Quality Assessment of Network-RTK in the SWEPOS^{TM} Network of Permanent GNSS Stations

Lars Jämtnäs, Johan Sunna, Ragne Emardsson and Bo Jonsson

Lantmäteriet, Sweden

LANTMÄTERIET

XXIV FIG International Congress, Sydney, April 13th 2010, Johan Sunna

SWEPOS

Table of Contents

- Introduction
- Background
  - SWEPOS (Swedish CORS Network)
- Assessing the quality of network-RTK using SWEPOS
  - Previous studies
  - CLOSE-RTK project
- Conclusion

LANTMÄTERIET

2010-04-13 2

SWEPOS

Introduction

- Positioning with GNSS technique is used by a variety of Swedish organizations
- Growing demands on high reliability and availability of high precision positioning services
- A number of field studies have been performed over the last ten years to asses the state and quality of network-RTK in Sweden
- This presentation will focus on the CLOSE-RTK project, which primarily is a theoretical study of the present and future state of network-RTK.

LANTMÄTERIET

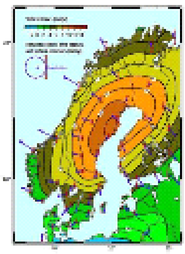
2010-04-13 3

SWEPOS

Background – SWEPOS (1)

Lantmäteriet (*the Swedish mapping, cadastral and land registration authority*) is responsible for the operation and development of SWEPOS in collaboration with the users. The purposes of SWEPOS are:

- Provide GNSS data for real-time and post processing applications
- Act as high-precision control points for GNSS users
- Provide data for scientific studies (e.g. climatology and tectonics)
- Monitor the integrity of the GPS/GLONASS (GNSS) system



LANTMÄTERIET

2010-04-13 4

Background – SWEPOS (2)

- SWEPOS Network-RTK Service
  - Based on the Virtual Reference Station concept
  - 185 (GPS/Glonass) reference stations (April 2010), plus a number of Norwegian and Finnish stations in the border regions
  - Average distances between stations ~ 70 km
  - 1500+ users
- Expected rover position uncertainty (68%)
  - Horizontal ~ 15 mm
  - Vertical (ellipsoidal height) ~ 25 mm

2010-04-13 5

Assessing the quality of network-RTK
Previous studies (1)

- A number of field studies with network-RTK has since 2001 been conducted as part of SWEPOS establishment projects and diploma works
- The focus of these studies have primarily been to:
  - Verify various aspect of the network-RTK technique (e.g. network-RTK software and rover functionality
  - Quantify some measures of accuracy for the user community

2010-04-13 6

SWEPOS

Previous studies (2)

- The rover positioning uncertainty with network-RTK seem to decrease over these years:
  - Horizontal: 15-20mm ⟶ 10-15mm (68%)
  - Vertical: 25-30mm ⟶ 20-25mm (68%)
- This can be explained by combination of factors, e.g.
  - Modernization of GNSS-equipment (e.g. GNSS antennas with more effective multipath reduction)
  - Better modeling of atmospheric errors in network-RTK software

LANTMÄTERIET

2010-04-13 7

SWEPOS

CLOSE-RTK project

- CLOSE-RTK was initiated by Lantmäteriet, SP Technical Research Institute of Sweden and Chalmers University of Technology
- Main objectives for this project were to:
  - Investigate the achievable levels of accuracy with present network-RTK based on a detailed study of contributing error sources
  - Evaluate the expected quality of network-RTK positioning in the future, given possible changes in the infrastructure of space and ground segments

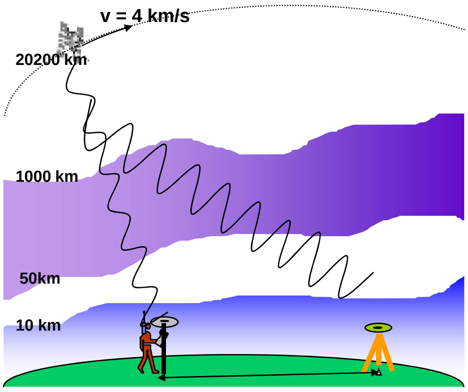
LANTMÄTERIET

2010-04-13 8

SWEPOS

CLOSE – Method
Error sources

- In order to estimate the measurements errors in network-RTK, the following error sources were studied and quantified:
  - Satellite clocks
  - Satellite orbits
  - Ionosphere
  - Troposphere
  - Local effects
- Studies of the error sources resulted in an "error budget" (total rms)



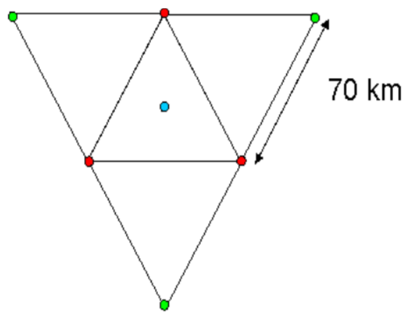
LANTMÄTERIET

2010-04-13 9

SWEPOS

CLOSE – Method
Assumptions

- Assumptions were made for a reference network with ~ 70 km distance between each station. Rover interpolation errors were estimated from six surrounding reference stations
- Error estimates were based on L1 solutions with a 13 degree elevation cut-off angle



LANTMÄTERIET

2010-04-13 10

SWEPOS

CLOSE – Method
Evaluation

- Expected rover position uncertainties were then estimated (error propagation) based on the error budget and satellite constellation of GPS and GLONASS of August 2008
- For evaluation of the simulated data, the results were compared with real-time measurements using SWEPOS Network-RTK service.
- The real-time measurements confirmed the simulated rover position uncertainty from the error budget

LANTMÄTERIET

2010-04-13 11

SWEPOS

CLOSE – Present situation
Results

Error source		Vertical Nominal situation (mm)	Horizontal Nominal situation (mm)
Satellite clocks		0	0
Satellite orbits		0	0
Ionosphere		16.6	10.7
Troposphere		20.9	3.9
Local Effects	Rover	5.6	3.5
	Reference sites	1.4	0.9
Total (RMS)		**27.3**	**12.0**

The table specifies the vertical and horizontal position uncertainty as they can be expected statistically for a nominal situation (68%)

LANTMÄTERIET

2010-04-13 12

SWEPOS

CLOSE – Future situation

Additionally the CLOSE project estimated positioning error components for different future situations:

- A future GNSS constellation including GPS, GLONASS, Galileo and Compass
- Densificaton of the SWEPOS network to ~ 10 - 35 km between the reference stations
- Combination of the two scenarios above

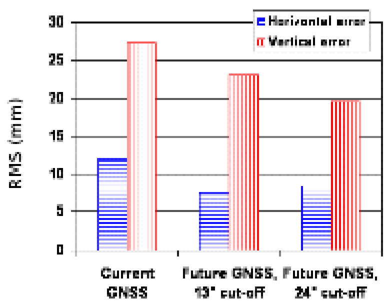
LANTMÄTERIET

2010-04-13 13

SWEPOS

CLOSE – Future situation
New GNSS constellation

- Future GNSS constellation results in a slightly better position accuracy using a higher elevation cut-off angle
- Future GNSS constellation provides a reduction in the error contribution from ionosphere and local effects
- The availability of future systems will reduce the vertical error from 27 mm to 20 mm



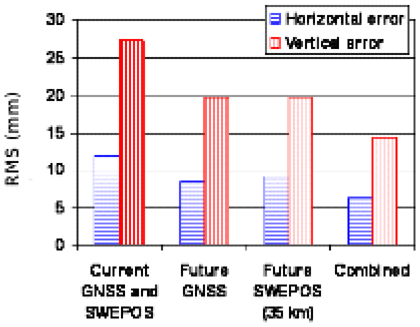
LANTMÄTERIET

2010-04-13 14

SWEPOS

CLOSE – Future situation
Densified reference network

- A densified network (35 km) reduces the vertical position uncertainty from 27 mm 20 mm with the current GNSS constellation
- The combination of a densified (35 km) and future satellite systems will result in a vertical position uncertainty of 14 mm
- The combination of a further densified network (10 km) and future satellite systems will results in an expected vertical position uncertainty of 8 mm



LANTMÄTERIET

2010-04-13 15

SWEPOS

Conclusion

- The theoretical simulation in the CLOSE project confirmed the empirical values for the vertical uncertainty
- Results from the CLOSE project and similar projects will continue to guide the development of SWEPOS to meet the demands of the user community
- This include a densification of the current reference station network, but also development of tools for real-time users, such as ionosphere monitoring via the SWEPOS web page
- The ongoing quality assessment of the SWEPOS Network-RTK services provides valuable information about the error sources and how they affect positioning

LANTMÄTERIET

2010-04-13 16

SWEPOS

References

- Emardsson R, Jarlemark P, Bergstrand S, Nilsson T, and Johansson J, 2009; Measurements Accuracy in Network-RTK, SP report 2009:23, ISBN 978-91-86319-10-6, SP Technical Research Institute of Sweden, Borås.

LANTMÄTERIET

2010-04-13 17

SWEPOS

Thanks for listening

Questions ?

Contact information
Mr. Johan Sunna
Lantmäteriet
801 82 Gävle
SWEDEN
Email: johan.sunna@lm.se
Web: www.swepos.com

LANTMÄTERIET

2010-04-13 18