Imaging the Rupture Process of Recent Earthquakes using Backprojection of Local High Frequency Records

Ioannis Fountoulakis, Christos Evangelidis, Olga-Joan Ktenidou

National Observatory of Athens, Institute of Geodynamic

Method: The Source Scanning Algorithm(SSA)

Using the SSA algorithm (Kao and Shan, 2004; Kao et al., 2008) we can identify the spatiotemporal distribution of the earthquake source.

When a specific earthquake source exists in spacetime, large amplitudes are expected at the predicted arrival times at each station. The effect of this is to obtain large brightness values (br) at the corresponding location and time.

The Scanning procedure for a spatiotemporal model requires a reliable velocity model, good station distribution, qualitative recordings without timing problems and with minimum site-effects influence.

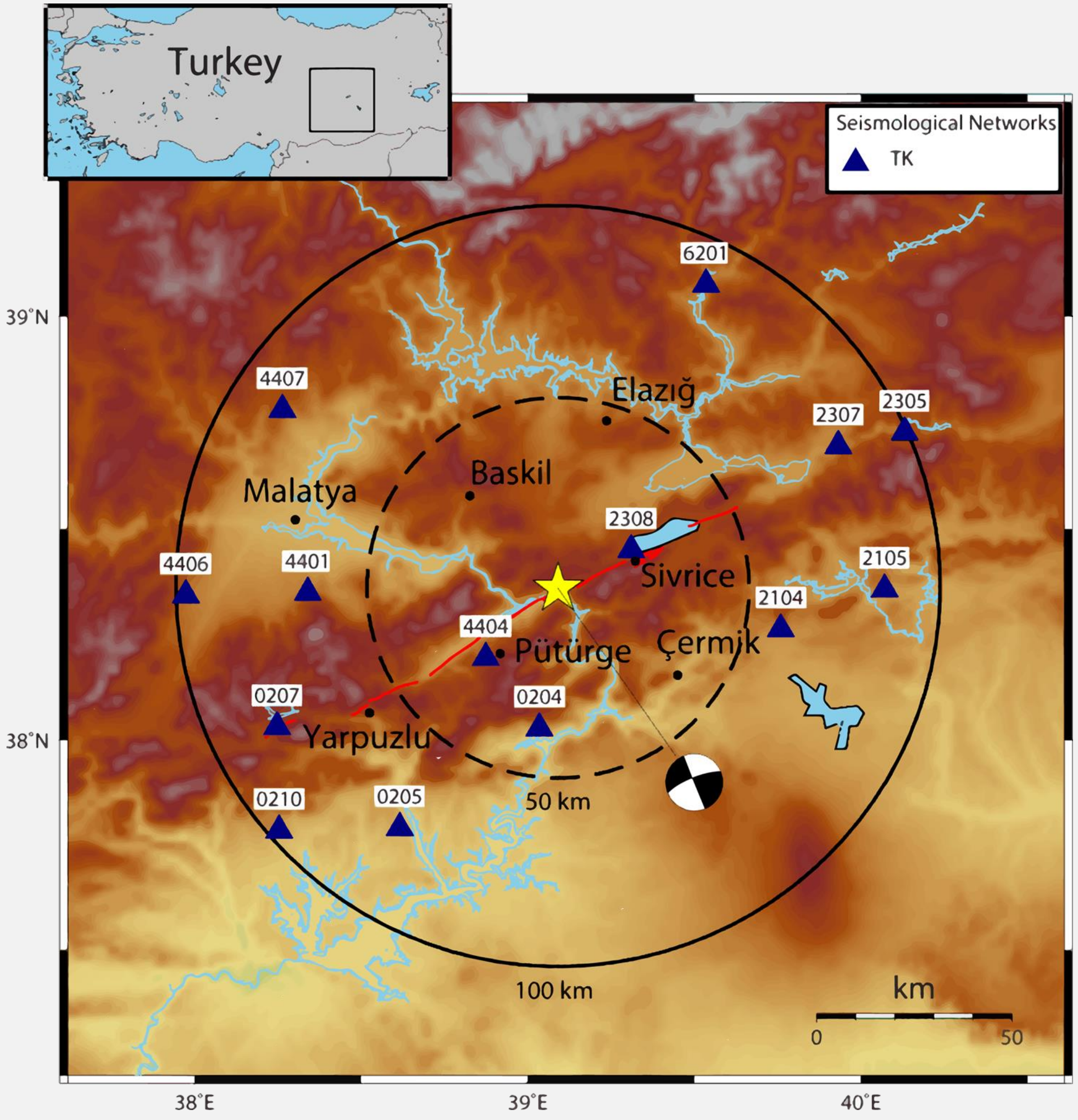
The Source Scanning Algorithm Formula

$$br(\eta,\tau) = \frac{1}{N}\sum_{n=1}^{N}\left\{\frac{\sum_{m=-M}^{M} U_n(\tau + t_{\eta n} + m\delta t + t_n^{cor})^2}{2M}\right\}$$

Where:

- U_n: The normalize envelope (P or S) at station n.
- $t_{\eta n}$: Traveltime from point η to station n.
- t_n^{cor}: Station correction.
- δt: The sampling interval.
- $2M$: The number of samples centered around the predicted arrival time.

Elazığ 2020 M_w 6.8 Earthquake



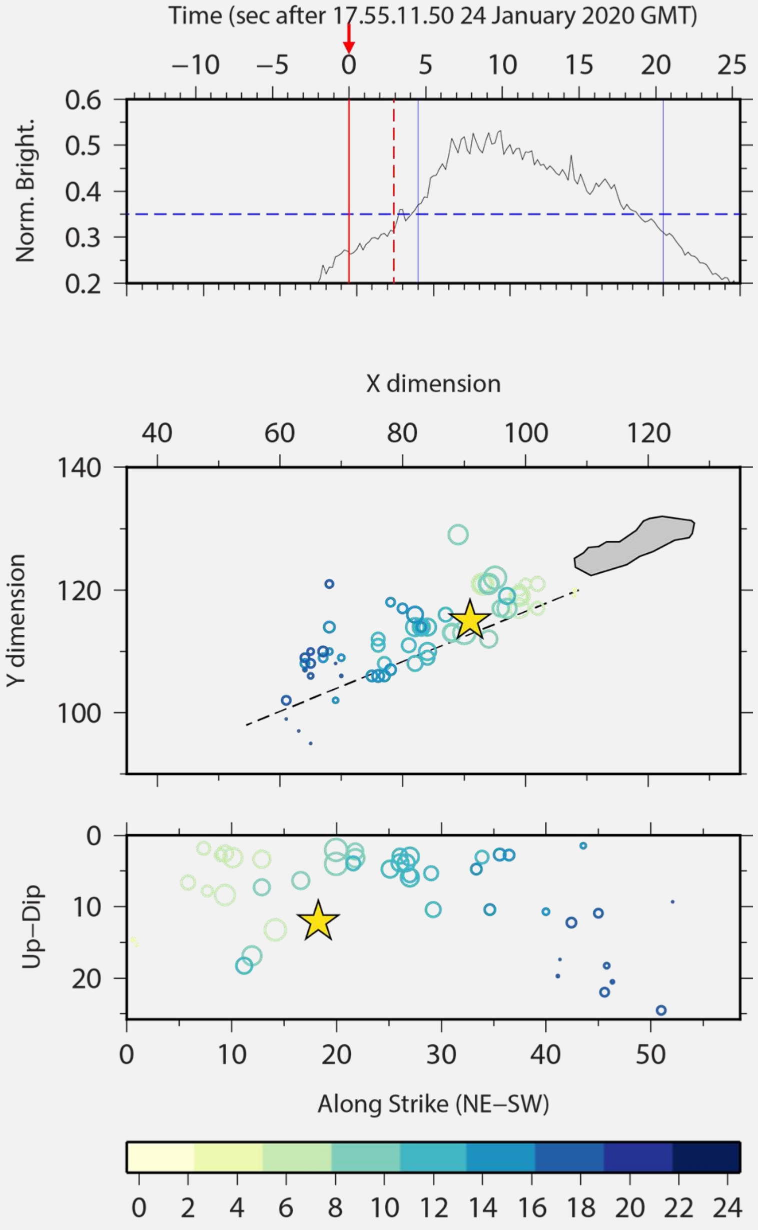
On 24/01/2020 at 17:55 UTC a strong earthquake with M_w 6.8 (AFAD) occurred at the southeastern Turkey in the Sivrice district.

The manual picking and moment tensor solution details indicate a shallow strike slip crustal earthquake.

Early analyses using seismic data (e.g. USGS finite-source model, IRIS Global Back-Projection product) reveal complex source process of the Elazığ earthquake.

In the present study we backproject S-wave envelopes from 14 stations of the TK network (National Strong-Motion Network of Turkey), seated in a circular region with a selected radius of 100 km.

Elazığ 2020 M_w 6.8 Earthquake



- Backprojection results are not constrained by any hypocentral solution i.e. no station corrections are introduced in the procedure.
- We applied a 2-8 Hz bandpass filter, keeping only the High Frequency (HF) part of the S waveforms.
- The HF energy initiates approximately 10 km NW from the hypocenter and gradually migrates along strike for ~30 km towards SW.
- The HF energy burst from the source lasted ~20 s after the origin time.
- The average rupture speed during the event is between 3-3.5 km s^{-1}

Figure: The maximum brightness locations in time. The normalized maximum brightness variation with time is shown on the top. The red arrow indicates the origin time of the earthquake. The following plotted locations are within the time window defined from the blue lines and for values higher than 0.35. The coloured plotted circles in the map view and cross-section represent maximum brightness location in time, sized proportionally to their values. The cross-section is along strike and dip, and its surface projection is marked on the map with a dashed line. The hypocenter is indicated by a yellow star (AFAD).

Elazığ 2020 M_w 6.8 Earthquake

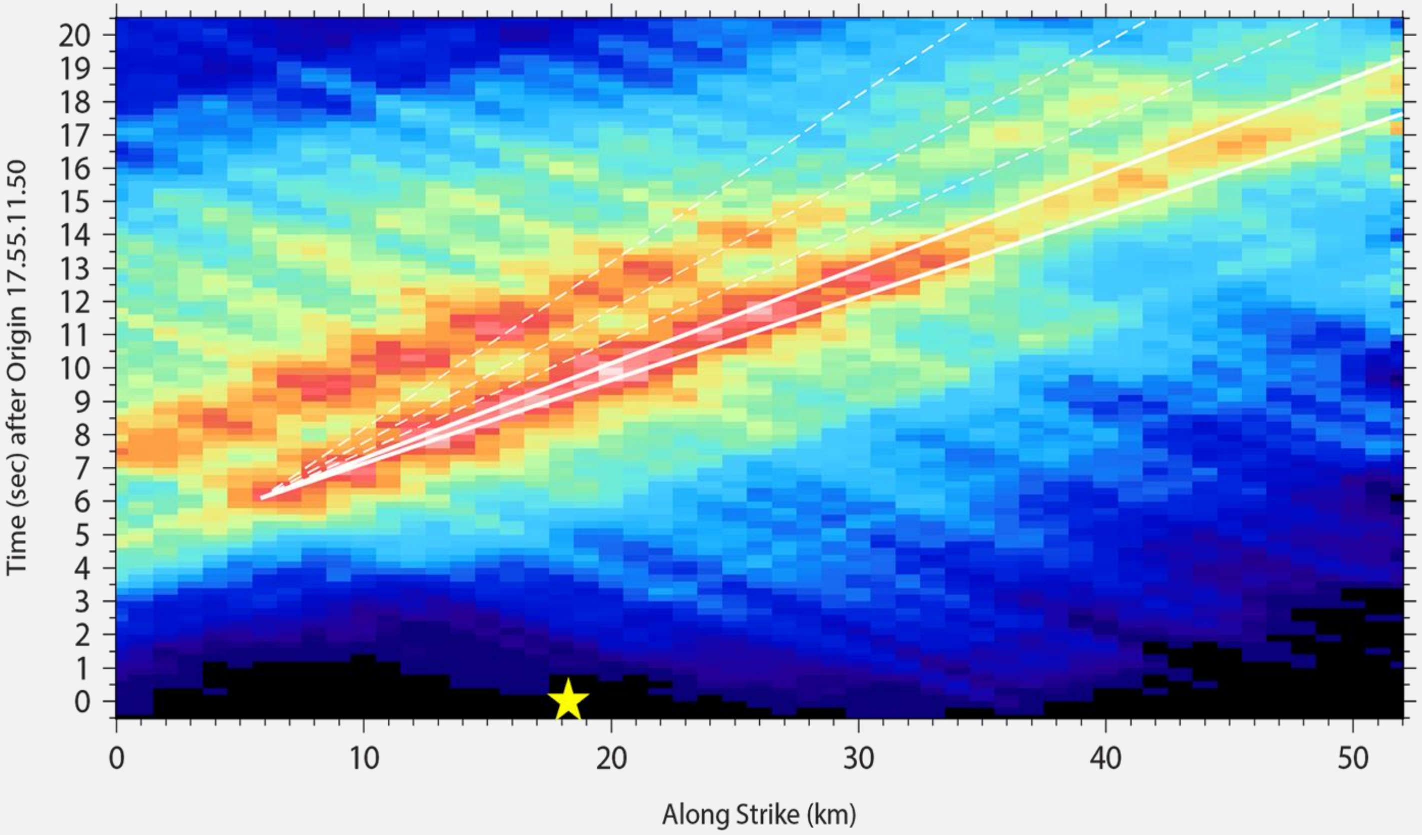


Figure: Time–distance plot of a composite stack along the fault. Dashed white lines represent various rupture speeds every 0.5 km s^{-1}, whereas the white line marks the preferred average rupture speed of 3-3.5 km s^{-1}.

- Using the SSA method we managed to determine the spatio-temporal imaging of the rupture without any-priori constrains.

- Our results manifest the complex rupture of the Elazig earthquake, with ~20 s source duration and at least 2 distinct HF energy emission spots, below 10 km depth.

- In synergy with conventional source inversion methods, it can provide useful information about the nature and the evolution of moderate to large seismic events using local waveform data.

Acknowledgements-References

Strong Motion waveform data used in this study were acquired by the Strong Ground Motion Database of Turkey of the Turkish Republic Disaster and Emergency Management Presidency, Earthquake Department (AFAD) (http://tdvm.afad.gov.tr/en/continuous-data, last accessed January 2020). Hypocentral solution and moment tensor results for the earthquake acquired from the EMSC (https://www.emsc-csem.org). The GMT mapping software (Wessel & Smith 1998) was used for the preparation of the figures for this presentation.

C. P. Evangelidis and H. Kao, 2013. High-frequency source imaging of the October 23, 2011 Van (Eastern Turkey) earthquake by back-projection of strong motion waveforms, *Geophys.J.Int*, **162**(2), 1060-1072.

Kao, H. & Shan, S.-J., 2004. The Source-Scanning Algorithm: mapping the distribution of seismic sources in time and space, *Geophys. J. Int.,* **157**(2), 589–594.

Kao, H., Wang, K., Chen, R.-Y., Wada, I., He, J. & Malone, S., 2008. Identifying the rupture plane of the 2001 Nisqually Washington, earthquake, *Bull. seism. Soc. Am.,* **98**(3), 1546–1558.