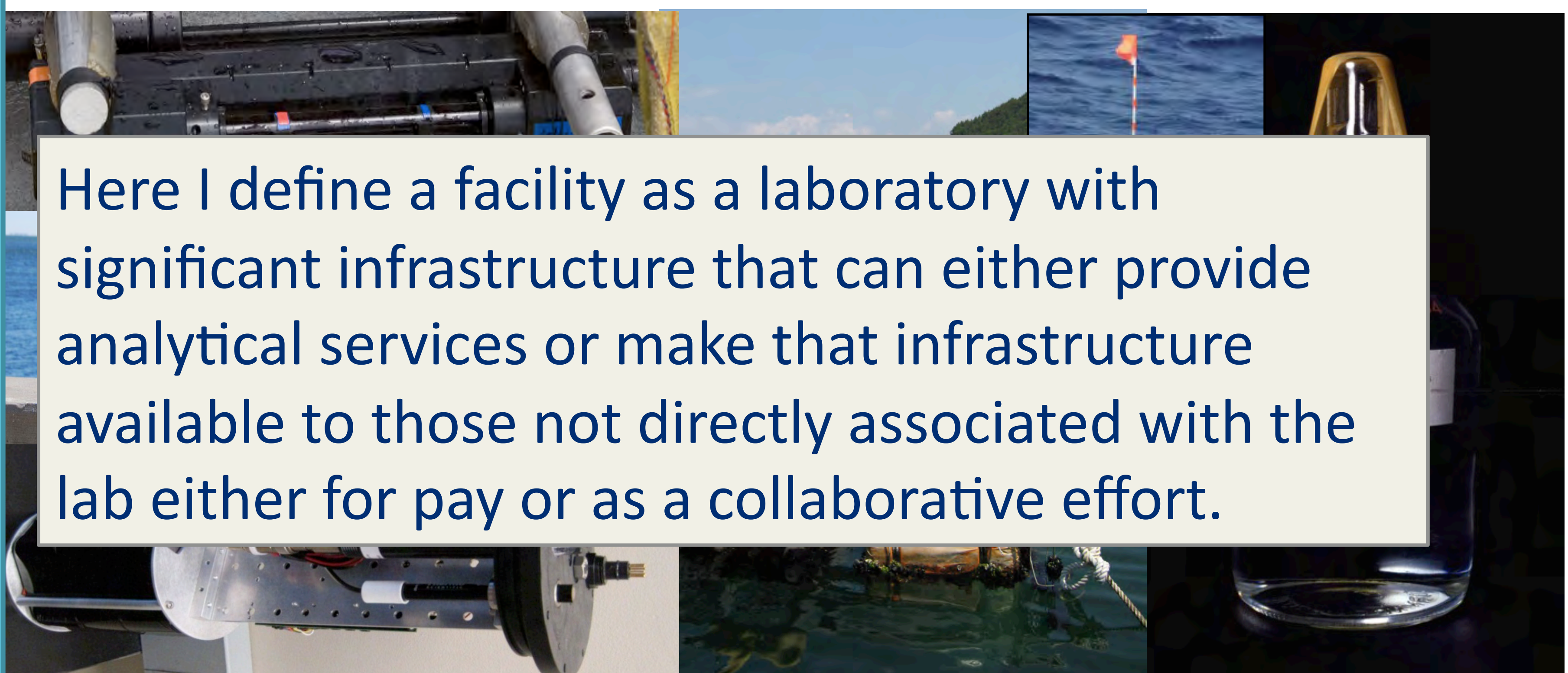
Summary of Facilities and Sensors

FACILITIES & SENSORS

18 Sensor/Platform Projects Submitted

We also received information on ~14 Facilities



Here I define a facility as a laboratory with significant infrastructure that can either provide analytical services or make that infrastructure available to those not directly associated with the lab either for pay or as a collaborative effort.

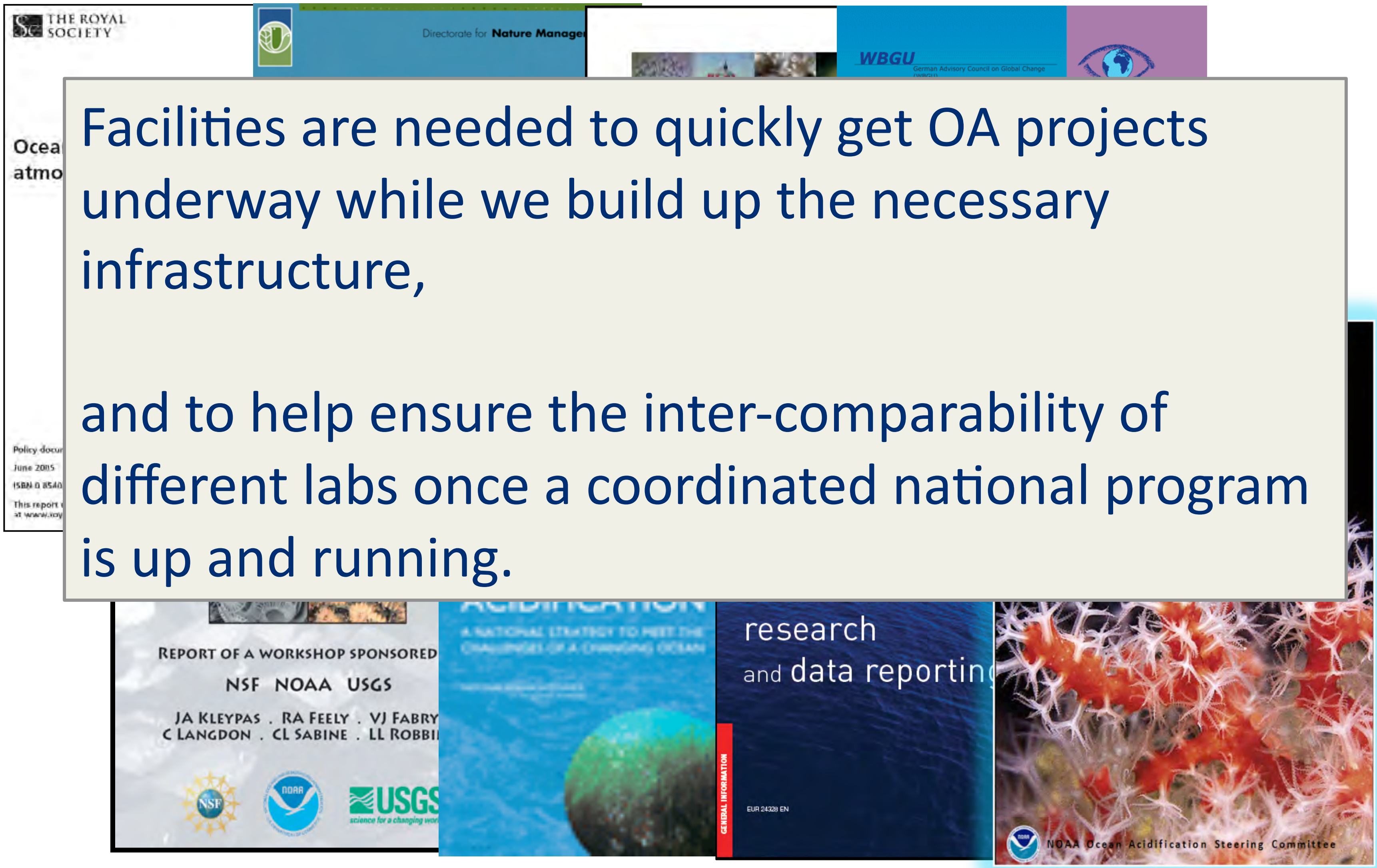
Summary of Facilities and Sensors

Caveat Emptor: I have done my best to summarize the project slides that have been submitted, but I apologize now if I have neglected or misrepresented anyone's project.

I recommend that if anyone would like additional information about a particular project or if you have concerns about anything that I have presented, please approach the relevant PI for that project.

Summary of Facilities and Sensors

FACILITIES & SENSORS



Facilities are needed to quickly get OA projects underway while we build up the necessary infrastructure,

and to help ensure the inter-comparability of different labs once a coordinated national program is up and running.

Autonomous pCO_2 Sensors

SENSORS

Mostly being developed in the commercial sector now

Currently available: Battelle, CARIOCA, Contros, Pro-Oceanus, SAMI 2-pCO_2, General Oceanics, Kimoto CO_2, SubCtech…

New development: Aandera, Piccaro, YSI

Marlin Atkinson (UH) is representing the ACT effort

ALLIANCE FOR COASTAL TECHNOLOGIES

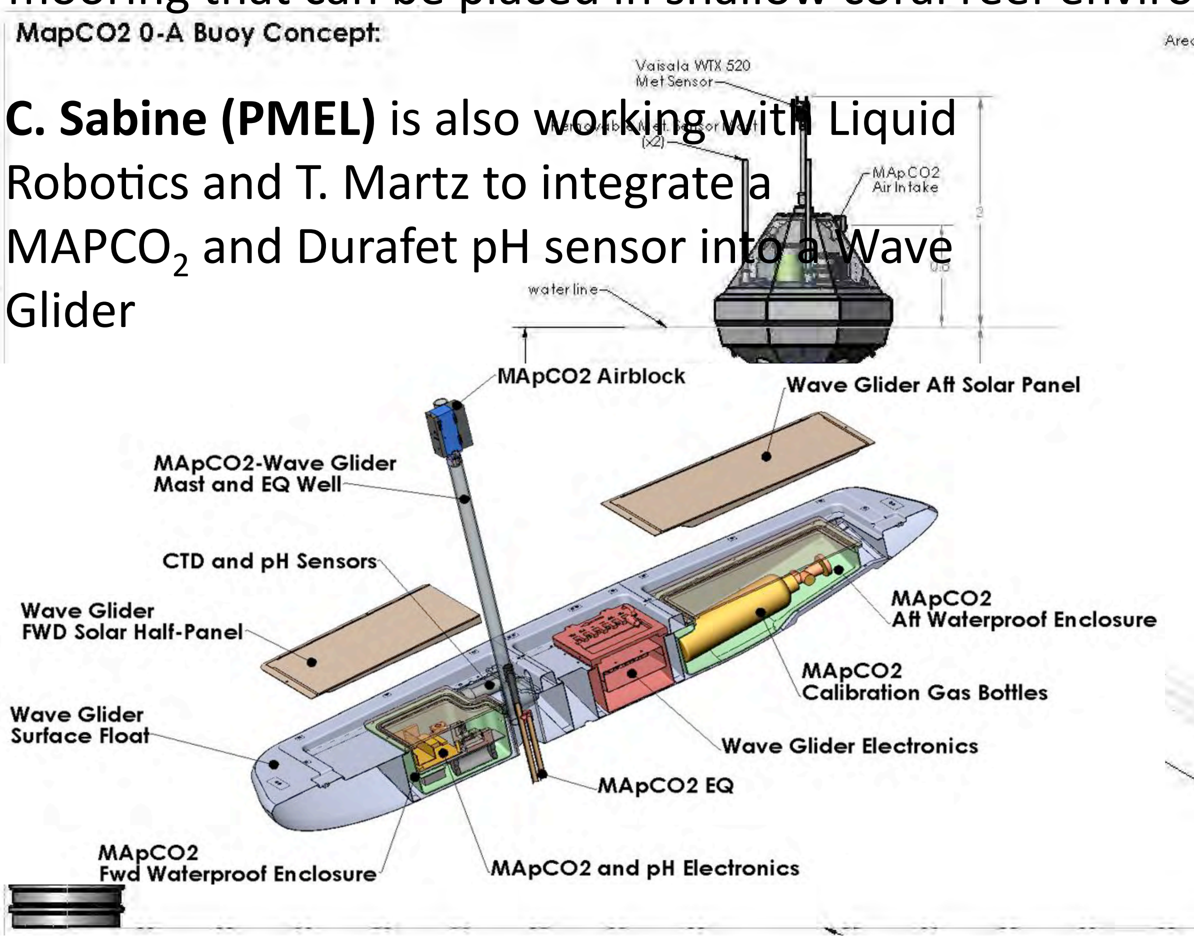
Enable existing and new technologies to be identified and made available for coastal science, management, and IOOS.

- **Types of Evaluations:**
  - **Performance Verification**
  - **Performance Demonstration**
- **Purpose:**
  - **Document performance under third party tests**
  - **NO certifications, recommendations, or comparisons**

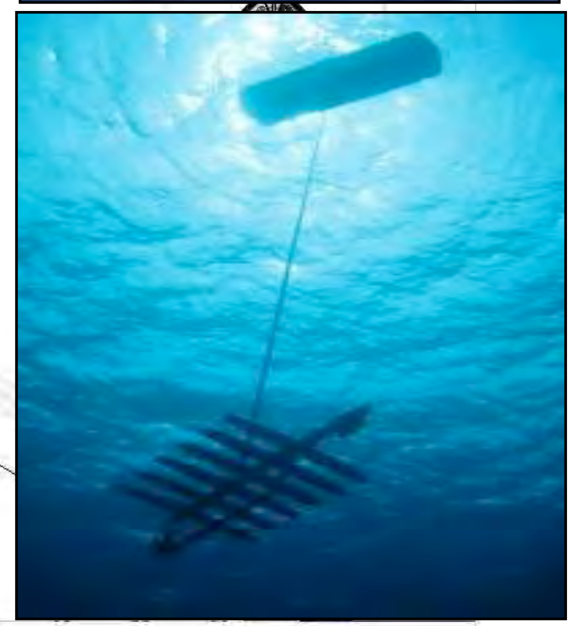
Autonomous pCO_2 Sensor Platforms

SENSORS

C. Sabine (PMEL) has been working with several collabo
over the past few years to develop a robust biogeochem
mooring that can be placed in shallow coral reef enviro



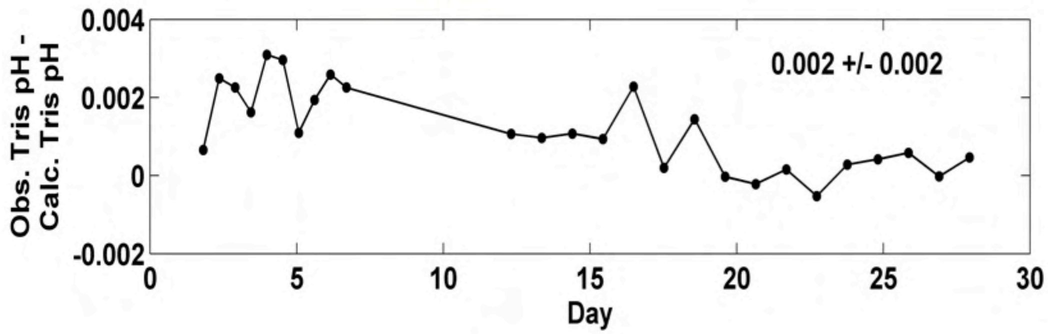
C. Sabine (PMEL) is also working with Liquid Robotics and T. Martz to integrate a $MAPCO_2$ and Durafet pH sensor into a Wave Glider

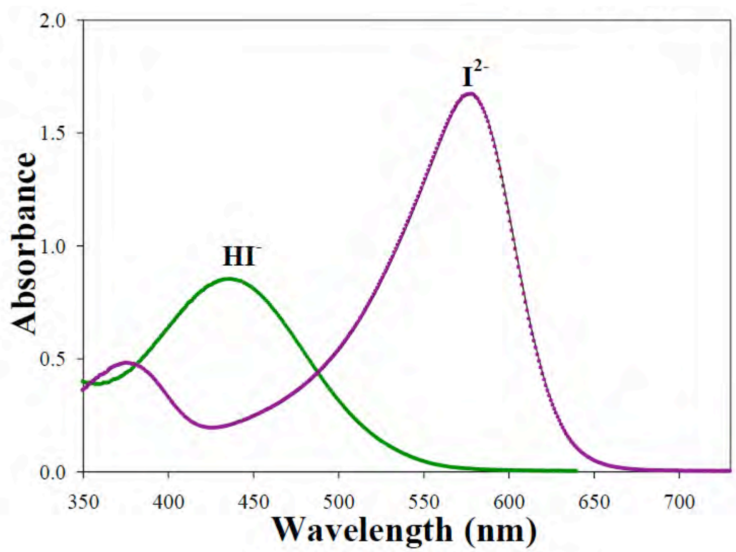


Autonomous pH Sensors

SENSORS

M. DeGrandpre (U. Montana) is working to add a Tris buffer to the SAMI-pH sensor





R. Byrne (USF) is working to better characterize the meta Cresol Purple absorbance ratios and equilibrium behavior in seawater.

R. Byrne is also developing techniques to purify the meta Cresol Purple for improved spectrophotometric pH measurements

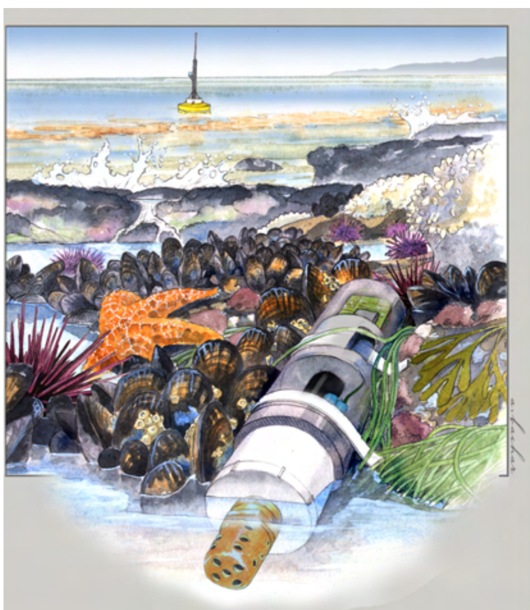
Autonomous pH Sensors

SENSORS

T. Martz (SIO) has a project to evaluate the Honeywell DuraFET® for use in autonomous systems operating in the upper 100m of the ocean.

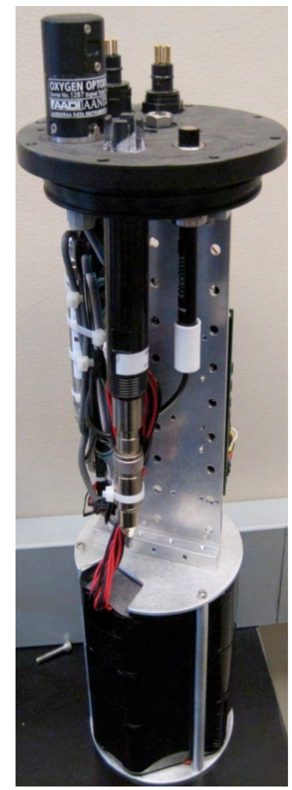
F. Chavez (MBARI) and colleagues are testing the DuraFET® sensor for intertidal applications

K. Johnson (MBARI) and others are working to adapt the DuraFET® for deep water applications; hope to use on profiling float



G. Hofmann (UCSB) testing the DuraFET® in cold estuary waters of McMurdo Sound

There are several other projects that are testing the DuraFET® sensor…



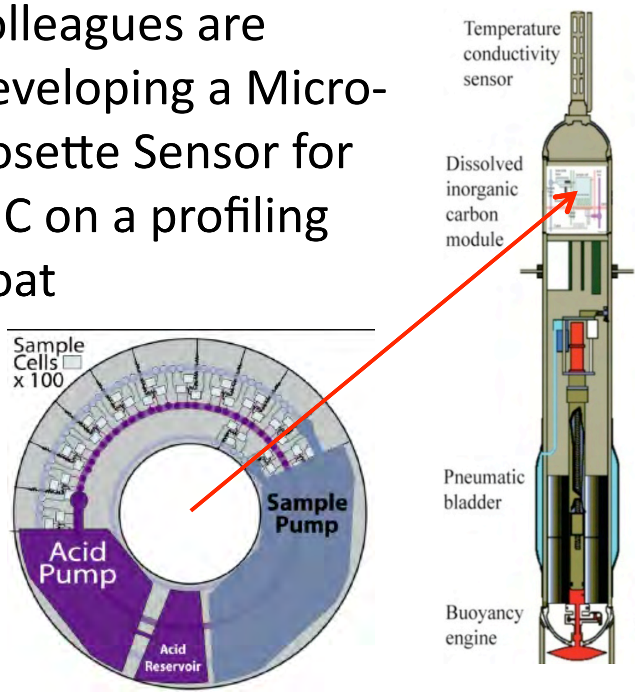
Autonomous DIC Sensors

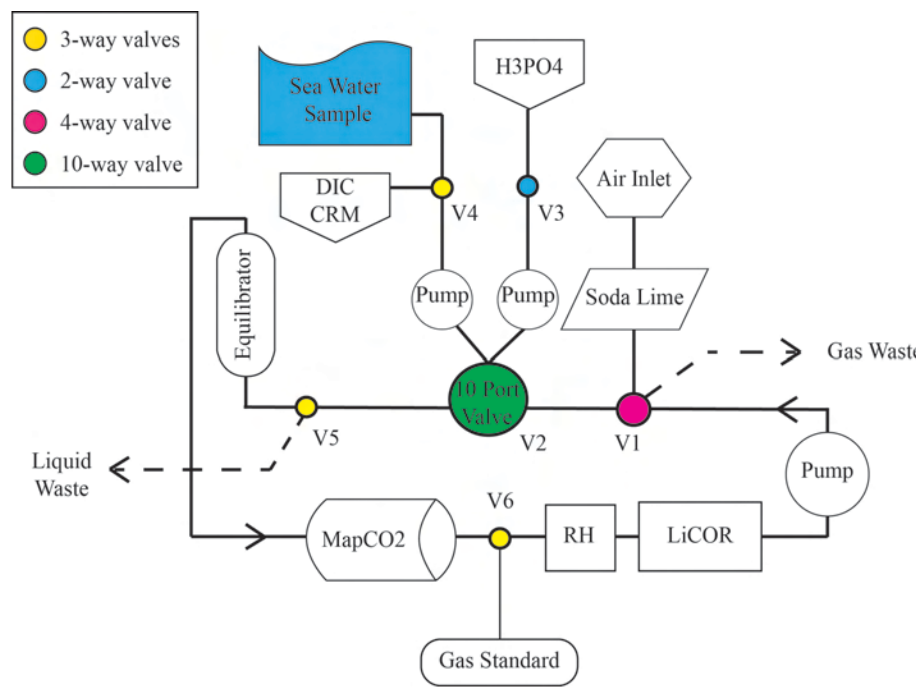
SENSORS

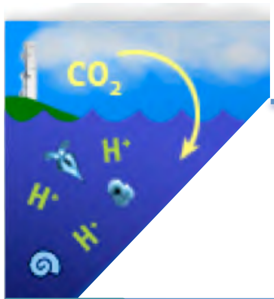
L. Adornato (SRI International) is developing an in situ DIC system based on Byrne's Spectrophotometric Elemental Analysis System (SEAS).

C. Sabine (PMEL) and colleagues are developing a moored DIC sensor based on MAPCO_2

T. Martz (SIO) and colleagues are developing a Micro-Rosette Sensor for DIC on a profiling float



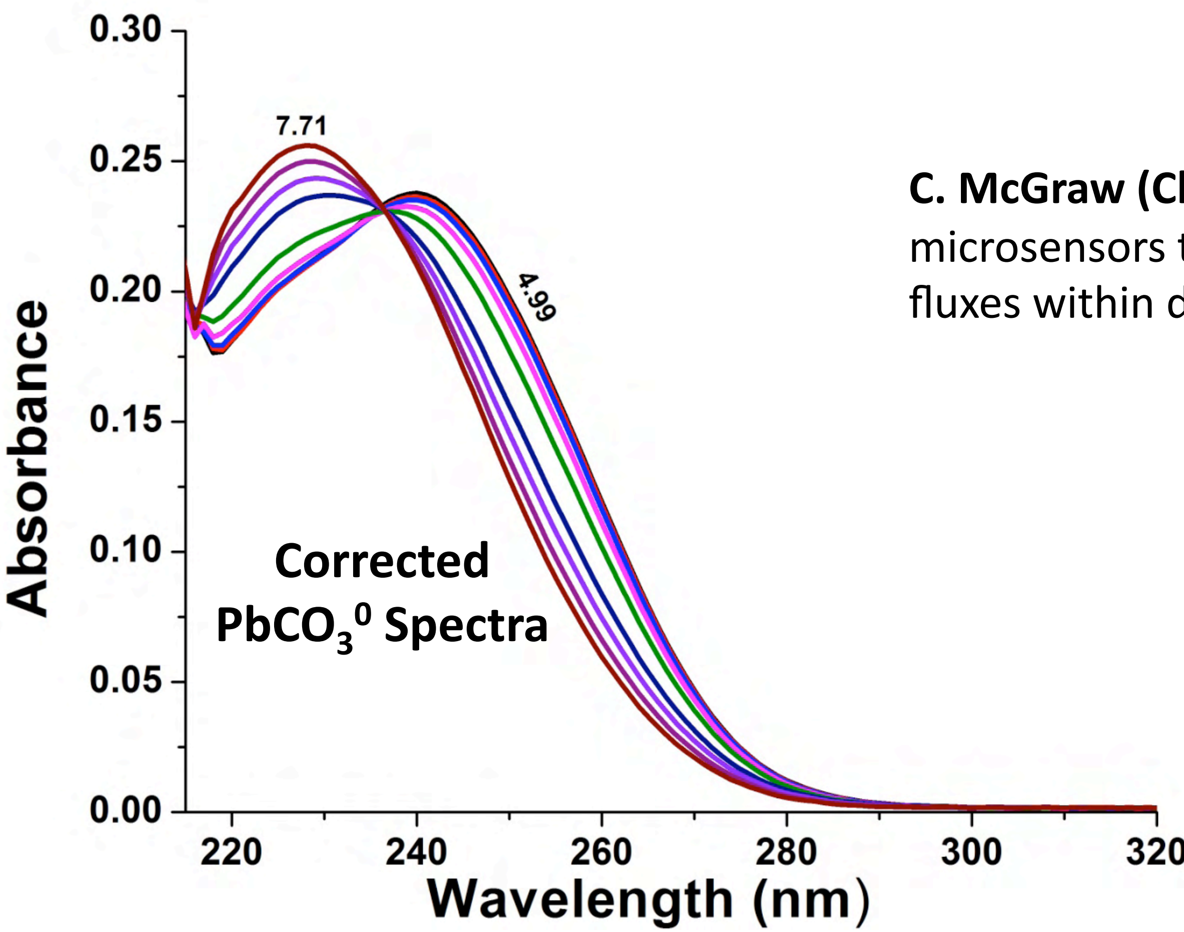




Carbonate Ion Sensors

SENSORS

R. Byrne (USF) is developing an in situ carbonate ion system using spectrophotometric techniques



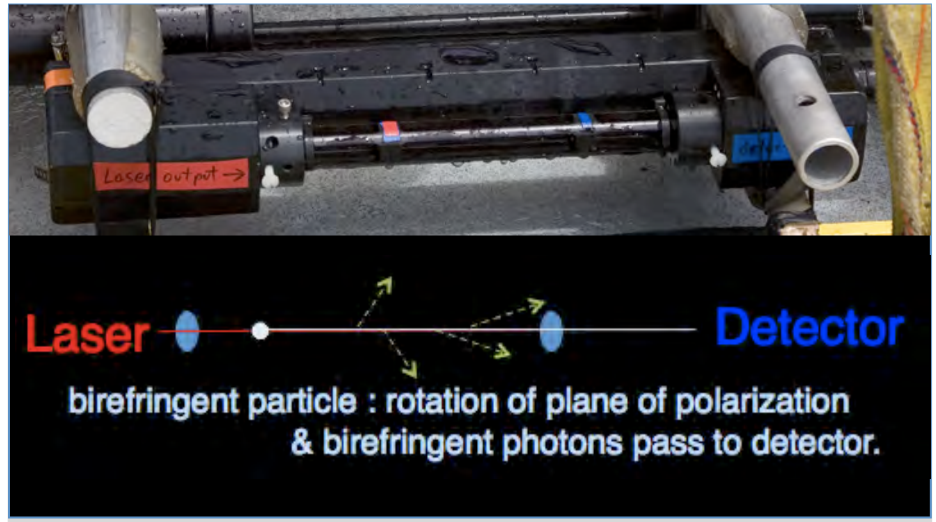
C. McGraw (Clark U.) is developing microsensors to measure carbonate ion fluxes within diffusion boundary layers.

Other Autonomous Sensors

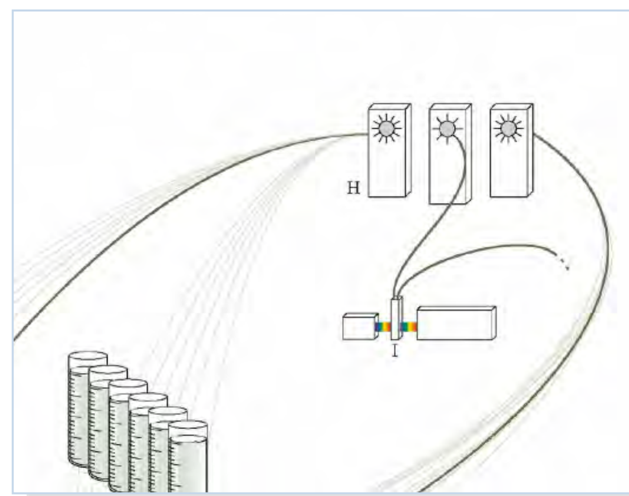
Autonomous OA culture systems with spectrophotometric pH measurement

SENSORS

J. Bishop (UC-Berkley) is developing an autonomous particulate inorganic carbon (PIC) sensor and a sedimentation sensor for a profiling float



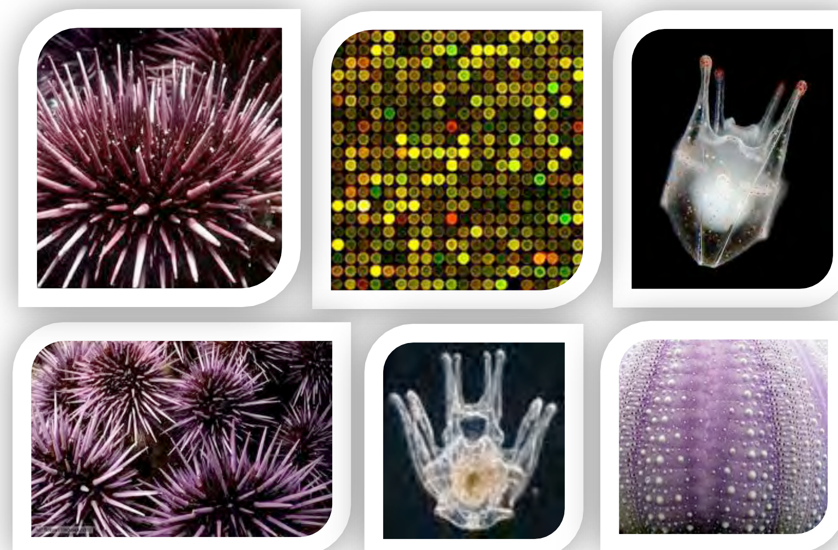
C. McGraw (Clark U.) has developed autonomous ocean acidification culture systems with spectrophotometric pH measurements



SENSORS

Genetic Assays

G. Hofmann (UCSB) is using a suite of experimental tools that span levels of biological organization



transcriptomics

F. Chan (OSU) and colleagues are sequencing data to link microbial process with N-transformations along wide gradients pH and oxygen gradients

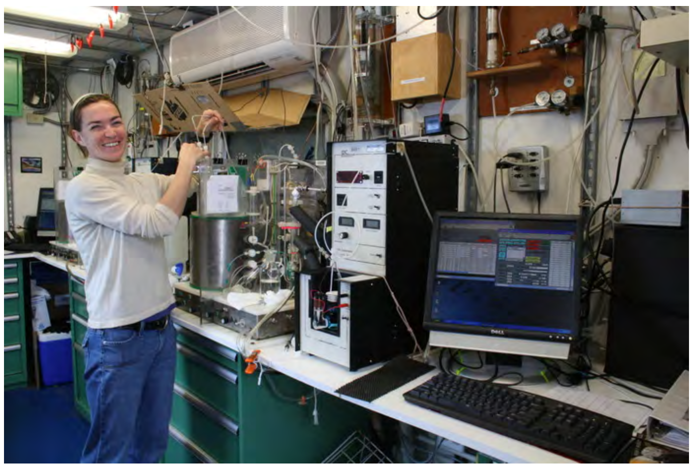
MI_LOCO

Microbial Initiative in Low Oxygen areas off Concepción and Oregon

FACILTIES

Inorganic Carbon Analyses

A. Dickson (UCSD) leads a facility to prepare, certify, and distribute certified reference materials



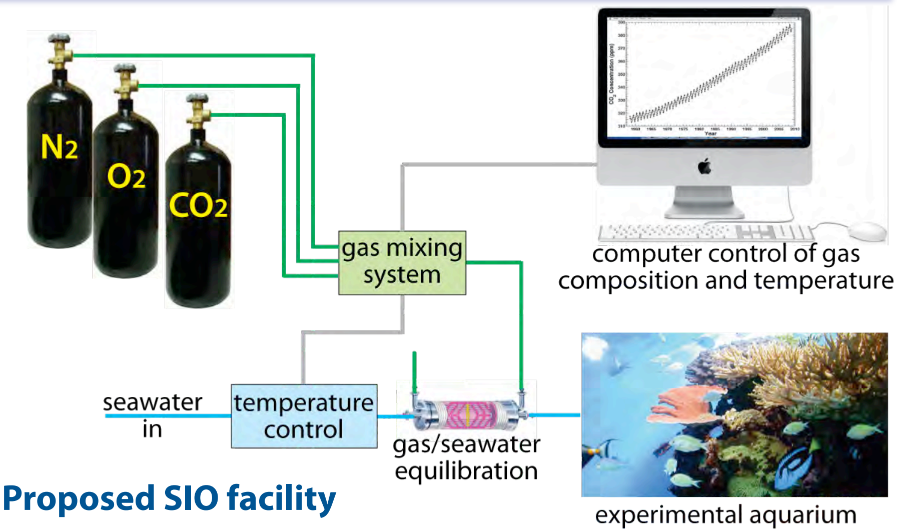
R. Feely (PMEL) and **R. Wanninkhof (AOML)** offer analytical services for analysis of discrete inorganic carbon samples

M. Poach (NEFSC), P. McElhany (NWFSC) and **M. Sigler (ASFSC)** are all developing ocean acidification facilities that include both inorganic carbon analytical capabilities as well as CO_2 and T controlled culturing systems

FACILTIES

CO_2 Experimental Tank Facilities

A. Dickson (UCSD) developing a facility for growing organisms under controlled CO_2, T and O_2 studies at Scripps



Proposed SIO facility

J. Murray (UW) The Friday Harbor Lab facility for experimental studies of small-scale single organism studies as well as multi-species food-web interactions. Both T and CO_2 levels can be manipulated. The facility includes a complete carbonate system analytical lab

CO_2 Experimental Tank Facilities

FACILTIES

G. Hofmann (UCSB) Portable CO_2 system for the culturing of marine invertebrate larvae using 'best practices' in larval culturing while also controlling CO_2 levels in a flow-through system.

There are several other labs with facilities that may be available under the right circumstances (e.g. **M. Atkinson (UH), C. Langdon (UM)**)

FACILTIES

Educational/Collaboration Facilities

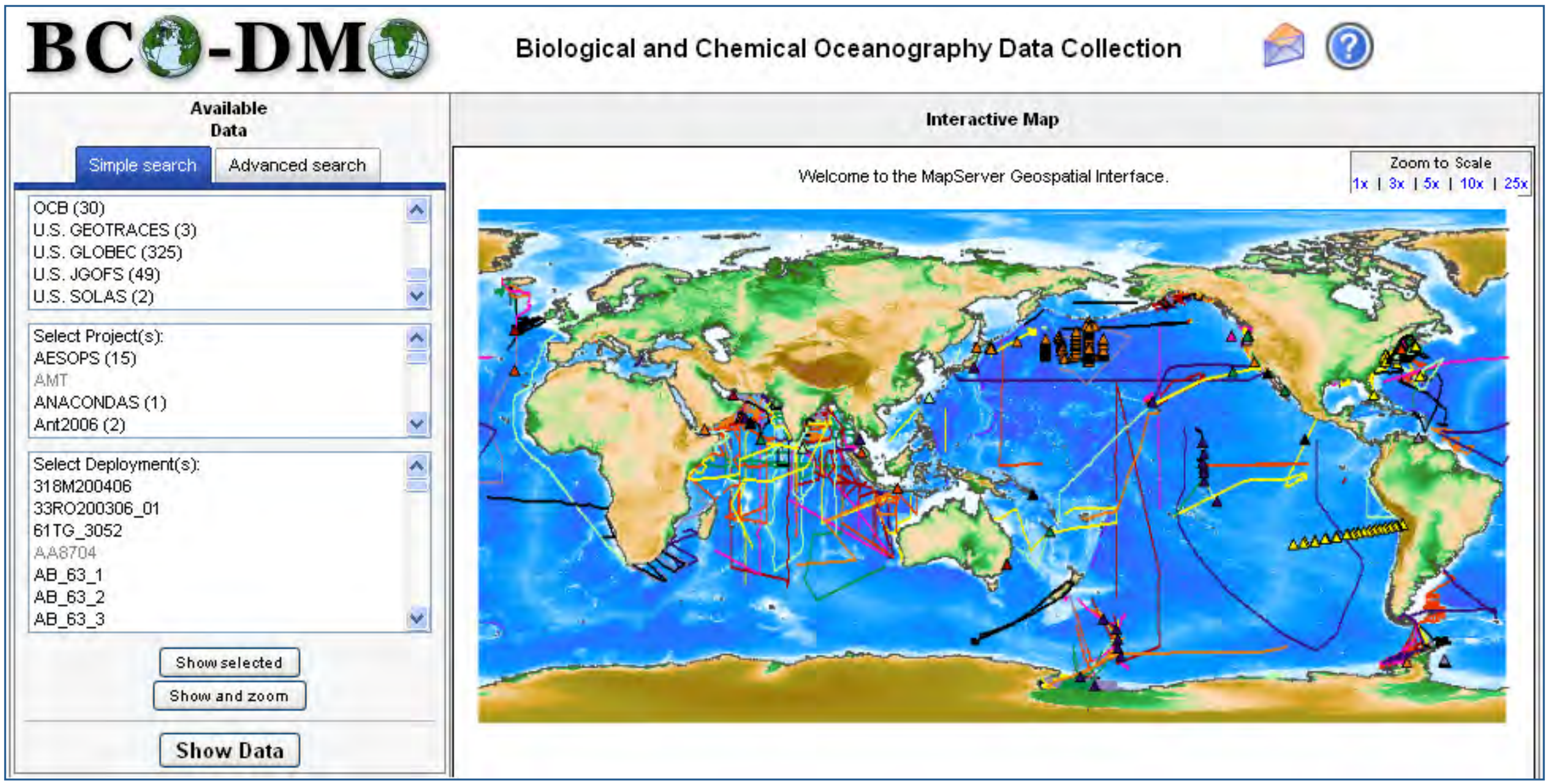
M. O'Donnell (UW) graduate training course at FHL to teach students technical skills, analytical chemistry, and experimental design for biological and ecological research

T. Klinger (UW) established regional research collaborations to address ocean acidification and associated stressors. Collaborations are inclusive of the entire west coast, and extend to federal & state agencies, industry, and NGOs

FACILTIES

Data Management Facility

C. Chandler (WHOI) represents the Biological and Chemical Oceanography Data Management Office



Providing data management support for NSF OCE Biology and Chemistry, and OPP ANT O&E funded researchers. http://bco-dmo.org

FACILTIES

Backup Slides

Andrew Dickson

UC San Diego

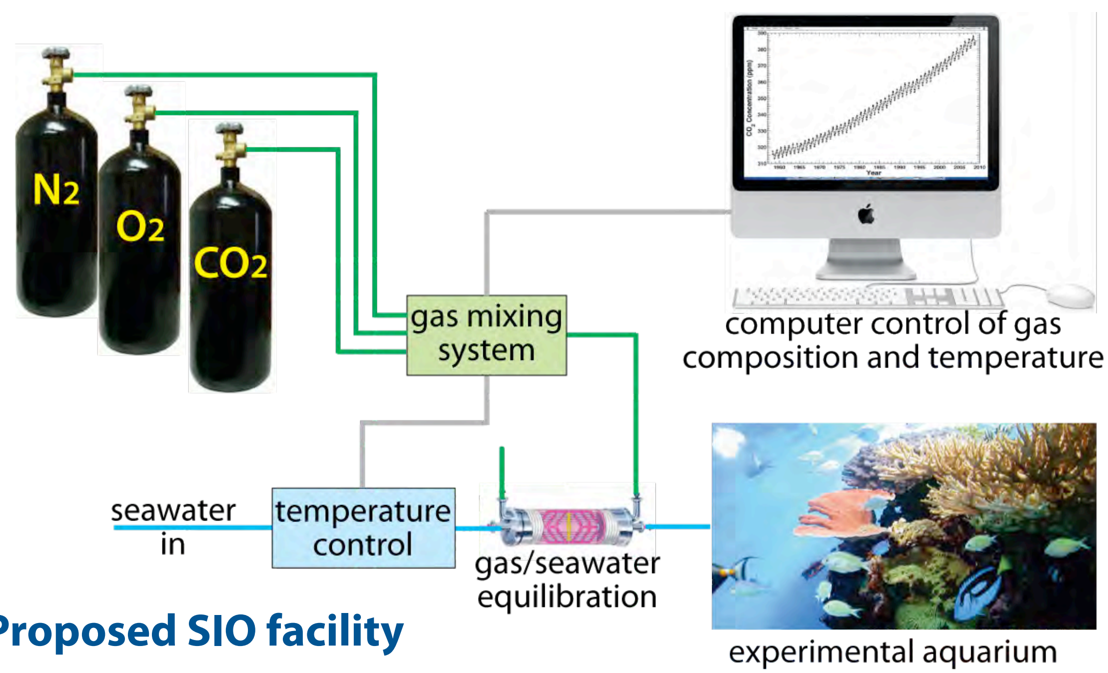
January 2011

FACILTIES

MRI: Development of instrumentation to control seawater composition for ocean acidification research.

Goal: Provide a high degree of control over *T*, $p(CO_2)$, and $p(O_2)$ in seawater that is being used to grow organisms for ocean acidification experiments

- ✓ Design and test system for control of gas composition
- ✓ Test use of membrane equilbrator for control of seawater composition
- Build and test single tank prototype system
- Scale up to full system



Proposed SIO facility

Andrew Dickson

UC San Diego

April 2010

The quality control of oceanic CO_2 measurements: Preparation, certification, and distribution of reference materials.

FACILTIES

Seawater based reference materials certified for total alkalinity, total dissolved carbon dioxide; pH reference materials based on Tris buffers in synthetic seawater

- ✓ Distribute ~8,000 bottles of seawater RM per year
- ✓ Prepare prototype batches of Tris buffer
- • Start preparing Tris buffers for regular distribution
- • Assess overall uncertainty of certified values assigned to reference materials

James W. Murray

University of Washington

March 2008

Ken Sebens, Bob Morris, Robin Kodner, Evelyn Lessard
Terrie Klinger, Michael O'Donnell, Emily Carrington

FHL Ocean Acidification Experimental Facility

FACILTIES

A new experimental facility has been constructed at UW Friday Harbor Laboratories (FHL)

- This facility includes the capability for experimental studies of small-scale single organism studies as well as multi-species food-web interactions. Both temperature and CO_2 levels can be manipulated. The facility includes a complete carbonate system analytical lab.
  - Our goal is to characterize biological and ecological response to increasing acidification and temperature
  - The first mesocosm experiment is planned for June 2011 in conjunction with a FHL Summer Course on Ocean Acidification

James W. Murray

University of Washington

March 2008

Ken Sebens, Bob Morris, Robin Kodner, Evelyn Lessard
Terrie Klinger, Michael O'Donnell, Emily Carrington

FHL Ocean Acidification Experimental Facility

FACILTIES

National Science Foundation - FSML Program

Kenneth P. Sebens, Terrie Klinger, James Murray, Emily Carrington, Michael O' Donnell, Sarah Gilman

UW Seattle & UW Friday Harbor Labs

James W. Murray

University of Washington

March 2008

Ken Sebens, Bob Morris, Robin Kodner, Evelyn Lessard
Terrie Klinger, Michael O'Donnell, Emily Carrington

FHL Ocean Acidification Experimental Facility

FACILTIES

Photo we'll insert

Gretchen Hofmann

UC Santa Barbara

August 2007

Portable CO_2 System for the culturing of marine invertebrate larvae

Hi Chris,
Yes, it is available to anyone who wants to use it. The system is set up at both UCSB and then we travel with a second to McMurdo. But it might not be an actual facility in terms of what one might think of in larger terms. These activities are part of the UC OA center and is open to others, but we have no funding etc. to disburse to encourage that.

Goal: To raise larval marine invertebrates using 'best practices' in larval culturing while also controlling CO_2 levels in a flow-through system. Can be used at home or away!

Funded by a supplement to NSF grant OCE-0425107 to GEH

FACILTIES

- ✓ System has been used in the Antarctic (Crary labs-McMurdo Station) and in Moorea
- ✓ On-site seawater chemistry facilitates monitoring of experimental conditions
- ✓ Methods paper published

Fangue, N.A., M.J. O'Donnell, M.A. Sewell, P.G. Matson, A.C. MacPherson and G.E. Hofmann (2010) A laboratory-based experimental system for the study of ocean acidification effects on marine invertebrate larvae. *Limnol. Oceanogr.: Methods* 8: 441-452

Culture system set up in Crary Labs aquarium room, McMurdo Station, Antarctica. Prof. Mary Sewell (L) & Dr. Pauline Yu (R)

Cyndy Chandler

WHOI

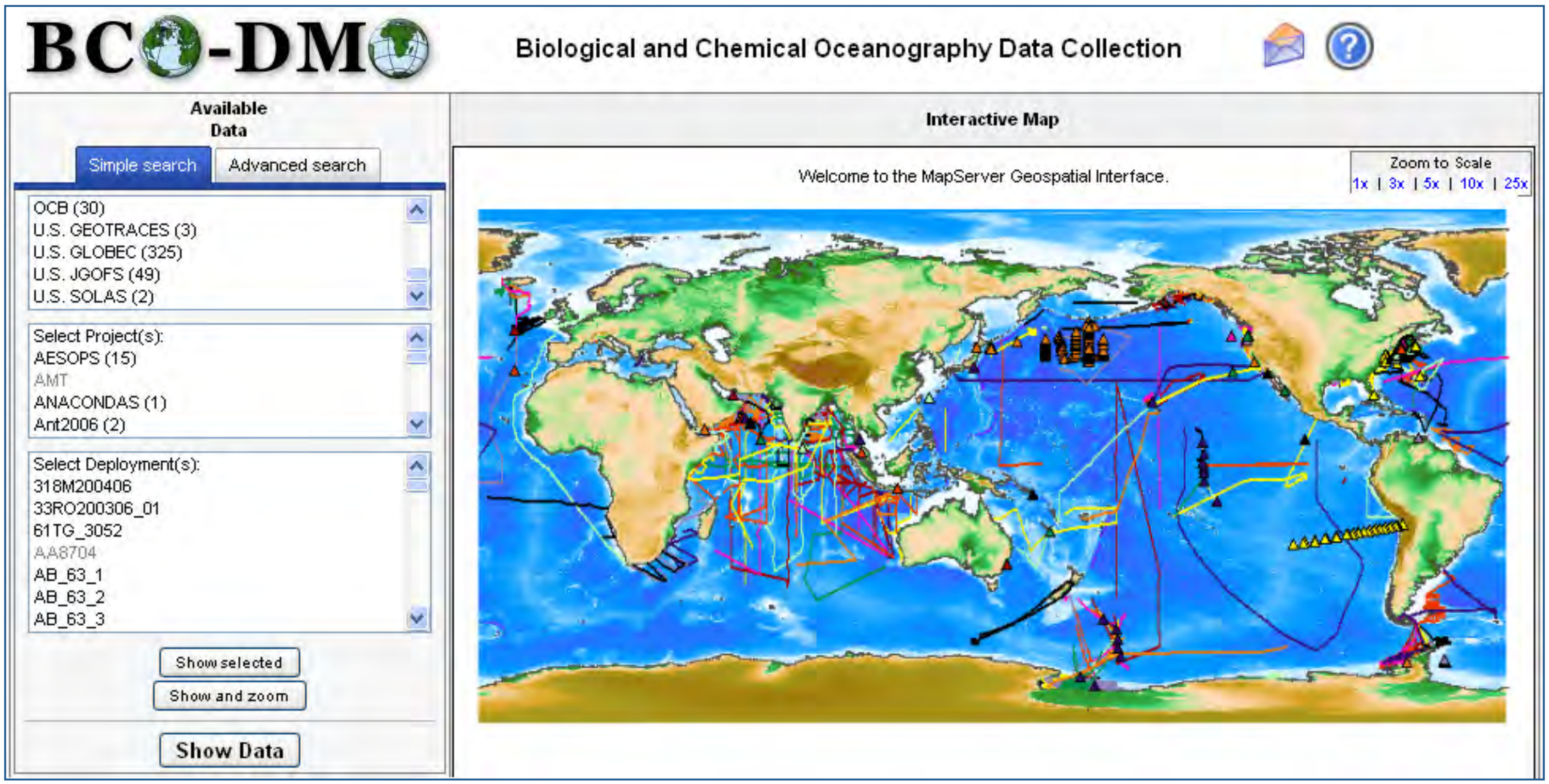
P. Wiebe, D. Glover, R. Groman

October 2006

FACILTIES

Biological and Chemical Oceanography Data Management Office

http://bco-dmo.org



Providing data management support for NSF OCE Biology and Chemistry, and OPP ANT O&E funded researchers.

Terrie Klinger

University of Washington

Regional Research Collaborations

We have established regional research collaborations to address ocean acidification and associated stressors. Collaborations are inclusive of the entire west coast, and extend to federal & state agencies, industry, and NGOs.

Key themes:

- Impacts on commercial fisheries, shellfish aquaculture, and key habitat-forming species
- Ocean observation via NANOOS and others
- Integrative graduate education
  - IGERT proposal pending
- Capacity for human adaptation

Moose O'Donnell
Terrie Klinger

University of Washington
Friday Harbor Laboratories

Summer 2011

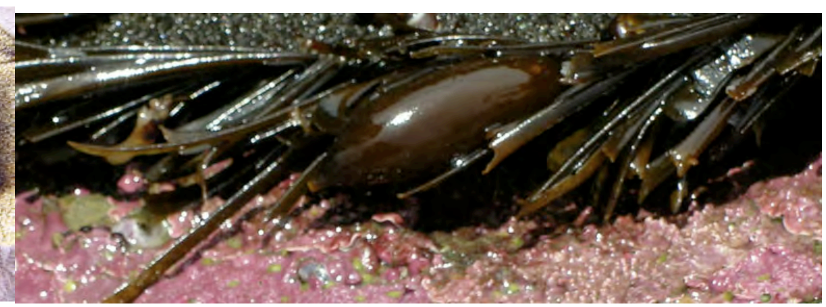
FACILTIES

Graduate course: Conducting acidification research

We will offer a *graduate training course* in performing manipulative experiments at FHL in summer 2011

- 5-week Intensive Residential Training
  - To teach students technical skills, analytical chemistry, and experimental design for biological and ecological research
  - Laboratory and in-water mesocosm facilities for student use, plus opportunities for field work
  - Opportunity to evaluate different experimental approaches
  - Number and diversity of applications indicate need





FACILTIES

Marlin Atkinson, Chris Langdon and others willing to share their culture facilities as part of a collaborative project

Lori Adornato

SRI International

Kaltenbacher, Byrne

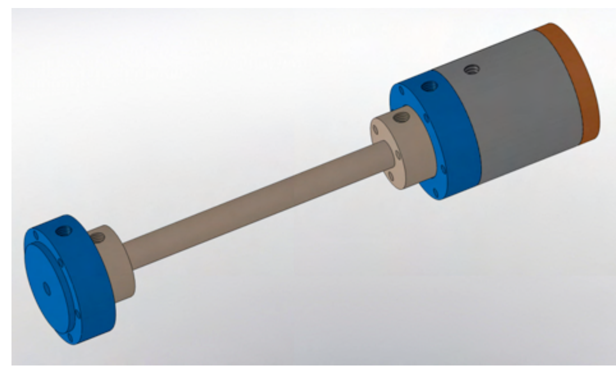
September 2010

Collaborative Research: Development of an in situ sensor for high-resolution measurements of total dissolved inorganic carbon

SENSORS

Develop and test a total carbon (C_T) measurement capability on the in situ Spectrophotometric Elemental Analysis System (SEAS) platform.

- ✓ Design and fabricate optical cell
- ➢ Conduct lab tests
- • Characterize C_T measurement temperature dependence
- • Field test
- • Collect concurrent pH and C_T field data
- • Publish results



James K B Bishop

Univ. Cal., Berkeley

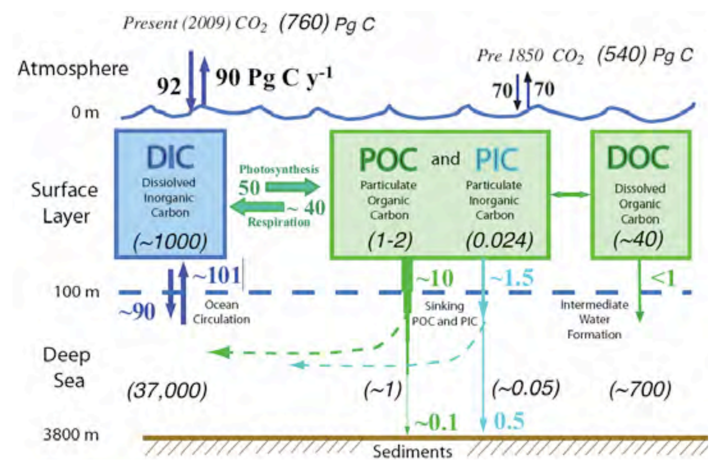
WETLabs, Inc.; Scripps Inst Dev Group

OCE 09654888 July, 2010

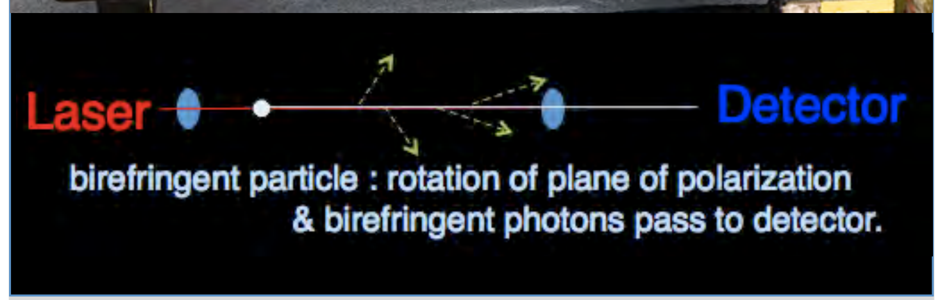
Autonomous Particulate Inorganic Carbon (PIC) Sensor

SENSORS

PIC concentration sensor
for CTDs / ARGO floats. $CaCO_3$ dynamics.



- ✓ Next Gen. Design: optics & electronics.
- ○ Thermal/Pressure Testing (in progress)
- Ship CTD deployment calibration (May, July, Aug 2011)
- Carbon Explorer Float deployment (2012) subarctic N Pacific.



James K B Bishop

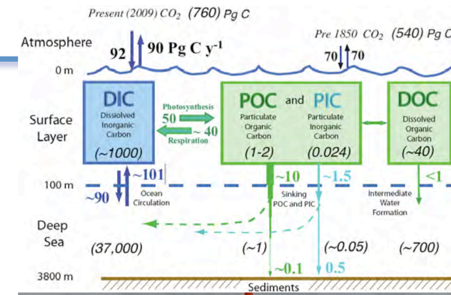
Univ. Cal., Berkeley

LBNL and Scripps Inst. Dev. Group

OCE 0936143, October, 2009

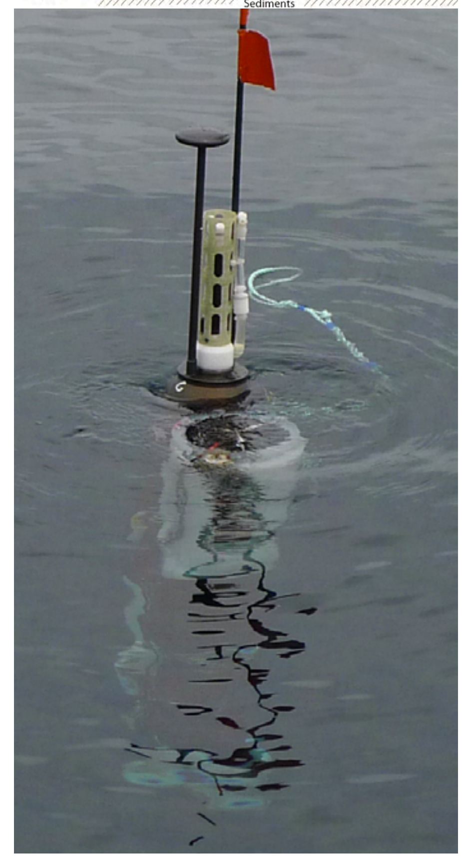
SENSORS

Carbon FLUX Explorer Development



sedimentation sensor on profiling float.

- *3 Imaging modes.*
  - Part. Org. C/ Inorg. C Flux.
- *twilight zone deployment (100-1500 m)*
- *Real Time 24/7/365 observations.*



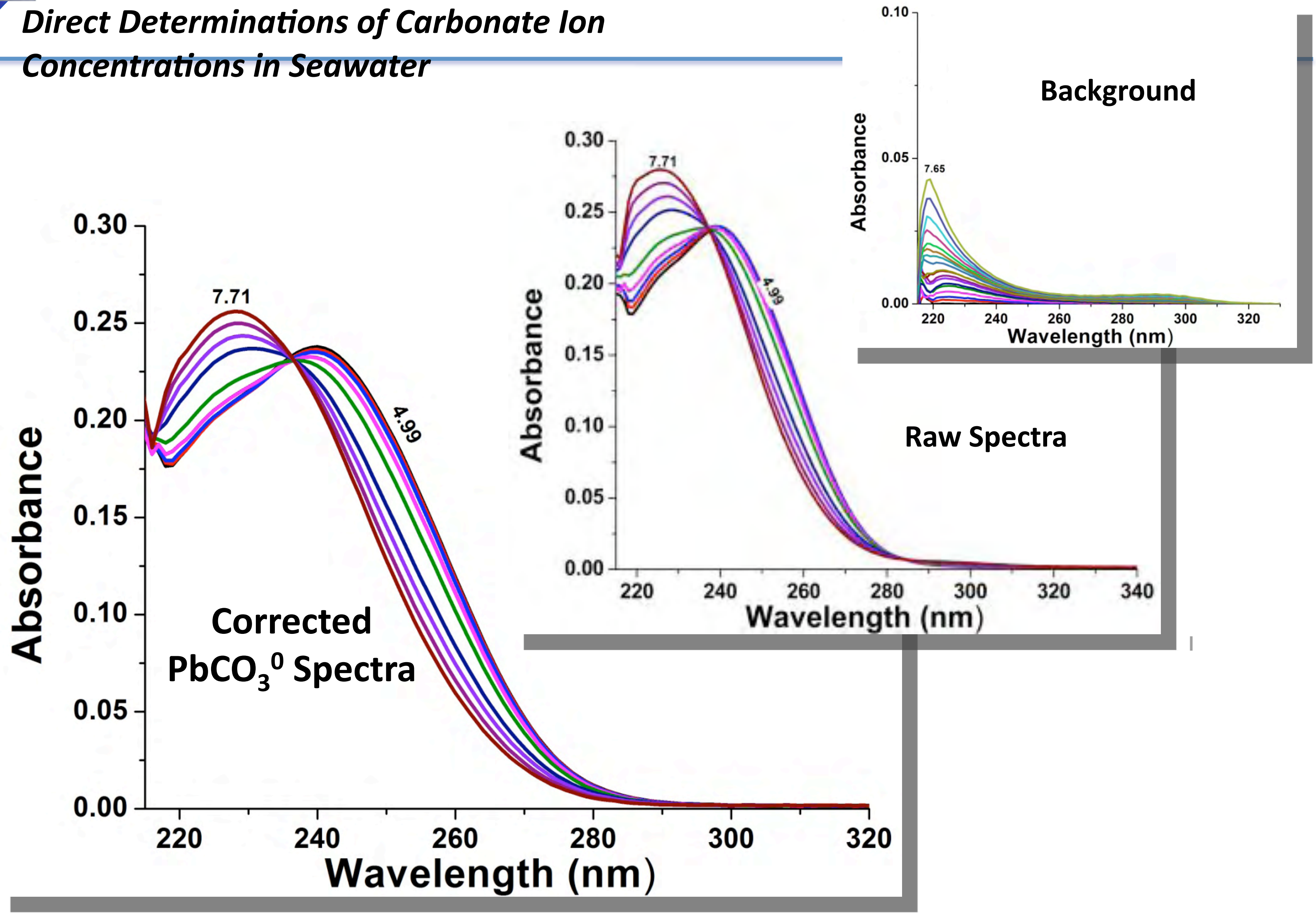
- ✓ Next Gen. Design: Imager/Systems
- ✓ Bench/Lab Testing; Ballasting
- ✓ Field test (October 2011)
- ○ Finalize Design (in progress)
- Field Testing 3 CFE's (May, July - Aug 2011)
- Operational Deployment (2012)

Robert H. Byrne

University of South Florida
March, 2011

SENSORS

Direct Determinations of Carbonate Ion Concentrations in Seawater

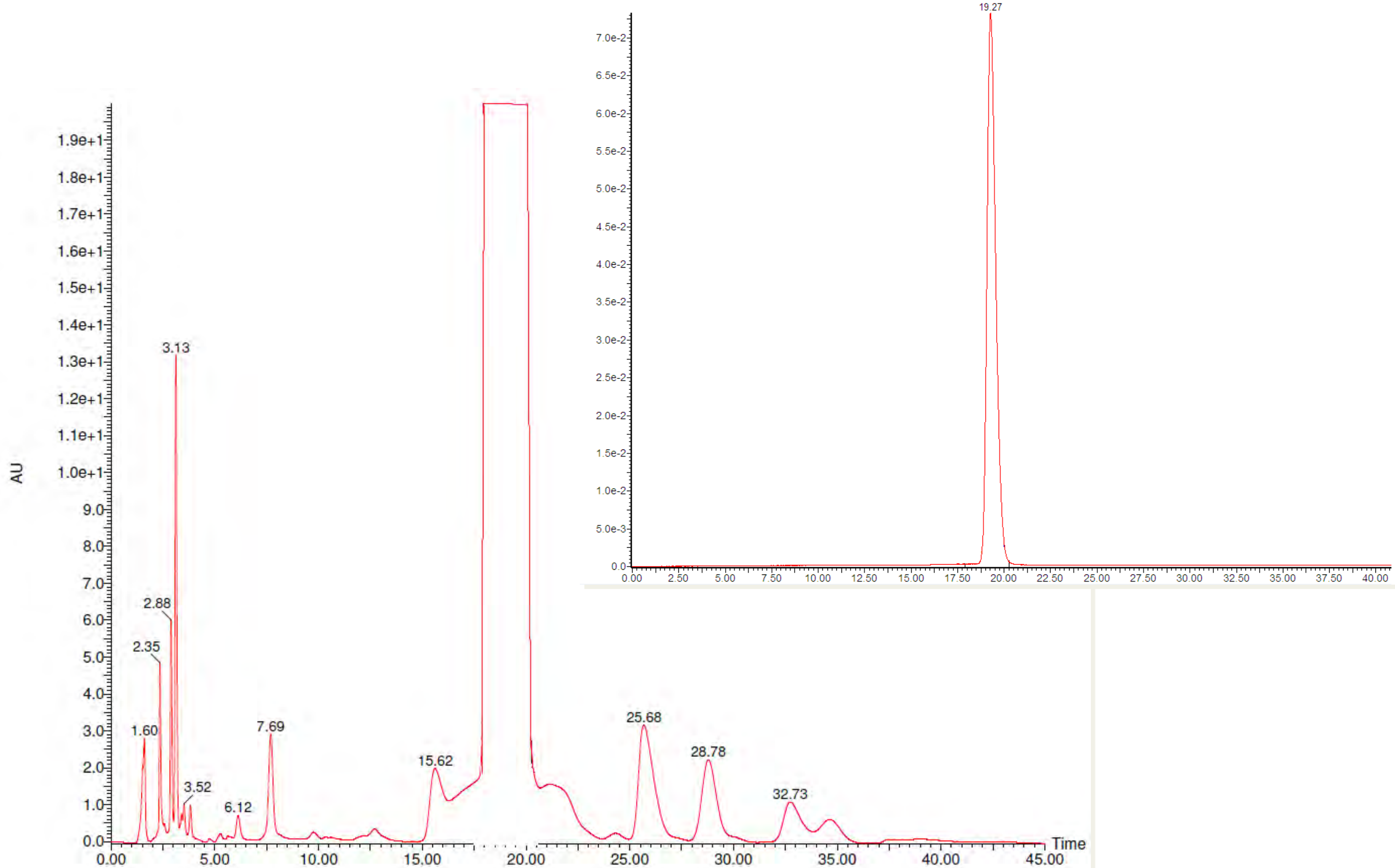


Robert H. Byrne

University of South Florida
March, 2011

Purification of meta Cresol Purple for Measurements of Solution pH

SENSORS



Chromatographs of raw and purified m-cresol purple

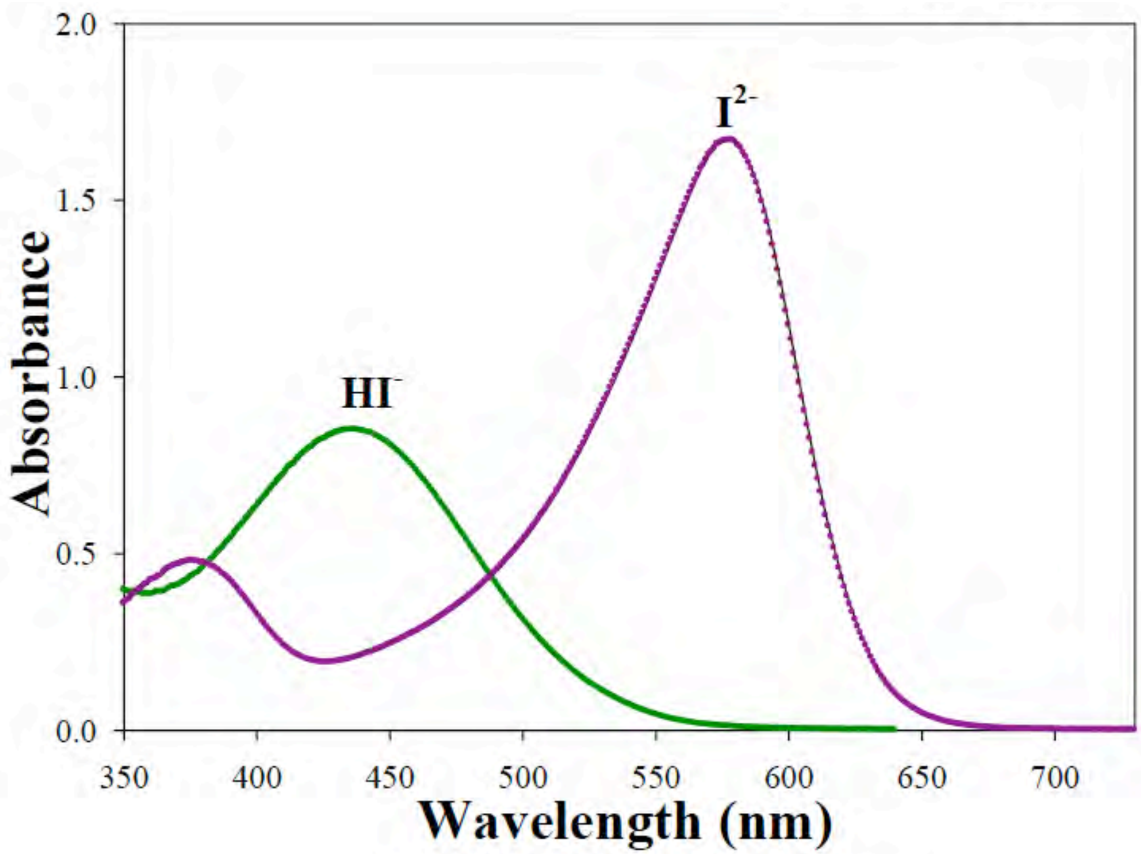
Robert H. Byrne

University of South Florida
March, 2011

Characterization of mCP Absorbance Ratios and Equilibrium Behavior in Seawater

SENSORS

$$pH = -\log(K_2^T \cdot e_2) + \log\left(\frac{R - e_1}{1 - Re_3/e_2}\right)$$



Todd Martz

Scripps Institution of Oceanography

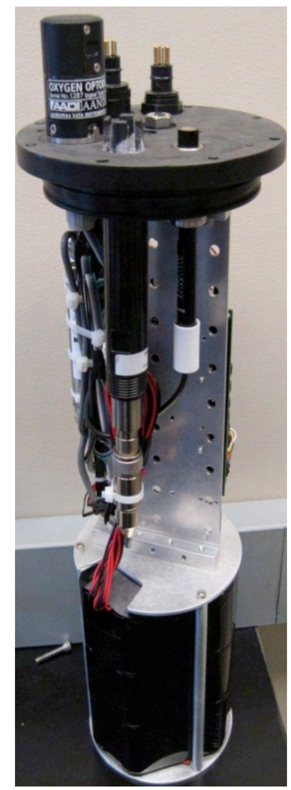
01/01/09 – 12/31/11

SENSORS

OCE-0844394 Evaluation and Adaptation of an Ion Sensitive Field Effect Transistor for Seawater pH Applications

Evaluate the Honeywell DuraFET® for use in autonomous systems operating in the upper 100m of the ocean.

- ✓ DuraFET modifications for dual reference electrodes and low-power design.
- ✓ "SeaFET" now being commercialized by Satlantic Inc.
- ✓ "SeapHOx" integrated sensor package includes a pumped manifold and additional sensors for oxygen & salinity.
- Now working to establish calibration protocols and validate sensor performance in field tests.



Chavez, Friederich, Barth, Chan, Hill, McManus, Russell, Washburn

MBARI, OSU, UCD, UCSB

Blanchette, Gaylord, Hofmann, Menge, Palumbi, Raimondi, Sanford

October, 2010

SENSORS

Collaborative Research: Acclimation and adaptation to ocean acidification of key ecosystem components in the California Current Large Marine Ecosystem

Develop, test and deploy a pH sensor for the intertidal. Provide ocean context

- ✓ Develop
- ✓ Test
- ✓ Field test
- Deploy April 1
- Moorings, ships
- Physics
- Seawater chemistry

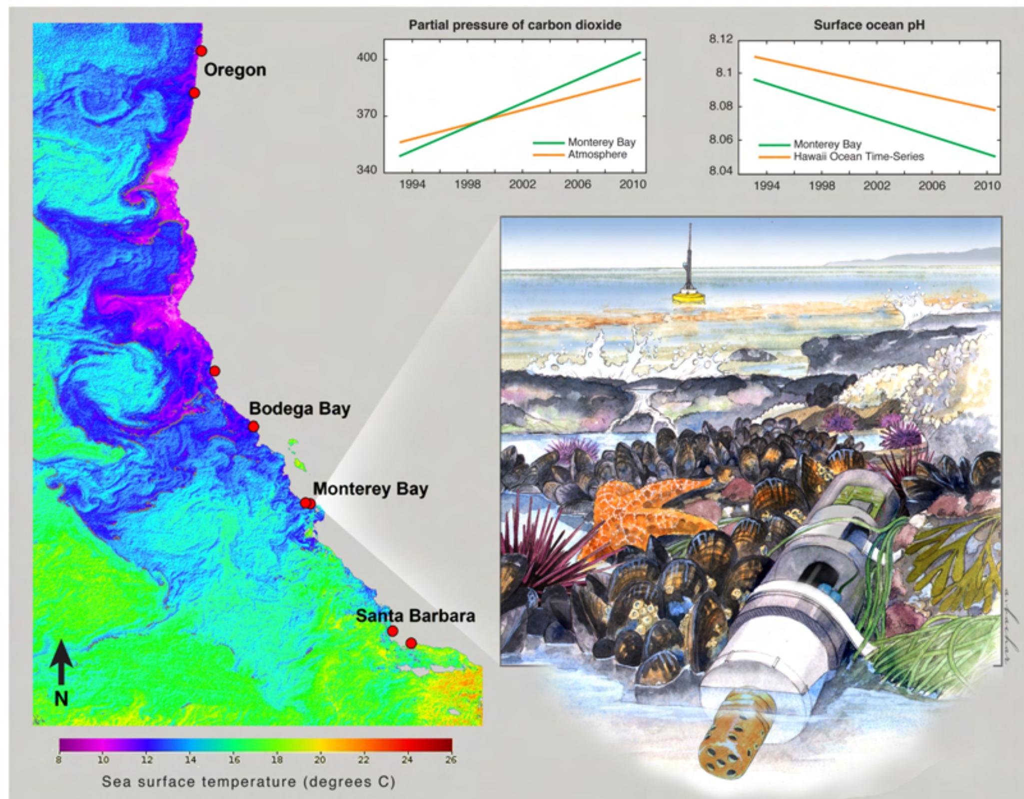


Photo we'll insert

Gretchen Hofmann

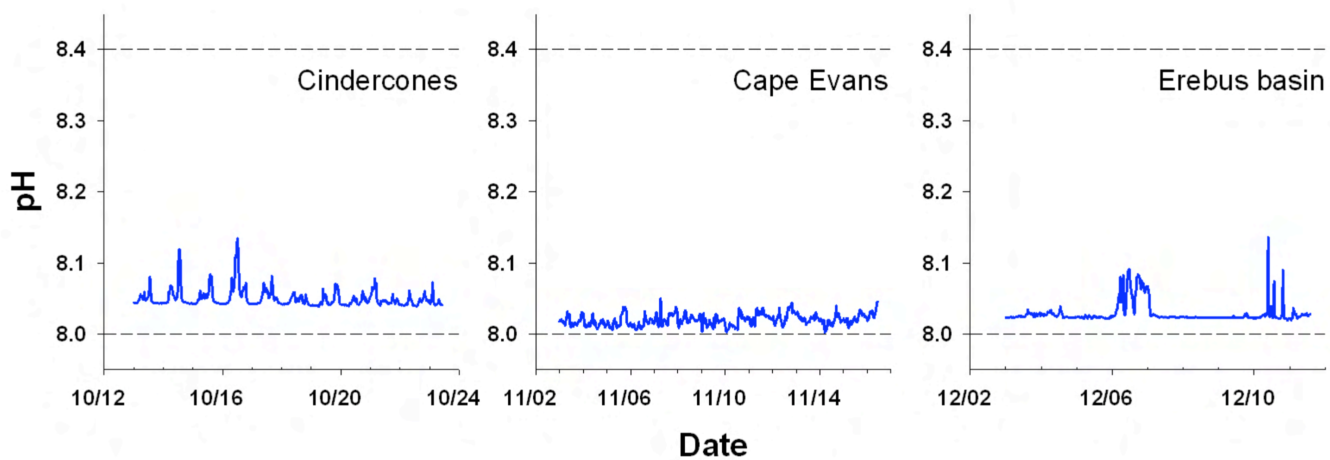
University of California, Santa Barbara

April, 2010

SENSORS

SeaFET deployment in McMurdo Sound

Using an autonomous pH sensor, we also explored the pH dynamics of the coastal waters of McMurdo Sound



<u>Time series data for SeaFET deployment at three sites in McMurdo Sound</u>

- At all sites, the sensor was deployed at ~15 m depth below the sea ice
- Two shallow sites (total depth of ~75 feet) had abundant adult urchins (Cindercones, Cape Evans) and sensor was deployed ~1m from the benthos
- Erebus Basin was a deep water site (depth is ~500m) and the sensor was suspended on the water column at 15m depth below the sea ice

Ken Johnson

MBARI

Todd Martz, Alex Gu, Stephen Riser

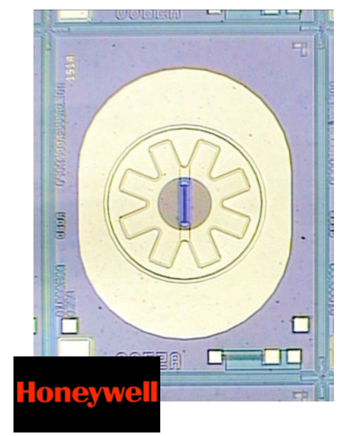
12/22/09 - 11/30/12

SENSORS

NOPP – Development of an Integrated ISFET pH Sensor for High Pressure Applications in the Deep-Sea

Modify the Honeywell DuraFET® for use on profiling floats

- ✓ Design a high-pressure test system for evaluating sensor prototypes (MBARI/SIO)
- ✓ Perform accelerated lifetime testing on prototype ISFET sensors over 0-2000 dbar (MBARI/SIO)
- Re-design the high-pressure ISFET encapsulation for high-volume production (HON).
- Establish T-P calibrations (MBARI/SIO)
- Deploy prototype Deep-Sea DuraFET on Apex floats in 2012-2013 (UW).



Michael DeGrandpre

University of Montana

Jim Beck, Andrew Dickson

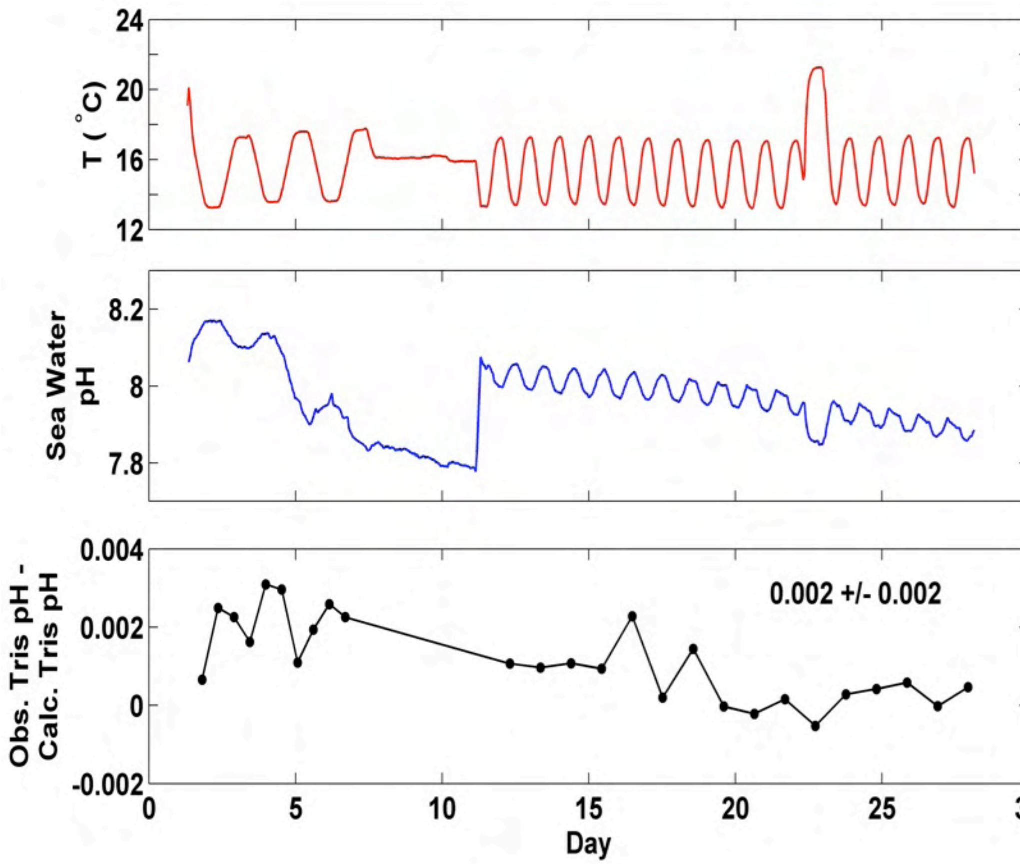
August 2008

Collaborative Research: An autonomous indicator-based pH sensor for oceanographic research and monitoring

SENSORS

Commercialize an autonomous, in situ indicator-based pH sensor for ocean measurements.

Results from the tank testing of a SAMI-pH instrument configured to occasionally measure the pH of a Tris buffer (at the instrument temperature) so as to provide quality control.



Todd Martz

Scripps Institution of Oceanography

Brian Ward, Paul Maguire, Jim MaLaughlin

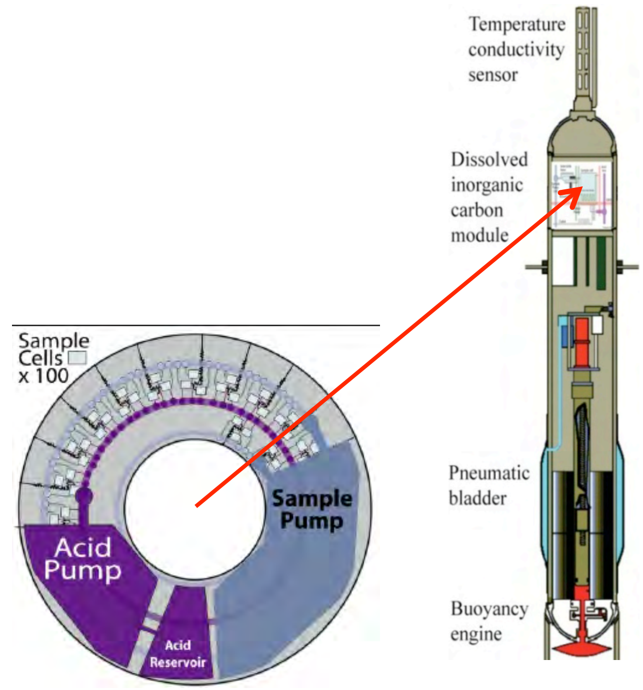
07/15/10 - 06/30/14

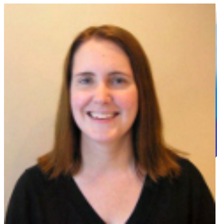
SENSORS

OCE 0961250 - Development of a Micro-Rosette Sensor for Total Dissolved Inorganic Carbon Measurement from Autonomous Lagrangian Ocean Profilers

Build the first microfluidic sampling device (“micro-rosette”) and use it to sample the ocean from profiling floats.

- Samples captured as the float ascends the water column.
- Samples analyzed at depth on an isopycnal during the float park cycle.
- Potential to analyze more properties because sensors are no-longer limited to fast-response devices that must measure on the fly as the float ascends.
- Requires multi-disciplinary work between chemical oceanographers and nanoengineers.





Christina McGraw

Clark University

K. Curie, P. Boyd, C. Hurd, K. Hunter

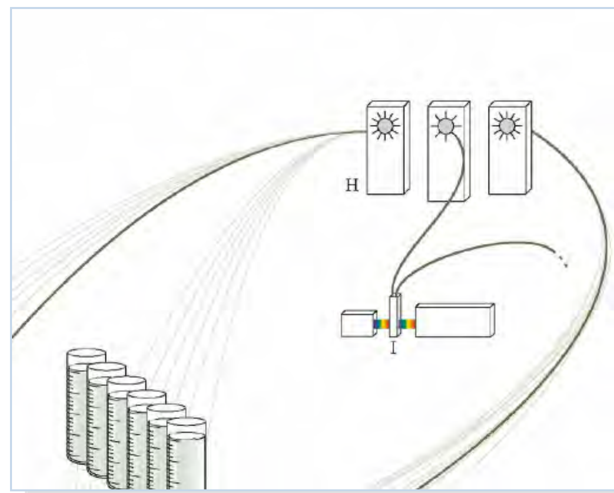
June 2008

Autonomous OA culture systems with spectrophotometric pH measurement

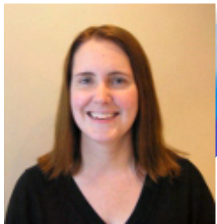
SENSORS

Culture systems control pH to within 0.02 pH units. A_T is also monitored so carbonate chemistry is each tank is known.

- ✓ 2 ship-board culture systems (deployed in the Tasman Sea)
- ✓ 2 trace-metal clean systems
- ✓ 24-tank system mimics daily and seasonal fluctuations



Culture systems are being used to study a wide range of New Zealand and Antarctic organisms.



Christina McGraw

Clark University

C. Hurd, A. Radu

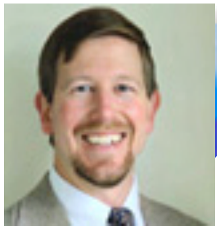
January 2011

New sensors for field measurements of the carbonate system

SENSORS

Two sensor platforms are being developed to obtain high resolution measurements of carbonate. Real-time monitoring will allow us to investigate regional differences and the interactive effects of multiple variables on calcification rates.

- 2011-2012
  - Incorporation of sensors into sensing networks to obtain time-resolved 3D maps of carbonate within defined areas
- 2012
  - Microsensors to measure gradients in ion fluxes within diffusion boundary layers



Christopher L. Sabine

NOAA/PMEL

Christian Meinig (NOAA/PMEL), Andrea Fassbender (Univ. of Washington)

May, 2010

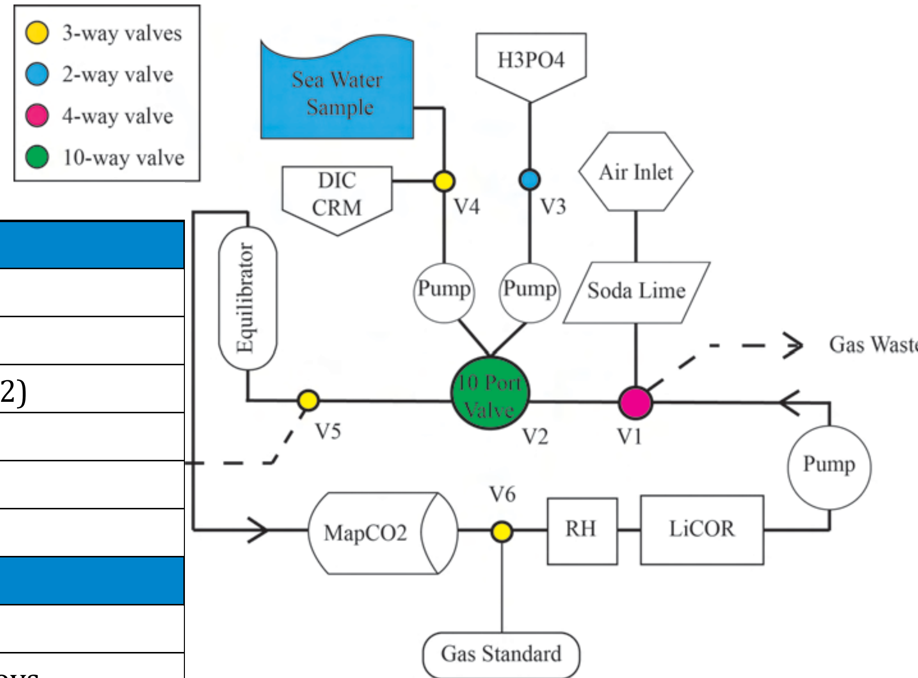
SENSORS

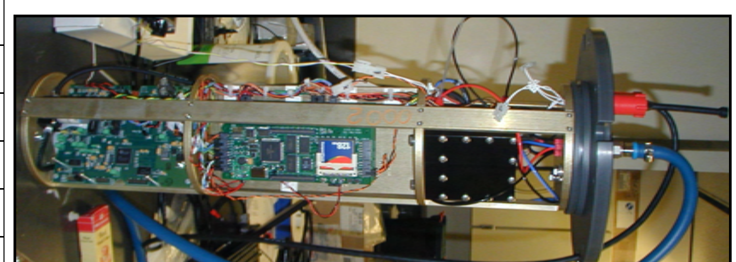
Development of a Robust Moored DIC Sensor for Carbon Cycle Studies

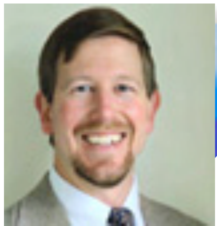
Goal: Develop a moored DIC system modeled after the MAPCO$_2$ sensor

Table 1. Scientific Requirements of the PMEL DIC System

Science Requirements	
Measurement Range	1500 to 2500 ± 2 μmol kg^{-1}
Technique	NDIR detection of acidified seawater
Calibration - gas	WMO standard gas (at least 1, maybe 2)
Calibration - liquid	Andrew Dickson CRM
Biofouling Protection	Maintain accuracy for 400 days
Endurance	Up to 400 days unattended
Engineering Capabilities and Functionality	
Cost	<$40K (similar to MAPCO$_2$)
Platform	Configurable to numerous surface buoys
Survivability	Robust design for tropics and high latitude
Configuration	Modular design, field serviceable
Service	Field serviceable by 1 technician w/ basic training
Power	Alkaline cells, field swapable
Aux Channels	2 ea.
Communications	Bi-directional Iridium Modem
Additional Sensors	GPS, CTD, MET, others as needed







Christopher L. Sabine

NOAA/PMEL

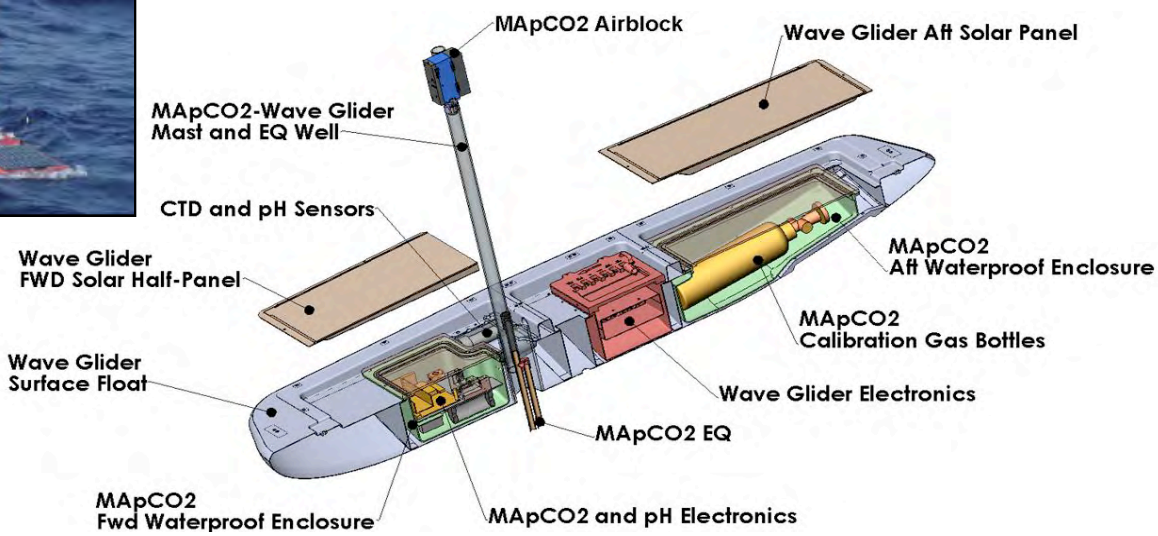
C. Meinig, N. Lawrence-Slavas, R. Bott, T. Martz (Scripps), Liquid Robotics Inc.

October , 2010

SENSORS

New Capabilities for Long-Term, Mobile CO_2 and Ocean Acidification Measurements

Goal: Integrate a carbon measurement package into a Wave Glider



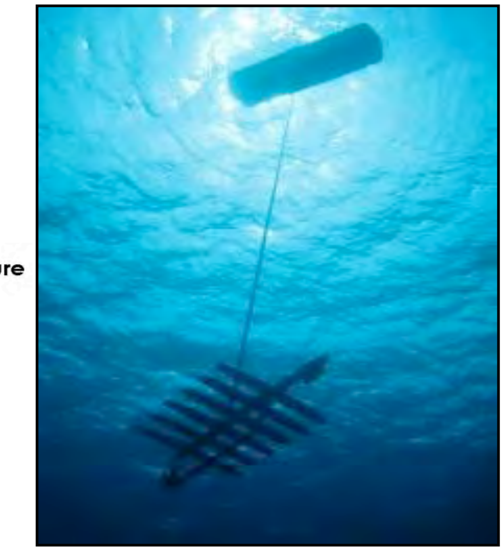


Table 1: Global Climate Change Carbon Science Payload for the Wave Glider AMV.

Supplier	Sensor	Measurement	Calibrated Range & Accuracy
NOAA PMEL	$MAPCO_2$	pCO_2 SW & Air (ppm)	200 to 600 ± 3 (stable over ~year)
Scripps (Martz)	custom pH	SW Acidity (pH)	0 to 14 ± 0.01 (±0.005 stability ~wks)
Seabird Electronics	Glider Payload CTD	Conductivity (S/m)	0 to 6 ± 0.0003 (0 to 9 ± 0.0010)
		Temperature (°C)	1 to 32 ± 0.002 (-5 to +45 ± 0.010)
		Pressure (dbar)	0 to 100 ± 0.1% FS (same)
		Salinity (PSS 78)	0 to 35 ± 0.005 (0 to 45 ± 0.015)

Francis Chan

Oregon State University

Oregon Team: Ricardo Letelier (lead PI), Jack Barth, Stephen Giovannoni, Alan Mix, Curtis Deutsch

Feb 2009

Microbial Initiative in Low Oxygen areas off Concepción and Oregon

SENSORS

To compare microbial assemblages and biogeochemical cycles associated with seasonal continental shelf hypoxia off Concepción and Oregon

- ❑Strong coupling between hypoxia and ocean acidification over shelf time-series station
- ❑Sequencing data to link microbial process with N-transformations along wide gradients pH and oxygen gradients

MI_LOCO

Microbial Initiative in Low Oxygen areas off Concepción and Oregon

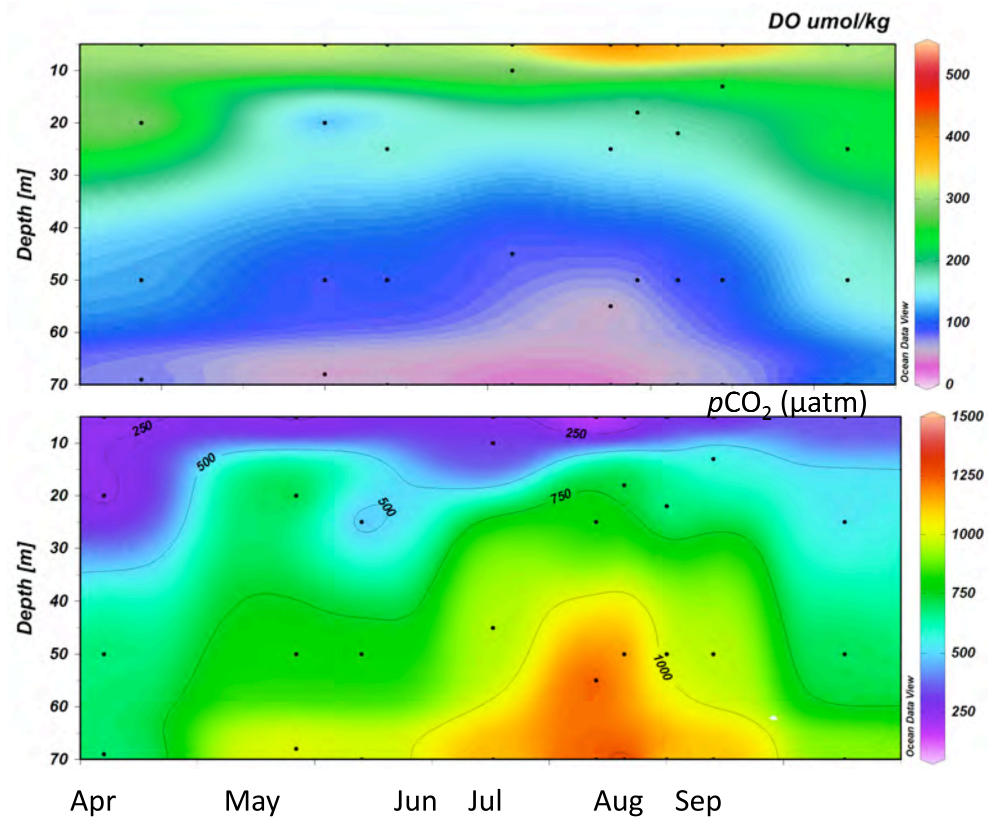


Photo we'll insert

Gretchen Hofmann

University of California, Santa Barbara

Evans TG, Yu P, et al.

SENSORS

Synergistic effects of climate-related variables on larval sea urchins

Characterize the response of larval purple sea urchins (*Strongylocentrotus purpuratus*) to the synergistic interaction of two climate change-related factors: ocean acidification and ocean warming (IOS-1021536)

Larvae cultured under varying levels of pCO_2 and temperature will be analyzed using a suite of experimental tools that span levels of biological organization:

- *Organismal*
  - -morphometric and survival analyses
- *Biochemical*
  - -calcification rate, respiration, lipid content, total protein
- *Physiological*
  - -transcriptomics