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NATIONAL REPORT

National Report of Sweden to the EUREF 2021 Symposium

– Geodetic Activities at Lantmäteriet

1. Introduction

Lantmäteriet, the Swedish mapping, cadastral and land registration authority, is responsible for the national geodetic infrastructure. The geodetic work is based on the new geodetic strategic plan presented late 2018 (Lantmäteriet, 2018). The activities in the fields of geodetic reference frames and positioning are focused on

- the operation, development and services of Swepos™, the Swedish national network of permanent reference stations for GNSS
- contributions of Swepos data to international initiatives such as EPN, EPOS and IGS as well as international analyses of GNSS data
- the implementation and sustainability of the Swedish national reference frame SWEREF 99 and the national height system RH 2000 (ETRS89 and EVRS realisations respectively)
- improvements of Swedish geoid models and renovation of the gravity network.

Sweden, through Lantmäteriet, is since 2018 member of the UNGGIM SCoG and is also leading its working group on Education, Training and Capacity Building.

2. Contributions from Lantmäteriet to EPN

The number of Swepos stations included in EPN is 27. Seven of the original Swepos stations have been included since the very beginning of EPN. These stations are Onsala, Mårtsbo, Visby, Borås, Skellefteå, Vilhelmina and Kiruna (ONSA, MAR6, VIS0, SPT0, SKE0, VIL0 and KIR0). The other 20 stations are represented by an additional monument located at the original Swepos stations. Daily and hourly data are delivered for all stations, while real-time data are delivered from nine stations.

Lantmäteriet operates the NKG EPN AC in cooperation with Onsala Space Observatory. The NKG AC contributes with weekly and daily solutions, since November 2019 based on CODE rapid products, using the Bernese GNSS Software. The EPN sub-network processed by the NKG AC consists of 100 reference stations (May 2021) concentrated to northern Europe.

3. EPN Related GNSS Analysis

The NKG GNSS AC is chaired by Lantmäteriet (Lahtinen et al., 2018). The project aims at a dense velocity field in the Nordic and Baltic area. Consistent and combined solutions are produced based on national processing using the Bernese GNSS Software version 5.2, following the EPN analysis guidelines. The reprocessing of the full NKG network including all Nordic and Baltic countries, covering the years 1997–2016 with a processing setup consistent with EPN Repro2, (Lahtinen et al., 2019) has been followed up with an updated coordinate and velocity solution including also operational data up to 2020.5. The weekly solutions from the reprocessing and the continued operational solutions contribute to the EPN densification project on a regular basis.

Lantmäteriet is one of the analysis centres in E-GVAP, as the Nordic GNSS Analysis Centre (NGAA), and undertook the data processing for approximately 750 GNSS stations mainly in Sweden, Finland, Norway, Denmark (Lindskog et al., 2017). Two near-real-time (NRT) ZTD products, i.e., NGA1 and NGA2, are currently provided. Both products are obtained from the Bernese GNSS Software ver. 5.2 using a network solution. The NGA1 product is updated every hour while the NGA2 product is updated every 15 minutes.

4. Swepos – the National Network of Permanent Reference Stations for GNSS

Swepos™ is the Swedish national network of permanent GNSS stations operated by Lantmäteriet; see the Swepos website, https://www.swepos.se.

The purposes of Swepos are

- providing single- and dual-frequency data for relative GNSS measurements
- providing DGNSS corrections and RTK data for distribution to real-time users
- acting as the continuously monitored foundation of SWEREF 99
- providing data for geophysical research and for meteorological applications
- monitoring the integrity of the GNSS systems.

By May 2021 Swepos consisted of totally 458 stations, of which 53 are of a higher class, the so-called class A, and the remaining 405 stations are of class B, see Figure 1. This means that the total number of Swepos stations has increased with 37 stations since the EUREF Symposium in 2019.

Figure 1: Left: Sveg is one of the Swepos class A stations. It has an old monument (established in 1993) as well as an additional monument (2011). Right: Gustavsberg is a Swepos class B station with a roof mounted GNSS antenna established mainly for network RTK purposes.

The class A stations are monumented on bedrock and have redundant equipment for GNSS observations, communications, power supply etc. Class B stations are mainly established on top of buildings for network RTK purposes. They have the same instrumentation as the class A stations (dual-frequency multi-GNSS receivers with choke ring antennas), but with somewhat less redundancy.

Five of the original 21 Swepos stations (Onsala, Mårtsbo, Visby, Borås and Kiruna) are included in the IGS network, as well as three of the additional monuments with newer steel grid masts (ONS1, MAR7 and KIR8).

5. Swepos Services

Swepos provides real-time services of metre level uncertainty (DGNSS) and centimetre level uncertainty (Network RTK), as well as data for post-processing in RINEX format. A transition from RINEX 2 to RINEX 3 has been implemented during the last years. An automated post-processing service, based on the Bernese GNSS Software, is also available.

Since data from permanent GNSS stations are exchanged between the Nordic countries, good coverage of the Network RTK service has been obtained in border areas and along the coasts. Several stations from SATREF in Norway and the Danish Agency for Data Supply and Efficiency are included together with stations from private operators in Norway, Denmark, and Finland as well as Sweden.

The Network RTK service has, in May 2021, approximately 7285 subscriptions, which means some 2800 additional users since the EUREF Symposium in 2019. Lantmäteriet also has cooperation agreements with seven international GNSS service providers using data from Swepos stations for their services. This is done to increase the use of Swepos data as well as optimising the benefits of the geodetic infrastructure.

The real-time services utilise Trimble Pivot Platform GNSS Infrastructure Software and are operating in virtual reference station mode. The Network RTK service distributes data for GPS, Glonass and Galileo as well as GPS L5 and L2C signals using RTCM MSM. The plan is to include BeiDou during 2021.

There is an increasing demand for uninterrupted availability of the real-time services, from current applications (e.g. agriculture) as well as future applications (e.g. autonomous vehicles). To meet these demands, a redundant server infrastructure has been established in a separate physical location – a so-called High Availability solution. This second data centre became operational in October 2020 and will protect against e.g. loss of electricity or Internet connectivity. During normal operation, the Network RTK users are distributed between both data centres, but in case of a failure at one data centre, the other data centre has the capacity to handle all users. This system will also facilitate system maintenance since all traffic can be redirected to the other location while e.g. updating is done.

6. Reference Frame Management – SWEREF 99

SWEREF 99 was adopted by EUREF as the Swedish realisation of ETRS89 in 2000 (Jivall & Lidberg, 2000) and is used as the national geodetic reference frame since 2007.

By defining SWEREF 99 as an active reference frame we are exposed to rely on the positioning services of Swepos, like the Network RTK service. All alterations of equipment and software as well as movements at the reference stations will in the end affect the coordinates. To be able to check all these alterations, approximately 300 nationally distributed passive so-called consolidation points are used. Each year, 50 of them are remeasured with static GNSS following a yearly programme.

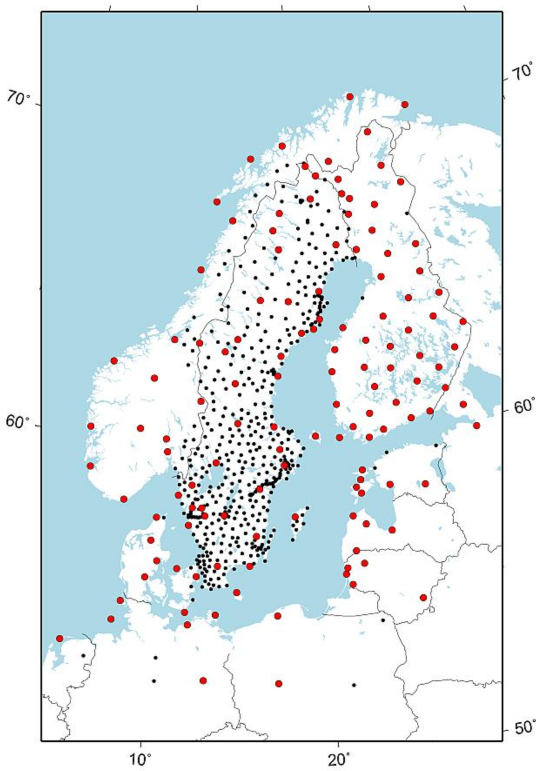
Since the original SWEREF 99 campaign, the coordinates of the Swepos stations (see chapter 4) have been updated when necessary, e.g. when GNSS antennas were exchanged and when new antenna models and computation strategies have been introduced. Corrections have been added in a cumulative way and stations have been determined in different epochs partly using different models of post-glacial deformation, leading to an increase of the uncertainties between stations.

Therefore, a review of the frame was undertaken during 2020 and updated coordinates were implemented in the Swepos services in the beginning of 2021. The new coordinates are based on GNSS-data from the autumn 2019 and the NKG_RF17vel land uplift model.

The purpose of the review and coordinate update was to achieve a more homogeneous SWEREF 99 that will be sustainable for the future. An overall measure has been taken to obtain a reference system that is consistent with today's measurements and computations.

The number of reference frame defining stations increased with the update, to some thirty stations in Sweden and, in addition, approximately 100 stations in our neighbouring countries (Jivall & Lilje, 2021). The number of foreign defining stations will however decrease with time, since there is no ambition to determine all foreign stations anew when they are altered.

Figure 2: Red dots show the defining stations of the SWEREF 99 updating campaign. The other stations in the campaign are shown in black.



The differences between the previous and the updated coordinates are, on the whole, small and lies within the specifications of the Swepos services.

A new set of transformation parameters between ITRF2014 and SWEREF 99 has been developed in cooperation within the Nordic Geodetic Commission. It is available at Lantmäteriet's web site and in the PROJ transformation library, starting from version 7.2.1. The transformation is based on the concept in (Häkli et al. 2016) and the NKG_RF17vel land uplift model.

7. Maintenance of the National Levelling Network

The third precise levelling of the mainland of Sweden lasted 1979-2003, resulting in the new national height system RH 2000 in 2005 (Ågren et al., 2007).

Our assessment is that RH 2000 will be the national height system for many years to come and that it will be based on levelling. The reason is that the precision of height determination with GNSS (height above the ellipsoid) is not as accurate as the levelling technique. Therefore, the maintenance of the height control network needs to be continued for the foreseeable future.

Since the beginning of the 1990s, a systematic inventory and updating of the network has continuously been performed, with replacement of the majority of destroyed points. To reduce costs – based on the fact that benchmarks founded in bedrock and nodal points – are more valuable for the perseverance of the network, new criteria for replacing destroyed points were introduced in 2010. With that new approach almost none of the destroyed points were replaced. During 2018 a review of the reduced updating programme was performed (Alfredsson et al. 2019), leading to an adjustment of the replacement criteria, to make sure that a sufficient number of destroyed benchmarks are replaced to secure the sustainability of the network.

When new height benchmarks are demarcated to replace destroyed benchmarks, the levelling of them is done through procurement procedures, which is also the situation for the re-measurements of the 300 consolidation points described in chapter 6.

8. Geoid Determination

According to Lantmäteriet's strategic plan (Lantmäteriet, 2018), an important goal is to compute a seamless geoid model of high accuracy that fulfils the needs of users both on land and at sea. Many activities are going on to realise this. A new gravity reference system/frame RG 2000 was finalised in 2019 (see chapter 9). New Swedish detail gravity observations are continuously being collected using Scintrex CG5 with the purpose to fill gaps or replace old data of low quality.

Figure 3: Marine gravity campaigns performed by Lantmäteriet during 2017-2020.

An important activity has been to improve gravity and geoid in the Baltic Sea within the project FAMOS, which we can also benefit from on land, mainly in the coastal areas.

The introduction of the common BSCD2000 (Baltic Sea Chart Datum 2000) (EVRS with land uplift epoch 2000.0) in the Baltic Sea (Schwabe et al., 2020) improves navigation and hydrographic surveying with GNSS-based methods and a geoid model in the Baltic Sea plays an important part here. The FAMOS geoid will realise BSCD2000 in the Baltic sea and connect to the EVRS realisations on land. Unfortunately, the EU funding for FAMOS was interrupted earlier than planned in June 2019, but the work now continues under the umbrella of the Chart Datum Working Group of the Baltic Sea Hydrographic Commission.

During 2019-2020, eight large dedicated marine campaigns were observed with Lantmäteriet's ZLS marine gravimeter. Gravity data has been delivered to the FAMOS database together with all data collected by the other participating countries/organizations around the Baltic Sea. The final FAMOS geoid model is planned to be finalised and released in 2022.

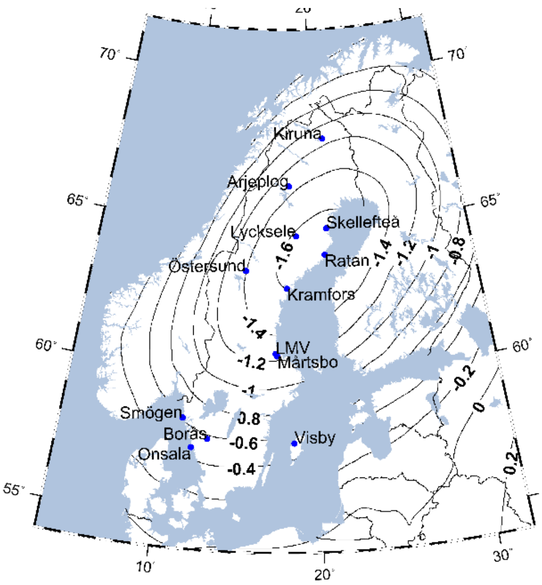
In the last years, much work has been spent on improving and densifying the Swedish national GNSS/levelling dataset. The core of the new, updated dataset is the so-called SWEREF GNSS points for which accurate levelled heights are available in RH 2000. A majority of these SWEREF points are also consolidation points (see chapter 6), which are redetermined every six years. This makes it possible to detect and remove unstable points. Since 2019, the levelled normal heights of the GNSS/levelling points are also checked by relevelling relative to the benchmarks in the national precise levelling network.

In 2020, an industrial PhD student was initiated at the University of Gävle in cooperation with Lantmäteriet. The main aim of this PhD project is to develop and investigate different methods for regional realisation of the International Height Reference System (IHRS) in Sweden and the Nordic/ Baltic countries.

9. Gravity Activities

In Sweden 13 stations (see Figure 4) are revisited with Lantmäteriet's absolute gravimeter, FG5X-233, with an interval of approximately one to three years. Since 2007, FGX-233 also regularly participates in local, regional and international AG inter-comparisons in order to keep track of possible systematic biases.

Figure 4: The 13 absolute gravity stations (for FG5) in Sweden (blue dots) with the land uplift model NKG2016LU_gdot, which shows the annual gravity change [µGal yr^{-1}].

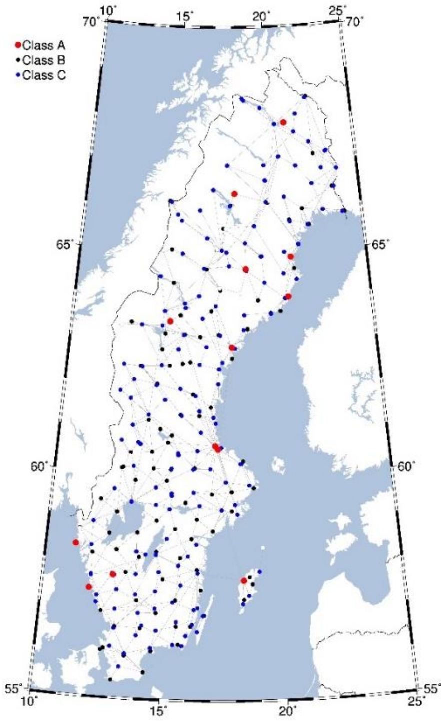


All Swedish absolute gravity sites for FG5 are co-located with Swepos stations. Ratan, Skellefteå, Smögen, Visby and Onsala are co-located with tide gauges. Onsala is also co-located with VLBI telescopes and a super-conducting gravimeter, which is annually calibrated with FG5X-233 AG observations.

In the beginning of 2018 the new Swedish gravity reference frame, RG 2000, became official (Engfeldt et al., 2019). The reference level is as obtained by absolute gravity observations according to international standards and conventions. It is a zero permanent tide system in post glacial rebound epoch 2000. RG 2000 is realised by the 13 FG5 stations mentioned above, 96 A10 points (measured by IGiK) and some 200 points observed with relative gravimeters; see Figure 5.

During the last year, all Lantmäteriet's detail gravity observations have got a gravity value in RG 2000. The about 4000 detail gravity observations measured from 2010 and later have got their gravity value without any transformation. The other about 22000 detail gravity observations are transformed from their original gravity system, RG 62 or RG 82. It should also be mentioned that in connection to the transformation, more than 1000 bad detail gravity observations were removed from the gravity database.

Figure 5: Reference points in RG 2000 (class A, B, C).

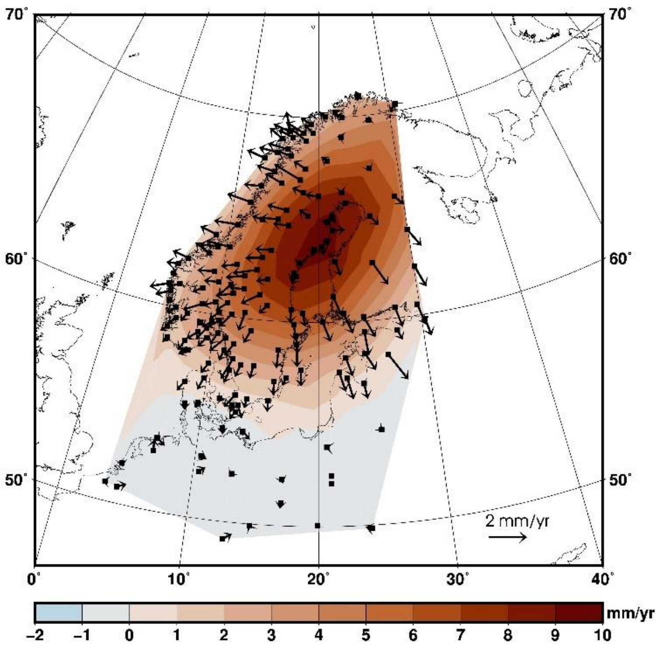


10. Geodynamics

The land uplift model NKG2016LU was released in 2016. It is a combination of levelling and GNSS data with a GIA model. Reliable uncertainty estimates have been introduced that consider both measurement and GIA model uncertainties. A description of the model can be found in Vestøl et al. (2019).

The GNSS data of NKG2016LU are based on the latest BIFROST effort, i.e. research regarding the 3D geometric deformation in Fennoscandia and adjacent areas; see Figure 6. A reprocessed velocity field based on 164 stations using the GAMIT/GLOBK software has been published in Kierulf et al. (2021) and contains a detailed analysis of different geodynamic processes that generate the 3D velocity field in northern Europe, such as elastic contributions (due to non-tidal ocean loading, atmospheric loading, glacier melt in Antarctica, Greenland and mountain glaciers, hydrology), GIA, sedi-

Figure 6: Figure 10 of Kierulf et al. (2021). BIFROST2015 velocity field after elastic correction of the vertical component and transformation to the reference frame given by the glacial isostatic adjustment process.



mentation, reservoir changes etc. The next reprocessing, BIFROST2020, has meanwhile been initiated which will largely extend the number of stations (300+) and observation time span.

The new 3D velocity model NKG_RF17vel for northern Europe has been released in 2019. The uplift part is based on NKG2016LU while the horizontal motions are generated from an updated four-layer GIA model that reduces the misfit in the horizontals. This GIA model includes a sub-lithospheric high-viscosity layer. A detailed documentation is currently in progress.

Lantmäteriet is involved in the EUREF effort on obtaining a high-resolution velocity model for Europe and adjacent areas. The first EUREF velocity model is presented at EUREF21 (Steffen et al., 2021a) based on a least-squares collocation method with moving variance and taking plate boundaries into account. The densified EPND2100 velocity field (https://epnd.sgo-penc.hu/) was used as input.

Another major activity is the generation of the strain-rate product within EPOS. The project is now in the pre-operational phase. Lantmäteriet has produced the first, though preliminary strain-rate grid for Europe (Lantmäteriet, 2021) which can be downloaded from the product portal at https://gnssproducts.epos.ubi.pt.

Lantmäteriet further contributes with GIA modelling studies in different fields. Latest results include coastal ridge pattern analysis in Estonia (Suursaar et al., 2019), a potential glacially triggered earthquake in Greenland with corresponding tsunami in the North Atlantic (Steffen et al., 2020), 3D GIA model uncertainties for North America (Li et al., 2020), and the identification of a glacially induced fault in Germany (Müller et al., 2020). Lantmäteriet further contributed to the generation of the International Database of Glacially Induced Faults (Munier et al., 2020) and a book on glacially triggered faulting (Steffen et al., 2021b).

11. Geodetic SAR and InSAR

During 2019-2021 Lantmäteriet participated in the ESA founded project Geodetic SAR for Baltic Height System Unification, led by the Technical University of Munich (Gruber et al., 2020). The main goal of the project was to investigate the possibility to connect tide gauges and national height systems around the Baltic Sea by means of absolute positioning by SAR, using active transponders. Three active transponders were installed in Sweden at the Swepos stations Mårtsbo, Kobben and Vinberget and they are now fully operational. Lantmäteriet also contributed to the project with high resolution geoid modelling at tide gauges.

Another SAR related project is the introduction of a nationwide ground motion service for Sweden (2020-2022). This project is coordinated by the Swedish National Space Agency and the service will be based on the same platform as InSAR Norway (https://insar.ngu.no/). Within this project the geodetic infrastructure in Sweden will be complemented with some 20 passive corner reflectors, co-located with Swepos stations. Lantmäteriet will also participate in an activity related to atmospheric corrections of the signals from the satellites.

12. Other Activities

12.1. Guidelines for Mapping and Surveying

The regulatory documents for Lantmäteriet states that one of its responsibilities is to contribute to efficient and standardised surveying and mapping in Sweden. One of the means to accomplish this is through a series of best-practice guidelines called HMK (a Swedish acronym roughly translated as “Guidelines for mapping and surveying”). HMK covers a wide variety of methods for geodata capture (e.g. laser scanning, aerial photography, geodetic surveying) as well as more general information about quality parameters and how they should be specified. The guidelines are reviewed by a stakeholder reference group on an annual basis and are published as new versions in case of major revisions. Several guidelines for geodetic applications were updated during 2020, e.g.

- Swedish geodetic infrastructure
- Control surveying
- Terrestrial detail surveying
- RTK detail surveying
- Support for geodetic survey tenders

All HMK guidelines are published online at https://www.lantmateriet.se/hmk, free of charge. The guidelines are also supplemented by online courses and technical literature that cover topics related to HMK more in-depth.

12.2. Review of the National Border with Norway

The national borders with Finland and Norway are reviewed approximately every 25 years, as bilateral cooperation. During 2020-2024, the border with Norway will be reviewed. The Swedish Government has appointed a so-called border commission at Lantmäteriet for the review, and the task is performed in cooperation with Kartverket, the Norwegian Mapping Agency. During this review, Sweden is responsible for the northern part of the border and Norway is responsible for the southern part.

The purpose is to get an updated documentation of the border and its demarcation. Border markers will be restored, and the border line will be cleared from trees and shrubs.

A helicopter reconnaissance along the border was performed in 2020, as well as initial field work. The plan for 2021 is to have three teams working in parallel along the border; to restore and measure approximately 100 border markers, stake out 40 km of border line and to clear 25 km of border line from vegetation.

Figure 7: An example of border line stake out.

12.3. "Reference Network in the Air"

The project "Reference Network in the Air" (in Swedish: Stomnät i luften 2.0) is a research and innovation project initiated by the Swedish Transport Administration and is based on earlier research concerning positioning systems for large-scale construction projects (Trafikverket, 2011). The aim of this project is, through 13 sub-activities, to secure that the Swedish Transport Administration uses a modern, robust and future-proof geodetic infrastructure for positioning based on GNSS technique.

Lantmäteriet is, together with the KTH Royal Institute of Technology and the RISE Research Institutes of Sweden, a major partner of this project and involved in most of the activities. The Swedish Transport Administration is also contributing.

The project started in 2019 and runs until the end of 2022.

12.4. Monitoring of EGNOS

The European Geostationary Navigation Overlay Service (EGNOS) is Europe's regional satellite-based augmentation system. It was developed to improve the performance of the GNSS systems and to provide safety-of-life navigation services to aviation, maritime and land-based users. Lantmäteriet is one of the partners in the project of EGNOS Service Performance Monitoring Support (SPMS) and participates the work package of local position performance assessment. Lantmäteriet's objective in this work package is to monitor the position obtained by Swepos class A stations in Överkalix and Visby using EGNOS corrections. The safety of life analysis of the data is done by Lantmäteriet. At the end of each quarter, we perform the following tasks:

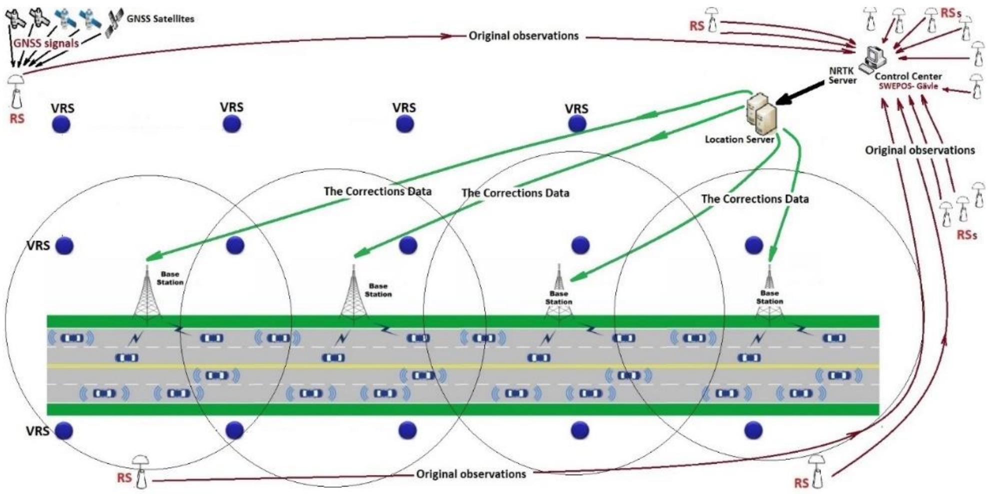
- Daily monitoring and assessment of the availability of the data and the processing.
- Quality check and analysis of the results.
- Prepare quarterly reports.

12.5. The NPAD Project

The NPAD project (Network RTK Positioning for Automated Driving) is a research project funded by Vinnova. The project started in May 2018 and finished in November 2020. Lantmäteriet, RISE, Ericsson, Einride, Volvo and Scania are the major partners in the project. The main purpose of NPAD was to develop, implement and test an efficient distribution system for Swepos (Network RTK) correction data in order to enable centimetre-level accuracy GNSS positioning for an unlimited number of mobile platforms, e.g. automated vehicles.

The proposed idea in the NPAD project is to use a grid of fixed VRSs (Virtual Reference Stations) which could be established to cover the required area – the test area in the NPAD project. The correction data from Swepos for the VRS grid will then be provided in broadcast mode through the cellphone network (location server) as shown in Figure 8.

Figure 8: The proposed configuration in the NPAD project.



In order to implement the idea suggested in the NPAD project, Lantmäteriet made a proposal to set up a new NTRIP caster on a server between the Swepos VRS NTRIP and the location server. Lantmäteriet and the other partners have implemented and tested the proposed correction data distribution system according to the 3GPP standard Release 15 in the assistance data of the LTE Positioning Protocol, and also implemented the needed software at the GNSS client side in order to test the distribution mechanism and how this is handled by a RTK-enabled GNSS receiver. The results showed clearly that the proposed solution works and allows an unlimited number of GNSS clients. The handling of changing from one VRS to another still needs to be handled and this can be done with using other sensors like IMU or other sensors.

12.6. The PNK4UTM Project

PNK4UTM – Positioning, Navigation, and Communication for Unmanned Aerial Traffic Management – project is a R&D project funded by the Swedish Transport Administration. The project started in April 2020 and runs until November 2024. The purpose of this project is to analyse, plan and implement the required infrastructure to prepare technology, processes and business development in the field of UAVs (Unmanned Aerial Vehicles). The long-term purpose is to significantly improve the functionality of the cellphone network and positioning services (as the Swepos services) to perform the long-term implementation of unmanned aerial traffic management. Furthermore, to test and suggest improvements on existing technology products, processes and methods to enable secure positioning, navigation and communication for the UAVs. The intention is to coordinate tests with the various subsystems in collaboration between the main partners in the project: RISE, Ericsson, Lantmäteriet, Telia, T2data, UMS Skeldar, Västervik municipality and Linköping University.

Lantmäteriet/Swepos intends, together with Ericsson, to develop and provide network RTK corrections to drones in an efficient manner via the 3GPP format (the NPAD principle). There is also an interest in looking at alternative positioning methods such as PPP or PPP-RTK.

12.7. Prepare Ships

Prepare Ships is a Horizon 2020 project funded by the European Union with participating partnership organizations from Sweden, Germany, and Norway. The aim of the project is to develop a decision support system for secure ship navigation by dynamic prediction of ship movements and sharing of such information ship-to-ship and ship-to-shore. This kind of system has several benefits including provision of secure navigation in form of fairway navigation and collision avoidance decision support, together with reduced emissions into the environment. The proposed system design incorporates several different techniques, like machine learning for dynamic predictions, resilient and precise EGNSS positioning with sensor fusion, and additionally employs a variety of transmission techniques and protocols.

Lantmäteriet's part in the project is to provide GNSS positioning support in form of network RTK corrections for precise centimetre-level positioning and resilient positioning by providing additional integrity information together with the correction data. As for the NPAD project, corrections will be provided from fixed VRS points along the coastline to ensure scalability with a potentially large number of future users. On Lantmäteriet's part, the main challenges lie in establishment of new GNSS reference stations, adaptation of correction data to comply with bandwidth limitations related to the dissemination channels unique to maritime applications, and development of integrity estimation and integrity messages for dissemination to the end-user.

The Prepare Ships project started in December 2020 and is planned to finish in end of January 2022 but might be delayed a couple of months due to the Covid-19 situation.

12.8. “Robust Satellite Positioning”

The project “Robust Satellite Positioning” (in Swedish: Robust satellit-positionering) is a research project initiated by Swedavia and financed by the Swedish Transport Administration. Participants in the project are Swedavia, FOI (the Swedish Defence Research Agency) and Lantmäteriet. The project started in August 2020 and runs until September 2021.

The main purpose of the project is to investigate if the Swepos GNSS reference stations located close to airports can be used to detect and survey electromagnetic interference in the GNSS band, to continuously monitor the reliability of GNSS data. The possibility to detect jamming with the use of information from Swepos’s GNSS receivers in combination with information from FOI’s detection systems is studied, as well as how this capability could be implemented in a nationwide detection system.

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Acronyms and Abbreviations

Table 1: Explanations of acronyms and abbreviations used in the report, in alphabetical order.

Acronym or abbreviation	Explanation
3GPP	3rd Generation Partnership Project
AC	Analysis Centre
AG	Absolute Gravity
BIFROST	Baseline Inferences for Fennoscandian Rebound Observations Sea level and Tectonics
BSCD	Baltic Sea Chart Datum
CODE	Centre for Orbit Determination in Europe
DEM	Digital Elevation Model
DGNSS	Differential GNSS
E-GVAP	The EUMETNET GNSS water vapour programme
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European GNSS
EPN	EUREF Permanent GNSS Network
EPOS	European Plate Observing System
ETRS	European Terrestrial Reference System
EU	European Union
EVRS	European Vertical Reference System
FAMOS	Finalising Surveys for the Baltic Motorways of the Sea
FOI	The Swedish Defence Research Agency (Totalförsvarets forskningsinstitut)
GIA	Glacial Isostatic Adjustment
GNSS	Global Navigation Satellite Systems
HMK	Guidelines for mapping and surveying (Handbok imät- och kartfrågor).
IGiK	Institute of Geodesy and Cartography, Poland
IGS	International GNSS Service
IHRS	International Height Reference System

Acronym or abbreviation	Explanation
IMU	Inertial Measurement Unit
InSAR	Interferometric Synthetic Aperture Radar
ITRF	International Terrestrial Reference Frame
LPP	LTE Positioning Protocol
MSM	Multiple Signal Message
NKG	Nordic Geodetic Commission (Nordiska kommissionen för geodesi)
NPAD	Network RTK Positioning for Automated Driving
NRT	Near Real-Time
NTRIP	Networked Transport of RTCM via Internet Protocol
PNK4UTM	Positioning, Navigation, and Communication for Unmanned aerial Traffic Management
PPP	Precise Point Positioning
R&D	Research and Development
RINEX	Receiver Independent Exchange format
RISE	Research Institutes of Sweden
RTCM	Radio Technical Commission for Maritime Services
RTK	Real-Time Kinematic
SAR	Synthetic Aperture Radar
UAV	Unmanned Aerial Vehicle
UNGGIM SCoG	United Nations initiative on Global Geospatial Information Management, Subcommittee on Geodesy
VLBI	Very Long Baseline Interferometry
VRS	Virtual Reference Station
WMS	Web map service
ZTD	Zenith Total Delay