

Seabed Resident Event driven Profiling System (SREP). Concept, Design and Tests

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Abstract—The seabed resident event driven profiling system (SREP) described here offers a novel, optimized approach to profiling in coastal waters from seabed to sea surface during the rough seas encountered in the southwest monsoon season (June-Sept). It consists of a winch system and a tethered instrumented profiler. The winch system launches and retrieves the profiler. The tethered profiler is programmed to move up and down the water column to sample and transmit water column properties when it reaches the sea surface. It uses standard oceanographic sensors to measure vertical structure at $\sim 0.25\text{m}$ resolution. The major challenges addressed in this paper are long endurance of three months, underwater acoustic communications between the sea bed and the profiler unit and data transmission by the profiler to the shore.

Keywords—Underwater winch system; profiler; acoustic modem; coastal upwelling.

I. INTRODUCTION

The southwest monsoon winds trigger upwelling along the west coast of India and causes nutrient rich upwelled waters to fertilise the upper oxygenated coastal water layers. This creates a rich pasture ground for growth of zooplankton, phytoplankton, fish and fish larvae resulting in large fish yields by end of the monsoons in October. Due to the extreme sea wave and wind conditions during this period it is practically impossible to deploy instrumented packages using research vessels. Therefore there exists a massive information deficit in our knowledge about what happens during this crucial period. In order to bridge the knowledge gap, we describe the on-going development of an unsupervised Autonomous Seabed Resident Event based Profiler system that will transmit vertical column profiles over the monsoon period and in fair weather to shore stations on the west coast of India. This technology can also play a significant role in establishing of upwelling, tracking onset of hypoxia and quantify variations during these phenomena over a period of time. The prior art here limits the description to three known profiling systems namely the **HOMER** (Homing Environmental Recorder), **CAPABLE** (Coastal Autonomous Profiling and Boundary Layer System) and **SeaCycler** which have similarities and relevance, but are quite different to the present development. This calls for a new mode of operation which addresses the challenge of data collection in rough weather.

II. TECHNICAL IMPLEMENTATION

The SREP system is designed to work during the monsoon months when high sea state conditions prevail with typical wave heights of $\sim 4\text{m}$ and wind gusts of $\sim 14\text{m/s}$ in coastal waters of less than 100m in depth. The SREP is parked on the sea bed (see Fig. 1).

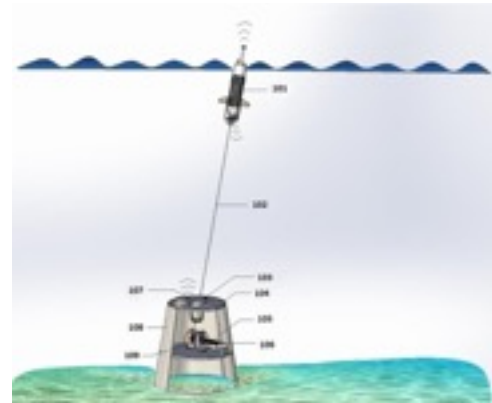


Fig. 1: Overview schematic of SREP system shows tethered profiler to winch on seabed unit.

101: profiler, 102: neutrally buoyant rope, 103: pressure sensor, 104: sea bed frame, 105: batteries, 106: electronics, 107: acoustic transponder, 108: protection jacket, 109: winch.

It consists of a winch system and a tethered instrumented profiler. The winch system launches and retrieves the profiler. The tethered profiler is programmed to move up and down the water column to sample and transmit water column properties when it reaches the sea surface. Innovative features on SREP are: (a) the profiler and the smart winch communicate with each other using a Sweep-Spread Carrier (S2C) acoustic communication technology, (b) the movable profiler (iAVP) is the inverted version of the patented Autonomous Vertical Profiler (AVP), (c) event based data acquisition technique for reduced power consumption and safe operation, (d) use of thrust force from the motor on the profiler to avoid rope slack, (e) use of thrust force from the motor on the profiler to assist in breaking the sea surface for data transmission, (f) enable the SREP system to degrade gracefully so as to function as an underwater repository should the line connecting it to the

iAVP snap by accidental means or through the real possibility of fish bites and (g) broadcast tide, temperature and location (X,Y,Z) coordinates or other useful information needed in the navigation of underwater vehicles and oceanographic research vessels or as a reference beacon for ships in ports and harbors.

A. Underwater winch system

A small winch system manufactured by NiGK Systems (Japan) has been identified and will be used in SREP (see Fig. 2). The winch system of the SREP is responsible for vertically, elevating or lowering the profiling unit attached to it, thus allowing measurements in a time-series manner at various depths. It consists of three main components, winch unit, tensioner and latch assembly. The winch system is controlled by the low power electronics module designed by NIO using the proprietary command list.



Fig. 2: Underwater winch

Table. 1: Winch specifications

Weight in air	45kg
Weight in fresh water	28.6kg
Working load	100N
Ascending speed	0.25m/sec
Descending speed	0.15m/sec
Rope	Neutrally buoyant ~ 1.0g/m
Recommended buoyancy for profiler	8 to 12kgf
Operating voltage	24V
Current (pay-out)	100mA
Current (pay-in)	2A at 10Kgf

Table. 2: Command list

Command Name	AT Command	Remarks
Switch Status Request	RD A02002CRLF	Returns status of latch and tension switch
Pulse-counter Status	RD A04002CRLF	Returns number of rotations of the winch drum
Pay out Rope	#R,01,03CRLF	Pays out the rope
Reel in Rope	#F,01,00CRLF	Reels in the rope
Stop the winch motor	#S,01,00CRLF	Stops the motor and maintains rope length

B. Mechanical design

The mechanical subsystem of the seabed unit consists of a circular SS-304, sea worthy frame of diameter 1.0m and height 1.6m. It houses the winch system, batteries acoustic modem, electronics, latch, tensioner and Hydraulic Crush Point foam (HCP 50) (see Fig. 3). It is modular and consists of two parts held together using 8 U-bolts. This configuration allows ease of assembly, deployment and transportation (Madhan et al).



Fig. 3: Sea bed unit

Table. 3: Brief specifications of SREP

Diameter of sea bed unit	1m
Height of sea bed unit	1.6m
Weight of sea bed unit (air)	248.6kg
Buoyancy of sea bed unit	118.45kgf
Endurance	~100days
Operational depth	200m
Pay out /pay in speed	0.25/0.15 m/sec
Sensors sea bed	pressure, temp, tilt
Sensors on profiler	CTD, DO, CHL

C. Power budget

The winch system is powered using 2 battery packs constructed using lithium primary batteries, each rated at 24 volts 60Ah. During upwelling conditions the ambient temperature at 200m meters water depth is ~15° Celsius. At these temperatures the battery packs deliver about 90% of its rated capacity (see Fig. 4).

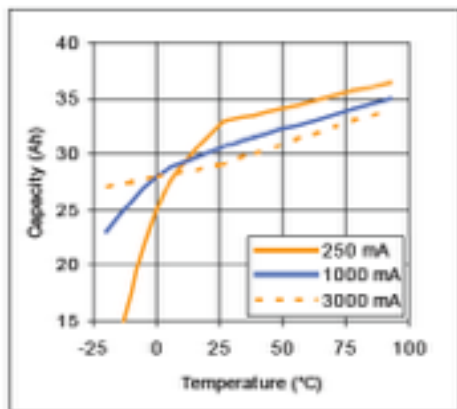


Fig. 4: Battery capacity v/s temperature

The NIO electronics unit would be powered using 1 battery pack of 24 volts 60Ah. For a 100 day deployment at sea at water depth of 200m and 50m, SREP would be capable to perform 1 dive/day and 2dives/day respectively.

D. Profiler

Profiler (iAVP) is the movable part of SREP and is the inverted version of the patented Autonomous Vertical Profiler (AVP) (E. De Sa et al), (See Fig. 5). It carries

standard oceanographic sensors and acoustic modem to measure (~0.25m resolution) and acoustically transmit to the sea bed unit (~1.0m resolution) vertical structure during the ascending (pay-out) phase of profiling.

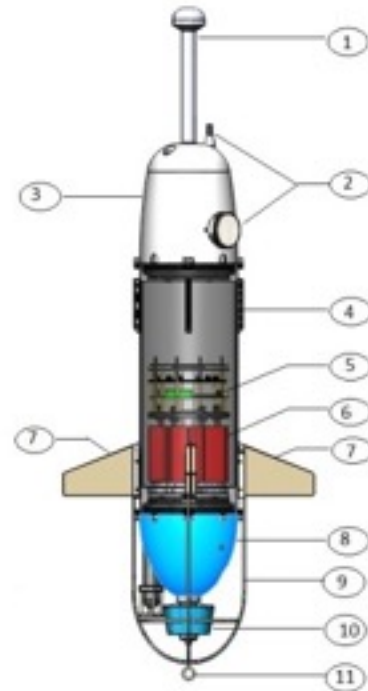


Fig. 5: Inverted AVP

1: GPS, 2: sensors, 3: nose cone, 4: hull, 5: electronics, 6: battery, 7: static fin, 8: tail cone, 9: cage 10: thruster, 11: tether hook.

E. Electronics interfacing, communication

Long term deployment constraint prompted us to use an ultralow power nano Watt XLP technology based PIC 18F97J94. An integrated temperature compensated crystal oscillator based real-time clock (RTC), DS3231 is used to wake up the microcontroller. Acoustic modems are used to exchange status and data between the seabed unit and the profiler. It has a wake-up module that can turn parts of the device off to optimize power consumption for battery-powered deployments. It checks for incoming acoustic signals and incoming data from a serial input-output interface (RS-232) and turns the rest of the device on only when such a signal is detected. Once the device completes receiving or transmitting data, everything but the wake-up module is switched off.

F. Web portal

The web portal for SREP is built on the existing AVP web portal (See Fig. 6). Between profiles the SREP will transmit data using a wireless/satellite network to a web portal for archival and distribution. The Web portal contains a Google map API for locating SREP, contains SREP & Sensor

information, dynamically plots data, communicates over wireless link, performs data integrity check & archiving and seamless extraction & visualization.



Fig. 6: Web Portal

III. FIELD TESTS

The key components of SREP i.e. acoustic modems, underwater winch system and iAVP have been tested independently.

A. Acoustic Modem

The SREP software routines were tested in a fresh water reservoir at Tillari in the Maharashtra state of India using acoustic modems in a hardware in loop simulation (P. Maurya et al). In all 3 modems were used. The description of the acoustic network is as follows;

- a. Acoustic Modem with aluminum casing rated for 1000 m depth mounted on the seabed unit.
- b. The acoustic modem with Delrin casing rated for 200m mounted on the profiler unit.
- c. A third acoustic modem, an OEM board was used for debug and interception.

The seabed unit was simulated using electronic hardware packaged in a water tight housing with acoustic modem connected externally. Commands for the winch were simulated by the sea bed unit and communicated via acoustic modem to the profiler unit consisting of a matching acoustic modem connected to a laptop PC running Ubuntu Linux and placed close to the surface. The profiler unit performed a simulated scientific data profile and successfully communicated vital information i.e. its simulated distance from the seabed unit. Both the units

went to sleep after the profile sequence was completed. However the seabed unit was put in the shallow sleep mode and was listening to the third acoustic modem (OEM) for 1 second at an interval of every 24 seconds. Four profiles were simulated in a one hour operation (profile every 15minutes). The OEM modem was used to intercept and command the seabed unit to execute a profile.

B. Underwater winch system

In-order to test the functionality and integrity of the winch system an 8m gantry test was set up in air. The profiling float was simulated using a 10kg weight. Using the Graphical User Interface (GUI) developed in-house, the winch system was programmed to execute a dive mission every 5minutes. This experiment gave us an in-depth knowledge about the functionality of the winch system, tensioner and the latch unit.

C. iAVP profiler

The initial testing of the iAVP profiler was carried out in a vertical 5m long, 0.6m dia. fiber glass cylindrical pipe closed at one end and containing water. The negatively buoyant iAVP was manually lowered in the column. After a short time interval the iAVP resurfaced with the help of the thruster. On reaching the surface the thruster was switched off by the software on board the iAVP and it sinks back to the base of the water column. The pressure values recorded during the process are shown (See Fig. 7).

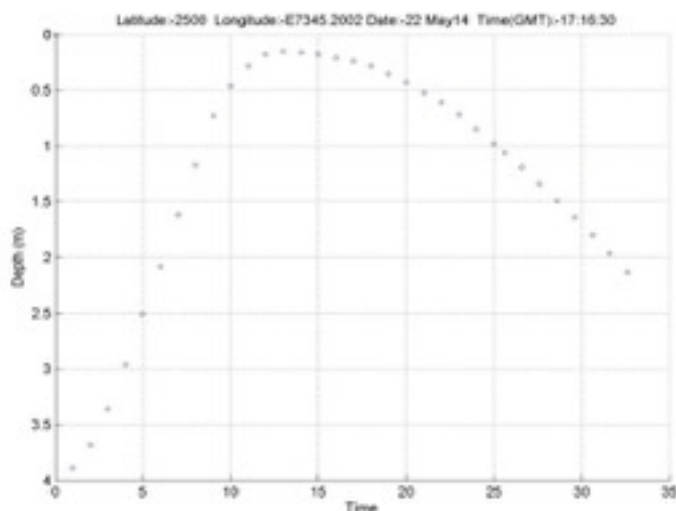


Fig. 7: iAVP profile

IV. CONCLUSION

This new strategy in sea bed profiling from sea bed to sea surface is well suited for use in the rough seas encountered in the monsoon season. The concept has been patented

(Application No. 158/DEL/2015) and the first phase of development on the seabed unit has been tested and simulated. This development throws open novel application in environmental monitoring of monsoon processes and also act as a strategic long term surveillance tool of coastal waters during the monsoon period on the west coast of India. Future work will involve real data runs of SREP in fair weather this year and then on to the monsoon period.

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VI. REFERENCES

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