ANALYSIS OF DIGITAL TERRAIN MODEL TECHNOLOGY DEVELOPMENT, WHILE USING SIMULTANEOUS SATELLITE AND TACHEOMETRIC MEASUREMENTS

Katarzyna Pająk, Marcin Uradziński, Adam Doskocz, Monika Biryło

University of Warmia and Mazury in Olsztyn
Faculty of Geodesy and Land Management
Chair of Land Surveying and Geomatics

1. INTRODUCTION

The development of digital terrain model (DTM) is a very large and occurs in many scientific fields. In addition DTM is used in many engineering projects. Test-relief and opportunity to its model in the computing environment, providing a wide assortment of its analysis, visualization and utilization, is an important and key element of many projects: designing, analysis, researching and creating the infrastructure for spatial databases (INSPIRE). With modern satellite, laser or remote-sensing techniques study area stretches of interest to us does not even require to be present at the area with equipment and measuring it. It is also possible to visualize terrain based on satellite images, aerial or laser scanning. However there is still one of the most popular methods of obtaining data for the DTM to be measured directly. As a result of the development of measurement technologies, in this method we can now use modern equipment that enables faster and easier observations. While the acquisition of points in real time using GNSS RTK technology facilitate and accelerate the work, total station instruments are considered to be the most accurate.
In this paper authors analyzed the technology of digital terrain model development, taking advantage of total station and RTK GNSS measurements.

2. ANALYSIS OF COLLECTED DATA

The creation of any digital terrain model requires the pooling of data. This study used survey data acquired by the two methods of direct measurements (Doskocz A., Uradziński M., 2010):

- **tacheometric (to measure the shape of the terrain electronic total station Leica TC 407 was used),**
- **satellite (to measure the shape of the terrain Topcon HiperPro RTK GNSS set was used with own base station).**

Measurements of the test area were conducted on the object called "Kortowska Hill". The spatial resolution of the obtained measurement data are presented in Figure 1.

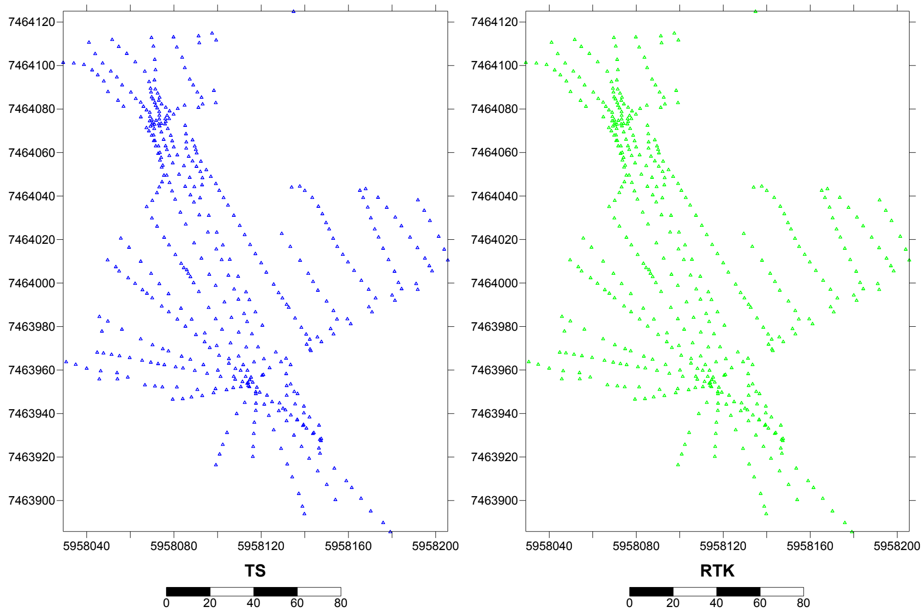

Fig. 1. The spatial distribution of measurement data.

3. ANALYSIS OF COORDINATE DIFFERENCES

Analysis of coordinate differences (excluding the point No. 391, 453 points were analyzed) was carried out based on the coordinates expressed in a reference system, using the following formula (Doskocz A., Uradziński M., 2010):

$$DX = X_{TS} - X_{RTK} \; ; \; DY = Y_{TS} - Y_{RTK} \; ; \; DH = H_{TS} - H_{RTK}$$

where:
(X,Y,H)TS - coordinates determined by measuring the point using TOTAL STATION
(X,Y,H)RTK - coordinates determined by measuring the point using RTK GNSS
Comparison of coordinates are presented in graphs, including differences DX and DY (Fig. 2) and DH (Fig. 3).

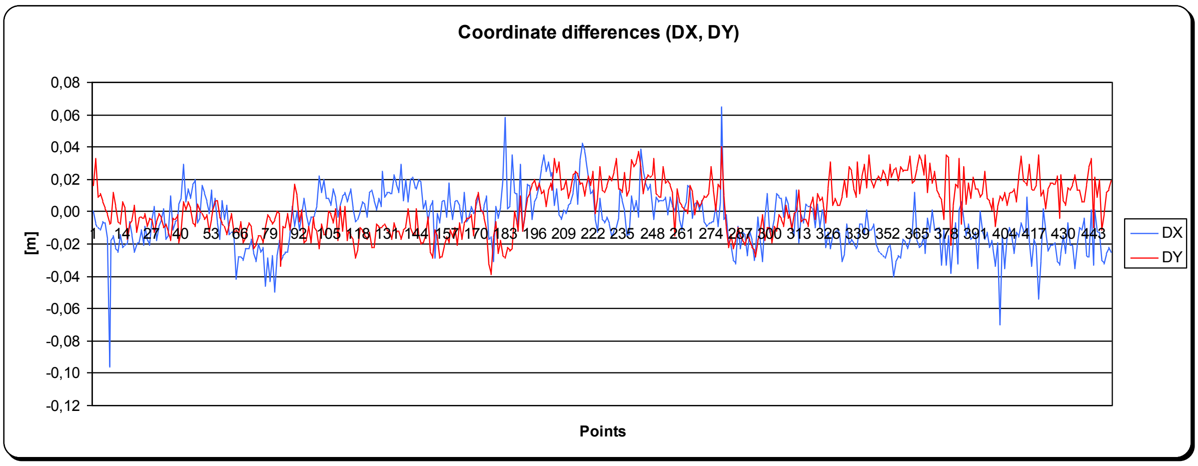

Fig. 2. Coordinate differences (DX, DY).

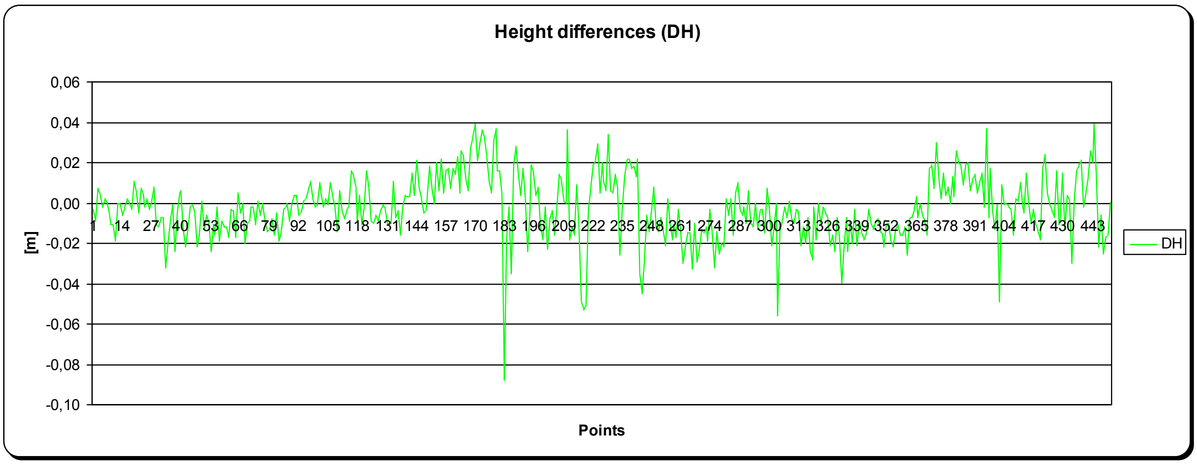

Fig. 3. Height differences (DH).

The values of the average differences, maximum, minimum, as well as RMS error and standard deviation are presented in Table No. 1.

Table 1. Summary of results

	AVERAGE [cm]	*MAX [cm]*	*MIN [cm]*	*RMS [cm]*	*STAND.DEV. [cm]*
X	*0,58*	*9,60*	*6,50*	*1,84*	*1,75*
Y	*0,29*	*3,90*	*4,00*	*1,62*	*1,60*
H	*0,27*	*8,80*	*3,90*	*1,57*	*1,55*

Summary of results: differences of average values, maximum and minimum, as well as RMS error and standard deviation are shown in Figure 4.

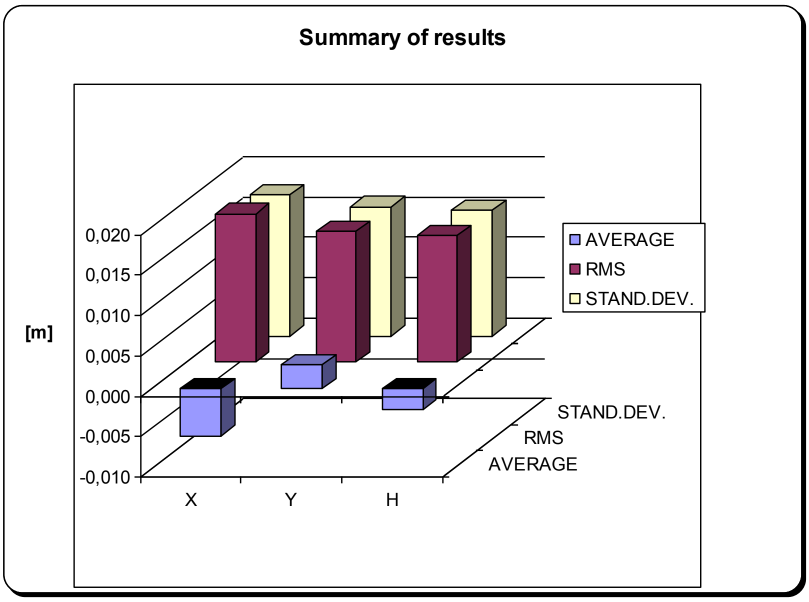

Fig. 4. Graphic presentation of average, maximum and minimum difference between the coordinates derived from the two measurement methods.

After calculations and tests carried out between the coordinates derived from two methods of direct measurement, the numerical terrain models were generated in the Golden Software's Surfer (Figure 5).

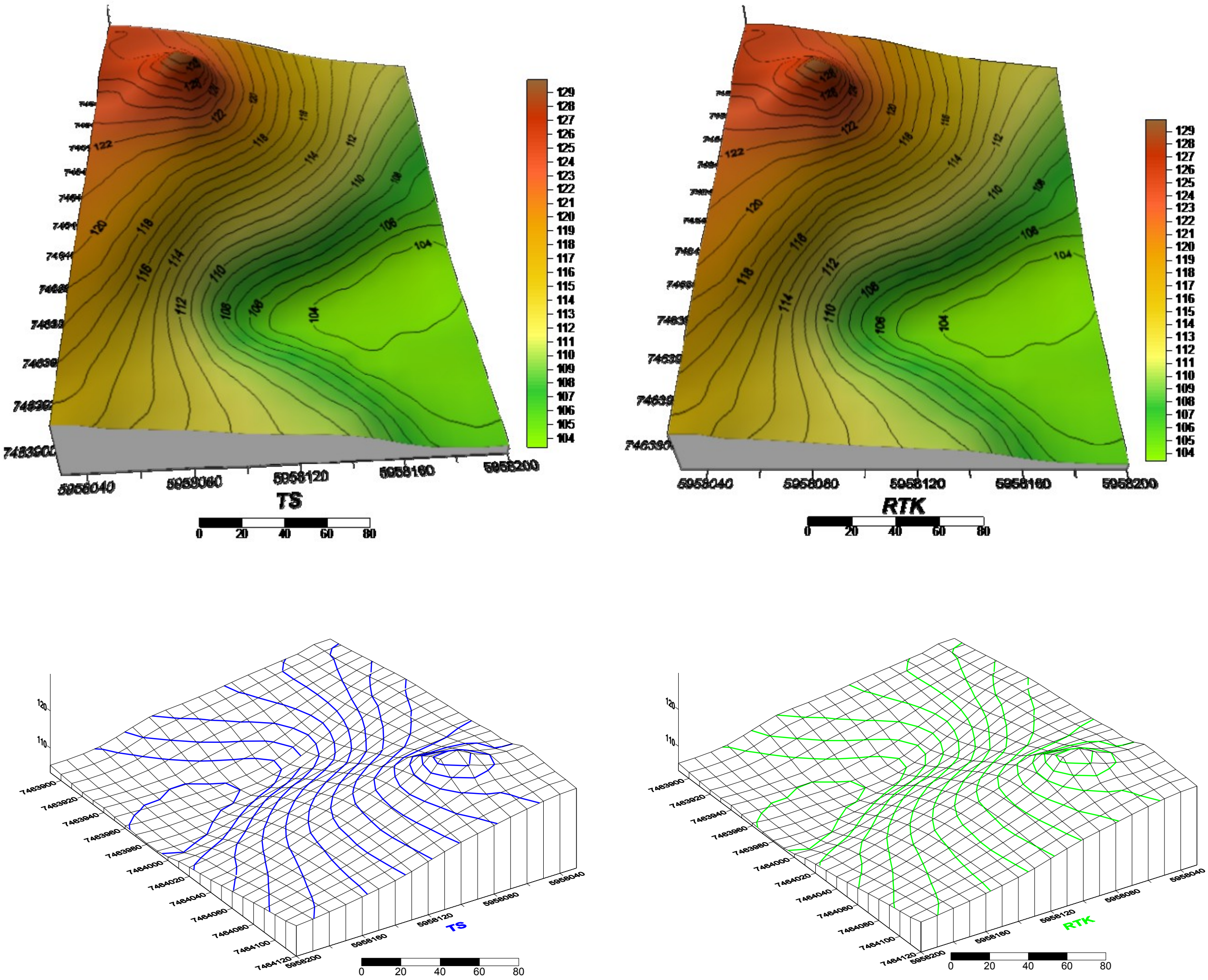

Fig. 5. Digital terrain model generated in the Golden Software's Surfer.

4. COMPARISON OF DEVELOPED GRID MODELS

An analysis of digital terrain models created from data obtained from direct measurement using tacheometric and satellite methods were conducted. The analysis was based on the GRID surfaces formed on the basis of data obtained from these two measurement methods. To assess the statistical GRID area, the following parameters were used (Baran L.W. 1999) :

• variance and standard deviation of the GRID surface (Pajak K., 2008),

$$DH_{AVE_{TS-RTK}} = \frac{(H_{1_{TS}} - H_{1_{RTK}}) + ... + (H_{n_{TS}} - H_{n_{RTK}})}{n}$$

$$V(H) = \frac{[(DH_{1_{TS-RTK}} - DH_{AVE_{TS-RTK}})]^2 + ... + [(DH_{n_{TS-RTK}} - DH_{AVE_{TS-RTK}})]^2}{n-1}$$

$$\delta(H) = \sqrt{V(H)}$$

where:

$DH_{1...n_{TS-RTK}} = DH_{1...n_{TS}}$ - $DH_{1...n_{RTK}}$ **– values of successive differences between the heights of the GRID surface obtained by direct tacheometric and satellite measurements,**
DH_{AVE} - the average height differences of the GRID surface obtained by direct tacheometric and satellite measurements,
n – number of points.

• RMS, root mean square error

$$\text{RMS} = \sqrt{\frac{\sum (DH_{AVE} - DH_i)^2}{n}}$$

where:

$DH_i=(H_{iTS}-H_{iRTK})$ – values of successive differences between the heights of the GRID surface obtained by direct tacheometric and satellite measurements,
$DH_{AVE}=[(H_{iTS}-H_{iRTK})/n$ - the average height differences of the GRID surface obtained by direct tacheometric and satellite measurements,
***n* – number of points.**

The analysis was based on calculation of the height differences in the surface mesh nodes GRID between the methods, standard deviation and RMS error, as shown in Table 2.

Table 2. Summary of results

	AVERAGE [cm]	***MAX [cm]***	***MIN [cm]***	***RMS [cm]***	***ST. DEV. [cm]***
$GRID_{TS-RTK}$	***-0,92***	***3,10***	***-5,00***	***1,27***	***1,37***

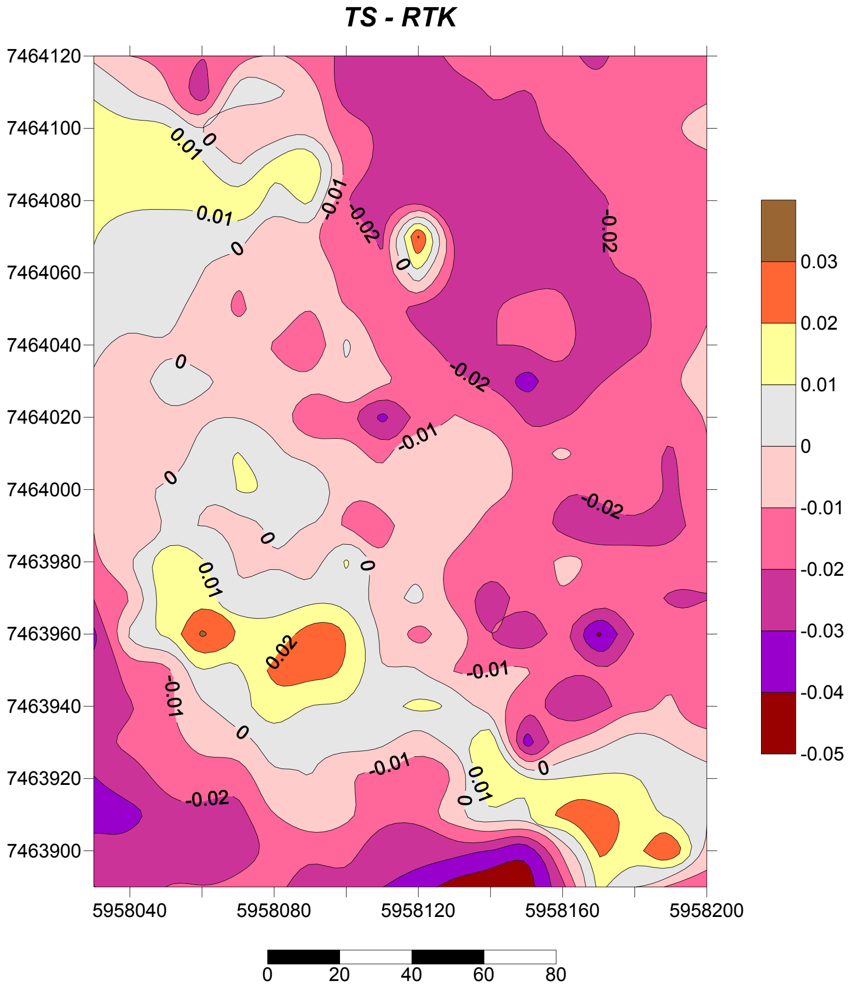

Fig. 6. The distribution of height differences for the GRID surface.

5. SUMMARY

There are many measurement methods for obtaining geometric information of the area. Among them, direct methods like tacheometric measurements are the most reliable and accurate (Technical Guidance Document K-2.8, 2001). However, for economic reasons tacheometric measurement method, as the sole or the lead, is not justified. Due to the speed of data acquisition and easy updating, the GNSS method of obtaining the automatic registration of such coordinates deserves special attention. Direct Satellite RTK method made it possible to gain points with high accuracy. The observed differences in the point coordinates (DX, DY and DH), obtained from the two methods are very small, their average size was as follows: dx = 0.58 cm, dy = 0.29 cm, dh = 0.27 cm. While a comparison of the two measurement methods for surfaces created as the GRID, average size of coordinate differences amounted to 0.92 cm in height, and their standard deviation was equal to 1.37 cm. RTK GNSS technology which was used to generate the DTM is fast, reliable and has a high degree of accuracy.

REFERENCES

Baran L.W., 1999. The theoretical basis for the development of geodetic measurements. Wydawnictwo Naukowe PWN.

Doskocz A., Uradziński M., 2010. Comparison of point coordinates obtained simultaneously by tachimetric and GNSS RTK measurements. KGS KBKiS Sciences Conference "Satellite methods of determining position in modern surveying and navigation", Olsztyn.

Golden Software's Surfer, ver. 8.

Leick A., 2003. GPS Satellite Surveying. Wiley, 3rd Edition.

Pająk K., Ciećko A., Oszczak S., 2006. Analysis of Different Methods used for Creation of Digital Terrain Model (DTM). 8th Bilateral Geodetic Meeting Poland-Italy, Wrocław, Poland, Reports and Geodesy No. 2(77).

Pająk K., 2008. Analysis of technology used to develop digital terrain model using classical, satellite and photogrammetric methods. PhD thesis, Olsztyn.

Technical Guidance Document K-2.8, 2001. Principles of exercise orthophoto maps in the scale 1: 10 000.