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RESEARCH PAPER

Predicting the Trajectories of Drifting Objects in the Eastern Mediterranean Sea

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Abstract

Forecasting of the tracks of drifting objects in the sea is a complicated process due to the effects of many phenomena such currents and wind. In this research, the problem is solved with model data and a basic approach. In this approach, we apply an iterative method based on surface current and wind data to predict the trajectories of possible drifting objects in the Eastern Mediterranean Sea. The main surface current circulation has a cyclonic nature, and its impact on the routes of drifting objects is clearly seen. The results of the study are useful for predicting the trajectories of drifting objects and the proposed method and calculations can be roughly used for drifting trajectory prediction. The advantage of this method is that it is user-friendly and provides many tracks in a minute. The biggest uncertainty in this work is obtaining accurate information about where and when the object started to drift.

Introduction

Ocean models are used for predicting sea temperature, salinity, currents, and waves. Use of those parameters is mainly limited to navigational and scientific purposes as well as tracking movements of zooplankton, phytoplankton, and nutrients, which are crucial for ocean life (Hackett et al., 2006). Besides those natural parameters, finding the track of drifting things such as oil spills, human bodies, and floating containers is also of concern for maritime safety. Humankind is more interested in how ocean variables such as current and waves can influence real matters (Hackett et al., 2006). Hence, society predominantly demands forecasts of the drift of containers, floating objects, oil, and naval mines.

The Mediterranean Sea, our study region, located between the three continents of Europe, Africa, and Asia, has been investigated by oceanographers for a long time for a better understanding of its oceanography. The Mediterranean Sea is a main artery for oil products and trade shipping. It has a unique characteristic with its almost land-locked environment. Surface, intermediate, and deep-water masses have different and independent current systems (El-Geziry & Bryden, 2010). The eastern part of the Mediterranean Sea is complex and its mean depth is around 1500 m (El-Geziry & Bryden, 2010). The deepest point in the Eastern Mediterranean Sea is in the northwest part close to the island of Rhodes with a depth of about 4500 m and the central part has depth values around 2500-3000 m as depicted in Figure 1 (Horvat et al., 2003). Due to its complex system with its

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anticyclonic and cyclonic eddies and gyres, the circulation pattern is highly variable (Özsoy et al., 1991; Pinardi & Masetti, 2000; Menna et al., 2012). Temporal and spatial SST variations were observed not only in the eastern but also in the western part of the Mediterranean Sea in accordance with expendable bathythermographs (XBTs) (Fusco et al., 2003). In general, it is considered a laboratory to work in due to its accessible environment, densely populated shores, fishing, research, energy production, transportation, and tourism (Zambianchi et al., 2014).

The Mediterranean Sea is almost an isolated sea due to its restricted interaction with the Black Sea through the Turkish Straits System, which has a two-layer current system (Özsoy & Ünlüata, 1997), the Atlantic Ocean with the Gibraltar Strait, and the Red Sea through the Suez Canal. The Mediterranean Sea is an oligotrophic region where air–sea interaction is strong and it has high salinity and density due to high evaporation (Robinson et al., 1992).

The circulatory system in the Mediterranean Sea has been studied using modeling, altimeter, and oceanographic data. Circulation in the Mediterranean Sea relies on complex interactions of meteorological factors, freshwater input, coastline, and bathymetry. Due to the Coriolis effect, the deflection to the right in the northern hemisphere, all surface waters of Mediterranean Sea basically have a tendency to move counterclockwise, and that is why the main sense of the Mediterranean surface current system is cyclonic as well as the Aegean Sea (El-Gindy & El-Din, 1986; Millot & Taupier-Letage, 2005; Olson et al., 2007). Besides the Coriolis effect, mesoscale variability is another driving phenomenon and anticyclonic gyres are also observed in the Mediterranean Sea (Robinson et al., 1992). Atlantic water, which compensates the water balance, is the result of the sea level difference between the Atlantic Ocean and the Mediterranean Sea since the sea level of the Mediterranean is decreasing due to the high evaporation rate (Millot & Taupier-Letage, 2005). Cochran et al. (2019) point out that the driving mechanism of the cyclonic circulation in the upper branch of the basin is also influenced by wind pattern and thermohaline forcings. In other words, atmospheric circulation and thermohaline forcings correspond to surface current circulation. Additionally, the monthly climatic upwelling map reveals that upwelling significantly varies seasonally not only in the Aegean Sea but also in the Mediterranean Sea (Bakun & Agostini, 2001; Tükenmez & Altiok, 2022).

The cold winter of 1993 can be seen as the beginning of the Eastern Mediterranean Transient (EMT), which started in the South Aegean Sea. The EMT was formed following the cold winters of 1992-1993 (Klein et al., 1999). The EMT, in simple terms, is the replacement of the Adriatic Sea by the Aegean Sea as the main deep water formation region in the early 1990s. Roether et al. (1996) were the first to report this issue. They stated that 20% of the bottom and deep waters in the Eastern Mediterranean were replaced by Aegean Sea waters and before this situation the source of the waters was only the Adriatic waters (Roether et al., 1996). As a result of this change, the salinity of the Aegean Sea increased (Roether et al., 1996).

The cyclonic and anticyclonic circulation in the Ionian Sea, an important component of the Mediterranean Sea, has an impact on the Mediterranean Sea, Adriatic Sea, and Aegean Sea (Gačić et.al.,2010; Estournel et.al.2021). During the anticyclonic cycle in the Ionian Sea, surface salinity increases in the Eastern Mediterranean Sea and, in the cyclonic cycle, the opposite situation occurs as the less salty waters coming from the Atlantic Ocean dominate the region. Surface circulation in the Eastern

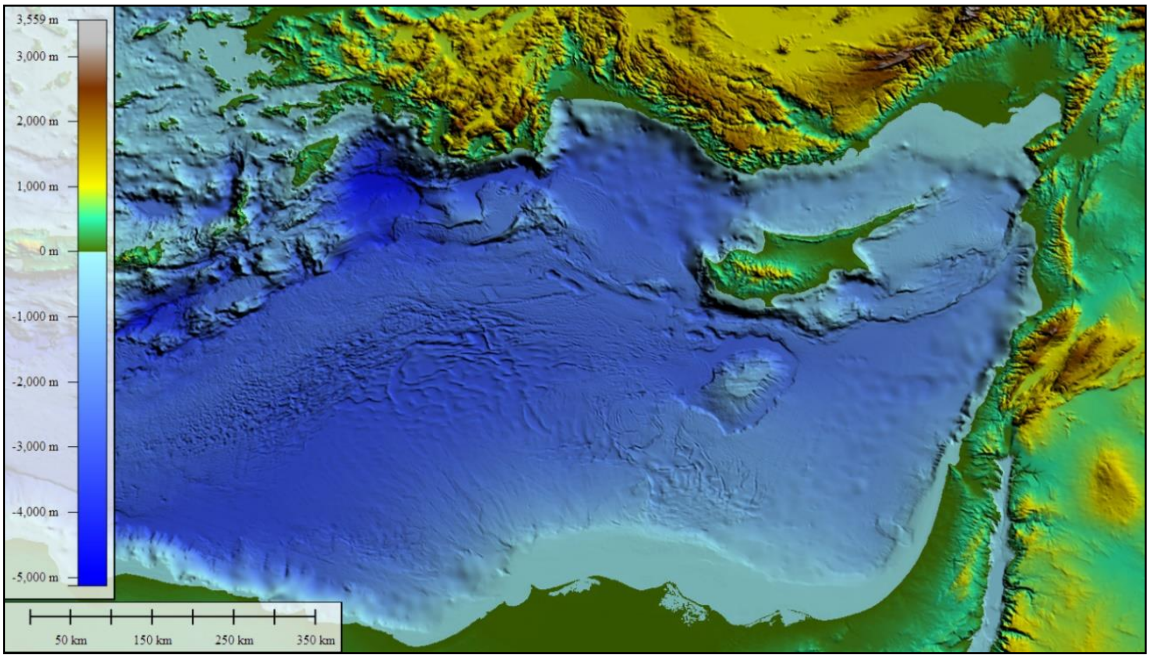


Figure 1. Bathymetry of the Eastern Mediterranean Sea (generated by using data from the General Bathymetric Chart of the Ocean (GEBCO)).

Mediterranean becomes more energetic and its complex mesoscale system has a positive tendency (Baaklini et al., 2022). Surface waters entering the Eastern Mediterranean Sea through the Strait of Sicily divide into two branches (Robinson et al., 1992). One of them goes through the region of Rhodes and Crete and the other branch moves to the east.

Shipping is currently the most popular way of transporting cargo (Liu et al., 2021). In the last six decades, container ships have become the mainstay vessels with the astounding growth rate in the volume of cargo (Broeze, 2017; Wan et al., 2022). Due to this increasing trend and marine traffic density, container ship collisions could occur anywhere in the seas and may have significant impacts on the marine environment in the near future. It should be also noted that the Mediterranean Sea is a region where serious container ship accidents happen. Besides mechanical and human errors, unfavorable meteorological and oceanographic conditions are the other reasons behind accidents at sea (Mei et al., 2021).

It is known that currents can carry substances (e.g., plastics) to distant regions, even in polar areas (Barnes et al., 2009; Law et al., 2010; Maximenko et al., 2012). The efficient transport system in the Mediterranean Sea can cause drifting materials to move far away from their initial positions (Zambianchi et al., 2014). Drifting objects, which may release marine litter, fossil fuels, or toxic chemical substances, could pose a great threat to both the marine environment and the safety of navigation. Encouraging results were obtained in a case study on predicting the drift of pollutants in the Western Mediterranean Sea with the MOTHY model and the MERCATOR & Mediterranean Forecasting Systems (Daniel et al., 2005). Apart from objects, Carniel et al. (2002) carried out a successful study on predicting the likely destination of a floating human body in the northwestern part of the Mediterranean by using numerical models. Moreover, Cordova and Flores (2022)'s work on search and rescue (SAR) operations benefited from a hydrodynamic model to provide an input to a particle drifter estimator for estimating the routes of floating particles. A quantitative performance evaluation of the results was conducted with *in situ* trajectory measurements and good agreement between the measured and modeled data was observed (Cordova & Flores, 2022). Besides SAR operations, data for running oil spill models to predict trajectories also could be derived from hydrodynamic models. For instance, Ülker et al. (2022)'s research on the mathematical modeling of oil spill weathering processes took advantage of the output of hydrodynamic models to obtain hydrodynamic data.

Oil spill modeling and tracking are complex physical, chemical, and biological processes since oil can spread, mix with water, and move with subsurface currents (Qiao et al., 2019). Additionally, weathering processes (evaporation and emulsification) are other factors to be considered for oil spill tracking.

Satellite images are a useful source of information for the assessment of a wide area (Poulain et al., 2013). Especially after 1979, those images have helped oceanographers to perform detailed analyses for understanding circulation. It is almost impossible to make a digital twin of an ecosystem of a large area with real data since it is not regular and simultaneous. Instead, numerical models are developed, and they have widely been started to be used for presenting ocean circulation in real time. In other words, attempts are made to create a digital copy of the ocean with numerical modeling to successfully accomplish the aim of the predicted ocean of the Ocean Decade. Different studies have been conducted to predict trajectories in the ocean (Ullman et al., 2006; Minguez et al., 2012; Chen et al., 2022). Improvements in high-resolution forecasts of the Mediterranean Sea increase the reliability of predictions of floating objects (Pinardi et al., 2003; Tonani et al., 2008).

There are limited studies on containers falling off ships at sea (Wan et al., 2022), although research on factors influencing shipping accidents has been performed (Hetherington et al., 2006; Abbassi et al., 2017; Abaei et al., 2018) and oil spills are a widely known topic attracting considerable public attention (Wilkinson et al., 2017; Chen et al., 2020). Apart from surface tracking, precise underwater tracking is also crucial for long-term missions of human divers. However, underwater tracking involves more challenges than surface tracking due to the unavailability of a global positioning system, the need for depth-varying sound speed measurements, and the difficulties in modeling underwater (Diamant et al., 2015).

In order to protect the safety of individuals and reduce the risk to the environment due to drifting containers, some precautions should be considered. Firstly, the behaviors of the substances should be simulated for monitoring and giving accurate information to decision makers since they need to know where the object may be headed. Then emergency response principles should be implemented. That is why there was a huge demand to develop a method for prediction of a drifting object automatically due to chaotic characteristics. This encouraged and motivated us to work on prediction of the trajectory from point of origin to last destination of drifting objects by using wind and surface current data obtained by ECMWF ERA5 (European Centre for Medium Range Weather Forecasts Fifth Generation Reanalysis) and the Copernicus Marine Environment Monitoring Service (CMEMS). That is why the main objective of the present research was to conduct an analysis and depict the trajectory of drifting objects over the course of the following days to guide decision makers during the processes of optimum search pattern planning. Herein we describe our recommended practice for defining the possible paths of floating objects with some case studies.

Materials and Methods

Data

Accurate modeling and understanding of the upper ocean drift are exposed to ocean currents that driven by atmospheric forcing, turbulent mixing, and waves (Röhrs & Christensen, 2015). Wind data alone are not enough to understand the drift in the uppermost part of the ocean. It is certain that both wind and upper-ocean current data are needed for the modeling of surface drift (Röhrs & Christensen, 2015). Wind, current, and the shape of the object are the information that can be used to estimate the trajectory of a drifting object (Hackett et al., 2006). Stokes' drift, a second-order effect, and a motion in the direction of surface waves (Kundu & Cohen, 2002), is also considered a parameter that will also affect the object (Philips, 1977; Holthuijsen, 2007).

Fortunately, technological advances in modeling enable us to make predictions of the likely destination of an object in near real time and we were able to combine the surface current and wind data at the same time.

Forecasting the track of drifting objects derived from the consequences of human activities in the Mediterranean Sea depends on knowledge of mainly surface currents and winds. Our calculations take into account the traditional factors of near surface currents and wind. In the present study, netCDF (network Common Data Form) files of hourly ECMWF ERA-5 data of 10-m wind speed-direction with a resolution of 0.25° and hourly CMEMS-Mediterranean Sea Physics Analysis and Forecast System (called Med-Physics) surface current data with a resolution of 0.042° were used to forecast the track of drifting objects. Our analysis covered time scales from 1 hour to any time data relied on to provide a time-evolving view of the object's drift.

Methods

The Eulerian based on the integration of the advection–diffusion equation and the Lagrangian based on the integration of stochastic models are two methods used to describe the distribution of a drifting object (Csanady, 1973; Kundu & Cohen, 2002; Zambianchi et al., 2014). In previous studies, OpenDrift was used for particle tracking in the ocean with its open-source Python package and own plotting properties (Knut-Frode et al., 2018).

As an alternative to the above methods, herein we used a quick calculation approach for drifting objects. We used a dynamic and deterministic model to calculate the possible hourly drift and created an iterative algorithm to repeat the movement from a starting time up to the available forecast data. Initial position and time are the key parameters for obtaining the final search area. Then we wrote a MATLAB code to obtain the possible routes for different starting points and times.

First of all, in order to determine the impact of the geometric characteristics of an object we take advantage of Breivik et al.'s (2011) work. The proportion of an unsubmerged part of an object is under the influence of surface winds. That critical effect should be defined in numbers to clearly detect the right track of a drifting object. Field studies on the detection of routes of different objects such as shipping containers, oil drums, and mines were conducted in the past (Geyer, 1989; Daniel et al., 2002; Breivik et al., 2011). Those studies present that the leeway ratios of 0.8%, 1.4%, and 2% are the estimated values for the drifting of an oil drum, shipping container, and mine, respectively (Breivik et al., 2011). The ratio of unsubmerged/submerged value is a critical parameter to make a rough estimate for wind influence on an object since windage characteristics of objects are not the same due to their vertical position and airside/waterside drag ratios (Röhrs & Christensen, 2015).

Those findings guided us on defining this impact numerically. Field work is expensive and time consuming but it is important to confirm the accuracy of the forecast. That is why Breivik et al.'s (2011) research is useful to apply for our study. In our work, with respect to our and previous calculations, we decided to use a ratio of 1.4% of wind speed values for our calculations to roughly estimate the routes of drifting objects. That percentage could be adjusted in accordance with future experimental studies. Our code allows us to change the weighting factors easily and calculate different results for each case. We were able to analyze and confirm the first results of the trajectories with satellite imagery and vessel observations. Then we can use the best fitting weighting factor for that case. The aim of the present research was to make an operational calculation rather than finding a best fit for the weighting coefficient.

Secondly, a computer calculation in MATLAB (2021b) and Python is employed to analyze the motion of drifting objects. Python makes the code more generic and adapted to Esri's ArcGIS Pro software to make it work within the software without the need for MATLAB. Then ArcGIS Pro is used for visualization for making the graphs user friendly. After obtaining the positions of tracks, backward and forward patterns of the possible drifting objects are drawn with ArcGIS Pro software. Instead of MATLAB, Python codes could be also applied in the open-source GIS software of QGIS.

$$\frac{du}{dt} = \mathrm{ck} * \frac{d(cu)}{dt} + \mathrm{wk} * \frac{d(wu)}{dt} \qquad 1$$

$$\frac{dv}{dt} = \mathrm{ck} * \frac{d(cv)}{dt} + \mathrm{wk} * \frac{d(wv)}{dt} \qquad 2$$

$$Lon(i+1, t+1) = Lon(i, t) + \frac{du}{dt} \qquad 3$$

$$Lat(i+1, t+1) = Lat(i, t) + \frac{dv}{dt} \qquad 4$$

In those formulas, *d(cu)* and *d(cv)* and *d(wu)* and *d(wv)* are calculated by multiplying the surface current and wind speed by 3600 (seconds) to obtain the distance of drift in the x (*u)* and y (*v)* directions due to current and wind. The letters "c" and "w" in *d(cu)*, *d(cv)*, *d(wu)*, and *d(wv)* are used for defining surface current (c) and wind (w). *Lon (i,t)* and *Lat (i,t)* refer to coordinates that present longitude (vertical lines) and latitude (horizontal lines), respectively. The parameters *ck* and *wk* are the weighting factors of current and wind speed on the drifting object. Those weighting factors should be adjusted with respect to the geometry of the object. This is the most challenging part of predicting the trajectories of different types of drifting object. After those mathematical analyses, $\frac{du}{dt}$ and $\frac{dv}{dt}$, which represent the total drift variations in the u and v directions, are calculated. By adding those total drift values to previous coordinates (longitude and latitude), the next possible location of the object is obtained. This is the basic algorithm applied in our research.

We used the newly created algorithm to predict the trajectory of containers using different numbers of points of coordinates for a certain period of time. The application is easy to use since it only requires basic parameters (longitude, latitude, and time) to be filled by the user.

In contrast to previous studies, our approach has a simple approach that depends on the data and does not include the z axis, a stochastic model, or chemical transformation. It is also worth adding that floating litter particles and underwater drifting are not within the scope of this article, so diffusion and movement in the z direction are not covered here. Since we investigate the trajectory of objects at the very surface, two important factors, effects of wind and surface currents on substances, are accounted for.

Most studies have been focused on stochastic methods to predict the drift of an object, but we used a deterministic approach. Our case study had the purpose of making predictions for items whose initial position and time are not known precisely. Moreover, the randomness is not included in our risk maps, which cover a certain area. Other methods may cover a larger area because of randomness being included, but those risk maps may cause time to be lost during operations.

Results

Forward Tracking

Predicting the pattern of drifting objects is not simple since it relies on not only oceanographic and meteorological parameters but also the geometry of the object. In our application, which works with an iterative algorithm, the results are obtained by considering surface currents and the impact of wind on the object.

It is clearly seen that there is high traffic density in the eastern part of the Mediterranean Sea and the danger of possible drifting containers could have serious negative marginal impacts on marine traffic. Figure 2, which is obtained from European Marine Observation and Data Network (EMODnet) Human Activities portal, whose development started in 2013, presents the density of marine traffic of all types of vessels for the years between 2017 and 2021. With respect to vessel traffic density, any dangerous object could have

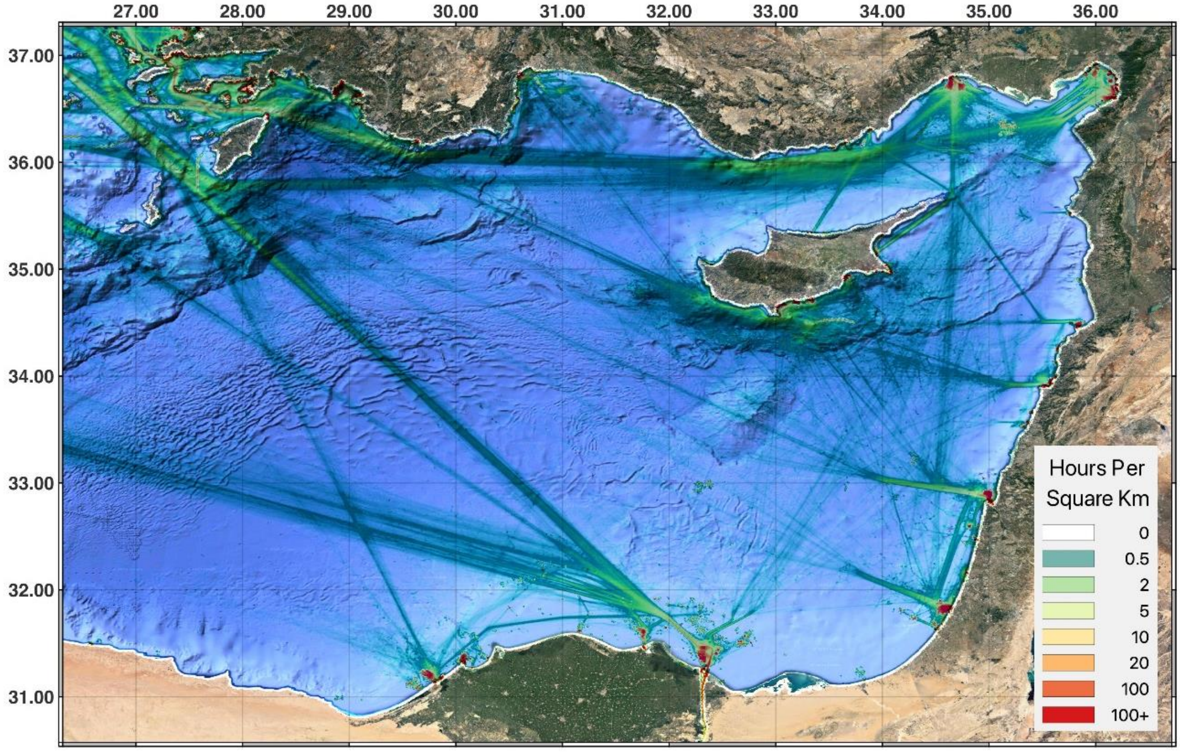


Figure 2. Marine traffic density in the Mediterranean Sea (generated by using data from EMODnet).

influence on the safety of navigation, so it is necessary to detect the trajectory of a container and find it as soon as possible.

Forward tracking analyses were conducted for randomly chosen areas. In this analysis, the probable tracks of the drifting objects that could move from random locations on different dates were calculated with our approach and the results of the simulation are presented in Figures 3 and 4. Each colored line indicates the routes to be followed by the objects. The trajectories of floating containers could be drawn as depicted in Figure 3. Figure 3 presents the trajectories of the container for the time between 01 October and 23 November 2022. Every line represents trajectory on a separate day for the period 01 October to 01 December 2022. In other words, 53 routes are shown on the map. The initial position of the container is assumed to be 35.75° N and 32.5° E by taking into account vessel traffic density.

The code can be run for many different cases. Instead of one object, the trajectories of many objects could be run for the closest location since the certain initial time and position of the drifting objects may not be known. That is why our approach is flexible and could be applied for different cases and occasions. The trajectories shown in Figure 3 indicate that wind and surface current can cause objects to follow different routes and this region is a dense area in terms of traffic.

Figure 4 simulates the probable trajectories of possible drifting objects from different locations, but it is worth noting that it does not show real cases. Different starting times and positions for possible drifting objects can be mapped with our application in order to conduct detailed analysis when needed.

The most useful aspect of this method is that 100 possible routes of drifting objects can be drawn in a minute with forward analysis. Drawing the 100 possible tracks manually could take at least 200 hours and is

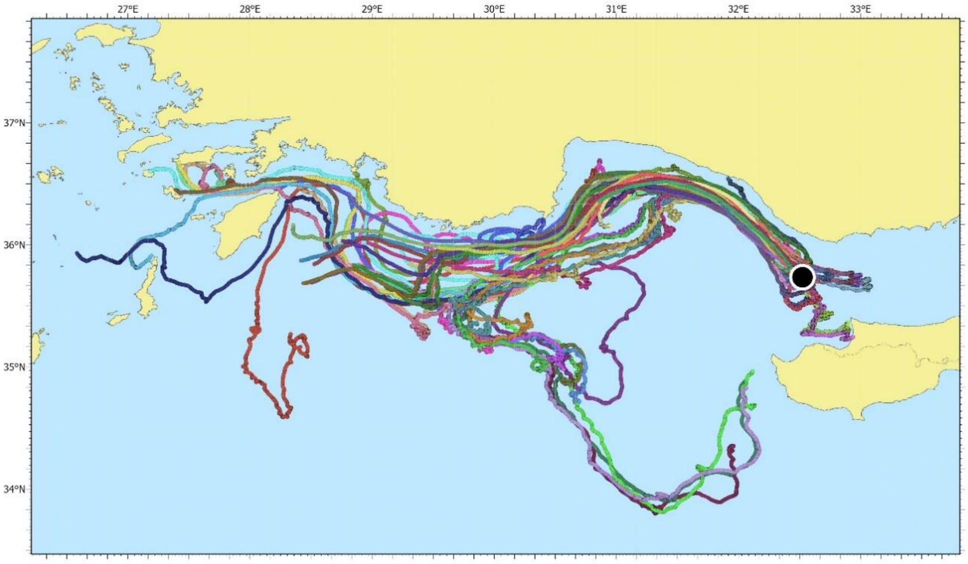
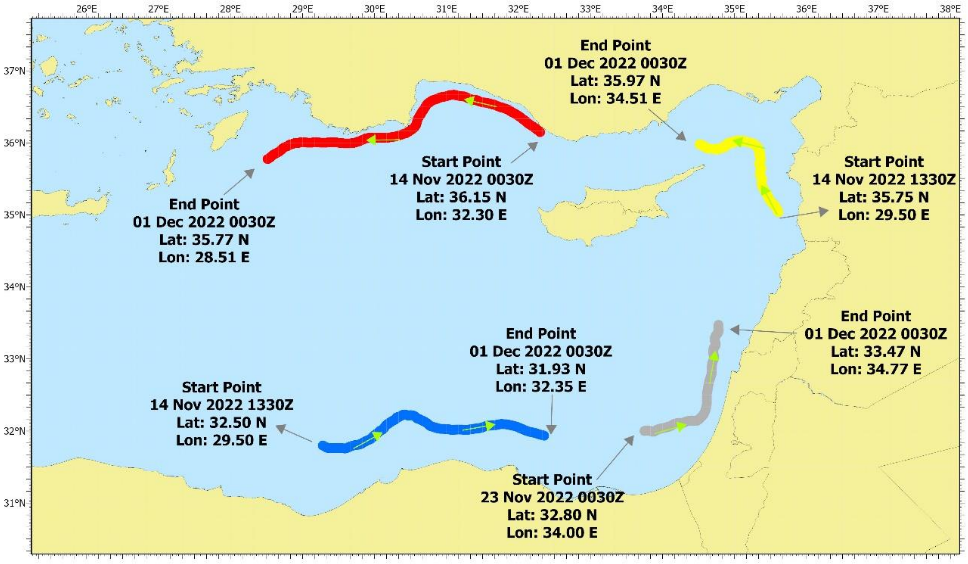


Figure 3. Trajectories of a drifting container with forward tracking code from 01 October to 23 November 2022.



End Point
01 Dec 2022 0030Z
Lat: 35.97 N
Lon: 34.51 E

Start Point
14 Nov 2022 0030Z
Lat: 36.15 N
Lon: 32.30 E

Start Point
14 Nov 2022 1330Z
Lat: 35.75 N
Lon: 29.50 E

End Point
01 Dec 2022 0030Z
Lat: 35.77 N
Lon: 28.51 E

End Point
01 Dec 2022 0030Z
Lat: 31.93 N
Lon: 32.35 E

End Point
01 Dec 2022 0030Z
Lat: 33.47 N
Lon: 34.77 E

Start Point
14 Nov 2022 1330Z
Lat: 32.50 N
Lon: 29.50 E

Start Point
23 Nov 2022 0030Z
Lat: 32.80 N
Lon: 34.00 E

Figure 4. Possible tracks of drifting objects with forward tracking code.

susceptible to human error. To further quantitatively compare and detect the accuracy of tracks of objects, we use the discrete locations of objects in the Eastern Mediterranean Sea. Distinct case studies for separate initial positions show that the trajectories of the objects follow the same pattern with general cyclonic circulation of the Mediterranean Sea (Fig. 4). Unlike the general cyclonic circulation, on very windy days or during different seasons objects could follow different patterns.

Backward tracking

Backward tracking codes could also be applied in the scripts to present the trajectory of the object for detecting the initial position. The case study on backward tracking led to the question "Why do we need backward tracking?" The reason behind that calculation is the need to know the starting point of movement of the object to use for different purposes such as legal requirements. One example for the backward tracking of a drifting object is shown in Figure 5. The last detected position and time of the object are typed in the code and then it presents the trajectory and initial position of the object. In this case study, 30 November 2022 and 33.5° N – 35.14° E are the known date and position of the drifting object. The possible trajectory of a backward drifting object is sufficient to conclude that traffic in the Eastern Mediterranean Sea could be influenced by the properties of the objects. It is obviously seen in both forward and backward tracking that the containers do not move from sea to the land directly since they could drift in accordance with surface current and wind data. These results are encouraging since the risk map covers significant areas that will be used during operations.

Performance Analysis

We conducted performance analysis of our approach by comparison with in situ floating drifter trajectory measurements of NATO Maritime GEOMETOC Centre of Excellence (COE) for the period from 25 June to 18 July 2022 in the Black Sea. To better understand the differences, both trajectories are plotted on the map by using ArcGIS Pro. Our application's trajectories were also evaluated by verifying initial and arrival locations of the floating drifter. The results provide good agreement for both datasets in the Black Sea. Our findings were compatible with the drifter data and almost following the same pattern even though they do not perfectly match. The difference between the final positions of both datasets was ~30 km on 18 July 2022 and they crossed at the same point on 13 July 2022. Difference in the two final points of model & real data was calculated after ~490km drift. Unfortunately, we could not illustrate the tests for the Mediterranean Sea due to not having the official data for any drifter; that is why we cannot present the findings/comparisons for that sea.

Predictions with code can be performed for subsequent days on an hourly basis. Due to hourly data, the position of the drifting object is disclosed to decision makers for planning with high temporal and spatial resolution. High resolution data will enable us to get highly accurate results. For instance, when the position and time information of an object detected by unmanned air vehicles or vessels is provided, calculations for forward tracking can be presented for the subsequent days based on the available data. In that case, the accuracy of the data has the top priority for an accurate prediction. In other words, our method

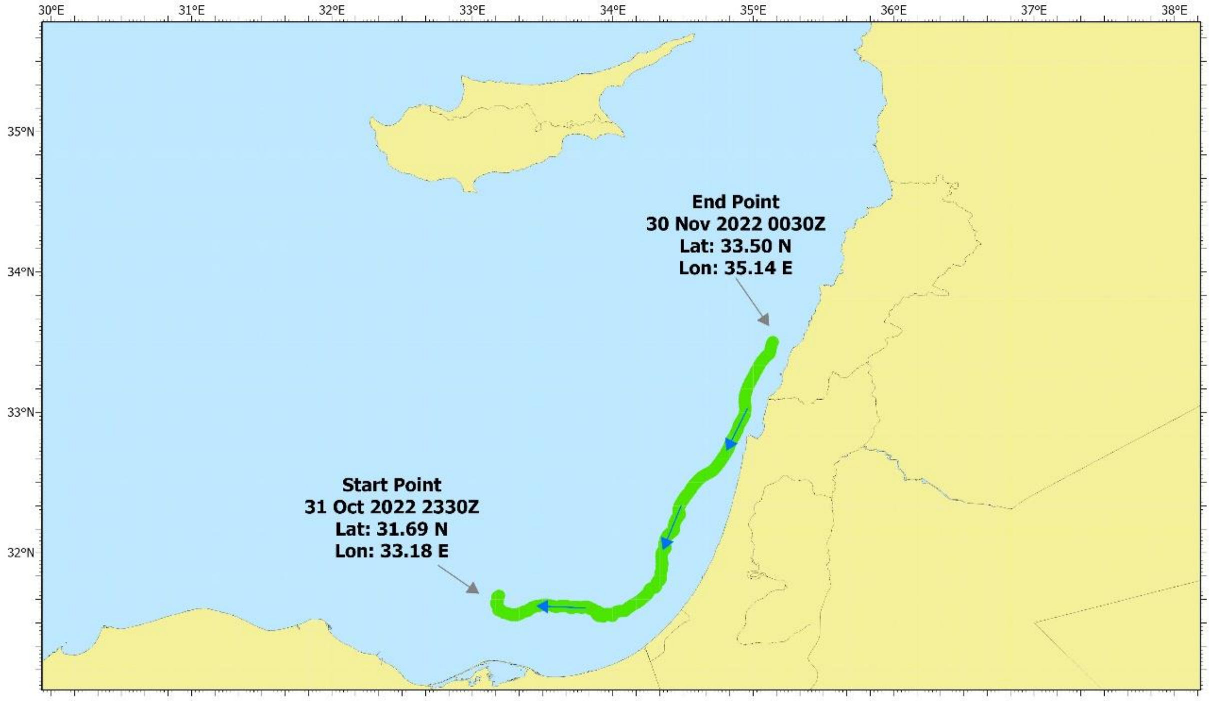


Figure 5. Possible tracks of a drifting object with backward tracking code.

requires accurate current and wind velocities in the upper layer, and more accurate data means more accurate estimates.

Conclusion

This research presents a novel drifting prediction application for sea-surface objects and the illustrative examples of it provide good accuracy and a good approach for real-life cases. Wind data from ECMWF and current data from CMEMS are used for applying our method. MATLAB and ArcGIS Pro are the software packages used for calculations.

The results of the study are useful for predicting the short-term trajectories of drifting objects. It is shown that the proposed method and calculations can be roughly used for drifting trajectory prediction in operational oceanography. This is a time- and cost-efficient approach. The biggest uncertainty in this work is to obtain accurate information about where and when the objects started to drift. More accurate information means a more accurate and correct algorithm and results. Given the dynamics of transport of the container and the nature of it, our approach depending on initial conditions is easy and suitable for studying floating containers. A search plan based on a certain location and time is of vital importance to avoid loss of time and fuel.

HF radar is powerful technology for mapping surface currents in real time for long distances more than 200 km (Paduan & Washburn, 2013). Real-time data are valuable for tracking floating substances and enabling improved SAR operations (Paduan & Washburn, 2013; Tükenmez, 2014). Considering the half-century of experience with HF radar, it is worth noting that HF radar technology could be an advantageous alternative to model data with its coverage. Not having a forecast component is the only disadvantage of this tool.

Although the method proposed in this research performs well, there are still some aspects that need to be improved. The accuracy of the trajectories completely depends on the accuracy of the current and wind data. A more appropriate method could be provided with experimental studies in the near future. It is also possible that significant wave height and direction could be included in the method since wave-driven movements may move objects off/onshore. Including a wave parameter in the calculations could be considered to make more precise predictions in the future. The next step for this research is ensuring that anyone can track floating objects by using new software in cell phones without the need to install MATLAB, Python, or ArcGIS.

Ethical Statement

Not applicable

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No funding was received to assist with the preparation of this manuscript.

Author Contribution

Serdar TOMBUL: Investigation; Analysis; Methodology; Modeling; Visualization.
Emre TUKENMEZ: Conceptualization; Investigation; Original Draft; Writing.
Murat OKSUZ: Analysis; Modeling; Visualization.
Husne ALTIOK: Supervision; Review & editing.

Conflict of Interest

The author(s) declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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