TALLINN UNIVERSITY OF TECHNOLOGY

MAA-AMET

New 5 mm geoid model for Estonia

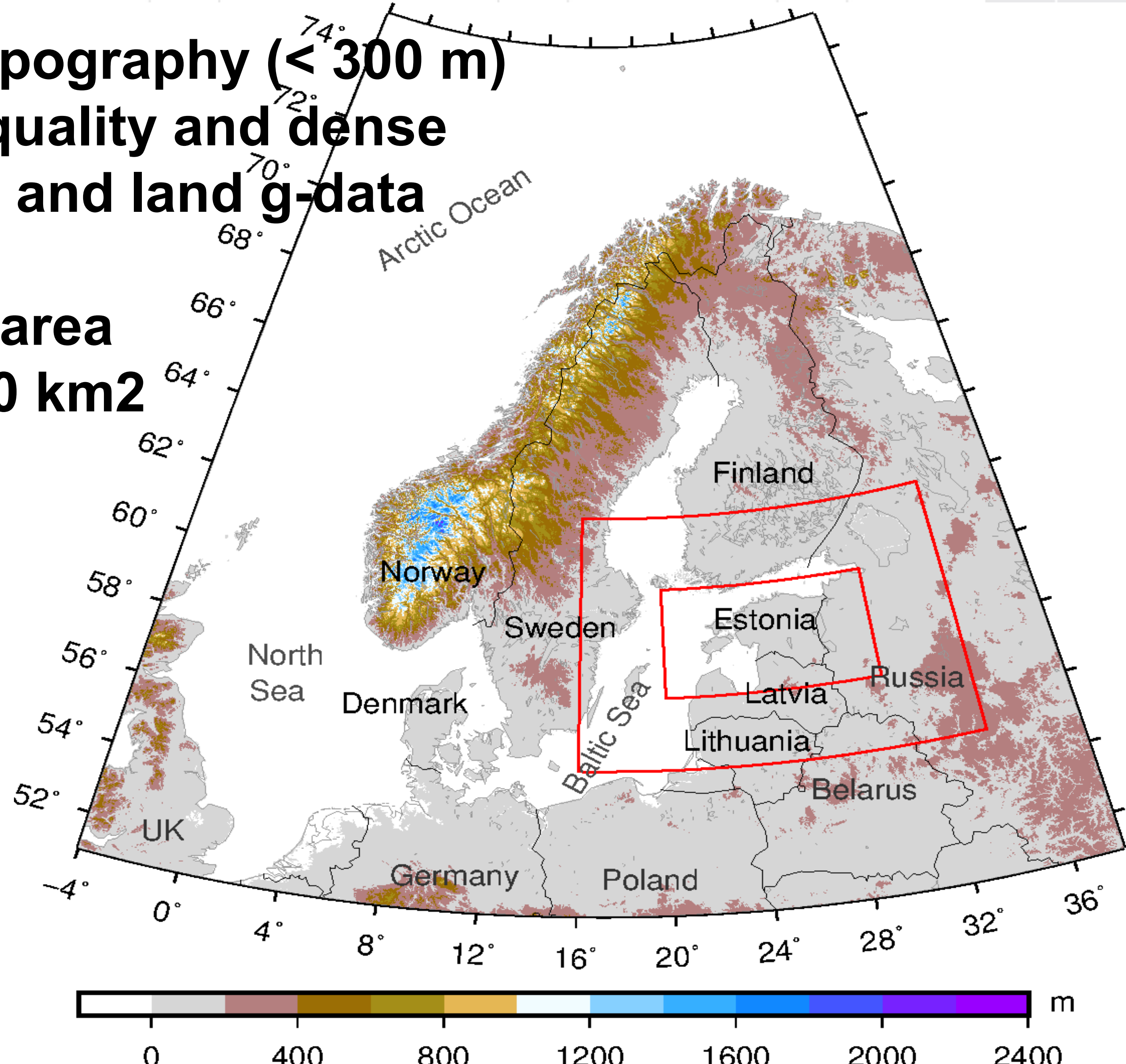
Artu Ellmann and Tõnis Oja

EUREF2019 symposium in Tallinn, May22-24, 2019

Study area

Low topography (< 300 m)
Good quality and dense marine and land g-data

Target area
180 000 km2



The study – an offspring of two large regional projects - the NKG2015 (completed) and FAMOS (ongoing) geoid modelling projects

Motivation of the study

Estonia has adopted a new height reference system (Estonian realisation of EVRS – normal heights with respect to the Amsterdam NAP)

New marine gravity data along the Estonian coasts (DTU Chekan 2016-2017 campaigns)

High precise GNSS/levelling points, the combined uncertainty ~5 mm

$$u_{GNSS-lev} = \sqrt{u_{GNSS}^2 + u_{lev}^2}$$

Availability of new GGM-s (e.g. GOCO05s and GOCO05c tested)

Gravity DATA

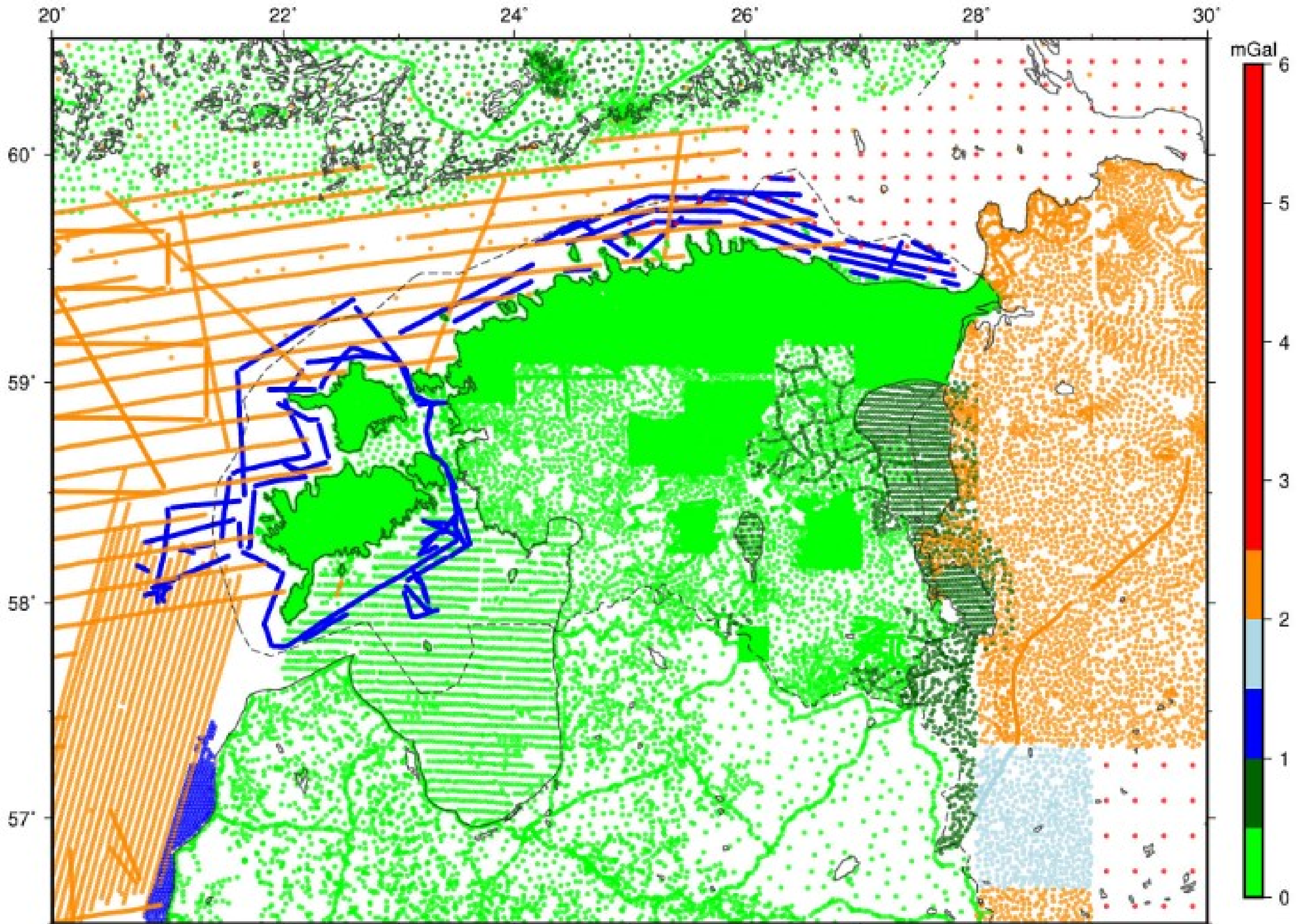
Adjacent to Estonia data originates from the Nordic Geodetic Committee gravity database (incl. uncertainty estimates, status of 2015)

Revised, cleaned, data voids filled

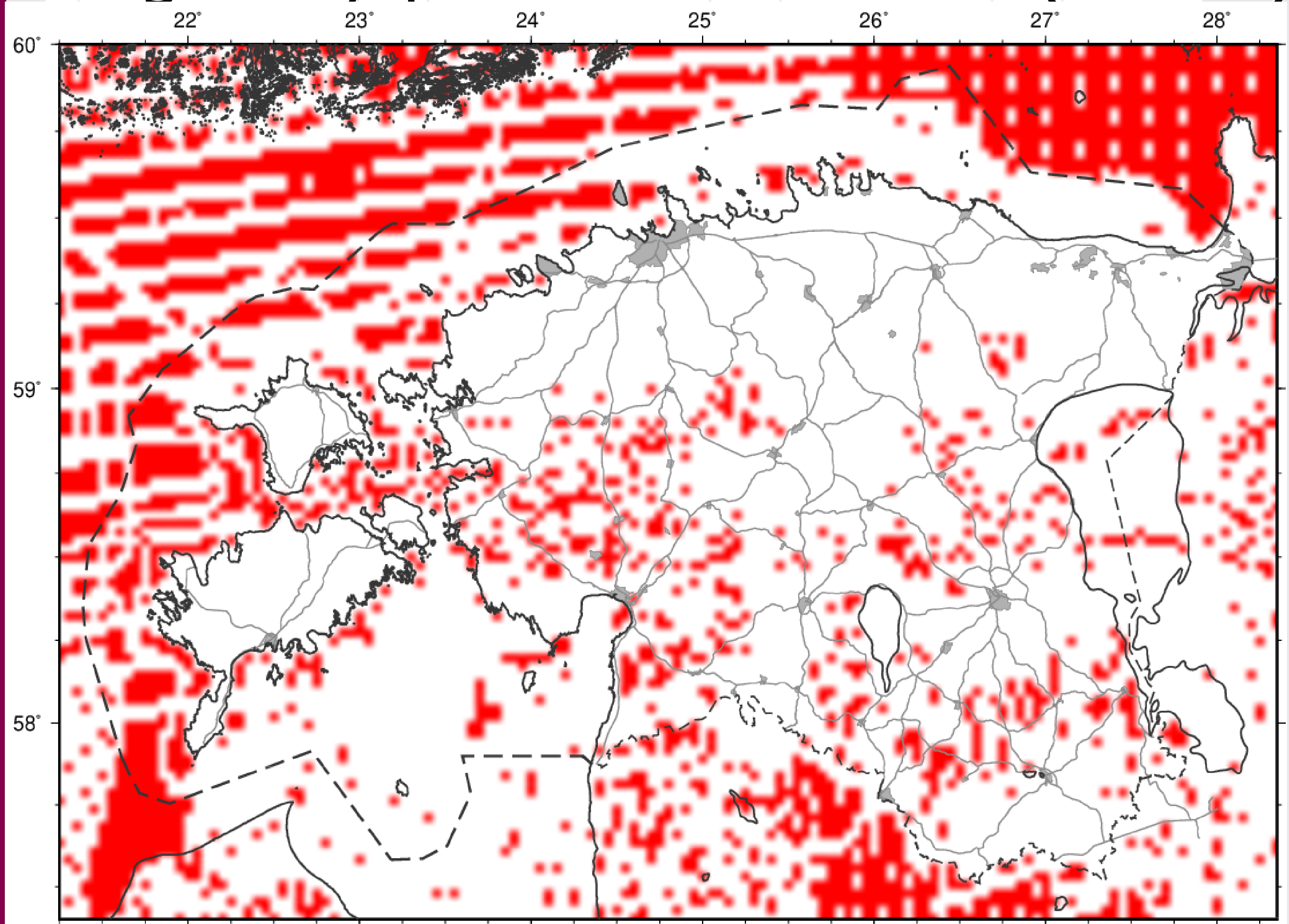
New data
FAMOS 2016 -2017 marine campaign in Estonian coastal waters (DTU Chekan)

~700+ new g-points from Estonia

Formal uncertainties of g-data
in average 0.5...0.75 mGal

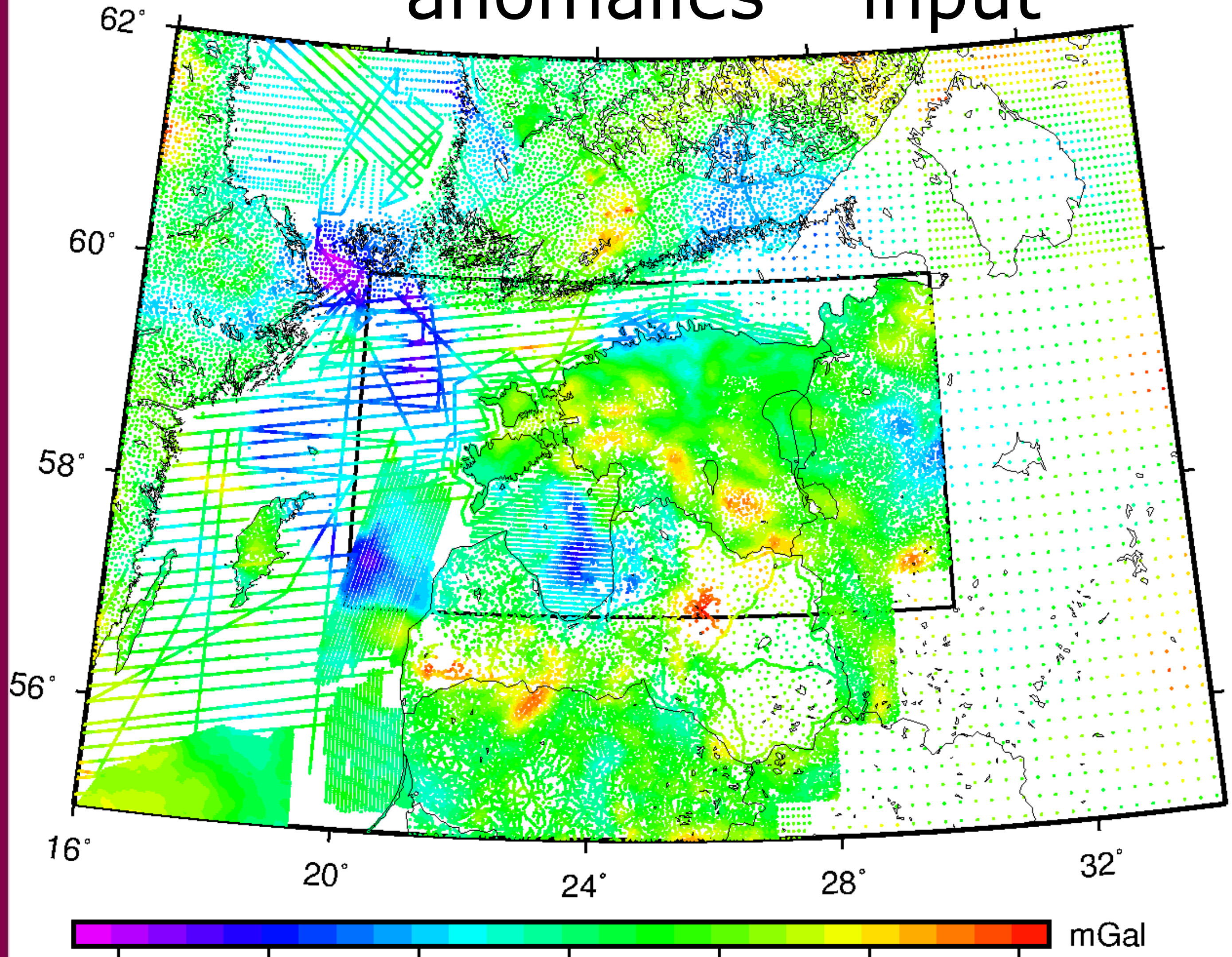


No gravity point within 3 km (in red)



Hypothesis – A 5 MM GEOID MODEL SHOULD BE ACHIEVABLE over most of Estonian land surface

Gravity data distribution and free –air anomalies – input



No: 88910 StdDev: 16.4729 Mean: −12.8550 Min: −84.0500Max: 44.5400rms: 20.8951

Gravity anomaly gridding

Gridding of gravity anomalies by RIR (remove-interpolate-restore) techique,

The LSC (least squares collocation, considers the assigned uncertainties of g-data) stochastic prediction was applied for the anomaly gridding

Geoid modelling

the method of unbiased (Sjöberg 1991) least squares modifications of Stokes formula with additive corrections (ULSMSA) appeared also to perform the best for the present study (also in NKG2015 geoid and previous EST-GEOID2011)

GRAVqgeoid-2017

Resolution 0.01° x0.02° (1 x 1 km²)

Combined atmospheric effects.
Ellipsoidal and downward continuation effects

GOCO05s ref. model

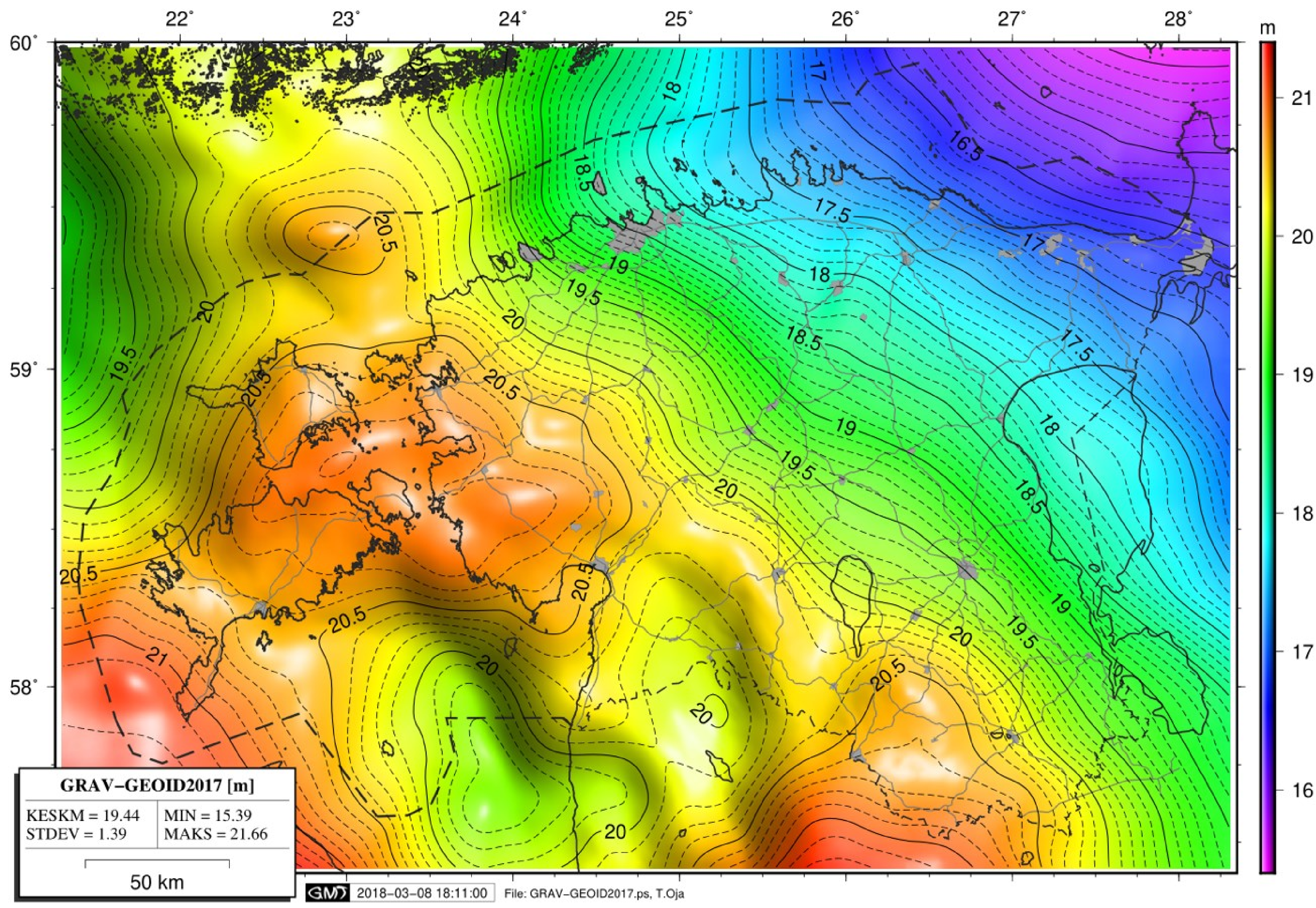
$$\tilde{N} \quad \frac{R}{4\pi\gamma}\iint_{\sigma_0} S^L(\psi)\Delta g d\sigma + c\sum_{n=2}^{M}\left(Q_n^L + s_n\right)\Delta\hat{g}_n + \delta N_{comb}^{Mod} + \delta N_{atm}^{Mod} + \delta N_{dwc}^{Mod} + \delta N_{e}^{Mod}$$

LS modification of Stokes's formula with additive corrections - ULSMSA

Modification limit M=L=200,
Integration radius 2°,

Boundaries 57°…60°N & 20°…30°E

Gravimetric qgeoid model GRAV-GEOID2017



GNSS-lev evaluation and fitting

Levelling network:

- Renovated national levelling network, (adjusted height uncertainty 1.8 mm)

Geodetic network (long lasting static GNSS, single campaign, year of solar minima, Bernese):

- geodetic heights, corrected for the land uplift (NKG2005LU),
- GNSS uncertainty 4.6 mm (1-sigma, h-component)

$$u_{GNSS-lev} = \sqrt{u_{GNSS}^2 + u_{lev}^2}$$

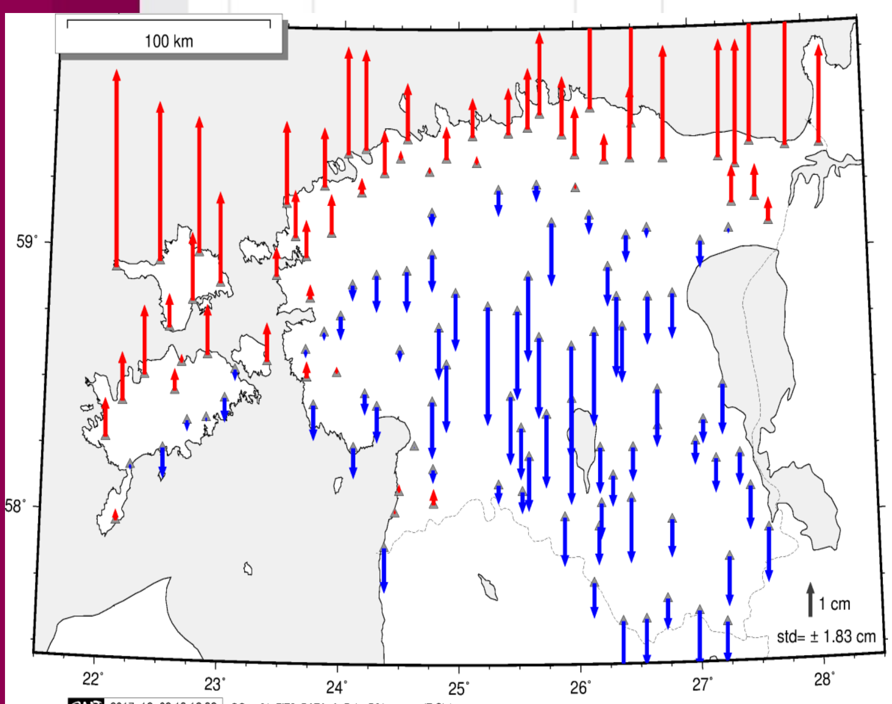
131 GNSS/levelling points

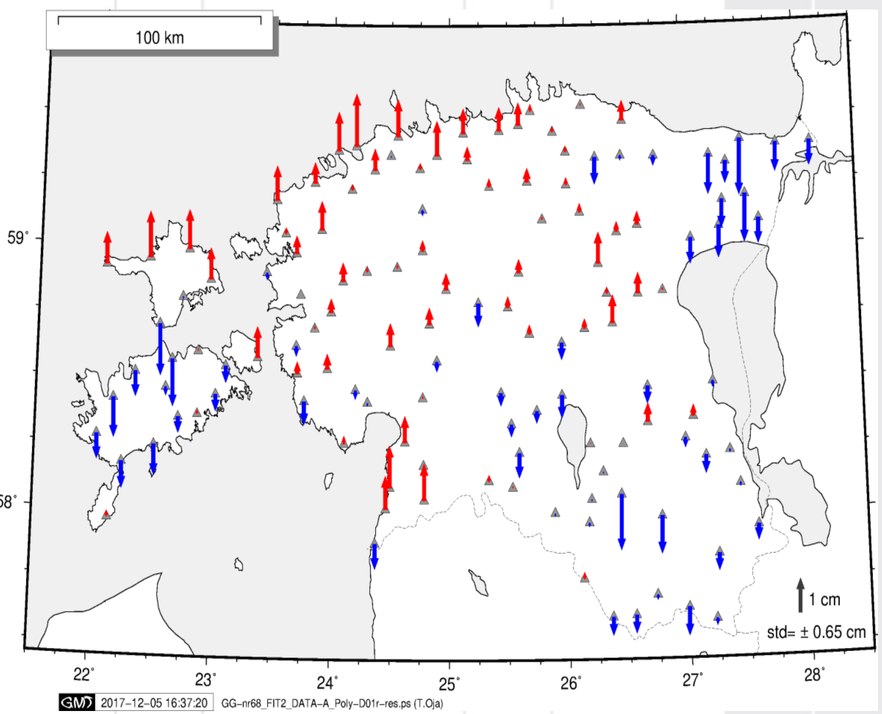
dN=N_{GG} – N_{obs} (*whereas* $N_{obs} = h - H$)

Firstly - polynomial fit (GMT)

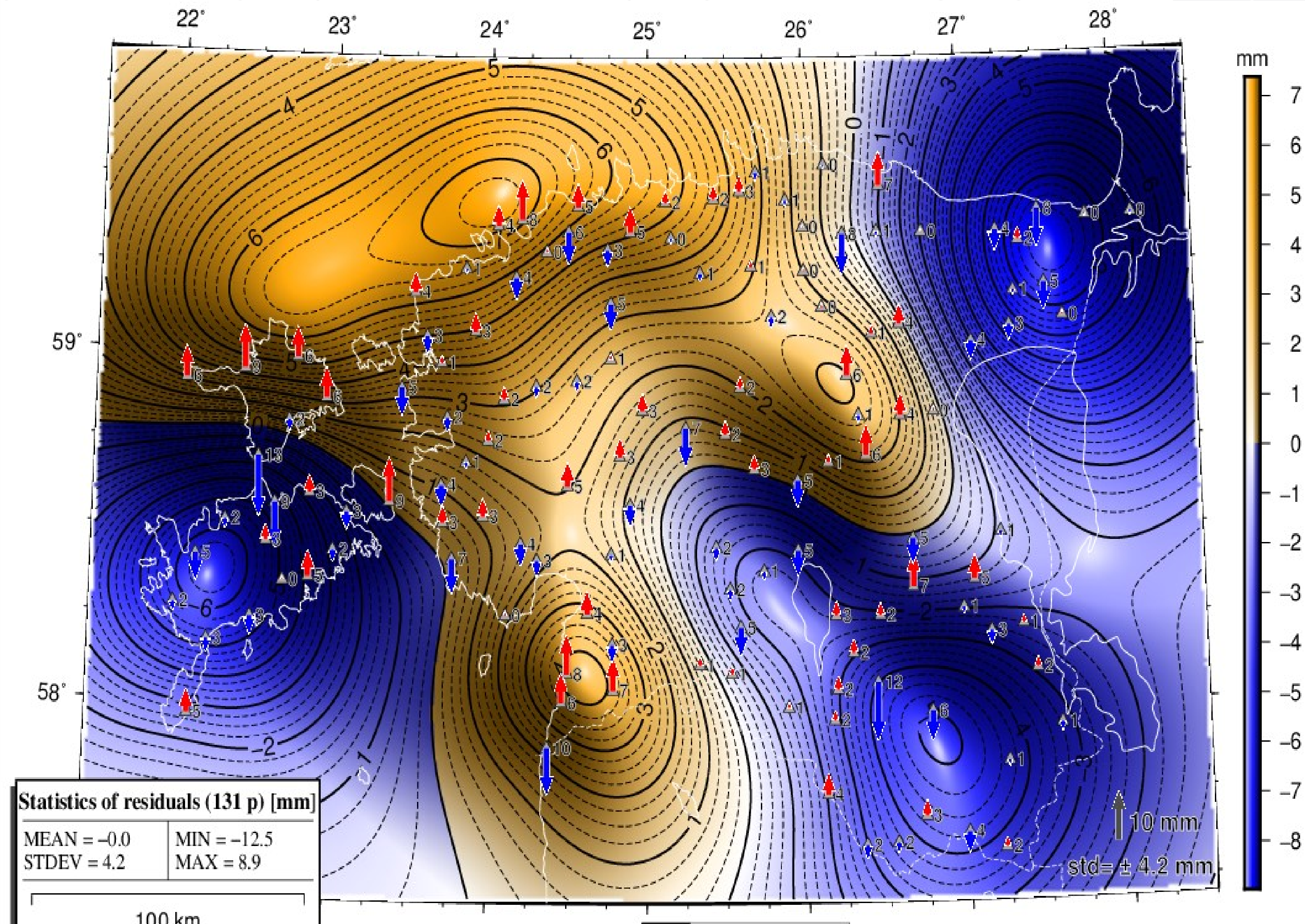
Method	DIFFs(cm): Average	StDev	Min	Max	NoPoints
GMTtrend2d deg-01r:	561.4	6.5	-16.3	15.1	131
GMTtrend2d deg-03r:	561.4	6.1	-17.7	13.2	131
GMTtrend2d deg-04r:	561.4	5.6	-18.3	16.0	131
GMTtrend2d deg-06r:	561.4	5.1	-14.9	13.0	131
GMTtrend2d deg-10r:	561.4	4.9	-15.0	11.1	131

GRAVGEOID-2011 **RESIDUALS (1D fit)** GRAVGEOID-2017

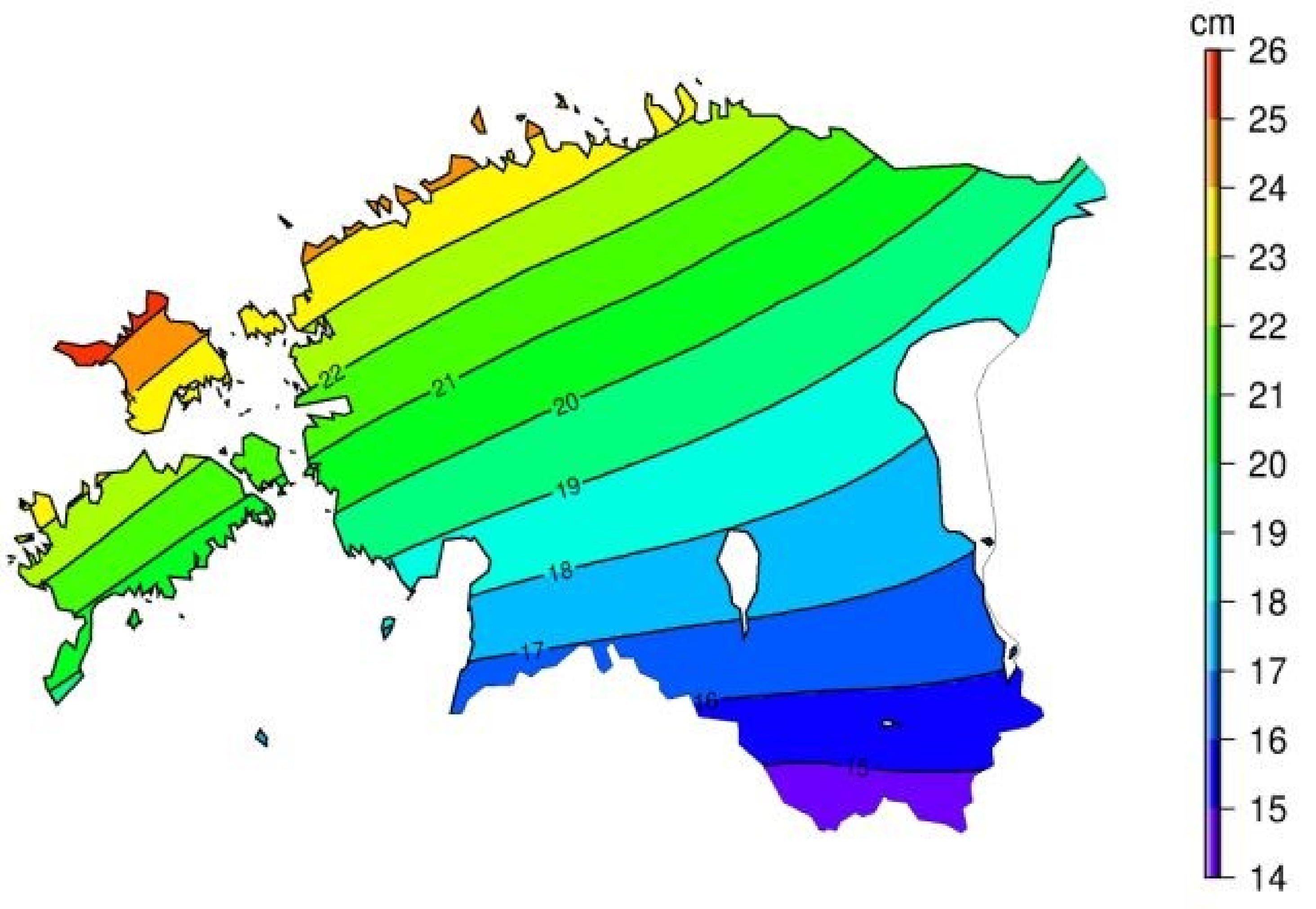




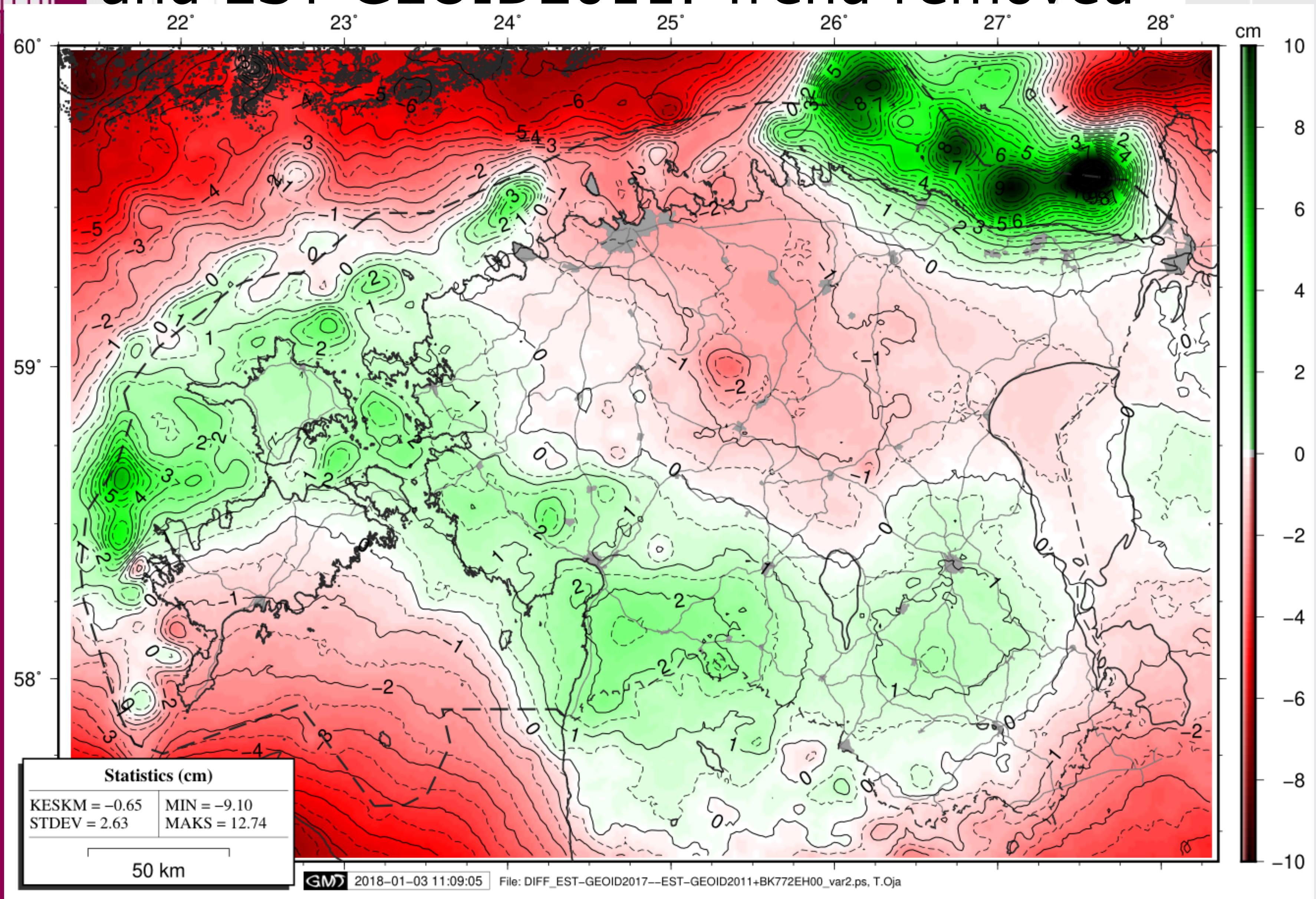
Final fit by using LSC stochastic prediction (based on GNSS/lev uncertainties, covariance analysis) More realistic, rather than just constraining to 0. The residuals at the GNSS/levelling points yielded StDev 4.2 mm (1 sigma).



Differences between the EST-GEOID2017 ja EST-GEOID2011. (tilt manifests deformations of the previous height system) Unit is cm



Improvements due to the new data Differences between the EST-GEOID2017 and EST-GEOID2011. Trend removed



Conclusions

The currently available land-based gravity data fulfill the 5 mm geoid modelling requirement for the Estonian mainland and islands.

This does not apply to the situation at sea, where the density of the airborne and shipboard gravity data do not allow the realization of a 5-mm quasi-geoid model (however, such a precise data-product is hardly needed for off-shore navigation/industry)

Future studies

Bridging the (coastal) gap in between the land-based geoid model and the open sea/ocean (where the retracked radar altimetry-derived SSH data can be useful)

Assessment of marine geod modelling by using GNSS profiles, whether the 5 cm geoid (a goal for FAMOS) in Estonian waters is achievable

Estonian Journal of Earth Sciences, 2019, **68**, 2, 55–75 https://doi.org/10.3176/earth.2019.06

Gravity anomaly field over Estonia

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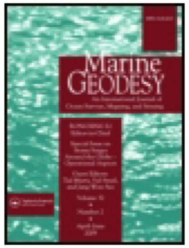
Received 4 December 2018, acc

Abstract. Different gravity ref
gravimetric measurements in E
required before their use in appli
of discrepancies between differe
territory and adjacent areas.



Marine Geodesy

ISSN: 0149-0419 (Print) 1521-060X (Online) Journal homepage: http://www.tandfonline.com/loi/umgd20

From discrete gravity survey data to a high-resolution gravity field representation in the Nordic-Baltic region

Silja Märdla, Jonas Ågren, Gabriel Strykowski, Tõnis Oja, Artu Ellmann, René Forsberg, Mirjam Bilker-Koivula, Ove Omang, Eimuntas Paršeliūnas, Ivars Liepinš & Jānis Kaminskis

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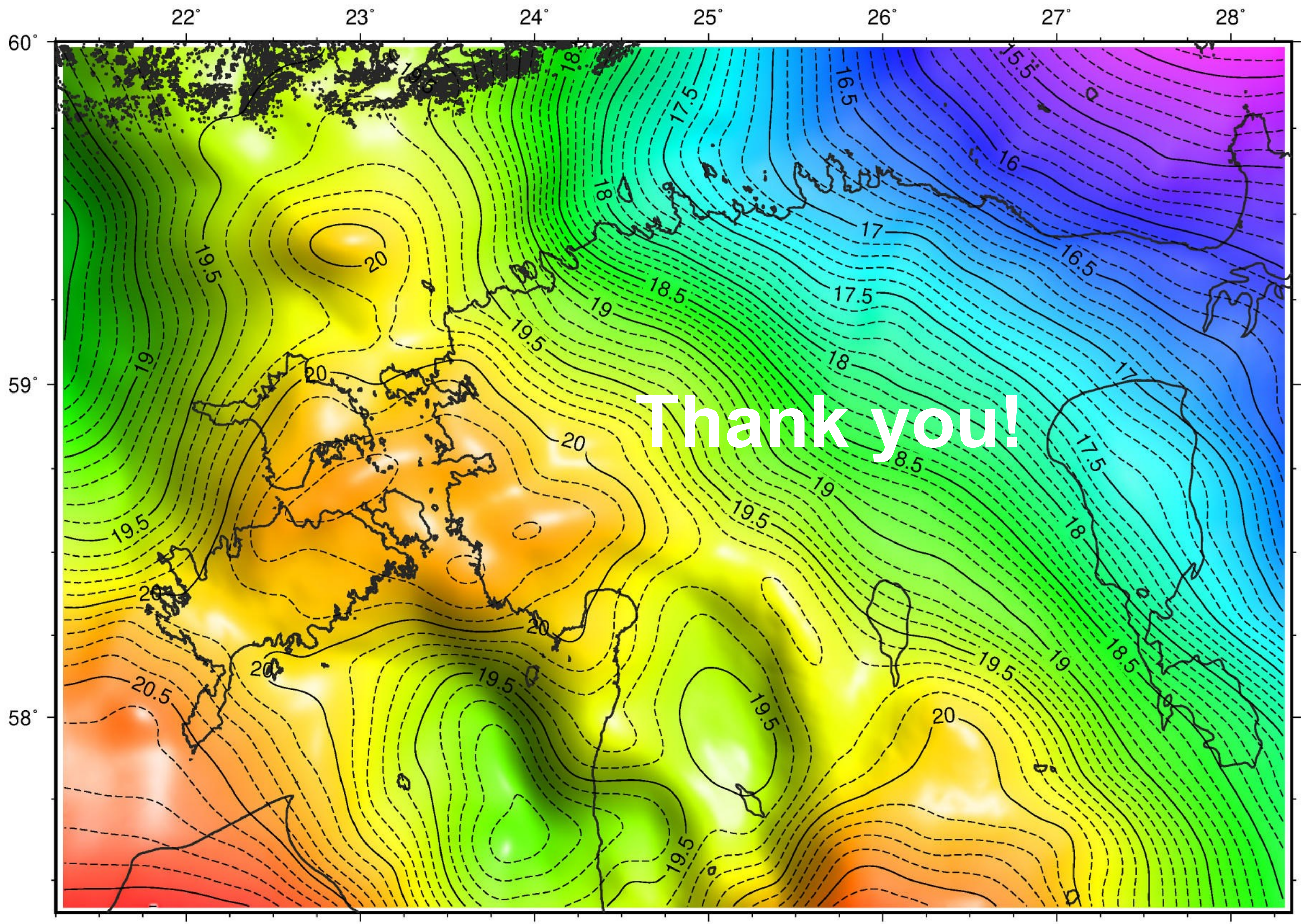
Survey Review

ISSN: 0039-6265 (Print) 1752-2706 (Online) Journal homepage: https://www.tandfonline.com/loi/ysre20

Related papers

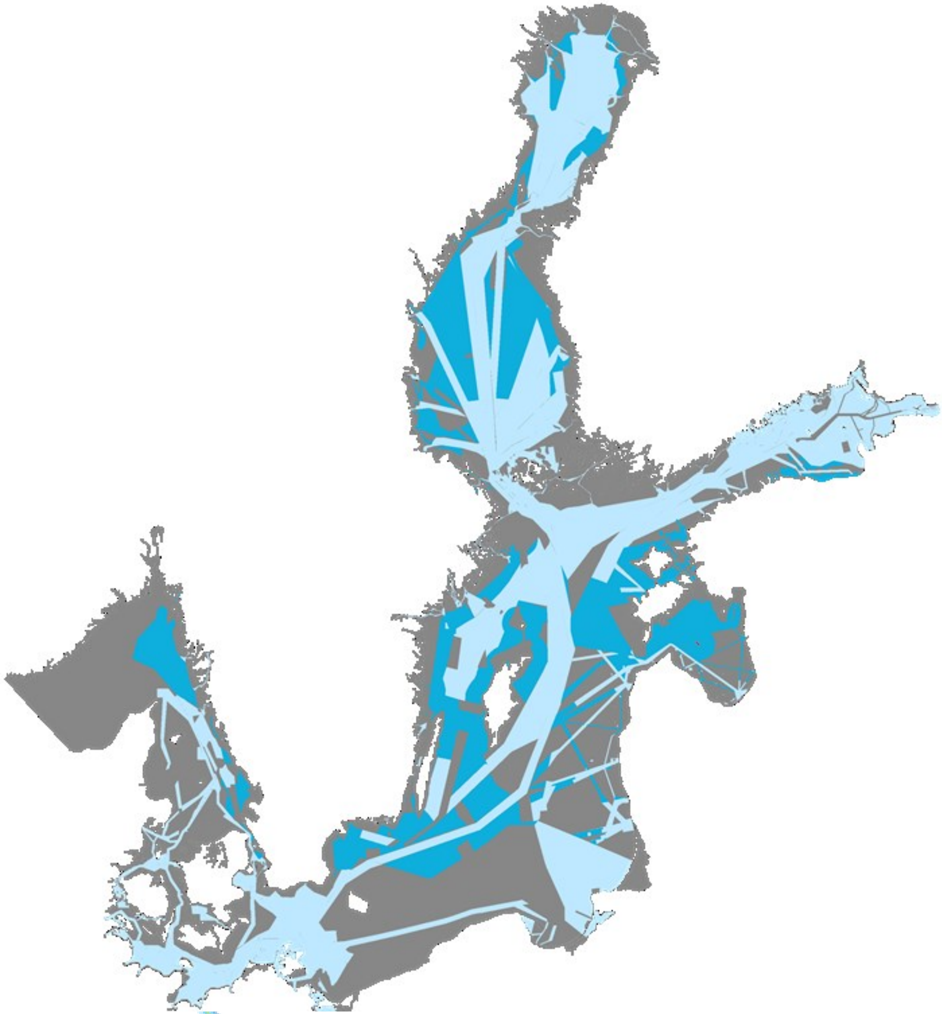
The 5 mm geoid model for Estonia computed by the least squares modified Stokes's formula

Artu Ellmann, Silja Märdla & Tõnis Oja


Thank you!
22° 23° 24° 25° 26° 27° 28°
60° 59° 58°

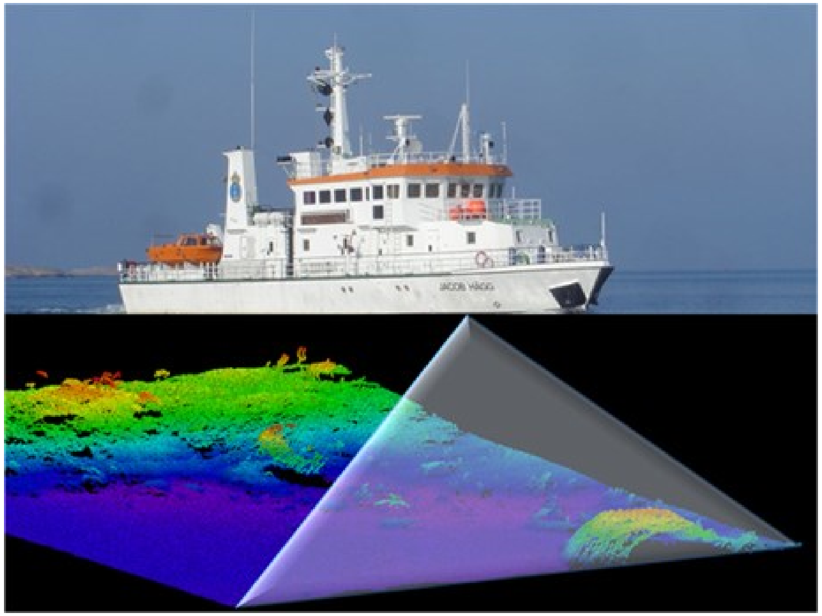
FAMOS slides

FAMOS –
Finalising Surveys for the Baltic Motorways of the Sea



The main part of FAMOS (Activity 1) is to finalise hydrographic surveying in areas of the Baltic Sea of interest for commercial shipping.

The FAMOS project started in 2014 and is planned to end in 2020 (hopefully).



FAMOS

FINALISING SURVEYS FOR THE BALTIC MOTORWAYS OF THE SEA

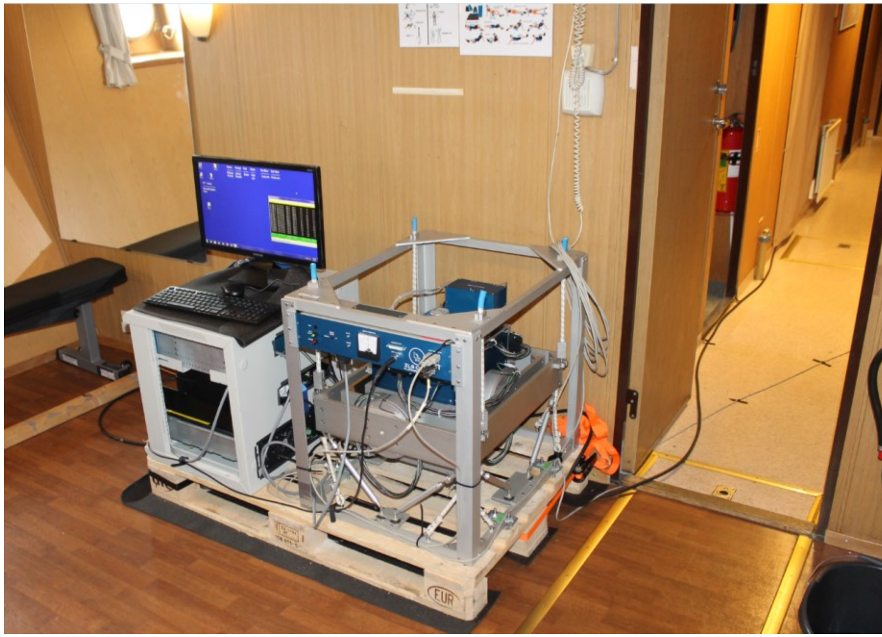
FAMOS Activity 2 - Harmonising vertical datum (FAMOS Freja)

Motivation: Contribute to future satellite navigation and hydrographic surveying with GNSS based methods by improving the marine geodetic infrastructure.

Mainly by supporting the introduction of Baltic Sea Chart Datum 2000 (EVRS, epoch 2000.0) as the common unified chart datum in the Baltic Sea.

Most important is to improve the Baltic Sea geoid model by making marine gravity measurements on board the FAMOS survey and other available vessels.

A quality controlled FAMOS geoid model with a verified standard uncertainty of 5 cm is planned for release by the end of the global FAMOS project in 2020 (or at the end of STM-FAMOS 2021, ?).



This geoid model will then be used to construct the BSCD2000 height reference surface that will realize the Baltic Sea Chart Datum 2000 at sea.

It will be used for GNSS-based navigation and hydrographic surveying in the future to get heights/depths in BSCD2000.

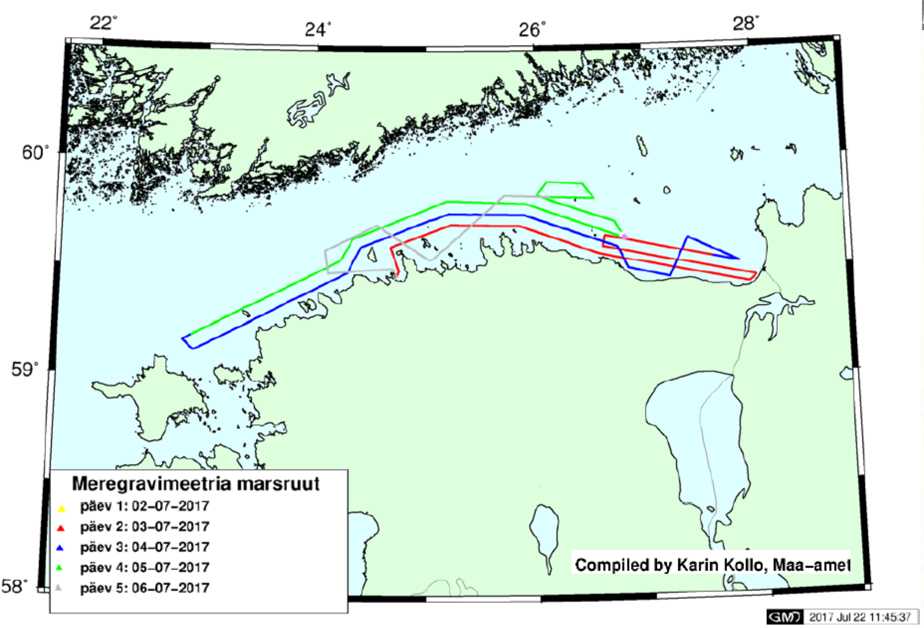
FAMOS
FINALISING SURVEYS FOR THE BALTIC MOTORWAYS OF THE SEA

Example of a dedicated marine gravimetry campaign: Sektori 2017 (Estonia)

July 2-6, 2017

DTU, TUT and VTA

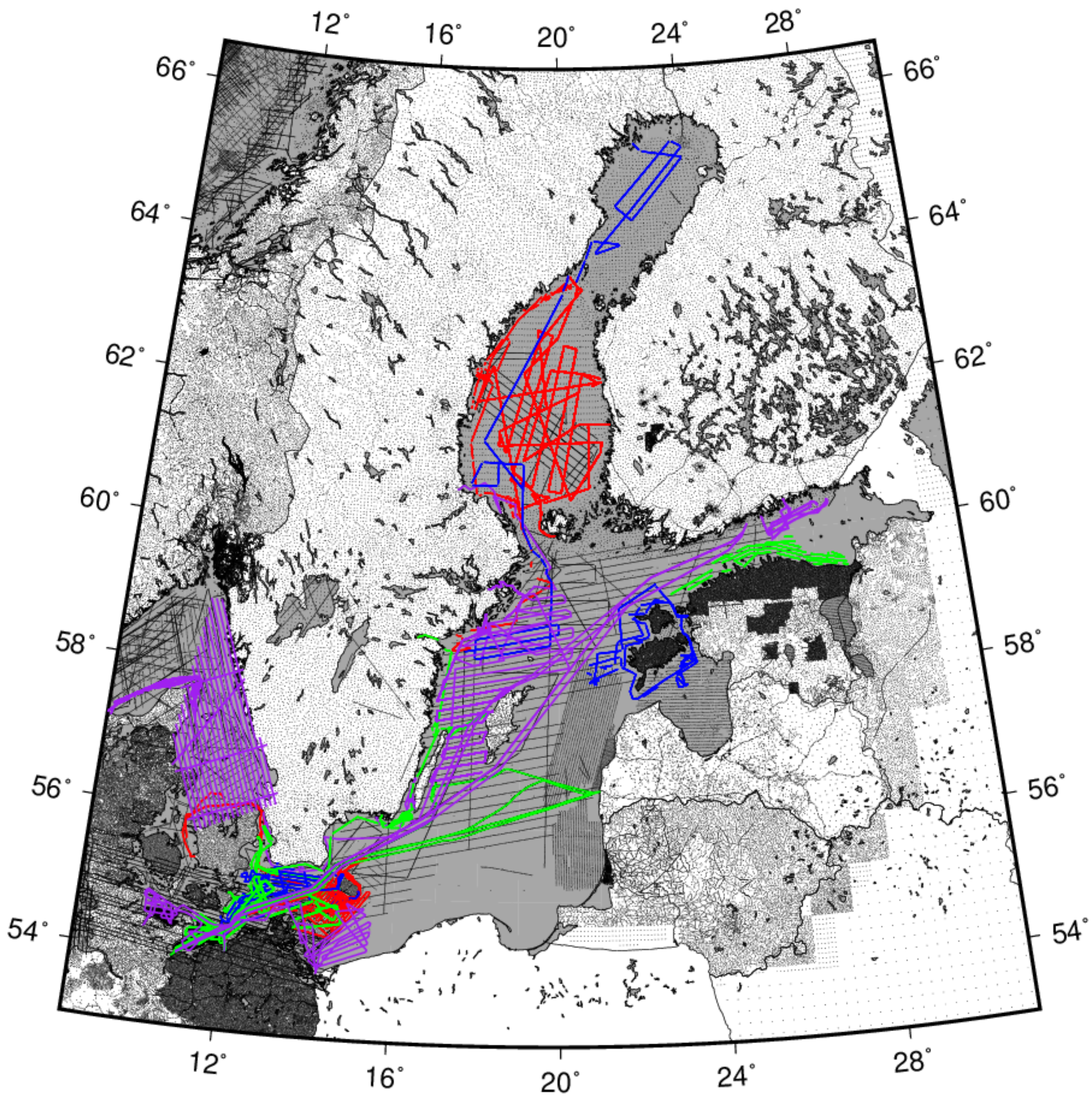
DTU's Chekan AM gravimeter



FAMOS

FINALISING SURVEYS FOR THE BALTIC MOTORWAYS OF THE SEA

Marine gravimetry campaigns in FAMOS



- Deneb 2015
- Airisto 2015
- Jacob Hägg 2015
- Jens Sørensen 2015
- Deneb 2016
- Jacob Prei 2016
- Jacob Hägg 2016
- Jens Sørensen 2016
- Deneb 2017
- Sektori 2017
- Jacob Hägg 2017a
- Jacob Hägg 2017b
- Jens Sørensen 2017
- Urd 2017
- Deneb 2018
- Jakob Hägg 2018
- Geomari 2018
- Fyrbyggaren 2018a,b
- Jens Sørensen 2018
- Finnlady 2018
- Kattegatt 2018* (airborne)