Transformation from ITRF to ETRF89 (EUREF89) in Norway

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Abstract

Today, for most practical applications it is preferred to use reference frames with fixed coordinates. Satellite-geodetic techniques readily provide time-dependent coordinates in a global reference frame like ITRF. Therefore, there is an increasing need for transformations from the time dependent ITRF coordinates to fixed coordinates like in the national realisations of ETRS89. The IAG subcommission EUREF has recommended a three-step procedure for this transformation where the last step is the correction for intraplate deformation. In the realisation of ETRS, most countries have neglected this term because of limited information of this phenomena. This means that the national ETRF89 realisations in reality have different reference epochs. The discrepencies between the national reference networks can be up to several centimeters. This paper describes different methodologies for the transformation between ITRF and the realisations of ETRS using the Norwegian realisation as example. For Norway, the intraplate motion is of the order 2 to 3 mm/yr in the horizontal components and -3 to 5 mm/yr in the vertical components. Time series from permanent GPS stations are used to assess four different transformations from ITRF2000 to EUREF89 in Norway.

1. Introduction

Coordinates given with respect to the International Terrestrial Refrence Frame (ITRF) are time dependent. In surveying and other practical applications users are not used to deal with time dependent coordinates. Therefore, through the IAG subcommission EUREF, the European geodetic community has defined a reference system, the European Terrestrial Reference System (ETRS), which per definition gives mean minimal residual velocities for the Eurasian plate with respect to this ETRS. This system allows to "freece" the coordinates at a certain reference epoch and keep them fixed over a long time. As reference epoch, the year 1989 was chosen and the system is denoted as ETRS89. Subsequently, this system has been realised in the European countries on the basis of GPS observation, though in slightly different ways (e.g. KRISTIANSEN & HARSSON, 1999, JIVALL & LIDBERG, 2000}, as the new reference frame. A full transition from the old national reference frame based on classical geodetic networks to the new frame based on space-geodetic techniques is in progress in most countries.

Using precise orbits and clocks in post-processing, satellite positioning techniques today can give a 3-dimensional position accuracy down to 1 cm in a global reference system. The accuracy is such that the definition of the reference frame itself is one of the primary limiting error sources.

Current and future satellite positioning systems can easily be used to determine time dependent coordinates in a recent ITRF. In fact, in many cases, this is the economically most effective way to get coordinates of a point not observed before.

However, for most practical applications such as land surveying and geo-databases, users will continue to prefer coordinates fixed in time. Coordinates determined in a certain ITRF can be transformed to the fixed national frames by first transforming to the national realisation of ETRS at the central epoch of measurements and then using the rigid plate motion model build into ETRS89 to transform to the reference epoch. However, this plate motion model only accounts for horizontal motion. Due to much shorter spatial scales, vertical motion cannot satisfactorily be described by rigid plate motion. Moreover, on various spatial scales there is also a motion in the horizontal components that causes so-called intra-plate deformation. Therefore, in a final step, the coordinates have to be corrected for this motion both in the horizontal and the vertical components. This final step requires a good knowledge of the three-dimensional velocity field at the Earth's surface.

ALTAMIMI & BOUCHER (2002} have pointed out that the rigid plate motion model included in the definition of ETRS89 (i.e. the NUVEL-1A-NNA model, DEMETS, 1994) results in residual velocities exceeding 3 mm/yr in the horizontal, which is equivalent to errors in the fixed position of more than 3 cm over 10 years. They determined a new rotation vector for the Eurasian plate on the basis of 19 carefully selected ITRF station velocities, and this rotation vector (denoted here as EUREF rotation vector) was adopted by EUREF in 2001. PLAG et al (2002) have pointed that this new rotation vector may be sensitive to the station selection and suggested an improved model for the description of the three dimensional surface velocity field. This extended model is used by KIERULF et al. (2002) to determine a rotation vector (denoted as EURASIA vector) largely independent of the station selection.

KIERULF et al. (2002) also show that using either the new EUREF or the EURASIA rotation vector, residual horizontal velocities seldom exceed 1 mm/yr, except for sites in active tectonic regions. Thus, errors in fixed horizontal coordinates are of the order of 1 cm per 10 years. In the present study, we look at the accuracy of four different transformations from ITRF to the realisation of ETRS in Norway and discuss the strategy for maintaining the national reference frame with fixed coordinates over a long time.

Finally, it is pointed out that for a positioning technique relative to a global reference frame, it is not really important

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whether time-dependent or fixed coordinates are used. In both cases, it is necessary to know the velocity field of the Earth surface to be able to relate coordinates to a common epoch or to compare coordinates from different epochs.

2. Transformation from ITRF to ETRF89

The approved EUREF guidelines for transformation from ITRF to ETRF89 recommend a three-step approach (see Boucher& Altamimi, 2001):

– Step 1 is to compute ITRF coordinates at central epoch of observations. That shall be done with coordinates and velocities from the most recent ITRF frame.
– Step 2 is to transform from ITRF central epoch to ETRF89 reference epoch taking into account only the rigid plate motion. This transformation is a 7-parameter Helmert transformation given as part of the ITRF but augmented with a rotation vector describing the rigid plate motion.
– Step3 is to correct for intraplate deformations.

Step 1 is a straight-foreward computation using e.g. the IGS precise orbits and clocks.

Step 2 incorporates both the offset and translation of ETRF with respect to ITRF as well as the rigid plate motion of the Eurasian plate caused by global plate tectonics. The rotation vector has to be chosen carefully in order to minimise the correction required for step 3. Originally, the NUVEL-1A-NNR rotation pole (DEMETS, 1994) was recommended by EUREF while in 2001, EUREF recommended the new rotation vector determined by BOUCHER & ALTAMIMI (2002) to be used. KIERULF (2002b) recommend to use a rotation vector representative for the whole Eurasian plate and not the pole currently adopted by EUREF (BOUCHER & ALTAMIMI 2002). However, both the rotation vector determined by KIERULF et al. (2002b) and (BOUCHER & ALTAMIMI 2002) results in rather small residual velocities for most parts of Europe. Thus, for most practical application, the choise of the rotation vector is not crucial.

Step 3 is intended to account for the residual velocity of a given point with respect to the rigid plate motion. This requires good knowledge of the residual velocities with respect to the rigid plate motion. For most parts of Scandinavia, intra-plate motion is caused by post-glacial rebound, which is a consequence of the last ice age. Geophysical models predict the horizontal velocities to be of the order of 1 to 2 mm/yr, while vertical velocities are of the order of 10 mm/yr (e.g. JOHANSSON et al., 2002).

In most Nordic countries, Step 3 was not included in the national realisation of ETRS because sufficient information on the intra-plate deformation was not available (see e.g. KRISTIANSEN & HARSSON, 1999, JIVALL & LIDBERG, 2000). Moreover, the NUVEL-1A-NNR rotation vector was used in step 2, with the residual horizontal velocities being of the order of 3 mm/yr (ALTAMIMI & BOUCHER 2002, P LAG et al. 2002). Consequently, the ten years-error in horizontal coordinates due to neglecting step 3 can exceed 3 cm while errors of the vertical coordinates can be as large as 10 cm if the vertical motion due to post-glacial rebound is not corrected.

For the new EUREF and EURASIA rotation vectors, observed residual horizontal velocities are smaller than those for NUVEL-1a-NNR vector (ALTAMIMI & BOUCHER, 2002, KIERULF et al., 2002b). In fact, they are of the same order as those predicted by the geophysical post-glacial rebound models. Thus, using these vectors to describe the rigid plate motion, errors in horizontal coordinates over ten years are of the order of 1 to 2 cm, if step 3 is not carried out.

3. Intra-plate deformation in Norway

The realisation of ETRS89 in Norway, which is denoted as EUREF89, was done on the basis of nation-wide GPS campaigns carried out in 1994 and 1995 (KRISTIANSEN & HARSSON, 1999). For Step 1, coordinates at central epoch were calculated in ITRF93. Step 2 was carried out according to then available EUREF recommendations (BOUCHER, 1994), which utilised the NUVEL-1A-NNR rotation vector for the Eurasian plate to account for the rigid plate motion. Step 3 was not carried out since the available models for intraplate deformation were not considered to be good enough. In reality, thus the ETRS was realised at epoch 1994 with respect to the intra-plate deformation.

Based on repeated campaigns on the national Norwegian GPS network of so-called 4-d points (4-d for four-dimensional, see PLAG et al., 2002, for a map), the residual horizontal velocities with respect to the rigid plate motion were determined to be of the order of 2-3 mm/yr. The errors in these residual velocities are of the order of 1 mm/yr. The residual velocities display a spatial pattern that can be described by a rotation and thus allow to determine a correction for the rigid plate motion included in Step 2, which reduces residual velocities under the error level.

The GPS campaigns do not provide a sufficient basis to determine the vertical velocities with an accuracy better than a few mm/yr. Therefore, the empirical uplift model determined by DANIELSEN (1999) is used. This model is mainly based on gravity measurements and classical levelling. PLAG et al. (2002) pointed out that there are significant differences between the empirical model set up by DANIELSEN (1999) and typical geophysical models. However, it can be stated that the magnitude of vertical post-glacial movements in Norway is of the order -3 to 5 mm/yr with the model uncertainties being as large as 3 mm/yr.

4. Transformation from ITRF to EUREF89

Bearing in mind that the national Norwegian realisation of ETRS, EUREF89, was based on ITRF93 coordinates given for the central epoch of observations, there are various ways to accomplish a transformation from the current ITRF (e.g. ITRF2000) to EUREF89. The most straight-forward and logical method is to start with coordinates given in the current ITRF, i.e. ITRF2000 central epoch, and convert these to ITRF93 at epoch t_r, that is, the central reference epoch of observations from 1994 and 1995 used for the establishment of EUREF89 in Norway. From there, the same transformation as determined by KRISTIANSEN & HARSSON 99) can be used to go to EUREF89.

Thus,

$$\vec{X}^{\mathrm{ITRF93}}(t_r) = \vec{T}^{\mathrm{ITRFxxxx}}_{\mathrm{ITRF93}} + R^{\mathrm{ITRFxxxx}}_{\mathrm{ITRF93}} \cdot \left(\vec{X}^{\mathrm{ITRFxxxx}}(t_c) + \vec{V} \cdot (t_r - t_c)\right) \quad (1)$$

is used for the first part and

$$\vec{X}^{\mathrm{EUREF89}} = \vec{T}^{\mathrm{ITRF93}}_{\mathrm{EUREF89}} + R^{\mathrm{ITRF93}}_{\mathrm{EUREF89}} \cdot \vec{X}^{\mathrm{ITRF93}}(t_r) \quad (2)$$

for the second part. Here, $\vec{X}$ is the position vector, t_c the central epoch of observation, t_r the reference epoch for the observations used to establish EUREF89, $\vec{T}$ the offset vector, R the rotation matrix, and $\vec{V}$ the velocity at $\vec{X}$.

Superscripts and subscripts are used to describe "from system to system". We assume now that

$$\vec{V} = S \cdot \vec{X} \quad (3)$$

i.e. the motion is a rigid plate motion only. S is expressed as

$$S = \begin{pmatrix} 0 & -r_z & r_y \\ r_z & 0 & -r_x \\ -r_y & r_x & 0 \end{pmatrix} \quad (4)$$

where r_x, r_y, r_z are small rotation velocities around the X, Y, and Z axis respectively.

Inserting this in eq. 1 we get

$$\vec{X}^{\mathrm{ITRF93}}(t_r) = \vec{T}^{\mathrm{ITRFxxxx}}_{\mathrm{ITRF93}} + R^{\mathrm{ITRFxxxx}}_{\mathrm{ITRF93}} \cdot \left(\vec{X}^{\mathrm{ITRFxxxx}}(t_c) + S \cdot \vec{X}^{\mathrm{ITRFxxxx}}(t_c) \cdot (t_r - t_c)\right) \quad (5)$$

The transformations beween different ITRF reference frames (i.e. the matrix $R^{\mathrm{ITRFxxxx}}_{\mathrm{ITRF93}}$ and the offset $\vec{T}^{\mathrm{ITRFxxxx}}_{\mathrm{ITRF93}}$) are provided by the IERS (see *ftp://lareg.ensg.ign.fr/pub/itrf/ITRF.TP*). However, to obtain an accurate result, the velocity v has to be known with high accuracy to convert from ITRF2000 central epoch, t_c, to the epoch 1995.0, t_r. Based on the velocity model selected, we distinguish here between three different transformations, namely:

– **AB1998**: ALTAMIMI and BOUCHER (1998, see *ftp://lareg.ensg.ign.fr/pub/euref/info/guidelines/REF.FRAME.SPECIFV4*) recommended to use the NUVEL-1A-NNR rotation vector for the Eurasian plate.

– **AB2002**: ALTAMIMI & BOUCHER (2002) recommended to use a new rotation vector determined on the basis of 19 European site velocities.

– **KETAL2002**: KIERULF et al. (2002b) determined a rotation vector for Eurasia from an extended version of eq. 3 which together with a geophysical model for post-glacial rebound models the velocity field of the whole Eurasian plate.

It should be noted here that the reference epoch t_r has to be choosen from the interval 1994 to 1995, since observations are used from both years. Any velocity error would thus result in a position error equivalent to one year times the velocity error. Moreover, there is a velocity between the two versions of ITRF and the total effect of choosing e.g. 1994.4 instead of 1995.7 would be 2 mm.

A different approach, **NMA2001**, which was used for an initial transformation between ITRF97 and EUREF89, is based on the repeated measurements on the 4-d points. The observed ITRF coordinates at different epochs and their EUREF89 coordinates are used to determine an (\em ad hoc) solution by establishing a 7-parameter transformation directly from ITRF97 central epoch to EUREF89, official Norwegian coordinates. A transformation based on 21 stations, which were observed in 1998, thus resulted in a transformation from ITRF97 at epoch 1998.6 to EUREF89. In this approach, the problems associated with uncertainties of the velocity model involved in the conversion between reference frames is omitted, but the transformation parameters themselves become time-dependent.

In order to be able to use the *ad hoc* transformation for coordinates determined from observations at any central epoch, these coordinates first have to be transformed from ITRF97 central epoch to ITRF97 epoch 1998.60. For that, we use a modified NUVEL-1A-NNR model, where the horizontal velocities have been corrected according to PLAG et al. (2002). For the vertical component we use the empirical land uplift model (DANIELSEN, 1999). In this way, the time interval for using the velocoity model is relatively short and errors in position resulting from the velocity model are kept on the few millimeter level.

In using a 7-parameter solution, it is implicitly assumed that the region does not exhibit any intra-plate deformation. For the horizontal motion in Norway this appears to be correct on the 2 mm/yr level. For vertical motion, this is not the case, and the intra-plate motion are of the order of -3 to 5 mm/yr. Therefore, prior to the determination of the *ad hoc* 7-parameter transformation, land uplift was corrected for the period 1998.60 to t_r. Here, it is important to note that in the establishment of EUREF89, the uplift between t_r and the ETRS reference 1989.0 was not accounted for.

The *ad hoc* transformation from ITRF97 central epoch to ETRF89 can also be used for cooordinates expressed in ITRF2000 central epoch. For that, the coordinates are first converted to ITRF97 central epoch using the parameters available at *ftp://lareg.ensg.ign.fr/pub/itrf/ITRF.TP*.

This alternative, somewhat *ad hoc* transformation was made available as the first offical transformation between ITRF and EUREF89. In the following, this transformation is denoted as NMA2001.

5. Comparison of transformations

The four transformations, namely AB1998, AB2002, KETAL2002, and NMA2001, are compared on the basis of data from nine continuously recording GPS sites in Norway. The time series are from the period 1998.73 to 2002.27 and cover nearly 4 years. The time series are realized as daily (24 hours) solutions obtained from precise point positioning (ZUMBERGE et al., 1997) using the GIPSY/OASIS-II software package. The referance frame for the time series is ITRF2000 and each daily sample is given for the central epoch.

These time series have been transformed to EUREF89 using the four transformations described above. Fig. 1 shows an example for the arbitrarily selected station Stavanger. In Table 1, the deviation of the site coordinates after transformation from ITRF2000 central epoch to EUREF89 from the official Norwegian EUREF89 coordinates are given for the four transformations. Table 2 shows the linear velocities determined from the time series transformed to EUREF89. Ideally, all these velocities should be zero.

Table 1: Accuracy of coordinates. Given are the deviations in mm from official Norwegian EUREF89 values after transformation from ITRF2000 central epoch to ETRF89. Database consists of the time series spanning the interval 1998.73 – 2002.27.

Station	AB98		AB01		KETAL02		NMA2001	
	n	e	n	e	n	e	n	e
kris	1.6	-7.5	3.3	-0.7	4.4	1.0	3.0	8.0
stav	1.5	-10.1	4.1	-2.6	3.4	-1.0	3.3	5.3
berg	-0.3	-10.1	2.3	-1.9	0.7	1.4	1.4	5.2
oslo	0.1	-12.2	0.6	-4.5	2.0	-2.5	1.2	2.8
ales	-2.0	-11.4	-0.1	-1.9	-3.8	2.0	-0.7	3.6
tron	2.2	-15.2	2.3	-5.4	-1.7	-1.8	2.7	-0.8
bodo	-0.1	-14.6	-2.2	-2.9	-6.9	0.0	-1.3	-1.3
tro1	9.2	-13.4	4.9	-0.6	0.3	0.0	6.5	-1.2
vard	4.8	-13.8	-4.2	-2.6	-4.8	-6.4	0.8	-4.5
mean	1.9	-12.0	1.2	-2.6	-0.7	-0.8	1.9	1.9
rms	3.2	2.4	2.8	1.5	3.6	2.4	2.2	3.8

Table 2: Accuracy of velocities. Given are the velocities in mm/yr after transformation from ITRF2000 central epoch to ETRF89. The database is the same as for Table 1. Note that in the ideal case, all velocities in ETRF89 would be zero.

Station	AB98		AB01		KETAL02		NMA2001	
	n	e	n	e	n	e	n	e
iris	0.7	-1.6	1.0	-0.4	1.2	-0.1	0.4	0.8
stav	0.8	-1.7	1.2	-0.5	1.1	-0.1	0.4	0.5
berg	0.3	-1.8	0.7	-0.3	0.4	0.2	-0.1	0.5
oslo	0.8	-2.2	0.9	-0.9	1.2	-0.5	0.3	0.1
ales	1.7	-2.1	2.0	-0.5	1.3	0.2	1.3	-0.1
tron	-0.2	-2.6	1.7	-0.9	1.0	-0.3	1.2	-0.5
bodo	2.3	-2.6	1.9	-0.6	1.0	-0.1	1.7	-0.6
tro1	4.6	-2.8	3.8	-0.7	3.0	-0.5	3.8	-0.7
vard	1.8	-1.4	0.2	0.5	0.1	-0.2	0.6	0.6
mean	1.4	-2.1	1.5	-0.5	1.1	0.2	1.1	0.1
rms	1.3	0.5	1.0	0.4	0.8	0.2	1.1	0.5

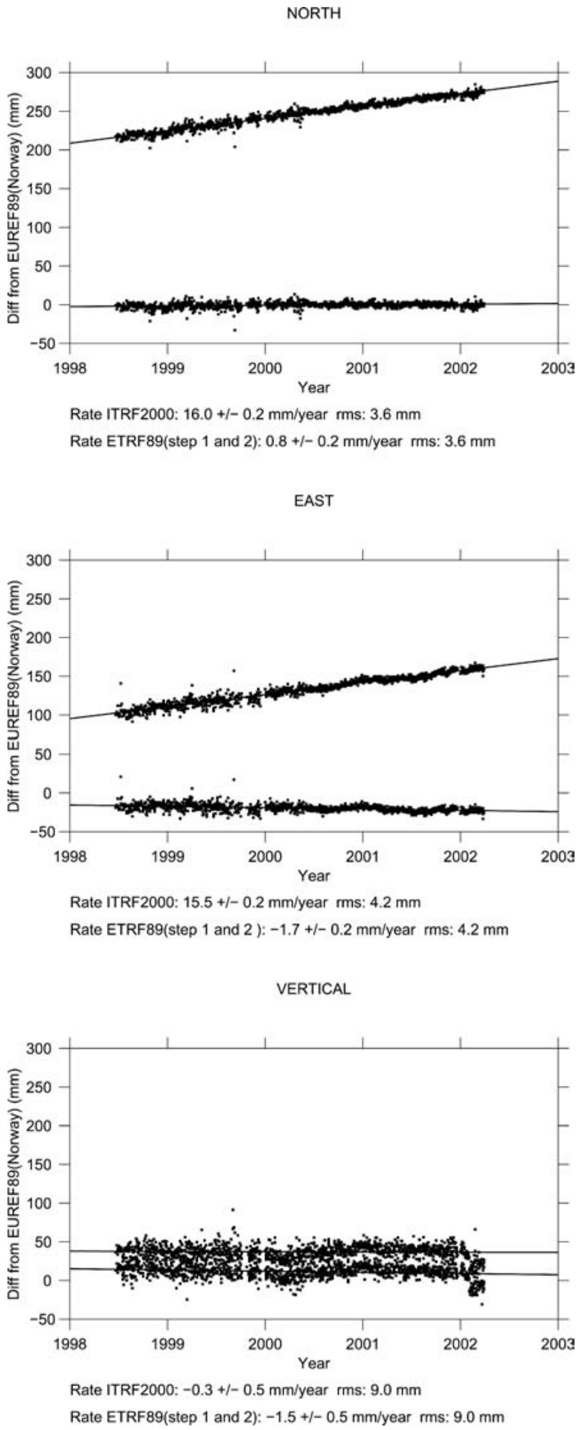

Figure 1: Coordinate time series for Stavanger after transformation to EUREF89.

Both for position and velocity, the method AB1998 results in the largest deviations. As expected, this transformation has a significant bias in the East component of approximately -12.0 mm. In the North component, the result for AB1998 is on the same level as those for the other transformations.

A significant 2-3 mm/yr bias in the East component of the NUVEL-1A-NNR model was previously noted by PLAG et al. 2002, ALTAMIMI & BOUCHER 2002). The time series used here cover a period approximately 10 years from the nominal reference epoch of EUREF89. Therefore, a discrepancy in the transformed and official coordinates of about 25 mm should be expected. However, the bias for AB1998 turns out to be only half of that. This is due to the fact AB1998 is only used to transform from current epoch to t_r . 1995.0 while from there to 1989.0, the same transformation as used in the establishment of EUREF is applied.

The three other transformations AB2001, KETAL2002, and NMA2001 turn out to be more or less equal in their overall statistics. Considering the mean deviation, KETAL 2002 is closer to official Norwegian ETRF89 values while AB2001 and NMA2001 have slightly better rms values with respect to the mean deviation.

The velocities summarised in Table 2 display the same pattern as the deviations given in Table 1, i.e. AB1998 results in transformed EUREF89 velocities of about -2.1 mm/yr in the East component. This velocity bias is coherent with the position errors discussed above. For the North component, all four transformations result in residual velocities on the same small level. KETAL2002 results in the lowest velocities.

It is pointed out here that KETAL2002 is valid for the whole Eurasian plate. Moreover, the method separates the 'rigid movement' from the intraplate deformation due to post-glacial rebound. In that, the method follows strictly the step procedure recommended by IAG subcommission EUREF.

6. Conclusion

Comparing coordinates given in the national reference networks in Europe, discrepancies of up to several centimeters can be found. These discrepancies are mainly due to neglection of the intraplate deformation, which should be corrected in the Step 3 of the recommended procedure for establishing these networks.

Step 3 corrections depend on the velocity model used for the rigid plate motion. Using NUVEL-1A-NNR, in Norway the step 3 corrections amount to 2 to 3 mm/yr in horizontal velocities. In the vertical, post-glacial rebound contributes a signal of -3 to 5 mm/yr.

Using the rigid plate motion model suggested by ALTAMIMI & BOUCHER (2002), Step 3 corrections reduce to about 1 mm/yr for the horizontal component, while the vertical is unchanged. KIERULF et al. (2002b) address both the step 2 and 3 velocity models and using their model, mean residual velocities in Norway are reduced to 0.2 mm/yr in east direction and 1.1 mm/yr in north direction.

The *ad hoc* method based on repeated GPS campaigns (NMA2001) results in residual velocities and associated position errors on approximately the same level.

In order to increase the lifetime of national realisations of the ETRS to several decades, better velocity for both the horisontal and vertical surface movements are needed. In order to separate the rigid plate motion from the intraplate plate motion, more complex models as recommended by KIERULF et al. (2002b) appear to be appropriate.

Acknowledgement

The autors are grateful to Jerry Mitrovica, who made the post-glacial rebound model available. The 1994 GPS campaign was carried out by staff of the Geodetic Institute under the lead of Bjørn Geirr Harsson. The 1998 GPS campaign was carried out by staff of Geodetic Institute under the lead of Lars Bockmann. Responsibility for the CGPS sites which give RINEX data to the time series is Svein Rekkedal from the Geodetic Institute. Oddgeir Kristiansen from the Geodetic Institute has analysed the CGPS RINEX data and provided the time series. Halfdan P. Kierulf, Geodetic Institute, has contributed with fruitful discussions and comments. This research is supported by the Norwegian Ministry of Environment.

Bibliography

ALTAMIMI Z., BOUCHER C., 2002. *The (ITRS) and (ETRS89) relationship: new results from (ITRF2000)*, in (em EUREF Publication No. 10/), edited by J. A. Torres & H. Hornik, pp. 49-52, Verlag des Bundesamtes für Kartographie und Geodäsie, Frankfurt a.M..

BOUCHER C., 1994. *Specification of reference frame fixing analysis of a (EUREF) (GPS) campaign*, Publication no. 3, EUREF.

BOUCHER C., ALTAMIMI Z., 2001. *Memo: (Specifications for reference frame fixing in the analysis of a EUREF GPS campaign)*, Unpublished memo available at *http://lareg.ensg.ign.fr/EUREF/*.

DANIELSEN J., 1999. *Landhevningen i Norge*, Report, Geodetic Institute, Norwegian Mapping Authority.

DEMETS C., GORDON R. G., ARGUS D. F., STEIN S., 1994. *Effect of recent revisions to the geomagnetic reversal time scale on estimates of current plate motions*, Geophys. Res. Lett., 21, 2191-2194.

JIVALL L., LIDBERG M., 2000. *Sweref 99 – an update Euref realisation for Sweden*, in Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Tromso, 22-24 June 2000, edited by J. A. Torres, H. Hornik, pp. 167-175, Verlag der Bayerischen Akademie der Wissenschaften in Kommission bei der C H. Beck'schen Verlagsbuchhandlung München.

JOHANSSON J. M., DAVIS J. L., SCHERNECK H.-G., MILNE G. A., VERMEER M., MITROVICA J. X., BENNETT R. A., JONSSON B., ELGERED G., ELOSEGUI P., KOIVULA H., POUTANEN M., RONNANG B. O., SHAPIRO I. I., 2002. *Continuous (GPS) measurements of postglacial adjustment in Fennoscandia 1. Geodetic results*, J. Geophys. Res., 107, B8.

KIERULF H. P., PLAG H.-P., KRISTIANSEN O., 2002. *A new velocity field for Europe*, in EUREF Publication No. 11, edited by J. A. Torres, H. Hornik, p. submitted, Verlag des Bundesamtes für Kartographie und Geodäsie, Frankfurt a.M.

KRISTIANSEN O., HARSSON B. G., 1999. *The new Norwegian national geodetic network – (EUREF89)*, in EUREF Publication No. 7/I, edited by E. Gubler, H. Hornik, vol. Band 6 of Mitteilungen des Bundesamtes f(ü)r Kartographie und Geodäsie, pp. 104-116, Verlag des Bundesamtes für Kartographie und Geodäsie, Frankfurt a.M.

PLAG H.-P., NORBECH T., KRISTIANSEN O., 2002. *Effects of intraplate deformations on fixing regional reference frames*, in EUREF Publication No. 10, edited by J. A. Torres, H. Hornik, pp. 118-124, Verlag des Bundesamtes für Kartographie und Geodäsie, Frankfurt a.M.

ZUMBERGE J. F., HEFLIN M. B., JEFFERSON D. C., WATKINS M. M., 1997. *Precise point positioning for the efficient and robust analysis of (GPS) data from large networks*, J. Geophys. Res., 102, 5005