

An Integrated Approach to Study Mud Banks of Alleppey Kerala using the Autonomous Vertical Profiler (AVP)

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Abstract—Mud Banks of Kerala are areas of the sea adjoining the coast that have a special property of dampening the waves and creating clearly demarcated areas of calm water during the roughest monsoon conditions of the sea. It is believed that these areas have a muddy bottom and suspended muddy sediments in the water column. The mere existence of mud in an area is not enough to form mud banks. However the mud of the right texture needs to get consolidated at the right depth where wave action could churn it up into a thick suspension (Gopinathan, C. K. et al. 1974). The mud banks are of socio-economic importance for the fisheries industry.

A consolidated effort was made from April to August 2014 to understand the evolution and properties of the Alleppey Mud Banks of Kerala. The Autonomous Vertical Profiler (AVP) developed at the National Institute of Oceanography was used to obtain high resolution profiles of conductivity, temperature, dissolved oxygen, PAR, chlorophyll and turbidity at 3 locations M1, M2 and M3. These profiles are presented in this paper. This effort was complemented by deploying a surface mooring with an identical AVP profiling on a taut line at a fixed location, M2 at about 6m water depth. AVP was programmed to perform 4 dives per day and transmit data to the laboratory using a cellular network.

During this deployment period the mooring AVP was subjected to wave break action and extreme monsoonal

and cyclonic conditions, high waves and strong wind gusts. The in-situ AVP and the AVP on the mooring was successfully deployed to obtain high resolution data of the Mud Banks. A total of 115 missions were executed, out of which about 44% achieved the required dive depth. Using the Mooring AVP, the variations of turbidity in the surface layer, mid-waters and bottom layer of the Allepy Mud Bank were studied over a period of 38 days. The Mud Bank was studied for the first time using an autonomous profiling unit.

Keywords: *Mud Banks, Autonomous Vertical Profiler, Turbidity*

I. INTRODUCTION

The AVP offers a fast, cost effective, optimized approach to profiling in coastal waters, dams, lakes and estuaries. It consists of a hands-free, motor driven in-situ robot profiler that requires no operator skill or deployment gear, while fulfilling the requirements of repetitive sampling in coastal waters. It uses standard oceanographic sensors, ie. conductivity, temperature, dissolved oxygen, PAR, chlorophyll and turbidity to measure vertical structure at high resolution (~10 cm) in waters as shallow as 5m and as deep as 200 m (Elgar de Sa et al. 2013). For autonomous long term monitoring at a fixed location, the AVP can be

deployed using a surface mooring. In this configuration the AVP profiles on a taut line and transmits data to a web portal using a cellular network. (R. Madhan et al. 2012) . Using this method one can acquire high resolution spatial and temporal physical and biogeochemical data.

II. IN-SITU PROFILING

The AVP was used to obtain high resolution depth profiles of conductivity, temperature, dissolved oxygen, PAR, chlorophyll and turbidity at 3 locations M1(76.3140°E, 9.4915°N), M2(76.3229°E, 9.4226°N) and M3(76.3076°E, 9.4187°N) with water depths of pier, 6m & 12m respectively, shown in figure 1.

These water column profiles were taken for nine days from end April to beginning of August. In all 60 data profiles were acquired as summarized in Table I.

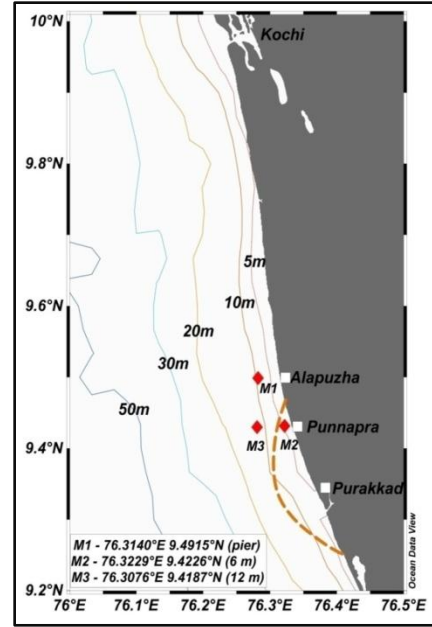


Fig 1. Station location

Sr. No	Date	Remarks
1	22-04-2014	3 dives each at M1, M2 & M3
2	30-04-2014	3 dives each at M1, M2 & M3
3	07-05-2014	3 dives at M2
4	22-05-2014	3 dives each at M1, M2 & M3
5	29-05-2014	3 dives each at M1, M2 & M3
6	13-06-2014	3 dives at M3
7	20-06-2014	No dives due to swells
8	27-06-2014	3 dives each at M1, M2 & M3
9	04-07-2014	3 dives each at M1, M2 & M3

Table I. Data collected during in-situ profiling

The specifications of the AVP sensors suit are listed in Table II, showing range, accuracy, and the maximum sampling rate. The sensors include an active fluorometer (EcoPuck Wetlabs, St. Philomath, OR) that measures chlorophyll and turbidity, a fast DO sensor (RINKO III, Nishi-ku, Kobe, Japan), CTD (FSI, Cataumet, MA) and PAR (Satlantic, Halifax, Canada)

Sensor	Range & Accuracy	Sampling	Response
Dissolved Oxygen	0 to 200% DO (μM) Linear \pm 2% FS	1s to 255 min. 1 Hz in AVP	\sim 1 s
Chlorophyll	0.02 to 60 $\mu\text{g/l}$	\sim 8 Hz	< 125 ms
Turbidity	0 to 25 NTU	(4 Hz in AVP)	< 125 ms
Conductivity	0 to 90 mS/cm (\pm 0.002 mS/cm)	\sim 8 Hz (4 Hz in AVP)	< 95 ms
Temperature	-5 to 45 $^{\circ}\text{C}$ (\pm 0.005 $^{\circ}\text{C}$)		100 ms
Depth	0 to 740 dBars ($<$ 0.08% FS)		25 ms
PAR	0 to 5000 $\mu\text{mol photons.m}^{-2}.\text{s}^{-1}$ \pm 5% NIST traceable	0.125 to 4 Hz (4 Hz in AVP)	100 to 500 ms Light dependent

Table II. Sensor specifications

Chlorophyll, Turbidity and Photosynthesis Available light Radiation (PAR) profiles acquired at M2 before and during the South West (SW) monsoons are

presented in figure. 2A & B. During the SW monsoon period there has been a significant increase in water column turbidity and chlorophyll.

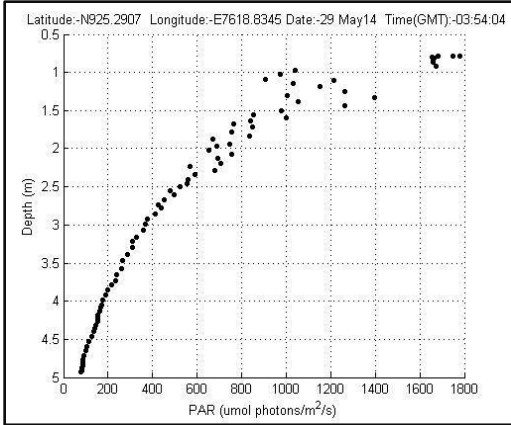
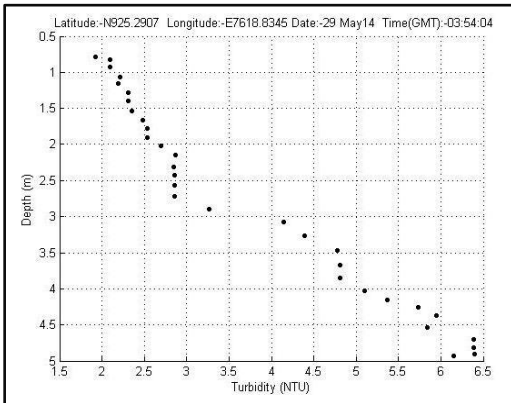
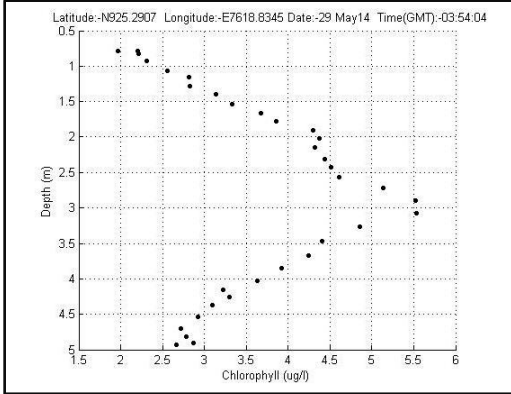


Figure. 2A. Chlorophyll, Turbidity and PAR profiles at M2 before SW Monsoons

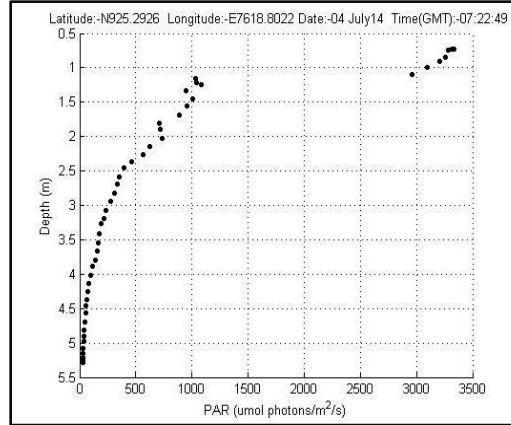
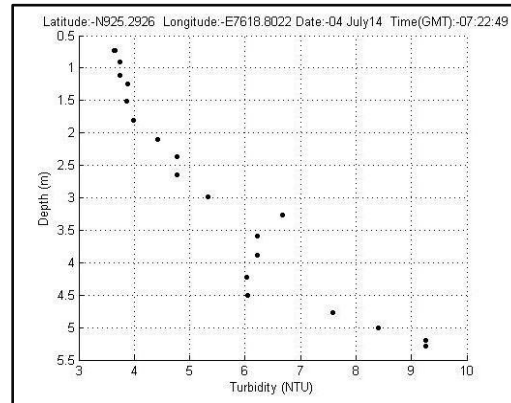
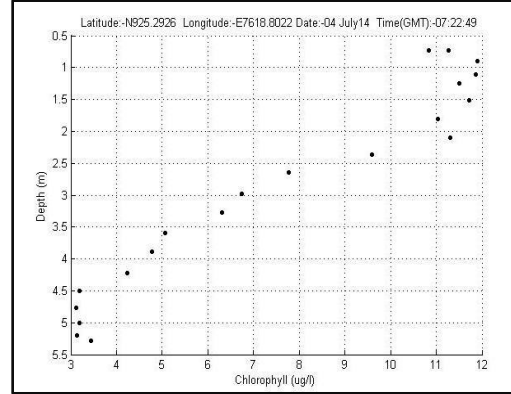


Figure. 2B. Chlorophyll, Turbidity and PAR profiles at M2 during SW Monsoons

III. AVP DEPLOYMENT USING SURFACE MOORING

A surface mooring ^[4] developed at the National Institute of Oceanography, with an identical AVP profiling on a taut line was deployed at M2. AVP was programmed to perform 4 dives per day and transmit data to the laboratory using a cellular network. The mooring scheme is shown in figure 3. Mooring system consists of a surface following positively

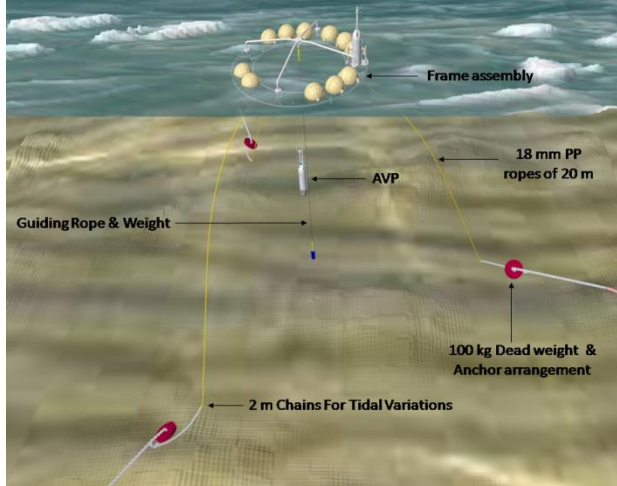


Figure 3. Mooring scheme for AVP deployment

buoyant mooring frame and tri- moor arrangement which anchors the mooring frame to the seabed. Mooring frame is attached with a taut guiding rope of 6 m length on which AVP glides during operation. Each mooring rope consists of 2m chain for tidal variation and 100kg of dead weight. Mooring Frame also has provision for GPRS unit, which aids in real time communication between the AVP and the base station.



Figure 4. Servicing of mooring assembly and sensor

A. Deployment Procedure

Mooring frame was assembled on the shore and the frame was tugged to the M2 location from the shore. Each mooring rope was assembled, as described in the above illustration. Two boats were used to maneuver and deploy the three mooring lines at equal angles. Later with help of a diver, centre guiding line was attached to the frame and AVP was deployed to obtain high resolution data of the Mud Banks. A total of 115 missions were executed, out of which about

44% achieved the required dive depth. The sensors and the mooring assembly was serviced periodically using available windows of fair weather as shown in figure 4. Using the Mooring AVP, the variations of turbidity in the surface layer, mid-waters and bottom layer of the Allepy Mud Bank were studied over a period of 38 days. Snap shots of turbidity values before the SW monsoons and during the SW monsoons are presented in Table III A & B.

Date	TIME (GMT)	0 ≤ depth ≤ 2m (NTU)	2 m < depth ≤ 4 m (NTU)	> 4 m (NTU)
27-05-2014	07:10:30	24.8758	-	-
28-05-2014	06:30:30	4.8042	6.344	7.0973
28-05-2014	12:30:30	2.1832	5.9360	15.1543
29-05-2014	12:30:30	2.4738	2.6908	2.7936
30-05-2014	06:30:30	4.6884	3.9229	7.2617
30-05-2014	12:30:30	0.5434	0.6799	1.1481
31-05-2014	06:30:30	5.4235	3.9300	4.0626
31-05-2014	12:30:30	3.2911	4.9978	6.6120

Table III A. Turbidity before SW monsoons

Date	TIME (GMT)	0 ≤ depth ≤ 2m (NTU)	2 m < depth ≤ 4 m (NTU)	> 4 m (NTU)
16-07-2014	06:30:30	6.3924	6.2415	11.7002
16-07-2014	12:30:30	3.3916	4.5326	8.0306
16-07-2014	18:30:30	2.5582	4.6919	9.2157
17-07-2014	00:30:30	3.3569	6.5301	8.3319
17-07-2014	06:30:30	-	10.2958	12.3716
17-07-2014	12:30:30	1.0431	1.0828	2.7084
17-07-2014	18:30:30	0.7962	1.0499	4.2732
18-07-2014	00:30:30	0.6193	1.3531	10.8532

Table III B. Turbidity during SW monsoons

IV. CONCLUSION

The AVP was successfully deployed to study the evolution and properties of the Alley Mud Banks in the state of Kerala. The AVP deployment using the surface mooring and the subsequent operation and maintenance of the system subjected to wave break and extreme weather conditions has given the group rich experience that would definitely come handy during the design of underwater systems.

V. ACKNOWLEDGEMENT

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