Gravity corrections for the updated Italian leveling network

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Outline

- The Italian leveling network: spirit leveling campaigns and gravity observations
- Gravity corrections / Normal corrections/ Normal corrections in the Molodensky's framework
- The Italian gravity dataset
- Results and future work

The considered leveling lines

- 33 leveling closed loops
- ~12900 km of leveling lines
- last campaigns in May- September 2016
- available gravity observations on ~50% of the total number of benchmarks

The orthometric corrections (H&M)

$$H_B - H_A = \Delta_{AB}L + \int_{l_{AB}} \frac{g-\gamma_0}{\gamma_0}\delta L + \frac{\bar{g}_A - \gamma_0}{\gamma_0}H_A - \frac{\bar{g}_B - \gamma_0}{\gamma_0}H_B$$

$\gamma_0 = 980.6294[\text{gal}]$ normal gravity on the reference ellipsoid at latitude 45°

$\bar{g}[\text{gal}] = g[\text{gal}] + 0.0424 \cdot 10^{-3} \cdot H[\text{m}]$ g actual gravity on the earth surface

The normal corrections (H&M)

$$h_B^* - h_A^* = \Delta_{AB}L + \int_{l_{AB}} \frac{g-\gamma_0}{\gamma_0}\delta L + \frac{\bar{\gamma}_A - \gamma_0}{\gamma_0}h_A^* - \frac{\bar{\gamma}_B - \gamma_0}{\gamma_0}h_B^*$$

$\bar{\gamma}[\text{gal}] = \gamma[\text{gal}] - \frac{1}{2}3.086 \cdot 10^{-4}h^*[\text{m}]$ γ normal gravity on the reference ellipsoid

Normal corrections in the Molodensky's context (Barzaghi et al., 2015)

$$h_B^* - h_A^* = \Delta_{AB} L - \int_{l_{AB}} h^* \frac{\partial \gamma}{\partial \varphi} \frac{1}{\gamma} d\varphi + \int_{l_{AB}} \frac{\Delta g}{\gamma} dh$$

$$\gamma_\varphi [\text{gal}] = 978.033 - 5.27448 \cdot 10^{-3} \sin(2\varphi)$$

a) $\int_{l_{AB}} h^* \frac{\partial \gamma}{\partial \varphi} \frac{1}{\gamma} d\varphi$

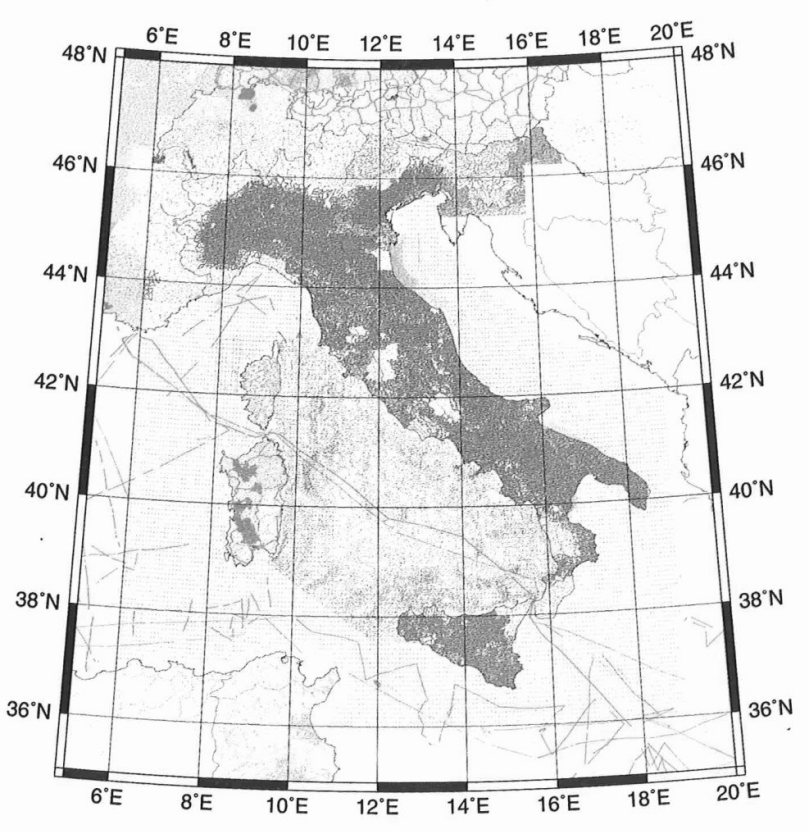
This correction term gives non vanishing contributions for profiles in the direction of the meridian, it has a value of 5cm for an average height of 2000m and a path 30km long

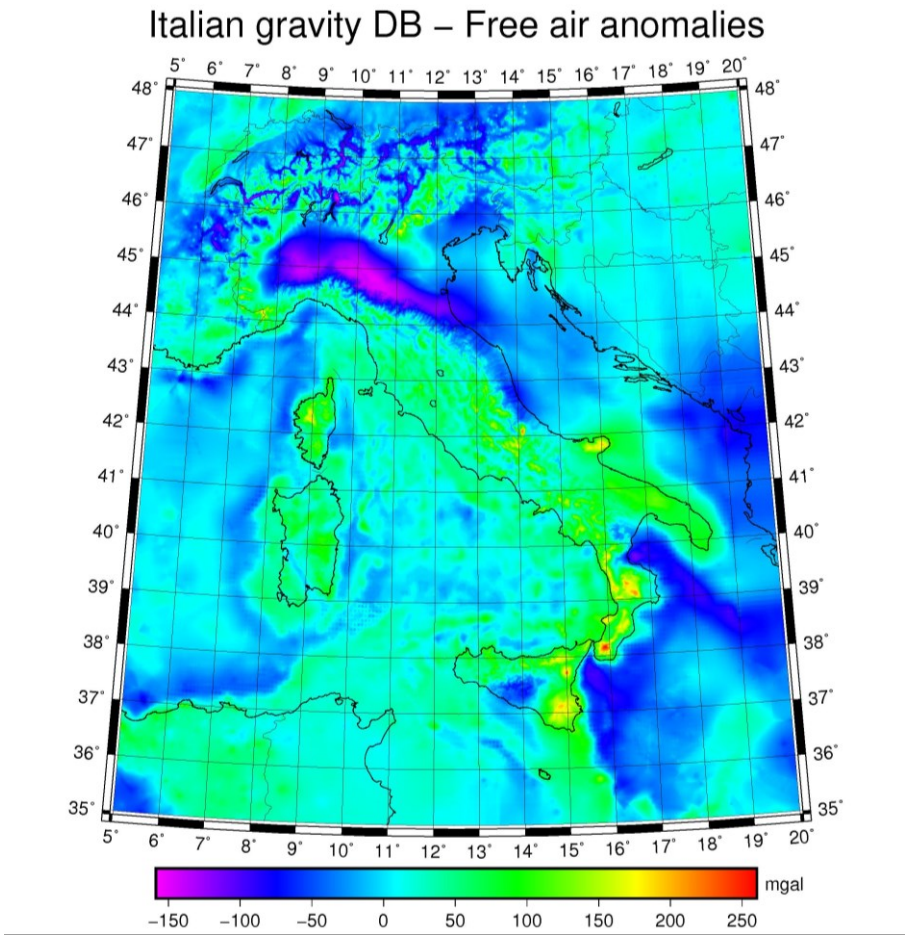
b) $\int_{l_{AB}} \frac{\Delta g}{\gamma} dh$

As $\Delta g / \gamma$ can reach a maximum of 10^{-4}, the second correction term can reach a maximum of about 20 cm for a height difference of 2000 m

Large uncertainties, say 10m, in the normal height along the leveling line has a negligible effect on the numerical evaluation of the correction terms

The Italian gravity dataset





The Italian gravity dataset: gravity prediction

Gravity anomalies have been predicted on the leveling benchmarks to fill the gaps of the observations, using the Italian gravity database.

The remove-restore technique with fast collocation algorithm has been applied.

The GGM EIGEN-6C4 has been used to d/o 1000.

i) $\Delta g_r^{P_i} = \Delta g_{fa}^{P_i} - \Delta g_{GGM}^{P_i} - \Delta g_{RTC}^{P_i}$ scattered gravity residuals

ii) $\Delta \hat{g}_r^{P_k^G}$ interpolated gridded gravity residuals

iii) $\Delta \hat{g}_{fa}(P_{lev}) = \Delta \hat{g}_r(P_{lev}) + \Delta g_{GGM}(P_{lev}) + \Delta g_{RTC}(P_{lev})$ prediction on lev. points

$$\hat{g}(P_{lev}) = \gamma(Q) + \Delta \hat{g}_{fa}(P_{lev})$$

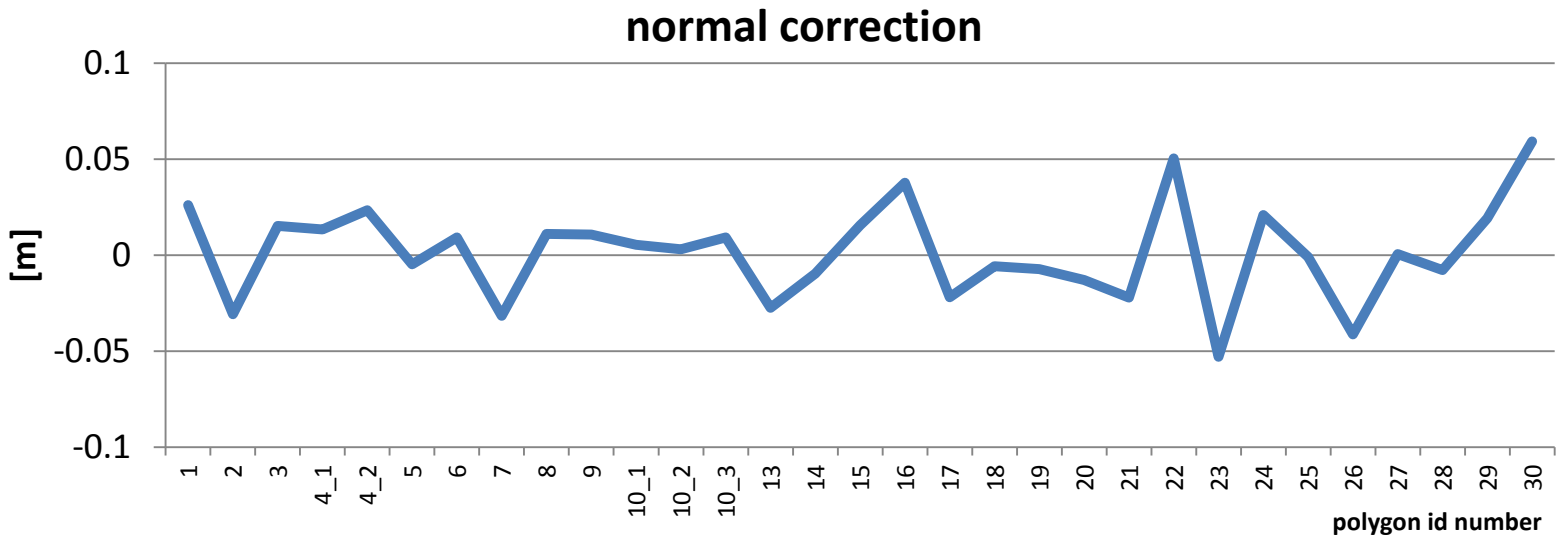
The Italian gravity dataset: gravity anomalies prediction

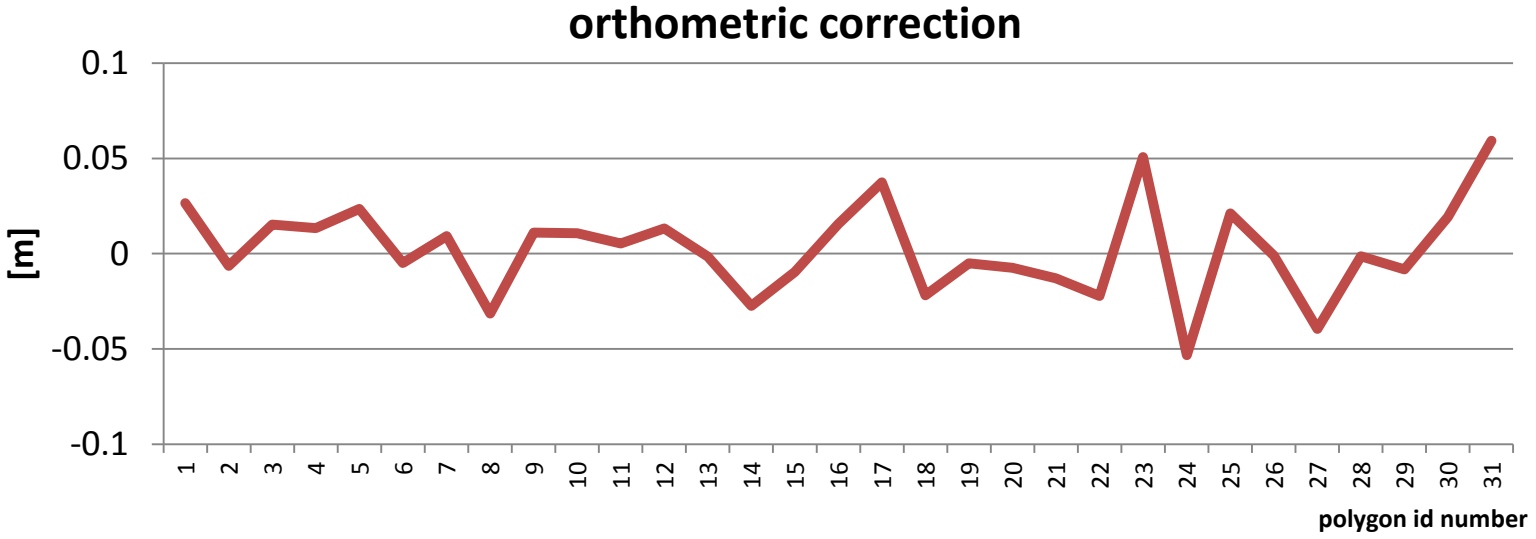
Where the observed gravity values are available, we have computed the statistics of:

- the differences between predicted gravity anomalies and the observed values
- the differences between EGM2008 gravity anomalies and the observed values

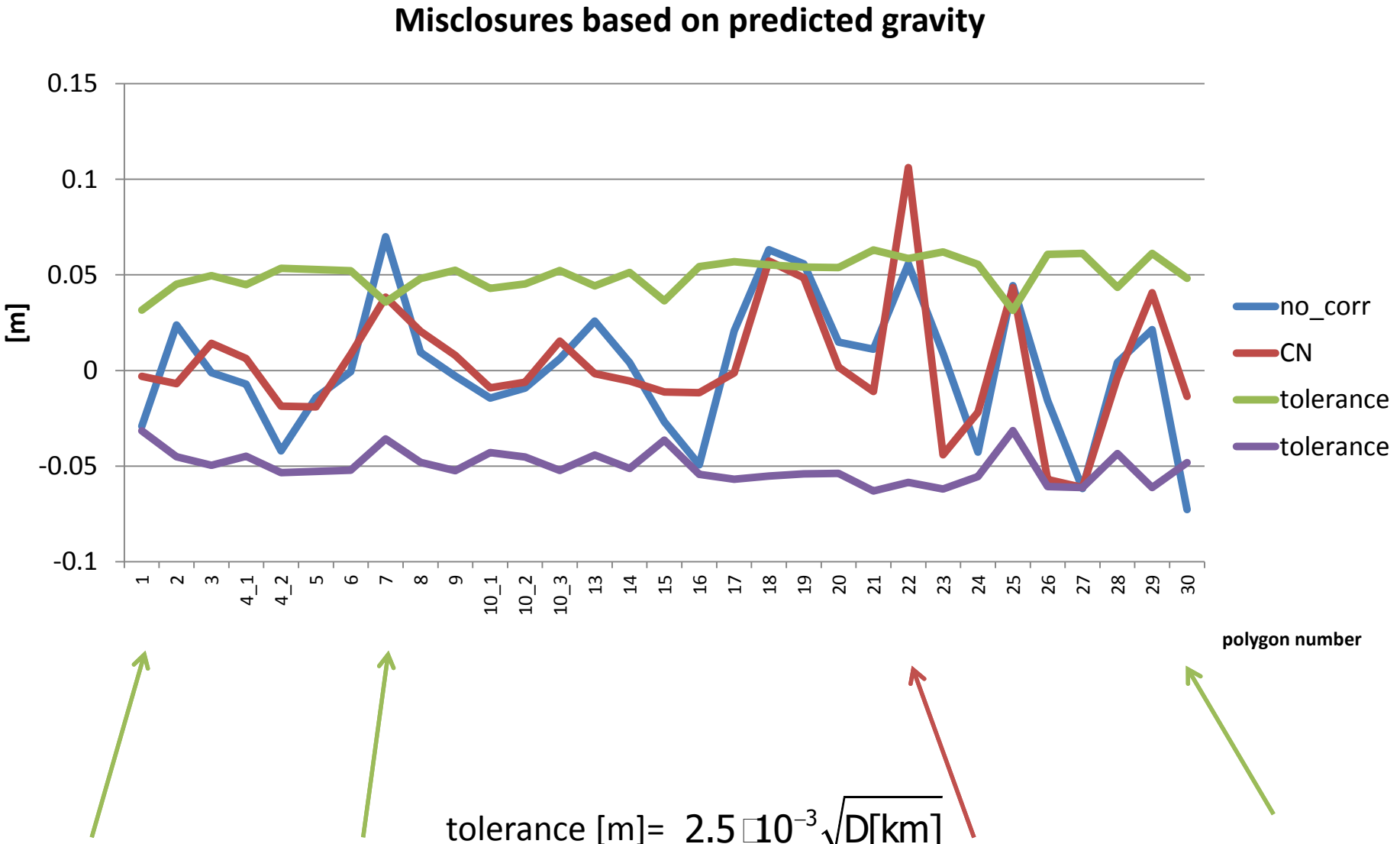
	$\Delta g_{predicted}-\Delta g_{obs}$ [gal]	$\Delta g_{EGM2008}-\Delta g_{obs}$ [gal]
#	4899	4899
Mean	-0.001	0.020
St Dev	0.009	0.034
Min	-0.087	-0.089
Max	0.095	0.177
RMS	0.009	0.039

Gravity corrections (predicted gravity)



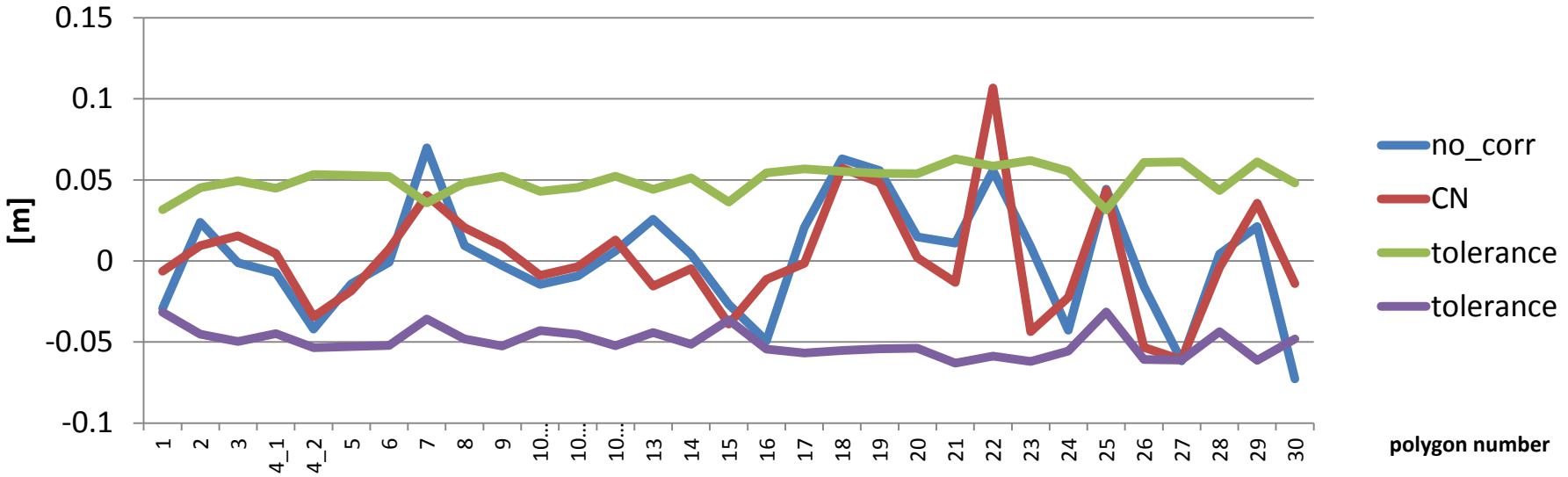


Normal correction

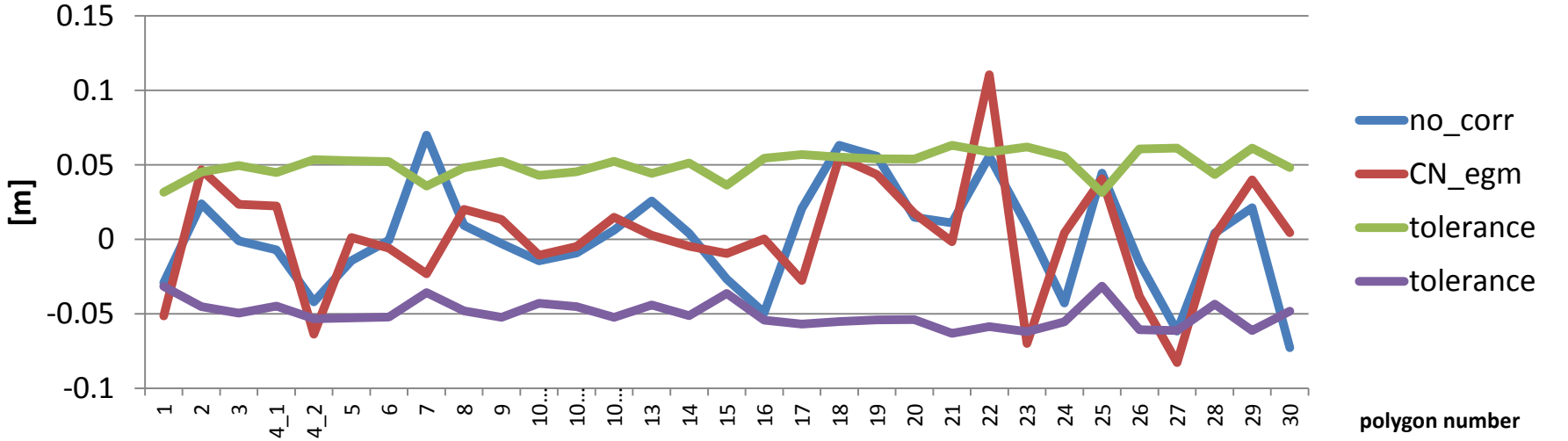


$$\text{tolerance [m]} = 2.5 \cdot 10^{-3} \sqrt{D[\text{km}]}$$

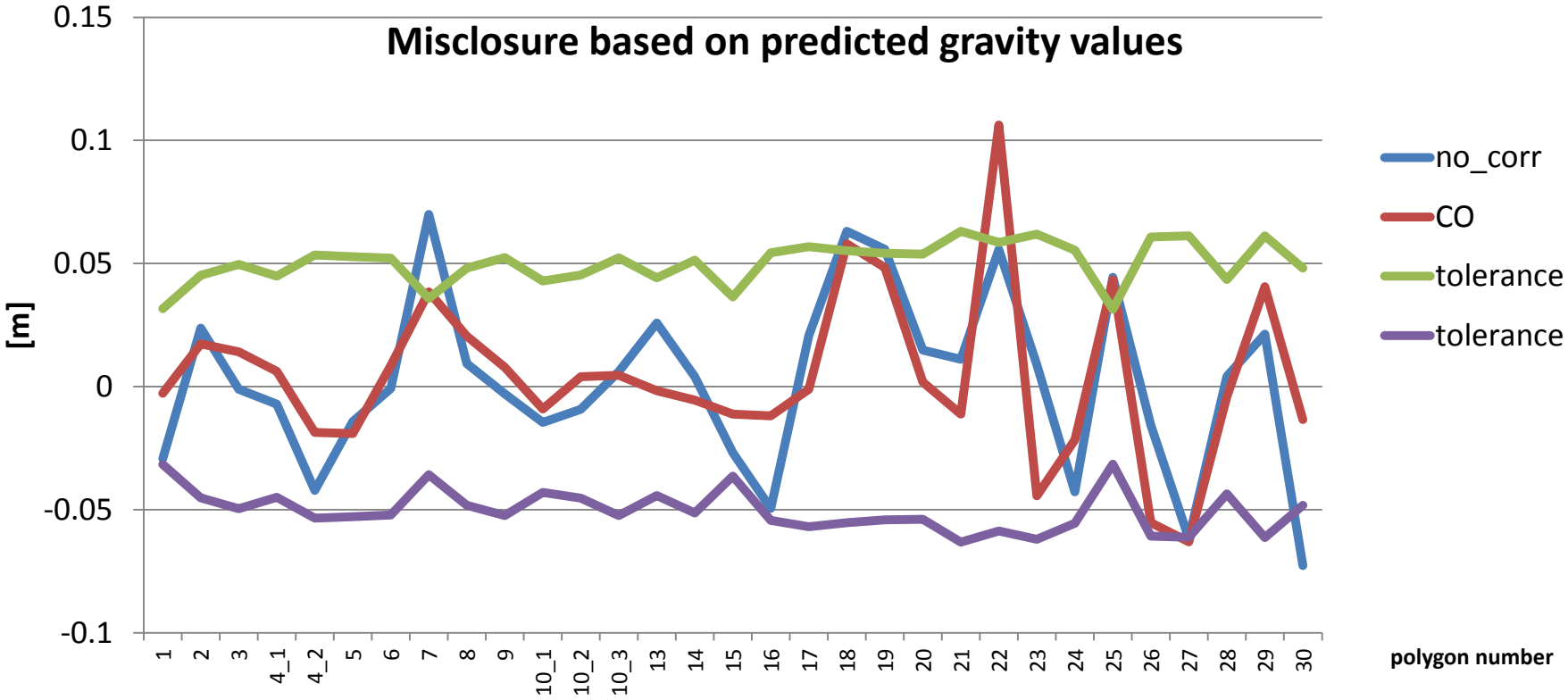
Misclosures based on observed/predicted gravity



Misclosures based on EGM2008

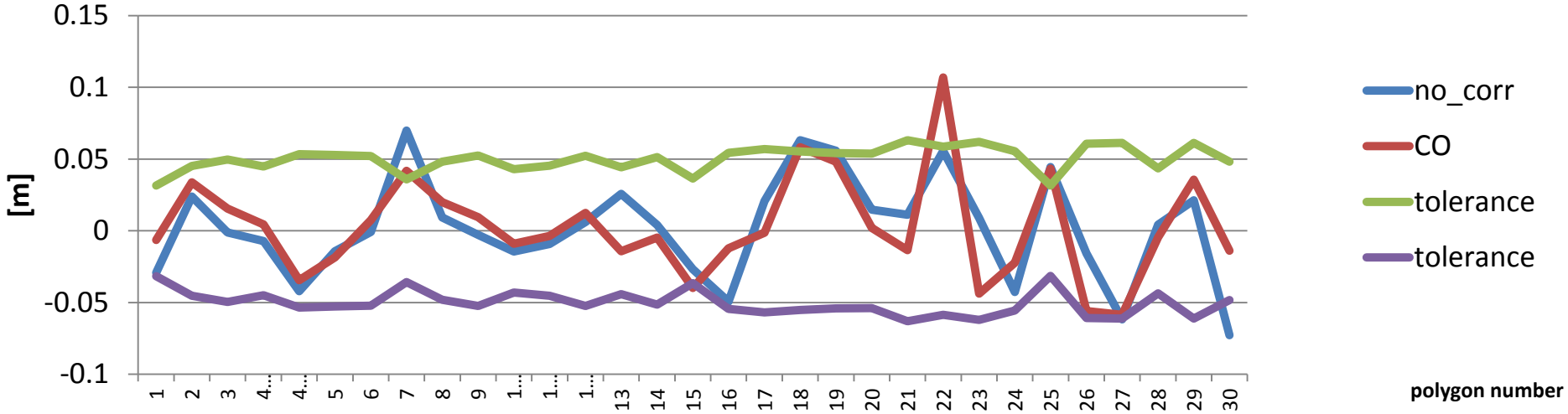


Orthometric correction

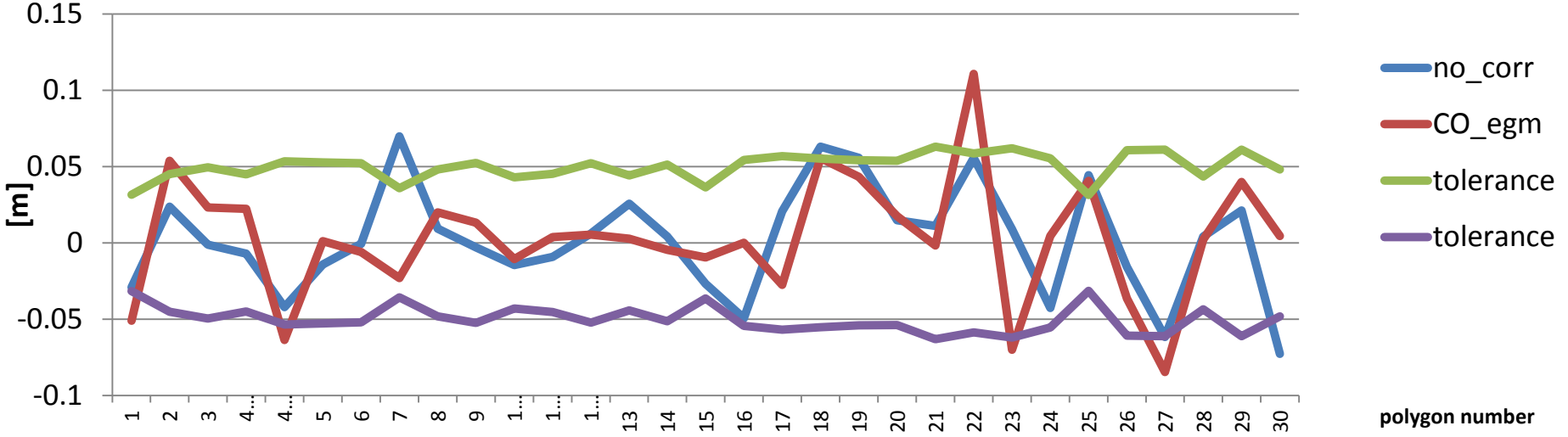


$$\text{tolerance [m]} = 2.5 \cdot 10^{-3} \sqrt{D[\text{km}]}$$

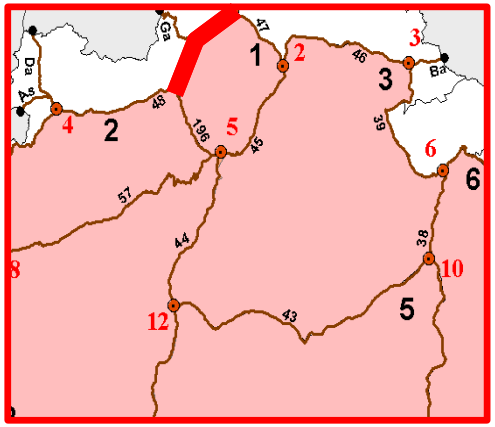
Misclosures based on observed/predicted gravity

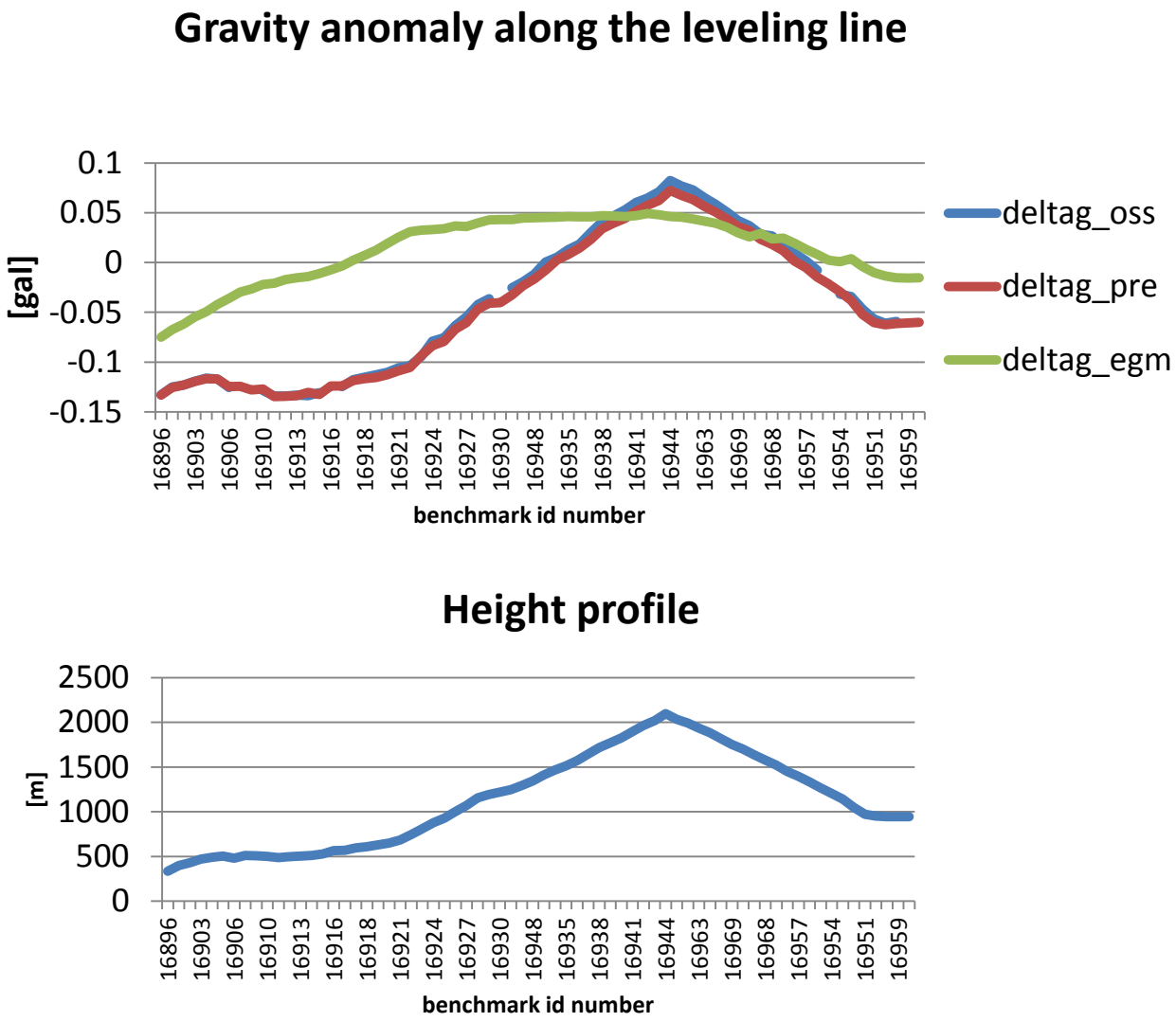


misclosures based on EGM2008

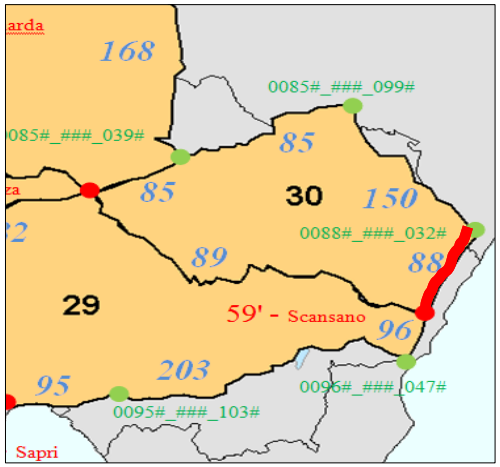


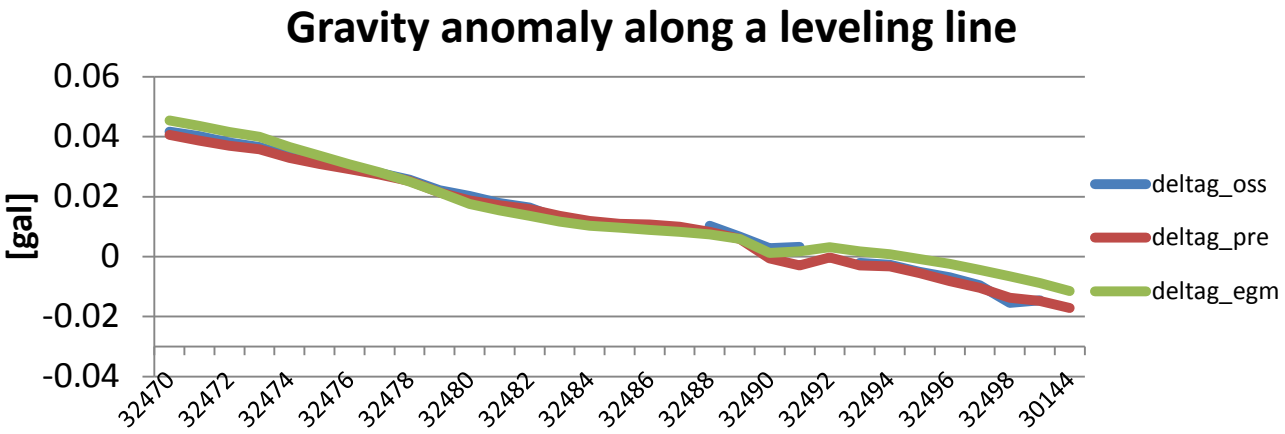
Loop 1- line 48

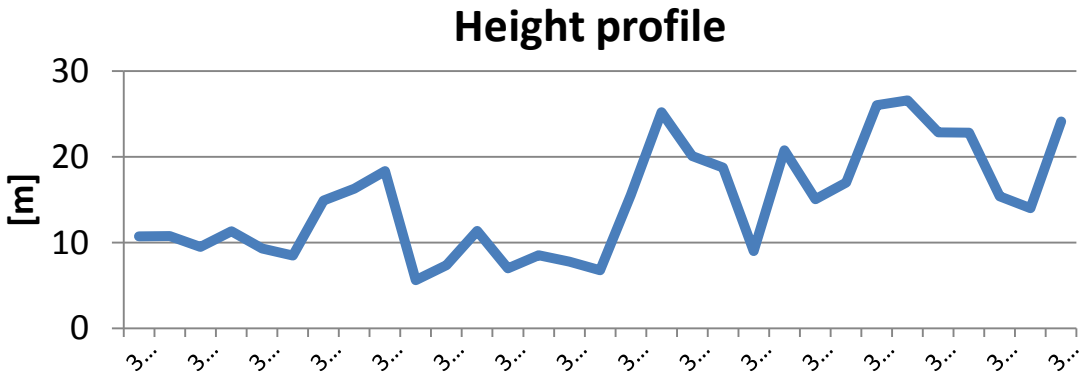




Loop 30 - line 88







Conclusions

- The new normal correction formula proved to be equivalent by the classical Heiskanen-Moritz's one.
- Interpolated gravity can be effectively used for computing gravity corrections
- EGM2008 proved to be less efficient in this application
- As expected, gravity corrections reduce misclosure errors within tolerance level in areas characterized by strong height/gravity variations
- Further investigations are needed to understand the misclosure error in loop 22 which, after corrections, is out of tolerance
- The same procedure will be applied once the new lines in Southern Italy and Sardinia will be available
- The global least squares adjustment will be finally preformed by IGM to estimate proper dynamic, normal and orthometric heights