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THE STUDY OF SEASONAL CHANGES OF PERMANENT STATIONS COORDINATES BASED ON WEEKLY EPN SOLUTIONS

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ABSTRACT. Daily and weekly coordinates solutions of GNSS permanent stations operating within EPN network allows to track long-term changes of coordinates caused e.g. by the local and global movements of tectonic plates. They are therefore an excellent tool for testing stability and repeatability of stations position. The article presents an analysis of coordinates changes of selected reference stations based on weekly EPN solutions. In addition the author proposes parameters of approximating function by assuming an existence of periodic, annually repeatable trend. The author performed also an independent fitting function for two different periods of two ITRF frames of routine time analysis and reprocessing.

Keywords: coordinate time series, EPN, EUREF, GNSS permanent network.

1. INTRODUCTION

An investigation of reference stations stability based on satellite techniques has been already widely conducted. This is a reliable tool for the variety purposes described by publications e.g. (Bruyninx 2006; Fastellini et al. 2011; Hefty et al. 2005; Kenyeres and Bruyninx 2009). While in the publication (Hefty et al. 2005) the authors also were calibrating functions into GPS permanent stations coordinate time series. This analysis involved daily solutions and the analysed period was only 2 years. In this publication the author match function, which consists of a polynomial and periodic trend into coordinate time series of about 30 GPS stations located in the Central Europe. It proves various behaviour of stations position. For some stations the authors show annual repeatable changes of all components of about 1-2 mm for each station.

In this article the author determined parameters of approximating function of analysed coordinates time series. Studies were subjected to weekly solutions of EPN stations from years 2001-2011 (1143-1631 GPS Week). In the end part of paper also were determined function's parameters based on EPN reprocessing 1 (Figurski et al. 2009; Volksen 2009). However the following article is only a proposal of an algorithm and methodology for study about behaviour and repeatability of reference stations. There were studied coordinate times series of nine Polish permanent EUREF and ASG-EUPOS stations: BOGI, BOGO, BOR1, JOZ2, JOZE, KATO, KRAW, LAMA and WROC (Fig. 1).

Fig. 1. Distribution of analysed stations

For each of the analysed coordinate time series the author chose corresponding 4-parameter approximating function by assuming existence of periodic annually changes of coordinates on each station. For such long period it was supposed to identify seasonal, annually changes of coordinates. Noteworthy two pairs of above station are very close to each other: BOGI-BOGO (~107 m) and JOZ2-JOZE (~84 m). Due to near distance trajectory of its coordinate time series should be very similar.

2. EUREF Permanent Network (EPN)

The International Terrestrial Reference System (ITRS) is defined by the International Earth Rotation and Reference Systems Service (IERS) based on the reference points spread across the globe. These coordinates are determined by using satellite techniques such as VLBI, SLR, GPS and DORIS. So far there were implemented several realizations of the International Terrestrial Reference Frame (ITRF), to the currently one called ITRF2008 (Altamimi 2009). Thus, the global system in the current ITRF implementation can provide a reference for other local coordinate systems. There was a necessity of creation a coordinate system for the Europe because of the movements of continental Eurasian plate relative to ITRF of about 1-2 cm/year for each of the components. Therefore, there was established an idea of a European Terrestrial Reference Frame 89 (ETRF89) closely connected with Eurasian continental plate. This frame had to provide a stability of points' position in relation to each other within the Eurasian plate. It allows systematizing data across the Europe in such areas as national and international control networks, geodynamical studies or cartographic analysis, etc. ETRS89 was created under Resolution No. 1 (EUREF 1990) of EUREF subcommision of International Association of Geodesy (IAG) (Bruyninx et al. 2009). In 1995 by virtue of Resolution No. 2 (IAG EUREF 1995) of IAG EUREF subcommision were established EUREF Permanent Network (EPN). Its main objectives are to define the ETRF89 (Bruyninx et al. 2011) and coordinates of all EPN points are determined in the current ITRF and ETRF realizations. The coordinates in the ETRS89 are consistent with the ITRS realization for epoch 1989.0, so the ITRF89 frame is initial for ETRF89. Starting from 1989.0 coordinates in ETRF frame changes relative to the global ITRF with a speed equalled to an annual speed of Eurasian continental plates. This causes a migration of the European station relative to ITRF frame speeds of about several millimetres per year (Altamimi 2008). Thus, the coordinates in the ETRF frame are nearly constant relative to each other. A slight speed of around tenths of millimetres is resulted from the Eurasian plate deformation or other local tectonic movements. Velocity vectors in the ETRF frame are much smaller than in the ITRF frame. For a European area it is assumed as V_{ETRF} = 0 mm/year. However there are areas where these changes are significant, for example in the Scandinavia countries velocity of up component is estimated to be changing of 8 mm/year (Kryński 2004). Velocity vectors for individual components of permanent stations are published by IGS (The International GNSS Service), IERS or EUREF. In an absence of such data, stations' speed may be obtained from the global tectonic plate model called NNR-NUVEL-1A (McCarthy 1996).

All data obtained by the EPN permanent stations are collected and analysed by 18 LAC (Local Analysis Centres). On the Polish territory there are two of them: (MUT) at the Military University of Technology in Warsaw and (WUT) at the Warsaw University of Technology. Each analysis centre processes data from the permanent stations within its own defined subnetwork. Connection of a permanent station with an appropriate subnetwork is created by conditional ensuring processing station's data by at least three LAC's (Bruyninx et al. 2006). Calculated by EPN station coordinates solutions are published in SINEX format[1]. These are daily or weekly solutions created basing on solutions from all analysis centres and published in the current realization of the ITRF (Table 1). At the end of 2011 within the EPN network there were 244 operated GNSS stations (http://epncb.oma.be) spread across Europe and 18 of them were on the Polish territory. The rules of including a new station into an existing network are determined by the EPN. The emphasis is put on developing a monitoring station network in direction of other GNSS systems. New stations are equipped with a possibility to receive GPS and GLONASS signals, and several stations can also receive signals from Galileo. Some stations included in the European network also works in global IGS network, these stations must also fulfil conditions set by the IGS. For example all stations must receive signals on two frequencies and any new created station must be equipped with an additional opportunity to receive the new GPS L5 frequency (1176.45 MHz).

3. DESCRIPTION OF THE MODEL

Between 1143th and 1631st GPS week there were two realizations of the ITRF: ITRF2000 and ITRF2005 (Table 1):

Table 1. Successive reference frames of the ITRF with a set of fiducial stations and alignment methods (http://epncb.oma.be)

Period (GPS Week)	Reference frame	Fiducial stations	Alignment method
Dec 2001 - Jan 2002 (1143 - 1147)	ITRF2000	BOR1, GRAS, GRAZ, KOSG, MATE, NYA1, ONSA, POTS, REYK, THU1, TRO1, VILL, WTZR	Heavy constraints on the fiducial stations
Jun 2002 - Jul 2004 (1148-1278)	ITRF2000	BOR1, GRAS, GRAZ, KOSG, MATE, NYA1, ONSA, POTS, REYK, TRO1, VILL, WTZR	Heavy constraints on the fiducial stations
Jul 2004 - Dec 2004 (1279-1302)	ITRF2000	BOR1, GRAS, GRAZ, KOSG, MATE, NYA1, ONSA, POTS, REYK, VILL, WTZR	Heavy constraints on the fiducial stations
Dec 2004 - Nov 2006 (1303-1399)	ITRF2000	BOR1, GRAS, GRAZ, KOSG, MATE, NYA1, ONSA, POTS, REYK, VILL, WTZR	Minimal constrained conditions on fiducial stations
Nov 2006 - Apr 2011 (1400-1631)	ITRF2005	BOR1, BRUS, CAGL, GLSV, GRAS, HOFN, JOZE, MATE, METS, NICO, NOT1, NYA1, NYAL, ONSA, POLV, POTS, RABT, RAMO, REYK, SFER, TRAB, TRO1, VILL, WSRT, WTZR, ZIMM	Minimal constrained conditions on fiducial stations

[1] ftp://ftp.iers.org/products/publications/messages/message_103.txt

The first change between ITRF2000 realizations in July 2004 were result of establishment of other reference stations. The second change in December 2004 was caused by a different method of network solution. Heavy constraints on the fiducial stations method were changed into minimal constrained condition on fiducial stations method. The change-over from the ITRF2000 to ITRF2005 system took place in November 2006 (1400 GPS Week). New realization had to be implemented because of an increased number of reference stations and a definition of new parameters of the frame. There was also a new way of antennas stations calibration. There was a giving away relative method to absolute method. An absolute antenna calibration method provides a more accurate determination of antenna’s phase center. This method takes into account changing position of antenna’s phase center, depending on a change of elevation and an azimuth of signal received by antenna (Schmid 2010; Rothacher and Mader 2002).

Analysed stations have different time of EPN inclusion. Figure 2 presents GPS Week of analysed station inclusion to EPN. Vertical lines presents analysed period (1143 and 1631 GPS Week).

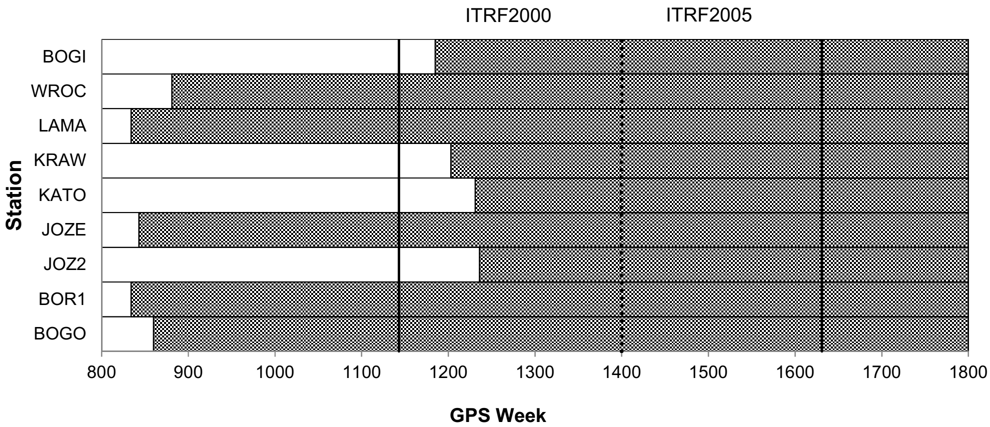

Fig. 2. Inclusion analysed stations to EPN.

The analyzed weekly EPN solutions are published in the form of SINEX file in a current realization of the ITRF. For a period 1143-1399 GPS Week it was ITRF2000 frame, for 1400-1631 GPS Week - ITRF2005. Coordinates in both frames were transformed into ETRF2000 at the observation epoch *t = 1400 GPS Week*, in accordance with the parameters recommended by the EUREF in the publication (Boucher and Altamimi 2011). Sinex data were converted into XYZ coordinates at observation epoch. Then observations by mean EUREF velocities were converted into one observations epoch *t = 1400 GPS Week* (5th November 2006). Then data were from both frames (ITRF2000, ITRF2005) transformed into ETRF2000 frame, and after into NEU coordinated. Cartesian coordinates were transformed to topocentric coordinates by using the formula:

$$\begin{bmatrix} N \\ E \\ U \end{bmatrix} = \begin{bmatrix} -sin\varphi_i cos\lambda_i & -sin\varphi_i sin\lambda_i & cos\varphi_i \\ -sin\lambda_i & cos\lambda_i & 0 \\ cos\varphi_i cos\lambda_i & \cos\varphi_i \sin\lambda_i & sin\varphi_i \end{bmatrix} \begin{bmatrix} dX_i \\ dY_i \\ dZ_i \end{bmatrix} \tag{1}$$

where:

$dX_i = X_i - \overline{X}$

$dY_i = Y_i - \overline{Y}$

$dZ_i = Z_i - \overline{Z}$

NEU components represent the coordinate deviations from the average value for all analyzed period. Movements for each station are specific (Hefty et al. 2005). For each coordinate time series in the subsequent realization of the ITRF frames there was selected function approximating annually changes in a form:

$$f(t) = a + b \cdot t + A \cdot sin\left[\frac{14\pi}{365.2422} t + \varphi\right] \qquad (2)$$

where:
f(t) – N, E, U [mm]
t – GPS Week
φ – phase shift

Only for BOR1 (till 1303 GPS Week, Table 1), which is fiducial EPN station was used linear function as:

$$f(t) = a + b \cdot t \qquad (3)$$

In the last phase for each analyzed station by least squares method above mentioned function with four unknowns (*a, b, A, φ*) was matched. Thus for each station there were chosen three different sets of parameters (*N*, *E*, *U*) for each component in two ITRF realizations (three periods for BOR1 station).

4. RESULTS – PART I

There were analyzed nine EPN stations located on the Polish territory between 1143[rd] and 1631[st] GPS week (December 2001-April 2011, Figure 1). During this time one change of reference frame took place (Table 1). For each station there were selected two time series, but for BOR1 there was an additional third time series from 1143[rd] to 1302[nd] GPS week, due to the adopted network solution during this period. For this period BOR1 station was a reference station with different method of network solution (Table 1). Thus the analyzed data before 1302 GPS Week for BOR1 station's components have linear function, which represents the local movements within the Eurasian plate. Starting from 1303 GPS week there were used alignment method called the minimal constraints conditions on fiducial stations. For other coordinate time series four parameters of the function in two periods (1143-1399 GPS Week for ITRF2000 and 1400-1631 - ITRF2005) were calculated.

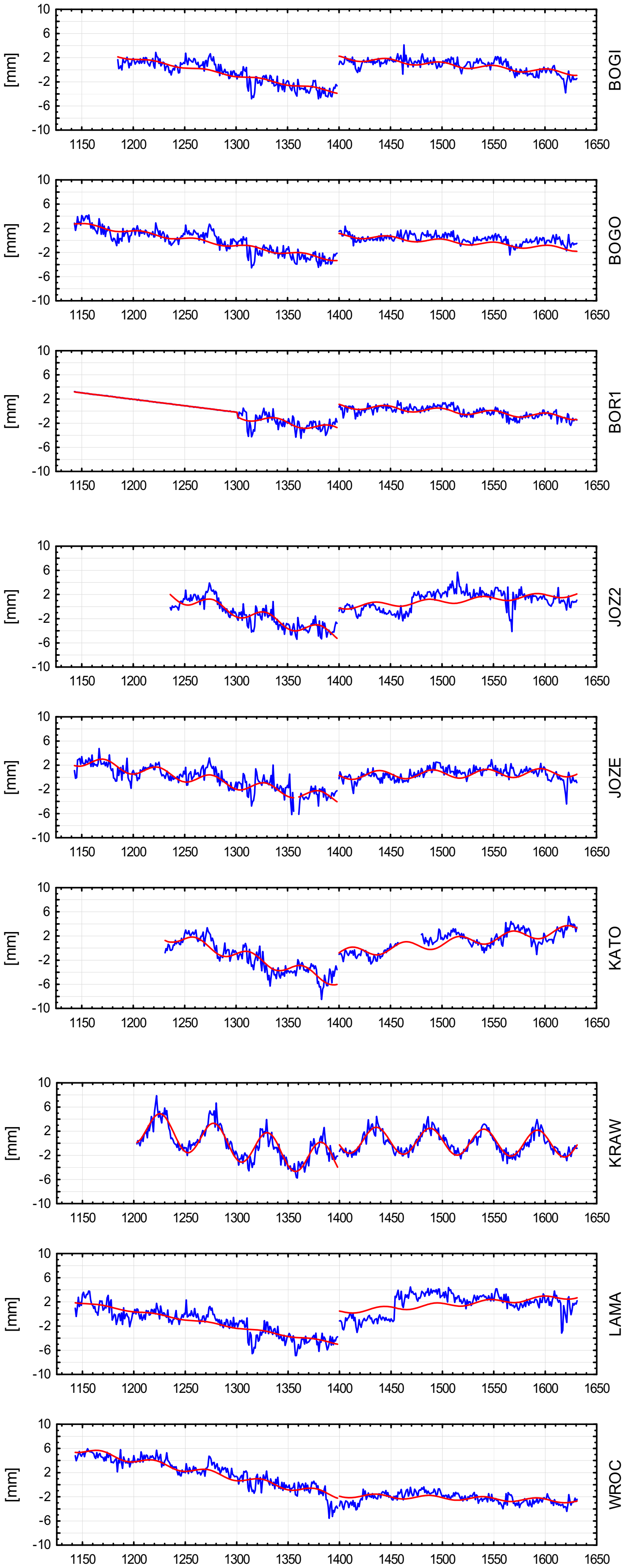

Fig. 3. North component with fitted function

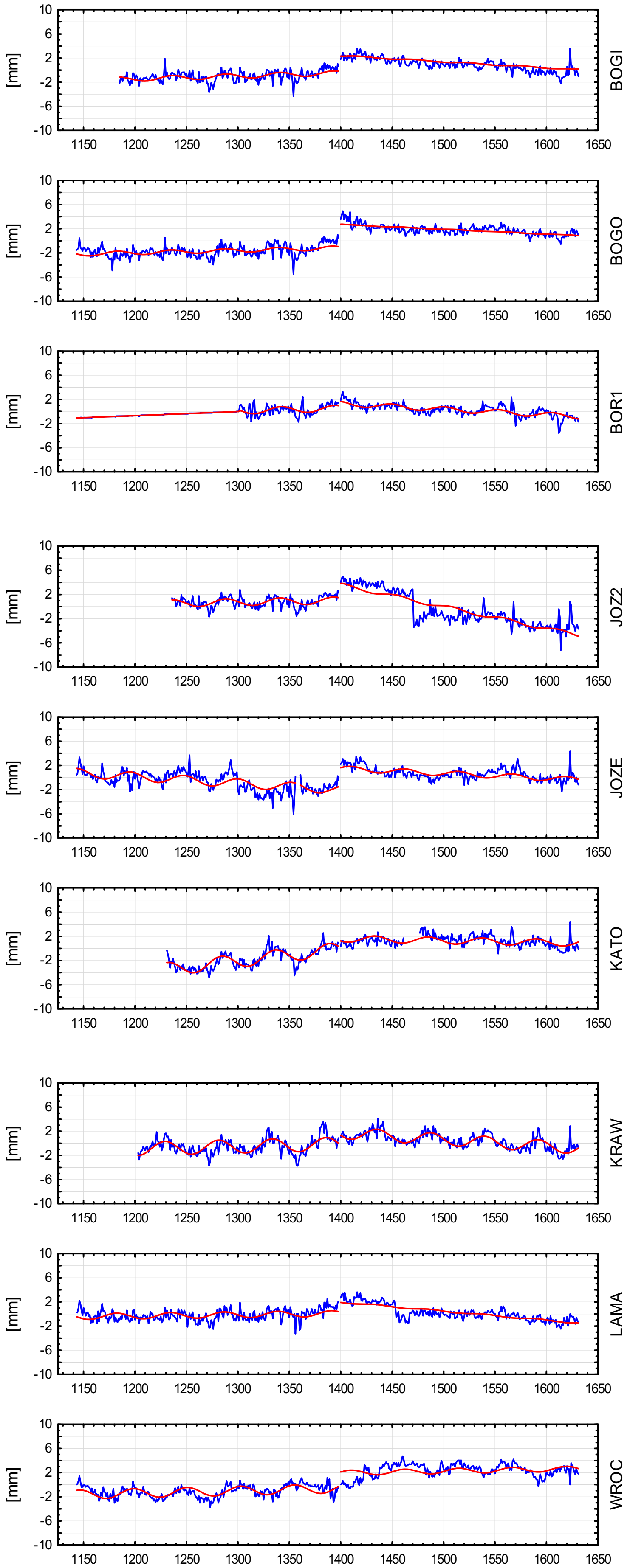

Fig. 4. East component with fitted function

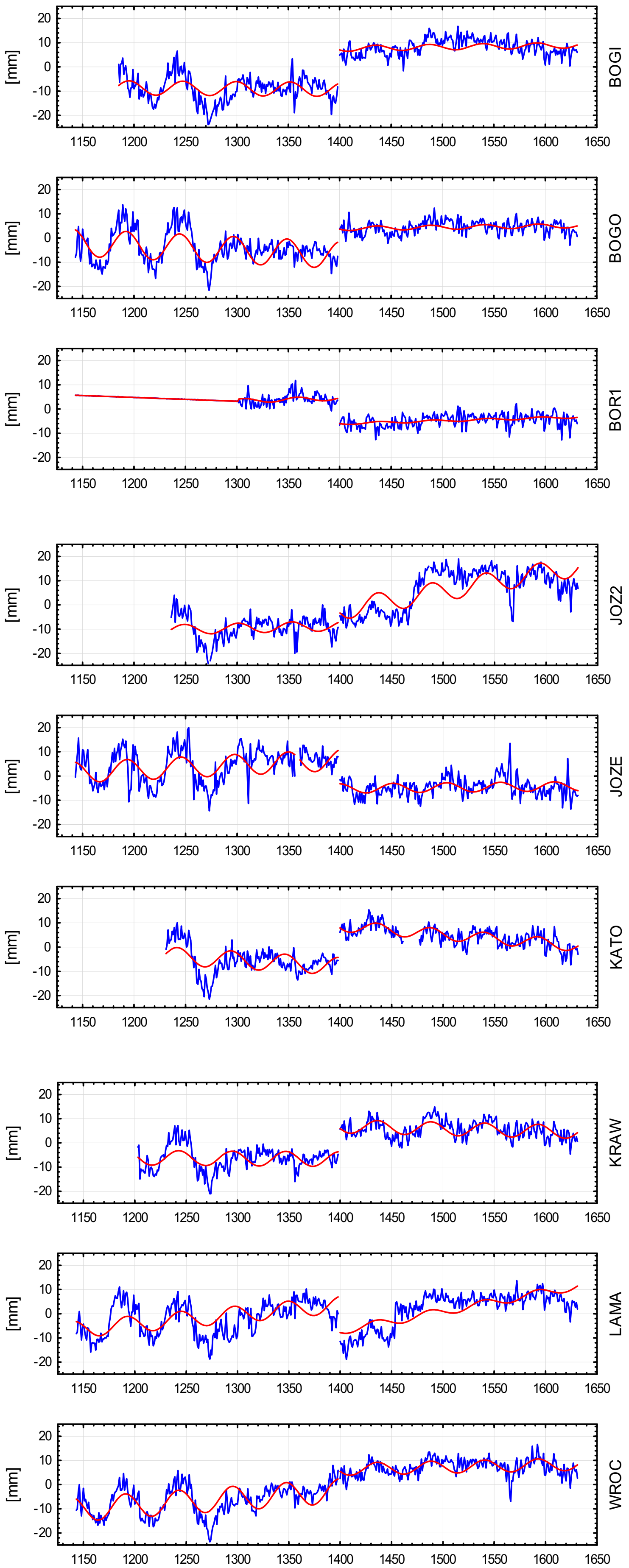

Fig. 5. Up component with fitted function

Figures 3-5 presents coordinate time series with matched, 4-parameter functions (red curves). Parameters *a* and *b* represents linear course of function; *φ* is a phase shift. Seasonal, annual changes represents parameter *A* – the amplitude. The bigger it is the bigger are annual coordinate fluctuations. In the case of some stations can be noticed repeatedly year-to-year changes.

BOR1 as a fiducial station due to EPN alignment strategy before 1303 GPS Week (Heavy constraints on the fiducial stations, Table 1) has almost fixed coordinates. With respect to this fact and elimination of global tectonic plate movement through transformation to ETRF2000 frame linear course of BOR1 coordinates represents small, local Eurasian plate movement. In relation BOR1 fit function accuracy for this period was not taken into account for following analysis.

In case of ITRF2000 frame clearly visible are year-to-year repeatable changes on few stations. For North-South direction on JOZ2, JOZE, KATO, KRAW stations determined amplitude is ~1 mm or greater (max. KRAW 2.8 mm). In East-West direction biggest amplitude 0.7-0.8 mm is on JOZE, WROC and ~1.1 mm on KATO and KRAW stations. In case of Up component the biggest recurrent changes are visible on BOGO, JOZE and WROC (amplitude > 4 mm) stations, but only for 1143-1302 GPS Week period. This phenomenon is follow by different strategy of EPN alignment method before 1303 GPS Week. Furthermore Up component is the least accurately determine coordinate (Góral 2003).

Transition to ITRF2005 caused smaller values of amplitude for majority of stations, so year-to-year coordinate trajectory repeatable would to be as visible as for ITRF2000 frame. The biggest amplitudes on North component are visible on JOZE (0.7 mm), KATO (0.85 mm) and KRAW (2.2 mm) station. For East component the greatest values of amplitude are on BOR1, JOZE, WROC (~0.4 mm), KATO (0.6 mm) and KRAW (1.0 mm) stations. And in the case of Up component on KATO, KRAW, WROC station visible are similar amplitude values (2.4-2.8 mm) and the greatest amplitude – 4,2 mm on JOZ2 station.

Analysis involves two pairs of very closely located stations: BOGI-BOGO (~107 m) and JOZ2-JOZE (~84 m). In the case of first pair char of its coordinates, parameters of the fitted function and standard deviations (Table 3) are almost the same. JOZ2-JOZE charts are subtly different, especially East component for ITRF2005 frame and Up component for all analysed period. It could be influence of antenna and receiver changes. On JOZ2 stations during analysed period were used 4 different receivers; antenna was changed once.

On all of analysed stations (except BOR1 – fiducial station) clearly visible are two kinds of coordinate fluctuations: depends on reference station and random. Reference station reliant fluctuations e.g. ~1315 or ~1360 GPS Week and are visible on North component on reference station (BOR1) as well as on other stations. Magnitude of these fluctuations depends on distance from reference stations, so bigger amplitude is on stations located in the northern part of Poland (BOGI, BOGO, JOZ2, JOZ2, LAMA). The other type are random, short (1-3 weeks) fluctuations. Its magnitude could reach even 6 mm, e.g. North component JOZ2 (1570 GPS Week). For Up component these kind of fluctuations could has magnitude as high as 10-15 mm, e.g. JOZE, ~15 mm (1310 GPS Week) or JOZ2, ~12 mm (1570 GPS Week).

Table 2. Parameters of fitted function

Station				BOGI		BOGO		BOR1		JOZ2		JOZE		KATO		KRAW		LAMA		WROC	
ITRF2000																					
N	a	σ_a		2.30	0.14	2.75	0.13	-0.81	0.24	1.93	0.21	2.83	0.19	2.17	0.19	2.77	0.16	2.04	0.16	5.89	0.12
	b	σ_b	[mm]	-0.03	0.00	-0.02	0.00	-0.02	0.00	-0.04	0.00	-0.03	0.00	-0.05	0.00	-0.03	0.00	-0.03	0.00	-0.03	0.00
	A	σ_A		0.22	0.10	0.31	0.09	0.56	0.16	0.98	0.15	0.89	0.13	0.95	0.13	2.82	0.12	0.16	0.11	0.51	0.09
	φ	σ_φ	[°]	-149.4	26.4	-8.5	17.5	-165.9	16.4	165.1	8.2	-114.2	8.4	-121.5	8.5	-75.1	2.3	-90.6	41.7	-85.7	9.8
E	a	σ_a		-1.55	0.11	-2.21	0.11	0.11	0.17	0.53	0.12	0.79	0.17	-3.46	0.13	-0.91	0.15	-0.44	0.14	-1.65	0.23
	b	σ_b	[mm]	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	A	σ_A		0.39	0.08	0.33	0.08	0.53	0.12	0.59	0.08	0.72	0.12	1.10	0.09	1.12	0.10	0.49	0.10	0.76	0.16
	φ	σ_φ	[°]	90.4	11.6	168.3	13.9	166.6	12.6	80.8	8.5	80.2	9.3	77.8	4.7	-96.9	5.3	173.2	11.8	60.9	10.5
U	a	σ_a		-8.64	0.71	-1.89	0.66	3.37	0.79	-10.25	0.82	1.47	0.78	-3.51	0.79	-6.13	0.67	-6.57	0.81	-10.34	0.55
	b	σ_b	[mm]	0.00	0.00	-0.02	0.00	0.01	0.01	0.01	0.00	0.02	0.00	-0.03	0.00	0.00	0.00	0.04	0.00	0.03	0.00
	A	σ_A		2.93	0.50	5.61	0.47	0.88	0.55	2.07	0.59	4.34	0.55	3.64	0.55	3.05	0.47	3.48	0.57	5.04	0.38
	φ	σ_φ	[°]	12.7	9.7	102.6	4.8	49.2	35.4	-4.7	15.6	98.5	7.2	6.2	8.8	169.0	8.8	102.9	9.4	114.5	4.4
ITRF2005																					
N	a	σ_a		1.99	0.11	0.87	0.08	0.87	0.08	-0.03	0.18	0.33	0.13	-0.93	0.13	0.57	0.10	0.39	0.22	-1.76	0.10
	b	σ_b	[mm]	-0.01	0.00	-0.01	0.00	-0.01	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00
	A	σ_A		0.39	0.07	0.36	0.05	0.44	0.05	0.45	0.13	0.71	0.09	0.85	0.09	2.19	0.07	0.40	0.15	0.35	0.07
	φ	σ_φ	[°]	126.3	10.8	119.3	8.5	134.5	7.1	-155.6	16.4	174.5	7.6	0.6	6.2	-164.6	1.8	159.2	22.2	-160.8	11.7
E	a	σ_a		2.40	0.08	2.72	0.09	1.30	0.08	3.63	0.19	1.51	0.11	1.61	0.11	1.75	0.10	1.99	0.11	1.95	0.38
	b	σ_b	[mm]	-0.01	0.00	-0.01	0.00	-0.01	0.00	-0.04	0.00	-0.01	0.00	0.00	0.00	-0.01	0.00	-0.02	0.00	0.00	0.00
	A	σ_A		0.10	0.06	0.05	0.07	0.40	0.06	0.29	0.13	0.44	0.08	0.55	0.08	0.97	0.07	0.11	0.08	0.42	0.27
	φ	σ_φ	[°]	-58.4	33.7	29.7	75.1	104.4	7.5	58.6	26.8	11.9	10.2	34.1	8.1	-161.8	4.2	-159.5	40.1	13.8	26.0
U	a	σ_a		7.60	0.42	3.92	0.34	-6.07	0.33	-2.13	0.76	-5.15	0.48	8.87	0.36	6.86	0.41	-7.14	0.62	6.33	0.38
	b	σ_b	[mm]	0.01	0.00	0.01	0.00	0.01	0.00	0.08	0.00	0.00	0.00	-0.04	0.00	-0.01	0.00	0.08	0.00	0.01	0.00
	A	σ_A		1.18	0.30	0.90	0.24	0.44	0.24	4.22	0.53	1.93	0.34	2.36	0.25	2.77	0.29	1.61	0.44	2.56	0.26
	φ	σ_φ	[°]	-157.4	14.5	-167.6	15.3	174.4	30.6	-169.0	7.3	88.5	10.1	-162.6	6.2	-167.4	5.9	-159.5	15.7	-166.2	6.0

Calculated standard deviation (σ) as a difference between the EPN solutions and the matched functions values included presents Table 3. The smaller σ is defined function is better fitted. Compare of standard deviations for ITRF2000 and ITRF2005 period clearly visible is that for majority of stations smaller values are for ITRF2005 period.

Table 3. Standard deviation of parameters of fitted function

Station	**GPS Week**	**σ_N [mm]**	**σ_E [mm]**	**σ_U [mm]**
BOGI	1143-1399	1.0	0.8	5.1
	1400-1631	0.8	0.7	3.2
BOGO	1143-1399	1.0	0.9	5.2
	1400-1631	0.7	0.6	2.5
BOR1	1143-1302	0.0	0.0	0.1
	1303-1399	1.0	0.8	2.2
	1400-1631	0.6	0.7	2.5
JOZ2	1143-1399	1.1	0.7	5.0
	1400-1631	1.4	1.4	5.7
JOZE	1143-1399	1.1	1.1	5.7
	1400-1631	0.9	0.8	3.5
KATO	1143-1399	1.2	0.8	5.0
	1400-1631	0.9	1.1	2.6
KRAW	1143-1399	1.1	1.0	4.6
	1400-1631	0.7	0.8	3.0
LAMA	1143-1399	1.1	0.9	5.8
	1400-1631	1.6	0.8	4.7
WROC	1143-1399	1.0	0.8	4.3
	1400-1631	0.8	1.1	2.8

For each station the largest oscillation around the mean value was observed in Up component. It is particularly evident at stations where during the analyzed period there were few changes of antenna or receiver (KATO, LAMA). For example at LAMA there were six changes of antenna/receiver or software (http://epncb.oma.be). But there is clearly seen a large increase of accuracy and consistency of all-time series after introduction ITRF2005 (different way of network solving, larger number of reference stations, different method of antenna calibration).

5. RESULTS - PART 2 (EPN REPROCESSING)

Routine data analysis is affected by correction models, analysis strategies, software packages or the reference frame changes (ITRFxx). Consistent coordinates using identical standards for the entire period of time can only by generated by reprocessing (Völksen 2010). Currently available is first part of reprocessing including 834-1408 GPS Weeks. For this paper author take into account period 1143-1399 GPS Week, to compare it with routine data analysis during ITRF2000 operation.

Schema of realization and methodology was adopted the same as for data in previous part. Figures 6-8 presents chart of EPN reprocessing data, Table 4 contains parameters of fitted function:

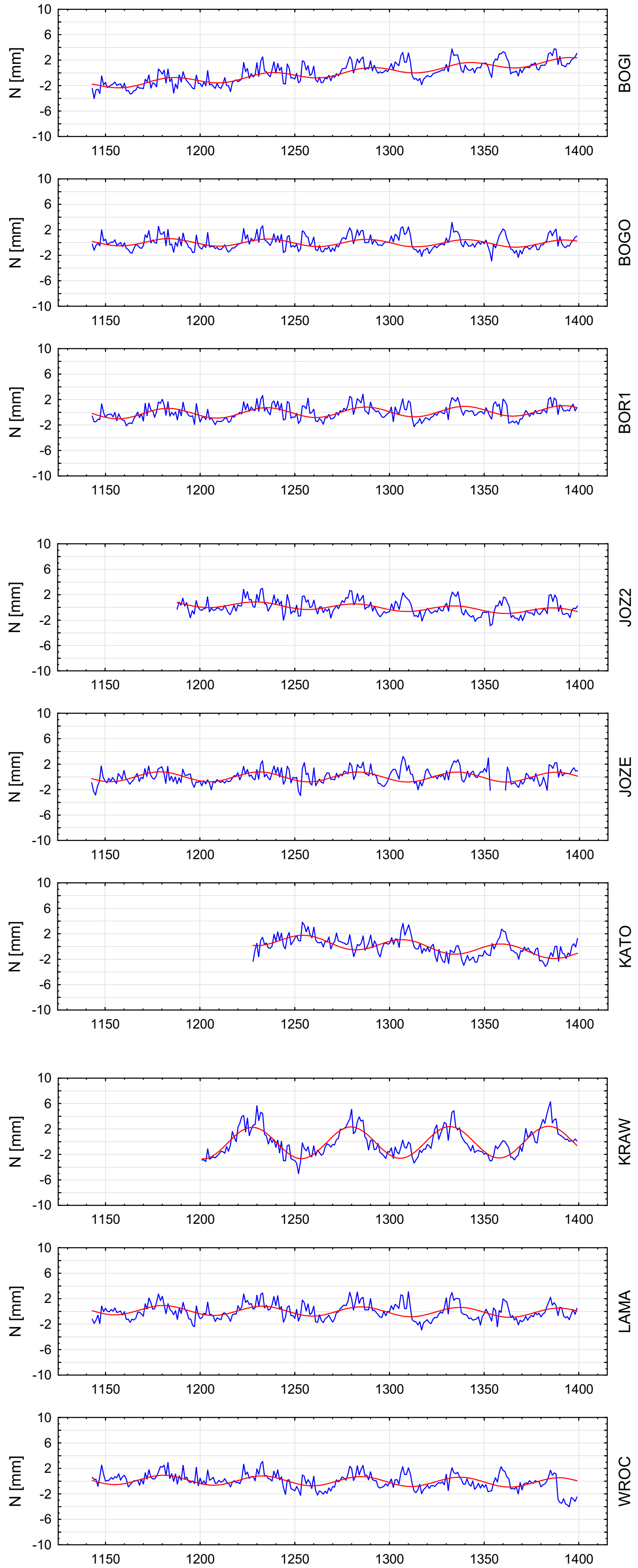

Fig. 6. North component with fitted function (reprocessing)

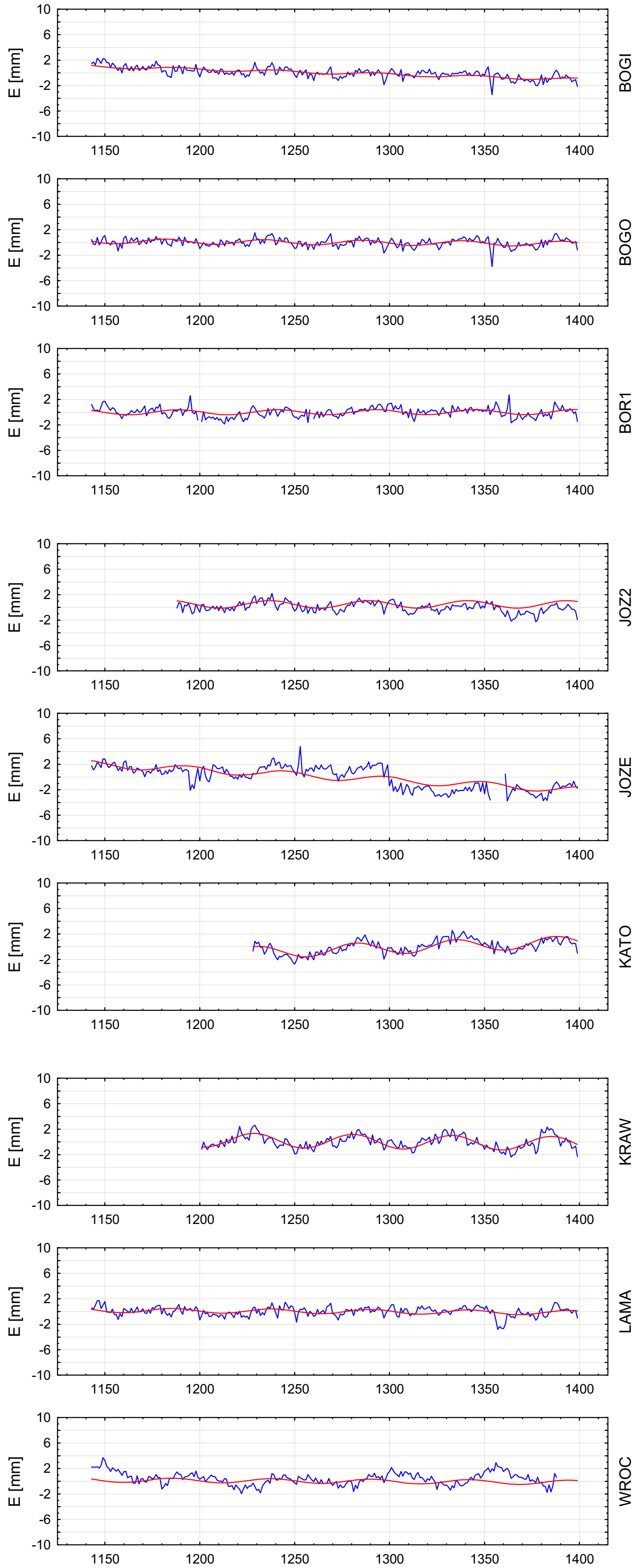

Fig. 7. East component with fitted function (reprocessing)

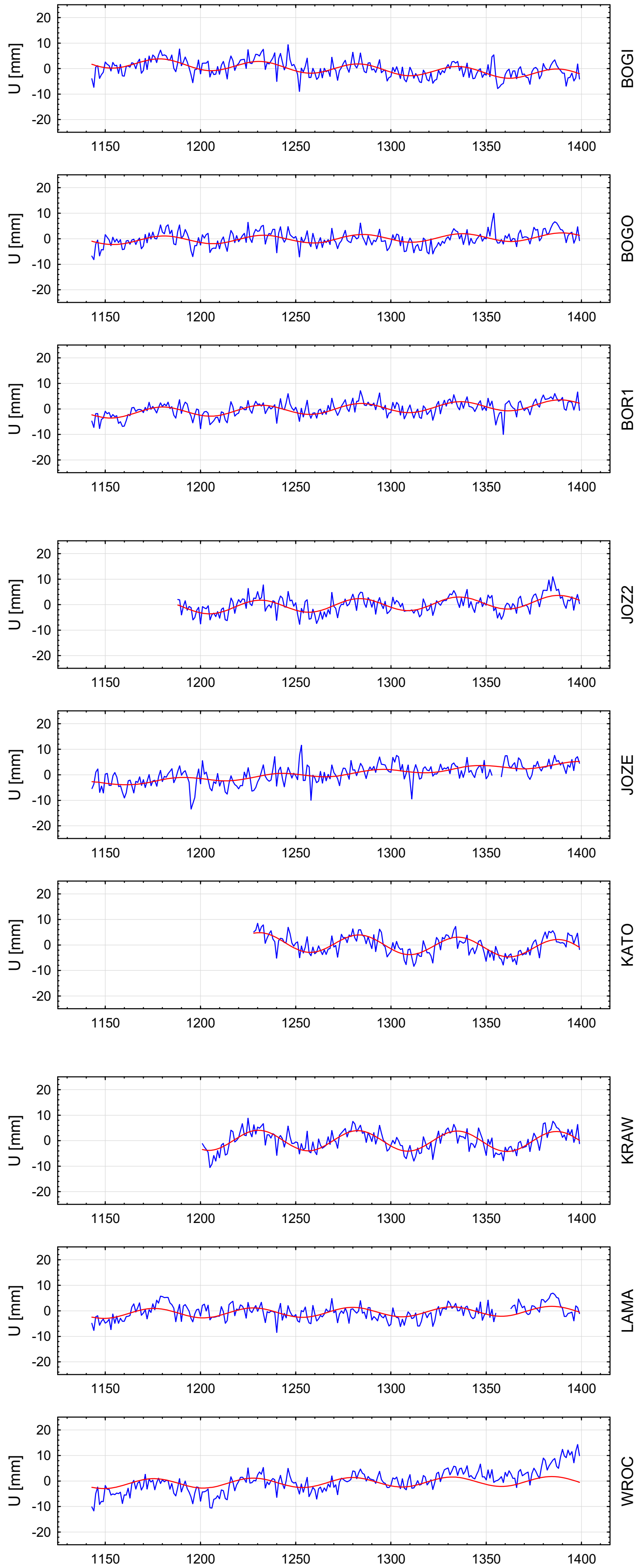

Fig. 8. Up component with fitted function (reprocessing)

Station				BOGI		BOGO		BOR1		JOZ2		JOZE		KATO		KRAW		LAMA		WROC	
N	a	σ_a		-1.99	0.13	0.08	0.13	-0.25	0.12	0.61	0.15	0.03	0.16	1.16	0.17	-0.23	0.18	0.24	0.14	0.88	0.14
	b	σ_b	[mm]	0.02	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
	A	σ_A		0.61	0.09	0.58	0.09	0.79	0.08	0.52	0.11	0.78	0.11	0.97	0.12	2.48	0.13	0.75	0.10	0.43	0.10
	φ	σ_φ	[°]	153.8	8.8	161.9	8.9	167.9	6.1	154.0	11.6	-165.4	8.3	-104.8	7.1	-99.7	2.9	-177.6	7.7	-164.0	13.5
E	a	σ_a		1.02	0.08	0.21	0.07	-0.01	0.10	0.47	0.09	2.06	0.18	-0.93	0.11	0.31	0.10	0.20	0.08	1.16	0.24
	b	σ_b	[mm]	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
	A	σ_A		0.21	0.05	0.39	0.05	0.40	0.07	0.59	0.06	0.53	0.13	0.95	0.07	1.11	0.07	0.35	0.06	1.15	0.17
	φ	σ_φ	[°]	129.7	14.5	176.4	7.6	127.8	10.5	107.0	5.9	98.9	14.0	66.2	4.5	-107.4	3.7	149.2	9.7	16.6	8.3
U	a	σ_a		2.45	0.34	-0.73	0.33	-1.73	0.28	-1.30	0.36	-3.50	0.39	1.25	0.40	0.20	0.38	-1.09	0.33	-4.89	0.31
	b	σ_b	[mm]	-0.02	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.03	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.04	0.00
	A	σ_A		2.05	0.24	1.59	0.23	1.96	0.20	2.51	0.26	1.02	0.27	3.64	0.28	3.98	0.27	1.89	0.24	2.66	0.22
	φ	σ_φ	[°]	-165.4	6.6	183.2	8.4	-169.0	5.8	145.9	5.8	124.4	15.4	60.6	4.5	-120.1	3.9	-140.7	6.9	-168.2	4.7

Table 4. Parameters of fitted function (reprocessing)

A reprocessing data shows couple of interesting results. First of all analyzed time series have much less number of random fluctuations. Due to this fact analyzed function is better slotted to reprocessing data charts, than to routine data analysis. It causes also smaller quantities of standard deviations (Table 4). Also reprocessing almost eliminates constant long-term shift of coordinates, which represents chart slope to x (time) axis (parameter b).

For all of analyzed station the biggest amplitude for each component occurred on KRAW (1.1-4.0 mm) and KATO (1.0-3.6 mm) stations. These stations are located the southernmost of all analyzed in this paper and distance between them is only 66 km. It could be explained by local, south tectonic plate movement. Rest of stations does not prove such big amplitudes after reprocessing.

Table 5. Mean square errors of parameters of fitted function (reprocessing)

Station	σ_N **[mm]**	σ_E **[mm]**	σ_U **[mm]**
BOGI	1.0	0.6	2.6
BOGO	1.0	0.6	2.6
BOR1	0.9	0.8	2.2
JOZ2	1.0	0.6	2.3
JOZE	1.2	1.4	4.4
KATO	1.1	0.8	3.0
KRAW	1.7	0.9	3.2
LAMA	1.1	0.7	4.3
WROC	1.2	2.2	3.7

In the event of standard deviations (Table 5) comparison of routine data analysis and reprocessing shows that analysed function is better fitted do reprocessing data for major of stations. It is result of unique data analysis strategy applied in reprocessing.

6. SUMMARY

An analysis of daily coordinates' time series solutions of GPS reference stations with a selection of approximating function have already been conducted. Performed in this study analysis of weekly solutions shows a wide variety of stations' coordinates. Some stations has a very clearly visible repeatable annually movements which has specific character typical its areas. In addition some time series has also a linear nature of changes resulting probably from station moves inside ETRF frame. In addition the author shown that ITRF2005 frame is characterized by a higher accuracy than the previous applied coordinates frame. Also results comparison of routine data analysis and reprocessing data shows, that new solution gives more stabilized and consistent results. So for further analysis for geodynamic studies of local and global movements of the earth's crust or other studies which uses time series analyses EPN reprocessing data should be used.

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