Computation of a new gravimetric geoid model over Sweden using the KTH method

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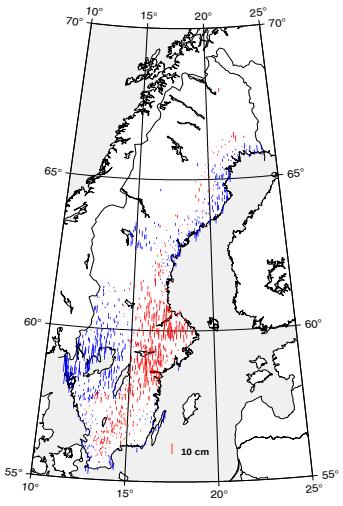
The Swedish geoid model* SWEN05_RH2000

NKG 2004 (1–par), 1178 res



- Official model since 2005
- Adapted to SWEREF 99 and RH 2000
- NKG 2004 gravimetric model (R-C-R with the RTM reduction, GRAVSOFT)
- Residual interpolation
- GPS/levelling geoid heights:

Table 1: The GPS/Levelling observations and their approximate standard errors.

Data set	#	Short description	Approximate standard errors (mm) GPS height	Normal height	Height anomaly
SWEPOS	20	Permanent GPS stations in the SWEPOS network, whose coordinates define SWEREF 99 (Jivall 2001)	5-10	5-10	7-14
SWEREF	88	Determined relative to SWEPOS using 48 hours of observations, DM T antennas and the Bernese software.	10-20	5-10	11-22
RIX 95	1070	Densification of the above stations using static GPS with 0.5-1.0 hours of obs. per session. Network adjustment.	15-30	5-10	16-32

*) The term *geoid model* is used even though the model is really a quasigeoid model.

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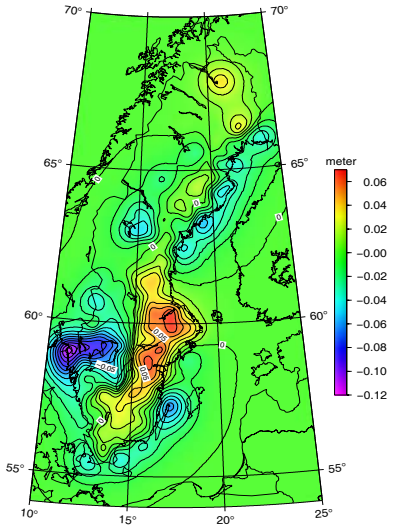
SWEN05_RH2000 residual surface



- 1-parameter shift and a smooth residual surface.
- Least squares collocation (GEOGRID) with 50 km correlation length.

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Accuracy of SWEN05_RH2000

Area	Approximate standard error (1 sigma) [mm] SWEN05_RH2000
Areas with dense GNSS/levelling	15 – 20
Reasonably flat areas	30 – 40
Rough mountain areas to the north-west	50 – 100
Gotland	-

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Recent work to improve the Swedish geoid model

- Started in 2005.
- Computation of an improved gravimetric model using the KTH method. Cooperation between Lantmäteriet and KTH (Prof. Lars E Sjöberg's group)
- Extended GPS/levelling data covering the whole country.
- Extension to Gotland, where RH 2000 was recently established.

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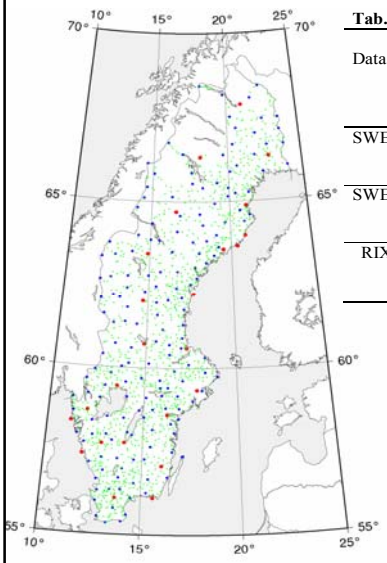
Updated GPS/levelling



Tab.1. *The GPS/Levelling observations and their approximate standard errors.*

Data set	#	Short description	Appr. standard errors (mm)		
			GPS height	Normal height	Height anomaly
SWEPOS	24	Permanent GPS stations whose coordinates define SWEREF 99 (Jivall 2001)	5-10	5-10	7-14
SWEREF	171	Determined relative to SWEPOS using 48 hours of obs, DM T antennas and the Bernese software	10-20	5-10	11-22
RIX 95	1362	Densification of the above stations using static GPS with 0.5-1.0 hours of obs. per session. Network adjustment	15-30	5-10	16-32

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The KTH method

The Least squares modification of Stokes' formula (stochastic kernel modification) with additive corrections.

- The height anomaly is computed as

$$\zeta = \frac{R}{4\pi\gamma}\iint_{\sigma_0} S^M(\psi)\Delta g\, d\sigma + \frac{R}{2\gamma}\sum_{n=2}^{M}\left(s_n + Q_n^M\right)\Delta g_n^{GGM} + \delta\zeta_{DWC} + \delta\zeta_{ATM} + \delta\zeta_{ELL}$$

$S^M(\psi)$ is the modified Stokes' function chosen according to Sjöberg (1991).

$\delta\zeta_{DWC}$ includes analytical continuation to point-level of both the gravity anomalies (Moritz 1980) and the spherical harmonic expansion; cf. Sjöberg (2003) and Ågren (2004).

$\delta\zeta_{ATM}$ is the atmospheric correction (Sjöberg and Nahavandchi 2000).

$\delta\zeta_{ELL}$ is the ellipsoidal correction (Sjöberg 2004).

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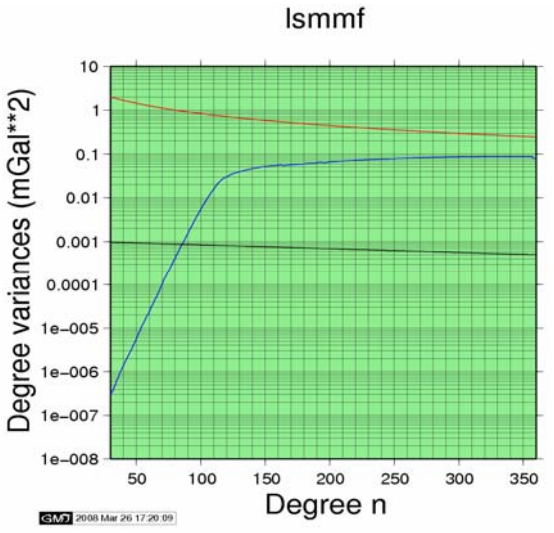
Choice of error degree variances



- We characterise the weightings by the spherical harmonic degree *K,* for which the error degree variance of the GGM is equal to that of the terrestrial gravity anomaly. For lower degrees the GGM is more accurate and vice versa.
- K≈65-85 yields the best fit to GPS/levelling. K=85 is chosen for the final model.

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Practical steps in the computation

- Collection and choice of Data
  - Surface and air gravity observations from the NKG-database.
  - GGM02C extended with EGM 96 from degree 201 to 360.
  - Swedish photogrammetric DEM with 100mx100m resolution.
    The Scandinavian DEM from the NKG 2004 computation (sdem2004.01).
    SRTM30plus to extend the model to the south.
- Gridding of the surface gravity anomalies
  - The gravity anomalies are first reduced for the long-wavelength effect from the GGM and the high-frequency effect from the topography (RTM reduction)
  - Gross error detection.
  - The residual gravity anomaly is gridded using Kriging/Collocation, 15 km corr. length. Comparatively dense grid used (0.01°x0.02°).
  - The reduced effects are finally restored.
- Geoid heights in a regular grid are finally estimated using the above theory. Haagman's 1D-FFT to evaluate Stokes' integral.

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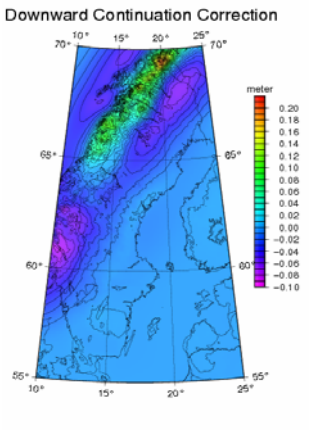
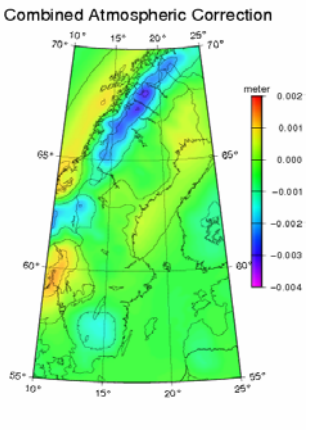
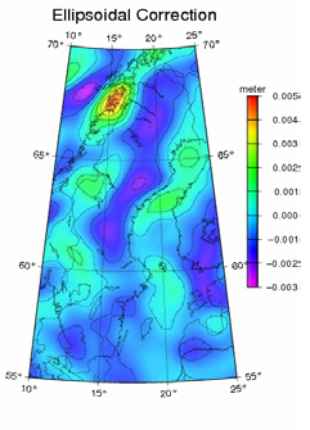
Additive corrections







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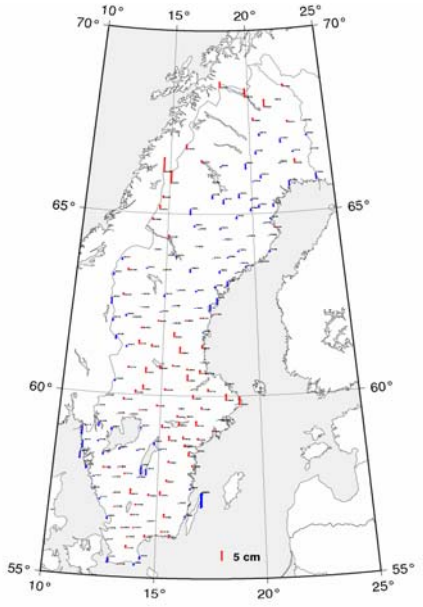
GPS/levelling residuals



- Residuals after 4-parameter fit/transformation
- Statistics:

#	Min	Max	Mean	StdDev	RMS
195	-0.074	0.070	0.000	0.020	0.020

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Final words

- A new improved gravimetric model has been computed using the KTH method.
- The Swedish GPS/levelling observations has been updated so that they now cover the whole of Sweden.
- The very good fit (RMS ≈ 2 cm) to GPS/levelling indicates that the reference systems (SWEREF 99/RH 2000) **and** the gravimetric model are of high quality.
- The gravimetric model will be used to compute the next official Swedish geoid model, SWEN08_RH2000.
- A smooth residual surface will be used as before, but now the magnitude of the residual corrections will be much smaller.

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