Satellite laser ranging at station 1893 (Katzively) in 2017 year.

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Abstract

The article presents the results of laser ranging in 2017 at the SLR 1893 (Katsively). Existing measurement errors are considered. The algorithm for preparing for measurements is presented. Features in the implementation of measurements are considered. The stages of multilevel filtering of measurements are analyzed. The optimization of the local computer network is considered to reduce the processing and data transfer time,

The application of the new binding scheme was considered. The application of external calibration was analyzed, and the possibility of combining external and internal calibrations was studied. The application of variants of blind guiding was considered. The reasons for good results on the accuracy of a single measurement are indicated. The application of the optical setup proposed for laser location proposed in [4] is considered.

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Method of comparing time scales:Accuracy Estimates and Corrections Required

Introduction

In 2017, the station SLR 1893 (Katsiveli) observed 49 satellites, the total number of passes 1975, selected points 253637, normal points 19073, the standard deviation of a single measurement according to the internal estimate is 4.35 sm. The accuracy of the SR-620 time counter is 50 ps The timing accuracy is 70 ps. The mean standard deviation (mean square error) of the internal calibration is 150–200 ps. The laser pulse duration is 200–250 ps.

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Station laser ranging "Katsiveli-1893"
Summary of satellite measurements from January to December 2017

satellite name	number of passes	duraion (hour:min)	selected points	normal points	standard deviation (sm)
Ajisai	285	23:08	68268	2811	4.62
Beacon-C	164	10:26	32587	2424	4.56
Cryosat-2	47	1:50	4212	399	3.67
Envisat	35	1:29	2635	307	6.92
GeoIK-2517	20	1:16	3321	156	5.44
GRACE-A	14	0:17	1198	171	3.41
GRACE-B	6	0:06	817	64	4.01
HY-2A	24	1:29	2771	179	3.52
Jason-2	128	8:27	10109	1496	3.19
Jason-3	190	13:40	17932	2445	4.43
KOMPSAT-5	56	2:06	7194	1041	3.98
LARES	116	8:38	8851	907	3.57
Larets	56	2:04	4241	279	3.51
PN-1A	10	0:22	888	154	4.68
SARAL	108	5:58	11515	1194	4.46
Sentinel-3A	111	5:24	10990	1110	3.73
Starlette	167	10:30	25757	1295	4.65
Stella	114	5:28	16031	726	4.28
STSAT-2C	18	0:30	1297	104	4.23
Swarm-A	12	0:18	976	154	5.17
Swarm-B	58	1:43	5331	842	4.11
Swarm-C	12	0:21	1242	198	3.93
TanDEM-X	24	0:40	811	189	3.49
TerraSar-X	16	0:28	669	155	3.15
Lageos-1	107	28:35	12492	840	3.05
Lageos-2	69	19:58	5330	491	3.10
Compass-M3	1	0:47	20	5	3.00
Etalon-1	6	3:07	205	34	3.70
Etalon-2	6	2:27	131	31	3.57
Galileo-104	1	0:33	33	5	4.25
Galileo-201	3	1:57	135	19	2.78
Galileo-202	5	2:22	350	31	3.00
Galileo-203	1	0:37	44	6	2.56
Galileo-205	1	0:40	15	3	2.03
Galileo-207	1	0:18	42	5	3.30
Galileo-213	1	0:22	15	5	1.79
GLO-128	13	7:15	948	88	3.52
GLO-129	4	2:24	191	24	3.32
GLO-131	20	9:46	1604	126	3.26
GLO-133	5	2:49	256	31	4.67
GLO-134(K)	6	3:03	409	32	3.39
GLO-136	6	2:20	296	30	3.11
Total	2047	195:58	262159	20606	4.26

When measuring, the “blind” guide is applied - when the following is superimposed on the monitor screen: the image coming from the guide camera and the computer model of the starry sky, corresponding to a specific satellite and the coordinates of the laser location station. The observer, using these images, adjusts the tracking parameters in such a way as to receive a response signal from the satellite. This method has shown its effectiveness in conditions of insufficient visibility (twilight, weather phenomena).

The simplification of the transition in measurements between the existing internal and external calibration schemes was investigated. Optical schemes for internal and external calibration at the Katsiveli station were outlined in [3]. There was also proposed, successfully implemented subsequently, the procedure of transition from internal to external calibration and back. This procedure was carried out several times in the 2016-2017 year and demonstrated stable results.

When processing measurements, a multi-stage filtering scheme of measurement results is used, which in general case boils down to the following: Calculate the O-C differences of the measured time intervals between sending and receiving laser pulses and the calculated values for these intervals. Next, the O-C differences are approximated by a polynomial in powers of time from 1 to 10. The residual O-C differences are calculated using the interval values calculated using the regression. Consistently selected groups of measurements, the most distant from the regression. Using the Fisher distribution, residual deviations are estimated. Measurements for which Fisher's emission test is performed are rejected, and the rest are returned to the total set of measurements and analyzed again.

The following method is used for rejecting emissions. Let there be a signal point (x_0, y_0), where x_0 – is the moment of the beginning of a single measurement in seconds from the beginning of the day (independent variable), y_0– is the measured time interval from sending a laser pulse to its fixation by the measuring equipment after reflection from the satellite (dependent variable).

Calculates the value $W^2 = \left(\frac{Y_0 - X_0^T \cdot B}{S\sqrt{1 + X_0^T \cdot C \cdot X_0}} \right)^2$,

where: S is the regression estimate;
C- is the matrix of normal equations;
B - is the vector of regression coefficients;
Y_0– the value of the dependent variable ($y_0 = Y_0$);
X_0 – the calculated regression vector (the degree of the independent variable, x0 is the first component of компонент X_0);
$X_0^T \cdot B$ – assessment of the dependent variable (T - means transposition).

(Assuming independence and normal distribution of measurement errors) the value of W^2 has a Fisher distribution $F(1, N-K-1)$.. Here N is the number of measurements, K is the degree of regression. To test the hypothesis that some (noted) value of the dependent variable is an outlier, the quantile of the specified distribution is calculated with a significance level $\alpha = \frac{A_0}{N}$, where A_0 - is the probability to accept the true observation of the outlier, α is the probability to take one of the N observations. The program is accepted $A_0 = 5\%$.

We accept the hypothesis that a point (x_0, y_0) is an outlier if $W^2 > F(1, N-K-1)$.

The initial degree of polynomial regression is equal to 1. At the next stages of processing observations, a polynomial regression is built to increase (at the user's choice and until the convergence conditions are satisfied) degrees. To assess the significance of improving the prediction associated with an increase in the degree of regression, the Fisher criterion is used.

The value $Z = \frac{(N-K-1) \cdot R^2}{K \cdot (1-R^2)}$, where R is the multiple coefficient of correlation, has a Fisher distribution $F(K, N-K-1)$ [2].

To test the hypothesis that the (next) increase in the degree of regression gives a significant improvement, the quantile of the specified distribution with the significance level β is calculated (1-β is the probability of erroneous detection of regression, i.e. the probability of mistakenly accepting the hypothesis that the polynomial regression of degree K gives a significant improvement in the estimate of the variance compared to the regression degree K-1).

If the quantile of the distribution F (K, N-K-1) with the significance level β is less than Z, then the hypothesis is rejected.

When processing observations taken β = 95% [2].

In the process of rejection of emissions, the user has the opportunity to visually select and check measurements similar to outliers.

The compilation of a schedule of observation sessions of the satellites for the current night is made taking into account factors affecting the quality and quantity of measurements. The user selects spans with a height above the horizon more than a certain value (usually 15 degrees) to exclude anomalous refraction and sufficient duration to accumulate the required number of measurements and normal points as recommended by ILRS (International Laser Ranging Service).

When measuring and processing observations, the mean value and standard deviation of the mean value of the calibration of the measuring system are analyzed before and after the measurement session, weather conditions in order to avoid sharp drops in the values of the above values. The frequency of the laser transmitter during the measurement session can be changed for low satellites within 3-8 pulses per second, and for high satellites within 3-10 pulses per second. When transferring measurement data for rejection, repeated and non-consistent measurements are deleted.

At the end of polynomial filtering in order to identify and eliminate the remaining outliers, measurements are placed in orbit. Next, the formation of normal points occurs, the measurement results are recorded in the CRD format and transmitted to international centers. Since filtering using polynomial regression by time degrees and filtering by imposing on an orbit do not correlate, we get a method that allows you to reliably reject outliers, get estimates of measurement accuracy, detect possible errors during measurements moments of the beginning and end of measurements). The introduction of batch processing and precise work of the local network of computers made it possible to bring the time interval from the end of the calibration after the measurement to the moment of transfer of the filtered CRD-converted measurements to international centers up to 2 minutes.

The scheme of organization of measurements and calibrations proposed in [4] requires further study and precise practical implementation. But it is already clear that to increase the accuracy of measurements, it is necessary and in the future it can serve as a means of controlling internal calibration and can be used to refuse internal calibration.

Work on the practical implementation of this scheme will be held at Katsively station in 2019-2020..

Conclusion

According to ILRS, the accuracy of normal points for Lageos-1 satellites at the Katsively station is based on the results of processing various international centers: 14 mm (Germany, without rejection), 13 mm (Japan, without rejection), 10 mm (China, 10 % rejected), 10 mm (CCF Russia, 10% rejected), 4.7 mm (USA, 25% rejected). Relatively good results on rms - the mean-square deviation of a single measurement for the Katsively station are associated with the features of receiving-measuring equipment (attenuation of the response signal so that a strong signal does not generate echo and signal shift), a new stage filtering of the results bindings of the received signal. At the same time, strong differences in the number of measurements by months of the year are caused not only by the weather, but also unstable, before the lamps are replaced, by the operation of the laser, unstable calibration due to the new tethering scheme.

References

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