Marine Monitoring using Fixed and Mobile Sensor Nodes

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***Abstract*- The use a small and low-cost Autonomous Underwater Vehicle (AUV), developed at CSIRO, is proposed to record data between fixed sensors with the aim of providing data sufficient to improve our understanding of the spatial extent of phenomena like the pycnocline and the effect of wind on salinity and temperature is. We suggest the spatial gap between time-series data collected from fixed nodes can be interpolated with data collected with an AUV.**

I. INTRODUCTION

There exist several initiatives for installing and managing sensor networks for monitoring marine environments [1, 2, and 4]. These systems are generally composed of fixed nodes that log data which are transmitted in real-time using various technologies. While fixed nodes can provide data at a high temporal resolution, the data is spatially poor due to logistic and economic constraints such as mooring restrictions and high sensor costs. Using temporal sensor data sets in hydrodynamic, biogeochemical or process models is a challenging prospect as interpolation and extrapolation in 3D space can lead to inaccuracies in model outputs. On the other hand, mobile sensors onboard autonomous vehicles such as AUVs can gather high-frequency real-time data over relatively extensive areas at the expense of poorer temporal resolution at the visited sites. Integrating these technological approaches can provide a means to extend our understanding of systems in space (with mobile nodes) and time (with fixed nodes). CSIRO is developing such a marine sensor network and associated technologies that allows complementary spatial-temporal data to be collected, shared and assimilated into models. The network known as the Tasmanian Marine Analysis Network (TasMAN) integrates fixed nodes utilising acoustic and RF communication modalities, with a low-cost custom-designed AUV. This paper describes the approach that supports robust integration between wireless sensor nodes and mobile nodes such as the Starbug AUV and its application to real-time hydrodynamic model updates.

Traditionally, high temporal frequency data are obtained from a limited number of fixed positions, which are used, for example, to calibrate biogeochemical models. The spatial representation of the models (i.e., interpolation in the model grid) is left to mathematical routines and little can be done to ensure the grid and the accuracy of the model is optimal. In the approach proposed in this paper, we utilise a small, low-cost Autonomous Underwater Vehicle (AUV), developed at CSIRO, to record data between fixed sensors. Our aim is to provide sufficient data in order to improve our understanding of the spatial extent of phenomena such as the pycnocline and the effect of wind on salinity and temperature. We suggest the spatial gap between time-series data between fixed nodes can be filled with data collected with an AUV.

II. THE TASMANIAN MARINE ANALYSIS NETWORK (TASMAN)

TasMAN has been established to provide real-time and near real-time data from the waterways of south-east Tasmania. Ensuring environmental sustainability of the region is vital and the data collected within the TasMAN project is crucial in managing the multiple uses of these estuaries and coasts, which include; heavy industry, aquaculture, shipping, tourism, commercial fishing and recreational uses.

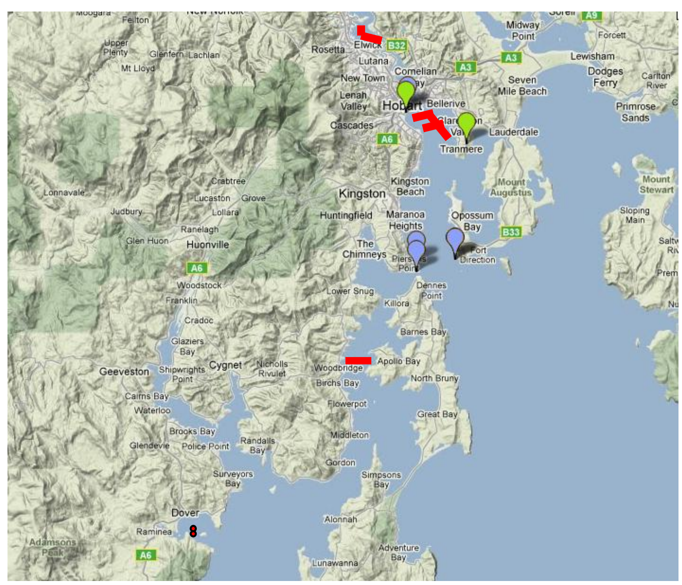

Fig. 1. Location of fixed nodes in the TasMAN sensor network. Red lines represents frequent AUV transects, red place markers show where low cost nodes were deployed, blue place markers show the locations of fixed nodes and green place markers, the weather stations. This illustration of Hobart area has approximately 40 km across.

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The network consists of both fixed sensors (shown in Fig. 1) and a mobile node, a small AUV [3].

Table I describes a list of characteristics of our sensor network.

TABLE I
CHARACTERISTICS OF OUR MARINE SENSOR NETWORK.

	Platform	Communication Gateway
Fixed Nodes	Surface buoy Riverbed nodes Low cost nodes	Acoustic / 3G Acoustic / absent 3G / Wireless
Mobile node	AUV Boats of opportunity	Wireless 3G / absent

A. Fixed Nodes

The fixed nodes deployed in our marine sensor network consists of different communication protocols (acoustic, wireless, 3G) and are consist of sensors sitting on the riverbed, fixed at the surface and portable low-cost nodes with a string of sensors.

Fig. 1: Fixed node at the surface, used to acoustically communicate with underwater sensors (Fig 2.) and wirelessly with the CSIRO station.

Each fixed node has a number of sensors (conductivity, temperature and depth) set at different depths in the water column, with dissolved oxygen sensors to also be deployed in the near future.

As shown in Table I, the fixed nodes generally communicate data via a 3G mobile phone network although, where a cluster of nodes are close together, they communicate with each other via a proprietary radio protocol, with a "sink" node transmitting data via the mobile telephone network. The real-time data are then integrated with models to produce nowcasts and forecasts of river conditions, and are made available via web and mobile applications for use by our partners.

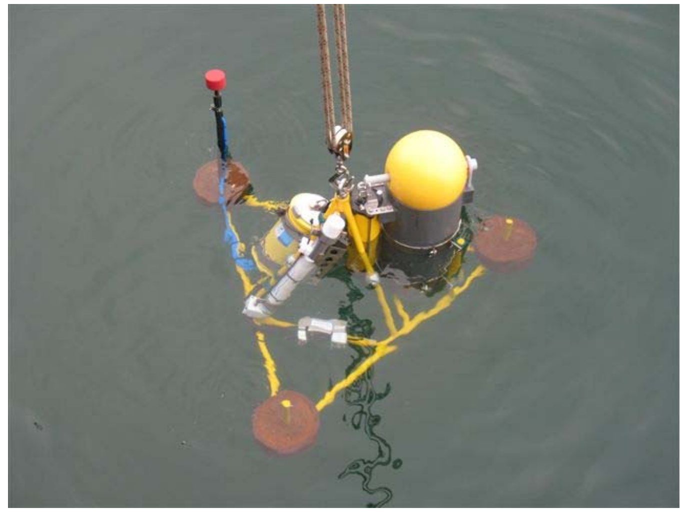

Fig. 2: Fixed riverbed node being deployed in the Derwent estuary, Tasmania, Australia.

B. Mobile Nodes

The mobile node consists of an AUV equipped with relevant sensors. This AUV has been deployed during the last two years, obtaining data from over hundreds of km of transects within shallow waters in SE Tasmania.

Boats of opportunity represents an interesting asset as operating costs are low for the project and regular transects can be obtained. However, the data recorded would only be related to surface temperature only.

Fig. 3: The mobile node (AUV) developed at CSIRO where sensors are installed to collect data between the fixed nodes. This AUV is 1.2-m long and is able to navigate up to 50-km a day and up to 100-m depth.

III. RESULTS AND DISCUSSION

The TasMAN project has collected data with a high temporal resolution using fixed surface (Fig. 1) and underwater (Fig. 2) nodes. These data have been complemented by data with high spatial resolution collected by an AUV (Fig. 3). Data collected with AUVs can be used to calibrate the fixed nodes and give an understanding of the spatial water-column characteristics between these nodes.

Fig. 4 shows good agreement between simultaneous temperature readings from a subsurface node and an AUV deployment at that depth. Additionally the AUV measured the depth of the pycnocline (4 to 6m) which is not possible using the current fixed node system (Fig. 5). At present, the deployment of AUVs is carried out infrequently, however, by investigating the long term relationships between the AUV data and the fixed node data, we are able to make inferences about water characteristics between the fixed nodes using just the fixed node data. It is intended that the AUV will play an increasingly regular role in the collection of spatial critical data in three dimensions.

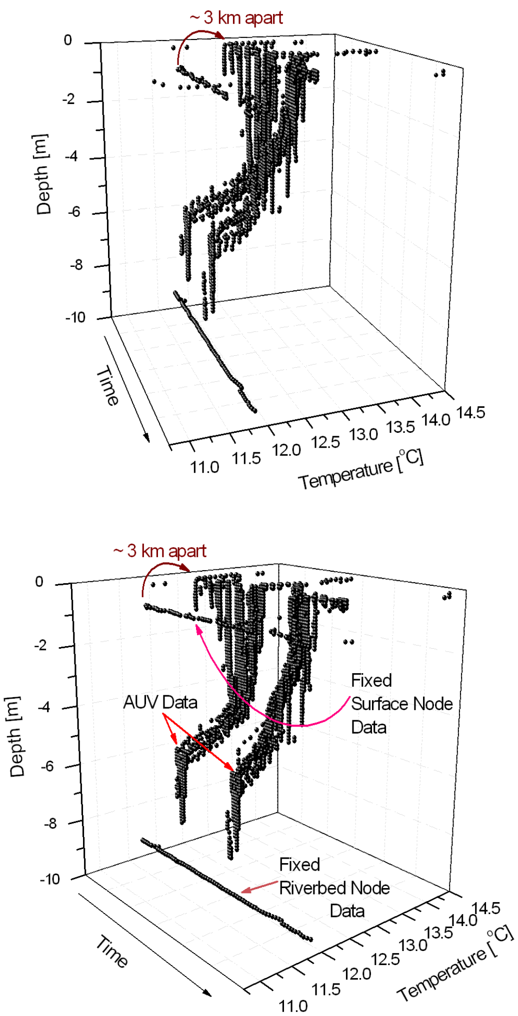

Fig. 4: Temperature data collected from fixed nodes (straight lines at -1 and -9.5) and mobile nodes. The pycnocline is visible as the rapid change in the temperature profile between -4 and -6 m. Fixed nodes and the AUV mission were approximately 3 km apart, hence, the data from the fixed node at -1 m were measured 3 km west of the AUV transect. The almost 1^{O}C deviation is an expected shift at this region of the estuary and relevant for the calibration of hydrodynamic models.

IV. CONCLUSIONS

The automated collection of data through combinations of fixed and 3-dimensionally enabled mobile nodes (AUVs) offers a new opportunity to support the prediction and confirmation of the estuarine and marine environment in real-time. This capability will support researchers, individuals, local councils and governments to increase their awareness and management of the complex areas. Techniques are being evaluated for the automated detection of real-time events, mission planning to confirm and (potentially avoid or manage) predictions of potentially catastrophic events. Additionally work is being undertaken to address the issue of automated QA/QC to ensure that the data collected is fit for purpose.

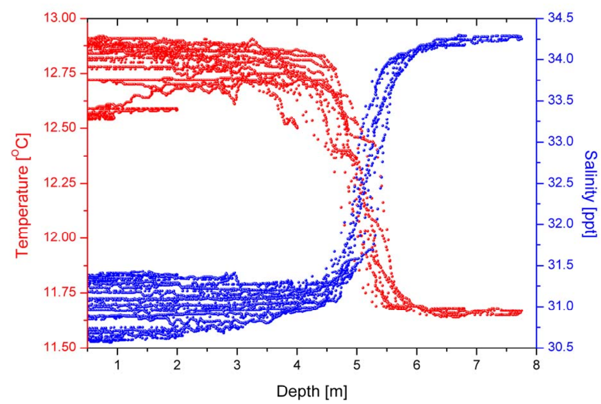

Fig. 5: Temperature and salinity collected by the mobile node at different depths. This data is the same as depicted in Fig. 4. The pycnocline is visible as the rapid change in the temperature profile between -4 and -6 m.

In this paper, we have reported on the initial results from the TasMAN sensor network. The network will continue to evolve and develop a range of fixed and mobile nodes in response to the improved detailed knowledge that results from the ability to provide high-fidelity temporal and spatial data. The network underpins the modeling and domain specific responses for the management of a range of users, leveraging the value of data being “collected once – used many times”.

ACKNOWLEDGMENT

The Tasmanian ICT Centre is jointly funded by the Australian Government through the Intelligent Island Program and CSIRO. The Intelligent Island Program is administered by the Tasmanian Department of Economic Development, Tourism and the Arts.

This research was conducted as part of the CSIRO Wealth from Oceans National Research Flagship.

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