DEVELOPMENT, ASSESSMENT, AND COMMERCIALIZATION OF A BIOGEOCHEMICAL PROFILING FLOAT FOR CALIBRATION AND VALIDATION OF OCEAN COLOR AND OCEAN CARBON STUDIES

Progress Report, Year 1

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Period covered: 1 October, 2009 – 3 August, 2010

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Grant number: NNX09AP51G

1 Overview, Planned Work, and Coordination

This document reports the progress on this project between 1 October, 2009 and 30 July, 2010. At completion of this project we will have integrated existing high precision bio-optical sensors (both active and passive) onto profiling floats, deployed and tested the floats in interesting dynamic ocean regimes, and demonstrated the efficacy of this stable, autonomous and sustainable technology for a.) the calibration and product validation of orbiting ocean color radiometers and b.) investigation of the dynamics of carbon in the upper ocean on time and space scales appropriate for the evaluation of the role of the ocean in the global carbon cycle.

The work is a collaborative project between seven partners. University of Maine has coordinated the work and provided guidance and standards for the mission's science goals. WET Labs and Satlantic have modified and produced instruments, housings, and control software. Teledyne Webb Research has made progress integrating their float software and hardware with the new instruments and flexible mission parameters needed for this project. CLS America has developed protocols for handling both the new data and the two-way communication it requires. NASA-Goddard (unfunded in year one) and CLS America have begun coordination to develop products that integrate real-time float data with NASA's satellite products around the location and time of the float's surfacing. Laboratoire d'Oceanographie, Villefranche-sur-mer (unfunded collaborator) has agreed to provide a ship of opportunity for deployment and evaluation of the float and is sharing expertise on calibration and validation activities and on the use of profiling floats with optical sensors.

Year 1 goals were:

1. Work package 1: develop, integrate, and test optical sensor packages on profiling float (Satlantic, WET Labs, Teledyne Webb, UMaine)
2. Work package 2: develop advanced communications capability for retrieving data and modifying mission parameters (CLS America, Teledyne Webb)
3. Work package 3: develop software for data system (CLS America, UMaine)

The bulk of joint efforts began in February, 2010, with a full-day meeting between partners at the at the Portland Hilton prior to the Ocean Sciences meeting in Portland, Oregon. UMaine has since coordinated weekly or bi-weekly conference calls with partners to coordinate developments and planning and to keep progress on schedule. Development, modification, and integration of sensors and the float platform are progressing on schedule to be completed in year 1. Communications capabilities are also being developed on schedule. Field tests of the biogeochemical profiling float are planned for October, 2010.

2 Vehicle

The vehicle is an APEX Float manufactured by Teledyne Webb Research in Falmouth, Massachusetts. The float is being adapted to support the suite of optical instrumentation for measuring the biogeochemical parameters required by the project. An upward-looking radiometer will be mounted to the top of the float to measure downwelling irradiance, and a package of instruments to measure backscatter, fluorescence, transmissometery, and upwelling radiance (downward-looking) will be mounted to the side of the float (figure 1). To date, mounting and cabling have been defined, and a preliminary mechanical layout has been completed for integrating the sensor packages with the float. An initial weight and buoyancy analysis has been completed, and a composite pressure hull will be utilized for weight savings. Energy budget calculations are underway and continue to be refined as the deployment plan is developed. Sensor descriptions and electronic integration is discussed in section 3.

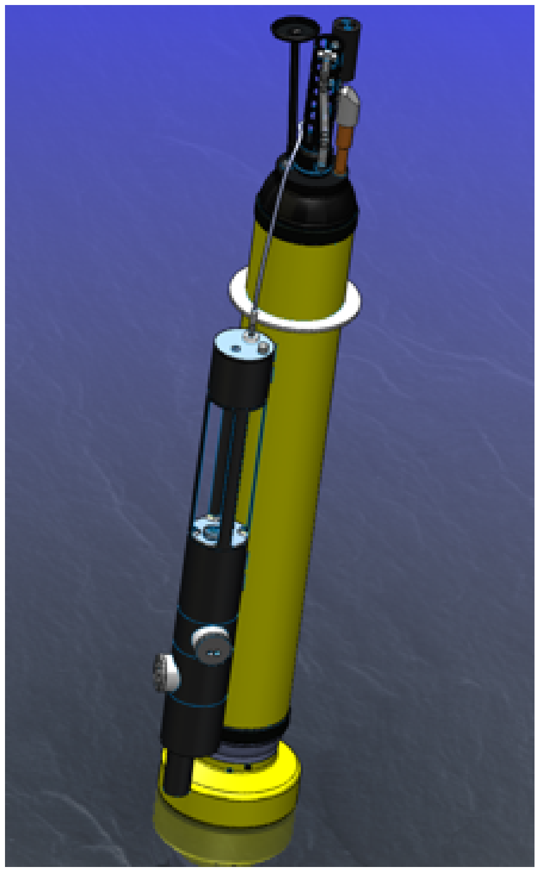

Figure 1: Biogeochemical float with optics suite attached to side and irradiance sensor on top.

3 Payload

The design of the sensor suite evolved from a number of options that were discussed at the February team meeting. The aim was to integrate seven instruments with the APEX in a manner that maintained acceptable float dynamics and that enabled the APEX to control the instruments through three available instrument ports by using a multiplexing component, called the Profiler Hub. The options considered had varying degrees of mechanical integration of the component instruments and varying selections of which instruments were to be combined. In the final design choice, the conductivity-temperature-pressure sensor (Seabird SBE-41CP) and oxygen sensor (Aanderaa Optode 4330) connect to APEX instrument ports on the top end cap, and the optical instruments are integrated by the Profiler Hub which connects to the third APEX instrument port, on the bottom end cap. The Hub will use input from the APEX controller and to store the data for later telemetry.

The bio-optical sensor suite has 5 main components (figure 2); the WET Labs C-Rover VII subassembly (650nm wavelength beam transmissometer), a WET Labs ECO FLBB subassembly (combined chlorophyll fluorometer and 700nm wavelength backscattering sensor), a WET Labs ECO BB2FL subassembly (combined 412 and 440 nm wavelength backscattering and CDOM fluorescence sensor), a downward-looking Satlantic OCR-504 R10W, and the Profiler Hub electronics subassembly (Satlantic and WET Labs). The upward-looking Satlantic OCR-504 ICSW is mechanically separate from the rest because of its field of view requirement, but is electrically and logically integrated like the others.

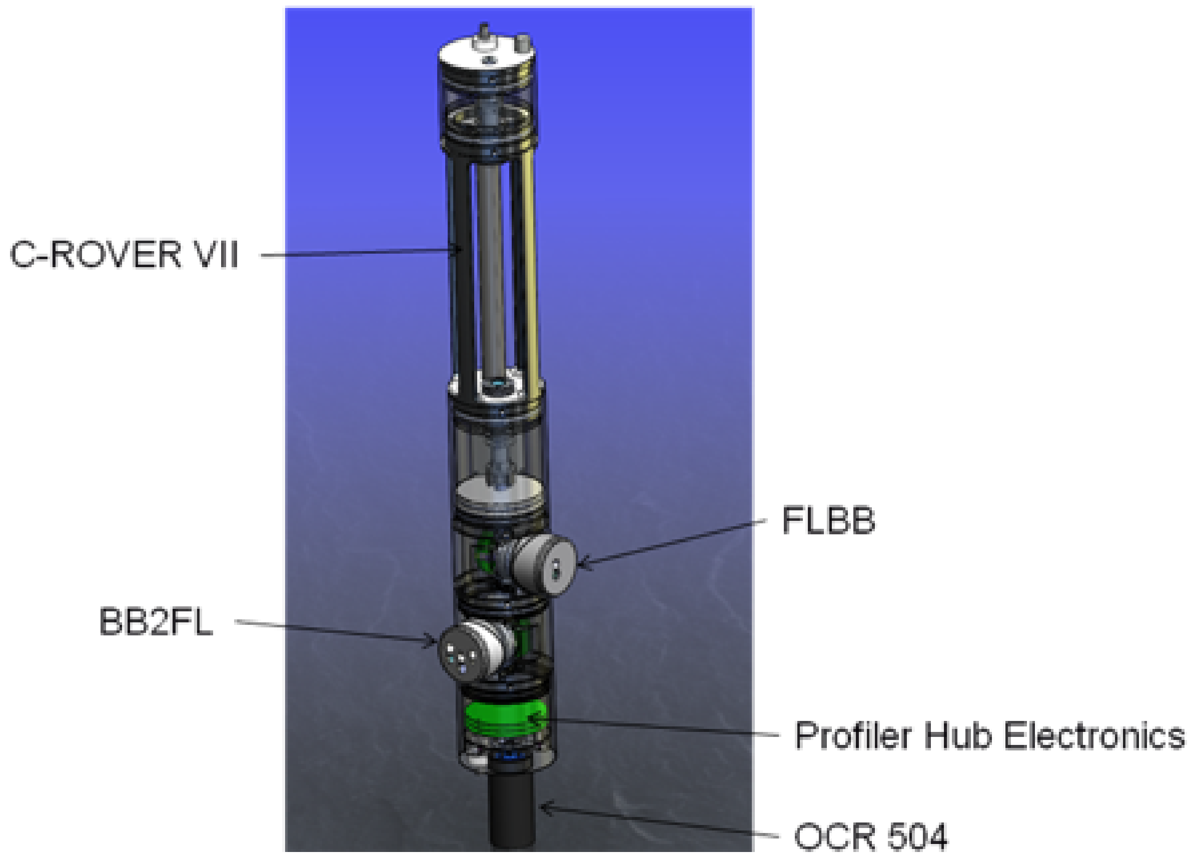

Figure 2: The optics suite.

The design constraints of the optics suite included in-water weight, center of buoyancy and mass, minimization of the number of external connectors, 2000m depth rating, long deployment lifetime, and manufacturability. The design of the system is modular, in that all of the components can be easily removed with electrical feed-through cables. This allows for the system to be assembled, calibrated and tested prior to shipping. The length and diameter of the optics suite, including the downward-looking radiometer are 88.5 cm and 10.1 cm, respectively. The mass estimate for the unit is 5840g with a displacement of 4340mL. Currently, WET Labs is completing construction of two units which will undergo pressure and performance testing. The first unit is scheduled to be shipped to Satlantic in early August 2010. Satlantic will then complete integration of the optics suite (OCR and the Hub electronics), perform final testing, and ship to Teledyne Webb Research in September 2010 for installation, balasting, and testing on the APEX float.

3.1 Transmissometer, Backscatter, and Fluorescence

Within the optics package, the WET Labs C-Rover VII beam transmissometer includes several design improvements over previous generations to enable reliable and stable measurements over extended deployment durations. These include using 6061 aluminum for the external housings flange and struts (improved corrosion resistance), new electronics to improve the thermal compensation, thicker and more rigid struts and optical component mounting. The C-Rover VII assembly includes a top end flange with a small zinc anode, a vacuum purge port, and an IE55 connector to connect to the upward-looking Satlantic OCR504 ICSW.

The FLBB subassembly includes a 2000m ECO chlorophyll fluorometer and 700nm backscattering head and electronics mounted in a modular housing. A similar subassembly for the BB2FL is located below this. Both subassemblies are constructed out of 6061 aluminum and the sensor heads are oriented 90 degrees relative to each other during assembly to reduce the potential of light interference. Each of these subassemblies can be calibrated and test prior to installation, and have feed-through electrical cables for connection to the Profiler Hub subassembly.

3.2 Radiance and Irradiance

Satlantic adapted their existing ocean color radiometers (OCR-504) for the Biogeochemical Profiler. The adaptation included developing pressure housings, modified electronics and firmware. The OCR-504 housings required strength to operate at the required operational depth and small displacement and low weight to minimize impact on APEX float dynamics. Two housings were developed.

The OCR-504 R10W radiance sensor requires a clear 10 degree half angle conical downward looking field of view. To provide this field of view, it is mechanically coupled to the bottom of the Profiler Hub. The Profiling Hub is mounted low enough on the APEX float. The coupling mechanism, a new design, was designed to be mechanically robust, cost efficient and to minimize weight and displacement. The coupling mechanism maintains the modularity of the instrument so that it can be manufactured and calibrated independent of the rest of the system. The instrument can be disconnected from the Profiler Hub, serviced or replaced without affecting the state of the other components of the integrated system.

The OCR-504 ICSW irradiance sensor requires a clear hemispherical upward looking field of view. A mounting arrangement was designed to locate the OCR-504 ICSW at the top of the CTD guard on the top end cap of the float, free of obstructions from float hull, antenna or other instruments. Therefore the instrument housing was designed to be as low weight as possible to minimize its impact on float stability particularly during periods at the surface when it would be completely out of the water. Its remote location from the integrated instrument suite requires it to be connected to the Profiler Hub by a cable running down the side of the float to the top of the optics assembly.

To reduce the weight of both instruments, a custom electronics version was designed to reduce components, and allow the instrument to be shortened. For the OCR-504 ICSW, the aluminum housing was replaced with PEEK. Custom OCR-504 firmware was developed for the Biogeochemical Profiler application. The calibration formula is integrated in the instrument logic so that it may be set to output data in calibrated physical units, rather than raw counts. This will be the default setting for this application. Secondly, the instrument may be set to output sample averages. For this application, the default setting will be to sample at 7 Hz and report the average at 1 Hz.

3.3 Profiler Hub

The Profiler Hub is one module in the mechanically integrated sensor suite and consists of control electronics that control power to and telemetry from the connected instruments. It is constructed by Satlantic and the electronics build on existing Satlantic technology from the Profiler II and the STOR-X (data logger). The Profiler Hub has an integrated compass and tilt sensor which provides orientation information which complements the radiometer data. The Profiler Hub subassembly is constructed of 6061 aluminum and is located beneath the BB2FL subassembly. The end of the Hub contains a mounting hole for the downward-looking OCR504, a vacuum purge port, and an IE55 connector to connect the to the APEX board (APF9i).

The Profiler Hub expands the instrument control scope of the APEX. It responds to sample commands from the APEX to collect data from specified subsets of the sensor suite, stores the data in integrated time-aligned records, and switches power to the sensors. The Profiler Hub supplies power to the instrument for the minimum time required to collect the specified data. It efficiently manages data by stripping instrument metadata and engineering data from the instrument telemetry, and by storing the data in a binary format in integrated records with shared depth and time references. The Profiler Hub stores all the bio-optical sensor data with pressure and time data provided by the APEX on board for upload at the end of each profile, under the control of the APEX. The Profiler Hub offloads the data in blocks tailored to the APEX Iridium telemetry medium.

The Profiler Hub provides access to the command console of each connected instrument for maintenance, configuration or troubleshooting. Data requirements may be changed mid-deployment by uploading new commands to the APEX to send to the Profiler Hub. The development of the Profiler Hub has included optional time-stamping and sample averaging schemes that will be evaluated during the pre-deployment testing and the initial deployment to determine their value in relation to the impact on power and data budgets.

4 Communications and Telemetry

During profiling, the data will be stored on either the APEX APF9i or the Profiler Hub, depending on the instrument. At the surface after each profile, the float will telemeter data to shore and will download new commands via Iridium. The APF9i will send data using established procedures for APEX floats. First, the salinity, temperature, depth, and oxygen data, stored on the APF9i, will be sent. Second, using protocols developed jointly by Teledyne Webb and Satlantic, the Profiling Hub will send the optics data in packets to the APF9i which will then send data to shore.

For initial deployment, communications to shore broadly follow standard protocols developed by CLS America. This float will be sending different file formats than in standard APEX operations. CLS is modifying their procedures for the high bandwidth, two-way satellite-based data communications and for the shore-side computing and network infrastructure for data delivery and enabling communication towards the floats for modifying mission parameters. The shore-side real-time computing and network infrastructure identified in Work Package 2 is currently in place and is operational. End-to-end tests are now being run to validate the ability of the data link and the access network to handle the rather large data files expected from the bio-floats. In addition, for Work Package 3 efforts, the software to extract the float geo-locations has been created and interface tests with NASA's Goddard Interactive Online Visualization And Analysis Infrastructure (Giovanni) will be scheduled as soon as possible. Creation of the Decoding, Processing, Archiving, Distributing modules is awaiting the definition of the specific structure and size of the data file that will be sent from the float. Candidate web-based access tools are being analyzed and evaluated.

The Goddard Earth Sciences Data and Information Services Center (GES DISC) was an unfunded partner, with major project activities slated to commence in September 2010. In conjunction with the other investigators, GES DISC has begun planning for integrating float data into Giovanni. This will include a Giovanni user interface for 8-day ocean color radiometry data for specific use by float managers and float data users.

5 Sampling Plan

A field test has been planned for the float. It will be deployed in October near the BOUSSOLE ocean optics mooring in the Mediterranean Sea operated by Laboratoire d'Oceanographie, Villefranche-sur-mer (LOV). The deployment is designed to test sensor calibration and examine the effectiveness of sampling strategies, especially in the presence of surface waves. Waves can affect measurements of irradiance through focusing and measurements of backscatter and transmissometry near the surface through bubble injection. Four sampling zones have been planned: deep, medium depths, shallow, and surface.

Nominal depths for these sampling zones are deep: 1000-500 m; medium: 500-50 m; shallow: 50 m to surface. Data will be burst-averaged in intervals of 25 db (deep), 10 db (medium) and 2 db (shallow). The surface interval will include five minutes of measurements. At the surface, data will be averaged or median filtered to 1-minute resolution. In the shallow and surface zones the radiometers will not be averaged and will sample at 1 Hz.

Although much telemetered data will be averaged, the full resolution data ($\sim$5 samples per burst, and continuous at the surface) will be stored on board. For most deployments the onboard storage will be too limited to be useful, but the trial deployment at BOUSSOLE will be short enough to store all the full resolution data. After recovery of the float this will allow improved estimates of optimal sample rates and burst lengths to be used in future deployments.

6 Summary

The project is moving forward on the original schedule. Instruments, software, and the float vehicle have been modified for use in this project. Integration and testing are ongoing, and the first field tests will occur early in year 2, in fall, 2010 (UMaine, LOV). Following field tests, evaluation and modifications will be performed (UMaine, WET Labs, Satlantic, Teledyne Webb). Concurrently in year 2, more advanced software for interface with the float and software for integrating float output with satellite products will be developed (UMaine, CLS America, NASA-Goddard).