Leica Geosystems

Accuracy analysis of surveying tripods

White Paper

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- when it has to be **right**

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1 Abstract

In the daily work of a surveyor, the accessories do not influence the accuracies that are normally required. However, with precision surveys and measurements over long periods, the influence of accessories becomes significant. Therefore it is necessary to have some knowledge about this influence.

In this paper, the effect of tripods on instrument accuracy is evaluated. The tripod requirements are defined by the International Standard (ISO 12858-2) in terms of height stability under load and torsional rigidity. In addition to these requirements, Leica Geosystems also evaluates the horizontal drift. For this paper, these three properties were tested on a range of tripods. Using the results, recommendations are made for which tripod to use depending on the instrument and the application.

The tests were all performed in stable laboratory conditions to achieve the best possible comparisons. The influence of temperature und humidity was not considered. To obtain comparable results, all tripod clamps were tightened with the same force using a torque wrench.

Two tripods of each Leica Geosystems type were evaluated. In order to achieve comparable results for a fibreglass tripod, two Trimax tripods of Crane Enterprises were included in all the tests. The results of the tests were similar for Tripod A and Tripod B of each type. Therefore only the graphs for Tripod A are shown in this paper.

The table below shows the models analysed:

Model Name	GST120-9	CTP101	Trimax	GST05	GST05L	CTP103
						
Material	Beech wood	Pine wood	Fibreglass	Pine wood	Aluminium	Aluminium
Surface treatment	Oil & Paint	Paint	Non	PVC coating	Non	Non
Leg clamp	Side screw	Side screw	Quick-clamp	Central screw	Central screw	Side screw
Country of origin	Hungary	China	USA	Hungary	Hungary	China
Weight	6.4 kg	5.7 kg	7.4 kg	5.6 kg	4.6 kg	4.5 kg
Maximum Height	180 cm	166 cm	175 cm	176 cm	176 cm	167 cm
ISO Classification	Heavy	Heavy	Heavy	Light	Light	Light

According to the ISO standard, tripods can be classified as either heavy- or light-weight. A heavy tripod is required to have a mass of more than 5.5kg. This tripod type can support instruments up to 15kg. Lighter tripods are suitable only for instruments weighing less than 5kg. For Leica Geosystems instruments, this includes only the Builder TPS, GPS antennas and prisms.

2 Height Stability

The ISO standard defines that the position of the tripod head may not vertically shift by more than 0,05 mm when subject to double the maximum instrument weight. Therefore the heavy duty GST120-9, CTP101 and Trimax require testing with 30kg. The GST05, GST05L and CTP103 are defined for light duty and were tested with 10kg.

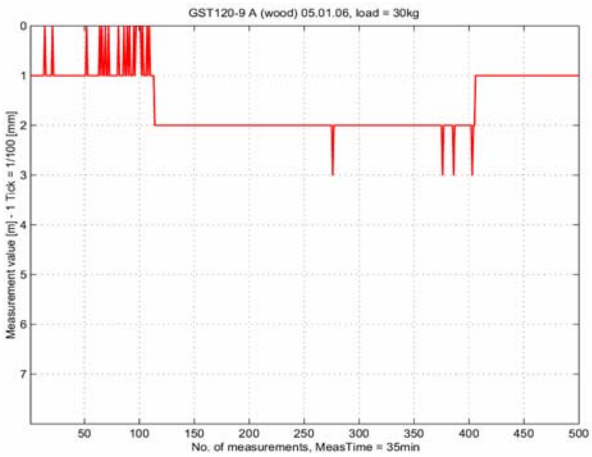
The defined vertical deformation of 0,05 mm is of such a small amount that the effect is insignificant on TPS angular accuracy. However, for precision levelling applications, the tripod height stability should be considered.

By considering measurement accuracy and automatic capability, a Leica DNA03 Digital Level was used to measure the deformations. Measurements were made to a GWCL60 invar scale, attached to the fixing screw of the tripod. 100 measurements were first made without load on the tripod. Using a pulley system, a weight was gently lowered onto the tripod plate. After another 400 measurements, the weight was removed.

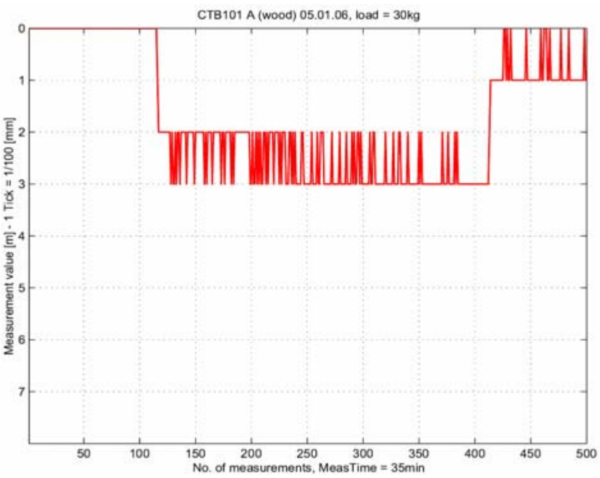
Test Results

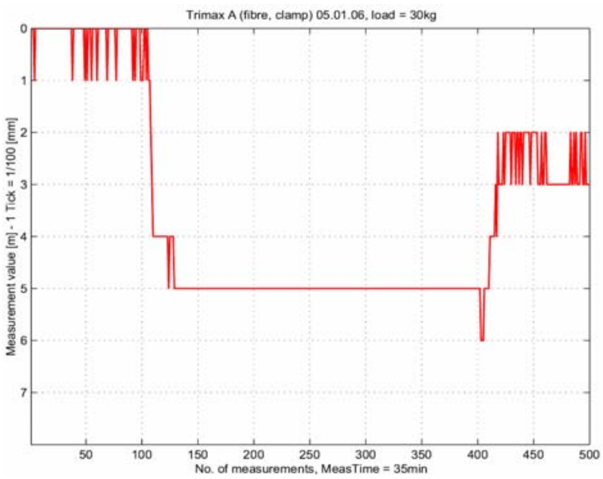
Heavy Tripods

The GST120-9 provides the best results with a height stability of 0.02mm. The CTP101 also demonstrates good results of 0.03mm. The CTP101 has 14cm shorter legs than the GST120-9, which assists in making this a more stable tripod.



The Trimax has a maximum distortion of 0.05mm. This value is at the limit of the ISO requirement. The tested tripod had quick-clamps, in comparison to all Leica Geosystems tripods that use screw clamps. The clamps might be the cause for the poor height stability.



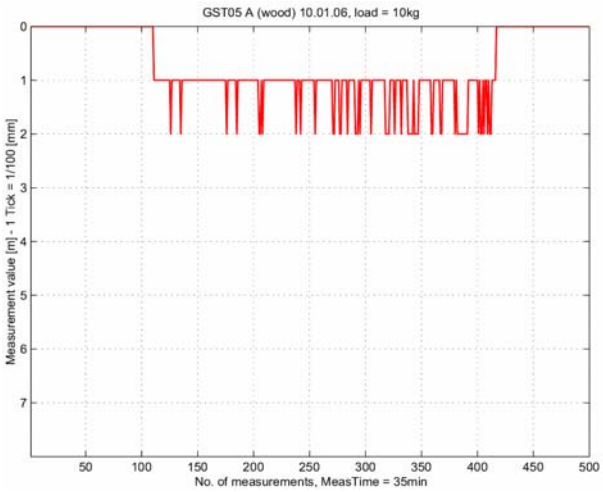


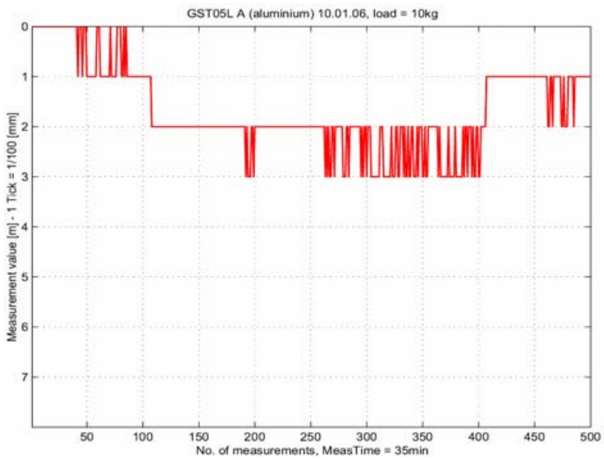
Light Tripods

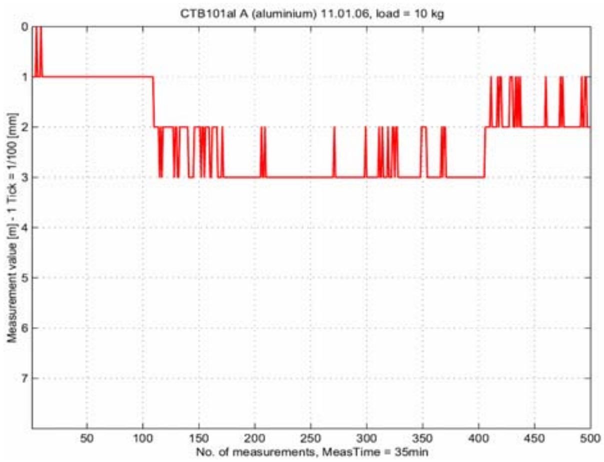
The GST05 shows the best performance for the light tripods. After a load of 10kg, the tripod deforms by a maximum of only 0.02mm.

The GST05L has a slightly higher vertical deformation of 0.03mm in comparison to the wooden GST05.

The CTP103 performs similarly to the GST05L with a maximum vertical movement of 0.03mm. Although this is also a low-cost product recommended for lower accuracy instruments, the ISO criteria are still fulfilled.



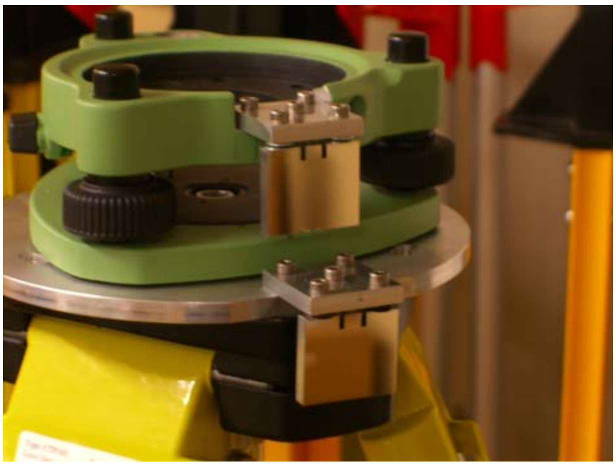




3 Torsional Rigidity

When an instrument rotates, the forces effect a horizontal rotation of the tripod head plate. The torsional rigidity is a characteristic of the tripod to absorb this horizontal rotation by returning to its original position when the instrument is stationary. The precision to which the tripod orientation returns to the original position is known as hysteresis.

In accordance with ISO standard, if the tripod plate is rotated by 200^{cc}, the maximum allowable hysteresis for heavy tripods is 10^{cc} (3") and for light tripods is 30^{cc} (10"). To obtain more practical results, the effect of a rotating motorized instrument was tested. A TPS1200 was used which exerts a horizontal torque of 56Ncm while accelerating and braking. Using the application "Sets of Angles", observations were automatically made on two prisms alternatively. This provided a rotation in both directions continuously during the observation time. Measurements were recorded for at least 200 seconds.



To measure the torsional rigidity, an electronic collimator was used to monitor the deformations through the principle of autocollimation. An output frequency of 16 Hz ensured a rapid tracking of the deformations.

A specially made plate was mounted between the tripod head and the tribrach. Measurements were made to a mirror mounted on the plate. In the picture above, a second mirror can be seen mounted on the tribrach. This allowed additional measurements to be made that took in the combined effect of the tripod and tribrach on the instrument.

Test Results

The large amplitude spikes occur during the acceleration and deceleration of the rotating instrument. Since no angular values are recorded on the instrument during this time, these influences may be ignored. The hysteresis value is determined by examining the maximum amplitude of the graph when the spikes are disregarded.

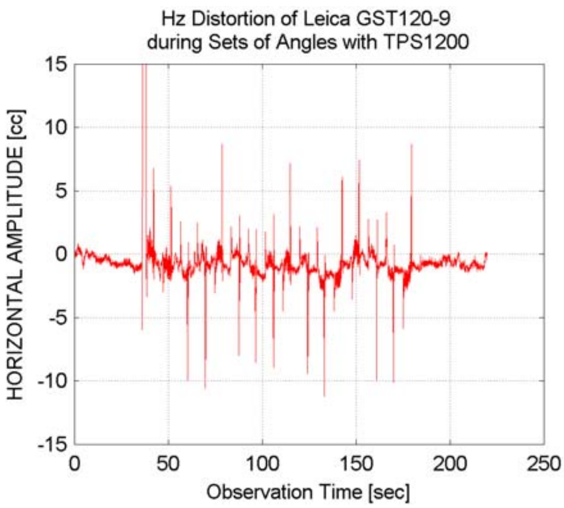
The results clearly show the difference in stability between the heavy and light tripods. The light tripods show up to several times the distortion. In addition, the fibreglass and aluminium tripods experience an overall linear trend. This means that the instrument constantly looses orientation over time.

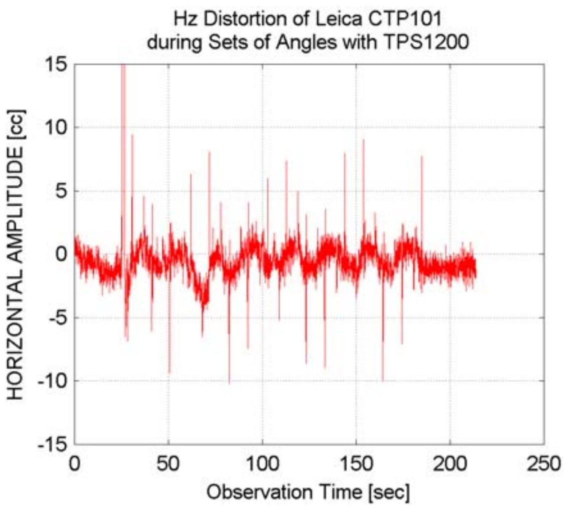
Heavy Tripods

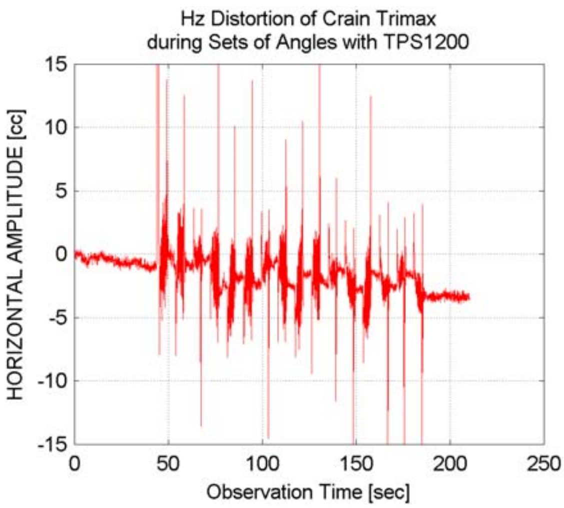
Of all the tripods tested, the GST120-9 has the lowest hysteresis of 2^{cc}. During the entire measurement process the tripod head plate remains extremely stable.

The CTP101 results have similarly low amplitude of 3^{cc}.

The Trimax shows an amplitude twice that of the other heavy tripods, of 6^{cc}. The overall linear trend indicates that the hysteresis constantly increases during the set-up time.

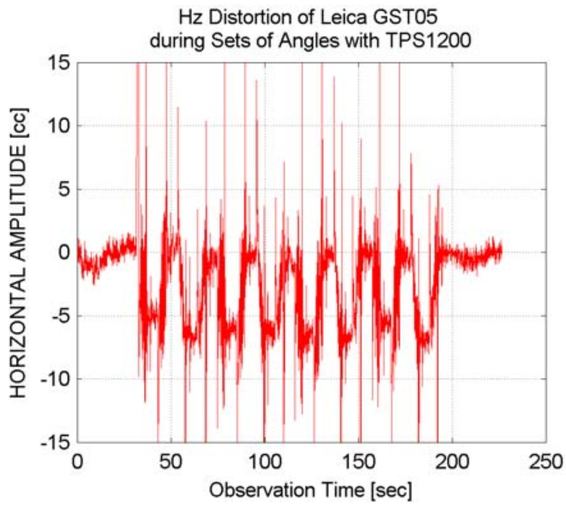


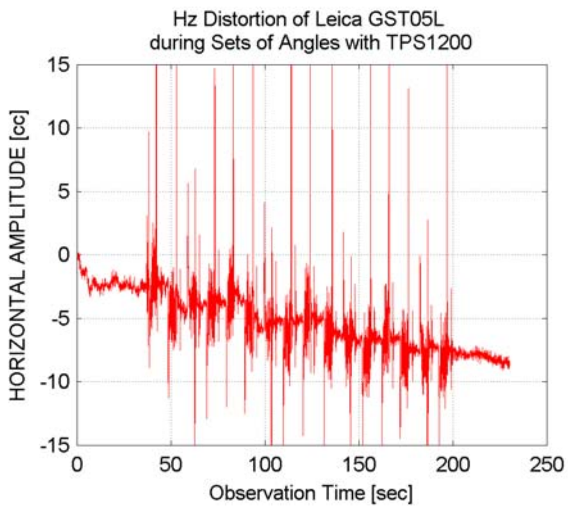


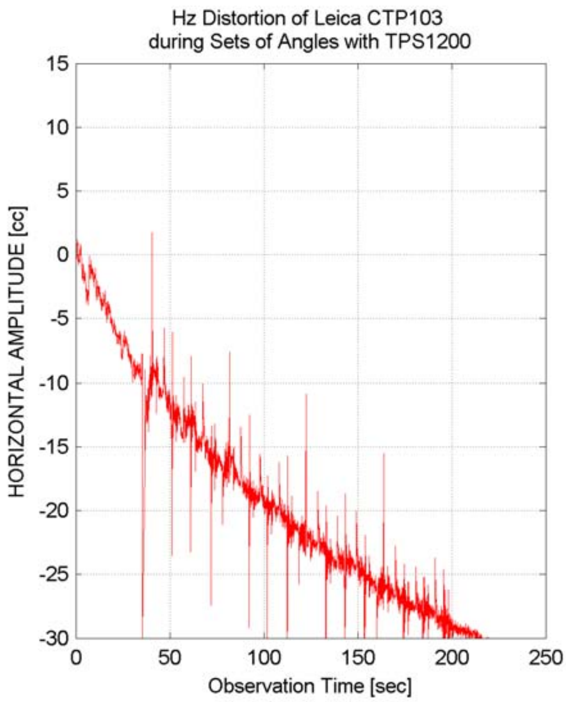


Light Tripods
For the light tripods, the wooden GST05 proves to be the most stable with a hysteresis of 8^{cc}.

Both the aluminium tripods have a large rotational deviation over time. After 200 seconds, the GST05L has a hysteresis of 11^{cc} and the CTP103 reaches 30^{cc}. The value of 30^{cc} is at the limit of the ISO standard for a light tripod.







4 Horizontal Drift

The horizontal drift of a tripod is the measurement of how its orientation changes over time. This is not an ISO requirement, but Leica Geosystems checks their tripods for this drift for the sake of quality assurance.

A similar measurement method as for torsional rigidity was used, but with the measurement period extended to a minimum of 3 hours. To reduce the amount data, the frequency of the collimator was reduced to 0.5Hz.

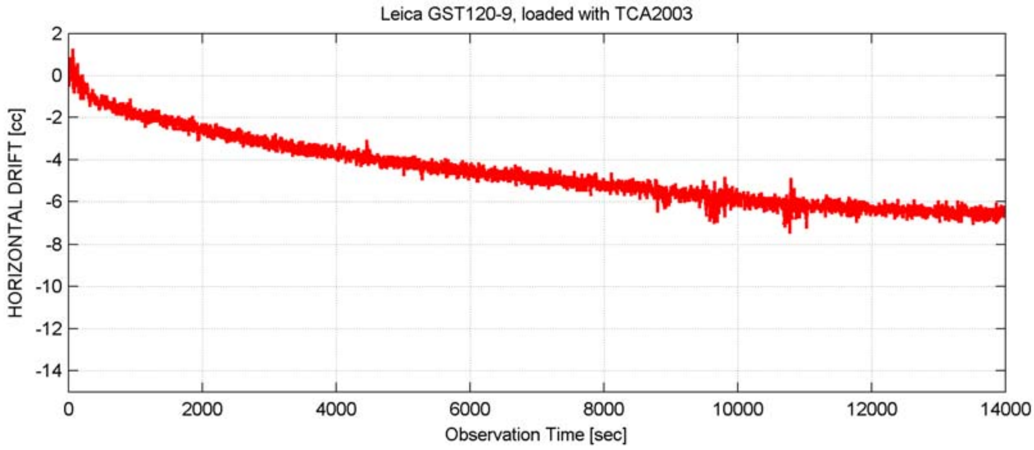
The TPS1200 was again mounted in the tribrach. However, during the measurement period, the instrument remained stationary. Therefore the instrument exerts no rotational force on the tripod. The movement of the tripod is only due to the instrument load.

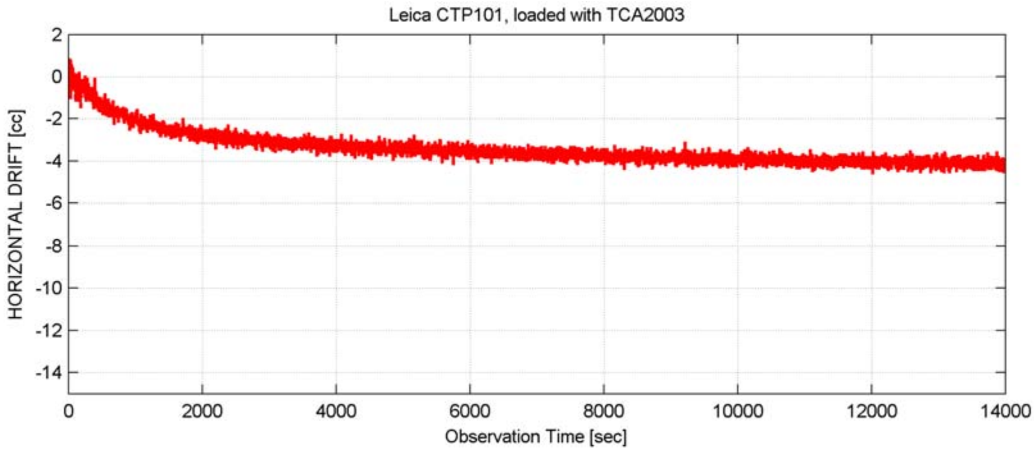
Test Results

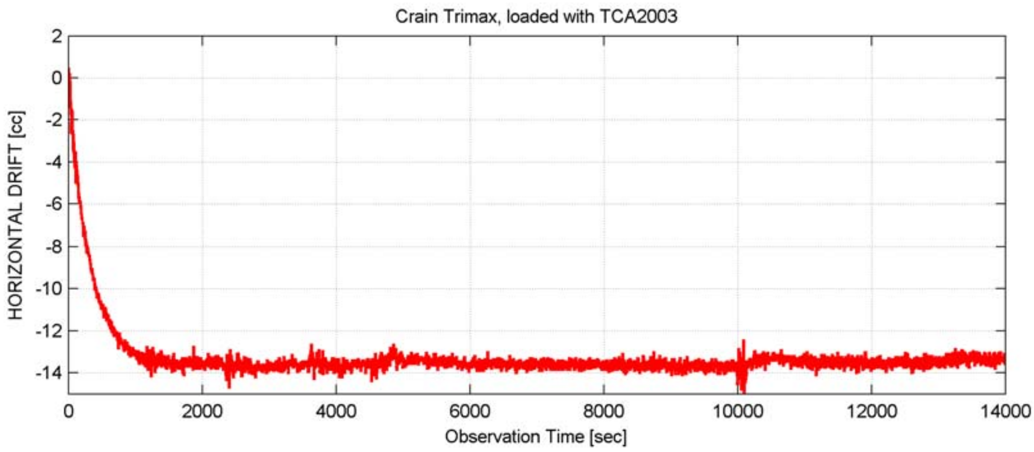
Similarly to the torsional rigidity test, the fibreglass and aluminium tripods loose orientation over time. This continues for approximately the first 20 minutes. After this time, the fibreglass Trimax becomes stable. The aluminium tripods continue to rotate, but at a slower rate.

Heavy Tripods

The CTP101 experiences the least drift, to a maximum of 4^{cc}. For the GST120-9, a constant linear change occurs throughout the measurement period. However, the drift remains small at 7^{cc} after 3 hours. The Trimax drifts rapidly after set-up, by as much as 12^{cc} during the first 10 minutes. However, after approximately 20 minutes the Trimax remains stable at 14^{cc}.

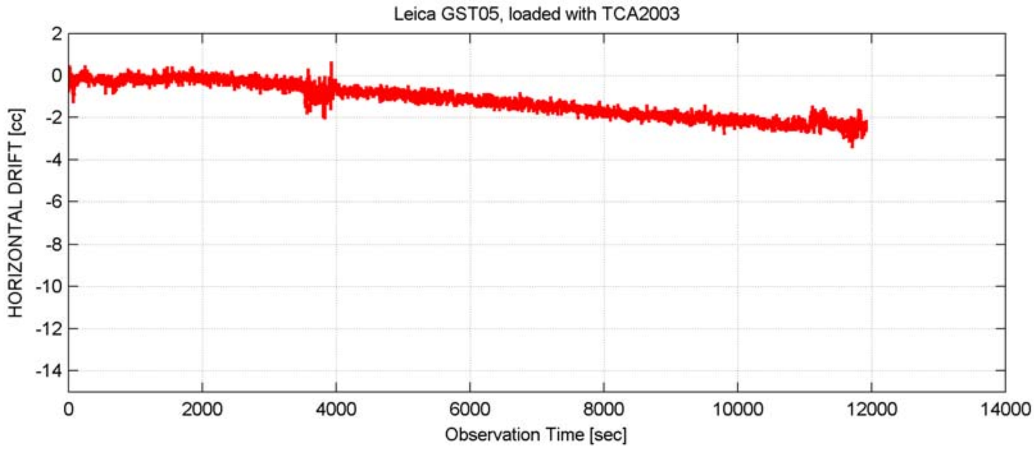


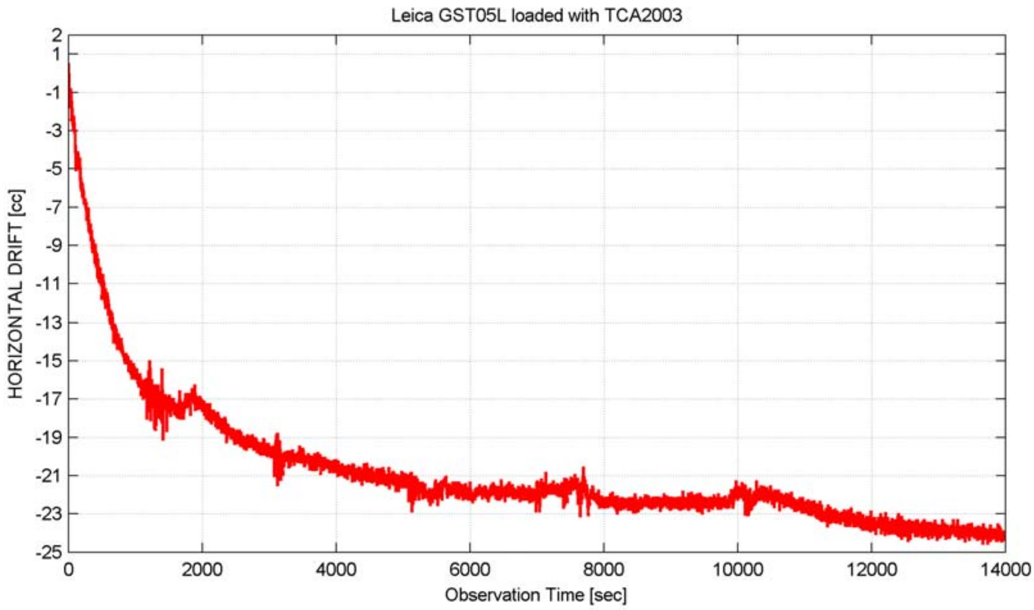


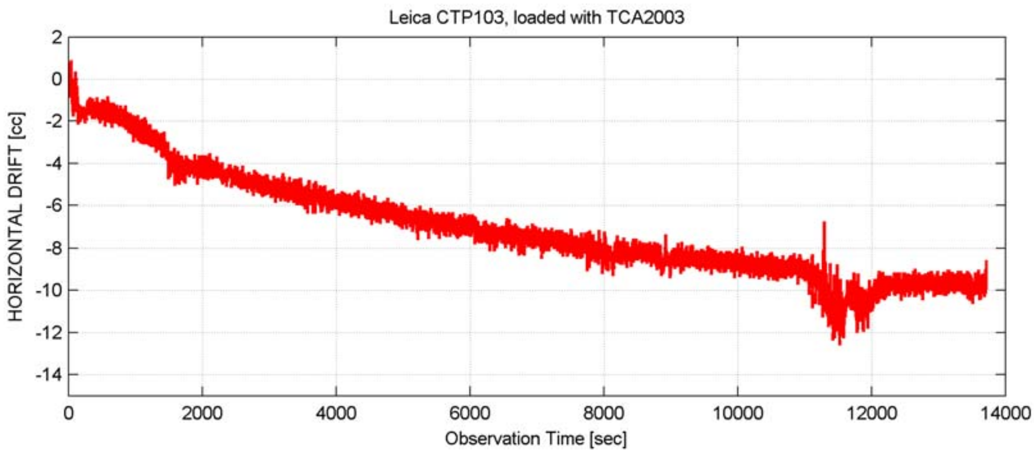


Light Tripods

The GST05 shows to be the most stable tripod of all those tested, with a drift of less than 3 ^{cc}. The aluminium tripods continue to deform for the entire measurement time. After the 3 hours, the GST05L has drifted by 23 ^{cc} and the CTP103 by 9 ^{cc}.







5 Usage recommendation

The table below summarises the results of the all the measurements taken during this project. The values shown are the maximum error occurred during the measurement time. To determine the total effect on TPS accuracy, the hysteresis value of the tribrach is also included in the table. Leica Geosystems recommends the GDF121 (1") with heavy tripods and the GDF111-1 (3") with light tripods. From the total possible influence, it is clear that the tripod and tribrach have a significant effect on TPS angular accuracy.

Model Name	**GST120-9**	**CTP101**	**Trimax**	**GST05**	**GST05L**	**CTP103**
Leica product for which the tripod is suitable	All TPS	All TPS	TPS >5"	GPS antenna Prisms	Levels Prisms	Levels Prisms
Material of legs	Beech wood	Pine wood	Fibreglass	Pine wood	Aluminium	Aluminium
ISO Classification	Heavy	Heavy	Heavy	Light	Light	Light
Height stability	0.02 mm	0.03 mm	0.05 mm	0.02 mm	0.03 mm	0.03 mm
Tripod hysteresis	1" (2^{cc})	1" (3^{cc})	2" (6^{cc})	3" (8^{cc})	4" (11^{cc})	10" (30^{cc})
Tribrach hysteresis	1" (3^{cc})	1" (3^{cc})	1" (3^{cc})	3" (10^{cc})	3" (10^{cc})	3" (10^{cc})
Max. possible influence	**2" (5^{cc})**	**2" (6^{cc})**	**3" (9^{cc})**	**6" (18^{cc})**	**7" (21^{cc})**	**13" (40^{cc})**
Hz Drift after 3 hours	2" (7^{cc})	1" (4^{cc})	5" (14^{cc})	1" (3^{cc})	8" (23^{cc})	3" (9^{cc})

As a material, wood has been proven to provide the most stable tripod. The GST120-9 has the best results for height stability and torsional rigidity and therefore suitable for all Leica TPS instruments. The horizontal drift results show that the wooden GST05 has the least distortion over an extended time. This makes the tripod ideal for GPS antennas and prism targets, which are usually set-up for long periods.

Aluminium tripods provide good height stability, but poor horizontal orientation. Therefore they should be avoided for use with angular measuring instruments. Since aluminium tripods are cheaper than wooden ones, light-weight and long lasting, they are recommended for levelling applications.

As shown by the horizontal drift graphs, aluminium and fibreglass experiences large distortions during the first 20 minutes of set-up. To obtain reliable results, it should be considered to allow this period to pass before starting observations. In addition, the orientation should regularly be checked during the measurement process.

The tripod analysis tests were all made under laboratory conditions. However, with deployment in the field, further effects such as temperature, humidity, ground type, wind, etc. additionally affect stability. As tripods age, it can also be expected that their stability would decrease. Therefore the influence of the tripod and tribrach must always be considered when determining the angular accuracy that can be achieved.

Using the values in the table the most suitable tripod can be chosen for the required surveying application. For precision surveys over long periods, it is recommended to use a concrete pillar. Alternatively, a sophisticated measurement process should be used which compensates for these errors.

6 Source

This document is a summary and translation of the Thesis named *Genauigkeitsanalyse von Vermessungsstativen und Dreifüssen unter der Belastung verschiedener Instrumente*. The Thesis was conducted during 2006 by Daniel Nindl of the Department Geodesy Engineering, Technical University of Vienna, under guidance of Mirko Wiebking of Leica Geosystems AG, Heerbrugg. The purpose of the thesis study was to analyse the effect of tripods and tribrachs on instrument accuracy. To shorten the content of this document, the analysis of tribrachs covered in the thesis are not included.