Romanian Reports in Physics **71**, 704 (2019)

# MONITORING THE BLACK SEA NATURAL HAZARDS USING NEW TECHNOLOGY AND EQUIPMENT

R. PARTHENIU[1,2], C. GHITA[1], V.E. TOADER[1], E. NASTASE[1,2], A. MUNTEAN[1], E. MURAT[1], I.A. MOLDOVAN[1], C. IONESCU[1]

[1] National Institute for Earth Physics, 12 Calugareni Street, Magurele, Romania
E-mails: raluca@infp.ro; cristi.ghita@infp.ro; victorin@infp.ro; eduard_nastase@infp.ro; muntean@infp.ro; edvin@infp.ro; irenutza_67@yahoo.com; viorel@infp.ro
[2] University of Bucharest, Faculty of Geology and Geophysics, Doctoral School of Geology, 6 Traian Vuia Street, Bucharest, Romania

*Received December 4, 2017*

*Abstract*. The Black Sea is prone area to natural hazards: earthquakes, tsunamis, storms, strong winds and other meteorological conditions. In order to monitor them, the National Institute for Earth Physics (NIEP) has installed different types of equipments, implemented into a system that can send warnings for tsunamis and earthquakes generated in the Black Sea. As part of the routine monitoring, the first tsunami early-warning system in the Black Sea was accomplished in 2013, providing sea level and seismic data exchange with the Black Sea surrounding countries. A number of 3 sea level monitoring stations and 7 GPS/GNSS stations are installed in different locations in Dobrogea area. An infrasound micro-barometer, a meteorological station and a vertical electric field monitor were also installed. Various parameters are measured, from water level variations to temperature, wind speed and direction, precipitations, etc. In order to centralize all data, a web portal for worldwide and regional tsunami monitoring was developed (tsunami.infp.ro), with a focus on the Black Sea. Some other objectives of NIEP are to continue monitoring the natural hazards triggered in the area, to increase regional and international collaboration, and to add seismic, GPS/GNSS, sea level and other equipment to the existing network.

*Key words*: natural hazard, Black Sea, earthquake, tsunami.

## 1. INTRODUCTION

The Black Sea is prone area to natural hazards such as storms, earthquakes, strong winds, tsunamis and other meteorological phenomena. In order to monitor them, the National Institute for Earth Physics (NIEP) has installed different equipments and implemented a system that can monitor and send warnings for earthquakes and tsunamis generated in the area.

As part of the routine earthquake and tsunami monitoring activity, the first tsunami early-warning system in the Black Sea has been implemented in 2013. Since then, new seismic and GPS/GNSS stations, sea level measuring equipments and other monitoring devices have been installed. The last four years of experience confirmed the effectiveness of using sea level measurements, which could be used to detect any tsunami before they reach the shore, by issuing automatic warnings to populations at risk in order to facilitate timely evacuations.

The Black Sea surrounding countries had been affected by tsunamis in the past with 22 documented events, triggered by earthquakes and/or landslides. Twelve of these events were generated in the 20th Century. This proves the necessity of continuous monitoring and also an increase of the research in the field. Moreover, an enlargement of the infrastructure for the Black Sea area is necessary and it might be even achieved in the near future.

NIEP is the national institution for earthquakes and tsunamis monitoring, detection and warning, with a wide background in basic and applied researches in geophysics and atmospheric sciences, and focus on seismic source and seismotectonics, seismic hazard and risk assessment, engineering seismology and earthquake prediction.

## 2. EQUIPMENT AND MEASUREMENTS

Numerous measuring devices and equipments were installed in Dobrogea area, in order to monitor the Black Sea natural hazards. There are a total of 17 seismic stations, 3 sea level measuring stations and 7 GPS/GNSS stations (2 on the coast) spread all over the area (see Fig. 1), for earthquake and tsunami monitoring of the Romanian shore.

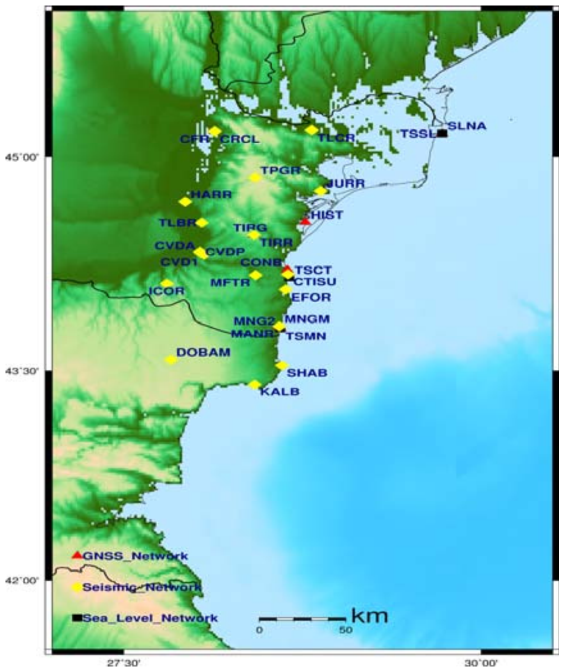


Fig. 1 – Locations of GPS/GNSS, seismic and sea level stations from Dobrogea area.

Other types of equipment such as an MBAZEL-2007 infrasound micro-barometer (Fig. 4), a meteorological station (Figure 5) and a BOLTECK EFM-100 vertical electric field monitor (Figure 6) were added to the seismic sensors in Mangalia and, respectively, the last two in Eforie Nord.

Different parameters are measured, from water level variations to temperature, precipitation rates, wind speed and direction, and other meteorological conditions [9, 10].

The sea level measuring stations were installed with the help and collaboration of the Joint Research Centre (JRC) in 2013, as being part of the "Inexpensive Device for Sea Level Measurements – IDSL" [1, 2]. Each station is equipped with a microwave sea level sensor. The stations have also barometric sensor, temperature and humidity sensors, water temperature sensor, wind speedometer and direction sensor (Fig. 2). The sea level sampling interval is 15 s, but the transmitted data rate is 1 sample per minute (average of 4 samples). All the Black Sea – IDSL stations are connected to the JRC centre through a GPRS system. The data are received at JRC and are sent in real time to NIEP. The data files format is ASCII format. Using locally developed plug-ins, the data is converted to mseed format using SeedLink. All the data are stored in NIEP Antelope database.

Fig. 2 – The sea level measuring equipment from Constanta port.

As for the GPS/GNSS stations, the first GPS permanent station from Dobrogea area was at Histria (HIST) in 2003 and recently the network increased to 7 permanent stations. Two of these 7 stations are located on the coast, being used for tsunami monitoring. The majority of them being equipments produced by Leica Company: GR10, GRX1200GGPro, SR 530 and the GRX1200 + GNSS receivers type and the antenna models used are LEIAT504, LEIAR10 and LEIAX1202GG. We also operate 2 stations with Septentrio equipment with AseRx2e HDC receivers and PolaNt-x MF antennas (Fig. 3). Data acquisition is achieved in real time, in RAW and RINEX DATA format, using Leica GNSS Spider and Septentrio Rx software. Furthermore, some of the network's stations simultaneously record Ring

Buffer data on receiver's internal memory at a rate of 20 Hz. (0.05s) for earthquakes monitoring.

Fig. 3 – GPS/GNSS receiver and antenna located in Mangalia.

The micro-barometer installed is MBAZEL-2007 type (Fig. 4), intended to be used for infrasound monitoring of the atmosphere. The micro-barometer is built around a differential pressure sensor (LPM5481-DRUCK). The differential pressure sensor has its ports connected to two enclosures, having a volume of 500 ml each. Enclosures are connected together through a precision, 16-turns adjustable, Cole-Parmer micro valve, having a maximum air flow rate of 200 ml/minute at 1 bar. The micro-barometer measures the differential pressure between the two enclosures (the input volume and the baking volume). The output signal of the sensor is a voltage between (0 … 10) V, with the midscale at 5 V. This signal is high-pass filtered with an RC circuit, consisting in a 2200 μF capacitor and a 10 kΩ resistor. The circuit has a cut-off frequency of approximate 10 mHz. The differential pressure range is between (–50 …50) Pa, that is 100 Pa full-range, resulting in a sensibility of 100 mV/Pa.

Fig. 4 – The MBAZEL-2007 micro-barometer.

Another instrument installed, for meteorological parameters monitoring, is a digital meteorological station (Fig. 5). Some recordings and its scheme are presented in Fig. 3. The station is providing different data such as: temperature (ºC), absolute pressure (hPa), relative humidity (%Hr), wind speed and direction (km/h), precipitations rates.

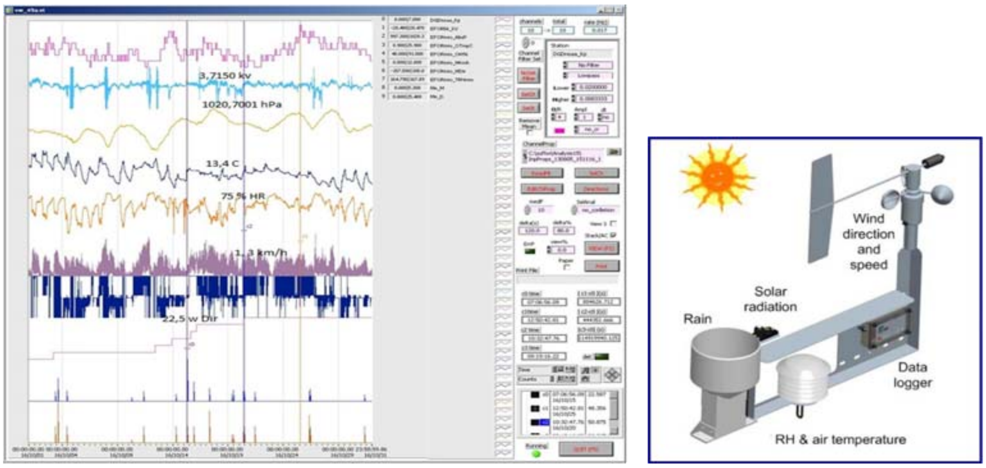


Fig. 5 – Digital meteorological station recordings and scheme.

Fig. 6 – The BOLTECK EFM100 electric field mill installed at Eforie Nord.

Measuring the static electric field generated by thunderclouds, the BOLTECK EFM-100 installed at Eforie Nord, at Dobrogea Seismological Observatory, not only detects nearby lightning, but can detect the atmospheric conditions which precede lightning.

In Fig. 7 there are some examples with the high amplitude electric signals variations at the Dobrogea Observatory, in comparison with the recordings from Plostina site (Vrancea Seismogenic zone). The huge differences between the atmospheric electric field intensities recorded in the two different sites, the first one at Dobrogea Observatory (DOB-RO) and the second one at Plostina (PLOR4), Vrancea, can be easily seen. The graphics for August and September 2010 in both recording sites are compared. In the DOB-RO graphics we can see a very large variation of the electric field intensity, on the whole time interval and not specifically related to some stormy days like in the PLOR4 figures.

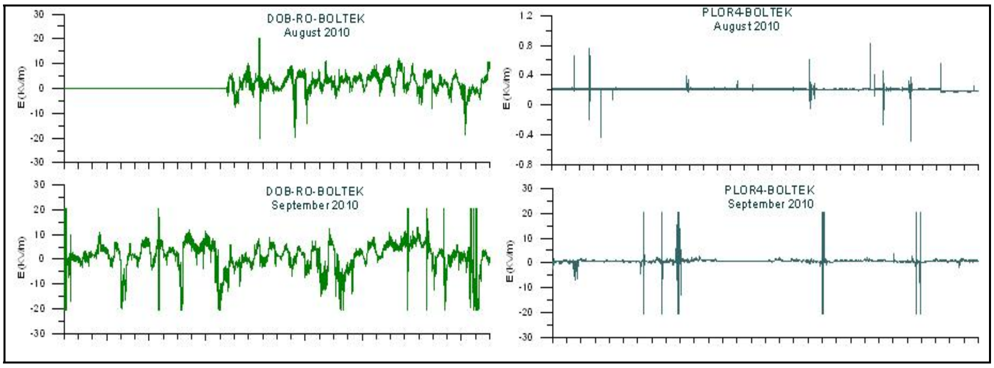


Fig. 7 – Electric field recordings at Eforie Nord and Plostina sites.

As one can see, for DOB-RO there are long period variations of 10 days and amplitudes changes from (–20 ... 10) kV/m. Moreover, the high frequency noise is also very large, about 4–5 kV/m from 40 kV/m (the recording scale) means 20 dB. Besides the extremely unstable character of this electric intensity variations (long and short period variations of the amplitudes in the whole values domain), we can observe that the atmospheric electric field recorded at DOB-RO has also a diurnal variation. A possible explanation is related to the high voltage power lines situated at less than 1 km distance from our recording site and the cultural electric fluctuations depending on the variable power consumption on this electric grid along a day [5].

The weather and the tectonic conditions are also influencing the time evolution of the electric field intensity. In next figures we have selected for example only some stormy days/hours, to show how lightning affect the electric recordings. We can see the moment when the charged clouds are approaching, passing above and going away from the electrometers, producing electric field intensities with values between (–20 ... 20) kV/m (Fig. 8).

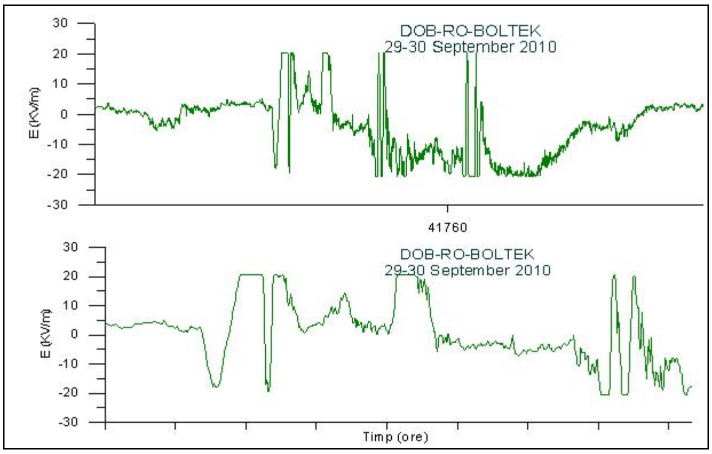


Fig. 8 – Examples of lightning signatures on the electric field recordings.

## 3. NATURAL HAZARDS MONITORING

As mentioned before, the earthquake and tsunami monitoring activity implies the existence, since 2013, of the first tsunami early-warning system from the Black Sea area, being active during these last years. The workflow of the system is presented in Fig. 9.

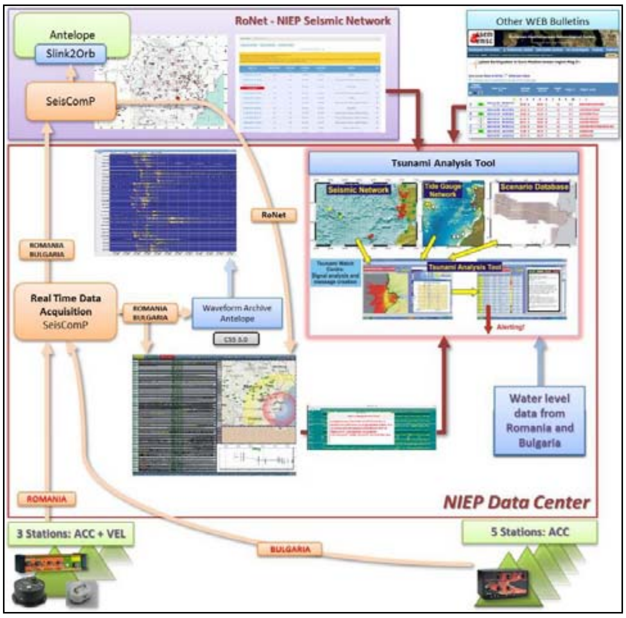


Fig. 9 – Earthquake and tsunami warning system workflow.

The system involves the acquisition of the seismic data through SeisComP and Antelope software, and together with data from other similar Centers or other sources (such as web-portals), the seismic real time data acquisition goes to the Tsunami Analysis Tool software, where tsunami simulations are accomplished and also sea level data are evidenced. Using the seismic and sea level data, and also information from the simulations, a better and improved monitoring of the phenomena is in progress.

A web portal for worldwide and regional tsunami monitoring was developed by NIEP (tsunami.infp.ro), mostly with a focus on the Black Sea area (Fig. 10).

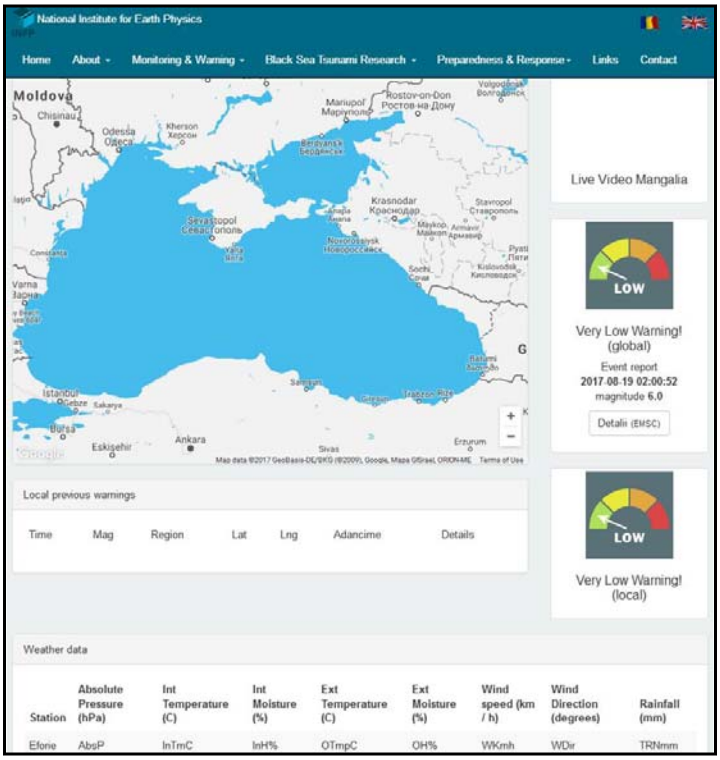


Fig. 10 – Regional tsunami warning portal implemented by NIEP.

The data are directly stored and also made available in real time at international level, on other profile websites and portals [3].

As an evidence of the seismic activity in the Black Sea area, all the events from January 2004 to June 2017 are displayed in Fig. 11. It can be observed that the activity is higher in the western part, with locations close to the Romanian and Bulgarian shores. The danger is quite obvious for future earthquakes followed by damages and casualties. However, the magnitudes of the events are not very high, from 1 up to 5, but the earthquakes are shallow (generated at depths lower than 30–40 km) and might trigger other related hazards.

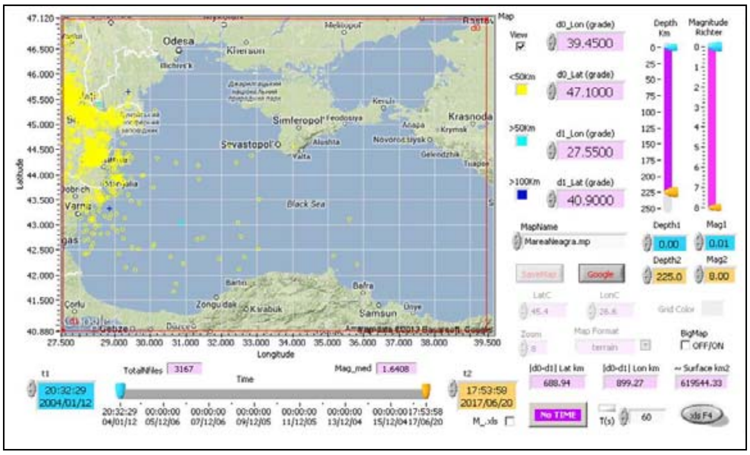


Fig. 11 – Location of earthquakes triggered between 2004-2016 in the Black Sea.

## 4. CASE STUDY

In order to exemplify the whole benefits of the monitoring facility and acquisition of different types of data, a case study for an earthquake in Turkey area will be displayed in the following pages [4].

The example is given for a recent earthquake from offshore Turkey (Black Sea), triggered on 15th of October 2016, at 08:18:33 UTC, 10 km depth, located 196 km from Istanbul and 124 km from Zonguldak, with a magnitude $M_l = 5.3$ and $M_w = 5.1$, displayed in Fig. 12.


Fig. 12 – Location and Intensity of the earthquake from 15.10.2016 (source: CSEM-EMSC).

The fault plane solution for this event was computed to be reverse fault and the maximum estimated intensity was 4.

The recording of the P arrival of HHZ channel for this event, at Mangalia seismic station, is displayed in Fig. 13.

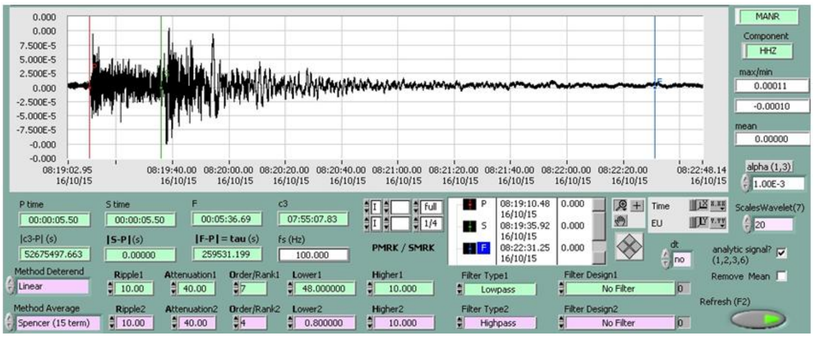


Fig. 13 – P arrival at Mangalia station, for the 15.10.2016 earthquake.

Infrasound data for 15th of October 2016 are shown in Fig. 14, with a detail around the time of the event. There is no obvious anomaly at the time of the earthquake in the monitored fields [7].

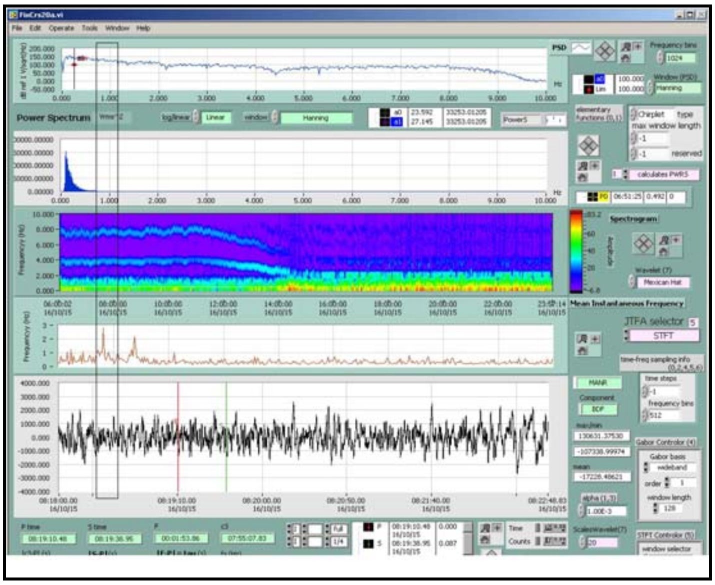


Fig. 14 – Infrasound recordings from Mangalia station on 15.10.2016.

Figure 15 displays the recordings of the 3 sea level stations (Mangalia, Sulina and Constanta), on October 2016, with an evidence for the date of the event.

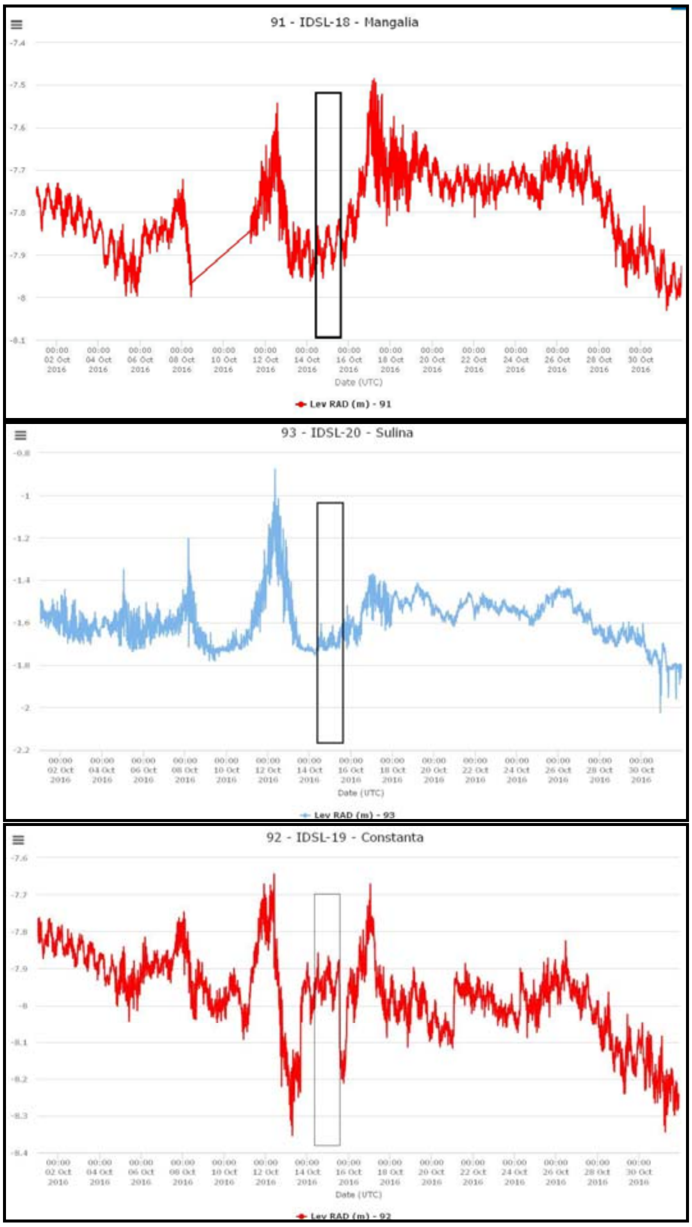


Fig. 15 – Sea level variations for October 2016, at Mangalia, Sulina and Constanta stations.

There is no evidence of any disturbance in the sea level variation on 15th of October at the time of the earthquake's generation, thus no tsunami waves were triggered for this event. Considering past studies and estimates [6, 8], only earthquakes with a normal or reverse fault plane solutions can trigger tsunami waves. Moreover, other conditions for tsunami generation are magnitudes higher than 6.0 and a shallow depth.

## 5. CONCLUSIONS

Monitoring the Black Sea natural hazards, mainly earthquakes, tsunamis, storms, strong winds, etc, is one of the main activities of the National Institute for Earth Physics. A complex system has been installed and implemented since 2013, using different types of equipments in order to monitor and send warnings for tsunamis and earthquakes generated in the area.

The detection performance of the system has been improved during these last 4 years, by adding new equipment and new measuring stations in strategic locations along the shore-line. A total of 17 seismic stations, 3 sea level measuring devices and 7 GPS/GNSS stations, an infrasound micro-barometer, a meteorological station and a vertical electric field monitor are installed in Dobrogea area.

A case study for an earthquake of magnitude $M_l$ = 5.3 generated offshore Turkey on 15th of October 2016, at 08:18:33 UTC, was presented and exemplifies the available measurements and capacity of Black Sea natural hazard detection. For such magnitude, no tsunami waves were generated.

The Institute is increasing the regional and international collaboration in the field of natural hazards monitoring and plans to add new seismic, GPS/GNSS, sea level stations and other types of equipments to the already existing network.

***Acknowledgements.*** This work was partially supported by: the FP7 FP7-ENV2013 6.4-3 “Assessment, Strategy And Risk Reduction For Tsunamis in Europe” (ASTARTE) Project 603839/2013 and PNII, Capacity Module III ASTARTE RO Project 268/2014, the “Global Tsunami Informal Monitoring Service – 2” (GTIMS2) Project, JRC/IPR/2015/G./2006/NC 260286, Ref. Ares (2015) 1440256 – 01.04.2015, the Nucleu Program, supported by ANCSI, projects no. PN 16 35 01 06, PN 16 35 03 01, and the Partnership in Priority Areas Program – PNII, under MEN-UEFISCDI, DARING Project no. 69/2014. We also acknowledge the support, help and collaboration of the Joint Research Center, from the European Commission, Ispra, Italy.

## REFERENCES

1. A. Annunziato, P. Probst, *Continuous Harmonics Analysis of Sea Level Measurements: Description of a new method to determine sea level measurement tidal component*, Publisher: Publications Office of the European Union, EUR28308 EN, doi:10.2788/4295 (2016).
2. M. Bavaro, D. Galliano, A. Annunziato, J. Fortuny, *GPS Sea Level Measurement Device*, Publications Office of the European Union, doi:10.2788/785155 (2016).
3. S. Consoli, R. D. Reforgiato, V. Zavarella, *A Survey on tidal analysis and forecasting methods for tsunami detection*, Science of Tsunami Hazards **33** (1), 1–56 (2014).
4. U. Hancilar, *Identification of elements at risk for a credible tsunami event for Istanbul*, Nat. Hazards Earth Syst. Sci. **12**, 107–119 (2012).

5. I.A. Moldovan, A.P. Constantin, P.F. Biagi, D. Toma Danila, A.S. Moldovan, P. Dolea, V.E. Toader, Maggipinto T., *The development of the Romanian VLF/LF Monitoring System as part of the International network for frontier research on earthquake precursors (INFREP)*, Romanian Journal of Physics **60** (7–8), 1203–1217 (2015).
6. I.A. Moldovan, M. Diaconescu, E. Popescu, M. Radulian, D. Toma-Danila, A.P. Constantin, A.O. Placinta, *Input Parameters for the Probabilistic Seismic Hazard Assessment in the Eastern Part of Romania and Black Sea area*, Romanian Journal of Physics **61**, 1412–1425 (2016).
7. I.A. Moldovan, V.E. Toader, A.S. Moldovan, D. Ghica, A.P. Constantin, *Spectral Investigation of infrasonic signals recorded on the Romanian Black Sea coast*, 17th International Multidisciplinary Scientific GeoConference (SGEM 2017) **17**(14), 405–413 (2017).
8. I.A. Moldovan, M. Diaconescu, R. Partheniu, A.P. Constantin, E. Popescu, D. Toma-Danila, *Probabilistic Seismic Hazard Assessment in the Black Sea area*, Romanian Journal of Physics **62**, 809 (2017).
9. V.E. Toader, I.A. Moldovan, A. Marmureanu, C. Ionescu, *Detection of Events in a Multidisciplinary Network Monitoring Vrancea Area*, Romanian Journal of Physics **61**, 1437–1449 (2016).
10. V.E. Toader, I.A. Moldovan, A. Marmureanu, P.K. Dutta, R. Partheniu, E. Nastase, *Monitoring of Radon and air Ionization in a seismic area*, Romanian Reports in Physics **69**, 709 (2017).