Acta Geodyn. Geomater., Vol. 4, No. 4 (148), 191-200, 2007

MONITORING OF PERMANENT GPS STATIONS AT THE SUDETY MOUNTAINS

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(*Received* May 2007, *accepted* August 2007)

ABSTRACT
The aim of this paper is to show time-dependent baseline variation between GPS stations situated in South-East Poland. This study was based on daily data analysis of selected GPS stations: WROC, GOPE, MOPI, KRAW and KATO. The start date of the analysis is linked at every station with the beginning of its operation and the closing date of the operation is in 2006. The multiresolution signal decomposition method has been used to analyze the periodic terms of the time series of the above. The estimated trends enable further coordinate analysis as well as determination of site displacements at the study area.

KEYWORDS: GPS stations, velocity, wavelets, wavelet decomposition, symlet, signal trend, multiresolution signal decomposition

INTRODUCTION

Many scientific centers around the world improve and develop the knowledge of GPS signals. A consortium of many universities joined to pioneer the use of Global Positioning System to trace for example the motion of Earth's crust, earthquake detection and monitoring. An ambitious plan to use ground-based GPS receivers that operate in much the same way as the space-based receiver is already taking shape across the world. Centre of Applied Geomatics in Military University of Technology in Warsaw collects, archives and processes GPS signals registered on permanent stations in Poland and in Europe. Collecting and processing as well as documentation of GPS signals gives us sufficient data sets gathered on our servers. Final coordinates estimations are done with the Bernese 5.0 analysis software (Dach et al., 2007).

Primary aim was to investigate the length variation of selected baselines connecting permanent stations. We chose stations placed within The Sudety Mountains area, so that the vectors could cross the mountains. Three stations in Poland were chosen (KATO; WROC; KRAW), one in Slovakia (MOPI) and one in the Czech Republic (GOPE). Location of the stations is shown in Figure 1 below.

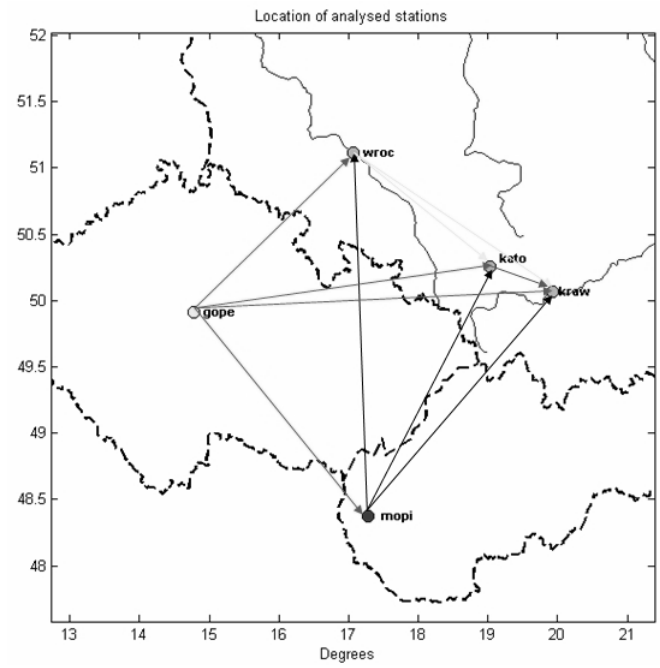


Fig. 1 Selected stations and the analyzed baselines.

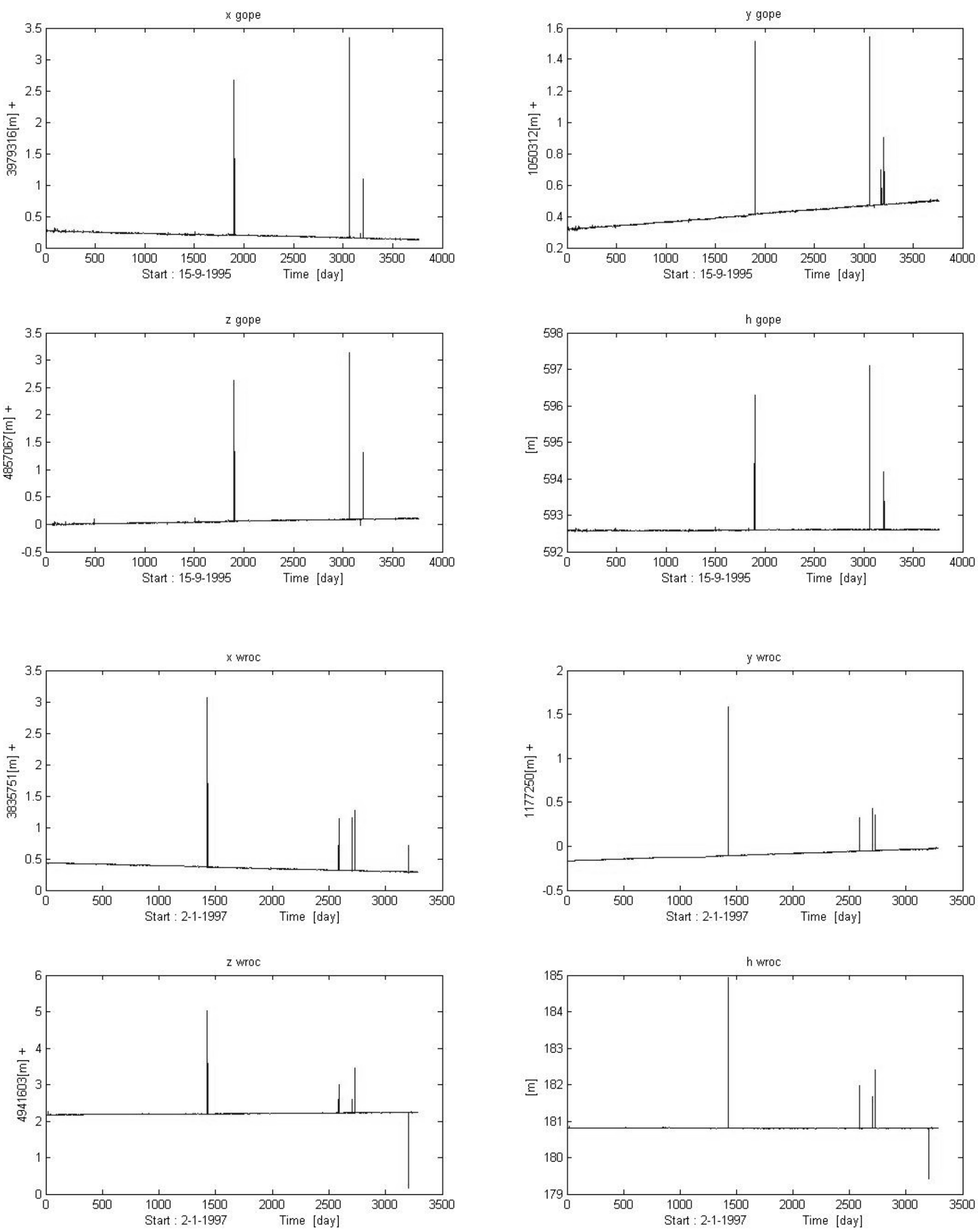


Fig. 2 ITRF2005X Y Z coordinates and ellipsoidal height series of GOPE and WROC.

All computations were done in CGS. Coordinates data were obtained by means of our 64-bit computer called FENIX. The most important concepts regarding the coordinate estimation are the following:

Software Used : Bernese 5.0, developed at AIUB (Dach et al., 2007). We made a few changes to Bernese: the DE405 planetary ephemeris (McCarthy et al., 2004), and the GMF tropospheric mapping functions (Boehm et al., 2006), were added. Changes were possible due to IGS reprocessing strategy. (Schmidt et al., 2006). Bernese was installed in 2006 by M. Figurski and L. Mervart on our FENIX computer (32xIA64).

Basic observations : GPS carrier phase. Code measurements are only used for receiver clock synchronization. The elevation cut-off angle used for the official solution is 3 degrees. The data sampling rate is 30 and 180 seconds.

Ground antenna: Absolute antenna phase center corrections based on IGS05 model (exceptions for stations with individual absolute calibrations listed in epnc_05.atx) considering antenna radome codes. If antenna/radome pair has no available calibrations, the corresponding values for the radome code "NONE" were used.

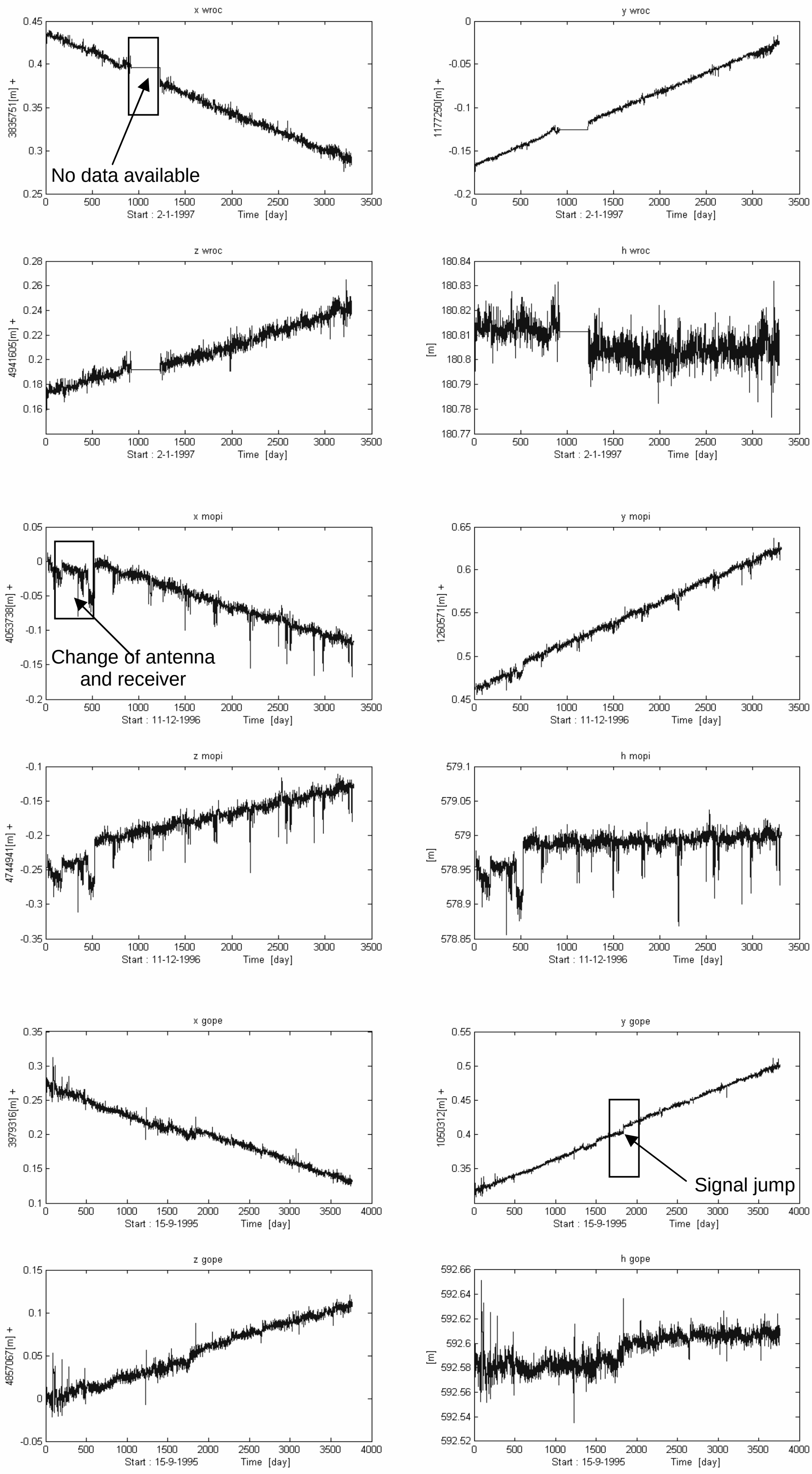
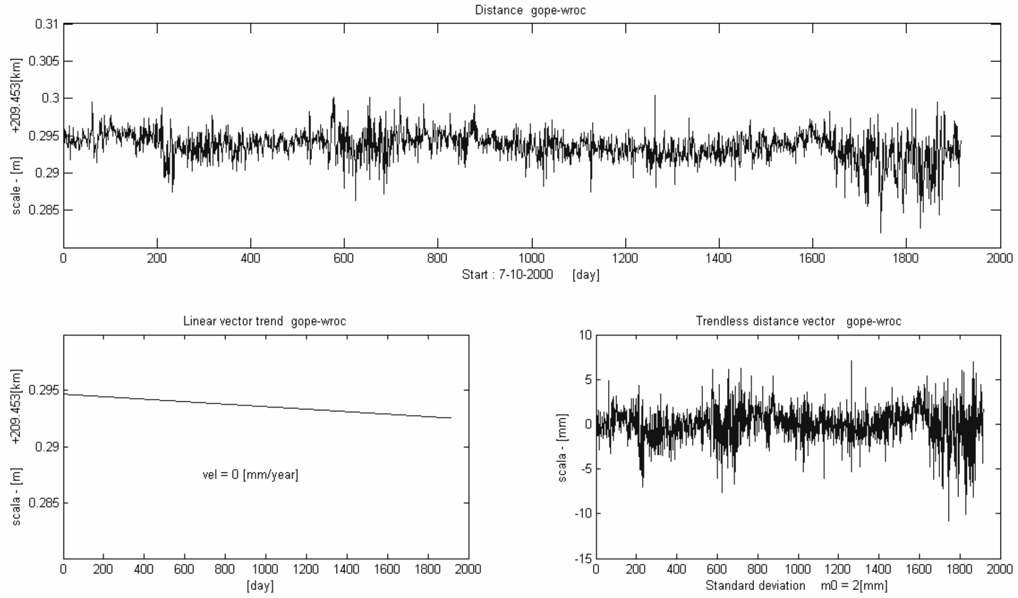
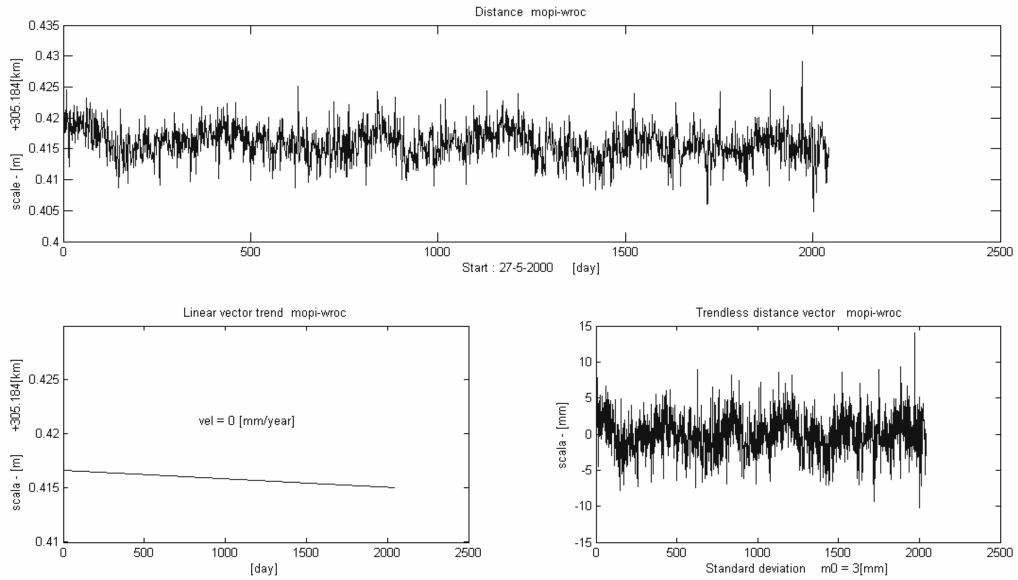
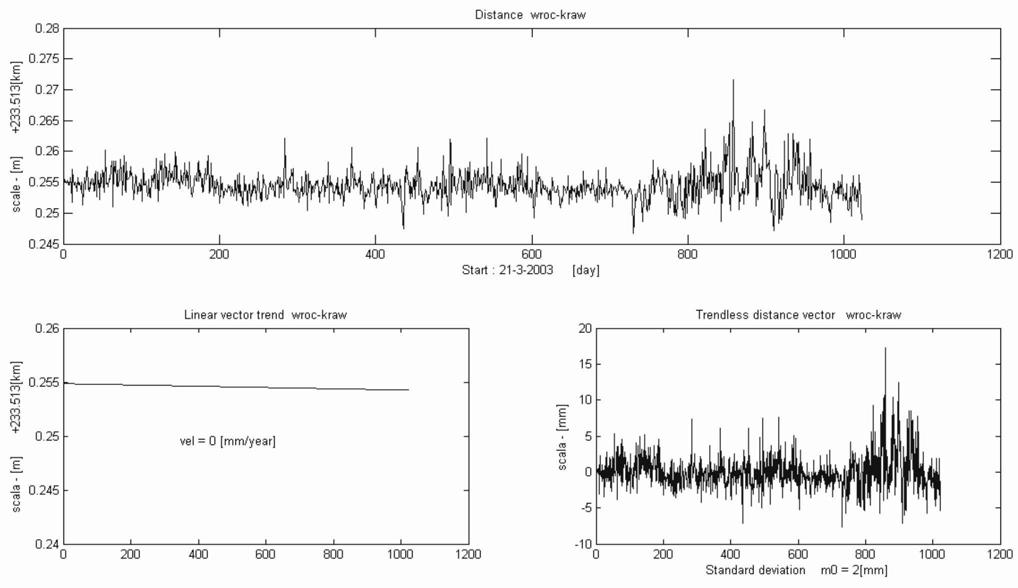


Fig. 3 Time series of coordinates in WROC, MOPI and GOPE stations.


Distance gope-wroc
scale - [m] +209.453[km]
Start : 7-10-2000 [day]
Linear vector trend gope-wroc
vel = 0 [mm/year]
[day]
Trendless distance vector gope-wroc
scala - [mm]
Standard deviation m0 = 2[mm]


Distance mopi-wroc
scale - [m] +305.184[km]
Start : 27-5-2000 [day]
Linear vector trend mopi-wroc
vel = 0 [mm/year]
[day]
Trendless distance vector mopi-wroc
scala - [mm]
Standard deviation m0 = 3[mm]


Distance wroc-kraw
scale - [m] +233.513[km]
Start : 21-3-2003 [day]
Linear vector trend wroc-kraw
vel = 0 [mm/year]
Trendless distance vector wroc-kraw
scala - [mm]
Standard deviation m0 = 2[mm]

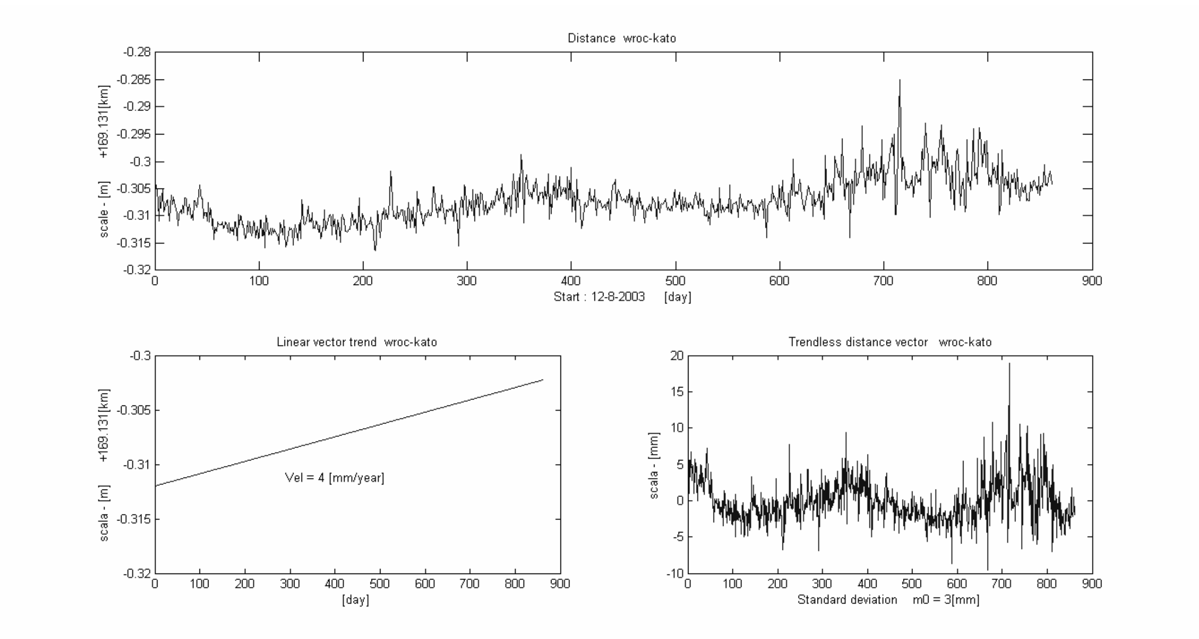


Fig. 4 Time series of baseline length, the plot of the estimated linear trend and the residual time series after removal of the constant part and the linear trend.

Satellite antenna: Absolute antenna phase centre corrections based on IGS05 model.

Troposphere: Dry-GMF – Global Mapping Functioning model, which is also used for GPS satellites, as a priori model, estimation of zenith delay corrections at 1-hour intervals for each station, using a wet-GMF mapping functioning, no apriori sigmas. Horizontal gradient parameters were estimated/day/station (TILTING), no apriori constraints were applied.

Datum definition : A 3-translation condition with respect to IGS05, the IGS realization of ITRF2005, is imposed (see also "orbits and ERPs"). The list of stations defining the datum currently includes the following IGS05 core stations:

ONSA; BOR1; WTZR; GRAZ; B;WTZR; GRAZ; BRUS; MATE; ZIMM

All analysis and graphical representations shown in this paper were prepared by means of our own operating system created under MATLAB Technical Computing Environment.

Figure 2 shows incorrectness of coordinate time series. Time series signals on permanent stations often contain quality weakness data, linked to various events. Days with big mistakes were regulated considering the previous and the following days.

Mistakes are related to some measuring events:

- receiver or antenna change
- signal interval
- signal shift

Sequence signals with mistakes were skipped in order to avoid the incorrectness listed above. Times series are reduced due to shipping the data till the moment a mistake happened.

Using the following formula

$$d = \sqrt{(X_B - X_A)^2 + (Y_B - Y_A)^2 + (Z_B - Z_A)^2} \quad ,$$

we computed the baseline length on a daily basis. They form the time series which reflects the distance variation between the stations.

In the next step we estimated a constant bias term, a linear trend and the corresponding standard deviation for each series. The baseline length time series, the estimated linear trend l and the de-trended series of the GOPE-WROC, MOPI-WROC and WROC-KRAW baselines are shown in Fig. 4 as an example.

Based on the determined linear trends we estimated inter-station velocities. It is clearly seen that the KATO station relative velocities are significantly larger than all others.

The baseline length variation for vectors involving KATO station is significantly different from 0 [mm/year], while for the others it is smaller than 0.5 [mm/year].

We may conclude that KATO station changes its position with respect to the other stations. If we exclude KATO station from the analysis we can observe that there were no movements between the stations. Even if the stations do move, they do it together or the movement is so insignificant that it is impossible to detect. We used multiresolution analyses to distinguish characteristic frequencies of those series.

To analyze the frequency of time series Fourier transformers or wavelet analysis might be used. Concerning the advantages of interpreting time and frequency at the same time, we chose wavelet

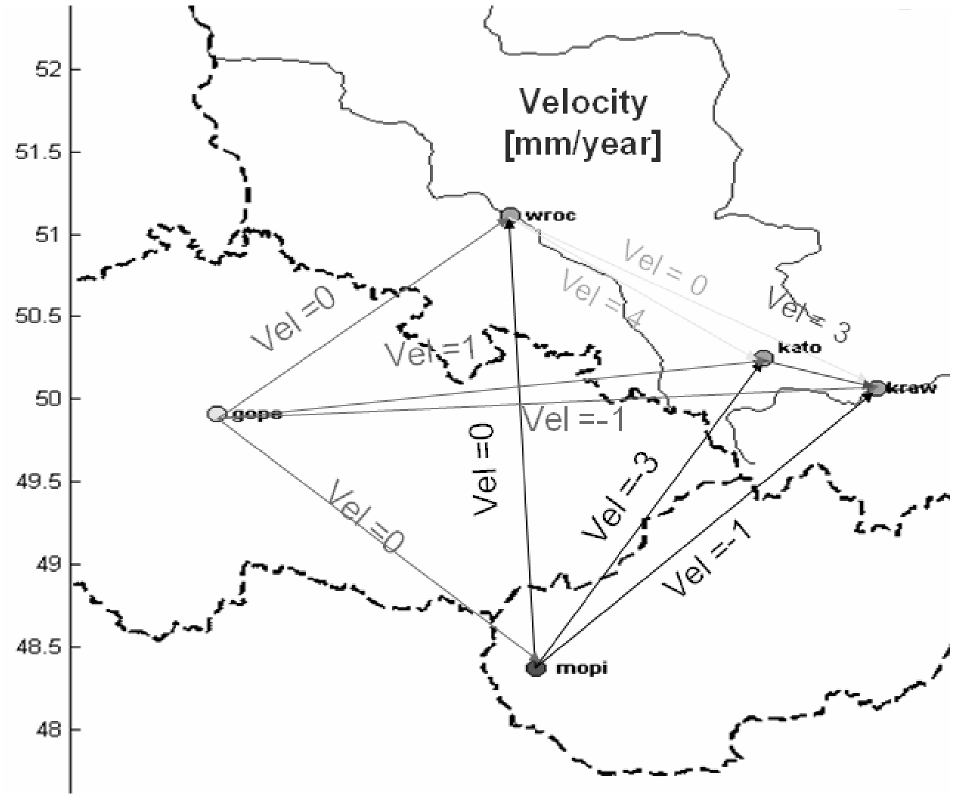


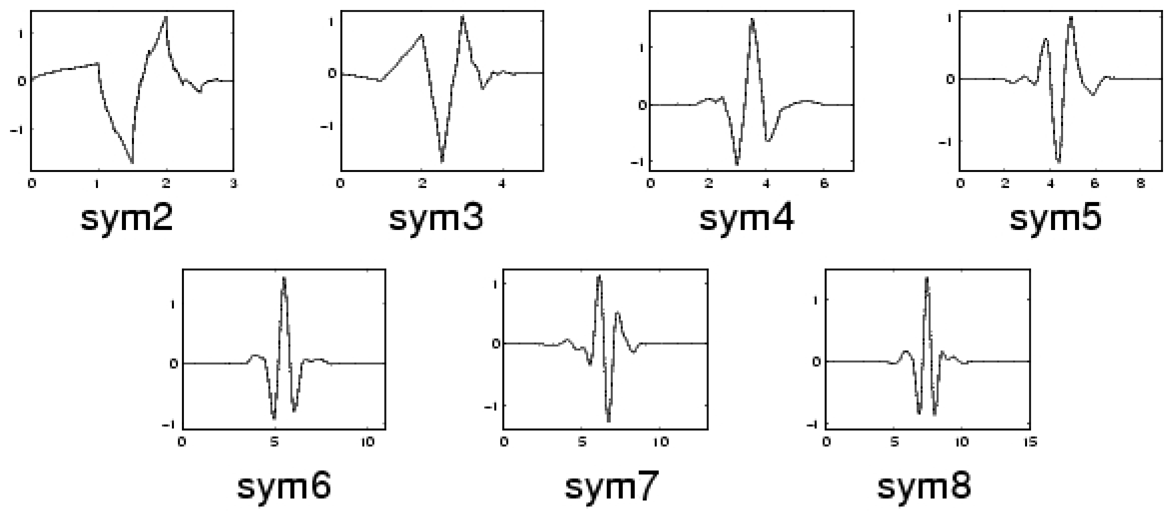
Fig. 5 The estimated relative velocity values between the stations.

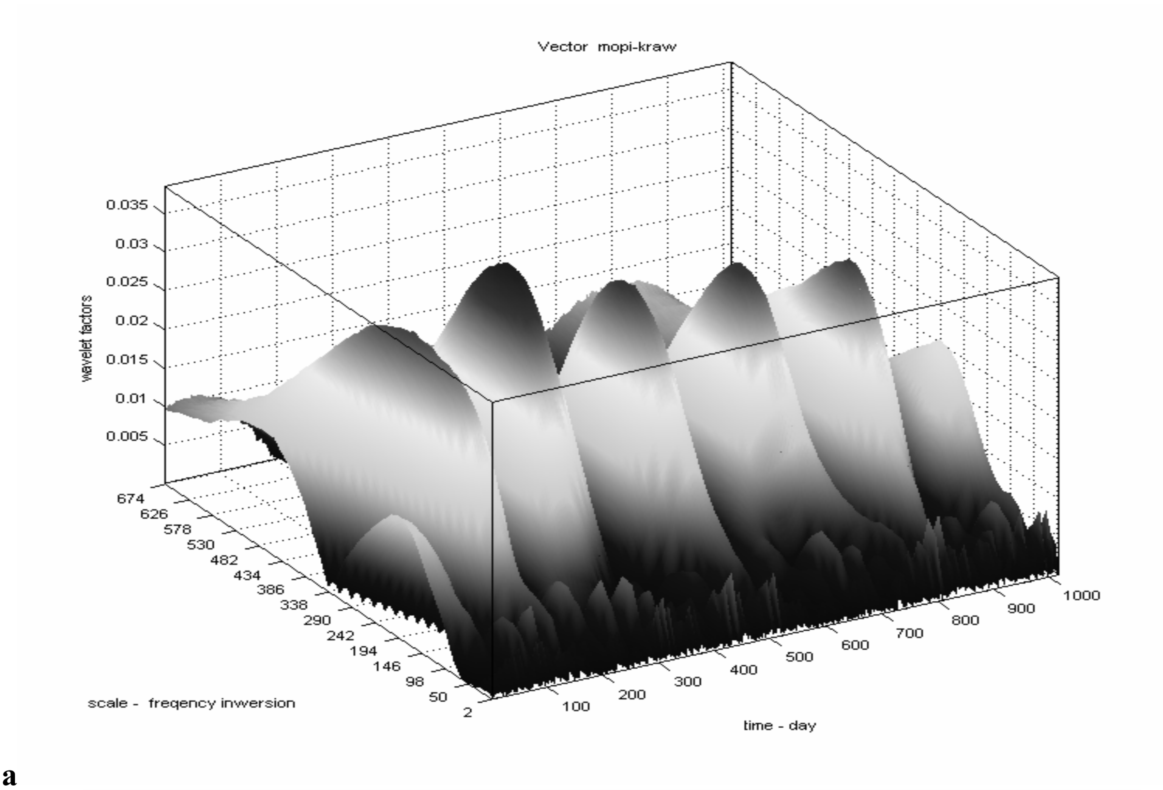
analysis. More on this can be found on the following web page:

http://www.amara.com/current/wavelet.html or http://cas.ensmp.fr/~chaplais/wavetour_presentation/Wavetour_presentation_US.html

The Wavelet Toolbox is a collection of functions built on the MATLAB® Technical Computing Environment. It provides tools for the analysis and synthesis of signals and images, and tools for statistical applications, using wavelets and wavelet packets within the framework of MATLAB.

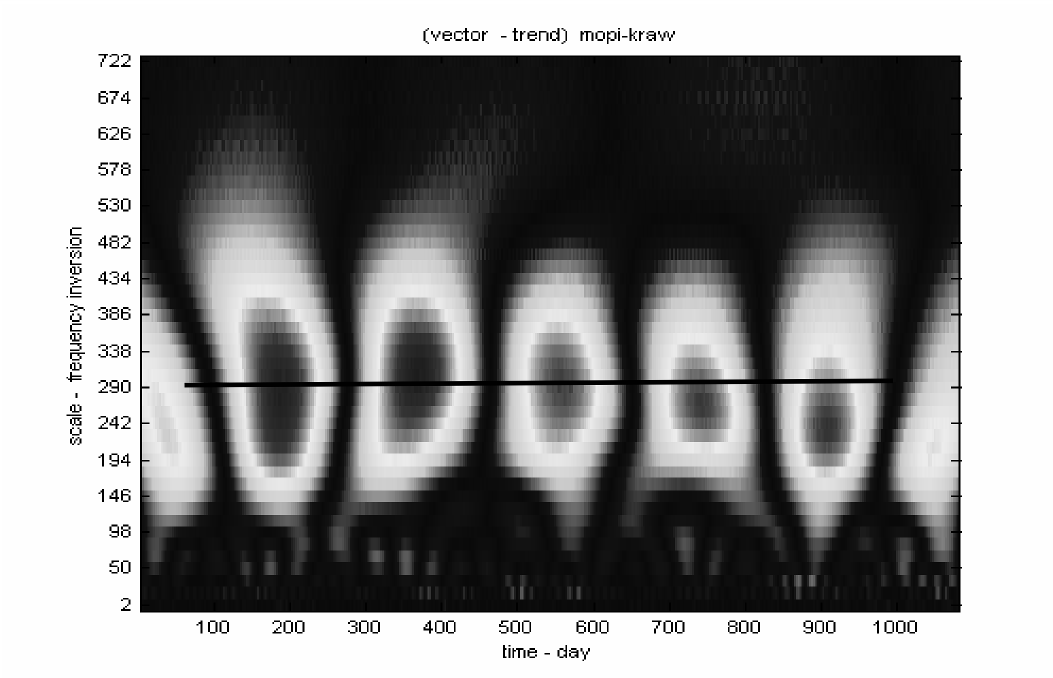
The symlets are nearly symmetrical wavelets proposed by Daubechies as modifications to the db(Matlab's shortcut) family. The properties of the two wavelet families are similar. Here are the wavelet symlet functions.





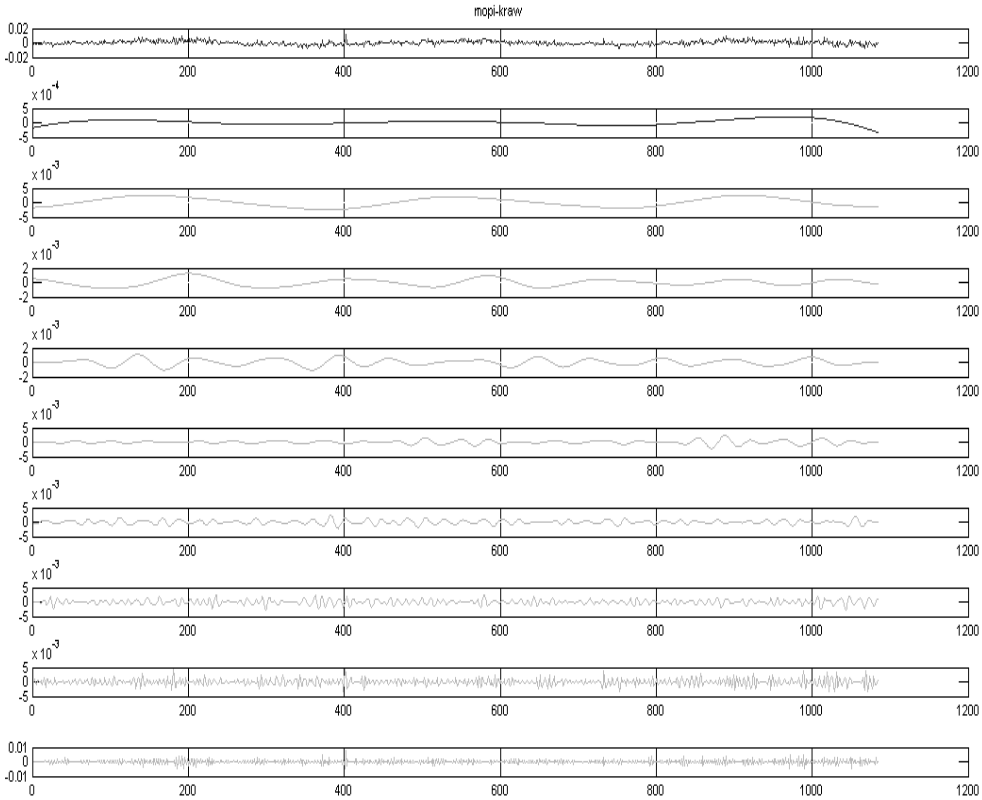
Vector mopi-kraw
0.035
0.03
0.025
0.02
0.015
0.01
0.005
wavelet factors
674
626
578
530
482
434
386
338
290
242
194
146
98
50
2
scale - freqency inwersion
100
200
300
400
500
600
700
800
900
1000
time - day

a



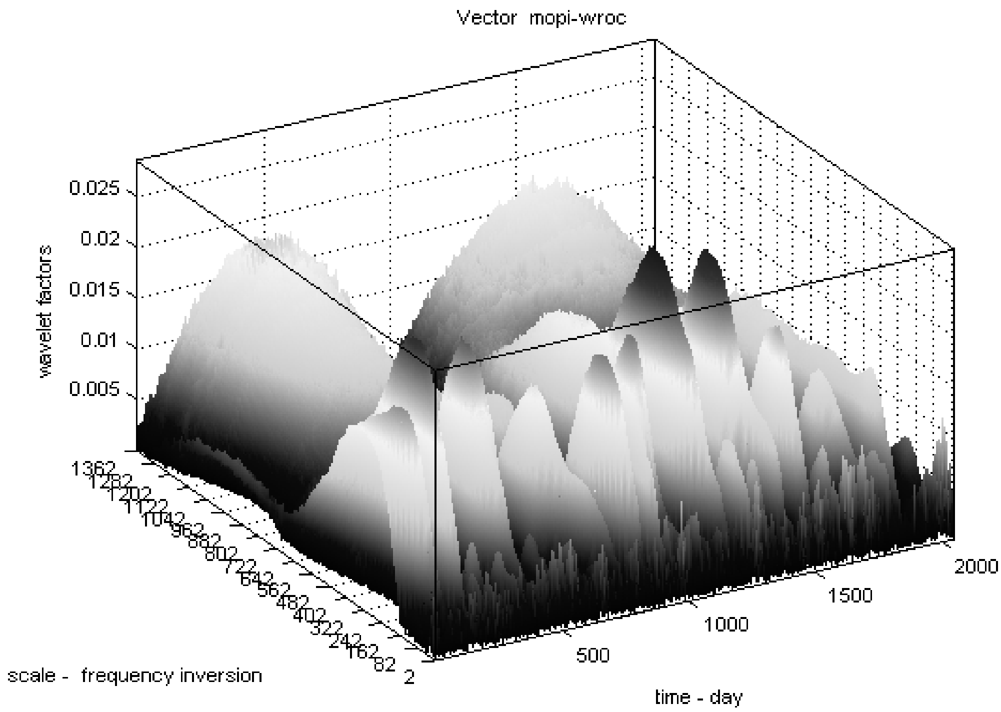
(vector - trend) mopi-kraw
722
674
626
578
530
482
434
386
338
290
242
194
146
98
50
2
scale - frequency inversion
100
200
300
400
500
600
700
800
900
1000
time - day

b

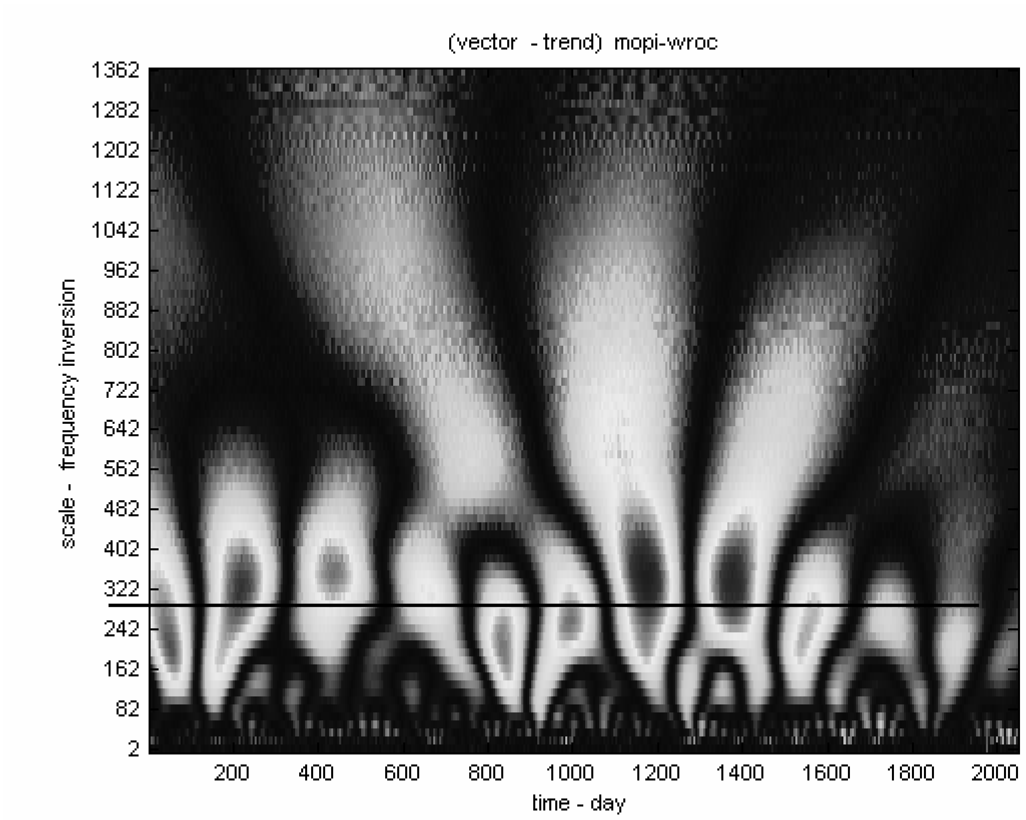


c

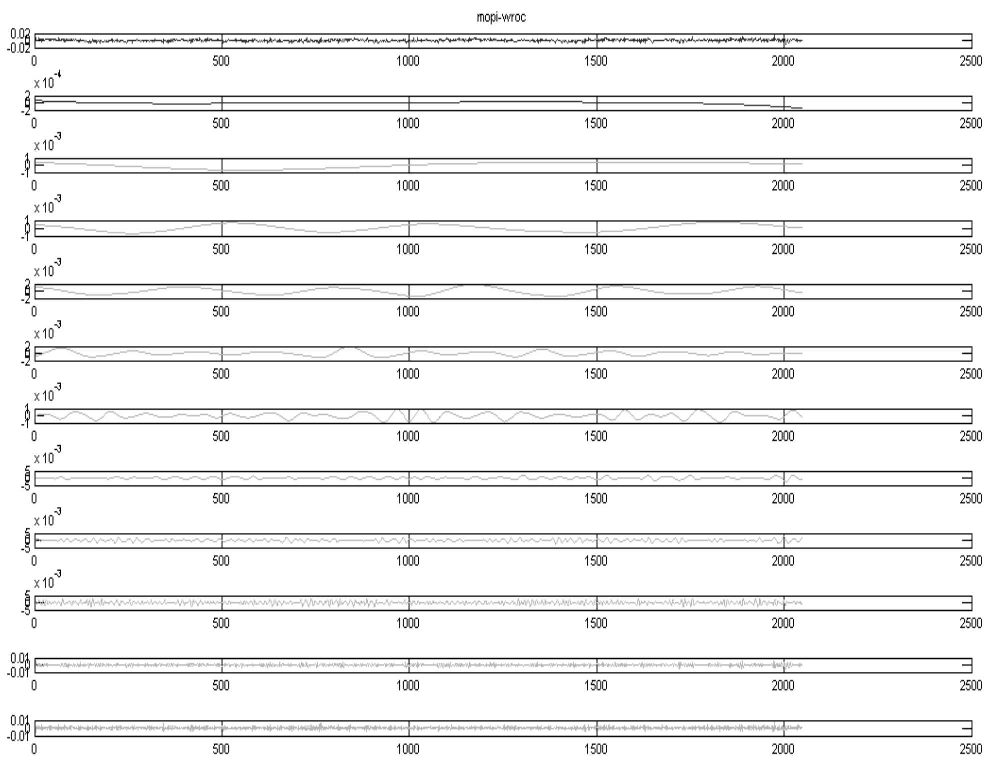
Fig. 6a,b,c Results of the wavelet decomposition by symlet8 for MOPI- KRAW baseline.



a



b



c

Fig. 7a,b,c Results of the wavelet decomposition by symlet8 for MOPI- WROC baseline.

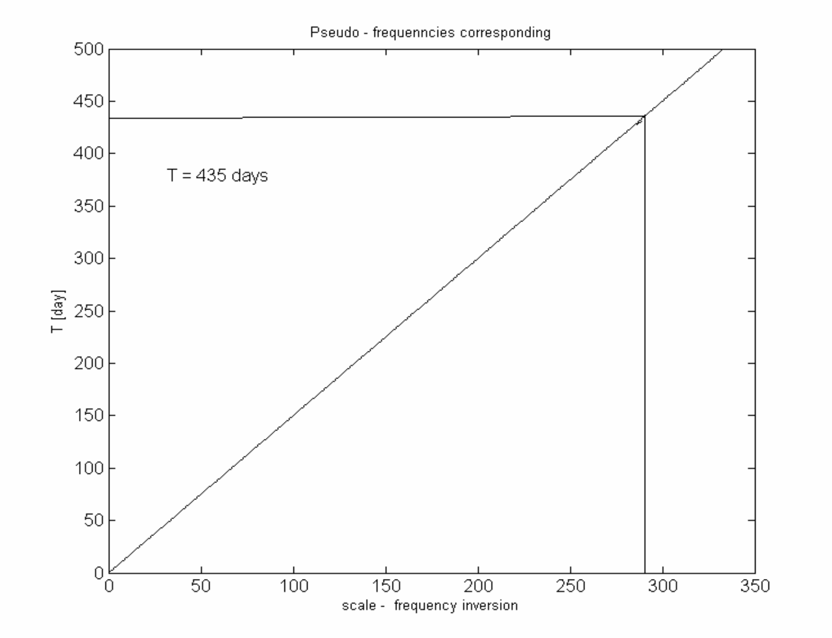


Fig. 8 Scaling curve.

After several attempts to match wave type we chose symlet8. The best effects were obtained through 9th and 10th degree of decomposition. The figures below present the results

In order to conduct frequency analysis in a correct way, we need to establish Figures from 6a, b, 7 a,b basing on scaling curve. The shape and all the parameters of scaling curve depend on type of wavelet we use. Our case illustrated is Figure 8.

In the figure we can see horizontal line which indicates frequency corresponding to most energetic oscillation discovered in time series.

RESULTS

The method we used gave us the possibility to detect some irregularities concerning KATO station which changes its position. The movement might be the consequence of the movements of the site or due to active mining activity.

Multiresolution analyses helped to detect highly energetic oscillations in the signals which might be linked to the Chandler Wobble of the Earth's Pole. Bernese should eliminate Pole movement but it does not happen yet. Our research proves that the equipment we use should be constantly improved. There is a possibility that new reprocessing we are actually developing might enhance the quality of results. New possibilities of reprocessing will be described in another article.

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