Iranian Journal of Astronomy and Astrophysics
Vol. 7, No. 1, Spring 2020
©Available online at http://journals.du.ac.ir
DOI:10.22128/ijaa.2020.407.1085

Iranian Journal of Astronomy and Astrophysics

Space and Time Evolution of the Rupture for the 2010 August 27 Mw 5.8 Kuh-zar earthquake

Nazila Asaadi[1] · Sonia Bazargan[2]

[1] Department of Physics, University of Zanjan, Zanjan, Iran;
email: nazilaasaadi@znu.ac.ir
[2] Institute of Geophysics, University of Tehran, Tehran, Iran;
email: bazargan.s@alumni.ut.ac.ir

Abstract. In this study, we investigated the spatiotemporal slip distribution of the 2010 August 27 Mw 5.8 Kuh-zar earthquake. Using constrained non-negative least-squares linear slip inversion method, we calculated the amount of displacement on the fault plane. The spatial slip distribution of this earthquake has been estimated by Bazargan et al. (2018) while the delta is 0.1 s (delta is sampling rate means 10 samples in 1 second). Here, we re-evaluated the slip with delta = 0.2 s to improve their result. In this study we used the same rupture velocity and rise time, namely 2.55 km/s and 1.8 s. In general, the rupture velocity is 80% to 90% of the shear wave velocity, except for the propagation of ultrasonic faults, in which it has dimensions equal to the P-wave velocity. Selecting the size of the rupture rate has a significant effect on the size of the slip and its area. Since the slip inversion results can have a high level of uncertainty, we tried to develop the previous results by using different delta and also adding time evolution to the calculations.

Keywords: the 2010 Juh-Zar earthquake, seismic data, slip inversion

1 Introduction

We aimed here to investigate the space and time evolution of the rupture for the 2010 Kuh-zar earthquake which occurred in Kuh-zar, a village in Damghan county, Semnan Province. Based on the seismic zoning of Iran by Mirzaei et al.(1998) [1], there are five major seismotectonic provinces in the country, that is Zagros in the southwest, Alborz-Azerbaijan in the north and northwest, Central East Iran, Kopeh Dagh in the northeast and Makran in the southeast of Iran. The Kuh-Zar earthquake is almost situated on the border of Alborz-Azerbaijan and central East Iran seismotectonic provinces which is in the proximity of the southern border of Alborz region. The epicenter of this event is located north of the Torud fault (Fig. 1) which is the causative fault for the 1953 Torud earthquake [2], one of the remarkable events of this area. Although the earthquake magnitude is moderate, it affected 12 villages i.e. Kuh-Zar, Salmabad, Tuchahi, Kelu, Shemi, Bidestan, Hoseynian, Moalleman, Satveh, Reshm, Mehdiabad, and Torud, which all are situated in Semnan Province. The study aimed to obtain finite-fault modeling of the broadband three-component displacement waveforms of the Kuh-Zar earthquake through a least squares inversion method for the spatiotemporal slip distribution.

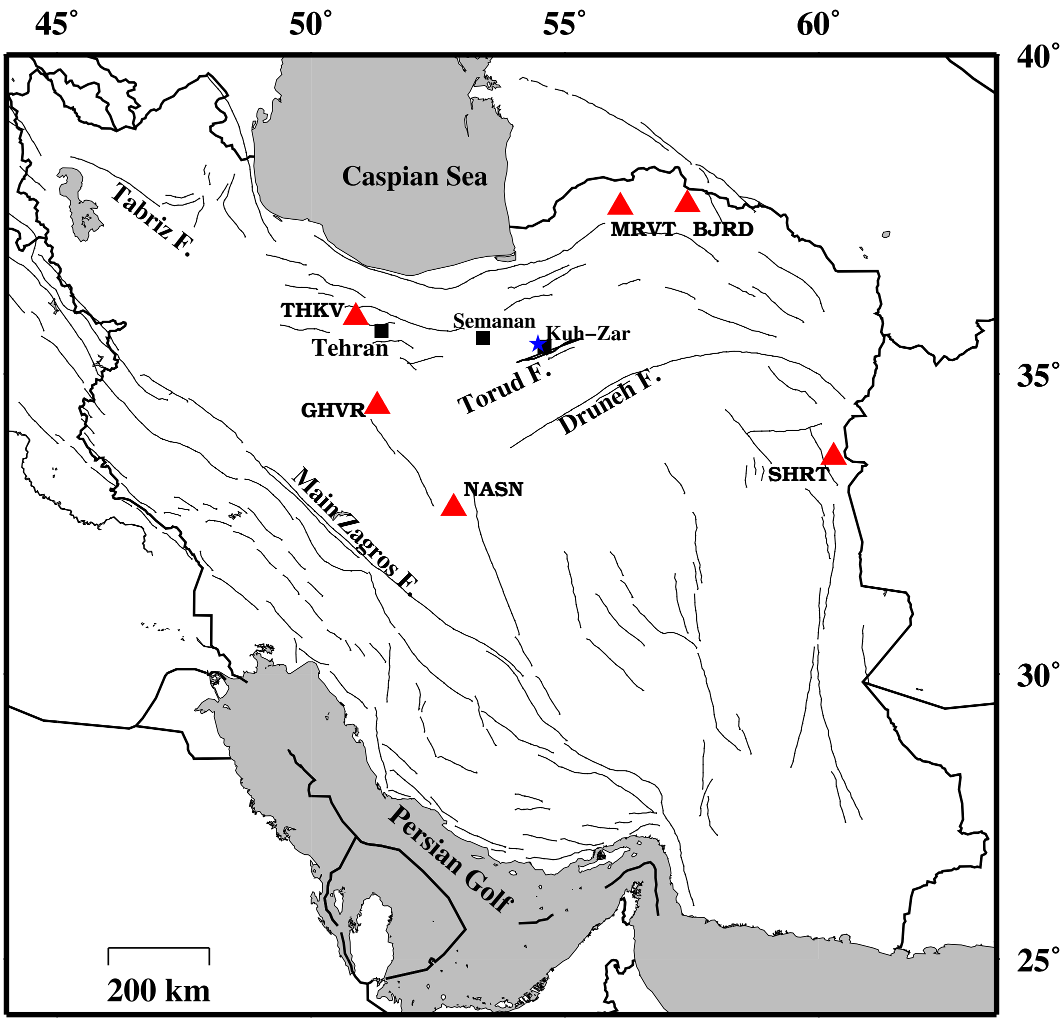

Figure 1: Distribution of stations for the Kuh-zar earthquake. Location of the epicenter is given by the blue star. Solid lines demonstrate fault traces of Iran. Three major faults of Iran such as Daruneh and Main Zagros faults are illustrated in the figure. Also, the Torud fault is shown in the south of the epicenter. Black squares symbolize Tehran and Semnan provinces, and Kuh-zar village. The event is almost situated on the border of Alborz-Azerbaijan and Central East Iran seismotectonic provinces which in the vicinity of Semnan province near Tehran.

Table 1: Recording stations and their epicentral distances.

Station names	Epicentral Distance (km)
mrvt	280.236
ghvr	312.472
thkv	330.817
nasn	336.096
shrt	569.186

2 Data

We obtained our data from a national broadband seismic network operated by the International Institute of Earthquake Engineering and Seismology (IIEES, www.iiees.ac.ir), which consists of 14 waveforms for the 27th of August, 2010 Mw 5 : 8 Kuh-Zar earthquake (Fig. 1). The stations and their epicentral distances are listed in (Table 1). In the process of preparing the data, we decimated them from the original 50 to 5 sample per second. The instrument responses were removed, and the data were then converted to displacement. A band-pass filter of $0.002 - 0.085$ Hz was applied to the displacement waveforms.

3 Model Parametrization

Green's functions were computed using the frequency-wavenumber integration code (FKRPROG) developed by Saikia (1994) [3]. Also, the inversion algorithm applied to the observed data is based on a stabilized constrained non-negative least-squares method introduced by Hartzell and Heaton (1983) [4]. The rupture history of this event is presented as a surface of 70 km by 40 km with equal-sized 1 km $\times$ 1 km subfaults, which successfully accommodates all of the displacement inside the given fault plane for both spatial and temporal slip distributions. The fault and subfault sizes are different from that of the study done by Bazargan et. al (2018) [5]. Other significant inputs for the slip distribution such as rupture velocity and rise time, namely 2.55 km/s and 1.8 s, respectively, are the same as the mentioned study. Different hypocenters reported by various seismological agencies, i.e., ISC, GCMT, USGS, and EMSC (Table 2) were tested. Since the nodal plane with a better fit to the data can be construed as the main fault plane [6], the focal mechanism (strike, dip, and rake (Fig. 2) of the fault reported by GCMT and NEIC were tested to find the nodal plane with the best fit (Table 3). Moreover, we used the hypocenter reported by CGMT and the focal mechanism stated by GCMT for this study. For the time evolution of slip, we added time in a way that there is 0.5 s increments between 6-time steps. In addition, we used the velocity model based on the study of Ashtari et al. (2005) [8] for our research.

4 Results

Running a great many inversions, we used spatial slip distribution of the Kuh-zar earthquake with 46% fit (Fig. 3) and the peak slip of 10 cm (Fig. 4). Due to the low resolution of the observed waveforms, some components had unsatisfactory fitting to the data. Thus, we omitted them to get rid of the uncertainty they brought to the slip model. The time evolution of the rupture incorporates time into the calculations and is supposed to provide a

Table 2: The hypocentral parameters recorded by different agencies for kuh-Zar earthquake.

*Agencies**	Lat.(°)	Lon.(°)	Depth (km)	Time
ISC	35.48	54.50	11.0	$19^h23^m48^s.87$
GCMT	35.53	54.49	14.9	$19^h23^m52^s.40$
USGS	35.49	54.47	7.0	$19^h23^m49^s.00$
EMGS	35.48	54.55	10.0	$19^h23^m48^s.30$

∗ ISC (www.isc.ac.uk), International Seismological Center;
GCMT (www.globalcmt.org), Global Centroid Moment Tensor;
USGS (www.earthquake.usgs.gov), United States Geological Survay;
EMSC (www.emsccsem.org), European-Mediterranean Seismological center

Table 3: The focal mechanisms reported by GCMT and NEIC.

2010 Kuh-Zar	Nodal plane 1 Srtike (°), Dip(°), Dike(°)	Nodal Plane 2 Strike(°), Dip(°), Dike(°)
GCMT	212, 78, -2	302, 88, -168
*NEIC**	20, 85, -10	111, 80, -175

∗ The National Earthquake Information Center

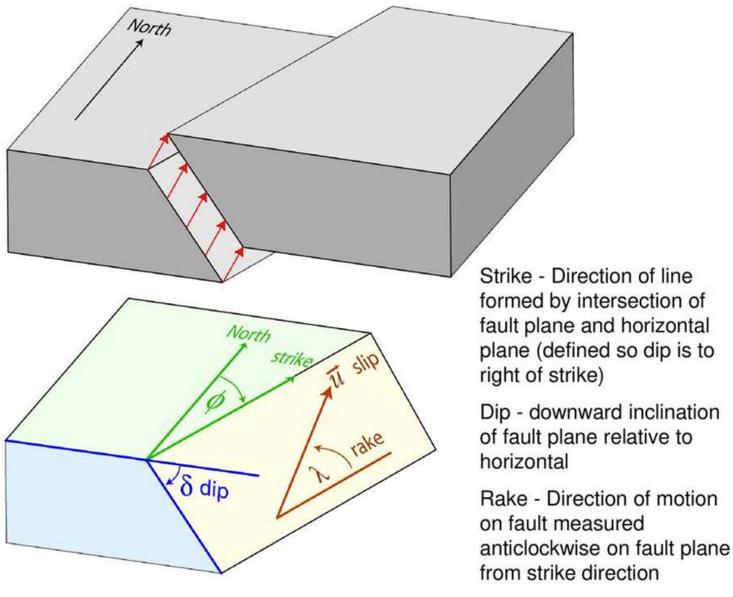

Figure 2: Strike, dip and rake definitions, www.slideplayer.com/slide/14475576/

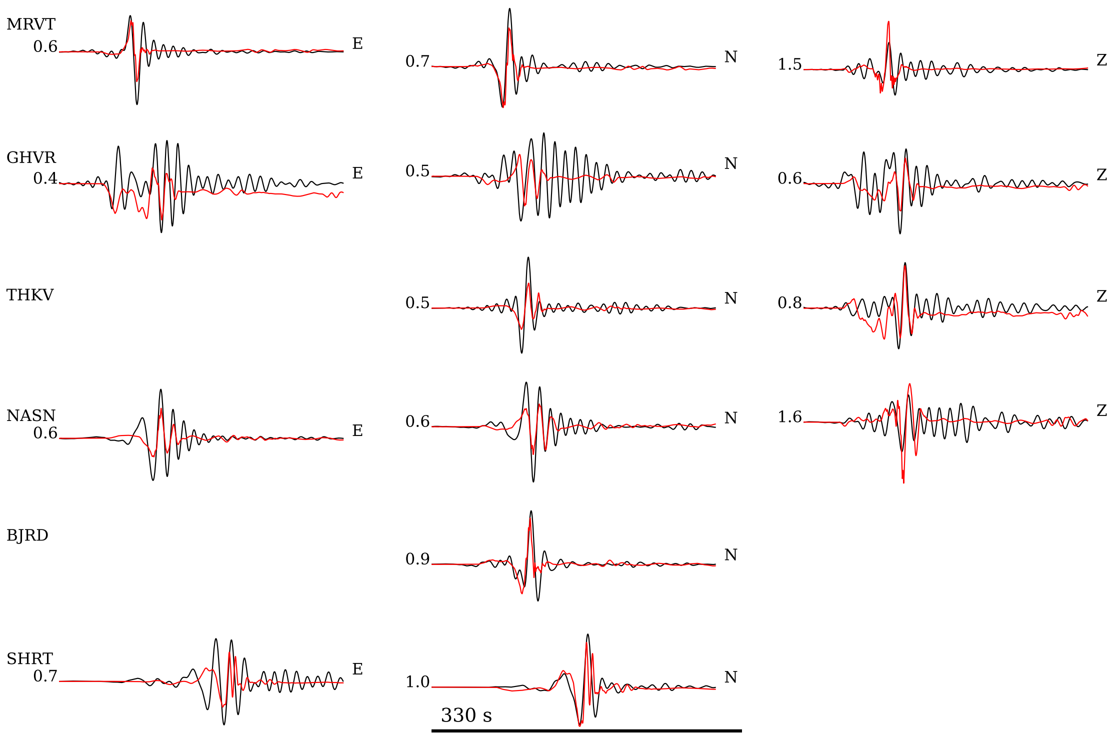

Figure 3: Observed data (black) and synthetics (red) for the spatial slip distribution of the Kuh-zar earthquake using the GCMT hypocenter and GCMT focal mechanism. These signals construct our preferred model with the total variance reduction of 46%, the rupture velocity of 2.55 km/s, and the rise time of 1.8 s. Some components of stations were omitted, for the presence of noise resulted in an unfavorable synthetic waveform. We omitted them to get rid of the uncertainty they brought to our calculations. Numbers on the left of each signal pair show the synthetic to observed amplitude ratio, and signals are displayed in order of increasing the distance from the epicenter. The time evolution of the rupture has the same fitting with the total variance reduction of about 48% (not shown here) resulting from the low resolution observed data and poor station distribution. In other words, there is not much to be changed in the data fit by the time evolution.

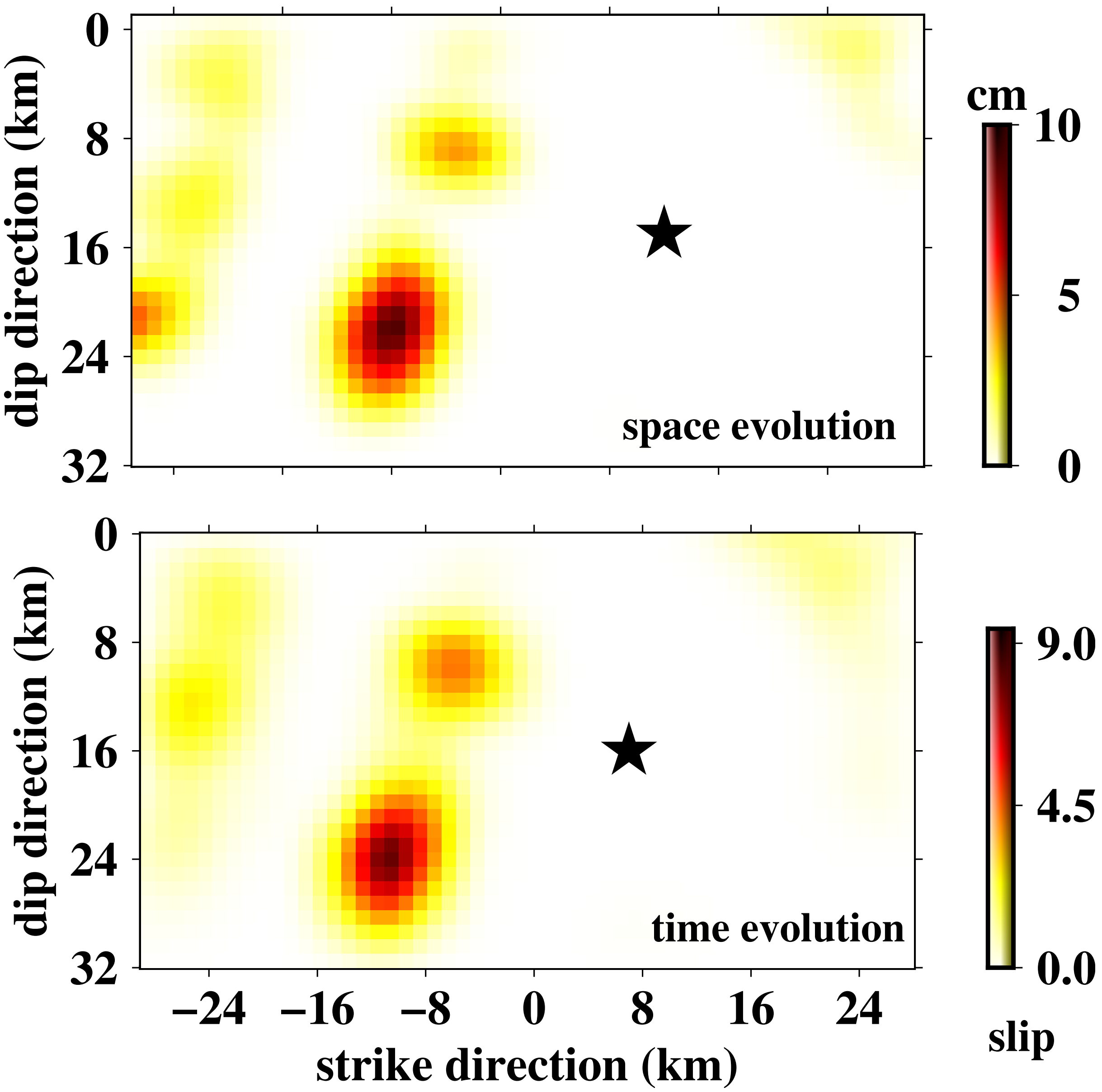

Figure 4: Space (up) and time (down) evolution of the rupture for the Kuh-zar earthquake. The black star shows the GCMT hypocenter. For the analyzation of these two slip distributions, see the explanation

better fitting between the observed and calculated waveforms. However, this is not the case for the Kuh-zar spatiotemporal slip distribution and there is not noticeable improvement in its time evolution. The reason is that owing to the low resolution of the observed waveforms and unfavorable distribution geometry of the stations, this earthquake did not yield a better fitting and all it results presented itself in the space evolution. Thus, there is not much to be changed in the data fit by the multi-time-window method and its fit is highly similar to the data fitting in the space evolution. The spatiotemporal slip distribution of this event got a data fit of 48% with 8 cm peak slip. The slip pattern resulted from both space and time evolution of the rupture can be seen in (Fig. 4). As mentioned earlier, since there is not a remarkable improvement in the spatiotemporal distribution, the slip pattern of the time evolution is similar to the space evolution with little changes in the marginal slip patches.

5 Discussion

The Kuh-Zar earthquake is one of the moderate earthquakes of Iran whose slip distribution is explored by linear finite-fault slip inversion method. The research, which is considered at nearly low frequencies, resulted in the main features of slip distribution of the event.

We presented a set of solutions for the earthquake, among which GCMT hypocenter and focal mechanism give the spatiotemporal slip distribution with a maximum total variance reduction of 48%. The peak slip value of this event is about 8 cm. Also, the main nodal plane is one which provided the maximum total variance reduction in the slip inversion. For the Kuh-Zar earthquake, the fault plane with strike, dip, rake: 212°, 78°, −2° satisfied this condition.

All in all, we improved the space evolution results done by Bazargan et al. That study used more stations especially with long epicentral distances which may added to the uncertainty in their model. We limited the number of stations and kept just close stations. Additionally, we used broader range of frequency content in order to add different frequencies to our calculations. Although there is not improvement in the time evolution of this study, we believe the space evolution of the rupture has been improved in comparison to the mentioned study.

References

[1] Mirzaei, N., Mengtan, G., & Yuntai, C. 1998, J. Earth Predict Res., 7, 465.

[2] Berberian, M., & Navai, I. 1977, A preliminary feild report and a seismotectonic, 51.

[3] Saikia, C. K. 1994, Geophys. J. Int., 118, 142.

[4] Hartzell, S. H., & Heaton, T. H. 1983, Seismol Soc. Am., 73, 1553.

[5] Bazargan, S., Asaadi, N., Hossein Shomali, Z., & Rezapour, M. 2018, IJAA, 5, 41.

[6] Abercrombie, R. E., Bannister, S., Pancha, A., Webb, T. H., & Mori, J. J. 2001, Geophys J. Int., 146, 134.

[7] Shahvar, M. P., & Zar'e, M. 2013, Natural hazards, 66, 689.

[8] Ashtari, M., Hatzfeld, D., & Kamalian, N. 2005, Tectonophysics, 395, 193.

[9] Hartzell, S. H., Liu, P., Mendoza, C., Ji, C., & Larson, K. M. 2007, Seismol Soc. Am., 97, 1911.