Baseline length repeatability and vertical point position accuracy of VLBI CONT05 sessions for different mapping functions and cut off angles

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Abstract

Because baseline lengths are independent of rotations of the polyhedron formed by several VLBI stations, baseline length repeatabilities can be taken as accuracy criteria of the VLBI network. In this study baseline length repeatabilities of 15 sessions of the VLBI CONT05 campaign were investigated for certain mapping functions (VMF1, GMF, NMF) and cutoff elevation angles (5, 7, 10, 15, 30 degrees). From the analysis with the VLBI software Occam 6.1, the following conclusions can be drawn: All three mapping functions yield about similar baseline length repeatabilities for the cutoff angles 5, 7 and 10 degrees, but significantly larger repeatabilities for 15 and 30 degrees. A cutoff angle of 7 degrees gives the best results for all mapping functions. Baseline length repeatabilities with VMF1 are slightly better than those with NMF and GMF. Additionally, the baseline length repeatabilities are converted to station height repeatabilities by adopting the geometrical relation and applying a least-squares approach where the baseline length and the vertical position errors are taken as measured values and unknowns of the adjustment, respectively. The comparison between these vertical position errors and the formal errors for the station heights provided by Occam for each 24 h session shows a good agreement, apart from a certain scale factor.

Baseline Length Repeatability

The term "mapping function" is used to describe the relation between the tropospheric delay at zenith direction and an arbitrary angle above the horizon. Throughout the history of VLBI, extensive attention has been paid to tropospheric mapping functions, in view of the dominance of tropospheric delay mismodeling in the error budget.

The baseline length is 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 σ 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)

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(L_i - L_0)^2}{n-2}}$$

Baseline length repeatabilities for CONT05

To describe the increase of the baseline length repeatability R with increasing baseline length L, the equation given below can be used.

$$y = a^2 + b^2 ppb^2 L^2$$

The above function is used for the representation of the scattered data σ with regard to baseline length (L) where a and b are parameters to be estimated by least-squares method (Niell, 2006).

Table 1. The parameters of the regression function for each mapping function and cut off angle

Mapping Functions	Parameters of the function for different cut off angles									
	5° (6156)		6°(6028)		7°(5907)		8°(5818)		9°(5646)	
	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b
VM1	0.505	0.853	0,515	0,817	0,517	0,801	0,523	0,796	0,510	0,836
GMF	0,524	0,879	0,521	0,844	0,521	0,823	0,522	0,806	0,512	0,844
NMF	0,528	0,879	0,520	0,844	0,521	0,826	0,522	0,808	0,512	0,845
Mapping Functions	10°(5502)		12°(5207)		15°(4730)		20°(3906)		30°(2491)	
	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b
VM1	0,501	0,859	0,489	0,927	0,428	1,078	0,404	1,229	0,657	1,542
GMF	0,500	0,866	0,488	0,931	0,426	1,081	0,403	1,229	0,656	1,542
IMF	0,500	0,867	0,489	0,931	0,428	1,081	0,404	1,228	0,655	1,543

Baseline Length Repeatability

When Table 1 and Figure 1 is investigated an unambiguous comparison can not be achieved. For that reason the initial parameter value of the regression function is fixed to 0.5 mm.

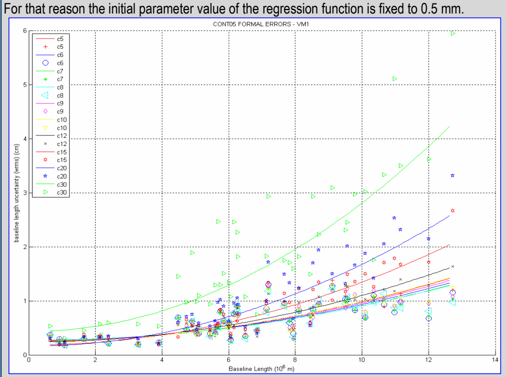


Figure 1. Baseline length uncertainty values calculated from Vienna Mapping Function (VM1) for certain cut off angles

Table 2. The parameters of the regression function for each mapping function and cut off angle (the parameter a of the regression function fixed to 0.5 cm in order to ensure an unambiguous comparability between mapping functions and cut off angles)

Mapping Functions	Parameters of the function for different cut off angles									
	5°(6156)		6°(6028)		7°(5907)		8°(5818)		9°(5646)	
	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b
VM1	0,5	0,597	0,5	0,559	0,5	0,537	0,5	0,540	0,5	0,582
GMF	0,5	0,657	0,5	0,605	0,5	0,577	0,5	0,554	0,5	0,595
NMF	0,5	0,660	0,5	0,605	0,5	0,580	0,5	0,558	0,5	0,597
Mapping Functions	10°(5502)		12°(5207)		15°(4730)		20°(3906)		30°(2491)	
	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b	a (cm)	b
VM1	0,5	0,600	0,5	0,680	0,5	0,823	0,5	0,994	0,5	1,506
GMF	0,5	0,610	0,5	0,685	0,5	0,824	0,5	0,993	0,5	1,505
IMF	0,5	0,611	0,5	0,686	0,5	0,826	0,5	0,992	0,5	1,506

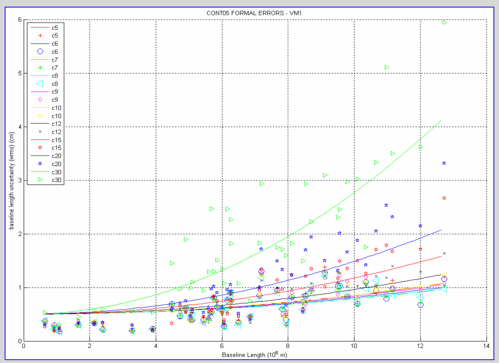


Figure 2. Baseline length uncertainty values calculated from Vienna Mapping Function (VM1) for certain cut off angles (coefficient a fixed to 0.5 cm)

Baseline length repeatabilities for CONT05

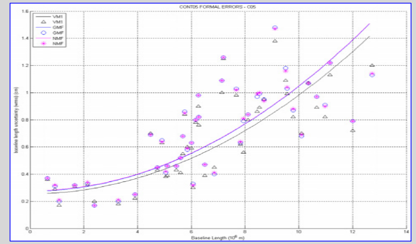


Figure 3. Baseline length uncertainty values provided by the models VM1, GMF and NMF for the cut off angle 5°

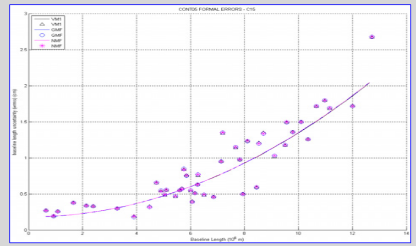
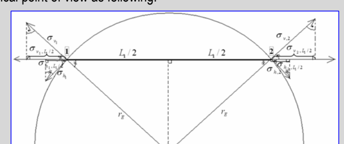


Figure 4. Baseline length uncertainty values provided by the models VM1, GMF and NMF for the cut off angle 15°

The relation between VLBI baseline length repeatabilities and the point position uncertainties

The relation between the baseline uncertainties and vertical point position errors are explained by a geometrical point of view as following:



$$\sigma_{L_1} = \sigma_{v_1, L_1/2} + \sigma_{h_1, L_1/2} + \sigma_{v_2, L_1/2} + \sigma_{h_2, L_1/2}$$

$$\sigma_{L_1} = \frac{L_1}{2r_E}\sigma_{v_1} + \frac{\sqrt{{r_E}^2 - (L_1/2)^2}}{r_E}\sigma_{h_1} + \frac{L_1}{2r_E}\sigma_{v_2} + \frac{\sqrt{{r_E}^2 - (L_1/2)^2}}{r_E}\sigma_{h_2}$$

Figure 5. The geometrical relation between baseline length repeatability and point position uncertainty in the direction of vertical and horizontal

σ_v = Vertical point position uncertainty,

σ_h = Horizontal point position uncertainty,

L = Baseline length,

σ_L = Baseline length repeatability,

r_E = Earth radius.

$\sigma_{v_j, L_i/2}$ = Fraction of vertical point position error (point, j) on the baseline length repeatability (baseline, i)

$\sigma_{h_j, L_i/2}$ = Fraction of horizontal point position error (point, j) on the baseline length repeatability (baseline, i)

The relation between VLBI baseline length repeatabilities and the point position uncertainties

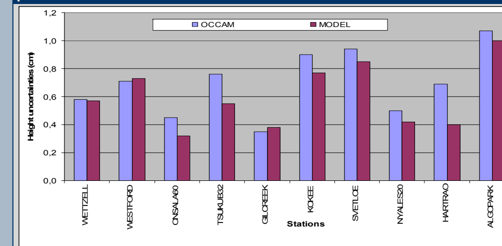


Figure 6. Height uncertainties derived from VLBI software OCCAM and the geometric model for VM1 and cut off angle 7°

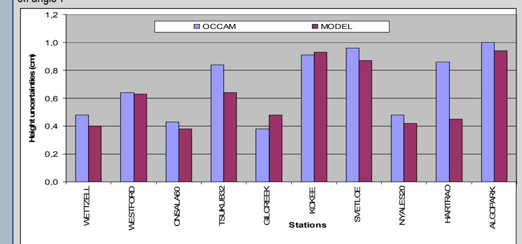


Figure 7. Height uncertainties derived from VLBI software OCCAM and the geometric model for VM1 and cut off angle 10°

Conclusions and outlook

From the CONT05 baseline repeatabilities obtained for different mapping functions (VM1, GMF, NMF) and cut off angles (5°, 6°, 7°, 8°, 9°, 10°, 12°, 15°, 20°, 30°) the following conclusions can be drawn:

- **The mapping functions produced rather similar baseline uncertainty values for cut off angles 5° to 12° whereas for 15°, 20° and 30° much greater uncertainty values were found. This difference occurred just because of the various number of sources and their distribution on the sky. In the processing stage, when the cut off angle was chosen in the interval [5°, 12°], the visibility of the sky permits to access much more observables than in the interval [15°, 30°]. Also the distribution of the sources is better.**
- **Despite of the relatively small differences in the interval [5°,8°] the cut off angle 8° gives the best outcomes for all mapping functions.**
- **The mapping function VM1 gives the best results comparatively to the other mapping functions.**
- **The baseline length repeatabilities were converted to station height repeatabilities by considering the geometric relation. The geometric model and the OCCAM outcomes of height uncertainties were compared and found out compatible with each other apart from a certain scale factor. Probably, this difference may be due to neglected correlations in the simple geometric model.**

References

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