The methods of converting observation data of SLR between two nearby stations

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Abstract

There are two methods of converting observations data of satellite laser ranging from one station to another nearby station. The first method is conditionally named analytical and it consists of ordinary geometrical conversation in system of the station A – station B – satellite S. The second method we are called differential and it is based on ephemeris data of the same pass of satellite for each station. We have converted observation data from two Ukrainian SLR station Simeiz 1873 and Katzively 1893 the distance is about 3 kilometers between them. The result of this conversation with Lageos 1 and Lageos 2 at 2004 year for both stations is present in article. On the basis of both algorithms the program has been created.

Introduction

It happens difficult to use observations of two nearby stations during processing of observations of network SLR stations. Especially sharply this question rises at processing of results of observations of a network into which the small amount of stations, for example, to Ukrainian network SLR stations. Thus it is necessary to exclude one of two stations from processing. Otherwise there will be very big correlations between both observations of nearby stations and the end result will be deformed. It would be expedient to process results of observations of two stations presents as observations of one that is not to exclude from processing one of stations. For this purpose it is necessary to transform observations of this station to other station.

In the given work it is presented two methods of transformation of results of observations of one station to another station. The first method is conditionally named by analytical and it is based on simple geometrical transformations to system station A – station B – satellite S. The second method consists of differences between ephemeris for the same passage of the satellites for each stations and addition of this differences to observations one of stations.

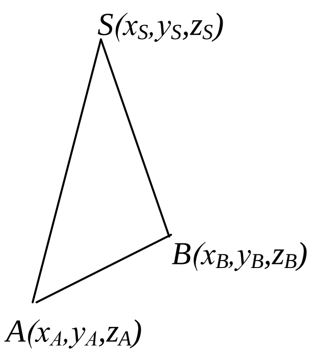

Figure 1. Conditional placing of objects of stations A, B and the satellites S

Analytical method

Start up at us there are two nearby stations A and B and the measured range (distance) from station A to satellite S. It is necessary to transform range of station A to station B. It is possible to find easily distances between them, if all of coordinates are in same frame.

Easier to make it in the Cartesian rectangular system of coordinates, for example, geocentric coordinates. Except coordinates of stations it is necessary to have satellite coordinates in the same frame. For this purpose it is possible to use accurate ephemeris. From geocentric coordinates of both stations we find distance between stations and topocentric coordinates station B relative to station A. If we will have the topocentric Cartesian coordinates station B and coordinates satellite S, that it is possible to find the distance between station B and satellite S, because these coordinates will be in same frame. We will write down all it by means of mathematical expressions.

The distance between stations will look like:

$$\vec{R} = \begin{pmatrix} X_B - X_A \\ Y_B - Y_A \\ Z_B - Z_A \end{pmatrix},$$

where X_A, Y_A, Z_A and X_B, Y_B, Z_B – geocentric coordinates respectively.

Topocentric coordinates station B rather station A will be calculated by means of such expressions (see [1-3]):

$$M = T_1 \times R,$$

$$N = T_2 \times M$$

$$R_{Top} = \begin{pmatrix} X_{BTop} \\ Y_{BTop} \\ Z_{BTop} \end{pmatrix} = T_3 \times N$$

Where:

$$T_1 = \begin{pmatrix} \cos\varphi & \sin\varphi & 0 \\ -\sin\varphi & \cos\varphi & 0 \\ 0 & 0 & 1 \end{pmatrix},\ T_2 = \begin{pmatrix} \sin\lambda & 0 & -\cos\lambda \\ 0 & 1 & 0 \\ \cos\lambda & 0 & \sin\lambda \end{pmatrix},\ T_3 = \begin{pmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{pmatrix},$$

φ and λ – latitude and longitude of station A.

Now, it is easily found required distance *SB* if we have the topocentric coordinates station B and satellite S:

$$SB = \sqrt{(X_{STop} - X_{BTop})^2 + (Y_{STop} - Y_{BTop})^2 + (Z_{STop} - Z_{BTop})^2}$$

Differential method

This method is based on calculated ephemeris [4]. Let we again need to transform observations of station A to station B.

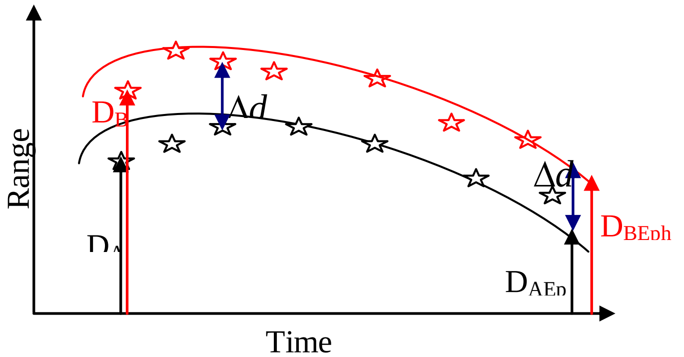

Figure 2. The conditional image of a differential method

For an illustration of a differential method it is possible to use figure 2. Black color is drawn observation and ephemeris of station A. Red colors is drawn ephemeris stations B and points where the observation of station A is transformed.

Δd – shift-size between ephemerides on which it is necessary to shift observation of station A for receive observation of station B.

The essence underlying the method is that find difference between calculated ephemerides for both stations. Then this difference interpolate for the moments of observations station A. And this difference it is added to observations station A. Also we find observation station B. That is:

$$\Delta d = D_{AEph} - D_{BEph} \ ,$$

where D_{AEph} – ephemeris station A, D_{BEph} – ephemeris station B, Δd – the difference of them. Then observations station B will be behind the formula:

$$D_B = D_A + \Delta d \ ,$$

where D_A – the observation of station A.

Comparing methods

For check of correctness of methods real observations of two nearby Ukrainian stations Simeiz 1893 and Katzively 1873, distance between of them is about 3 km, have been used. The observations were taken in the form of files of normal points with the server http://www.cddis.gsfc.nasa.gov [3]. The ephemerides were taken from this site too[4]. It is used for testing the passage of satellites LAGEOS 1 for March, 31st, 2004 and passage of satellite LAGEOS 2 for the July, 10th, 2004 which location was spent by both stations.

To check up correctness of the principle of an analytical method it has been transformed by this method ephemeris station A to station B. The differences between ephemeris station B and transformed ephemeris station And to station B is presented in figure 2. Apparently from figure, the difference between ephemerides makes an order of 10^{-6} meters. It gives the chance to us to assert, that algorithm and the software is developed correctly.

To check up correctness of a differential method so simply it will not turn out. On it already ready results transaformed by both methods were compared. The observations of station Katzively have been transformed to the station Simeiz for all 2004, and we have compared results. Comparison has shown, that the data received by both methods identical to within picoseconds.

Approximation of results

As there are some joint observations of the same passages of satellites it would be expedient to check up how the transformed observation and real observation of station on which transformations of observations were made will be adjust.

[3] ftp://cddis.gsfc.nasa.gov/slr/data/npt/lageos1/2004/
ftp://cddis.gsfc.nasa.gov/slr/data/npt/lageos2/2004/

[4] ftp://cddis.gsfc.nasa.gov/slr/predicts/2004/lageos1/
ftp://cddis.gsfc.nasa.gov/slr/predicts/2004/lageos2/

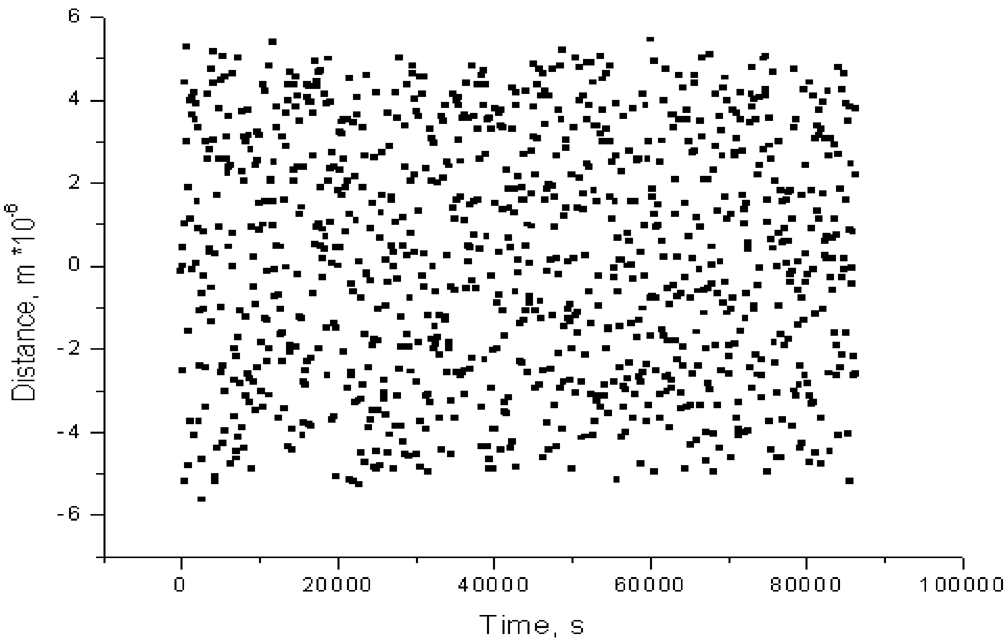

Figure 3. The difference between real ephemeris and transformation ephemeris

The transformed observations of station Katsiveli to station Simeiz are taken for an example. Results it is submitted in figures 4 and 5.

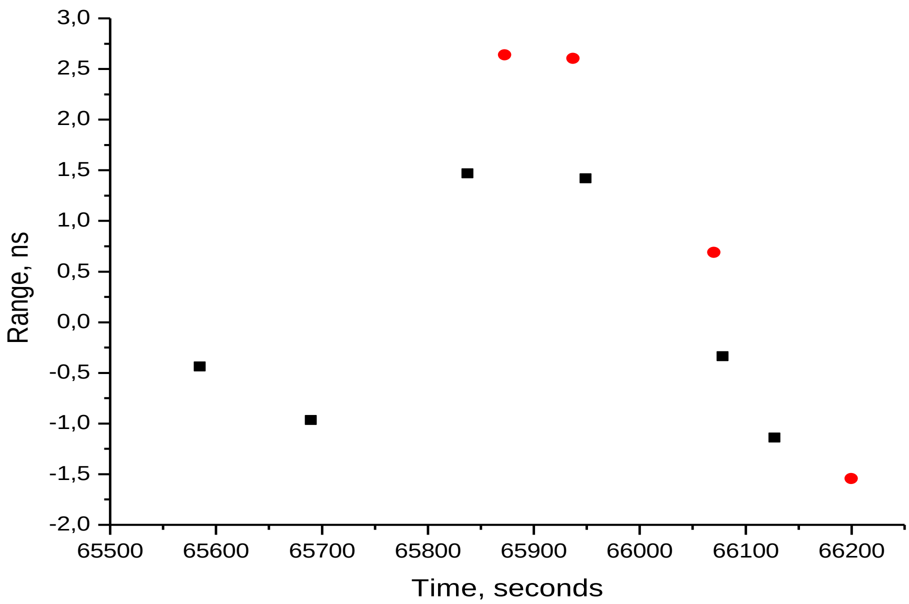

Figure 4. Difference between observations and ephemeris of station Simeiz (black) and difference between transformation observations of station Katzively and ephemeris of station Simeiz (red), satellite LAGEOS 1 for 31.03.2004

Differences between range and ephemeris stations Simeiz are represented for the best perception in figures, but not range in it. Black color represents observations of Simeiz, and red – the transformed observations of station Katzively.

In figure 4 it is visible, that observations of two stations will be to good agreement among themselves. In figure 5 observations will be to good agreement among themselves too, but from this figure follows that ephemeris is inexact. At it is present range bias order 99 nanoseconds, which identical to both stations. On it to avoid the errors connected with ephemeris, it is make better to use a differential method.

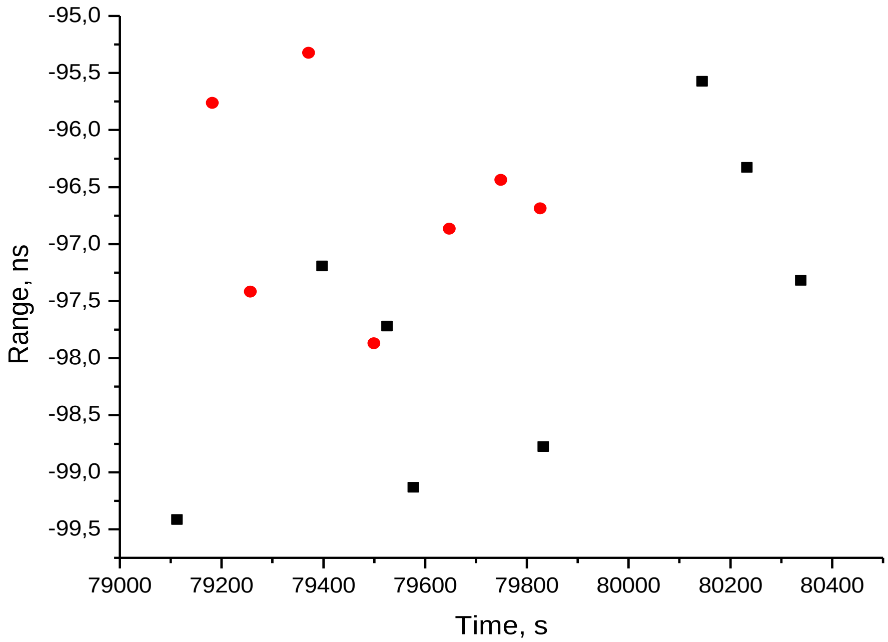

Figure 5. Difference between observations and ephemeris of station Simeiz (black) and difference between transformation observations of station Katzively and ephemeris of station Simeiz (red), satellite LAGEOS 2 for 10.07.2004

Further we have compared, on how many the transformed observations actually differ from the real observations. The observations of station Simeiz for the moments of observations of station Katzively have been interpolated for this purpose at the general intervals and are taken differences between the transformed and interpolated observations. The results it is shown in figure 6 and 7.

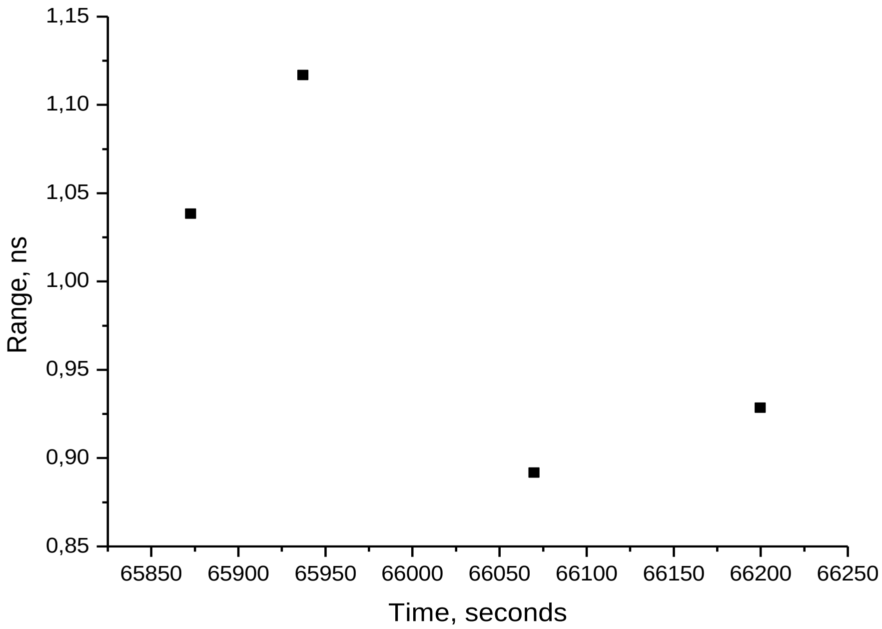

Figure 6. The difference between transformed and interpolated observation, satellite LAGEOS 1 for 31.03.2004

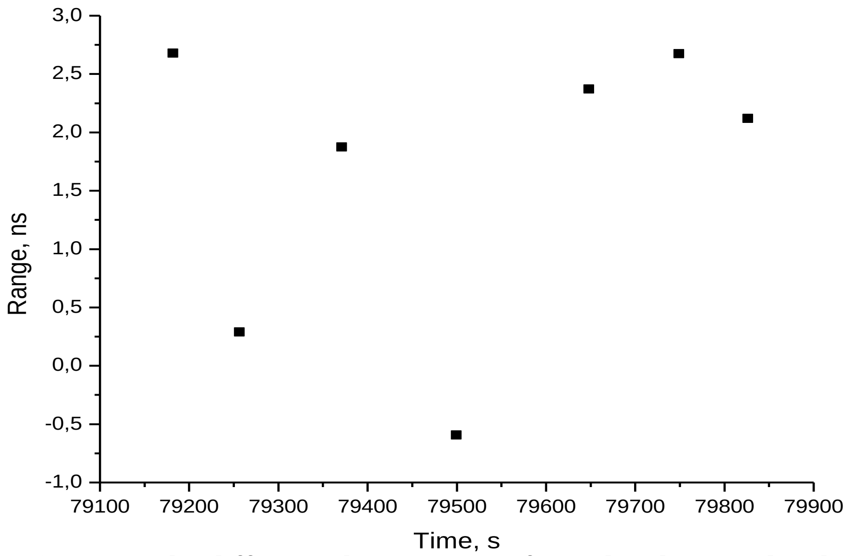

Figure 7. The difference between transformed and interpolated observation, satellite LAGEOS 2 for 10.07.2004

This figures are shown that the difference between real and transformed observations is less then 3 nanoseconds or 45 centimeter in distance.

Conclusion

It is developed two techniques for transformation of observations from one station to other nearby station. Both techniques have identical result. From the mathematical point of view, a differential method is much easier to use. Both techniques it is possible to use in the centers of processing of results of observation. Also both methods can be used for comparison of relative quality of observation, for example, presence time bias, size of range bias. The program for transformation of observation by both methods is developed and it can be used in the centers of processing observations. This program is freeware.

References

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