TRANSFORMING ITRF COORDINATES TO NATIONAL ETRS89 REALIZATION IN THE PRESENCE OF POSTGLACIAL REBOUND - EVALUATION OF NORDIC GEODYNAMICAL MODEL IN FINLAND

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INTRODUCTION AND METHODS

EUREF created European Terrestrial Reference System 89 (ETRS89) and fixed it to the Eurasian plate in order to avoid time evolution of the coordinates. However, e.g. the Fennoscandian area in Northern Europe is affected by postglacial rebound (PGR) causing intraplate deformations with respect to the stable part of the Eurasian tectonic plate. The absolute land uplift (up component of PGR with respect to the reference ellipsoid) in Fennoscandia has a maximum of approx. 10 mm/year being 3-9 mm/year in Finland. Horizontal part of the PGR is smaller; up to 2 mm/year in Finland.

Finnish ETRS89 realization consisting of 100 points was measured in ITRF96(1997.0) and transformed according to the EUREF recommendations. The transformation moves coordinates back to 1989.0 for rigid plate motion but does not correct the intraplate deformation caused by the PGR. Thus, the realization has two epochs, external epoch for rigid plate motion and internal epoch for intraplate deformations. Therefore Finnish ETRS89 realization can be represented as ETRF96(1997.0). To distinguish this realization from other ETRS89 realizations it was named EUREF-FIN.

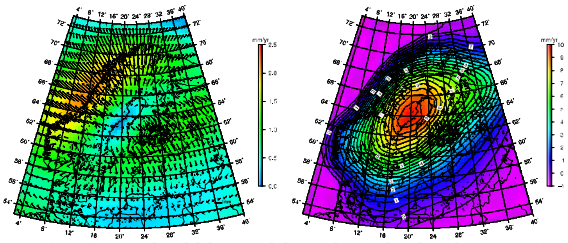

Fig. 1. NKG_RF03vel model, horizontal (left) and vertical (right) velocities, mm/yr.

The purpose of this study was to evaluate a new transformation method that takes into account intraplate deformations. The transformation was created by NKG (Nordic Geodetic Commission) working group and it was compared to the transformation recommended by EUREF. Transformations were evaluated using the re-measurement of the 100-point Finnish ETRS89 realization done in 2006. The campaign was processed in ITRF2000(2006.5) with Bernese 5.0 and transformed to EUREF-FIN using different approaches. The resulting coordinates were compared to the official EUREF-FIN coordinates.

First transformation was made according to the EUREF recommendation given in "memo" by Boucher and Altamimi (version 7). The transformation is done in two steps, first from ITRF2000(t_c) to ITRF96(t_c) and then to ETRF96. This transformation does not correct intraplate deformations.

Second transformation was done according to the recommendations given by the NKG WG. This transformation takes into account intraplate deformations using velocity model NKG_RF03vel (Fig.1). The model corrects both horizontal and vertical intraplate deformations. The transformation is done through Nordic NKG_RF03 frame. NKG_RF03 was realized with NKG2003 GPS campaign processed in ITRF2000(2003.75). First step is to transform ITRF2000(t_c) coordinates to ITRF2000(2003.75) with ITRF2000 rotation pole and correct intraplate velocities between epochs 2003.75 and t_c. Then ITRF coordinates are corrected for intraplate deformations to the reference epoch (t_r) of the national ETRS89 realization, in Finland t_r=1997.0. These intraplate corrected ITRF2000(2003.75) coordinates are then transformed to EUREF-FIN with pre-defined transformation parameters. These parameters were determined from intraplate corrected NKG_RF03(t_r) to Nordic ETRS89 realizations.

EVALUATION OF TRANSFORMATIONS

Memo transformation. Fig. 2 shows the residuals for horizontal coordinates (top) and for vertical coordinates (bottom) that remain when transforming ITRF2000(2006.5) coordinates to EUREF-FIN according to the official memo transformation. Residuals in vertical coordinates are several centimetres and show the remaining effect of the PGR (cf. to contours of the most recent land uplift model NKG_RF03vel, Fig. 1). The horizontal residuals of all points have approximately same direction but they are larger in Northern Finland. In order to estimate the reason, also intraplate deformations were further subtracted from the results. After removing the effect of PGR, horizontal residuals are quite equal of size and direction in whole Finland. The horizontal residuals are in this case approximately 15-20 mm and direction is to N-NW. This bias is probably mainly due to differently determined plate motions in ITRF96 and ITRF2000 and uncertainties in velocity estimates. For example in Finland ITRF96 and ITRF2000 coordinates have drifted on average over 5 cm apart in 9.5 years (1997.0-2006.5).

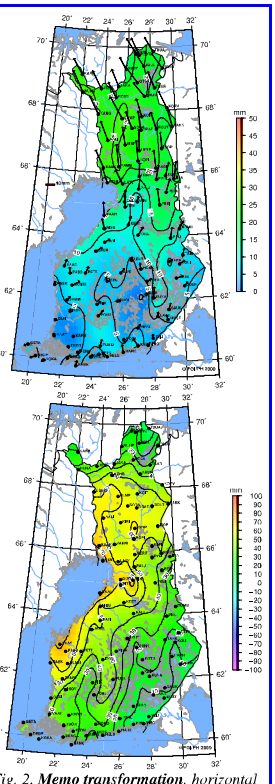

*Fig. 2. **Memo transformation**, horizontal residuals on top, vertical at the bottom.*

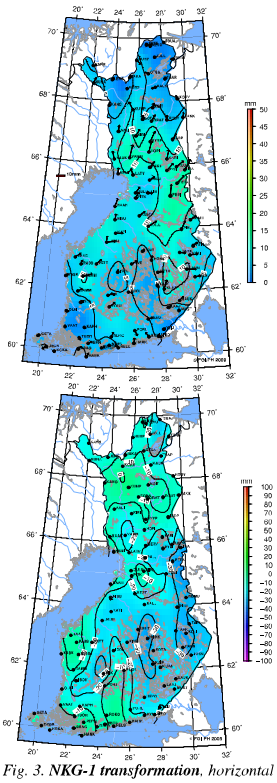

*Fig. 3. **NKG-1 transformation**, horizontal residuals on top, vertical at the bottom.*

NKG transformation. The NKG transformation was done with two slightly different parameters. Fig. 3 shows the residuals after transforming the ITRF2000 coordinates according to the parameters given by the NKG WG (NKG-1). These parameters were determined with NKG_RF03 and EUREF-FIN coordinates. Residuals are at a few cm-level. Horizontal residuals seem to be quite random of nature but vertical residuals are biased by an average of -16.9 mm. The bias was found out to be caused mainly by NKG_RF03 coordinates. The NKG_RF03 frame is in ITRF2000(2003.75) but in Finland especially vertical coordinates of NKG_RF03 differ approximately 1-3 cm from those coordinates computed with published ITRF2000 positions and velocities. Fig. 4 shows the residuals when new parameters were determined analogously (with 12 permanent FinnRef GPS stations at epoch 2003.75) between "official" ITRF2000 and EUREF-FIN coordinates (NKG-2). This corrects most of the bias in vertical residuals. The accuracy (rms) of this transformation is better than 1 cm. The residuals of different transformations are summarized in Table 1.

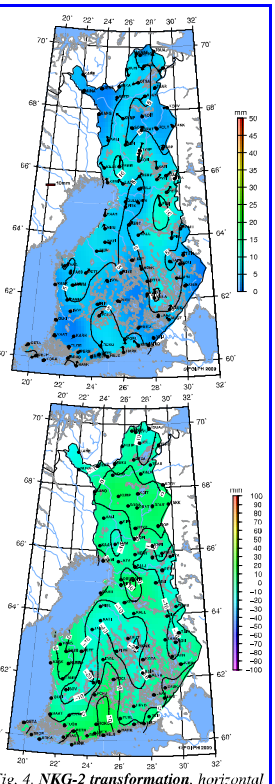

*Fig. 4. **NKG-2 transformation**, horizontal residuals on top, vertical at the bottom.*

ITRF2005. The NKG-2 transformation was also tested with ITRF2005. Transformations are otherwise similar but ITRF2005 transformation has additional step from ITRF2005 to ITRF2000 and 2.06 years more correction for rigid plate motion with ITRF2000 rotation pole and intraplate deformations with NKG_RF03vel model. Table 2 summarizes the residuals for 12 permanent FinnRef stations. Accuracy of ITRF2005 transformation is slightly worse as expected. This is partly caused by different epochs (two years difference) but the majority is probably due to diverging ITRF2005 and ITRF2000 plate velocities (and their uncertainties) that are used for extrapolating positions from the reference epoch of each ITRF to the epoch of observations. However, 1 cm accuracy (rms) can be achieved also from ITRF2005 to ETRS89.

Table 1. Statistics of evaluated transformations.

(mm)	Memo			NKG-1			NKG-2		
n=95	N	E	U	N	E	U	N	E	U
Average	10.8	-1.6	37.7	3.7	3.0	-16.9	2.2	0.7	-3.5
Std	8.0	5.5	18.8	4.1	3.5	9.5	4.0	3.3	8.1
rms	**13.4**	**5.7**	**42.1**	**5.5**	**4.6**	**19.4**	**4.5**	**3.3**	**8.8**
Min	-3.3	-13.9	1.1	-5.5	-4.9	-39.8	-8.3	-7.0	-22.2
Max	26.0	8.6	75.4	14.6	10.8	-0.0	12.1	9.0	15.0

Table 2. ITRF2005 and ITRF2000 transformations

	ITRF2000(2006.50)			ITRF2005(2008.56)		
n=12	N	E	U	N	E	U
Average	1.1	1.9	-1.8	-1.3	-4.3	-3.1
Stdev	2.7	2.3	5.2	4.2	1.3	7.6
rms	**2.8**	**2.9**	**5.3**	**4.2**	**4.4**	**7.9**
Min	-3.0	-2.0	-12.0	-11.7	-7.1	-18.6
Max	4.7	5.2	3.8	3.1	-2.4	7.1

CONCLUSIONS

It is obvious that regional deformation models are needed in many places if cm-level accuracies are desired. However, guidelines for using such models are missing or their use is not recommended. In order to fully exploit the accuracy of ITRF frames e.g. in maintaining the national (ETRS89) realizations, guidelines for correcting possible deformations would be desirable. NKG has presented one possible way to accomplish this task.

The results show that cm-level transformation from ITRF to Nordic ETRS89 realizations with pure 7-parameter (or 14-parameter) similarity transformation is not possible without taking into account intraplate motions that are deforming the realizations non-linearly in time. When intraplate deformations are taken into account better than 1 cm accuracy can be achieved.