Agency for Data Supply and Infrastructure

National Report – Agency for Data Supply and Infrastructure, SDFI 2018-2021

Contents

The Danish CORS network

The Danish CORS network has been expanding since the beginning in 1998. SDFI now operates 14 continuously operating GNSS stations. All of these stations are class A stations.

Figure 1 Map of the 14 Danish class A GNSS stations, and 2 Class B Stations.

Three of the CORS stations are EPN stations and have provided more than 20 years of data. Unfortunately, the station SMID has to be demobilized in autumn 2022 for which reason we have built a new one called GREJ. The temporal overlap between the two stations is approximately three months.

All the stations are equipped with multi-frequency, multi-constellation GNSS receivers and high-quality antennas based on Dorne-Margolin elements. All the stations are sending 1Hz GNSS data to SDFI. GNSS data from the stations are free of charge and can be downloaded from Dataforsyningen.dk. SDFI is working on a NTRIP Caster, so the data can be streamed in real time.

Two (three) of the Stations are included in the EUREF Permanent GNSS network (EPN).

GNET – Greenland GNSS Network

The future and continuous existence of the Greenlandic GNSS Network (GNET) has been secured. This is due to a successful transfer of GNET to the Danish Government and inclusion of the network in the Danish Financial Act from January 1st 2019. The daily responsibility, administration, maintenance and evolution of GNET has been delegated to SDFI which thereby effectively is the owner of GNET.

GNET is a network of currently 60 continuously operating GNSS stations located all around the coast of Greenland. With 42 remote sites and 18 sites in towns and settlements, GNET covers a great part of the ice-free part of Greenland. With a setup suited for and continuously updated to withstand the harsh environment of the Arctic, GNET delivers GNSS data all year long with a few exceptions at the very far north. Furthermore, Realtime RTCM streams are being setup from the 18 sites in towns and settlements since these are installed with landline communication.

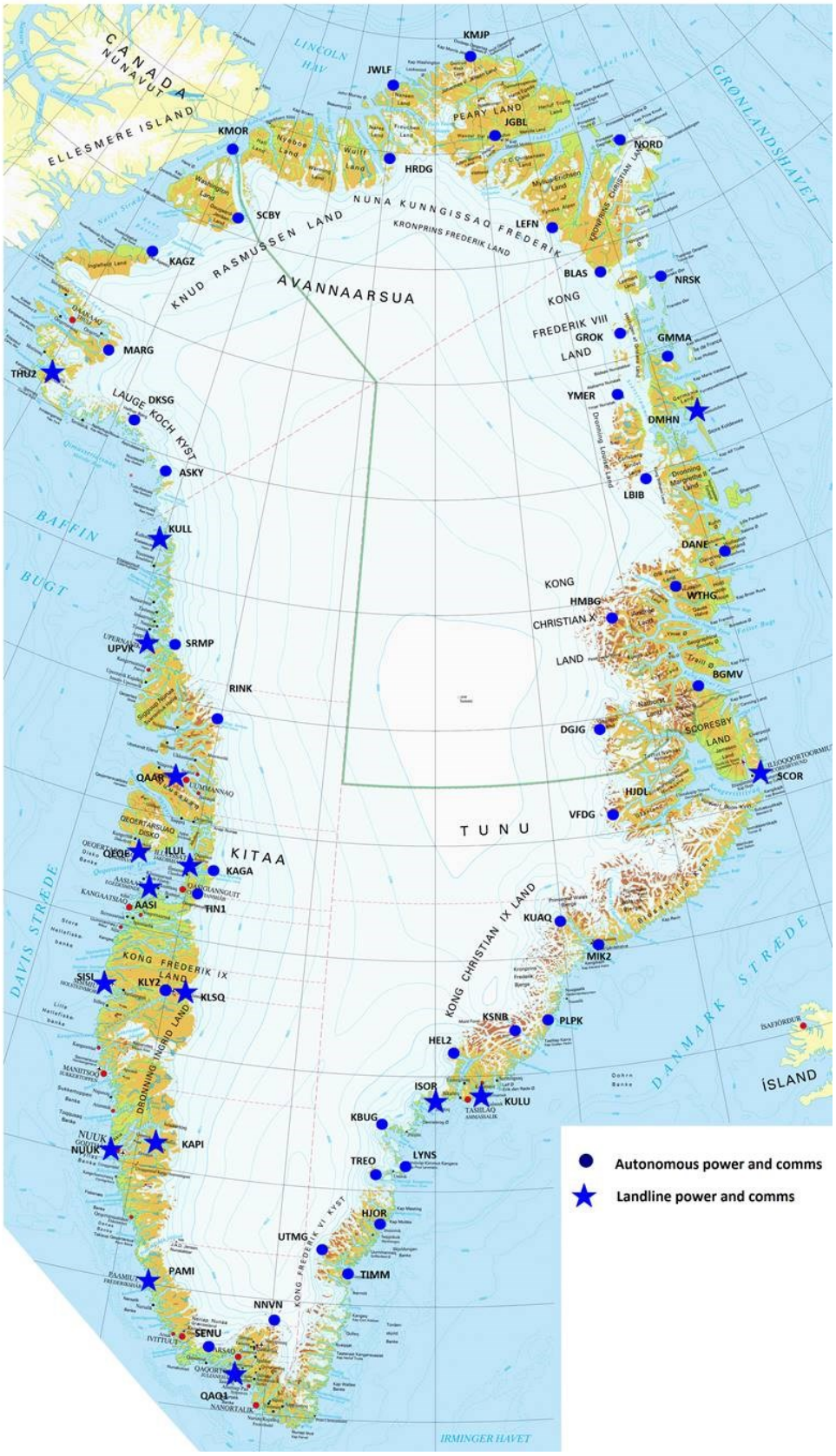

Figure 2 The 60 GNET stations are located on the coast of Greenland. Stations marked with stars are installed with landline power and communication. Stations marked with dots are installed with autonomous power and communication.

GNET is continuously monitored concerning station health and data quality. The monitoring of the stations and data quality is carried out with DTU Space as the primary operator and UNAVCO as the secondary, through a cooperation agreement with SDFI.

With the addition of a governance structure, free data, and international stakeholders from many fields, the future of GNET as a continuously updated geodetic infrastructure is bright. On top of this, SDFI is continuously working on ways to improve and upgrade GNET to match the needs and possibilities. Recently, SDFI initiated a pilot project to condense the network in and around Nuuk to the benefit of the Greenlandic society.

Testbed in Aarhus for Precision Positioning and Autonomous Systems

Testbed in Aarhus for Precision Positioning and Autonomous Systems (TAPAS) was established in 2019, and is a project together involving the Municipality of Aarhus, DTU Space and SDFI. TAPAS is a next-level GNSS real-time kinematic (RTK) positioning system for R&D purposes. TAPAS is based on 11 very densely positioned GNSS reference stations located in and around the city of Aarhus in Denmark with a distance between the reference stations of approximately 10 km.

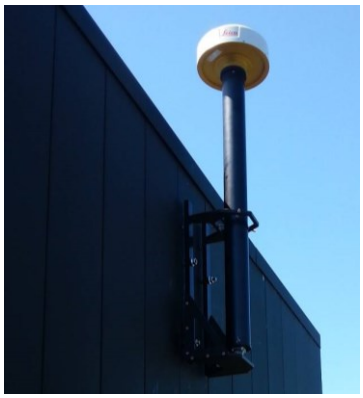

Figure 3 TAPAS station TA04.

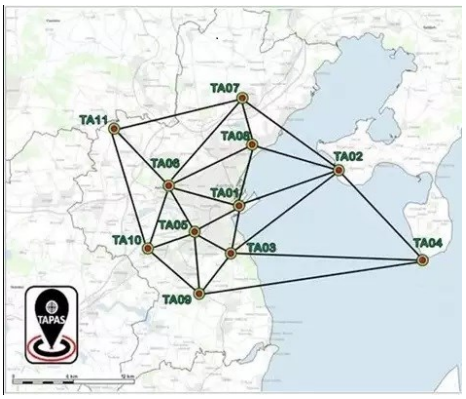

Figure 4 The TAPAS GNSS stations in Aarhus.

The users apply the corrections to obtain high accuracy positioning at the 1 cm-level in real-time in the most challenging urban environments such as street canyons. TAPAS data can be accessed free of charge for R&D purposes.

The background for establishing TAPAS was that the demand for basic digital infrastructures in modern societies is increasing in line with the desire for green solutions that also allow for growth and efficiency. TAPAS is a research and development project aimed at addressing the demand for accurate real time positioning infrastructure. This is done by probing to which extent an improved infrastructure can contribute to exploiting the full advantage of the technical possibilities of GNSS including the European Galileo service. The project is described on tapasweb.dk.

Inside the GNSS network we have also built a monitor station. The monitor station is equipped with eight identical RTK GNSS receivers that make it possible to test different types of GNSS solutions.

Replacing the geodetic registry

At the beginning of 2019, work towards a new geodetic database system started. At the time, the existing database, REFGEO was more than 20 years old and the surrounding software had seen no significant development in years due to changes in personnel and higher prioritized projects. Continued development

of REFGEO proved difficult due to a lack of familiarity with the legacy SQL libraries used, and the convoluted C code involved.

The geodetic database system is central for managing and producing levelling data. This includes both storing information on benchmarks, observations and coordinates and distributing benchmark descriptions and coordinates to end-users. Also, the modules levelling adjustment are tightly coupled to the database.

The new database system is called FIRE (abbreviation of the Danish word for benchmark database; “FIkspunktREgister”). The FIRE system is developed using well-known open source principles and the source code is distributed freely [https://github.com/SDFIdk/FIRE]. The system is built on top of an Oracle database and the surrounding business logic is implemented in Python. The initial implementation was built as a minimum viable product that had just enough functionality to accommodate the day-to-day maintenance of municipal height networks.

The data model in FIRE is made to be extremely flexible, which allows for infinitely many types of observations, coordinate systems, and attributes. This solves a fundamental problem in the old system that required several new tables whenever a new reference system was introduced, which led to software depending on REFGEO needing to be rewritten to accommodate the new tables.

The new database system was adopted into production at the beginning of 2021. Since then, the development has continued from a minimum viable product towards a fully functional geodetic database. There is still a long way to go. The next big goal is to develop better tools for handling time series of both levelling and GNSS data.

Modernizing the processing and distribution of GNSS data

An increase in GNSS stations under SDFIs custody as well as the demand for GNSS data – both real time (RTCM/NTRIP) and asynchronous (RINEX) – has sparked the development of a new GNSS data management system. The existing system is difficult to maintain and neither integrates adequately with SDFI’s IT infrastructure, nor lives up to the cybersecurity requirements of the Danish government.

To remedy all this, a new system is under way, which focuses on modularity, ease of development, and deployment. The new system will mainly be based on reusable components such as the BKG NtripCaster, EPOS-GNSS, and various other GNSS tools.

Once finished, the system will keep an organized archive of all data from Danish and Greenlandic GNSS stations. The archive will be available through SDFI’s existing data distribution channels and EPOS-GNSS. Additionally, real time data for a subset of the stations will be available via NTRIP2 streams.

PROJ

PROJ in general

SDFI holds two seats on the PROJ board (Kristian Evers (chair) and Thomas Knudsen). Additionally, Kristian Evers serves as release manager for PROJ releases, and has been managing the release of the PROJ 5, 6, 7, 8 and 9 major releases (and a large number of minor and patch releases) since the previous NKG general assembly. As indicated by the sheer number of major releases, PROJ has been through major developmental strides since what we may call the first "modern PROJ" version, PROJ 5.0.0 on 2018-03-01. With that version, the concept of transformation pipelines was introduced by SDFI, and since then the entire architecture of PROJ has been extended from the classic PROJ 2D projection world view to a modern, fully 4D geodetic transformation-enabled library and a corresponding transformation program.

PROJ NKG-trans

With support of the NKG presidium, the NKG PROJ study group was established in 2017 and completed its task of PROJ promotion and PROJ-enabling of the NKG transformations already in the prior NKG report period. The work has, however, resulted in a 2020 update of the PROJ implementation of the revised NKG transformations - this time utilizing new deformation grid file formats (another PROJ innovation).

ISO 19111 support

On 2018-05-15, the "GDAL Coordinate System Barn Raising" initiative, with PROJ chair Kristian Evers as one of the organizers, reached its funding goals (cf. https://gdalbarn.com), for streamlining the Open Source support for the ISO 19111 standard "Referencing by coordinates", and its companion ISO 19162 "Well-known text representation of coordinate reference systems". This led to hectic activity in the PROJ code repository over the next years, resolving over 500 issues, merging a substantial number of pull requests, and implementing a number of updates of the internal and external architecture, leading to a corresponding flux in the version flow. Most of the ISO 19111 support code was provided by Even Rouault of Spatialys Inc., under contract to the GDALbarn initiative.

PROJ related publications from SDFI, 2018-2021

Thomas Knudsen, Kristian Evers, Geir Arne Hjelle, Guðmundur Valsson, Martin Lidberg and Pasi Häkli, 2019: The Bricks and Mortar for Contemporary Reimplementation of Legacy Nordic Transformations. Geophysica Vol. 54, No. 1, pp. 107-116, https://www.geophysica.fi/pdf/geophysica_2019_54_1_107_knudsen.pdf

Kristian Evers and Thomas Knudsen, 2018: KMSTrans2 går på pension - PROJ overtager tronen. Landinspektøren, Vol. 60, no. 1, pp. 7-9

Surveying

GNSS surveying of the so-called 5D net continues with 3-day observations at the bench marks, which is sub-surfaced torsional plugs, every 3-5 years. A few new bench marks are added each year as well as a few are replaced due to construction work or similar. The net consists of approx. 150 bench marks throughout the country.

SDFI continues the motorized levelling (MTL) mainly for the municipalities however we do face some issues using the setup for high productivity as well as high quality. The monitoring, in terms of height, of the national tide gauges is continuing as well.

Figure 5 The 1.5 m long torsional plug ready to be mounted into the ground.

Towards a 5 mm geoid in 2023

In the past years DTU Space has acquired much gravity data (See DTU's report) in Denmark in order to validate existing data as well as covering areas without data. The new data have created a better and more consistent gravimetric geoid, which better links the land and sea areas compared to the previous geoid from 2013.

Over the past years, we have adjusted and fitted the gravimetric geoid to the Danish height system DVR90 using approximately 150 primary benchmarks instead of 700 used in 2013. That is due to a belief that the heights of the primary benchmarks are more accurate due to several GNSS and levelling surveys. Furthermore, the benchmarks themselves are 1,5 m long steel 'torsional plugs', located, sub soil, in solid ground close to the original (100 years) sub soil precise levelling points. In this way, we 'give more power' to the gravimetric geoid, which also has been enhanced by numerous new gravity surveys in the previous 10 years. We expect the final fitting to be done at the end of 2022.

Ground deformation monitoring using SAR interferometry (InSAR)

Wide-area deformation monitoring

In the years 2018–2020, SDFI acquired and freely distributed nationwide deformation maps over Denmark based on radar imagery from the Copernicus satellite Sentinel-1. The imagery has a medium spatial resolution of 5 x 20 m, and the maps were generated by TRE Altamira. They contained both persistent (PS) and distributed (DS) scatters.

The deformation maps can be applied for a wide range of purposes, such as for monitoring infrastructure and landslides and for supporting climate change adaptation. No matter the application area, the data can contribute to a better basis for decision-making.

In order to support this and thus foster the user uptake, the data were published for free together with a Danish user's guide and a general introduction to the technique. We also organized end-user meetings. This led to the adoption of the deformation maps in a number of applications in both the public and private industries in Denmark.

Concurrently, the SDFI was a member of the Advisory Board for the establishment of the European Ground Motion Service (EGMS). A service, implemented by the European Environment Agency.

Investigating high-resolution imagery

In order to further stimulate the use of InSAR data, we distributed a PS-based deformation map over Copenhagen based on high-resolution imagery from the German TerraSAR-X satellite. This allowed for detecting the ground motion with a higher level of detail than in the S1-based map.

The deformation map was generated via a collaboration agreement with DTU Space and was also distributed for free, together with an introduction and a user's guide. This has been applied mainly for the monitoring of infrastructure.

Field-test of Compact Active Transponders

In late 2019, a test setup consisting of three compact active transponders (CATs) and one corner reflector (CR) was established by the HABY GNSS station. The purpose was to facilitate a multi-year field test of CATs and more specifically to test the stability and overall performance of the instruments under realistic operation conditions. During the course of the field test, manual deformations were applied to two of the CATs, while all instruments were frequently monitored using precise levelling.

Especially in the beginning, several problems regarding the operability of the CATs were encountered. These problems included weak or completely missing return signals as well as one instance of water leaking into a CAT.

In 2021, PSI deformation maps of the CATs were generated by both DTU Space and TRE Altamira using the CR as a stable reference. Based on comparisons between the maps and levelling data, it was possible to conclude that vertical deformations can be determined at the mm-level by means of the CATs. However, only continued testing in the years to come can reveal whether the operational stability of the instruments is sufficient for the intended purposes.

Future efforts

Some essential next steps are:

- the investigation of the quality and range of application areas with the EGMS to understand how to adapt to the data on a nationwide scale,
- the securing of funding to continue the efforts towards a free and open distribution of satellite-based ground deformation maps over Denmark,
- continued investigations of the possibility for using CATs and CRs in the maintenance of the national height network.

Publications related publications from SDFI, 2018-2021

J. Balasis-Levinsen, M. Nissen, K. Keller, J. P. Merryman Boncori, M. Falkenberg, and N. Broge. National monitoring of ground motion and infrastructure using Sentinel-1. *Danish uses of Copernicus – 50 user stories based on Earth observation*, pages 12–13,2021. Published by the Danish Agency for Data Supply and Efficiency and Municipality of Copenhagen. URL: https://www.copernicus.eu/sites/default/files/2021-01/Copernicus_ENG_digital.pdf.

J. Balasis-Levinsen, and M. Nissen. Introduktion til kortlægning af landbevægelser fra satellit. URL: https://sdfi.dk/Media/637600488590554048/Introduktion%20til%20kortl%c3%a6gning%20af%20landbev%c3%a6gelser%20fra%20satellit_web2021.pdf, 2021.

J. Balasis-Levinsen, and M. Nissen. Kortlægning af landbevægelser fra satellit: leverancebeskrivelse. URL: https://sdfi.dk/Media/637600485765019866/Leverancer_monitorering%20af%20infrastruktur%20og%20landbevaegelser%20fra%20satellit_2021_online_web.pdf, 2021.

J. Balasis-Levinsen, K. Keller, M. Nissen, and A. Meister. Exploiting Copernicus data: Linking InSAR-based deformation monitoring with the national geodetic infrastructure in Denmark. American Geophysical Union, 2019, San Francisco, USA. URL: https://www.researchgate.net/publication/337946453_Exploiting_Copernicus_data_Linking_InSAR-based_Deformation_Monitoring_with_the_National_Geodetic_Infrastructure_in_Denmark_Agency_for_Data_Supply_and_Efficiency_Background

The secret boxes buried in Greenland in 1952 are now excavated.

Since 2002 we have known of two secret boxes buried by state geodesist J.F. Chantelou in 1952, near the town of Sisimiut, Greenland. But we didn´t know the exact location. The boxes were supposed to contain micro film/images of all the present (in 1952) geodetic data, such as locations, coordinates and heights for all Danish bench marks in one box and all geodetic observations for Greenland (as the coordinates were not calculated at that time) in another box.

However, in 2019 we found Chantelous secret note book at the National Archives. The note book contains the full documentation of how and where the boxes were buried, a few km west of Sisimiut including the coordinates and geodetic observations. In September 2020 an expedition went to Sisimiut, found and excavated the two boxes, which were shipped back to Denmark. The boxes were opened and the micro film were digitized, analyzed and found to contain exactly as described by Chantelou.

Going through the archives only very little has been written about the secret story of the micro film in the two boxes, and only very few questions can be answered. We do not know if Chantelou were ordered to do so or if it was an act of his own. But we do know that it was a major geodetic back-up of all geodetic data in case of a "catastrophe should occur in Europe and destroy all the geodetic information" as Chantelou writes in a letter filed together with the micro film.

Figure 6 Left: One box excavated in 2020. Right: State geodesist J.F. Chantelou at the same site in 1952 and his survey equipment.