A Preliminary Attempt of a Quasi-Geoid for Saudi Arabia

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Key words: Geoid, Saudi Arabia,

SUMMARY

This proposal describes the need to undertake a national geoid (quasi-geoid) model study for Saudi Arabia to fully utilize the three dimensional location satellite technology now available on a global basis. Development of a national geoid model will provide a means of applying the available technology and replace many aspects of conventional topographic surveying by accurate, rapid and cost effective satellite based methodology.

The aims and scope of this study are to generate a high resolution geoid model for Saudi Arabia with suitable accuracy for rapid and efficient surveying methods related to Geodesy and Engineering (e.g. levelling for water distribution and flow, dams, roads and railways etc). The proposed study is to work in close collaboration with KACST (King Abdulaziz city for Sciences and technology) to acquire the necessary GPS and gravity data

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1. INTRODUCTION

Altimetry has become more and more important nowadays due to the facility to derive accurate heights from satellite technologies, in particular with the Global Navigation Satellite System (GNSS). The first step in the process is to select a consistent height system. The most suitable height system from a practical point of view is the normal height. It relates the physical surface of the Earth to the quasi-geoid. It is important to emphasize that in the oceans the geoid and the quasi-geoid are coincident. Throughout the continents the deviations between the two surfaces is dependent of the irregularities of the physical topography.
The geodetic coordinates latitude (ϕ), longitude (λ) and geodetic height (h) can be derived from GNSS observations with a very high accuracy using suitable phase measurements. Due to constraints of this technology the methodology that has to be used is the so called Differential GNSS. This implies that the surveyed points have to be observed simultaneously with a reference station. On the other hand, gravity measurements are also carried out in a differential process using relative spring gravity meters.

Helmert gravity anomaly can be computed from a compilation of all existing gravity surveys of Saudi Arabia and a quasi-geoid model estimated. In the computations, the reference field provided by a suitable geopotential model, like GRACE, to a proper degree and order will be removed from the anomalies. In the end the long wavelength component will be restored to the quasi-geoid heights using the same geopotential model.

Once the geoid has been derived, it can be used with GNSS data to accurately estimate the normal height of a point very quickly and efficiently. This can eliminate the need for conventional levelling which is costly and time consuming.
The expected accuracy and resolution achievable by this study based on the current GNSS and gravity instrumentation and methodology used will be in Absolute: better than 0.5 m and relative: approximately 0.1cm per km with wavelength: wider than 20km, these expected results in the eastern part of Saudi Arabia where there is a good coverage of gravity data, however huge area in the western of Saudi Arabia must be surveyed during this project to achieve geoid accuracy compatible with the differential GNSS.

2. OBJECTIVES

The objectives of this project are numerous and are not limited to the one referred to here. A new common height system for Saudi Arabia will be implemented through this project this height system that will simplify determining heights and locations very accurately and help in designing and installation of water pipelines, drainage systems, road design, railway design, the construction of bridges (precise 3D location of piers) and providing reference coordinate system for maps.
Once the geoid has been derived, it can be used with GNSS data to accurately estimate the normal height of a point very quickly and efficiently. This can eliminate the need for

conventional leveling which is costly and time consuming. Thus Organizations that provide surveying services such as KACST and the General Surveying Organization of Saud Arabia can then provide a fast and economic GNSS leveling and surveying services to all other interested organization governmental and private. Provision of such services will enable recouping the costs of the geoid construction.

3. LITERATURE REVIEW

Quasi-Geoid was implemented recently in some countries as a practical alternative to geoid estimations which is constrained by gravity lateral variations within the Earth and therefore the orthometric height derived by geoid model requires a precise observation of gravity anomalies above the sea level which is practically undetectable. However, in the quasi-geoid modeling an approach was first introduced by Molodensky (Moritz, 2005) where he solved the geodetic boundary value problem by refereeing the gravity anomalies to the ground. This new Quasi-Geoid estimation approach was applied adequately in some countries for example Iran (Kiamehr, 2008), and Belgium (Barzaghi et al., 2003). And New Zealand (Amos and Featherstone, 2009). This technique is an effective part of Dubai Virtual Reference System (Dubai VRS) that uses real time positioning from GPS satellites signals at the cm accuracy in major civil engineering applications. Coupled with the newly developed quasi-geoid model (El-Mowafy et al. 2006).

4. PROPOSED WORK

The compilation of the Quasi Geoid or Geoid of Saudi Arabia will require first of all a first order network of Absolute Gravity Measurements and GPS network, with suitable distribution of points, on the levelling network, and associated modern gravity base station network in Saudi Arabia. Four fieldwork teams will be deployed during this project for duration of 12 months to tie and resurvey some gravity stations and to level all existing gravity survey to consistent datum. Selective accurate existing GPS network in Saudi Arabia will be utilized as needed.

First step is to reprocess all existing gravity and GPS data seen in Figure 1. It is obvious that these data were collected by different organization over a large time span. Therefore , different quality of the data and. also possible data inconsistency are already seen in some of surveys, necessary work will be focusing in collecting and in homogenizing the gravity and GPS observation. Then the field work will be in four phases for each region surveyed. Proposed area would be divided into 4 regions with each region being surveyed in turn and interlinked with previously surveyed regions, this to tie an integrated network of GPS and gravity measurements. Densification of this network with secondary GPS and gravity measurements tied to a main precise network would result in the determination of an accurate Quasi Geoid or Geoid.

4.1 Approach

• Reprocessing all existing gravity and GPS data.
• Collecting and in homogenizing the gravity and GPS observation.
• Tying an integrated network of GPS and gravity measurements.
• Densification of this network with secondary GPS and gravity measurements tied to a main precise network.
• Determination of an accurate Quasi Geoid or Geoid.

4.2 Phases

• Compiling all existing Gravity and Geodetic Data
• Establishing First-order Absolute-Gravity network using the Micro-g FGL Absolute Gravimeter.
• Field trips to tie the existing networks of GPS and gravity with the new Absolute Gravity network.
• Field trips to densify Gravity points in areas with no Gravity surveys like some part of the Arabian Shield.
• Processing of all Gravity/ Geodetic and GPS data, and bringing all data (old and new) to a common datum.
• Calculation of Quasi Geoid and Geoid using all existing data.
• Testing the new Quasi Geoid and Geoid against GPS/leveling surveys.

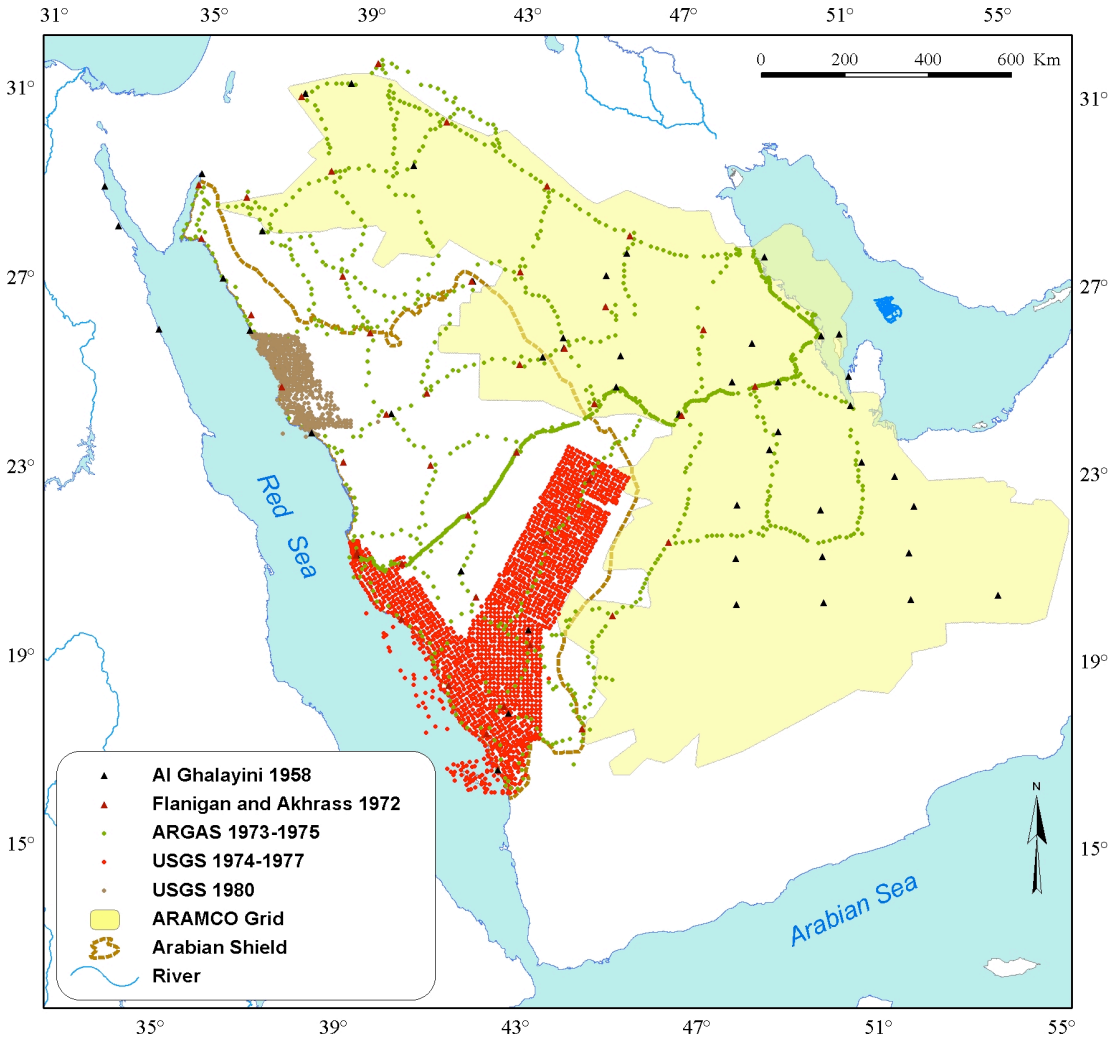

Figure 1 Map shown existing gravity surveys of Saudi Arabia.

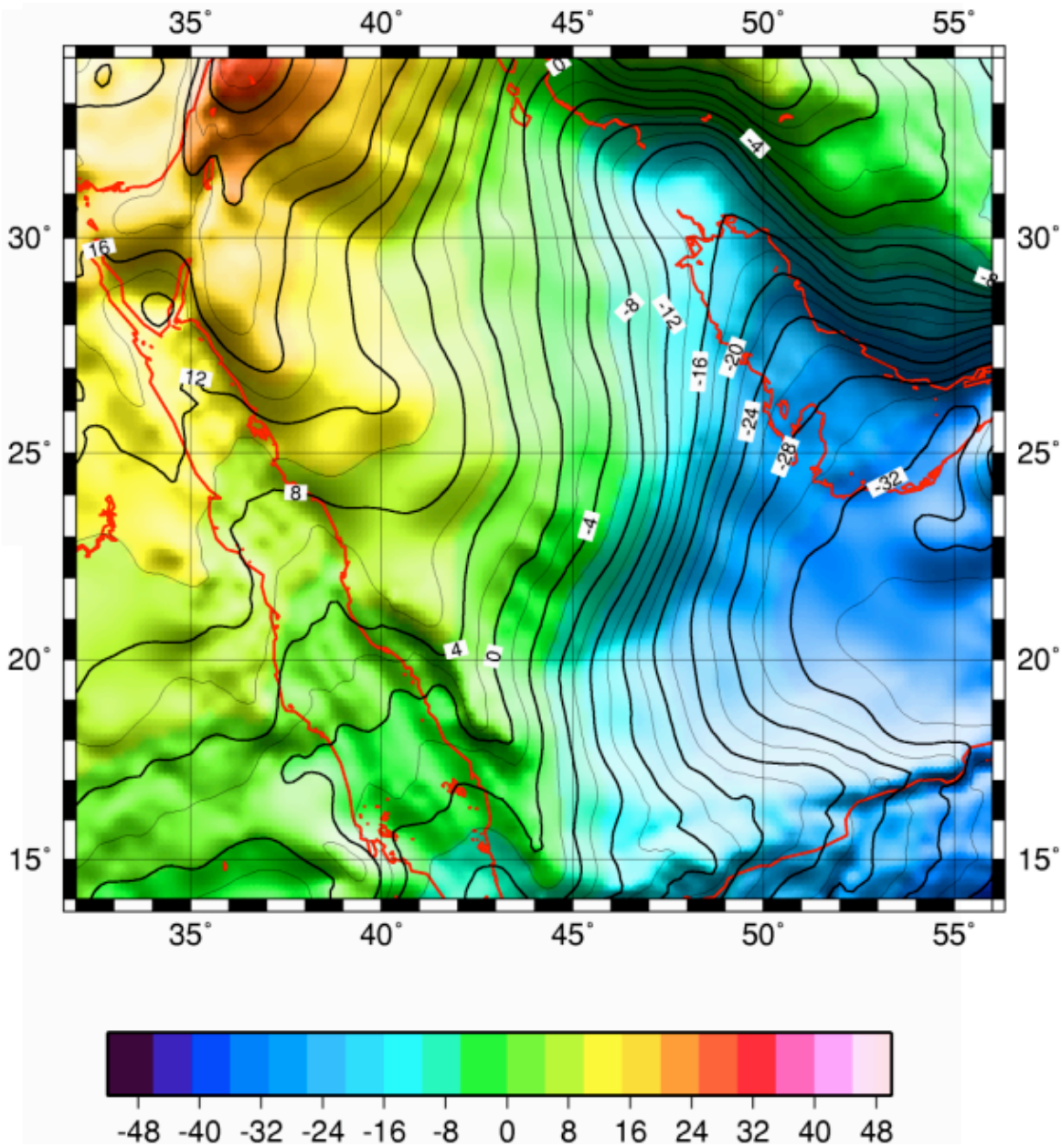

Figure 2 An estimation of a preliminary quasi-geoid model for Saudi Arabia. The calculation was based on the Helmert gravity anomaly.

5. RESEARCH METHODOLOGY

Geoid estimations over large area can be done in a rapid and efficient way by means of FFT techniques (Sideris, 1994; Forsberg and Sideris, 1993) or fast collocation (Bottoni and Barzaghi, 1993) which lead to geoid estimates over large areas. Accurate global geopotential models (e.g CRACE) will be used as the long wave length components of the Geoid model and the new available detailed DTM will make an effective reduction of the gravity. The Helmert gravity anomaly will computed from a compilation of all existing gravity surveys of

Saudi Arabia and a quasi-geoid model estimated (preliminary geoid is shown in Figure 2). In the computations, the reference field provided by a suitable geopotential model, like GRACE, to a proper degree and order will be removed from the anomalies. In the end the long wavelength component will be restored to the quasi-geoid heights using the same geopotential model. Once the geoid has been derived, it can be used with GNSS data to accurately estimate the normal height of a point very quickly and efficiently. This can eliminate the need for conventional levelling which is costly and time consuming. The expected accuracy and resolution achievable by this study based on the current GNSS and gravity instrumentation and methodology used will be in Absolute: better than 0.5 m and relative: approximately 0.1cm per km with wavelength: wider than 20km, these expected results in the eastern part of Saudi Arabia where there is a good coverage of gravity data, however huge area in the western of Saudi Arabia must be surveyed during this project to achieve geoid accuracy compatible with the differential GNSS.

6. EXPECTED RESULTS

- A new detailed Quasi-Geoid model over the areas of Saudi Arabia with good coverage of Gravity and GPS/Leveling
- A new prices Geodetic network.
- A first-order national-wide Absolute Gravity network.
- Propose a new consistent height system for Saudi Arabia.

Once the geoid has been derived, it can be used with GNSS data to accurately estimate the normal height of a point very quickly and efficiently. This can eliminate the need for conventional levelling which is costly and time consuming. The precise geoid undulation is a necessity to optimize the accuracy and to minimize the cost of obtaining elevation data using GPS technology. The project will make consistent vertical datum between all provinces of Saudi Arabia. It will provide a consistent datum for disaster management. The GPS Leveling with high accuracy geoid model has many applications including determining heights and locations very accurately will help the design and installation of water pipelines, drainage systems, road design, railway design, the construction of bridges (precise 3D location of piers) and providing reference coordinate system for maps.

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BIOGRAPHICAL NOTES

Saad Mogren completed a B.Sc. in Geophysics from King Saud University, Riyadh, and PhD in Geophysics at Newcastle, England on Geophysical investigations on the Najd Fault System, his PhD thesis were focused on processing and interpreting the gravity and magnetic data of the Arabian Shield and Cover Rocks. He is now in charge of the Geospatial information center at the Geology and Geophysics Department, King Saud University at Riyadh; where he also teaches Gravity magnetic methods. His main scientific interests in 3D modeling of gravity and magnetic data, Geoid calculation based on gravity data and Decorrugation of the aeromagnetic data. and Observing and monitoring absolute gravity changes using FGL absolute gravimeter.

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