LANTMÄTERIET

LANTMÄTERIRAPPORT 2022:3
– GEODETIC REPORT

Geodetic activities in Sweden 2018–2022

Holger Steffen, Mohammad Bagherbandi, Mehdi Eshagh, Milan Horemuz, Jan Johansson

Lantmäteriet, PHONE +46 (0)771 636363 E-MAIL lantmateriet@lm.se WEBSITE www.lantmateriet.se

LANTMÄTERIET

Gävle 2022

Authors: Holger Steffen, Mohammad Bagherbandi, Mehdi Eshagh, Milan Horemuz, Jan Johansson

Total number of pages: 67

Lantmäterirapport 2022:3 ISSN 0280-5731

Preface

This report covers the geodetic activities at Lantmäteriet (the Swedish mapping, cadastral and land registration authority) and at universities in Sweden for the years 2018–2022. The report was presented at the 19th General Assembly of the Nordic Geodetic Commission (NKG) in Copenhagen, Denmark, where it was held 5–8 September 2022. The following universities contributed to and participated in the compilation of the report:

- KTH Royal Institute of Technology (Kungliga Tekniska högskolan) in Stockholm,
- Onsala Space Observatory at Chalmers University of Technology in Gothenburg (Onsala rymdobservatorium vid Chalmers tekniska högskola i Göteborg),
- University of Gävle (Högskolan i Gävle), and
- University West (Högskolan Väst) in Trollhättan.

Sadly, we must mention that geodesist at RI.SE Research Institutes of Sweden AB Per O.J. Jarlemark passed away on 13 July 2022 at the age of 60 and that former geodetic employee at Lantmäteriet Stieg Vennström passed away on 15 April 2022 at the age of 83.

This report contains many acronyms and abbreviations which are summarized in Table A1.

Table of Contents

Geodetic activities in Sweden 2018–2022

1. Geodetic activities at Lantmäteriet

LANTMÄTERIET

1.1. Introduction

Lantmäteriet, the Swedish mapping, cadastral and land registration authority, is responsible for the national geodetic infrastructure. The geodetic work is based on the geodetic strategic plan presented in 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), and
- improvements of Swedish geoid models.

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

1.2. Satellite positioning (GNSS)

The number of SWEPOS stations included in EPN is 28. 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 21 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 13 stations.

Lantmäteriet operates the NKG EPN AC on behalf of the NKG. 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 104 reference stations (November 2022) concentrated to northern Europe. This means that 14 stations have been added to the NKG AC sub-network since the previous NKG General Assembly four years ago.

Lantmäteriet contributes to the NKG GNSS AC project which produces consistent, combined, and dense velocity field solutions in the Nordic and Baltic area based on national processing using the Bernese GNSS Software version 5.2, following the EPN analysis guidelines. A second reprocessing of the full NKG network including all Nordic and Baltic countries is under planning and will be consistent with EPN Repro3. The weekly solutions from the earlier reprocessing (Lahtinen et al., 2019) and the continued operational solutions contribute to the EPN densification project on a regular basis.

Lantmäteriet is the NGA in E-GVAP, processing data for approximately 750 GNSS stations mainly in Sweden, Finland, Norway, Denmark (Lindskog et al., 2017). The two NRT ZTD products 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. Due to the limited access to real-time data, the NGA2 product is currently only provided for all Swedish stations together with 19 stations from Finland and 5 stations from Norway using real-time GNSS data streams from the EPN.

1.3. 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.

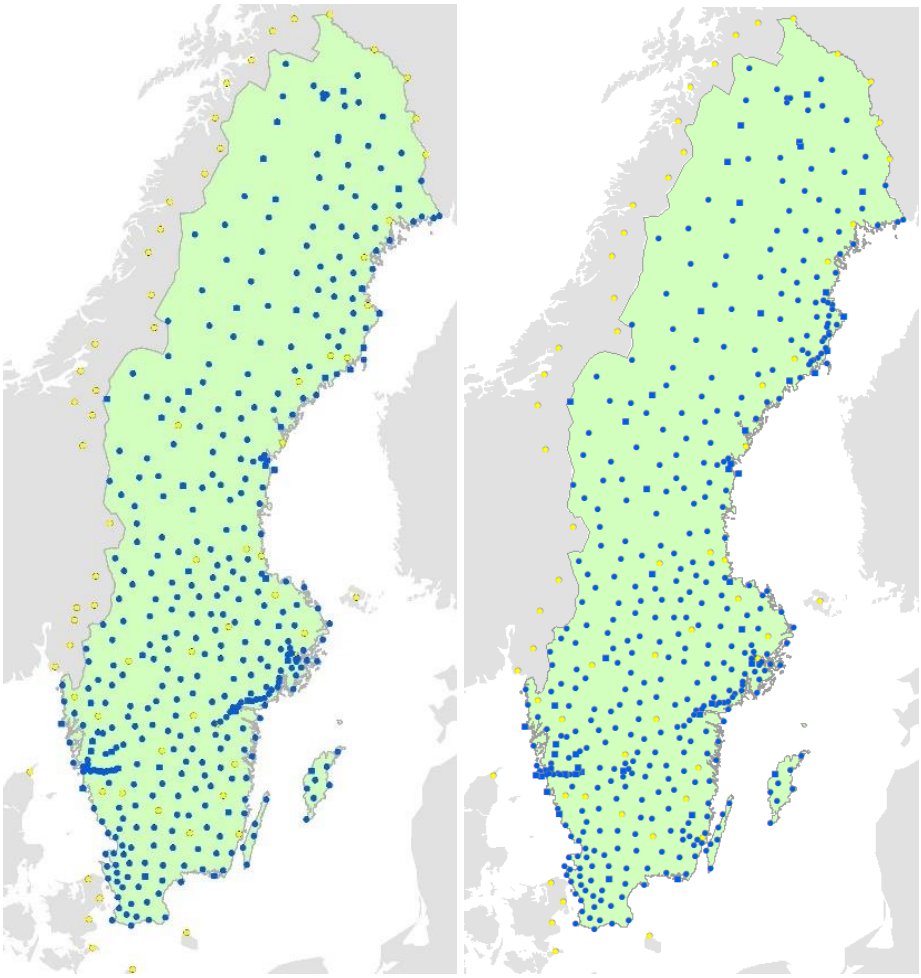
The purposes of SWEPOS are

- 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, and
- monitoring the integrity of the GNSS systems.

By September 2022 SWEPOS consisted of totally 461 stations (*Figure 1.1*), of which 53 are of the highest class (class A) and 408 stations of class B. This means that the total number of SWEPOS stations has increased with 60 stations (12 of class A and 48 of class B) since the NKG General Assembly in 2018.

Class A stations (see Figure 1.2) are dual-frequency multi-GNSS receivers with choke ring antennas monumented on bedrock. They 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 class A stations but with somewhat less redundancy.

Figure 1.1: SWEPOS network development in the past 4 years. The SWEPOS network by the time of the previous NKG General Assembly in 2018 is shown to the left and by the time of the 19th NKG General Assembly in September 2022 to the right. Blue squares mark class A stations, blue dots class B stations, and yellow dots stations in neighbouring countries and from other service providers used in the SWEPOS Network RTK Service.



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), which are also included in IGS-MGEX.

1.4. 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 is implemented. An automated post-processing service, based on the Bernese GNSS Software, is also available.

Figure 1.2: Example of a SWEPOS class A station. The photo shows the station in Kramfors together with the hut for absolute gravity measurements. Photo: Holger Steffen.

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

The Network RTK service has, in September 2022, approximately 8,800 subscriptions, which means ca. 4,900 additional subscriptions since the last NKG General Assembly in 2018. Note that a subscription for agriculture allows network access for up to five single users. 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 soon.

A redundant server infrastructure, a so-called High Availability solution, was established in October 2020 in a separate physical location to meet the demands for uninterrupted availability of the real-time services, from current (e.g., agriculture) to future applications (e.g., autonomous vehicles). This solution will protect against e.g., loss of electricity or internet connectivity. System maintenance is facilitated since all traffic can be

redirected to the other location, e.g., in case of failure or while updating one location.

1.4.1. NEAR REAL-TIME DATA PROCESSING

In December 2021, Lantmäteriet started to produce a new coordinate solution given by an NRT GNSS data processing. The main objective of the NRT data processing is to obtain hourly coordinates for all SWEPOS stations. The coordinates are used as an independent data set for the monitoring of the quality of the reference stations used for e.g., the Network RTK service.

The Bernese GNSS Software version 5.2 is used to acquire ionospheric free linear combination measurements and process data in a network solution. We use the ultra-rapid GNSS orbit products provided by CODE. For each hourly data processing, besides the data for the last hour, four more hours of data are added to the session to stabilise the estimation of ambiguity parameters. After the ambiguity resolution step and in the final solution step only the data for the last hour were used.

In the end of each NRT data processing, all estimated hourly coordinates are connected to SWEREF 99. The displacements of the hourly coordinates with respect to the "official" coordinates of the stations are calculated in east, north, and up directions. The displacement information is further distributed to the interface of the SWEPOS monitoring system.

Since the NRT data processing produces solutions for every hour, large variations of the stations can be detected faster than daily and weekly solutions. In addition, the hourly coordinates are useful to detect and study the variations due to short-lived interferences, e.g., sudden large ionospheric variations, which otherwise will be averaged out by the daily and/or weekly solution.

1.4.2. GNSS SIGNAL DISTURBANCE MONITORING

As part of the SWEPOS data quality monitoring, a near-real-time GNSS signal interference detection system was developed to detect (un)intentional signal disturbances of various sources using the SWEPOS network. The system (Abraha et al., 2021) utilises hourly RINEX files and detects disturbances by monitoring and characterizing variations in signal level (SNR). All available frequencies from GPS, GLONASS, Galileo and BeiDou are monitored. If a disturbance is detected, an alert is sent to a focus group within SWEPOS that addresses the issue to investigate it further and determine a solution. The system has successfully identified critical disturbances at several SWEPOS stations.

1.5. 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. The work regarding the implementation of SWEREF 99 among different authorities in Sweden, such as local ones, is

almost finalised (only one of the 290 Swedish municipalities still remains to replace their old reference frames with SWEREF 99).

When necessary, e.g., when GNSS antennas were exchanged and when new antenna models and computation strategies have been introduced, the coordinates of the SWEPOS stations are regularly updated.

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 autumn 2019 and the NKG_RF17vel land uplift model (Häkli et al., 2019). The differences between the previous and the updated coordinates are, overall, small and lie within the specifications of the SWEPOS services.

There are about thirty reference frame defining stations in Sweden and, in addition, approximately 100 stations in our neighbouring countries. 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.

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 eventually 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.

A set of transformation parameters between ITRF2014 and SWEREF 99 is available at Lantmäteriet's website and in the PROJ transformation library, starting from version 7.2.1.

1.6. Maintenance of the national levelling network

The third precise levelling of the mainland of Sweden during 1979–2003 resulted in the national height system RH 2000 in 2005 (Ågren et al., 2007).

RH 2000 is deemed the national height system for many years to come. It will be based on levelling because the precision of height determination with GNSS (height above the ellipsoid) is not as accurate as the levelling technique. Consequently, 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 is performed continuously. All benchmarks are visited but since benchmarks founded in bedrock and nodal points are more valuable for the perseverance of the network, destroyed points are replaced according to specific criteria. This approach ensures that enough destroyed benchmarks are replaced, securing the sustainability of the network and at the same time keeping costs down.

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 section 1.5.

The implementation of RH 2000 among different authorities in Sweden is in its final stages. About 98% of the 290 Swedish municipalities have replaced their local height systems with RH 2000.

1.7. Geoid determination

The current Swedish national geoid model is SWEN17_RH2000, which has been computed by combining the Nordic NKG2015 gravimetric model with Swedish GNSS/levelling data. Activities for its improvement are manifold:

- The new gravity reference system/frame RG 2000 was finalised in 2019 (see section 1.8).
- New gravity observations with Scintrex CG5 instruments are continuously collected to fill gaps or replace old data of lower quality.
- Within the FAMOS project (see section 1.11.1), a geoid model for the Baltic Sea will be computed that connects the BSCD2000 (an EVRS with land uplift epoch 2000.0) in the sea to the EVRS realisations on land. This will not only improve the geoid model at sea but also in the border between land and sea.
- Shipborne gravity measurements on Lake Vättern were performed to fill data gaps over the lake.

Recent focus is on improving and densifying the Swedish national GNSS/levelling dataset. The number of stations will increase from 185 in 2021 to around 300 in 2023. The core of the new, updated dataset is the so-called SWEREF GNSS stations for which accurate levelled heights are available in RH 2000. A majority of these SWEREF points are the consolidation points (see section 1.5) which allows to detect and remove unstable points. Since 2019, the levelled normal heights of the GNSS/levelling points are also checked by re-levelling relative to benchmarks in the national precise levelling network.

The Swedish national GNSS/levelling dataset consisting of 185 stations was delivered in 2022 to the EUREF working group “European Unified Height Reference” and the ongoing work with the EHRS.

In 2020, an industrial Ph.D. student was initiated at the University of Gävle in cooperation with Lantmäteriet. This Ph.D. project aims at developing and investigating different methods for regional realisation of the IHRS in Sweden and the Nordic/Baltic countries.

1.8. Gravimetry

In the beginning of 2018 the Swedish gravity reference frame, RG 2000, became official (Engfeldt et al., 2019) and in 2019 another realisation was accomplished (Engfeldt, 2019). The reference level is obtained by absolute gravity observations according to international standards and conventions.

RG 2000 is in a zero permanent tide system in postglacial rebound epoch 2000, realised by totally 343 points of three different classes.

Since 2021, all Lantmäteriet's detail gravity observations got a gravity value in RG 2000, no matter of which origin the observations were. The quality of the older detail gravity observations is frequently investigated and more detail gravity observations will be performed in the upcoming years wherever needed.

So-called class A points in RG 2000 are 13 stations (see Figure 1.2) that are revisited with Lantmäteriet's absolute gravimeter, FG5X-233, with an interval of approximately one to three years. These absolute gravity stations are co-located with SWEPOS stations. Ratan, Skellefteå, Smögen, Visby and Onsala are further co-located with tide gauges. Onsala is also equipped with VLBI telescopes and a superconducting gravimeter, which is annually calibrated with absolute gravity observations.

Since 2007, FG5X-233 regularly participates in local, regional and international absolute gravity intercomparisons to keep track of possible systematic biases. In 2022, Lantmäteriet together with Onsala Space Observatory and the Finnish Geospatial Institute arranged an intercomparison at Onsala Space Observatory as a mission from the NKG. The intercomparison lasted between May and July and gathered 16 different instruments. Results will be published in 2023.

Postglacial gravity change in Fennoscandia is studied by means of repeated absolute gravity observations in long time series. The first combined, open accessible database of three decades of 688 separate observations at 59 stations in the Nordic and Baltic countries was published by Olsson et al. (2019).

1.9. Geodynamics

Lantmäteriet performs geodynamic research to support the understanding of the physical mechanisms behind plate motion and deformation, and the Fennoscandian GIA process. This may also include, depending on the study or project, research regarding sea-level change, climate changes and earthquakes. Results help improve correction models for these processes in geodetic observations.

Studies of crustal deformation in Fennoscandia with continuous GNSS observations were carried out within the BIFROST effort. The latest reprocessed velocity field is based on 164 stations (Kierulf et al., 2021). These data served as input for the official land uplift model NKG2016LU (Vestøl et al., 2019) and the 3D velocity model NKG_RF17vel (Häkli et al., 2019). The next reprocessing of GNSS data, BIFROST2022, has been initiated which will largely extend the number of stations (500+) and observation time span.

Based on an analysis of three decades of absolute gravity observations in the Nordic and Baltic countries, Olsson et al. (2019) introduced NKG2016LU_gdot, a model of GIA-induced gravity rate of change in

Fennoscandia. It is achieved by means of the NKG2016LU land uplift model, together with the geophysical relation between gravity rate of change and uplift recommended in Olsson et al. (2015).

Lantmäteriet is involved in the EUREF effort on obtaining a high-resolution velocity model for Europe and adjacent areas. The densified EPND2150 velocity field (https://epnd.sgo-penc.hu/) will be used to provide the first official EUREF velocity model EuVeM2022 based on a new least-squares collocation method with moving variance and taking plate boundaries into account (Steffen et al. 2022).

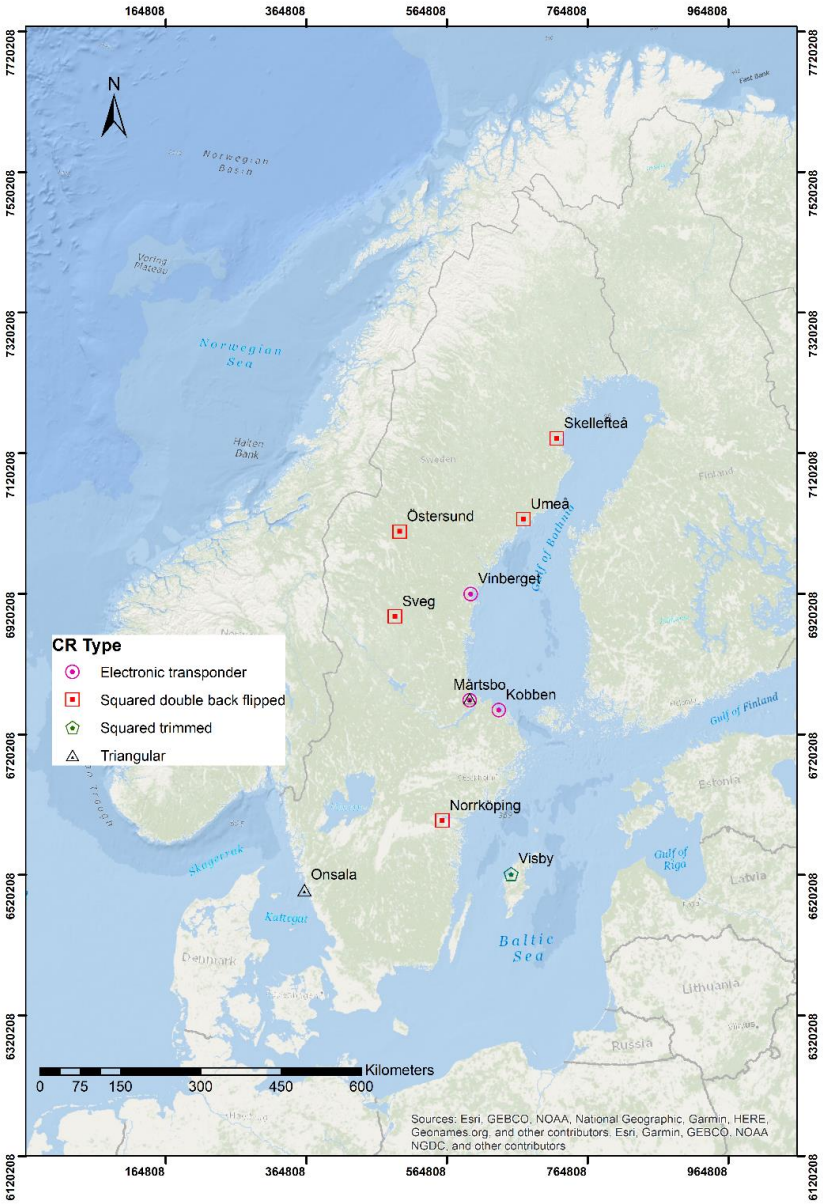
The generation of the strain-rate product has become Lantmäteriet's responsibility within EPOS. This European project is currently in the sustainability phase (EPOS-SP). The first strain-rate grid for Europe can be downloaded from the EPOS GNSS product portal at https://gnssproducts.epos.ubi.pt. The Swedish consortium EPOS-Sweden has been officially formed in 2022 and is supported as an infrastructure project by the Swedish Research Council.

1.10. InSAR and Geodetic SAR

The geodetic infrastructure in Sweden will be complemented with at least 20 passive corner reflectors (Figure 1.3), co-located with SWEPOS stations, to support InSAR measurements. So far, 11 passive corner reflectors have been installed. The network of passive corner reflectors will support a nationwide GMS for Sweden and the EGMS. The Swedish GMS coordinated by the Swedish National Space Agency is introduced between 2020 and 2022. The first product is the result of processing of 6 years Sentinel-1 data (2015–2021) over Sweden and is available via the web-based service at https://insar.rymdstyrelsen.se. It is based on the same platform as InSAR Norway (https://insar.ngu.no/). The nationwide GMS visualises the localisation of deformation in different parts of Sweden and includes the time series of displacements for ~1.5 billion measurement points. Lantmäteriet will also participate in an activity related to atmospheric corrections of the signals from the satellites.

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., 2022). 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 still fully operational. Lantmäteriet performed high resolution geoid modelling at tide gauges. Projects results including the final report are available from the project website https://eo4society.esa.int/projects/sar-hsu.

Figure 1.3: Map overview of the distribution of the transponders and newly installed passive corner reflectors in Sweden.



1.11. Projects

1.11.1. FAMOS

Since 2015, Lantmäteriet is engaged in the EU project FAMOS. The main purpose of FAMOS is to increase the safety of navigation in the Baltic Sea, mainly by finalising hydrographic surveying in areas of interest for commercial shipping. Other important aims are to improve navigation and hydrographic surveying with GNSS-based methods in the future and to support the introduction of the new BSCD2000 in the Baltic Sea (Schwabe et al., 2020).

An important basis for future GNSS-based offshore navigation is an improved geoid model in the Baltic Sea area. The forthcoming FAMOS geoid will realise BSCD2000 in the Baltic Sea and connect to the EVRS realisations on land. To achieve this, new marine gravity data are collected over sea to check and improve the existing gravity data as well as to fill gaps. Lantmäteriet procured a ZLS marine gravimeter in 2017 which was used to observe 12 shipborne and one airborne campaign since 2018 related to FAMOS (Figure 1.4). Gravity data are continuously delivered to the FAMOS database together with all data collected by the other participating countries/organisations around the Baltic Sea.

During 2021, Lantmäteriet computed a so-called FAMOS interim geoid model based on the latest version of the FAMOS gravity database, which was submitted to the project. The final FAMOS geoid model is expected to be finalised and released during 2023.

1.11.2. "REFERENCE NETWORK IN THE AIR 2.0"

The research and innovation project "Reference Network in the Air 2.0" (in Swedish: Stomnät i luften 2.0) is initiated by the Swedish Transport Administration and is based on earlier research concerning positioning systems for large-scale construction projects (Trafikverket, 2011). Lantmäteriet is, together with the KTH Royal Institute of Technology, RISE Research Institutes of Sweden and WSP, 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.

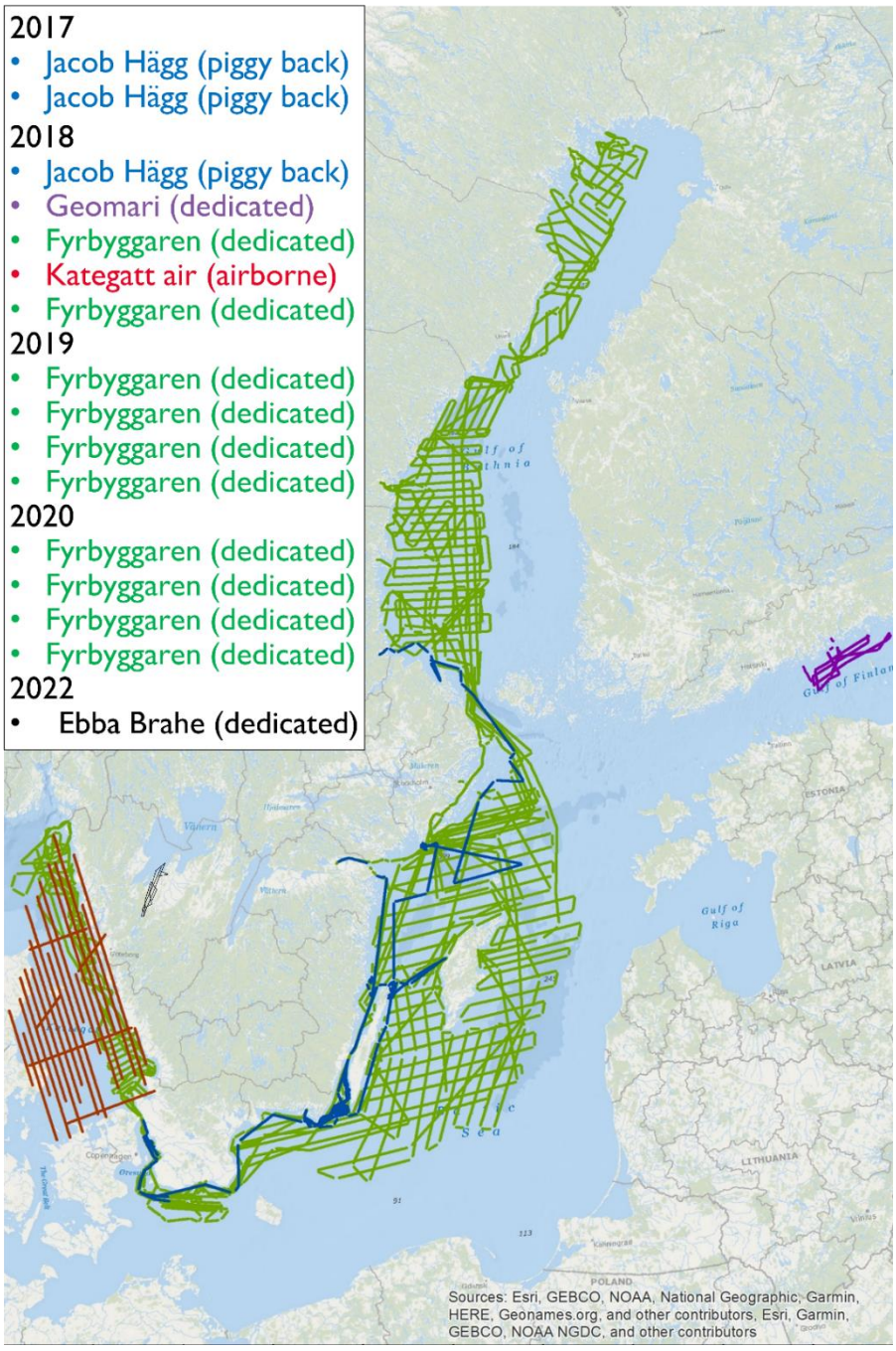
The aim of this project is, through 13 sub-activities, to secure that the Swedish Transport Administration uses a modern, robust, and future-proof geodetic infrastructure for GNSS positioning.

1.11.3. MONITORING OF EGNOS

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 EGNOS SPMS project and participates in the work package of local position performance assessment where its objective is to monitor the position obtained by two 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, the following tasks are performed:

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

Figure 1.4: List of used vessels and map overview of measured tracks with Lantmäteriet's dynamic gravimeter, ZLS D13, during 2017–2022.



1.11.4. NPAD

The research project NPAD – Network RTK Positioning for Automated Driving – was funded by Vinnova with major partners being Lantmäteriet, RISE, Ericsson, Einride, Volvo and Scania. The project started in May 2018 and finished in November 2020.

The main purpose of NPAD was to develop, implement and test an efficient distribution system for SWEPOS (Network RTK) correction data to enable

centimetre-level uncertainty GNSS positioning for an unlimited number of mobile platforms, e.g., automated vehicles.

The proposed idea was to use a grid of fixed VRSs which could be established to cover the test area in the NPAD project. The correction data from SWEPOS for the VRS grid were then provided in broadcast mode through the cell-phone network (location server). 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 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. They also implemented the needed software at the GNSS client side to test the distribution mechanism and how this is handled by an 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.

1.11.5. PNK4UTM

The PNK4UTM – Positioning, Navigation, and Communication for Unmanned Aerial Traffic Management – project is a R&D project funded by the Swedish Transport Administration. The main partners in the project are RISE, Ericsson, Lantmäteriet, Telia, T2data, UMS Skeldar, Västervik municipality and Linköping University. 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. In the long-term, this shall significantly improve the functionality of the cell-phone network and positioning services (as the SWEPOS services) to perform the long-term implementation of unmanned aerial traffic management. Furthermore, existing technology products, processes and methods to enable secure positioning, navigation, and communication for the UAVs are tested and improvements will be suggested.

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

1.11.6. PREPARE SHIPS

PREParE SHIPS – Predicted Positioning Based on EGNSS for Ships – was a Horizon 2020 project funded by the European Union with participating partnership organisations from Sweden, Germany, and Norway. The project started in December 2020 and ended with the final seminar in May 2022.

The aim of the project was 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 provided 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 (section 1.11.4), corrections were provided from fixed VRS points along the coastline to ensure scalability with a potentially large number of future users. The main challenges were 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.

1.11.7. "ROBUST SATELLITE POSITIONING"

The research project "Robust Satellite Positioning" (in Swedish: Robust satellitpositionering) was initiated by Swedavia and financed by the Swedish Transport Administration (Alexandersson et al., 2021). Participants in the project were Swedavia, FOI and Lantmäteriet. The project started in August 2020 and ran until September 2021.

The main purpose of the project was 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' GNSS receivers in combination with information from FOI's detection systems was studied, as well as how this capability could be implemented in a nationwide detection system.

1.11.8. DINPAS

DINPAS – Digital Infrastructure Enabling Accurate Positioning for Autonomous Systems – is an R&D project funded by Vinnova, Sweden's innovation agency. Involved partners are RISE, AstaZero, Combitech, Ericsson, IBG, Katla Aero, Lantmäteriet, Telia and u-blox. The project started in October 2021 and will run until September 2023.

The aim of the DINPAS project is to evaluate the requirements of future autonomous airports in terms of reliable, precise positioning as well as scalability to large numbers of devices, to benefit the next generation of industrial digital solutions. The targeted implementation, including software for generating corrections, 3GPP-based delivery, and navigation device, will be used for evaluating relevant performance.

Lantmäteriet's contribution to the project comprises implementing a new software for generation of GNSS corrections with the SSR technique. The SSR corrections will be based on data from the SWEPOS stations, and different configurations of reference stations as input for generation of corrections will be evaluated during the project. GNSS positioning based on SSR corrections will then be compared to positioning using corrections based on the OSR technique which are used in the ordinary SWEPOS Network RTK service.

1.12. Further activities

1.12.1. REVIEW OF THE NATIONAL BOUNDARY BETWEEN SWEDEN AND NORWAY

The national boundaries with Finland and Norway are reviewed approximately every 25 years, as bilateral cooperation. During 2020–2024, the boundary with Norway is reviewed. The Swedish Government has appointed a so-called boundary 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 boundary and how it is marked. The boundary markers will be restored, and the five-metre-wide clearing along the boundary line is cleared from trees and shrubs (below the tree line). It is worth noting that the field work is carried out predominantly in demanding mountain terrain far from civilisation, and hence, planning is always dependent on the constantly changing weather.

A helicopter reconnaissance and initial field work along the border was performed in 2020. The field season in 2021 had up to three teams working in parallel along the border who restored and measured 200 boundary markers with high-quality coordinates and marked and cleared 60 km of boundary line. This corresponds to approximately 45% of the total amount of field work.

An important part of the work in summer 2022 was the restoration of Treriksröset (Figure 1.5), where the national boundaries of Finland, Norway and Sweden meet. After two days of intensive work, 260 kilos of mortar and 5 litres of paint, the cairn is again in top condition. Treriksröset was inspected on 18 August 2022 by the national boundary commissions of Sweden, Norway and Finland who also signed a protocol confirming the work (see Figure 1.5).

The field work in 2022 completed another 45% of the restoration and coordinate determination work, so that the work in 2023 and 2024 can primarily be devoted to completion and documentation.

Figure 1.5: Treriksröset. Here meet the national boundaries of Sweden, Norway, and Finland. Personnel from Lantmäteriet restored the cairn during 2022 and the boundary commissions from Sweden, Norway and Finland inspected the restoration on 18 August 2022. Photo: Dan Norin.

1.12.2. PARTICIPATION IN PROJECTS OVERSEAS

Lantmäteriet is involved in several projects abroad. Many projects have a geodetic part and typical components are development of the geodetic infrastructure and implementation of modern surveying techniques based on GNSS. Countries which geodetic personnel have visited for assignments over the last four years are Albania, Belarus, Bosnia and Herzegovina, Botswana, Georgia, North Macedonia, Rwanda, and Serbia.

Besides the projects overseas, Lantmäteriet has also been represented and involved in different international seminars and working groups. For example, Mikael Lilje is since 2017 one of the four vice presidents of FIG and Martin Lidberg is since 2019 the president of EUREF. Rebekka Steffen chairs the Joint Study Group 3.1: Geodetic, Seismic and Geodynamic Constraints on Glacial Isostatic Adjustment of the IAG and was the EGU Geodesy Division Early Career Scientist Representative in 2021/22. The UN Subcommittee on Geodesy Focus Group on Education, Training and Capacity Building was headed until early 2022 by Sweden (Mikael Lilje). Lantmäteriet supports the management of the geodetic UNESCO World Heritage Struve Geodetic Arc, both nationally and internationally, and Thomas Eiderman is since 2022 the Chair of the Struve Geodetic Arc Coordinating Committee.

1.12.3. ARRANGED WORKSHOPS AND SEMINARS

For Swedish GNSS users, seminars were arranged in Gävle in October 2019 and October 2021. The aim of these seminars held every second year is to highlight the development of GNSS techniques, applications of GNSS and experiences from the use of GNSS. Many locally organised seminars had key speakers from Lantmäteriet, who informed about e.g., SWEPOS, SWEPOS services and national reference frames. Lantmäteriet is also giving courses in e.g., geodetic reference frames and GNSS positioning.

In 2019, Lantmäteriet hosted the International GIA Training School. Lectures by 16 international instructors were attended by 41 students from all over the world. An excursion led to prominent places witnessing the former glaciation and sea-level change.

1.12.4. PH.D. AND DIPLOMA WORK

Martin Håkansson successfully defended his Ph.D. on "GNSS hardware biases in code and carrier phase observables" in 2020 at KTH. Anders Alfredsson is currently working on his Ph.D. at the University of Gävle. During the period 2019–2022 totally 18 diploma works have been performed at Lantmäteriet by students from KTH, Karlstad University, Luleå University of Technology, the University of Gävle and Chalmers University of Technology (not all published). They have mainly been focused on GNSS and the SWEPOS services.

1.12.5. WEBSITE AND DIGITAL GEODETIC ARCHIVE

In the beginning of 2019, several new Digital Geodetic Archive services were released. The services provide information about the national geodetic control points as open data (under CC0 license):

1. A web self-service: https://stompunkt.lantmateriet.se.
2. A WMS, which supplies the information in raster format, for import into users' own GIS.
3. A direct access service providing information via M2M, for integration of data in the users' own applications.

Besides the Digital Geodetic Archive, Lantmäteriet hosts the analogue Geodetic Archive, founded in 1805. It contains data and documents regarding the basic geodetic measurements of Sweden from around 1750 up till now.

During 2019 the review of the Geodetic Archive was completed, and the structure of the information is now in accordance with Swedish archive regulations.

1.12.6. GTRANS

Gtrans is a software for transforming coordinates for geodetic and cartographic purposes. The programme is developed by the Geodesy department at Lantmäteriet and meanwhile widely distributed outside the authority. The transformations and calculations are made with correct algorithms and with sufficient precision.

In 2022, the new version 4.0 with a completely new graphical user interface was released. All current transformations between Swedish national and regional coordinate systems are included in the installation. The user can create and add custom transformations and coordinate systems as well as programme own plugins to read and write additional formats. The calculation part of Gtrans can also be built into other programme systems.

1.12.7. GUIDELINES FOR MAPPING AND SURVEYING

Lantmäteriet contributes to efficient and standardised surveying and mapping in Sweden 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) and includes recommendations for professional surveyors as well as potential clients that need to specify such services.

The guidelines are reviewed by a stakeholder reference group on an annual basis and are published as new versions in case of major revisions. Five documents covering geodetic applications were updated in the last 4 years:

- Geodetic infrastructure
- Control surveying
- Terrestrial detail surveying
- GNSS-based detail surveying
- Terrestrial laser scanning

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.

2. Geodetic activities at the KTH Royal Institute of Technology, Stockholm

2.1. Organisation and staff

Division of Geodesy and Satellite Positioning organisationally belongs to the Department of Real Estate and Construction Management since 2018. Since January 2015, Professor Anna Jensen was head of the Division, who was appointed as professor in September 2014 following the retirement of Lars Sjöberg. In 2018 she quit her full-time professorship and became guest professor until 2021. Currently she is not associated with KTH.

At present, there are two full-time employees at the Division: associate professor Milan Horemuz, who has been head of Division since 2018 and associate professor Huaan Fan. Mohammad Bagherbandi is also part-time (20%) employed at the Division as researcher. Furthermore, Dr. Johan Vium Andersson is associated with the Division. He is employed at WSP, and he collaborates with KTH in research and supervision of students.

2.2. Education

2.2.1. BACHELOR

KTH-Geodesy mainly contributes with teaching in geodetic surveying techniques, map projections and reference frames in year 1 and 3 of the Degree Programme in Civil Engineering and Urban Management (Swedish: Civilingenjörsutbildning i samhällsbyggnad). A total of around 150 students are enrolled in this programme and 5–10 of these choose to specialise in Geodesy and Geoinformatics in year 3.

To a smaller degree, KTH-Geodesy also contributes to the bachelor in Constructional Engineering and Design with courses in geodetic surveying techniques, laser scanning and 3D building modelling.

2.2.2. MASTER

At the master level, KTH-Geodesy contributes to the master programme Transport and Geoinformation Technology with courses in GNSS, laser scanning, geodata quality and adjustment theory. The master programme has a total of around 40 students and 2–5 of these do their master thesis in geodesy. The most popular topics for master theses have been laser scanning in various applications, sensor integration, geodetic aspects of building information modelling and geodata quality issues. Most of the

master theses are carried out in cooperation with private companies or governmental organisations.

To a smaller degree, KTH-Geodesy contributes to the master in Aerospace Engineering with a GNSS course and co-supervision of master theses.

2.2.3. PH.D.

Ph.D. students at KTH-Geodesy are enrolled in the Ph.D. programme in Geodesy and Geoinformatics with specialisation in Geodesy.

Four Ph.D. students have been active during 2019–2022; three of them completed their studies (Martin Håkansson in 2020, Nureldin Gido in 2020, Gustaf Uggla in 2021).

2.3. Research

Research at KTH-Geodesy is done partly by the staff being permanently employed without external funding, and partly within the frame of externally funded research projects where most of the funding is used for salaries for Ph.D. students.

Research topics are physical geodesy, satellite gravimetry, GNSS- based positioning and navigation, atmospheric effects on GNSS satellite signals, geodetic reference systems and applications, geodetic surveying and theory of errors, integration of GNSS and terrestrial surveying techniques, geodynamics, laser scanning, and geodata quality.

External funding for research projects at KTH-Geodesy during 2018– 2022 was related to:

- Industrial Thinking through the Full Value Chain in Coupling Geodesy, Geodata Quality and Building Information Modelling, funded by the Swedish Transport Administration, 2017–2021.
- Data Quality and Data Responsibility in the Built Environment, funded by Smart Built Environment and Formas, 2017–2019.
- Control network in the air 2.0 (Stomnät i luften 2.0) funded by the Swedish Transport Administration, 2018 – 2022.

Also, during 2019–2022 KTH-Geodesy has participated in the following projects on capacity building in geodesy education and research. These projects are funded by the EU's Erasmus+ Programme:

- Geodesy and Geoinformatics for Sustainable Development in Jordan, led by KTH-Geodesy, 2017–2020.
- Enhancing innovation competences and entrepreneurial skills in Engineering Education, led by KTH-Geodesy, 2016–2019.
- Interdisciplinary Reform in Tourism Management and Applied Geoinformation, led by Polytechnical University of Valencia, Spain, with KTH-Geodesy as project partner, 2016– 2019.
- Doctoral studies in GeoInformation Science, led by Obuda University, Hungary, with KTH-Geodesy as project partner, 2017–2020.

- Developing Interdisciplinary Postgraduate Programmes and Strengthening Research Networks in Geoinformation Technologies in Armenia and Kyrgyzstan (GeoTAK), led by Polytechnical University of Valencia, Spain, with KTH-Geodesy as project partner, 2021–2023.

All staff members of KTH-Geodesy also contribute to review of scientific papers, participate in editorial boards of international scientific journals, act as opponent and committee members at Ph.D. defences, perform review of research proposals etc.

2.4. Other activities

KTH-Geodesy has been involved in several external activities with the Swedish geodetic community as well as internal obligations in committees and boards within the university.

Examples of external activities by KTH-Geodesy:

- Cooperation with the Vasa Museum; deformation monitoring of the Vasa-ship twice yearly.
- Cooperation with the company Trimtec on continued education in measurement uncertainty and GNSS for professionals in Sweden; several one-day courses have been held every year since 2012.
- A seminar series on geodesy and building information modelling arranged in cooperation with the Swedish Transport Administration with two seminars per year since 2016.
- Presentations at national conferences, seminars, and workshops, for instance Kartdagarna (the Swedish Mapping days) and Geodesidagarna (the Surveying Days).
- Consulting for private and public organisations.

Examples of internal tasks at KTH undertaken by staff of KTH-Geodesy:

- Deputy programme responsible for the master in Transport and Geoinformation Technology.
- Director of studies of the Geo-IT specialisation of education at the School of Architecture and Built Environment.
- Member of the KTH Scholarship council.
- Member of the KTH Space Centre.
- Member of the KTH Employment Committee.
- Deputy programme responsible for the research education (Ph.D.) in Geodesy and Geoinformatics.

3. Geodetic activities at Onsala Space Observatory — Chalmers University of Technology

3.1. Organisation and staff

The Onsala Space Observatory (OSO) is the Swedish National Facility for Radio Astronomy as well as the Swedish Geodetic Fundamental site. and member of the GGOS Space Geodesy Network. OSO is hosted by SEE at Chalmers University of Technology. OSO operates a variety of space geodesy and geoscience instrumentation, among these geodetic VLBI, GNSS, a superconducting gravimeter, tide gauges, and radiometers, and e.g., has the longest time series of geodetic VLBI observations worldwide. Since 2021 Lantmäteriet is providing financial support for the operational space geodesy activities at OSO.

Until the end of August 2021, the Space Geodesy unit was part of the Onsala Space Observatory division. During 2021 a few internal re-organisations were carried out at SEE affecting the OSO division that hosts the OSO infrastructure activities. The Space Geodesy unit left the OSO division to become a part of a new GEO Division within SEE, starting in September 2021. The Space Geodesy unit remained however a key part of the OSO infrastructure with the responsibility to manage OSO's geoscience activities. The new structure did not work as well as expected, and it was recently decided that the Space Geodesy unit will move back into the Onsala Space Observatory division starting from January 2023.

Staff in the Space Geodesy group at the Onsala Space Observatory during 2018–2022:

Seniors staff members:

Rüdiger Haas, Gunnar Elgered, Peter Forkman, Jan Johansson (Adj. prof), Thomas Hobiger (–2018), Maxime Mouyen (2018–), Marcin Rajner (PostDoc 2018), Hans-Georg Scherneck (–2019), Eskil Varenius (2019–), Armin Corbin (project assistant 2019), Karine Le Bail (2020–), Frédéric Jaron (project assistant 2020), Peng Feng (PostDoc 2021–), Marie Cherrier (project assistant 2022)

Guest Professors supported by the Hasselblad Foundation:

James L. Davis (2018–2022), Matt King (2018–2021), Cornelia Eschelbach (2022–)

Ph.D. examinations:

Niko Kareinen (2018), Grzegorz Kloptek (2020), Joakim Strandberg (2020)

Current list of Ph.D. students (2022-10-01):

Periklis Diamantidis, Yiting Cai, Rebekka Handirk, Uttama Dutta

3.2. Education

The group working on geosciences at OSO national infrastructure takes part in the academic teaching at Chalmers at bachelor, MSc, and Ph.D. level. The infrastructure supports teaching by making a small fraction of the time on its telescopes available for exercises by students on Chalmers and other Swedish academic courses. The staff are also sometimes involved in teaching and providing exercises at specialised graduate level schools that are organised from time to time at the Observatory. Specifically, at Chalmers, the 20 m telescope and SALSA, small antennas dedicated to teaching, were used in astronomy and physics courses, the 25 m telescope (Figure 3.1) in a satellite-communication course, GNSS equipment in a satellite-positioning course, and laboratory equipment in courses on microwave, millimetre wave, and THz technology. Students in the engineering programmes at Chalmers made visits to the observatory.

3.3. Geophysical research infrastructure at Onsala

Geodetic VLBI: The geodetic VLBI observing sessions, using the Onsala 20 m telescope with its S/X frequency band receiver system, are 24 h long and include regular IVS sessions in the R1-, RD-, RDV-, T2- and EUR-series. In total > 200 S/X sessions in the IVS programme were observed during 2018–2022. All sessions were recorded with the DBBC2 in vdif-format on the FlexBuff recorder for geodetic VLBI. These data were then e-transferred to the respective correlator.

Onsala twin telescopes (OTT): In 2018–2022, the OTT (see Figure 3.1) were used for about 100 VGOS sessions of different kinds, for a total observing time of approximately 600 hours/year.

Figure 3.1: The Onsala twin telescopes (OTT) and the 25 m telescope. Photo: Magnus Thomasson.

GNSS stations: OSO's primary GNSS station, called ONSA, has been operated continuously during 2018–2022. It is a station in the SWEPOS

network operated by Lantmäteriet. It is also one of the fundamental reference sites used in the global IGS network, as well as in the European EUREF network. An additional station, ONS1, has also delivered data continuously the same networks network. In addition to ONSA and ONS1, the 6 GNSS stations close to the Onsala twin telescopes were all running continuously. Of special interest is the experimental station OTT5 which was equipped with antireflecting material in periods during 2018–2022 to study the possible improvement from decreasing the impact of unwanted signal multipath propagation (see Figure 3.2).

Figure 3.2: Some of the GNSS installations at OSO.

Gravimeter laboratory: The main purpose of the gravimeter laboratory at Onsala is to maintain a gravity reference and calibration facility co-located with space geodetic techniques. The facility is one component of the Onsala Fundamental Geodetic Station. The laboratory is furnished with platforms for visiting absolute gravimeters, which happens on average one to three times per year. The laboratories primary instrument is a superconducting gravimeter (model GWR 054). In international context the instrument is called OSG054 and has been operated continuously with very few breaks in recording (less than 10 days) since its installation in June 2009.

Tide gauges: The Onsala tide gauge station was running uninterrupted for the entire period, 2018–2022 excluding the yearly cleaning of the well, causing a data gap of approximately 2 hours each year. The sea level observations are available from the official web site of national sea level data operated by SMHI. Onsala's other GNSS-based tide gauge station was also operated continually over the years providing observations with a sampling rate of 1 Hz. Data are stored in RINEX format and include multi-GNSS (i.e., GPS, GLONASS, Galileo, Beidou) code- and carrier-phase observations as well as SNR measurements.

Water Vapour Radiometers: The two water vapour radiometers, Astrid and Konrad, measure the sky brightness temperatures at 21 GHz and 31 GHz from which the radio wave propagation delay in the atmosphere is inferred. During 2019 Astrid and Konrad operated side by side in a continuous mode up to July 2019, when a thunderstorm damaged Astrid. Thereafter, Konrad has been operating continuously. An order for a new

water vapour radiometer has been placed with Radiometer Physics, Meckenheim, Germany. The delivery is expected in February–March 2023.

Aeronomy station: The aeronomy station consists of two radiometers: 1) A single sideband H2O system (water vapour) that measures the sky brightness temperature at 22 GHz, and 2) the double sideband CO/O3 system (carbon monoxide and ozone) that measures the sky brightness temperatures at 111 and 115 GHz. Spectra from both radiometer systems are used to retrieve vertical profiles of the observed molecules in the middle atmosphere. During 2019 the mirror pointing system of the H2O radiometer was rebuilt.

Seismometer station: OSO hosts a seismograph station in the SNSN at the Uppsala University. We have data access to the local seismometer and keep a continuous archive of its recordings. The station's waveform files are used in delay calibration of the superconducting gravimeter and for noise reduction in absolute gravity measurements.

Time and frequency laboratory: The time and frequency laboratory host a hydrogen maser, necessary for VLBI observations, but which also contributes to the universal atomic time. OSO also collaborates with RISE on a Swedish time-keeping system. RISE owns a second hydrogen maser and a caesium clock that are also installed at Onsala. These instruments are used for comparison measurements and provide redundancy of accurate reference time (and frequency) for the VLBI observations (both astronomy and geodesy) at the observatory.

3.4. Users of the geoscience research infrastructure

The OSO geoscience instruments, including the geodetic VLBI observations as the major activity, do not have individual scientific users who apply for observing time. Rather the geoscience instruments make long-term measurements of Earth parameters – which are thereafter stored in international databases with open access. The data and the derived products such as station positions, Earth’s orientation/rotation rate, and gravity field are then used both by the global geophysics community for scientific purposes and by civil society for a variety of practical applications including supporting accurate geo-location services and monitoring of global change. As far as we know, all use of the data for scientific purposes was within the subject area 105 Earth and Related Environmental Sciences.

3.5. Outreach

During none-pandemic years over 1500 people visit Onsala Space Observatory per year, its telescopes and exhibition. The observatory organises guided tours, of which school groups of all ages accounted for the most. Around 450 visitors/year come as part of three public open days, during the Gothenburg Science Festival, on the Mother’s Day open day in May and in conjunction with Rymdveckan in September.

During 2022 a new visitor centre was inaugurated at the observatory. The project has been coordinated in collaboration with Chalmers's fundraising office, Chalmersfastigheter and the host department at Chalmers (SEE). We communicated news from Onsala facilities and research by Chalmers scientists to the media in collaboration with Chalmers press office and partner organisations.

4. Geodetic activities at the University of Gävle

4.1. Organisation

The Department of Computer and Spatial Sciences at the University of Gävle (HiG, https://www.hig.se) offers graduate and postgraduate education as well as performs research in geodesy, land surveying engineering, geomatics, GIS and built environment processes.

4.2. Education

There are four different programmes at HiG, where three of them are at the master level.

4.2.1. STUDY PROGRAMME IN LAND MANAGEMENT/SURVEYING (3 YEARS)

HiG offers two specialisations at the bachelor level in the land surveying programme, i.e., Land Management (cadastral surveying) and Land Surveying Engineering. The two specialisations share several courses for both, such as surveying courses related to geodata capturing in 3D using terrestrial, aerial, and satellite-based geodetic sensors. The programme contributes with new knowledge/methods utilizing geospatial information. In the land surveying engineering programme, students learn geodata collection, management, analysis, and visualisation (location-based information). The studies are focused on measurement technology and GIS. The students get a solid theoretical foundation while they will work very practically with the measuring instruments and software used in the industry. Students learn to use geodetic sensors and make measurements in digital images from drones as well as aerial and satellite images. More information at https://www.hig.se/TGLAK.TEKN.

4.2.2. STUDY PROGRAMME FOR A MASTER OF ENGINEERING IN LAND SURVEYING (5 YEARS)

The programme was established in 2020 and is called “Civilingenjörsprogrammet i lantmäteriteknik” in Swedish. It focuses primarily on collecting, managing, analysing and visualisation of spatial data. The programme consists of five-year full-time studies and results in a degree at Master level. It gives students knowledge in high demand and a deep understanding of geospatial data, land surveying (geodesy), GIS, computer programming, sustainable societal development, and smart cities. After two common years, students choose between two specialisations, either concentrating on technical land surveying or on GIS. Besides courses in the specific subject matter, a broad education is provided in mathematics,

computer science and the built environment. More information at https://www.hig.se/TACIM.

4.2.3. MASTER PROGRAMME IN GEOSPATIAL INFORMATION SCIENCE (2 YEARS)

The Master in Geospatial Information Science aims to help address challenges in the environment and society. The programme is a multidisciplinary subject (established in 2015) that includes ideas, theories, and methods from geosciences, in its broadest sense, and information technology. The topic integrates technical and natural science and social science research traditions. The focus is on knowledge building around technical solutions and methods to collect, analyse, model, calculate, and visualise all types of spatial, geographic, or georeferenced data. Geospatial information science is traditionally an applied subject and tackles challenges in e.g., social planning, decision making and industrial applications (engineering or social science-oriented use).

HiG's geodetic group contributes to the master programme in Geospatial Information Science with the supervision of theses, courses within geodetic surveying, laser scanning, satellite sensors and their applications in Geospatial Information Science (satellite gravimetry, satellite altimetry, InSAR, reference system, GNSS). More information at https://www.hig.se/TAGSM.

4.2.4. MASTER PROGRAMME IN GEOMATICS (1 YEAR)

This postgraduate programme in geomatics is a one-year programme and requires an undergraduate programme in geomatics, or equivalent, as prerequisite for admission. The geomatics programme consists of one thesis project and nine taught courses. HiG's geodetic group contributes to the master programme in geomatics with the supervision of theses, courses within geodetic surveying, laser scanning, satellite sensors and their applications in Geospatial Information Science (satellite gravimetry, satellite altimetry, InSAR, reference system, GNSS). More information at https://www.hig.se/TAGEM.

4.2.5. PH.D.

Ph.D. students in geodesy are enrolled in the Geospatial Information Science programme. Till now, three Ph.D. students have been enrolled at HiG in geodesy.

Hadi Amin (2017–September 2022)

- Thesis title: Study on the Earth's Surface Mass Variations using Satellite Gravimetry Observations
- Supervisors: M. Bagherbandi, F. Nilfouroushan, L. Sjöberg

Arash Jouybari (2018–2023 planned)

- Thesis title: Quality assessment in 3D mapping using aerial photogrammetry data
- Supervisors: M. Bagherbandi, F. Nilfouroushan, A. Ekholm

Anders Alfredsson (2020–), industrial Ph.D. student from Lantmäteriet

- Thesis title: Investigation of methods for regional realisation of the International Height Reference System with case studies for Sweden and the Nordic/Baltic countries
- Supervisors: J. Ågren, P.-A. Olsson

4.3. Research

The research conducted within the research group has been done based on external and internal funding. The research topics have primarily been focused on applied geodesy, such as:

- Geodata capturing using different terrestrial, aerial (including drones) and satellite-based geodetic sensors for 3D mapping
- Using drones (Unmanned Aircraft Systems) and different sensors for environmental surveillance
- Change detection of engineering structures and hazard monitoring using geodetic approaches
- Studying Earth's gravity field and its applications (physical geodesy)
- Study on the geodetic reference system and datum unification
- Geodynamics and Earth Observation:
    1. Climate change studies using satellite gravimetry and altimetry (sea level rise, glacier melting, groundwater depletion and subsidence)
    2. Measurement and analysis of anthropogenic and natural ground/structural deformation using GNSS and SAR Interferometry (InSAR)
    3. GIA-related vertical land motion modelling using satellite geodesy techniques
    4. Earth's interior parameter modelling (crustal thickness, viscosity).

In addition, HiG and Lantmäteriet decided to collaborate more on different research platforms in 2016. They decided to work on the strategies, relevant research areas, and common interests such as:

- Automated decision making.
- Information supply in Geodata area (Change detection, image analysis, 3D modelling, building information modelling and crowd-sourcing).
- Information presentation and visualisation.

The collaboration plan is realised by elaborating joint doctoral students within each area through research funding applications.

Table 4.1 shows external funds for research projects that HiG's geodesy research group participated in during 2019–2022. The research group is active and works continuously with research applications with external actors according to the department plan every year.

Table 4.1: External funds for research projects during 2019–2022.

Financier	Title	Time period
Tillväxtverket	Spatial data innovation (SDI)	2019–2021
Trafikverket	Satellite monitoring of railways using InSAR	2020–2021
SWECO (Richert)	Cost-effective data capture, including satellite images for settlement monitoring in Gävle	2019–2020
KKS Avans 20	Geodata competence at advanced level (for developing Civil engineering programme in surveying technology)	2020–2022

5. Geodetic activities at University West, Trollhättan

5.1. Educational activities

In February 2018 two senior lecturers in Geodesy, one full-time and one part-time, were employed in the SE education programme of University West (UW). Shortly after, the HoD of engineering science decided to divide the SE programme into two separate programmes, a pure SE with a higher admission requirement than the old SE programme and a land surveying covering Cadastre and land management with the old. A part-time senior professor in Geodesy and a laboratory engineer in technical surveying were employed after. The education curricula and new courses were developed, and modern instruments were bought in consulting with the industrial sectors. The university recruited new students in both programmes in the first year, but the year after, the land survey programme moved to the department of economy. On the 15th of March 2021, the HoD paused the student recruitment in the programme for 2021, due to an over-production, created by establishing several other education programmes, and lack of connection of the SE to production technology, the only higher education programme in engineering at UW. None of these plans and decisions were discussed with or informed to the SE programme responsible teacher. All supports and concerns from different industrial sectors (about 20 support letters) were not successful and the HoD paused the student recruitment again three months later for 2022. In such a situation and based on the university rules, a consequence analysis needed to be performed for the future of the programme. An external investigator was appointed, and he submitted a report supporting the programme. However, in January 2022, the university vice-chancellor, following the suggestion of the HoD and after other formalities, decided to close the programme. In May 2022, the full-time teachers were unemployed, and all activities in the geodetic educations were ended.

5.2. Research projects

In 2019, the members of the SE programme succeeded to have a two-year research project, granted by the SNSA with the title “On using satellite altimetry to determine the crust-mantle density contrast on the oceans”, but due to some internal administrative reasons and the pandemic, the grant was used for four years. After closing the SE programme and stopping all geodetic research at the university, the project grant moved to Uppsala University by its leader. A small one-year project, granted by SWECO with the title “Deformation Monitoring over Västra Götaland using InSAR data of Sentinel-1 satellite mission” was performed at UW. In addition, UW

succeeded to receive an Erasmus+ grant from the European Commission for a mobility project, between UW and University of Addis Ababa, Ethiopia. Some Ph.D. students and teachers visited UW for short geodetic research sabbaticals, and some teachers from UW visited University of Addis Ababa and gave lectures before the pandemic.

5.3. Ph.D. education

In December 2021, one Ph.D. in Geodesy was produced in collaboration between UW and University of Addis Ababa, with the main supervisor from the university and another Ph.D. in Geomatics in collaboration with University of Sherbrooke in Canada with a co-supervisor from UW.

References

Abraha K.E., Frisk A., Westberg M., Wiklund P. (2021): SWEPOS data quality monitoring – GNSS Signal Disturbances Detection System. Lantmäterirapport, 2021:1, Lantmäteriet, Gävle, Sweden.

Alexandersson M., Fors K., Stenberg N., Frisk A., Nilsson T., Wiklund P., Abraha K.E. (2021): Robust satellitnavigering med Swepos. FOI-R—5187--SE, FOI (in Swedish).

Engfeldt A. (2019): RG 2000 – a comprehensive overview on the new national gravity frame of Sweden. Lantmäterirapport, 2019:3, Lantmäteriet, Gävle, Sweden.

Engfeldt A., Olsson P., Steffen H., Lidberg M., Ågren J., Sekowski M., Krynski J., Bryskhe H., Nielsen J., Strykowski G. (2019): RG 2000 – the New Gravity Reference Frame of Sweden. Geophysica, 54(1), pp. 69–92.

Gruber T., Ågren J., Angermann D., Ellmann A., Engfeldt A., Gisinger C., Jaworski L., Kur T., Marila S., Nastula J., Nilfouroushan F., Nordman M., Poutanen M., Saari T., Schlaak M., Świątek A., Varbla S., Zdunek R. (2022): Geodetic SAR for Height System Unification and Sea Level Research – Results in the Baltic Sea Test Network. Remote Sensing, 14(14), 3250.

Häkli P., Lidberg M., Jivall L., Steffen H., Kierulf H., Ågren J., Vestøl O., Lahtinen S., Steffen R., Tarasov L. (2019): New horizontal intraplate velocity model for Nordic and Baltic countries. Proceedings of the 81st FIG Working Week "Geospatial information for a smarter life and environmental resilience", Hanoi, Vietnam, Conference Paper 10078.

Jivall L. & Lidberg M. (2000): SWEREF 99 – an updated EUREF realisation for Sweden. In Torres & Hornik (eds): Report on the symposium of EUREF held in Tromsø, 22–24 June 2000. EUREF, 2000 Symposium, 22–24 June 2000, Publication No 9, pp. 167–175, Tromsø, Norway.

Kierulf H.P., Steffen H., Barletta V.R., Lidberg M., Johansson J., Kristiansen O., Tarasov L. (2021): A GNSS velocity field for geophysical applications in Fennoscandia. Journal of Geodynamics, 146, 101845.

Lahtinen, S., Jivall, L., Häkli, P., Kall T., Kollo K., Kosenko K., Galinauskas K., Prizginiene D., Tangen O., Weber M., Nordman M. (2019): Densification of the ITRF2014 position and velocity solution in the Nordic and Baltic countries. GPS Solutions, 23, 95.

Lantmäteriet (2018): Geodesi 2018 – Lantmäteriets geodesistrategi 2018–2025. Lantmäteriet, 12 pp., Gävle, Sweden (in Swedish).

Lindskog M., Ridal M., Thorsteinsson S., Ning T. (2017): Data assimilation of GNSS zenith total delays from a Nordic processing centre. Atmospheric Chemistry and Physics, 17(22), pp. 13983–13998.

Olsson P.-A., Breili K., Ophaug V., Steffen H., Bilker-Koivula M., Nielsen E., Oja T., Timmen, L. (2019): Postglacial gravity change in Fennoscandia –

three decades of repeated absolute gravity observations. Geophysical Journal International, 217(2), pp. 1141–1156.

Olsson P.-A., Milne G., Scherneck H.-G., Ågren J. (2015): The relation between gravity rate of change and vertical displacement in previously glaciated areas. Journal of Geodynamics, 83, pp. 76–84.

Schwabe J., Ågren J., Liebsch G., Westfeld P., Hammarklint T., Mononen J., Andersen, O. (2020): The Baltic Sea Chart Datum 2000 (BSCD2000): Implementation of a common reference level in the Baltic Sea. International Hydrographic Review, 23, pp. 63–83.

Steffen R., Legrand J., Ågren J., Steffen H., Lidberg M. (2022): HV-LSC-ex^2: velocity field interpolation using extended least-squares collocation. Journal of Geodesy, 96(3), 15.

Trafikverket (2011): Slutrapport Stomnät i luften för anläggningsprojekt. Trafikverket, Borlänge, Sweden (in Swedish).

Vestøl O., Ågren J., Steffen H., Kierulf H., Tarasov L. (2019): NKG2016LU: a new land uplift model for Fennoscandia and the Baltic Region. Journal of Geodesy, 93(9), pp. 1759–1779.

Ågren J., Svensson R., Olsson P.-A., Eriksson P.-O., Lilje M. (2007): The Swedish height system as a national realization of EVRS. In Torres & Hornik (eds): EUREF Publication No 16, EUREF Symposium, 14–16 June 2006, pp. 65–73, Riga, Latvia.

Acronyms and Abbreviations

Table A1: Explanations of acronyms and abbreviations used in the report, in alphabetical order.

Acronym or abbreviation	Explanation
3GPP	3rd Generation Partnership Project
AC	Analysis Centre
BIFROST	Baseline Inferences for Fennoscandian Rebound Observations Sea level and Tectonics
BSCD	Baltic Sea Chart Datum
CODE	Centre for Orbit Determination in Europe
DGNSS	Differential GNSS
E-GVAP	The EUMETNET EIG GNSS water vapour programme
EGMS	European Ground Motion Service
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European GNSS
EGU	European Geosciences Union
EHRS	European Height Reference Surface
EIG	Economic interest grouping
EPN	EUREF Permanent GNSS Network
EPOS	European Plate Observing System
ETRS	European Terrestrial Reference System
EUREF	International Association of Geodesy Regional Reference Frame sub-commission for Europe
EUMETNET	European Meteorological Network
EVRS	European Vertical Reference System
FAMOS	Finalising Surveys for the Baltic Motorways of the Sea
FIG	International Federation of Surveyors
FOI	The Swedish Defence Research Agency (Totalförsvarets forskningsinstitut)
GGOS	Global Geodetic Observing System

Acronym or abbreviation	Explanation
GIA	Glacial Isostatic Adjustment
GIS	Geographic Information System
GLONASS	Globalnaja navigatsionnaja sputnikovaja sistema
GMS	Ground Motion Service
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
HMK	Guidelines for mapping and surveying (Handbok i mät- och kartfrågor).
HoD	Head of Department
IAG	International Association of Geodesy
IGS	International GNSS Service
IGS-MGEX	IGS Multi-GNSS Experiment
IHRS	International Height Reference System
IMU	Inertial Measurement Unit
InSAR	Interferometric Synthetic Aperture Radar
ITRF	International Terrestrial Reference Frame
ITRS	International Terrestrial Reference System
IVS	International VLBI Service
LPP	LTE Positioning Protocol
LTE	Long Term Evolution
M2M	Machine to machine communication
MSM	Multiple Signal Message
NGA	Nordic GNSS Analysis Centre
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

Acronym or abbreviation	Explanation
OSO	Onsala Space Observatory
OSR	Observation Space Representation
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
SALSA	Such a lovely small antenna (or in Swedish: “Sicken Attans Liten Söt Antenn”)
SAR	Synthetic Aperture Radar
SE	Surveying Engineering
SEE	Department of Space, Earth and Environment
SMHI	Swedish Meteorological and Hydrological Institute
SNR	Signal-to-noise ratio
SNSA	Swedish National Space Agency
SNSN	Svenska nationella seismiska nätet
SPMS	Service Performance Monitoring Support
SSR	State Space Representation
UAV	Unmanned Aerial Vehicle
UNGGIM SCoG	United Nations initiative on Global Geospatial Information Management, Subcommittee on Geodesy
VGOS	VLBI Global Observing System
VLBI	Very Long Baseline Interferometry
VRS	Virtual Reference Station
WMS	Web map service

Acronym or abbreviation	Explanation
ZTD	Zenith Total Delay

Appendix 1 – Lantmäteriet: Geodetic publications 2019–2022 in international journals, proceedings, and books

Abril C., Tryggvason A., Gudmundsson Ó., Steffen R. (2021): Local Earthquake Tomography in the Tjörnes Fracture Zone (North Iceland). Journal of Geophysical Research - Solid Earth, 126, e2020JB020212.

Alissa S., Håkansson M., Henkel P., Mittmann U., Huffmeier J., Rylander R. (2021): Low Bandwidth Network-RTK Correction Dissemination for High Accuracy Maritime Navigation. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, 15(1), pp. 171–179.

Alissa S., Håkansson M., Rieck C., Dutta U., Nord S., Bergljung P., Bagge A. (2021): Distribution of the adapted-NRTK correction data via VDES for the shipping navigation safety. Proceedings of ION GNSS+ 2021, St Louis/online, USA, pp. 521–534. *(not peer-reviewed)*

Bagherbandi M., Jouybari A., Nilfouroushan F., Ågren J. (2022): Deflection of Vertical Effect on Direct Georeferencing in Aerial Mobile Mapping Systems: A Case Study in Sweden. The Photogrammetric Record, 37, pp. 285–305.

Bagherbandi M., Jouybari A., Nilfouroushan F., Ågren J. (2022): Importance of precise gravity field modeling on direct georeferencing and aerial photogrammetry: a case study for Sweden. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLIII-B2-2022, pp. 15–20.

Brandes C., Plenefisch T., Tanner D.T., Gestermann N., Steffen H. (2019): Evaluation of deep crustal earthquakes in northern Germany – Possible tectonic causes. Terra Nova, 31(2), pp. 83–93.

Charlot P., Jacobs C.S., Gordon D., Lambert S., de Witt A., Böhm J., Fey A.L., Heinkelmann R., Skurikhina E., Titov O., Arias E.F., Bolotin S., Bourda G., Ma C., Malkin Z., Nothnagel A., Mayer D., MacMillan D.S., Nilsson T., Gaume R. (2020): The third realization of the international celestial reference frame by very long baseline interferometry. Astronomy & Astrophysics, 644, A159.

Chisenga C., Jianguo Y., Zhao J., Atekwana E.A., Steffen R. (2020): Density Structure of the Rümker Region in the Northern Oceanus Procellarum: Implications for Lunar Volcanism and Landing Site Selection for the Chang'E-5 Mission. Journal of Geophysical Research – Planets, 125(1), eJE005978.

Chisenga C., Van der Meijde M., Jianguo Y., Fadel I., Atekwana E.A., Steffen R., Ramatoroko C. (2020): Gravity derived crustal thickness model of Botswana: Its implication for the Mw 6.5 April 3, 2017, Botswana earthquake. Tectonophysics, 787, 228479.

Colgan W., Henriksen H.J., Bennike O., Ribeiro S., Keiding M., Karlsson Seidenfaden I., Graversgaard M., Busck A., Fruergaard M., Helt Knudsen M., Hopper J., Sonnenborg T., Skjerbæk M., Bjørk A., Steffen H., Tarasov

L., Nerem R.S., Kjeldsen K.K. (2022): Sea-Level Rise in Denmark: Paleo Context, Recent Projections and Policy Implications. Geological Survey of Denmark and Greenland Bulletin, 49, 8315.

Craddock A., Blick G., Keenan R., Lilje M., Sarib R. (2021): A geodesy and positioning thematic layer – identifying tools to connect the GGRF and IGIF. Proceedings of FIG Working Week 2021, online, Conference Paper 11081. *(not peer-reviewed)*

Dangendorf S., Kelln J., Arns A., Gräwe U., Steffen H., Hofstede J., Jensen J. (2022): Untersuchungen zur Rekonstruktion des Meeresspiegels und vertikaler Landbewegungen an den deutschen Küsten. Die Küste, 91, 37 pp.

Darvishi M., Cuozzo G., Bruzzone L., Nilfouroushan F. (2020): Performance evaluation of phase and weather-based models in atmospheric correction with Sentinel-1data: Corvara landslide in the Alps. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 13, pp. 1332–1346.

Dutta U., Rieck C., Håkansson M., Gerbeth D., Alissa S., Nord S. (2021): Satellite selection in the context of network RTK for limited bandwidth applications. Proceedings of ION GNSS+ 2021, St Louis/online, USA, pp. 2474–2492. *(not peer-reviewed)*

Edey A., Allen M., Nilfouroushan F. (2020): Kinematic variation within the Fars Arc, eastern Zagros, and the development of fold-and-thrust belt curvature. Tectonics, 39(8), e2019TC005941.

Elgered G., Ning T., Forkman P., Haas, R. (2019): On the information content in linear horizontal delay gradients estimated from space geodesy observations. Atmospheric Measurement Techniques, 12, pp. 3805–3823.

Engfeldt A., Olsson P., Steffen H., Lidberg M., Ågren J., Sekowski M., Krynski J., Bryskhe H., Nielsen J., Strykowski G. (2019): RG 2000 – the New Gravity Reference Frame of Sweden. Geophysica, 54(1), pp. 69–92.

Falk R., Pálinkáš V., Wziontek H., Rülke A., Val'ko M., Ullrich C., Butta H., Kostelecký J., Bilker-Koivula M., Näränen J., Prato A., Mazzoleni F., Kirbaş C., Coşkun I., van Camp M., Castelein S., Bernard J.D., Lothhammer A., Schilling M., Timmen L., Iacovone D., Nettis G., Greco F., Messina A.A., Reudink R., Petrini M., Dykowski P., Sękowski M., Janák J., Papčo J., Engfeldt A., Steffen H. (2020): Final report of EURAMET.M.G-K3 regional comparison of absolute gravimeters. Metrologia, 57(1A), Technical Supplement, 07019.

Fernandes R., Bruyninx C., Crocker P., Menut J.-L., Socquet A., Vergnolle M., Avallone A., Bos M., Bruni S., Cardoso R., Carvalho L., Cotte N., D'Agostino N., Deprez A., Fabian A., Geraldes F., Janex G., Kenyeres A., Legrand J., Ngo K.-M., Lidberg M., Liwosz T., Manteigueiro J., Miglio A., Soehne W., Steffen H., Toth S., Dousa J., Ganas A., Kapetanidis V., Batti G. (2022): A new European service to share GNSS Data and Products. Annals of Geophysics, 65(3), DM317.

Fors K., Stenberg N., Nilsson T. (2021): Using the Swedish CORS network SWEPOS for GNSS interference detection. Proceedings of ION GNSS+ 2021, St Louis/online, USA, pp. 4323–4333.

Fryksten J. & Nilfouroushan, F. (2019): Analysis of Clay-Induced Land Subsidence in Uppsala City Using Sentinel-1 SAR Data and Precise Leveling. Remote Sensing, 11(23), 2764.

Ghomsi F.E.K., Pham L.T., Steffen R., Ribeiro-Filho N., Tenzer R. (2022): Delineating structural features of North Cameroon using EIGEN6C4 high-resolution global gravitational model. Geological Journal, 57(10), pp. 1–15.

Ghomsi F.E.K., Tenzer R., Njinju E., Steffen R. (2022): The crustal configuration of the West and Central African Rift System from gravity and seismic data analysis. Geophysical Journal International, 230, pp. 995–1012.

Gido N., Amin H., Bagherbandi M., Nilfouroushan F. (2020): Satellite monitoring of mass changes and ground subsidence in Sudan's oil fields using GRACE and Sentinel-1 data. Remote Sensing, 12(11), 1792.

Gido, N.A.A., Bagherbandi, M., Nilfouroushan. F. (2020): Localized Subsidence Zones in Gävle City Detected by Sentinel-1 PSI and Leveling Data. Remote Sensing, 12(16), 2629.

Glaser S., König R., Neumayer K.H., Nilsson T., Heinkelmann R., Flechtner F., Schuh H. (2019): On the impact of local ties on the datum realization of global terrestrial reference frames. Journal of Geodesy, 93, pp. 655–667.

Goyal R., Ågren J., Featherstone W., Sjöberg L., Dikshit O., Balasubramanian N. (2022): Empirical comparison between stochastic and deterministic modifiers over the French Auvergne geoid computation test-bed. Survey review, 54(382), pp. 57–69.

Gradmann S. & Steffen R. (2021): Crustal-Scale Stress Modelling to Investigate Glacially Triggered Faulting. In Steffen et al. (eds.) Glacially-Triggered Faulting, Cambridge University Press, Cambridge, pp. 402–416.

Gruber T., Ågren J., Angermann D., Ellmann A., Engfeldt A., Gisinger C., Jaworski L., Kur T., Marila S., Nastula J., Nilfouroushan F., Nordman M., Poutanen M., Saari T., Schlaak M., Świątek A., Varbla S., Zdunek R. (2022): Geodetic SAR for Height System Unification and Sea Level Research - Results in the Baltic Sea Test Network. Remote Sensing, 14(14), 3250.

Gruber T., Ågren J., Angermann D., Ellmann A., Engfeldt A., Gisinger C., Jaworski L., Marila S., Nastula J., Nilfouroushan F., Nordman M., Oikonomidou X., Poutanen M., Saari T., Schlaak M., Świątek A., Varbla S., Zdunek R. (2020): Geodetic SAR for Height System Unification and Sea Level Research - Observation Concept and Preliminary Results in the Baltic Sea. Remote Sensing, 12(22), 3747.

Håkansson M. (2019): Characterization of GNSS observations from a Nexus 9 Android tablet. GPS Solutions, 23(1), 21.

Håkansson M. (2020): Nadir-dependent GNSS code biases and their effect on 2D and 3D ionosphere modelling. Remote Sensing, 12(6), 995.

Häkli P., Lidberg M., Jivall L., Steffen H., Kierulf H., Ågren J., Vestøl O., Lahtinen S., Steffen R., Tarasov L. (2019): New horizontal intraplate velocity model for Nordic and Baltic countries. Proceedings of the 81st FIG Working Week "Geospatial information for a smarter life and environmental resilience", Hanoi, Vietnam, Conference Paper 10078. *(not peer-reviewed)*

Huang P., Wu P., Steffen H. (2019): In search of an ice history that is consistent with composite rheology in Glacial Isostatic Adjustment modelling. Earth Planetary Science Letters, 517, pp. 26–37.

Jäggi A., Weigelt M., Flechtner F., Güntner A., Mayer-Gürr T., Martinis S., Bruinsma S., Flury J., Bourgogne S., Steffen H., Meyer U., Jean Y., Sušnik A., Grahsl A., Arnold D., Cann-Guthauser K., Dach R., Li Z., Chen Q., van Dam T., Gruber C., Poropat L., Gouweleeuw B., Kvas A., Klinger B., Lemoine J.-M., Biancale R., Zwenzner H., Bandikova Y., Shabanloui A. (2019): European Gravity Service for Improved Emergency Management (EGSIEM)—from concept to implementation. Geophysical Journal International, 218(3), pp. 1572–1590.

Jämtnäs L., Ohlsson K., Dahlström F., Kempe C. (2022): Best practice guidelines – enhancing the value of the surveyor. Proceedings of XXVII FIG Congress, Warsaw, Poland, Conference Paper 11569. *(not peer-reviewed)*

Jensen T.E., Olesen A.V., Forsberg R., Olsson P.-A., Josefsson Ö. (2019): New Results from Strapdown Airborne Gravimetry Using Temperature Stabilisation. Remote Sensing, 11(22), 2682.

Jivall L. & Saandar M. (2019): The National Reference MONREF97 in Mongolia and its developments. Mongolian Geoscientist, 49, p. 63.

Jouybari A., Bagherbandi M., Nilfouroushan F. (2021): Comparison of the strip- and block-wise aerial triangulation using different exterior orientation parameters weights. Journal of Spatial Science, 67(3), pp. 377–394.

Jouybari A., Bagherbandi M., Nilfouroushan F. (2022): Impact of GNSS signal outage on EOPs using forward Kalman filter and smoothing algorithm. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLIII-B2-2022, pp. 59–64.

Karbon M., Belda S., Nilsson T. (2019): Impact of the terrestrial reference frame on the determination of the celestial reference frame. Geodesy and Geodynamics, 10(1), pp. 58–71.

Kaviani A., Mahmoodabadi M., Rümpker G., Pilia S., Tatar M., Nilfouroushan F., Yamini-Fard F., Moradi A., Ali M. (2021): Mantle-flow diversion beneath the Iranian plateau induced by Zagros' lithospheric keel. Scientific Reports, 11(1), 2848.

Keenan R., Craddock A., Lilje M., Sarib R. (2020): A global survey of reference frame competency in terms of Education, Training and Capacity Building (ETCB): Results, analysis and update. Proceedings of FIG Working Week 2020, online, Conference Paper 10753. *(not peer-reviewed)*

Kelln J., Dangendorf S., Gräwe U., Steffen H., Jensen J. (2022): Entwicklung des mittleren Meeresspiegels entlang der südwestlichen Ostseeküste. Die Küste, 91, 40 pp.

Kenyeres A., Bellet J.G., Bruyninx C., Caporali A., de Doncker F., Droscak B., Duret A., Franke P., Georgiev I., Bingley R., Huisman L., Jivall L., Khoda O., Kollo K., Kurt A.I., Lahtinen S., Legrand J., Magyar B., Mesmaker D., Morozova K., Nágl J., Özdemir S., Papanikolaou X., Parseliunas E., Stangl G., Ryczywolski M., Tangen O.B., Valdes M., Zurutuza J., Weber M. (2019): Regional integration of long-term national dense GNSS network solutions. GPS Solutions, 23, 122.

Khorrami F., Vernant P., Masson F., Nilfouroushan F., Mousavi Z., Nankali H., Saadat S., Walpersdorf A., Hosseini S., Tavakoli P., Aghamohammadi A., Alijanzade M. (2019): An up-to-date crustal deformation map of Iran using integrated campaign-mode and permanent GPS velocities. Geophysical Journal International, 217(2), pp. 832–843.

Khoshlahjeh Azar M., Shami S., Nilfouroushan F., Salimi M., Ghayoor Bolorfroshan M., Reshadi M.A.M. (2022): Integrated analysis of Hashtgerd plain deformation, using Sentinel-1 SAR, geological and hydrological data. Scientific Reports, 12, 21522.

Kierulf H.P., Kohler J., Boy J.-P., Geyman E.C., Mémin A., Omang O.C.D., Steffen H., Steffen R. (2022): Time-varying uplift in Svalbard – an effect of glacial changes. Geophysical Journal International, 231(3), pp. 1518–1534.

Kierulf H.P., Steffen H., Barletta V.R., Lidberg M., Johansson J., Kristiansen O., Tarasov L. (2021): A GNSS velocity field for geophysical applications in Fennoscandia. Journal of Geodynamics, 146, 101845.

Kierulf H.P., Valsson G., Evers K., Lidberg M., Häkli P., Prizginiene D., Hjelle G.A., Vestøl O., Håkansson M., Knudsen P., Poutanen M. (2019): Towards a dynamic reference frame in Iceland. Geophysica, 54(1), pp. 3–17.

Kitpracha C., Nilsson T., Heinkelmann R., Balidakis K., Modiri S., Schuh H. (2022): The impact of estimating common tropospheric parameters for co-located VLBI radio telescopes on geodetic parameters during CONT17. Advances in Space Research, 69(9), pp. 3227–3235.

Knudsen T., Evers K., Hjelle G.A., Valsson G., Lidberg M., Häkli P. (2019): The bricks and mortar for contemporary reimplementation of legacy Nordic transformations. Geophysica, 54(1), pp. 107–116.

Lahtinen, S., Jivall, L., Häkli, P., Kall T., Kollo K., Kosenko K., Galinauskas K., Prizginiene D., Tangen O., Weber M., Nordman M. (2019):

Densification of the ITRF2014 position and velocity solution in the Nordic and Baltic countries. GPS Solutions, 23, 95.

Lahtinen S., Jivall L., Häkli P., Nordman M. (2022): Updated GNSS velocity solution in the Nordic and Baltic countries with a semi-automatic offset detection method. GPS Solutions, 26, 9.

Li T., Wu P., Wang H.S., Steffen H., Khan N.S., Engelhart S.E., Vacchi M., Shaw T.A., Peltier W.R., Horton B.P. (2020): Uncertainties of Glacial Isostatic Adjustment model predictions in North America associated with 3D structure. Geophysical Research Letters, 47(10), e2020GL087944.

Lidberg M., Jarlemark P., Johansson J., Ohlsson K., Jivall L., Ning T. (2019): Station calibration of the SWEPOS GNSS network. Geophysica, 54(1), pp. 93–105.

Lidberg M., Løvhøiden L., Brown N., Bouman J., Jørgensen A. (2020): UN Global Geodetic Centre of Excellence – progress from the UN-GGIM Sub Committee on Geodesy. Proceedings of FIG Working Week 2020, online, Conference Paper 10590. *(not peer-reviewed)*

Lidberg M., Söhne W., Sacher M., Legrand J., Kenyeres A. (2020): EUREF – an important component of the European geodetic infrastructure. Proceedings of FIG Working Week 2020, online, Conference Paper 10687. *(not peer-reviewed)*

Lidberg M., Söhne W., Kollo K. (2021): Advancing the geodetic infrastructure in Europe through EUREF. Proceedings of FIG Working Week 2021, online, Conference Paper 11184. *(not peer-reviewed)*

Lidberg M., Soehne W., Kollo K. (2021): Faire progresser l'infrastructure géodésique en Europe grâce à l'EUREF. xyz, 168, pp. 45–49.

Mehrabi A., Derakhshani R., Nilfouroushan F., Rahnamarad J., Azarafza M. (2022): Spatiotemporal subsidence over Pabdana coal mine Kerman Province, central Iran using time-series of Sentinel-1 remote sensing imagery. Episodes, https://doi.org/10.18814/epiiugs/2022/022009.

Müller K., Polom U., Winsemann J., Steffen H., Tsukamoto S., Günther T., Igel J., Spies T., Lege T., Frechen M., Franzke H.-J., Brandes C. (2020): Structural style and neotectonic activity along the Harz Boundary Fault, northern Germany: A multimethod approach integrating geophysics, outcrop data and numerical simulations. International Journal of Earth Sciences, 109, pp. 1811–1835.

Nield G.A., King M.A., Steffen R., Blank B. (2022): A global, spherical, finite-element model for postseismic deformation using ABAQUS. Geoscientific Model Development 15, pp. 2489–2503.

Nilsson T., Balidakis K., Heinkelmann R., Schuh H. (2019): Earth orientation parameters from the CONT17 campaign. Geophysica, 54(1), pp. 19–25.

Ning T. & Elgered G. (2021): High-temporal-resolution wet delay gradients estimated from multi-GNSS and microwave radiometer observations. Atmospheric Measurement Techniques, 14, pp. 5593–5605.

Olesen O., Steffen H., Sutinen R. (2021): Future Research on Glacially Triggered Faulting and Intraplate Seismicity. In Steffen et al. (eds.) Glacially-Triggered Faulting, Cambridge University Press, Cambridge, pp. 419–428.

Olsson P.-A., Breili K., Ophaug V., Steffen H., Bilker-Koivula M., Nielsen E., Oja T., Timmen, L. (2019): Postglacial gravity change in Fennoscandia – three decades of repeated absolute gravity observations. Geophysical Journal International, 217(2), pp. 1141–1156.

Pisarska-Jamroży M., Belzyt S., Börner A., Hoffmann G., Hüneke H., Kenzler M., Obst K., Rother H., Steffen H., Steffen R., Van Loon A.J. (2019): The sea cliff at Dwasieden: Soft-sediment deformation structures triggered by glacial isostatic adjustment in front of the advancing Scandinavian Ice Sheet. DEUQUA Special Publications, 2, pp. 61–67.

Pisarska-Jamroży M., Belzyt S., Börner A., Hoffmann G., Hüneke H., Kenzler M., Rother H., Steffen R., Steffen H. (2022): Late Pleistocene earthquakes imprinted on glaciolacustrine sediments at Gnitz Peninsula (Usedom Island, NE Germany). Quaternary Science Reviews, 296C, 107807.

Rashidi A., Abbassi M., Nilfouroushan F., Shafiei Bafti S., Derakhshani R., Nemati M. (2020): Morphotectonic and earthquake data analysis of interactional faults in Sabzevaran Area, SE Iran. Journal of Structural Geology, 139, 104147.

Rashidi A., Khatib M., Nilfouroushan F., Derakhshani R., Mousavi S., Kianimehr H., Djamour Y. (2019): Strain rate and stress fields in the West and South Lut block, Iran: Insights from the inversion of focal mechanism and geodetic data. Tectonophysics, 766, pp. 94–114.

Rosentau A., Klemann V., Bennike O., Steffen H., Wehr J., Latinović M., Bagge M., Ojala A., Berglund M., Peterson Becher G., Schoning K., Hansson A., Nielsen L., Clemmensen L.B., Hede M.U., Kroon A., Pejrup M., Sander L., Stattegger K., Schwarzer K., Lampe R., Lampe M., Uścinowicz S., Bitinas A., Grudzinska I., Vassiljev J., Nirgi T., Kublitskiy Y., Subetto D. (2021): A Holocene relative sea-level database for the Baltic Sea. Quaternary Science Reviews, 266, 107071.

Sánchez L., Ågren J., Huang J., Wang Y., Mäkinen J., Pail R., Barzaghi R., Vergos G., Ahlgren K., Liu Q. (2021): Strategy for the realisation of the International Height Reference System (IHRS). Journal of Geodesy, 95, 33.

Scherneck, H.-G., Rajner, M., Engfeldt, A. (2020): Superconducting gravimeter and seismometer shedding light on FG5's offsets, trends, and noise: what observations at Onsala Space Observatory can tell us. Journal of Geodesy, 94, 80.

Schuh H., Heinkelmann R., Beyerle G., Anderson J.M., Balidakis K., Belda S., Dhar S., Glaser S., Jenie O.S., Karbon M., Kitpracha C., Küreç Nehbit P., Liu L., Lunz S., Mammadaliyev N., Modiri S., Nilsson T.J., Raut S., Soja B., Wang J., Xu M. H. (2021): The Potsdam Open Source Radio Interferometry Tool (PORT). Publications of the Astronomical Society of the Pacific, 133(1028), 104503.

Schwabe J., Ågren J., Liebsch G., Westfeld P., Hammarklint T., Mononen J., Andersen, O. (2020): The Baltic Sea Chart Datum 2000 (BSCD2000): Implementation of a common reference level in the Baltic Sea. International Hydrographic Review, 23, pp. 63–83.

Shami S., Khoshlahjeh Azar M., Nilfouroushan F., Salimi M., Reshadi M. (2022): Assessments of ground subsidence along the railway in the Kashan plain, Iran, using Sentinel-1 data and NSBAS algorithm. International Journal of Applied Earth Observation and Geoinformation, 112, 102898.

Steffen H. & Steffen R. (2021): Indications on Glacially Triggered Faulting in Polar Areas. In Steffen et al. (eds.) Glacially-Triggered Faulting, Cambridge University Press, Cambridge, pp. 366–380.

Steffen R., Ivins E.I. (2021): Joint Study Group 3.1: Geodetic, Seismic and Geodynamic Constraints on Glacial Isostatic Adjustment. GIM International, 3/2021, pp. 33–34. *(not peer-reviewed)*

Steffen R. & Steffen H. (2021): Reactivation of non-optimally orientated faults due to glacially induced stresses. Tectonics, 40(11), e2021TC006853.

Steffen H., Olesen O., Sutinen R. (2021): Glacially-Triggered Faulting, Cambridge University Press, Cambridge, 492 pp.

Steffen H., Olesen O., Sutinen R. (2021): Glacially Triggered Faulting: A Historical Overview and Recent Developments. In Steffen et al. (eds.) Glacially-Triggered Faulting, Cambridge University Press, Cambridge, pp. 3–19.

Steffen H., Steffen R., Tarasov L. (2019): Modelling of glacially-induced stress changes in Latvia, Lithuania and the Kaliningrad District of Russia. Baltica, 32(1), pp. 78–90.

Steffen R., Legrand J., Ågren J., Steffen H., Lidberg M. (2022): HV-LSC-ex^2: velocity field interpolation using extended least-squares collocation. Journal of Geodesy, 96(3), 15.

Steffen R., Steffen, H., Weiss R., Lecavalier B.S., Milne G.A., Woodroffe S.A., Bennike O. (2020): Early Holocene Greenland-ice mass loss likely triggered earthquakes and tsunami. Earth Planetary Science Letters, 546C, 116443.

Steffen R., Wu P., Lund B. (2021): Geomechanics of glacially triggered faulting. In Steffen et al. (eds.) Glacially-Triggered Faulting, Cambridge University Press, Cambridge, pp. 20–40.

Suursaar Ü., Kall T., Steffen H. (2019): Application of glacial isostatic adjustment models at the edge of the Fennoscandian ice sheet. IEEE International Geoscience and Remote Sensing Symposium, Yokohama, Japan, 2019, pp. 4165-4168.

Suursaar Ü., Kall T., Steffen H., Tõnisson H. (2019): Cyclicity in ridge patterns on the prograding coasts of Estonia. Boreas, 48(4), pp. 913–928.

Van Malderen R., Pottiaux E., Klos A., Domonkos P., Elias M., Ning T., Bock O., Guijarro J., Alshawaf F., Hoseini M., Quarello A., Lebarbier E., Chimani B., Tornatore V., Zengin Kazancı S., Bogusz J. (2020): Homogenizing GPS integrated water vapor time series: Benchmarking break detection methods on synthetic data sets. Earth and Space Science, 7, e2020EA001121.

Varbla S., Ågren J., Ellmann A., Poutanen M. (2022): Treatment of Tide Gauge Time Series and Marine GNSS Measurements for Vertical Land Motion with Relevance to the Implementation of the Baltic Sea Chart Datum 2000. Remote Sensing, 14(4), 920.

Varenius E., Haas R., Nilsson T. (2021): Short-baseline interferometry local-tie experiments at the Onsala Space Observatory. Journal of Geodesy, 95, 54.

Vestøl O., Ågren J., Steffen H., Kierulf H., Tarasov L. (2019): NKG2016LU: a new land uplift model for Fennoscandia and the Baltic Region. Journal of Geodesy, 93(9), pp. 1759–1779.

Wang H., Xiang L., Steffen H., Wu P., Jiang L., Shen Q., Li Z., Hayashi M. (2022): GRACE-based estimates of groundwater variations over North America from 2002 to 2017. Geodesy and Geodynamics, 13(1), pp. 11–23.

Wang H., Xiang L., Steffen H., Wu P., Jiang L., Shen Q., Piretzidis D., Sideris M.G., Hayashi M., Jia L. (2019): Converse trends of the terrestrial and ground water storage changes in Canada and the United States. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 42(2/W13), pp. 1793–1796.

Wang H., Zhang H., Xiang L., Jiang L., Shen Q., Steffen H. (2020): Effects of climatic factors on the mass balance from 2003 to 2017 in High Mountain Asia and adjacent areas. Journal of Geodesy and Geodynamics, 40(12), pp. 1211–1218.

Wang Y., Sanchez L., Ågren J., Huang J., Forsberg R., Abd-Elmotaal H., Ahlgren K., Barzaghi R., Basic T., Carrion D., Claessens S., Erol B., Erol S., Filmer M., Grigoriadis V., Isik M., Jiang T., Koc Ö., Krcmaric J., Li X., Liu Q., Matsuo K., Natsiopoulos, D., Novak, P., Pail R., Pitonak M., Schmidt M., Varga M., Vergos G., Veronneau M., Willberg M., Zingerle P. (2021): Colorado geoid computation experiment : overview and summary. Journal of Geodesy, 95(12), 127.

Wu P., Steffen R., Steffen H., Lund B. (2021): Glacial Isostatic Adjustment Models for Earthquake Triggering. In Steffen et al. (eds.) Glacially-Triggered Faulting, Cambridge University Press, Cambridge, pp. 383–401.

Xiang L., Wang H., Jiang L., Shen Q., Steffen H., Li Z. (2021): Glacier mass balance in High Mountain Asia inferred from a GRACE release-6 gravity solution (2002 to 2016). Journal of Arid Land, 13(3), pp. 224–238.

Xiang L., Wang H., Steffen H., Qiao B., Feng W., Jia L., Gao P. (2022): Determination of weak terrestrial water storage changes from GRACE in the interior of the Tibetan Plateau. Remote Sensing, 14(3), 544.

Zurutuza J., Caporali A., Bertocco M., Ishchenko M., Khoda O., Steffen H., Figurski M., Parseliunas E., Berk S., Nykiel G. (2019): The Central European GNSS Research Network (CEGRN) dataset. Data in Brief, 27, 104762.

Appendix 2 – KTH: Geodetic publications 2019–2022 in international journals, proceedings, and books

Agha Karimi, A., Bagherbandi M., Horemuz M. (2021): Multidecadal sea level variability in the Baltic Sea and its impact on acceleration estimations. Frontiers in Marine Science, 8, 702512.

Amin H., Bagherbandi M., Sjöberg L. (2020): Quantifying barystatic sea-level change from altimeters, GRACE and Argo observations over 2005 to 2016. Advances in Space Research, 65 (8), pp. 1922–1940.

Amin H., Sjöberg L.E., Bagherbandi M. (2019): A global vertical datum defined by the conventional geoid potential and the Earth ellipsoidal parameters. Journal of Geodesy, 93, pp. 1943–1961.

Bagherbandi M., Amin H., Wang L., Shirazian M. (2022): Mantle viscosity derived from geoid and different land uplift data in Greenland. Journal of Geophysical Research: Solid Earth, 127, e2021JB023351.

Bagherbandi M., Jouybari A., Nilfouroushan F., Ågren J. (2022): Deflection of Vertical Effect on Direct Georeferencing in Aerial Mobile Mapping Systems: A Case Study in Sweden. The Photogrammetric Record, 37, pp. 285–305.

Bagherbandi M., Jouybari A., Nilfouroushan F., Ågren J. (2022): Importance of precise gravity field modeling on direct georeferencing and aerial photogrammetry: a case study for Sweden. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLIII-B2-2022, pp. 15–20.

Gido N., Amin H., Bagherbandi M., Nilfouroushan F. (2020): Satellite monitoring of mass changes and ground subsidence in Sudan's oil fields using GRACE and Sentinel-1 data. Remote Sensing, 12(11), 1792.

Gido N.A.A., Bagherbandi M., Nilfouroushan. F. (2020): Localized Subsidence Zones in Gävle City Detected by Sentinel-1 PSI and Leveling Data. Remote Sensing, 12(16), 2629.

Gido N.A.A., Bagherbandi M., Sjöberg L. (2019): A gravimetric method to determine Horizontal Stress field due to flow in mantle in Fennoscandia. Geoscience Journal, 23, pp. 377–389.

Gido N.A.A., Bagherbandi M., Sjöberg L., Tenzer R. (2019): Studying permafrost by integrating satellite and in situ data in the northern high-latitude regions. Acta Geophysica, 67, pp. 721–734.

Goyal R., Ågren J., Featherstone W., Sjöberg L., Dikshit O., Balasubramanian N. (2022): Empirical comparison between stochastic and deterministic modifiers over the French Auvergne geoid computation test-bed. Survey review, 54(382), pp. 57–69.

Jouybari A., Bagherbandi M., Nilfouroushan F. (2021): Comparison of the strip- and block-wise aerial triangulation using different exterior orientation parameters weights. Journal of Spatial Science, 67(3), pp. 377–394.

Jouybari A., Bagherbandi M., Nilfouroushan F. (2022): Impact of GNSS signal outage on EOPs using forward Kalman filter and smoothing algorithm. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLIII-B2-2022, pp. 59–64.

Leiseder K., Shoushtari H., Willemsen T., Bagherbandi M., Sternberg H. (2021): Ubi-T: Smart Surveying Instrument Using Ubiquitous Computing Concept. FIG e-Working Week 2021. Conference paper 10954. *(not peer-reviewed)*

Maciuk K., Kudrys J., Bagherbandi M., Bezmenov I. (2020): A new method for quantitative and qualitative representation of the noises type in Allan (and related) variances. Earth Planets and Space, 72(1), 186.

Shirazian M., Bagherbandi M., Karimi H. (2021): Network-Aided Reduction of Slope Distances in Small-Scale Geodetic Control Networks. Journal of Surveying Engineering, 147(4), 04021024.

Shirazian M., Jazireeyan I., Bagherbandi M. (2020): Reality measure of the published GPS satellite ephemeris uncertainties. Journal of Spatial Science, 67(2), pp. 287–295.

Sjöberg L.E. (2019): The topographic bias in gravimetric geoid determination revisited. Journal of Geodetic Science, 9, pp. 59–64.

Sjöberg L.E. & Bagherbandi M. (2020): Upper mantle density and surface gravity change in Fennoscandia determined from GRACE monthly data. Tectonophysics, 782-783, 228428.

Uggla G., Horemuz M. (2020): Identifying roadside objects in mobile laser scanning data using image-based point cloud segmentation. Journal of Information Technology in Construction, 25, pp. 545–560.

Uggla G., Horemuz M. (2021): Towards synthesized training data for semantic segmentation of mobile laser scanning point clouds: Generating level crossings from real and synthetic point cloud samples. Automation in Construction, 130, 103839.

Uggla G., Horemuz M. (2021): Conceptualizing georeferencing for terrestrial laser scanning and improving point cloud metadata. Journal of Surveying Engineering, 147(2), 02520001.

Appendix 3 – Onsala Space Observatory: Geodetic publications 2019–2022 in international journals, proceedings, and books

Asgarimehr M., Hoseini M., Semmling M., Ramatschi M., Camps A., Nahavandchi H., Haas R., Wickert J. (2021): Remote Sensing of Precipitation Using Reflected GNSS Signals: Response Analysis of Polarimetric Observations. IEEE Transactions on Geoscience and Remote Sensing, 60(1), 5800412.

Bergstrand S., Herbertsson M., Rieck C., Spetz J., Svantesson C.-G., Haas, R. (2019): A gravitational telescope deformation model for geodetic VLBI. Journal of Geodesy, 93, 669.

Corbin A., Niedermann B., Nothnagel A., Haas R., Haunert H. (2020): Combinatorial optimization applied to VLBI scheduling. Journal of Geodesy, 94(2), 19.

Diamantidis P.-K., Haas R., Varenius E., Schartner M., Matsumoto S. (2022): Combining VGOS, legacy S/X and GNSS for the determination of UT1. Journal of Geodesy, 96, 55.

Diamantidis K.-P., Klopotek G., Haas R. (2021): VLBI and GPS inter- and intra-technique combinations on the observation level for evaluation of TRF and EOP. Earth, Planets and Space, 73, 68.

Elgered G., Ning T., Forkman P., Haas, R. (2019): On the information content in linear horizontal delay gradients estimated from space geodesy observations. Atmospheric Measurement Techniques, 12, pp. 3805–3823.

Forkman P., Flygare J., Elgered G. (2021): Water vapour radiometry in geodetic very long baseline interferometry telescopes: assessed through simulations. Journal of Geodesy, 95, 117.

Geremia-Nievinski F., Hobiger T., Haas R., Liu W., Strandberg J., Tabibi S., Vey S., Wickert J., Williams S. (2020): SNR-based GNSS reflectometry for coastal sea-level altimetry: results from the first IAG inter-comparison campaign. Journal of Geodesy, 94, 70.

Greiwe A., Brechtken R., Lösler M., Eschelbach C., Haas R. (2020): Erfassung der Hauptreflektordeformation eines Radioteleskops durch UAV-gestützte Nahbereichsphotogrammetrie. Publikationen der Deutschen Gesellschaft für Photogrammetrie, Fernerkundung und Geoinformation e.V, 29, pp. 346–357.

Haas R. (2020): Clock comparison using black holes. Nature Physics, 17(2), pp. 164–165.

Haas R., Varenius E., Matsumoto S., Schartner M. (2021): Observing UT1-UTC with VGOS. Earth, Planets and Space, 73, 78.

Halsig S., Bertarini A., Haas R., Iddink A., Kodet J., Kronschnabl G., Neidhardt A., Nothnagel A., Plötz C., Schüler T. (2019): Atmospheric

refraction and system stability investigations in short-baseline VLBI observations. Journal of Geodesy, 93, 593.

Han S., Nothnagel A., Zhang Z., Haas R., Zhang Q. (2019): Fringe fitting and group delay determination for geodetic VLBI observations of DOR tones. Advances in Space Research, 63(5), pp. 1754–1767.

Holst C., Nothnagel A., Haas R., Kuhlmann H. (2019): Investigating the gravitational stability of a radio telescope's reference point using a terrestrial laser scanner: Case study at the Onsala Space Observatory 20-m radio telescope. ISPRS Journal of Photogrammetry and Remote Sensing, 149, pp. 67–76.

Hoseini M., Semmling M., Nahavandchi H., Rennspiess E., Ramatschi M., Haas R., Strandberg J., Wickert J. (2021): On the Response of Polarimetric GNSS-Reflectometry to Sea Surface Roughness. IEEE Transactions on Geoscience and Remote Sensing, 59, pp. 7945–7956.

Hu Y., Yuan X., Liu W., Wickert J., Jiang Z., Haas R. (2021): GNSS-IR Model of Sea Level Height Estimation Combining Variational Mode Decomposition. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 14, pp. 10405–10414.

Kierulf H.P., Steffen H., Barletta V.R., Lidberg M., Johansson J., Kristiansen O., Tarasov L. (2021): A GNSS velocity field for geophysical applications in Fennoscandia. Journal of Geodynamics, 146, 101845.

Klopotek G., Hobiger T., Haas R., Jaron F., La Porta L., Nothnagel A., Zhang Z., Han S., Neidhardt A., Plötz C. (2019): Position determination of the Chang'e 3 lander with geodetic VLBI. Earth, Planets and Space, 71, 23.

Klopotek G., Hobiger T., Haas R., Otsubo T. (2020): Geodetic VLBI for precise orbit determination of Earth satellites: a simulation study. Journal of Geodesy, 94(6), 56.

Lösler M., Haas R., Eschelbach C., Greiwe A. (2019): Gravitational deformation of ring-focus antennas for VGOS: first investigations at the Onsala twin telescopes project. Journal of Geodesy, 93, 2069.

Ning T. & Elgered G. (2021): High-temporal-resolution wet delay gradients estimated from multi-GNSS and microwave radiometer observations. Atmospheric Measurement Techniques, 14, pp. 5593–5605.

Nothnagel A., Holst C., Haas R. (2019): A VLBI delay model for gravitational deformations of the Onsala 20 m radio telescope and the impact on its global coordinates. Journal of Geodesy, 93, pp. 2019–2036.

Parker A.L., McCallum L., Featherstone W.E., McCallum J., Haas R. (2019): The Potential for Unifying Global-Scale Satellite Measurements of Ground Displacements using Radio Telescopes. Geophysical Research Letters, 46, 11841.

Purnell D., Gomez N., Chan N.H., Strandberg J., Holland D.M., Hobiger T. (2020): Quantifying the Uncertainty in Ground-Based GNSS-Reflectometry

Sea Level Measurements. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 13, pp. 4419–4428.

Rajabi M., Hoseini M., Nahavandchi H., Semmling M., Ramatschi M., Goli M., Haas R., Wickert J. (2022): Polarimetric GNSS-R Sea Level Monitoring Using I/Q Interference Patterns at Different Antenna Configurations and Carrier Frequencies. IEEE Transactions on Geoscience and Remote Sensing, 60, 5801613.

Scherneck, H.-G. & Rajner, M. (2019): Using a Superconducting Gravimeter in Support of Absolute Gravity Campaigning – A feasibility study. Geophysica, 54(1), pp. 117–135.

Scherneck, H.-G., Rajner, M., Engfeldt, A. (2020): Superconducting gravimeter and seismometer shedding light on FG5's offsets, trends, and noise: what observations at Onsala Space Observatory can tell us. Journal of Geodesy, 94, 80.

Strandberg J. & Haas R. (2020): Can We Measure Sea Level with a Tablet Computer? IEEE Geoscience and Remote Sensing Letters 17, pp. 1876–1878.

Strandberg J., Hobiger T., Haas, R. (2019): Real-time sea-level monitoring using Kalman filtering of GNSS-R data. GPS Solutions, 23, 61.

Varenius E., Haas R., Nilsson T. (2021): Short-baseline interferometry local-tie experiments at the Onsala Space Observatory. Journal of Geodesy, 95, 54.

Varenius E., Maio F., Le Bail K., Haas R. (2022): Broad band flux-density monitoring of radio sources with the Onsala twin telescopes. Experimental Astronomy, 54, pp. 137–155.

Appendix 4 – University of Gävle: Geodetic publications 2019–2022 in international journals, proceedings, and books

Agha Karimi, A., Bagherbandi M., Horemuz M. (2021): Multidecadal sea level variability in the Baltic Sea and its impact on acceleration estimations. Frontiers in Marine Science, 8, 702512.

Amin H., Bagherbandi M., Sjöberg L. (2020): Quantifying barystatic sea-level change from altimeters, GRACE and Argo observations over 2005 to 2016. Advances in Space Research, 65 (8), pp. 1922–1940.

Amin H., Sjöberg L.E., Bagherbandi M. (2019): A global vertical datum defined by the conventional geoid potential and the Earth ellipsoidal parameters. Journal of Geodesy, 93, pp. 1943–1961.

Bagherbandi M., Amin H., Wang L., Shirazian M. (2022): Mantle viscosity derived from geoid and different land uplift data in Greenland. Journal of Geophysical Research: Solid Earth, 127, e2021JB023351.

Bagherbandi M., Jouybari A., Nilfouroushan F., Ågren J. (2022): Deflection of Vertical Effect on Direct Georeferencing in Aerial Mobile Mapping Systems: A Case Study in Sweden. The Photogrammetric Record, 37, pp. 285–305.

Bagherbandi M., Jouybari A., Nilfouroushan F., Ågren J. (2022): Importance of precise gravity field modeling on direct georeferencing and aerial photogrammetry: a case study for Sweden. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLIII-B2-2022, pp. 15–20.

Darvishi M., Cuozzo G., Bruzzone L., Nilfouroushan F. (2020): Performance evaluation of phase and weather-based models in atmospheric correction with Sentinel-1data: Corvara landslide in the Alps. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 13, pp. 1332–1346.

Edey A., Allen M., Nilfouroushan F. (2020): Kinematic variation within the Fars Arc, eastern Zagros, and the development of fold-and-thrust belt curvature. Tectonics, 39(8), e2019TC005941.

Engfeldt A., Olsson P., Steffen H., Lidberg M., Ågren J., Sekowski M., Krynski J., Bryskhe H., Nielsen J., Strykowski G. (2019): RG 2000 – the New Gravity Reference Frame of Sweden. Geophysica, 54(1), pp. 69–92.

Fryksten J. & Nilfouroushan, F. (2019): Analysis of Clay-Induced Land Subsidence in Uppsala City Using Sentinel-1 SAR Data and Precise Leveling. Remote Sensing, 11(23), 2764.

Gido N., Amin H., Bagherbandi M., Nilfouroushan F. (2020): Satellite monitoring of mass changes and ground subsidence in Sudan's oil fields using GRACE and Sentinel-1 data. Remote Sensing, 12(11), 1792.

Gido N.A.A., Bagherbandi M., Nilfouroushan F. (2020): Localized Subsidence Zones in Gävle City Detected by Sentinel-1 PSI and Leveling Data. Remote Sensing, 12(16), 2629.

Gido N.A.A., Bagherbandi M., Sjöberg L. (2019): A gravimetric method to determine Horizontal Stress field due to flow in mantle in Fennoscandia. Geoscience Journal, 23, pp. 377–389.

Gido N.A.A., Bagherbandi M., Sjöberg L., Tenzer R. (2019): Studying permafrost by integrating satellite and in situ data in the northern high-latitude regions. Acta Geophysica, 67, pp. 721–734.

Goyal R., Ågren J., Featherstone W., Sjöberg L., Dikshit O., Balasubramanian N. (2022): Empirical comparison between stochastic and deterministic modifiers over the French Auvergne geoid computation test-bed. Survey review, 54(382), pp. 57–69.

Gruber T., Ågren J., Angermann D., Ellmann A., Engfeldt A., Gisinger C., Jaworski L., Kur T., Marila S., Nastula J., Nilfouroushan F., Nordman M., Poutanen M., Saari T., Schlaak M., Świątek A., Varbla S., Zdunek R. (2022): Geodetic SAR for Height System Unification and Sea Level Research - Results in the Baltic Sea Test Network. Remote Sensing, 14(14), 3250.

Gruber T., Ågren J., Angermann D., Ellmann A., Engfeldt A., Gisinger C., Jaworski L., Marila S., Nastula J., Nilfouroushan F., Nordman M., Oikonomidou X., Poutanen M., Saari T., Schlaak M., Świątek A., Varbla S., Zdunek R. (2020): Geodetic SAR for Height System Unification and Sea Level Research - Observation Concept and Preliminary Results in the Baltic Sea. Remote Sensing, 12(22), 3747.

Jouybari A., Bagherbandi M., Nilfouroushan F. (2021): Comparison of the strip- and block-wise aerial triangulation using different exterior orientation parameters weights. Journal of Spatial Science, 67(3), pp. 377–394.

Jouybari A., Bagherbandi M., Nilfouroushan F. (2022): Impact of GNSS signal outage on EOPs using forward Kalman filter and smoothing algorithm. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLIII-B2-2022, pp. 59–64.

Kaviani A., Mahmoodabadi M., Rümpker G., Pilia S., Tatar M., Nilfouroushan F., Yamini-Fard F., Moradi A., Ali M. (2021): Mantle-flow diversion beneath the Iranian plateau induced by Zagros' lithospheric keel. Scientific Reports, 11(1), 2848.

Khorrami F., Vernant P., Masson F., Nilfouroushan F., Mousavi Z., Nankali H., Saadat S., Walpersdorf A., Hosseini S., Tavakoli P., Aghamohammadi A., Alijanzade M. (2019): An up-to-date crustal deformation map of Iran using integrated campaign-mode and permanent GPS velocities. Geophysical Journal International, 217(2), pp. 832–843.

Khoshlahjeh Azar M., Shami S., Nilfouroushan F., Salimi M., Ghayoor Bolorfroshan M., Reshadi M.A.M. (2022): Integrated analysis of Hashtgerd

plain deformation, using Sentinel-1 SAR, geological and hydrological data. Scientific Reports, 12, 21522.

Leiseder K., Shoushtari H., Willemsen T., Bagherbandi M., Sternberg H. (2021): Ubi-T: Smart Surveying Instrument Using Ubiquitous Computing Concept. FIG e-Working Week 2021. Conference paper 10954. *(not peer-reviewed)*

Maciuk K., Kudrys J., Bagherbandi M., Bezmenov I. (2020): A new method for quantitative and qualitative representation of the noises type in Allan (and related) variances. Earth Planets and Space, 72(1), 186.

Mehrabi A., Derakhshani R., Nilfouroushan F., Rahnamarad J., Azarafza M. (2022): Spatiotemporal subsidence over Pabdana coal mine Kerman Province, central Iran using time-series of Sentinel-1 remote sensing imagery. Episodes, https://doi.org/10.18814/epiiugs/2022/022009.

Rashidi A., Abbassi M., Nilfouroushan F., Shafiei Bafti S., Derakhshani R., Nemati M. (2020): Morphotectonic and earthquake data analysis of interactional faults in Sabzevaran Area, SE Iran. Journal of Structural Geology, 139, 104147.

Rashidi A., Khatib M., Nilfouroushan F., Derakhshani R., Mousavi S., Kianimehr H., Djamour Y. (2019): Strain rate and stress fields in the West and South Lut block, Iran: Insights from the inversion of focal mechanism and geodetic data. Tectonophysics, 766, pp. 94–114.

Sánchez L., Ågren J., Huang J., Wang Y., Mäkinen J., Pail R., Barzaghi R., Vergos G., Ahlgren K., Liu Q. (2021): Strategy for the realisation of the International Height Reference System (IHRS). Journal of Geodesy, 95, 33.

Shami S., Khoshlahjeh Azar M., Nilfouroushan F., Salimi M., Reshadi M. (2022): Assessments of ground subsidence along the railway in the Kashan plain, Iran, using Sentinel-1 data and NSBAS algorithm. International Journal of Applied Earth Observation and Geoinformation, 112, 102898.

Shirazian M., Bagherbandi M., Karimi H. (2021): Network-Aided Reduction of Slope Distances in Small-Scale Geodetic Control Networks. Journal of Surveying Engineering, 147(4), 04021024.

Shirazian M., Jazireeyan I., Bagherbandi M. (2020): Reality measure of the published GPS satellite ephemeris uncertainties. Journal of Spatial Science, 67(2), pp. 287–295.

Sjöberg L.E. & Bagherbandi M. (2020): Upper mantle density and surface gravity change in Fennoscandia determined from GRACE monthly data. Tectonophysics, 782–783, 228428.

Steffen R., Legrand J., Ågren J., Steffen H., Lidberg M. (2022): HV-LSC-ex^2: velocity field interpolation using extended least-squares collocation. Journal of Geodesy, 96(3), 15.

Varbla S., Ågren J., Ellmann A., Poutanen M. (2022): Treatment of Tide Gauge Time Series and Marine GNSS Measurements for Vertical Land

Motion with Relevance to the Implementation of the Baltic Sea Chart Datum 2000. Remote Sensing, 14(4), 920.

Vestøl O., Ågren J., Steffen H., Kierulf H., Tarasov L. (2019): NKG2016LU: a new land uplift model for Fennoscandia and the Baltic Region. Journal of Geodesy, 93(9), pp. 1759–1779.

Wang Y., Sanchez L., Ågren J., Huang J., Forsberg R., Abd-Elmotaal H., Ahlgren K., Barzaghi R., Basic T., Carrion D., Claessens S., Erol B., Erol S., Filmer M., Grigoriadis V., Isik M., Jiang T., Koc Ö., Krcmaric J., Li X., Liu Q., Matsuo K., Natsiopoulos, D., Novak, P., Pail R., Pitonak M., Schmidt M., Varga M., Vergos G., Veronneau M., Willberg M., Zingerle P. (2021): Colorado geoid computation experiment : overview and summary. Journal of Geodesy, 95(12), 127.

Appendix 5 – University West: Geodetic publications 2019–2023 in international journals, proceedings, and books

Abrehdary M. & Sjöberg L.E. (2019): Recovering Moho constituents from altimetric and gravimetric data for Europe and surroundings. Journal of Applied Geodesy, 13, pp. 291–303.

Abrehdary M. & Sjöberg L.E. (2020): Estimating a combined Moho model for marine areas via satellite altimetric – gravity and seismic crustal models. Studia Geophysica et Geodaetica, 64, pp. 1–25.

Abrehdary M. & Sjöberg L.E. (2021): A new Moho depth model for Fennoscandia with special correction for the Glacial isostatic effect. Pure and Applied Geophysics, 178, pp. 877–888.

Abrehdary M. & Sjöberg L.E. (2021): A Moho density contrast model in Antarctica determined by satellite gravimetry and seismic data. Geophysical Journal International, 225, pp. 1952–1962.

Abrehdary M., Sjöberg L.E., Sampietro D. (2019): Contribution of satellite altimetry in modelling Moho density contrast in oceanic areas. Journal of Applied Geodesy, 13(1), pp. 33–40.

Amin H., Sjöberg L.E., Bagherbandi M. (2019): A global vertical datum defined by the conventional geoid potential and the Earth ellipsoidal parameters. Journal of Geodesy, 93, pp. 1943–1961.

Ashagrie Gedamu A., Eshagh M., Bedada T.B. (2020): Moho Determination from GOCE Gradiometry Data over Ethiopia. Journal of African Earth Science, 163, 103741.

Ashagrie Gedamu A., Eshagh M., Bedada T.B. (2021): Effects of Mantle Dynamics on Estimating Effective Elastic Thickness of the Lithosphere. Journal of African Earth Sciences, 183, 104318.

Eshagh M. (2020): Satellite Gravimetry and the Solid Earth. Elsevier, Amsterdam, 786 pp.

Eshagh M. (2021): The Earth's gravity field and its role in Geodesy and large-scale Geophysics, Geodetic Sciences, Theory, Applications, and recent developments. In: Erol, B. & Erol S. (Eds.), Geodetic Sciences – Theory, Applications and Recent Developments, IntechOpen, https://www.intechopen.com/chapters/76431.

Eshagh M. (2022): An optimal design of GNSS interference localisation wireless security network based on time-difference of arrival for the Arlanda international airport. Journal of Geodetic Science, 12, pp. 154–164.

Eshagh M. (2023): Optimisation of basepoints' configuration in localisation of signal interference device. Journal of Surveying Engineering, 149(1), 04022019.

Eshagh M. & Berntsson J. (2019): On quality of NKG2015 geoid model over the Nordic countries. Journal of Geodetic Science, 9, pp. 97–110.

Eshagh M. & Pitoňak M. (2019): Elastic thickness determination from on-orbit GOCE data and CRUST1.0. Pure and Applied Geophysics, 176, pp. 685–696.

Eshagh M. & Tenzer R. (2021): The temporal viscoelastic model of flexural isostasy for estimating the elastic thickness of the lithosphere. Geophysical Journal International, 227(3), pp. 1700–1714.

Eshagh M., Fatolazadeh F., Tenzer R. (2020): Lithospheric stress, strain and displacement changes from GRACE-FO time-variable gravity: case study for Sar-e-Pol Zahab Earthquake 2018. Geophysical Journal International, 223, pp. 379–397.

Eshagh M., Pitonak M., Tenzer R. (2019): Lithospheric elastic thickness estimates in central Eurasia. Terrestrial, Atmospheric and Oceanic Sciences, 30(1), pp. 73–84.

Eshagh M., Tenzer R., Eshagh M. (2019): Elastic thickness of the Iranian lithosphere from gravity and seismic data. Tectonophysics, 774, 228186.

Fatolazadeh F., Eshagh M., Goita K. (2020): A new approach for generating optimal GLDAS hydrological products and uncertainties. Science of the Total Environment, 730, 138932.

Fatolazadeh F., Eshagh M., Goita K. (2022): New spectro-spatial downscaling approach for terrestrial and groundwater storage variations estimated by GRACE models. Journal of Hydrology, 615A, 128635.

Fatolazadeh F., Eshagh M., Goita K., Wang S. (2022) A new spatio-temporal estimator for downscaling GRACE gravity models for terrestrial and groundwater storage variation estimation, Remote Sensing, 14, 5991.

Mahbooby H., American Y., Nikoofard A., Eshagh M. (2021): Application of the nonlinear optimisation in regional gravity field modelling using spherical radial base functions. Studia Geophysica et Geodaetica, 65, pp. 261–290.

Meghraoui M., Sundarajan N., Banerjee S., Hinzen K.G., Eshagh M., Roure F., Chaminé H.I., Maouche S., Michard A., Alamri A. (2021): Advances in Geophysics, Tectonics and Petroleum Geosciences. Proceedings of the 2nd Springer Conference of the Arabian Journal of Geosciences (CAJG-2), Tunisia 2019, Springer Nature.

Pitoňak M., Novák P., Eshagh M., Tenzer R., Šprlák M. (2020): Downward continuation of gravitational field quantities to an irregular surface by spectral weighting. Journal of Geodesy, 94, 62.

Rathnayake S., Tenzer R., Chen W., Eshagh M., Pitoňak M. (2021): Comparison of different methods for a Moho modelling under oceans and marginal areas – A case study over Indian Ocean. Surveys in Geophysics, 42, pp. 839–897.

Rathnayake S., Tenzer R., Eshagh M., Pitoňak M. (2019): Gravity maps of lithospheric structure beneath the Indian Ocean. Surveys in Geophysics, 40, 5, pp. 1055–1093.

Sjöberg L.E. (2020): Unbiased least-squares modification of Stokes' formula. Journal of Geodesy, 94, 92.

Sjöberg L.E. (2021): Arne Bjerhammar – a personal summary of his academic deeds. Journal of Geodetic Science, 11, pp. 1–6.

Sjöberg L.E. (2022): Geoid model validation and topographic bias. Journal of Geodetic Science, 12, pp. 38–41.

Sjöberg L.E. & Abrehdary M. (2021): On Moho Determination by the Vening Meinesz-Moritz Technique. In: Erol, B. & Erol S. (Eds.), Geodetic Sciences – Theory, Applications and Recent Developments, IntechOpen, https://www.intechopen.com/chapters/76513.

Sjöberg L.E. & Abrehdary M. (2021): The uncertainty of CRUST1.0 Moho depth and density contrast models. Journal of Applied Geodesy, 15(2), pp. 143–152.

Sjöberg L.E. & Abrehdary M. (2022): Combination of three global Moho density contrast models by a weighted least-squares procedure. Journal of Applied Geodesy, 16(4), pp. 331–339.

Sjöberg L.E. & Abrehdary M. (2022): MOHV21: A least squares combination of five global Moho depth models. Journal of Geodesy, 96, 45.

Reports in Geodesy and Geographical Information Systems from Lantmäteriet, the Swedish mapping, cadastral and land registration authority

2014:5 Ohlsson Kent: Studie av mätosäkerhet och tidskorrelationer vid mätning med nätverks-RTK i Swepos 35 km-nät.

2015:1 Fredriksson Annika & Olsson Madeleine: Jämförelse av höjdmätning med olika GNSS-mottagare i Swepos Nätverks-RTK-tjänst.

2015:2 Norin Dan, Johansson Jan M, Mårtensson Stig-Göran, Eshagh Mehdi: Geodetic activities in Sweden 2010–2014.

2015:4 Andersson Bengt, Alfredsson Anders, Nordqvist Anders, Kilström Ronald: RIX 95-projektet – slutrapport.

2016:1 Engfeldt Andreas: RG 2000 – status March 2016.

2016:2 Engfeldt Andreas: Preparations and plans for the new national gravity system, RG 2000.

2016:4 Kempe Christina (ed.): Proceedings of the NKG General Assembly. Göteborg, Sweden, 1–4 September 2014.

2016:5 Berggren Anna: Inledande försök till mätning med Europas navigeringssystem Galileo.

2018:3 Svensson Vilhelm & Tobler Fredrik: Utvärdering av olika metoder för fri stationsetablering med nätverks-RTK.

2018:4 Norin Dan, Jensen Anna B O, Bagherbandi Mohammad, Eshagh Mehdi: Geodetic activities in Sweden 2014–2018.

2018:5 Jivall Lotti & Nilfouroushan Faramarz: Mast-based versus pillar-based networks for coordinate estimation of SWEREF points – using the Bernese and GAMIT-GLOBK software packages.

2019:1 Alfredsson Anders, Alm Linda, Dahlström Fredrik, Jivall Lotti, Kempe Christina, Wiklund Peter: Förvaltning av de nationella geodetiska referensnäten.

2019:3 Engfeldt Andreas: RG 2000 – a comprehensive overview on the new gravity reference frame of Sweden.

2021:1 Abraha Kibrom Ebuy, Frisk Anders, Westberg Mats, Wiklund Peter: SWEPOS data quality monitoring – GNSS signal disturbances detection system.

2022:1 Jivall Lotti, Nilfouroushan Faramarz, Al Munaizel Naim: Analysis of 20 years of GPS data from SWEREF consolidation points – using BERNESE and GAMIT-GLOBK software.