EUREF-Austria 2002

EUREF-Campaign for the introduction of ETRS89 in Austria

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1. Motivation

The ETRS89 system defined by EUREF is already used for scientific and practical purposes in Austria. In the future it will be adopted as the basis of the national reference frame. Therefore Austria participated in the realization since EUREF-89 (GURTNER et al. 1992). In 1996 the first contribution was extended in 1994/5 (PESEC, 1996) designated EUREF-A94/95 and approved as an extension except the site GRMS (GUBLER, E., HORNIK, H., ed., 1996). After that time the system of permanent stations developed to the EPN (European Permanent Network). The backbone of the national reference system should consist of permanent stations within IGS and EUREF. However, there are several stations in Austria which are not included officially into the international services, possessing and observing quality similar to the "official" stations. It would be desirable to attach all of them together to one international reference system, preferably ETRS89. Therefore the way of "pseudo-campaign" was chosen to select seven days of data of permanent stations to declare them as epoch stations. Because not all of them are public stations, the commitments of the private firms will be attached to secure the publication of GPS data for post-processing, to allow system monitoring, to store data for several years and to continue observing.

The purpose of this proposal is therefore

- to accept the new stations HKBL, VLCH, WIEN (public) and GUES, KOET (private),as epoch stations with quality class B,
- to withdraw the old epoch markers GERL, GSST, HAID, HOPY, MAYB, OSWA to reduce the number of markers to the limit for Austria,
- to notify that the former markers HFLK and PFAN are replaced by permanent stations and should not be counted further as epoch stations.

The first campaign of 2001 was not accepted by the TWG at Ponta Delgada in 2002. Therefore a new campaign was set up including the remaining epoch station HUTB (Hutbiegl, renamed to AT01 11027M002 at EUVN 1997) to have a consistent network. The other demands and the changes proposed at TWG of Delft 2002 have been obeyed too. To avoid problems with potential removable devices in the future the antenna heights of VLCH and WIEN have been changed, referring now to the pillar.

2. Observation Design

For the inclusion of the candidate stations into the EUREF network seven consecutive daily observations were used adding the nearest IGS and EUREF stations. The geographical distribution of the stations is given in figure 1. An overview of the campaign is given in tables

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1-3. Due to the outage of PFAN only five sessions are available. The marker AT01 was observed during three full sessions only.

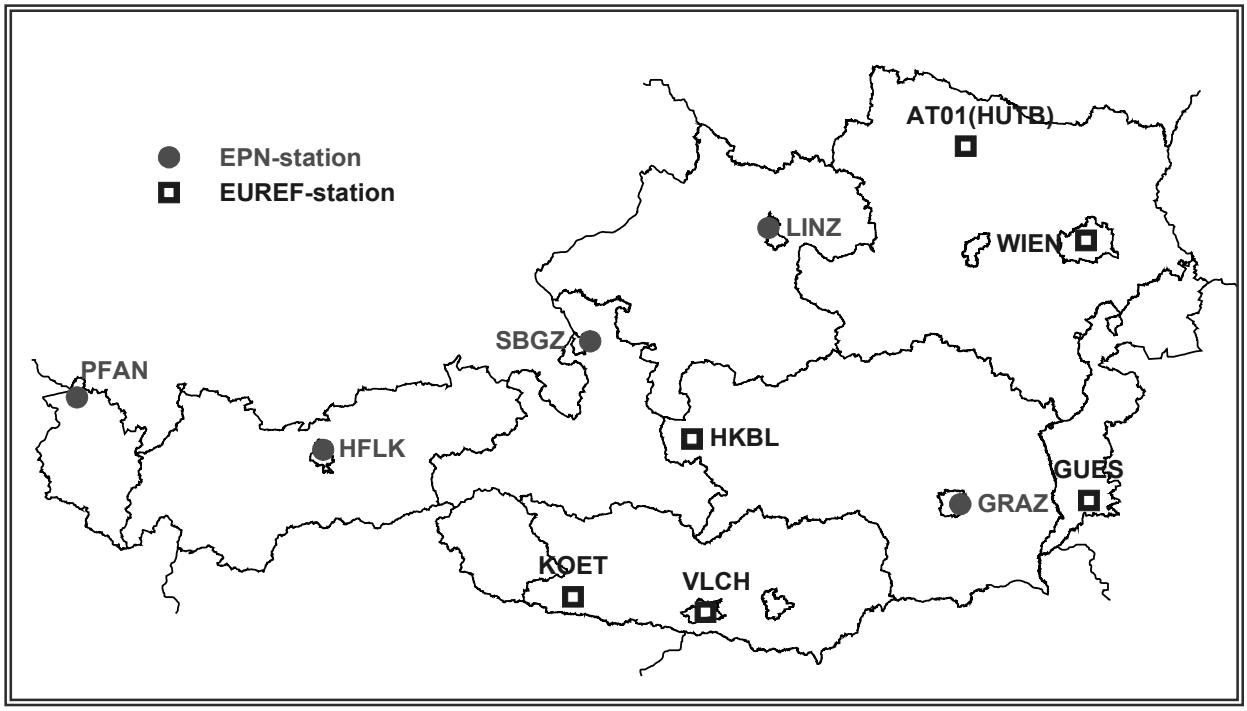

Figure 1: Geographical distribution of EPN- and EUREF-Stations in Austria

STATION, DOMES N. NAME	APPR. COORDINATES LAT./LON./HEIGHT	FUNCTION
GRAZ 11001M002 Graz Lustbuehel	47°04'/15°30'/ 500 m	IGS permanent station
HFLK 11006S003 Hafelekar	47°19'/11°23'/2400 m	IGS permanent station
LINZ 11033S001 Linz	48°19'/14°17'/ 300 m	EUREF permanent station
PENC 11206M006 Penc	47°47'/19°17'/300 m	IGS permanent station
PFAN 11005S002 Pfaender	47°31'/09°47'/1100 m	EUREF permanent station
SBGZ 11031S001 Salzburg	47°48'/13°07'/1300 m	EUREF permanent station
WTZR 14201M010 Wettzell	49°09'/12°53'/ 700 m	IGS permanent station
ZIMM 14001M004 Zimmerwald	46°53'/07°28'/1000 m	IGS permanent station
GUES 11045M001 Guessing	47°04'/16°19'/ 300 m	Candidate station (private, permanent)
HKBL 11039S001 Hauser Kaibling	47°23'/13°46'/1900 m	Candidate station (public, permanent)
AT01 11027M002 Hutbiegl	48°39'/15°36'/ 500 m	EUREF marker HUTB
KOET 11046M001 Koetschach	46°40'/13°01'/ 800 m	Candidate station (private, permanent)
VLCH 11036S001 Villach	46°36'/13°51'/ 600 m	Candidate station (public, permanent)
WIEN 11035S001 Wien BEV	48°13'/16°22'/ 200 m	Candidate station (public, permanent)

Table 1: Station overview

DATE	GPS WEEK AND DAY NO.	SESSION NUMBER	START TIME (UTC)	STOP TIME (UTC)
21-July-2002	11760	2020	00:00:00	23:59:30
22-July-2002	11761	2030	00:00:00	23:59:30
23-July-2002	11762	2040	00:00:00	23:59:30
24-July-2002	11763	2050	00:00:00	23:59:30
25-July-2002	11764	2060	00:00:00	23:59:30
26-July-2002	11765	2070	00:00:00	23:59:30
27-July-2002	11766	2080	00:00:00	23:59:30

Table 2: Session table

STATION	NATIONAL NUMBER	RECEIVER (IGS CODE)	ANTENNA (IGS CODE)	ANT. HEIGHT
GRAZ	T 306 164 B1	ASHTECH UZ-12	ASH701945C_M	1.964 m
HFLK	T 25 118 L1	TRIMBLE 4000SSI	TRM29659.00	-0.020
LINZ	-----	LEICA SR9500	LEIAT504	0.000
PENC	-----	TRIMBLE 4000SSE	TRM14532.00	0.030
PFAN	T 39 82 L2	TRIMBLE 4000SSI	TRM29659.00 GRAZ[1)]	0.000
SBGZ	-----	TRIMBLE 4000SSI	TRM29659.00 GRAZ[1)]	0.000
WTZR	-----	AOA SNR-8000 ACT	AOAD/M_T	0.071
ZIMM	-----	TRIMBLE 4000SSI	TRM29659.00	0.000
GUES	-----	JPS LEGACY	JPSREGANT_DD_E	0.000
HKBL	T 72 127 M2	LEICA SR9500	LEIAT504 GRAZ[1)]	0.051
AT01	T 73 21 B1	TRIMBLE 4000SSI	TRM29659.00	0.130
KOET	-----	JPS LEGACY	JPSREGANT_DD_E	0.000
VLCH	T 384 201 L1	TRIMBLE 4000SSI	TRM29659.00 GRAZ[1)]	0.030
WIEN	T1350 59 J1	LEICA SR520	LEIAT504 GRAZ[1)]	0.030

Table 3: List of equipment and antenna heights ([1)] Radom construction GRAZ)

3. Data Processing

Data Processing was carried out at two analysis centres, OLG (Observatory Lustbuehel Graz, a joint centre of the Austrian Academy of Sciences and the Federal Office of Metrology and Surveying) and TUW (Technical University of Vienna). Both ACs use the Bernese Software, official release 4.2. The processing strategy followed the most recent EUREF guidelines given in the proceedings of the 3rd Analysis Centre Workshop held in Warsaw, Poland, May 31st to June 1st 2001. Both centres used double differenced GPS observations.

OLG:

- IGS orbits, ERPs and clocks used
- Phase centre correction of IGS applied
- Minimum elevation angle set to 10°
- Observation lengths of <5 minutes deleted
- Predefined baselines as a mix of SHORTEST and OBSMAX used
- L5/L3 ambiguity fixing method with ionospheric model of CODE used
- Tropospheric modelling with one absolute (r.m.s. 5.0 m) and 23 relative (r.m.s. 5.0 m) parameters each day, using elevation dependent weighting and DRY NIELL model
- Network estimation applying fixed ambiguities for each day, GRAZ coordinates of ITRF2000 epoch 2002.56 constrained to ±0.1 mm, “EUREF solution”: coordinates

ITRF2000, epoch 2002.56 of GRAZ, PENC, WTZR and ZIMM constrained to ±0.1 mm

TUW:

- IGS orbits, ERPs and clocks used
- Phase centre correction of IGS applied
- Minimum elevation angle set to 12°
- Observation lengths of <5 minutes deleted
- Predefined baselines used (STAR plus OBSMAX)
- L5/L3 ambiguity fixing method
- Tropospheric modelling with one absolute (r.m.s. 5.0m) and 11 relative (r.m.s. 5.0m) parameters each day, using elevation dependent weighting and DRY NIELL model
- Network estimation applying fixed ambiguities for each day, GRAZ coordinates of ITRF2000 epoch 2002.56 constrained to ±0.1 mm
- "EUREF solution": Network estimation applying fixed ambiguities for each day, GRAZ, PENC, WTZR and ZIMM coordinates of ITRF2000 epoch 2002.56 constrained to ±0.1 mm

The data processing resulted into 14 daily solutions, two of each day processed. Finally the 14 normal equations were combined after some formal refinements. The differences are shown in Figure 2. For the combination GRAZ was chosen as the reference station with the same constraints of ±0.1 mm for each component. The percentage of fixed ambiguities was always larger than 80%, the shorter baselines have more than 90% ambiguities fixed.

4. Comparisons and results

4.1 Comparisons to ITRF2000

For comparison the minimal constrained network with reference to the coordinates of GRAZ ITRF2000, epoch 2002.56, was used.

STATION	X [M]	Y [M]	Z [M]
GRAZ 11001M002	4194423.959	1162702.549	4647245.328
HFLK 11006S003	4248505.175	855575.595	4667172.195
PENC 11206M006	4052449.626	1417680.986	4701407.038
PFAN 11005S002	4253560.144	733544.827	4681452.883
SBGZ 11031S001	4180931.104	973735.295	4703203.448
WTZR 14201M010	4075580.685	931853.660	4801568.054
ZIMM 14001M004	4331297.177	567555.732	4633133.840

Table 4: Coordinates of accepted stations in ITRF2000, epoch 1997.0

STATION	V_X [M/Y]	V_Y [M/Y]	V_Z [M/Y]
GRAZ 11001M002	-0.0176	0.0181	0.0082
HFLK 11006S003	-0.0134	0.0187	0.0111
PENC 11206M006	-0.0166	0.0181	0.0082
PFAN 11005S002	-0.0137	0.0187	0.0112
SBGZ 11031S001	0.0097	0.0258	0.0415
WTZR 14201M010	-0.0157	0.0172	0.0087
ZIMM 14001M004	-0.0138	0.0185	0.0100

Table 5: Velocities of accepted stations in ITRF2000, epoch 1997.0

The accepted values of ITRF2000 are shown in Tables 4 and 5. The comparison has been made in the ITRF2000 with the values of Table 6. SBGZ was omitted a priori because of its very poor values in ITRF2000 allowing comparison at the decimetre level only. The residuals between the accepted and the coordinates computed from the minimal constraint solution have been compared by a translation. It can be seen from Table 7 that they are small.

STATION	X [M]	Y [M]	Z [M]
GRAZ 11001M002	4194423.861	1162702.650	4647245.374
HFLK 11006S003	4248505.100	855575.699	4667172.257
PENC 11206M006	4052449.534	1417681.087	4701407.084
PFAN 11005S002	4253560.068	733544.931	4681452.945
WTZR 14201M010	4075580.598	931853.756	4801568.102
ZIMM 14001M004	4331297.100	567555.835	4633133.896

Table 6: Coordinates of accepted stations in ITRF2000, epoch 2002.56

STATION	NORTH [MM]	EAST [MM]	UP [MM]
GRAZ 11001M002	0.4	4.0	-10.7
HFLK 11006S003	2.7	-1.0	10.9
PENC 11206M006	-1.8	0.7	-4.9
PFAN 11005S002	-1.9	1.4	0.2
WTZR 14201M010	0.1	-1.4	0.3
ZIMM 14001M004	0.3	-2.7	4.5

Table 7: Residuals after a translation of the solution constrained to GRAZ to the ITRF2000 values, epoch 2002.56, Translation parameters in X/Y/Z : 8.3/-1.8/7.5 mm

4.2 Results

In a second step the network was constrained to the ITRF2000 (Epoch 2002.56)-coordinates of the stations GRAZ, PENC, WTZR and ZIMM. The results are listed in Table 8. HFLK was intentionally not used because its seasonal variations with a maximum amplitude of more than 10 mm is still under investigation. A comparison of the network with 4 heavily constraint stations to that one constrained to GRAZ only is given below in Table 9. The additional constraints do not distort the results in a considerable way.

STATION	X [M]	Y [M]	Z [M]	
GRAZ 11001M002	4194423.862	1162702.649	4647245.374	fix
PENC 11206M006	4052449.534	1417681.087	4701407.084	fix
WTZR 14201M010	4075580.598	931853.756	4801568.102	fix
ZIMM 14001M004	4331297.100	567555.835	4633133.896	fix
HFLK 11006S003	4248505.093	855575.698	4667172.246	
LINZ 11033S001	4118898.680	1048597.320	4740105.856	
PFAN 11005S002	4253560.066	733544.928	4681452.945	
SBGZ 11031S001	4180931.089	973735.417	4703203.588	
GUES 11045M001	4176515.983	1222812.346	4647591.332	
HKBL 11039S001	4203798.897	1030321.048	4671679.852	
AT01 11027M002	4066170.533	1135173.349	4765611.988	
KOET 11046M001	4272082.663	987022.289	4617541.898	
VLCH 11036S001	4262285.569	1050898.288	4612277.791	
WIEN 11035S001	4085097.451	1200224.363	4733306.933	

Table 8: Results of the constrained adjustment OLG+TUW, ITRF2000, Epoch 2002.56

STATION	NORTH [MM]	EAST [MM]	UP [MM]
GRAZ 11001M002	0.4	2.6	-6.3
HFLK 11006S003	0.1	-0.9	2.2
LINZ 11033S001	0.3	0.3	-0.3
PENC 11206M006	-1.5	0.3	-0.6
PFAN 11005S002	0.1	-1.2	2.8
SBGZ 11031S001	0.0	-0.3	0.7
WTZR 14201M010	0.2	-1.4	4.6
ZIMM 14001M004	0.4	-2.6	8.8
GUES 11045M001	-0.3	0.9	-2.1
AT01 11027M002	0.0	0.5	-1.2
HKBL 11039S001	0.1	0.1	-0.6
KOET 11046M001	0.0	0.5	-1.6
VLCH 11036S001	0.0	0.6	-1.7
WIEN 11035S001	-0.1	0.9	-2.1

Table 9: Residuals after a translation of the solution constrained to GRAZ to the solution constrained to GRAZ, PENC, WTZR and ZIMM, translation parameters X/Y/Z: 5.5/-2.1/4.2

The constrained solution has to be transformed into ETRS89 by using the formula of (Boucher, Altamimi 2001), listed below. The corresponding values for the translation parameters T1/T2/T3 are taken from (BOUCHER, ALTAMIMI, 2001) Appendix 1, Table 3 (54/51/-48 mm). The rotation values are taken from Appendix 2, Table 4 (0.081/0.490/-0.792 0.001"/year) of the same publication, $\Delta t = 13.56$.

$$\begin{pmatrix} X_E(t) \\ Y_E(t) \\ Z_E(t) \end{pmatrix} = \begin{pmatrix} X(t) \\ Y(t) \\ Z(t) \end{pmatrix} + \begin{pmatrix} T_1 \\ T_2 \\ T_3 \end{pmatrix} + \begin{pmatrix} 0 & -dR_3/dt & dR_2/dt \\ dR_3/dt & 0 & -dR_1/dt \\ -dR_2/dt & dR_1/dt & 0 \end{pmatrix} \bullet \begin{pmatrix} X(t) \\ Y(t) \\ Z(t) \end{pmatrix} \bullet \Delta t$$

The coordinates in ETRS89 are computed using the values of the constrained network and applying the corresponding transformations. The results are given in Table 10.

AT01 (HUTB) was already approved in 1996 (PESEC, 1996) and reoccupied during EUVN97 (INEICHEN et al., 2002) the differences in North/East/Up to the new solution are –8/5/-10 for 1994 and -4/0/-12 mm for 1997, which seems to be sufficiently small for such a long period, considering different ITRF systems and adjustment strategies.

STATION	X [M]	Y [M]	Z [M]
GRAZ 11001M002	4194424.126	1162702.457	4647245.197
HFLK 11006S003	4248505.342	855575.503	4667172.065
LINZ 11033S001	4118898.941	1048597.131	4740105.680
PENC 11206M006	4052449.813	1417680.902	4701406.913
PFAN 11005S002	4253560.309	733544.733	4681452.764
SBGZ 11031S001	4180931.346	973735.225	4703203.410
WTZR 14201M010	4075580.855	931853.569	4801567.928
ZIMM 14001M004	4331297.333	567555.636	4633133.711
GUES 11045M001	4176516.251	1222812.154	4647591.156
HKBL 11039S001	4203799.155	1030320.855	4671679.674
AT01 11027M002	4066170.800	1135173.163	4765611.815
KOET 11046M001	4272082.917	987022.093	4617541.718
VLCH 11036S001	4262285.827	1050898.092	4612277.611
WIEN 11035S001	4085097.719	1200224.177	4733306.760

Table 10: Transformed coordinates from ITRF2000 epoch 2002.56 to ETRS89

5. Conclusions

The used data set for the new epoch stations is embedded in a steadily monitored data flow which started at some stations as early as 1997, except the marker AT01 which is observed occasionally, at least every second year within the CEGRN campaign (e.g. 1994, 1995, 1996, 1997, 1999, 2001). This marker shows a remarkable good repeatability, however. The set chosen for a simulated campaign represents the average quality for all stations, therefore.

6. References

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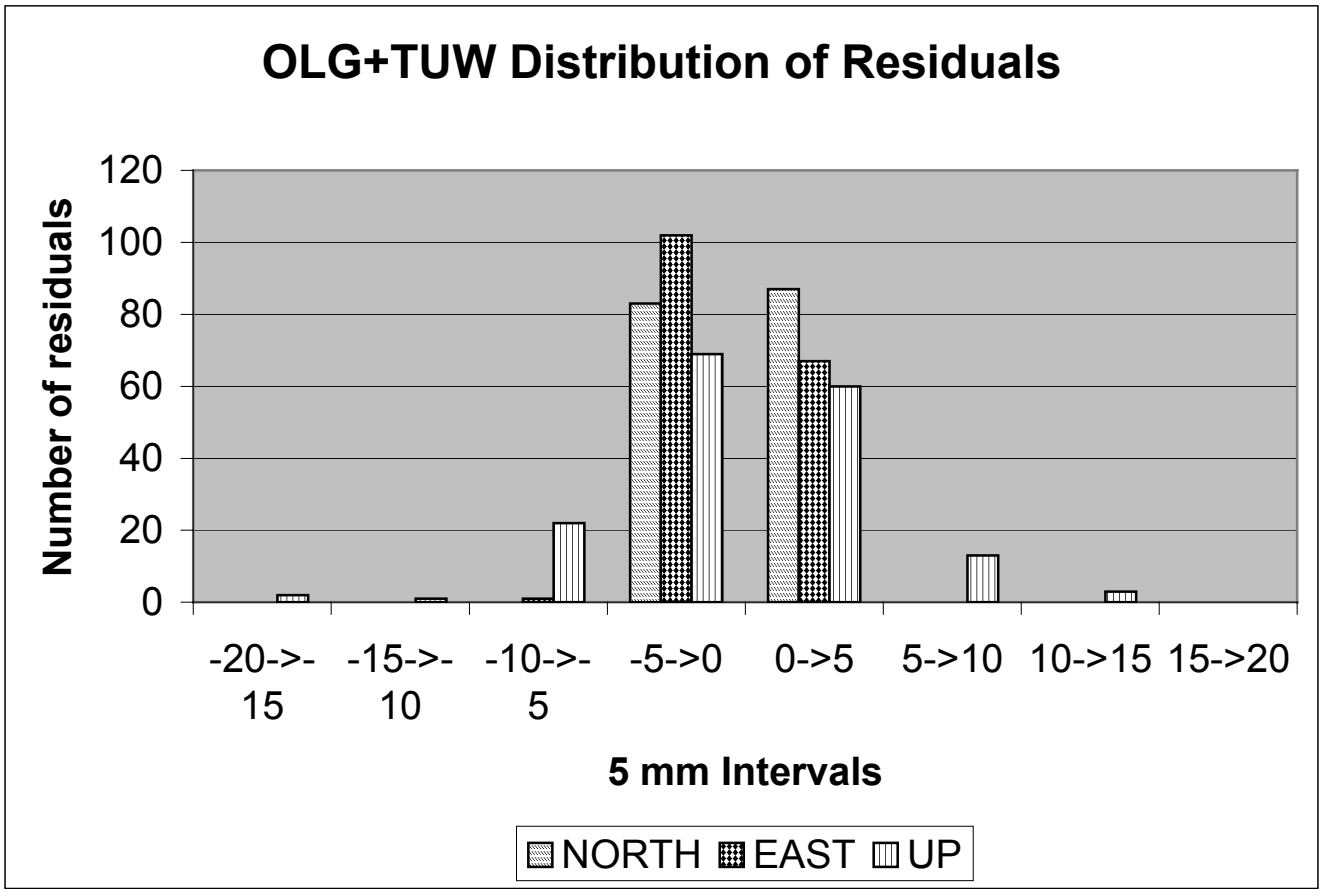

Figure 2: Distribution of differences between the analysis centres OLG and TUW.