Precise Orbit Determination and Measurement Bias Analysis for Starlette with SLR of the Korean SLR Station "DAEDEOK-73592601"

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Abstract

The Korea Astronomy and Space Science Institute (KASI) has developed the first satellite laser ranging (SLR) station of Korea, "DAEDEOK-73592601". The DAEK station has been provided SLR normal point (NP) data to International Laser Ranging Service (ILRS) data centers since August, 2013 and became an active station in April, 2014. As a new active ILRS stations, quality assessment of SLR NPs from DAEK station are required. In this study, precise orbit determination (POD) for Starlette and measurement bias analysis of ILRS stations are performed for quality check of DAEK SLR NPs. The NASA/GSFC GEODYN II software is used for POD and a weekly-based strategy is applied to process SLR NPs from January, 2013 to July, 2014 from 27 ILRS global stations. For drag coefficients and empirical acceleration parameters estimation, 8h-based strategy is applied. For orbit quality assessment, post-fit residuals for total periods are investigated. For measurement bias estimation, quick orbital analysis from pass-by-pass approach is utilized. The mean RMS of post-fit residuals for total period is 0.96 cm and that of DAEK station is 0.73 cm. The mean range bias and bias stability of DAEK station are -1.4 mm and 34.8 mm, respectively.

Introduction

The first Satellite Laser Ranging (SLR) station of Korea, "DAEDEOK-73592601", was developed by the Korea Astronomy and Space Science Institute (KASI). The information of DAEK station is presented in Table 1. The DAEK station has been provided SLR normal point (NP) observations to International Laser Ranging Service (ILRS) data centers since August, 2013. In April, 2014, the DAEK station became an active station and quality assessment of uploaded SLR NPs from DAEK station are required as a new active ILRS stations. In this study, precise orbit determination (POD) for Starlette and measurement bias analysis are accomplished for quality assessment of DAEK NPs. Table 2 shows the specification of Starlette and Fig. 1 describes the shpe of Starlette with 60 corner cubes.

Table 1. The information of DAEK station.

Item	Information
Station ID	7359
Code	DAEK
Site	Daejeon, Korea
Status	Active
SOD	73592601

Table 2. The specification of Starlette.

Category	Specification
Sponsor	CNES (France)
Applications	Gravity field & POD
Launch date	February 6, 1975
LRA diameter	24 cm
NP bin size (s)	30
Orbit	Circular
Inclination (deg)	49.83
Eccentricity	0.0206
Perigee (km)	812
Period (min)	104
Weight (kg)	47

Figure 1. Starlette with 60 corner cubes.

Precise Orbit Determination

For POD, workstation with Intel Xeon E5645@2.40GHz (64bit Linux OS) and NASA/GSFC GEODYN II software [1] are used. Detail models and parameter setting of system are presented in Table 3.

Table 3. The models and parameter setting of POD.

Model/Parameter	Description
Reference Frame	
Reference system	Inertial reference system
Precession/nutation	IAU2000
Polar motion	C04 IERS
Station coordinates	SLRF2008 [3]
Numerical Integration	Cowell's method
Step size	60 s
Arc length	7 days
Dynamic Model	
Earth geo-potential	GGM-2C (90 by 90) [4]
Planetary ephemeris	JPL DE-403 [5]
Earth tide	IERS convention 2003 [6]
Ocean tide	GOT00.2 [7]
Dynamic polar motion	Applied
Relativistic effect	Applied
Atmospheric density	MSIS-86 [8]
Solar radiation	Cannon ball
Earth Albedo pressure	Applied
Empirical acceleration	Radial, along and cross-track
Measurement Model	
Observations	30s SLR normal points
Tropospheric delay	Mendes and Pavlis [9,10]
Center of mass correction	78 mm
Estimation Parameters	Position and velocity of satellite

A weekly-based POD strategy is applied to process SLR data (77 weeks, 124,555 NPs) from January, 2013 to July, 2014 from 27 ILRS global stations. Table 4 gives the information of included stations in SLR data processing. For drag coefficients and empirical acceleration parameters estimation, 8h-based strategy is applied. The center of mass correction for Starlette is used as a value of 78 mm [2]. For measurement bias estimation, quick orbital analysis by pass-by-pass is performed.

Table 4. ILRS stations list for Starlette POD.

Station	Station Location	Station	Station Location	Station	Station Location
1824	Golosiiv	7124	Tahiti	7824	San Fernando
1873	Simeiz	7237	Changchun	7825	Mt. Stromlo
1884	Riga	7249	Beijing	7838	Simosato
1888	Svetloe	7359	Daedeok	7839	Graz
1890	Badary	7406	San Juan	7840	Herstmonceux
7080	McDonald	7501	Hartebeesthoek	7841	Potsdam
7090	Yarragadee	7810	Zimmerwald	7845	Grasse
7105	Greenbelt	7820	Kunming	7941	Matera
7110	Monument Peak	7821	Shanghai	8834	Wettzell

Precise Orbit Determination Results

The mean root mean square (RMS) value of post-fit residuals of Starlette is 0.96 cm. Table 5 shows the previous studies of Starlette POD. The precision of post-fit residuals in this study is better than those of previous studies [11,12,13,14]. The mean RMS value of post-fit residuals of DAEK station is 0.73 cm. Figure 3 shows the mean of post-fit residual of each arc for Starlette POD. The quarterly summary of POD is presented in Table 6.

Table 5. Studies of Starlette POD.

Research	Post-fit residual (cm, RMS)	Arc Length	Gravity	Drag	Accel.
Lejba et al. [11]	1.30	10 day	60x60	24h	6h
Jeon et al. [12]	1.93	7 day	90x90, 180x180	8h	7d
Lejba & Schillak [13]	1.87	10 day	75x75	12h	6h/12h
Jagoda & Rutkowska [14]	2.40	7 day	2,159x2,159	7d	7d

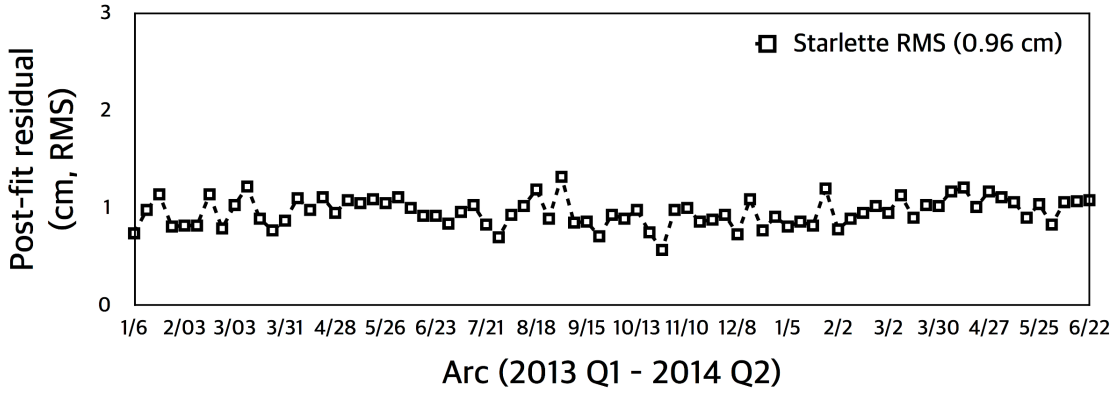

Figure 3. The mean of post-fit residuals for Starlette POD.

Table 6. Quarterly summary of Starlette POD.

	2013 Q1	2013 Q2	2013 Q3	2013 Q4	2014 Q1	2014 Q2
Mean RMS (cm)	0.93	1.02	0.93	0.87	0.94	0.96
# NP	17,813	21,914	21,008	19,009	23,880	20,931

Measurement Bias Analysis

The results of measurement bias analysis from August, 2013 to July, 2014 are presented by range bias of each pass. The outlier of range bias statistics is < |100 mm|. Detail results of measurement bias estimation are described in Fig. 2.

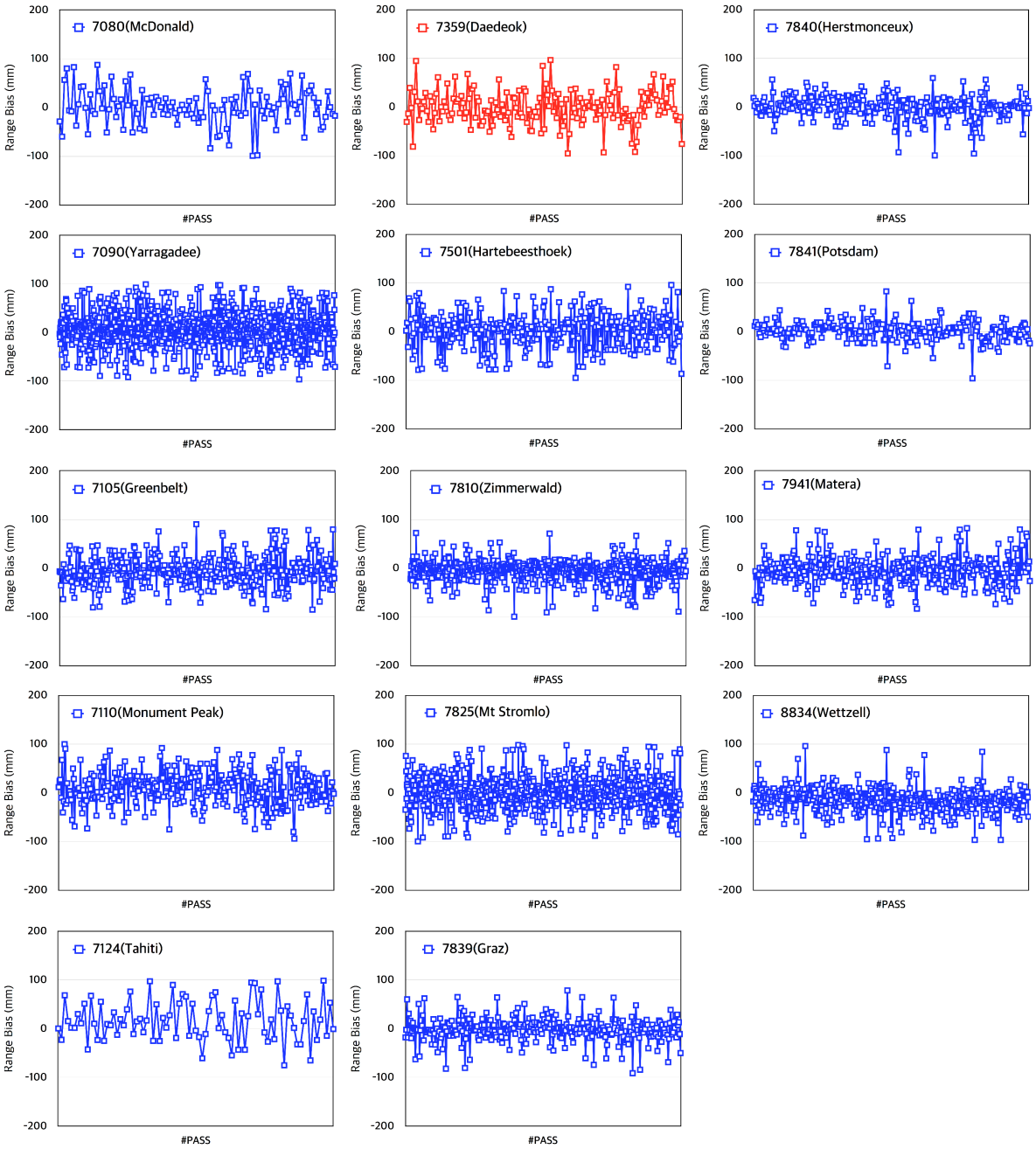

Figure 4. Measurement bias estimation results of ILRS stations

The mean value of range bias from DAEK station is -1.4 mm. Table 7 and Fig. 5 present mean bias and stability of ILRS stations. The range bias stability of DAEK station is 34.8 mm.

Table 7. Mean bias and stability of stations.

Station	Mean (mm)	Std. dev. (mm)	#Pass	Station	Mean (mm)	Std. dev. (mm)	#Pass
7080	1.2	37.6	119	7810	-4.7	20.7	647
7090	6.0	32.7	1057	7825	0.3	32.0	777
7105	-6.2	28.4	417	7839	-1.7	23.5	335
7110	9.1	33.5	330	7840	0.4	23.1	283
7124	17.2	41.5	86	7841	2.4	20.2	232
7359	**-1.4**	**34.8**	**178**	7941	-4.7	27.7	387
7501	2.4	36.1	301	8834	-14.6	23.6	520

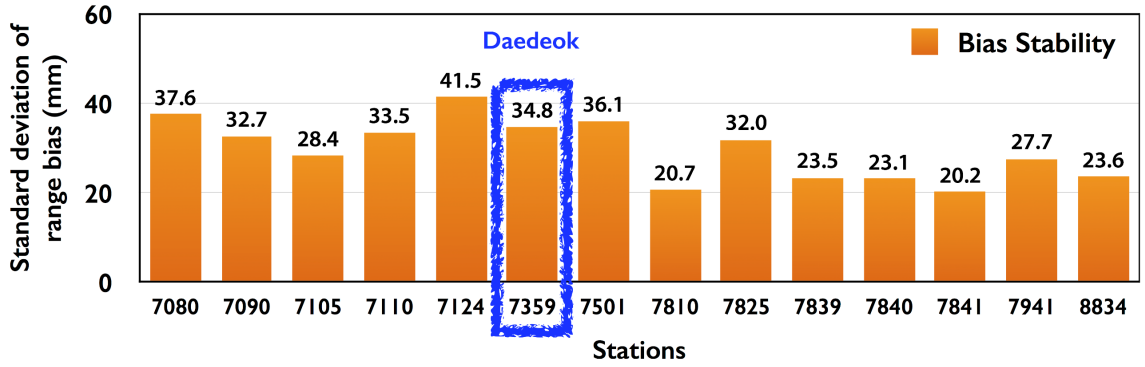

Figure 5. Bias stability.

Conclusions and Future Works

We performed POD and measurement bias analysis for Starlette with SLR observations including DAEK SLR NPs. We obtained the mean post-fit residuals of all ILRS stations is 0.96 cm including DAEK station. The mean post-fit residuals of DAEK station only is 0.73 cm. The calculated mean range bias of DAEK stations is -1.4 mm. The range bias stability of DAEK is 34.8 mm. For quality assessment of DAEK station, continuous POD works using SLR NPs is required. Additionally, for better understanding, long term bias stability of DAEK station will be performed.

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