Introduction to Oceanography

Sea Trial Analysis Report

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Abstract

This is a report on the data processing and analysis conducted for data collected on 12/10/2023 on a sea trial that departed from Port de Brégaillon La Seyne-sur-Mer. Additionally, data from a similar sea trial conducted on 10/10/2023 was analysised.

Contents

1 Introduction **4**

2 Drifters Analysis **4**

2.1 Locating all drifters for two days of trials 4

2.2 Investigating velocity for 12/10/2023 6

2.3 Investigating velocity for 10/10/2023 7

2.4 Current Velocities Comparison 8

3 CTD Analysis **8**

3.1 Investigating fine spatial differences on CTD profiles 9

3.2 Investigating two separate days of CTD profiles 10

4 Physical Explanation **12**

5 Conclusion **15**

List of Figures

1 Drifters Trajectories for two days of Sea Trials 5

2 Drifters' velocities over the trajectory for 12/10 6

3 A closer look at the trajectories and velocities of each drifter for 12/10 . 7

4 Drifters' velocities over the trajectory for 10/10 8

5 A closer look at the trajectories and velocities of each drifter for 10/10 . 9

6 Comparing temperature, salinity and oxygen profiles for each station for day 12/10 10

7 CTD profiles for 10/10 and 12/10 for Station 1 11

8 CTD profiles for 10/10 and 12/10 for Station 2 12

9 CTD profiles for 10/10 and 12/10 for Station 3 13

10 Wind speed hindcast for the period 10/10 to 12/10 14

11 Weather hindcast for La Seyne-sur-Mer October 14

12 Wind direction hindcast for the period 10/10 to 12/10 15

List of Tables

1 Station Locations 4
2 Sea Trial Logistics Summary 4

1 Introduction

The focus of this oceanographic report is to observe and explain the results from processing data that was collected on 12/10/2023 on a sea campaign in the Mediterranean Sea off the coast of La Seyne-sur-Mer (Toulon Bay). Surface drifters were deployed at three different stations. Only yellow Southtek drifters were deployed as the website to receive the white Lagrangian drifters' transmission signal was not available. Additionally, a Conductivity, Temperature and Depth (CTD) profiler was deployed at each station. Table 2 summarises the locations of these stations as well as which drifter was deployed. It includes information for the 10/10/2023 as this day was chosen to compare results with.

In Section 2, the drifters trajectories and velocities for each day is analyzed and compared. Section 3 investigates the CTD profiles for temperature, salinity and oxygen and details differences between the stations and sea trial days. Finally, a brief physical explanation is given in Section 4 to collate these results and reinforce claims by using weather hindcasts.

Table 1: Station Locations

Station	Approximate Station Coordinates
1	43°04' N, 6°00 E
2	42°99' N, 6°00 E
3	42°96' N, 6°00 E

Table 2: Sea Trial Logistics Summary

Sea Trial Date	Station	Instruments Deployed
12/10/2023	1	Yellow Drifter 273, CTD downcast to 257 m
12/10/2023	2	Yellow Drifter 386, CTD downcast to 600 m
12/10/2023	3	Yellow Drifter 384, CTD downcast to 600 m
10/10/2023	1	Yellow Drifter 273, CTD downcast to 257 m, white drifters
10/10/2023	2	Yellow Drifter 384, CTD downcast to 600 m, white drifters
10/10/2023	3	Yellow Drifter 386, CTD downcast to 600 m, white drifters

2 Drifters Analysis

2.1 Locating all drifters for two days of trials

The drifters were deployed at the three stations, and collected on the return trip. Figure 1 shows the trajectory of each yellow drifter for each day. Longer trajectories suggest that they were in the water for a longer time. Checked against the log sheet, this is generally true for the very short trajectories like Drifter386 for 10/10 at Station 3 and Drifter384 for 12/10 at Station 3. However, the length of trajectory could also correspond to a slower or faster velocity. The current might have been stronger and thus the drifter moved faster. We will consider velocities in the following sections. Another interesting aspect of the shape of these trajectories is how they change. For both days, Station 1 and 2 have comparable shapes but for the final station, the shapes are very different. This could be due to wind direction changing at some point in the day or perhaps the current slowly shifts as we get further into the open ocean as there would be less disturbance from the coastlines.

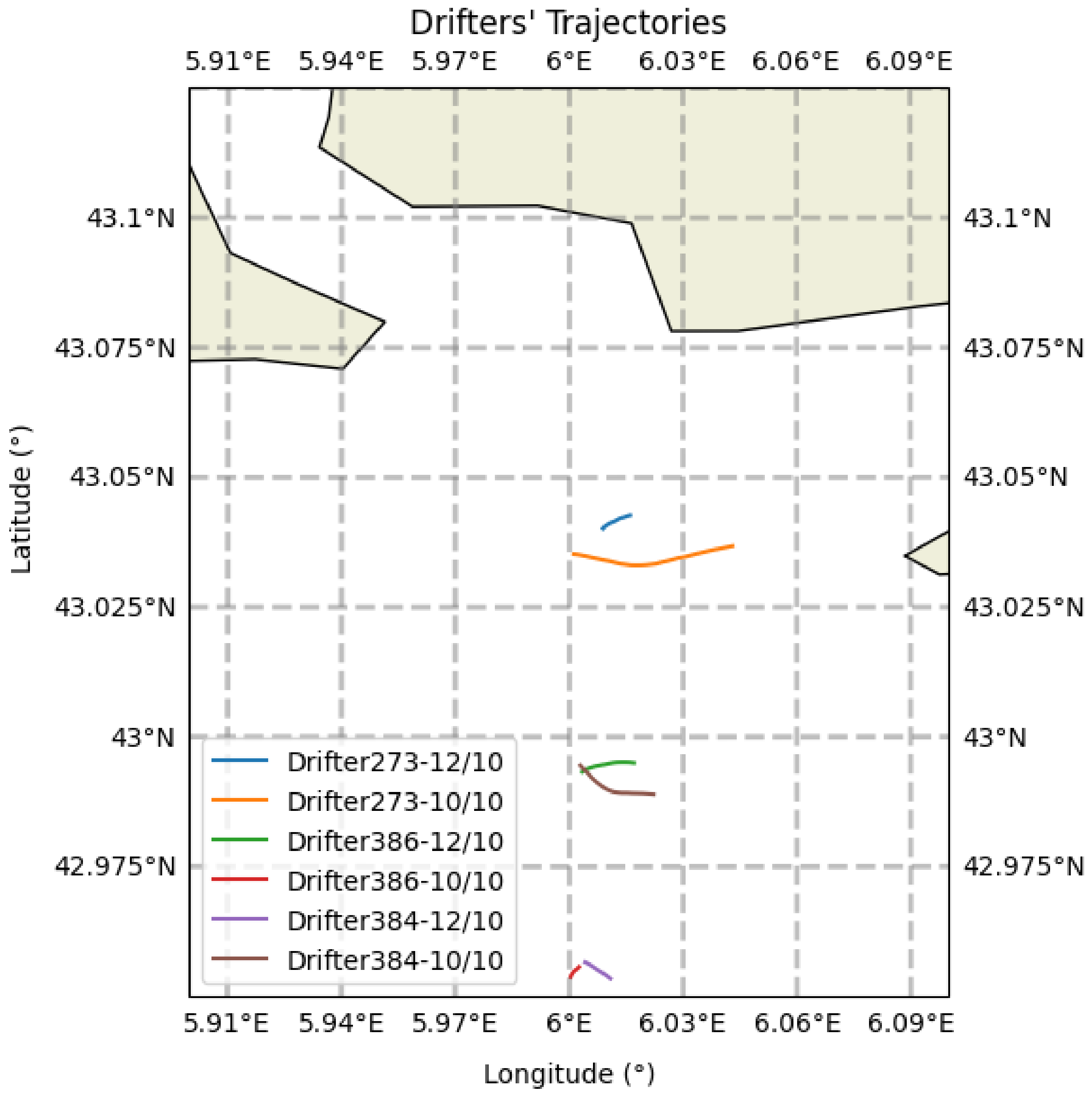

Figure 1: Drifters Trajectories for two days of Sea Trials

2.2 Investigating velocity for 12/10/2023

Velocities throughout the drifters' trajectories ranged between 12 cm/s and 16 cm/s. Drifters deployed earlier have more data points as they had more time to drift. According to the log files, Drifter273 was delpoyed at Station 1. It should have the most data points. However, it has fewer data points than Drifter386 which was deployed at Station 2. A potential explanation for this anomoly is that there was a mislabeling of files somehow. It is possible that the data was cleaned incorrectly, although cleaning was done based on what made sense with the trajectory plots - straight line paths were removed as they represent the research vessel's movement. However, the starting location for Drifter386 does correspond with Station 2's location. For now, we will assume that there may be missing data for Drifter273.

Observing the velocities in Figure 2, the current moved steadily faster at Stations 2 and 3 as time progressed, perhaps indicating a slightly faster wind. However, at the tail end of Drifter273's trajectory, the last drifter to be recovered, the velocity is on the lower spectrum. This suggests that the wind might have decreased again or that the current was just generally weaker towards the higher latitude, nearer to the coastline.

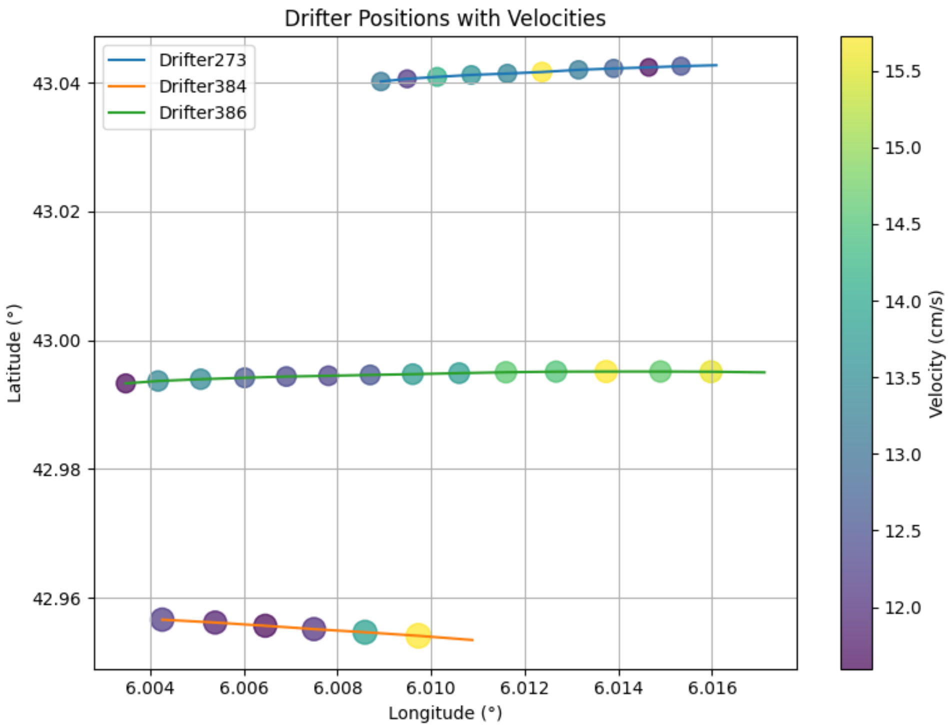

Figure 2: Drifters' velocities over the trajectory for 12/10

Figure 5 provides a closer examination of the trajectory shapes. There is a trend of the trajectories arching downward as time progresses until Drifter384 (deployed at Station 3) has a much more steep, downward trajectory. The wind direction might have changed in this case, affecting the movement of the current.

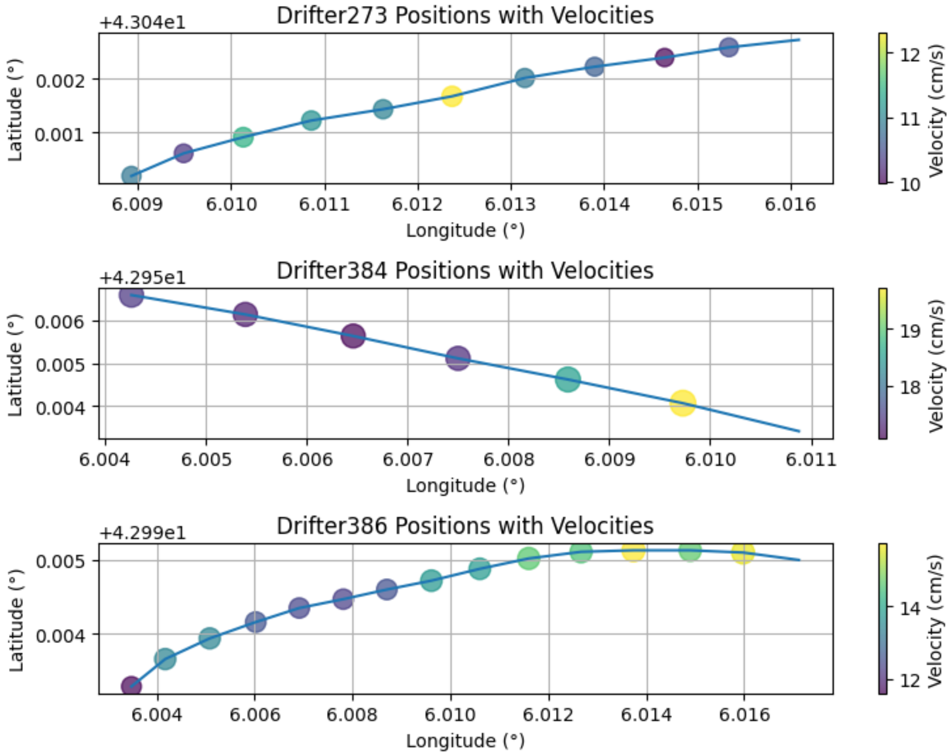

Figure 3: A closer look at the trajectories and velocities of each drifter for 12/10

2.3 Investigating velocity for 10/10/2023

The drifter trajectories with their velocities for 10/10/2023 are plotted in Figures 4 and 5. These trajectories make physical sense as the earliest deployed (Drifter273) has the most data points and the other drifters have the correct proportional decrease in data points over time. Cross-referencing with the log sheet, these drifters were also deployed earlier in the day. This correlates with reality as the sea trial on 12/10 encountered technical difficulties and therefore the drifters did not have as much time to drift.

All three drifters for 10/10 seem to have a had a linearly increasing velocity over time. This indicates that the current became stronger, possibly due to wind speed increasing.

The shapes of these trajectories' are interesting as Figure 5 emphasizes. Overtime, the current direction changed as Drifter386 (deployed at Station 3) has a downward trajectory; its end-point is on the same longitude as the other two drifters' start point. This shift to a downward trajectory is also evident with Drifter384. However, the opposite occurred over time with Drifter273, indicating different current patterns at different spatial locations.

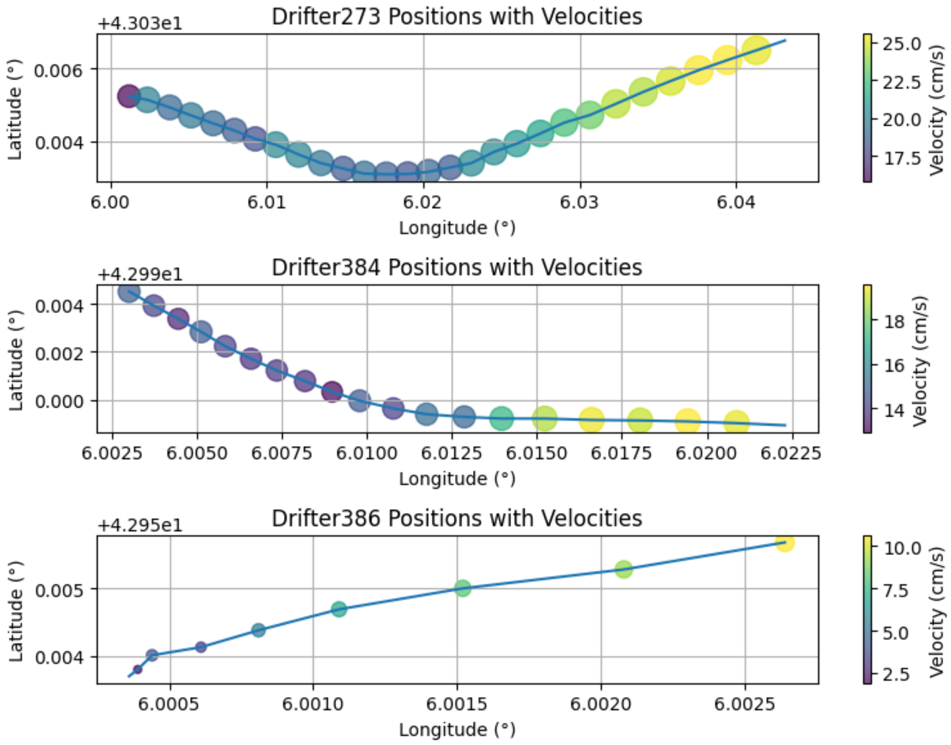

Figure 4: Drifters' velocities over the trajectory for 10/10

2.4 Current Velocities Comparison

We can conclude this drifter analysis by noting the following:

- There is something strange with the data for Drifter273 for 12/10. Either it was cleaned incorrectly or there is discrepancy in the file labeling or there is missing data. The latter of these options seems most likely as the coordinates of the start points of the drifters do match their station.

- There were different dynamics on each day and this could be due to different prevailing weather conditions.

- Both days show changing current patterns according to spatial location, indicating something inherent in the current dynamics of the area that is related to weather but not only explained by weather.

3 CTD Analysis

At each station, the CTD was downcast to a particular depth (250 m or 600 m). The CTD analysis was done on temperature, salinity and oxygen. The effect of spatial and temporal dynamics on the profiles are considered.

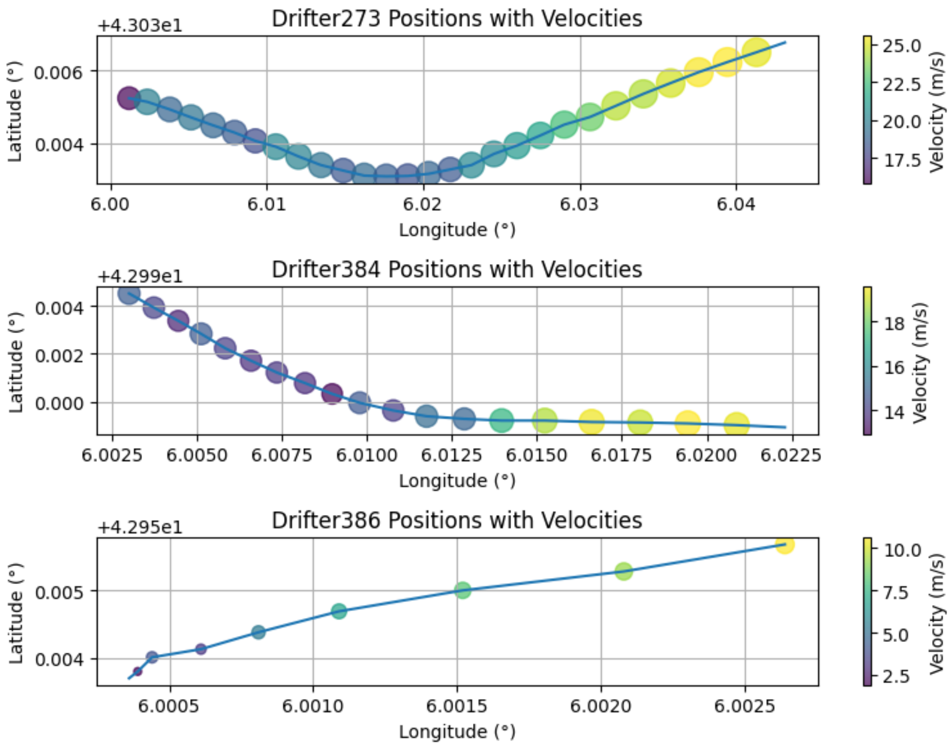

Figure 5: A closer look at the trajectories and velocities of each drifter for 10/10

3.1 Investigating fine spatial differences on CTD profiles

Figure 6 shows temperature, salinity and oxygen profiles for each station for 12/10. There is very little variation between the temperature profiles, apart from Station 1 only going down to around 250 m. Although, at the surface, the temperature does vary very slightly. In general, this is a typical temperature profile that matches the theory of mixed waters at the surface and cold, dense waters after a gradual transition through the first 100 m of depth.

The salinity profile is also normal but with slightly more variation between the three stations. The most significant difference is Station 2 which has a higher salinity at the tail end of the halocline, just before descending into deep waters at around 180-200 m.

The oxygen profile does not vary significantly between stations. It confirms the theory of what we expect of vertical oxygen profiles in the deep. At around 50m, before the transition to deep waters, there is a concentration of very small changes in oxygen. This is where the oxygen content is greatest (at the elbow of the curve). This matches what we know of the process that brings oxygen to the surface. There was likely an upwelling, causing there to be a high level of oxygen relatively close to surface. This depth and area would likely have a high level of biological productivity.

We can conclude that spatial variation actuated little to no difference in the salinity, temperature and oxygen profiles.

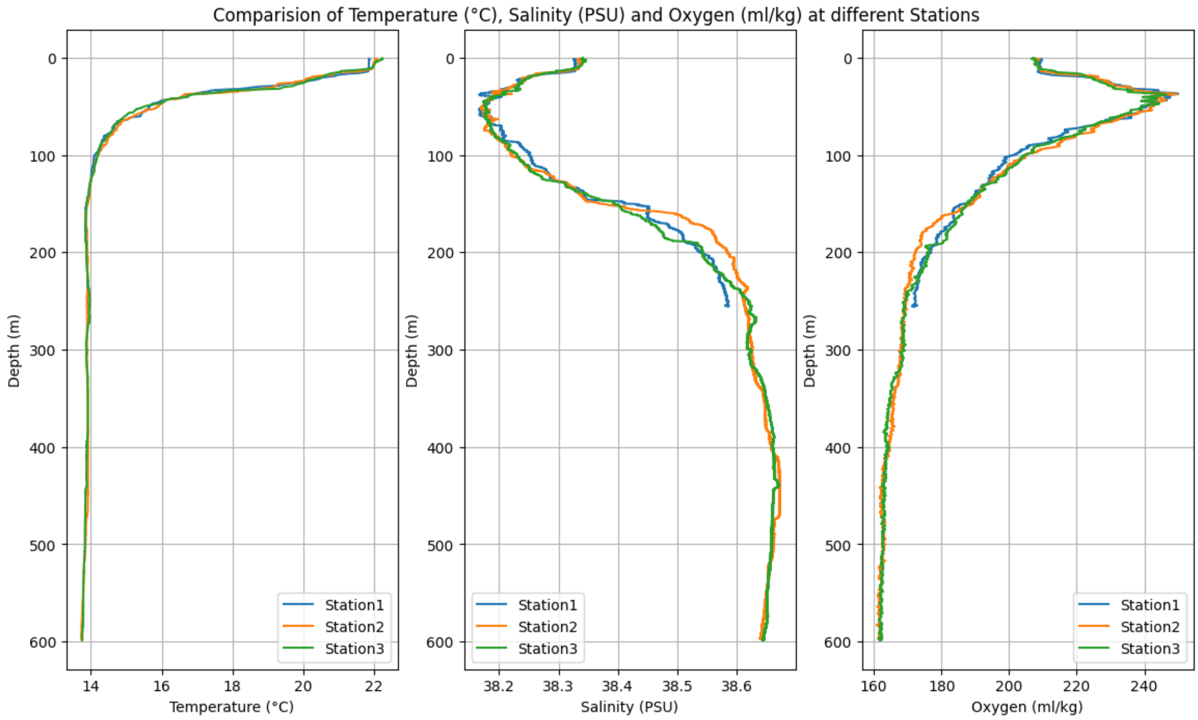

Figure 6: Comparing temperature, salinity and oxygen profiles for each station for day 12/10

3.2 Investigating two separate days of CTD profiles

On the other hand, the profiles – although the same typical shape – do result in different values across time. Figures 7, 8 and 9 show the temperature, salinity and oxygen profiles for 10/10 and 12/10 for each station.

Observing Station 1 in Figure 7, there are clear variations between each day for salinity and oxygen. This is less apparent in the temperature profile. For salinity, there appears to be more water mass mixing on 12/10 – evidenced by the oscillatory values at around 40 m. This greater degree of water mass mixing also shows at the same place in the oxygen profile. Then between 70 m and around 160 m, the salinity values for 12/10 are slightly lower. This means the water mass was less dense on 12/10. They then converge to be almost the same at deeper waters. This confirms what we know of local conditions – difference in time and space are more likely to be evident near to the surface (the first 100 to 200 m). This is because the effects of the atmosphere, wind-induced currents, and other environmental factors at the surface generally have an impact that does not extend to very deep waters.

For Station 2 in Figure 8, there are fewer noticeable differences in the profiles. The

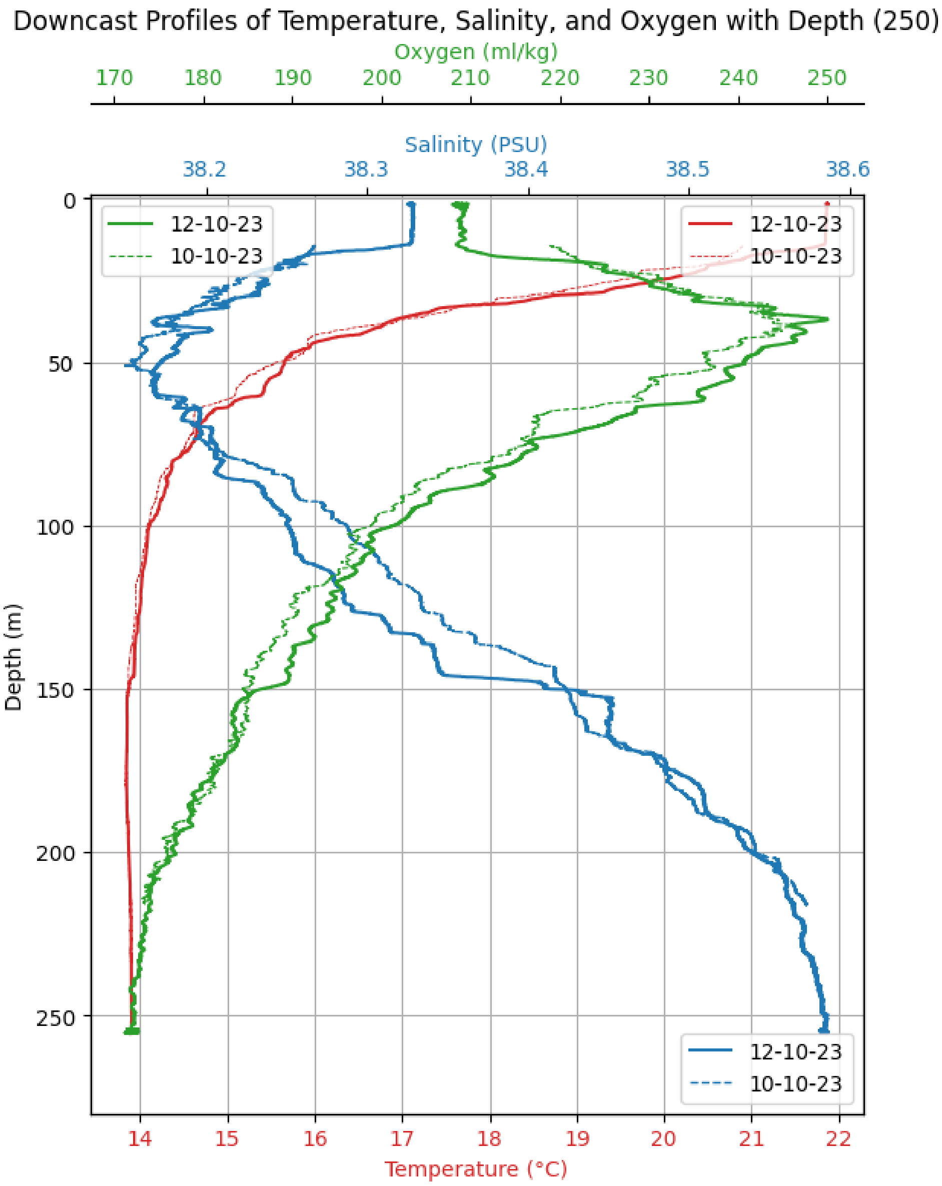

Figure 7: CTD profiles for 10/10 and 12/10 for Station 1

main difference is at the elbow of the salinity curve – at around 200 m – the 10/10 profile has a higher value. This corresponds with what we observe in Station 1 except that the salinity is higher at the this point for both days than it was at Station 1.

For Station 3 in Figure 9, there are even fewer differences in the profiles. We can note the same pattern with salinity except that difference between the days extends a shorter range of depth than at Station 1 and 2.

We can conclude this CTD analysis by summarizing that:

- There are temporal differences in the profiles. Each day has slightly different values and vertical structures. However, the general trend we expect is the same.

- These differences are more significant for salinity and oxygen than temperature.

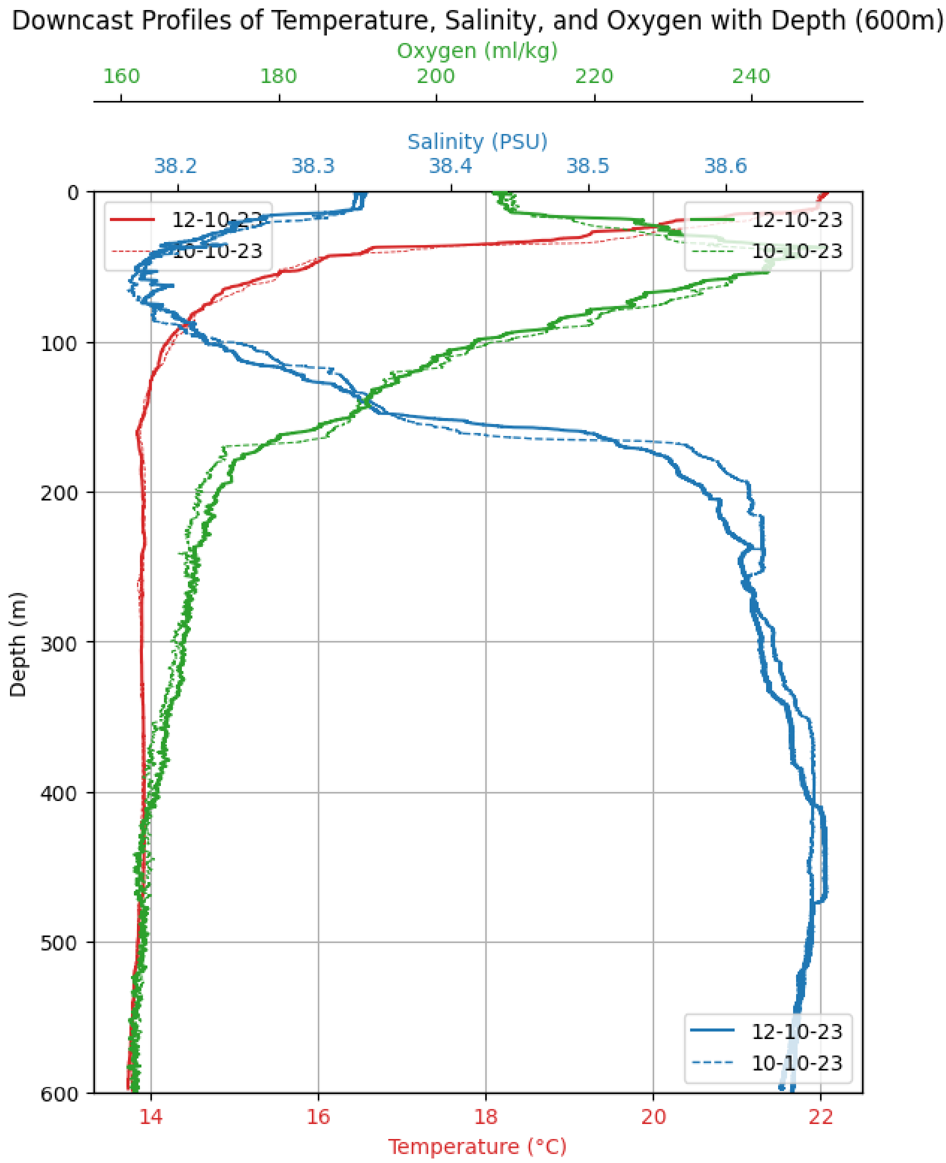

Figure 8: CTD profiles for 10/10 and 12/10 for Station 2

- These differences decrease with depth, and also with location. The stations that were further away from the continent had less difference and for a shorter range of depth.

4 Physical Explanation

There are possible meteorological and theoretical explanations for the drifter behaviour described in Section 2. This section considers weather hindcasts to see if the theories expressed can be proven to any extent through other data.

The velocities of the drifters for 12/10 were mostly irregular. There was not a significant trend of increasing or decreasing velocity - each data point varied slightly or stayed

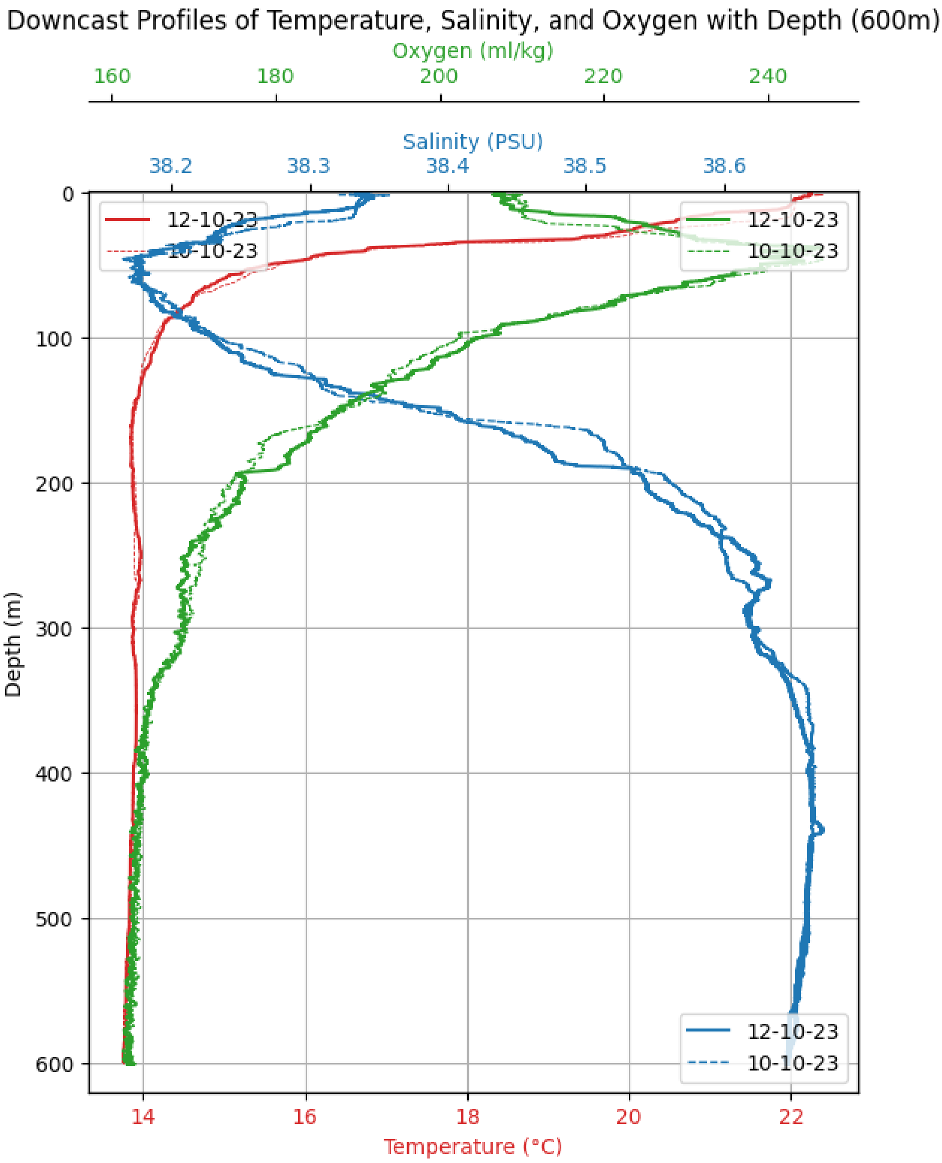

Figure 9: CTD profiles for 10/10 and 12/10 for Station 3

at a constant velocity. Figure 10 and Figure 12 shows the wind speed and wind direction hindcast for Toulon from 10/10/2023 to 12/10/2023 [1]. This can give a general idea of the weather that day – although it may not be entirely accurate for what the weather was like at sea.

Figure 10 contradicts the observations made for 10/10. The wind speed actually decreased during the drifters' drift while the velocities increased which suggests that wind speed does not explain the velocity increase. However, we can consult a different hindcast.

Figure 11 provides the temperature, wind speed, wind direction and precipitation

[1]Taken from `https://www.windguru.cz/archive.php?id_spot=278492&id_model=3`.

GFS 13 km	Wind speed (knots)																							
	00h	01h	02h	03h	04h	05h	06h	07h	08h	09h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
10.10.2023	12	12	12	12	12	11	11	11	11	10	9	10	9	9	10	11	12	12	12	12	11	11	11	11
11.10.2023	11	10	9	8	8	7	5	4	2	2	2	1	2	5	7	8	9	10	10	9	9	8	8	8
12.10.2023	7	7	7	7	6	6	5	6	7	7	7	8	9	10	11	11	12	12	12	11	11	10	9	8

Figure 10: Wind speed hindcast for the period 10/10 to 12/10

hindcast for La Seyne-sur-Mer for the first fifteen days of October[2]. Looking at the wind speed for the morning of 10/10, we see that the wind speed increased. This is potentially a more reliable hindcast as the sea trial left from a port in La Seyne-sur-Mer. Relying on this hindcast, the wind speed is verified to have increased which matches what the drifters' revealed about current velocity.

Considering 12/10, we observe that wind speed increased in the very early morning and stabilized at around the period that the drifters were drifting. The spike at midday corresponds to Drfiter384 and Drfiter386 having their highest velocity at the end of their trajectory (around midday when they were retrieved). Additionally, the wind speed values are slightly higher than 10/10 during the drift times which explains the higher velocity values on 12/10.

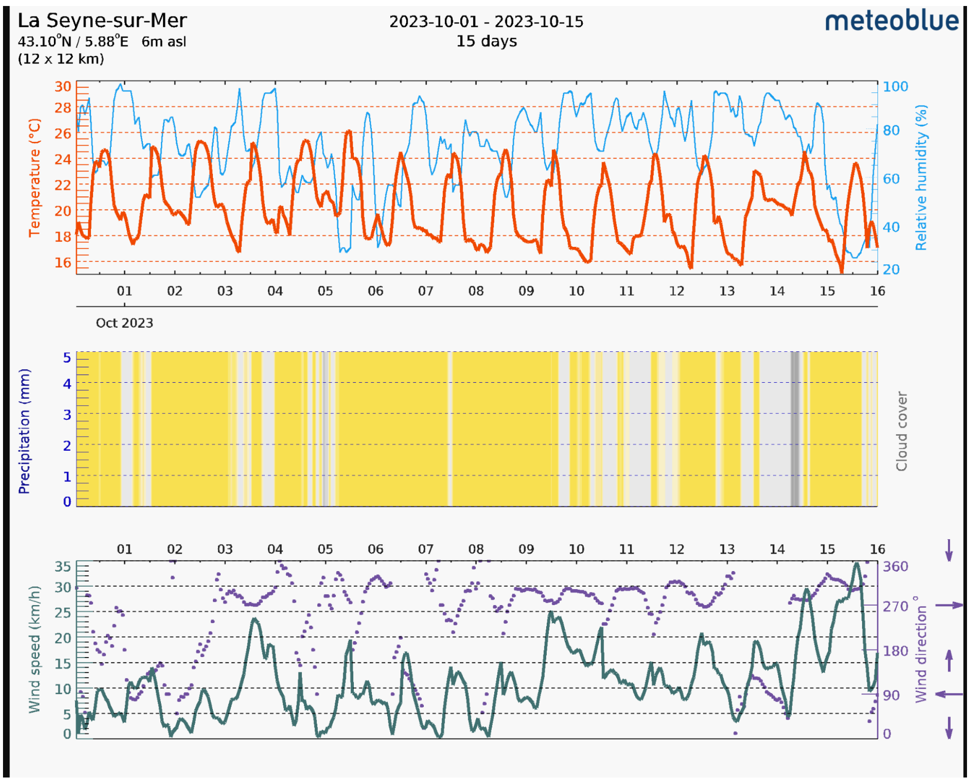

Figure 11: Weather hindcast for La Seyne-sur-Mer October

[2]Taken from `https://www.meteoblue.com/en/weather/historyclimate/weatherarchive/la-seyne-sur-mer_france_3006414`

We noted that the trajectories shape and direction changed through the day. We can consider wind direction to explain this. The wind direction hindcast for Toulon in Figure 12 is not informative as for both days it shows the wind direction varied only very slightly during the drift period.

However, the more reliable hindcast in Figure 11 contains more detail. For 10/10, the wind came from the west for most of the morning. At midday, there is a gradual but noticeable shift to a north-westerly wind. This correlates with the trajectories taking a more downward slope as the day progressed.

For 12/10, the wind was primarily a north-westerly which explains most of the drifter shapes but not Drifter384 at Station 3. This suggests that it was not only wind-induced currents affecting the drifters' trajectories. Indeed, we would not expect this as circulation on the ocean surface is more complicated.

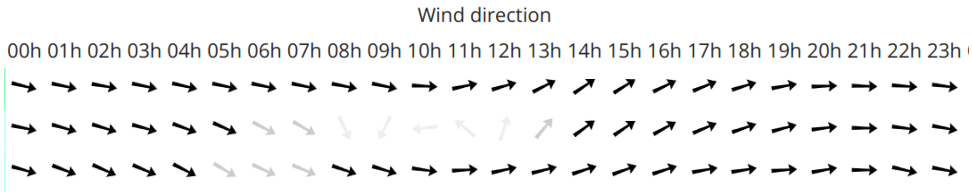

Figure 12: Wind direction hindcast for the period 10/10 to 12/10

When it comes to physically explaining the CTD profiles, there is not much need as all the profiles matched the theoretical vertical structure of the ocean. The temporal and spatial impacts observed are not unusual as the profiles will always shift slightly according to local conditions.

5 Conclusion

Observations were made to interrogate velocity, trajectory shape and CTD profiles. Two days of sea trials were compared. This report found that the theory of wind-induced currents explained most of the drifter behaviour. Meteorological hindcast data was used to correlate the theory. Further work could be done to explain some of the anomalies in the drifter trajectory and salinity differences in the CTD profiles. This work could include examining other data from the Mediterranean Sea, like the physics analysis and forecast dataset from the Copernicus Marine Service.