Spatial and Temporal Measurements of Benthic Optical Properties

FINAL REPORT

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Prepared for

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13. ABSTRACT ***(Maximum 200 Words)***

This work was an initial design of a sensor system to measure profiles of optical properties at high spatial and temporal resolution just above the sea bottom. The sensor system, called the Benthic Stationary Autonomous Profiler (BSAP), consists of a surface buoy and a bottom tripod containing sensors that measure surface spectral downwelling irradiance and upwelling radiance, and plane and scalar irradiances and radiance near the bottom. This initial design work was completed under a subcontract to HOBI Labs, which is continuing with the construction of the instrument under separate funding.

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SPATIAL AND TEMPORAL MEASUREMENTS OF BENTHIC OPTICAL PROPERTIES

FINAL REPORT

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SPATIAL AND TEMPORAL MEASUREMENTS OF BENTHIC OPTICAL PROPERTIES

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LONG-TERM GOAL

The long-term goal of this project is to characterize the spatial and temporal variability of spectral bottom reflectance and the boundary layer of water just above the bottom in optically shallow coastal environments. The overall goal is to develop and test radiative transfer models for optically shallow waters that can be applied to problems in underwater visibility, bottom-type classification, lidar bathymetry, hyperspectral remote sensing, and submerged aquatic vegetation productivity.

OBJECTIVES

I wish to investigate the temporal changes in bottom spectral reflectance for a variety of bottom types including corals, seagrasses, and siliceous and calcareous sediments. Spectral bottom reflectance is expected to change due to changing environmental conditions and forcing mechanisms such as wind and waves, tides, subsurface currents, and insolation. Conducting this investigation requires new instruments and methods. Thus one of my objectives is to develop a new type of moored system for measuring the relevant parameters needed to characterize and quantify bottom spectral reflectance. I call this system BSAP, for Benthic Stationary Autonomous Profiler. My major first-year objective is to complete the development of BSAP and begin testing in Monterey Bay. Related to this objective is to develop shallow-water optical models that can be tested with BSAP and with additional shipboard and diver synoptic measurements. Another major objective is to measure and model photon propagation in the top layer of sediment and in seagrass canopies.

APPROACH

My approach to characterizing and quantifying the spectral bottom reflectance, remote-sensing reflectance, and their changes in time and space, is with a new type of moored system. The major components of this system, called BSAP, are a surface buoy with a mooring system and several bottom mounted platforms containing a variety of optical and physical sensors. The buoy will be mounted with sensors that measure meteorological parameters including wind speed and direction, air temperature, and barometric pressure. A dual spectrometer designed to measure downwelling spectral irradiance and upwelling radiance at the surface will also be mounted on the buoy. There will be three bottom mounted platforms. Two of the platforms will be nearly identical, containing a bank of eight spectrometers each, designed with underwater fiber-optic light collectors for measuring spectral plane irradiance, scalar irradiance, and radiance near and of the bottom. The third platform will be mounted with a wave and tide gauge, temperature sensor, and backscattering sensor. Data will be collected and initially stored with a datalogger located inside the buoy. For approximately 5 minutes every hour, the stored data will be transmitted to a ground station using a VHF link. The ground station computer will be programmed to immediately process all data for easy retrieval, display, and analysis.

In addition to the BSAP measurements, I will be conducting shipboard profiles of the water column during regular trips to service the mooring. The profile data will consist of a complete set of inherent optical properties, which includes the absorption and beam attenuation coefficients, the backward scattering coefficient, and the volume scattering function. Most of the time BSAP will be moored in selected regions in Monterey Bay and we expect to conduct servicing trips about once every six weeks. We hope to coordinate some of these excursions with airborne hyperspectral sorties conducted by C. Davis. BSAP will also be deployed in the Bahamas during the CoBOP biannual experiments near Lee Stocking Island.

The seagrass canopy modeling work is being conducted in close collaboration with R. Zimmerman and C. Mobley. The in-water light field above the canopy is computed by C. Mobley using his Hydrolight model [Mobley, 1996]. His calculations serve as input to the canopy light field model developed by Maffione and Zimmerman [submitted]. The canopy light field is then fed into a seagrass productivity model developed by Zimmerman and Maffione [submitted]. I am also working in collaboration with C. Mazel to develop a coral reflectance and fluorescence model [Maffione and Mazel, in progress]. In-sediment light fields will be measured in the laboratory with fiber-optic microprobes coupled to a dual spectrometer. This laboratory setup is being conducted in collaboration with B. Bebout at NASA/Ames. Using these results we hope to develop a model based on the nature and composition of the sediment that can predict its spectral reflectance. All of the models mentioned above will be tested and refined using BSAP and synoptic measurements in the field.

WORK COMPLETED

On the hardware side, we have completed the design and purchasing of BSAP components. We expect to have all of the components assembled into a system that will be first tested in Monterey Bay around February, 1998. METOCEAN Data Systems Limited has been subcontracted to build the buoy and mooring system and we expect to take delivery shortly. The bottom sensor platforms are being developed in-house here at HOBI Labs. The spectrometers are made by Ocean Optics, Inc., which we have incorporated into pressure housings linked with an array of fiber-optic light collectors. We are currently in the process of characterizing and calibrating these sensors.

In collaboration with R. Zimmerman, we have completed the development of a two-part submerged canopy model. The first part of the model computes the spectral radiance transfer through the canopy [Maffione and Zimmerman, submitted], and the second part of the model uses the canopy spectral light field to estimate seagrass productivity [Zimmerman and Maffione, submitted]. An extension of this combined model currently under development, which involves light field calculations made with Hydrolight, will incorporate the remote sensing reflectance of submerged aquatic vegetation [Maffione et al., in progress]. Finally, significant progress has been made in building a laboratory setup for measuring in-sediment light fields which would not have been possible without the extensive help of B. Bebout at NASA/Ames.

RESULTS

Understanding and modeling light propagation through submerged aquatic vegetation (SAV) presents a unique set of challenges quite apart from radiative transfer modeling of terrestrial canopies and of the water column. The problem is how to combine both approaches in a useful way that takes into account the interaction of the light field with both the canopy itself and the water within the canopy. Moreover, the model must incorporate parameters that can be measured or reasonably estimated. For modeling productivity, we found that significant errors can result in ignoring the spectral content of the light field, both at the top of the canopy and its modification within the canopy [Maffione and Zimmerman, submitted; Zimmerman and Maffione, submitted]. Previously, most investigators used the simple approach of calculating SAV productivity based on PAR estimated or measured at the top of the canopy which can result in significant overestimations of productivity.

The light-field canopy model developed by Maffione and Zimmerman [submitted] includes the effects of leaf orientation, spectral absorption and scattering by the leaves, and the leaf density and gap fraction. Our model also rigorously couples the spectral light attenuation by the leaves and the water within the canopy. Indeed, this was one of the most challenging aspects of developing the canopy model. We found that an incorrect mathematical coupling of these two effects can result in significant errors in propagating light through a submerged canopy [Maffione and Zimmerman, submitted].

Resuspended sediments and phytoplankton blooms can have a severe impact on the productivity of SAV due to the attenuation of light that they cause. Thus we have developed and incorporated a bio-sediment-optical model in our canopy modeling work [Maffione, 1997; Zimmerman et al., submitted]. Our preliminary investigations point to the need for a systematic effort to quantify specific absorption and scattering coefficients of suspended sediments. Not only is this characterization important to SAV productivity, but it will be an important component to properly modeling shallow water radiative transfer.

IMPACT/APPLICATIONS

The long-term measurements from BSAP are expected to have a profound impact on our understanding of changes in spectral bottom reflectance and our ability to model the shallow-water optical environment. To the author's knowledge, BSAP will provide the first spectral data of the daily, seasonal, and annual changes in bottom reflectance. Ancillary measurements by other BSAP instruments and the synoptic shipboard profiles will allow us to correlate bottom reflectance changes with other environmental changes and forcing mechanisms. The resulting database is expected to be used widely in formulating descriptive and predictive models of the shallow-water optical environment. Also, additional BSAP systems deployed by other investigators will provide unprecedented data on the causes and effects of changes in SAV, corals, and the benthic ecology in general. It is also expected that the models we are developing, described above, will be used by the Navy in shallow-water applications, by coastal environmental monitoring laboratories, and by investigators who are studying coastal ecology.

TRANSITIONS

The bio-sediment-optical model and SAV canopy model we developed are being applied to understanding the impact of dredging on seagrass beds in Laguna Madre, Texas. This work is being conducted by a group at Texas A&M and is funded by the US Army Corps of Engineers. In August of this year we conducted a field experiment in Laguna Madre where we measured the inherent optical properties of the water column, the spectral light field and reflectance of the bottom, and the concentrations of total suspended solids. By using the same modeling and analysis techniques we developed this year on CoBOP, we were able to quantify the effects of dredging on the benthic light field and hence on seagrass production. Recently we have also been receiving interest in using BSAP-type instruments for environmental monitoring in San Francisco Bay and Chesepeake Bay; so we are expecting additional transitions in the near future.

RELATED PROJECTS

1. The SAV canopy modeling work is being conducted in close collaboration with R. Zimmerman who is separately funded by ONR.

2. The in-water light field and remote sensing modeling is being conducted in collaboration with C. Mobley who is separately funded by ONR.

3. The in-sediment light field measurements are being conducted in collaboration with B. Bebout, who is funded by NASA/Ames. Also collaborating with us on this work is P. Reid, A. Decho, and F. Dobbs, all of whom are separately funded by ONR.

4. The coral reflectance and fluorescence modeling work is being conducted in close collaboration with C. Mazel, who is separately funded by ONR.

5. Through separate funding from Texas A&M and the Army Corps of Engineers, I am working with L. Cifuentes and P. Eldredge on studying the effects of dredging and resuspended sediments on seagrass beds in Laguna Madre.

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