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SLR data processing status of Korean SLR system

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Abstract. *Korea Astronomy and Space Science Institute (KASI) installed SLR station (Daedeok, Monument: 7359) and joined the ILRS network in 2012 (Park et al. 2012). In addition, from early in 2013, KASI planned to prepare the SLR data processing. In this paper, we present current status and results of precise orbit determination (POD) and geodetic parameter estimations using satellite laser ranging (SLR) observations. The NASA/GSFC GEODYN II and SOLVE programs were used for processing the normal point observation data set of LAGEOS-1, LAGEOS-2, Etalon-1 and Etalon-2. A weekly-based orbit determination strategy was employed to process SLR observations and the coordinates of ILRS sites were determined.*

Introduction

In this research, the precise orbital and geodetic parameter estimation using SLR observations were performed. The precise orbit determination (POD), terrestrial reference frame (TRF), and Earth orientation parameters (EOPs) solutions of geodetic satellites (LAGEOS-1, LAGEOS-2, Etalon-1, and Etalon-2) were analyzed. The NASA/GSFC softwares GEODYN II and SOLVE were emplyed for precise orbital and geodetic parameter estimation (Pavlis et al. 1998, Ullman 2010). Normal point (NP) data in consolidated laser ranging data format (CRD) from ILRS active sites were used for observations. For investigating orbit solutions, the POD post-fit residuals results of LAGEOS-1, LAGEOS-2, Etalon-1, and Etalon-2 were analyzed and a precision analysis of our solutions by applying a stability analysis of TRF and a comparison of EOPs solution with EOP 08 C04 (http://hpiers.obspm.fr/eop-pc/) by International Earth rotation and Reference systems Service (IERS) were performed.

Precise orbit determination

Using the SLR CRD NP data of LAGEOS-1, LAGEOS-2, Etalon-1, and Etalon-2, weekly-based POD was performed by NASA/GSFC GEODYN II software. 26 ILRS stations SLR observation data (42 weeks from January 7^{th} to October 28^{th}, 2013) are used for POD. The information of ILRS stations for POD is displayed in Table 1. The POD configuration of GEODYN II is summarized in Table 2. The post-fit residual results – weighted root mean square (WRMS) value for each week (arc) and total mean value - LAGEOS-1,2 & Etalon-1,2 are summarized in Table 3. The mean WRMS values for 4 geodetic satellites were less than 1cm.

Table 1. The information of 26 ILRS stations for POD

Station Number	Station Name	Station Number	Station Name
1868	Komsomolsk	7403	Arequipa
1873	Simeiz	7406	San Juan
1879	Altay	7501	Hartebeesthoek
1884	Riga	7810	Zimmerwald
1893	Katzively	7821	Shanghai
7080	Mcdonald	7824	San Fernando
7090	Yarragadee	7825	Mt Stromlo
7105	Greenbelt	7839	Graz
7110	Monument Peak	7840	Herstmonceux
7237	Changchun	7841	Potsdam
7249	Beijing	7845	Grasse
7359	Daedeok (KASI)	7941	Matera
7308	Koganei	8834	Wettzell

Table 2. Model and parameter configuration for POD

Model/Parameter	Description
Earth gravity	GGM02C 30X30
Planetary ephemeris	JPL DE-1403
Atmospheric density	Jacchia 1971
Station coordinates	ITRF2005 SLR rescaled
Precession/nutation	IAU2000
Tropospheric refraction	Mendes-Pavlis model
Earth tide	IERS Conventions 2003
Ocean tide	GOT99.2
Solar radiation pressure	C_R coefficient 1.13
Numerical integration	11^{th} Cowell's method step size = 150 s (LAGEOS) = 300 s (Etalon)
Editing strategy	3.5σ editing

Table 3. Post-fit Residual for LAGEOS-1,2 & Etalon-1,2 (2013/01 – 2013/10)

ARC# (Week)	LAGEOS-1 (cm, WRMS)	LAGEOS-2 (cm, WRMS)	Etalon-1 (cm, WRMS)	Etalon-2 (cm, WRMS)
1	0.86	0.72	1.21	0.84
2	1.00	0.83	0.72	0.76
3	0.83	0.74	0.51	0.36
4	0.93	0.76	0.81	0.64
5	0.82	0.78	0.50	0.81
6	0.82	0.81	0.69	0.69

7	0.78	0.63	0.74	0.50
8	0.85	0.84	0.46	0.84
9	0.74	0.82	0.54	0.53
10	0.94	0.88	0.38	0.63
11	0.72	0.66	0.66	0.95
12	1.12	0.77	0.43	1.02
13	0.92	0.75	1.24	1.45
14	1.01	0.80	0.50	0.51
15	0.78	0.69	0.62	0.47
16	1.02	0.75	0.65	0.42
17	1.01	0.91	1.05	0.92
18	1.02	0.93	0.39	0.91
19	0.69	0.86	0.89	0.65
20	1.05	0.80	0.99	0.72
21	0.87	1.06	0.55	0.94
22	0.83	1.16	0.56	0.50
23	0.79	0.88	0.60	1.15
24	0.76	0.78	1.07	0.71
25	0.84	1.08	1.52	0.63
26	0.68	0.83	0.62	0.62
27	0.60	0.78	0.56	1.08
28	1.21	0.71	0.56	0.98
29	0.65	0.73	0.71	0.55
30	0.63	0.62	0.53	0.49
31	0.58	0.91	0.54	1.22
32	0.64	0.68	0.42	0.52
33	1.07	0.95	0.76	0.82
34	0.69	1.09	1.39	0.45
35	1.05	0.81	0.40	0.92
36	1.10	0.63	0.88	0.42
37	0.69	0.64	0.75	0.54
38	0.96	0.58	0.36	0.62
39	0.72	0.72	0.74	0.97
40	0.71	0.72	1.58	0.54
41	0.70	0.58	0.87	0.46
42	0.85	0.68	0.64	0.47
Mean	**0.85**	**0.79**	**0.73**	**0.72**

KASI TRF and EOPs solutions

The TRF and EOPs solutions are the main ILRS analysis products. SLR observations on LAGEOS-1, LAGEOS-2, Etalon-1 and Etalon-2 are reduced in 7-day (weekly) arcs to generate the individual TRF and EOPs solutions. ILRS analysis center (AC) and associated analysis centers (AAC) are free to follow their own computation model and/or analysis strategy. In Table 4, the AC and KASI strategies for TRF and EOPs solutions were described. For verification of KASI TRF and EOPs solutions, the stabilities of ILRS station coordinate are analyzed and a comparison with EOP 08 C04 by IERS were performed (Kim et al. 2013) using 9 ILRS core sites observation data - 7090 (Yarragadee, Australia), 7105 (Greenbelt, MD, USA), 7110 (Monument Peak, CA, USA), 7501 (Hartebeesthoek, South Africa), 7810 (Zimmerwald, Switzerland), 7825 (Mount Stromlo, Australia), 7839 (Graz, Austria), 7840 (Herstmonceux, UK), 7941 (Matera, Italy).

For KASI-TRF-solution, station positions (X, Y, and Z) of 9 ILRS core sites are calculated from LAGEOS-1, LAGEOS-2, Etalon-1, and Etalon-2 POD solutions through SOLVE software and the stability of the directions of the station positions X, Y, and Z are calculated by using as follows (Lejba & Schillak 2011) for verification :

$$S_X = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \bar{X})^2}{N-1}}$$

where i is the number of weekly arc, $\bar{X}$ is the mean value of the X_i direction. The stability of Y and Z are calculated similarly. The 3D stability are calculated as:

$$S = \sqrt{\frac{{S_X}^2 + {S_Y}^2 + {S_Z}^2}{3}}$$

In Table 5, 3D stabilities of KASI-TRF-solution were shown for 9 ILRS core sites. 3D stabilities of KASI-TRF-solution are distributed from 3.1 mm to 11.0 mm (mean value: 5.8mm). Comparing with the research of Schillak (2012), KASI-TRF-solutions have a consistent precision with those from previous results.

For KASI-EOPs-solution, polar motion X_P, Y_P, and polar motion rates are also calculated from LAGEOS-1, LAGEOS-2, Etalon-1, and Etalon-2 POD results using SOLVE software. Figure 1 shows daily polar motion from January 7th to October 28th, 2013. For verification KASI-EOPs-solution, IERS 08 C04 times series are used. Figure 2 and Figure 3 show the residuals of polar motion X_P and Y_P with respect to IERS 08 C04 values, respectively. The standard deviations of differences of polar motion X_P and Y_P between KASI-EOPs-solution and IERS 08 C04 are 0.87 micro-arcseconds and 0.88 micro-arcsenconds, respectively.

Table 4. The strategies for combined TRF and EOPs solutions

Satellite	**KASI**	**ASI**	**DGFI**	**GFZ**	**JCET**
Software	GEODYN II/SOLVE	GEODYN II/SOLVE	DOGS_OC/DOGS_CS	EPOSOC	GEODYN II/SOLVE
Products	TRF (Weekly) EOPs (Daily)	TRF (Weekly) EOPs (Daily)	TRF (Weekly) EOPs (Daily)	TRF (Weekly) EOPs (Daily)	TRF (Weekly) EOPs (Daily)
Satellites	L1, L2, E1, E2	L1, L2, E1, E2	L1, L2, E1, E2	L1, L2	L1, L2, E1, E2
Data editing	3.5 sigma	3.5 sigma	3.0 sigma	3.0 sigma	3.5 sigma
Constraints	1 m on TRF, equivalent for EOPs	Loose	> 1 m on TRF, equivalent for EOPs	1 m on TRF, 30 mas for EOPs	1 m on TRF, equivalent for EOPs

L1: LAGEOS-1, L2: LAGEOS-2, E1: Etalon-1, E2: Etalon-2, mas: milli-arc-seconds

Table 5. The stability analysis result of the 10 ILRS core stations

Monument	Sx (mm)	Sy (mm)	Sz (mm)	S (mm)
7090 (YARL)	6.6	7.1	8.0	7.2
7105 (GODL)	4.9	3.2	5.9	4.8
7110 (MONL)	4.2	4.4	7.3	5.5
7501 (HARL)	10.1	11.5	11.5	11.0
7810 (ZIML)	9.1	6.1	8.1	7.9
7825 (STL3)	3.5	1.8	3.7	3.1
7839 (GRZL)	6.2	4.3	6.1	5.6
7840 (HERL)	9.8	6.3	7.4	8.0
7941 (MATM)	6.1	4.6	5.7	5.5
Mean	**6.1**	**5.5**	**5.9**	**5.8**

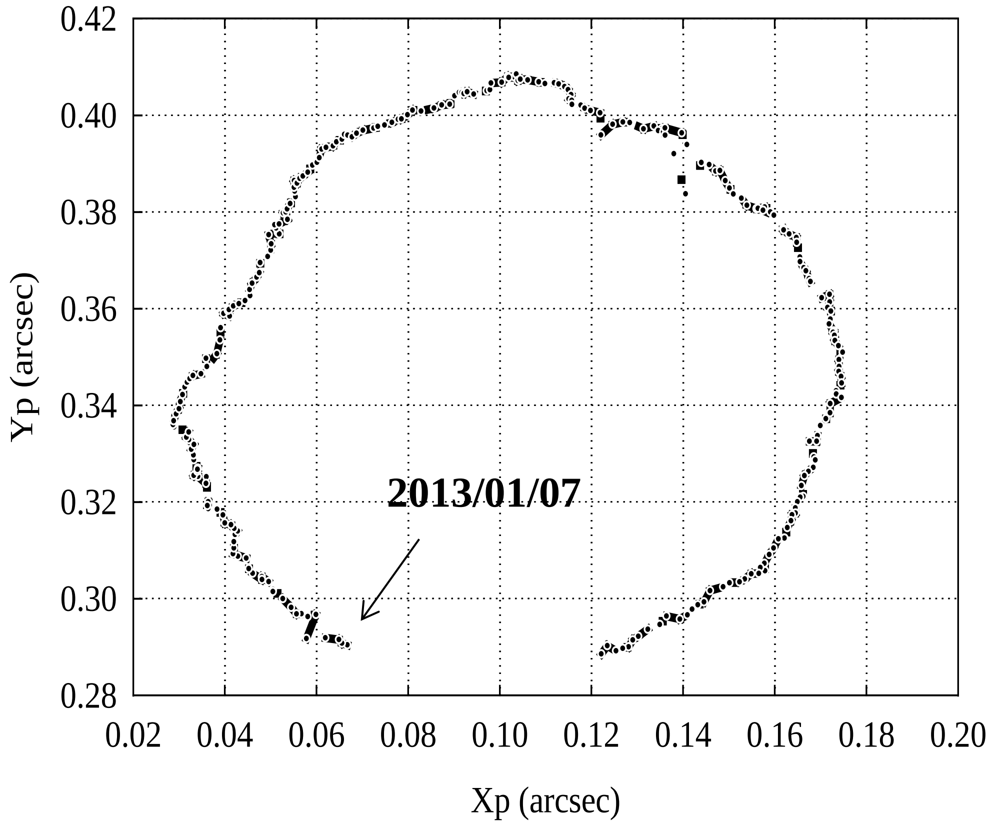

Figure 1. Daily polar motion

4. CONCLUSIONS

In this paper, the results of POD and combined TRF and EOPs solutions - as a study preparing for ILRS AAC - were described. SLR CRD NP observation data of LAGEOS-1, LAGEOS-2, Etalon-1, and Etalon-2 for 42 weeks in 2013 and NASA's GEODYN II and SOLVE software were used. As a result of POD, the mean post-fit residuals were less than 1cm RMS for four satellites. For KASI-TRF-solution, the mean 3D stability of 9 ILRS core sites coordinates in KASI-TRF-solution was at levels of 6.0 mm. For KASI-EOPs-solution, it was compared with IERS 08 C04 EOP series. Sub-centeimter level POD results using geodetic satellites and 7-day arcs based combined TRF and EOPs solutions are one of the most important products of ILRS AAC and AC. Hence, the results of this research are significant achievment to prepare an ILRS AAC.

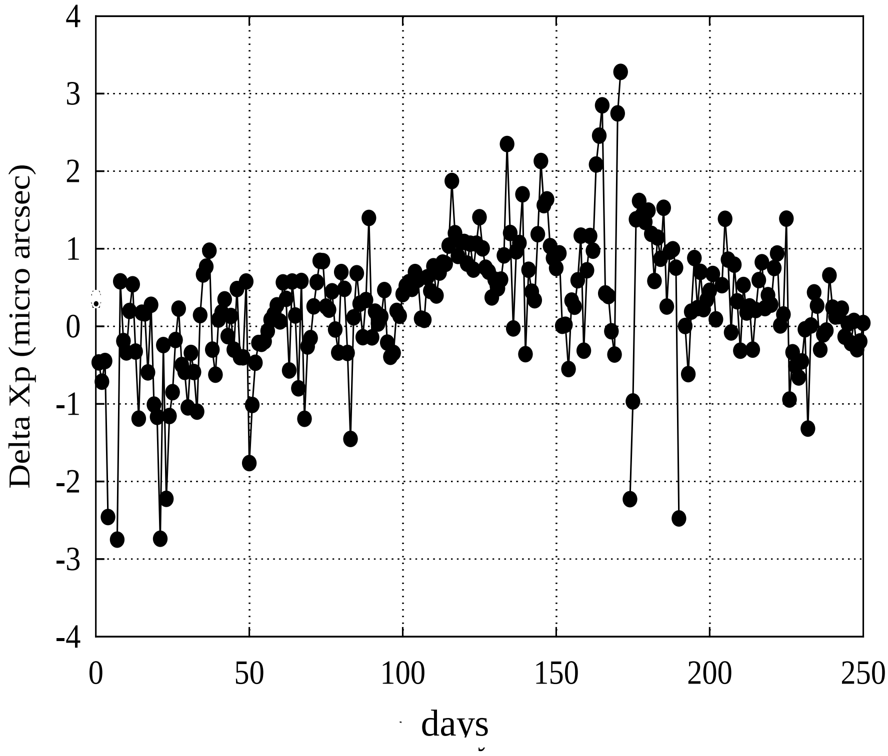

Figure 2. D KASI EOPs – IERS C04 (Xp), standard devation value: 0.87 (micro-arcseconds)

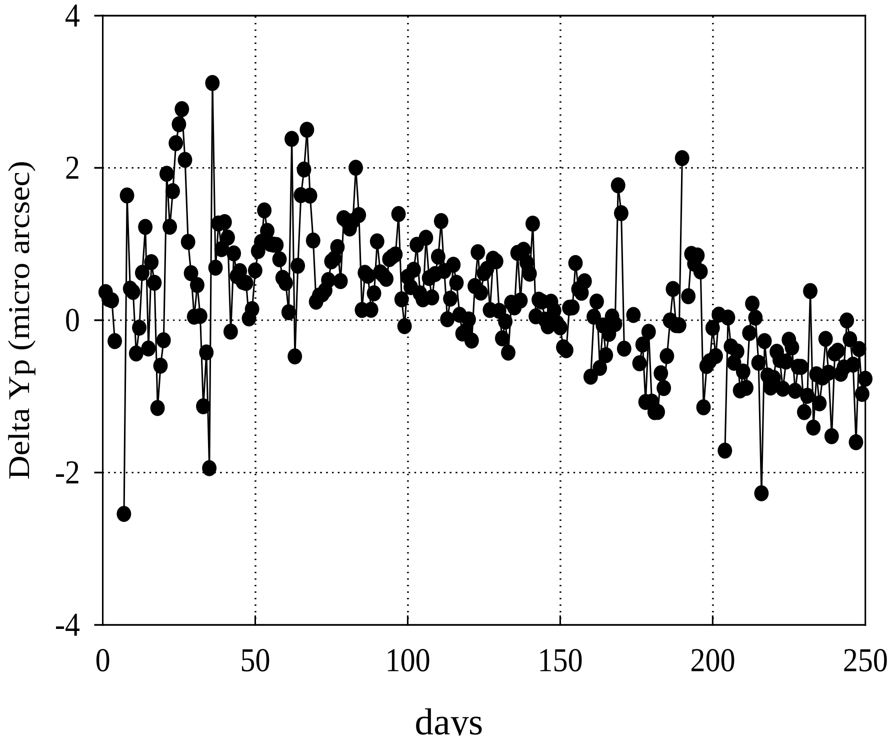

Figure 3. KASI EOPs – IERS C04 (Yp), standard devation value: 0.88 (micro-arcseconds)

References

Kim Y-R, Park E, Oh H-J, Park S-Y, Park C-D, Precise Orbital and Geodetic Parameter Estimation using SLR Observations for ILRS AAC, JASS, 30, 269-277 (2013). http://dx.doi.org/10.5140/JASS.2012.29.3.275

Park E, Yu S-Y, Lim H-C, Bang S-C, Seo Y-K, et al., *Status and progress of ARGO-M system development*, Publications of the Korean Astronomical Society, 27, 49-59 (2012). http://dx.doi.org/10.5303/PKAS.2012.27.3.049

Pavlis DE, Luo S, Dahiroc P, *GEODYN II system description*, Hughes STX Contractor Report, Greenbelt, Maryland, July (1998).

Schillak S, *Determination of the SLR stations coordinates in 1994–2008*, Reports on Geodesy, 92, 227-236 (2012).

Ullman RE, *SOLVE program: user's guide 2010*, Raytheon STX Contractor Report, Contract NAS5-31760, Greenbelt, Maryland, February (2010).