Autonomous Profilers for Carbon System and Biological Observations

Casey Moore
Western Environmental Technology Laboratories, Inc. (aka WET Labs, Inc.)
PO Box 518, Philomath, OR 97370-0518
Phone: (541) 929 5650 fax: (541) 929 5277 email: casey@wetlabs.com

Contract Number: N00014-99-C-0449

This grant is part of a National Ocean Partnership Program (NOPP) with

James K.B. Bishop
EO Lawrence Berkeley National Laboratory
1 Cyclotron Road, MS90-1116
Berkeley, CA 94720-0001

Russ E. Davis
Scripps Institution of Oceanography
La Jolla CA 92093-0230

LONG-TERM GOALS

Our long-term goal is to understand the biogeochemical dynamics of the ocean's upper kilometer. Such an understanding is fundamental to prediction of the processes partitioning carbon between atmosphere and ocean and to the redistribution of carbon and associated elements within the water column. Key to predictability is understanding day-to-day variability of processes governing abundances of carbon species (dissolved and particulate, inorganic and organic) in the water column.

OBJECTIVES

Our primary objective is to demonstrate the concept of low-cost autonomous profiling vehicles outfitted with a suite of low-power optical, physical and chemical sensors as a means for measuring carbon products and their variability in water column. When widely deployed, these will permit high-frequency four-dimensional observations of ocean biological processes, carbon biomass, upper ocean physics, and parameters of the carbon system in the upper 1000 m. It is envisioned that once proven, such vehicles can be widely deployed to explore carbon variability on global scales. Our specific focus in this effort is to demonstrate that we can explore Particulate Organic Carbon (POC) and Particulate Inorganic Carbon (PIC) biomass variability in the water column on daily to seasonal time-scales in remote and extreme environments.

APPROACH

Platform. The autonomous platform to be used is the Sounding Oceanographic Lagrangian Observer (SOLO; Davis et al., 2000), a low-cost autonomous profiling float. This well-proven ocean physics platform, augmented with new optical sensors for biogeochemistry, will permit the rapid and precise determination of two important products of photosynthesis, particulate organic carbon (POC) and particulate inorganic carbon (PIC), as well as physical data (T, S and derived density stratification) relevant to understanding the variability of these products.

POC sensor. Bishop (1999) and Bishop et al. (1999) demonstrated that beam attenuation at 660 nm is strongly correlated to POC in open ocean waters. Accurate and precise long-term high-frequency measurement of POC in the upper 1000 m requires the following: (1) a stable and precise measurement, (2) long term endurance to fouling and other submersion effects, and (3) packaging suitable for autonomous profiler integration and deployment . Work on these issues was led by WET Labs, Inc.

PIC sensor. Particulate inorganic carbon occurs mostly as the mineral calcite and in most locations calcite is the dominant mineral in suspension. LBNL researchers developed the conceptual framework for a sensor that will look at birefringence in the water to measure calcite. WET Labs applied this concept in developing an *in-situ* device for the detection on PIC in the ocean.

WORK COMPLETED

POC Sensor- The POC meter consists and optical transmitter and receiver seperated by a fixed distance water path. The collimated transmitter emits light at 660 nm. The transmitter incorporates an active reference stabilization circuit to compensate for ambient temperature, package temperature, and long term LED decay. The receiver refocuses the light through a 1 mm aperture upon a detector. Light travelling through water between the transmitter and the receiver is absorbed and scattered from the primary path. This light, in turn, isn't seen by the receiver and results in a net loss in beam transmittance. Figure 1 shows a schematic representation and photo of the constructed POC sensor.

Outside of the euphotic zone the primary signal fluctuations are dominated by scattering. This scattering in-turn is correlates with POC concentrations in the water column. Fluctuations in this signal are on the order of 0.001 m^{-1}. This is at or below the precision level for commercial transmissometers. For this reason instrument stability with time and temperature were paramount in the design.

Two float-capable POC sensors were developed and deployed on SOLO floats in April 2001, near the NOAA, PAPA mooring site at 53 deg N, in the Berring Sea. These sensors and floats remain deployed. In addition two addition sensors were built and underwent long-term laboratory simulations to approximate long-term stability. These sensors were, in turn, deployed upon a SOLO during August 2001 in an intensive 10 day trial.

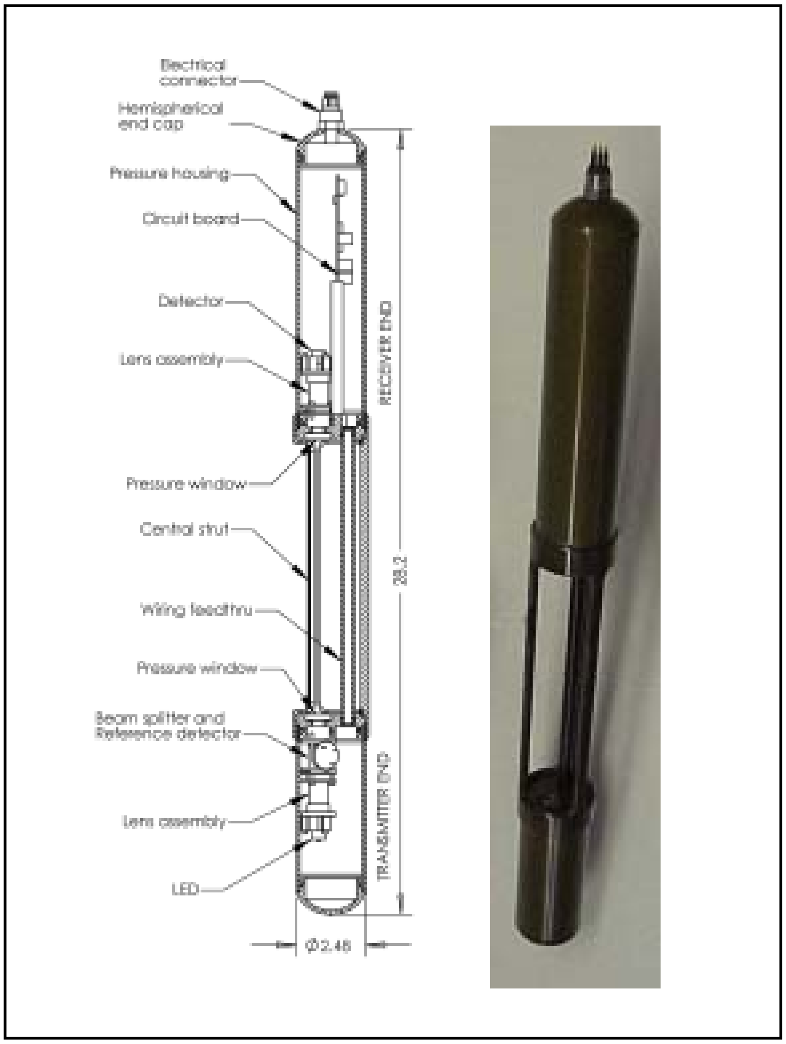

Figure 1 – POC meter schematic and picture

PIC Sensor – The PIC sensor incorporates a transmittance-based design with 90-degree crossed-polarizers at the transmitter and receiver respectively to measure calcite birefringence, and from this, estimate concentrations of PIC within the water column. Figure 2 shows a schematic representation of this sensor. The PIC sensor incorporates a modulated laser diode with a beam expander as a source in its transmitter, and employs a receiver similar in design to the POC meter of a standard transmissometer. A special flow tube with the crossed polarizing plates resides in the flow path. The pressure upon the polarizing plates remains hydrostatic, and thus eliminates light leakage through the plates due to pressure-induced distortion.

We built a PIC sensor for normal profiling deployment early in the year. After field tests in April, the sensor underwent a series of modifications, redesigns, and rebuilds. These efforts resulted in a sensor with substantial improvements in sensitivity, which was deployed by our LBNL partners in August.

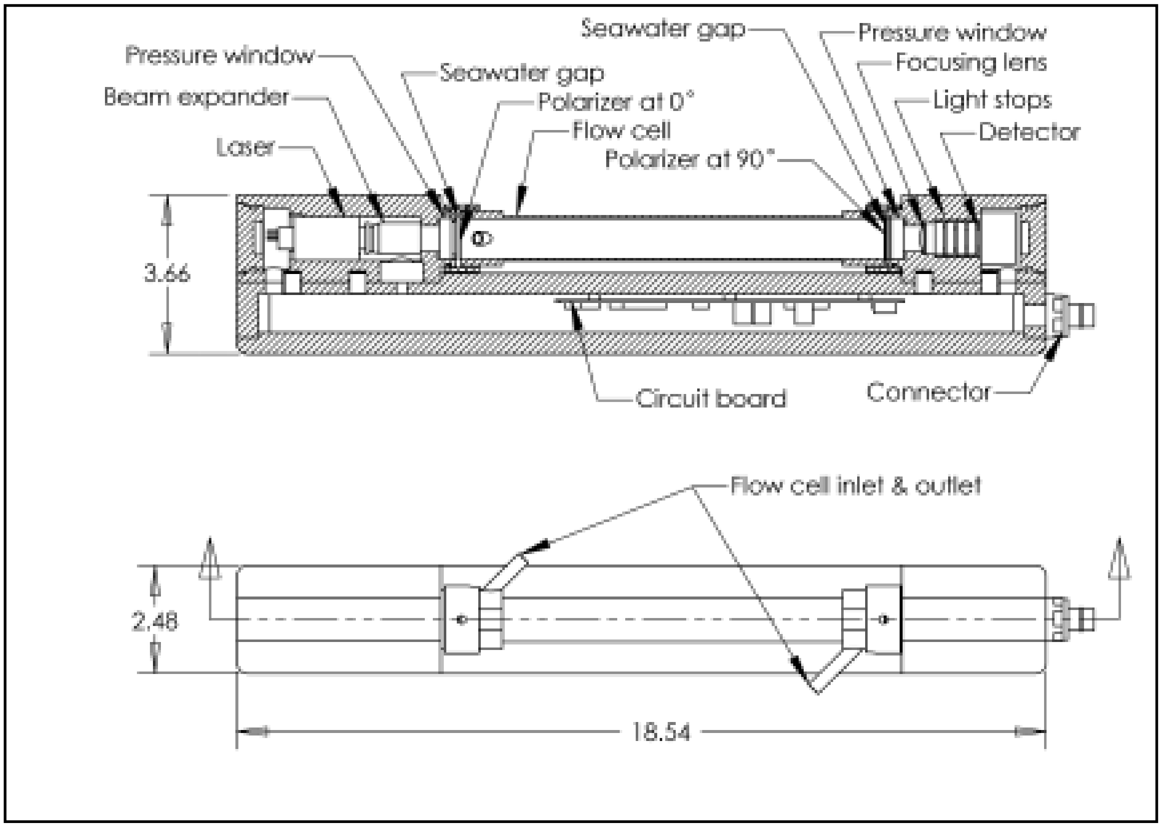

Figure 2 - PIC sensor schematic

RESULTS

POC sensor -After a test cruise in early March, two SOLO floats with POC sensors were deployed by our LBNL partners in April of this year. After 5 months of operation one POC sensor began to report erratic data. Since the float is still deployed at time of publication no cause for the intermittent operation has yet to be established. The other sensor and float remain fully functional. In August another float with a POC sensor was deployed in the same location and remains in operation. Discussion of the data is presented by NOPP partner, James Bishop, within this same edition.

Before deployment the sensors underwent extensive characterization in order to assure viable performance in the field. Results showed that short-term standard deviation of signal was on the order of 0.000006 m^{-1}. Signal variance with temperature was approximately 0.001 m^{-1}. These results demonstrated order of magnitude performance over present commercial transmissometers. In addition we conducted long term periodic sampling tests with two meters, to roughly simulate sampling conditions upon a SOLO float. The first meters showed signal degradation of approximately 1% over a six month deployment period, the second showed approximately 0.5% change over the same period.

PIC sensor – Development efforts on the PIC sensor focused primarily upon increasing signal to background response to detect small concentrations of calcite (< 0.05 µmole). Our approach involved both of the elimination of light leakage and to provide greater signal. Through multiple iterations we developed a laser diode based transmitter that provided a 20X overall signal to noise improvement over our original prototype. This improvement included a more than 2X improvement in response and an almost 10X improvement in noise performance.

While the signal to noise improvements in the sensor resulted in an theoretical sensitivity to calcite of 0.009 micromoles, short term signal fluctuations induced by the pressence of the suspended calcite substantially reduced the detection limits of the sensor in the lab.

Discussion of the data from the August cruise will be discussed by James Bishop in this edition.

IMPACT/APPLICATIONS

The ability to effectively measure carbon products within the ocean is vital to understanding global carbon flux. Work on this project has thus far, clearly demonstrated that sensors for detection of these parameters can be successfully implemented and deployed long-term on the new classes of autonomous platforms. With the implementation of higher bandwidth satellite communications, widespread use of such sensors and platforms in monitoring global variability of biological and chemical variability is imminently feasible.

TRANSITIONS

The POC sensor will be made available as a commercial product in 4 Qtr., 2001.

RELATED PROJECTS

Jim Bishop (LBNL) and Russ Davis (SIO) are supported separately by ONR under this National Ocean Partnership Program project.

WET Labs is working in partnership with Percy Donaghay and Margaret Dekshineks of the University of Rhode Island and Alfred Hanson of SubChem Systems, Inc. in developing novel chemical and biological sensors for an autonomous profiler system.

WET Labs is working in partnership with Mary Jane Perry of the University of Maine and Charles Erickson of the Applied Physics Laboratory at the University of Washington in developing new biological and chemical sensors for the APL virtual glider mooring.

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