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USING HYDROGRAPHIC SURVEYS IN THE STUDY OF WATER BODIES DEPTHS

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Abstract

More than 70% of Earth's surface is covered by water bodies. The underwater relief is very diverse, from continental shelf to deepest trenches and is mostly insufficient known. Water bodies play an important role for our planet and human life, mainly because of helping to regulate the mass and energy transfer between Earth's layers, being source of food and supporting transportation. Due to the high importance of the water bodies, a better knowledge of the water bodies depths and protecting the underwater environment are vital. Though reaching the seabed for exploration could be difficult, modern technologies based on acoustic, optical or radio methods and bathymetric equipment allows hydrographic surveying in order to study the underwater relief. Therefore, strategies concerning climate change, reducing water pollution and environmental negative impact could be elaborated, ensuring sustainability.

***Key words**: bathymetric equipment, depth, hydrographic survey, underwater body.*

INTRODUCTION

Natural phenomena (such as geological, hydrological, geotechnical, and environmental), as well as human activities, are causing deformations of the Earth surface (subsidence, landslides, floods, sinking, tectonic activity). These deformations take place at an increasing rate. Water bodies cover more than two thirds of our planet's surface; therefore, many changes are due to extreme events, most likely to be driven by climate change (Geomatics Research & Development SRL, 2021).

Knowing the depth and shape of the water bodies is fundamental for understanding ocean circulation, tides, tsunami forecasting, fishing resources, sediment transport, environmental change, underwater geo-hazards, infrastructure construction and maintenance, cable and pipeline routing and much more (https://www.gebco.net/).

The before-mentioned aspects can lead to negative and sometimes even destructive impacts on the Earth surface covered by water, and could even eventually be leading to a collapse. The sensitivity to different hazards puts forward the need for an integrated and cost-effective bathymetric monitoring capability (Geomatics Research & Development SRL, 2021).

An important role in the study of water bodies is played by the spatial measuring and monitoring. Spatial measurements offer precise observations and corelated data that can be used in monitoring our planet and the impacts of climate change. Therefore, Earth monitoring programmes using spatial observations are considered key-elements in adaptation strategies. As an example, the analysis of the sea level rise due to global warming require high-precision monitoring of tide gauges. This can be achieved using conventional levelling techniques combined with GPS positioning and bathymetric surveys (Hannah, 2014). Earth monitoring programmes require spatial information management, referring to (Hannah, 2014): databases for relevant data collection and storage and data integration into a common coordinate framework.

A corresponding spatial information management allows data mining, interpretation, and visualization of different climate change mitigation and adaptation strategies. A range of adaptation strategies and disaster risk management can be embedded into Earth monitoring programmes so as to reduce water pollution and environmental negative impacts, ensuring sustainability (Hannah, 2014).

Earth monitoring programmes can be achieved based on collections of large volumes of data

spread over long periods of time, expressing the complex interactions within the Earth system.
Such global, comprehensive, detailed, reliable and consistent data are collected both by Earth fixed and space borne instrumentation (Hannah, 2014). Longer time series of observation data allows better changing analysis and more reliable results interpretation. For a global approach concerning climate change and sustainable development, data collection and integration from multiple sources and multiple platforms is required (Hannah, 2014).
According to the monitored objectives, Earth observations are divided into nine areas such as disaster, health, energy resources, climate, water, weather, ecosystems, agriculture and biodiversity. The assessment of climate change and its evidences can be found in nearly all these areas: storms frequency and intensity, ice cap melt, sea level rise, etc. Long time series of data show the association of natural changes with anthropogenic forcing (Hannah, 2014).
In turn, the large amount of reliable spatial data requires stable, consistent reference systems, which themselves rely upon Earth observations on the variable shape, gravity field and rotation, allowing the definition of time dependent coordinates – an indispensable foundation for all sustainable Earth observations. Time dependent coordinates provide the spatial location of the analysed data to assess important elements of climate change processes (Hannah, 2014).

MATERIALS AND METHODS

Research and monitoring of the water bodies have a great role in scientific fields, leading scientists to innovation and progress, by discovering and improving new underwater resources. The more accurate information and educational programs are, the better understanding of the changing Earth surface, including water functions. The main objectives for ensuring a sustainable future for humanity are to educate the public concerning environmental aspects, climate change and its impacts, as well as reaching awareness of the population about the ecosystem's vulnerability. Only then, actions for environmental protection and responsible use and conservation of the water resources can be taken (Elhassan, 2015; https://www.gebco.net/; Chișbac & Dreghici, 2023).

Data Acquisition

The datasets collected and used for climate change studies include trigonometric data, tide gauge data, meteorological data, ocean temperature data, gravity data, ice core data, salinity and currents data. Hydrographic data collection refers to the usage of bathymetric equipment, such as single- and multi-beam, side scan sonar, sound velocity profilers etc. Data collection tools allow the monitoring of Earth surface and features very accurately. The collected datasets, when accurately geo-referenced and integrated, allow detailed analyses of continuous global change (Hannah, 2014).
Nowadays, we face a continuous technological development, that bring surveyors in front of modern technologies, complex surveying equipment and methods, leading to a better accuracy and efficiency. Depending on the main goal and the type and depth of the water body to be surveyed, there are different bathymetric surveying methods and equipment, based on acoustic, optical and radio pulses and their propagation through water (Figure 1) (Dreghici, 2023; Chișbac & Dreghici, 2023).

Data Integration and Analysis

Spatial data integration represents combining different geospatial datasets into a complete heterogeneous one. These datasets correspond to natural or artificial phenomena or information and should be homogenous. The new dataset can then be used for analysis or information retrieval purposes, enabling object-based image analysis, multi-scale and multi-dimensional phenomena analysis, impact visualization, and the assessment of ecosystem dynamics. Finally, the analysis can lead to better decision-making. Spatial data integration can be carried out in order to establish relationships amongst corresponding object instances represented by different, autonomously produced spatial datasets of the same geographic space. Such an approach is essential for assessing and achieving sustainable development and climate change scenarios (Hannah, 2014).

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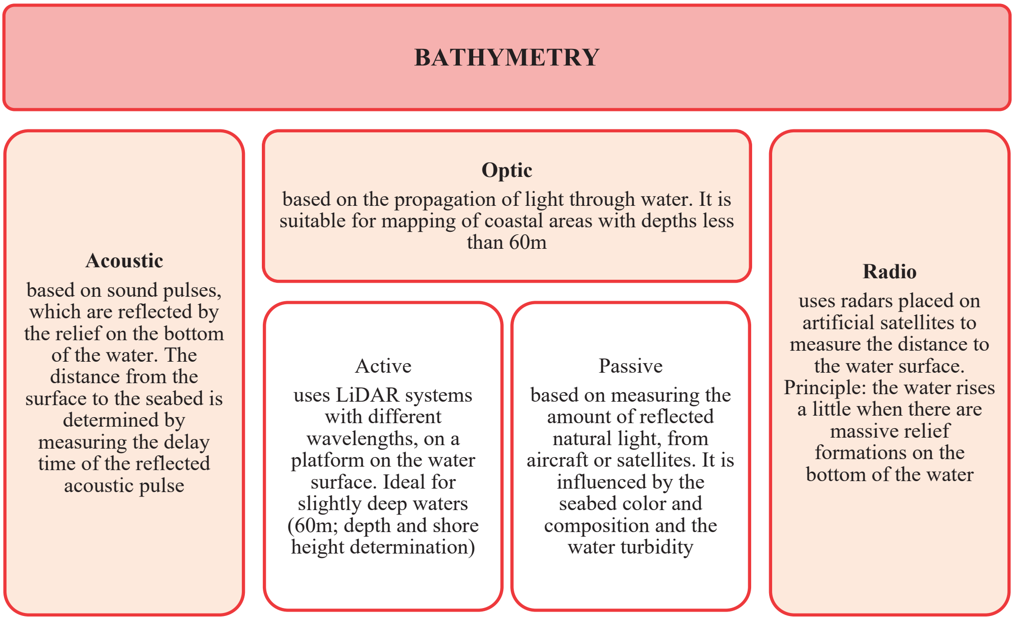

Figure 1. Bathymetric surveying methods (Chișbac & Dreghici, 2023)

Spatial data integration consists of three stages (Hannah, 2014):

– Pre-Integration: choosing the common schema for the geospatial datasets used;

– Matching and Modelling: results in global or local reciprocal modelling framework for the different datasets;

– Integration: may involve vector or raster data (images, raster maps and digital terrain models), or a mixture of both. This involves the use of image-processing and image-recognition techniques, spatial data registration, matching and transformation.

Datasets analytical tools are used in determining the extent of climate change and its impacts, to quantify changes or to monitor motions or changes from satellite-based measurement data. Analysing integrated datasets can lead to a better understanding of climate change processes expressed by environmental indicators, quantitative climatic conditions, numerical model simulations, etc. (Hannah, 2014).

Climate change should not be treated as a local geographical problem which can be solved by local or regional means. On the contrary, it should raise global awareness and seek global solutions in an integrated manner (Hannah, 2014).

Bathymetric Observation Programmes

Worldwide there are research institutions, extend and organizations dealing with Earth monitoring on local, regional or global level, offering products and services support for public sector, holding key roles in shaping global policies, helping to better understand our natural world and to protect its precious resources extends beyond national borders to monitor global weather and climate, and working with partners around the world (https://www.noaa.gov/).

Nowadays, water bodies are covered with bathymetric open source data. Using this data, underwater representations can be created, as well as high definition bathymetric maps. The so created bathymetric products can then be used for a wide range of applications. The modeling workflow, weather using self-collected data or open source data, is the same: data collection, data preliminary processing (preparatory works), data conversion (main processing, interpolation, drawing up the bathymetric map), data interpretation, quality assessment (checking if the results reach the high-quality requirements) and data usage in different applications (further research can be carried out) (Dumpis & Lagzdiņš, 2020).

European Space Agency and EU member states are implementing the world's largest Earth observation programme, Copernicus, under the coordination of the European Commission. In achieving the objectives of the programme, global, continuous, autonomous, high quality, wide range data is collected from a constellation of artificial satellites, called Sentinels. Radar equipment is mounted on artificial satellites, and then radar data collected id correlated with data from sensors on board and on the ground. Monitoring the Earth surface and the environment includes the assessment and management of water resources. There are time-series parameters, such as water body surface, the number of micro-algae in suspension, temperature, ice cover, etc., that can indicate the pollution degree of studied areas (https://www.esa.int/; Elhassan, 2015; https://argans.co.uk/; Chișbac & Dreghici, 2023).

General Bathymetric Chart of the Oceans, GEBCO, is an organization aiming to provide bathymetric data sets and products of the world's oceans: global gridded bathymetric data sets, undersea feature names, world map, web map services and a reference manual on how to build bathymetric grids. Data acquisition is mainly based on acoustic measuring systems, such as multibeam echosounders. Data acquisition also relies on crowdsourced bathymetry (CSB), a collection of bathymetric data collected from vessels, using standard navigation instruments, while engaged in routine maritime operations. GEBCO uses CSB to supplement the more rigorous and scientific bathymetric coverage done by hydrographic offices, industry, and researchers around the world. Bathymetric data collected by other than conventional means are examined how best to be incorporated, managed, and used (https://www.gebco.net/).

NOAA is an agency whose objectives are observing, measuring, assessing, protecting, and managing coastal areas and oceans. Their mission is to understand and predict changes in climate, weather, ocean, and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resources (https://www.noaa.gov/).

Mare Nigrum is a Romanian multifunctional marine research vessel of pan-European interest, involved in many researches and monitoring European projects. It provides various research activities in the fields of geology and geophysics, marine biology and ecology, being equipped with modern research equipment (bathymetric multibeam, seismo-acoustic, magnetometric, gravimetric equipment, various sensors etc.). Mare Nigrum carried out over 2400 scientific expeditions in the Black Sea: exploration campaigns in Romania's national waters (high-resolution geophysical surveys and geological surveys) and in international waters (Bulgaria, Georgia, Ukraine, Turkey) (https://geoecomar.ro/nave/mare-nigrum/).

In the present article, for the purposed case study, open-source data for the Black Sea was used.

The Black Sea, as one of the most important seas in the Euro-Asian region, oriented from East to West, even if it is small, arouses significant interest in terms of the study and mapping of its seabed. Six countries lie on its shores: Bulgaria and Romania to the west, Ukraine to the north, the Russian Federation to the northeast, Georgia to the east, and Turkey to the south. The Black Sea Basin is characterized by a significant depth and an elongated shape, located between parallels 40°56' and 46°33' north latitude. The Crimean Peninsula and the convexity of the Anatolian Coast divide the Black Sea into two distinct sub-basins. From a bathymetric perspective, the Black Sea basin is segmented into four distinct elements: shelf (continental plateau), slope, piedmont and abyssal plain, with a relatively uneven distribution between them, thus approximately 50% of the basin's surface is in the abyssal plain, located below -2000m, while 25% represents the area of continental shelves. The remaining 25% is distributed between continental slopes and continental glaciations (Vespremeanu, 2005).

The generation of a digital model of the Black Sea is an essential component of this effort, having significant implications in areas such as navigation, geological research and protection of the marine environment (Vespremeanu, 2005). For the proposed modeling of the digital model, there was used open-source data provided by GEBCO (General Bathymetric Chart of the Oceans). The data consists in a raster of sea depths globally. This raster is a valuable resource for marine mapping, with a resolution of 15 arcseconds, with elevation values recorded in the center of the grid cells. GEBCO's global elevation models are generated by assimilating heterogeneous data, assuming that they are all referenced to mean sea level (https://www.gebco.net/).

RESULTS AND DISCUSSIONS

After importing the raster into the GIS environment, using the Arc GIS Desktop 10.6.1 solution, a pre-processing was performed to eliminate possible errors or discontinuities thus ensuring the coherence and reliability of the data, essential in the development of a precise elevation model (Figure 2) (Miller et al., 2010).

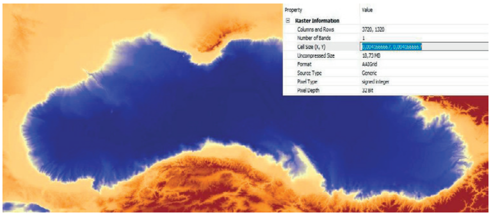

Figure 2. Pre-processing the image

The global integration of the data set is considered appropriate, provided that a vector layer containing a single object is imposed, the spatial constraint vector being in the form of an irregular polygon, in which its limits coincide with the limits given by the average water surface unaffected by the presence of waves (tide) (Figure 3).

Figure 3. Applying the constraint vector in the model delineation

By construction, a value field signifying the maximum elevation can be attached to it, so that the resulting model is based on two altimetric sources. In this way, the outer portions of the Black Sea basin are cancelled, attention being directed to its submerged relief (Miller et al., 2010).

The symbology was applied aiming at a classification of depths on equal intervals, omitting the isobaths and the filling aspect automatically included in the model generation; several classification methods can be used, the most common being those user-defined (by imposing quota ranges) (Figure 4). It is also possible to highlight or exclude certain interest data or that led to the generating of an erroneous model (Miller et al., 2010).

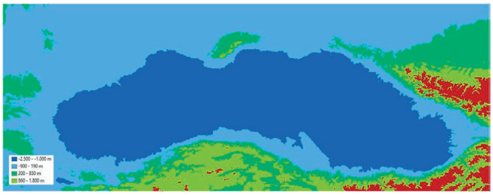

Figure 4. Symbology usage in defining elevation ranges

The performed delineation also affects the actions intended to prepare the three-dimensional model in the sense of applying the height base in relation to the modeled surface, and in the case of vertical exaggeration, the same constraining factor is necessarily applied to the vector entity, delineation tool (Figure 5) (Miller et al., 2010).

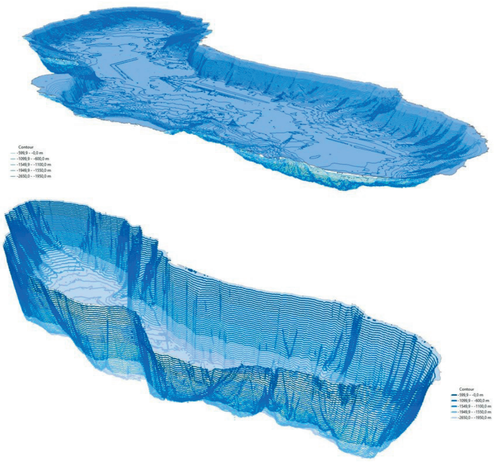

Figure 5. Three-dimensional models of the Black Sea basin

CONCLUSIONS

The Black Sea has been a key element for human lives since ancient times, being the mean of transportation, trade, migration and war. The water body helps regulating our climate and weather patterns, supports marine transportation, supports water-dependent businesses, provides us with many unique activities, from fishing to boating, provides seafood and food ingredients, as well as medicinal products.

Due to the great importance and impact of water into human lives, it is vital to know and understand the underwater world. Bathymetric data collection technologies (acoustics, optics and radar) and processing methods developed and improved rapidly in the last century. Lately, bathymetric products began to be used more and more often in a large variety of applications. Acquisition methods via radio bathymetry are characterized to be less accurate comparing to other methods, therefore acoustic bathymetric surveys are required to validate gravimetric bathymetry in remote regions of the world. Also, open source data play an important role in bathymetric researches, offering users high-resolution data.

Drawing the bottom line, bathymetry has a high potential in studying still unknown areas covered by water, which could be the key in ensuring sustainability.

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