Transformasjon fra ITRF2005 til EUREF89 (ETRF89) for petroleumsvirksomheten i Norge

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Torbjørn Nørbech and Halfdan P. Kierulf: An Approximate Transformation from ITRF2005 Current Epoch to EUREF89(ETRF89) in Norway for Offshore use

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The Offshore sector has requested a transformation from ITRF2005 current epoch to EUREF89(ETRF89). So far sufficient data are not available to make such a transformation with geodetic accuracy (better then 1 cm). An approximate transformation is therefore released. The transformation gives EUREF89 coordinates within –3 cm to +3 cm in north and east components, and within –6 cm to +6 cm for the vertical component at epoch 2007.0.

Key words: ITRF, transformation, EUREF89, ETRF89

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Introduction

A transformation with geodetic accuracy (better than 1 cm) from ITRF2005 current epoch to EUREF89 could be performed in several ways [Nørbech et al. 2002]. In general we must know the velocity of each station. In Norway it is not sufficient to use a general velocity model (e.g. Nuvel) for transformations with geodetic accuracy. The Glacial Isostatic Adjustment (GIA) process in our region causes motions which are not taken into account in plate tectonic motion models like Nuvel1A or by the ITRF2000 Euler rotation velocity for Eurasia [Altamimi et al. 2003] [Altamimi et al. 2007]. These GIA motions are deforming the crust and can not be absorbed with a rigid plate motion model. This postglacial rebound process causes relative motions up to 3 mm a year in a horizontal direction and 11 mm a year in a vertical direction in Scandinavia [Danielsen 1999] [Kierulf et al. 2002] [Nørbech et al. 2001] [Plag et al. 2001] [Nørbech 2000]. These relative motions are called intraplate deformations and are defined relative to a stable tectonic plate. The left side of Fig. 1, below, shows the (horizontal) plate tectonic motion in mm/yr according to the ITRF2000 Euler rotation velocity for Eurasia. The right figure shows the intraplate deformations according to the NKG_RF03 velocity model. These intraplate deformations are relative to the stable Eurasia tectonic plate as defined by ITRF2000 Euler rotation velocity for Eurasia [Lidberg et al. 2006] [Nørbech et al. 2006] [Vestøl 2006]. Therefore the transformation has to be split into two parts. The first part corrects for intraplate deformations and the second part corrects for the rigid motion (primarily caused by the plate tectonic motion).

When Norway performed its ETRS89 realizations (EUREF89) based on GPS measurements in 1994 and 1995, correction for intraplate deformations was not applied [Kristiansen et al. 1998]. The main reason for not doing this was that this deformation was not known with sufficient accuracy at that time. A correction for intraplate deformation should therefore be performed for the period from the current epoch back to the reference

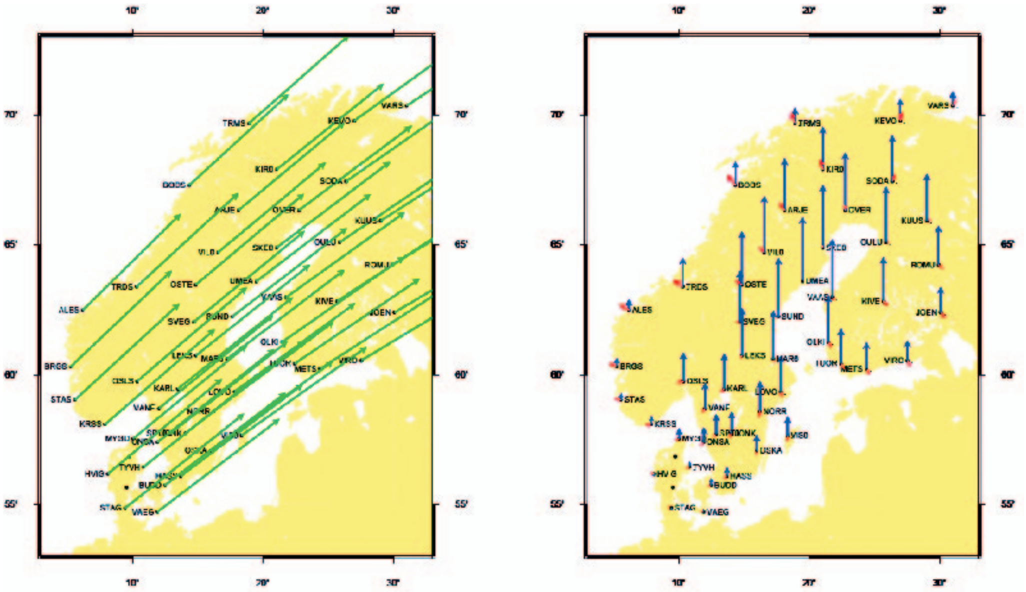

Fig 1. The left figure shows the horizontal plate tectonic motion (in mm/yr) according to the ITRF2000 Euler pole for Eurasia. The right figure shows the intraplate deformations according to the NKG_RF03 velocity model which is relative to the stable Eurasia tectonic plate as defined by the ITRF2000 rotation pole for Eurasia. The red arrows show the horizontal velocities, and the blue arrows show the vertical velocity with respect to the earth centre of mass, also in mm/yr. The arrows are in scale 1:1.

epoch of the ETRS89 realization (1994.665) instead of 1989.0. The purpose of this transformation is to obtain Norway's ETRS89 realization and not the "true" ETRS89.

The abovementioned intraplate deformation model NKG_RF03 is a model for the whole of Scandinavia. This model may not have sufficient accuracy for Norway. GPS observations performed during 2007 will be used to improve this model.

For practical applications which require less accuracy, the transformation can be simplified by omitting the intraplate deformation and using only a 7-parameter transformation. Such a transformation could be done from a selected reference epoch, for example 2007.0. To transform from the current epoch to the common reference epoch 2007.0 the ITRF2005 Euler rotation velocity for Eurasia may be used as an approximation.

An Approximate Transformation from ITRF2005 Current Epoch to EUREF89 (ETRF89)

The transformation from ITRF2005 epoch 2007.0 to EUREF89 is performed using official documented transformations.

First step is a transformation from ITRF2005 epoch 2007.0 to ITRF2000 epoch 2007.0 [http://itrf.ensg.ign.fr/ITRF_solutions/2005/tp_05-00.php].

Second step is to apply the ITRF2000 Euler rotation velocities for Eurasia from epoch 2007.0 to epoch 1994.665 [http://lareg.ensg.ign.fr/EUREF/memo.pdf].

Third step is to transform from ITRF2000 epoch 1994.665 to ITRF93 epoch 1994.665 [http://itrf.ensg.ign.fr/pub/itrf/ITRF.TP].

Fourth step is to transform from ITRF93 epoch 1994.665 to EUREF89(ETRF89) [Kristiansen et al. 1998].

These four transformation steps may be combined into one equation, see Eq(2).

Equation(1) is the transformation from ITRF2005 current epoch to ITRF2005 at reference epoch 2007.0. The rotation velocities $(\dot{R}_1 \quad \dot{R}_2 \quad \dot{R}_3)$ are the ITRF2005 Euler rotation velocities for Eurasia [http://lareg.ensg.ign.fr/EUREF/memo2007.pdf].

The rotation and rotation velocities in the two equations are given in milliarcseconds and milliarcseconds/year, respectively, and must be converted into radians and radians/year before use.

In Equation(1) and Equation(2) *X, Y, Z* are geocentric coordinates. The superscripts and subscripts of the coordinate vectors give the reference frame and reference year (reference epoch) respectively. t_c is the current epoch.

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{2007.0}^{ITRF2005} = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{t_c}^{ITRF2005} + (t_c - 2007.0)\begin{pmatrix} 0 & -\dot{R}_3 & \dot{R}_2 \\ \dot{R}_3 & 0 & -\dot{R}_1 \\ -\dot{R}_2 & \dot{R}_1 & 0 \end{pmatrix}\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{t_c}^{ITRF2005} \qquad (1)$$

$\dot{R}_1$ (0.001"/yr)	$\dot{R}_2$ (0.001"/yr)	$\dot{R}_3$ (0.001"/yr)
0.054	0.581	–0.781

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}^{EUREF89} = \begin{pmatrix} T_X \\ T_Y \\ T_Z \end{pmatrix} + (1+D)\begin{pmatrix} 1 & R_Z & -R_Y \\ -R_Z & 1 & R_X \\ R_Y & -R_X & 1 \end{pmatrix}\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{2007.0}^{ITRF2005} \qquad (2)$$

T_x (m)	T_y (m)	T_z (m)	D (ppb)	R_x (0.001")	R_y (0.001")	R_z (0.001")
0.011	0.058	–0.064	3.0	–1.689	–9.996	14.239

Accuracy

The transformation Equation(1) and Equation(2) gives EUREF89 coordinates within –3 cm to +3 cm in north and east components, and within –6 cm to +6 cm for the vertical component at epoch 2007.0. In the coastal zone, the land uplift is variable and has a positive value. No observations are available offshore but a slight subsidence is expected. Consequently, the transformed vertical component is expected to be within a range of –6 cm to 0 cm compared to the official EUREF89 in the coastal zone, and from 0 cm to + 6 cm offshore.

Observations so far indicate that the approximate transformation will have an accuracy degradation of 3 mm/yr for the vertical component and about half of that amount for the horizontal components, due to the postglacial rebound process. At epoch 2017.0 the horizontal error interval will therefore be –4.5 cm to + 4.5 cm, and the vertical error interval –9 cm to + 9 cm.

Examples of transformed points

The following 3 examples are points that may be used to verify the implementation of the transformations presented above.

EXAMPLE 1

X	Y	Z	epoch	ref.frame
3369503.259	354149.063	5385737.723	2007.42	ITRF2005
3369503.265	354149.057	5385737.720	2007.00	ITRF2005
3369503.572	354148.840	5385737.512		EUREF89

EXAMPLE 2

X	Y	Z	epoch	ref.frame
2633682.166	608033.438	5757709.841	2007.42	ITRF2005
2633682.173	608033.433	5757709.839	2007.00	ITRF2005
2633682.513	608033.264	5757709.669		EUREF89

EXAMPLE 3

X	Y	Z	epoch	ref.frame
1821623.036	1009742.137	6008281.767	2007.42	ITRF2005
1821623.044	1009742.134	6008281.766	2007.00	ITRF2005
1821623.421	1009742.020	6008281.640		EUREF89

References

Altamimi Z, Sillard P, Boucher C (2003) The impact of a No-Net-Rotation Condition on ITRF2000. Geophysical Research Letters, vol. 30, no 2, 1064, doi:10.1029/2002GL016279.

Altamimi Z, Collilieux X, Legrand J, Garayt B, Boucher C (2007) A new release of the International Terrestrial Reference Frame based on time series of station positions and Earth Orientation, J. Geophys. Res., submitted, 2007.

Danielsen J, (1999) Landhevingen i Norge. Report, Geodetic Institute, Norwegian Mapping Authority.

Kierulf H.P, Plag H.P, Kristiansen O, Nørbech / (2002) Towards the true rotation of rigid Eurasia. EUREF meeting Ponta Delgada May 2002. *http://www.eurefiag.net/symposia/symposia_2002_PDelgada.html*

Kristiansen O., B. G. Harsson (1998) The New Norwegian National Geodetic Network EUREF 89. In Jonsson B., (Editor) Proceedings of the General Assembly of the Nordic Geodetic Commission, 25–29 May, 1998, ISSN 0280-5731 LMV-rapport 1999.12, pg 162–195.

Lidberg M, J. M. Johansson, H.-G. Scherneck, J. L. Davis (2006). An imporoved and extended GPS derived 3D velocity field of the glacial isostatic adjustment (GIA) in Fennoscandia. Journal of Geodesy, DOI 10.1007/s00190-006-0102-4 (in press)

Nørbech T, Ensager K, Jivall L, Knudsen P, Koivula H, Lidberg M, Madsen B, Ollikainen M, Weber M (2006) Transformation from a common Nordic Reference Frame to ETRS89 in Denmark, Finland, Norway, and Sweden-status report

Nørbech T, Plag H.P (2002) Transformation from ITRF to ETRF89(EUREF89) in Norway. EUREF meeting Ponta Delgada May 2002. *http://www.eurefiag.net/symposia/symposia_2002_PDelgada.html*

Nørbech T, Plag H.P (2001) Detection of Horizontal Movement Due to Postglacial Rebound in Norway. Oral presentation EUREF meeting Dubrovnik May 2001.

Nørbech T (2000) Practical Consequenses of having a "moving" Geodetic Network with Fixed Coordinates.EUREF meeting in Tromsø June 2000. *http://www.euref.iag.net/symposia/symposia_2000_Tromso.html*

Plag H.P, Nørbech T, Kristiansen O, (2001) Effects of Intraplate Deformations in Fixing Regional Reference Frames. EUREF meeting Dubrovnik May 2001 *http://www.eurefiag.net/symposia/symposia_2001_Dubrovnik.html* 2_9

Vestøl O. (2006) Determination of postglacial land uplift in Fennoscandia from levelling, tide-gauges and continuous GPS stations using least squares collocation. J Geod 80:248–258. DOI 10.1007/s00190-006-0063-7.