

# National Report of Sweden to the EUREF 2006 Symposium

## - geodetic activities at Lantmäteriet, the National Land Survey of Sweden

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### 1. Introduction

At Lantmäteriet (the National Land Survey) the activities in the fields of geodetic reference frames and geodetic reference networks are focused on introducing the ETRS 89<sup>1</sup> realisation SWEREF 99, introducing the national height system RH 2000, improving our geoid models and the ongoing project RIX 95. Large efforts are also carried out concerning the operation and expansion of the Swedish network of permanent reference stations SWEPOS<sup>TM</sup>. Some of the activities are done within the framework of NKG<sup>2</sup>.

### 2. Contributions from Lantmäteriet to EPN<sup>3</sup>, ECGN<sup>4</sup> and EUVN\_DA<sup>5</sup>

Seven SWEPOS stations are included in EPN. The stations are Onsala,

Mårtsbo, Visby, Borås, Skellefteå, Vilhelmina and Kiruna (ONSA, MAR6, VIS0, SPT0, SKE0, VIL0 and KIR0). Both daily and hourly data are delivered.

Furthermore, Onsala, Mårtsbo, Visby, Borås and Kiruna are also included in the IGS<sup>6</sup> network. Skellefteå (SKE0) is proposed to be a new IGS station. All the Swedish EPN/IGS stations are equipped with dual-frequency GPS<sup>7</sup>/GLONASS<sup>8</sup> receivers and Dorne Margolin antennas.

Lantmäteriet operates the NKG EPN Analysis Centre in co-operation with Onsala Space Observatory.

Sweden has, according to the co-ordination made within the framework of NKG, offered all seven Swedish EPN stations except Vilhelmina for ECGN. NKG has also created a Nordic

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<sup>1</sup> ETRS 89 = European Terrestrial Reference System 89

<sup>2</sup> NKG = Nordic Geodetic Commission

<sup>3</sup> EPN = EUREF Permanent Network

<sup>4</sup> ECGN = European Combined Geodetic Network

<sup>5</sup> EUVN\_DA = European Vertical Network, Densification Action

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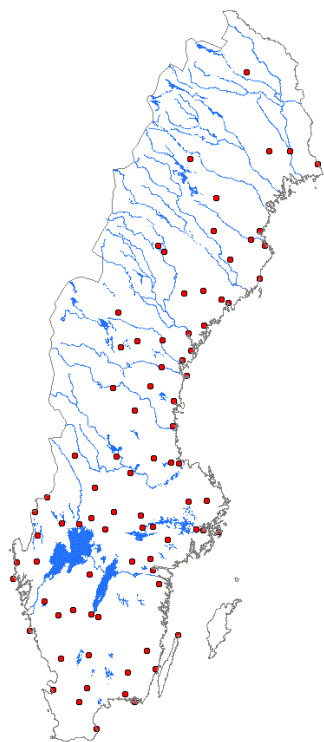
<sup>6</sup> IGS = International GPS Service

<sup>7</sup> GPS = Global Positioning System

<sup>8</sup> GLONASS = Globalnaya Navigatsionnaya Sputnikovaya Sistema

densification called NGOS<sup>9</sup> (Poutanen et al, 2005).

Sweden has delivered 84 stations to the EUVN\_DA, see figure 1. The normal heights and geopotential numbers are given in epoch 2000.0 and are reduced for land-uplift using the NKG2000LU model. The estimated accuracy of the given gravity values is generally about 1-2 mgal (68 % conf. level). In connection with the ongoing densification of SWEREF 99 there will "soon" be an additional update for the northern parts of the country.



*Figure 1: Swedish EUVN\_DA sites (Jan, 2006)*

### 3. ETRS 89 realisations in Sweden and a common Nordic reference frame

SWEREF 99 was adopted by EUREF as the Swedish ETRS 89 realisation at the

EUREF 2000 symposium in Tromsö (Jivall & Lidberg 2000).

A common Nordic reference frame in ITRF 2000 epoch 2003.75 has been established within the framework of NKG (Jivall et al, 2005). It will not replace the national ETRS 89 realisations in the Nordic Countries, but is proposed to replace the ETRS 89 realization of EUREF-BAL'92 in Latvia and Lithuania (after reduction to ETRS 89). The common Nordic reference frame will act as a node in the transformations between ITRF and the national ETRS 89 realizations.

A velocity model has been developed for use in the transformations (NKG\_RF03vel). The north and east components origin from the Glacial Isostatic Adjustment (GIA) model presented in Milne 2001. The velocity field from this model has been transformed to the GPS-derived velocity field in Lidberg [2004]. Thus, the horizontal velocity field in the grid files describe horizontal displacements relative to stable Eurasia as defined by the ITRS2000 and its rotation pole for Eurasia (Altamimi et al., 2003).

For the up component has the NKG2005LU(ABS) model been used. This model origins from the NKG2005LU(APP) model – see section 7.

The implementation of SWEREF 99 is dealt with in section 6.

### 4. Network of permanent reference stations (SWEPOS™)

SWEPOS is the Swedish network of permanent GNSS<sup>10</sup> stations providing real-time services on both meter level

<sup>9</sup> NGOS = Nordic Geodetic Observing System

<sup>10</sup> GNSS=Global Navigation Satellite Systems

(DGPS/DGNSS) and cm level (network-RTK, regional coverage) as well as data for post-processing. (Kempe et al. 2004).

SWEPOS also offers an automated post-processing service, based on the Bernese software (Kempe & Jivall 2002), see [www.swepos.com](http://www.swepos.com). The purpose of SWEPOS is to:

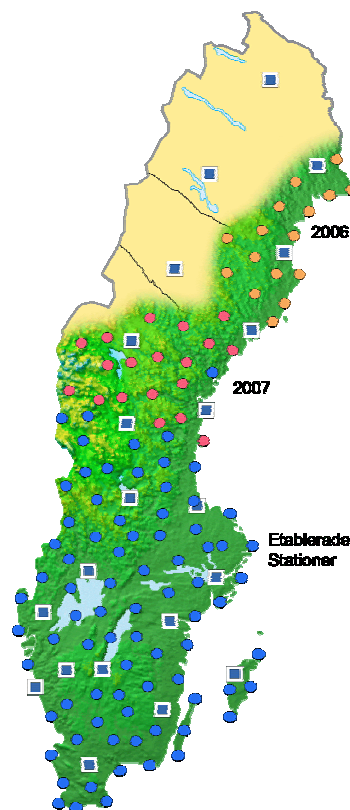
- provide single- and dual-frequency data for relative GNSS measurements.
- provide DGPS<sup>11</sup>/DGNSS<sup>12</sup> corrections and RTK<sup>13</sup> data for distribution to real-time users.
- act as the continuously monitored foundation of the Swedish geodetic reference frame SWEREF 99.
- provide data for geophysical research.
- monitor the integrity of the GNSS systems.

Most of the 21 fundamental stations have been in operation since autumn 1993 (the last one was added 1996). These stations are monumented on bedrock and have redundant equipment for GNSS observations, communications, power supply, etc. They have also been connected by precise levelling to the national precise levelling network.

The rest of the stations are mainly established on top of buildings for network RTK purposes but have a

variety of instrumentation and monumentation.

The total number of SWEPOS stations is 105 and another 16 stations will become operational during June 2006. All SWEPOS stations are equipped with dual-frequency GPS/GLONASS<sup>14</sup> receivers and with antennas of Dorne Margolin type.



**Figure 2:** The SWEPOS network in May 2006. Squares are the 21 fundamental SWEPOS stations. Blue dots are the rest of the existing stations (except for a few densifications). Orange dots are stations that will become operational during June 2006 and red dots are the plan for expansion during 2007.

A regional network RTK service was launched on January 1<sup>st</sup> 2004. This service (SWEPOS Network RTK Service)

<sup>11</sup> DGPS = Differential GPS

<sup>12</sup> DGNSS=Differential GNSS

<sup>13</sup> RTK = Real Time Kinematic

<sup>14</sup> GLONASS = Globalnaya Navigatsionnaya Sputnikovaya Sistema

covers the most populated areas of Sweden and has today (June 2006) approximately 450 subscriptions. The intended coverage for 2007 is shown as the green area in figure 2, which includes the stations for the planned establishment project Mellan-RTK (red dots). The stations for Nordost-RTK (orange dots) will be operational during June 2006.

The service uses the network RTK software GPSNet from Trimble. GSM<sup>15</sup> is used as distribution channel, but since November 1<sup>st</sup> 2005, also wireless Internet (mainly GPRS<sup>16</sup>, but also UMTS<sup>17</sup> or WLAN<sup>18</sup>) can be used. Tests have also been made to broadcast the RTK data through satellite communication and this distribution channel is also possible to use. The satellite telephone service Global Star can also be used.

The establishment of a Nordic Positioning Service based on network DGPS is in progress within the framework of the NKG project Nordic Positioning Service.. Actions that have been carried out are the establishment of a computer network between the national control centres, the development of a Nordic web-portal for post-processing data and test measurements with network DGPS.

## 5. RIX 95

The project RIX 95 project involves GPS measurements on triangulation

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<sup>15</sup> GSM = Global System for Mobile communication

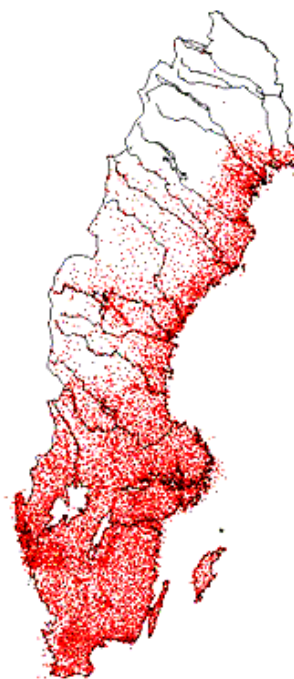
<sup>16</sup> GPRS = General Packet Radio Service

<sup>17</sup> UMTS = Universal Mobile Telecommunications System

<sup>18</sup> WLAN = Wireless Local Area Network

stations and selected local control points. It has been running since 1995. The work is financed by a group of national agencies. The principal aims are to connect local coordinate systems to the national reference frames (SWEREF 99 and RT 90) and to establish new points easily accessible for local GPS measurements.

Concerning the connection of local coordinate systems, transformation parameters based on different transformation models are developed. The parameters are mainly based only on direct projection with Transverse Mercator, but in some cases also combined with similarity transformations in two or three dimensions. Now (June 2006) transformation parameters for 220 of the 290 Swedish municipalities are available.



*Figure 3: Completed areas in RIX 95 (June 2006).*

The measurements in the project will be finalised in 2006. Each year about 350 triangulation stations and 500 new

points (mainly existing local control points) has been measured. The present situation for the measurements is shown in figure 3.

To a large extent the measurements are made with standard equipment and procedures for static observations. However, more accurate coordinates in SWEREF 99 are determined for one point every 50 km. These points are observed for 2x24 hours with a new set up between the sessions. The observations for these points are made with Dorne Margolin T-type antennas, and the Bernese software is used for the processing.

## **6. Implementation of the ETRS 89 realisation SWEREF 99**

SWEREF 99, which is the Swedish realisation of ETRS 89, is used as the national geodetic reference frame for GPS since 2001.

Lantmäteriet has further decided that SWEREF 99 shall be the official reference frame that will replace RT 90 for surveying and mapping.

A formal decision regarding map projections for national mapping as well as for local surveying was taken in 2003 (Lantmäteriet 2003). All the projections are of Transverse Mercator type. The implementation of SWEREF 99 in databases and in product lines at Lantmäteriet will take place in early 2007.

A proposal for a new map sheet division and index system has been developed.

The work with implementing SWEREF 99 among other authorities in Sweden, such as local ones, is in progress. Approximately 70 of the 290

Swedish municipalities have started the process to replace their old reference frames with SWEREF 99. Eleven of them have so far finalised the replacement.

To rectify distorted geometries of local reference frames, correction models used by the municipalities are together with the transformation parameters obtained from RIX 95. The models obtained are based on the residuals of the transformations and the rectification is made by a so-called rubber sheeting algorithm. The result is a homogenous network in SWEREF 99 and geographical data with less deformations.

## **7. The new national height system RH 2000**

The third precise levelling of Sweden was finalised in 2003. The final adjustment of the new national height system was made in the beginning of 2005. The name of the system is RH 2000 and it has 2000.0 as epoch of validity (in the perspective of the Fennoscandian glacial isostatic adjustment).

The work to define RH 2000 was made in co-operation with the other Nordic countries. It is defined as the Swedish realisation of EVRS<sup>19</sup> (Ågren et al. 2006). The network consists of about 50 000 benchmarks, representing roughly 50 000 km double run precise levelling measured by the motorised levelling technique.

The final computation was made using a land uplift model based on a

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<sup>19</sup> EVRS = European Vertical Reference System

combination and modification of the mathematical model of Olav Vestøl and the geophysical model of Lambeck, Smither and Ekman, named NKG2005LU(APP) (Ågren & Svensson, 2006).

To connect the national network to the Normal Amsterdam Peil (NAP), the adjustment is made in a common adjustment of the nodal points in a data set called the BLR<sup>20</sup> (figure 4). This set consists of data from mainly the Nordic countries, the Baltic states, Poland, Germany and Holland. The latter data has been provided by UELN<sup>21</sup>-database. The work has been made within the NKG. The Swedish network is then adjusted in a number of steps, keeping the nodal points from the BLR data set fixed.



*Figure 4: The BLR data set.*

## 8. Implementation of RH 2000

The work with implementing RH 2000 among other authorities in Sweden is in progress. Approximately 45 of the 290 Swedish municipalities have, in co-operation with Lantmäteriet, started the process of analysing their local networks, with the aim of replacing the local height systems with RH 2000. So far 4 municipalities have finalised the replacement for all activities.

## 9. The Geoid model

A new geoid model to transform heights above the ellipsoid in SWEREF 99 to heights in RH 2000 has been developed and introduced during 2005. The name of the geoid model is SWEN 05LR. It is based on the gravimetric geoid model NKG 2004, calculated by the NKG working group on geoid determination. The model is then fitted to SWEREF 99 and RH 2000 using 1178 GPS/levelling points. Information of the fit residuals is also included in the model, so that the users will receive heights as close as possible to RH 2000. The expected accuracy (rms) for a user is 1,5-2 cm (figure 5).

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<sup>20</sup> BLR = Baltic Levelling Ring

<sup>21</sup> UELN = United European Levelling Network

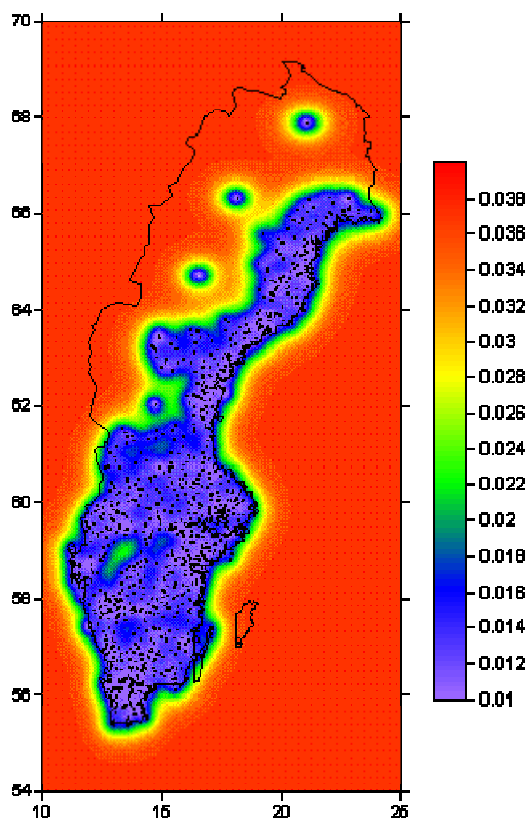


Figure 5: Expected accuracy (rms) for the geoid model SWEN 05LR (m).

## 10. Gravity activities

Absolute gravity measurements in Sweden have been carried out at eleven sites (Onsala, Göteborg, Borås, Mårtsbo, Kramfors, Östersund, Arjeplog, Skellefteå (also known as Furuögrund), Kiruna (KIR0, also known as Esrange), Visby and Smögen), see figure 6. Totally 27 measurements on ten of the sites have been performed during the period 2002-2005 by BKG<sup>22</sup>, IfE<sup>23</sup>, UMB<sup>24</sup> and FGI<sup>25</sup> in co-operation with Lantmäteriet and often with field assistance from

<sup>22</sup> BKG = Bundesamt für Kartographie und Geodäsie, Germany

<sup>23</sup> IfE = Institut für Erdmessung, Universität Hannover, Germany

<sup>24</sup> UMB = Universitetet for Miljø og Biovitenskap, Norway

<sup>25</sup> FGI = Finnish Geodetic Institute, Finland

Lantmäteriet. All points are co-located with permanent reference stations for GNSS in the SWEPOS network except Göteborg. Onsala is also co-located with VLBI<sup>26</sup>. Smögen are co-located with a tide gauge and Visby and Skellefteå have tide gauges nearby.

The red stars in figure 6 have been measured in 2003, 2004 and 2005. The purple stars have been measured in 2004 and 2005. The orange star has been measured in 2003. The brown star has not been measured during the period 2002-2005

In 2006 absolute gravity measurements will be carried out on the main part of the sites by IfE and on three sites by UMB (Kiruna, Onsala and Smögen).

Lantmäteriet is investigating the need for owning its own absolute gravimeter. Decision will be made during 2006.

<sup>26</sup> VLBI = Very Long Baseline Interferometry



*Figure 6: Absolute gravity sites in Sweden.*

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