Multidisciplinary GIS for Geodynamic Research

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Key words: Geoinformation/GI, GIM, GIS

SUMMARY

Geographical Information Systems are multifunctional systems where all type of geographical data are efficiently used, stored, updated, analyzed and the final products are presented as maps. The main purpose of creating and using information systems is to develop geodatabase system with all concerned data in which stored, analyzed with the users' demand and request. From the beginning of 90's, geodetic surveys with geodynamic purposes have been performed in regions of high seismicity by Geodesy Department of Bogazici University, Kandilli Observatory and Earthquake Research Institute. For the best visualization and performance, all products of these geodynamic studies are organized and stored in a Geographical Information System with relative metadata. Designing a geodetic database involving inhomogeneous and time-dependent data from different measuring techniques and disciplines is challenging. This study is a good example for addressing the importance of GIS in geodynamic studies. The database design and some possible analysis examples will be presented in this paper.

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1. INTRODUCTION

Geographical Information Systems (GIS) are multifunctional systems where all type of geographical data are efficiently used, stored, updated, analyzed and the final products are presented as maps. GIS is a computer-based system which is composed of five components. These components are hardware, software, system, data and people. Moreover, these components must be well integrated in order to use GIS efficiently. In many countries, GIS are essential tools in education, government, non-profit organizations and business case studies. GIS plays important role to develop data-driven solutions that help many organizations visualize, analyze, interpret and present data. The field of earth science is one of them.Thousands of earthquakes have been recorded worldwide and scientists try to learn from these events to construct analytical and numerical models and predict the future distribution of earthquakes in space and time. This requires a careful understanding of historical earthquake events and a combination with field data. Visualization of spatial information plays a prominent role in this process and GIS can be used as a powerful tool to visualize earthquake data. GIS is increasingly used to visualize elements associated with seismicity. It enables an efficient interactive exploration and spatial analysis of attributed geographical data. GIS provides a convenient platform for data collection, organization, and research with multidisciplinary datasets. As more groups adopt GIS applications, the earth sciences community will be in a position to prepare a unified global database for more efficient, productive, and rewarding research (Seber, 1997).

Its immense capacity makes GIS process all type of complex geo-location data. High technology brings about GIS usage not only in technically development but also using and merging with different disciplines data (Ulugtekin and Bildirici, 1997). GIS data come from different sources and in a variety of formats. For combining multiple files on the same display, data must be in the same spatial reference system. GIS is an ideal technology in order to use with multidisciplinary topics and issues (Figure 1).

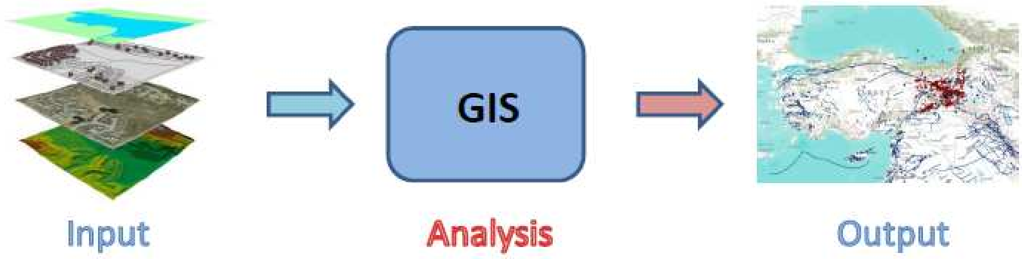

Figure 1: GIS input, analysis and output

2. STUDY AREA

Turkey is situated in tectonically active region that experiences frequent destructive earthquakes. 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 (Garagon Dogru, Toz., 2008). Earthquakes are associated with extreme, widespread disruption that occurs suddenly, without reliable short-term prediction. After 17 August 1999 and 12 November 1999 earthquakes in Marmara region, earthquake research and studies have been increased dramatically in our country. Both of them occurred on segments of the well-known North Anatolian Fault Zone (NAFZ) (Figure 2), the most important active fault zone in Turkey. These earthquakes were brought about thousands of people death and millions dollar economic losses.

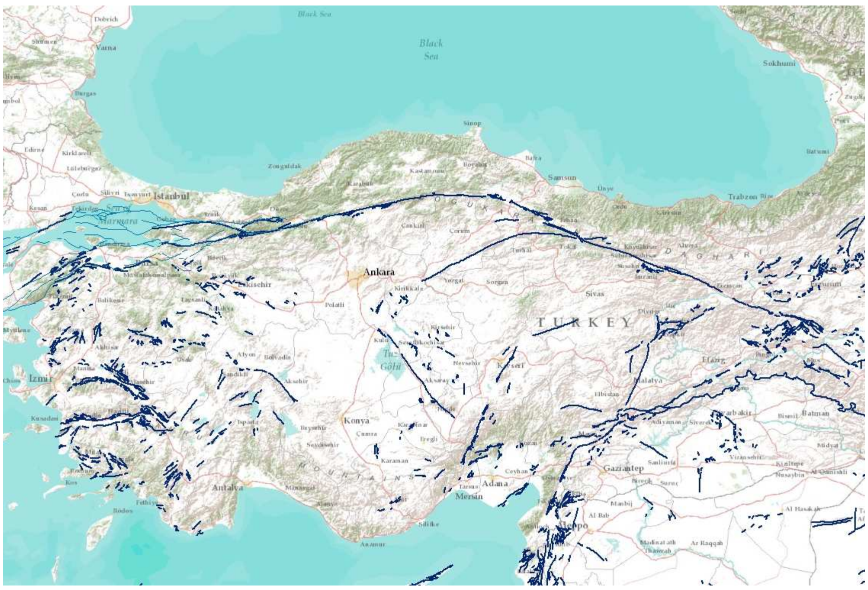

Figure 2: The North Anatolian Fault Zone and active faults in Turkey

GIS and its techniques have been applied extensively in earth science studies such as earthquake disaster prediction, decision making, disaster region layout and so on for many years. In order to understand the earthquake mechanism, processing and analysing all data which are obtained from different disciplines such as geodesy, geophysics and geology (Garagon Dogru, Toz., 2007). Thus merging different disciplines data and multiple sources in GIS is the significant progress for the earthquake research.

From the beginning of 90's, geodetic surveys with geodynamic purposes have been performed in regions of high seismicity of Turkey by Geodesy Department of Bogazici University, Kandilli Observatory and Earthquake Research Institute (Sabuncu A. et al., 2011). For the best visualization and performance, all products of these geodynamic studies are organized and stored in a Geographical Information System with relative metadata. Figure 3 displays the four GPS networks, NAFZ and the submarine fault data based on Armijo in the Marmara Sea.

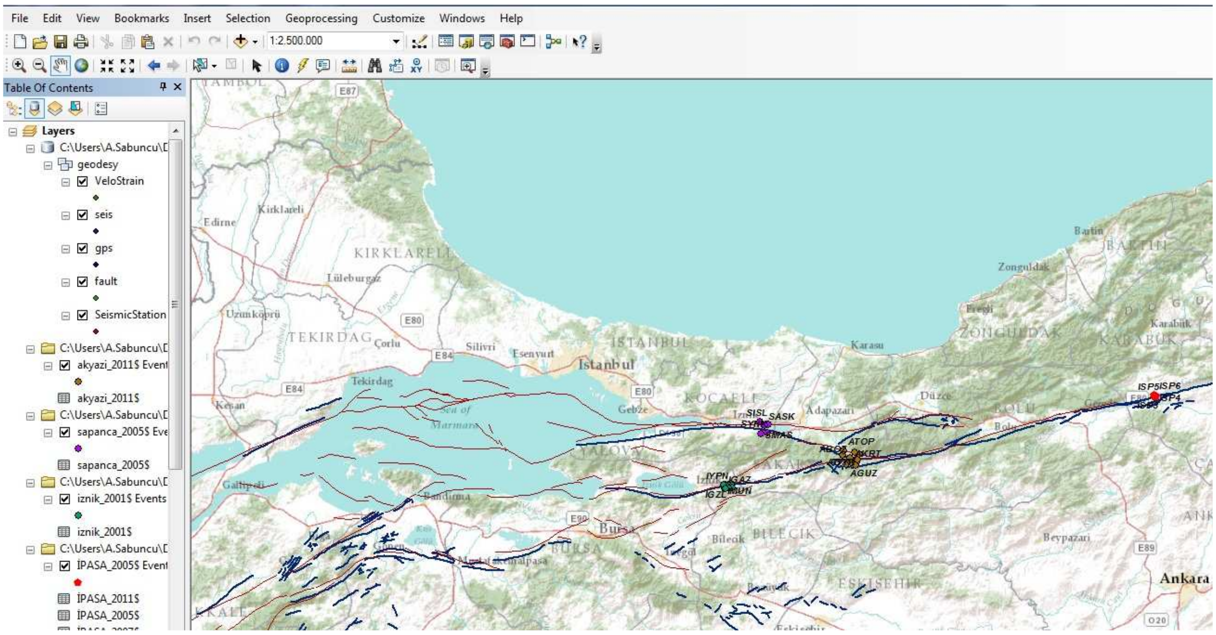

Figure 3: Submarine fault in Marmara sea, NAFZ, four GPS networks

3. GEODATABASE SYSTEM AND APPLICATIONS

To facilitate the management of a large amount of collected data a GIS structure has been developed. The database is essential for using modern GIS. Without geodatabase, mapping would be largely a drawing process, with little analysis. GIS with powerful database is performing valuable data visualization presentation. There are numerous reasons in order to design and install the comprehensive geodatabase system for the Geodesy department studies. The expected benefits of this system are;

- Designing sites locations and network geometry of geodynamic GPS networksfor the field works,
- Forming a base frame for future studies,
- Integrating multidisciplinary data,
- Temporal and spatial analysing with long term data. For instance, using NEMC earthquake data, querying different attribute data and making analysis of earthquakes in terms of time and location. Figure 4 shows the histogram of the earthquakes occured in the study area.

Additionally, the intended geodatabase provides the user several queries. These queries allow the user to filter the data in a map layer based upon criteria are specified.

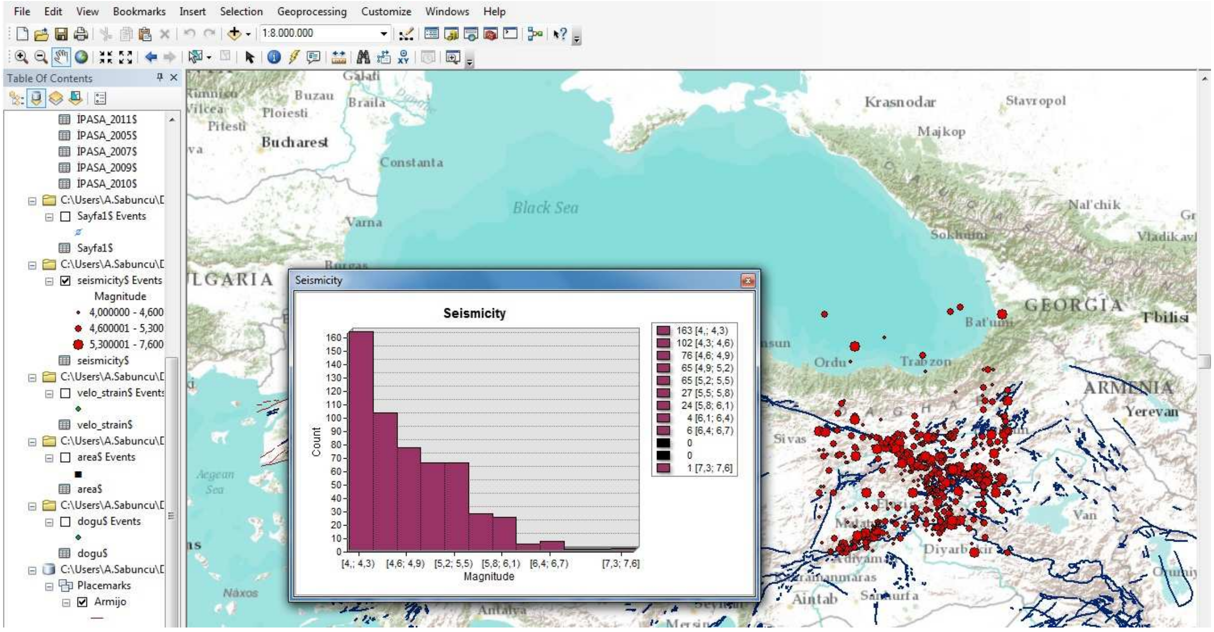

Figure 4: The histogram of the earthquakes in the eastern Anatolia (M ≥ 4) 1900-2008

3.1 Data Analyzing and GIS Applications

The concept of database system is the native data structure and the primary data format used for editing and data management. Additionally, geodatabase system is a warehouse in which is stored by set of different type of data for their usage aims mentally and physically. Geodatabase offer numerous benefits to projects and organizations. These benefits are;

- Convenience
- Flexibility
- Decrease redundancy and error
- Standardization

The structural elements of a geodatabase, are some of the elements used to develop a rich GIS, such as

- Attribute data
- Geographic features
- Satellite and aerial images (raster data)
- CAD data
- Surface modeling or 3D data
- Utility and transportation systems
- GPS coordinates
- Survey measurements

The major aim is to generate and use the database system is to form a geodata base with existing data. The main goal of this multidisciplinary GIS project is to combine all type of data in a GIS environment. The most outstanding issue in this context is integration of data from different disciplines in the same structure. In order to avoid the struggles of this issue is to make a standardization of the data.

The existing and new data sets are stored and merged in the same well-condition warehouse, is the major purpose of this study. For this purpose, Arc Catalog software is used. Arc Catalog is the interface application due to the manipulating vector and raster data by ESRI. The following steps are performed by Arc Catalog.

- Form Arc GIS data format
- Visulization data and data management
- Form geodatabase field and determine attribute

3.2 Data Type and Acquisition in the Study Area

In this project, the study area covers the high seismicity regions of Turkey. These regions are Aegean, North Anatolian Fault Zone and East Anatolian Fault Zone. Raster and vector geographic data types are used in this study. Vector data is spatial data represented as points, lines and polygons meanwhile raster data is all based data such as aerial imagery and digital elevation model. These data come from different sources and in a variety formats. All data should be in the same formats and spatial reference system due to combine the multiple files. Table 1 shows the data type and data set in the study. In this study, most of the GIS data was collected from the field study (Figure 5). Turkey map with SRTM data displays in Figure 6.

Data Set	Data Type	Data Source
Boundaries, rivers, lakes, roads	Vector	GTOPO30
Earthquakes (Historical & instrumental)	Vector	KOERI-NEMC
Fault Line	Vector	GDMRE (Saroglu et al 1992)
GPS & Levelling Stations	Vector	KOERI-Geodesy Department
Displacements by GPS	Vector	KOERI-Geodesy Department
Stations Photo	Raster	KOERI-Geodesy Department
DEM (SRTM 90 m resolution)	Raster	NASA -

Table 1: Data types and datasets

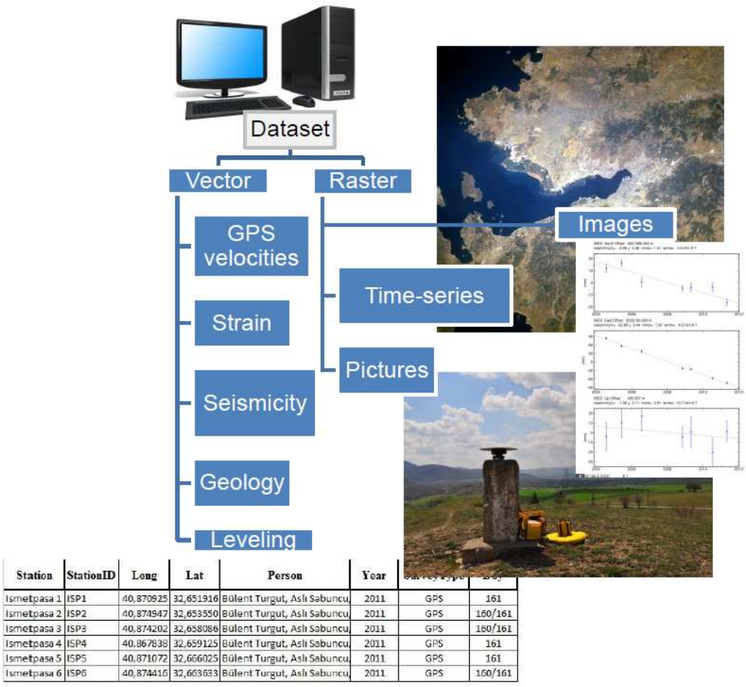

Figure 5: Type of the datasets (Ozener et al., 2011)

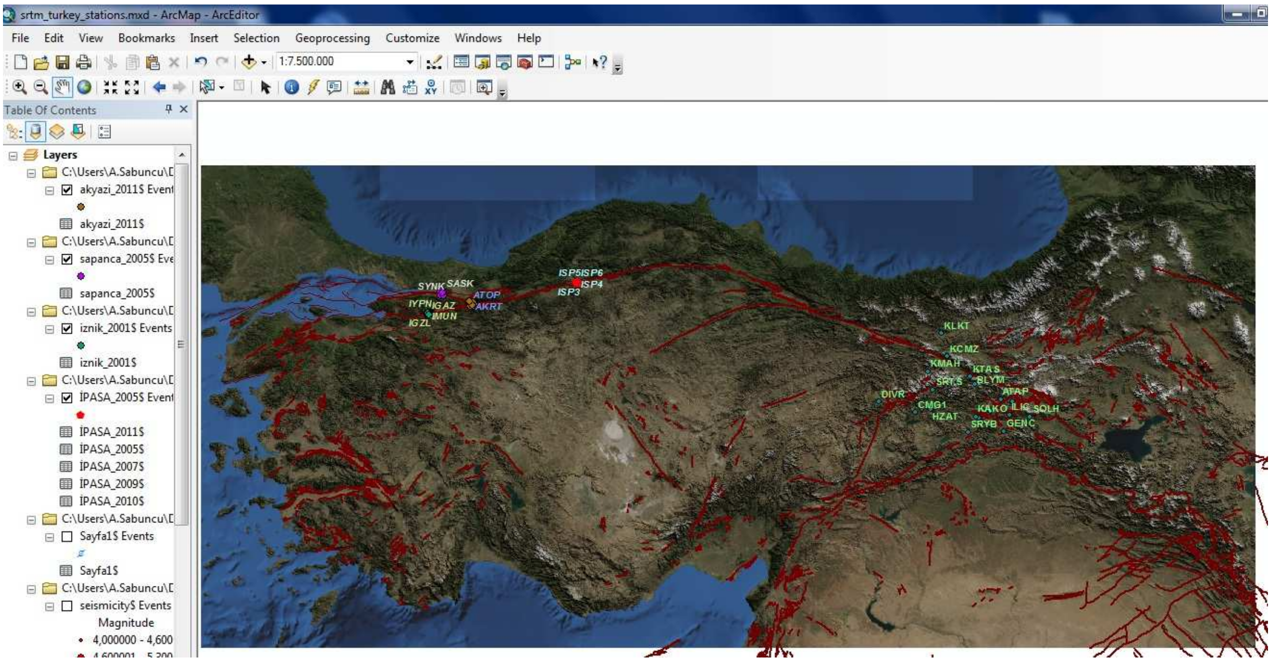

Figure 6: DEM of Turkey derived from 90 m resolution SRTM data

A geodatabase was developed as an initial step in the development of a comprehensive data system for Kandilli Observatory and Earthquake Research Institute Geodesy Department. GPS campaigns were carried out along the North Anatolian Fault Zone. During GPS campaigns, different types of data set were obtained. These data sets were formed as table in Microsoft Excel initially. Table 2 displays the significant earthquakes of the study area. Using Arc Scene interface, focal mechanism solution can be represented in Figure 7.

No	Location	Latitude N (deg)	Longitude E (deg)	Magnitude Mw	Depth (km)	Date d/m/y	Time h/m/s
1	Askale (Erzurum)	40.05	40.70	5.6	16.4	25.03 2004	19:30:54.6
2	Askale (Erzurum)	40.07	40.74	5.6	18.9	28.03.2004	03:51:16.3
3	Sivrice (Elazig)	38.50	39.09	5.6	14.3	11.08.2004	15:48:30.1
4	Karliova (Bingol)	39.42	40.79	5.6	16.1	12.03.2005	07:36:15.0
5	Karliova (Bingol)	39.44	40.77	5.8	12.0	14.03.2005	01:56:01.6
6	Karliova (Bingol)	39.42	40.71	5.6	15.1	23.03.2005	21:44:56.4
7	Karliova (Bingol)	39.44	40.87	5.6	15.4	06.06.2005	07:41:33.9
8	Karliova (Bingol)	39.48	40.75	5.4	20.3	10.12.2005	00:09:54.5
9	Karliova (Bingol)	39.49	40.78	5.0	15.0	02.07.2006	19:39:44.2

Table 2: Focal mechanism solutions of earthquakes occurred during East Anatolia GPS project

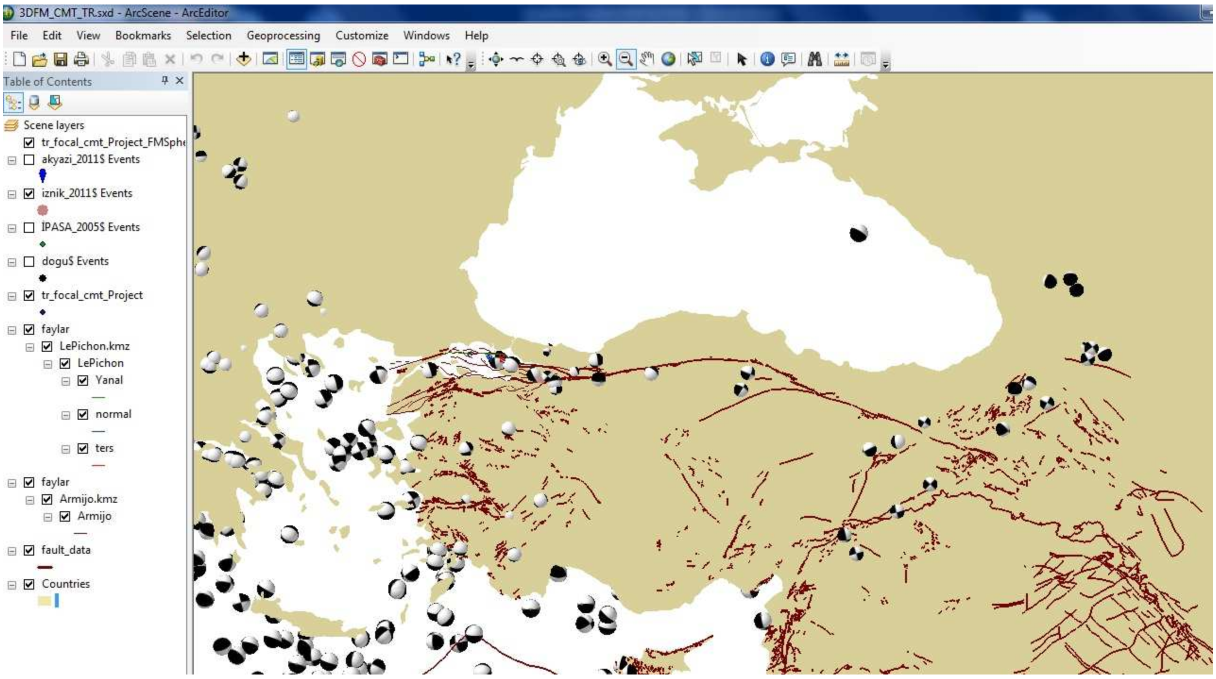

Figure 7: The focal mechanism solutions for the major earthquakes in Turkey (30 years)

For the GPS stations layer, further field attributes were added. These attributes are GPS station name, GPS Station ID, latitute, longitude, surveyors, survey type, year and day of year information (Figure 8) (Sabuncu A. et al., 2011).

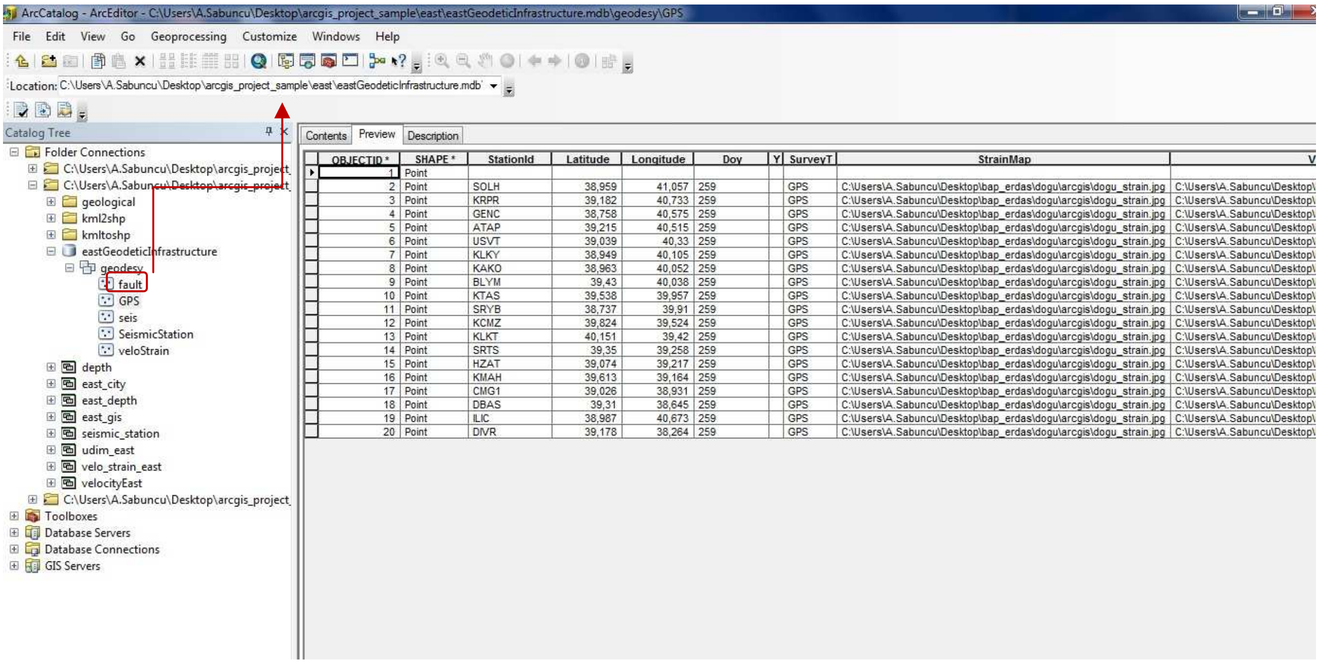

Figure 8: The geodatabase for the eastern Anatolia

All type of data were added in Arc Catalog then Arc Map was used for the visualization. Velocity and strain maps were calculated from GPS data were added into database as new layers. After adding all different layers in Arc Map, identify tool can be used in order to inform the users. Figure 9 shows the map display in the GIS environment.

Arc Catalog is a module of Arc GIS desktop that allows us to manage GIS and related datasets. In other words, Arc Catalog helps us manage and organize all the geographic information from simple tables to large datasets to complex maps. Arc Catalog provides numerous tools such as

– viewing available GIS data sets in a catalog tree
– looking what the data looks like (preview tab)
– reading available documents which comes with the data.
– viewing and updating metadata
– managing databases of all kinds

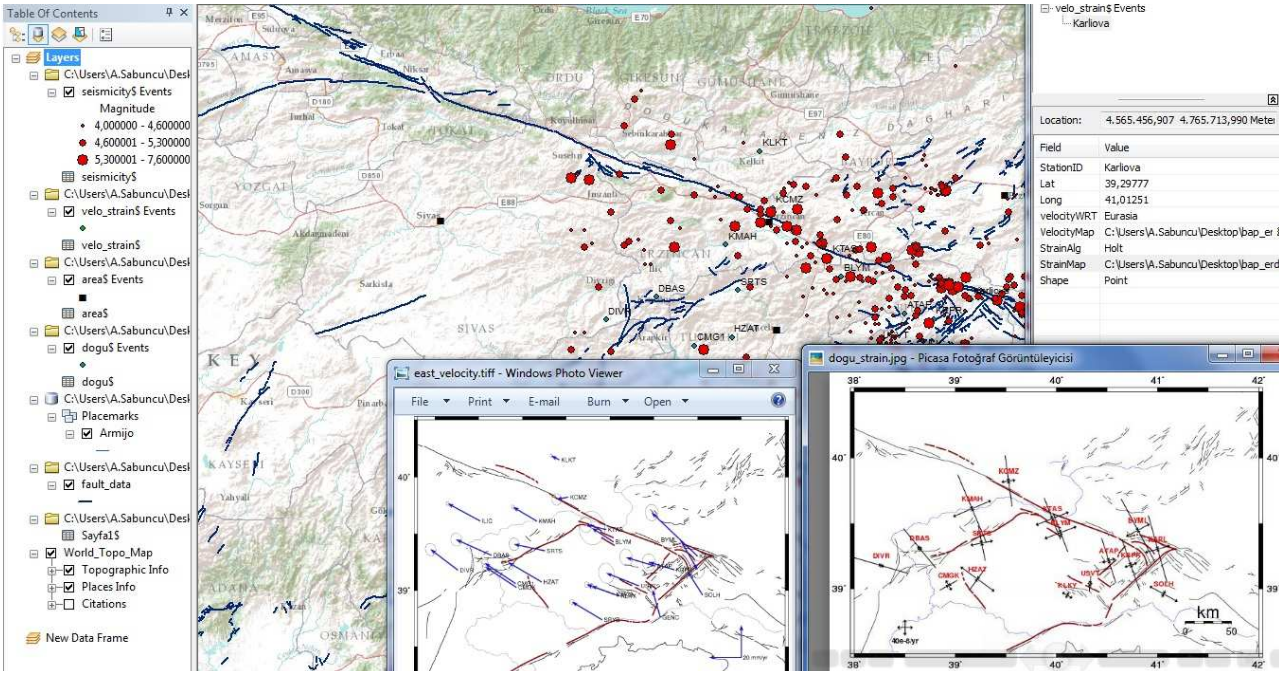

Figure 9: The map display for the Eastern Anatolia study area.

All layers can be seen in Figure 10.

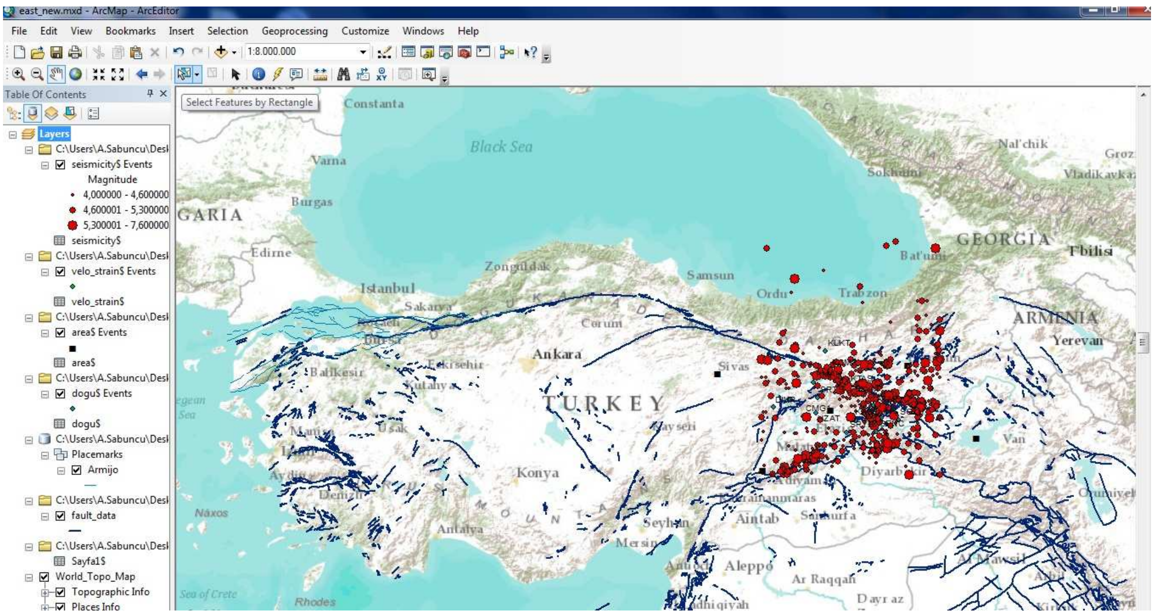

Figure 10: GIS overlapping layers

4. CONCLUSION, DISCUSSION AND FUTURE WORKS

- The use of the information technologies and GIS in the geodynamic studies are not optional as it increases the efficiency. GIS should be used to combine data different disciplines and multiple sources for a long time span.

- This study has been inspired from the necessity of such a project needed to be initiated with the collaboration of the Earth science institutions to create a system for integrating, modernizing, and expanding earthquake related studies. Distribution of accurate information and analysis facilities related to earthquakes is vital for scientists as well as for decision makers. Data management in many fields of Earth sciences in Turkey is still in a period of transition. There is an overflow in all of the branches of science today, especially in Earth sciences. The most important thing here is the harmonisation of data. Because the harmonisation of data in GIS layers is one step on the road from "discovery to inter-operability". And the best way to harmonise data sets is to share them and to work on them together. Scientists have to make harmonised and quality geographic information available for the purpose of formulation, implementation, monitoring and evaluation of community policy-making. Harmonising methodology is also vital for assessing vulnerability. As such IT studies increase in the field of Earth science, better methodologies will be continued to be produced.

In this study, a GIS was designed and implemented to be used for the tectonic geodesy studies in our department. New data will be continued to add into the system. In addition to, a web application is going to be developed which provides to process GPS data and visualize them.

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BIOGRAPHICAL NOTES

Assist. Prof. Dr. **Asli DOGRU** was born in 1976. She received the B.S. degree (1999), and the M.Sc. (2002) in Geodesy and Photogrammetry Engineering both from Istanbul Technical University and Ph.D. (2008) degree in Geomatic Engineering from the same university. She is currently working at the Geodesy Department of Kandilli Observatory and Earthquake Research Institute, University of Bogazici. She has ten years experience in earthquake studies on North Anatolian Fault Zone and carried out more than 15 scientific research as a researcher. Her main interests are application of information technologies to the solution of problems in geoscience, geodesy, InSAR applications in geoscience research, GPS and crustal deformation using precise geodetic techniques. She has authored or co-authored over 50 scientific papers. She is a member of the Turkish Chamber of Surveying Engineers and the American Geophysical Society.

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. He is currently is the Vice 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 Zone/East Anatolian Fault 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).

Taner SELCUK graduated from Istanbul Technical University in 1991 as Geodesy and Photogrammetry Engineer. He obtained M.Sc. degree from Bogazici University KOERI Geodesy Department. He is currently working in Turkish Land Forces Command.

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