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Satellite Laser Ranging at the Shimosato Hydrographic Observatory

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Abstract. *The Shimosato Hydrographic Observatory, central Japan, has been carrying out Satellite Laser Ranging observation since 1982. More than 33,000 passes have been obtained as of September 30, 2013. From SLR observations, we determined the transformation parameters from the Tokyo Datum to the world geodetic system. Furthermore, we revealed the intraplate deformation caused by the subduction of the Philippine Sea Plate off Shimosato in the interseismic phase and the coseismic crustal movements associated with the 2004 off the Kii Peninsula earthquake (Mw 7.5) and the 2011 off Tohoku earthquake (Mw 9.0).*

1. Introduction

The Shimosato Hydrographic Observatory (SHO, Figure 1, 2) in Wakayama Prefecture, central Japan, has been carrying out Satellite Laser Ranging (SLR) observation for AJISAI, LAGEOS-1, LAGEOS-2 and other geodetic and earth observation satellites since 1982. The primary purpose is to establish marine geodetic control network in Japanese islands for precise nautical charts.

Before SLR observation, astronomical observations were used to determine the positions of Japanese islands and the local geodetic datum named the Tokyo Datum was established. However, it was known that the Tokyo datum deviated from the worldwide geodetic systems due to the deflection of the vertical line in Tokyo. SLR observation enabled us to determine the precise position of Japan on worldwide geodetic systems such as ITRF. Based on this, we determined the transformation parameters from the Tokyo Datum to the world geodetic system. In addition, we have detected crustal movements at Simosato, such as the intraplate deformation caused by the subduction of the Philippine Sea Plate off Shimosato in the interseismic phase and the coseismic crustal movements associated with the 2004 off the Kii Peninsula earthquake (Mw 7.5) and the 2011 off Tohoku earthquake (Mw 9.0).

In this poster, we summarize the SLR observation at Simosato over 30 years.

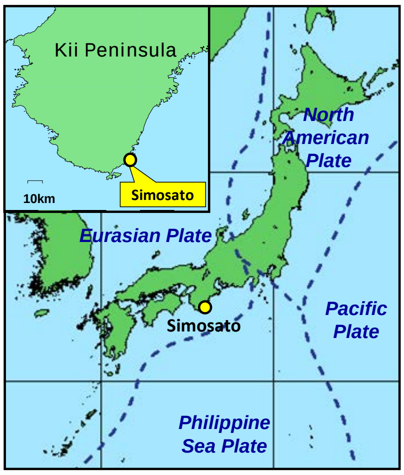

Figure 1. Location of Simosato station

Figure 2. Shimosato Hydrographic Observatory

2. History of the Shimosato Hydrographic Observatory and SLR observations

In 1954, the SHO was originally established to start geomagnetic observation for nautical charts. In 1959, astronomical observation, mainly lunar occultation, was started. In 1978, geomagnetic observation was transferred to Hachijo-jima island, located about 300 km south of Tokyo, due to the opening of the electrical trains near the observatory.

In 1982, SLR observation was started at the SHO. In addition, from 1987 to 2001, we conducted campaign SLR observations with a transportable SLR system at 15 sites in off-lying islands and coastal areas of Japan to determine baseline vectors between those sites and Simosato. In 2007, the laser unit was broken down due to aging. So, we wholly replaced our observation system from 2007 to 2009. We have been carrying out SLR observation with the new system since December 2009.

As of September 30, 2013, 33,571 passes have been obtained at Simosato (Figure 3). We have obtained more than 1,500 passes per year mainly for AJISAI, LAGEOS-1, LAGEOS-2 and have met the ILRS standards since 2000 except the replacement period.

The monthly average of Ajisai normal point rms values are shown in Figure 4. The fiture indicates that the observation accuracy at Simosato have been gradually improved and is about 1 cm at present.

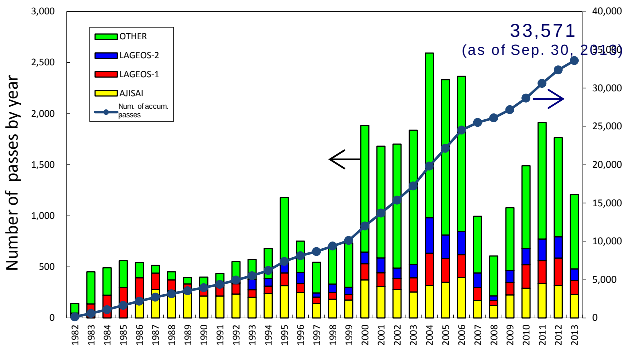

Figure 3. Numbers of passes obtained at Simosato station from 1982-2013.

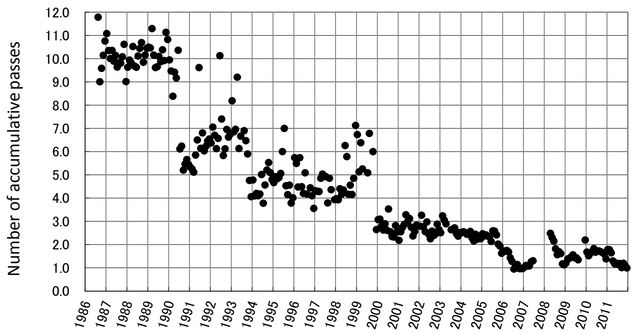

Figure 4. Monthly average of Ajisai normal points rms from 1986 to 2011.

3. SLR system

The specifications of our observation system are shown in Table 1. Due to aging, the SLR observation equipment except the mount of the telescope was replaced from 2007 to 2009 (Suzuki et al., 2010).

Table 1. Specifications of SLR systems at Simosato station

		Old system (1982-2007)	New system (Dec. 2009-)
Laser	Wave length	532nm	
	Pulse width	＜100ps	＜20ps
	Output energy (per pulse)	120mJ	60mJ
	Repetition rate	4Hz	5Hz
Telescope	Optical type	Cassegrain	Nathmyth
	Transmitter/Receiver diameter	Transmitter：17cm Receiver：60cm	75cm (common use)

Receiver	PMT at the back of telescope	PMT in the observation room
Flight time counter	Time interval counter （resolution：4ps）	Event timer （resolution：1ps）
Time control	GPS and cesium oscillator	

4. Major results

4.1. Transition from the Tokyo Datum to the World Geodetic System

The SLR observation at Simosato revealed that the position of Simosato on the Tokyo Datum was incorrect by 465 m toward southeast relative to that on the world geodetic system (Tatsuno and Fujita, 1994; Sengoku et al., 1999).

Furthermore, the SLR campaign observations by the transportable SLR system, conducted at off-lying islands and coastal areas of Japan from 1987 to 2001 detected that the errors of optical and astronomical surveys at those sites (Fujita and Sengoku, 1997; Sengoku et al., 1999).

By these results, the Japanese geodetic system was transferred from the Tokyo Datum to the World Geodetic System in April 2002.

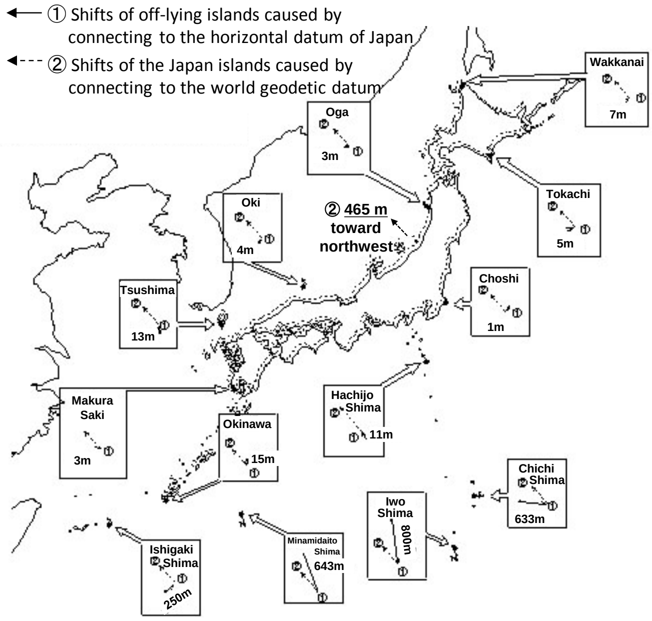

Figure 5. Shifts of the Japanese and off-lying islands determined by SLR.

4.2. Intraplate movement at Simosato

The intraplate velocities at Simosato within the Eurasian plate was estimated from Ajisai SLR data for 8 years from 1986 to 1994 (Sengoku, 1998) and LAGEOS SLR data for 10 years from 1995 to 2004 (Sato et al., 2009) (Figure 6).

As the results, it was revealed that Simosato is moving at a rate of about 3 cm/year toward west-northwest during an interseismic period.

This is caused by the subduction of the Philippine Sea plate off Simosato and helps us understand the strength of interplate coupling which will induce large earthquakes in the future.

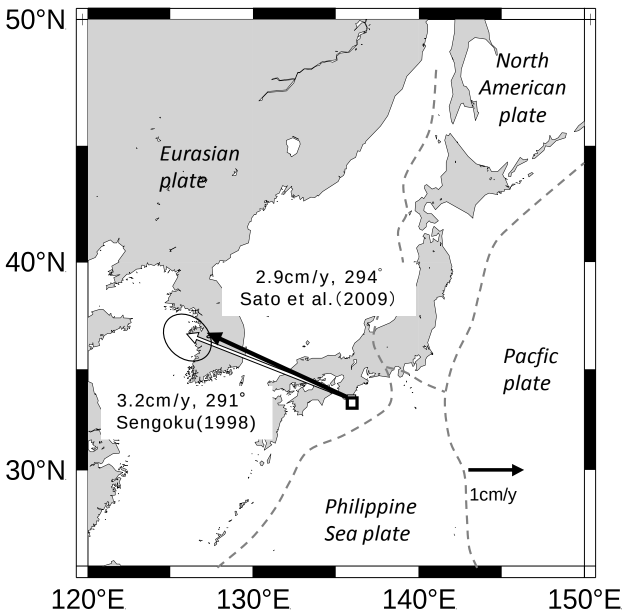

Figure 6. Intraplate velocities at Simosato.

4.3. Coseismic displacement associated with the 2011 Tohoku-oki earthquake

On March 11, 2011, a huge interplate earthquake with magnitude of 9.0 occurred off northeastern Japan, causing devastating damage mainly to the Pacific coast of northeastern Japan.

Although Simosato is located about 800 km away from the epicenter, coseismic displacement of about 3 cm toward east-northeast was detected from SLR observation before and after the event. The displacement vector is shown in Figure 7, together with the result by GPS measurements (JCG, 2013), which is roughly consistent with that by GPS measurements.

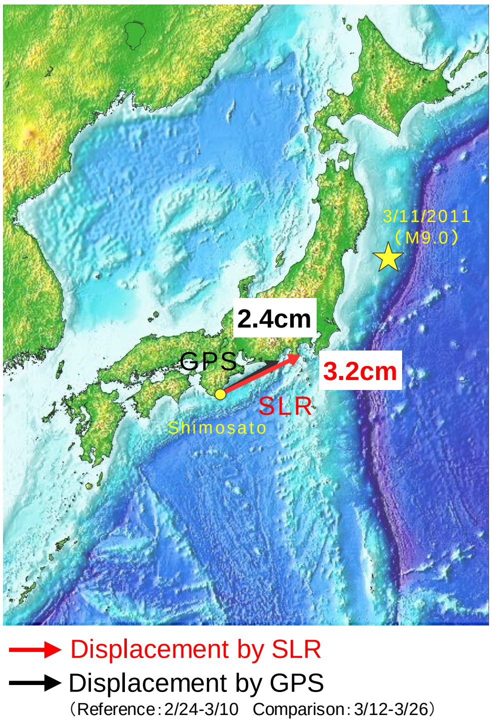

Figure 7. Coseismic displacement associated with the 2011 Tohoku-oki earthquake detected by SLR and GPS.

5. Summary

The Shimosato Hydrographic Observatory has been carrying out SLR observation since 1982. More than 33,000 passes have been obtained as of September 30, 2013. From the past observations, we determined the parameter to transform from the Tokyo Datum to the World Geodetic System and revealed crustal movement at Simosato, such as intraplate deformation and coseismic displacements associated with large earthquakes.

We will continue SLR observation to monitor the position of Simosato based on the World Geodetic System.

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