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Detection of Seismic Movements Using GNSS Data

Rasha Mosad [1], Ashraf El-kutb[2], Ahmed El-Hattab[3], Mostafa Rabah [3] and, Ashraf El-Koshy[5]

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ABSTRACT

Nowadays, detecting the response level of ground shaking and studying its effect on the measurements of the surface motion are considered very important, because of the spread of natural disasters, such as earthquakes, volcanoes, and tsunamis. Such disasters lead to changes in the Earth's crust and hence movements of some points. Therefore, studying these movements has great benefits, such as the ability to predict the occurrence of an earthquake, which helps to control and minimize human and economic damages. It is possible to evaluate accurately the magnitude of point displacements and to find the factors affecting these displacements. In this research work, we explain the seismic monitoring techniques using the global navigation satellite system (GNSS), which considered a powerful tool for monitoring the ground points displacements, Bernese GNSS Software 5.2[4], was used to obtain high-precision of the results of the IGS stations data and their displacements, with the application on the network stations in the study area of Turkey,(Aegean sea earthquake).

KEYWORDS: Earthquake, point movement, GNSS, IGS data, Bernese5.2.

1. INTRODUCTION

Many earthquakes with moderate magnitude have occurred in many areas in the world The common procedures to extract the dynamic responses are mainly dependent on monitoring the change of the point or some other points in a time interval.[3]

Turkey is one of the countries has suffered from some of the worst earthquake, caused killing a lot of people and loss of much property. Turkey has a history of destructive seismic activity, and the recent days, the earthquakes are repeated each short time, so it is important to study the ground surface motion and the station's displacement as a result of shaking the earthquake.

The main objective of this paper is to study the effects of the Aegean sea,(Turkey) earthquake at 21/7/2017 in Turkey, and getting the station displacements on the earth's crust.depened on the time domain, that is mean we monitoring the response of earth in the three different days, on the day of the earthquake, a week before shaking and a week after shaking.

Global Navigation Satellite System has been proven to be an effective tool for monitoring the natural hazard as the earthquakes, by extracting the dynamic parameters accompanied by the earthquake, analyzing the seismic wave, and detecting the displacements of the points on the ground surface as a result of earthquake shaking.[9].

First step, getting data from the International GNSS Service (IGS) which provides, the highest-quality GNSS data, Earth observation and research; positioning, navigation, timing products, and services in support of the terrestrial reference frame(ITRF).then the second step to processing these data by Bernese 5.2 GNSS processing software to obtain results within accuracy reach to millimeters.

The IGS stations [3], cover a closed network surrounding the epicenter of the Aegean earthquake (Kara Ada island), consisted of an inner network contains four stations: (ANKR-DYNG-MERS-NICO), which surrounded by an external network eight stations (ISTA-BUCU-BSHM-MAT1-ORDI-ISBA-ARUC).Figure(1).

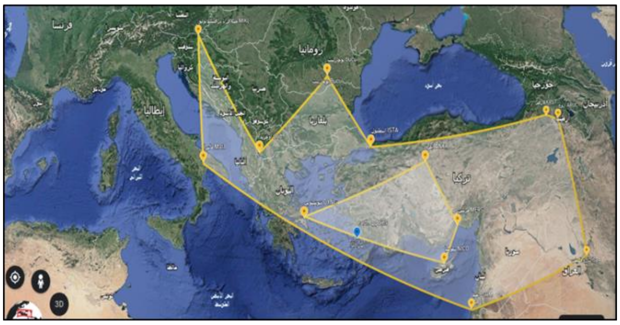

Figure 1: The earthquake stations network with epicenter KARA ADA. (Google Earth).

1 Civil Engineering Department, Faculty of Engineering, Port-said University, Egypt, corresponding author, email:rashamosaad@gmail.com
2 Geodynamics Department, National Research Institute of Astronomy and Geophysics, Helwan, Cairo. email:Ashrafmousa07@gmail.com
3 Civil Engineering Department, Faculty of Engineering, Port-said University, port said, Egypt, email:dr.ahmed.elhattab@gmail.com
4 Civil Engineering Department, Faculty of Engineering, Banha University, Egypt, email: mostafa_rabah@eng.psu.edu.eg
5 Civil Engineering Department, Faculty of Engineering, Port-said University, Egypt, E-mail: dr.aelkoushy@gmail.com

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2. GNSS SYSTEM FOR THE EARTHQUAKES

Global Navigation Satellite Systems (GNSS))[1], such as Global Positioning Systems (GPS) consist of several satellites orbiting high above the Earth in near-circular orbits Figure (2). A receiver can determine its location within a few minutes by measuring the time it takes a signal to travel to it from each satellite, utilizing the right equipment and accurate data processing; centimeter-level positioning can be achieved [2].

GNSS can be used to determine the magnitude of large earthquakes. This is achieved by measuring the displacement of the ground caused by the earthquake itself and monitoring stations close to the fault. For the largest earthquakes, such displacements can be huge: as large as several meters, and permanent displacements of a few millimeters can be identified thousands of kilometers away using GNSS. Figure(3).

The networks of GNSS monitoring stations can be used to estimate the amount of stress on a fault and hence be used to estimate seismic hazard, so GNSS can measure displacement in three dimensions, but only at specific points on the ground where the receivers are located.

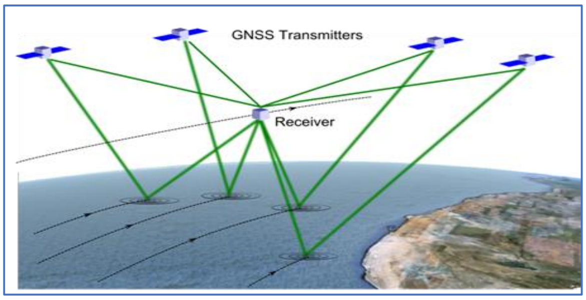

Figure 2: The GNSS system

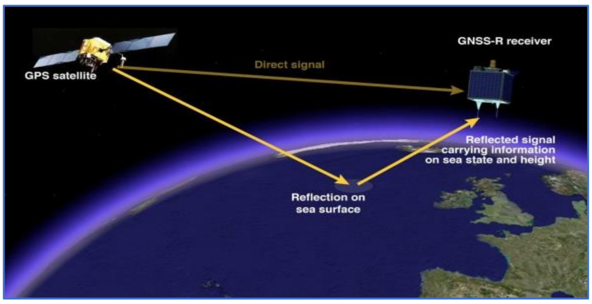

Figure 3: Get location by GNSS system

3. THE AEGEAN EARTHQUAKE

The 2017 Aegean Sea earthquake was a magnitude 6.٦ on the Richter scale. with is considered very strong and caused a strong tsunami which had a maximum height of 1.9 m. It occurred on 21 July 2017, about 10 km (6.2 mi) south-southeast of Bodrum, Turkey, at depth of about 10 km.[6].

The earthquake's epicenter was located just southwest of the small island of Kara Ada on the northern side of the Gulf of Gökova. The gulf is a result of extensional tectonics related to the ongoing subduction of the African Plate beneath the Aegean Sea Plate.Figure(4)

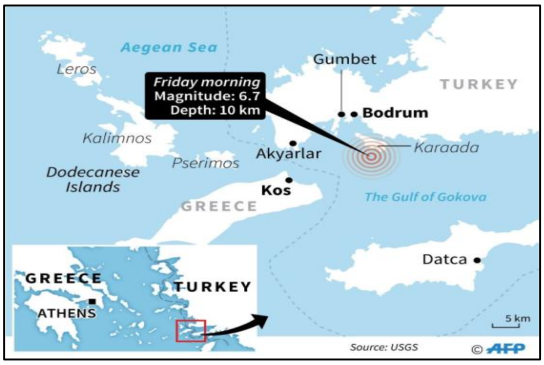

Figure 4: Map of KARAADA island, the epicenter of the earthquake.

4. METHODOLOGY OF GETTING POINTS POSITIONS USING GNSS DATA

The proposed methodology is to make a network of IGS stations surrounding the Aegean earthquake epicenter, the baselines linked to each other deployed within the borders of Turkey and abroad, table(1), then monitor shaking effects of these stations and the Earth's crust movements in all directions X, Y, Z, and obtain all possible information can help us to make a tool of early prediction of earthquakes and reduce many of the risks and victims. The time-domain starts with the day of the Aegean earthquake that occurred at 21/7/2017, then one week before the earthquake at 14/7/2017, and finally on the day of one week after the earthquake at 28/7/2017.

After getting all the required data from IGS service, the second step, making the processing of all data in each monitoring time separately, by using Bernese 5.2 GNSS software. [8].

The following flow chart, Figure (5), explains all steps from collecting data to process data with two main operations first, the pre-processing stage, and the processing stage.

The output after Bernese processing appears in the ADDNEQ file, which contains the solution of each selected station of our network, such as the estimated station's coordinates and velocities, RMS error, and several observations and parameters for 24 hours to each point. And all steps of the previous operation repeated for the other two campaigns with different day. Figure (5)

Tabel 1: The chosen Network Baselines Stations

station1	station2
DYNG	NICO
DYNG	MERS
MERS	NICO
NICO	ANKR
DYNG	ANKR
DYNG	ISTA
DYNG	ORID
DYNG	MIKL
MAT1	DYNG
MAT1	MIKL
NICO	ISBA
BSHM	NICO
ANKR	ARUC
ISBA	ARUC
DYNG	BSHM

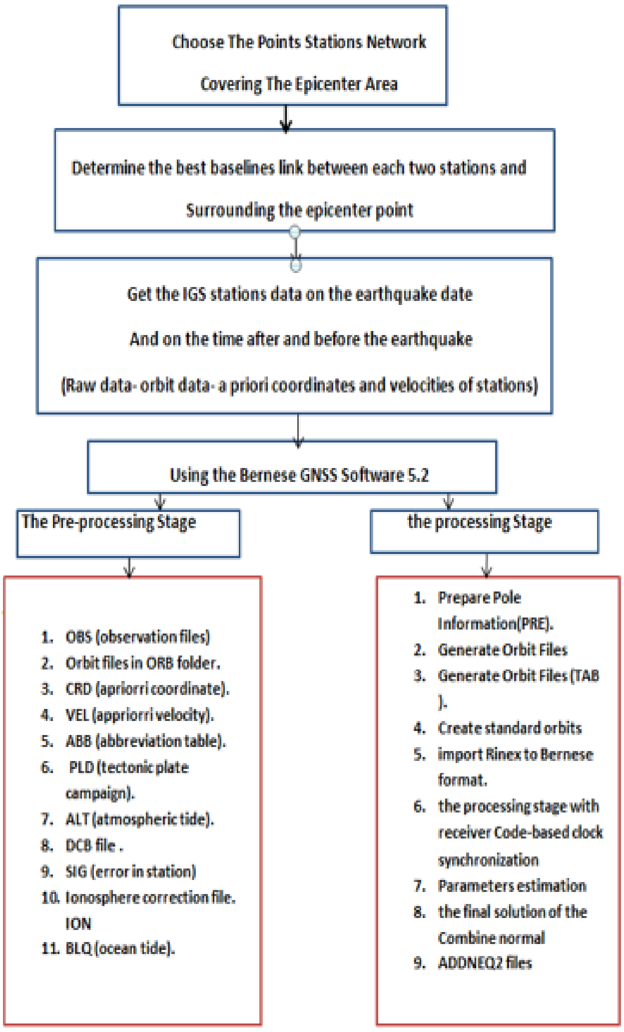

Figure 5: Flow Chart of work methodology

4.1. The Data of three different days of the Aegean Earthquake

After getting the final result file (ADDNEQ file) from Bernese GNSS software version 5.2, we get all the estimated coordinates X, Y and Z for date 14/7/2017 of Aegean earthquake, and computed dX=X1-X2, which X1, X2 the coordinates of station1 and station2 for the baseline number 1, Similarly, we computed dY=Y1-Y2 and dZ=Z1-Z2. Tabel (2).

Table 2: Baselines Data before the earthquake

Aegean Sea-Earthqauke -Turky			the day before 14-7	
station1	station2	X1	X2	dX2 (m)
DYNG	NICO	4595220.08403	4359415.53318	235804.55085
DYNG	MERS	4595220.08403	no data	no data
MERS	NICO	no data	4359415.53318	no data
NICO	ANKR	4359415.53318	4121948.46664	237467.06654
DYNG	ANKR	4595220.08403	4121948.46664	473271.61739
DYNG	ISTA	4595220.08403	4208830.11909	386389.96494
DYNG	ORID	4595220.08403	4498451.54271	96768.54132
DYNG	MIKL	4595220.08403	3698553.77461	896666.30942
MAT1	DYNG	4641951.25943	4595220.08403	46731.17540
MAT1	MIKL	4641951.25943	3698553.77461	943397.48482
NICO	ISBA	4359415.53318	3808364.65438	551050.87880
BSHM	NICO	4395951.24856	4359415.53318	36535.71538
ANKR	ARUC	4121948.46664	3500416.72025	621531.74639
ISBA	ARUC	3808364.65438	3500416.72025	307947.93413
DYNG	BSHM	4595220.08403	4395951.24856	199268.83547

It is Noticeable that there is no available data for MERS station for day 14/7/2017 because there was no raw data on this date at the IGS site, it was maybe due to the maintenance work of the station or change of the receiver which makes the station to stop working.

Likewise, the rest of the data was calculated in the two other dates. Tables (3,4).

Table 3: Table of Baselines Data on the day of the earthquake

		Day 21-7-2017
X1	X2	dX1 (m)
4595219.96307	4359415.40638	235804.55669
4595219.96307	4239149.20328	356070.75979
4239149.20328	4359415.40638	120266.20310
4359415.40638	4121948.34884	237467.05754
4595219.96307	4121948.34884	473271.61423
4595219.96307	4208829.99693	386389.96614
4595219.96307	4498451.42195	96768.54112
4595219.96307	3698553.65981	896666.30326
4641951.14757	4595219.96307	46731.18450
4641951.14757	3698553.65981	943397.48776
4359415.40638	3808364.53802	551050.86836
4395951.13511	4359415.40638	36535.72873
4121948.34884	3500416.60685	621531.74199
3808364.53802	3500416.60685	307947.93117
4595219.96307	4395951.13511	199268.82796

Table 4: Baselines Data after the earthquake

		After 28-7-2017
X1	X2	dX3 (m)
4595220.01173	4359415.46265	235804.54908
4595220.01173	4239149.26264	356070.74909
4239149.26264	4359415.46265	120266.20001
4359415.46265	4121948.39849	237467.06416
4595220.01173	4121948.39849	473271.61324
4595220.01173	4208830.05050	386389.96123
4595220.01173	4498451.50160	96768.51013
4595220.01173	3698553.70386	896666.30787
4641951.20065	4595220.01173	46731.18892
4641951.20065	3698553.70386	943397.49679
4359415.46265	3808364.58276	551050.87989
4395951.18193	4359415.46265	36535.71928
4121948.39849	3500416.65806	621531.74043
3808364.58276	3500416.65806	307947.92470
4595220.01173	4395951.18193	199268.82980

Like these data in the tables, we computed dY and dZ in the three different days of an Aegean earthquake. Take the first baseline (DYNG-NICO) is an example to compare between results of dX,dY, and dZ in meter on the three different days as a bar chart. Fig (6,7,8).

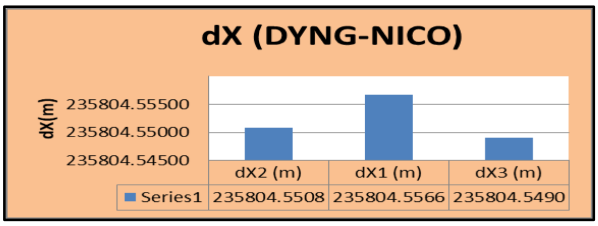

Figure 6: dX bar chart of the baseline

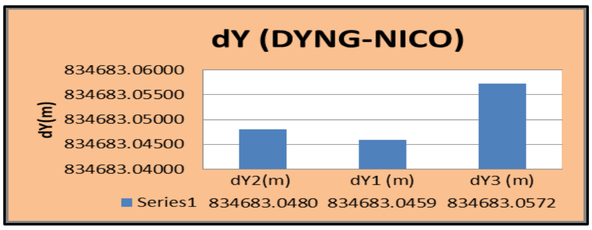

Figure 7: dY bar chart of the same baseline

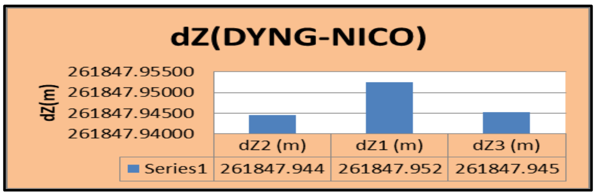

Figure 8: Diagram of dZ bar chart of the same baseline

The values of dX2,dY2, and dZ2are represent the data a week before the earthquake at 14/7/2017, while the dX1,dY1and dZ1 on the day of the earthquake at 21/7/2017, and dX3,3and dZ3 are the data of one week after the earthquake at 28/7/2017.

From the previous bar charts, we noticed that that dX2 is lower than dX1. dX1 increases, and then decreases to reach value dX3 which seems to go to the normal statue after an earthquake finished. Figure(6).

Figure(7) shows that dY increased at the day before the earthquake then decreased by small value on dY1, then increased again after the earthquake is over. Maybe this happened when the earthquake forces were still affecting the earth surface due to the nature of the earth in this region or maybe another earthquake will occur soon.

In figure (8), it is noticed that dZ increased on the day of the earthquake than before it, and then decreased again as begin. But we found that the magnitude of values increased from 1mm to 1cm in the three coordinates of point stations, it may be because of the nature of the ground in these stations regions.

4.2. Compute The Values of The Baselines Length's displacements

It is very important to compute the baseline displacement value between all the network points stations Δdx, Δdy, Δdz, to tell us the amount of expansion or contraction values happened on these baselines, so it can be a monitoring tool of the movement of the point on the surface of the earth's crust.Table(5)

Tabel 5: Shows all Δdx, ΔdY, and ΔdZ of the all baselines network in meter.

Baselines	ΔdX1 m	ΔdX3 m	ΔdY1 m	ΔdY3 m	ΔdZ1 m	ΔdZ3 m
baseline1	-0.00584	0.00177	0.00214	-0.00919	-0.00801	-0.00074
baseline2	no data	no data	no data	no data	no data	no data
baseline3	no data	no data	no data	no data	no data	no data
baseline4	0.00900	0.00238	0.00683	0.00060	-0.01560	-0.00745
baseline5	0.00316	0.00415	-0.00469	-0.00979	-0.00759	-0.00671
baseline6	-0.00120	0.00371	0.00102	-0.00119	-0.00458	-0.00390
baseline7	0.00020	0.03119	-0.00078	0.01531	-0.00493	-0.09176
baseline8	0.00616	0.00155	-0.00562	-0.01415	-0.01573	-0.01701
baseline9	-0.00910	-0.01352	-0.00148	0.00561	-0.00319	-0.00519
baseline10	-0.00294	-0.01197	-0.00710	-0.00854	-0.01254	-0.01182
baseline11	0.01044	-0.00109	-0.01216	-0.00512	0.01295	0.00735
baseline12	-0.01335	-0.00390	-0.01026	-0.00210	0.01527	0.00705
baseline13	0.00440	0.00596	-0.00892	-0.01144	-0.00318	-0.01123
baseline14	0.00296	0.00943	0.00359	0.00692	-0.00583	-0.01133
baseline15	0.00751	0.00567	-0.00812	-0.01129	0.00726	0.00631

In table (5), shows the values of the network baselines displacements of ΔdX, ΔdY, and ΔdZ, taking into consideration that: Δdx1 = Δdx2-Δdx1 (m), and Δdx3 = Δdx2-Δdx3 (m), This mean that we took Δdx2 as a reference value of our calculations, likewise, ΔdY2 and ΔdZ2 was taken as a reference of the equations to get values of ΔdY1, ΔdY3, ΔdZ1and ΔdZ3.

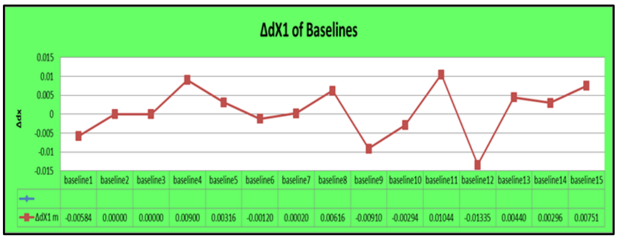

Figure 9:The diagram of ΔdX1on the day of the Earthquake

From the diagram, Figure(9). we noticed that the length of the first baseline (DYNG-NICO) increased by 5mm which ΔdX1= -0.005m (5mm), which ΔdX1=(dX2-dX1) m and this is referred to the effect of the earthquake on these two stations which is considered one of the nearest stations from the epicenter of the earthquake. The two baselines number 2and 3 (DYNG-MERS) and (MERS-NICO) we could not draw their changes, because there was no raw data of MERS station on 14/7/2017. the baseline number 4 (NICO-ANKR) decreases its length by 9mm where ΔdX1=+0.009 m. we noticed that the earthquake shaking affected these two stations because of their closeness from the earthquake center. The baseline number 5 (DYNG-ANKR) also decreased its length by 3 mm on the day of one week before the earthquake, this could be an indication of the accumulation of the forces of this earthquake to occur on its close time. With such a study, the prediction of earthquakes will be easier, keeping the daily monitoring of earth crust movements help us to have an early warning system.

The baseline number 6 (DYNG-ISTA) has ΔdX1= -0.001m, that shows the increase in the length of baseline on the day of the earthquake from the day before it by 1mm. The length of baselines number 8 reduced about 6mm, and baselines 9and 10 have increased their lengths of 2mmto 9mm, but we noticed that baseline 11 has a contraction of 1cm and number 12 have an expansion of 1cm as the two stations near from the epicenter of the earthquake, and the final baselines 13,14 and 15 all have length reduction about 2mm to 7mm.

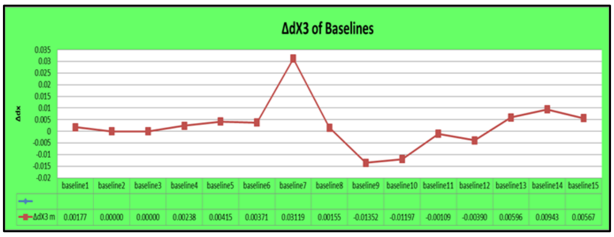

Figure 10: The Diagram of ΔdX3 a week after the earthquake

This graph, Figure (10), illustrates the changes of values dx after a week of the earthquake shaking, the first baseline decreased, which Δdx3 = +.0.00177 m, about 2mm that means The Earth's crust returns gradually to its normal case. There is no change in baselines numbers 2 and 3 as no available data for MERS station. The baselines 4,5 and 6 the Δdx with a positive signal that means the lengths were less than its previous value before the earthquake of about 2 to 4 mm. This means the Earth's crust begins to be relatively stable again. Even though we noticed that the baseline number 7 (DYNG-ORID) changed very clearly, up to 3 cm, the reason for that high displacement value probably as a result of the proximity of the two stations to the epicenter of the earthquake or because of the mountain topography of Macedonia, which included the ORID station and exposed consecutively with earthquakes. Like these displacements, it may be indicated that an earthquake will be coming soon or the aftershocks sequence. The other baselines displacements have values ranging from 1mm and 5mm except baseline numbers 9 and 10 equal 1cm.

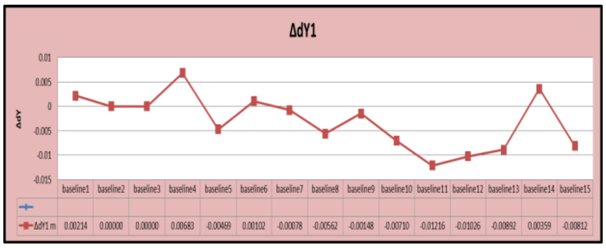

Figure 11: The Diagram of ΔdY1 on the day of the earthquake

The graph in figure (11), shows that the baselines numbers 1,4,6, and 14 were subjected to a decrease in their lengths between each two stations in a range of 1mm to 4mm.

On the other hand, the rest of the baselines were exposed to an increase in the length between each of them in a range of 1mm to 1cm as a maximum value.

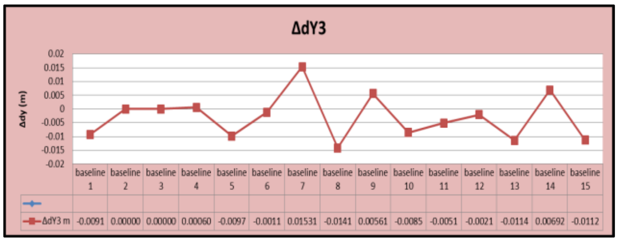

Figure 12: The Diagram of ΔdY3 a week after the earthquake

the graph in figure (12), explains that the changes in ΔdYof baselines number 7,8,10,13and 15 reached to values 1 cm to 1.5 cm. because some of their stations are near the epicenter like (DYNG, ANKR, ISTA), but we noticed also that the far stations (MIKL, ORID, NICO, ARUC, and BSHM), linked between the same baselines 7,8,10,13,15. So, this displacement value may be a result of the nature of the rocky ground and the frequency rate of natural disasters in these areas. I.e.it makes the storage of earthquakes forces inside the earth not finished yet and the surface stability will be delayed.

In Figure (13) we noticed that values range in most of baselines from 3mm to 8mm at stations NICO, DYNG, ISTA which considered closer to the earthquake center.it may be a sign of station movements before earthquake shaking as a result of gathering the forces of an earthquake underground surface and then an earthquake will occur after a certain time. The Baselines numbers 10,11 and 12 have values of 1cm, it may be dependent on the soil nature of their regions which helped to make bigger movements of their points.

In Figure (14), most points have small displacements ranged between 6mm and 7mm, so it was easy to reach to their stability case. For some other stations, the values of ΔdZ3 were very big, like stations of ORID the value equal 9cm, which may indicate another earthquake in its area will happen soon.

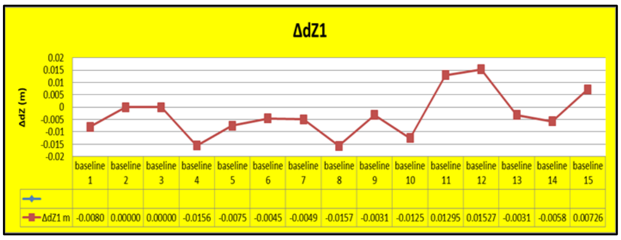

Figure 13: The Diagram of ΔdZ1 on the day of the earthquake

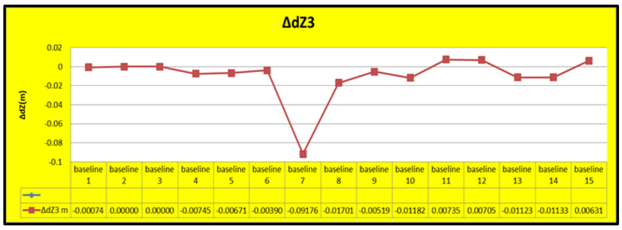

Figure 14: The Diagram of ΔdZ3 on a week after the earthquake

5. THE HEIGHTS DISPLACEMENT OF THE BASELINES POINTS

From the output file of Bernese GNSS processing, we extracted also the heights values of each station of our Aegean network, and calculated the height difference between every two stations of the baselines. the following tables explain the values of stations heights difference in the three different dates from the earthquake. Tables (6,7,8).

Table 6: The station's height difference values on a week before the earthquake

14/7/2017				
station1	station2	h1(m)	h2(m)	dh2 week before anearthquke
DYNG	NICO	510.60444	190.05154	320.55290
DYNG	MERS	510.60444	no data	no data
MERS	NICO	no data	190.05154	no data
NICO	ANKR	976.03127	190.05154	785.97973
DYNG	ANKR	976.03127	510.60444	465.42683
DYNG	ISTA	510.60444	147.27504	363.32940
DYNG	ORID	773.04057	510.60444	262.43613
DYNG	MIKL	510.60444	93.93712	416.66732
MAT1	DYNG	534.55785	510.60444	23.95341
MAT1	MIKL	534.55785	93.93712	440.62073
NICO	ISBA	190.05154	72.38347	117.66807
BSHM	NICO	225.08876	190.05154	35.03722
ANKR	ARUC	1222.16714	976.03127	246.13587
ISBA	ARUC	1222.16714	72.38347	1149.78367
DYNG	BSHM	510.60444	225.08876	285.51568

Table 7: The station's heights difference values on the day of the earthquake

21/7/2017				
station1	station2	h1(m)	h2(m)	dh1 the day of earthquke
DYNG	NICO	510.48986	189.92874	320.56112
DYNG	MERS	510.48986	38.48829	472.00157
MERS	NICO	189.92874	38.3816	151.54714
NICO	ANKR	975.93072	189.92874	786.00198
DYNG	ANKR	975.93072	510.48986	465.44086
DYNG	ISTA	510.48986	147.16701	363.32285
DYNG	ORID	772.93157	510.48986	262.44171
DYNG	MIKL	510.48986	93.85211	416.63775
MAT1	DYNG	534.4531	510.48986	23.96324
MAT1	MIKL	534.54922	93.85211	440.69711
NICO	ISBA	189.92874	72.28833	117.64041
BSHM	NICO	224.98775	189.92874	35.05901
ANKR	ARUC	1222.08394	975.93072	246.15322
ISBA	ARUC	1222.08394	72.28833	1149.79561
DYNG	BSHM	510.48986	224.98775	285.50211

Table 8: The station's heights difference values on a week after the earthquake

28/7/2017				
station1	station2	h1(m)	h2(m)	dh3 week after of earthquke
DYNG	NICO	510.49534	189.95338	320.54196
DYNG	MERS	510.49534	38.40763	472.08771
MERS	NICO	189.95338	38.40763	151.54575
NICO	ANKR	975.93607	189.95338	785.98269
DYNG	ANKR	975.93607	510.49534	465.44073
DYNG	ISTA	510.49534	147.17193	363.32341
DYNG	ORID	773.01540	510.49534	262.52006
DYNG	MIKL	510.49534	93.84612	416.64922
MAT1	DYNG	534.45982	510.49534	23.96448
MAT1	MIKL	534.45982	93.84612	440.61370
NICO	ISBA	189.95338	72.30099	117.65239
BSHM	NICO	225.00105	189.95338	35.04767
ANKR	ARUC	1222.09551	975.93607	246.15944
ISBA	ARUC	1222.09551	72.30099	1149.79452
DYNG	BSHM	510.49534	225.00105	285.49429

To evaluate the changes happened on the height displacements we calculated the values of Δdh1and Δdh3,Where, as with X, Y and Z, Δdh1=dh2-dh1 in meter, and Δdh3= dh2-dh3 in meter. The dh2 values are taken as a reference to calculate both of Δdh1 and Δdh3.

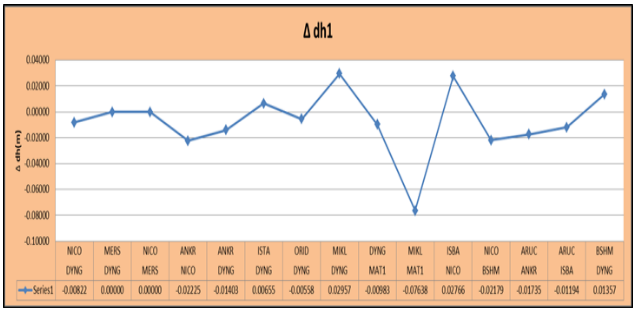

Figure 15: The graph of Δdh1 on the day of an earthquake

The graph in figure (15), shows the magnitude of changes in the height displacement of the stations on the day of an earthquake, the first baseline increased about 8mm. the next two baselines have no data available because of MERS station has no raw data on this date, then the baselines number 4, 5 height increased 2cm and 1cm. Similarly, most values increased or decreased in the range of 5mm to 2cm. But the baseline (MIKl-MAT1) has a more increased value of 7cm, that means the baseline greatly affected the earthquake because of their statins locations and topography.

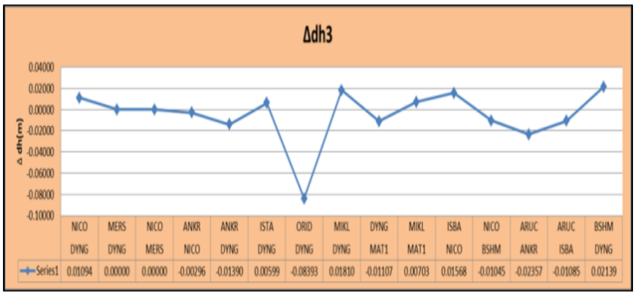

Figure 16: The graph of Δdh3 a week after the earthquake

From this graph 16, we notice that the height of the first baseline decreased about 1cm after its increase on the day of the earthquake. In the next two baselines, the heights displacements increased by 2 mm and 1cm, which means that some stations return to its stability gradually from the day of the earthquake until a week after it.

But the big height displacement happened on the baseline of (ORDI-DYNG) which has an increased value of 8 cm. Although it has a slight value on the day of earthquake equal 5 mm, it may be a sign of another earthquake near this area or these stations.

The baseline (MIKL-DYNG) has about a 2cm decreased value, but on the day of an earthquake, it has a displacement value of about 3 cm. we notice that the biggest displacement value of the baseline (MIKL-MAT1) on the day of the earthquake was 7 cm increased value. But it changed after one week to reach a value of 7 mm as a decrease value, that change makes us believe that the station returned to its normal case after finishing the effect of earthquake forces.

6. THE AFTERSHOCK AEGEAN EARTHQUAKE DISPLACEMENTS

To make the study of the movement of points of the Earth's crust an important tool for predicting the earthquakes, it is necessary to periodically monitor these stations at consecutive and regular periods to achieve the greatest accuracy of the results and help us in the future.

So the Aegean aftershocks were monitored three months later at 27/10/2017, first we used the Bernese GNSS software 5.2 to processing the raw data of our stations in the same network get finally the estimated coordinates of all points according to the free network solution. then we get all data we needed in the three different days of aftershock the day of earthquake 27/10/2017, a week before the earthquake 20/10/2017, and after two weeks from shocking on 10/11/2017, because there was not any available raw data on the date of a week after an earthquake. The same previous scenario will be repeated in the calculation of aftershock displacements.

Table 9: dX for the network baselines on day of

	the day of earthqauke 27-10-2017			
STATIONS1	STATIONS2	X1(m)	X2(m)	dX1(m)
NICO	DYNG	4359415.50618	4595220.05789	235804.55171
DYNG	MERS	4595220.05789	4239149.30559	356070.75230
MERS	NICO	4239149.30559	4359415.50618	120266.20059
NICO	ANKR	4359415.50618	4121948.44327	237467.06291
DYNG	ANKR	4595220.05789	4121948.44327	473271.61462
DYNG	ISTA	4595220.05789	4208830.09197	386389.96592
DYNG	ORID	4595220.05789	4498451.52004	96768.53785
DYNG	MIKL	4595220.05789	3698553.75646	896666.30143
MAT1	DYNG	4641951.23944	4595220.05789	46731.18155
MAT1	MIKL	4641951.23944	3698553.75646	943397.48298
NICO	ISBA	4359415.50618	3808364.63131	551050.87487
BSHM	NICO	4395951.22298	4359415.50618	36535.71680
ANKR	ARUC	4121948.44327	3500416.70471	621531.73856
ISBA	ARUC	3808364.63131	3500416.70471	307947.92660
DYNG	BSHM	4595220.05789	4395951.22298	199268.83491

Table 10: dY and dZ for the network baselines

Y1(m)	Y2(m)	dY1(m)	Z1(m)	Z2(m)	dZ1(m)
2874117.21017	2039434.16125	834683.04892	3650777.99348	3912625.93267	261847.93919
2039434.16125	2886968.01203	847533.85078	3912625.93267	3778877.15882	133748.77385
2886968.01203	2874117.21017	12850.80186	3778877.15882	3650777.993	128099.16534
2874117.21017	2652187.86010	221929.35007	3650777.993	4069023.85355	418245.86007
2039434.16125	2652187.86010	612753.69885	3912625.93267	4069023.85355	156397.92088
2039434.16125	2334850.52755	295416.36630	3912625.93267	4171267.36788	258641.43521
2039434.16125	1708267.23569	331166.92556	3912625.93267	4173591.985	260966.05196
2039434.16125	2308676.21135	269242.05010	3912625.93267	4639769.615	727143.68219
1393053.90251	2039434.16125	646380.25874	4133281.059	3912625.93267	220655.12592
1393053.90251	2308676.21135	915622.30884	4133281.059	4639769.615	506488.55627
2874117.21017	3734430.20182	860312.99165	3650777.993	3485693.68	165084.31343
3080707.21539	2874117.21017	206590.00522	3433498.25	3650777.993	217279.74372
2652187.86010	3390432.73954	738244.87944	4069023.85355	4103027.64111	34003.78756
3734430.20182	3390432.73954	343997.46228	3485693.68	4103027.64111	617333.96106
2039434.16125	3080707.21539	1041273.05414	3912625.93267	3433498.25	479127.68291

The same table for dX,dY, and dZ for the other two different times of the earthquake have been calculated also. then we calculated the values of the baselines displacements to know the movement of both of the joint stations in the baseline in the three chosen times, determine whether there has been an expansion or contraction of its original length due to the impact of the earthquake.Tables (9,10,11,12,13).

Table 11: ΔdX1 and ΔdX3 of the network baselines

station1	station2	dX2 (m)	dX1 (m)	dX3 (m)	ΔdX1=(dx2-dx1)m	ΔdX3=(dx2-dx3)m
NICO	DYNG	235804.55385	235804.55171	235804.55784	0.00214	-0.00399
DYNG	MERS	356070.75204	356070.75230	356070.75848	-0.00026	-0.00644
MERS	NICO	120266.19819	120266.20059	120266.20064	-0.00240	-0.00245
NICO	ANKR	237467.06012	237467.06291	237467.05820	-0.00279	0.00192
DYNG	ANKR	473271.61397	473271.61462	473271.61604	-0.00065	-0.00207
DYNG	ISTA	386389.96631	386389.96592	386389.97091	0.00039	-0.00460
DYNG	ORID	96768.53870	96768.53785	96768.53855	0.00085	0.00015
DYNG	MIKL	896666.30607	896666.30143	896666.30537	0.00464	0.00070
MAT1	DYNG	46731.02890	46731.18155	46731.17817	-0.15265	-0.14927
MAT1	MIKL	943397.33497	943397.48298	943397.48354	-0.14801	-0.14857
NICO	ISBA	551050.87344	551050.87487	551050.87167	-0.00143	0.00177
BSHM	NICO	36535.72353	36535.71680	36535.72104	0.00673	0.00249
ANKR	ARUC	621531.73878	621531.73856	621531.74383	0.00022	-0.00505
ISBA	ARUC	307947.92546	307947.92660	307947.93036	-0.00114	-0.00490
DYNG	BSHM	199268.83032	199268.83491	199268.83680	-0.00459	-0.00648

Table 12: ΔdY1 and ΔdY3 of the network baselines

station1	station2	dY2(m)	dY1(m)	dY3(m)	ΔdY1=(dy2-dy1)m	ΔdY3=(dy2-dy3)m
NICO	DYNG	834683.04689	834683.04892	834683.04458	-0.00203	0.00231
DYNG	MERS	847533.84553	847533.85078	847533.85001	-0.00525	-0.00448
MERS	NICO	12850.79864	12850.80186	12850.80543	-0.00322	-0.00679
NICO	ANKR	221929.34304	221929.35007	221929.34541	-0.00703	-0.00237
DYNG	ANKR	612753.70385	612753.69885	612753.69917	0.00500	0.00468
DYNG	ISTA	295416.36473	295416.36630	295416.36593	-0.00157	-0.00120
DYNG	ORID	331166.92723	331166.92556	331166.92366	0.00167	0.00357
DYNG	MIKL	269242.04727	269242.05010	269242.04964	-0.00283	-0.00237
MAT1	DYNG	646380.26107	646380.25874	646380.25828	0.00233	0.00279
MAT1	MIKL	915622.30834	915622.30884	915622.30792	-0.00050	0.00042
NICO	ISBA	860312.99648	860312.99165	860312.99630	0.00483	0.00018
BSHM	NICO	206590.00852	206590.00522	206590.01201	0.00330	-0.00349
ANKR	ARUC	738244.87632	738244.87944	738244.87473	-0.00312	0.00159
ISBA	ARUC	343997.46320	343997.46228	343997.46698	0.00092	-0.00378
DYNG	BSHM	1041273.05541	1041273.05414	1041273.05659	0.00127	-0.00118

Table 13: ΔdZ1 and ΔdZ3 of the network baselines

station1	station2	dZ2(m)	dZ1(m)	dZ3(m)	ΔdZ1=(dZ2-dZ1)m	ΔdZ3=(dZ2-dZ3)m
NICO	DYNG	261847.94291	261847.93919	261847.94298	0.00372	-0.00007
DYNG	MERS	133748.78066	133748.77385	133748.77974	0.00681	0.00092
MERS	NICO	128099.16225	128099.16534	128099.16324	-0.00309	-0.00099
NICO	ANKR	418245.86414	418245.86007	418245.86252	0.00407	0.00162
DYNG	ANKR	156397.92123	156397.92088	156397.91954	0.00035	0.00169
DYNG	ISTA	258641.43196	258641.43521	258641.43105	-0.00325	0.00091
DYNG	ORID	260966.04824	260966.05196	260966.05097	-0.00372	-0.00273
DYNG	MIKL	727143.67894	727143.68219	727143.67911	-0.00325	-0.00017
MAT1	DYNG	220655.25003	220655.12592	220655.12224	0.12411	0.12779
MAT1	MIKL	506488.42891	506488.55627	506488.55687	-0.12736	-0.12796
NICO	ISBA	165084.31234	165084.31343	165084.30983	-0.00109	0.00251
BSHM	NICO	217279.60576	217279.74372	217279.73971	-0.13796	-0.13395
ANKR	ARUC	34003.91870	34003.78756	34003.78383	0.13114	0.13487
ISBA	ARUC	617334.09518	617333.96106	617333.95618	0.13412	0.13900
DYNG	BSHM	479127.54867	479127.68291	479127.68269	-0.13424	-0.13402

These results are represented in graphic relationships to show the extent of the change in the movement of network stations, Figures (17,18,19,20,21 and 22).

From figures (17) and (18), we note the following; the baseline number 1 decreased 2mm in its length on the day of the aftershock at 27/10/20 in the X direction, but at 10/11/2017, after two weeks from the earthquake, we found that the value of ΔdX3 has no change in its length, the baseline 2 have no change in ΔdX1vaue but in ΔdX3 increased about 4mm. The baselines numbers 3,4 and 5 have a displacement values about 2mm to 3mm. there isn't any change in length of baseline numbers 7 and 8, then a little change in baseline 11 and 14. We notice a great jump in ΔdX1values of baselines numbers 9 (MAT1-DYNG) and baseline10 (MAT1-MIKL), where the value of ΔdX1 equals about 15 cm and 14 cm, respectively. This indicates that these stations are the most affected by the earthquake shaking. Because of the Earth's surface still preserved the impact of the earthquake’s internal forces, so this indicates the possibility of an earthquake near these two lines in this region.

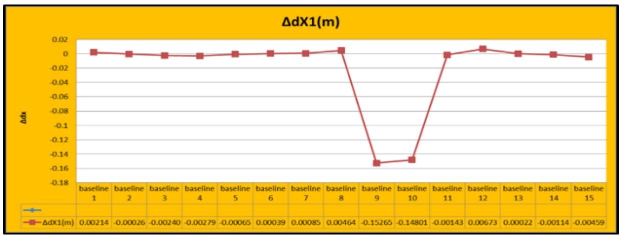

Figure 17: Diagram of all values of ΔdX1 of all baselines on the day of the earthquake.

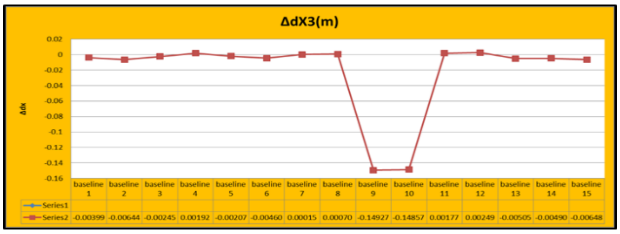

Figure 18: Diagram of all values of ΔdX3 of all baselines after the earthquake.

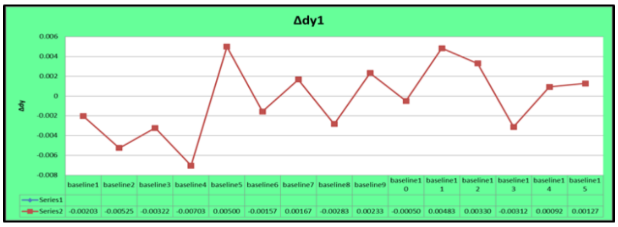

Figure 19: Diagram of all values of ΔdY1 of all baselines.

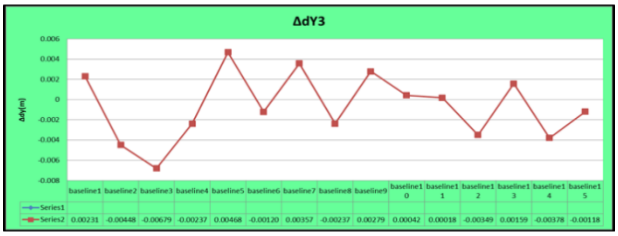

Figure 20: Diagram of all values of ΔdY3 of all baselines after the earthquake.

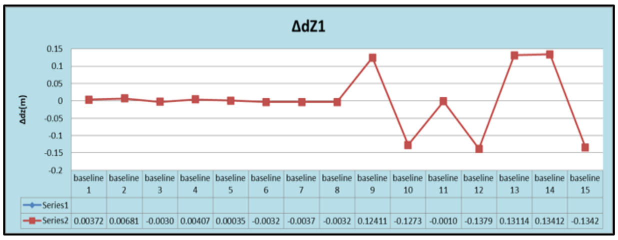

Figure 21: Diagram of all values of ΔdZ1 of all baselines.

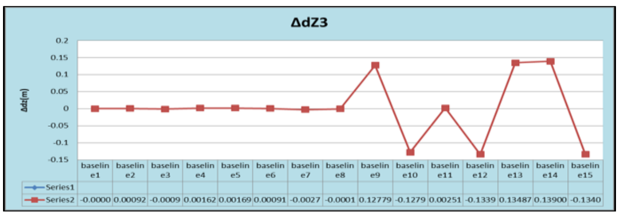

Figure 22: Diagram of all values of ΔdZ3 of all baselines.

For the graph of ΔdX1 and ΔdX3, figures (17,18), we found that most values in a range of 1mm to 6 mm as a maximum as an increase or decrease values, but two baselines number 9 and 10 have large displacement values equal about 15 centimeters, as their stations are close to the epicenter of the earthquake, so most affected.

For graphs of ΔdY1and ΔdY3, we noticed that in ΔdY1 values of the baselines number1,2,3,4,6, 8,10, and 13 increased about 2mm to 7mm, and the rest of the other lengths decreased in a range of 1mm to 5mm. At ΔdY3 figure (20), we noticed that values after two weeks from the earthquake were closed together from 1mm to 6 mm as maximum.

For values of ΔdZ, the ΔdZ1 in the graph of Figure (21), we found that the change range from 1mm to 6 mm as a maximum. A number of baselines increased more like baseline numbers 9,10, 12,13,14, and 15 they have displacement values about 12 to13 cm, which means they have the most effects of the earthquake and led to big station motions, after two weeks from the earthquake we found the values of ΔdZ3 have ranged between 1mm to 2mm, but the baselines numbers 9,10,12,13,14 and15 increased much and to reached of 12cm to 14cm.

7. CONCLUSION

This paper studies the use of the GNSS system for the detection of the displacement values of all network points surrounding the earthquake area (Aegean earthquake 2017 in turkey) and also the station displacements of the same Aegean network under the earthquake aftershock that was after three months from the Aegean earthquake. Then an evaluation of the displacements of all network baselines was made for three consecutive days, on the day before the earthquake, on the day of the earthquake, and the day after. The objective is to assess how the earthquake affects the ground station's movements and to find out the specific factors causing the changes in the magnitude of these displacements. The study also evaluates the station's height displacements caused by the earthquake. The more elements that are studied under the effect of the earthquake shaking, the more we can know the response of the ground surface and the movement of points in a better and more accurate way. Seismic monitoring was made using the global navigation satellite system (GNSS) which is considered an effective tool for natural hazard monitoring. Bernese 5.2 GNSS Software was used to obtain high-precision results of the IGS station data. This technique may be used as a tool to predict the occurrence of earthquakes in the areas which are known to be subjected to frequent earthquakes. It was also found that by increasing the monitoring periods, more accurate results may be obtained which helps in preventing considerable human and economic losses.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

R. Mosad: Research and analysis, Writing –original Draft **Elkutb**: Methodology, Software, Review, Data Curation, Supervision. **A.ElHattab:** Conceptualization, Methodology, Review, Supervision, **M.Rabah:** Conceptualization, Formal Analysis, Review, Resource. **A.Elkoshy:** Review-editing, Supervision, Validation, Resource.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interest or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

[1] S. Gleason and, D. Gebre-Egziabher & D. G. Egziabher "GNSS Applications and Methods". Boston, MA: Artech House, 2009.

[2] G. Beutler, A. W. Moore, and I. I. Mueller. Journal: Journal of Geodesy, Volume 83, Number 3-4, 2009, Page 297

[3] G. Beutler, J. Kouba, & T. Springer, "Combining the orbits of the IGS Analysis Centers". Bulletin Géodésique 69, 200–222, 1995. https://doi.org/10.1007/BF00806733

[4] R. Dach, and P.Walser. "Bernese GNSS Software Version 5.2.", 2015.

[5] F. N. Teferle, E. J. Orliac and, R. M. Bingley. "An assessment of Bernese GPS software precise point positioning using IGS final products for global site velocities." GPS solutions 11.3, 2007: 205-213.

[6] "M 6.7 - 10km SSE of Bodrum, Turkey". United States Geological Survey. 21 July 2017. Retrieved 20 July 2017.

[7] N. C.T Sai and, G. W. Housner. "Calculation of surface motions of a layered half-space." Bulletin of the Seismological Society of America 60.5, 1970: 1625-1651.

[8] J. Dhanya, , M. Gade, and S. T. G. Raghukanth. "Ground motion estimation during artlthe 25th April 2015 Nepal earthquake." Acta Geodaetica et Geophysica 52.1, 2017: 69-93.

[9] Ö . Aydan, R. Ulusay, and H. Kumsar. "Seismic, ground motion and geotechnical characteristics of the 2011 Van-Erciş and Van-Edremit earthquakes of Turkey, and assessment of geotechnical damages." Bulletin of Engineering Geology and the Environment 73.2, 2014: 643-666.