BIOGEOCHEMICAL SENSING SYSTEMS FOR AUTONOMOUS PROFILING FLOATS

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ABSTRACT

A bio-optical sensor system for profiling floats to be used for ocean color satellite calibration and validation and ocean carbon studies was developed. The challenge of realizing the biogeochemical float is in augmenting the proven Argo float with an expanded sensor system that is robust, efficient, and economical so as to achieve satisfactory mission duration. Satlantic and WET Labs jointly developed the sensor system and collaborated with Teledyne Webb Research to integrate it with the APEX float. The sensor system includes an integrating hub that manages up to six additional instruments. The hub controls power switching, implements sampling strategies, and logs data minimizing energy consumption and data size thus maximizing float mission duration. The modular sensor system design allows for building user specified variants. The initial system provided upwelling and downwelling radiometry at four wavelengths, scattering at three wavelengths, beam attenuation, chlorophyll, and CDOM measurements to complement core float sensors for pressure, temperature, salinity and dissolved oxygen. The system architecture and performance are described with emphasis on data quality and the impact on float energy budget and thus mission duration. Initial deployment results are presented.

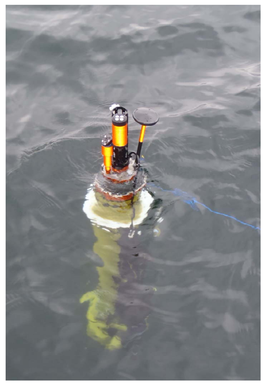


Figure 1. Sea Trial in Bedford Basin, Nova Scotia, 10 February 2011
Greg Gerbi, Emmanuel Boss, Diego Sorrentino, Keith Brown, Matt DeDonato

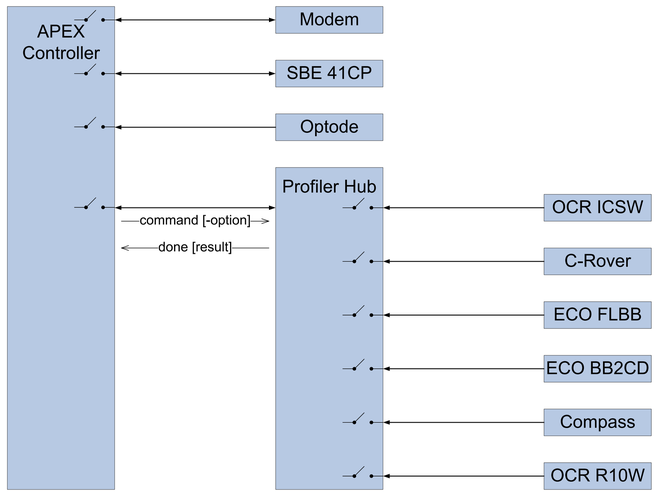


Figure 2. System Architecture

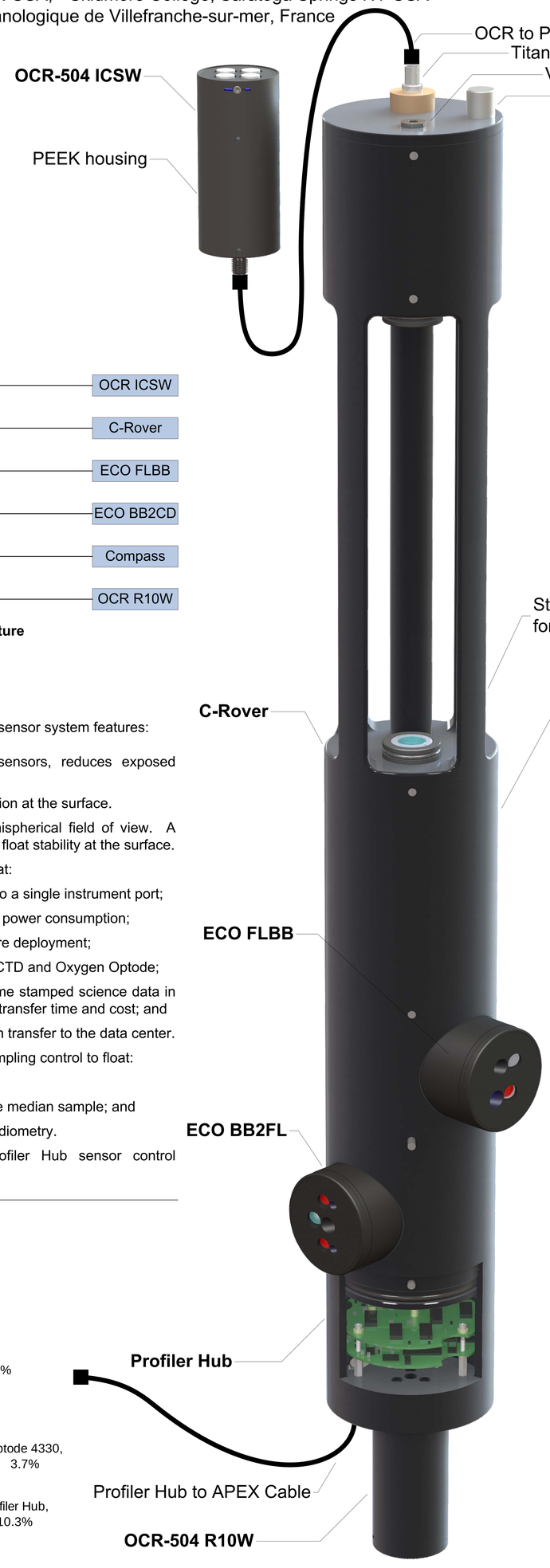


Figure 4. Bio-optical Sensor System

DESIGN GOALS

Sensor Performance. Proven instruments are adapted to operate in Argo service conditions (depth, extended duration, no maintenance) without compromise of fundamental performance qualities of accuracy, sensitivity and stability, particularly for the calibration and validation mission.

Robust. The Biogeochemical Profiler consisting of the core APEX float with CTD and Oxygen Optode combined with the bio-optical suite is designed with the goal of being as reliable as a traditional Argo CTD float.

Operational. The system is designed to withstand deployment forces, retain satisfactory float dynamics despite the addition of external sensors, and provide conditions for bio-optical sensor operation such as field of view requirements.

Modularity. The bio-optical sensor system is a sustained product, not a one-of-a-kind research project. The flexible, modular design minimizes engineering to tailor the system to differing requirements.

Economical. The integrated system must be practical to manufacture, delivering the enhanced qualities of the individual sensors required for this application, without making assembly, test and delivery economically impractical.

Incremental Development. The bio-optical sensor system builds on the experience of previous developments and adapts to the current APEX float, in particular aspects of its mechanical, electrical and control configuration. Adaptations of the float are required as well, including selection of hull and battery options, ballast and trim management, development of sensor mounting arrangements , and extensive software development, see Ref.2.

ARCHITECTURE

These considerations led to the following bio-optical sensor system features:

- Strengthened housing mechanically integrates sensors, reduces exposed cables and maintains optical stability.
- Mounts low on the float to maintain vertical orientation at the surface.
- Irradiance sensor mounts high to achieve a hemispherical field of view. A lightweight radiometer housing mitigates impact on float stability at the surface.
- Profiler Hub expands the sensor capacity of the float:
  - Integrates the bio-optical sensors to connect to a single instrument port;
  - Manages sensor power switching to minimize power consumption;
  - With large storage capacity, logs data for entire deployment;
  - Logs data for profile for all sensors including CTD and Oxygen Optode;
  - Removes redundant meta data and stores time stamped science data in a compact binary format for economy of data transfer time and cost; and
  - Transfers data to the float controller for Iridium transfer to the data center.
- Profiler Hub command set extends fine grained sampling control to float:
  - Polled and continuous sampling;
  - Single or bursts of up to 20 samples, calculate median sample; and
  - Individual or sets of sensors, e.g. All, IOP, Radiometry.
- Modular housing components and generic Profiler Hub sensor control functionality provide for flexible configurations.

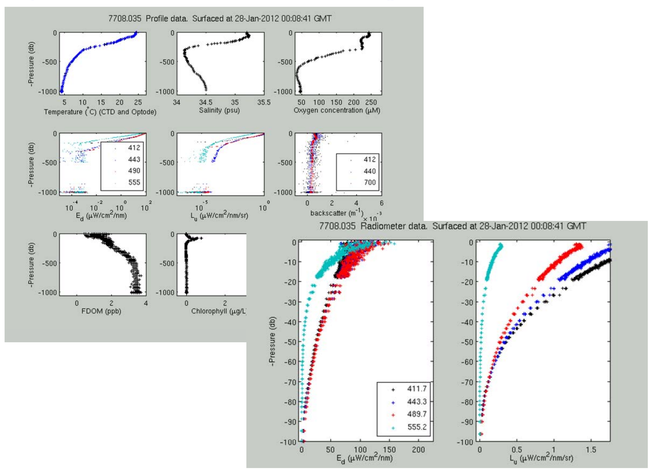
Table 1. Bio-optical Sensor System Variants

Bio-Optical Sensor System		Std	Lite	Mini	
CDOM		●	●	●	ECO BB2CD
Backscattering, b_b	412 nm	●			
	440 nm	●			
	700 nm	●	●	●	ECO FLBB
Chlorophyll *a*		●	●	●	
Beam Attenuation, c	650 nm	●	●		CRV
Downwelling Irradiance, E_d	412 nm	●	●	●	OCR ICSW
	443 nm	●	●	●	
	490 nm	●	●	●	
	555 nm	●			
	PAR		●	●	
Upwelling Radiance, L_u	412 nm	●			OCR R10W
	443 nm	●			
	490 nm	●			
	555 nm	●			
Heading, Pitch, Roll		●	●	●	Pro Hub

Standard Lite Mini
Figure 5. Variants

RESULTS

See Biogeochemical Profiler data from past and current deployments at the University of Maine, School of Marine Sciences
http://misclab.umeoce.maine.edu/research/bgcfloats/index.html



ENERGY CONSUMPTION

Energy budget modeling will improve with deployment experience. The estimates shown below use average sensor current draws based on measurements of a small sample of sensors at a constant voltage. The profile consists of five segments described below.

Sample Profile

1000 m – 500 m, 25 m intervals
CTD, Oxygen 1 sample
IOP, 5 samples
500 m – 50 m, 10 m intervals
CTD, Oxygen, 1 sample
IOP, Radiometry, 5 samples
50 m – surface, 2 m intervals
CTD, Oxygen, 1 sample
IOP, 5 samples per event
50 m – surface, 4.5 cm (1 s) intervals
Radiometry 1 sample
Surface, Sample for 5 minutes
Oxygen 1 sample every 20 seconds, 15 samples
IOP, Radiometry, 1 sample per second, 300 samples

Sample Profile Energy Summary

Data logged	107 KB
Buoyancy engine energy	8.66 KJ
Controller energy	2.07 KJ
Data collection energy	4.24 KJ
Data telemetry energy	1.81 KJ
Total energy per profile	16.79 KJ
Expected number of profiles	180
Based on initial reserve	3032 KJ

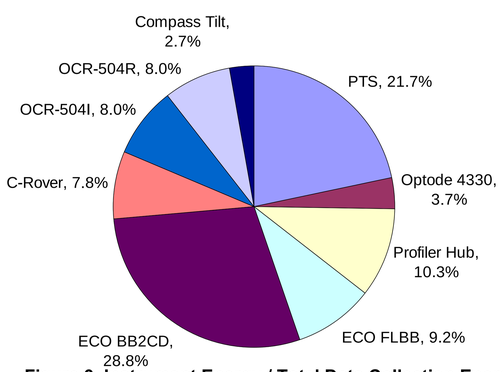


Figure 3. Instrument Energy / Total Data Collection Energy

Table 2. BOSS Deployments

SN	Variant	Float	Deployments	Deployed	Recovered	Profiles	Status
1	Std	7054	BOUSSOLE	13-Jul-11	17-Sep-11	29	Test deployment complete
			BOUSSOLE	17-Feb-12			Planned
2	Std	5293	BOUSSOLE	13-Jul-11	17-Sep-11	29	Test deployment complete
			BOUSSOLE				1-Feb-12 delayed - shipping damage
9	Std	7688	MOBY	17-Dec-11		56	Operational, Ed sensor damaged during deployment
10	Std	7708	MOBY	17-Dec-11		45	Operational
12	Std		MOBY	?-Apr-12			
13	Std		MOBY	?-Apr-12			

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REFERENCES

See also:

1. Gerbi, G, E. Boss, D. Antoine, A. Barnard, K. Brown, M. DeDonato, B. Woodward. Measurements of Solar Radiation from an Autonomous Profiling Float – Opportunities and Results for Validation and Calibration Activities. **Session 044 Friday 11:45**

2. DeDonato, M, B. Wallace, H.E. Fargher. Scheduling Sensors for Biogeochemical Profiling Floats. **Poster A0115 Session 041 Wednesday 16:00**