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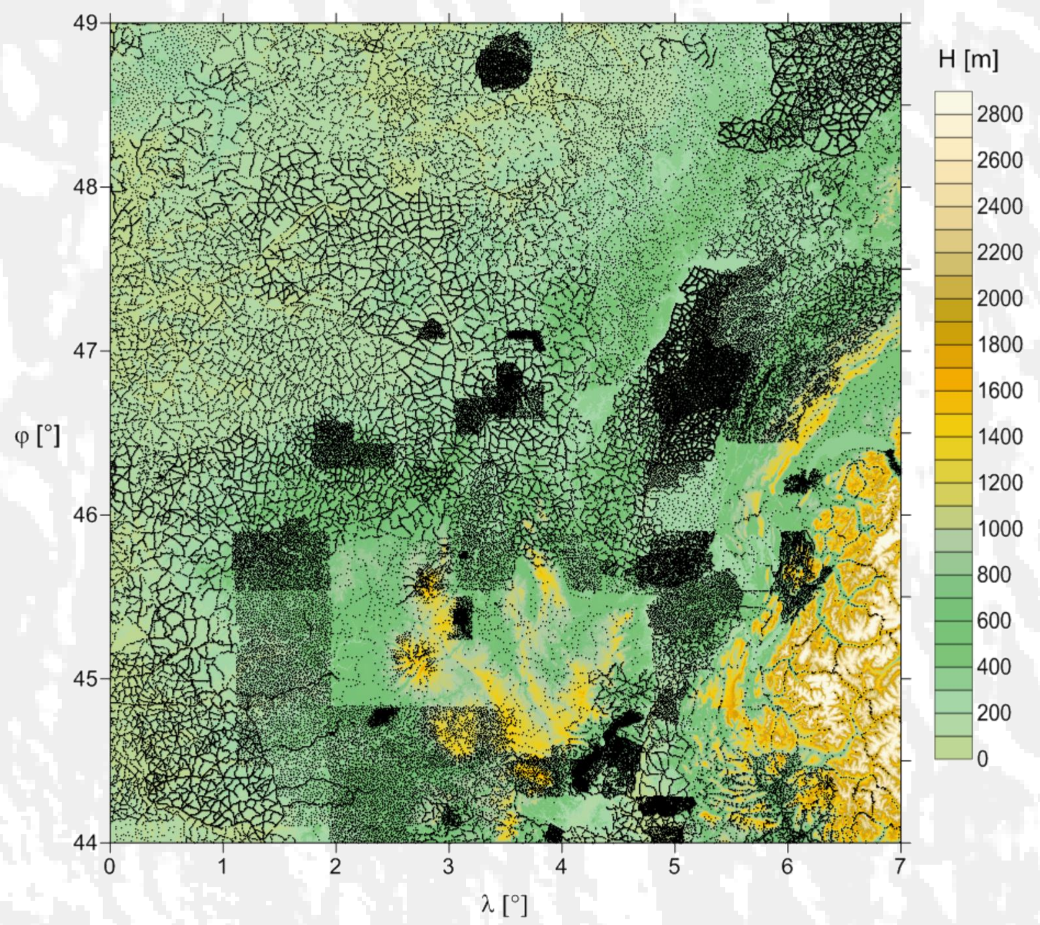
Two different ways of residual terrain effect computation: case study in Auvergne region

Application of residual terrain effect to minimisation of the omission error of global gravity models is becoming a standard procedure during the last years. However, there are still several questions in this topic to be solved, e.g. determination of the optimal integration radius and its dependence on the terrain roughness, effective way of solving the singularity problem when computation point is located inside the masses or evaluation of efficiency of residual terrain effect application when dealing with potential or quantities directly derived from potential (e.g. the height anomalies). We chose the Auvergne test region in France to compute the residual terrain effect on gravity anomaly using two different approaches: method based on general polyhedron and tesseroid method with an analytical integration in radial direction. Both methods are compared, differences are analyzed and tested by independent set of gravity points in total amount of approximately 160 000 points (Duquenne, 2007). The edge effect is estimated and optimal integration radius is suggested.

Distribution of calculation points:



The problem occurs if the calculation point lies under the mean DTM so the gravitational effect needs to be calculated inside the masses and thus the singularity has to be solved.

First approach:

In the first approach we used program Toposk (Marušiak et al., 2013). The calculated area is divided to several circular zones: inner zone with radius 250 m, intermediate zone from 250 to 5240 m and outer zone to the given radius (e.g. equal to 15'). The topography within the inner zone is approximated by one 3D polyhedral body, which gravitational effect is calculated using the formula of Pohánka (1988). This formula enables the calculation of the topographic effect in arbitrary point, so also inside the topographic masses. Since there is a discrepancy between calculation point height and DEM, the topography within this zone is "shifted" to the calculation point height. The topography within the intermediate zone is approximated by the set of segments of the vertical cylinder. The inner and intermediate zones are treated in planar approach (this yields a negligible error), DEM in local orthogonal coordinates were used. The topography within the outer zone is approximated by the set of segments of the spherical layer calculated by the formula of Mikuška et al. (2006).

Second approach:

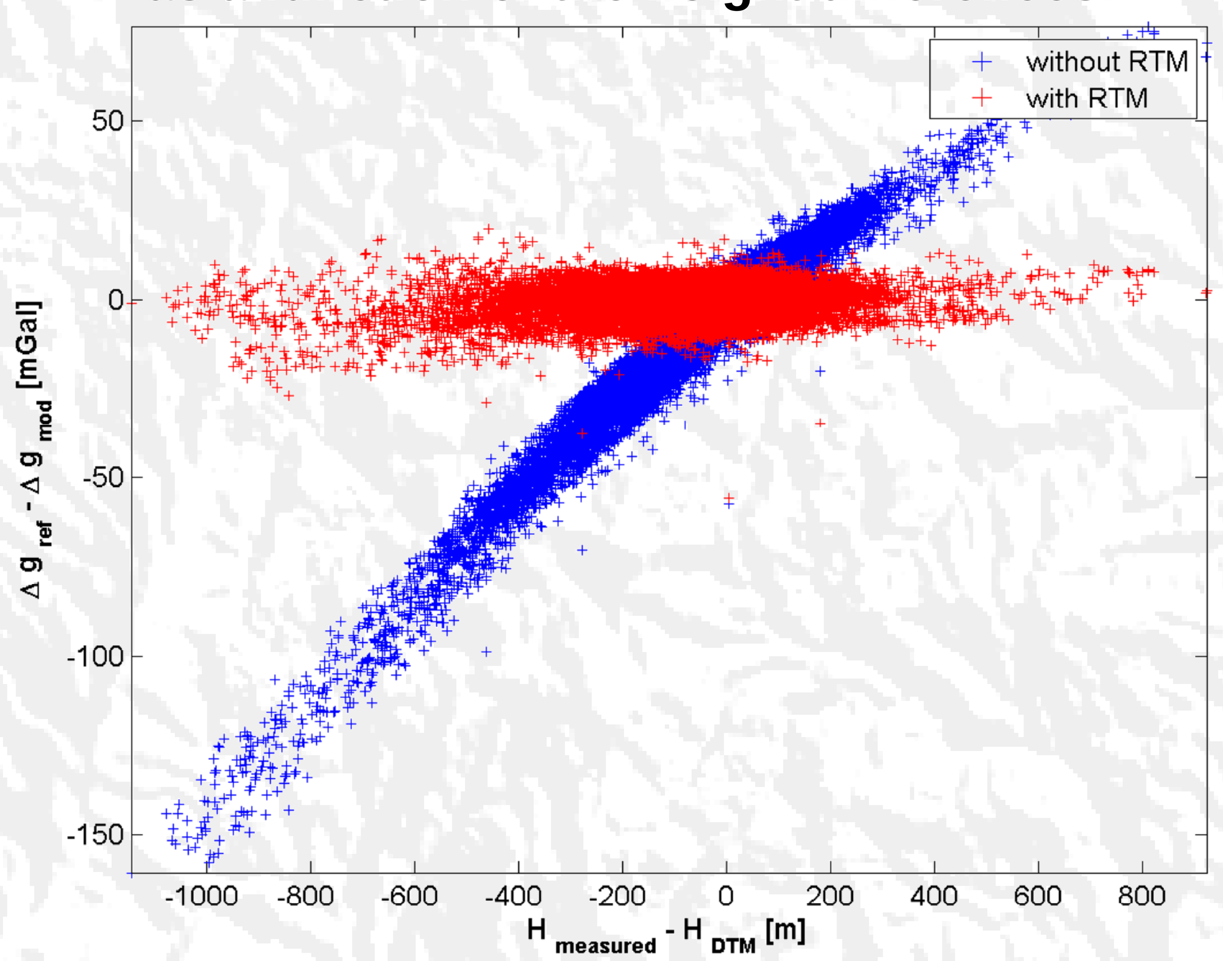
In this approach we used the method proposed by Kadlec (2011) for the elimination of singularity caused by evaluation of RTM effect inside the masses in spherical approximation. In order to avoid the singularity we divided the RTM effect into four parts: the effect of Bouguer layer of thickness *H* (from detailed DTM) and corresponding terrain effect and the effect of Bouguer layer of thickness H^m (mean DTM) and corresponding terrain effect. For the calculation of the gravitational effect of limited Bouguer shell we used formula presented in (Heck, 2006). For the calculation of corresponding terrain effects we used formula derived from the definition of gravitational potential in spherical coordinates. The analytical solution of the inner integral was derived by Martinec (1998). The final gravitational effect is obtained as a sum of gravitational effects of individual tesseroids.

Reference value of free-air anomaly (Δg_{ref}) was compared with the free-air anomaly computed from global geopotential model EGM2008 up to maximum degree in two cases: without using RTM (Δg_{mod}) and with using RTM (Δg_{RTM}) in both approaches for spherical radius 20'.

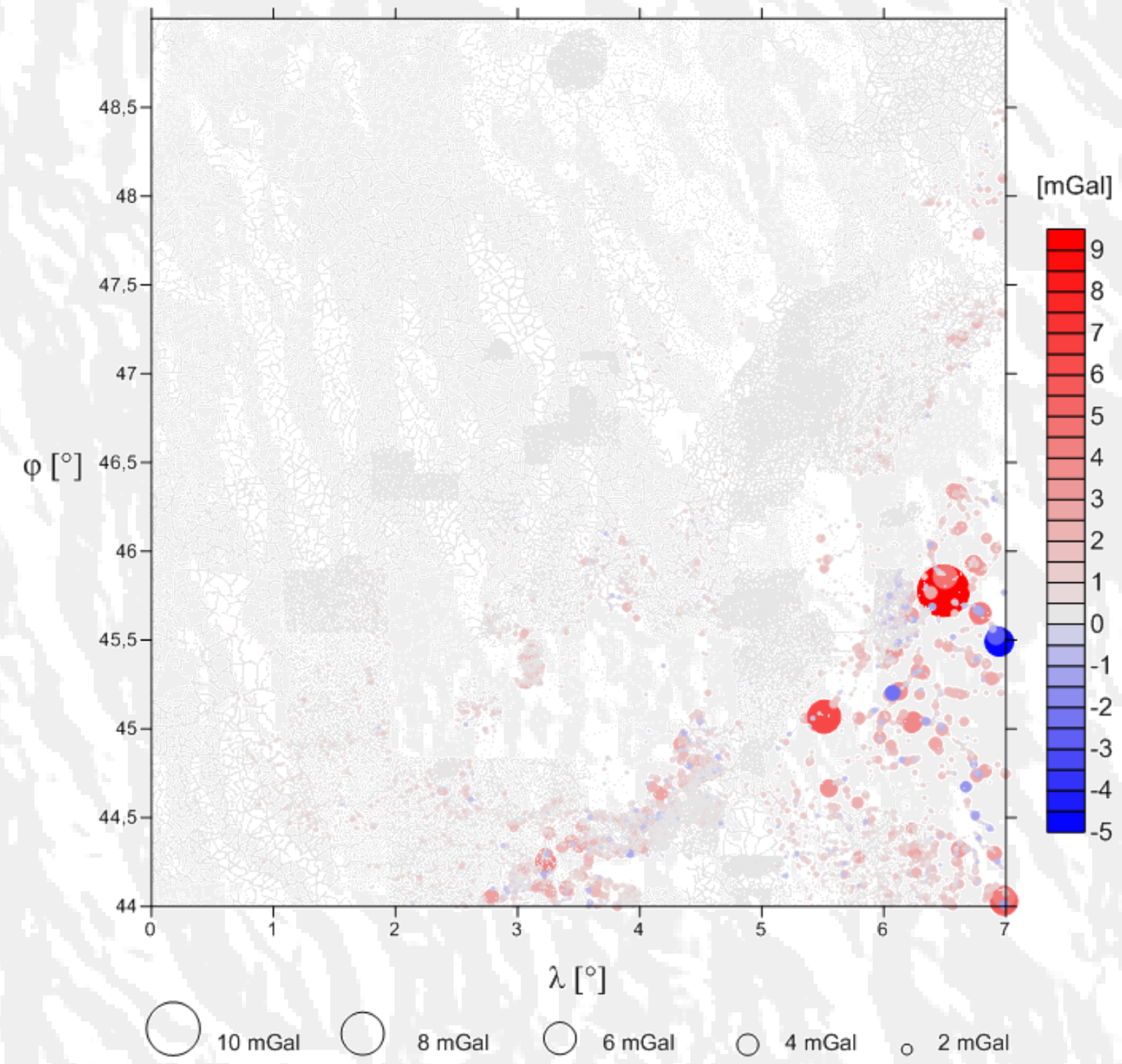
Statistics of differences between reference and modeled free-air anomaly:

Statistics (radius 15')	Δg_{ref} - Δg_{mod} [mGal]	Δg_{ref} - Δg_{RTM} [mGal] **1. appr.**	Δg_{ref} - Δg_{RTM} [mGal] **2. appr.**
STD	9.946	2.550	2.553
mean	-1.935	0.033	-0.001
max	76.754	20.084	19.263
min	-160.367	-55.700	-55.774

Differences between reference and modeled free-air anomaly with and without using RTM as a function of the height differences:



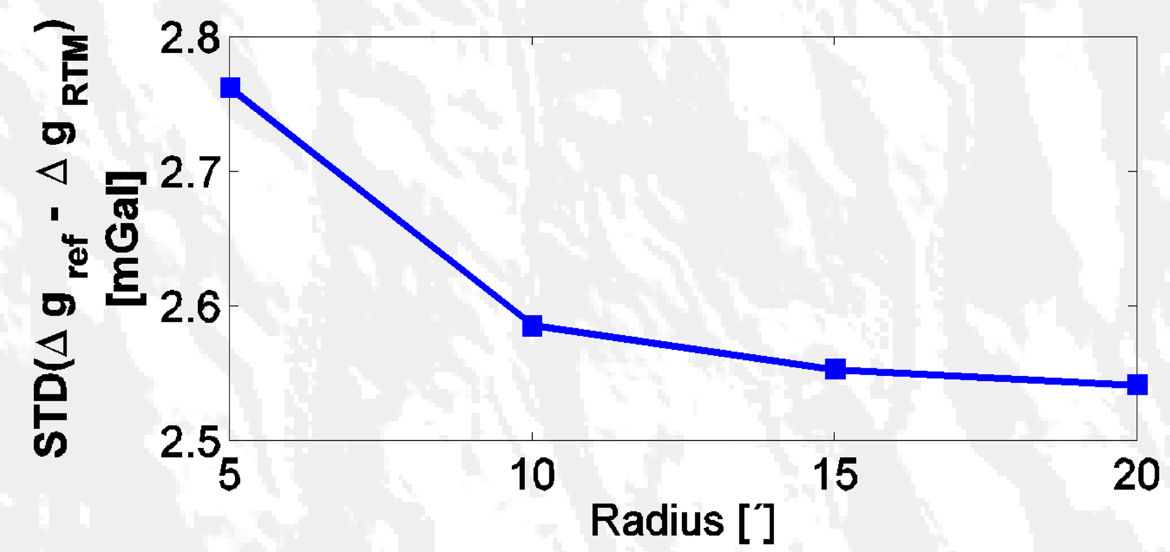
Differences in effect of RTM between two approaches:



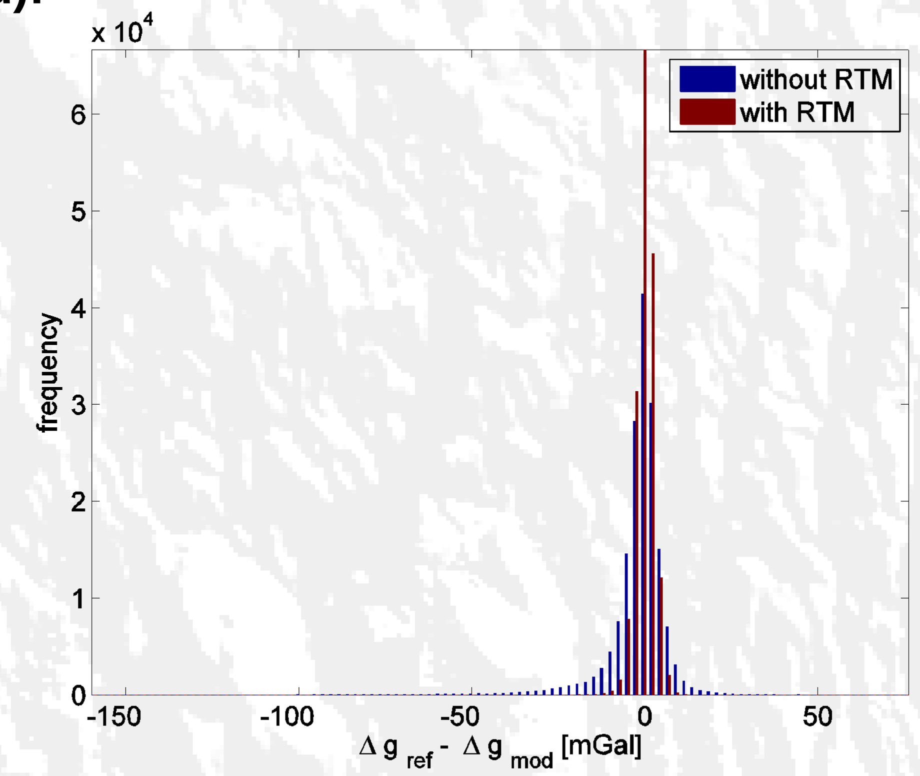
Statistics of differences between reference and modeled free-air gravity anomaly for different radius:

Statistics 2. approach	Δg_{ref} - Δg_{mod} [mGal]	Δg_{ref} - Δg_{RTM} [mGal] **radius 5'**	Δg_{ref} - Δg_{RTM} [mGal] **radius 10'**	Δg_{ref} - Δg_{RTM} [mGal] **radius 15'**	Δg_{ref} - Δg_{RTM} [mGal] **radius 20'**
STD	9.946	2.762	2.586	2.553	2.542
mean	-1.935	-0.118	-0.031	-0.001	0.013
max	76.754	17.472	17.270	19.263	20.131
min	-160.367	-55.892	-55.817	-55.774	-55.761

Standard deviation of differences Δg_{ref} - Δg_{RTM} for different radius:



Histogram of Δg_{ref} - Δg_{mod} (blue) and Δg_{ref} - Δg_{RTM} (red):



Conclusions:

In our experiment, the reference values of free-air gravity anomalies from Auvergne data set (Duquenne, 2007) was compared to the values computed from GGM EGM2008 up to d/o 2190. For elimination of the omission error two different methods for evaluation of gravitational effect of residual terrain model were used. Differences between the reference and modelled values for both approaches were compared in terms of standard deviation, mean, maximum and minimum value. Two different approaches give very similar results in case of the same calculation conditions (treatment of height of calculation points). From the comparison of statistics for different integration radii we can see that the results obtained for integration radius larger than three times of spatial resolutions of used GGM (5') shows only slight improvement in standard deviation but the time consumptions is significantly higher. For this reason we consider the integration radius three times of spatial resolution of used GGM as optimal. From the bottom left figure we can see that without using RTM method there is a strong dependency between the deviation of mean surface from real terrain and the deviation of modeled value of free-air gravity anomaly from the reference value.

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