Slip Rates Estimate of Western North Anatolian Fault System in Turkey

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Keywords: GPS, NAFZ, Slip rates, Strain

SUMMARY

Since 1970s, geodetic studies have been carried out for detecting crustal movements along North Anatolian Fault Zone in Turkey. In this context, three geodetic control networks were installed in the regions having significant seismic hazard. One of them is located in Iznik, an area of low seismicty; the other one is Sapanca which is the most seismically active region; and the third network is located in Akyazi; where the fault splays in two branches. These networks have been measured by conventional geodetic techniques since 1990, then GPS technique has been applied and they have been connected to regional geodynamic GPS Networks. These networks have importance in contributing to the assesment of seismic hazard in the region inferred from episodic GPS observations. Furthermore, two additional geodetic networks has been surveying by GPS technique for several years. These networks are Ismetpasa (established by Istanbul Technical University [ITU] in 1981) and Iznik-GCM (established by ITU and General Command of Mapping in 1941) networks. GPS technique plays a very important role in understanding of earthquake mechanism in each phase of seismic cycle, i.e., the pre-, co- and postseismic stage. Co-seismic movements depend on the amount of slip and the depth of the earthquake. Near-field GPS observations can be used to obtain strain accumulating across locked faults and can therefore help us to determine the seismic potential of the region of interest. It is also necessary to link the short-term geodetic observations to the medium and long-term trends. In this study, we aimed to ensure the continuity of the measurements, examine the change in the magnitude of the velocity vectors, and identify the current velocity field and strain rates through these geodetic networks. The velocities in ITRF2008 reached up to 24±1 mm/yr relative to the Eurasia and strain rates indicated up to 98 nanostrain/yr. Directions of the extension and compression showed consistency with present day kinematics of the area.

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1. INTRODUCTION

The Earth is monitored by different kind of sensors and methods every day. Turkey has historically been characterized by massive and destructive earthquakes due to its location within the Africa–Eurasia collision zone. There is a complex boundary between the African and Eurasian plates in this region which includes the Hellenic Arc in the west, the Cyprus Arc in the south-east and the diffuse fault system of the Eastern Anatolian fault zone in the east. The North Anatolian Fault is one of the most seismically active faults in the world. The NAFS is a major right lateral strike-slip fault which is extending about 1200 km from the Karliova junction in the eastern to the northern Aegean Sea in Turkey (Fig1) [1-9]. A sequence of earthquakes occurred on the NAFS, starting with Erzincan earthquake 1939 and followed by 1942, 1943, 1944, 1951, 1957, 1967 and finally 1999 during the 20th century. Understanding of earthquake structure is the important way to assess and evaluate the earthquake hazard estimation and mitigation the earthquake losses.

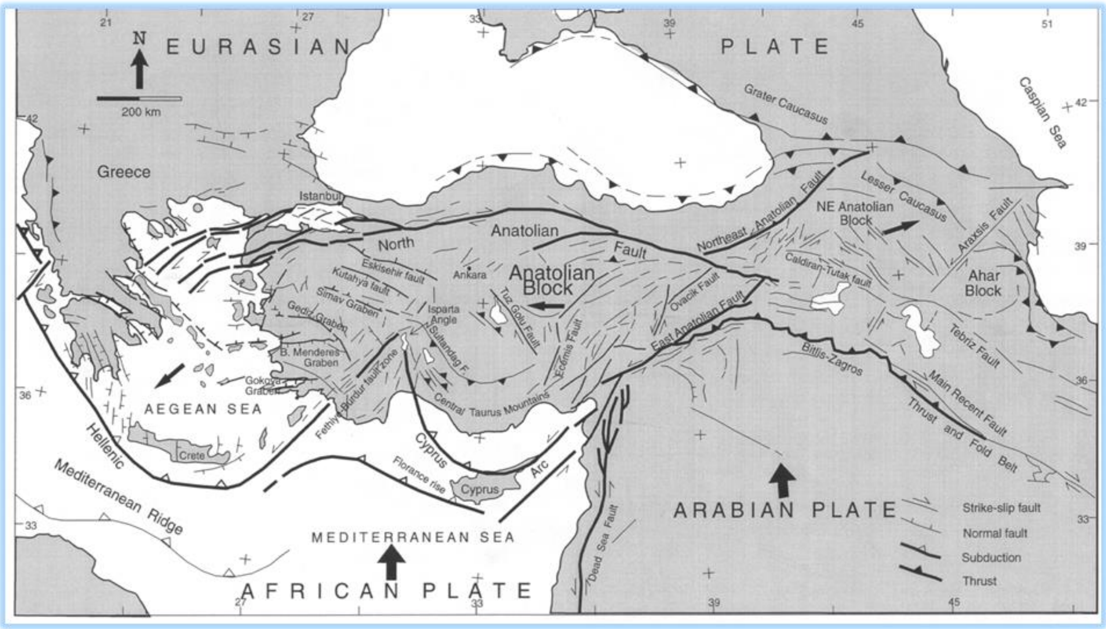

Figure 1: Tectonic Settings of Turkey

2. NETWORKS ON THE NAFZ

In order to determine the crustal deformation along the North Anatolian Fault zone, geodetic studies have been performed since 1970s. Geodesy Department of Kandilli Observatory and Earthquake Research Institute of Bogazici University were started research for the crustal movement monitoring on the western part of NAFZ in 1990. Three geodetic networks were established in the eastern Marmara region. These networks are Iznik, Sapanca and Akyazi. These networks had been measured by means of terrestrial techniques such as theodolite and electromagnetic distance meter instruments. The measurements were repeated annually until 1993. GPS measurements have been performed in the network to determine the crustal movements in the region since 1994 [10]. Besides, two further networks have been surveyed by GPS techniques for years. These networks are Ismetpasa and Iznik-GCM. Ismetpasa is located at the intersection of Karabuk and Cankiri country which is located 350 km east of Istanbul [11]. Iznik-GCM network is situated near the Iznik network. Figure 2 displays all networks in the Marmara region.

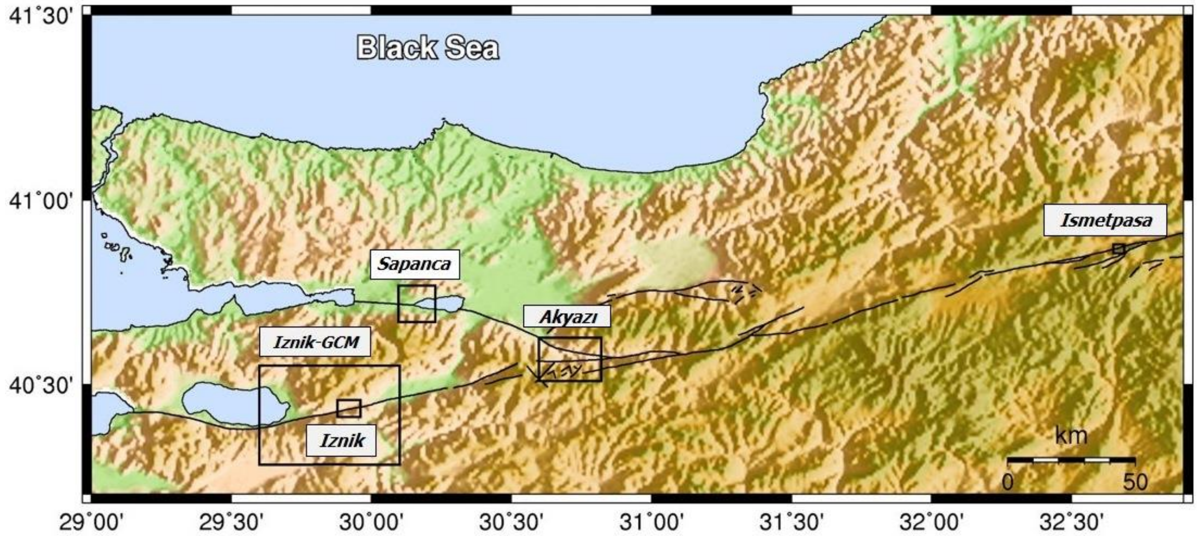

Figure 2: Location of all geodetic networks (Iznik, Sapanca, Akyazi, Iznik-GCM, Ismetpasa)

3. DATA PROCESSING & ANALYSIS

Global Positioning System (GPS) is the most important conventional technique in order to determine the crustal motion in the Earth's surface precisely. All networks observation time interval displays in Table 1. Trimble 4000 SSI and 4000 SSE GPS receivers were used to obtain geodetic data. 10-hour/day observation was realized at each campaign-based station. The elevation mask was 10^{o} and the logging interval was 15 seconds. The processing and evaluation of the GPS campaigns was carried out with the GAMIT/ GLOBK software package. Each campaign were processed using the International Terrestrial Reference Frame; the ITRF2008. Precise orbit by International GPS Service (IGS) was obtained in SP3 (Standard Product 3) format from SOPAC (Scripps Orbit and Permanent Array Center). Earth Rotation Parameters (ERP) came from USNO_bull_b (United States Naval Observatory_bulletin_b). 9-parameter Berne model was used for the effects of the radiation and the pressure. Scherneck model (IERS standards, 1992) was used for the ocean tide loading effect. Zenith Delay unknowns were computed based on the Saastamoinen a priori standard troposphere model with 2-hour interval. Iono-free LC (L3) linear combination of L1&L2 carrier phases was used. The model which depended on the height was preferred for the phase centers of the antennas.

Years **Networks**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Iznik	X	X	X	X	X	X	X	X	X	X
Iznik-GCM			X					X	X	X
Sapanca	X	X	X		X	X	X	X	X	X
Akyazı	X						X	X	X	X
Ismetpaşa	X		X		X	X	X	X	X	X

Table1: Observation spans of networks

Horizontal velocity fields of networks in Eurasia-fixed reference frame is displayed in figure 3.

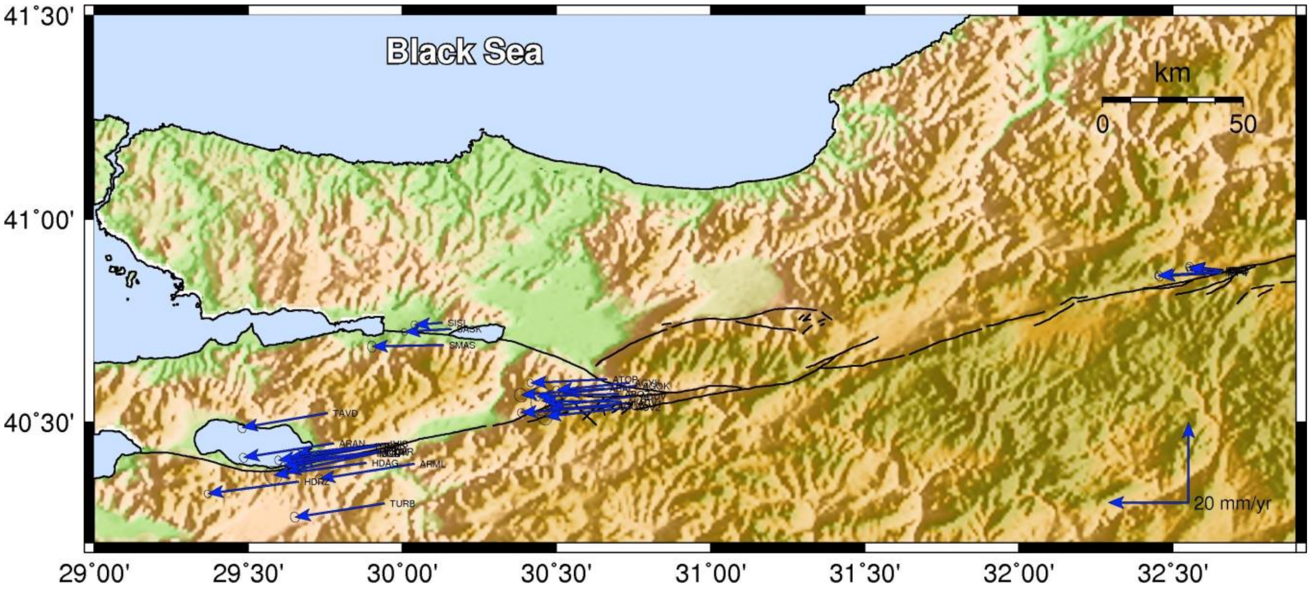

Figure 3: Horizontal velocity field of networks in Eurasia-fixed reference frame. (with 95% confidence ellipses). Black line displays the North Anatolian Fault

Data from the continuous GPS stations can be create strain maps. Strain is the key element in order to understand the seismic hazard analysis. We analyzed periodic GPS observations of these networks to derive velocity vectors and principal components of crustal strain rates. In this study, strain rates are calculated only Iznik-GCM network. We use a simple way to calculate strain rates from 3 GPS sites. We divided network into triangles (delaunay) (Figure 4). For a strike slip fault, the strain varies with distance from the fault. Since we observed very near-fault GPS data, we ignore variations and use a uniform approximation [12].

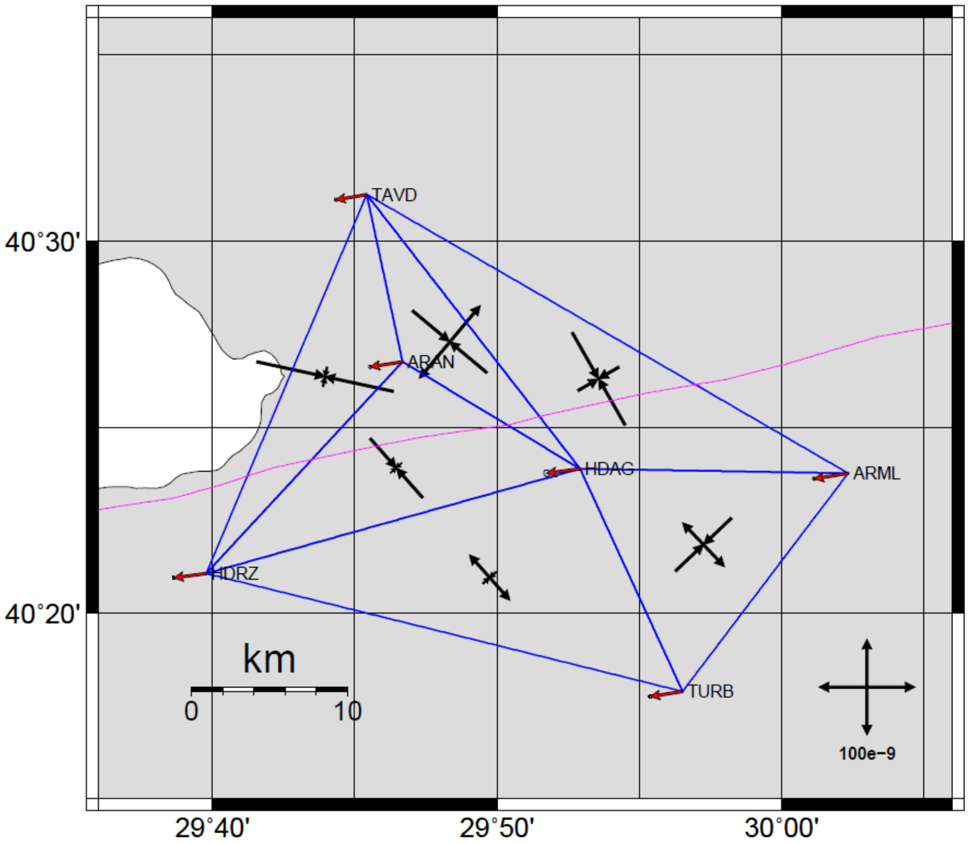

Figure 4: Principal strain rates (ε1 and ε2). Arrows directed outside and inside indicate maximum extension and compression respectively.

4. DISCUSSION & CONCLUSION

The purpose of this study is to ensure the continuity of the measurements, examine the change in the magnitude of the velocity vectors and identify the current velocity field and strain rates through these geodetic networks.

According to the velocities of Iznik network, southern branch of western NAF is without the presence of significant tectonic deformation. North and south parts of the fault move toward southwest relative to Eurasia with the same rate. Although spatial coverage within Sapanca is relatively low, here we obtained velocities ranged between 6.70±1 and 17.90±1 mm/y. The southern part of this fault branch seems to agree with the expected rate which is higher than the upper part. Site velocities in Akyazi network are consistent with limits of 18.30-22.80±1 mm/y. NAF splays into two branches here. GPS site velocities determine in this network reflect the movements of different segments. For the Iznik-GCM network, velocities varies between 21.60±1 and 24.00±1 mm/y. The maximum strain rate is 98 nstrain/y agreeing with the region tectonics. The largest magnitude of horizontal velocities relative to Eurasia detected at GPS sites at western Black Sea (Ismetpasa) is 19.70±1 mm/y and relative to a northern GPS site (ISP2) is 7.83±1 mm/y. So that the creep rate from 2005 is approximately 7 mm/y. [12].

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BIOGRAPHICAL NOTES

Prof. Dr**. Haluk OZENER** was born in 1967. He graduated from Istanbul Technical University in 1988. He obtained his M.Sc. and Ph.D. degrees from Bogazici University in 1992 and 2000. He is currently Vice Director of Kandilli Observatory and Earthquake Research Institute of Bogazici University and Chair of the Geodesy Department. He is also serving as Chair of Earthquake Association, Chair of the Tectonics and Earthquake Geodesy Sub-Commission of International Association of Geodesy (IAG), Chair of the Geodynamics Working Group of Turkish National Geodesy Commission, Chair of Geodesy and Navigation Commission of Chamber of Survey and Cadastre Engineers, and Chair of International WEGENER Working Group. His main research interests are geodesy, GPS, geodynamics, tectonics, earthquake hazards, deformation of engineering structures, Geoinformation Systems/GIS applications, and stochastic modeling.Prof. Ozener has contributed to around 40 national and international projects as a project manager or a researcher He is co-authored over 200 papers, and 27 of them in peer-reviewed international journals (covered by SCI).

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