The development and validation of a profiling glider deep ISFET-based pH sensor for high resolution observations of coastal and ocean acidification

Frontiers in Marine Science, in review

Grace Saba, Elizabeth Wright-Fairbanks, Travis Miles

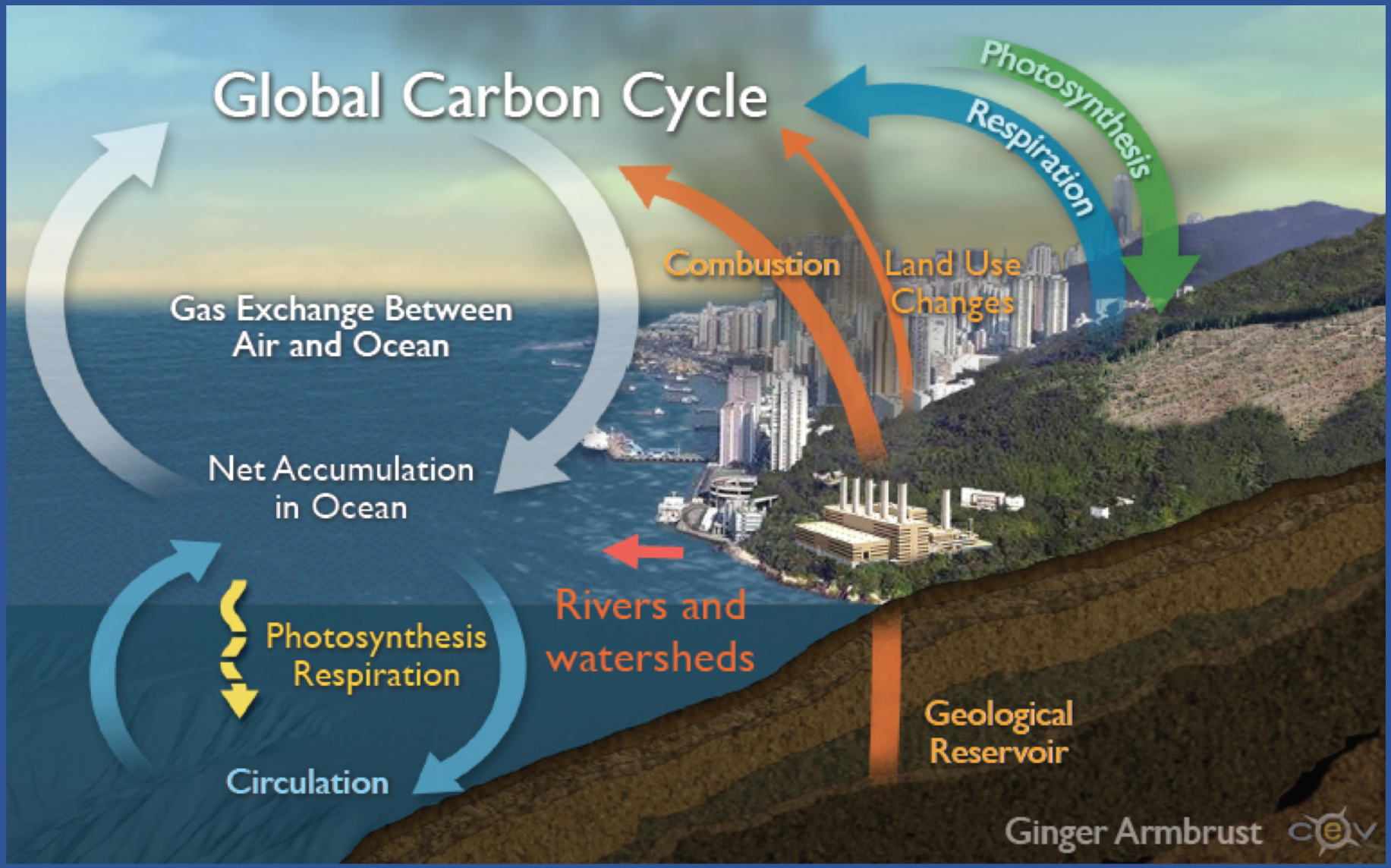
Baoshan Chen, Wei-Jun Cai, Kui Wang

Andrew Barnard, Charles Branham

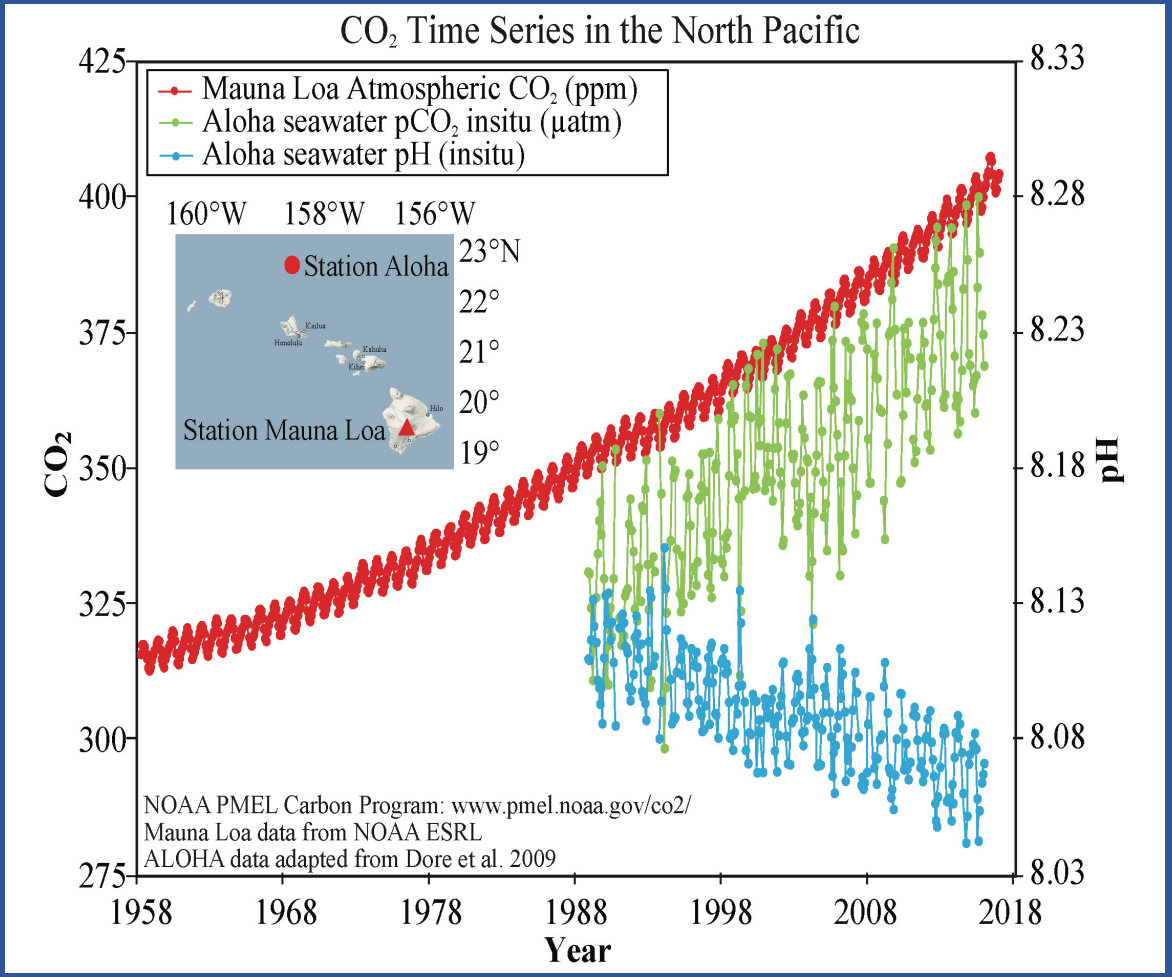
Clayton Jones

Ocean Acidification

Driven by the ocean's absorption of increasing atmospheric carbon dioxide (CO_2)

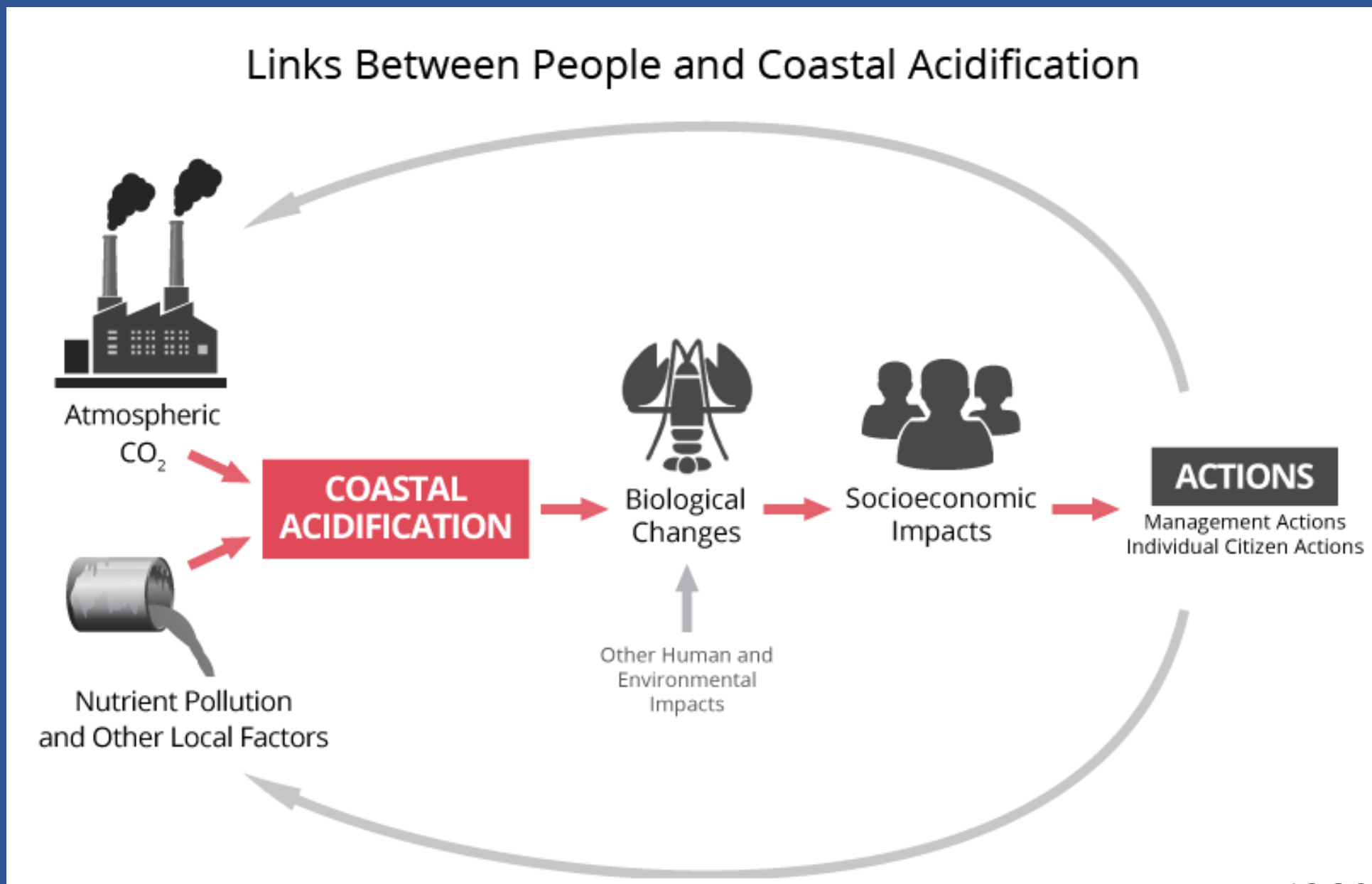


Ocean acidification: The "Other" CO_2 Problem

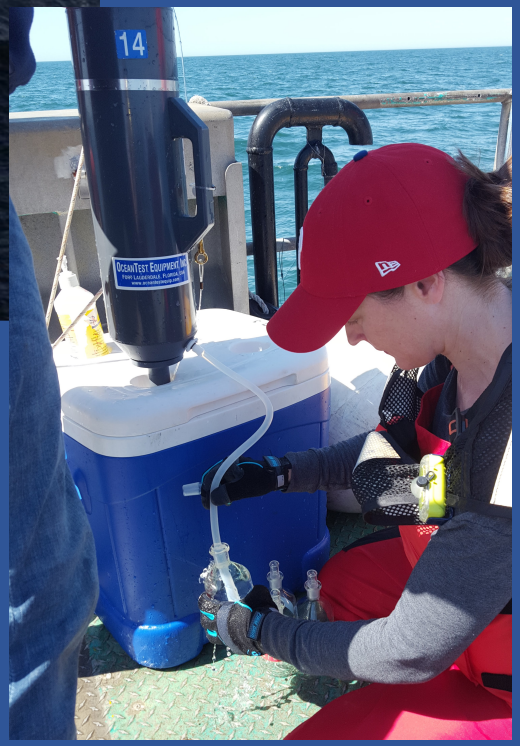


Atmospheric CO_2 has increased 40% globally since the 1800s

- Drop of 0.1 pH unit = 28% increase in ocean acidity
- CO_2 is projected to double by 2100 (IPCC) = drop of 0.2-0.3 pH units
- Rate of change 10x faster than anything experienced over the past 50 million years

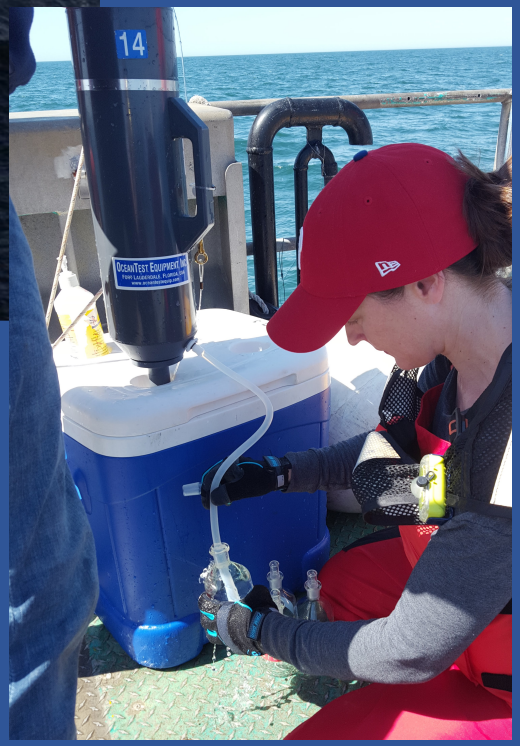

Links Between People and Coastal Acidification
Atmospheric CO_2
Nutrient Pollution and Other Local Factors
COASTAL ACIDIFICATION
Biological Changes
Other Human and Environmental Impacts
Socioeconomic Impacts
ACTIONS
Management Actions
Individual Citizen Actions
IOOS

Traditional OA Monitoring Platforms



Traditional OA Monitoring Platforms

Most gaps can be addressed through advancements in sensor technology



Improvements in pH Sensor Design and Application

Depth-profiling deep-sea ISFET pH

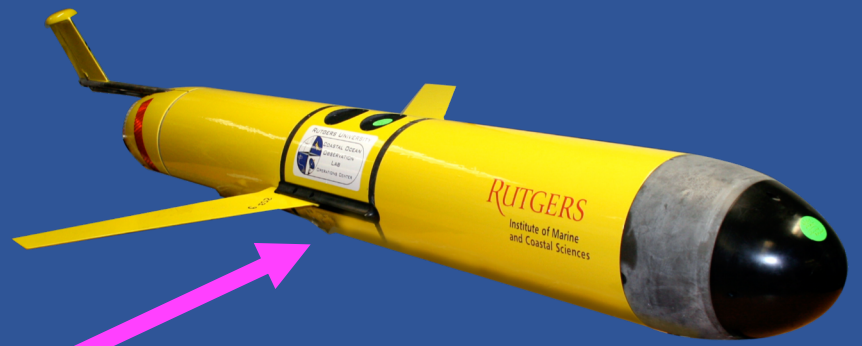
Johnson et al., 2016

Academic and Industry collaboration:
Ken Johnson, MBARI
Todd Martz, Scripps
Honeywell
Sea-Bird Scientific

*Finalists in the Wendy Schmidt Ocean Health XPRIZE

Project Goals

- Develop and integrate a Deep-Sea ISFET profiling pH sensor into a glider and conduct laboratory testing and calibration



- Conduct glider deployments to demonstrate high resolution measurements of pH in coastal regions in near real-time

Sensor Development and Integration

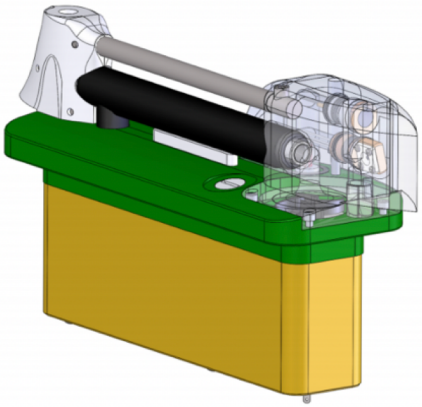
Deep-Sea DuraFET profiling pH sensor

Power/Data Connector

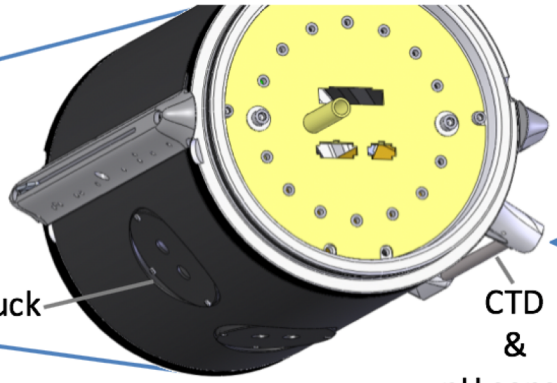
ISFET Sensor and External Reference Electrode

MODIFICATION

pH sensor integrated with pumped CTD

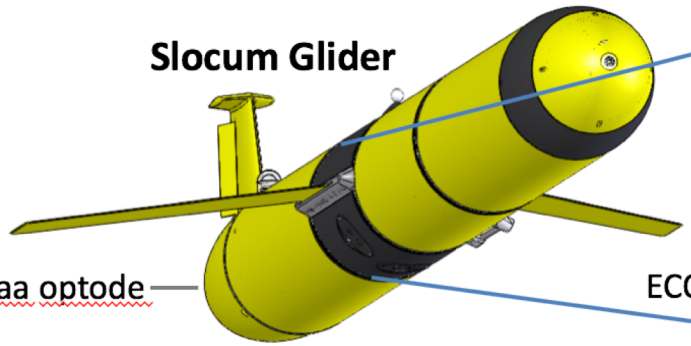


Glider Payload Bay



INTEGRATION

Slocum Glider

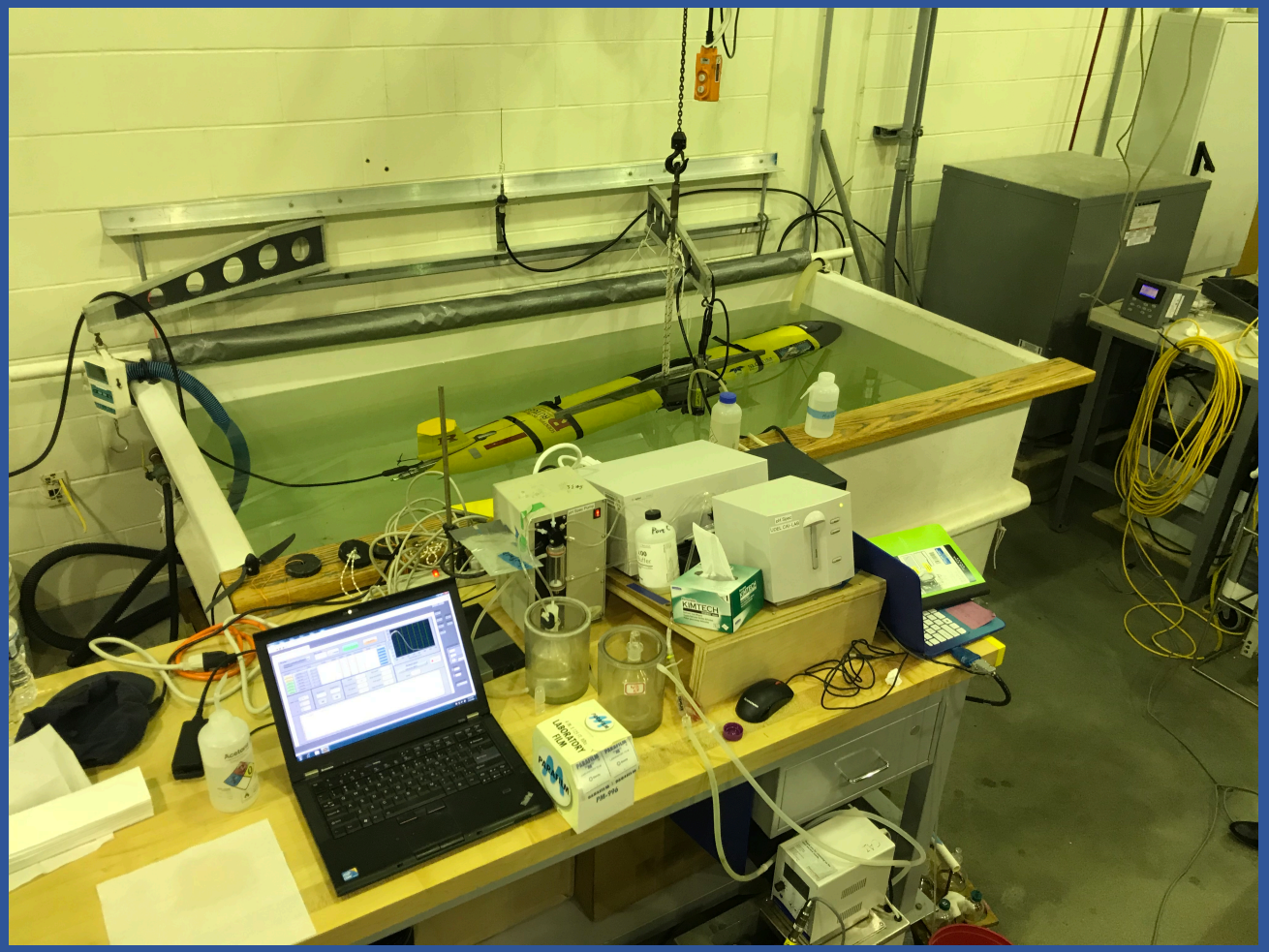


Aanderaa optode

ECO puck

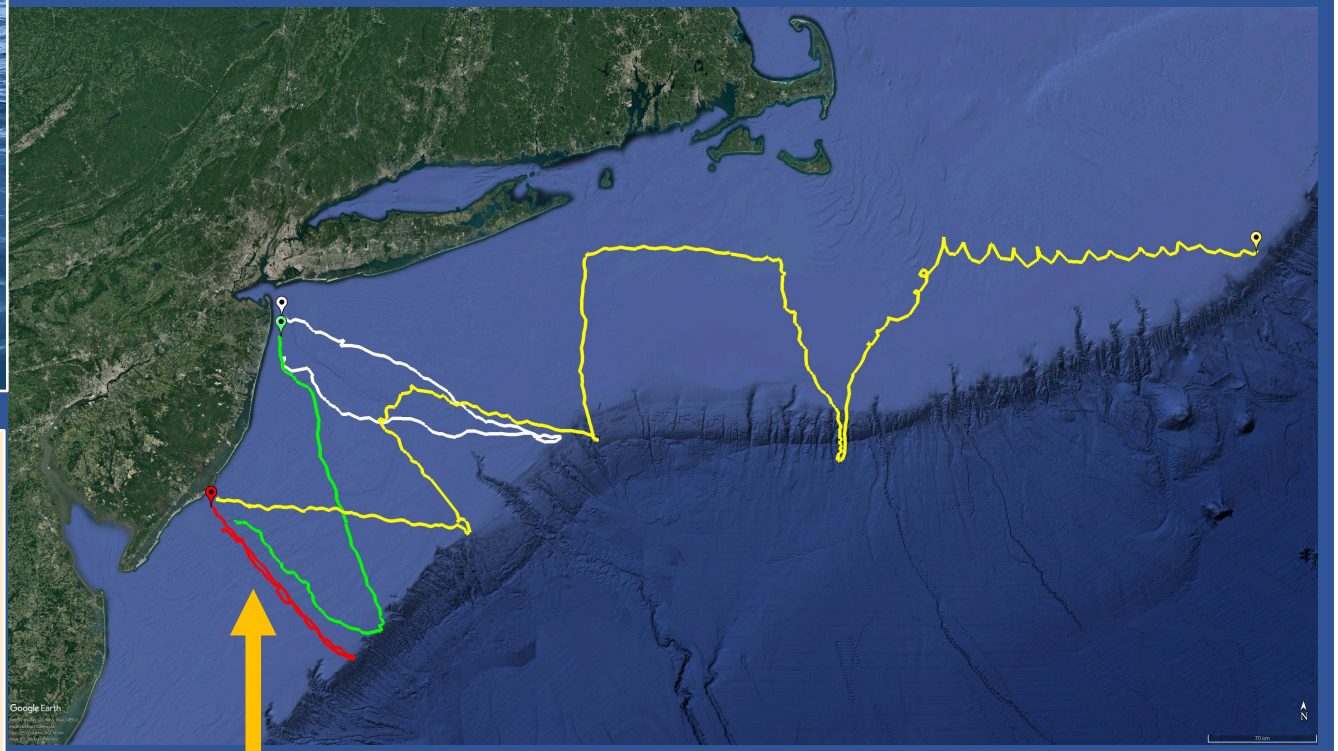
CTD & pH sensor

Tank Tests

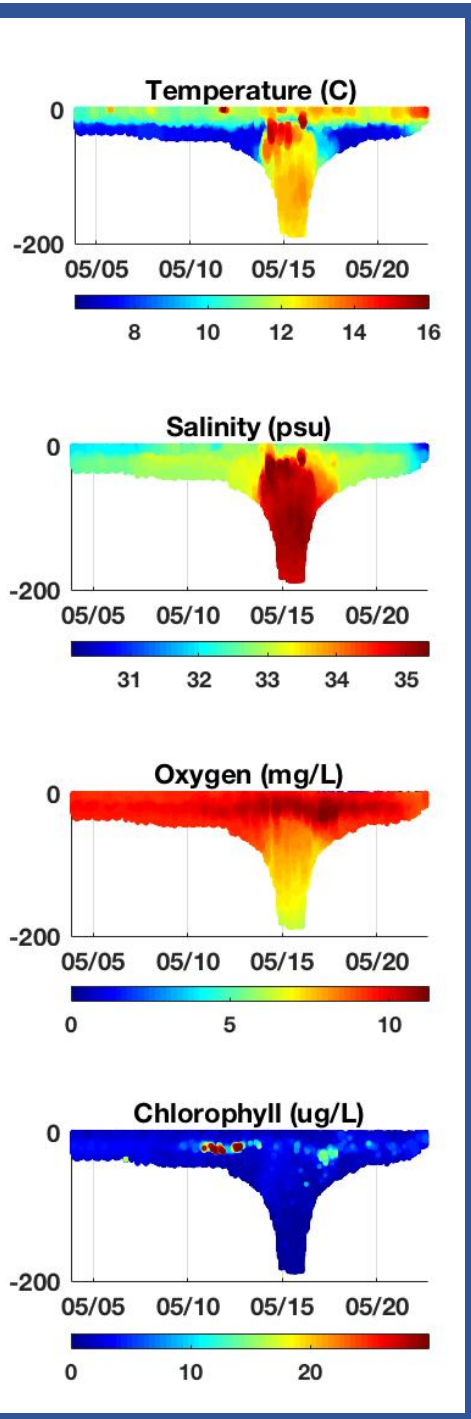


- Conditioning time: 4-6 days
- Sensor accuracy: 0.000 – 0.015
- Sensor precision: 0.000 –0.007

pH Glider Deployments



May 2018 Deployment



Cross Shelf Profiles

May 2018 – NJ cross-shelf

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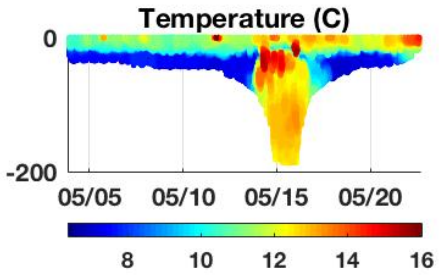
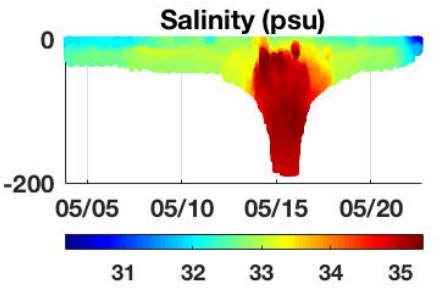
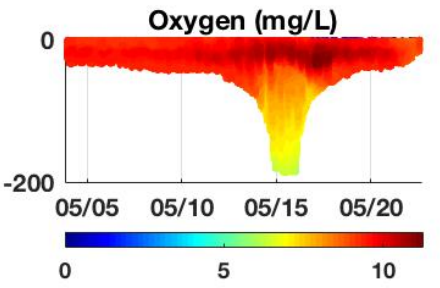
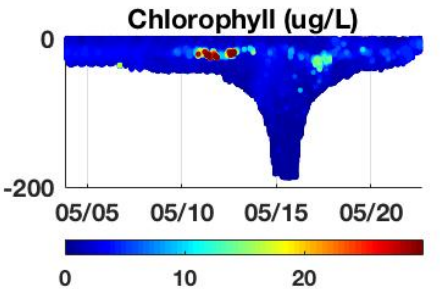
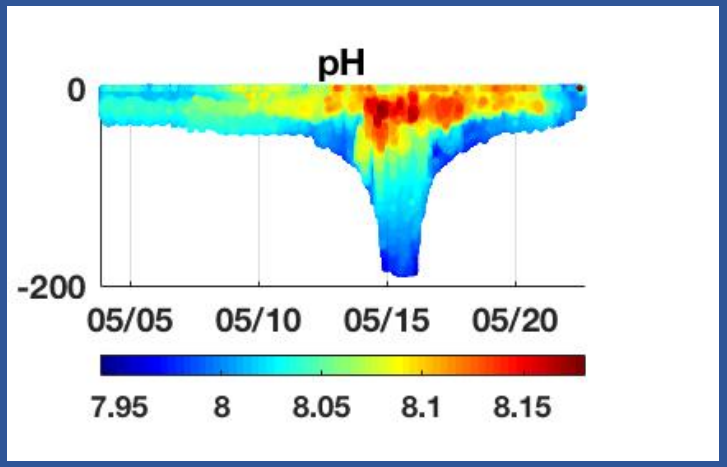
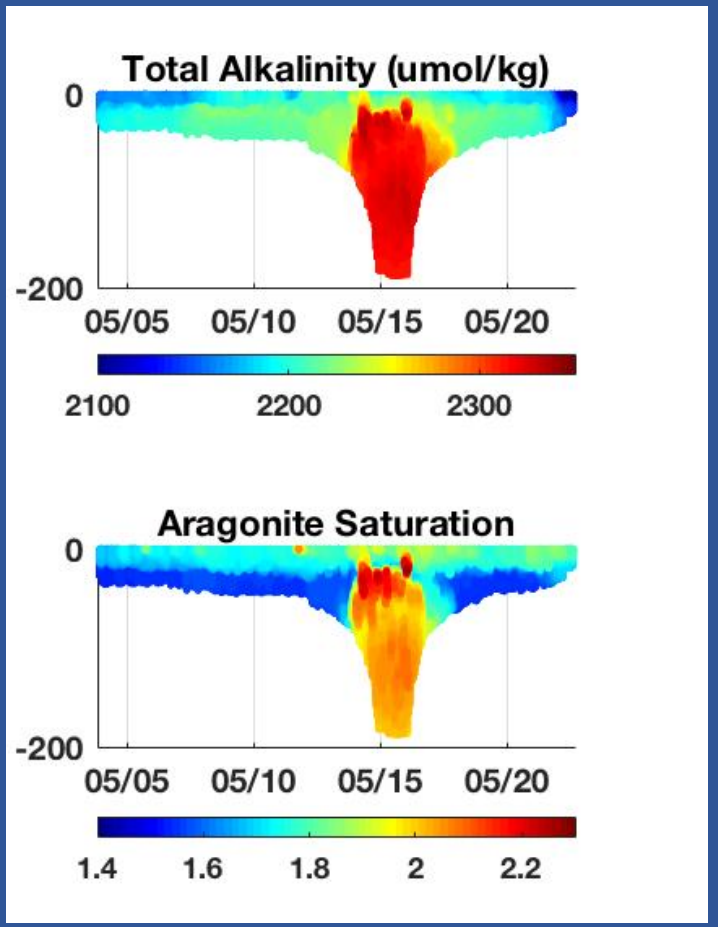








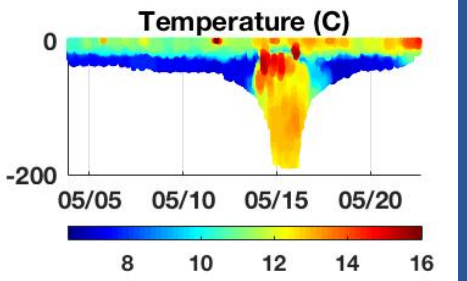


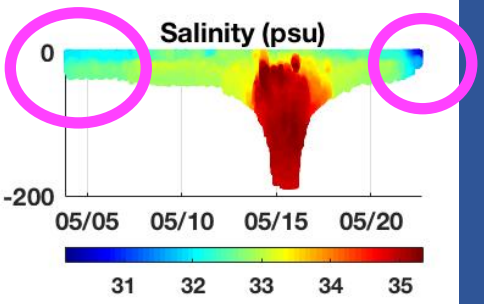


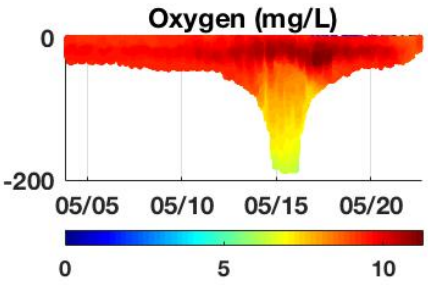
- Field accuracy: 0.001 – 0.017 pH units
- Field precision: 0.0007 – 0.008 pH units

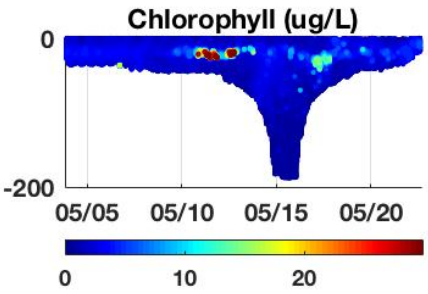
Cross Shelf Profiles

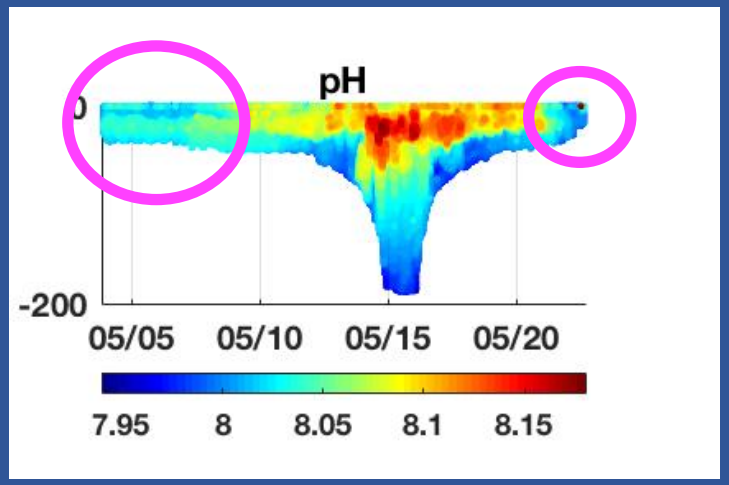
May 2018 – NJ cross-shelf

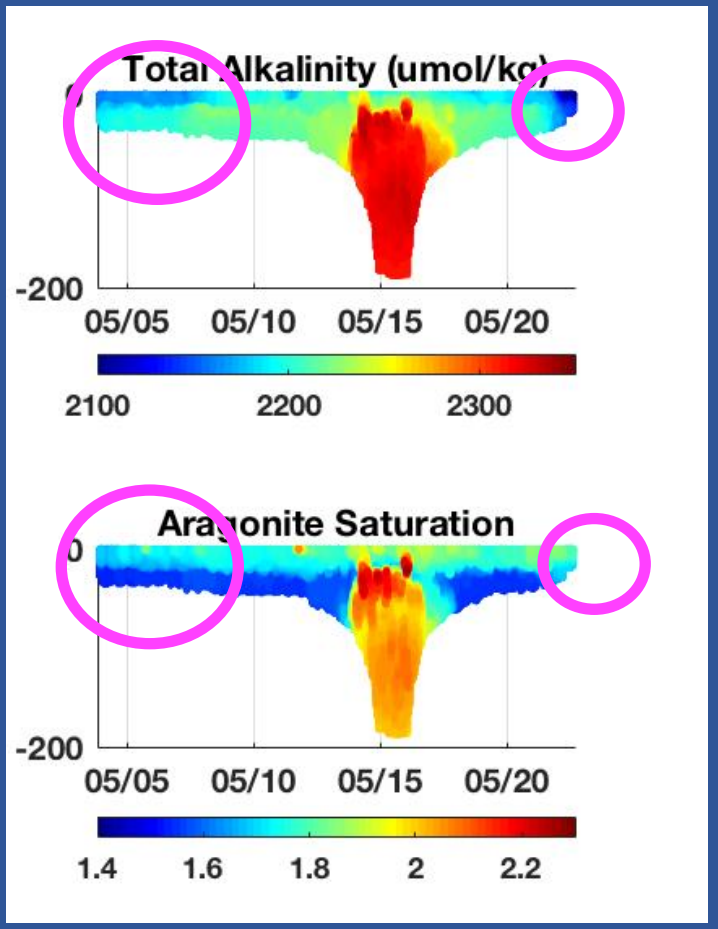












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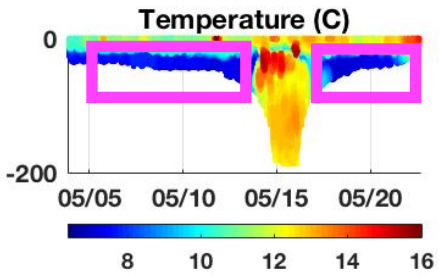

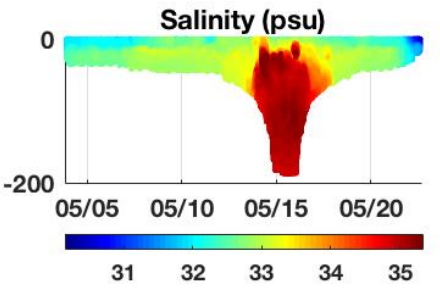

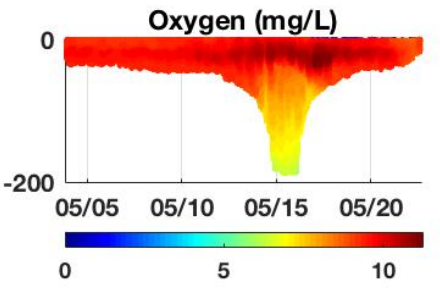

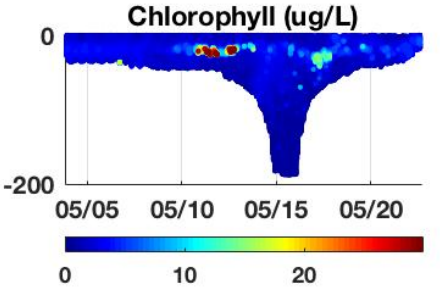

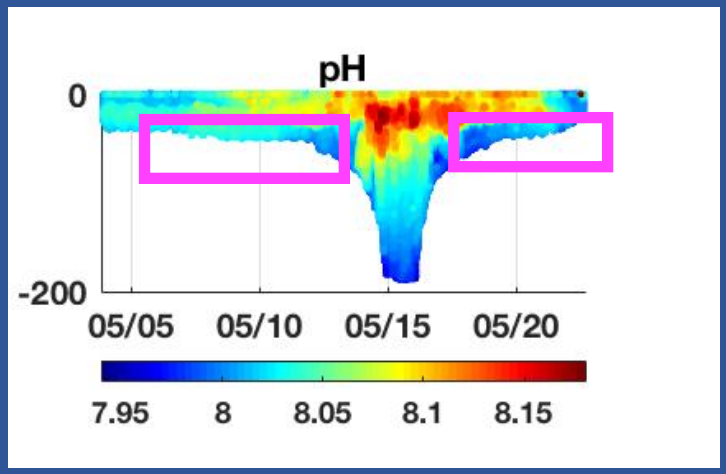

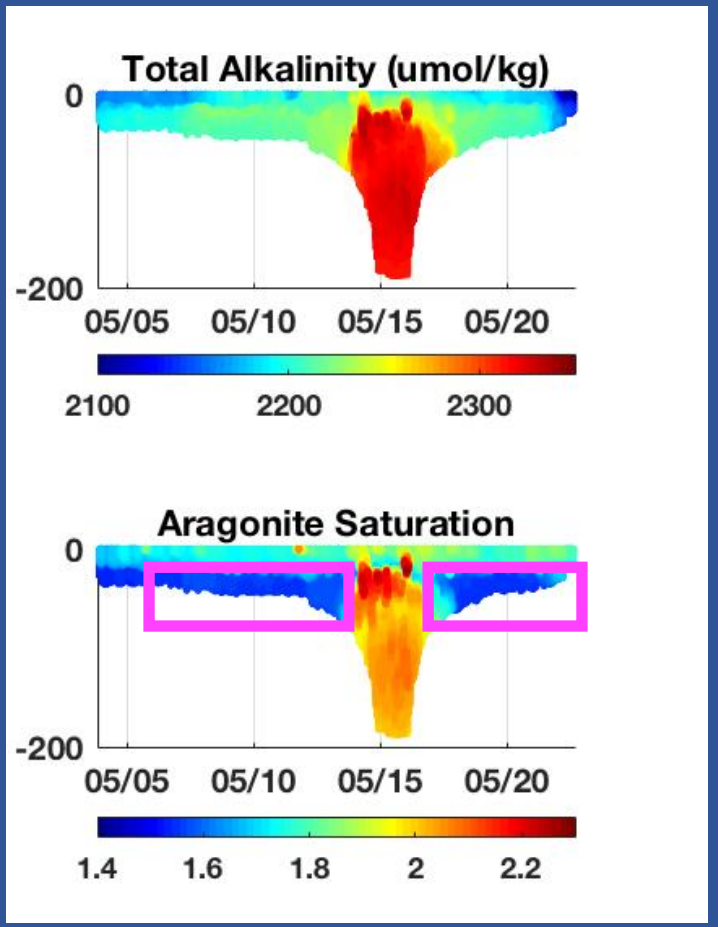

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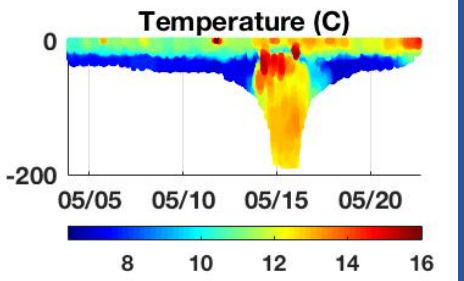

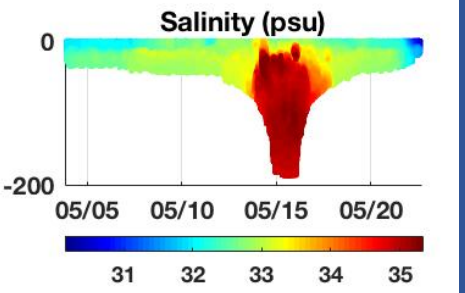

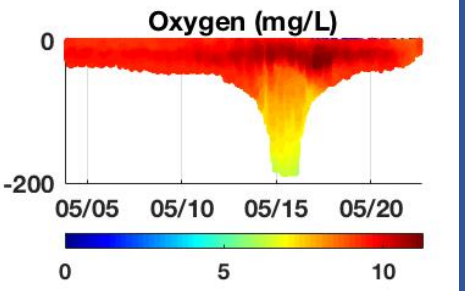

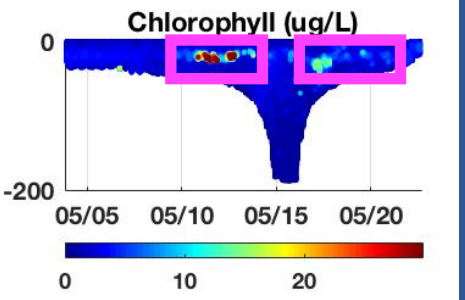

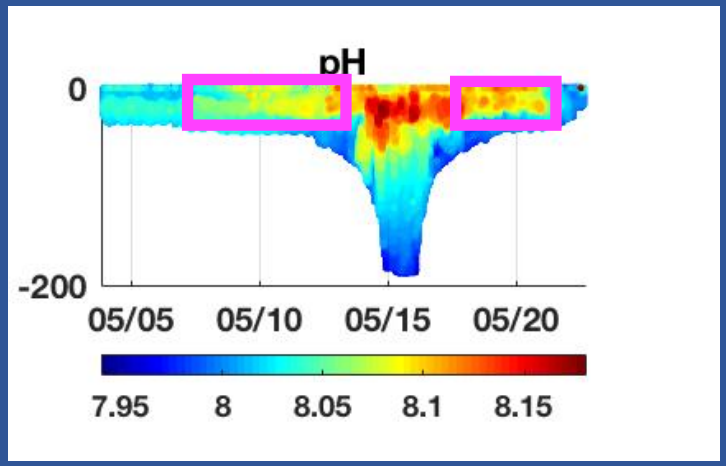

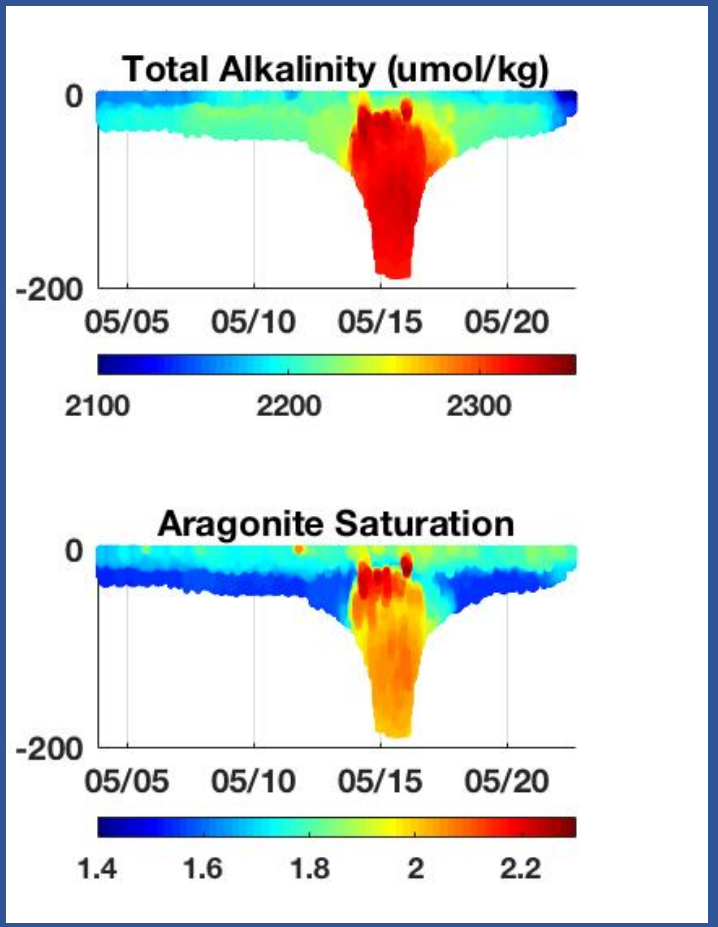

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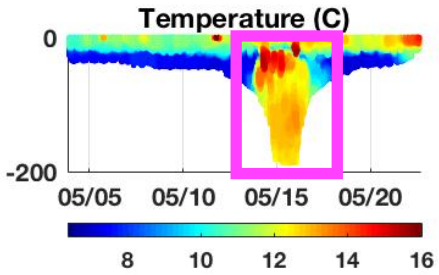

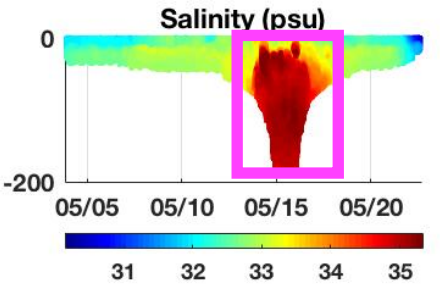

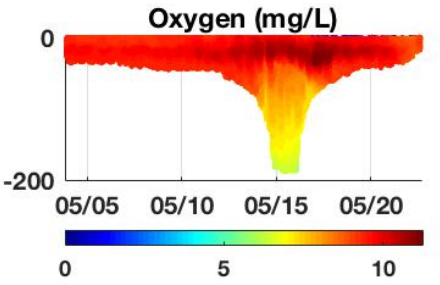

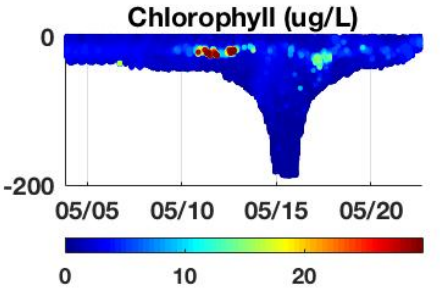

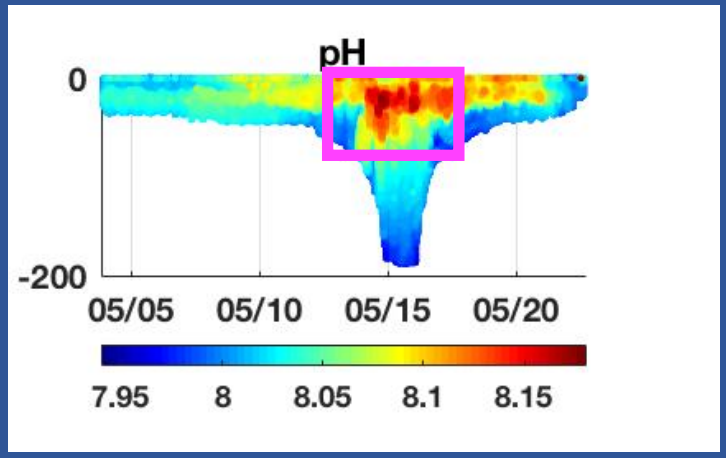

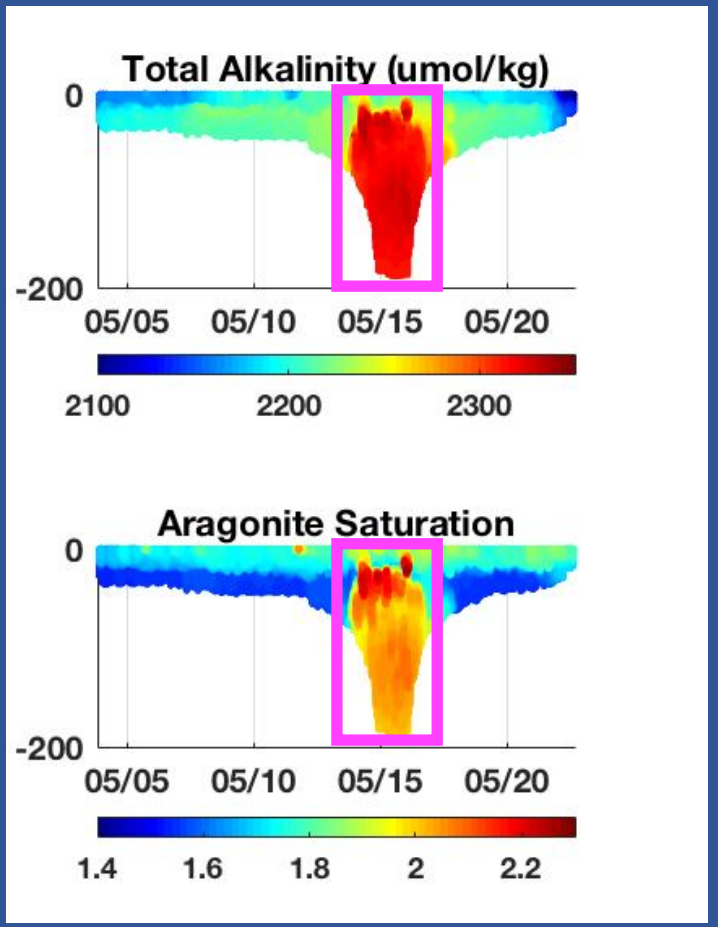

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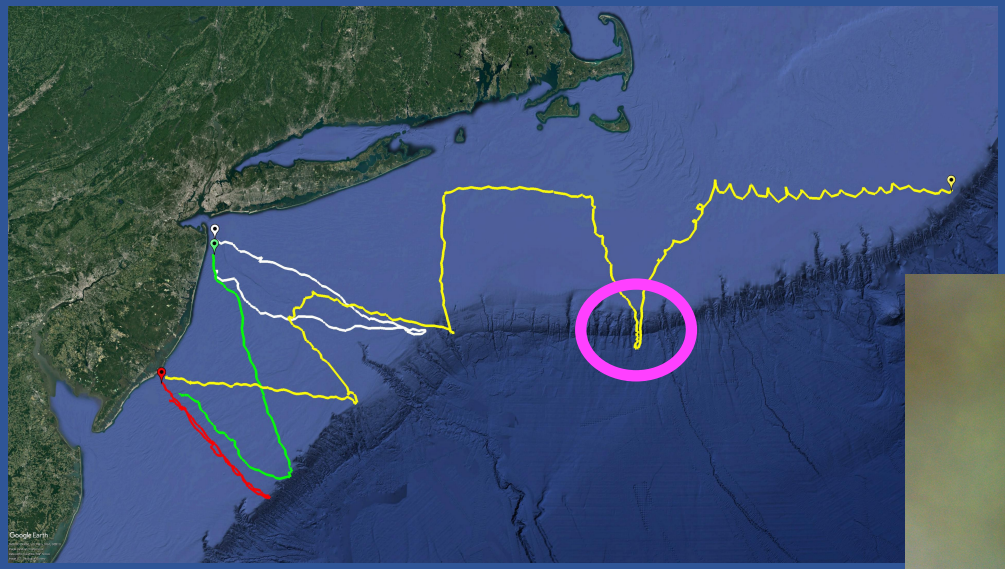
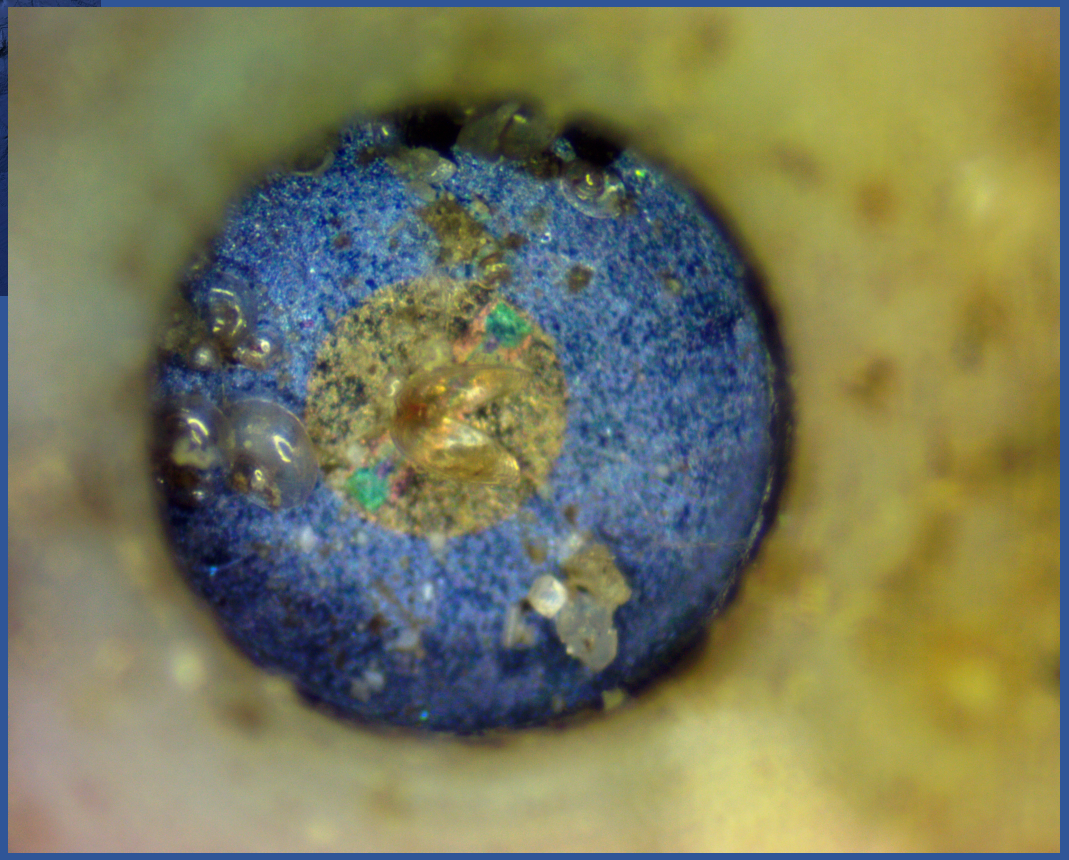
Challenges to Overcome

- Biofouling



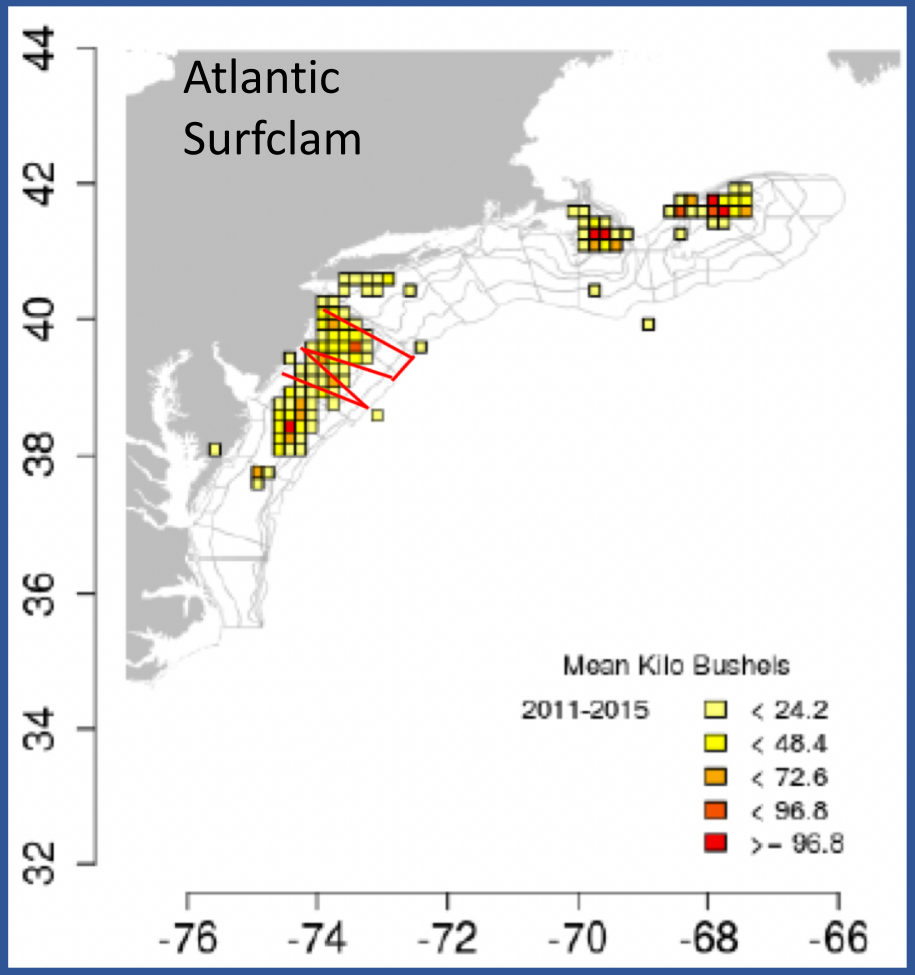


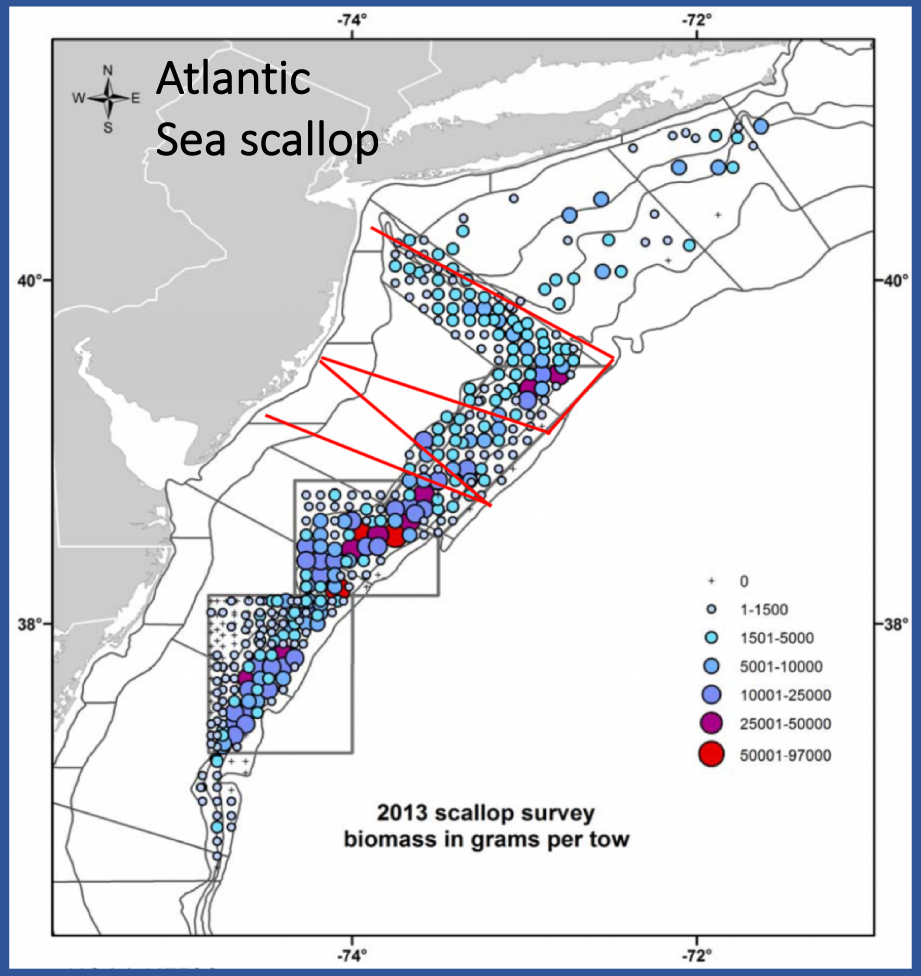
Offsets after warm-core ring:
-0.144 to +0.081

Offsets upon recovery:
-0.084 to +0.249

Applications – Habitat Assessment

- Determine natural variability and monitor habitats of species that are sensitive to ocean acidification

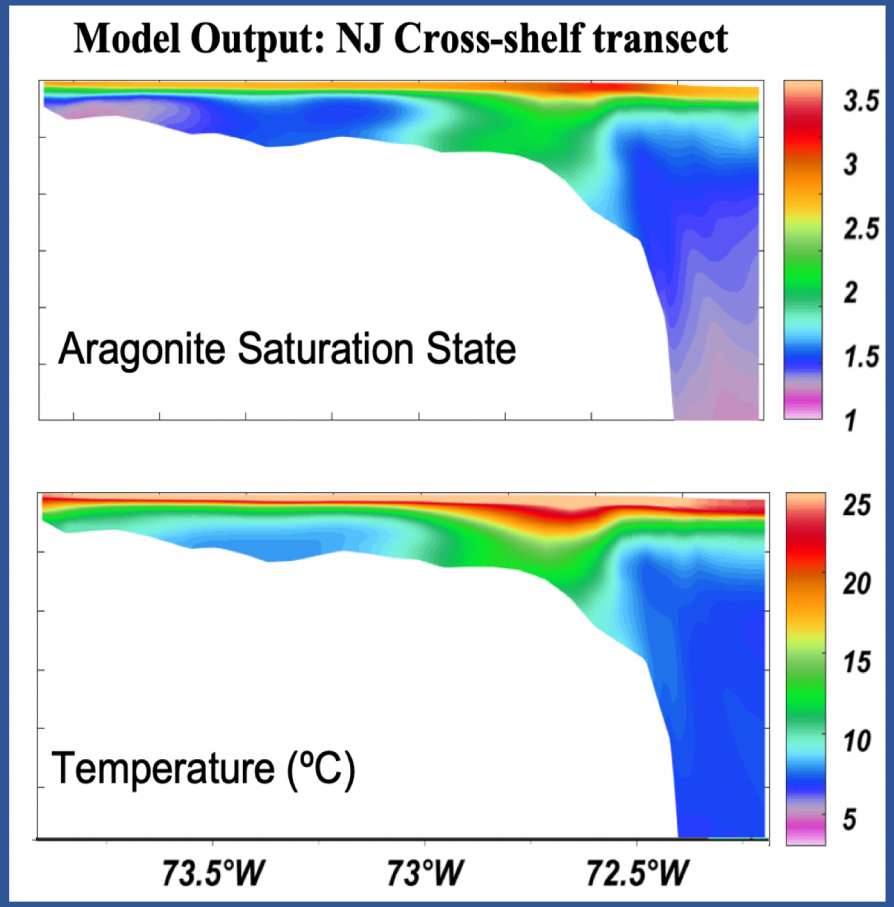




Seasonal/Habitat efforts: Liza Wright-Fairbanks

Applications – Model Development

- Incorporating acidification (pH, TA, Ω_{Arag}) into regional models (ROMS) and glider-based model evaluation/parameterization



Coupled ROMS/BGC model (J. Wilkin, MARACOOS)

- Work up to seasonal/daily forecasts

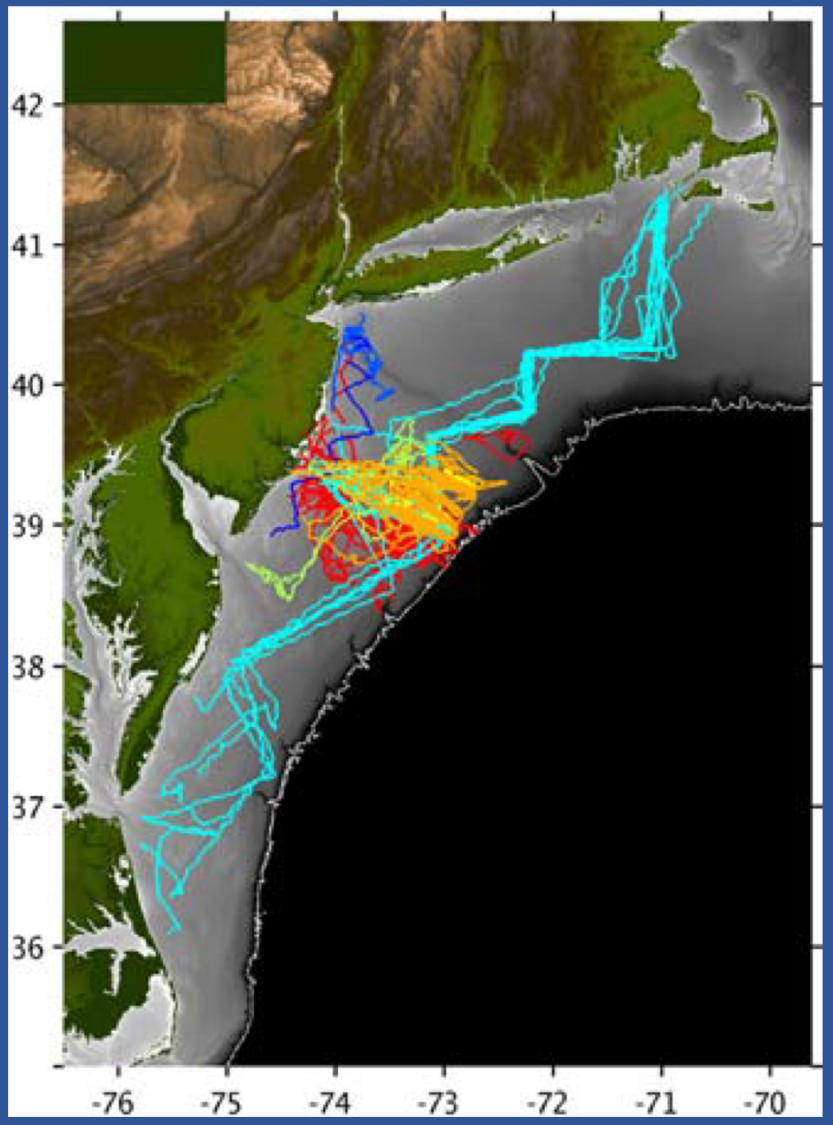
Next Steps – Glider-Based OA Networks

Regional Level

PAPER

A Regional Slocum Glider Network in the Mid-Atlantic Bight Leverages Broad Community Engagement

Schofield et al. 2010, MTS



MARACOOS
Ocean Information for a Changing World

REGIONAL INFORMATION COORDINATION ENTITY CERTIFIED

OCEAN OBSERVATORIES INITIATIVE

Next Steps – Glider-Based OA Networks

National Level

IOOS
Integrated Ocean Observing System

Toward a U.S. IOOS® Underwater Glider Network Plan:
Part of a comprehensive subsurface observing system

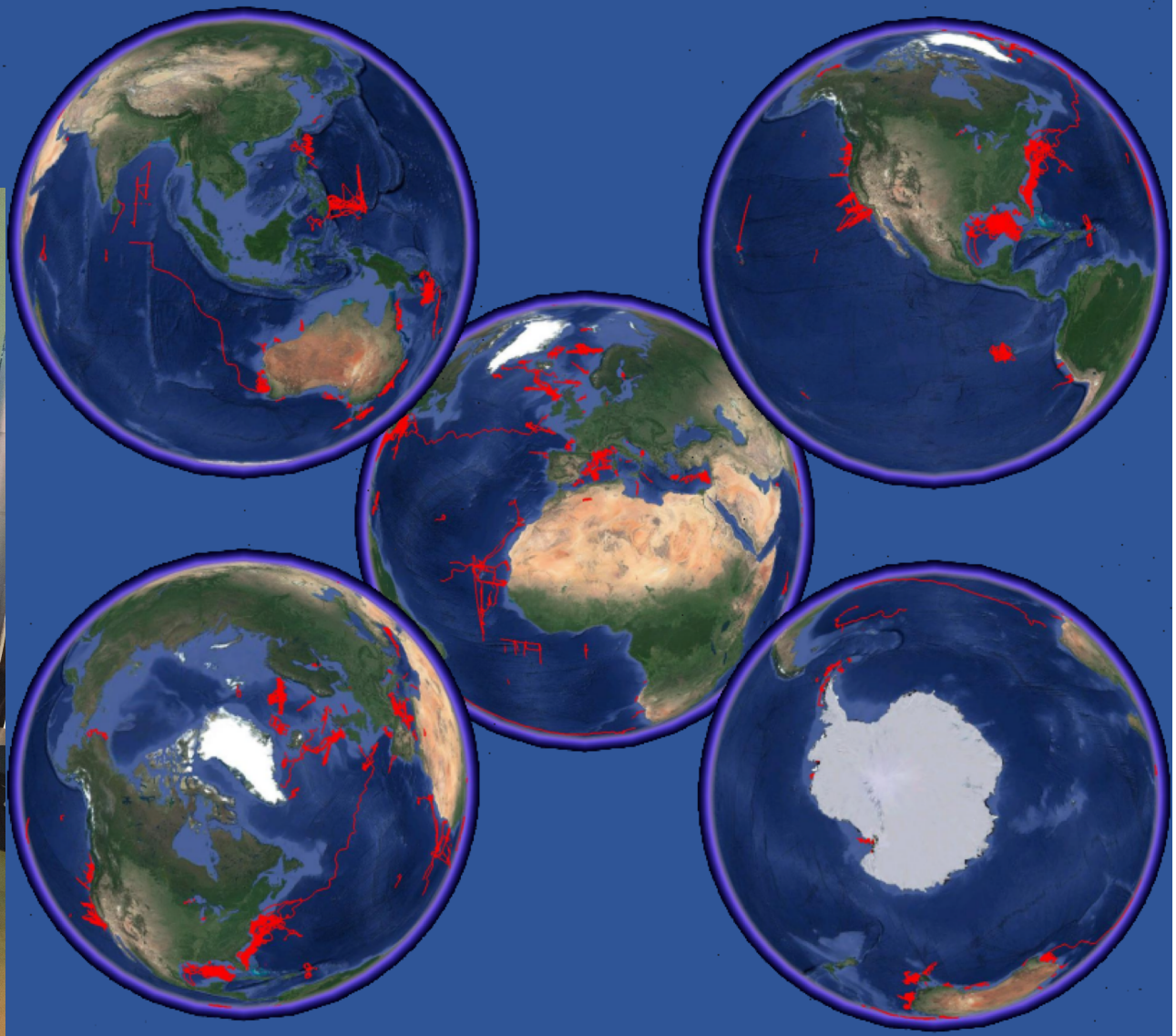
"Glider technology may be able to resolve some of the issues involved in measuring essential ocean variables like sea surface salinity, pCO_2, pH, nutrients, and phytoplankton biomass, health, and composition."

Glider tracks along the U.S. coast: 2002-2014

"As pH sensors mature, gliders will provide excellent platforms for monitoring ocean acidification."

Next Steps – Glider-Based OA Networks

Global Level



Testor et al., Ocean Obs'19

Thanks!

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Special thanks to:

RU glider & software teams

David Aragon

Chip Haldeman

Nicole Waite

John Kerfoot

Laura Nazzaro

RU Undergraduates

Brandon Grosso

Laura Wiltsee

Teledyne Webb

Clara Hulburt

Chris DeCollibus

NSF OTIC Program
(OCE #1634520)

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