The new pointing model of telescope based on tracking data

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Abstract

There is a new error model for pointing the telescope to the satellite for satellite laser ranging. It is based only upon data which is obtained during SLR observations. The observations from about 40 satellites passes have been taken from beginning of September of the year 2008 for the construction of the model. The parameters of the model, and the mode of constructing the model are included in this article. We analyze advantages and disadvantages of the model. This model is currently used at SLR station "Kyiv-Golosiiv 1824".

Introduction

The trend of the SLR technique has been directed to creation of automatized systems which can do observations of satellites in semiautomatic and automatic modes, thereby making the jobs of station personnel easier. Thus it is necessary to have as exact a model of errors of the telescope as possible for successful satellite tracking. These errors always have the characteristics caused by telescope type, quality of adjustments of the optical system, workmanship of mechanical systems, etc. It is possible to provide automatic supervision, if we have high-precision model of errors of the telescope and the possibility of operator control or specification of this model. Besides, using a system with exact prompting and object support essentially raises the overall performance of a laser station even if it works under active management of the observer. This is especially true when operating on a daylight schedule when the majority of satellites are invisible to the observer.

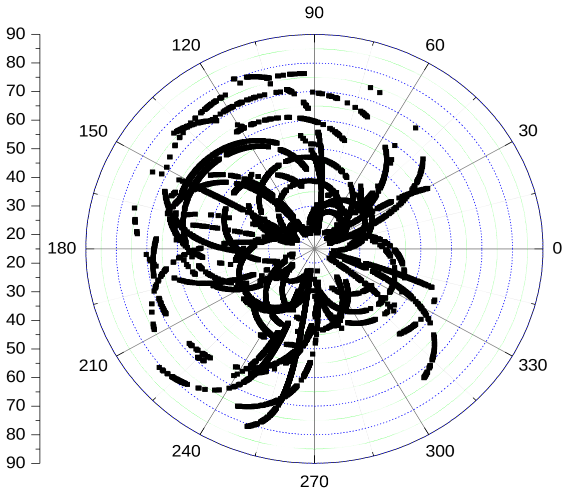
Such a model of telescope errors can be constructed by using laboratory methods of characterizing discrepancies in manufacturing of an azimuthal platform, and the encoders errors (if there are encoders). It is also possible to construct a model of errors by observing stars as, for example, the system which has been developed in MAO of NAS of Ukraine [1]. This system can be realized only with photodetectors of PMT type as it is necessary to count the photons from a star. PMT works in a counting mode and has no "dead time", as contrasted with semi-conductor avalanche photodetectors (APD, SPAD). Avalanche photodetectors can register separate photons, but after each pulse they have some interval of time when their sensitivity is very low. As some photons will arrive from a star during these intervals of time, the system cannot register them. It will lead to decrease sensitivity on the one hand and errors of measurement of intensity of a star on the other hand. It all leads to an increase in errors of measurements.

We offer a way to construct an error model of a telescope which is based on the data received during satellite ranging. The principles of constructing a model in such a way are described in [5]. In summary, this method is based on encoder data which are captured at the beginning of every second during ranging. Further the difference between observed positions of the target (at the moment of time when the return from satellites has been received) and calculated position (ephemeris) is analyzed.

Zenith distance, degrees

The given method has some advantages: time for supervision, a considerable quantity of points over the sky, the possibility of the operator control of the correction model, independence from the photodetector, and freedom from spending time on separate mount model data gathering.

It is sufficient to use 10 – 40 passes for construction of the model; it is dependent on how these passes cover the hemisphere of the sky. For this discussion, 40 passes were used. This data totals 18 thousand points. The width of a laser beam during ranging was 15´´. The sky covering is shown in fig. 1. Initial O-C residuals are presented in fig. 2-5.



Azimuth,

Figure 1. Sky

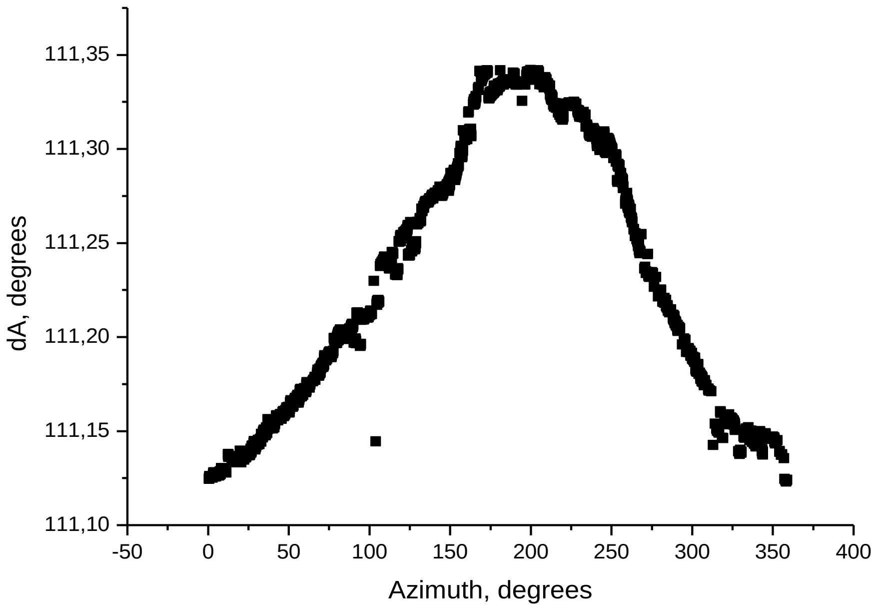


Figure 2. Dependence of azimuth differences O-C on azimuth

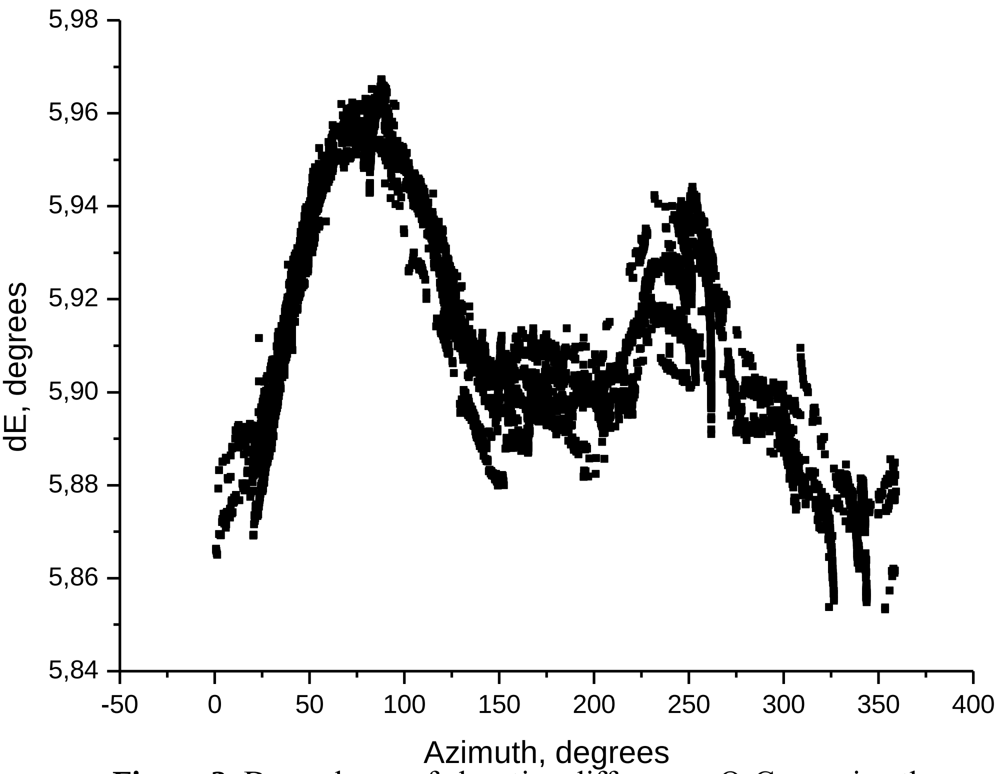


Figure 3. Dependence of elevation differences O-C on azimuth

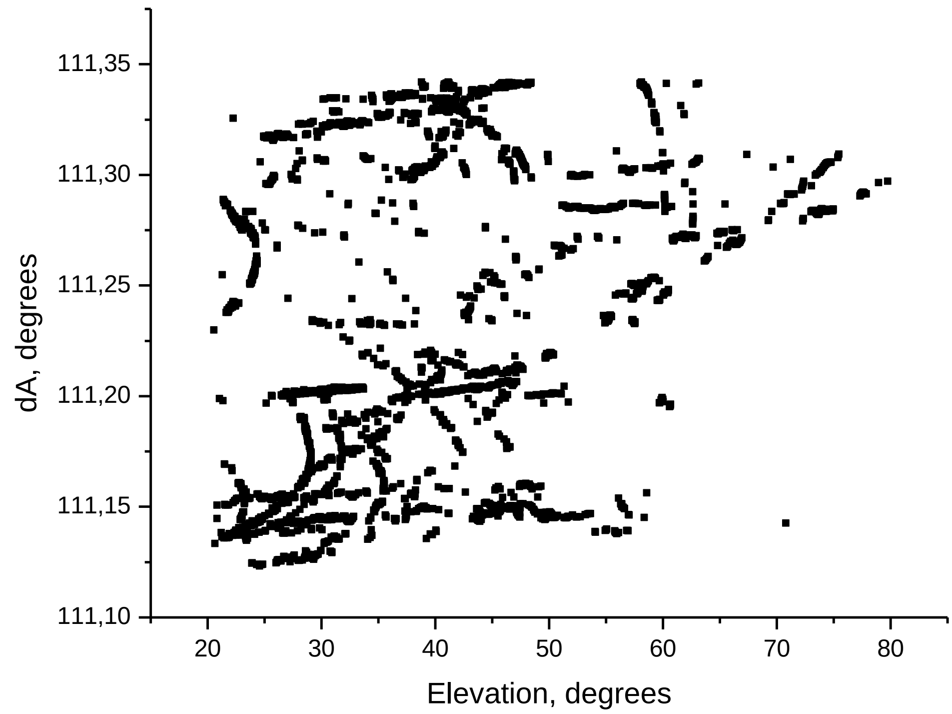


Figure 4. Dependence of azimuth differences O-C on elevation

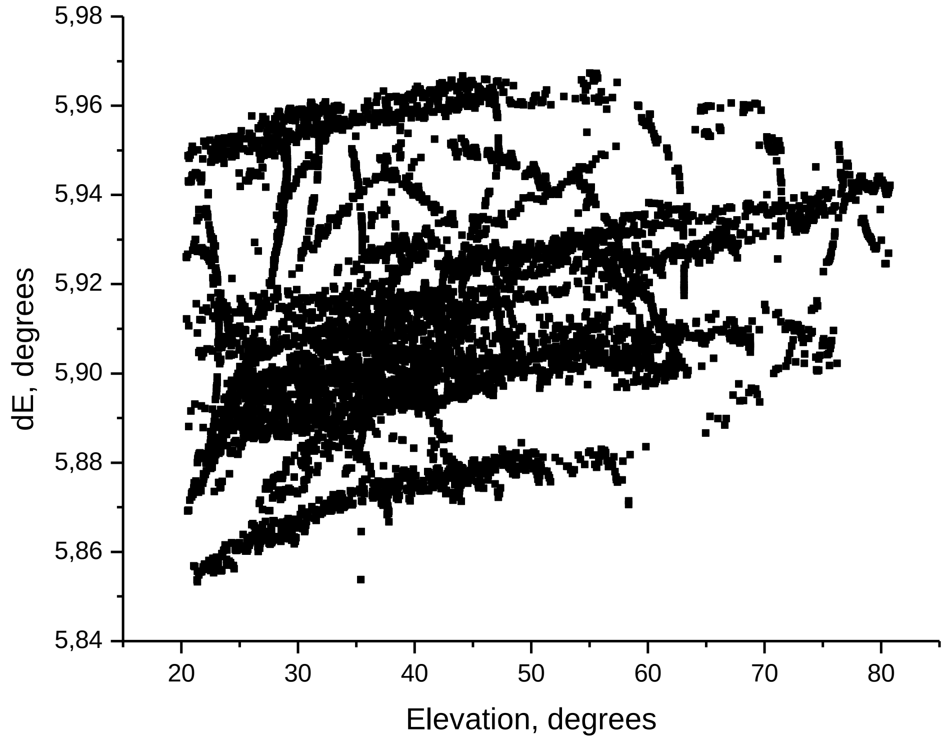


Figure 5. Dependence of elevation differences O-C on elevation

It was not obvious that there would be a dependence of the azimuth O-C residuals on elevation; only azimuth O-C dependences on azimuth were defined. It is apparent from fig. 3 that elevation O-C residuals depend on azimuth. When both curves (fig.2 and 3) are divided into 10 parts; in each it is possible to describe the O-C residuals as polynomial of 1 or 2 degrees. Resulting coefficients and intervals are presented in table 1.

The azimuthal model looks like: $\mathbf{dA=A+B1*az+B2*az^2}$

The elevation model accordingly: $\mathbf{dE= A+B1*az+B2*az^2}$,

Where the coefficients A, B1, B2 for each intervals are different, one set for azimuth, and one set for elevation, and

az – azimuth.

Table 1. The parameters of model

№	Interval, degrees	Azimuth, arcsec			Elevation, arcsec		
		A	**$B1*10^{-4}$**	**$B2*10^{-5}$**	**A**	**$B1*10^{-4}$**	**$B2*10^{-5}$**
1	0-20	111.12346	7.18078	0	5.86998	9.93361	0
2	20-50	111.11447	9.63814	0	5.84123	19.0	0
3	50-113	111.10540	11.4	0	5.80338	38.4	-2.40053
4	113-132	111.11167	11.1	0	6.08559	-13.5	0
5	132-164	112.20648	-139.1	5.17286	5.93494	-2.32794	0
6	164-224	110.43937	94.2	-2.46413	6.00440	-11.4	3.08847
7	224-250	112.93676	-125.8	2.41212	5.86798	2.28252	0
8	250-270	112.09860	-31.8	0	6.10770	-7.34310	0
9	270-346	112.83370	-94.0	1.30325	6.03878	-4.96045	0
10	346-360	112.13579	-28.4	0	5.96367	-2.48787	0

After subtraction of the new model terms we have received the following residuals dA and dE, figures 6,7:

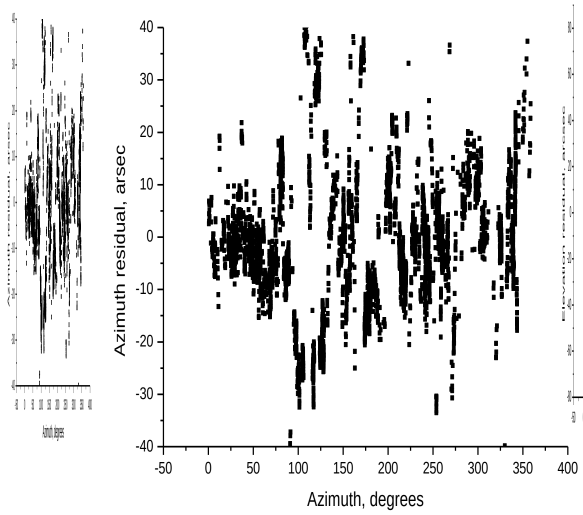


Figure 6. Dependence of azimuth residual on azimuth

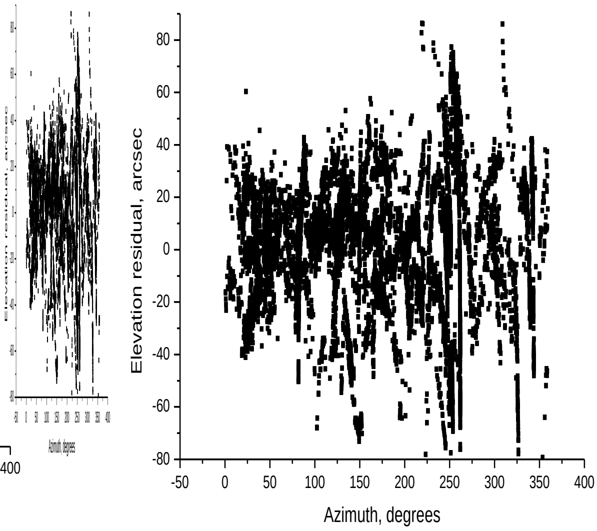


Figure 7. Dependence of elevation residual on azimuth

In figures 8 – 9 it is shown, how azimuth residuals depend on elevation and the elevation residuals depend on elevation.

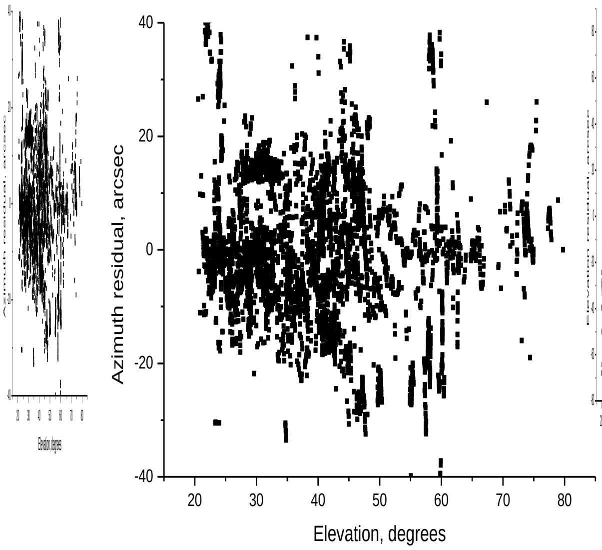


Figure 8. Dependence of azimuth residual on elevation

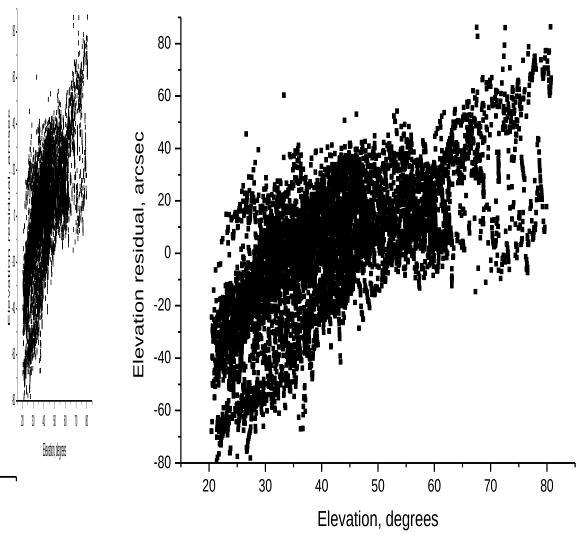


Figure 9. Dependence of elevation residual on elevation

The obvious dependence of the residual in azimuth on elevation had not been previously noticed. There is considerable dependence of the residuals of elevation on elevation in figure 9. This dependence is approximated by a parabola:

$$dE= -0.02972 + el*9.70274*10^{-4} – el^2*5.79624*10^{-6},$$

where el – elevation, dE – residuals on elevation. This parabola has been removed, with the following result (figure 10).

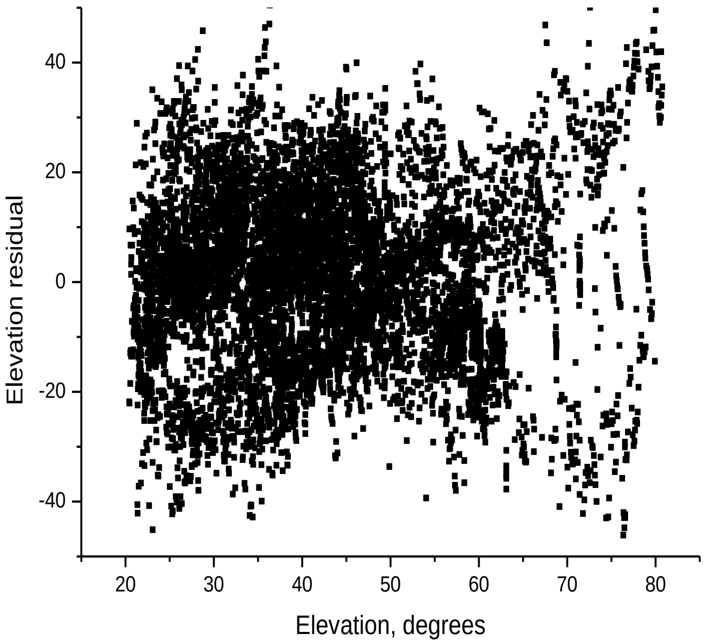


Figure 10. The elevation residual

Conclusion

The model which has an accuracy of 20′′ is constructed using about 40 passes which have been taken over 6 nights. The present model has allowed us to observe invisible satellites. This model is used at station Kyiv-Golosyiv 1824 at present time.

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