Spatial and Temporal Measurements of Benthic Optical Properties

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LONG-TERM GOAL

The overall 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. Part of this 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 benthic productivity.

OBJECTIVES

In this program we are investigating the temporal changes in bottom spectral reflectance for a variety of bottom types including corals, seagrasses, and both silicate and calcite dominated 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. We call this system BSAP, for Benthic Stationary Autonomous Profiler. There are a variety of BSAP's developed for this research, each designed for a specific application and method of deployment. 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 objective is to measure and model photon propagation in the top layer of sediment and in seagrass canopies.

APPROACH

Our 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 sensor systems containing a variety of optical and physical sensors. The buoy is 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 are also mounted on the buoy. There are a variety of bottom mounted sensor systems that include spectral radiometers for measuring benthic reflectance and the light field, inherent-optical property instruments for measuring the IOP's of the water column, and physical instruments for measuring wave spectra, water column height and temperature. All of the bottom-mounted instruments are designed to operate autonomously or they can be connected to the surface buoy for central data logging and transmission to a ground-based workstation.

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In addition to the BSAP measurements, we will be conducting shipboard profiles of the water column on a regular basis. 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 deployed in selected regions in Monterey Bay and we expect to conduct servicing trips about once every three to four 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 out of Lee Stocking Island.

Part of our modeling effort is to relate spectral bottom reflectance to the physical and biological state of the benthos. The benthic characterization is being conducted by a number of investigators on the CoBOP program with whom we are collaborating, including P. Reed, F. Dobbs, L Brand, M. Allison, and M. Lesser. Modeling of seagrass canopy reflectance and productivity is being conducted in collaboration with R. Zimmerman. We are developing a canopy spectral light-field model that is coupled with a seagrass productivity model. In-sediment light fields are measured in the laboratory with fiber-optic microprobes coupled to a dual spectrometer. This laboratory work is being performed in collaboration with B. Bebout at NASA/Ames. These results will aid us in developing 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

BSAP is now a fully developed and tested system that we expect will provide highly accurate data of bottom spectral reflectances and their changes in time and space due to environmental forcing. One of the more notable accomplishments in developing BSAP is the variety of new self-contained, hyperspectral radiometers we invented. These new hyperspectral radiometers can be used in a variety of ways to measure both bottom reflectance and water column reflectance, including the remote-sensing reflectance. They can be moored, diver deployed and operated, or deployed from a ship for measuring surface RSR or profiling the water column. Our hyperspectral radiometers are based on miniature fiber-optic spectrometers. For the types of radiometric measurements we need to make on CoBOP, we had to develop a new and accurate fiber-optic irradiance collector. A photo of this collector is shown in Figure 1, and its underwater angular response is shown in Figure 2. During the next major CoBOP field experiment at Lee Stocking Island, we plan to deploy more than 30 of these radiometers to measure spectral reflectances over a wide area with various bottom types.

Figure 1. Underwater fiber-optic irradiance collector

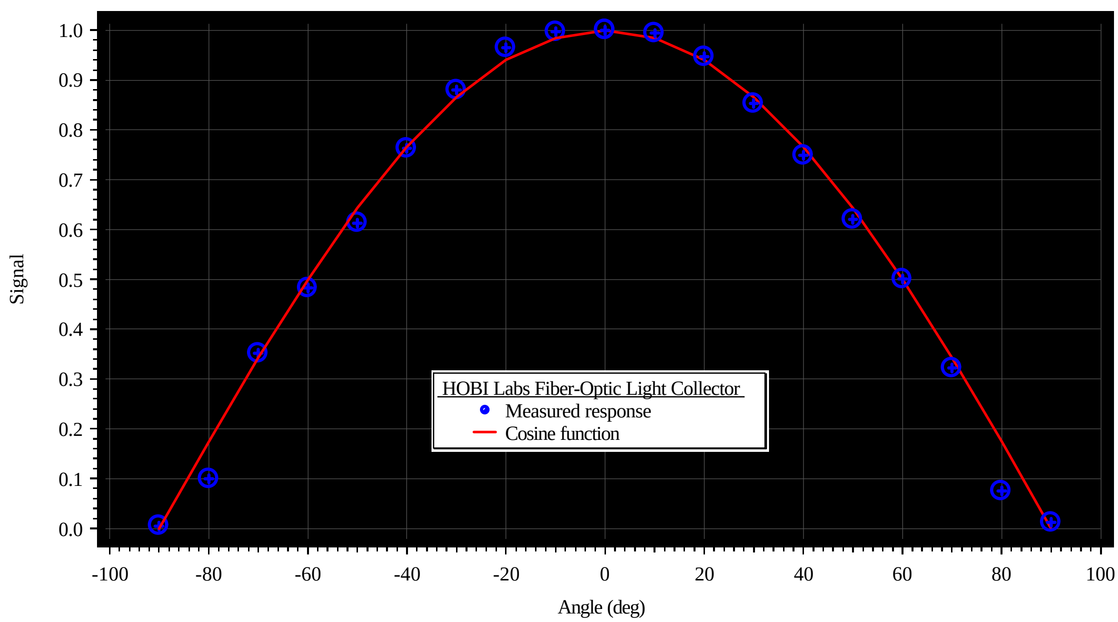

Figure 2. Angular response of fiber-optic irradiance collector.

RESULTS

During the CoBOP LSI experiment in May, 1998, we measured the benthic spectral irradiance reflectance at several sites, including the channel marker site, the main dock site, the boathouse dock site, and Rainbow Gardens. At the Rainbow Gardens site we deployed a buoy which was outfitted with sensors to measure hyperspectral remote-sensing reflectance and standard meteorological parameters. In addition to the time series measurements made by BSAP at these sites, we measured water column optical properties at a wide range of sites around Lee Stocking Island.

Except for the regular diel changes in water column height and currents due to tides, there were no major changes in environmental forcing mechanisms during the LSI experiment. Bottom spectral reflectance as measured by BSAP at the various sites remained fairly constant, although there were significant differences in bottom irradiance reflectances among the different bottom types. Presenting the spectral reflectances of the different sites would exceed the limitations of the ONR report requirements. For up-to-date reports of our results, visit our web site at http://www.hobilabs.com and go to Research/CoBOP.

The spectral backscattering coefficient b_b of the water column around Lee Stocking Island during the May 1998 CoBOP experiment was found to vary only slightly, at least on average. A typical profile of b_b is shown in Figure 3.

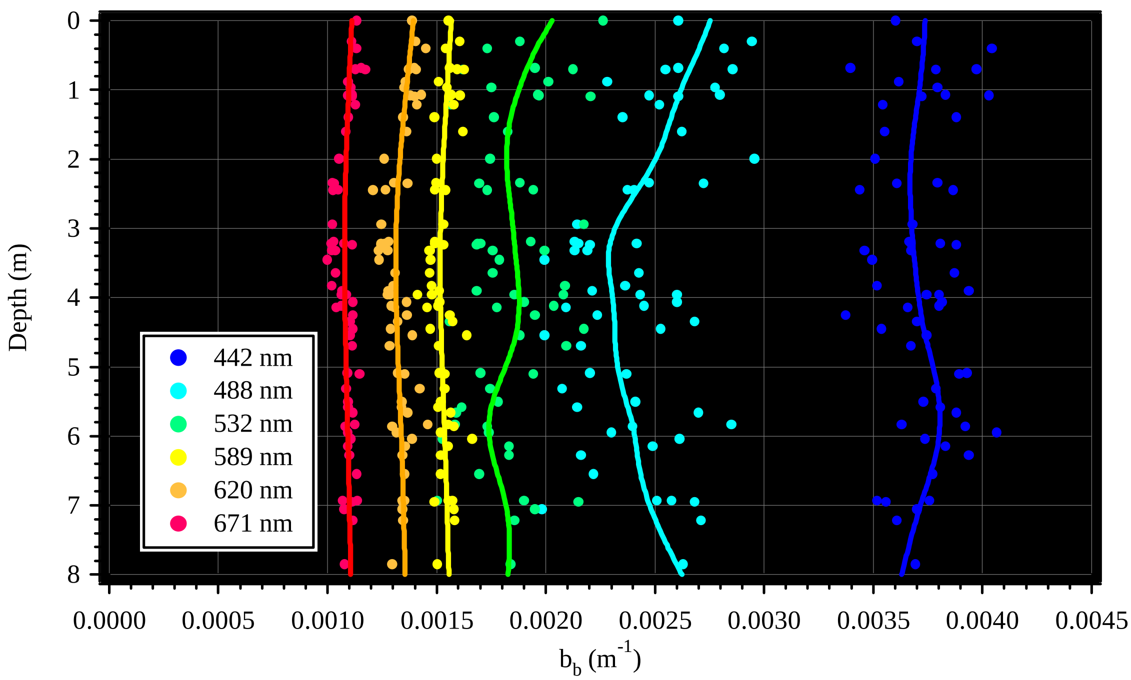

Figure 3. Backscattering coefficient profile measured with the HydroScat-6. North Perry Reef, May 30, 1998, 1400 hrs.

IMPACT/APPLICATIONS

The hyperspectral radiometers developed by HOBI Labs as part of this CoBOP program offer a significant advance in instrumentation for measuring spectral light-field parameters, including bottom irradiance reflectance, water column apparent optical properties, and remote-sensing reflectance. The versatility of these new hyperspectral radiometers will have wide application in environmental optics. They can be operated by divers to measure the irradiance reflectance of specific benthic species. They can be easily moored to measure time series of bottom reflectance. And they can be integrated into profiling or buoy systems to measure remote-sensing reflectance and underwater light field parameters.

TRANSITIONS

The hyperspectral radiometers developed as part of BSAP are already being used by investigators on CoBOP and on other ONR environmental optics programs. The bio-sediment-optical model and seagrass 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 March and October of this year we conducted field experiments 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 for CoBOP, we were able to quantify the effects of dredging on the benthic light field and hence on seagrass production.

RELATED PROJECTS

1. A significant portion of the measurement technology and modeling capability developed on CoBOP is now being applied to the ONR HyCODE program.

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

3. The hyperspectral radiometers we developed on CoBOP are now the central optical component of the Monterey Bay NOPP project, which involves HOBI Labs, the Naval Postgraduate School (NPG), and the Monterey Bay Aquarium Research Institute (MBARI).

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