Summer Courses in Ocean Optics and Biogeochemistry: Monitoring the Oceans with Coastal Observatories and Radiative Transfer and Remote Sensing at the University of Maine Darling Marine Center

FINAL REPORT

On Work Performed by

Curtis D. Mobley

Sequoia Scientific, Inc.
2700 Richards Road, Suite 109
Bellevue, WA 98005

Under Contract N00014-04-C-0213

Prepared for

Dr. Steven Ackleson
Environmental Optics Program
Code 322OB
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217-5000

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2700 Richards Road, Suite 107
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Office of Naval Research
800 North Quincy Streen
Arlington, VA 22217-5000
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13. SUPPLEMENTARY NOTES

14. ABSTRACT
These two intensive courses allowed graduate students from diverse disciplines to learn the fundamentals of optics in a coastal/estuarine environment. The first course emphasized instrumentation and observatory science, and the second course emphasized radiative transfer theory and ocean color remote sensing. Both courses emphasized the links between optical measurements and the underlying biogeochemistry, with due regard for system integration and errors in data products. The main components of the courses were (1) formal lectures; (2) laboratory, field, and modeling exercises; (3) demonstrations of new instrumentation; (4) readings from texts and primary journal literature; and (5) student projects. Mobley prepared numerous lectures and labs on topics including radiometry, scattering, analytical and numerical solution of the radiative transfer equation, statistical methods in remote sensing including neural networks, remote sensing in optically shallow waters, visibility and imaging, LIDAR remote sensing and bathymetry, polarization and its applications, measurement of particle size distributions, and use of Hydrolight.

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optical oceanography, ocean color remote sensing, oceanographic observatories, education, Hydrolight

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"Radiative Transfer and Remote Sensing"
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1. Objectives

These two courses created an opportunity for graduate students from diverse disciplines to interact with senior researchers in biological and optical oceanography and ocean color remote sensing to learn the fundamentals of optics in a coastal/estuarine environment. The first course of three weeks duration (June 28-July 16, 2004) emphasized instrumentation and observatory science to prepare participants to integrate their knowledge in existing and planned observatories. The second course of two weeks duration (July 19-30, 2004) emphasized radiative transfer theory and ocean color remote sensing. Both courses emphasized the links between optical measurements and the underlying biogeochemistry , with due regard for system integration and errors in data products. Overall course objectives were to provide a learning environment in which graduate students could integrate optics, remote sensing, and oceanography *and* to provide a forum for discourse on new directions in oceanography in general and optics in particular. The long-term goal underlying these courses was the education of a cadre of students who will have a broad perspective of the field and make a difference future research integrating optics, remote sensing, and observatory science into all subdisciplines of oceanography.

Students also learned a team-building approach to collaborative data acquisition from arrays of complex instrumentation and to data processing. Past students of the ocean optics courses acclaim this method for its value in achieving more than the sum of its parts and for preparing them to participate productively in complex, interdisciplinary efforts.

2. Approach

The classes used a teaching laboratory and a computer laboratory where 16 Dell computers were available for the required modeling and analyses. Matlab code for merging and processing data was available to the students during the course, as was the Hydrolight radiative transfer model and a Monte Carlo radiative transfer model. Instrumentation included a bench-top spectrophotometer, fluorometer, microscope, Coulter multisizer 3, LISST particle sizer, Barnestead pure water system, and filtration equipment; above-water hand-held spectroradiometer; and in-water radiance/irradiance sensors, absorption and scattering sensors, and fluorometers.

The main components of the courses were (1) formal lectures; (2) laboratory, field, and modeling exercises, with an emphasis on deployment methods and interpretation of measurements via models and theory; (3) demonstrations of new instrumentation; (4) readings from texts and primary journal literature; and (5) student projects, in which the students use data from the field experiments to investigate a specific, focused question and conclude with power point reports to be posted at the class website.

3. Work Completed

Mobley prepared numerous lectures and labs on topics including

Light and radiometry
Measurement and modeling of scattering
Analytical solution of the radiative transfer equation
Monte Carlo solution of the radiative transfer equation
Use of his Hydrolight numerical model
Use of his BMC3D numerical model
Statistical methods in remote sensing: band ratios to neural networks
Remote sensing in optically shallow waters: semi-analytic models to look up tables
Visibility and imaging
LIDAR remote sensing and bathymetry
Polarization and its applications
Measurement of particle size distributions

In addition, Mobley worked closely with students on their research projects.

3. Scientific Impact

Optical sensors are the primary method by which we observe the ocean's biogeochemistry at the same scales we sample the ocean's physics. With the recent emphasis on in-situ observatories and autonomous platforms, knowledge of the available optical technology, the theory behind the measurements, and relationships to the underlying biogeochemistry is a must. Our course addressed these important topics, which to our knowledge are not addressed formally in any courses taught at US institutions of higher learning.

Likewise, we introduced students to a broad range of optical remote sensing techniques, ranging from band-ratio algorithms to neural networks and spectrum-matching and look-up-table approaches to extracting environmental information from remotely sensed multi- and hyperspectral signatures obtained by airborne and satellite systems. The emphasis throughout was on complex coastal environments.

This course has three important impacts. First, the course provides a valuable dimension in the education of the next generation of oceanographers, well versed in optical oceanography and knowledgeable about the available technology. Second, the knowledge and experience the students gained in this course directly benefits their advisors, most of whom are federally-sponsored investigators. Thirdly, because a few of the participants were non-U.S. students, international connections were established, which may prove valuable in the future.