



REPUBLIC OF ESTONIA
LAND BOARD



GeoRefAct

Harmonization of Estonian and Latvian geodetic systems in border areas

Andres Rüdja
on behalf of the GeoRefAct team

NKG WGRF, Tallinn, Estonia, March 30 - 31 2023

Project team



- Department of Geodesy

Jānis Sakne

Madara Znotiņa

Vents Zuševics

Aigars Keiselis

Elmārs Ozoliņš

Andrejs Brants

Viesturs Sproģis

Jānis Lukstenieks

Toms Līdumnieks

Imants Biļinskis

Ksenija Kosenko

Ivars Liepiņš

Ervīns Rumsons



- Support

Inese Skolmeistere

Ilze Platace

Sanita Grotusa

Arita Burve

Lilija Ļvova

Iveta Gruzīte

Valdis Bērziņš

Mārtiņš Liberts

- Department of Geodesy

Andres Rüdja

Jaanus Metsar

Arvi Taru

Toivo Tomingas

Karin Kollo



REPUBLIC OF ESTONIA
LAND BOARD

- Support

Aigi Sarjas

Anu Ots

Kalver Keskküla

Ene Raudsepp

Helen Ernesaks

Helena Orusalu

Riho Kalda (KEMIT)

Artu Ellmann

Tambet Tiits

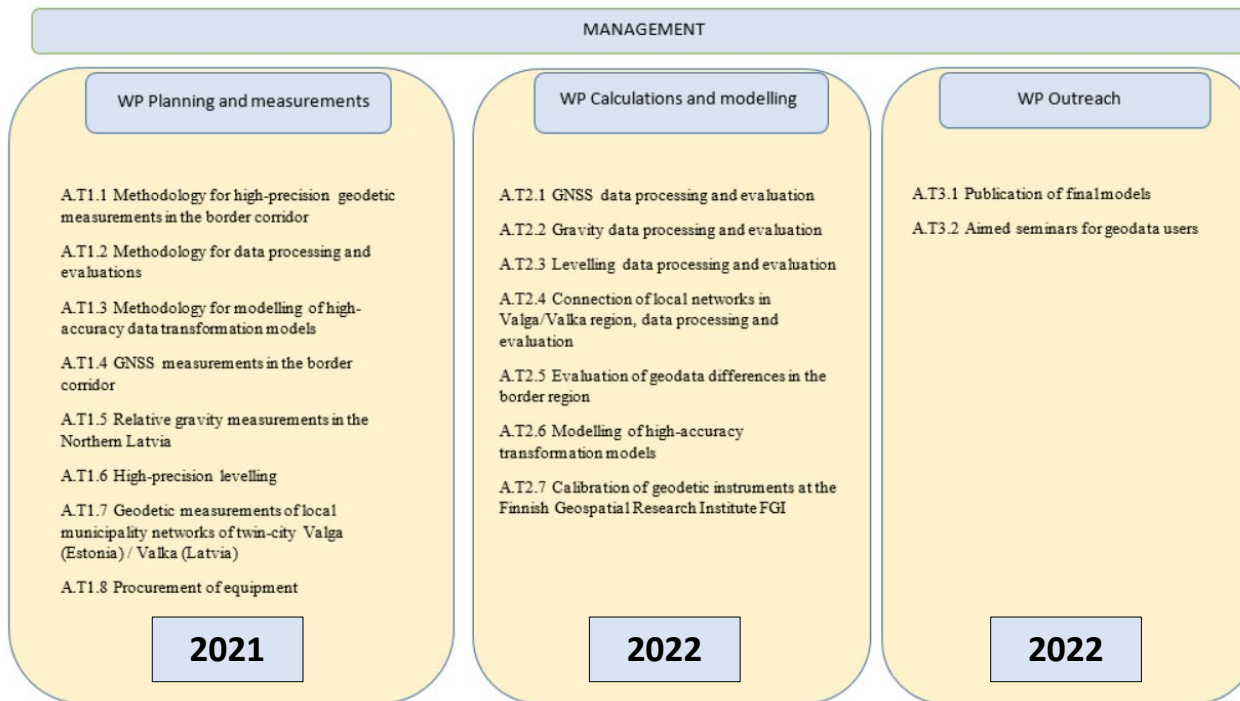
Project „GeoRefAct“

- Interreg V-A Estonian-Latvian programme
- Project period 2021-2022
- Partners: Estonian Land Board (leader partner), Latvian Geospatial Information Agency

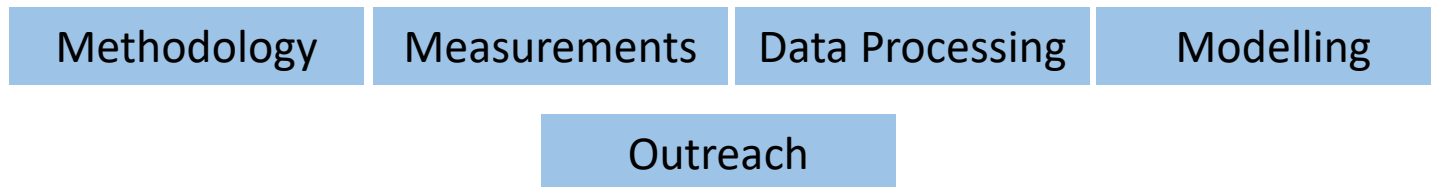
Tasks:

- Measurement and data processing of national GNSS and levelling networks in border area and in the twin-city of Valga/Valka and a gravity survey in Northern Latvia
- Estimation and modelling of coordinate and height differences
- Coordinate and height transition models for the border area, including their free availability as web-based services
 - ✓ Coordinates EE: EUREF-EST97 ↔ LV: LKS-92 (planar L-EST97 ↔ LKS-92 TM)
 - ✓ Heights EE: EH2000 ↔ LV: LAS-2000,5
 - ✓ Valga/Valka EUREF-EST97 ↔ LKS-92 (planar L-EST97 ↔ LKS-92 TM), EH2000 ↔ LAS-2000,5

Project „GeoRefAct“



Working groups




Estonia–Latvia programme 2014–2020
We support ideas that help Estonia and Latvia to grow through neighbourly cooperation

PROJECT

GeoRefAct
Harmonization of Estonian and Latvian geodetic systems in border areas

Financed by the European Regional Development Fund:	Co-financed by the partners:
425 000 €	75 000 €

www.estlat.eu



**Interreg
Estonia-Latvia**
European Regional Development Fund



EUROPEAN UNION

Procurement of equipment

- Relative gravimeter
- High-precision level
- High-precision total station
- Upgrade of GNSS receiver (Leica GR25 -> GR50)
- Reference station GNSS receiver and antenna
- Meteorological sensor
- Geodetic software
- Field computers
- Establishment of geodetic benchmarks
- Calibration of geodetic instruments (level + rods, total station)



Networking

- Mostly online meetings and e-mails **Covid!**
- Few physical meetings as well
- Measurements were made separately on the EE and LV sides, cross-border measurements were made together
- Relative gravity measurements in Latvia were done by LGIA and levelling in Valga/Valka by ELB
- Data processing and modelling were done independently by both partners, and then the results were evaluated together
- A series of solutions were calculated during the various data processing steps, the final ones of which are described below

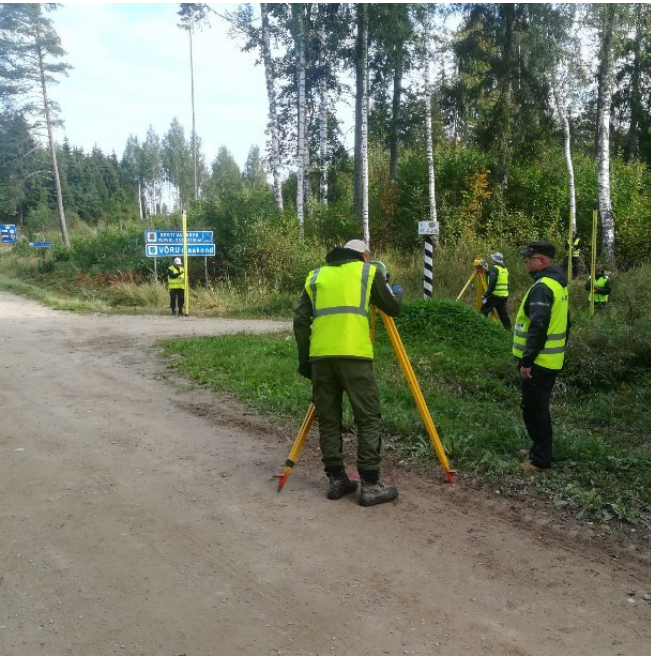
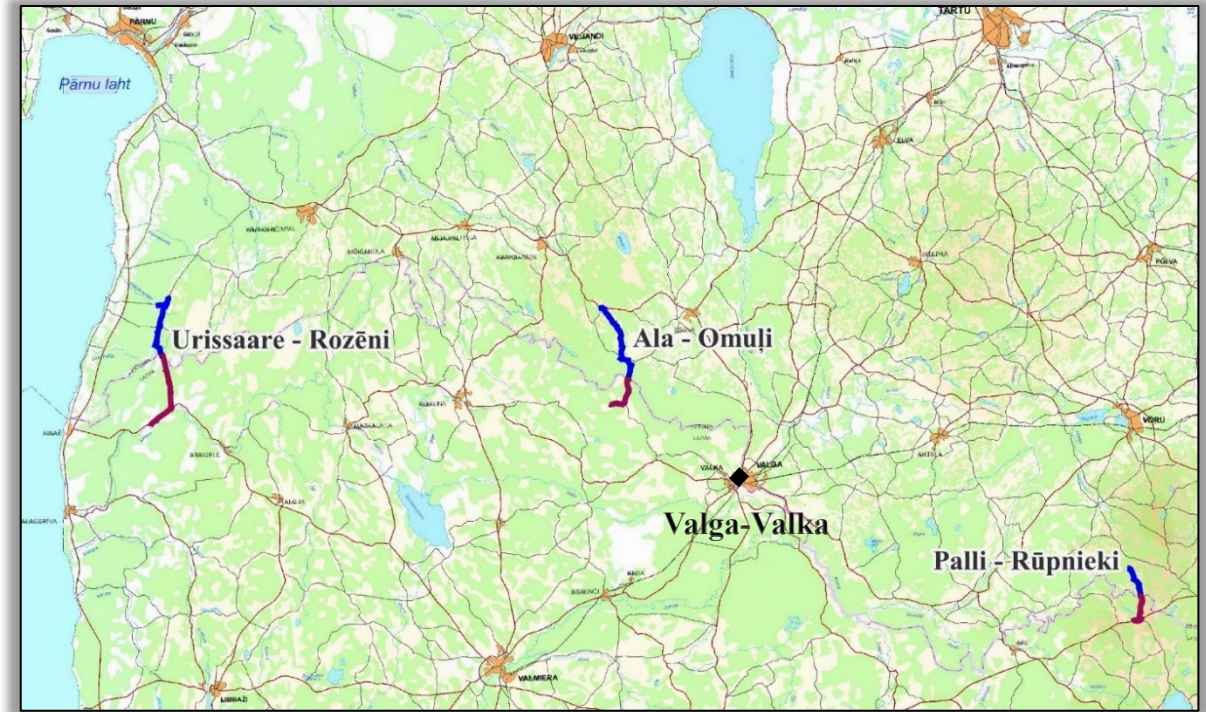
Management meeting in Valga, 25.08.2021



Working group meetings
Tallinn and Valga 2022

Levelling

- Four new connection lines in addition to four existing, 55 km
- High precision levelling, Leica LS15 (LGIA) and Trimble DiNi03 (ELB) + invar staff
- Measurements: 01.09 – 30.09.2021

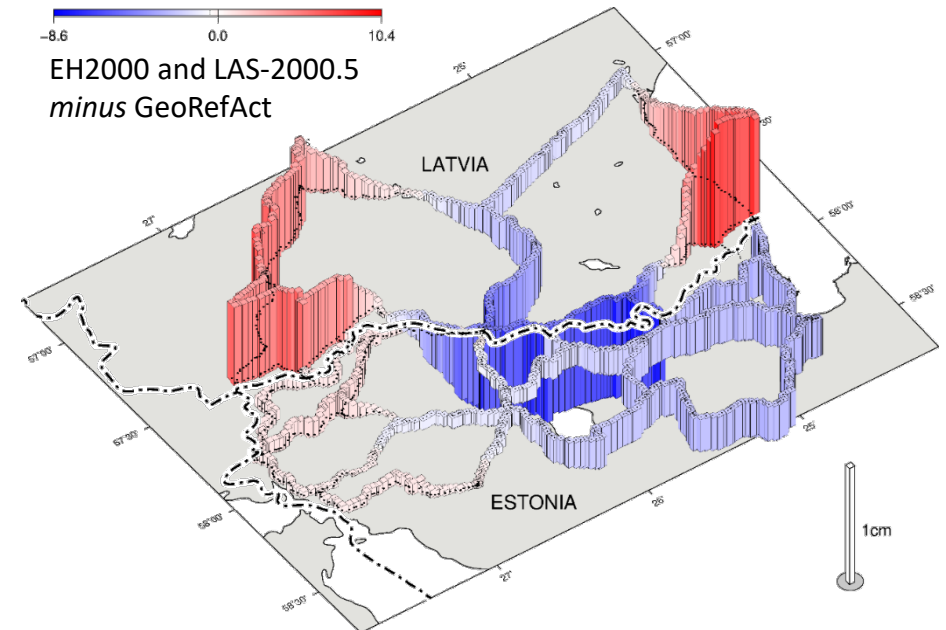
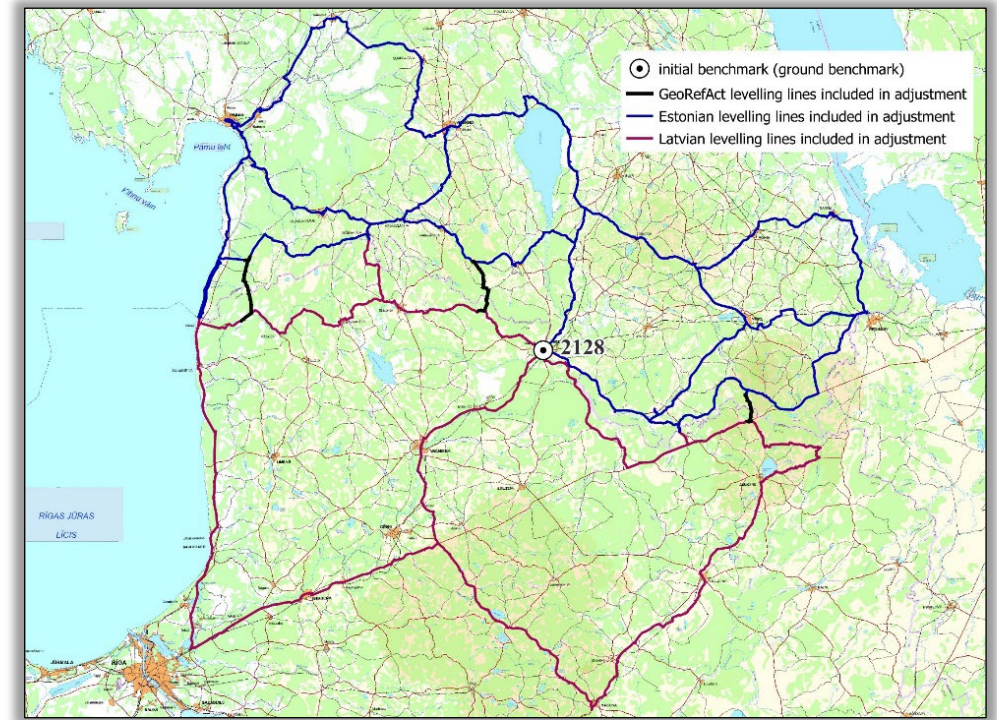


Levelling data processing

- Minimum constrained adjustment, EH2000 height of the benchmark No 2128 fixed
- Weighting by line groups
- Epoch 2000.0, NKG2005LU
- Zero tide

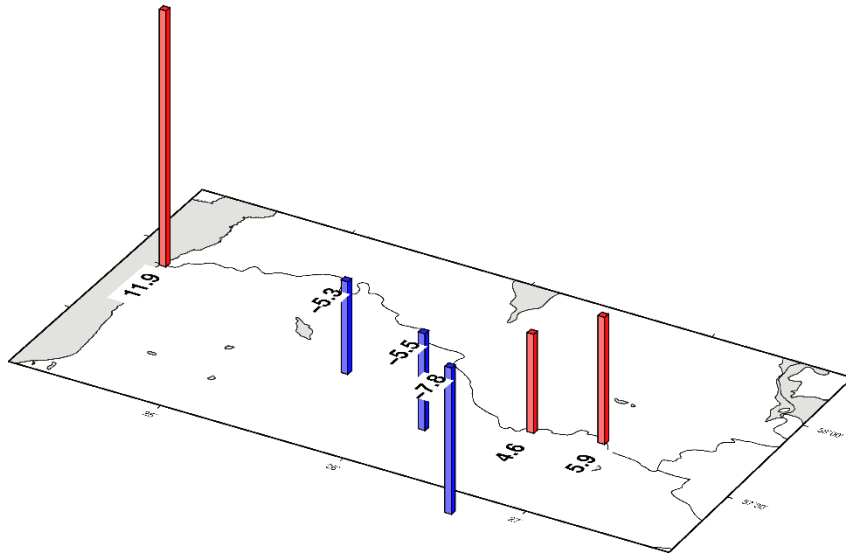
Estimated variance component	1.0	
Largest residual [mm]	1.15	
Average precision, H [mm]	± 1.45	
Homogeneity of precision, H [mm]	Standard deviation	± 0.98
	MAX	± 6.93
	MIN	± 0.05

- Due to small differences, 3 mm or less, EH2000 and GeoRefAct heights were considered the same
- ΔH LAS-2000,5 - EH2000/GeoRefAct were used for modelling

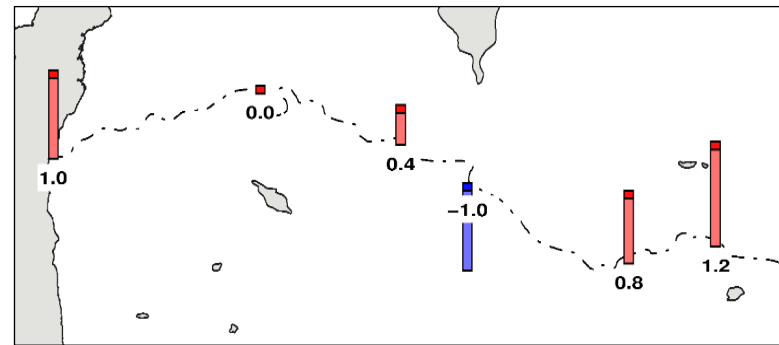


Height transition model

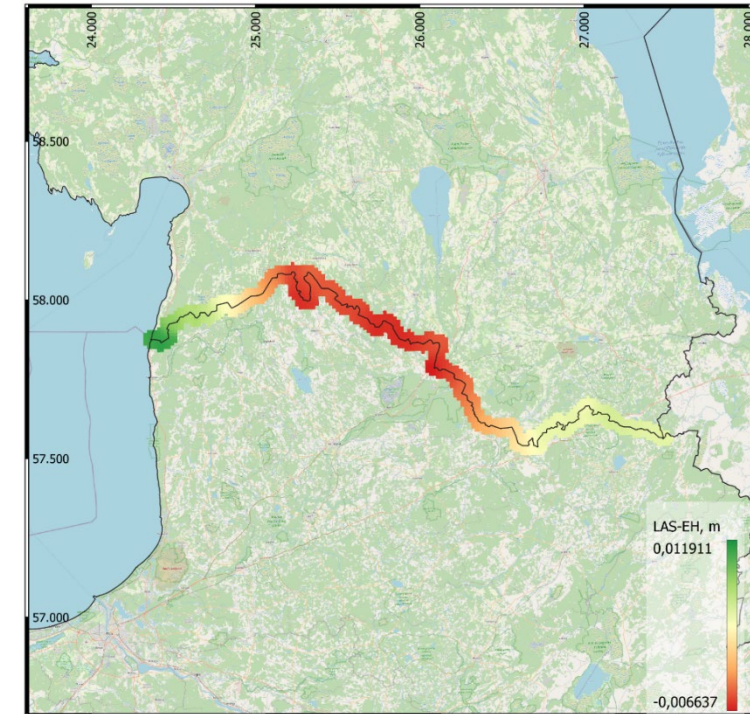
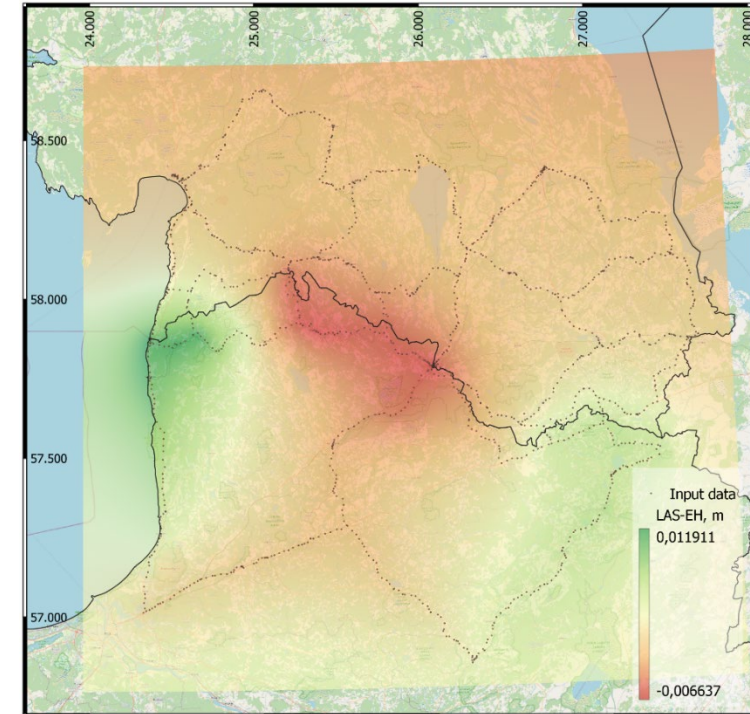
- GMT (*Generic Mapping Tools*) splines in tension, grid resample using splines
- Model area B : $24.2 - 27.5^\circ$, L : $57.4 - 58.2^\circ$
- Grid step: $0.02^\circ/0.01^\circ$ (*ca* 1.1 km)
- The model was cut into a 2+2 km wide buffer
- Estimates at observation points were at sub-mm level



EH2000-LAS-2000,5 differences, unit mm

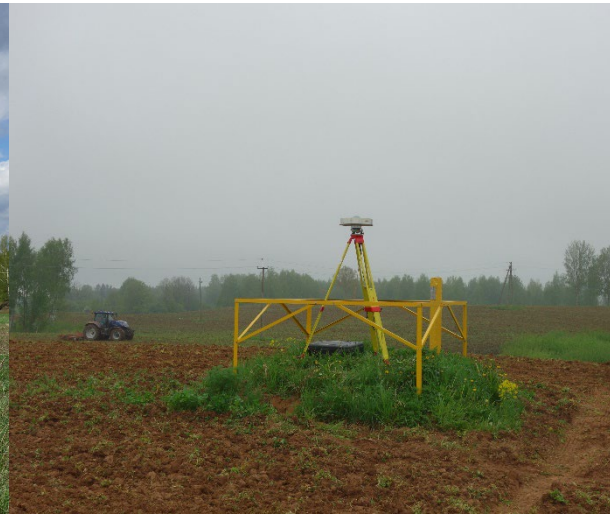
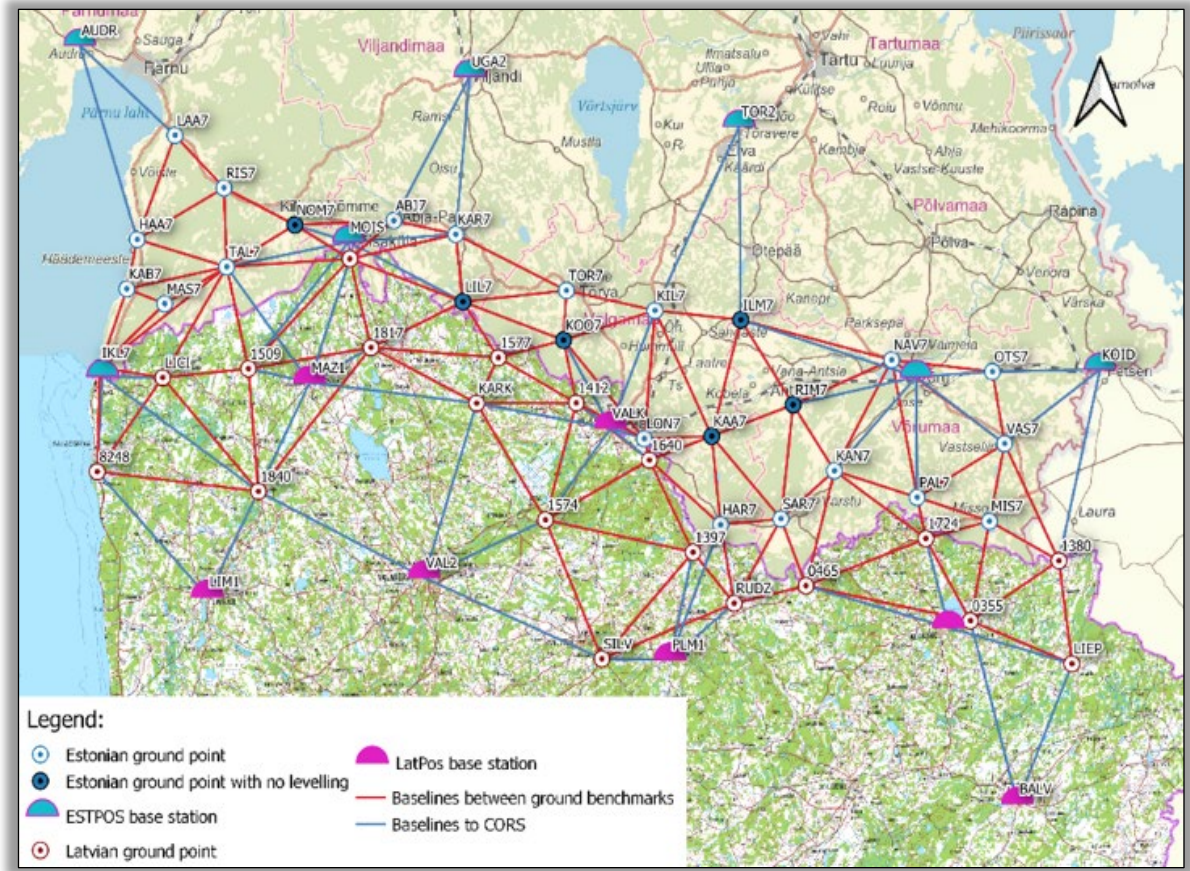


Model residuals, unit mm



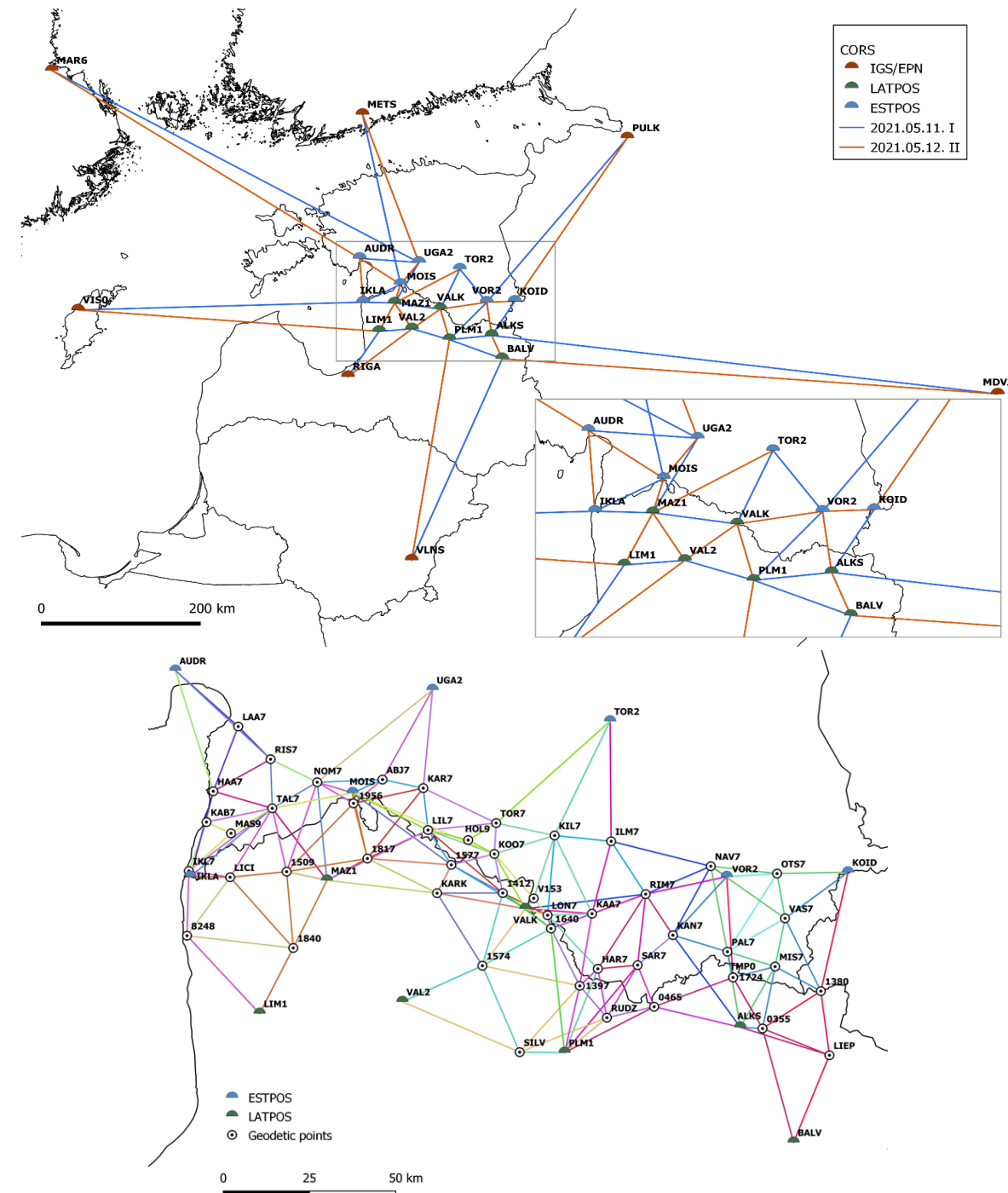
GNSS measurements

- LGIA: Leica Viva GS10 receivers/ Leica AR20 antennas
ELB: Leica GRX1200GG PRO receivers/
LEIAT504GG antennas
- Static GNSS, 6h sessions, one session per day, at least twice at each point
- 47 benchmarks, 14 ESTPOS/LATPOS
- Measurements: 11.05. - 4.06.2021



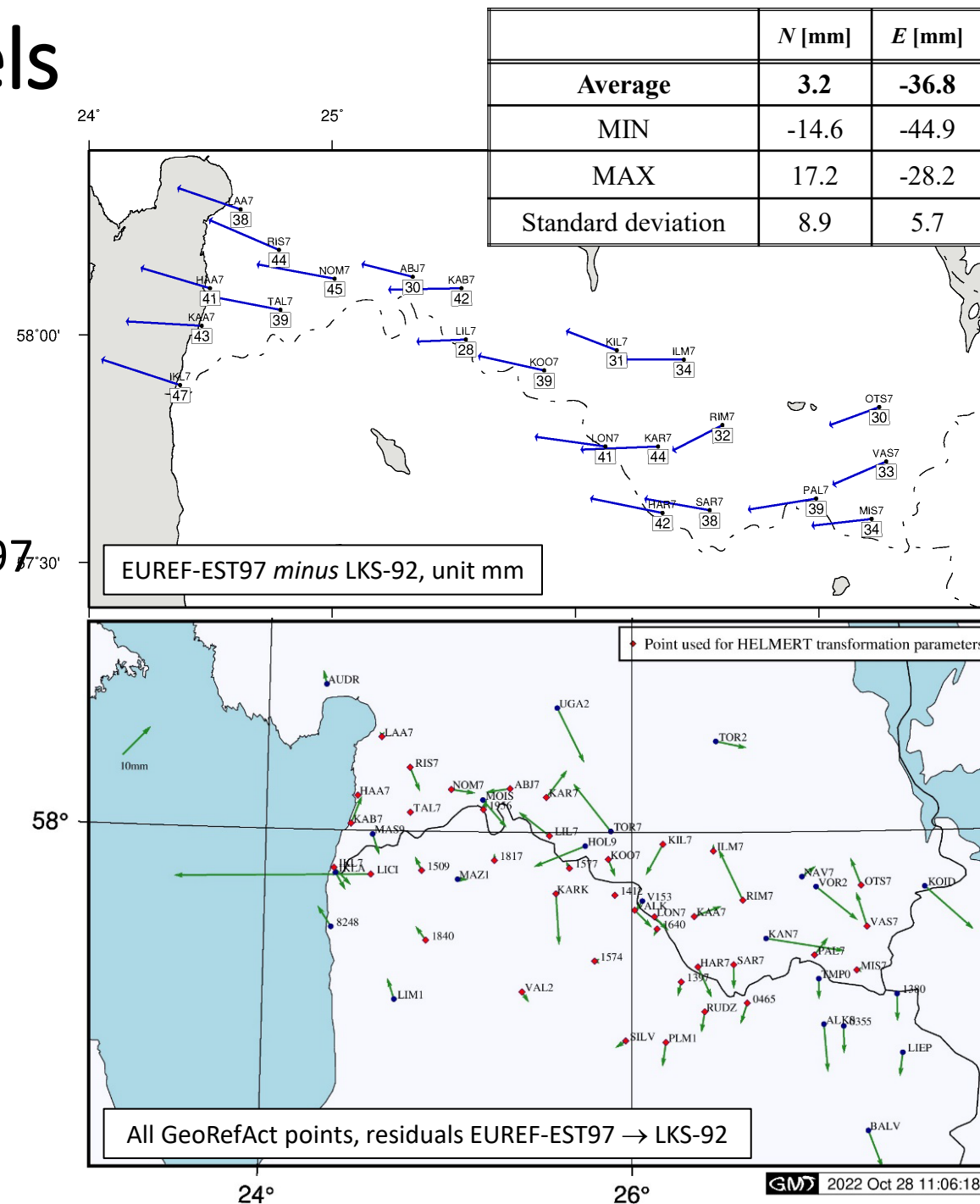
GNSS data processing

- Bernese 5.2 GNSS software, NKG and EPN guidelines with local refinements
- In two steps:
 - Step1: LatPos and ESTPOS stations with EPN/IGS stations as reference in IGB14
 - Step2: the GNSS static measurements with LatPos and ESTPOS stations as reference (epoch 2021.03.24)
- Repeatability, Step1:
 $N = \pm 0.55 \text{ mm}$, $E = \pm 0.67 \text{ mm}$, $Up = \pm 2.29 \text{ mm}$
- Repeatability, Step2:
 $N = \pm 3.87 \text{ mm}$, $E = \pm 3.57 \text{ mm}$, $Up = \pm 5.00 \text{ mm}$



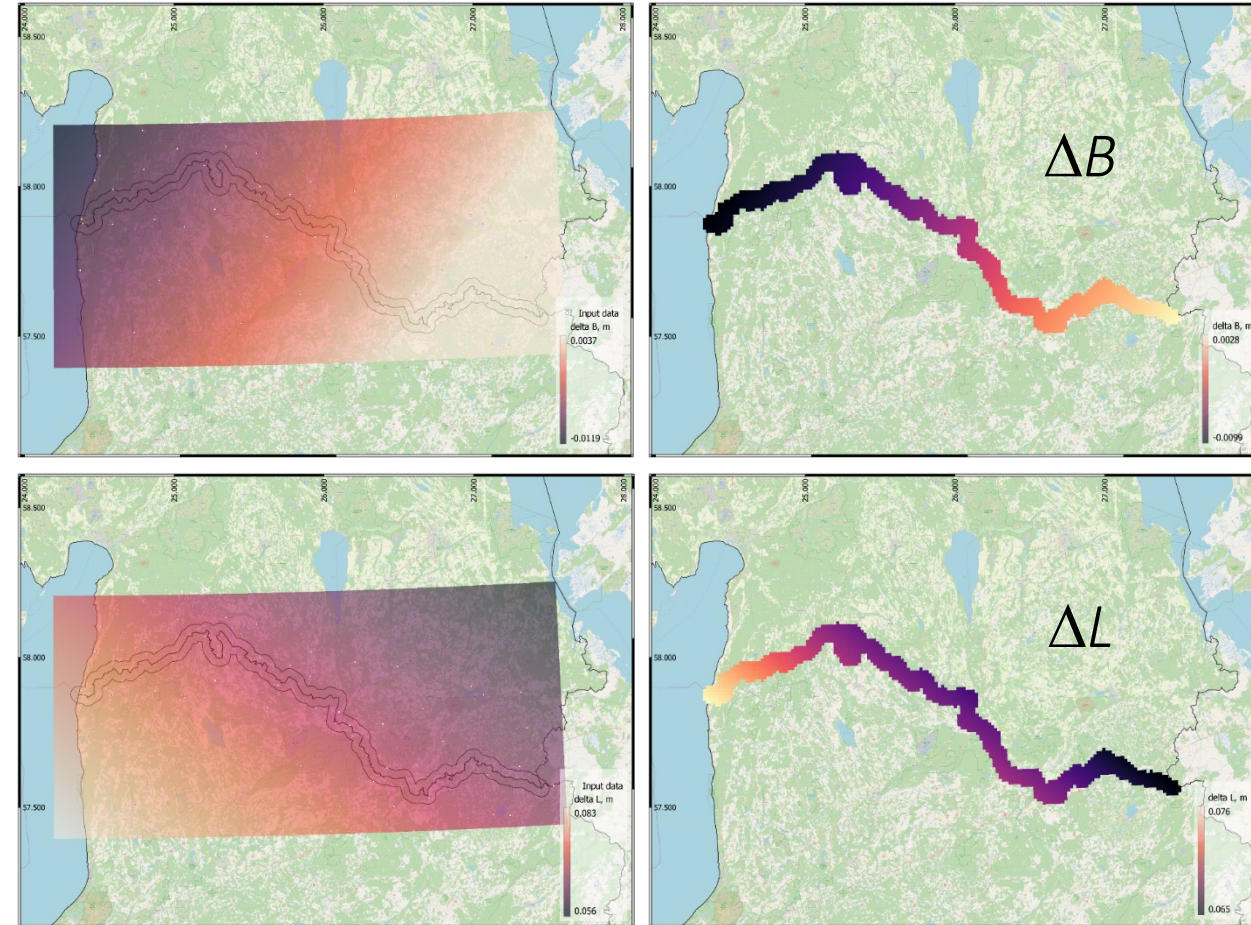
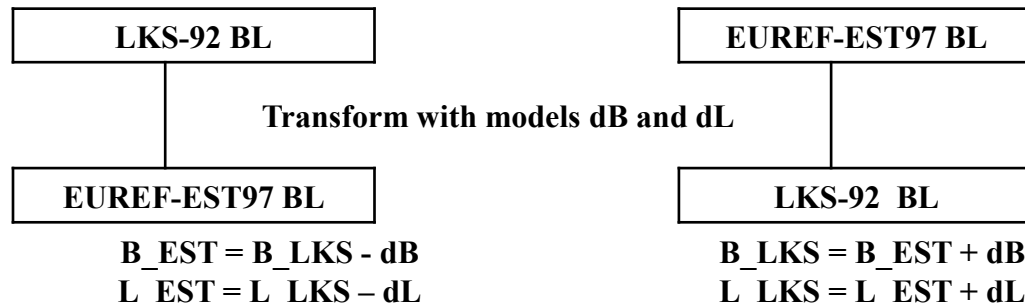
Coordinate transition models

- To obtain the official LKS-92 coordinates, the Step2 network was readjusted using the LatPos official LKS-92 coordinates as reference in the minimum constraint solution
- To obtain the EUREF-EST97 coordinates for the points located in Latvia, the Step2 network was readjusted using the ESTPOS official EUREF-EST97 coordinates as reference in the minimum constraint solution
- 39 points, Helmert 7-paramter transformation LKS-92 → EUREF-EST97
- Estimates at observation points were at the sub-cm level



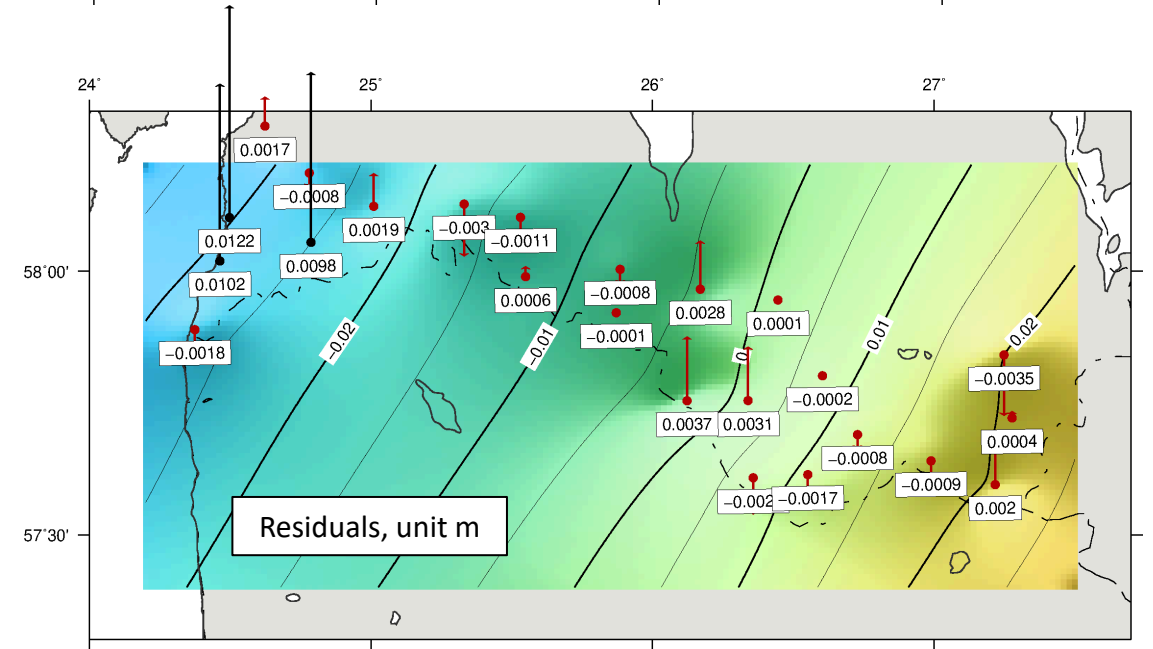
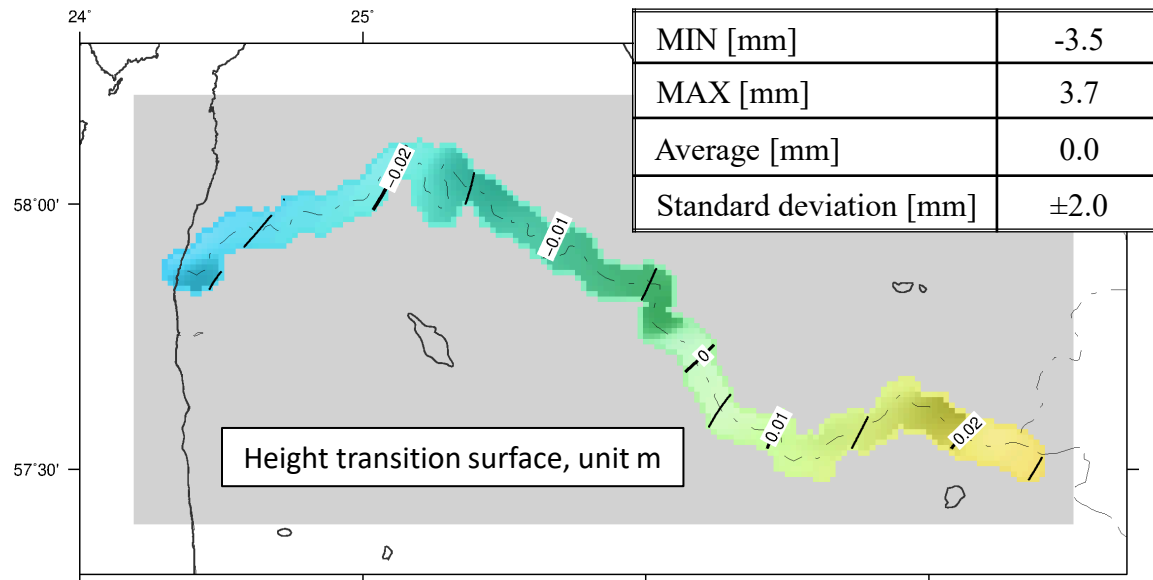
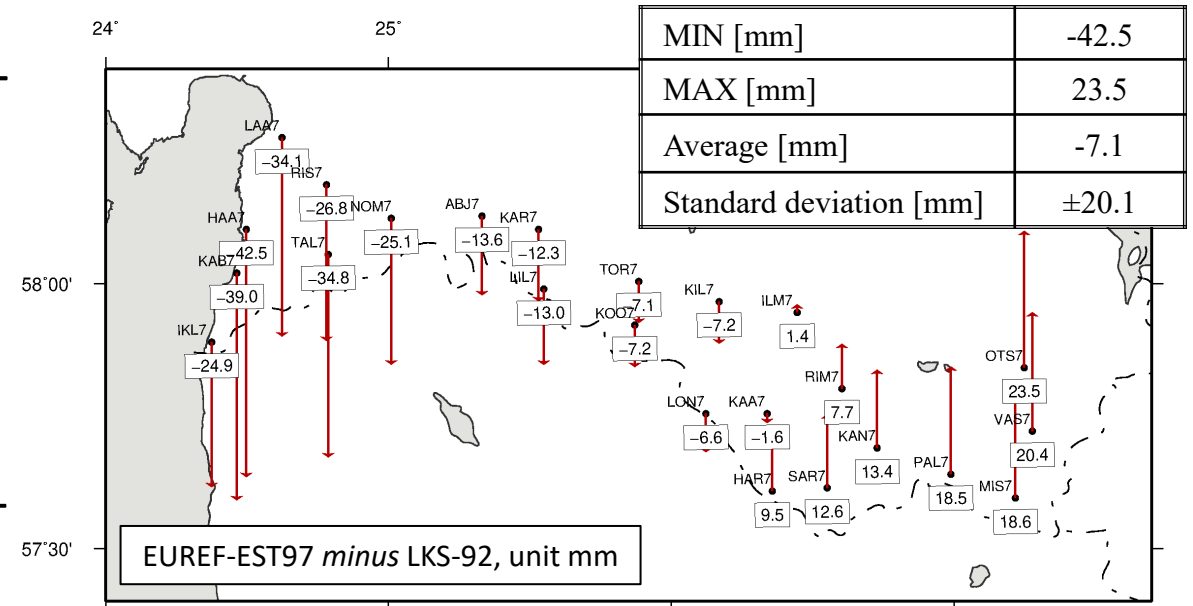
Coordinate transition surface

- From transformation the ΔL and ΔB differences LKS-92 \rightarrow EUREF-EST97 were obtained
Sign reversed ΔL and ΔB for EUREF-EST97 \rightarrow LKS-92
- ΔL , ΔB gridding: 58 points, GMT splines in tension
- Model area B : $24.2 - 27.5^\circ$, L : $57.4 - 58.2^\circ$
- Grid step: $0.02^\circ/0.01^\circ$ (≈ 1.1 km)
- The model was cut into a 2+2 km wide buffer



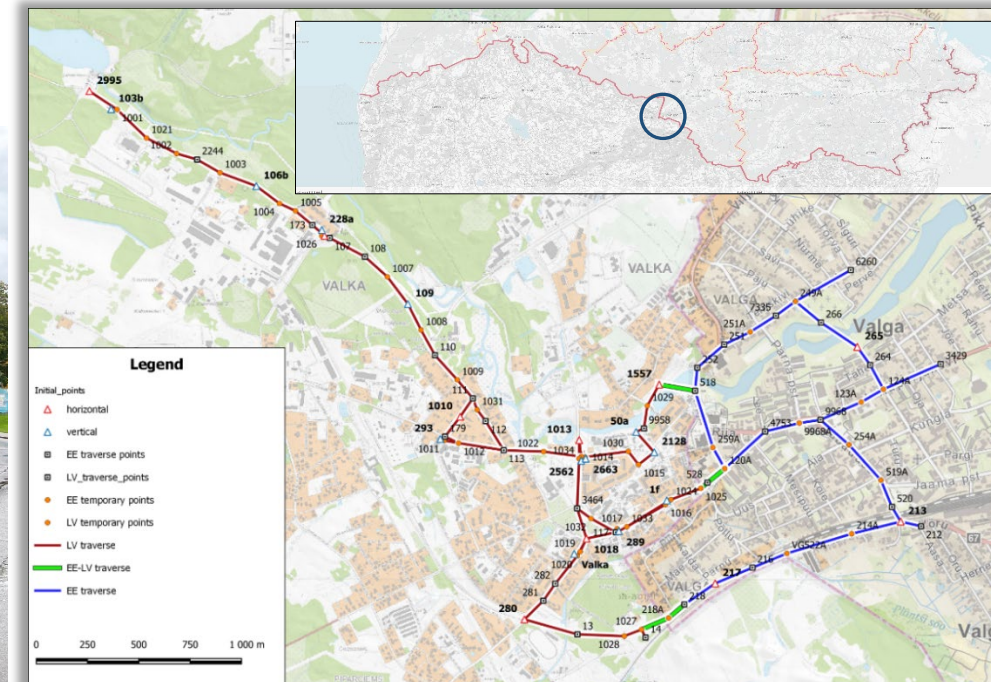
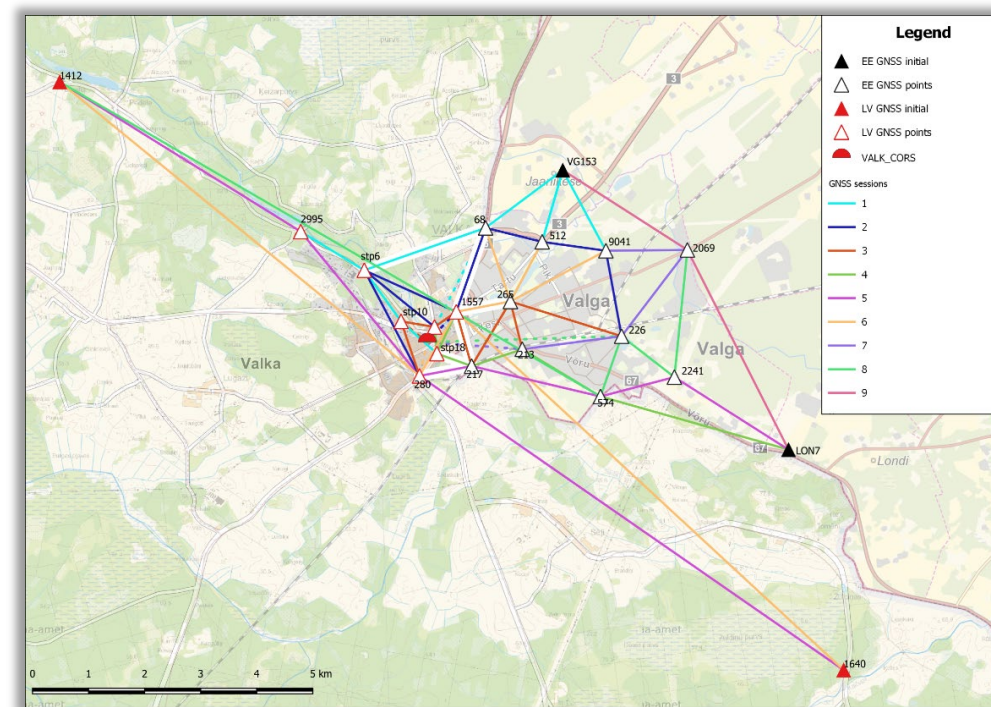
Transition surface for ellipsoidal heights

- Gridding EUREF-EST97 \leftrightarrow LKS-92: 24 points, GMT splines in tension
- Model area B : $24.2 - 27.5^\circ$, L : $57.4 - 58.2^\circ$
- Grid step: $0.02^\circ/0.01^\circ$ (*ca* 1.1 km)
- The model was cut into a 2+2 km wide buffer
- Estimates at observation points were at the sub-mm level



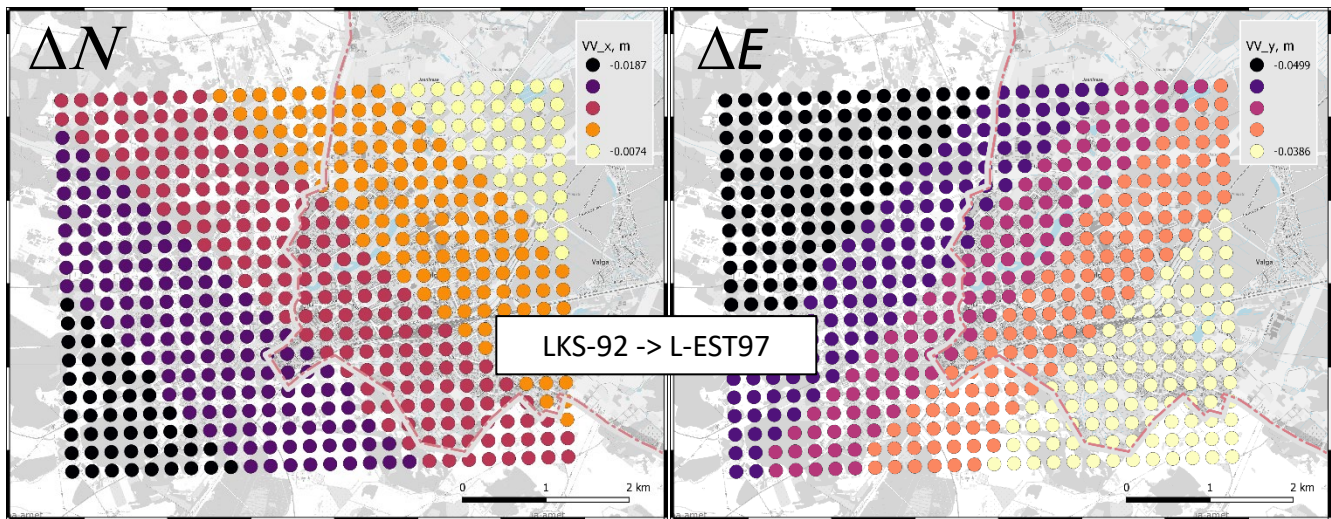
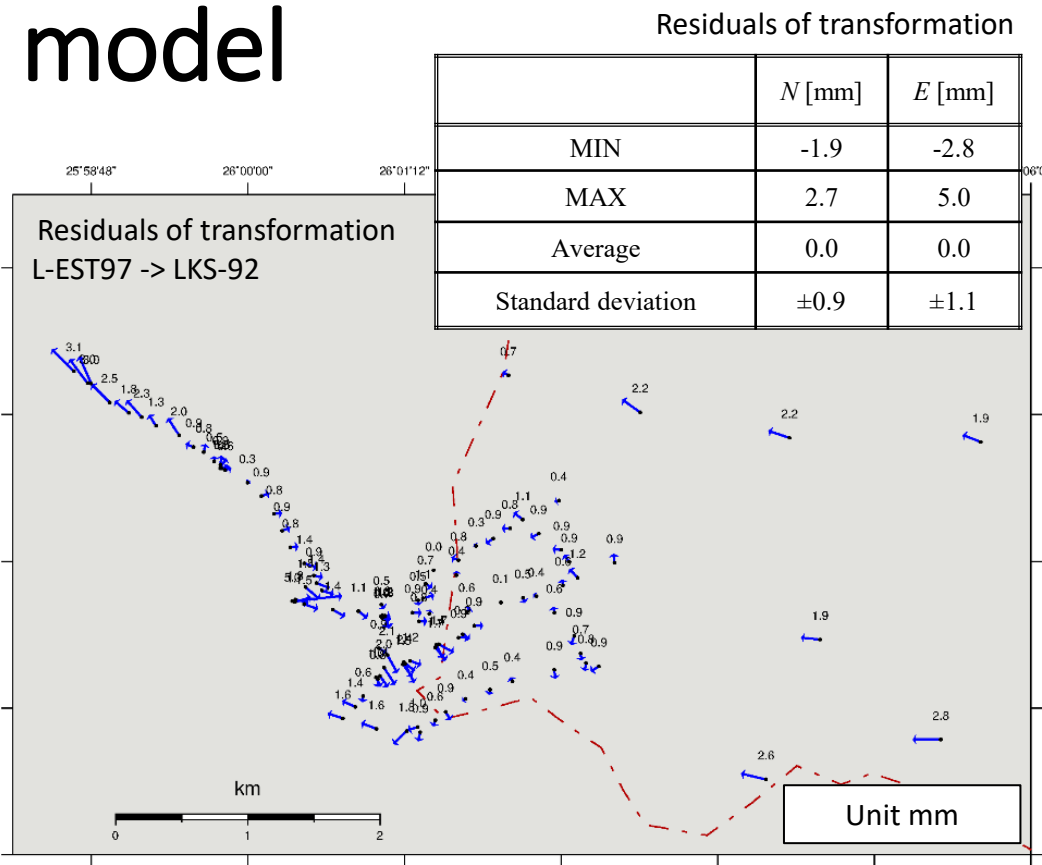
Twin city Valka\Valga

- Static GNSS: 1.5 hours, at least twice at each point
- Traverse: Trimble S9 0.5" Robotic DR Plus (LGIA) and Leica TS60 (ELB), three full sets measured
- Measurements: 17.08. - 27.08.2021
- GNSS data processing: Trimble BC (LGIA), Leica Infinity (ELB)
- Traverse: TopoNet 6.3 (LGIA), Leica iCON (ELB), adjusted in LKS-92, L-EST97 and LKS-20, coordinates from GNSS network were used as reference



Valka\Valga coordinate transition model

- In two steps:
 - Step 1: Helmert 2D transformation L-EST97 → LKS-92 TM with coordinates in the EE map projection LAMBERT-EST (LKS-92 TM_{x,y} → LKS-92_{B,L} → LKS-92_{LAMBERT-ESTx,y})
 - Step 2: by applying the transformation parameters, ΔN and ΔE between L-EST97 and LKS-92 (L-EST97 → LKS-92_{LAMBERT-ESTx,y}) at grid nodes were obtained
- Sign reverse for LKS-92 → EUREF-EST97
- Grid area B : 25.98 - 26.08°, L : 57.76 - 57.80° (ca 6×4.5 km)
- Grid step: 0.004°/0.002° (ca 220 m)
- Estimates at observation points were at the sub-mm level



Coordinate differences L-EST97 minus LKS-92

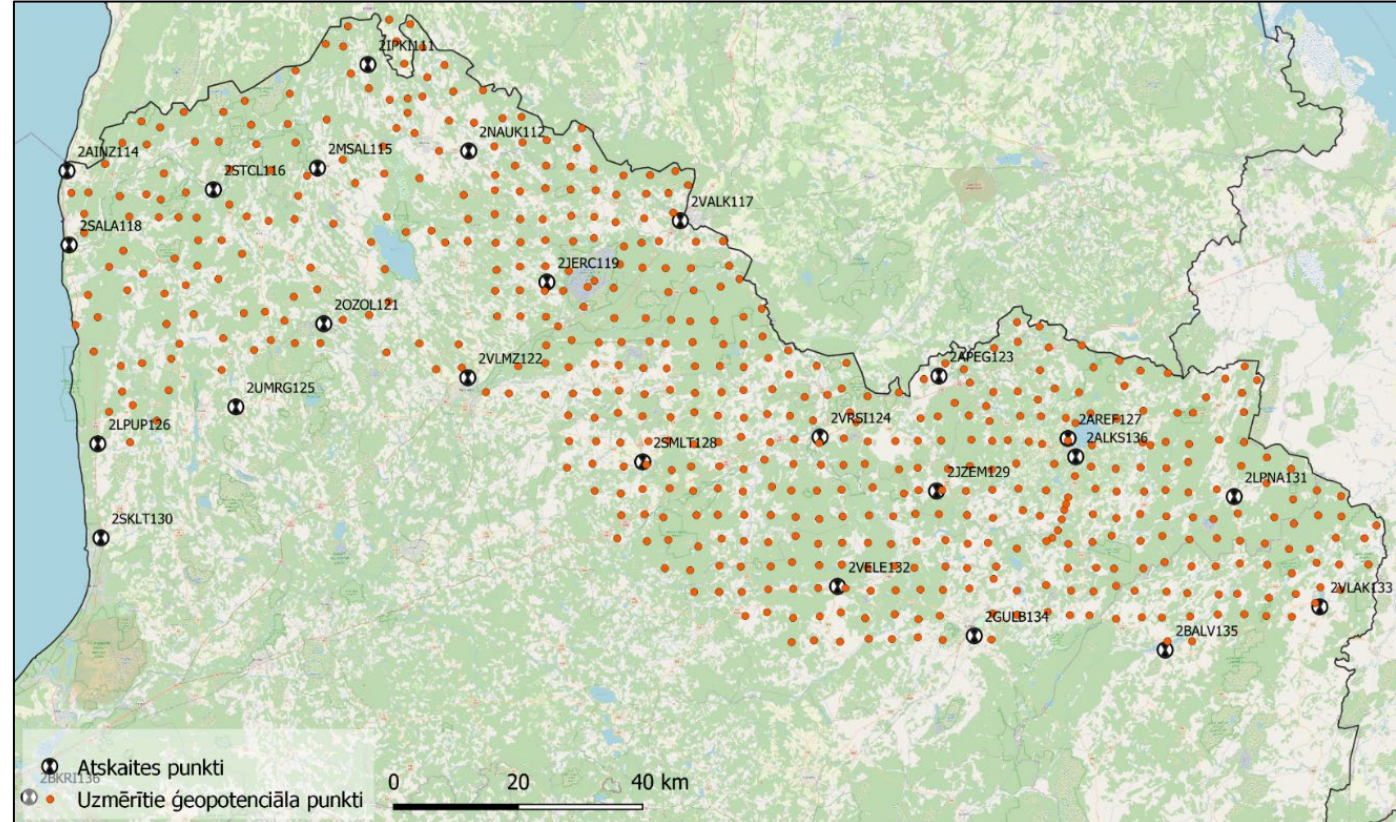
	N [mm]	E [mm]
Average	-13.0	-44.2
MIN	-7.1	-38.3
MAX	-18.9	-50.0
Standard deviation	2.5	2.5

Coordinate differences border corridor

	N [mm]	E [mm]
Average	3.2	-36.8
MIN	-14.6	-44.9
MAX	17.2	-28.2
Standard deviation	8.9	5.7

Gravity measurements

- Scintrex CG-5 and CG-6 gravimeters
- Base station approach - loops ending at the same point (about every 30 km)
- Measurements with step of 4 km in an area of 40 km from the border
- Measured April - October 2022
- Gravity verification on levelling lines



Interreg V-A Estonian-Latvian programme

- Web-based calculators, free of charge
 - ✓ EUREF-EST97 ↔ LKS-92 (L-EST97 ↔ LKS-92 TM)
 - ✓ EH2000 ↔ LAS-2000,5
 - ✓ Valga/Valka EUREF-EST97 ↔ LKS-92 (L-EST97 ↔ LKS-92 TM)
- The large amount of geodetic information and measurement data collected during the project will enable solving other geodetic, geoinformatics and engineering tasks in the future

 **MAA-AMET**

Geodeetiliste punktide andmekogu

ELB+KEMIT

Otsi nime järgi Otsi GPA ID järgi Otsi koodnumbri järgi Otsi koordinaatide järgi Otsi asustusüksuse järgi Kalkulaatorid ▾

EH2000 ja LAS-2000,5 kõrguste ülemineku kalkulaator

Üksipunkti kõrguse arvutus Failist üles laetud kõrguste arvutus Vormi kaudu saadetud kõrguste arvutus

☒ EH2000 kõrgus -> LAS-2000,5 kõrgus ☐ LAS-2000,5 kõrgus -> EH2000 kõrgus

X_{L-EST97} või LKS-92 TM või B_{EUREF-EST97} või LKS-92* Y_{L-EST97} või LKS-92 TM või L_{EUREF-EST97} või LKS-92* H_{EH2000}

6415172 521503 1.919

* B ja L kümnendkraadides

Arvuta

Vastus: H_{LAS-2000,5} = 1.930

Kalkulaator on loodud Interreg Eesti-Läti projekti „Geodeetiliste süsteemide harmoniseerimine Eesti-Läti piirilalal“ (GeoRefAct) raames.

 **Interreg**
Estonia-Latvia
European Regional Development Fund

 **EUROPEAN UNION**

© 2022 - Maa-amet

