Marine and Maritime Intelligent Robotics Program M1

MIR UE12 Introduction to Oceanography

Submitted by

Grpup 02

Name	Id
Abubakar Aliyu Badawi	22303696
Celil	22303715
Md Ether Deowan	22303698
Md Shamin Yeasher Yousha	22303716
Shahriar Hassan	22303704
Tihan Mahmud Hossain	22303703
Tayyab Tahir	22303713

Submitted to

Anne Molcard
Professor,University of Toulon

December 18, 2023

Table of Contents

Contents

Experiment 1

1 Introduction

1.1 Background and Significance of the Study

The Mediterranean Sea poses a fascinating challenge to scientists due to its intricate ocean dynamics. Interpreting the complexities of ocean currents, temperature fluctuations, and variations in salinity and oxygen levels is crucial for a comprehensive understanding of climate patterns and ecosystem dynamics. This sea trial utilizes the use of some in-situ instruments and strategic deployment tactics to gather ocean data, particularly from the Mediterranean Sea.

The primary objective is to unravel the profile of ocean currents in the Mediterranean Sea. Utilizing cutting-edge tools and strategically placing drifters, the study aims to uncover the precise mechanisms governing these currents. Simultaneously, we are investigating variations in temperature, salinity, and oxygen levels at different depths. This in-depth analysis seeks to enhance our understanding of the Mediterranean Sea's hydrodynamics, contributing valuable insights to the broader field of oceanography.

1.2 Objectives of the Report

The primary goals of this report are to document and analyze the oceanographic experiment conducted in the Mediterranean Sea. By strategically deploying drifters and employing advanced Conductivity, Temperature, and Depth (CTD) instruments and Niskin bottles, the primary aim is to characterize the region's ocean currents. Concurrently, the study seeks to gather comprehensive data on crucial environmental parameters at varying depths, focusing on understanding how different properties like temperature, salinity, oxygen, and pressure change with depth.

Additionally, the report aims to contribute valuable insights by comparing the obtained results with other datasets. This comparative analysis will evaluate our findings against the data accessible from the Copernicus Marine Service dataset—a website that offers free oceanographic data worldwide. By undertaking these comparisons, we aim to not only deepen our understanding of the Mediterranean's oceanography but also to validate and contextualize our findings within the broader spectrum of global oceanographic research.

2 Methodology

2.1 Data Collection

2.1.1 Description of Data Collection Processes (CTD and Drifter)

The collection of data involved a structured process at three distinct stations, where we measured conductivity, temperature, pressure, and oxygen levels with the help of CTD and Niskin bottles. The procedure included deploying CTD to various depths (depths of 250 meters, 500 meters, and 700 meters) underwater which varies at different stations to capture a comprehensive profile of the water column while simultaneously measuring the conductivity, temperature, pressure, and oxygen level.

On the other hand, we deployed 3 drifters per station, which included 1 drifter with fins commonly used in oceanographic research where accurate tracking of currents is crucial. They are employed to study features such as eddies, upwellings, and large-scale ocean circulation patterns, 1 drifter without fins, which is used in applications where a more natural drift is desired, lastly, we also deploy a drifter with a length of 1 meter to measure more water column. At each station, the drifters were left in the sea while we headed to the next station, for each deployment, the drifter number, deployment time, latitude, and longitude were recorded. This approach not only facilitated the acquisition of detailed data but also allowed for a comprehensive understanding of the spatial and temporal variations within the Mediterranean Sea.

The drifter data was sent via satellite communication through a website. After completing the measurements at the third station, we returned to retrieve the drifters using the GPS coordinates associated with each drifter.

2.1.2 Data Cleaning Process Description:

To maintain the trustworthiness of our collected data, we implemented a careful data-cleaning process. This systematic refinement aimed to find and fix potential issues like outliers, calibration errors, and inconsistencies from environmental factors or equipment malfunctions.

For this, we used a specialized MATLAB code designed for automated data refinement. The code focused on extracting only the initial and final positions of the data, removing any points before the start or after the end of the intended observation period. Additionally, to make our dataset more precise, the code was designed to get rid of any 'nan' values, making sure that only reliable data contributed to the following analysis. This systematic approach not only made our dataset stronger but also made the next analytical steps smoother by providing a polished and accurate foundation for interpretation.

2.1.3 Criteria for Data Inclusion and Exclusion

The inclusion/exclusion criteria were established to maintain data quality. Data points meeting the predefined standards of accuracy and reliability were included, while those failing to meet these criteria were systematically excluded. This stringent approach enhances the credibility of the findings and ensures the robustness of the scientific conclusions drawn from the dataset.

3 Results and Data Analysis

This section elucidates the approach undertaken to analyze the oceanographic parameters obtained during the sea trials. The data, collected through CTD instruments, encapsulates the quartet of conductivity, temperature, and Salinity. The analytical process bifurcates into two primary comparison fronts—inter-day comparison and year-on-year comparison with Copernicus Global Ocean Physics datasets.

3.1 CTD Profile Analysis

In this segment, we delve into the systematic examination of the collected oceanographic data, primarily focusing on the Conductivity, Temperature, and Depth (CTD) measurements from the 11th of October. The analytical journey begins with the plotting of the CTD profiles at Station 3 (ST3), which serves as the fulcrum for our analysis. The illustrative representations include:

3.1.1 CTD Profiles for 11 Oct Data at ST3

These profiles provide a visual representation of the conductivity, temperature, and depth measurements, illustrating the vertical stratification of water properties.

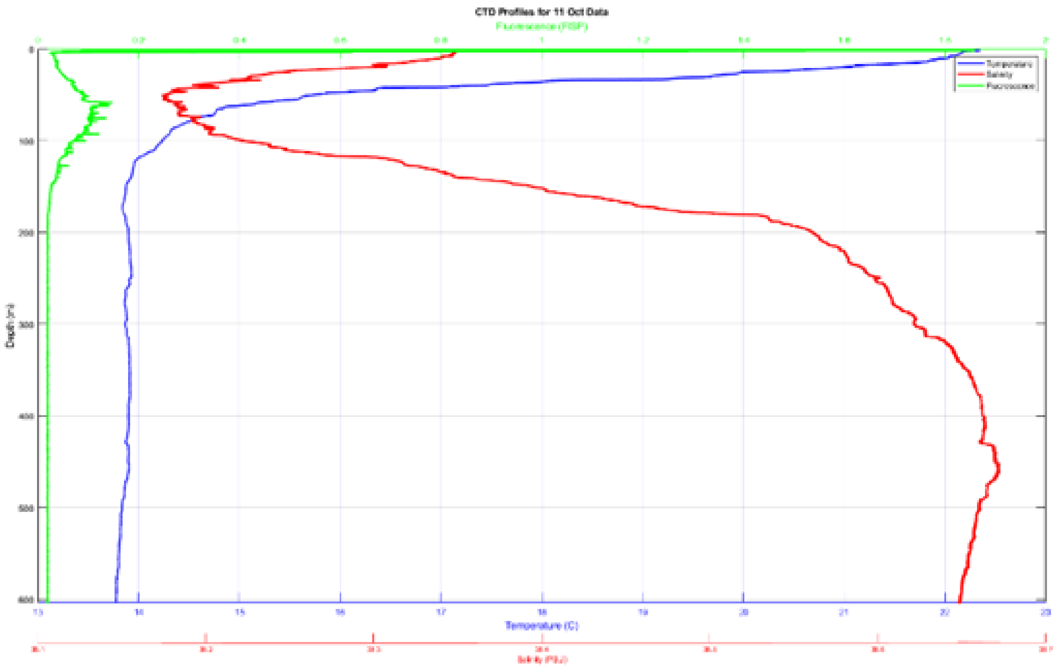


Figure 2: CTD Profiles for 11 Oct Data

This graph presents a set of CTD (Conductivity, Temperature, and Depth) profiles for oceanographic data collected on the 11th of October. Each line represents a different parameter measured at various depths of the ocean at Station 3 (ST3), which is a significant method for understanding the physical and chemical state of the water column.

Temperature (Blue Line): The blue line descending through the graph represents the temperature profile of the water column in degrees Celsius. The temperature shows a thermocline, where it decreases with depth, particularly between the surface and approximately 200 meters, after which the rate of decrease slows down, indicating a well-mixed deeper layer.

Salinity (Red Line): The red line represents salinity in Practical Salinity Units (PSU). It appears relatively stable throughout the upper layer but shows a distinct halocline at a depth similar to where the temperature decline moderates. The halocline indicates a layer of water where the salinity changes rapidly with depth, which can be a result of freshwater influx, evaporation, or water mass convergence.

Fluorescence (Green Line): The green line shows fluorescence measured in relative units, which is an indicator of chlorophyll concentration, thus a proxy for phytoplankton biomass. The fluorescence is high at the surface, indicating abundant biological activity, and decreases sharply with depth. This surface concentration is likely due to the availability of sunlight for photosynthesis, which diminishes with depth, leading to a lower concentration of phytoplankton.

The intersection and divergence of these profiles provide insights into the structure and dynamics of the water column. Where the temperature and salinity profiles intersect, there may be an indication of a water mass with specific density characteristics. Additionally, the sharp decrease in fluorescence with depth reveals the euphotic zone's boundary, beyond which light availability is too low for substantial photosynthetic activity.

3.2 Comparison with Other Data

The second analytical phase compared the data across consecutive days to discern any observable patterns or anomalies. This comparison utilized the data collected by different teams on 10, 12, and 13 October at the same station:

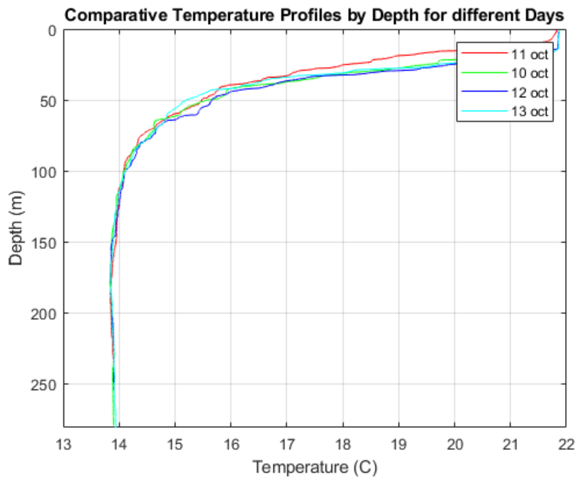
3.2.1 Comparative Temperature Profiles by Depth at ST1, ST2, and ST3

The comparative analysis of temperature profiles by depth across four consecutive days (10th to 13th of October) at Stations 1, 2, and 3 reveals a remarkable temporal consistency in the thermal structure of the water column. This stability is indicative of a quiescent oceanographic regime, potentially governed by a steady-state balance between atmospheric forcing and oceanic thermal inertia.

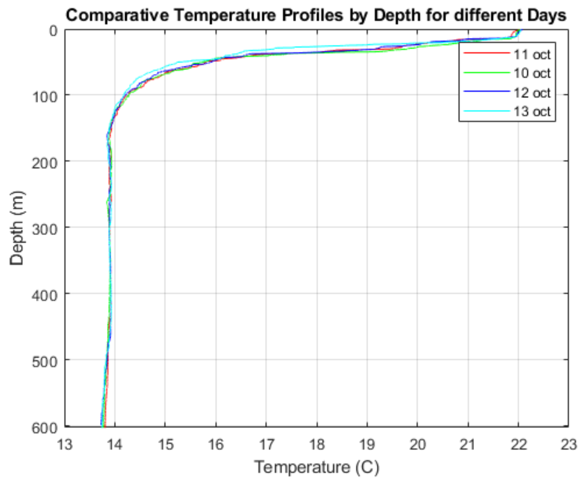
Surface Homogeneity Notably, the surface waters (0-50m) exhibit negligible variation in temperature across the sampled days. This homogeneity may be attributed to the prevalent weather conditions which lacked significant perturbations such as storms or heatwaves that could introduce thermal anomalies to the surface layer.

Thermocline Dynamics The thermocline, a critical transitional layer between the warmer mixed surface waters and the cooler deep waters, is well-defined in each profile. It appears consistently across the days, situated roughly between 50m to 100m. The persistence of the thermocline's depth and gradient across the sampling dates denotes a stable stratification that could be instrumental in delineating the nutrient dynamics and the distribution of marine biota, as it typically impedes vertical mixing.

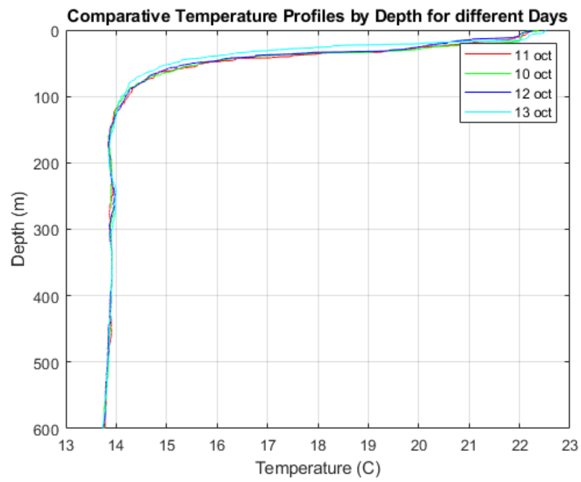
Deep Water Constancy At greater depths, beyond the influence of solar radiation, the temperature profiles converge, demonstrating a uniformity characteristic of the ocean's abyssal regions. This uniformity is consistent with the expectation that the deep ocean is less susceptible to diurnal and short-term meteorological variations, instead reflecting long-term climatic and oceanographic processes.



(a) ST1



(b) ST2



(c) ST3

Figure 3: Comparative Temperature Profiles by Depth

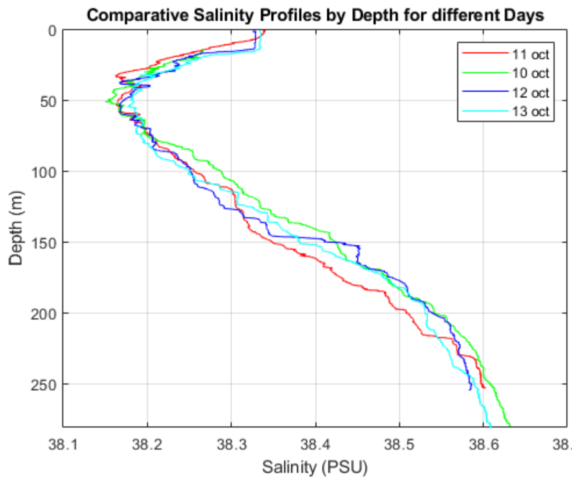
Inter-Day Comparability The overlap in temperature profiles from day to day at each station suggests a period of oceanographic stasis, without significant advective processes such as upwelling or downwelling events, which would otherwise manifest as temperature discrepancies at varying depths.

3.2.2 Comparative Salinity Profiles by Depth at ST1, ST2, and ST3

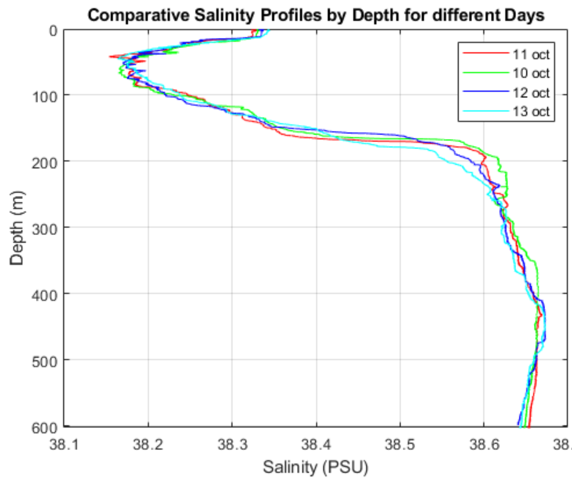
The salinity profiles derived from Conductivity, Temperature, and Depth (CTD) measurements provide a lens into the marine environment's haline structure over a four-day period.

Station-specific Observations

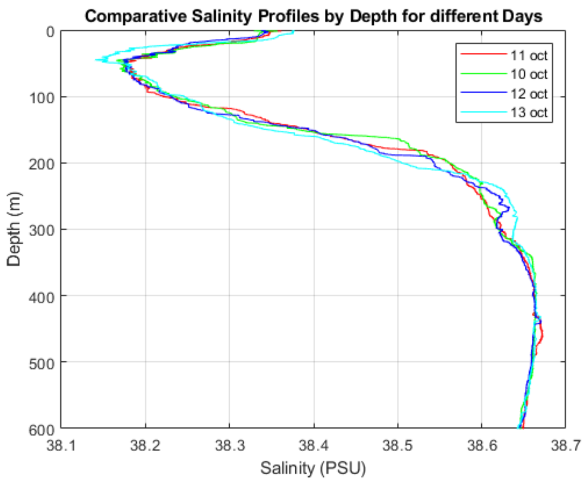
At Station 1 (ST1), Station 2 (ST2), and Station 3 (ST3), the salinity profiles indicate a remarkable temporal consistency, with slight fluctuations that can be attributed to natural diurnal and spatial variations or to the precision of the measurement instruments. Notably, the salinity ranges from approximately 38.1 to 38.7 Practical Salinity Units (PSU), with the profiles from different days closely overlapping, especially in the upper 100 meters of the water column.



(a) ST1



(b) ST2



(c) ST3

Figure 4: Comparative Salinity Profiles by Depth

Salinity Gradient and Stability

The upper layer of the ocean, typically influenced by evaporation, precipitation, and freshwater inputs, shows a stable salinity gradient across the sampled days. This suggests that during the time of measurement, there were no significant weather events or hydrological inputs, such as heavy rainfall or river discharge, that might otherwise disrupt the salinity structure.

Deep Water Salinity Consistency

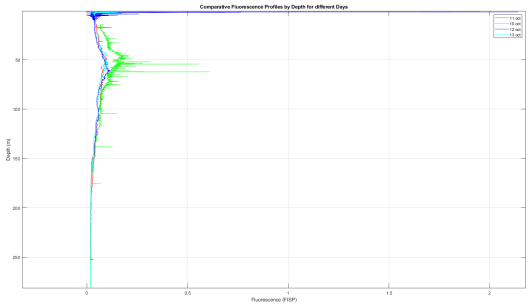
Beyond the upper mixed layer, the salinity remains relatively consistent in the deeper waters, a characteristic often observed in open ocean conditions where salinity is less affected by surface processes and more governed by the water masses present in the region.

Inter-Day and Spatial Comparability

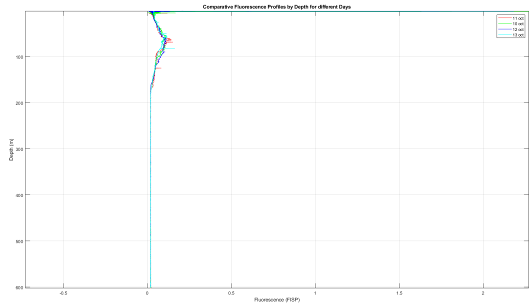
The consistency across the days at each station suggests that the oceanographic conditions remained stable during the sampling period. This stability is important for the marine organisms that rely on predictable environmental conditions. Moreover, the lack of significant spatial variability between the stations suggests a homogenous water body in terms of salinity, which might imply similar water masses or well-mixed conditions in the study area.

3.2.3 Comparative Fluorescence Profiles by Depth at ST1, ST2, and ST3

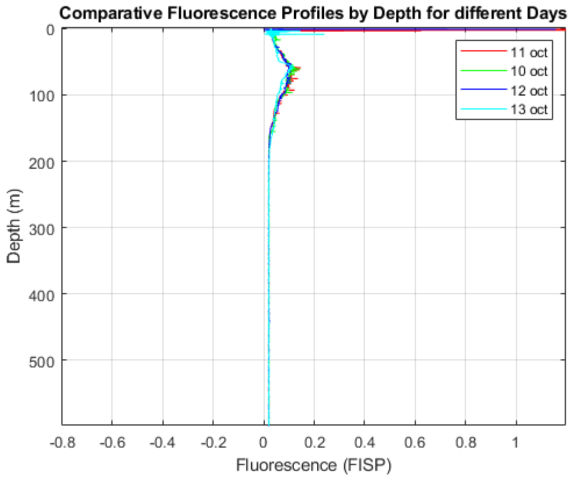
Fluorescence profiles serve as proxies for chlorophyll concentration, offering a glimpse into the primary productivity of the marine ecosystem. The figures represent fluorescence measurements taken on four consecutive days at three stations, affording an insight into the vertical distribution of phytoplankton within the water column.



(a) ST1



(b) ST2



(c) ST3

Figure 5: Comparative Fluorescence Profiles by Depth

Fluorescence Intensity and Distribution At all three stations, fluorescence intensity is highest at the surface and diminishes with depth, which is indicative of the photic zone where light penetrates the ocean and supports photosynthetic life. The observed peak in fluorescence near the surface suggests a high concentration of phytoplankton, which could be attributed to the availability of sunlight and nutrients in the upper layers of the ocean.

Temporal Consistency Across the different days, the fluorescence profiles remain relatively consistent, especially in the upper 100 meters. This consistency points towards stable conditions for phytoplankton growth and suggests that no significant disruptive events (such as storms or nutrient depletion) occurred during the sampling period.

Depth-Related Decline The fluorescence profiles exhibit a marked decline with increasing depth. This trend is expected as light availability decreases, reducing the capacity for photosynthesis. The sharp decline delineates the boundary of the euphotic zone, below which the light is insufficient for substantial phytoplankton growth.

Station Comparison When comparing the fluorescence profiles across the three stations, one can observe a remarkable similarity in the shape and depth of the profiles, implying that the stations share similar biological conditions and possibly similar water masses or circulation patterns.

3.2.4 Comparison with Copernicus Global Ocean Physics Data

In the absence of synchronous data for the current year, the analysis was carried out by comparing our findings against the Copernicus Global Ocean Physics Data from 11 October 2022 [1]. This comparison enabled a year-on-year analysis to ascertain any significant deviations or trends that may have emerged:

Temperature Profile Observations This comparison explores any significant shifts in temperature profiles that could indicate changes in oceanographic conditions over the year.

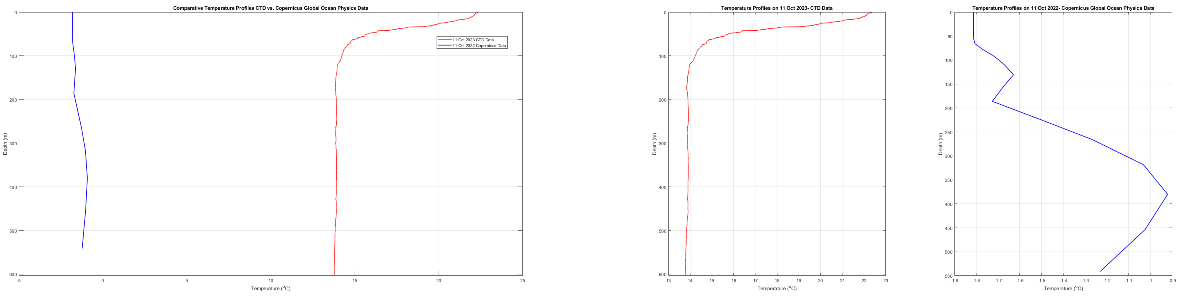


Figure 6: Comparative Temperature Profiles CTD vs. Copernicus Global Ocean Physics

Surface Temperatures: At the surface, the CTD data show warmer temperatures when compared to the Copernicus data. This could be indicative of seasonal variations or a response to short-term meteorological events, such as increased solar insulation or altered atmospheric conditions over the study area.

Thermocline Comparison: Both datasets exhibit a thermocline, although the transition from warmer surface water to cooler deep water appears to occur at slightly different depths. The CTD data suggest a shallower thermocline, which could suggest changes in ocean stratification between the two years.

Deep Water Temperatures: In deeper waters, the profiles tend to converge, suggesting that the deeper parts of the water column remain relatively insulated from annual atmospheric variations. This consistency is typical due to the slow response of deep ocean waters to surface temperature changes.

Interannual Variability The observed differences between the two datasets highlight the importance of interannual variability. Such variability could be attributed to a multitude of factors, including climatic phenomena like El Niño or La Niña events, long-term ocean warming trends, or regional changes in ocean currents and heat distribution.

Salinity Profile Analysis Similar to temperature, salinity comparisons may reveal changes in freshwater influx, evaporation rates, or other factors influencing salinity over an annual cycle. The next section will distill these comparisons into a coherent presentation of results, underscoring significant findings and their implications.

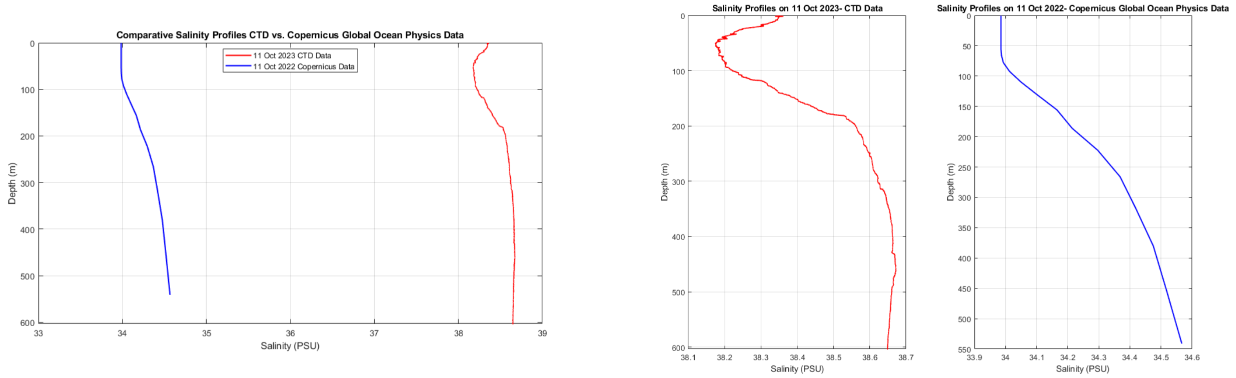


Figure 7: Comparative Salinity Profiles CTD vs. Copernicus Global Ocean Physics

Surface Salinity Variability: The salinity profiles indicate a noticeable difference in surface salinity between the two years. The CTD data from 2023 show higher salinity levels compared to the 2022 Copernicus data, which could be attributed to differences in evaporation rates, precipitation, or freshwater inflow, such as river discharge or melting ice, which could have varied between the two years.

Halocline Presence and Intensity: Both profiles exhibit a halocline, where there is a rapid change in salinity with depth. However, the halocline's depth and intensity differ slightly between the datasets. This variance may suggest alterations in water mass formation or regional shifts in ocean currents that affect salinity distribution.

Deep Water Salinity: Deeper in the water column, salinity profiles from both datasets appear to converge, indicating that deep ocean salinity remains relatively stable year over year. This stability is consistent with the understanding that deep ocean salinity is less subject to short-term environmental changes.

Interannual Differences : The interannual differences observed may be indicative of broader oceanographic or climatic shifts. Factors such as altered wind patterns, changing ocean currents, or long-term climate change effects could drive these differences.

3.3 Drifter data analysis

Understanding the patterns of the ocean vastly depends on the study of the ocean waves. Studying the ocean wave requires gathering information about the ocean currents and other factors. In this study, we have used yellow drifters to gather information about the ocean current. The procedure starts with activating the drifters and taking note of the time when we are deploying them. After that, we keep syncing the data with our systems and take feedback from the drifter every 10 minutes. After we gather the location for the drifter every 10 minutes, we can make some general calculations to find the velocity of the drifters. The velocity of the drifters will also implicate the wind flow, wave currents characteristics, and other various ocean factors that are crucial to understanding the Earth's Ocean behavior. In the following, we can simulate the trajectory and the velocity profiles of the drifters separately.

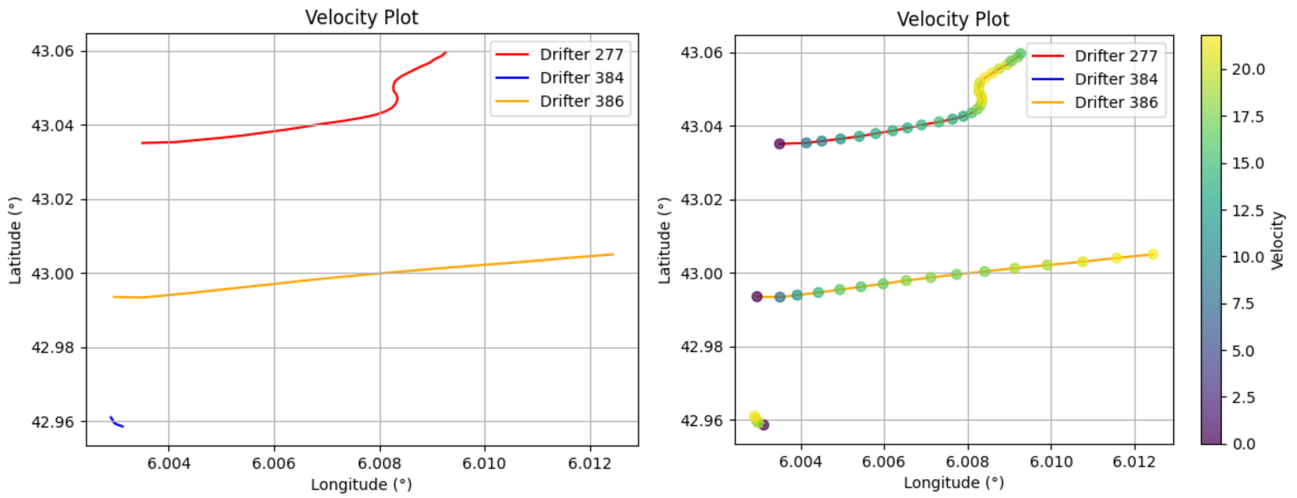


Figure 8: Trajectory of yellow drifters with velocity profiles

At Station 1 (43N02.100, 6E00.237): Our drifter-277 was deployed for a substantial 4-hour duration in this location where we were able to conduct a more in-depth observation of its trajectory. We can see that the red trajectory moves towards the longitude direction and the latitude direction as well. We can see a steady movement toward the shore direction. But a slight change in direction can also be seen in that trajectory. Most probably unsteady wind profiles in that region are the reason for this change. We can get a more general idea by observing the velocity profile of the red trajectory. We can see that, in the longitude window [6.008, 6.009] there is a very sharp change in the velocity, which we can conclude as a sharp change in the wind and/or the ocean current. Based on this graph analysis, we can also imply the direction of the wind and/or ocean wave current direction.

At Station 2 (42N59.599, 6E00.298): our drifter-386 had a slightly shorter deployment duration of 3 hours. Nevertheless, this timeframe provided us with crucial information about the ocean currents. We know from our deployment that this drifter was deployed offshore, a bit far from the coastal area. In that case, we can already predict that the wave and the wind will be significantly more in magnitude in that region. It is implied from the trajectory that the drifter is moving very fast towards the longitude direction due to high velocity. According to the velocity profile, we can see that a high magnitude of velocity is applied to the drifter. We can easily predict that the high magnitude of wind is flowing in that direction.

Station 3 (42N57.429, 6E00.245): This was the deployment of our drifter-384 for the shortest duration among the three stations, specifically 1 hour. This is the shortest period we have observed a drifter during our sea trial. Even though we can observe some plots from our simulation using Python, this is not enough to make solid conclusions about that region. But we can make some implications that the velocity profile is very very high in the ocean region as we can see from the velocity profile at the beginning of the last drifters trial period. Unlike other drifters, we can see that the last drifter's velocity is high.

3.3.1 Trajectory plots for Yellow drifters:

We can see the trajectory of the drifters in general in the left plot and the trajectory of our drifters with direction bearing on the left side. Full visualization of the bearing can be seen in the code that

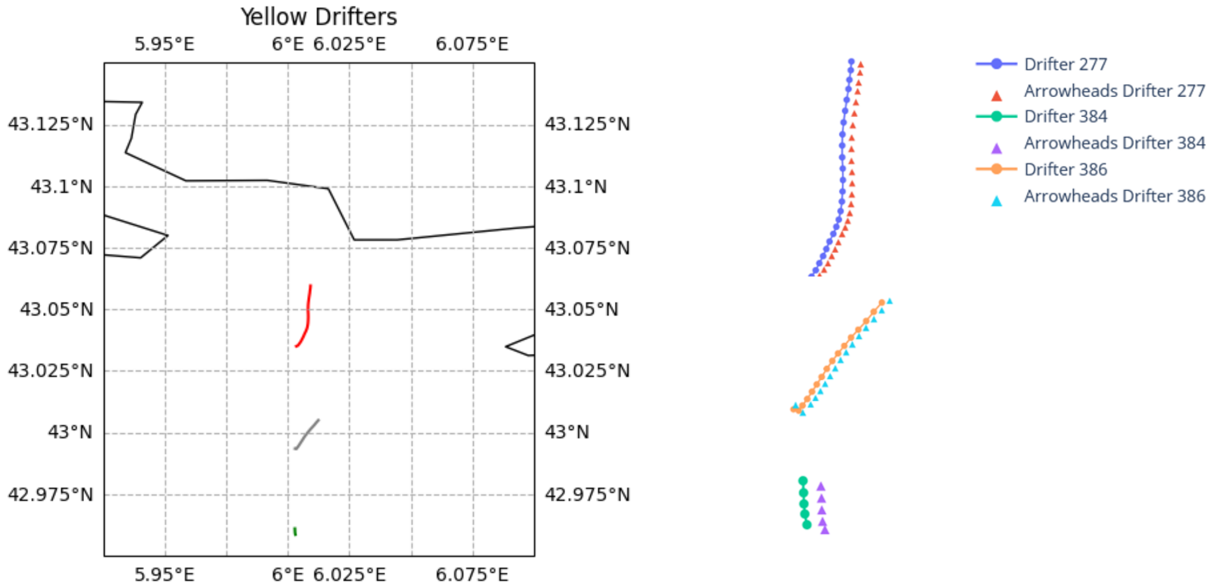


Figure 9: Trajectory of yellow drifters

will be provided as an attachment.

3.3.2 Comparison with other Group: (10-10-2023)

We compare the simulated results with the yellow drifters from the day 10th Oct sea trials. Below are the velocity profiles along with the trajectory from the day 10th Oct sea trial.

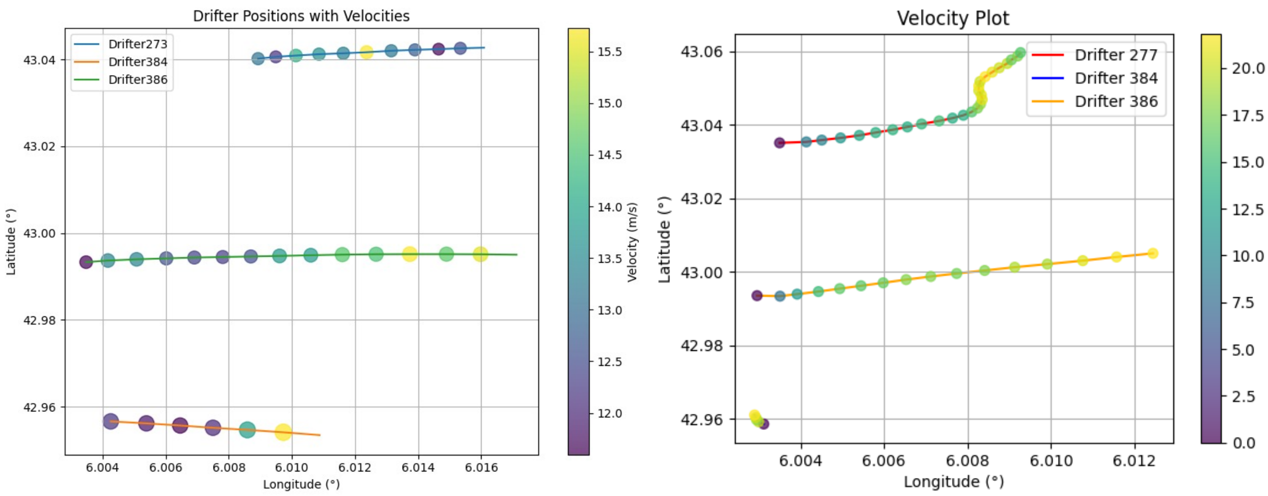


Figure 10: Sea trial day 10,Sea trial day 11

As we can see, on the sea trial day 10, the drifters are diverging along the longitude. This behavior implicates the wind and ocean current was flowing along the longitude, creating the flow of drifter in the same direction as well. If we try to compare the velocity as well, we notice that the velocity is higher on day 11 and in smaller magnitude on day 10. It can also be concluded that on day 10 the wind and ocean currents were very stable in coastal region, offshore region and in the sea as well. On the other hand, on day 11, there was slight instability near the coastal region. But the offshore and ocean

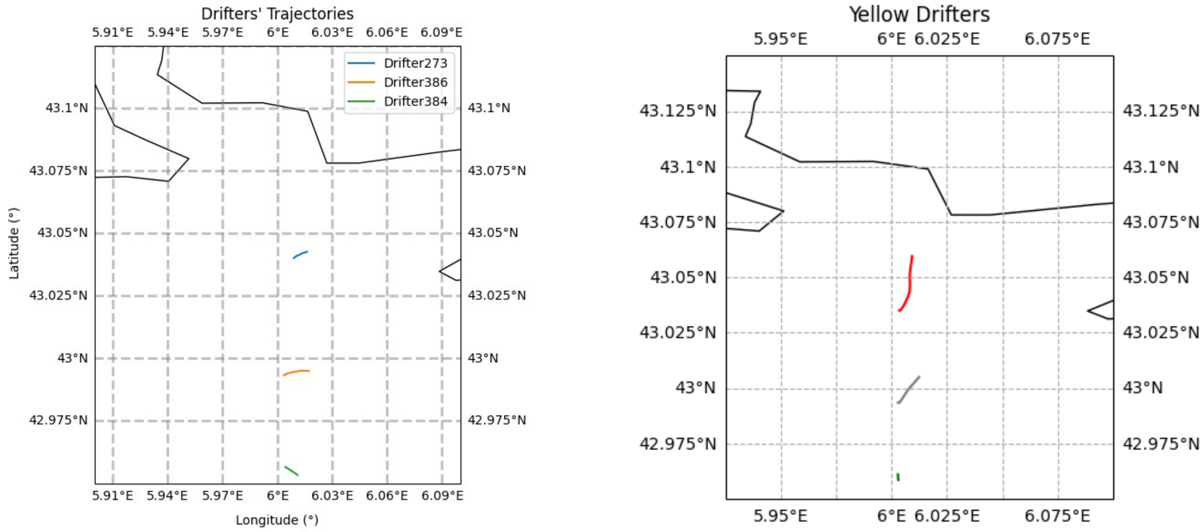


Figure 11: Day 10 trajectories vs Day 11 drifter trajectories

region was slightly stable.

3.3.3 Drifters With Fin and Without Fin

Deploying drifters with and without fins at three distinct stations offered valuable insights into water velocity and current profiles in our study area. These drifters, equipped with and without specialized fins, allowed us to track their trajectories and understand the movement of water masses. Here's an analysis of the observations based on the provided data:

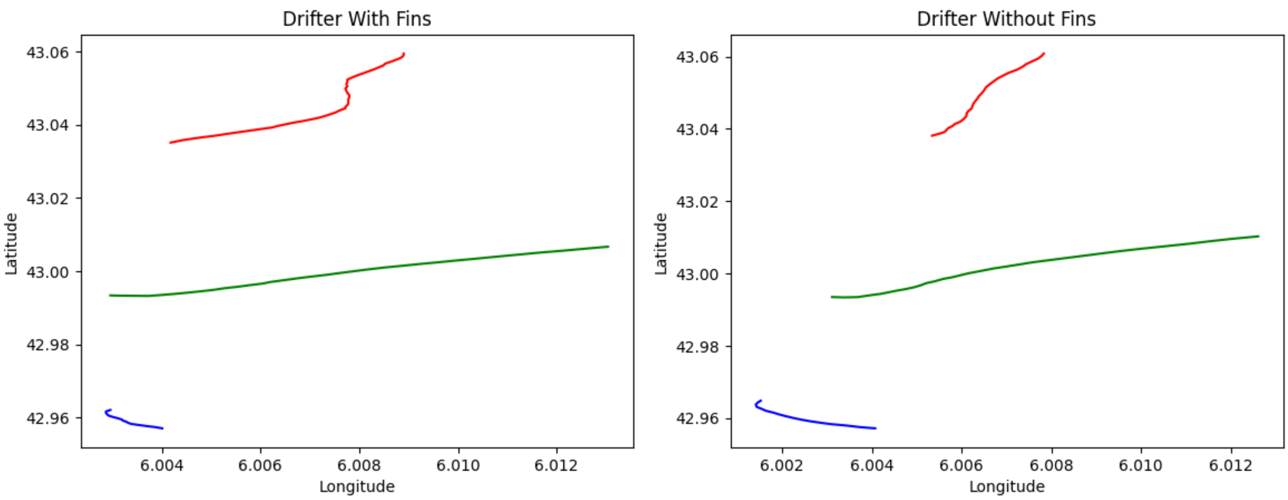


Figure 12: Trajectory of Drifters with/Without fin

The described scenario involves the comparison of two types of CARTHE drifters, one with panels underneath and one without. As expected, the drifters without fins or panels demonstrated a relatively greater speed compared to their counterparts with panels. Interestingly, NOMAD drifters and CARTHE drifters with panels exhibited similar trajectories, indicating vertical dimensional similarities

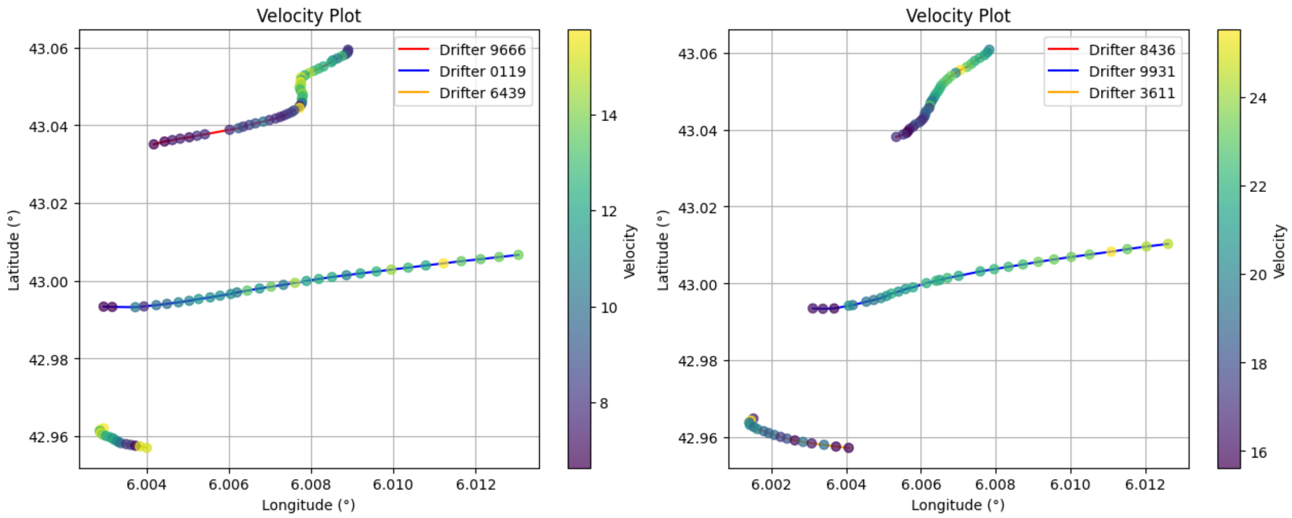


Figure 13: Velocity Trajectory of Drifters with/Without fin

between them. This suggests that the shape of the drifters plays a significant role in influencing their speeds and trajectories, providing valuable insights into their behavior in ocean currents.

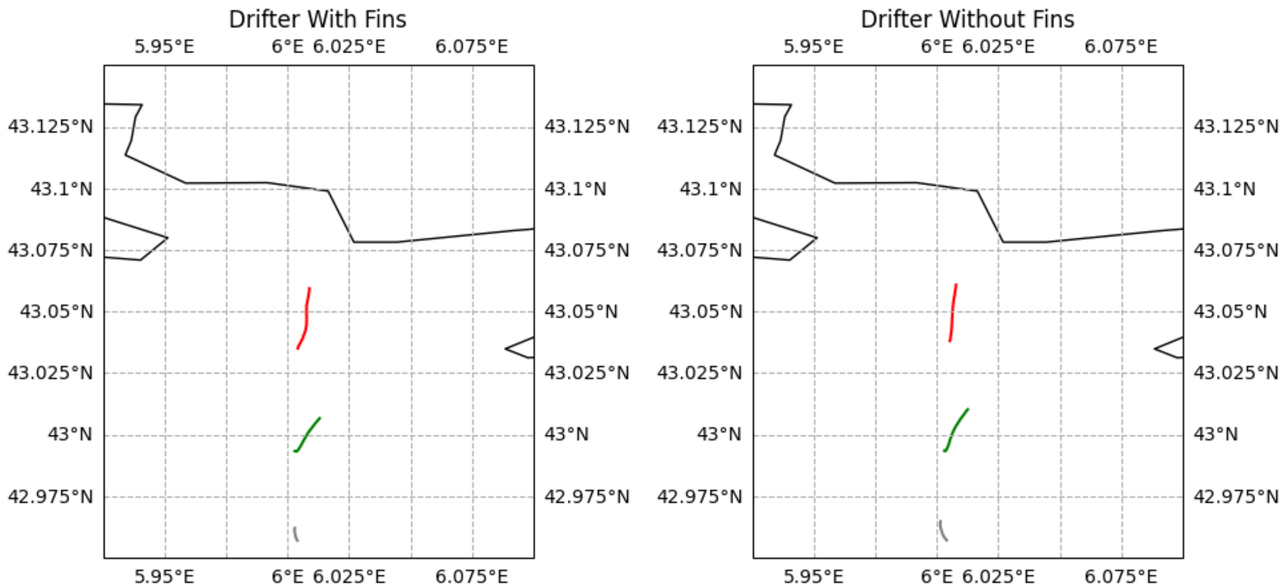


Figure 14: Trajectory of Drifters with/Without fin

Broadly, the drifters exhibited a movement pattern from the southern to the northern direction. As anticipated, the initial deployment recorded the slowest speeds, with the drifters attaining speeds ranging from 0 to 0.25 m/s over the course of the study. The drifters' speeds were variable and not consistent. Notably, surface drifters displayed higher speeds and larger displacements in contrast to drifters equipped with drag, the speeds of which remained relatively uniform due to minimal variations at the water's surface.

4 Conclusion

In summary, the Mediterranean Sea trial, focusing on ocean currents and environmental factors, has offered valuable insights into the region's hydrodynamics. Utilizing advanced tools like CTD instruments, Niskin bottles, and strategically placed drifters, the study documented oceanographic features. The use of state-of-the-art instruments allowed for a detailed examination of temperature, salinity, and fluorescence profiles at various depths. The precision of the dataset, ensured through data cleaning with MATLAB code, enhances the dependability of our results.

By unraveling the complex ocean current profile using drifters with and without fins, the study not only captured dynamic water velocity, wind and current patterns but also highlighted the impact of these instruments on observed trajectories. This focus on instruments and ocean characteristics enriches our understanding of the Mediterranean Sea's hydrodynamics. The interdisciplinary nature of this research, combining physical oceanography, environmental science, and data analytics, positions it as a cornerstone for understanding and monitoring marine environments. In essence, this sea trial significantly advanced our knowledge of the Mediterranean Sea's oceanographic intricacies, emphasizing the pivotal role of sophisticated instruments.

5 References

[1] Copernicus Marine Service. *GLOBAL_MULTIYEAR_PHY_001_030 files*. [Online; accessed 12-December-2023]. 2022. URL: `https://data.marine.copernicus.eu/product/GLOBAL_MULTIYEAR_PHY_001_030/files?subdataset=cmems_mod_glo_phy_myint_0.083deg_P1D-m_202311&path=GLOBAL_MULTIYEAR_PHY_001_030%2Fcmems_mod_glo_phy_myint_0.083deg_P1D-m_202311%2F2022%2F10%2F`.

6 Appendix

Note: All code are attached with this file.

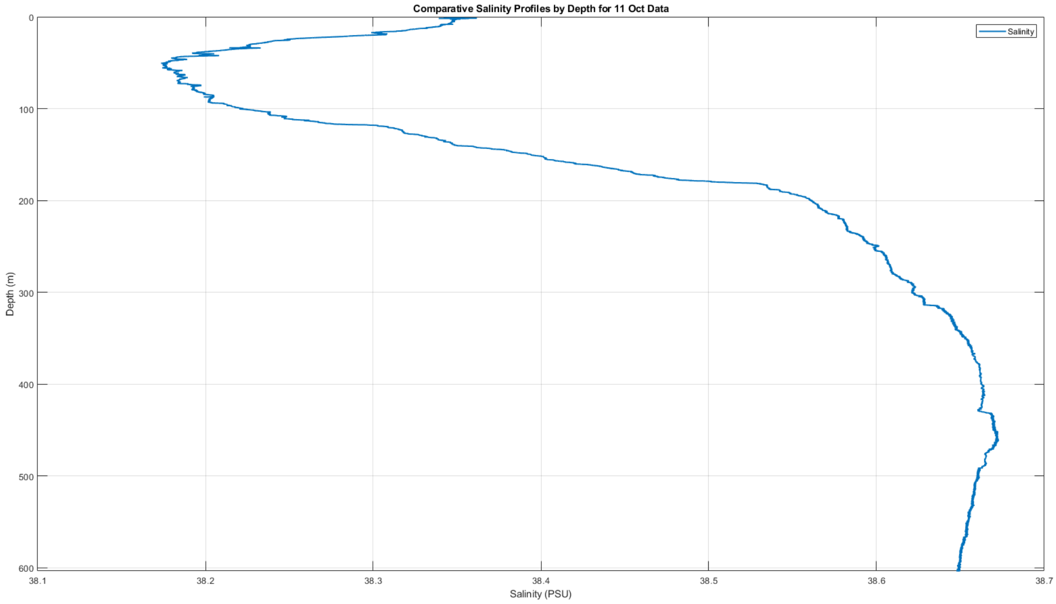


Figure 15: Comparative Salinity Profiles by Depth for 11 Oct Data

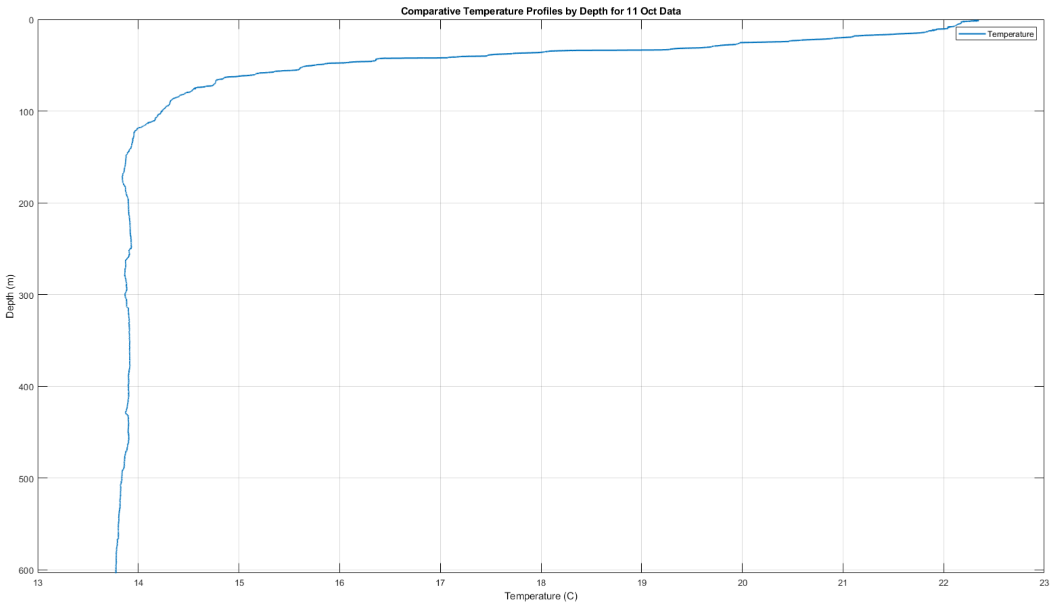


Figure 16: Comparative Temperature Profiles by Depth for 11 Oct Data