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Determining the Effects of the 2020 Elazığ-Sivrice/Turkey (Mw 6.7) Earthquake from the Surrounding CORS-TR GNSS Stations

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ABSTRACT

In this study, co-seismic displacements originating from Elazığ-Sivrice earthquake in the Eastern Anatolian Fault Zone (EAFZ) on 24 January 2020 were investigated. For this purpose, data of 11 CORS-TR stations in the nearby earthquake focal point were used. Receiver Independence Exchange (RINEX) observation data of 11 stations between the dates of 1-30 January 2020 (30 days) were obtained from CORS-TR servers and analyzed. Analyzes were carried out with GAMIT/GLOBK V10.71 software and coordinate time series were created from daily solutions. Co-seismic displacement caused by earthquake was revealed by coordinate time series and total displacements (co-seismic) were calculated by coordinate differences between the before and after the earthquake. According to the results, an earthquake-induced motion of 20-60 mm was detected at the GNSS stations located in the nearby of earthquake epicenter. In addition, vertical movement was not detected at any of the 11 CORS-TR GNSS station.

1. INTRODUCTION AND TECTONIC SETTING

Global Navigation Satellite System (GNSS) technique is widely used for geodetic and geodynamic modeling studies such as monitoring tectonic plate movements, earthquake observation, crustal deformation, etc. as it can produce high precision, low-cost and 3D positioning in a global coordinate system. An important part of these studies has been done in Anatolia due to tectonic diversity (McClusky et al., 2000; Ustun et al., 2010 Tiryakioğlu et al., 2019).

Turkey has been a natural laboratory for multidisciplinary studies involving earthquake observation and related research. Most of the studies consist of monitoring with GNSS on the North Anatolian Fault Zone (NAFZ) and Eastern Anatolian Fault Zone (EAFZ) (e.g. Ambraseys, 1989; Ozener et al., 2010; Tiryakioglu et al., 2017; Tiryakioglu et al., 2018; Bletery et al., 2020), which produces large and destructive earthquakes (Figure 1).

The EAFZ starts from Karlıova in the northeast and extends to Kahramanmaraş in the southwest and forms the southeast border of the Anatolian plate. It is about 500 km long between the Arabian and Anatolian plates and is a left-lateral strike-slip fault zone. The left lateral movement along the fault zone contributes to the escape of Anatolia to the west (Allen 1969; Dewey et al., 1986). Relative plate motion occurs with slip rates ranging from 6 to 10 mm/year and has resulted in destructive earthquakes in eastern Turkey (Bulut et al., 2012).

Considering the historical earthquake activity of EAFZ in past 60 years, some of the most important earthquakes on this fault are 1964 Malatya *Ms 5.7*, 1971 Bingöl *Ms 6.9* , 1977 Palu *Mw 5.2* , 1986 Doğanşehir-Malatya *Ms 5.9,* 2003 Bingöl *Mw 6.3*, 2004 Sivrice *Mw 5.5* and 2010 Kovancılar-Elazığ *Mw 6.1*.

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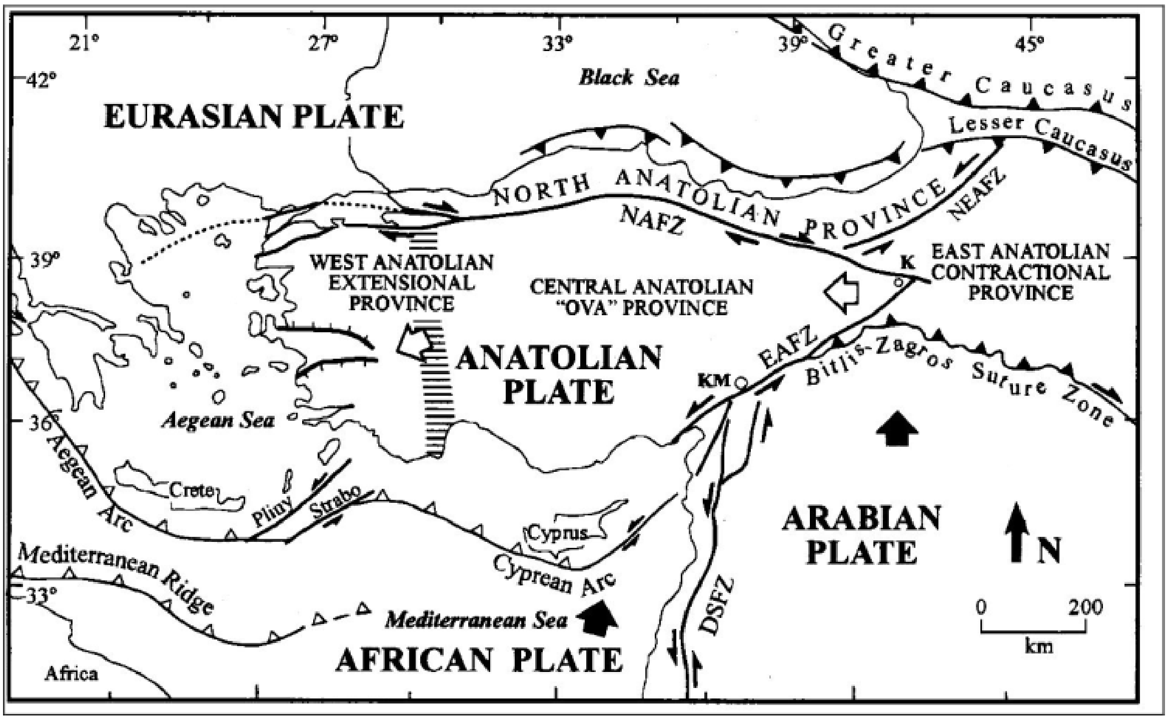

Figure 1. Important neotectonic structures in Turkey (Bozkurt, 2001).

The latest earthquake recorded on EAFZ was the Doğanyol-Sivrice earthquake (Fig. 2) with Moment magnitude (Mw) 6.7 on January 24, 2020 (Lat: 38.3590 N, Long: 39.0628 E). The depth of the earthquake, which is strongly felt in Malatya and Diyarbakır, especially in Elazig, is reported as 8 km (AFAD, 2020). According to AFAD (2020), it is assumed that the approximately 55-60 kilometers-long fault segment of the EAFZ zone, located in the southwest of the Hazar Lake, west of Sivrice and Pötürge district, has been broken up bilaterally and caused the Elazığ-Sivrice earthquake (Fig. 2).

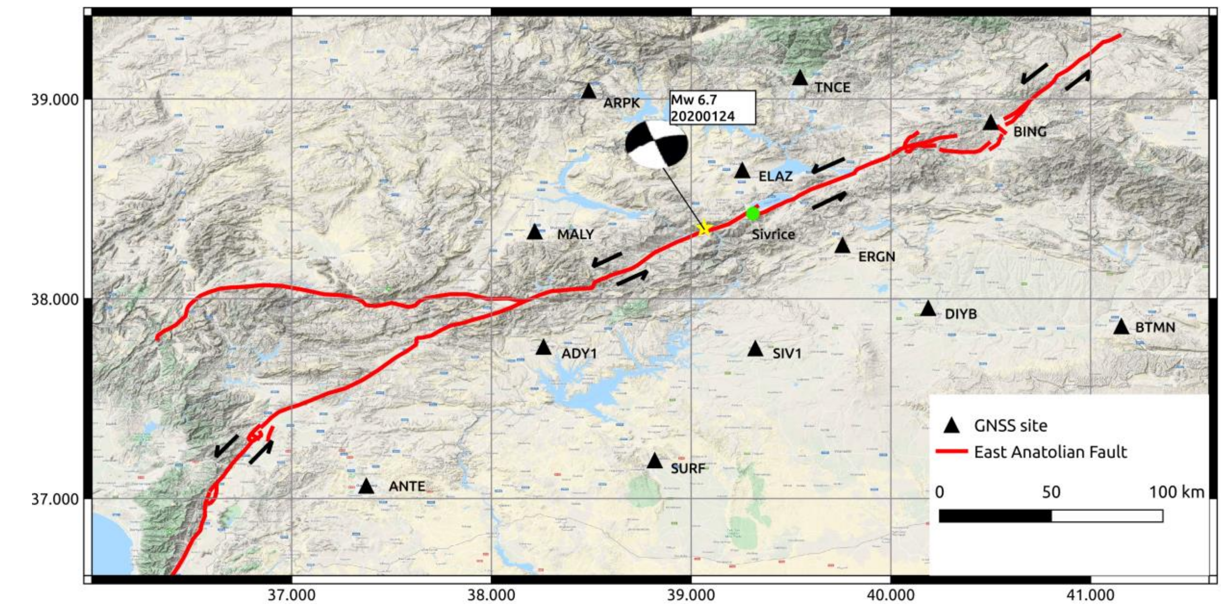

Figure 2. The East Anatolian Fault Zone (EAFZ), epicenter of the Doğanyol-Sivrice Mw 6.7 earthquake (yellow star) and surrounding CORS-TR GNSS stations

2. GEODETIC STUDY OF THE EARTHQUAKE

Determining the amount of displacement generated by earthquakes will play an important role in revealing the earthquake kinematics and consequently understanding the related tectonic movements. In this context, the data of Continuously Operating Reference Station (CORS) GNSS stations nearby of the earthquake epicenter provides great convenience. The CORS stations located in Turkey called as CORS-TR network consists of 146 GNSS reference stations and was mainly designed to provide Real-Time Kinematic (RTK) applications. However, reference station data of this network with 30 seconds interval is archived and provides important contributions to reveal crustal deformations.

In this study, 11 GNSS stations data of CORS-TR network located nearby of the epicenter of the Elazig-Sivrice earthquake are obtained and analyzed. The analyzes cover the period from the day of the year (DoY) of 1 to the 30th of 2020 and were carried out with the GAMIT/GLOBK V10.71 software according to the relative GNSS analysis technique (Herring et al., 2010). The earthquake-related displacements were estimated by examining the time series produced from daily solutions.

3. GNSS NETWORK DESIGN AND ANALYSIS

As mentioned in the previous section, eleven stations (ANTE, MALY, ADY1, SURF, SIV1, ARPK, TNCE, ELAZ, ERGN, DIYB, BING, and BTMN) from CORS-TR network were used in this study (Fig. 2). In order to make earthquake effect clearly (co-seismic displacement) visible in the time series, thirty-day consecutive data were analyzed from January 1 to January 30 of 2020. The (Receiver Independence Exchange) 24 hours of RINEX observation files with 30 seconds interval were obtained from CORS-TR servers for 30 days period.

Daily 24-hour of RINEX observation files from the 11 stations were processed using GAMIT/GLOBK V10.71 software. The analyses were carried out in two basic steps. In the first step, the relative coordinates were estimated on the basis of the weighted least squares algorithm using the ionosphere-free linear combination (LC) of the phase observable by the GAMIT module. The orbital and clock parameters were obtained from International GNSS Service (IGS) and minimum constraint (with respect to the ANKR site) procedure was used for ambiguity fixing in 5 cm for both horizontal and vertical directions. In the second step, the reference frame definition was performed for the daily solutions by using the GLRED module. Then, a 7-parameter Helmert transformation was applied and its parameters were estimated by means of 10 IGS stations (ANKR, ARUC, BSHM, HAMD, ISTA, MATE, NICO, ORID, TUBI, and ZECK) with coordinates and the velocity defined in ITRF14.

4. GNSS-DERIVED DISPLACEMENT

From the daily solutions, time series were created by combining the coordinates estimated with a precision of 2-3 mm in the horizontal direction and 7-8 mm in the vertical direction during the monitoring period (30-days). Time series belonging to ELAZ and ERGN stations, where significant movement is obtained since it is closest to the earthquake epicenter, is presented in Figures 3 and 4 for the horizontal direction.

By comparing to the station coordinates of the CORS-TR GNSS sites from daily solutions before and after the Elazığ-Sivrice earthquake (DoY 24), obtained the co-seismic displacement.

The co-seismic displacements from monitoring period results were determined according to Equation (1).

$$\begin{aligned} \Delta n_{cos} &= n_{post} - n_{pre} \\ \Delta e_{cos} &= e_{post} - e_{pre} \\ \Delta u_{cos} &= u_{post} - u_{pre} \end{aligned} \qquad (1)$$

Where Δn_{cos}, Δe_{cos} and Δu_{cos} are the co-seismic displacements, n_{post}, e_{post}, u_{post}, n_{pre}, e_{pre} and u_{pre} indicate the average GNSS based positions estimated from before (23 days) and after (6days) the earthquake. Co-seismic displacement values obtained for 11 CORS-TR GNSS stations according to the above procedure are presented in Table 1.

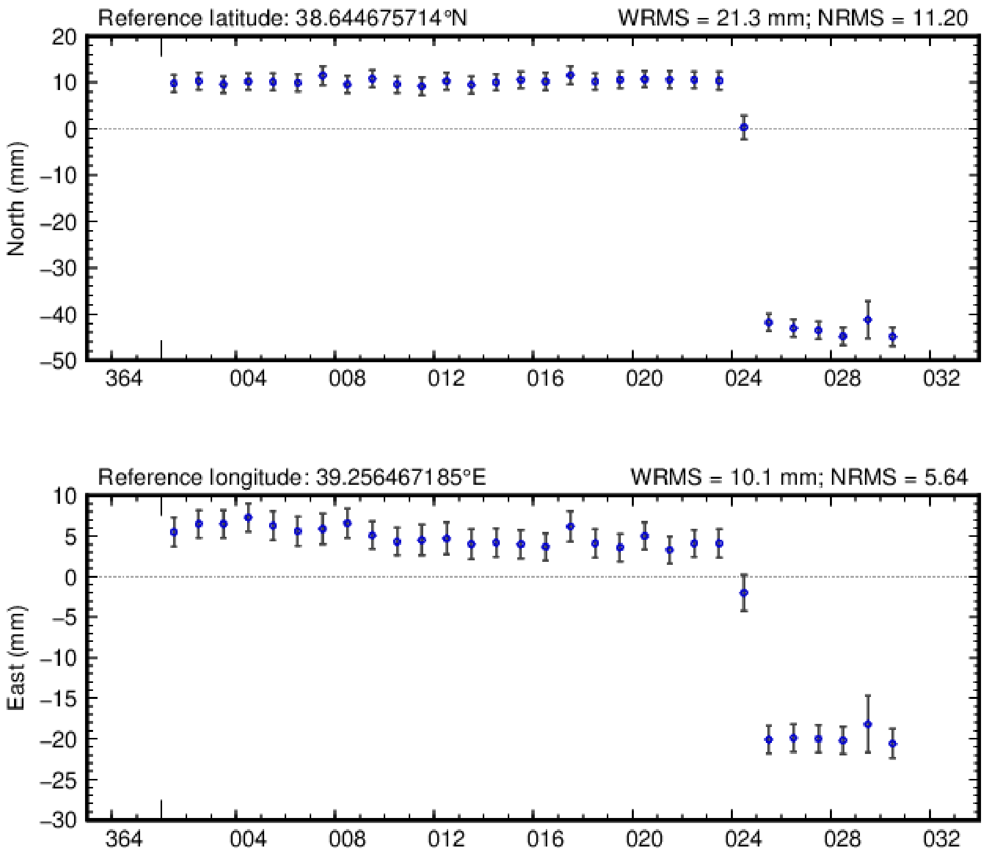

Figure 3. Coordinate time series obtained for ELAZ station during monitoring

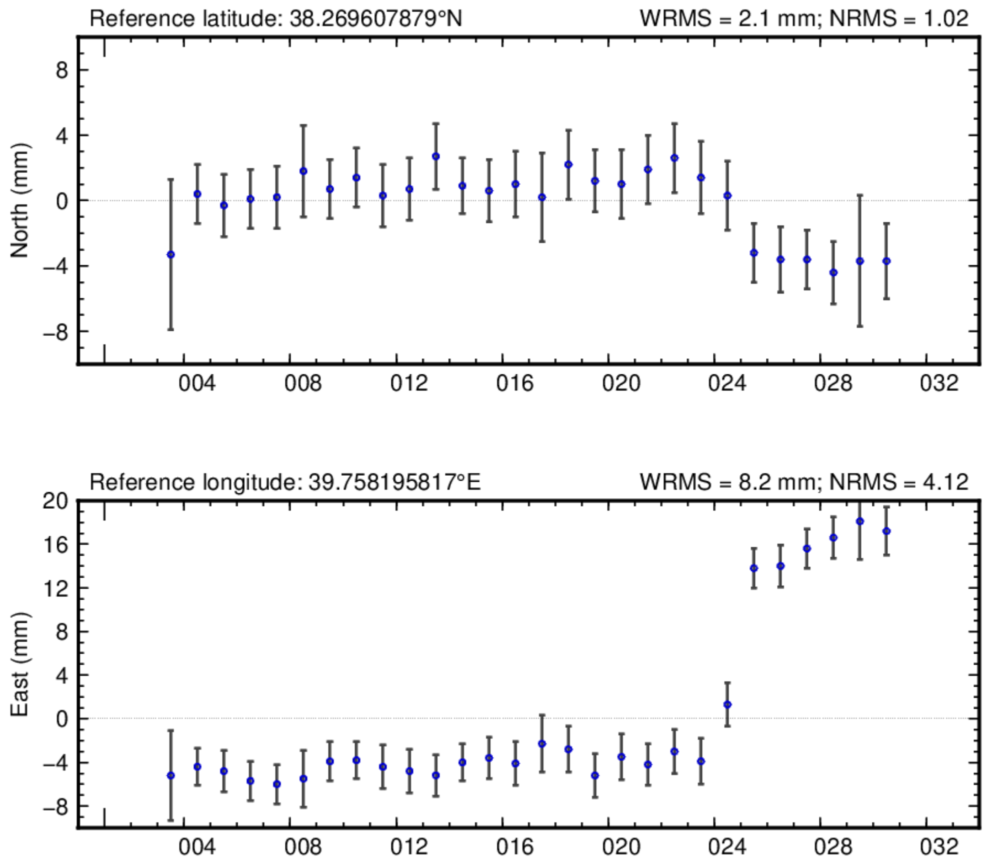

Fig 4. Coordinate time series obtained for ERGN station during monitoring

Table 1. Co-seismic displacement values calculated with Equation 1 for the CORS-TR stations (in mm).

Station	North	East	Up
BTMN	1.0	3.0	-2.9
BING	-0.4	1.2	1.0
DIYB	-0.4	6.6	3.2
ERGN	-6.5	20.2	-3.6
TNCE	-8.1	-2.4	-1.1
SIV1	3.1	5.6	-0.9
ELAZ	-53.5	-20.9	0.5
SURF	4.0	2.4	0.9
ADY1	5.7	2.8	-0.1
MALY	4.5	-16.6	-2.5
ANTE	5.7	2.8	-0.3

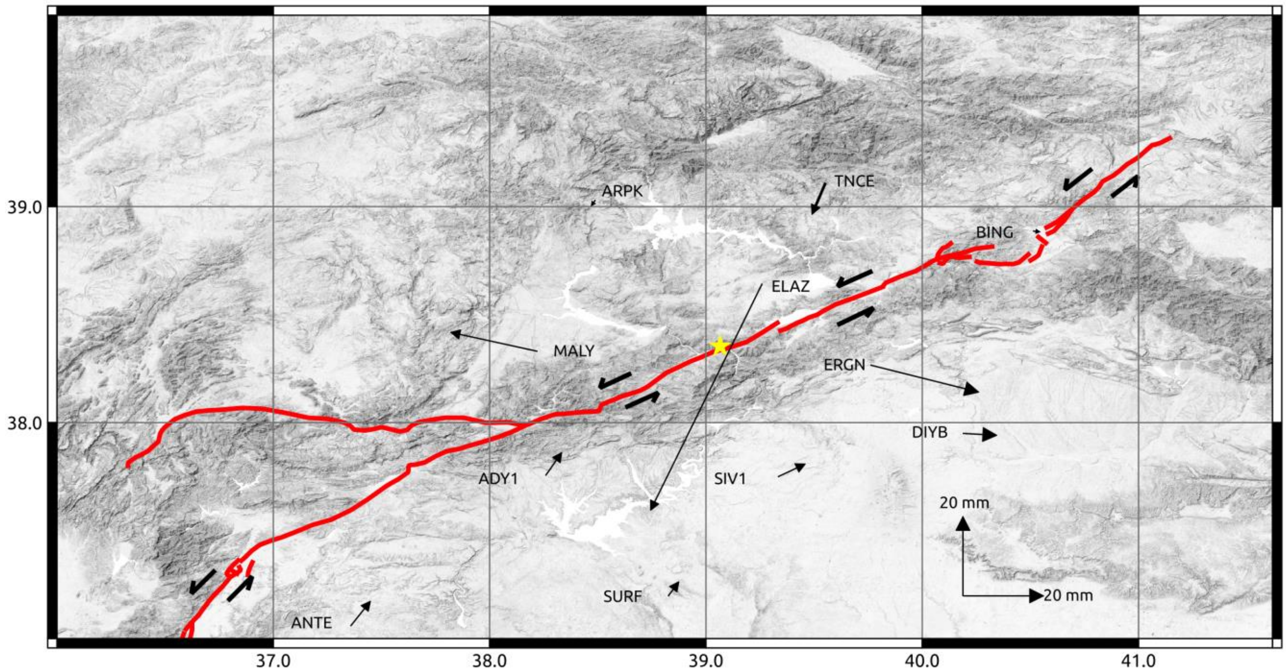

Figure 5. Earthquake-induced horizontal displacement vectors

5. DISCUSSION AND CONCLUSION

In this study, horizontal and vertical displacements (co-seismic) caused by 24 January 2020 Elazığ-Sivrice/Turkey (Mw 6.7) Earthquake have been successfully estimated by means of the relative GNSS analysis technique. For this purpose, 11 GNSS stations which belong to CORS-TR data nearby earthquake epicenter are used. Horizontal direction displacements, estimated from the 30-day coordinate time series, were successfully estimated with precision sub-mm, and vertical motions with the precision of 2-3 mm. The results obtained from displacement estimation are listed below:

- The highest horizontal displacement value with 57 mm magnitude in the South-West direction was obtained at the ELAZ station located in the north of EAFZ and approximately 30 km from the earthquake epicenter.

- In the ERGN and MALY stations, which are approximately 70 km from the earthquake epicenter and located on opposite sides of the EAFZ, 21 mm and 17 mm opposite directional horizontal motion were detected, respectively.

- The horizontal motion obtained at other stations is less than the three stations mentioned above, and the horizontal motion estimated at the stations is related to the distance from the earthquake epicenter.

- No vertical movement due to the earthquake was obtained at any station.

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