7.3 GLOBAL STATION COORDINATES DERIVED FROM SLR AND VLBI OBSERVATIONS

By

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Running Title: Station coordinates: SLR and VLBI

ABSTRACT

The Keystone network developed around the Tokyo metropolitan area consists of four stations each of which deploys VLBI and SLR observation systems. The VLBI systems have been operational for three years, whereas the SLR systems are in the engineering test stage and have only produced a small amount of preliminary range data. Using the SLR data obtained between February and May, 1998, the station coordinates were firstly solved by our orbit analysis software, CONCERTO, and then compared with the VLBI results.

The positions of four VLBI antennas were determined using the 34 m VLBI antenna at Kashima whose coordinates are listed in the ITRF96. Those of four SLR stations were estimated by orbit analysis, fixing the coordinates of other global stations to the ITRF96. After the correction of local ties, the global station coordinates from the two space geodetic techniques were compared; there were less than 15 mm difference in the vertical components and less than 50 mm difference in the horizontal components.

Keywords: Collocation, Very Long Baseline Interferometry, Satellite Laser Ranging, Terrestrial Reference Frame

1 Introduction

The improvements in a space geodetic technique have made it possible to form the global reference frame. The improvement also means that the coordinates of “good” stations on which plenty of high quality data is available can be stabilized to within a few millimeters. However, if one wants to unite all of the individual terrestrial reference frames, the only solution is to put "collocation" sites on Earth where the multiple reference points from some different geodetic techniques are placed close together and their positions are precisely tied by local surveys. An example of a united reference frame is the IERS Terrestrial Reference Frame (ITRF)[1] being updated every one or two years.

In the Keystone project, all of the four sites have the VLBI (Very Long Baseline Interferometry) system, the GPS (Global Positioning System) system and the SLR (Satellite Laser Ranging) system. They can, therefore, be used as the collocation sites. There already exist tens of collocation sites with VLBI+GPS or SLR+GPS combinations around the world, but there are not so many sites with VLBI+SLR+GPS that are expected to provide the more permanent and strong collocation place. The emergence of precise collocation sites in Asia will contribute to the uniform site distribution on Earth.

The station identification numbers of CRL geodetic sites are listed in Table 1. The CDP numbers were assigned by the Crustal Dynamics Project at the National Aeronautics and Space Administration, USA, and the DOMES numbers were assigned by the International Earth Rotation Service at the Institut Géographique National, France.

2 Determination of the global coordinates

2.1 VLBI

The position and velocity of Keystone VLBI antennas are determined through their experiments using the Kashima 34-meter antenna whose coordinates are listed in the ITRF96.[1] The solutions are described in this issue.[2]

2.2 SLR

From February 16 to May 22, 1998, the four Keystone systems were operational and obtained the range data from Lageos-1 and Lageos-2 satellites. The number of observations during the 96 days was 54 passes (567 normal points) at Koganei, 27 passes (227 normal points) at Kashima, 38 passes (202 normal points) at Miura, and 23 passes (157 normal points) at Tateyama. Possibly because of an insufficient optical link, the number of normal points per pass was generally lower than other global stations.

Although this data was for preliminary engineering use and the quality and quantity were limited, we applied the global analysis(3) to it using the orbit analysis software CONCERTO.(4)(5) In this study, only the Keystone station coordinates were solved without a velocity adjustment, whereas those of other stations were fixed to the ITRF96. Range bias was estimated for all the stations. The initial state of the satellite orbit, that is, six elements and some force coefficients, was solved for every two days.

Most of post-fit residuals of the Keystone data converged well to around 1.5 cm rms, but only those of Kashima did not go below 2.5 cm rms. This is why Kashima station obtained most of the range data in the first one month when the SLR system was not mature.

Another analysis option, the short-arc analysis,(3) can not be applied to this data set because of the lack of the co-observed passes.

3 Collocation

3.1 Local survey

The positions of tens of the geodetic points in and around each Keystone site were precisely surveyed at the end of 1997. The surveyed points include the telescope reference points of the VLBI and the SLR systems. The reference point (origin) of the radio/optical telescope is defined at the intersection of the azimuth axis and the elevation axis, and its local position should not change for any telescope direction. Therefore, the telescope reference points were identified by searching the invariant point, through the repeated surveys for various telescope directions. The local vector from the VLBI antenna origin to the SLR telescope origin is shown in Table 2 for all the four sites in the WGS84 coordinates. As long as the local relative coordinates are within a hundred meters of each other, the discrepancy between the WGS84 reference frame and the ITRF96 reference frame can be ignored. Hence, we used these values for the local tie described in the next subsection. The table also gives the local vector from the marker to the SLR telescope origin, since we defined the primary reference point for the SLR as one of the short pillar's targets (markers).[6]

3.2 Results and discussions

The station coordinates in the ITRF96 individually derived from VLBI and SLR observations are listed in Table 3. After the correction of the local tie, the estimated VLBI and SLR coordinates were three-dimensionally compared in Fig. 1. The VLBI coordinates were defined as of April 5, 1998, the middle of the SLR analysis period. The center marks represent the VLBI antennas, and the marks with error ellipses (1-sigma) represent the SLR telescope origin. The discrepancy was within 5 cm of each other in the horizontal components and within 1.5 cm in the vertical components, though the 5 cm deviation in latitude of Kashima is considered to be caused by its lower quality of SLR data during the observation period. The consistency between vertical components indicates that the Keystone SLR system has offset biases of no more than a few centimeters.

In this way, the two totally different techniques, VLBI and SLR, showed that the three-dimensional coordinates were consistent to within several centimeters at the Keystone sites. The number of the “good” worldwide collocation sites have helped the different terrestrial reference frames to be consistent with each other.

Note that amount of the Keystone SLR data is still not sufficient, compared with the international recommendation that requires an SLR station to obtain more than 400 Lageos passes per year. Other error factors such as the ground survey and the VLBI observation should also be checked throughout the repeated operations. As firstly pointed out, the collocation sites are not uniformly distributed on the Earth, and the lack of stable collocation sites around Eastern Asia might be one of the reasons of the discrepancy between the reference frames derived from the different geodetic techniques.

4 Conclusions

The station coordinates of the Keystone VLBI were redefined in the ITRF96, and those of the Keystone SLR were also solved in the ITRF96 using the engineering range data. With the local survey results, the coordinates of VLBI and SLR at four sites agreed within 5 cm in the horizontal components and within 1.5 cm in the vertical components.

It will help considerably to establish a globally consistent terrestrial reference frame to put the Keystone sites in Eastern Asia where the precisely collocated geodetic points are sparse. In the future, we plan to add the station coordinates derived from the GPS observations, which can be defined with respect to the densely placed GPS observatories in Japan.

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References

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Table/Figure captions:

Table 1

The CDP numbers and DOMES numbers assigned for the CRL sites.

Table 2

The local vectors in the WGS84 according to the ground survey (unit:meters). "VLBI -> SLR" is a vector from the VLBI antenna origin and the SLR telescope origin, and "SLR(Marker) -> SLR" is a vector from the SLR marker to the SLR telescope origin.

Table 3

The ITRF96 station coordinates of the telescope invariant points.

Fig. 1

Comparison of station coordinates for four Keystone sites (VLBI = the center "+" marks, and SLR = the "+" marks with error ellipses).

Site name	DOMES number	CDP number	Designation
Kashima	21701M001		Metal station mark (Denken 1)
	21701M002	7335	Geodetic ground marker for SLR
	21701S001	1856	26m VLBI antenna (GSI)
	21701S004	1857	34m VLBI antenna
	21701S006	7334	11m VLBI antenna
	21701S007		GPS antenna
Koganei	21704M001	7328	Geodetic ground marker for SLR
	21704S001	7308	1.5m SLR telescope (CRLLAS)
	21704S004	7327	11m VLBI antenna
	21704S005		GPS antenna
Miura	21739M001	7337	Geodetic ground marker for SLR
	21739S001	7336	11m VLBI antenna
	21739S002		GPS antenna
Tateyama	21740M001	7339	Geodetic ground marker for SLR
	21740S001	7338	11m VLBI antenna
	21740S002		GPS antenna

Table 1

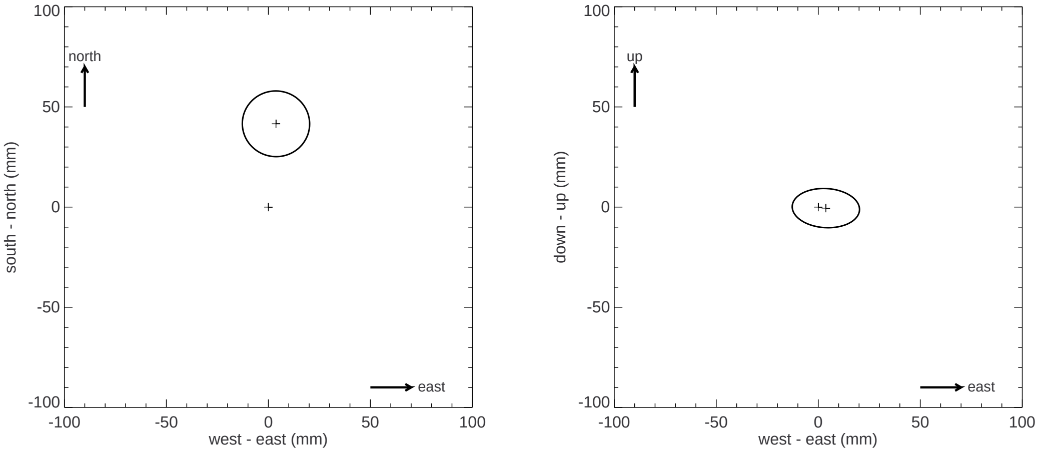
Site name	Relative vector	x	y	z
Kashima	VLBI -> SLR	22.1323	- 34.1682	66.6215
	SLR (Marker) -> SLR	0.7990	- 2.6351	10.7180
Koganei	VLBI -> SLR	- 24.0272	- 2.3899	- 26.6077
	SLR (Marker) -> SLR	- 20.2026	- 21.0036	13.0071
Mura	VLBI -> SLR	- 41.9379	13.8388	- 61.8711
	SLR (Marker) -> SLR	- 10.1841	- 8.6810	4.6824
Tateyama	VLBI -> SLR	18.6120	32.9878	- 13.6636
	SLR (Marker) -> SLR	- 9.5928	- 1.4964	- 1.3261

Table 2

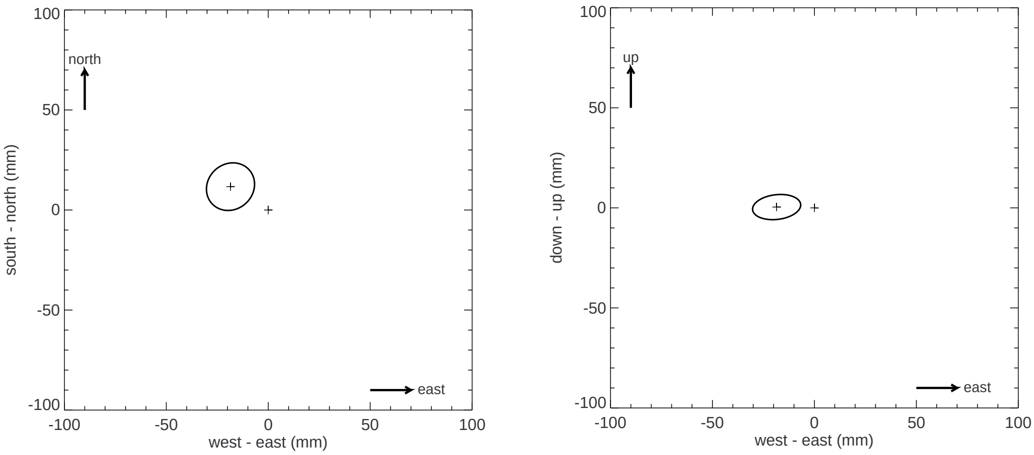
Site name	Point	Position (m) (epoch: 1997.0)			Velocity (mm/year)		
		x	y	z	x	y	z
Kashima	VLBI	-3997505.658	3276878.393	3724240.695	-1.30	2.40	-12.90
	SLR	-3997483.510	3276844.209	3724307.332	-	-	-
Koganei	VLBI	-3941937.433	3368150.896	3702235.287	-2.79	2.01	-7.83
	SLR	-3941961.446	3368148.518	3702208.678	-	-	-
Miura	VLBI	-3976129.956	3377927.877	3656753.837	12.43	-1.17	-5.18
	SLR	-3976171.867	3377941.696	3656691.995	-	-	-
Tateyama	VLBI	-4000983.402	3375275.950	3632213.183	11.32	-0.03	-0.06
	SLR	-4000964.777	3375308.947	3632199.533	-	-	-

Table 3

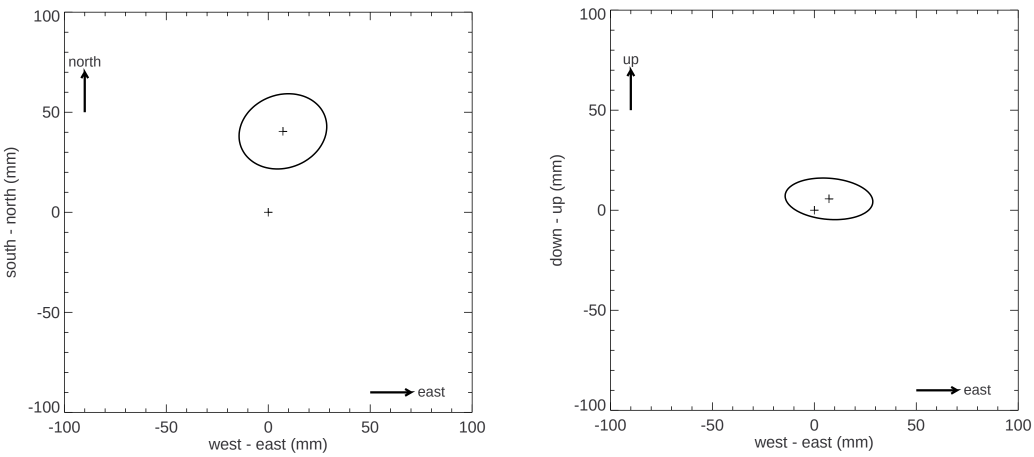
Kashima



Koganei



Miura



Tateyama