Analysing methods of detailed gravity field modelling from terrestrial data

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Motivation

Gravity field models in a regional scale are needed for

- regional geoid computation
- processing of precise levelling data
- geological mapping and modelling
- etc.

Aim

Investigating the influence of

1. using different gridding methods
2. including realistic or unit weights
3. resampling dense gravity data according to estimated uncertainty values
4. including new gravity data with higher accuracy

in regional geoid modelling.

1. FFT vs. LSMSA
   - BM + SURF + FFT (2011)
   - KRIG + LSMSA (2011)
2. Unit vs. realistic weights
   - BM (unit weights) + SURF (2011)
   - BM (realistic weights) + SURF (2011)
3. BM vs. FILT
   - BM + SURF + FFT (2014)
   - FILT + SURF+ FFT (2014)
4. EGA2014 vs. EGA2011
   - BM + SURF + FFT (2014)
   - KRIG+ LSMSA (2011)

Methods of creating a free-air anomaly (FAA) grid

KRIG

Using ordinary **KRIG**ing on complete Bouguer anomalies from which to calculate an FAA grid [1].

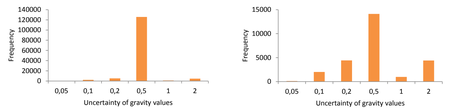
BM + SURF

Using the Generic Mapping Tools (GMT) ***B**lock**M**ean* and ***SURF**ace* (with T=0.25) modules [2].

FILT + SURF

FILTering gravity data (in some areas as dense as 4 p/km²) so that in each 1x1 km² cell would remain only the most accurate gravity data point*.

Fig. 1: No. of points with different uncertainty values in EGA2014 before (left) and after (right) filtering:



*As an advanced version a number (e.g. 4) of the most accurate points should be kept to minimize the effect of possibly erroneous points.

Methods of geoid computation

FFT

Using the GMT *grd**FFT*** module to perform a planar Fast Fourier Transformation [2] after removing the global FAA signal using the GO_CONS_GCF_2_TIM_R3 [3]. This rapid method is useful for test computations.

LSMSA

Using **L**east **S**quares **M**odification of **S**tokes Formula with **A**dditive Corrections [4].

Test data

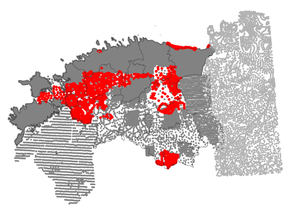
EGA2011

The gravity database used for calculating GRAV-GEOID2011 covering an area of 14°...35° E and 51°...64° N [6].

EGA2014

The Estonian gravity database in 2014 (areas not covered were filled with EGA2011).

Fig. 3: EGA2014; new gravity data gathered since 2011 in red, corrected data in the East in lighter gray



GRAV-GEOID2011

The official gravimetric geoid model of Estonia [5] covering an area of 20°...30° E and 57°...60° N computed using LSMSA.

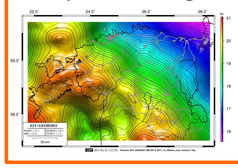
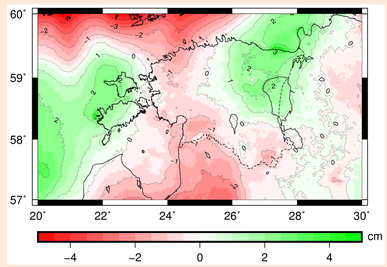


Fig. 2: GRAV-GEOID2011

1. FFT vs. LSMSA



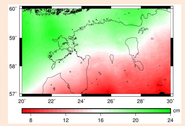
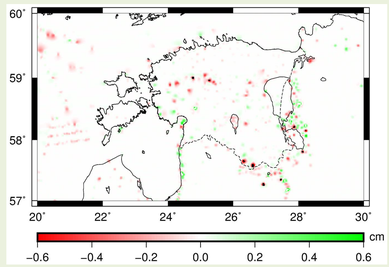


Fig. 4: BM + SURF + FFT (2011) minus KRIG + LSMSA (2011)

Fig. 5: After removing a linear trend from Fig. 4

>> The effect of using a simpler FFT process instead of a more correct LSMSA calculation remains within ±3 cm in the reasearch area.

2. Unit vs. realistic weights



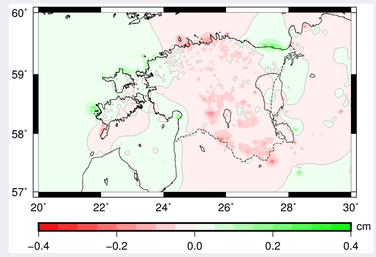
Realistic weights ≈ 1/(stdev)²,
where stdev is the standard deviation of the gravity value.

Fig. 6: BM (unit weights) + SURF (2011) minus BM (realistic weights) + SURF (2011)

>> The effect of using realistic weights instead of unit weights in the BM process is local and remains within ±2 cm while in most areas is in the order of a few mm.

3. BM vs. FILT

Fig. 7: BM + SURF + FFT (2014) minus FILT + SURF + FFT (2014)



>> The effect of filtering gravity data according to estimated uncertainty values instead of using the BM averaging process remains within ±4 mm.

4. EGA2014 vs. EGA2011

Fig. 9: After removing Fig. 4 from Fig. 8 i.e. removing the effect of using different computation methods

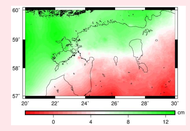
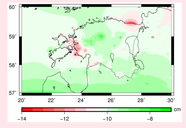


Fig. 8: BM + SURF + FFT (2014) minus KRIG + LSMSA (2011)



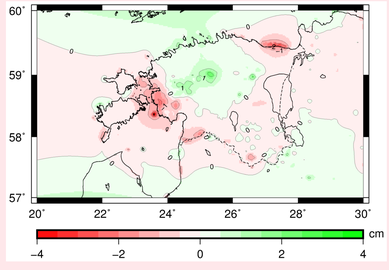


Fig. 10: After removing a linear trend from Fig. 9

>> New gravity data changes the geoid model significantly, especially in central and West Estonia and near the terrace in the North where the effects are over ±2 cm.

Conclusions

- FFT can be used for quickly analysing different data processing methods (a trend surface caused by differences of methods needs to be removed from comparisons to reduce the effect of using a simpler FFT approach).
- Realistic weighting has a local and relatively small effect in Estonia where the gravity data is quite homogenous on land; the effect might be more signifacnt in areas of more heterogenic data.
- Filtering gravity data according to its uncertainty has very little effect on the resulting geoid model making it possible to reduce large datasets without significant loss of accuracy.
- Improved gravity data (EGA2014 vs. EGA2011) can change the next Estonian regional geoid model by quite a few cm in the final geoid modelling process.

References:

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