Hyperspectral Remote Sensing Of The Coastal Ocean: Adaptive Sampling And Forecasting Of Nearshore In Situ Optical Properties

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LONG-TERM GOAL

The Oceanographic Systems Laboratory (OSL) has proposed to develop an optical sensor package for deployment on the REMUS autonomous underwater vehicle and operate the "optical AUV" at the Rutgers University Long-term Ecosystem Observatory (LEO-15) as part of the Hyperspectral Coupled Ocean Dynamic Experiment (HyCODE). The combination of the new sensor package with standard REMUS sensors will provide a comprehensive physical/optical/biological data set. As part of this project, the data set will support multiple efforts including:

- Nowcasting and forecasting the 3-dimensional evolution of inherent optical properties in coastal waters to determine follow-on sampling strategies.
- Development of hyperspectral remote sensing techniques for optically complex coastal waters.
- Coupled data assimilative hydrodynamic ecosystem models currently under development at Rutgers University.

Long-term, we are hopeful that development and demonstration of this new "optical" REMUS will lead to advancement and increased use of autonomous underwater vehicles in ocean research.

OBJECTIVES

Our objectives include:

- Design of the optical sensor package, consisting of multi-channel downwelling irradiance and upwelling radiance sensors and a fluorometer, for the REMUS AUV.
- Development of vehicle mission plans to best support the research objectives.
- Operation of the "optical" REMUS and a standard ADCP REMUS at the LEO-15 site to collect optical, physical and biological data in the nearshore region.
- Upon completion of a vehicle mission, rapid transfer of the scientific data in the required format to support forecasting, modeling and algorithm development.
- Providing the "optical REMUS" for other research programs.

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APPROACH

In its' five years of existence, the REMUS vehicle has progressed from a research project to an useful oceanographic tool. OSL has installed a number of sensors or sensor modules on REMUS vehicles. The sensors include side scan sonar, acoustic doppler current profiler (ADCP), altimeter, CTD and a light scattering sensor. Sensor modules include the turbulence module, consisting of shear probe, acoustic doppler velocimeter and a CTD, and the bioluminescence module, which consists of a fluorometer, bioluminescence sensor and light scattering sensor. Techniques used in design and integration of the optical module will be similar to those used in the past developments.

The optical module will consist of multi-channel downwelling irradiance and upwelling radiance sensors and a fluorometer. This package will be complemented by the standard REMUS sensors, which include a CTD and light scattering sensor. Depending on the size of the optical module, an ADCP may also be installed in the optical vehicle to provide additional physical measurements. A second REMUS vehicle, with an ADCP and CTD, will also be available to augment data collection.

OSL has participated in the Coastal Predictive Skill Experiments (CPSE) each of the past three summers at the LEO-15 observatory offshore Tuckerton, New Jersey. The REMUS vehicles have generally been outfitted with an ADCP and CTD. There have been significant improvements in vehicle performance, mission time, data collection and data transfer each field season. This program has the advantage of using the experience garnered during the past seasons.

"Optical" REMUS missions will be similar to missions conducted during the previous experiments. The vehicle will generally swim a twenty kilometer trackline oriented roughly perpendicular to the shoreline. An advantage of the long trackline is that the vehicle will often swim through regions with significantly different optical properties during the same mission. If an upwelling center forms as the field season progresses, the vehicle mission may be modified to closely survey this phenomena, which is a focus of research at Rutgers University.

WORK COMPLETED

The focus in 1999 was to initiate the design of the optical module. The optical module sensors have been selected. The are the OCI-300 Downwelling Irradiance and OCR-300 Upwelling Radiance sensors from Satlantic and a WetStar fluorometer from WetLABS. The irradiance and radiance sensors each have seven channels. The selected wavelengths are 412, 443, 490, 510, 555, 665 and 683 nanometers. The bandwidth at each wavelength will be 10 nanometers. Several mechanical configurations have been developed with the intention of minimizing shadowing and the impact on vehicle drag and control. The optical module design will be finalized in early 2000 and fabricated in time for testing near Woods Hole prior to the HyCODE field exercises.

As part of this and other ONR and NSF sponsored efforts (see related projects section) a third LEO-15 profiling node, outfitted with optical instrumentation, was constructed and then deployed during the 1999 CPS experiments. Connected to the inshore node, the profiler transmitted real-time data from three optical sensors back to the shore station.

In a collaboration with scientists at University of California, Santa Barbara, a bioluminescence sensor module was installed in a REMUS AUV and demonstrated at LEO-15.

RESULTS

Since the "optical" REMUS is still in development and the initial HyCODE field season at LEO-15 is during the summer of 2000, there are no project results as of yet. However, significant results were obtained in the related projects. Nighttime missions with the bioluminescence sensor installed on a REMUS AUV were conducted at LEO-15. A sixty-hour experiment was conducted with the optical profiler to define the importance of tides on the variability of *in situ* inherent optical properties. Data from these operations are being evaluated by the scientists and will lead to improvements in the experiments during the 2000 field season.

Figure 1. ADCP and Bioluminescence REMUS vehicles prior to deployment

During the 1999 field season at LEO-15, the REMUS vehicles logged over 500 kilometers measuring current, conductivity, temperature and pressure. This data was assimilated in the modeling and forecasting efforts. Figure 1 shows two REMUS vehicles and an example of REMUS bioluminescence data generated at LEO-15 is presented in figure 2.

IMPACT/APPLICATION

This program is the development of a new platform, a small AUV, for making optical measurements in the ocean. The platform is very portable, easily deployed from small boats and allows rapid recovery of data. Operable for more than 12 hours with lithium batteries, the "optical" REMUS will provide significant data sets for the HyCODE program and should receive strong consideration for use on other similar projects.

TRANSITIONS

The “optical” REMUS data will support a number of different efforts. The data format and time requirements may vary for the different efforts. In the past OSL developed the ability to rapidly provide data for review or modeling inputs. This is best exemplified by the REMUS surveys conducted during the National Ocean Partnership Program Coastal Predictive Skill Experiments conducted at LEO-15 during July of 1999. REMUS data was generally available to the forecast modelers an hour after the AUV was recovered.

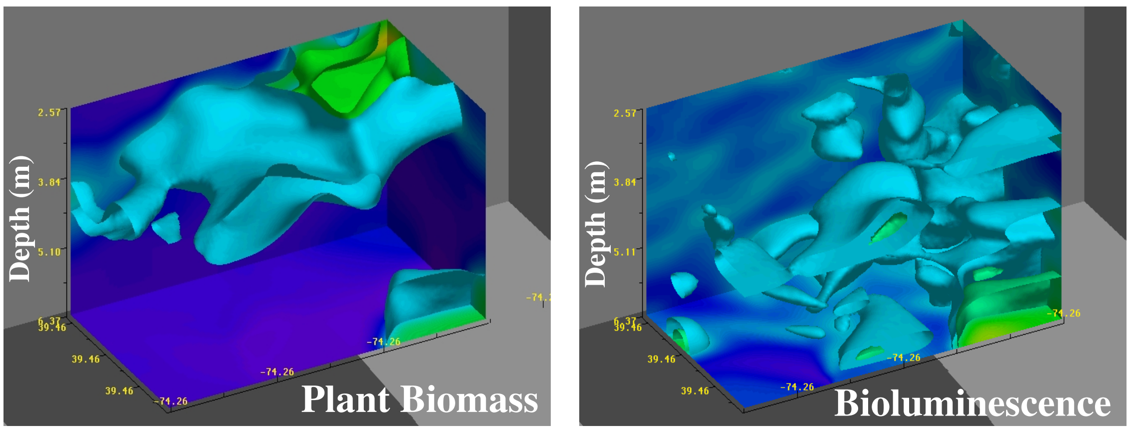
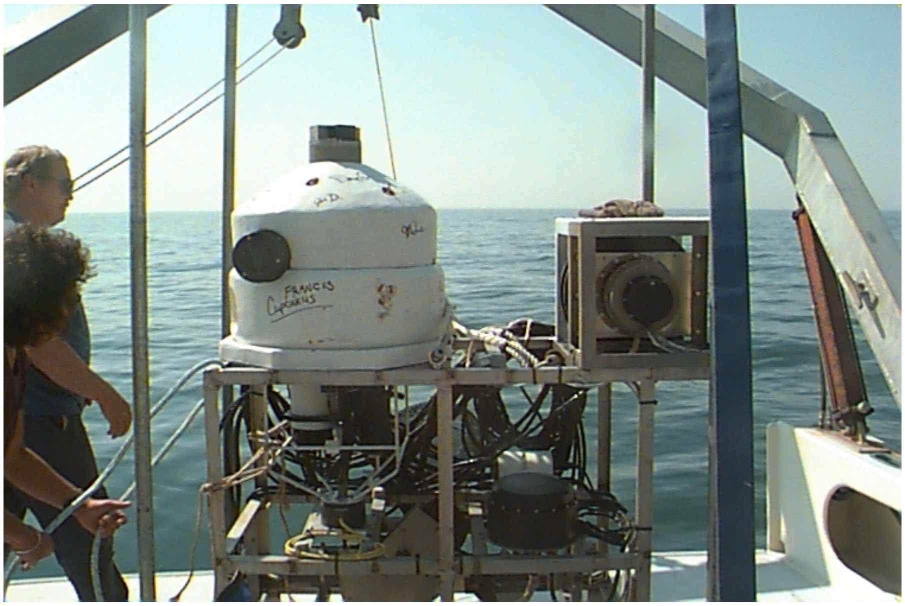


Figure 2. Volume rendering of fluorescence (left) and bioluminescence potential (right) obtained from a REMUS deployment at LEO-15 in July 1999. The fluorescence isosurfaces are 380 (light blue) and 961 (green) voltage units. Bioluminescence isosurfaces are rendered at $5x10^{10}$ (light blue) and $1.1x10^{11}$ (green) photons/sec/L. The LxWxH axis are Longitude (~300m), Latitude (~150m) and Depth (2-7 meters). For orientation, east is to the right and north is into the page. Data cubes are rendered using kriging interpolation techniques.

RELATED PROJECTS

1 - An “optical” vertical profiler was designed and built in early 1999, and then deployed at LEO-15 in July of 1999. The profiler was plugged into the LEO-15 Node A, which connects to shore via an electro-optic cable that allows real-time communication. The profiler was outfitted with an absorption/attenuation meter (AC-9), a fast repetition rate fluorometer, and a laser particle sizer (LISST-100) during the July deployment. Additional sensors, including a fluorometer/optical backscatter sensor (Hydroscat-2) and bioluminescence sensor, will be added for follow-on deployments in support of the HYCODE program. Figure 3 shows the optical profiler on the deck of the R/V Arabella prior to deployment.

Figure 3. Optical Profiler on the R/V Arabella prior to deployment



2 - The REMUS bioluminescence module integration was completed in early 1999. It was tested at LEO-15 in July of 1999 and will be tested in the Gulf of Mexico in November of 1999.

3 - OSL is working with scientists at WHOI and at the Woods Hole Research Center to develop a technique for evaluating relative eutrophication of coastal embayments using aerial video imagery. OSL engineers are designing an instrumented tow body that will make measurements similar to the "optical" REMUS to calibrate the aerial video imaging system.