LASER PLUMMET TESTING WITH THE USE OF THE OPTOELECTRONIC ELEMENTS

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INTRODUCTION

Geodetic works realized with the use of angle-measuring instruments and rangefinders are associated with the procedure of a correct setting up of the measurement instrumentation on the control points and the points moved to different building levels in investment processes. The accuracy of the setting up of the measurement instrument over the point depends on i.a. the precision of the rectification of the until recently mounted optical plummet and the recently more and more frequently applied laser plummet. This is connected with the number of advantages, that have been introduced to the land surveying by the laser technique. The development of optoelectronic technique, that in many problems takes the role of an „observator", gives a broad spectrum to create the measurement apparatus. Nowadays especially the use of the CCD converters is commonly possible, owing to the undoubtedly low costs of their purchase.
In this paper there have been presented the results of the experimental testing works with the use of the optoelectronic elements of the three laser plummets, that account for the equipment of the Leica and Trimble total stations.

MEASUREMENT SITE FOR TESTING OF THE PLUMMENTS

In figure 1 there is presented the position of the measurement set elements for testing of the plummets. The set consists of the autocolimation mirror, arranged on the tribrach under the instrument, which laser plummet is checked. The CCD converter is placed on the tribrach in a fixed distance from the instrument. The screen of the CCD converter is set on the height reflected from the laser mirror beam. The incident laser plummet beam is observed in a form of a spot on the computer screen, which is linked to the CCD converter by the transmition line. Both the mirror and the CCD converter tribrach are equipped with the levels, which enable the correct setting up in the space of the mirror and the screen of the CCD camera.

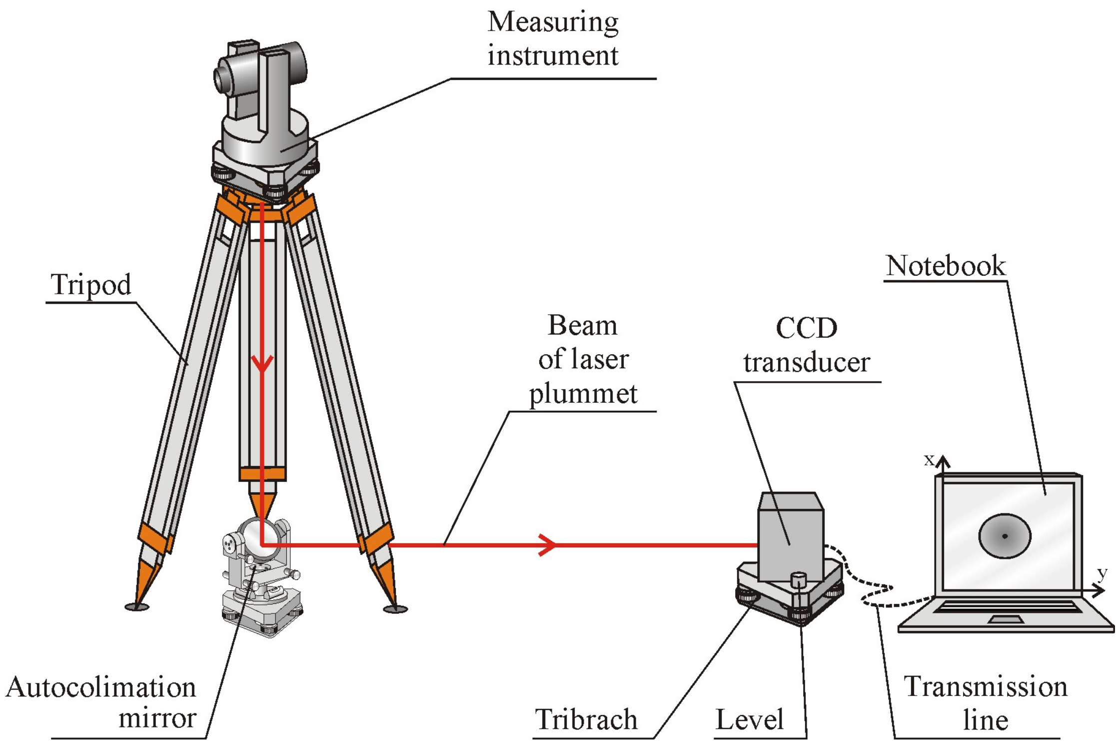


Fig. 1.The picture of the set of instruments during laser plummet testing.

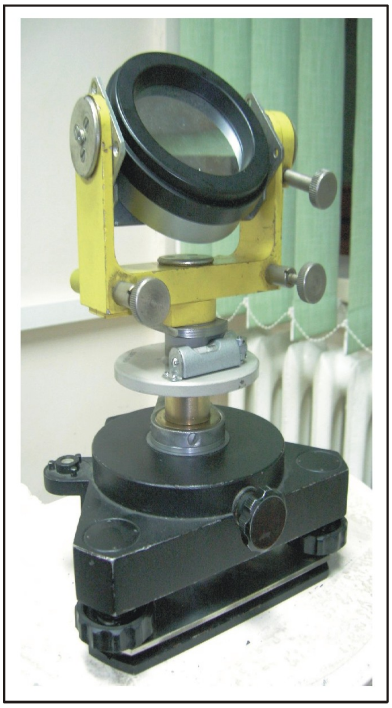
The autocolimation mirror (fig.2) is set on the body, which is equipped with the clamps for the slow-motion screws. They enable the inclination and rotation of the surface autocolimation mirror in both planes. The rotation and the inclination of the plane mirror enable to steer the laser beam on the screen of the CCD camera converter. The connection between the camera and the computer allows to observe in real time the image of a laser beam, falling on the projection screen (fig.3). As a result, there is a possibility for visually positioning of the beam image in a local coordinate system of a screen.

The second function of the computer is the possibility to register the sequence of images in a defined measurement periods (fig.3). On the basis of the registered images there could be analytically determined the position of the electrical center of a laser beam. To realize this task there has been built up a software in the Matlab environment, which uses procedures of a digital image analysis.

If the laser plummer is correctly rectified, then the plummet axis is at the same position as the rotation axis of the alidade of the geodetic instrument. In that situation during the alidade rotation the laser beam position on the projection screen does not change (fig.3). If the investigated instrument is equipped withe the unrectified plummer, then referring to the points 1,2,3 and 4, the laser beam could be observed at the same time on both the projection mirror and the monitor screen, during the alidade rotation and after the reflection from the mirror (fig.3). The appropriate position of the mirror under the instrument extends a distance of a laser beam running and consequently the error of the non-overlapping plummet and instrument rotation axis could be determined with a higher degree of accuracy.

In figure 4. there is presented the arrangement of particular instruments and appliances on the testing laboratory length base. On the length base there are marked points in

fixed intervals with the use of the plates. The CCD converter is positioned then on these points.



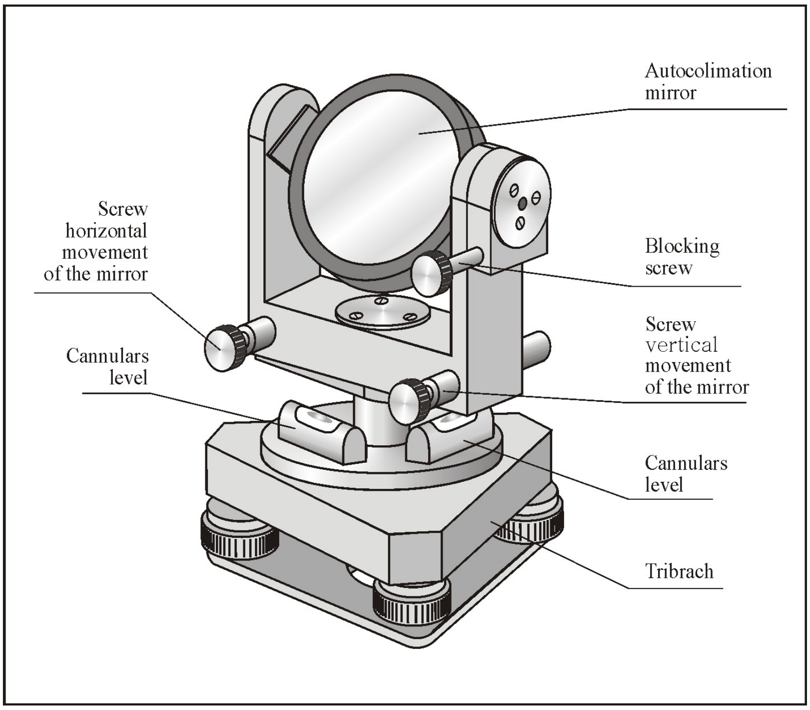


Fig. 2. The picture of the autocolimation mirror on the measurement site.

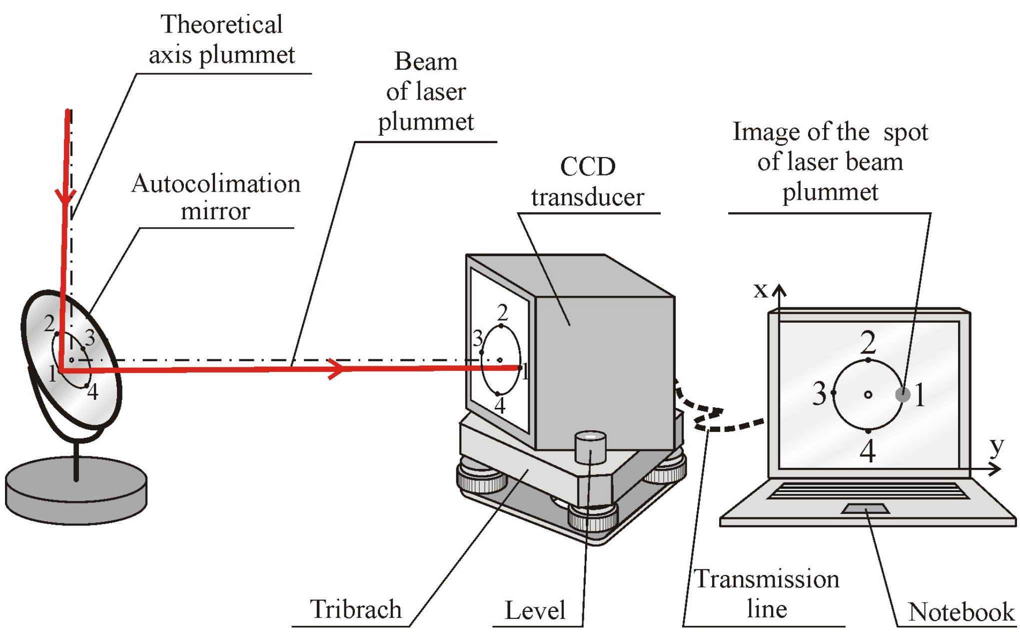


Fig. 3. The scheme of a laser beam during the plummet testing.

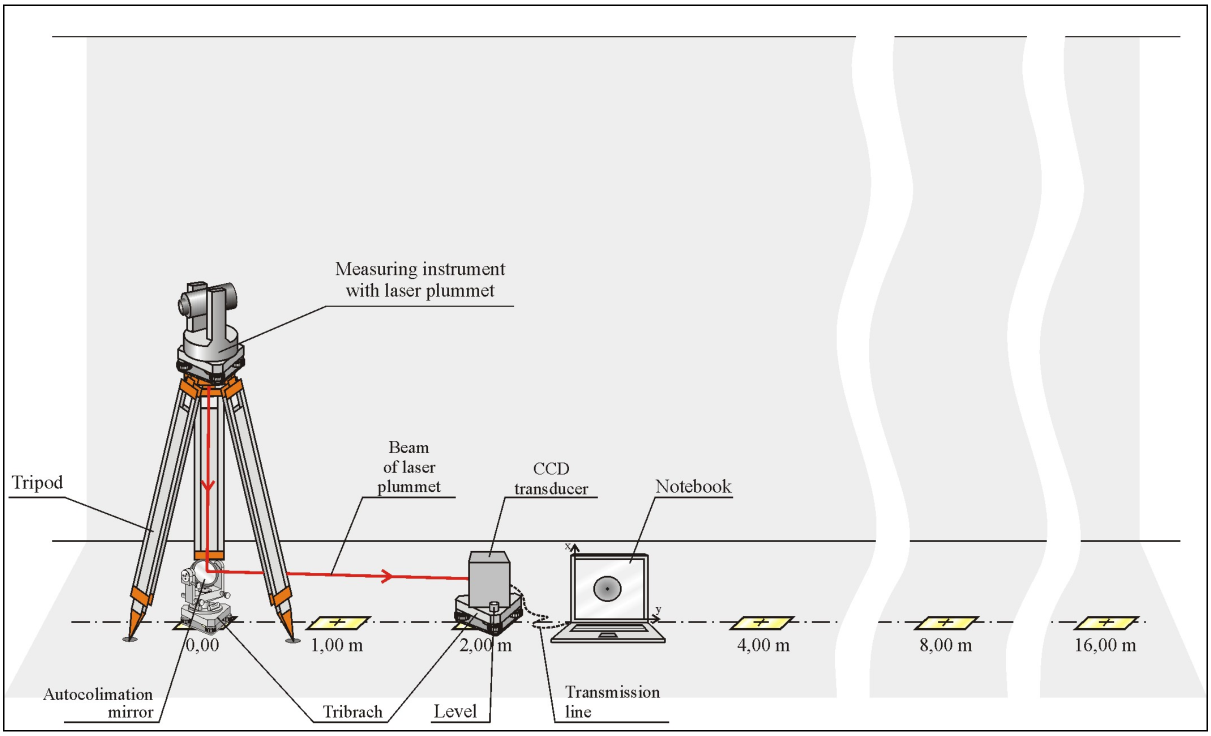


Fig. 4. The arrangement scheme of the measurement set on the testing base.

EXPERIMENTAL WORKS

The experimental works have been carried out on the testing laboratory length base, situated in the basement of the building of the Institute of Geodesy and Geoinformatics of the Wroclaw University of Environmental and Life Sciences. For the research there have been used three total stations, equipped with the following laser plummets: Leica TCR407 Power, Trimble M3 DR 2" and Trimble M3 DR 3". Over the first base point there has been set up the instrument with the tested plummet, under which on the tribrach there has been set up the autocolimation mirror (fig.5). On the measurement points there is arranged the CCD converter with the computer. After turning on the plummet, its beam should be directed to the projection screen of the converter by the inclination of the surface mirror. The measurement consists in a disk registration of a sequence of laser plummet images during the alidade rotation of the instrument around the vertical axis. The measurement cycle has been composed of the 9, every 50^g changing alidade positions. The measurements of the plummets have been carried out on the following length bases: 1.00, 2.00, 4.00, 8.00, 12.00 i 16.00 m.

In figures 6.and 7. there has been presented the examples of registered laser beam images of the plummets of the instruments: Leica TCR407 Power i Trimble M3 DR 3".

In figure 8. there could be seen the next graphs illustrating the position of the electrical center of a laser beam image during the alidade rotation of the investigated instruments.

Fig. 5. The picture of the measurement set instruments during experimental works.

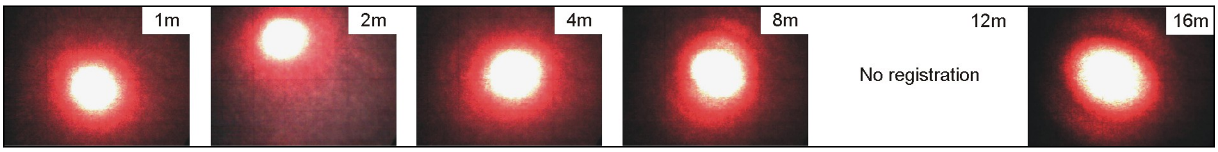


Fig. 6. The registered laser beam images of the Leica TCR407 Power. instrument plummet

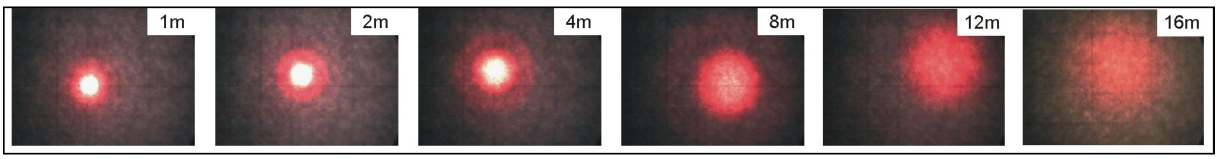


Fig.7. The registered laser beam images of the Trimble M3 instrument plummet.

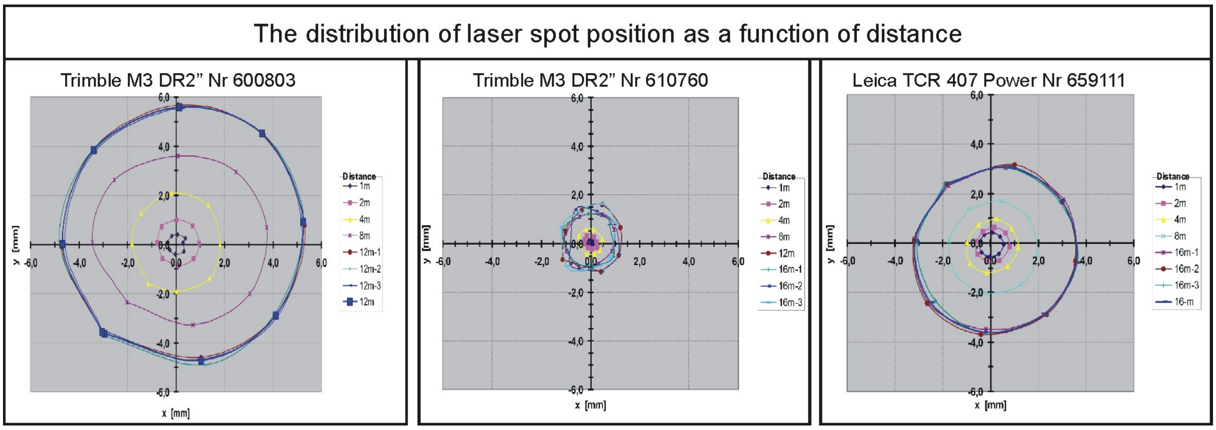


Fig. 8. The graphs illustrating the position of the electrical center of a laser beam image of the investigated plummets during the alidade rotation of the instruments.

Table 1 presents the results of the measurements on the registered laser beam images of the Leica TCR407 Power instrument plummet. The position coordinates of the electrical center of a laser beam image have been determined with the use of the own software, built up in the Matlab environment. In a second part of table 1. there have been presented the results of the accuracy analysis. While conducting them there have been computed the final mean errors m_{0x} i m_{0y} of a standard observation. A standard observation is an observation (a weight of p=1), performed twice from the distance of 4.00 m. (D=4.00m), with an estimated a'priori error of 1 pixel (0.047 mm).

Tab.1. The results of the measurements on the registered laser beam images of the Leica TCR407 Power instrument plummet with the accuracy analysis

Order	Distance	The angle of rotation of instrument alidade	The position coordinates of the electrical center of a laser beam image						The average value of the coordinate center of the spot		Mean error arithmetic mean		Deviation		Weight	Mean error of single observations		
			Measuring 1		Measuring 2		Measuring 3											
	D		x	y	x	y	x	y	$x_{śr}$	$y_{śr}$	m_x	m_y	$v_x=m_x-m_{xśr}$	$v_y=m_y-m_{yśr}$	p	m_{xi}	m_{yi}	m_{pi}
	[m]	[g]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]		[mm]	[mm]	[mm]
1	1.0	0	-0.269	0.343														
2		400	-0.266	0.348					-0.267	0.346	0.002	0.002	-0.047	-0.027	3.929	0.017	0.010	0.020
3	2.0	0	-0.350	0.444														
4		400	-0.305	0.480					-0.328	0.462	0.023	0.018	-0.026	-0.011	0.399	0.053	0.031	0.062
5	4.0	0	-0.434	0.812														
6		400	-0.562	0.710					-0.498	0.761	0.064	0.051	0.015	0.021	0.142	0.089	0.052	0.104
7	8.0	0	-0.954	1.355														
8		400	-0.941	1.338					-0.948	1.346	0.006	0.009	-0.042	-0.021	1.080	0.032	0.019	0.038
9	16.0	0	-1.674	2.311	-1.831	2.384	-1.866	2.405										
10		400	-1.863	2.362	-1.805	2.376	-1.959	2.464	-1.833	2.384	0.038	0.021	-0.010	-0.009	0.802	0.038	0.022	0.044
11		50	-3.182	0.182	-3.208	0.129	-3.076	0.000	-3.156	0.104	0.040	0.054	-0.008	0.024	0.258	0.066	0.039	0.077
12		100	-2.573	-2.460	-2.665	-2.434	-2.303	-2.326	-2.514	-2.406	0.108	0.041	0.060	0.011	0.150	0.087	0.051	0.101
13		150	-0.171	-3.495	-0.392	-3.694	-0.247	-3.601	-0.270	-3.597	0.065	0.057	0.016	0.028	0.201	0.075	0.044	0.087
14		200	2.208	-2.890	2.340	-2.882	2.225	-2.890	2.258	-2.887	0.042	0.003	-0.007	-0.027	0.419	0.052	0.031	0.060
15		250	3.550	-0.811	3.553	-0.732	3.632	-0.764	3.578	-0.769	0.027	0.023	-0.022	-0.007	0.493	0.048	0.028	0.056
16		300	3.078	1.755	2.999	1.665	2.904	1.661	2.994	1.694	0.050	0.031	0.002	0.001	0.295	0.062	0.036	0.072
17		350	0.627	3.046	1.007	3.187	0.689	3.051	0.775	3.095	0.118	0.046	0.069	0.017	0.138	0.091	0.053	0.105
Total													0.000	0.000	8.3			
											$m_{xśr}$	$m_{yśr}$	mean error of standard observation			m_{0x}	m_{0y}	m_{0p}
											0.049	0.030				0.034	0.020	0.039

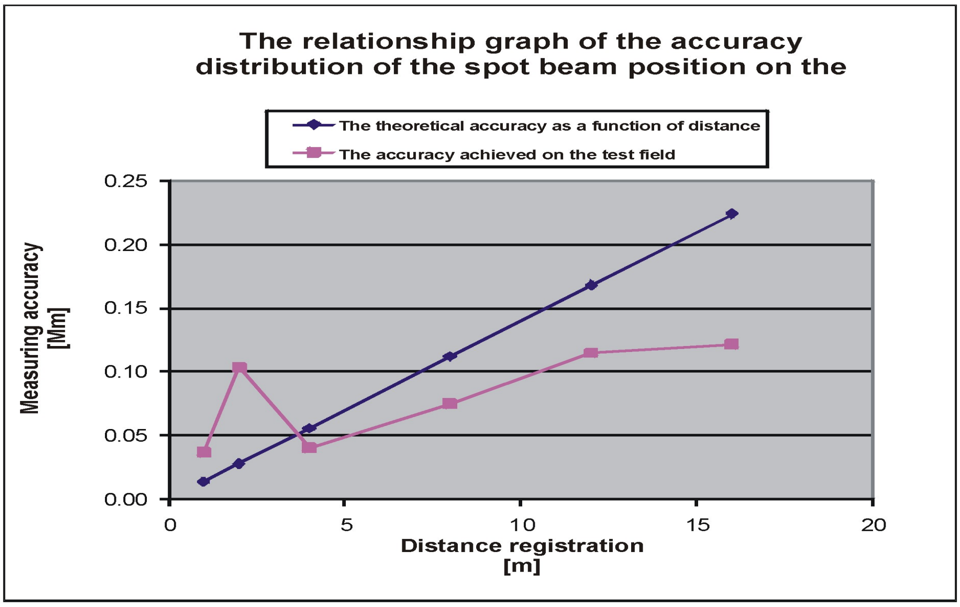


Fig. 9. The relationship graph of the accuracy distribution of the beam position measurement and the mirror-register camera distance.

CONCLUSION

The conducted experimental surveys on the length base have confirmed the applicability of the presented set of instruments and measurement appliances for laser plummet testing of the geodetic instruments. The use of the CCD camera with the computer enables registration of the laser beam images. Besides this, using the own software it is possible to identify automatically the electrical center of a registered laser beam images.
The investigated instruments characterize with different laser parameters, used in the plummets. This fact has an influence on the size, power and shape of the laser beam, which is observed on the screen in distance function. As a result, the identification accuracy of the electrical center of the registered laser beam image is different for each instrument.
The conducted accuracy analysis has revealed, that the standard observation error of the Leica total station has not exceeded the value of ±0.04 mm, whereas the single observation mean error has been a distance-dependent and has taken the values between ±0.02 do ±0.10 mm. For the Trimble total stations plummets the values for distances to 8.00 m. are similar, whereas for larger distances they diverged importantly.
The conducted surveys confirm the rectification of all plummets.

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