SATELLITE LASER RANGING OBSERVATIONS IN 1996

Summary - Satellite laser ranging observations have been continued by a fixed type satellite laser ranging station at the Simosato Hydrographic Observatory (JHDLRS-1) and by a transportable one (HTLRS) . The total numbers of returns obtained by the JHDLRS-1 in 1996 are 107,922 from 89 passes of Lageos-I, 145,391 from 107 passes of Lageos-II, 33,524 from 53 passes of Starlette, 253,724 from 250 passes of Ajisai, 15,457 from 35 passes of ERS-1(European Remote Sensing Satellite-1) 34,949 from 62 passes of ERS-2, 66,853 from 69 passes of TOPEX/POSEIDON, 24,757 from 49 passes of Stella, 4,824 from 7 passes of Etalon-2, 1,561 from 11 passes of GFZ-1, 8,045 from 19 passes of ADEOS, and 82 from 1 pass of GPS-36, respectively. Those obtained by the HTLRS at Tyosi in 1996 are 37,683 from 64 passes of Ajisai, 439 from 8 passes of Lageos-I, 2,258 from 18 passes of Lageos-II, 902 from 8 passes of Starlette, 70 from 1 pass of Stella, 2,607 from 4 passes of TOPEX/POSEIDON, and at Titi Sima in 1996 are 12,234 from 35 passes of Ajisai, 1,050 from 12 passes of Lageos-I, 5,851 from 26 passes of Lageos-II, 743 from 3 passes of Starlette, 177 from 2 passes of Starlette, 6,346 from 10 passes of TOPEX/POSEIDON, respectively.

Key words: satellite laser ranging(SLR) - global geodesy - Lageos-I - Lageos-II - Starlette - Ajisai - ERS-1- ERS-2 - TOPEX/POSEIDON - Stella - Etalon-2 - GFZ-1 - ADEOS - GPS-36 - JHDLRS-1 - HTLRS.

This is a report of the satellite laser ranging (SLR) observations made at the Simosato Hydrographic Observatory by a fixed type satellite laser ranging station called JHDLRS-1 (Sasaki et al., 1983) and by a transportable one called HTLRS (Sasaki, 1988). This report contains the lists of data obtained at these stations in 1996.

Previous data obtained by the JHDLRS-1 appear in the Series of Astronomy and Geodesy, Data Report of Hydrographic Observations for the period from 1982 to 1985, and in the Series of Satellite Geodesy from 1986 to 1995; those obtained by the HTLRS appear in the Data Report of Hydrographic Observation, Series of Satellite Geodesy, No. 3 - 10.

1. Observation

The routine ranging observation for Lageos-I, Starlette, and Beacon (BE)-C started in April 1982 by the JHDLRS-1 under the mutual cooperation between the Hydrographic Department of Japan (JHD) and the National Aeronautics and Space Administration (NASA) of the United States of America. In August 1986, the Japanese first Geodetic Satellite "Ajisai" was launched and its tracking observation by the JHDLRS-1 started. The observation of BE-C was terminated in July 1986. Thereafter, 12 satellites were added in the routine observation after their launches: "ERS-1" in July 1991, "TOPEX/POSEIDON" in August 1992, "Lageos-II" in October 1992, "Stella" in September 1993, "Etalon-1","Etalon-2" in November 1994 ,"ERS-2" in May 1995, "GFZ-1" in June 1995, "GPS-35","GPS-36" in August 1995, and "ADEOS" in October 1996.

The range observation for Lageos-I, Starlette and Ajisai, by the HTLRS started in December 1987 in a campaign style. Lageos-II, ERS-1, TOPEX/POSEIDON and Stella have been also observed by the HTLRS. The range observations by the HTLRS at off-lying islands and at some coastal areas have been carried out as follows.

Jan. - Mar. 1988	:	Titi Sima
Jul. - Sep. 1988	:	Isigaki Sima
Jan. - Mar. 1989	:	Minamitori Sima
Jul. - Sep. 1989	:	Okinawa Sima
Oct. - Nov. 1989	:	Tusima
Sep. - Oct. 1990	:	Oki Shoto
Dec. 1990 - Feb. 1991	:	Minami-Daito Sima
Aug. - Nov. 1991	:	Tokati
Jan. - Mar. 1992	:	Iwo Sima
Aug. - Oct. 1992	:	Wakkanai
Jan. - Mar. 1993	:	Hatizyo Sima
Jan. - Mar. 1994	:	Makurasaki
Jul. - Oct. 1994	:	Oga
Feb. - Mar. 1995	:	Bisei
Jul. - Aug. 1995	:	Bisei
Jan. - Mar. 1996	:	Tyosi
Sep. - Dec. 1996	:	Titi Sima

The major specifications of the JHDLRS-1 and the HTLRS are listed in Table 1 and Table 2 (Sasaki et al., 1983, Sasaki, 1988). The locations of the systems and fiducial stone markers set up near the systems are shown in Table 3 (Takemura, 1983), Table 4 and Table 5.

The observation schedule of the JHDLRS-1 was made by selecting passes whose maximum elevation were over 30 degrees for Starlette, Ajisai, ERS-1, ERS-2, TOPEX/POSEIDON, Stella, Etalon-1, Etalon-2, GFZ-1, ADEOS, GPS-35, GPS-36, and over 30 degrees in the nighttime and 35 degrees in the daytime for Lageos-I and Lageos-II. The observation schedule of the HTLRS was made by selecting passes whose maximum elevations were over 20 degrees only in the nighttime. When the HTLRS was in operation, the same criterion was applied to the JHDLRS-1. Routine observation was not carried out on Saturday and Sunday. The priority of the selection for simultaneous transits was in the order of Ajisai, Lageos, ERS, TOPEX/POSEIDON, Starlette, Stella, GFZ-1, Etalon, and GPS.

IRV orbital elements of the satellites obtained from the Goddard Space Flight Center(GSFC) of NASA via ftp were used for scheduling and tracking. The tracking was carried out when the elevation of satellites was above 20 degrees. The temperature, atmospheric pressure and relative humidity were measured once in a pass. Before and after ranging satellites, the ranging calibrations were made by using a ground target.

In order to improve ranging precision, the JHDLRS-1 has been upgraded several times. A Micro-Channel-Plate photomultiplier was introduced in the JHDLRS-1 in January 1985. A GPS clock was introduced into the JHDLRS-1 in December 1988 to monitor and correct the atomic clock used in the system, and it has been in operation since April 1989. A GPS clock has been also used in the HTLRS. A laser subsystem of the JHDLRS-1 was upgraded to a Quantel YAG 460-5 at the beginning of June 1990. Receiving electronics was also upgraded and RMS was improved in December 1993.

The total numbers of returns and passes obtained by the JHDLRS-1 at Simosato and by the HTLRS at Tyosi and Titi Sima in 1996 are listed in Table 6, Table 7 and Table 8.

2. Polynomial fitting and preliminary analysis of range data

False range data were removed by a visual rejection system. The system works on CRT screens by applying a filter of polynomial fitting to measured range itself by use of the on-site computer. Preliminary values of standard deviation for each pass were estimated in this process.

A part of obtained data, named quick-look (QL) data, were sent to the GSFC from Simosato within one day through INTERNET. QL data of TOPEX/POSEIDON was sent to the GSFC from Simosato within 8 hours through INTERNET. QL data of ERS-1, ERS-2, and GFZ-1 were also sent to the Deutsches Geodatisches Forschungsinstitut (DGFI) within one day through INTERNET. All the range data, after application of the correction of the internal time delay of the SLR systems obtained by the ground target ranging, named full-rate (FR) data, were recorded on a hard disk in MERIT-II Format (CSTG, 1987) together with the satellite ID, the station ID, the transmitted time corrected into UTC (USNO MC), the meteorological data, the preliminary measurement standard deviation and some preprocessing indications. All the FR data were sent to the GSFC.

The weighted mean range precisions estimated by using the polynomial fitting for all the data obtained by the JHDLRS-1 in 1996 are 5.2cm for Lageos-I, 5.4cm for Lageos-II, 3.8cm for Starlette, 4.7cm for Ajisai,4.0cm for ERS-1, 4.3cm for ERS-2, 4.0cm for TOPEX/POSEIDON, 3.9cm for Stella, 9.7cm for Etalon-2, and 5.0cm for GFZ-1, 2.7cm for ADEOS, 9.4cm for GPS-36 respectively, as shown in Table 6. The same for the HTLRS at Tyosi are 5.7cm for Ajisai, 8.8 cm for Lageos-I, 5.5cm for Lageos-II, 14.5cm for Starlette, 3.4cm for Stella, 4.8cm for TOPEX/POSEIDON, as shown in Table 7, and at Titi Sima are 4.6cm for Ajisai, 5.5cm for Lageos-I, 4.1cm for Lageos-II, 3.9cm for Starlette, 2.9cm for Stella, 4.2cm for TOPEX/POSEIDON, respectively, as shown in Table8.

The QL data sent to the GSFC were used to update orbital elements. These data were transferred from the GSFC to the Center for Space Research(CSR) of the University of Texas at Austin and were used for the estimation of the polar motion and the variation of the angular velocity of the earth rotation by processing with the SLR data from other sites in the world. All the FR data were also analyzed in the CSR and other SLR analysis centers, and more precise values for the earth rotation parameters have been estimated. The FR data sent to the GSFC were used to detect crustal movements and global plate motions.

The JHD has been processing FR data obtained at Simosato and other SLR sites by using an original orbital processor (Sasaki, 1984) and GEODYN-II/SOLVE made NASA(Eddy et al., 1990). A result of the geodetic coordinates for the cross point of azimuth and elevation axes of the JHDLRS-1, obtained as the Marine Geodetic Result (Tatsuno and Fujita, 1994), is 33° 34' 39."700N, 135° 56' 13."337E, 101.62 m for latitude, longitude and height above the reference ellipsoid of 6378137m semi-major axis and 1/298.257 flattening, respectively.

The observations of satellite laser ranging were made by K. Muneda, M. Suzuki, Y. Takanasi, Y. Narita, H. Fukura, N. Koshin, E. Kurihara and M. Takahashi of the Simosato Hydrographic Observatory and K. Matsumoto, K. Terai, Y. Watanabe, S. Toyama, K. Sawada, H. Noda, H. Fukura, Y. Sumiya and H. Watanabe of the JHD Headquarters.

Calculations and compilation for this report have been made by K. Terai, M. Fujita, H. Matsushita and H. Watanabe of the JHD Headquarters, and K. Muneda and Y. Narita of the Simosato Hydrographic Observatory.

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Table 1. Principal Specifications of Satellite Laser Ranging Station of the Simosato Hydrographic Observatory (JHDLRS-1)

Subsystem	Specification
Mount configuration	Elevation over azimuth/Coude path
Angular resolution	20bits (1.2 arcsec)
Transmitter diameter	17 cm
Receiver diameter	60 cm
Laser wave length	532 nm
Output energy	125 mJ
Laser pulse width	100 ps
Repetition rate	4 pps
Receiver detector	Micro-Channel-Plate PMT
Flight time counter	20 ps resolution
Frequency standard	Rubidium oscillator
Time comparison	GPS (TrueTime, XL-DC602)
Computer	32-bits personal computer with hard disks, 3.5inch floppy disk drive, printer, CRTs and a TA

Table 2. Principal Specifications of the Hydrographic Department Transportable Satellite Laser Ranging Station (HTLRS)

Subsystem	Specification
Mount configuration	Elevation over azimuth/Coude path
Angular resolution	20bits (1.2 arcsec)
Transmitter diameter	10 cm
Receiver diameter	35 cm
Laser wave length	532 nm
Output energy	50 mJ
Laser pulse width	50 - 100 ps
Repetition rate	5 pps
Receiver detector	Micro-Channel-Plate PMT
Flight time counter	20 ps resolution
Frequency standard	Cesium oscillator
Time comparison	GPS (MAGNAVOX, MX4200)
Computer	16 - bits personal computers with hard disks 3.5 inch floppy disk drive, printer, CRTs and a modem

Table 3. Geodetic coordinates of JHDLRS-1

Location	Site ID	Coordinates (Tokyo Datum)		
		°	′	″
Cross point of Az. and El. axes of JHDLRS-1	International 7838 Domestic SHO-L	33 135	34 56	27.496N 23.537E 62.44m
The fiducial stone marker at the Simosato Hydrographic Observatory	Domestic SHO-H0	33 135	34 56	28.078N 23.236E 58.36m

Table 4. Geodetic coordinates of HTLRS

Location	Site ID	Coordinates (Tokyo Datum)		
		°	′	″
Cross point of Az. and El. axes of HTLRS at Tyosi	International 7322	35 140	42 51	04.463N 19.708E 53.85 m

Table 5. Geodetic coordinates of HTLRS

Location	Site ID	Coordinates (Tokyo Datum)		
		°	′	″
Cross point of Az. and El. axes of HTLRS at Titi Sima	International 7844	27 142	5 13	15.363N 11.500E 212.85 m

Table 6. Data acquisition at the Simosato Hydrographic Observatory in 1996

Satellite	No. of ranges	No. of passes	RMS
Lageos-I	107,922	89	5.2 cm
Lageos-II	145,391	107	5.4
Starlette	33,524	53	3.8
Ajisai	253,724	250	4.7
ERS-1	15,457	35	4.0
ERS-2	34,949	62	4.3
TOPEX/POSEIDON	66,853	69	4.0
Stella	24,757	49	3.9
Etalon-2	4,824	7	9.7
GFZ-1	1,561	11	5.0
ADEOS	8,045	19	2.7
GPS-36	82	1	9.4

Observers : K. Muneda, Y. Takanashi, Y. Narita, N. Koshin, H. Fukura, M. Takahashi, E. Kurihara, M. Suzuki*, M. Matsushita*, Y. Sumiya*.

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Table 7. Data acquisition at Tyosi in 1996

Satellite	No. of ranges	No. of passes	RMS
Ajisai	37,683	64	5.7 cm
Lageos-I	439	8	8.8
Lageos-II	2,258	18	5.5
Starlette	902	8	14.5
Stella	70	1	3.4
TOPEX/POSEIDON	2,607	4	4.8

Observers : K. Matsumoto, K. Terai, Y. Watanabe, K. Sawada, H. Noda, H. Watanabe, Y. Narita*, M. Takahasi*.

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Table 8. Data acquisition at Titi Sima in 1996

Satellite	No. of ranges	No. of passes	RMS
Ajisai	12,234	35	4.6 cm
Lageos-I	1,050	12	5.5
Lageos-II	5,851	26	4.1
Starlette	743	3	3.9
Stella	177	2	2.9
TOPEX/POSEIDON	6,346	10	4.2

Observers : K. Matsumoto, K. Terai, S. Toyama, H. Fukura, Y. Sumiya, H. Watanabe, Y. Narita*, N. Koshin*.

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