GGM REFINING BY USING RTM TECHNIQUE IN REGIONS WITH POOR CONVENTIONAL GRAVITY COVERAGE

“Refinamento de Modelos do Geopotencial Global com base na técnica da modelagem da topografia residual (RTM) em regiões de baixa cobertura gravimétrica convencional”

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BACKGROUND:

Topographic and bathymetry models are useful for reducing the omission error of modern high degree combined GGMs (e.g. EGM2008 with resolution up ~ 9 km).

Combined models are usually built with basis in several data basis with different spatial resolution and reference frames.

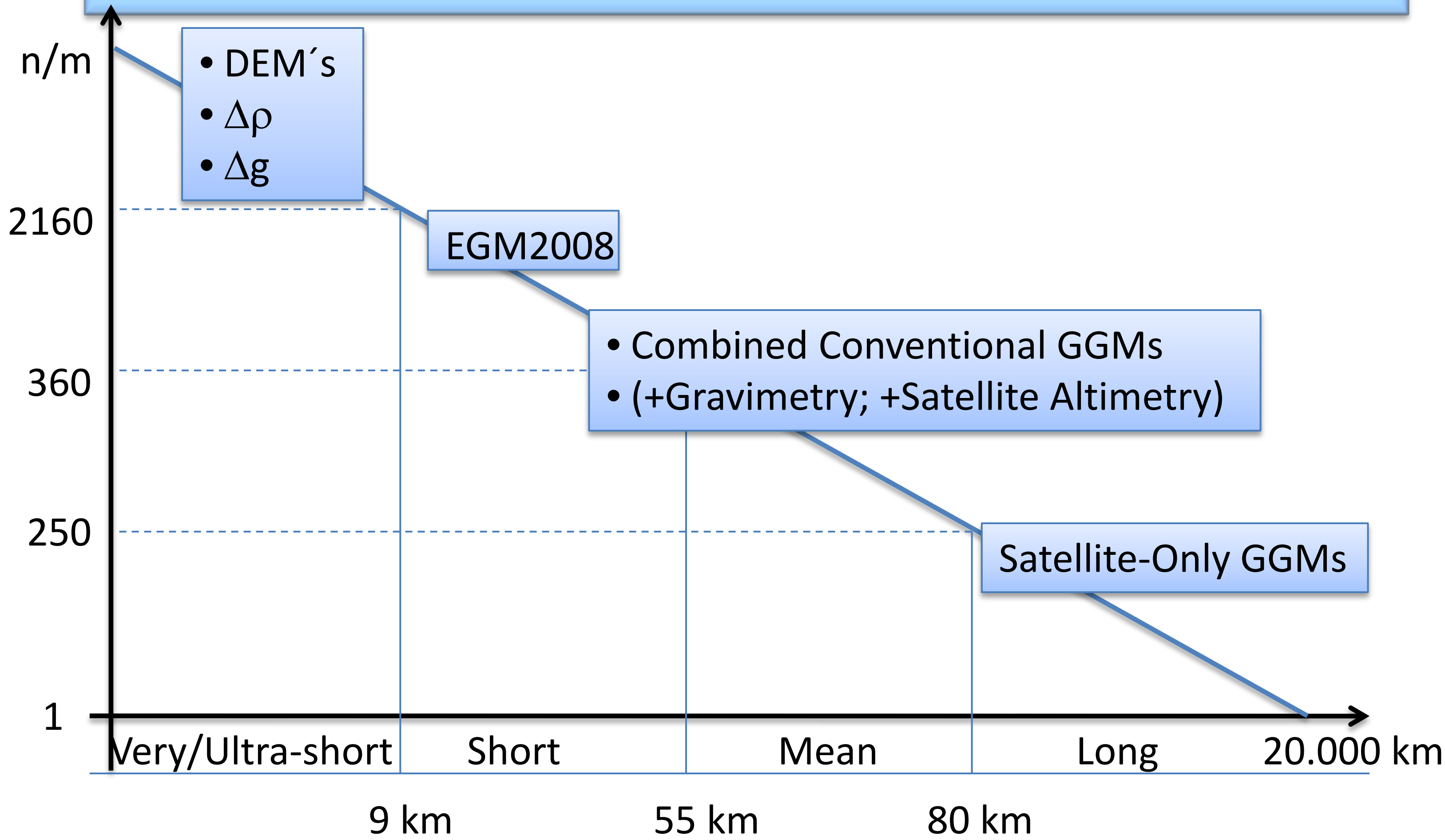
In general, the spatial accuracy combined GGMs is not globally uniform.

When a regional better resolution in a delimited region is searched it is necessary the use of regional information about the gravity field not involved in the GGM generation.

Besides conventional terrestrial gravity data in a regional basis other terrestrial data can improve the knowledge of gravity field and the resolution of GGMs.

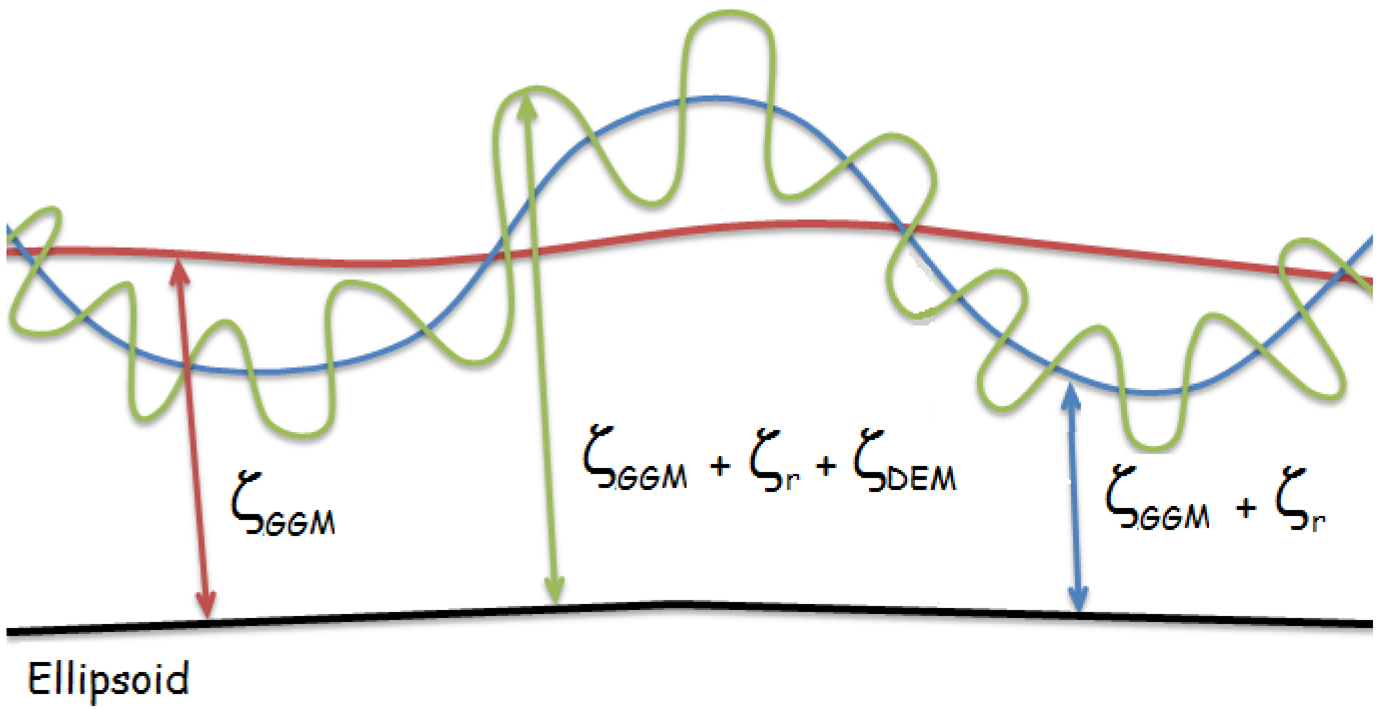
Then, a fundamental aspect to be considered in regions with poor conventional terrestrial gravity coverage is the contribution of modern DEMs.

SPECTRAL RESOLUTION BASED ON HARMONIC EXPANSION



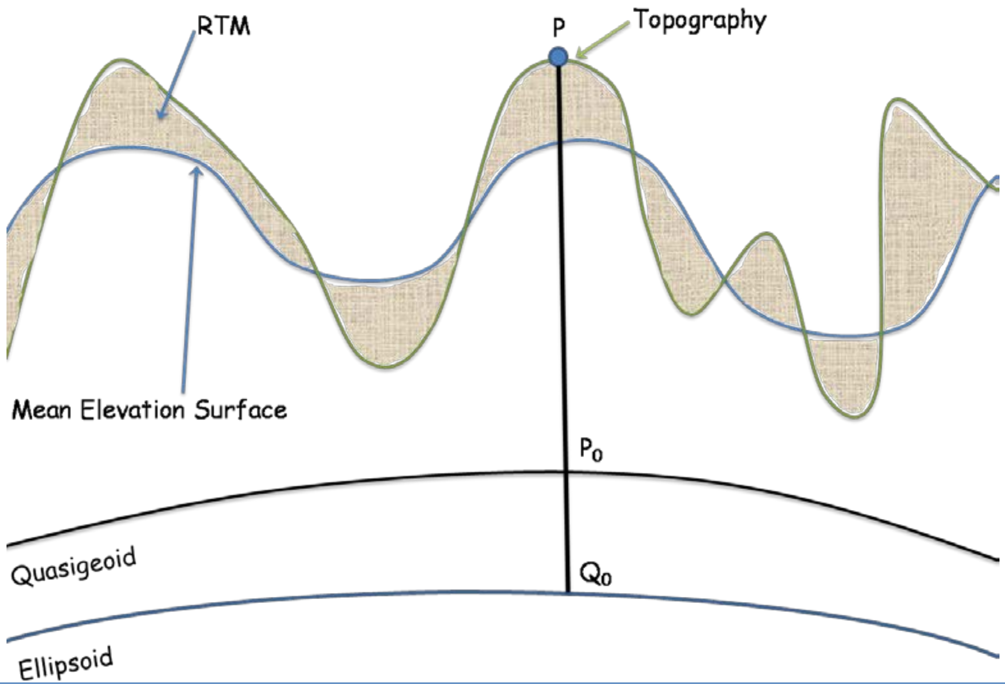
Spatial resolution and degree/order of harmonic developement of GGMs without a true scale for a better understanding

CONTRIBUTION OF THREE DIFFERENT WAVELENGTH BANDS FOR HEIGHT ANOMALY

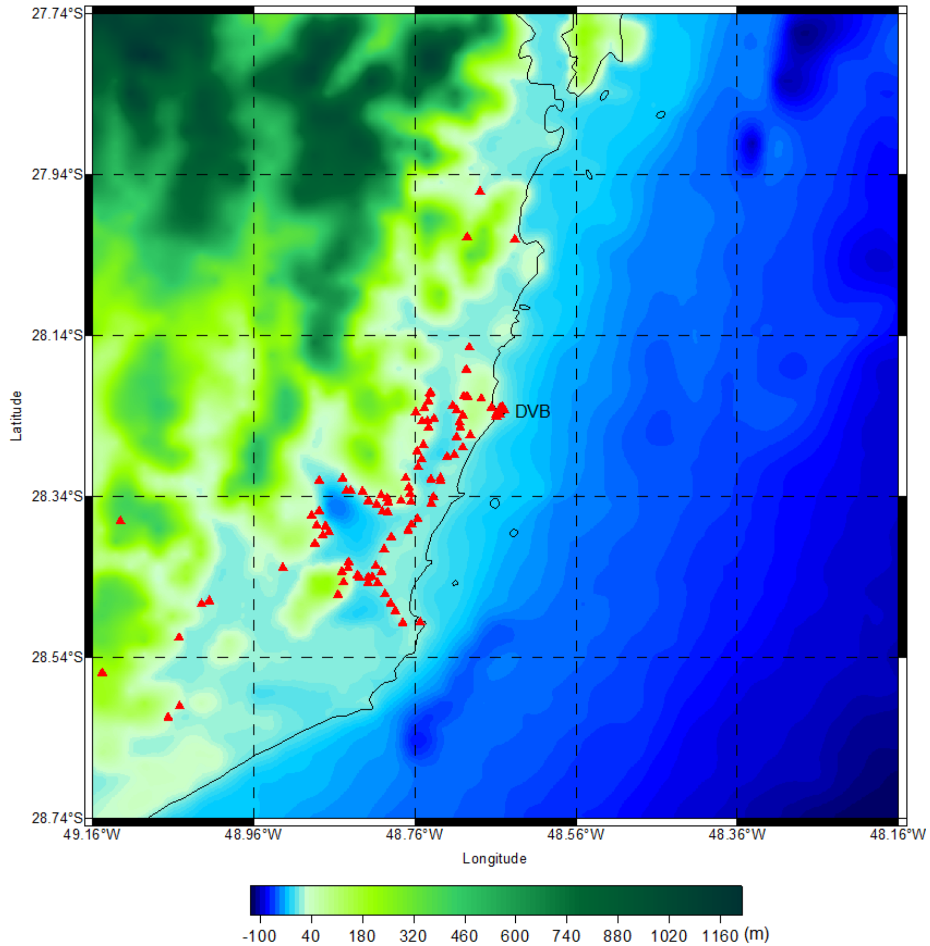


RESIDUAL TERRAIN MODEL(RTM)

RTM is a technique for computing the effects of topography/bathimetry on the short and ultra-short wavelengths of gravity field. It is based on a mean topographic surface with of the same degree/order of MGG harmonic development. It acts as a high-pass filter for a DEM with resolution at very and ultra-short wavelengths. The gravitational effects of residual topography is then used for reducing the GGM omission error.



Topography/batimetry in a study area around BVD-IMBI



Refinamento de Modelos do Geopotencial Global com base na técnica da modelagem da topografia residual (RTM) em regiões de baixa cobertura gravimétrica convencional

$$\zeta_{Final}^{N\max}(\varphi,\lambda) = \zeta_{GGM}^{N\max\, up100\, to\,(n,m)}(\varphi,\lambda) + \zeta_{RTM}^{N>(n,m)\, to\,(\frac{\pi R}{DEMresolution})}(\varphi,\lambda)$$

Degree and order	Used GGMs (available ICGEM)
100	AIUB-CHAMP03S
160	AIUB-GRACE03S EGM2008
200	GO_CONS_GCF_2_TIM_R3
250	GO_CONS_GCF_2_TIM_R2 GOCO02S EGM2008
360	EIGEN-5C EGM2008
720	EGM2008
1420	EIGEN-6C EGM2008
2159	EGM2008

SRTM30_PLUS;
GMRT v2.0

DTM2006;
ETOPO1

DEGREE and ORDER of DTM2006.0 or ETOPO1 in agreement with the used GGM

USED DEMs FOR ESTABLISHING HIGH-PASS FILTER

DTM2006.0

Developed until 30arc second max resolution. It is the base DEM for EGM2008.

PAVLIS, N. K.; FACTOR, J. K.; HOLMES, S. A. Terrain-related gravimetric quantities computed for the next EGM. In: Proceedings of the 1st International Symposium of the International Gravity Field Service. Harita Dergisi, Istanbul: [s.n.], v. 18, p. 318–323. 2007.

ETOPO1

Available in harmonic development until 1arc minute for elevation and bathimetry [http://icgem.gfz-potsdam.de/ICGEM/].

AMANTE, C.,B. W. EAKINS. ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. NOAA Technical Memorandum NESDIS NGDC-24, p.19, March 2009.

USED DEMs FOR MODELING RESIGUAL TOPOGRAPHY/BATHIMETRY

SRTM30_PLUS

ftp://topex.ucsd.edu/pub/srtm30_plus/

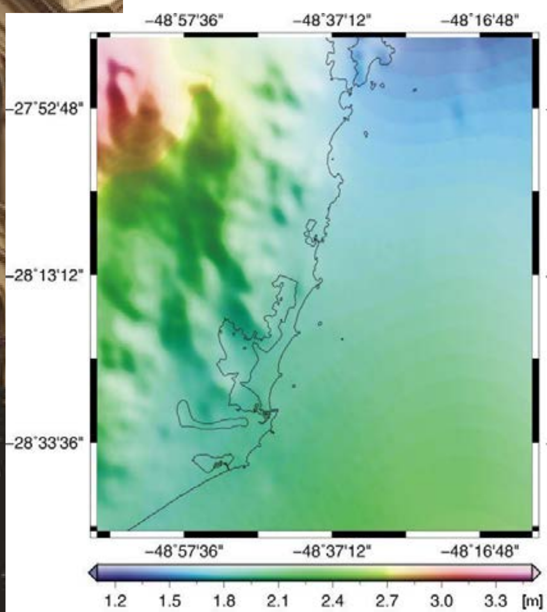
BECKER J. J., et al. 'Global Bathymetry and Elevation Data at 30 Arc Seconds Resolution: SRTM30_PLUS', Marine Geodesy,32:4,p. 355 - 371. 2009.

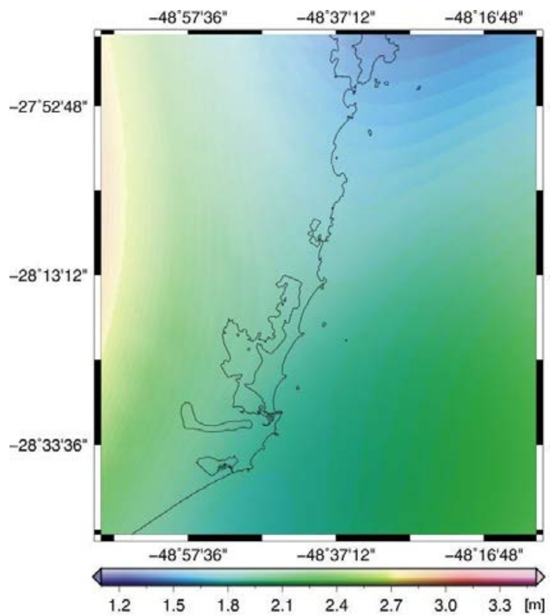
GMRT v2.0

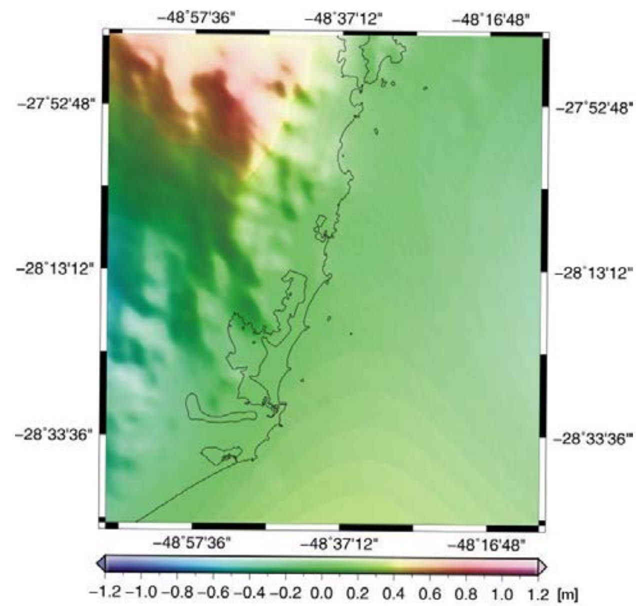
Global Multi-Resolution Topography Model 10m resolution in EUA and 30m in the world for elevation and minimum of 100 m for bathimetry.

Details in http://www.marine-geo.org/portals/gmrt/

Refinamento de Modelos do Geopotencial Global com base na técnica da modelagem da topografia residual (RTM) em regiões de baixa cobertura gravimétrica convencional







$$\zeta_{Final}^{N\max}(\varphi,\lambda)=\zeta_{GGM}^{Nto250}(\varphi,\lambda)+\zeta_{RTM}^{N_{>250}}(\varphi,\lambda)$$

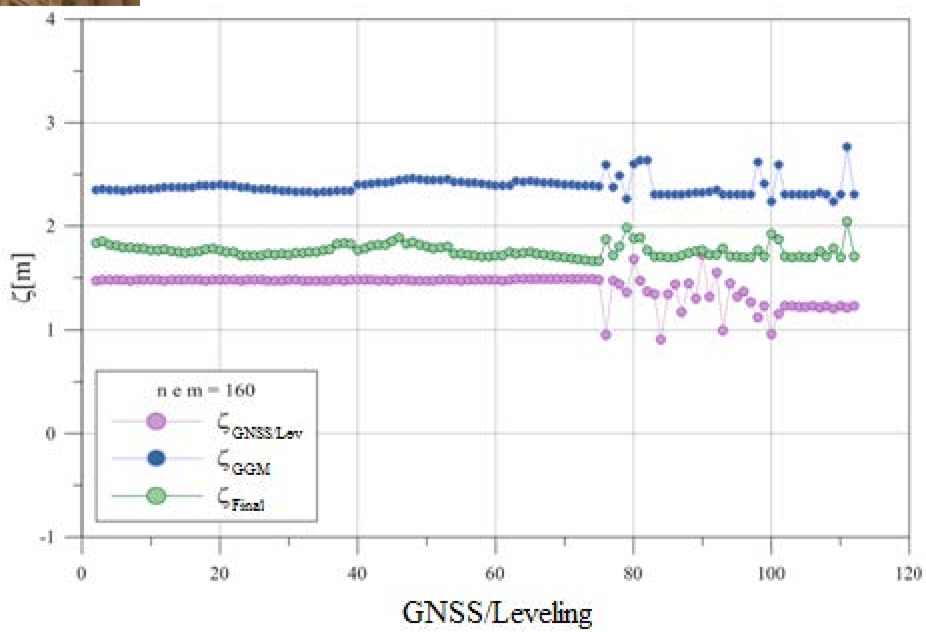
ABSOLUTE ANALYSIS

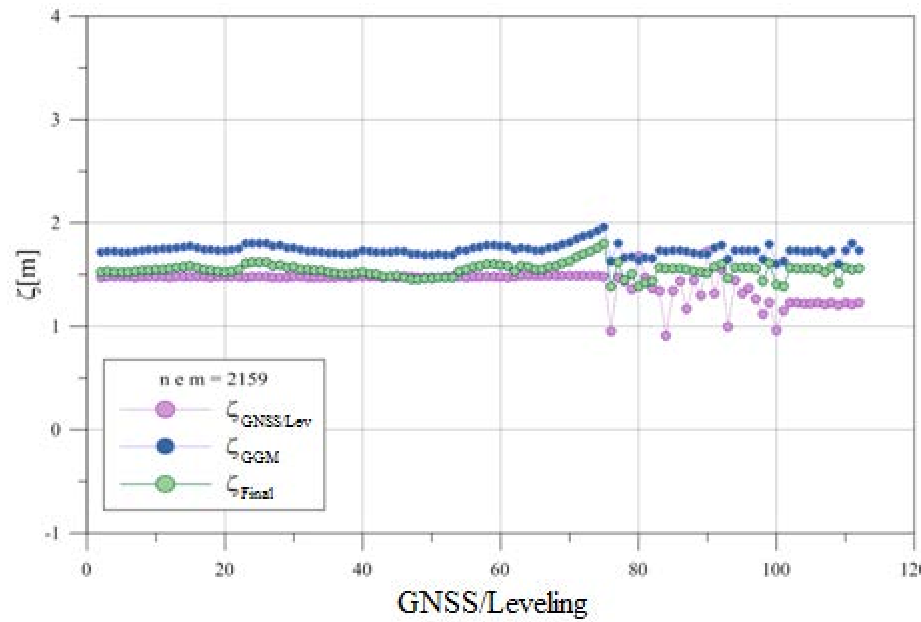
112 GNSS/leveling stations in the region

$$\varepsilon_{Absolute \rightarrow GGM} = \zeta_{GNSS/Leveling} - \zeta_{GGM}^{N_{\max up 100 to 2159}}$$

$$\varepsilon_{Absolute \rightarrow Final} = \zeta_{GNSS/Leveling} - \zeta_{Final}^{N_{\max up 100 to 2159}}$$

$$\zeta_{GNSS/Leveling} = h - H^{N}$$





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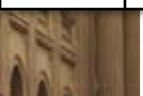
de baixa cobertura

$\varepsilon_{Absolute \rightarrow GGM}$		Mean	Mean deviation	Standard deviation	RMS
		(m)			
100	AIUB-CHAMP03S	1,75	0.21	0.36	1.76
160	AIUB-GRACE03S	0,97	0.12	0.28	0.98
	EGM2008	1,07	0.14	0.30	1.08
250	GO_CONS_GCF_2_TIM_R2	0,51	0.12	0.28	0.56
	GOCO02S	0,51	0.12	0.28	0.55
	EGM2008	0,68	0.11	0.26	0.71
360	EIGEN-5C	0,16	0.17	0.29	0.32
	EGM2008	0,36	0.14	0.27	0.43
720	EGM2008	0,36	0.11	0.26	0.42
1420	EIGEN-6C	0,23	0.11	0.26	0.33
	EGM2008	0,32	0.11	0.26	0.39
2159	EGM2008	0,32	0.12	0.26	0.39



$\varepsilon_{Absolute \rightarrow Final}$		Mean	Mean deviation	Standard deviation	RMS
		(m)			
100	AIUB-CHAMP03S	1.77	0.15	0.22	1.76
160	AIUB-GRACE03S	0.40	0.11	0.16	0.42
	EGM2008	0.50	0.11	0.17	0.52
250	GO_CONS_GCF_2_TIM_R2	0.48	0.10	0.13	0.49
	GOCO02S	0.47	0.10	0.13	0.48
	EGM2008	0.65	0.09	0.12	0.65
360	EIGEN-5C	0.20	0.13	0.17	0.26
	EGM2008	0.40	0.11	0.14	0.42
720	EGM2008	0.36	0.10	0.14	0.38
1420	EIGEN-6C	0.27	0.10	0.13	0.30
	EGM2008	0.36	0.10	0.13	0.38
2159	EGM2008	0.18	0.10	0.14	0.22

SRTM30_PLUS;
DTM2006;

Refinamento de Modelos do Geopotencial Global com base na técnica da modelagem da topografia residual (RTM) em regiões de baixa cobertura

$\varepsilon_{Absolute \to Final}$		Mean (m)	Mean deviation (m)	Standard deviation (m)	RMS (m)
100	AIUB-CHAMP03S	1,80	0.15	0.22	1.79
160	AIUB-GRACE03S	-0,35	0.11	0.16	0.37
	EGM2008	-0,45	0.11	0.17	0,47
250	GO_CONS_GCF_2_TIM_R2	-0,43	0.10	0.13	0.44
	GOCO02S	-0,43	0.10	0.13	0.44
	EGM2008	-0,60	0.09	0.12	0.61
360	EIGEN-5C	-0,16	0.13	0.17	0.23
	EGM2008	-0,36	0.11	0.14	0.38
720	EGM2008	-0,32	0.10	0.14	0.34
1420	EIGEN-6C	-0,23	0.10	0.13	0.26
	EGM2008	-0,32	0.10	0.13	0.33
2159	EGM2008	-0,13	0.10	0.14	0.19

GMRT v2.0;
DTM2006;

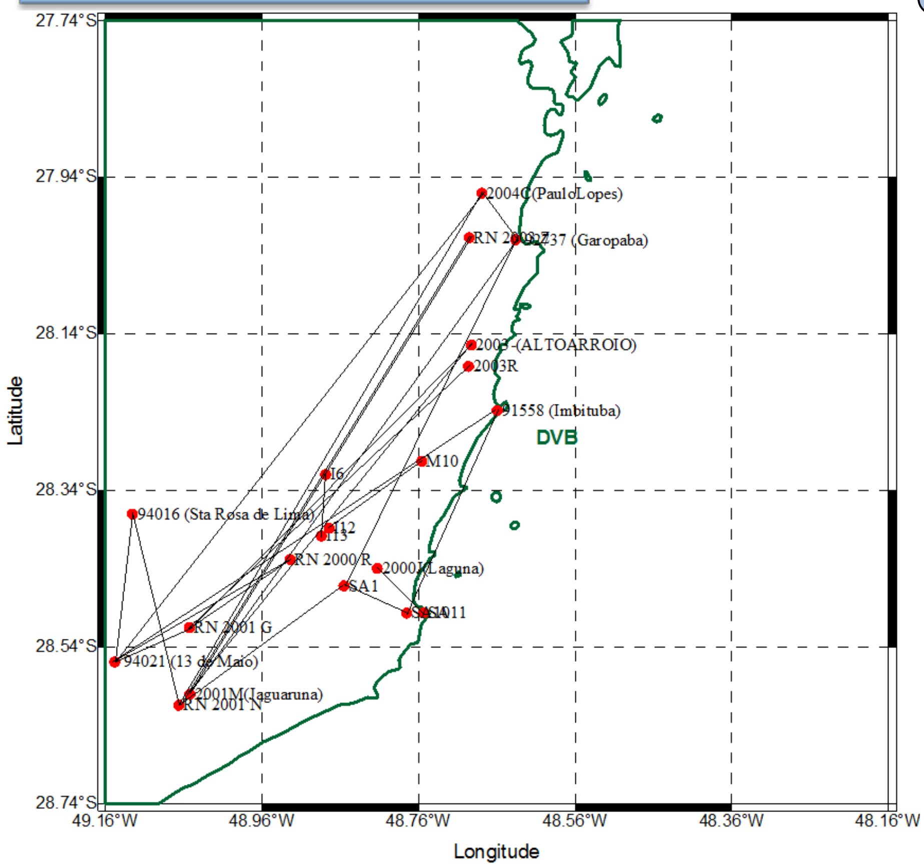
$\varepsilon_{Absolute \to MGG}$		Mean (m)	Mean deviation (m)	Standard deviation (m)	RMS (m)
200	GO_CONS_GCF_2_TIM_R3	0,46	0.12	0.18	0.49

GMRT v2.0;
ETOPO1

$\varepsilon_{Absolute \to Final}$		Mean (m)	Mean deviation (m)	Standard deviation (m)	RMS (m)
200	GO_CONS_GCF_2_TIM_R3	0.10	0.11	0.18	0.20

Refinamento de Modelos do Geopotencial Global com base na técnica da modelagem da topografia residual (RTM) em regiões de baixa cobertura gravimétrica convencional

RELATIVE ANALYSIS



22 control points forming baselines with lenghts covering the usual GGMs resolutions

$$res_{GGM} = \frac{\pi R}{n_{máx}} [km]$$

$$\varepsilon_{\text{Relative}\rightarrow GGM\text{orFinal[ppm]}} = \left| \frac{\delta \Delta H_{1-2}}{D_{1-2(km)}} \right| = \left| \frac{([\Delta N_{1-2}]_{GNSS/Leveling} - \Delta\zeta_{1-2})_{mm}}{D_{1-2(km)}} \right|$$

Refinamento de Modelos do Geopotencial Global com base na técnica da mo... bertura

Relative resolutions in ppm

N/M	$\varepsilon_{Relative \rightarrow GGM}$	9 km	14 km	28 km	55 km	80 km
100	AIUB-CHAMP03S					13,16
160	AIUB-GRACE03S					3,45
	EGM2008					7,86
250	GO_CONS_GCF_2_TIM_R2					5,88
	GOCO02S					5,42
	EGM2008					3,54
360	EIGEN-5C				4,35	2,10
	EGM2008				2,92	3,22
720	EGM2008			4,22	0,01	2,77
1420	EIGEN-6C		3,69	3,04	0,61	1,56
	EGM2008		3,06	2,76	1,05	1,30
2159	EGM2008	4,14	2,74	3,86	1,49	0,65

SRTM30_PLUS;
DTM2006;

N/M	$\varepsilon_{Relative \rightarrow Final}$	9 km	14 km	28 km	55 km	80 km
100	AIUB-CHAMP03S					1,28
160	AIUB-GRACE03S					1,48
	EGM2008					2,93
250	GO_CONS_GCF_2_TIM_R2					0,24
	GOCO02S					0,22
	EGM2008					2,14
360	EIGEN-5C				1,04	0,06
	EGM2008				0,40	1,18
720	EGM2008			2,84	1,84	0,03
1420	EIGEN-6C		3,41	1,22	1,28	0,53
	EGM2008		2,78	1,49	1,72	0,27
2159	EGM2008	0,20	3,89	0,27	0,67	1,41

Refinamento de Modelos do Geopotencial Global com base na técnica da modelagem da topografia residual (RTM) em regiões de baixa cobertura gravimétrica convencional

N/M	$\varepsilon_{Relative \to Final}$	9 km	14 km	28 km	55 km	80 km
100	AIUB-CHAMP03S					1,31
160	AIUB-GRACE03S					1,78
	EGM2008					3,04
250	GO_CONS_GCF_2_TIM_R2					0,17
	GOCO02S					0,42
	EGM2008					2,15
360	EIGEN-5C				1,34	3,14
	EGM2008				0	1,41
720	EGM2008			2,32	1,34	0,05
1420	EIGEN-6C		3,26	0,84	0,67	0,79
	EGM2008		2,63	0,84	1,17	0,54
2159	EGM2008	20,16	4,52	0,64	0	1,16

GMRT v2.0;
DTM2006;

Relative resolutions in ppm

N/M	$\varepsilon_{Relative \to GGM}$	9 km	14 km	28 km	55 km	80 km
200	GO_CONS_GCF_2_TIM_R3					0,45

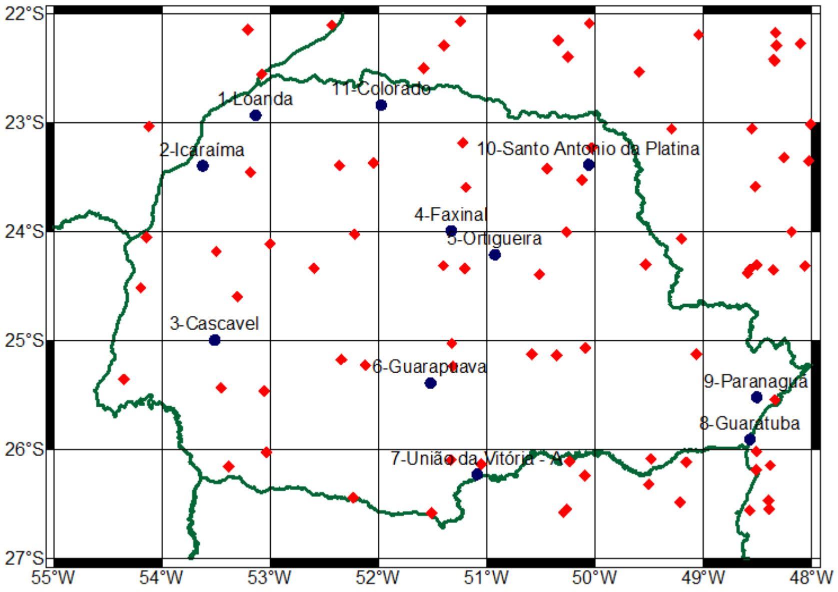
GMRT v2.0;
ETOPO1

N/M	$\varepsilon_{Relative \to Final}$	9 km	14 km	28 km	55 km	80 km
2159	EGM2008	17,88	2,63	0,47	0,84	0,67
200	GO_CONS_GCF_2_TIM_R3					2,08

In view the final solutions, for which data were used and SRTM30_PLUS DTM2006.0, there was an improvement in the resolution of 9 km (which corresponds to the maximum degree of EGM2008) from degree and order 360, varying from 71% (1420) to 95% (2159).

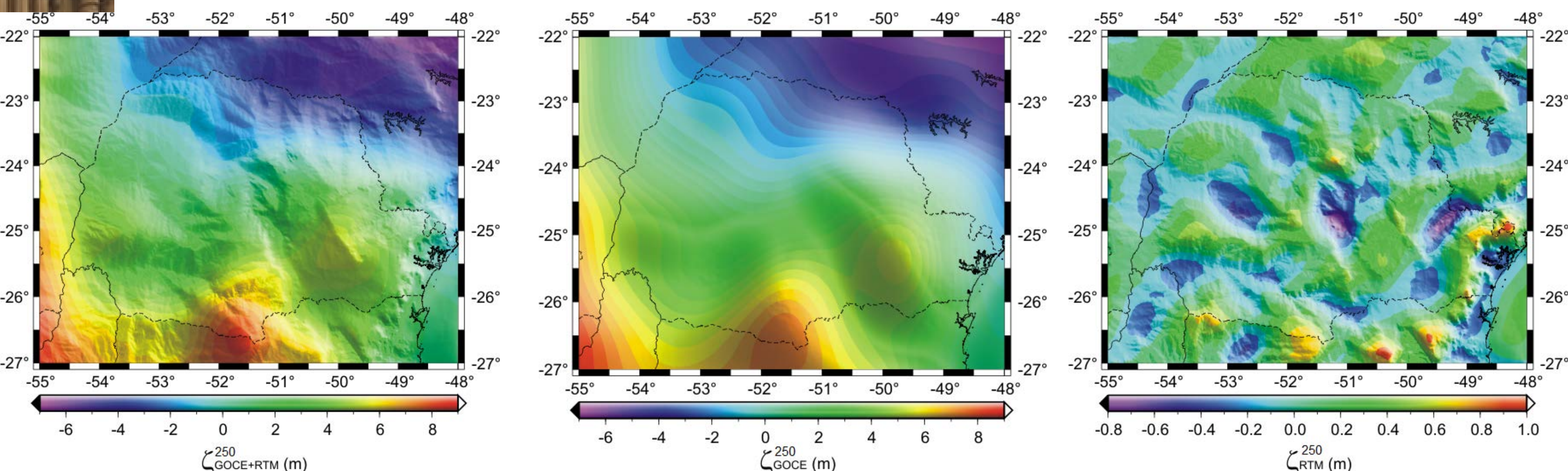
In the resolution of 14 km, a significant improvement on all models except the EGM2008 degree and order 250 and 2159. In a resolution of 28 km, in contrast to the above, the EGM2008 at its most improved 93% in the final solution along with the degree and order 360 (81%). Already in the resolution of 55 km, the EGM2008 greatly improves the final solution to degree and order 250 (99%). At 80 km, all models were better, ranging from 40% to 99%, with the exception of EGM2008 the maximum degree.

Another analysis on the technique RTM was realized in the region of Paraná State, between parallels 22º S and 27º S and meridians 48° W and 55° W, with an bathimetry/elevation from -100m to 1500m, where there are 90 control points with observation GPS on bench marks of RAFB (GNSS / Leveling).



Refinamento de Modelos do Geopotencial Global com base na técnica da modelagem da topografia residual (RTM) em regiões de baixa cobertura gravimétrica convencional

They were used GGMs arising from the GOCE mission, the GO_CONS_GCF_2_DIR_R2 available at degree and order 240, and GO_CONS_GCF_2_TIM_R2 in degree order 250, the GGM coming from the GRACE and GOCE missions, the GOCO02s in degree and order 250, and combined GGM EIGEN-06C (to degree and order 1420). The RTM method, based on DEM GMRTv2.0 and ETOPO1 was applied.



$$\zeta^{N\max}_{Final}(\varphi,\lambda) = \zeta^{Nto250}_{GGM}(\varphi,\lambda) + \zeta^{N>250}_{RTM}(\varphi,\lambda)$$

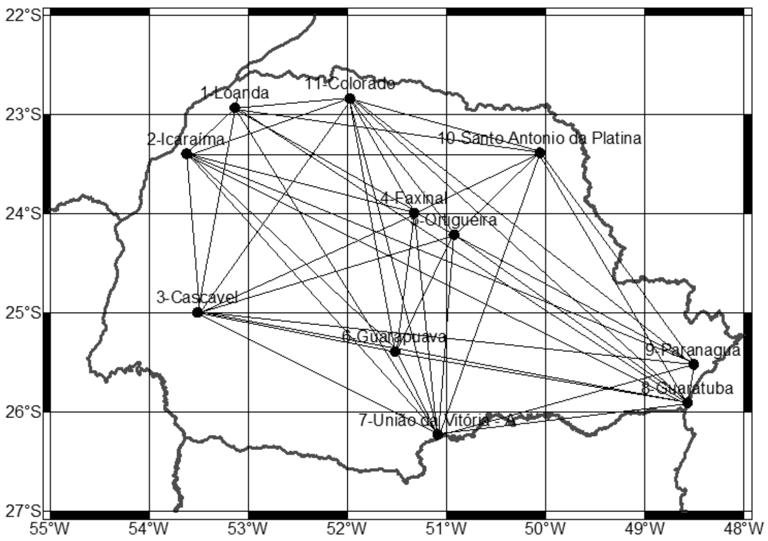
ABSOLUTE ANALYSIS

($n_{max}=m_{max}=240$)	GO_CONS_GCF_2_DIR_R2	
	$\varepsilon_{Absolute \to GGM}$	$\varepsilon_{Absolute \to Final}$
	(m)	
Range	1,89	1,39
Mean	-0,38	-0,31
Mean deviation	0,30	0,26
Standard deviation	0,38	0,32
RMS	0,53	0,44

($n_{max}=m_{max}=250$)	GO_CONS_GCF_2_TIM_R2		GOCO02S	
	$\varepsilon_{Absolute \to GGM}$	$\varepsilon_{Absolute \to Final}$	$\varepsilon_{Absolute \to GGM}$	$\varepsilon_{Absolute \to Final}$
	(m)			
Range	1,82	1,38	1,82	1,38
Mean	-0,39	-0,32	-0,38	-0,31
Mean deviation	0,26	0,21	0,27	0,21
Standard deviation	0,34	0,28	0,34	0,28
RMS	0,50	0,41	0,50	0,40

$(n_{max}=m_{max}=1240)$	EIGEN-06C	
	$\varepsilon_{Absolute \rightarrow GGM}$	$\varepsilon_{Absolute \rightarrow Final}$
	(m)	
Range	1,05	1,02
Mean	-0,35	-0,25
Mean deviation	0,14	0,15
Standard deviation	0,19	0,19
RMS	0,39	0,31

RELATIVE ANALYSIS

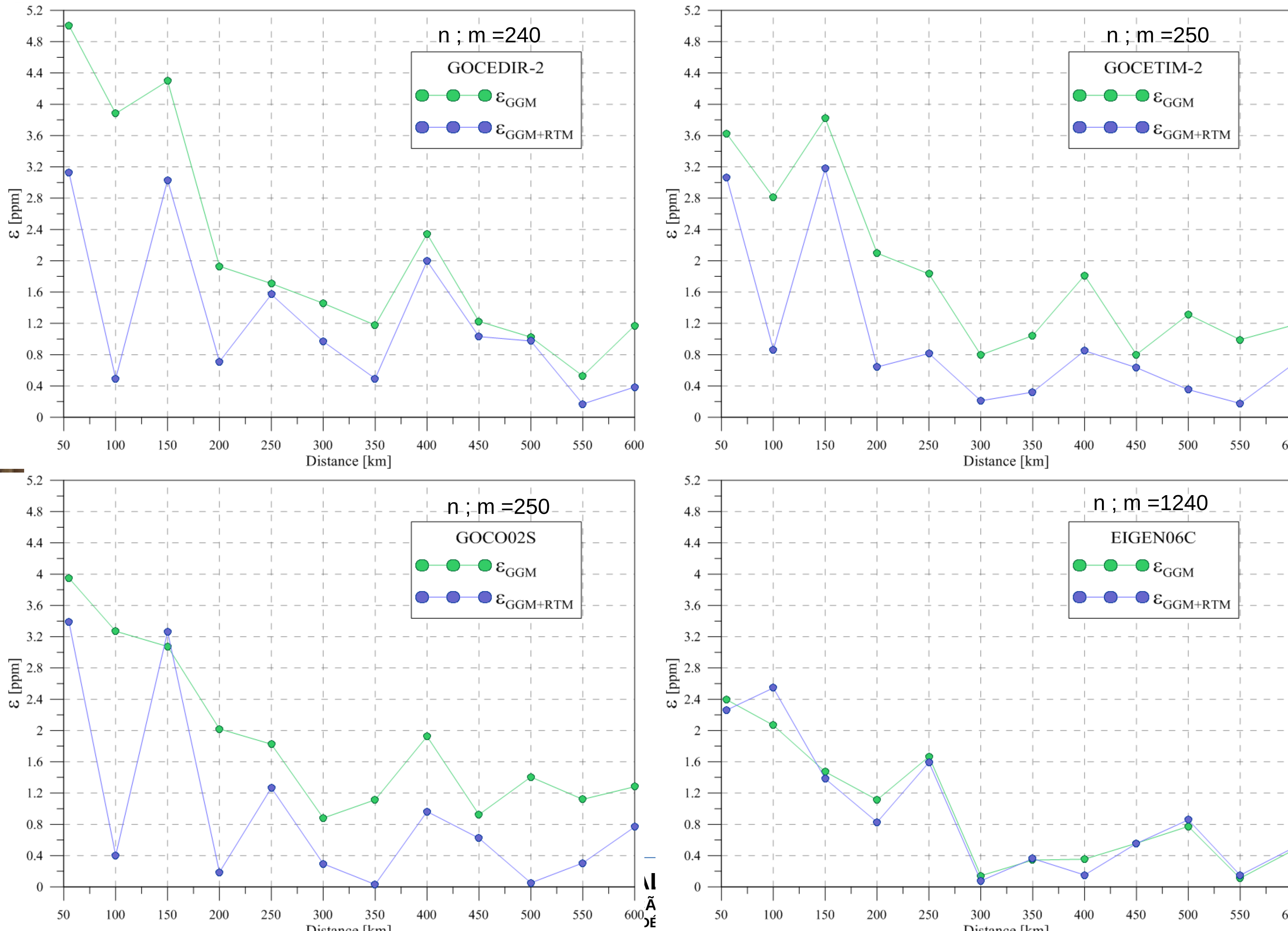


Analysis was undertaken by using 11 control points on GNSS / Leveling. Between these points, it was possible to establish multiple baselines varying from about 50 km to 600 km.

SIRGAS

24-26 Oct – Ciudad de Panamá, Panamá

Refinamento de Modelos do Geopotencial Global com base na técnica da modelagem da topografia residual (RTM) em regiões de baixa cobertura gravimétrica convencional



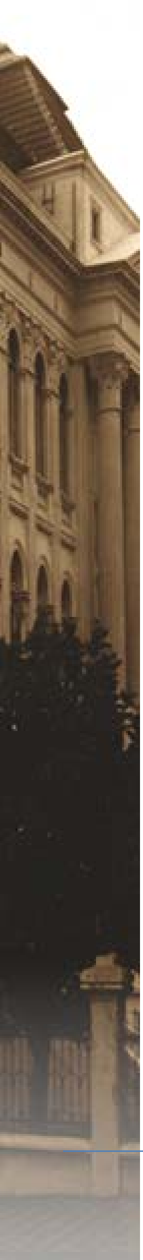
Summary and Conclusions

We explored the RTM technique as a tool to overcame the dependence on the terrestrial gravimetry;

Some recent GGMs, including the latest based in satellite-only data were analysed in their original resolution and by applying RTM technique based in recent DEMs including bathimetry in the two study areas;

The final RMS for all GGMs were reduced by applying RTM technique. Expressive results were obtained for EGM2008 (n=m=2159 and GMRT v2.0; DTM2006) 0.39m -> 0.19m; For GO_CONS_GCF_2_TIM_R3 (n=m=200 and GMRT v2.0; ETOPO1) 0.49m -> 0,20m;

Reductions in relative errors are significant, especially in the final solution with n / m = 2159 where EGM2008 had a suitability its spatial resolution (9 km) at DVB-I region (up to 95%!); In all relative analysis were observed improvements after RTM corrections;



Thank you very much!

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