The Submetric Gemid of Mexico

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Key words: GPS, Local geoid models, precise geoid determination, Gravimetric geoid.

SUMMARY

The increasing use and application of the Global Positioning System (GPS) that in the last years has had in Mexico, combined to the necessity at been able to use this type of equipment to determine vertical positions referred to a system of heights based on orthometrics heights, motivated the necessity at counting with a geoidal solution for the Mexican area, according to the positional precision that generate this type of instruments.

This presentation shows advances in the project that the National Institute of Statistics, Geography and Informatics (INEGI) of Mexico is developing in order to have the most accurate geoidal solution for the country as possible, which in principle, will be consistent with the developed for the North American Gravity and Geoid Subcommission of the International Geoid Service. Up to date we have a preliminary solution, which has a root mean square error near to a meter, trying to achive a solution at centimetric level within the next three years. The purpose of this project has as fundamental intention, determining a mathematical model that defines the form of the geoid, with respect to GRS80 ellipsoid, in the area of the Mexican Republic, in order to take the terrestrial observations to a true geodetic system referred to the ITRF92 epoch 1988.0, which is the official reference frame for Mexico. The solution adopted use the Stokes-Helmert scheme, developed at University of New Brunswick under leadership of Prof. Petr Vaníček.

RESUMEN

El incremento en el uso y aplicaciones del Sistema de Posicionamiento Global (GPS) que en los últimos años se ha tenido en México, combinado con la necesidad de poder usar este tipo de equipos en la determinación de posiciones verticales referidos a un sistema de alturas basado en alturas ortométricas, motivaron la necesidad de contar con una solución geoidal para el área mexicana, acorde con la precisión posicional que generan este tipo de instrumentos. En este trabajo se muestran los avances en el proyecto que el Instituto Nacional de Estadística, Geografía e Informática (INEGI) de México ha tenido con objeto de contar con la solución geoidal posible mas exacta, la cual en principio, será consistente con al que desarrolla la Subcomisión para la Gravedad y el Geoide de Norteamérica del Servicio Internacional del Geoide. A la fecha se cuenta con una solución preliminar, la cual tiene un error medio cuadrático cercano al metro, buscándose lograr una solución a nivel centimétrico dentro de los próximos tres años. El propósito de este proyecto tiene la intención fundamental de establecer un modelo matemático que defina la forma del geoide, con respecto al elipsoide GRS80, en el área de la República Mexicana, con el propósito de llevar las observaciones terrestres a un sistema geodésico verdadero referido al ITRF92 época 1988.0, el cual es el

sistema oficial de México. La solución adoptada emplea el esquema Stokes-Helmert, desarrollado en la Universidad de New Brunswick bajo el liderazgo del Prof. Petr Vaníček.

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1. INTRODUCTION

Mexico adopted the Stokes-Helmert's geoid software (SHGEO) for developing a geoid solution for the country. SHGEO is a scientific software for precise geoid determination based on the Stokes-Helmert theory of determination of the gravimetric geoid. The software has been developed during more then 10 years period under leadership of professor Petr Vaníček at the Department of Geodesy and Geomatics Engineering, University of New Brunswick. Authors of particular programs are: M. Najafi, P. Novák, J. Huang, J. Janák and R. Tenzer. We also have to mention Z. Martinec, A. Kleusberg, L.E. Sjöberg, W.E. Featherstone, W. Sun whose research presented in their papers was incorporated into the SHGEO software. SHGEO software uses various global models (e.g. TUG87, GRIM4-S4, EGM96). These global models play an important role in the geoid computation scheme. [Tenzer, R. et al, 2003].

The Stokes-Helmert scheme for determination of the precise geoid can be summarized in the following steps:

- Formulation of the boundary value problem on the Earth surface.
- Evaluation of the Helmert gravity anomalies on the Earth surface.
- Downward continuation of the Helmert gravity anomalies onto the geoid.
- Stokes's integration (solution to the Stokes's boundary value problem).
- Transformation of geoidal heights from the Helmert space to the real space.

The structure of SHGEO software is illustrated at figure 1.

2. THE DATA

For a successful precise geoid determination, the input data has the most important role. The data must have an adequate accuracy and distribution over the interested area. SHGEO required at least two of three different kinds of data, e.g. elevations and point gravity values. The third one is topo-density, lateral density model of the masses above the geoid.
Elevations data consist of three different source of data:

- Detailed digital elevation model with a resolution of 3" by 3" or if it exist a 1" by 1",
- Digital elevation model of mean heights, e.g. GTOPO30, and the last one
- Global model, e.g. TUG87.

To complete the first kind of elevation data, we use the digital elevation model produce by INEGI, re-sampling elevation data to 1", in the area covered by Mexico, and elevation data derived by STRM for United States, Central America, and Caribbean area.

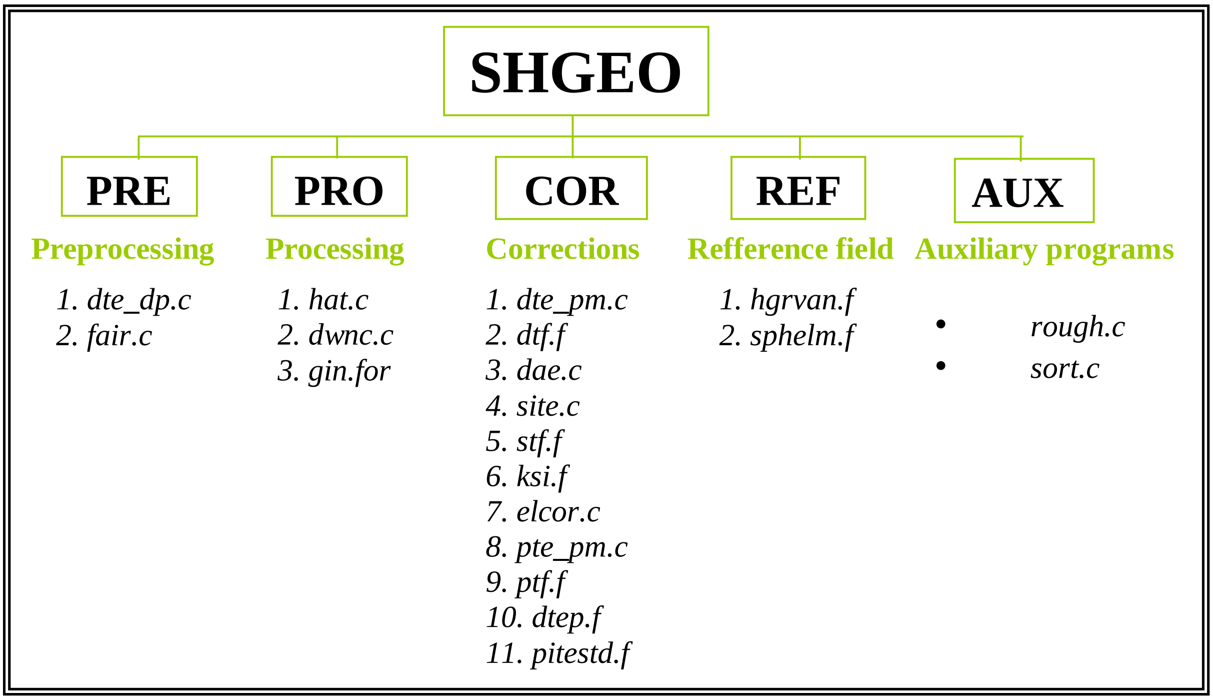

Figure 1. Structure of SHGEO software

Gravity data must be in two different ways: detailed point gravity values with a density of one value in a region of 5’ by 5‘ at the interest region. The second source of gravity data come from global model like GRIM-4S for the reference field, and EGM96 to complete empty areas.

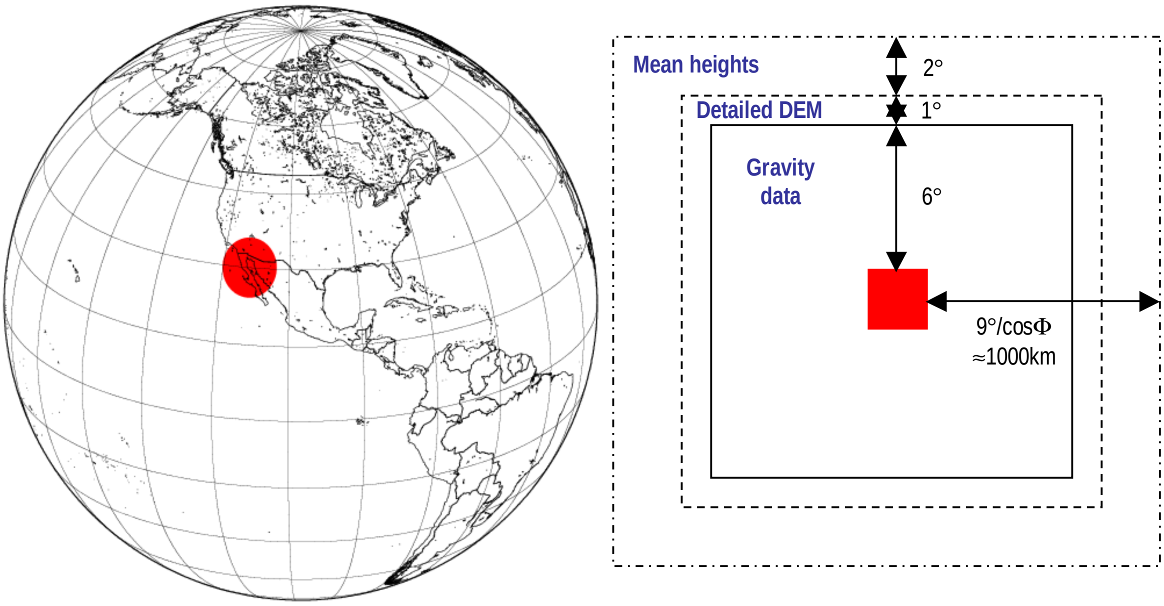

Figure 2. Recommended input coverage

At the moment, for the area of interest of the geoid solution, INEGI's Geodesic Data Base on its Gravimetric branch account with an inventory of 527371 ground stations with values of gravity obtained by direct observation and 788556 values in the marine area derived from TOPEX-POSEIDON mission; what gives like result 1315927 values of gravity.

The recommended input data coverage is shown in Figure 2, and the computational scheme is shown on Figure 3. For a complete description of the mathematical model used see the references listed in [UNB, 2002].

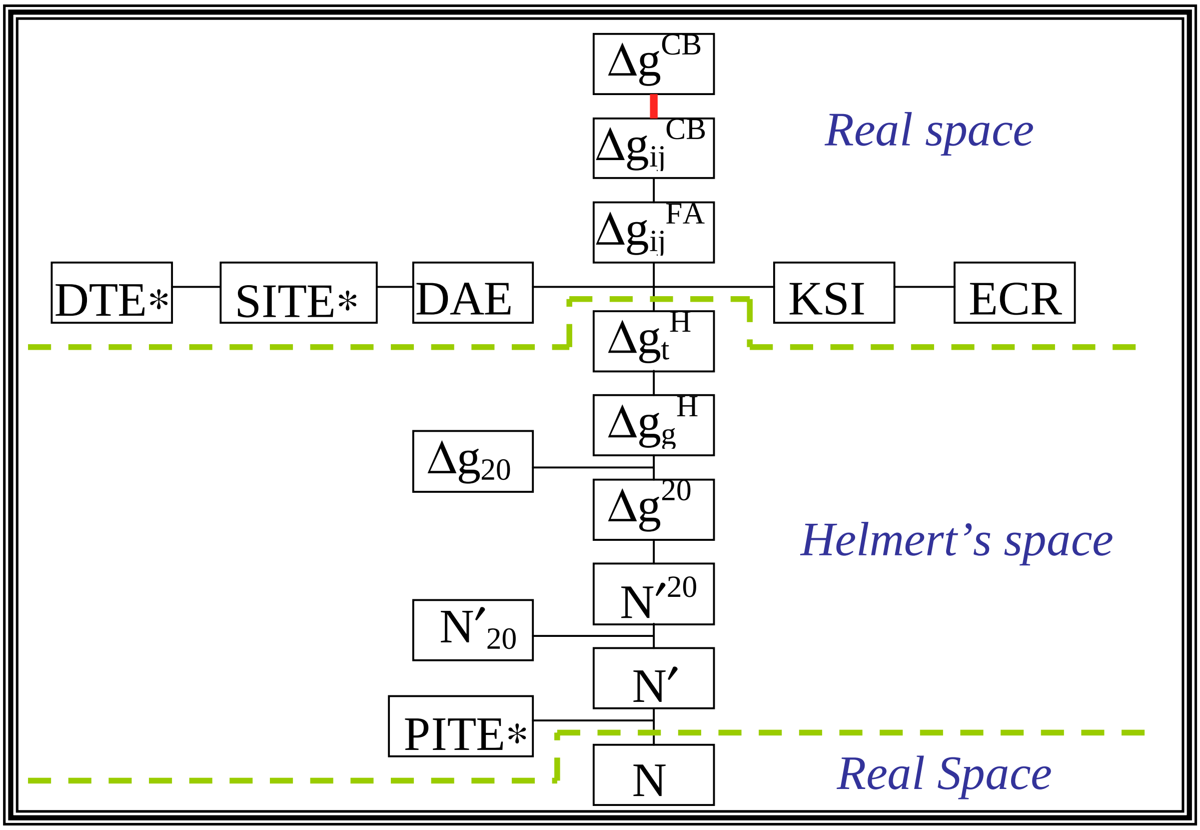

Figure 3. Computational schema

3. TEST AREA

The geoid solution shown here (Figure 4), was produced during the SHGEO software training, held at INEGI's headquarters during the second half of July, 2002. Unfortunately the gravity data and digital elevation model was unpolished, and the geoidal solution was not enough good, as the technique claim.

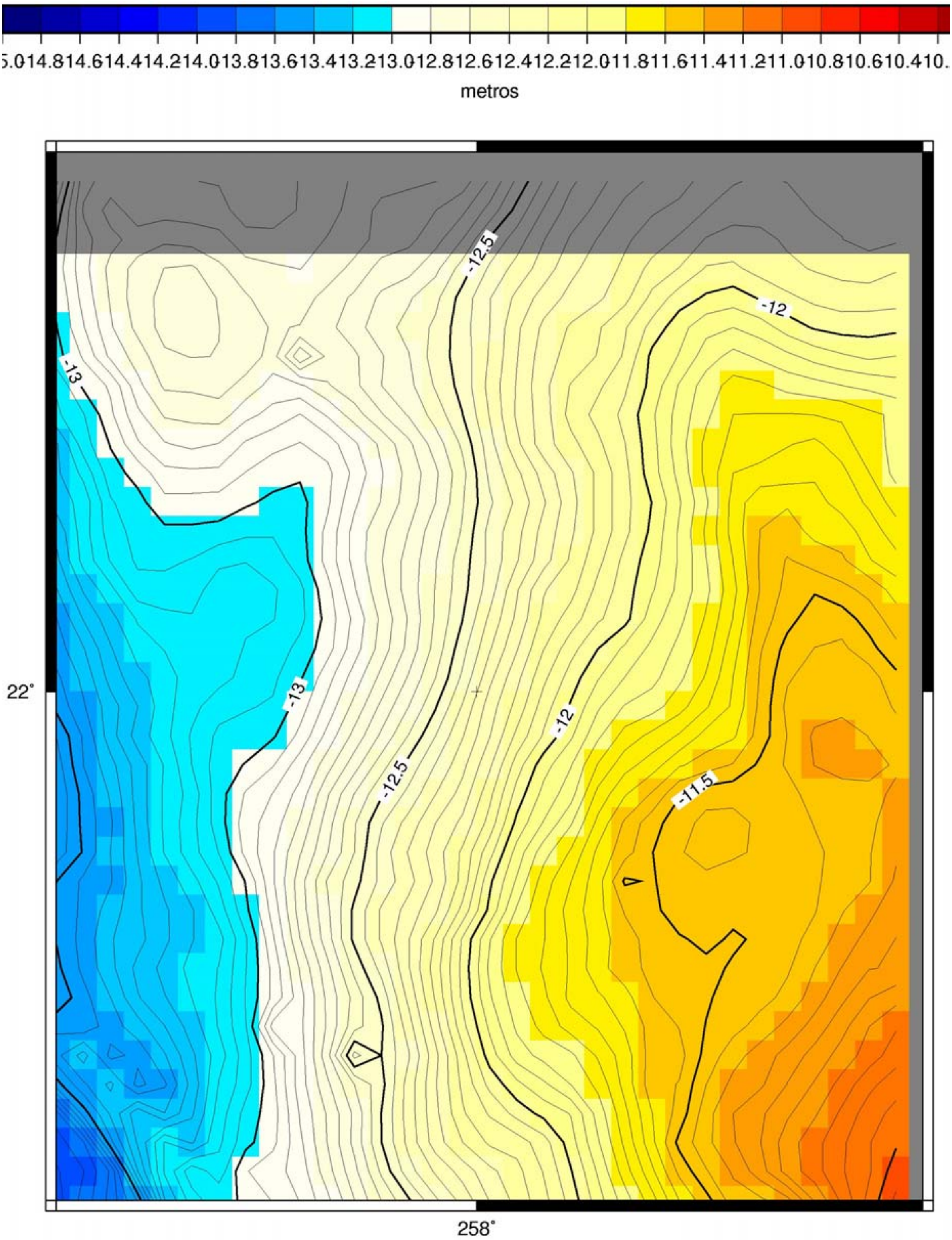

Figure 4. The Geoid solution

The test area for the numerical experiment was selected in the central part of Mexico, and consists in a square of 2° of latitude by 2° of longitude. Perhaps the amount of gravity data was enough, but it has some undetected blunders. Also the DEM's was generated in two differents reference geodetic systems NAD27 and ITRF92 epoch 1988.0.

In order to have an estimation of the gravimetrical geoid, the solution was compared with 13 geoidal heights derived from GPS observations made over first order leveling bench marks. In relation to these bench marks, one important thing to be in mind is that in the test area due to the agricultural activity, great amount of water of the subsoil is extracted, taking place a sinking of 1.5 cm per month. This value has been observed in the GPS's continuous reference station located in the central part of the test area.

The root mean square (RMS) error derived from the comparison of the gravimetric geoid and the geoidal undulations derived from GPS is ±0.599 m. Frequencies of differences between gravimetric geoid heights and geoidal undulation derived from GPS over bench marks are shown in Figure 5, all values are in meters. These same 13 geoidal heights were compared to MEX97 geoidal solution derived by the National Geodetic Survey [NGS, 2001] and the RMS resultant is ±0.562 m. The difference between both RMS is too small, reason why we think that debugging the gravimetric information and the digital elevation models, results applying the Stokes-Helmert's scheme could have to be better results.

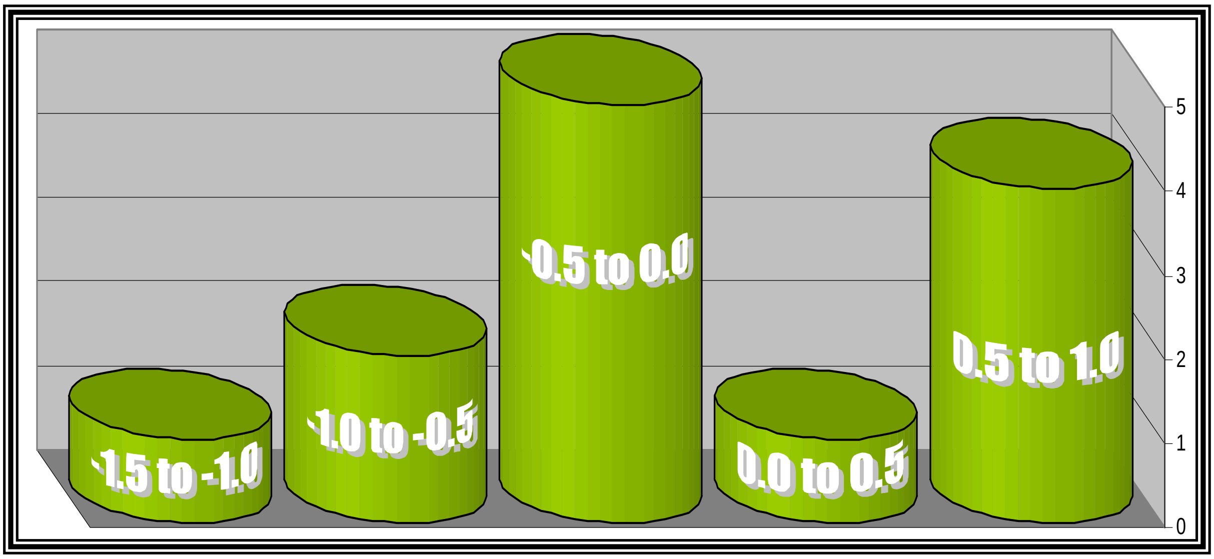

Figure 5 GPS/leveling vs. geoidal model

Nevertheless, we will continue working cleaning of the data source, as well as in the generation of new gravimetric data, and additional GPS observations over first order leveling bench marks, and also the re-leveling of the national first order vertical network of the country.

We hoped to count on the necessary information for the project in the course of next three years, generating the precise geoidal solution for the country during year 2006.

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BIOGRAPHICAL NOTES

Antonio Hernández-Navarro has a bachelor in Surveying and Geodetic Engineering from the National Autonomous University of Mexico. Since 1980 has been work at the Mexican National Institute of Statistics, Geography and Informatics always involved in geodetic activities.

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