

New Developments in the SWEPOS Network

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BIOGRAPHIES

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Mr. Bo Jonsson is working as GPS Program Manager and Deputy Head of the Geodetic Research Division at Lantmäteriet since 1996.

ABSTRACT

During the last years the SWEPOS network of permanent GNSS reference stations has slowly approached the stage when all of the Swedish land territory is covered by a centimeter level positioning service. The last part of Sweden to be covered by a dense network of permanent stations is in the extreme North. In this area a dense network of reference stations was for long seen as uneconomical. However the problems with land subsidence caused by the large iron mines in Kiruna and MalMBERGET made an extension of SWEPOS in the area necessary.

The project - RTK Malmfalten - with the task to establish 20 new SWEPOS stations in the extreme North of Sweden has also introduced new features in the SWEPOS network. Because the mining industry will be an important user, support for machine guidance applications is planned from the beginning. Permanent GNSS reference stations from Sweden, Norway and Finland will co-operate to cover the project area.

Other projects for the development of SWEPOS e.g. CLOSE are also briefly presented.

INTRODUCTION

Networks of permanent reference stations for GNSS (Global Navigation Satellite Systems) has become an important component in the geodetic infrastructure in many countries. From the spidery IGS network that spread over the globe in the early nineties to the rapidly growing RTK networks that are now covering many countries with ever diminishing mesh sizes. SWEPOS started in 1993 with 200 km between the stations. In 2001 we where designing RTK networks with a maximum distance of 70 km between the permanent stations. During 2009 the project CLOSE has been active. It is a simulation study of Network RTK and a co-operation between SP - Technical Research Institute of Sweden, Chalmers University Onsala Space Observatory and Lantmäteriet. Network RTK errors are simulated as functions of inter-station distances, number of visible satellites, elevation angle etc. The output of this project is very important for the future development of SWEPOS.

In the coming years the activity in the ionosphere will inevitably increase. At the same time a whole group of new GNSS signals will be introduced like the GPS L2C, L5, GLONASS L2C and L3. By 2013 Galileo will be added to the GNSS signal mix. To be able to handle Network RTK with all these signals in an optimal way, Lantmäteriet has been engaged in the RTCM SC-104 committee who develops the formats for RTK corrections.

During the last 10 years the Network RTK user group has widened from traditional surveyors looking for cm accuracy to users in the construction business using GNSS for machine guidance. This means that the average user has changed from being a technique enthusiast to being a user not particularly interested in the technique at all. GNSS has simply become a tool of the trade. This change makes information to and the interaction with the users very important. The ambition to keep a very high availability of the services is of course also very important.

THE SWEPOS NETWORK

The SWEPOS network consists of 188 permanent reference stations, see figure 1. All stations are equipped with redundant GPS/GLONASS receivers and Dorne-Margolin antennas. The stations are divided into two classes depending on the foundation under the antenna stand. Class A is mounted on pillars on bedrock, see figure 2 and class B are usually situated on top of buildings, see figure 3.

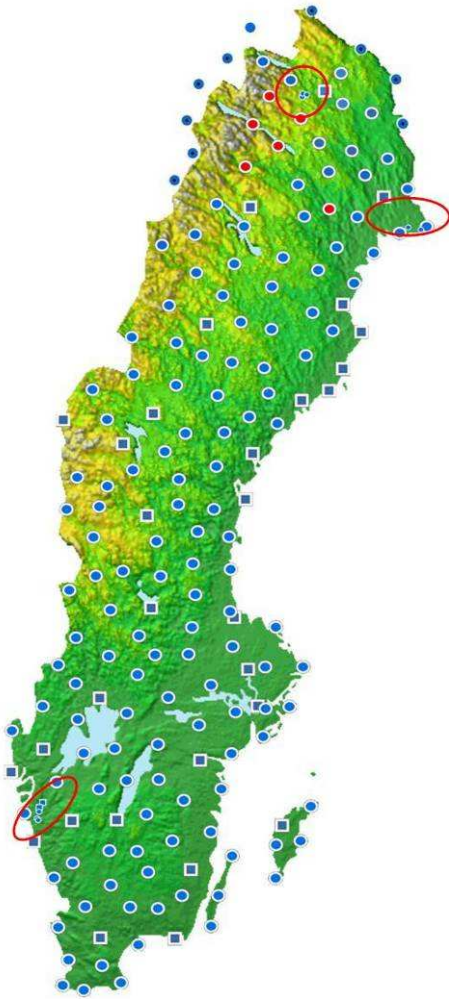


Figure 1 The SWEPOS Network in autumn 2009

The SWEPOS Network of permanent reference stations is part of the national geodetic infrastructure. The basic investments are made with government funding. Running costs and equipment upgrades are covered by user fees.

The goals of SWEPOS were decided during the early nineties as:

- Supplying GNSS-data for navigation, positioning, science and education.
- Act as the basis for the realisation of the National Reference System: SWEREF 99.
- Checking the integrity of the GNSS systems.



Figure 2 The SWEPOS class A station in Vänersborg.



Figure 3 The SWEPOS class B station in Zinkgruvan

Currently SWEPOS is providing the following services:

- Rinex-data and virtual Rinex-data.
- SWEPOS computation service.
- Real-time services
 - Network RTK
 - Network DGPS
 - EPOS (DGPS)
- SWEPOS homepage
 - Transformations
 - Satellite predictions
 - RTK monitoring

A price list for the Network RTK services is provided below.

Table 1 New price list for SWEPOS Network RTK (1 January 2009).

Type of subscription	Number of subscriptions	Price
Network RTK (GPS/GLONASS)		
Starting fee		500€/sub
Flat fee	1 – 5	1500€/yr/sub
Flat fee	6 -	Quotation
Metered fee		500€/yr+0.5€/min Max price 1500€

Currently (October 2009) the network RTK and DGPS services together have 1600 paying users that can be divided into different user groups, see figure 4.

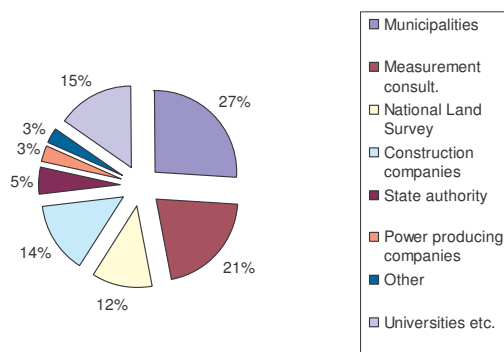


Figure 4 Network RTK and DGPS service user groups (October 2009).

Network RTK for large-scale projects

Dense RTK networks with 10-15 km between the stations have been established in three areas of Sweden, see red circles in figure 1, as support for

large-scale construction projects. Machine guidance is the main application in these projects. Following common practice for machine guidance parallel distribution of RTK corrections via radio modem and GSM/GPRS is implemented. Real-time monitoring of the corrections and a post-processing computation service are also included in these networks.

SWEPOS expansion in Lapland.

Shortly after the year 2000 SWEPOS was designed to cover about 70% of Sweden with permanent reference stations, on average separated by 70 km. With these design parameters roughly 120 permanent reference stations would be needed.

However, in Northern Sweden there are huge iron ore deposits under the cities of Malmberget (Gällivare) and Kiruna. Since the price of iron ore has gone up very much after the year 2000, there is a strong incentive to dig deeper after iron ore. Unfortunately, both at Malmberget and Kiruna the iron ore lode is inclined towards the city centers. This has led to severe problems with land subsidence. If the mining activity is going to go on at the same level as now, these problems will increase, see figure 5. Therefore both cities have decided to move large parts of their city centres to land areas with more stable ground.

In the summer 2008 Lantmäteriet, Metria, the municipalities of Kiruna, Pajala and Gällivare, LKAB (the mining company), the Swedish Rail Administration, the Swedish Road Administration decided to join the project “RTK Malmfälten” with the goal to extend the SWEPOS network into the northernmost part of Sweden.

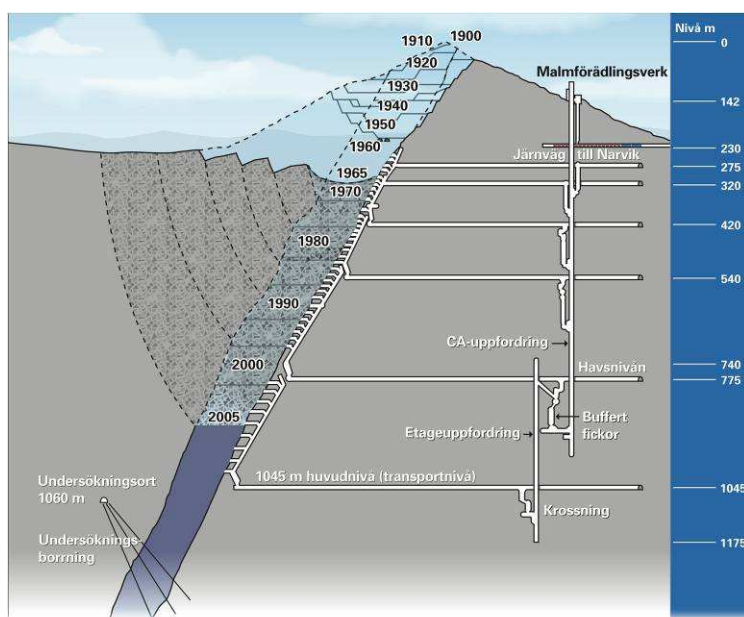


Figure 5 Cross-section of the iron mine in Kiruna, showing the depth of activity the last 100 years.

During 2009 this project will establish 18 new RTK stations in the extreme north of Sweden. To get full RTK coverage of the project area, six Norwegian SATREF stations and 4 Finnish Geotrim stations will also be used in the project, see figures 6 and 7. Actually this project in the extreme North of Sweden will be the first in Sweden to use data from several stations in the Norwegian and Finnish RTK Networks. Deformation measurements will be performed by LKAB (the mining company) using post-processing of observation data from the SWEPOS stations and their own deformation monitoring stations. Radio modems for the broadcasting of RTK corrections to the construction site in Kiruna has been established from the start.

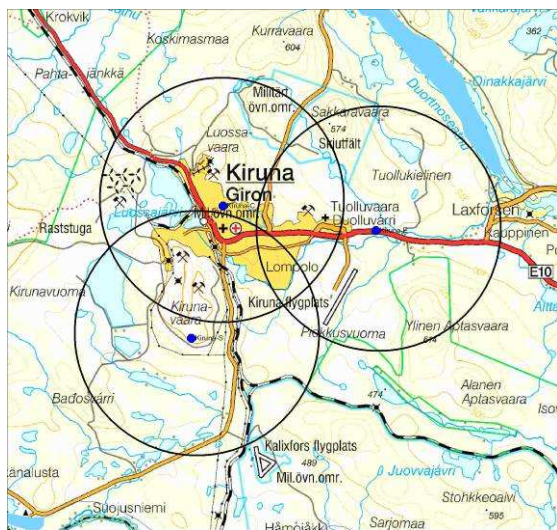


Figure 7 3 GNSS reference stations around Kiruna.

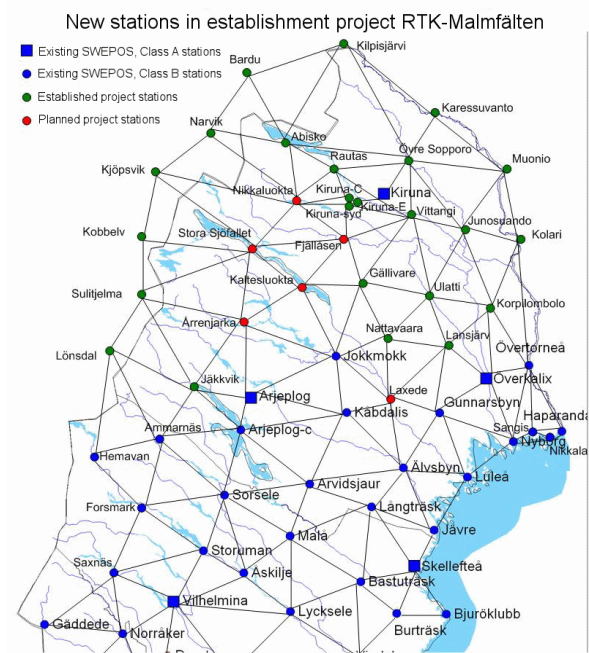


Figure 8 SWEPOS stations in the North of Sweden. (Note the 6 Norwegian stations and 4 Finnish stations.)

CLOSE

The project CLOSE is a study of different errors affecting measurements with the network RTK technique. Assumed distances between reference stations are 70 km, 35 km, 20 km and 10 km. What will happen when more satellites and new satellite systems are added to the current configuration is also studied. For the study period we have (autumn 2008) on average 11 satellites GPS and GLONASS visible with 13 degrees as elevation mask. In the future we will have on average more than 30 satellites visible, GPS, GLONASS, Galileo and Compass. The main error sources are troposphere, ionosphere and local effects, such as receiver noise and multipath (Emardson et al, 2009).

If the results of the CLOSE study are summarized very much and we only look at the errors in the vertical, a number of important points about inter-station distances and the influence of future satellite systems are found.

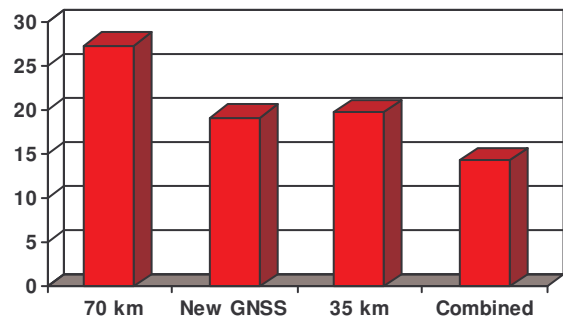


Figure 8 Vertical errors with new GNSS, 35 km between the reference stations and combined.

The figure shows that with the new satellite systems the vertical accuracy will go from 27 mm to 20 mm. The same improvement will happen if the inter-station distance is diminished from 70 km to 35 km. With both future GNSSs and diminished distances the accuracy will go down 14 mm.

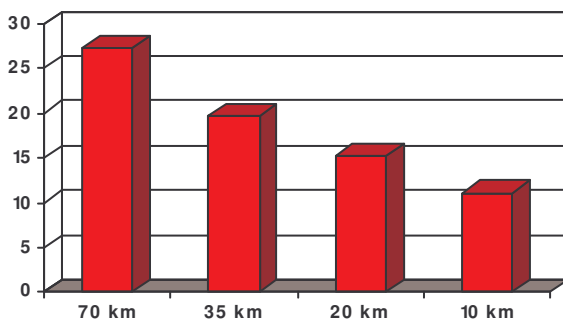


Figure 9 Vertical errors with different distances between the reference stations.

A remarkable result of CLOSE can be seen in figure 10. Here you can see that in the future with about 30 satellites visible, a high elevation cut-off angle of 25 degrees will give an optimal height estimate.

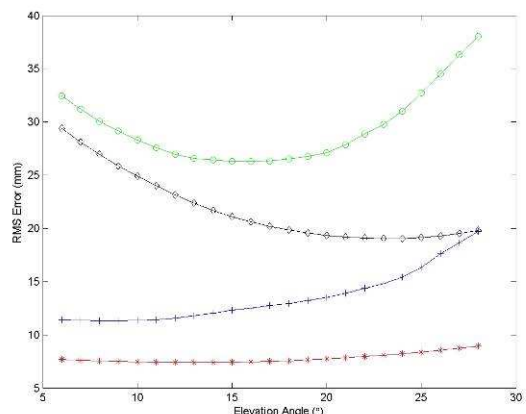


Figure 10 Errors as function of elevation angle. Vertical error using current satellite constellation (green circles), vertical error future constellation (black triangles), horizontal error current constellation (blue pluses), horizontal error future constellation (red stars).

This is a positive result for people who would like to measure heights inside cities with many high buildings.

CLOSE has a sequel in the form of the CLOSE II project which is aiming to develop a web based ionosphere monitor and an ionosphere prediction service. These services will give information and support to the SWEPOS users during the next sunspot maximum.

CONCLUSIONS

With 188 permanent reference stations and more than 1500 Network DGPS and RTK users. SWEPOS has come a long way since the start in 1993 with 21 stations. The strategy has been to have a unified network for very different purposes like basis of the National Reference Frame, RTK surveying, navigation and post-processing applications. SWEPOS has also been used extensively for scientific applications in the first place by Onsala Space Observatory, EUREF and IGS. Sometimes these multiple purposes have led to problems and tensions but we still think that a unified network of permanent reference stations is the key to optimal benefit of the governmental investments in the SWEPOS network.

REFERENCES

Emardson R., P. Jarlemark, S. Bergstrand, T. Nilsson and J. Johansson. Measurement accuracy in Network-RTK , SP Report 2009:23, [http://www-v2.sp.se/publ/user/default.aspx?RapportId=10192](http://www.v2.sp.se/publ/user/default.aspx?RapportId=10192) (cited Nov. 2009).