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Testing the Correlation Between the Vertical Crustal Movements and Temperature Changes on the Example of Selected Vectors Permanent GNSS Stations

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Abstract. In the last years air temperature increasing gradual. It also changes depending on the area: metropolitan, rural. The temperature changes directly affects the expansion of materials of which are made geodetic control network and support infrastructure. This may be influenced on the daily change in the amount determined for permanent GNSS stations. The main aim of the article is to examine the relationship between height changes and temperature changes. Daily difference in height between the selected stations Polish ASG EUPOS and the temperature in the vicinity of the stabilization of these stations data were used. Three year period was taken to the analysis. The results give a view on the article thesis.

Keywords: temperature, vertical crustal movements, testing correlation.

Conference topic: Technologies of geodesy and cadastre.

Introduction

In Poland, three maps of vertical crustal movements have been estimated with the use of levelling data. The last map has been made with double-levelling data (Kowalczyk 2005). In order to create a kinematic model of vertical crustal movements in Poland, the first tests were conducted just in 2008 (Kowalczyk 2008). The used data concerned areas around Warsaw. Having collected sufficient materials (Bednarczyk, Janowski 2014; Kowalczyk, Bednarczyk 2009; Kowalczyk *et al.* 2011), the kinematic models of vertical crustal movements from three levelling campaigns were created (Kowalczyk, Rapiński 2013). Due to the long breaks between the levelling campaigns, it is difficult to evaluate the influence of temperature on the estimated results.

Levelling lines create a geodetic network. The connections of permanent networks should be determined with the use of mathematical and network solutions (Baryła, Paziewski 2014; Kowalczyk *et al.* 2014c; Kowalczyk, A., Kowalczyk, K. 2014a; Kowalczyk, A., Kowalczyk, K. 2014b; Kowalczyk 2015). The above-mentioned solutions were used in creating the methodology for determining vertical crustal movements in Poland with the use of GNSS data gained from Polish stations of ASG-EUPOS networks (Rapiński, Kowalczyk 2016). The movements were estimated from height differences between GNSS permanent stations in twenty-four-hour intervals and they created time series. During the analysis of the series, the authors found the occurrence of seasonal factors.

The collected materials (Rapiński, Kowalczyk 2016) were based inter alia on the information included in .log files (Table 1) of particular stations (www.asgeupos.pl). They include detailed data concerning the stability of given antennas. The majority of the antennas are stabilized on buildings with steel or aluminum pipes of various lengths which serve as connectors.

Table 1. The examples of the stabilization of selected permanent stations in Polish ASG – EUPOS network

Four character	Monument description	Height of the Monument	Monument Foundation	Foundation Depth	Tectonic Plate
BART	ALUMINIUM MAST	1.50	ROOF		Eurasian
BIAL	ALUMINIUM MAST	1.50	ROOF		Eurasian
BILG	ALUMINIUM MAST	1.50	ROOF		Eurasian
BOGI	CONCRETE PILLAR COVERED WITH WOODEN CASING	1.20	CONCRETE BLOCK	2.5 m	Eurasian
BPDL	ALUMINIUM MAST	2.00	ROOF		Eurasian

End of Table 1

BRSK	ALUMINIUM MAST	1.50	ROOF		Eurasian
BUZD	ALUMINIUM MAST	1.50	ROOF		Eurasian
BYDG	ALUMINIUM MAST	1.10	ROOF		Eurasian
DZIA	ALUMINIUM MAST	1.50	ROOF		Eurasian
ELBL	STEEL TRIPOD FIXED TO THE CHIMNEY	0.40	ROOF		Eurasian
GDA1	STAINLESS STEEL MAST	1.38	ROOF		Eurasian
GIZY	ALUMINIUM MAST	1.50	ROOF		Eurasian

The information about the stabilization allows for estimating thermal expansion of particular connectors. The formula for linear thermal expansion of solids (e.g. 1) and the coefficient of thermal expansion of steel and aluminum were used for the estimations.

$$x = x_0 \left(1 + \propto \Delta T\right), \quad (1)$$

where: x – length of the object after the temperature change; x_0 – initial length; $\propto$ – coefficient of thermal expansion; ΔT – difference of the temperature between the two recorded strains.

The estimated results allowed for evaluating the influence of temperature on the estimated heights and assessing the influence of temperature on the pace of height changes between the stations. They can also be used to improve the precision GNSS surveys (Paziewski 2015).

Data

For the analysis twenty-four-hour height differences between two permanent stations of ASG EUPOS network (ELBL and OLST) and the average temperature around the stations were used (Fig. 1).

Fig. 1. The stabilization of the stations selected for the research (www.asgeupos.pl), left – ELBL, right – OLST

The ELBL antenna is connected with the building with an aluminum pipe, 1.4m long. The antenna on OLST station is connected with the building with a steel pipe, 0.4m long (.log files taken from www.asgeupos.pl).
The temporal resolution of height differences (Fig. 2) and the temperature (Fig. 3) was 3 years.

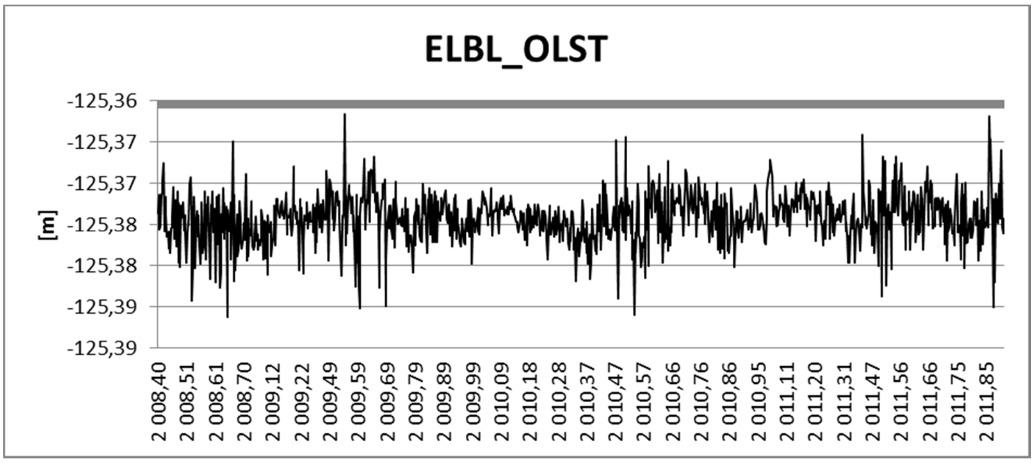

Fig. 2. Time series of height differences between ELBL and OLST stations

The change of height on ELBL_OLST vector fluctuates between 2cm; occasionally, it is bigger.

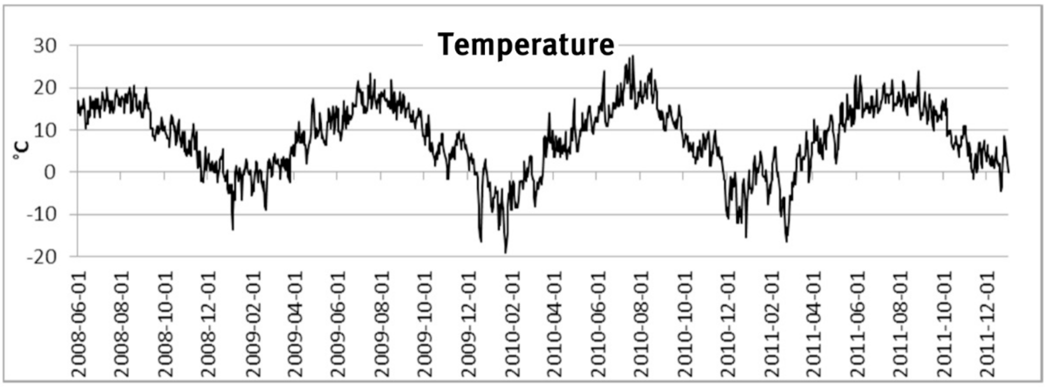

Fig. 3. The diagram of temperature changes around ELBL stations

The diagram (Fig. 3) clearly shows the temperature seasonality in one year cycles. The minimal negative trend can be also seen. The amplitude fluctuates between –20^{o}C and +23^{o}C. On the basis of the collected average daily temperature, the author estimated the twenty-four-hour changes in the antenna's height due to thermal expansion of the connector. Figure 4 and Figure 5 present the height changes in ELBL station and in OLST station respectively.

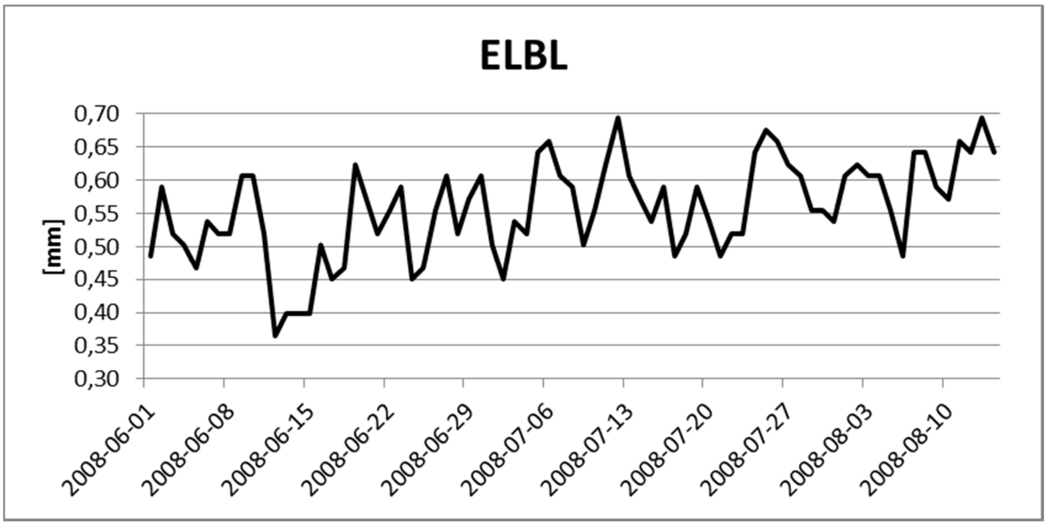

Fig. 4. Changes in height of the antenna located on ELBL station in relation to thermal expansion of the connector

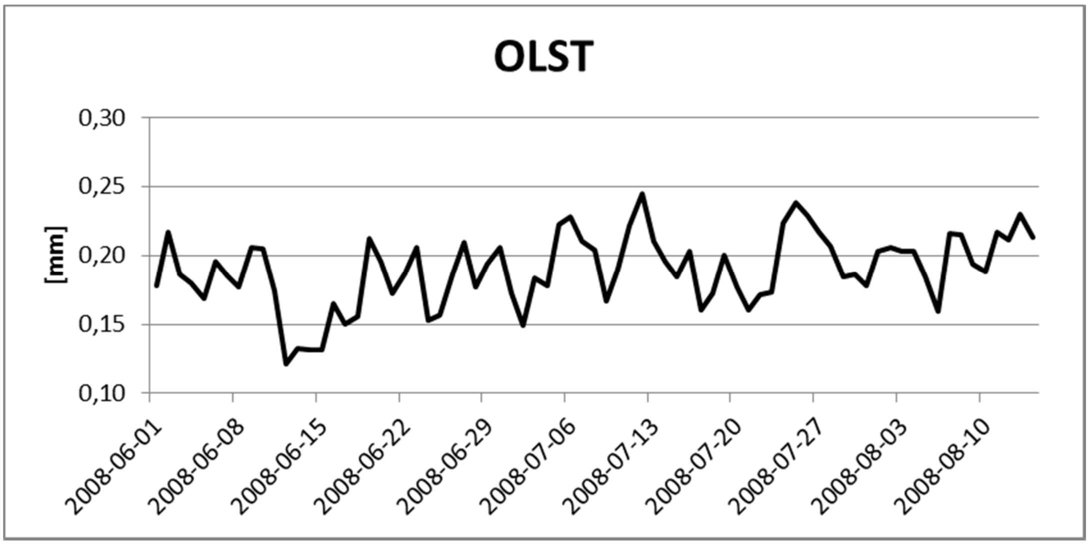

Fig. 5. Changes in height of the antenna located on OLST station in relation to thermal expansion of the connector

The figures (Fig. 4 and Fig. 5) show that changes in height of the antenna is strongly correlated with the type of material the connector is made of and the connector's length. For ELBL station, the amplitude of the antenna's height changes is from 0.35mm to 0.7mm. In OLST station, the amplitude is from 0.12mm to 0.25mm.
Due to estimating height changes between the stations, the author estimated the height changes of the antennas located on the stations. Figure 6 presents the influence of thermal expansion of the connector on daily height changes between the stations.

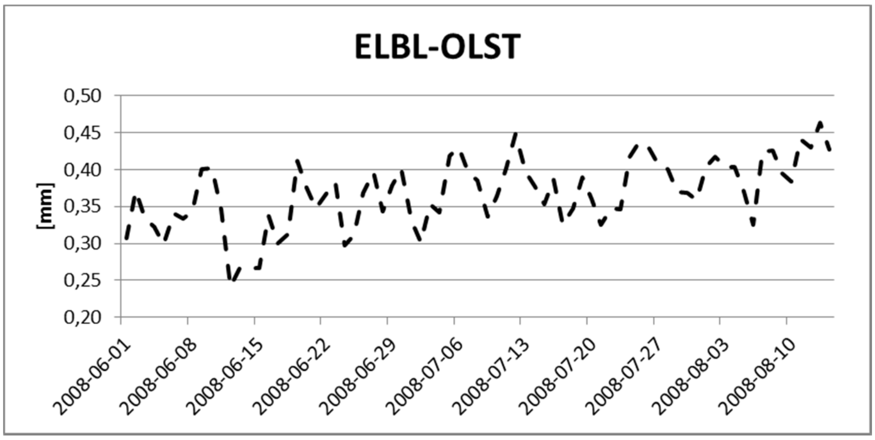

Fig. 6. Daily height changes of antennas between ELBL and OLST stations in relation to thermal expansion of the connectors

The height changes of the antennas fluctuate between 0.25mm and 0.45mm.

The author performed the time series decomposition of height differences between ELBL and OLST stations. Figure 7 shows the values of the seasonal coefficient.

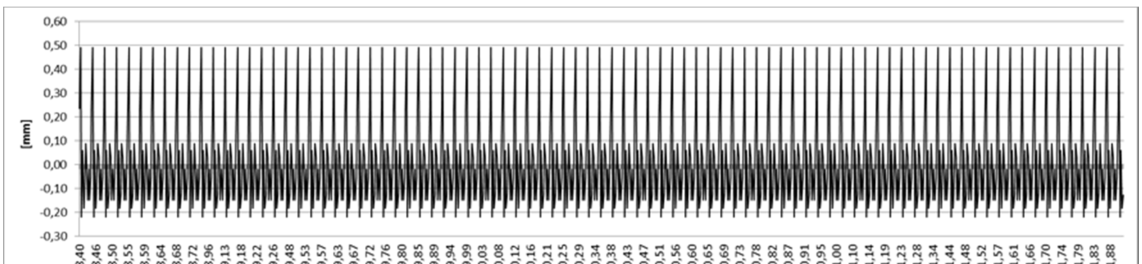

Fig. 7. The seasonal coefficient for the primary height difference

Figure 7 presents the influence of seasonality on the level from 0.2mm to 0.5mm. It coincides with the amplitude of thermal expansion of the connectors (Fig. 6).

In order to determine the influence of thermal expansion on vertical crustal movements on ELBL_OLST vector, the linear trend for the height differences between the stations was estimated. Moreover, the linear trend for height differences between the stations supplemented with the information about the influence of temperature was estimated as well. The results are presented in Table 2. The trend difference is 0.1mm/year.

Having removed the seasonality from the time series of height differences, a linear trend was determined (Table 2). It correlates with the trend estimated with the use of height differences supplemented with the information about thermal expansion of the connectors.

Table 2. The estimated linear trends

Trend from the signal [mm/y]	Trend from the signal considering thermal expansion of the connectors [mm/y]	Trend from the signal with the removed seasonality [mm/y]
–0.42	–0.48	–0.48

Figure 8 presents the value of noise for the time series of height differences between ELBL_OLST stations.

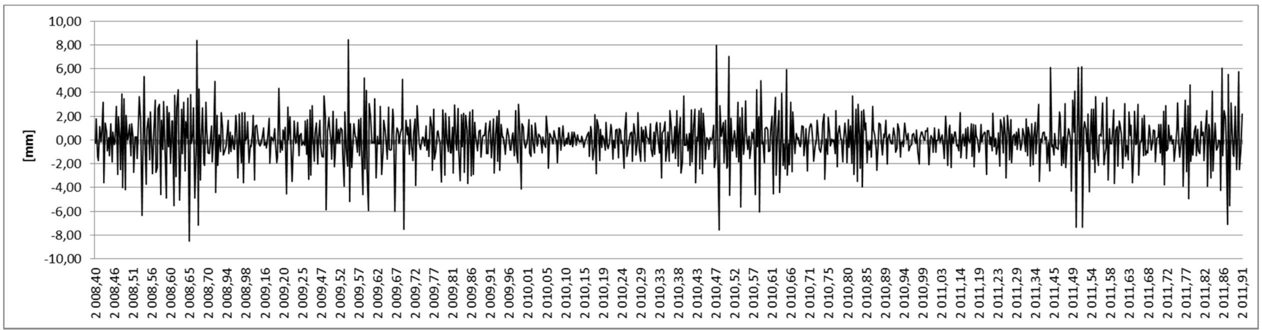

Fig. 8. The value of noise for time series of height differences between ELBL_OLST stations

Conclusion

The connectors between the antennas and the buildings change their length under the influence of temperature. Consequently, the ambient temperature has an influence on the estimated heights on permanent stations. The influence depends mainly on two factors: the type of materials used in making the connector and its length. They also influence the height differences between the stations, especially when the connectors on the stations are made of different materials and have different length. Moreover, that has also an impact on the estimated trends of height differences (vertical movement). The influence of thermal expansion of materials on the estimated vertical crustal movements between the stations are about 0.1mm/year.

Doing the decomposition of the time series of height differences, the influence of thermal expansion of antennas' connectors is eliminated.

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