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Changes in the OLG GPS time series due to new adjustment models

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Abstract

IGS [1] (IGS = International GNSS Service, GNSS = Global Navigation Satellite System) and EPN (European Permanent Network) Local Analysis Centres changed their adjustment strategy, starting with GPS week 1400. The most important were the change from relative to absolute antenna phase calibrations, the transition to the reference frame IGS05/ITRF2005 (International Terrestrial Reference Frame 2005) and the lowering of the minimum elevation. The jumps in the time series of the coordinates in two networks of the analysis centre OLG (Observatory Lustbuehel Graz), AMON (Austrian Monitoring Network) und MON (Monitoring Oriental Network), are shown in examples.

Kurzfassung

Die Auswertungsstrategie von IGS [1] (IGS = International GNSS Service, GNSS = Global Navigation Satellite System) und EPN (European Permanent Network) wurde mit der GPS-Woche 1400 massiv geändert. Die wichtigsten Änderungen sind die Verwendung von absoluten Kalibrierwerten für die Antennen, die Senkung der Mindestelevation und ein neues Referenzsystem IGS05/ITRF2005 (International Terrestrial Reference Frame 2005). Die Auswirkungen auf die Zeitreihen zweier nach den internationalen Standards ausgewerteter Netze des Analysezentrums OLG (Observatory Lustbuehel Graz), AMON (Austrian Monitoring Network) und MON (Monitoring Oriental Network), werden exemplarisch beschrieben.

1. Introduction

Starting with GPS week 1400 (November 2006) the analysis centres of IGS altered officially several items in their computation strategy of the GPS orbits. The main differences are the use of absolute antenna phase calibrations for space vehicles and ground receivers and the adoption of a new reference frame IGS05. The EPN analysis centres also changed their strategies at the same time, adding some other features which should improve the repeatability of the coordinates, especially of the vertical component. The major changes are given in Table 1. Not all required basic data are available at this time (March 2007). Concerning the calibration values a sub-set has no absolute calibrations; especially certain combinations of antenna plus dome are not yet measured. The fallback rules are to use the calibration values of the corresponding antenna without dome which might lead to improper results. IGS05 is derived from a set of coordinates computed with absolute calibration values for several months. However, it is very well aligned to ITRF2005 which is based on relative calibrations for the GPS contribution [2]. Presently there are no coordinates and velocities for several EPN stations in ITRF2005. Based on a transformation formula [3] [4] the ETRF (European Terrestrial Reference Frame), the realization of ETRS89 (European Terrestrial Reference System 1989) is connected to ITRF. Because several countries adopted ETRS89 as the basic reference system for geodesy it is necessary to know how the coordinates of the realizations (= permanent and epoch GPS stations) will change. Based on the coordinate series derived from processing data from two networks of permanent GPS stations this study highlights the different processing strategy. The transformation of AMON into ETRS89 is needed as a basis of the geodetic reference frame of Austria. The effect of the change on the coordinates is compared to another network, MON, which covers the Eastern Mediterranean and the Western Indian Ocean. It is too early to investigate the effect on the station velocities but it is expected that already some conclusions for the future estimations can be drawn.

2. Networks

Two networks, which are computed at a weekly basis since at least 1999 at the analysis centre OLG are the basis for this study.

The first, AMON, serves as the Austrian realization of the reference systems ITRS2000

Item	Old Strategy	New Strategy	Remarks
Antenna Phase Calibrations	Relative from IGS and NGS	Absolute from IGS plus individual calibrations, if available	Robot measurements and transformed values relative → absolute
Reference Frame	ITRF2000	IGS05	IGS05 based on a transformation of ITRF2005
Minimum Elevation	10 degrees	3 degrees	Optional (recommended)
Troposphere Model	Dry Niell	Wet Niell	Estimation of zenith delays
Horizontal Gradients of the Troposphere	No	Yes, 24 h tilting	Optional (recommended)

Table 1: Major changes in processing before and after GPS week 1400, EPN analysis centres.

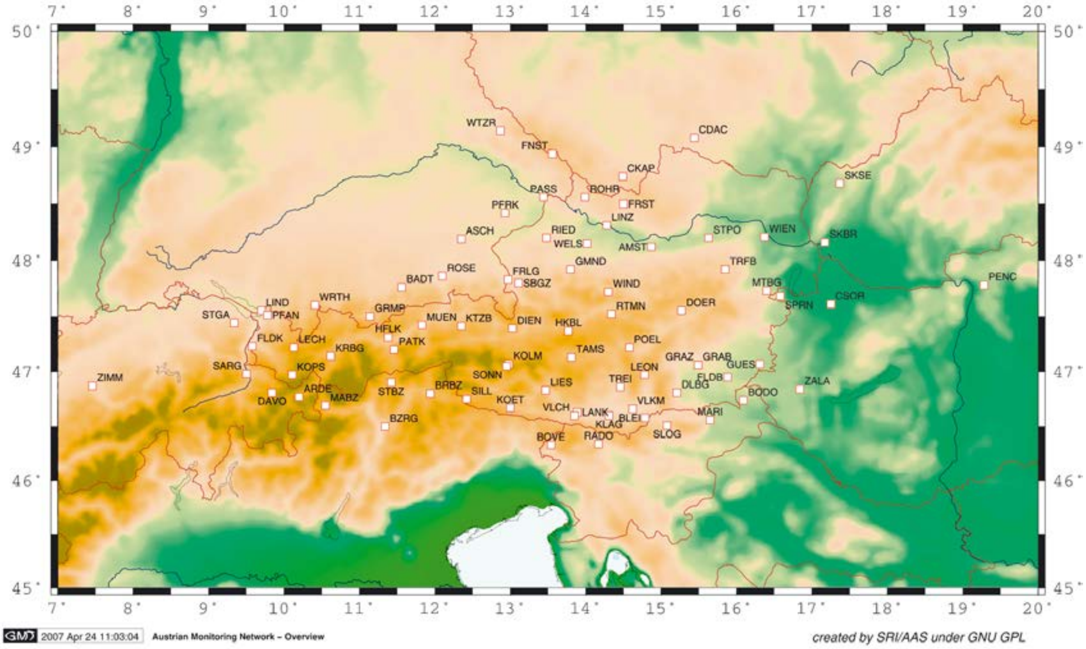

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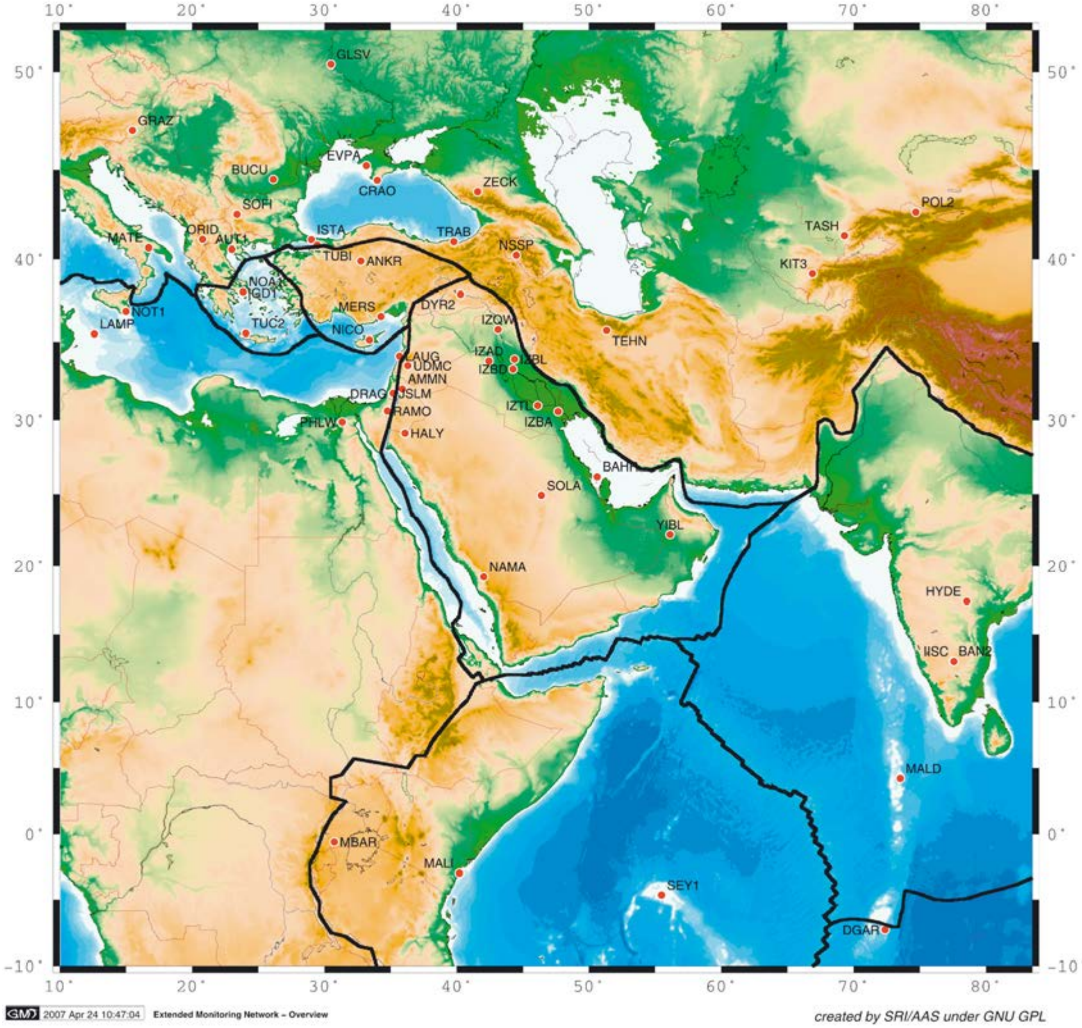
Figure 1: Austrian Monitoring Network (overview)

and ETRS89. It is a very compact and precise network consisting of about 80 stations. As can be seen from Figure 1 the network do not only cover Austria, also parts from Germany, Italy, Switzerland, Slovenia, Hungary, Slovakia and the Czech Republic are included.

The second network, MON, covers the Eastern Mediterranean, Arabia and the Western half of the Indian Ocean. Compared to the AMON network, where the mean baseline length is approximately 50 km, this one covers a larger area with baselines up to 3500 km. Figure 2 shows the distribution of more than 50 stations, which presently are part of the network.

In Table 2 the stations of AMON and MON are listed, arranged according to their status (IGS, EPN or both). GPS sites which are neither IGS nor EPN stations are here not mentioned.



GMT 2007 Apr 24 10:47:04 Extended Monitoring Network – Overview

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Figure 2: Monitoring Oriental Network (overview)

IGS	IGS+EPN	EPN
AMMN, BAHR, BAN2, CRAO, DGAR, DYR2, HALY, HYDE, IISC, KIT3, MBAR, MTBG, NAMA, POL2, SOLA, TEHN, YIBL	ANKR, BUCU, BZRG, DRAG, GLSV, GRAZ, HFLK, ISTA, MATE, NICO, NOT1, NSSP, ORID, PENC, RAMO, SOFI, TRAB, TUBI, WTZR, ZECK, ZIMM	AUT1, EVPA, LINZ, NOA1, PFAN, SBGZ, TRFB, TUC2

Table 2: AMON and MON stations according to their status

The receivers and antennas used at the GPS stations are from TRIMBLE, LEICA, ASHTECH, JAVAD and TOPCON. Due to the consideration of individual antenna calibrations since November 2006 the radome types of the stations became very important. The radome types which are used in the two networks are listed in Table 3 including the number of stations where the radomes are applied.

Radom	Number of stations (AMON)	Number of stations (MON)
NONE	19	24
TZGD	10	—
LEIC	9	—
LEIS	9	2
BEVA	11	—
GRAZ	16	—
UNAV	1	2
SNOW	1	7
CONE	2	—
SCIS	—	2
SCIT	—	1

Table 3: Radome types

MON includes no stations with calibrated antennas, but AMON contains nine GPS sites with calibrated antenna-radome combinations (Table 4).

3. Generation of Time Series

For both networks the weekly solutions generated from daily ones are used. The processing was done to the standards of EPN [5] of the valid epoch. MON was reprocessed for the years 1999-2001 because the original network was small and needed to be extended. Despite different processing algorithms in the past the changes seemed to be negligible. Only the last change can be seen in the time series producing substantial offsets. In a first step the normal equations were stacked together with equal weight. Because this was already done in the past, the offsets and outliers found have been applied already. The time series were revised and searched for new offsets or old offsets to be corrected or new outliers. The reference was chosen from stations with consistent coordinates and velocities in ITRF2000 plus some EPN and AMON stations to keep the balance in the Austrian network. MON was attached to stations which are all supposed to be on the Eurasian Plate. Each weekly solution was transformed to the system of selected stations using minimum constraints.

The different quality in precision between AMON and MON is shown in Figure 3. The distribution of the r.m.s values from the weekly repeatability show that the lateral residuals of AMON are concentrated at the 1 mm level, the vertical ones around 3 mm. The MON stations have not a good distribution, the good ones are at the 3 mm (lateral) and 5 mm (vertical) level. There are some stations in the Indian Ocean which have r.m.s worse than 10 mm, the largest (Up component) has 34 mm r.m.s. All stations summed up in Figure 3 are active since more than one year. The recent ones normally show larger r.m.s. because the seasonal variations have a larger influence.

GPS station	Receiver	Antenna	Radome
DOER	TRIMBLE NETRS	TRM41249.00	TZGD
FLDB	TRIMBLE NETRS	TRM41249.00	BEV A
HKBL	TRIMBLE NETRS	TRM29659.00+50	BEV A
KRBG	TRIMBLE NETRS	TRM41249.00	BEV A
MUEN	LEICA SR520	LEIAT504	BEV A
POEL	TRIMBLE NETRS	TRM41249.00	TZGD
TAMS	TRIMBLE NETRS	TRM41249.00	TZGD
WELS	TRIMBLE NETRS	TRM41249.00	BEV A
WTZR	TPS E_GGD	AOAD/M_T	NONE

Table 4: Calibrated antenna-radome combinations of AMON

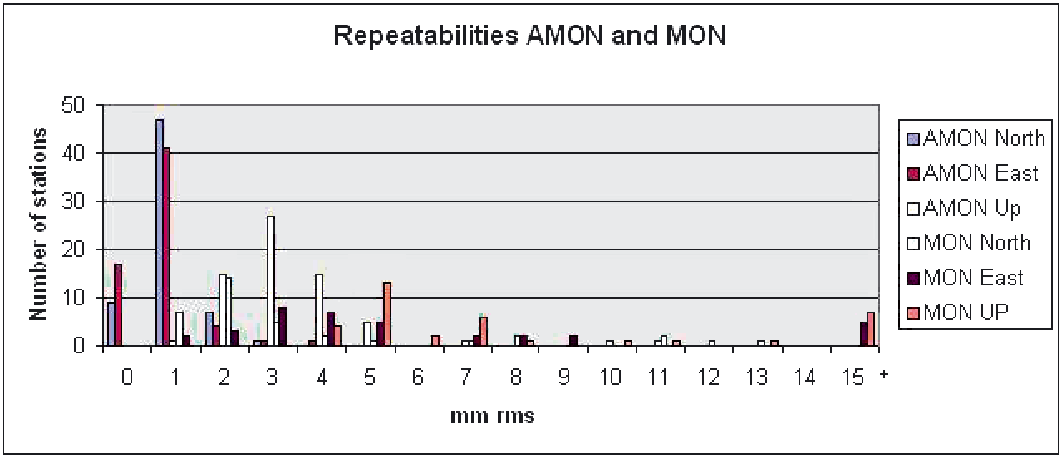

Figure 3: *Histogram of r.m.s values for AMON and MON in North/East/Up*

4. Offsets and Outliers

Offsets are jumps in the time series, which remain during plenty of weeks. Outliers on the other hand show up for fewer weeks, frequently only one week and the values are larger than those of offsets. Both effects can be caused by equipment modifications and processing changes. Outliers can also be affected by bad weather conditions like hard snowfall. The detection of offsets and outliers occurs graphically. Outliers larger than ±10 mm in North and East and larger than ±20 mm in Up are eliminated. Offsets are estimated with an accuracy of 0.1 mm and applied to the time series.

Figure 4 shows the time series of Krahberg / Landeck in Austria. The blue circle marks an outlier in the North component which was not eliminated due to its small value (about 7 mm).

The green lines in Figure 4 present the equipment changes (GPS weeks 1334, 1339 and 1353), whereas the change of antenna and receiver in GPS week 1334 causes an offset of −2.1 mm in North, +2.4 mm in East and −9.1 mm in the Up component. The processing changes since GPS week 1400 associate also offsets (yellow line) which are not yet estimated due to the low amount of available data since that point in time.

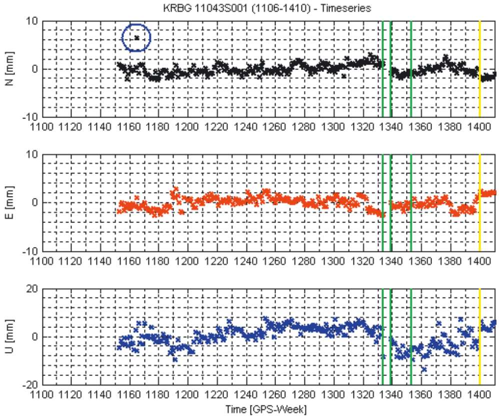

Figure 4: *Example of typical offsets in the time series (KRBG)*

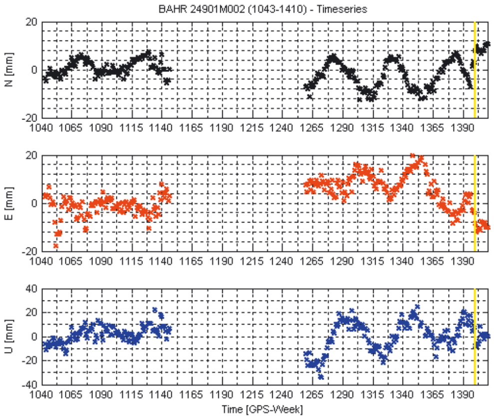

Figure 5: *Time series with large periodic features (BAHR)*

The GPS station in Manama/Bahrain features periodic effects in each direction (Figure 5). The amplitudes are nearly 10 mm in North and East and 20 mm in the Up component. The periodicity shows an annual term and is influenced by the seasons. The first part of the time series, which results from the reprocessing, shows a smaller amplitude compared with the end of the series. This effect is caused by the strategy changes, where the former strategy, which was adopted at the reprocessing and is now a part of the new strategy (low elevation angle, horizontal gradients, Niell wet part), seems to smooth the time series in this part.

For closer investigation of amplitudes and phases it is planned to generate the phase spectrum of the time series to get more information about seasonal effects.

5. Comparison and Results

The changes due to the new adjustment strategies can be seen in the time series. Because there were many changes the contribution of each change sums up to a common change which seems to have a general component and an individual one. To get an insight into the different contributions GPS week 1400 was investigated by varying the major changes:

- Relative calibrations + minimum elevation 10 degrees, no horizontal gradients (old solution),
- Relative calibrations + minimum elevation 10 degrees + horizontal gradients,
- Relative calibrations + minimum elevation 3 degrees, no horizontal gradients,
- Relative calibrations + minimum elevation 3 degrees + horizontal gradients,
- Absolute calibrations + minimum elevation 10 degrees, no horizontal gradients,
- Absolute calibrations + minimum elevation 10 degrees + horizontal gradients,
- Absolute calibrations + minimum elevation 3 degrees, no horizontal gradients.

These seven variants were tested against the new solution (absolute calibrations + minimum elevation 3 degrees + horizontal gradients). It turned out that generally AMON is not too sensitive to the changes whereas in MON at some stations changes of several centimetres appear. In Table 5 examples of stations are given with slight changes (ORID) and with the maxima in the vertical component. The two most relevant cases (old strategy and old strategy with absolute calibration values) are shown. Due to the fact that the Bernese Software (BSW) in version 4.2 [6] ignored the calibration values the differences at SBGZ should be considered as the change to the correct antenna type. Worth of mention is that the coordinates of SBGZ in the EUREF (European Reference Frame) [7] sub-network were always correct. The stations GUES and SKSE demonstrate that stations with low elevation observations are only affected if the minimum elevation is lowered.

The very poor quality at DGAR and SEY in MON is the result of large data gaps which occur nearly every day. DGAR shows a consistent difference whether absolute or relative calibrations are applied whereas SEY1 might suffer from a combined effect (calibration values, data gaps). Considering the estimation at low elevations we can see that both stations are very sensitive. In the horizontal component the comparison between old and new strategy yields a difference up to 20 mm. Introducing absolute calibration values reduces the difference to 5 mm. This means that a combination of different azimuth/elevation corrections of the antenna and a change in the model of the troposphere may be responsible for those changes. The influence of the horizontal gradients seems to be in the range of several millimetres. The baselines configuration can reduce the effect of observations at low elevations whereby large changes are almost randomly distributed. The Bernese Software offers a baseline adjustment strategy (OBSMAX), which uses the number of observations as optimization criterion. Also the calibration of different antenna types (new calibration, relative transformed to absolute values only) may play a certain role. Altogether the common effect for both networks due to the change is rather small (< 2 mm for AMON, 5 mm for MON).

6. Conclusions

The effect of the new adjustment strategy on the time series is well seen. In the future it would not be possible to derive station velocities without further actions. The best way would be to reprocess the old solutions with the new strategy. The reprocessing of MON in 2006 for the years 1999-2001 showed that approximately one year reprocessing would request one month of computation time. A quicker way would be to estimate the offsets caused by the changed strategy. Probably this is not too incorrect because very few stations observed below five degrees in the past and one

Station	Calibration absolute Minimum elevation 10 degrees, no horizontal gradients [mm]	Calibration relative Minimum elevation 10 degrees, no horizontal gradients (old solution) [mm]
SBGZ	9.2	10.1
GUES	−1.0	13.7
SKSE	−0.1	−10.9
ORID	1.2	−0.6
SEY1	−12.7	8.1
DGAR	−23.0	−24.9

Table 5: Change of Up component for GPS week 1400 against new adjustment strategy

important contribution of the offsets comes from the lowering of the minimum elevation at some stations. The second important contribution, the new calibration values, cannot be investigated very easily because most of the antenna-radome combinations have been neglected in the past. The use and the meaning of the horizontal gradients should be investigated further more. Despite the positive effect there might be a geophysical influence in the seasonal variations which is now filtered away. Concerning the Austrian national reference system estimating the offsets can be estimated and applied. It is a political question which coordinates should be "official", the old ones or the new ones. As shown above the maximum change in Austria will be about 10 mm in the vertical component. It has to be decided if this change should be applied for a handful of stations. A large distortion in the Austrian national reference network will not take place because the average changes are much smaller. Concerning MON the new adjustment would bring a big benefit in the future because the time series become considerably smoother. For this reason it seems really necessary and worthwhile to consider a reprocessing in the next years.

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