Yoshimitsu Masaki et al.: Local Tie Survey at VERA Ogasawara Station at Site Chichijima, IVS 2006 General Meeting Proceedings, p.366–370
http://ivscc.gsfc.nasa.gov/publications/gm2006/masaki

Local Tie Survey at VERA Ogasawara Station at Site Chichijima

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Abstract

We made a local tie survey between the VERA-Ogasawara VLBI station of the National Astronomical Observatory of Japan (DOMES number 21732S005), and the GPS station CCJM at Chichijima (DOMES number 21732S003). Chichijima is one of the Bonin (Ogasawara) Islands on the Philippine Sea plate. Since there is no other suitable site for geodetic observations nearby, the local ties at Chichijima play an important role for the maintenance of the terrestrial reference frame. This is the first local tie at this site, not counting the one classified as 'a dubious tie'.

Our result shows that the relative position between these two stations is determined with uncertainties of (X, Y, Z) = (2.0mm, 1.4mm, 1.5mm). We show error budgets in our analysis process and found that the GPS accuracy has a key role to obtain precise local ties.

1. Introduction

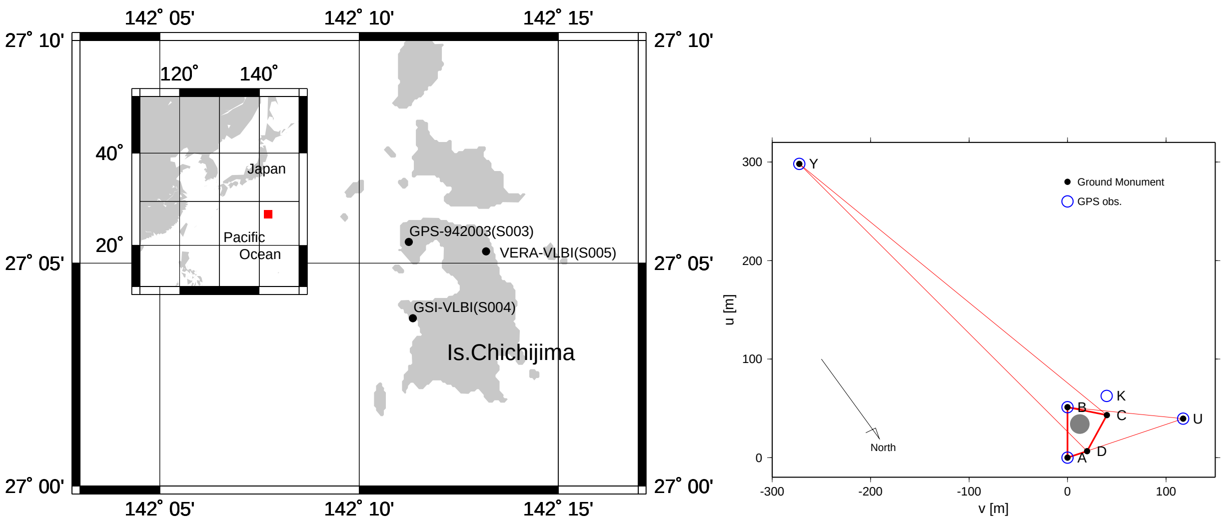
Local ties play an important role for construction and maintenance of a terrestrial reference frame (TRF) because local ties are the only techniques that can combine geodetic solutions obtained by different space geodetic techniques (VLBI, GPS, SLR, etc.) into a unique one. The current accuracy required for local ties is about 1 cm, but mm-level accuracy should be achieved in the next decade (Altamimi et al. [2]). On the other hand, non-uniformly distributed local ties over the world may cause serious problems for the global consistency of a TRF. Filling observation gaps is a key issue to solve the problem.

In this paper, we report our local tie survey made on the island of Chichijima (site number 21732, approximate location: 27°05′N, 142°10′E). This site is classified as an important site for the construction of a TRF (see Altamimi (2001) [1]). The island is located on the Philippine Sea plate, where no other sites are available near by. In spite of the importance of local ties at the site, no survey has been made until the current survey, not counting one classified as a dubious tie.

The VERA project, promoted by the National Astronomical Observatory of Japan, is aiming at precise radio astrometry observation with 10 μas accuracy and precise geodetic observation. Four stations were constructed, the Ogasawara station is one of them. The current status of the VERA project was presented by Jike et al. (2006) [3] and Kobayashi et al. (2006) [4] at this meeting.

2. Survey and Analysis

We made an in-situ survey on the island during December 10-20, 2003. We tried to make a tie between the GPS station S003 and the VERA VLBI station S005. Our local survey network is shown in Figure 1.



(a) (b)

Figure 1. (a) Island Chichijima (site number 21732). The island is located on the Philippine Sea plate. The baseline length between the GPS station S003 and the VERA-Ogasawara station S005 is about 3,200 meters. (b) Our survey network. The VLBI antenna is located in the quadrangle formed by ABCD.

Our analysis process is composed of four steps. First, we determined the positions of six ground monuments (designated as A to D, U and Y in Figure 1). Second, we measured the relative positions of a CATEYE reflector attached to the rigid support of the VLBI antenna with respect to the four ground monuments, A to D. (Matsuzaka et al. [5] describe details on the reflector.) Because a target reflector moves on a spherical shell centered at the VLBI reference point during Az-El driving, we can determine the spherical center by using a least squares method (Step 3).

We also made GPS observations at the four ground monuments A, B, U and Y, in order to relate the local coordinates (U, V, W) to the global Cartesian coordinates (X, Y, Z) using a Helmert transformation. In Step 4, we transform the local coordinates of the antenna reference position into the global coordinates by a Helmert transformation.

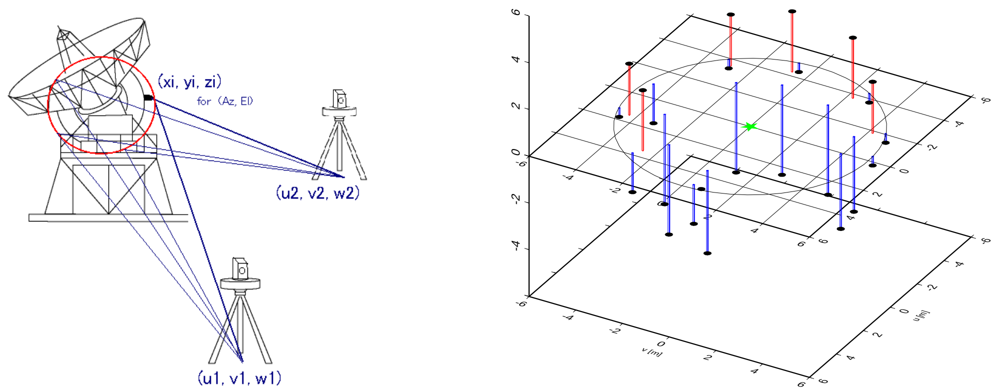
3. Results

Our results on the relative baseline vector from the GPS S003 to the VLBI S005 are:

$$\begin{aligned} dX &= -2143.0748 \pm 0.0020 \quad [\mathrm{m}] \\ dY &= -2358.3014 \pm 0.0014 \quad [\mathrm{m}] \\ dZ &= -\ 343.6853 \pm 0.0015 \quad [\mathrm{m}], \end{aligned} \tag{1}$$

or (the coordinates (N, E, U) are tangent to the reference ellipsoid at the GPS station S003)

$$\begin{aligned} dN &= -418.5073 \pm 0.0007 \quad [\mathrm{m}] \\ dE &= 3176.9961 \pm 0.0008 \quad [\mathrm{m}] \\ dU &= 63.4282 \pm 0.0026 \quad [\mathrm{m}]. \end{aligned} \tag{2}$$



(a) (b)

Figure 2. (a) Explanatory illustration how to determine the positions of a CATEYE reflector from two ground monuments. (b) The 3-D distribution of the measured CATEYE positions (black dots) for the estimation of the VLBI reference point. The reference point of the antenna (equivalent to the spherical center of CATEYE positions) is determined with errors $(\sigma_U, \sigma_V, \sigma_W) = (0.28, 0.31, 0.44)$ [mm] in the local coordinates. The RMS fitting error of a spherical shell in the radial direction is 0.19 mm.

The baseline vector from the GPS station K to the VLBI S005 (tangent to the reference ellipsoid at K) is:

$$\begin{aligned} dN &= 7.1660 \pm 0.0007 \quad [\mathrm{m}] \\ dE &= 38.9515 \pm 0.0009 \quad [\mathrm{m}] \\ dU &= 7.5730 \pm 0.0031 \quad [\mathrm{m}]. \end{aligned} \tag{3}$$

For the sake of accuracy check, we compare this result to another one obtained independently for the baseline vector from the GPS antenna K to the VLBI S005. These two horizontal positions show good agreement.

4. Future Improvements

As summarized in Table 1 and 2, GPS positions determined from a 24-hour session degrade uncertainties to a sub-mm level, despite smaller uncertainties of $(\sigma_U, \sigma_V, \sigma_W) = (0.28, 0.31, 0.44)$ [mm] achieved in the determination of the antenna reference point through our ground survey.

When we collect GPS data for much longer sessions, the uncertainties of GPS positioning are supposed to be decreased by an inverse square-root law with time. In theory, GPS data for more than two weeks is necessary to achieve the uncertainties within 1mm.

5. Acknowledgements

The authors acknowledge to Y. Sasaki, M. Shibahara, T. Tsutsumi and J. Miyamoto (Geographical Survey Institute) for this successful in-situ survey with us, and K. Horiai and O. Kameya (National Astronomical Observatory of Japan) for their sincere supports for using the VERA facility.

Table 1. Errors of our local tie analysis. Units are [mm]. We fix the position of A during a net adjustment. The VLBI reference point in the local coordinates (U, V, W) is obtained through Step 3. GPS uncertainties are given for baseline measurements relative to the GPS station S003. The last three columns are expected uncertainties after a Helmert transformation. GPS data at Y is excluded from the determination of transformation parameters due to its large misfits.

Monument	ground survey (Steps 1 and 3)			GPS obs.			after Helmert trans. (Step 4)		
	σ_U	σ_V	σ_W	σ_N	σ_E	σ_U	σ_N	σ_E	σ_U
A	-	-	-	0.64	0.66	3.00	0.65	0.69	3.23
B	0.59	0.15	0.14	0.83	0.86	3.97	0.79	0.99	4.24
C	0.53	0.48	0.15	-	-	-	1.28	0.65	3.23
D	0.13	0.25	0.10	-	-	-	0.66	0.76	2.96
U	0.65	1.31	1.46	0.58	0.60	2.62	1.29	1.25	4.15
Y	1.71	1.79	2.47	0.57	0.61	2.61	..	..	..
VLBI ref. point	0.28	0.31	0.44	-	-	-	0.73	0.90	3.12

Table 2. Summary of the error budgets of our local-tie analysis.

Steps	Position(s) to be determined [Uncertainties quatified by]	Position uncertainties
Step 1	Ground monements [Standard deviations of a net adjustment]	a few mm
Step 2	Cateye reflector [RMS discrepancies in CATEYE positions between two measurements]	a few mm
Step 3	VLBI antenna reference point in local coordinates (U, V, W) [RMS spherical shell fitting errors by least squares method]	sub-mm
Step 4	VLBI antenna reference point in global coordinates (X, Y, Z) [Formal errors propagated through a Helmert transformation with GPS observation data]	several mm (sub-cm)

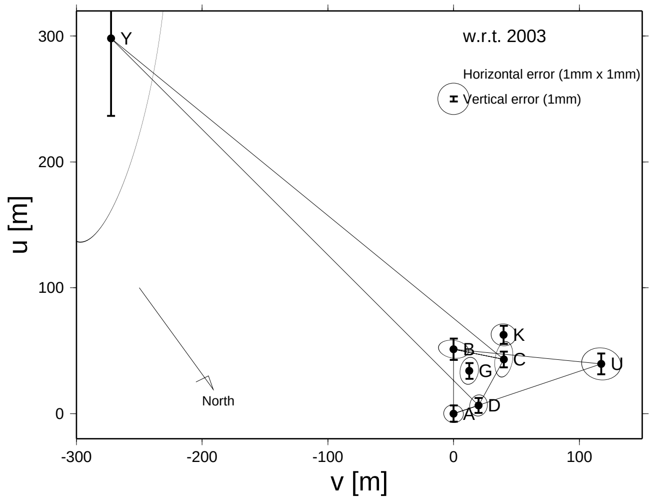


Figure 3. Expected uncertainties of the relative positions to the GPS station S003 after a Helmert transformation into the (N, E, U) coordinates. See also Table 1. We discard GPS data at Y due to its quality.

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