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SWEREF 99 - an Updated EUREF Realisation for Sweden

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1. Abstract

SWEREF 99 will replace SWEREF 93, which has been used as the Swedish EUREF realisation since 1994. SWEREF 93 is aligned to EUREF by a fit to the original EUREF 89 campaign and has until now mainly been used for intermediate steps in GPS processing.

We have now decided to upgrade SWEREF according to the EUREF guidelines before we start to use it as our official national reference frame. This paper describes SWEREF 99, which is based on ITRF 97 epoch 1999.5.

2. Introduction

SWEREF 93 was established 1993-94 before there were any official guidelines how to realise ETRS 89. SWEREF 93 was aligned to EUREF 89 by a 6-parameter transformation to the coordinates of 11 stations from the original EUREF 89 campaign. The RMS of the residuals are 14, 14 and 23 mm for the north, east and height components, respectively. SWEREF 93 has a high internal accuracy but differs at the 5 cm level to the neighbouring ETRS 89 realisations in the Nordic countries. SWEREF 93 has mainly been used for intermediate steps in GPS processing and the use of it for final presentation is so far limited, but this will change very soon. In the national project RIX95, which aims at getting transformation formulae between different reference frames used in Sweden and at densifying the national reference network, thousands of points have been preliminary determined in SWEREF 93.

There is an on-going discussion at the National Land Survey about replacing our national reference frame RT 90, which is based on the Bessel ellipsoid, with a globally aligned reference frame. It is important that the new reference frame will be appropriate for a long time. SWEREF 93 does not fulfil this criterion perfectly. It is not officially approved by the European community and it differs to the ETRS 89 realisations in the neighbouring countries. Furthermore it represents the relations between the points, with respect to the land uplift, at epoch 1993. Since then we have had movements in the vertical component of c. 5-6 cm within the country.

Choosing an ETRS 89 solution approved by EUREF and originating from recent observation data, would give us good possibilities to get a reference frame that could last for a long time. Of course the land uplift will continue, and also the new set of coordinates will get obsolete if we do not take the land uplift into account after some years. Starting from the land uplift epoch 1999.5 will give us some more years to develop models for the movements within our country (and, not the least, methods to handle those models).

Before the campaign described in this report was approved, the following official EUREF sites existed in Sweden: 5 stations belonging to permanent EUREF (ONSA, KIR0, MAR6, VIL0 and VIS0), 6 EUVN stations (SE02, SE03, SE04, SE05, SE06 and SE07) and additional 2 stations from the original EUREF 89 campaign (Klinta and Bureberget).

3. The campaign

The processing of the new ETRS 89 solution in Sweden is based on observations from GPS-week 1014-1019 (June-July 1999) at the permanent reference stations in Sweden (SWEPOS), Denmark, Finland (FinnRef) and Norway (SATREF). In all, data from 49 stations were processed - see figure 1. 21 Swedish stations (all Swedish stations except Gävle, Västerås, Göteborg and Malmö) are proposed to become official EUREF sites.

The stations Onsala and Metsähovi were equipped with Dorne Margolin B antennas. For all other stations antennas of type Dorne Margolin T were used.

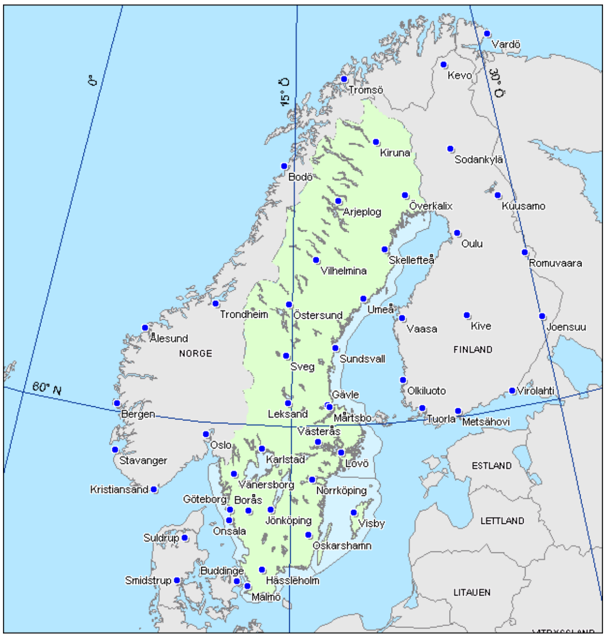

Figure 1: Stations included in the campaign.

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4. Processing strategy

The processing of weeks 1015, 1016 and 1019 was performed using the Bernese GPS Software ver 4.2. To strengthen the solution, three weeks (1014, 1017 and 1018) were added from the weekly processing of SWEPOS (25 stations), which for those weeks were performed with the Bernese GPS Software ver 4.0. The same processing strategy has been used in both cases.

The apriori coordinates used were obtained by a preliminary solution similar to the constrained alternative 2 - see section 4.2.4. Coordinates for the constraint in this preliminary solution are in ITRF 97 epoch 1999.5, originating from the IERS ITRF 97 solution.

4.1. Processing for each session

1. Conversion of RINEX data to Bernese format.
2. Generation of standard orbits from precise ephemeris. Precise orbits from Center for Orbit Determination in Europe (CODE) were used together with the earth rotation parameters belonging to these orbits.
3. Estimation of receiver clock offsets for each epoch. Satellite clocks from precise ephemeris (CODE) were used.
4. Creation of single differences of carrier phase data using the OBSMAX strategy.
5. Pre-processing of the single difference phase measurements using triple differences. In this step cycle slips were detected and removed (if possible), outliers were detected and removed and multiple ambiguities were introduced if needed. Sampling rate 30 seconds.
6. Ambiguity resolution baseline by baseline, using the Quasi Ionospheric Free method (QIF) in combination with an ionospheric model from CODE. Sampling rate 30 seconds.
7. Final ambiguity-fixed session solution. The solution was performed as a multi-station adjustment with the correlations correctly modelled. The following options were used for each session:
   - ONSA 10402M004 was constrained to the apriori coordinates (ITRF 97 epoch 1999.5)
   - Ionospheric free linear combination (L3).
   - Eight tropospheric parameters were estimated for each station and 24-hour session. This means that every parameter covers approximately 3 hours. The tropospheric model of Saastamoinen was used as standard model.
   - Elevation cut off angle: 15 degrees.
   - No elevation dependent weighting.
   - Sampling rate: 60 s.
   - The normal equations were saved.
8. The coordinates from the final session solution were fitted to the IERS ITRF 97 epoch 1999.5 coordinates with a 3-parameter transformation (translation).

4.2. Combination of sessions

4.2.1. Weekly combinations

The normal equations from the session solutions were combined into weekly solutions. ONSA 10402M004 was constrained to the apriori coordinates (ITRF 97 epoch 1999.5). The weekly normal equations were also saved for later combination of the whole campaign. The Bernese program ADDNEQ was used.

4.2.2. Minimum constrained solution for the campaign

The six weekly normal equations were combined into a solution where ONSA 10402M004 was constrained to its apriori coordinates (ITRF 97 epoch 1999.5). The normal equations were saved. The Bernese program ADDNEQ was used for the task. The resulting coordinates from the minimum constrained solution were fitted to the IERS ITRF 97 epoch 1999.5 coordinates.

4.2.3. Constrained solution – alternative 1

The six weekly normal equations were combined into a solution where 10 stations (permanent EUREF and IGS –see figure 2) were heavily constrained (0.01 mm, i.e. fixed in ADDNEQ sense) to their IERS ITRF 97 epoch 1999.5 coordinates.

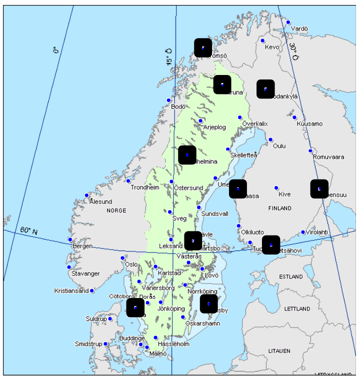

Figure 2. Constrained stations in constrained alternative 1.

4.2.4. Constrained solution – alternative 2

In this alternative the constraining was done in two steps. In the first step (step 1) 6 weekly solutions from permanent EUREF (weeks 1014-1019) were combined and heavily constrained to IERS ITRF 97 epoch 1999.5 on the 14 IGS Core stations (see figure 3) in Europe. In the second step (step 2) the six weekly solutions from the "Nordic network" where combined and heavily constrained to the coordinates from step 1 of the 10 IGS/Permant EUREF stations (the same 10 stations as in alternative 1).

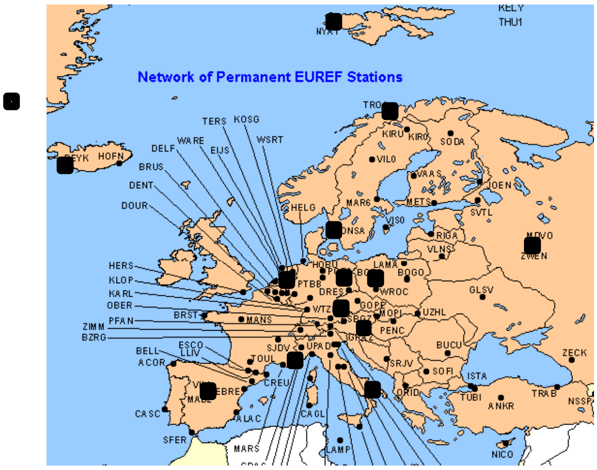

Figure 3: Constrained stations in step 1 of constrained alternative 2.

The reason for this alternative is to get a solution which is less dependent on the velocity vectors of IERS ITRF 97. This strategy is only dependent on the velocity vectors of the IGS stations. These stations have longer time series than the other permanent EUREF sites.

4.3. Transformation into ETRS 89

The conversion to ETRS 89 was performed according to the guidelines in "Specifications for reference frame fixing in the analysis of a EUREF GPS campaign" version 4.0 (1998-01-08) by C.Boucher and Z. Altamimi. The last step, which is to take the velocities within the European plate into account, has not been performed since we lack a good model for the movements within the European plate.

The following model and parameters were used for the conversion:

$$X_E(1999.5) = X_{97}(1999.5) + \begin{bmatrix} T1_{97} \\ T2_{97} \\ T3_{97} \end{bmatrix}$$

$$+ \begin{bmatrix} 0 & -\dot{R}3_{97} & \dot{R}2_{97} \\ \dot{R}3_{97} & 0 & -\dot{R}1_{97} \\ -\dot{R}2_{97} & \dot{R}1_{97} & 0 \end{bmatrix} \cdot X_{97}(1999.5) \cdot (1999.5 - 1989.0)$$

$X_E(1999.5)$ = coordinates in ETRS 89 at epoch 1999.5 (ETRF 97)

$X_{97}(1999.5)$ = coordinates in ITRF 97 at epoch 1999.5

$T1_{97} = 4.1\,\text{cm}$

$T2_{97} = 4.1\,\text{cm}$

$T3_{97} = -4.9\,\text{cm}$

$\dot{R}1_{97} = 0.00020''/Y$

$\dot{R}2_{97} = 0.00050''/Y$

$\dot{R}3_{97} = -0.00065''/Y$

5. Results from the processing

5.1. Quality of the daily and combined solutions

The estimated unit weight errors for the daily solutions and the average percentage of resolved ambiguities are shown in figures 4 and 5.

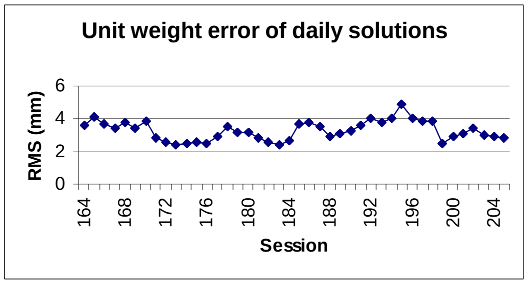

Figure 4: Unit weight error of daily solutions.

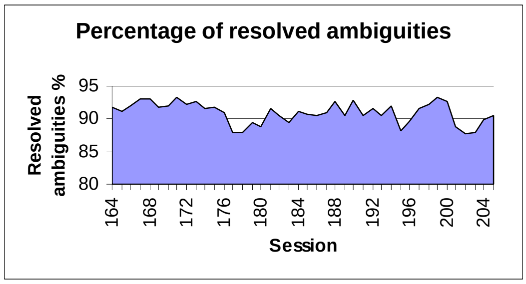

Figure 5: Percentage of resolved ambiguities.

The unit weight error of the combined weekly solutions are 2.7 - 4.1 mm. The unit weight errors of the minimum constrained solution and the two constrained solutions are all 2.8 mm.

No solution was considered as outlier in this step.

5.2. Comparison of daily solutions

The coordinates from the daily solutions were compared with the Bernese program COMPAR. The coordinate difference from the average value was studied for stations, sessions and baselines. No outliers were detected. In figure 6 the RMS values of the differences for each station are presented.

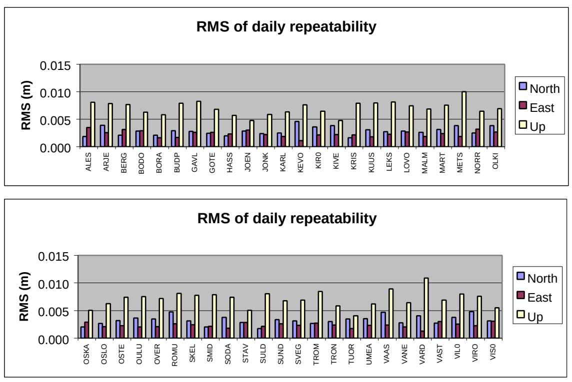

Figure 6: RMS of daily repeatability for each station.

5.3. Comparison with IERS ITRF 97

The final solution each day was compared with the reference coordinates (IERS ITRF 97 epoch 1999.5). The daily comparisons show the same pattern as the combined minimum constrained solution. Therefore, only the latter is included in this report.

The minimum constrained solution was compared with the reference coordinates (IERS ITRF 97 epoch 1999.5). The residuals of the 3-parameter (translation) transformation in table 1 shows that the 4 non IGS/permanent EUREF stations (OSLO, VARD, STAV and TRON) are not consistent with the new solution. In table 2 those stations are excluded.

Table 1: Residuals of the 3-parameter fit (translation) to IERS ITRF 97 epoch 1999.5.

Unit:mm	North	East	Up
TROM 10302M006	6.6	4.5	0.3
OSLO 10307M001	-3.4	-19.6	-20.7
VARD 10322M002	-13.7	-3.1	39.5
STAV 10330M001	3.5	-9.5	-9.4
TRON 10331M001	-1.6	17.3	27.1
ONSA 10402M004	-1.2	-2.6	8.5
MAR6 10405M002	1.3	0.8	1.3
KIR0 10422M001	-0.4	-3.0	-0.9
VIS0 10423M001	-0.7	0.9	-10.9
VIL0 10424M001	-0.5	1.0	-6.3
METS 10503S011	0.0	-2.3	-15.4
VAAS 10511M001	-0.9	3.0	-2.3
JOEN 10512M001	0.1	3.6	-5.5
SODA 10513M001	0.3	4.4	-4.3

In table 2 both Onsala and Metsähovi have large residuals in the height component. Also Tromsö has quite large residuals in the north and east components. All stations are IGS stations, coordinates of which are determined also by other techniques than GPS (SLR, VLBI).

Table 2: Residuals of the 3-parameter fit (translation) to IERS ITRF 97 epoch 1999.5, non IGS/EUREF sites excluded.

Unit:mm	North	East	Up
TROM 10302M006	5.6	3.7	3.9
ONSA 10402M004	-1.5	-3.2	12.3
MAR6 10405M002	0.8	0.1	5.1
KIR0 10422M001	-1.3	-3.8	2.7
VIS0 10423M001	-0.9	0.1	-7.2
VIL0 10424M001	-1.3	0.3	-2.6
METS 10503S011	-0.4	-3.3	-11.7
VAAS 10511M001	-1.5	2.0	1.4
JOEN 10512M001	-0.3	2.4	-1.9
SODA 10513M001	-0.5	3.3	-0.8

The discrepancy at Onsala has also another explanation. February 1, 1999, the Turbo Rogue SNR-8000 receiver at Onsala was replaced by an Ashtech Z-XII3. At the same time the conical shaped radome was replaced by a hemispherical radome of the same type as on all other SWEPOS stations – see figure 7. In IGS mail 2133 it was anticipated that this change might introduce a jump in the coordinate time series, which later on showed to be the fact – see figure 8.

Figure 7: GPS antenna with radome at Onsala before and after February 1, 1999.

The time series in figure 8 was taken from the BIFROST project. The coordinates of Onsala have been computed by precise point positioning (PPP) with GIPSY using products from JPL.

A shift is clearly visible in the up component. Onsala has sunk. Some disturbances could be noticed in the north and east components, but no significant shift.

The shift in the height component of Onsala means that the ITRF 97 coordinates will not be valid for epoch 1999.5 (or any other epoch after 1999-02-01). The shift has to be estimated and corrected for, if Onsala should be used for the constraint.

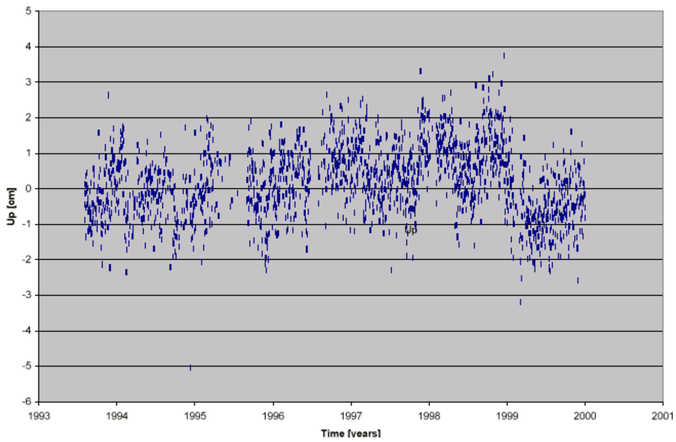

Figure 8: Coordinate time series (from the BIFROST project) of the up component at Onsala.

The shift at Onsala was estimated from the daily processing at SWEPOS, which uses exactly the same processing strategy as for the SWEREF 99 solution. The estimation is based on baselines to the two closest SWEPOS stations for 57 days around February 1 1999. The average of the estimation from the two baselines is –20 mm.

6. Comparison with other EUREF solutions

Several solutions, with different handling of the constraint, were produced. Three main versions are compared to other existing EUREF solutions:

- Minimum constrained solution fitted by a 3-parameter transformation (translation) to IERS ITRF 97 epoch 1999.5 with correction at Onsala. The non IGS/permanent EUREF stations as well as Metsähovi were not used as fitting points.
- Constrained solution according to alternative 1 (with corrected coordinates at Onsala). Metsähovi has not been used for the constraint.
- Constrained solution according to alternative 2 (Onsala corrected). Tromsö has not been used for the constraint in step 1. All 10 stations are used for the constraint in step 2.

6.1. SWEREF 93

SWEREF 93 is based on the DOSE 93 campaign, which was observed August 24-27, 1993. A special solution, DOSE 93A, was aligned to EUREF 89 by a 6-parameter-transformation (fixed scale) to 11 stations with coordinates from the original EUREF 89 campaign. The DOSE 93A coordinates thus transformed were used to define SWEREF 93. SWEREF 93 is compared to SWEREF 99 in table 4.

Note that this comparison approximately could be interpreted as the comparison to the original EUREF 89 campaign. (The difference between SWEREF 93 and ETRF 89 epoch 89.0 at Onsala is below 1 cm in the horizontal components.) This indicates that ETRS 89 has drifted away c. 5 cm since 1989 – see table 4 !

Table 4: SWEREF 93 minus SWEREF 99.

Unit:	Translated			Constrained alt 1			Constrained alt 2		
mm	North	East	Up	North	East	Up	North	East	Up
ARJE 0	-0.004	0.062	-0.015	-0.004	0.063	-0.013	-0.006	0.066	-0.007
BORA 0	0.016	0.043	0.010	0.017	0.045	0.012	0.017	0.048	0.017
GAVL 1	0.005	0.052	-0.020	0.006	0.053	-0.019	0.005	0.055	-0.013
GOTE 0	0.017	0.042	0.012	0.019	0.043	0.014	0.018	0.046	0.020
HASS 0	0.011	0.037	0.022	0.012	0.039	0.024	0.012	0.041	0.029
JONK 0	0.013	0.041	0.003	0.015	0.042	0.005	0.014	0.045	0.010
KARL 0	0.014	0.049	-0.005	0.015	0.050	-0.003	0.014	0.053	0.002
KIR0	-0.009	0.059	0.000	-0.007	0.063	-0.003	-0.011	0.062	0.006
LEKS 0	0.012	0.056	-0.019	0.013	0.057	-0.017	0.013	0.059	-0.012
LOVO 0	0.008	0.048	-0.015	0.009	0.049	-0.013	0.008	0.052	-0.007
MALM 0	0.016	0.041	0.029	0.018	0.042	0.031	0.018	0.045	0.036
MAR.6	0.006	0.048	-0.025	0.006	0.048	-0.031	0.006	0.052	-0.017
NORR 0	0.012	0.042	-0.018	0.013	0.043	-0.016	0.012	0.046	-0.010
ONSA	0.018	0.048	0.029	0.020	0.051	0.036	0.020	0.052	0.036
OSKA 0	0.013	0.040	0.009	0.014	0.041	0.011	0.014	0.044	0.016
OSTE 0	0.007	0.056	-0.006	0.008	0.057	-0.004	0.006	0.060	0.001
OVER 0	-0.013	0.061	-0.031	-0.013	0.061	-0.029	-0.014	0.064	-0.023
SKEL 0	-0.003	0.056	-0.044	-0.003	0.057	-0.042	-0.004	0.059	-0.036
SUND 0	0.002	0.055	-0.030	0.002	0.056	-0.029	0.001	0.059	-0.023
SVEG 0	0.007	0.055	-0.022	0.008	0.056	-0.020	0.007	0.059	-0.014
UMEA 0	-0.001	0.054	-0.043	0.000	0.055	-0.041	-0.002	0.058	-0.036
VANE 0	0.014	0.046	0.003	0.015	0.047	0.005	0.014	0.050	0.010
VAST 0	0.010	0.048	-0.018	0.011	0.049	-0.017	0.010	0.052	-0.011
VIL0	0.001	0.062	-0.019	0.003	0.062	-0.017	0.000	0.065	-0.010
VIS0	0.006	0.044	-0.018	0.007	0.045	-0.012	0.007	0.048	-0.012
RMS	**0.011**	**0.050**	**0.022**	**0.012**	**0.051**	**0.022**	**0.012**	**0.054**	**0.020**
MAX	**0.018**	**0.062**	**0.044**	**0.020**	**0.063**	**0.042**	**0.020**	**0.066**	**0.036**

6.2. Denmark

The Danish EUREF 89 originates from the EUREF-DK94 campaign and is based on ITRF 92 epoch 1994-09-15. The Danish permanent reference stations had not started their operation in 1994 and are therefore not included in the EUREF-DK94-campaign. Buddinge has got EUREF 89 coordinates by excentric measurements and the other two permanent reference stations by connection to EUREF-DK94 and its densification.

Table 5: Danish EUREF 89 minus SWEREF 99

Unit:	Translated			Constrained alt 1			Constrained alt 2		
mm	North	East	Up	North	East	Up	North	East	Up
BUDP	-0.002	-0.015	0.006	0.000	-0.014	0.009	-0.001	-0.011	0.014
SMID	-0.008	-0.009	-0.015	-0.006	-0.008	-0.013	-0.006	-0.004	-0.008
SULD	-0.015	-0.011	-0.010	-0.013	-0.010	-0.008	-0.013	-0.007	-0.003
RMS	**0.010**	**0.012**	**0.011**	**0.008**	**0.011**	**0.010**	**0.008**	**0.008**	**0.009**
MAX	**0.015**	**0.015**	**0.015**	**0.013**	**0.014**	**0.013**	**0.013**	**0.011**	**0.014**

6.3. Finland

The Finnish EUREF 89 originates from the EUREF-FIN-campaign and is based on ITRF 96 epoch 1997.0.

Table 6: EUREF-FIN minus SWEREF 99

Unit:	Translated			Constrained lalt 1			Constrained alt 2		
mm	North	East	Up	North	East	Up	North	East	Up
JOEN	-0.001	-0.004	-0.011	-0.001	-0.006	-0.010	-0.003	0.000	0.002
KEVO	0.002	-0.002	-0.012	0.002	-0.002	-0.011	0.000	0.000	-0.004
KIVE	-0.003	-0.003	-0.015	-0.002	-0.003	-0.013	-0.004	0.000	-0.007
KUUS	-0.006	-0.003	-0.023	-0.006	-0.003	-0.021	-0.008	-0.001	-0.014
METS	-0.005	-0.006	-0.006	-0.004	-0.005	-0.004	-0.006	-0.002	0.003
OLKI	-0.002	-0.006	-0.012	-0.002	-0.005	-0.010	-0.003	-0.002	-0.004
OULU	-0.003	-0.005	-0.024	-0.002	-0.004	-0.022	-0.004	-0.002	-0.016
ROMU	-0.001	-0.003	-0.016	0.000	-0.003	-0.014	-0.002	-0.001	-0.008
SODA	-0.005	-0.005	-0.028	-0.004	-0.008	-0.028	-0.006	-0.002	-0.015
TUOR	-0.003	-0.004	-0.008	-0.002	-0.004	-0.006	-0.003	-0.001	0.000
VAAS	-0.002	-0.005	-0.019	0.000	-0.007	-0.021	-0.003	-0.002	-0.007
VIRO	-0.004	-0.004	-0.008	-0.003	-0.004	-0.006	-0.004	-0.001	0.001
RMS	**0.003**	**0.004**	**0.017**	**0.003**	**0.005**	**0.016**	**0.004**	**0.001**	**0.009**
MAX	**0.006**	**0.006**	**0.028**	**0.006**	**0.008**	**0.028**	**0.008**	**0.002**	**0.016**

6.4. Norway

The Norwegian EUREF 89 originates from the EUREF-NOR94 campaign and is based on ITRF 93. The SATREF stations are not primary carriers of the Norwegian EUREF 89 and there are different sets of EUREF 89 coordinates on the SATREF stations. The reason for the multiple sets of coordinates is uncertainties in the eccentricity measures. We have chosen a solution made by Oddgeir Kristiansen October 1998 for the comparison.

Table 7: Norwegian EUREF 89 minus SWEREF 99

Unit:	Translated			Constrained alt 1			Constrained alt 2		
mm	North	East	Up	North	East	Up	North	East	Up
ALES 0	0.004	0.014	-0.010	0.005	0.015	-0.007	0.005	0.018	-0.003
BERG 0	-0.006	0.011	-0.003	-0.005	0.013	0.000	-0.006	0.016	0.005
BODO 0	0.002	0.028	-0.009	0.002	0.029	-0.008	0.001	0.032	-0.001
KRIS 0	0.001	-0.001	-0.007	0.002	0.000	-0.005	0.002	0.003	0.000
OSLO	-0.001	0.015	-0.013	0.000	0.017	-0.011	0.000	0.020	-0.006
STAV	0.002	0.013	-0.006	0.003	0.015	-0.004	0.003	0.018	0.001
TROM	-0.002	0.024	-0.012	-0.007	0.021	-0.017	-0.005	0.027	0.002
TRON	0.000	0.021	-0.004	0.000	0.022	-0.002	0.000	0.025	0.003
VARD	-0.010	0.024	-0.021	-0.011	0.023	-0.019	-0.012	0.026	-0.012
RMS	**0.004**	**0.019**	**0.011**	**0.005**	**0.019**	**0.010**	**0.005**	**0.022**	**0.005**
MAX	**0.010**	**0.028**	**0.021**	**0.011**	**0.029**	**0.019**	**0.012**	**0.032**	**0.012**

6.5. EUVN 97

The result from the EUVN97 campaign is in ETRF 96 epoch 1997.4. Nine permanent EUREF stations and two other SWEPOS stations are included both in the EUVN 97 campaign and SWEREF 99. The Swedish tide gauge pillars SE02, SE04, SE06 and SE07 are not included in SWEREF 99. Coordinates in SWEREF 99 for those pillars have been obtained in the following way. Observation data on the pillars from the EUVN 97 campaign has been processed together with the SWEPOS network. For each tide gauge pillar this solution has been fitted by a 6-parameter transformation to SWEREF 99 (Translated minimum constrained, Constrained alternative 1 and Constrained alternative 2 respectively) using the 6-8 nearest SWEPOS stations.

Table 8: EUVN 97 minus SWEREF 99.

Unit: mm	Translated			Constrained alt 1			Constrained alt 2		
	North	East	Up	North	East	Up	North	East	Up
JOEN	-0.002	-0.011	-0.011	-0.002	-0.013	-0.010	-0.003	-0.007	0.002
KIR0	-0.004	-0.006	-0.003	-0.002	-0.003	-0.006	-0.006	-0.003	0.003
MAR.6	0.000	-0.005	-0.013	-0.001	-0.004	-0.018	0.000	-0.001	-0.004
METS	-0.001	-0.002	-0.006	0.000	-0.002	-0.004	-0.003	0.001	0.003
ONSA	-0.001	0.002	0.006	0.001	0.005	0.013	0.000	0.006	0.013
OSTE 0	-0.002	0.000	-0.010	-0.002	0.002	-0.008	-0.003	0.004	-0.002
SE02	-0.002	0.000	0.007	-0.001	0.001	0.010	-0.001	0.003	0.014
SE04	-0.003	-0.002	-0.018	-0.002	-0.001	-0.016	-0.004	0.001	-0.010
SE06	-0.002	-0.001	0.002	0.000	0.000	0.004	-0.001	0.003	0.009
SE07	0.000	-0.002	-0.007	0.000	-0.001	-0.007	0.000	0.002	0.001
SKEL 0	-0.003	-0.003	-0.016	-0.002	-0.003	-0.014	-0.004	0.000	-0.008
SODA	-0.008	-0.007	-0.028	-0.008	-0.009	-0.028	-0.010	-0.003	-0.016
VAAS	-0.003	-0.007	-0.018	-0.001	-0.009	-0.021	-0.004	-0.004	-0.006
VIL0	-0.002	-0.005	-0.010	-0.001	-0.005	-0.009	-0.004	-0.001	-0.002
VIS0	0.000	-0.004	0.002	0.001	-0.003	0.009	0.001	0.000	0.008
RMS	**0.003**	**0.005**	**0.013**	**0.002**	**0.005**	**0.013**	**0.004**	**0.003**	**0.008**
MAX	**0.008**	**0.011**	**0.028**	**0.008**	**0.013**	**0.028**	**0.010**	**0.007**	**0.016**

7. Choice of final solution

The primary demand on the new Swedish ETRS 89, besides that it should be officially approved, is that it should be accurate, homogeneous and consistent with normal GPS processing, so that a usual GPS user will not run into problems due to the reference frame. The new Swedish ETRS 89 should also agree as well as possible with the ETRS 89 realisations used in our neighbouring countries – Denmark, Norway and Finland. The new Swedish ETRS 89 should have a specific epoch with respect to the land uplift, as we later on intend to model this kind of movements within Sweden.

The constrained alternative 2 solution is the solution that best fulfils the above-mentioned demands and is therefore chosen as the final solution.

The constrained alternative 2 solution is the constrained solution that has the best agreement with the minimum constrained solution (and also with weekly solutions from SWEPOS spring 2000). It is not dependent on the velocity vectors of non-IGS sites. Furthermore, this solution agrees best with other existing EUREF realisations.

The final coordinates of the 21 proposed new EUREF sites in Sweden are found in table 9.

Table 9: Final coordinates in SWEREF 99 for the 21 proposed new EUREF sites.

Station	X	Y	Z	Latitude	Longitude	Height
ARJE_0	2441775.4373	799268.0366	5818729.1711	66 19 4.85691	18 7 29.49556	489.145
BORA_0	3328984.8136	761910.0660	5369033.4748	57 42 53.84111	12 53 28.84159	219.904
HASS_0	3464655.8414	845749.9472	5270271.4971	56 5 31.97370	13 43 5.06237	114.016
JONK_0	3309991.8454	828932.0763	5370882.2638	57 44 43.69608	14 3 34.57899	260.352
KARL_0	3160763.3610	759160.1384	5469345.4948	59 26 38.46674	13 30 20.23720	114.265
KIR0_10422M001	2248123.5038	865686.5326	5886425.5943	67 52 39.26375	21 3 36.84353	497.965
LEKS_0	3022573.1884	802945.6368	5540683.9551	60 43 19.71351	14 52 37.21262	478.092
LOVO_0	3104219.4534	998383.9817	5463290.5080	59 20 16.08058	17 49 44.08197	79.605
MAR6_10405M002	2998189.7132	931451.5886	5533398.4735	60 35 42.50805	17 15 30.67778	75.375
NORR_0	3199093.3220	932231.2871	5420322.4852	58 35 24.82429	16 14 46.96242	40.917
ONSA_10402M004	3370658.8318	711876.9387	5349786.7450	57 23 43.06580	11 55 31.84722	45.534
OSKA_0	3341340.1876	957912.3012	5330003.2150	57 3 56.29169	15 59 48.50148	149.753
OSTE_0	2763885.5164	733247.3303	5682653.3430	63 26 34.04843	14 51 29.03061	490.01
OVER_0	2368885.0271	994492.1727	5818478.1810	66 19 4.28199	22 46 24.12554	222.887
SKEL_0	2534031.1978	975174.4040	5752078.3436	64 52 45.10136	21 2 53.82526	81.197
SUND_0	2838909.9330	903822.0452	5620660.2035	62 13 56.90159	17 39 35.57936	31.776
SVEG_0	2902495.1066	761455.7889	5609859.6815	62 1 2.67953	14 42 0.03006	491.183
UMEA_0	2682407.9229	950395.8843	5688993.1146	63 34 41.29143	19 30 34.53185	54.498
VANE_0	3249408.2921	692757.9173	5426396.9317	58 41 35.24916	12 2 5.99772	169.664
VIL0_10424M001	2620258.8912	779137.9797	5743799.2762	64 41 52.24160	16 33 35.73391	449.936
VIS0_10423M001	3246470.5614	1077900.3132	5365277.9025	57 39 13.92217	18 22 2.32437	79.778

8. How do we proceed?

After the new ETRS 89 realisation has been approved by EUREF, we will recalculate all stations that have been determined in SWEREF 93 in the RIX 95 project.

Since the new ETRS 89 realisation, SWEREF 99, will not just replace SWEREF 93, but also our official national reference frame RT 90, we need an official map projection. The map projection is not just a question for geodesists, it has to be handled and decided by a wide group of representatives from different Swedish user groups.

Transformation formulae between SWEREF 99 and local reference frames can then be produced based on the results of the RIX 95 project.

It is also urgent to start the work to develop models and methods for handling the movements due to the land uplift.

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