

The New Swedish Height System RH 2000 and Geoid Model SWEN 05LR

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XXIII FIG Congress
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The third precise levelling of Sweden

- 1979 – 2003
- Approximately 50 000 km double run precise levelling
- Around 50 000 benchmarks
- Motorised levelling



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Definition of RH 2000

- It was decided that RH 2000 should be defined as the Swedish realisation of EVRS.
- In agreement with the available EVRS definition in 2005 (which is rather general),
 - ✓ normal heights are utilised and
 - ✓ a zero system is applied for the permanent tide.
- To be as "European" as possible, the Normaam Amsterdams Peil (NAP) is used as zero level (as for EVRF 2000).
- The reference epoch is chosen to 2000.0 on the Nordic level (NKG).
- The postglacial land uplift model is constructed as a combination of
 - ✓ The geophysical model of Lambeck, Smither and Ekman (1998).
 - ✓ The early 2005 version of the mathematical (empirical) model of Olav Vestøl.

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The Baltic Levelling Ring (BLR)

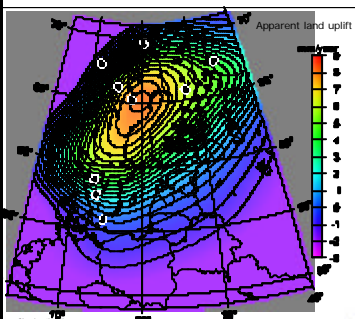
- The latest precise levellings from all the Nordic and Baltic countries as well as Poland, Germany and the Netherlands.
- The processing has been made as a Nordic cooperation within the Working Group for Height Determination of the Nordic Geodetic Commission (NKG).
- A new developed model of the post glacial rebound (land uplift) has been applied.



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The geophysical land uplift model of Lambeck et al. (1998)



Adjusted to fit

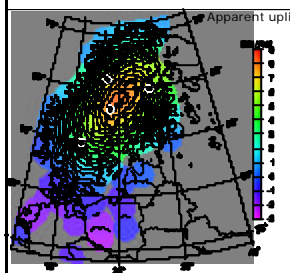
- ✓ the land uplift from the tide gauges of Ekman (1996).
- ✓ some lake level observations.
- ✓ ancient shore lines.

The digitised version (NKG) is here assumed as Lambeck's model

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Vestøl's model (January 2005)



Observations:

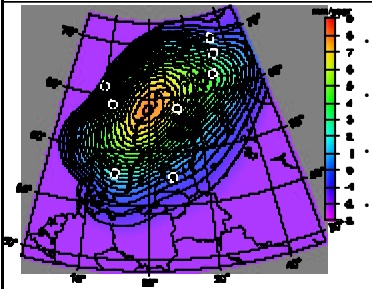
- ✓ Tide gauges (Ekman 1996)
- ✓ Permanent GPS (Lidberg 2004)
- ✓ (Repeated) Levelling from Finland, Norway and Sweden (Saaranen, Vestøl and Svensson).

Least squares collocation with unknown parameters to estimate the uplift in the observation points.

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RH 2000 LU/NKG2005LU

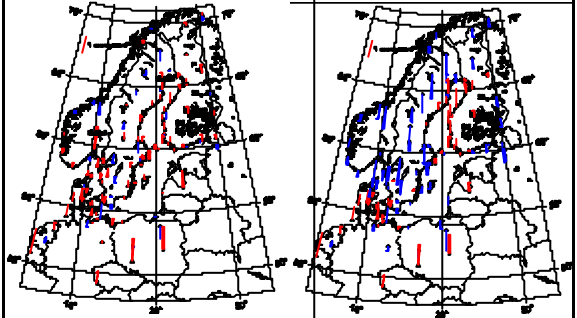


- A combination of the models of Vestøl and Lambeck.
- A smoothed version of Vestøl's model in the central parts of the area
- A smooth transition to Lambeck's model in the outskirts.
- The model RH 2000 LU was adopted as the Nordic model NKG2005LU

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NKG2005LU vs Lambeck

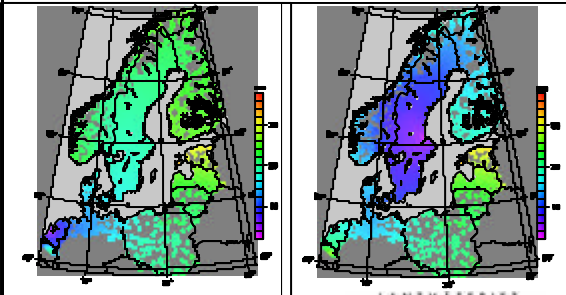


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Accuracy of the BLR Heights

standard error relative NAP

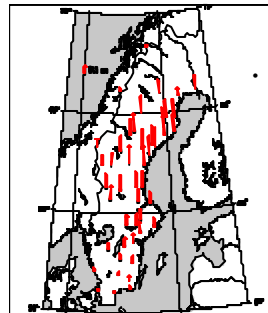
standard error relative Gävle



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Difference between RH 2000 and EVRF 2000

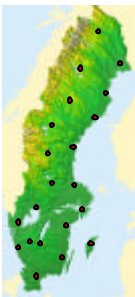


- Large differences due to the different land uplift epochs (1960/2000)

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SWEREF 99



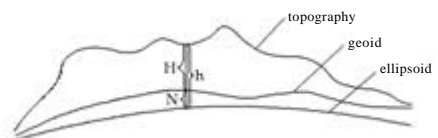
- A 3-dimensional Reference System
- Internal accuracy: on centimeterlevel
- SWEREF 99 is a certified EUREF-solution in agreement with other european ETRS 89-realizations on the 1-5 cm level.
- Ellipsoid: GRS 1980, Epoch: 1999.5, Tectonic Plate Epoch: 1989.0
- Based on 21 permanent reference stations for GPS (SWEPOS) as well as data from a number of stations in our neighbouring countries.

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Geoid Model SWEN 05LR

- National Geoid Model adapted to SWEREF 99 (3-D) and the Vertical Reference System RH 2000 (1-D).
- Is used to convert heights above ellipsoid h , captured by GPS, to "heights above sea-level" H



$$H_{RH2000} = h_{SWEREF99} - N_{SWEN05LR}$$

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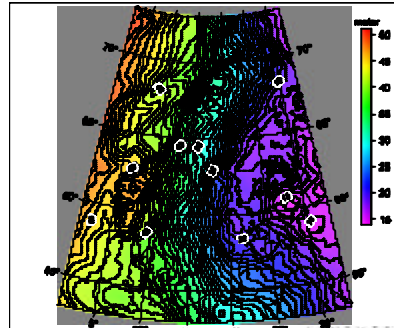
How was SWEN 05LR created?

- Combined gravimetric and geometric geoid determination
- Based on the gravimetric geoid NKG 2004
- Adapted to 1178 GPS/levelling points Corrected for land uplift (0.5 yr) ((and permanent tidal system for h : non-tidal => zero))
- Integrated with a model of the residuals on GPS/levelling observations

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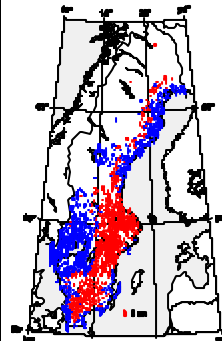
Illustration of NKG 2004



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Residuals



- The gravimetric model (NKG 2004) has been corrected with the *mean value* of the deviations from GPS/levelling (1-parameter shift)

Statistics residuals [m]:

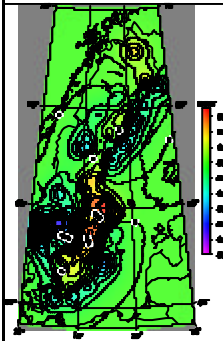
#	Min	Max	Mean	Std dev
1178	-0.151	0.097	0.000	0.037

- A clear systematic distribution. Very likely indications of long wavelength errors in the gravimetric geoid model (NKG 2004).

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SWEN 05LR: Residual Surface



- To reduce (adjust) the influence from errors in GPS-observations a comparably smooth surface is used.

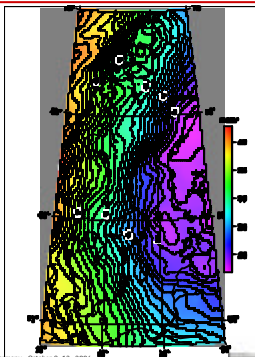


- Interpolation/extrapolation: Collocation with apriori standard deviations 10, 20, 30 mm representing different orders of accuracy of GPS/levelling observations.
- Covariance function using 50 km length of correlation.

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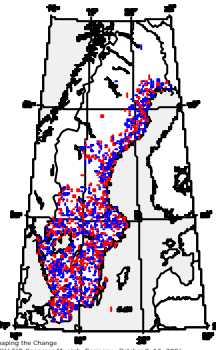
Illustration of SWEN 05LR



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SWEN 05LR: Accuracy



- Crossvalidation
 - One GPS/levelling observation point is excluded
 - A geoid model is computed without the excluded observation point
 - The difference between the interpolated and the given value in the excluded point is computed
 - The procedure is repeated until all points has been excluded, one at a time.
- Statistics Crossvalidation [m]

#	Min	Max	Mean	Std dev
1178	-0.056	0.052	0.000	0.013

- Gives a fairly good estimation of the real accuracy in areas with GPS/levelling observations.

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Summary

- **RH 2000** is defined as the Swedish realisation of **EVRS**.
- The RH 2000 adjustment was made using data from the whole Baltic Levelling Ring (BLR) with the Normaal Amsterdams Peil (**NAP**) as zero level .
- All levelling observations are reduced for the postglacial rebound to the reference **epoch 2000.0** using the newly developed land uplift model **NKG2005LU** .
- The difference between RH 2000 and **EVRF 2000** is large due to the different land uplift epochs for the Nordic block.
- A combined gravimetric/geometric Geoid Model, **SWEN 05LR** was developed as a link between the national 3-D and vertical Reference Systems.