On the work to improve the Swedish gravity data for the next generation of geoid models

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Geodesy 2010 - Lantmäteriet's strategic plan 2011-2020

A strategic plan for Lantmäteriet's geodetic activities
2011 – 2020

Our vision

– is to be able to meet Swedish society's needs for a homogeneous, sustainable geodetic infrastructure and to guarantee its availability and use.

- Ultimate goal is to get a 5 mm (1 sigma) geoid model by 2020. Realistic? (depends also on method and theoretical limitations)
- Develop a new gravity network and system/frame, RG 2000**.**
- Improve the national gravity database of Lantmäteriet.
- 4000 new detail gravity measurements planned until 2015.
- Notice that the philosophy here is to try to save of as much as possible of the existing gravity data.

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Purpose and contents

- The purpose of this presentation is to describe the ongoing efforts to clean up the Swedish gravity infrastructure,
- and to analyse in what way the new measurements improve the computed gravimetric quasigeoid model.
- This will be made by comparing the Swedish gravimetric model KTH08 (underlying the national height correction model SWEN08_RH2000) with a preliminary version of the Nordic NKG2015 geoid model, for which new and updated Swedish gravity data have been utilised.
- Note that these two gravimetric models also differ due to many other factors. The NKG gravity database has for instance been thoroughly cleaned and updated (a very complex task).

Ongoing activities at Lantmäteriet

- The new gravity network/system RG 2000 is under construction, based mainly on the FG5 and A10 absolute gravity stations (not finished yet).
- A digital production line has been developed for detail gravity measurements using Scintrex CG5.
- Ice measurements were made on Lake Vänern in March 2010 (SGU) and in March 2011 (Lantmäteriet).
- Detail gravity data are now being collected in weak areas, for instance in Fjällen (Swedish mountains to the north).
- On-going project to compute the new Nordic geoid model NKG2015.
- Improvement of the gravity data and geoid in the Baltic Sea by gravity measurements on bathymetric surveying ships in the FAMOS Freja project.

Lantmäteriet's new CG5 detail gravity measurements

Foto: Andreas Engfeldt

- In the standard case, observations in 5 minutes using Scintrex CG5.
- Height and horizontal position measured using SWEPOS Network RTK and the national geoid model SWEN08_RH2000 (ell. height also stored for the future).

  => SWEREF 99 (ETRS89 realisation) and RH 2000 (EVRS realisation).
- Connection to A10/FG5 station in the morning and evening (at the very least)
- Will be computed in RG 2000 when this system is finished.
- Meanwhile, the final results are transformed to the old gravity system RG 82 (using the best available transformation also depending on the postglacial land uplift).

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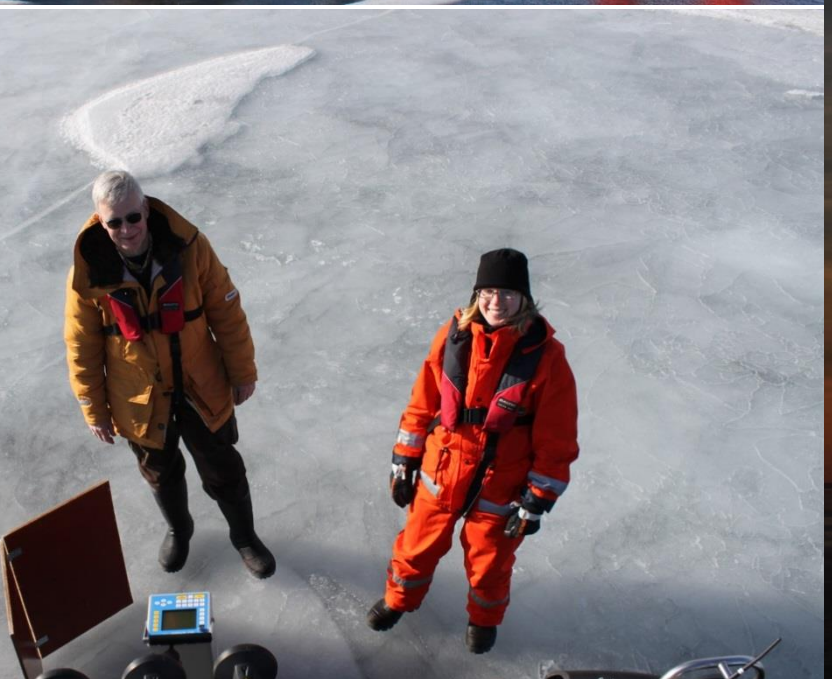
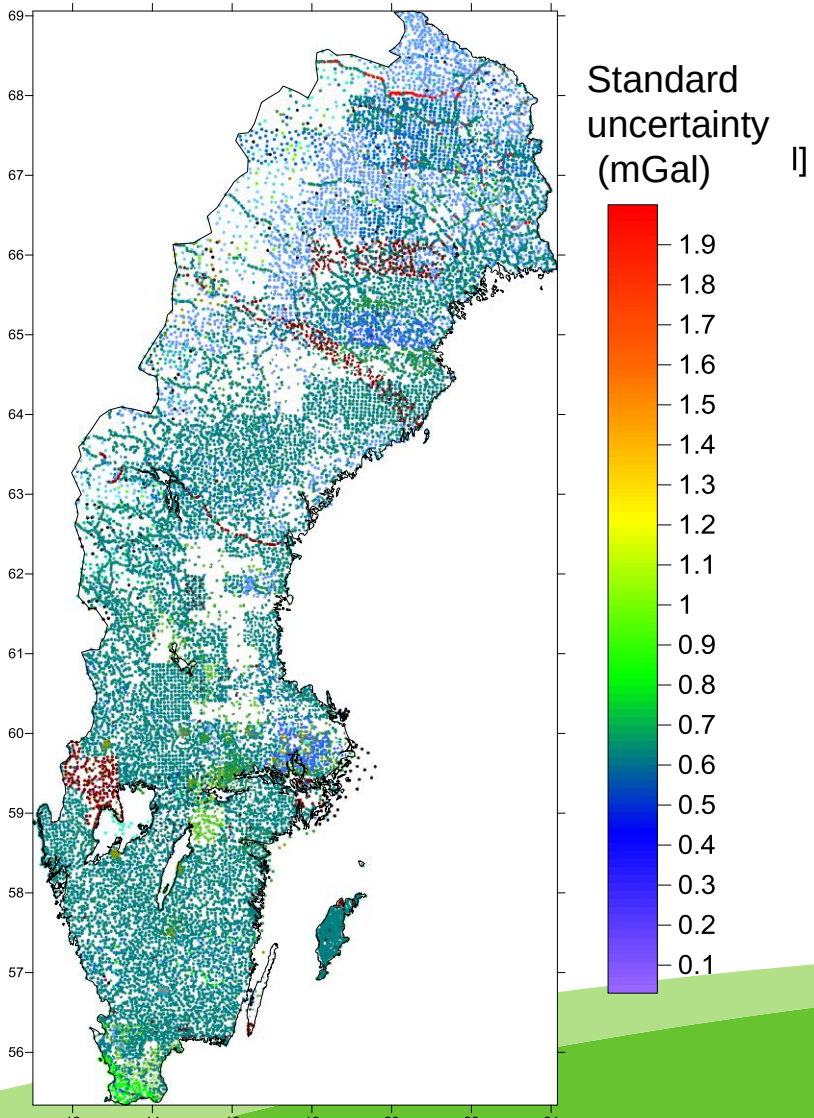
Gravity on Lake Vänern



Lantmäteriet's old detail gravity database

Situation in the old database before 2010 (around 26000 observations)



- Older gravity observers stored the standard uncertainties of both gravity and height in the Swedish gravity database (among other metadata).
- This seems to have been done in a comparatively careful way.
- This information have been used to compute the standard uncertainty of the gravity anomaly:

$$\sigma_{\Delta g} = \sqrt{\sigma_g^2 + \left(\frac{\partial \gamma}{\partial H^*}\right)^2 \sigma_{H^*}^2}$$

which is shown to the left.

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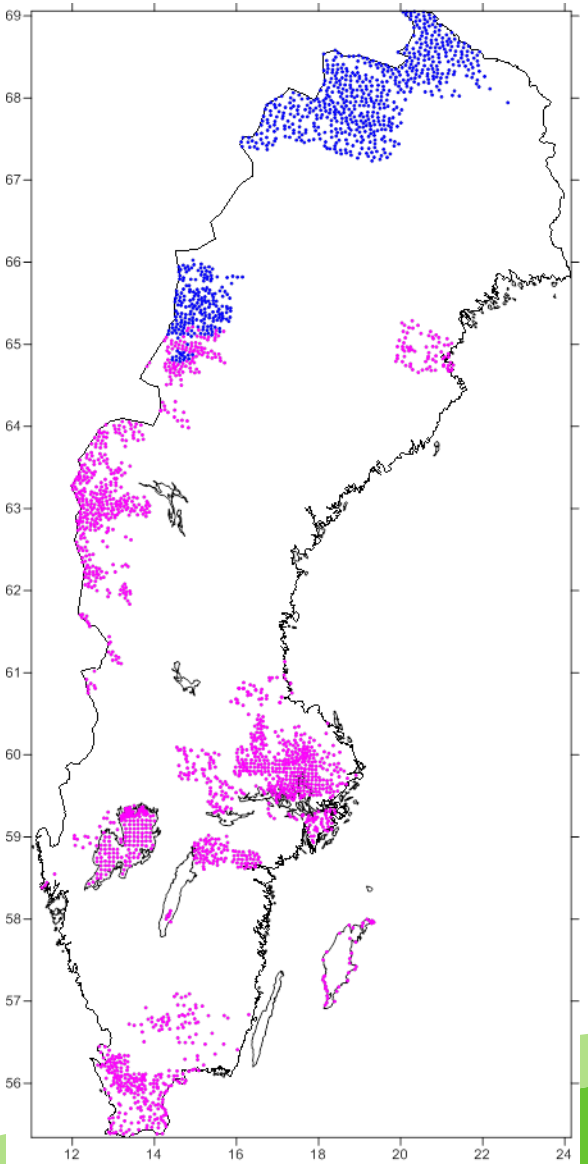
Selection of new CG5 points

New stations observed since 2010 (about 2563 observations)



- The location of the new CG5 points are chosen to get one good detail gravity value every 5 km.
- If an existing gravity value fulfils the following requirements,
  - Standard uncertainty of gravity lower than 1 mGal.
  - Standard uncertainty of height lower than 2 meters
  - Observed after 1960 (using Lacoste&Romberg or Scintrex CG5 gravimeter)

  then it is counted as good (with some exceptions, of course)
- We also plan to re-measure a selection of good points and smaller areas as a check, but this comes later after we have connected everything to the upcoming gravity system RG 2000.
- Only the 1754 purple observations are included in the comparisons below (in the NKG2015 geoid model)

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Computation of the gravimetric quasigeoid model KTH08

- Underlying gravimetric geoid model to the national height correction model SWEN08_RH2000 (adapted to the Swedish reference systems using GNSS/levelling).
- KTH08 was computed by the Least Squares Modification of Stokes' formula with Additive corrections (LSMSA or KTH-method; see Sjöberg 1991, 2003,…) in the way described in Ågren et al. (2009).
  - Least squares (stochastic) kernel modification (Sjöberg 1991).
  - Additive corrections for downward (analytical) continuation, atmosphere and the ellipsoidal correction.
  - Surface gravity anomalies gridded using a remove-interpolate-restore technique. EGM and RTM effects removed/restored. RTM effect computed using TC (Forsberg).
- The following observations were used:
  - Gravity observations from the NKG gravity database 2004 (with Lantmäteriet's old database above included - but also other old Swedish data).
  - GGM02C extended with EGM 96 from degree 201 to 360
  - Swedish photogrammetric DEM with 0.001x0.002 degrees resolution, SCANDEM_2004 DEM with 1 km resolution outside this.

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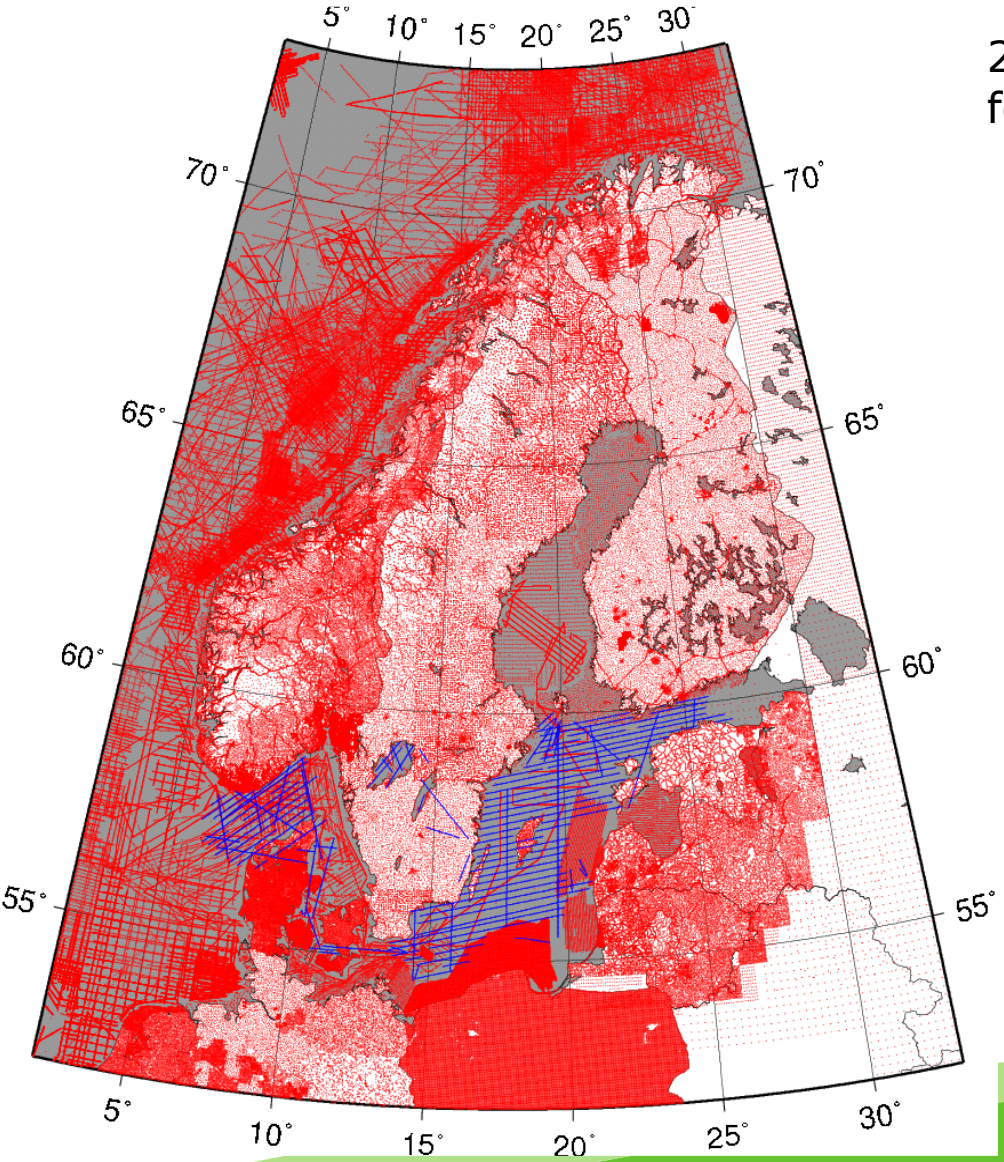
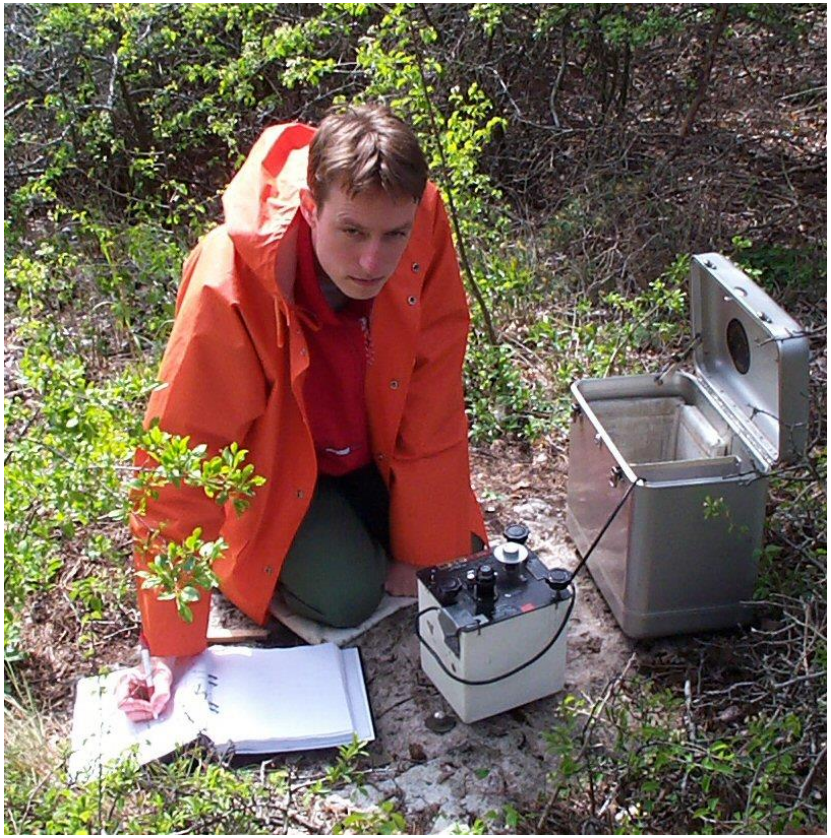
The NKG gravity database (2004 version)



270 204 gravity observations were used for KTH08 (SWEN08_RH2000)



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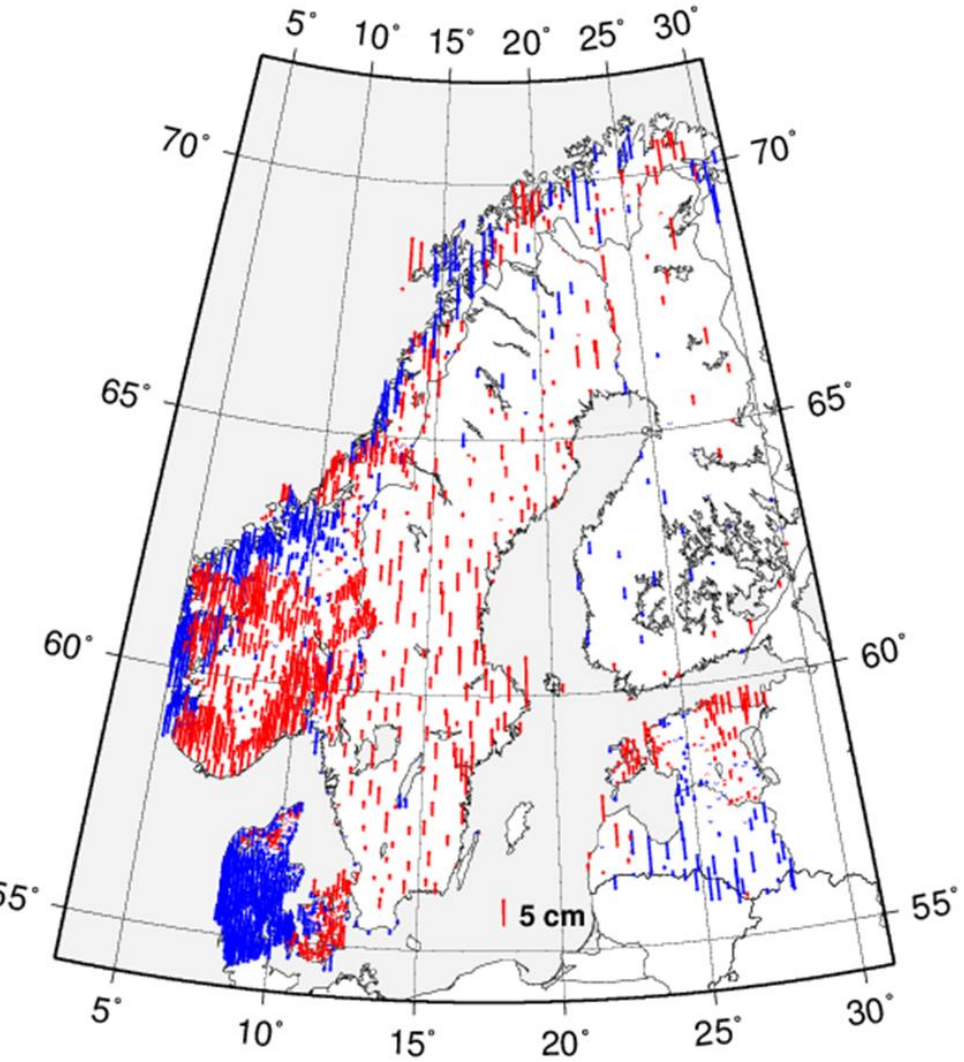
The NKG2015 geoid model project

GNSS/levelling residuals after a 1-parameter fit
NKG2015_prel_LS2_150312
(Using national EVRS realisations
with GNSS heights transformed to ETRF2000 epoch 2000)



- A new Nordic geoid model is presently being computed in Nordic and Baltic cooperation under the umbrella of NKG.
- Expected to be finished during 2015.
- Much efforts has been spent on updating the NKG databases for gravity and GNSS/levelling. A new NKG Digital Elevation Model (DEM) and ice thickness model have been produced
- The project is now in the computation phase. At least three computation centres will compute models using different methods. Then comparison and analyses.
- The preliminary results presented below have been computed using a similar method as for KTH08 (but with the satellite-only EGM GO_CONS_GCF_2_DIR_R5).

#	Min	Max	Mean	StdDev
1991	-0.135	0.143	0.000	0.028

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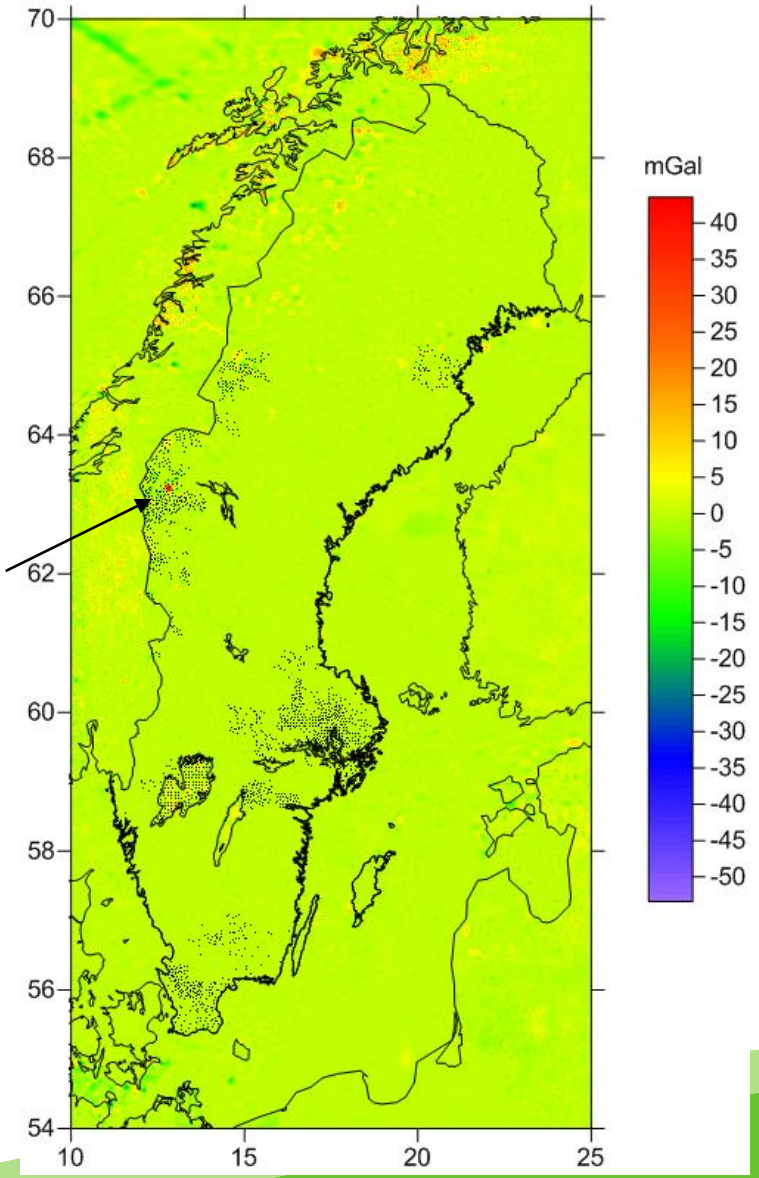
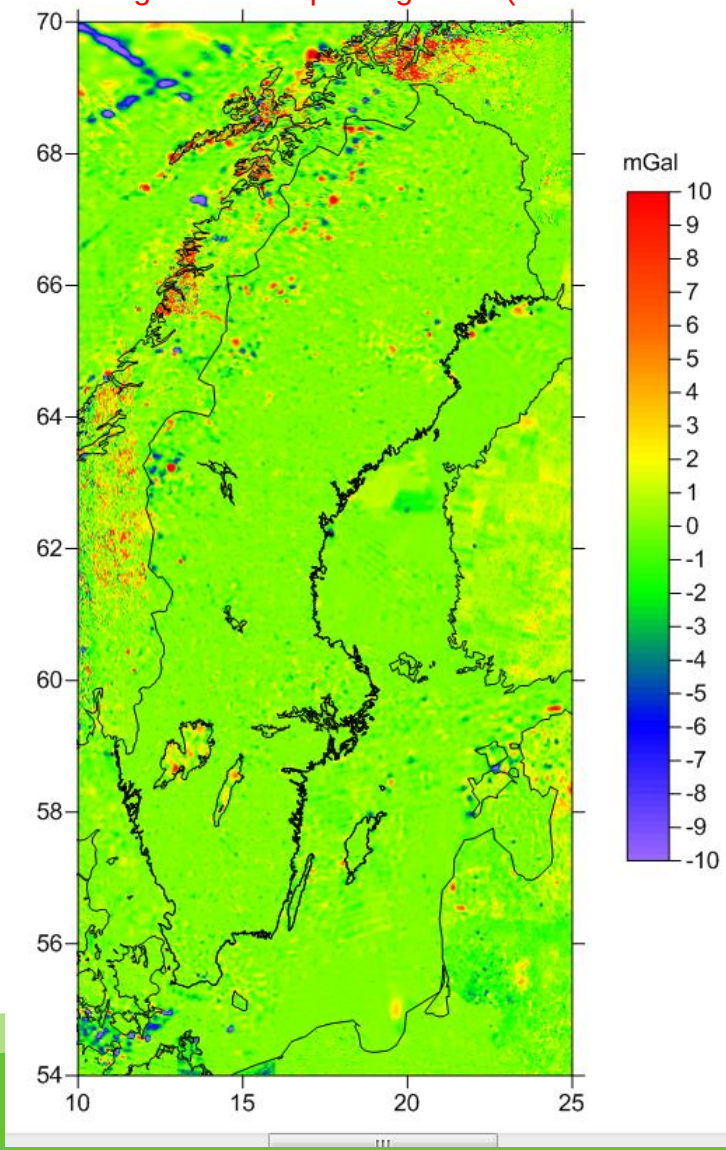
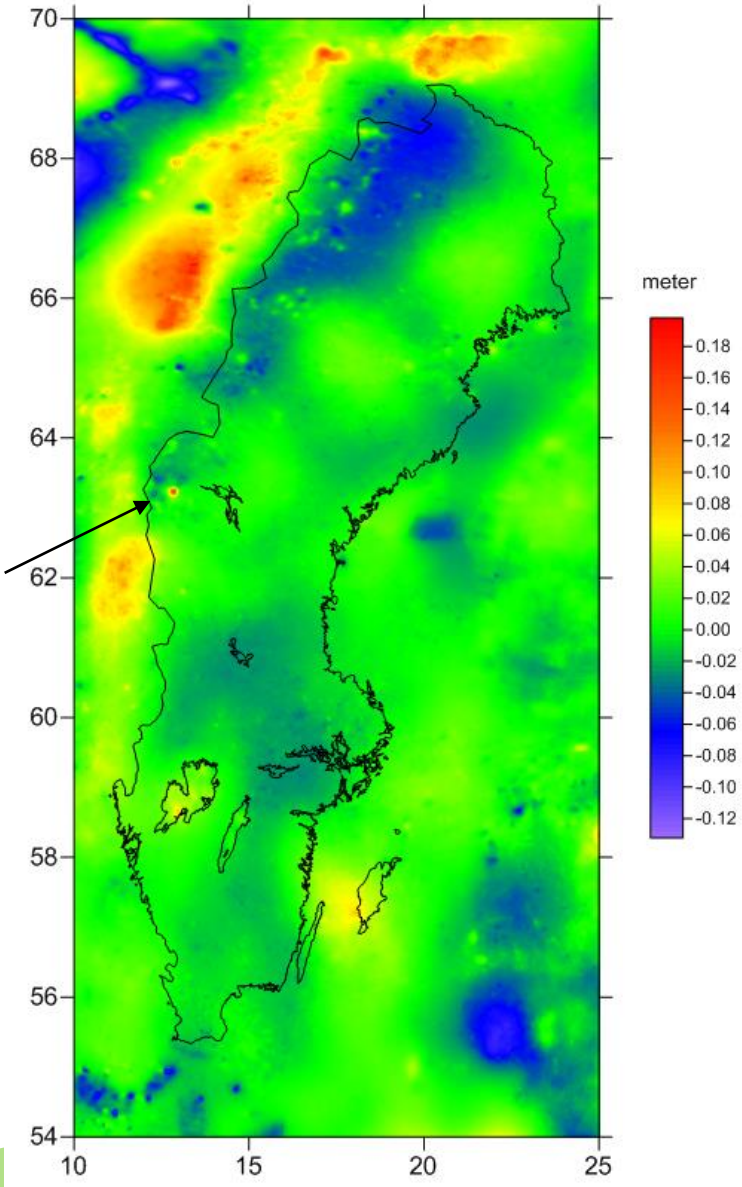
Surface gravity anomaly difference between KTH08 and the preliminary NKG2015 geoid (using the new Swedish CG5 data)



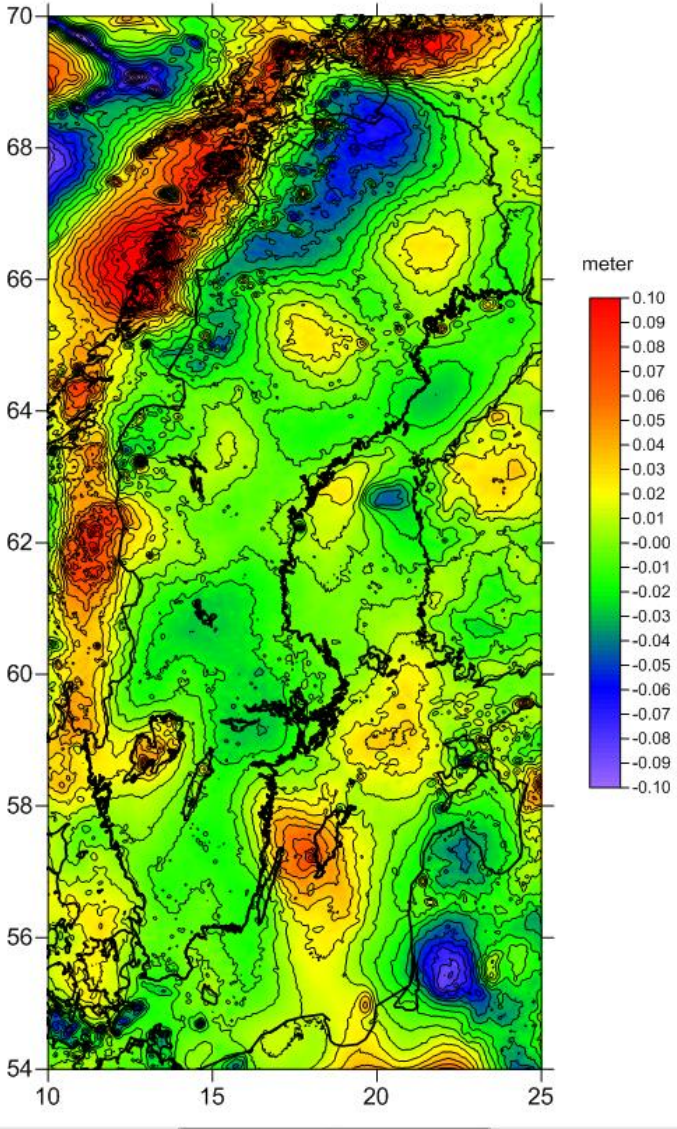
Using a different plotting scale (-10 to +10 mGal)



Height anomaly difference between KTH08 and the preliminary NKG2015 geoid (using the new Swedish CG5 data)

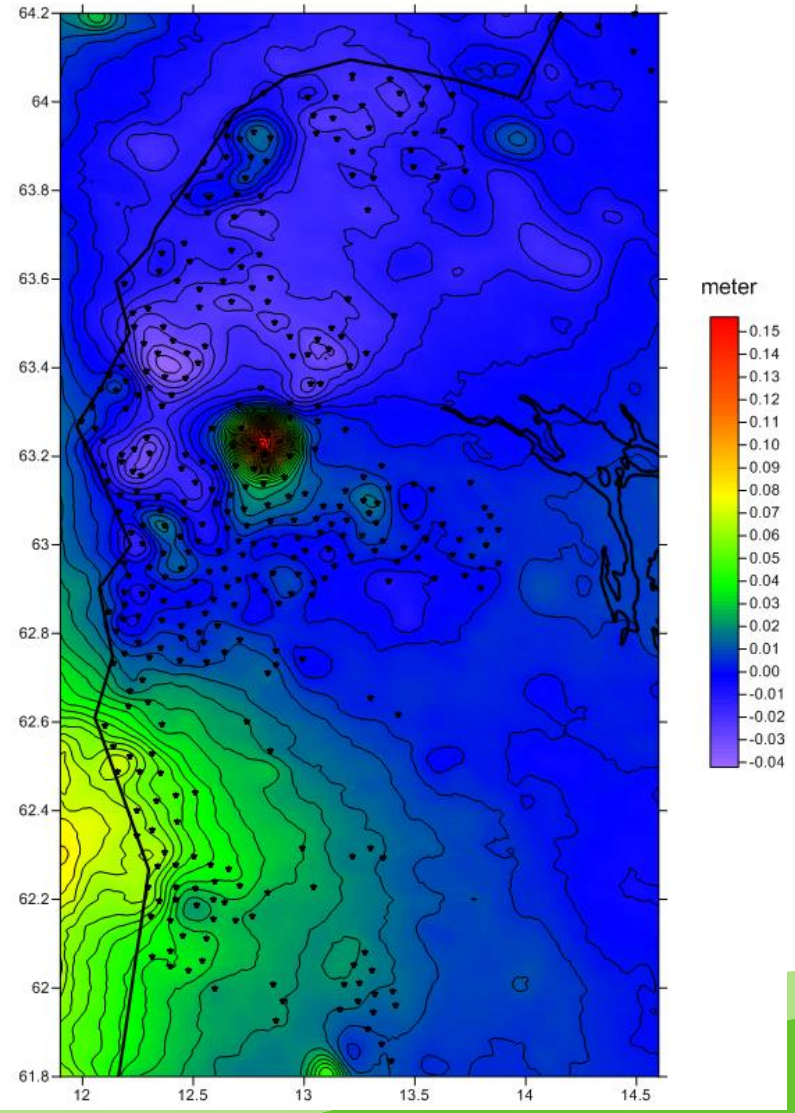


Using a different plotting colour scale (-10 to +10 cm)
1 cm contour lines:

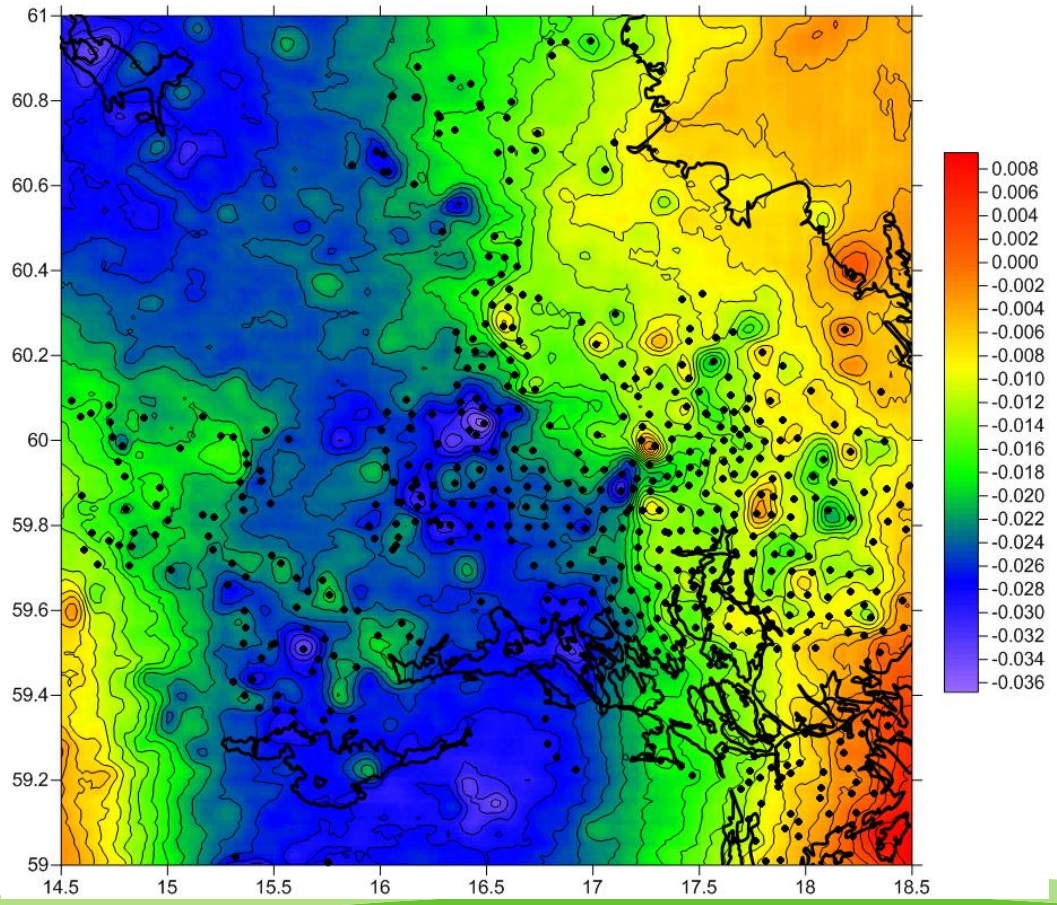


Height anomaly difference between KTH08 and the preliminary NKG2015 geoid (using the new Swedish CG5 data)

Jämtland, 5 mm contour lines



Uppsala, 2 mm contour lines



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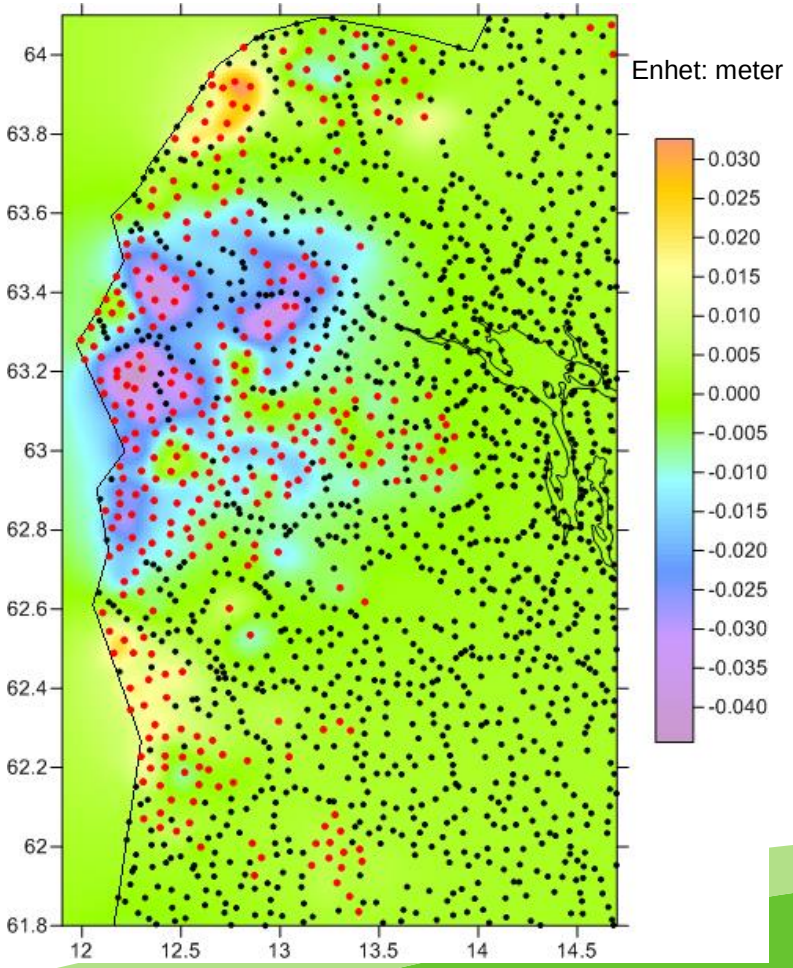
Comparison of adding the new CG5 observations using otherwise exactly the same computation

Red = new CG5
Black= Old remaining (high quality)

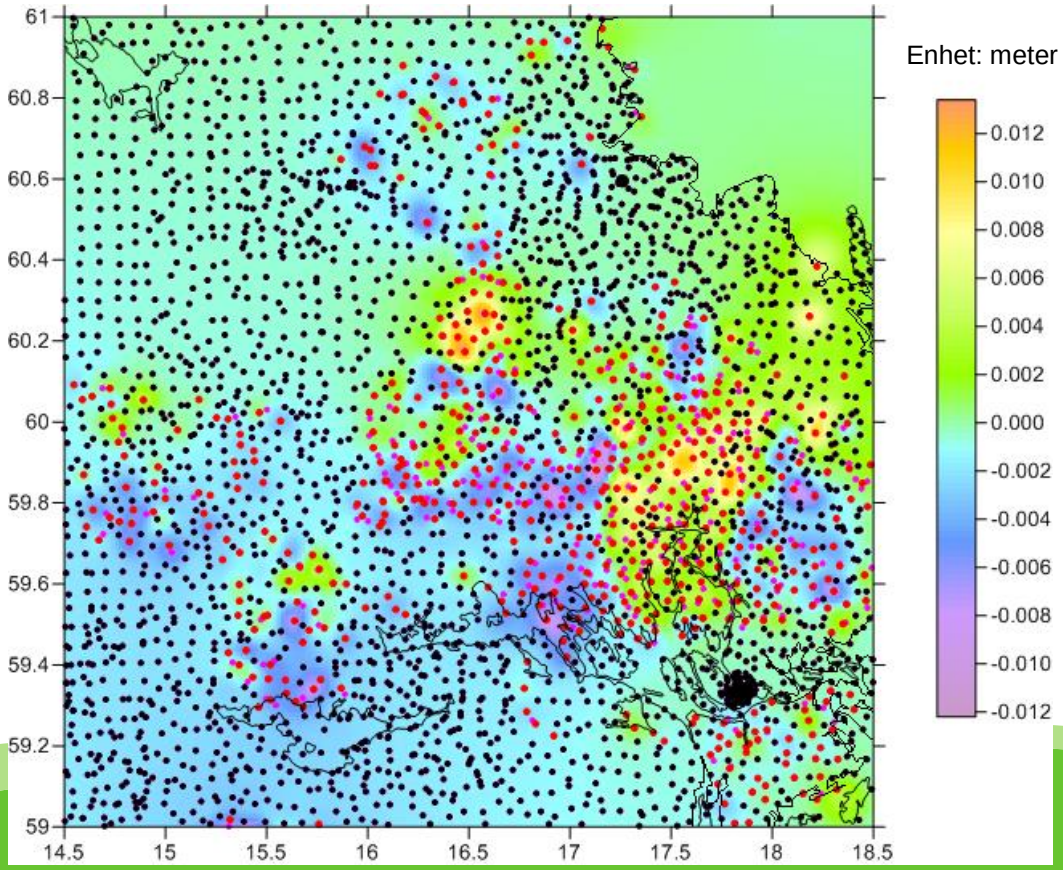
Large gross error eliminated.

When the new observations have been added, the old ones closer than 2 km from a new have been removed.

Jämtland



Uppsala



Conclusions

- The new CG5 gravity observations improve the result in their neighbourhood, but not as much as expected. The old data seem in several cases better than expected (after cleaning at least).
- One very large outlier has been discovered and removed (this is an interesting story).
- The cleaning both of the Lantmäteriet and NKG gravity databases for the NKG2015 geoid model project also yields significant improvements.
- The most notable differences/improvements are the long wavelength features, which depends on that different GGMs are used,
  - ✓ GGM02C for KTH08 (GRACE, combined)
  - ✓ GO_CONS_GCF_2_DIR_R5 for preliminary NKG2015 (GRACE and GOCE, satellite only)

  but also on that the NKG gravity database is now expected to include l less long wavelength errors.
- The kernel modifications are also tuned a little differently.
- Many large differences outside Sweden depends on that the target area for the old KTH08 was only Sweden (for instance, only 1 km DEM used in Norway).