Investigation of the Displacements from 1941 to 2007 using Terrestrial and Gps Measurements along the Western Part of North Anatolian Fault in Marmara Region

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Key words: Displacement, Marmara Region, GPS

SUMMARY

We present the results of terrestrial and Global Positioning System observation of GCM-ITU (The General Command of Mapping-Istanbul Technical University) network located in the vicinity of southern branch of North Anatolian Fault. The network was monitored in 1941 and 1963 by triangulation, in 1981 by trilateration, as well as by GPS observations in 2004 and 2007 in order to obtain displacements. First, internal deformation of the network was estimated which was ranging between 7mm/yr and 18mm/yr. Then, GPS observations re-processed in extended network by adding new stations from MAGNET (Marmara Region Continuous GPS Monitoring Network) on Eurasian-fixed reference system. The results varied between 8mm/yr and 13 mm/yr.

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1. INTRODUCTION

Iznik Mekece fault is one of the strands of North Anatolian Fault (NAF) in Marmara Region The network implemented by General Command of Mapping as constitution of nine pillars scattered around south and north of this fault. The network was measured by trilateration and triangulation methods by GCM and Istanbul Technical University in 1941, 1963, and 1981. After KOERI (Kandilli Observatory and Earthquake Research Institute) Geodesy Department joined GCM-ITU net in Marmara microgeodetic project, the network was also monitored by GPS Campaigns in 2004 and 2007.

This study is based on the use of repeated observations over the network and on the analysis of the results obtained from different epochs by means of displacements. Thus, first all epoch of observations were computed and then the amount of displacements were analyzed judging by the fault movement and the accuracy values for each observation method. In addition to this, in order to check the coherence of results, GPS campaign data have been processed in detail.

2. INVESTIGATION OF DISPLACEMENT OF GCM-ITU NETWORK BETWEEN 1941 AND 2007

In 1941 and 1963, the GCM-ITU network (Figure 2-1) was monitored by triangulation method. In addition to this in 1981, both trilateration and triangulation methods were applied. The first measurements obtained from the network were in 1941 and 1963. These observations had poor geometry and low accuracy. Therefore, it is decided to unite both measurements and adjust them as a single observation. However, the new results were also not accurate enough to determine displacements.

In 1981, both trilateration and triangulation methods were applied. The constrained adjustment method was applied for the observation and the same control stations accepted as fixed coordinates. Changes in the coordinates of 4215 Tavsandede Tepe, 202 Aygiran and 226 Hacidag stations were examined relative to these control stations. The maximum root mean square error was obtained ±14 cm for 1981 adjustment.

Figure 2-1: The constellation of GCM_ITU network. Hidirellez, Turbetepe and Armutlu are fixed sites.

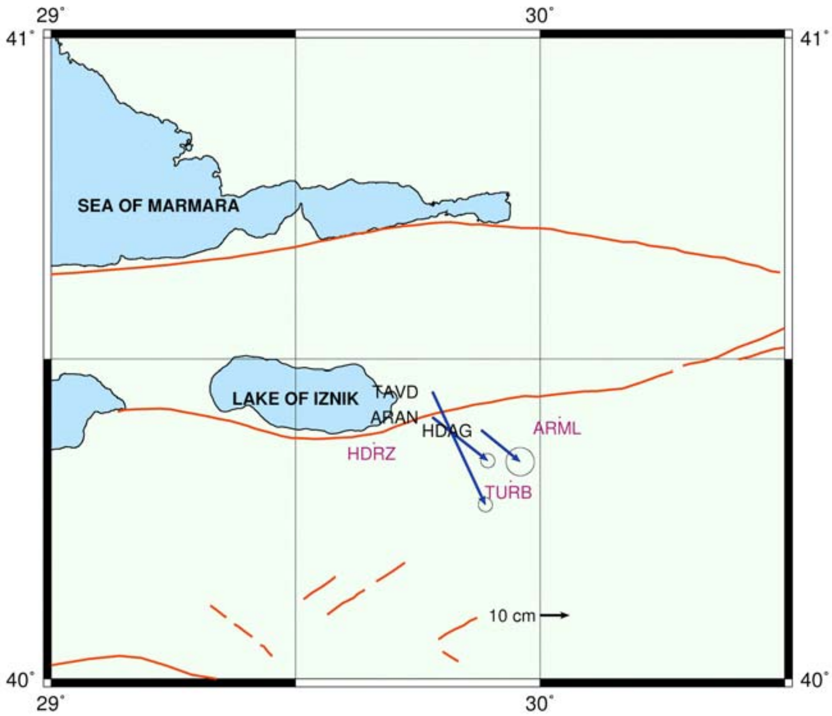

Figure 2-2: The amount of displacement between 1981 and 2004&2007 on the study area.

GPS measurements were carried out in 2004 and 2007 using campaign method. Trimble Geomatics Office Software (TGO) (Trimble Navigation Limited) was employed to process GPS data using precise orbits gathered from GNSS web site.

Table 2-1: Movements on the easting and northing components of GCM-ITU network stations Campaigns between 1981 and 2004&2007.

Stations	Campaign Year	Easting+ RMS (m±cm) (±) Differences (m)	Northing + RMS (m±cm) (±) Differences
Tavsandede Tepe	1981	479437.590 ± 11.2	4487596.270 ± 8.8
		(+) 0.183	(-) 0.391
	2004&2007	479437.734 ± 2.0	4487595.879 ± 1.3
Aygiran	1981	481183.916 ± 7.9	4479288.022 ± 6.1
		(+) 0.191	(-) 0.150
	2004&2007	481184.107 ±1.7	4479287.872 ± 1.7
Hacidag	1981	490035.818 ± 5.8	4473934.716 ± 5.0
		(+) 0.134	(-) 0.109
	2004&2007	490035.952 ± 2.2	4473934.607 ± 2.7

Comparing the terrestrial data to the GPS outcomes, baseline components were separated from coordinate results and designating as raw data and then processed individually as trilateration measurements by constrained adjustment with stable stations in ED-50 datum. Apart from the individual adjustment of each campaign, we combined them and used as a single trilateration network in free network adjustment in order to increase the degree of freedom.

While analyzing the adjusted coordinates of GPS observations and their mean square errors, it has been concluded that, because of the datum difference from terrestrial ones, the GPS data does not fit the requirements of constrained adjustment. Consequently, for detecting rotation, scaling and translation factors, the Two Dimensional Helmert Transformation is applied to coordinates gathered from free network adjustment of combined 2004 and 2007 GPS data.

Where X0, Y0 represents two translation parameters with a scale factor k and rotation α, the 2D-Helmert Transformation Formula between (U,V) and (X,Y) coordinate system is,

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} X_0 \\ Y_0 \end{bmatrix} + k \begin{pmatrix} \cos\alpha & -\sin\alpha \\ \sin\alpha & \cos\alpha \end{pmatrix} \begin{bmatrix} U \\ V \end{bmatrix} \quad (1)$$

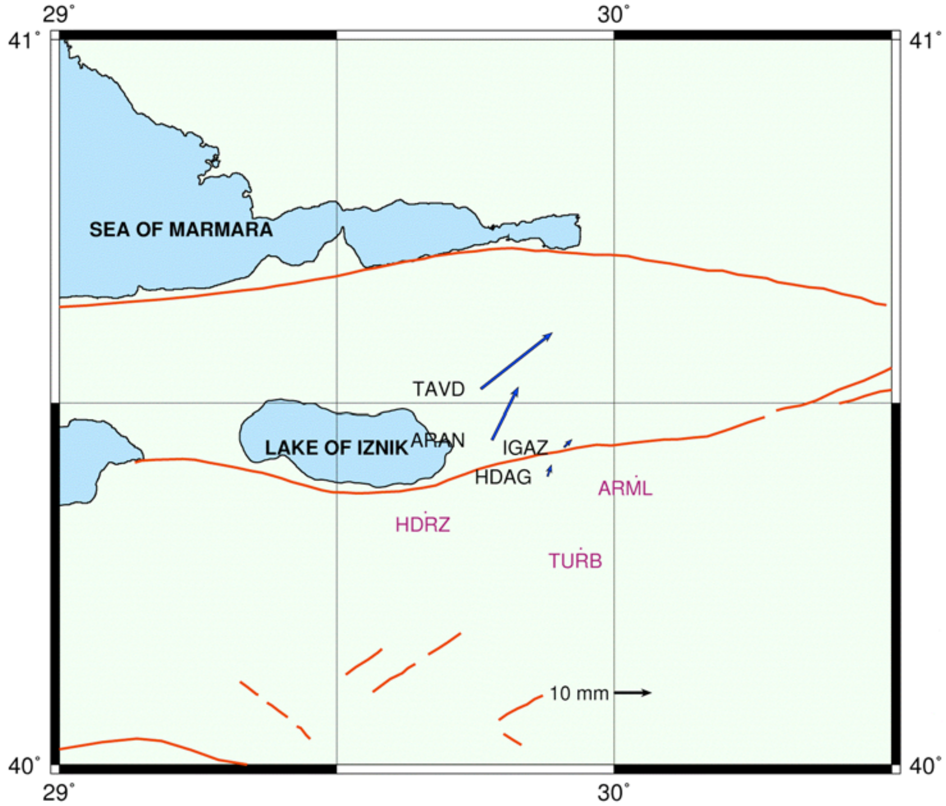

Figure 3-1: The amount of displacement between 2004 and 2007 on the study area.

From Helmert Transformation the scale factor was evaluated -10.814 ppm. Then the displacements were investigated between the outputs of constrained adjustment results for Tavsandede Tepe, Aygiran and Hacidag sites from 1981 campaign to combined 2004 and 2007 GPS campaign. The displacements of the network between 1981 and 2004&2007 are shown in Table 2-1 and Figure 2-2.

3. INVESTIGATION OF DISPLACEMENT OF GCM-ITU NETWORK BETWEEN 2004 AND 2007

GCM-ITU Network started to being observed again in 2004 and 2007 using GPS technique by KOERI Geodesy Department as a research project supported by Research Fund of Bogazici University (Gurkan et al., 1999) However, only six of the stations could survive to this time, so Gazkesmez station was added to densify the northern part.

The method of static GPS measurement was performed in this study. Therefore the campaigns had been planned to monitor the network at least eight hours, but some environmental problems lessen that time.

Table 3-1: Movements on the easting and northing components of GCM-ITU network stations Campaigns between 2004 and 2007.

Stations	Campaign Year	Easting+ RMS (m±mm) (±) Differences (m)	Northing + RMS (m±mm) (±) Differences
Tavsandede Tepe	2004	479247.287 ± 0.2	4485618.806 ±0.2
		(+) 0.019	(+) 0.015
	2007	479247.306 ± 0.3	4485618,821 ± 0.3
Aygiran	2004	480993.,036 ± 0.1	4477314.089±0.1
		(+) 0.007	(+) 0.014
	2007	480993,043± 0.2	4477314,103± 0.3
Hacidag	2004	492033.864 ± 0.1	4476380.896±0.1
		(+) 0.001	(+) 0.003
	2007	492033.865 ± 0.2	4476380.899 ± 0.3
Gazkesmez	2004	489841.470 ± 0.1	4471963.021±0.1
		(+) 0.001	(+) 0.003
	2007	489841.471 ± 0.2	4471963.024 ± 0.2

Trimble Geomatics Office Software and GIPSY/OASIS II (GPS Inferred Positioning System/Orbit Analysis and Simulation Software) (NASA-JPL) (Zumberge et al., 1997) (Gregorius, T., 1996) software were used in GPS processing. The analysis strategy was similar to the terrestrial analysis in order to compare the outcomes. For adjustment, constrained adjustment option in TGO was employed. In addition to this, precise coordinates of stable stations was gathered using precise point positioning method in GIPSY.

As displayed on Figure 3-1, the direction of movements is different from the terrestrial observation results and the all stations are directed to northeast in Anatolian fixed reference frame.

In order to investigate other effects on GCM network rather than the Iznik-Mekece fault and to extend the research area, three stations were added into the study from MAGNET (Marmara Continuous Global Positioning System Network). This network was established before the Izmit earthquake in 1999 for crustal deformation associated with strain accumulation along the western NAF system (Ergintav, S., 2007). It consists of 18 sites scattered along Marmara Region.

TGO software was also employed for GPS processing step of the extended network. Although the method of the process was the same, the adjustment model differs from previous one. TUBI station was selected as the stable point and minimally constrained adjustment was applied to data. The displacements between 2004 and 2007 on extending network are displayed on Figure 3-2.

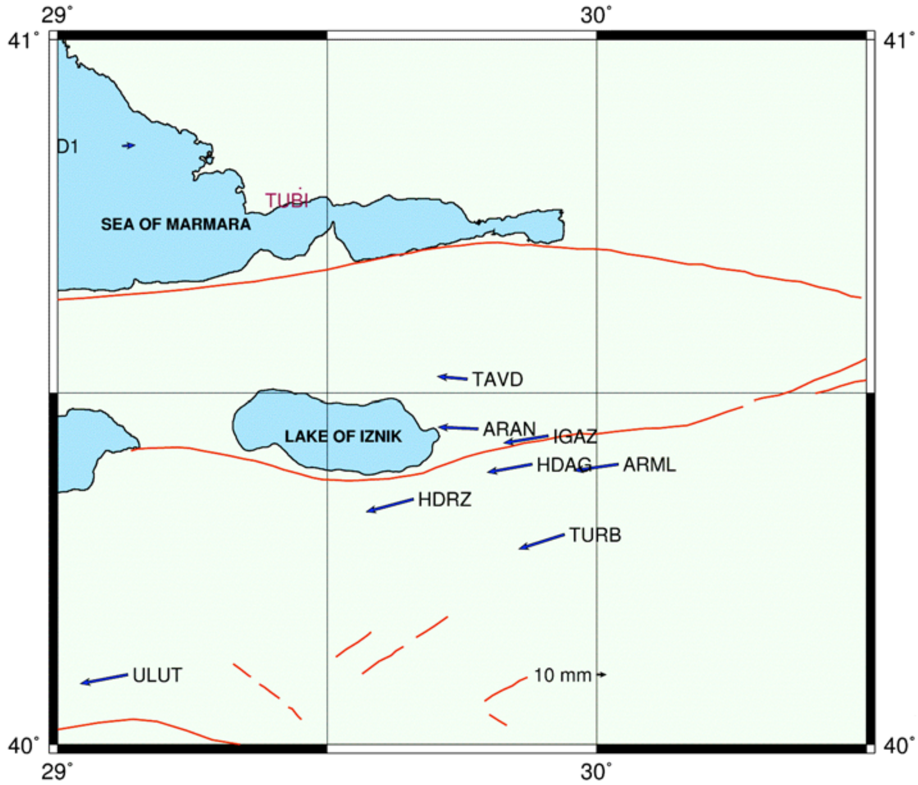

Figure 3-2: The amount of displacement between 2004 and 2007 on the extended network

4. CONCLUSIONS

There were three analysis conducted on the GCM-ITU network in the study. Both GPS and terrestrial observations results demonstrated that the stations at both the south and north of the fault have moved to the same direction during the 1981-2007 periods. In terrestrial analysis, the north of the fault the movement of Tavsandede Tepe and Aygiran stations is in the direction of southeast. Contrarily, the station Hacidag moves within the same direction, even though the location of the point is different from the others.

In GPS analysis all movements are directed to northeast are consistent with the movements of Iznik-Mekece fault. The biggest changes are found in Tavsandede Tepe site which is the furthest one with respect to the fault. Accordingly, the minimum movement is found in Hacidag which is the nearest station to the fault.

Furthermore, in the extended network, all sites below the Iznik fault move together to the west relative to TUBI station.

ACKNOWLEDGEMENTS

The authors wish to thank NASA's Jet Propulsion Laboratory for allowing us to use GPS Inferred Positioning System Orbit Analysis and Simulation Software (GIPSY-OASIS), satellite orbit, and clock solution files. We are also grateful to the Trimble Navigation Limited for providing TGO software. The maps were made using the GMT software. (Wessel&Smith1995).

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BIOGRAPHICAL NOTES

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