Updated NKG2020 transformation for the Nordic and Baltic countries

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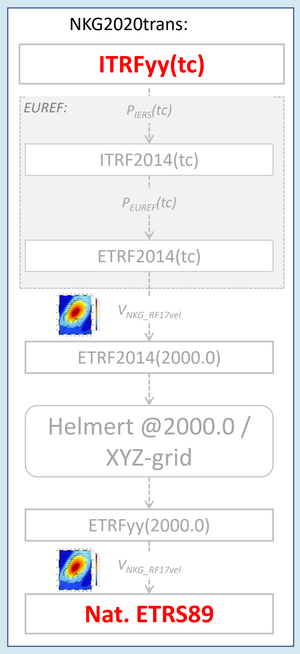
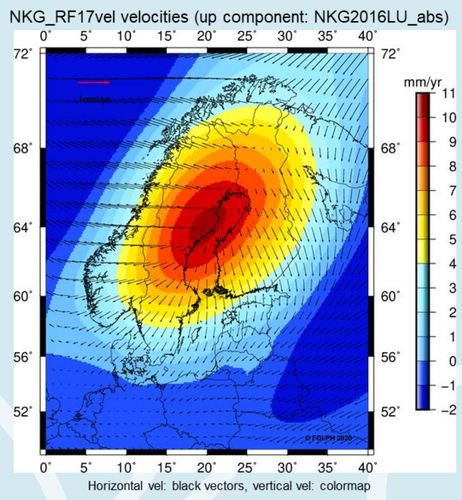
Abstract. Coordinates in global reference frames are becoming more and more common in positioning whereas most of the geospatial data are stored in registries in national reference frames. It is therefore essential to know the relation between global and national coordinates, i.e. transformation, as accurately as possible. Officially provided pan-European transformations do not account for the special conditions in the Nordic and Baltic countries, namely crustal deformations caused by the Glacial Isostatic Adjustment (GIA). Therefore, they do not fulfill the demands for most accurate applications like long-term reference frame maintenance. Consequently, Nordic Geodetic Commission (NKG) has developed customized and accurate transformations from global ITRF to national ETRS89 realizations for the Nordic and Baltic countries. We present the latest update called NKG2020 transformation and its implementation to make it widely available for geodetic and geospatial communities.

Methodology. The basis of the method is the standardized pan-European transformation provided by EUREF (Altamimi 2018). It includes two steps: global transformations between different ITRS realizations defined by IERS and pan-European parameters to comply with the ETRS89 definitions. However, this approach does not account for the crustal deformations like GIA in the Nordic and Baltic countries leading up to a couple of decimeter residuals today. Therefore additional intraplate corrections and national transformation (Helmert) parameters were added by NKG leading to a method called **NKG transformation**. Reasoning is given in Häkli et al. 2016. Currently, two versions NKG2008 and NKG2020 transformations exist, see NKG2020 method in the figure in the right.

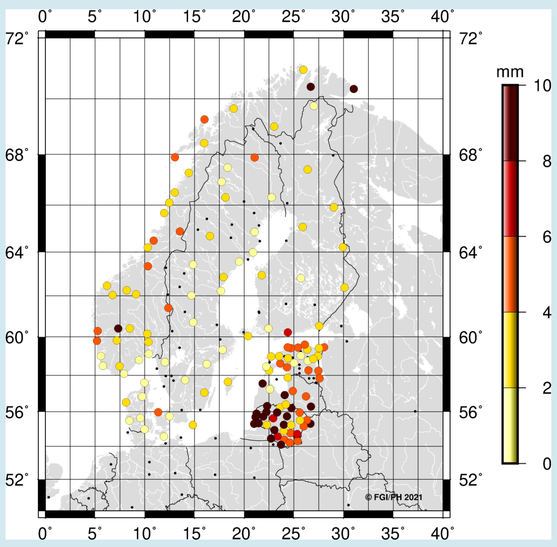


Data. As shown in the figure of the NKG transformation method (left), the data consists of ITRF and national ETRS89 coordinates, several transformation parameters (of which P_{IERS} and P_{EUREF} are predefined) and corrections from the NKG_RF17vel deformation model. The final ”result” of the work are the national transformation parameters (Helmert/XYZ-grid in the left figure).

For the national parameter estimation, global ITRF coordinates were taken from the NKG Repro1 solution (Lahtinen et al. 2019). Coordinates were estimated in ITRF2014 at the epoch 2015.0. National ETRS89 coordinates were communicated with each Nordic and Baltic country and they represent official coordinates of the country.



The NKG deformation model NKG_RF17vel (top-right figure) is a 2D+1D model. The vertical velocities equal to NKG2016LU_abs model developed in the NKG WGGEO and WGFHSG (Vestøl et al. 2019). Horizontal velocities were developed in the NKG WGRF.



National residuals in 3D at the epoch of transformation (2000.0).

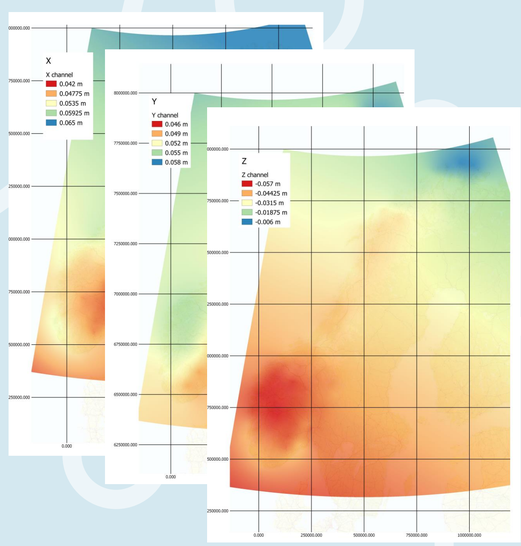
Results. National transformation parameters were estimated from ETRF2014 coordinates at epoch 2000.0 that is a common transformation hub for all countries. National ETRS89 coordinates were corrected to the same epoch with the NKG_RF17vel model before parameter estimation. National parameters were estimated with 7-parameter Helmert transformation (parameters not shown here). National transformation residuals (figure in the left) describe consistency of the two coordinate sets at the transformation epoch. In most cases residuals are at a few millimeter level (see table below). Larger residuals in Latvia and Lithuania can be explained by early ETRS89 realizations based on EUREF-BAL'92 campaign in 1992 with an estimated accuracy of a couple of centimeters.

Rms of transformation residuals (NEU):

	dN	dE	dU
DK	0.4	0.5	1.8
EE	1.9	2.2	2.4
FI	1.5	1.8	2.6
LT	3.5	3.2	12.6
LV	1.4	3.1	6.1
NO*	2.0 (0.7)	1.2 (0.7)	3.8 (2.7)
SE	0.9	0.7	2.1

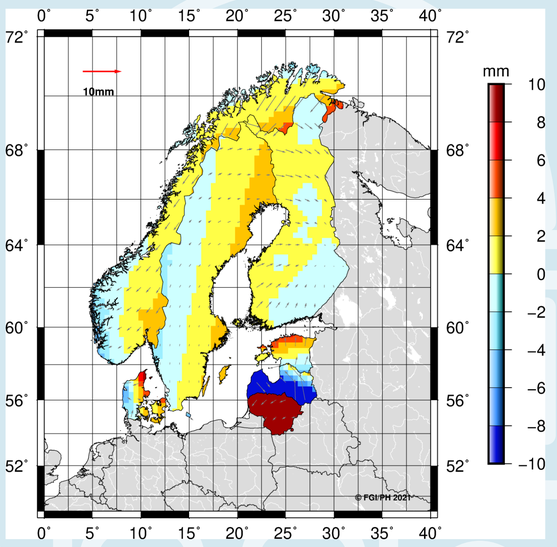
* Norwegian transformation has no Helmert residuals. Here rms refers to coordinate differences between transformed NKG Repro1 and official ETRS89 coordinates (in brackets values from the grid estimation).

In Norway residuals were considered too large for the fundamental transformation. Therefore, instead of Helmert parameters, a correction grid was estimated for Norway as a new method (figure in the right). The grid was estimated with the least-squares collocation method and it can correct (small) discrepancies between the data sets to a chosen level.



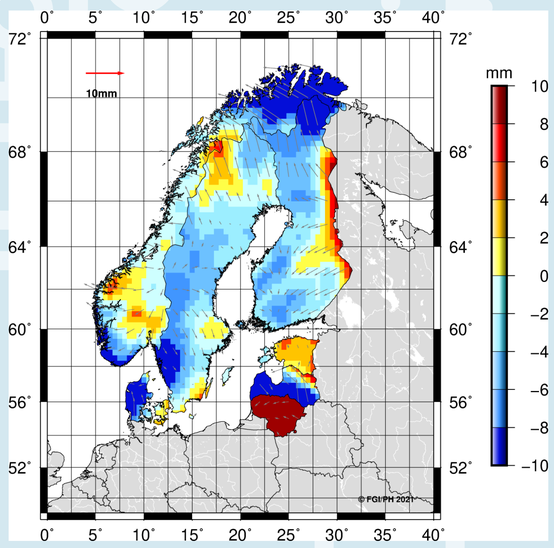
Norwegian correction grids in geocentric cartesian X, Y and Z coordinates.

Analysis. Transformations can serve as a tool to monitor or even maintain national reference frames hence setting high demands on the accuracy. Small transformation residuals (or coordinate differences) at the epoch of the transformation (2000.0) meet the requirements but the accuracy should not either degrade over time. The main factor for the time-dependency is the accuracy of the used deformation model. The overall accuracy of the NKG_RF17vel model was estimated to as 0.1, 0.1 and 0.4 mm/yr (in North, East, up respectively with respect to NKG Repro1). However, the accuracy may vary spatially and depending on the reference data. In Finland the time-dependency of the NKG2020 transformation was estimated to be below 0.1 mm/yr for stations with long time series and hence producing almost static coordinates over time.



NKG2020 minus NKG2008 @2000.0

NKG2020 transformation is a major update and even superseding NKG2008 in some countries due to updated national coordinates. In many countries the difference between the transformations is almost zero at the epoch of transformations (2000.0; figure in the left) but the differences are growing in time due to different deformation models (example @2020.0 in the right-hand figure). This should be understood as an improvement.



NKG2020 minus NKG2008 @2020.0

Accessibility. To make the NKG2020 transformation available to users, it was implemented to PROJ generic coordinate transformation software. A prerequisite is proper data licences. NKG2020 transformation and associated data (e.g. NKG_RF17vel model) were attributed to CC-BY4.0 license to give wide permissions of use. The NKG2020 transformations were added to PROJ database and associated data is easily accessible via PROJ. Through PROJ the NKG2020 transformation is easily available for command line applications, transformation services and many GIS software that are utilising PROJ.

Discussion. The NKG2020 transformation is intended as a technical solution to harmonize the transformations from global ITRF coordinates to the national ETRS89 realizations in the Nordic and Baltic countries. As a collaborative work, it already has an official status in many countries but this should always be confirmed from the approriate national authority if needed. As a technical solution, the NKG2020 transformation offers an accurate link between global and national coordinates. As such it also provides an option for maintaining static national reference frames under influence of crustal motions. As an example, Finland has deployed the NKG2020 transformation for determining the highest order coordinates of the national EUREF-FIN reference frame.

Globalization in geospatial data domain means analysis of data from different sources. At the same time demands for accuracy are increasing. In many places technical solutions exist (like NKG2020 transformation) but the standardization is still lagging or under development. Therefore, it is crucial to develop standardization for reference frames and transformations to ensure seamless and errorless data analysis without misinterpretations. NKG joins the work with plans to register the NKG2020 transformation to EPSG in the nearest future. Also the national authorities are encouraged to participate with their data.

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI