second version has been used in the MakaiEx'05 (Pacific), Blue- Planet'07 (Mediterranean), RADAR'07 (Atlantic), and UAB'07 (Hopavagen Bay and Trondheimsfjord) sea trials.

(a)

(b)

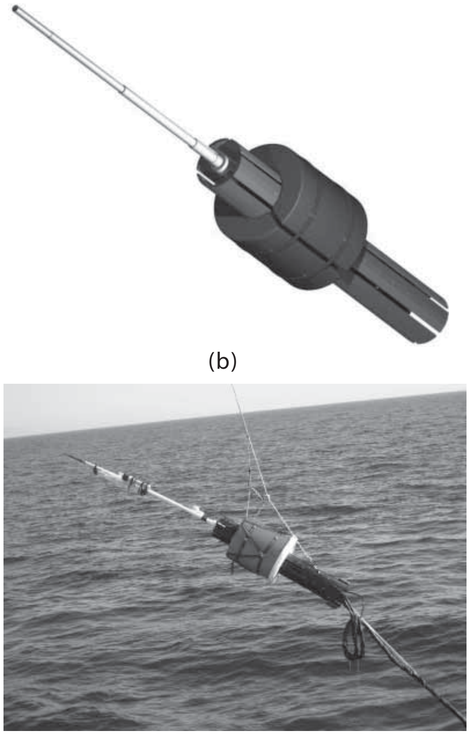

Figure 1. Acoustic Oceanographic Buoy: drawing from CAD software (a); deployment (b).

The first version of the AOB has been used in the MREA'03 [3], [4] and MREA'04 [5] sea trials mainly for ocean acoustic tomography and geoacoustic inversions at low frequencies. The second versions of the AOB has been used in high frequency acoustics for tomography and underwater communications in the MakaiEx'05 [6] and the RADAR'07 sea trial.

In recent sea trials two scientific concepts such as real-time network tomography (BluePlanet'07 and RADAR'07) and underwater acoustic barriers (UAB'07) that explore the AOB's characteristics were tested. The former application requires communication facilities and operationality in equipment deployment and recovery, since at least two receiving equipments must be used. The latter requires communication facilities since the received signals have to be immediately transmitted to the platform holding the acoustic source, time-reversed and retransmitted back to the receivers.

III. CONCLUSION

Throughout the past four years, the AOB has demonstrated to be handy, allowing for several deployments in each sea trial, and was used with success in a wide range of applications, and have operated as a service to the international underwater research community in relevant number of sea trials.

REAL-TIME ENVIRONMENTAL INVERSION USING A NETWORK OF LIGHT RECIEVING SYSTEMS

C. Soares and S. M. Jesus

Institute for Systems and Robotics, Universidade do Algarve,
Campus de Gambelas, 8005-139 Faro, Portugal.
Telephone: +351 289 800 949
e-mail: csoares@ualg.pt

I. INTRODUCTION

The estimation of ocean parameters by means of the inversion of acoustic signals is a research topic that aroused significant interest during the 1990s, and in several occasions its viability has been demonstrated [1], [2], [3]. However, most of the experimental shallow-water studies aiming at the estimation of ocean parameters by means of the inversion of acoustic signals used only a single vertical array for data collection and a single acoustic emitter. This limits the spatial coverage to the environment between the acoustic emitter and the receiver system. As an attempt to increase the spatial coverage, the emitter may eventually be towed over the area of interest remaining, however, still limited to "look" into a single direction at each time, being therefore unable to simultaneously estimate environmental properties of multiple ocean transects. Multiple ocean transects can be simultaneously estimated if a network of receiving nodes is used as this allows for collecting acoustic waves traversing the ocean in different directions. Another aspect is related to operationality issues: environmental inversion concepts such as ocean tomography may become significantly more interesting if performed as real-time application [4]. For example, if estimates on oceanographic properties such as water temperature could be obtained shortly after the reception of the acoustic signals, these could be fed into existing ocean circulation models that nowadays can produce oceanographic forecasts up to 48 hours [5].

The RADAR'07 sea trial, held in the sea of Tria off the Portuguese coast approximately 50 km South of Lisbon, served the purpose of testing a network of receiving systems with two nodes, and perform real-time environmental inversion using that network receiving systems. This area has a very string activity in terms of internal tides. Each node consist of an exemplar of the Acoustic Oceanographic Buoy (AOB) [6], which uses a surface buoy and an underwater array of acoustic sensors (AOB1 with 8, and AOB2 with 16) and non-acoustic sensors. Among several other characteristics the surface buoy includes a digital storage unit for the acquired data, a wireless communications system for remote monitoring and data transmission, and GPS system. These features allow for carrying out inversions as the data can be transfered from the buoy to a platform equipped with processing capabilities before recovery. These buoys are easily deployed and recovered for their small dimensions, and since they can record their geographic coordinates they can be deployed in a free-drifting configuration. In few words the AOBs' design represents a significant step towards operationality in comparison to traditional acoustic receiving systems.

II. EXPERIMENTAL RESULTS

This paper considers the environmental inversion of acoustic data via Matched-Field Processing (MFP) [7], [8]. In MFP forward models for candidate parameter solutions are iteratively computed in order to obtain replica fields. Those replica fields are then compared to acoustic field observation in order to find the best match.

During the RADAR'07, multi-tones in the band 500 to 800 Hz collected on July 14 were inverted for temperature in the watercolumn and seafloor properties. The watercolumn was modeled by means of Empirical Orthogonal Functions obtained from temperature measurements performed during the four nights before. The coordinates of the acoustic source and receiver were known, with source-receiver range between 1.2 and 5.4 km. The source depth was assumed unknown, since it varied with ship speed and depth measurements were not available in real-time. Source depth varied between 4.5 and 8 m. The bathymetric variability along the propagation track relevant to the actual data was moderate, and full knowledge on it was incorporated in the inversion as a priori information.

The experiments aiming at environmental inversions consisted in deploying the two AOBs in a free-drifting configuration at different points of the area of interest while the acoustic source transmitting several waveform was towed by the research vessel NRP D. Carlos I. In the research vessel laboratory a computer network consisting of a server, two dual processing nodes, and several laptops was available. The server was connected to a a wireless antenna which allowed for accessing the AOBs for downloading acoustic and telemetric data. A software controlling the inversion was running on the server. This software downloads the acoustic data from the AOBs and extracts the received signal of interest. Then it starts the inversion process which is based on a genetic algorithm that generates candidate solutions. These candidate solutions are fed to the processing nodes in order to compute the forward models to generate field replicas, compare the field replicas with the observed field data, and return the result back to the main process on the server. During the RADAR'07 the software worked very effectively and attained complete stability after corrections of errors in initial tests.

III. CONCLUSION

The quality of water temperature and seafloor estimates varies with source to receiver range. At ranges up to 2 km, rapid temporal and spatial variability of the water column can be followed with detail in both ocean transects. At long ranges, above 4 km a degradation in the ocean parameters is observed as unlikely estimates of the temperature profile are obtained, specially for AOB1 which attains longer ranges and has only 8 receivers. Unlikely results can be ruled out either by performing range-depth source localization using those models, or by observing behavior of the complete parameter set. As simultaneous estimates over two different look directions were obtained also spatial variability of the water temperature can be observed.

In this paper two novel aspects in environmental inversion by means of acoustic inversions are explored. One is the possibility of increasing the spatial coverage by using a network of acoustic receiving systems, and the other is the extension of an environmental inversion concept to a realtime application. These features could be included into the environmental inversion concept thanks to the design of the Acoustic Oceanographic Buoy meeting high operational requirements.

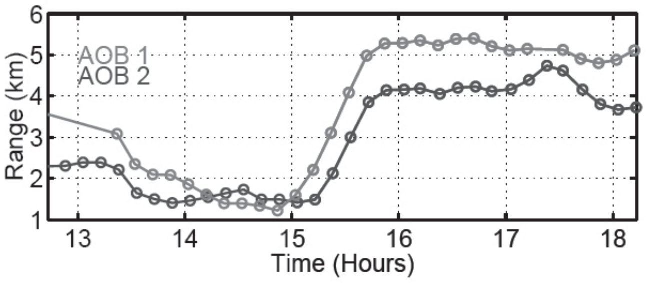

Figure 1. Range between acoustic source and AOBs over time.

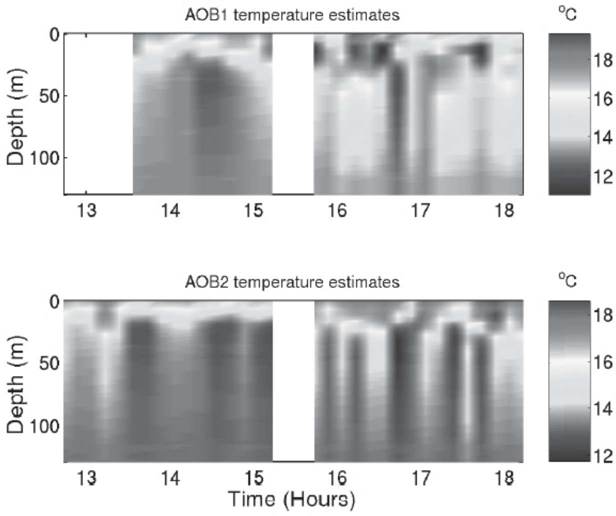

Figure 2. Temperature estimates over time obtained by inversion of acoustic data collected with each AOB.

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