LOCO with a Shipboard Lidar

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LONG-TERM GOALS

Our goal is to use light detection and ranging (lidar) technology to characterize the regional distribution, frequency of occurrence, horizontal extent, vertical structure, and temporal cycles of biological thin layers. Biological thin layers are defined as concentrations of phytoplanktonic and/or zooplanktonic organisms occurring in a vertical thickness of several centimeters to several meters with contiguous horizontal extents on the order of kilometers. A solid body of work has established the existence of thin layers of biological organisms in both fjord and coastal ocean environments. Observations of these structures indicate that they are episodic and that their formation is induced by a combination of stratification and vertical shear (Cowles et al., 1998, Cowles, 2003). The initial studies of the physical, biological, and chemical processes associated with thin layers have shown that they are dynamic structures in the spatial domain, that they can persist for days to weeks, and that their biological and chemical rate processes are substantially more intense than those in the surrounding water column (Hanson and Donaghay, 1998; Dekshenieks et al., 2001). We do not know the extent of their presence throughout the marine environment, how important thin layers are to the overall productivity of the regional coastal ecology, or how they may interact with the oceanic ecosystem.

In order to fully understand the impact of thin layer structures on coastal ecosystems and regional coastal-oceanic ecological interactions, the biological and chemical processes and process rates must be investigated within the context of their physical phenomenology. In order to understand and define the physical context for the formation of layers, high resolution spatial data is needed over the time period spanning their formation, evolution, and senescence.

Our goals for the *LOCO* Program are:

1) to develop a ship based, self contained, high vertical resolution lidar sensor providing positioning and optical density data that will enable us to

a) detect and map the horizontal extent, the depth location, the vertical boundaries (when possible), and the temporal duration of biological thin layers in the marine water column at sub meter scale resolution.

b) acquire optical attenuation data to correlate with measurements from the fixed point high resolution in situ profilers and gliders deployed during the field study.

Our long-term goals are:

1) to correlate the lidar attenuation coefficient data with in situ IOP measurements and define empirical relationships between the two types of optical data that will enable us to establish a means for deriving environmental optical properties over geographically relevant areas of the ocean. This type of synoptic optical data is needed to predict the performance of Navy Electro Optic systems and to sea truth ocean color remote sensors.

2) to understand how thin layers affect the performance of current and future Navy Electro Optic sensors. How important are thin layer physical structure (depth location, thickness, horizontal extent) and temporal dynamics (episodic nature, persistence) to EO sensor detections and false alarms?

OBJECTIVES

The objectives of the FY 2005 effort were to assemble the ship mounted lidar system called SeaTROLL, deploy it during the LOCO 2005 field test in Monterey Bay, California and collect an extensive data set of highly resolved optical profiles for inter-comparison with in-situ instruments over large special and temporal scales. The lidar data set will also provide a contiguous record of measurements to fill in the gaps in the traditional in situ profiling methods.

APPROACH

State-of-the-art, off the shelf parts were chosen to create a lidar system with high vertical resolution. To achieve this goal several system parameters were targeted: a 2 nanosecond wide laser pulse, a 250 MHz bandwidth optical receiver, a 5 giga-sample per second digitizer, and an INS/GPS system with pointing accuracies of less then 0.1 degree and position accuracies of less then 1 meter. All system components will be mounted on an optical breadboard for stability and placed in a watertight enclosure for mounting on the bow of a ship.

We will participate in a phenomenological field study at the selected *LOCO* site. The coastal region in shore, off shore, and within Monterey Bay, California has been chosen as the study area. The field experiment has been scheduled for August/September 2005. In Monterey Bay at the end of summer thin layers appear to be a recurrent phenomenon, supported by the seasonal stratification and the episodic upwelling/relaxation cycles driven by alongshore winds.

SeaTROLL will detect and optically parameterize the physical extent and integrity of thin layers in situ during the one-month field test. We will use a combination of adaptive, grid transect sampling, and edge mapping. Our goal is to ground truth the lidar attenuation and optical density measurements with the in situ observations made by the glider fleet, AUV's, (REMUS), and profiling packages. The lidar observation experiments, or transects, will be conducted from the bow of a regional to ocean class oceanographic research vessel and performed in close collaboration with Tim Cowles, Al Hanson, Percy Donaghay, Margaret McManus, Van Holiday, Lou Goodman and Dave Fratantoni. Lidar maps will be generated and shared with the other PI's for use during the field experiment to track thin layer structures and provide mission planning information for the profiler deployments and glider sampling.

Figure 1 SeaTROLL During Assembly
[a side view of the optical breadboard with most of the system components attached]

WORK COMPLETED

In FY05 NAVAIR has assembled and fielded the SeaTROLL system. The system was mounted on the bow of the R/V New Horizon as shown in Figure 2 and collected data from August 25 thru September 8, 2005 as part of the LOCO field test in Monterey Bay. Approximately 4 million lidar profiles were collected during this period. During the field test the profiles were processed to show relative changes in water optical properties and to reveal water column structure in real time. In Figure 3, the upper plot is an example showing a strong sub-surface change in optical properties and shown in the lower plot an estimate of the depth of the change is shown. Further processing is required to estimate optical density and physical properties such as thickness, integrity and extent.

Figure 2 SeaTROLL mounted on the bow of R/V New Horizon during field test
[Fully assembled SeaTROLL system mounted on rails and extended out over bow of ship]

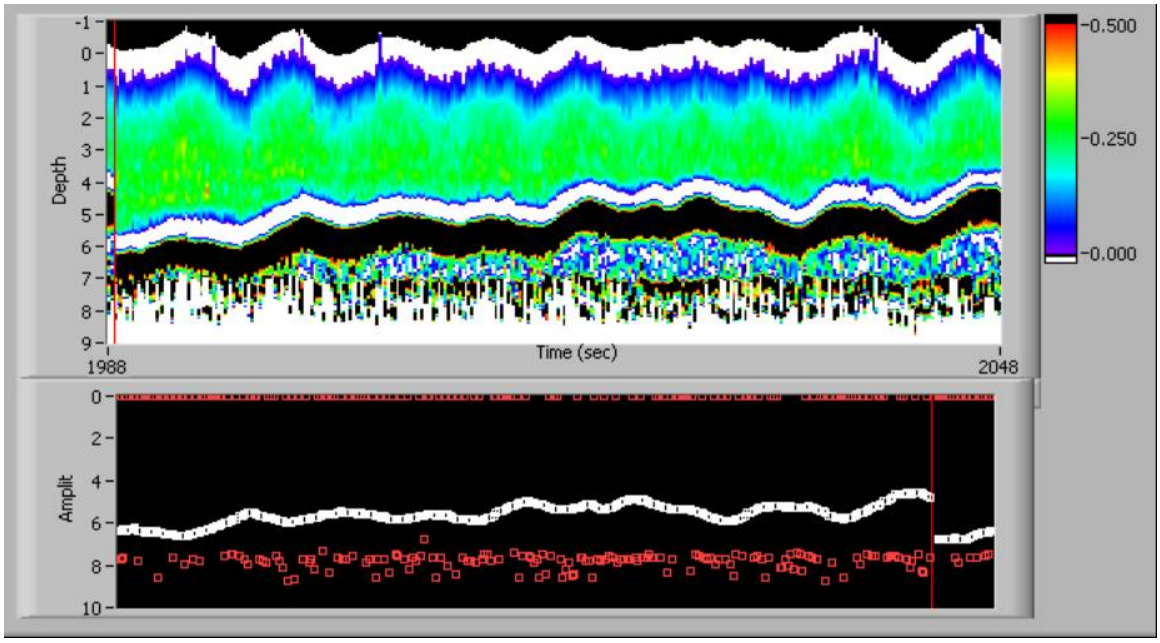

Figure 3 SeaTROLL Real-time data product
[screen shot of processed lidar data showing 2 plots, both time versus depth; the top plot shows horizontal, color coded bands with a wavy black band at approximately 7 meters depth and noisy mixed colors in the band below, the bottom plot shows a white line that corresponds to the upper edge of the wavy black band in the top plot]

RESULTS

A ship-mounted lidar was developed to characterize the regional distribution, frequency of occurrence, horizontal extent, vertical structure, and temporal cycles of biological thin layers. The system was deployed in concert with in situ profiling instruments, ship-board flow through instruments and acoustic profiling instruments. An extensive, cohesive data set was collected and includes large special regions as well as two 24 hour, single location time series. This data set, in conjunction with a fixed array of in situ instruments and in situ observations made by AUVs, ROVs and profiling packages constitute an extraordinary opportunity to study the physical, chemical, optical and biological conditions under which thin, biological layers develop.

IMPACT/APPLICATIONS

This on-going research is providing the opportunity to expand the applications of lidar technology by optimizing it as a tool for providing synoptic ocean optical data. The data collected with the SeaTROLL system will eventually be valuable in improving the results of light propagation and electro optic system performance models.

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