COMPARISON OF SRTM AND ASTER DEM TO THE PREDICTION OF THE MEAN GRAVITY ANOMALIES

R. Alpay ABBAK and I. Oztug BILDIRICI and H. Tuba Arlı IL, Turkey

Keywords: ASTER, DEM, gravity anomaly, interpolation, SRTM.

SUMMARY

Gravity surveys that are collected on the physical surface of Earth are not used directly in geoid determination. They should be reduced to the mean sea level. Grid nodes should be interpolated from gravity surveys. Then, free-air gravity anomalies are evaluated in Stokes' function, which produces a geoid height in a computation point. For the interpolation of free-air gravity anomalies we need mean heights of the grid nodes from a Digital Elevation Model (DEM). Recent developments in technology provide us to determine precise DEMs with help of remote sensing techniques. For example, SRTM (Shuttle Radar Topography Mission) and ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) yielded two of the most popular global DEMs in worldwide. The resolution of both DEMs is 1 arc second at global scale.

In this study gravity surveys that are randomly distributed in Konya Closed Basin are interpolated in grid nodes to get mean gravity anomalies by using both SRTM DEM and ASTER DEM. Differences of free-air gravity anomalies between SRTM and ASTER DEMs are ranging at approximately 5 mGal level, which should be considered in geoid modelling studies.

COMPARISON OF SRTM AND ASTER DEM TO THE PREDICTION OF THE MEAN GRAVITY ANOMALIES

R. Alpay ABBAK and I. Oztug BILDIRICI and H. Tuba Arlı IL, Turkey

1. INTRODUCTION

Geoid is an equipotential surface of Earth gravity field, which coincides with the mean sea level and extends inside continents. The geoid is especially important for the geodesists to use it as the reference surface of heights and depts. Additionally, with the development of GPS (Global Positioning System) technology, the precise geoid can be used to convert ellipsoidal heights to orthometric heights directly.

Geoid determination is classified into three sections according to data used: Astro-geodetic, gravimetric and GPS-levelling methods. Astro-geodetic method uses the vertical of the deflection, which is the difference between ellipsoidal and astronomic coordinates. Gravimetric geoid model is the synthesis from terrestrial gravity surveys, digital elevation model (DEM) and global geopotential model (GGM). On the other hand, the GPS-levelling or geometric method utilises the ellipsoidal height derived from GPS and the precise levelling at the same point.

With the gravimetric method, gravity surveys should be reduced to free-air gravity anomalies, and then these anomalies are evaluated by using Stokes function. However, gravity anomalies should be interpolated to regular grids by using a technique. In this case, the mean height values in grid node are needed for the whole data area. Nowadays global DEMs have been used for this purpose where an accurate regional DEM is not available.

In geodetic literature, there are limited amounts of paper that concerns effect of a DEM on the gravity field. Merry (1999) compares some global and regional DEMs in determination of height anomaly in Africa by using Molodensky approximation. Moreover, Kiamehr and Sjoberg (2005) examine the contribution of SRTM DEM (at 3 arc-second resolution) to geoid determination by taking account the some global and regional DEMs. Finally, Abbak (2014) studied on the comparison of ASTER and SRTM (at 3 arc-second resolution) to predict mean gravity anomalies in Auvergne test region (France), which has a moderate rough topography with over-determined gravity surveys.

In this study, the effect of ASTER and SRTM DEMs on the prediction of the mean gravity anomalies was investigated in Konya Closed Basin (Turkey). This study considers both DEMs at one-arc second resolutions in a mountainous test area with sparse gravity data when compared to earlier studies.

This paper starts with a brief review of the prediction of mean gravity anomalies by Bouguer approximation. Subsequently terrestrial gravity surveys in the test area, SRTM and ASTER DEMs are discussed respectively. Afterwards, SRTM and ASTER DEMs are absolutely evaluated by the levelling data in the test area, and then a numerical comparison about the prediction of mean gravity anomalies was realized by using both DEMs for mean height data. Finally a concluding remark gives a summary.

2. INPUT DATA

In this section, the input data used for investigations over the study area is discussed and also their global/regional accuracy is outlined.

2.1 Study Area

Our study area is Konya Closed Basin that lies on central Turkey. It is bounded by 37°—39° latitudes and 32°—35° longitudes. It covers approximately 50 000 km^2 area. Heights in the area are ranging from 600 m at Göksu valley to 3500 m at the top of Taurus Mountains. Average heights in the area is approximately 1100 m. Fig. 1 shows the topography of the study area.

2.2 SRTM DEM

United States of National Aeronautics and Space Administration (NASA), the National Imagery and Mapping Agency (NIMA), the German Space Agency (DLR) and Italian Space Agency (ASI) jointly realized the SRTM project. On February 2000, during ten days a radar shuttle collected 3 dimensional images of Earth surface. These images were used for the production of a global DEM. The DEM wholly covers between ±60° latitudes.

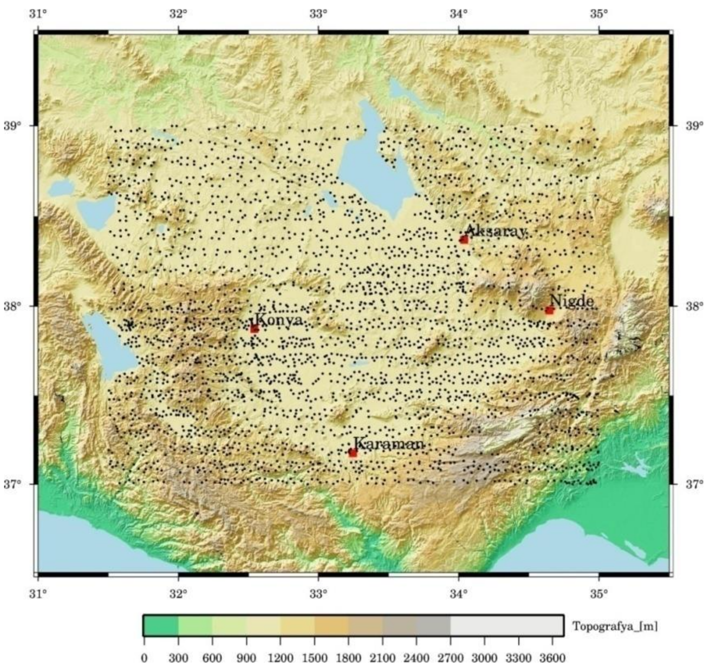

Figure 1: Topography of the test area

Whereas the DEM was distributed at 3 arc-seconds resolution up to 2015, now the DEM at one-arc second resolution is publicly available on Internet by NASA servers (URL 1). Its vertical and horizontal datum definitions are EGM96 and WGS84, respectively. Global accuracy of the DEM is approximately 16 m at the 90 % confidence level according to its validation team. Other technical specifications about the SRTM DEM can be available on the Internet (URL 1).

2.3 ASTER DEM

ASTER sensor placed on the satellite Terra is an achievement of an international project between METI (Ministry of Economy, Trade and Information of Japan) and NASA.

ASTER produced a DEM, which was generated from a stereo image pair acquired with nadir and backward angles over the same area. Its strategy provided a global DEM with enhanced accuracy due to multiple images. As a result of the project, ASTER DEM covers all land area that is ranging from 83˚N to 83˚S even in steep mountainous areas. Vertical and horizontal datum of the DEM is EGM96, and WGS84, respectively. Vertical accuracy of the DEM is estimated to be 7–14 m. Other technical specifications about the ASTER DEM can be available on the Internet (URL 2).

2.4 Gravity Surveys

Abbak et al (2012) supplied the terrestrial gravity data for the current research. The gravity data is in the International Gravity Standardization Net 1971 (IGSN71), and its geographical datum is WGS84. The accuracy of gravity values has been estimated as 1–2 mGal. On the other hand the distribution of gravity surveys in the study area is not satisfactory. The number of available gravity points within the study area is about 3078, which corresponds to a density of one point per 22 km^2, approximately. The geographical distribution of all gravity data points in the area is shown in Fig. 1.

3. PREDICTION OF MEAN GRAVITY ANOMALY

3.1 Free-air Approximation

Gravity survey on the Earth's surface is denoted as g_P. At the same point, normal gravity is denoted as γ_P. Difference among them,

$$\delta g = g_P - \gamma_P$$

is called gravity disturbance.

On other hands, gravity anomaly can be calculated as follows,

$$\Delta g = g_P - \gamma_Q$$

where γ_Q is determined on telluride where it has same normal potential with the surface point P ($W_P=U_Q$).

The gravity anomaly is used in gravimetric geoid determination and it was called free-air gravity anomaly.

3.2 Bouguer Anomaly

Before using free-air gravity anomaly in geoid determination, it should be interpolated in grid nodes. However, free-air anomaly is very sensitive to the point height. Thus Bouguer anomalies that represent very smooth surface of Earth can be used for interpolation. Free-air anomaly (FA) is converted to Simple Bouguer (SB) anomaly,

$$\Delta g_{SB} = \Delta g_{FA} - 0.1119 * H$$

where *H* represents to orthometric height of the computation point. Point height exists in gravity surveys.

After interpolating simple Bouguer in grid nodes, Free-air anomaly should be reversed by,

$$\Delta g_{FA} = \Delta g_{SB} + 0.1119 * H$$

where *H* represents to orthometric height of the grid nodes. Grid node height is taken from any DEM such as SRTM, ASTER etc.

4. NUMERICAL APPLICATIONS

In this section we treated independent SRTM and ASTER DEMs in two comparisons. The first step evaluates the DEMs by means of the levelling data; secondly effects of each DEM on gridding gravity anomalies are examined.

4.1 Absolute Validation of DEMs

Gravity surveys data covers the orthometric height of the point, which is determined a terrestrial method. Thus this information (ground truth) was used for validation of SRTM and

ASTER DEM. By using latitude and longitude of points, SRTM and ASTER heights of all points was determined with the help of thin plate spline interpolation method (TPS), respectively. Then original and DEM-based heights were compared. Gross errors, which are higher than 50 m, were removed from data.

Nevertheless, two types of height data are not compared directly. Due to systematic errors, direct comparison does not give reliable results. Thus a corrector surface can used which are ranging from a linear model to seven parameters similarity model. In this study, seven parameters corrector surface was preferred for the comparison since it gives more reasonable results. Numerical results are tabulated in Table 1.

Table 1: Comparison of SRTM and ASTER DEM with respect to levelling points [m]

Model	Min	Max	Mean	RMSE
SRTM	-50.46	47.43	0.00	11.64
ASTER	-52.77	50.47	0.01	12.80

According to Table 1, SRTM DEM is slightly better than ASTER DEM with respect to RMS and error distribution. In order to determine the datum bias between national and DEMs' datum, one parameter model was tried. Results show that ASTER DEM (2.41 m) has absolutely larger datum bias than SRTM DEM (-1.48 m).

On the other hand DEMs are compared with each other. Minimum and maximum of the differences at grid node are -31.84 and 11.29 m, respectively. This statistic shows that there is no large difference between ASTER and SRTM DEMs.

4.2 Prediction of Mean Gravity Anomalies

Our gridding scheme of gravity anomalies can be described as follows: The gravity observations distributed randomly were directly reduced to the simple Bouguer gravity anomalies. Then, Bouguer gravity anomalies were interpolated to grid nodes by using the nearest neighbouring technique. During interpolation process the maximum interpolation radius was 12 arc-minutes and also the minimum and maximum number of the points for every grid point was chosen 2 and 4, respectively. Finally free-air gravity anomalies in grid nodes (0.02*0.02 arc-degree resolution) were retrieved from simple Bouguer anomalies by restoring the mean Bouguer plate effects.

The gridding strategy mentioned above was conducted by using each DEMs in the mean Bouguer plate effects. Then results are compared with each other. Minimum and maximum of free-air anomaly differences between SRTM and ASTER DEMs are 3.564 and 1.263 mGal, respectively. Geographical distribution of the differences among the models is depicted in Fig. 2. According to the figure, differences are mainly increased with respect to topography as well as direction of the satellite Terra in some part of study area.

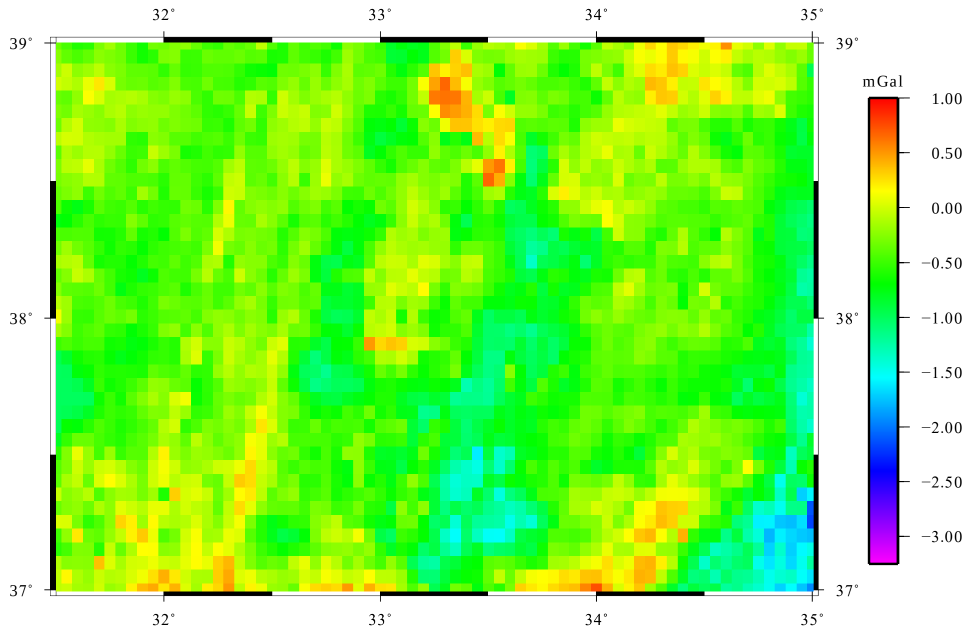

Figure 2: Anomaly Differences between ASTER and SRTM

5. CONCLUSION AND SUGGESTION

In this study the two independents SRTM and ASTER DEMs are tested by using levelled control points in Konya Closed Basin in the central Turkey. Numerical results show that ASTER DEM is slightly worse than SRTM DEM in test area according to our levelling points. Additionally differences between SRTM and ASTER DEM in the prediction of the mean gravity anomaly are ranging from -3.563 to 1.264 mGal, which should be considered in geoid modelling studies. Consequently, it is suggested that ASTER and SRTM should be compared before they are used in any project. Particularly, in areas where SRTM DEM is not available, ASTER DEM can be used in geoid determination.

ACKNOWLEDGEMENT

This study is supported by the Coordinatorship of Scientific Research Projects of Selcuk University (Project Nr. 17401084).

REFERENCES

Abbak RA (2014) Effect of ASTER DEM on the prediction of mean gravity anomalies: a case study over the Auvergne test region, Acta Geod Geophys, 49:491–502.

Abbak RA, Sjoberg LE, Ellmann A, Ustun A (2012) A precise gravimetric geoid model in mountainous areas with scarce gravity data – a case study in Central Turkey. Studia Geophysica et Geodaetica 56:909–927.

Kiamehr R, Sjöberg LE (2005) Effect of the SRTM DEM on the determination of high-resolution geoid model: a case study in Iran, Journal of Geodesy, 79:540–551.

Merry CL (2003) DEM-induced errors in developing a quasi-geoid model for Africa, Journal of Geodesy, 77:537–542.

URL 1: https://www2.jpl.nasa.gov/srtm/

URL 2: http://www.jspacesystems.or.jp/ersdac/GDEM/E/

CONTACTS

Doç.Dr. Ramazan Alpay ABBAK
Selcuk University Engineering Faculty
Kampus Selcuklu
Konya
TURKEY
Tel. +90 332 223 1898
Email: aabbak@selcuk.edu.tr

Prof.Dr. Ibrahim Oztug BILDIRICI
Selcuk University Engineering Faculty
Kampus Selcuklu
Konya
TURKEY
Tel. +90 533 4671074
Email: bildirici@selcuk.edu.tr
Web site: http://www.iobildirici.com