NORDISKA KOMMISSIONEN FÖR GEODESI

Nordic Geodetic Commission, Working Group of Reference Frames
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NKG Working Group of Reference Frames

Minutes for the meeting in Copenhagen, Denmark,

March 25–26, 2019

Place: SDFE office building

Rentemestervej 8, 2400 Copenhagen NV

Participants

Denmark:	Kristian Evers, Mette Weber (secretary), Thomas Knudsen, Aslak Meister
Estonia:	Karin Kollo, Tarmo Kall
Iceland:	Dalia Prizginiene, Gudmundur Valsson
Finland:	Pasi Häkli (chairman), Sonja Lahtinen (Skype on March 26)
Latvia:	Ksenija Kosenko, Inese Vārna
Lithuania:	Karolis Galinauskas, Simonas Valotka
Norway:	Michael Dähnn, Hans-Sverre Smalø, Karoline Skaar
Sweden:	Lotti Jivall (secretary), Martin Lidberg, Tina Kempe

The slides of the presentations are available at the SDFE's FTP server.

Session 1: Scientific/technical presentations

- **Martin Lidberg: Analysis of effects from installation of the antenna at GNSS reference stations.** Martin presented examples and results from the CLOSE III projects (by Jan Johanson). The investigations show that there is no perfect way to establish a permanent GNSS site. Every single element of the construction affects the GNSS signals. It could e.g. be a tribrach, a radome and the colour of the steel mast (white will not get as hot as black -> less expansion). Even a bird can be detected in the signal analysis.
- **Martin Lidberg: Deformation model for Europe: Application of the least-square collocation.** Martin presented deformation models (horizontal components) based on two data sets: "EPN densification filtered" (by Kenyeres) and "WG EU Dense Velocities" (by Lutz & Brockmann). Development of a method that includes correlation between horizontal component and information of plate boundaries and testing between

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different methods. A plan for a complete model also including the vertical component will be prepared later. Non-stationarity is neither included yet.

- **Kristian Evers: New functionalities in PROJ6.** Kristian presented the features of the new version of PROJ; PROJ6. It supports now the unified geodetic registries like EPSG and the French IGNF registry etc.. PROJ6 uses late-binding transformations (does not anymore use WGS84 as a hub by default and uses database to select best possible transformation). It also supports WKT/WKT2 (ISO standardised geodesy language) and has updated datum grid packages that include e.g. the NKG transformation. PROJ6 has a new application "projinfo" and some new coordinate operations as well. Many GIS software manufacturers need to get ready for PROJ6. A EUREF tutorial on PROJ is scheduled in May 2019; Kristian and Thomas are instructors.
- **Inese Vārna: Velocity analysis of the Latvian CORS time series for 2011-2018.** Inese presented Bernese time series from the Latvian CORS 2011-2018. The velocity field is compared with the NKG land uplift models. The time series are based on GPS data up to 2015 and GPS/GLONASS data beyond 2015. Further work will include reprocessing of 2011-2014 with GPS/GLONASS data and reprocessing+inclusion of data from 2007-2010.
- **Lotti Jivall: The update of SWEREF 99 coordinates on SWEPOS and plans for a future improved solution.** Lotti presented the plans for updating the SWEREF99 coordinates on SWEPOS stations. During the years there has been antenna changes, new stations has been added and changes in processing routines and models. An update is necessary due to increasing uncertainties and higher demands for accurate and consistent coordinates. The plans will include e.g. physical changes on the stations (antenna replacements because of aging of original antennas), and possibly (under consideration) implementation of defrosters, new local control measurements, tree cutting and establishment of more class-A stations along the Norwegian border. They have also identified the need for the updated deformation model and possible benefits from cumulative NKG GNSS AC solution.
- **Michael Dähnn: Midgard – a Python geodesy library.** Michael presented Midgard that is a library including geodesy related Python functionalities outsourced from the software Where. Midgard has several functionalities related to configuration, data sets, logging, mathematics, models, parsers and site information. Midgard is open source and available in github: https://github.com/kartverket/midgard. More information is available: https://kartverket.github.io/midgard/.

Session 2: National reports

Denmark:

- New GNSS station SKEJ (2019) and antenna changes at SULD and GESR (2019).
- TAPAS high density GNSS testbed now fully deployed and operational.

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- Ownership of GNET stations in Greenland transferred from NSF/USA to SDFE from 1/1 2019.
- SDFE is now using motorized trigonometric levelling instead of motorized geometric levelling.
- Development of PROJ and a new database.

Estonia:

- New GNSS station MOIS and reconstruction at TOR2 (to be re-located).
- Connection of tide gauges to levelling network and tide gauge data analysis.
- Analysis of relative gravity measurements and completion of a new gravity system EG2000.
- Regional land uplift modelling.
- Submission of data to EPOS from nine sites.

Finland:

- Densification of FinnRef network from 20 to 47 (+4 old EPN) stations of which now 20 are EPN stations.
- New FINPOS positioning service operational in the summer 2020.
- Velocities of Trimnet network processed and analysed. Stations are mounted on roofs and walls of buildings etc. (~class B) but still found more than 80 good quality stations. The results agree well the NKG repro1 velocities but some checks and analysis is still to be done.
- All FinnRef stations will be connected to the precise levelling network. The work has been started in 2018.
- New GNSS/levelling data set: processing of 78 GNSS points, observed in 2016/2017, completed in 2019.
- Development of the geodetic research station Metsähovi: Satellite laser ranging system build continues. VLBI telescope installed in summer 2018, receiver under construction in Yebes (Spain), installation and tests in autumn 2019.
- Renewal of benchmark registry: current registry outdated regarding the platform (updates, security,…) and supports only passive benchmarks. New will handle active (permanent GNSS stations) and gravity benchmarks as well and will support also dynamic reference frames (include velocity, uncertainty and time information and validity of coordinates (time windows) and global reference frames). GUI will be built on QGIS.

Iceland:

- New transformation tool using PROJ: cocodati.lmi.is

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- Preparations for a Post Processing Service (PPS) – web interface is ready.
- Three new stations in the IceCORS network for real time corrections.
- On-going operational calculations for NKG AC.

Latvia:

- A department of geodesy is established.
- Benchmark inspection in two regions.
- Levelling of 1st order national levelling network in four cities.
- Combined state geodetic network in Daugavpils.
- A new 0 order CORS (LATREF), five stations in total.
- Preservation of point at the Struve geodetic arc
- Absolute gravity measurements at seven sites – five sites are 0 order CORS.
- Comparison of EVRF2007 and EVRF2019 heights (differences: mean zero, ~2-3mm in general and max about 12 mm).

Lithuania:

- National GNSS Network LitPOS with 40 stations – more station will come in the future
- Velocities for LitPos estimated with TSview.
- Preliminary velocity results for LitPos stations with CATREF.

Norway:

- Systematic GNSS quality control (e.g. tree clearing).
- Recalculation of the passive GNSS network.
- Updated Norwegian transformation library using PROJ and a new transformation web service.
- Working with dynamic reference frames.
- The new observatory in Ny Ålesund opened in June 2018
- The library Midgard is not included in Where anymore, it is now a stand-alone library. Midgard should now be easier to use.
- Where: tool for analyzing VLBI, SLR and GNSS data. VLBI analysis started to deliver operational contributions to IVS. VLBI part of Where is open source and available under GitHub: https://kartverket.github.io/where/. SLR analysis is still under development. Signal-in-space range error analysis is implemented and operationally used for monitoring Galileo orbit and clock performance. GNSS analysis will be extended by Single Point Positioning solution based on code observations.
- Norway has now a common reference frame on- and off-shore.

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- A new web site for visualization of sea level changes.
- New GNSS station at Jan Mayen for strengthening EPOS in the Arctic.
- Investigations of how InSAR can improve geodetic reference frames.
- Investigations of Intelligence Transport Systems (ITS)

Sweden:

- The new gravity reference frame RG2000 is finalized and a publication is ready.
- Marine gravimetry in the Swedish waters in 2018 and coming years
- Inventory and updating the national levelling network and on-going implementation of RH2000 in the municipalities (90 % is using RH2000).
- New report on maintenance of national geodetic reference networks (in Swedish).
- SWEREF99 is now introduced in all municipalities except two.
- Four new tide gauges connected to RH2000 (27 tide gauges in total).
- Geodetic SAR project funded by ESA for Baltic Sea height system unification and sea level research.
- Establishment of active transponders and corner reflectors.
- E-GVAP: Hourly processing of almost 700 stations. 15 min estimates in test phase.
- Galileo included in the SWEPOS real time service.

Session 3: WGRF 2018-2022 (Reflections from the NKG general assembly 2018)

- Pasi presented the **updated structure of the NKG in 2018-2022**. NKG has identified two particularly important focus areas for the period: dynamic reference frames and future positioning services. There was some changes in working groups and their chairs as well. The working groups and chairpersons for the period 2018-2022 are: Reference Frames (Pasi Häkli, Finland), Future Height System and Geoid (Dagny Lysaker, Norway), Future Positioning Services and Applications (Anna Jensen, Denmark) and Geodynamics and Earth Observation (Holger Steffen, Sweden). There is now a new Coordinating board in the NKG structure whose task is to follow the progress in ongoing projects, coordinate the entire portfolio and allocate necessary resources.
- Pasi presented also the **resolutions from the NKG General assembly**, of which resolution 1 on dynamic reference frame is mostly touching the WGRF. The resolution recommends NKG to continue the DRF activities in close cooperation with the NKG working groups. Consequently, also WGRF activities have been communicated and coordinated with the NKG DRF project.
- Pasi presented also the **NKG DRF project plan** where also most of WGRF activities have been included. In the deformation model package (DRF-P1) WGRF is responsible

of compiling existing deformation models (and finalizing ongoing activities on new horizontal intraplate model) for the NKG-area and customizing them for DRF and semi-DRF use. This is conducted in the NKG transformation project. Reference Frame realization package (DRF-P5) includes activities related to NKG GNSS Analysis Centre as well as some tasks for the NKG transformation project.

- More detailed planning is carried out within the projects sessions, see below.

Session 4: Project NKG GNSS AC

4.1 Combined coordinate and velocity solution from NKG GNSS AC

Sonja presented the progress in NKG reprocessing (NKG repro1). Since the last meeting in 2018 extensive time series analysis (pre-analysis with Tsview), CATREF combination, estimation of uncertainties, finalisation of products and documentation (manuscript) were carried out. As a result final ITRF2014 velocities has been released (main goal) together with velocity uncertainties and coordinate solution. The coordinates and velocities are based on CATREF solution and uncertainties were estimated with Hector using Flicker noise plus white noise combination (that was found out to be the best of tested noise models).

4.2 Implementing RINEX3 and Galileo in EPN-processing

Tina presented some background, experiences and hints for implementing RINEX3 and Galileo signals in the EPN processing. The activities are based on EPN recommendation to ACs to change using of RINEX3 instead of RINEX2 and EUREF resolution in 2018 that encourages ACs to build capability for processing of Galileo observations. EPN has already announced that Galileo will be included in the operational final solution from GPS week 2044 onwards. All this will influence to NKG GNSS AC too as we are following the EPN guidelines. So we need to start preparations for Galileo and RINEX3.

4.3 Status reports from all LACs incl. combination and SDFE-ftp

SDFE-ftp:

Mette reported on the status of the SDFE-ftp server and reminded about the changes proposed and agreed on two years ago, which not have been implanted yet. There are two types of logins, the technical and personal logins. Each country/LAC has one **technical login** which is used in upload scripts and has only upload rights to NKG_GNSS_AC, but no deleting rights. It uses ordinary ftp and is less safe. Then each user in NKG GNSS AC has a **personal login** which uses secure ftp (sftp) and has deleting rights in own folder under NKG_GNSS_AC/Products. This user should not be used in scripts for security reasons. In addition, Lotti, Sonja and Mette have full rights to all folders.

In 2017 we decided to create two new login types with the purpose to give people outside the NKG GNSS AC access to our products and for people within NKG additionally access to e.g. minutes, presentations, guidelines e.t.c.:

- NKG-members: read-only access to all folders

- People outside NKG: read-only access to NKG_GNSS_AC/Products. No access to other folders.

In connection to this, the folder Products will be moved one step higher to be directly under NKG (and at the same level as NKG_GNSS_AC). This will facilitate the settings of rights to the folder.

Martin pointed out that it could be a delicate question to define who is NKG member or not. The two logins could however be very useful, so we decided to implement them anyway and then Mette has to decide from case to case which login is applicable.

Mette will implement this before June 1st and will warn the analysis centers in NKG NSS AC before moving of the folder "Products". See further slides from Mette.

Reports from the analysis and combination centres

The operational solutions have been running on time for most of the LACs, except some single LAC, which consequently led to delays in the combined solutions. There has also been and will be some reprocessing for single LACs to correct errors or extend time series backwards of new stations. The solution checks and combinations have during some periods been made with minimal efforts. See further slides from Lotti, Sonja and Mette.

New stations have been added to the Danish and Finnish sub-networks and will be added for the Latvian, Lithuanian and Icelandic sub-networks. Latvia announced also antenna changes on all stations for the next years.

There has been/will be some changes concerning personnel for some LACs. Oddvar is now running the SK_ solutions again, but Hans Sverre is also working on the setup of the processing on a new environment. He has experienced some problems, most probably related to different releases of the Bernese and confusion on which scripts belong to the Bernese and which are adopted for NKG, and he requests some guidelines for the setup. Lotti explained that the BPE setup at the SDFE-ftp-server is from the time when we started up and after that each country has made some adaptations in their own BPE-setup (concerning naming, archives, ambiguity resolution strategy, optimizing for clusters or full network, predefined baselines….) and of course gradually implemented new releases from Bernese, which means that we do not have any up-to-date common NKG BPE-setup at the FTP-server. Lotti will review the information on the FTP-server and try to clarify which scripts are original Bernese which have been adapted for NKG. Kristian Evers proposes to use GITHUB to keep track on files and releases and offers his help.

Karolis runs the LIT-solutions with help from Rimvydas but will in the future hand over to Simonas Valotka.

Both LIT and EST LAC have started to use CATREF for estimating coordinates and velocities in ITRF2014 for their national networks.

4.4. Planning of the period 2018-2022

The list of coming activities was discussed following the following priority list.

Implementation of Galileo and RINEX3 in operational processing

We decided to implement Galileo and RINEX3 from **GPS-week 2055** in the operational processing.

Tina will upload the BPE-setup for the EPN_NKG processing to the FTP-server as an example with some instructions.

To prepare the switch a benchmark test will be run on **GPS-week 2044**. All LACs will process the same network both using the old (GPS+GLO, RINEX2) and new (GPS+GLO+GAL, RINEX3) strategy. This will also be a good check that our processing setups are still consistent. Lotti and Tina will define instructions for the Benchmark test.

Contribution to EUREF and EPN activities

Estonia and Latvia (Latvian University) have contributed with operational solutions on a regular basis for many years to the **EPN densification** project led by Ambrus Kenyeres. In addition, all countries have contributed with their sub-networks from the NKG Repro1 (except Latvia where the contribution comes from Latvian university). Ambrus have now asked us for a continuation with operational solutions and the question came up whether it is most feasible if we contribute with solutions country by country (as we did for Repro1) or if it is better to contribute with combined solutions. Lotti will ask Ambrus if he has any preferences.

Concerning the **EUREF dense velocity field** led by Elmar Brockman we decided to contribute with the Sonja's solution from Repro1. Sonja and Lotti will coordinate this. Later, we may consider if we also should contribute with the NKG_RF17vel-grid.

Cumulative solutions based on Repro1 and operational solutions

There is a need for updated position and velocity solutions, e.g. from the DRF-project, so the idea is to prepare solutions similar with the EPN cumulative solutions, where the Repro-solutions are stacked together with the operational solutions. Sonja will start to look on this during the spring and will follow up with a skype meeting after the vacations. Repro1 is based on the IGb08.atx antenna models and need to be corrected to igs14.atx antenna models. Jaanus Metsar have prepared some scripts for this in connection to the work with the Estonian network.

Global solutions

In the inclusion of a global solution, i.e. an additional solution with maybe 50-100 globally distributed stations, would most probably be beneficial to the Icelandic network and for other stations in the outskirts of our network as well as for the reference frame alignment in general. The setup of such a global solution need development of strategies, selections of good stations and a lot of testing and we think that we do not have the resources for it this year. We would also like to do it coordinated with EPN as it does not make sense that each regional network should have their own global solution. Tomasz Liwosz at EPN has done some testing. The results are good, but there are discussions within the EUREF GB on whether EPN should develop in this direction. We will follow the development in EPN.

An alternative to a fully global solution would be to process an extended regional solution with stations surrounding our network. We need take up the question for the next year.

Next Repro

The next NKG Repro will be based on IGS14 products and igs14.atx and maybe also ITRF2020. We note that the first IGS products have got available (from JPL) but we do not know the plan for the CODE products and the next repro has not yet been discussed within EPN. We will follow the development, but we do not have to plan for a new reprocessing the coming year anyway.

What we can do now to prepare for our next repro and also EPN's next repro is to complete the EPN historical database with missing RINEX files. It is mainly old data before a station became operational EPN that is missing. Lotti encourages everybody to check and complete the data for their national EPN stations.

Rapid solutions

There is a request from the NKG DRF project to perform processing with short delay. The setup of rapid processing with a delay of 1-2 days based on rapid CODE products is maybe not necessary nor possible for all LACs. First, we need also to implement it for the EPN_NKG solution. Another possibility mentioned is to activate rapid processing just as certain periods, e.g. when there is some volcanic activity in Iceland, but it presupposes that the setup is prepared beforehand anyway. The motivation for this work need to be identified to find a proper solution and priority for it.

Troposhere products

We have produced troposphere solutions as a bi-product to our operational and repro solutions since the start of NKG GNSS AC. These solutions could be interesting to the meteorological or climate community but would most probably first need to be combined. Lotti will ask Tong Ning and Rosa Pacione if there is an interest in our solutions and how and when we could best contribute. The efforts from our side need to be limited as we have many other requests with higher priority for us.

Session 5: Project NKG transformations

5.1 Land uplift modelling – status of the NKG_RF17vel

Pasi presented the status of the new horizontal (intraplate) velocities of the NKG_RF17vel model. Since the last WGRF meeting in 2018, routines have been developed and tested: NKG2016GIA_prel0907 GIA model has been fitted to GNSS velocities and subsequent least-squares collocation routines on Helmert fit residuals (GNSS minus GIA) have been developed. The methodology and some preliminary results were presented in the NKG general assembly 2018. The preliminary model (version 2018-09-05) was based on BIFROST GNSS solution and was compared to recently released EPN densification solution. From the comparison it was found that Baltic region is less accurate due to only a few GNSS stations in the BIFROST solution in that area. At the same time first preliminary version of the NKG repro1 solution was released including more stations in Baltic countries and having longer time series as well. The main conclusion was to wait for the NKG repro1 to be finalized and to utilize that in the NKG_RF17vel model. We concluded to use "combined" NKG+BIFROST solution in the model because BIFROST solution was already used in the NKG2016LU_abs model (vertical component of the NKG_RF17vel). Consequently, a lot of testing on optimum "combination"

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was conducted and in the end conclusion was to use NKG repro1 with all common stations and to amend the solution with BIFROST-only stations. The pre-analysis step included station qualification tests (outlier checks) and transforming of BIFROST velocities (in IGb08) to agree with NKG repro (ITRF2014). Subsequent steps were (re-)performed similarly as before: GIA model aligned to (a subset of) combined NKG+BIFROST solution and then using collocation for the differences GNSS-GIA. Resulting preliminary model NKG_RF17vel_20190323 was presented in the meeting. Pasi presented differences model minus NKG repro velocity country by country and requested feedback on possible suspicious stations that should be rejected from the modelling. Pasi was asked to send the presentation (see SDFE ftp server) together with the plots to each corresponding country for evaluation.

5.2 Updating the NKG transformation

Pasi presented the status of NKG transformations (see slides in SDFE ftp). The methodology follows that of Häkli et al. 2016 (https://doi.org/10.1515/jogs-2016-0001) but both input coordinates (ITRFyy and ETRFyy) will be changed or revised and the intraplate model will be replaced by the NKG_RF17vel. ITRF2014 coordinates have been taken from the NKG repro1 solution using time stamp 2015.0 both for the epoch of the coordinates and the solution number (in case of discontinuities). Pasi showed some exceptions for solution numbers that had to be made. The NKG transformation was carried out using the preliminary NKG_RF17vel_20190323 model (see above) and the coordinates from NKG repro1 (ITRF2014) and from each country (official ETRS89). The transformation includes common frame in ETRF2014 at epoch 2000.0 and the resulting coordinates were compared to EPN cumulative solution. RMS of differences were ~2mm in horizontal components and ~8mm in vertical that proves adequacy of the method. Pasi showed also the country-wise transformation residuals and requested feedback on possible suspicious stations to be rejected from parameter estimation. Pasi was again asked to provide the plots together with the presentation and residual data to be evaluated by each corresponding country.

5.3 Status and continuation of PROJ study group

Thomas presented status of the PROJ study group. The group has worked since fall 2017 and has had one workshop in Copenhagen in November 2017 and session in WGRF meeting in 2018. The study group identified some missing features in PROJ but more importantly the possibilities to get geodetic transformations (and thus national geodetic reference frames) available to users. The NKG transformation was implemented to PROJ in December 2017 so it is now easily available for transformations from global to national reference frames. Since the last WGRF meeting, the activities of the study group were presented in the NKG General Assembly and concluded in a peer-reviewed manuscript submitted to Geophysica. One of the main conclusions is still lack of standardized open file formats and data structures needed to disseminate the data material in an efficient way. Some identified further work that NKG can do is to support and assist those Nordic and Baltic countries that have not yet implemented their transformations to PROJ. All countries were encouraged to include their national transformations to EPSG as well (see also presentation by Evers in session 1) and utilise PROJ mailing list for searching and/or providing solutions to others. It was agreed that PROJ is necessary to keep in the task list of the WGRF but it was also noted that a separate study group is no longer needed and therefore the study group was closed.

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During the WGRF meeting the EUREF tutorial on PROJ was also planned with a strong contribution from the members of the WGRF.

5.4 Planning of period 2018-2022

The tasks of the NKG transformation project are now coordinated with the NKG DRF project, see session 3. The tasks for the coming year are to finalize the NKG_RF17vel model and the updated NKG transformation and to implement that in PROJ. Some other possible tasks were also identified but planning of these were delayed to the next WGRF meeting.