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5. GPS SYSTEM OF KSP GEODETIC NETWORK

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ABSTRACT

We have established the KSP/GPS system to confirm the results of crustal deformation detected by VLBI and SLR in the KSP network. Preliminary results indicate that site velocities obtained by GPS at three KSP sites (Koganei, Miura, and Tateyama) almost completely agree with those from VLBI. The KSP /GPS system will also be used to collocate all space geodetic techniques to the international reference frame at subcentimeter levels and to investigate the propagation delay effects caused by a neutral atmosphere including the atmospheric gradient.

Keywords: Crustal deformation, GPS, VLBI

1. Introduction

One of the main objectives of the Key Stone Project (KSP) is to monitor regional deformation and strain accumulation at the plate boundary region of the Kanto district. For this purpose observations of very long baseline interferometry (VLBI) and satellite laser ranging (SLR) are being continued in the KSP network. Results from VLBI analysis spanning the last two years indicate that Miura and Tateyama sites are moving with respect to Kashima at velocities of 14.4 and 18.7 mm/year toward the NNW, respectively. Unfortunately, results from SLR are insufficient to determine the site velocities. Though we consider that these movements are caused by subduction of the Philippine Sea plate beneath northern Honshu along the Sagami Trough, we have to confirm the velocities from VLBI by comparing them with an independent method to judge the a rate of strain accumulation precisely. Thus, we started global positioning system (GPS) measurements in July 1997 in order to evaluate the results from VLBI. Here, we describe the observation and data analysis systems of the KSP/GPS system.

2. GPS Facility and Data Analysis

GPS measurements at each KSP site (Koganei, Kashima, Miura, and Tateyama) have been carried out since July 1997. We installed GPS receivers nearby each KSP VLBI antenna to take advantage of comparisons be-

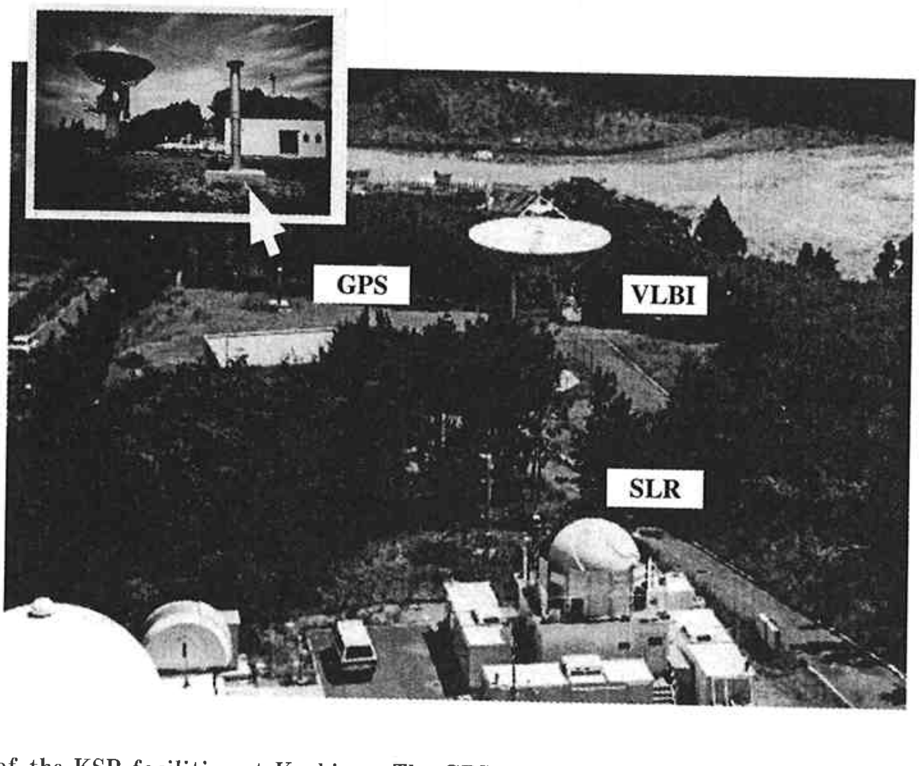

Fig. 1 Photograph of the KSP facilities at Kashima. The GPS receiving antenna on the top of the steel pillar is shown in the upper-left of the photograph. The 11-m VLBI antenna and the SLR facility are also shown.

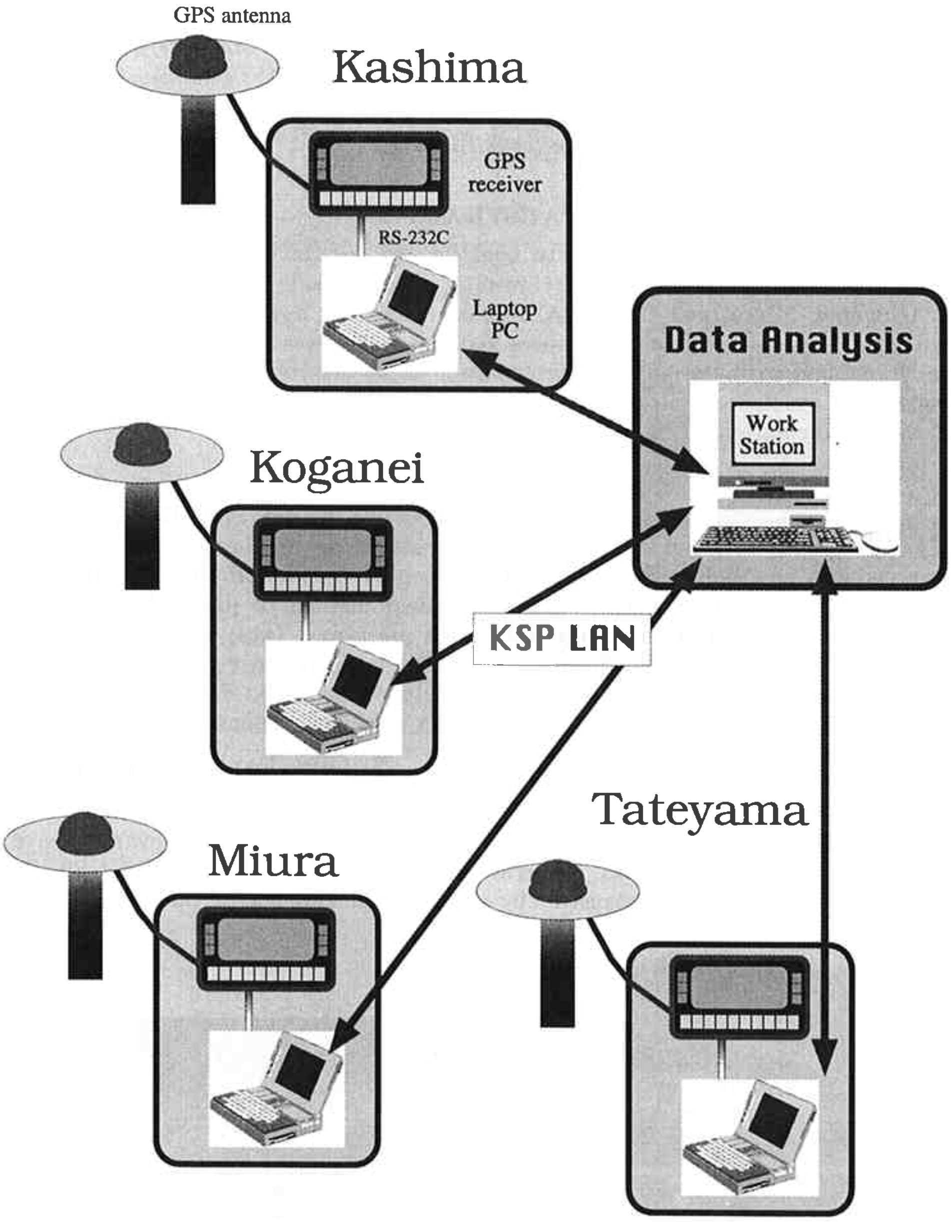

Fig. 2 Schematic figure of continuous KSP/GPS observation system.

tween GPS and VLBI. We use TOPCON GP-R1DY receivers (OEM of Ashtech Z-XII) and Geodetic III antennas (Model 700718) mounted on steel pillars. The pillars at Kashima and Miura are 3 m high. A 1.5-m pillar at Koganei is installed on a roof of the Koganei VLBI facility. The remaining Tateyama site uses a different type of antenna mount to keep enough satellite visibility. The pillar is made of invar and it is 10 m high. The antenna is covered with hemisphere radome made of fiber glass.

Metallic plates were attached on the top of the pillars at three sites (Koganei, Kashima, and Miura) until June 11, 1998. These materials can cause systematic error in both the horizontal and vertical components by scattering of the carrier phase[1]. We therefore placed a microwave absorber on the top of these pillars to reduce the carrier phase multipath on June 12, 1998. The mounted GPS receiver antenna and the VLBI and SLR facilities at Kashima are shown in Fig. 1.

Receiver data are downloaded in 24-hour segments (0000-2400 UT) sampled at 30-sec intervals, translated to the Receiver Independent Exchange Format (RINEX)[2], compressed to compact RINEX format[3], and then transferred to a scientific workstation via the KSP local area network[4]. Data from seven sites (FAIR: Fairbanks, GUAM: Guam, IRKT: Irkoutsk, KOKB: Kokee Park, SHAO: Shanghai, TSKB: Tsukuba, USUD: Usuda) of the International GPS Service (IGS) are simultaneously collected from an IGS operational data center maintained by the Geographical Survey Institute (GSI) in Japan. Precise GPS satellite ephemerides and earth rotation parameters are also collected from the data center of GSI. The basic components of our data collection and data analysis are

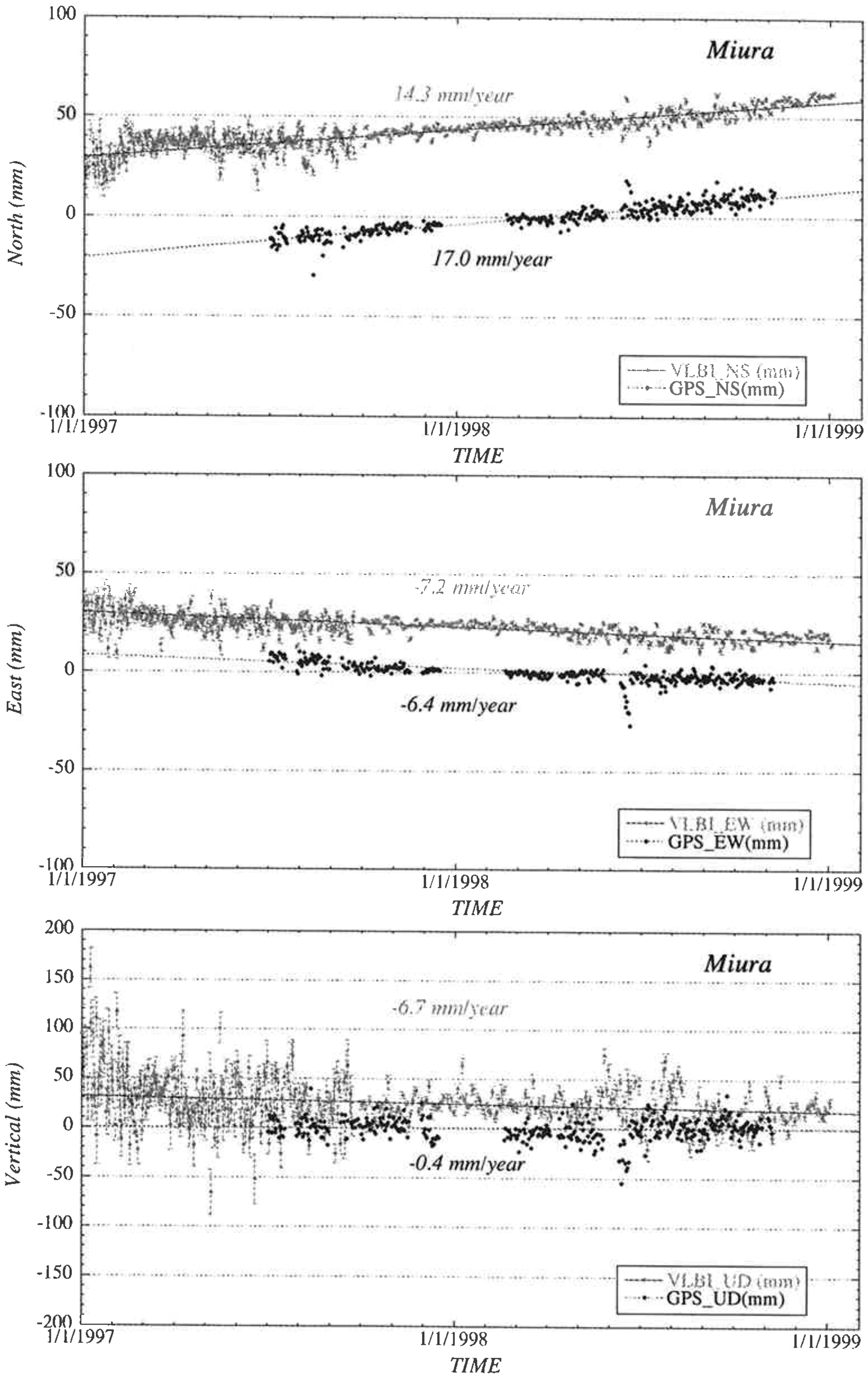

Fig. 3 Time series for north, east, and vertical components of Miura site. Results from both VLBI and GPS are shown.

shown in Fig. 2

The KSP/GPS and IGS data are semiautomatically analyzed using the Bernese software version 4.0 with the Bernese processing engine (BPE)[5]. We estimate all positions of KSP sites and the IGS sites, the wet tropospheric zenith delays for each site, and the carrier phase

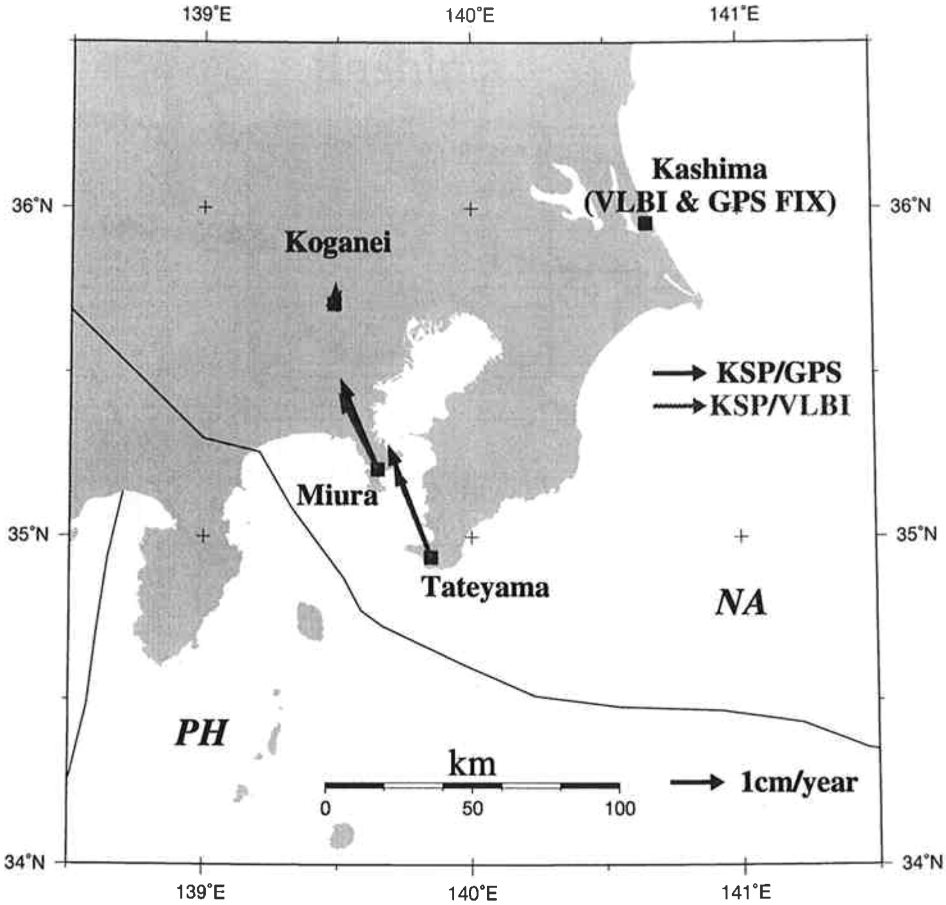

Fig. 4 Observed horizontal site velocities (centimeter per year) relative to Kashima site. The velocities from VLBI are indicated by black arrow and those from GPS are indicated by gray arrow.

ambiguities are estimated using the strategy of ionospheric-free linear combination (LC) of the dual frequency data measurements. The a priori sigma of the coordinates at the five IGS sites (FAIR, GUAM, IRKT, KOKB, SHAO) are tightly constrained with 1-3 mm. The coordinates of remaining two IGS sites (TSKB and USUD) and all KSP sites are loose constrained with 3 cm. The coordinates and velocities of the IGS sites are referred to the international terrestrial reference frame of 1996 (ITRF96). Tropospheric zenith delays are estimated as constant values for 1-hour intervals. The elevation cutoff angle is 10° for comparison with VLBI solutions.

3. Results

Daily estimates of site positions using KSP/GPS data have been obtained since July 1997, though we sometimes didn't have enough measurements due to failure of the data download system. Fig. 3 shows an example of the time series for the north, east, and vertical components (relative to nominal values) of Miura relative to Kashima. Fig. 4 shows the observed horizontal site velocities (millimeters per year) at three KSP sites (Koganei, Miura, Tateyama) relative to Kashima. KSP/VLBI solutions are also shown in these figures for comparison.

The east components of 28-month KSP/VLBI and about 16-month KSP/GPS velocities for Koganei, Miura, and Tateyama agree within less than 1 mm/year. Moreover, the north components of KSP/GPS velocities for Miura and Tateyama are 2.7 mm/year and 3.9 mm/year more than those obtained by KSP/VLBI, respectively. Both directions of horizontal vectors from VLBI and GPS at three sites show good agreement with each other. The velocities moving toward NNW at Miura and Tateyama suggest the effect of the subducting Philippine Sea plate beneath northern Honshu along the Sagami Trough. We think that discrepancies between the north components of the velocities are due to the short period of GPS measurements. The installation of the microwave absorber and antenna height change due to the ground survey may affect the estimation of site velocities. We will discuss this problem when more results from GPS are accumulated. In addition, the westward drift of the east component in June 1998 is seen in Fig. 3. We consider that this phenomenon is due to a satellite problem such as the errors of the precise orbit or satellite maneuver because the similar drifts are also shown in the coordinate solutions of all KSP sites. We are now investigating the causes of this problem.

The KSP/GPS system is also used to collocate the GPS result to VLBI and SLR results using the global geodetic reference at a millimeter accuracy level. The preliminary results of collocation are discussed in another paper[6]. Moreover, we also apply KSP/GPS data to investigate the effects of atmospheric gradient on GPS and VLBI. Preliminary results of elevation cutoff test indicate that the atmospheric gradient dominantly affect horizontal coordinate of the site position in both VLBI and GPS analyses[7]. The estimated tropospheric delays and gradient will be evaluated by comparing with those obtained by water vapor radiometer (WVR) data sets. This topic will be discussed in another paper.

4. Concluding Remarks

We have established a KSP/GPS system in order to confirm the results of crustal deformation detected by VLBI and SLR in KSP. Site velocities obtained by GPS at three KSP sites (Koganei, Miura, and Tateyama) with respect to Kashima site almost completely agree with those from VLBI, though about 3-mm/year discrepancies between the north components at Miura and Tateyama are seen. We think that a longer time series will improve our understanding of the crustal deformation detected by the KSP network. Moreover, the KSP/GPS system has significant advantages in using the collocation of allspace geodetic techniques at millimeter levels and the research for propagation delay effects caused by a neutral atmosphere including the atmospheric gradient.

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