TURNER DESIGNS
Reliable Instruments for an Unreliable World

Fluorometers; Experiences with Autonomous Vehicles

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Outline

- Fluorometers specifically designed for system-level integration
- Fluorometer calibration: objectives, methods and limitations
- PacX Mission Introduction
- PacX Scientific Highlights: Open Ocean Phytoplankton Bloom
- PacX Scientific Highlights: Intersection with Tropical Cyclone Freda
- Slocum Glider Darwin: Fluorometer Intercomparison
- Navocean: HAB mapping
- Acknowledgements/References

Fluorometers for Integration

Desirable characteristics of a fluorometer intended for system level integration:

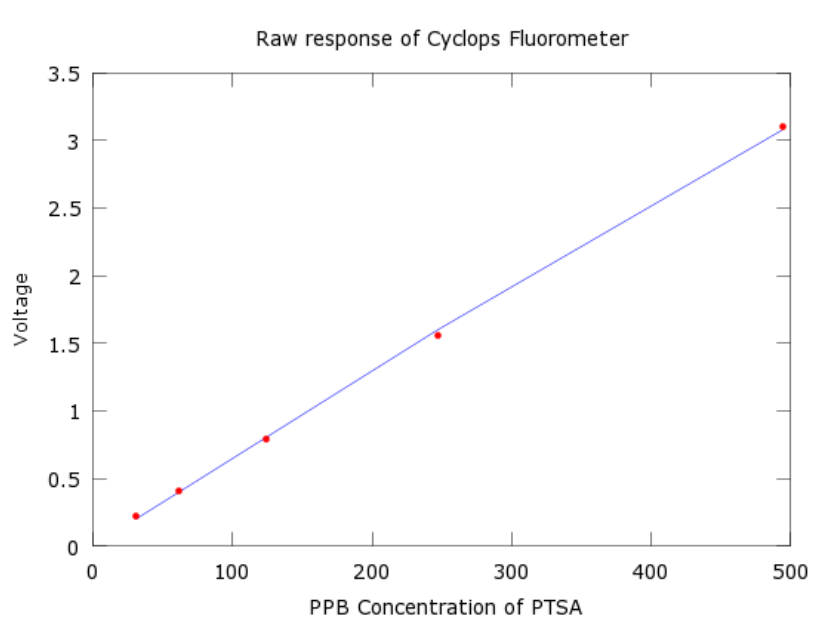
- Low Power !
- Configurable (form factor and optics)
- Anti Biofouling (wiper, copper, uv irradiation)

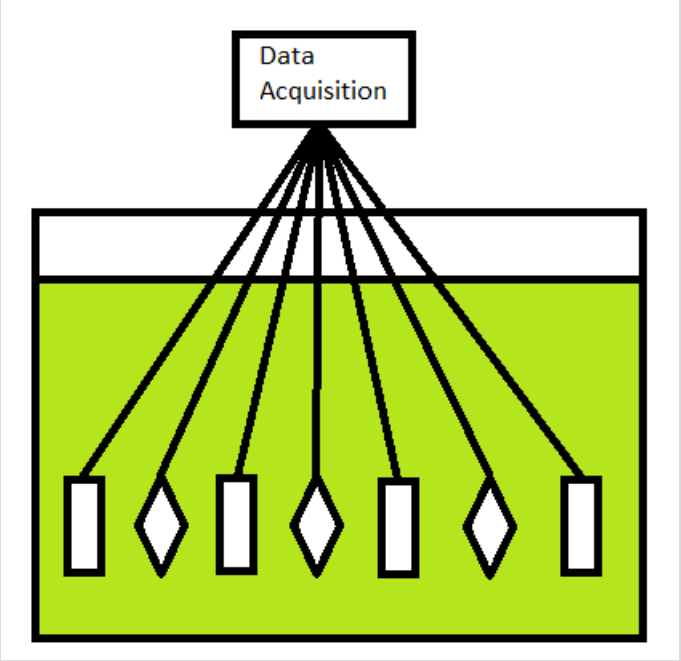
Manufacturer	Model	Max Current Draw
Turner Designs	Cyclops Integrator	80 mA
WET Labs	ECO Triplet	60 mA
Turner Designs	Cyclops	25 mA

Fluorometer Calibration

Objectives behind the calibration of a fluorometer:

- Monitor stability of instrument before and after a deployment
- Convert raw response to be representative of organisms being measured





PacX Mission Introduction

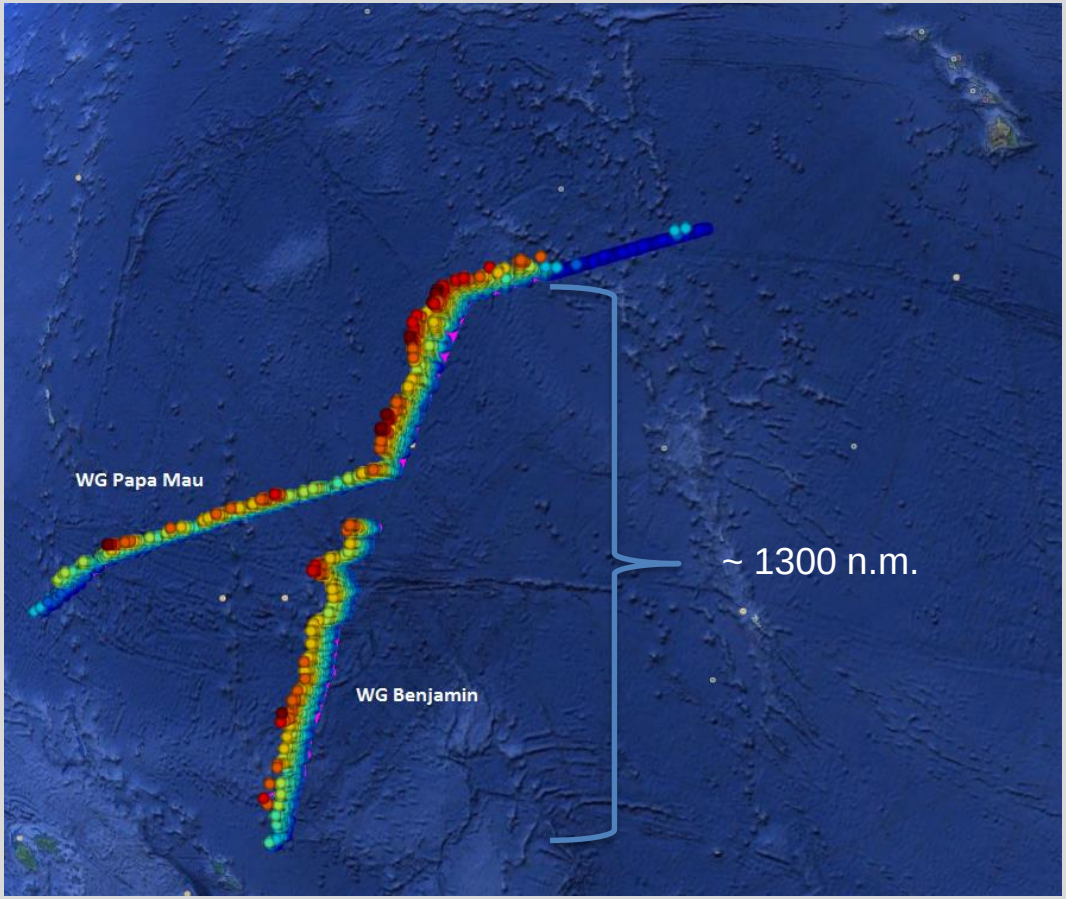
On November 17th 2011, Liquid Robotics launched 4 Wave Gliders from San Francisco with the goal of 2 traveling to Japan and 2 traveling to Australia

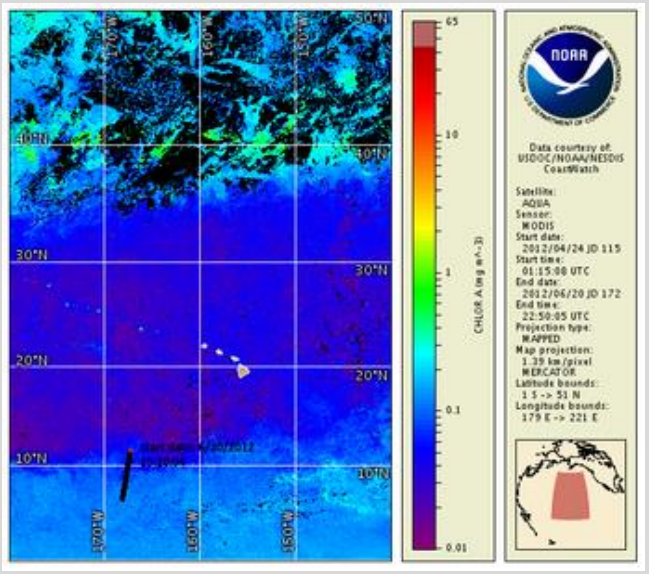
Each vehicle carried identical scientific payloads including a CTD, weather station, wave sensor, and a Turner Designs C3 Fluorometer. In addition to collecting millions of data points, a Guinness world record was set !

Furthest Distance traveled by an Unmanned Surface Vehicle: 7,939 nm

PacX Mission Scientific Highlights: Open Ocean Phytoplankton Bloom

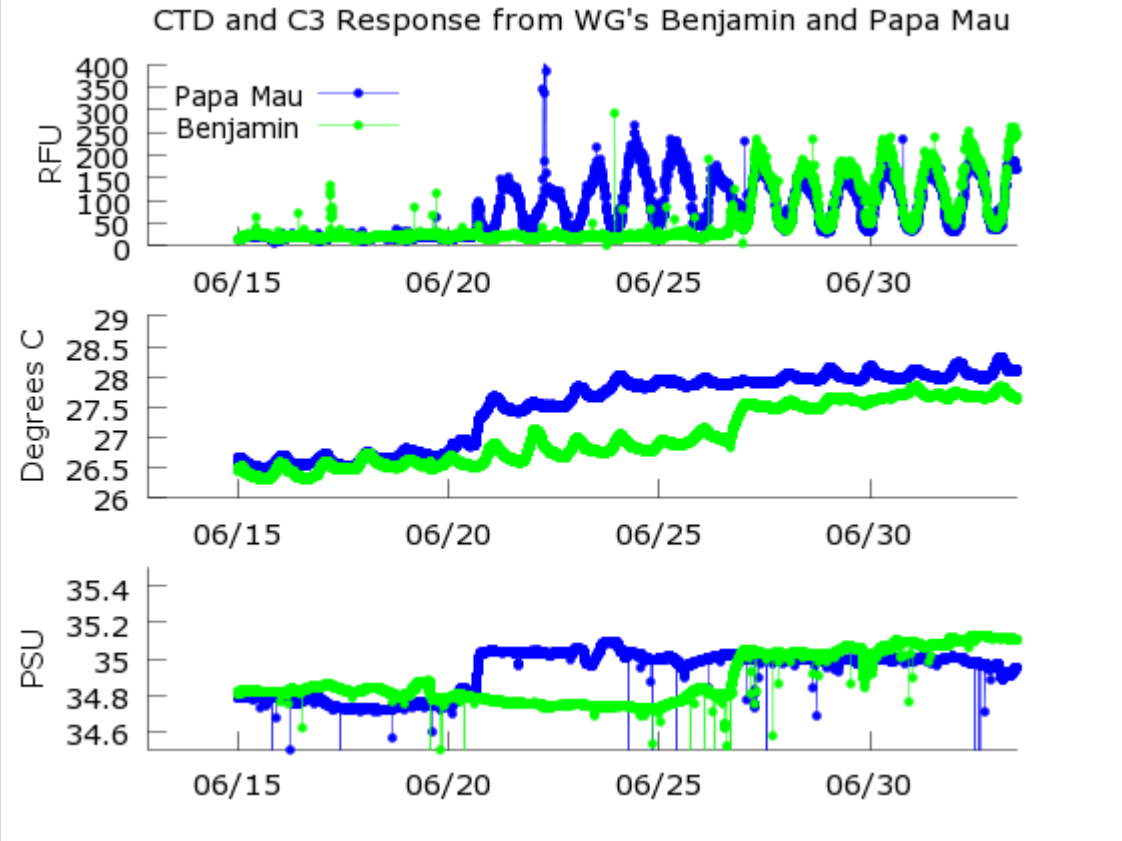
One of the scientifically critical capabilities offered by the combination of a persistent platform and reliable fluorometers is the monitoring of open ocean primary productivity





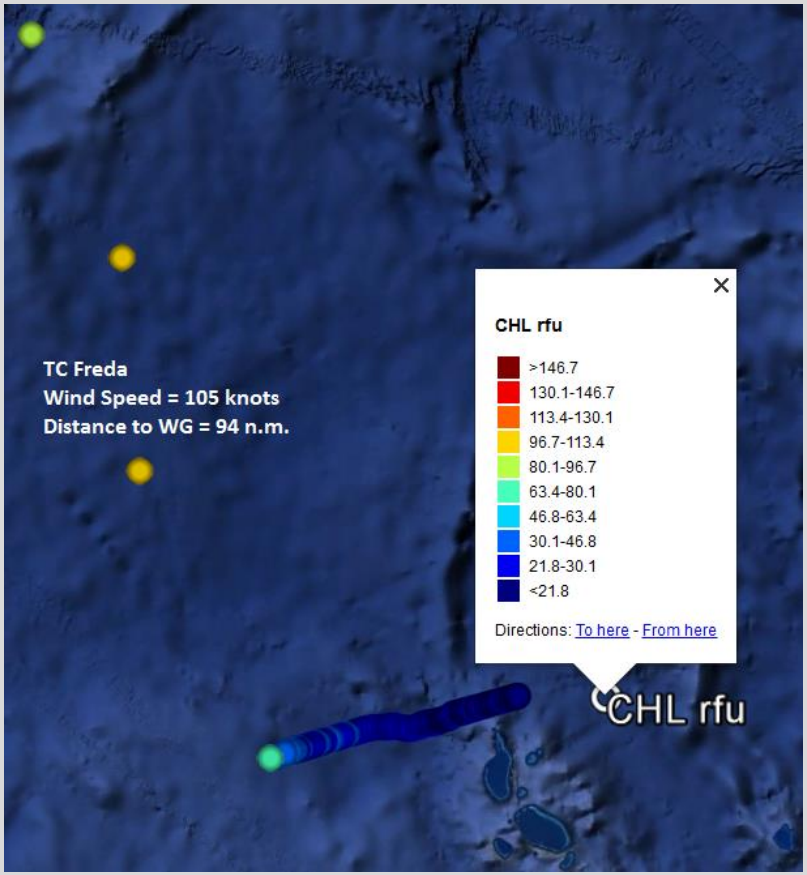
PacX Mission Scientific Highlights: Open Ocean Phytoplankton Bloom

The response to the bloom registered across multiple instruments and multiple vehicles. Wave Glider Benjamin was 1st to encounter the bloom with Papa Mau validating the measurements 6 days later. Coincidental changes in the physical and biological sensors representative of the vehicles entering the equatorial upwelling zone.

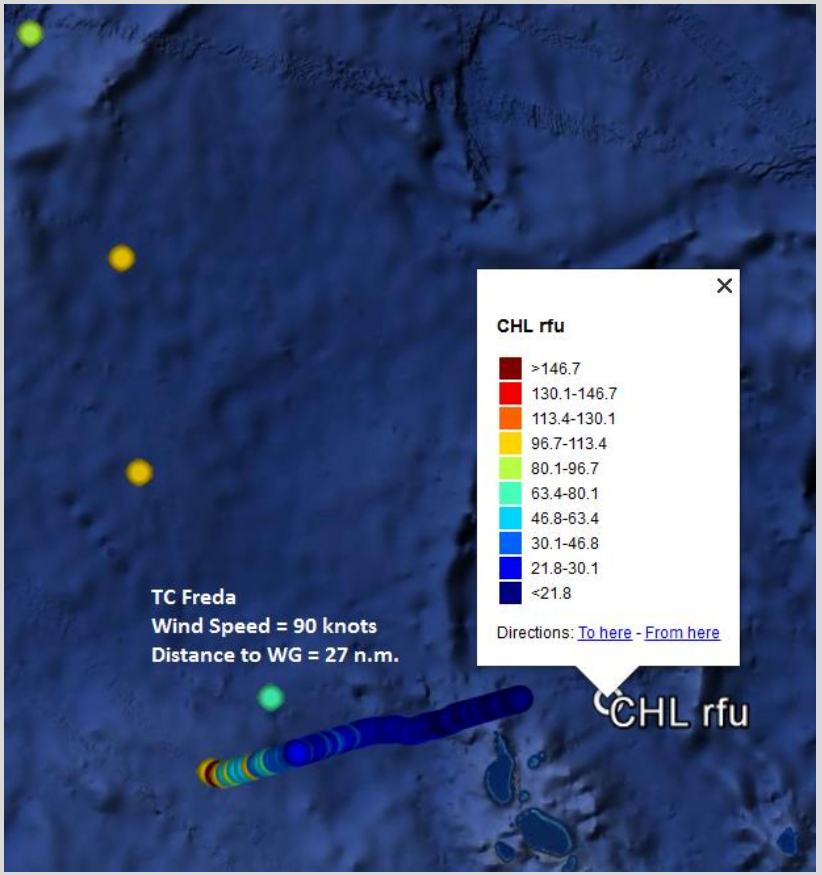


PacX Mission Scientific Highlights: Benjamin Intersection with Freda

On December 31st 2012, Benjamin encountered Tropical Cyclone Freda in the Coral Sea. Instrumentation operated during the event capturing the biological response to this significant physical forcing.



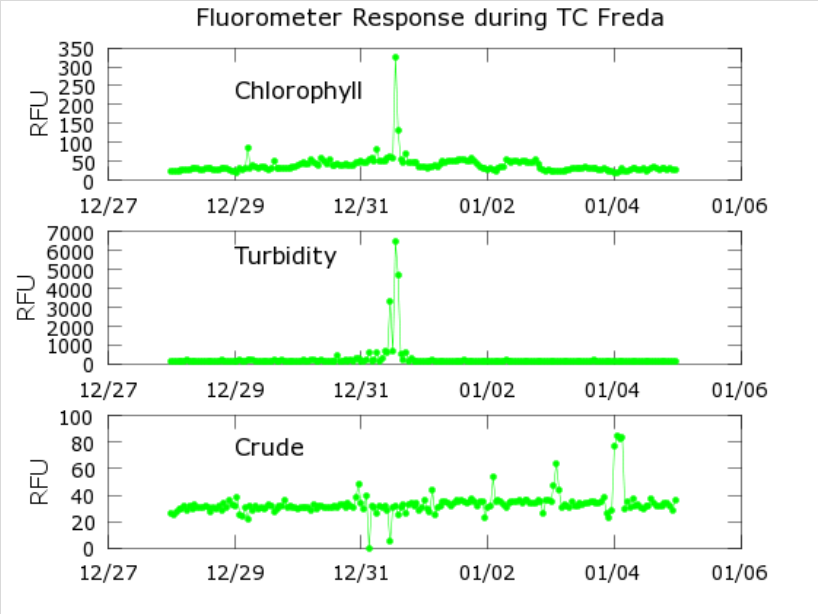
Midnight on Dec. 31st

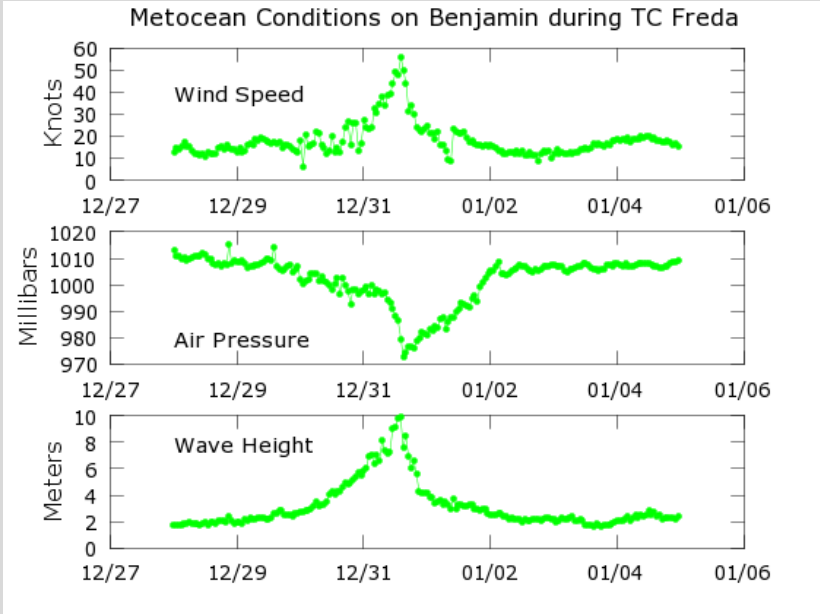


Noon on Dec. 31st

PacX Mission Scientific Highlights: Benjamin Intersection with Freda

Data from the ctd and fluorometer were recorded during this extreme event showing intense perturbation of the background oceanic conditions.



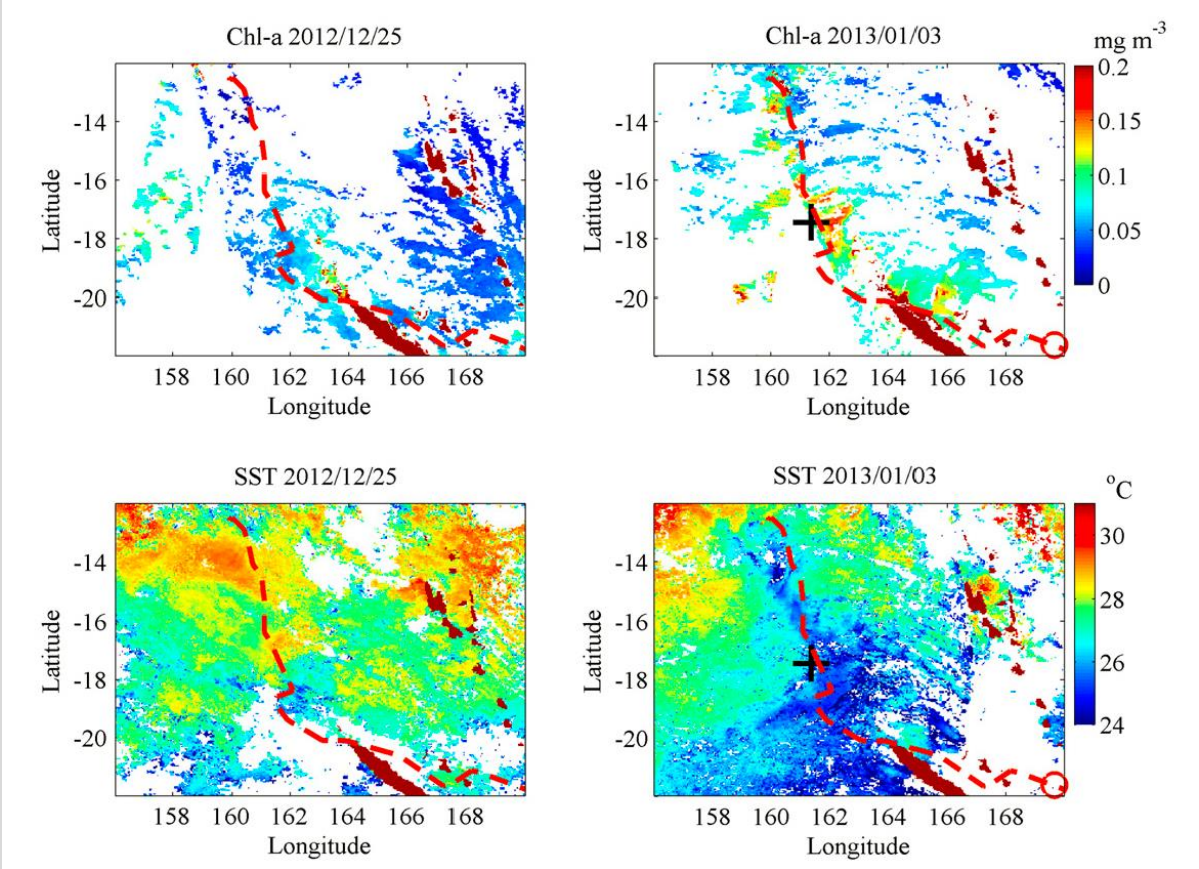


PacX Mission Scientific Highlights: Benjamin Intersection with Freda

This particular event was studied in detail by Luc Lenain and W. Kendall Melville from Scripps Institute of Oceanography. Satellite imagery from MODIS was used to corroborate the chlorophyll fluorescence measured by the Wave Glider.

Before TC Freda

After TC Freda

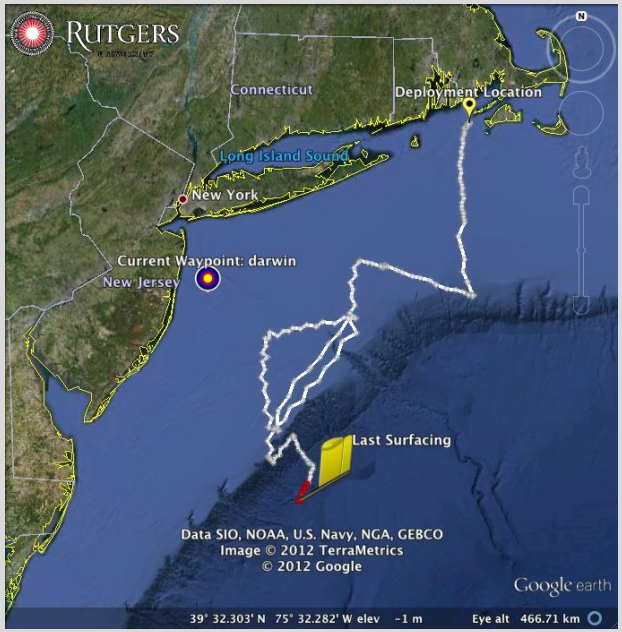


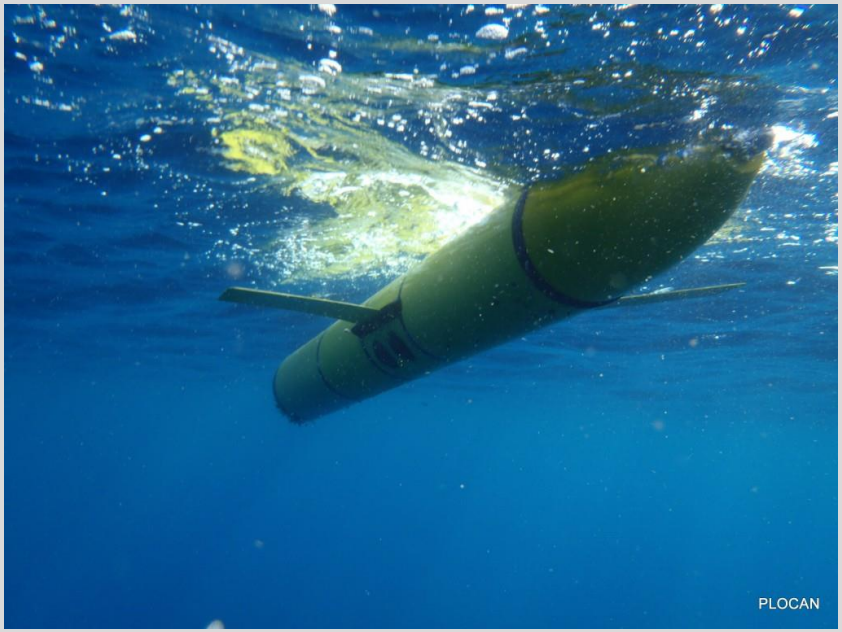
Chl-a

Water Temp.

Slocum Glider Darwin: Fluorometer Intercomparison

With cooperation between Rutgers I-COOL program and Teledyne WEB Research, the Slocum Glider Darwin was deployed off the east coast USA to evaluate the performance of the Turner Designs C3 Fluorometer against a WETLabs ECO Puck. The deployment lasted 45 days starting from September 7th, 2012





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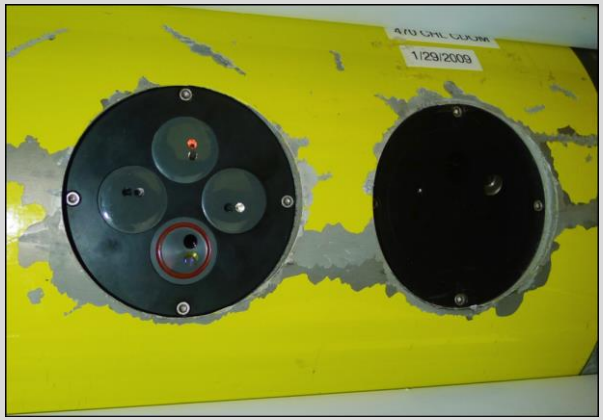
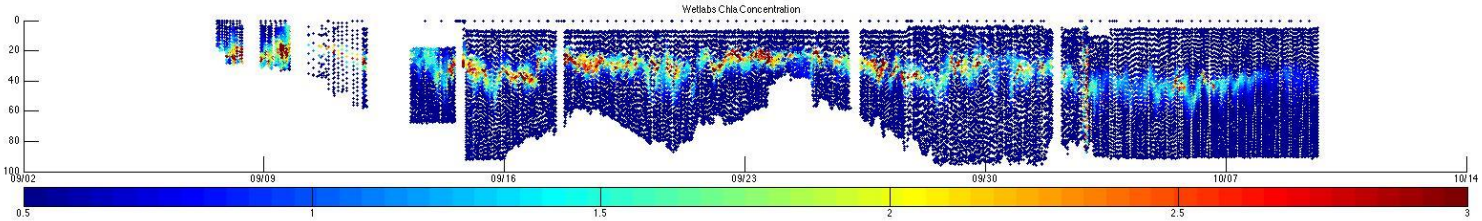
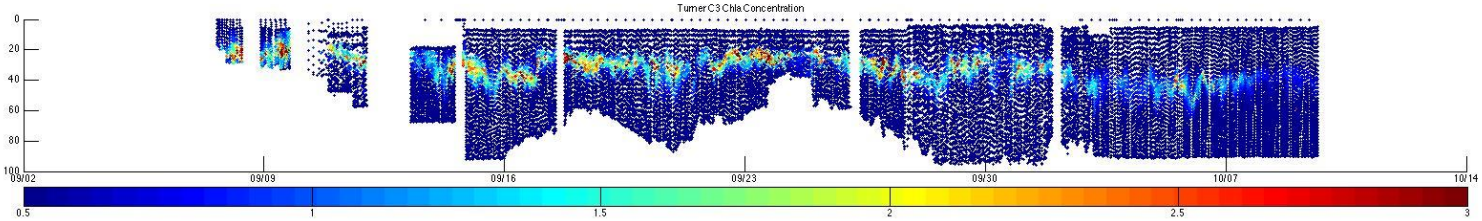
Slocum Glider Darwin: Fluorometer Intercomparison

Two instruments co-located provide an excellent opportunity to compare performance. Each instrument had 2 channels that were directly comparable; chlorophyll and CDOM. The spatial time series of chlorophyll below shows similar response to significant structure in the water column.

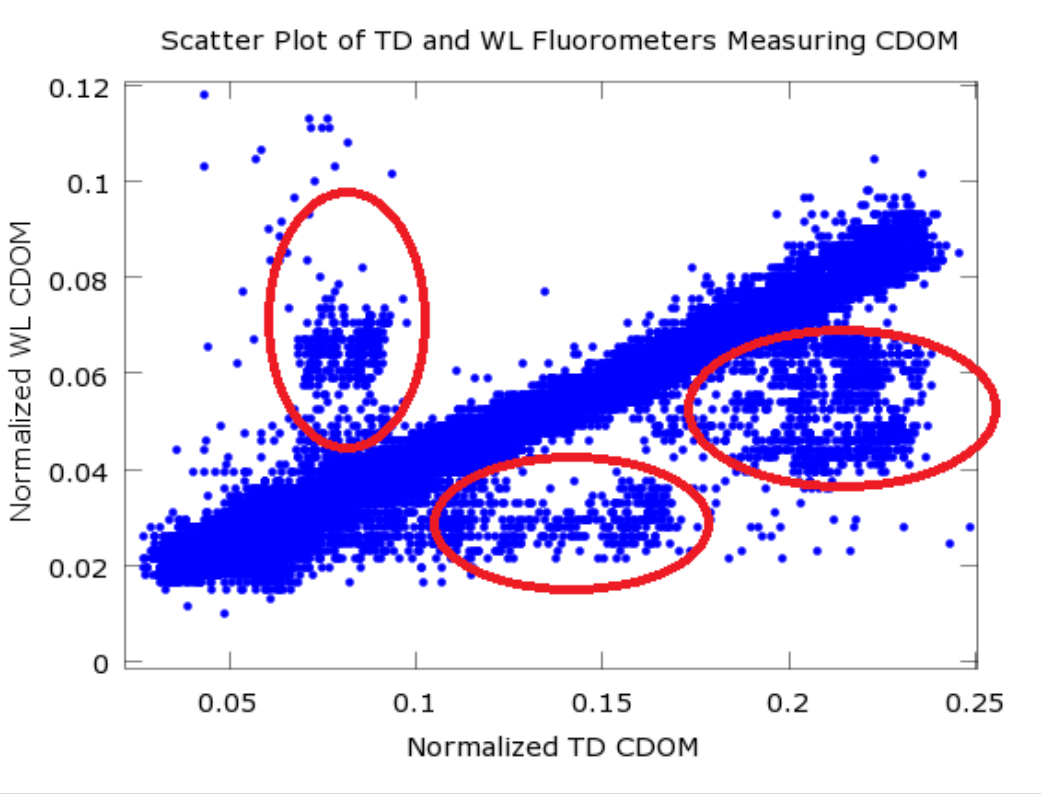






Slocum Glider Darwin: Fluorometer Intercomparison

Taking a closer look at a scatter plot, it's apparent that a strong linear relationship exists between the measurements but that relationship suffers from the inclusion of anomalous CDOM pairs. Closer examination of the anomalous CDOM pairs finds they might be representative of bio-fouling.



Regression of entire record: r2 = 0.59
n = 44101

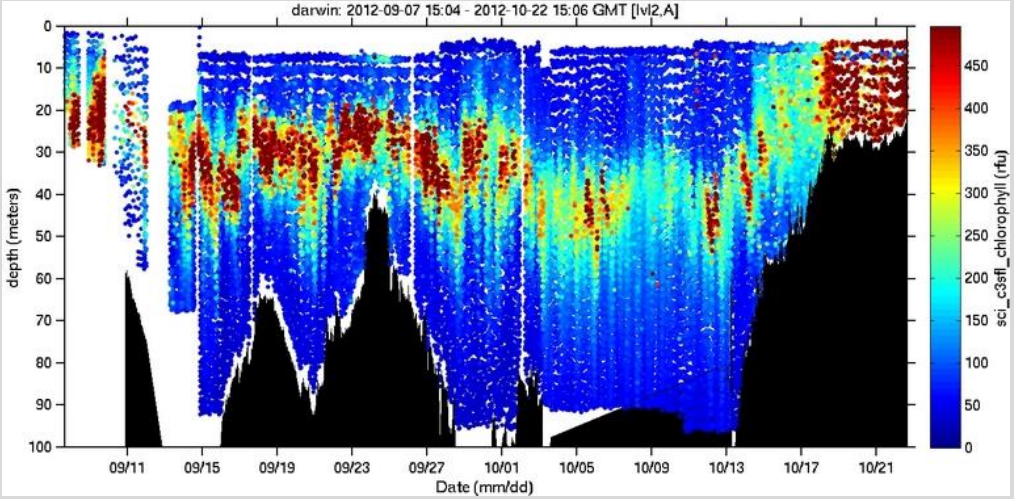
Regression of linear population: r2 = 0.94
n = 42575

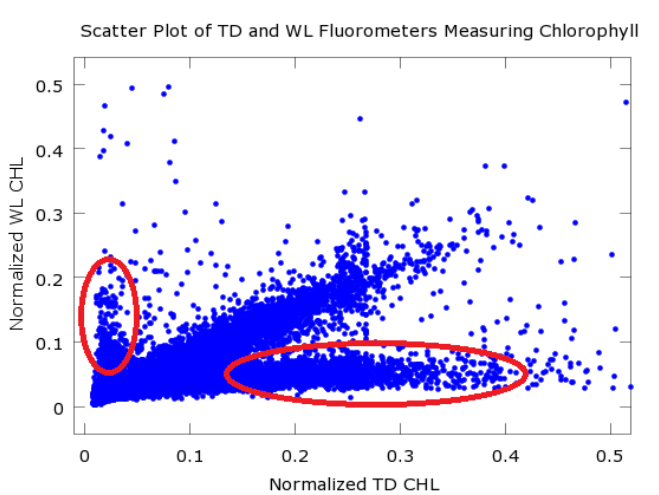
Slocum Glider Darwin: Fluorometer Intercomparison

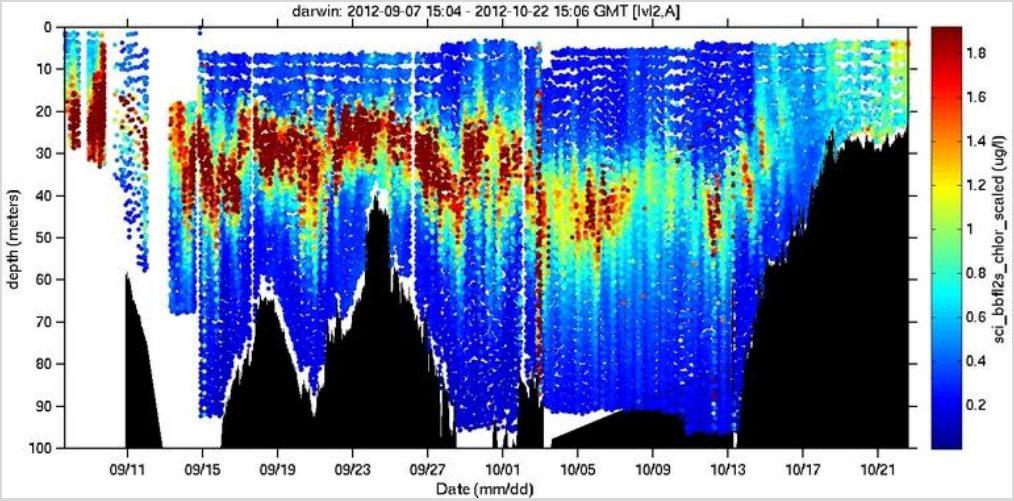
Looking at the chlorophyll scatter plot, again there is an apparent strong linear relationship but a systematic problem starting on 10/17 negatively affected the relationship.

Regression of entire record: r2 = 0.44
n = 44101

Regression of record up to 10/17: r2 = 0.86
n = 32043







Navocean HAB mapping

The presence of harmful algal blooms(HABs) has significant effects on both the east and west coast of the USA, as well as the Great Lakes.

- Mass mortality of wild and farmed fish
- Mass mortality of marine mammals and seabirds
- Human death from ingestion of contaminated finfish and shellfish

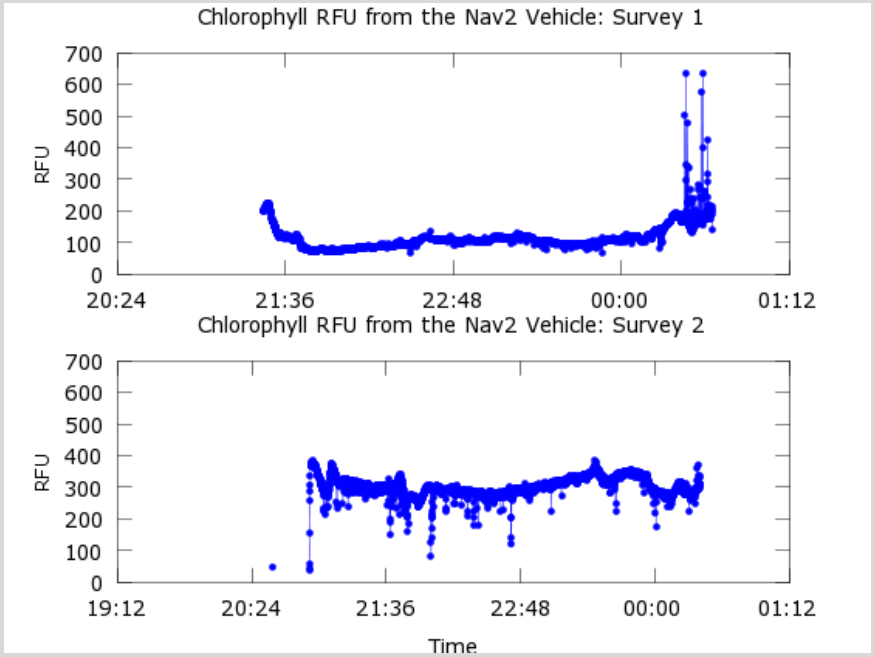
This past spring, Navocean installed a Turner Designs Cyclops Integrator Fluorometer into a Nav2 autonomous vehicle. The combination of these provides real-time fluorescence data and adaptive sampling capability.

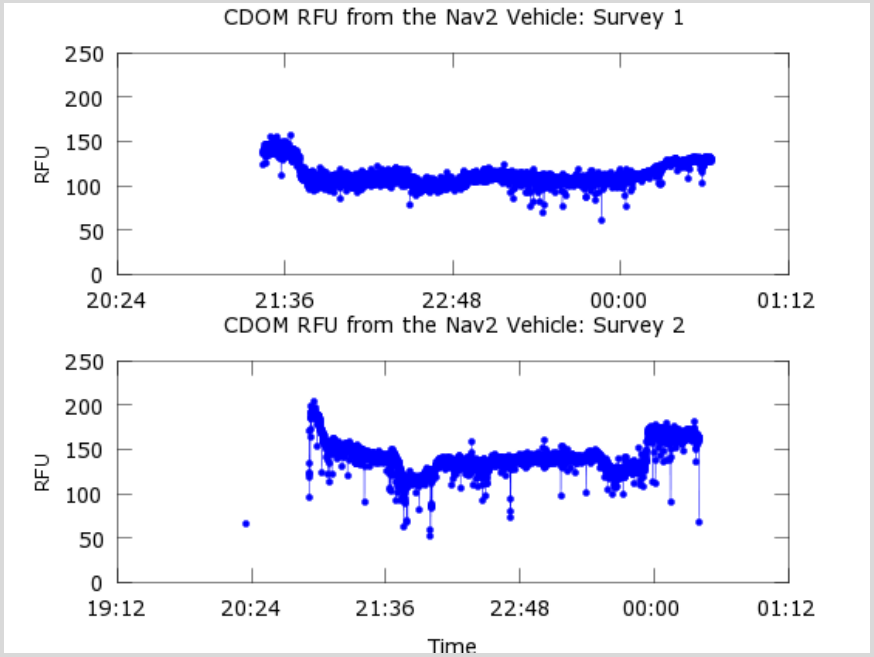
- CT cell
- Cyclops Integrator Fluorometer
- Thruster

Navocean HAB mapping

The Cyclops Integrator integrated into the Nav2 is a 3-channel instrument measuring CDOM, chlorophyll, and turbidity. The vehicle completed 2 surveys between 6/13/16 and 6/14/16 off the gulf coast of Florida where HABs are common.

Survey 1: Offshore from 6/12/16 21:20 - 6/13/16 00:40
Survey 2: Onshore from 6/13/16 19:55 - 6/14/16 00:24

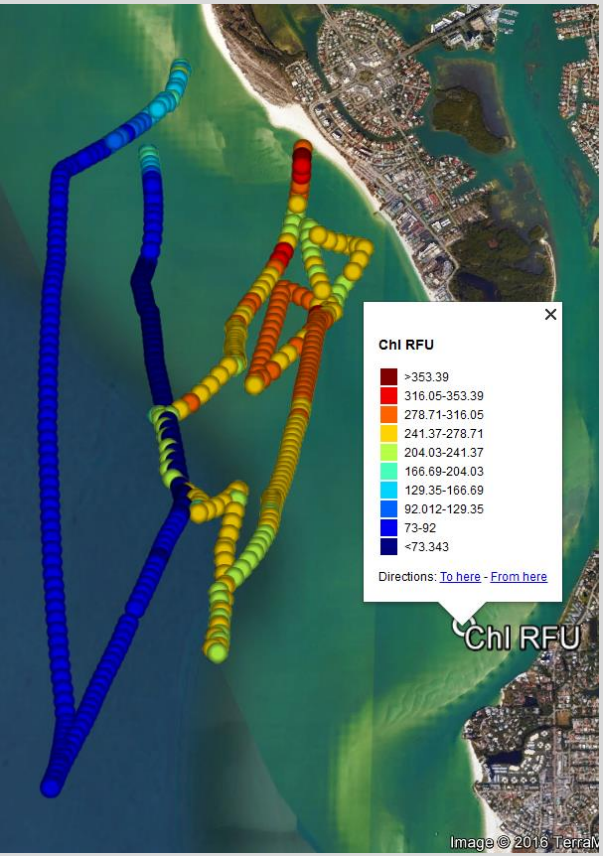




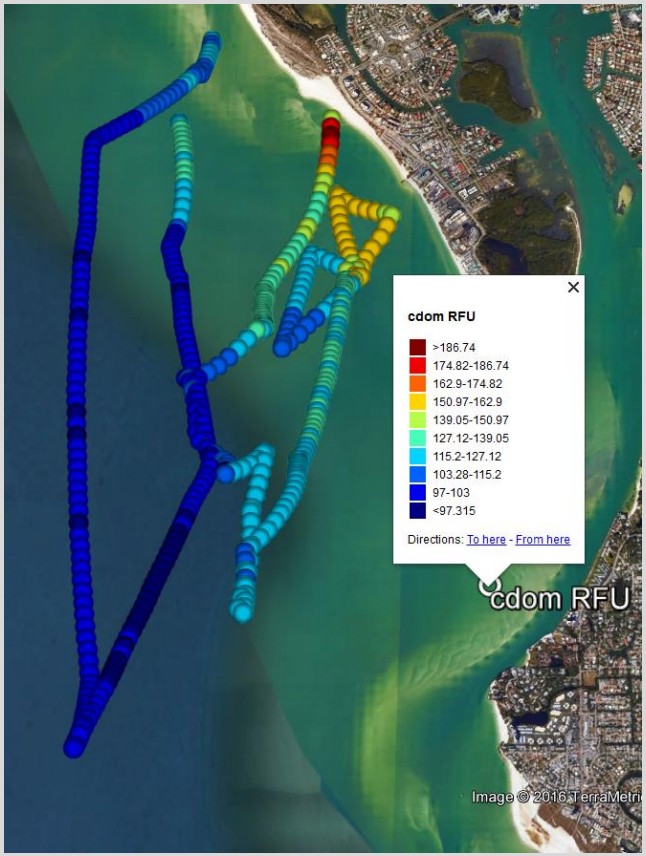
Navocean HAB mapping

Survey 1: Offshore from 6/12/16 21:20 - 6/13/16 00:40 UTC
Survey 2: Onshore from 6/13/16 19:55 - 6/14/16 00:24 UTC

Chlorophyll



CDOM



Turbidity

Acknowledgements and References

- PacX data available at:
  ftp://ftp.nodc.noaa.gov/nodc/archive/arc0062/0114435/1.1/data/0-data/PacX_NODC_master_folder/

  Special thanks to Tracy Villareal from University of Texas at Austin

- Slocum Glider data available at:
  https://marine.rutgers.edu/~kerfoot/slocum/deployments/2012/darwin-364/

  Special thanks to Chris DeCollibus at Teledyne Marine

- "Autonomous Surface Vehicle Measurements of the Ocean's Response to Tropical Cyclone Freda" available at:
  http://journals.ametsoc.org/doi/abs/10.1175/JTECH-D-14-00012.1

Thank you

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