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EARLY WARNING SYSTEMS - EWS (EARTHQUAKES AND TSUNAMIS) AND THEIR EFFECTIVENESS

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Abstract: *The new and modern tool about prevention and safety in case of earthquakes and tsunamis are discussed from the recent point of view considering possibilities to apply and perform such systems in Bulgaria. The last destructive earthquakes and possible tsunamis expected in the Black Sea are the cases which can need the creation of such systems. The effectiveness in case of regional and local EWS is different due to the local peculiarities.*

Introduction

The early warning systems are new and modern tool about prevention and safety of the infrastructure and population. The great Sumatra (2004) and Japan (2011) earthquakes and tsunamis show the difference about societies equipped with and without EWS.

The recent development of the technology and the fast information transfer is the main basis of the development and implementation of the early warning systems (EWS) about different natural hazards. Since several decades the early warning systems considering different hazardous phenomena have been developed in different countries on global, regional and local scale. They are based on the physical properties, destructive potential and better organization of the information dissemination to the decision makers, specialized institutions and population. During the last years, sophisticated satellites are following the forest fires and floods development, desertification, droughts spreading, etc. All these distant methods have been developed in close cooperation with the surface observations and monitoring. During the last years (especially after the destructive Sumatra tsunami in the Indian ocean, 2004 and Japan, 2011) large actions and funding have been targeted to the GEOS (Global Earth Observing System). They are focusing on multipurpose targets – continuous monitoring, fast data exchange, easy accessibility of the end users. New experiments of establishing regional and local early warning systems targeting to the increased reliability to relatively fast processes and phenomena – tsunamis, earthquakes, flash floods, volcanic gas and lava eruptions, etc. are under development. Staring with the Pacific tsunami early warning system (PTEWS) (established in the early 60-ties with headquarters located at Hawaii), the first experiences have been collected. The observations, modeling (travel time calculations, the locations of the strong, powerful tsunamigenic earthquakes) and the fast and reliable warnings dissemination have been launched among the priorities of that system. After that, the positioned stationary satellites have been launched on orbits and used for the fast communication. During the last times satellites and land based recent systems started operation to the volcanic continuous observations. With some successful eruption predicted these technologies are used as well as about the different mass movements observations, modeling and forecast – landslides, avalanches, slope processes and mining activities and consequences, etc. The recent technology transfer and fast development of the communication technologies put new challenges to all existing, new established and newly developing early warning systems.

The main aims of this paper are to investigate and formulate the possible effectiveness, reliability and possible fast transfer to the end users. The both sides of this phenomenon are considered: The early warning system as the physical basis of the used parameters for higher reliability from one side and the compromise between fast alerts and reliability on the other.

Some methodologies, world experience and successful/unsuccessful early warnings disseminated by EWS are also considered. The possible creations in Bulgaria of the EWS about earthquakes and tsunamis have been discussed.

EWS - physical fundamentals

The seismic EWS are based on the physical properties of the seismic wave propagation are among the most frequently discussions and applications. They are modeled regarding the difference of the wave propagation respectively of the P and S seismic waves. It is well known that P waves are faster then the S waves. The velocities are expressed by the equation:

(1) $$Vs= 2^{1/2} Vp$$

Due to the physical properties of the medium where P and S waves are propagated, usually they have the amplitude ratio of As/Ap =3-4. Thus P waves are faster and have lower amplitudes and Vs are slower, but have greater amplitudes and can create much more destructions. This is due to the peculiarities of S waves. Except they have larger amplitudes, as well as the rotational component of the medium is additional destructive factor to the constructions. The time difference Ts-Tp is the main parameter responsible about the seismic early warning system effectiveness. As larger is the difference as longer time for application of different measures is available.

The compilation of a seismic EWS needs large preliminary job. The selection of the equipment, location of the stations, staff and maintenance of the system are difficult tasks. The models of the optimal distribution of stations needs performance of seismic travel time curves of the P and S waives, as well as the time differences Ts-Tp. The effectiveness of the seismic EWS is a function the seismic sources coverage, time delay and warning message issue. Usually several levels of reliability of the areas covered and the warnings are selected on the base of preliminary computed scenarios. One of the most difficult tasks to guarantee the effectiveness is related to the warning dissemination. This must be secure and reliable. The best practices also need great preliminary education work to the population to explain the capacity and possibilities of the seismic EWS. It is very important to mention, to explain and to insist about understanding to all end users that seismic EWS is nothing to do with the prediction and forecast of earthquakes. The main purpose of the seismic EWS is to provide a warning giving the possibility to eliminate (or minimize) the damages caused by the secondary negative effects – fires, catastrophes of trains, metro, trams and other transportation lines, technological accidents, leakage of radioactivity (and/or poisons and dangerous chemicals), gas and oil pipeline damages, blasts, power supply and information networks disconnections, etc. Sometimes (in well conditions – long epicenter (hypocenter) distance to the seismic sources) EWS can provide time of the individuals' reactions to safe and protect human lives. Always the seismic EWS are combined with the strong motion monitoring system to use the data about the post event processing. Such data gives reliable information about the seismic forces acting during the seismic event and could be used about post event analysis, normative codes and rules creation, etc.

The tsunami EWS are developed on the basis of the velocity differences of the seismic waves (in average about 8 km/s in the mantle) and the tsunami waves – 700-900 km/h for the deep water and 40-100 km/s for the shallow water. The most sophisticated and universal devices about tsunami EWS consist are so called DART stations. Usually they have several sensors (most frequently OBS and MBG) located on the ocean bottom and use satellite communication links. The principles of operation usually have the following steps:

- Registration of strong earthquake with automatic location and magnitude determination.
- Assessment of the tsunamigenic potential of the registered earthquake based on historical data, earthquake mechanism and magnitude selection (usually the threshold of a certain magnitude is in use).
- First step of warning issue based on these data.
- Microbarograph prove about the tsunami generation
- Second step of the early warning issue
- Microbarograph registrations and other evidences about the tsunami generation and confirmation
- Third step of the early warning issue with expected arrival times to different selected destinations based on pre-computed scenarios together with the expected amplitudes of the waves or
- Cancellation of the early warnings given by the first two steps, if the tsunami is not confirmed by wide spread sensors.

These steps are typical about global or large regional tsunami EWS. In case of local or small regional systems several complications are introduced due to the very small lag of time which needs some

other confirmation criteria (sometimes using strong motion devices, GPS measurements, laser interferometer, etc.)
Frequently complex monitoring stations are combined with the DARTs to use more effective the system for the monitoring of the ocean parameters in real or near to real time.

The tsunami EWS have much more possibilities about practical measures such as evacuation for the population and boats threaten. The principle of an evacuation about boats is usually to go in the open ocean (not in bays or behind the wave brackers). The population evacuation follows two ways in case of emergency – “distant” and “higher” or a combination of both. The “distant” evacuation means – “farer-better” and “higher” – means “higher-better”. Both could be performed by pedestrians and/or cars movements.

Examples and EWS applications

The acting seismic warning system operates only in Japan. After five years of preparation, installation and education of the population the EWS operation started during 2007. Several warnings have been issued about strong earthquakes, but the real examination was the event of 11th March 2011. The system worked perfectly and issued warning after the P-waves arrivals to the first registration stations. All warnings have been disseminated by TV, radio, Internet and cellular i-phones, smart-phones, etc. People know about the strong seismic event and all “shinkansen” trains and other facilities like NPP’s and dangerous productions have been switched off. People remembered that after the shaking stopped unusual silence have been registered all over the country, even in such high populated regions like Tokyo and Osaka.

Recently similar systems (much simpler) have been installed in Istanbul (high buildings, hospitals, bridges, etc.), Mexico City and some other mega polices like Santiago and Lima. LA intends to create such a system including mass population which is interested about this issue and like to participate installing simple devices in their owners’ yards, gardens, buildings, etc.

The tsunami EWS have much larger history and development. They started with the Pacific TWES around 1960 with headquarters in Hawaii. Then many other institutions have been included

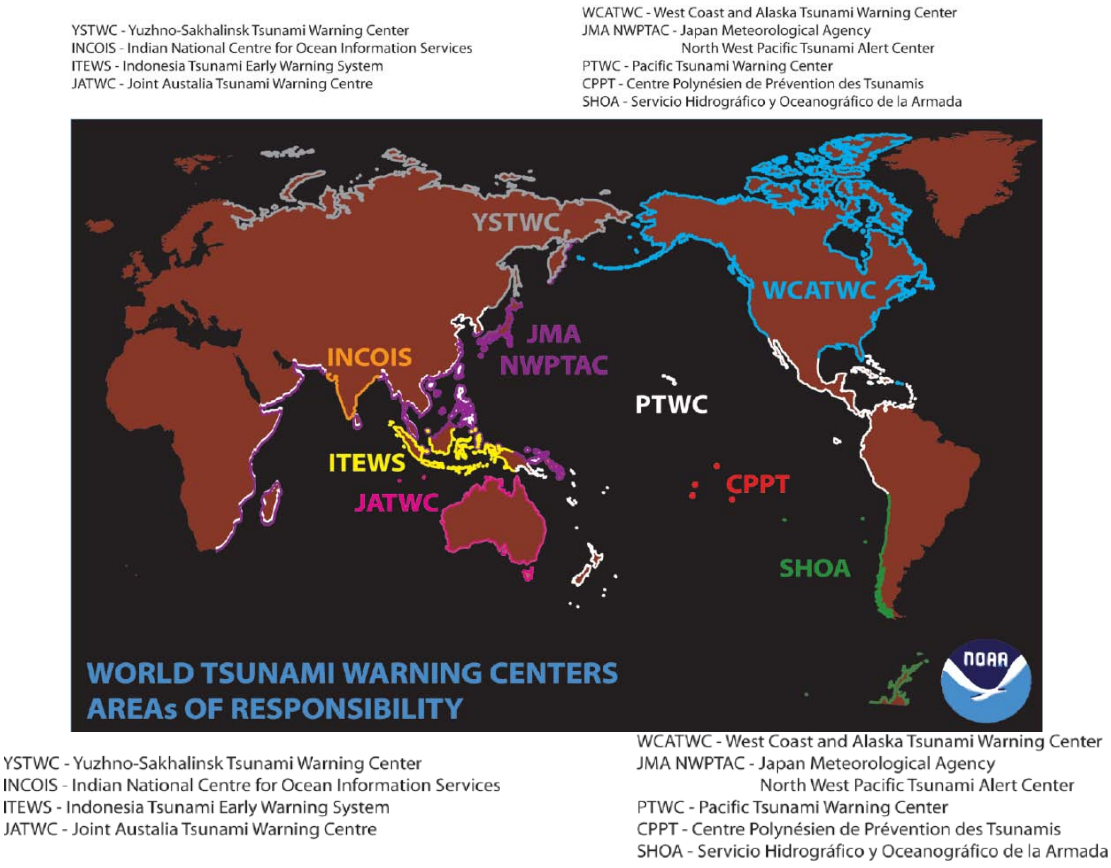

Fig.1. World tsunami warning centers (Internet-NOAA)

Almost all of these centers are equipped with so called DART's – multifunctional complex stations – Fig. 2.

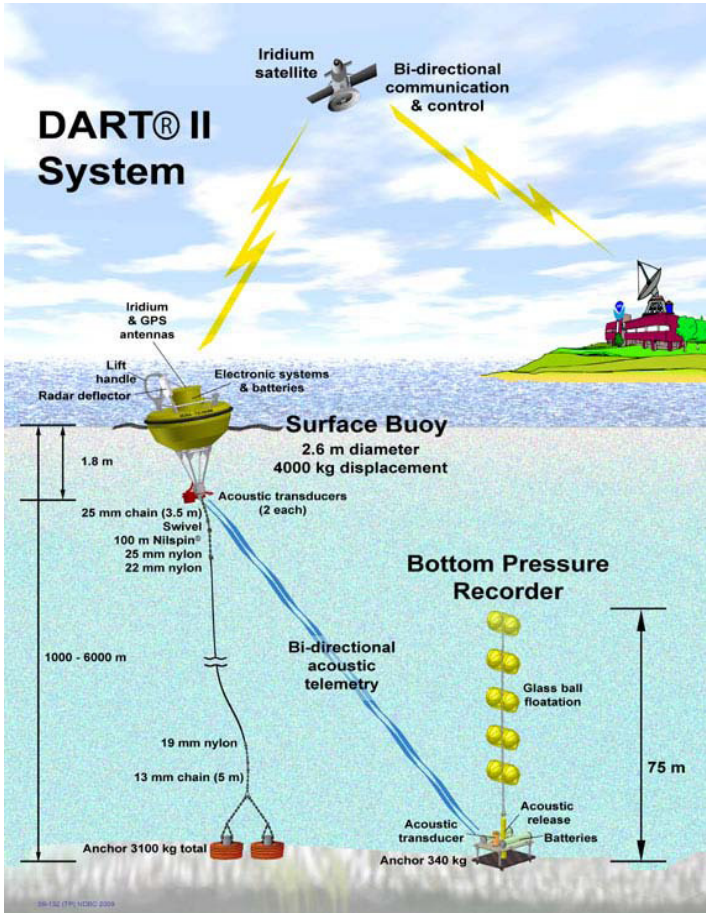

Fig. 2. DART complex tsunami warning station (Internet)

Such stations are deployed all over the Pacific (initially) and spread now in Atlantic and Indian oceans – Fig. 3.

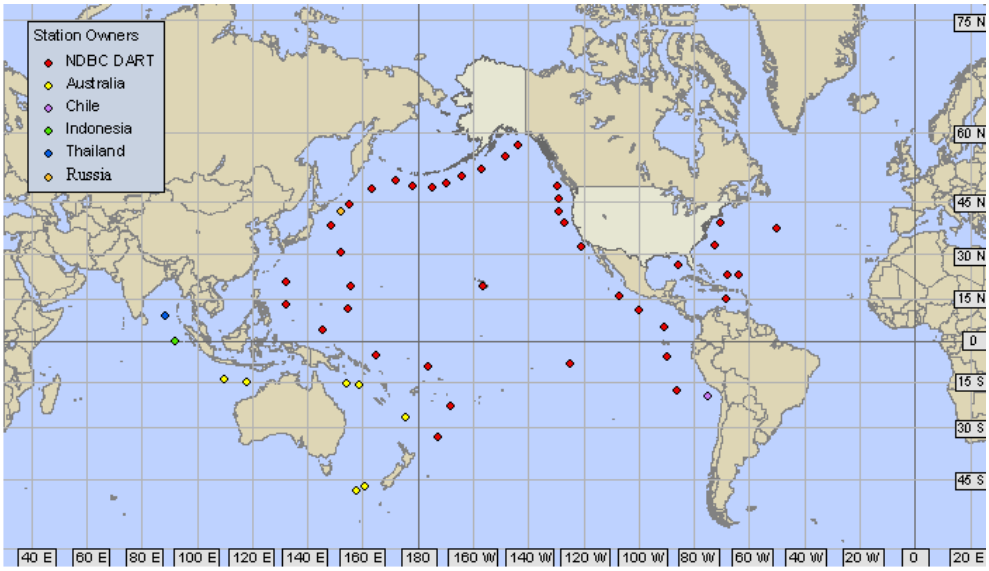

Fig. 3. World DART complex tsunami warning stations (Internet)

The experience and functioning of these systems have been proved during the Japan tsunami of 11 March, 2011. As the epicenter and the tsunami source have been off shore about 130 km from the east coast of Japan, there were about 30-40 minutes before the first arrivals of the tsunami wave reached the costal zone of Japan. During that time the tsunami warning has been announced by the JMA – the local Japan tsunami EWS. As a result a lot of people lives have been saved and several measures applied. Many boats enter the open sea and survive. Many other, which were not prepared to go in the open sea have been washed to the shore. A lot of debris and many smaller structures have been moved by the giant waves. The ocean level changed to 10-12 meters, in some places 9closed bays) – more then 15 -17 meters. This tremendous catastrophe created a lot of damages in the NPP's – Fukushima, oil refineries and metal production factories. The nearest airport was strongly affected. Many bridges, roads and other infrastructures have been heavy damaged. Despite the early warning many people were killed.

Economical calculations and management process about future EWS in Bulgaria

The model about EWS creation is applied to calculate the funds necessary about seismic and tsunamis EWS in Bulgaria. It is considered on simple and rough calculations on the prices of the equipment and the expenses of the staff, as well as the expenses about the maintenance process of the systems:

Seismic EWS:
If 1 Seismic station (SS) costs about 1 000 EUR – if it is a portable autonomic device (together with the installation), then 100 SS cost 100 000 EUR. The staff salaries and maintenance is about 100 000 EUR per year.

Tsunami EWS:
1 complex ocean station (COS) is about 100 000 EUR
10-15 COS are about 1 000 000 to 1 500 000 EUR.
A system of 10-15 GPS receivers is about 100 000 EUR (this is an advantage opportunity to get such stations incorporated in the system).
A system of 10-15 SSM devices also is about 100 000 EUR.
The staff salaries and maintenance is about 200 000 EUR per year.

If such model of calculations is accepted both systems will cost in total about 1.3 to 1.8 MEURO about the equipment and communications (GSM and satellite - doubled for safety reasons) and 0.3MEURO about the staff salaries and maintenance.

Conclusions

The paper deals with a modern and sophisticated tool about people protection and safety measures. EWS are the most advanced systems about people and infrastructure protection and are in use since several years in different countries and under different conditions. Bulgaria is a prone country to seismic and tsunami risk. Such investigations and models can help significantly to improve the safety measures about the population. As shown the EWS are not very expensive tools, but need high educational level of the decision makers and population and a safety use of the EWS. It can be proved only on the national basis and governmental support as well as good communication and coordination between the institutions responsible about the people safety.

The importance of the EWS is significant after the introduction of the new communication technologies – such as i-phones, smart phones, tablets, as they can be used as the very fast communication autonomic and automatic devices providing the necessary information in real time.

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