

# NON TIDAL PLUMB LINE VARIATIONS OBSERVED WITH HELP OF THE LONG WATER-TUBE AND HORIZONTAL PENDULUMS TILTMETERS IN GEODYNAMIC LABORATORY OF PAS IN KSIAZ

Marek Kaczorowski

*Space Research Centre, Polish Academy of Sciences  
Bartycka 18A, 00-716 Warsaw, Poland  
e-mail: marekk@cbk.waw.pl*

## 1. INTRODUCTION

We are able to separate signals of plumb line variations on periodical part of tidal origin and non-periodical part or long period effects produced mainly by hydrological, meteorological as well as geodynamical phenomena. Separation of these signals is relatively simple because we know exactly frequencies of tidal waves. This circumstance allows us to perform the tidal analyses of observations to determine coefficients of the amplitudes and phases of tidal waves (Kaczorowski, 2004). Non tidal part of plumb line variations is much more difficult for investigation. Beyond daily effect of thermal wave other non-tidal phenomena producing plumb line changes are not periodic or their periodicity is not stable. This is the reason of difficulties with separation of non-tidal effects of plumb line variations and instrumental drift. In the case of long water-tube tiltmeter elimination of drift resulting from effects of water condensation or evaporation as well as effects generated by displacements of the tubes we applied differential method. Differentiation of signals obtained on opposite ends of the tubes causes double magnification of geodynamic signals as well as elimination of instrumental drift (Kaczorowski, 2006a). For long water-tube tiltmeter residual signals obtained after lowpass filtration contain non-tidal signals without instrumental drift. This circumstance helps us to investigate long-standing, non-tidal signals. During the period 2004 to 2007 we observed five epochs of strong non-tidal signals. Observed magnitude of non-tidal signals of plumb line variations exceeded hundred of miliarcsecond of arc (mas).

## 2. OBSERVATIONS OF NON-TIDAL PLUMB LINE VARIATIONS BY HORIZONTAL PENDULUMS AND WATER TUBE TILTMETERS

Existence of long standing non-tidal signals of irregular character was demonstrated several times in many year long series of measurements of quartz horizontal pendulums (Chojnicki T., Weiss J., 1981 and 1987). During thirty years of observations we irregularly observed epochs of unstable work of horizontal pendulums (Fig. 1). Almost every year there happened several weeks long periods when pendulums rapidly (during a few days) changed their azimuths of equilibriums until arms of pendulums connected the limiters. Changes of azimuths occurred irregularly not only in transition periods between autumn-winter and winter-spring but also in the middle of summer or winter. Maximal values of variations of azimuths corresponded to hundred miliarcsecond of arc (a few tidal amplitudes of plumb line variations).

On account of construction of pendulums and expected instrumental drift we tried to explain changes of azimuths of measurements by instrumental, not geodynamic reasons. Installation of long water-tube tiltmeter in Ksiaz Geodynamic Laboratory opened new possibilities of investigations of long standing irregular signals. Special features of new tiltmeter such as high sensitivity, lack of instrumental drift as well as application of differential method (Kaczorowski, 2006a) allowed us to investigate phenomena of strong, irregular signals of non-tidal plumb line variations.

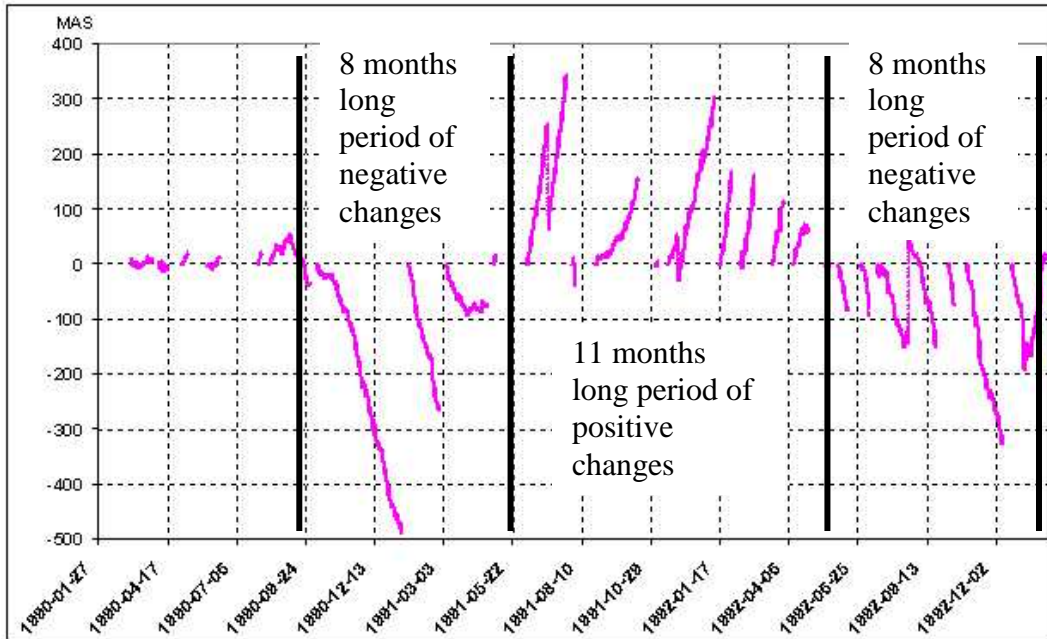


Fig.1. Three epochs of the azimuth of equilibrium of pendulum H75 changes (Azimuth ~90) in period 1990 to 1993.

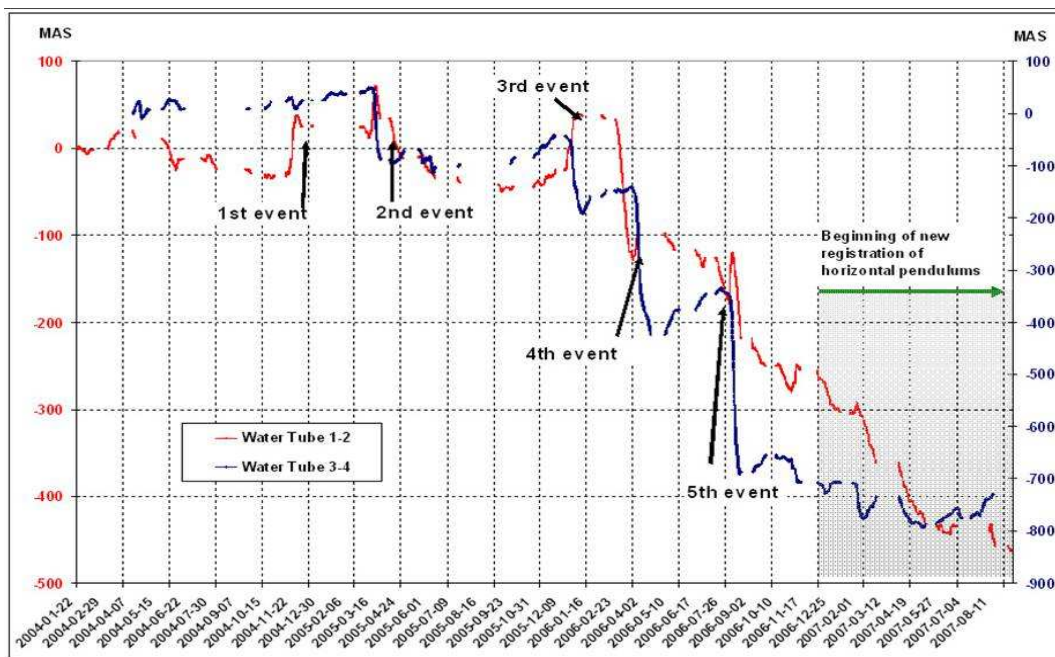


Fig.2. Non-tidal signal observed by long water-tube tiltmeter in period 2004-2007 in azimuth 58.6 [deg] (difference of signals 1-2) and in azimuth 148.6 [deg] (difference of signals 3-4).

Application of differential method eliminates instrumental drift produced by effects of condensation and evaporation of water from hydrodynamic system of instrument (dashed lines on figures 3-6) as well as eliminates effects caused by displacements of the tubes (Kaczorowski, 2006a). In next step time series of plumb line variations are performed with help of program ETERNA 3.4 to eliminate tidal signals. After low pass filtration we obtain time series of non-periodical character. During 2004-2007 we could observe five epochs of strong signals of plumb line variations (Fig. 2). These phenomena took place in the autumn-winter and winter-spring transition periods as well as in the middle of summer (July 2006). Therefore, we are able to exclude seasonal phenomena producing plumb line variations as reasons of non-tidal signals.

Table 1. The strongest non-tidal signals determined from differentiating of the channels 1-2 and 3-4 (1, 2, 3, 4 - numbers of channels) in period 2004-2007.

PERIODS OF STRONG SIGNALS AND DAYS OF DURATION			AZIMUTHS AND AMPLITUDES OF PHENOMENA IN [MAS]		MEAN VELOCITY OF PLUMB LINE VARIATIONS [MAS]/DAY		RESULTANT AZIMUTH OF PLUMB LINE VARIATIONS	
From:	To:	Number of days	Tube 1-2 -121.4 (58 <sup>0.6</sup> )	Tube 3-4 -31.4 (148 <sup>0.6</sup> )	Tube 1-2	Tube 3-4		
17 November 2004	13 Decemb. 2004	26	60	No data	2.31	No data	No data	
11 March 2005	28 March 2005	17	45	-140	2.64	-8.24	-13 <sup>0</sup>	
16 December 2005	09 January 2006	23	56	-131	2.43	- 5.70	-8 <sup>0</sup>	
24 March 2006	14 April 2006	20	-156	-290	-7.80	-14.50	-3 <sup>0</sup>	
28 July 2006	18 August 2006	0	-109	-350	-5.45	-17.50	-13 <sup>0</sup>	
Since September 2007 strong signals have not been registered								

Very strong non-tidal signals were registered two times in 2006. Observed magnitude exceeded 300 mas. Final azimuths of resultant plumb line variations differ less than 10 [deg] (Table 1) for all events. Resultant azimuths are close to direction of tectonic plates motions observed in Central Europe by GPS permanent stations. Courses of strongest events are similar. The strongest effects occurred in azimuth close to the azimuth -31.4 of the tube named 3-4. For tube 3-4 moments of initiation of strong effects were preceded by few weeks long intervals with tidal and vaporization effects only (Fig.3 and 5). Then, main effects of systematic trends of tilts lasting dozen or so days arrived. In azimuth -121.4 of the tube 1-2 plots of tilts during strong effects show us extremes. For azimuth -121.4 strong effects were not preceded by long intervals with tidal and vaporization effects only.

In 2006 we resumed measurements with help of horizontal pendulums equipped with new system of electronic registration. We expect that this circumstance allowed us a verification of strong non-tidal signals detected by long water-tube tiltmeter.

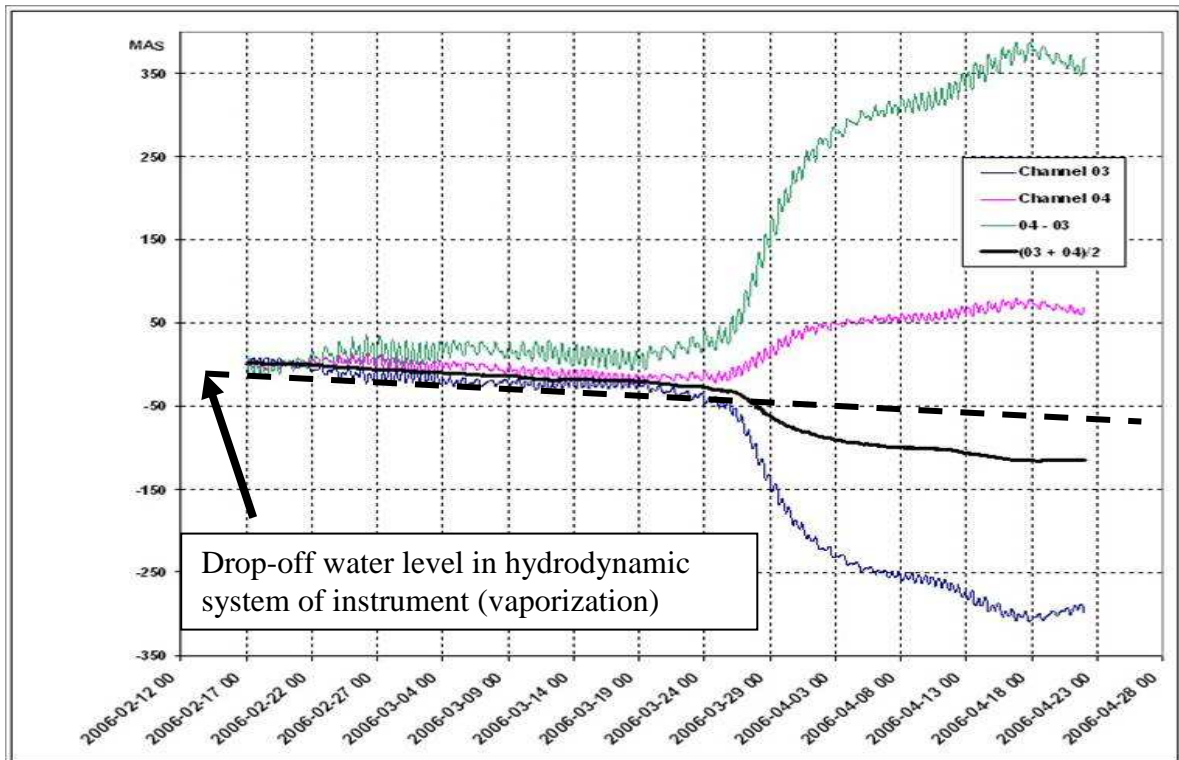


Fig.3. Raw signals (tidal and non-tidal) observed by tube 03-04 in March 2006 (event 4th)

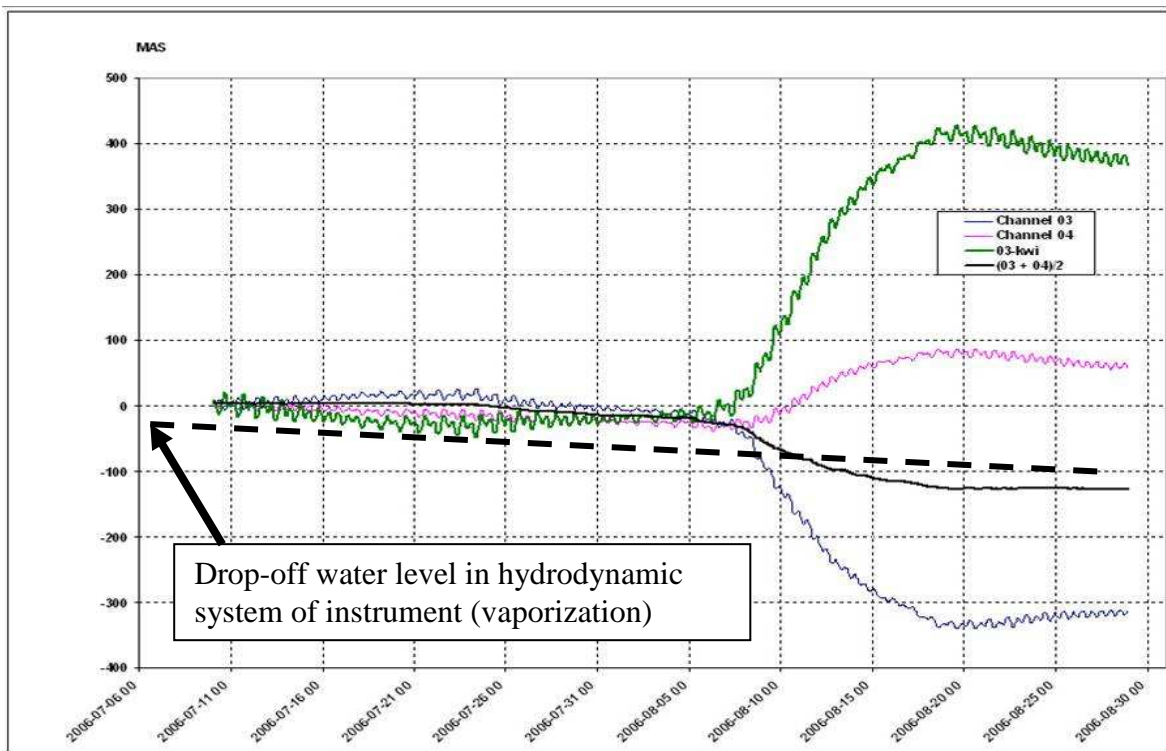


Fig.4. Raw signals (tidal and non-tidal) observed by tube 03-04 in July 2006 (event 5th).



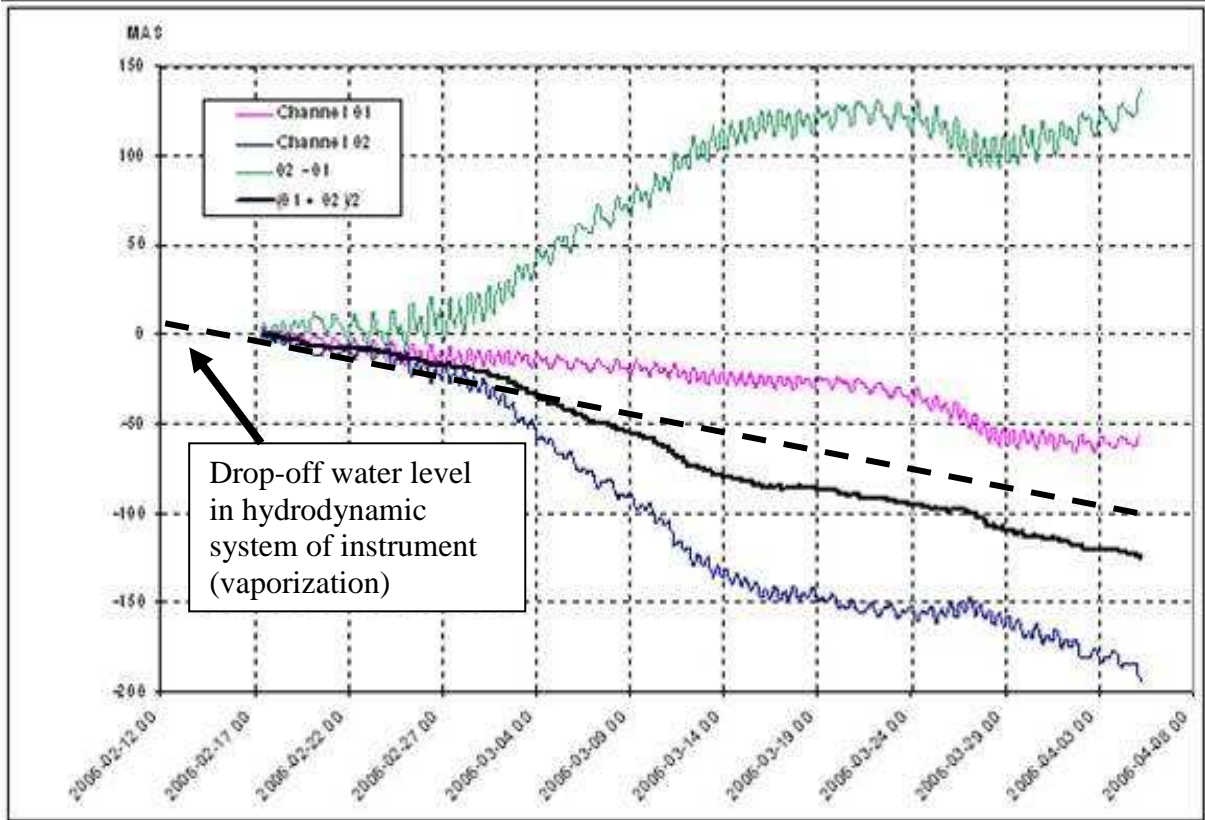


Fig.5. Raw signals (tidal and non-tidal) observed by tube 01-02 in March 2006 (event 4th).

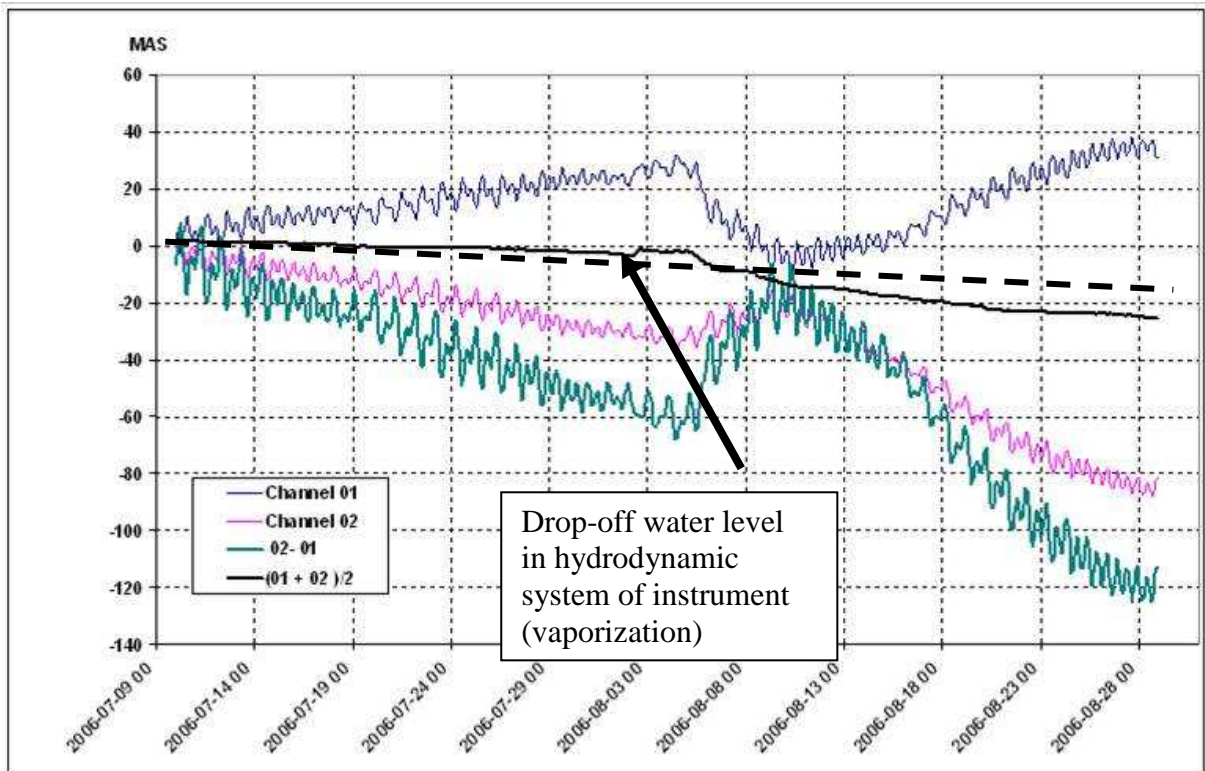


Fig.6. Raw signals (tidal and non-tidal) observed by tube 01-02 in July 2006 (event 5th).

Detection of correlation between both tiltmeters confirmed additionally thesis that observed large signals have geodynamic origin, not instrumental origin. In the case of positive verification we will apply thirty year's long series of pendulums observations to investigate strong non-tidal signals.

### 3. POSSIBILITY OF GENERATION OF NON-TIDAL SIGNALS BY LOCAL EFFECTS SUCH AS PRESSURE OR TEMPERATURE VARIATIONS IN CORRIDORS OCCUPIED BY WATER-TUBE TILTMETER

Changes of pressure in underground can produce water level variations in tubes of tiltmeter by inverse barometric effect. Gradient of pressure along water-tubes is necessary condition to change water level. In the case when pressure gradient appears, it produces at the ends of the tubes asymmetric water level variations which are erroneously interpreted as non-tidal signal of plumb line variations. For 85 meters long tube and difference of pressure equal to  $4 \times 10^{-3}$  [hPa] inverse barometric effect produces signal of magnitude 100 mas (pressure gradient is  $5 \times 10^{-5}$  [hPa/m]). The corridors where tubes of tiltmeter were installed are open to inside and closed to outside. Surface of section of corridors exceed sixteen square meters what assured quick compensation of horizontal pressure gradient. Appearing in corridor horizontal component of pressure gradient generates permanent motion of air along corridors from one side to opposite until pressure compensation. Therefore existence of few weeks lasting horizontal pressure gradient in corridors occupied by water-tubes is difficult to explain. It does not mean that in corridors gradient of air pressure equal to  $5 \times 10^{-5}$  [hPa/m] cannot appear. Probably, we are able to expect such great gradient during process of compensation of air pressure from inside into outside of underground during strong meteorological phenomena associated with rapid pressure variations. When process of compensation occurs variations of air pressure at both ends of the corridor (at both ends of the tubes) have the same trends increasing or decreasing. Pressure variations of identical trends neither affect pressure gradient in corridors nor produce asymmetric signals of water level variations.

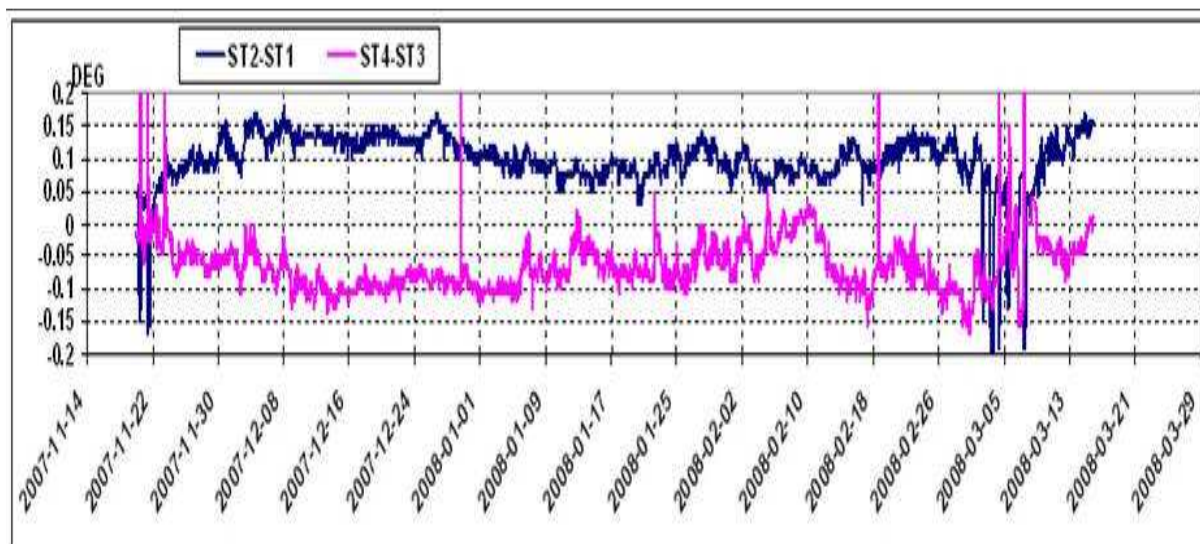


Fig.6. Plots of differences of temperature between ends of tubes during winter 07/08.

Meteorological phenomena associated with effect of pressure compensation in underground lasted few days after which trends of compensation became opposite. Therefore, explanation few weeks lasting systematic effects of water level variations by meteorological phenomena of pressure variations is improbable. Also temperature variations in underground are suspected of generation asymmetric signals of water level variations in water-tube tiltmeter. Temperature variations cause water density changes as well as height of water column above reflected lens. To solve this problem at the end of 2007 we built system of continuous monitoring temperature, pressure and humidity variations in the underground of laboratory. System consists of 26 sensors and its resolution amount 0.01 [deg] in temperature, 0.01% of relative humidity and 0.1 [hPa]. Sensors were distributed at the ends of the tubes and in the room of horizontal pendulums. The results of measurements from October 2007 to March 2008 showed us that differences of temperature at the ends of the tube were close to  $10^{-1}$  [deg]. Taking into account small value of water thermal expansion (1.00004) and height of water column in interferometer (0.005 m) we evaluate thermal effect of water level variations on  $10^{-7}$  [m] corresponding to 0.2 mas of plumb line variations. Temperature variations of density of water and height of water column above reflected lens produce symmetric signals only under specific condition - temperature variations at the ends of the tubes ought to have opposite trends – increasing and simultaneous decreasing. Fulfill this condition seems to be improbable.

#### 4. CONCLUSIONS

The measurements from period 2004-2007 carried out by the long water-tube tiltmeter contained five epochs of strong (>100 mas) non-tidal signals. Strong non-tidal signals appeared in different months: November, March, December, and in the middle of summer. Therefore, we are able to exclude any seasonal phenomena producing plumb line variations. Large, non-tidal signals registered by long water-tube and quartz pendulums can not be simply explained by local effects such as pressure or temperature variations. In 2006 the system of permanent monitoring temperature, humidity and pressure variations was installed. It allowed us to obtain information about possibility of generation of large, non-tidal signals caused by these changes. Magnitude of temperature variations ( $\gg 0.1$  deg) as well as horizontal gradient of temperature along the tubes ( $\gg 0.01$  deg/m) observed between October 07 and March 08 exclude temperature variations as reason of large, non-tidal signals. It is also impossible to explain strong non-tidal signal by any pressure variations in underground of laboratory. There is difficult to show any mechanism of generation of lasting few weeks air pressure gradient in laboratory as well as explain mechanism of simultaneous decreasing and increasing pressure at opposite ends of the corridors. In addition, to observations of water-tube observations carried out with help of horizontal pendulums also contain strong non-tidal signals. Small size of pendulums, their construction and location in underground, exclude temperature and pressure effects as reason of strong non-tidal signals. Resume at the end of 2006 measurements of horizontal pendulums 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. On the basis of previous experiences we find that large non-tidal signals exceeding 100 mas are neither instrumental nor local origin. Because of magnitude of non-tidal signals we are able to exclude phenomena such as all non-tidal loading and Newtonian effects of ocean or atmospheric origin. Resultant directions of plumb line variations during strong events are closed to direction of plates motions in Central Europe. In this moment of investigations we incline to thesis that large strong non-tidal signals of plumb line variations are produced by recent crust movements.

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