COORDINATE TIME SERIES OF THE GPS PERMANENT STATIONS LOCATED IN THE MOUNTAINS

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Abstract

Many geodynamical networks, especially located in mid- and eastern Europe are covering mountain areas. The location of these nets is obvious because the movements that upthrusted the terrain may still take place. Hence, there is need of monitoring those movements because of possible threats it generates i.e. earthquakes, terrain slides, further upthust etc. But these stations (hardware) may be affected by the conditions that occurs especially in mountain areas, hence coordinate time series of the permanent stations will be distorted. In this paper, author presented time series of two points located on Biskupska Kupa (BISK) and Snezka (SNEC) moutains, and how these time series have been affected by those conditions. Author also described possible strategies of dealing with bad time series.

Key words

coordinate time series, permanent station, mountains

1 LOCATION OF BISK AND SNEC PERMANENT STATIONS

BISK and SNEC are the GPS permanent stations, established and managed by the Institute of Rock Structure and Mechanics of the Academy of Sciences of the Czech Republic in Prague [7]. Both stations were included to EPN (EUREF Permanent Network) on April 25, 2005.

Station BISK was established on September 2001 on the top of stone tower that was built on the top of Biskupska Kupa mountain which is located on Czech-Polish border, east of Zlate Hory, and south of Glucholazy. Moutain height is 889 meters above sea level, the tower is 18 meters height. There are no special weather conditions in this area.

Station SNEC was established on August, 2001 on top of the old brick chimney filled with concrete. Snezka mountain is located on Czech-Polish border, south of Karpacz town. Its height is 1603 meters above sea level, the chimney height is 5.6 meters. This mountain has very special weather conditions with mean year temperature of about 0^{o} C, and the highest recorded temperature of 24^{o}C. It has precipitation level of mean 1000 mm per year, sum of clear visibility days is no more than 100 per year, wind speed sometimes exceeds 80 m/s. It is clear that this are very tough weather conditions mostly during winter, and they must affect coordinate time series [6].

Both stations are remote operated from Prague, and have good almost real-time monitoring system, so the supervisor is informed of any event very quickly [4, 5]. Nevertheless, if at any station occurs an event that will disturb data gathering, there is long time of response – may be longer than few days because this stations are long distant from Prague, and weather can make it impossible to get to the site. This can create gaps in time series.

2 BISK AND SNEC COORDINATE TIME SERIES

The coordinate time series for station BISK starts with the establishment of GPS equipment there, and this is from September 2001. As one can see on figure (fig. 1) there is strong correlation between weather conditions and time series. Winter time is clearly visible on the chart as outliers at the end and beginning of each year. There is also few gaps due to equipment failures and instabilities of solution. But one can see that overall trend is stable, and that time series are quite good.

Opposite situation is for SNEC permanent station, one can see from the first sight that these time series are very bad (fig. 2). As for BISK station, here one can observe outliers, but these are much grater, and lasts much longer – for about half year or even longer (as for East component, year 2005). Such big outliers are caused by large snow cap on top of the antenna during winter and early spring– according to supervisor the snow cover is more than 40 cm thick. This affects that GPS signal is greatly distorted rather than weight of snow changes position of antenna.

Here one can also see large gap at the beginning of 2006. This was caused by some instability in the receiver (the problem and solution is described at EPN website), and has been solved by replacing both receiver and antenna.

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There are also clearly visible jumps, especially for East component, of an unknown origin. The jump in Height component at the beginning of 2006 was caused by receiver and antenna change but further trend seems to be stable. But it is impossible to tell if North or East component were affected in the same way due to large outliers, and short span of recorded data. There is also a large jump in North component around the middle of year 2005, the reason of which is also unknown, but it looks that trend, after the gap, returned to its previous value.

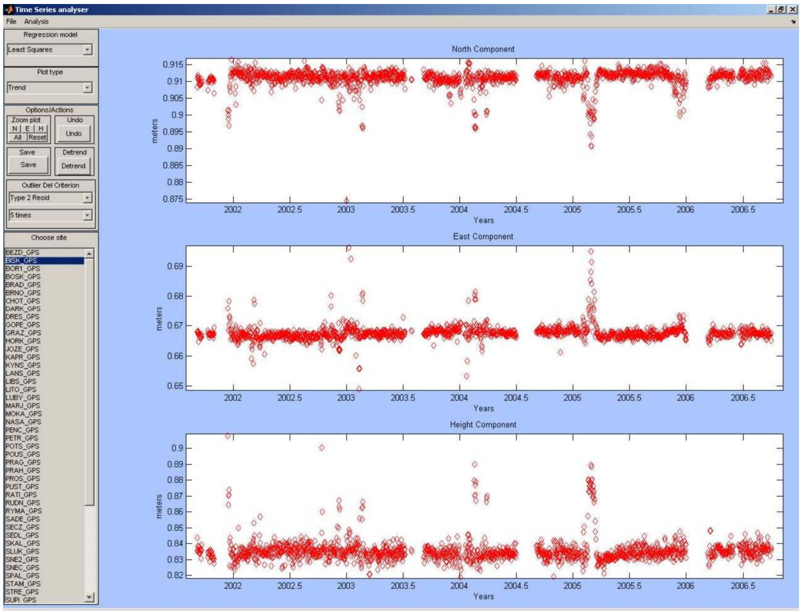

Fig. 1 BISK time series

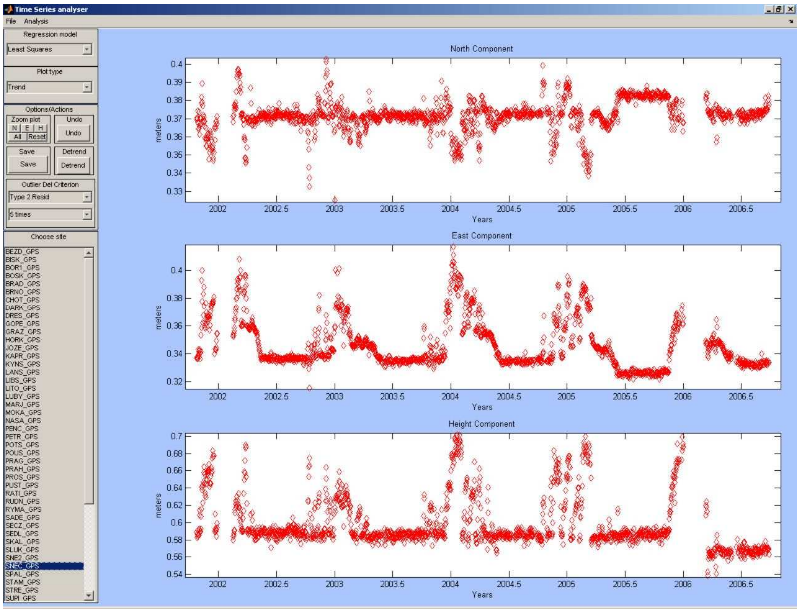

Fig. 2 SNEC time series.

3 PROCESSING TIME SERIES

The processing of coordinate time series is step-by-step procedure, one must eliminate the influence of many different factors. If there is need of calculation local velocities, the first step is to eliminate the influence of continental plate, and as for this example velocity of Eurasian plate must be removed. In this case author used NNR-NUVEL-1A plate motion model.

The second step is detection, recognition and reduction of as many periodic effects as it is possible. First and most obvious periodic effect is annual and semiannual trend, which appears in every time series acquired from GPS long time measurements (especially for permanent stations). In example chart for station WROC (fig. 3) this effect is very easy to see and detect [3].

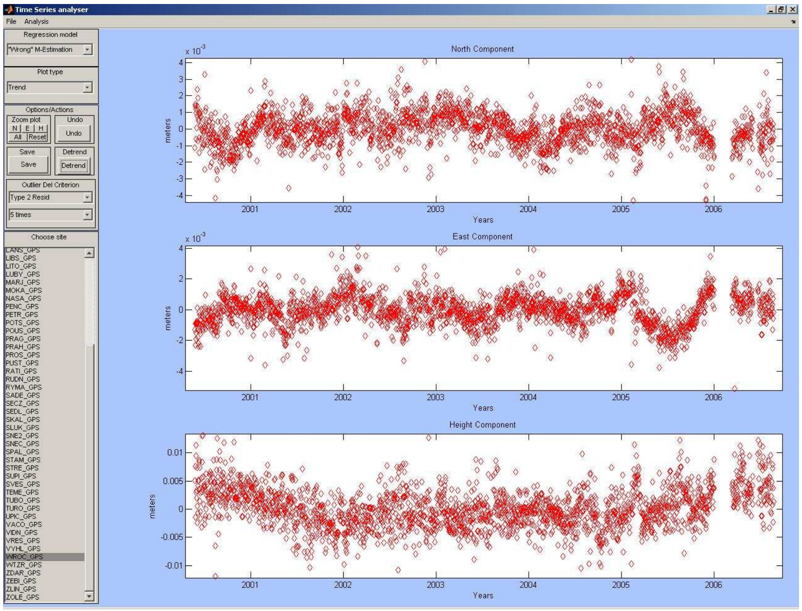

Fig. 3 WROC time series

The detection in the simplest way is performed by the Fast Fourier Transform (FFT) which calculates amplitude, period and phase of sine function [1]. Next step is reduction time series by this periodic function, and after that the whole process (FFT) is redone until calculated values of amplitude are still significant.

Next step is to find jumps that may occur in time series. This may be performed with use of Kalman Filter, but any other method that shows significant jump could be implemented. As for WROC station the method of finding such events was proposed by [3]:

- finding nearby pairs of observations for which deltas (ΔN, ΔE, ΔU) were more than twice big the RMS
- finding nearby triplets of observations with the same condition as described above
- finding nearby triplets packs of observations with same conditions
- finding nearby triplets for which trend lines are shifted more than twice big the largest or smallest RMS

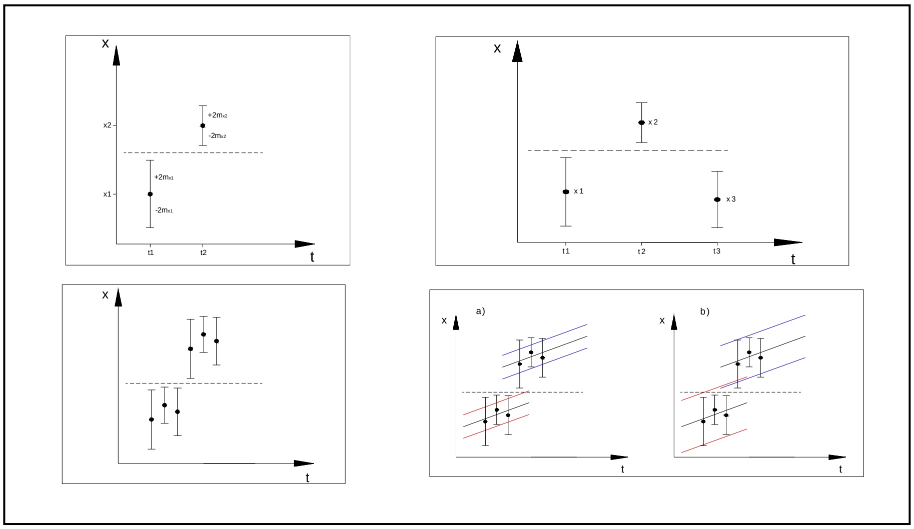

Fig 4. Detection of jumps (Kontny et al., 2006)

This method did not find any event that could affect the time series with any jumps that are significant, and would need correction for WROC station (Kontny et al., 2006). Estimated periodic effects are shown below (tab. 1), with most significant values marked with bold.

Tab 1. Periodic effects for permanent station WROC [3]

N			E			U		
Period T [week]	**Amplitude [mm]**	**Phase [DEG]**	**Period T [week]**	**Amplitude [mm]**	**Phase [DEG]**	**Period T [week]**	**Amplitude [mm]**	**Phase [DEG]**
237 (4.5 year)	**1,16**	277,3	474 (9 years)	**2,21**	61,2	474 (9 years)	**3,98**	47,8
158 (3 years)	0,49	175,3	237 (4.5 year)	0,58	-42,5	52 (1 year)	**3,80**	151,1
52 (1 year)	0,47	326,2	52 (1 year)	0,45	-283,2	47 (0.9 year)	2,90	226,8
474 (9 years)	0,45	121,9	158 (3 years)	0,44	-210,5	237 (4.5 year)	2,77	-48,2
68 (1.3 year)	0,38	95,7	47 (0.9 year)	0,32	-153,9	68 (1.3 year)	1,76	314,2

Different approach must be taken into consideration when processing stations BISK and especially SNEC. Any affect that can distort FFT must be removed from data, and as for BISK the most influent are outliers. The outliers removal process can be divided in two steps; first by cleaning points with too large RMS (any RMS more three times big the mean RMS can be cleared). Second step by deleting points for which residuals are X times bigger the mean residual (X – is multiplayer). Residuals are calculated from robust regression or regression with M-estimation, or any other that prevents from distortion from outliers [2]. This step must be taken very carefully, because one can not delete more points that it is necessary – with every good point that has been deleted valuable information is lost For station BISK the number X may be set 4, and as it s shown below this is effect satisfying (fig 5), and one can proceed with FFT.

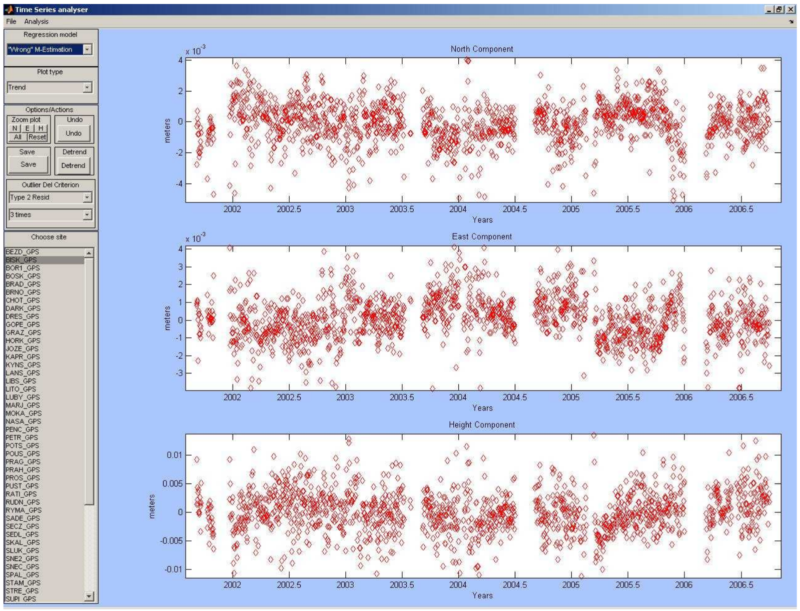

Fig. 5 BISK station cleared from outliers

SNEC requires much complicated approach, because periodic effects one wants to compute with FFT are greatly distorted and they just changed to outliers. The biggest deviations can be cleared, but it is very difficult to set the ***X*** number. Setting it as 3 does not remove all bad observations, but does not remove data that could be still useful. One could try to develop periodic function that will let corrections for at least some observations, but it would be very difficult to construct such function.

Another way could be deleting all points in time spans that are greatly distorted, so all winter data will be lost. This will provide good data for FFT, but on the other hand, huge amount of points will be deleted, hence much information will be lost, so FFT could not be able to provide valid periodic coefficients. Nevertheless, it is possible that information from winter periods is already lost, and presents noise only. In this case, removal of outliers may also remove annual periodic effect.

One can not forget about events that caused jumps, those has to be also removed if proper outlier cleaning could take place. So, the whole process of data cleaning should start with deletion of most deviated points, then jumps detection, and again outliers cleaning. After these steps one can perform FFT.

4 CONCLUSION

Stations that are located on the mountain tops can contain strong periodic effects. As it is clearly visible the worst time for any kind of measurements is winter. As for stations located in the areas where weather conditions does not divert much from those is flatlands it is moderately easy to clean data from outliers. But as for Snezka, with its local very tough weather conditions, time series are affected the most and requires much different and complicated approach, and one must keep in mind that a lot of data will be lost.

Literature

[1] Cooley, J. W. and J. W. Tukey, - *An Algorithm for the Machine Computation of the Complex Fourier Series Mathematics of Computation*, Vol. 19, April 1965, pp. 297-301

[2] Huber P.J., - *Robust Statistics*, New York, Wiley, 1981

[3] Kontny B., Szwed S., Zając M., - *Modelowanie ruchu stacji EPN/IGS Wrocław na podstawie analizy ciągów czasowych obserwacji GPS*, VIII Sympozjum „Współczesne problemy podstawowych sieci geodezyjnych", Kraków, 18-19.09.2006, Wydawnictwo AGH Kraków, (in print).

[4] Kottnauer P., Rucky A., Schenk V., Schenkova Z. - *Note to remote control of GPS observatory using GSM modem*, 2003, Acta Montana, series A, No. 24 (131), 163-165.

[5] Mantlik F., Kottnauer P., Schenk V., Schenkova Z., - *Transmission of continuously recorded data from remote GPS permanent stations to IRSM Central Unit*, 2005, Acta Geodynamica et Geomaterialia, Vol. 2, No. 3 (139), 69-73.

[6] Mantlik F., Kottnauer P., Fucik Z., - , *GNSS observace za zhoršených meteorologických podmínek a ve vysokých nadmořských výškách*, Seminář Seminář Výzkumného centra dynamiky Země, zámek Třešť, 12.-14. října 2006.

[7] Schenk V., Kottnauer P., Schenkova Z., Rucky A., Psenicka J., Rehak J. Jr., - *New permanent GPS observatories in the Czech Republic – Snezka and Biskupska Kupa*, 2002, Acta Montana, series A, No. 20 (124), 41-44.

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