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Research Article

Comparison of Publicly Available Bathymetric Data with Real Measurements in the Southeastern Black Sea

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Abstract

Being able to access accurate and reliable depth information has uncountable benefits for not only fields of oceanography, geophysics, geology, natural resources but also navigation & logistics. There is an ever-increasing demand for high-resolution bathymetric data for those fields since only a small portion of the world seas and oceans have been explored, observed, and charted so far. There are some sources which provide publicly available global bathymetric data to its stakeholders and users such as widely used European Marine Observation and Data Network (EMODnet) and General Bathymetric Chart of the Oceans (GEBCO). In general, it is challenging for researchers to select the best fit for their studies among available datasets, due to the fact that their sole reliability is not well-assessed. The purpose of our study, thus, is to compare those publicly available bathymetric data with field measurements obtained from the surveys carried out by the Turkish Navy Office of Navigation, Hydrography and Oceanography for an area of interest in the southeastern Black Sea comprising various characteristics as to the bottom topography (i.e. homogeneous elevation, steep slope, mild slope, etc.). Validation is conducted focusing on these distinct features by means of visual assessment and quantitative comparison. Results reveal that, even though there is an overall agreement, local discrepancies are also present. Nonetheless, GEBCO and EMODnet datasets are proved to be great assets for any hydrospatial application that does not necessarily require high spatial resolution.

Keywords: Bathymetry Grid, EMODnet, GEBCO, Seafloor Mapping, Ocean Modeling.

Introduction

The seas and oceans constitute approximately 71% of the Earth's surface. Since the environment we live in is mostly water, which affects life significantly, knowing the most fundamental data (bathymetry) precisely is a crucial first step in understanding this huge ecosystem and benefiting from it. Bathymetry, the study of vertical distance from surface to sea bottom, provides essential data for not only the safety of navigation but also many research areas, namely tsunami analyses, ocean circulation modeling, climate change monitoring, and geological studies (Vrdoljak, 2021). The interest in and need for reliable high-resolution bathymetric data are ever-growing due to their operational use for wind turbine installation, pipeline laying, fiber-optic cable laying, coastal zone management, fishery, and tourism along with scientific applications (Hell and Jacobsson, 2012).

Even though early bathymetric measurements go back to the mid-19th century, only 20% of water bodies have been surveyed (UNESCO, 2022). While the need for reliable and up-to-date data is increasing, agencies around the world have difficulty fulfilling this demand. In order to ensure the collaborative support of all countries and emphasize the need for ocean research, the United Nations (UN) Decade of Ocean Science for Sustainable Development (2021-2030) was declared in 2021 (UNESCO-IOC, 2021). Mapping the unsurveyed ocean floor topography systematically by 2030 is one of the key elements of the Ocean Decade to provide sustainable development and comprehensive understanding of ocean dynamics (Wölfl et al., 2019). Understanding the marine ecosystem depends on accurate ocean depth information since biological activities are directly influenced by oceans. Achieving the goal of having full coverage of the world's seas and oceans will not only increase our knowledge of the seafloor, but also allow us to fully understand the effects of these water bodies on life from a broad perspective.

Although underwater topography data can be measured in different ways such as by altimeters, modeling, and satellites, they are mainly collected by ship-based systems. Multibeam echo sounders, which provide high resolution data using vessels, have been used since the 1970s (Glenn, 1970). However, large areas cannot be surveyed with great accuracy due to the fact that quality is low in deeper areas. Even though this method is time-consuming and costly, it yields reliable data with good accuracy. Space technological advances in data acquisition of mapping were developed in 1970 (Wölfl et al., 2019). There are two widely known techniques to conduct bathymetry. One of them is satellite-derived bathymetry (SDB), which maps shallow waters rapidly and depends heavily on water clarity (Sandwell et al., 2002). Collecting underwater topography data in shallow waters takes longer and is more dangerous than in open oceans. Thus, the relatively new and cost-effective SDB approach mentioned above can fill in the gaps (Wölfl et al., 2019). The other remote sensing technique is altimetry, which provides an estimate over large areas with indirect measurements and is useful for deep parts of the oceans on a global scale where coarser resolution data are sufficient for mappers (Van Doornik, 2016; Wölfl et al., 2019). Those measurements still are not reliable enough for detailed ocean mapping, but they are good options where data do not exist.

New improvements in mapping technology have increased the quality of environmental parameters such as ocean mapping (Mayer, 2014). Even though the reliability of the model data is increasing, publicly available environmental parameters obtained by models at different scales are rarely used by hydrographers (Masetti et al., 2018:2020).

Since hydrographic departments are responsible for producing navigational charts and generally do not tend to share their data, bathymetry data providers try to present seafloor topography using alternative sources. There are some open-source portals that provide users with access to publicly available global bathymetric data with low resolution. The General Bathymetric Chart of the Ocean (GEBCO) is the best known and largest source (Ward, 2010). It acquires data from paper charts and works with survey companies and their customers (Marks and Smith, 2006, Wölfl et al., 2019). The European Marine Observation and Data Network (EMODnet), which assembles European marine data from different sources of organizations and countries, is another example of a large and regional bathymetric dataset (Schaap, 2015). The crowdsourced bathymetry working group of the International Hydrographic Organization (IHO) is also encouraging all vessels to provide data during their routine voyages.

The purpose of the present study is to examine the reliability of publicly available bathymetric data and point out possible applications for which they can be sufficient. Therefore, the objective of this paper is to analyze, test, and compare different low-resolution GEBCO and EMODnet bathymetric datasets with high resolution multibeam echo sounder data in a region of interest in the southeastern Black Sea where different topographic characteristics coexist (i.e., generally regular, steep slope).

Materials and Methods

This section describes the data, method, and study areas selected for analysis and comparison. The study area was chosen with respect to the best available and latest data. In addition to the availability of the latest data, associated variables such as slope, ridges, and troughs are considered significant indicators during location selection. The selected site (~2504 km2) is the region between 36°20′ & 36°54′ East and 41°53′ & 42°21′ North (Fig. 1). Different subregions in the chosen area were studied for testing the performance of EMODnet and GEBCO depth information.

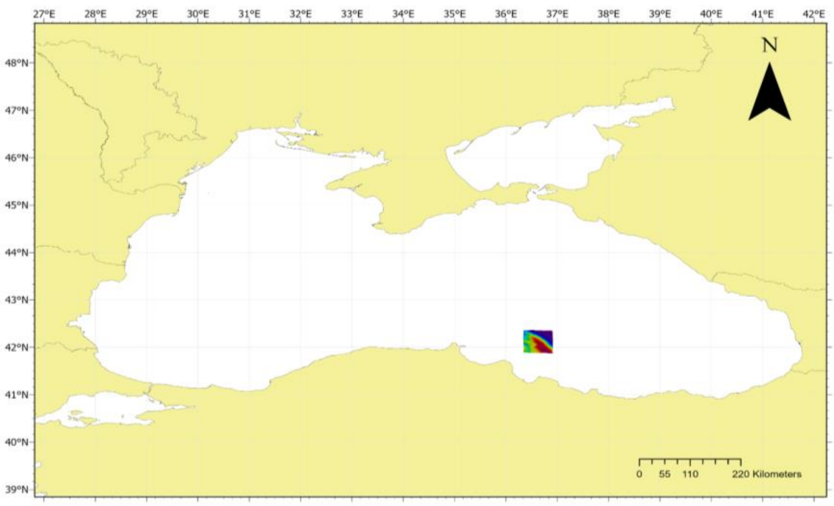

Fig. 1. Location of the study site.

The first dataset used in the research is GEBCO, which is publicly available worldwide bathymetry dataset and is provided in the WGS84 coordinate system with the vertical reference of mean sea level (Van Doornik, 2016). The distance between the grid points for the data is around 460 meters in the study area. GEBCO covers both land and ocean terrains. MATLAB, ArcGIS Pro and CARIS HIPS & SIPS are used for calculations and visualizations. Linear interpolation method is applied to datasets in the phase of analysis. Unlike MATLAB and ArcGIS Pro that are multi-purpose tool sets, CARIS HIPS & SIPS is a tailored product, released by Teledyne CARIS, and focuses solely on postprocessing of sonar acquisition. This postprocessing includes data interpretation, data manipulation, and data quality checks.

Data collected by both single/multi-beam echosounders and side scan sonars can be analyzed through this software. Echosounder data analyses can be undertaken in three different categories, namely; bottom topography, water column, and backscatter. Due to all these above said functionalities, CARIS HIPS & SIPS is a crucial asset of the CARIS ecosystem which aims to provide an end-to-end pipeline from online monitoring of data acquisition till nautical chart production.

The other dataset, namely EMODnet, comprises different sources, and has higher resolution than GEBCO. The EMODnet marine portal provides access to distinct data such as oceanographic and human activities. The resolution of the data is 85 meters in the research region and provides the data with the WGS84 coordinate system. Both publicly available datasets provide full coverage of our research area.

High resolution bathymetric data from the Turkish Navy Office of Navigation, Hydrography and Oceanography (ONHO) with 25-m grid spacing obtained from multibeam data in the area of the Black Sea were used. EMODnet and GEBCO have coarser resolutions compared to multibeam data. Due to having different resolution for model data, the multibeam echo sounder data were resampled; in other words, to obtain identical resolution, the multibeam echo sounder data were converted to the coarser grid size.

In the first step, the mentioned datasets were obtained. Then, general descriptive statistics including standard deviation, mean, maximum, and minimum were calculated, and visual comparisons were conducted. The differences between datasets were also analyzed visually. Root mean square error (RMSE), the difference between the real and predicted data, was used to calculate the errors. Moreover, mean absolute error (MAE), the mean value of a deviation of an actual value from model data, was determined. Lastly, to compare the datasets thoroughly a sample cross section was investigated.

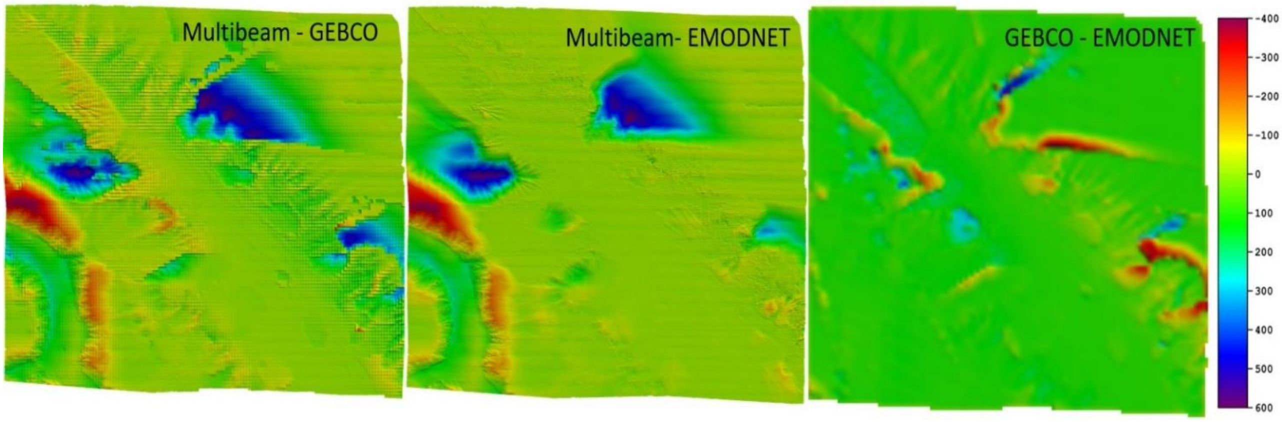

Fig. 2. Map of depth differences between Multibeam and GEBCO, Multibeam and EMODnet and GEBCO-EMODnet.

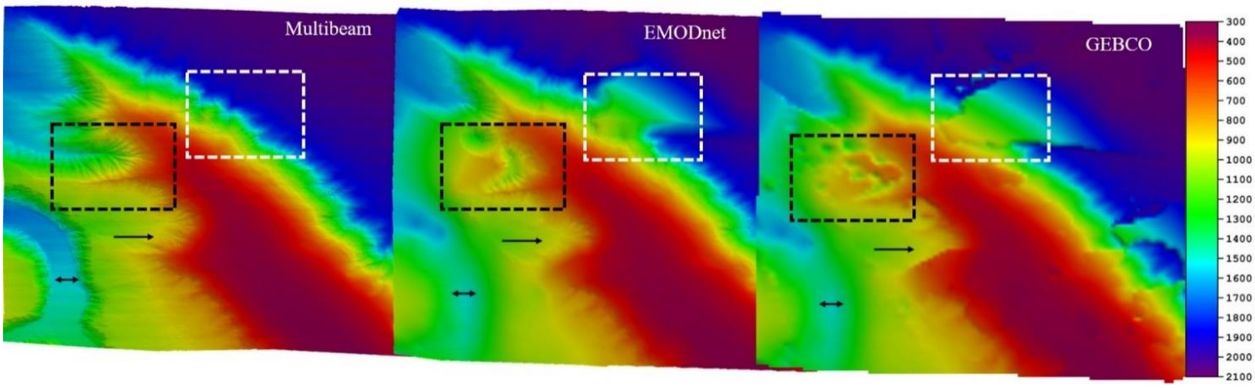

Fig. 3. Depth maps of Multibeam echosounder, EMODnet and GEBCO data.

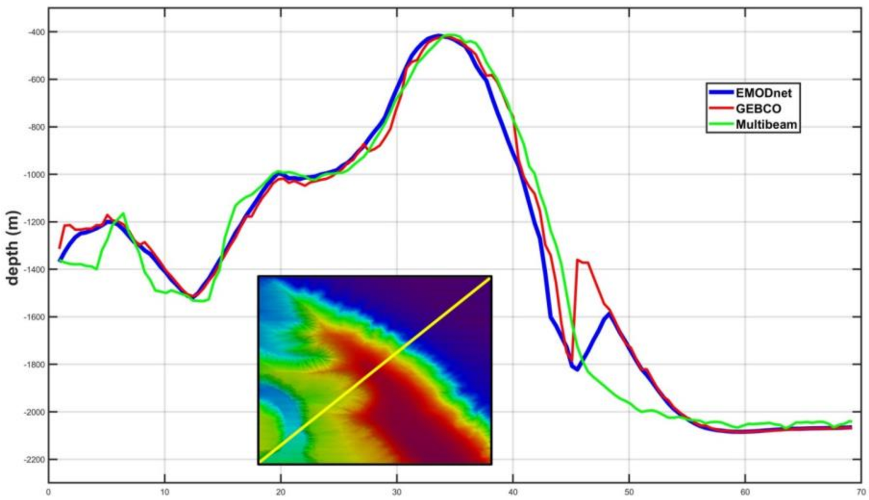

Fig.4. Cross section of the datasets by using MATLAB.

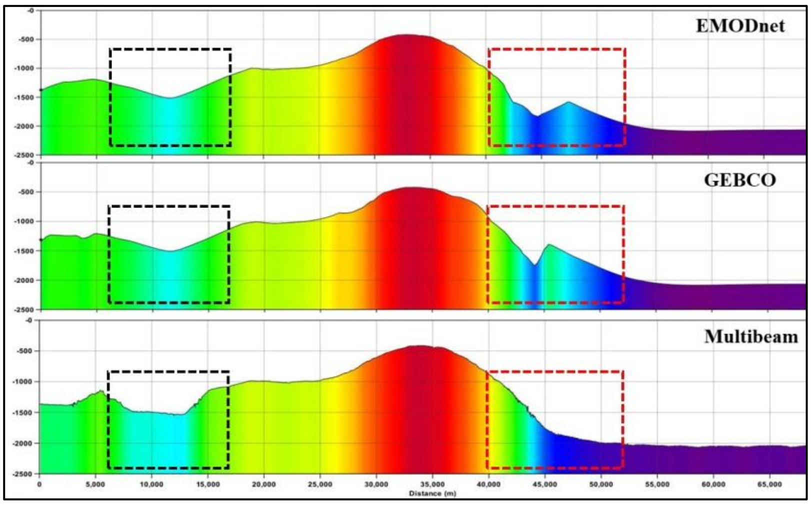

Fig.5. Detailed view of the cross sections of all data.

Results

Comparisons and analyses of two publicly available grids were performed. Firstly, general statistical values of the chosen area including standard deviation, mean, maximum, and minimum were calculated and are given in Table 1. It shows that EMODnet, GEBCO, and real data have unique statistical results, but the numbers are quite similar. Moreover, RMSE and MAE were calculated and are depicted in Table 2.

Table 1. Statistics of bathymetric data (m)

Data	**Max**	**Min**	**Mean**	**Std. Dev.**
EMODnet	2097.2	357.1	1256	570.1
GEBCO	2096	353	1240.7	566.6
Multibeam	2098.7	349.1	1262.7	578.4

Table 2. RMSE and MAE calculations.

Data	**RMSE**	**MAE**
GEBCO-Multibeam	538.41	414.66
EMODnet-Multibeam	508.56	387.60
EMODnet-GEBCO	345.08	248.53

Those error values indicate high variations between the datasets. This indicates that differences could be expected for those different versions of sources. Visual assessment of the differences between those datasets is observed in Fig. 2 as well. GEBCO, EMODnet, and real soundings are subtracted and illustrated by using CARIS HIPS software. Secondly, bathymetry grids from EMODnet and GEBCO were compared and examined with high resolution bathymetry with the visual inspection of seafloor data for each source. It is easily noted by visual assessment that inconsistency in resolution is evident. The squares in Figure 3 depict the main differences between datasets. The maps of those areas evidently different from each other in terms of geometry of the seafloor (slope, flat) are shown in Fig. 3. Difference between the seafloor maps of the regions is also observed in certain locations as shown in Fig. 3. Both are inaccurate for those regions and do not represent the real topography. Depth variations up to ~420 meters are observed in especially slope and irregular areas. It is understood that as the test area is not flat, spikes are seen more in the public data. Analysis of the vertical cross section of the three datasets indicates that water depth does follow the same pattern, with some discrepancies especially in slopes (Fig. 4). Fig. 5 also shows the cross section of data with CARIS HIPS & SIPS software as in Fig. 4. Those figures reveal that patterns generally coincide with each other except for the locations covering major variations. Especially in regions where topography varies considerably it is observed that the public data could not reflect the tendency correctly, as seen in Fig. 5.

Discussion and Conclusion

The research objective was to compare and test different bathymetric datasets in the southeastern Black Sea. The analyses of and comparison between two publicly bathymetric grids in the southeastern Black Sea reveal that the quality of both datasets appeared to be not suitable for navigation and mapping purposes. The analysis, however, showed that those datasets can be used for other purposes such as ocean circulation modeling. It was also found that EMODnet that provides regional data produced better accuracy and resolution than global bathymetric data source called GEBCO. Unfortunately, neither public dataset depicts real seafloor mapping, but they represent the general picture with main slopes and flat areas due to coarser resolution and interpolation. The GEBCO and EMODnet bathymetry data have some shortcomings, and no correlation is observed at certain locations. Both public datasets deviate from the reference data of a multibeam echo sounder. In addition to seismic data, mapping the faults in the sea needs high resolution bathymetry. In the light of that information, the public data may give an idea but cannot provide seafloor topography detailed enough for examination of active faults. Our findings present not only enormous value of multibeam echosounder data but also the need for high resolution depth information in marine research and mapping purposes. In summary, GEBCO and EMODnet datasets are indeed valuable assets for a wide range of hydrospatial applications, particularly those that do not require extremely high spatial resolution. These datasets provide a solid foundation for understanding and managing the marine environment.Those data could be used as an alternative source for ocean researchers at present. A long-term strategy for ocean floor mapping to collect high resolution data is essential and needs to be thought about thoroughly for a promising and manageable road map to be created. For further studies, we could suggest working on shallower areas and different seas for comparing accuracy of those works with our study.

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