

A Report on JAXA Tanegashima Station (GMSL)

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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 poster reports on 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.

SLR Orbit Determination Operation in JAXA

Daily Operation

- SLR Orbit Determination/Estimation (everyday)
- Accuracy evaluation of determined/predicted orbit (once a week)
- Distribution of predicted ephemeris (CPF) (everyday)

SLR Orbit determination

Estimation conditions/models

Item	Description
Orbit models	
Gravity Field	JGM-3(70*70)
Solid Earth Tide	ON
Ocean Tide	ON
Polar Tide	ON
Third-body Gravity	Sun/Moon/all planets
Solar radiation pressure	ON
Earth radiation pressure	ON*AJISAI only
Air Drag	ON
Atmospheric density model	Jacchia-Roberts
Satellite model	Spherical
Measurement models	
Solid Earth Tide	ON
Ocean Tide	ON(FES99)
Polar Tide	ON
Elevation cutoff angle	15deg
Center of Mass correction	1.010m
Observation Nose	1cm

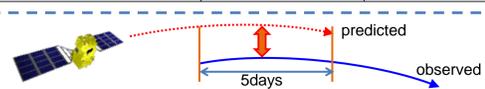
Satellites

- AJISAI (EGS)
- LAGEOS-1
- LAGEOS-2



Estimate parameter

Item	Description	A priori σ
Satellite Orbit	Position/Velocity	Position:1km Velocity:1cm/s
Dynamic parameter		
SRP Coefficient (F1)	const	1.0
Air drag Coefficient (p1)	const* AJISAI only	1.0
Empirical acceleration	OFF	
Observation parameter		
SLR Range bias	const (every pass)	300m
Station position	Certain stations	1m



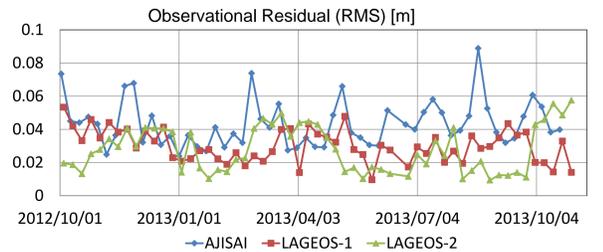
value of the difference between the predicted and the observed ephemeris (see above). We have an index of the 20 m for evaluating accuracy. As shown in the figure on the right, The value in LAGEOS1 and 2 satellites is very stable, which indicates that the accuracy of the predicted ephemeris is within 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 LAGEOS1 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.

Accuracy evaluation of Orbit determination (O-C)

For the three satellites of AJISAI, LAGEOS-1 and 2, we have estimated the orbit 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, check the data quality of each SLR station. As shown in the figure on the right, orbit accuracy of this one year is stable being within a few centimeters.

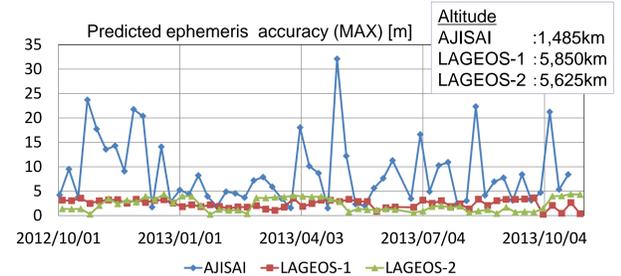
Arc Length

AJISAI : for 5 consecutive days of before and on the day of orbit determination
LAGEOS-1,2 : for 8 consecutive days of before and on the day of orbit determination



Accuracy evaluation of Predicted ephemeris (CPF)

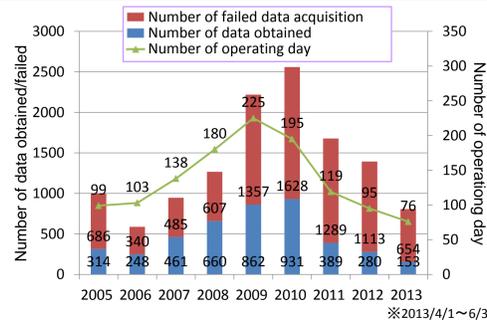
For the three satellites of AJISAI, LAGEOS-1 and 2, we have distributed the CPF every day and evaluated the orbit accuracy once a week. We have checked the maximum value of the difference between the predicted and the observed ephemeris (see above). We have an index of the 20 m for evaluating accuracy. As shown in the figure on the right, The value in LAGEOS1 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 LAGEOS1 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.



Operation Status of GMSL

Operation Status – Past

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. The figure in right shows the number of operating day. 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.



Operation Status – Present

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 this month. 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.

QZS-1 Tracking Campaign Results

Quasi-Zenith Satellite System (QZSS) is a Japanese navigation satellite system. QZSS has slightly elliptical and highly inclined orbits. 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, which is the first satellite of QZSS, orbit solutions compared to SLR observations.

QZS-1 orbital elements

Semi-major Axis	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 below Table. 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 Tracking Summary Table. Note that blue letter imply data not provided to ILRS because GMSL was under quarantine.

Tracking Summary

Tanegash Station Tracking 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)

	Yarragad		Changchu		Tokyo		Tanegash		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

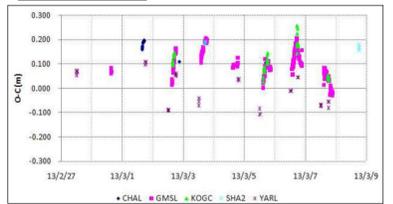
Evaluation of QZS-1 ephemeris by SLR observations

JAXA have published precise ephemeris of QZS-1 in QZSS project site (<http://qz-vision.jaxa.jp/USE/en/finalp>) from December of 2012. SLR observations acquired in QZS-1 Tracking Campaign are used to evaluate the accuracy and biases of the ephemeris.

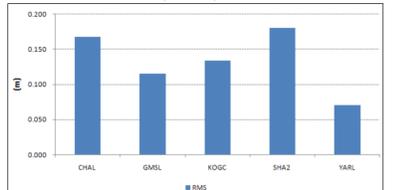
The figure on the right shows SLR residuals of precise ephemeris of QZS-1. The result of overlap comparison between consecutive precise ephemeris is shown in the bottom figure for reference. The overlap period is one-day. The overlap result during the tracking campaign is relatively stable, whereas it 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 in this way through cooperation of other ILRS stations. We would like to repeat the Campaign for improvement of QZS-1 ephemeris.

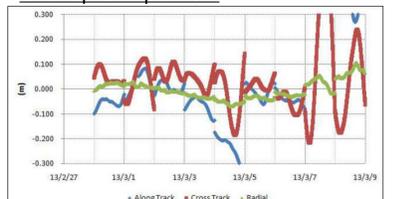
SLR Residual



SLR Residual (RMS)



Overlap Comparison



Summary and Future Prospects

JAXA has been continuously conducting orbit determination for AJISAI and LAGEOS-1 and 2 and estimating 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 within this month. 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 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. We are looking forward to make more contribution in various fields of SLR.