The continuous data improvement for Quasi-geoid estimation in South America

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Abstract. A report on geoid computations in South America, based on the existing gravity data base collected in the framework of the South America Gravity Project (SAGP) is presented. Two estimation methods will be described. One of these is the standard "remove-restore" technique. The gridding of the residual gravity values (i.e. free air gravity anomalies minus the global geopotential model and the terrain effects) has been performed using, with some refinements, the GEOGRID program of the GRAVSOFT package (Tscherning et al., 1994) and the residual quasi-geoid signal has been evaluated through the 1D FFT approach (Haagmans et al., 1993) which allows a fast and rigorous computation of this component.
The second approach is based on 1D FFT method applied on mean Helmert's gravity anomalies, having removed the low frequency components using EGM96 model up to degree 50.

Keywords.
Geoid, gravity data, South America

1 Introduction

Geoid computations over large continental areas, aiming at refining the global geopotential model implied undulations, are nowadays one of the most important tasks in Geodesy.

This can be done in a fast 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, so avoiding subareas computation and patching of subsolutions.

Furthermore, accurate global geopotential models (e.g EGM96) and, over some regions, detailed DTM allow an effective reduction of the gravity data, thus implying an optimal application of the "remove-restore" procedure.

Continental geoid solution have been computed in such a way in Europe, USA and Canada, leading to high precision estimates of the geoid undulation which, as it is well known, is needed in connection to GPS to derive orthometric heights.

The similar approach is presented here for quasi-geoid computation in South America. The main difference with the previously mentioned examples is the coverage and the quality of the gravity data.

In South America there are large unsurveyed areas; hence, large data gaps are present in the data base, implying unreliable geoid solutions over those areas.

Furthermore, the existing data have been collected from many different sources over a large time span. So, different quality of the data and.also possible data inconsistency are to be expected. Thus, a relevant effort must be done in collecting and in homogenizing the gravity data base in this particular area of the world. A decisive step forward in this direction has been accomplished in the last ten years with the SAGP project (Green and Fairhead, 1991). In the framework of this project, gravity data in South America have been collected to form a data base consisting at the moment of 291866 gravity points on land.

Argentina (IFIR, IGM, UNLP), Uruguay (SGM), Ecuador, Paraguay (DSGM), Venezuela (LUZ, IGVSB), Chile (IGM), Colombia (IAC), Brazil (with the Anglo-Brazilian Gravity Project) contributed in forming such valuable gravity data set in a initiative of SCGGSA (Sub-commission of the Geoid and Gravity in South America).

The quasi geoid computation which is presented in this paper took also benefit from a new DTM that NIMA has prepared over South America as well as new topographic maps digitised. This has great improved the quality fo the existing height data base.

Using the collected gravity data, the above mentioned DTM and the EGM96 global geopotential model, new estimates of the South America quasi-geoid have been computed based on a cooperation among NIMA, IGeS and EPUSP and they will be soon distributed, through the IGeS website, to the geodetic community.

These are new refined estimates (following preliminary geoid computations made at EPUSP; Blitzkow, 1999) which, we hope, will be used as a common reference field for local quasi-geoid computations/comparisons in South America.

2 The quasi-geoid computation procedures

The gravity data coverage is presented in fig. 1

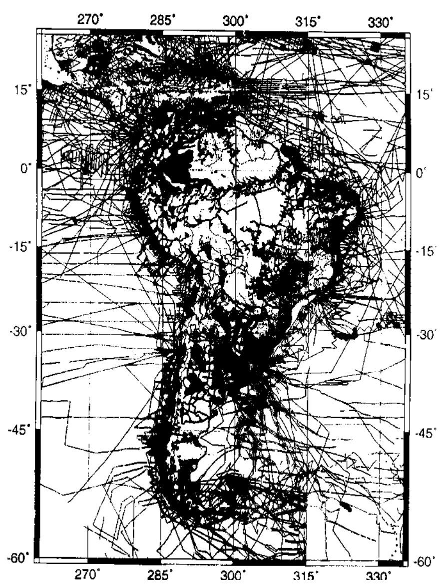

Fig. 1 Gravity data distribution

As one can see, relevant gaps are present in large areas, mainly in the Amazonian forest, where we probably computed biased geoid undulations.

The remove step was based on the EGM96 geopotential model (Lemoine et al., 1998), that we used up to degree 360, and on a 30”×30” DTM which was assembled at NIMA. The gravity model component as well as the Residual Terrain Correction (RTC) gravity effect were computed pointwise at DTM derived elevations. Particularly, the RTC effect was evaluated using the TC software (GRAVSOFT package) (Tscherning et al., 1994). The reference DTM has been obtained by means of a moving average applied to the detailed one with a cap size of 30’ and a sampling rate of 10’ both in latitude and longitude.

RTC effect was calculated using two grids: the detailed one (30”×30”) up to 22 km from the computation point and a coarser grid (5’×5’) from 22 km to 220 km (the 5’×5’ DTM was derived by averaging the 30”×30” DTM).

Point residual gravity data, were then gridded using the GEOGRID software (GRAVSOFT package). For computing the quasi-geoid estimate, we selected a 5'x5' resolution grid covering the area $-60 \leq \varphi \leq 15$; $-85 \leq \lambda \leq -30$. Although it seems quite an ambitious target, the 5'x5' grid probably have a reasonable resolution at least in those areas where we have a good data coverage and where we can expect to have reliable estimates.

The gridding procedure that was adopted was based on the collocation option of GEOGRID and was improved using a local tuning of the covariance function parameters.

For each grid point, residual gravity values have been selected up to a distance of one degree and an empirical covariance has been estimated. On such an estimate, model covariance function parameters used in the prediction have been set up. Hence, each gridded value has been predicted using a covariance which reflects the local features of the residual gravity field. The plot of the gridded residual gravity field Δg_r^G and the associated prediction error are plotted in fig.2 and fig. 3 respectively ; statistics of the Δg_r^G are listed in the table 1.

As one can see, the accuracy plot reflects only partially the plot of the coverage; the worst accuracies are reached along the Andes probably due to the combination of poor data coverage and roughness of the gravity field.

Table 1. Statistics of the gravity residuals Δg_r^G

#	Average	σ	min	max
594000	0.46	13.58	-351.40	647.30

The residual quasi-geoid component ζ_r has been evaluated using 1D FFT technique(Haagmans et al., 1993), implemented in the FFTGEOID software by M. Sideris (Sideris, 1994): integration cap has been fixed to 1.5 degree.

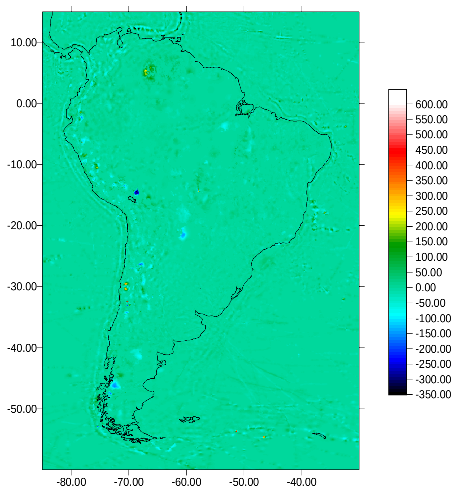

Fig. 2 Residual gravity data Δg_r^G (mGal)

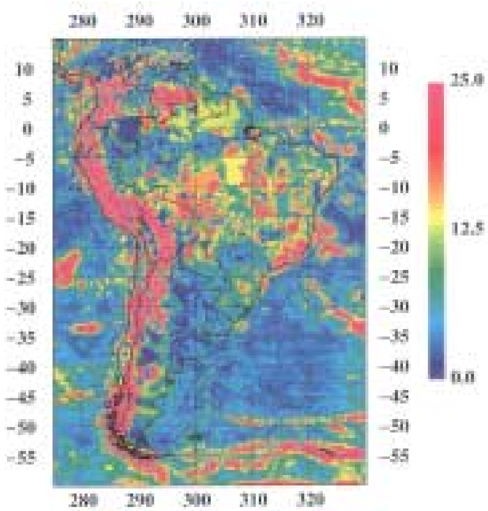

Fig. 3 Prediction error of the gridded residual gravity field data Δg_r^G (mGal)

The statistics of the 5'x5' ζ_r are presented in table. 2 while the plot of the values is shown in fig. 4.

As expected, high frequency pattern in Δg_r^G (see fig. 2) are spread on a larger area in terms of ζ_r: a careful outliers rejection will be performed in the near future to avoid such effects, probably connected to outliers or inconsistency in the gravity data.

Table 2. Statistics of the quasi-geoid residuals ζ_r

#	Average	σ	min	Max
594000	0.09	0.76	-12.52	13.38

The total quasi-geoid estimate is plotted in fig. 5

The values have been obtained through the "restore" step using the TC program for the RTC component and the EGM96 model up to degree 360 for the long wavelength part. Computation of ζ_{rtc} and ζ_M have been carried out on the 5'x5' prediction grid at DTM derived elevations. Heights for each grid knot have been estimated via bilinear interpolation on the 30"x30" high resolution DTM used in the RTC effect computation.

Statistics of the total quasi-geoid values are in tab. 3.

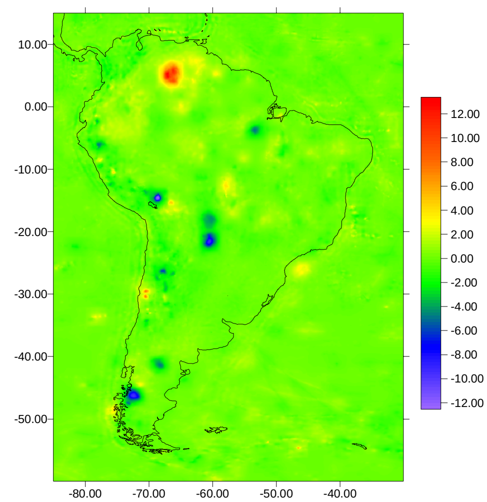

Fig. 4 Quasi-geoid residuals ζ_r (m)

Table 3. Statistics of the quasi-geoid ζ

#	Average	σ	min	max
594000	1.90	16.86	-58.155	50.94

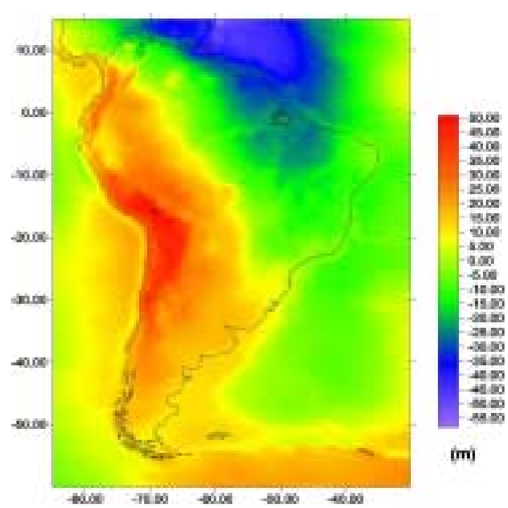

Fig. 5 Quasi-geoid undulation ζ (m)

A parallel computation has been also carried out at EPUSP. The point gravity data available at GETECH have been processed in order to derive 5' mean free air and Bouguer gravity anomalies. A grid of 10' mean values has been derived from 5'. A digital terrain model of 3' (DTM3) has been used to derive mean heights for the 10' grid; the terrain correction has been estimated using the DTM3 grid and then averaged to 10’. The quasi-geoid solution has been computed on the 10’ grid using mean Helmert's gravity anomaly and 1D FFT with an integration cap of 4°. The long wavelength component has been removed and restored using EGM96 geopotential model up to degree and order 50. The quasi-geoid obtained following this procedure is shown in fig.6.

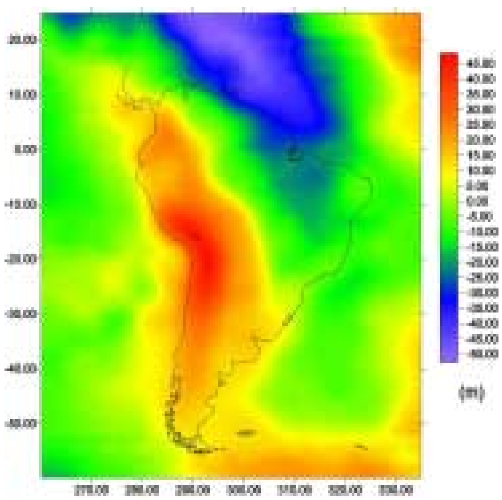

Fig. 6 Quasi-geoid undulation ζ (m) computed by EPUSP.

3 Conclusions and future perspectives

These refined preliminary geoid estimates over the area covering South America have been computed using the existing gravity data bases, following different approaches.

These solutions must be considered a first step in continuous effort for future computations both of global and local type, i.e. for computations on the whole South America continent and for estimates covering only limited areas.

Comparisons between these will probably give a deeper insight in the problems that we have pointed out in this paper.

Furthermore, comparisons with GPS derived undulations, obtained in the framework of the SIRGAS project, will be carried out, to asses the accuracy of the two solutions.

Key points for improved estimates will be a new careful outliers rejection, based on collocation, and a better data coverage which will be achieved due to the remarkable ongoing efforts of the Sub-Commission for Gravity and Geoid in South America (SCGGSA).

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