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TSUNAMI VULNERABILITY ALONG THE WESTERN BULGARIAN BLACK SEA COAST - FROM THE HISTORICAL REVIEW TOWARDS MULTIDISCIPLINARY ASSESSMENT APPROACH

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Content

- The research area – our focus is the Black Sea region
- Analysis of performed investigations of collected data and information
- Main results from preliminary analysis
- Limitations and future research
- Discussion and conclusions

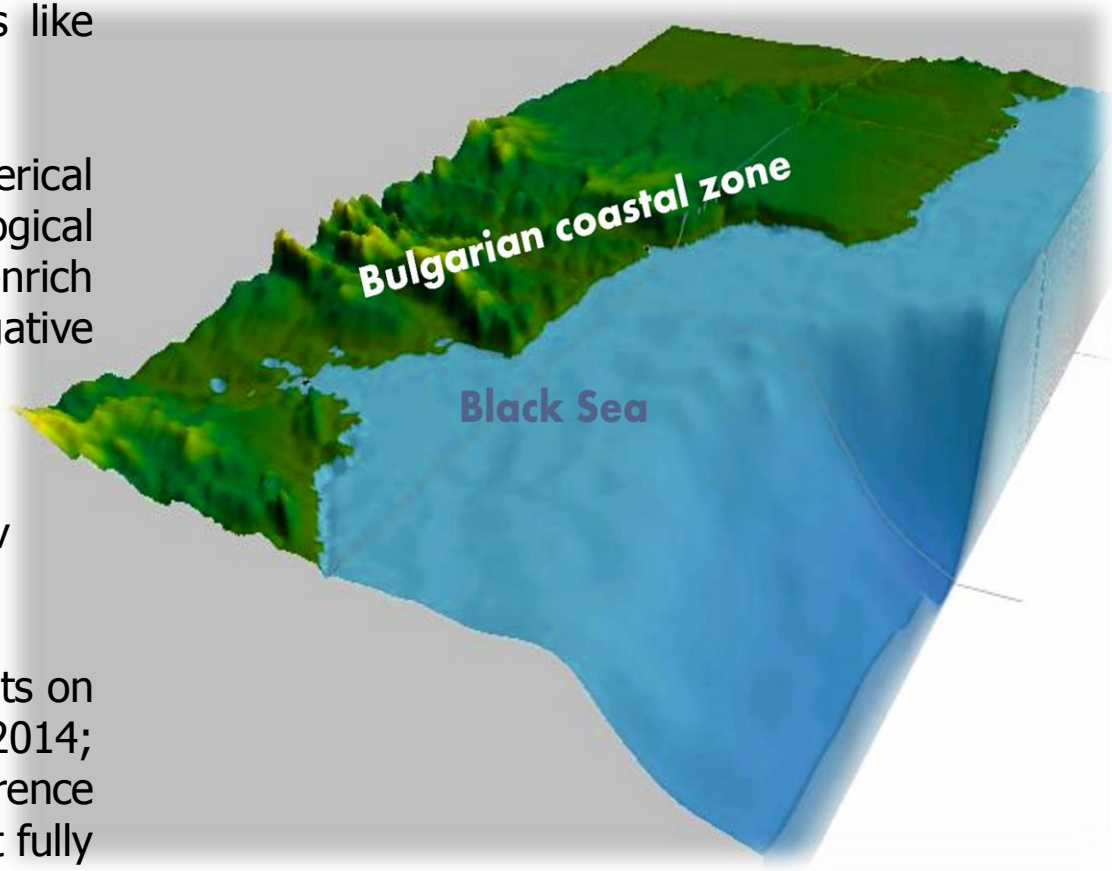
Introduction

- An overview of historical information can help for a better understanding of the main factors that lead to extreme events like tsunamis despite their rare happening in the Black Sea.

- Improving the accuracy and increasing the resolution of numerical models of land and seabed topography, as well as new methodological approaches to the analysis of the geological environment, enrich scientific knowledge and opportunities to prevent negative consequences of such events by building early warning systems.

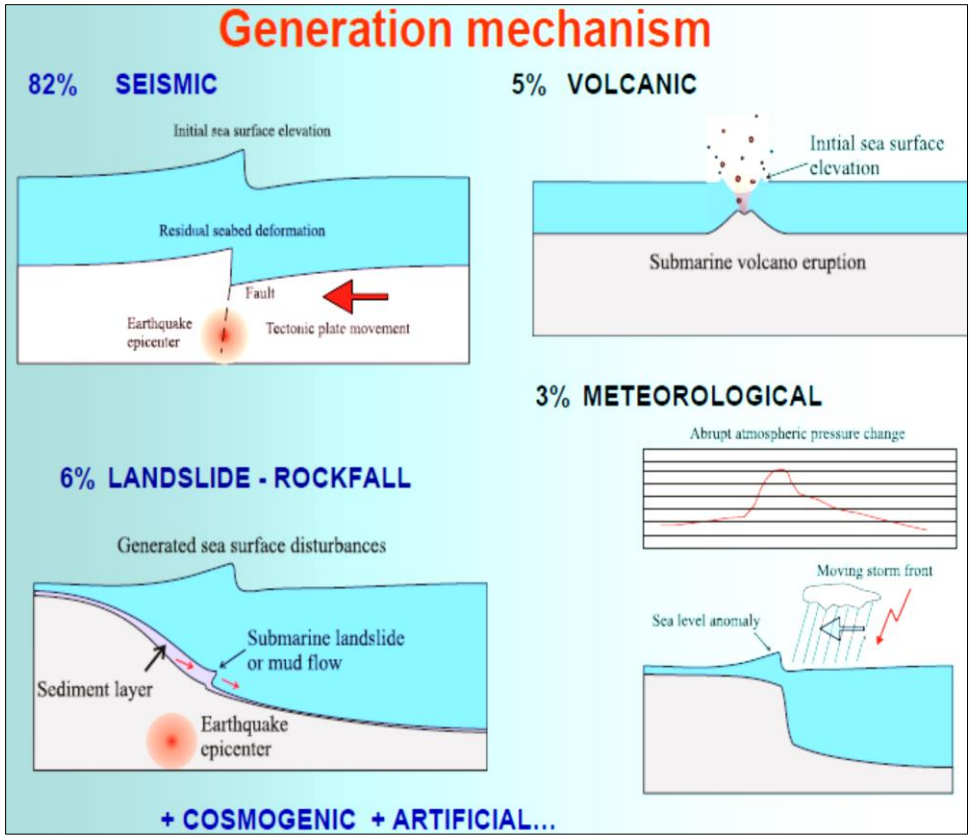
- Studies on the potential danger of tsunamis along the Bulgarian Black Sea coast have been conducted since the 1980s (Ranguelov and Mardirossian, 2009)

- Interdisciplinary studies focused on mapping and dating past events on the Black Sea coast (Yalciner et al., 2004; Papadopoulos et al., 2014; Rabinovich, 2020), determining the causes, frequency of recurrence and current prospects for occurrence (risk) of tsunamis are not yet fully clarified or are in their infancy for the Bulgarian Black Sea coast.



Research objectives

- Contribute to improving scientific knowledge of tsunami waves regionally and nationally by evaluating, comparing, refining and documenting methods for hazard analysis and risk assessment, the associated uncertainties and the cascading effect in the Black Sea region
- Analysis of available DEM models in the Bulgarian Black Sea coastal zone
- Multidisciplinary studies focused on mapping and dating past events on the Black Sea coast, determining the causes, frequency of recurrence, and current prospects for tsunamis occurrence (risk) are not yet fully clarified or are in their infancy
- Contribution to the improvement of national methodologies for risk assessment in the coastal zone, e.g. Flood hazard methodology
- Improving the spatial and temporal resolution of the input data in numerical tsunami modeling
- Filling in the gaps in the data collected for past events and documented by registration at sea level via TG along the Bulgarian coastal zone
- QA/QC of the Bulgarian TGs records covering observed tsunami events in the Black Sea after 1928 until 2012 (from analogue paper marigrams) and after 2013 (from digital records)



http://www.theplasmaverse.com/pdfs/meteorological-tsunamis-destructive-atmosphere-induced-waves-observed-in-the-worlds-oceans-seas-seiches-abiki-milghuba.pdf

Preliminary analysis of collected data and information

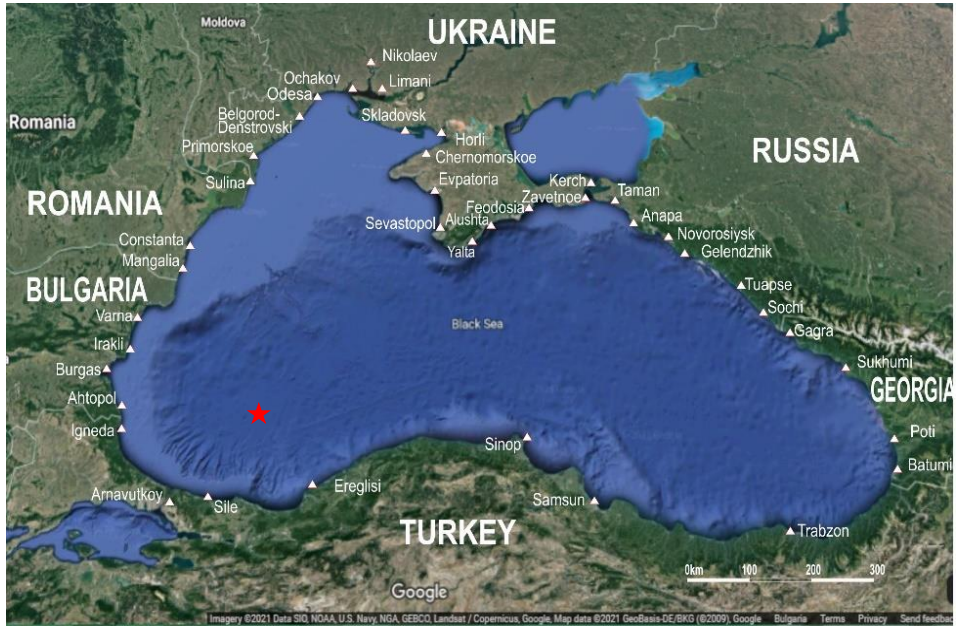
- **Tsunami modelling**
- In most simulations of the tsunami on the western Black Sea coast (Dimova, 2018; Dimova & Raykova, 2018; 2019), synthetic tidal amplitudes and a vertical water column on land have been calculated at certain points, without being verified with data from actual registrations at sea level.
- **Seismic data**
- Collection of all earthquakes for the Black Sea region [40^{0}N:48^{0}N; 26^{0}E:42^{0}E] from various catalogues in the period 1905 - 2021 with magnitudes M ≥ 3 and their analysis as potential seismic sources of tsunamis (See **EGU21-8278** Poster)
- For comparisons with TG data – List of earthquakes registered with M>5 for the region [40^{0}N:48^{0}N; 26^{0}E:42^{0}E] and verification of available marigrams after 1928 – 134 events are identified

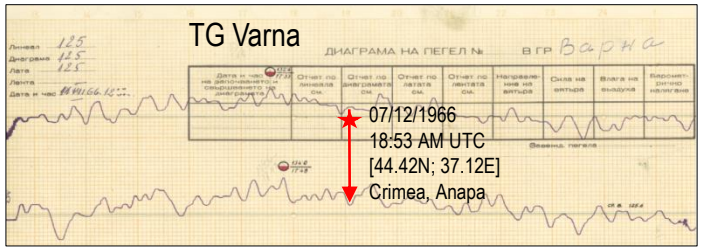
Date	Time	Magnitude	DOY	Longitude	Latitude	Depht
26-Sep-19	10:59:00	5.7	269	28.1900	40.8700	7.0
28-Oct-18	0:56:00	5.6	301	26.3588	45.6244	150.6
15-Oct-16	8:18:00	5.1	289	30.6900	42.2000	10.0
23-Sep-16	23:11:00	5.7	267	26.6200	45.7100	92.0
22-Nov-14	19:42:00	5.5	326	27.1511	45.8563	35.0
22-Nov-14	19:14:00	5.6	326	27.1600	45.8700	39.0
6-Oct-13	1:37:00	5.3	279	26.6900	45.6400	134.0
28-May-13	0:09:00	5.2	148	41.5800	43.2200	2.0
23-Dec-12	13:31:00	5.7	358	40.9800	42.5800	10.0
7-Jun-12	20:54:00	5.1	159	27.9200	40.8500	14.0
3-Nov-10	2:51:00	5.3	307	26.3000	40.4300	10.0
25-Apr-09	17:18:00	5.3	115	26.6300	45.7000	96.0
27-Oct-04	20:34:00	6	301	26.7700	45.8300	76.0
6-Jul-03	19:10:00	5.7	187	26.0240	40.4450	17.1
9-Nov-02	2:18:00	5.5	313	37.7680	45.0030	10.0
20-Jul-01	5:09:00	5.3	201	26.7340	45.7490	128.6
6-Jun-00	4:11:00	5.5	158	32.8431	40.7496	25.9

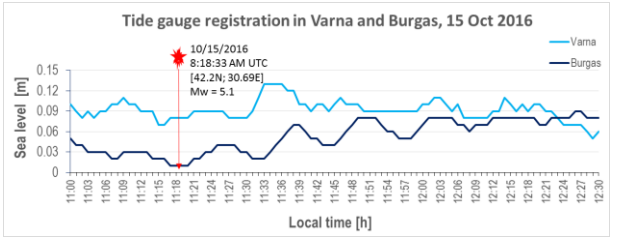
Results – analysis of Bulgarian TG data

- Collection, verification and digitization of analogue marigrams for the Bulgarian geodetic TGs with continuous registration of the Black Sea level in case of earthquakes after 1928
  - ✓ Varna (from 1928 to the present day)
  - ✓ Irakli (1970-2006)
  - ✓ Burgas (1928-2018)
  - ✓ Ahtopol (1970-2001)
- Digitalization of old hard-copy records (marigams) for earthquakes events happened to analyze the registered sea level height by TGs for the period 1929 – 2013 – in progress
- Analysis of the digital registration at sea level of radar TGs installed in 2013 in Varna and Burgas.

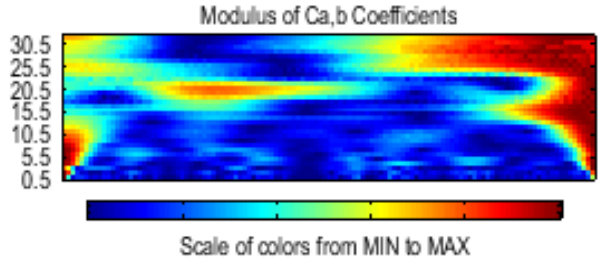
TGs along the Black Sea coast



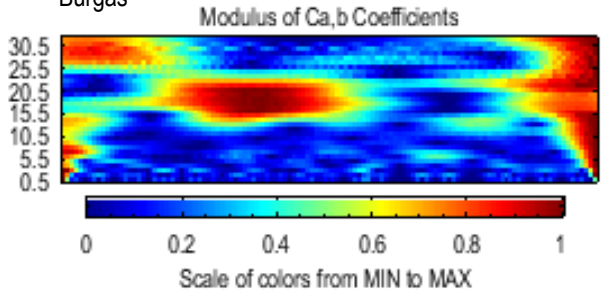




Varna



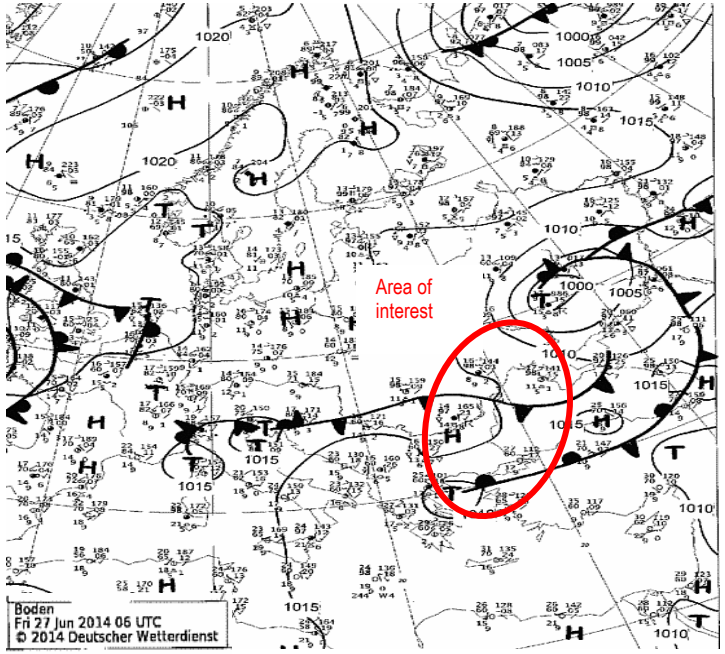
Burgas

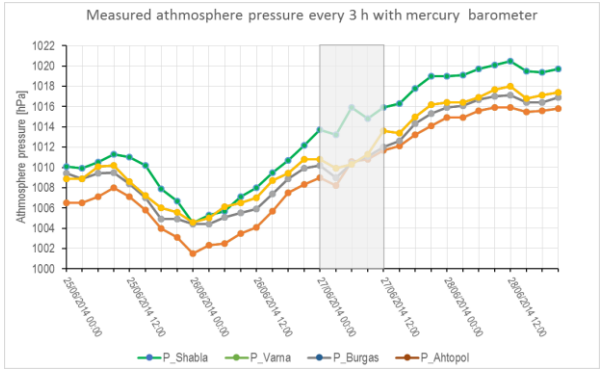


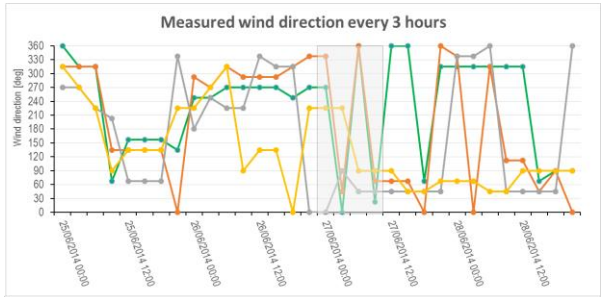
Filling the research gap – case study

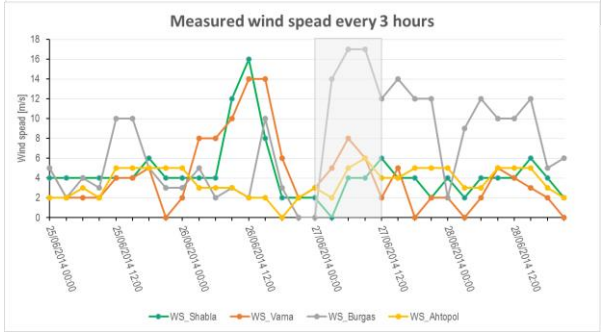
I. A case study of the meteotsunami on June, 25-27 2014 (Šepić et al.,2015) - different interpretations of unusual phenomena on 7 May 2007 near Balchik, northern Bulgarian coast line: due to earthquake, marine landslide and seishe

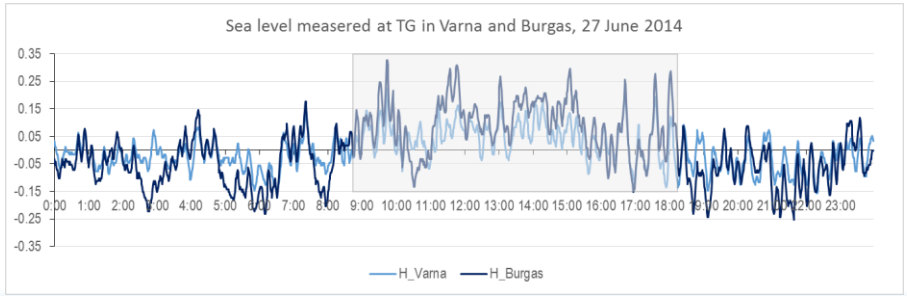
- Analysis of collected data - description of sea-level variability combined with an analysis of meteorological data
  - A cold cyclone front system crosses the Black Sea from the north starting on 26.06.2014 leading to an increase of the wind speed between 18h on 26.06 and 06h on 27.06 and small-scale instability lines in atmospheric pressure
  - Atmospheric pressure and wind measured in 4 meteorological stations – Shabla, Varna, Burgas and Ahtopol
  - Sea level oscillation at TGs in Varna and Burgas on 27 June 2014

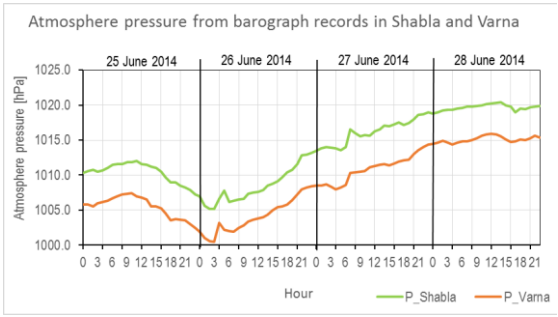






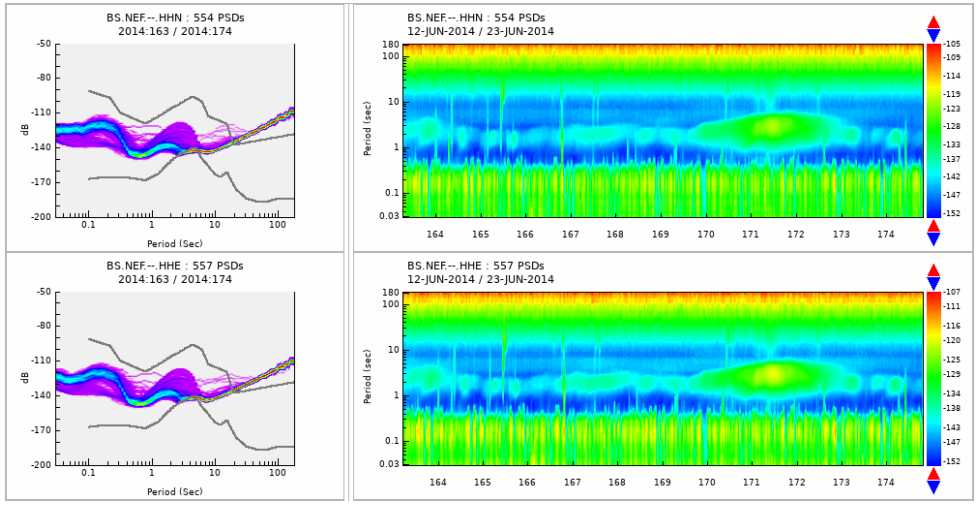


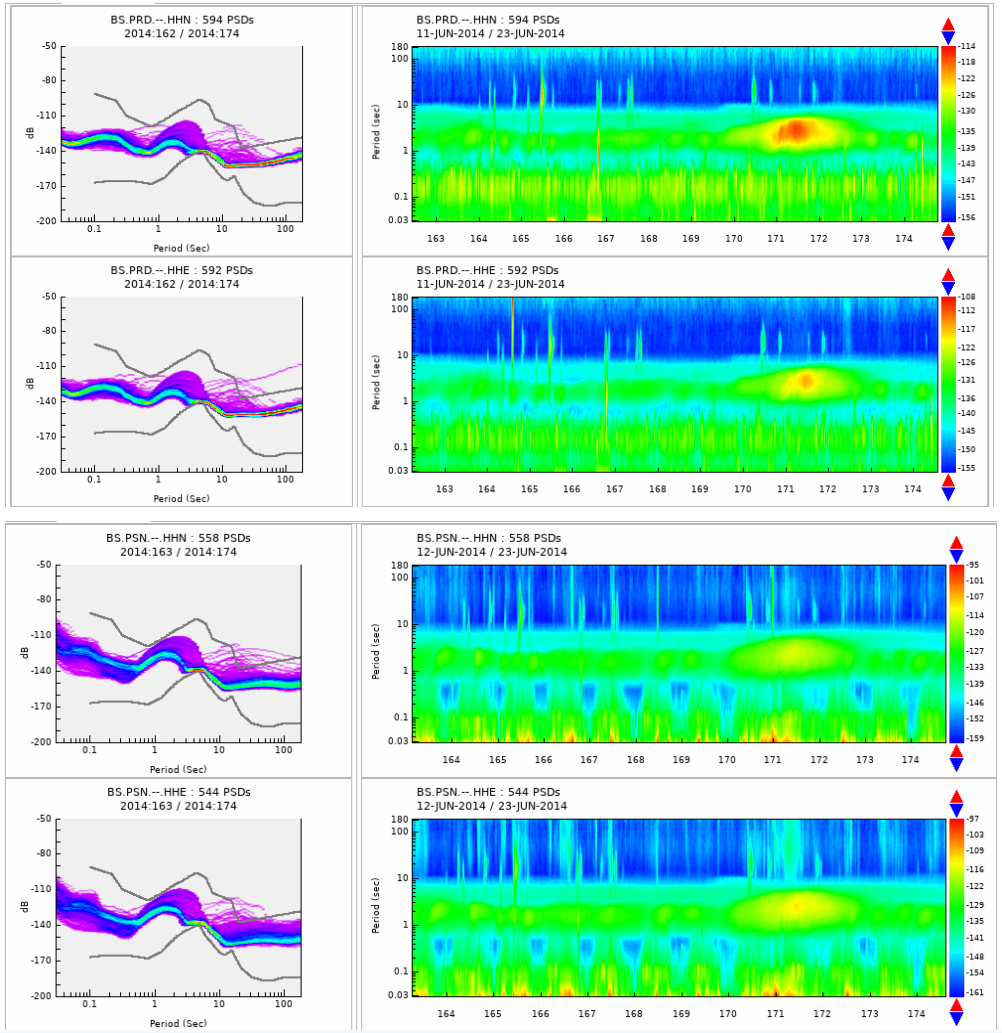




Filling the research gap – case study

- Determination of seismic noise in three Bulgarian seismic stations located near the northern Black Sea coast, before the meteosunami on June 25-27, 2014.



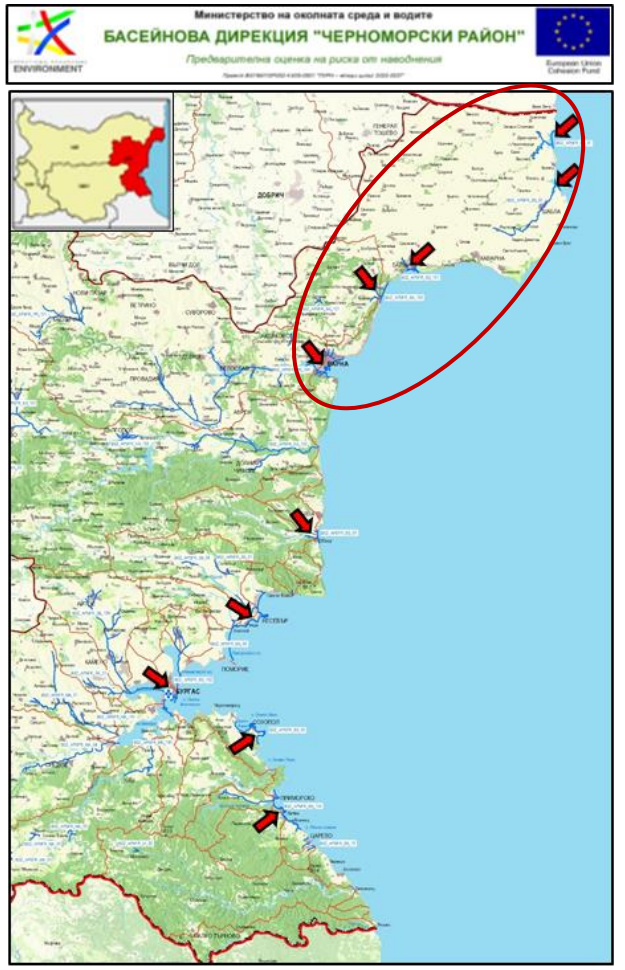


Main inferences from preliminary analysis

- **General conclusions**
  - ✓ Despite the research projects implemented for the marine geohazards in the Black Sea region, there is a lack of publically accessible information in Bulgaria about such risks for the coastal zone
  - ✓ Tsunami simulation for the Bulgarian coastal zone are in the initial stage due to some difficulties in providing data with the necessary detail and accuracy, such as active faults, parameters of earthquake mechanisms, high precision DEMs, etc.
  - ✓ Temporal accuracy is not enough to catch up the peculiarities of the happened events, i.e. tsunami generated by earthquakes, meteorological conditions, submarine landslides or another source
  - ✓ the available research infrastructure provides data with different spatio-temporal resolution and with some gaps, which hampered their comparison and joint analysis
- **For seismic data**
  - ✓ The compiled catalogue (1905-2021) has fullness to be used for analysis of the seismicity, seismic sources and geodynamic in the region of the Black Sea and surroundings.
  - ✓ Function based tsunami hazard estimates recurrence of historical tsunami heights.
- **For geodetic and TD data**
  - ✓ DEM for land and seabed topography with high spatial and vertical resolution are needed for the Bulgarian coastal zone
  - ✓ The available DEMs , e.g. EMODnet; https://www.emodnet.eu/en/bathymetry are not accurate enough for high-precision tsunami modeling
- **Meteorological data**
  - ✓ The manifestation of meteorological tsunamis phenomenon occurring due to sudden changes of the atmospheric pressure and strong winds depends on the orientation of the coast relative to the direction of atmospheric cyclones' movement.

Future work

- Preliminary studies of the available DEM and bathymetry data sets for specific coastal locations show that they currently need to improve the spatial and vertical resolution in the APSFR.
- A test study by UAV of one APSFR in the northern Bulgarian coast is planned (one of 10 coastal areas determined as APSFR (FRD, 2007/60/EC) along 378 km of Bulgarian coastline according to an updated PFRA, 2020) for obtaining high-precision DSM/DEM for further tsunami simulation.
- Comparison of the calculated run-up for selected places in the Bulgarian coastal zone by numerical simulation using different tsunami software
- Some consideration regarding the available and newly establish research infrastructure in the western Black Sea are also discussed.
- Organization of collected data and information for tsunami hazard events in QGIS GeoDatabase.



https://www.bsbd.org/bg/index_bg_965885.html

Recommendations for improving research results

- Good spatial coverage and distribution of in situ stations on the land and in offshore
  - ✓ Modernization of the sparse and undeveloped research infrastructure along the Bulgarian Black Sea area
  - ✓ Sustainable maintaining the installed digital sensors for long-term monitoring of geophysical, geodetic, oceanographic and meteorological parameters; Avoiding duplication of the installed equipment on the land and in the offshore
  - ✓ Establishing of co-located permanent TG@GNSS@MET stations (Pashova & Yovev, 2010) for long-term monitoring in real-time
  - ✓ Distribution of seismic stations in the Black Sea region, suitable for reliable determination of focal mechanisms of earthquakes
  - ✓ Access to archived and in real-time data from built stations for determining the parameters of the marine environment (http://masri.io-bas.bg/)
  - ✓ Necessity of in-depth scientific morphotectonic studies of active faults in the western Black Sea basin, e.g. as suggested by Radulov (2020)
- Interdisciplinary collaboration between scientists from different geosciences disciplines for delivering scientific evidence required to sustainable marine planning
- The application of advanced multidisciplinary methods could improve the elucidation of potential tsunami hazard along the Bulgarian coastal zone

Conclusions

- A database of past and recent tsunami events and their impact in the Bulgarian Black Sea coastal region is in the process of being established.
- The optimization and modernization of the monitoring infrastructure, providing early warnings for extreme events are a prerequisite for sustainable management of the Bulgarian coastal zone.
- Effective preparedness for DRR in the Bulgarian Black Sea coastal region - capacity to catalyze and attract stakeholders
- Developing Web-based emergency management & early warning systems

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