Improving of the covariance functions of the clock and troposphere parameters (P-13)

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Abstract

The QUASAR [1] software is developed at the IAA RAS for VLBI data processing. The software uses the least square collocation technique for the estimation of the stochastic parameters: the clock and the troposphere. The aim of this work is to estimate the covariance functions of the stochastic signals of the clock and the troposphere from VLBI data processing. Covariance functions were calculated on hourly intervals and on daily intervals for further processing of hourly and daily VLBI sessions respectively. The parameters of the covariance function of the clocks of various VLBI stations were estimated. New covariance functions were used in VLBI data processing.

Covariance functions in the Least Square Collocation method

VLBI observations in the Least Square Collocation method are described by this formula:

$$l = Ax + Us + r,$$

where i — O-C vector, x – vector of unknown parameters, u – vector of stochastic signals, A – matrix composed of all first order derivatives of the observations to unknown parameters (x), U – matrix composed of all first order derivatives of the observations to stochastic signals (s), r – vector of residuals.

If we know Q_{rr} – covariance matrix of residuals, Q_{ss} – covariance matrix of stochastic signals, we can rewrite this formula (using w – new vector of residuals, $Q_{ww} = UQ_{ss}U' + Q_{rr}$ – its covariance matrix) and get x:

$$l = Ax + w$$

$$x = (A'Q_{ww}A)^{-1}A'Q_{ww}l$$

We use QUASAR software for the processing of the VLBI observations. QUASAR uses wet troposphere parameters and clock parameters of VLBI stations as unknown parameters with stochastic parts. Pictures 1 and 2 illustrate that troposphere delays after removing hourly trend become stochastic. Now QUASAR allows to use covariance functions on daily interval, so the signals are correctly estimated for the daily VLBI session. In this work we compute covariance functions on hour interval and use it for processing of hourly VLBI sessions.

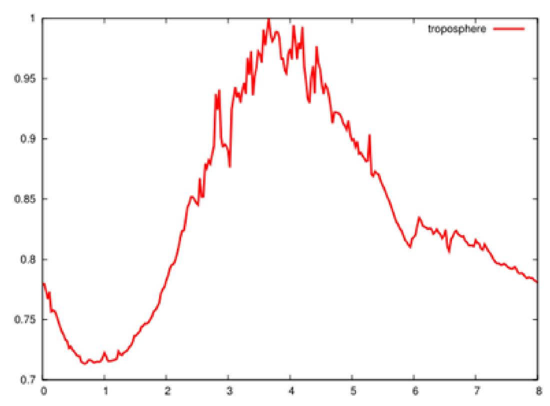

Figure 1: Troposphere delay of one station before removing daily/hourly trend

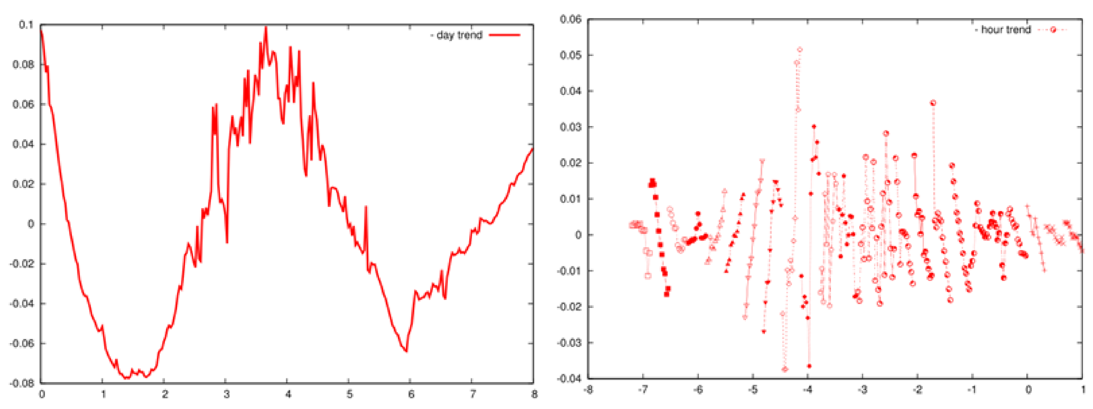

Figure 2: Troposphere delay of one station after removing daily trend (left) and after removing hourly trend (right)

Calculating covariance functions on hour intervals of stations Badary, Svetloe, Zelenchk

In order to compute covariance functions on an hour interval we made a global solution of approximately 6000 VLBI sessions using QUASAR software. Then we use signals of the clock and wet parameters of stations Badary, Svetloe, Zelenchk estimated from 190130XA session for constructing hourly covariance functions. The method of constructing of the covariance functions is outlined in [2]. We use this model of the covariance functions:

$$q(t) = \sigma e^{-\alpha t}\cos(\beta t + \varphi),$$

where $q(t)$ is covariance function, t is time (0 to 1 hour for hour covariance function, 0 to 1 day for daily covariance function), α, β, φ – parameters of the covariance function.

The results of constructing of the covariance functions are presented in pictures 3, 4, 5 and table 3.

Also, we estimate the parameters of daily covariance functions of stations Badary, Svetloe, Zelenchk using daily VLBI sessions [3] of 2019 year. The parameters are presented in the table 2. The used in QUASAR parameters are presented in the table 1. The parameter σ in the table 2 is more than in 3 which is the main reason of the difference between the results of processing VLBI observations using daily and hourly covariance functions.

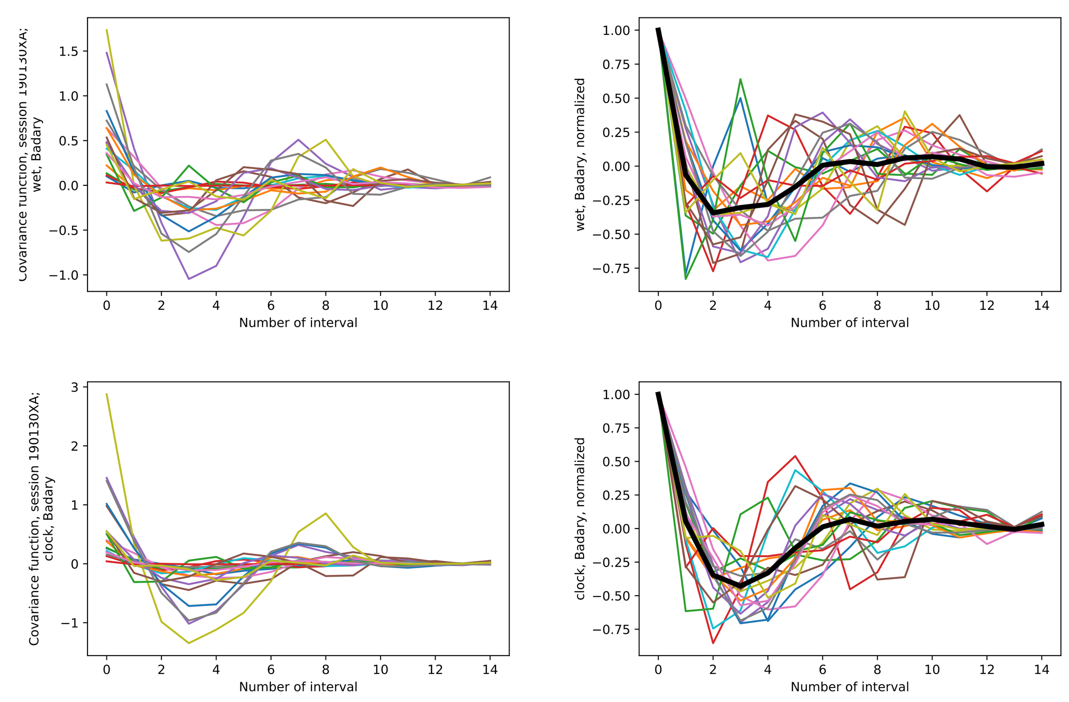

Figure 3: Covariance functions on hour intervals of station Badary

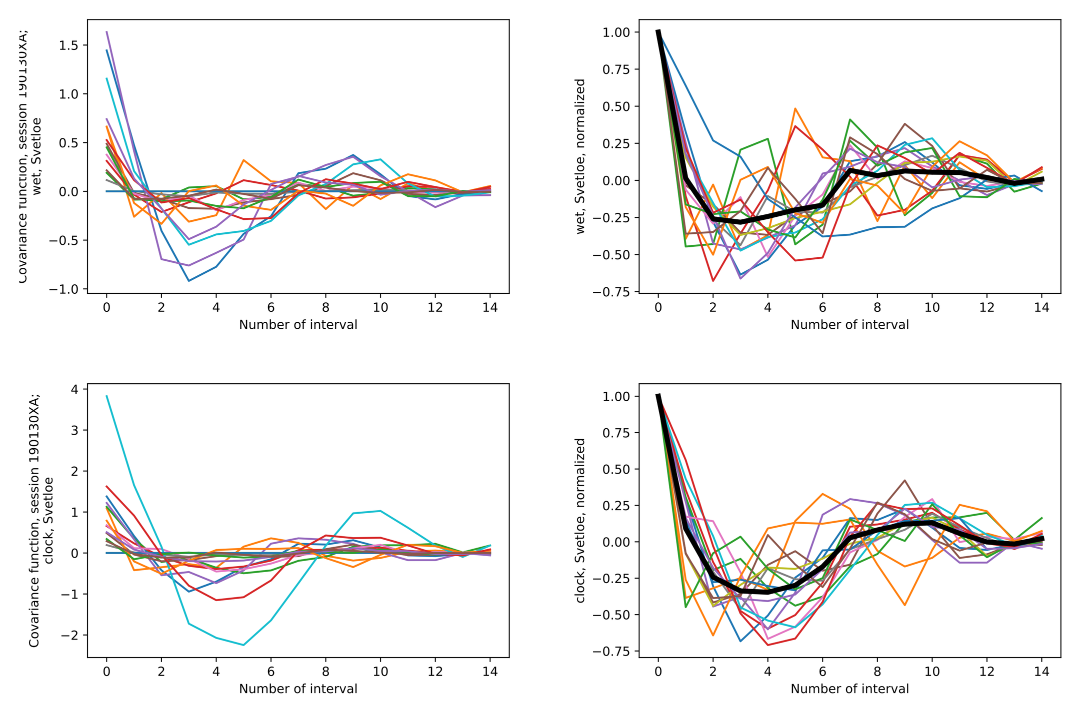

Figure 4: Covariance functions on hour intervals of station Svetloe

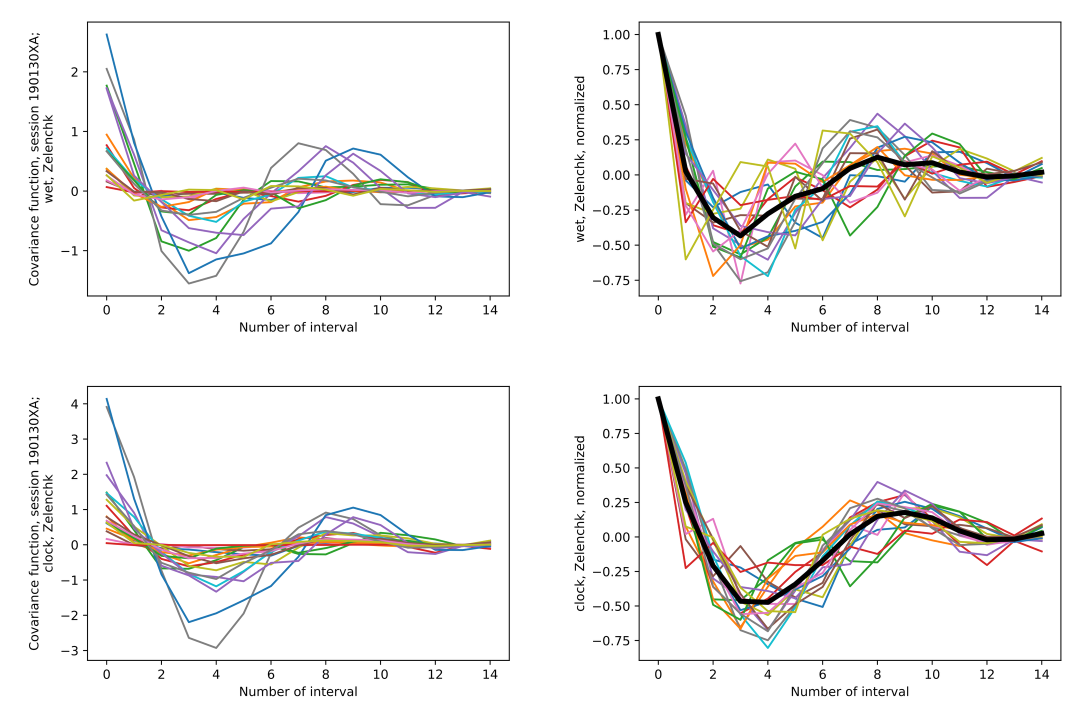

Figure 5: Covariance functions on hour intervals of station Zelenchk

Table 1: Parameters of covariance functions on daily intervals, QUASAR software

Station	Parameter	σ, mm^2	α, 1/day	β, rad	φ, rad
Badary	Clock	401.94	4.61	6.71	0.64
Svetloe	Clock	401.94	4.61	6.71	0.64
Zelenchk	Clock	401.94	4.61	6.71	0.64
Badary	Wet	140.90	3.35	6.26	0.69
Svetloe	Wet	140.90	3.35	6.26	0.69
Zelenchk	Wet	140.90	3.35	6.26	0.69

Table 2: Estimated parameters of covariance functions on daily intervals

Station	Parameter	σ, mm^2	α, 1/day	β, rad	φ, rad
Badary	Clock	152.22	0.08	6.08	-6.82
Svetloe	Clock	147.95	0.16	0.15	0.96
Zelenchk	Clock	196.28	0.12	6.12	-3.92
Badary	Wet	21.53	0.16	0.16	-2.28
Svetloe	Wet	41.94	0.15	6.09	-7.08
Zelenchk	Wet	26.53	0.14	0.20	0.79

Table 3: Estimated parameters of covariance functions on hourly intervals

Station	Parameter	σ, mm^2	α, 1/hour	β, rad	φ, rad
Badary	Clock	0.63	0.40	0.61	0.89
Svetloe	Clock	0.89	0.35	-0.52	2.27
Zelenchk	Clock	0.84	0.24	-0.59	2.45
Badary	Wet	0.57	0.55	0.52	1.08
Svetloe	Wet	0.56	0.52	-0.44	2.06
Zelenchk	Wet	1.28	0.42	0.58	0.92

Using new covariance functions on hourly intervals in VLBI data processing

We process RU VLBI sessions of 01.01.2020-01.06.2020 using QUASAR software. Parameters ΔUT, station clocks and its rate, wet zenith delay were estimated, station clocks and wet zenith delay have stochastic part. Some sessions were processed incorrectly with daily covariance functions, their χ^2 was less than 1 (pic. 6). Applying hourly covariance functions instead of daily covariance functions makes χ^2 greater than 1 and reduces formal errors of ΔUT1 (pic. 8). Corrections to ΔUT1 are almost the same for hourly and daily covariance functions (pic. 7).

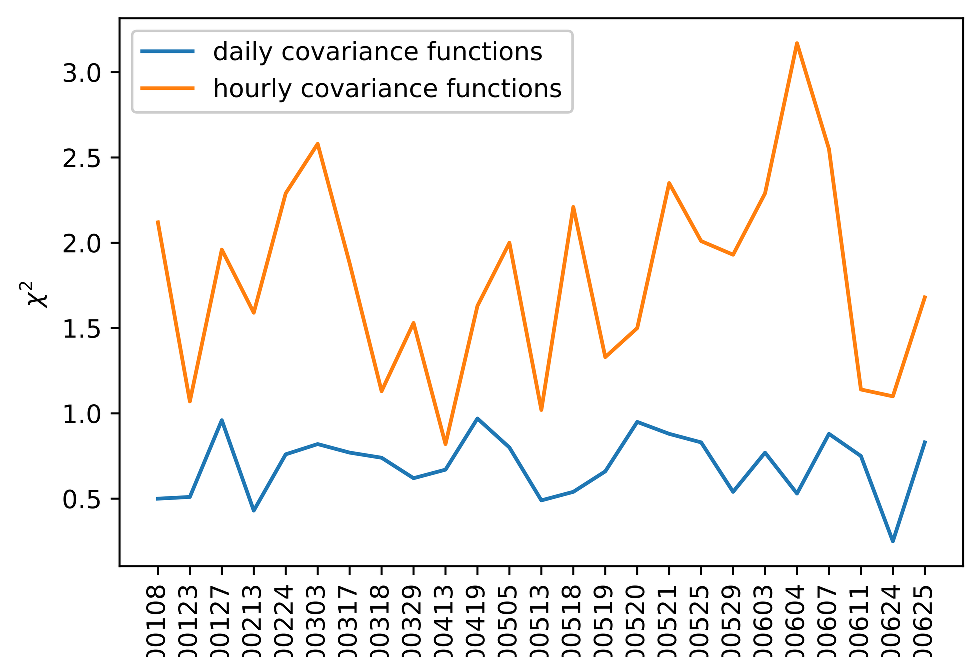

Figure 6: χ^2 of hourly RU sessions with daily or hourly covariance functions

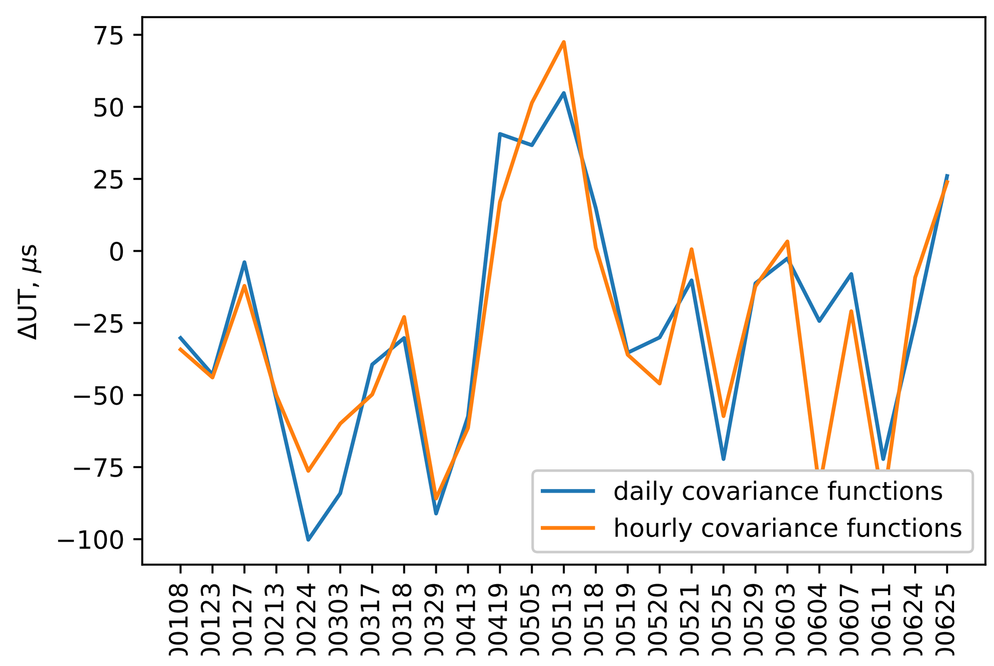

Figure 7: Parameter ΔUT1 estimated by hourly RU sessions with daily or hourly covariance functions

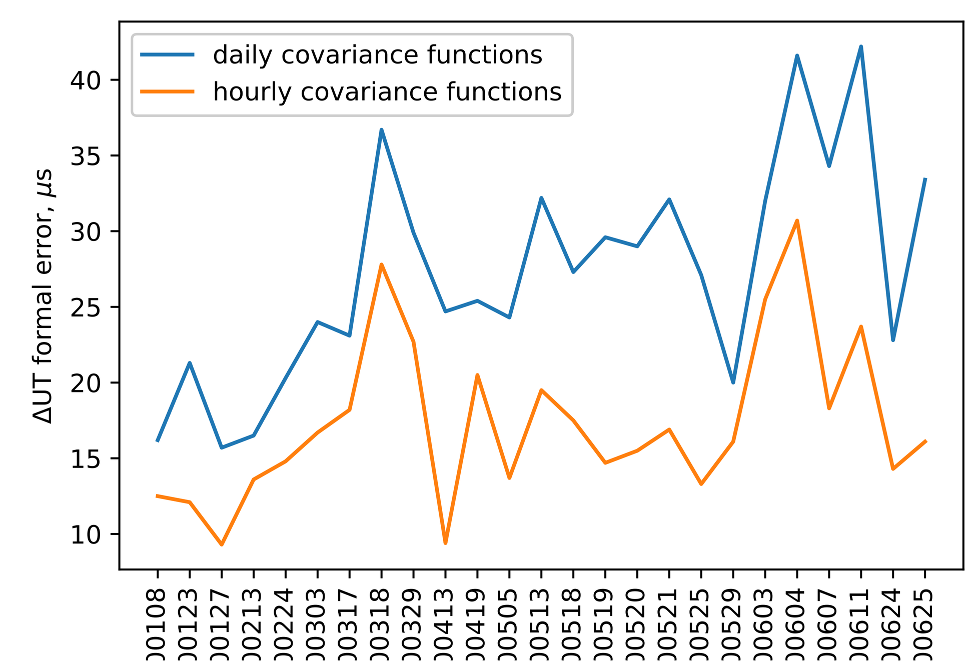

Figure 8: Formal error of parameter ΔUT1 estimated by hourly RU sessions with daily or hourly covariance functions

Conclusions

1. Parameters of hourly and daily covariance functions of stations Badary, Svetloe, Zelenchk were estimated. Hourly covariance functions were implemented in QUASAR software.
2. Hourly RU sessions of 01.01.2020-01.06.2020 were processed using QUASAR software with old daily and new hourly covariance functions.
3. Parameters χ^2 of the number of hourly RU sessions were less than 1 for daily covariance functions. Parameters χ^2 increased and formal errors of ΔUT1 decreased for hourly covariance functions.

References

1. S. L. Kurdubov, V. S. Gubanov. Global solution of VLBI-observations, IAA RAS, v. 23 (2012).
2. S. L. Kurdubov, Covariance analysis of the stochastic parameters of the model of the VLBI observations, IAA RAS, v. 14 (2006).
3. https://www.iers.org