Université de Toulon
MIR – EMJMD in Marine and Maritime Intelligent Robotics

Marine Environment

Oceanography Report

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1 Introduction

Collecting data on the Toulon Bay is crucial for improving navigation for water vessels and underwater vehicles, as well as weather forecasting. In order to gather information on surface currents in Toulon Bay, from the 10th to the 13th of October 2022, three drifters were cast at different water depths over a period of several hours, directly measuring the displacement of water in the bay. During this report similarities between these currents are investigated, along with comparisons regarding wind strength and the change of wind during the mission. We will also be comparing two different types of drifter data from an expedition carried out by MIR student's in 2021: data collected from physical drifters deployed at sea, and the other generated through simulation. Additionally, two CTD's were cast out, to gather information on the salinity, temperature and oxygen level over the depth of a water column. A comparison between these two locations will be made, along with reasoning about differences in their characteristics.

On the 13th October 2022 the third MIR group left the Ifremer research center, along with two professors overseeing the course. The mission was undertaken on the research vessel Antedon II, located at La Seyne-sur-Mer. During the time-span of five hours three groups of drifters were cast out and two measurements of CTD's were made.

2 Data Analysis of the CTDs

For the purposes of this mission the temperature, the oxygen saturation, as well as the salinity of seawater at two locations in Toulon Bay were measured. Additionally, during the first of the downcasts, two Niskin bottles were closed remotely, to bring deep-sea water to the surface. Information on the exact locations of each measurement can be found in the table below:

Measurement	Time	Longitude	Latitude	Depth
CTD-1	2022-10-13 12:57:00	006° 0.623′	42° 59.599′	500m
CTD-2	2022-10-13 14:02:00	005° 59.033′	43° 4.674′	56m

Table 1: Measurement locations and times for the CTDs

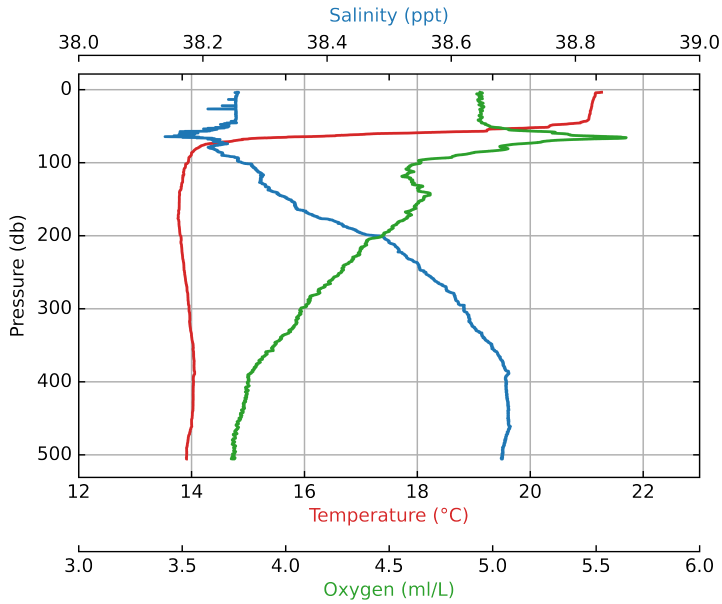

Figure 1: CTD-1: The change in temperature, salinity and oxygen levels over the depth of 500m.

The first measurement is made down to a depth of 500m. The data obtained from the CTD can be seen in real time, allowing the group to collect samples, should a depth of interest be observed.

Fig. 1 shows the change of salinity, temperature and oxygen level over a depth of 500m from the first measurement. The three layers of the ocean are clearly visible in the temperature data, with a short mixed layer at the surface, a transition layer marked by a sharp drop in temperature, called the thermocline, and a deep layer with relatively constant temperature. Salinity tends to increase with depth due to the organization of water based on the density gradient. However, surface currents result in small disruptions in the upper layers in the mixed layer. Oxygen levels tend to decrease with depth due to the absence of sunlight, which is necessary for the presence of phytoplankton in the water. There is a spike in the transition layer, where the ratio of phytoplankton to zooplankton is higher, resulting in an increase in oxygen levels. A similar trend can be seen in the measurement of seawater turbidity, which is closely related to plankton populations and exhibits a similar pattern, however this data was not recorded.

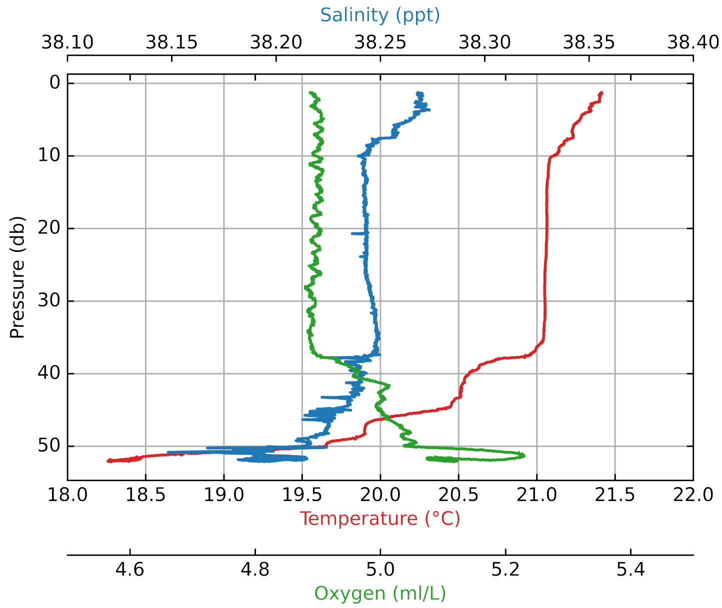

Figure 2: CTD-2: The change in temperature, salinity and oxygen levels over the depth of 500m.

Fig. 2 presents the CTD-2 measurement up to a depth of 56 meters, as the water in this area is shallower. The measurement is taken at a shallow depth, resulting in the majority of the diagram depicting the structure of the mixed layer. The transition layer is evident at a depth of approximately 40 meters, as shown by the beginning of a thermocline and an increase in oxygen levels. The big variations towards the sea-floor were probably caused by the movement of the CTD itself, causing turbidity and a mixing of water.

A comparison of the first 56m of measurement from CTD-1 and CTD-2 reveals similar levels of temperature, salinity, and oxygen saturation. This result is expected, given the proximity of the two measurement locations. While the two figures may differ visually, Fig. 2 shows the upper most water layer, due to its shallow depth, while the entire three-layered water structure can be observed in Fig. 1.

3 Data Analysis of the Drifters - 2022

In order to compare ocean currents at different depths, groups of drifters were deployed at separate locations, over the time span of three consecutive days. Each drifter measured the current at a different depth. This allowed us to analyze the differences in the currents at these different depths and understand how they may vary over time and space.

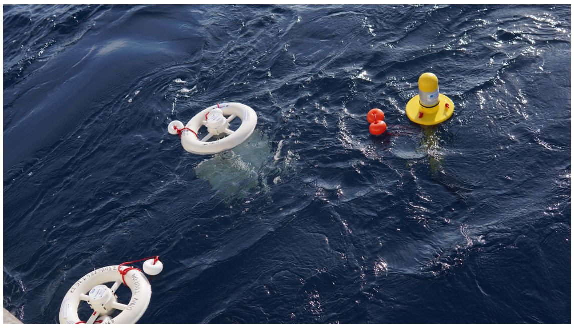

Figure 3: Three different types of drifters used during the experiment can be seen.

In Fig. 3 the fins of the buoys can be seen extending to different depths, influencing the corresponding drifters as they move through the water. The yellow buoy on the right is used to measure current speeds at a depth of one meter, while the white one next to it measures speeds at a depth of 0.5 meters. The buoy in the bottom left corner is only affected by surface speeds.

By sending out its position at regular intervals, each drifter allowed us to reconstruct its path through the water. The data collected from the drifters is cleaned and plotted, as depicted below. This visualization provided a clear illustration of the movement of the drifters over time and the influence of the ocean currents on their trajectory.

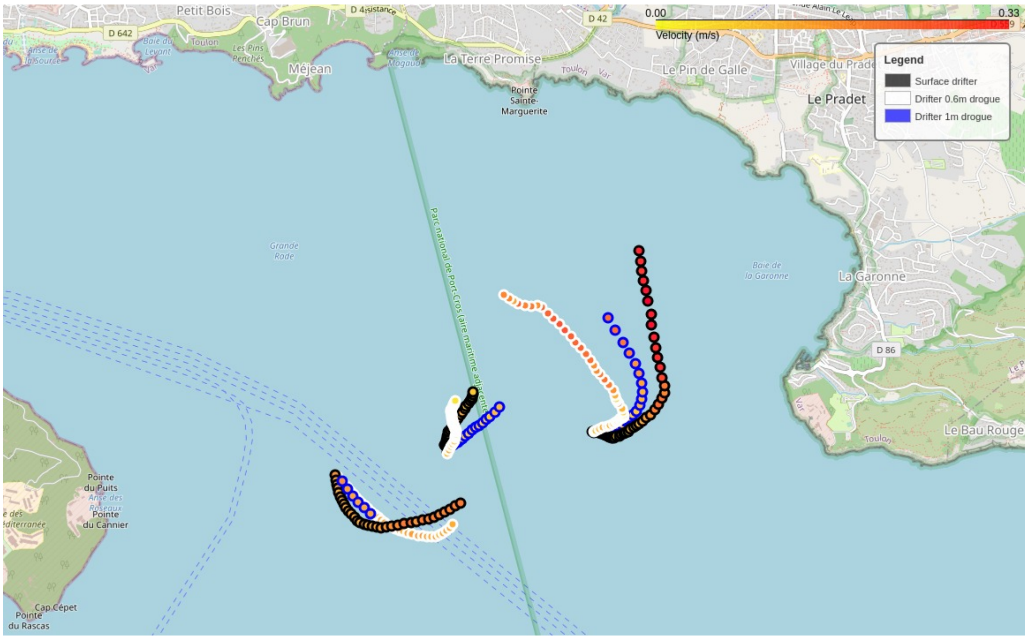

Figure 4: Drifters set out the 11. October 2022

Fig. 4 shows the path of the drifters set out by MIR group 1. Notably the movement of the surface drifter is more influenced by the changing wind, moving north-wards at a higher . A probable cause for this is the higher current velocity at the surface, paired with a lower drag force. Also, while the group set out farthest to the east is moving north, into the bay, the west-most group moves to the south-east. This could indicate a small gyre, created by the closed off volume, pushing water in on one side and out on the other.

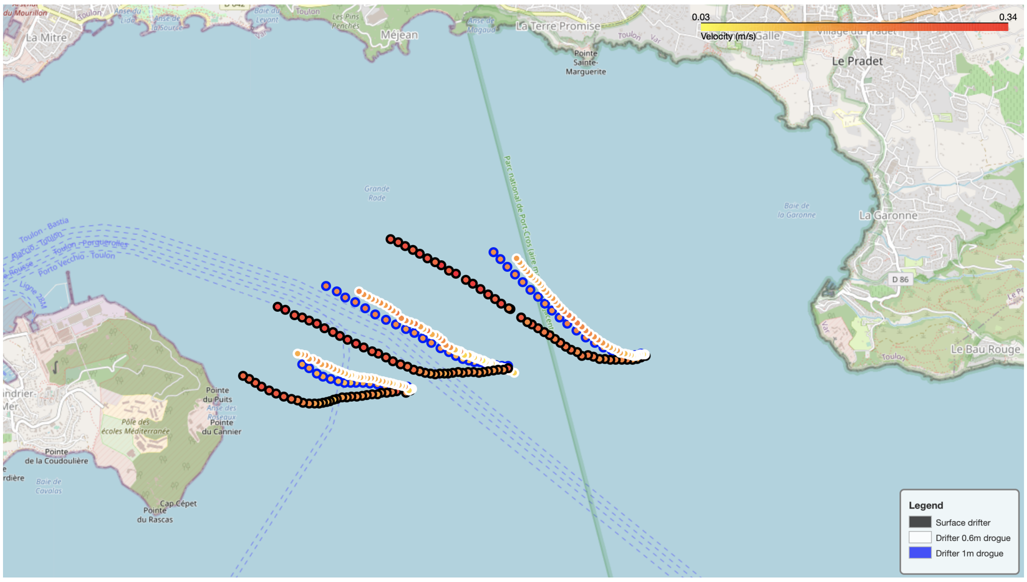

Figure 5: Drifters set out the 12. October 2022

The drifters set out on day 2, as shown in Fig. 5 show a west-ward trajectory. Similar paths between the three groups suggest relatively stable wind conditions. This matches the continuous wind direction towards the west observed during that day. As in the figure above, the surface level drifters are moving with a higher velocity due to their reduced drag.

On day 3, the wind started blowing towards the west and started changing it's direction by 180°. This change is reflected by the movement of the drifters, as shown in Fig. 6, which move in the same direction. Certain irregularities in the trajectories indicating missing measurements can be seen in certain drifter paths. This is estimated to be due to missing GPS signals of the drifters, given that they are not 100% accurate.

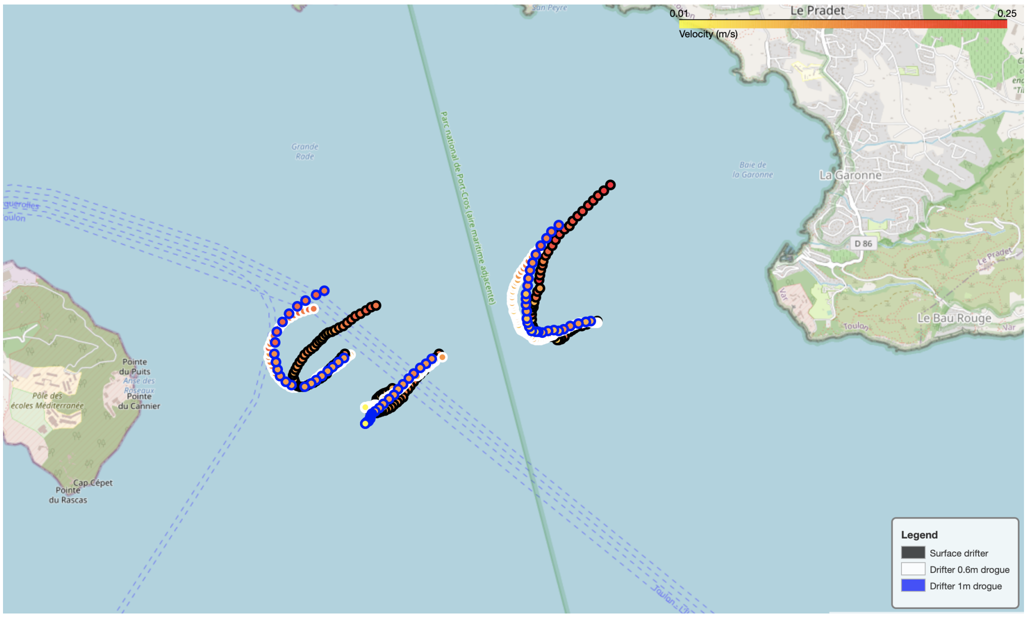

Figure 6: Drifters set out the 13. October 2022

Comparing the days among each other, the strong dependence of the drifter trajectories of the wind is clearly recognisable. The deeper the drogue of the drifter, the bigger is inertia is, with regards to the wind. During each day, the velocity of the drifters increased throughout the day, hinting at a recurring wind pattern in the Toulon Bay.

4 Comparison between the Simulated and Real World Data

This section compares the data collected by MIR students the 14th of October 2021 with a simulation using wind and current data from the same day. The feasibility of the simulation is tested, along with potential causes for non-aligning drifter paths.

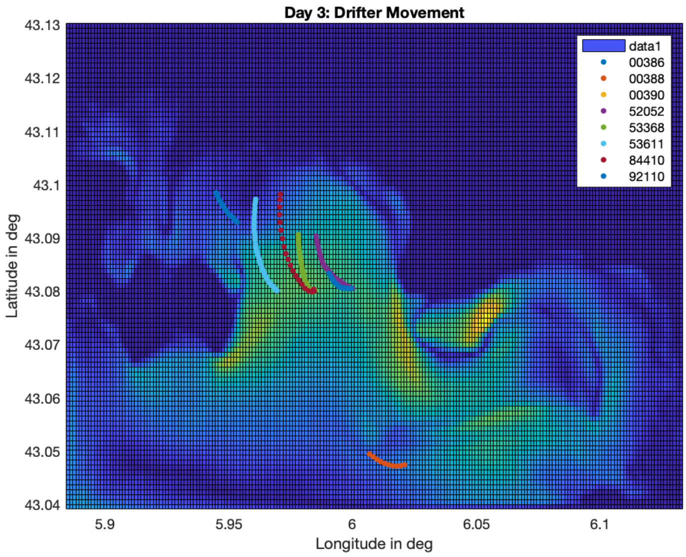

Figure 7: Drifters set out the 14. October 2021

The simulation of three drifters measuring ocean currents using MATLAB involved inputting data on the location, movement, and characteristics of the drifters and the ocean currents. This allows to accurately predict the trajectory of the drifters based on the influence of the currents. In order to fully capture the movement of the drifters, the simulation is set up with the starting positions recorded from the log sheet of the mission in 2021, where eight drifters were set out in total. Due to inaccuracies in the protocol, two of these entries were removed. Additionally, the data used in the simulation is specifically selected to represent the top level currents, which aligned with the movement of the surface level drifter.

As demonstrated by Fig. 8, the simulated drifters exhibited faster movement through the water when they were set out farther to the west. This is due to the influence of the current wave velocity, whose magnitude is seen in the background of the simulation and is depicted as moving the drifters farther to the north and which matches the wind movement during this time frame. The data used in the simulation provided the positions of the drifters at hourly intervals, allowing for the creation of six simulation steps over the course of the six-hour boat trip.

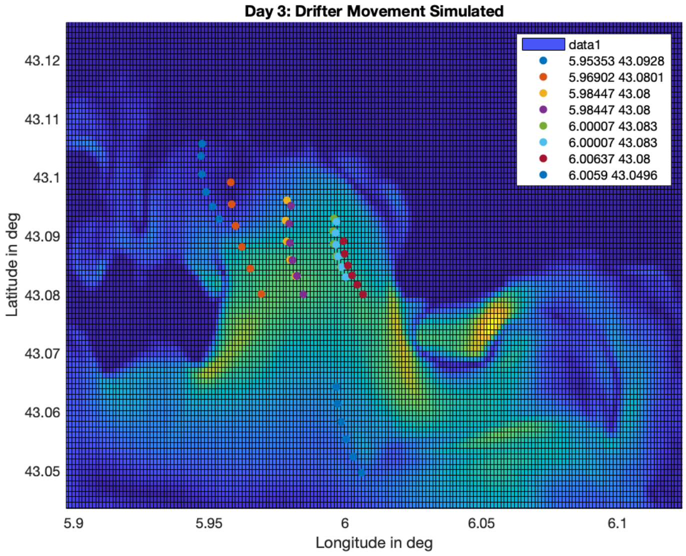

Figure 8: Drifters simulated for the 14. October 2021

The biggest mismatch between the simulation and real-life data occurs with the most southern drifter, "00388": while in reality its movement was mainly towards the west, the simulation showed a fast north-ward movement. Possibly, a short current was recorded during the measurement, but quickly changed its path after. Inaccuracies in the simulation are also found in the group of drifters set out in the middle and east; while the real-life drifter followed a faster more west-ward trajectory, the simulation failed to account for this. A possible reason for this discrepancy is the low sample rate of the data: Currents changing in between each measurement, cannot be accounted for in the simulation.

It is important to note that the simulated results do not perfectly match up with the real-life measured values. One potential reason for this is the low sample time used in the simulation compared to the duration of the actual trip. When the sample time is too low, the simulation may not accurately capture the full range of variations and complexities in the ocean currents and the movement of the drifters. This can lead to discrepancies between the simulated and measured values, particularly over longer periods of time. It may be necessary to increase the sample time or interpolate through time to improve the accuracy of the model.

5 Conclusion

During this report, data from the boat trip for the oceanography course is analysed. First, two CTD measurements at different locations and depths are compared, showing the layered structure over the depth of the Toulon Bay. Next, drifters, set out at various locations and depths are plotted and their trajectories are analysed. A strong dependence of the current, due to the wind is observed, as well as a direct correlation between depth and inertia towards sudden wind movements. Lastly, drifter data from 2021 is compared with a simulation, taking into account wind and current recordings of that day. The trajectories are followed correctly by the method used and possible adaptations for increasing accuracy are proposed.

Appendix

A Measurement Protocol for Drifters

Measurement	Depth	Time Out	Longitude	Latitude	Time In	Longitude	Latitude
2052	0 m	9:54	005º59.972	43º4.813	14:45	006º0.041	43º5.421
3368	0.6 m	9:54	005º59.972	43º4.813	14:39	005º59.593	43º5.133
LCI00274	1.0 m	9:54	005º59.972	43º4.813	14:41	005º59.716	43º5.224
8436	0 m	10:03	005º58.987	43º4.686	13:52	005º58.677	43º4.495
6439	0.6 m	10:03	005º58.987	43º4.686	13:55	005º58.499	43º4.402
LCI00279	1.0 m	10:03	005º58.987	43º4.686	13:58	005º58.501	43º4.335
119	0.6 m	10:21	005º58.416	43º4.669	14:30	005º58.209	43º4.851
7230	0 m	10:21	005º58.416	43º4.669	14:22	005º58.569	43º4.882
LCI00273	1.0 m	10:21	005º58.416	43º4.669	14:24	005º58.265	43º4.949
9666	0.6 m	10:55	006º0.678	42º59.547	11:39	005º45.322	42º58.672

Table 2: Measurement protocol for drifters