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# Towards unification of gravity data sets in Estonia for the improvement of national geoid model

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## Topics

- Latest gravimetric geoid models
- Historic gravity data sets in Estonia
- Evaluation of these sets on the basis of new accurate observations (GV-EST)
- New gravity surveys
- Calibration of relative gravimeters



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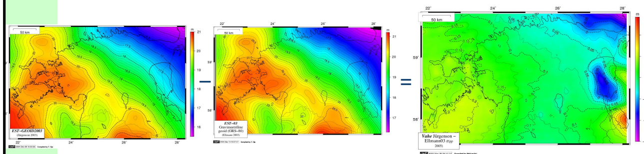
## Gravimetric geoid models

- Latest gravimetric geoid models in Estonia:
  - in 2003 EST-Geoid2003 by HJ (r-c-r method) – deterministic approach
  - in 2004 BALTgeoid-04 by AE (unbiased LS modification of Stokes' formula) – stochastic approach
  - RMS of the post-fit residuals (of the fit with GPS-levelling data) about ± 2… ± 3 cm




E.Rohumägi 2005



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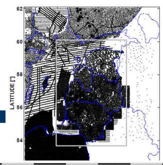
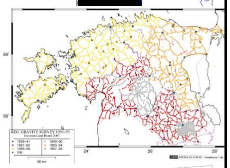
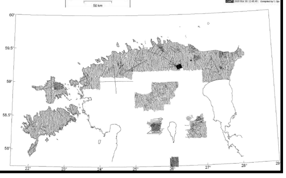
## Gravity datasets used:

- NKG gravity database
- Survey 1949-1958 by IG*
- gravity network of 1999
- A/D conversion of the paper anomaly maps* (Gulf of Riga, lakes, border areas of Russia)
- SU MG geological surveys* 1960-1990* (Spetzgeofizika, Neftegeofizika)
- Survey of GSE* (1966-…)
- Baltic Aerogravity 1999

*transformed by -15.4 or -14.0 mGal



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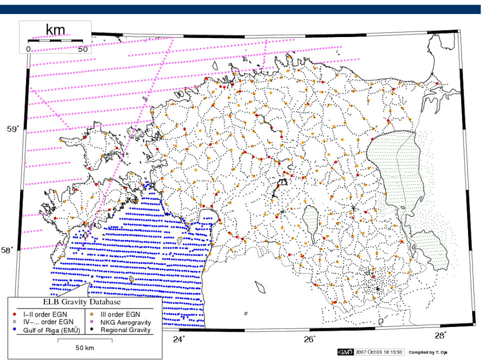
## In 2007 gravity data to the European Gravity and Geoid Project (EGGP)



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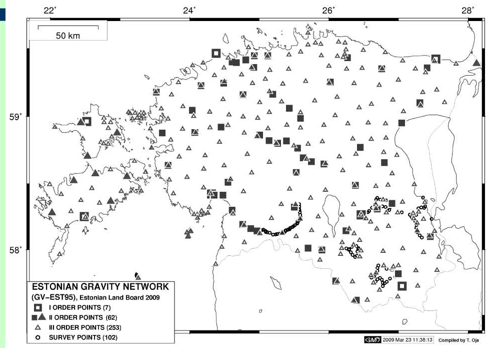



**Fig. 2.** Distribution of gravimetric control points used in the present study. The total number of control points is 424, comprising 322 national gravity network points and 102 Estonian Land Board precise gravity survey points.

## Accuracy of these data sets?

- Check the level and scale of historic networks (realisations of gravity systems):
  - several Potsdam system realisations (1930, 57, ~66)
  - IGSN71 (?,1975, 83, 92)
- Control data: GV-EST (I, II, III order) as a realisation of EGS,
  About GV-EST, see e.g. Oja(2008)
  http://www.vgtu.lt/leidiniai/vgtu_leidiniai/lt/environmental_engineering/21609.17037





## Accuracy of these data sets?

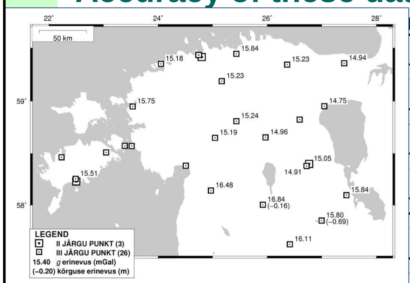
| Jknr | Punkt Nimi | Punkt nr | Potsdam a | IGNS71 b | EGS c | Vahed (mGal) a-b | a-c | b-c |
|---|---|---|---|---|---|---|---|---|
| 1 | Toompea | 5703844 | 839,6 (1930)[1] | 826,63 (1992)[6] | 826,690 (2007) | 13,0 | 12,9 | -0,06 |
| | | | 842,0 (1957)[2] | | | 15,4 | 15,3 | |
| | | | *-2,4* | | | | | |
| 2 | Tartu LV * | 367 | 796,73 (1955)[2] | | 781,680 (2002) | | 15,05 | |
| | | | 795,4 (1958)[3] | | | | 13,7 | |
| | | | *1,3* | | | | | |
| 3 | Tallinna LV * | 389 | 843,4 (1965)[3] | 829,81 (1983)[5] | 829,742 (1992/95) | 13,6 | 13,7 | 0,07 |
| | | | | | 829,711 (2005)[5] | | 13,7 | 0,10 |
| | | | | | *0,031* | | | |
| 4 | **Harku** | 80017 ** | 843,93 (1966)[4] | 828,61 (1992)[6] | 828,534 (2003) | 15,32 | 15,40 | 0,08 |
| 5 | **TTÜ** | 80910 ** | 848,64 (?)[5] | 834,742 (1975)[6] | 834,638 (2003) | 13,90 | 13,99 | 0,104 |
| | | | | 834,706 (1986)[5] | | 13,93 | 14,00 | 0,068 |
| | | | | *0,036* | | | | |
| 6 | **Tallinna LV** | 81691 ** | | 830,466 (1986)[5] | 830,306 (2005) | | | 0,160 |
| | | | | 830,384 (1993)[5] | | | | 0,078 |
| | | | | *0,082* | | | | |

Oja 2007 (http://www.egu.ee/public/files/Geo35_Oja.pdf)





## Accuracy of these data sets?




**Joonis 6.** TA GI 1957. a võrgu raskuskiirenduse väärtuste erinevus ($g_{Postdam} - g_{EGS}$) tänase võrgu tasemest. Vahede keskmine 15,49 mGal. 1957. a mõõtmistulemuste algallikas: Маасик, 1958.


| IGNS71 b | EGS c | Vahed (mGal) a-b | a-c | b-c |
|---|---|---|---|---|
| 826,63 (1992)[6] | 826,690 (2007) | 13,0 | 12,9 | -0,06 |
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| | | | 13,7 | |
| 829,81 (1983)[5] | 829,742 (1992/95) | 13,6 | 13,7 | 0,07 |
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| | *0,031* | | | |
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| *0,082* | | | | |

Oja 2007 (http://www.egu.ee/public/files/Geo35_Oja.pdf)






## Project ETF**7356** (EstSF grant)

- **Application of space technologies to improve geoid and gravity field models over Estonia**
- 1/1/2008 - 12/31/2010
- Principal investigator: prof. Artu Ellmann
- Joint coop. between TUT, ELB, EULS, GSE (12 people)
- information from www.etis.ee (Estonian Research Information System)
- 1st main task: **comparison of different gravity datasets** (new, historical)





## Control data, interpolation

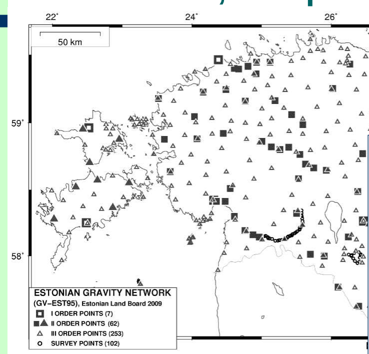



Fig. 2. Distribution of gravimetric control points used in the present study. The total number of 322 national gravity network points and 102 Estonian Land Board precise gravity survey points.

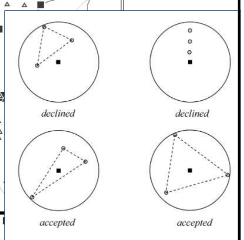


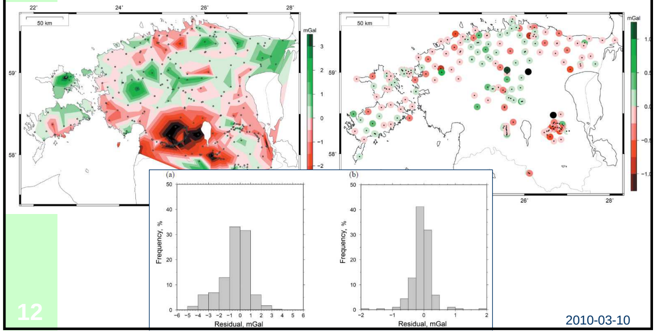

Fig. 5. Examples of the accepted and declined interpolation cases. In the upper (declined) cases the search radius is





## The results of comparisons

- with the 1949-58 data
- with the GSE data



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# Publication

http://www.kirj.ee/public/Estonian_Journal_of_Earth_Sciences/2009/issue_4/earth-2009-4-229-245.pdf

Estonian Journal of Earth Sciences, 2009, **58**, 4, 229–245 doi: 10.3176/earth.2009.4.02

**Towards unification of terrestrial gravity data sets in Estonia**

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[b] Geological Survey of Estonia, Kadaka tee 82, 12618 Tallinn, Estonia; t.all@egk.ee
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Received 6 April 2009, accepted 15 July 2009

**Abstract.** Gravity data in Estonia have been collected by different institutions over many decades. This study assesses the suitability of available gravity data for ensuring a 1 cm geoid modelling accuracy over Estonia and in the Baltic Sea region in general. The main focus of this study is on the determination and elimination of discrepancies between three nationwide datasets. It was detected that one tested historic gravity dataset contained inadmissible systematic biases with respect to other tested datasets. Possible ways of gravity data improvement are discussed. More specifically, new field observation campaigns and aspects of using their outcomes in subsequent regional geoid modelling are suggested.

**Key words:** gravity, Bouguer anomaly, anomaly prediction, geoid, Estonia.

**INTRODUCTION AND MOTIVATION OF THE STUDY**

Gravity measurements are used for studying the figure, ... the spirit levelling has been applied to accurate height determination. However, a precise geoid model can be employed to convert the geodetic (GPS-derived) height into a conventional (i.e. sea level-related) height value.



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IAG2009 poster: tonis.supercow.ee/poster/IAG2009/

# New surveys:

Field work was carried out from October 2008 to March 2009, whereas GPS RTK and relative Scintrex gravimeters CG5 were used for precise positioning (with uncertainty <±10 cm) and gravity determinations, respectively (Fig.4). Hundreds of new points were determined along the roads and on large ice-covered water bodies (Fig.5). Despite bad weather conditions and unstable observation base of the gravimeter (which was set up either on the bank of the road or on the ice surface), uncertainty better than ±0.15 mGal (1.5 μm/s²) was estimated from the least squares adjustment of gravimeter's readings.

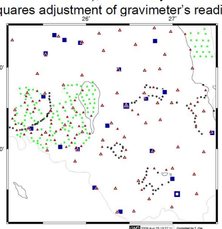

*Figure 5. New gravity survey points (green dots) observed in 2008-2009 with Scintrex CG5 and Trimble GPS RTK. Legend and map area can be found from Fig. 2.*


*Figure 4. Gravity survey on the road (a), in the snow storm (b) and on ice-covered lake (c) with Scintrex CG5 and Trimble GPS RTK .*



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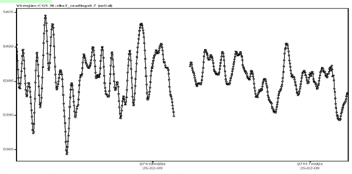
# Measuring gravity on ice-covered lakes



converge readings in most cases.

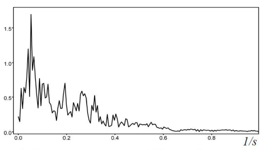
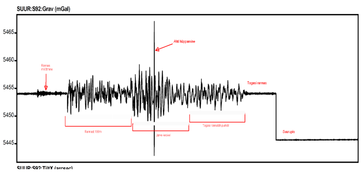



*Figure 7. Left: raw signal (6 Hz, converted to mGal) of Scintrex CG5 gravimeter (two 60 s readings) on the ice covered lake Võrtsjärv, right: its spectrum.*



Joonis 3. Scintrex CG5-92 toorandmestik ehk 6 Hz raw-signaal (mGal) Harku järve kaldal ja jää peal.



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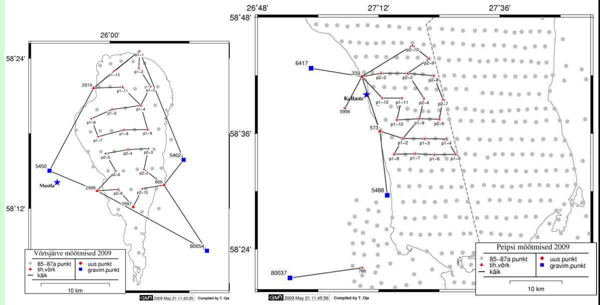
# Measuring gravity on ice-covered lakes



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### 4. Comparison of historic and new data

After the collection of new gravity data, a Kriging with variogram modeling was applied to form the Bouguer anomaly grids of the historic and the new datasets (Fig.8).

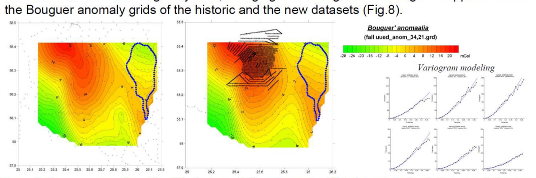


*Figure 8. Bouguer anomaly grids of the historic (left) and new (middle) datasets in South-Estonia. A Kriging with proper variogram modeling was sucessfully applied.*

After the grid computation of gravity data the cross valic objective method of assessing the quality of a gridding as well as data. From cross validation the standard deviation of historic dataset anomaly grid was esti-mated to be **±1.06** mGal. For the grid of new dataset this value is **±0.16** mGal (Mäekivi 2008).

The comparison of the resulting grids in South-Estonia revealed biases up to -4 mGal at certain regions (Fig. 9). The differences are mostly negative and are clearly variating from place to place.

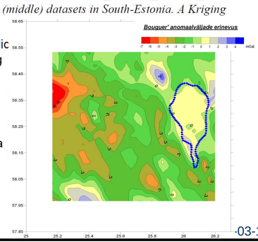


*Figure 9. The grid of differences between the anomalies of old and new datasets ( $dg_{new} - dg_{old}$ ).*



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# Conclusions, discussion

- Historic data need to be replaced in S-Estonia
- For the new surveys 2 LCR G meters loaned from NGA in 2009
- Harli will talk about new gravity surveys by Tartu team
- **Calibration of the gravimeters is important** to produce accurate gravity data!
- Future: surveys over the Gulf of Riga, Väinameri, Gulf of Finland

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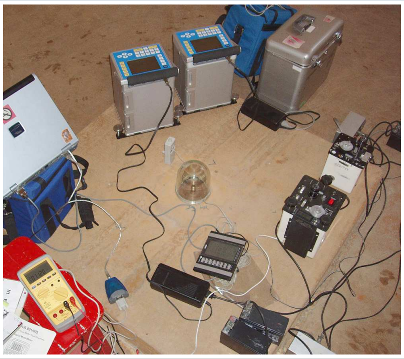
# Gravimeters in Suurupi in 2009





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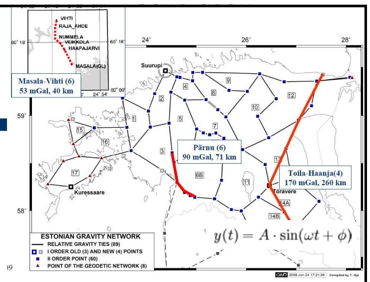
# Calibration



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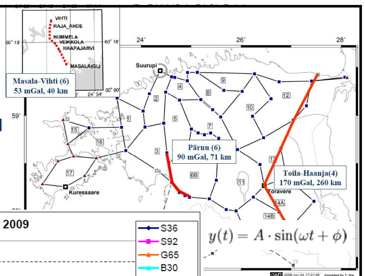
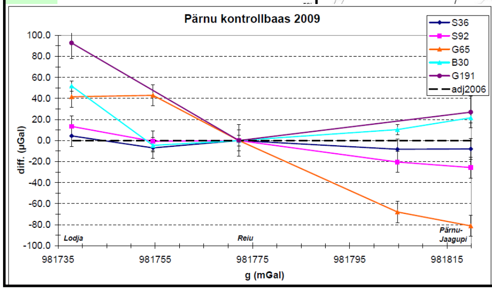
# Calibration



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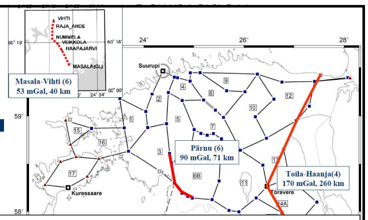
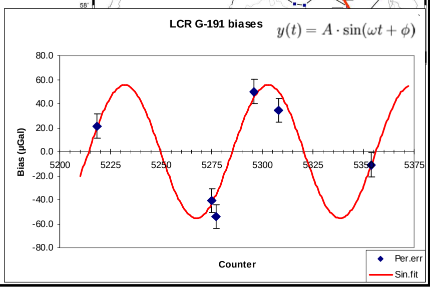
# Calibration



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# Other issues:

- Accuracy and density of points with geodetic, normal heights (GPS/levelling datasets)
- Current situation of Estonian GNSS and height network (in national report)
- Different methods (both deterministic, stochastic) will be used for geoid modeling in Estonia