

**The Secretary of the Navy/Chief of Naval Operations
Chair in Oceanographic Sciences**

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LONG-TERM GOALS

The primary long-term goals of this work have been to accelerate ongoing research, and to enhance the educational value of my teaching of undergraduate and graduate students.

OBJECTIVES

The general long-term research objective for this work has been to advance understanding and predictive capabilities in three areas:

- 1) upper ocean physical, bio-optical, and biogeochemical responses to intense wind events including hurricanes and typhoons,
- 2) interactions of optical, biological, and physical processes in the upper ocean,
and
- 3) physical, bio-optical, and biogeochemical dynamics of ocean mesoscale eddies.

The overall educational objective has been to contribute to the development of students, especially those who will seek careers in the ocean sciences.

An overall transitional objective has been to coordinate field studies and to stimulate new interactions among ocean scientists.

APPROACH

The approach for achieving the research goals has been to utilize and build upon ongoing interdisciplinary research in the areas of optics, biology, and physics, upper ocean response to hurricanes, and mesoscale eddies. Field and modeling efforts were involved in these activities. One of the key efforts centered upon the ONR Radiance in a Dynamic Ocean (RaDyO) program described below. Other work has utilized our data sets previously collected off Bermuda and Hawaii.

WORK COMPLETED

I served as the lead PI for the ONR-sponsored Radiance in a Dynamic Ocean (RaDyO) program (Figure 1). A primary goal of RaDyO was to develop models capable of predicting the relationships among several optical properties and environmental factors as well as enabling improved models for imaging applications. In this work, we have studied the propagation of light across the air-sea interface and into and exiting the surface and upper ocean boundary layers. The first field experiment (benign sea-state conditions) was conducted in the Santa Barbara Channel in September 2008 and the second field experiment (high sea-state conditions) off Hawaii was executed August-September 2009. I led both field efforts and coordinated the organization of data, special sessions at meetings, and the editing of special journal publications (JGR) for the project. A comprehensive website for RaDyO (www.opl.ucsb.edu/radyo/) was developed. Graduate student Francesco Nencioli contributed to the RaDyO experiment by collecting optical and physical data from R/P FLIP in the Santa Barbara Channel. Graduate student Jen Sirak collected data from R/V Kilo Moana for RaDyO during the Hawaii experiment. RaDyO results will be valuable for fleet operations involving visibility and imagery aspects. Results from these experiments are described in a paper (Dickey et al., 2012) that was published as the introductory/overview paper for a Special Section of the Journal of Geophysical Research. This paper was honored as a Spotlight Paper in EOS recently. I am a co-author of two other papers that have been published in this Special Section. In addition, we published a paper based largely on RaDyO research in Physics Today (Dickey et al., 2011).



Figure 1. Platforms used for the RaDyO Santa Barbara Channel experiment, September 2008. These were used again in August-September 2009 off Hawaii (with the exception of the Odyssey AUV).

Mesoscale eddies and their roles in biogeochemical cycling were studied with my graduate student, Francesco Nencioli through Chair funding, collaborators, and other members of my group. This research involved data sets collected off Hawaii during the NSF E-FLUX experiment. Again, interdisciplinary modeling of these eddies is a major thrust of the research. Several papers have been

written on biogeochemical cycling (see Dong et al., 2009; Honda et al., 2009; Lomas et al., 2009, Nencioli et al., 2009a,b). This research is of interest to naval operations in the presence of mesoscale features in the ocean.

I have continued my leadership in optimizing interdisciplinary observing systems, which bear on naval applications.

Educational efforts included the mentoring of two graduate students, Francesco Nencioli and Jen Sirak. In addition, I have taught a large introductory oceanography class (~200 students) and have brought my research activities and experiences into the classroom.

IMPACT/APPLICATIONS

We anticipate several impacts. In particular, RaDyO entails the examination of spectral time-dependent oceanic radiance distributions in relation to dynamic surface boundary layer (SBL) processes, construction of a radiance-based SBL model, validation of the model with field observations, and investigation of the feasibility of inverting the model to yield SBL light conditions. These activities bear on understanding and predicting impacts of SBL processes and ocean biogeochemistry and ecology on the underwater light field, imaging, and thus operational problems involving naval operations. The feasibility of obtaining ocean surface estimates using underwater camera data are being explored. The work in the areas of upper ocean responses to hurricanes and mesoscale eddies will be valuable for improving predictive models of fundamental oceanographic processes and are of naval interest.

TRANSITIONS

We anticipate that major transitions will develop in the form of testing and commercialization of new sensors by RaDyO collaborators (e.g., MASCOT and radiance cameras). We expect that the RaDyO project will accelerate interdisciplinary ocean measurement technology capabilities by 1) increasing the variety of optical variables which can be measured autonomously, 2) improving the robustness and reliability of interdisciplinary sampling systems, and 3) developing more accurate predictive models of the optical and physical environment of the ocean. In terms of the mesoscale eddy work, transitioning of observational methodologies and predictive model parameterizations is an expected outcome.

RELATED PROJECTS

There are several projects that took place in the Santa Barbara Channel during RaDyO that relate to the RaDyO program. Spatial surface current data (using CODAR) were collected by Libe Washburn's UCSB group (<http://www.icess.ucsb.edu/iog/realtime/index.php>) and are useful for characterizing major current features and passages of sub-mesoscale features and eddies; ship-based bio-optical data collected by the Plumes and Blooms Program (Dave Siegel, lead-PI; <http://www.icess.ucsb.edu/PnB/PnB.html>) facilitate interpretation of the RaDyO bio-optical data; surface hydrocarbon slicks and slick dynamics are being investigated (Ira Leifer and Jordan Clark, PIs; <http://www.bubbleology.com/>); and ship-based data collected by the Santa Barbara Channel Long-Term Ecological Research (LTER; Dan Reed, lead-PI; with focus on land-ocean margin; <http://sbc.lternet.edu/>) program. Mark Moline of Cal Poly collected physical and optical data in conjunction with the Santa Barbara Channel RaDyO field experiment and collected data during the

RaDyO Hawaii experiment. Satellite sea surface temperature and ocean color data were collected by our group, and Ben Holt (Jet Propulsion Laboratory, JPL) has collecting synthetic aperture radar (SAR) data. These remote sensing data sets along with others provide spatial context. By combining and synthesizing these data sets with ours, it will be possible to describe and quantify the three-dimensional evolution of several key water property parameters on time scales of a day to the interannual. Modelers working with us on these data sets include Charles Jones (UCSB), Leila Carvalho (UCSB), Charles Dong (UCLA), and Yi Chao (JPL).

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