

Tsunami research in Bulgaria: recent developments, gaps and further directions

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Main goal

- The work
 - ✓ reviews and systematizes main achievements in the field of tsunami research in Bulgaria,
 - ✓ defines the available gaps and deficiency,
 - ✓ provides some recommendations, and outlines the prospects for future Black Sea tsunami research

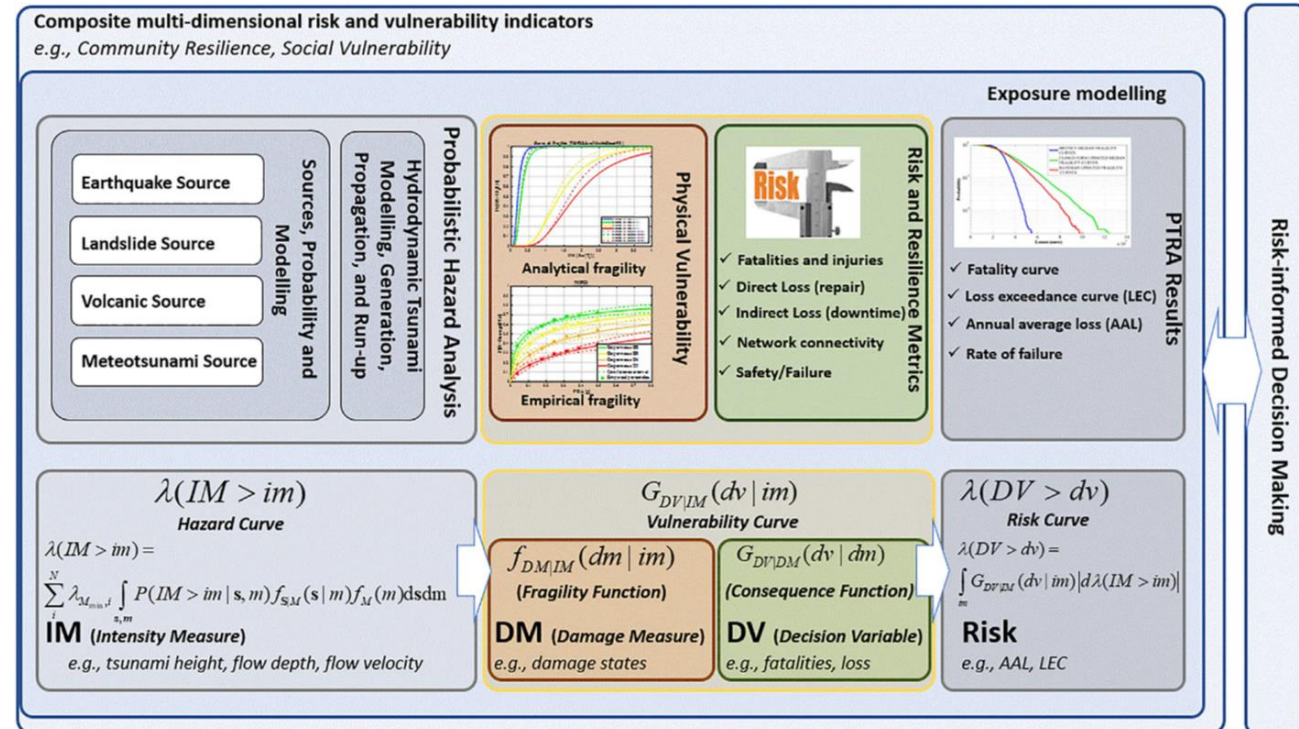
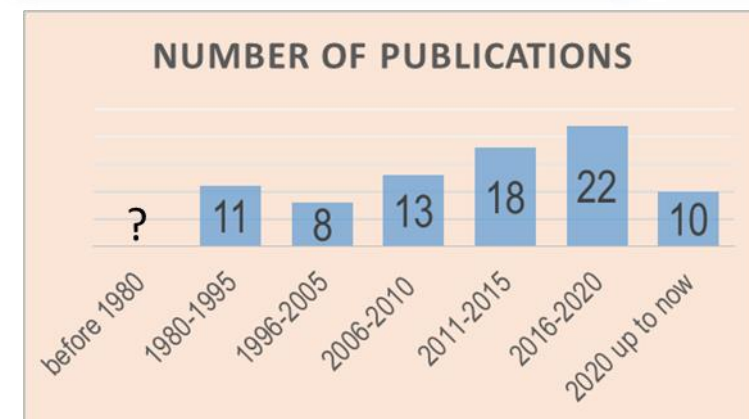


Fig.1: Roadmap of PTHA and PTRa frameworks (Behrens et al., 2021)

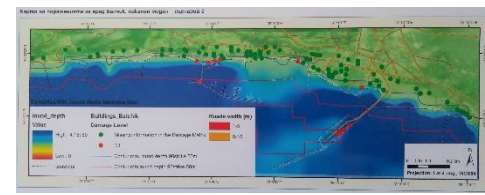
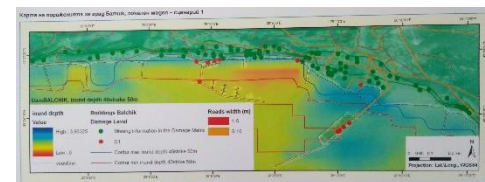
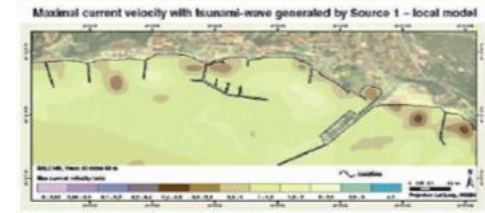
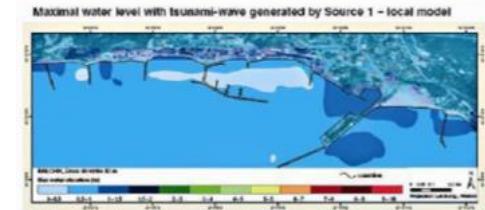
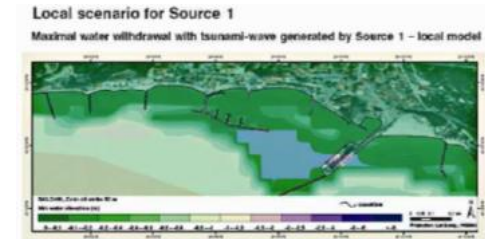
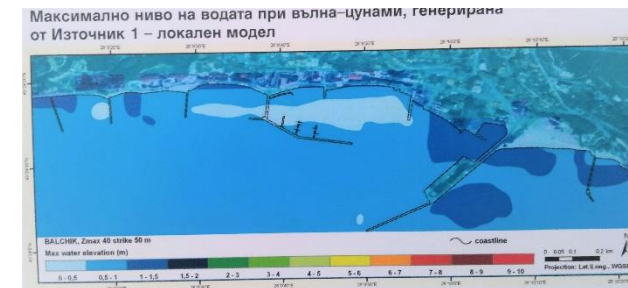
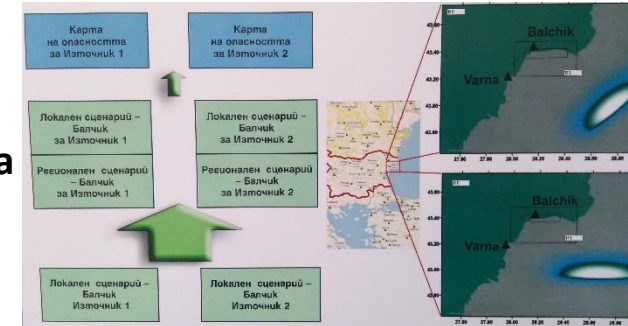
Main developments and achievements

- International, bi-lateral and national research projects related to tsunami research - GITEC-TWO (1996-1998), TRANSFER (2006-2009), SCHEMA FP6 EC (2007-2010), MARINEGEOHAZARDS (2010-2013), CABARET (2016-2019), etc.
 - ✓ Contribution to the collection of historical data about the tsunami events registered along the Bulgarian coastal zone: research started in the 80th of last century
 - ✓ Initial Identification, characterization and mapping of tsunami sources in close vicinity to the Bulgarian coast
 - ✓ Analysis of the historical tsunami events and their source
 - Earthquake
 - Landslide
 - extreme hydro-meteorological events
 - and other sources
 - ✓ Initiate the establishment of a tsunami early warning system (TEWS) on the western Black Sea coast
 - ✓ Tsunami modelling using different scenario and data inputs:
 - earthquake sources (mainly), faults geometry, DEM of land&sea bottom, etc.
 - ✓ Research publications – more than 80



Main developments and achievements

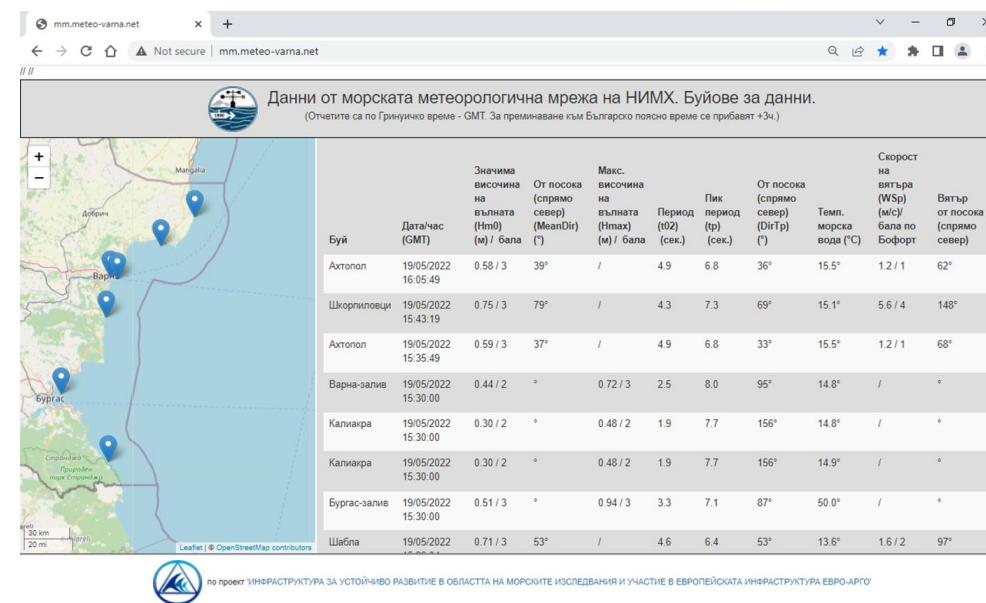
- Preliminary research of the tsunami hazards and risk assessment
 - ✓ Tsunami modelling along the Bulgarian coast (**Atlas for test sites Varna and Balchik, 2010**) - credible worst-case scenario approach applied to the Balchik test site (SCHEMA project)
 - ✓ Vulnerability and risk analyses performed in selected test site Balchik based on chronology and Intensity scale (Papadopoulos & Imamura, 2001 - on the right panel)
 - ✓ Probabilistic approach applied to risk zonation: the Balchik test site (SCHEMA project) – determined inundation line and risk zonation
 - ✓ Identification of possible underwater landslide offshore - computed maximum water elevation of the possible induced tsunami based on selected scenario – event
 - ✓ On some places close to the Bulgarian coast are performed swath bathymetry imaging and high-resolution mapping of marine sediments – **still not oriented to tsunami generation studies**
 - ✓ Establishing TEWS along the western Black Sea
 - ✓ Detailed tsunami numerical simulations for the region of northeast coast of Bulgaria using UBO-TSUF2 software tool (Dimova et al., 2017)



Main developments and achievements

- Improvements of the research infrastructure
 - ✓ installation of new tide gauge (radar sensors) in Balchik, Varna, Shkorpilovtsi, Pomorie and Burgas, which registered 1-minute sea-level variations
 - ✓ installation of several buoys for extreme meteorological, seismic and tsunami monitoring in real-time - not all of them are active

<http://mm.meteo-varna.net/>; bgodc.io-bas.bg/sofar-buoys/



МАСРИ
ИНФРАСТРУКТУРА ЗА УСТОЙЧИВО РАЗВИТИЕ В ОБЛАСТТА НА МОРСКИТЕ ИЗСЛЕДВАНИЯ,
ОБВЪРЗАНА И С УЧАСТИЕТО НА БЪЛГАРИЯ В ЕВРОПЕЙСКАТА ИНФРАСТРУКТУРА (EURO-ARGO)

СИСТЕМА ЗА НАБЛЮДЕНИЕ НА ВЪЛНЕНИЕТО

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Местоположение	Време (UTC)	Температура на водата (град. C)	Вълнение (бала)	Височина на вълната (м)	Посока вълна (град.)	Скорост на вятъра (м/сек)
Шабла (НИМХ)	19.05.2022 08:29:04 ч.	11.66	3	0.99	50.128	6
Варна залив (НО-БАН)	17.05.2022 17:34:55 ч.		3	0.56	181.536	5.6
Шкорпиловци (НО-БАН)	19.05.2022 08:43:19 ч.	14.96	3	0.72	59.76	5.6
Емине (НИМХ)	05.11.2021 22:17:49 ч.	15.1	2	0.41	128.306	5.6
Ахтопол (НИМХ)	19.05.2022 09:05:49 ч.	14.96	3	0.83	37.103	5.6

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Identified gaps

- Research gaps

- ✓ Need for significant improvements in research infrastructure (seismological, GNSS, geophysical and other sites) - avoiding duplication of the installed equipment on the land and in the offshore
- ✓ Some difficulties in providing data with the necessary detail and accuracy, such as active faults, parameters of earthquake mechanisms, high precision DEMs, etc.
- ✓ Low efficiency of the tsunami modelling and simulation due to the limited spatial and temporal accuracy of the input data
- ✓ Incomplete, difficult to access and scattered information about past tsunami events due to the different sources of origin on the Bulgarian coast
- ✓ due to the small number and poorly documented events, it is difficult to assess the danger and risk of tsunamis - it is estimated on the basis of the repetition of historical heights of tsunami waves along the coast
- ✓ Gaps in tsunami hazard and risk analysis – lack of spatial data with needed accuracy for 3D modelling (e.g. BIM&GIS integration modelling)

- Institutional gaps and deficiency

- ✓ Lack of good coordination, communication and cooperation between stakeholders, incl. scientific organizations, government institutions, business organizations, insurers, NGOs, etc.
- ✓ Missing publically accessible information in Bulgaria about tsunami risks for the Bulgarian coastal zone
- ✓ Lack of the respective legislation about early warnings

Future perspectives

- In near perspective
 - ✓ Complete the inventories: tsunami events, paleotsunamis, seismic sources (faults and zones), non-seismic sources (especially landslides in seismic areas)
 - ✓ Performing UAV surveying for detailed DEM of the land&bathymetry of one test site along the Bulgarian coast
 - ✓ Better understanding of tsunami generation processes
 - ✓ Development of tsunami real-time observation systems and integration with the management of the coastal zone
 - ✓ Exploitation of technical solutions provided for the marine seismic and tsunami stations to other Black Sea sites
 - ✓ Improve and validate numerical codes for landslide-induced tsunamis
 - ✓ Special attention and research of nonseismic tsunamis – asteroid impact, meteotsunami, etc.
 - ✓ Improve and validate models to address inundation in the complex inland environment (e.g. with account for buildings, infrastructures, ...)
 - ✓ Necessity of in-depth scientific morphotectonic studies of active faults in the western Black Sea basin
 - ✓ Analysis of tsunami hazard-to-risk in a multi-risk dimension and integrated into the management of the coastal zone
 - ✓ Explore methods for tsunami forecasting in view of the TEWS implementation in the Euro-Mediterranean region
 - ✓ Exploration and destabilization of the sensitive spots on the coast due to the refraction, coastal and bathymetry influence
- In the long-term timeframe
 - ✓ Improvement of methods for early tsunami detection and warning
 - ✓ Extend hazard-to-risk analyses to all coastal areas under a tsunami threat
 - ✓ Explore and develop viable countermeasures against tsunami attacks and define codes for buildings and plants on exposed coasts
 - ✓ Define standards for vulnerability and risk analyses
 - ✓ Outreach and education on tsunamis for the Bulgarian coastal communities
 - ✓ Developing Web-based emergency management & early warning systems

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