Ocean Response Coastal Analysis System

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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 technologies allows a better 3D/4D representation of the optical field for Navy applications. The new technology that is explored in this research is the using self-contained, small portable optical/biological/chemical moorings. This information will be used to improve visibility and vulnerability estimates for operational scenarios.

OBJECTIVES

The joint objectives of NRL and CNMOC in this portion of the 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). These algorithms will be used to develop standard Navy products for the warfighter in areas of diver visibility and vulnerability. The new algorithms will be transitioned to the Naval Oceanographic Office (NAVOCEANO) for incorporating into products using data from their Data Warehouse. The sensors being considered 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 this new optical instrumentation for Fleet applications and as input into the Littoral Optics Geospatial Integrated Capability (LOGIC) framework and databases in use at NAVOCEANO.

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. To identify and mitigate gaps in R&D and the transition process, CNMOC established the project Gauging Littoral Optics for the Warfighter (GLOW). The GLOW project teamed with others to form the ORCAS initiative funded under NOPP.

GLOW was initiated in 1998 and had previously conducted two experiments in which existing algorithms for diver visibility were applied to field data and then compared to actual visibility as observed by Navy divers. 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 amphibious 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 are currently being used to 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.

In preliminary work, the results indicate that, indeed, visibility algorithms need to be reviewed and most likely revised (actual diver visibility was underestimated by theory by a factor of 2 to 3). However there were questions about angle of approach, the ambient light, and direct light versus scattered light that was visible by the Navy divers. GLOW has 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) developed a model that included turbid water backscattering, contrast differences, ambient light, and viewing angle. This model has been incorporated into NAVOCEANO's LOGIC. Also being considered for transition to LOGIC is DiVA, a camera-based visibility algorithm that should be particularly useful for applying data from the new absorption/attenuation–backscattering instruments (HOBI Labs, Inc.). There is a need to compare the output of the various visibility models and then determine which are best applied in specific warfighter applications. Also to consider is which models offer the most accurate information using the least amount of information. Therefore, selection of the most appropriate model(s) for generating Fleet support products may be situation and data dependent.

LOGIC is the GIS-based infrastructure being developed for use by NAVOCEANO to integrate and analyze optical data, to generate optical support products such as diver visibility and vulnerability for Fleet applications, and to facilitate transitions from R&D. The LOGIC framework already provides estimates of diver visibility using the Preisendorfer algorithms (Duntley, 1952; Preisendorfer 1976, 1986) tested under previous GLOW exercises. The LOGIC framework is compatible with the REACT (Rapid Environmental Assessment Chart-Tactical) product fusion used by the Warfighting Support Center of NAVOCEANO.

The approach here is to develop algorithms and instrumentation that can be used to generate optical products for the warfighter. The development of ORCAS with its small autonomous profiling instrumentation will allow a more accurate 3D/4D representation of the optical field. A prototype of the maxi-profiler used this year, together with four mini-profilers, will be used to provide real-time estimates of the optical field. 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, this program will apply the developed profiling technology to specific military applications by collaborating with the GLOW project. The participation by the Navy in this program is targeted toward several areas: 1) testing and improving or developing algorithms to relate optical measurements to warfighter concerns of diver visibility and vulnerability, 2) utilizing small, autonomous sensor suites to provide optical properties for Navy applications, 3) utilizing maxi-sensor packages with state-of-the-art scattering and absorption instrumentation as source data for Navy algorithms and databases, and 4) validating new optical technology to implement into either LOGIC or its successor for development of Navy-relevant products.

The development of the ORCAS with its small biological and nutrient sensors was tested successfully this year. A more complete test with the optical system is scheduled for the upcoming year in the Gulf of Mexico. NAVOCEANO has committed fifteen days of shiptime of the RV Longhorn (13-28 Sept 2001) for this purpose. During this experiment, visibility and vulnerability will be assessed by Navy divers using Navy and NOPP assets while the ORCAS and mini-profilers are deployed. For this deployment, CNMOC and NRL will deploy its optical package that has a bioluminescence sensor, several WET Labs attenuation/scattering sensors (already used by NAVOCEANO), and HOBI Labs *a*-beta and *c*-beta instruments into the maxi-sensor. These exercises will be designed to test revised new visibility algorithms available to the Fleet (McBride, Maffione) and to test the availability of input parameters for these models.

The exercise this past year was conducted at the Longterm Ecological Observation station in 15 meters of water (LEO-15) in collaboration with the Coastal Ocean Observation Laboratory (COOL). This site was selected for study since contrast targets, an imaging camera, and several profiling optical packages were all being deployed as part of other projects (HYCODE). Navy divers were used to compare observed visibility variability and to test new algorithms (applied to *in situ* data) using a black and white and a solid black target.

Years one and two also involve the development of a standard vulnerability model for use by the Fleet. Presently, the only nighttime diver vulnerability model is a qualitative scale developed by LaPota and Geiger (unpublished). However, the new bioluminescence sensor tested and deployed at LEO-15 should provide the Navy and scientific community with enhanced spatial and temporal information on bioluminescence potential. NAVOCEANO (Geiger) is working on the transfer function between this bioluminescence sensor and the Navy standard bioluminescence measurement (HIDEX). The first two years will be used to add bioluminescence to the visibility models and to refine diver vulnerability estimates using available optical and biological data collected by ORCAS. During each exercise, there is a daytime and nighttime operation. The daytime operations are used for both visibility and vulnerability while the night operations concentrate on vulnerability aspects. The results will be incorporated into the diver vulnerability algorithms.

For both visibility and vulnerability experiments, any available remote ocean color imagery will also be included in the analyses as was done at LEO-15. 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.

The last task is in optimizing products for Fleet applicability and making the products "user-friendly" by putting the users in the loop and getting their feedback on the product. This provides a product that is realistic to the operational community and thus is more likely to be used by them. As products are developed that fit into the NAVOCEANO LOGIC infrastructure, candidate products for diver visibility and vulnerability will be presented to the Fleet for their consideration. If they like the product, this program will recommend advancement of the product as a candidate for a standard product (e.g., the Oceanographic and Atmospheric Measurement Library) and recommend that it go through the validation and verification process within the Fleet.

WORK COMPLETED

While waiting for completion of the mini-mooring package, the CNMOC/NRL partners participated in the LEO-15 experiments off New Jersey in July 2000. The goals for our portion of the NOPP were to characterize the local bioluminescence in both turbid and clear waters of LEO-15, to investigate solar angle dependencies on underwater horizontal visibility of black/white and black targets, and to evaluate the visibility of a black target using vertical observations. A profiling package was constructed similar to the MACRO profiler (without the nutrients) proposed by URI. It included measurements of conductivity, depth, temperature, scattering at three wavelengths and three angles, a nine channel absorption/attenuation meter, a hundred-channel absorption/attenuation meter, and the Variable Aperture Beam Attenuation Meter (VABAM). Additionally, since ONR is considering use of the HOBI Labs *a*-beta and *c*-beta instruments and the DiVA model, these instruments were added to the profiler. The exercise was divided into day operations the first week and night operations the second week. The daylight operations were to be in collaboration with HOBI Labs, but they left after the first day of operations due to weather and other commitments.

For the day operations, targets were deployed at 10 and then at 30 foot depths. Navy divers then approached the black/white or black target from each of four directions relative to the sun's position (toward, away, left perpendicular, right perpendicular). During the runs of the divers, both profiles and time series (at diver depth) of optical properties were collected in as close proximity to the divers as safety allowed (100 feet).

Plans are already being made for future work with the URI mini-profilers in the Gulf of Mexico for the upcoming year. NAVOCEANO has already committed shiptime from its UNOLS allocation for this purpose. The Gulf of Mexico was chosen for two reasons. First it is logistically easier to deal with from the Navy divers side. But more importantly, it offers a wide dynamic range of conditions from dirty coastal waters of the Mississippi Sound to the clean waters of the loop current. The western Gulf also has a "dead" zone where anoxic conditions and optical layering can be persistent during the summer and fall months. These optical layers have been observed and their impact on visibility is unclear, thus warranting further investigation.

RESULTS

We have been looking over the data from the recent GLOW horizontal visibility studies. Due to the rough weather that occurred during the LEO-15 experiment, the amount of data is less than desired. However, the preliminary data do indicate an important aspect of operational significance: that the ability of a diver to detect a target is dependent on angle of approach and time of day. On one of the better days, at 1400 local time, there was a difference of 25 to 30% when the approach was from the north/south versus from then east/west. Horizontal visibility was greater along an east/west line. However, later in the day (1800 local time), this difference was no longer observed (all observations were within 10%). However, there is reason to expect that the subsurface light field was more diffuse at this time period, with more of a skylight contribution.

For the vulnerability, the bioluminescence characterization was measured on each side of a front where activity could be considered high and low. These data are being analyzed with the optical data together to determine an appropriate vulnerability. This information will be supplied after reviewing classification guidelines.

IMPACT/APPLICATIONS

The impact of the directionality on diver visibility is important since neither the existing visibility nor the proposed DiVA models take this dependency into account in the visibility calculations. The 30% deviation can mean the difference of identifying a mine at 14 feet or getting closer than 10 feet. This has a direct consequence to tactical situations and stand-off distances used by Explosive Ordnance Demolition (EOD) divers. The bioluminescence characterization showed the importance of knowing this value together with the optical properties to predict diver vulnerability.

TRANSITIONS

No transitions have occurred at this early stage of the program.

RELATED PROJECTS

LCDR Davis-Lunde has a separate project within NAVOCEANO that builds the LOGIC framework for input and analysis of mission critical METOC optical parameters for dissemination to the Fleet.

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