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The first year of Antarctic VLBI observations

Takaaki Jike^{1*}, Yoshihiro Fukuzaki², Kazuo Shibuya³,
Koichiro Doi³, Seiji Manabe¹, David L. Jauncey⁴,
George D. Nicolson⁵ and Peter M. McCulloch⁶

¹National Astronomical Observatory, Osawa 2-21-1, Mitaka-shi, Tokyo 181-8588

²Geographical Survey Institute, Kitasato 1-ban, Tsukuba 305-0811

³National Institute of Polar Research, Kaga 1-chome, Itabashi-ku, Tokyo 173-8515

⁴Australia Telescope National Facility, CSIRO, Epping NSW, Australia

⁵Hartebeesthoek Radio Astronomy Observatory, Krugersdorp, South Africa

⁶Physics Department, University of Tasmania, Hobart, Australia

*Corresponding author. E-mail: jike@miz.nao.ac.jp

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Abstract: We are undertaking a series of geodetic VLBI observations between the Syowa Station 11-m antenna in Antarctica, and the 26-m antennas in Hobart Tasmania and Hartebeesthoek South Africa. These observations are the beginning of our campaign to monitor the motion and stability of the Antarctic plate. We describe here the results of the first year's observations made during the southern summer and winter of 1998. Two mutually incompatible recording systems, K4 and S2, are used. The Mitaka FX Correlator was used to correlate these data. By using software called CALC3/MSOLV, the mean position of the antenna's geodetic reference point was found to be $X = 1766194.152 \pm 0.006$ m, $Y = 1460410.923 \pm 0.005$ m and $Z = -5932273.329 \pm 0.015$ m at the epoch of 1998.9 in the International Terrestrial Reference Frame 2000 (ITRF2000) system. From a comparison with measurements made with other space geodetic techniques we estimate that our results have typical uncertainties of no more than 2 to 3 cm in each coordinate.

key words: VLBI, the Mitaka FX Correlator, the Syowa VLBI reference point

1. Introduction

Syowa Station (39.6°E, 69.0°S) is one of the largest earth scientific observation sites in the world and is an important station for global geodynamics. Several space geodetic observation facilities such as the Global Positioning System (GPS), Doppler Orbitography and Radiopositioning Integrated by Satellites (DORIS) and Precise Range and Range-Rate Equipment (PRARE) are situated at the site and are in regular operation as part of the Japanese Antarctic Research Expedition (JARE) program (e.g. Shibuya *et al.*, 2003).

The 11-m S/X band multipurpose antenna (Syowa 11-m antenna) which is usable for Very Long Baseline Interferometry (VLBI) was installed on site in 1990 (Hirasawa *et al.*, 1990) during the 30th Japanese Antarctic Research Expedition (JARE-30). The first VLBI observations were undertaken in January 1991 (Kurihara *et al.*, 1991;

Jauncey, 1991) to demonstrate the VLBI capability during JARE-30. However, a regular monitoring program was not commenced until 1997.

From JARE-38, a research program for monitoring earth scientific phenomena occurring in the Antarctic plate was started. Routine geodetic VLBI monitoring observations were started in 1998 with JARE-39. In addition to its geodetic purpose, these observations are also used to strengthen the celestial and terrestrial reference frames in the Southern Hemisphere. The geodetic program is designed to monitor the motion and stability of the Antarctic plate, and the VLBI data are to be combined with the other geodetic and geophysical data obtained at Syowa Station.

A standard geodetic VLBI observation system, which includes two sets of hydrogen maser frequency standard, was permanently installed at Syowa Station by JARE-39 during the southern summer of 1998, and operates at the standard S/X geodetic frequencies. Our VLBI monitoring campaign started regular operations during the southern winter of 1998, JARE-39 (e.g. Jike *et al.*, 1999), and is coded as “JA”.

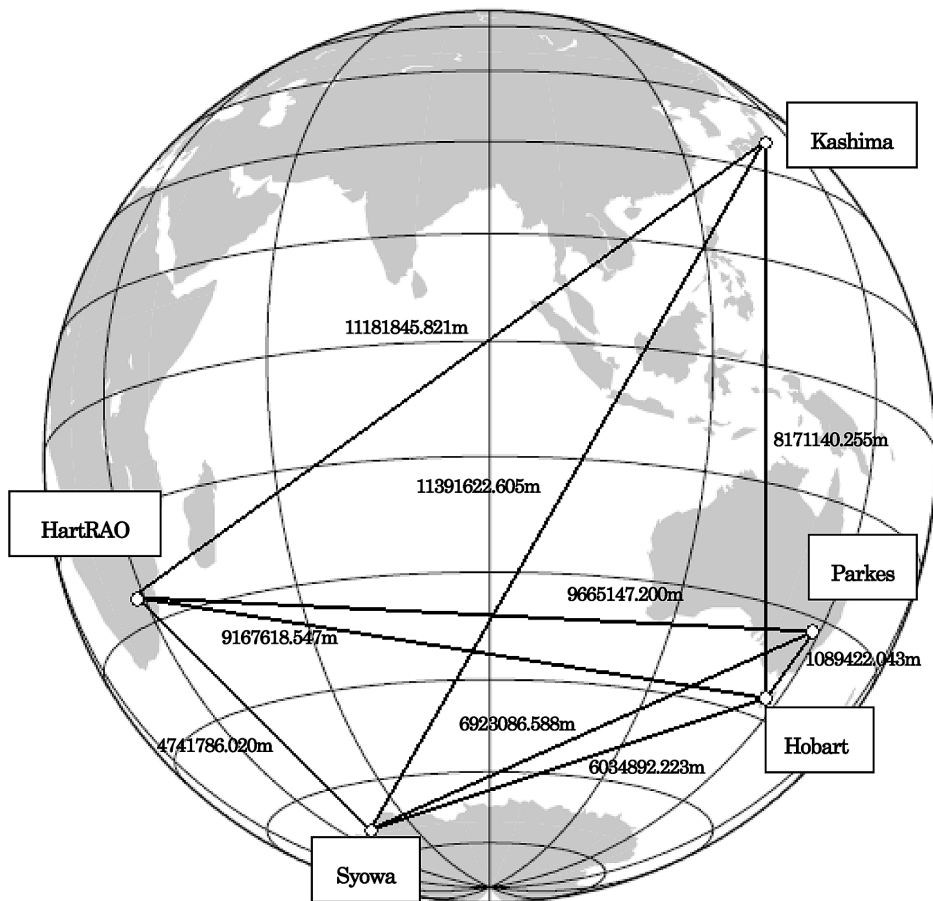


Fig. 1. Geographic distribution of stations participating in the Antarctic VLBI project.

JARE-39 established the observing procedures and set up the necessary logistics for the continuation of the program.

In addition to the Syowa 11-m antenna, the VLBI campaign includes the University of Tasmania's Hobart 26-m antenna (Hobart) in Australia and the 26-m antenna of the Hartebeesthoek Radio Astronomy Observatory (HartRAO) in South Africa. In addition we occasionally made use of the Parkes 64-m radio telescope of the Australia Telescope National Facility (ATNF) and the 26-m Kashima antenna of the Geographical Survey Institute (GSI) in Japan. The geographic distribution of these facilities is shown in Fig. 1.

For reliability, the Syowa and Kashima VLBI observations were made using their standard K4 system (Kiuchi *et al.*, 1991) while Hobart, HartRAO and Parkes using their regular Canadian S2 system (Cannon *et al.*, 1997). Thus it was necessary to consider compatibility of recording systems in the correlation processing. All correlations were made at the National Astronomical Observatory of Japan's (NAOJ) Mitaka FX Correlator (Shibata *et al.*, 1998) which can accept both recording modes. This correlator had previously been used only for astronomical image processing. Some modifications were necessary to translate the raw correlator output into the standard delay and delay-rate format used in the geodetic analyses (Jike *et al.*, 2002).

This paper reports the results for the first year of operation of the geodetic program. We also report some characteristics of the VLBI observations which are specific to Syowa Station.

2. Summary of observations and correlation processing

We present here the results from the 48-hour sessions from 1998 February, May, August and November of the JARE-39 observations. Kashima took part in part of the February and May observations while Parkes took part in the full 48 hours in November. The observations are summarized in Table 1. Observation specifications and frequency settings of individual channels are listed in Tables 2 and 3, respectively.

The JA session used incompatible recording systems as stated before. The K4 and S2 recording systems adopt different recording media of different formats. When our

Table 1. Summary of the experiments conducted during JARE-39.

Experiment name	Start epoch (UT)	End epoch (UT)	Number of observations	Station ID
JA981a and b	98/Feb/09 0813	98/Feb/11 0810	318	Hh, Ho, Ka*, Sy
JA982a and b	98/May/11 0800	98/May/13 0801	347	Hh, Ho, Ka*, Sy
JA983	98/Aug/09 0800	98/Aug/11 0808	337	Hh, Ho, Sy
JA984	98/Nov/09 0800	98/Nov/11 0812	398	Hh, Ho, Pk, Sy

Hh: HartRAO, Ho: Hobart, Ka: Kashima, Pk: Parkes, Sy: Syowa.

* Kashima participated only in JA981a and JA982a.

Table 2. *Observation specifications.*

Observation setting	Summary
Bandwidth of the base band	4 MHz
Sampling mode	8 MHz-1 bit-16 ch
Number of frequency channels used	14
S-band, number of channels and RF bandwidth	6 ch, 2217–2302 MHz
X-band, number of channels and RF bandwidth	8 ch, 8210–8570 MHz

Table 3. *Frequencies used in observations.*

Channel number of base band convertor	Frequency code	Radio frequency (MHz)
1	X	8210.99
2	X	8220.99
3	X	8250.99
4	X	8310.99
5	X	8420.99
6	X	8500.99
7	X	8550.99
8	X	8570.99
9	S	2217.99
10	S	2222.99
11	S	2237.99
12	S	2267.99
13	S	2292.99
14	S	2302.99

project started, only the Mitaka FX Correlator was capable of cross-correlating the K4 tapes with the S2 tapes. The data on S2 tapes were copied to K4 tapes beforehand with the help of the Time Synchronize Signal (TSS) and the thus copied K4 tapes were played back on the Mitaka FX Correlator.

It was only possible to cross-correlate Syowa data with other data after return of recorded tapes from Syowa Station. This caused us serious difficulties in setting up the observing system because the data quality could not be evaluated until the correlation processing ended, and we had to check the system without confidence in Syowa Station. Given that we had serious difficulties with Syowa system, as summarized in Table 4, we suggest that in the future fringe checks be undertaken by transmitting short data packets over the high-speed satellite link.

In the February experiment, we could not detect fringes in the X band for the baselines including Syowa Station because of a yet unknown reason. One year later, JARE-40 reported a rapid increase of system noise temperature of the receiving system in their June experiment. This might have been resulted from the extremely low temperature in the Syowa antenna receiver room. As for the May experiment, the

Table 4. Results of correlation of the Syowa experiment conducted by JARE-39.

Baseline	JA981a	JA981b	JA982a	JA982b	JA983	JA984
Hh-Ho	○	○	—	○	×	○
Hh-Sy	S	S	○	×	×	○
Hh-Ka	○	—	—	○	—	—
Hh-Pk	—	—	—	—	—	○
Ho-Sy	S	S	—	×	×	○
Ho-Ka	○	—	—	○	—	—
Ho-Pk	—	—	—	—	—	○
Sy-Ka	S	—	—	×	—	—
Sy-Pk	—	—	—	—	—	○

○: Fringes were detected successfully. ×: No fringe was detected. S: Fringes were detected only S band data.

quality of Syowa recorded data was found to have deteriorated gradually as the observation schedule progressed at Syowa Station; the recorder head may have gradually become dirty because of very low humidity. In the August experiment, no fringe was detected. The cause of this is still unclear. In the November experiment, no trouble occurred at all and fringes were detected for all of the baselines. Therefore we analyze only this data set and obtain geodetic solutions.

3. Analysis

3.1. Parameter settings

The principal purpose of these VLBI observations is to determine the coordinates of the Syowa 11-m antenna. To do so we used the CALC3/MSOLV software package. These tools are developed and maintained by NAOJ and they were described briefly in the report to the International Earth Rotation Service (IERS) by Manabe *et al.* (1991).

The CALC3 has almost the same structure as that of CALC, which was developed by the research group at NASA Goddard Space Flight Center (GSFC). However, CALC3 adopts different geophysical models than those adopted by CALC. The differences have the effect of several ten pico seconds at maximum, but we adopted CALC3 to calculate the predicted delay.

The geophysical models adopted by CALC3 are summarized as follows. For comparison, the models used in CALC (version 9.1, released in 1999) are also described.

- 1) Earth tidal deformations are computed on the basis of Wahr's Love and Shida numbers (Wahr, 1981), and the tidal-generating potential by Cartwright and Tayler (1971) and Cartwright and Edden (1973), while CALC uses the IERS 1996 model described in IERS Conventions (1996).
- 2) Ocean tide loading displacements are computed by using GOTIC2 (Matsumoto *et al.*, 2001) on the basis of the NAO99b global ocean tide model (Matsumoto *et al.*, 2000). On the other hand, CALC adopts the IERS Standards model (IERS Conventions, 1996) on the basis of the calculation module for ocean tide loading effect with

the Schwiderski model (Schwiderski, 1980), GOT99.2 model (Ray, 1999), etc. as global ocean tide models.

- 3) Atmospheric loading displacements are not taken into account in our analysis. CALC also unmounts this module.
- 4) Niell's hydrostatic mapping function (Niell, 1996) is adopted for the atmospheric propagation delay and its rate by both CALC and CALC3.
- 5) The IAU1980 nutation model (Wahr, 1981; Seidelman, 1982) is adopted, while CALC uses the IERS96 nutation model by Herring (IERS Conventions, 1996).
- 6) Earth rotation parameters are taken from the IERS Bulletin B by both CALC3 and CALC.
- 7) Stations and radio source positions are taken from the GSFC global VLBI solutions (Ma and Ryan, 1998).
- 8) The ionospheric propagation delay and its rate are not predicted by either CALC or CALC3, as we can estimate them by using the difference between the observed delay and its rate in the X and S bands.

In using MSOLV, the parameters such as the coordinates of the Syowa VLBI reference point, zenith atmospheric delay at every one hour at each station, clock polynomial coefficients at each station, and nutation in longitude and obliquity at the mean epoch of the observations are estimated simultaneously. The radio source positions are taken from the International Celestial Reference Frame 2000 (ICRF2000) catalogue (Ma *et al.*, 1998); the sources' names and their coordinates are listed in Table 5.

Table 5. Radio source coordinates taken from ICRF2000.

Name	Right ascension			Declination		
	hour	min	s	deg	min	s
1057-797	10	58	43.30979	-80	3	54.15949
1921-293	19	24	51.05596	-29	14	30.12115
1741-038	17	43	58.85614	-3	50	4.61668
1958-179	20	0	57.09045	-17	48	57.67251
0208-512	2	10	46.20041	-51	1	1.89200
1034-293	10	37	16.07973	-29	34	2.81322
0537-441	5	38	50.36155	-44	5	8.93908
1954-388	19	57	59.81927	-38	45	6.35626
0637-752	6	35	46.50793	-75	16	16.81533
1144-379	11	47	1.37070	-38	12	11.02353
2145+067	21	48	5.45868	6	57	38.60422
1334-127	13	37	39.78278	-12	57	24.69323
0048-097	0	50	41.31739	-9	29	5.21021
0003-066	0	6	13.89289	-6	23	35.33530
1424-418	14	27	56.29756	-42	6	19.43762
0727-115	7	30	19.11247	-11	41	12.60048
0528+134	5	30	56.41674	13	31	55.14955
0104-408	1	6	45.10797	-40	34	19.96036
1610-771	16	17	49.27640	-77	17	18.46743

3.2. Obtained coordinates of the Syowa VLBI reference point

We fixed the coordinates of Hobart and HartRAO to the International Terrestrial Reference Frame 2000 (ITRF2000) values (Altamimi *et al.*, 2002) and solved for Syowa VLBI reference point. Parkes was not used in the first stage of the analysis, as the Parkes position is not well determined compared with the precision of both Hobart and HartRAO. The initial coordinates of the stations are listed in Table 6. In this estimation, the number of observations used is 459 and the total number of adjusted parameters is 107. The data period is from 1998/11/09/1403:18 through 1998/11/11/0755:18.

Table 6. Initial station coordinates on November 10, 1998 based on ITRF2000.

Station	x (m)	y (m)	z (m)
HartRAO*	5085442.7777	2668263.5287	-2768696.9829
Hobart*	-3950236.8149	2522347.5776	-4311562.4611
Syowa	1766194.1464	1460410.9481	-5932273.3739
Parkes	-4554232.0965	2816758.9637	-3454035.7724

* HartRAO and Hobart are fixed at the ITRF2000 values for subsequent analyses.

The final coordinates determined for the Syowa VLBI reference point at the epoch of November 11, 1998 (1998.9) are:

$$X = 1766194.152 \pm 0.006 \text{ m}, Y = 1460410.923 \pm 0.005 \text{ m} \text{ and} \\ Z = -5932273.329 \pm 0.014 \text{ m},$$

in the geocentric Cartesian coordinates of the ITRF2000 system. Standard deviations in the local topocentric system are estimated to be $\sigma_{N-S} = 0.0044 \text{ m}$, $\sigma_{E-W} = 0.0042 \text{ m}$ and $\sigma_{U-D} = 0.0151 \text{ m}$, where σ_{N-S} , σ_{E-W} and σ_{U-D} denote standard deviations of the North-South, East-West and Up-Down components, respectively. The associated error ellipsoid is shown in Fig. 2.

The errors are almost of the same magnitude for both the N-S and the E-W components; this shows that the azimuthal distribution of observed radio sources is almost isotropic (Fig. 3). The error for the vertical component is about three times as large as those of the horizontal components. The magnitude of the standard deviations obtained in this analysis is of typical values from recent inter-continental VLBI experiments, as shown by *e.g.* Takahashi (1994).

The position of Parkes was then determined by fixing the Syowa position along with those of Hobart and HartRAO. We find:

$$X = -4554231.156 \pm 0.102 \text{ m}, Y = 2816758.791 \pm 0.065 \text{ m} \text{ and} \\ Z = -3454035.602 \pm 0.080 \text{ m},$$

with $\sigma_{N-S} = 0.0137 \text{ m}$, $\sigma_{E-W} = 0.0084 \text{ m}$ and $\sigma_{U-D} = 0.1439 \text{ m}$, again in the ITRF2000

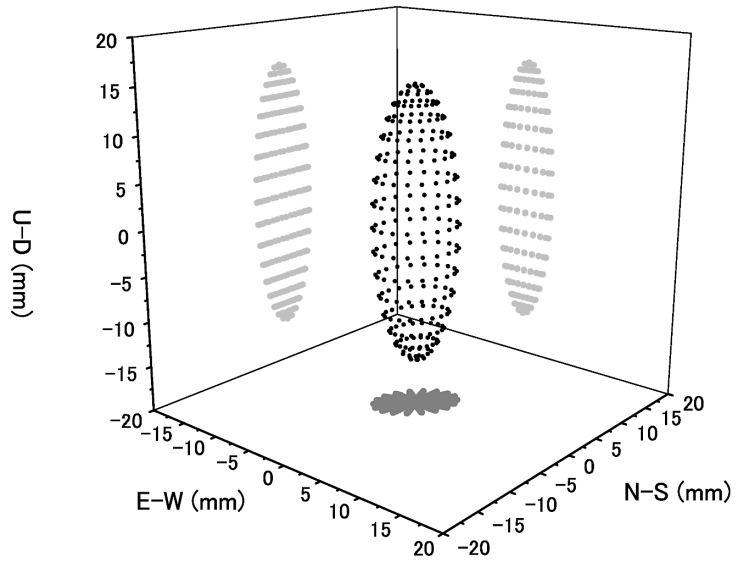


Fig. 2. Error ellipsoid of the estimated position of Syowa VLBI reference point. Lengths of the principal axes are 1.51 cm, 0.47 cm and 0.39 cm. Note that the direction of the major axis almost coincides with the vertical.

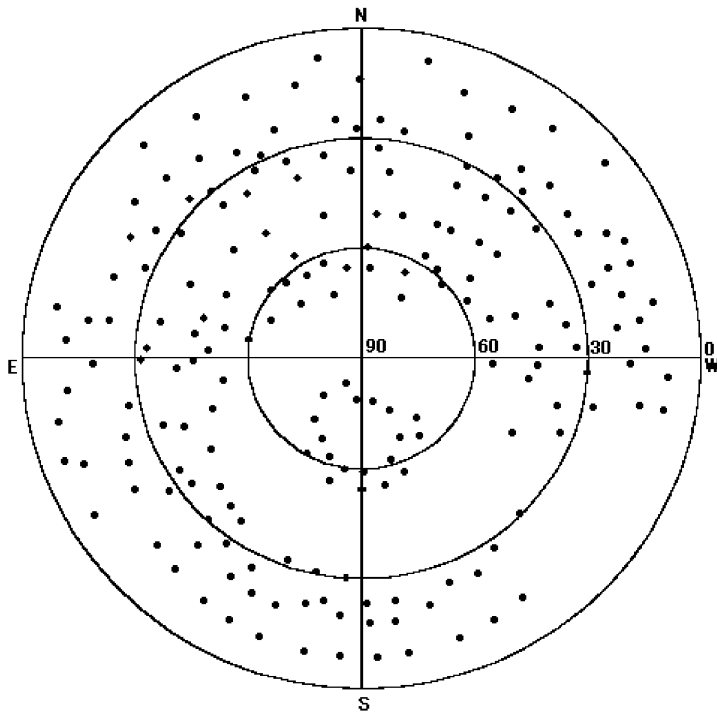


Fig. 3. Sky distribution of scans in the latter half of JA984 in November at Syowa Station.

system. The large value of vertical component error follows from the high value of 30° for the lower elevation limit of Parkes telescope and is also reflected in a high correlation with the zenith atmospheric delay. However, the positioning accuracy of the Parkes antenna reference point must be improved about 1 m as compared with the initial position in Table 6. The position was updated toward 225° azimuth (south-west) and toward -60° dip (near to ground), respectively.

Unfortunately, we have only one successful experiment in 1998. In order to provide an additional determination of the Syowa VLBI reference point, we have undertaken exactly the same reduction procedures as above on the data returned from the September, October and November 1999 observations (SYW995, SYW996 and SYW997) undertaken during JARE-40. The data from each observation were reduced to those of epoch 1998.9 by applying the plate motions given by the NNR-NUBEL-1A (DeMets *et al.*, 1994) plate motion model. The resulting mean positions and their formal errors were found to be:

$$X = 1766194.147 \pm 0.004 \text{ m}, Y = 1460410.916 \pm 0.010 \text{ m} \text{ and} \\ Z = -5932273.304 \pm 0.022 \text{ m},$$

respectively, in excellent agreement with the values and their uncertainties found for the 1998 observations.

4. Comparison with independent estimates

Our present measurements of the position of Syowa VLBI reference point can be compared with both the earlier and later VLBI measurements as well as with the GPS measurements at the Syowa IGS (International GPS Service for Geodynamics) point.

4.1. First VLBI experiment at Syowa Station in 1990 by JARE-30

The first successful geodetic VLBI observations in Antarctica were undertaken in January 1990 during JARE-30 using the Syowa antenna, the 34-m NASA Deep Space Station antenna, DSS45, at Tidbinbilla and the Kashima 26-m antenna (Kurihara *et al.*, 1991; Jauncey, 1991). The coordinates of Syowa VLBI reference point is:

$$X = 1766194.099 \pm 0.061 \text{ m}, Y = 1460410.899 \pm 0.010 \text{ m} \text{ and} \\ Z = -5932273.311 \pm 0.096 \text{ m},$$

in the ITRF92 system at the epoch of 1992.0. These coordinate values are taken from Kanao *et al.* (1995).

4.2. COHIG experiments in the ITRF2000 catalogue

The coordinates and velocities of the Syowa VLBI reference point at the epoch of 1997.0 are given in ITRF2000_VLBI.SSC published by the IERS (taken from http://igs.ifag.de/root_ftp/ITRF/ITRF2000/). These coordinates were determined from four observations called COHIG which were carried out on November 8, 10 and 11 of 1999 and February 10 of 2000. The observation network consisted of Fortaleza in Brazil, Kokee Park in Hawaii, HartRAO, O'Higgins Station on the Antarctic Peninsula, Hobart and Syowa Station. All of the stations except Kokee Park are located in the

Southern Hemisphere. The data were analyzed by Bonn University. Since the observation period spans only three months, which is not long enough to determine velocities, the velocities determined from the Syowa IGS Station and the Syowa DORIS Station are used in the catalogue.

The coordinates of the Syowa VLBI reference point in ITRF2000_VLBI.SSC at the epoch of 1997.0 are expressed as:

$$X = 1766194.139 \pm 0.011 \text{ m}, Y = 1460410.951 \pm 0.011 \text{ m} \text{ and} \\ Z = -5932273.371 \pm 0.022 \text{ m},$$

with the velocities

$$V_X = 0.0038 \pm 0.0008 \text{ m/yr}, V_Y = -0.0015 \pm 0.0008 \text{ m/yr} \text{ and} \\ V_Z = -0.0015 \pm 0.0018 \text{ m/yr},$$

where V_X , V_Y and V_Z are the x-, y- and z-component of the velocity in the geocentric Cartesian coordinate system, respectively.

4.3. JARE experiments since JARE-40

Fukuzaki *et al.* (2005) determined coordinates and velocities of the Syowa VLBI reference point by using data from 25 experiments obtained from SYW and OHIG (renamed from COHIG) sessions from 1999 through 2002. The CALC and SOLVE software from NASA/GSFC are used in their analyses. They obtained the values in the ITRF2000 system at the epoch of 2000.0 as:

$$X = 1766194.125 \pm 0.003 \text{ m}, Y = 1460410.920 \pm 0.002 \text{ m} \text{ and} \\ Z = -5932273.309 \pm 0.005 \text{ m},$$

and

$$V_X = 0.00576 \pm 0.00098 \text{ m/yr}, V_Y = 0.00148 \pm 0.00077 \text{ m/yr} \text{ and} \\ V_Z = -0.00279 \pm 0.0020 \text{ m/yr}.$$

4.4. IGS GPS result

The Syowa IGS point is located on a bare-rock area and its distance from the Syowa 11-m antenna is only several hundred meters. Therefore we can consider that the Syowa 11-m antenna and IGS point are under the same tectonic circumstances.

The coordinates and velocities of the Syowa IGS point determined by the Jet Propulsion Laboratory (JPL), which is one of the IGS analysis centers, are open to the public as a time series of daily solutions from 1999 to 2004; the values at the epoch of 2004.0 are given as:

$$X = 1766207.868 \pm 0.0003 \text{ m}, Y = 1460290.334 \pm 0.0003 \text{ m}, \\ Z = -5932297.696 \pm 0.0007 \text{ m},$$

$$V_X = 0.00405 \pm 0.00013 \text{ m/yr}, V_Y = -0.00349 \pm 0.00013 \text{ m/yr} \text{ and} \\ V_Z = -0.00152 \pm 0.00030 \text{ m/yr},$$

(taken from <http://sideshow.jpl.nasa.gov/mbh/all/table.txt>).

The local-tie vector from the Syowa IGS point to the Syowa VLBI reference point was obtained by several JARE surveys (Kanao *et al.*, 1995; Fukuzaki *et al.*, 2005). The most probable local-tie vector is estimated with maximum probable error of 1–2 cm for each component. We adopt the local-tie vector $(\delta_x, \delta_y, \delta_z) = (-13.714 \text{ m}, 120.574 \text{ m}, 24.362 \text{ m})$ by Fukuzaki *et al.* (2005), in order to reduce the coordinates of the IGS point to the VLBI reference point. The offset-corrected IGS coordinates at the epoch of 2004.0 are calculated as

$$X = 1766194.154 \text{ m}, Y = 1460410.908 \text{ m} \text{ and } Z = -5932273.334 \text{ m},$$

by adding this local-tie vector component, respectively.

4.5. Intercomparison of the position estimates

The coordinates and velocities described in Subsections 4.1–4.4 are expressed in different terrestrial reference frames and epochs. In order to make comparison, ITRF 2000 is adopted as a common terrestrial reference frame. The epoch of 1998.9, which is the epoch of our present analysis, is chosen as the common epoch. Since all of the position estimates are not associated with the velocity estimates, NNR-NUVEL-1A global plate motion model values,

$$V_{X_NUVEL} = 0.0047 \text{ m/yr}, V_{Y_NUVEL} = 0.0013 \text{ m/yr} \text{ and } V_{Z_NUVEL} = 0.0017 \text{ m/yr},$$

are used to correct for the plate motion.

The six sets described above are summarized in Table 7. They are also plotted in Fig. 4 as differences from our result. Coordinates and their error bars given in Table 7 and Fig. 4 are expressed in the geocentric Cartesian coordinate system.

The results including JA or SYW sessions (1, 2 and 5) are consistent as seen in Fig. 4, and the maximum difference among them is about 3 cm. Other results (3, 4 and 6) show the tendency to scatter around our result in session 1. Different observation methods and analysis methods are likely to result in a large discordance of the solutions. Even when we consider the uncertainty in the velocity solution of session 1, our position solution can be considered as accurate enough to keep the error within 3 cm.

Table 7. List of various determinations of coordinates of the Syowa VLBI reference point in the ITRF2000 geocentric Cartesian coordinate system at the epoch of 1998.9.

	X (m)	Y (m)	Z (m)	σX (m)	σY (m)	σZ (m)
1	1766194.152	1460410.923	-5932273.329	0.006	0.005	0.014
2	1766194.147	1460410.916	-5932273.304	0.004	0.010	0.022
3	1766194.114	1460410.896	-5932273.288	0.061	0.010	0.096
4	1766194.147	1460410.948	-5932273.374	0.012	0.012	0.029
5	1766194.120	1460410.918	-5932273.312	0.004	0.003	0.007
6	1755194.134	1460410.891	-5932273.340	0.001	0.001	0.002

1: Our result, 2: Average of SYW995, SYW996 and SYW997, 3: Result of JARE-30, 4: ITRF2000 catalogue, 5: Fukuzaki *et al.*, 2005, 6: Syowa IGS point by JPL.

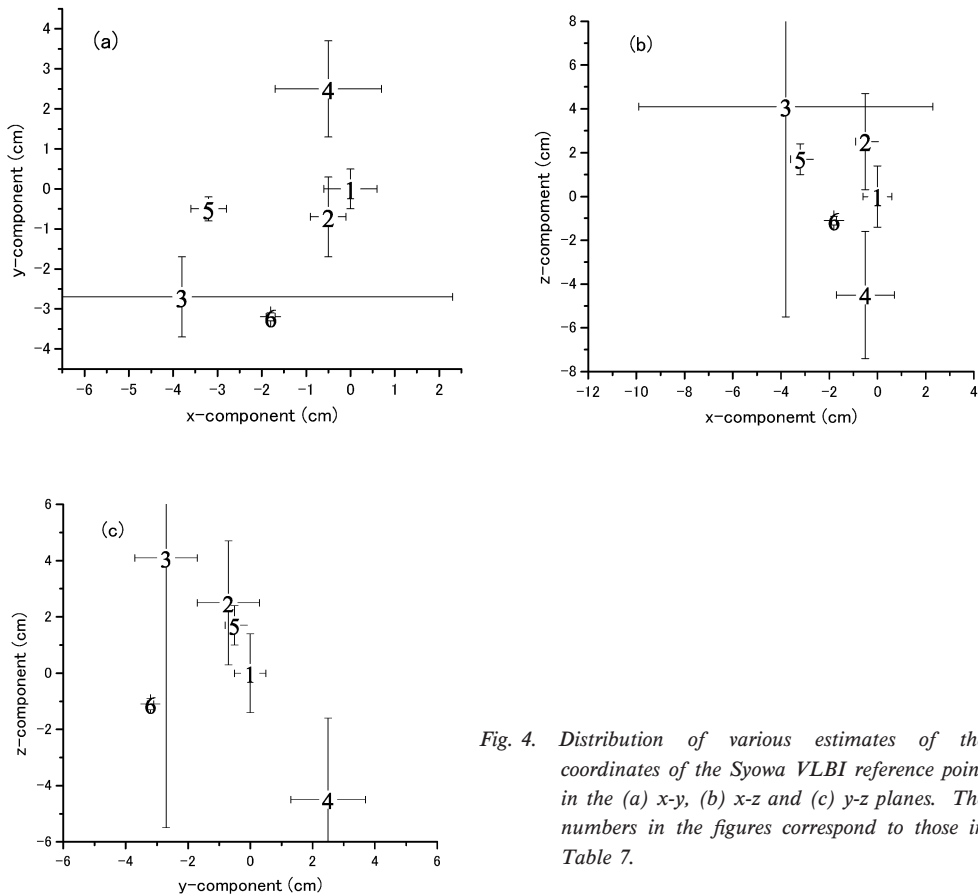


Fig. 4. Distribution of various estimates of the coordinates of the Syowa VLBI reference point in the (a) x - y , (b) x - z and (c) y - z planes. The numbers in the figures correspond to those in Table 7.

5. Geodetic interpretation

A rigid plate is a good approximation to Antarctic plate motion, and geodetic observations at Syowa Station located on the tectonically stable continental shield are important to understand global geodynamics. Although Kubo *et al.* (1998) and Yamada *et al.* (1998) derived anomalous motion of IGS points in Antarctica including Syowa Station, internal deformation within the entire Antarctic Plate has not been detected yet clearly.

Post Glacial Rebound (PGR) is also an interesting subject of Antarctic geosciences. Miura *et al.* (2002) suggested upheaval of 2–3 mm/yr from geomorphological records of the seashore lines and ages of the fossil shells in the Lützow-Holm Bay region. On the other hand, Odamaki *et al.* (1991) estimated an apparent sea level fall of 9.5 mm/yr at Syowa Station from tide gauge data from 1981 to 1987. However, these studies measure vertical motion on a geological time average or are affected by inaccurate determination of the mean sea level. In order to reveal whether PGR is

ongoing or not, it is very important to directly detect present-day vertical motion by precise geodetic measurements.

Fukuzaki *et al.* (2005) estimated the change-rates of horizontal baseline lengths including Syowa Station, and found that it does not differ significantly from the predictions of the NNR-NUVEL-1A model. For upward motion, 4.6 ± 2.2 mm/yr is obtained, but it requires much a longer time span to obtain a definite conclusion for the uplift rate. For reference, the vertical velocity at Syowa Station derived from ITRF 2000_VLBI.SSC gives another estimate of 1.8 mm/yr. We expect that upheaval by PGR and intra-plate deformation of the Antarctic Plate will become much clearer by continuing VLBI observations in the Southern Hemisphere.

6. Summary and conclusions

A regular geodetic VLBI experiment was resumed at Syowa Station in JARE-39 (1998) as one of the important research subjects of Antarctic geosciences after an 8-year interruption from JARE-31. Continuous observations are now under way. JARE-39 carried out 4 experiments during the wintering. The Mitaka FX Correlator was used in the correlation processing of K4 and S2 recorded VLBI raw data. Fringes which were strong enough for geodetic analysis are detected from the experiment in November 1998.

The coordinates of the Syowa VLBI reference point were determined with the geodetic analysis software CALC3/MSOLV developed by NAOJ. The formal errors were about 4 mm for the horizontal components and 15 mm for the vertical component. These errors are consistent with those of recent intercontinental geodetic VLBI observations. The comparison of our 1998 November experiment with three experiments in 1999 which were analyzed under the same conditions showed good consistency within the associated errors.

The coordinates of the Syowa VLBI reference point at the epoch of 1998.9 were compared with other results obtained by several space geodetic methods. Our result was in good agreement with those from other VLBI experiments which were analyzed by using different software CALC/SOLVE developed by GSFC/NASA. We conclude that hybrid operations of completely different types of VLBI data acquisition system, K4 and S2, can be performed successfully in geodetic experiments in Antarctica using the Mitaka FX Correlator.

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