Effects of Salinity and Chlorophyll on Underwater Optical Communication and Detection

Peter C. Chu, Ph.D.
Distinguished Professor, Oceanography
Chair, Department of Oceanography
Support from the NPS Foundation is highly appreciated.
The Problem / Opportunity

• What is the effect of ocean environment such as salinity and Chlorophyll on the underwater optical transmission?

• This project has contributed to find an alternative underwater detection/communication technology to underwater acoustics.
Underwater Optical Communication
MINE DETECTION

- Optical properties of the water are important in MIW

- Clarity of water column, vertically and horizontally, is vital in mine detection and classification.

- Information on vertical structure of optical properties could provide guidance of deployment strategies of underwater sensors.
ANTI-SUBMARINE WARFARE (ASW)

- Mechanically stimulated bioluminescence offers a mean of detecting and tracking surface and subsurface movement during the night.

- Complements acoustics - does not replace it.

- Prevalent in the acoustically noisy littoral where submarines must operate shallow.
Salinity \rightarrow \text{Underwater Optic Parameters:}
Backscattering Coefficient, b(z)
Refractive Index
Attenuation Coefficient, C(z)
Scattering Phase Function, \( \beta \)

Light Propagation \rightarrow \text{Radiance} \quad L(t, r, s)

\[
\left[ \frac{1}{v} \frac{\partial}{\partial t} + \mathbf{s} \cdot \nabla + c(z) \right] L(t, r, s) = b(z) \int_{2\pi} \beta(s, s')L(t, r, s')d\Omega'
\]

\text{Optical Communication/Detection}
Instrumentation/Data Source

NAVOCEANO bioluminescence instrumentation suite includes BIOLITE, HIDEX and TOWDEX bathyphotometers.

At present, the HIDEX and TOWDEX have been put into storage. NAVOCEANO is working to replace the BIOLITE system with a new instrument called the Underwater Bioluminescence Assessment Tool (UBAT). UBAT is manufactured by WET Labs and currently still in the testing phase.
<table>
<thead>
<tr>
<th><strong>Slocum Glider</strong></th>
<th><strong>Seaglider</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Steering</strong></td>
<td>Active Rudder</td>
</tr>
<tr>
<td><strong>Depths</strong></td>
<td>4 to 200 m (option: 1000)</td>
</tr>
<tr>
<td><strong>Horiz. Speed</strong></td>
<td>0.5 knots</td>
</tr>
<tr>
<td><strong>Nominal</strong></td>
<td></td>
</tr>
<tr>
<td>– <strong>Endurance</strong></td>
<td>4 months</td>
</tr>
<tr>
<td>– <strong>Range</strong></td>
<td>600 - 4000 km</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>Alkaline/Lithium</td>
</tr>
<tr>
<td><strong>Hull Dia.</strong></td>
<td>21 cm</td>
</tr>
<tr>
<td><strong>Length</strong></td>
<td>1.5 m</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>123 lb</td>
</tr>
<tr>
<td><strong>Comms</strong></td>
<td>Iridium satellite phone</td>
</tr>
</tbody>
</table>

Approved for Public Release – Distribution Unlimited
Slocum

Scattering and Attenuation

Environmental Characterization Optics

Conductivity, Temperature, and Depth
Instrumentation

1) Seabird Electronics’ SBE 41 CTD sensor

- Samples at 1 Hz
- T accurate to 0.001 degrees C
- Salinity accurate to 0.005 PSU*
- Pressure accurate to 2 dbar*

2) WET Labs, Inc ECO bb2fl optical sensor

- Optical Backscatter @ 470nm and 650nm*
- Fluorometer: Chlorophyll-A @ 470 nm*
- Samples in top 300m to preserve battery life

Both sensors record and present data using NetCDF* data format which MATLAB manipulates quite easily
GPS and Iridium antenna at tail

Nose down orientation at surface provides robust communications

Change buoyancy to dive or ascend

Wings for forward propulsion

Move batteries fore and aft to change pitch

No propeller, or other external moving parts.
An Example of NAVO Glider Operations

Western Pacific

- Primarily east of the Ryuku Islands
- Dynamic area encompassing portion of Kuroshio WBC
- Total area: ~ 435,000 km²
Location and time are not shown due to restricted data.
Vertical Cross Sections of (T, S, Fluorescence) Along Glider Tracks
Vertical Cross Section of Bioluminescence Along Tracks
Cross Section of Fluorescence Along Tracks
Cross Section of Transmission (490 nm) Along Tracks
Three US Navy METOC/PO Theses in FY16

• Alexander J. Cullen, Environmental Effects on Underwater Optical Transmission in the Adriatic. MS in Meteorology and Oceanography, June 2016.


Outcome of SEED & Funding Support from NPS Foundation

- OPNAV-N97 is the topic sponsor for this project in the Naval Research Program (NRP) → “Transfer and Correlation Functions between Underwater Hydrographical and Optical Parameters”

The principal investigator will obtain $135,000 for FY17.

- Four USN students (LCDR Walter Young, LT Sabrina Cummings, LT John Martin, LT Eric Wishnie) are doing research on this project for MS degrees in FY17.

- Support from the NPS Foundation is highly appreciated.