Dawn of ecosystem sampling using autonomous gliders

Oscar Schofield on behalf of many
The Path Forward: 24:7 365 4-D sampling of the system, make the ocean your lab

Rutgers University’s Coastal Ocean Observation Lab (RU COOL)
How an underwater Glider works...

1. At surface, pump/diaphragm decreases volume, Glider descends

2. At depth pump/diaphragm increases volume, Glider ascends

3. Glider flies a saw tooth pattern, collecting environmental data along it’s path

4. Glider surfaces, acquires GPS, communicates to shore via satellite
Glider’s are “steerable” underwater vehicle with real-time communications that can cover great distances over long periods.

- Long duration
- Grand space scales

Moline et al. 2009
What can science data can be collected by gliders?

**WATER COLUMN PHYSICS**
- Temperature
- Salinity
- Turbulence

**CHEMISTRY**
- Optical nutrients
- Optical CO2
- Optical pH
- Mass Spectrometers

**ZOOPLOANKTON**
- Concentration
  - Acoustic backscatter
  - Imagery (visual, holography)
- Diversity
  - Multi frequency Acoustics
  - Imagery (visual, holography)
  - “Omics”

**IN SITU OPTICS**
- Inherent optics
  - Absorption ($\lambda$)
  - Scattering ($\lambda$)
  - Volume scattering
  - Attenuation ($\lambda$)
  - Refractive Index
  - Apparent Optics
    - ($\lambda$) Light intensity
      - up & down

**PHYTOPLANKTON**
- Concentration
  - Spectral Backscatter
  - Hyperspectral Absorption
  - Chlorophyll fluorescence
  - Imagery (visual, holography)
- Diversity
  - Spectral Backscatter (proxy for composition/size)
  - Imagery (visual, holography)
  - “Omics”
- Rates
  - Kinetic fluorescence
  - Photoacoustics
  - Stimulated oxygen kinetics

**HIGHER TROPHIC LEVELS**
- Concentration
  - Acoustic backscatter
  - Imagery (visual, holography)
- Diversity
  - Multi frequency Acoustics
  - Imagery (visual, holography)
  - “Omics”
  - Passive acoustics
  - Acoustic tags + Receiver

**ORGANIC MATTER FLUX**
- Concentration
  - Spectral Backscatter spikes
  - Particle settling rate
  - Imagery (visual, holography)
- Diversity
  - Imagery (visual, holography)
  - “Omics”
  - Mass Spectrometers
- Rates
  - Spatial calibrated fall rates
  - via imagery

Schofield et al. MTS 2015

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**TRANSPORT**
- ADCP
- Estimated geostrophic currents

**TRACE GASES**
- Optical Oxygen
- Optical CO2
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**TEP, DOM**
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**Marine snow & Export Flux**
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Darwin’s Odyssey
State of New Jersey is now using gliders to map summer water quality. Is low bottom water oxygen due to outflows from the New York city or is a naturally driven by natural dynamics.

State sponsored state wide surveys providing 3-4 missions each summer, and provides close to 10,000 profiles/summer as opposed to ~150 profiles/summer by ship/
Since 2003
Represents 36 years at sea
6 times around the planet
Case Study Hurricanes and Typhoons
Evacuate vs Shelter-In-Place decisions are often made 3-5 days ahead based on the forecast intensity at landfall

Close the gap from both sides: forecasting and response
Tropical Cyclone Heat Potential - Rapid Intensification Proxy

But published research shows ...

Irene & Sandy $87 B
- Glenn et al., 2016 Nature Comms
- Seroka et al., 2016 MWR
- Seroka et al. 2017 JGR Oceans
- Miles et al. 2017 JGR Oceans
- Watkins Ph.D. Thesis

Harvey $128 B
- Potter et al., 2019
Hurricane Irene
August 28, 2011
NOAA/NHC Damage:
>$15 Billion, #15.
Track Accurate;
Intensity Over-predicted.

Avila & Cangialosi, 2012, Tropical Cyclone Report

Hurricane Sandy
October 29, 2012
NOAA/NHC Damage:
>$72 Billion, #4.
Track Accurate;
Impacts Under-predicted.

Essential Ocean Feature - Mid-Atlantic’s Cold Pool
A continental shelf-wide cold bottom layer beneath a warm summer surface layer

The Cold Pool is not monitored from space – we use Gliders, HF Radar, and Models
Essential Ocean Processes in Hurricane Irene:
Ahead of eye center – Vertical Shear > Mixing > Cooling > Weakening

Glenn et al., Nature Comms, 2016
Irene - Impacts of Warm (top row) vs Cold (bottom row) SST

<table>
<thead>
<tr>
<th>Surface Heat Flux</th>
<th>Wind Speed</th>
<th>Storm Surge</th>
<th>Total Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WARM SST</strong></td>
<td><strong>SST COLD</strong></td>
<td><strong>Warm Run</strong></td>
<td><strong>Cold Run</strong></td>
</tr>
<tr>
<td><strong>MAXIMUM WATER LEVEL:</strong></td>
<td>1.9 m</td>
<td>1.4 m</td>
<td></td>
</tr>
<tr>
<td><strong>Sign Change</strong></td>
<td><strong>10 knot reduction</strong></td>
<td><strong>0.5 m reduction</strong></td>
<td><strong>35 mm reduction</strong></td>
</tr>
<tr>
<td>as observed</td>
<td>to observed</td>
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One year later…
Superstorm Sandy

October 2012

GOFS 3.0 = Navy’s operational Global Ocean Forecast System
RTOFS = NOAA’s operational global Real Time Ocean Forecast System
2018 Community Gliders deployed in 3 Picket Lines

>30 Hurricane Sentinel Gliders from the Navy, NOAA, NSF, Academic & Industry Partners reporting ocean conditions through the U.S. IOOS Glider Data Assembly Center (DAC) ahead of Hurricanes Florence, Isaac and Helene on September 11, 2018.
2018 Hurricane Season – 62 Gliders in IOOS Glider DAC

25% Hurricane Gliders
75% Shared Community Gliders
123,335 Total Glider Profiles
Hurricane Sentinel Gliders deployed in 3 Picket Lines

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Data Availability
Leveraging Global Tropical Cyclone Expertise

Drawn from an expanding Global Network

58 Institutions
Moving
1) Maximize collaboration and partnerships
2) Capacity Building