GPS-Constrained Estimate of Present-Day Slip Rate Along Major Faults of Turkey

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Key words: GNSS/GPS, positioning, crustal deformation, fault slip rates, active faults

SUMMARY

Turkish Active Fault Map published in 1992 by General Directorate of Mineral Research and Exploration provided a template for various research studies. However, a comprehensive revision study was initiated in view of the developments in earth sciences in the last 20 years and it was completed and published in 2012 and 2013 successively. The revised active fault map involves twice as many active faults as the previous active fault map. The revised fault map shows that there are 500 active faults in Turkey. In order to understand the earthquake potential of these faults, it is needed to determine the slip rates. Although many regional and local studies were performed in the past, the slip rates of the active faults in covering whole Turkey have not been determined. In this study, the block modeling, which is the most common method to produce slip rates, is used. GPS velocities required for block modeling is being compiled from the published studies and the raw data provided, then velocity field is combined. To form a homogeneous velocity field, different stochastic models will be used and the optimal velocity field will be achieved. In literature, GPS site velocities, which are computed for different purposes and published, are combined globally and this combined velocity field are used in the analysis of strain accumulation. It is also aimed to develop optimal stochastic models to combine the velocity data. We also perform new GPS observations. Real time, survey mode and published GPS observations is being combined in this study. Furthermore, micro blocks and main fault zones from Active Fault Map Turkey are being determined and homogeneous velocity field is used to infer slip rates of these active faults. Here, we present the result of first two years of the study. This study is being supported by THE SCIENTIFIC AND TECHNOLOGICAL RESEARCH COUNCIL OF TURKEY (TUBITAK)-CAYDAG with grant no. 113Y430.

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1. INTRODUCTION

Turkey Active Fault Map, which is published by General Directorate of Mineral Research and Exploration in 1992, has been used as a base map in various research until today. On the other hand, in the view of developments on geosciences in recent two decades, a revision has been begun and finalized in 2012. The upgraded new active fault map includes twice as many active faults as than the previous one. The new active fault map reveals that there are about 500 faults which can generate earthquakes. It is necessary to have a Seismotectonic Map of Turkey to make a newer Turkey Active Fault Map, for estimation of earthquake risk and making analysis by using aerial photographs, satellite images and geologic field works. For this purpose, it is needed to analyze the active faults by using seismological and geodetic data and determine the fault zones accumulating high strain energy. To predict the potential of earthquake, it is needed to determine the annual slip rates by using geodetic methods. For this purpose, episodic GPS observations are widely used.

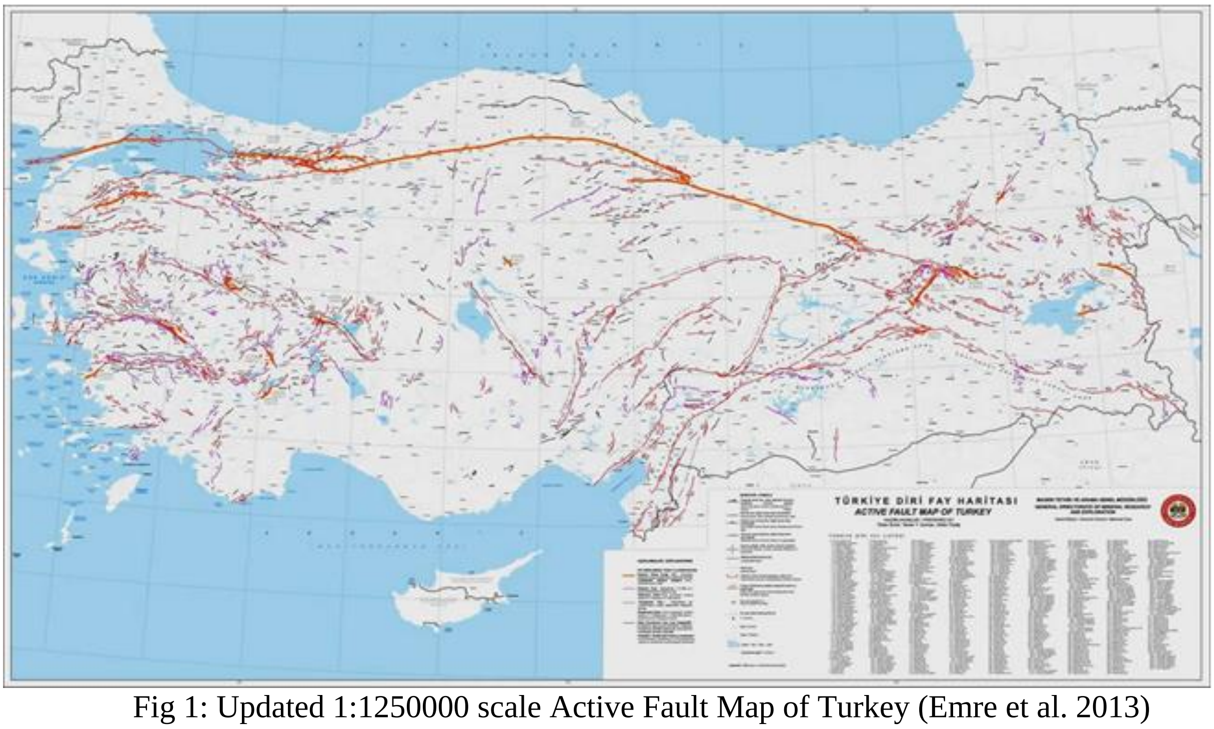

Fig 1: Updated 1:1250000 scale Active Fault Map of Turkey (Emre et al. 2013)

Although many regional and local studies were performed in the past, the slip rates of the active faults in covering whole Turkey have not been determined. To determine the slip rates, which are the main input to produce seismotectonic maps, geodetic measurements are the most common methods. In this project, the block modelling, which is the most common method to produce slip rates, are being studied. GPS station velocities required for block modeling are compiled from the published studies and the raw data are provided, then velocity field are combined. To form a homogeneous velocity field, different stochastic models are used and the optimal velocity field is achieved. In literature, GPS site velocities, which are computed for different purposes, are combined globally and this combined velocity field are used in the analysis of strain accumulation. Global Strain Rate Map Project is an example for this. Even the homogeneous data set in this project covers the whole country, the scope of this project is broader than combined velocity field. Within this project, not only strain rates but also slip rates are determined.

Table 1: The number of the stations which has been collected from the studies including IGS stations

Current Velocity Fields	**Number of Stations**
Aktug and Kılıcoglu (2006)	53
Aktug et al. (2009)	204
Aktug et al. (2013a)	137
Aktug et al. (2013b)	133
Ayhan et al. (2002)	136
Dogru et al. (2014)	75
Erdogan et al. (2008)	16
Ergintav et al. (2014)	112
Mahmoud et al. (2013)	44
Ozener et al. (2010)	55
Ozener et al. (2013)	35
Ozener et al. (2013b)	28
Reilinger et al. (2006)	433
Reilinger et al. (2011)	227
Tatar et al. (2012)	48
Tiryakioglu et al. (2013)	39
CORS-TR stations	146
Yavasoglu et al. (2011)	16

Data sources in the project are as follows:

- Turkey National Permanent GPS Stations and Turkey National Permanent GPS Stations – Active (TUSAGA-Active)
- Turkish National Fundamental GPS Network
- Episodic GPS Observations (GPS campaigns were held to combine velocity fields)
- Published GPS Velocity Data in the Literature

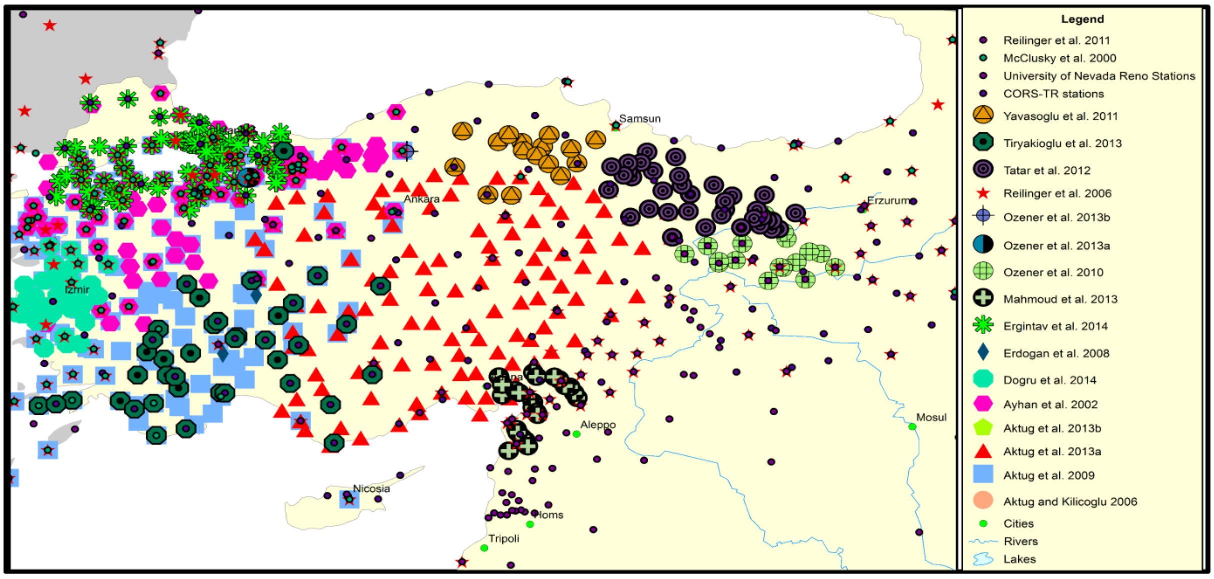

Fig 2: Locations of GNSS sites used in the study

Coordinates of GNSS sites can be converted from one datum to another if the relationship is known. Modern three dimensional datums can be converted each other using similarity transformations. The seven parameter transformation expresses the relationship between the two datums in terms of translation, rotation, and scale factor. Detailed formula can be found in Soler, (1976 and 1998). The 14-parameter transformation is a variation of the seven parameter transformation in which each parameter is assigned both a value at a reference epoch and a rate of change. The 14-parameter transformation is often used to express the relationship between modern high accuracy datums (e.g. ITRF).

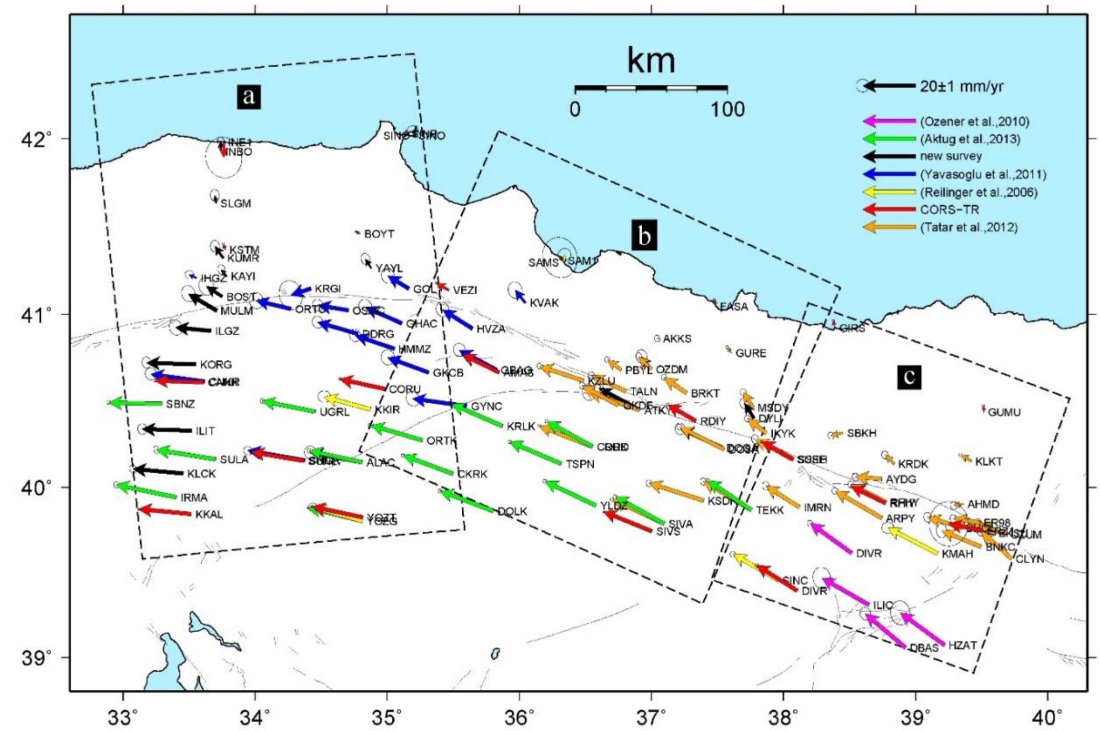

Fig 3: Velocity field of central and eastern part of North Anatolian Fault System

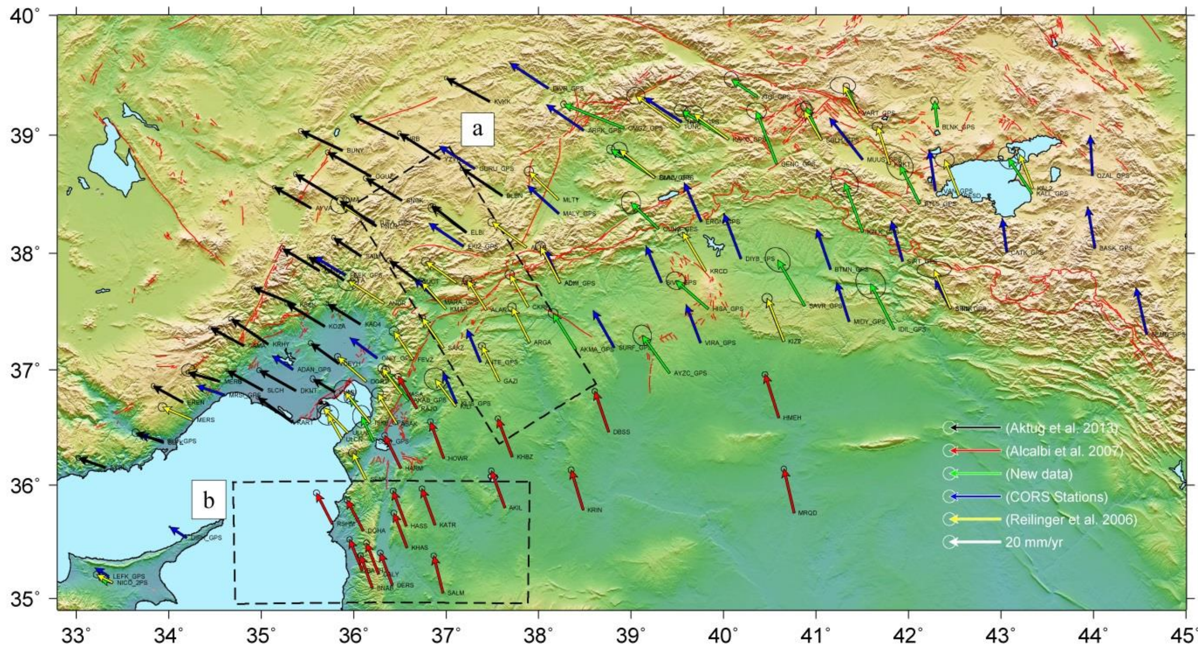

Fig 4: GPS observations employed in this study. The velocity error ellipses are et 95% confidence level.

2. DATA PROCESSING AND CONCLUSIONS

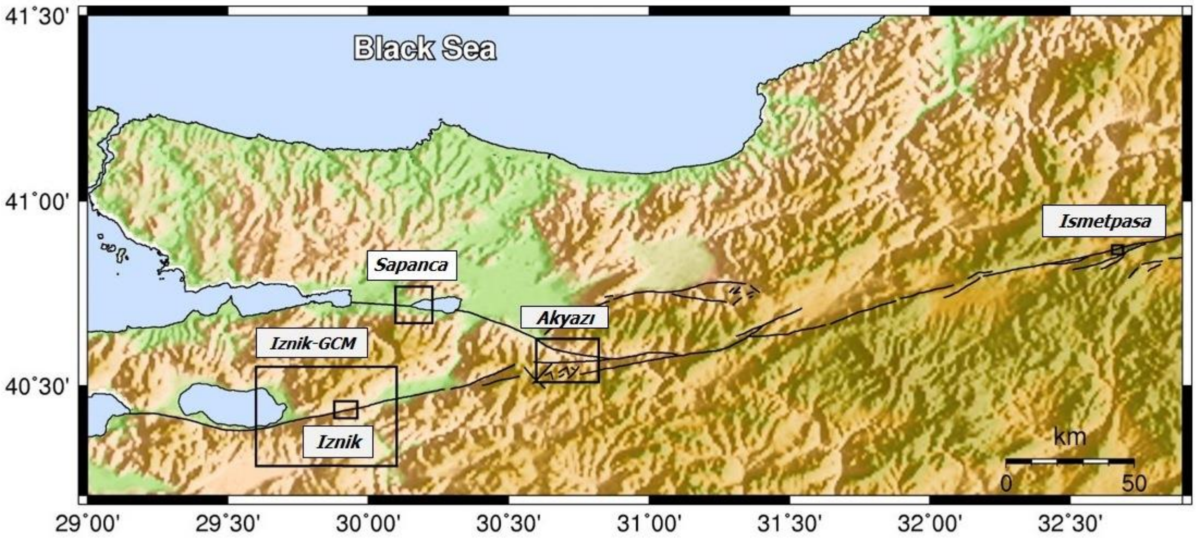

Fig 5: GPS networks located at western part of North Anatolian Fault System

In 2015, a GPS campaign was performed at 35 stations. GPS data processing was carried out using GAMIT (Herring et al., 2010) scientific processing software. Each campaign was processed using the International Terrestrial Reference Frame ITRF2008. 14 of IGS stations were included in the process to calculate Earth Rotation Parameters more precisely and to associate the local network with global network. Precise final orbits by the International GNSS Service (IGS) were 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). The 9-parameter Berne model was used for the effects of radiation and the pressure. Scherneck model was used for the ocean tide loading effects. Zenith Delay unknowns were computed based on the Saastamoinen a priori standard troposphere model with 2-h intervals. Iono-free LC (L3) linear combination of L1 and L2 carrier phases was used. Losely constrained daily solutions obtained from GAMIT were included in the ITRF2008 reference frame.

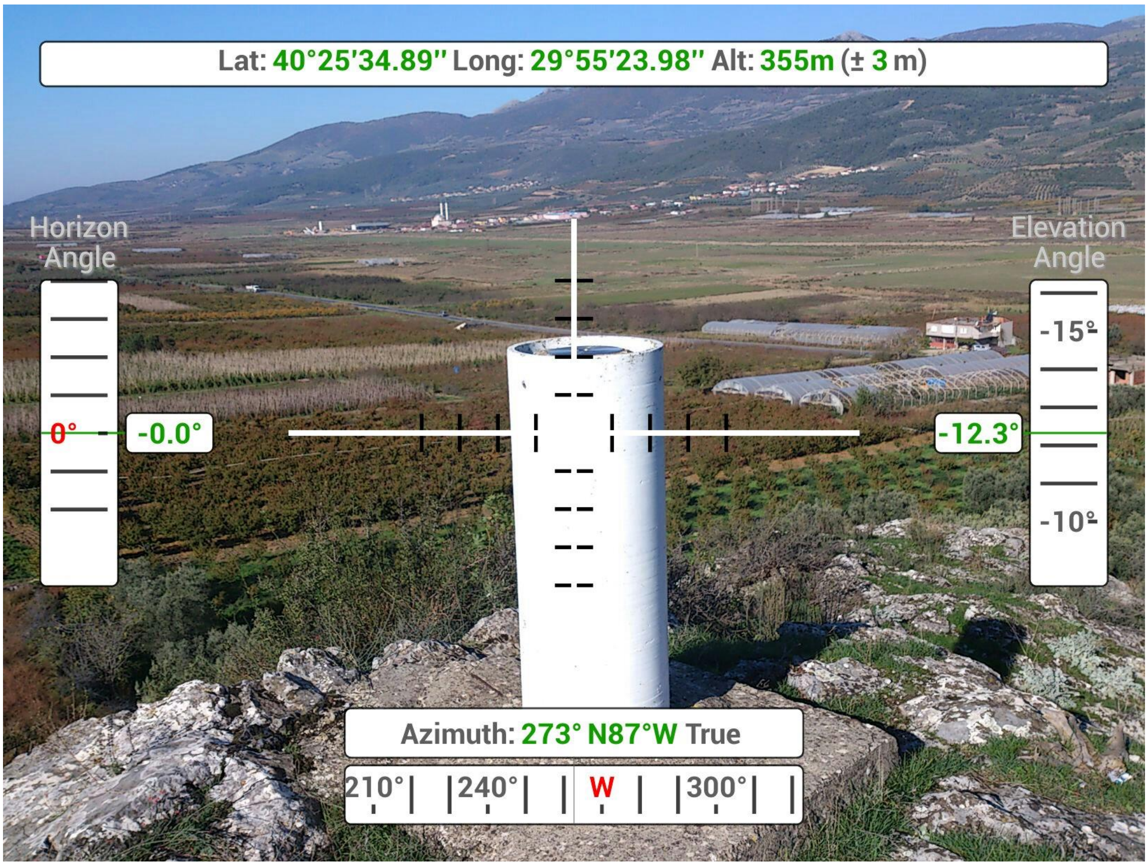

Fig 6: Picture of a pillar used as tie point to combine velocity fields

Transformation from a velocity field to another involves non-static reference frames that account for the effects of crustal movements. In this study, we develop optimal stochastic models to combine the velocity data of the sites. After that homogeneous velocity field will be used to infer slip rates of these active faults. These slip rates will be primary input for Turkey Seismotectonic Map.

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BIOGRAPHICAL NOTES

Prof.Dr. **Haluk OZENER** was born in 1967. He graduated from Istanbul Technical University in 1988 as Geodesy and Photogrammetry Engineer. He obtained M.Sc. and Ph.D. degrees at Bogazici University. He is currently is the Director of Kandilli Observatory and Earthquake Research Institute of Bogazici University and is also chairing the Geodesy Department. His primary field of research is Tectonic Geodesy. He is member and director of over 20 research projects and the author/co-author of over 100 publications related to Active Tectonics of North Anatolian Fault System/East Anatolian Fault System and Aegean Extensional Regime, geodetic monitoring of deformation, establishment of geodetic networks, GPS applications to Earth Science, earthquake hazards, bathymetric surveying, Geoinformation Systems/GIS applications. He also serves as the chair of sub-commission 3.2 (Tectonics and Earthquake Geodesy) of IAG (International Association of Geodesy).

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