DESIGN OF A SYSTEM FOR RAPID ASSESSMENT OF EARTHQUAKE HAZARD IN TURKEY FOR DECISION MAKING

Haluk Ozener

Istanbul Technical University, Department of Geodesy and Photogrammetry Engineering, Surveying Technique Division, Maslak, 34469, Istanbul, Turkey[1]

Asli Dogru

Bogazici University, Kandilli Observatory and Earthquake Research Institute, Geodesy Department, Cengelkoy, 34680, Istanbul, Turkey [2]

Keywords

Earthquake, GPS, Strain, Decision making

Abstract

The Earth is being monitored every day by all kinds of sensors. This leads an overflow in all of the branches of science today, especially in Earth sciences. Data storage and data processing are the problems to be solved by current technologies, as well as accessing to these large size data and analyzing them. Rapid access to data provided by GPS is increasingly important for deformation monitoring and rapid hazard assessments. Today, reliable and fast collection and distribution of data is a challenge and advances in the information technologies have made it easier to provide the needed data. This paper describes a system which will be able to generate seismic hazard maps by strain using continuous GPS data. Strain rates are a key factor in seismic hazard analyses. Turkey, as an earthquake country, has a long history of earthquake disasters and Earth scientists study for understanding Earth's crust structure and seismic hazards. Nevertheless, constructing models, accessing related data and analyze them are extremely slow. But the combination of information technologies with continuous GPS data can be a solution to overcome this problem. This system would have a potential to answer important questions to assess seismic hazard, for example: How much stretching, squashing and shearing is taking place in different parts of Turkey? How does velocity change from place to place? Seismic hazard estimation is the most effective way to reduce earthquake losses. It is clear that relying on data and on-line services will support the preparation of strategies for disaster management and planning to cope with hazards. To deliver scientific results to decision makers will develop methodologies for managing the risks.

Introduction

Serving as a bridge between Europe and Asia, Turkey is located at the intersection of these two continents. And North Anatolian Fault Zone (NAFZ) of Turkey is situated at a point where two of the Earth's tectonic plates meet, Eurasia and Anatolian plates. The NAFZ runs along the northern part of Turkey connecting the East Anatolian compressional regime to the Aegean extensional regime with about 1200 km in length (Figure 1).

[1] Tel. + 90 212 2853819 Fax + 90 212 2856587 Email: haluk.ozener@itu.edu.tr
[2] Tel. + 90 216 5163377 Fax + 90 216 3320241 Email: asli.dogru@boun.edu.tr

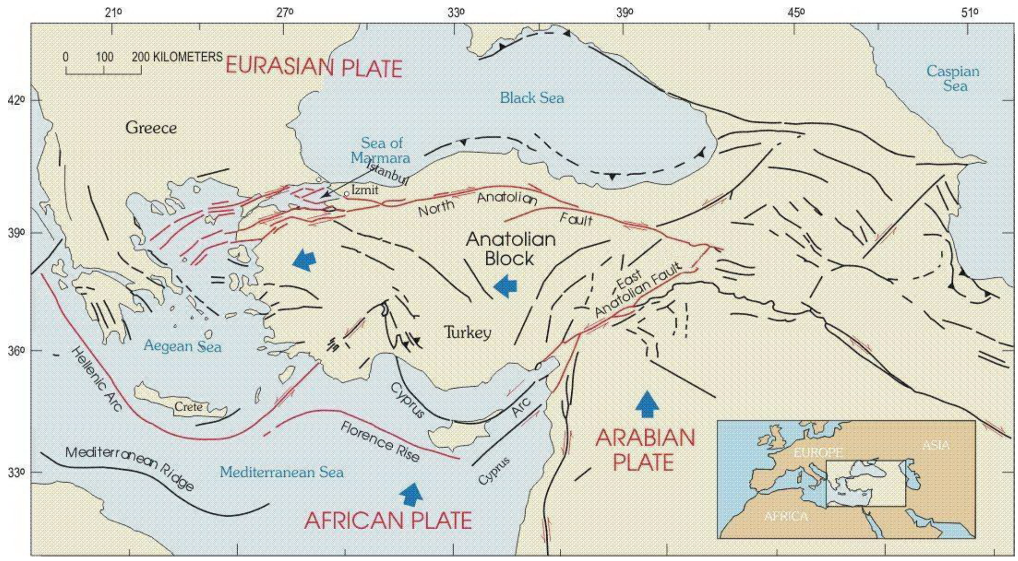

Figure 1. Tectonic setting of Turkey (Modified from Barka, 1992).

As a result of this tectonic setting, Turkey has a long history of natural hazards and disasters (Figure 2). 96 percent of the land containing 66 percent of the active faults is affected by earthquake hazards and 98 percent of the population lives in these regions. Marmara region includes 11 large cities with populations of more than one million and 75 percent of the country's largest industrial complexes. Scientific understanding of earthquakes is vital for assessing earthquake hazards. And earthquake hazard estimation is the most effective way for Earth scientists to reduce earthquake losses. So the investigation of crustal strain which means long-term prediction of earthquake hazards can provides strategies for effective earthquake risk reduction.

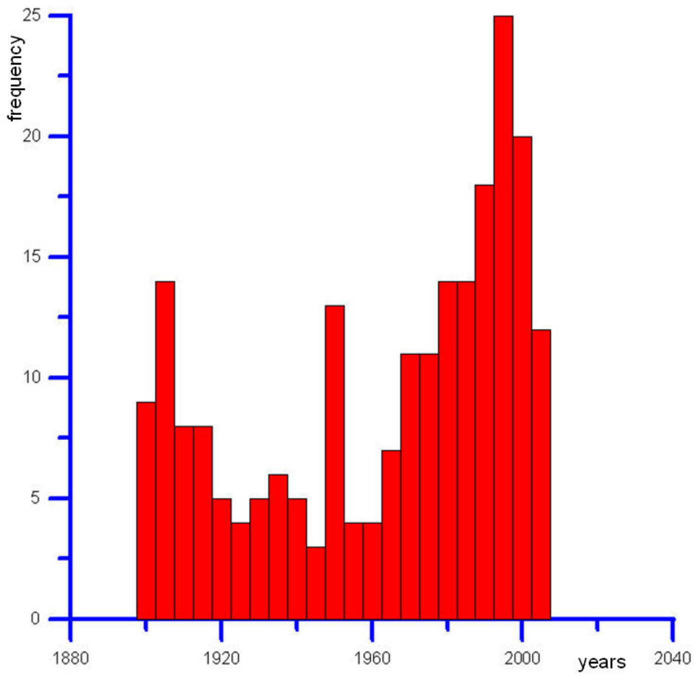

Figure 2. Frequency of earthquakes in Turkey

This study describes a system approach to solve the problem related to converting data to the information in earthquake research as quickly and effectively as possible. The rapid analysis of the huge amount of raw data gathered by the sensors that are increasing in number especially in the scientific area of Space Geodesy has gaining crucial importance for Earth scientists. In case, the exigency of rapid analysis, interpretation and presentation is secured then the end results will ensure having high temporal resolution leads to accurate interpretations of the earthquake phenomena. So it leads to mitigate the earthquake damage.

Data and Method

The studies of monitoring horizontal crustal movements on the western part of NAFZ have started by Geodesy Department of Kandilli Observatory and Earthquake Research Institute of Bogazici University in 1990. The region of the country exposes highly seismic hazard risk because of the region's tectonics. Three geodetic control networks were established in eastern Marmara (Iznik, Sapanca, and Akyazi regions) in order to monitor crustal displacements. The first period observations had been performed by means of terrestrial methods and these observations had been repeated annually until 1993 by theodolite and electromagnetic distance-meter instruments. Since 1994 GPS measurements have been carried out at the temporary and permanent geodetic control points in the area and the crustal movements have been monitored. In order to investigate tectonic deformation in Marmara region, GPS campaigns have been performed in every year at distributed points that spread over the region by another collaborative project among BU, MIT, TUBITAK, GCM, and ITU. This network includes selected two points from each network mentioned above. Further information about this network can be reached at Ergintav et al. (2002).

Turkey has a GPS network named Marmara Continuous GPS Network (MAGNET) (Ergintav et al., 2002) collaborated by TUBITAK-MRC (Turkish Scientific and Technological Research Council – Marmara Research Center), MIT (Massachusetts Institute of Technology), ITU (Istanbul Technical University), GCM (General Command of Mapping) and Geodesy Department of KOERI (Kandilli Observatory and Earthquake Research Institute) of Bogazici University. The network currently has 21 permanent GPS stations operated by TUBITAK-MRC. GPS sensors are observing 24 hours at these points for deformation monitoring. One of these points called KANT is located at Kandilli Campus of Bogazici University. KANT has been collecting data since July 6, 1999. GPS data is recorded for 24 hours a day with logging interval is 30 seconds. In this study, the crustal strain over the crust of the Marmara region in Turkey has been investigated for seismic hazard assessment using GPS velocity data obtained from these geodetic networks. In order to expand the coverage, MAGNET stations are used in the process (Figure 3).

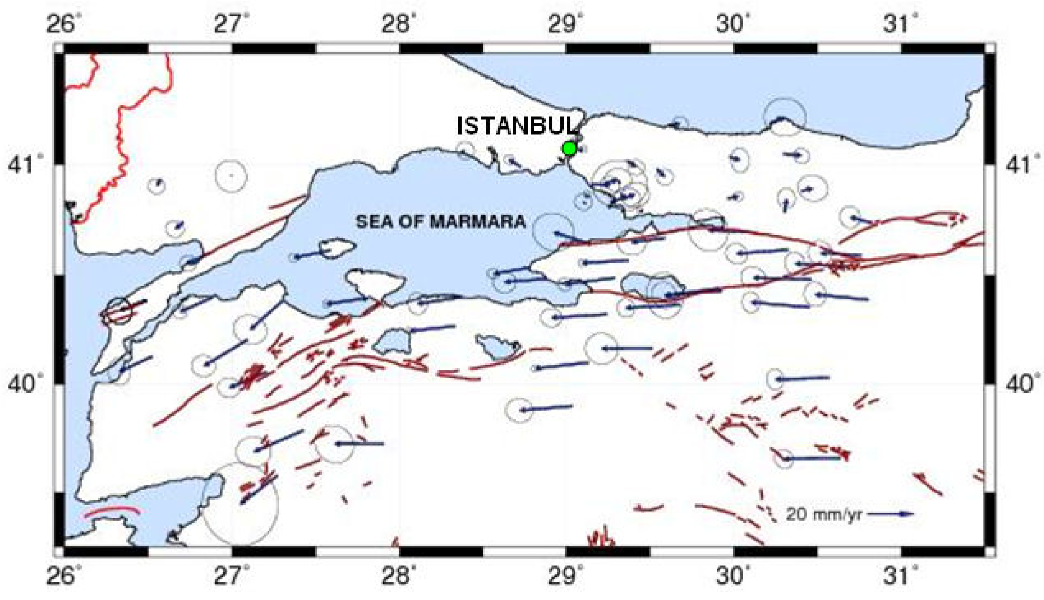

Figure 3. Horizontal velocity field of the Marmara region in a Eurasia-fixed reference frame (ellipses are at 95% confidence level and the data covers 2003–2005 time intervals).

After the production of GPS velocities, these data is processed for the strain assessment using the system. With the use of the data gathered by the campaign-based stations, the system computerizes the strain rates and velocity field maps which are to be the input information for the hazard estimation. The temporal resolutions of data provided by continuous GPS stations and campaign-based GPS stations are not the same. Different data collection strategy requires separate computation methods. A continuous strain map is estimated from permanent stations, whereas semi-annually or annually strain map is produced for the campaign-based data depending on data collection interval. The method which was developed by Haines and Holt (1993) in order to estimate a strain rate and velocity model is followed to carry out this study. A comprehensive overview of the methodology can be found in Haines et al. (1998).

Results and Discussion

The results show that the east-west shortening and north-south extension of north-western Turkey are closely related to right-lateral faulting (Figure 4). The velocity value by the evaluation of three GPS campaigns is reaching approximately 25 mm/yr. And the minimum velocity is 0.42 mm/yr. This has an agreement with the region tectonics.

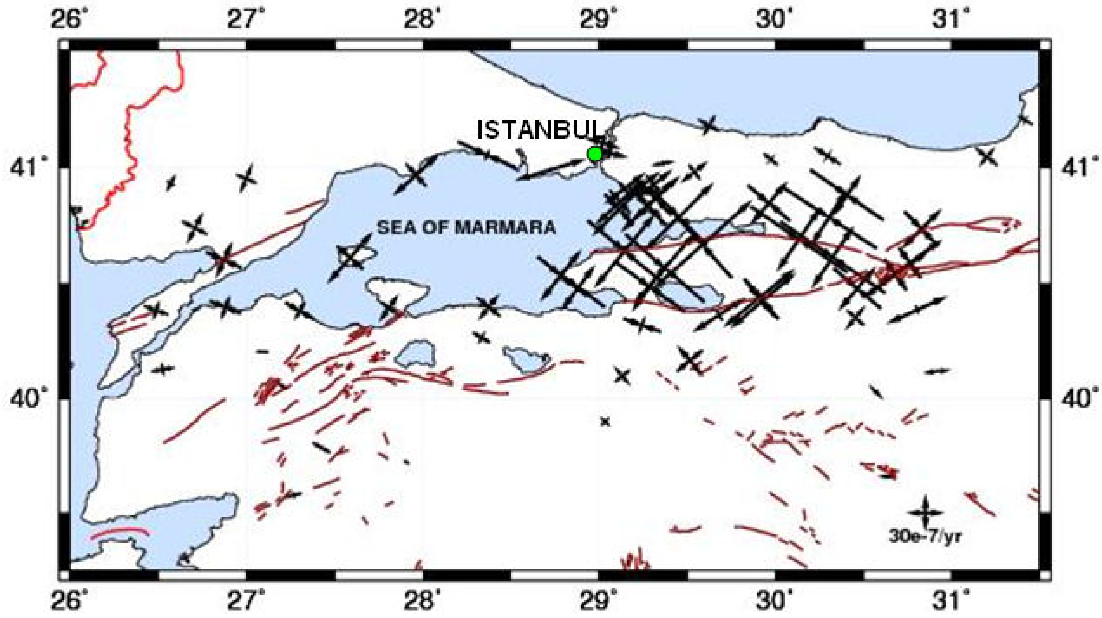

Figure 4. Principal strain rates (ε_1 and ε_2) for Marmara region from the inversion of GPS velocities. Inside arrows indicate compression directions and outside arrows indicate extension directions (Ozener et al., 2008).

Assessment of strain accumulation throughout Turkey or in specifically targeted areas can be obtained by using geodetic data from GPS receivers. Determination of strain accumulation can identify areas of high seismic hazard in Turkey. In order to improve the understanding of the relationship between strain accumulation and seismic hazard assessment, integration of geodetically derived data from regional and national networks with the existing seismic catalog is needed.

From the results of this study, we can reach to a conclusion that the losses of life and property due to earthquake activity in Turkey seems to be unavoidable. However, the amount can be reduced. The geodetic deformation field is dominated by right-lateral strike-slip deformation along NAFZ. And western NAFZ where has large urban and industrial centers has the potential for large earthquakes. The eastern NAFZ is also capable of generating major earthquakes in every 3-4 years. To conclude, there is an exigency for a system which will have the ability to computerize earthquake hazard maps as quickly as possible to provide information for making decisions on risk assessments and emergency managements.

Results of crustal strain investigation (long-term prediction) can provide strategies for effective earthquake risk reduction. This surely requires taking advantages of the recent advancements in Earth sciences, computers, and communication technologies. Long-term prediction of earthquakes is very important for development of building design, strengthening existing structures, and land-use planning. Relying on data and on-line services will support the preparation of strategies for disaster management and planning to cope with natural multi-hazard events. This contributes to the reduction of the resulting economic losses and to the development of a more secure country. In order to reach these results in disaster cycle, building a bridge between scientists and decision makers and including "end-users" from the land use planning are necessary as well as scientific research (Figure 5). This system can maximise the interaction between scientists and land-use planners, which will lead to improvements in risk management. It will provide better maps of the hazard, which will inform decision-makers attempting to develop strategies for mitigating risk.

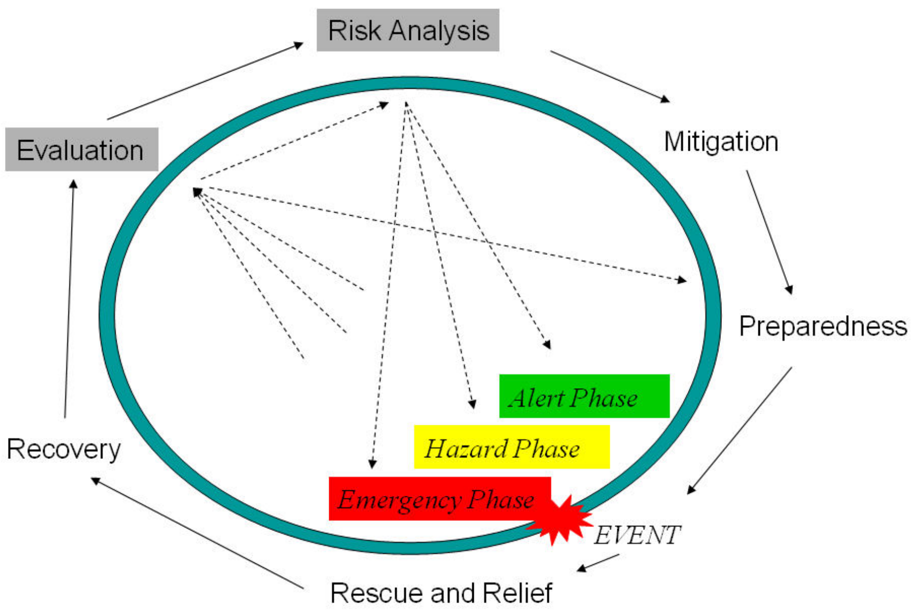

Figure 5. Disaster cycle

Separate from strain analysis, other applications can be and must be integrated into this study such as Coulomb stress, tsunami modelling, or landslides since they are inter-related. Earthquakes can trigger landslides and tsunamis, and landslides can trigger tsunamis. Disaster prevention and loss mitigation has three major steps. Understanding geophysical processes by visualising data and applying models is the first step in tackling "multi-risk". The second step is considering the relationships between hazards. Usually considered separately in risk analyses, these hazards must be analysed together. This requires bringing together the data associated with each hazard into a single GIS. This will provide "multi-hazard" maps which is the second step in tackling "multi-risk". The third step in assessing risk is to evaluate the vulnerability to a given hazard. These three steps can identify areas that are too hazardous. To deliver scientific results to decision makers will develop methodologies for managing the risk.

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Author Biography

Associate Professor Haluk Ozener was born in 1967. He received the B.S. degree (1988) in Geodesy and Photogrammetry Engineering from Istanbul Technical University, and the M.Sc. (1992) and Ph.D. (2000) degrees in Geodesy from the University of Bogazici. He is currently working in the Surveying Technique Division of the Department of Geodesy and Photogrammetry Engineering of ITU in Turkey.

Dr. Asli Dogru was born in 1976. She received the B.S. degree (1999), and the M.Sc. (2002) in Geodesy and Photogrammetry Engineering from Istanbul Technical University and Ph.D. (2008) degree in Geomatic Engineering from the same university. She is currently working in the Geodesy Department of Kandilli Observatory and Earthquake Research Institute, University of Bogazici in Turkey.