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driftViewer: Optimization of drifter trajectory search and export of oceanographic parameters

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ABSTRACT

The study and analysis of drifter trajectories, such as buoys and floating devices, have become fundamental to understanding oceanographic phenomena. The detailed analysis of oceanographic parameters using specialized software allows researchers to study environmental changes on different temporal and spatial scales. This article explores the importance and functionalities of this type of software, highlighting its role in improving research methodologies and generating scientific knowledge applicable to oceanography and meteorology. drifViewer is a MATLAB package designed to optimize the search for drift trajectories and analyze oceanographic parameters. It allows researchers to search for drift trajectories in the AOML dataset quickly, create summary tables, and export data to MATLAB and NetCDF formats. driftViewer contributes to scientific research in oceanography and marine geology by improving the ability to model and predict drifting currents, which is essential for studies on climate change, ocean current dynamics, and marine habitat conservation. It is also a useful tool for studying the trajectories of oil slicks, microplastics, and chemical and living species.

Code metadata

Current code version	*v2.3*
Permanent link to code/repository used for this code version	https://github.com/SoftwareImpacts/SIMPAC-2024-245
Permanent link to reproducible capsule	https://codeocean.com/capsule/0884276/tree/v1
Legal code license	*MIT License*
Code versioning system used	*Zenodo*
Software code languages, tools and services used	*MATLAB*
Compilation requirements, operating environments and dependencies	*MATLAB 2023*
If available, link to developer documentation/manual	https://zenodo.org/records/13893564/files/driftViewer_v2.3_2024_UserManual.pdf?download=1
Support email for questions	humberto.varona@ufpe.br

1. Introduction

In oceanographic and meteorological research, optimizing drifter trajectory searches and analyzing oceanographic parameters are critical components in understanding and predicting complex environmental dynamics [1]. Technological advancements have led to the development of specialized software that not only facilitates these tasks but also drives significant progress in the way researchers study the

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oceans and atmosphere. The study and analysis of drifter trajectories, such as buoys and floating devices, have become fundamental to understanding oceanographic phenomena such as the circulation of currents, the dispersion of pollutants, and the dynamics of marine ecosystems [2,3]. These devices, equipped with sensors to measure variables such as current velocity, temperature, and salinity, among others, provide crucial data that allow researchers to track movements over long distances and answer questions about the interaction between different water masses and external environmental influences [4,5], and they are designed to follow the currents while minimizing direct influence from the wind (known as wind slippage or windage) and waves, since oceanographers are primarily interested in the currents.

Over time, drifting objects have been designed for a variety of surfaces and have been used for centuries to represent currents. In the 1960s, the first global programs began using drifters to map ocean currents and turbulence. These drifters came in various shapes and employed different techniques to mimic 'water-following cells,' often using drogues (anchors attached to the main floating body) [6]. Furthermore, drift trajectories are not limited to surface buoys. Since the 1980s, neutrally buoyant floats, positioned at depth through the triangulation of acoustic signals (known as SOFAR floats, and more recently RAFOS floats), have been used [7]. Since the beginning of the Argo program, drift is also deduced from the floats' trajectories at their parking depth (typically 1000 m), providing estimates of deep current climatology [8]. Finally, the drifters assembled at AOML by Rick Lumpkin consist of surface drifters from the SVP or DBCP program (the global drifter program has gone by various names) with a uniform design intended to follow currents in the mixed layer, specifically at 15 m depth [9].

The importance of optimizing the search for trajectories in large databases and their rapid localization lies in the need to maximize the efficiency of data collection missions, which can cover large oceanic areas over extended periods. Advanced computational tools now play an essential role in this process, using sophisticated algorithms that consider multiple oceanographic and meteorological variables to calculate optimal routes and accurately predict future movements [10]. Furthermore, detailed analysis of oceanographic parameters using specialized software allows researchers to study environmental changes at different temporal and spatial scales. This analysis not only helps to understand seasonal and long-term variations in water characteristics but also provides critical data to assess environmental impacts and support the sustainable management of marine resources [11,12].

This article explores the importance and functionalities of this type of software, highlighting its role in improving research methodologies and generating scientific knowledge applied to oceanography and meteorology. By integrating these tools into research practices, a more rapid understanding of complex ocean–atmosphere interactions is promoted, thus driving innovative solutions to address global environmental challenges.

The software presented in this article is of significant importance to oceanographic and meteorological research due to its capacity to optimize and streamline the exploration of drifter trajectories and the analysis of key oceanographic parameters. By efficiently optimizing the search for trajectories, this software allows researchers to effectively track and predict the motion of ocean drifters, which are crucial for understanding ocean currents, water circulation patterns, and pollutant dispersion. It also facilitates the analysis of oceanographic parameters such as ocean currents and temperature, providing researchers with valuable insights into environmental trends and changes over time.

2. Software details

driftViewer is a MATLAB 2023b package designed to assist oceanographers and meteorologists in research requiring surface ocean data. It provides an integrated set of functions, such as a quick search for drifter trajectories from the AOML dataset [13] in a given geographical region, creating a summary table with the IDs of each drifter, the initial and final date and time of the drifter trajectory, and the mean values of the surface current velocity intensity and Sea Surface Temperature (SST). Furthermore, it allows the plotting of each trajectory on a map, as well as the time series of the surface current and SST components. Data from each drifter can be exported to separate files in MATLAB and NetCDF format (Fig. 1). The trajectory maps can be customized for subsequent export as images in different formats. In the plotting of the maps, in addition to the trajectory of the drifters, the coastline and rivers are included (taken from [14]), the latter can be deactivated.

The operation mode of this MATLAB package is very simple, starting by selecting the region of study. From here, it is possible to select the search criteria, and this search is performed through the "Query" button. After the query is finished, a summary table appears at the bottom with the identifier of each drifter, the initial and final instants of each pathway and the mean velocity of the surface current and SST during the period. Then the maps of the drifters and the time series of the current components, current intensity and SST are obtained. At this point, all the data of the selected drifter can be exported, and the map is customized for subsequent export in an image with 500 DPI resolution. As long as the study region or the search criteria are not changed, the process explained above can be repeated as many times as rows exist in the summary table (Fig. 1).

3. Software algorithms

Basically, what this package does is to search for all the drifter data, by means of a **SQL** statement, in a table contained in a **SQLite** database. It uses four search criteria which are the search in a specific month, in a specific week, in a specific day, or in a specific date range. All this is restricted to the previously selected study region. The mean surface current velocity and SST over the period are also computed.

4. Related works

In [15], this software was used to validate the pathways of oil slicks of 3 densities (35, 25 and 15°API), hypothetically spilled at 3 points located at the 30°W meridian and at the 6°S, 7°S and 8°S parallels (Fig. 2a,b). Through driftViewer it was shown in [16] that sediments are transported northward on the coast of Rio Grande do Norte. This region is very active in terms of coastal dynamics because the annual mean significant wave height obtained from the WAVERYS model (product GLOBAL_MULTIYEAR_WAV_001_032 [17]) ranges from 0.28 to 1.94 m (Fig. 2c).

5. Impact overview

This MATLAB package is used to track drifter trajectories, which contributes to the advancement of scientific research in the field of oceanography and marine geology. This type of software improves the ability to model and predict sediment movements [16], which is essential for studies on climate change, ocean current dynamics and marine habitat conservation [5,11,18,19]. The integration of these data into computational models allows scientists to more accurately assess the future impacts of natural phenomena and human activities on the marine environment, thus promoting sustainability and the preservation of natural resources. The data generated by this package are crucial for understanding sedimentation and erosion patterns [5,16,20], which in turn facilitates the planning of coastal engineering projects, ecosystem protection and water resource management. By providing an accurate and detailed visualization of how sediments move, it also enables informed decisions to mitigate environmental damage and optimize infrastructure design.

This software plays a crucial role in the validation of Lagrangian simulations of oil slicks [2,5,15] and living species [21]. By providing accurate data on the movement of floating objects in water bodies,

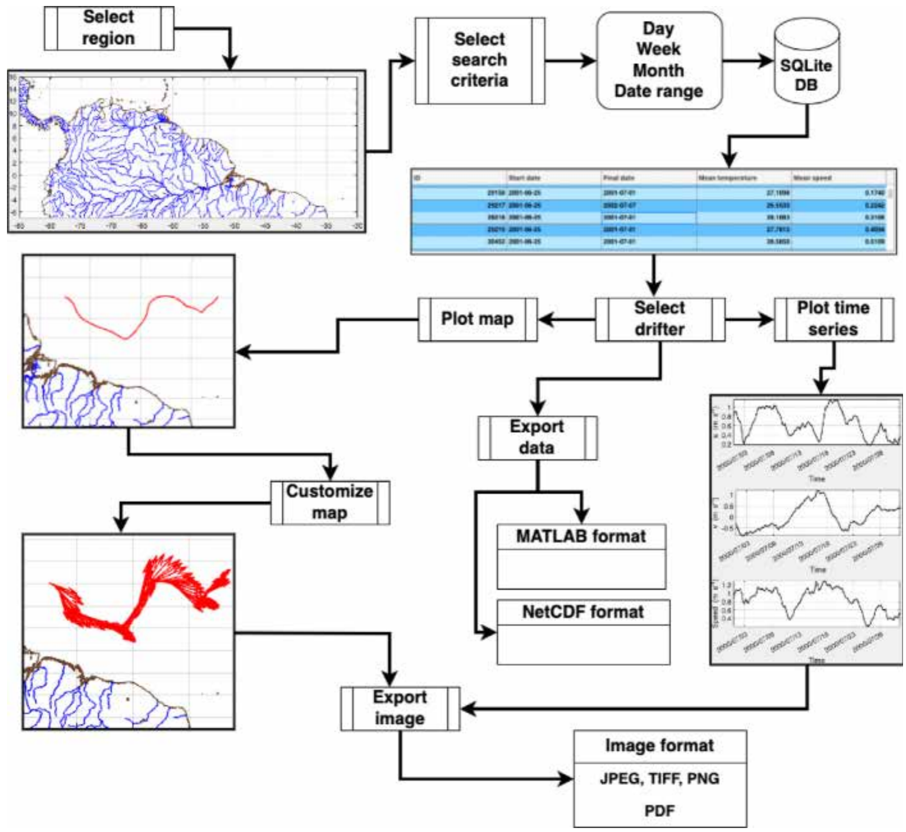

Fig. 1. Steps to quickly search and export PhOD/AOML/NOAA drifter figures and data with driftViewer.

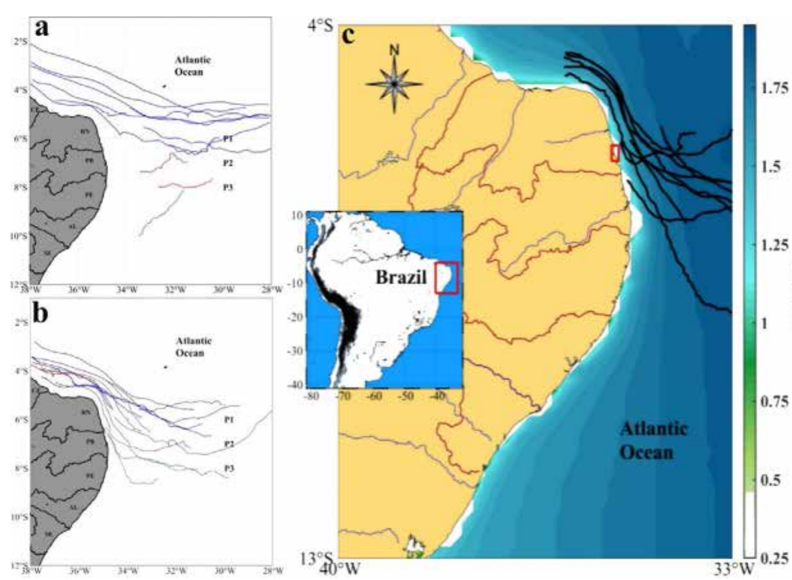

Fig. 2. Sample of the software application: (a) pathways of NOAA drifters in April, located at the nearby points where the hypothetical oil spills occurred [15], (the symbols of P followed by a number refer to the points of particle releases); (b) NOAA drifter pathways in September, located in the nearby locations where the hypothetical oil spills occurred [15]; and (c) NOAA drifter pathways showing the transport of sediment suspended by waves in NE Brazil (SWH is the height of significant waves) [17].
Source: Adapted from [15,16]

this software also allows comparing and calibrating simulated oil slick trajectories with real observations [11,15,20]. This is critical for improving the accuracy of predictive models, ensuring that simulations reliably reflect oil spill dynamics under various ocean conditions. Validation using drifter trajectories increases the reliability of simulations, which in turn strengthens environmental disaster response capabilities and optimizes mitigation strategies. In addition, this software enables environmental protection and emergency management. The ability to accurately validate oil slick trajectories enables authorities and response organizations to plan and execute containment and cleanup measures more effectively. This not only reduces the ecological and economic damage associated with oil spills, but also improves efficiency in resource allocation and coordination of efforts during an emergency.

Furthermore, this software serves as an invaluable tool for education and collaborative research in marine sciences. By making advanced drift monitoring and analysis accessible, it enables students and researchers to interact with real-world data, improving their understanding of oceanographic processes. The open nature of this software fosters interdisciplinary collaboration, encouraging innovation and the exchange of methodologies across different fields, making it a versatile resource for a wide range of applications, from academic studies to the development of government policies contributing to sustainable management and the preservation of ocean ecosystems worldwide [22,23].

6. Future development of the software

In the current version of driftViewer the drift database is until December 2021, so in future versions it will be updated until December 2023. Other drift trajectory databases will also be added.

7. Final remarks

driftViewer is a practical, fast, and efficient tool to perform validations of sea surface currents, heat transport, salt transport, and biogeochemical parameter transport, as well as to validate Lagrangian models such as trajectories of oil slicks in the ocean and the migration of marine species.

CRediT authorship contribution statement

H.L. Varona: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Formal analysis, Conceptualization. **C. Noriega:** Writing – review & editing, Writing – original draft, Visualization, Conceptualization. **S. Herold-Garcia:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Conceptualization. **S.M.A. Lira:** Writing – review & editing, Visualization, Conceptualization. **M. Araujo:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Conceptualization. **F. Hernandez:** Writing – review & editing, Supervision, Software, Methodology, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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