AUTONOMOUS PLATFORMS FOR STUDIES IN THE COASTAL ZONE

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1. Introduction

Global ocean programs have been driven by the need to understand the nature and variability of open ocean processes and the role they play in climate change. Open ocean research driven by a relatively small number of countries with well established ocean traditions and know how, have been serviced through the use of ocean going ships with profiling instrument packages, XBT sections, moored and drifting buoys, CPR systems, Argo profiling floats, and more recently the emergence of new technologies of AUVS, Gliders and ASVS [1], [2], [12], [4], [5], [6]. There are also well established implementing structures for protocols on data exchange, websites with real time data availability, and products for general regional benefit.

The Coastal Ocean is however a neglected area at the inter-governmental level, though it is often the most interesting and important aspect for developing member states since a large proportion of their population lives there, it is prone to extreme events, provides a major portion of the protein needs, and acts as a sink of pollutants. With climate change impacting local coastal phenomena, it becomes important for these Member States (MS) to be active participants in monitoring, and predicting the coastal zone to be able to benefit from and to look after their own waters. Measurements at sea are expensive and often out of the reach of many MS. One option is to promote satellite data products, world data centre holdings, and meteorological real time data that can be assimilated into near-coastal and regional models and provide the sort of first order appreciation of the impacts of human activities on coastal waters. The Decision Support Tools (DST) of Remote Sensing data, models and GIS are a strong set from which fledgling institutes can provide the sort of policy back up for their decision makers. How these DST can benefit from the preferred set of coastal parameters and the technology required for these measurements is the purpose of this short paper.

2. Common Variables

The reports ([7],[13]) on the Coastal module of GOOS articulates the need for measuring a selected desirable set of variables that would be required for monitoring and timely detection and prediction of local phenomena that are of maximum benefit to users. These also need to be examined against the needs and capacities of developing countries. The top ten variables selected for coastal observations of GOOS are tentative and are ranked in the following order (1) Sea level , (2) Water temperature (3) Currents (4) Bathymetry and its changes, (5) Salinity, (6) Surface waves, (7)Sediment grain size (8) Benthic biomass (9)Shoreline changes (10)Dissolved Oxygen. Phytoplankton biomass (or its measure by chlorophyll ***a***) at rank 15 is important in ecosystem studies of underwater blooms and its role in coastal eutrophication that can result spreading anoxic zones [8], [9]. From the perspective of a developing country, it would be worthwhile to examine appropriate technologies that are able to reliably measure at least some of the common variables if not all, so that a start can be made towards an operational coastal observing system while keeping in mind the following guidelines to improve effectiveness:

1. Can existing infrastructure in MS be usefully harnessed to reduce costs of data collection?
2. Can some traditional ship based approaches be replaced by automated platforms?
3. Can the cost of current technology used in open ocean research be adapted through the use of less accurate sensors but still suffice as valid data for coastal prediction models ?

The identification of common variables are initial steps to observations that can characterise coastal ecosystems and yet be used by global coastal system for detection and prediction purposes. It is understood that not all the variables may apply to diverse coastal waters. Given these guidelines, we need to examine in a general manner which variables are do-able by developing coastal communities?

1. **Sea level** measurements are well addressed by the Global Sea Level Observing System (GLOSS) of approximately 290 stations with some uniformity in global spread. Whilst not a stated goal of GLOSS, some of these stations measure additionally surface variables of air pressure, salinity, and water temperature. Therefore at some stations 3 of the top 10 recommended coastal variables are being measured, and in these cases, these will be useful feeds into models for the prediction of sea-level rise on a regional scale.

2. **Coastal bathymetry** as traditionally acquired is an intensive procedure. However some first order information for coastal engineering models can be obtained by using traditional infrastructure of fishing trawlers and boats that can be equipped with low cost GPS receivers and echo-sounders to automatically log such data when fishermen go out to sea. Integrating the data sets from a mesh of diverse fishing transects and interpolating these datasets, whilst not of topographic quality, can provide first order bathymetric maps of coastal zones that in many cases may never have been mapped before. The cost of realising this important dataset is within reach and may need minimal support from interested sponsors. Refinements to this data using a DGPS reference station and tide data from nearby GLOSS stations would improve the quality of the bathymetry.

3. **Mapping of coastal currents** is a speciality area that will require external assistance from developed nations that possess the technology, and who may consider supporting such a need with a view to improving regional data sets. One possible approach would be to fix bottom mounted ADCPs placed at strategic locations in the coastal zone, and receive the data either manually, by cable, or by wireless.

4. **Secchi depth** measurements due to their simplicity and utility can be routinely sampled by fishing trawlers, coast guard, and ferries to provide information on changes in seawater constituents in the water column and how they might be affected by sediment load and eutrophication. This variable has been proposed in the coastal module of GOOS report 125 and involves minimal cost while providing information on water clarity. Simple empirical algorithms between satellite penetration depth and Secchi depth have been derived for different coastal waters in the Arabian Sea by Suresh et al 2006[10]. This can be extended to many coastal communities world wide.

5. **Salinity, temperature, chlorophyll and dissolved oxygen** are important common variables in the dynamics of coastal ecosystems as it is clear that a close coupling between physical and biological processes over short time scales exists in many coastal waters. We describe the development of new technology of rapid autonomous in-situ vertical profilers that fulfil the requirements of high frequency and repetitive sampling using in-situ wet sensors to measure water column vertical structure. We propose that this technology could be adopted as part of the suit of in-situ autonomous systems in a coastal observing system (see brief description of the AVP below)

Routine monitoring of the eight (8) common variables identified here can form the basis of a simple but useful operational coastal observing system that can link to Decision Support tools of Satellite Remote Sensing, a suite of physical/ecosystem models, and GIS.

3. The Autonomous Vertical Profiler (AVP)

The AVP is an example of an in-situ automated platform developed at NIO, Goa to obtain high resolution profiles of salinity, temperature, chlorophyll, turbidity, and dissolved oxygen in shallow coastal zone waters. It belongs to the class of propelled robot vehicles that traverse the water column rapidly while sensing and storing the vertical structure of water column properties. The concept of a thruster driven profiler was first described in US Patent 6786087 [11].The AVP can be programmed to descend at variable speeds to a given depth set by the user. It ramps down the motor thrust, reaching zero velocity at a desired depth layer above the sea bed. Being lightly buoyant for safety purposes, it ascends relatively slowly to the sea surface without power. In order to locate the profiler after it breaks surface, the AVP transmits its GPS (Global Positioning System) coordinates via RF or through a satellite modem. A low frequency acoustic pinger is strapped to its hull for additional safety (see photograph in Fig.1). Other refinements that have been tested on the AVP include a control system that invests it with the capability of hovering at any set depth so that time series of a feature can be studied in detail [12]. The AVP does not require specialised ship gear for deployment or retrieval. It is therefore ideally suited for countries where such facilities are not available. Moreover, not being attached to the launching platform with a cable or rope ensures that ship or platform movement does not colour the vertical profiles.

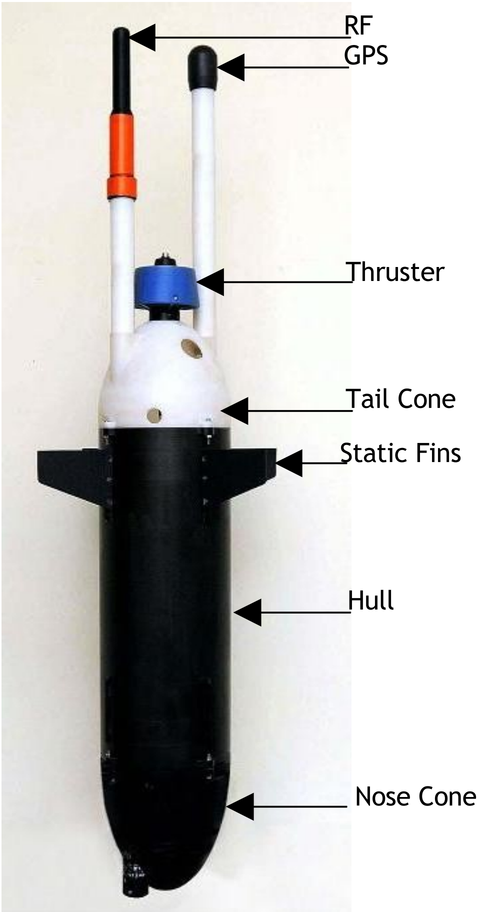

Table 1 Specifications of the AVP

Length & Diameter:	1.17m, Ø 0.18m
Weight:	13 Kgs
Depth:	200m (Max.)
Material:	Hull – Aluminium Alloy End Cones – Acetal
Propulsion:	Single DC Thruster
Speed:	0.1 to 1.0 m/sec
Batteries:	Lithium Polymer (324 WHr)
Communication:	Radio Modem (2.4 GHz) Satellite Modem (Iridium)
Endurance:	2.5 days with 12dives/day to 100m depth
Vehicle Sensors:	Pressure, Echosounder, GPS
Scientific Sensors:	Conductivity, Temp, Depth Oxygen Optode, Chlorophyll & Turbidity

Figure 1. Photograph of AVP (on left) and Table 1 on minimum specs. The AVP is shown with static fins (to minimize rotation during a dive), thruster motor, and sensors on nose cone. The communications antennae are mounted on the rear cone.

3.1. Proof-of-concept outputs from the AVP

1. Proof-of–concept trials of the AVP were made in a shallow depth reservoir in Goa, and in recent ship cruise in the Western Arabian Sea. Figure 2 tracks the variability of a chlorophyll layers over a period of 6.5 hrs by commanding the AVP to dive repeatedly every 5mins to a depth of 50m while the ship drifted. As the mixed layer shallows, chlorophyll maxima begin to develop and rise to shallower depths by noon time.

2. The AVP profiles have been compared to other standard instrumented packages on the ship. Figure 3 shows that the temperature structure on AVP profiles are reproducible by running it at a speed of 0.7 m/s and at a sampling frequency of 4 Hz.

4. Challenges for the future in Coastal Observing Technologies

Our aim in this write-up has been to propose and recommend appropriate technology that would benefit the community of marine scientists in developing countries who may need to develop capacity to understand their own near shore areas. The example of using fishing trawlers to gather bathymetric data on routine fishing expeditions during the fishing seasons is one that at low cost will yield high returns allowing observation to be assimilated into a suite of models. Another example described in greater detail is the Autonomous Vertical Profiler (AVP) developed with the following advantages: (i) obtaining true profiles decoupled from ship perturbations, (ii) repeatability from multiple profile data that provides error statistics through the use of less expensive sensors, (iii) ease of launching from a trawler or inflatable, (iv) autonomous operation that saves time and reduces cost, and (v) building as much smartness in the software code to ensure safety and optimal use of energy on board. The use of RF and satellite modems is now widely available and this has been used to beam valuable data back to shore computer. If needed, data profiles can also be transmitted to an Internet server for addition to the databases of the coastal GOOS. Measurements of coastal currents do not seem tractable for low cost options as outlined for the other variables. We therefore advocate technologies to measure coastal currents using ADCPs that would need greater expenditure. Such coastal data could be collected under suitable cooperative and collaboration programs between developed and developing nations keeping in mind the need to enhance an operational Global Coastal Observing System.

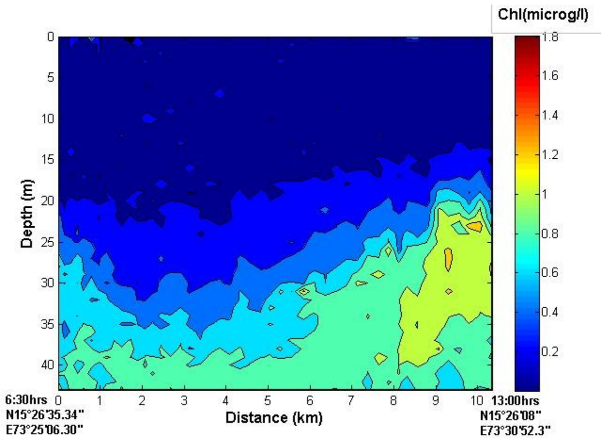

Figure. 2 A depth section of chlorophyll, measured by the AVP from the ship drift over a distance 10kms. In this period the AVP executed 48 dives to 50m every 5mins from 6:30am to 13:00hrs on the 30 April 2009. The profile were used to make the curtain plot

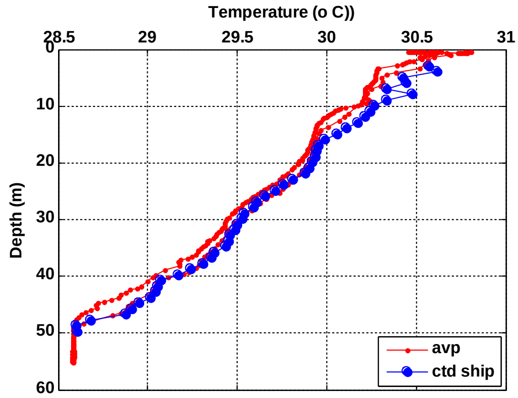

Figure.3 A comparison of the temperature profiles from the AVP CTD sensor and the Seabird CTD on the ship. The small offset is due to a calibration offset on the depth sensor of the ship's CTD.

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6. Acronyms

GOOS : Global Ocean Observing System, GIS : geographic Information system
GLOSS : Global Sea Level Observing System, CPR : Continuous Plankton Recorder
XBT : Expendable Bathythermograph, CTD : Conductivity Temperature Depth,
ADCP: Acoustic Doppler Current Profiler