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MARINEGEOHAZARDS PROJECT – AN EARLY WARNING SYSTEM IN THE BLACK SEA

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Abstract: *The general frame of the BG-ROM MARINEGEOHAZARDS Project is considered. The Project is about set-up and implementation of the key core components of a regional early-warning system for marine geohazards of risk to the Romanian-Bulgarian Black Sea costal area The main focus is on the data and information about the investigations related to the creation of the marine geo hazards early warning system. The target topics are on the earthquakes, landslides, tsunamis, floods and similar natural hazards. Maps and schemas about the main hazards have been created for the Bulgaria-Romania cross border area – both in marine and coastal environment. The typology and quantification of the hazards and their dangerous elements support the key core elements selection and the infrastructure of the early warning system targeted to the population and society safety.*

Keywords: *Marine geohazards, early warning system, Black Sea*

Bringing together the expertise of the two countries – Bulgaria and Romania, the MARINEGEOHAZARD project aims for the establishment of a joint regional early-warning system and of a common decision tool, which can support in an efficient manner the emergency managers and decision makers in their activity related to protection of the local communities, environment and assets within the cross-border area, from consequences of natural marine geohazards. This is a pilot project and first attempt in this area and brings all risks of such innovative approach.

Project Coordinator: National Institute of Marine Geology and Geoecology – GeoEcoMar (Romania)

Partners: Geological Institute Bulgarian Academy of Sciences (GI-BAS); Institute of Oceanology – Varna (IO BAS); National Institute of Research and Development for Earth Physics (Romania)

General objective: Implementation of an integrated early-warning system accompanied by a common decision-support tool, and enhancement of regional technical capability, for the adequate detection, assessment, forecasting and rapid notification of natural marine geohazards of risk to the Ro-Bg Black Sea cross-border area. The future intention includes as well as integration with the local authorities to provide warning issues.

Specific objectives [8]:

- Define and implement a unified and integrated approach to assessment of marine geohazards of risk for the Romanian-Bulgarian Black Sea cross-border area.

- Install a real-time, fully automatic detection system comprising of deep Black Sea complex measurement stations (gauges), of on-shore marine seismicity monitoring and digitalized GPS stations.
- Implement a common decision-support tool (DST) by provision of unique forecast and assessment software package and development of a joint database of scenarios, to facilitate and support management and mitigation of marine geohazards.
- Create the regional technical capability to perform marine seismic measurements.
- Prepare joint, updatable databank by integrating the existing national data, the real-time data from deep-sea gauges and the on-line data from sea-level gauges, remote sensing and national seismographic networks and by performing coordinated marine geohazard investigations to fill-in the lacking data.
- Cluster and enhance the regional expertise by training the staff and establishment of data exchange platform between national institutions.

Bulgaria partners play equivalent role in the creation and functioning of a center in Varna – Bulgaria (and Constanta – Romania) about an early warning issue in case of marine hazards and risks development on the cross border region of the Black Sea.

Research and investigations about the general marine geohazards

In the frame of the Project a lot of research and investigations have been done, common maps created and gaps identified. Several marine geo hazards have been identified (according the previous projects – TRANSFER and SCHEMA).

Seismic hazard

A common catalogue of the Bulgaria-Romania cross border area about the Black Sea aquatory of the both countries has been compiled, including historical and instrumental seismicity. The main seismic sources have been identified and investigated according their tsunamigenic potential [8].

In total nine separate zone have been identified and their space-time characteristics studied. Most dangerous (meaning with highest seismic potential are the zones: Shabla-Kaliakra, Crimea, Caucasus and Turkish coastal zones. Shabla-Kaliakra seismic zone located near the Bulgarian coast is able to produce earthquake up to magnitude M8.0. Crimea – to M6.5-7.0. Caucasus has almost the same seismogenic potential. Turkish coast – M8-8.5, but the sources are related mainly with the North-Anatolian fault, which is located outside the aquatory of the Sea.

The analysis performed shows that according the aims of the Project, main attention has to be paid to the Shabla-Kaliakra seismic zone. It has a specific regime – long intervals of quiescence and bursts of strong shocks no regularly distributed in the time domain.

The tsunami hazard

Deep investigations about the tsunami hazard have been performed. Previous results obtained during the execution of other EU Project have been incorporated and critically assessed.

The Atlas [3] is a collection of tsunami-wave-risk maps along the Northern Bulgarian Black Sea coast, Balchik site. These maps are the result of research work performed by a broad international scientific consortium using unified methods. This research work according (Ranguelov et al., 2008) was performed in accordance with the work programme of a scientific research project under the 6th EU FP, entitled SCenarios for Hazard induced Emergencies MAnagement (SCHEMA). The entire project is aimed at dedicated studying of tsunami hazard and risk, using the most advanced technologies for the purpose (satellite images, complex non-linear methods, detailed elevation and bathymetric data and the like).

In scenario definition, data and information about previous tsunami waves in the Black Sea were used, which had negative effects on the coast. These include: historical descriptions from annals and data from previous research; available paleo-tsunami deposits; effects on the coast, settlements, and/or surface or sub-surface facilities [1].

In numerical modelling, the following were used: surface or subsurface elevation maps to various scales and satellite images; tsunami sources (here, only seismic sources were taken into account); theoretical models accounting for wave propagation and wave-cost interaction (the major part of this work was performed by the National Observatory of Athens) [3].

In analysing vulnerability and risk, the following were used: vulnerability and damage classification, derived mostly from field observations (tsunami impact in the Indian Ocean on 26 December 2004); inundation distance of tsunami waves; travel times of tsunami waves from their source to various coastal points; model registrations on some virtual tide gauges; satellite images of buildings and facilities of various types.

The presented maps are thematic and may be divided into two basic types: regional (comprising the coastal area between the town of Varna and the Romanian frontier); local (covering only the coastal area of the town of Balchik). The maps are of the following types: maps of the arrival time from the source to the coast; maps of the maximal water inundation; maps of the maximal water withdrawal into the sea; maps of the velocity of the water turbulences generated during water movement; maps of the vulnerability for the town of Balchik; maps of the tsunami risk for the town of Balchik.

At the end chapter, some applications are provided, facilitating the understanding and use of the obtained results. These results are ONLY approximate and might benefit end users, such as the Civil Protection Service, local administrations, research institutions, companies and more. All activities under the SCHEMA Project were performed through the close collaboration of the teams from the project participating institutions.

The following cases of tsunami effects have been recorded in some way or other since ancient times until nowadays [3].

3rd (1st) Century BC

"The Greek colony of Bizone (nowadays town of Kavarna) *is sinking into the sea"*. This is how, in 1st century BC, Strabo described the consequences of an earthquake which triggered a gigantic slide (that may be seen as of today at the Chirakmana Cape; Fig. 2). Probably, Strabo quotes Demetrius Calatius who lived in the 3rd century B.C. Since then, the town of Kavarna was moved to the plateau.

Year 544/545

An earthquake featuring possible magnitude of M≈7.5 probably generated a local tsunami, activated landslides, destroyed (or added to the final destroyed of) the Cybele Temple and buried its ruins. Historical data about this event are to be found in the book of Emanuela Guidoboni, *Earthquakes in Ancient Times*, as well. The revealed sediments in the Cybele Temple are located at a depth of approximately 4.5 m above modern sea level and 100 m off the coast (Fig. 3). This case was used as a major reference event based on which the effects on all maps contained in work were modelled.

31 March, 1901

An earthquake featuring magnitude of M≈7.1 took place in the sea aquatoria. Serious destructions were observed in the epicentre area, reaching up to grade X after the Medvedev-Sponheuer-Karnik (MSK) Intensity Scale for Measurement of Severity of Earthquake Shaking (Fig. 4). Five settlements were seriously affected, over 800 houses collapsed. The aftershocks continued for about 7 years. Cases of slides, destructions, and collapses were reported. Witnesses observed sea level oscillations of approximately 2-3 m, nowadays defined as tsunamis.

The 7th May 2007 case

Along the entire Black Sea coast, sea level change was observed for a couple of hours, in the absence of any seismic activity whatsoever. Sea level change amplitudes reached up to 2-3 m, while the frequency in the different places varied between 4 and 8 minutes. Though taking no human toll, the effects were manifested in ship damages, tetrapods shift in the Port of Kavarna, about 2 m intrusions along the Balchik coast (water withdrawal exceeding 10-15 m), great turbulences (featuring diameter of more than 200 m;), powerful currents (featuring velocity of about 1 m/s).

Two hypotheses for the origin of this event were examined: sub-surface slide according (Ranguelov et al., 2008); meteorological reasons (Viliblic et al., 2011). The results from both approaches are acceptable and comply with the observations.

To model the possible effects of the event similar to the one which took place in 544/545, one source was selected (actually, two sources located in the same place and differing only in the direction of the main fault which generated the tsunami waves). It is important to note that for the lack of reliable data on the earthquake-generating source, its location and the fault directions were chosen by analogy and are burdened with great imprecision.

The major thematic maps for both regional and local scenarios are: maps of the maximal withdrawal (actually, the minimal water level); maps of the maximal water level; maps of the maximal velocity of generated currents.

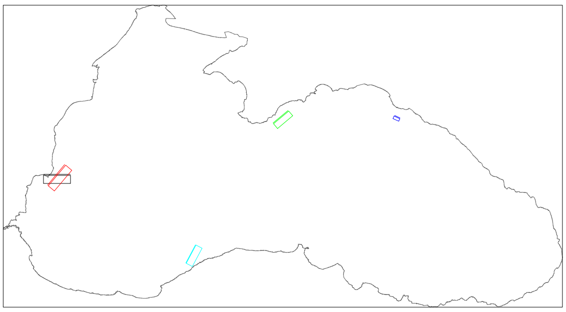

Figure 1. Schematic views of the tsunamigenic seismic sources in the Black Sea

Time/Type of event	Hazardous events observed	Tsunami intensity (Papadopoulos-Imamura scale)
3rd (1st) century BC (Complex)	Earthquake, slides, regional tsunami inundation	IX–X
Year 544/545 (Complex)	Earthquake, slides, local tsunami inundation	VII
31 March, 1901 (Complex)	Earthquake, slides, rockfalls, local tsunami inundation	V
7 May, 2007	Non-seismic sea-level oscillations	V

Table 1. List of the tsunami events along the Northern Bulgarian Black Sea coast

It should be pointed out that, for the lack of detailed bathymetric maps, the modelling of the maximal water withdrawal into the sea, the maximal water level, and the movement velocity of turbulent water masses is greatly impeded and the obtained results are only approximate. On obtaining more detailed bottom bathymetry data they might experience significant changes. Based on these maps, the damages were also assessed, based on the previously made vulnerability classification for the buildings and facilities in the Balchik coastal area.

L (m)	57000	57000	41700	13200	43650
W (m)	22000	22000	20400	9120	18200
Strike	90°	40°	50°	115°	28°
Dip	40°	40°	50°	50°	38°
Rake	270°	270°	270°	270°	90°
Slip (m)	2	2	2	1	2
Position, coordinates	28.7°, 43.4°,	28.7°, 43.4°,	34.5°, 44.5°,	37.5°, 44.5°,	32.17°, 41.90,
Depth (km)	2	2	2	2	2
M	7	7	7	6	7
Fault	1	2	3	4	5

Table 2. Parameters of the tsunamigenic seismic sources (according TRANSFER Project) [6]

According this table and the presented in it parameters several numerical models of the expected tsunamis generated by these sources have been calculated and presented in the TRANSFER Project web site (fig. 1).

After some years new model have been performed together with the National Observatory in Athens by the team of Prof. Gerassimoss Papadopoulos. The results have been published as a separate Atlas of maps about the tsunami tisk areas of the North Bulgarian Black Sea coast in the frame of the EU SCHEMA Project. The basics of data are as follows:

Source Fault 1 (fig. 2):
Length (km) 57
Width (km) 22
Strike (°) 40
Dip (°) 40
Rake (°) 270
Slip (m) 2
Depth (km) 20

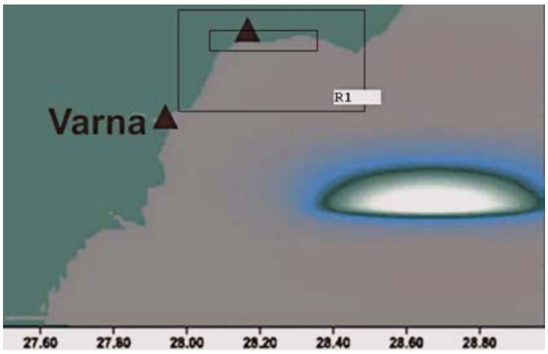

Figure 2. First source model

Source Fault 2 (fig.3) :
Length (km) 57
Width (km) 22
Strike (°) 90
Dip (°) 40
Rake (°) 270
Slip (m) 2
Depth (km) 20

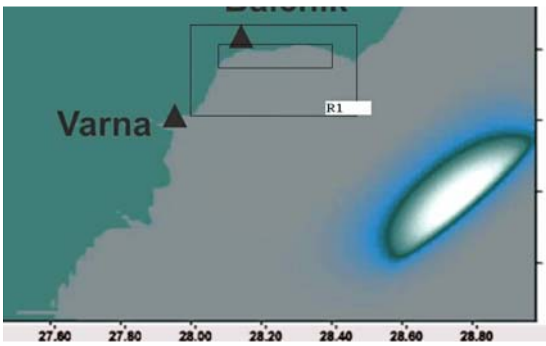

Figure 3. Second source model

Intended equipment

It is visible from the results of the research and investigations that the main hazards creating risk for the population and coastal infrastructure are strong earthquakes and possible tsunamis (Ranguelov, 2008). As previous investigations show the area is very sensitive as well as to other secondary expected hazards – such as landslides and underwater turbidities. There are real existing mud volcanoes, gas seeps, gas hydrates, H_2S accumulations and other potential hazards in the waters of the Black Sea. According the work plan of the Project several systems integrated in unified clusters of different equipment located on Romania and Bulgaria territory and/or territorial sea waters providing information for the two data centres (in Varna and Constanta) are intended: (fig.4)

System of complex marine stations for the measurements of different sea parameters – OBS, microbarographs, meteorological complex measurements, etc.

System of GPS receivers on land.

System of strong motion devices on land.

System of extensometers on land

Communication system for data transfer.

Specialised software about computation and selection of the best fitted scenarios about the warning issue in real time.

These systems are intended to work simultaneously and to provide data to the data centres [4]. The communication system will use satellite links, INTENET, radio and telephone lines. The duplication of the centres provides safety and secures data transfer. In case of major disaster the chance of both systems to be destroyed is practically nullified. The correct work of the whole system is based on the precomputed scenarios, which will be selected automatically on the basis of maximum similarity and the best coincidence of the input parameters provided by the data loggers and the scenario parameters used for the respective calculations. Such approach safe time for the reaction of authorities and population.

This methodology needs very accurate numerical models of the tsunami generation, propagation and interaction with the coast.

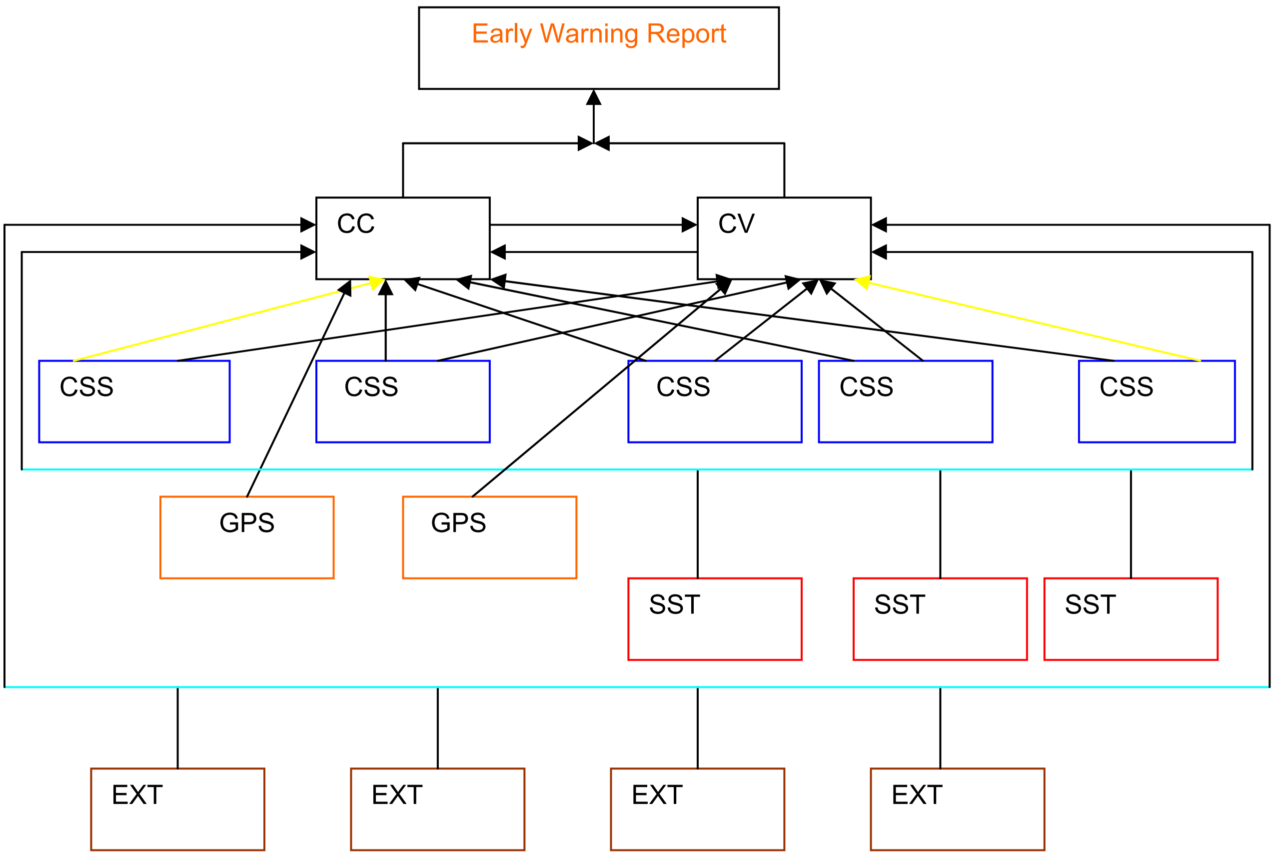

Figure 4. Block diagram of the equipment and communication

Legend to Figure 4.

- CC – Centre Constanta
- CV – Centre Varna
- Both Centers are equivalent
- LEGEND
- CSS – Complex Sea Station
- SST – Strong motion Station
- GPS – GPS Station
- EXT – Extensometer Station
- SAT – Satellite communication
- INT – Internet Communication
- COLORS
- Dark Blue – SEA MODULE
- All other colors – LAND MODULE
- Yellow – Satellite Communication
- Light blue – INTERNET

Early Warning Report

To provide such accuracy the sea detailed bathymetry mapping will be performed to the whole costal area of Bulgaria and Romania. Then these data will be used for the numerical models performed by the system. It is important to mention that the Project MARINEGEOHAZARDS is only the initial phase for the complete early warning system which is intended to cover the whole Black Sea and to incorporate all countries threatened by the same hazards of risks.

Conclusions

During the first stage of the execution of the MARINEGOEHAZARDS Project a lot of investigations and models have been performed. The main marine geohazards have been identified, outlined and deeply investigated. The results obtained confirmed that the main hazards for the population and coastal infrastructure are strong earthquakes and tsunamis. Despite of that other hazards are also under observations and assessment – floods, gas seeps, gas hydrates, surface and submarine landslides, etc.

The horizontal links with other similar thematic projects (like TRANSFER and SCHEMA) have been used to extend the cooperation and use of the previously obtained results on the same topics. Next stage needs equipment delivery, installation and put in operation, staff training and coordination with the local authorities, media campaign about information dissemination for the aims and achievements of the Project.

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