AL HOCEIMA LAUNCHES ITS FIRST FUNCTIONAL MARINE OBSERVATORY IN NORTH AFRICA

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Abstract

In the framework of the European project ODYSSEA, the Moroccan Association leader of the Marine Observatory of Al Hoceima AGIR, has successfully performed two glider missions in the South Alboran Sea. The vehicle was a SeaExplorer glider (manufactured and commercialized by ALSEAMAR, France) equipped with a CTD probe (GPCTD, seabird) and a novel microplastic sensors (LEITAT). These glider missions, permitted the acquisition of hydrological parameters at an unprecedented high spatio-temporal resolution for the area, and to fill a huge data gap. The first glider mission was mainly dedicated to the sampling of the western gyre of the Alboran Sea (WAG), a major dynamical structure of the area. During this mission the glider dived following a typical sawtooth trajectory within the water-column, from the surface and up to 500 m-depth. Glider data revealed the vertical structure of the WAG and provided an interesting insight of its dynamics (water-currents, variability, etc.), supplementing information obtained by satellite. To our knowledge, this pioneer work is among on the first oceanographic survey entirely dedicated to the study of the WAG.

Keywords: western Alboran Sea; gyre; underwater glider; thermocline; isopycnal vertical excursions; autonomous mechanical system

1. Introduction

The association AGIR, Moroccan partner of the ODYSSEA Project funded by the European Union, has successfully deployed SeaExplorer (Alseamar, France) underwater gliders in the south Alboran Sea. Underwater gliders are autonomous buoyancy-controlled UUV that move through the water column by changing their density, coming periodically to the surface for data transmission (Rudnick *et al.*, 2004). These vehicles are beginning to prove their large potential in modern oceanography and have an increasingly important place in ocean monitoring studies. Two marine prospection missions were achieved. The first mission took place in late fall, from November 10 to December 11, 2020 (30 days). During this 1-month mission the glider performed a total of 753 cycles. The second mission occurred in late winter – early spring, from February 11 to March 23, 2021 (40 days, 873 cycles).

The glider was equipped with novel microplastic sensor developed in the framework of the ODYSSEA project and a typical GPCTD probe that allow for the measurement of pressure (P), temperature (T) and conductivity. GPCTD data were adjusted from thermal lag effect and processed according the procedure described in Garau *et al.*, 2011. Salinity (S) was derived from raw conductivity measurements and the density was approximated with the 48-term function of T, S and P (TEOS-10). GPCTD data are acquired with a 4s sampling period and subsampled to 30s for real-time data transmission by Iridium.

In this paper, only measurements acquired during the first mission by the GPCTD are presented. Data from the second period and from the microplastic sensor are still being analyzed and will not be discussed hereafter.

2. Mission design

A large part of the first glider mission (17 days, November 10-27) was devoted to monitor offshore Moroccan Mediterranean waters (Figure 1) and, more precisely, the Western Alboran Gyre (WAG) that is one of the largest and most persistent features in the Alboran Sea (e.g. Brett *et al.*, 2020). The last 10 days of the mission aimed to focus on coastal areas of interest along the Moroccan coast (Figure 1), namely the Al Hoceima Marine Park, the Xauen Bank and the Tofino Bank, which are proposed as future MPAs.

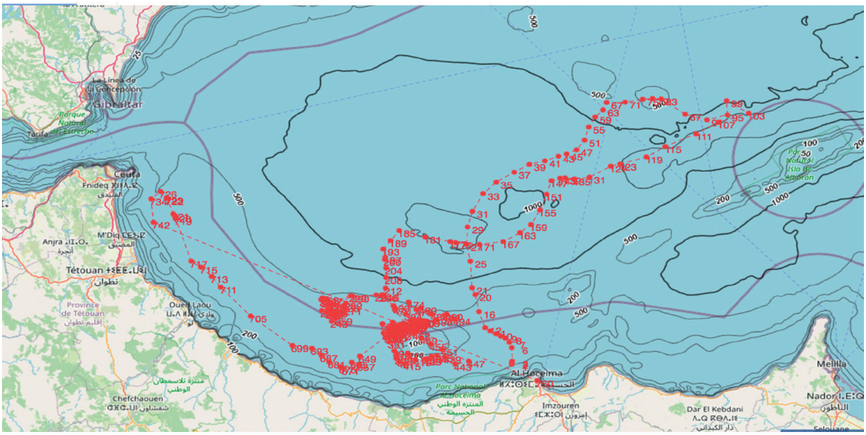

Fig. 1. Map showing the route and cycles of the Glider during the first mission.

The WAG was first tracked using satellite maps of sea surface temperature (SST) that is characterized by warm waters (SST anomaly higher than 1°C in the gyre's core, at the time of the mission). Satellite maps confirmed the presence of the anticyclonic structure, although its size and location were varying in time (Figure 2). These information were used in real-time by glider pilots. The objective was to cross the WAG, passing approximately through its center. At the end, two transects were realized (Figure 2).

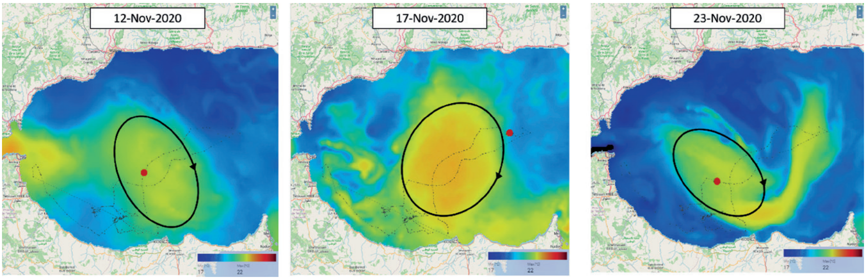

Fig. 2. Map of the SST (data downloaded on https://marine.copernicus.eu/)and glider trajectory. The position of the glider on the date of the map is indicated by the red dot.

3. Results obtained with the glider

3.1 GPCTD data

These results will shed light on the intermediate and deep MW that subsequently circulate and can still be identified more or less far from their area of origin [Millot & Taupier-Letage, 2004]. They continuously mix and, finally, outflow at Gibraltar as a rather homogeneous water ('the' Mediterranean Water), which is colder (13.0 – 13.5 °C), saltier (38.0 – 38.5) and denser (28.0 – 28.5) than AW there. Therefore, the Mediterranean Sea is a machine that transforms AW present at the surface right west of the Strait of Gibraltar into denser water that is recognised at 1000 – 1200 m in most of the northern Atlantic Ocean.

Indeed,T and S vertical profiles acquired from November 10 to November 27 are represented Figure 3. Overall, the vertical distribution of T is characterized by decreasing values with depth. T is in the range 17-20°C in surface and fall to 13.5°C à 500m-depth. The thermocline is found between 50 and 200 m-depth in agreement with previous studies (Romero-Cózar). Regarding S, minimum values are measured in surface (36-36.5) with typical characteristics of the Atlantic Water (AW), and maximum S values are found at depth (38.5 at 500 m).

Superimposed to this general feature, glider data although highlight a large variability, specifically in the first 300 m of the water-column. It can be observed isopycnal vertical excursions (black lines on Figure 3) that are directly related to position of the glider relative to the WAG. At the time when the glider is located within the WAG, surface waters are warm (>20°C) and relatively fresh (<36.5), up to about 150 m-depth. This results in the deepening of isothermal layers of several tens meters. Conversely, when the glider is outside the structure (e.g. the 16-17th November 2020, Figure 1 et 2), isopycnal are the shallowest with cold and salty deep-waters reaching almost the surface.

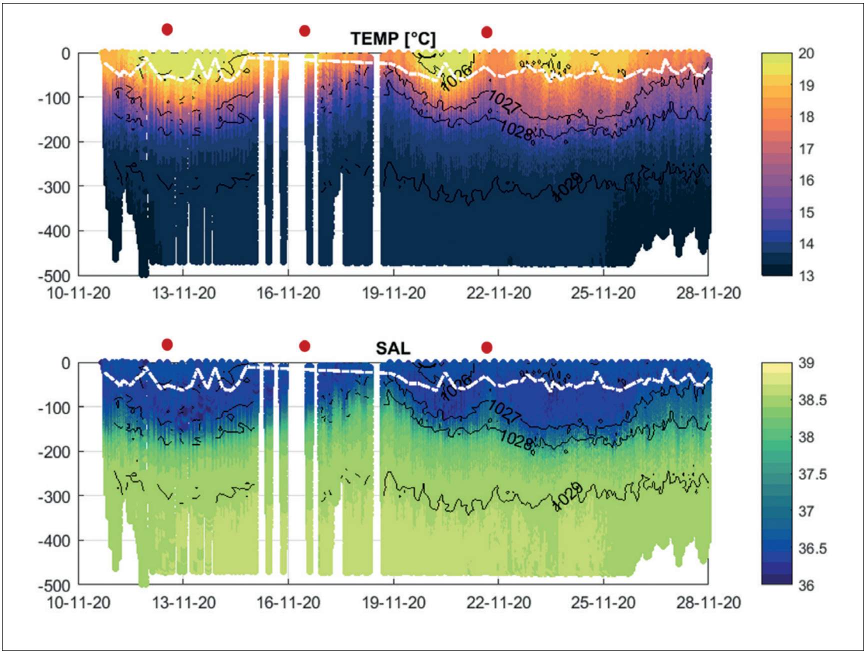

Fig. 3. Temperature and salinity data acquired during the first part of the mission. The black lines are the isopycnal levels and the white dashed line is the depth of the mixed layer (density criterion of 0.003 kg.m^3). The red dots are related to the same profile as in Figure 2.

3.2 Water-current data

Estimating water-current was of particular interest. On a hand it can help to understand the hydrodynamic context in which the glider mission take place. On the other hand, this provides useful information for piloting purpose. In particular, the winter period of the Glider deployment coincided with a very strong long temporal in the Alboran Sea generating strong currents that made sea operations and glider navigation tricky.

From the glider it is possible to assess water-currents using additional information:

- In surface, currents can be obtained by the glider drift and GPS fixes, each time the glider surfaces;
- Within the water-column, vertically averaged values can be estimated by comparing the dead-reckoned displacement (theoretical glider displacement in a quiescent ocean) and the observed glider position at surface.

Results are shown in Figure 4. First, it is interesting to observe that the surface velocities are strongly related to the subsurface (geostrophic) flow. Indeed, the variations of surface currents and vertically averaged currents are observed simultaneously in intensity and direction. At the surface, the measured velocities are high even offshore, and can reach up to 1 m.s^{1}, confirming very strong current during the mission, as it can be expected for the season. In the subsurface, the average value of the current in the 0-500 m layer is in the range 0.05-0.3 m.s^{1} which is quite high challenging for the glider navigation (one can compare these values with the horizontal speed of the glider ~0.2-0.3 m.s^{1}).

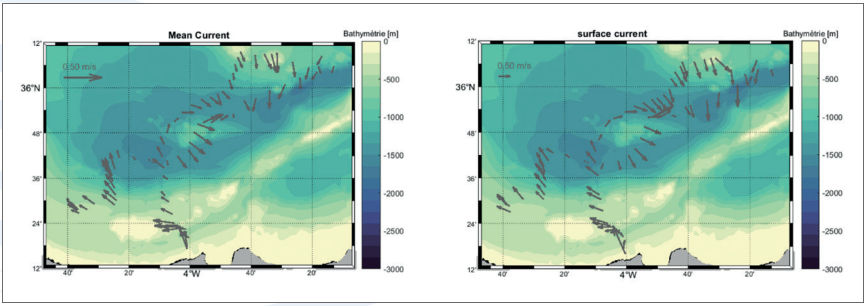

Fig. 2. Map of (left) average current from dead-reckoned track and (right) surface current estimated from GPS position. The color bar indicates bathymetry (EMODnet).

The rotating structure of the current again confirms the presence of the WAG. This pattern is particularly apparent during the first transect, i.e. when the structure was rather stationary. This confirms that WAG play a key role in dynamic of the whole the area. Another interesting feature of the area is the strong westward coastal current observed at low bathymetry, when the glider approached the coast.

In addition, further micro-analyses of the in-situ data provided by the two missions, could possibly provide additional elements to contribute to the clarification of circulation problems, currently posed within the Mediterranean [Millot & Taupier-Letage, 2004]; and enrich the debate on the major characteristics of the circulation in the western basin. Indeed, for the first time these two missions from the Al Hoceima

Observatory in the southern Al Boran Sea, will reinforce the intensive experiments involving numerous and sophisticated instruments, as well as theoretical and numerical studies, conducted in the Western Basin from the main laboratories were from the riparian (northern) countries, so that the general characteristics are better described and known.

4. Conclusion

This glider mission, as such, can be considered of huge interest considering the amount of new data collected and the overall historical data scarcity in the south Alboran Sea. This mission can also be considered as one of the very few works done on the WAG using in-situ measurements. Glider data provided crucial information that complement satellite observations and revealed the vertical structure of the WAG at an unprecedented spatio-temporal resolution. These results are a preliminary analysis. Further work is needed to fully investigate the mechanism involved, to highlight the suspected role of the WAG in homogenizing the freshwater masses of the Atlantic jet with the warmer and saltier water masses of the Mediterranean, or the WAG rule to increase the resilience of the Alboran marine ecosystem to the effects of climate change. This mission also shows the great potential of using gliders in integrated, multi-platform marine observatories.

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