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Using PPP-GNSS Technique for Detecting Surface Motion due to Earthquake Shaking based on time-domain analysis

Rasha Mosad [1], Ashraf El-kutb[2], Ahmed El-Hattab[3], Mostafa Rabah[4] and, Ashraf El-Koshy[5]

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ABSTRACT

Many earthquakes with moderate magnitude have occurred in many areas of the world. The common procedures to extract the dynamic responses mainly depend on monitoring the change of the points in a time interval. This method could not be used to fully extract all dynamic parameters accompanied by the earthquake. To overcome these defects, and to analyze the seismic wave of those earthquakes, the GNSS precise point positioning (PPP) can be an effective tool for getting the values of the displacement of the point more accurate up to millimeters. In this paper, we apply the PPP technique to evaluate the station's displacement components and the station's heights in three different periods from the earthquake, Canadian Spatial Reference System Precise Point Positioning (CSRS-PPP) is used here [1]. Bernese GNSS 5.2 software is used as a reference to evaluate the PPP results [2]. Finally, it was found that PPP is an important tool for obtaining a high accuracy of our needed observations.

Keywords: Precise Point Position, GNSS, Precise Orbit, point displacement, IGS Service.

1. INTRODUCTION

PPP is a positioning technique that removes or models GNSS system errors to provide a high level of position accuracy from a single receiver, A PPP solution depends on GNSS satellite clock and orbit corrections, once the corrections are calculated, they are delivered to the end-users via satellite.

These corrections are used by the receive resulting in decimeter-level, or better positioning with no base station required.PPP delivers accuracy up to 3 centimeters. A typical PPP solution requires time to converge to decimeter accuracy to resolve any local biases such as the atmospheric conditions, multipath environment, and satellite geometry. The actual accuracy achieved and the convergence time required depends on the quality of the corrections and how they are applied in the receiver but the main error sources for PPP which affect its accuracy are the ionospheric delay, the satellite orbit, and clock corrections, the tropospheric delay, and carrier-phase ambiguities.

It seems clear that PPP constitutes a major step forward in the development of high accuracy positioning, so this paper involved a study of using the PPP technique to reach a high accuracy of the station's network displacements according to the earthquake shaking, we extract the values of the movements of the points in three dimensional X, Y, Z are extracted. The data used here are a network data from the IGS (International GPS Service) [3].

2. PROCESS OF THE AEGEAN EARTHQUAKES DATA USING BERNESE 5.2 SOFTWARE

On 21 July 2017, a strong earthquake of magnitude of 6.6 occurred in the Aegean Sea, Turkey. The earthquake strike about 10 km (6.2 mi) south southeast of Bodrum, Turkey, at depth of 7.0 km. The earthquake's epicenter was located just southwest of the small island of Kara Ada, on the northern side of the Gulf of Gökova,[6]. Which is a small Turkish island at the entrance of the harbor of Bodrum at the Aegean Sea? This earthquake is the focus of the current paper, Figure (1).

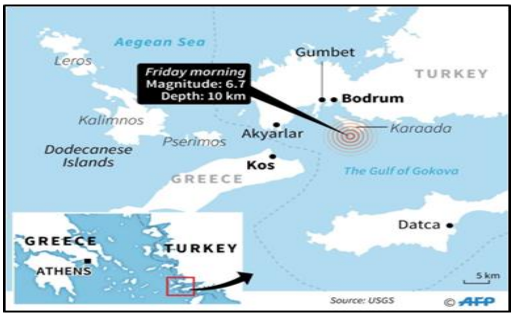

Figure 1:The epicenter of the Aegean earthquake

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[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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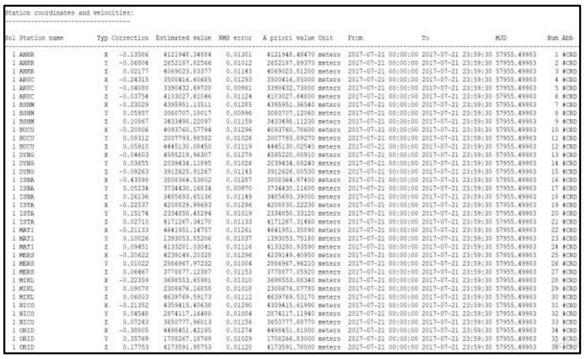
Time-domain analysis is used here as an effective tool for earthquake prediction. The processing is made on three different times, to be able to extract as accurate data as possible, The analyzed time are; the first day of an earthquake that occurs 21/7/2017, the second time in one week before at 14/7/2017, third time is one week after the earthquake 28/7/2017.All needed data from IGS service, such as the GPS week, day of the week, day of the year, orbit data (Orbit file), Raw data for all points (Rinex file), the station's coordinates, Atmosphere file, and the ionosphere file

PPP requires a global network of GNSS reference stations to estimate precise satellite orbit and clock parameters in real-time, these parameters are transmitted to users, who can compute their position with an accuracy of 0.1 m using code and carrier observations. the main disadvantage of PPP takes a long time to converge to this accuracy, about 30-45 minutes. By Bernese GNSS software program version 5.2, our collected data of the Aegean network stations have been processed for each day we want to monitor the earthquake separately, and extract the required results in the ADDNEQ file that contains the outputs, tables(1,2)



```
Station coordinates and velocities:
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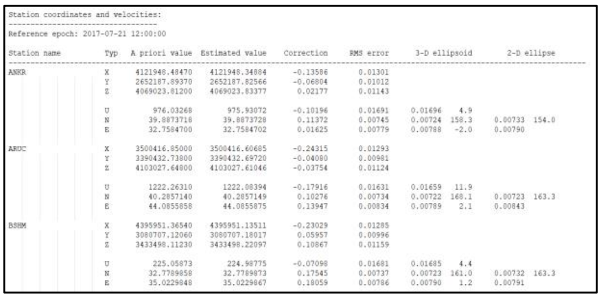
Sol Station name         Typ Correction  Estimated value  RMS error   A priori value Unit    From                To                  MJD           Num Abb
-------------------------------------------------------------------------------------------------------------------------------------------------------
  1 ANKR                   X    -0.13586    4121948.34884    0.01301    4121948.48470 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983     1 #CRD
  1 ANKR                   Y    -0.06804    2652187.82566    0.01012    2652187.89370 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983     2 #CRD
  1 ANKR                   Z     0.02177    4069023.83377    0.01143    4069023.81200 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983     3 #CRD
  1 ARUC                   X    -0.24315    3500416.60685    0.01293    3500416.85000 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983     4 #CRD
  1 ARUC                   Y    -0.04080    3390432.69720    0.00981    3390432.73800 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983     5 #CRD
  1 ARUC                   Z    -0.03754    4103027.61046    0.01124    4103027.64800 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983     6 #CRD
  1 BSHM                   X    -0.23029    4395951.13511    0.01285    4395951.36540 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983     7 #CRD
  1 BSHM                   Y     0.05957    3080707.18017    0.00996    3080707.12060 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983     8 #CRD
  1 BSHM                   Z     0.10867    3433498.22097    0.01159    3433498.11230 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983     9 #CRD
  1 BUCU                   X    -0.20806    4093760.57794    0.01296    4093760.78600 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    10 #CRD
  1 BUCU                   Y     0.09312    2007793.98582    0.01026    2007793.89270 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    11 #CRD
  1 BUCU                   Z     0.05910    4445130.08450    0.01119    4445130.02540 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    12 #CRD
  1 DYNG                   X    -0.04603    4595219.96307    0.01279    4595220.00910 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    13 #CRD
  1 DYNG                   Y     0.03655    2039434.11895    0.01026    2039434.08240 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    14 #CRD
  1 DYNG                   Z    -0.09263    3912625.91267    0.01143    3912626.00530 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    15 #CRD
  1 ISBA                   X    -0.43598    3808364.53802    0.01287    3808364.97400 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    16 #CRD
  1 ISBA                   Y     0.05234    3734430.16834    0.00970    3734430.11600 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    17 #CRD
  1 ISBA                   Z     0.26136    3485693.65136    0.01149    3485693.39000 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    18 #CRD
  1 ISTA                   X    -0.22537    4208829.99693    0.01296    4208830.22230 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    19 #CRD
  1 ISTA                   Y     0.15174    2334850.48294    0.01019    2334850.33120 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    20 #CRD
  1 ISTA                   Z     0.02710    4171267.34170    0.01133    4171267.31460 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    21 #CRD
  1 MAT1                   X    -0.21133    4641951.14757    0.01261    4641951.35890 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    22 #CRD
  1 MAT1                   Y     0.10026    1393053.85206    0.01037    1393053.75180 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    23 #CRD
  1 MAT1                   Z     0.09451    4133281.03041    0.01116    4133280.93590 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    24 #CRD
  1 MERS                   X    -0.20622    4239149.20328    0.01296    4239149.40950 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    25 #CRD
  1 MERS                   Y     0.01022    2886967.97232    0.01004    2886967.96210 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    26 #CRD
  1 MERS                   Z     0.06467    3778877.12387    0.01153    3778877.05920 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    27 #CRD
  1 MIKL                   X    -0.22359    3698553.65981    0.01310    3698553.88340 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    28 #CRD
  1 MIKL                   Y     0.09078    2308676.16858    0.01018    2308676.07780 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    29 #CRD
  1 MIKL                   Z     0.06003    4639769.59173    0.01112    4639769.53170 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    30 #CRD
  1 NICO                   X    -0.21352    4359415.40638    0.01290    4359415.61990 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    31 #CRD
  1 NICO                   Y     0.04548    2874117.16488    0.01004    2874117.11940 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    32 #CRD
  1 NICO                   Z     0.07243    3650777.96013    0.01156    3650777.88770 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    33 #CRD
  1 ORID                   X    -0.38805    4498451.42195    0.01274    4498451.81000 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    34 #CRD
  1 ORID                   Y     0.35769    1708267.18769    0.01029    1708266.83000 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    35 #CRD
  1 ORID                   Z     0.17753    4173591.95753    0.01120    4173591.78000 meters  2017-07-21 00:00:00 2017-07-21 23:59:30 57955.49983    36 #CRD
```

Table 1: Part of the output Addneq file showing the station coordinates and RMS error values.



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Station coordinates and velocities:
-----------------------------------
Reference epoch: 2017-07-21 12:00:00

Station name         Typ   A priori value  Estimated value    Correction     RMS error      3-D ellipsoid        2-D ellipse
------------------------------------------------------------------------------------------------------------------------------
ANKR                  X     4121948.48470    4121948.34884      -0.13586       0.01301
                      Y     2652187.89370    2652187.82566      -0.06804       0.01012
                      Z     4069023.81200    4069023.83377       0.02177       0.01143

                      U         976.03268        975.93072      -0.10196       0.01691    0.01696    4.9
                      N       39.8873718       39.8873728        0.11372       0.00745    0.00724  158.3     0.00733  154.0
                      E       32.7584700       32.7584702        0.01625       0.00779    0.00788   -2.0     0.00790

ARUC                  X     3500416.85000    3500416.60685      -0.24315       0.01293
                      Y     3390432.73800    3390432.69720      -0.04080       0.00981
                      Z     4103027.64800    4103027.61046      -0.03754       0.01124

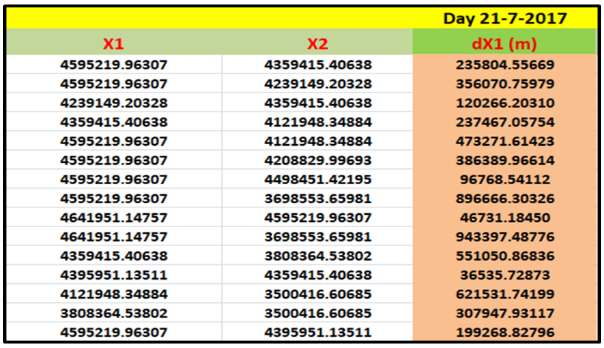
                      U        1222.26310       1222.08394      -0.17916       0.01631    0.01659   11.9
                      N       40.2857140       40.2857149        0.10276       0.00734    0.00722  168.1     0.00723  163.3
                      E       44.0855858       44.0855875        0.13947       0.00834    0.00789    2.1     0.00843

BSHM                  X     4395951.36540    4395951.13511      -0.23029       0.01285
                      Y     3080707.12060    3080707.18017       0.05957       0.00996
                      Z     3433498.11230    3433498.22097       0.10867       0.01159

                      U         225.05873        224.98775      -0.07098       0.01681    0.01685    4.4
                      N       32.7789858       32.7789873        0.17545       0.00737    0.00723  161.0     0.00732  163.3
                      E       35.0229848       35.0229867        0.18059       0.00786    0.00790    1.2     0.00791
```

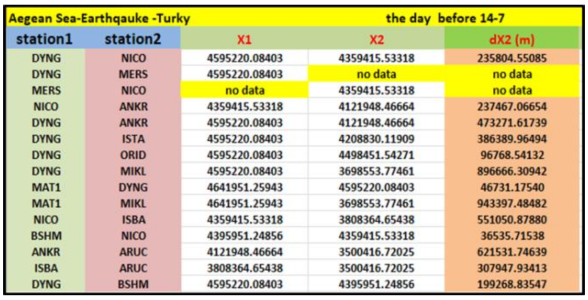
Table 2: Example of Stations Coordinates in two types of coordinates system X, Y, Z, and U, N, V.

After we get the estimated coordinates for each station and the error value in each one we can know the station's displacements in all directions X, Y, Z by subtracting the a priori coordinate from the estimated coordinates for each point on the three different dates. Tables (3, 4, and 5).



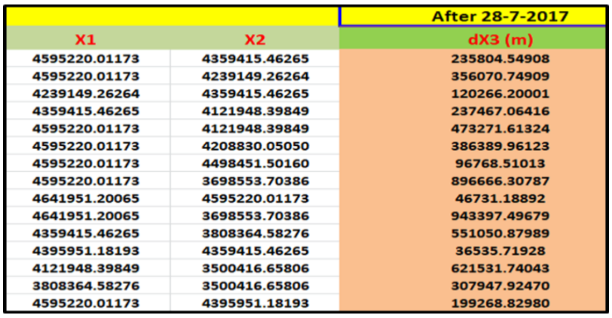
		Day 21-7-2017
X1	X2	dX1 (m)
4595219.96307	4359415.40638	235804.55669
4595219.96307	4239149.20328	356070.75979
4239149.20328	4359415.40638	120266.20310
4359415.40638	4121948.34884	237467.05754
4595219.96307	4121948.34884	473271.61423
4595219.96307	4208829.99693	386389.96614
4595219.96307	4498451.42195	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 3: X coordinate for the baselines network on the day of 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

Table 4: X coordinate for the baselines network on a week before 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

Table5: X coordinates for the baselines network on a week after the earthquake.

Likewise, both Y and Z coordinates are tabulated for each monitored date of the earthquake. It is noticeable that there is no available data for MERS station for day 14/7/2017 because there was no raw data for that date in the IGS service, it may be due to the maintenance work of the station or a change of the receiver. Figures (2, 3, and 4) are examples of the changes of baseline stations X coordinates component's for one baseline (DYNG-NICO) on different three times of the Aegean earthquake.

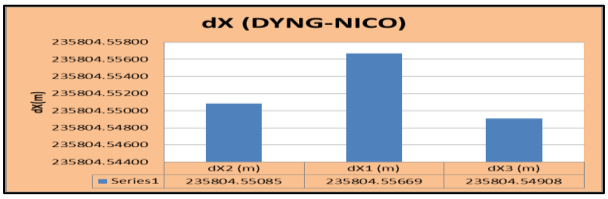


Figure 2: The dX values of baseline (DYNG-NICO)

Figure (2) shows that dX2 on a week before the earthquake is lower than dx1 on the day of the earthquake with about 5 mm, dx1value increased, and then decreased on the week after the earthquake with about 7mm this indicates that the ground surface will go to the normal statue.

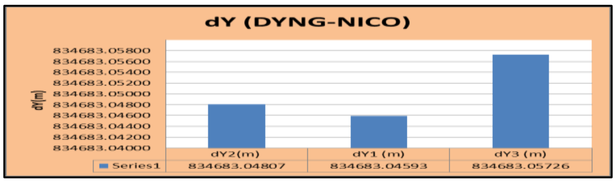


Figure 3: The dY values of baseline (DYNG-NICO)

In figure (3), we found that dY2 increased on the day before the earthquake about 3mm, then on the day after one week from shaking dY3 increased about 1cm than the day of the earthquake, it may happen because the forces of the earthquake were still affecting the earth surface due to the nature of the earth in this region, or maybe another earthquake will occur soon.

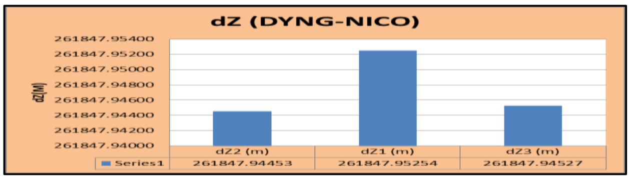


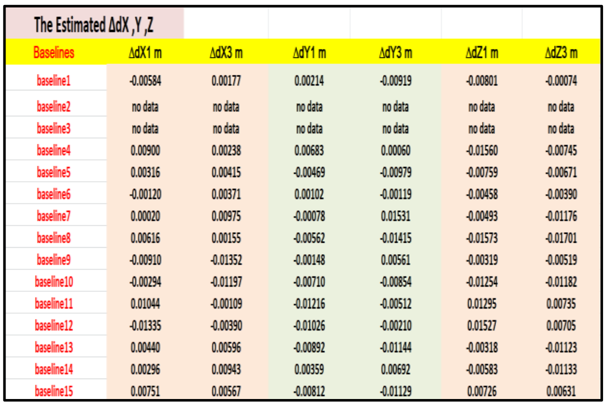
Figure 4: The dZ values of baseline (DYNG-NICO)

We found in figure (4) that dZ increased on the day of the earthquake more than before and after the earthquake's shock ended, we noticed that dZ decreased again and began to reach stability.

3. THE DISPLACEMENTS COMPONENTS OF THE NETWORK BASELINES LENGTH’S

In this step, we calculated the displacements values for all network baselines which are joint between two stations,(Table 6). dX2, dY2, dZ2 are taken as a reference to get other values, it means $\Delta dX1=(dX2-dX1)$m, $\Delta dX3=(dX2-dX3)$m and so on the other values of ΔdY1,ΔdY3,ΔdZ1,ΔdZ3.according to the result sign (+ or-)we can know if this baseline increased its length or decreased, so we can know the movements of both baseline end.

Table١ : Meter Values of Δdx, ΔdY, & ΔdZ of Baselines Network



The Estimated ΔdX ,Y ,Z

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	0.00975	-0.00078	0.01531	-0.00493	-0.01176
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

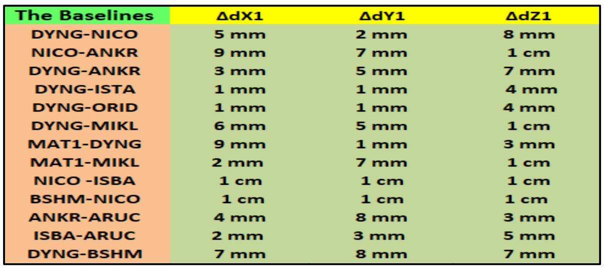
From the Table 6, we noticed that there is no data for baseline numbers 2 and 3. Because there was not any available raw data of MERS station on the date of 14/7/2017on the day before one week from the earthquake. It maybe happened because of any maintenance work or change the receiver which takes many days that the station stops working.

Baseline number1 (DYNG-NICO), it is noticed that its length of the first baseline increased by 5mm, whereby ΔdX1= -0.005 (5mm), and $\Delta dX1=(dX2-dX1)$ m. On the day after a week, ΔdX3is decreased 1 mm only. It may be an indication that the effect of shaking that happened on the day of the earthquake was more than normal and that the stations started to go to their stability after one week from the earthquake shaking.

In Y direction we found that ΔdY1 decreased 2 mm, but after a week the length increased 9 mm. It means that the stations were still affected by the earthquake forces under the ground surface. And it may be a sign of occurring an earthquake as soon on that region. As each of both stations are close to the epicenter of the earthquake and the Aegean sea. In Z direction, it is found the value of ΔdZ1= -0.008m, So the baseline length has increased 8 mm, but on the day after a week from the earthquake, the value ΔdZ3 = 0.-0007 m, which means that the length increased also only 1mm.

The resulted displacements are arranged in tables 7and 8, for the day of the earthquake and the day after one week from the earthquake.

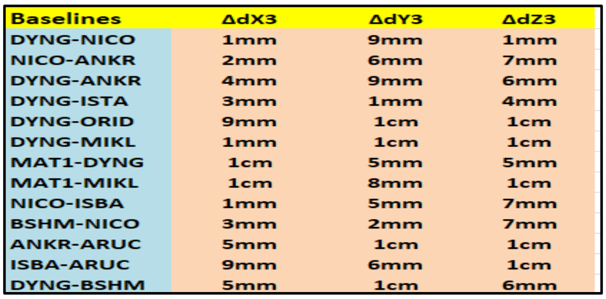
Table7: Estimated Displacements on the day of the earthquake.



The Baselines	ΔdX1	ΔdY1	ΔdZ1
DYNG-NICO	5 mm	2 mm	8 mm
NICO-ANKR	9 mm	7 mm	1 cm
DYNG-ANKR	3 mm	5 mm	7 mm
DYNG-ISTA	1 mm	1 mm	4 mm
DYNG-ORID	1 mm	1 mm	4 mm
DYNG-MIKL	6 mm	5 mm	1 cm
MAT1-DYNG	9 mm	1 mm	3 mm
MAT1-MIKL	2 mm	7 mm	1 cm
NICO -ISBA	1 cm	1 cm	1 cm
BSHM-NICO	1 cm	1 cm	1 cm
ANKR-ARUC	4 mm	8 mm	3 mm
ISBA-ARUC	2 mm	3 mm	5 mm
DYNG-BSHM	7 mm	8 mm	7 mm

In table 7, it is noticed that many baselines have displacement value reached to 1 cm, like (NICO-ANKR), (NICO-ISBA) and (BSHM-NICO), Because of NICO station is considered the nearest stations to the epicenter. So it is affected greatly. The station ISBA in the baseline (NICO-ISBA), is one of the most distant stations in the network from the epicenter. But maybe its topography and the nature of its ground surface make it vulnerable to the earthquake shaking. Or maybe its surface keeps the earthquake forces for a longer period. All of the above reasons may be led to big displacement values. Also, the baseline (NICO- BSHM) has big displacements values in all directions; the reason for that is both stations are closed to the epicenter, and their geographical location makes their baselines near the sea coast. So it is has affected clearly. The rest of the network baselines have also varying values of displacements, starting from 1 mm to 9 mm, which depends on the distances between stations or baselines and the epicenter of the earthquake.

Table8: Estimated Displacements on the day after a week of the earthquake.



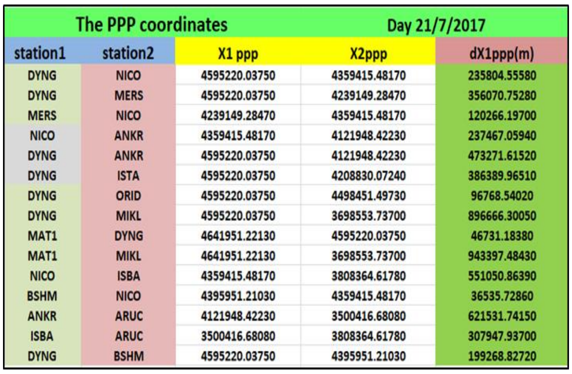
Baselines	ΔdX3	ΔdY3	ΔdZ3
DYNG-NICO	1mm	9mm	1mm
NICO-ANKR	2mm	6mm	7mm
DYNG-ANKR	4mm	9mm	6mm
DYNG-ISTA	3mm	1mm	4mm
DYNG-ORID	9mm	1cm	1cm
DYNG-MIKL	1mm	1cm	1cm
MAT1-DYNG	1cm	5mm	5mm
MAT1-MIKL	1cm	8mm	1cm
NICO-ISBA	1mm	5mm	7mm
BSHM-NICO	3mm	2mm	7mm
ANKR-ARUC	5mm	1cm	1cm
ISBA-ARUC	9mm	6mm	1cm
DYNG-BSHM	5mm	1cm	6mm

The displacement values on the day after the week of the earthquake are shown in table 8, it is noticed that some baselines have normal movement values ranged from 1 mm to 2 mm but there are big values as well. An example of these baselines is the baseline (DYNG-ANKR), which has values of 4 mm to 9 mm, this is maybe due to the very close distance between stations and the epicenter. Baselines (DYNG-ORID) and (DYNG-MIKL) have values of 9mm, 1cm, and 1cmand 1mm,1cm,1cm respectively. Because stations are close to the epicenter. The displacement values are evidence of any change in the Earth's crust. These changes may be attributed to the surface layer of the earth's crust is weak in this region, which leads to a large movement of these stations. On the other hand, it may indicate an early warning of any natural disaster close to this area such as an earthquake or a volcano. But to ensure that it requires daily monitoring of the Earth's crust in such areas to facilitate earthquake prediction. other values are between 3mmto 9mm as a maximum

4. STATIONS DISPLACEMENTS USING THE PRECISE POINT POSITIONS (PPP) TECHNIQUE

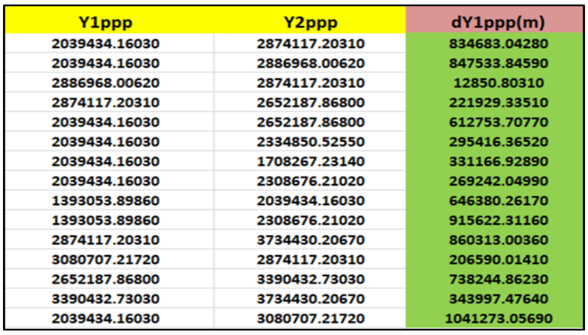
Precise Point Positioning (PPP) is a technique used to determine the position of the receiver antenna without communication with the reference station, using a single global navigation satellite system (GNSS) receiver. PPP uses carrier phase observations as the principal observable for position determination which capable of providing very high positioning accuracy. PPP needs accurate satellite orbit and clock information to mitigate orbit and clock errors. So the PPP solution depends on GNSS satellite orbit and clock corrections. The permanent services which execute calculations with PPP technique are: Automatic Precise Positioning Service (APPS), Canadian Spatial Reference System Precise Point Positioning (CSRS-PPP), GNSS Analysis and Positioning Software (GAPS) and magicPPP - Precise Point Positioning Solution (magic GNSS). In this paper we used the Canadian Spatial Reference System Precise Point Positioning (CSRS-PPP) for determining station coordinates, the static processing mode is used, the datum is ITRF 14, and the RINEX observation file of each station sends. A mail with a PPP file for each point was then received. Finally, stations with PPP coordinates with high accuracy on three different times are obtained, on the day of the earthquake on 21/7/2107, on a week before the earthquake at 14/7/2017, and a week after the earthquake at 28/7/2017.

Table 9: PPP Coordinates of the Network Baselines on the day of the Aegean Earthquake.



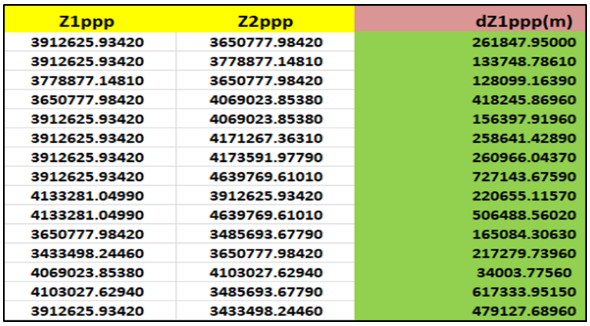
The PPP coordinates			Day 21/7/2017	
station1	station2	X1 ppp	X2ppp	dX1ppp(m)
DYNG	NICO	4595220.03750	4359415.48170	235804.55580
DYNG	MERS	4595220.03750	4239149.28470	356070.75280
MERS	NICO	4239149.28470	4359415.48170	120266.19700
NICO	ANKR	4359415.48170	4121948.42230	237467.05940
DYNG	ANKR	4595220.03750	4121948.42230	473271.61520
DYNG	ISTA	4595220.03750	4208830.07240	386389.96510
DYNG	ORID	4595220.03750	4498451.49730	96768.54020
DYNG	MIKL	4595220.03750	3698553.73700	896666.30050
MAT1	DYNG	4641951.22130	4595220.03750	46731.18380
MAT1	MIKL	4641951.22130	3698553.73700	943397.48430
NICO	ISBA	4359415.48170	3808364.61780	551050.86390
BSHM	NICO	4395951.21030	4359415.48170	36535.72860
ANKR	ARUC	4121948.42230	3500416.68080	621531.74150
ISBA	ARUC	3500416.68080	3808364.61780	307947.93700
DYNG	BSHM	4595220.03750	4395951.21030	199268.82720

Table 10: PPP of Y Coordinates of the Network Baselines on the day of the Aegean Earthquake



Y1ppp	Y2ppp	dY1ppp(m)
2039434.16030	2874117.20310	834683.04280
2039434.16030	2886968.00620	847533.84590
2886968.00620	2874117.20310	12850.80310
2874117.20310	2652187.86800	221929.33510
2039434.16030	2652187.86800	612753.70770
2039434.16030	2334850.52550	295416.36520
2039434.16030	1708267.23140	331166.92890
2039434.16030	2308676.21020	269242.04990
1393053.89860	2039434.16030	646380.26170
1393053.89860	2308676.21020	915622.31160
2874117.20310	3734430.20670	860313.00360
3080707.21720	2874117.20310	206590.01410
2652187.86800	3390432.73030	738244.86230
3390432.73030	3734430.20670	343997.47640
2039434.16030	3080707.21720	1041273.05690

Table 11: PPP of Z Coordinates of the Network Baselines on the day of the Aegean Earthquake

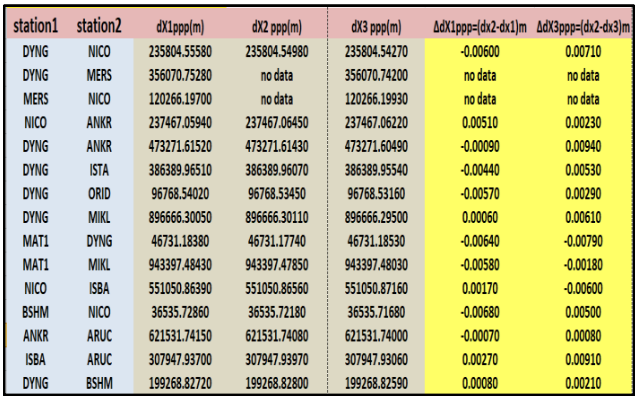


Z1ppp	Z2ppp	dZ1ppp(m)
3912625.93420	3650777.98420	261847.95000
3912625.93420	3778877.14810	133748.78610
3778877.14810	3650777.98420	128099.16390
3650777.98420	4069023.85380	418245.86960
3912625.93420	4069023.85380	156397.91960
3912625.93420	4171267.36310	258641.42890
3912625.93420	4173591.97790	260966.04370
3912625.93420	4639769.61010	727143.67590
4133281.04990	3912625.93420	220655.11570
4133281.04990	4639769.61010	506488.56020
3650777.98420	3485693.67790	165084.30630
3433498.24460	3650777.98420	217279.73960
4069023.85380	4103027.62940	34003.77560
4103027.62940	3485693.67790	617333.95150
3912625.93420	3433498.24460	479127.68960

Likewise, the precise coordinates of all network stations on the day of the earthquake are extracted on tables (9,10,11). It was repeated in the other two days before and after one week of the earthquake.

The sconed stage is computing the precise baseline displacements of the network. On the three different days from the earthquake as in tables 12,13,and14.

Table 12: Calculations of ΔdX1ppp, & ΔdX3ppp Values

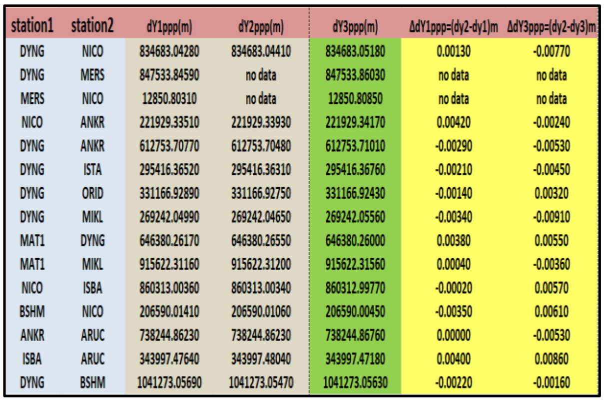


station1	station2	dX1ppp(m)	dX2 ppp(m)	dX3 ppp(m)	ΔdX1ppp=(dx2-dx1)m	ΔdX3ppp=(dx2-dx3)m
DYNG	NICO	235804.55580	235804.54980	235804.54270	-0.00600	0.00710
DYNG	MERS	356070.75280	no data	356070.74200	no data	no data
MERS	NICO	120266.19700	no data	120266.19930	no data	no data
NICO	ANKR	237467.05940	237467.06450	237467.06220	0.00510	0.00230
DYNG	ANKR	473271.61520	473271.61430	473271.60490	-0.00090	0.00940
DYNG	ISTA	386389.96510	386389.96070	386389.95540	-0.00440	0.00530
DYNG	ORID	96768.54020	96768.53450	96768.53160	-0.00570	0.00290
DYNG	MIKL	896666.30050	896666.30110	896666.29500	0.00060	0.00610
MAT1	DYNG	46731.18380	46731.17740	46731.18530	-0.00640	-0.00790
MAT1	MIKL	943397.48430	943397.47850	943397.48030	-0.00580	-0.00180
NICO	ISBA	551050.86390	551050.86560	551050.87160	0.00170	-0.00600
BSHM	NICO	36535.72860	36535.72180	36535.71680	-0.00680	0.00500
ANKR	ARUC	621531.74150	621531.74080	621531.74000	-0.00070	0.00080
ISBA	ARUC	307947.93700	307947.93970	307947.93060	0.00270	0.00910
DYNG	BSHM	199268.82720	199268.82800	199268.82590	0.00080	0.00210

Table 12 explains the values of ΔdX1 on the day of the earthquake which ΔdX1= (dX2-dX1) m. Taken value of dX2 as reference. Likewise, computes the ΔdX3 values of on a week after the earthquake, with ΔdX3= (dX2-dX3) m. From the tabled values we noticed that on the day of the earthquake the minimum value of length change was 1mm and reached 6mm as the maximum value. The stations near the epicenter of an earthquake have a big movement regardless of the result signal positive or negative, such as stations NICO, DYNG, ISTA, ANKAR, and MAT1, where the change value about 3mm to 6mm. But the other far stations had fewer values about 1mm as stations BSHM, MIKL, and ARUC.

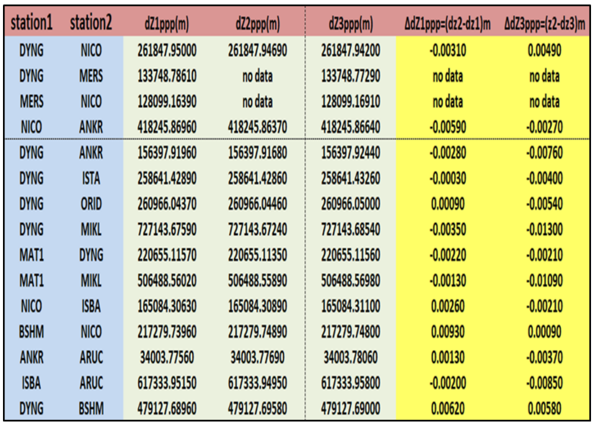
A week after an earthquake, it was noticed that the values of ΔdX3ppp are clearly increased on all the nearest baselines from the epicenter such as (DYNG-NICO) had a value of 7mm, (DYNG –ANKR) =9mm,(DYNG –MIKL) = 6mm, These changes mean that the baseline with stations closer to the center suffering huge displacement. Even if the baseline was connected between two stations, one was far, but the other station was very close to the center of the earthquake that produced also a significant change in the location of the point on the earth's crust. Thus, the station location is the main factor that affects the magnitude of its displacement when the earthquake occurs.

Table13: Calculations of Δdy1ppp, & Δdy3ppp Values



station1	station2	dY1ppp(m)	dY2ppp(m)	dY3ppp(m)	ΔdY1ppp=(dy2-dy1)m	ΔdY3ppp=(dy2-dy3)m
DYNG	NICO	834683.04280	834683.04410	834683.05180	0.00130	-0.00770
DYNG	MERS	847533.84590	no data	847533.86030	no data	no data
MERS	NICO	12850.80310	no data	12850.80850	no data	no data
NICO	ANKR	221929.33510	221929.33930	221929.34170	0.00420	-0.00240
DYNG	ANKR	612753.70770	612753.70480	612753.71010	-0.00290	-0.00530
DYNG	ISTA	295416.36520	295416.36310	295416.36760	-0.00210	-0.00450
DYNG	ORID	331166.92890	331166.92750	331166.92430	-0.00140	0.00320
DYNG	MIKL	269242.04990	269242.04650	269242.05560	-0.00340	-0.00910
MAT1	DYNG	646380.26170	646380.26550	646380.26000	0.00380	0.00550
MAT1	MIKL	915622.31160	915622.31200	915622.31560	0.00040	-0.00360
NICO	ISBA	860313.00360	860313.00340	860312.99770	-0.00020	0.00570
BSHM	NICO	206590.01410	206590.01060	206590.00450	-0.00350	0.00610
ANKR	ARUC	738244.86230	738244.86230	738244.86760	0.00000	-0.00530
ISBA	ARUC	343997.47640	343997.48040	343997.47180	0.00400	0.00860
DYNG	BSHM	1041273.05690	1041273.05470	1041273.05630	-0.00220	-0.00160

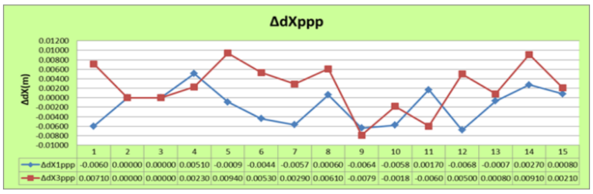
Table14: Calculations of ΔdZ1ppp, & ΔdZ3ppp Values



station1	station2	dZ1ppp(m)	dZ2ppp(m)	dZ3ppp(m)	ΔdZ1ppp=(dz2-dz1)m	ΔdZ3ppp=(z2-dz3)m
DYNG	NICO	261847.95000	261847.94690	261847.94200	-0.00310	0.00490
DYNG	MERS	133748.78610	no data	133748.77290	no data	no data
MERS	NICO	128099.16390	no data	128099.16910	no data	no data
NICO	ANKR	418245.86960	418245.86370	418245.86640	-0.00590	-0.00270
DYNG	ANKR	156397.91960	156397.91680	156397.92440	-0.00280	-0.00760
DYNG	ISTA	258641.42890	258641.42860	258641.43260	-0.00030	-0.00400
DYNG	ORID	260966.04370	260966.04460	260966.05000	0.00090	-0.00540
DYNG	MIKL	727143.67590	727143.67240	727143.68540	-0.00350	-0.01300
MAT1	DYNG	220655.11570	220655.11350	220655.11560	-0.00220	-0.00210
MAT1	MIKL	506488.56020	506488.55890	506488.56980	-0.00130	-0.01090
NICO	ISBA	165084.30630	165084.30890	165084.31100	0.00260	-0.00210
BSHM	NICO	217279.73960	217279.74890	217279.74800	0.00930	0.00090
ANKR	ARUC	34003.77560	34003.77690	34003.78060	0.00130	-0.00370
ISBA	ARUC	617333.95150	617333.94950	617333.95800	-0.00200	-0.00850
DYNG	BSHM	479127.68960	479127.69580	479127.69000	0.00620	0.00580

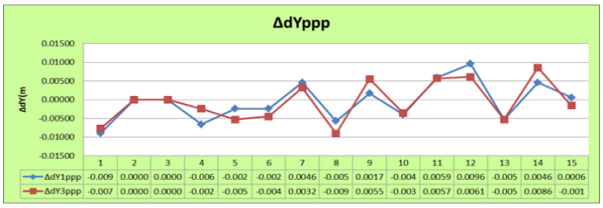
The same previous scenario has been done on the rest values of the displacements in Y and Z directions which are evident from the previous tables 13 and14. The most important note is that the closer the station to the epicenter of the earthquake, the greater the change in the Earth's crust, therefore the more points displacements from their fixed location on the earth's crust, and vice versa also the more the station moves away from the epicenter of the earthquake, the less the change in the Earth's crust, so the less the displacement of points.

Now, these results will be presented in a graphic relationship in figures (5, 6, and 7). They show the difference between point displacements for each baseline of the network surrounding the epicenter of the earthquake.



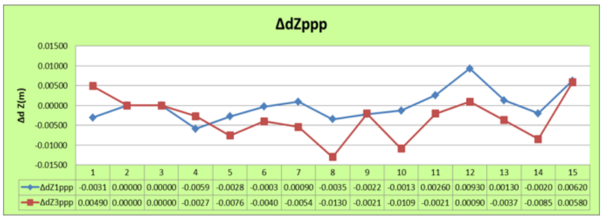
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ΔdX1ppp	-0.0060	0.00000	0.00000	0.00510	-0.0009	-0.0044	-0.0057	0.00060	-0.0064	-0.0058	0.00170	-0.0068	-0.0007	0.00270	0.00080
ΔdX3ppp	0.00710	0.00000	0.00000	0.00230	0.00940	0.00530	0.00290	0.00610	-0.0079	-0.0018	-0.0060	0.00500	0.00080	0.00910	0.00210

Figure 5: ΔdX1PPP Values for the Network Baselines



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ΔdY1ppp	-0.009	0.0000	0.0000	-0.006	-0.002	-0.002	0.0046	-0.005	0.0017	-0.004	0.0059	0.0096	-0.005	0.0046	0.0006
ΔdY3ppp	-0.007	0.0000	0.0000	-0.002	-0.005	-0.004	0.0032	-0.009	0.0055	-0.003	0.0057	0.0061	-0.005	0.0086	-0.001

Figure 6: ΔdY1PPP Values for the Network Baselines



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ΔdZ1ppp	-0.0031	0.00000	0.00000	-0.0059	-0.0028	-0.0003	0.00090	-0.0035	-0.0022	-0.0013	0.00260	0.00930	0.00130	-0.0020	0.00620
ΔdZ3ppp	0.00490	0.00000	0.00000	-0.0027	-0.0076	-0.0040	-0.0054	-0.0130	-0.0021	-0.0109	-0.0021	0.00090	-0.0037	-0.0085	0.00580

Figure 7: ΔdZ1PPP Values for the Network Baselines

The precise displacement values are shown in the previous curves. So the difference of station displacement values according to the time domain have been noticed.

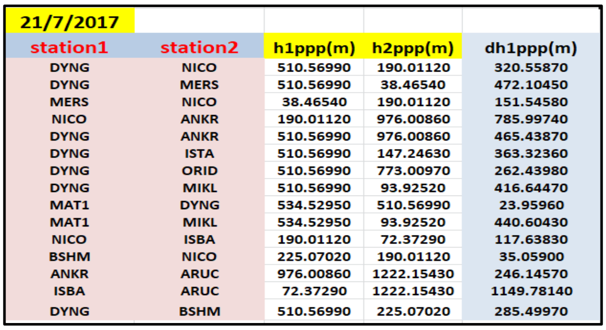
5. FIND THE HEIGHT CHANGE OF STATIONS USING THE PRECISE POSITION TECHNIQUE

Among the factors that have been monitored to know the point displacement is dH. The calculation of the height displacement of the network stations according to the output file from Bernese 5.2 software. We should make a reference data guide contains all parameters that are affected when earthquakes occur. To serve our community and protect it from the earthquake's danger and create an effective earthquake prediction tool soon.

Table15: The Output of Stations Heights from Bernese Processing Software

21/7/2017				
station1	station2	h1(m)	h2(m)	dh1(m)
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

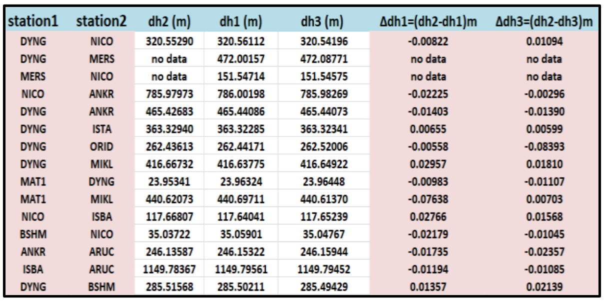
Table 16: PPP Stations height using the Canadian Spatial Reference System (CSRS-PPP).



21/7/2017				
station1	station2	h1ppp(m)	h2ppp(m)	dh1ppp(m)
DYNG	NICO	510.56990	190.01120	320.55870
DYNG	MERS	510.56990	38.46540	472.10450
MERS	NICO	38.46540	190.01120	151.54580
NICO	ANKR	190.01120	976.00860	785.99740
DYNG	ANKR	510.56990	976.00860	465.43870
DYNG	ISTA	510.56990	147.24630	363.32360
DYNG	ORID	510.56990	773.00970	262.43980
DYNG	MIKL	510.56990	93.92520	416.64470
MAT1	DYNG	534.52950	510.56990	23.95960
MAT1	MIKL	534.52950	93.92520	440.60430
NICO	ISBA	190.01120	72.37290	117.63830
BSHM	NICO	225.07020	190.01120	35.05900
ANKR	ARUC	976.00860	1222.15430	246.14570
ISBA	ARUC	72.37290	1222.15430	1149.78140
DYNG	BSHM	510.56990	225.07020	285.49970

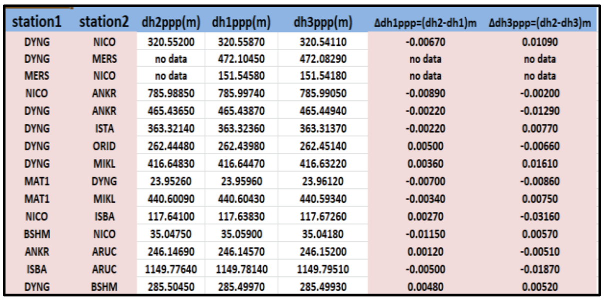
Tables 15 and 16 display the point's height values in the two solutions on the day of the earthquake. Then calculate the difference heights between every two stations of the baseline, which (dh = h1-h2). We will repeat the same steps to find the height difference dh on the other two days from the earthquake. The first day is on 14/7/2017, before one week, and the day of 28/7/2017 after one week from the earthquake.

Table17: Station's Heights Displacements using Bernese solution



station1	station2	dh2 (m)	dh1 (m)	dh3 (m)	Δdh1=(dh2-dh1)m	Δdh3=(dh2-dh3)m
DYNG	NICO	320.55290	320.56112	320.54196	-0.00822	0.01094
DYNG	MERS	no data	472.00157	472.08771	no data	no data
MERS	NICO	no data	151.54714	151.54575	no data	no data
NICO	ANKR	785.97973	786.00198	785.98269	-0.02225	-0.00296
DYNG	ANKR	465.42683	465.44086	465.44073	-0.01403	-0.01390
DYNG	ISTA	363.32940	363.32285	363.32341	0.00655	0.00599
DYNG	ORID	262.43613	262.44171	262.52006	-0.00558	-0.08393
DYNG	MIKL	416.66732	416.63775	416.64922	0.02957	0.01810
MAT1	DYNG	23.95341	23.96324	23.96448	-0.00983	-0.01107
MAT1	MIKL	440.62073	440.69711	440.61370	-0.07638	0.00703
NICO	ISBA	117.66807	117.64041	117.65239	0.02766	0.01568
BSHM	NICO	35.03722	35.05901	35.04767	-0.02179	-0.01045
ANKR	ARUC	246.13587	246.15322	246.15944	-0.01735	-0.02357
ISBA	ARUC	1149.78367	1149.79561	1149.79452	-0.01194	-0.01085
DYNG	BSHM	285.51568	285.50211	285.49429	0.01357	0.02139

Table18: Calculation Values of Δdh1PPPand Δdh3 PPP



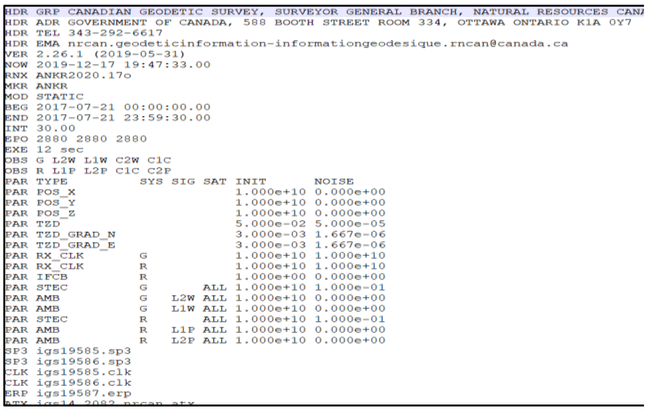
station1	station2	dh2ppp(m)	dh1ppp(m)	dh3ppp(m)	Δdh1ppp=(dh2-dh1)m	Δdh3ppp=(dh2-dh3)m
DYNG	NICO	320.55200	320.55870	320.54110	-0.00670	0.01090
DYNG	MERS	no data	472.10450	472.08290	no data	no data
MERS	NICO	no data	151.54580	151.54180	no data	no data
NICO	ANKR	785.98850	785.99740	785.99050	-0.00890	-0.00200
DYNG	ANKR	465.43650	465.43870	465.44940	-0.00220	-0.01290
DYNG	ISTA	363.32140	363.32360	363.31370	-0.00220	0.00770
DYNG	ORID	262.44480	262.43980	262.45140	0.00500	-0.00660
DYNG	MIKL	416.64830	416.64470	416.63220	0.00360	0.01610
MAT1	DYNG	23.95260	23.95960	23.96120	-0.00700	-0.00860
MAT1	MIKL	440.60090	440.60430	440.59340	-0.00340	0.00750
NICO	ISBA	117.64100	117.63830	117.67260	0.00270	-0.03160
BSHM	NICO	35.04750	35.05900	35.04180	-0.01150	0.00570
ANKR	ARUC	246.14690	246.14570	246.15200	0.00120	-0.00510
ISBA	ARUC	1149.77640	1149.78140	1149.79510	-0.00500	-0.01870
DYNG	BSHM	285.50450	285.49970	285.49930	0.00480	0.00520

From tables 17and 18, we can see a comparison between the station's height displacement values in the two solutions, it is found the baseline number 1 has Δdh1= 8mm as height difference in Bernese case and in PPP equal 6 mm Δdh1PPP. After one week from the earthquake Δdh3 =1cm equal the value of Δdh3ppp= 1 cm. The day when an earthquake occurred the vertical estimated displacements were about 1 to 2cm and also after one week the values were within nearly the same range.in PPP solution also there a lot of values have about this value range. So it should be continuous monitoring of points displacement to ensure the correctness of these displacements for each point. Taking into account all influencing factors such as the point location, the geographical location and the strength of the earthquake as well.

6. DETERMINE THE PRECISE DISPLACEMENTS FOR THE NETWORK STATIONS

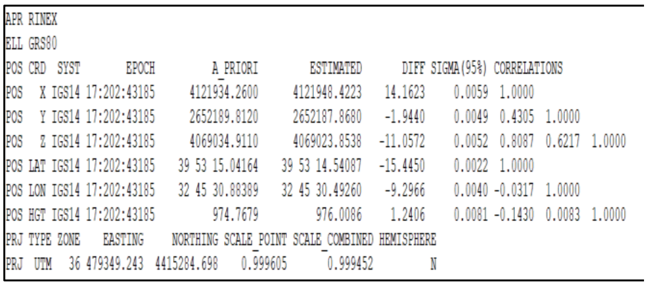
The online service of The Canadian Geodetic Survey of Natural Resources (CSRS-PPP) is used to get the precise values. We have requested to get the results in the ITRF datum at an epoch other than the epoch of GNSS data. The solution is returned via an email at the address provided on the submission page and downloaded directly to a user. The CSRS-PPP outputs are the solution report (.pdf) presenting the PPP results in a combination of textual and graphical information, summary file (.sum) which contains the parameters and the results of the PPP processing, and A position file (.pos) containing the positioning information for each epoch processed. So each station of our network sends its name and its raw data and then have an email with its precise position. As shown in tables 20 and 21.

Table 20: Part of the summary file (.sum) which contains the parameters of the PPP processing



```
HDR GRP CANADIAN GEODETIC SURVEY, SURVEYOR GENERAL BRANCH, NATURAL RESOURCES CANA
HDR ADR GOVERNMENT OF CANADA, 588 BOOTH STREET ROOM 334, OTTAWA ONTARIO K1A 0Y7
HDR TEL 343-292-6617
HDR EMA nrcan.geodeticinformation-informationgeodesique.rncan@canada.ca
VER 2.26.1 (2019-05-31)
NOW 2019-12-17 19:47:33.00
RNX ANKR2020.17o
MKR ANKR
MOD STATIC
BEG 2017-07-21 00:00:00.00
END 2017-07-21 23:59:30.00
INT 30.00
EPO 2880 2880 2880
EXE 12 sec
OBS G L2W L1W C2W C1C
OBS R L1P L2P C1C C2P
PAR TYPE             SYS SIG SAT INIT      NOISE
PAR POS_X                        1.000e+10 0.000e+00
PAR POS_Y                        1.000e+10 0.000e+00
PAR POS_Z                        1.000e+10 0.000e+00
PAR TZD                          5.000e-02 5.000e-05
PAR TZD_GRAD_N                   3.000e-03 1.667e-06
PAR TZD_GRAD_E                   3.000e-03 1.667e-06
PAR RX_CLK           G           1.000e+10 1.000e+10
PAR RX_CLK           R           1.000e+10 1.000e+10
PAR IFCB             R           1.000e+00 0.000e+00
PAR STEC             G       ALL 1.000e+10 1.000e-01
PAR AMB              G   L2W ALL 1.000e+10 0.000e+00
PAR AMB              G   L1W ALL 1.000e+10 0.000e+00
PAR STEC             R       ALL 1.000e+10 1.000e-01
PAR AMB              R   L1P ALL 1.000e+10 0.000e+00
PAR AMB              R   L2P ALL 1.000e+10 0.000e+00
SP3 igs19585.sp3
SP3 igs19586.sp3
CLK igs19585.clk
CLK igs19586.clk
ERP igs19587.erp
```

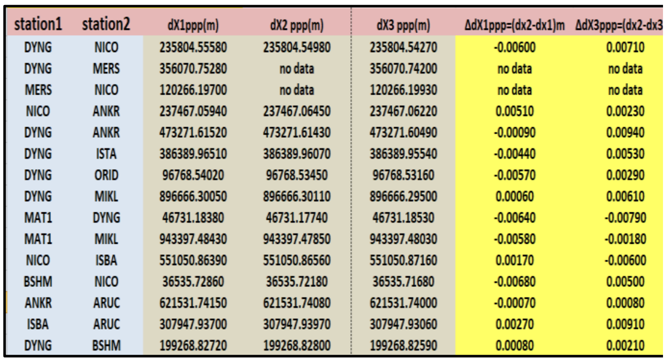
Table21: Part of the summary file contains the results of the PPP processing.



```
APR RINEX
ELL GRS80
POS CRD  SYST       EPOCH          A_PRIORI        ESTIMATED       DIFF SIGMA(95%) CORRELATIONS
POS   X IGS14 17:202:43185      4121934.2600      4121948.4223    14.1623   0.0059  1.0000
POS   Y IGS14 17:202:43185      2652189.8120      2652187.8680    -1.9440   0.0049  0.4305  1.0000
POS   Z IGS14 17:202:43185      4069034.9110      4069023.8538   -11.0572   0.0052  0.8087  0.6217  1.0000
POS LAT IGS14 17:202:43185    39 53 15.04164    39 53 14.54087   -15.4450   0.0022  1.0000
POS LON IGS14 17:202:43185    32 45 30.88389    32 45 30.49260    -9.2966   0.0040 -0.0317  1.0000
POS HGT IGS14 17:202:43185          974.7679          976.0086     1.2406   0.0081 -0.1430  0.0083  1.0000
PRJ TYPE ZONE    EASTING    NORTHING SCALE_POINT SCALE_COMBINED HEMISPHERE
PRJ  UTM   36 479349.243 4415284.698    0.999605       0.999452          N
```

We will present the precise displacements of the network baselines in the directions X, Y, and Z(see tables 22,23,24). Then compare these results with the estimated displacements resulted by Bernese processing, table (26).

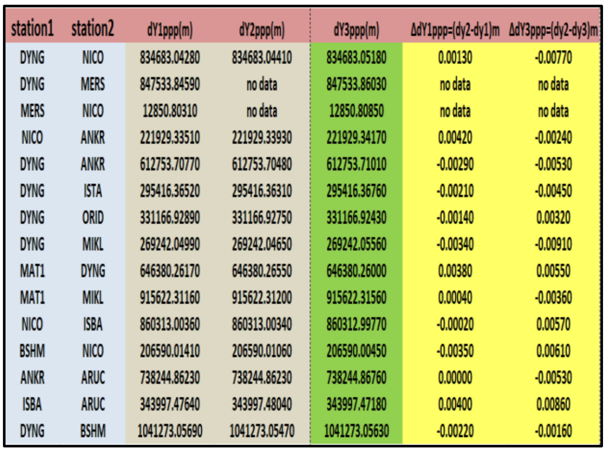
Table 22: Calculations of ΔdX1ppp, & ΔdX3ppp Values



station1	station2	dX1ppp(m)	dX2 ppp(m)	dX3 ppp(m)	ΔdX1ppp=(dx2-dx1)m	ΔdX3ppp=(dx2-dx3
DYNG	NICO	235804.55580	235804.54980	235804.54270	-0.00600	0.00710
DYNG	MERS	356070.75280	no data	356070.74200	no data	no data
MERS	NICO	120266.19700	no data	120266.19930	no data	no data
NICO	ANKR	237467.05940	237467.06450	237467.06220	0.00510	0.00230
DYNG	ANKR	473271.61520	473271.61430	473271.60490	-0.00090	0.00940
DYNG	ISTA	386389.96510	386389.96070	386389.95540	-0.00440	0.00530
DYNG	ORID	96768.54020	96768.53450	96768.53160	-0.00570	0.00290
DYNG	MIKL	896666.30050	896666.30110	896666.29500	0.00060	0.00610
MAT1	DYNG	46731.18380	46731.17740	46731.18530	-0.00640	-0.00790
MAT1	MIKL	943397.48430	943397.47850	943397.48030	-0.00580	-0.00180
NICO	ISBA	551050.86390	551050.86560	551050.87160	0.00170	-0.00600
BSHM	NICO	36535.72860	36535.72180	36535.71680	-0.00680	0.00500
ANKR	ARUC	621531.74150	621531.74080	621531.74000	-0.00070	0.00080
ISBA	ARUC	307947.93700	307947.93970	307947.93060	0.00270	0.00910
DYNG	BSHM	199268.82720	199268.82800	199268.82590	0.00080	0.00210

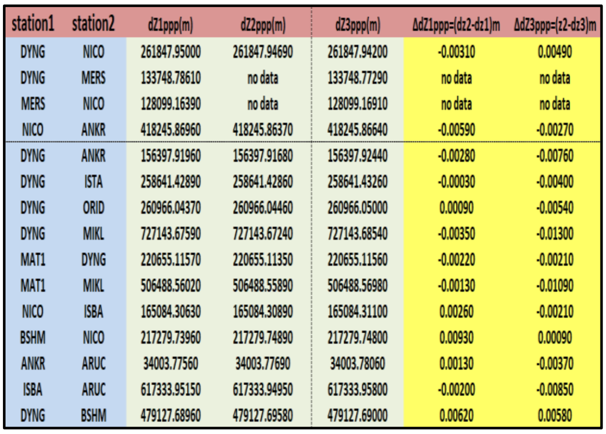
From table 22, the baseline displacements in X direction explain that the values on the day of the earthquake ranged between 1mm to 6mm as a maximum value. For the day after a week of the earthquake, the values of ΔdX3ppp clearly increased on all baselines near the epicenter. Evidently, DYNG-NICO had a value of 7mm; DYNG-ANKR = 9 mm; DYNG-MIKL = 6mm; and DYNG- MAT1 =8mm.

Table 23: Calculations of Δdy1ppp, & Δdy3ppp Values



station1	station2	dY1ppp(m)	dY2ppp(m)	dY3ppp(m)	ΔdY1ppp=(dy2-dy1)m	ΔdY3ppp=(dy2-dy3)m
DYNG	NICO	834683.04280	834683.04410	834683.05180	0.00130	-0.00770
DYNG	MERS	847533.84590	no data	847533.86030	no data	no data
MERS	NICO	12850.80310	no data	12850.80850	no data	no data
NICO	ANKR	221929.33510	221929.33930	221929.34170	0.00420	-0.00240
DYNG	ANKR	612753.70770	612753.70480	612753.71010	-0.00290	-0.00530
DYNG	ISTA	295416.36520	295416.36310	295416.36760	-0.00210	-0.00450
DYNG	ORID	331166.92890	331166.92750	331166.92430	-0.00140	0.00320
DYNG	MIKL	269242.04990	269242.04650	269242.05560	-0.00340	-0.00910
MAT1	DYNG	646380.26170	646380.26550	646380.26000	0.00380	0.00550
MAT1	MIKL	915622.31160	915622.31200	915622.31560	0.00040	-0.00360
NICO	ISBA	860313.00360	860313.00340	860312.99770	-0.00020	0.00570
BSHM	NICO	206590.01410	206590.01060	206590.00450	-0.00350	0.00610
ANKR	ARUC	738244.86230	738244.86230	738244.86760	0.00000	-0.00530
ISBA	ARUC	343997.47640	343997.48040	343997.47180	0.00400	0.00860
DYNG	BSHM	1041273.05690	1041273.05470	1041273.05630	-0.00220	-0.00160

Table 24: Calculations of ΔdZ1ppp, & ΔdZ3ppp Values



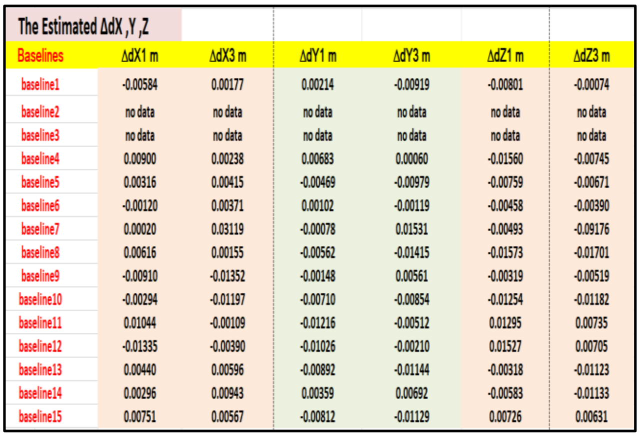
station1	station2	dZ1ppp(m)	dZ2ppp(m)	dZ3ppp(m)	ΔdZ1ppp=(dz2-dz1)m	ΔdZ3ppp=(z2-dz3)m
DYNG	NICO	261847.95000	261847.94690	261847.94200	-0.00310	0.00490
DYNG	MERS	133748.78610	no data	133748.77290	no data	no data
MERS	NICO	128099.16390	no data	128099.16910	no data	no data
NICO	ANKR	418245.86960	418245.86370	418245.86640	-0.00590	-0.00270
DYNG	ANKR	156397.91960	156397.91680	156397.92440	-0.00280	-0.00760
DYNG	ISTA	258641.42890	258641.42860	258641.43260	-0.00030	-0.00400
DYNG	ORID	260966.04370	260966.04460	260966.05000	0.00090	-0.00540
DYNG	MIKL	727143.67590	727143.67240	727143.68540	-0.00350	-0.01300
MAT1	DYNG	220655.11570	220655.11350	220655.11560	-0.00220	-0.00210
MAT1	MIKL	506488.56020	506488.55890	506488.56980	-0.00130	-0.01090
NICO	ISBA	165084.30630	165084.30890	165084.31100	0.00260	-0.00210
BSHM	NICO	217279.73960	217279.74890	217279.74800	0.00930	0.00090
ANKR	ARUC	34003.77560	34003.77690	34003.78060	0.00130	-0.00370
ISBA	ARUC	617333.95150	617333.94950	617333.95800	-0.00200	-0.00850
DYNG	BSHM	479127.68960	479127.69580	479127.69000	0.00620	0.00580

Tables 23 and 24 show the computed displacement values of ΔdY1ppp, ΔdY3ppp, ΔdZ1ppp, and ΔdZ3ppp. They imply that the displacements in the Y direction ranged from 1mm to 7mm and that in the Z direction the values were from 2mm to 7mm, except for the two values of the baselines DYNG-MIKL and MAT1-MIKL that reached 1cm. Being the closest to the epicenter, the DYNG station hit the biggest displacement value.

7. COMPARING THE BASELINES COORDINATES DISPLACEMENTS VALUES

The baseline displacements values are tabled in tables 25and26, to can extract any important notes and any differences between both solutions.

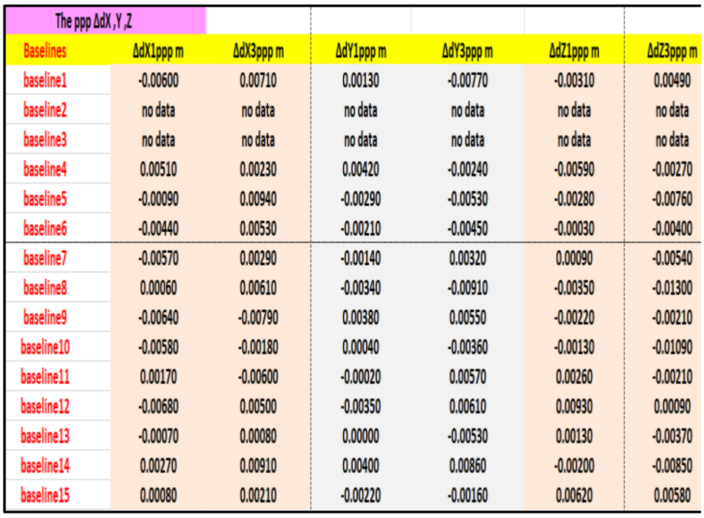
Table 25: Displacement Values of ΔdX, ΔdY, & ΔdZ of all Network Baselines



The Estimated ΔdX ,Y ,Z

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

Table 26: Precise Displacement Values of ΔdXppp, ΔdYppp, & ΔdZppp of all Network Baselines



The ppp ΔdX ,Y ,Z

Baselines	ΔdX1ppp m	ΔdX3ppp m	ΔdY1ppp m	ΔdY3ppp m	ΔdZ1ppp m	ΔdZ3ppp m
baseline1	-0.00600	0.00710	0.00130	-0.00770	-0.00310	0.00490
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	0.00510	0.00230	0.00420	-0.00240	-0.00590	-0.00270
baseline5	-0.00090	0.00940	-0.00290	-0.00530	-0.00280	-0.00760
baseline6	-0.00440	0.00530	-0.00210	-0.00450	-0.00030	-0.00400
baseline7	-0.00570	0.00290	-0.00140	0.00320	0.00090	-0.00540
baseline8	0.00060	0.00610	-0.00340	-0.00910	-0.00350	-0.01300
baseline9	-0.00640	-0.00790	0.00380	0.00550	-0.00220	-0.00210
baseline10	-0.00580	-0.00180	0.00040	-0.00360	-0.00130	-0.01090
baseline11	0.00170	-0.00600	-0.00020	0.00570	0.00260	-0.00210
baseline12	-0.00680	0.00500	-0.00350	0.00610	0.00930	0.00090
baseline13	-0.00070	0.00080	0.00000	-0.00530	0.00130	-0.00370
baseline14	0.00270	0.00910	0.00400	0.00860	-0.00200	-0.00850
baseline15	0.00080	0.00210	-0.00220	-0.00160	0.00620	0.00580

When the absolute meter values of ΔdX1 and ΔdX1ppp on the day of the earthquake are compared, it becomes clear that the highest values are close to one another in two cases. For example, the estimated displacement value and the PPP value of baseline 1 are correspondingly equal. It is noticed that the difference between the estimated displacement values and the PPP displacement values on the day of the earthquake ranges from 3mm to 5mm.

As for the displacement values of ΔdX3 and ΔdX3ppp on the day after a week of the earthquake, the difference between the Bernese solution and the PPP solution at most stations ranges from 2mm to 6mm. Yet, the baseline MAT1-MIKL hits the displacement value of 1cm, but it is only 1mm in the PPP. On the other hand, baseline DYNG-ORID records 3cm in the Bernese solution while it is 3mm in the PPP solution. This indicates that an evident change occurs in the coordinates of these two solutions.

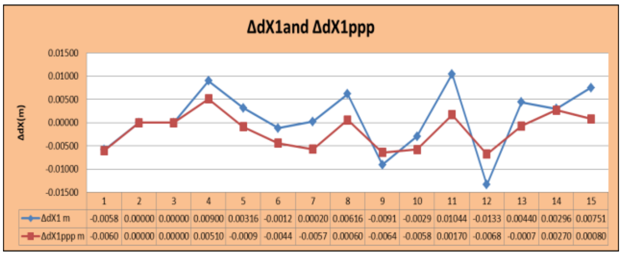


Figure١ : Graph of the Difference Between ΔdX1 & ΔdX1 PPP

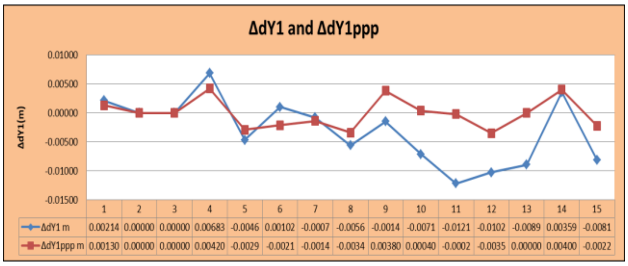


Figure13: Graph of the Difference Between ΔdY1 & ΔdY1 PPP

Tables 25 and 26 also show the difference between the baseline displacements in the Y direction of the two cases. On the day of the earthquake, the values of ΔdY differed from ΔdYppp about 1mm to 3mm at the baselines 1, 4, 5, 6, 7, 8, 9, 10, and 15. Baseline 11 had 1cm as the displacement value of ΔdY on the day of the earthquake, but in ΔdYppp it was equal to 0.0002m. This means that these two points had no detected movement on the crust of the earth when the PPP solution was used but, with the use of the Bernese solution, the displacement value hit 1cm. that means that Bernese have accurate and logical results, which It is proportional to the earthquake shake and its impact on the earth's crust.

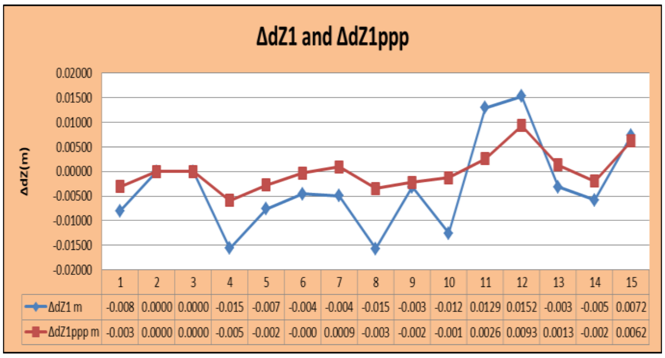


Figure14: Graph of the Difference Between ΔdZ1 & ΔdZ1PPP

The displacement values in the Z direction on the day of the earthquake were ranged from 3mm to 1cm in the Bernese solution, but their corresponding values in the PPP solution were from 1mm to 6mm. Baseline BSHM–NICO had the same displacement value in both solutions, that is, 1cm. Being one of the closest stations to the earthquake epicenter, station NICO had such an effect on displacement. On the day after a week of the earthquake, the values of the Bernese solution changed from 1mm to7mm. Yet, many baselines (e.g., ARUC-ANKR, ARUC-ISBA, & MIKL-DYNG) had displacement values of 1cm. Baseline DYNG-RID had 9cm. However, in the PPP solution, these values changed from 1mm to 8mm, except for the two baselines MAT1-MIKL and DYNG-MIKL that had the displacement value of 1cm.

8. CONCLUSION

This paper explains using the precise point positioning (PPP) technique to evaluate the precise coordinates for the network stations surrounding the epicenter of the Agean earthquake in turkey. Using The Canadian Geodetic Survey of Natural Resources, the CSRS-PPP service, then evaluates the network baselines horizontal displacements in the three directions X, Y, Z, and the vertical displacements. By computing the station's height changes, and analyzing data using the time domain. That means evaluating all the requirements in three different periods, the first, on the day of occurrence of the Aegean earthquake, the second, before one week from the earthquake, and the third time on the day after one week from the earthquake. We compared the results displacement values from the PPP system and the results we have got before from data processing using the Bernese 5.2 program software. Our paper explains the different results between the two techniques for monitoring the response of the ground surface under the effect of the seismic shaking, and which technique gives us more observation accuracy. We found that the PPP technique gives the accurate results in the displacement of the point, but also we should repeat the processing for some points value to be ensured of our results accuracy and can depend on. Because any error when sending raw data of points, or an error in the user datum results in a large error in the results, so it is important to use a processing program that gives accurate results to ensure the displacements and results for each point. So we should be depending on the most accurate way to build an accurate database of point’s displacements around any earthquake area in the world. To be as a reference guide can help the world soon to be an earthquake predicting tool. And try to make an early warning system to help countries for saving lives, properties and to reduce losses as possible.

CrediT authorship contribution statement

Elkutb: Methodology, Software, Review, Data Curation, Supervision.**A.ElHattab:** Conceptualization, Methodology, Review, Supervision, Writing –original Draft **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.

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