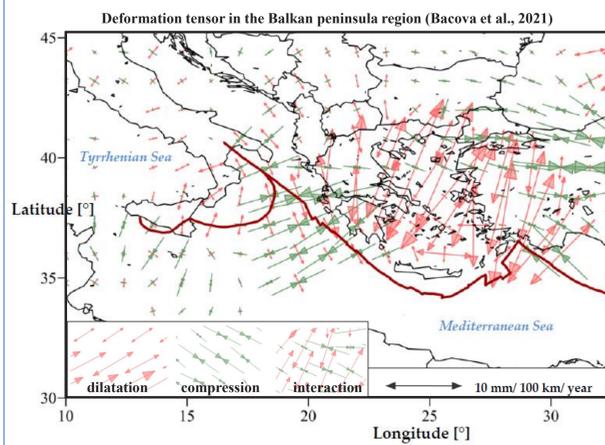


Investigation of the focal mechanisms of earthquakes with magnitude $M \geq 4$ in the territory of Bulgaria and its surroundings

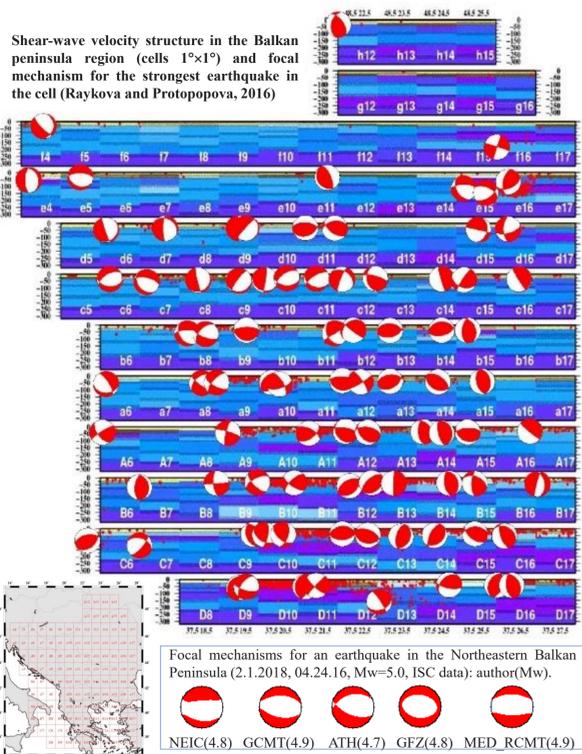
Project guidelines

The main goal of the project is the determination of the mechanisms of earthquakes on the territory of Bulgaria and its surroundings in the last 10 years (magnitude $M \geq 4$), applying the nonlinear method for inversion of the seismic waveforms INPAR (Sileny et al., 1992). Analysis of the obtained information will give an idea of the modern geodynamic processes in the studied area. An additional goal of the project is the expansion of the seismic network of Sofia University with a broadband seismic station, the records of which will be used to analyze the mechanisms of earthquakes on the territory of Bulgaria and its surroundings.

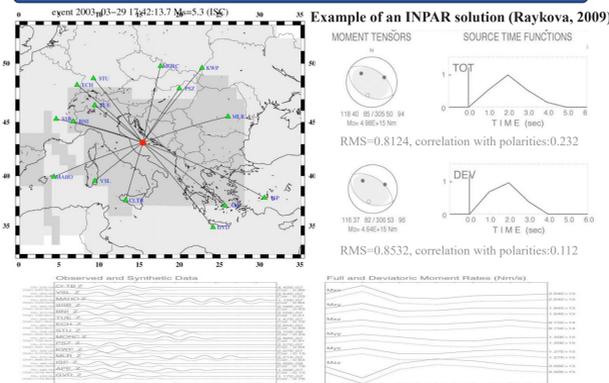


Introduction

The mechanisms of destruction in earthquake foci are the main indicators of the ongoing geodynamic processes in the Earth's tectonosphere. Knowing them in areas with a complex and unclear geodynamic situation, such as the Balkan Peninsula and Bulgaria in particular, is essential for clarifying the ongoing geodynamic processes. In global seismic practice, the mechanisms of $M \geq 5$ earthquakes are determined (www.globalcmt.org, rcm2.bo.ingv.it) using global velocity models for the Earth with poor accuracy for shallow earthquakes. For the territory of Bulgaria, a study of the focal mechanisms of earthquakes was conducted until 2013 (V. Protopopova, PhD thesis 2015, NIGGG of the Bulgarian Academy of Sciences), using the FOCMEC methodology. This method uses data on the first arrivals of seismic waves and has some significant drawbacks: it needs a large number of stations around the focus, the first arrivals can contain significant inaccuracies caused by seismic noise. The Earth's crust is the most heterogeneous part of the Earth's structure both horizontally and vertically. Knowledge of the velocity structure of the Earth's crust is essential in determining the depth of earthquakes, and hence the mode of fracturing in the earthquake source. Another issue is that different seismic centers use varying sets of stations and methods, often resulting in significant differences in the focal mechanisms assigned to the same earthquake.

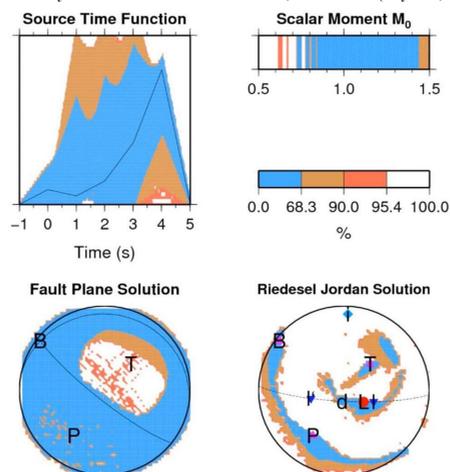


Methodology



The INPAR method is one of the few methods for determination of the focal mechanisms of regional and local earthquakes with magnitude $M < 5$, with a limited number of seismic stations that recorded the corresponding event. It has been successfully applied in the region of Vrancea (Romania), the Shetland Islands (Antarctica), Egypt, Italy, etc., and the magnitude threshold of the studied events reaches values below $M = 2$. The method is very suitable for the territory of Bulgaria, where the magnitude of earthquakes in the past 40 years rarely exceeds 5. The expansion of the seismic network of Sofia University with a broadband seismic station will improve the coverage of the territory of Bulgaria with seismic stations and will provide high-quality records for scientific analysis. The methodology includes the preparation of the necessary input information: catalog of earthquakes; seismic records; velocity model of the medium beneath each station and between the earthquake and the station. Processes in the Earth are non-linear, and the method implements calculation of theoretical seismograms and comparing them with observed ones. The best fitting model is tested for robustness of the solution. The seismic moment and the temporal function of destruction in the seismic source are calculated - basic parameters for understanding the fracturing processes. An analysis of the obtained earthquake mechanisms will determine the main trends in the geodynamics of the studied area.

The probability distribution of the INPAR solution, shown above (Raykova, 2009)



Research project: 70-123-265/2024.

Research field: Earth physics



Head of the research project
Assoc. Prof. Reneta Raykova

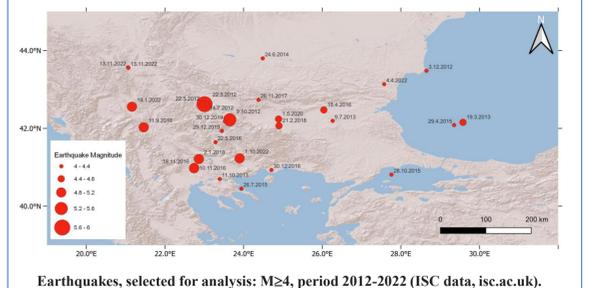
Members of the group

PhD Lyuba Dimova

Student Elitza Pandourska

Results

The project started in March 2024. Since then, we have been examining and selecting a number of earthquakes for analysis. Additionally, we have been exploring the feasibility of acquiring waveform data from seismic stations with open access. The majority of these stations belong to the Virtual Seismic Network of Sofia University. However, over time, some stations have stopped providing waveform data, necessitating the inclusion of new stations. Unfortunately, only three Bulgarian stations (operated by NOTSSI and NIGGG of BAS) have freely distributed data, and during the study period (2012-2022), two of them encountered registration issues. We are compiling a list of stations and corresponding time ranges to request from NIGGG-BAS to study seismic processes in earthquake sources within Bulgaria and its surroundings.



EVENTID	TYPE	AUTHOR	DATE	TIME	LAT	Lon	DEPTH	DEPFX	AUTHOR
601031496	de	ISC	22.5.2012	0:00:32.47	42.6205	23.0074	10.8		MOS
601031499	fe	ISC	22.5.2012	1:30:50.00	42.6251	22.9694	6.5		NEIC
601273332	fe	ISC	14.7.2012	12:52:07.00	42.6229	23.0849	11.1		MED_RCMT
601996003	fe	ISC	3.12.2012	18:58:40.00	43.4808	28.6509	22.3		MED_RCMT
602709710	fe	ISC	19.3.2013	12:44:30.00	42.1544	29.579	12.2		MED_RCMT
603229895	fe	ISC	9.7.2013	17:12:01.00	42.1942	26.265	8.4		NEIC
609095921	ke	ISC	11.10.2013	5:15:48.00	40.6978	23.3933	8.6		NEIC
604760254	ke	ISC	24.6.2014	19:39:54.00	43.7983	24.487	12.1		NEIC
607260605	ke	ISC	29.4.2015	4:40:53.00	42.0837	29.3537	15.5		AFAD
607507340	ke	ISC	26.7.2015	18:40:43.00	40.4511	23.9439	11.6		AFAD
607996442	ke	ISC	28.10.2015	16:20:02.00	40.8119	27.7602	0.9		AFAD
613407262	ke	ISC	18.4.2016	6:46:14.00	42.473	26.0406	3.6		AFAD
608816431	ke	ISC	22.5.2016	8:58:32.00	41.6431	23.2877	7		AFAD
609439166	ke	ISC	11.9.2016	13:10:07.00	42.0259	21.4598	11.3		ROM
615025364	ke	ISC	10.11.2016	12:12:43.19	40.9803	22.7441	13.3		BJI
615046661	ke	ISC	18.11.2016	23:22:48.04	40.9742	22.7396	10.5		BJI
609941717	ke	ISC	30.12.2016	1:56:25.00	40.9304	24.7087	10.3		AFAD
611533558	ke	ISC	26.11.2017	19:01:32.00	42.7338	24.38	12.7		AFAD
611614918	ke	ISC	2.1.2018	04:24:17.29	41.212	22.864	12.4		ISC
611703383	ke	ISC	21.2.2018	23:41:59.00	42.066	24.9	9.3		AFAD
617004562	ke	ISC	29.12.2019	17:36:53.00	41.9341	23.4486	16.5		AFAD
617005826	ke	ISC	30.12.2019	18:01:41.00	42.1803	23.5272	9.3		AFAD
618213868	ke	ISC	1.5.2020	11:01:39.00	42.2389	24.8899	11.3		AFAD
636149680	se	TIR	19.1.2022	16:50:58.00	42.556	21.161	15	TRUE	TIR
625793593	ke	MOS	4.4.2022	10:59:38.00	43.134	27.577	7		AFAD
636889302	se	JSO	1.10.2022	1:25:29.00	41.23	23.9	750		JSO
625210842	ke	BEO	13.11.2022	4:44:42.00	43.566	21.063	5		TIR
625210834	ke	BEO	13.11.2022	4:57:18.00	43.558	21.071	5		TIR

Conclusion

The expected scientific contributions include two scientific publications, as well as the construction of a seismic station with a broadband seismometer, expanding the scientific research opportunities of the Seismological Network of Sofia University. A student and a young scientist participate in the project, which guarantees the transfer of knowledge and skills during the implementation of the project.

The expected results during the first stage of the project is the publication of an article in the Journal "Review of the Bulgarian geological society (WoS) with a summary study of the velocity structure of the Earth for the region of Bulgaria and its surroundings. During the second stage of the project, the data from the analysis of the seismic stations will be published in Reports of the Bulgarian Academy of Sciences (Scopus). An extended version of the publication in BAS Reports will be submitted for publication in the International Journal of Geophysics.

CONTACTS:

Assoc. prof. PhD Reneta Raykova (rreykova@phys.uni-sofia.bg)
Physicist PhD Lyuba Dimova (lyuba_dimova@phys.uni-sofia.bg)
Bachelor student Elitza Pandourska (elitzapiano@gmail.com)
Address:
Meteorology and Geophysics Department
Faculty of Physics, Sofia University "St Kliment Ohridski"
5 James Bourchier Blvd., 1164 Sofia, Bulgaria

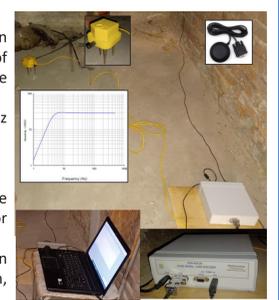
Recent state of the seismological network of Sofia University

Seismic station FzF (SU)

The station began operating on September, 11th 2023 in the basement of building V at the Faculty of Physics. The equipment consists of:

- three-component Geophone 4.5 Hz seismometer
- digitizer PSA-ADS24, Webtronics
- GPS antenna for time receiving
- portable computer with the software WinSDR (www.seismicnet.com) for registering and archiving data.

Geographic coordinates of the station are 42.67°N, 23.33°E, altitude: 597 m, sampling rate of the data: 100 samp/s



Second seismometer

Seismic set "Velbox" (Sara EI) consists of a 0.2 Hz seismometer SS02 and a digitizer SLO6 with internal memory and pre-installed software SeismoNEX. At present the equipment is installed in the same location at the Faculty of Physics and it is working as seismic station FzF_10 from 23.10.2023.