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Status and Results of JARE Syowa Station, Antarctica

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Abstract

The Japanese Antarctic Research Expedition (JARE) has started regular VLBI experiments at Syowa Station (69.0° S and 39.6° E) on East Ongul Island, Antarctica in 1998. This series of experiments was called 'Syowa VLBI session' or 'SYW session.' Three stations in the Southern Hemisphere, Syowa, Hobart (Australia) and HartRAO (South Africa), have participated in this session. Since 1999, Syowa Station has also participated in 'OHIG session'. SYW session ended in December 2004 and Syowa Station started to participate in CRF deep-south (CRD) session in addition to OHIG in 2005. The K5 recording system was partly introduced in 2004 and fully replaced K4 in 2005 at Syowa Station. Until the end of 2005, Syowa Station has performed 65 experiments, 42 experiments of which were carried out from May 1999 to December 2004 have been reduced and analyzed using CALC/SOLVE. The results show that the length of the Syowa-Hobart baseline is increasing linearly with a rate of 54.4 ± 0.9 mm/yr. The Syowa-HartRAO baseline is also increasing, but at the lower rate of 11.1 ± 0.7 mm/yr. These results approximately agree with those of GPS and the NNR-NUVEL-1A plate motion model. On the other hand, we cannot find a significant change with the Syowa-O'Higgins baseline. The current status of Syowa Station and the results of the analysis are briefly reported.

1. Status of the Station

Syowa Station is located at 69.0° S and 39.6° E on East Ongul Island, Antarctica, which is the southernmost VLBI station. It has grown to be one of the key stations for global geodynamics in the Southern Hemisphere. There are an IGS GPS station, a DORIS beacon, a superconducting gravimeter, a seismometer and a tide gauge in addition to VLBI, as reported in [1].

Regular experiments started in February 1998 with Hobart and HartRAO. This series of experiments was named 'SYW session.' Syowa Station has also participated in 'OHIG session' since 1999. The 1999 experiment was the first VLBI observation on an intra-Antarctic plate baseline. SYW session ended in December 2004 and Syowa Station started to participate in CRF deep-south (CRD) session in addition to OHIG in 2005. Until the end of 2005, 65 experiments were performed.

The K4 recording system was used until 2004. The K5 recording system was partly introduced in 2004 and fully replaced K4 in 2005. The data obtained by K5 system in 2005 were brought back from Syowa Station to Japan and ftp-transferred to Haystack Observatory via NiCT server to be converted into the Mark 5 format.

2. Analysis Results

2.1. Variation of Baseline Length

We used the CALC/SOLVE analysis software developed by GSFC. The versions of CALC and SOLVE that were used are 9.12 and 2003.05.16, respectively. We chose Hobart, HartRAO, Fortaleza and Kokee as stations with fixed station coordinates and velocities in ITRF2000, and solved for the station coordinates and velocities of Syowa, O'Higgins and TIGO-Concepción for each epoch. The models for Earth orientation parameters, ocean tide loading and atmospheric effects used in our analysis are listed in Table 1.

Table 1. List of the models used in our analysis

	VLBI	**GPS**
Earth Orientation Parameter	NASA Goddard Space Flight Center VLBI group	IERS EOP Product Center
Ocean Tide Loading	Scherneck model	Scherneck model
Atmosphere		
Dry and Wet	Niell's mapping function	Niell's mapping function
Gradient	Not applied	Not applied
Pressure Loading	Not applied	Not applied

The 42 baseline solutions for the sessions from 1999 through 2004 are estimated by using the SOLVE interactive mode. Solid diamonds with error bars in Figure 1 show the results for the baseline lengths for Syowa-Hobart (top), Syowa-HartRAO (middle), and Syowa-O'Higgins (bottom), respectively. Applying a simple linear model for baseline evolution, secular changes in baseline lengths are detectable. The length of the Syowa-Hobart baseline is increasing with a rate of 54.4 ± 0.9 mm/yr. The Syowa-HartRAO baseline shows a smaller but still significant increase of 11.1 ± 0.7 mm/yr. The Syowa-O'Higgins baseline gives a small (-1.9 ± 3.2 mm/yr) apparent shrink.

On the other hand, the GPS baseline length results are estimated by using the GIPSY OASIS II software package in precise point positioning (PPP) mode. The point positioning results of both ends of a baseline from the corresponding daily files are used to calculate the baseline lengths and plot the daily solutions. In the analysis, default models of different Earth orientation parameters that are not used for the VLBI analysis were applied as summarized in Table 1. The results from VLBI and GPS are summarized in Table 2.

Table 2. Summary of the baseline change rates from VLBI and GPS

	VLBI (mm/yr)	**GPS** (mm/yr)
Syowa - Hobart	54.4 ± 0.9	56.0 ± 0.3
Syowa - HartRAO	11.1 ± 0.7	13.0 ± 0.2
Syowa - O'Higgins	-1.9 ± 3.2	0.6 ± 0.7

2.2. Coordinates

By using the SOLVE batch mode, the VLBI coordinates and velocities of the antenna reference point were obtained in the ITRF2000 frame at the epoch of 1997.0 as given in column 1 (VLBI estimate) of Table 3. For comparison, the ITRF2000 website gives the corresponding coordinates from GPS at the epoch of 1997.0 as given in column 4 (GPS from ITRF2000).

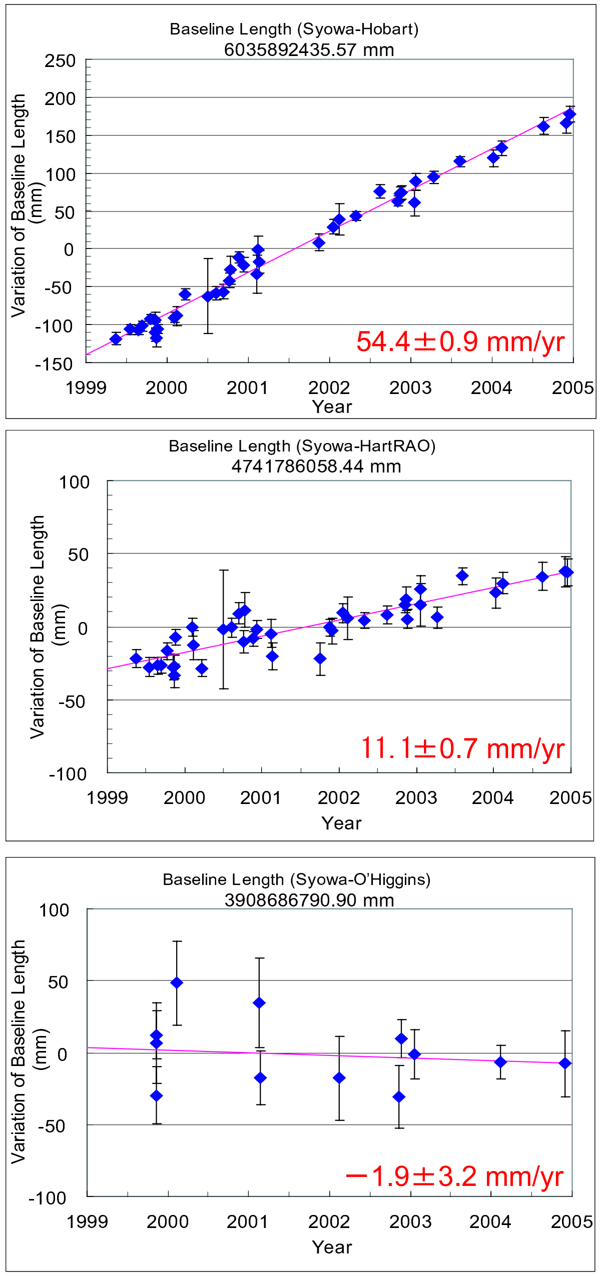

Figure 1. Time-series of 3D baseline lengths for Syowa-Hobart (top), Syowa-HartRAO (middle) and Syowa-O'Higgins (bottom).

The current best estimate of the local tie vector is obtained as -13.714 m for X component, 120.574 m for Y component, and 24.362 m for Z component, respectively. The maximum uncertainties are on the order of 1-2 cm for each component.

A summary of VLBI and GPS coordinates is given in Table 3. We note that subtracting the local tie (column 2) from the estimated VLBI coordinates (column 1) results in offset-corrected

VLBI coordinates at the IGS GPS marker; these values are tabulated in column 3 (offset-corrected VLBI).

Subtracting the GPS from ITRF2000 coordinates (column 4) results in the differences shown in column 5 (difference). They are less than 2 cm, constituting the current degree of consistency between the VLBI system and the GPS system at Syowa Station.

Table 3. Summary of VLBI and GPS coordinates

	VLBI estimate, this paper (m)	local tie (m)	offset-corrected VLBI (m)	GPS from ITRF2000 (m)	difference (cm)
X	1766194.111 ± 0.002	-13.714 ± 0.01	1766207.825	1766207.841 ± 0.003	-1.6
Y	1460410.924 ± 0.002	120.574 ± 0.01	1460290.350	1460290.350 ± 0.002	0.0
Z	-5932273.308 ± 0.005	24.362 ± 0.02	-5932297.670	-5932297.680 ± 0.007	1.0

2.3. Topocentric Position Change

When we convert the geocentric coordinates of Syowa Station into topocentric coordinates and plot the measured height versus time after each observation epoch, the vertical change rate amounts to 1.5 ± 1.2 mm/yr from VLBI and 2.3 ± 0.3 mm/yr from GPS. The topocentric velocities of the Syowa reference points are summarized in Table 4.

In a similar fashion, the crustal uplift rates for O'Higgins Station can be estimated to 4.4 ± 0.7 mm/yr from VLBI and 5.9 ± 0.5 mm/yr from GPS.

Table 4. Topocentric velocities of the Syowa reference points

Up (mm/yr)	**East (mm/yr)**	**North (mm/yr)**	**reference**
1.5 ± 1.2	-4.3 ± 0.3	2.8 ± 0.4	VLBI (1999-2004), this paper
2.3 ± 0.3	-4.4 ± 0.2	-0.2 ± 0.2	GPS (1999-2003), this paper
2.5 ± 0.3	-5.4 ± 0.1	0.8 ± 0.1	GPS (1999-2004), JPL website
3.6 ± 0.2	-6.5 ± 0.8	3.2 ± 0.9	DORIS (1999-2004) from P. Willis

2.4. Comparison with Plate Motion Model

Since the vertical uplift trend at Syowa and O'Higgins Stations will cause some change in the horizontal baseline, we correct for this by assuming the uplift rates of 2 mm/yr (Syowa) and 5 mm/yr (O'Higgins), respectively. Thus the estimated opening rates are 53.5 ± 0.9 mm/yr (VLBI) and 55.1 ± 0.3 mm/yr (GPS) for Syowa-Hobart, 10.4 ± 0.7 mm/yr (VLBI) and 12.3 ± 0.2 mm/yr (GPS) for Syowa-HartRAO, and -2.9 ± 3.2 mm/yr (VLBI) and -1.6 ± 0.7 mm/yr (GPS) for Syowa-O'Higgins, respectively.

The predicted rates of the baseline length change by the NNR-NUVEL-1A model are 52.73 mm/yr (Syowa-Hobart) and 11.46 mm/yr (Syowa-HartRAO), respectively. Since the NNR-NUVEL-1A model adopts one rigid Antarctic-plate, the model postulates zero change for the Syowa-O'Higgins baseline length. The horizontal baseline change rates are summarized in Table

5.

Table 5. Summary of the horizontal baseline change rates from VLBI, GPS and NNR-NUVEL-1A

	VLBI (mm/yr)	**GPS** (mm/yr)	**NNR-NUVEL-1A** (mm/yr)
Syowa - Hobart	53.5 ± 0.9	55.1 ± 0.3	52.73
Syowa - HartRAO	10.4 ± 0.7	12.3 ± 0.2	11.46
Syowa - O'Higgins	-2.9 ± 3.2	-1.6 ± 0.7	—

3. Summary

- Routine geodetic VLBI observations at Syowa Station have been made since 1998 among the Southern Hemisphere network including O'Higgins, Hobart, HartRAO, Fortaleza and TIGO-Concepción.
- SYW session ended in December 2004 and Syowa Station started to participate in CRF deep-south (CRD) session in addition to OHIG in 2005.
- K5 recording system was partly introduced in 2004 and fully replaced K4 in 2005.
- The data of 42 experiments carried out from May 1999 to December 2004 have been reduced and analyzed using CALC/SOLVE. The rates of change of baseline length as measured with VLBI are consistent with those determined by GPS and NNR-NUVEL-1A within 3 sigma. The results do not yet have a high level of significance of the change in the baseline length between Syowa (East Antarctica) and O'Higgins (West Antarctica).
- The estimated vertical change rates with VLBI indicate 2 and 4 mm/yr uplift rates at Syowa and O'Higgins Stations, respectively.
- The offset-corrected VLBI coordinates at Syowa Station have inconsistencies of less than 2 cm against the independently estimated GPS coordinates, where the accuracy of local tie is estimated as 1-2 cm for each component.

References

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