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GOCE DATA TO ANALYZE MOHO UNDULATION IN BRAZIL

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A) GOAL

Deep crustal structure is important to understand the regional tectonic evolution and find local unknown masses.

- Moho is a geophysical boundary between 2 different density layers: crust and mantle.
- GOCE resolution is able to unveil Crust Mantle Boundary (CMB), while EGM2008 model is able to reveal small and superficial mass anomalies. Mean Earth Ellipsoid is a model defined by several layers with constant density (in hydrostatic equilibrium), deviation from this model would indicates stress in earth's body.
- IASP91 model shows continent average of Moho at 35 km
- Under craton and topographic elevations: Moho is > 35 km, while under ocean it is << 35 (about 20-10 km).

B) METHODOLOGY

- Spherical harmonic expansion of potential field: gravity anomaly, reduce topographic effect and obtain Bouguer anomaly.
- Using several global gravity models: GOCE, EGM08 (see Table 1).
- Have in mind nominal maximum resolution of global gravity model) is: $\lambda/2$ =20000 / Nmax (Hofman-Wellenhof and Moritz, 2005)
- EGM08 resolution is quite small (9 km = d/o 2159) because GRACE and previous satellite mission are integrated with terrestrial data (GRACE has only up to d/o 70 of potential field = 285 km). Terrestrial data offer a good resolution in some areas, but they are heterogeneous and sometimes they have some problems, as in remote land (Africa, South America for example). So, to offer a quality control of EGM08 data we calculate *standard deviation* between EGM08 and GOCE model around all world and part of South America region.
- We employed GOCE data to detect isostatic balance in the Paraná basin. We proceed with the solution of the inverse gravity problem to compare gravity signal with seismic Moho and isostatic Moho models.

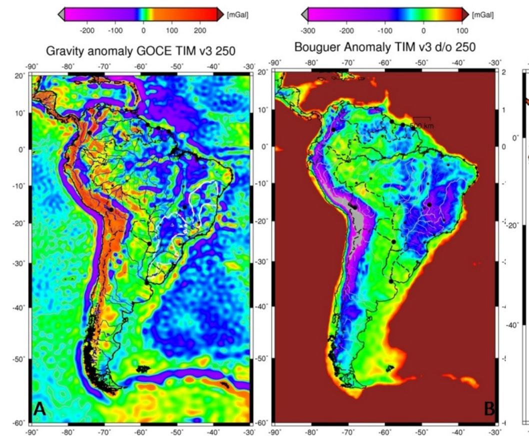

Fig.1 - Gravity field for South America using GOCE, A: Free Air anomaly calculated at 7000 m with GOCE TIM v3 up to d/o 250; B: Bouguer

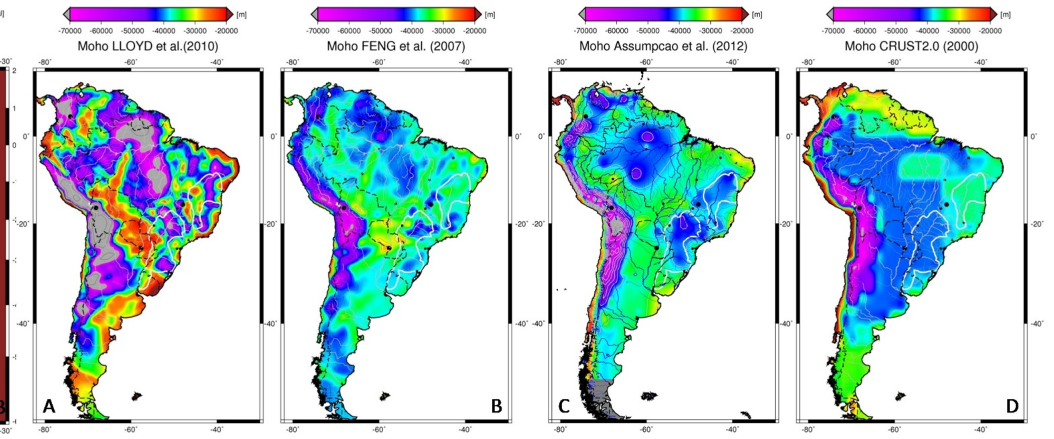

Fig. 2 - Seismic Mohofor South America using, A: Lloyd et al., (2010); B: Feng et al., (2007); Crust2.0 (Laske et al., 2000) and Assumpção et al., (2012).

Model	Max degree [°]	$\lambda/2$ [km]	λmax [km]	Reference
EGM 2008	2159	9	18	Pavlis et al. (2008)
GOCE 250 (TIM) v2	250	80	160	Pail et al. (2011)
GOCE 250 (TIM) v3	250	80	160	Pail et al. (2011)
GOCO02S 250	250	80	160	Goiginger et al. (2011)

Table 1 - Global gravity models.

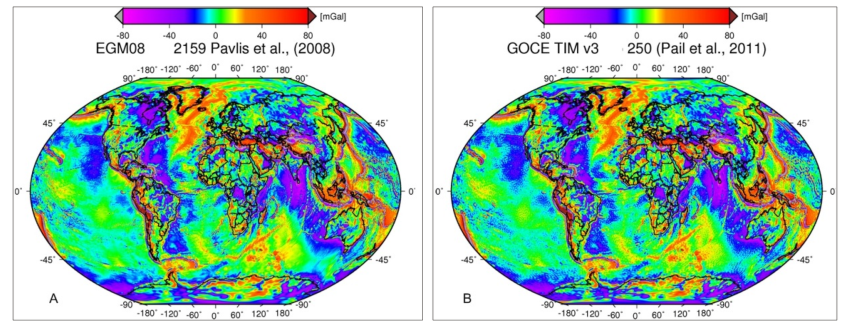

Fig. 3 - Global Free Air anomaly, in A: EGM2008 models up to d/o 2159; in B: GOCE TIM version 3, up to d/o 250.

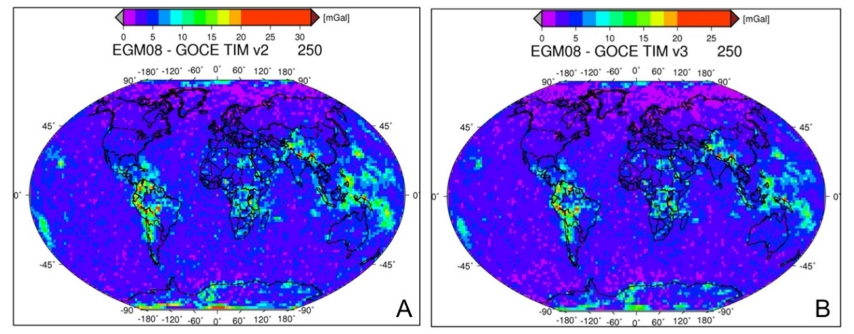

Fig. 4 - Standard deviation of free air difference between EGM2008 model and GOCE TIM, A) GOCE TIM version 2 , B) GOCE TIM version 3 (360 days of data).

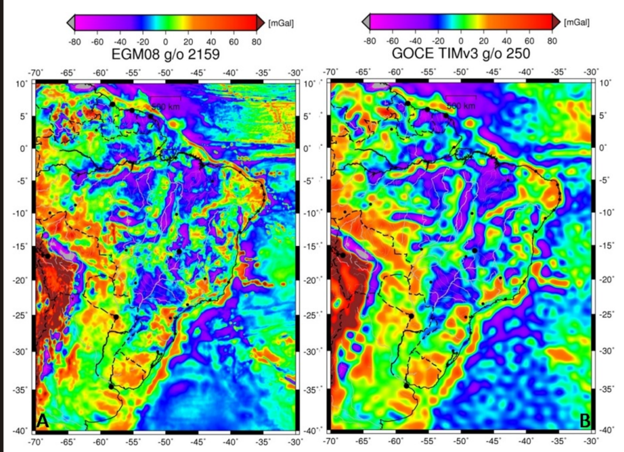

Fig. 5 -Free Air anomaly of studied area of South America, in A: EGM2008 models up to d/o 2159; in B: GOCE TIM version 3, up to d/o 250.

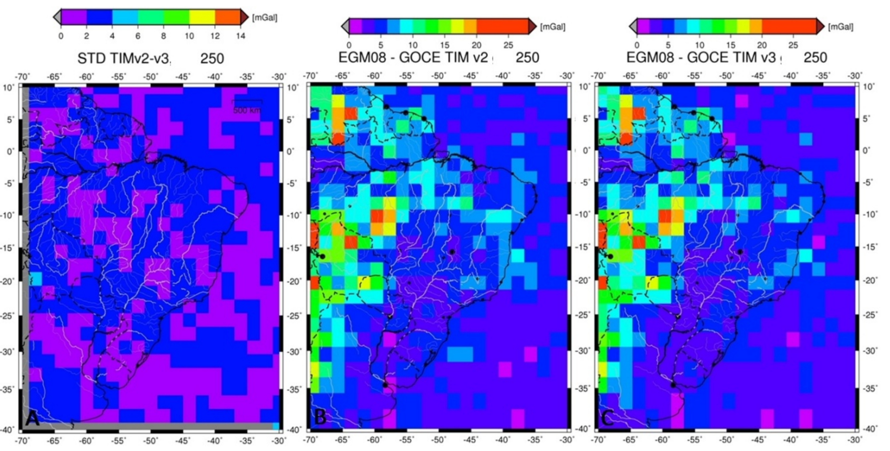

Fig. 6- Standard deviation between: A) GOCE TIM version 2 (v2= 8 months) and version 3 (v3= 360 days) developped up to d/o 250; B) EGM2008 and GOCE TIM v2 up to d/o 250, C) B) EGM2008 and GOCE TIM v3 up to d/o 250.

Free Air Anomaly Calculation:

- Model used GOCE and EGM08 models;
- Height of calculation is 6200 m, maximum height of the studied area;
- We compute the grid on the surface of a geocentric sphere, data are equispaced in geocentric latitude using an average earth radius of 6378136.3 m.

C) BOUGUER ANOMALY

To calculate Bouguer Anomaly corrected Free Air Anomaly for the effect of topography.

We also calculated residual Bouguer corrected from sediments effect, see poster N: EGU2012- 5183.

D) GRAVITY INVERSION FOR MOHO RECOVERY

- We proceed with the solution of an inverse gravity problem to map the Moho under the Paraná basin and surrounding area.
- Can we apply gravity inversion using GOCE data?
- Yes, because maximum degree of development of spherical harmonic is consistent with Moho wavelength.
- Where seismological Moho is not known, Bouguer anomaly Inversion allows to define Moho undulation (e.g. South America lack of seismic data);
- Isostatic and seismological Moho agree in the area where isostatic balance is achieved;
- In the opposite situation, Isostatic and seismological Moho do not agree where isostatic balance is not achieved,and reveal unknown body masses as overload (=underplating) or lack of masses (=salt).
- We use LITHOFLEX software, and we test several contrast densities between mantle and crust (Fig. 9, 10).

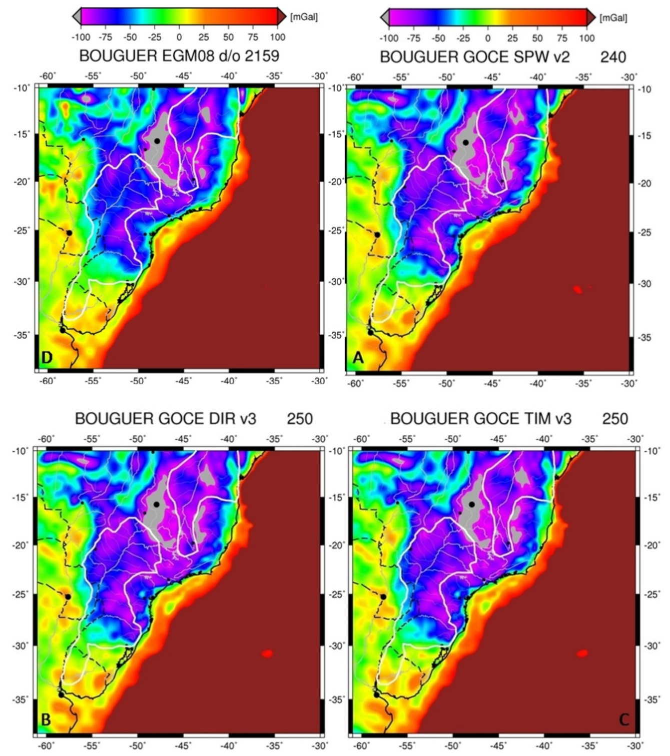

Fig. 7 - Bouguer Anomaly for model: D) EGM2008 models up to d/o 2159; A) GOCE SWP v2, up to d/o 240; in B) GOCE DIR v3 up to d/o 240; and C) TIM v3, up d/o 250.

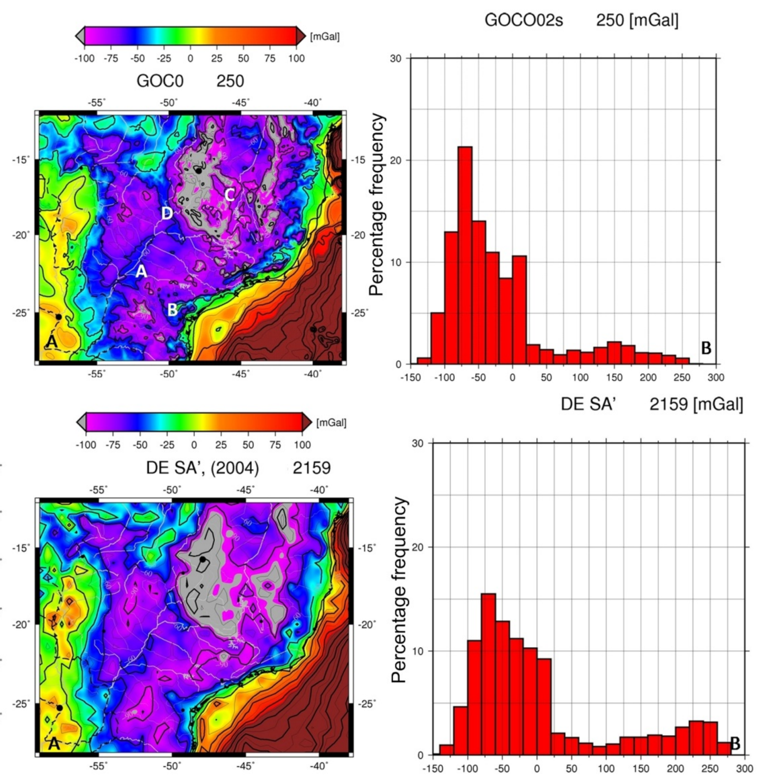

Fig. 8 - Bouguer Anomaly and Histogram analysis:upper row: GOCO02s model up d/o 250;on lower row: DE SA', (2004) model with integration of terrestrial data.

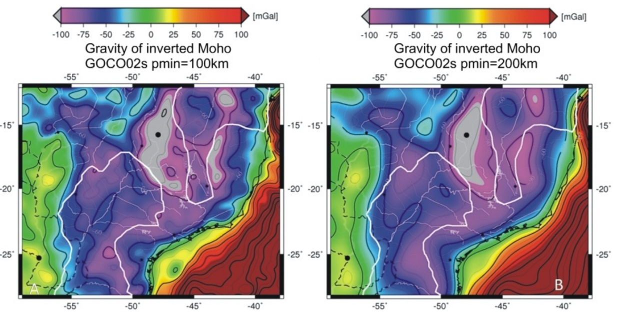

Fig. 9 - Effect of Gravity root using GOCO02s model and considering a contrast density of -0.3 Mg/m^3. We test two different cut off periods: left 100 km, right 200 km.

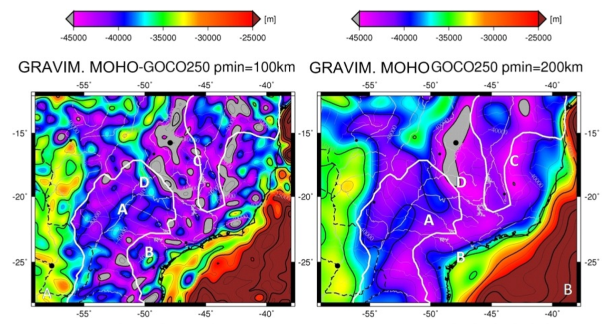

Fig. 10 - Gravimetric Moho using GOCO02s and considering a contrast density of -0.3 Mg/m^3. We test two different cut off periods (pmin): left 100 km, right 200 km. White letters indicate main anomaly areas.

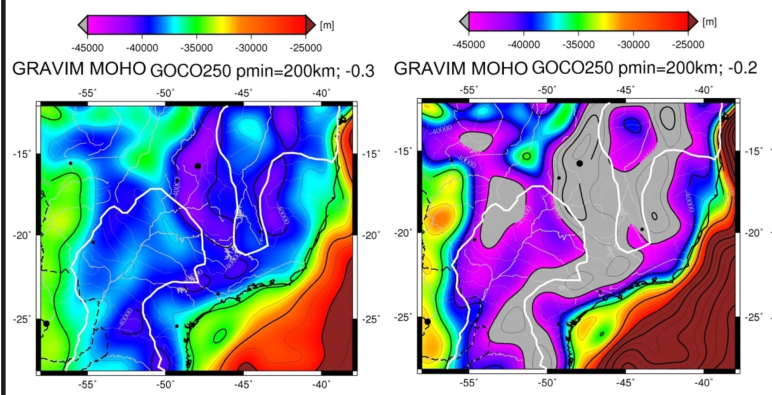

Fig. 11 -Testing CMB with : -0.3, -0.2 Mg/m^3 without correcting for sediment gravity effect of known sediments.

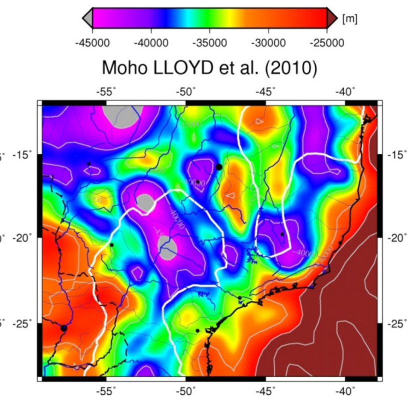

Fig. 13 - Seismological Moho of Lloyd et al. (2010).

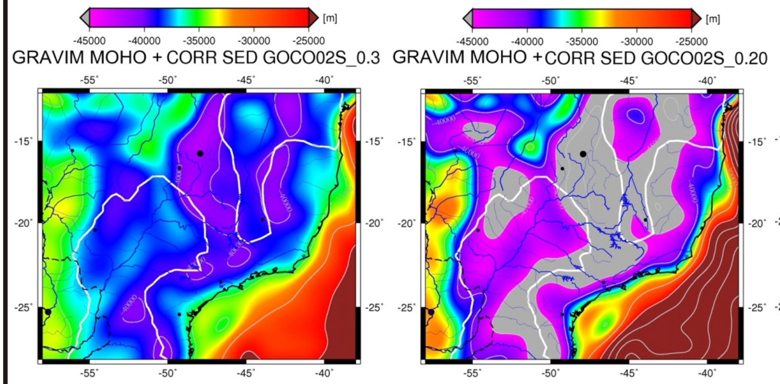

Fig. 12 -Testing CMB with : -0.3, -0.2 Mg/m^3 with correction of sediment gravity effect of known sediments.

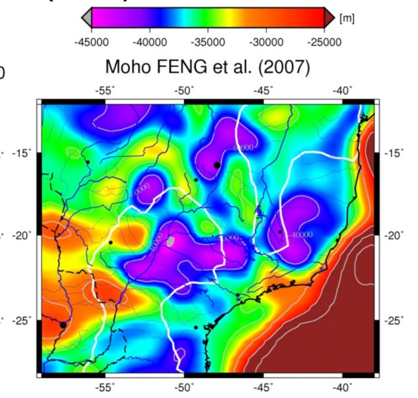

Fig. 14 -Seismological Moho of Feng et al. (2007).

F) DISCUSSION

- In Fig. 11 and 12, we test different density contrast between crust and mantle: -0.3, -0.2 Mg/m^3 without (Fig. 11) or with (Fig. 12) correction of gravity effect of known sediments. We compare our gravity inversion undulation with seismological Moho of Feng et al. (2007), Lloyd et al. (2010), and Assumpçao et al. (2012).
- We see that if we increase crustal density (densification of crust respect to a normal crust) we obtain deeper CMB, but with a pattern very different to the seismological Moho. This pattern reflects a maximum relative of undulation in agreement with maximum relative Bouguer anomaly.
- Seismological Mohos show large difference between models: the Crust 2.0 and Assumpção Moho under continental region of Paraná region are quite deeper and flatter than Feng and Lloyd models. Lloyd Moho shows greater amplitude and higher frequency undulations than other models. Under the northern and southern part of basin Moho depth is in agreement between models. Taking into account sediment load and positive gravity signal a shallow Moho would be expected but a deep Moho is found. We invoke mafic layer of rocks to explain the gravity signal (see poster EGU2012-5183 to obtain more details).

G) CONCLUSION

- **What is new using GOCE data?**
- We showed GOCE data are more useful then EGM08 models to investigate extended and deeper structure. Using EGM08 in remote area, terrestrial osservations sometime are missing, and wrong. We propose a methodology to control quality of EGM08 using new GOCE data.
- Gravity inversion compared to seismological model recognizes significant differences correlated to geology.
- The comparison between seismic Moho, gravity inversion Moho and isostatic Moho reveals that: in northern and central - southern part of Paraná basin basalt volcanism trapped in crust, and melted material much greater than what is found on surface, while southern area is in isostatic equilibrium.

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E) PROFILES ALONG OUR MODEL

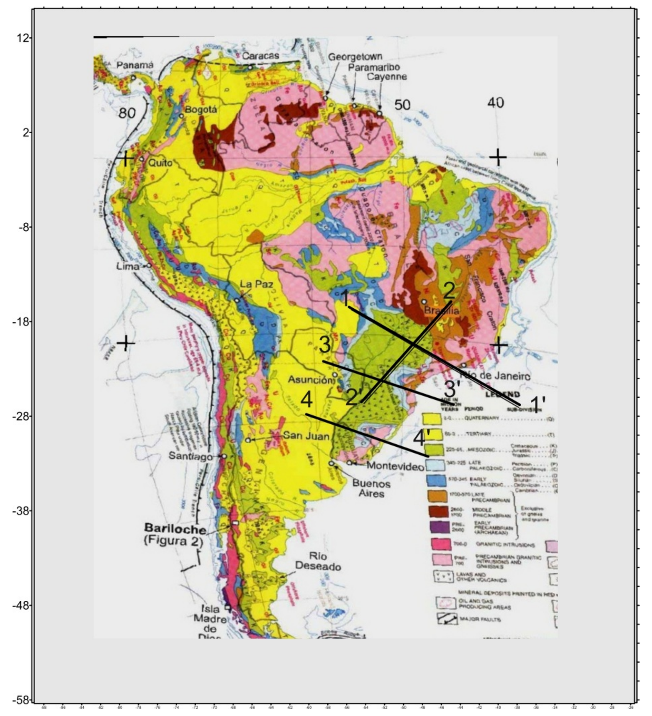

Fig. 15 -Geological map of South America and examinated profile lines.

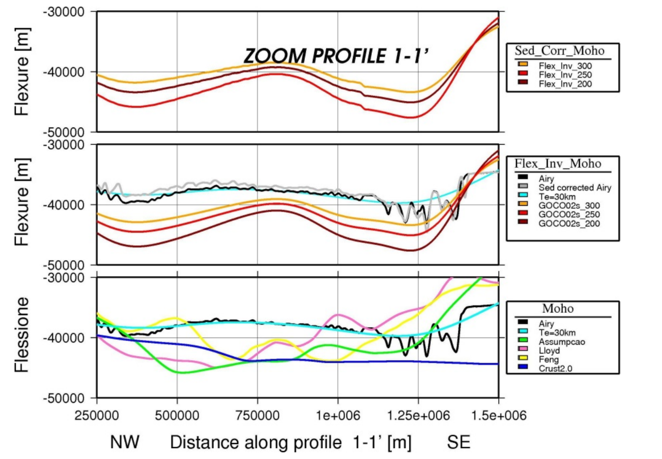

Fig. 16 - Zoom along profile 1-1'. We show seismological Moho and gravity inversion boundary without or with gravity effect sediments. See legend.

Moho seismological depth is:		
shallower than	**deeper than**	**equal to**
✓ Chaco basin, Pantanão basin: isostatic rebound caused by light sediment effect or by foreland Andes. ✓ Bananal basin: deeper mantle anomaly→ azimuth 125° Igneous Alkaline and Carbonatitic Provinces ✓ **Central Paraná basin**: Lloyd and Feng models maybe wrong: in disagreement with newer model.	✓ **Northern Paraná basin** seismological crustal thickness > 40 km, notices that is deeper than São Francisco cratons and surrounding fold belts. ✓**Central Paraná** basin (Crust2.0; Assumpção).	✓ Continental margin but no seismological data off shore; ✓ **Southern Paraná** basin to isostatic and gravity Moho.

Table 2 - Synthesis Moho flexure along studied area.

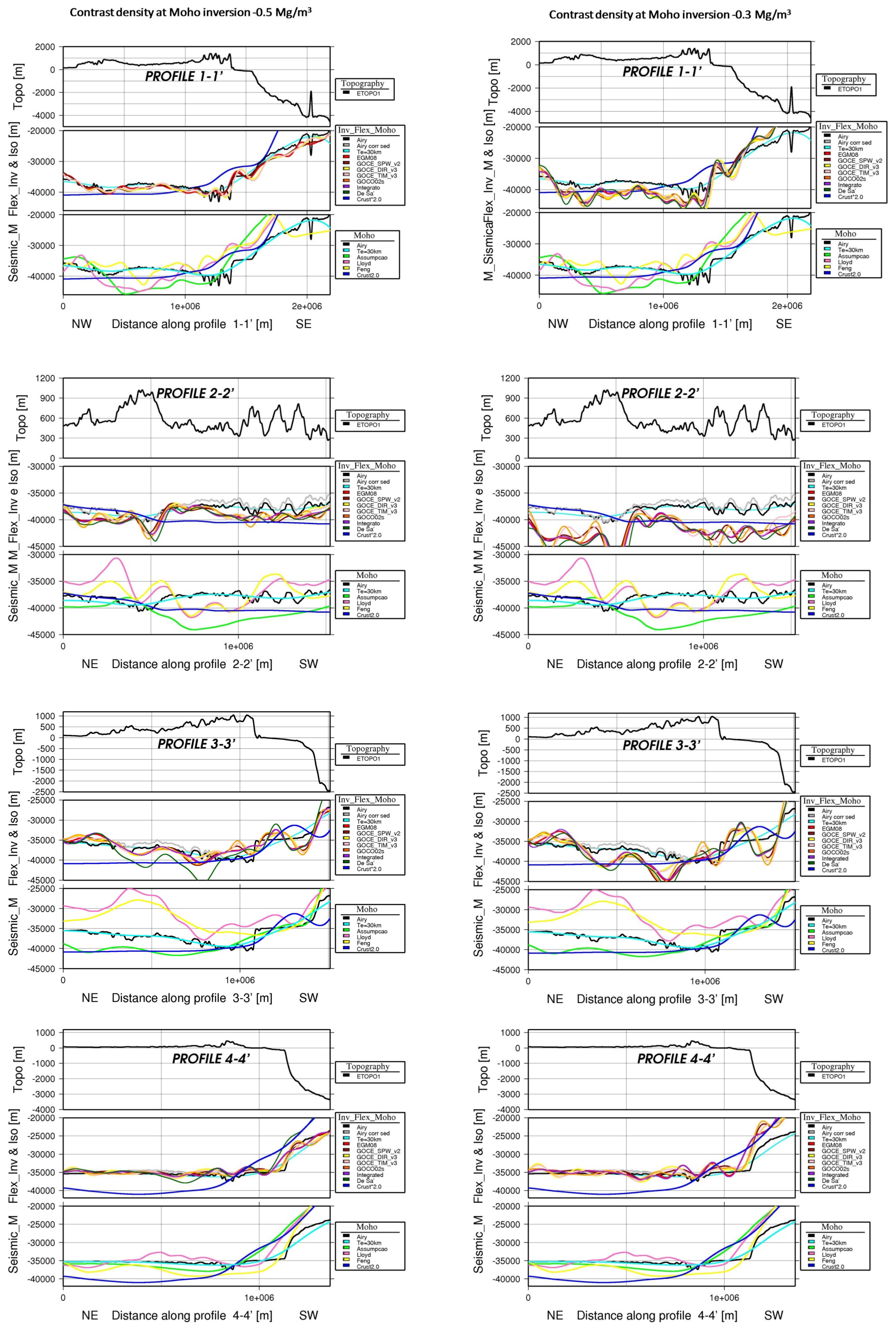

Fig. 17- Profile along Paraná Basin. First row shows profile 1-1', NW-SE direction crossing northern sector of Paraná Basin; second row along profile 2-2' NE-SW direction, between Brasilia Fold belts and northern part of Paraná Basin; third row profile 3-3' almost parallel to 1-1' but it cuts central part of basin, and the fourth row shows profile 4-4' parallels again to 1-1'profile along southern part of the basin.

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