Accuracy Evaluation of QZS-1 Precise Ephemerides with Satellite Laser Ranging Sachiyo Kasho[1], Kyohei Akiyama[1], Satoshi Kogure[1], Motoyuki Miyoshi[1], Erik Schoenemann[2], Cristina Garcia Serrano[2], Werner Enderle[2], [1]Japan Aerospace Exploration Agency (JAXA), [2]European Space Operations Center (ESA/ESOC)

Introduction: The Quasi-Zenith Satellite System (QZSS) is a Japanese navigation satellite system. JAXA is promoting Precise Point Positioning (PPP) experiments using precise orbit and clock data obtained from QZSS-LEX (L-Band Experiment) signals in order to provide PPP service. LEX signals contain accurate information about orbit and clock biases, thereby improving the accuracy of positioning for PPP users.

JAXA has developed a precise orbit determination tool (named MADOCA) for PPP experiments with QZSS-LEX signals. The required orbit accuracy of MADOCA is 7 cm for QZSS.

SLR observation data, which has a high ranging accuracy in radial direction, was used to evaluate the accuracy of different QZS-1 orbit solutions. QZS-1 is the first satellite of QZSS. This article evaluates the accuracy of different QZS-1 ephemerids by an analysis of the corresponding SLR residuals.

Table 1. Ephemerides Evaluated

name	reference
MAD	Orbit processed with MADOCA
QZF	JAXA final products http://qz-vision.jaxa.jp/USE/archives/final/
TUM	TUM Multi-GNSS EXperiment products ftp://cddis.gsfc.nasa.gov/pub/gps/products/mgex
ESOC	Orbit processed with ESOC software

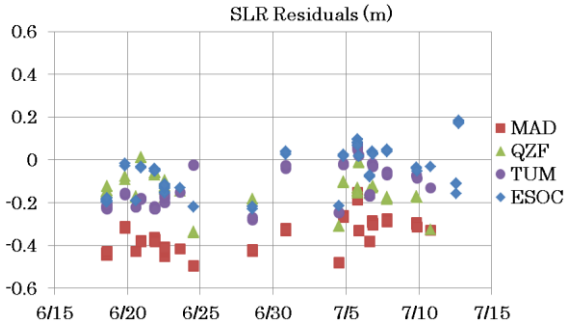

Figure 1. SLR Residuals (m)

Table 2. SLR Residuals

	AVE(m)	STD(m)	RMS(m)
MAD	**-0.3568**	**0.0829**	**0.3663**
QZF	**-0.1391**	**0.0745**	**0.1578**
TUM	**-0.1228**	**0.0980**	**0.1571**
ESOC	**-0.0538**	**0.1078**	**0.1205**

Table 3. Mean Differences in Radial Direction (m)

MEAN(R)	MAD	QZF	TUM	ESOC
MAD	-	0.290	0.279	0.326
QZF	-	-	-0.010	0.028
TUM	-	-	-	0.046
ESOC	-	-	-	-

Table 4. Mean Differences in Along Track (m)

MEAN(A)	MAD	QZF	TUM	ESOC
MAD	-	0.020	-0.135	1.075
QZF	-	-	-0.172	0.854
TUM	-	-	-	1.209
ESOC	-	-	-	-

Table 5. Mean Differences in Cross Track (m)

MEAN(C)	MAD	QZF	TUM	ESOC
MAD	-	0.005	-0.177	-0.119
QZF	-	-	-0.183	-0.136
TUM	-	-	-	0.058
ESOC	-	-	-	-

Table 6. Differences 3D-RMS (m)

3D-RMS	MAD	QZF	TUM	ESOC
MAD	-	0.386	0.685	1.492
QZF	-	-	0.663	1.026
TUM	-	-	-	1.689
ESOC	-	-	-	-

Result: Table 1 shows QZS-1 ephemerides subjected to this analytical evaluation. The evaluation period was 26 days of June 16 to July 12, 2013.

Figure 1 shows SLR residuals of the ephemerides and Table 2 also shows the statistics of SLR residuals. As shown in these results, MAD had a large bias. The other ephemerides (QZF, TUM, and ESOC) also had a bias but its magnitude was smaller than the one with MAD and they matched each other in radial.

Tables 3 to 6 show the statistics of difference between ephemerides. As shown in these results, MAD most closely matched with QZF except for the bias in radial. Furthermore, QZF closely matched with TUM and ESOC in radial direction. Accordingly, it appeared that QZF is the definitive ephemeris at present.

Summary: SLR data allow reliable accuracy evaluations. This result indicates that MAD processed with MADOCA achieves the accuracy within 40 cm, and QZF achieves the accuracy within 20 cm.

MAD, however, had a large bias in radial. There is a need to investigate this issue over a long term. The bias could be eliminated by reviewing parameters or models, thus leading to a further improvement in accuracy.