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The progress of the geoid in south America under GRACE and EGM08 models

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This presentation shows the particular efforts for the establishment:
Geoid (quasi-geoid) model in South America

Limited by 15º N and 57º S in latitude
95º W and 30º W in longitude

The software package SHGEO developed by the University of New Brunswick-Canada Ellmann, 2005a;2005b) was used for the partial calculation combined with modified Stokes integral proposed by Featherstone et al. (1998) using FFT

The Stokes-Helmert scheme for geoid determination is:

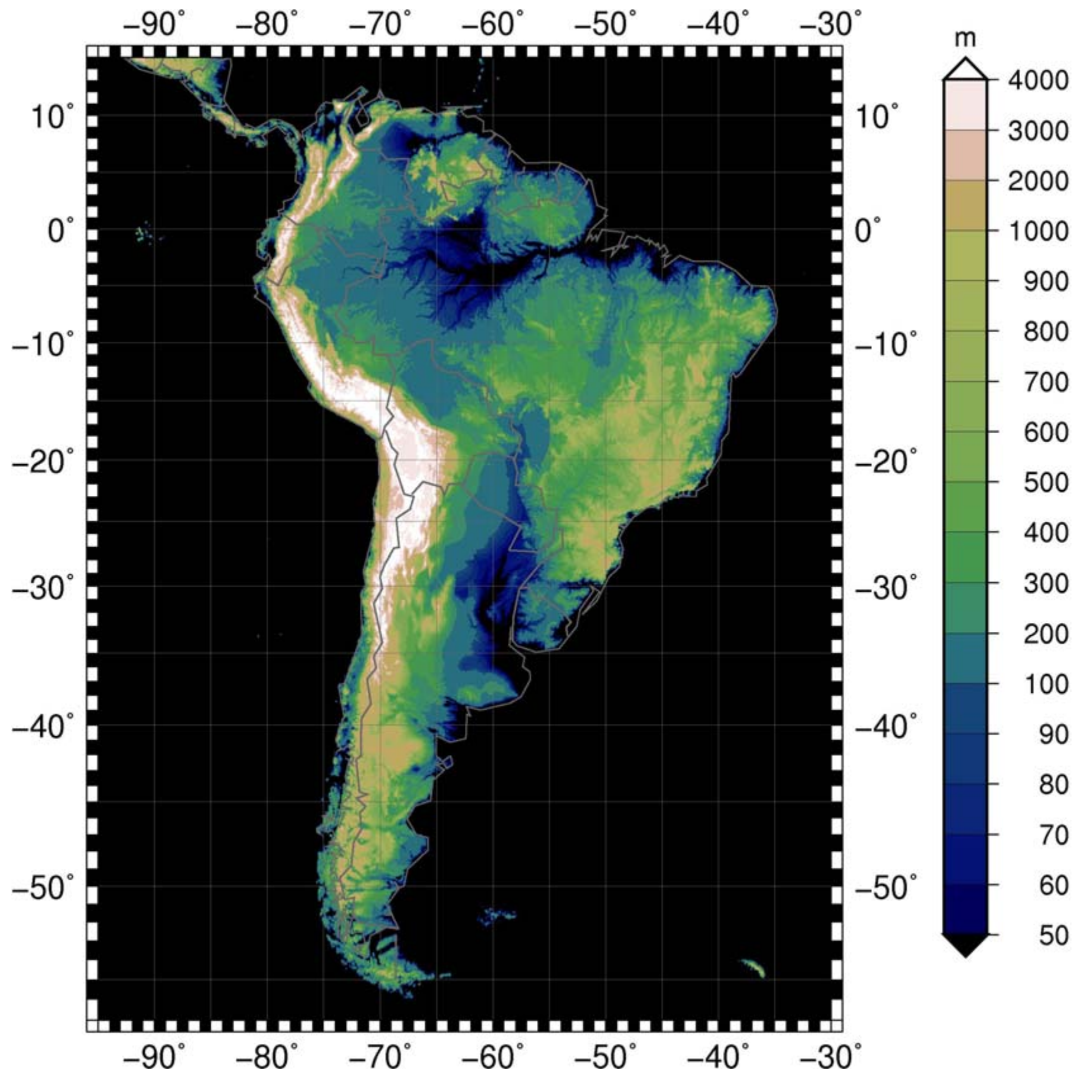
- **Formulation of the boundary value problem on the Earth's surface;**
- **Evaluation of the Helmert gravity anomalies on the Earth's surface;**
- **Modified Stokes´s integration (solution to the Stokes´s boundary value problem);**
- **Computing the quasi-geoid**

DIGITAL TERRAIN MODEL

SAM3s_v2 with a grid size of 3” x 3” (~90m x 90m) was used. This model consists of SRTM3 (Farr *et al.,* 2007), but EGM96 (Lemoine et al., 1998) geiodal heights used in the SRTM3 was substituted by EIGEN-GL04C (Förste et al., 2006); in order to derive the orthometric height.. The gaps were filled by digitising maps and DTM2002 (Saleh and Pavlis, 2002, Blitzkow *et al.*, 2007). The SHGEO package also needs:

❖Mean heights with resolution of 30” x 30”, 5’ x 5’. These models were derived from direct averaging of SAM3s_v1.

❖Global mean height 60’ x 60’: derived from ETOPO5 (1988).



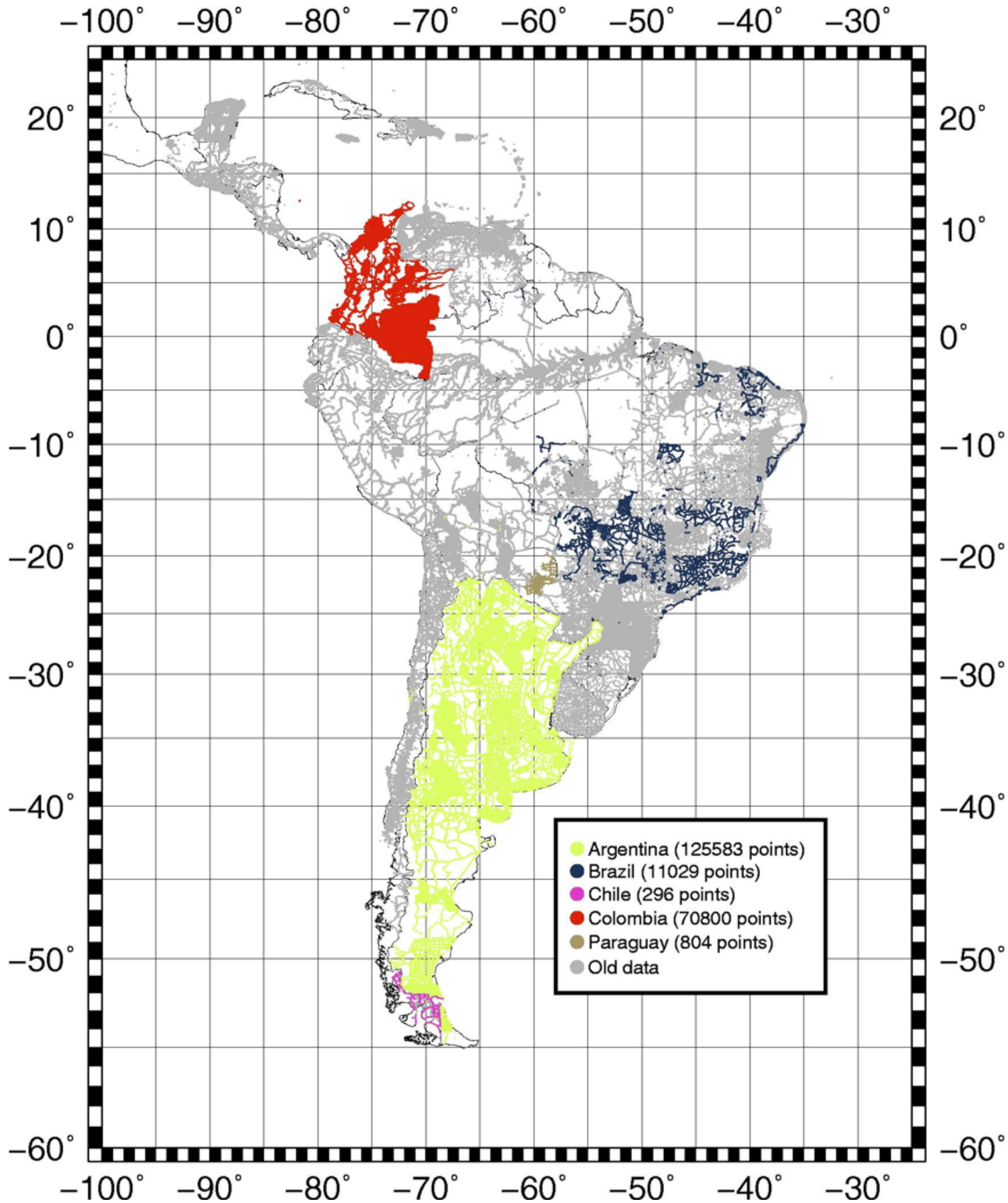
GRAVITY DATA

Many activities going on by different organizations, universities and research institutes.

It is important to mention:

- IBGE
- NGA
- GETECH
- the many civil and military institutions in several countries of South America.

Due to the big efforts undertaken by the different organizations in the last few years to improve the gravity data coverage all over the countries there are available at the moment approximately **924,600 point gravity data** in the continent, including Central America.



COMPLETE BOUGUER GRAVITY ANOMALY MAP

Derived according to:

FREE AIR GRAVITY ANOMALY AT MEASUREMENT POINTS

ADDING

BOUGUER CORRECTION AS A FUNCTION OF THE HEIGHT FROM GRAVITY DATABASE

AND

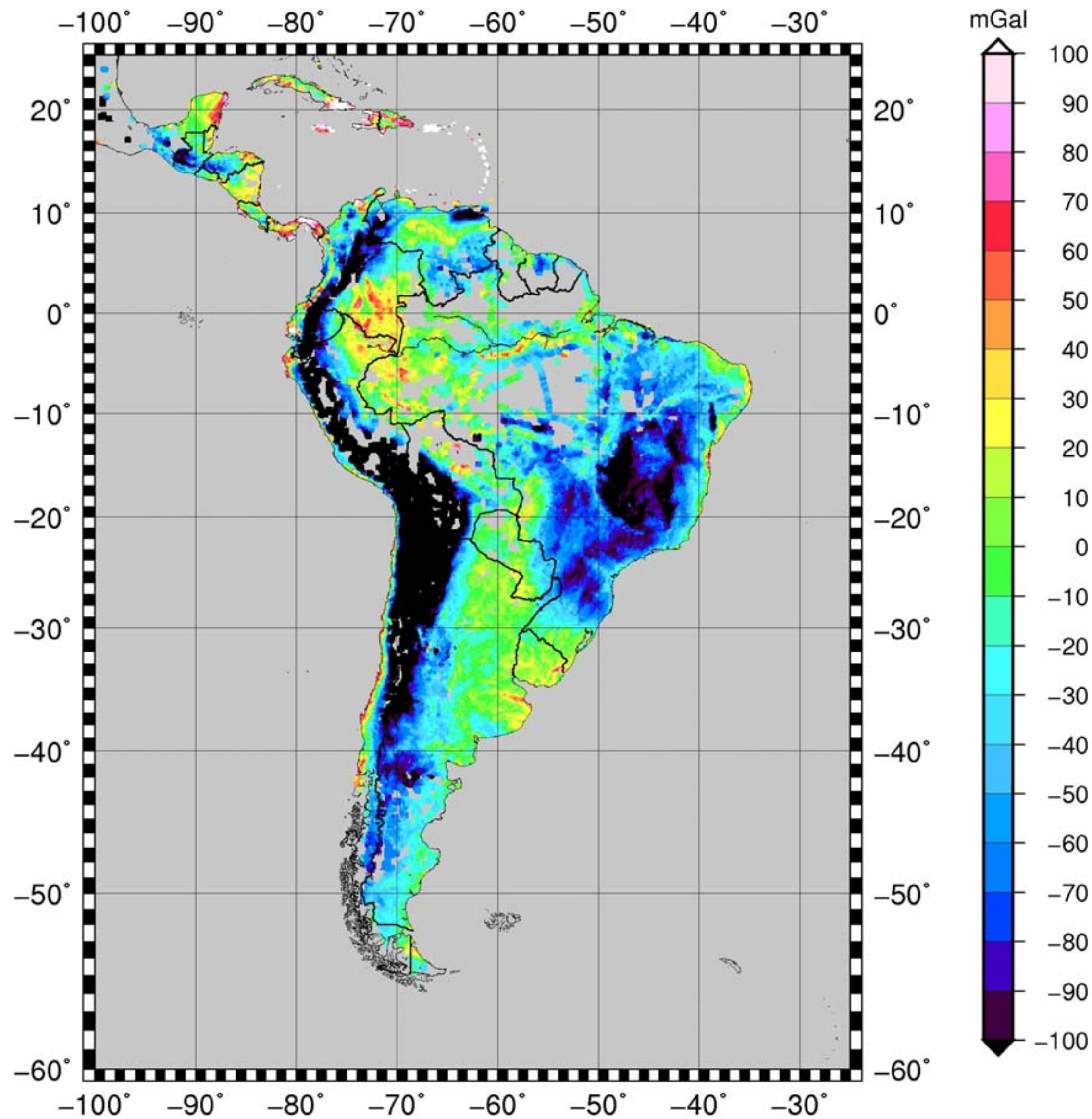
TERRAIN CORRECTION (SPHERICAL APROXIMATION)

Mean= -51.78 mGal

STD= 82.47mGal

Max.=195.30 mGal

Min.= -455.31 mGal



FREE-AIR ANOMALIES (FA)

Mean free-air gravity anomalies in a 5’ grid were derived from point gravity data.

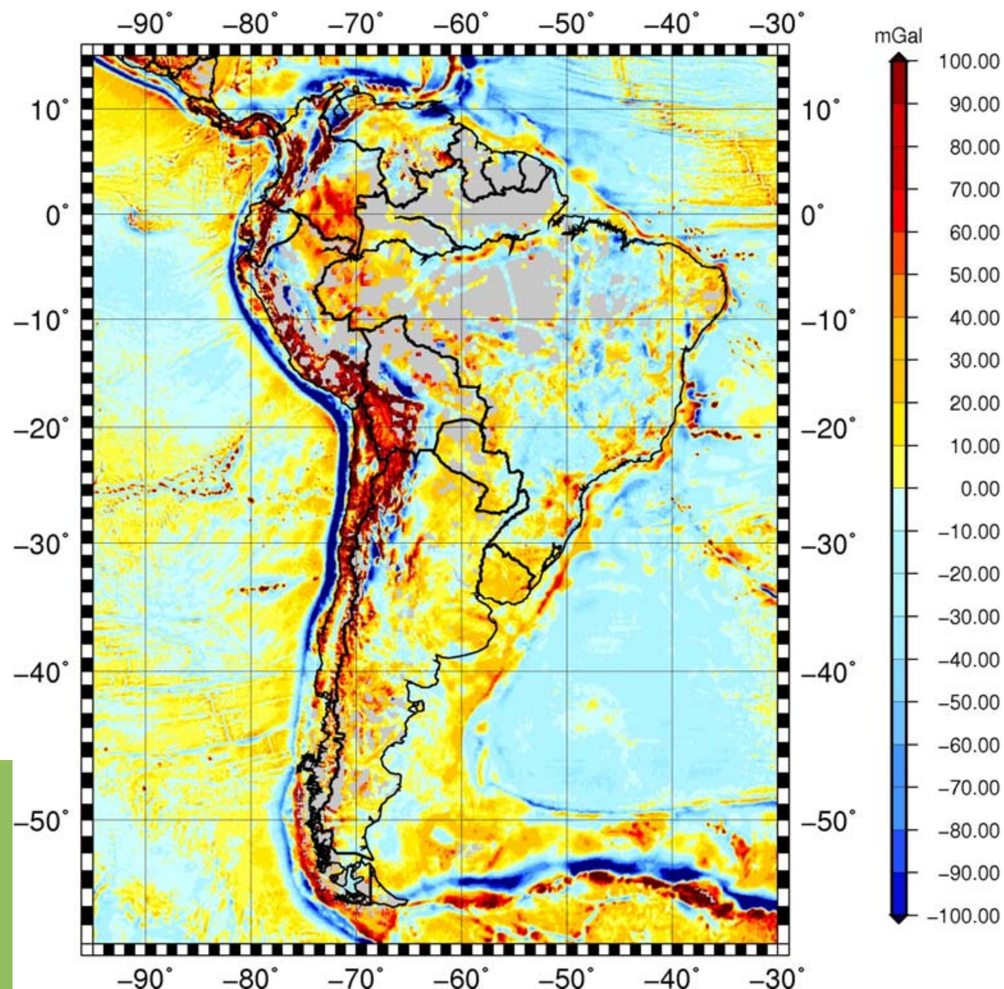
The free air gravity anomaly over the ocean were obtained from Danish National Space Center (DNSC08-GRA) with resolution 1’ x 1’ (Andersen et al., 2008)

HELMERT GRAVITY ANOMALY REFFERED TO THE EARTH’S SURFACE (HGES)

It was obtained from the sum of the free-air gravity anomaly, the direct and secondary indirect topographic effects on the gravitational attraction, direct atmospheric effect and geoid-quasigeoid correction to the fundamental formula of physical geodesy (Vaníček *et al*., 1999).

effects (mGal)	mean	std	max	min
FA	-0.66	35.02	486.36	-253.49
DTE	0.30	3.35	105.25	-87.34
SITE	-0.016	0.04	-0.004	-0.36
DAE	-0.82	0.04	-0.61	-0.84
geoid-quasigeoid	-0.009	0.05	0.06	-0.77
HGES	-0.43	34.64	486.37	-253.49

HGES



The Stokes boundary value problem employs a modified Stokes's formula in conjunction with the low-degree contribution of the Global Geopotential model. In the case of Argentina geoid, EGM2008 (Pavlis *et al.*,2008) was used up to the degree and order 150 as a reference spheroid.

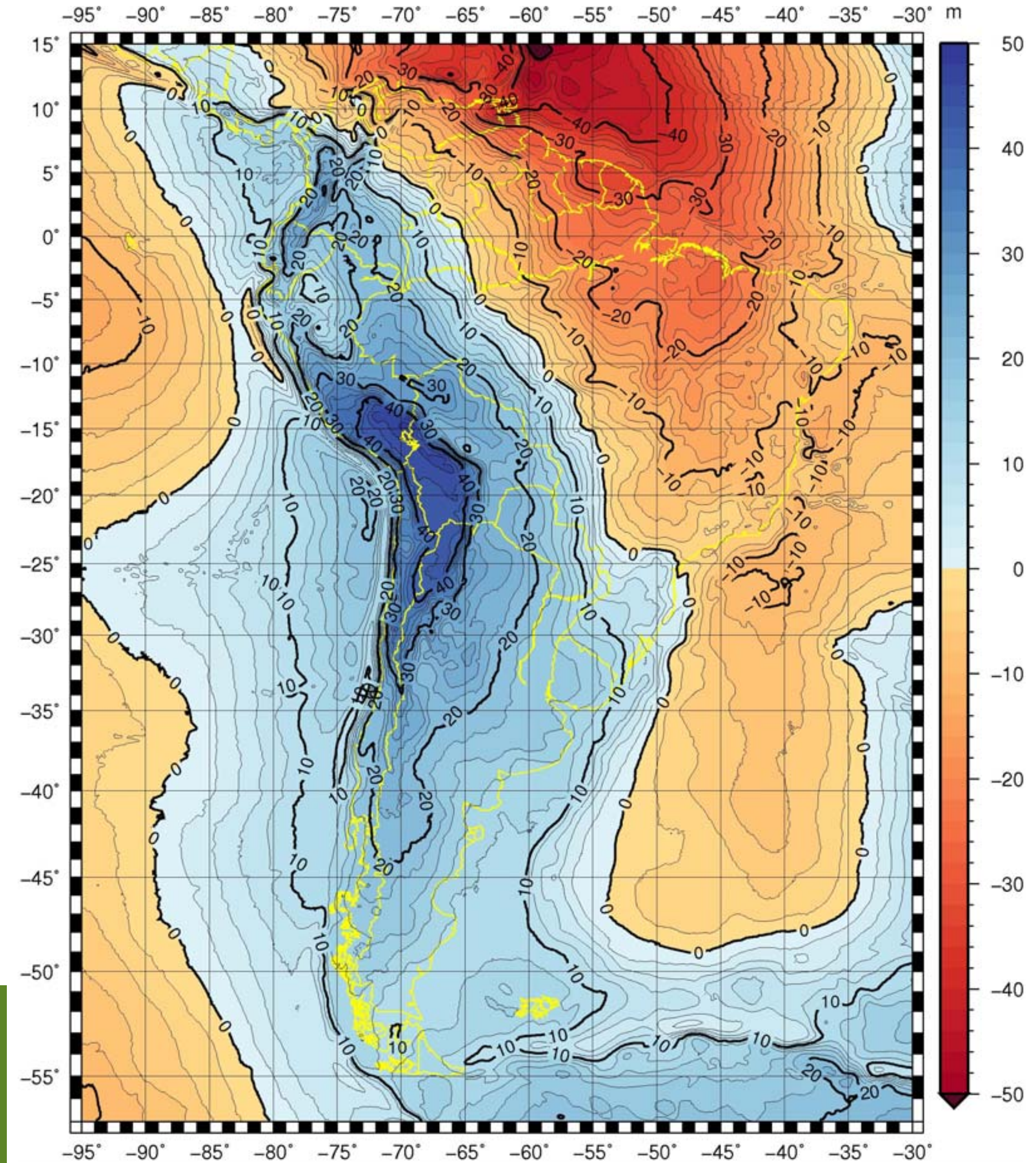
The processing of the modified Stokes integral proposed by Featherstone et al. (1998) was carried out using FFT. This application uses the Meissl (1971) modification to the Vaníček and Kleusberg (1987) kernel.

FINAL SOLUTION OF THE GEOID

= residual co-geoid
+ reference spheroid
+ primary indirect atmospheric effect
+ primary indirect topographical effect

effects	(meter)	mean	std	max	min
PIAE		-0.006	0.0001	-0.0054	-0.0065
PITE		-0.06	0.18	-0.014	-1.96
Geoid		0.44	15.19	48.87	-57.39

South America Geoid (quasi-geoid)



GLOBAL MODELS

The new geoid model were compared with height anomalies obtained by Global Geopotential Models (GGMs).

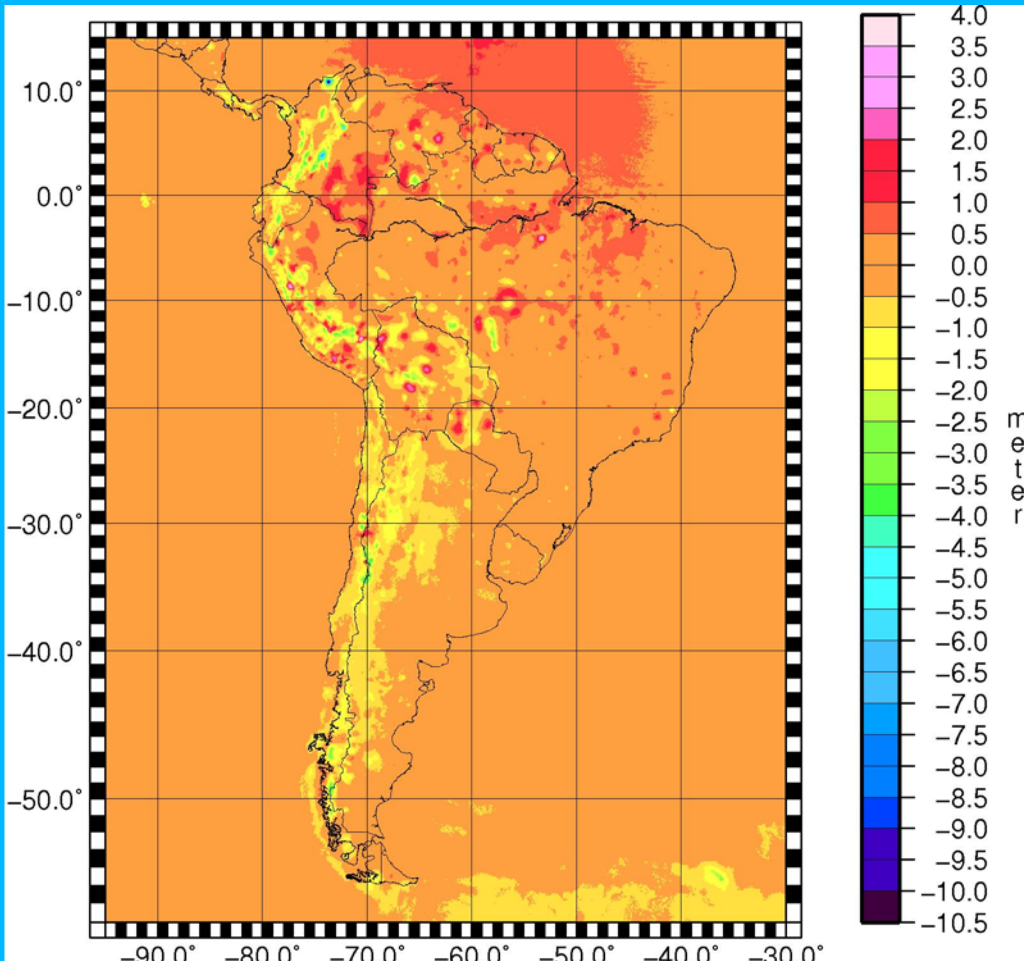
The attention has been addressed to the following GGMs :

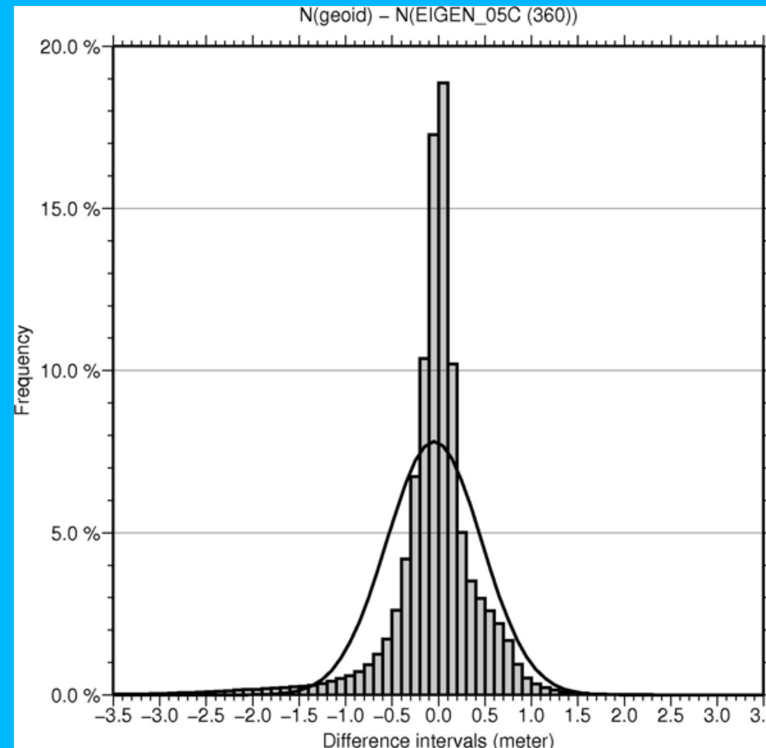
- **EIGEN-GL05C** (n=m=360) (Foerste *et al.*,2008) and
- **EGM2008** (n=m=2160) and Tide Free system.

No zero-order term was considered to the geoid undulations in all cases.

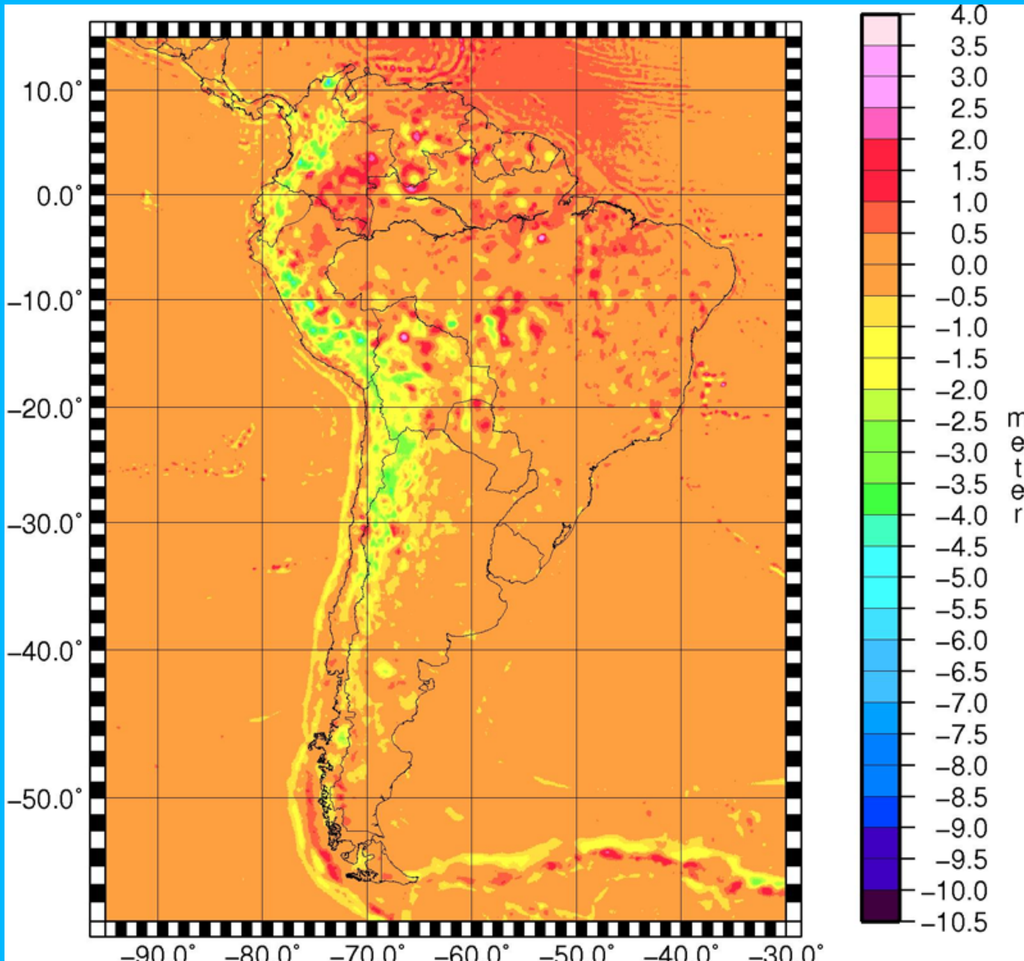
geoidal heights - height anomalies	Mean (m)	Stand. Desv. (m)	Max. value (m)	Min. value (m)	Kurtosis	Skewness
EIGEN_05C (360)	-0.05	0.51	3.38	-6.89	10.98	-2.04
EGM2008 (2160)	-0.00	0.42	3.61	-10.41	16.46	-1.56

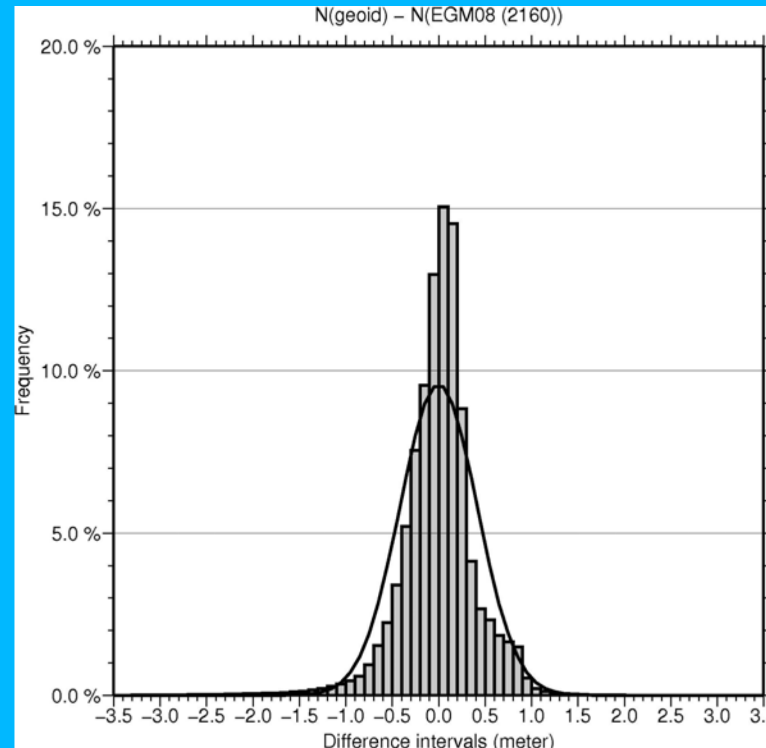
South America Geoid - EGM08





South America Geoid – EIGEN_05C





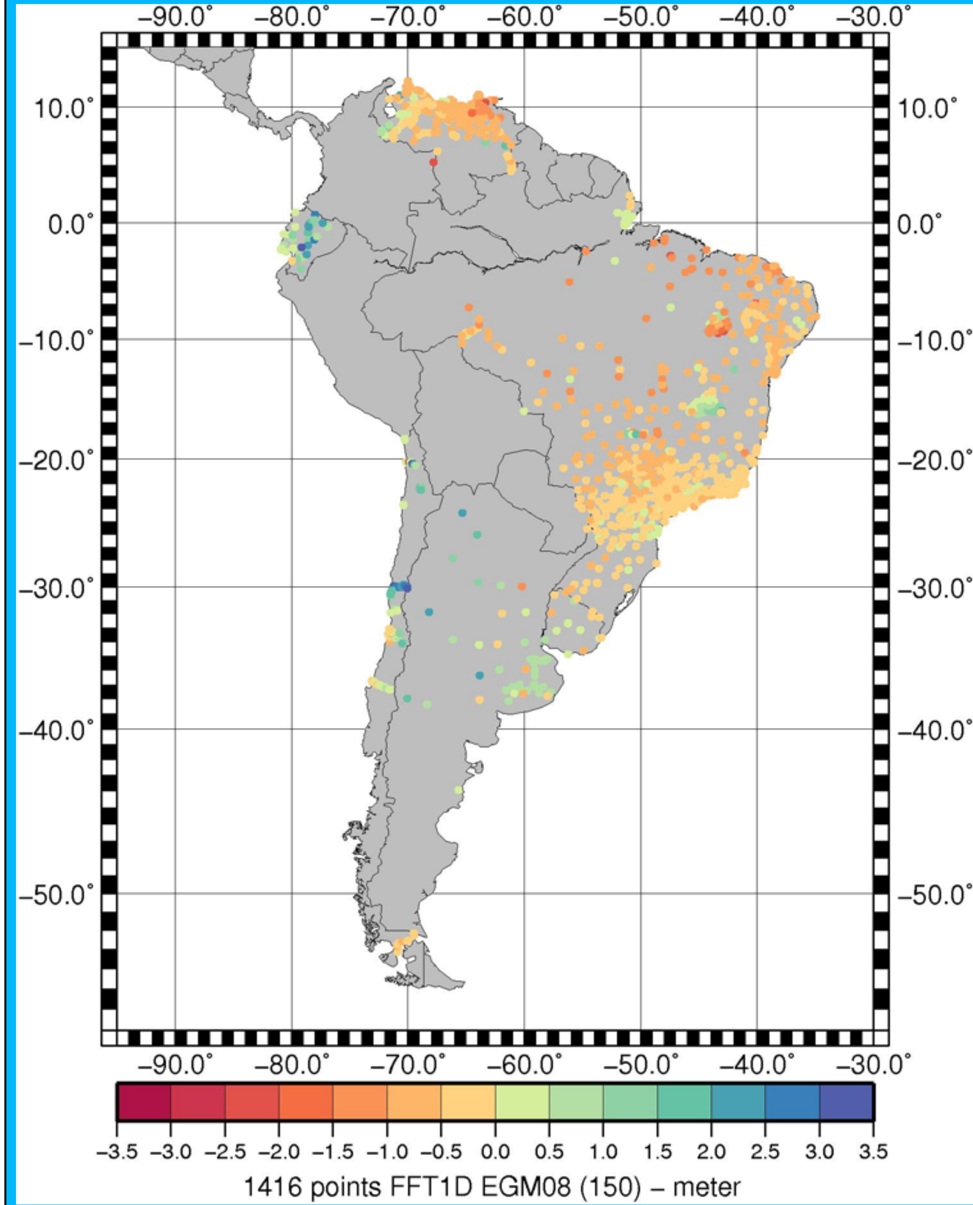
GPS DATA OVER BENCH MARKS I

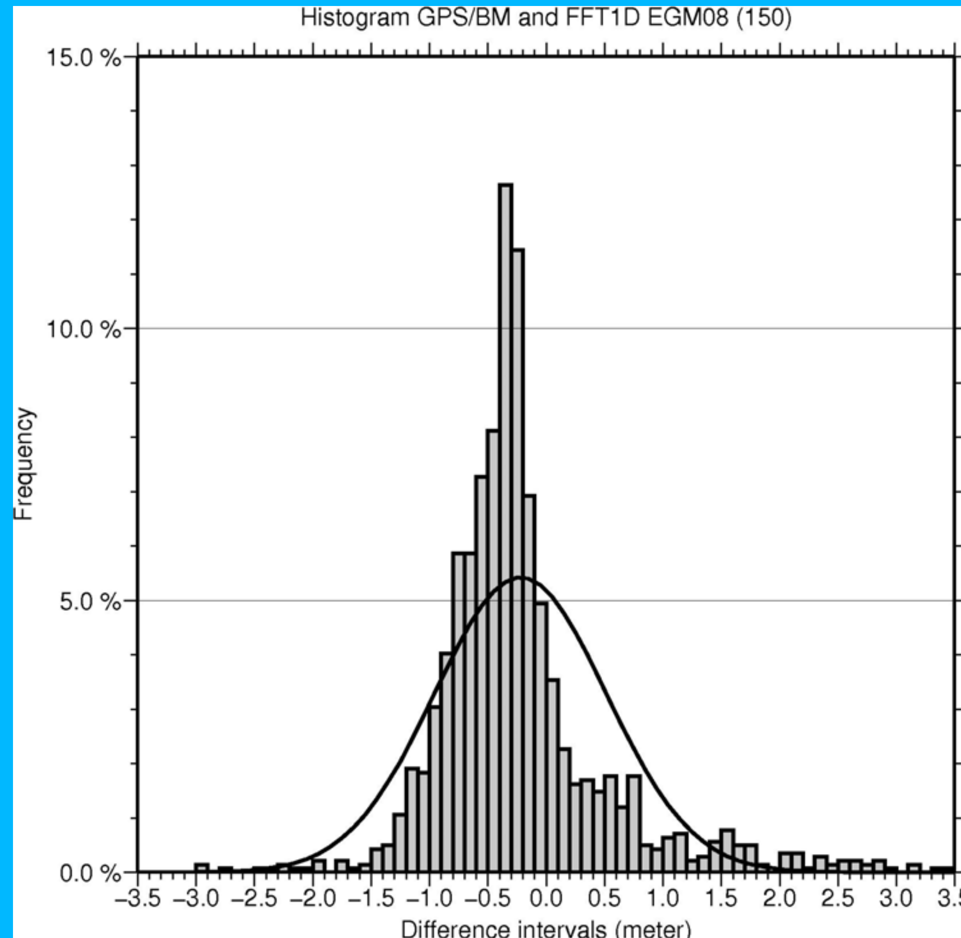
The new geoid model has been compared with GPS observations carried out on benchmarks of the spirit levelling network in South America (Argentina, Brazil, Chile, Equador, Uruguay and Venezuela).

A total of 1416 GPS/BM points are available in this area.
They have been delivered referred to WGS84 (SIRGAS2000)

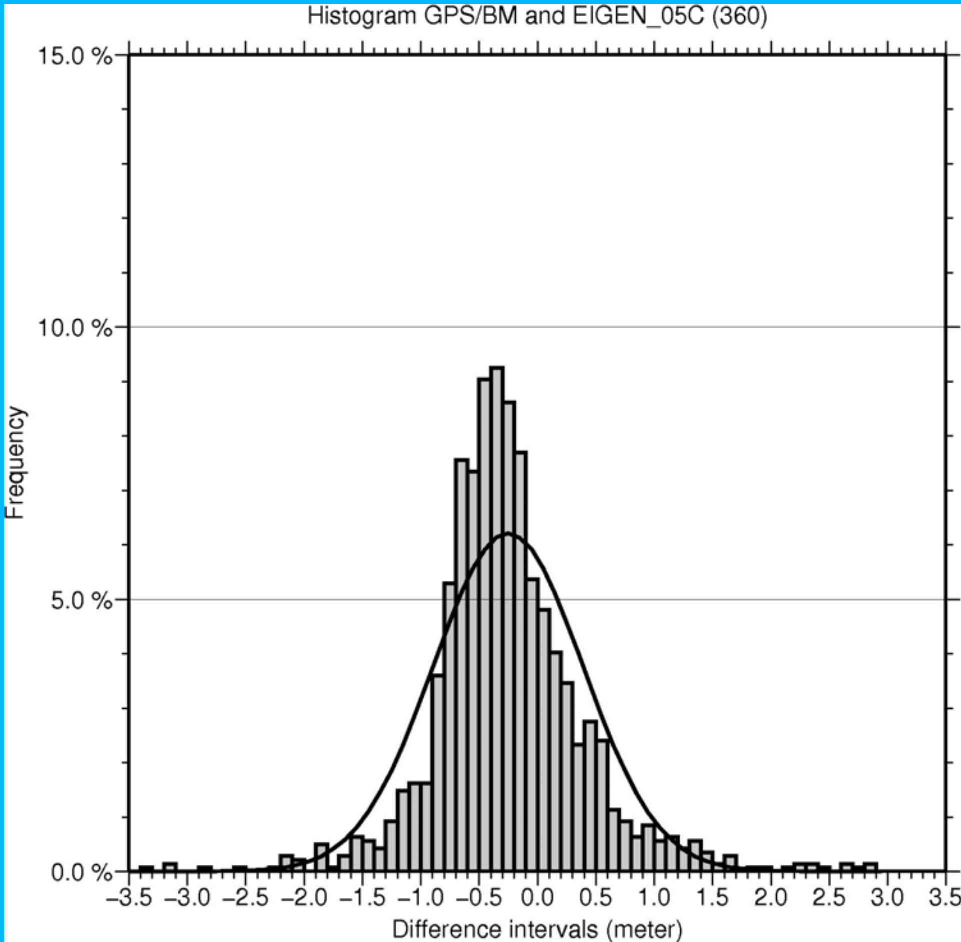
Statistic in South America

GPS/BM -	Mean (m)	Stand. Desv. (m)	Max. value (m)	Min. value (m)	Kurtosis	Skewness
Geoid	-0.22	0.74	3.46	-2.95	4.42	1.44
EIGEN_05C (360)	-0.25	0.64	2.87	-3.38	3.68	0.52
EGM2008 (2160)	-0.18	0.63	3.32	-3.64	7.05	1.41



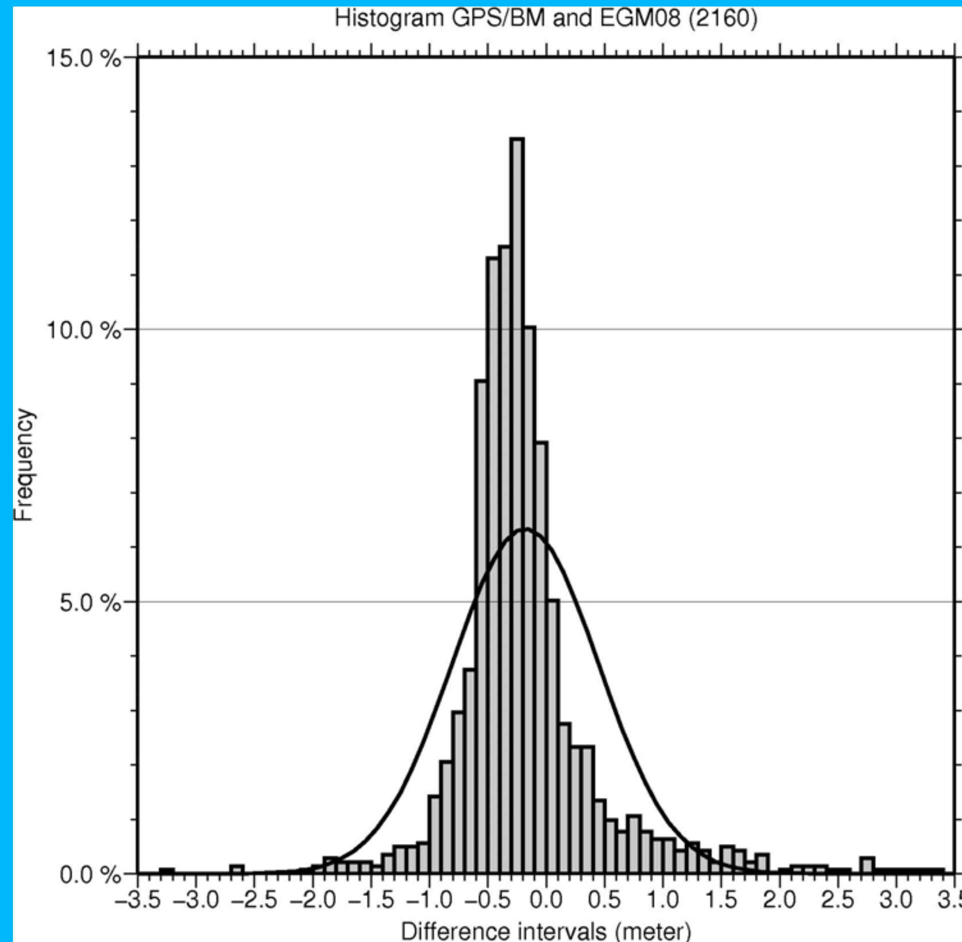


GPS data over Bench Marks X GEOID



GPS data over Bench Marks X EIGEN_05C(360)

GPS data over Bench Marks X EGM2008 (2160)



GPS DATA OVER BENCH MARKS II

The new geoid model has been compared with GPS observations carried out on benchmarks of the spirit levelling network in Brazil

A total of 916 GPS/BM points are available in this area.
They have been delivered referred to SIRGAS2000

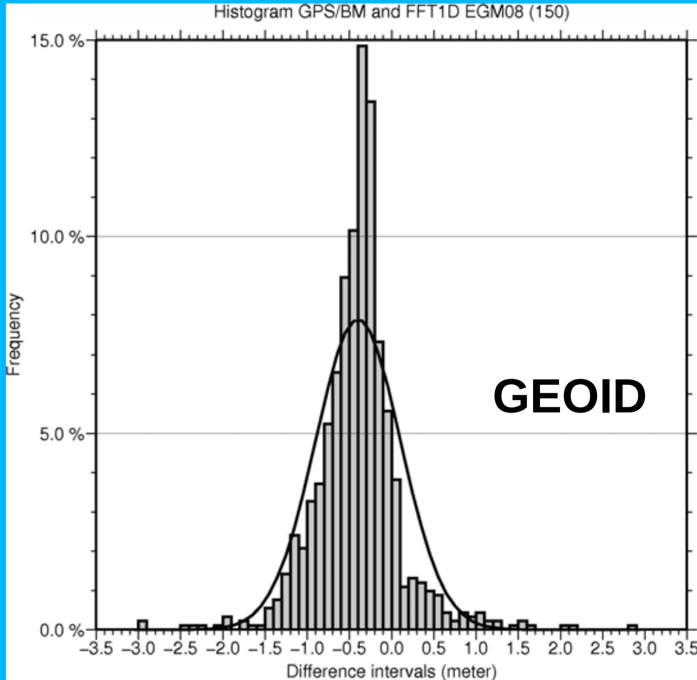
Statistic in Brazil

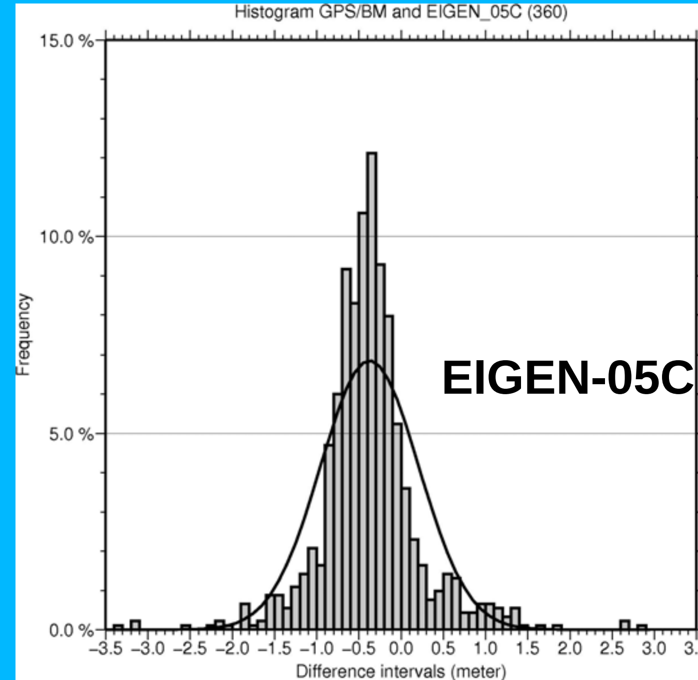
GPS/BM -	Mean (m)	Stand. Desv. (m)	Max. value (m)	Min. value (m)	Kurtosis	Skewness
Geoid	-0.40	0.51	2.88	-2.95	6.10	0.43
EIGEN_05C (360)	-0.37	0.58	2.87	-3.38	5.11	0.39
EGM2008 (2160)	-0.27	0.53	3.11	-3.64	7.16	0.61
MAPGEO 2004	0.52	0.66	3.97	-4.13	6.55	0.31

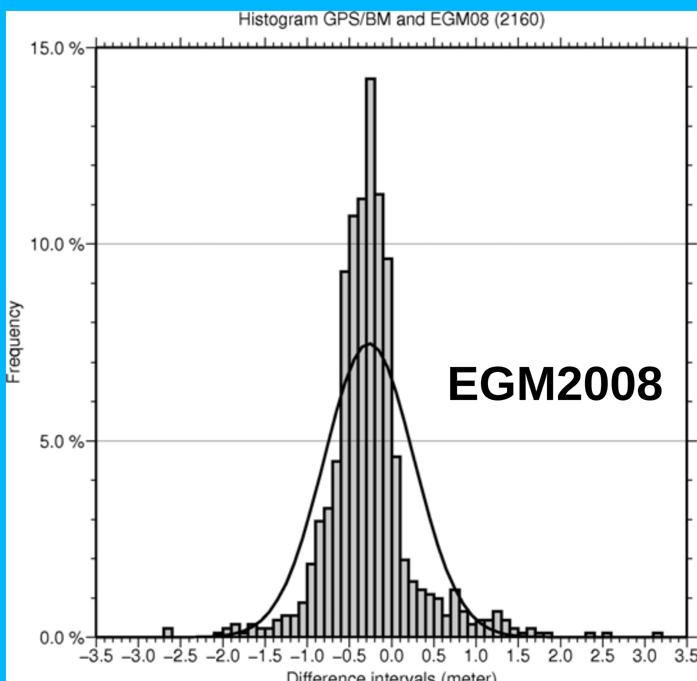
BRAZIL

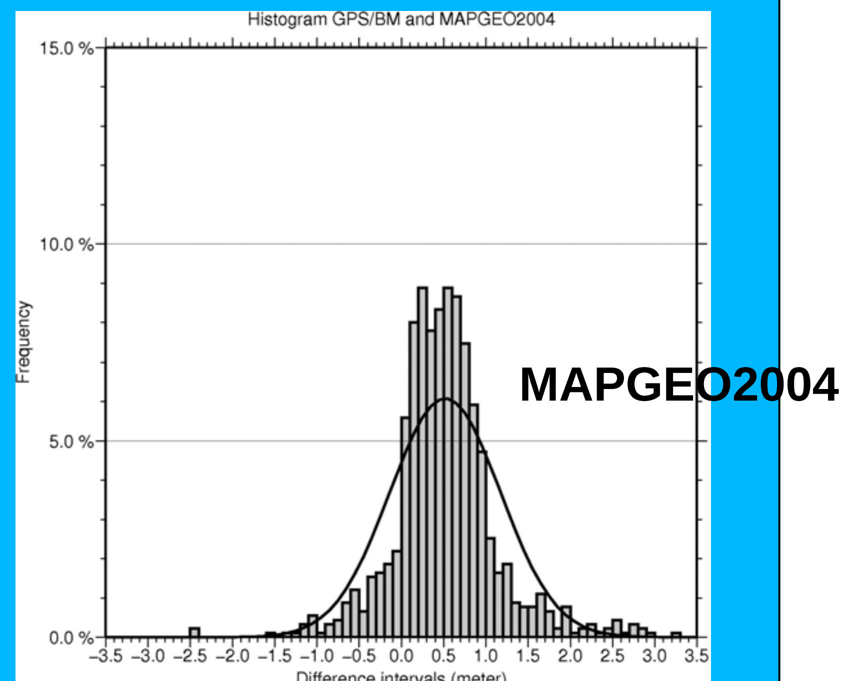
GPS/BM

X









CONCLUSION

The GGMs with total order and degree show few difference statistics between geoidal heights with the mentioned geoid model, in flat areas. The highest differences are in the Andes and regions without terrestrial gravity data.

The differences between geoidal heights and height anomalies derived from EGM08 are smaller than EIGEN05C. Despite of the efforts in recent years of different organizations, universities and research institutes to fill in the areas without terrestrial gravity data, there are still large gaps. The GGMs with total order and degree may show inconsistencies in these regions.

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