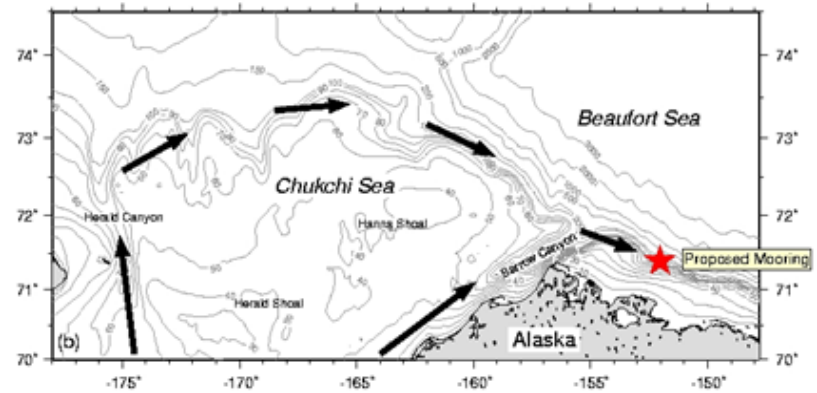
Bob Pickart (WHOI)
Kate Stafford (APL – UW)

University of Alaska Fairbanks

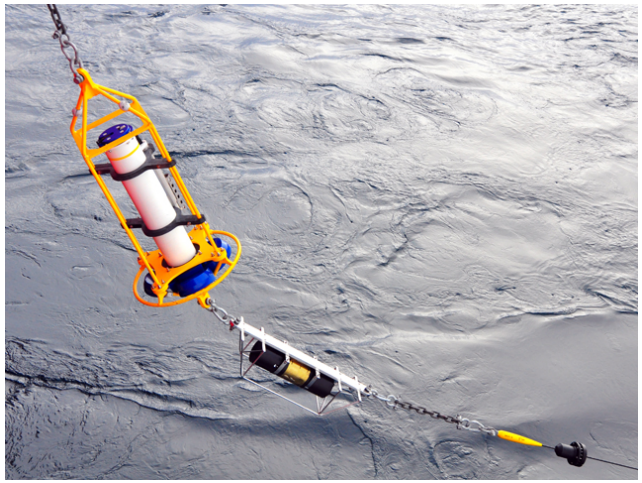
Deployed in September, 2010

OBSERVATIONS & MONITORING

An Interdisciplinary Monitoring Mooring in the Western Arctic Boundary Current: Climatic forcing and ecosystem response (Funding from NSF)

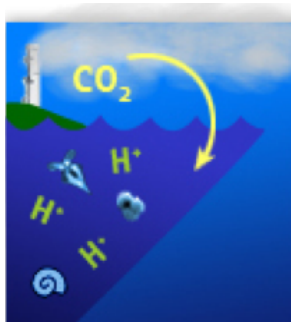


The mooring contains two profilers (one attached to the mooring wire and one tethered to the top float) working in tandem to sample the entire water column from the seafloor to the underside of the ice.



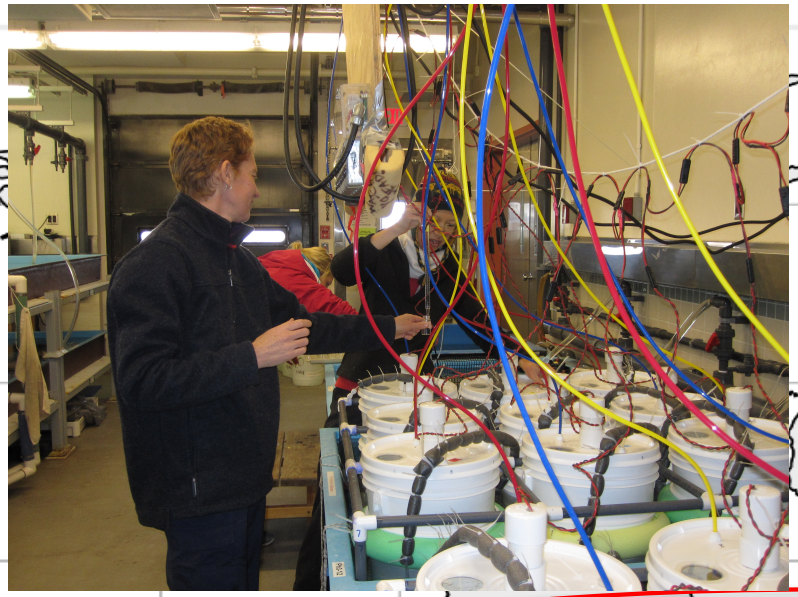
Each profiler is measuring **pressure**, **temperature**, **conductivity** (salinity), **dissolved oxygen**, **pH**, **turbidity**, **chlorophyll fluorescence**, and **nitrate**. It will provide one complete profile a day, and a second profile from 40m to the bottom. Two **SAMI II *p*CO_2 sensors** are deployed at fixed depths on the mooring (30 m and 100 m).

The mooring will be in place for 5 years.



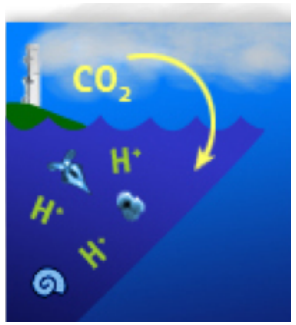
Observations:

High Latitudes, cont

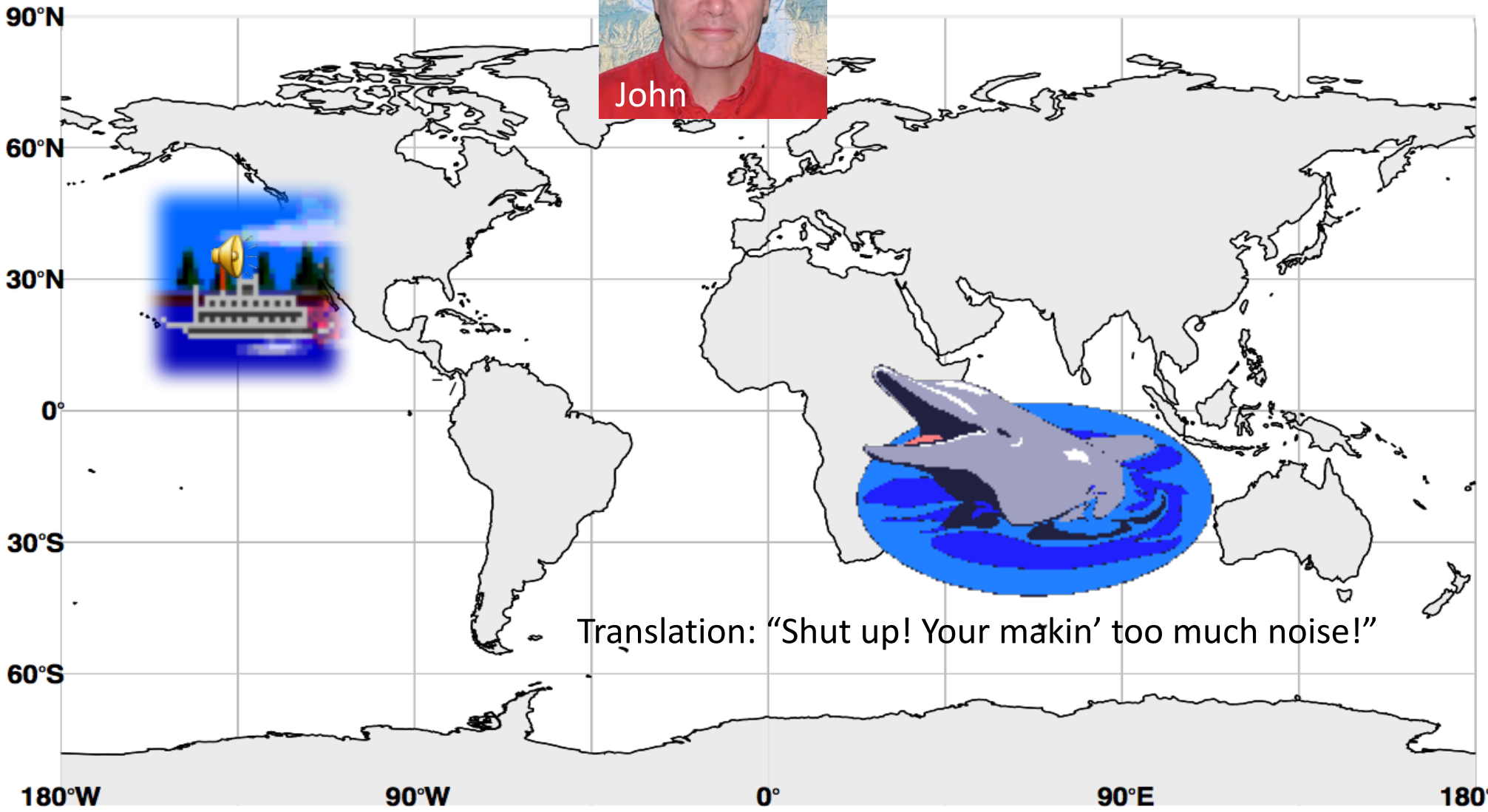


Time series data for SeaFET deployment at three sites in McMurdo Sound

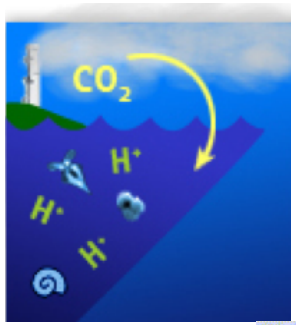
90°N
60°N
30°N
0°
30°S
60°S
180°W
90°W
0°
90°E
180°E



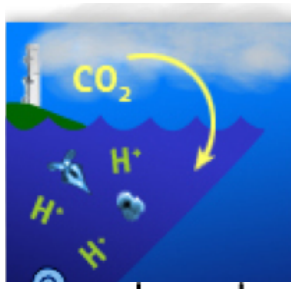
Observations: Physical properties



Translation: “Shut up! Your makin’ too much noise!”

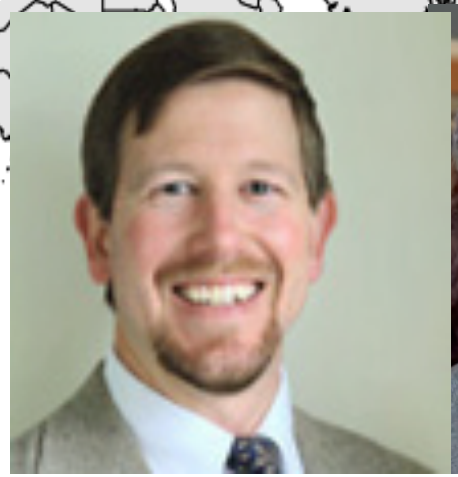


Assessment and Impact of Carbon Variability in the Nordic Seas



NOAA Ocean Acidification Monitoring Project & Series

25 So Far and Taking Over the World!



80°N
60°N
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20°N
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20°S
40°S
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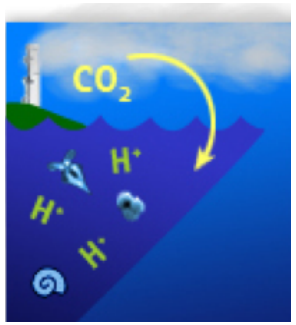
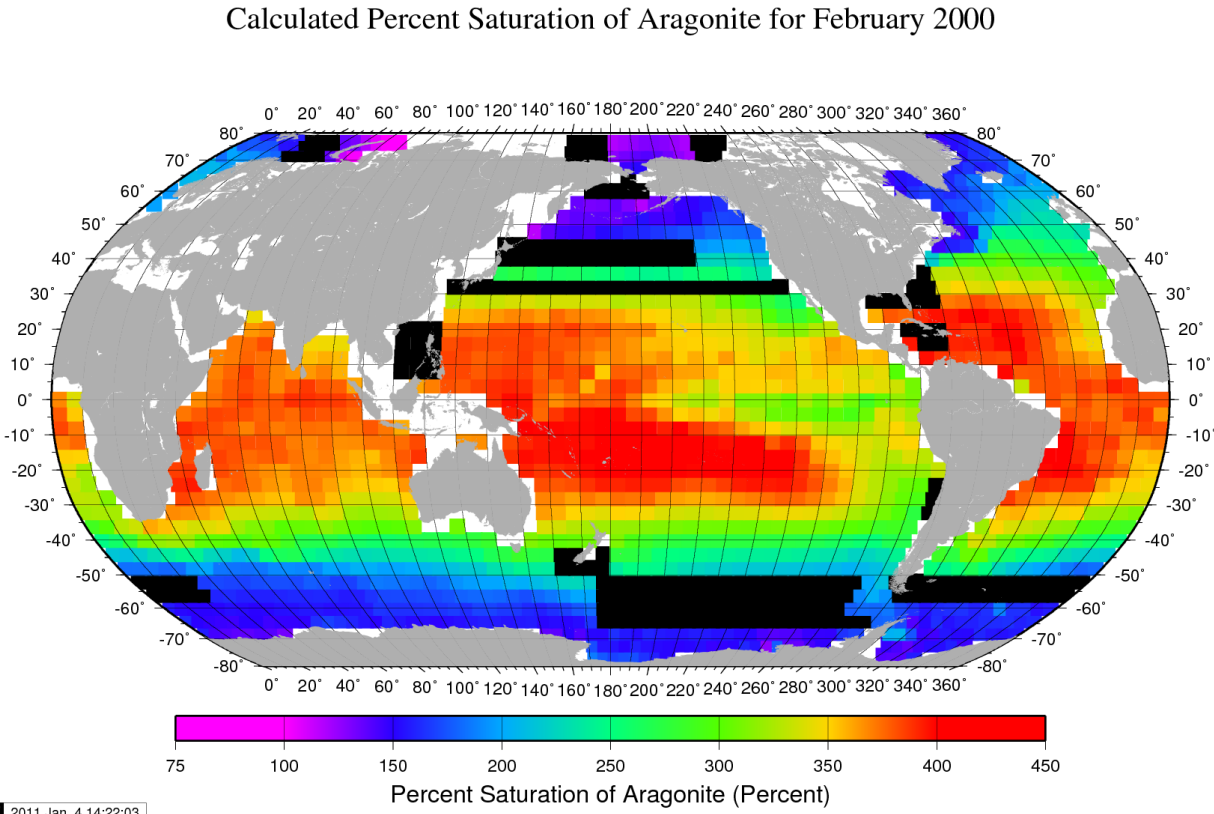
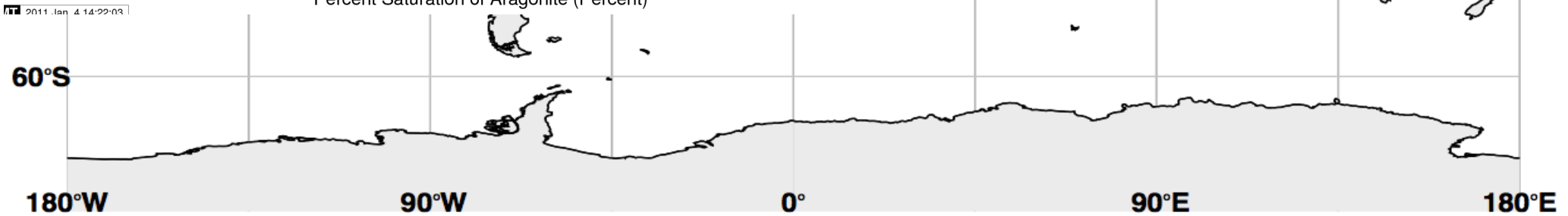
20°E
60°E
100°E
140°E
180°E

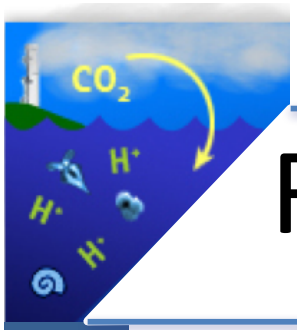


Observations: Global

Climatological Mean Distribution of pH in Surface Waters in the Unified pH Scale and Mean Rate of changes in Selected Areas



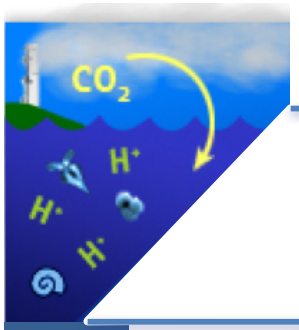




Field time-series observations

OBSERVATIONS & MONITORING

- Kimberly Yates
- Julie Reichert
- Wei Jun Cai
- Jason Grear
- Dan McCorkle
- Paul McElhany
- Jeremy Mathis
- Chris Langdon
- Lisa Levin/ Christina Tanner
- Tim Wootton
- John Joseph
- Rusty Brainard
- Denise Breitburg
- Kris Holderied
- Lisa Robbins
- Christopher Sabine
- Adrienne Sutton
- Sergio Signorini
- Rik Wanninkhof
- Andreas Andersson
- Dick Feely
- Francis Chan
- Gareth Lawson
- Derek Manzello
- Gretchen Hofmann
- Francisco Chavez



Moorings or "on station"

OBSERVATIONS & MONITORING

- Kimberly Yates
- Julie Reichert
- Wei Jun Cai
- Jason Grear
- Dan McCorkle
- Paul McElhany
- Jeremy Mathis
- Chris Langdon
- Lisa Levin/ Christina Tanner
- Tim Wootton
- John Joseph
- Rusty Brainard
- Denise Breitburg
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- Lisa Robbins
- Christopher Sabine
- Adrienne Sutton
- Sergio Signorini
- Rik Wanninkhof
- Andreas Andersson
- Dick Feely
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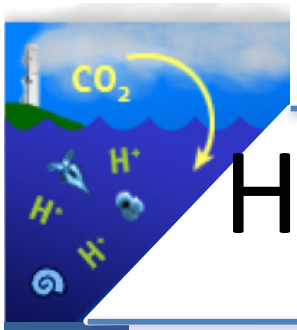
- Gareth Lawson
- Derek Manzello
- Gretchen Hofmann
- Francisco Chavez



Hypoxia or low O2 observations

OBSERVATIONS & MONITORING

- Kimberly Yates
- Julie Reichert
- Wei Jun Cai
- Jason Grear
- Dan McCorkle
- Paul McElhany
- Jeremy Mathis
- Chris Langdon
- Lisa Levin/ Christina Tanner
- Tim Wootton
- John Joseph
- Rusty Brainard
- Denise Breitburg
- Kris Holderied
- Lisa Robbins
- Christopher Sabine
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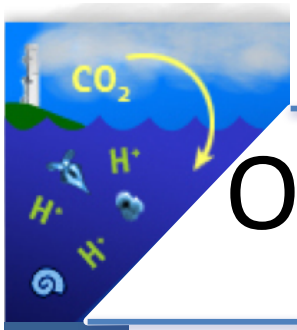
- Sergio Signorini
- Rik Wanninkhof
- Andreas Andersson
- Dick Feely
- Francis Chan
- Gareth Lawson
- Derek Manzello
- Gretchen Hofmann
- Francisco Chavez



Observations used for specific species

OBSERVATIONS & MONITORING

- Kimberly Yates
- Julie Reichert
- Wei Jun Cai
- Jason Grear
- Dan McCorkle
- Paul McElhany
- Jeremy Mathis
- Chris Langdon
- Lisa Levin/ Christina Tanner
- Tim Wootton
- John Joseph
- Rusty Brainard
- Denise Breitburg
- Kris Holderied
- Lisa Robbins
- Christopher Sabine
- Adrienne Sutton
- Sergio Signorini
- Rik Wanninkhof
- Andreas Andersson
- Dick Feely
- Francis Chan
- Gareth Lawson
- Derek Manzello
- Gretchen Hofmann
- Francisco Chavez

Observations & Monitoring
Panel Discussion

Goal: where can collaborations can be made? Where are gaps in research? What are the real frontiers?

- Are there presently any actual or seeming overlaps among research projects?
- Are there major research gaps?
- Are there developing technologies that may help?
- What level of monitoring is reasonable given our need for data vs. practical constraints?
- What types of sensors are needed?
- Are there old technologies that can be adapted?

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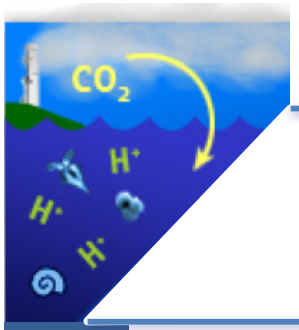
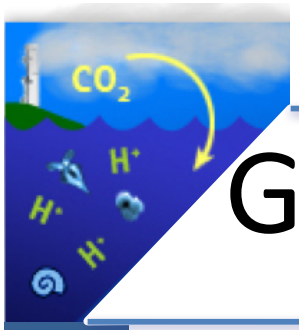


Organisms & Ecosystems

OBSERVATIONS & MONITORING

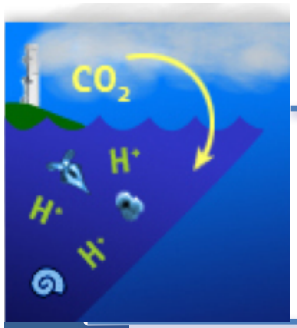
- Lisa Levin/ Christina Tanner
- Tim Wootton
- John Joseph
- Rusty Brainard
- Denise Breitburg
- Francis Chan
- Gareth Lawson
- Derek Manzello
- Gretchen Hofmann
- Francisco Chavez



Geographic areas & Time Series

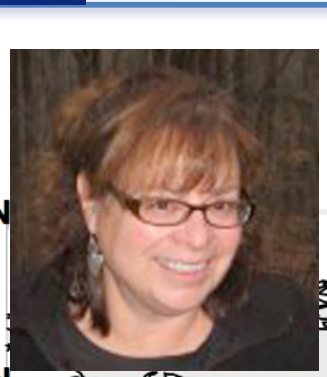
OBSERVATIONS & MONITORING

- Kimberly Yates
- Julie Reichert
- Wei Jun Cai
- Jason Grear
- Dan McCorkle
- Paul McElhany
- Jeremy Mathis
- Chris Langdon
- Matthew Poach
- Aleck Wang
- Kris Holderied
- Lisa Robbins
- Christopher Sabine
- Adrienne Sutton
- Sergio Signorini
- Rik Wanninkhof
- Andreas Andersson
- Dick Feely
- Taro Takahashi



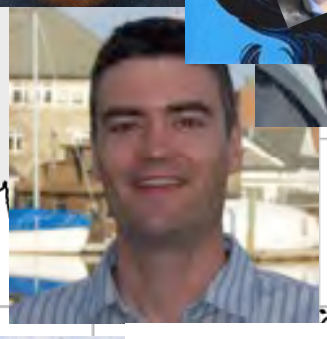
To inform models & experiments

OBSERVATIONS & MONITORING



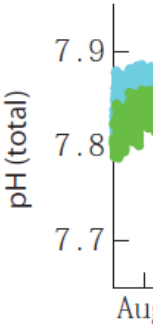


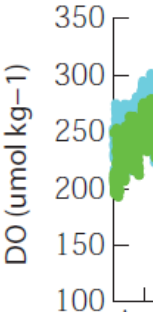


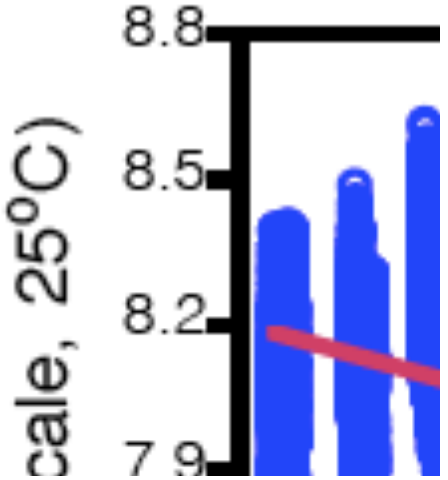


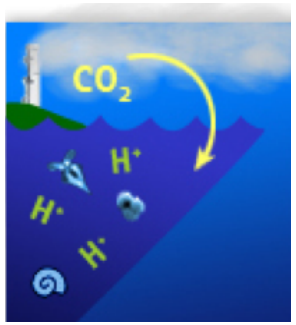


90°N
60°N
60°S
180°W
90°W
0°
90°E

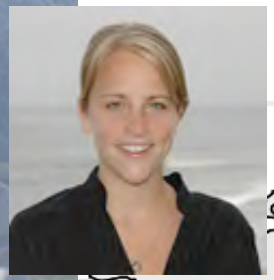


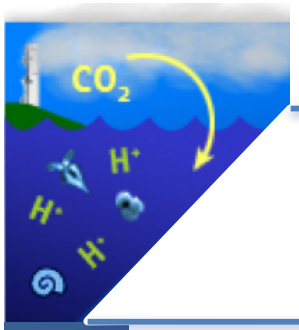






OA Observations: Organisms





OBSERVATIONS & MONITORING