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

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Abstract

Very Long Baseline Interferometry (VLBI) has reached centimeter precision for baseline lengths and station coordinates determined in a global terrestrial reference frame. However, future expectations are to improve the precision of these parameters to millimeter level. The baseline length and station coordinate repeatabilities are dependent on the precision of coordinate determination of earth-based stations, the amount of observables, and the lengths of the baselines, but also on the accuracy of models, e.g. the tropospheric delay model. There is a trade-off between smaller correlations of zenith delays, and station heights when using low elevation observations on the one hand and mapping function errors, which become larger at low elevations on the other hand. In this study, the effects of baseline lengths and cut off elevation angles on the baseline length repeatabilities are investigated with the troposphere mapping functions NMF, GMF and VMF1. We also investigate different cut off elevation angles (between 3° and 30°) for low elevation observations of IVS-R1 and IVS-R4 sessions.

1. Introduction

The speed 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 Very Long Baseline Interferometry (VLBI) measurements. The term "mapping function" is used to describe the relation between the tropospheric delay at zenith direction and an arbitrary angle above the horizon. Various mapping functions have been developed to map the tropospheric delay onto zenith direction. Most of the geodetic-quality mapping functions use the continued fraction form (Niell, 1996). All the parameters in the mapping function can be estimated by least-squares fitting with ray-tracing delay values at various elevation angles. The accuracy of VLBI results significantly depends on the reduction of tropospheric delay to zenith direction. Among various outcomes of VLBI, baseline length repeatabilities can be considered as important accuracy criteria since baseline lengths are independent of rotations of the polyhedron formed by several VLBI stations. This makes it a good independent measure of the accuracy achieved for geodetic VLBI (Niell, 2006). For each baseline, the repeatability can be determined as the standard deviation of the n estimates L_i with regard to the mean value L_0 on a regression polynomial of first order (Boehm et al., 2006)

2. Baseline Length Repeatabilities of R1 and –R4 Sessions

The purpose of the IVS-R1 and IVS-R4 sessions is to provide twice weekly EOP results on a timely basis. The "1" and "4" indicate that the sessions are on Mondays and Thursdays, respectively. The "R" stands for rapid turnaround because the stations, correlators, and analysts have a commitment to make the time delay from the end of recording to results as short as possible. The time delay goal is a maximum of 15 days [URL-1]. In Figure 1 the VLBI stations which include in the IVS-R1 and IVS-R4 sessions are shown.
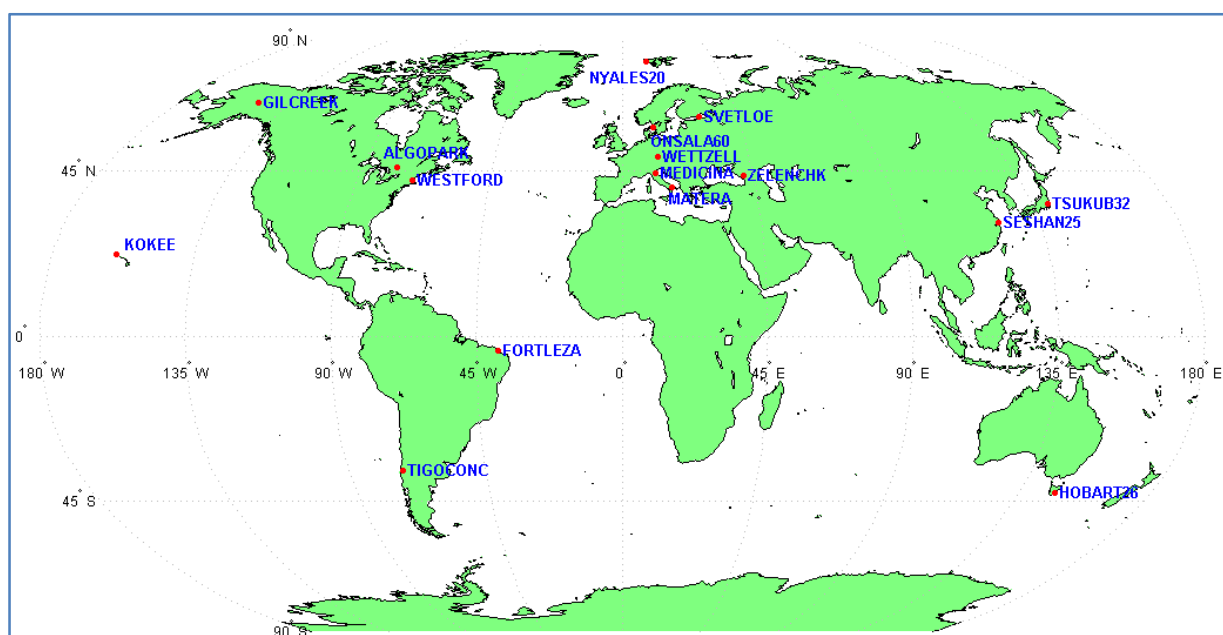

Figure 1. Sites included in IVS-R1 and IVS-R4 sessions

To find out the baseline length repeatabilities of IVS-R1 and R4 Sessions from 01/04/2002 (mjd:52278) to 06/29/2007 (mjd:54280) a linear function was formed as follows:

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

where, $B_i(t_j)$ is the baseline length of the baseline i for the session j and the day of the session denotes to t_j, $a_{i(1)}$ and $a_{i(2)}$ are the unknown parameters of the linear regression function for the baseline i. The unknown parameters of the function were produced by LSM. RMS value of the each fit was considered as the baseline length repeatability. Below is the time series plot of Wettzell – Westford baseline included in R1- and R4-Sessions with VMF1 and cut off angle 7°.
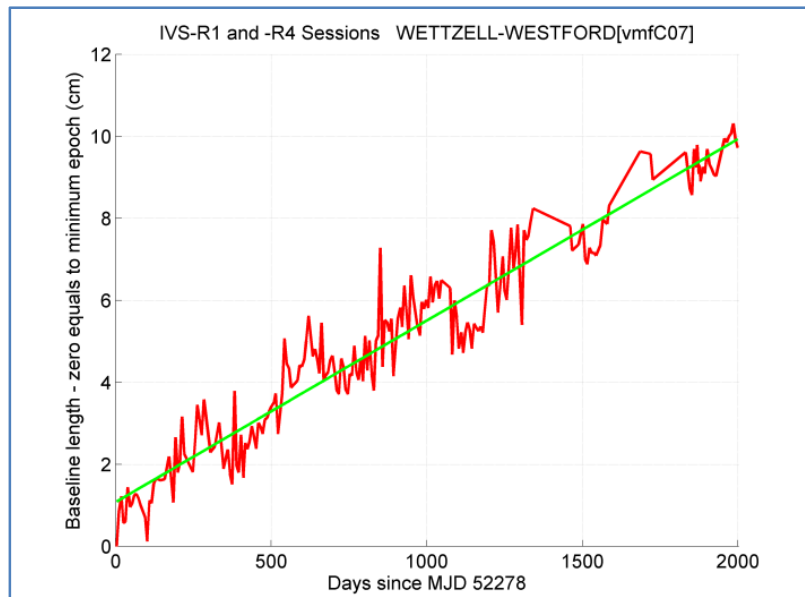
Figure 2. Time series of Wettzell – Westford baseline with VMF1 and for cut off angle 7°

Because of the Denali Earthquake (03/11/2002), two regressions functions were formed before and after the Earthquake for the baselines of station Gilcreek. Below is the time series plot of Gilcreek – Tigoconc baseline included in R1- and R4-Sessions with VMF1 and cut off angle 7°.
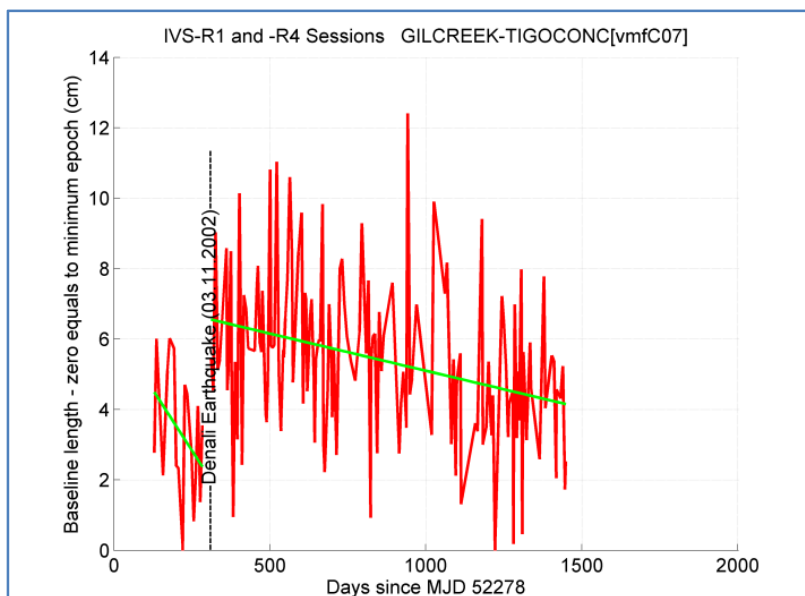

Figure 3. Time series of Gilcreek – Tigoconc baseline with VMF1 and cut off angle 7°

The baseline length repeatabilities of VLBI R1- and R4-Sessions were investigated for certain mapping functions (VMF, GMF, NMF) and cut off elevation angles (3°, 5°, 7°, 10°, 15°, 20°,

30°). A quadratic polynomial was formed to fit the repeatabilities (without linear term) [Niell 2006] as follows:

$$r_n = k_{m(1)} + k_{m(2)}^2 (B_n) \tag{2}$$

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 to the selected mapping function and cut off elevation angle (e.g. m = 1 denotes to VMF1, cut off angle 3°). The unknown parameters of the function were produced by LSM. In Figure 4 and 5 some plots of the repeatabilities of the baseline lengths for different mapping functions and cut off angles are shown.
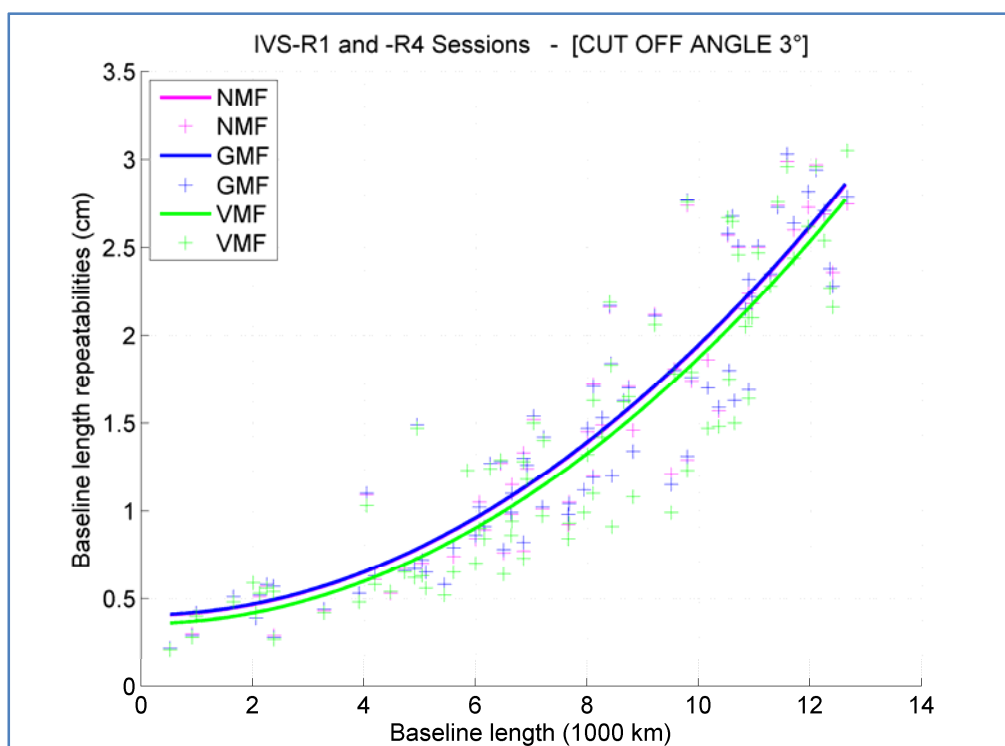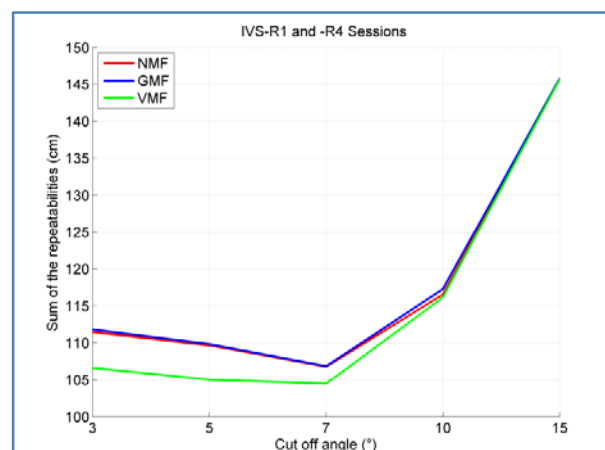

Figure 4. Baseline length repeatabilities with VMF1, GMF and NMF for the cut off angle 3°
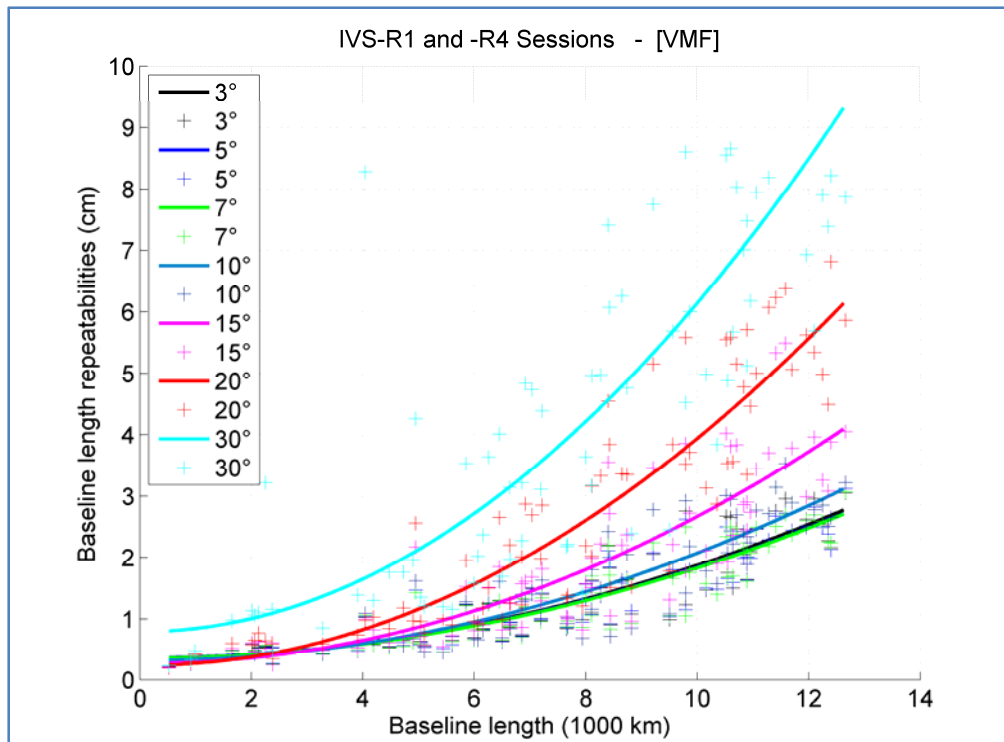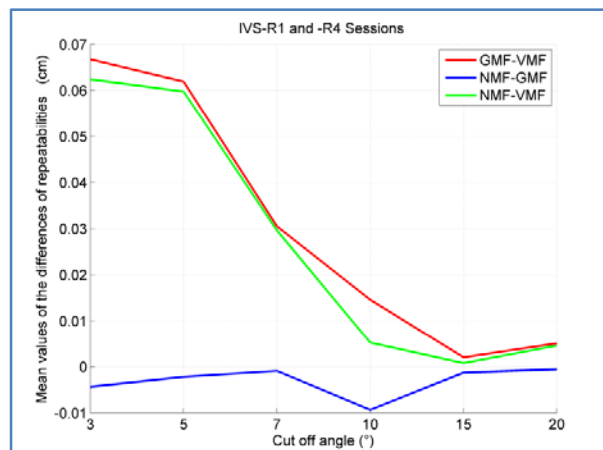
Figure 5. Baseline length repeatabilities with VMF1 for the cut off angles 3°, 5°, 7°,10°, 15°, 20°, and 30°

The mapping functions yielded similar baseline repeatabilities for cut off angles 3°, 5°, 7° and 10°, whereas from 15° onwards, the repeatabilities grew 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. As to interpret by a global accuracy criteria the sum of the repeatabilities are produced for each mapping function for different cut off angles (Figure 6).
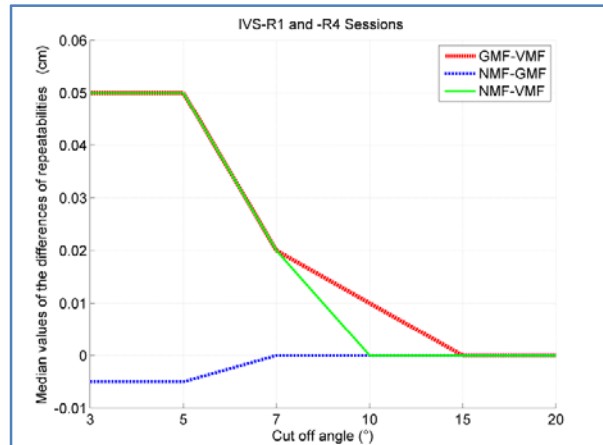

Figure 6. Sum of the baseline length repeatabilities provided by VMF1, GMF, and NMF for the cut off angle 3°, 5°, 7°,10°, 15°, 20°, and 30°

The sum of the repeatabilities of the mapping function VMF1 is smaller than NMF and GMF up to 10°. Above 10° all the mapping functions produce approximately the same sum of repeatabilities. Figures 7 and 8 show the mean and median differences of baseline length repeatabilities between VMF1, GMF, and NMF. There is a clear improvement with VMF1 at low elevation angles.

Figure 7. Mean differences of repeatabilities between VMF1, GMF and NMF for the cut off angles 3°, 5°, 7°,10°, 15°, 20°, and 30°

Figure 8. Median differences of repeatabilities between VMF1, GMF and NMF for the cut off angles 3°, 5°, 7°,10°, 15°, 20°, and 30°

3. Conclusions

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 cutoff elevation angles [3° to 10°].
- The repeatabilities are lowest with a cutoff elevation angle of 7°.

There is no significant difference in repeatabilities between NMF and GMF.

- For cutoff elevation angles larger than 10°, VMF1, NMF, and GMF yield the same baseline length repeatabilities.

References

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Niell, A:, 2006, Baseline Length Repeatability, Report, MIT Haystack Observatory.

URL-1. http://ivscc.gsfc.nasa.gov/