

# **Ocean Response Coastal Analysis System**

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Document Number N0001499WX20342

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Document Number N0001402AS00002

## **LONG-TERM GOALS**

The joint goal of the Naval Research Laboratory (NRL) and the Commander, Meteorology and Oceanography Command (CNMOC) is to develop a capability to describe diver visibility and vulnerability, and demonstrate how new, innovative technology allows a better 3D/4D representation of the optical field for Navy applications. The new technology that is explored in this research is the use of self-contained, small portable optical/ biological/chemical moorings. These data will be used to validate and/or improve visibility and vulnerability estimates for operational scenarios.

## **OBJECTIVES**

The joint objectives of NRL and CNMOC in this program are to test and improve existing diver visibility and vulnerability algorithms using sensors that are to be incorporated onto the Ocean Response Coastal Analysis System (ORCAS). Sensors to be tested include a bioluminescence profiling package (University of Southern California at Santa Barbara) and the multi-angle scattering sensor and 20-channel multi-spectral absorption and attenuation meter (WET Labs, Inc.). The goal is to test and validate new optical instrumentation and to apply the resulting data toward tailored optical products via the Naval Oceanographic Office (NAVOCEANO) to support Naval and Joint operations.

The development of ORCAS small autonomous profiling instruments will allow more accurate 3D/4D representation of the optical field in realtime. However, algorithms that use the output of these instruments must be compared against a more complete optical set of measurements as well as actual diver visibility and vulnerability measurements. Thus, the project Gauging Littoral Optics for the Warfighter (GLOW) has joined the ORCAS team to collaborate to apply the developing profiler technology to specific military applications.

## Report Documentation Page

*Form Approved*  
*OMB No. 0704-0188*

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|   |                                    |   |   |                                 |                                 |
|---|------------------------------------|---|---|---------------------------------|---------------------------------|
| 1. REPORT DATE<br><b>30 SEP 2002</b>  | 2. REPORT TYPE                     | 3. DATES COVERED<br><b>00-00-2002 to 00-00-2002</b> |   |                                 |                                 |
| 4. TITLE AND SUBTITLE<br><b>Ocean Response Coastal Analysis System</b>  |                                    | 5a. CONTRACT NUMBER                                 |   |                                 |                                 |
|   |                                    | 5b. GRANT NUMBER                                    |   |                                 |                                 |
|   |                                    | 5c. PROGRAM ELEMENT NUMBER                          |   |                                 |                                 |
| 6. AUTHOR(S)  |                                    | 5d. PROJECT NUMBER                                  |   |                                 |                                 |
|   |                                    | 5e. TASK NUMBER                                     |   |                                 |                                 |
|   |                                    | 5f. WORK UNIT NUMBER                                |   |                                 |                                 |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br><b>Naval Research Laboratory, Code 7331,,SSC,,MS, 39529</b>   |                                    | 8. PERFORMING ORGANIZATION REPORT NUMBER            |   |                                 |                                 |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)   |                                    | 10. SPONSOR/MONITOR'S ACRONYM(S)                    |   |                                 |                                 |
|   |                                    | 11. SPONSOR/MONITOR'S REPORT NUMBER(S)              |   |                                 |                                 |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT<br><b>Approved for public release; distribution unlimited</b>   |                                    |   |   |                                 |                                 |
| 13. SUPPLEMENTARY NOTES   |                                    |   |   |                                 |                                 |
| 14. ABSTRACT<br><b>The joint goal of the Naval Research Laboratory (NRL) and the Commander, Meteorology and Oceanography Command (CNMOC) is to develop a capability to describe diver visibility and vulnerability, and demonstrate how new, innovative technology allows a better 3D/4D representation of the optical field for Navy applications. The new technology that is explored in this research is the use of self-contained, small portable optical/ biological/chemical moorings. These data will be used to validate and/or improve visibility and vulnerability estimates for operational scenarios.</b> |                                    |   |   |                                 |                                 |
| 15. SUBJECT TERMS   |                                    |   |   |                                 |                                 |
| 16. SECURITY CLASSIFICATION OF:   |                                    |   | 17. LIMITATION OF ABSTRACT<br><b>Same as Report (SAR)</b> | 18. NUMBER OF PAGES<br><b>7</b> | 19a. NAME OF RESPONSIBLE PERSON |
| a. REPORT<br><b>unclassified</b>  | b. ABSTRACT<br><b>unclassified</b> | c. THIS PAGE<br><b>unclassified</b>                 |   |                                 |                                 |

## APPROACH

In support of diver operations in any area of interest, the Navy (via NAVOCEANO) provides optical planning products to support the mission. At present, these products depict estimates of diver visibility in the horizontal (addressing the issue of how far they will be able to see) and the vertical (addressing the issue of how easily they will be seen; i.e., vulnerability). These products depict either a monthly or seasonal average; however, they are inadequate to support most littoral operations and do not forecast for areas where the optical properties can change over finer scales than modeling and remote imagery reveal. Given recent developments in optical instrumentation and the application of collected data to Navy issues, the technology now exists to provide better estimates of diver visibility and vulnerability. CNMOC established the GLOW project to forward this goal and to identify and mitigate gaps in R&D and transition processes. The limited case of the Preisendorfer algorithms (Duntley, 1952; Preisendorfer 1976, 1986) used by NAVOCEANO to generate diver visibility products is  $4/c$ , and in some cases  $4/[c+K\cos(\theta)]$  is used when sufficient data are available. However, previous GLOW exercise results indicate this may be so limited an application, that an expanded version of these algorithms may be necessary for littoral waters.

Until recently, optical measurements used to support diver visibility and vulnerability have relied on Secchi-depth values taken from surveys as far back as the 1930's. These data are difficult to use in depicting the strong dynamic nature of the coastal environment where very shallow-water operations occur. With the advent of relatively new instruments such as the absorption-attenuation meter and three-angle scattering sensor (WET Labs, Inc.) and the absorption/attenuation-backscattering instruments (HOBI Labs, Inc.), improved measurements of optical properties are available. Such data do or will populate the optical databases of NAVOCEANO and thus are vital source material for fleet support products. However, the algorithms that derive visibility from optical properties were either formulated prior to the development of these modern in situ instruments, or as in the case of the DiVA (Diver Visibility Algorithm) model, there is concern about the measurement parameters themselves and use of an instrument-specific model. Therefore, the algorithms must be tested in light of these improved measurements to determine if the models of the past are applicable and to determine the optimized products given our improved measurement potential.

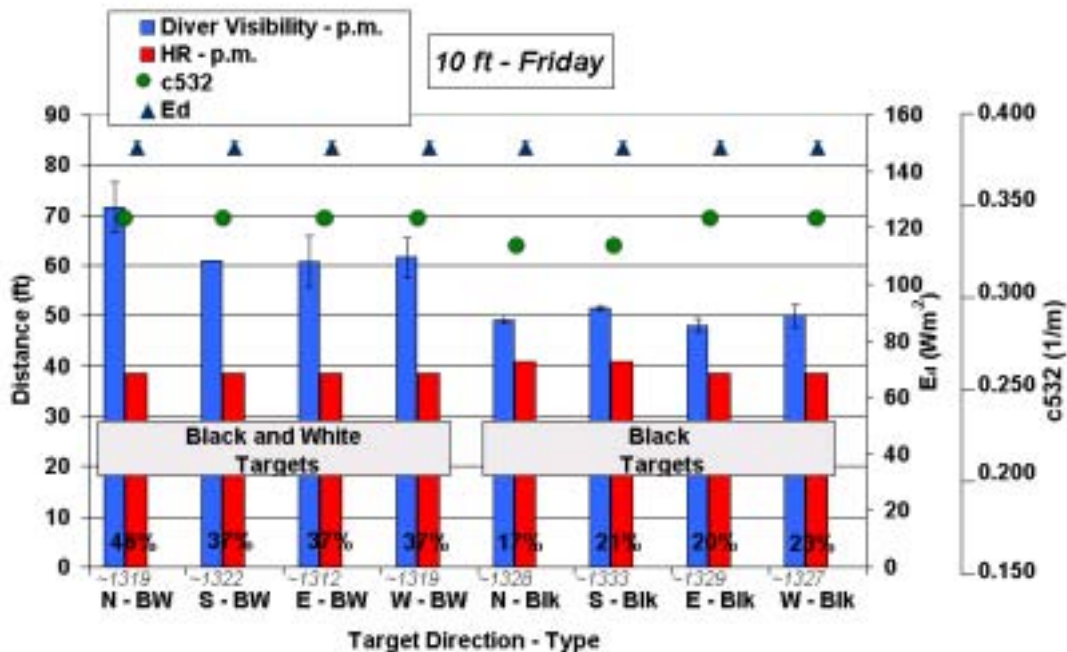
Five GLOW experiments have been conducted since it was initiated in 1998, two preceding ORCAS and three since. In all experiments, existing algorithms for diver visibility were applied to field data and then compared to actual visibility as observed by Navy divers. Results of the preliminary GLOW experiments indicate that, indeed, visibility algorithms need to be reviewed and most likely revised (actual diver visibility was generally underestimated by theory by a factor of 2 to 3). However, there were questions concerning angle of approach, ambient light, and direct light versus scattered light that was visible to the Navy divers. GLOW identified the R&D need to revalidate/revise existing diver visibility algorithms and to standardize the elements of both daytime and nighttime vulnerability. In response to the uncertainty in diver visibility, McBride (unpublished) extended the Preisendorfer algorithms to handle varying target reflectivity, target tilt angle, and an azimuthally symmetric radiance distribution. Under the current ORCAS/GLOW research, Bowers (2002) has further expanded this CTT implementation to include stratified in-water optical conditions, bottom effects, and more complex radiance distributions.

For both visibility and vulnerability experiments, any available remote ocean color imagery will also be included in the analyses. Although in situ measurements and resultant capabilities are the focus of

this work, remote imagery is an important complement for characterizing the synoptic field and for potentially gathering preliminary data in “denied access” regions prior to the covert deployment of an operational ORCAS system in the future. It also allows for the direction of the study into potentially important areas of either high/low visibility and high/low vulnerability.

## WORK COMPLETED

During the third and final year of this NOPP project, a fifth exercise was conducted off the Texas coast. Operations were planned to support daytime visibility and vulnerability studies, as well as nighttime vulnerability. Weather difficulties complicated logistics and nighttime diver operations were cancelled. However, data collected using the USC/SB bioluminescence profiling sensor were collected as part of the ORCAS effort. Three days of daytime visibility and vulnerability measurements were collected coincident with in-water diver observations. Collected data from all GLOW/ORCAS exercises confirm that the NAVOCEANO implementation of the Contrast Transmittance Theory (CTT) is extremely limiting and therefore is not a good predictor of the distance a diver will see an underwater target. Figure 1 shows an example of the data collected during these exercises.



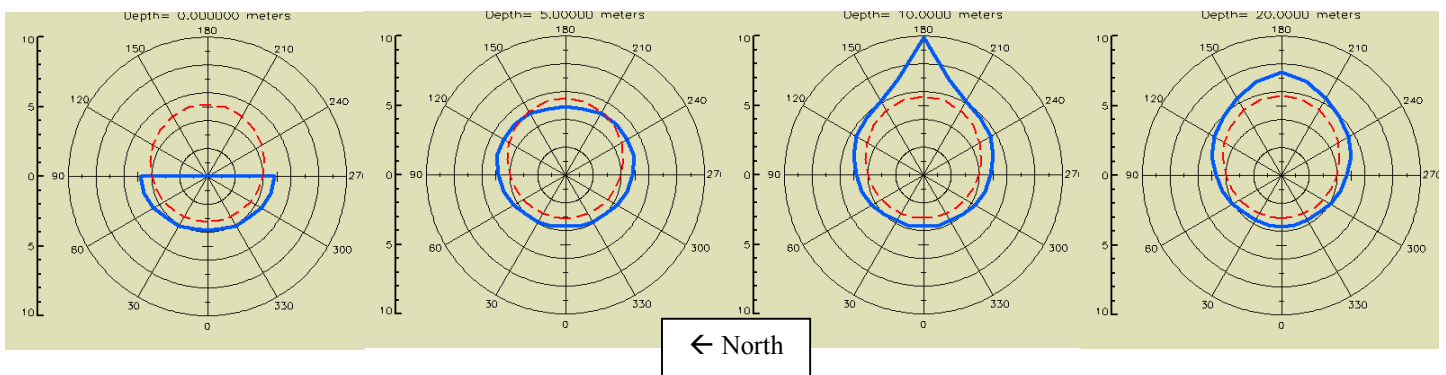
**Figure 1. Example of data collected during GLOW/ORCAS exercises indicating the difference between hydrologic range (as determined from the 4/c implementation of CTT- red lines) and the distance at which divers observed underwater targets – blue lines.**

Data collected during the GLOW/ORCAS exercises was used to develop an enhanced application of CTT to better predict diver visibility using ambient conditions, and will be presented in partial fulfillment of Master’s degree requirements at the University of Southern Mississippi later this year. A brief discussion of this implementation is described in the following section. Data collected during all GLOW-related exercises will be available upon request on a CD to be available in October 2002.

## RESULTS

Based on the data from the GLOW exercises, an enhanced implementation of CTT, has been developed. The Bowers Implementation of CTT, or BIC, is a radiance-based approach that computes inherent target field and background radiances for all depths and observer angles, then applies results via CTT to calculate a visibility distance. In general, this approach requires parameters that have been assumed as constant in the  $4/c$  implementation to be either input by a user or calculated based on user inputs. Specifically, BIC allows for inputs of solar irradiance, stratified optical properties, bottom reflectivity, target properties, and the angle of a diver's approach.

Figure 2 shows some example results from BIC. These figures show the computed visibility distance for all angles of approach, with  $0^\circ$  looking straight down at a black (0% reflectivity) target and  $180^\circ$  looking straight up at the same target for depths of 0, 5, 10, and 20 meters, respectively. Concentric circles indicate an interval distance of 2-meters. BIC results are given as a blue line, in comparison to a slightly expanded version of CTT,  $4/[c+K\cos(\theta)]$ , which is shown by a dashed red line.



**Figure 2. BIC results for simple case of homogeneous optical properties, sun angle directly overhead, and 0% reflective black target, at waters depths of 1, 5, 10, and 20 meters.**

As one can see from an analysis of these plots, even under simplistic environmental scenarios, the distance at which a diver can detect the target is not consistent with depth or with angle of approach. In fact, under certain conditions (20-m water depth at  $180^\circ$  for example), the limited application of CTT significantly underestimates this distance. Note too that the differences between the  $4/[c+K\cos(\theta)]$  implementation and BIC are not linear. Adding more complex environmental scenarios (stratified conditions, varying sun angles, more realistic target reflectivity) serves to further complicate the 'rosette' determined by BIC.

Results for the daytime vulnerability data have been much less rigorously analyzed, due to time and funding constraints. An informal report was generated that reviewed data collected from GLOW III and GLOW IV exercises more closely. This report suggests that Secchi data may have a significant application in fleet programs as a rough determination of the vulnerability of a diver under various optical (in-air and in-water) conditions. From looking at the data from these two exercises, it appears that the distance at which a diver will be detected can be estimated at one-half the Secchi depth (observer located on ship's deck and looking down along the side of the ship). If an observer is placed in the water and does not have the effects of the air/water interface as an additional observational barrier, this distance increases greatly (to a factor of two times the Secchi depth, based on observations

only). This remains consistent with previous research (Preisendorfer, 1986), but emphasizes the application of such a measurement.

The GLOW program was designed to provide additional insight into the quantification of diver vulnerability at night. However, there were a number of circumstances (sensor development and integration, logistics of divers and equipment, severe weather) that prohibited coincident sensor and diver observations. Additional exercises will be recommended for any future GLOW program support.

## **IMPACT/APPLICATIONS**

The impact of the directionality and target reflectivity on diver visibility is important since neither the existing visibility algorithms ( $4/c$  and  $4/[c+K\cos(\theta)]$ ) nor other proposed models take this dependency into account in the visibility calculations. BIC addresses the major environmental factors adding to the variability seen in underwater visibility measurements in littoral waters. In turn, this calculated distance has a direct consequence to the tactics used by Explosive Ordnance Disposal (EOD) divers in an operational scenario. Relationships of vertical optical properties during the day (as used in determining diver vulnerability) have applications to mine countermeasures, special operations, and possibly to homeland security. The bioluminescence characterization is important in combination with the optical properties to predict nighttime diver vulnerability; however, additional data are required before any results can be reported with any confidence.

## **TRANSITIONS**

Currently, no transitions have taken place from this effort. However, refinements to BIC are expected as a result of continuing thesis work and it is expected BIC will be transitioned at a later date.

## **RELATED PROJECTS**

Evaluation of the a-Beta Instrument and DiVA Model, ONR Code 32, PI: Alan Weidemann, NRL.

Validation of the Distance Visibility Algorithm (DiVA) and the Impact of the Mesoscale Approximation to Mine Warfare Applications, ONR Code 32, PI: Alan Weidemann, NRL.

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