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DETERMINATION OF PRECISE POSITIONS OF TITI SIMA AND ISIGAKI SIMA BY SATELLITE LASER RANGING †

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Abstract

Satellite Laser Ranging (SLR) Observations were carried out at Titi Sima and Isigaki Sima in 1988. The positions of these islands in the global geodetic network were determined by using SLR data obtained at these two islands, Simosato Hydrographic Observatory (SHO) and foreign SLR stations. Two analysis methods, a global analysis of Lageos and a very short arc analysis (SPORT) of Lageos and Ajisai, were tried. The baseline length between Titi Sima and Simosato are determined precisely by SPORT. The precision of rectangular coordinates of Titi sima and Isigaki Sima is about 5 cm.

Keywords : Satellite Laser Ranging (SLR) —Simosato Hydrographic Observatory (SHO) —Titi Sima —Isigaki Sima—SPORT

1. Introduction

Since 1982, the SLR observation of geodetic satellites has been continued at the Simosato Hydrographic Observatory (SHO) in order to determine the position of SHO in the framework of worldwide geodetic system. SHO is the fundamental fiducial point in the Marine Geodetic Control Network (Kubo, 1988) of Japan. The position of Simosato has been determined by the Hydrographic Department (Sasaki, 1990) and each SLR analysis center of IERS (International Earth Rotation Service), such as CSR (Center for Space Research, University of Texas, USA), GSFC (Goddard Space Flight Center, National Aeronautics and Space Administration : NASA, USA), DUT (Delft University of Technology, the Netherlands). As a permanent SLR station in Asia, Simosato has greatly contributed to the establishment of the conventional terrestrial reference frame.

A project to determine precise positions of the selected major islands was started at the beginning of 1988. These islands, which are called the first order control points, were not connected to the main land geodetically at all or connected very poorly. SLR observation and direction observation by photographs have been carried out at the islands in order to determine the relative positions of the islands to the fiducial point. Analyzing the data obtained at the islands, Simosato and foreign SLR stations, we can determine the positions of the islands precisely. In this paper, the results of SLR analysis of Titi Sima and Isigaki Sima are presented.

2. Observation

The first observation of the transportable SLR system of the Hydrographic Department (Sasaki, 1988a), named the HTLRS (Hydrographic Department Transportable Laser Ranging Station),

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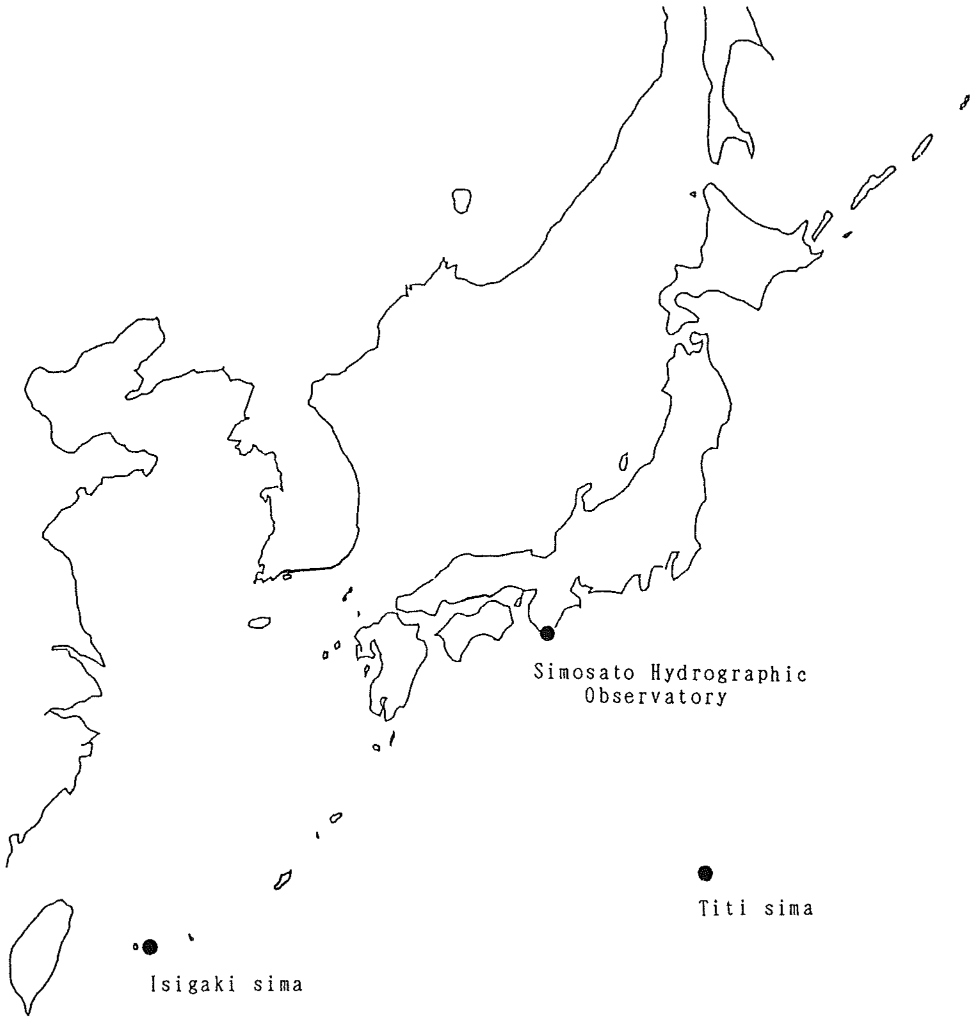

Figure 1. SLR observation in 1988.

was carried out at Titi Sima from January 5 to March 13, 1988. The second observation of the HTLRS was made at Isigaki Sima from July 18 to September 17, 1988 (Fig. 1, Sengoku et al., 1990, Fukushima et al., 1991). Observation schedules were made by selecting passes whose maximum elevation was over 30 degrees. The HTLRS was operational only at night. Observing sites are shown in Fig. 2 and 3. Pass tables of observation passes at Titi Sima and Isigaki Sima are shown in Table 1 and 2. Passes which were simultaneously observed at islands and SHO are indicated by asterisks in these tables. During the period of Titi Sima observation, 20 Ajisai passes, 1 Lageos pass and 1 Starlette pass were commonly observed at both sites. During Isigaki Sima observation, 5 Ajisai passes, 9 Lageos passes and 1 Starlette pass were commonly observed.

3. Analysis Methods

The positions of Titi Sima and Isigaki Sima were determined by using two methods. The one was a global analysis of 5-day-arcs of Lageos using global SLR data and the other was a very short arc

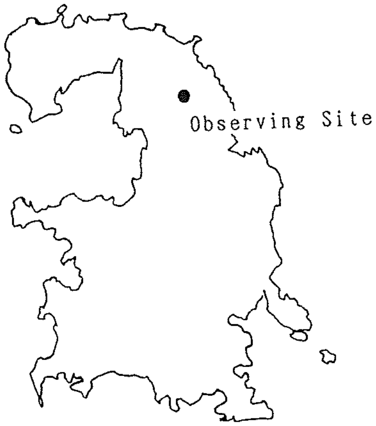

Figure 2. Observing site at Titi Sima in 1988.

Figure 3. Observing site at Isigaki Sima in 1988.

analysis (SPORT) of Ajisai and Lageos.

3-1. The global analysis of 5-day-arcs of Lageos

The global analysis of 5-day-arcs of Lageos was made by using the software developed by Sasaki and Sengoku (Sasaki, 1984, Sengoku, 1986, Sasaki, 1988), which is called HYDRANGEA (HYdrographic Department RANGE data Analyzer). Applied dynamical models are summarized in Table 3. Used data were collected and delivered by NASA/CDDIS (Crustal Dynamics project's Data Information System, Noll et al., 1987). The positions of several stations were fixed as fiducial points. Adopted positions of fiducial stations (Table 4) were based on SSC(CSR)85L07 (Tapley et al., 1986) and the plate motion model of AM0-2 (Minster and Jordan, 1978). The epoch of station coordinates was 1988. 1. These stations were selected in order to obtain robustness of the network. The positions of all the other stations were estimated. In order to determine the relative positions of Titi Sima (Isigaki Sima) to Simosato precisely, the position of Simosato was fixed, because observation data at Simosato might be scarce during the analyzed period. The same station coordinate set was used in the analyses of both Titi Sima and Isigaki Sima.

Estimated parameters in the global analysis were initial position and velocity of Lageos, positions of unknown stations, GM (G : Gravitational constant, M : mass of the Earth), the dynamical form factor of the Earth (J_2), the Earth orientation parameters (x_p , y_p , $d\omega$), a ballistic air-drag coefficient (β), reflectivity coefficient (γ) and an empirical force on Lageos ($\Delta\alpha$). These unkowns were estimated in every 5-day-arc.

3-2. SPORT

Generally, just as described in the former section, SLR analysis is made by using global SLR data. This global analysis can determine positions of stations in the geocentric coordinate system, Earth orientation parameters (EOP), physical parameters of satellites and some physical quantities of the Earth. However, in this methed, we have to deal with large amount of global data which result in long CPU time. Furthermore, we have to wait for more than a half year after the observation to collect global data.

Table 1. Observation passes at Titi Sima in 1988
(* : commonly observed with Simosato)

Pass Table of Ajisai(EGS) 8606101

Station ID.	Start yy/mm/dd	Start hh:mm:ss		End yy/mm/dd	End hh:mm:ss	Number of returns
* 7844	88/01/23	19:48:19	~	88/01/23	19:56:15	136
* 7844	88/01/24	18:51:29	~	88/01/24	19:00:48	507
* 7844	88/01/24	20:54:27	~	88/01/24	21:05:46	389
* 7844	88/01/25	11:44:24	~	88/01/25	11:55:09	802
* 7844	88/01/25	13:50:03	~	88/01/25	13:55:49	268
7844	88/01/25	18:02:23	~	88/01/25	18:03:49	25
* 7844	88/01/25	19:58:16	~	88/01/25	20:10:24	895
* 7844	88/01/26	12:51:47	~	88/01/26	13:02:48	1395
* 7844	88/01/26	19:11:17	~	88/01/26	19:13:15	222
7844	88/01/27	09:57:15	~	88/01/27	10:05:19	773
7844	88/01/30	09:17:00	~	88/01/30	09:24:41	555
7844	88/01/30	11:15:49	~	88/01/30	11:28:19	1453
7844	88/01/30	13:25:47	~	88/01/30	13:27:19	32
7844	88/01/30	17:32:37	~	88/01/30	17:40:49	814
7844	88/01/30	19:31:54	~	88/01/30	19:39:52	1197
7844	88/02/01	09:29:31	~	88/02/01	09:37:30	914
7844	88/02/01	11:33:48	~	88/02/01	11:34:37	123
7844	88/02/04	08:48:12	~	88/02/04	08:52:27	67
7844	88/02/04	10:54:01	~	88/02/04	10:54:37	79
* 7844	88/02/04	17:04:11	~	88/02/04	17:14:06	1158
* 7844	88/02/04	19:07:33	~	88/02/04	19:16:00	597
7844	88/02/05	09:56:03	~	88/02/05	10:07:47	1299
* 7844	88/02/05	16:10:56	~	88/02/05	16:11:34	61
* 7844	88/02/05	18:11:17	~	88/02/05	18:22:43	1120
* 7844	88/02/06	15:18:27	~	88/02/06	15:22:45	77
7844	88/02/11	16:51:29	~	88/02/11	16:58:05	724
* 7844	88/02/12	09:49:16	~	88/02/12	09:52:18	87
* 7844	88/02/12	14:00:23	~	88/02/12	14:04:52	279
* 7844	88/02/12	15:57:09	~	88/02/12	16:08:17	575
* 7844	88/02/14	14:08:38	~	88/02/14	14:20:21	1004
* 7844	88/02/14	16:15:41	~	88/02/14	16:16:52	17
* 7844	88/02/22	11:05:06	~	88/02/22	11:06:51	75
* 7844	88/02/22	13:03:19	~	88/02/22	13:13:07	187
7844	88/02/26	11:31:32	~	88/02/26	11:38:54	414
7844	88/02/26	13:32:55	~	88/02/26	13:37:55	167
7844	88/02/27	10:35:01	~	88/02/27	10:42:13	132
7844	88/02/27	12:36:15	~	88/02/27	12:40:24	35

Total number of passes : 37
Total number of returns : 18654

In order to overcome these disadvantages, we have developed a very short arc analysis method, which is named SPORT (Successive Passes Orbit Revising Technique, Sengoku, to be published). In SPORT, only two passes which are successively and commonly observed at two stations are used (Fig. 4). SPORT is applicable to only local baseline determination since commonly observed data are needed. The characteristics of SPORT can be summarized as follows.

1) Initial position and velocity of a satellite and position of one station are estimated. Position of the other station should be fixed.

Table 1. (continued)

Pass Table of Lageos 7603901

Station ID.	Start yy/mm/dd	Start hh:mm:ss		End yy/mm/dd	End hh:mm:ss	Number of returns
7844	88/02/01	09:13:39	~	88/02/01	09:16:32	44
7844	88/02/03	10:01:55	~	88/02/03	10:03:47	28
7844	88/02/05	10:56:38	~	88/02/05	11:12:42	644
7844	88/02/05	19:51:55	~	88/02/05	20:04:59	200
7844	88/02/12	08:42:08	~	88/02/12	08:47:32	160
* 7844	88/02/12	20:39:44	~	88/02/12	20:59:58	115
7844	88/02/14	09:11:20	~	88/02/14	09:35:38	578
7844	88/02/22	08:45:28	~	88/02/22	09:08:45	1115
7844	88/02/26	19:19:39	~	88/02/26	19:51:11	752
7844	88/02/27	08:58:17	~	88/02/27	09:28:27	1458
7844	88/02/29	18:52:18	~	88/02/29	19:13:49	388

Total number of passes : 11
Total number of returns : 5482

Pass Table of Starllete 7501001

Station ID.	Start yy/mm/dd	Start hh:mm:ss		End yy/mm/dd	End hh:mm:ss	Number of returns
7844	88/02/03	13:05:47	~	88/02/03	13:09:27	169
7844	88/02/05	11:56:46	~	88/02/05	12:02:18	115
* 7844	88/02/12	10:33:16	~	88/02/12	10:41:20	209
7844	88/02/14	11:12:40	~	88/02/14	11:17:16	102

Total number of passes : 4
Total number of returns : 595

2) Influence of errors in force models is smaller than the global analysis.
3) CPU time is shorter.
4) Results can be obtained quickly since only data of two stations are required.
5) Baseline length is estimated precisely.
6) Global parameters of force models can hardly be determined.
7) Successively and commonly observed passes are necessary.

Titi Sima—Simosato baseline and Isigaki Sima—Simosato baseline were analyzed by SPORT. The position of Simosato was fixed to the value in Table 4. Adopted Earth orientation parameters are estimated by IRIS (IRIS bulletin A).

4. Titi Sima

4-1. Results by the global analysis

The global analysis of Lageos was carried out for three 5-day-arcs. The analyzed data sets are listed in Table 5 and 6. These data were picked up from full rate data. Since our purpose was to determine the position of Titi Sima, data obtained at Titi Sima and Simosato are enhanced in number of data while data of other stations were reduced. There was a commonly observed pass in data set #

Table 2. Observation passes at Isigaki Sima in 1988
(* : commonly observed with Simosato)

Pass Table of Ajisai(EGS) 8606101

Station ID.	Start yy/mm/dd	Start hh:mm:ss		End yy/mm/dd	End hh:mm:ss	Number of returns
7307	88/07/27	18:09:47	~	88/07/27	18:15:22	71
7307	88/07/29	12:07:06	~	88/07/29	12:16:03	629
* 7307	88/07/31	12:22:21	~	88/07/31	12:28:05	350
* 7307	88/07/31	18:34:54	~	88/07/31	18:46:29	1764
7307	88/08/01	19:43:13	~	88/08/01	19:43:54	38
7307	88/08/02	18:55:55	~	88/08/02	19:00:09	659
* 7307	88/08/04	10:53:34	~	88/08/04	10:54:53	51
7307	88/08/05	16:06:42	~	88/08/05	16:13:36	535
7307	88/08/05	18:07:13	~	88/08/05	18:16:25	548
7307	88/08/10	15:40:43	~	88/08/10	15:51:04	689
7307	88/08/10	17:43:55	~	88/08/10	17:45:23	49
7307	88/08/16	14:19:11	~	88/08/16	14:30:49	757
7307	88/08/16	16:22:03	~	88/08/16	16:29:08	160
* 7307	88/08/17	13:32:21	~	88/08/17	13:35:02	339
7307	88/08/17	15:26:26	~	88/08/17	15:36:41	673
7307	88/08/18	12:34:00	~	88/08/18	12:39:47	158
7307	88/08/18	14:31:18	~	88/08/18	14:44:16	985
7307	88/08/19	13:40:48	~	88/08/19	13:50:19	1249
7307	88/08/21	14:00:37	~	88/08/21	14:01:09	44
7307	88/08/22	10:58:08	~	88/08/22	11:03:12	71
7307	88/08/22	12:57:38	~	88/08/22	13:07:36	1437
7307	88/08/23	12:03:31	~	88/08/23	12:12:42	650
7307	88/08/24	11:09:41	~	88/08/24	11:17:24	474
7307	88/08/24	13:17:34	~	88/08/24	13:23:08	412
* 7307	88/08/25	12:17:15	~	88/08/25	12:29:35	1465
7307	88/08/26	13:25:48	~	88/08/26	13:35:14	1321
7307	88/08/28	11:37:41	~	88/08/28	11:49:19	635
7307	88/09/02	11:10:07	~	88/09/02	11:21:33	1223

Total number of passes : 28
Total number of returns : 17436

2. Simosato data were poor in number of data in data set #2 and #3.

The results are shown in Table 7. The rms residual is 4.8cm and is nearly the noise level. Distribution of residuals is nearly Gaussian. The bottom line of Table 7 shows a weighted mean and a formal error of each component.

It is clear in Table 7 that internal errors of estimated components in respective data sets are smaller than the scatter, which might be caused by some unmodeled errors in force models or in raw range data. Therefore, we introduce system error. Total error can be expressed as follows.

$$(\text{total error})^2 = (\text{formal error})^2 + (\text{system error})^2 \quad \cdots\cdots(1)$$

System error is assumed to be 10cm for rectangular coordinates and 5cm for baseline length, which are half of peak to peak scatter.

The weighted mean of geocentric position of Titi Sima (U_T, V_T, W_T) and distance between Titi Sima and Simosato (D_{TS}) are as follows.

Pass Table of Lageos 7603901

	Station ID.	Start yy/mm/dd	Start hh:mm:ss		End yy/mm/dd	End hh:mm:ss	Number of returns
	7307	88/07/27	16:46:53	~	88/07/27	17:05:29	1032
*	7307	88/07/31	14:47:44	~	88/07/31	15:12:08	1510
*	7307	88/07/31	18:11:35	~	88/07/31	18:20:16	182
	7307	88/08/01	13:32:03	~	88/08/01	13:35:29	57
	7307	88/08/01	17:01:31	~	88/08/01	17:13:30	278
	7307	88/08/02	15:30:26	~	88/08/02	15:54:46	719
	7307	88/08/04	16:09:50	~	88/08/04	16:29:22	404
*	7307	88/08/05	14:50:40	~	88/08/05	15:19:18	664
	7307	88/08/10	15:01:57	~	88/08/10	15:28:00	720
*	7307	88/08/17	12:49:40	~	88/08/17	13:07:34	207
	7307	88/08/19	16:53:18	~	88/08/19	17:09:07	388
*	7307	88/08/22	16:22:44	~	88/08/22	16:47:43	474
	7307	88/08/23	15:20:00	~	88/08/23	15:32:53	154
*	7307	88/08/25	15:45:22	~	88/08/25	16:22:38	280
	7307	88/09/02	15:25:33	~	88/09/02	16:02:29	2212
*	7307	88/09/08	14:17:43	~	88/09/08	14:55:19	2558
	7307	88/09/09	13:14:50	~	88/09/09	13:33:30	1250
	7307	88/09/11	14:14:32	~	88/09/11	14:20:36	105
*	7307	88/09/12	12:24:34	~	88/09/12	12:54:06	673
*	7307	88/09/12	15:56:47	~	88/09/12	16:22:37	24
	7307	88/09/13	14:28:00	~	88/09/13	14:49:35	1755

Total number of passes : 21
Total number of returns : 15646

Pass Table of Starllete 7501001

	Station ID.	Start yy/mm/dd	Start hh:mm:ss		End yy/mm/dd	End hh:mm:ss	Number of returns
	7307	88/08/24	11:43:18	~	88/08/24	11:49:57	137
*	7307	88/09/13	12:54:06	~	88/09/13	13:00:14	379

Total number of passes : 2
Total number of returns : 516

Table 3. Adopted dynamical models

items	references
Astronomical constants	IAU 1976 system
Precession	Lieske, et al. (1977)
Nutation	Wahr (1979)
Definition of UT	Aoki et al. (1982)
Geopotential	Marsh et al. (GEM-T1, 1987)
Earth model	Gilbert and Dziewonski (1066A, 1975)
Solid Earth tide	Shen and Mansinha (1976), Sasao et al. (1977) and Wahr (1979)
Tidal variation of UT1	Yoder et al. (1981)
Atmosphere	exponential model
Radiation pressure	MERIT standards (Melborne et al., 1982)
Satellite constants	ibid.
Ephemerides of the moon and the sun	Japanese ephemeris

Table 4. Adopted station coordinates

Station ID	Station Name		U	V	W
7090	Yarragadee	Australia	-2389.00764894	5043.33189385	-3078.52695084
7109	Quincy	USA	-2517.23605066	-4198.55834275	4076.57178458
7834	Wettzell	FRG	4075.53013450	931.78128422	4801.61842697
7838	Simosato	Japan	-3822.38837195	3699.36349408	3507.57310611
7939	Matera	Italy	4641.96513189	1393.06990688	4133.26238539

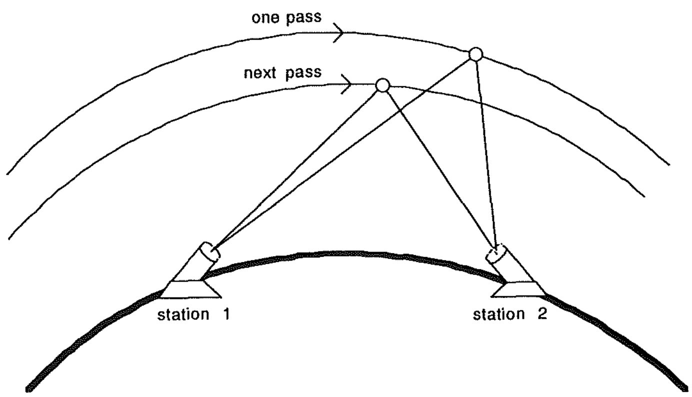

Figure 4. Successive Passes Orbit Revising Technique (SPORT).

$$U_T = -4491072.549\text{m} \pm 0.058\text{m}$$

$$V_T = 3481527.972\text{m} \pm 0.059\text{m} \qquad \cdots\cdots(2)$$

$$W_T = 2887391.714\text{m} \pm 0.059\text{m}$$

$$D_{TS} = 937665.080\text{m} \pm 0.031\text{m}$$

Estimated errors are as much as 6cm. The precision of baseline determination between Simosato and Titi Sima is poor in number of data in data set #3 because of a shortage of Simosato data.

4-2. Results of SPORT

SPORT analysis of Ajisai data was also made for 7 sets of successive passes (Table 8). There was no data set of successive passes of Lageos during Titi Sima observation. Full rate data of Titi Sima and Simosato were used in SPORT.

The results are shown in Table 9. The rms residual is 6.0cm, which is nearly the noise level. Titi Sima data were poor in data set #6, which results in large formal errors. System error of baseline length is assumed to be 2.0cm in SPORT. The weighted mean of U_T, V_T, W_T and D_{TS} estimated by SPORT are as follows.

Table 5. Used SLR station in the global analysis of Titi Sima

Station ID	Station NAME		Pass	Return	Noize ratio
					%
7090	Yarragadee	Australia	11	985	0.2
7105	G.S.F.C.	USA	1	141	0.0
7109	Quincy	USA	12	782	0.6
7110	Mon Peak	USA	12	339	0.6
7122	Mazatlan	Mexico	8	425	0.0
7210	Haleakala	USA	18	533	10.7
7834	Wettzell	FRG	2	25	28.0
7835	Grasse	France	25	1,875	3.3
7838	Simosato	Japan	7	454	2.7
7839	Graz	Austria	2	17	0.0
7840	RGO	UK	27	367	5.4
7844	Titisima	Japan	10	1,615	0.5
7939	Matera	Italy	5	28	32.1
Total			161	7,912	3.7

$$U_T = -4491072.524\text{m} \pm 0.042\text{m}$$

$$V_T = 3481527.841\text{m} \pm 0.042\text{m} \qquad \cdots\cdots\cdots(3)$$

$$W_T = 2887391.771\text{m} \pm 0.042\text{m}$$

$$D_{TS} = 937665.056\text{m} \pm 0.009\text{m}$$

It is noteworthy that repeatability of baseline length is quite good. It was mainly because geometry of sky coverage was fortunately good in most used passes (Fig. 5). Gound tracks of Ajisai were nearly parallel to Titi Sima—Simosato baseline, and the influence of orbital errors to baseline length was small.

Table 6. Analyzed data in Titi Sima analysis (the global analysis, Lageos)

No.	time	Adopted data SHO	Titi	others	total	residuals SHO	Titi	others	total
1	1990 Feb. 1 - 5	236	488	1712	2436	0.071m	0.044m	0.048m	0.049m
2	11 - 15	75	497	1661	2233	73	43	42	43
3	26 - 29	22	622	1980	2624	83	46	52	51

Table 7. Results of Titi Sima analysis (the global analysis, Lageos)

No.	U_T	V_T	W_T	D_{TS}
1	-4491072.548m +/- .010m	3481527.901m +/- .009m	2887391.666m +/- .015m	937665.127m +/- .011m
2	.541 +/- 10	.942 +/- 09	.758 +/- 14	.053 +/- 12
3	.558 +/- 17	8.082 +/- 29	.717 +/- 26	.060 +/- 29
mean	-4491072.549m +/- .058m	3481527.972m +/- .059m	2887391.714m +/- .059m	937665.080m +/- .031m

Table 8. Analyzed data in Titi Sima - Simosato baseline analysis (SPORT, Ajisai)

No.	time	Adopted data SHO	Titi	total	residuals SHO	Titi	total
1	1988 Jan. 24 18h - 21h	1104	890	1994	0.076m	0.043m	0.064m
2	Feb. 4 17 - 19	857	1755	2612	.068	.038	.050
3	5 16 - 18	1528	1181	2709	.076	.036	.062
4	12 13 - 16	634	852	1486	.073	.040	.056
5	14 14 - 16	636	1019	1655	.077	.036	.056
6	22 10 - 13	456	160	616	.078	.035	.069

Table 9. Results of Titi Sima - Simsoato baseline analysis (SPORT, Ajisai)

No.	U_T	V_T	W_T	D_{TS}
1	-4491072.490m +/- .007m	3481527.867m +/- .016m	2887391.742m +/- .014m	937665.044m +/- .007m
2	.586 +/- 15	.942 +/- 24	.798 +/- 15	.058 +/- 06
3	.576 +/- 15	.790 +/- 16	.839 +/- 13	.059 +/- 06
4	.607 +/- 16	.897 +/- 25	.823 +/- 16	.066 +/- 07
5	.417 +/- 23	.819 +/- 19	.676 +/- 17	.047 +/- 07
6	.460 +/- 38	.706 +/- 54	.739 +/- 70	.062 +/- 21
mean	-4491072.524m +/- .042m	3481527.841m +/- .042m	2887391.771m +/- .042m	937665.056m +/- .009m

Table 10. Used SLR station in the global analysis of Isigaki Sima

Station ID	Station NAME		Pass	Return	Noize ratio
					%
7090	Yarragadee	Australia	14	559	0.0
7105	G.S.F.C.	USA	19	799	1.4
7109	Quincy	USA	37	2,314	1.3
7110	Mon Peak	USA	25	1,148	10.5
7210	Haleakala	USA	21	607	19.5
7307	Isigaki	Japan	18	2,790	3.1
7834	Wettzell	FRG	14	281	12.7
7835	Grasse	France	61	3,824	2.2
7838	Simosato	Japan	10	2,104	15.4
7839	Graz	Austria	16	206	0.6
7840	RGO	UK	41	339	5.6
7907	Arequipa	Peru	22	72	38.9
7939	Matera	Italy	33	72	44.3
Total			331	15,115	6.1

5. Isigaki Sima

5-1. Results by the global analysis

The global analysis of Lageos data was carried out for five 5-day-arcs. The analyzed data sets are listed in Table 10 and 11. The strategy of data selection was the same as Titi Sima analysis. Simosato data were poor in data set #3.

The results are shown in Table 12. The rms residual is 5.4cm. System error is the same as section 4-1. The weighted mean of geocentric position of Isigaki Sima (U_I, V_I, W_I) and distance between Isigaki Sima and Simosato (D_{IS}) are as follows.

$$U_I = -3265753.894\text{m} \pm 0.050\text{m}$$

$$V_I = 4810001.007\text{m} \pm 0.050\text{m} \qquad \cdots\cdots(4)$$

$$W_I = 2614265.506\text{m} \pm 0.050\text{m}$$

$$D_{IS} = 1530149.045\text{m} \pm 0.026\text{m}$$

Data set #5 is omitted because there might be biases in SLR data at Isigaki Sima during this

Table 11. Analyzed data in Isigaki Sima analysis (the global analysis, Lageos)

No.	time	Adopted data SHO	Isigaki	others	total	residuals SHO	Isigaki	others	total
1	1990 Jul. 27 - 31	531	543	1761	2835	0.091m	0.045m	0.069m	0.068m
2	Aug. 1 - 5	241	526	1895	2662	.071	.045	.044	.046
3	17 - 21	67	587	2689	3343	.062	.040	.039	.040
4	22 - 26	460	544	1792	2796	.073	.041	.048	.051
5	Sep. 8 - 12	480	575	1620	2675	.091	.045	.061	.063

Table 12. Results of Isigaki Sima analysis (the global analysis, Lageos)

No.	U_I	V_I	W_I	D_{IS}
1	-3265753.827m +/- .012m	4810000.942m +/- .011m	2614265.510m +/- .010m	1530149.019m +/- .013m
2	.879 +/- .012	1.045 +/- .008	.445 +/- .009	.113 +/- 09
3	.972 +/- .010	1.094 +/- .011	.637 +/- .008	.002 +/- 12
4	.898 +/- .015	0.948 +/- .007	.432 +/- .006	.043 +/- .008
5	.930 +/- .012	0.792 +/- .007	.581 +/- .011	8.844 +/- .011
mean	-3265753.894m +/- .050m	4810001.007m +/- .050m	2614265.506m +/- .050m	1530149.045m +/- .026m

* : Data set #5 is excluded.

Table 13. Analyzed data in Isigaki Sima - Simosato baseline analysis (SPORT, Lageos)

No.	time	Adopted data SHO	Isigaki	total	residuals SHO	Isigaki	total
1	1990 Jul. 31 14ʰ - 18ʰ	471	1688	2159	0.065m	0.040m	0.047m
2	Sep. 12 12 - 16	903	694	1597	.100	.056	.084

Table 14. Results of Isigaki Sima - Simsoato baseline analysis (SPORT, Lageos)

No.	U_I	V_I	W_I	D_{IS}
1	-3265753.813m +/- .076m	4810000.907m +/- .029m	2614265.447m +/- .053m	1530149.035m +/- .018m
2	.941 +/- 127	.792 +/- 79	.562 +/- 109	8.838 +/- 41
mean	-3265753.813m +/- .126m	4810000.907m +/- .104m	2614265.447m +/- .113m	1530149.035m +/- .027m

* : Data set #2 id excluded.

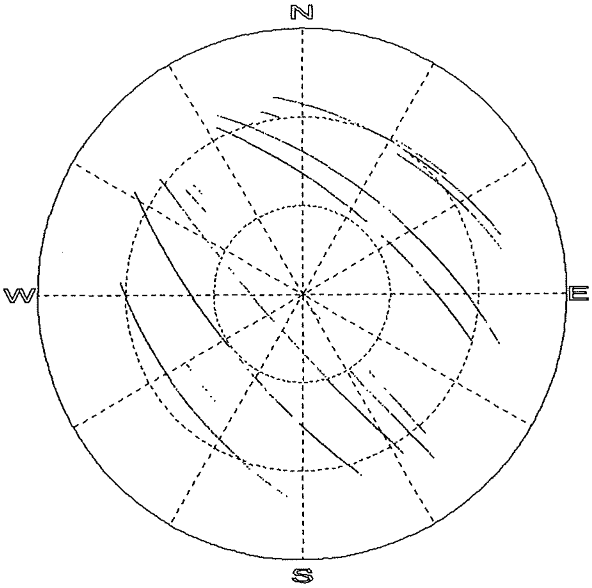

Figure 5. Sky coverage of analyzed of passes at Titi Sima (SPORT).

period (see next section).

SPORT analysis of Lageos data was also made for 3 sets of successive passes (Table 13). There was no data set of successive passes of Ajisai. Full rate data of Isigaki Sima and Simosato were used in the analysis.

The results are shown in Table 14. The rms residual is 6.6cm. U_I, V_I, W_I and D_{IS} estimated by SPORT are as follows.

$$U_I = -3265753.813\text{m} \pm 0.126\text{m}$$

$$V_I = 4810000.907\text{m} \pm 0.104\text{m} \qquad \cdots\cdots\cdots(5)$$

$$W_I = 2614265.447\text{m} \pm 0.113\text{m}$$

$$D_{IS} = 1530149.035\text{m} \pm 0.027\text{m}$$

Data set #2 is omitted because residuals are significantly larger than the noise level. There might be a time bias or a clock offset in Isigaki data in data set #2. Data set #2 is a subset of data set #5 in the previous section. A formal error of each component is much larger than the previous section because of the pass geometry.

6. Conclusions

The baseline length between Titi Sima and Simosato are determined precisely by SPORT. It is because SPORT is a semi-geometrical methed and the influence of orbital errors to baseline length is generally small. SPORT is effective for determination of baselines of a few thousand kilomerters of less. SPORT can be applied to Lageos, Ajisai and other satellites. Unfortunately, since there were not enough commonly observed passes at Isigaki Sima and Simosato, the baseline length between Isigaki Sima and Simosato determined by SPORT is not reliable.

The precision of rectangular coordinates of Titi Sima and Isigaki Sima determined by the global analysis is about 5cm.

Geocentric rectangular coordinates seem to be better determined by the global analysis of Lageos. One reason is that the effect of gravity model errors on Lageos orbit is smaller than Ajisai. Another reason is that the global analysis does not suffer from any difference of reference frames. In SPORT, EOPs are fixed, and inconsistency of reference frames might cause a systematic error in 3-D position of an unknown station.

The difference between the results of the global analysis and SPORT is several centimeters. The reason why such difference exists is a problem to be solved.

Recently, many new Earth's gravity models, such as GEM—T2 (Marsh et al., 1989) or GRIM—S1 (Reigber, 1990), have been developed for altimeter satellites which will be launched in the early 1990's. Adopting these new models, we will be able to analyze global data of Ajisai in the near future.

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衛星レーザー測距による父島・石垣島の精密位置の決定（要旨）

仙 石 新

人工衛星レーザー測距観測が、1988年に父島と石垣島において行われ、解析を行なった結果両島の位置が精密に求まった。５日毎のラジオスの全世界データを用いたグローバル解析と、下里と父島（石垣島）の連続した同時観測パスのみを用いた短アーク解析（SPORT法）を行った結果、両島の位置が三次元的に約５cmの精度で求められた。父島一下里基線は、SPORT法により精度９mmで決定された。