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PRELIMINARY RESULTS OF INVESTIGATIONS OF LONG LASTING NON-TIDAL SIGNALS OBSERVED BY MEANS OF HORIZONTAL PENDULUMS AND LONG WATER TUBE TILTMETERS IN LOW SILESIAN GEODYNAMIC LABORATORY OF POLISH ACADEMY OF SCIENCES IN KSIAZ

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ABSTRACT

Thirty years long measurements of plumb line variations carried on with help of horizontal pendulums provided us information of non-tidal effects. Installation of the long water tube tiltmeter opens for us new possibility to answer the question, which part of non-tidal effects observed by means of pendulums was associated with geodynamic phenomena and which part was of instrumental or local origin. Two years long measurements of the long water-tube tiltmeter showed us some important similarities between non-tidal effects registered by both instruments: comparable amplitudes of non-tidal effects, time of durations of non-tidal effects as well as irregularity of occurring of non-tidal events. In spite of disjunction of time series of measurements obtained with help of horizontal pendulums and long water-tube tiltmeters we are able to conclude that the reasons of large non-tidal effects can not be simply explained by influence of temperature or pressure variations.

KEYWORDS: geodynamic, Earth tides, tidal and non-tidal plumb line variations, tiltmeters

1. INTRODUCTION

We are able to separate signals of plumb line variations on periodical and non-periodical part of tidal and non-tidal origin. Separation of both signals is relatively simple because we exactly know frequency of tidal waves (Melchior, 1978). Investigations of non-tidal effects make difficulties for scientist on account of problem of differentiation of instrumental and geodynamic signals. During thirty years of work we irregularly observed seasons of unstable work of horizontal pendulums. Almost every year there happened several weeks long series when pendulums changed their azimuths of measurements (Chojnicki, 1981 and 1987). Changes of azimuths occurred in transition periods between autumn-winter and winter-spring but also inside of summer or winter seasons. Maximal values of azimuths variations achieved order of hundred miliarcsecods (several tidal amplitudes) of plumb line variations. On account of construction of pendulums possibilities of influence of variations of temperature, pressure or humidity on the instrument was considered. Before initiation measurements with help of long water-tube tiltmeter (i. e. about 2001) we tried to explain changes of azimuths of pendulums by instrumental, not geodynamic reasons. The special peculiarities of new tiltmeter such as high resolution of measurements as well as possibilities of elimination of instrumental drift (Kaczorowski, 2004) allowed us to start investigations of non-tidal effects. We are able to eliminate instrumental drift when measurements are carried simultaneously on four ends of the tubes (Kaczorowski, 2006b)

Complete measurements on four ends of the tubes we began at the end of 2003.

2. FIVE YEARS LONG SERIES OF NON-TIDAL SIGNALS REGISTERED BY QUARTZ HORIZONTAL PENDULUMS

On the basis of specially chosen fragment (1992 to 1997) of pendulums registration we evaluate possibilities of explanation of non-tidal trends by temperature, pressure or humidity variations. Five years long interval of non-tidal signals measured by horizontal pendulums in azimuths EW and NS was taken into account. To eliminate tidal signals time series of plumb line variations were performed with help of program "Analyze" from packet ETERNA 3.4 (Wenzel, 1996). After low pass filtration we obtained time series of non-tidal plumb line variations. A chosen interval of observations was divided into three epochs: asymmetric signals epoch (1992 to 1994), transition period (1994-1995) and epoch of symmetric signals (1995 to 1997) (Fig. 1). During this time physical conditions in underground as well as placement of pendulums in gallery were not changed. Instruments are situated in underground gallery the best protected against influence of the surface variations of pressure and temperature (Fig. 2). Pendulums stand on concrete shelf in distance one meter next to each other. Close placement of pendulums fully guarantees that arising long lasting, gradient of pressure or temperature between both instruments is impossible. Let us assume the observed non-tidal signals (Fig. 1) were associated with variations of temperature, pressure or humidity parameter. Comparing both plots we notice that in October 1994 influence of active parameter on one pendulum was changed while in the case of the second pendulum this influence stays unchanged. Other way the mechanism of influence of temperature, pressure or humidity on pendulums does not change in the time. Analyzing plots of non-tidal signals (Fig. 1) we conclude that:

- In case of EW component main extremes occurred in December, May, December, May, August, September, April, October, and February.
- In case of NS component main extremes occurred in January, May, December, May, December, August, May, August, and May.
- The maximum variations reach hundred millisecond of arc in both series.
- Time of duration of single trend lasted several months, maximally five months.

3. NON-TIDAL SIGNALS REGISTERED IN FEBRUARY TO APRIL 2005 BY WATER-TUBE TILTMETER

To discuss non-tidal effects we applied differentiation method for elaboration 43 days long raw data series from spring 2005. Registered in azimuths -121^0.4 and -34^0.4 water level variations were performed with help of differentiation method (Fig.3 and 4). Blue and green color plots describe raw observations obtained from opposite ends of the tubes and recalculated on mas units. On the plots there are visible daily and half daily tidal undulations as well as systematic trends. Since 21 of February to 17 of March green and blue plots were parallel and slightly tilt because evaporation effect and (Figs. 3 and 4). During this time plots of resultant signals (red color) composed with tidal and non-tidal signals were horizontal. Situation unexpectedly changed in 17 of March. In both independent hydrodynamic system of water-tube tiltmeter we observed changes of trends. Distances between green and blue plots rapidly increased to several tidal amplitudes in both azimuths -121^0.4 and -34^0.4. At the ends of the tubes 02 and 03 (Fig. 2) level of water increased while at the ends of tubes 01 and 04 level of water decreased. In azimuth -121^0.4 resultant functions consist of the sum of tidal signals and non-tidal trend (red plot) reached maximum equal 40 of mas in 22 of March (Fig. 3). For -121^0.4 azimuth non-tidal signal reduced to zero at 31 of March. In azimuth -31.4^0 the green and blue colors plots of raw observations crossed each other and then permanently headed in opposite directions (Fig. 4). Resultant plot (red color) composed with tidal signals and non-tidal trend has not extreme. Non-tidal trend reaches 240 of mas and increased. For better understanding physical conditions of measurements of the long water-tube we describe that tubes there are in crossing corridors which section amount twenty square meters (Fig. 2). If we assume that active parameter producing non-tidal signals is pressure gradient along the tubes it is difficult to answer two questions:

- how permanent pressure gradient can exist in corridor during two weeks ?
- why pressure gradient vanished in corridors of azimuth -121^0.4 while in corridors in azimuth -34^0.4 pressure gradient permanently increased ?

Existing of the horizontal pressure gradient in corridors is associated with two weeks lasting permanent motion of air from closed end of corridor to opposite end. In the case when active parameter generating non-tidal signals is temperature gradient there are also some questions difficult to answer:

- What is the mechanism of cooling one ends of the tubes and simultaneously heating in equal degree opposite ends of the tubes (symmetry of green and blue plots) (Figs. 3 and 4)?
- Why effects of temperature gradient vanish in azimuth -121^0.4 and simultaneously increase in azimuth -34^0.4.

In case of pressure or temperature effects especially difficult to explanation is symmetry of blue and green plots in relation to yellow plot (sum of raw signals from opposite ends of the tubes) representing effect of water evaporation from hydrodynamic system of instrument mainly. Symmetry of blue and green plots implicates that pressure or temperature variations at opposite ends of the tubes were also symmetrical. Because all geodynamic phenomena produce in water-tube tiltmeter symmetric signals, yellow plots do not contain geodynamic signals, especially tidal signals. Asymmetric part of signals is produced by local effects such as decreasing or increasing of water capacity in hydrodynamic system of tiltmeter, settling of the tubes or variations of their capacity. Mentioned effects do not disturb symmetric part of signals.

4. NON-TIDAL SIGNALS IN DATA SERIES FROM YEARS 2004 AND 2005 REGISTERED BY THE LONG WATER-TUBE TILTMETER

We took into account the time series simultaneously measured at the both ends of the tubes in years 2004 and 2005. Data series were performed to eliminate tidal signals. We applied low pass filters from ETERNA 3.4 (Wenzel, 1996) packet. Green and blue plots describe time series of residuals of data series obtained at the opposite ends of the tubes in azimuths -121^0.4 and -34^0.4 (Figs. 5 and 6). Differences between residuals were shown by red plots. For better presentation initial values of all series were reduced to zero. On account of technical reasons there are several interruptions in data series. These interruptions are the reason of difficulties with fully credible interpretation of the non-tidal signals. At the figures 5 and 6 we can notice blocks of data where green and blue plots are almost parallel and blocks where both curves have opposite trends. When the plots are approximately parallel they always go down and plots of their difference are almost horizontal (red curves). It means that in such blocks of data signals non-tidal residuals are small as well as simultaneously take place effects such as decreasing of water capacity in hydrodynamic system of tiltmeter, settling of the tubes or increasing capacity of the tubes. When distance between green and blue plots is growing, it means that some of non-tidal effects produce water level variations. On account of contribution of local effects producing asymmetric signals such as variations of water capacity etc. we observe asymmetry between green and blue plots. The time series of non-tidal residuals from 2004 to 2005 contain several blocks in which non-tidal residuals are especially large (red plots). In azimuth -121^0.4 the largest effects of non-tidal residuals happened three times in December 2004, March 2005, and in December 2005 and exceeded 70 mas (Fig. 5). In two cases trends were positive while in remind part of data series the trends were mostly negative. The largest effects of non-tidal residuals in azimuth -31^0.4 happened twice in March 2005 and in December 2005 and exceeded -140 mas (Fig. 6). Belong these two blocks trends in other blocks of non-tidal residuals data were positive. It is characteristic that all long lasted (tens of days) large variations of non-tidal residuals rapidly (in a single day) change their trends from negative to positive and vice versa. We formulate an important question - why in December 2004 large variation of non-tidal residuals took place only in azimuth -121^0.4 while in December 2005 large variation of non-tidal residuals happened on both components? Answer this question helps us to solve main problem – explanation of the origin of large signals of non-tidal. We compile complementary of non-tidal residuals (red color plots in Figs. 5 and 6) to create hypothetic plots of variations of non-tidal residuals in the space (Fig. 7). Interruptions in data series were completed with linear trends (blue lines) with consideration trends of plots of surrounding data. Since 2004 to 2005 plot of non-tidal residuals arc full angle twice in clockwise direction (Fig. 7). Center of symmetry of plot from 2005 was moved in relation to the center of symmetry of plot from 2004 of about 100 mas. In Figure 7 we related curve of non-tidal residuals variations to local tectonic structure of Low Silesian Geodynamic Laboratory surrounding. There are not any distinctive directions on the plot indicating existence of any relations with local tectonics. We are able to inscribe plot of non-tidal residuals variations in circle. On account of interruptions of series of non-tidal residuals variations from 2004-2005 we have to limit our conclusions to general comments:

- Largest variations of plumb line of non-tidal origin exceeding 100 of mas take place at transitional seasons of autumn-winter and winter-spring.
- Especially large effects of plumb line variations are terminated rapidly through changes their trends into opposite.
- There are no visible relations between shape of plot of non-tidal plumb line variations from 2004-2005 and local tectonic structure.
- During the years 2004 to 2005 plumb line arc full angle twice, what suggests existence of yearly effect. Both years direction of rotation of plumb line agreed with clockwise rotation.

5. DISCUSSION ABOUT THE POSSIBILITIES OF EXPLANATIONS OF LARGE NON-TIDAL EFFECTS BY PRESSURE OR TEMPERATURE VARIATIONS.

There is important question to answer - what kind of local effects can produce symmetric effects such as effects of tidal and non-tidal phenomena? Two phenomena, pressure and temperature variations in underground are especially suspected. Horizontal gradient of pressure occur along the tubes of tiltmeter produces water level variation by so called inverse barometric effect. We discuss time series of non-tidal signals registered in azimuth -31^0.4 in March 2005. During the chosen interval amplitudes of non-tidal signals variation exceeded 100 mas (Fig. 4). On the basis of relation between tilting and water level changes (Kaczorowski, 2006a) we obtained for 100 mas tilt associated water level variation equal to 4.0486 10^{-3} [cm]. Such effect of water level variation is produced by inversed barometric effect while difference of air pressure at the ends of the tube amounts to 4 10^{-3} [hPa]. The corridors where tubes of tiltmeter were installed are open to inside and closed to outside (Fig. 2). Length of corridors amount tens of meters and surface of the section of corridors exceeds sixteen square meters. For such geometry of corridors fundamental mod of resonance frequencies of air is close to fraction of hertz and time of relaxation of pressure gradient does not exceed single minutes. Effect of horizontal component of pressure gradient generates horizontal motion of air in corridors results in pressure gradient compensation. Point out of the mechanism of creation in corridors horizontal component of pressure gradient lasted few weeks is difficult. On account of much greater inertia of water than inertia of air as well as on account of numerous narrowings included into the tubes of tiltmeter variations of water level are substantially delayed in relation to variations of air pressure gradient.

Thus, before accommodation of the water level to temporary pressure gradient there happens the great part of pressure gradient will be reduced by self acting effect of pressure gradient compensation in large space of corridors. This effect was well visible during the experiment with acoustic infra-waves generated in underground. Disturbances of water level produced by infra-waves lasted only single seconds after turn off the generator. It does not mean that gradient of air pressure of the order 10^{-5} [hPa/m] can not happen. We expect arise such gradient during process of compensation of air pressure between inside and outside of underground. Air pressure gradient in underground is associated with meteorological effects of atmospheric pressure variations. Taking into account that large meteorological effects of pressure variations amount few days the meteorological effects can not produce pressure gradient in corridors lasted several weeks. Otherwise, when effect of compensation happens, variations of air pressure at both ends of the corridor ought to have the same trends, increasing or decreasing. Therefore, signals of water level variations from opposite ends of the tubes ought to be asymmetric. We expect that water level variations at both ends of the tube produced by effect of pressure compensations ought to be slightly delayed each other of about single minute.

Similarly to pressure variations the temperature variations in underground are also suspected generation of symmetric signals of water level variations. We made several precise measurements of air temperature in underground. The results showed us existence of vertical gradient of temperature of the order of several hundredths of degree per meter and about half of degree between floor and ceiling. This is the reason of generation of permanent vertical motions – convection motions of air in corridors. Vertical motions of air as well as vertical component of pressure gradient do not affect differences of water levels at the ends of the tubes. The measurements of temperature confirmed existence in underground daily signal – daily thermal wave of the order of several hundredths of degree. Except of daily signal of temperature variations we observed seasonal temperature variations in the underground. Depending on location in underground the temperature variations of air change in a range 0.3 to 1 degree between summer and winter. Temperature variations affected the long water-tube tiltmeter on several manners:

- Variations of capacity of water in hydrodynamic system of tiltmeter.
- Variations of capacity of the tubes.
- Variations of water density and height of water column above reflecting lens in state of hydrostatic equilibrium.
- Variations of fasting screws length of measuring platform.

Variations of capacity of water as well as capacity of the tubes produce asymmetric signal of water level variations – simultaneously increasing or decreasing of water level at the both ends of the tubes. Variations of water density as well as variations of the length of fasting screws produce symmetric signals only in the case of opposite trends of temperature variations at the ends of the tubes. We discussed on few weeks long series of non-tidal signals from March 2005 (Figs. 3 and 4). During this time the temperature on the Earth surface quickly changed. Let us suppose that in 17 of March stream of warmth from surface of the Earth reached undergrounds and initiate processes of non-tidal signals generation. After 17 of March, changes of temperature generated divergence of non-tidal signals (green and blue plots) in both azimuths (Figs. 3 and 4). In 23 of March in azimuth -121^0.4 we observed changing of trends of water level variations on opposite, while in azimuth -31^0.4 trends of water level variations (green and blue plots) stayed unchanged until end of series. Continuing our deliberations registrations in azimuth -121^0.4 indicates that in 23 of March trend of temperature variations was changed on opposite and gradient of temperature was reduced while in azimuth -31^0.4 trend of temperature variations stayed unchanged and gradient of temperature increased until end of data series. Appearing the phenomenon of simultaneously increasing and decreasing gradient of temperature in two joined corridors is difficult to explain (Fig. 2).

6. CONCLUSIONS

We are able to formulate conclusion that large, symmetric, non-tidal signals of water level variations registered by long water-tube tiltmeter can not be simply explained by pressure or temperature variations. It is difficult to point out any mechanism of generation in corridors air pressure gradient lasting few weeks as well as point out the reason of simultaneously decreasing and increasing temperature at opposite ends of the corridors. In 2006 common measurements of the long water-tube and quartz horizontal pendulums equipped with new system of registration were initiated. Additionally to verify presented in first sentence of chapter hypothesis we installed in underground high resolution system for permanent monitoring temperature, pressure and humidity variations. Common measurements will help us to answer the question which part of large non-tidal signals observed by means of pendulums and water tube is associated with geodynamic phenomena and which part is of instrumental or local origin.

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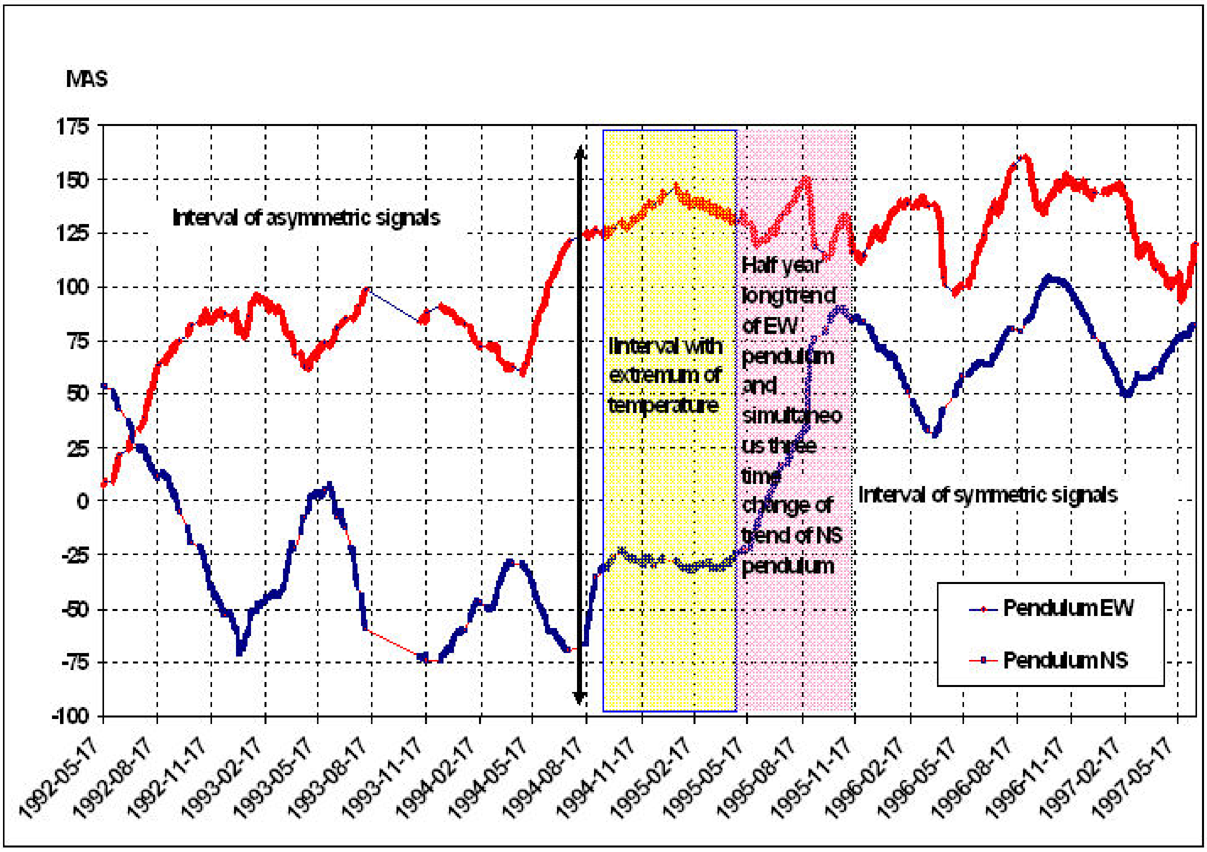

Fig. 1 Series of low-pass filtered observations of horizontal pendulums registered in years 1992-1997 in principal azimuths.

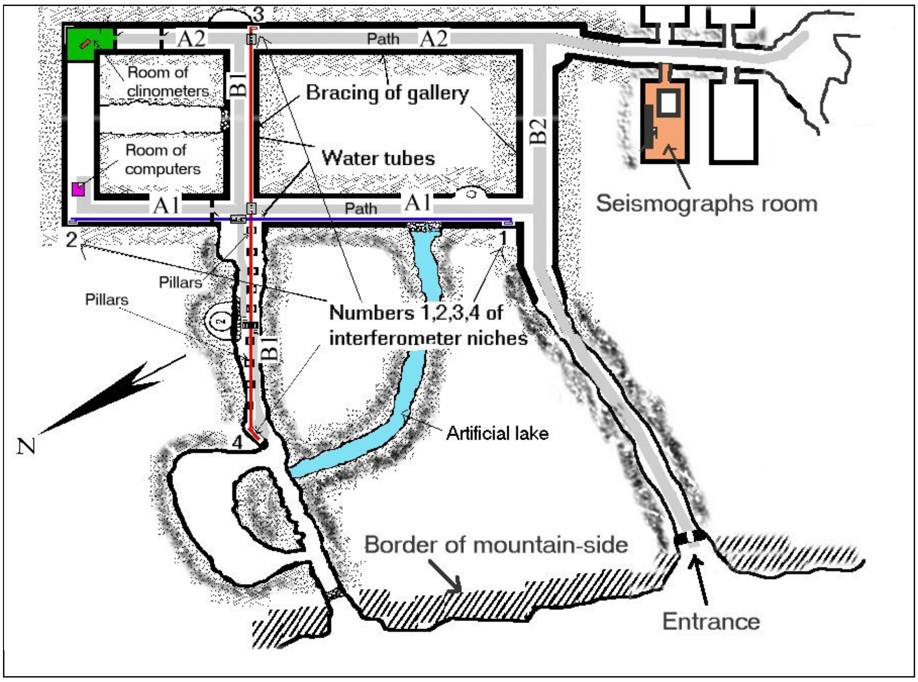

Fig. 2 Plan of underground with marked locations of horizontal pendulums and long water-tube tiltmeters.

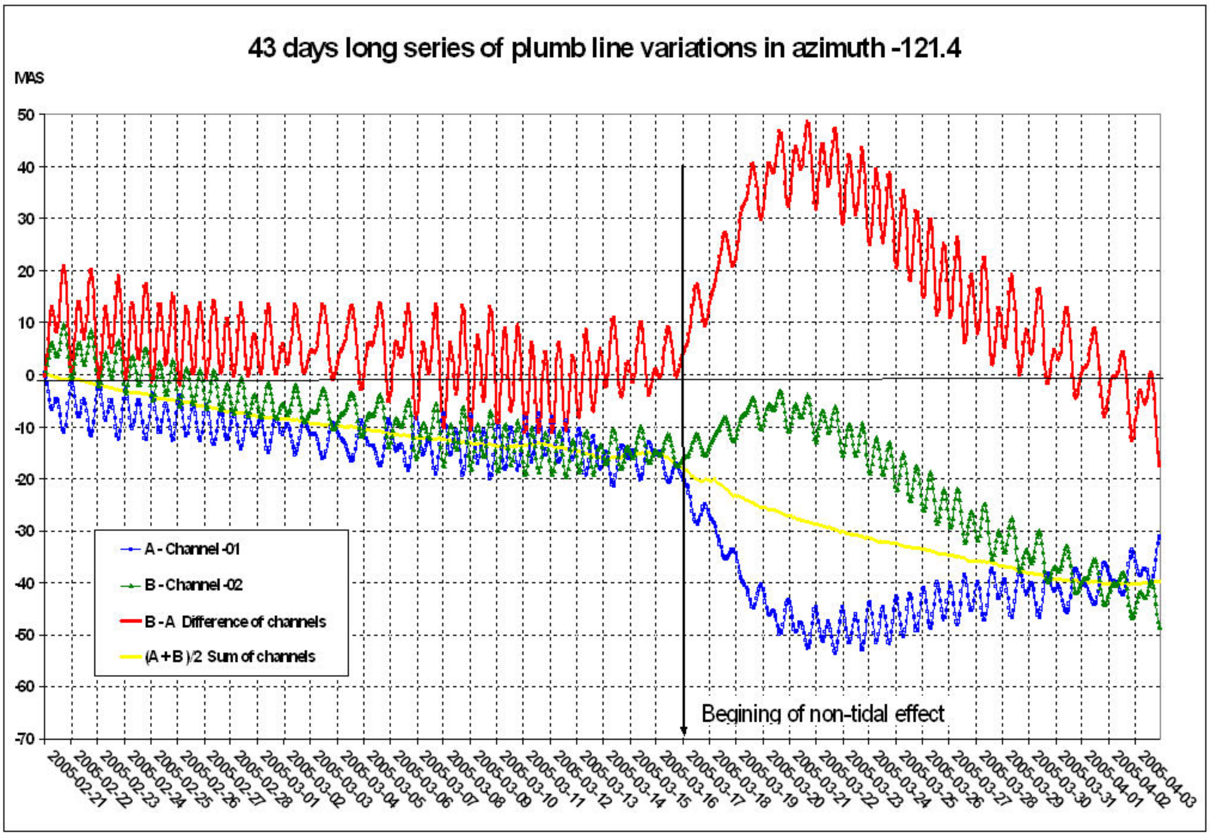

Fig. 3 43 days long series of raw observations with distinct non-tidal trend obtained with help of long water-tube tiltmeter in azimuth -121^0.4.

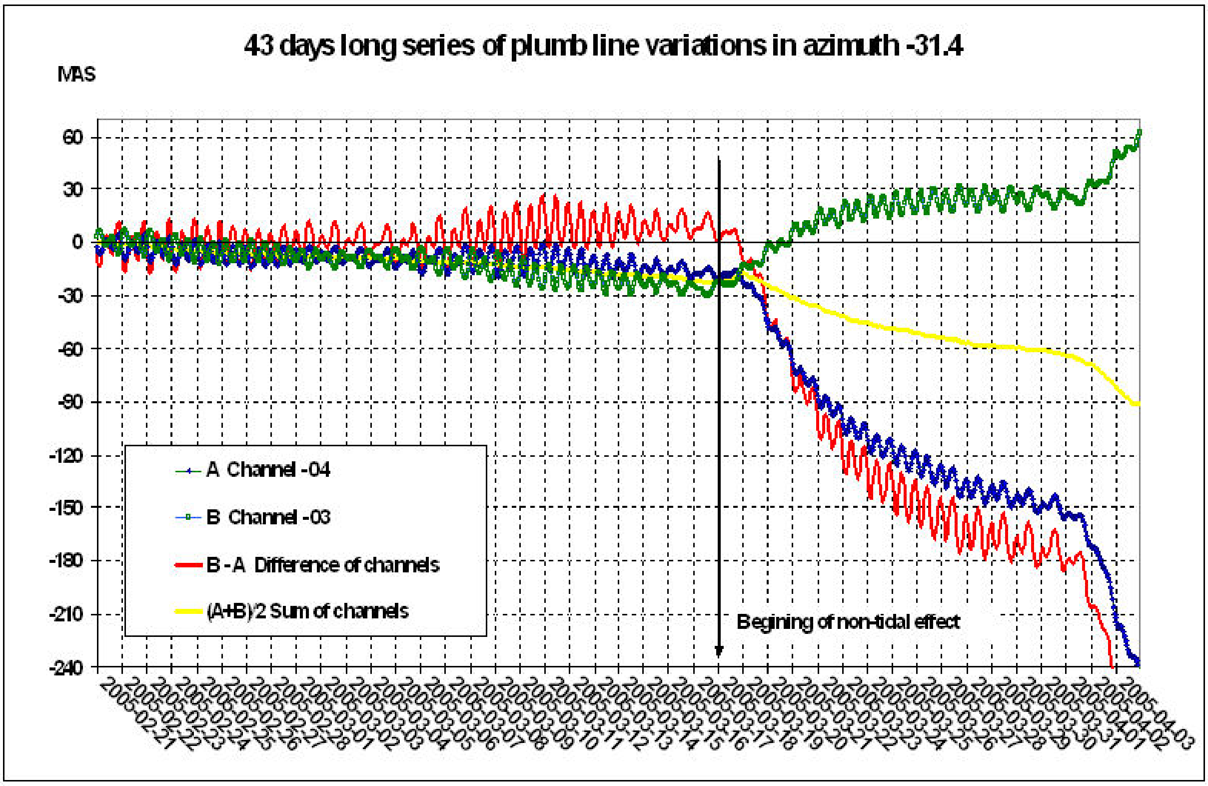

Fig. 4 43 days long series of raw observations with distinct non-tidal trend obtained with help of long water-tube tiltmeter in azimuth -31^0.4.

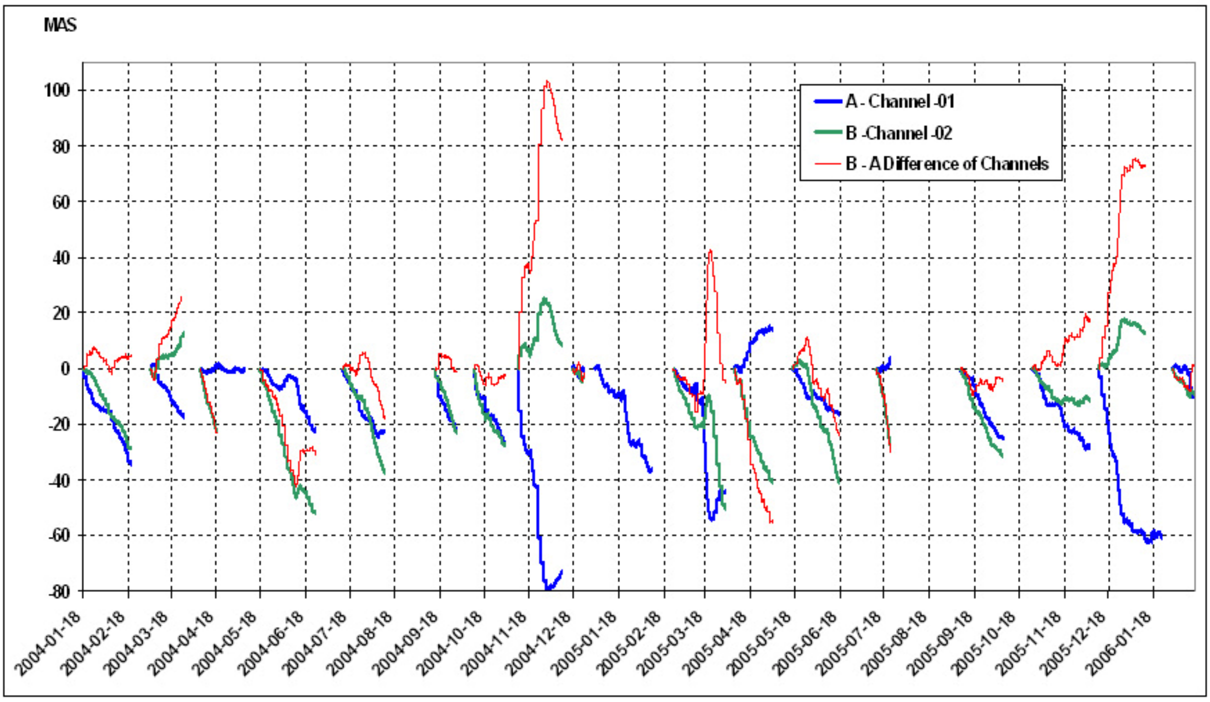

Fig. 5 Series of low-pass filtered observations obtained in years 2004-2005 with help of long water-tube tiltmeter in azimuth -121^0.4.

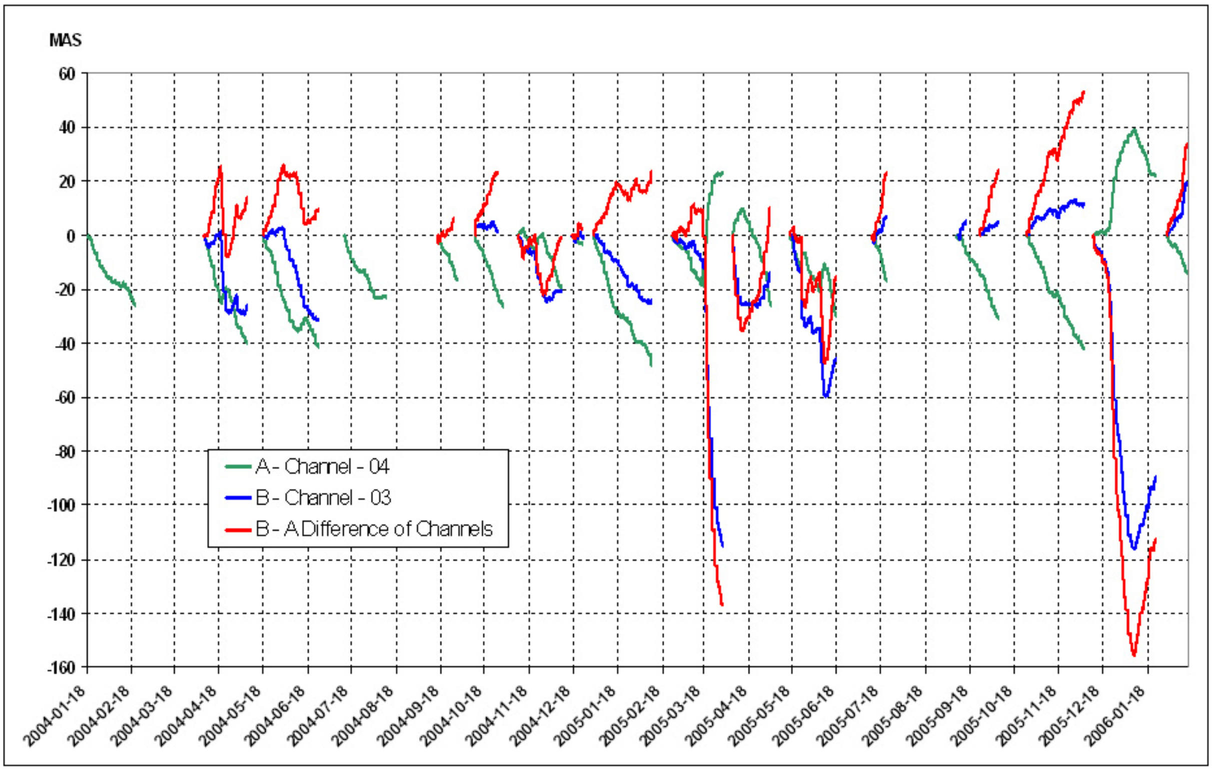

Fig. 6 Series of low-pass filtered observations obtained in years 2004-2005 with help of long water-tube tiltmeter in azimuth -31^0.4.

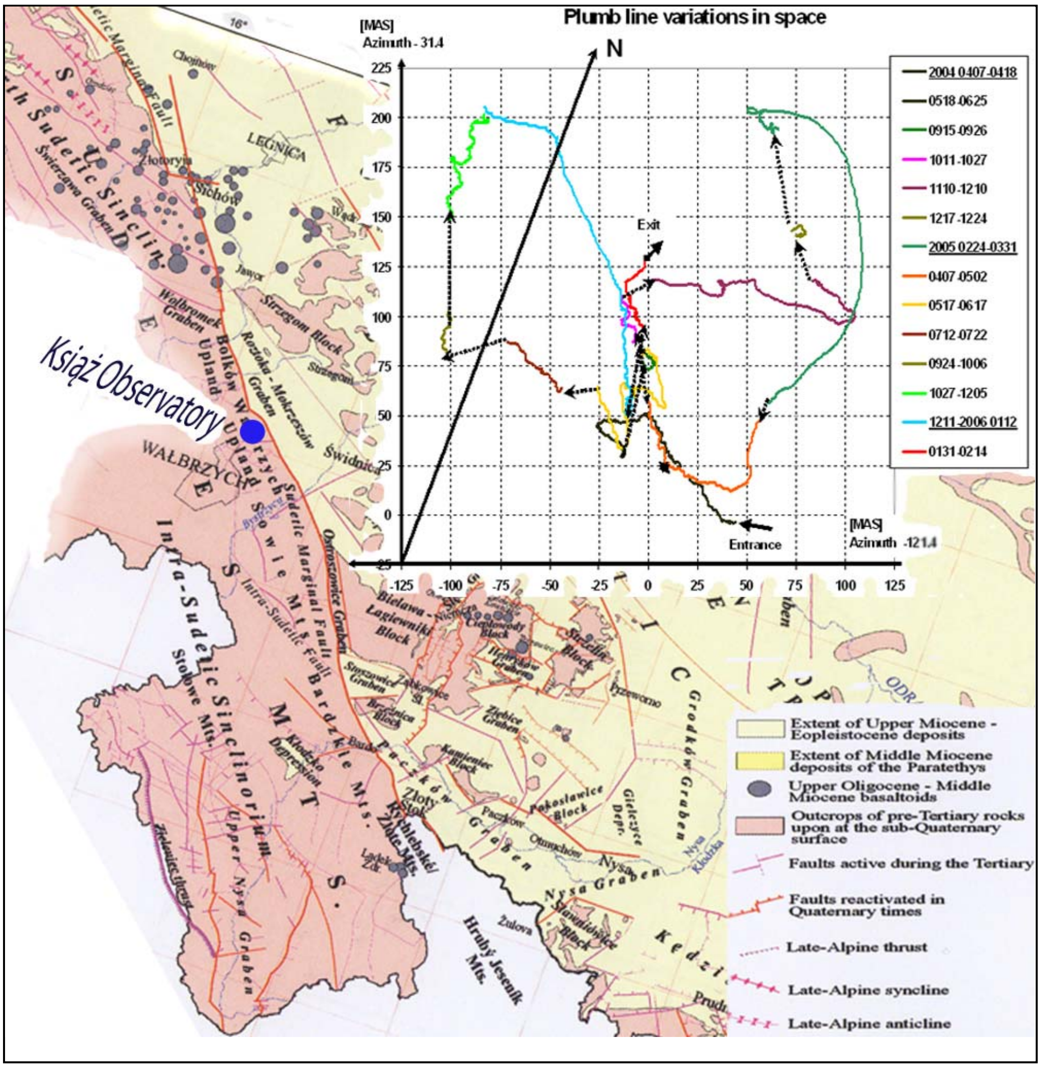

Fig. 7 Plot of compiled low-pass filtered observations obtained in years 2004-2005 in azimuths -121^0.4 and -31^0.4. Plot was drown in accordance with principal directions on geo-tectonic map of Sudetic area.