

GEON: Geophysical data add the 3rd dimension in geospatial studies

Aldouri, R.; Keller, G. R.; Gates, A.; Rasillo, J.; Salayandia, L.; Kreinovich, V.; Seeley, J.; Taylor, P.; Holloway, S.

University of Texas at El Paso, GEON and PACES Research Teams

Abstract

A major trend in GIS is the addition of subsurface information to provide a 3-D perspective on data. Geophysical data provide information about subsurface structures and conditions, but require considerable analysis. The 4-D emphasis with the GEON projects has required the development of many sophisticated tools to allow users to utilize geophysical datasets that will be available on the GEON grid. Our group has created tools that will allow users to search new gravity and magnetic databases of the entire U.S. These tools will extract specific records from an Oracle database, and display the points over a map, grid and create a raster image for more analysis and interpretation. New tools are under development to allow a user to upload their own data sets in text format that will use ArcGIS tools to combine these data with other datasets, create map displays, or create a raster image.

Introduction

A key effort to study the Earth in 3-D is the integration of geophysical data into a GIS database and analysis. The geophysical community has a history of sharing data and software so a considerable amount of useful public domain data is available. For example, a community effort to compile a new gravity database for the lower 48 states has recently produced a new version of the database, and it can be freely downloaded via the internet (<http://paces.geo.utep.edu>). This website features the data, documentation, a tutorial, and modeling software. This joint effort by the geophysics groups at the University of Texas at El Paso (UTEP), U. S. Geological Survey (USGS), NGA (National GeoSpatial-Intelligence Agency), and NOAA is an outgrowth of a new geosciences community initiative called Geoinformatics of which the GEON (Geosciences Network, www.geongrid.org) project is one manifestation. The lack of standardization and distribution of available geoscience's data, the lack of documentation about them, the lack of easy-to-use tools to access and map data, and the lack of computer codes to assist in their analysis are major obstacles for scientists, industry, government agencies, and educators alike. Therefore, construction and maintenance of a public domain gravity database and development of the

software tools needed to access, use, and expand it were undertaken in part as a demonstration project of what can be done via cooperative efforts. The primary goal of upgrading the U.S. gravity database and ultimately creating a robust data system is to provide more reliable data that support societal and scientific investigations of national importance. An additional reason is the international intent to compile an enhanced North American gravity database that will be critical in understanding regional geologic features, the tectonic evolution of the continent, and other issues that cross national boundaries.

Gravity Data

Studies of the Earth's gravity field find broad applications in geodesy, geophysics, and geology including determining the detailed shape of the Earth (geodesy), predicting the orbits of satellites and the trajectories of missiles, determining the Earth's mass and moment of inertia, and conducting geophysical mapping and interpretation of lithospheric structure and geodynamic processes. In studies of the upper crust, gravity data can help address a broad range of basic geologic questions, delineate geologic features related to natural hazards (faults, volcanoes, landslides), and aid in the search for natural resources (water, oil, gas, minerals, geothermal energy). Such studies provide elegantly straightforward demonstrations of the applicability of classical physics and digital processing to the solution of a variety of geological problems.

Website Access to Gravity Information

The scientific community working with gravity data has been traditionally small and well networked with a history of open cooperation and sharing of data. However, technical developments such as GPS and the rising recognition of the utility of gravity data are creating a demand for gravity data by non-specialists, as well as an expanding ability to collect new gravity data. Thus, it is highly desirable to establish one consistent database that includes all of the public domain data possible. The database compiled for the U. S. was made accessible from a web portal. In addition, we will provide a mechanism for insuring quality control, capturing corrections when bad data points are identified, and making additions. This latter effort is important because researchers often begin their investigations of a specific area with the unclassified data NGA has regularly released. They then identify areas with sparse coverage in their region of interest and conduct a field campaign to fill in these areas and/or attempt to find data from other sources. However, a lack of infrastructure, standardization, and documentation guidelines (metadata) often results in the new data resulting never appearing in existing national databases. Consequently, groups build overlapping and duplicative datasets in which the identity of truly new data is lost.

Another consideration is the relative ease of accessing various existing gravity databases and of acquiring new gravity data, which can lead newcomers to overlook important details that are not widely known except by specialists. For

example, NGA is the curator of an international network of base stations for gravity surveys that must be used if workers are to add data that can be merged into the existing databases. Because the existence of the network is not widely known, newcomers to the field do not access station information. To address this, information about the base stations is accessible from our website.

An important issue in development of an upgraded national database is ensuring the integrity of the data. A system is being devised to insure integrity. The first step after compiling all gravity data points is focused on advanced techniques of identifying and eliminating erroneous data points and duplicates in a gravity database, because their inclusion can degrade the quality of the resulting data processing and analysis. We believe that this effort is particularly important because the same problems will emerge in other geospatial databases in which measurement results made by different groups are combined.

The ultimate goal of this project is a fully integrated web-based data system populated with high quality, freely available data, as well as a robust set of software for data reduction and analysis that will facilitate the efforts of researchers and students who wish to collect data from regions currently not represented adequately in the database.

Long Term Goals of the Data System

The data system that we are building is designed to meet general criteria that would make it easily adaptable to other geospatial data. Our ultimate goal is to facilitate the creation of an open and flexible data system populated and maintained by user-members of the Geosciences community. Community involvement is central to the vitality and longevity of the data system. Simplicity and flexibility are also crucial in developing a system that can respond to changing technologies and user needs. The data system must be flexible and have minimal infrastructure requirements (i.e., minimization of operating system dependencies, various data management protocols, and peripheral hardware requirements), and a minimum of mandated data format requirements. In order to make the transition from raw data sets to database to data system, the development of a toolbox is a vital task. This software element of the system requires development and maintenance of a well designed front-end for a variety of programs needed to extract, map, process, model the data, and provide ready access to these programs as public domain, user-friendly, and platform independent tools. ASP.net was used to create the interface that connects the web service with Oracle database where the gravity data is residing. This GUI will also provide other tools in the future that will be built using Arc Objects and will provide users with the gridding, surface fitting and mapping tools. A use-case diagram illustrating the main features of the system is shown in (Figure 1). The data base tables created in Oracle are shown in (Figure 2) with all the variables assigned to each table and the relations between the tables.

An Example of an Application Using GIS Technology

The Hueco Bolson is the main source of groundwater supply for El Paso, Texas and the only source of municipal water for Ciudad Juarez, Chihuahua,

Mexico. The fresh water in the Bolson is concentrated along the eastern boundary of the Franklin Mountains. Pumping of the Hueco Bolson has caused movement of brackish groundwater into wells that previously had pumped fresh groundwater. A joint effort by El Paso Water Utilities and Fort Bliss to build a large brackish groundwater desalination facility prompted the search for a viable site for a deep well injection of the brine concentrate that will be a by-product of the plant.

A combination of drilling of test holes and geophysical surveys was employed in the search and gravity measurements became the dominant geophysical tool. A gravity survey was undertaken and the results were combined with older data in a GIS environment to produce the map shown as (Figure 3). The test holes are triangles on this map. A series of profiles were constructed using GIS tools and modeled using software developed during our effort. One gravity model is shown in (Figure 4) and represents a quantitatively derived cross-section extending in a NE-SW direction through test holes 1 and 3. The modeling delineated fault-bounded basin shown in (Figure 4) and its extent is shown by the NNW-trending gravity low (blue colors) in (Figure 3). In addition, a network of faults was mapped using the gravity models and terrain analysis of our DEM. These faults are shown as lines on (Figure 3).

Our analysis of the faults, DEMs, test holes and gravity data yields the conclusion that the main structure in the area is a NNW-trending basin that is clearly outlined by a gravity low on the Bouguer anomaly map (see Figure 3). This basin is a topographic low that contains as much as 210 m (340 ft) of young low-density sediments, but the drilling data show that it also contains a thickened section of older (late Paleozoic age) strata. The northeast wall of the basin is faulted in a staircase manner, while the southwest portion is dominantly formed by a large normal (high-angle) fault.

This analysis done entirely in a GIS environment is a key element in planning for a major water project that will serve 800,000 people.

References

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