

TOWARDS THE NEXT EARTH GRAVITATIONAL MODEL

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Summary

The development of a new Earth Gravitational Model (EGM) to degree 2160 is progressing with the availability of improved versions of worldwide 5'x5' gravity databases and GRACE-derived satellite solutions. Critical to the success of this endeavour is the compilation of a complete and accurate 5'x5' global gravity anomaly database that takes advantage of all the latest data and modeling for both land and marine areas worldwide. This paper will provide an overview of the data being used in the model, describe the status of the development of the new EGM, show comparisons of preliminary models with independent truth data, and discuss the plans for finalizing the model.

Introduction

The last major EGM effort undertaken by the National Geospatial-Intelligence Agency (NGA) in the mid-1990's produced EGM96, a degree and order 360 model that utilized worldwide gravity data at a 30 minute by 30 minute resolution, long-wavelength information from ~40 satellites, elevation data from 29 different sources, and satellite altimetry from TOPEX, ERS-1, and GEOSAT for the marine areas. The accuracy goal for the EGM96 geoid was 0.5-1.0 meters RMS worldwide and an independent validation performed by a special working group under the International Association of Geodesy (IAG) confirmed that EGM96 achieved its accuracy goal. The accuracy goal for the new EGM is more ambitious, 5'x5' mean resolution equating to a degree and order 2160 model with a geoid accuracy of 15 centimeters RMS worldwide. This will require an improved long wavelength model from GRACE, improved terrain and altimetry data, and the very best surface gravity database that can be compiled from available data.

Theory and Methods

The new Earth Gravitational Model under development at the NGA requires worldwide coverage of gravity information at the 5'x5' mean resolution. This gravity database will be composed of surface (land, marine, and airborne) gravity data, and gravity anomalies estimated over (most of) the ocean areas from satellite altimetry. Unlike the altimetry-derived gravity anomalies, which form a fairly homogeneous dataset, the terrestrial dataset still contains gaps (e.g., over Antarctica, parts of Africa, south America, and south-east Asia), as well as areas occupied by data of poor or questionable quality. Significant effort has already been put into the compilation of this 5'x5'

terrestrial gravity database, benefiting from the Arctic Gravity Project and other collections and projects worldwide. Some notable and recent surveys that have contributed to this effort are NGA-sponsored aerogravity missions over Mongolia and Ethiopia.

Many areas of the world have readily available gravity information that has been provided to NGA for this effort and can be used directly in the new EGM. NGA does collect a significant amount of gravity that is classified as proprietary and has restricted use and distribution. Significant amounts of effort have been devoted to creating synthetic anomalies in the areas of the world where proprietary data exists, and these synthetic anomalies are developed using techniques that combine GRACE, lower-resolution gravity, and terrain data to create a 5'x5' mean anomaly dataset that protects the proprietary nature of the original data, while providing a mean anomaly with an adequate high-frequency component.

The sources used in preliminary NGA compilations are shown in Fig. 1. The source code in white is where synthetic anomalies will be utilized.

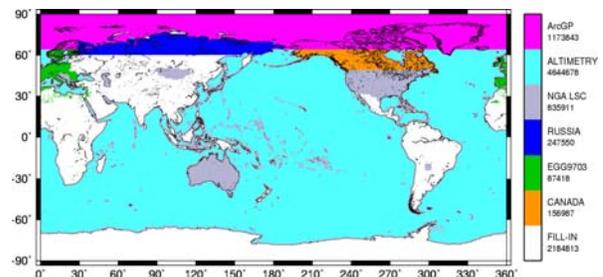


Figure 1. 5'x5' Gravity Anomaly Data Sources (v080306)

The long wavelength part of the new EGM is currently being defined by the GRACE satellite mission data, which is significantly more accurate than the satellite modeling used for the long wavelength portion of previous EGMs, e.g., the NASA GEM models, JGM-1/2, JGM-3, EGM96. The latest and most accurate GRACE model available will be used in the new EGM. NGA has been using the GRACE model to degree and order 60 in preliminary models developed in this effort. An update to GGM02S is anticipated this year.

The development of a new worldwide elevation database has been an important part in the development of the new

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EGM. The Shuttle Radar Topographic Mission (SRTM) data has been used with other elevation sources (GTOPO30, ICESat, etc.) to develop a worldwide 30 sec by 30 sec topographic database that is being used for terrain corrections and Residual Terrain Modeling (RTM) of all the surface gravity data. This topographic database is a major advance over EGM96, which utilized elevation data from 29 different sources. As a result, EGM96 required significant effort to correct elevation inconsistencies in South America, Africa, and other places on earth where Digital Terrain Elevation Data (DTED) was not available. SRTM provides one consistent and accurate elevation source between 60° N and 58° S and makes up the majority of the new elevation data over land areas. ICESat has been used over Antarctica and other polar regions above the SRTM coverage along with other available altimetry sources. The RTM anomalies produced from this 30 second topographic database are a fundamental source to terrain correct gravity data and fill-in areas of proprietary or other areas lacking in gravity and is extremely important in the compilation of the 5'x5' mean gravity database.

The development of a Mean Sea Surface (MSS) over the oceans and associated Dynamic Ocean Topography (DOT) has been one of the key components for the new EGM. A major effort has been undertaken by the Danish National Space Center to produce a new MSS utilizing data from altimetry satellites TOPEX/Poseidon, JASON-1, ERS-1/2, GEOSAT, ENVISAT, GFO, and ICESat. Advances in orbit modeling and corrections have been a major factor in improvements to the altimetry data along with re-tracking waveforms, particularly with the ERS and GEOSAT Geodetic Mission data. The new MSS is still in development with a final version not yet available. When it is available, a new DOT produced from GRACE and the MSS will be produced which will then be used to reduce the MSS to the geoid. The next step will be the generation of the altimetry gravity anomalies which fill in approximately 65% of the world's gravity anomaly field.

The team at SGT, Inc. working with NGA on this effort has world-class experience in the estimation of high degree geopotential models and has developed the methodologies and techniques used for this EGM development. Along with state-of-the-art numerical techniques for the new EGM, the SGT team has also developed new techniques for error propagation which will provide realistic error estimates for the full 2160x2160 model.

Conclusions

The new EGM development will utilize worldwide databases of the best available gravity information from land, marine, and airborne sources and from satellite missions. As milestones are reached in the EGM

development, the data and models are combined to produce test gravitational solutions. These interim solutions help gauge our progress, identify problems, and indicate possible alternative solution strategies.

As part of this effort, an international working group under the IAG has been formed to evaluate the new EGM and perform tests of the geoid versus GPS/levelling, satellite orbits, deflections of the vertical, marine gravity and sea surface topography models, etc..

Harmonic Synthesis software and "test" coefficient sets have been provided by NGA on its website: <http://earth-info.nima.mil/GandG/wgs84/gravitymod/index.html> recognizing that the calculation of the new 2160x2160 EGM is a major undertaking. The IAG validation team is performing a valuable service by independently testing the new EGM as it is being finalized and their results will play a major role in the final model selection.

The new EGM is anticipated to be a significant step forward in accuracy for the geodetic and geophysical community. For example, the geoid produced from the new EGM will be used with GPS, enabling the geodetic and surveying community to define their vertical positioning and orthometric heights with a much greater accuracy. This is very important in modernization efforts and infrastructure development for users and countries around the world.

We will present the comparisons of preliminary models to a variety of other "truth" sets, identify areas of improvement, and highlight our future activities including the timeframe for release of the new EGM.