

Some Preliminary Results of an Analysis of Coordinates Time Series of RTK Network LitPos

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Abstract. LitPOS (Lithuanian Positioning System), the network of permanent reference GNSS stations, became operational in July 2007. It provides data both for real-time and post-processing applications. Coordinate time series were obtained from LitPOS reprocessing data for years 2008–2014. The reprocessing was done using Bernese 5.2 software. The analysis of time series was done with Matlab routine “GITSA” (GPS Interactive Time Series Analysis). In this paper the review of obtained coordinate time series will be given, in addition error tracking and some of the results will be assessed. An analysis of discontinuities and outliers with possible problem solutions will be provided. As a result more consistent accumulated multi-year solution is presented.

Keywords: coordinates time series, LitPOS, Bernese 5.2 software, GITSA, FODITS.

Conference topic: Technologies of Geodesy and Cadastre.

Introduction

LitPOS (Lithuanian Positioning System), the network of permanent reference GNSS stations, became operational in July 2007. It provides data both for real-time and post-processing applications. LitPOS stations cover the whole territory of Lithuania. Total number of LitPOS GNSS stations is 30 (till 2015 was 25). Also LitPOS network includes 3 ASG-EUPOS (Poland) and 6 LATPOS (Latvia) stations to ensure measurement quality at the borders (Wajda *et al.* 2008; Ryczywolski *et al.* 2010; Zvirgzds 2012; Dobelis, Zvirgzds 2016). Its main objective is to provide the 24/7 real time precise positioning service with national-wide coverage for the geodetic, cartographic, cadastral and construction applications.

During its operational period large amount of data was gathered what gives a possibility to construct reliable coordinates time series. Coordinates time series analysis is an important part of Geodesy and Geodynamics studies, especially when continuous GPS observations are used to explore very low rate deformations. In this domain, having precise and robust tools for processing and analyzing position time series is a prerequisite (Goudarzi *et al.* 2015). Having long time series of station coordinates, it is possible to analyze them searching for discontinuities, velocity changes, and outliers. These are caused by various reasons and represented in time series like gaps and offsets (jumps) (Klos *et al.* 2015; Williams *et al.* 2004; Caporali 2003; Kenyeres, Bruyninx 2009). Main reasons for outliers and discontinuities are equipment change, environmental conditions like snow coverage or birds on antenna radome, earthquakes.

In this study Matlab program “GITSA” (GPS Interactive Time Series Analysis) (Goudarzi 2016) and FODITS (Find Outliers and Discontinuities in Time Series) program of Bernese GNSS Software Version 5.2 will be used to analyse the coordinates time series of 2008–2014 year period of LitPOS RTK network data (Kenyeres 2006).

“GITSA” software

“GITSA” is an open source scientific software developed for processing, analysis and visualization of GPS time series for Geodesy and Geodynamics studies. “GITSA” software has been developed at the Center for Research in Geomatics (CRG), Laval University using MATLAB language (Goudarzi *et al.* 2012, 2015).

MATLAB script `snx2gtv` (developed by Mahommad Ali Goudarzi) is created to read the SINEX files, and makes coordinates input files in the *.gtv format for the GITSA software. The script reads both the estimate and the matrix-estimate blocks of the SINEX files, and therefore, the output *.gtv files contain coordinates and their corresponding coefficients of the upper triangular covariance matrix. This script does not change coordinate system of the estimated coordinates or covariance matrices.

“FODITS” program

The program FODITS, which is embedded in the Bernese GNSS Software Version 5.2, has been designed to analyze and clean coordinate time series (Haritonova *et al.* 2014; Haritonova *et al.* 2015) in an automated way (see Ostini 2007). The program FODITS verifies the significance of lists of predefined events such as a list of equipment changes and a list of worldwide registered earthquakes, identifies discontinuities and outliers in the time series (Ostini *et al.* 2008), and creates the metadata to obtain high accuracy multi-year solutions and cleaned coordinate time series (Ostini 2012).

FODITS computes approximated coordinates and velocities of the stations, but these results should not be taken as the final solution, because FODITS does the analysis station-by-station, so the covariance information and the impact of other estimated parameters are neglected (Dach *et al.* 2015).

Preliminary assessment of coordinate time series

The preliminary analysis of time series is made by Matlab program “GITSA”. After combining weekly solutions for year 2008 the huge jump in all LitPOS network stations for the same week was detected (Fig. 1). The reason of this jump was malfunction of one fiducial station MDVJ. To solve this problem, MDVJ station was eliminated for GPS week 1497 (excluded in STA file field “Handling of station problems”).

Combining daily solutions for year 2008–2011 two more jumps in all LitPOS network stations for the same epochs were detected (Fig. 2). The cause of this leap was wrong observations of one fiducial station – RIGA. Solution of this problem was to eliminate RIGA station for 2010 179 and 2011 89 days.

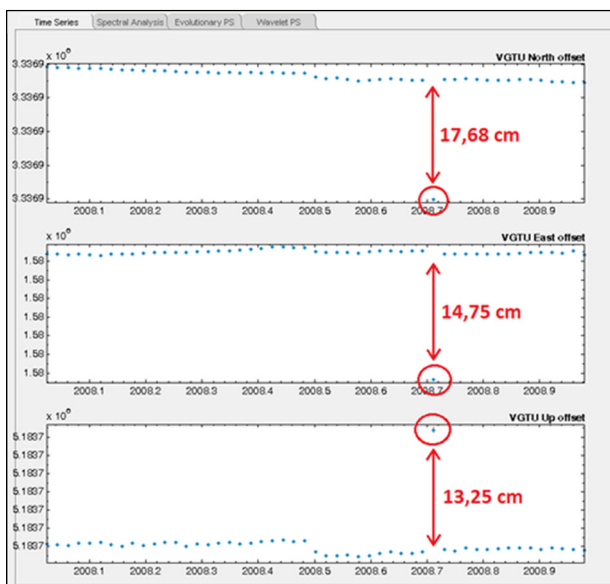


Fig. 1. Outlier induced by MDVJ station malfunction

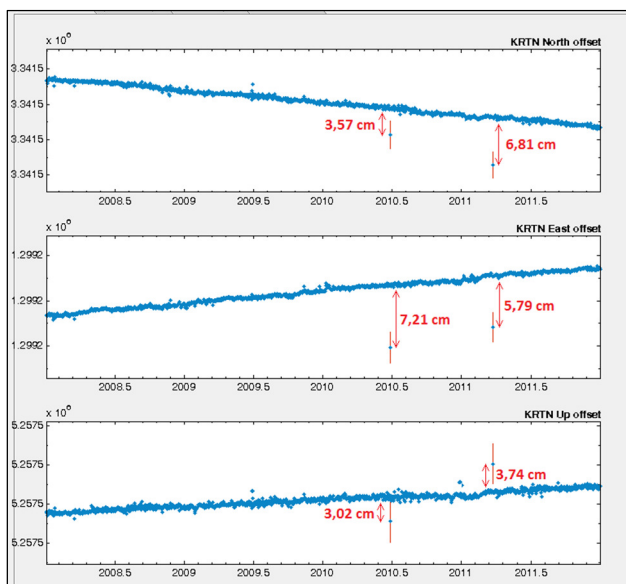


Fig. 2. Outliers induced by RIGA station

Further data processing for 2008–2011 year showed more errors related with MDVJ station. Because of MDVJ station daily solutions causing big outliers, it was decided to eliminate this station from calculations for epochs: 2009 22-35, 2009 323-325, 2010 328-2011 59 (Fig. 3 and Fig. 4).

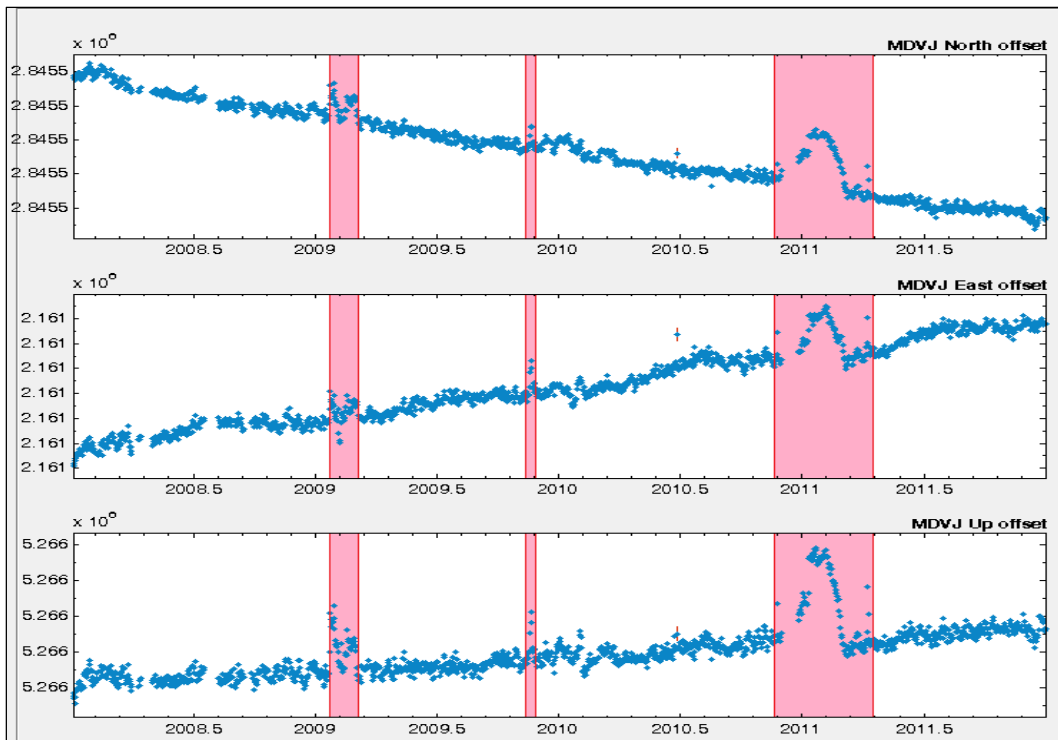


Fig. 3. Outliers induced by MDVJ station malfunction

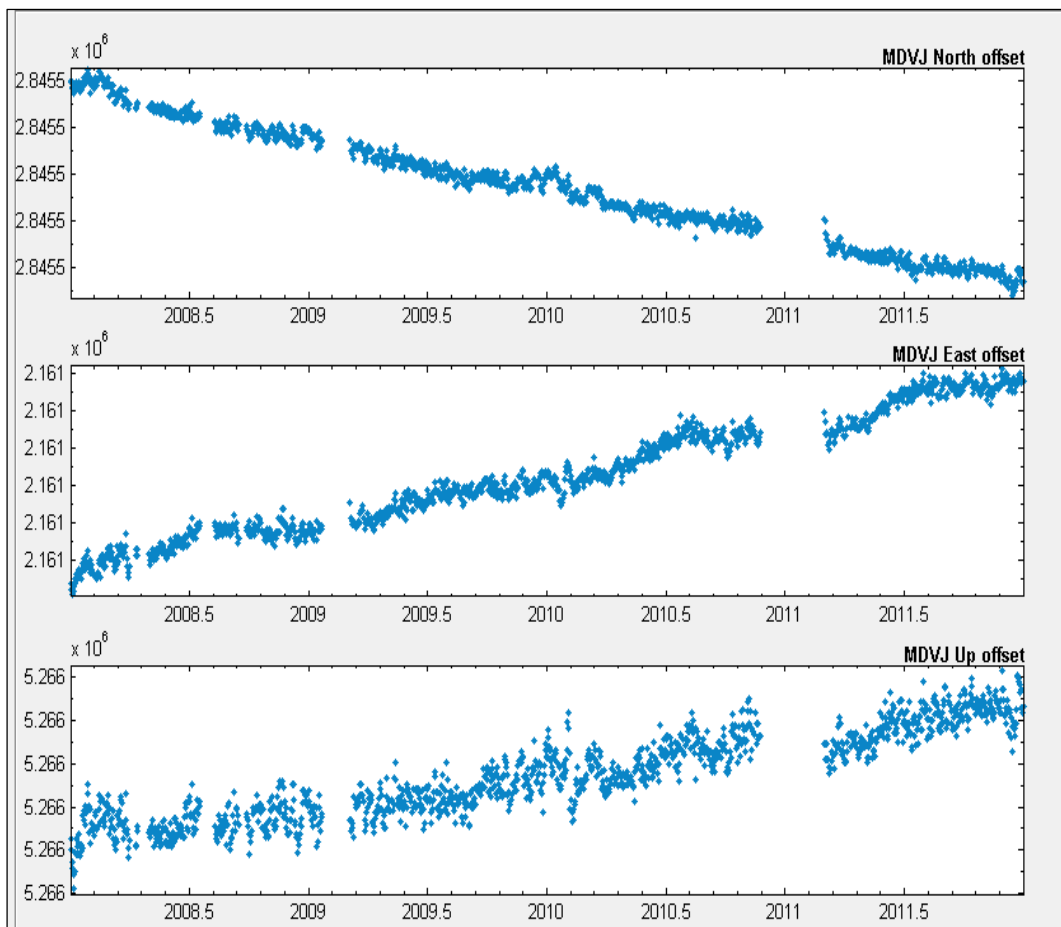


Fig. 4. Gaps showing excluded data

Quality assessment of LitPOS network

Quality analysis was made for 25 stations of LitPOS network. Outlier analysis with GITSA is performed by setting the confidence level parameter (in percentage value). In this study confidence level was set to 95%. The detected outliers are marked in coordinate time series plots for north, east and up components. It should be noted that analysis has to be done for each station separately. Example of distinguished outliers shown at Fig. 5 and Fig. 6. Highlighted points are indicated outliers. Results for all stations are shown in the Table 1.

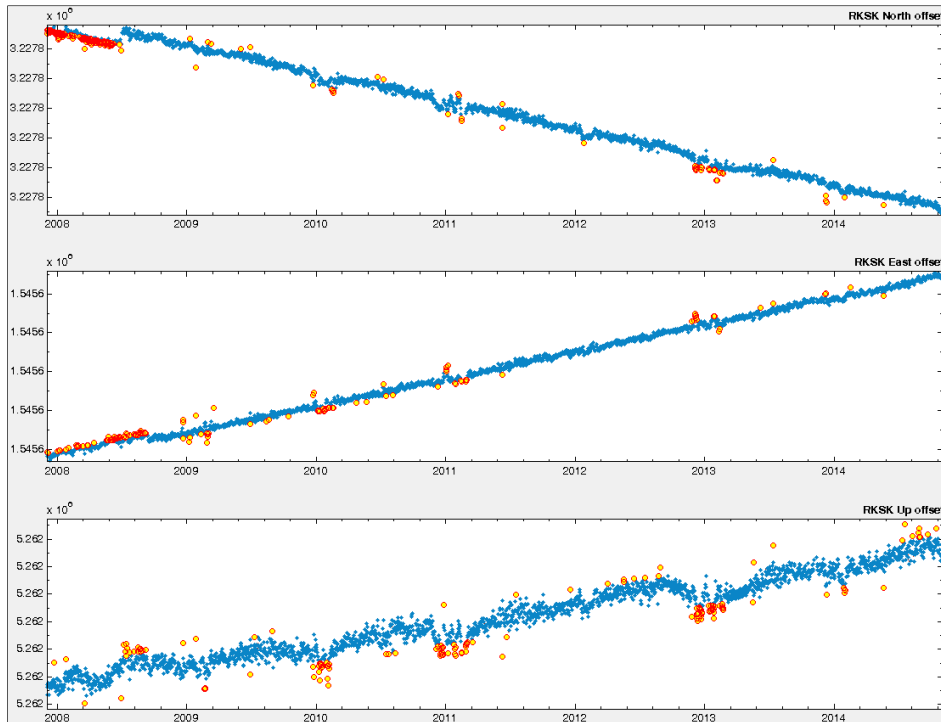


Fig. 5. Highlighted outliers for RSKS station

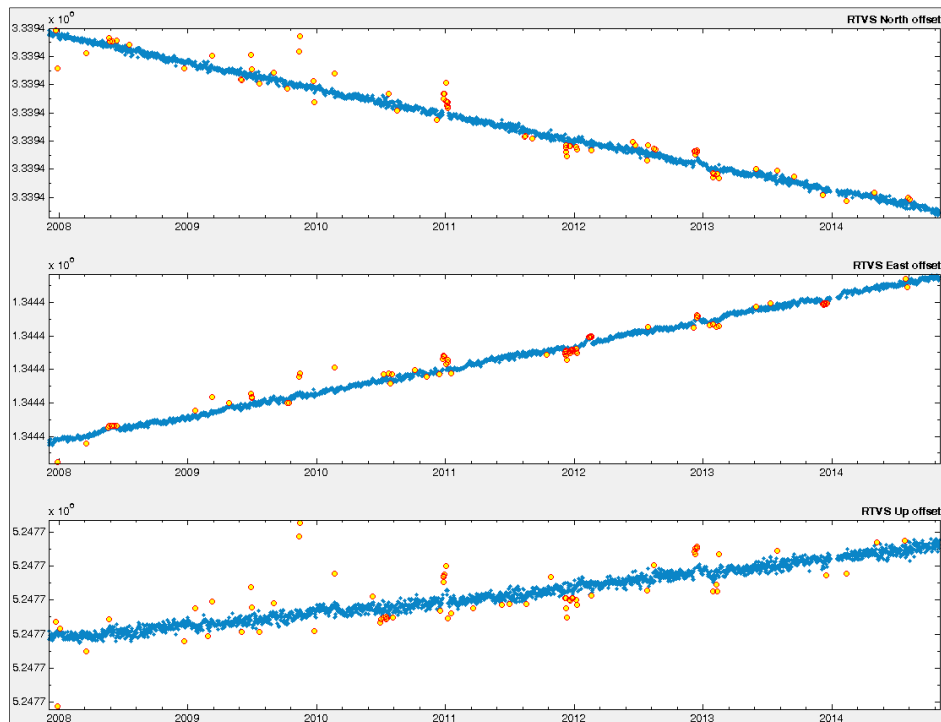


Fig. 6. Highlighted outliers for RTVS station

Table 1. Information on detected outliers and calculated standard deviations of stations by GITSA

Station name	Number of epochs	Number of Outliers	Percentage of detected data as outliers	Standard dev., mm		
		N/E/U		N	E	U
ALYT 10803M001	2464	125/130/111	5%	1.4	0.8	1.9
BIRZ 10804M001	2348	122/109/144	6%	1.4	0.8	2.1
DKST 10806M001	2225	177/122/77	8%	2.0	1.1	2.7
ELKT 10807M001	2390	134/89/114	6%	1.3	0.8	1.8
JNSK 10808M001	2386	156/103/121	7%	1.6	0.9	2.2
KAUN 10809M001	2484	120/130/126	5%	1.2	0.7	1.8
KEDN 10810M001	2462	122/115/139	6%	1.3	0.7	1.9
KELM 10811M001	2427	105/165/51	7%	1.5	0.9	2.2
KRTN 10812M001	2500	132/122/122	5%	1.8	0.9	2.5
MAZK 10813M001	2476	120/102/113	5%	2.4	1.2	3.5
MRJM 10814M001	2447	106/178/132	7%	1.2	0.7	1.9
PNVZ 10816M001	2506	146/137/129	6%	1.3	0.8	1.9
RTVS 10817M001	2450	72/79/66	3%	1.2	0.7	1.8
RKSK 10818M001	2485	171/137/142	7%	1.3	0.8	2.0
SAKI 10819M001	2142	101/121/104	6%	1.3	0.7	1.8
SAUL 10820M001	2326	117/118/116	5%	1.3	0.8	1.9
SILT 10821M001	2488	117/105/141	6%	1.6	0.9	2.2
SLCN 10822M001	2482	110/121/103	5%	1.4	0.8	2.0
SVNL 10823M001	2372	100/103/102	4%	1.4	0.9	2.1
TAUR 10824M001	2492	131/98/90	5%	2.1	1.1	2.9
TELS 10825M001	2453	106/132/100	5%	1.5	0.9	2.2
UTEN 10827M001	2483	125/103/133	5%	1.4	0.8	2.0
VARN 10828M001	2274	102/124/89	5%	1.3	0.7	1.7
VEIS 10829M001	2458	84/119/139	6%	1.3	0.7	1.8
VGTU 10830M001	2444	131/94/101	5%	2.2	1.1	2.9
VLNS 10801M001	2228	130/133/135	6%	1.8	1.0	2.4

The biggest number of outliers for LitPOS network stations was found at RKSK station. At the north component 171 epochs were distinguished as outliers, east – 137 and up – 142. Smallest number of outliers detected at RTVS station. North component have 72 outliers, east – 79 and up – 66. Standard deviation analysis have shown that deviations varies between 1.2–2.4 millimeters in the North component, 0.7–1.2 mm in the East component and 1.7–3.5 mm in the Up component.

In order to make a successful program FODITS run it is necessary to prepare some initial files. In this study program run was made on ADDNEQ2 plot file with residuals (*.plt). ADDNEQ2 program creates *.plt files for each day separately, so it is necessary to combine these files into one. Additionally, it is necessary to have coordinate, velocities and station information files. Information about earthquakes was gathered from USGS earthquakes lists (USGS earthquake catalog 2017). Further options defines the criterions of analysis. In this case, two options should be emphasized: threshold for relative improvement (set value: 0.005) and N* sigma criterion for outliers (set value: 5.0) in panel FODITS 5: Statistical tests.

Three output files conclude about successful program run: time series event list, updated station information file and plot file containing corrected residuals. Event list file contains information about event epoch length, amplitude (Poutanen *et al.* 2003) of north, east and up components, type and significance. In STA file graph Type 003: handling of station problems, FODITS adds exclusions for significant events (Dach *et al.* 2015). Examples of results for RTVS and RKSK stations are represented in Figure 7 and Figure 8 (vertical lines picture the outliers). Some results of coordinate time series analysis by FODITS are presented in the Table 2.

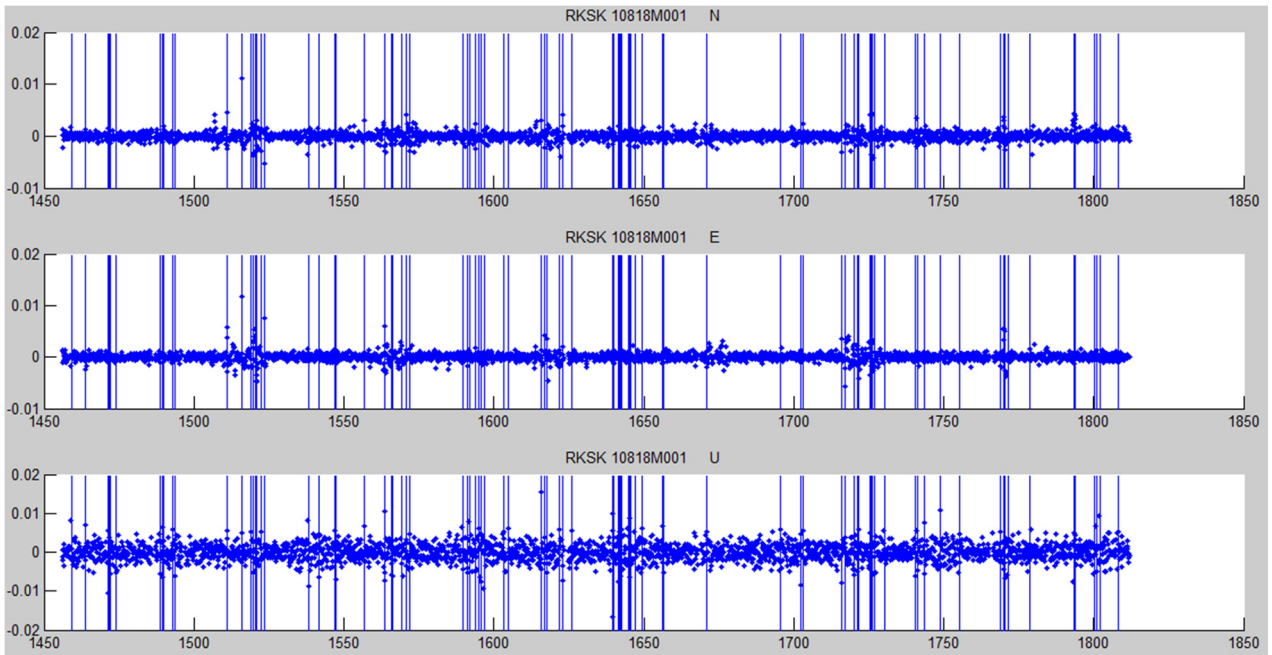


Fig. 7. Highlighted outliers for RSKK station

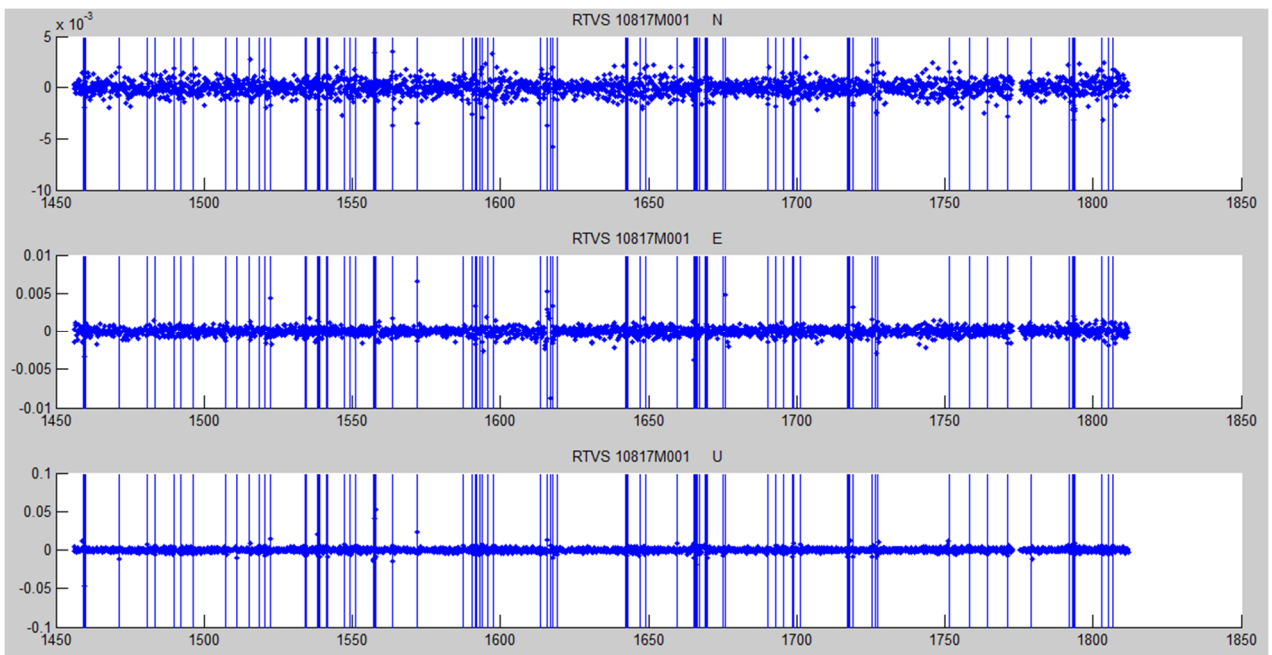


Fig. 8. Highlighted outliers for RTVS station

Table 2. Information on detected outliers and discontinuities by FODITS

Station name	Number of epochs	Number of outliers	Number of discontinuities
ALYT 10803M001	2464	100	1
BIRZ 10804M001	2348	86	2
DKST 10806M001	2225	91	3
ELKT 10807M001	2390	100	3
JNSK 10808M001	2386	100	3
KAUN 10809M001	2484	100	1
KEDN 10810M001	2462	100	2

End of Table 2

Station name	Number of epochs	Number of outliers	Number of discontinuities
KELM 10811M001	2427	100	2
KRTN 10812M001	2500	100	2
MAZK 10813M001	2476	100	2
MRJM 10814M001	2447	88	2
PNVZ 10816M001	2506	100	3
RTVS 10817M001	2450	100	1
RKSK 10818M001	2485	100	3
SAKI 10819M001	2142	88	1
SAUL 10820M001	2326	93	1
SILT 10821M001	2488	100	2
SLCN 10822M001	2482	100	1
SVNL 10823M001	2372	100	1
TAUR 10824M001	2492	100	4
TELS 10825M001	2453	100	1
UTEN 10827M001	2483	100	2
VARN 10828M001	2274	100	1
VEIS 10829M001	2458	100	2
VGTU 10830M001	2444	100	9

Numbers of outliers detected are similar to results received by GITSA software. However, due to difference of parameters used in the analysis, it is impossible to compare accuracies of outlier detection. Besides, since FODITS uses more files to gather information about stations, it gives more detailed results about events and their types in time series.

Conclusions

1. During the quality analysis of LitPOS stations by GITSA software, biggest number of outliers was detected for RKSK station (north component 171, east – 137, up – 142), smallest for RTVS station (north component 72 outliers, east – 79 and up – 66). However, GITSA did not involve equipment change information in outlier detection. For this reason coordinate offset of RKSK station was identified as outlier.

2. Quality analysis made by program FODITS gave more detailed results about events in coordinate time series. FODITS identifies event in coordinate time series and creates an event list file, where information about event epoch length, amplitude for north, east and up components, type and significance is stored. Also FODITS updates station information file, which can be used in further ADDNEQ2 runs to exclude detected outliers from solutions.

3. Coordinate time series analysis is very useful for detecting and identifying various errors and visualizing position change during time flow. Both programs are worthy attention and useful for time series analysis, but for different purposes. GITSA is easier to operate and provides instant visualization. FODITS does analysis for all stations at once and provides data which can be used in further reprocessing steps.

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