Comparisons of Global Geopotential Models with Terrestrial Gravity Field Data Over *Santiago del Estero* Region, NW: Argentine

42

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Abstract

The recent improvements in satellite tracking data processing, the availability of new surface gravity data sets, and the availability of a new mean sea surface height model from altimetry processing gave rise to the generation of several new global gravity field models. However, to know their potentiality for using in practical situations, we understood that it was necessary their applications in a limited regions. This paper we compare recent geopotential models with gravimetric data over leveling points of Argentinean National Geografhical Institute (ANGI) vertical network in *Santiago del Estero* region, northwestern Argentine. We have highlighted the most important information, we have established the future expectations to continue with such applications. Results of comparisons are presented.

42.1 Introduction

The development diverse Global Geopotential Models (GGM) occurred in the last decades have shown successive increase in the spatial resolution and accuracy. These improvements have been due essentially to the incorporation of better quality data coming from diverse sources for all the Earth. In order to evaluate what of these released models is the well adapted one for the *Santiago del Estero* region, a set of recent GGM have been compared. In this first stage of work, the Free-Air Gravity Anomalies (FAGA) extracted of models EIGEN-05C, GGM03C and EGM2008, everyone developed up to degree and order 360, and EGM2008 complete development up to degree 2190 and order 2159. These GGM were compared with the calculated FAGA from measures of gravity carried out by ANGI. (Amos and Featherstone 2005, 2006). This comparison has been realized on points ANGI. The GRS used is WGS 84. The tide_system used is free_tide. In order to determine the model that better adjusts to the region we used a series of statistical on the resulting residuals, such as: minimums (MIN), maximums (MAX), average (AVER) and root mean square (RMS). The RMS is adopted to evaluate the GGM that better adjustment to the terrestrial data. Consequently the GGM that presents the smaller RMS as a result of the contrast with the terrestrial data is the one that better adjusts to the region.

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Table 42.1 Global geopotential models

Model	Year	Degree	Data	Reference
GGM03C	2009	360	S (Grace), G, A	Tapley et al. (2007)
EIGEN-5C	2008	360	S (Grace, Lageos), G, A	Förste et al. (2008)
EGM2008	2008	2190	S (Grace), G, A	Pavlis et al. (2008)
EGM2008	2008	360	S (Grace), G, A	Pavlis et al. (2008)

42.2 Description and Results

The zone of study has been defined between −25° to −30° latitude and −60.5° to −65.5° longitude. It corresponds approximately with the territory of the province of *Santiago del Estero*, Northwest of Argentine. The adopted Global Geopotential Models for the present study appear in Table 42.1. These Models are derived from the combination of satellite data (S), observations of terrestrial gravity (G) and satellite altimetry data (A). In Table 42.1 they specify the year of liberation, the Degree of harmonic coefficients, the origin of the data, and the reference.

GGM03C Model released in 2009 is sustained by the previous GGM02 model that is based on the analysis of data coming from 363 observation days of the mission GRACE, from April 4th, 2002 until December 31th, 2003. It is developed up to degree and order 360 and incorporates gravity and altimetry data. The model EIGENGL-05C was released in September 29th, 2008. It is developed up to degree and order 360. It is base in a combination of data from the mission GRACE and LAGEOS (January 2002–December 2006), gravimetric data 0.5 × 0.5 degrees and altimetry data. Its, space resolution is about 55 km on the terrestrial surface. EGM2008 Model has been released by the National Geospatial-Intelligence Agency (NGA). This gravitational model is complete for degree and order 2159 and contains additional coefficients up to the degree 2190 and order 2159.

750 land gravity data performed by ANGI over 19 leveling lines have been used for the present work over *Santiago del Estero* region. The gravity measures were obtained on 741 normal benchmark (BMK) and 9 nodal ones of the High Precision Leveling Network for the province. The BMK have geocentric latitude and longitude in WGS84 system with variable accuracy. The values of gravity are referred IGSN71 system. (ANGI 1979, 1983).

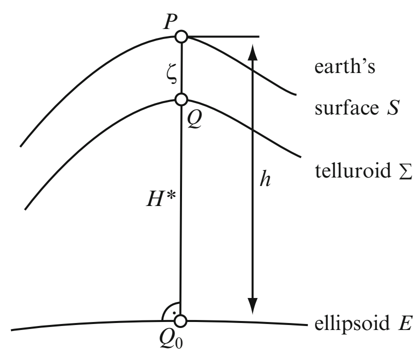

Fig. 42.1 Telluroid, ellipsoid and earth surface. (Hofmann-Wellenhof and Moris 2006)

There is no adequate information about ellipsoidal height for the BMK for that reason is realized the comparison on gravimetric anomalies (Del Cogliano 2006).

Free air gravity anomalies have calculated for terrestrial gravity data using the equation in the context of Molodensky's theory (Hofmann-Wellenhof and Moris 2006; Heiskanen and Moritz 1967; Zakatov 1997):

$$\Delta g = g_P - \gamma_Q \tag{42.1}$$

Where Δg is the free – air gravity anomalies, g_P is the gravity observed in the terrestrial surface and γ_Q is the normal gravity in the telluroid. See Fig. 42.1.

The equations (42.2), (42.3), (42.4) and (42.5) and parameters (Table 42.2) used for the calculation of γ_Q are (Hofmann-Wellenhof & Moris 2006; Heiskanen and Moritz 1967; Zakatov 1997):

$$\gamma_Q = \gamma - 2\gamma_a/a[1 + f + m + (-3f + 5/2m)\sin^2\varphi]h + 3\gamma_a/a^2h^2 \tag{42.2}$$

$$\gamma = \gamma_a(1 + f^*\sin^2\varphi - 1/4f_4\,\sin^2 2\varphi) \tag{42.3}$$

Table 42.2 Parameters and derived constants of the WGS84 (Hofmann-Wellenhof and Moris 2006)

WGS 84 Parameter	Description	Value
a	Semimajor axis of the ellipsoid	6378137 m
b	Semiminor axis of the ellipsoid	6356752.3142 m
f	Flattening of the ellipsoid	1/298.25722356
GM	Geocentric gravitational constant of the earth (including the atmosphere)	3986004.418 10^8 m^3seg^{-2}
γ_a	Normal gravity at the ecuator	9.780325336 m^2seg^{-2}
γ_b	Normal gravity at the pole	9.832184938 m^2seg^{-2}
M	Mass of the earth (includes atmosphere)	5.9733328,10^{24}kg
m	$m = \omega^2a^2b/(GM)$	0.003449787

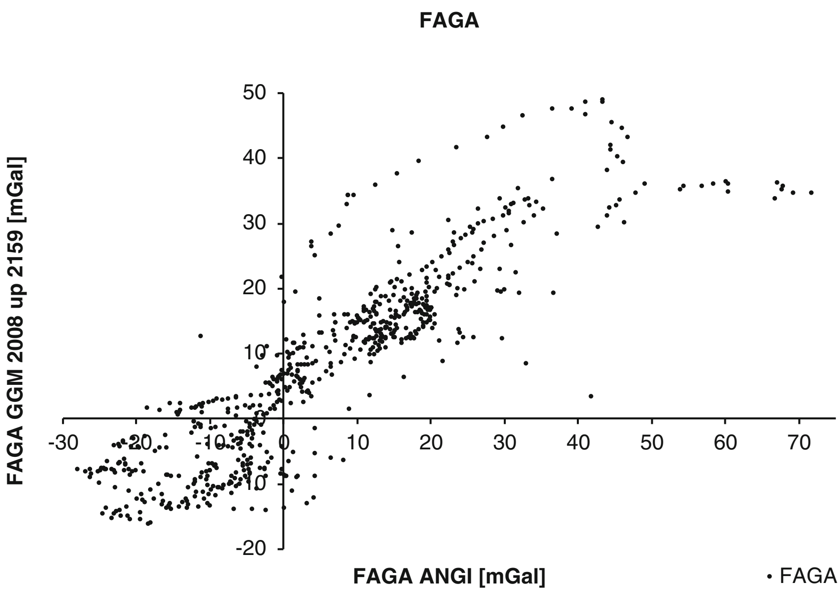

Fig. 42.2 Correlation of the free-air anomalies with height for *Santiago del Estero* region

$$f^* = (\gamma_b - \gamma_a)/\gamma_a \quad (42.4)$$

$$f_4 = -1/2f^2 + 5/2fm \quad (42.5)$$

On the other hand free – air gravity anomalies of each one of the GGM specified more above (Table 42.1) for the zone of study have been determined. From the comparison of the values of FAGA between the GGM and Argentinean National Geographical Institute points, the residuals for the points of leveling of the ANGI have been obtained (42.6).

$$\Delta g_{RES} = \Delta g_{ANGI} - \Delta g_{GGM} \quad (42.6)$$

Where Δg_{RES} is the free – air gravity anomalies residual, Δg_{ANGI} is ANGI points free – air gravity anomalies and Δg_{GGM} is GGM free – air gravity anomalies.

The statistics are in Table 42.3.

It is possible to be observed that EGM2008 model presents the smaller RMS of 8.996 mGal reason why is inferred that this model presents the best adjustment for the zone of study. A good general correlation in both magnitudes can be observed, with greater emphasis in the positive anomalies (Fig. 42.2). The dispersion of the magnitudes is greater in correspondence with the major heights of the region.

Two leveling lines are emphasized in the analysis because their different behavior: the line 313 is comprised between the points number 720 and 760 and the line 180 between the points 1 and 57. Their graphic representation related to heights ANGI, the gravimetric anomalies and the resulting residuals are in the Fig. 42.3 (Introcaso, 1997, 2006).

The line 313 is characterized to present mean sea level heights between 150 and 220 m (Fig. 42.3a). The variation of the gravimetric anomaly of the terrestrial data is in agreement to this variation the anomaly of the model (Fig. 42.3b). The FAGA residuals present low values pointing out a good adjustment between ANGI data and EGM2008 (Fig. 42.3c). The magnitude of the residuals are in the interval ±5 mGal. This line has a main directorate from the north-west to south-east in the North zone of the province. It is characterized for being a plain with slopes in the same direction. On the other hand the line 180 is characterized by a strong variation in height, with values between 110 and 630 m (Fig. 42.3d). It is possible to emphasize that the variation of the gravimetric anomaly of the terrestrial data is in agreement to this variation whereas the anomaly of the model presents a smoothed curve (Fig. 42.3e). The residuals take values from 40 to −10 mGal, where the bigger values are in correspondence with the bigger heights (Fig. 42.3f). This line is developed between the mountain ranges of Sumampa and Ambargasta to the south of the province with a North-South direction. FAGA and residuals are shown in Fig. 42.4a, b (Corchete & Pacino 2007).

Figure 42.4a shows free air gravimetric isoanomalies curves of EGM2008 up 2190 model over an image SRTM 90 m of the territory of the province (Galván et al. 2009). It could be observed that in the south of the province the anomalies grow in

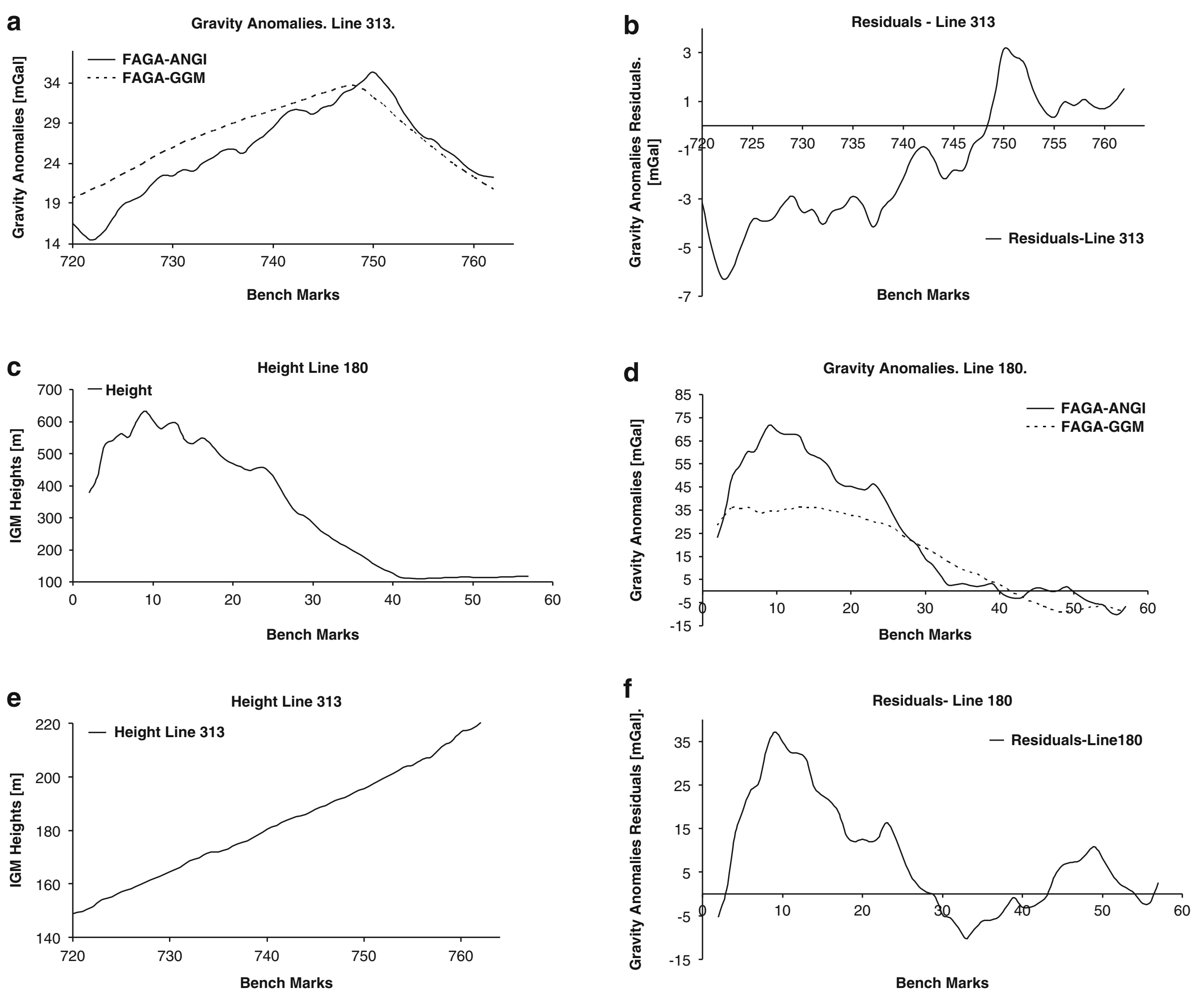

Fig. 42.3 Heights (**a**, **d**), AAL (**b**, **e**) and Residuals (**c**, **f**) of Leveling Lines 313 and 180 for *Santiago del Estero* region

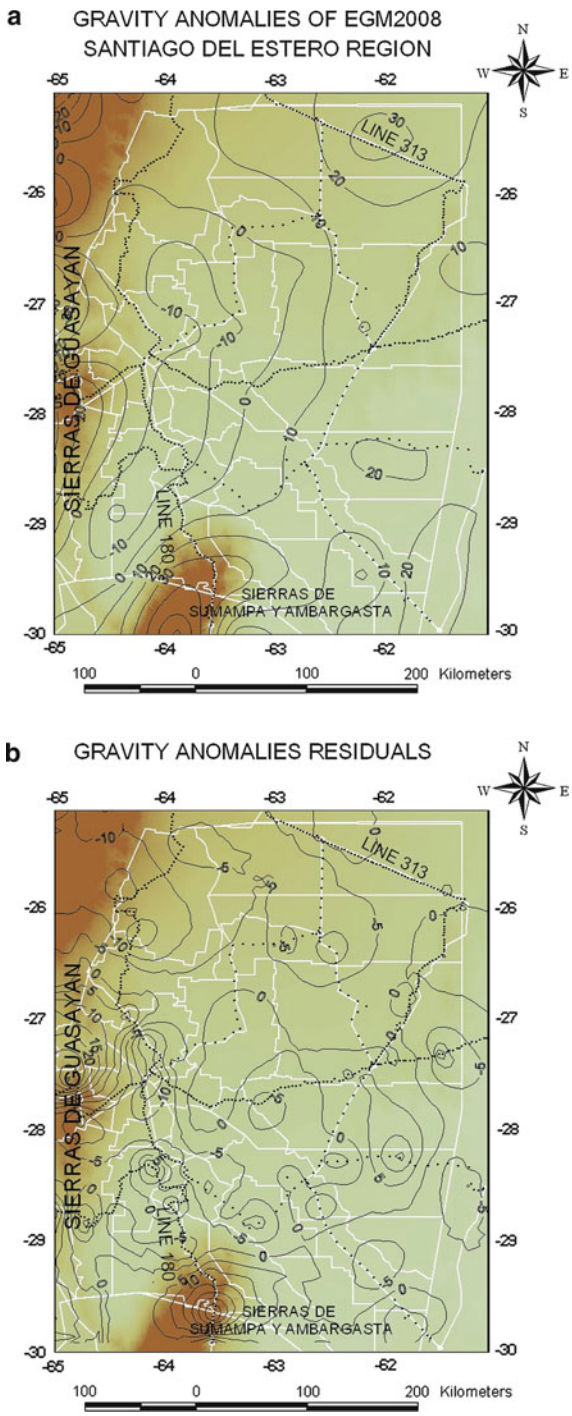

Fig. 42.4 Map of Gravity Anomalies (FAGA) (**a**) and Map of Gravity Anomalies Residuals of EGM2008 up 2190 Model (**b**) for *Santiago del Estero* region

Table 42.3 Statistical comparisons between FAGA residuals of GGM and terrestrial data

MODEL	MAX (mGal)	MIN (mGal)	MEAN (mGal)	RMS (mGal)
GGM03C	43,747	−24,856	−3,024	9,884
EIGEN-GL05C	44,783	−24,511	−2,396	9,403
EGM2008	38,443	−25,379	−2,322	8,996
EGM 2008 up to 360	45,202	−24,649	−2,647	9,303

agreement with the Mountain ranges of Ambargasta and Sumampa and in the west agrees with the Mountain ranges of Guasayán. The rest of the territory characterizes by a surface with general slope in sense the north-west to south-east. In this sector the curves of isoanomalies take positive and negative values. Also the lines of leveling of the ANGI are represented by sequence of points.

Figure 42.4b shows space distribution of the differences between the FAGA of the EGM2008up2190 model with the terrestrial data. It is possible to be observed that in ample zones of the territory small residues of the order of ±5 mGal appear. The highest residues are positioned in the zones of mountainous areas already-mentioned and they coincidence with the majors values of anomalies.

Conclusions

The results of comparisons of recent selected GGM in the present work (EIGEN-GL05C, GGM03C and EGM2008 upto 360 and EGM2008 complete) with terrestrial gravity data of ANGI show the EGM2008 upto 2190 model presents the better fits to the investigated region. For the comparison free air gravity anomalies calculated in 750 ANGI points and data of free air gravity anomaly of each one of the models have been used. They were calculated the respective residuals for each GGM. The small mean residuals (−2.322 mGal) and RMS were found for the EGM2008 model. Last model is the one that has been used for the space analysis. Two zones with high residual values of FAGA have been detected that correspond with the mountain ranges of Sumampa and Ambargasta to the south and the mountain range of Guasayán to the west of the province.

The rest of the territory presents FAGA residuals in the range of about ±5 [mGal].

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To Cristina Pacino by the original idea.

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