Gravity works in Estonia

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Topics

1. Instrumentation
2. Calibration
3. Estonian Gravity Network
4. Other campaigns
5. Future

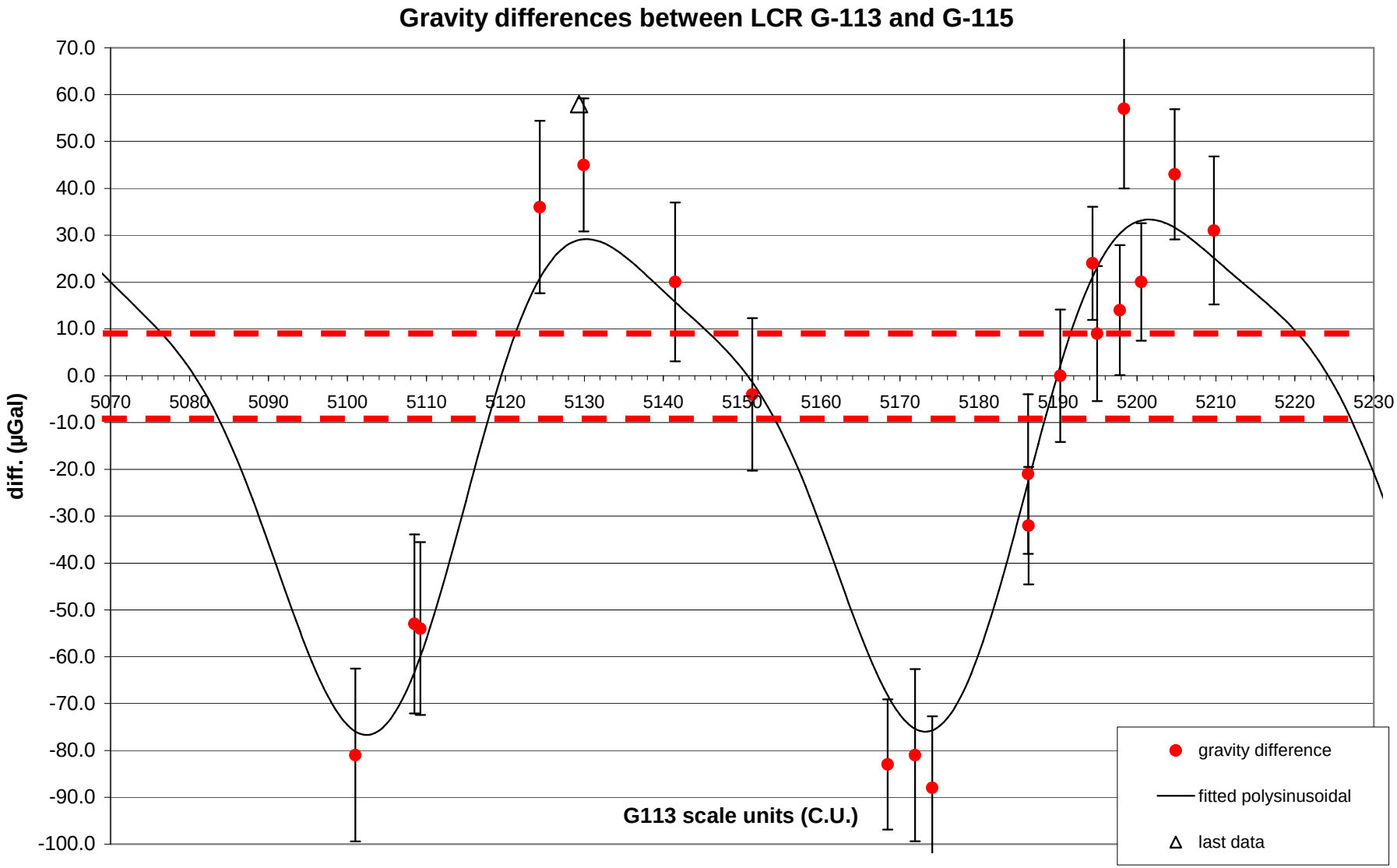
1.1 Instruments - LCR

- NGA (former NIMA) loaned 2 LCR G meters (4, 113) in 2001
- G-115F in 2002
- All LCR’s returned last year
- Differences between the results of gravimeters over 100 µGal !?

1.1 Cooperation with NGA

Loan of LCR G-4, G-113, G-115F

1.1 Problems with NGA gravity meters ⇒ periodical errors ?!



1.2 Instruments - Scintrex

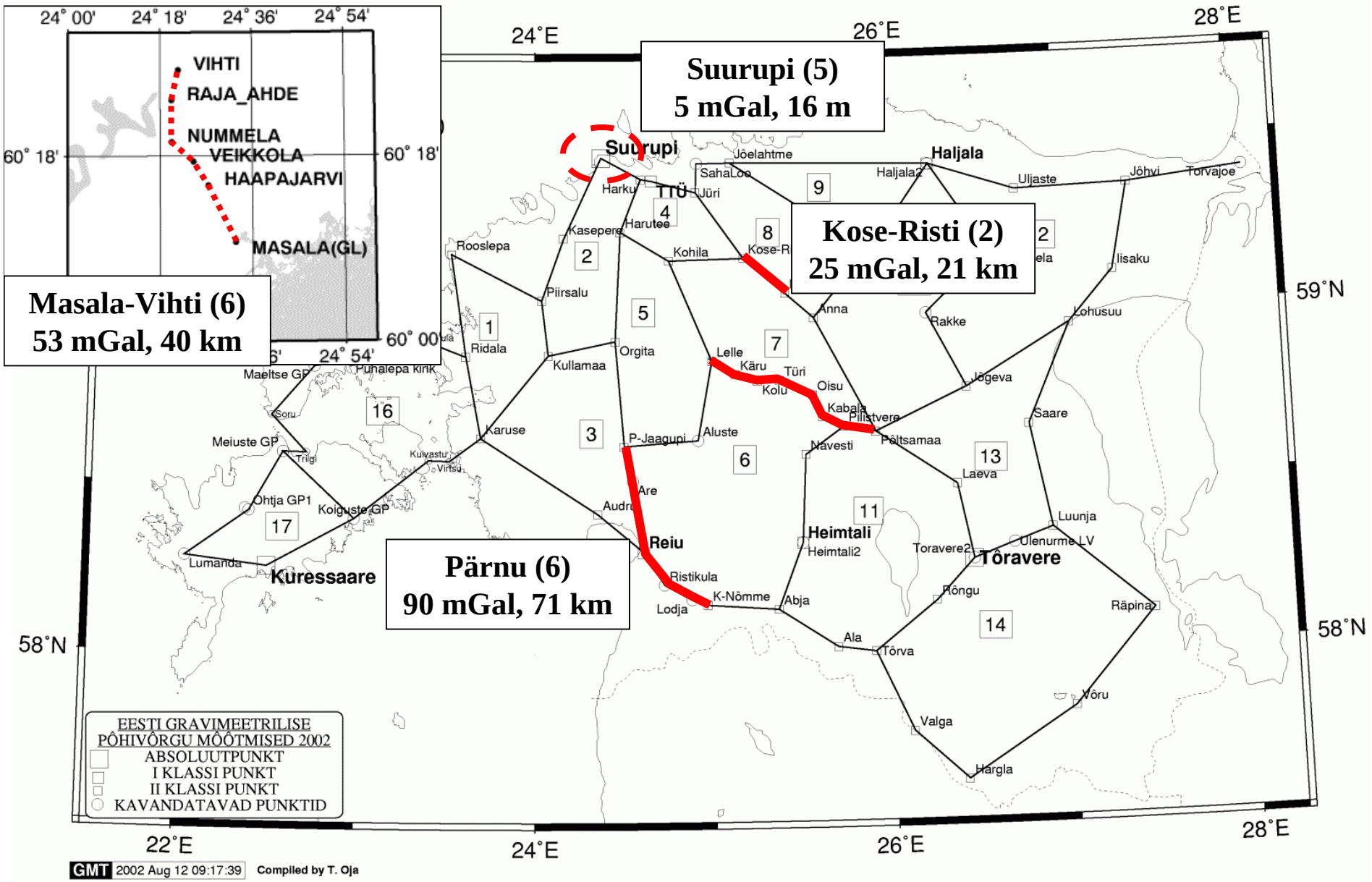
- In 2003 and 2004 ELB acquired two fully automatic Scintrex CG-5 gravimeters
- Remarkably precise
- Well calibrated
- Convenient and timesaving
- Still some inconveniences
- Certainly need further studies

1.2 Scintrex CG-5’s of ELB

2 Calibration

- 4 lines in Estonia:
  - Kose-Risti (1957)
  - Pärnu (1983)
  - Põltsamaa-Lelle geodynamic line (1970)
  - Vertical line in Suurupi lighthouse (2002)

- Masala-Vihti line in Finland

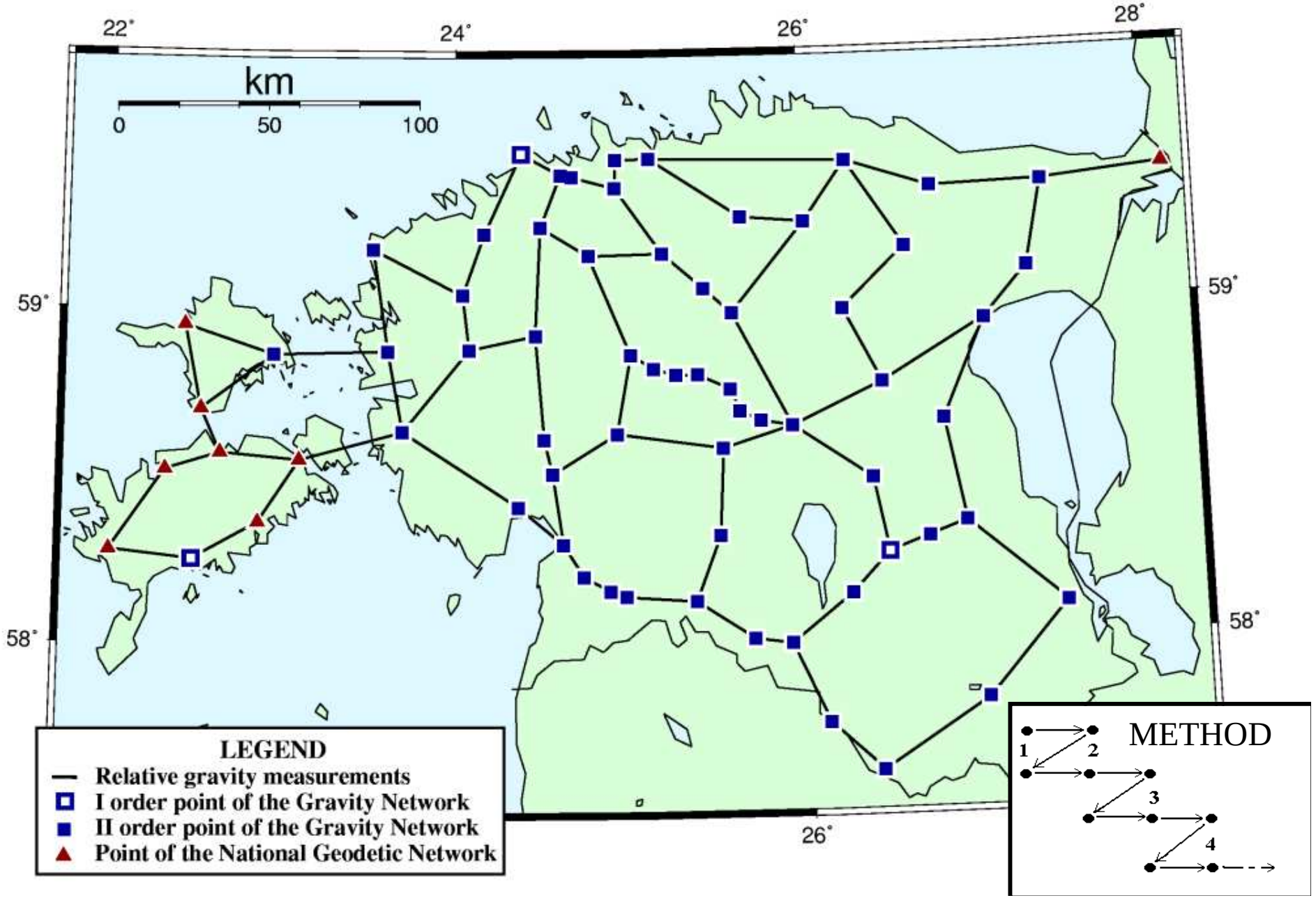


Calibration lines visited several times from 2002 to 2004

3. Estonian gravity network

- Measured in 2003 (started already 2002)
- 3 LCR G gravimeters involved
- Rigorous and uniform methodology during the whole measuring campaign

Measurements of Estonian gravity network in 2003



Observation in process at Haljala in 2003

4. Other campaigns

- Fennoscandian uplift line 63° in 2002
- Estonian Geodetic network in 2001-2004 (ongoing in 2005)
- Levelling lines (2005-2007)
- Qualification of old Soviet networks (2001-2005) and database of Geological Survey

5. Data process and results

- Pre-process
- Calibration
- Network solution for every single campaign (one epoch)
- Network solution for all campaigns (several epochs)
- Statistical testing and assessment of the results

5.1 Pre-process

1) tidal correction applying Tamura (1987) tidal potential development and local parameters (gravity factor, phase lag) interpolated from global grid [Wenzel and Timmen 1994]
2) atmospheric correction using local air pressure and a coefficient -0.3 µGal/hPa
3) free air correction (–0.31 µGal/mm when real local gradients for stations are still unknown)
4) correction for polar motion (δ = 1.16)

5.1 Pre-process

Output of GRREDU2:

				¦--C.U.---¦---------CORRECTIONS (uGal)--------¦---mGal---¦							
station number # G-115F	date,	time UT # 0	nr	reading	tides	air- pres.	free- air	period. error	polar motion	reduced reading	station name
30018	250603,	9.045	1	5228.7860	41.0	-0.9	29.9	6.2	1.8	5526.1361	Harutee
30043	250603,	10.060	2	5222.5275	29.6	-1.0	28.1	21.4	1.8	5519.5274	Orgita
30018	250603,	11.065	3	5228.8120	10.9	-0.5	29.6	5.9	1.8	5526.1369	Harutee
30043	250603,	12.040	4	5222.5630	-8.0	-0.6	28.1	21.4	1.8	5519.5277	Orgita
30032	250603,	13.160	5	5216.3650	-30.9	-0.5	23.5	14.9	1.8	5512.9407	Kullamaa
30043	250603,	14.140	6	5222.6010	-46.4	-0.5	27.8	21.4	1.8	5519.5298	Orgita
30032	250603,	15.040	7	5216.3810	-55.4	-0.4	23.5	15.1	1.8	5512.9345	Kullamaa
30044	250603,	15.580	8	5219.5210	-61.5	-0.1	28.4	12.7	1.7	5516.2504	Piirsalu
30032	250603,	16.440	9	5216.3850	-63.9	-0.1	23.5	15.1	1.8	5512.9310	Kullamaa
30044	250603,	17.285	10	5219.5240	-64.7	0.1	28.4	12.7	1.7	5516.2497	Piirsalu
30032	260603,	6.555	11	5216.2940	49.4	1.1	23.5	14.1	1.7	5512.9483	Kullamaa
30026	260603,	8.125	12	5190.2215	64.2	1.0	25.9	0.1	1.7	5485.3992	Karuse
30032	260603,	9.175	13	5216.2770	62.0	0.9	23.5	13.9	1.7	5512.9441	Kullamaa
30026	260603,	10.335	14	5190.2365	46.9	0.8	25.9	0.3	1.7	5485.3962	Karuse
30051	260603,	11.520	15	5227.7015	17.9	0.8	27.5	5.9	1.6	5524.9685	Ridala
30026	260603,	13.230	16	5190.3060	-19.5	0.6	25.9	1.2	1.7	5485.4030	Karuse
30051	260603,	14.415	17	5227.7645	-46.4	0.8	27.2	5.2	1.6	5524.9687	Ridala
30055	260603,	16.000	18	5227.2575	-63.3	0.9	28.1	4.2	1.6	5524.4165	Rooslepa
30051	260603,	17.135	19	5227.7920	-70.3	0.7	27.5	4.9	1.6	5524.9747	Ridala
30055	260603,	18.240	20	5227.2625	-71.0	0.8	27.8	4.3	1.6	5524.4137	Rooslepa

5.2 Calibration

- No rigorous calibration possible
  - few absolute stations available
  - temporal change of g
- Proposed algorithm
  A. select most reliable and precise gravimeter(s)
  B. validate them first on the calibration lines
  C. combined solution of both
  D. calibrate other gravimeters

5.2 Calibration

Previous observation model (program GRADJ):

$$y(t) = g + a + Dt$$

New observation model (GRADJ2):

$$y(t) = g^{T_0} + \dot{g}^{T_0}(t - T_0) + a + \sum_{p=1}^{r} D_p (t - t_0)^p + \\ + \sum_{k=1}^{m} Y_k z^k + \sum_{l=1}^{n} A_l \sin(2\pi z / T_l + \varphi_l)$$

Polynomial drift

Temporal change

Calibration

5.2 Results of calibration

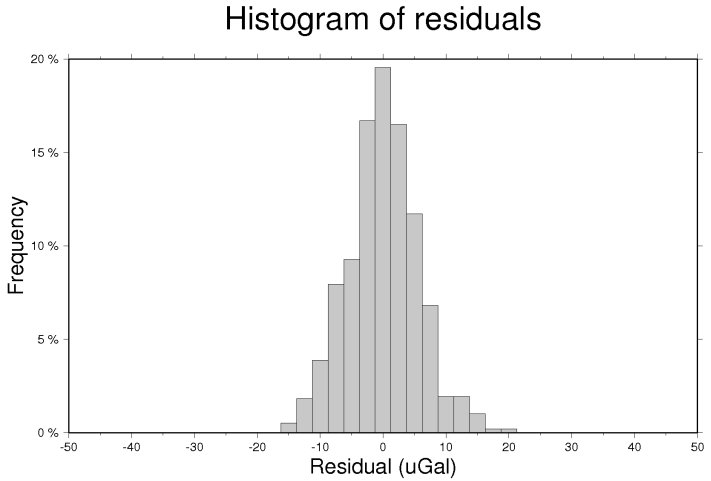
Gravimeter	G-4				G-113				G-115				S-36	
Linear scale factor	0.996309 (±41)				1.000145 (±42)				1.000105 (±168)				1.000152 (±169)	
Periodic errors *T (C.U.)*	*A*		φ		*A*		φ		*A*		φ		*A*	φ
1.0000	4.3	±1.0	340.9	±12.3	-	-	-	-	2.1	±0.5	69.7	±13.7	-	-
3.9412	3.4	±0.8	212.7	±14.4	-	-	-	-	-	-	-	-	-	-
7.8824	6.7	±0.9	173.1	±9.4	6.2	±0.7	260.2	±6.5	4.6	±0.6	45.8	±8 .0	-	-
35.4706	4.1	±1.0	105.0	±18.1	8.5	±0.9	1.8	±5.2	10.9	±0.8	214.0	±4.0	-	-
70.9412	5.2	±1.4	48.7	±15.3	50.4	±1.0	326.2	±1.1	7.1	±0.8	8.2	± 8.0	-	-

Table 1. Corrections for calibration functions. Periodic error, E, is introduced in the form $E = A\sin\left(2\pi z/T + \varphi\right)$, where A is amplitude (μGal), z gravimeter reading in counter units (c.u.), T period (c.u.) and φ phase in degrees

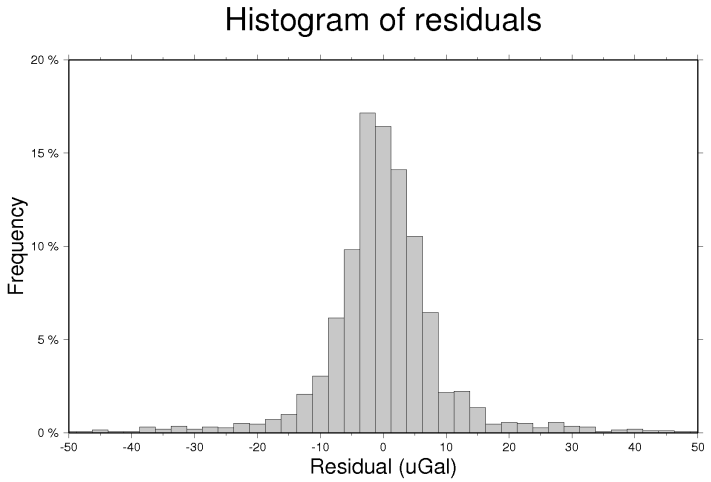
Computation time: 24.08.2004

5.3 Network solutions

A) STATISTICS OF THE SOLUTION OF 2003:
Adjustment observations: 985
Stations: 72
Total unknowns: 363
Degrees of freedom: 622
SIGMA1 (apriori standard dev. of unit weight) : 0.005 mGal
SIGMA2 (aposteriori standard dev. of unit weight): 0.007 mGal

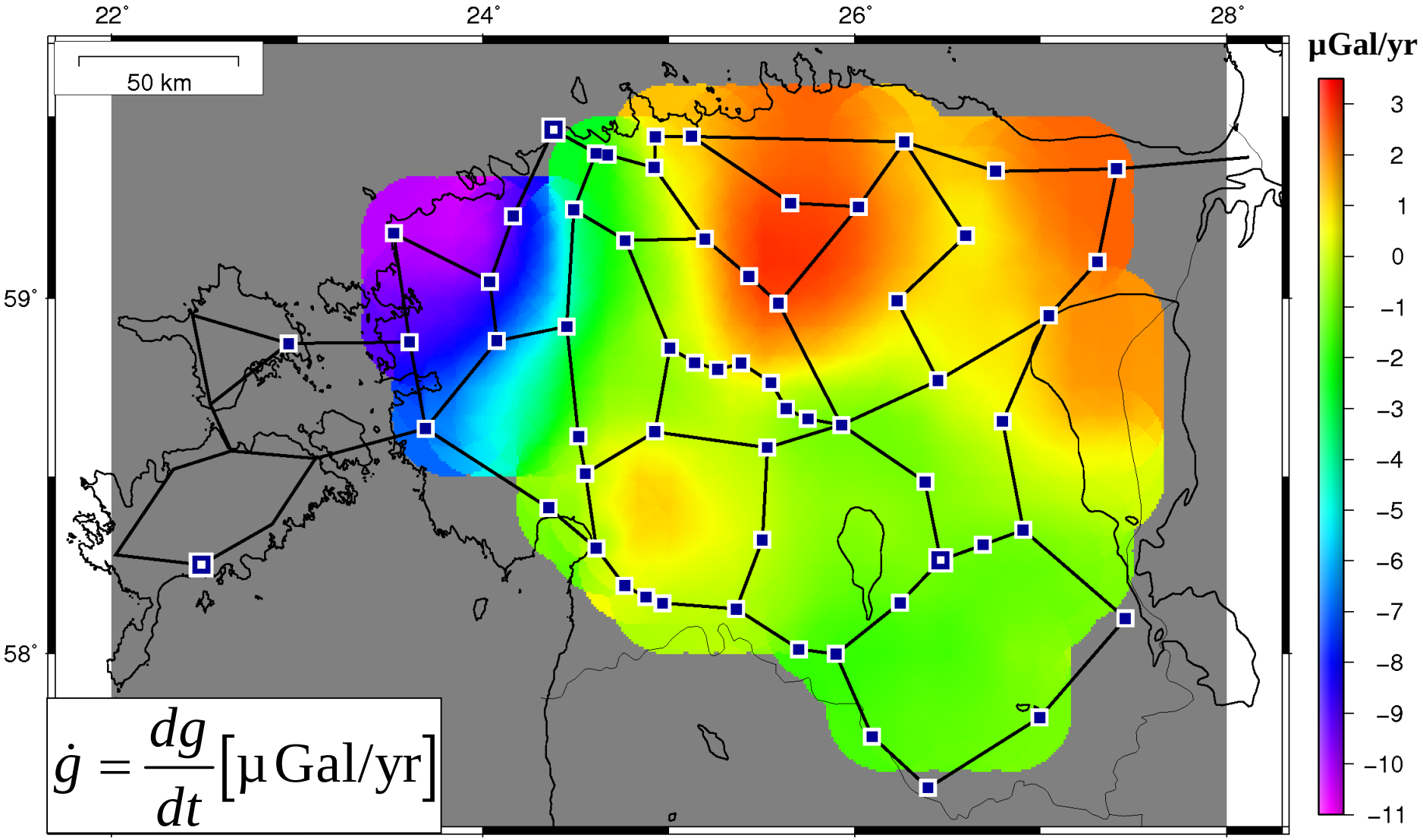


B) STATISTICS OF THE SOLUTION OF 1977,1992-2004:
Adjustment observations: 1943
Stations: 89
Total unknowns: 734
Degrees of freedom: 1209
SIGMA1 (apriori standard dev. of unit weight) : 0.010 mGal
SIGMA2 (aposteriori standard dev. of unit weight): 0.026 mGal



Temporal changes of gravity in Estonia

(SOLUTION OF 1977,1992-2004)



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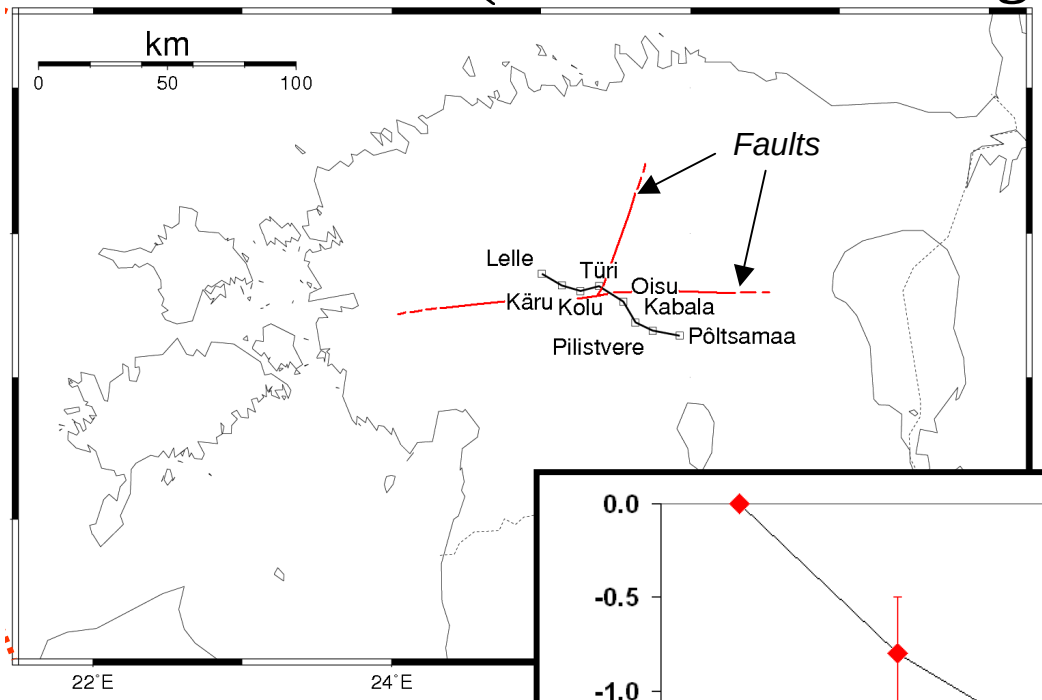
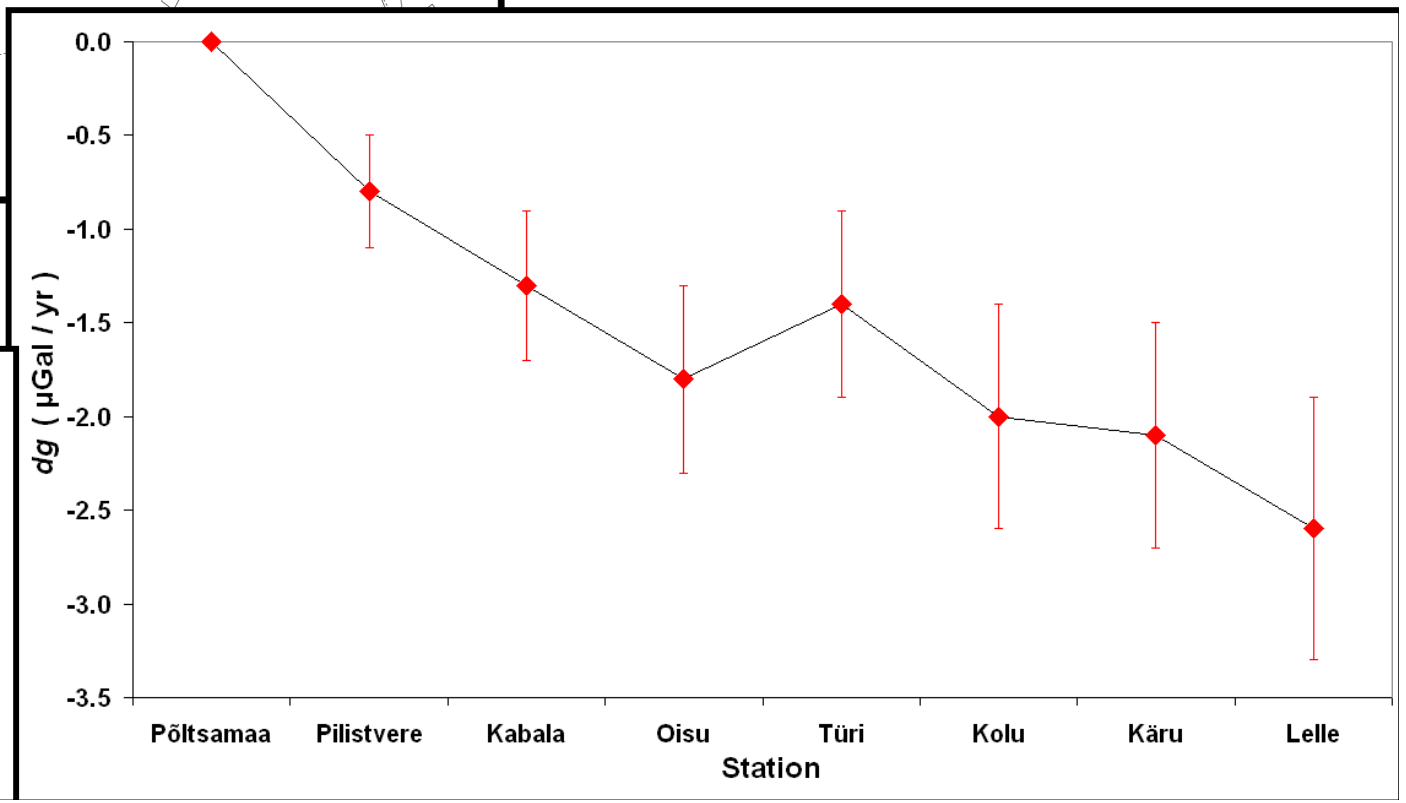
Temporal changes of gravity in Estonia
(Põltsamaa – Lelle geodynamic line)



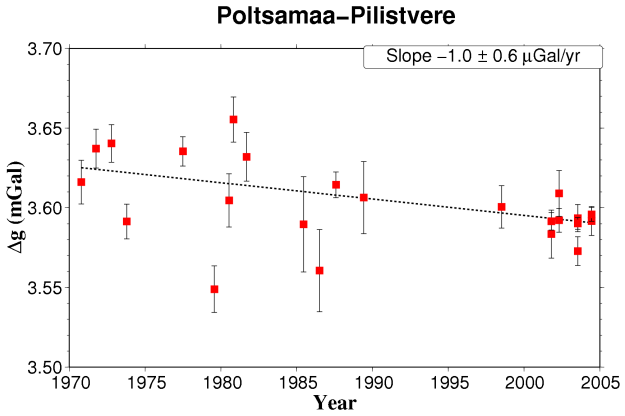
Least squares adjustment with gravity change estimation (solution 1)

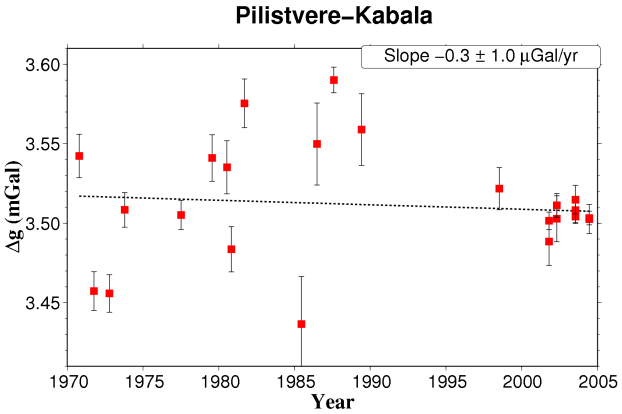
Põltsamaa	0.0	± 0.0
Pilistvere	-0.8	± 0.3
Kabala	-1.3	± 0.4
Oisu	-1.8	± 0.5
Türi	-1.4	± 0.5
Kolu	-2.0	± 0.6
Käru	-2.1	± 0.6
Lelle	-2.6	± 0.7

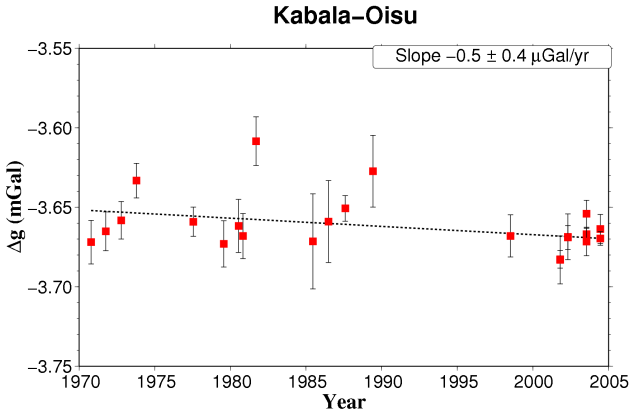


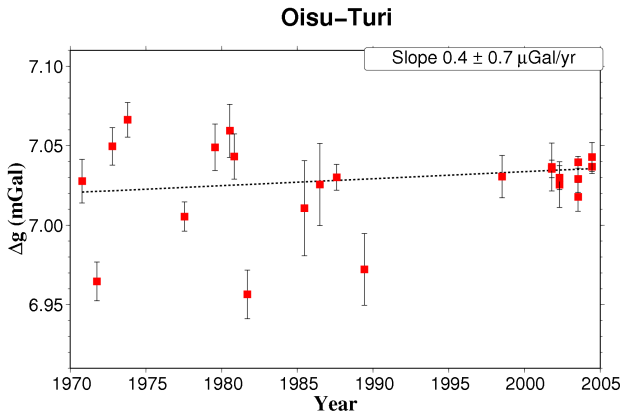
Temporal changes of gravity in Estonia
(Põltsamaa – Lelle geodynamic line)

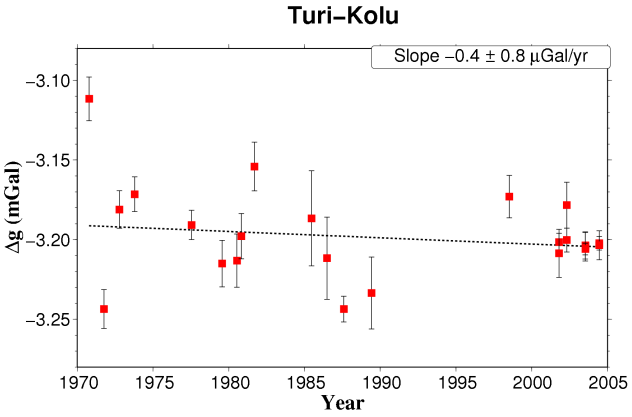
Weighted least squares linear regression for the annual means of gravity differences (solution 2)

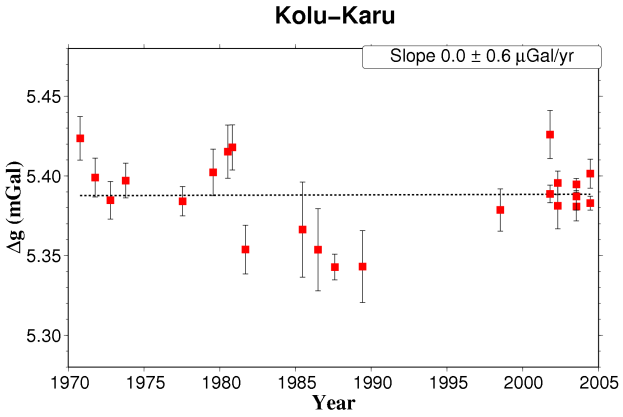


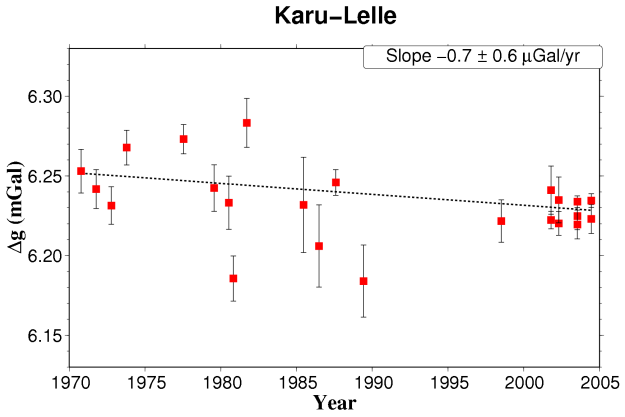








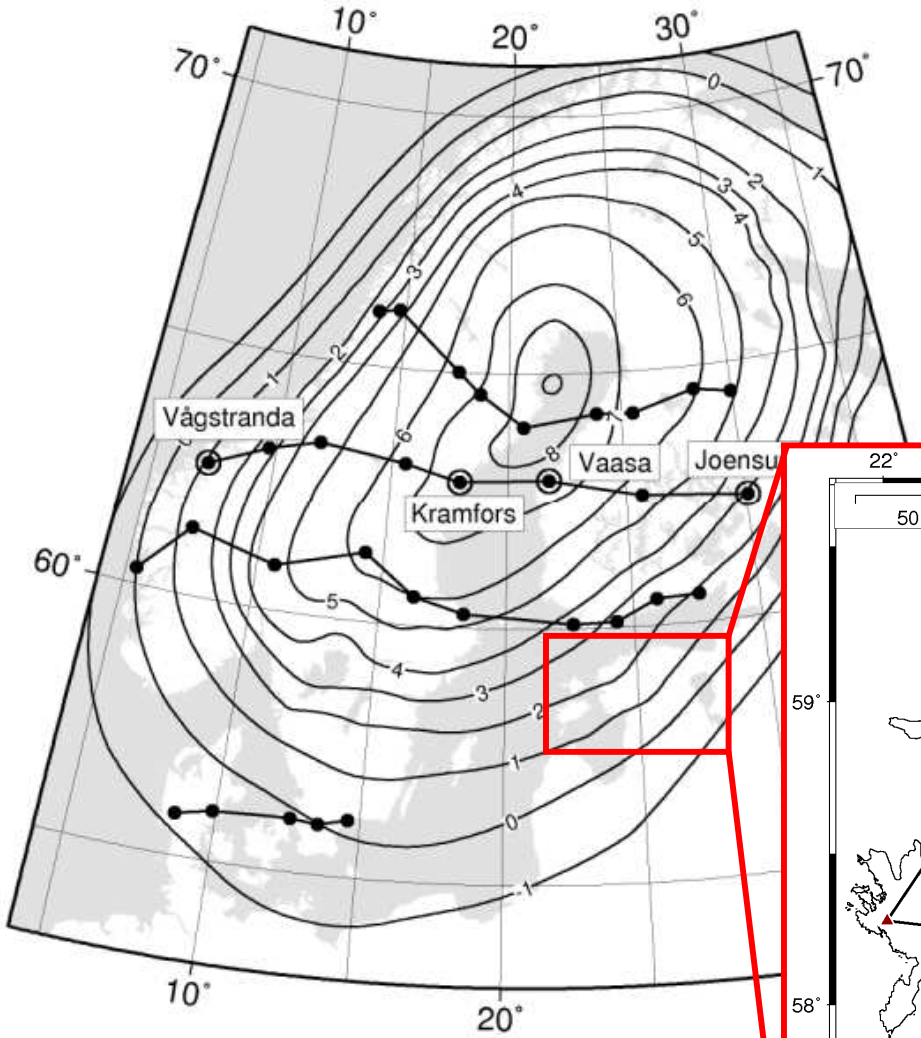




6. Future

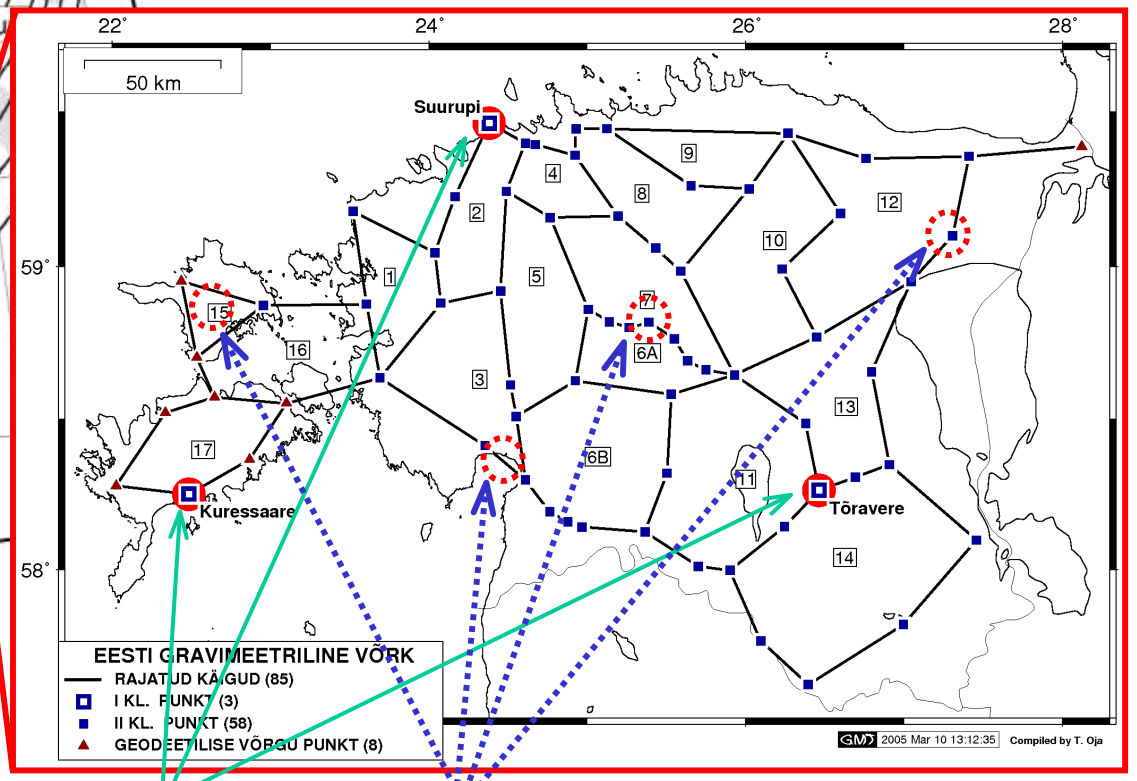
- Data from 1970-1989 (4 network campaigns) into digital database (MySQL)
- Final network solution in 2006
- Statistical testing and thorough evaluation of the results
- Increasing demand for new absolute *g* measurements

Welcome to Estonia!



PGR rates relative to MSL
by Ekman (1996)
(Mäkinen et al. 2004)

6. juuni 2005. a.



Existing and planned absolute stations in Estonia

Tänan tähelepanu eest!