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A SLR Pre-Processing Algorithm Based on Satellite Signature Effect

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1.Abstract

Satellite signature effect is the one of major SLR error sources. The reflected signal is deformed and spread with a long tail in temporal distribution due to Satellite signature effect. To reduce the satellite signature effect on the SLR precision, we recently simulated the satellite signature effect removal process for normal point algorithm. The simulation is conducted based on a revised model of satellite response, which fully considering the structural and distribution characteristics of retroreflectors. In order to eliminate both long-term and short-term satellite signature effect, a clipping method for SLR da-ta processing is proposed by defining the clipping location as 5.6mm away from the mean value of the long-term fit residuals to select effective returns for normal points. We applied the clipping method for SLR data processing of Changchun station. The results indicate that compared to normal points algorithm, the stability of RMS is im-proved 53% and both the stability of skewness and Kurtosis for LAGEOS-1 also improved. The new method has stronger robustness and applicability, which can further minimize the influence of satellite signature effect on the SLR production. The results have been published in Appl. Sci.

2. the simulation of satellite signature effect

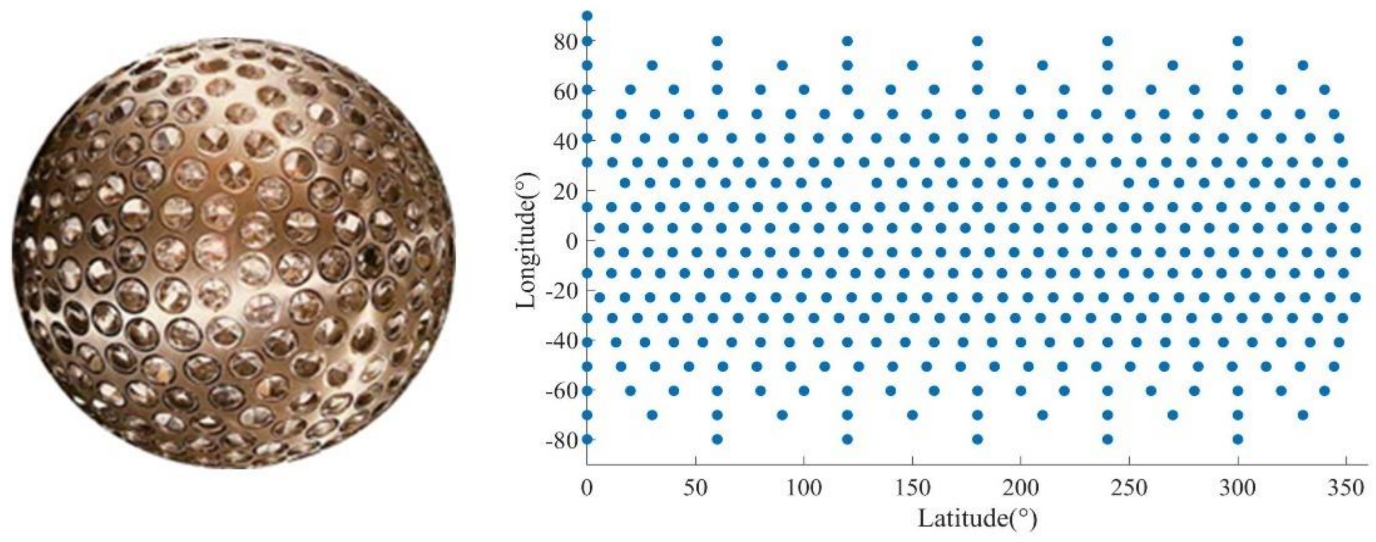

Fig.1 LAGEOS-1 and positions of retroreflector on the surface

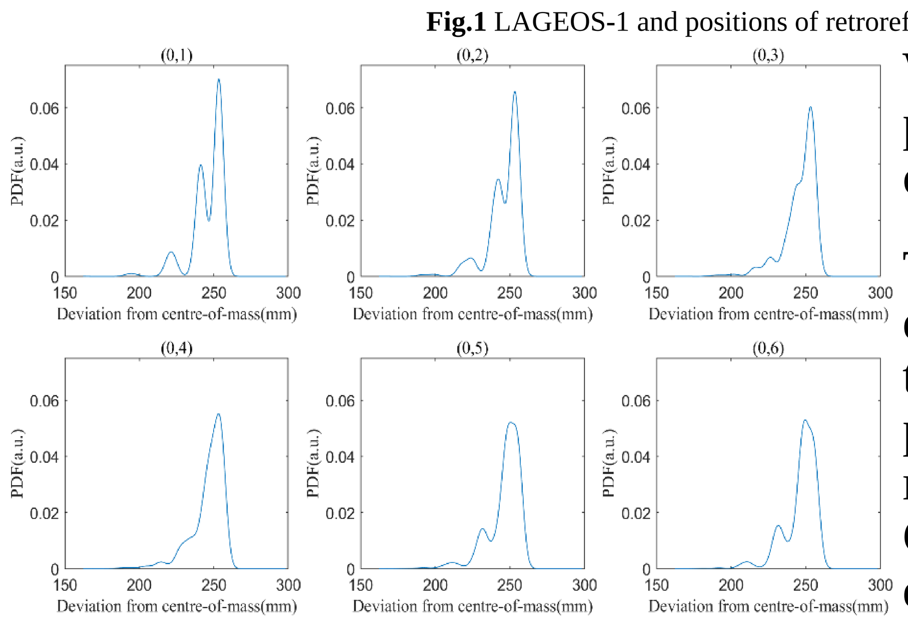

Fig.2 Simulated reflection distribution of LAGEOS-1 with the laser incident direction from (0°, 1°) to (0°, 6°).

We simulate the LAGEOS-1 reflected pulse by the distribution of retroreflector over LAGEOS-1 is indicated in Figure 1.

The waveform of a reflected pulse for different incident angles are simulated by the parameters of Changchun station, and parts of them are plotted in Figure 2. The return pulse has evolved from a standard Gaussian shape to be an asymmetric distribution. The reflected intensity will change when the incident laser pulse glides across the surface of LAGEOS-1.

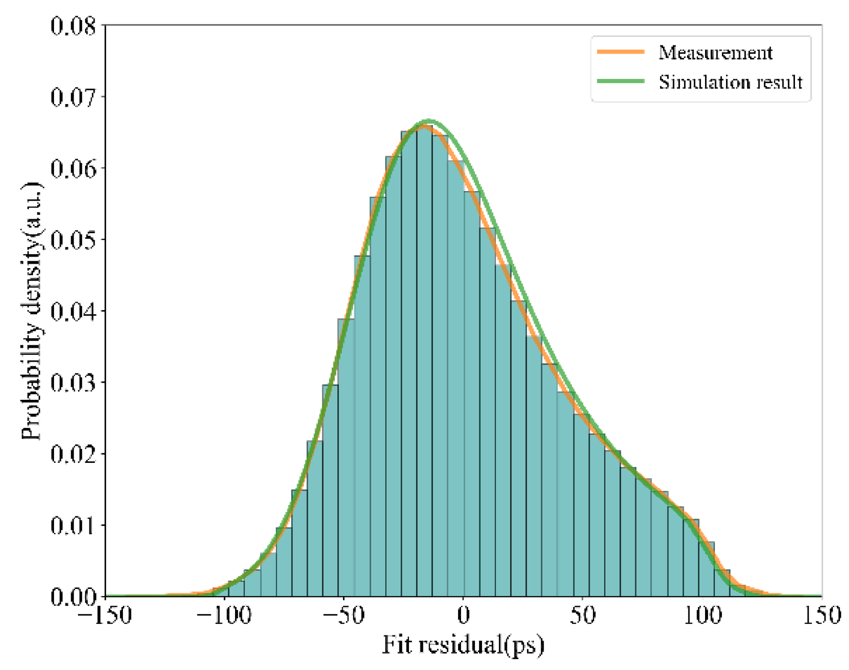

Fig.3 The fit residuals distribution of LAGEOS-1.

To verify the effectiveness of the above simulation, we compare the numerical simulation result with the observation data provided by Changchun station(Fig.3). The Pearson correlation coefficient of these two long-term full rate residual profiles is calculated to be 0.98, which means the simulation based on the revised satellite signature effect can accurately reflect the long-term distribution of the returned signal.

3. New clipping algorithm based on satellite signature effect

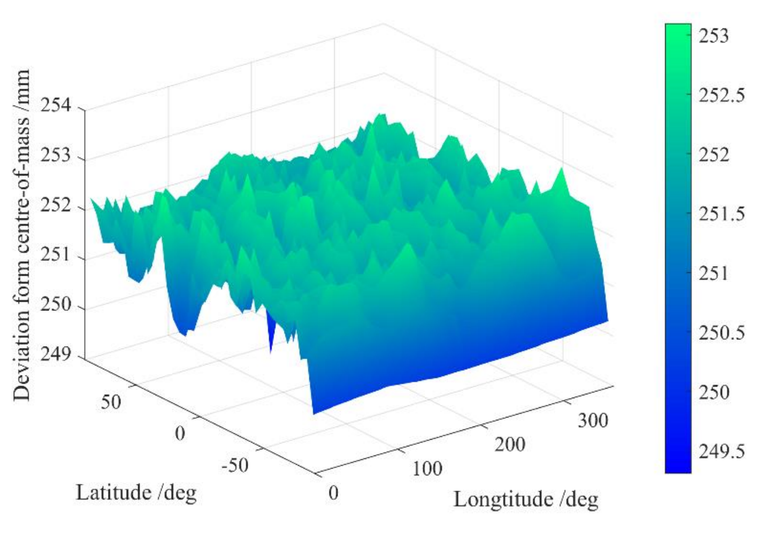

Fig.4 The variation of the COM of the reflected signal processed by normal point algorithm.

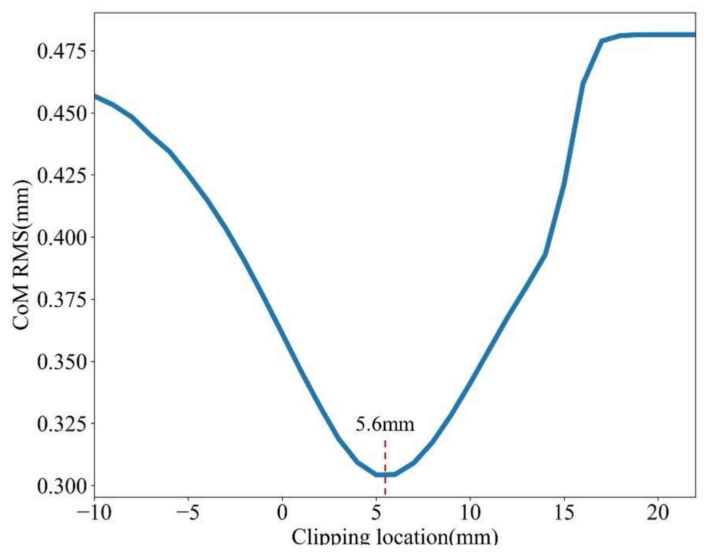

Fig.5 The relationship between clipping location and mean value RMS.

Fig.4 illustrate that normal point algorithm can reduce the long-term effect of satellite signature on reflected signal but not erase the instability of SLR data distribution introduced by the variation of satellite signature effect for each observation.
To further minimize the short-term satellite signature effect and improve the stability of the observation data, We use the mean value of the long-term fit residuals distribution instead of the leading edge as the fixed reference point for normal points. The distribution of fit residuals and the corresponding CoM are calculated at different acceptance levels by adjusting the value of the distance between the clipping location from the reference point(fig.5). Due to the distortion at the front and back edge of the fit residuals distribution, the curve of mean value RMS presents to be concave. And we define the minimum(5.6mm) in the curve as the clipping location in the new method.

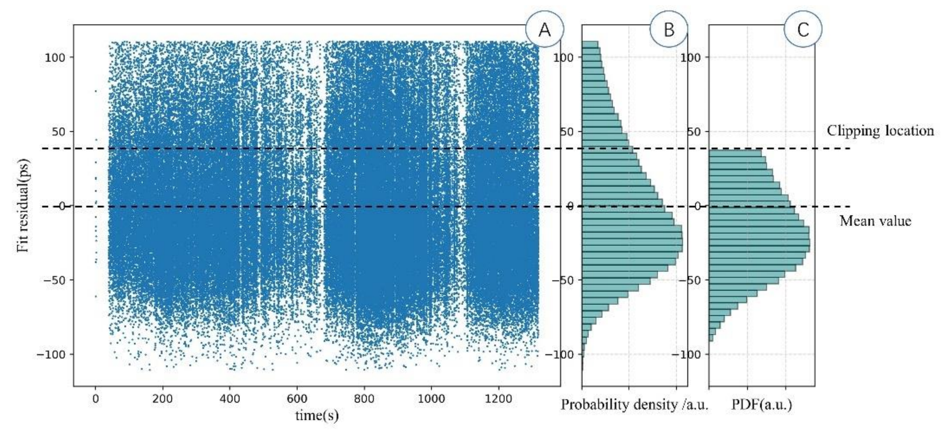

Fig.6 The diagram of the clipping method.

Fig.6 shows the main data processing of the clipping method for LAGEOS-1 observation points. The result shows the distribution of fit residuals proceed by the clipping method is more centralized, while both the unstable leading edge and distorted tail of observation data have been dramatically reduced.

4. Results

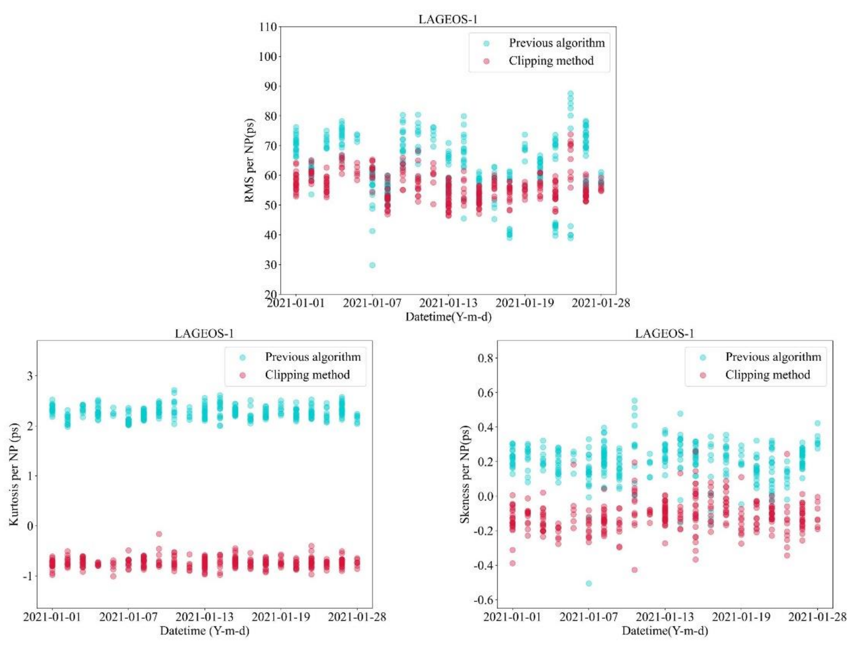

Fig.7 RMS, kurtosis, skewness per normal point for LAGEOS-1 obtained by the different pre-processing algorithms.

The RMS per normal point (NP) obtained by the clipping method has decreased significantly and become more concentrated, while the skewness and kurtosis are also obviously reduced. Compared to the normal point algorithm, LAGEOS-1 observation data processed by clipping method has higher precision and better stability and reliability, which indicates the clipping method can not only eliminate the long-term but also re-duce the short-term satellite signature effect from raw ranging data files.

	Normal point algorithm	Clipping method
RMS per NP	62.90±9.9mm	56.07±4.69mm
Skewness per NP	0.2±0.10mm	0.11±0.08mm
Kurtosis per NP	2.27±0.13mm	2.26±0.09mm

Tab.1 The average statistical results of LAGEOS-1 observation points for January,2021 with different SLR data pre-processing method.

5. Conclusions

On this basis, a new clipping method is proposed and applied for SLR data processing of Changchun SLR station. We adopt Poisson filter and rejection of 2.5 × RMS to reduce noise points but retain the most of returned waveform. Defining clipping location as 5.6 mm away from the mean value of the long-term fit residuals is important to select the effective returns for normal points. The experimental results illustrate that, compared to normal point algorithm, the RMS per NP for LAGEOS-1 processed by the new clipping method is reduced from 62.90 ± 9.9 mm to 56.07 ± 4.69 mm, and the stability of observation data is improved 53%. Both the stability of skewness and Kurtosis for LAGEOS-1 also improved. It is concluded that the clipping method can minimize both long-term and short-term satellite signature effect and improve the ranging precision and stability of SLR observation data. This study improves the satellite signature effect model. In this paper, the fluctuation of CoM value caused by satellite signature effect is simulated for the first time. By simulating the effectiveness of different clipping location, the pre-processing algorithm is successfully improved and achieved good results. This paper provides a reference for other stations to build their own data processing algorithm and further enriches the theory of system errors for SLR systems.