The 5^{th} IVS General Meeting Proceedings, 2008, p. 173–177

VLBI Baseline Length Repeatability Tests of IVS-R1 and -R4 Session Types

Kamil Teke, Robert Heinkelmann, Johannes Boehm, Harald Schuh

Institute of Geodesy and Geophysics, Vienna University of Technology, Austria

Abstract. In this study, baseline length repeatabilities from analysis of geodetic VLBI data are investigated with the troposphere mapping functions NMF, GMF, and VMF1, and with different cut off elevation angles (between $3°$ and $30°$) for IVS-R1 and IVS-R4 sessions. Each mapping function yields similar baseline repeatabilities for cut off angles $3°, 5°, 7°$ and $10°$, but from $15°$ onwards the repeatabilities grow significantly. VMF1 gives the best repeatabilities in the interval $3°$ to $10°$ with the lowest value at $7°$. Above $10°$ all three mapping functions more or less yield the same repeatabilities.

1. Introduction

The speed and the path of microwave radio signals that radiate from a quasar is altered when passing through the troposphere due to the particular atmospheric conditions. This effect is called tropospheric delay and is included in the mathematical model of VLBI measurements. VLBI has reached sub-centimeter precision for baseline lengths and station coordinates determined in a global terrestrial reference frame from 24 hour sessions [7]. However, future expectations are to improve the precision of these parameters to millimeter level. The baseline length and station coordinate repeatabilities depend on the amount of observables, the lengths of the baselines, but also on the accuracy of mathematical models, e.g. the tropospheric delay model including the mapping functions that are used to describe the relation between the tropospheric delay at zenith direction and at an arbitrary angle above the horizon. Due to the longer path through the atmosphere when decreasing the elevation angle, difficulties in tropospheric delay modeling increase. From this point of view observations should be made near the zenith zone. On the other hand, including observations that are widely separated over all elevation and azimuth angles allows us to decrease the observational correlations [3]. Thus, there is a trade-off between smaller correlations of zenith delays and station heights as well as larger mapping function errors when using low elevation observations. Baseline length repeatabilities can be considered as important accuracy criteria for VLBI analysis, since baseline lengths are independent of rotations of the polyhedron formed by several VLBI stations [6]. For each baseline, the repeatability can be determined as the standard deviation of the n estimates Li with regard to the mean value L_0 on a regression polynomial of first order [1].

2. Baseline Length Repeatabilities of IVS-R1 and IVS-R4 Sessions

The major purpose of the IVS-R1 and IVS-R4 sessions is to provide twice-weekly Earth Orientation Parameters (EOP). The "1" and "4" indicate that in general the sessions are on Mondays and Thursdays, respectively. The "R" stands for rapid turnaround because the stations, correlators, and analysts have taken the commitment to make the time delay from the end of recording to results as short as possible. The time delay should not exceed 15 days. To determine the baseline length repeatabilities of the IVS-R1 and R4 sessions from 04/01/2002 (mjd:52278 begin with R4) to 29/06/2007 (mjd:54280 end with R4) a linear function was fitted as

$$B_i(t_j) = a_{i(1)} + a_{i(2)}(t_j - t_0), \qquad (1)$$

where $B_i(t_j)$ is the baseline length of the baseline i for session j and t_j is the day of the session. $a_{i(1)}$ and $a_{i(2)}$ are the unknown parameters of the linear regression function for baseline i which are estimated by a least-squares adjustment. The RMS value of each fit is considered as the baseline length repeatability. The baseline length repeatabilities of the IVS-R1 and R4 sessions were determined using three mapping functions: Niell Mapping Functions [5], Global Mapping Functions [2], and Vienna Mapping Functions 1 [1]. The principle of Vienna Mapping Function (VMF1) is to use the best empirical coefficients b and c available, and to determine the coefficient a of the continued fraction form (2) from a ray-trace at $e_0 = 3.3°$ initial elevation angle through a Numerical Weather Model (NWM)

$$m(e) = (1 + a/(1 + b/(1 + c)))/(sin(e) + a/(sin(e) + b/(sin(e) + c))). \qquad (2)$$

Two regression functions were formed before and after the Earthquake for the baselines with station Gilcreek, because of the Denali Earthquake (03/11/2002). For a more sophisticated model of the motion of Gilcreek we refer to [4]. The cut off elevation angle was set to 3°, 5°, 7°, 10°, 15°, 20°, or 30°. A quadratic polynomial was adjusted to the repeatabilities (without linear term) [6] as follows

$$r_n = k_{m(1)} + k_{m(2)}(B_n)^2, \qquad (3)$$

where B_n is the baseline length, and r_n is the repeatability value of the baseline n, $k_{m(1)}$ and $k_{m(2)}$ are the unknown parameters of the regression function, m denotes the selected mapping function and the cut off elevation angle (e.g. $m = 1$ denotes VMF1, cut off angle 3°. The unknown parameters were estimated by a least-squares adjustment. Fig. 1 and 2 show the repeatabilities of the baseline lengths for different mapping functions and cut off angles. The mapping functions yield similar baseline repeatabilities for cut off angles $3°, 5°, 7°$, and $10°$, but from $15°$ onwards, the repeatabilities grow significantly. VMF1 gives the best repeatabilities in the interval $3°$ to $10°$ with the lowest value at $7°$. Above $10°$ all three mapping functions more or less yield the same repeatabilities. Fig. 3 shows the sum of the repeatabilities for each mapping function and cut off elevation angle. The sum of the repeatabilities with VMF1 is smaller than

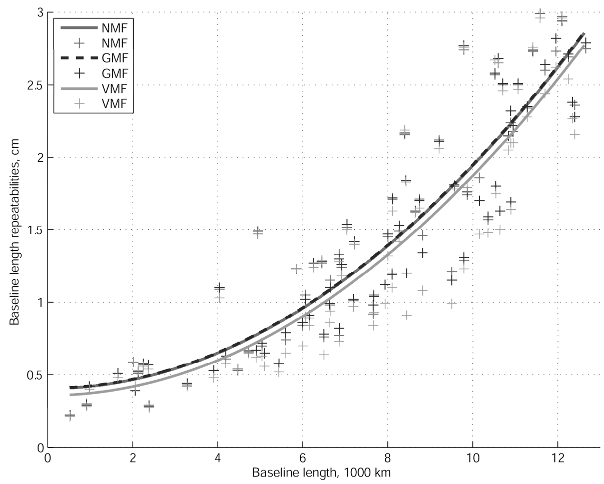

Figure 1. Baseline length repeatabilities with VMF1, GMF, and NMF for a cut off angle $3°$ for IVS-R1 and R4 sessions

with NMF or GMF, at least below ($10°$). Above ($10°$) all mapping functions produce approximately the same sum of repeatabilities. In Tabl. 1, the total number of observations of R1 and R4 sessions from 04/01/2002 to 29/06/2007 and the mean number of observations per session is given for each cut off elevation angle. In this time span, 277 sessions of R1 and 268 sessions of R4 were analysed.

3. Conclusions and Outlook

From the investigations of R1 and R4 sessions baseline repeatabilities for the mapping functions VMF1, GMF, and NMF and the cut off angles $3°, 5°, 7°, 10°, 15°, 20°$, and $30°$ the following conclusions can be drawn:

- VMF1 gives the best repeatabilities for low cut off angles $3°$ to $10°$,
- the repeatabilities are smallest with a cut off elevation angle of $7°$. For cut off elevation angles above $10°$, VMF1, NMF, and GMF yield approximately the same baseline length repeatabilities,

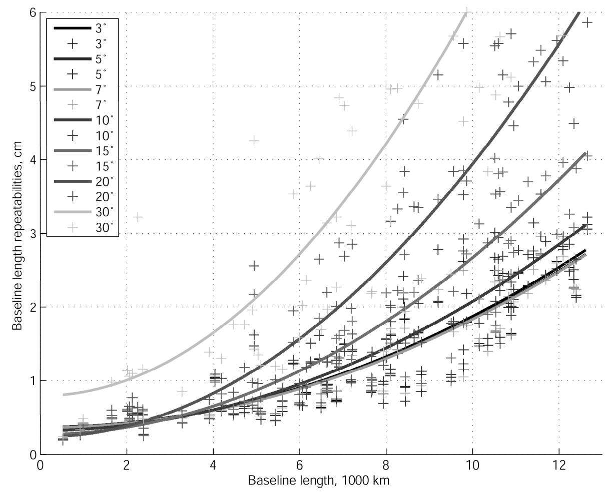

Figure 2. Baseline length repeatabilities with VMF1 for the cut off angles $3°, 5°, 7°, 10°, 15°, 20°$, and $30°$

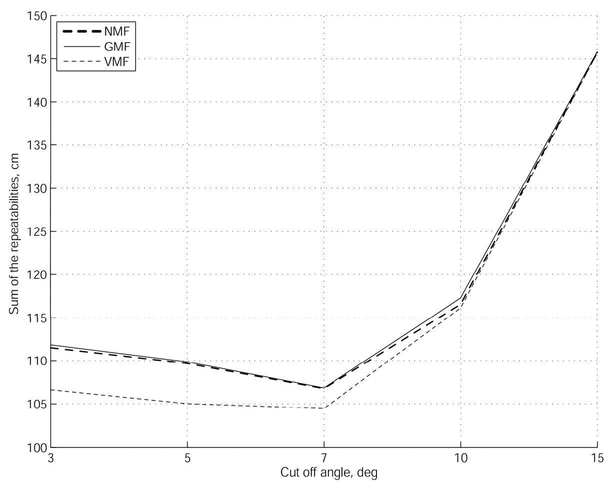

Figure 3. Sum of the baseline length repeatabilities with VMF1, GMF, and NMF for the cut off angles $3°, 5°, 7°, 10°$, and $15°$

- there is no significant difference in repeatabilities between NMF and GMF.

Using different cut off elevation angles means that not the same number of observations is used. Thus, these tests will be repeated removing observations randomly when a low cut off elevation angle is applied so that the number

Table 1. Number of observations for sessions from 04/01/2002 to 29/06/2007

Cut off	Total Obs.(R1)	Mean Obs.(R1)	Total Obs.(R4)	Mean Obs. (R4)
3^0	519259	1875	350536	1308
5^0	515212	1860	348347	1300
7^0	492457	1778	337583	1260
10^0	451846	1631	313850	1171
15^0	380012	1372	267530	998
20^0	312135	1127	220201	822
30^0	193116	697	139688	521

of observations is identical for all cut off angles. Investigations with down weighting of low elevation observations have to be carried out, too.

References

[1] Boehm, J., B. Werl, H. Schuh. Troposphere mapping functions for GPS and very long baseline interferometry from European Centre for Medium-Range Weather Forecasts operational analysis data. J. Geophys. Res., v. 111, B02406, DOI 10.1029/2005JB003629, 2006a.

[2] Boehm, J., A. Niell, P. Tregoning, et al. Global Mapping Function (GMF): A new empirical mapping function based on numerical weather model data. Geophys. Res. Lett., 33: L07304, DOI 10.1029/2005GL025546, 2006b.

[3] Malkin, Z. Influence of the Cut-off Elevation Angle and Elevation-Dependent Weighting on Parameter Estimates: A Case of CONT05. 5th IVS General Meeting, 2008. This volume.

[4] Heinkelmann, R., J. Freymueller, H. Schuh. A postseismic relaxation model for the 2002 Denali earthquake from GPS deformation analysis applied to VLBI data. 5th IVS General Meeting, 2008. This volume.

[5] Niell, A.E. Global mapping functions for the atmosphere delay at radio wavelengths. J. Geophys. Res., v. 101, B2, 3227-3246, 1996.

[6] Niell, A. Baseline Length Repeatability, Report. MIT Haystack Observ., 2006.

[7] Seeber, G. Satellite Geodesy. De Gruyter, 2nd edn. Berlin/Newyork, 2003.