# Spatial and Temporal Monitoring of Dissolved Oxygen in Coastal Waters using Glider AUVs

**Josh Kohut and Jack Barth**
**Rutgers University and Oregon State University**

**And MANY MANY MANY OTHERS**

# Autonomous Underwater Glider

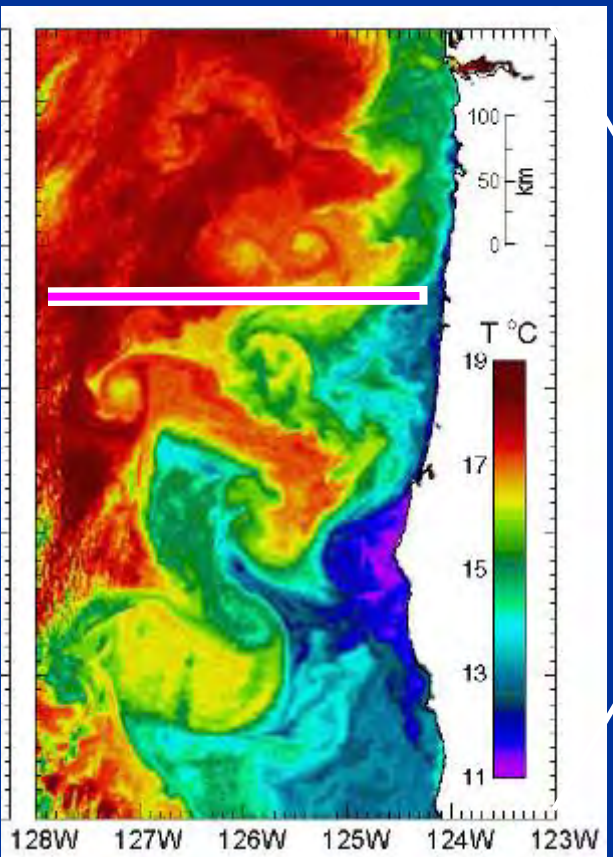
## Teledyne Webb Research

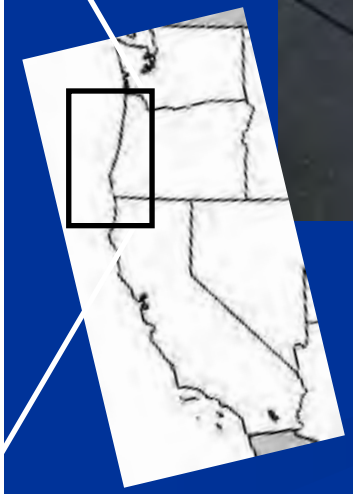

# Autonomous Underwater Gliders off Newport, OR

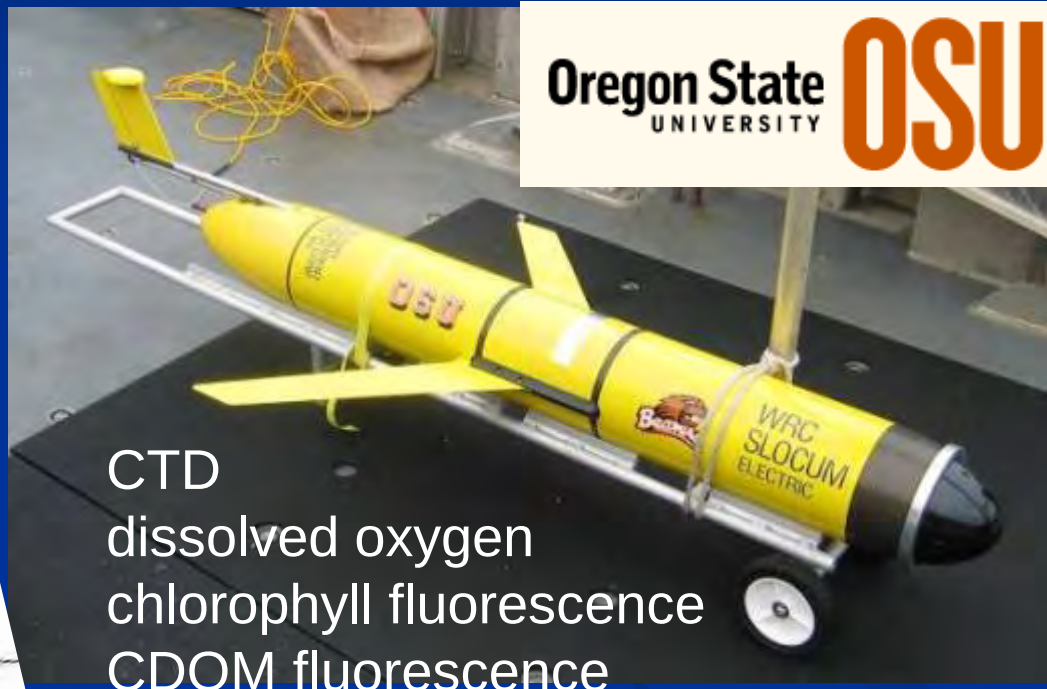
Co-PIs: Jack Barth and Kipp Shearman
Technicians: Anatoli Erofeev and Zen Kurokawa

Graduate Students: Kate Adams
Piero Mazzini
Gonzalo Saldias

cross-margin transect twice per week since April 2006
Along historic NH line (50+ years)






CTD
dissolved oxygen
chlorophyll fluorescence
CDOM fluorescence
light backscatter

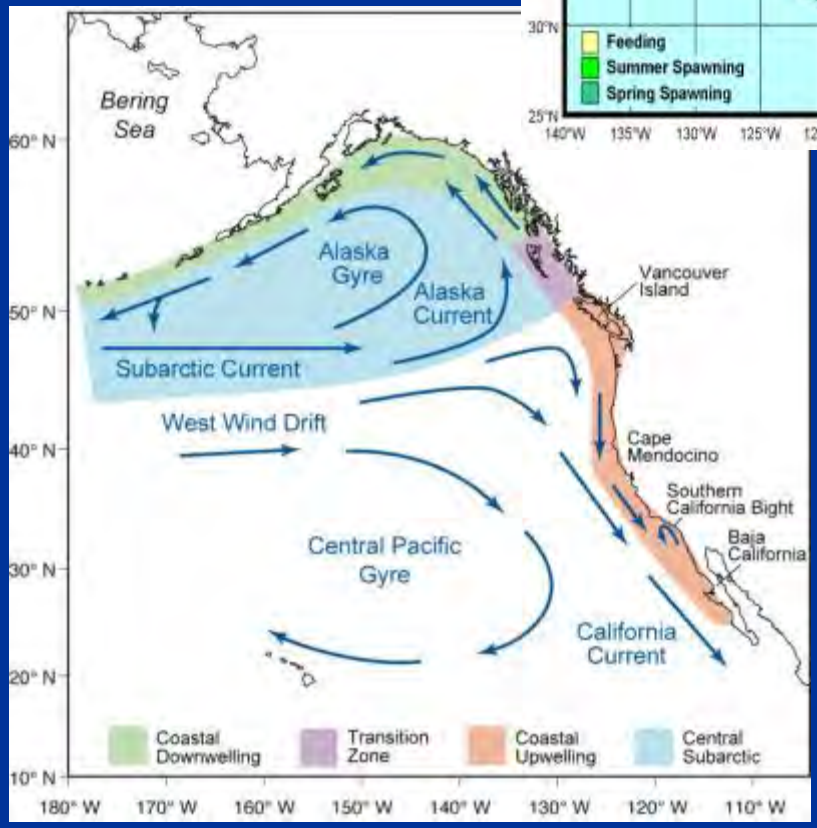
Oregon State University OSU

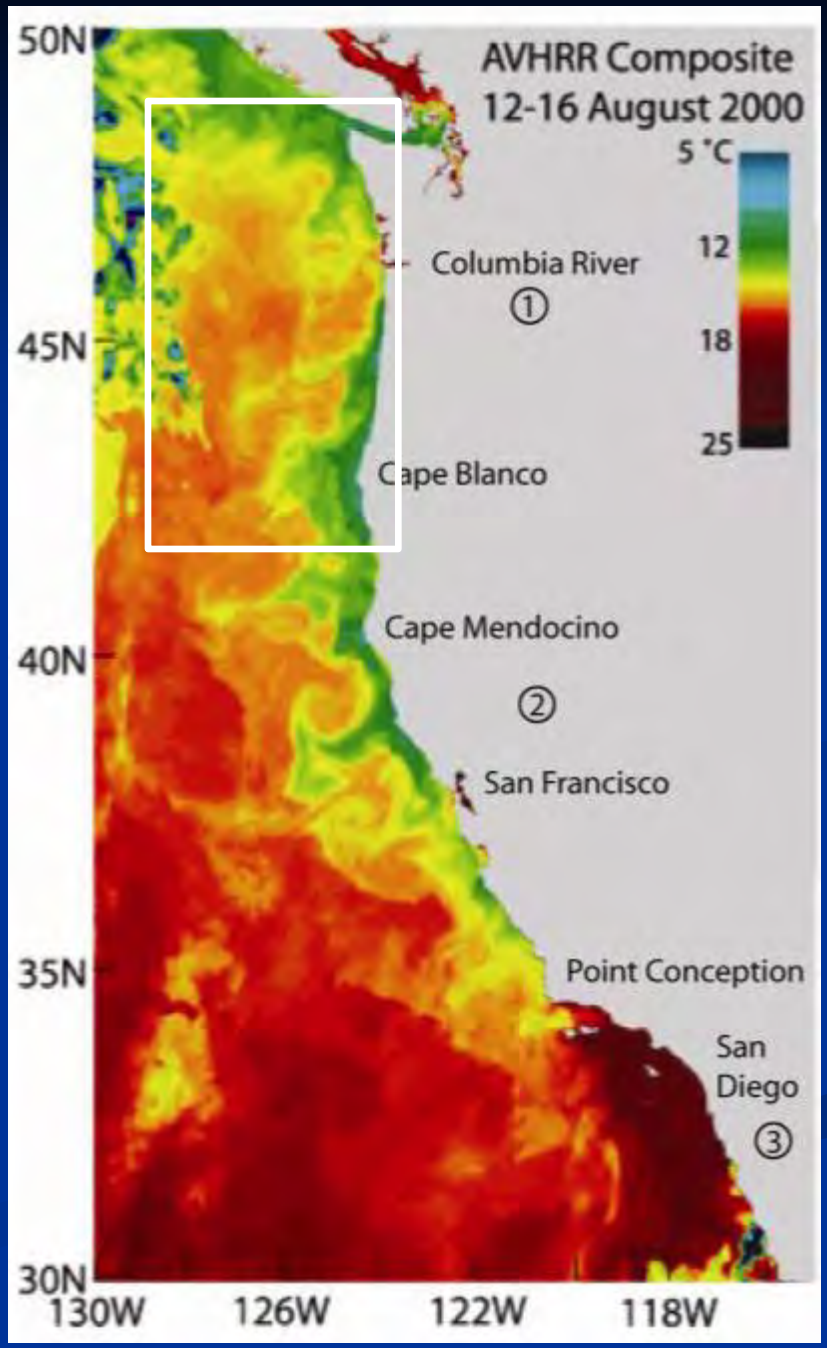
NSF

NANOOS

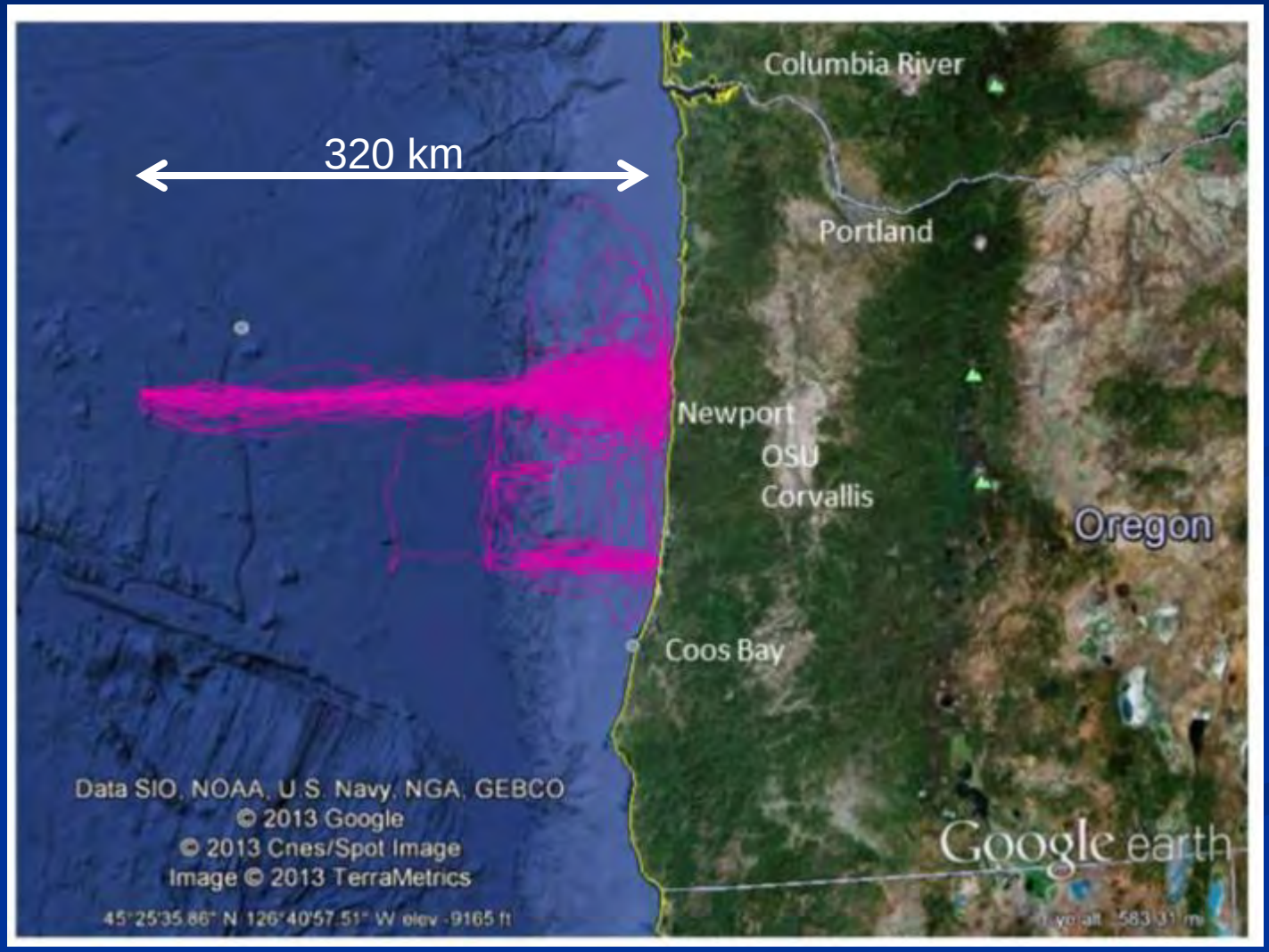
GORDON AND BETTY MOORE FOUNDATION

# Northern California Current System

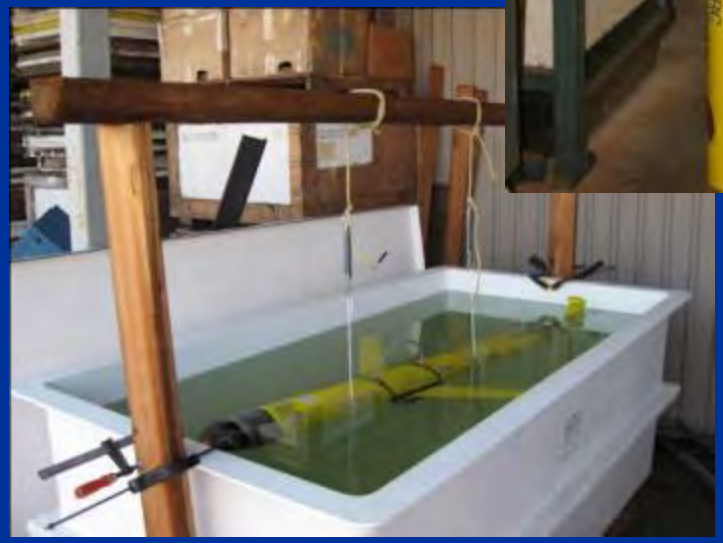



# Oregon State University glider tracks off central Oregon

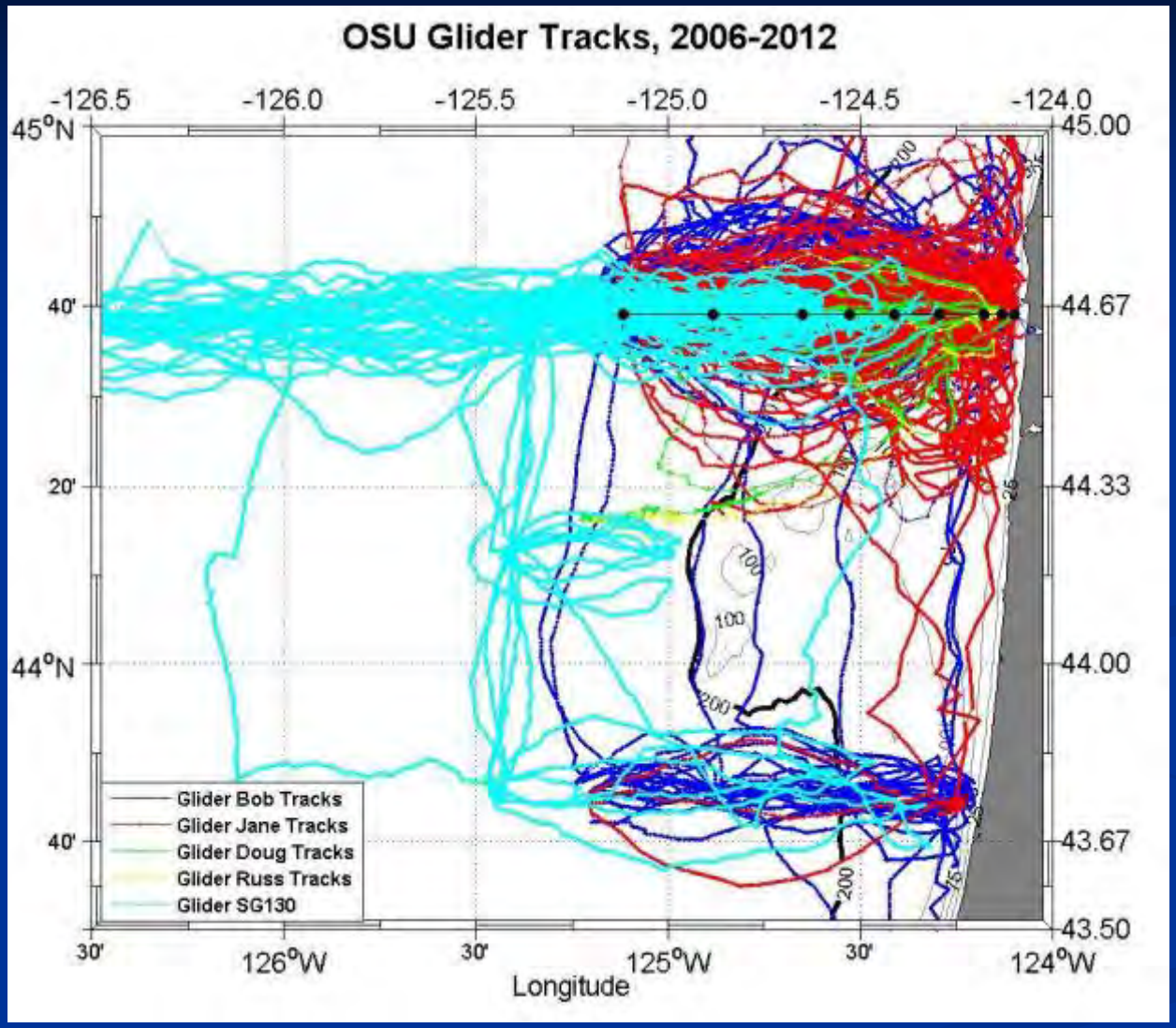


# Glider Operations and Maintenance

- deploy
- execute mission
- recover
- refurbish
- calibrate
- repair/test
- deploy



# OSU Glider Operations



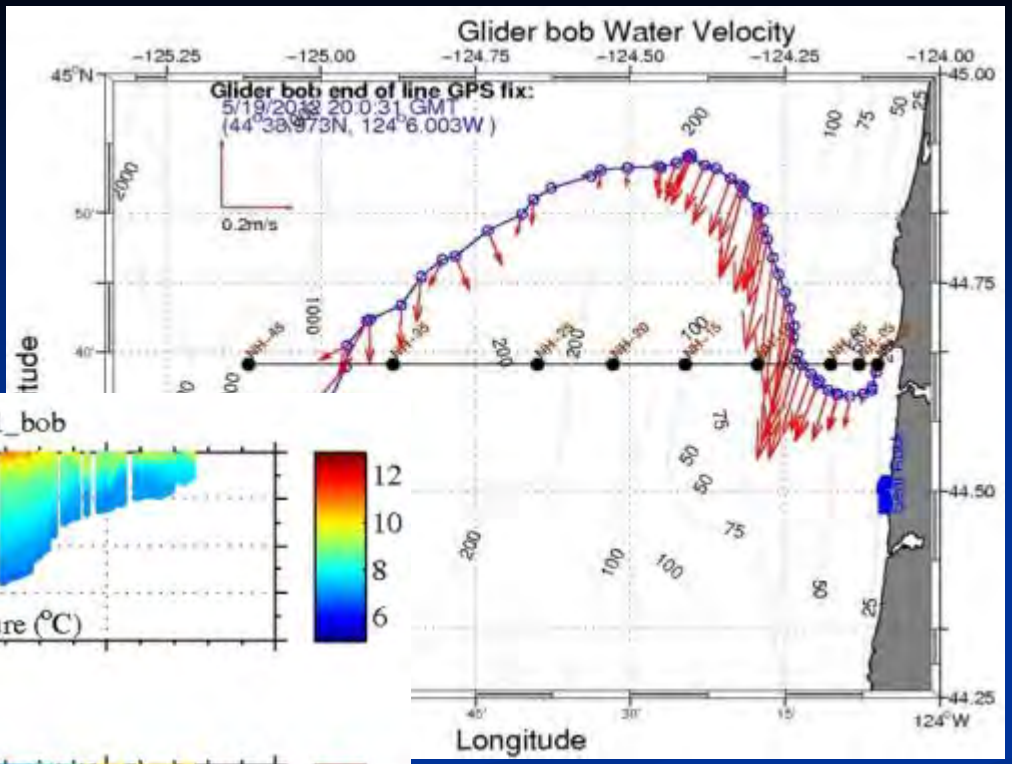

- strong currents (50+ cm/s)
- abrupt bathymetry
- large freshwater inputs
- historical observations

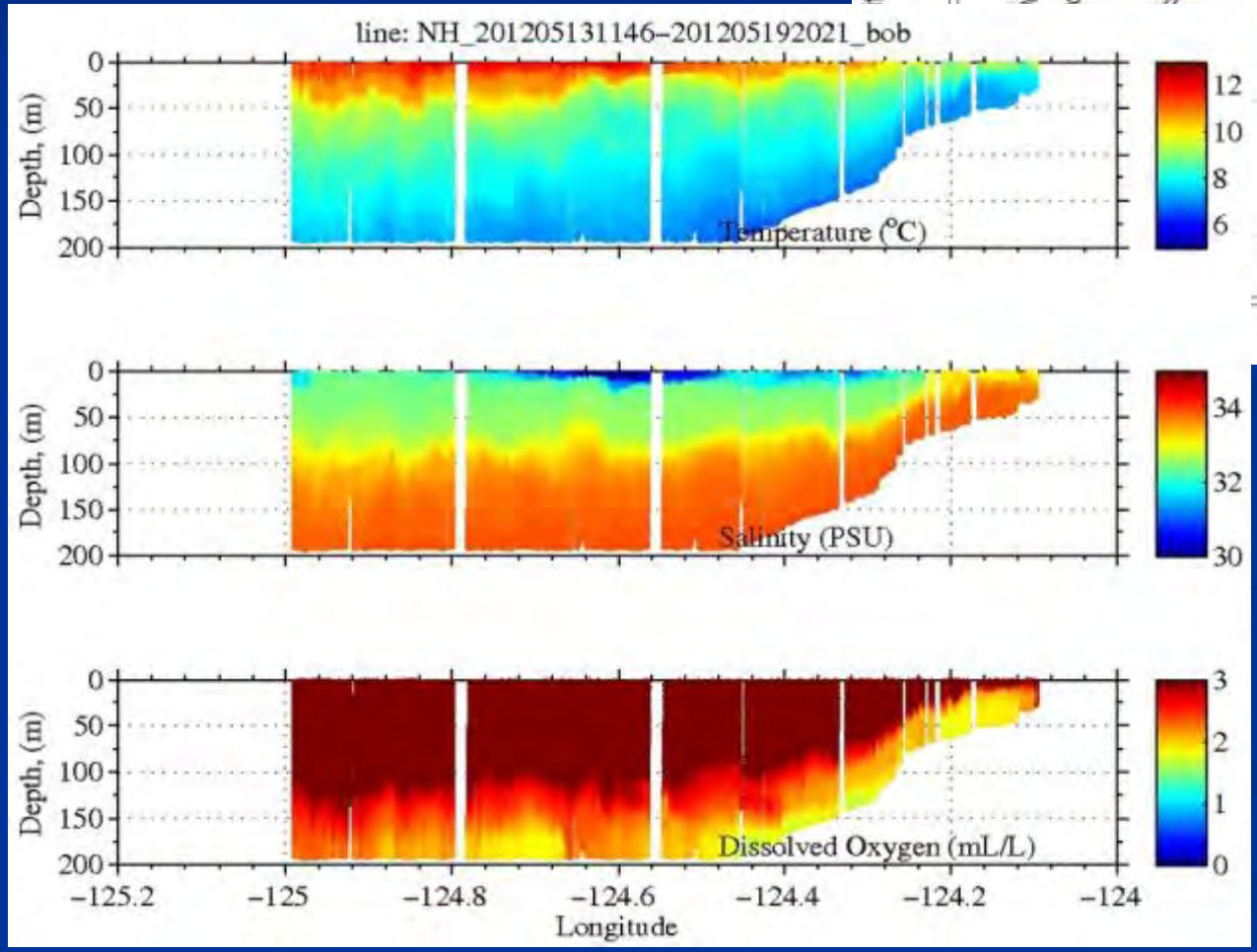
- April 2006– July 2012
- 2835 glider-days
- ~800 sections
- 208,500+ vertical profiles (~4000 in archive prior to ‘05)
- 67,000+ km

**May 13-19, 2012**

Navigating across a strong upwelling jet

Note upwelling of cold, salty, low-oxygen water

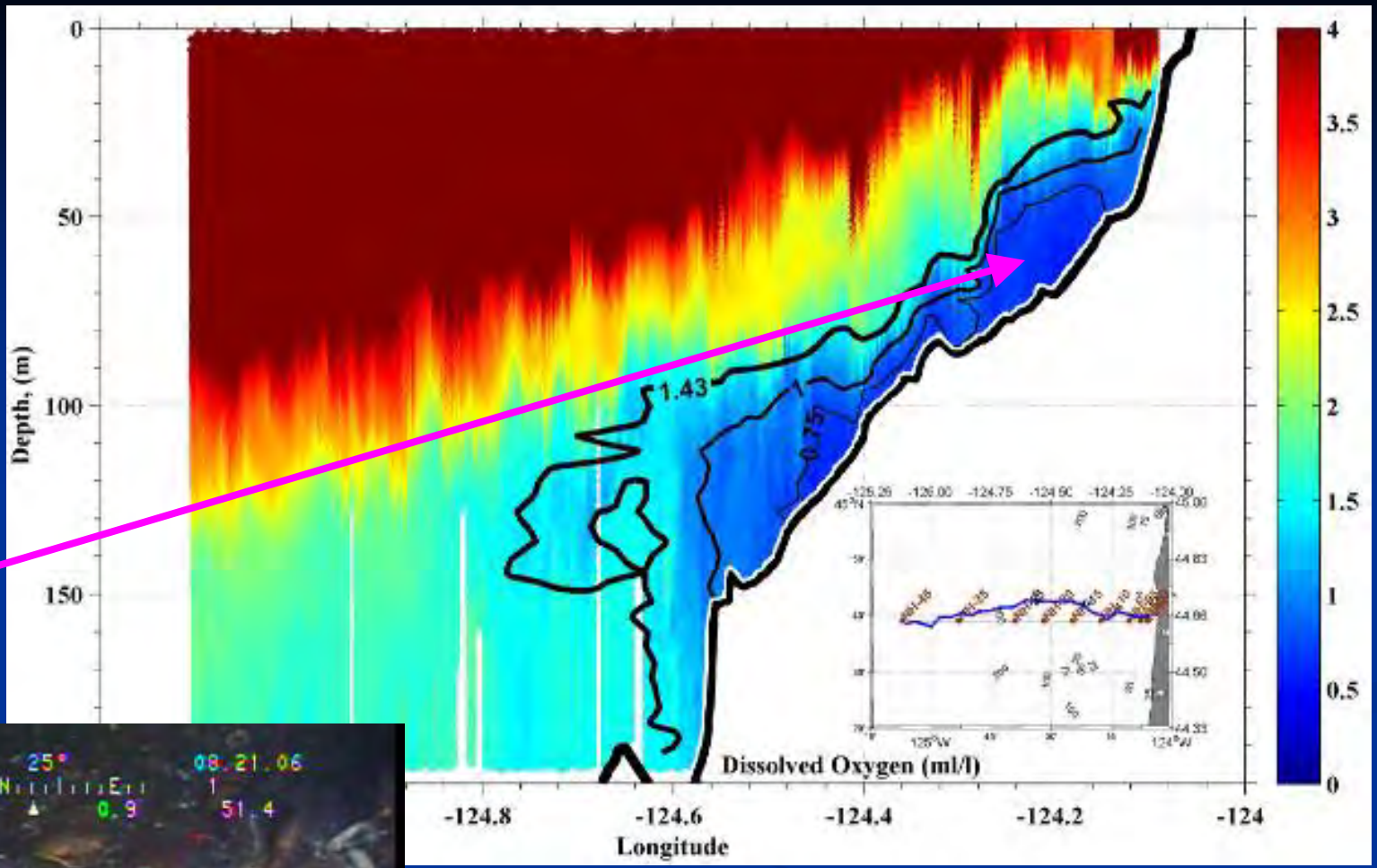



http://gliderfs2.coas.oregonstate.edu/gliderweb/

**Dissolved Oxygen from glider**

**Hypoxia**


**July 2006**

Barth et al. (in prep.)

# Spatial and Temporal Monitoring of Dissolved Oxygen in NJ Coastal Waters using AUVs

Darvene Adams
USEPA – Region 2

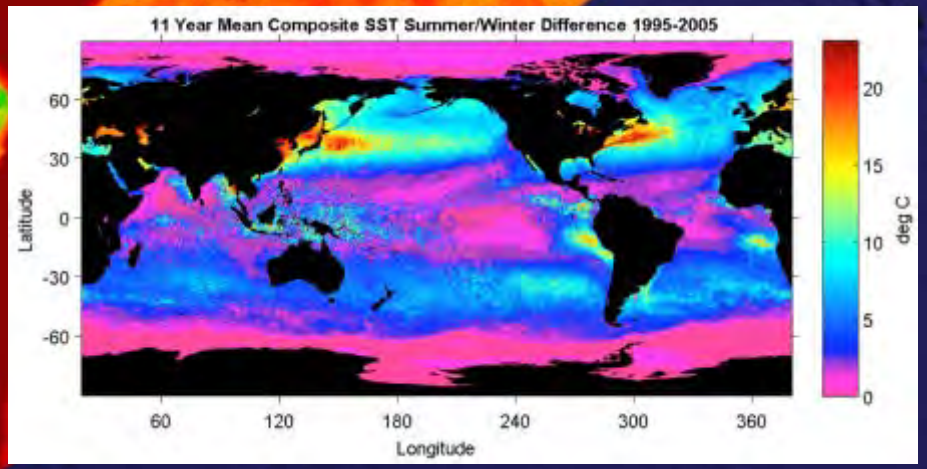
Josh Kohut
Rutgers University/MARACOOS

Robert Schuster
New Jersey Department of Environmental Protection



MARACOOS
Ocean Information for a Changing World

# Physical Oceanography of the Mid Atlantic Bight

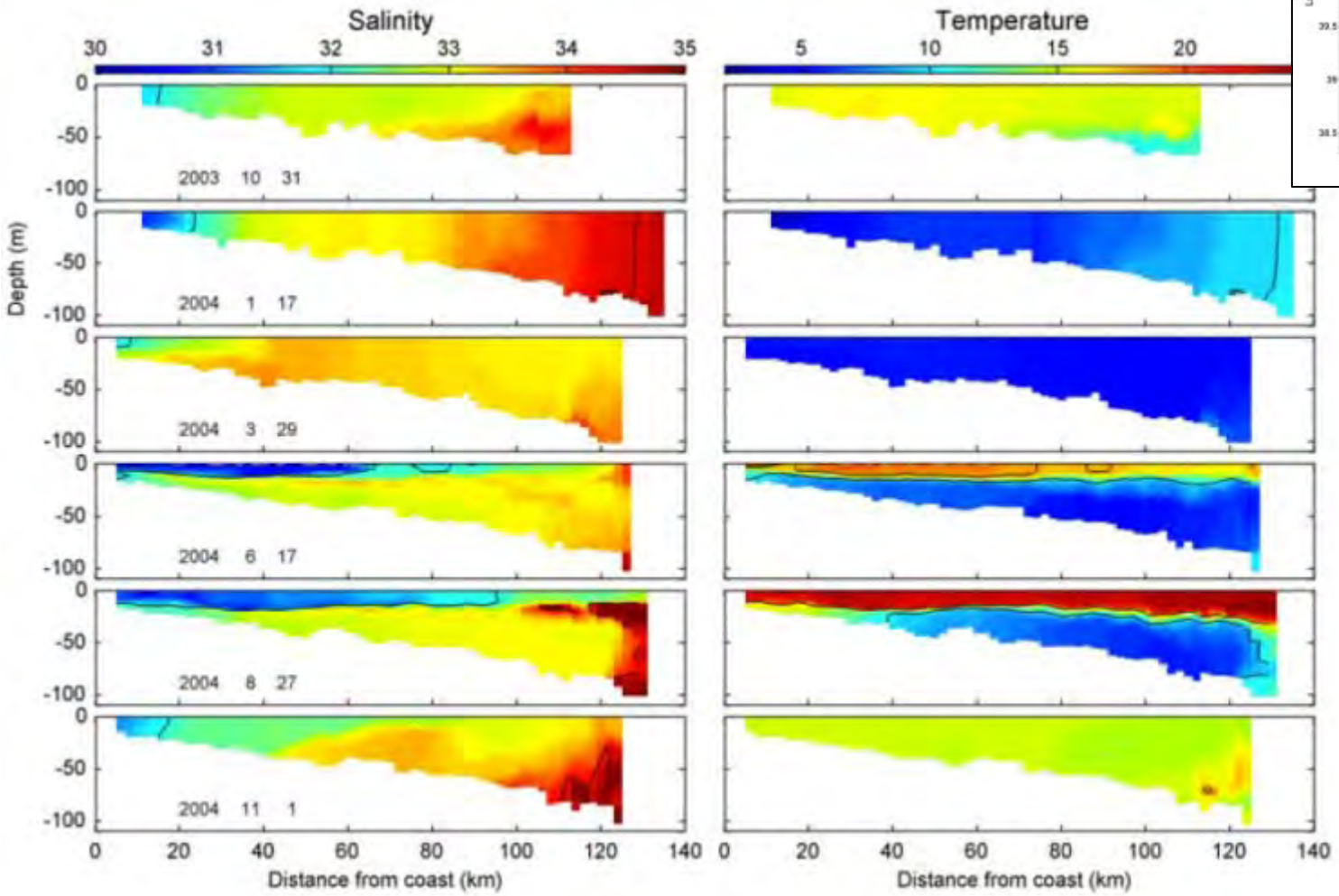


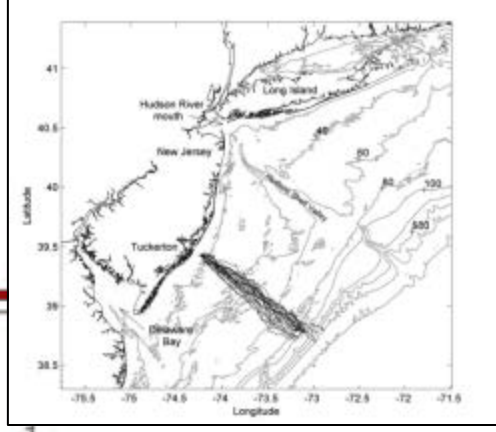

Ocean Seasonality

MARACOOS
Ocean Information for a Changing World

IOOS®
INTEGRATED OCEAN OBSERVING SYSTEM

# Seasonality

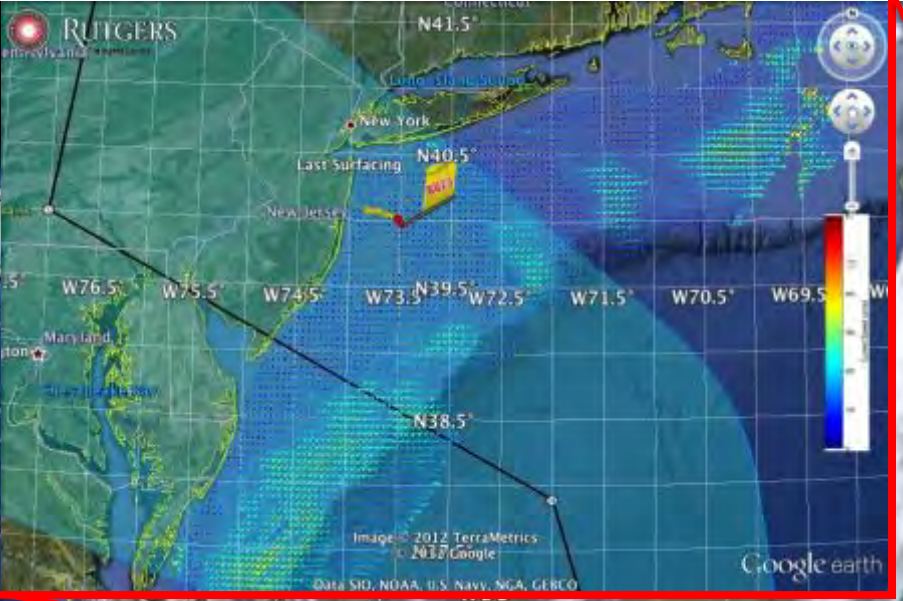


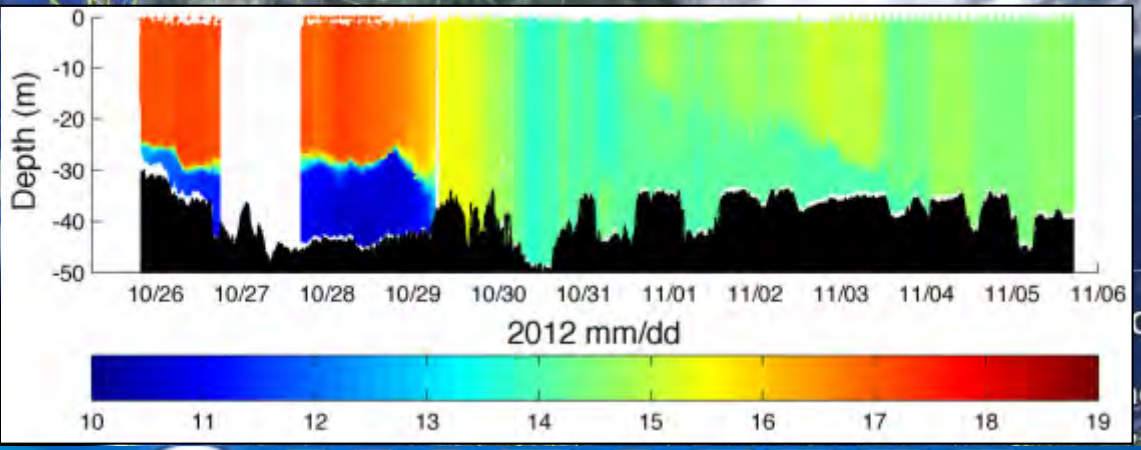




*Castelao et al. 2008*

# Hurricane Sandy

## *RU23 Glider Deployment*



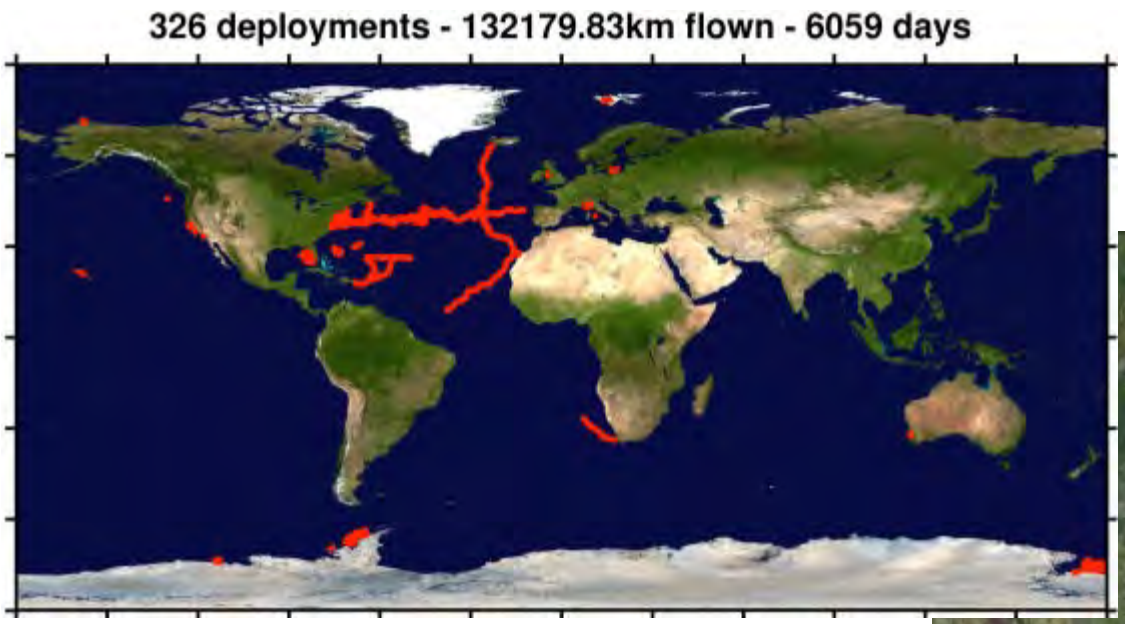





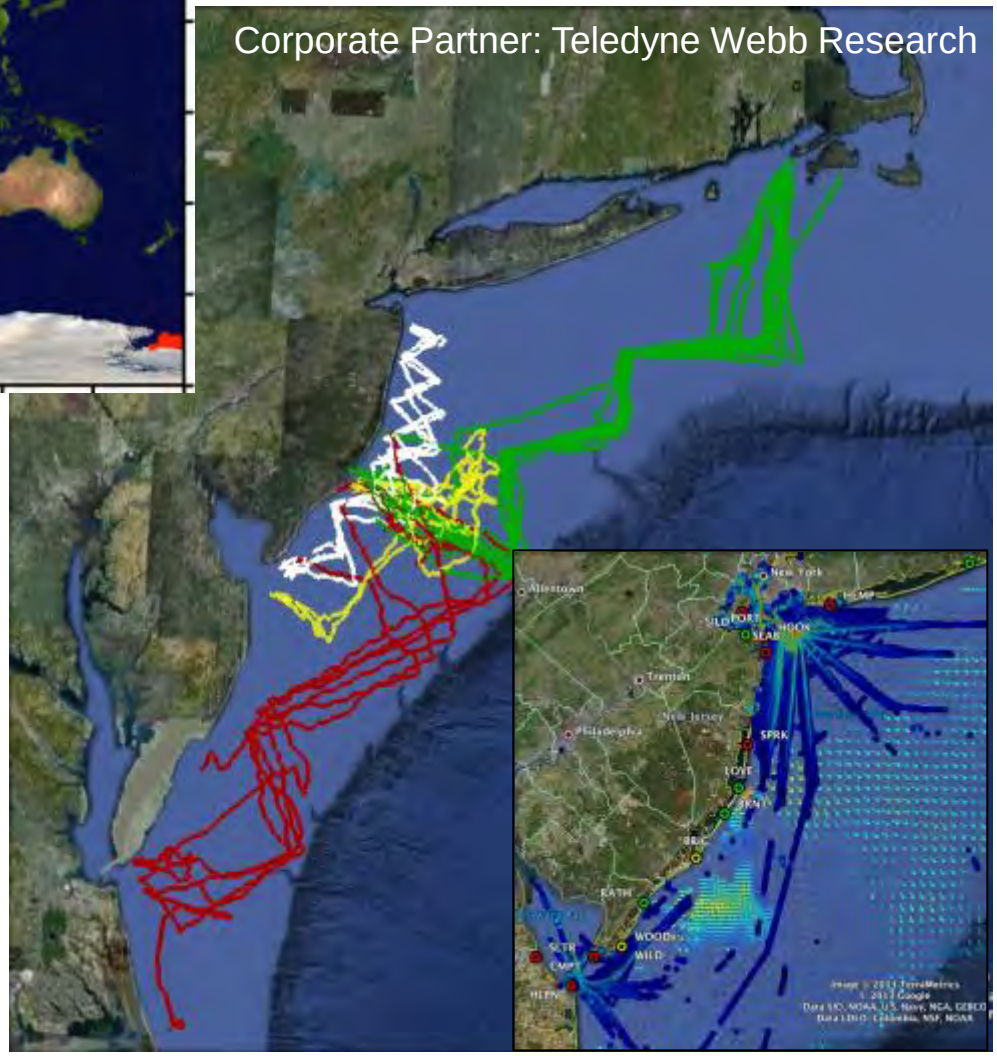

MARACOOS
Ocean Information for a Changing World

IOOS
INTEGRATED OCEAN OBSERVING SYSTEM

# Rutgers University Glider Operations Since 1998




Corporate Partner: Teledyne Webb Research



## DO Monitoring in Shallow Water (8-30m)

# Partners

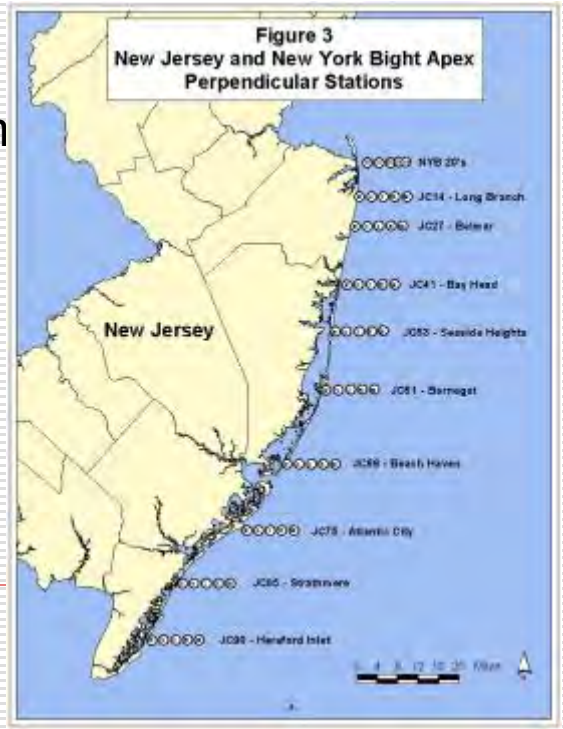
- Rutgers University – Institute of Marine and Coastal Science (IMCS)
- NJ Department of Environmental Protection
- USEPA-Office of Research and Development
- USEPA-Region 2

# Background

- Historical and current D.O. concerns
  - Fish kills
  - Harmful Algal Blooms
  - Loss of productivity and food web disruption

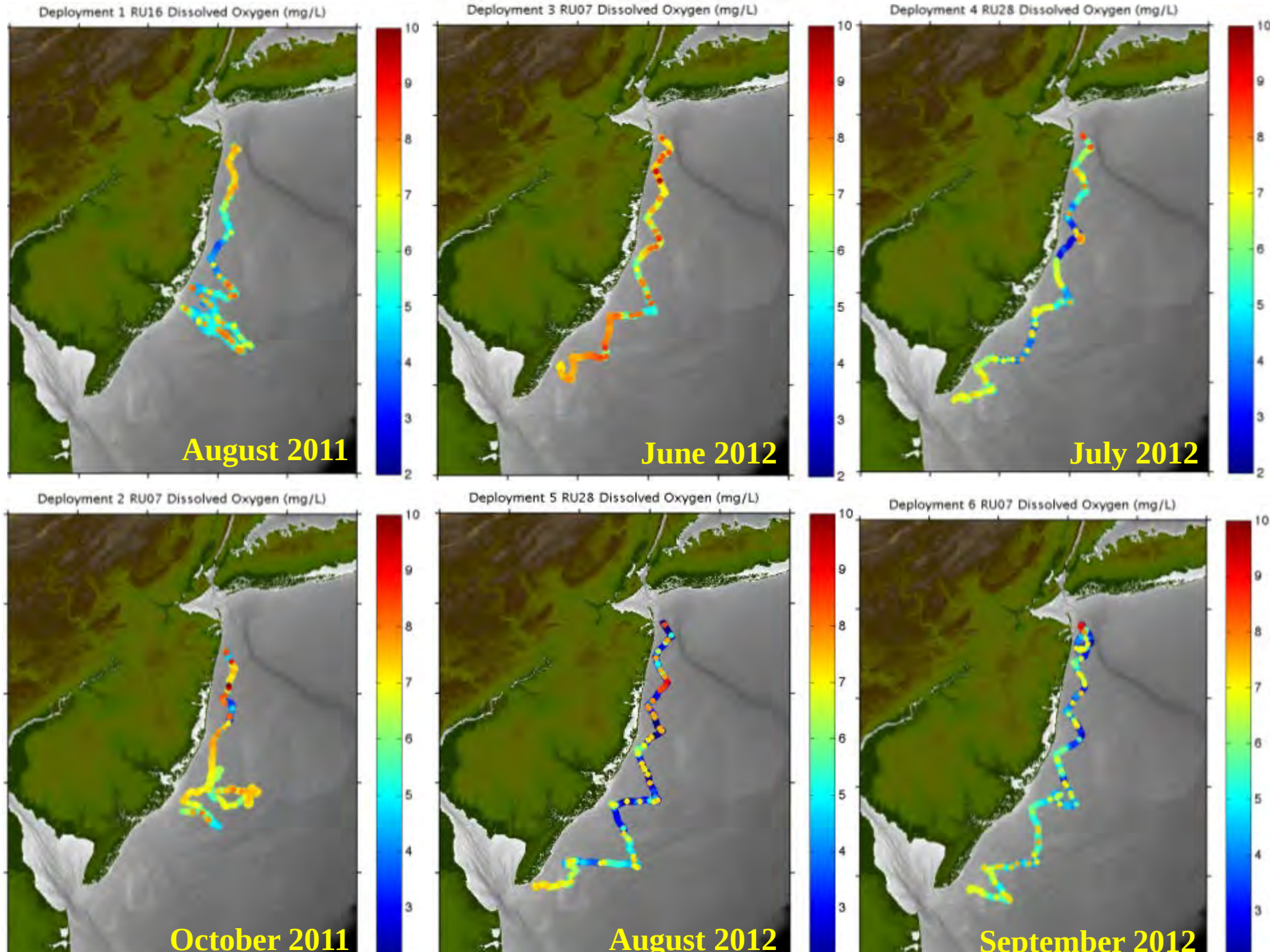
- Clean Water Act requires states report water quality impairments, identify causes and actions
  - Entire NJ coastal zone “impaired” for D.O.
    - Temporal and spatial extent not known

- Existing D.O. monitoring program eliminated
  - 1977 – 2005
  - Labor intensive
  - Not representative



# Project Objectives

- Evaluate the use of AUVs/real-time sensors to continuously monitor D.O. over a broad spatial area for regulatory purposes
- Support the development of a numeric endpoint for D.O. in the coastal zone
- Develop SOPs and QA documentation to support EPA and state use of AUV data


Deployment 1 RU16 Dissolved Oxygen (mg/L)
August 2011
Deployment 3 RU07 Dissolved Oxygen (mg/L)
June 2012
Deployment 4 RU28 Dissolved Oxygen (mg/L)
July 2012
Deployment 2 RU07 Dissolved Oxygen (mg/L)
October 2011
Deployment 5 RU28 Dissolved Oxygen (mg/L)
August 2012
Deployment 6 RU07 Dissolved Oxygen (mg/L)
September 2012
10
9
8
7
6
5
4
3
2

# Autonomous Platforms: Dissolved Oxygen 2011-2012

Spatial and Temporal Monitoring of Dissolved Oxygen (DO) in New Jersey Coastal Waters Using AUVS

Data Quality Assurance Project Plan

Prepared by: 7/12/2011
Dr. Josh T. Kohut, Rutgers project lead
Rutgers, The State University of New Jersey
New Brunswick, NJ 08901

Approved by:
Michael Borst, EPA project officer, date

Approved by: 6/17/11
Daryene Adams, EPA Region 2 project technical lead, date

Approved by: 6/17/11
Carol Lynes, EPA Quality Assurance Officer, date

Approved by: 6/23/11
Robert Schuster, NJDEP technical point of contact, date

Approved by: 7/12/2011
John Kerfoot, Rutgers data management lead, date

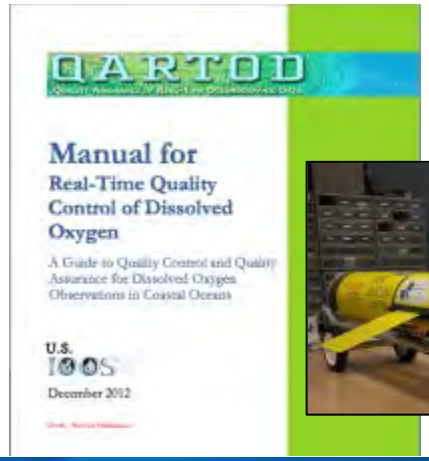
Approved by: 7/12/2011
Chip Haldeman, Rutgers glider logistics lead, date

Revision Log

| Revision Date | Reason for Revision |
|---|---|
| | |

Quality Assurance Project Plan:

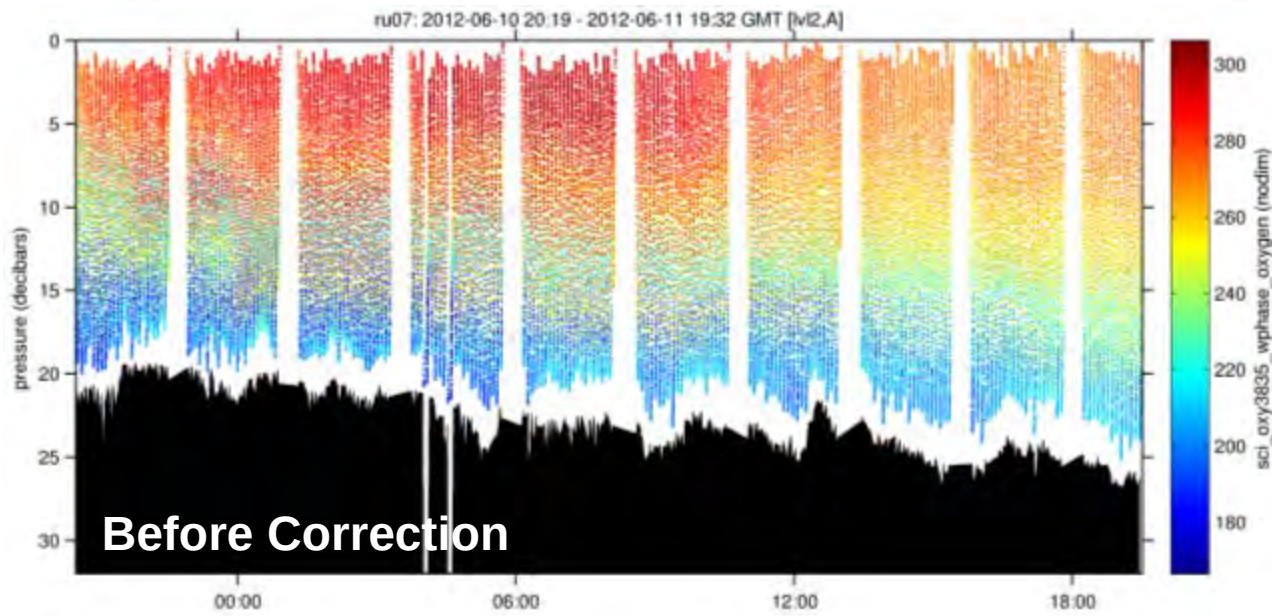
- Glider Mission Planning
- SeaBird CTD
- Aanderra Optode 3835
- Documents for pre- and post- deployment glider, CTD and DO QA

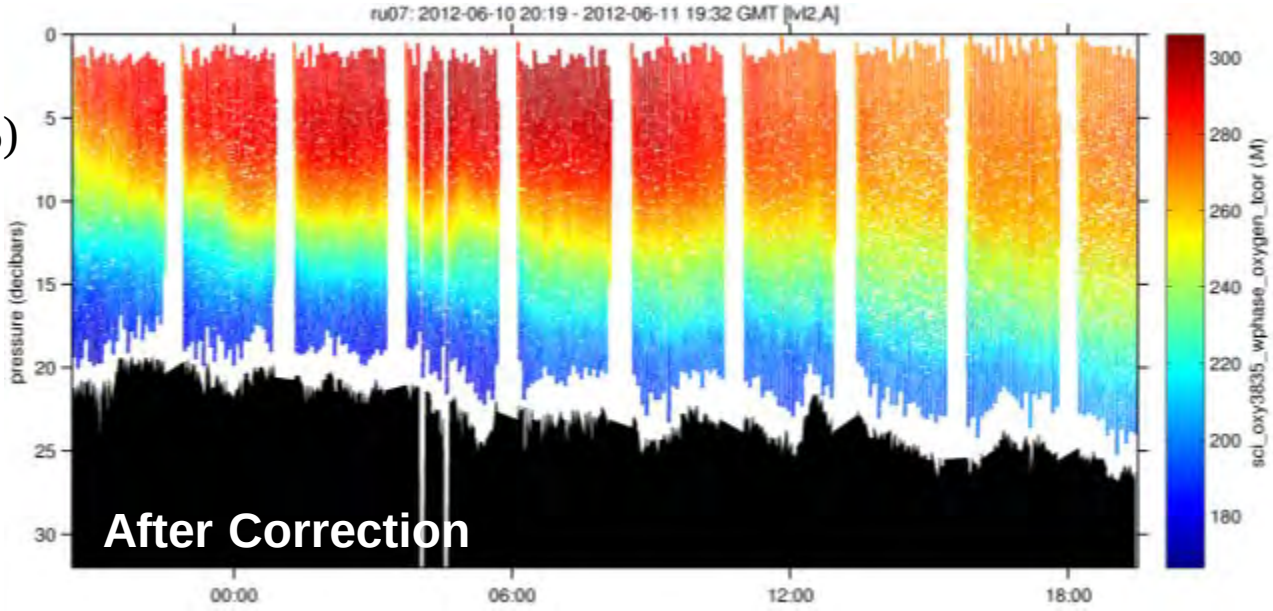



# Aanderra Optode: Real-Time Processing

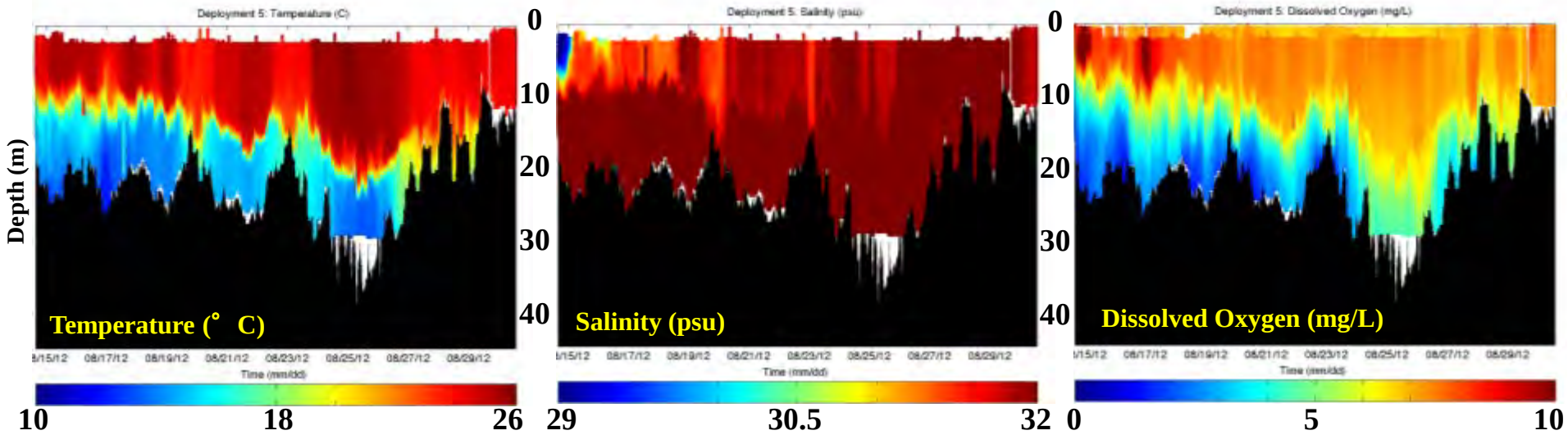
**What we now do for Real-time:**

- Annual factory calibration
- Pre- and post- deployment titration (0% & 100%)
- Use up and downcasts to apply sensor offset



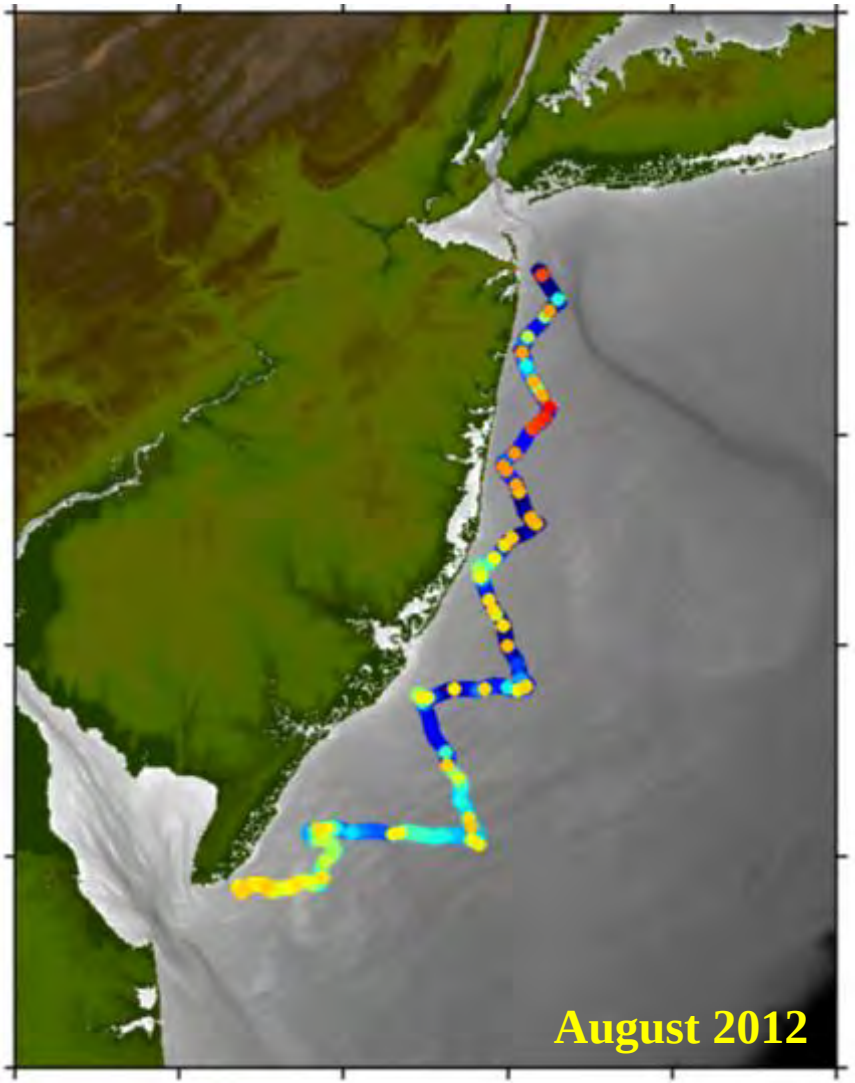
# Mission Summaries – Data Mean and Range

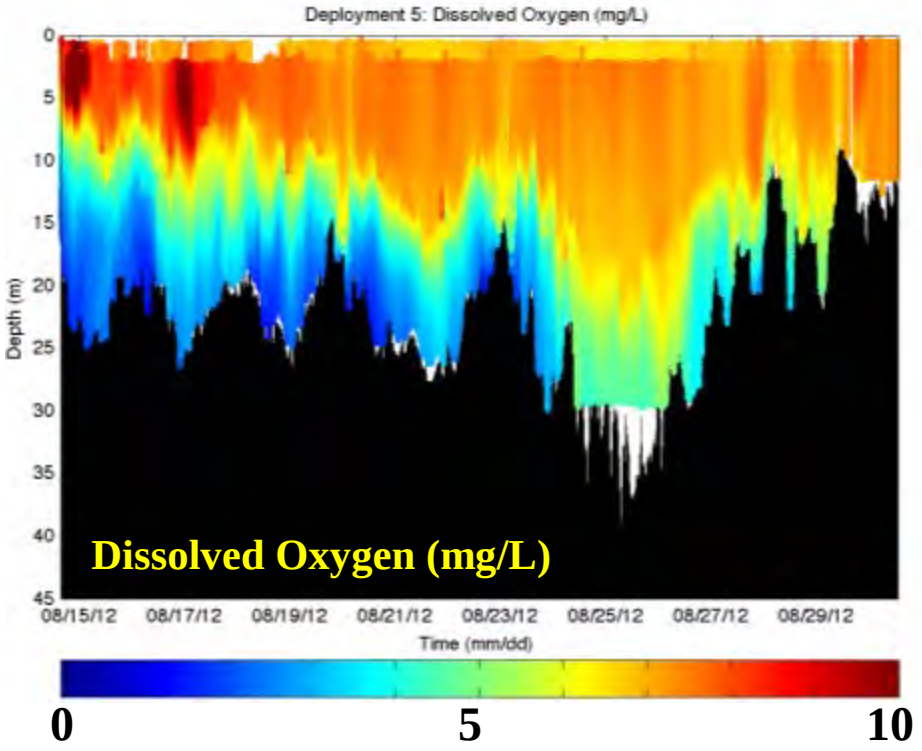



| | | | | | Temperature | | Salinity | |
|---|---|---|---|---|---|---|---|---|
| Deployment | Deployment | Recovery | Length (Days) | # Profiles | Min | Max | Min | Max |
| #1 | August 10, 2011 | September 9, 2011 | 30 | 3,952 | 9.3 | 25.2 | 29.3 | 33.3 |
| #2 | October 6, 2011 | October 27, 2011 | 21 | 6,757 | 15.5 | 20.1 | 25.5 | 32.8 |
| #3 | June 7, 2012 | June 19, 2012 | 12 | 6,636 | 11.3 | 20.5 | 27.7 | 32.9 |
| #4 | July 10, 2012 | July 30, 2012 | 20 | 14,641 | 12.3 | 26.5 | 29.7 | 33.2 |
| #5 | August 14, 2012 | August 30, 2012 | 16 | 9,084 | 12.2 | 26 | 28.1 | 33 |
| #6 | September 13, 2012 | October 4, 2012 | 21 | 11,577 | 11 | 23.8 | 29.3 | 35.1 |

| | Dissolved Oxygen | | Mean Temperature | | Mean Salinity | | Mean Dissolved Oxygen | |
|---|---|---|---|---|---|---|---|---|
| Deployment | Min | Max | Surface | Bottom | Surface | Bottom | Surface | Bottom |
| #1 | 3.07 | 9.23 | 22.6 | 14.2 | 30.5 | 31.7 | 7.7 | 4.81 |
| #2 | 1.73 | 11.76 | 17.9 | 17.5 | 29.7 | 30.7 | 7.74 | 5.82 |
| #3 | 4.07 | 12.43 | 19.3 | 16.6 | 31 | 31.7 | 8.34 | 6.71 |
| #4 | 1.88 | 9.81 | 24.3 | 18.4 | 31.5 | 32 | 7.29 | 4.87 |
| #5 | 0.94 | 12.7 | 24.5 | 17.4 | 31.7 | 32.1 | 7.42 | 3.87 |
| #6 | 0.82 | 13.29 | 20.8 | 16.8 | 31.9 | 32.3 | 7.1 | 4.2 |

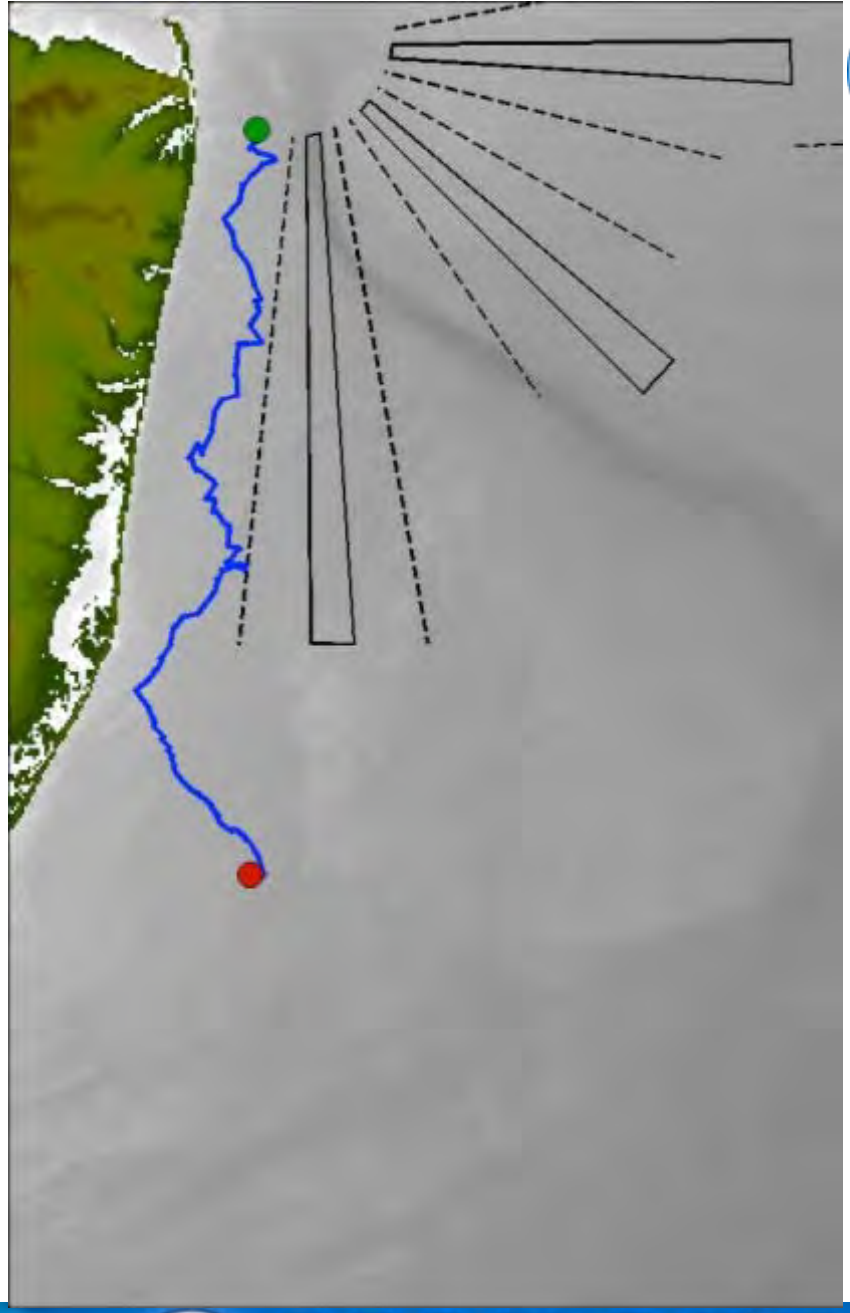
# Decorrelation Scales – Top and Bottom

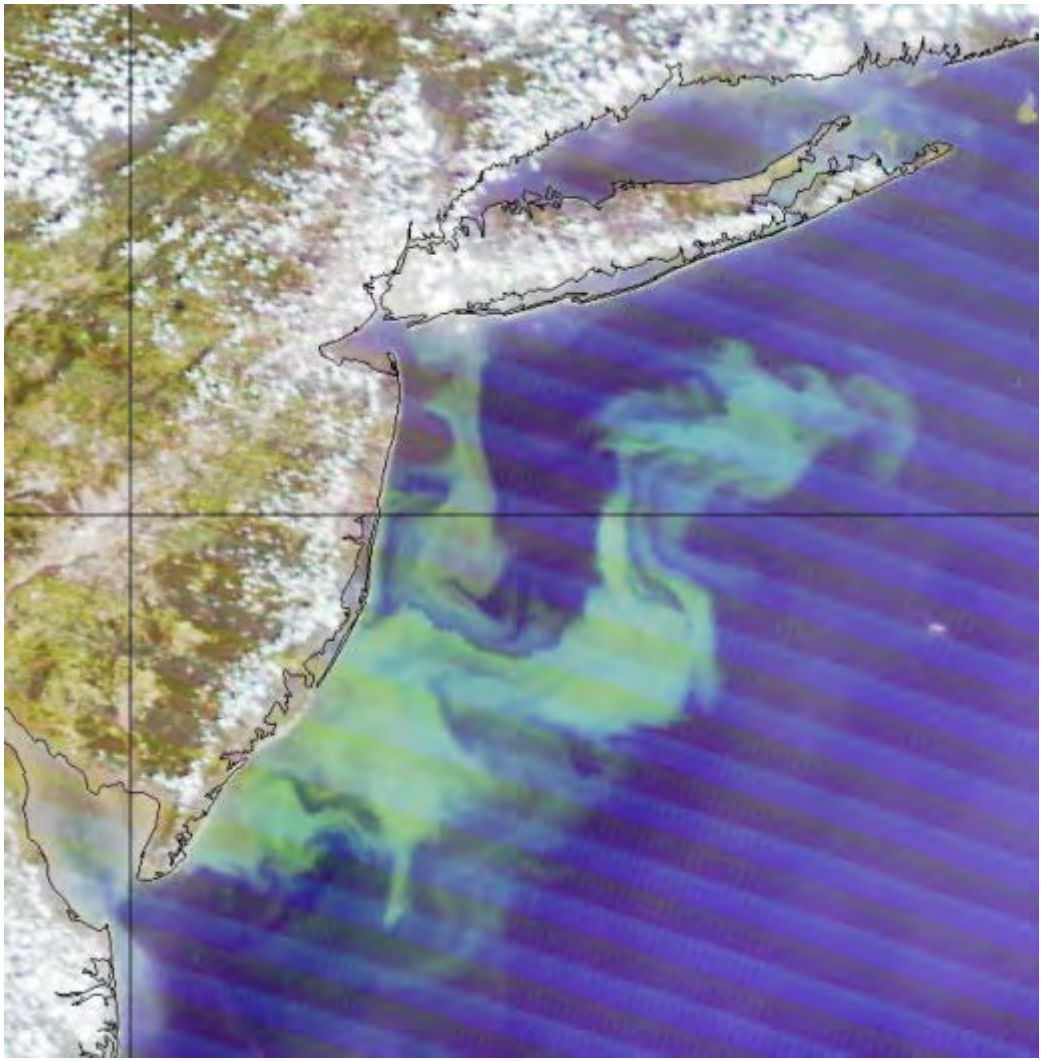


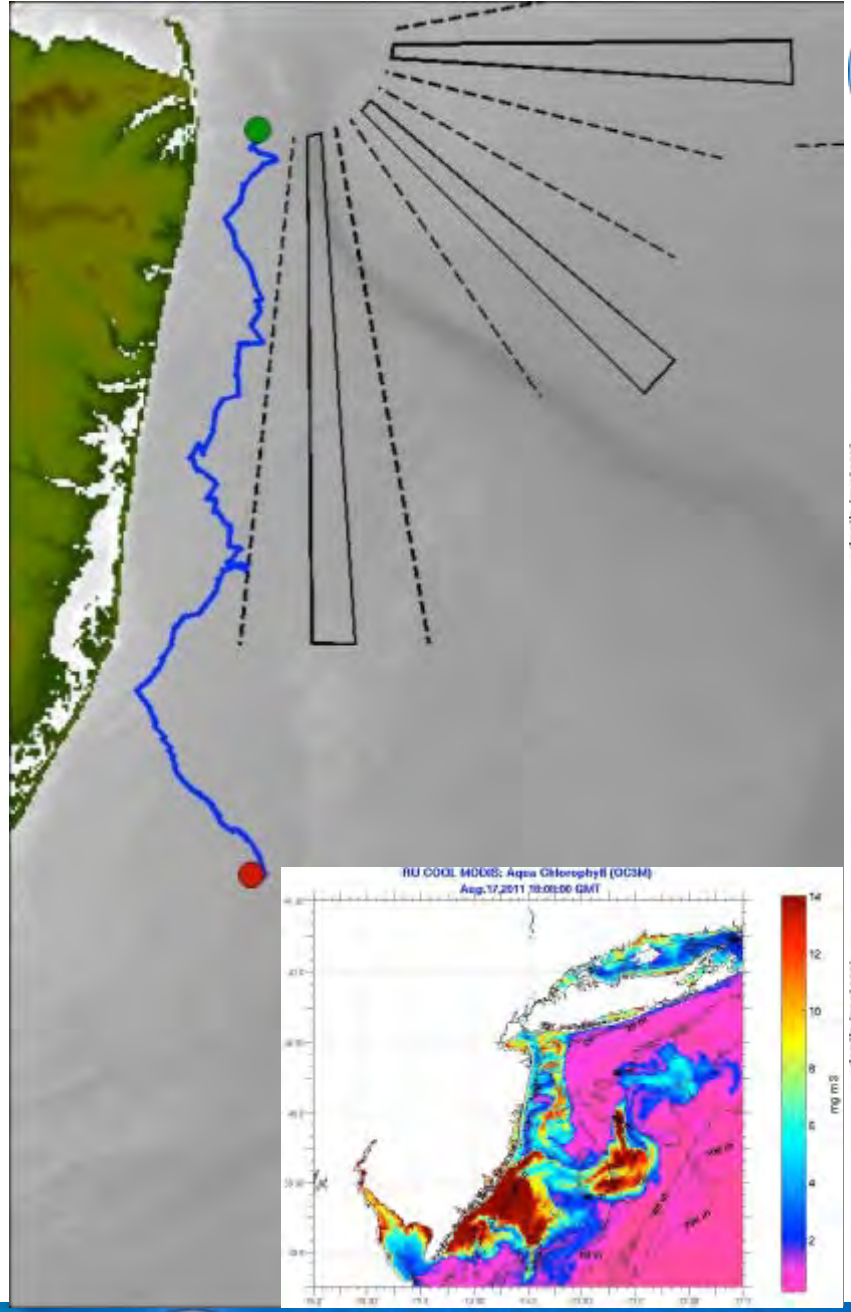

| | Space Scales (km) | |
|---|---|---|
| | Surface | Bottom |
| Deployment 1: August 2011 | 62.0 | 70.6 |
| Deployment 2: October 2011 | 76.7 | 77.5 |
| Deployment 3: June 2012 | 77.9 | 74.1 |
| Deployment 4: July 2012 | 49.8 | 62.9 |
| Deployment 5: August 2012 | 97.9 | 107.5 |
| Deployment 6: September 2012 | 38.0 | 162.8 |
| **Project Average** | **67.1** | **92.6** |

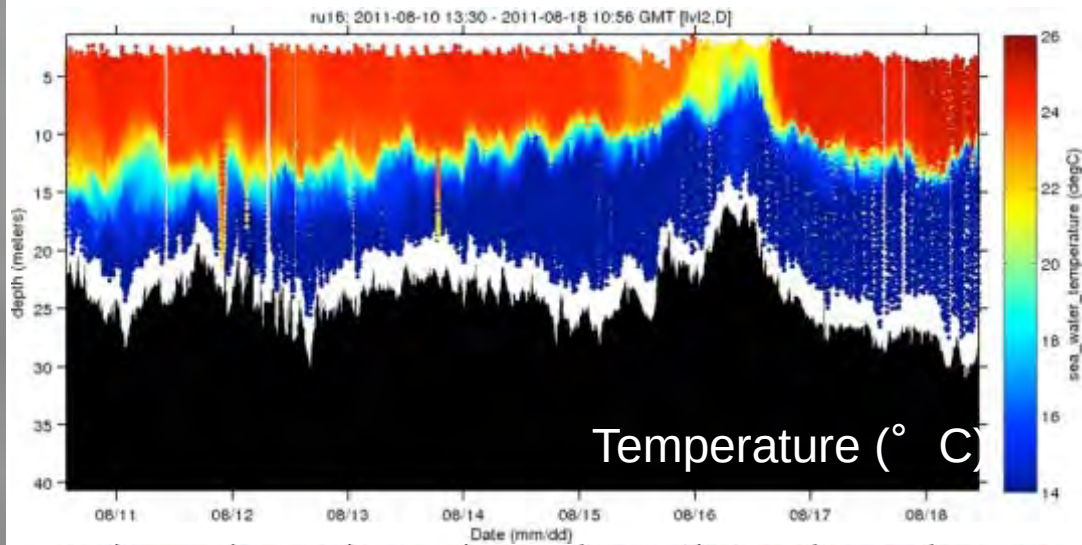
# Autonomous Platforms: Dissolved Oxygen 2011-2012

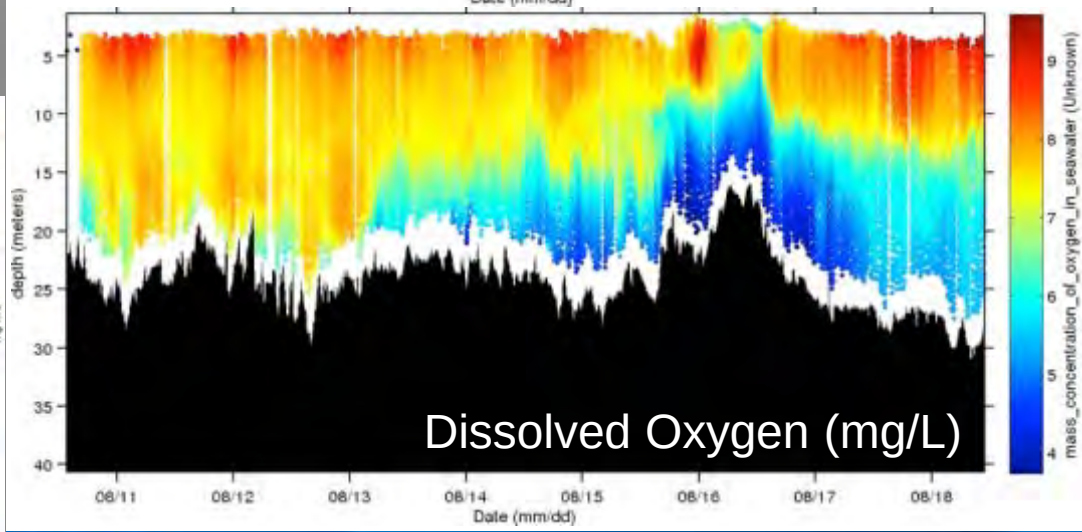




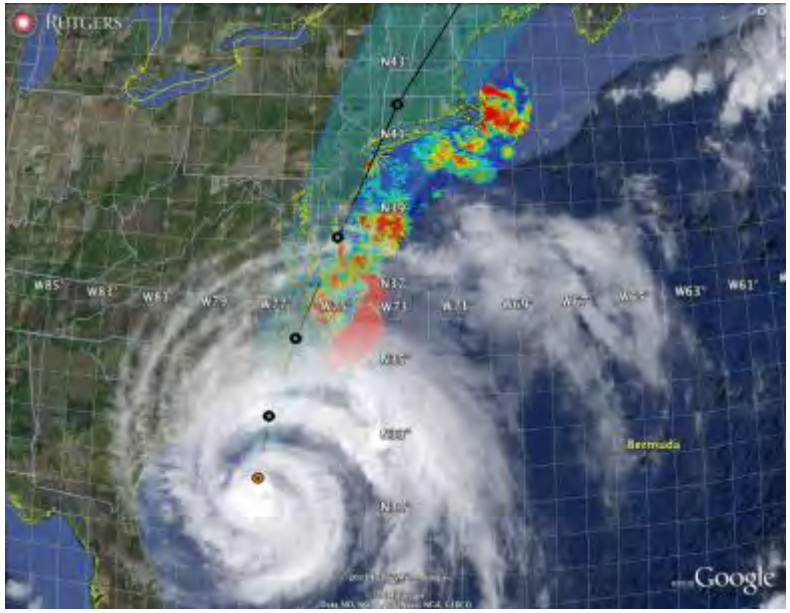
# Autonomous Platforms: Dissolved Oxygen 2011-2012

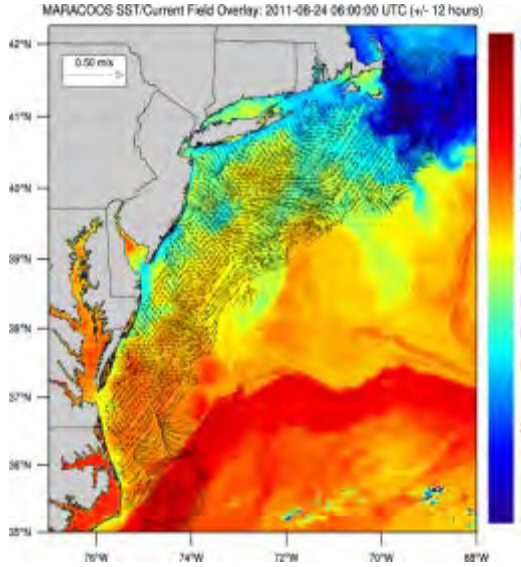


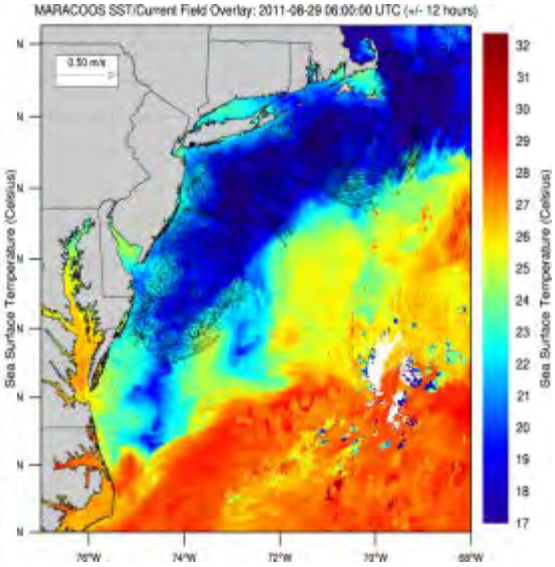



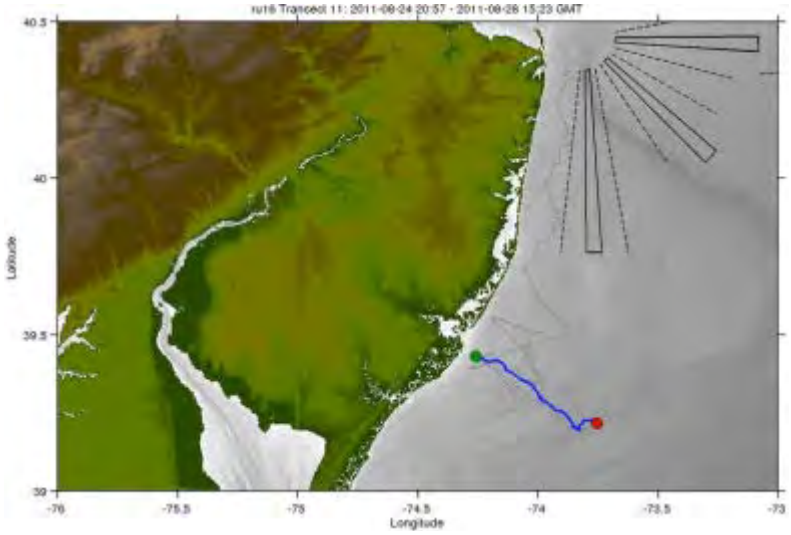



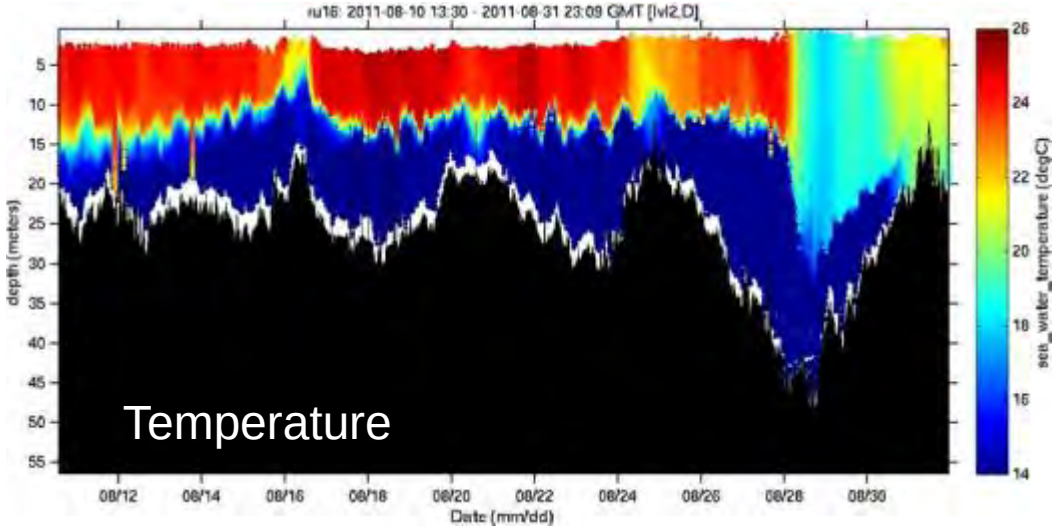
# Water Quality – Tracking Hurricane Irene



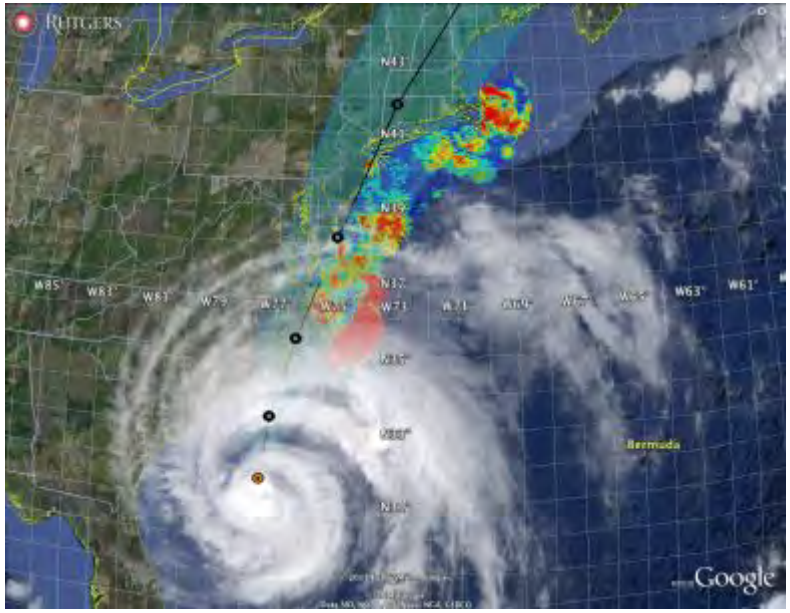



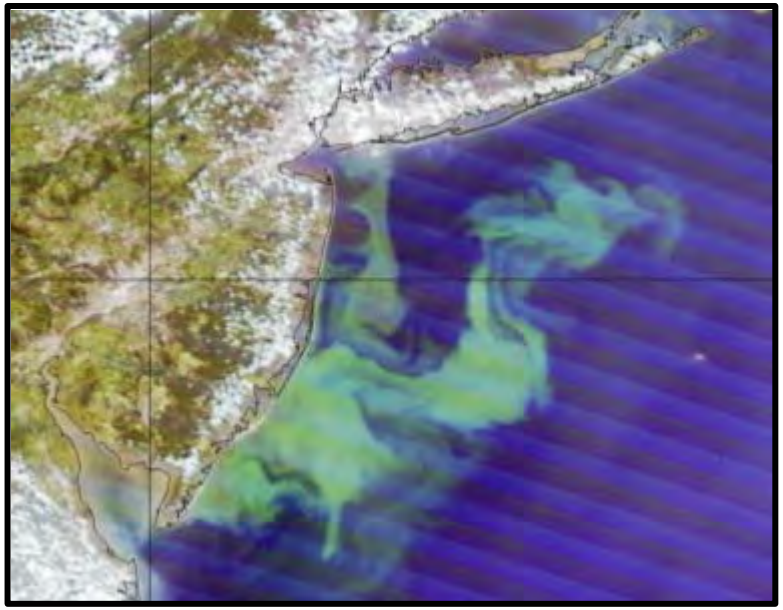



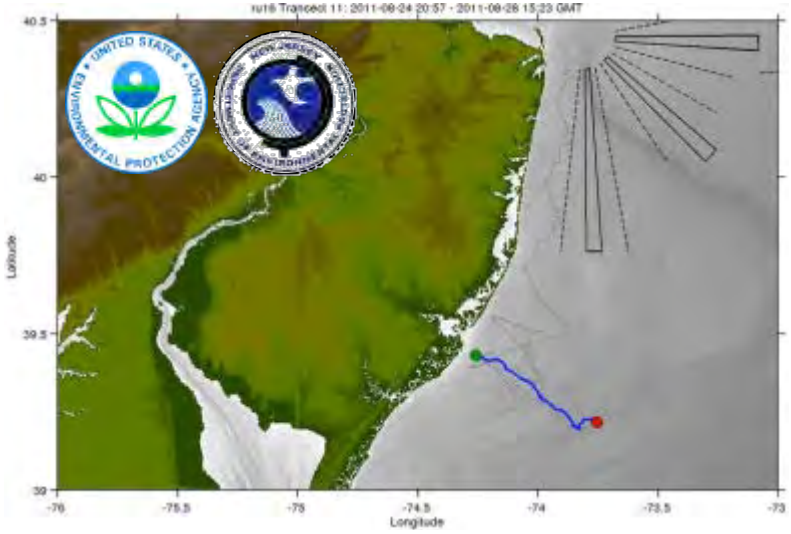



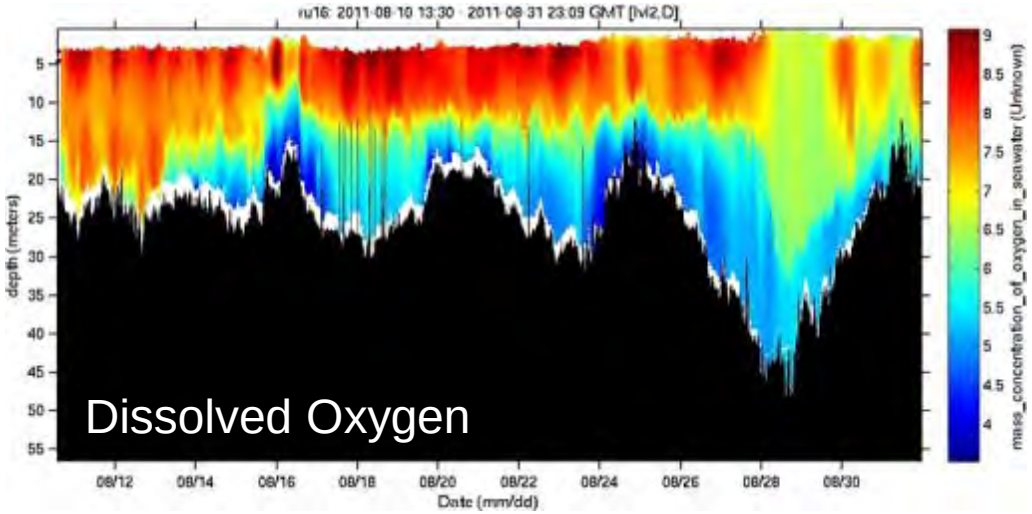



# Water Quality – Tracking Hurricane Irene

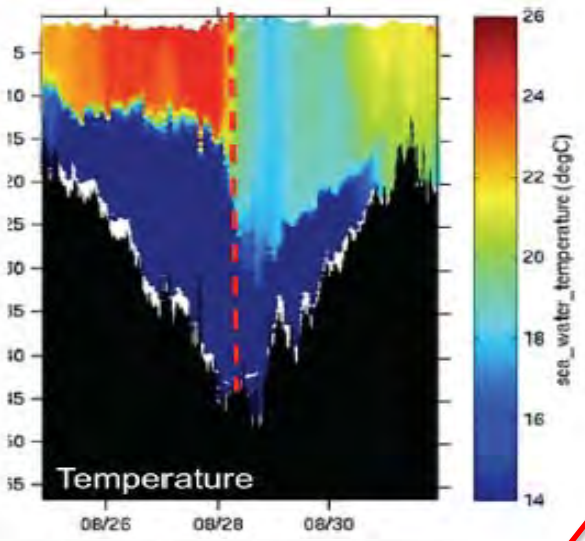


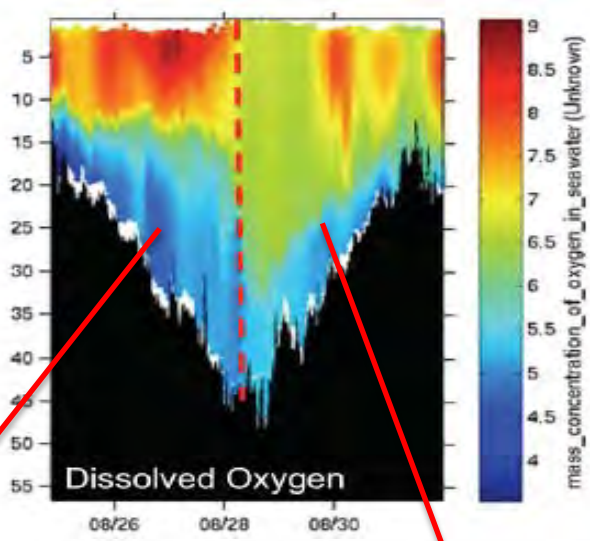



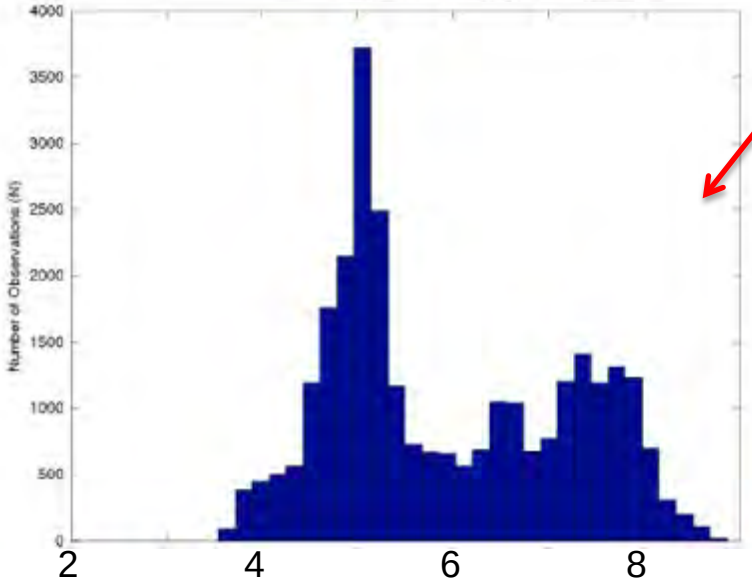


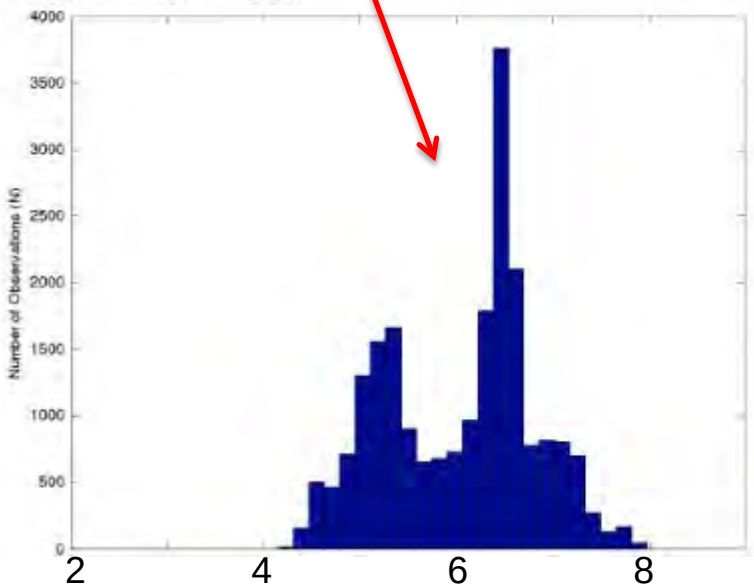



# Water Quality – Tracking Hurricane Irene




Dissolved Oxygen (mg/L)

# Lessons learned (Oregon State Univ. glider group)

- **Be considerate of glider team re: 24/7/365; burnout is an issue**
- **Communicate with ocean users to tell them about gliders, what they look like, and what they can measure**
- **Never give up on a "lost" glider → "fail safes" are amazing**
- **Make use of all data you can get your hands on for operations (wind, waves, currents, freshwater discharge, forecasts); this is the IOOS paradigm**
- **Gliders and glider data need attention**
  - **Compass calibrations**
  - **Winkler-based lab calibrations of glider dissolved oxygen sensors between missions**
  - **Test, prepare, analyze, & calibrate yourselves**

# Future Needs

- QA/QC procedures
  - Quality Assurance Project Plan (QAPP)
  - Additional verification of results?
- Data Analysis
  - Specifically for CWA assessment
- Data Management
  - Include aircraft and satellite data

Summary:

- Water Quality Monitoring and Event Response is coordinated through an IOOS partnership of local, state, and federal entities.
- Quality Assurance is maintained for real-time data as indicated in the Quality Assurance Project Plan