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OCEANOGRAPHIC ENVIRONMENTAL ASSESSMENT USING UNDERWATER GLIDERS

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Abstract: REP(MUS) 21 is an annual exercise jointly organised by the Portuguese Navy, the University of Porto, NATO's Centre for Maritime Research and Experimentation (CMRE) and the NATO Maritime Unmanned Systems Initiative. The exercise gives Allies and NATO partners a chance to field and evaluate new maritime technologies. A Rapid Environmental Assessment warfare group was formed using Maritime Unmanned Systems to perform an environmental assessment of this area, by collecting data from the upper ocean region (0- 200 m.), sea surface, littoral shallow waters, and river estuary. Underwater Gliders were used in the REPMUS21 exercise, brought by several partners, to conduct environmental observations from the underwater domain of the exercise's Joint Operations Area (JOA). This paper focuses on the use of Seaxplorer underwater gliders to collect oceanographic data during the exercise, and the operational impact of using this knowledge to compile the Recognized Environmental Picture of the exercise area.
Key words: environmental assessment, maritime unmanned systems, oceanography, REPMUS21 exercise, underwater glider

1. INTRODUCTION

Gliders have a long history in collecting oceanographic data in different challenging environments, since the 90´s [1]. They have been used in military environmental data collection since they have long-endurance and can send rapidly in-theatre data.

Geospatial, meteorological, and oceanographic knowledge is critical to optimize the employment of sensors, weapons, targeting, logistics, equipment and personnel and is a key decision superiority to enable safe, effective and successful operations.

Operating in unfamiliar areas may require a dedicated mission to assess the environmental conditions of the TO and to provide NATO commanders with the opportunity to better plan, execute, support and sustain their operations. When these tasks are to be conducted in non-permissive theatres or to complement conventional military capabilities, the use of Maritime Unmanned Systems (MUS) becomes a game-changer.

REP(MUS)21 stands for Robotic Experimentation and Prototyping Augmented by Maritime Unmanned Systems. The REP (MUS) exercise is an experimentation exercise for Maritime Unmanned Maritime Systems. It started in 2010, being organized by the Portuguese Navy and the Faculty of Engineering of the University of Porto (FEUP). This exercise has expanded in the last years capturing attention by many NATO Nations, companies, and Academia.

The REP(MUS)21 exercise area was situated in a coastal region along the Portuguese continental shelf and inside the Sado estuary, limited from Sesimbra to Sines harbours, as seen in Figure 1. The main experimentation activities were executed around Troia peninsula and Sesimbra harbour, from deep ocean domains into very shallow coastal waters and inshore river areas.

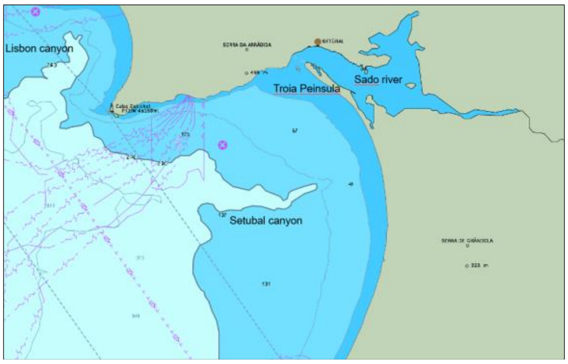

Figure 1 Area of the REP(MUS)21 exercise

The main reason for assessing oceanographic parameters, from a military perspective, is to achieve a tactical advantage over one's adversary by exploiting

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environmental and ocean conditions. To do this, it is important to possess a detailed knowledge of what these conditions are and how they are likely to vary both spatially and temporally. Moreover, it is essential to know how such conditions are likely to affect one's sensors and weapons, and those likely to be used by one's adversary.

Because underwater conditions usually have the greatest effect on anti-submarine warfare where most weapons and sensors rely on sound propagation to function, a good knowledge of the underwater domain oceanographic parameters is fundamental to the support that can be provided by a Rapid Environmental Assessment warfare group (REA WG). There is, however, a growing need to understand in more depth the aspects of oceanography, because military operations involving sophisticated platforms, weapons and sensors, are increasingly affected by such environmental factors in ways that were not previously foreseen.

Underwater gliders are autonomous platforms that profile and sample the water column by altering the volume of the platform's hull [2], to control its ascent and descent. After each dive, the glider surfaces and establish satellite link communication with the Command and Control (C2) systems, sending collected data from sensors and platform, via Satellite telemetry, to Datahubs (presently held by each Industry Partners). This process is conducted under 2-way communication which also enables the navigation control (piloting) of the assets during the execution phase.

These platforms are being used by the scientific community to study the upper ocean dynamics and the military community is exploring them to the evolution of the ocean Mix Layer Depth (MLD) [3], especially for Anti-Submarine Warfare (ASW) and Mine Counter Measures Warfare (MCM) [4].

A major advantage of this technology is the low power consumption that enables long endurance and collection of long datasets along with significant ocean domains (up to approximately a year depending on sampling mode and sensors used). Their lightweight and compact design make them easy to deploy by small boats as by large research vessels, as seen in Figure 2.

Figure 2 Alseamar Seaexplorer glider

2. MATERIALS AND METHODOLOGY

Driven by buoyancy changes, this type of underwater vehicle silently glides up and down the water column while collecting physical, chemical, biological and/or acoustic data depending on the fitted sensors. This state-of-the-art technology enabled the data collection and assessment of the upper ocean's physical properties (including underwater ambient noise).

To assess the employment and performance of the glider technology, an integrated survey plan was drawn to assure that all gliders conducted complementary JOA sections and evenly contributed to building a common upper ocean assessment, as seen in Figure 3.

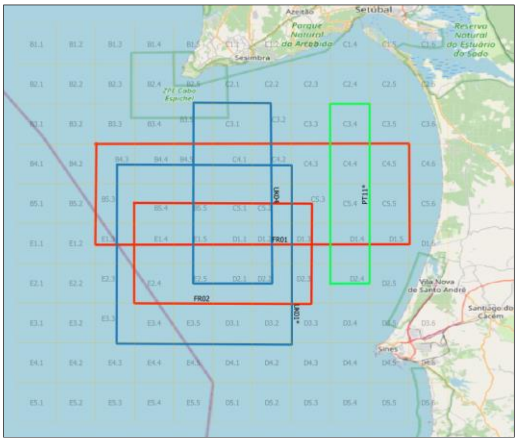

Figure 3 Gliders survey plan

The outcome of this plan got a "spaghetti" shape to guarantee a periodic re-visit of the area, profiling from the surface up to 200 m depths, achieving a comprehensive oceanographic assessment of the JOA, during the entire period of the exercise. The importance of this approach revealed to be appropriated since the oceanographic features in this region can be small-scaled and very dynamic. The reason for this is due to the complex bathymetry shape of the continental shelf of the JOA, where we can find two submarine canyons, as well a dynamic shallow water area outside of a freshwater run-off from the Sado river (sandy banks and bottom channels).

Gliders are full autonomous platforms that execute pre-defined survey plans. However, as a profiler, each time the platform reaches the surface there is an opportunity to remotely communicate with the system. This time window enables the data transfer between the platform and the Host Datahub, a satellite navigation fix, as well as to receive new course, profile and sampling setting commands (survey plan changes by remote piloting)[1].

Regarding navigation accuracy, gliders use Global Navigation Satellite System (GNSS) solutions which guarantee high accuracy in their positioning. However,

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each time they dive, they depend on their inertial navigation, wings and propulsion systems to keep the course track (dead reckoning). Under strong underwater current speed conditions (1 to 2 Knots) and strong water density gradients, the glider's navigation accuracy becomes limited. As a remark, Teledyne gliders have, as an optional feature, an additional thruster that can be used in these challenging environments.

Gliders offer a wide range of commercial sensors that can be fitted to the platform (both internal and external payloads). Presently Industry offers miniaturized sensors that can be mounted inside a specific payload module, which is independent of the glider system itself (engine, batteries, pumps, navigation system). Also, bigger sensors can be mounted outside of the platform (e.g., single point or towed array hydrophones). These solutions were used and validated during the REPMUS21 exercise and revealed to be tailored to the mission's purpose. However, payload configuration still needs to be set in the factory, reducing operational flexibility.

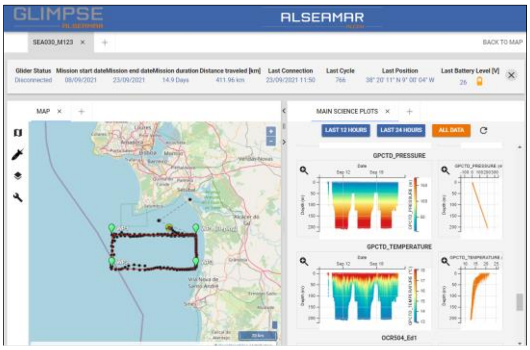

Figure 4 Glider piloting platform

Every sensor, onboard each glider, is integrated with the main control system that compiles the scientific data to be sent to a shore station by Satellite link, each time the platform reaches the water surface. This data is normally available via proprietary manufacturer's tools, accessible by the Internet (web tool), as seen in Figure 4.

4. RESULTS AND DISCUSSION

In REPMUS 21 exercise, the REA WG tried to achieve as a proof of concept the ability to use together with different glider technologies in a common observations plan. To achieve this goal, both manufacturers the partners provided datasets in a standardised format (NetCDF) enabling a unique data handling procedure and validation. By using a common standardised format, it is possible to explore all datasets with a single available 3rd party commercial or freeware tools (Panoply, ODV, Python, etc.)

Important oceanographic features like internal waves can be seen in the Figures 5 and 6, pictured as vertical displacements of the temperature gradient in short wavelength structures. They are normally generated by internal tides over uneven bathymetry features, like the two submarine canyons from the JOA. For the operation, knowledge of the movement of internal waves is critical for Anti-Submarine Warfare, as it has a big impact on how the underwater sound propagates within the upper layers of the ocean.

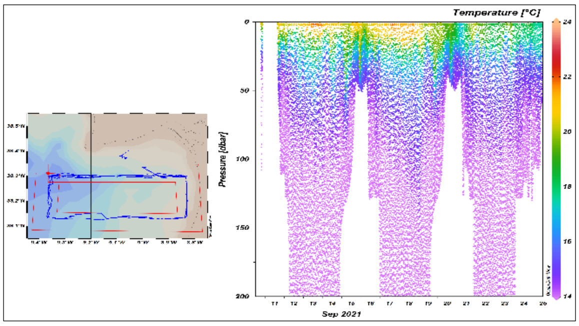

Figure 5 Temperature plots

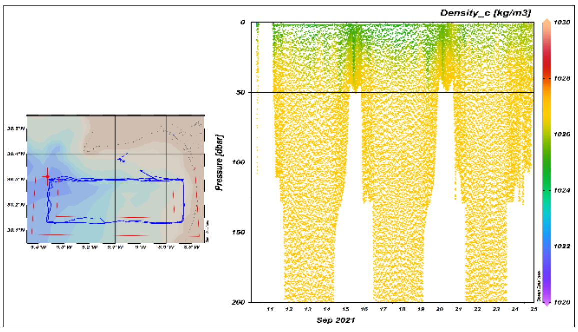

Figure 6 Density plots

During the execution phase, the REA WG cell was capable to monitor in near real-time all glider tracks (Figure 4), which assured the plan execution as well as the safety of the platforms. The assessment of the gliders tracking compilation confirmed the high level of navigation accuracy of all the assets (including Alseamar gliders) as seen in Figure 7. Nevertheless, it is important to highlight that the environmental conditions observed during the exercise were favourable, with water current velocities below 1 Knot and significant wave height below 3m.

Figure 7 Real tracks of the gliders during the exercise

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5. CONCLUSIONS

Gliders were evaluated during REPMUS 21 exercise with a high maturity level, to conduct autonomous time extended REA observations over large upper ocean areas.

An important advantage on the use of this technology is its low-logistics footprint and size, making them easy to deploy, operate and recover. Moreover, underwater gliders can provide valuable data for offshore industry, pollution monitoring [5][7], renewable and wave energy sector [6][7][8].

Underwater gliders are the perfect tool to monitor climate change effects, to study the relationships between different meteorological and oceanographic parameters in this continuous transformation of the ocean waters [9].

Glider's platform architecture assures a modular use since payloads and sensors are installed separately from the navigation and power systems. This enables the adoption of a wide range of sensors, as a tailored solution for different missions. Although still being a piece of expensive scientific equipment, these platforms can be improved and tailored for military use. Present commercial glider sensor sets can be optimized to address critical environmental parameters for military requirements. Adopting plug and play payload solutions can increase platform setup flexibility and lower operational costs. Reducing the number of sensors to the critical ones (CTD complemented, if necessary, by acoustic payloads), can optimize SATCOM time and costs, as well as increase platform endurance.

An important feature to be considered in this military adaptation is the development of a self-calibration capability to enable their projection from the underwater, surface, and air combat platforms. Moreover, Artificial Intelligence (AI) [10] and Machine Learning (ML) algorithms can be adopted to fuse scientific data collection and piloting data to bring autonomy behaviour capability when gliders are tasked to follow underwater contacts (e.g., marine mammals or submarines) or oceanographic features (e.g., ocean eddies, fronts, or specific water masses).

Concerning data transfer, it is important to assure secure protocols and the use of NATO standard formats to explore their use in a military context (especially for underwater acoustics monitoring and strategic environmental data collection). Regarding integration into Naval Forces, where these assets can be employed and controlled by onboard combat systems, manufacturers should consider developing appropriate Application Programming Interfaces (API).

6. ACKNOWLEDGMENTS

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