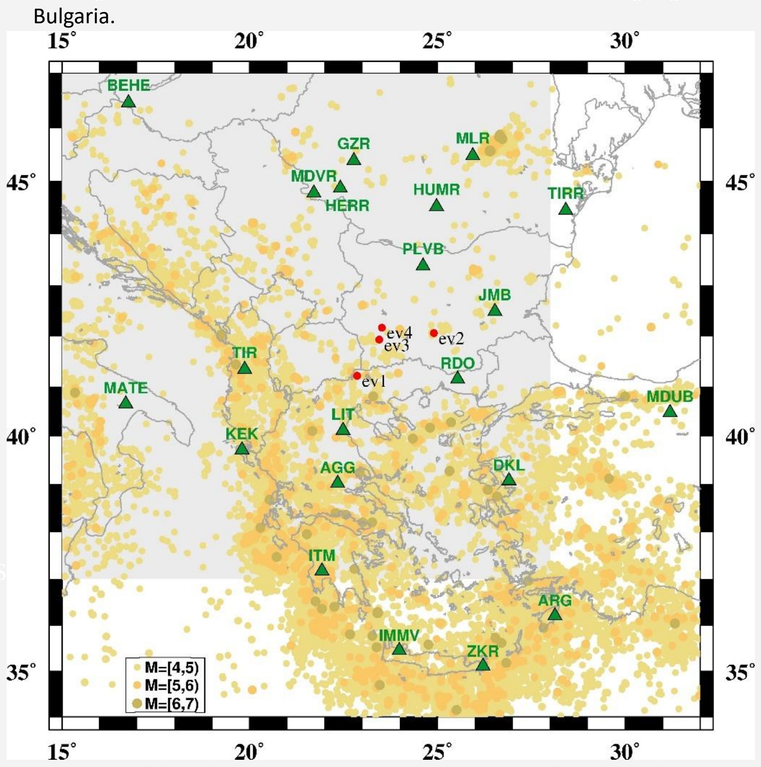
Research Group 3.4 project 70-123-265

Research Area GEOPHYSICS

Focal mechanisms: first results by application of INPAR method in Bulgarian region

INTRODUCTION

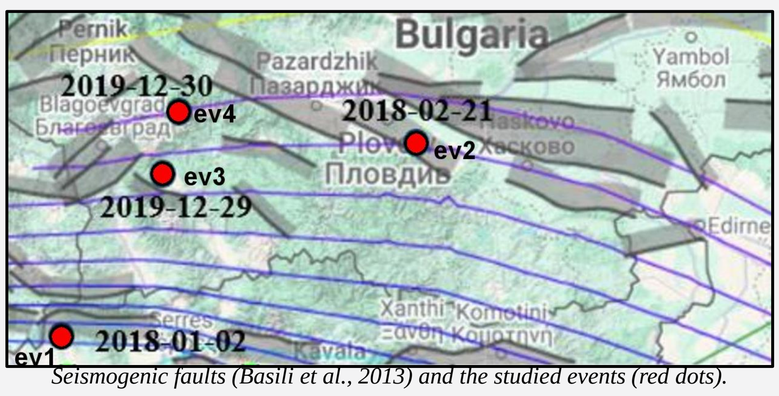
This study presents the focal mechanisms of several moderate earthquakes (4 < M < 5) in Bulgaria and its surroundings obtained by applying the nonlinear INPAR method for the inversion of a limited number of seismic waveforms. The applied methodology includes the preparation and standardization of the necessary input information: catalogs of earthquakes, seismic records, velocity structure of the medium beneath each station, each event, and the average model between each earthquake and station. Since seismic processes are non-linear, the INPAR method involves calculating theoretical seismograms and comparing them with observed ones. The best-fitting model is tested for the robustness of the solution. The basic parameters for understanding the fracturing processes (seismic moment and the temporal function of destruction in the seismic source) are determined as results of the applied method. The Bulgarian University Seismic Network (BUSN), operated by the Faculty of Physics at Sofia University since 2023, is extended by the newly established broadband seismic station SRKO. This study presents the first results from SRKO, in operation since August 2024, applying the INPAR method to investigate focal mechanisms of earthquakes in the surrounding regions of Bulgaria.



Location of the selected seismic stations - green triangles. Studied events – red dots. Gray area is covered by structural models from Raykova et al. (2018) and white area – models from Du et al. (1998). Yellow-orange-beige dots scaled by magnitude denote epicenters of earthquakes in the region with magnitude M ≥≥4 from 1970 to 2020 (ISC, 2025).

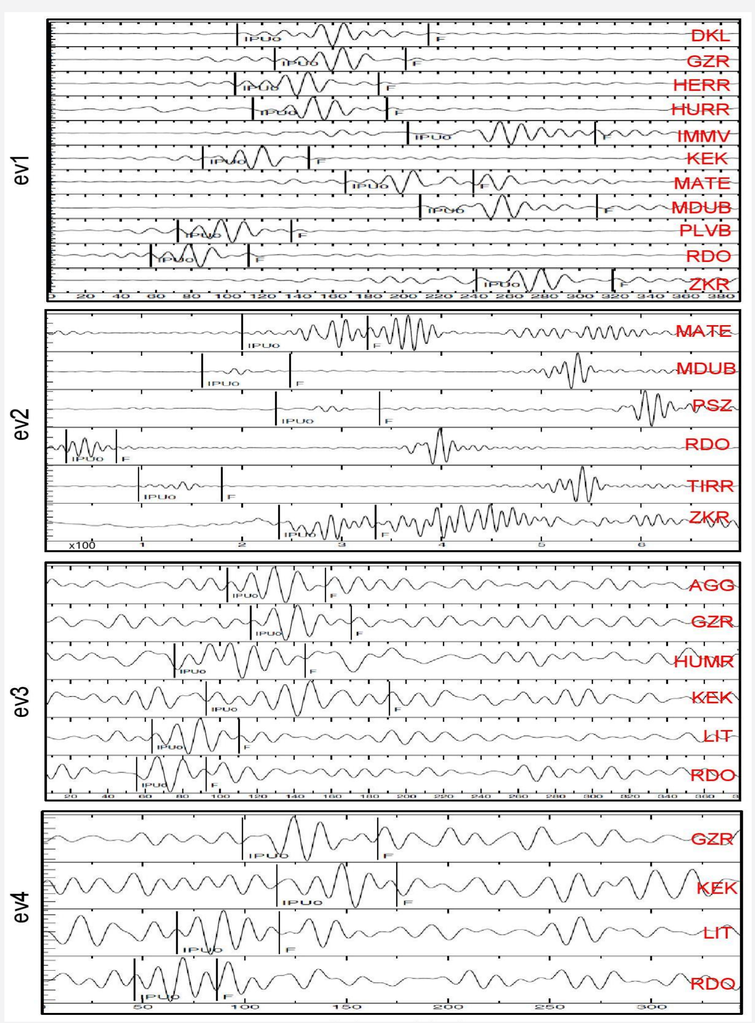
METHOD

We decided to implement the INPAR method (INdirect PARametrization; Šílenỳ et al., 1992) for focal mechanism determination, as it is designed for local or regional earthquakes where the epicenter-to-station distance does not exceed 2500 km. The method uses a point source approximation, allowing parameterization of both the depth and location of the earthquake. The solution is determined by fitting observed seismograms to synthetic ones, calculated for a specific Earth model (Panza et al., 2000). Since the inversion process is highly non-linear, stability tests (Šílenỳ, 1998) are applied to refine the final solution. The INPAR method has been successfully used to resolve focal mechanisms in various regions, even for earthquakes with magnitudes as low as 1.7 and a limited number of stations (Guidarelli, Panza, 2006; Ali et al., 2012).

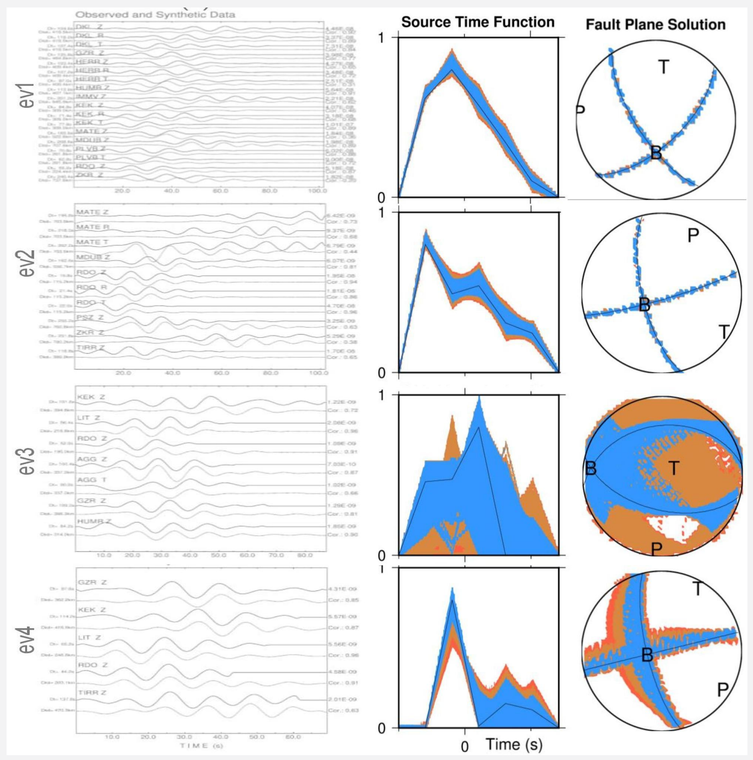


Seismogenic faults (Basili et al., 2013) and the studied events (red dots).

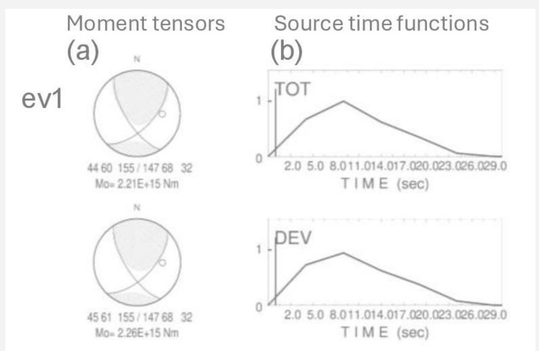
RESULTS



Recorded seismograms (waveforms) for the studied events after low-pass filtering at 0.1 Hz. Only vertical components are illustrated. The time on the horizontal axes is in seconds from the origin time. The sections of the waveforms between the vertical lines are used in the INPAR in-version process.



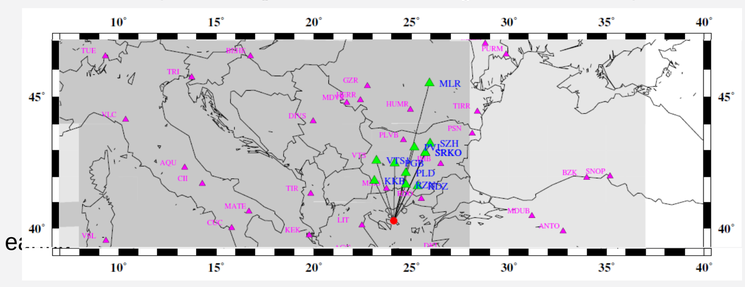
Results of the inversion for all events: waveform fit between synthetics and observed seismograms (left graphs). Robustness genetic solution for the analyzed events: source time function (middle graphs) and fault plane solution (right graphs) with noted pressure (P) and tension (T) sections.



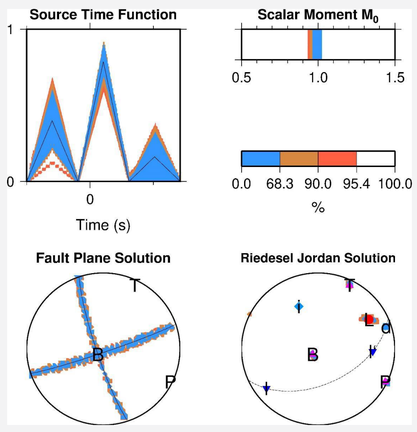
Example of the inversion for event 1: the total and deviatoric moment tensor (a); source time functions for total and deviatoric moment tensor (b)

SRKO: FIRST BROADBAND STATION FROM SEISMIC NETWORK OF SU

Seismic station SRKO: SS08 is a broad-band, triaxial seismometer designed for quick and simple installation and safe transport. Main features: high sensitivity ultra low noise design; self noise below Peterson's noise model (NLNM); automatic mass centering; electric mass lock upon command; magnetic shielding; low power consumption allows SS08 to be used in remote installation with limited energy source. SL06 is a digitiser and a recorder with 3 channel for remote permanent monitoring and automation features.



Analyzis of an earthquake with a moment magnitude of 4.5 that occurred in the Aegean Sea on 12.08.2024. Nine Bulgarian stations, including SRKO and one Romanian station are selected. Examples of waveforms from stations SRKO and KEK show the occurrence of earthquake series in Aegean Sea and Italy.



The color-coded diagram next to the STF shows the uncertainty and variation in moment release over time for a solution coming from the robustness test. The scalar moment plot represents the range of the moment tensor solutions, where the majority of the solutions fall within the confidence range of around M0 = 1×1016 Nm.

CONCLUSIONS

The preliminary results reveal the complex geodynamic processes in the intricate region of Bulgaria and its surroundings: there is not always a good correlation between synthetic and observed waveforms, solutions are not always robust, and there is instability in the localization of the events, especially concerning the depth of the events. Analyzed events possessed mainly strike-slip or combination between strike-slip and trusts faults that indicate predominant horizontal movements between the tectonic units in the region.

Head of the research project
Assoc. Prof. Reneta Raykova
Members of the group
PhD LyubaDimova
BcD Elitza Pandourska

Contacts:
Faculty of physics, Department of Meteorology and Geophysics
rraykova@phys.uni-sofia.bg
Mob. 0887603187

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