# Analysis Center at Communications Research Laboratory

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**Abstract**

The aim of the Key Stone Project is to obtain precise relative positions of four stations using VLBI, SLR, and GPS on a daily basis by the Communications Research Laboratory. VLBI results spanning the last three and half years indicate that the Miura and Tateyama KSP sites are moving NNW with respect to Kashima at velocities of 17.0 and 20.9 mm/year, respectively. For two months after June 2000, the baseline length between Kashima and Tateyama was shortened by about 5 cm caused by a dike intrusion and co-seismic offsets between the Izu islands. We also carried out research and development such as evaluations of tropospheric path delay and ionospheric electron content, monitoring of flux-density variations of radio sources using the KSP network. This report summarizes the results from these research fields using the KSP network of CRL to the end of 2000.

## 1. Introduction

The KSP has been carried out around the Tokyo metropolitan area, Japan by the Communications Research Laboratory (CRL), using VLBI, SLR, and GPS. One of the main objectives of the KSP is to monitor regional deformation and strain accumulation at the plate boundary region of the Kanto district. The KSP is not only aimed at monitoring crustal deformation but also utilized for research and technical development of space geodesy. It is designed to make frequent observations possible with a minimum of human operations and to provide analyzed results as fast as possible. In particular, its automated design allows frequent VLBI experiments. By placing the three above-mentioned techniques close together at each site, the different and independently obtained results can be compared. We describe some analysis results using the KSP network in this report.

## 2. Analysis Results using the KSP Network

### 2.1. Crustal deformation

Figure 1a plots the estimated lengths of the baseline between Kashima and Tateyama stations using VLBI. This figure shows gradual improvements in VLBI data quality which are evident based on the scattering of plots and their formal errors. The results after September 30, 1997 are remarkable, reflecting the extended duration of each experiment.

Figure 1b shows the observed horizontal site velocities (millimeters per year) using VLBI and GPS at three KSP sites (Koganei, Miura, and Tateyama) relative to Kashima from January 1997 to June 2000. These VLBI measurements span the last three and half years and indicate that the Miura and Tateyama sites are moving with respect to Kashima at velocities of 17.0 and 20.9 mm/year toward the NNW, respectively. 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.

Figures 1a and 2a show extraordinary drifts in both VLBI and GPS measurements after the end of June 2000, namely the baseline length between Kashima and Tateyama is shortened by about 5 cm in two months. Accumulated displacement at KSP sites toward north-east are presented in

figure 2b. Similar displacement at four GPS sites (Katsuura, Kyonan, Miura, and Tateyama) of GEONET by Geographical Survey Institute (GSI) are also shown in the figure.

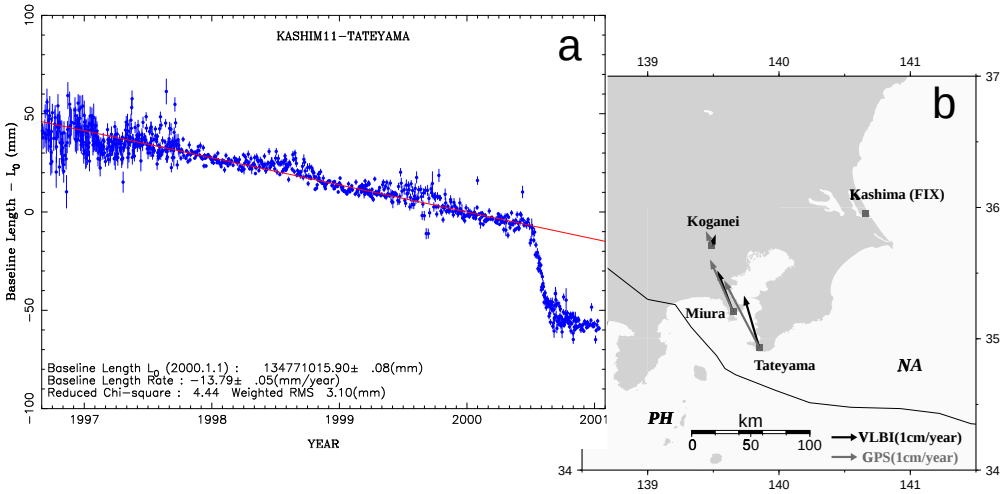


Figure 1. (a) Estimated baseline length between Kashima and Tateyama using VLBI. The formal error of each estimation is shown by a vertical bar in both figures. The variations in baseline length are fitted by linear lines and the best fit line is shown by straight solid lines. (b) Observed horizontal site velocities (centimeter per year) relative to Kashima site. The velocities from VLBI and KSP GPS from January 1997 to June 2000 are shown.

Following the magma intrusion in the Izu Islands (about 150 km south of Tokyo), during June 26 and 27, 2000, crater subsidence and volcanic eruptions continued in July and August at one of the islands, Miyakejima. In addition, high seismic activity and significant crustal deformation has continued around Miyakejima and Niijima-Kodushima since the end of June. According to the inversion using half-infinite elastic model, the crustal deformation at Tateyama, located about 100 km north-east of Kodushima island, is caused by a dike intrusion at about 3 km depth and co-seismic offsets between the islands [1]. The strike of the simulated dike is N140E, which is almost perpendicular to the azimuth from Kodushima toward Tateyama. This geometrical configuration can move the Tateyama site toward the north-east by the deformation due to the simulated dike.

## 2.2. Evaluation of tropospheric path delay

The repeatability of the baseline length of KSP VLBI measurements tends to be degraded in summertime. A correlation analysis between measured baseline lengths and surface temperature data was made, and it suggested that an apparent position change of the Kashima site occurred [2].

In June 1998, we initiated a field experiment for detecting and characterizing water vapor variations using water vapor radiometers (WVRs) at KSP Kashima site and Tsukuba. A WVR at Tsukuba is deployed by the Meteorological Research Institute (MRI) of the Japan Meteorological Agency (JMA). Time series of atmospheric gradients estimated by WVR slant delays at Tsukuba and Kashima are compared.

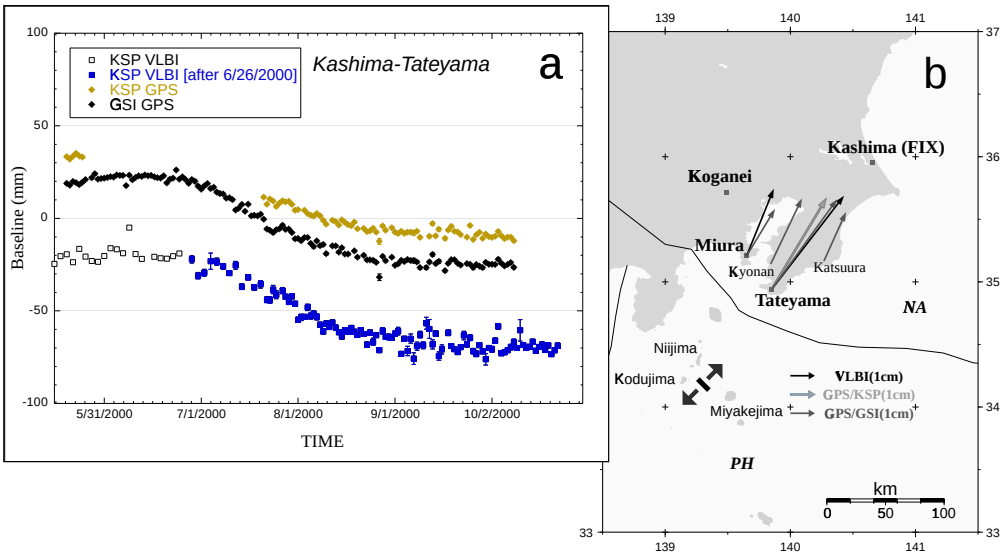


Figure 2. (a) Estimated baseline length between Kashima and Tateyama using VLBI and GPS of the KSP network. GPS results of the GEONET by Geographical Survey Institute (GSI) are also shown. (b) Accumulated displacements from VLBI, KSP GPS and GEONET GPS sites from July to September 2000.

In spite of relatively short distance between Tsukuba and Kashima (about 54 km) the atmospheric gradients solutions are significantly different. This result suggests that the mesoscale weather pattern caused large differences. We are now analyzing the output of high resolution numerical weather prediction models in order to investigate these results more deeply.

## 2.3. Evaluation of ionospheric electron content

Ionospheric delay correction with GPS-based Earth ionosphere total electron content (TEC) measurement is useful for single band VLBI application; for example, pulsar astrometry and geodetic VLBI with a single band receiver. To investigate the accuracy of GPS-based ionospheric TEC measurement, three cases of TEC estimation methods were compared with those from dual band VLBI observations of the Kashima-Koganei baseline [3]. The comparison study indicated the GPS-based TEC measurement can correct ionospheric delay in VLBI observations in almost the same accuracy with S/X dual band VLBI observation. This result is encouraging to apply GPS derived TEC to single band astrometric VLBI observation. Also realizing single band geodetic VLBI benefit at lower cost single band receiver instead of dual band receiver and more data channels can be used for X band signal.

## 2.4. Monitoring flux density variations of radio sources

Compact and strong radio sources are repeatedly observed in regular geodetic VLBI experiments under the KSP [4]. The two main purposes of the KSP VLBI network are to precisely measure relative site positions and to monitor their variations with a minimum delay of processing time. For these purposes, time delays between signals received at two sites and their rates of

change are obtained through data correlation and bandwidth synthesis processing performed in real-time. The five years of the observed data show irregular variations in the flux densities were detected for several radio sources using the source 2134+004 as the calibrator.

## 3. Staff

The staff members who are contributing to KSP Analysis Center at the CRL are listed below:

- Kondo Tetsuro, Responsible for overall operations and performance.
- Koyama Yasuhiro, Development of data analysis software.
- Ichikawa Ryuichi, Research for crustal deformation and atmospheric modeling.
- Amagai Jun, Maintenance of data analysis system.

## 4. Current Status and Future Plans

As of mid-September 2000, the crustal deformation around Izu islands almost decayed according to the results from continuous GPS measurements of GEONET at the Izu islands by GSI. However, it is very important to monitor a postseismic stage in order to understand the tectonic process of the recent event around the islands. Thus, we made a decision to continue the KSP observations at least for one year regularly though we had a plan to close the KSP in spring 2001.

At present, the atmospheric gradient models [5][6] are not used in the operational analysis of the KSP VLBI. We are now modifying the VLBI analysis software to improve the accuracy of the position determination using atmospheric gradient model.

The web server for the Analysis Center is provided by CRL. The URL address is

`http://ksp.crl.go.jp/index.html`

The KSP web site holds all the data obtained by the KSP VLBI network. Baseline lengths, site positions, flux densities of observed radio sources, estimated earth orientation parameters are available on our web site. Our analysis results of the site positions have been generated using SINEX format.

## References

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