Evaluation of GOCE/GRACE GGMs over Argentina with GPS/Leveling and gravity anomaly data

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Introduction, Problem and Objectives

With the GOCE mission having reached its end, an unprecedented volume of gravity field related data have become available.

From the use of GOCE gradients alone or in combination with GRACE and/or terrestrial data, a significant amount of Global Geopotential Models (GGMs) have become available.

They employ various amounts of GOCE information, i.e., releases 1, 2, 3 and 4 while the 5th generation models are expected using the lower altitude GOCE observables.

Moreover, given a methodological scheme for the GOCE data analysis various GGMs were generated, namely the TIM, DIR and SPW ones along with combination models such as GOCO and EIGEN-XXc.

The focus of this work is put on the evaluation of all available GOCE/GRACE GGMs, both satellite and combined ones, over Argentina.

To this extent, GPS/Leveling collocated geoid heights are used along with terrestrial free-air gravity anomalies to evaluate the GOCE/GRACE GGMs.

EGM2008 is used as the ground truth GGM against which all others are compared and evaluated.

This is achieved by adding to the satellite models signal from EGM2008 and topographic effects through an RTM model.

The evaluation is performed with an incremental step of one in harmonic degree, so that the most detailed possible evaluation of the GOCE/GRACE GGMs will be performed.

The RTM effects that represent the high ad ultra-high frequencies of the gravity field spectrum are evaluated over the entire country through a 30 arcsec DTM.

Therefore, the effective maximum degree and order that it resolved is 216,000, i.e., the omission error is at the mm-level.

To reduce the omission error due to the limited harmonic expansion of the GOCE/GRACE GGMs, synthetic GGMs are evaluated.

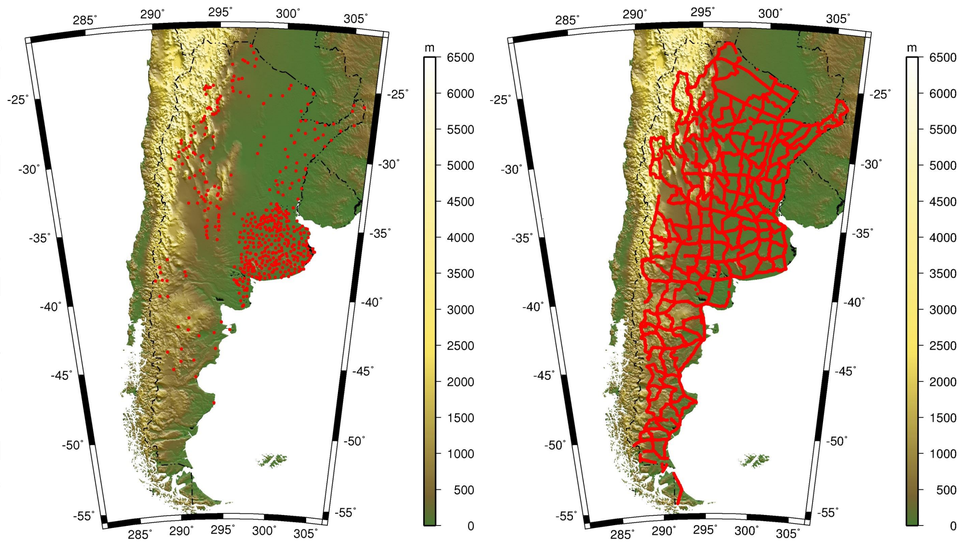

Figure 1: The available GPS/Lev BMs (left) and the gravity anomaly stations (right) in the area under study

Data availability & GOCE/GGM evaluation

The following conventions have been used for all GGM evaluation(s):

- Mean Tide to Tide Free conversion for orthometric heights
- GGM Zero Tide to Tide Free when necessary
- All computations in GRS80 & IGSN71/GRS80
- N_o relative to the IERS W_o of 62636856.0 m^2/s^2 *(-0.4369 m)*

The residual geoid heights and residual gravity anomalies have been evaluated as:

$$\Delta N = N^{GPS/Lev} - N^{GOCE}\Big|_2^{n_1} - N^{EGM2008}\Big|_{n_1+1}^{2160} - N^{RTM} - N_o$$

$(n_1 \le n_{max}$ & $n_{i+1} = n_i + 1)$

$$\Delta g_{res} = \Delta g - \Delta g^{GOCE}\Big|_2^{n} - \Delta g^{EGM08}\Big|_{n+1}^{2160} - \Delta g^{RTM}$$

19 GGMs used to their maximum d/o (satellite only – GOCE/GRACE – and combined information)

- EGM2008 as reference model (Pavlis et al., 2008 - expansion to d/o 2160)
- EIGEN models (5C, 6C, 6C2 and 6C3-stat – Förste et al., 2008, 2011, 2012, 2014)
- GOCE models (DIR 1 – 5, Bruinsma et al., 2010, 2013 and TIM 1 – 4, Pail et al., 2010, 2011)
- GOCO models (01S – 03S, Pail et al., 2010; Goinginger et al., 2011; Mayer-Gürr et al., 2012)
- ITG-Goce02 (Schall et al. 2014), GOGRA02S (Yi et al., 2013), JYY-GOCE02S (Yi et al., 2013)

Statistics of the BMs ellipsoidal, orthometric and GPS geoid height (m)

	max	min	mean	rms	std
h	3386.6810	17.3730	291.4458	546.2595	±462.0160
H	3347.6874	2.2934	272.5588	532.6363	±457.6168
N^{GPS}	40.7315	5.1155	18.8870	19.6400	±5.3863
N^{RTM}	0.6489	-0.6466	-0.0306	0.1132	±0.1090

Statistics of the available gravity anomalies and RTM effects (mGal)

	max	min	mean	rms	std
Δg_f	498.1600	-136.5700	4.8148	99.5121	±99.3956
Δg^{RTM}	77.3671	-124.3769	-7.5480	17.4933	±15.7812

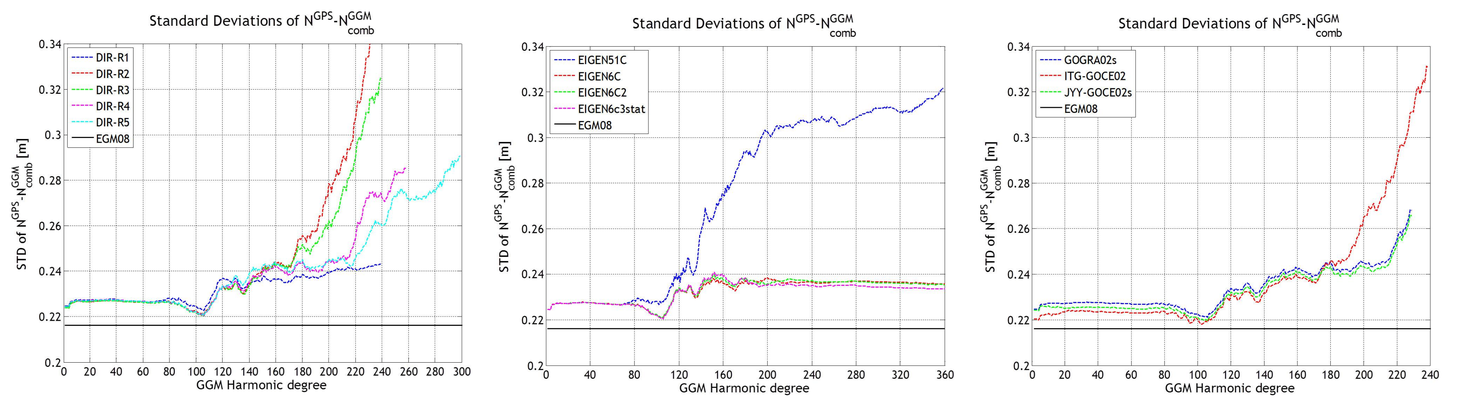

Figure 2: Standard deviations for the differences between the combined GOCE/GRACE GGM and GPS/Lev geoid heights

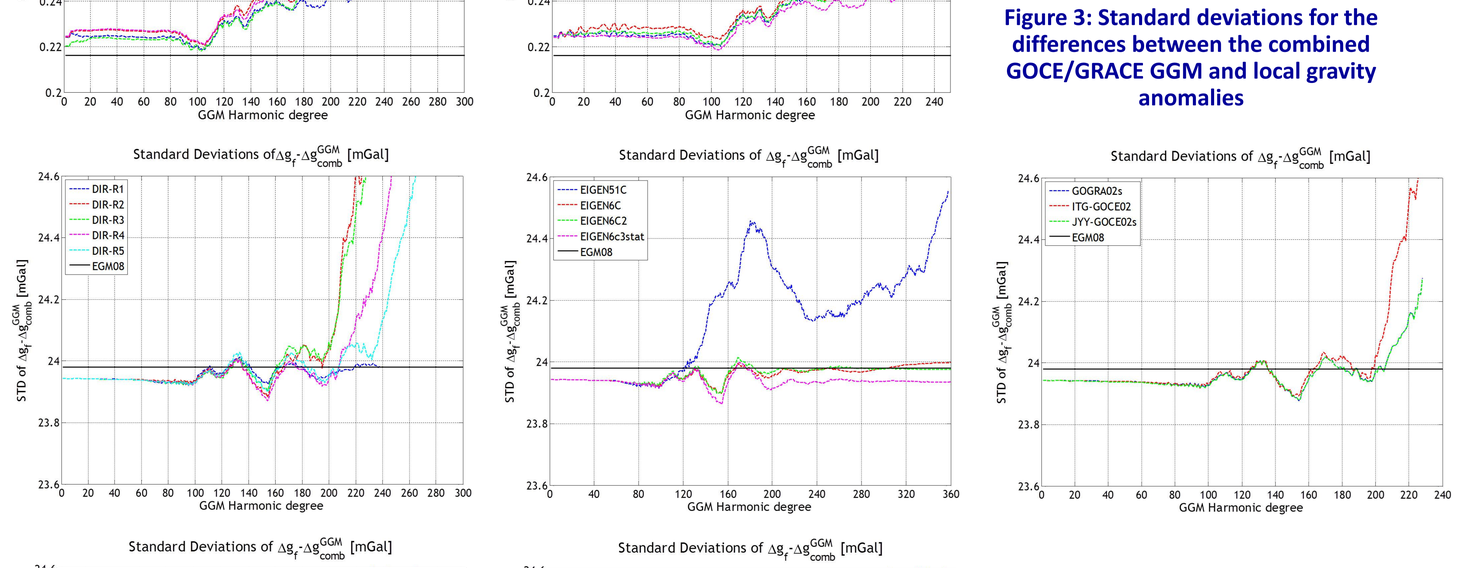

Figure 3: Standard deviations for the differences between the combined GOCE/GRACE GGM and local gravity anomalies

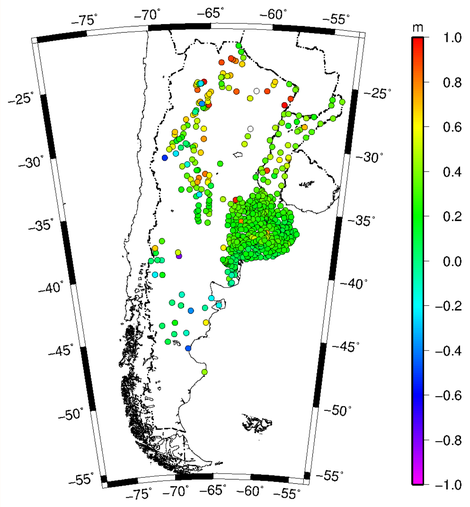

Figure 3: Differences between DIR-R5 combined and GPS/Lev geoid heights (d/o=107, std=22.1 cm)

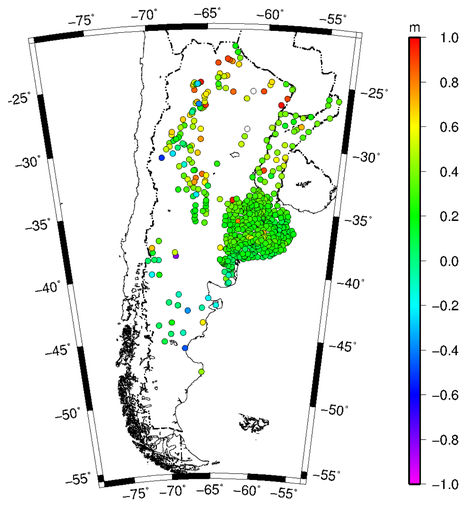

Figure 4: Differences between TIM-R4 combined and GPS/Lev geoid heights (d/o=107, std=21.9 cm)

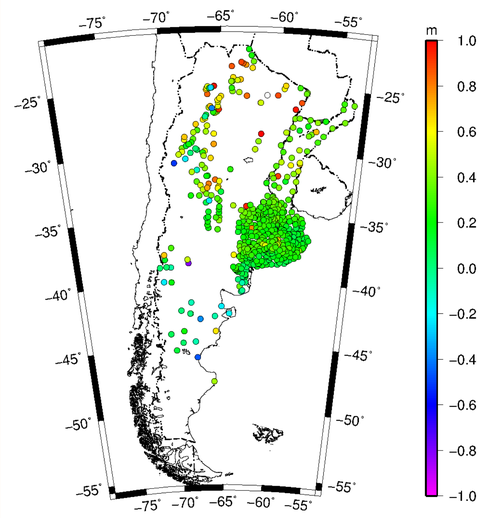

Figure 5: Differences between ITG-GOCE02s combined and GPS/Lev geoid heights (d/o=107, std=21.8 cm)

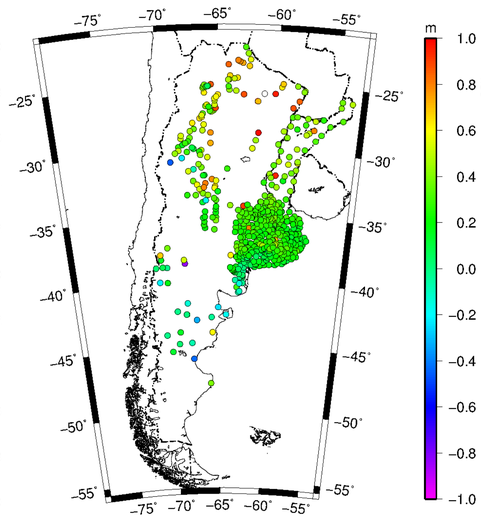

Figure 6: Differences between EGM2008 and GPS/Lev geoid heights (d/o=2160, std=21.6 cm)

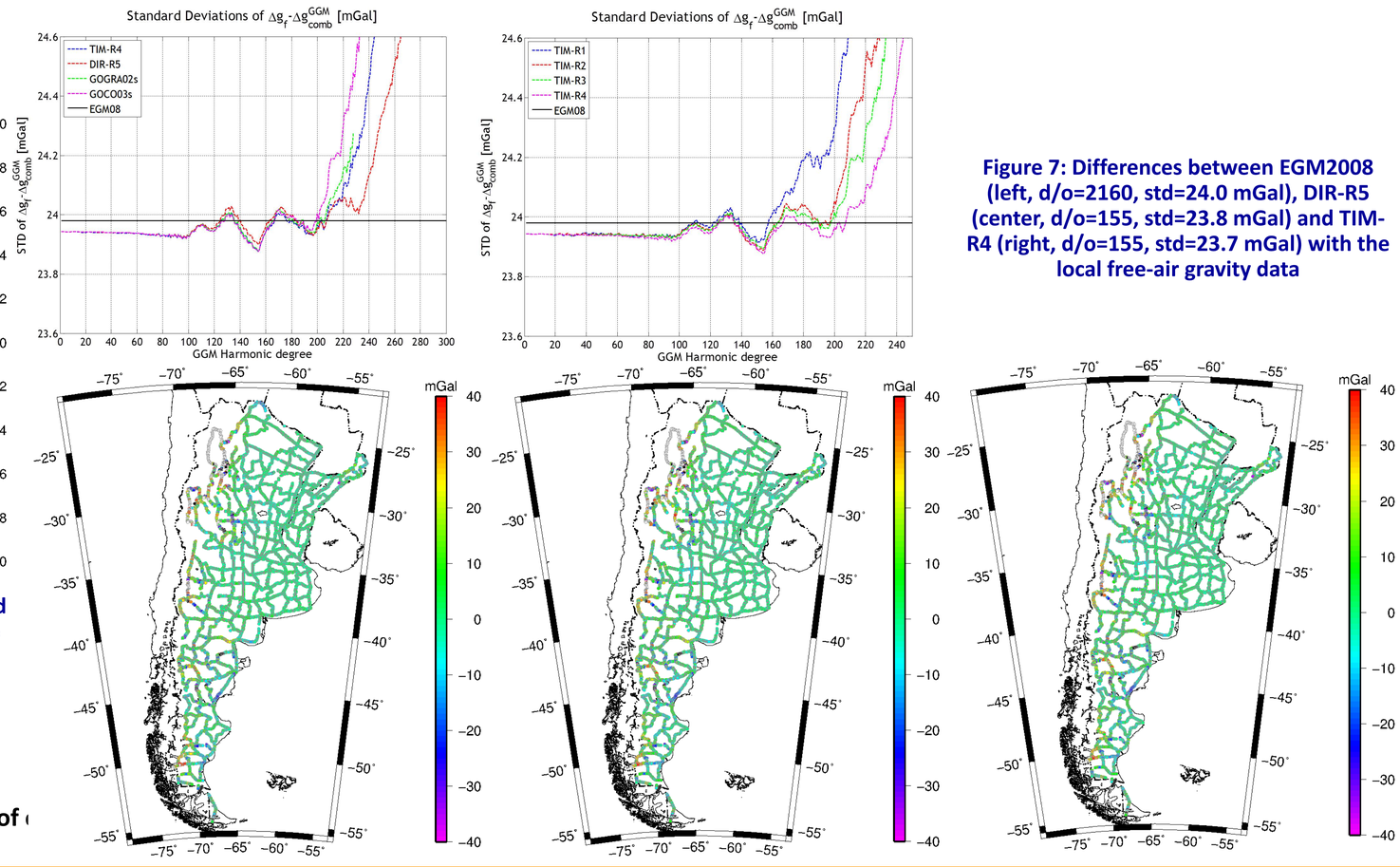

Figure 7: Differences between EGM2008 (left, d/o=2160, std=24.0 mGal), DIR-R5 (center, d/o=155, std=23.8 mGal) and TIM-R4 (right, d/o=155, std=23.7 mGal) with the local free-air gravity data

Conclusions

- EGM08 is better by few mm as far as the geoid heights are concerned
- Contrary, GOCE/GRACE GGMs are better at the sub-mGal level
- DIR-R5 boosts the GOCE/GRACE GGM performance by ~20 degrees to an n_{max} of d/o 235