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A Report on JAXA Tanegashima Station (GMSL)

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Abstract. *JAXA conducted the 2nd QZS-1 tracking campaign from February 25 to March 7, 2013. In this period, a lot of SLR tracking data were obtained through cooperation of many ILRS stations. This paper describes a summary of this tracking campaign and evaluation results of QZS-1 orbits using SLR observations. An operation status of Tanegashima station (GMSL) for the last one year is also described. Although this station has been suspending its operation for a failure of the telescope since July 2013, a plan of its resumption is underway. Furthermore JAXA is currently examining a possibility of tracking space debris by leveraging our SLR system, of which latest status is also shared.*

Introduction

The SLR station that JAXA installed in Tanegashima island (GMSL) has been operational for 10 years. In the framework of International Laser Ranging Service (ILRS), we have been distributing predicted ephemeris of AJISAI and LAGEOS-1 and 2 on a daily basis, as well as providing ranging data of SLR satellites. In the spring of 2013, we actively promoted a 2nd tracking campaign of QZS-1 and successfully gathered a lot of tracking data through cooperation of other ILRS stations. This paper describes the operational status of the GMSL for the last one year and its future plans as well as on the 2nd QZS-1 tracking campaign.

1. SLR Orbit Determination Operation in JAXA

JAXA have estimated the orbit of the three satellites, AJISAI, LAGEOS-1 and 2 every day and evaluated their orbit accuracy once a week. If the maximum value of the residual exceeds 50 cm in the orbit determination process, we check the data quality of each SLR station. This evaluation and improvement keeps their orbit accuracy within a few centimeters over the past year as shown in Fig. 1.

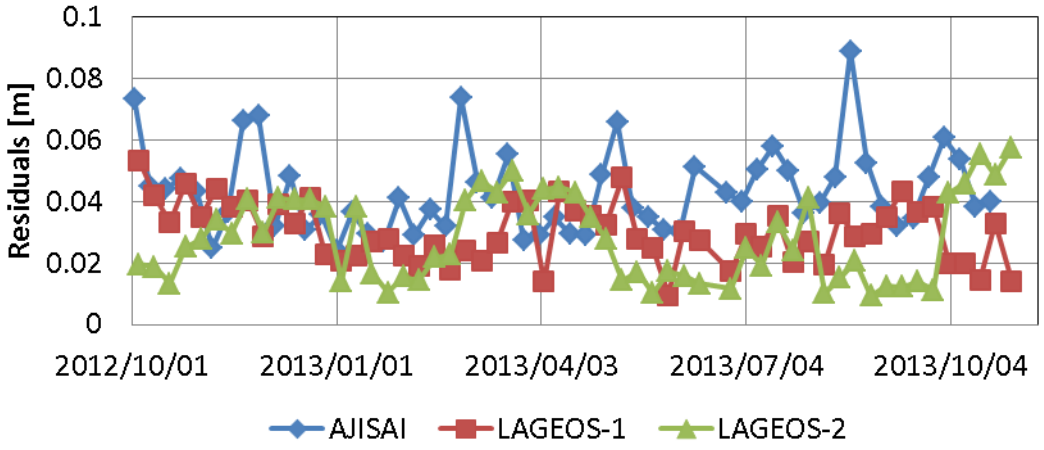

Fig. 1 Residuals of three satellites over the past year (RMS)

Also we have distributed the predicted ephemeris (CPF) for the three satellites every day and evaluated the orbit accuracy once a week. We have checked the maximum value of the difference between the predicted and the observed ephemeris (see Fig. 2).

Fig. 3 shows the maximum value of the difference between the predicted and the observed ephemeris of three satellites over the past year. The value in LAGEOS-1 and 2 satellites is very stable, which indicates that the accuracy of the predicted ephemeris is within a few meters. On the other hand, the accuracy of AJISAI sometimes exceeded 20 m. This degradation can be attributed to the uncertainty of the atmospheric drag because the altitude of AJISAI is lower than that of LAGEOS-1 and 2. Therefore we deem that such difference is acceptable. Through implementation of such assessments, JAXA continues to provide the predicted ephemeris with high accuracy.

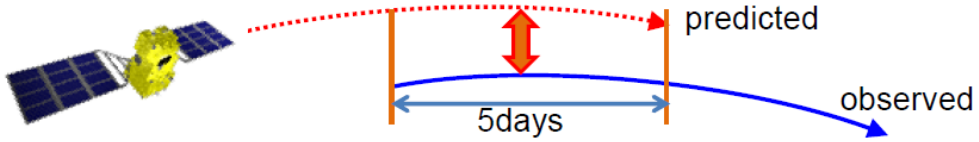

Fig. 2 Accuracy evaluation method of predicted ephemeris (CPF)

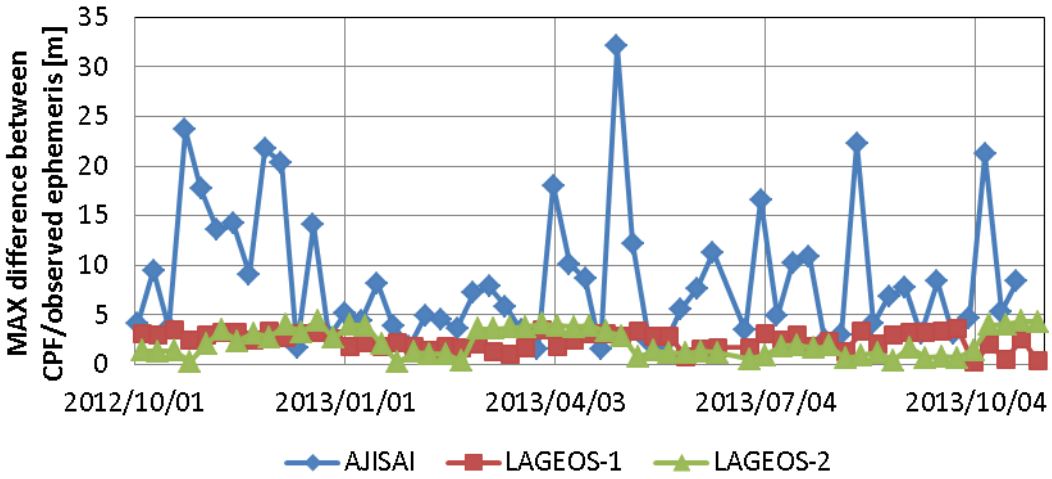

Fig. 3 Maximum value of the difference between predicted/observed ephemeris

2. Operation Status of GMSL

JAXA's SLR station was installed in 2004 and now celebrating its 10th anniversary of operation. We have been participating in the ILRS since 2004. Although the amount of data provision is yet to be improved, our ranging accuracy is one of the best. In Fig. 4 the line chart shows the number of operating day and the bars show the number of data obtained and failed data acquisition. Note that, in 2013, only data from April to June are included. It indicates a steady increase in data acquisition until 2010, which can be attributed to accumulation of know-how for the operation. The decreasing trend after 2010 can be explained by system failures that occurred rather often due to aging degradation. Looking at the situation, the discussion on SLR facility upgrade is ongoing.

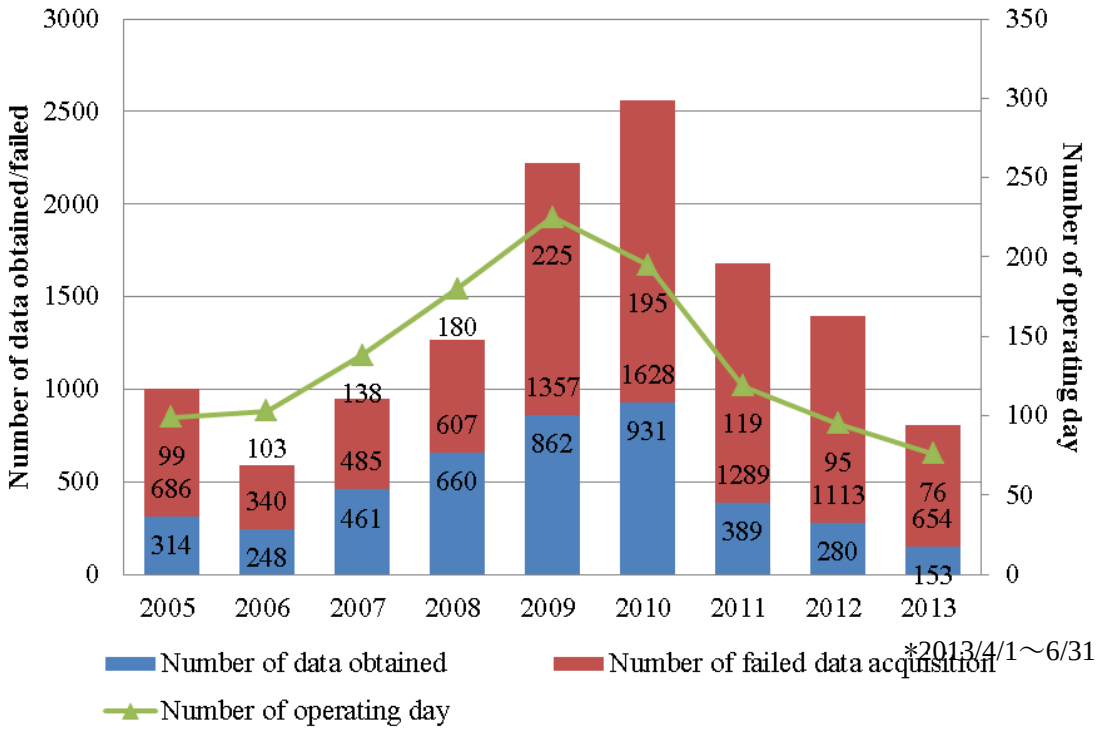

Fig. 4 Sammary of operational status in GMSL

Although the long-term suspension of the operation due to failure of MCP-PMT and its telescope resulted in no observation data being provided to ILRS since summer 2012, we have procured a new MCP-PMT and, after confirming its operation when used with a gate driver, we have sent the new device to the station. As for the telescope, investigation on the cause of failure is progressing and its operation is expected to restart soon. When it becomes operational, we will be able to obtain ranging data of LAGEOS-1 and 2 and LARES and their data will be provided to ILRS for AWG analysis.

3. QZS-1 Tracking Campaign Results

Quasi-Zenith Satellite System (QZSS) is a Japanese navigation satellite system. QZSS has slightly elliptical and highly inclined orbits. Orbital elements of QZS-1 which is the first satellite of QZSS is shown in Table 1 and ground track is shown in Fig. 5. QZSS can provide a seamless service from a high elevation angle to improve the positioning availability and enhance GPS performance in downtown and mountainous areas. In order to bring about the realization of its benefits, it is necessary to determine and distribute a precise orbits of QZSS. This section provides a brief overview of the accuracy evaluation of QZS-1, orbit solutions compared to SLR observations.

Fig. 5 QZS-1 Ground Track

Table 1 QZS-1 orbital elements

Semi-major Axisz	42,164 km (average)
Eccentricity	0.075 ± 0.015
Orbital Inclination	43° ± 4°
Argument of Perigee	270° ± 2°
Central Longitude of Ground Track	135°± 5° East

JAXA conducted the QZS-1 tracking campaign from February 25 to March 7, 2013. In order to get as much data as possible during the period, our station conducted the ranging to QZS-1 in the period shown in Table 2. With the cooperation of many ILRS stations, a lot of SLR tracking data were obtained during the period. The amount of observation data increased from March 1, especially data is abundant for the three days of 3/5-7, as shown in Table 3. Note that blue letter imply data not provided to ILRS because GMSL was under quarantine.

Table 2 Tanegashima station tracking time during the campaign

Day	Time
2013/2/25	15:00～23:15 (JST)
2013/2/26	15:00～23:15 (JST)
2013/2/27	15:00～23:15 (JST)
2013/2/28	15:00～23:15 (JST)
2013/3/1	16:20～09:50 (JST)
2013/3/2	15:00～23:15 (JST)
2013/3/3	15:00～23:15 (JST)
2013/3/4	16:20～09:50 (JST)
2013/3/5	17:20～09:50 (JST)
2013/3/6	17:20～09:50 (JST)
2013/3/7	17:20～09:50 (JST)

Table 3 Tracking summary during the campaign

	Yarragadee		**Changchun**		**Tokyo**		**Tanegashima**		**Shanghai**	
	Pass	NP	Pass	NP	Pass	NP	Pass	NP	Pass	NP
2/25										
2/26			**1**	**4**						
2/27	**1**	**4**								
2/28										
3/1	**1**	**4**	**1**	**12**						
3/2	**2**	**8**	**1**	**1**	**2**	**10**	**6**	**30**		
3/3	**1**	**4**					**7**	**44**	**1**	**5**
3/4	**1**	**3**					**3**	**4**		
3/5	**1**	**4**	**1**	**3**	**2**	**13**	**8**	**40**		
3/6	**2**	**7**			**2**	**13**	**10**	**55**		
3/7	**2**	**7**			**1**	**8**	**8**	**42**		
total	**11**	**41**	**4**	**20**	**5(7)**	**44(34)**	**42**	**215**	**1**	**5**

SLR observations acquired in QZS-1 tracking campaign are used to evaluate the accuracy of the precise ephemeris of QZS-1 published in QZSS project site (http://qz-vision.jaxa.jp/USE/en/finalp) from December of 2012.

Fig. 6 and Fig. 7 shows the SLR residuals and its RMS value of precise ephemeris of QZS-1. The result of overlap comparison between consecutive precise ephemeris is shown in Fig. 8 for reference. The overlap period is one-day. The overlap result during the tracking campaign is relatively stable, whereas it shows slightly rough between 3/7-3/9. In particular, accuracy of radial component related to the SLR residuals is within a 10 cm. On the other hand, SLR residuals are within a 20 cm (RMS) with each station. This result indicates that the accuracy of QZS-1 precise ephemeris in radial is within about 10 to 20 cm.

QZS-1 tracking campaign ended in success with the cooperation of other ILRS stations. We plan to repeat the campaign for improvement of QZS-1 ephemeris.

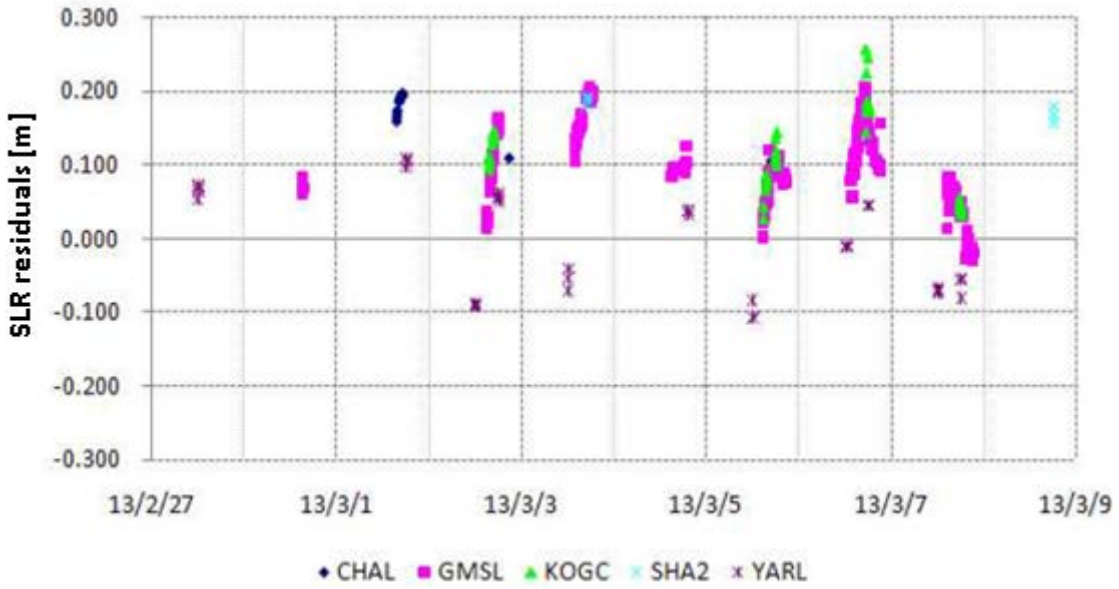

Fig. 6 SLR residuals of QZS-1 precise ephemeris

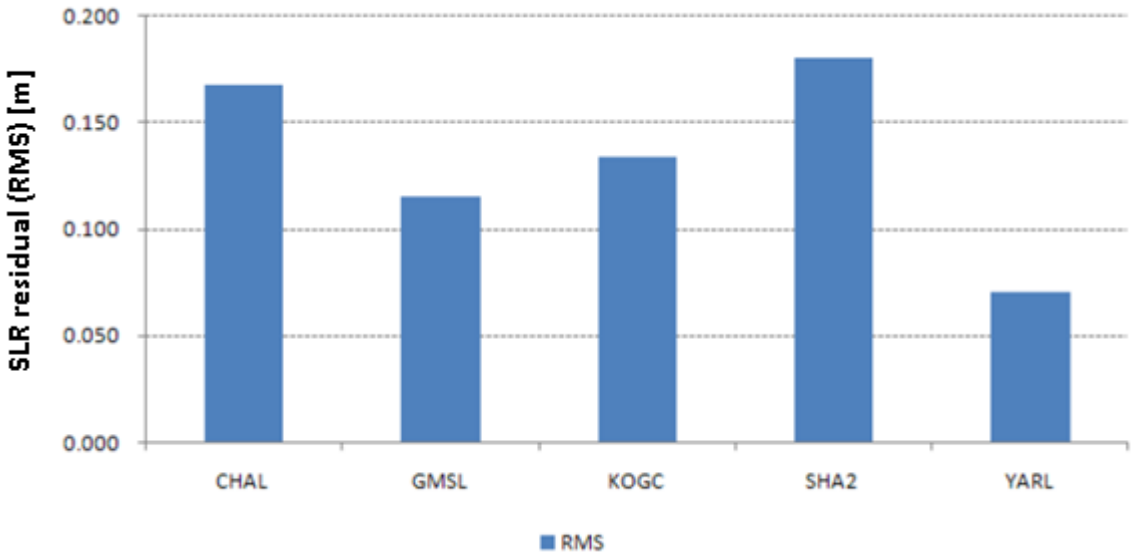

Fig. 7 SLR residuals of QZS-1 precise ephemeris (RMS)

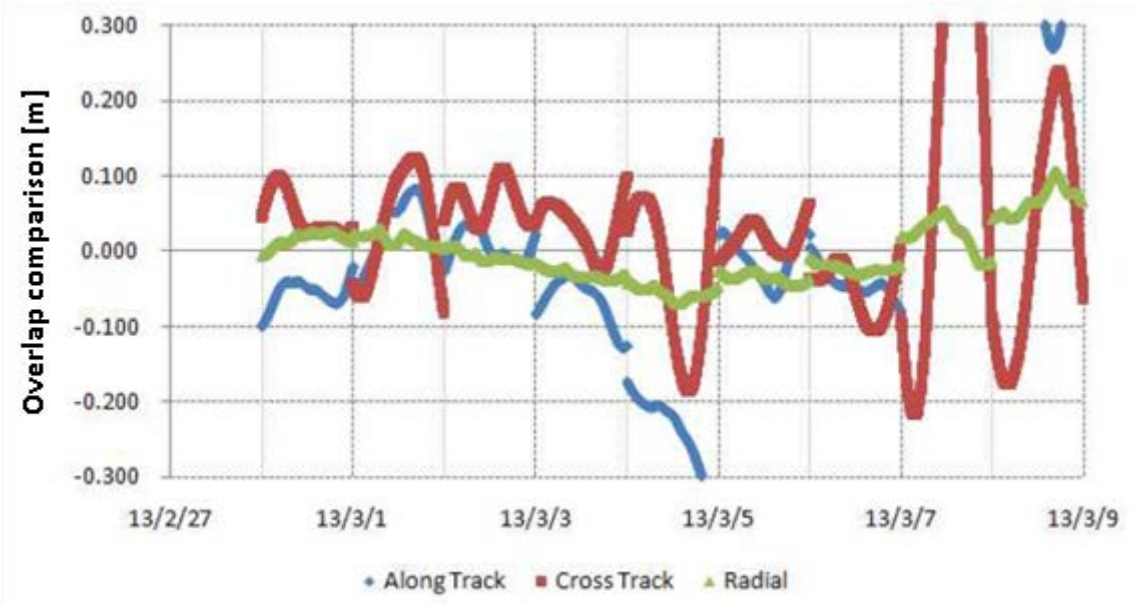

Fig. 8 Overlap comparison between consecutive precise ephemeris of QZS-1

4. Summary and Future Prospects

JAXA has been continuously conducting orbit determination for AJISAI and LAGEOS-1 and 2 and distributing their ephemeris. We also regularly assess the accuracy of our orbit determination. The GMSL is out of operation at the moment, however, the investigation is under way and it is expected that the station will restart its operation soon. We hope to distribute more observation data with high accuracy and thereby contribute to ILRS. We would like to express our gratitude to all those who generously cooperated for the QZS-1 tracking campaign and allowed it to be a great success. Furthermore, JAXA is currently examining a possibility of tracking space debris by leveraging our SLR system. We successfully demonstrated to prepare the predicted ephemeris from Two Line Element (TLE) and utilizing the ephemeris in our SLR system, which would allow us to conduct space debris ranging as soon as the station becomes operational.