Daniel Hernandez et al.: GPS on the VLBI Telescopes at Onsala and Ny-Ålesund, IVS 2006 General Meeting Proceedings, p.167–171
http://ivscc.gsfc.nasa.gov/publications/gm2006/hernandez-haas

GPS on the VLBI Telescopes at Onsala and Ny-Ålesund

Daniel Hernandez, Rüdiger Haas

Onsala Space Observatory, Department of Radio and Space Science, Chalmers University of Technology
Contact author: Rüdiger Haas, *e-mail:* haas@oso.chalmers.se

Abstract

In the years 1999 and 2000 the VLBI stations at Onsala and Ny-Ålesund were equipped with GPS antennas mounted on top of the radio telescopes. Since then several GPS measurement campaigns were carried out to check the stability of the telescopes and to monitor the local tie between the reference monuments for the International VLBI Service for Geodesy and Astrometry (IVS) and the International GPS Service (IGS). In this paper we present the results of the analysis of the GPS observations recorded since the antennas were installed.

1. Introduction

The Onsala Space Observatory has a long record in geodetic VLBI observations, going back to the late 60ies of the last century [1]. Today it is an active network station in the International VLBI Service (IVS). Since the late 1980ies, the observatory is also active in using the Global Positioning System (GPS), and contributes today as network station to the International GNSS Service (IGS). The Ny-Ålesund Geodetic Observatory is active in both IVS and IGS since the 1990ies [2].

Both space geodetic stations play an important role for the International Terrestrial Reference Frame (ITRF) due to their northern location and the availability of co-located geodetic techniques. The precise knowledge of the local geodetic tie between the reference points of the co-located techniques and the monitoring of its stability over time is fundamental for the maintenance of the ITRF. Furthermore it is a crucial prerequisite for a combined use and interpretation of VLBI and GPS data for geophysical and geodynamical investigations.

2. GPS Antennas on the Radio Telescopes at Onsala and Ny-Ålesund

In the summer of 1999 two choke ring GPS antennas were installed on the 20 m radio telescope at Onsala [3]. One of the antennas was permanently mounted on the top of the sub-reflector structure close to its Apex position, therefore this antenna is referred as APEX in the following. The other antenna was sporadically mounted close to the Vertex position of the telescope and is therefore referred as VTEX in the following.

The 20 m radio telescope at Ny-Ålesund is different from the one at Onsala. The most important differences are that this telescope is of prime-focus type, thus does not have a sub-reflector, and that it is not enclosed by a radome. The ideal position to install a GPS antenna was the Vertex position where an antenna was mounted in the summer of 2000 [4], called NVTX in the following. The installation project was supported as an LSF-project of the EC and by the Norwegian Mapping Authority (Statens Kartverk). Unfortunately, the GPS antenna had to be dismounted in the summer of 2004.

3. GPS Data and Analysis

GPS observations were performed with APEX, VTEX and NVTX on campaign basis. The campaign could only be observed when the radio telescopes were not occupied with other observing activities, e.g. geodetic VLBI measurements. Thus, no continuous observation campaigns for longer than a week were available, and there are large gaps between different campaigns.

During the observation campaigns GPS data were recorded every 30 seconds while the telescopes were pointing close to zenith for at least 24 hours. The data were analyzed using the two software packages GIPSY-Oasis II [5] and Bernese GPS Software Version 5.0 [6].

For the first analysis step we used GIPSY-Oasis II with the Precise Point Positioning strategy (PPP) [7]. This analysis approach allows a quick first check of the data quality and reveals epochs with obvious problems that have to be excluded from the further data analysis. The left picture in Fig. 1 shows an example of postfit phase residuals from a PPP-solution for the APEX antenna at Onsala. The residuals are roughly within ±3 cm and indicate that the data are useful for a more detailed analysis.

The next analysis step was performed with the Bernese GPS software. Here we used the double difference approach on the short baselines between the local IGS monuments and the GPS antennas on the radio telescopes. The main advantage is that this strategy completely eliminates the satellite and receiver clock errors. We estimated relative tropospheric parameters for one of the stations on the short baselines, applying standard mapping functions [8]. A quasi-ionosphere-free analysis approach was used since the distance between the telescopes and the reference stations are very short, i.e. less than 100 m. The data of the IGS reference stations were downloaded from SOPAC GPS data archive [9]. The right picture in Fig. 1 shows an example of residuals for an L1-only solution on the baseline ONSA–APEX. The residuals are roughly within ±1 cm, indicating that the double difference approach is more accurate than the PPP-solution.

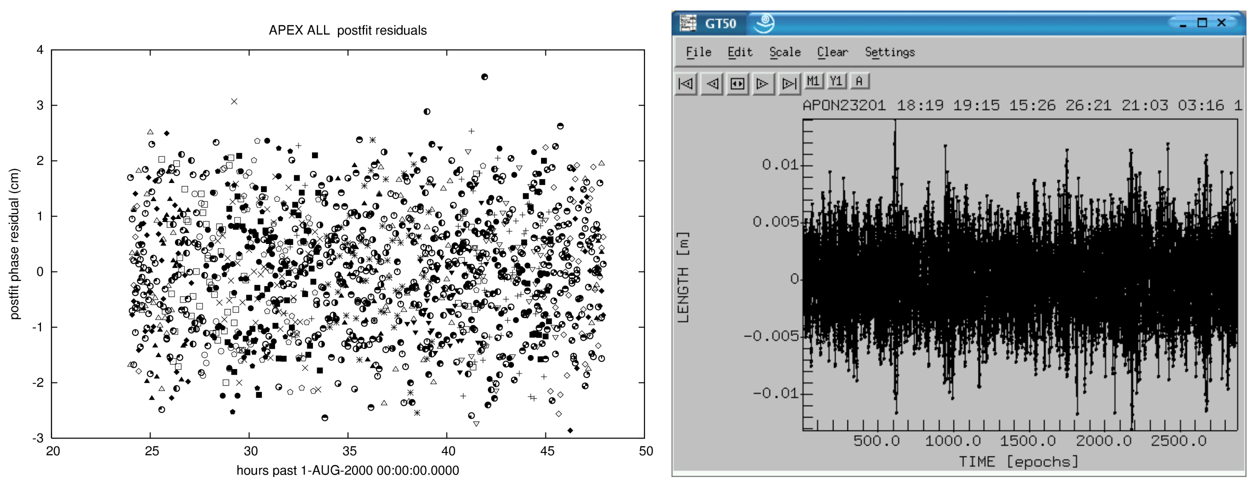

Figure 1. Left: Postfit phase residuals in (cm) from a GIPSY PPP-solution. Right: L1-residuals in (m) from a Bernese double-difference analysis for the baseline APEX-ONSA.

4. Results for North, East and Up Components

Data from both stations were analyzed in detail with Bernese using the double differencing strategy. We performed L1-only, L2-only, and ionospheric-free L3-solutions. The L1- and L2-only solutions gave clearly better results. The results are baseline components relative to the local IGS reference stations. Unfortunately, the telescopes at both stations were not positioned exactly into the zenith position during the GPS campaigns, but deviated by up to 1.5° in elevation. We tried to correct for this mis-positioning by applying a correction for it whenever we had exact information about the telescope position. We used an average elevation for those epochs where we did not have the exact information about the telescope elevation. Mean positions were subtracted from the coordinates, resulting in time series of relative north, east and up components. Obviously outliers were removed from the time series. For Ny-Ålesund we also analyzed data from the second IGS site NYA1 as a reference in order to be able to check the reliability of the NVTX analysis. We picked the same epochs for which data for NVTX were available.

Fig. 2 shows time series of North, East and Up components relative to a mean value for APEX in the left and VTEX in the right picture. The results for NVTX and NYA1 at Ny-Ålesund are shown in Fig. 3 in the left and right picture, respectively. The formal errors of the individual data points are on the order of 0.2-0.3 mm for the North and East components, and 1.0-1.3 mm for the Up component. The corresponding repeatabilities for APEX, VTEX, NVTX and NYA1 expressed as root-mean-square (RMS) values are shown in Table 1.

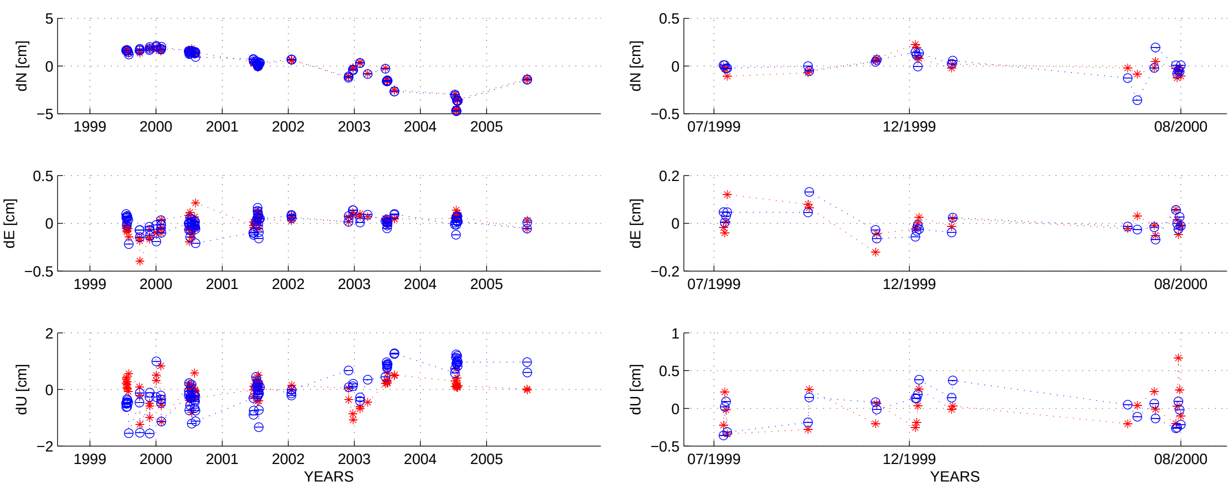

Figure 2. Time series of daily solutions for APEX (left) and VTEX (right). Shown are delta North (dN), delta East (dE) and delta Up (dU) in centimeters with respect to a mean value. Stars (red) correspond to L1-solutions, circles (blue) to L2-solutions.

5. Discussion and Conclusions

The results show that the repeated GPS campaigns on the radio telescopes at Onsala and Ny-Ålesund do give RMS repeatabilities on the order of a couple of mm to cm. The two different solutions, L1 and L2, mainly follow each other quite well, however with biases.

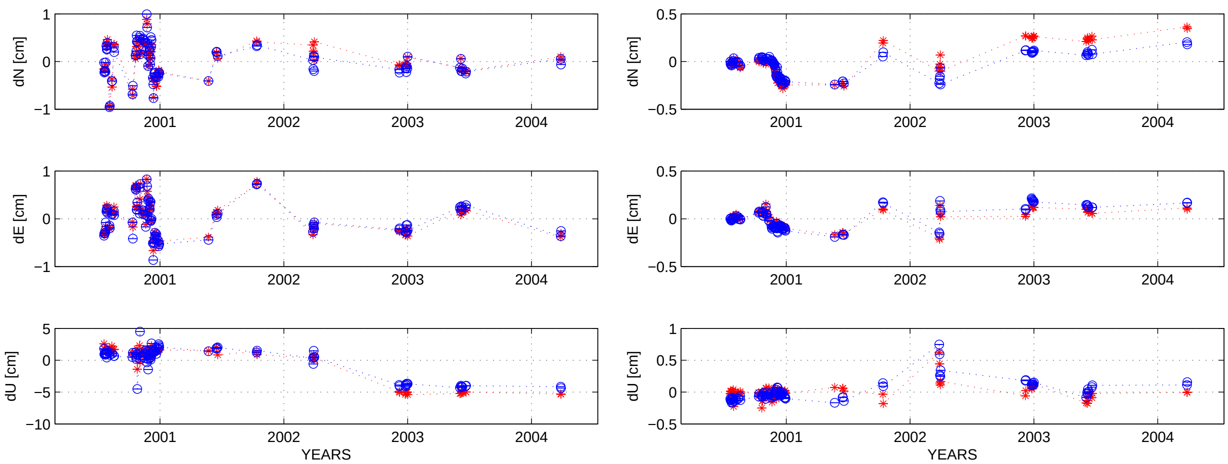

Figure 3. Time series of daily solutions for NVTX (left) and NYA1 (right). Shown are delta North (dN), delta East (dE) and delta Up (dU) in centimeters with respect to a mean value. Stars (red) correspond to L1-solutions, circles (blue) to L2-solutions.

Table 1. North, East and Up repeatabilities in mm for APEX, VTEX, NVTX and NYA1 for L1 and L2 solutions. The footnotes for NVTX mean: (1) all NVTX data, (2) only NVTX data until July 2002, (3) only NVTX data after July 2002.

	APEX		VTEX		NVTX[1]		NVTX[2]		NVTX[3]		NYA1	
component	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2
North	20.0	20.0	0.8	1.0	3.5	3.5	4.1	3.9	0.9	1.0	1.6	1.1
East	0.8	0.7	0.4	0.4	3.3	3.3	2.8	2.8	2.4	2.4	0.9	1.0
Up	3.0	6.6	2.2	2.0	28.8	23.1	4.4	4.8	1.5	2.0	1.1	1.4

The APEX North component appears to show some drift over time that also reflects in the large RMS value of about 20 mm. The values in 1999 and 2000 lie close together, however the later values differ from these first data points. We do not have an explanation for this, but suspect that there was a difference between the different observation campaigns concerning whether a pointing model was used or not. The use of a pointing model does slightly change the telescope elevation and azimuth. Unfortunately, we do not have information about the telescope elevation for all observation epochs, and thus could not correct for the deviation from the zenith for all epochs with appropriate corrections. Also the Up component of APEX seems to show some drift. However, a mis-pointing of the telescope does influence the North and East components much more than the Up component. Therefore, we hesitate to explain the variation in the Up-component by whether a pointing model was used or not. The APEX East component gives an RMS repeatability below 1 mm.

For VTEX we have unfortunately only few data points. Due to modifications in the telescope receiver cabin it was not possible to keep the mounting equipment for the VTEX antenna in place after 2000. The RMS repeatability values are on the order of roughly 3 mm.

We suspect that both APEX and VTEX did suffer from increased multipath effects due to the metal structure of the radome enclosing the Onsala 20 m radio telescope.

The time series for NVTX show better results for the North and East components than for the Up component. The Up component appears to be affected by a bias in the summer of 2002, which reflects in the large RMS values of 29 and 23 mm for the L1 and L2 solutions. The exact reason for this bias is unknown to us, but may be due to dismounting and re-mounting of the antenna during an LSF-project in the summer of 2002 [10]. If we use only data before or after July 2002 the RMS repeatability for the Up component reduces considerably, see Table 1. Compared to NYA1, the NVTX results are worse by a factor of about 3. This might partly be explained by a higher level of multipath at the vertex position of the radio telescope compared to the NYA1 GPS monument.

In general, the current level of accuracy of the performed measurements does not allow to monitor local-ties with sub-mm accuracy. This appears only to be possible with classical geodetic methods that have been performed at Ny-Ålesund and Onsala previously [10], [11]. For the GPS measurements on the VLBI telescopes the knowledge of the exact position of the radio telescope in terms of elevation and azimuth is of crucial importance. Thus, in future measurement campaigns we need to monitor the antenna position more precisely.

References

[1] Scherneck, H.-G., Elgered, G., Johansson, J.M., Rönnäng, B.O.: Space geodetic activities at the Onsala Space Observatory: 25 years in the service of plate tectonics. *Phys. Chem. Earth*, **23**, 811–824, 1998.

[2] Digre, H. G., Rekkedal, S., Holland, D. C., Hanssen, R. I., Plag, H.-P.: NYAL Ny-Åelsund 20-metre Antenna. *IVS Annual Report 1999*, ed. N. R. Vandenberg, NASA/TP-1999-209243, 80–84, 1999.

[3] Bergstrand, S., Haas, R., Johansson, J.: An Independet Stability Check of the Onsala 20m Radio Telescope Using the Global Positioning System. *14th Working Meeting on European VLBI for Geodesy and Astrometry*, ed. P. Tomasi, F. Mantovani, M. Perez Torres, 83–88, 2000.

[4] Haas, R., Bergstrand, S., Johansson, J.: Establishing a New GPS-VLBI tie at NyÅlesund. *14th Working Meeting on European VLBI for Geodesy and Astrometry*, ed. P. Tomasi, F. Mantovani, M. Perez Torres, 73–78, 2000.

[5] Webb, F. H., Zumberge, J. F.: An introduction to GIPSY/OASIS-II. *JPL Publication D-11088*, Jet Propulsion Laboratory, Pasadena, 1993.

[6] Hugentobler, U., Dach, R., Pierre, F.: Bernese GPS Software Version 5.0. *Printing Office of the University of Bern*, 2004.

[7] Zumberge, J. F., Hefflin, M.B., Jefferson, D.C., Watkins, M.M., Webb, F.H.: Precise point positioning for the efficient and robust analysis of GPS data from large networks. *J. Geophys. Res.*, **102(B3)**, 5005–5018, doi:10.1029/96JB03860, 1997.

[8] A.E. Niell, "Global mapping functions for the atmosphere delay at radio wavelength", *J. Geophys. Res.*, **101(B2)**, 3227–3246, doi:10.1029/95JB03048, 1996.

[9] `ftp://garner.ucsd.edu/pub/rinex`

[10] Steinforth, C., Haas, R., Lidberg, M., Nothnagel, A.: Determination of Local Ties at Ny-Ålesund. *Proc. IERS Workshop on site co-location*, ed. B. Richter, W. Schwegmann, and W. R. Dick, **IERS TN-33**, Verlag des Bundesamtes für Kartographie und Geodäsie, 84–92, 2005.

[11] Haas, R., Eschelbach, C.: The 2002 Local Tie at the Onsala Space Observatory. *Proc. IERS Workshop on site co-location*, ed. B. Richter, W. Schwegmann, and W. R. Dick, **IERS TN-33**, Verlag des Bundesamtes für Kartographie und Geodäsie, 55–63, 2005.