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USING REMOTE SENSING DATA AND GIS IN RESEARCH OF MORPHOMETRIC CHARACTERISTICS OF THE COASTAL AREA IN BULGARIA

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Abstract

Remote sensing methods provide information on both the natural objects on the earth's surface, water bodies, water-land boundaries, and relief and relief forms. Satellite images were used to determine the characteristics of the coastline and Black Sea area (about 50 km distance) of the Republic of Bulgaria. Its fractal dimension and curvature are determined. A number of thematic maps have been generated through the digital elevation model to assist in the interpretation and geomorphologic characteristics of the study area. A database was created as part of the project MARINEGEOHAZARD – "Set-up and implementation of key core components of a regional early-warning system for marine geohazards of risk to the Romanian-Bulgarian Black Sea coastal area" from CBC Romania-Bulgaria Programme.

Introduction

Since 2005, the international scientific community has started implementing the 10-year Global Earth Observing Systems (GEOSS) program. It is part of the Earth Observatory Group (GEO). In December 2017, the European Commission completed a large-scale study analyzing the economic, social and environmental benefits of the Copernicus program, focusing only on Europe for the period 2017–2035. The timely and cost-effective provision of information depends to a large extent on the successful implementation of the INSPIRE Directive, which provides for the creation and exchange of data and metadata, on the implementation of EU policies, and in particular in the field of environmental protection [8].

Remote sensing methods provide information on both the natural objects on the earth's surface, water bodies, water-land boundaries, and relief and relief forms. Increasingly large archives of freely available space images and products (of different spatial resolution and of different satellites) make it possible to observe and study different processes and phenomena occurring on the Earth's surface, oceans and atmosphere. Filling in the archives with new data on the current state of the Earth allows tracking of processes and phenomena over time.

Study area

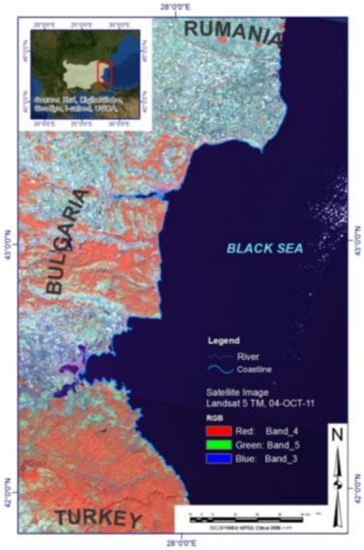

Fig. 1. Study area

The study area in this article is the coastline and Black Sea area (about 50 km distance) of the Republic of Bulgaria (Fig. 1).

The purpose is to collect a coastal strip survey data, using remote sensing methods, in a GIS environment as part of the project: MARINEGEOHAZARD – "Set-up and implementation of key core components of a regional early-warning system for marine geohazards of risk to the Romanian-Bulgarian Black Sea coastal area".

Materials and Methods

Satellite data and DEM

The data used is collected entirely from free-access sources. From Land Processes Distributed Active Archive Center, the data for a digital elevetion model (ASTER GDEM, v.3) cell size ~ 30×30 m were downloaded. Eight granules representing 3601×3601 pix size raster images in *.tiff format and 16 Bit pixel depths were downloaded.

Freely available vector databases and satellite images were used to determine the characteristics of the coastline from which the water-land boundary given in Table 1 was derived. Vector data is in *.shp format and images are downloaded from Earth Observation Data Huband Copernicus Open Access Hub as scenes in *.tiff format.

The capabilities of remote sensing methods, image processing methods, geographical information systems, statistical and cartographic methods for analyzing the collected data were used. All data are in the WGS 1984 coordinate system, UTM projection, zone 35N.

Results and Discussions

Satellite data processing

The satellite images most clearly show the terrestrial surface and the relief with its shapes and structures. The relief along with the geological structure (Fig. 2 and Fig. 3) define the complete geological-geomorphological space. The lithologic diversity of the rock base along the Black Sea coast implies a different degree of resistance to endogenous processes occurring at the land-water boundary.

Satellite images are one of the current sources for accurately determining the ground-water boundary through the ability to use different combinations of spectral channels. The geo-bases make it possible to obtain data on the Black Sea border of Bulgaria on different scales. The measured coastline length depends on the spatial resolution (PDS) in satellite images and on the scale of the information sources (Table 1).

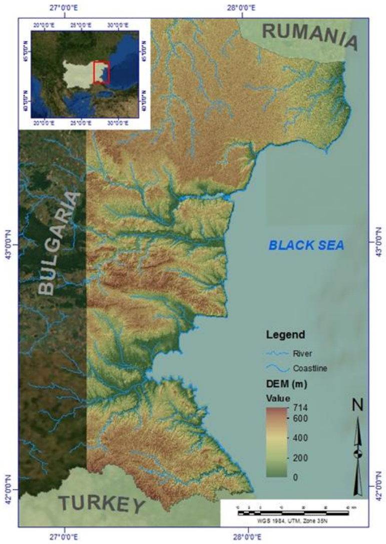

Fig. 2. Map of DEM

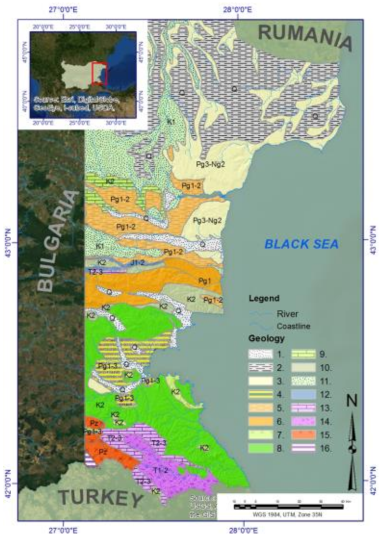

Fig. 3. Geological map[1]

Due to its character, the coastal strip is a natural fractal, characterized by sel-similarity on different scales – fractal dimension [7]. Regardless of the difference in length, the fractal dimension and the curvature of the coastline are the same (Table 1) and are calculated by the formulas:

1) $D = \frac{\log(n)}{\log(n)+\log(\frac{d}{L})}$,

2) $S = L/d$,

where: D is the fractal dimension, n is the number of segments, d is the distance between the start and end points along the arc of the terrestrial spheroid and L is the length of the coastline (the sum of the length of the segments), S is the curvature.

[1]The legnd is from Geological maps for Bulgaria (M 1:500 000)

The close to one (1.10) fractal dimension indicates the more complex nature of the shoreline relative to a simple linear structure and at the same time a relatively slightly indented line (Table 1).

Table 1. Sources, fractal dimension and curvature of the Bulgarian coastline

Source	n	d (m)	L (m)	D	S
Landsat-5 MSS/TM	59102	200203	536216,90	**1,10**	**2,68**
Landsat-7 ETM	5145	200203	409174,00	**1,09**	**2,04**
Sentinel2	8651	200203	481602,15	**1,11**	**2,41**
Jika GIS database	12248	200203	415464,13	**1,08**	**2,07**
NaturalEarth, M 1:10,000,000	174	200203	337003	**1,11**	**1,68**
NaturalEarth, M 1:110,000,000	5	200203	224646	**1,08**	**1,12**

DEM processing

From the digital elevation model (Fig. 2.) were made thematic maps of some basic morphometric characteristics. The morphometric parameters were calculated using mathematical formulas from the altitude output variables and the planned coordinates [5]. Using the Spatial Analyst Tools tool and the Surface function in ArcGIS environment, a number of thematic layers were formed in thematic maps.

Map of relief types (Fig. 4); Based on the digital elevation model (Fig. 2), a thematic map of relief types is drawn up. The map shows that the altitude of the Bulgarian Black Sea coast is low – from 0 to about 700 m (maximum 714 m). Nearly 55 % of the territory, the relief is lowland with an altitude of up to 200 m, including the eastern parts of Dobrudzha, the estuaries of the Provadiyska (Varna-Beloslavski) rivers, Batova, Kamchia, Burgas lowlands, parts of the Strandzha part of the coast. Between 200 m and 500 m altitude is 45 % of the territory (hilly terrain), and these are the Dobrudzha, Frangensko, Momino (Avrensko) plateaus, the hills surrounding the Burgas lowland, the Kamchiiska, Eminska and Aytoska mountains, the Bosnia ridge. Only 0.4% is low mountainous terrain (over 500 m) and includes the highest ridges of the Balkan Range and Strandzha [9].

Map of relief forms (Fig. 5); The "incline slope" morphometric indicator (Table 2, Fig. 6) shows the actual inclines of the slope and serves as a basis for the classification of the relief forms. Nearly 19 % of the area is dominated by accumulation processes. These are the plain parts, river terraces, ridge and technogenic levels. The area with active gravitational and gravitational-aqual processes is 3.5 % and is attached to the river breaches in the Strandzha and the Stara Planina Strip, as well as at a number of places along the coastline. Among the relief forms in the strip on the Bulgarian Black Sea coast are the remains of past relief forming activity. Residual relief forms have two stages of leveling (two denudation surfaces). The Pontic (Old Pliocene) denudation surface occupies the upper flattened parts of the Dobrudzha, Frangen and Momino Plateau, the ridge of the Emina Mountain and the highest parts of the Strandzha Coast at about 450 m above sea level. The younger Levantian (Young Pliocene) denudation surface is represented as a slope of the plateau in the North Coast and the Eminska Mountains, as well as along the ridge levels of the Kamchiyska and Aytoska Mountains [4].

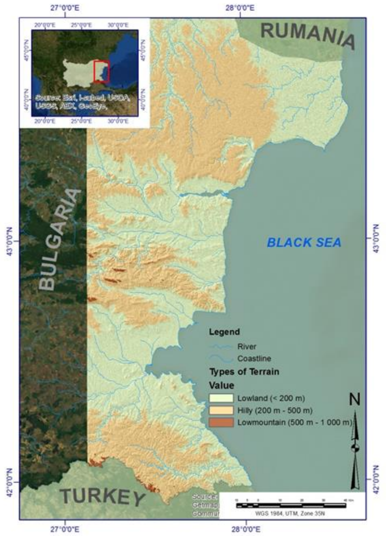

Fig. 4. Map of Types of Terrain

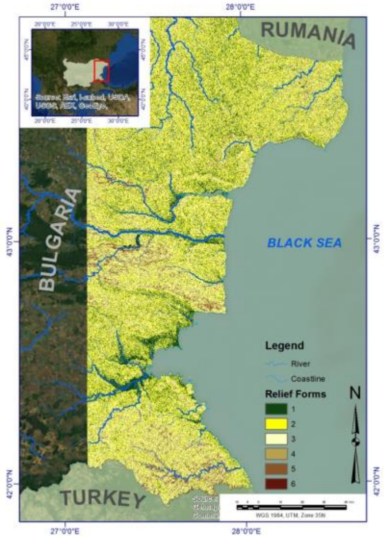

Fig. 5. Map of Relief Forms described in Table 2

Map of actual inclines of the slopes (Fig. 6); For each cell, the incline is calculated as the maximum rate of change in the altitude value of the cell of its neighbors. In principle, the maximum change in the level and distance between the cell with the adjacent eight identifies the steepest descents from the cell and represents the actual incline of the slope. They in turn serve as a basis for the classification of relief forms (Table 2, Fig. 5);

Map of the slope exposition (Fig. 7); The exposure reflects the maximum value of the orientation change in the maximum slope of each cell relative to its neighbors. It is measured clockwise in degrees from 0º (north) to 360º (again north), in a complete circle. Flat areas (–1) are areas where the slope is close to 0º. Both physical and biological factors in the study area are related to the nature of the exhibition.

Table 2. Area distribution of the types of processes and forms of relief in relation to the incline of the slope

No	Incline of slope (◦)	Forms of relief		Types of processes	Area	
					(km^2)	%
1	0–3	Plain, river terraces, grasslands and technogenic levels		No erosion processes, accumulation processes; (plain, river terraces, grassland and technogenic)	2987.87	18.87
2	3–7	The beginning of the foot		Lower boundary of the foot, furrow (stream) erosion	6170.84	38.97
3	7–15	The foot		Upper limit of the foot, (trenches)	5222.98	32.98
4	15–20	Slope	Slanting	Gravity-aqual processes (fluvial (constantly flowing water) and slope processes)	897.27	5.67
5	20-30		Steep		485.35	3.06
6	> 30		Very steep	Gravity processes (collapses, rock falls)	72.06	0.46
				∑ Area:	**15836.37**	**100.00**

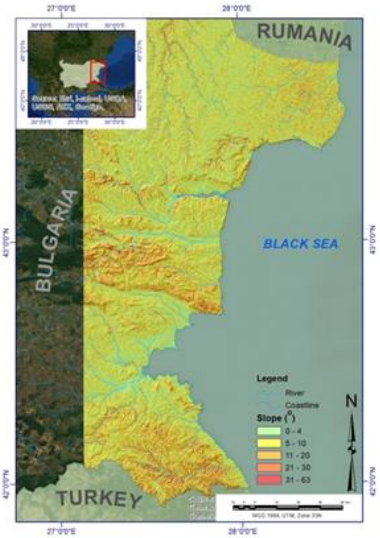

Fig. 6. Map of Slope

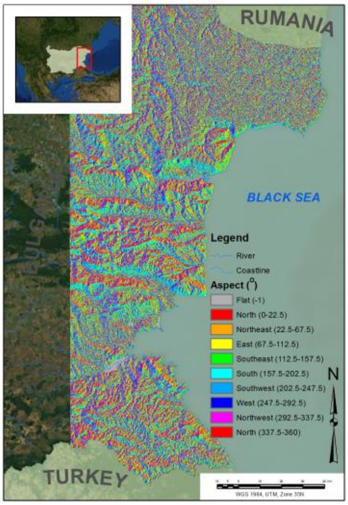

Fig. 7. Map of Aspect

Map of the vertical partition of the relief (Fig. 8); The vertical partition of the relief enables the determination of the type and nature of the relief, outlines territories with different vertical elevation rates, global or regional block structures. Spatially outlines the various relief forms (valleys, depressions, plateaus, ridges, etc.).The field of vertical division represents the plasticity of the relief as a function of the differences in the type and sign of the vertical deformations of the individual earthquake blocks that make up the study area, as well as of the lithology of the rocks that make up the catchments.

Map of the horizontal partition of the relief (Fig. 9); The study of the intensity of the erosion breakdown of the relief based on morphometric methods is important for predictive assessments of the possible manifestation of modern morphogenetic processes and is an objective morphometric factor allowing the separation of areas subject to different types of geo-hazards. The map is a graphic expression of the relief plastic as a function of sculptural (exogenous) processes. It also reflects the density of the river and / or hostile network.

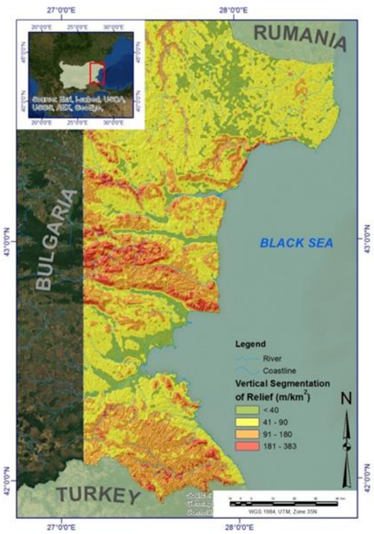

Fig. 8. Map of Vertical Segmentation of Relief

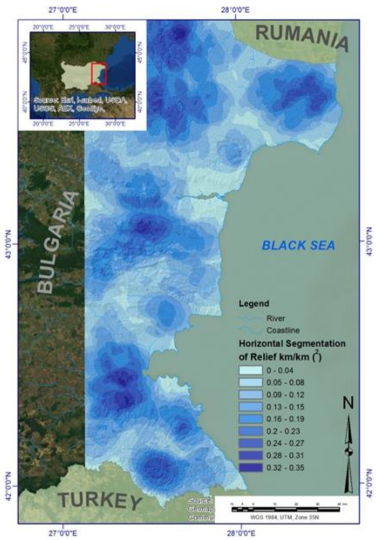

Fig. 9. Map of Horizontal Segmentation of Relief

Map of slope curvature (Fig. 10); The slope curvature is calculated as a derivative of the value from the surface, or the incline of the slope for each cell relative to its adjacent. Three types of curvature are calculated – general, profile curvature (vertical) (Fig. 11), which is in the direction of maximum slope and curvature in plan (horizontal) (Fig. 12) – perpendicular to the direction of maximum slope. From an application point of view, slope curvature can be used to describe the physical characteristics of the catchment area in an effort to understand erosion and bogging processes. The slope reflects the degree of movement on the slope. An aspect determines the direction of movement of a stream. The profile curvature reflects the acceleration and deceleration of flow, therefore affecting erosion and accumulation (deposition). Plan curvature affects the convergence and divergence of the flow.

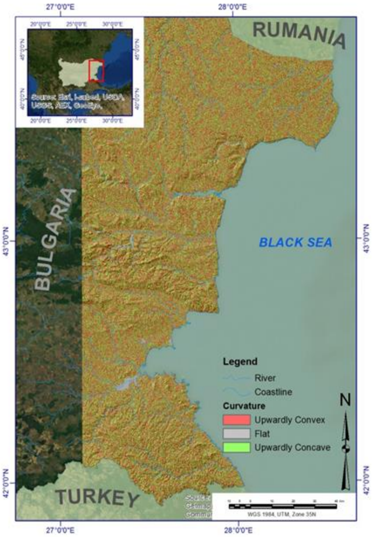

Fig. 10. Map of Curvature

Fig. 11. Map of Profile Curvature

A positive overall curvature indicates that the surface is convex in this cell. A negative curvature indicates that the surface is concave in this cell. A value of 0 indicates that the surface is flat.

For the profile curvature, a positive value indicates that the surface is vertically convex in this cell (convex slopes), a negative value indicates that the surface is concave in this cell (concave slopes). A value of 0 indicates the surface is flat.

For the curvature in plan, a positive value indicates that the surface is convex horizontally in this cell (divergent slopes). A negative value indicates that the surface is concave horizontally in this cell (convergent slopes). A value of 0 indicates the surface is flat.

Negative values of curvatures and profile and plan outline areas of accumulation of eroded material, surface species, pollutants and more. Areas with positive values of the two types of curvature are export areas (denudation) of eroded material, surface species, pollutants, etc. In the other seven combinations between the values of the curvatures by profile and by plan, zones of transit of eroded material, surface species, pollutants, etc. are outlined [5].

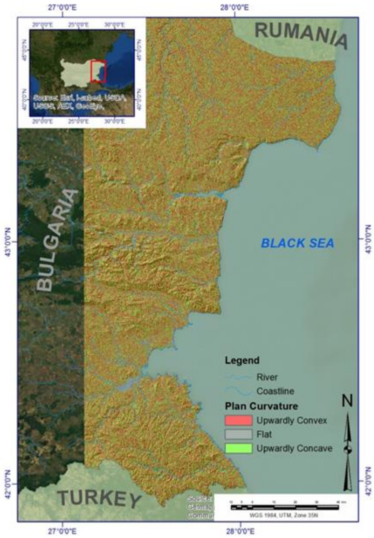

Fig. 12. Map of Plan Curvature

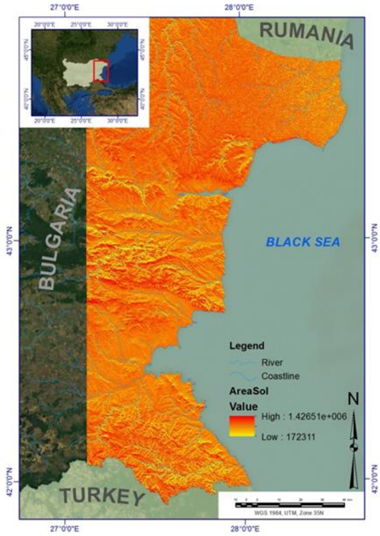

Fig. 13. Map of Solar Radiation

Map of global solar radiation (solar radiation) (Fig. 13); Solar radiation is the solar radiation of a given region and is calculated on the basis of the hemispherical visibility method and algorithm (hemispherical view shedalgorithm) developed by P. Rich, 1989 [3] and further developed in 1999–2000.

The map of global solar radiation spatially outlines and makes it possible to analyze the impact of sunlight on a given geographical area for specific periods of time.

The total amount of radiation calculated for a given place or area is given as global radiation. The calculation of direct, diffuse and global solar radiation is made for each characteristic location or for any location on the topographic surface and is a map of global solar radiation for the entire geographical area.

Global solar radiation is calculated as the sum of direct and diffuse solar radiation over the entire surface by celestial sectors. The total amount of incoming solar radiation (sunshine) is the driving force for the planet's physical and biological systems. Knowledge of the magnitude of radiation at a particular geographical location is useful in various fields such as agriculture, resource management, meteorology, civil engineering and environmental studies.

Conclusion

Based on the collected and generated layers and thematic maps, it can be seen that in the strip of the Bulgarian Black Sea coast there are characteristic coastal (abrasion) processes and landforms formed under the influence of sea water such as cliffs, surfboards, abrasion terraces. In general, the coastline, as already indicated, is slightly cut (its fractal dimension is 1.10). Mostly the mechanical type of abrasion is developed as a result of the wave-surf activity. Abrasion is weak - about half of Cliff's coast is poorly susceptible to destruction. The highest rate of abrasion processes occurs in landslide sites. Landslides are characteristic of the northern part of the Black Sea coast (Balchik, Varna) and less widespread in the south. The strongest abrasion processes are in the presence of storm northeast winds and the formation of large sea waves. The coastline north of Cape Shabla is the most severely destroyed due to the presence of loess (Fig. 3). The abrasion terraces are not very well preserved due to the susceptibility of the rocks to collapse. The Lower and Middle Pleistocene terraces constitute a single complex, with their formation occurring under the conditions of the predominance of abrasion processes.

The Upper Pleistocene terraces form a separate complex, widespread throughout the coast. They occupy the capes along the Burgas-Strandzha and Stara Planina coasts. Along the Dobrudzha and Varna coasts, the terraces are cut in old landslides.

The Holocene terraces form a narrow strip along the beaches, with the base of the slopes adjacent to them, as well as the firth and lagoon lowlands. The beaches occupy 1/3 of the length of the Bulgarian coast. The largest beaches are located north of Varna and between Bourgas and Cape Emine. As a result of the accumulative wind activity southwest of Nessebar, dunes reaching 8–10 m were formed. height. As a result of the sinking of the coast, the estuaries of the Batova and Kamchia rivers formed at the end of the Quaternary. Estuaries represent wide alluvial lowlands. The sandy forms accumulated from the coastal streams have blocked the river mouths and turned them into estuary lakes. Such are the Durankulak, Burgas lakes and others. During the upper Miocene and during the Pliocene, two planning stages and two ascents occur, leading to the formation of denudation levels of Sarmatian-Pontic and Levantine ages. The first level is observed in the highest parts of the Dobrudzha, Frangen, Avren plateau, Emina mountain and Strandzha ridges. The Levantian denudation level has the character of a slope step located at a height of 120–140 m [9].

The main conclusions can be drawn

Modern remote sensing methods provide information and monitoring of active processes occurring along our Black Sea coast (abrasion, landslides, collapses, storage, etc.).

To perform this research, it is necessary that a number of data be processed in vector and / or raster format as layers in a single geographical information system. Creating and organizing the available data as thematic layers in the GIS database enables the sharing of heterogeneous and large-scale information about the studied objects and processes by applying spatial analyzes.

All geomorphological forms have a clear expression in the relief and are emphasized by the calculated various morphometric indicators. All these geomorphological forms are observed on cosmic images and their evolution over time can be traced. They have a clear expression in the relief and are emphasized by the calculated different morphometric parameters.

Acknowledgements

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ИЗПОЛЗВАНЕ НА ДИСТАНЦИОННИ ДАННИ И ГИС ПРИ ИЗСЛЕДВАНЕ НА МОРФОМЕТРИЧНИ ХАРАКТЕРИСТИКИ НА КРАЙБРЕЖНАТА ЗОНА НА Р. БЪЛГАРИЯ

Г. Желев

Резюме

Чрез дистанционните методи се получава информация както за природните обекти на земната повърхност, водни обекти, границите вода–суша, така и за релефа и релефните форми. Използвани са спътниковите изображения за определяне на характеристиките на бреговата ивица и Черноморска зона (около 50 km отстояние) на Р. България. Определена е нейната фрактална размерност и кривина. Чрез дигиталния модел на релефа са генерирани редица тематични карти, които помагат при интерпретацията и геоморфоложката характеристика на изследвания район. Създадена е база данни, като част от работата по проект MARINEGEOHAZARD – “Set-up and implementation of key core components of a regional early-warning system for marine geohazards of risk to the Romanian-Bulgarian Black Sea coastal area” from CBC Romania-Bulgaria Programme.