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IV. RELATED RESULTS AND ACTIVITIES IN WESTERN PACIFIC VLBI NETWORK

IV.1 THE METROPOLITAN DIAMOND CROSS EXPERIMENTS

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ABSTRACT

VLBI measurements using stations around the Tokyo metropolitan area started in 1992 in cooperation with the Geographical Survey Institute to monitor regional crustal deformation there and to establish reference points for a local geodetic survey. Repeated measurements have revealed that the 100 km baseline between two of stations (Kashima and Koganei) has been becoming shorter at a rate of about 5 mm/year due to a compressional stress field owing to the subducting Pacific plate.

Keywords: VLBI, Tokyo metropolitan area, crustal deformation

1. Introduction

Japan often has severe earthquakes. The country lies at the junction of four subterranean plates (see Fig. 1) and their relative motion is thought to be the cause of large earthquakes. A big earthquake is expected to occur at the Sagami trough in the future, and the Tokyo metropolitan area faces a similar threat. And since Tokyo has a huge concentrating population and economic activities, even a relatively small earthquake there would cause severe damage, if it occurred immediately beneath the metropolitan area. It is therefore highly desirable to develop a reliable method of predicting earthquakes to reduce the potential damage as much as possible.

A number of scientists in several countries have tried various approaches to predict the occurrence of earthquakes. The basic idea of these approaches is to try to detect a precursor of earthquake events. One such approach is electromagnetical observation, i.e., monitoring the changes occurring in the geo-magnetic field, resistive anomalies, and electric current under the ground.

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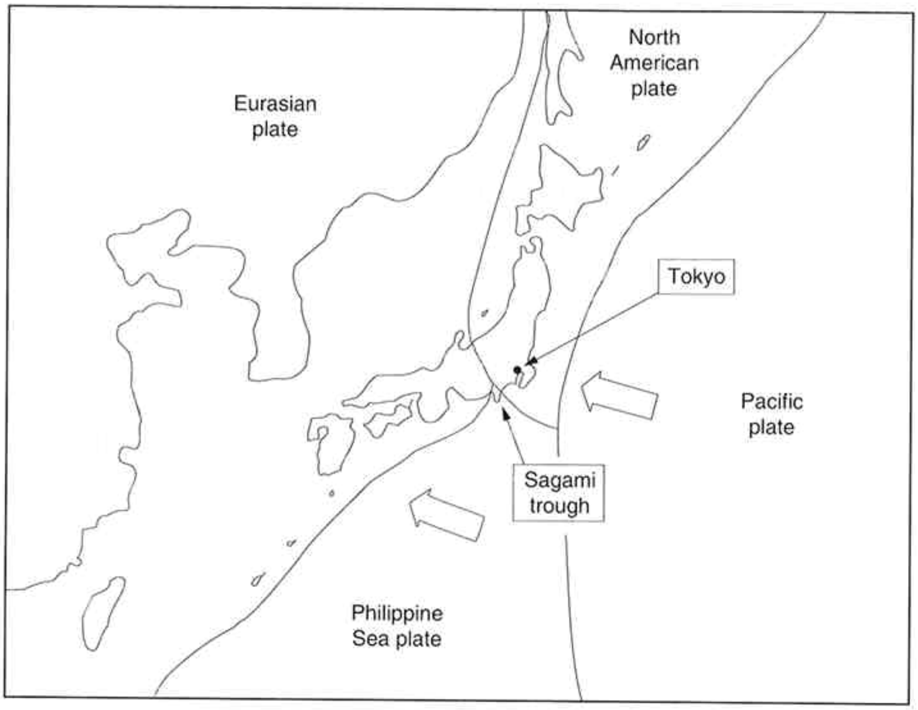

Fig. 1 The four subterranean plates around the Japanese islands. The arrows show the direction of oceanic plate motions.

Another attempt to detect a precursor is precise measurement of crustal deformation. In the former approach, observations are sometimes affected by man-made noises, and thus the latter approach is thought to be more practical for use in the metropolitan area because it is not subject to this disadvantage.

To investigate the feasibility of geodetic measurements using VLBI technique for earthquake prediction in the metropolitan area we started a series of VLBI experiments using a network surrounding the Tokyo metropolitan area in 1992. These experiments were conducted in cooperation with the Geographical Survey Institute (GSI) with financial support from the Science and Technology Agency of Japan. The main purpose of the experiments is to establish reference points in the metropolitan area and to monitor regional crustal deformation. The VLBI network consisted of three stations, Kashima, Koganei, and Tsukuba in its initial phase, and later was expanded to include Kanozan when the development of a mobile station used there was finished. The final network consisting of four stations is named the metropolitan diamond cross (MDX) after its configuration.

Prior to starting the experiments on the MDX network (or baseline), a VLBI measurement was carried out on the baseline between Kashima and Koganei in 1988. As a result, 5 years of data on the position of the Koganei is available, and this enables us to estimate the motion of Koganei relative to the Eurasian or the North American plate.

At Koganei the position has been also measured by other space geodetic techniques, i.e., satellite laser ranging (SLR) and the global positioning system (GPS). Measured positions are then connected to one another and compared. The results are described in a separate article[1] in this issue (see IV-3). In this paper, therefore, we describe only the observations and results obtained in the VLBI measurements.

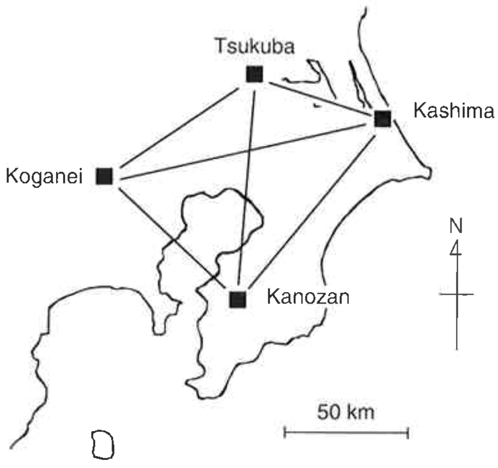

Fig. 2 Site locations and Metropolitan Diamond Cross (MDX) network

2. Metropolitan Diamond Cross Network

Figure 2 shows the locations of the VLBI stations which form the Metropolitan Diamond Cross (MDX) network surrounding the Tokyo metropolitan area, i.e., Kashima, Koganei, Tsukuba and Kanozan. All stations are located on the North American plate. The Japanese islands are thought to be in a compressional stress field owing to subducting oceanic plates, the Pacific plate and the Philippine sea plate. It is therefore suggested that any changes in baseline length or in relative station positions could be detected as a reflection of this stress field. In addition, there are many active faults reported in the Kanto plain, and thus some baselines of the MDX network are thought to cross these faults. This means that there may be a chance to detect changes occurring due to active faulting.

The key station in the MDX network is Kashima, where a large antenna (26 m or 34 m antenna) is used for the MDX session. Data processing including correlation processing is carried out there. The Koganei station has a mobile 3 m antenna with an X band receiving system(2). Tsukuba is operated by GSI and is equipped with a 5 m antenna with dual S and X band receivers. Kanozan is also operated by GSI and has employed a mobile 2.4 m antenna with an X band receiver since 1993. Hydrogen masers are employed as a frequency standard at all stations.

3. Observations

Eight 24-hour VLBI sessions have been conducted since March, 1992 up to the present time (October, 1994) as MDX experiments. The first VLBI observation at Koganei was carried out in 1988, before the start of MDX experiments as a campaign experiment using a highly transportable VLBI station. MDX experiments at Kanozan did not begin until 1993. Table 1 shows the dates and locations of the MDX sessions and the pre-MDX session which were conducted. In conventional geodetic VLBI, both S and X band radio signals are received to calibrate the ionospheric excess delays. In contrast, only X band signals are received in the MDX sessions because Koganei and Kanozan VLBI stations are equipped only with X band receiving antennas. Thus no explicit compensation for the ionospheric delays is taken in the data reduction for MDX experiments.

Table 1 MDX experiments conducted to date

Date	Kashima		Koganei	Tsukuba		Kanozan
yy/mm/dd	26 m	34 m	3 m	5 m	2.4 m	2.4 m
88/09/20	✓		✓			
92/03/19		✓	✓	✓		
92/05/24		✓	✓	✓		
92/10/15	✓		✓		✓	
92/11/26	✓		✓			
93/05/27	✓		✓			
93/07/26		✓	✓			✓
93/07/28		✓				✓
93/08/24		✓	✓	✓		

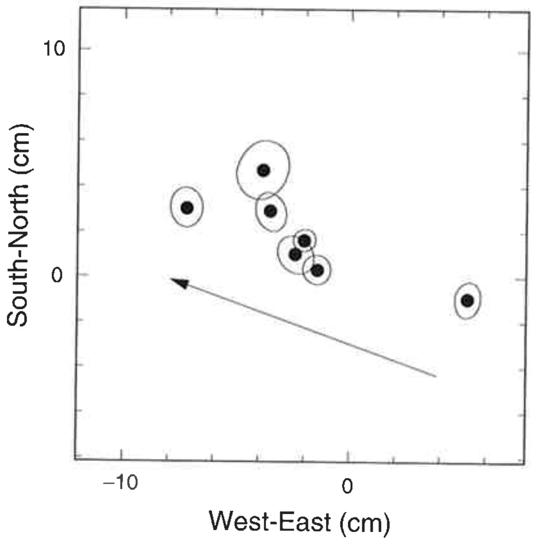

Fig. 3 Motion of Koganei relative to the Eurasian plate. The arrow indicates the least squares fitting motion over 5 years.

However, the baseline lengths between the MDX stations are considerably shorter than the scale length in the ionosphere (several hundred kilometers), so that the lack of ionospheric correction is thought to affect geodetic results only at the sub-millimeter level.

In the analysis, Kashima is treated as a reference station whose coordinate is given by the ITRF92 (IERS Terrestrial Reference Frame-92, Boucher et al., 1993)[3] which defines the position and velocity of stations at the epoch (1988.0).

Table 2 Position of Koganei

X (m)	−3942077.154 ± 0.006
Y (m)	3368332.197 ± 0.009
Z (m)	3701904.831 ± 0.017

Table 3 Baseline vector between Kashima 26 m and 34 m antennas

X (m)	243.019
Y (m)	109.493
Z (m)	160.607
Length (m)	311.194

Table 4 Measured baseline vector between Kashima 34 m and Kanozan

X (m)	−5901.825 ± 0.013
Y (m)	−78371.007 ± 0.011
Z (m)	63053.545 ± 0.012
Length (m)	100760.090 ± 0.005

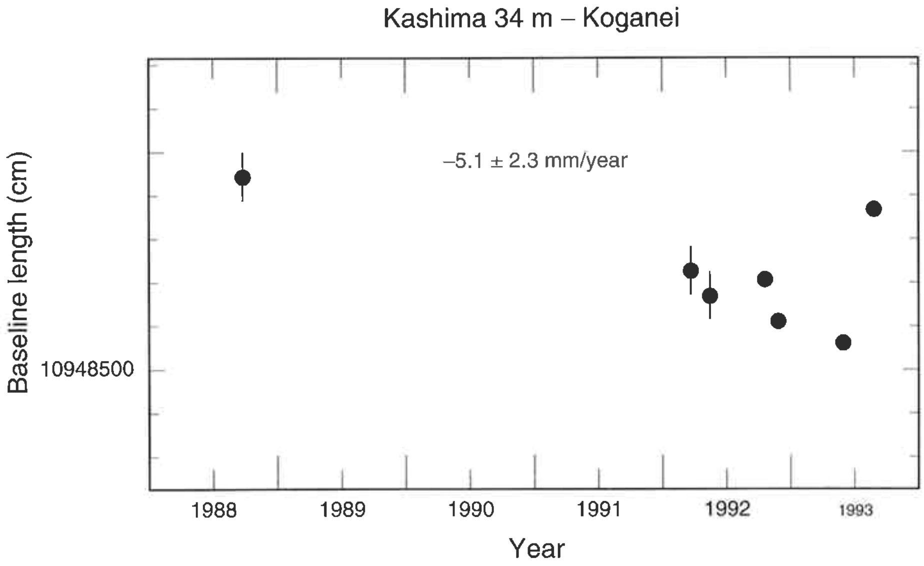

Fig. 4 Evolution of baseline length between Kashima and Koganei

4. Results

Figure 3 shows the Koganei motion against the Eurasian plate in the horizontal plane measured from 1988 on. Each ellipse represents a one sigma formal error. Estimated motion by the least squares fitting method is depicted by an arrow. The position of Koganei is summarized in Table 2 as an average the positions measured in 1992. Figure 4 shows the evolution of baseline length between Kashima and Koganei since 1988. Some measurements taken using the 26 m antenna at Kashima are converted to Kashima 34 m antenna using the relative position vector between the 26 m and 34 m antennas shown in Table 3. The measurements show that baseline length between Kashima and Koganei becomes shorter at a rate of about 5 mm/year. In the meantime, repeated measurements of the Kashima position in the international VLBI network have revealed its local motion with sub millimeter per year accuracy. Kashima is moving in the NW direction relative to both the North American and Eurasian plates at a rate of 2.4 cm/year and 1.4 cm/year, respectively, which is almost the same as the direction of the subducting Pacific plate motion (Heki et al., 1990)[4]. This movement is thought to be attributed to a compressional stress field caused by a subducting oceanic plate. If motion results from elastic uniform deformation over the area between the forward and backward arcs of the Japanese islands (about 300 km), strain rates of the shortening reach an order of 10^{-7}. This is fairly consistent with a shortening rate of 5 mm/year on the Kashima–Koganei baseline of about 100 km in length. The rate of change in the baseline length, however, is strongly affected by the measurements taken in 1988. It is therefore necessary to conclude that further measurements must be taken to discuss these characteristics in detail.

There is insufficient data for the Kanozan station to discuss any changes in station position or baseline length. The position measured in 1993 as a vector from the Kashima 34 m antenna is summarized in Table 4.

5. Concluding Remarks

VLBI session using stations around the Tokyo metropolitan area commenced in 1992. An MDX (Metropolitan diamond cross) network consisting of four stations, at Kashima, Koganei, Tsukuba, and Konozan, was used in carrying out the experiments. Repeated measurements on the baseline between Kashima and Koganei have revealed a shortening of its length at a rate of about 5 mm/year. This is thought to reflect the existence of a compressional stress field due to subduction of the Pacific plate. Further accumulation of position measurements for Koganei is necessary to discuss this point in detail because the results shown here are strongly affected by a pre-MDX measurement made in 1988. Moreover, Kanozan was not installed in the network until 1993, and thus further measurements are needed to more clearly determine the nature of strain in the MDX network.

6. Acknowledgments

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References

(1) H. Kunimori, K. Heki, E. Kawai, T. Otsubo, T. Yoshino, F. Takahashi, and Y. Takahashi, "IV-3 Collocation of VLBI, SLR and GPS in CRL," J. Commun. Res. Lab., 1995 (this issue).

(2) J. Amagai, H. Kiuchi, A. Kaneko, and Y. Sugimoto, "Geodetic experiments using the highly transportable VLBI station," J. Commun. Res. Lab., **37**, pp. 63–73, 1990.

(3) C. Boucher, IERS Tech. Note 15, 1993.

(4) K. Heki, Y. Takahashi, and T. Kondo, "Contraction of northeastern Japan: Evidence from horizontal displacement of a Japanese station in global very long baseline interferometry networks," Tectonophysics, **181**, pp. 113–122, 1990.