Activities in South America: Gravity and Geoid Projects

Segundo Taller de Grupo de Trabajo I
SIRGAS

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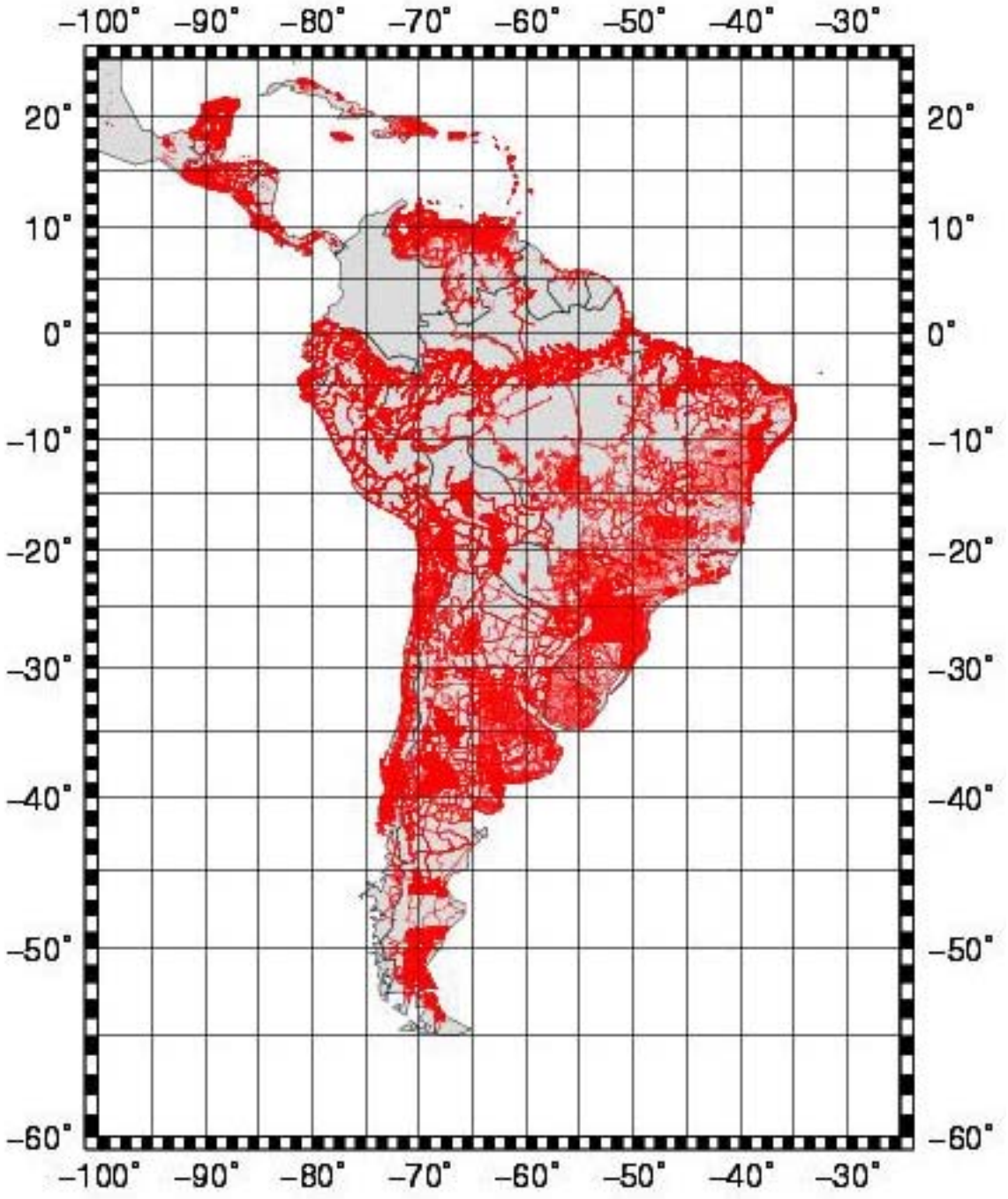
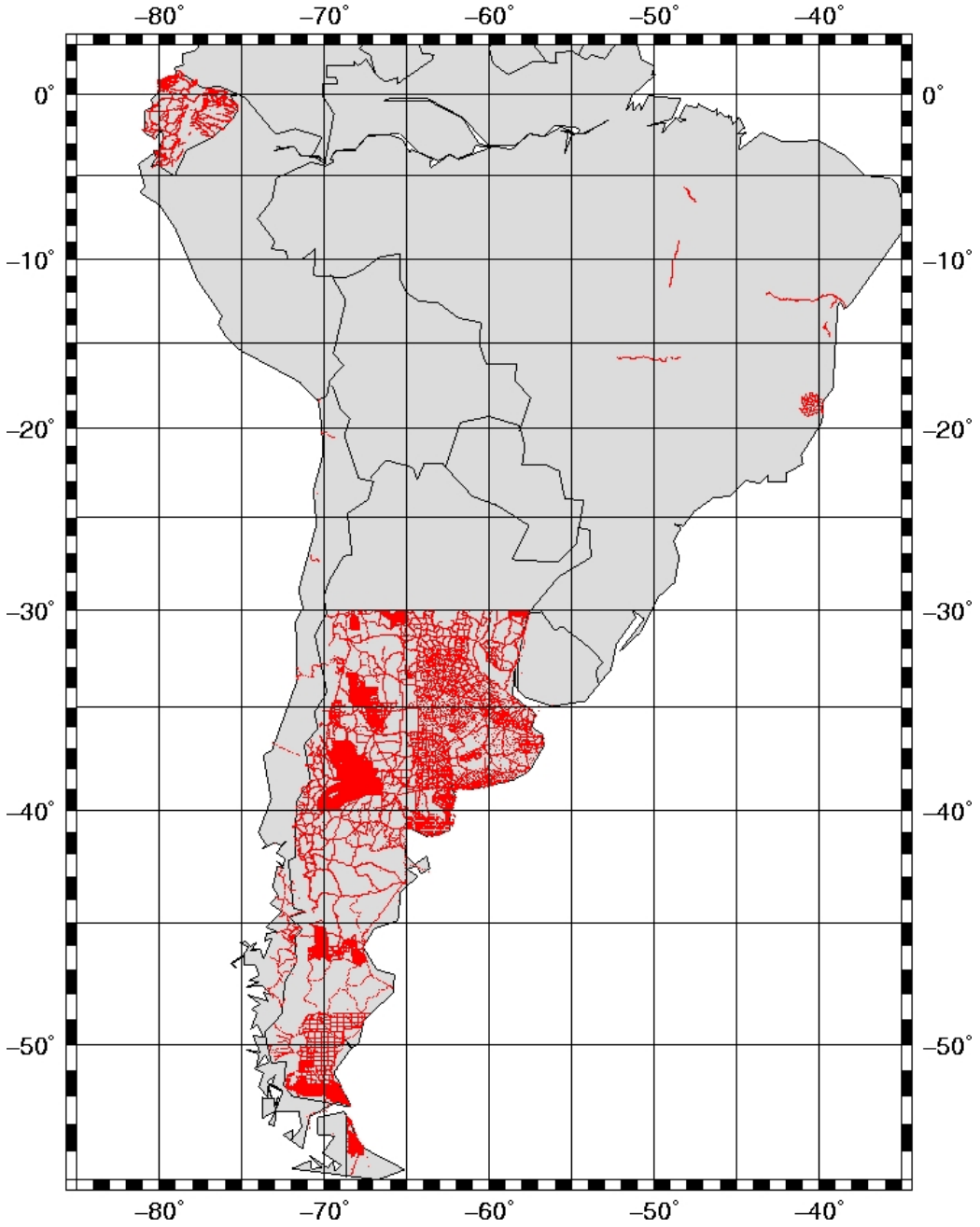


Last 16 years: concentrated efforts to encrease the gravity data distribution and to validate the existing data in the countries of South America. Presently a total of 849,363 gravity points data are available.

Terrestrial Gravity

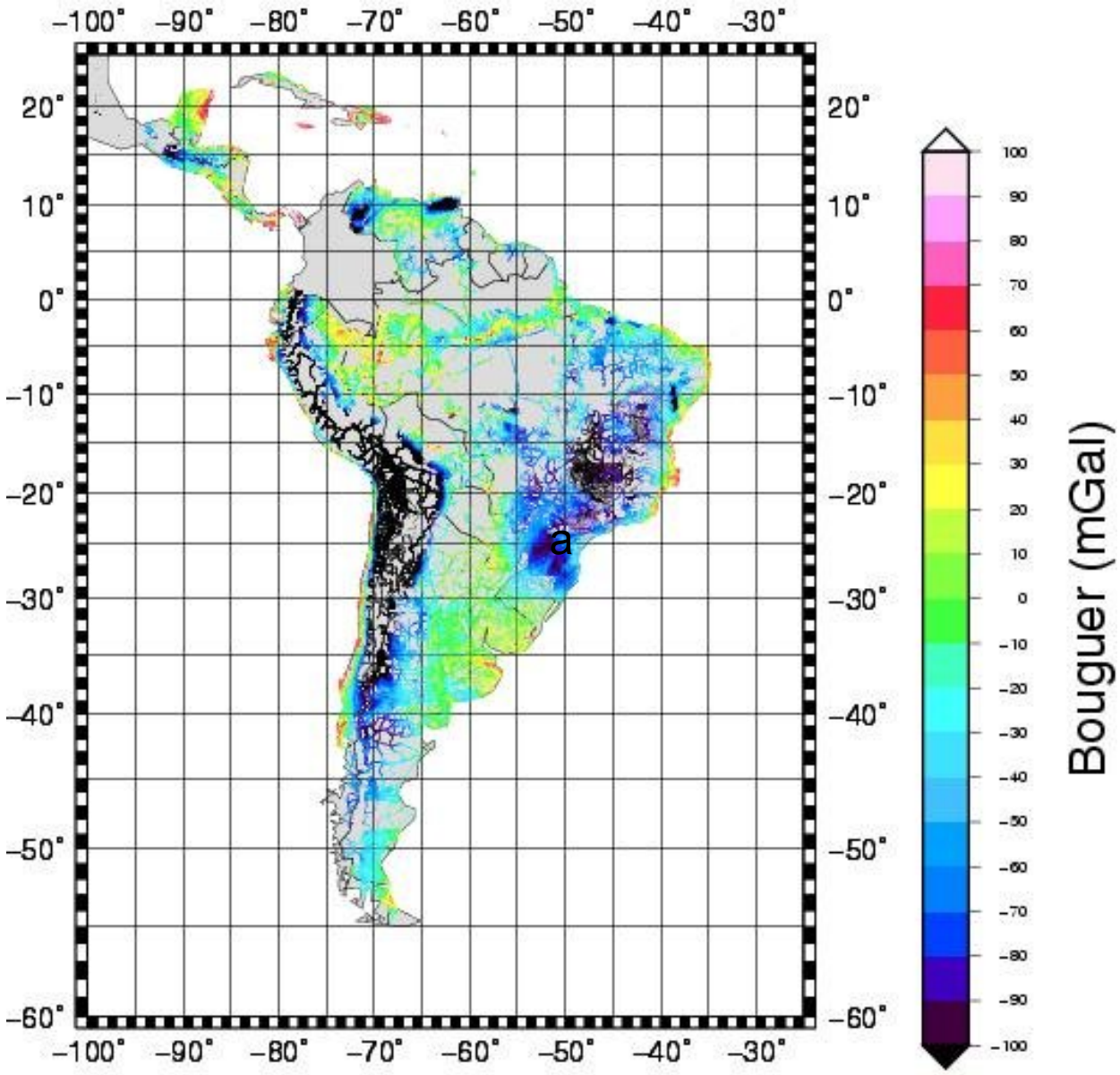


Updated effort in the last year

Brazil	582 points
Argentina	95,948 points (new + old data validated)
Chile	616 points
Ecuador	10,946 points (new + old data validated)

Complete Bouguer Anomaly

Software SHGEO – developed at the University of New Brunswick. Available to EPUSP and IBGE through the Project PIGN (Projeto de Infraestrutura Geodésica Nacional).



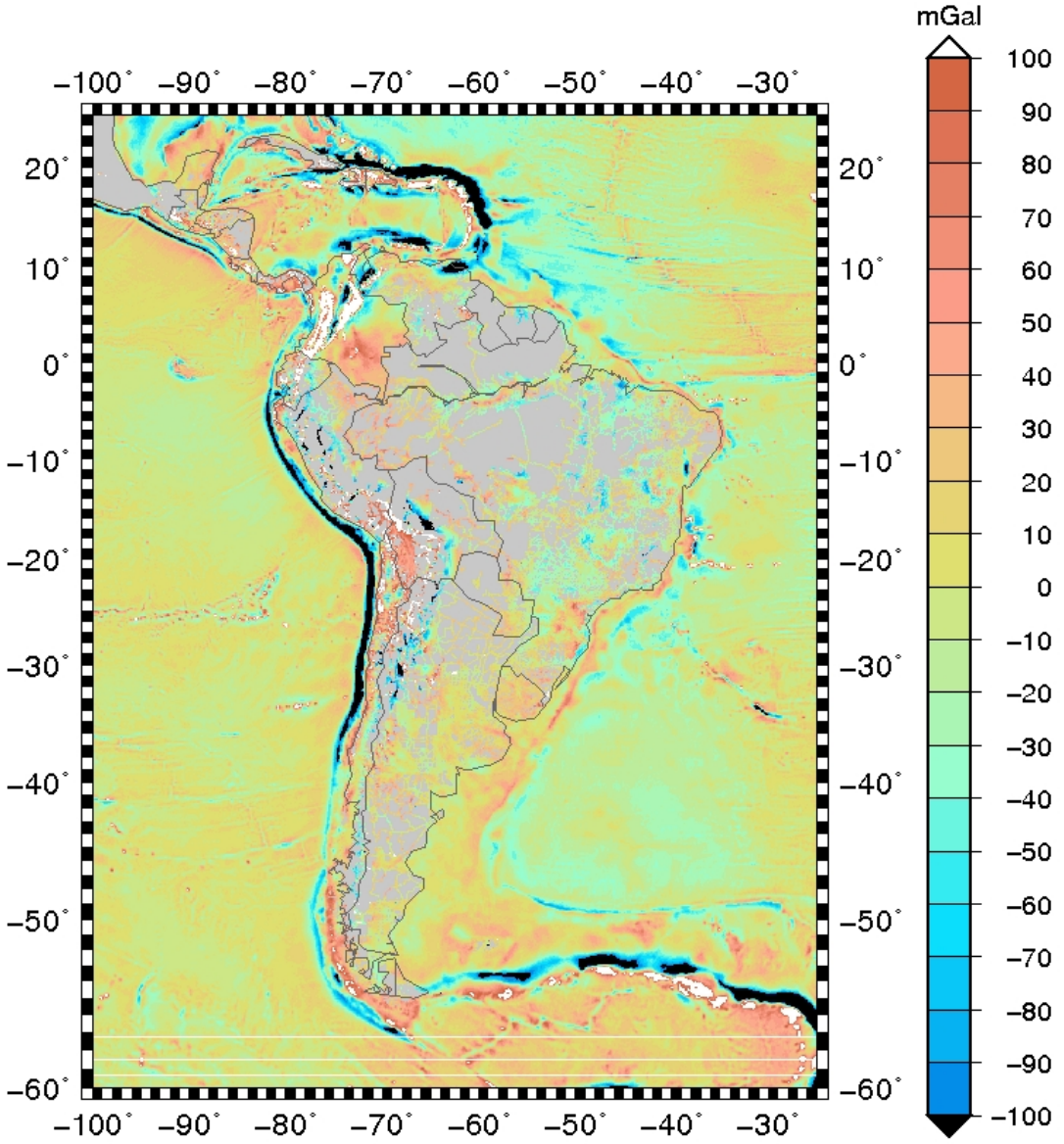
Helmert gravity anomaly grid: 5´x 5´

Helmert gravity anomaly grid of 5’ x 5’ in the continental area.

Brazil - gravity data base from IBGE, Petrobras and other organizations.

Other countries - military and civil organizations.

Ocean area: KMS2002



Digital Terrain Model (DTM)

Using topographic maps digitised in Brazil, Uruguay and Argentina, bathimetric data in the coast of Brazil and Argentina and the analysis of the SRTM (Shuttle Recovery Topography Mission) data, 11 DTMs were created in South America. The two most important, SAM_3sv1 and SAM_3sv2.

Height Discrepancies analysis of SRTM with respect to Bench Marks (BM)

Objective

Looking to the existing discrepancies between SRTM and BM, they are originated from possible errors in the BM coordinates or in the reliability of SRTM in some specific areas.

Institutes involved

Brazil - Instituto Brasileiro de Estatística e Geografia (IBGE)
Argentina, Chile and Ecuador - respective military geographic institutes (IGM)

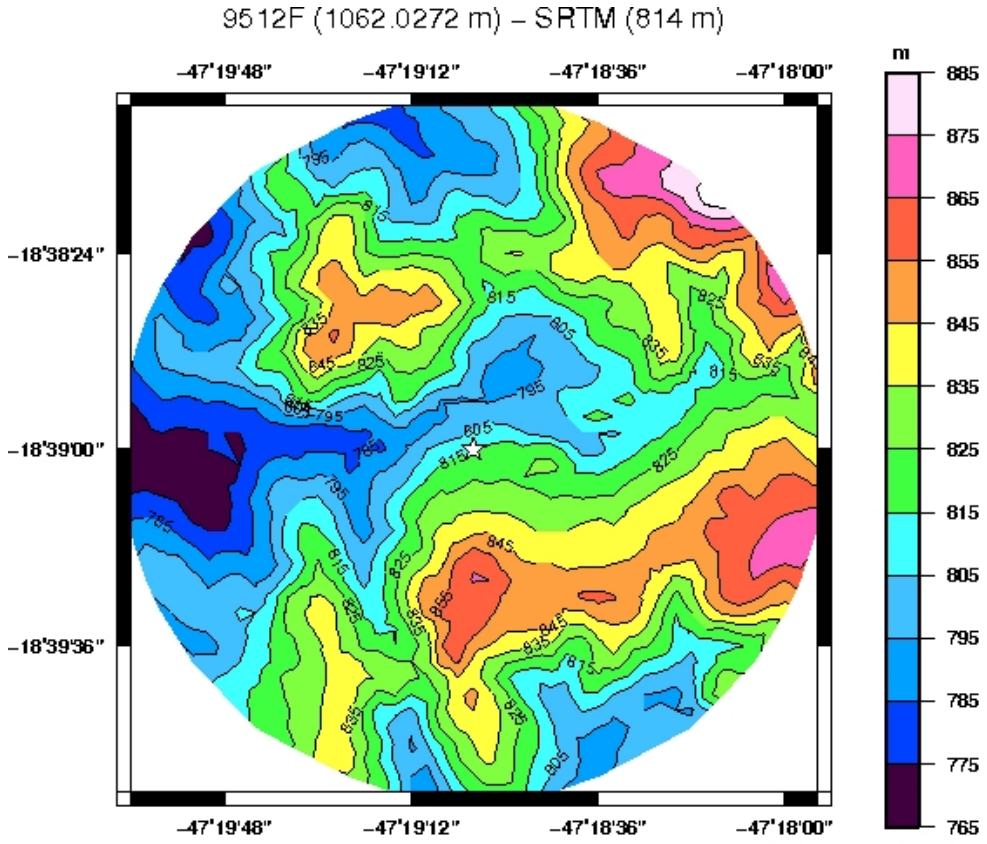
SRTM used: SRTM3 version 2 with resolution of 3".
Bilinear interpolation to derive the coordinates at the BM.

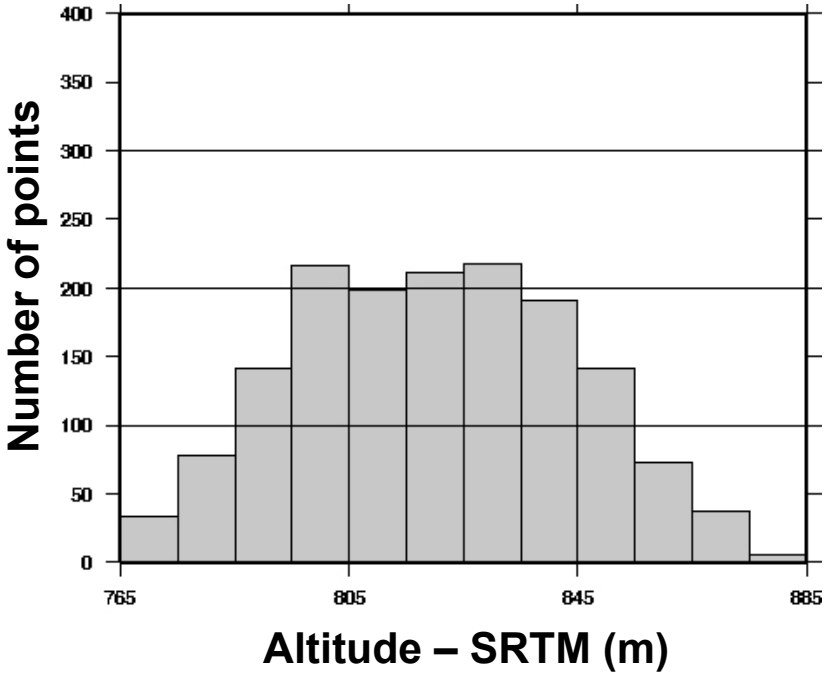
SRTM validation through the use of BMs

	N. points	|Δ|≤10m %	10m<|Δ|≤20m %	20m<|Δ|≤30m %	30m<|Δ|≤40m %	|Δ|≤50m %	|Δ|>50m %	N. of BM bads (total) – (real)
IBGE-Brazil	63,585	67.2	14.55	6.35	3.66	2.21	6.03	(3,837) – (708)
IGM-ARG	13,723	75.31	9.31	4.18	2.13	1.47	7.6	(1,043) - (502)
IGM-Chile	1,081	68.55	20.17	4.53	2.13	1.2	3.42	(37) - (9)
IGM-Ecuador	432	64.35	15.05	8.80	3.01	1.85	6.94	(30) – (12)

Analysis of the SRTM heights around 1’ of the BMs

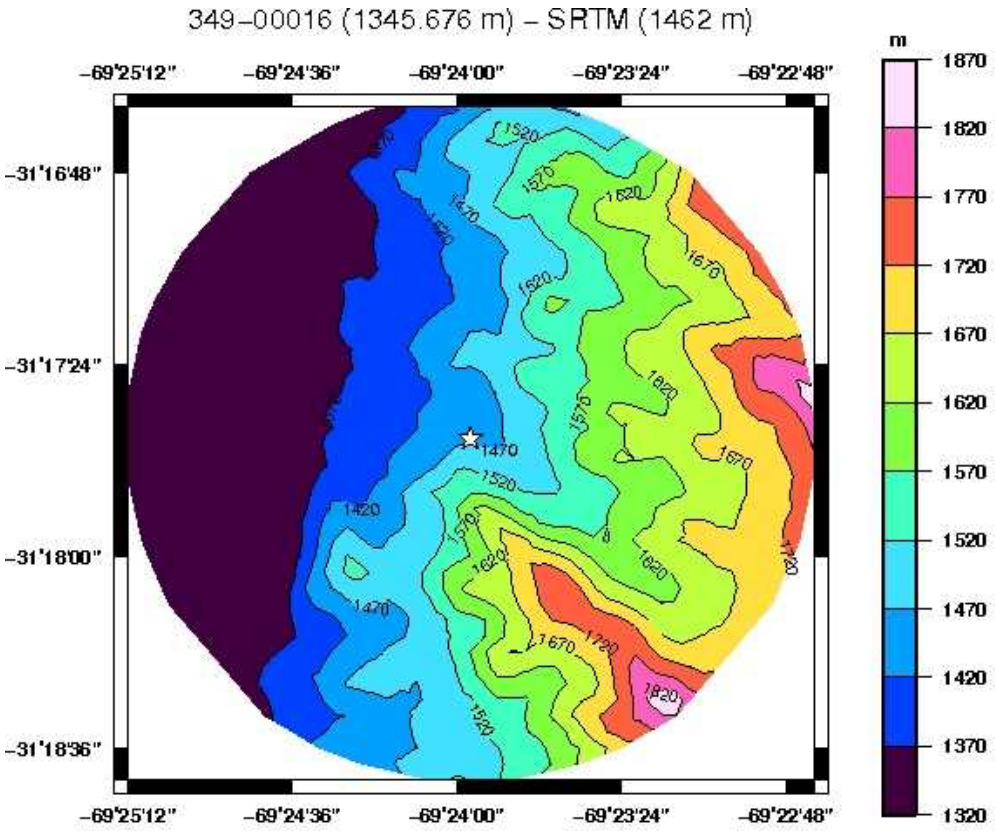
BM 9512F: no similar value of the BM inside a circle of 1’ radius in the SRTM data.

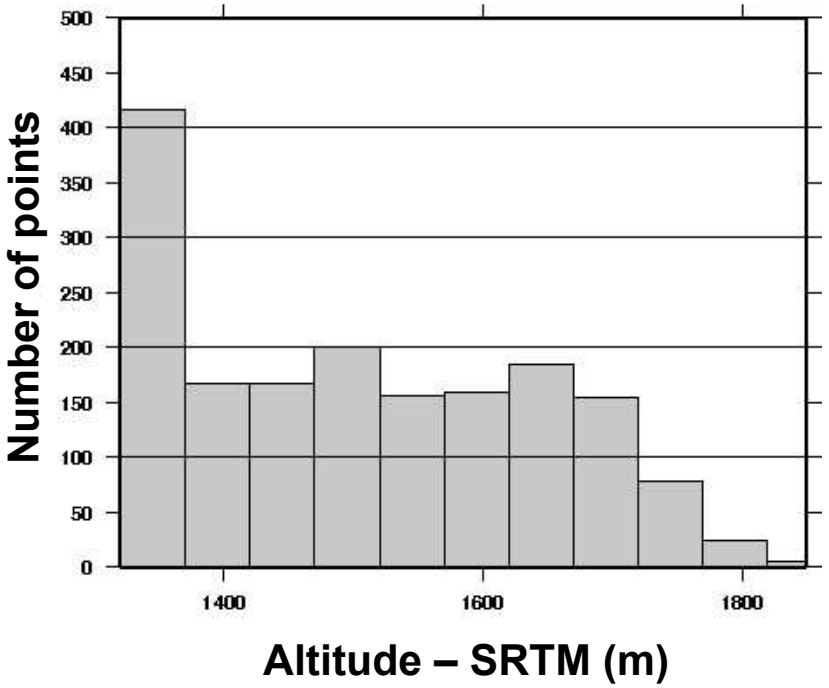




Analysis of the SRTM heights around 1’ of the BMs

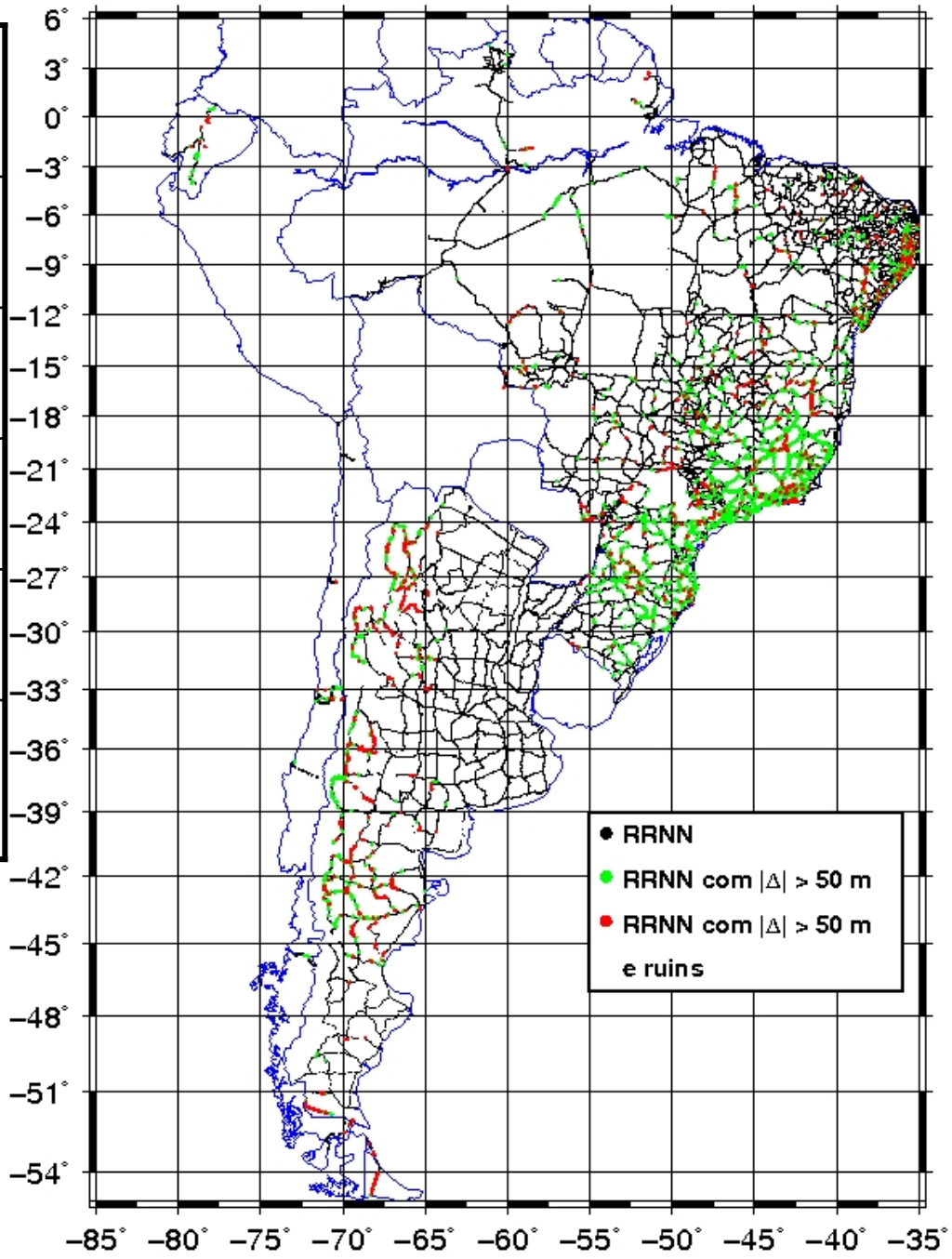
BM 349-00016 existing height in a circle of 1’ radius around the point in the SRTM data.





Country	Number of BMs	|Δ| > 50 m	|Δ| > 50 m Bad
Brasil	63,585	3,837 (6.03%)	708 (1.1%)
Argentina	13,723	1,043 (7.3%)	502 (3.7%)
Chile	1,081	37 (3.42%)	9 (0.8%)
Ecuador	432	30 (6.94%)	12 (2.8%)
Colour	black+ green+ red	green+ red	red

It has been verified that in most of the BMs with **|Δ| > 50 m**, the reason of the difference is due to the inaccuracy of the coordinates, not to the DTM value.

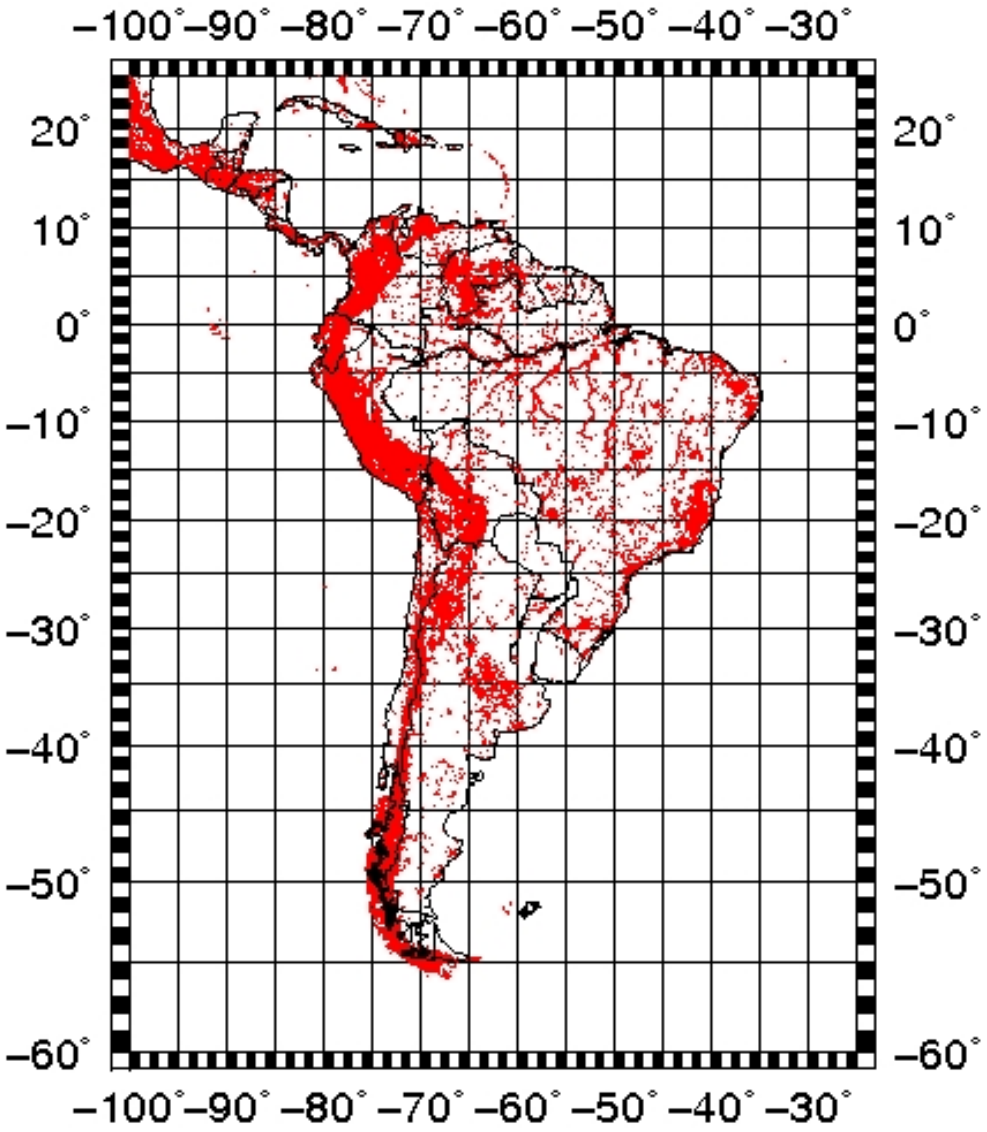


Analysis of the areas without SRTM height information

In the study area SRTM3 has **8,032,860 points** without height information which corresponds to 0.28% of the total points of the area in South America. From the total amount **764,316** points are in **Brazil**. The lack of information exists with more frequency in:

.Mountaineous region
Example: Andes, Caparaó, National Park of Neblina pike, etc;

.Areas close to rivers of great extension.
Example: Araguaia, Japurá, Madeira, Negro, Tapajós, etc.



Comparison of height anomalies computed with EGM96 and with EIGEN-GL04C

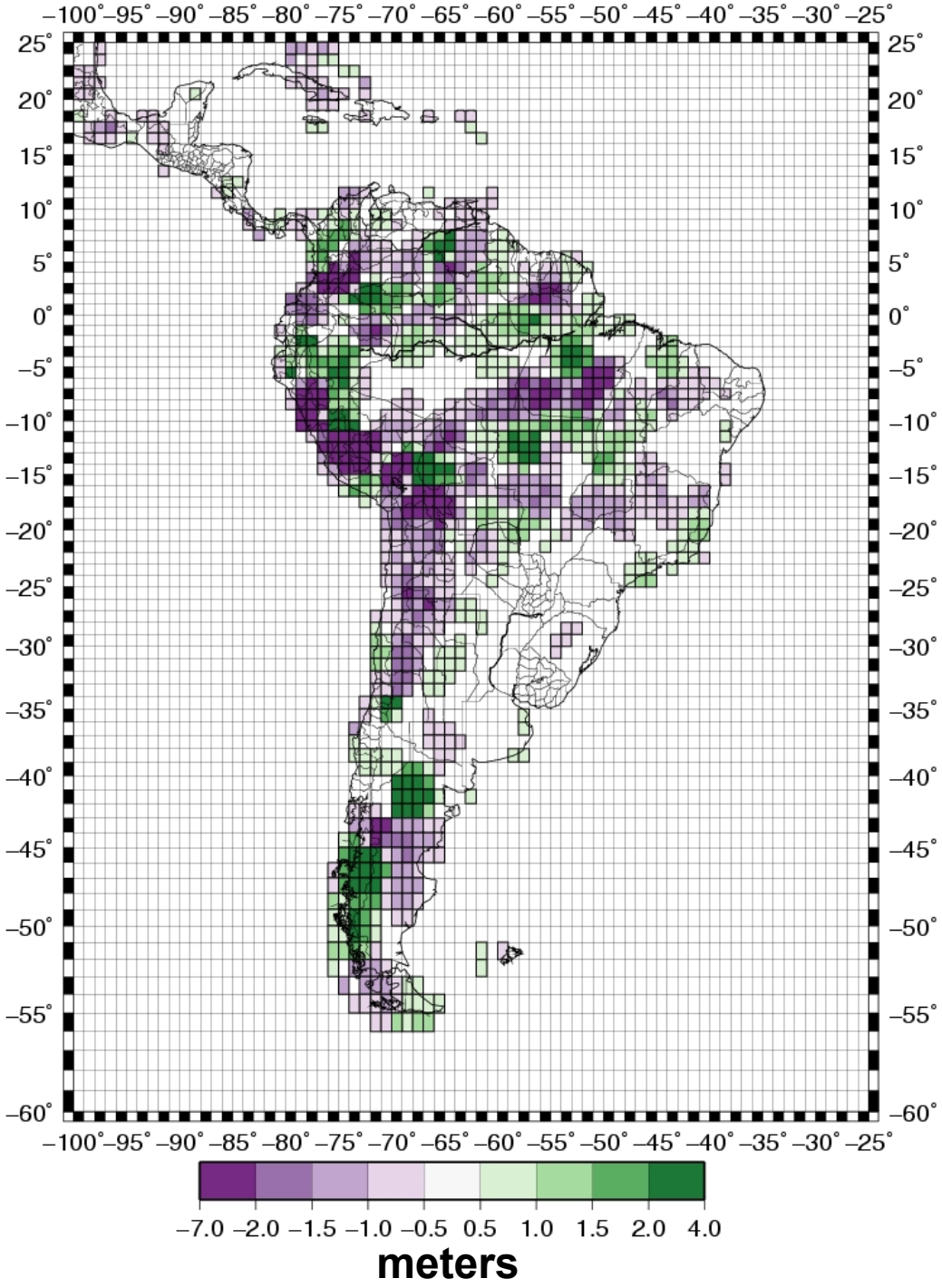
A grid of height anomalies was generated with EGM96 and EIGEN-GL04C at 15´ interval. From this grid the values were interpolated at the SRTM grid for the comparison.

The number of 1º x 1º blocks where the differences greater than 0.5 m exist, is 1,176. The total number of blocks analysed was 2013.

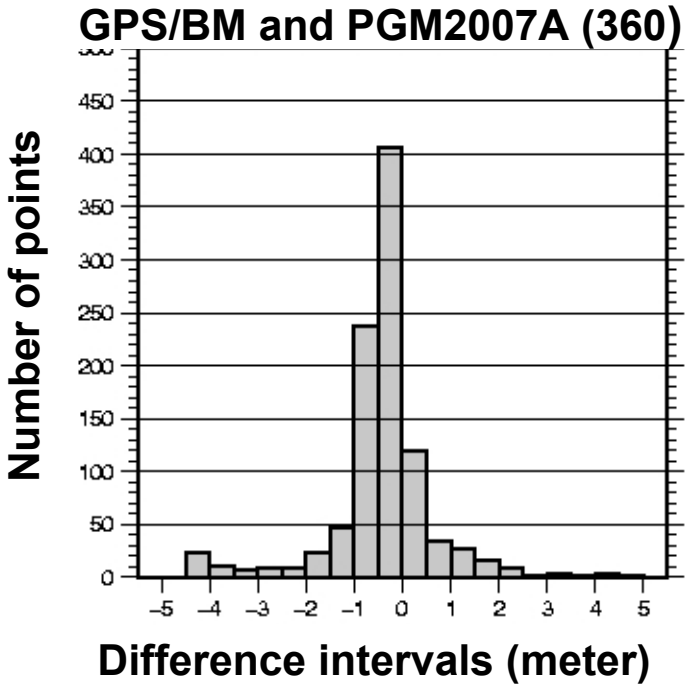
The highest differences are in the Andes.

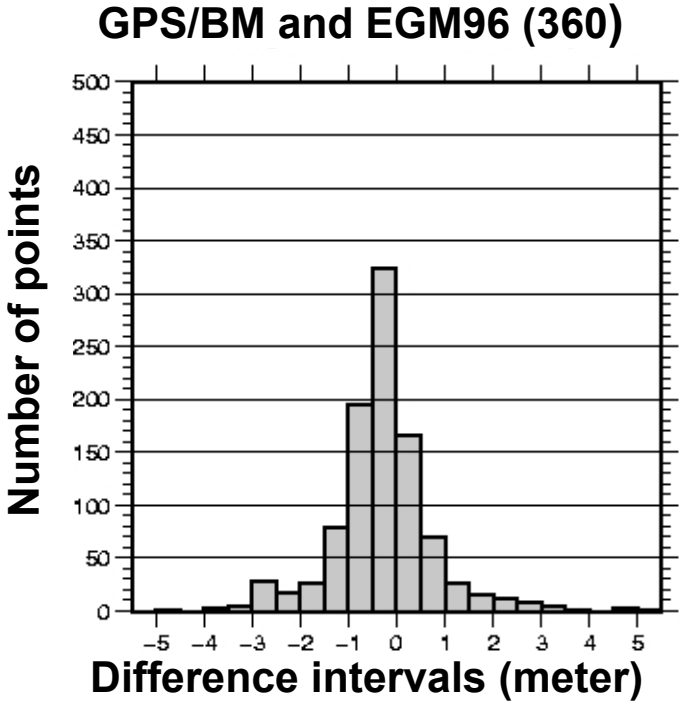
In Brazil, the biggest differences are in the Amazon and in the centre-west part.

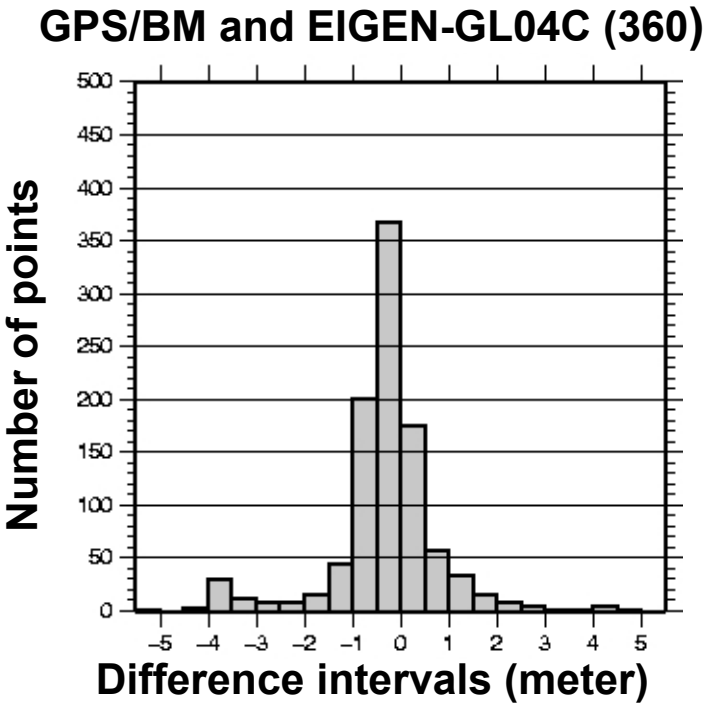
The spatial resolution of the referred MGs with order and degree 360 is 0.5º (~50 km)



Differences between GPS geoidal heights in 995 points on BMs and height anomalies from EGM96, EIGEN-GL04C and PGM2007A (n=m=360)

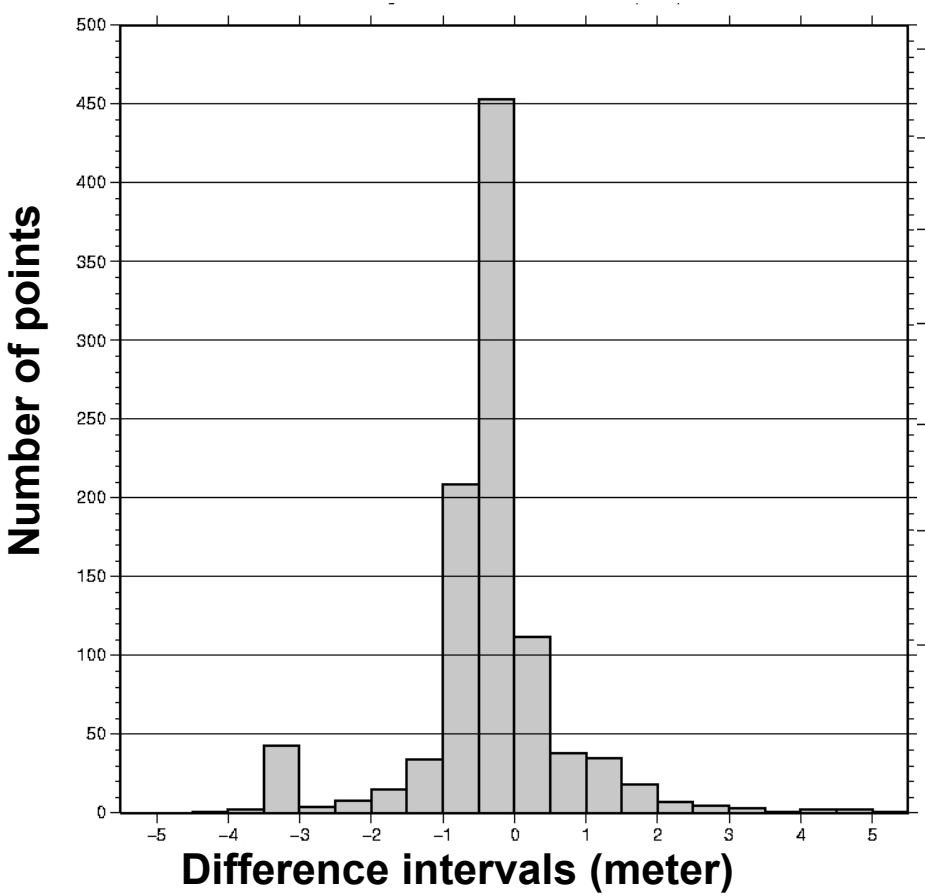


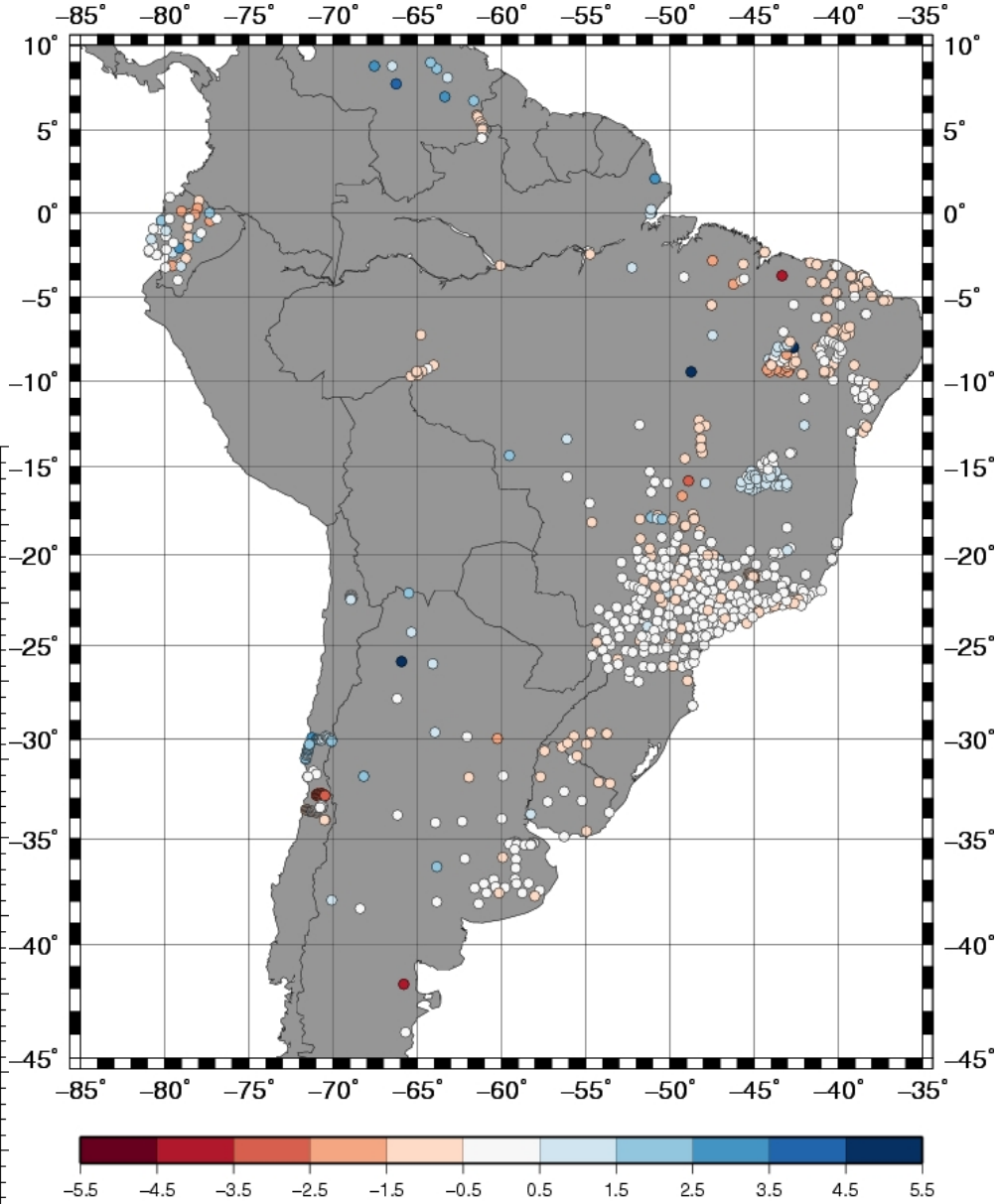




Differences between GPS geoidal heights in 995 points on BMs and the height anomalies derived from PGM2007A (n=m=2160)

Histogram GPS/BM and PGM2007A





GPS/BM and PGM2007A - meter

DTM in South America

SAM

SAM_1mv2

In the continent:

Digitised maps

- ✓Brazil (IBGE, Petrobras and GETECH) 1:50,000 and 1:100,000
- ✓Argentina (IGM) 1:250,000
- ✓Uruguay (IGM) 1:100,000
- ✓+ SRTM+DTM2002

In the Ocean:

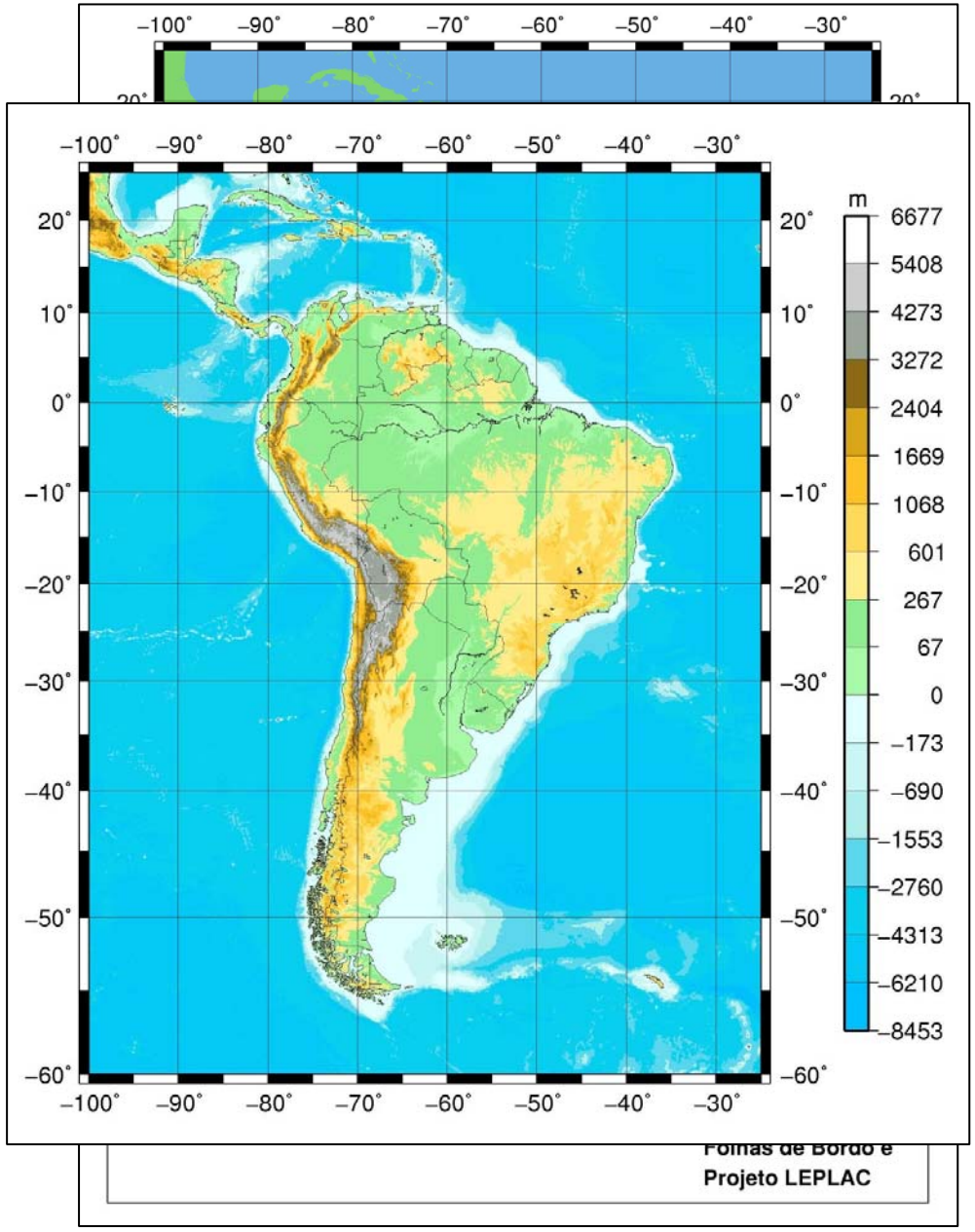
- ✓Brazil maps, boarding maps, project LEPLAC (CHM)
- ✓Argentina maps (SHN)
- ✓+DTM2002

SAM_30s

SRTM+DTM2002

SAM_1mv1

SRTM+DTM2002



Ocean area – bathymetric data

✓Brazil

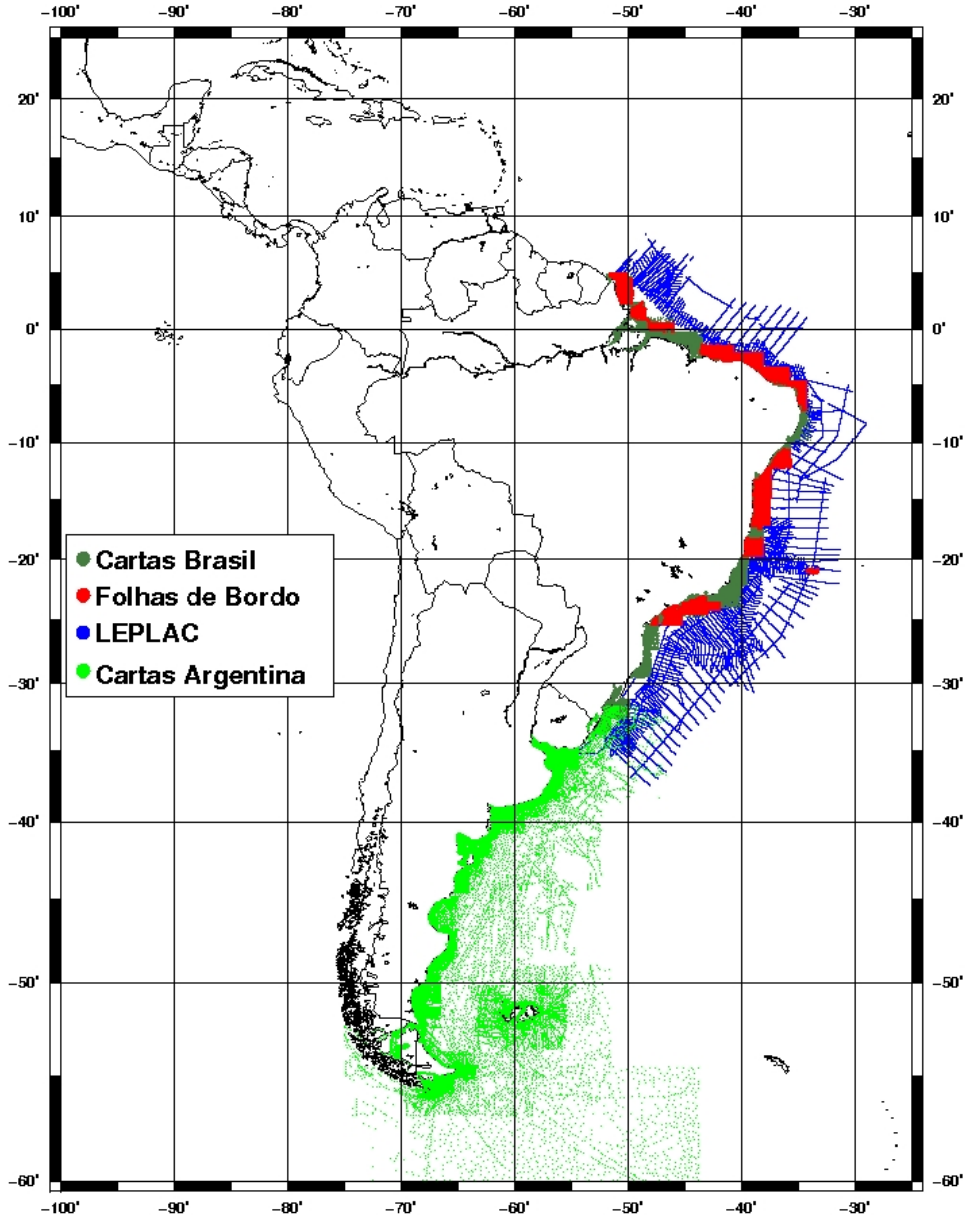
111 nautical charts (141,998 points)
(dark green)

38 boarding maps (210,650 points)
(red)

20 project LEPLAC (956,948 points)
(blue)

✓Argentina

26 nautical charts (56,270 points)
(green)



DTMs of 3”

Two Digital Terrain Models were derived.

Limits: latitude - **25º N to 60º S** longitude: **100º W to 25º W**. Resolution of 3” of arc in **6,061 blocks of 1º x 1º**, using mainly information from SRTM3.

They are:

.**SAM_3sv1:** consist of SRTM3, with gaps substituted by DTM2002.

.**SAM_3sv2:** EGM96 used in the SRTM3 was substituted by EIGEN-GL04C in order to derive the orthometric height. Here the gaps were substituted by digitising maps and DTM2002.

DTMs with grid spacing of 30”, 1’ and 5’ of arc were generated too.

These models were derived by estimating the mean altitude at the referred resolution using the basic models SAM_3sv1 and SAM_3sv2.
The areas applications: geodesy, geophysics, hydrology, engineering projects, etc.

SAM_3sv2

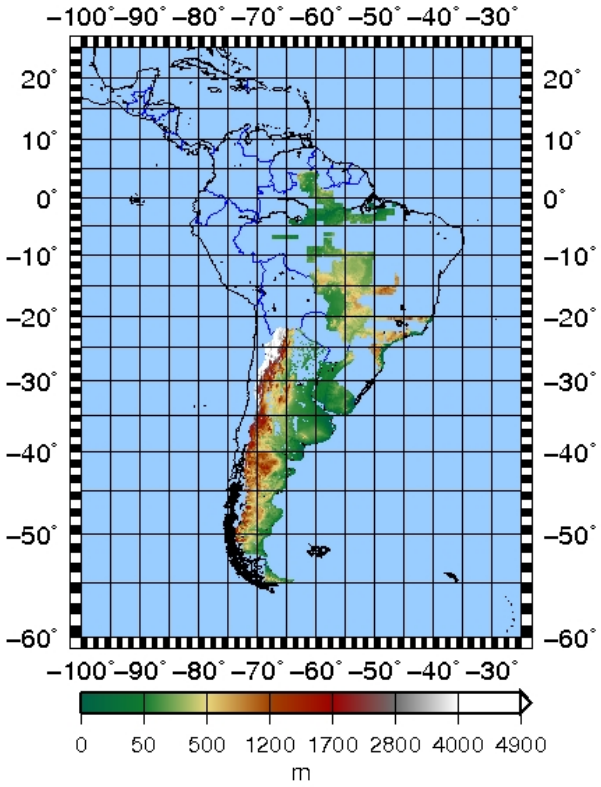
The geodetic height was recovered in the **SRTM3** using the geopotential model (MG) **EGM96** (Lemoine et al., 1998); then substituted by **EIGEN-GL04C** (n=m=360) (Förste et al., 2006).
It means to use the following expression:

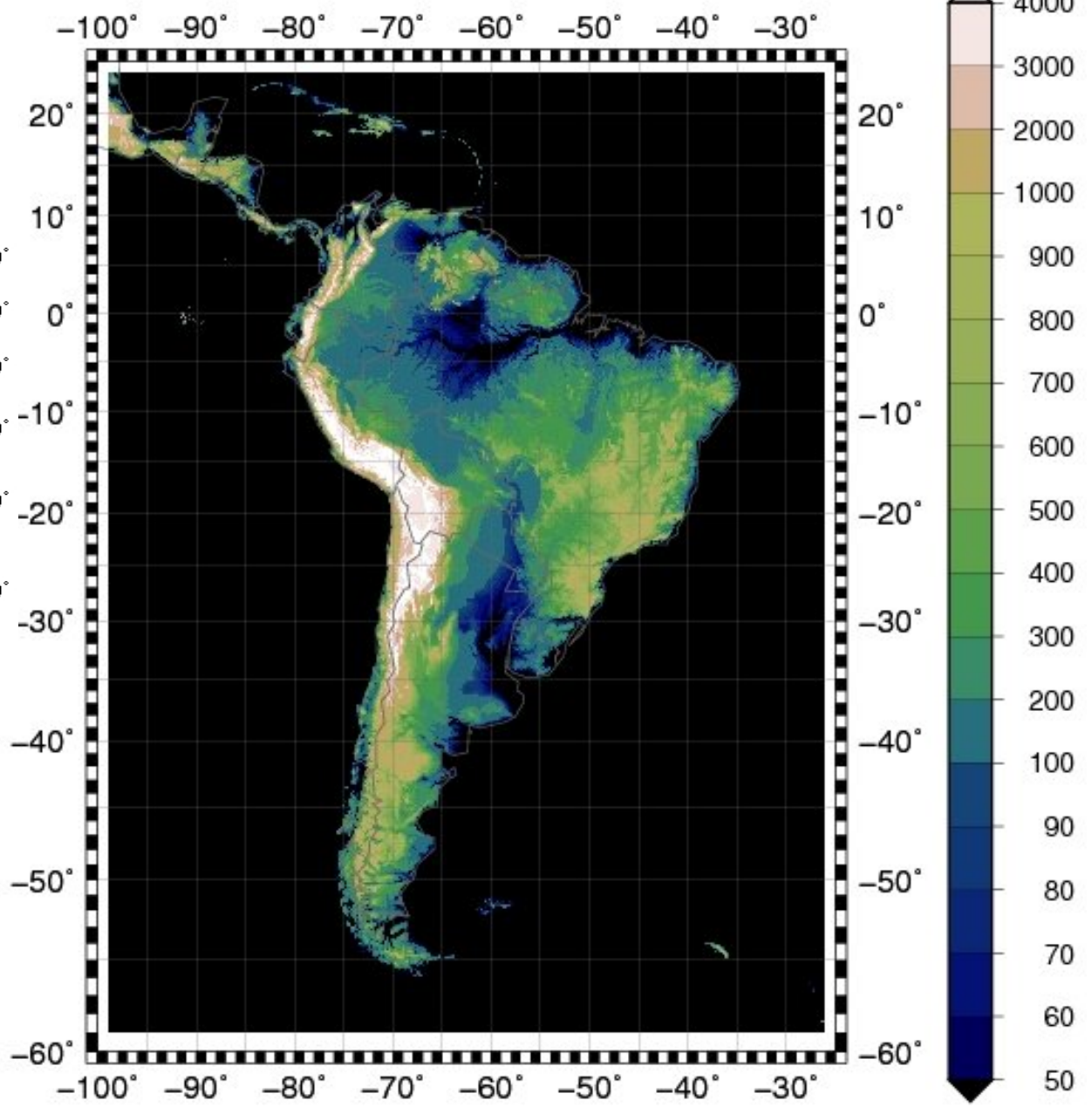
$$h \cong N + H$$

where N was calculated by EGM96.

EIGEN-GL04C is combinations of GRACE (Gravity Recovery and Climate Experiment) and LAGEOS (LAser GEOdynamics Satellite), plus gravity and satellite altimetry data.

SAM_3sv2





SAM3sv2_5m
Hmax: 6016.5 m
(-68.5417°,-27.125°)

Geoid models using Stokes-Helmert methodology

Areas used to test the DTM models SAM_3sv1 e SAM_3sv2.:

- **Amazon:** latitudes 5° N to 5° S and longitudes 70° W to 50° W

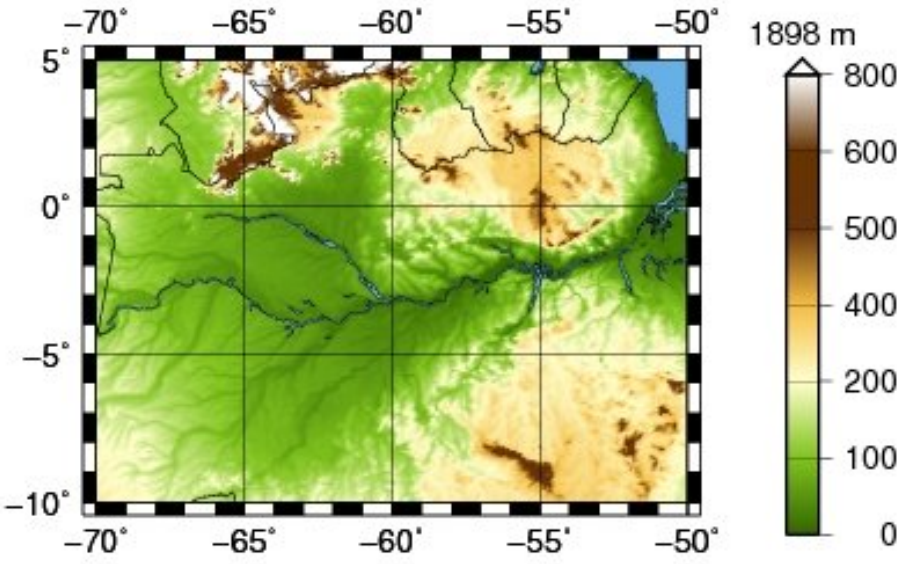
- **South east part of Brazil:** latitudes 15° S to 30° S and longitudes 55° W to 40° W

Geoid models have been generated using Stokes-Helmert methodology in a cooperation agreement IBGE/CIDA with the participation of UNB (University of New Brunswick) and EPUSP (Escola Politécnica da USP). SHGEO sofware package was developed at Geodetic and Geomatic Engeneering Department – UNB, implemented at LTG.

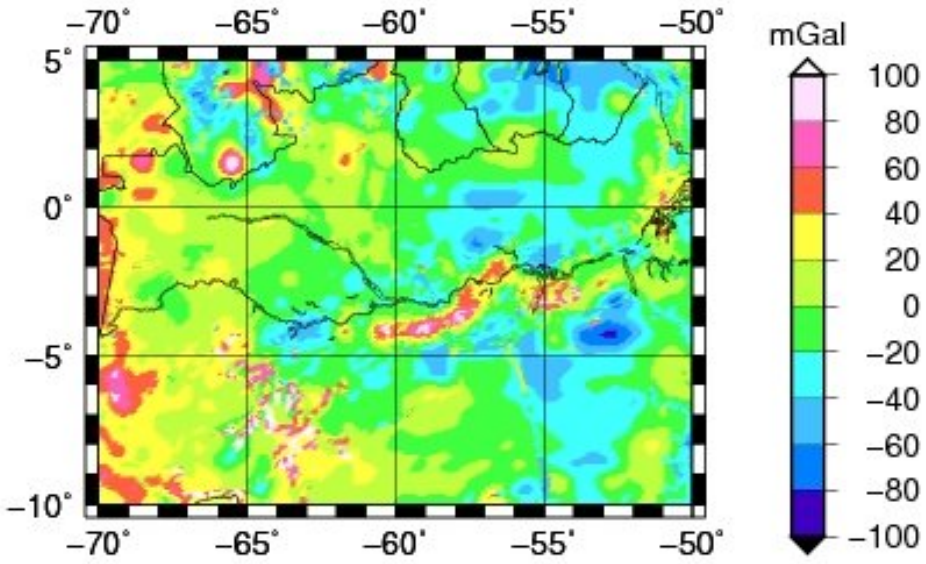
Geopotential model used as reference field was **EIGEN-GL04S**.

Geoid Model for Amazon

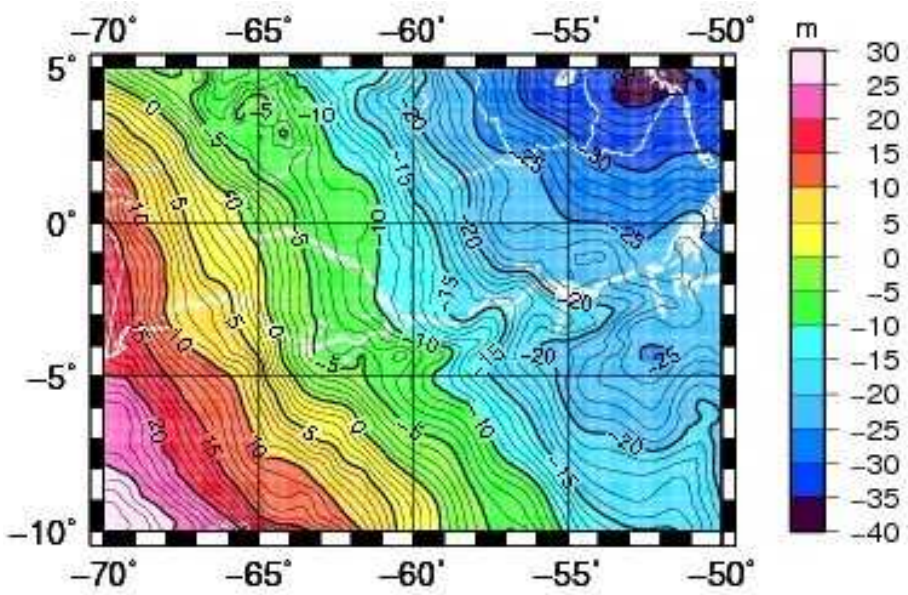
DTM



Mean Free Air Gravity Anomnaly



Geoid - GEOAMA

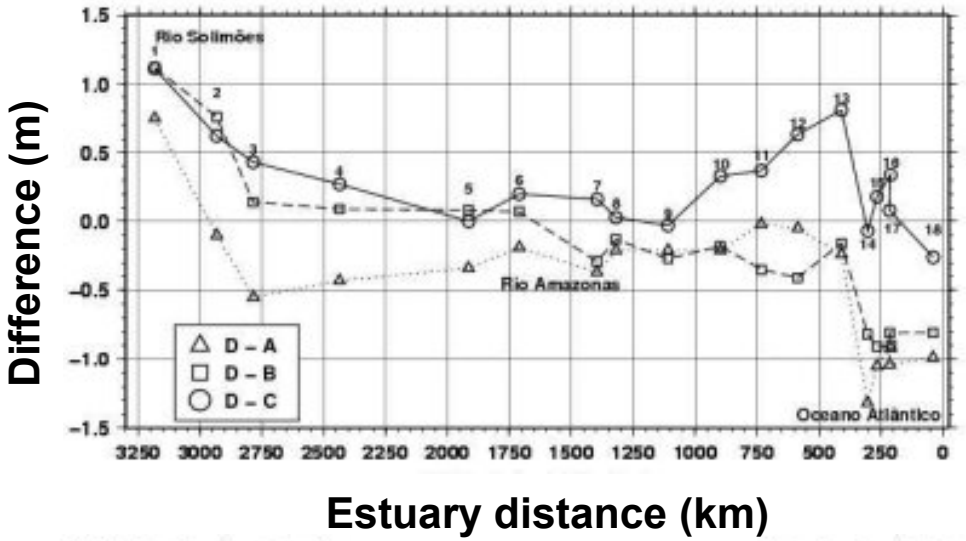


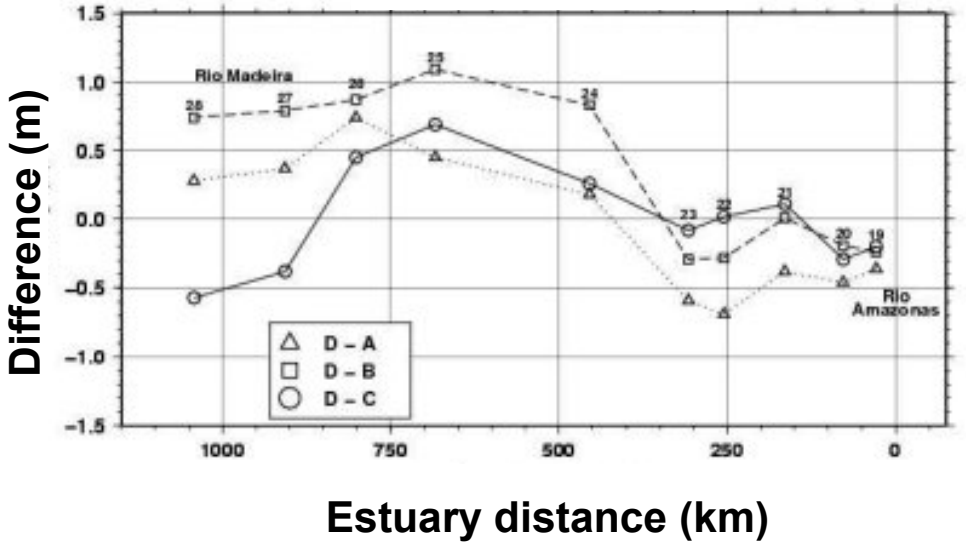
Geoid Model for Amazon

28 hydrographic stations (limnimeters) with geodetic coordinates (ϕ, λ, h) referred to the zero of the scales

Geoidal height (height anomaly) has been estimated in these points using **EGM96 (A)** (Lemoine et al., 1998), **MAPGEO2004 (B)** (Lobianco et al., 2005) and **EIGEN-GL04C (C)** (Förste et al., 2006) for comparison with **GEOAMA (D).**

A special attention was addressed to the comparison of GEOAMA with MAPGEO2004.
The greatest differences of these models are close to the Amazonas estuary, at the Solimões River close to brazilian border (Peru border) and at the lower part of Madeira River (Manicoré up to Porto Velho).





Geoid Model for Amazon

Statistics

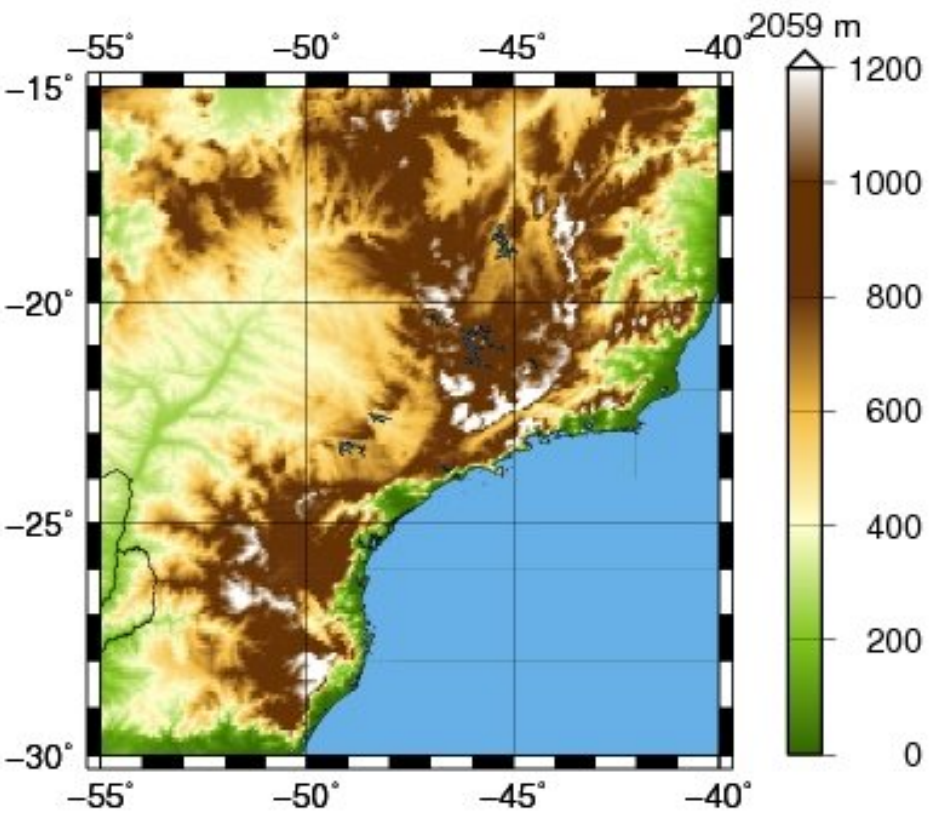
EGM96 (A)
MAPGEO2004 (B)
EIGEN-GL04C (C)
GEOAMA (D)

	D-A	D-B	D-C
Mean	-0.28	-0.02	0.19
RMS	0.52	0.61	0.38
Maximum Difference	0.75	1.12	1.11
Minimum Difference	-1.32	-0.91	-0.57

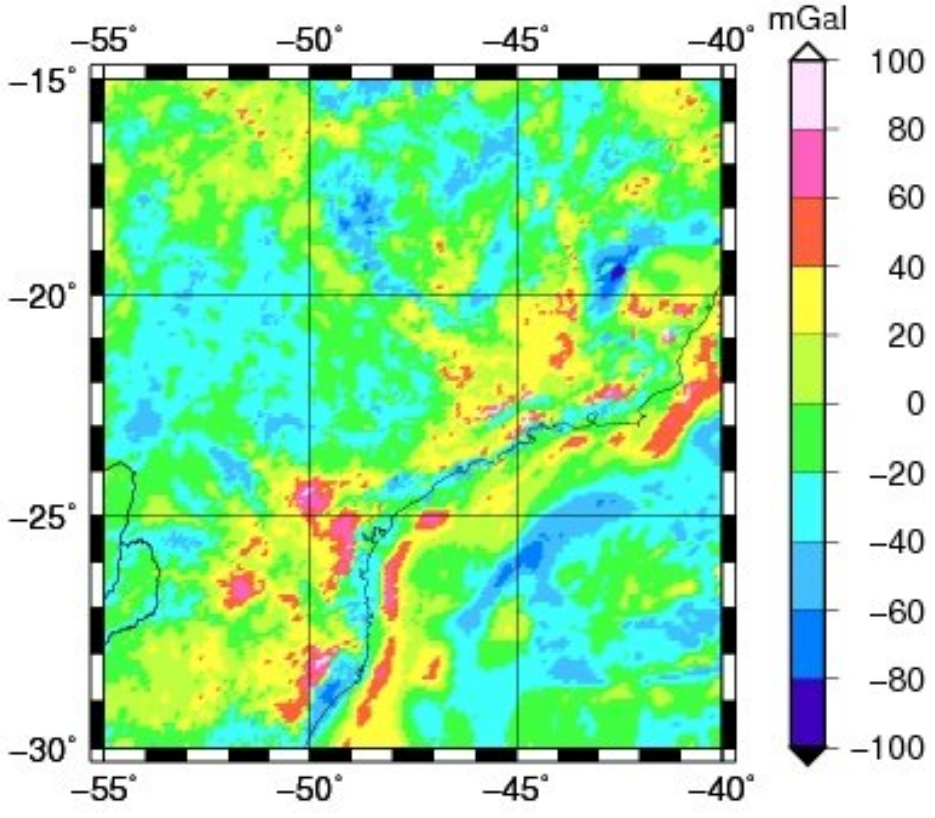
Geoid Model for South and Southeast regions of the Brazil

SAM_3sv2

DTM

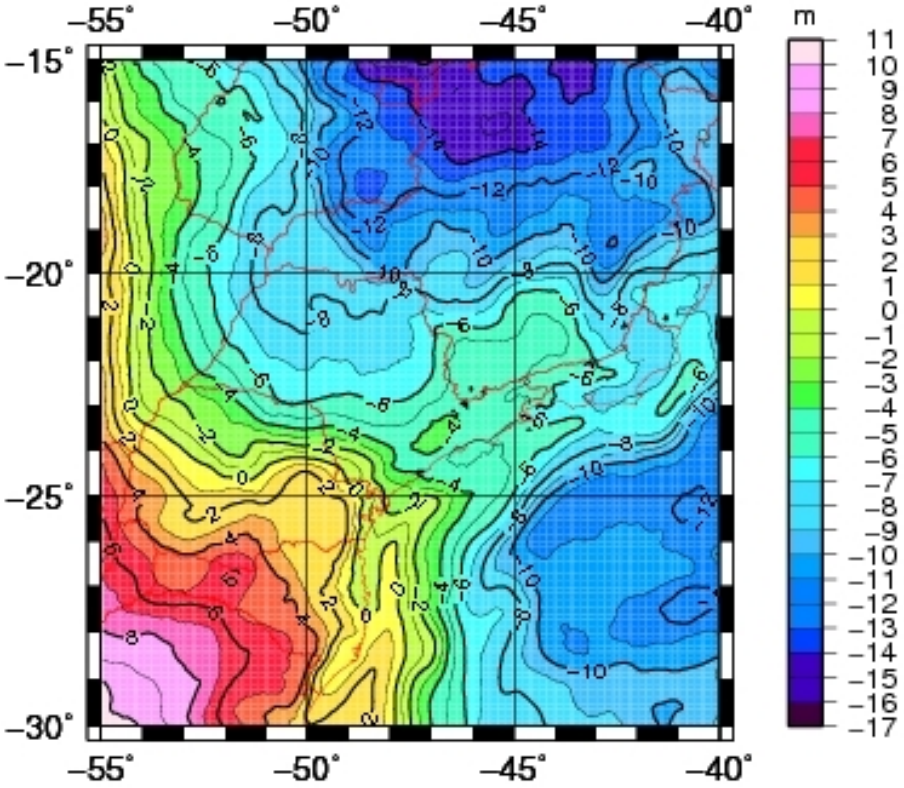


Mean Free Air Gravity Anomnaly

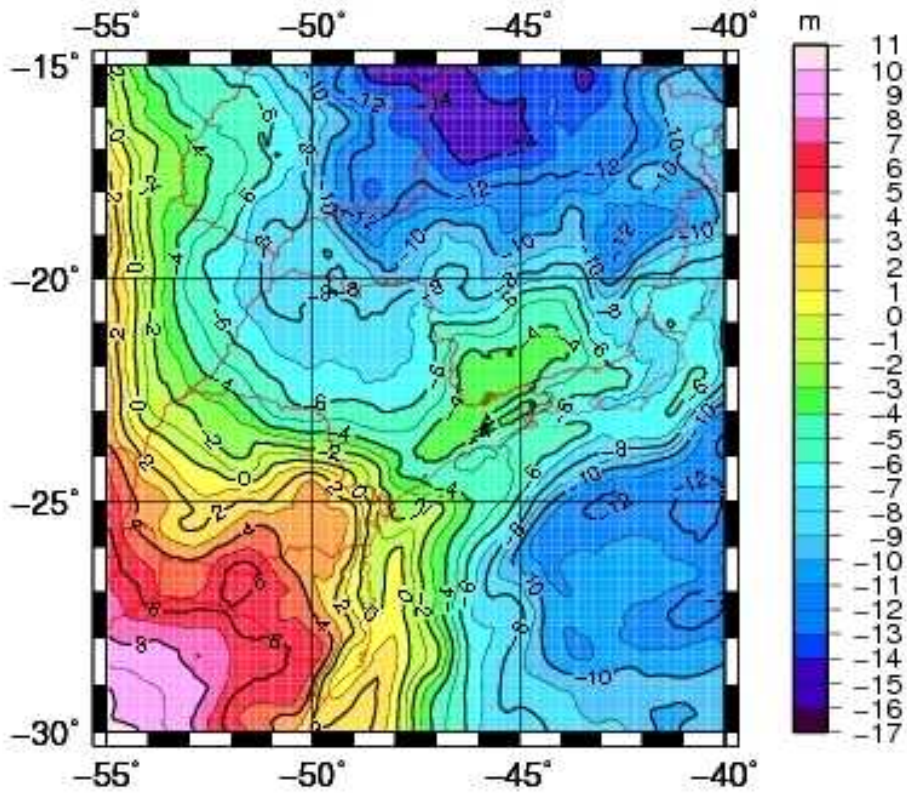


Geoid Model for South and Southeast regions of the Brazil

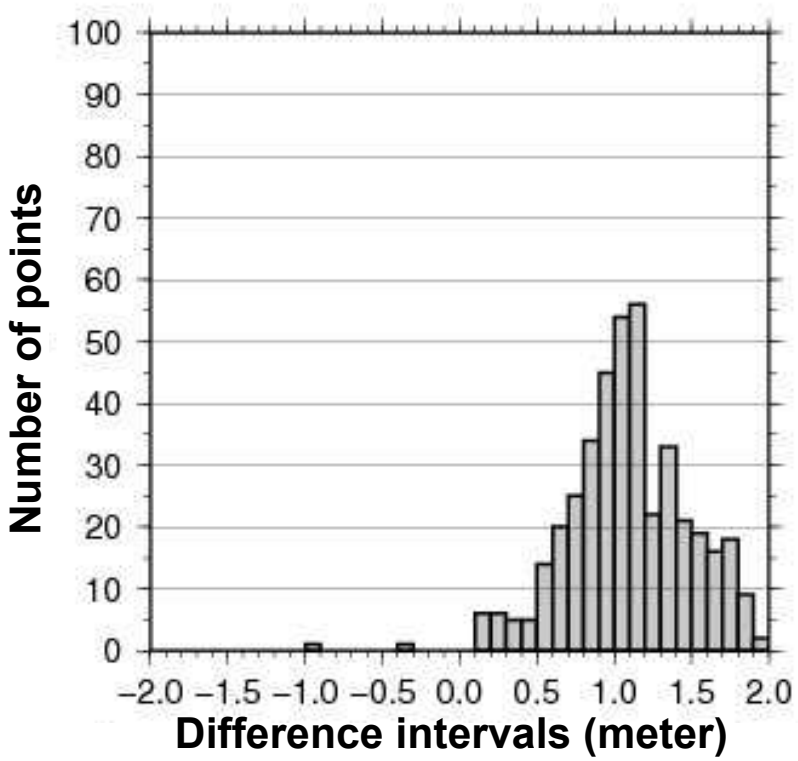
Geoid model GEOSULv2 (SAM_3sv2)



Geoid model GEOSULv1 (SAM_3sv1)

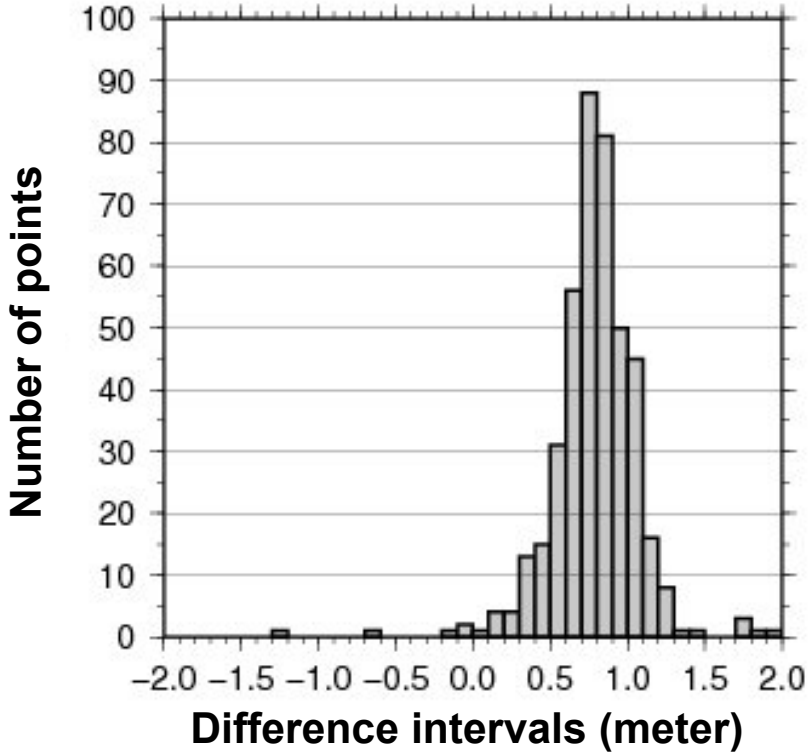


Geoid Model for South and Southeast regions of the Brazil



Histogram of differences of geodetic heights of GPS points over Bench Marks with those obtained by GEOSULv1

DTM used SAM_3sv1

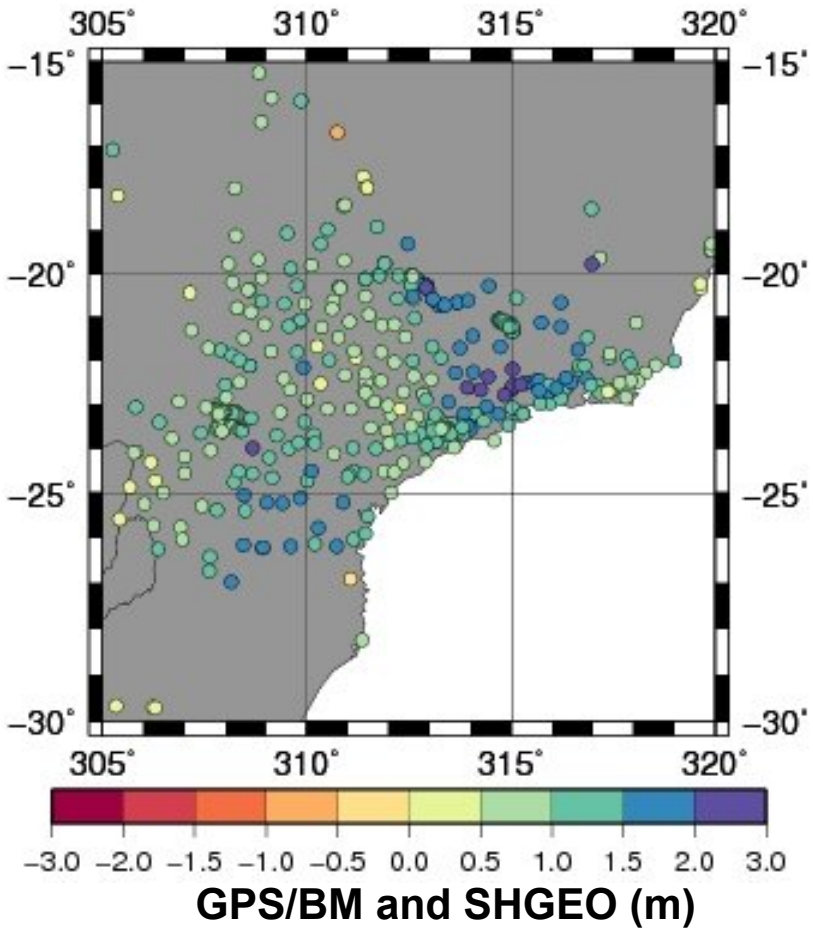


Histogram of differences of geodetic heights of GPS points over Bench Marks with those obtained by GEOSULv2

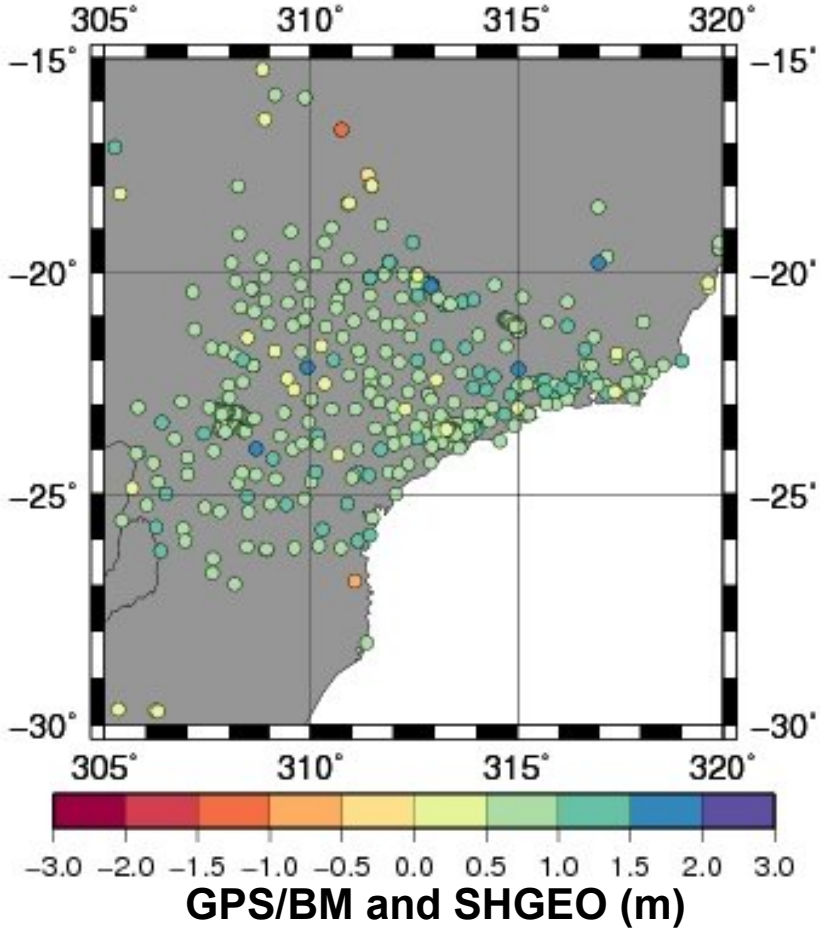
DTM used SAM_3sv2

Geoid Model for South and Southeast regions of the Brazil
Distribution of GPS points on Bench Marks

Comparison with the geodetic heights obtained by GEOSULv1.



Comparison with the geodetic heights obtained by GEOSULv2.



Geoid Model for South and Southeast regions of the Brazil

Statistics

	Mean (m)	RMS (m)
GEOSULv1	1.02	0.39
GEOSULv2	0.80	0.28

New geoid to South America

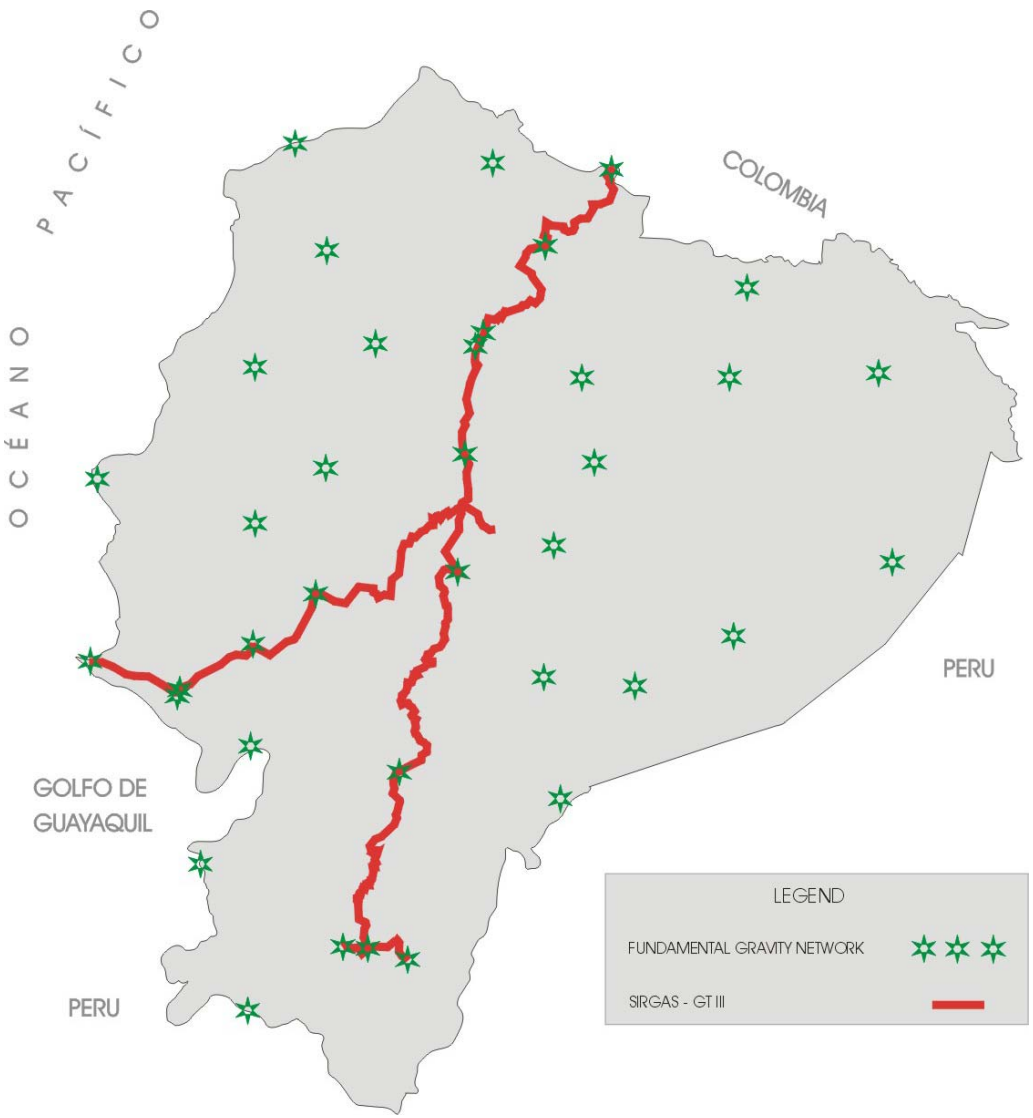
New gravity geoid model to South America, used the "remove-restore" technical together with the modification of Stokes integral kernel proposed by Featherstone, FFT computation, in numerical integration computation.

The gravimetric information used in the computations were compiled, validated and homogenized to generate a 10’ x10’ Helmert mean gravity grid, on terrestrail areas, and free-air, on ocean.

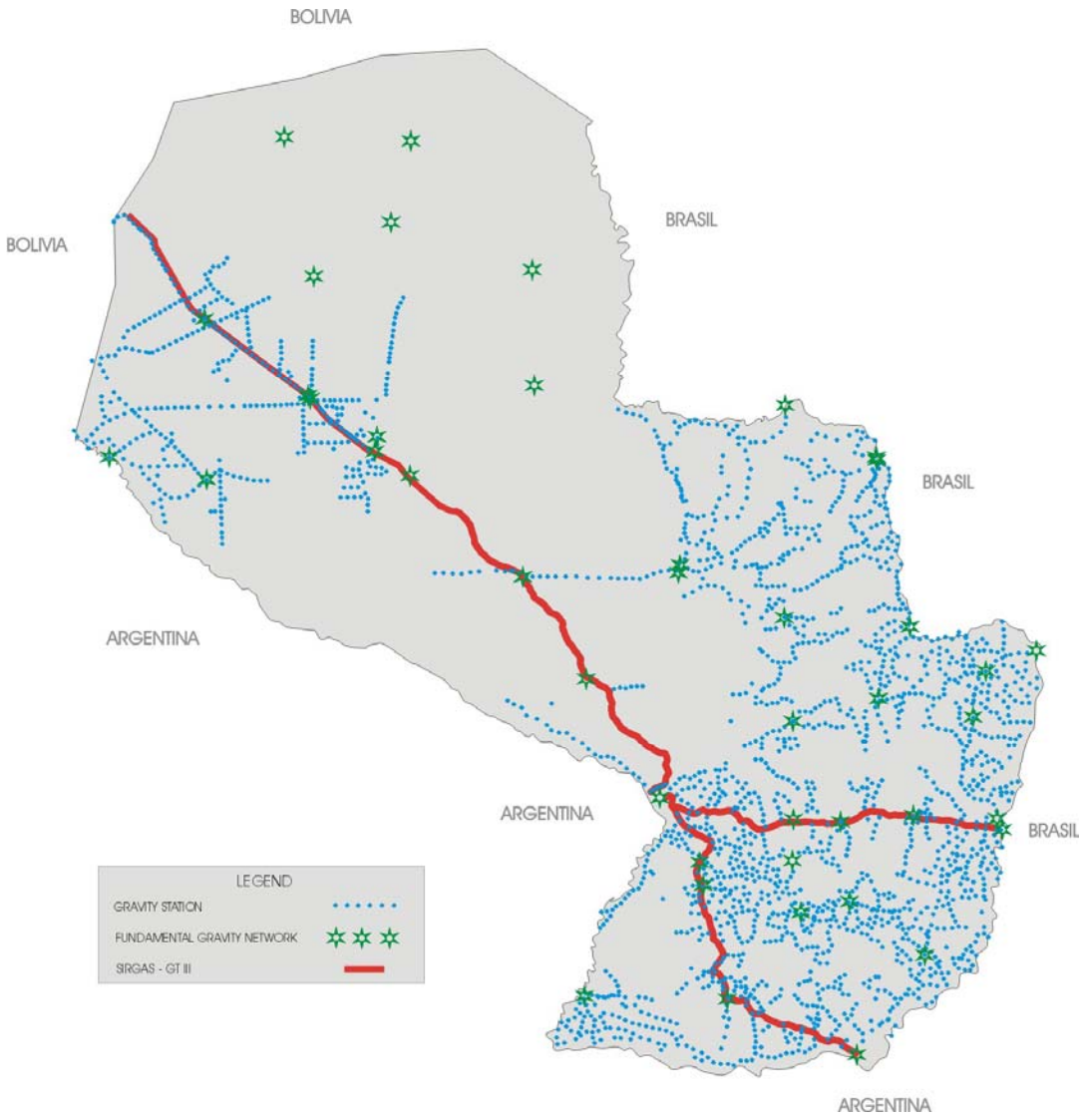
The geoid long wavelength contribution is provided by geopotencial model EIGEN-GL04S.

The digital terrain model SAM_3sv2 (also 30’’ and 5’ grid) was used to compute the complete Bouguer anomaly, terrain correction and indirect effect.

Gravimetry and spirit levelling



Gravimetry and spirit levelling



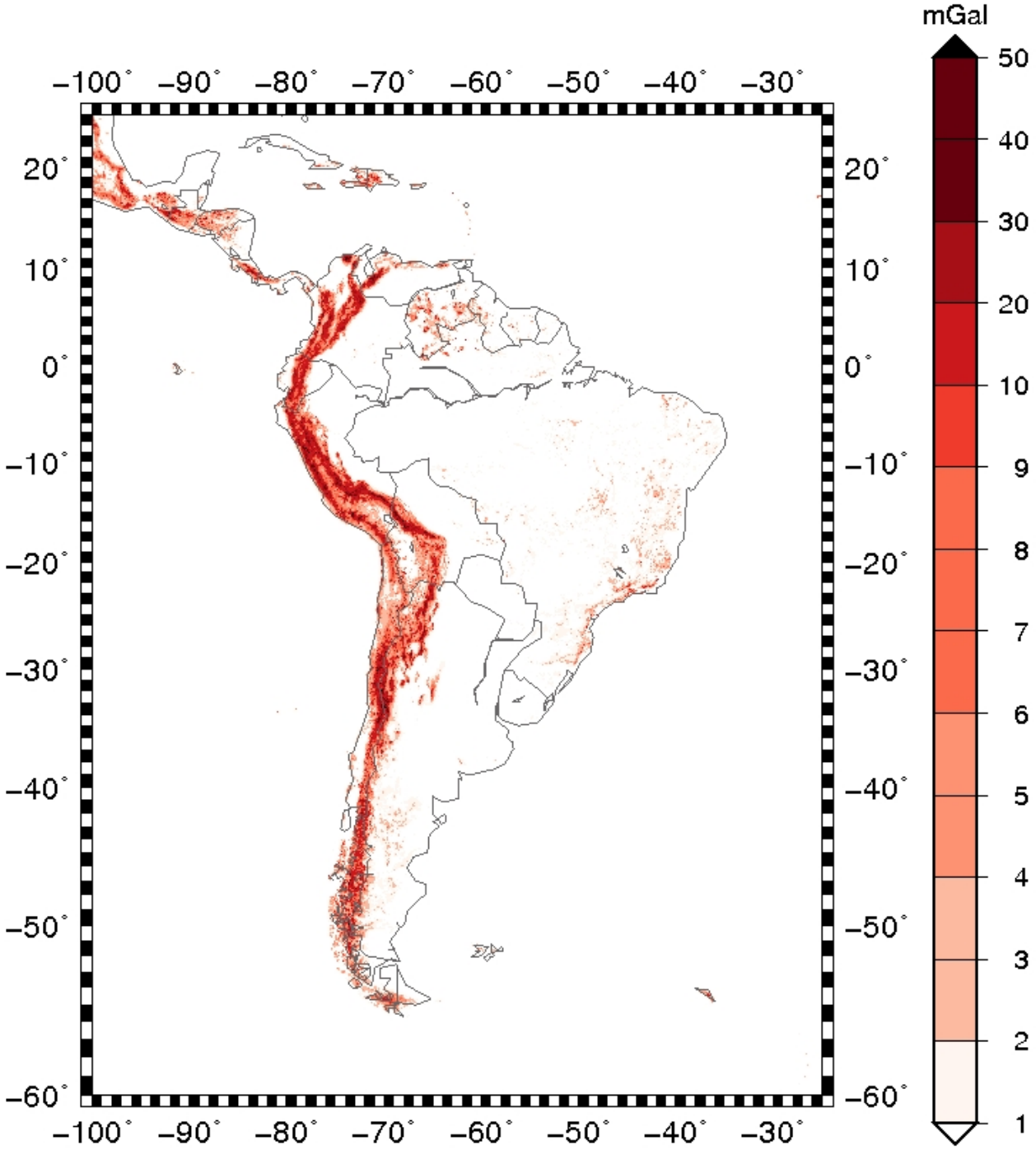
Terrain Correction

TC program (Tscherning)

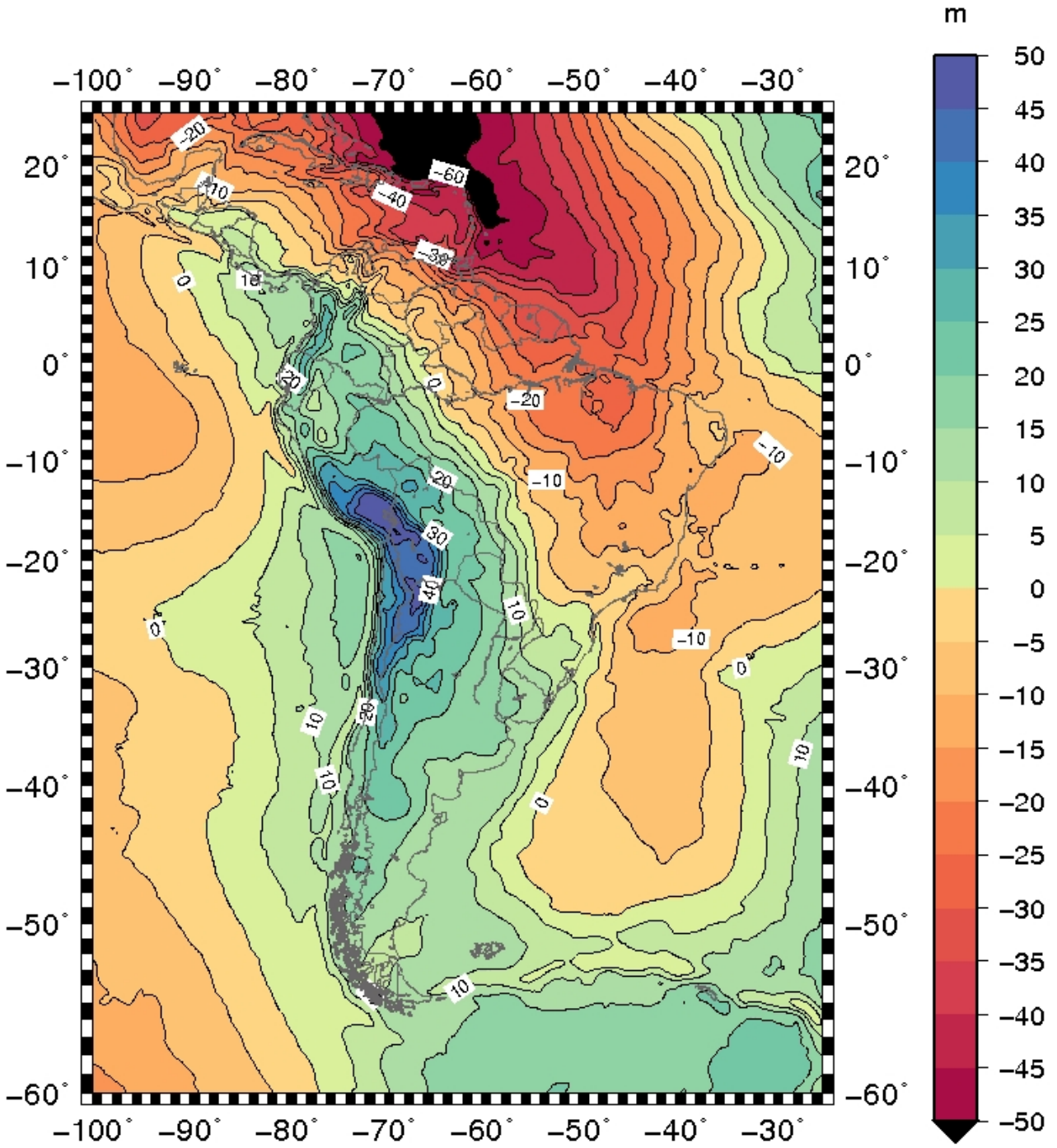
TCmax: 81.15 mGal
(-76.2083°, 5.04167°)

Mean: 0.51 mGal
RMS: 2.51mGal

SAM_3sv2



New version of the geoid for South America



Comparisons

The results will be compared with existing GPS observations on BM. The idea is to validate the consistency of the geoid model with the leveling network.