Co-location Surveys & Results in GSI's Space Geodetic Network

Shigeru Matsuzaka, Hiromitchi Tsuji, Yuki Hatanka, and Kazuhiro Takashima

Geographical Survey Institute, Japan, 1 Kitasato, Tsukuba, Ibaraki, 305-0811 Japan
Contact author: shigeru@gsi.go.jp

Abstract. We report on the present results of our co-location surveys at our domestic VLBI network sites and a preliminary comparison of VLBI and GPS solutions on a baseline between Tsukuba and Shintotsukawa. The comparison shows no systematic differences exceeding 10^{-8} between the two techniques. The biggest errors in co-location surveys lie in coordinate transformation process to align the local tie-vector to a global one.

1 Introduction

Geographical Survey Institute (GSI), Japan has established and maintains nationwide space-geodetic networks consisting of 4 VLBI stations and 1,200 GPS tracking sites (GEONET: GPS Earth Observation NETwork), see Figure 1. Accurate tie information is indispensable for the maintenance of the high-precision terrestrial reference frame and it is true for our new geodetic system (JGD2000) as it is based on the fundamental network consisting of VLBI and GPS. In the establishment of JGD2000, we mainly used local GPS observations to connect the accuracy of the ties was estimated as 5mm for the horizontal and 20mm for the vertical component [6].

As the precision of space geodetic measurement improves, co-location should be established with same as or better than the accuracy of these techniques and for more precise ties, we adopted a conventional survey method to connect reference points of VLBI and GPS. This is the report of our co-location surveys to improve our space-geodetic ties in the new geodetic coordinate system. A brief introduction of method and procedure of our local surveys is described in section 2. To check the results in section 3, preliminary comparison was made between the time series of baseline solutions in section 4.

2 Method of local-tie

For GPS and VLBI connection, conventional terrestrial survey method was chosen for the 3D positional determination of reference points. Specifically, we made electro-optical measurements for distance and angles and/or leveling observations. In a small local network conventional survey could yield mm-accuracy (Figure 2).

2.1 Procedures

We took the following procedures:

- Establishment of permanent ground monuments
- Network survey of the monuments
- Determination of space-geodetic reference points from the ground monuments around them.
  Reference point was defined as:
  - for VLBI, intersection of azimuth and elevation axis (the center of a spherical shell on which a target on the antenna traces as the antenna points to various directions);
  - for GPS, designated position on the antenna, phase center calibration will be done by GPS analysis software.
- Alignment of local tie vector to a global frame (see [3] for details)

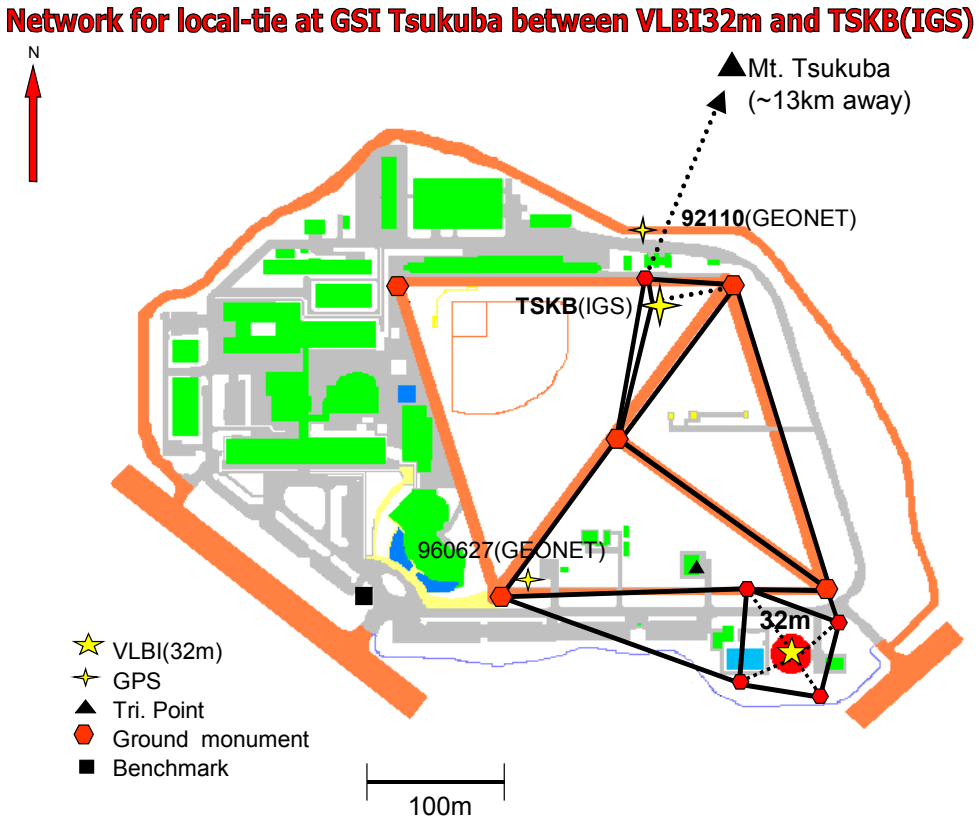

Fig. 2: Local Network at Tsukuba VLBI station

2.2 Alignment of the tie vector to a global frame

To be used in a comparison or integration of multi techniques, a local vector must be transformed into a global reference system. Specifically, the orientation and vertical direction of a local network should be known. We made GPS observation for orientation and used deflection of the vertical from past astronomical observations. Alternatively 7 parameters in Helmert transformation could be obtained only by GPS observations, which we did not adopt here.

We think the biggest errors would be introduced here in the transformation process from local to global coordinates although GPS observation was a typical 24-hour session for precise surveying. GPS errors could be as big as a few cm due to environmental situation or statistical variation as the time series solutions of continuous GPS network show. Continuous or multi-day observations will be necessary to get highly reliable GPS vectors for transformation.

3 Results

Connection of reference points by ground survey yielded a precise tie at each of the three stations in a local system (Table 1).

Table 1. Determination of reference positions

rms (mm)		Shintotsukawa-3.8m	Tsukuba-32m	Aira-10.3m
3D positions of ground monuments		1-2	0-1	1-4
VLBI reference position	3D	0.7	0.2	0.5
	Radial component	1.0	0.6	0.3

We could see VLBI references were determined very well and each antenna structure was rigid enough to show no noticeable axis offsets.

For transformation of the local relative vector to global ITRF system, we made GPS observations between the network and a direction maker 7-13km away from the site to determine the network's horizontal orientation and used the deflection of the vertical at the site. For the deflection of the vertical, we used the value obtained by astronomical observations at Tsukuba (1980-1983) and interpolated one from Japan's Geoid model (GSIGEO2000, [3]) at Shintotsukawa. The interpolation was compared with several sites with observed values and considered good enough for the transformation.

4 Comparison of domestic VLBI and GEOENT GPS solutions

Two sets of time series solutions were compared on the baseline vector from GEONET 92110 (Tsukuba) to 942001 (Shintotsukawa). VLBI solutions were converted to the GPS baseline with simple vector additions as depicted in Figure 3. Analysis system was Calc/Solve for VLBI and Bernese for nationwide GPS network [1]. Figure 4 shows the two sets of solutions from 1995 to 2003 for each component of the vector. No artificial offset between the two series was added. In horizontal components no systematic differences exceeding a few cm are seen. In contrast, the vertical series differ by a few cm or more and we'll need to investigate what causes this discrepancy. Possible causes are, simple error of calculation, snow on GPS antenna, local site-specific effects, etc.

5 Conclusions and future works

An accurate local-tie was established at 3 of 4 GSI VLBI sites in Japan. Co-location survey will be completed in 2004-5 if the remaining Chichijima site is co-located. Now that domestic VLBI experiment has tripled its frequency (once per month in 2003) and time series solutions will be a reference for Japan's geodetic network by comparing and combining with daily GPS solutions.

Connections of VLBI and GPS reference points were established at sub-mm level by conventional surveying method. There still remain more than a few mm uncertainties when it comes to align the local vectors to a global frame due mainly to the uncertainties of GPS observations. We should increase the number of GPS observations for taking data for a few to ten days.

Preliminary comparison of VLBI and GPS time series solutions showed the relative differences are smaller than 10^{-8} on an 840km baseline of our VLBI network for horizontal components and length, whereas the height components differ significantly than expected from the internal consistency and we should re-check the comparison process and clear the possible reasons.

Investigation on smaller geophysical, meteorological and environmental effect on site positions becomes more important than ever as we further pursue the improvement of space geodetic observation. We will have to look into antenna thermal deformation, various loading effects and site specific environmental effect, see ex. [5] and [6] for the case of Tsukuba.

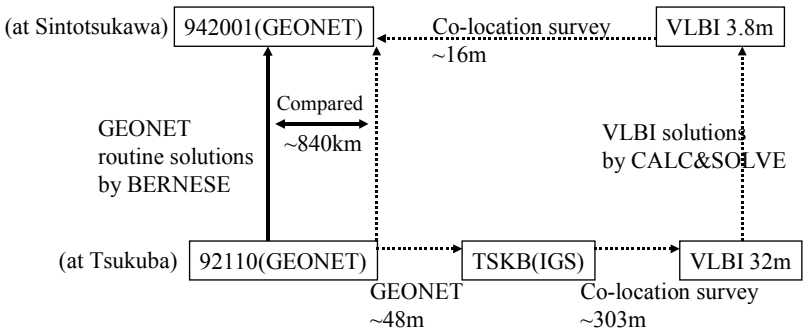

Figure 3. Comparison of domestic VLBI and GEONET GPS solutions.
GEONET and VLBI+co-location solutions were compared
on the baseline vector (942001-92110)

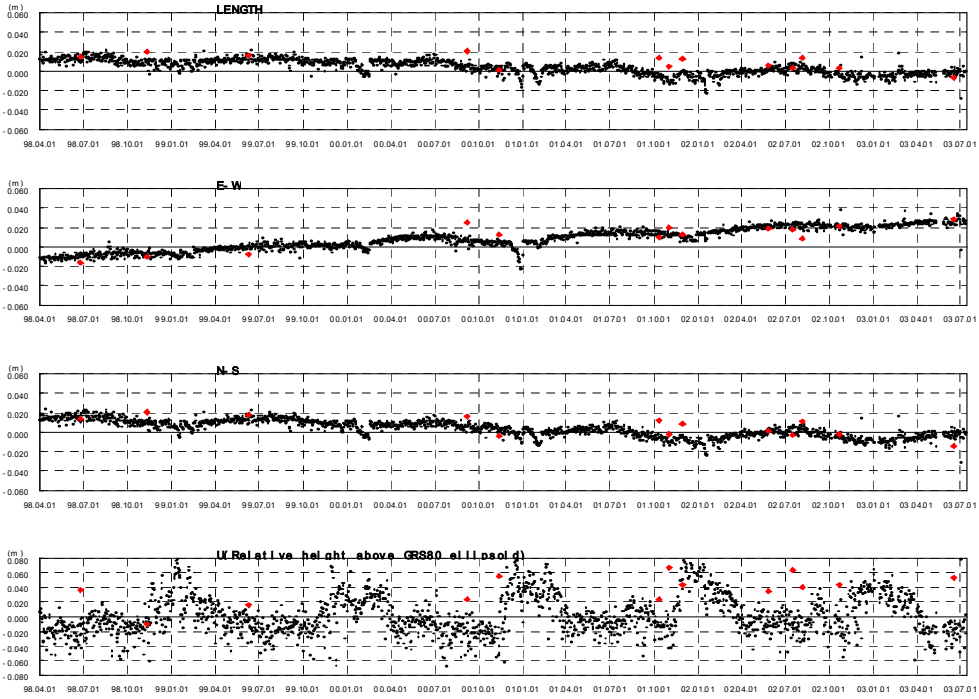

Figure4. TSUKBA-SINTOTSUKAWA baseline vector Time Series
(GPS •, VLBI ◆)

References

[1] Hatanaka, Y., T. Iizuka, M. Sawada, A. Yamagiwa, Y. Kikuta, J. M. Johnson and C. Rocken: Improvement of the Analysis Strategy of GEONET, Bulletin of the Geographical Survey Institute, 49, 1-35, 2003.

[2] Kuroishi, Y., H. Ando and Y. Fukuda: A new hybrid geoid model for Japan, GSIGEO2000 derived from the gravimetric geoid model, JGEOID2000 and the nationwide net of GPS at benchmarks, Journal of Geodesy 76, 428-436, Springer, 2002.

[3] Matsuzaka, S., Y. Hatanaka, K. Nemoto, Y. Fukuzaki, K. Kobayashi, K. Abe and T. Akiyama: VLBI-GPS Collocation Method at Geographical Survey Institute, International VLBI Service for Geodesy and Astrometry 2002 General Meeting Proceedings, 96-100, 2002.

[4] Munekane, H., M. Tobita and K. Takashima: Groundwater-induced vertical movements observed in Tsukuba, Japan, GRL, 31, L12608, doi:10.1029/2004GL020158, 2004.

[5] Tobita, M., H. Munekane, M. Kaidzu, S. Matsuzaka, Y. Kuroishi, Y. Masaki and M. Kato: Seasonal variation of groundwater level and ground level around Tsukuba, J. Geod. Soc. Japan, 50, No.1, 27-37, 2004.

[6] Tsuji, H., and S. Matsuzaka: Realization of Horizontal Geodetic Coordinates 2000, Bulletin of the Geographical Survey Institute, 51, Special Number: Outline of the New Japanese Geodetic System, 11-30, 2004.