NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

Quick and dirty to NKG2020 transformation

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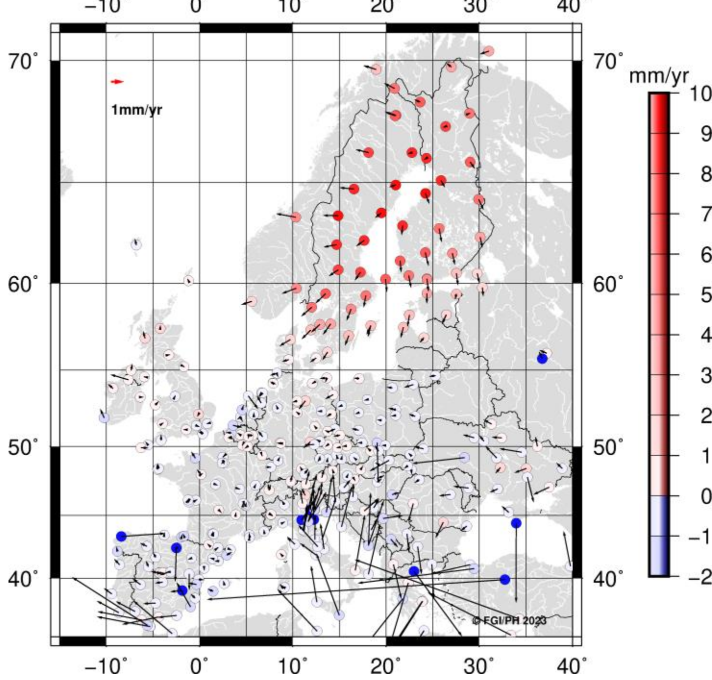
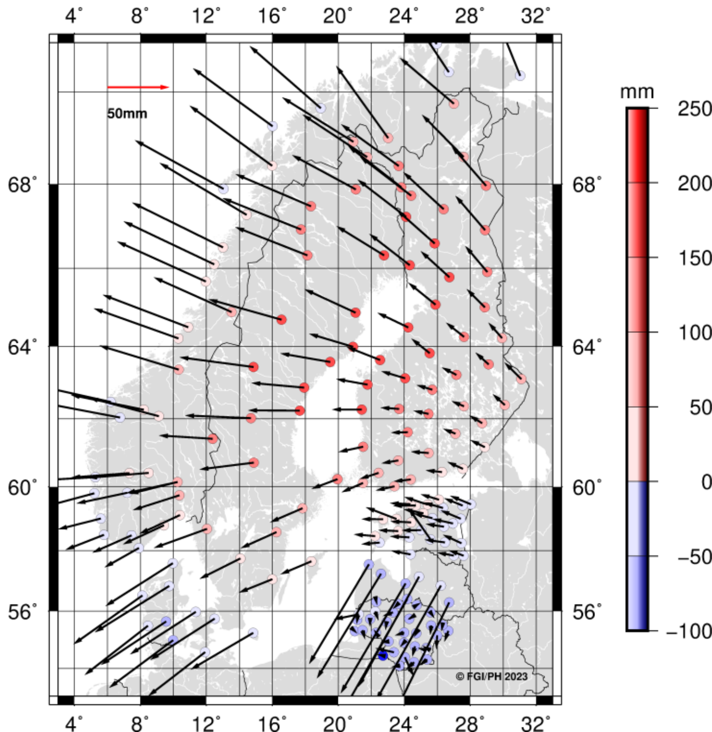
Background

- Glacial Isostatic Adjustment (GIA) causes intraplate deformations in the Nordic and Baltic countries
  - Up to 1cm/yr in vertical and a few mm/yr in horizontal (see ETRF2014 velocities from EPN_ETRF2014_C2235 in the top figure)
- ETRS89 as a plate-fixed frame minimizes time-variability of coordinates via standardized EUREF transformation
  - It considers only the rigid Eurasian plate motion but not any intra- or interplate deformations → residuals may reach a few dm (see ITRF2014@2023.0 -> Nat. ETRFyy in the bottom figure)
  - Intraplate corrections not recommended (based on ETRS89 definition) but recognized necessary for some cases
- GIA has been one of the most important study subjects for the Nordic Geodetic Commission (NKG), e.g.:
  - Several land uplift models and NKG transformation approach



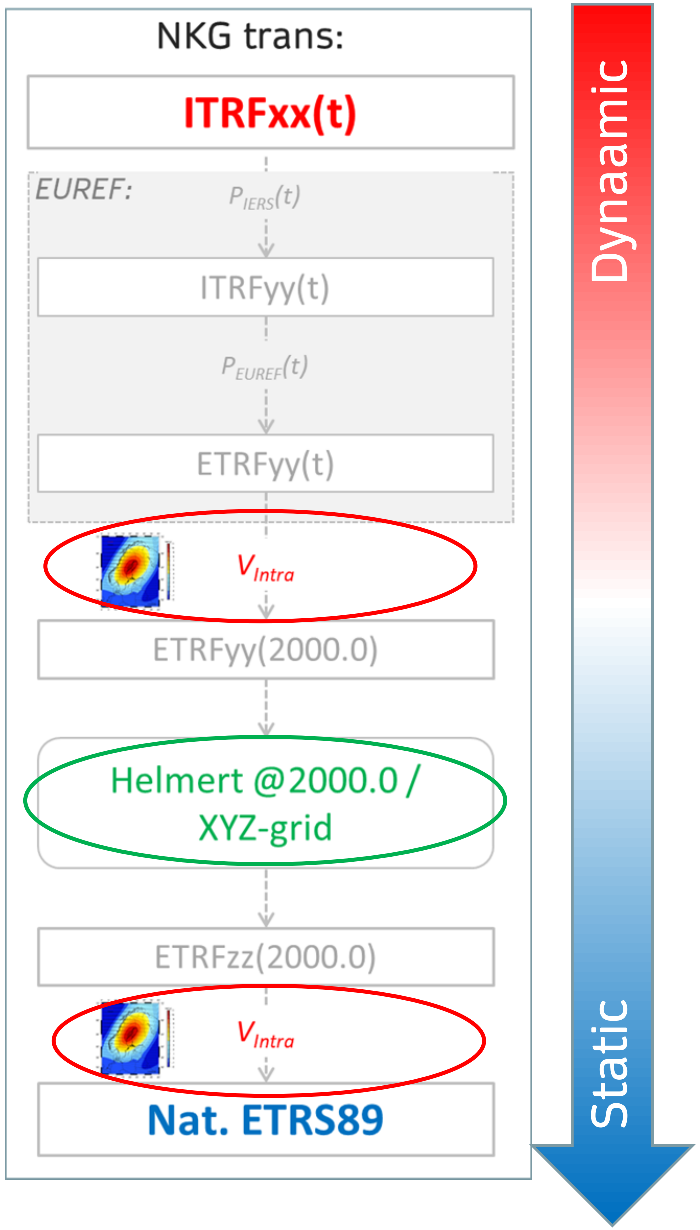


NKG transformation

- **Storing of geodata**: national, static reference frame (Nordic-Baltic region: ETRS89 realizations)
- **Positioning (coordinates)**: most accurate, global, dynamic reference frame (ITRFyy)
- **Transformation** considers crustal motions between these two reference frames (”two-frame approach”, ”semi-dynamic RF”):
  - Basis: EUREF transformation
  - Deformation model: intraplate corrections
  - National transformation parameters: differences btw pan-European and national realizations

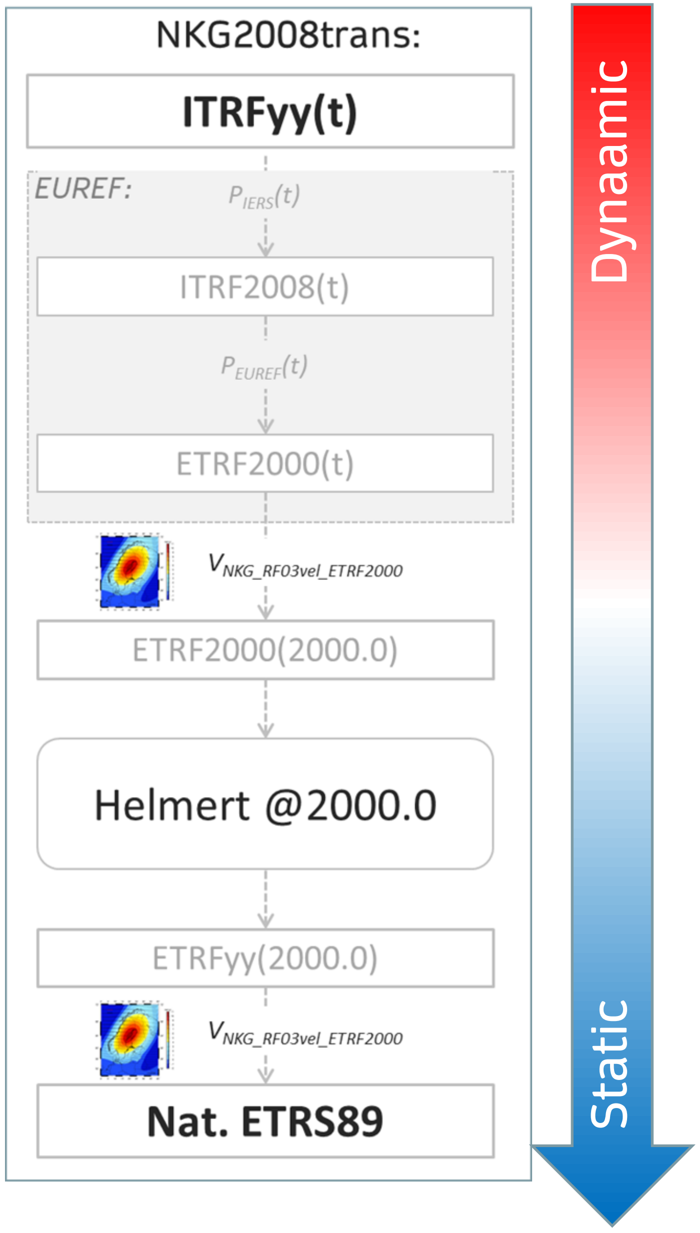
→ **Accurate link between global (ITRFyy) and Nordic-Baltic (ETRFyy) reference frames**

  - E.g. for reference frame maintenance and monitoring
  - Released versions: NKG2008, **NKG2020**



NKG2008 transformation

- Released in 2016
  - https://doi.org/10.1515/jogs-2016-0001

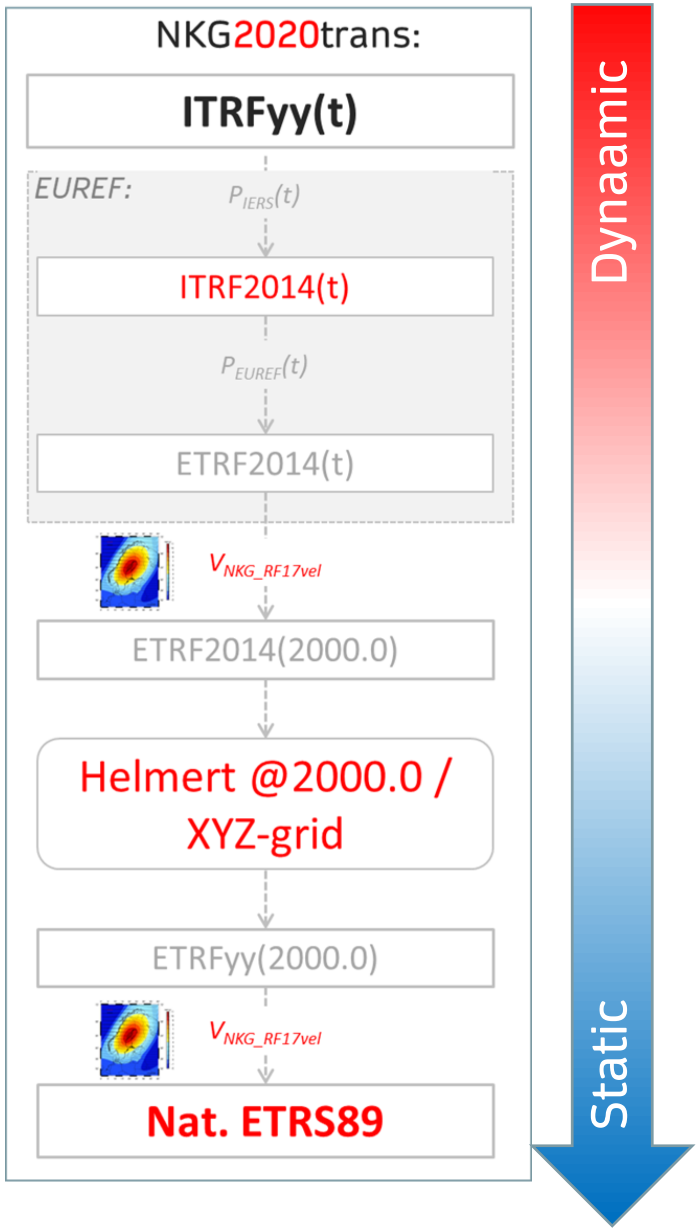


NKG2020 transformation

- Released in 2021
  - Uncertainty estimates and documentation in 2023
- Same methodology but all data updated:
  - ITRFyy coordinates: ITRF2014(2015.0) from **NKG Repro1**
  - National ETRFyy coordinates: revised and even some updated realizations
  - Deformation model: **NKG_RF17vel**
  - National transformations:
    - New Helmert parameters: Denmark, Estonia, Finland, Latvia, Lithuania and Sweden
    - New method: **correction grid** for Norway

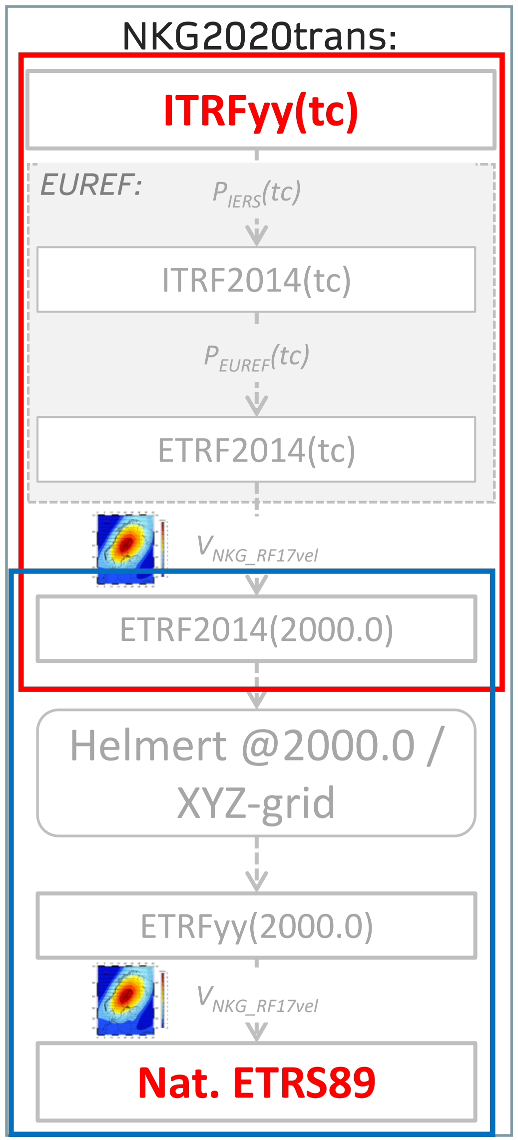
→Major update

- Supersedes NKG2008 transformation



NKG2020 uncertainty

- Helmert transformation residuals (and coordinate differences after correction grid)
  - A few mm accuracy (uncertainty) for most countries
  - Gives a picture of the expected uncertainty level but valid only for the coordinates used to determine the transformation parameters
- NKG2020 transformation has several steps that contain their uncertainties
  - Part of the steps time-dependent → also NKG2020 uncertainty time-dependent
  - Uncertainty can be divided into constant and time-dependent parts
- Uncertainty can be estimated in several ways, here empirical approach selected
  - Estimated with different data sets



NKG2020 uncertainty: constant part

- Constant part of the uncertainty estimated with four data sets:
  - NKG Repro1_upd2020, EPN_IGb14_C2220, ITRF2020, IGS20 (not shown due to only a few common stations)
  - Epoch: 2015.0 (same as for parameter estimation)
  - Reference frame: ITRF2014 (IGb14), ITRF2020 (+IGS20)
- Accuracy: approximately same level for all solutions and compared to the residuals
  - Constant part (overall, for comparison purposes): 1.7mm, 1.8mm, 3.6mm for N, E, U respectively
- NKG2020 transformation works also for ITRF2020 with the same accuracy

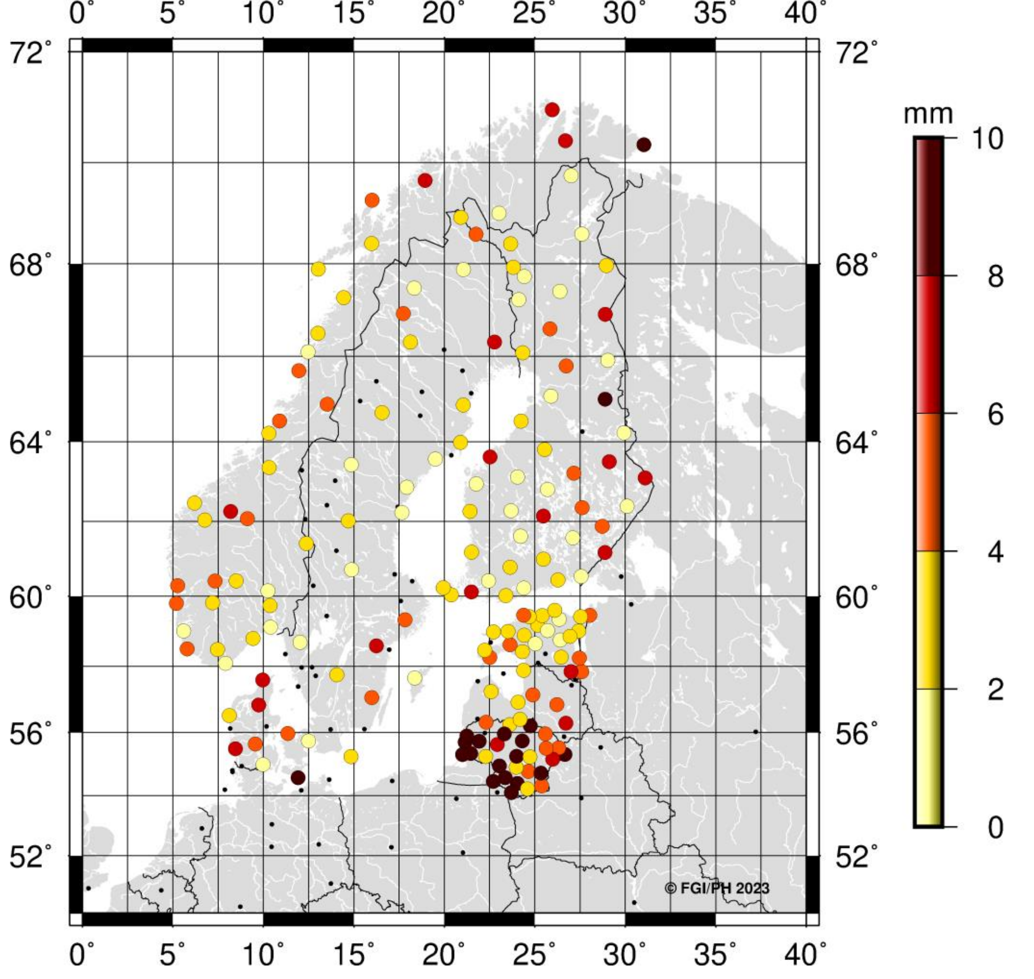


*Table 6. NKG Repro1 upd2020: IGb14@2015.0, EPN_IGb14_C2220: IGb14@2015.0 and ITRF2020@2015.0 transformed to national ETRS89 realizations. rms of coordinate differences. * Norway w/ correction grid*

rms	NKG Repro1 upd2020: IGb14@2015.0				EPN_IGb14_C2220: IGb14@2015.0				ITRF2020@2015.0			
Country	n	dN [mm]	dE [mm]	dU [mm]	n	dN [mm]	dE [mm]	dU [mm]	n	dN [mm]	dE [mm]	dU [mm]
DK	10	0.84	1.94	5.45	3	0.51	1.71	3.21	5	1.19	2.06	2.77
EE	25	1.89	2.10	2.10	4	3.01	2.93	2.54	1	2.50	2.50	0.00
FI	46	1.05	1.34	3.53	19	0.64	0.40	1.36	3	1.18	1.09	2.81
LV	6	0.96	3.29	2.38	1	5.10	2.60	25.20	0			
LT	29	3.56	4.21	9.39	1	6.50	2.30	36.10	1	6.70	1.30	41.50
NO*	35	2.01	1.39	3.35	5	2.49	2.87	2.59	6	2.88	2.75	3.30
SE	67	1.17	1.18	2.67	30	1.26	1.44	2.49	21	1.39	1.19	3.26
Total	**222**	**1.69**	**1.78**	**3.59**	**64**	**1.47**	**1.59**	**2.41**	**39**	**1.79**	**1.84**	**3.31**

NKG2020 uncertainty: time-dependent part

- Time-dependent part of the uncertainty evaluated with position time series: NKG Repro1_upd2020
  - Length of time series: 3.3-23.5 years, average: 13 years
  - Data cleaned: same discontinuities and data rejections as for NKG Repro1_upd2020, number of solutions in TS: 1-6
  - Daily ITRF2014 coordinates transformed with NKG2020 transformation and compared to national ETRS89 coordinates → residual time series
- Residual time series analyzed with Hector
- Time-dependency (overall, rms): 0.1, 0.1, 0.3 mm/yr for N, E, U respectively
  - These values suggest a few millimeter stability over 10 years that can be considered very good result

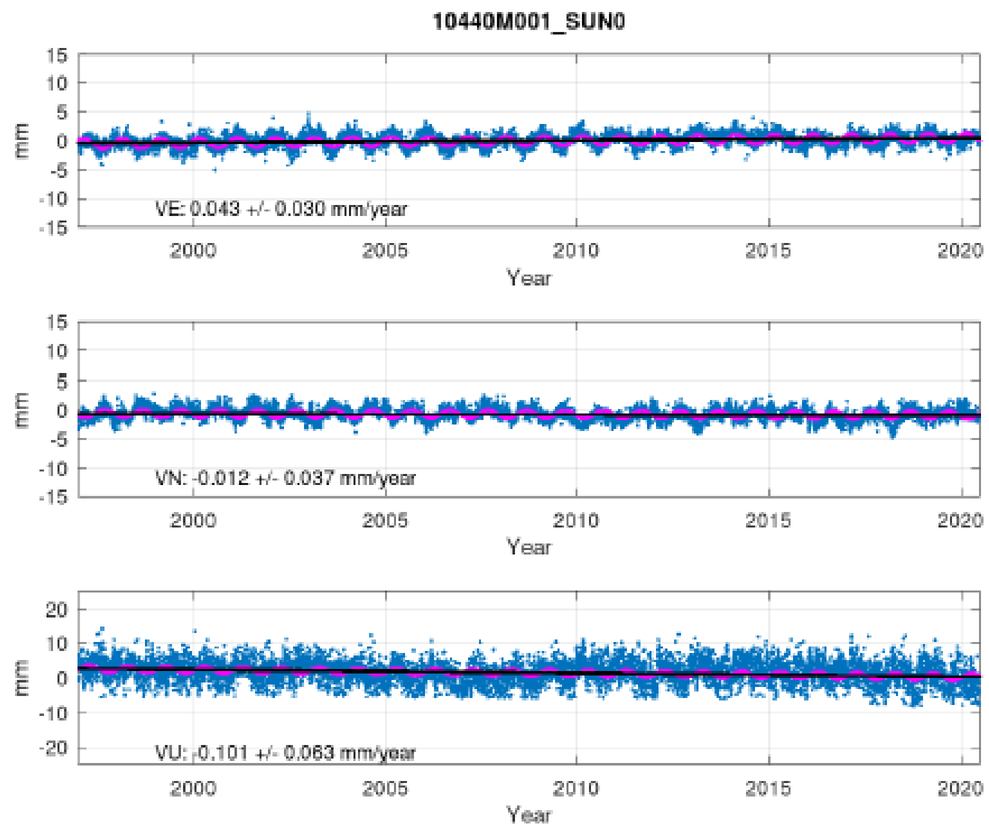


Figure 12. Example of the residual time series and velocities for SUN0 station in Sweden.

Conclusions

- NKG2020 transformation supersedes previous version NKG2008.
- NKG2020 transformation serves as a link between ITRFyy and Nordic-Baltic ETRFyy realizations at a few millimeter-level, also over time.
  - Overall, we found the empirical accuracy (uncertainty at epoch 2015.0): 1.7 mm +/- 0.1 mm/yr, 1.8 mm +/- 0.1 mm/yr and 3.6 mm +/- 0.3 mm/yr in North, East and Up components, respectively (1σ).
  - As a result, the accuracy degrades only a few millimeters in 10 years.
  - NKG2020 transformation was also shown to operate equally with the recently released ITRF2020.
- NKG2020 has been implemented in PROJ and in the future into EPSG and ISO registries
- Full documentation available: https://doi.org/10.1515/jogs-2022-0155

DynPos

(Dynamic coordinates in FINPOS positioning service)

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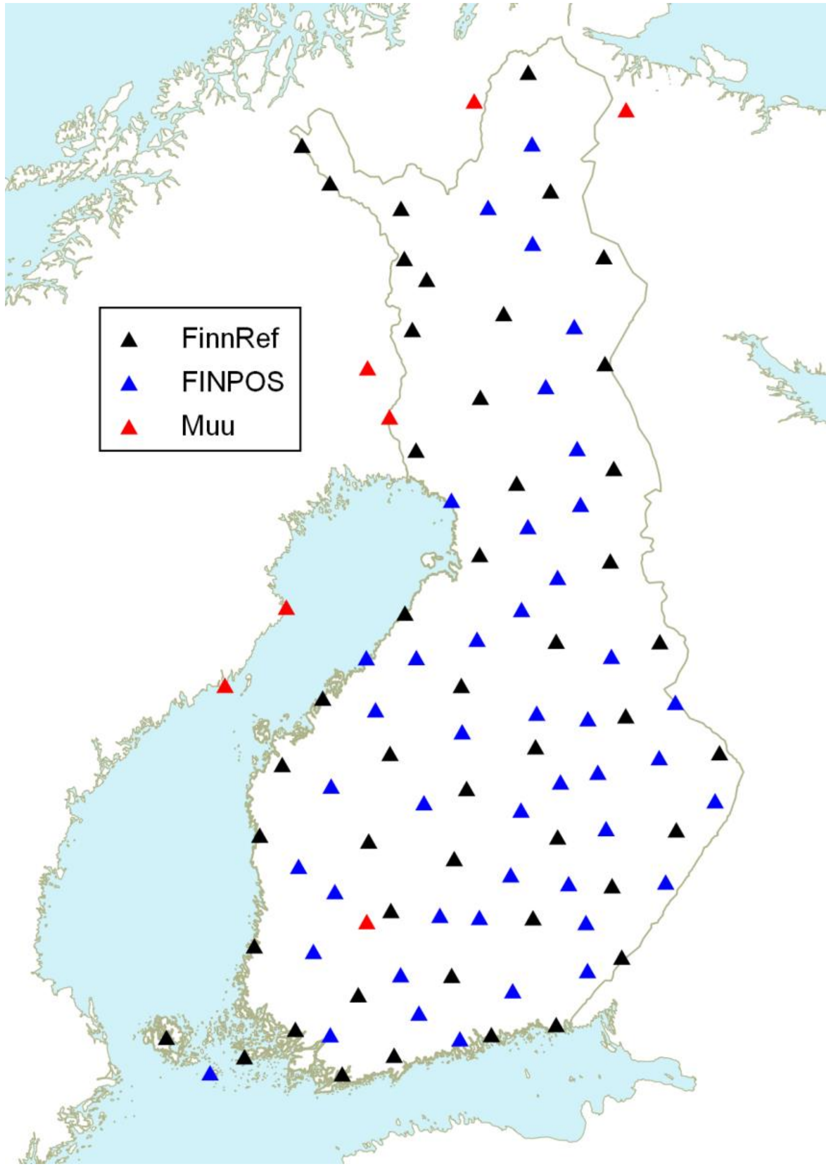
DynPos project

- A short pilot project carried out in 2020
- FINPOS is the positioning service of the NLS.
- FINPOS (like most of the positioning services) operates with official static EUREF-FIN coordinates that cannot account for the crustal motions and therefore become more and more inaccurate in time
- Purpose of the DynPos project was to study if the FINPOS positioning service can:
  1. be set up to operate in a dynamic reference frame,
  2. provide user positions in dynamic and semi-dynamic reference frames,
  3. and if these improve the accuracy of the service



DynPos: methods

- Investigation of settings for positioning service software (GNSMART) for the use with dynamic coordinates
  - Only GNSMART 1 tested due to short project
  - Two servers in parallel:
    - Production service: static EUREF-FIN coordinates (internal deformation corrections to stations)
    - Research service: ITRF2014 coordinates, velocities and transformations
- Necessary data:
  - Dynamic ITRF2014 coordinates for FinnRef stations at epoch 2015.0 (NKG Repro1)
  - Station velocities (ITRF2014), with which GNSMART can determine coordinates at the observation (current) epoch
  - ITRF2014 reference coordinates for the mean epoch 2020.75 of the test
  - Semi-dynamic coordinates using GNTRSRVR transformation module and associated parameter file (system import format, sif)
    - Transformations according to the NKG2008 transformation (NKG2020 not yet available at the time):
      - Helmert parameters
      - Crustal motion corrections from NKG_RF03vel model
    - Transformations sent via RTCM 3.2, message types 1021 and 1023

DynPos: methods

- Positioning service tested in a dynamic (DRF), semi-dynamic (semi-DRF) and static (SRF) reference frame with real-time VRS measurements
  - Test performed at two CORS stations (not included in the FINPOS service)
    - CORS data splitted to two GNSS receivers (same data) but corrected with different corrections from the positioning service (different mountpoints) → two of the above (DRF/semi-DRF/SRF) could be compared at the same time
  - Position time series, couple of days of data, new initialisation every minute
  - Positioning results compared to reference coordinates
    - DRF: ITRF2014(2020.75)
    - semi-DRF and SRF: EUREF-FIN

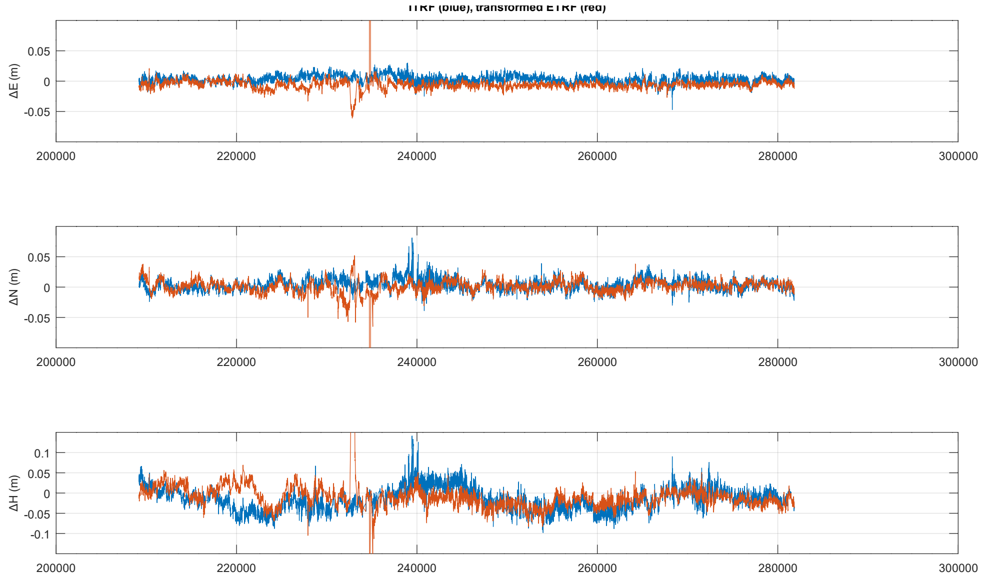
DynPos: results

Accuracies (see figures):

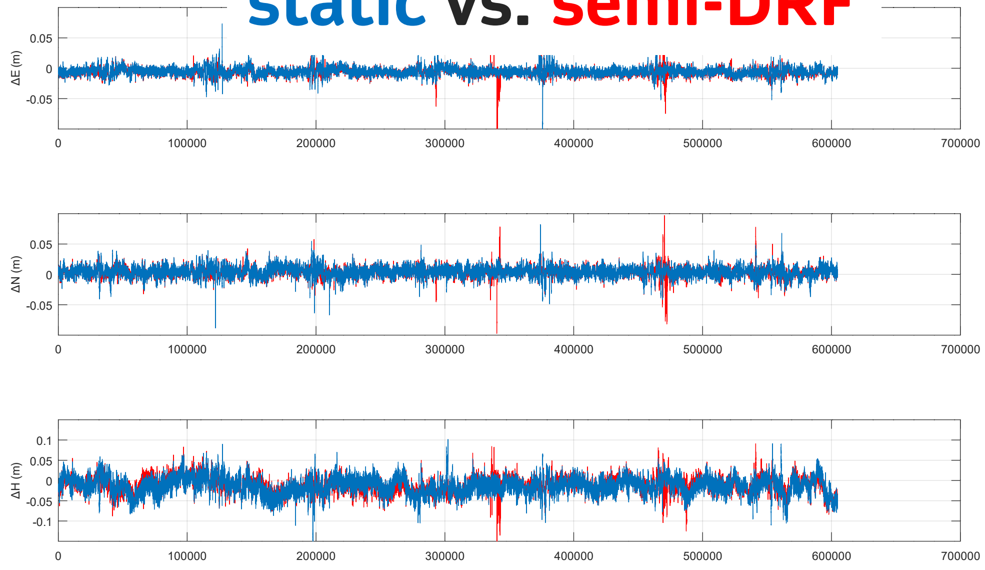
1. Dynamic ITRF2014@2020.75
2. Semi-dynamic EUREF-FIN (ITRF2014@2020.75 + NKG transformation → EUREF-FIN)
3. Static EUREF-FIN, (without transformation; from "production" service, software defines coordinate corrections)

- Based on short tests accuracies approximately the same with all three methods
  - Horizontal: ~1cm
  - Vertical: ~2cm

DRF vs. semi-DRF



static vs. semi-DRF



DynPos: conclusions

- It is possible to set up FINPOS service to operate and provide positions in a global dynamic and semi-dynamic reference frames
  - Enables user positioning in a global reference frame, e.g. for aviation and maritime applications.
  - Enables implementation of a semi-dynamic reference frame (=NKG transformation)
- Accuracies approx. same with three methods, thus alternative methods provide same accuracies as the current production service
  - But NKG transformation approach more correct and transparent compared to the current method (where the software defines the corrections itself: ”black box”)
- Short test/project, therefore results preliminary and based on older version of the positioning service software, further tests needed:
  - Approach for GNSMART2 software
  - More testing needed with different RTK rovers, deeper analysis, etc

Knowing the Earth – Securing the future

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