A NEW REALIZATION OF THE CZECH GRAVITY SYSTEM

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Outline

1. Introduction
2. Data
3. Data processing
4. Adjustment
5. Results
6. Conclusion

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ORIGINAL REALIZATION OF THE GRAVITY SYSTEM 1995 (S-GR95)

MAIN FEATURES

- Common adjustment of three countries (Czech, Slovak and Hungary), 16 absolute stations together.
- Based on two absolute stations on the Czech territory only.
- Absolute gravity measurements before 1995 ⇒ bigger systematical errors.
- Mostly Sharpe and Worden relative gravimeters.
- Local deformation of about 100 μGal in the mountain areas because of a lack of absolute stations.
- $m_0 = 26\,\mu$Gal from the adjustment.
- Almost twenty years old ⇒ extinction of stabilizations.

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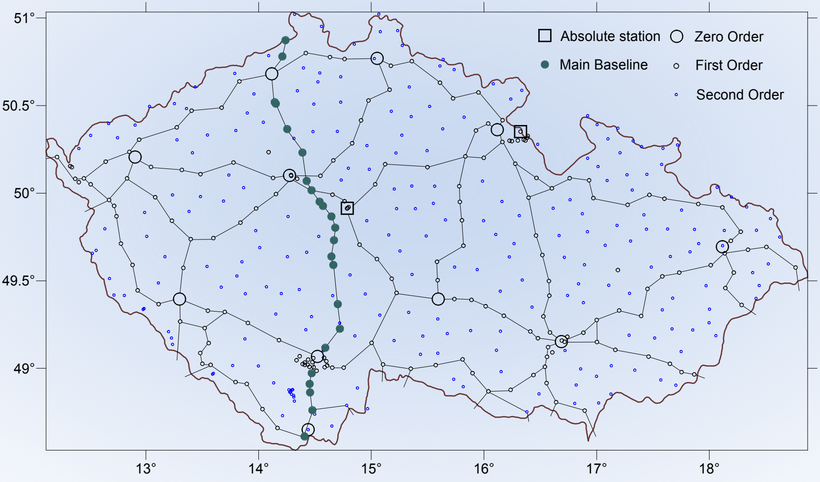
GRAVITY STATIONS DIVIDED TO THE UNITS/ORDERS



New gravity system requirements

Main Goals

- Usage of all accessible absolute and relative measurements.
- Elimination of systematical errors of gravimeters.
- Reprocessing of all data with help of database possibilities.
- New vertical gradients calculation (by using data from gravity mapping and digital terrain model).
- Position review of all stations with an assistance of map webservers and cartometric calculations.
- A posteriori error at the gravity system stations better than 10 μGal.
- A chance of the secular gravity trend determination in the adjustment.

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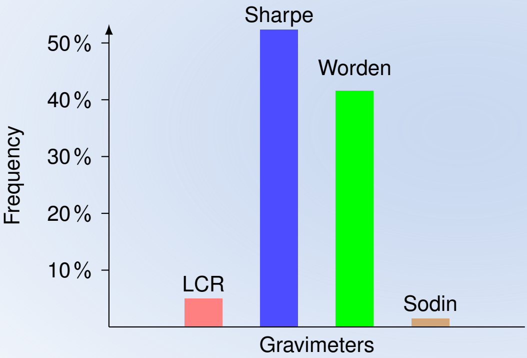
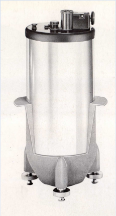
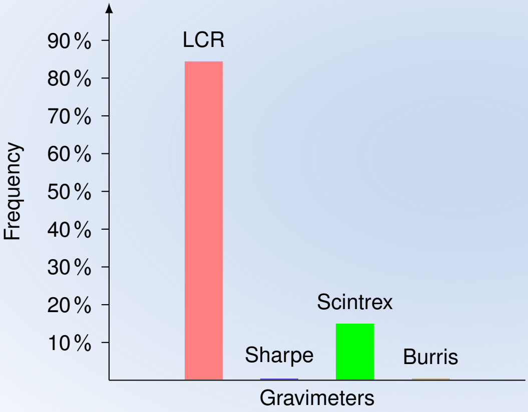
Relative measurements till 1995



- 4 002 day units
- 842 gravity stations
- 31 relative gravimeters
- 42 491 observations



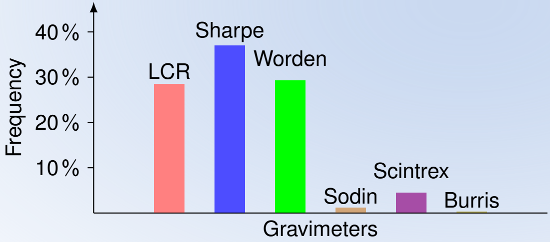
RELATIVE MEASUREMENTS 1995 – 2013

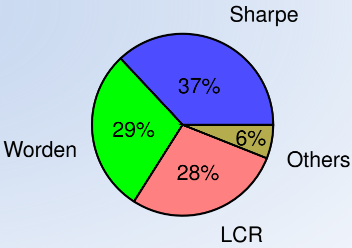


- 1 734 day units
- 517 gravity stations
- 25 relative gravimeters
- 17 202 observations

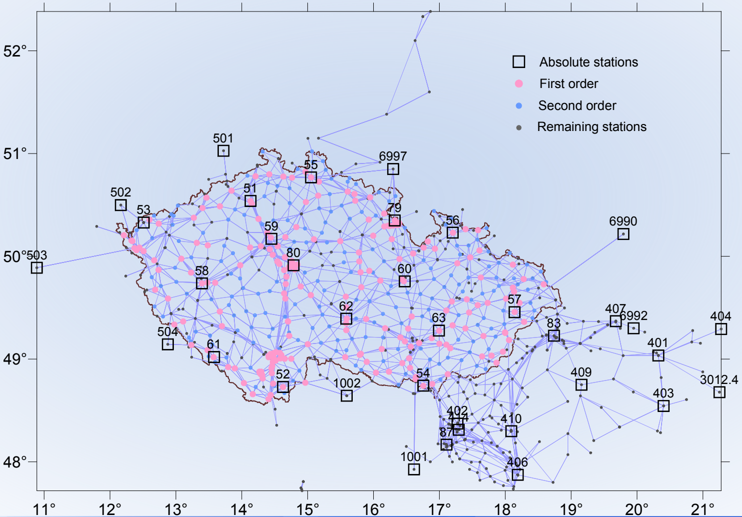
All relative measurements

Relative gravity measurements from the great time period 1967 – 2013



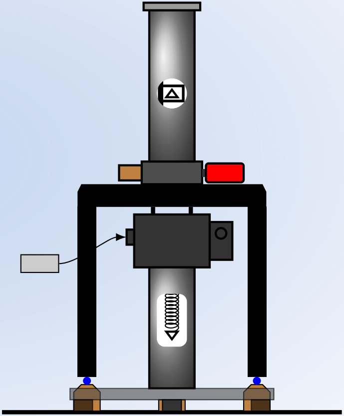


Polygons of relative gravity measurements

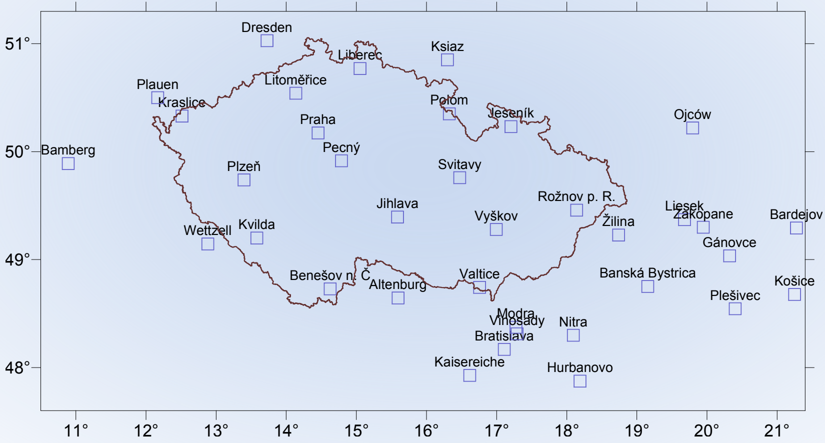


Absolute gravity measurements

- Till 1995 only two absolute stations (Pecný and Polom).
- 15 absolute stations presently (all of them minimally two times measured with FG5 No. 215) in the Czech territory.
- Relative cross-border connections to the another 21 absolute stations.
- Together frame of 36 absolute station covered with 295 absolute observations (mostly at the Pecný station).



International frame of absolute stations



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Data preparation

New, complete data processing directly from field books

⇒ data conversion to a relational database:

- all day units (observations) impotrted to the database
- gravity catalogues and instrument tables converted to a relational data model too
- data management: definition of gravity networks, subnetworks, tasks, etc.

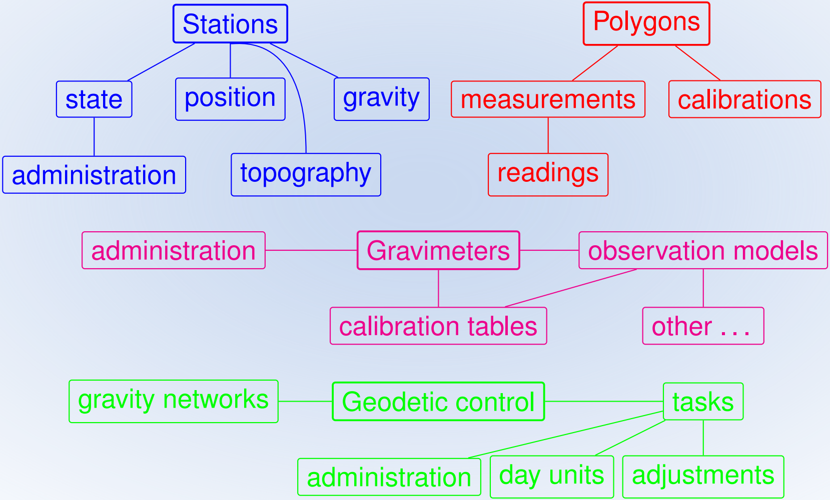
⇒ PostgreSQL database & R statistical software → data clean-up:

- fill-up missing information (e.g. atmospheric pressure)
- find out data inconsistencies and try to repair them
- outliers detection

⇒ Observation model and systematic errors determination:

- nonlinear and time-dependent scale
- periodical effects on scale
- gravity sensor barometrical effect

Relational data structures



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Observation equation

Internal instrument effects and scale factor should be described as

$$g_{\text{ef.}} = [C(z,c) + B(p) + L(t)]\,\xi + Z(t)\,. \tag{1}$$

On the other hand the external effects in the observation we summarize as

$$g_{\text{ef.}} = g_{\text{ref.}} + o_t(t) + o_p(p) + o_h(h_s) + o_a(t) + o_{\text{sec.}}(t)\,. \tag{2}$$

Laying an equality between the (1) and (2) yields in the observation equation in our approach

$$\begin{aligned} l &= \left(g_{\text{ref.}} + o_t(t) + o_p(p) + o_h(h_{\text{ef.}}) + o_a(t) + o_{\text{sec.}}(t)\right) - \\ &- [C(z,c) + B(p) + L(t)]\,\xi + Z(t)\,. \end{aligned} \tag{3}$$

Software solution

We can approximate the equation (3) with the linear model for unknowns parameters **x** in the form

$$l = l_0 + \mathbf{a}^T \mathbf{x}\,, \qquad (4)$$

where we obtained the linear system for more measurements

$$\mathbf{A}\mathbf{x} + \mathbf{l}_0 = \mathbf{v}\,. \qquad (5)$$

The optimalizing condition, with introduction of weights, has the form

$$\left\| \sqrt{\mathbf{w}}\,(\mathbf{l}_0 + \mathbf{A}\mathbf{x}) \right\|^2 \rightarrow \min\,. \qquad (6)$$

The linear system (5) is solved using LSM by the SVD method, with consideration that $\mathbf{A} = \mathbf{U}\Sigma\mathbf{V}^T$, according the notation

$$\mathbf{x} = \mathbf{V}\Sigma^{-1}\mathbf{U}^T\mathbf{l}_0\,. \qquad (7)$$

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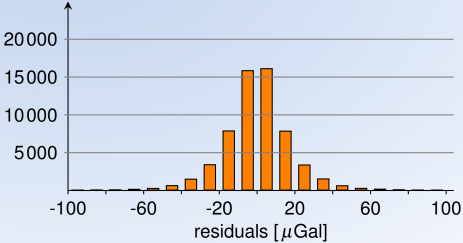
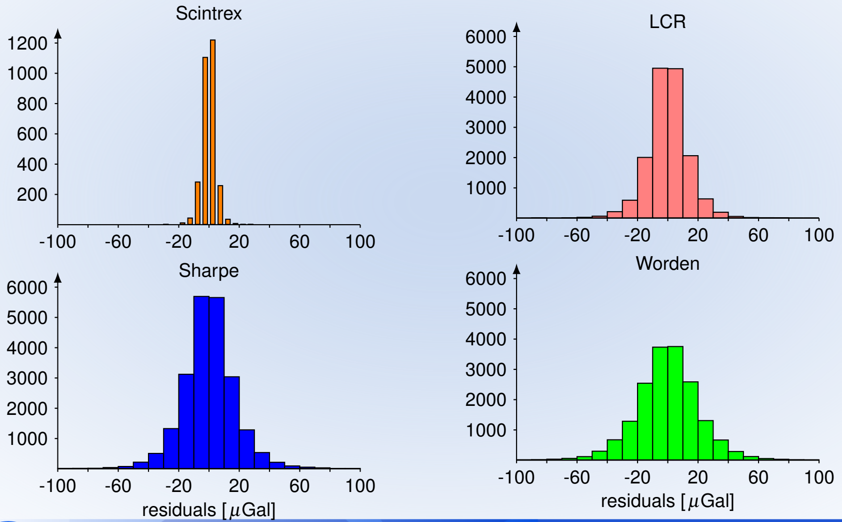
Common adjustment - results

- The level and the scale were derived from the absolute measurements (*zero – tide* system).
- Observation weights set according to a gravimeters
- Determined parameters ⇒ DU drifts, stations gravities, additional calibration factors per year and gravimeter.

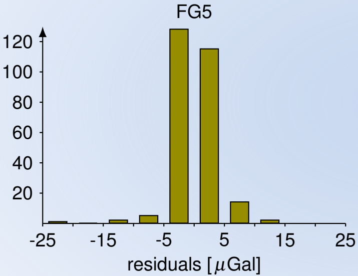
- $m_0 = 1.64$
- 59 693 equations
- 6 031 polygons
- 61 gravimeters

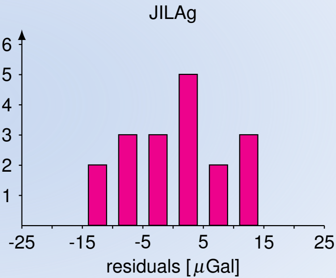


Residuals for relative gravimeters

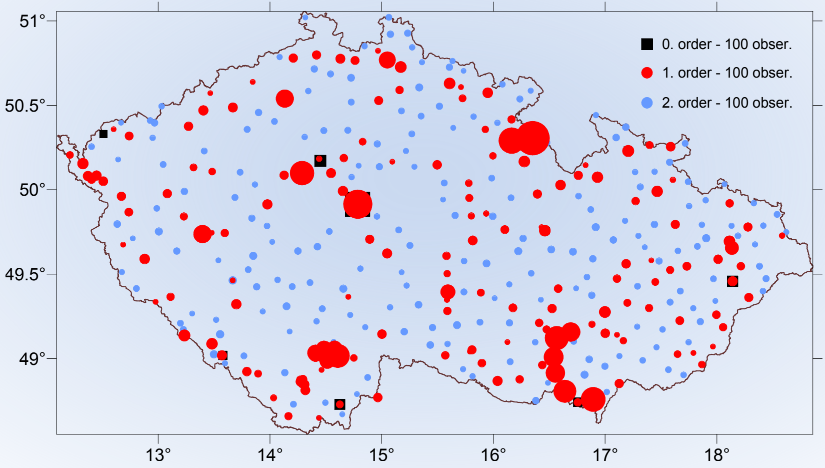


Residuals for absolute gravimeters

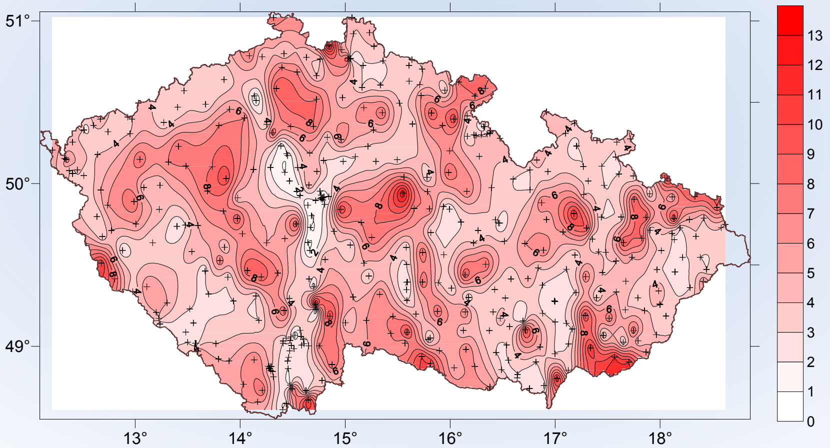




Number of observations



Distribution of the standard deviation after the adjustment in μGal



Distribution to orders 1/2

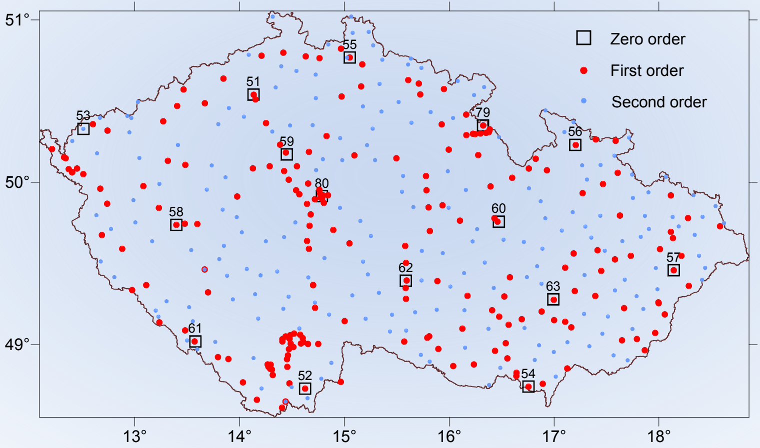
As the result of the adjustment we obtained 1 045 gravity values g_{ref} and 167 scale factors ξ as the unknown parameters. 424 stations were chosen as the new realization of the gravity system. Distribution to orders is subsequent:

15 Zero order $\Rightarrow$ absolute stations ($\overline{m}_g = 1.7\,\mu$Gal)

212 First order $\Rightarrow$ gravimetric baselines, stations of the Czech geodynamical network, others stations of higher precision ($\overline{m}_g = 3.4\,\mu$Gal)

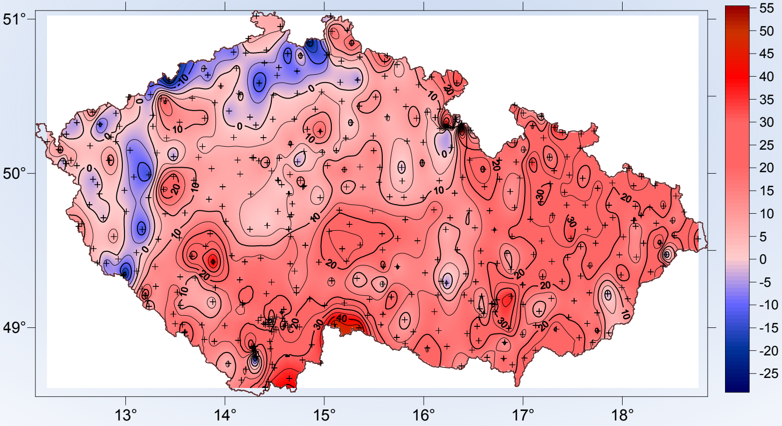
197 Second order $\Rightarrow$ stations of less importance ($\overline{m}_g = 6.0\,\mu$Gal)

Distribution to orders 2/2



Comparison with S-Gr95

From 458 identical stations $\Rightarrow \Delta\overline{g} = g_{S-Gr95} - g_{S-Gr10} = +13\,\mu\text{Gal}$



Transformation between S-Gr95 and S-Gr10

From the previous figure is visible the evident linear scale dependence on the latitude. It should be represent by the following term

$$^{tr}g^{10} = g^{95} + x + \Delta g^{95} y + l\lambda,$$

where the computation ready form is

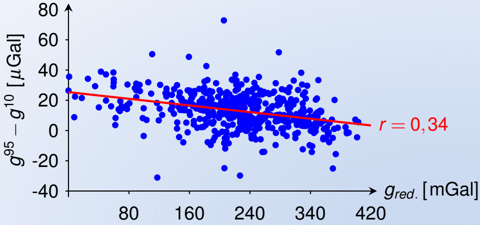
$$^{tr}g^{10} = g^{95} + 0.042 + 6.8 \cdot 10^{-5} (g^{95} - 980\,935.014) - 0.0036\,\lambda^{\circ}. \quad \text{[mGal]}$$

For an elimination of local deformations of the S-Gr95 the more accurate term was derived using the additional term $o(\varphi, \lambda)$ dependent on the location

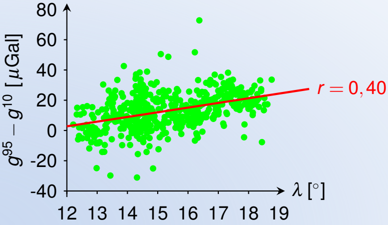
$$^{tr}g^{10} = g^{95} + x + \Delta g^{95} y + l\lambda + o(\varphi, \lambda).$$

A grid of $o(\varphi, \lambda)$ was interpolated by the *kriging* method (Surfer® 8).

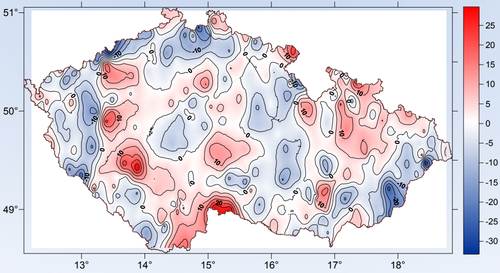
Scale dependence on the gravity



Scale dependence on λ

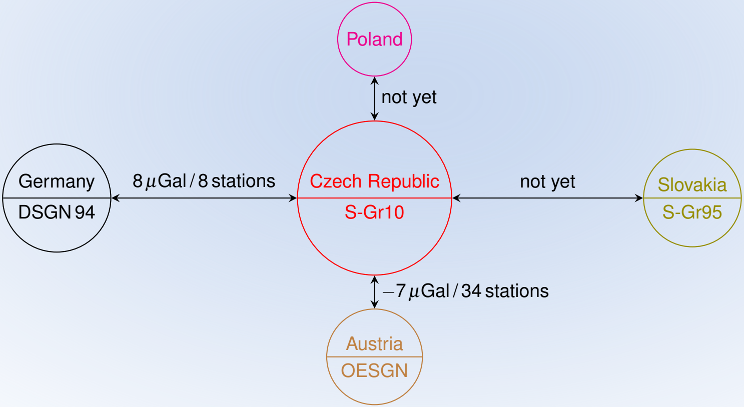


Interpolated grid of residuals ⇒ local deformations of S-Gr95



Comparison with neighbouring countries

Due to relative gravity connecting measurements a few stations in neighbouring countries have gravities in S-Gr10. An average difference was calculated $\Delta\overline{g} = \sum \left(g_{(S-Gr10)} - g_{(NGS)} \right) / n$.



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Conclusions

New realization of the Czech gravity system

- Reprocessing of all relative gravity observations from time period 1967 – 2013
- Novel systematical error analysis and modelling
- Frame of 15 absolute stations in the Czech Republic (each station measured minimally twice with FG5 No. 215) $\Rightarrow$ considerable level and scale improvement
- New software solution based on relational database, new abilities (secular or periodical gravity time changes)
- Standard deviations of gravity accelerations approximately two times better than the S-Gr95

Thank you for your attention !

Acknowledgements: Thanks to the colleagues from neighbouring countries for providing the data