Vol. 42 No. 1 *Journal of the Communications Research Laboratory* *March 1995*
Printed in Tokyo, Japan *pp. 57 – 63*

III. GEODETIC RESULTS OF THE EXPERIMENTS
III.2 MOVEMENT OF THE MINAMIDAITO STATION

By
Jun AMAGAI, Tetsuro KONDO, Michito IMAE, Noriyuki KURIHARA, Yuji SUGIMOTO, Taizoh YOSHINO, Fujinobu TAKAHASHI, Hitoshi KIUCHI, Shin'ich HAMA, Yukio TAKAHASHI, Hiroshi TAKABA, Takahiro IWATA, Yasuhiro KOYAMA, Yuko HANADO, Mamoru SEKIDO, and Akihiro KANEKO

(Received on November 21, 1994)

ABSTRACT

Geodetic VLBI experiments on the baselines including Minamidaito island were carried out in 1990 and 1991. This was the first attempt to measure the movement of the Philippine Sea plate in multibaseline VLBI experiments. The data obtained in these experiments was used to estimate the Philippine sea plate motions relative to the Eurasian plate and the North American plate. The estimated plate velocity is greater than that derived from seismological data and the results of GPS observations. The direction of the observed movement of Minamidaito relative to the Eurasian plate is N78.1° W and close to the result obtained by GPS measurement.

Keywords: Minamidaito, VLBI, Philippine Sea plate, ionospheric delay

1. Introduction

Minamidaito is located on the Philippine Sea plate (PH, see Fig. 1). The movement of the PH had not been confirmed by direct measurement until 1989. There had been only predictions derived from earthquake slip vectors(1). The first attempts to measure the motion of the PH were performed by VLBI on the baseline between Kashima and Chichijima in 1987 and 1989(2), and results agreed within two-sigma with the prediction of Seno et al.(1). Because these experiments were carried out on the baseline whose direction was different from the expected relative movement of the station, they derived the plate motion only from the vector change, which is easily affected by the uncertainties of the earth orientation parameter. Recently, however, GPS measurements were carried out at Minamidaito, with islands of the Ryukyu Arc. These measurements have been made annually since 1990, and initial results indicate that velocity of Minamidaito relative to the Ryukyu Arc is 8.7 ± 3.1 cm/yr and that the direction of this motion is N70° W(3).

The Communications Research Laboratory (CRL) in November 1990 and December 1991 conducted VLBI experiments on the baselines connecting Minamidaito, Kashima, and Shanghai. The Kashima and Shanghai stations are nominally located on the North American plate (NA) and the Eurasian plate (EU), respectively. These plates and the PH adjoin each other. Since the positions and velocities of Kashima and Shanghai stations have been precisely determined in the worldwide VLBI

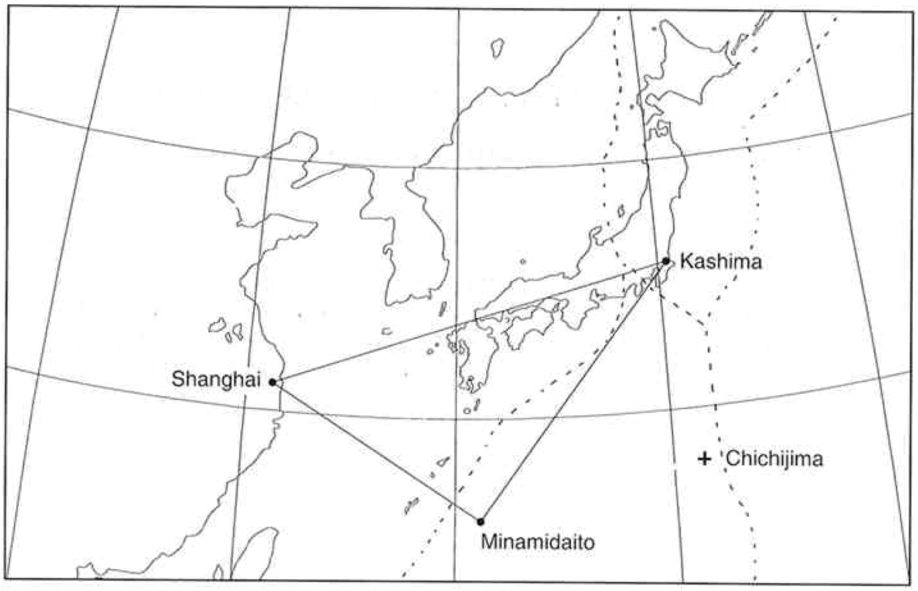


Fig. 1 Locations of the stations

terrestrial reference system by international VLBI experiments[4], we can treat these stations as references for the baseline analysis. The Shanghai-Minamidaito baseline is suitable for measurement of the relative motion of PH with EU because the direction of baseline vector is close to that of the relative plate motion expected.

The highly transportable VLBI station (HTVS)[5][6] developed by the CRL was used for Minamidaito. The HTVS is equipped only with an X band receiving system. Ionospheric delay corrections for the baselines including HTVS were performed by using the data of total electron contents of the ionosphere (TEC) observed by a TECMETER[7]. Unfortunately, since the quality of the TEC data observed at individual stations was not good, ionospheric delay corrections for the data of the baselines including Minamidaito were not satisfactory. The estimated position of Minamidaito is thought to be affected by the ionospheric delay corrections adopted inadequately.

2. Experimental Conditions

Four VLBI observing sessions have been carried out, and the experimental conditions of each session are summarized in Table 1. In addition to the Minamidaito and Kashima stations, which participated in each session, the Shanghai station joined in experiment sessions SDE90B and SDE91A.

We transported the HTVS to Minamidaito before SDE90A, to avoid effects of reinstalling it, the HTVS was kept fixed until all the experiments were completed. HTVS uses a 3 m antenna with a receiving bandwidth greater than that of the usual VLBI systems, a compact data acquisition system, and a compact frequency standard consisting of a cesium frequency standard and a high quality quartz oscillator. The low sensitivity due to the small antenna aperture and unstable frequency standard is largely compensated by using a larger receiving bandwidth. The HTVS receives signals in

Table 1 Summary of experiments

Code	Date	Stations
SDE90A	26 November 1990	Minamidaito, Kashima
SDE90B	28 November 1990	Minamidaito, Kashima, Shanghai
SDE91A	3 December 1991	Minamidaito, Kashima, Shanghai
SDE91B	5 December 1991	Minamidaito, Kashima

Table 2 Specifications of the stations

	Minamidaito	Kashima	Shanghai
Antenna diameter	3 m	34 m	25 m
Aperture efficiency	40%	68%	50%
System noise	120 K	52 K	100 K
Receiving band	Wide X	Wide X, S	Wide X, S ('90) Normal X, S ('91)
Frequency standard	Cs + X'tal	H Maser	H Maser
Video bandwidth		2 MHz each	

a lower part of the X band (7860 MHz to 8280 MHz) in addition to the conventional X band signals (8180 MHz to 8600 MHz) widely used for geodetic VLBI. The effective bandwidth of the HTVS is therefore about 1.6 times larger than that of the usual VLBI systems. The number of video channels used for the bandwidth synthesis is also increased: from 8 to 14. Although the HTVS does not use the S band receiving system for ionospheric delay correction, this correction can be done by using the TEC data obtained by a TECMETER.

The Kashima station uses a receiving band as wide as the one the HTVS uses, but Shanghai originally had only a normal bandwidth receiver. An additional lower X band receiving system was therefore transported to Shanghai from Kashima and installed in the system for one of the sessions in 1990 (SDE90B). Every station participated in SDE90B use wideband receivers and TECMETERs.

For the session of 1991 (SDE91A), the wide band was received for the Minamidaito-Kashima baseline but the Shanghai station observed only the normal receiving band signal. Ionospheric delay correction for the baseline with Minamidaito was done by TECMETER and for the Kashima-Shanghai baseline was done by the S-X dual band method.

3. Analysis

The raw data were cross-correlated at Kashima, and the correlation functions obtained were further processed using the bandwidth synthesis software to calculate the time delay and delay rates. The baseline analysis with the LOCAL software system was also performed at Kashima.

The dry components of the tropospheric delays were calculated by using the model of Saastamoinen(8) and the CFA2.2 mapping function(9). The wet component of tropospheric delay to the zenith direction was estimated as a linear function of time with breaks every 3 hours. To prevent an artificial sharp bend in the atmospheric zenith delay from being estimated, a continuity constraint

Table 3 Frequency arrangements used for the experiments

	SDE90A, SDE90B, SDE91B	SDE91A (Daito, Kashima 1)	SDE91A (Shanghai, Kashima 2)
Channel 1	7894.99 MHz	7894.99 MHz	8214.99 MHz
Channel 2	7904.99 MHz	7904.99 MHz	8224.99 MHz
Channel 3	7934.99 MHz	7984.99 MHz	8254.99 MHz
Channel 4	7984.99 MHz	8044.99 MHz	8314.99 MHz
Channel 5	8054.99 MHz	8104.99 MHz	8424.99 MHz
Channel 6	8104.99 MHz	8154.99 MHz	8504.99 MHz
Channel 7	8214.99 MHz	8214.99 MHz	8554.99 MHz
Channel 8	8234.99 MHz	8224.99 MHz	8574.99 MHz
Channel 9	8274.99 MHz	8254.99 MHz	2217.99 MHz
Channel 10	8344.99 MHz	8314.99 MHz	2222.99 MHz
Channel 11	8404.99 MHz	8424.99 MHz	2237.99 MHz
Channel 12	8494.99 MHz	8504.99 MHz	2267.99 MHz
Channel 13	8544.99 MHz	8554.99 MHz	2292.99 MHz
Channel 14	8564.99 MHz	8574.99 MHz	2302.99 MHz
Summary of X band			
Number of channels	14	14	8
Mean frequency	8211.42 MHz	8225.70 MHz	8383.74 MHz
RMS freq. (FRMS)	228.99 MHz	220.31 MHz	140.22 MHz
FRMS*SQRT(N)	856.81 MHz	824.31 MHz	396.60 MHz
Summary of S band			
Number of channels	NONE	NONE	6
Mean frequency			2257.16 MHz
RMS freq. (FRMS)			33.09 MHz
FRMS*SQRT (N)			81.06 MHz

with a tolerance value of 50 ps/hr/epoch was introduced. The cable length between a receiver system and ground system was always monitored at every station by using a delay calibrator, and the cable length data were used in the analysis.

The earth orientation parameters (i.e. UT1-UTC and the position of earth's rotation pole) were fixed to the *a priori* values obtained from the monthly bulletin of IERS (IERS bulletin B). To ensure the consistency of the reference frames, ITRF90 was used as the terrestrial reference frame and ICRF was used as the celestial reference frame. Kashima station and Shanghai station had carried out many CDP VLBI experiments and the positions and velocities of the antennas had been determined precisely. For these stations the positions and velocities were calculated and not estimated. These calculations were based on the site position of the ITRF90 system at the epoch of 1988.0 and used the site velocity obtained from GSFC solution GLB659[10].

Ionospheric delay corrections for the baseline including Minamidaito were performed using TEC data obtained by a TECMETER. TEC data measured by a TECMETER are not directly observed along the line-of-sight toward the observed radio source but those toward the GPS satellites, so the TECs obtained for GPS directions were projected to the radio star directions using the projection model developed by Kondo[7].

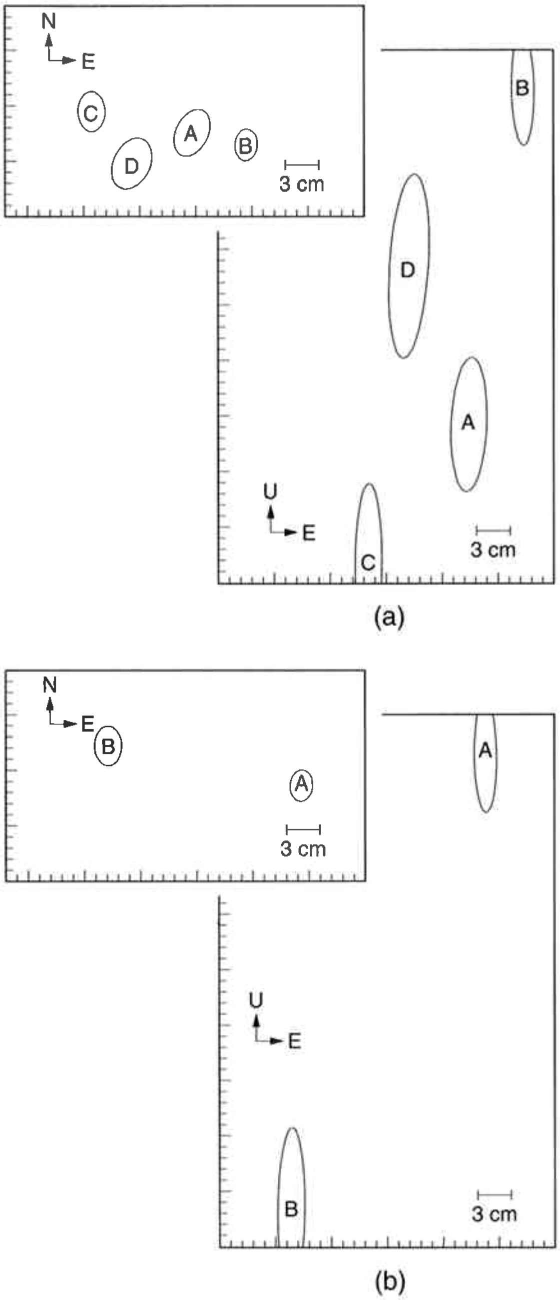
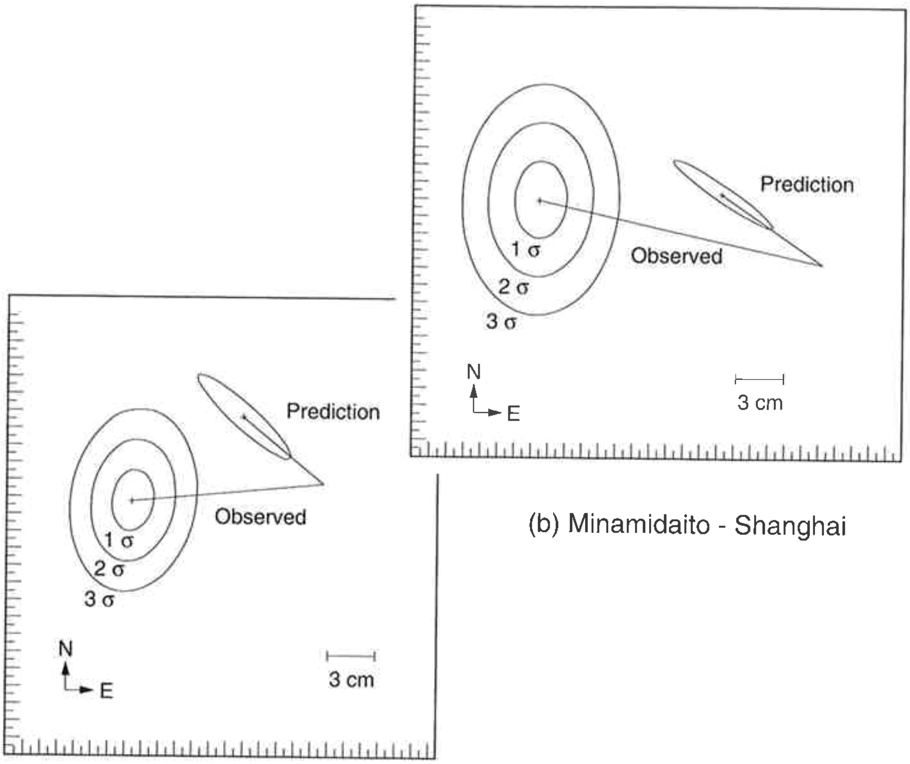


Fig. 2 Estimated positions of Minamidaito for each experimental session: (a) relative to Kashima station, (b) relative to Shanghai station. The letters A to D respectively denote SDE90A, SDE90B, SDE91A, and SDE91B.



(b) Minamidaito - Shanghai

(a) Minamidaito - Kashima

Fig. 3 Movement of Minamidaito station relative to (a) Kashima station, (b) Shanghai station.

Because only 16 GPS satellites were available at the time of the VLBI sessions and the distribution of the satellites were not uniform, not enough good TEC data were obtained to enable precise ionosphere delay corrections.

4. Geodetic Results

The estimated position of Minamidaito for each experiment is shown in Fig. 2. The vertical positions have a large scatter, which might be due to inadequate ionospheric delay correction. Figure 3 shows the relative movements of Minamidaito horizontal position calculated by comparing the positions at two epochs. The movements calculated from PH-EU and PH-PA relative rotation vectors predicted by Seno et al.[1] are also shown in the figure. Local movements of Kashima and Shanghai were not taken account in these predicted movements. The observed station velocity is more than twice the velocity predicted. Since the error of ionospheric delay estimated from TEC data is not accounted for in the baseline analysis, the error of the estimated station movements is thought to be smaller than the practical error. Nevertheless this disagreement between observed and predicted movements is too large to be explained by the local movements of Kashima and Shanghai station (which is less than 3 cm/yr[11][12]) or by the Earth orientation parameter error (which is less than 1 cm for a 1000 km baseline). The observed direction of the station movement is closer to westerly than the direction predicted by Seno et al.[1]. These tendencies, larger velocity and westerly direction, also appeared in the results of the GPS observation[3].

5. Conclusions

Our VLBI experiments on the baselines with Minamidaito indicated a larger velocity and more westerly direction than had been expected, but the inadequately corrected ionospheric delays may have affected the estimated station positions. We thus cannot further discuss crustal movement using these short period measurement results. To determine the velocity of the movement of Minamidaito precisely, future VLBI/GPS measurements must be performed.

6. Acknowledgments

We thank the staff members of the Minamidaito Meteorological Observation station and all the members of Shanghai Observatory for the joint VLBI experiments.

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