GOCE gradient downward continuation for local/regional gravity field recovery

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Introduction

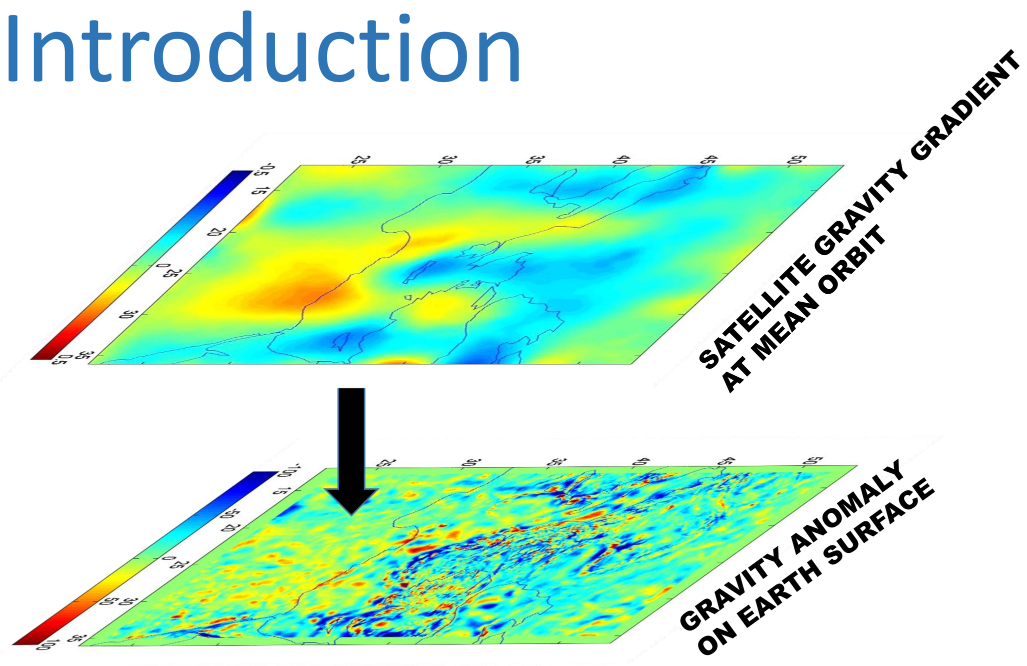

Figure 1: MAIN TASK DESCRIPTION

MAIN TASK: Combination of SGGs at mean orbit and ground gravity anomaly data on the Earth's surface trough GOCE gradient downward continuation for local/regional gravity field recovery by:

- Using a Monte Carlo Method (Simulated Annealing) for solution of inverse problems
- Application of Quasi-random generator (QG)

Background

MOTIVATION: TO COMBINE SGG AT MEAN ORBIT WITH GRAVITY ANOMALY DATA ON THE EARTH SURFACE FOR REGIONAL GRAVITY FIELD MODELLING

REGIONAL GEOID MODELING: for performing calibration of SGGs with external gravity information on a grid to use all available data at highest possible resolution

- HOW? By application of a Monte-Carlo method (Simulated Annealing). Simulated annealing (SA) is a probabilistic method proposed by Kirkpatrick, Gelett and Vecchi (1983) for finding the global minimum of a cost function that may possess several local minima. It works by emulating the physical process whereby a solid is slowly cooled so that when eventually its structure is 'frozen', this happens at a minimum energy configuration.
- WHY? SA allows solving inverse problems like downward continuation of SGGs from mean orbit to the Earth's surface using an iterative Monte Carlo procedure based on quasi-random generator.
- WHAT TO DO? 1)Quasi-random generation of gravity anomalies on earth surface in the form of grid; 2) Upward continuation to mean orbit by MIMOS – Forward step; 3) Comparison of SGG observations with upward SGGs and 'freeze' those satisfying SA criteria; 4) Repetition of 1-3 till all generated SGGs meet the SA criteria.

FOPWARD STEP : MULTIPLE INPUT OUTPUT SYSTEMS (MIMOS) FOR UPWARD CONTINUATION (TO THE MEAN ORBIT) (SIDERIS 1996 - MODIFIED)

$$FFT\left\{T_{ij}^{MO}\right\} = FFT\left\{\mathbf{K}_{ij}^{MO,ES}\left(LT^{ES}\right)\right\} .* FFT\left\{LT^{ES}\right\}, \quad i,j = x,y,z$$

where : FFT - Fast Fourier Transform;

T_{ij}^{MO} - the gravity gradients at mean orbit along the axis i, j

LT^{ES} - Functional of disturbing gravity potential (gravity anomaly) on Earth surface

$\mathbf{K}_{ij}^{MO,ES}$ - Kernel for transformation of the functional of disturbing potential LT^{ES} on Earth Surface to the gravity gradient T_{ij}^{MO} at mean orbit (Eshagh , 2010)

where: ES – Earth's surface; MO – mean satellite orbit at 260 km
{.*} – element by element multiplication

Experiment description and results

- Application area: 22 < latitude < 53; 12 < longitude < 36
- Applied to: on 2D regional 6' x 6' grid for Tzz
- Gridding – standard procedure with Delaunay triangulation
- Time interval covered: 01/11/2009 – 30/04/2011 (16 months) with 421 days of SGG data
- Data type and source: EGG_NOM_2, GOCE HLPF, ESA/ESRIN
- SGG description: normal potential gradients are evaluated at the LNOF and transformed to the GRF. Disturbing potential gradients are computed and then filtered with an FIR band-pass filter (5-100 mHz) with a Hamming window for spectral leakage. The filtered T_{ij} are then reduced to a mean orbit.
- Reference Gravity Field Model: GOCE DIR R4
- Ground data: EGM 2008 Gravity Anomaly Model generated on Earth's surface
- Type of model SGG data: DIR R4 GPM generated directly at mean orbital altitude
- Type of wavelets used: DB 10 (2D Daubechies wavelets)
- Number of levels for 2D signal decomposition and reconstruction: 3 – for additional filtering out high frequencies
- Number of separate runs: 30
- Number of iterations necessary to reach SA criteria per every run: 500

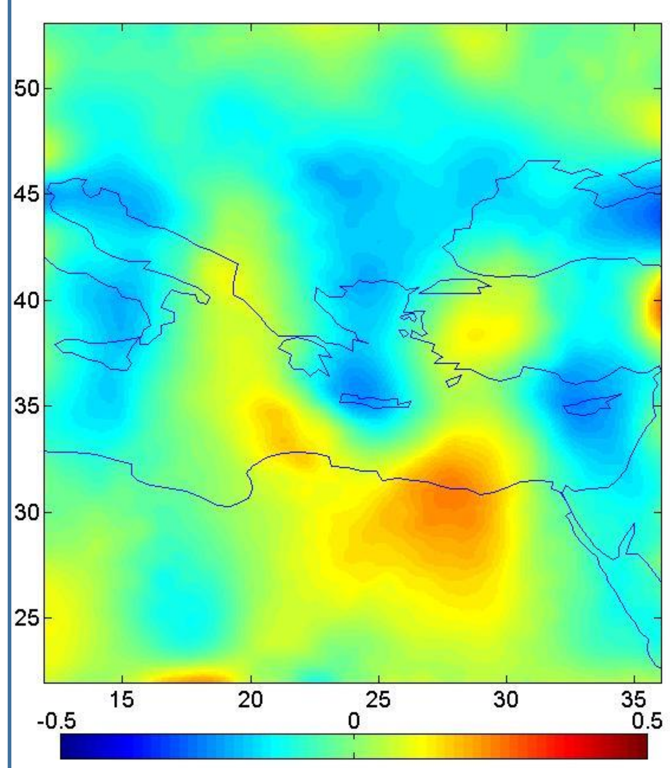

Figure 2: Filtered GOCE Tzz [Eotvos]

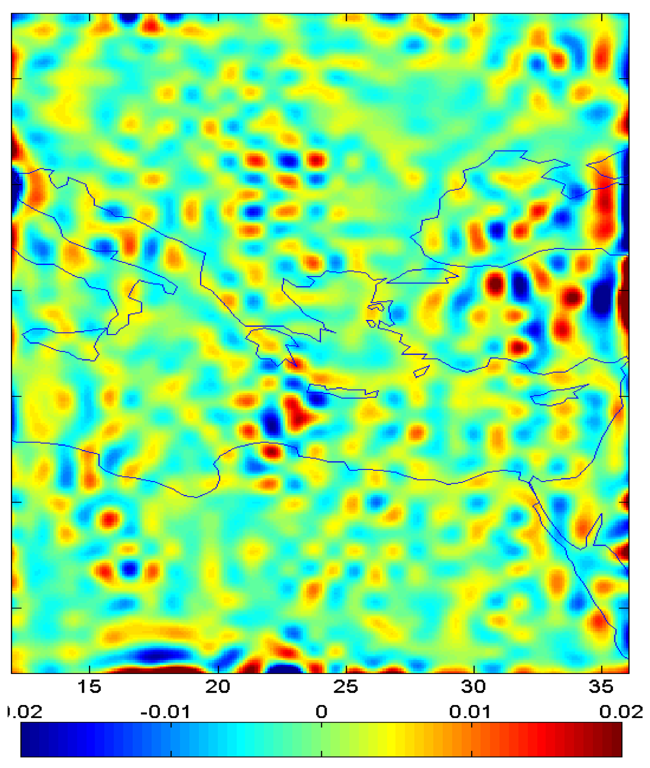

Figure 3. Differences between filtered and generated GOCE Tzz [Eotvos]

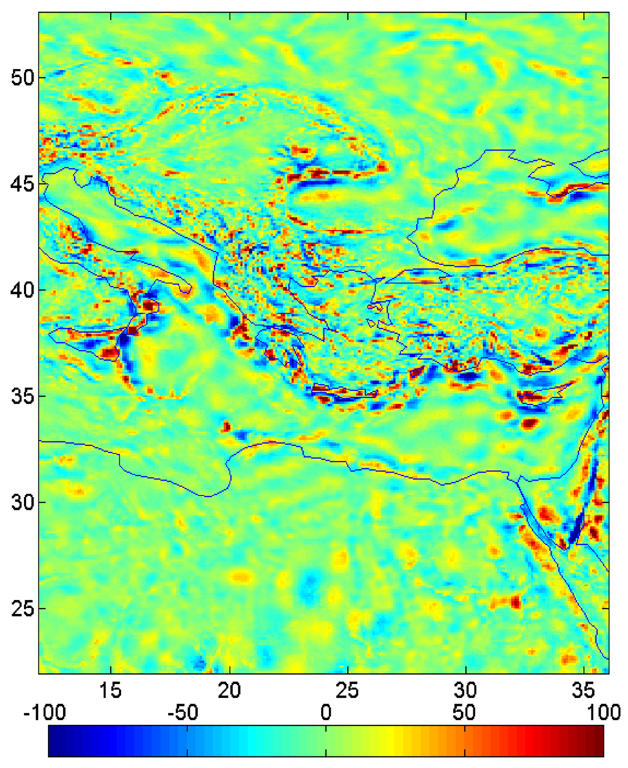

Figure 4: EGM 2008 Gravity anomalies on Earth surface [mGal]

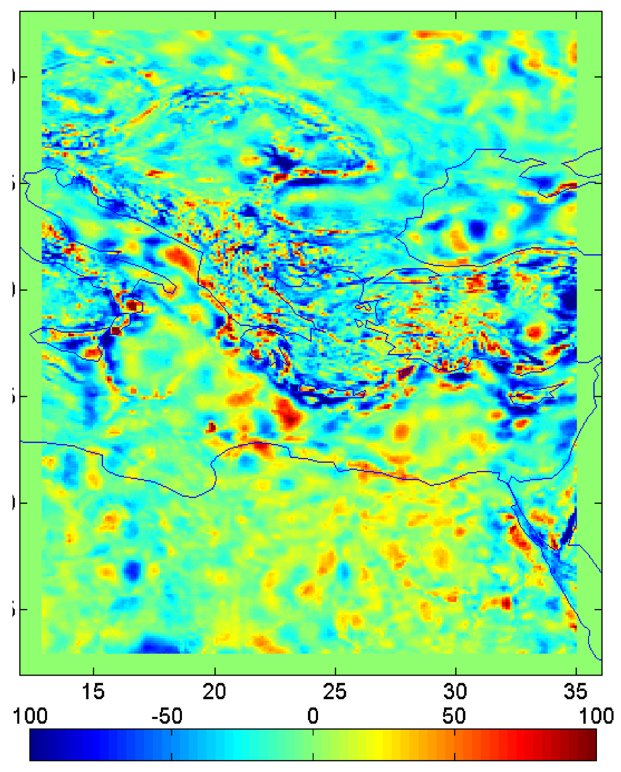

Figure 6:Generated Gravity anomalies on Earth surface [mGal]

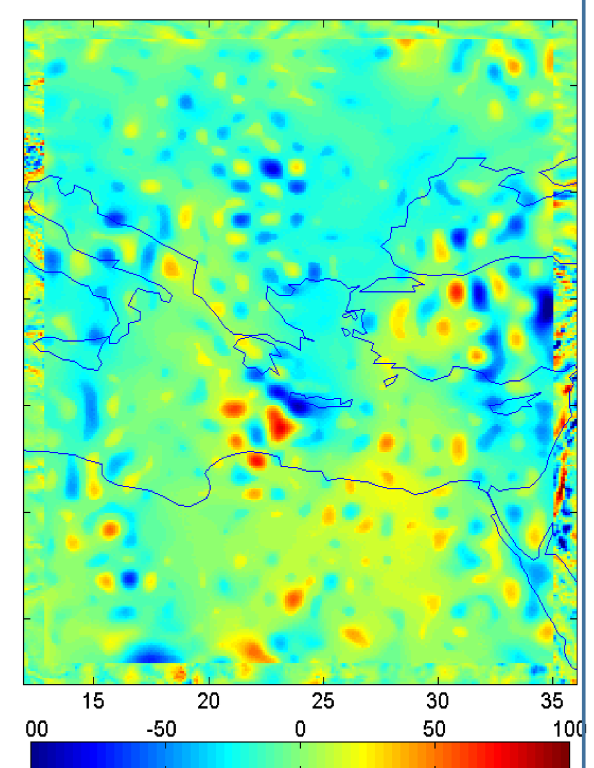

Figure 7: Effect of GOCE Tzz on gravity anomalies [mGal]

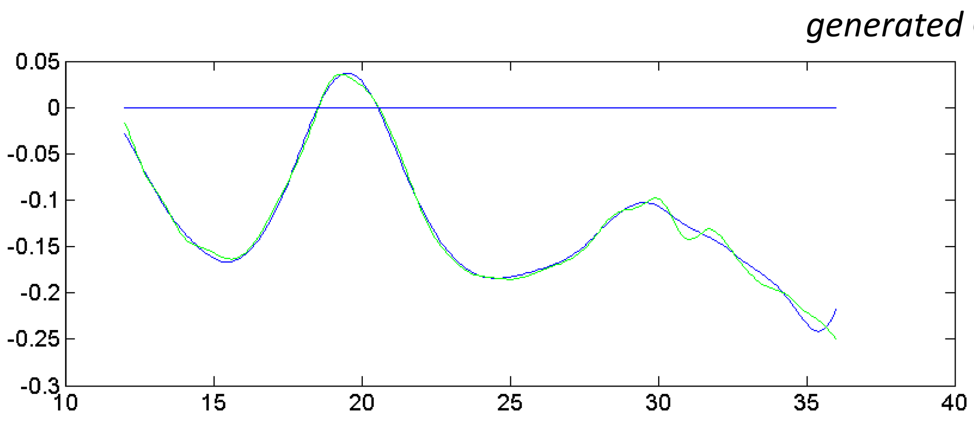

Figure 8: Filtered (green) & Generated (blue) Tzz for latitude 43°

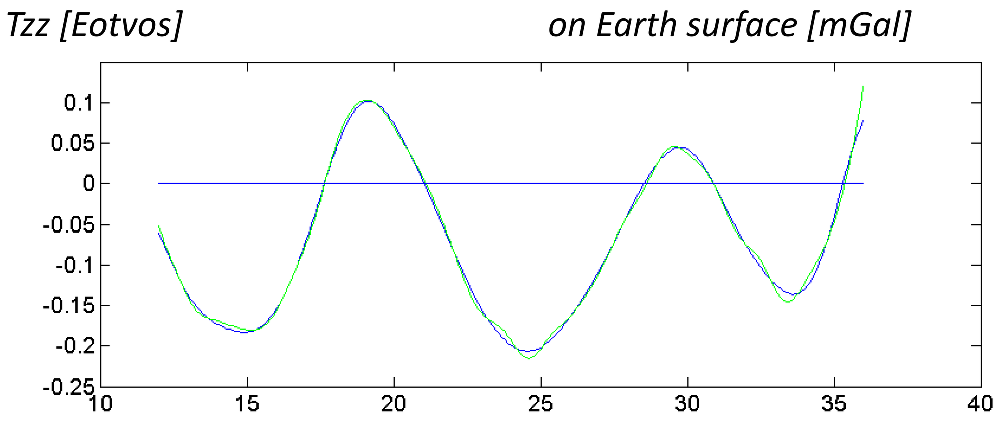

Figure 9: Filtered (green) & Generated (blue) Tzz for latitude 41°

DATA	MIN	MAX	MEAN	STD
GENERATED GAs (average of 30 runs)	-189.99	177.46	-7.65	7.64
GENERATED - EGM08 GA (separate run)	-118.04	82.13	-7.39	18.73
GENER. – EGM08 (average of 30r runs)	-116.37	80.29	-7.39	3.41

Table 2: Statistics of generated GA and differences w.r.t. EGM08 [mGal]

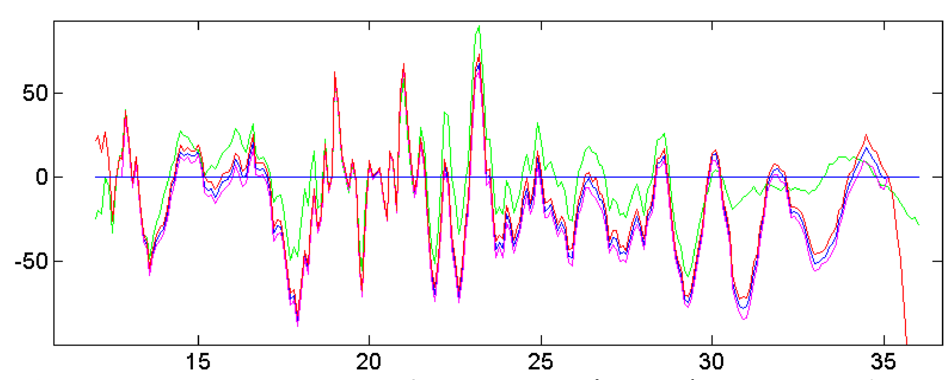

Figure 10: Gravity anomalies EGM08 (green), generated average (blue),max(red),min(magenta) gravity anomalies for latitude 43°

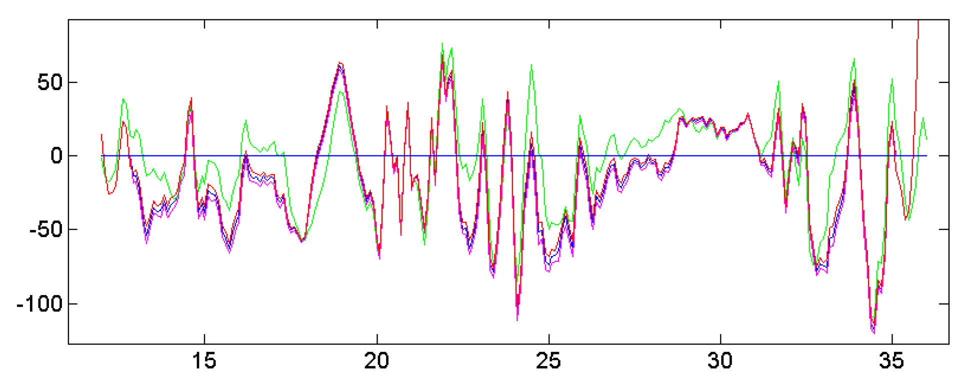

Figure 11: Gravity anomalies EGM08 (green), generated average (blue),max(red),min(magenta) gravity anomalies for latitude 41°

- Generated SGGs are very close to observed (5 mEötvös)
- Generated GAs per separate run are in the range of +/-8 mGal (STD) – same range is between min and max Gas
- Min & Max per separate run and the average are in the range of 3 mGal (STD for averaged of 30 runs GAs)
- The effect of downward GOCE data on EGM08 are significant (see Figure 7 & Figure 2)

Conclusions:

- The developed procedure for downward continuation of GOCE SGG from mean orbit to the Earth surface using Simulated Annealing Monte Carlo method can be successfully applied for regional/local al gravity field recovery;
- It provides convergence after 500 iterations per separate run with a stable mean value (changes of 0.3 mGal) and STD of 19 mGal w.r.t. to EGM08;
- After 30 runs (15000 iterations) the mean value for averaged GAs (-7.39 mGal) is same as for a separate run and STD (3.41 mGal) approaches 3σ of GOCE SGGs;
- The effect of downward SGG Tzz on the gravity anomalies on Earth surface is significant with a strong corelation with the observed Tzz at mean orbit (see Fig. 2 & Fig. 7)

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