Determination of Velocity Field and Strain Accumulation of Densification Network in Marmara Region

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INTRODUCTION

- After the 1999 earthquakes, in order to eliminate effects of earthquake Turkish National Fundamental GPS Network (TNFGN) and Turkish National Vertical Control Network (TNVCN) were renovated.
- Densification of points, tied to fundamental vertical and horizontal networks, was also performed in this region. Istanbul GPS Triangulation Network (IGTN) and Marmara Earthquake Region Information System (MERLIS) including cities like Izmit, Adapazari and Yalova were formed.
- Test network of Continuously Operating Reference Stations (CORS-TR) were established from some of the network points mentioned above as a national continuous GPS stations network in 2006 (CORS-TR, 2006). GPS measurements and adjustments of the test network were done by companies such as TOPCON, TRIMBLE, and LEICA.
- The aims of this study are to evaluate the coordinate differences between the initial coordinates of the stations in test network (reduced to 2000.45 epochs) and average of adjusted coordinates which were calculated by three different companies (reduced to 2006.60 epochs) and to determine strain accumulation in Marmara Region after the earthquakes.

TEST NETWORK AND OBSERVATIONS

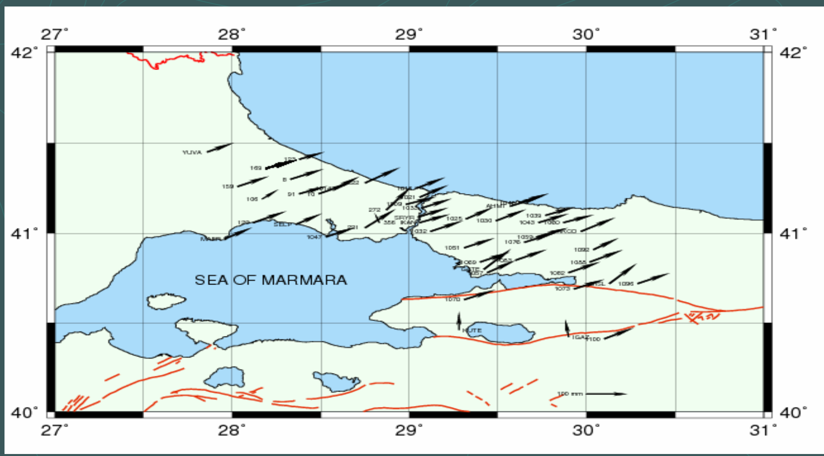
Points of test networks were chosen from TNFGN, MERLIS and IGTN networks in Marmara Region.

$$\left.\begin{array}{l}\text{TNFGN}\\ \text{MERLIS}\\ \text{IGTN}\end{array}\right. \xrightarrow{\text{were tied to}} \text{TNFGN} \xrightarrow{\text{was tied to}} \text{IGS in ITRF96 datum}$$

$$CORS-TR \xrightarrow{\text{was tied to}} \text{IGS in ITRF2000 datum}$$

Therefore, test networks had different datum for each epoch.

TEST NETWORK AND OBSERVATIONS



The displacement vectors between 2000.45 epoch and 2006.60 epoch in test network

DETERMINATION OF EFFECTS OF DATUM AND STRAIN ACCUMULATION

- Determination of Effects of Datum

The coordinates of two epochs by using different IGS stations and different datum (ITRF96, ITRF2000) had an effect on coordinate differences was examined.

TNFGN
MERLIS —were tied to→ TNFGN —was tied to→ IGS in ITRF96 datum
IGTN

ONSA,MADR,WTZR, MATE,ANKR,ZWEN, KIT3,NICO,BAHR points

CORS-TR —was tied to→ IGS in ITRF2000 datum

ANKR,TUBI,DRAG, NOT1,SOFI,BUCU MATE points

By applying Helmert transformation between the coordinates of ITRF96 and ITRF2000 of IGS stations which made up datum of two networks, whether or not there were any significant scale changes and rotation were examined.

DETERMINATION OF EFFECTS OF DATUM AND STRAIN ACCUMULATION

	TNFGN (ANKR, WTZR, MATE, ONSA, KIT3, ZWEN, NICO, BAHR)	CORS-TR (ANKR, SOFI, MATE)
Scale	1.000000001 ± 0.0000000006	1.000000190 ± 0.0000000270
Rotation about X	-0°00'00.00046" ± 0.00014"	-0°00'00.01077" ± 0.01260"
Rotation about Y	0°00'00.00027" ± 0.00021"	0°00'00.00089" ± 0.02874"
Rotation about Z	-0°00'00.00003" ± 0.00015"	-0°00'00.00371" ± 0.00597"
X translation	0.015 ± 0.006m	-0.639± 0.613m
Y translation	0.019 ± 0.004m	-0.322 ± 0.255m
Z translation	-0.022 ± 0.005m	-1.008± 0.725m

The table indicated that there was a significant translation between datum of two epochs.
The translation had an effect on coordinate differences.

DETERMINATION OF EFFECTS OF DATUM AND STRAIN ACCUMULATION

- Determination of Strain Accumulation

The most appropriate way to determine strain parameters which were independent from datum is using ratio of baselines. Observations at two epochs are used for least square adjustment separately. Linear extension of a baseline in a network becomes;

$$\varepsilon = \frac{S' - S}{\Delta t . S}$$

If time interval between two epochs, Δt is given, strain rate ε is found.
However; if Δt isn't taken into account, ε will become strain accumulation.
Linear extension of the baseline which has t azimuth is

$$\varepsilon = e_{xx}\cos^2 t + e_{xy}\sin 2t + e_{yy}\sin^2 t$$

DETERMINATION OF EFFECTS OF DATUM AND STRAIN ACCUMULATION

By using this general equation, parameters of strain tensor are calculated. Therefore, the network has to be constructed of triangles and strain tensor has to be calculated for each triangle. For each baseline of a triangle, three general equations are created. Thus, e_{xx}, e_{xy}, e_{yy} are found for time interval between 2000.45 and 2006.60 epochs. These parameters of strain tensor are the strain parameters of the point of equilibration of each triangle.

Triangles for the network were constructed by using Delaunay triangulation method. Then strain tensor for each triangle was calculated.

DETERMINATION OF EFFECTS OF DATUM AND STRAIN ACCUMULATION

$$\Delta = e_{xx} + e_{yy}$$

$$\gamma_1 = e_{xx} - e_{yy}$$

$$\gamma_2 = 2e_{xy}$$

$$\gamma = \sqrt{\gamma_1^2 + \gamma_2^2}$$

Δ dilatancy
γ_1 principal shear strain
γ_2 engineering shear strain
γ total shear strain

$$E_1 = \frac{1}{2}(\Delta + \gamma)$$

$$E_2 = \frac{1}{2}(\Delta - \gamma)$$

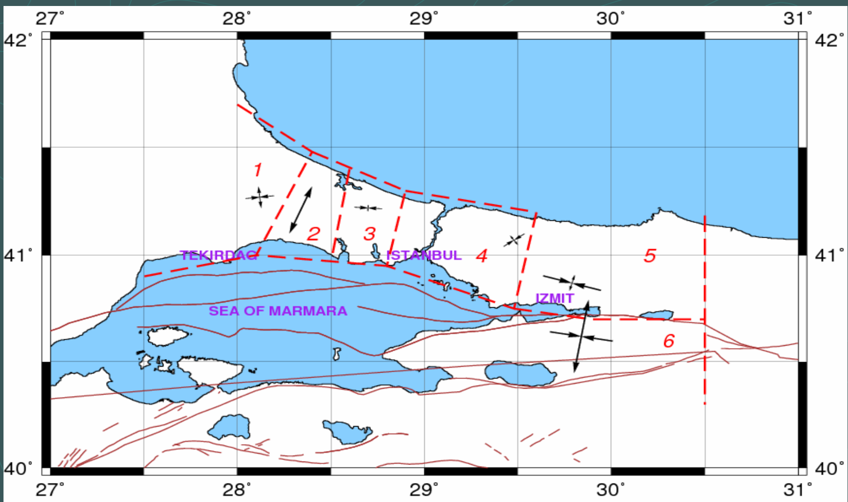
$$\beta = \arctan\left(\frac{e_{xy}}{E_1 - e_{xy}}\right)$$

E_1 maximum principal strain
E_2 minimum principal strain
β direction of maximum principal strain arc

DETERMINATION OF EFFECTS OF DATUM AND STRAIN ACCUMULATION

Group Number	Average of Coordinates of Point of Equilibration		Average of Principal Strain Components		Average of Angle of the Principal Strain β (grad)
	Latitude (degree)	Longitude (degree)	E_1 (μs)	E_2 (μs)	
1	41,27	28,12	1,00	-1,15	7,08
2	41,21	28,34	2,31	0,03	-25,27
3	41,22	28,70	0,30	-1,09	-4,27
4	41,07	29,48	0,55	-1,00	39,76
5	40,87	29,79	0,77	-2,38	-17,92
6	40,62	29,84	3,40	-2,51	-10,82

DETERMINATION OF EFFECTS OF DATUM AND STRAIN ACCUMULATION



CONCLUSIONS

- Coordinate differences indicated that there were significant displacement vectors between 2000.45 and 2006.60 epochs of test networks. Directions of these vectors are compatible with directions of displacement vectors derived from geodynamic studies.
- In the computation of strain, choosing the model should be done according to the state of datum of networks. Strains should be calculated from data which were independent to datum. Most suitable model for this study was the determination of strain with finite element model that relied on the deformations of baselines of network.
- Averages of strain accumulation around Tekirdag were found 2.31μs, around Izmit 3.40μs. Average of strain accumulation around Istanbul was found 0.55μs.
- The results were compatible with different geological structure of Tekirdag, Izmit and the Istanbul areas.

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