Analysis of Changes in Coordinates Before and After the Earthquake of 26 November 2019 of Geodetic Points in the Durres - Tirana Area

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Abstract: - The earthquake that struck the Durres-Tirana area on November 26, 2019, significantly impacted the region's geodetic points. Through this study, which presents the change of coordinates in plan and height in known Geodetic points (which are the Second-order passive network points of the Geodetic datum in the Durres - Tirana area), we aim to analyze the changes in coordinates of these points before and after the seismic event to understand better the deformation caused by the earthquake. It describes the geodetic equipment used to perform GNSS measurements, the GNSS measurement method, the Rinex data processing program, and the calculation of the final points coordinates of the selected geodetic points in the Durres-Tirana area. Rinex data with 1" interval from the ALBCORS Global Positioning System were used to process GNSS measurements of measured points. Also, in the process of processing the coordinates of the points, the corrections of the daily and final ephemerides have been introduced. The coordinates are calculated in the official Geodetic system of Albania "KRGJSH" Geodetic Reference Frame of Albania. An assessment of the change in the coordinates of the points was made, including the analysis of the displacement vector of the points and the presentation of the shift graphically and analytically. The maximum change in the plan is 0.052 cm and the minimum change is 0.027 cm. The maximum change in height is 0.020 cm and the minimum change is -0.122 cm. It is recommended that GNSS measurements should be made at known geodetic points at a certain time interval to study local deformation processes in the Republic of Albania. The research encompasses both temporal and spatial analysis, evaluating the extent of displacement and deformation observed in the aftermath of the earthquake. Additionally, factors such as ground subsidence, and structural damage are considered in interpreting the observed changes in coordinates. The findings of this study provide valuable insights into the geodynamic processes triggered by the earthquake, aiding in the assessment of seismic hazards and the implementation of effective mitigation strategies in the Durres-Tirana region.

Key-Words: - Coordinate, Deformation, Analysis, Geodynamic, Surveying, Changes, Earthquake, Accuracy.

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1 Introduction

Analyzing the changes in coordinates of 2nd order geodetic points before and after the earthquake of 26 November 2019, in the Durres-Tirana area involves examining data from geodetic monitoring stations of ALBCORS in the region. Geodetic points are fixed locations with known coordinates used for surveying, cadastral, and mapping purposes. The earthquake likely caused significant ground motion, which could be detected by these stations, [1], [2].

To perform the analysis, the following steps were followed:

- Data Collection,
- Data Comparison,
- Analysis of Changes,
- Interpretation and Visualization,
- Reporting.

This analysis can provide valuable information for understanding the seismic activity in the region, assessing earthquake hazards, and informing disaster preparedness and response efforts, [3], [4].

ASIG has created the networks (the State Network of Global Positioning, etc.) that make up the Geodetic Reference Frame of Albania (KRGJSH) with high accuracy to guarantee spatial reference according to European standards in all its components.

KRGJSH provides a unique base where various geoscience disciplines are supported to measure and interpret phenomena related to Geology, Hydrology, Seismology, Earth Meteorology, etc.[5], [6].

All the above rules have been applied for the realization of this study.

2 Materials and Methods

2.1 Case Study

The Durres - Tirana area is taken for the study and the 2nd-order points of the State Passive Global Positioning Network were measured. The measured points are shown in Figure 1. Figure 1 shows where the Tirana - Vore - Durres and their surrounding area measured points are located. The points of the second order are located in stable and safe positions. The Figure 1 shows the displacement of points from 2018 before the earthquake and from 2021 after the earthquake.

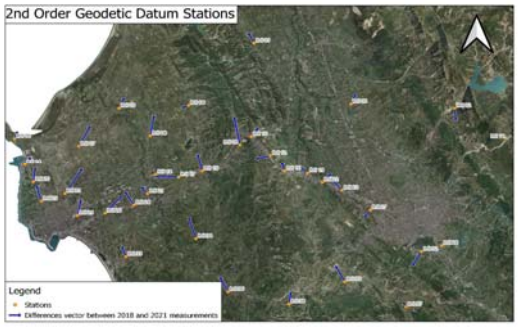

Fig. 1: Second-order Passive Global Positioning State Grid points that have been measured

2.2 Active and Passive Global Positioning State Network

The National Global Positioning Network, based on GNSS systems, is an essential network to enable geodetic control in Albania. This network represents the supporting geodetic infrastructure, built in two components.

2.2.1 State Active Global Positioning Network (ALBCORS)

The State Active Global Positioning Network in the territory of the Republic of Albania is represented by the ALBCORS network, which has been implemented in the European Terrestrial Reference System ETRS89 and at the same time serves for the maintenance of this reference in the territory of the country ours. This network consists of 21 CORS stations built with concrete blocks, 6 CORS stations (roof type), and a control center located on the premises of ASIG, [7], [8].

Figure 2 shows how the points are located on the ground, while Figure 3 shows the points that are located on stable objects.

Fig. 2: Pillar Type

Fig. 3: Roof Type

The State Active Global Positioning Network, ALBCORS, depending on the measurement method and ideal conditions of GNSS field surveys, guarantees to its users the following accuracy: The coordinates of the ALBCORS system provide these accuracies in the service:
Accuracy of RTK service: ±2 cm (2D); ±3 cm (3D)
Service accuracy (post-processing): ± 1cm (2D, 3D)

Figure 4 shows the points of The State Active Global Positioning Network, ALBCORS, distributed uniformly throughout the territory of the Republic of Albania. This network covers the entire territory and guarantees accuracy in making measurements.

Fig. 4: State Active Global Positioning Network, ALBCORS

2.2.2 State Passive Global Positioning Network

The State Passive Global Positioning Network consists of two orders, [9].

2.2.3 State Passive Global Positioning Network, First Order

The State Passive Global Positioning Network, First Order consists of points located in such a way that together with the points of the Active State Global Positioning Network ensure an almost uniform distribution in the territory of Albania. Figure 5. Shows a photo of a satellite receiver measuring at passive first-order points.

Fig. 5: Global Positioning Passive State Network Point, First Order

2.2.4 State Passive Global Positioning Network, Second Order

The Second Order Passive Global Positioning State Network serves to densify the First Order Passive State Network. Figure 6 shows second-order passive points, which are located at stable locations.

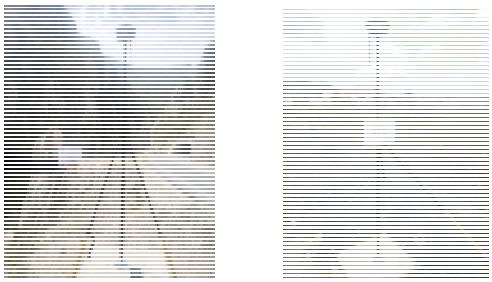

Fig. 6: Second Order Passive Global Positioning State Network Point

2.2.5 Order II Passive

Second-order passive points were measured in the Durres-Tirana area. These points were measured in 2018 and 2021 before and after the earthquake of November 26, 2019.

2.3 Method of Measurements

The points of the ALBCORS global positioning system that are located in the Durres-Tirana region may have stability movements due to the earthquake that occurred on November 26, 2019. Based on guide no. 3, dated 06.09.2013, [10].

I. The duration of GNSS measurements depends on:
- The nature of the base station.
- The average length of all the vectors of the Geodetic Grid.
- The individual length of each vector used for connection to remote starting points.

II. The duration of GNSS measurements can be increased in the following cases:
- To achieve higher accuracy, the measurement duration is doubled.
- When connecting base stations to the network, the duration increases twice.

The measurements were made with the static method, with a time interval of 2 hours, and the data was recorded every 1".

This method was used for the measurements that were carried out in 2018 and 2021.

2.3.1 Geodetic Equipment Used

The GNSS Sokkia GRX2 satellite receiver was used to perform the measurements in 2018 and 2021.

Figure 7 shows the specifications of the GNSS instrument that was used for measurement.

GRX2 Specifications

Tracking capability			
Number of channels*1		226 channels	
Tracked signals*1	GPS	L1 CA, L1/L2 P-code, L2C	
	GLONASS	L1/L2 CA, L1/L2 P-code	
	SBAS	WAAS, EGNOS, MSAS, QZSS	
Positioning accuracy*2			
Static	L1+L2	H: 3mm + 0.5ppm	V: 5mm + 0.5ppm
	L1 only	H: 3mm + 0.8ppm	V: 4mm + 1ppm
Fast static	L1+L2	H: 3mm + 0.5ppm	V: 5mm + 0.5ppm
Kinematic	L1+L2	H: 10mm + 1ppm	V: 15mm + 1ppm
RTK	L1+L2	H: 10mm + 1ppm	V: 15mm + 1ppm
DGPS		<0.5m	

Fig. 7: GRX2 Specifications Geodetic equipment

2.3.2 Processing of Measurements

Post-processing of static measurements was done with TBC (Trimble Business Center) version 5.2. The main stations of the ALBCORS system that were taken for the post-processing process are those that cover the area in which the points of the second order that were taken in the study are located, such as Shengjin, Durres, Divjake, Lushnje, Elbasan, Burrel, Rreshen.

2.3.3 Geodetic System

The data for the geodetic system are:
EPSG: 6870 (ETRS89/Albania TM). *ETRF2000, Epoch 2014.177.*
Projection: Tranverse Mercator
Datum: ETRS89
Planar Units: Meters

Parameters:
Scale Factor – 1
Central Meridian – 20
Origin Latitude – 0
False Easting (m) – 500000
False Northing (m) – 0
Rotation Angle – 0

3 Results

3.1 2018 Measurements Results

Table 1 gives the coordinates of the Second-order Passive Global Positioning State Network measured in 2018 before the earthquake of 2019. N-North, E-East, and h-Ellipsoidal heights that are given were obtained after processing the measurements.

Table 1. Coordinates of the Second order Passive Global Positioning State network measured in 2018

No	Symbol	Coordinates of measured points in 2018		
		N (m)	E (m)	h(m)
1	R II 28	4575011.263	486796.087	238.272
2	R II 32	4574424.511	485093.888	158.000
3	R II 27	4578246.898	480762.507	112.078
4	R II 23	4580061.665	478362.193	94.949
5	R II 22	4580790.383	476714.391	85.795
6	R II 19	4581633.990	475479.174	81.034
7	R II 16	4581810.314	473538.691	93.482
8	R II 12	4583301.693	472334.827	99.101
9	R II 10	4585044.052	470707.910	85.689
10	R II 09	4584265.694	469759.999	77.201
11	R II 15	4581722.989	466634.418	60.714
12	R II 17	4581134.182	464685.633	59.207
13	R II 18	4581345.408	462744.261	59.901
14	R II 21	4579555.338	462086.682	54.016
15	R II 24	4578477.435	460966.751	51.178
16	R II 26	4577691.348	458549.038	48.713
17	R II 31	4579490.330	455158.654	36.037
18	R II 29	4577451.857	456224.930	35.729
19	R II 25	4578757.278	453179.698	46.796
20	R II 20	4580553.565	452509.503	40.489
21	R II 14	4582175.801	451775.590	36.652
22	R II 06	4584625.665	450887.945	35.712
23	R II 04	4587883.317	465427.107	79.185
24	R II 08	4585019.306	462253.209	44.819
25	R II 03	4587557.942	459605.594	41.310
26	R II 07	4583977.849	456273.907	36.701
27	R II 33	4573665.373	460332.956	64.774
28	R II 34	4575405.465	466184.210	94.693
29	R II 01	4593726.578	470847.373	56.253
30	R II 05	4588163.257	479022.648	103.797
31	R II 35	4571535.176	478697.319	156.643
32	R II 36	4570486.020	468922.202	110.423
33	R II 37	4569263.398	483856.073	166.499
34	R II 38	4569409.682	474055.536	101.332
35	R II 02	4587876.954	487723.484	212.009
36	R II 11	4585076.098	492106.043	394.790

3.2 2021 Measurements Results

Table 2 gives the coordinates of the Second-order Passive Global Positioning State Network measured in 2021 after the earthquake of 2019. The N-North, E-East, and Ellipsoidal heights that are given were obtained after processing the measurements.

Table 2. Coordinates of the Second order Passive Global Positioning State network measured in 2021

No	Symbol	Coordinates of measured points in 2021		
		N (m)	E (m)	h(m)
1	R II 28	4575011.265	486796.084	238.295
2	R II 32	4574424.538	485093.903	158.009
3	R II 27	4578246.913	480762.517	112.076
4	R II 23	4580061.640	478362.215	95.040
5	R II 22	4580790.367	476714.376	85.808
6	R II 19	4581633.978	475479.188	81.020
7	R II 16	4581810.297	473538.696	93.487
8	R II 12	4583301.700	472334.852	99.096
9	R II 10	4585044.035	470707.898	85.708
10	R II 09	4584265.642	469760.009	77.182
11	R II 15	4581722.956	466634.426	60.783
12	R II 17	4581134.181	464685.675	59.232
13	R II 18	4581345.403	462744.263	59.914
14	R II 21	4579555.325	462086.693	54.026
15	R II 24	4578477.41	460966.767	51.176
16	R II 26	4577691.315	458549.01	48.717
17	R II 31	4579490.283	455158.625	36.046
18	R II 29	4577451.827	456224.924	35.715
19	R II 25	4578757.249	453179.706	46.798
20	R II 20	4580553.538	452509.5	40.494
21	R II 14	4582175.786	451775.58	36.635
22	R II 06	4584625.651	450887.94	35.749
23	R II 04	4587883.322	465427.118	79.307
24	R II 08	4585019.268	462253.203	44.889
25	R II 03	4587557.922	459605.585	41.337
26	R II 07	4583977.811	456273.888	36.751
27	R II 33	4573665.353	460332.963	64.786
28	R II 34	4575405.425	466184.223	94.743
29	R II 01	4593726.559	470847.383	56.238
30	R II 05	4588163.238	479022.64	103.818
31	R II 35	4571535.146	478697.335	156.64
32	R II 36	4570485.992	468922.216	110.421
33	R II 37	4569263.389	483856.078	166.506
34	R II 38	4569409.659	474055.533	101.345
35	R II 02	4587876.977	487723.482	211.998
36	R II 11	4585076.104	492106.042	394.77

3.3 Changes in the Coordinates of the Measured Points between 2018 and 2021

Table 3 gives the differences in the coordinates of the points measured in 2018 and 2021 of the Second-order Passive Global Positioning State Network in ΔN (m), ΔE (m), and Δh (m).

Figure 8 shows, the changes of coordinates Δx, (X=North). In the graph below, the maximum and minimum values of the X-coordinate differences are given.

Table 3. The differences in the coordinates of the points measured in 2018 and 2021 in ΔN (m), ΔE (m), and Δh (m)

No	Symbol	The differences in the coordinates of the points between 2018 and 2021		
		ΔN (m)	ΔE (m)	Δh (m)
1	R II 28	0.002	-0.003	0.023
2	R II 32	0.027	0.015	0.009
3	R II 27	0.015	0.010	-0.002
4	R II 23	-0.025	0.022	0.091
5	R II 22	-0.016	-0.015	0.013
6	R II 19	-0.012	0.014	-0.014
7	R II 16	-0.017	0.005	0.005
8	R II 12	0.007	0.025	-0.005
9	R II 10	-0.017	-0.012	0.019
10	R II 09	-0.052	0.010	-0.019
11	R II 15	-0.033	0.008	0.069
12	R II 17	-0.001	0.042	0.025
13	R II 18	-0.005	0.002	0.013
14	R II 21	-0.013	0.011	0.010
15	R II 24	-0.025	0.016	-0.002
16	R II 26	-0.033	-0.028	0.004
17	R II 31	-0.047	-0.029	0.009
18	R II 29	-0.030	-0.006	-0.014
19	R II 25	-0.029	0.008	0.002
20	R II 20	-0.027	-0.003	0.005
21	R II 14	-0.015	-0.010	-0.017
22	R II 06	-0.014	-0.005	0.037
23	R II 04	0.005	0.011	0.122
24	R II 08	-0.038	-0.006	0.070
25	R II 03	-0.020	-0.009	0.027
26	R II 07	-0.038	-0.019	0.050
27	R II 33	-0.020	0.007	0.012
28	R II 34	-0.040	0.013	0.050
29	R II 01	-0.019	0.010	-0.015
30	R II 05	-0.019	-0.008	0.021
31	R II 35	-0.030	0.016	-0.003
32	R II 36	-0.028	0.014	-0.002
33	R II 37	-0.009	0.005	0.007
34	R II 38	-0.023	-0.003	0.013
35	R II 02	0.023	-0.002	-0.011
36	R II 11	0.006	-0.001	-0.020

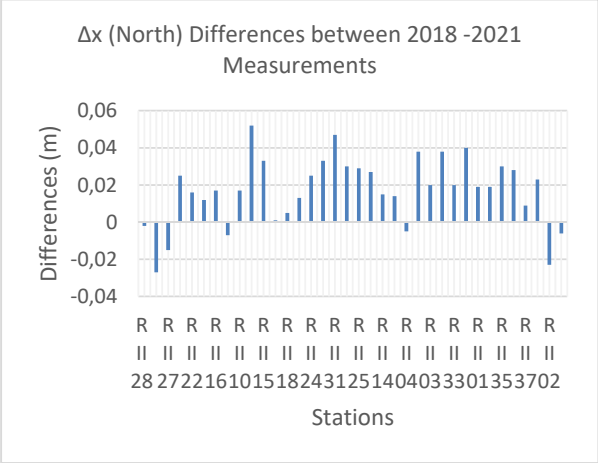

Fig. 8: The changes of coordinates Δx, (X=North) between 2018-2021 Measurements

Figure 9 shows, the changes of coordinates Δy, (Y=East). In the graph below, the maximum and minimum values of the Y-coordinate differences are given.

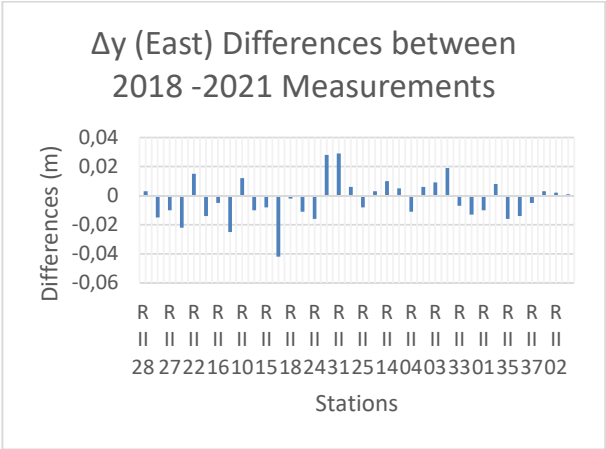

Fig. 9: The changes of coordinates Δy, (Y=East) between 2018-2021 Measurements

Figure 10 shows, the changes of coordinates Δh, (h=Ellipsoidal Height). In the graph below, the maximum and minimum values of the h-coordinate differences are given.

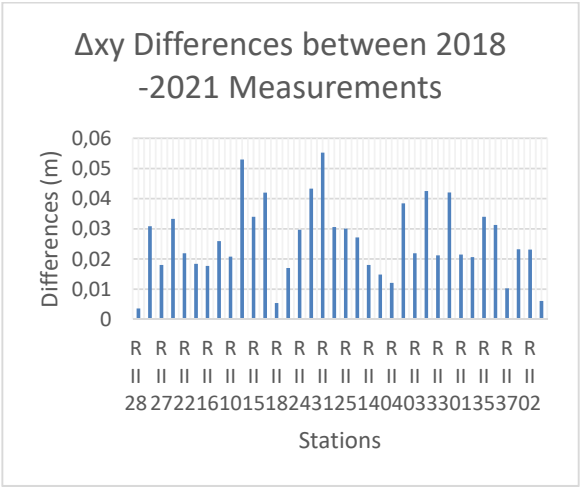

Fig.10: The changes of coordinates Δh, (h=Ellipsoidal Height) between 2018-2021 Measurements

Table. 4 Values from minimum to maximum are given, and standard deviation and RMSE

	Δx	Δy	Δh	Δs
Min (m)	-0.027	-0.042	-0.122	0.00360
Max (m)	0.052	0.029	0.020	0.05522
Range (m)	0.079	0.071	0.142	0.05162
Average (m)	0.01694	-0.00292	-0.01617	0.02608
Std Dev. (m)	0.01823	0.01430	0.03133	0.01233
RMSE (m)	0.02489	0.01459	0.03525	

Table 4 gives the changes in the coordinates of the points in X, Y and h of the points of the passive network second order and the are summarized. Values from minimum to maximum are given, and standard deviation and RMSE.

4 Discussion

This study, which presents the change of coordinates in plan and height in known Geodetic points (which are the Second-order passive network points of the Geodetic datum in the Durres - Tirana area), aims to analyze the changes in coordinates of these points before and after the seismic event to understand better the deformation caused by the earthquake. It describes the geodetic equipment used to perform GNSS measurements, the GNSS measurement method, the Rinex data processing program, and the calculation of the final points coordinates of the selected geodetic points in the Durres-Tirana area. Rinex data with 1" interval from the ALBCORS Global Positioning System were used to process GNSS measurements of measured points. Also, in the process of processing the coordinates of the points, the corrections of the daily and final ephemerides have been introduced.

The coordinates are calculated in the official Geodetic system of Albania "KRGJSH" Geodetic Reference Frame of Albania. An assessment of the change in the coordinates of the points was made, including the analysis of the displacement vector of the points and the presentation of the shift graphically and analytically. The maximum change in the plan is 0.052 cm and the minimum change is 0.027 cm. The maximum change in height is 0.020 cm and the minimum change is -0.122 cm. It is recommended that GNSS measurements should be made at known geodetic points at a certain time interval to study local deformation processes in the Republic of Albania.

To perform GNSS measurements at known Geodetic points, we must use the data of the Global Positioning System ALBCORS. Based on the study, it turns out that the Geodetic points located in the Durres-Tirana Region have displacements in plan and height. For this reason, the coordinates of the points of the Global Positioning System ALBCORS must be recalculated from the Permanent Stations of the GNSS network of EUREF, EPN class A to achieve the highest possible accuracy. EUREF "Reference Frame for Europe" consists of a network of GNSS reference stations (Global Navigation Satellite Systems, such as GPS, GLONASS, Galileo, Beidou, ...) that operate continuously and provide data in real-time. The main principles that will be considered for the measurement campaign are:

- Measurements will be done simultaneously in all stations.
- It will be 10 sessions with 24-hour observation.
- As supporting stations will be used only EPN Class A stations, it will be the freshest solution.

After calculating the coordinates of the points of the ALBCORS global positioning system from the Class A EPN Network, we can obtain an accurate deformation model for the Durres-Tirana region.

5 Conclusions

- The maximum values of the X -coordinate differences are $\Delta x=0.052$ m, the maximum change of coordinates in Y is $\Delta y=0.029$ m and the maximum change in height is $\Delta h=0.020$ m.
- The minimum change of coordinates in X is $\Delta x= -0.027$ m, the maximum change of coordinates in Y is $\Delta y= -0.042$ m and the maximum change in height is $\Delta h= -0.122$ m..
- Changes in the coordinates of the grid points of second passive order in the Durres-Tirana area are on average 2-3 cm.
- The combination of GNSS, seismic, gravimetric, and geodetic measurements makes it possible to create an accurate deformation model for the entire territory of the Republic of Albania.
- To create an accurate deformation model, the coordinates of the points of the ALBCORS system must be recalculated from the EPN stations (EUREF Permanent GNSS Network).

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGPT to enhance the clarity and coherence of the text. After using this tool/service, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

- Eduart Blloshmi carried out the measurements, processing, and calculation of the final coordinates and prepared the report.
- Bledar Sina carried out the measurements and prepared the report.

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Conflict of Interest

The authors have no conflicts of interest to declare.