Piecewise linear offsets for VLBI parameter estimation

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Abstract. In the scope of developing a new software package (Vienna VLBI Software, VieVS), for the analysis of Very Long Baseline Interferometry observations, all parameters to be estimated are basically modelled with piecewise linear offsets at integer hours, or at integer fractions or integer multiples of integer hours. In this presentation, we illustrate the outputs of the new software with several plots. These are piecewise linear offset estimates of clocks, Earth orientation parameters, antenna coordinates, tropospheric gradients, and zenith wet delays with their respective covariance matrices. The EOP covariance matrices depend on the number of antennas which are fixed. Besides, we investigate the effect of reference clock choice on the zenith wet delay piecewise linear offsets.

Piecewise linear offsets. Clocks, zenith wet delays, tropospheric gradients, Earth orientation parameters, and coordinates of the radio telescopes are estimated as piecewise linear offsets (Equation 1) illustrated in Figure (1).

$$y(t) = a_{n-1} + \frac{a_n - a_{n-1}}{t_n - t_{n-1}}(t - t_{n-1}) \qquad (1)$$

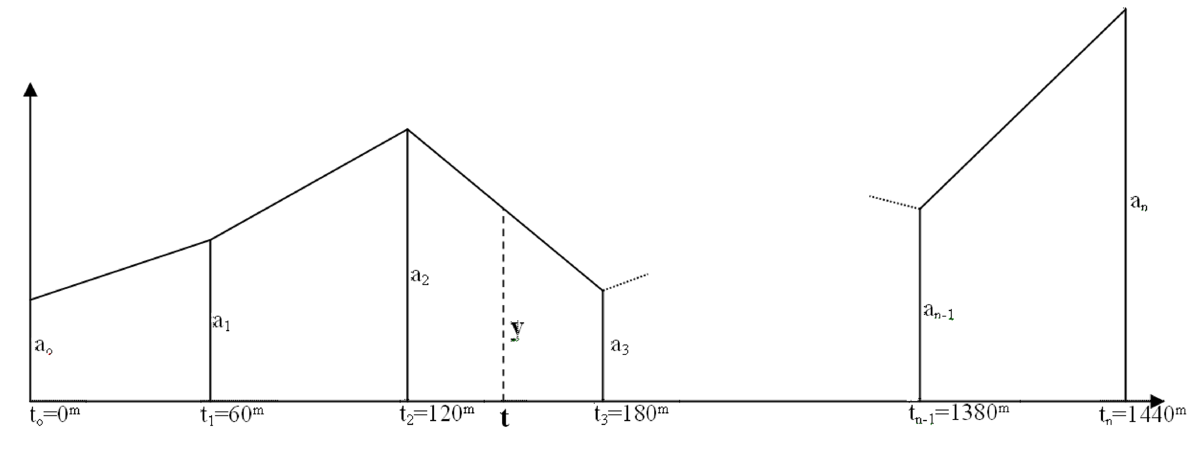

Figure 1. Piecewise linear offsets (a_i) of a daily (1440 minutes) session for 60 minutes ($t_{i+1} - t_i$) estimation intervals.

Estimating piecewise linear offsets with least squares. VLBI parameters can be estimated as piecewise linear offsets with Least Squares (LS) (Titov et al. 2004). Offsets are chosen as the parameters of a continuous piecewise linear function**.** The partial derivatives of the observation equations are given below.

$$\frac{\partial y}{\partial a_n} = \left(\frac{t - t_{n-1}}{t_n - t_{n-1}}\right) da_n \qquad \frac{\partial y}{\partial a_{n-1}} = \left(1 - \frac{t - t_{n-1}}{t_n - t_{n-1}}\right) da_{n-1} \qquad (2)$$

partial derivatives of the continuous piecewise linear offset functions which are the elements of the design matrix

Estimation strategy. The interval length for piecewise linear modelling of the parameters is usually set to values between 1 day to 20 minutes. Due to the limited number of observations in a session, estimation intervals should be selected accordingly. Too short estimation intervals for every parameter will cause unrealistic results. In addition, too many unknowns will decrease the accuracy of the estimated parameters and may lead to several singularity problems. In order to avoid numerical problems (as e.g. rank deficiencies) and to stabilize the parameter estimation process, constraints (or pseudo-observations) have to be included in intervals with only a small number of observations. Loose constraints as pseudo-observations can be added to the design matrix for each estimation interval to efficiently bridge gaps in the data (Kutterer, 2003). The weights of the constraints (pseudo-observations) have to be chosen accordingly to those of the real observations. Below are some results of the first 24h session of CONT05 processed by the Vienna VLBI Software (VieVS) which is developed at the Institute of Geodesy and Geophysics, Vienna University of Technology.

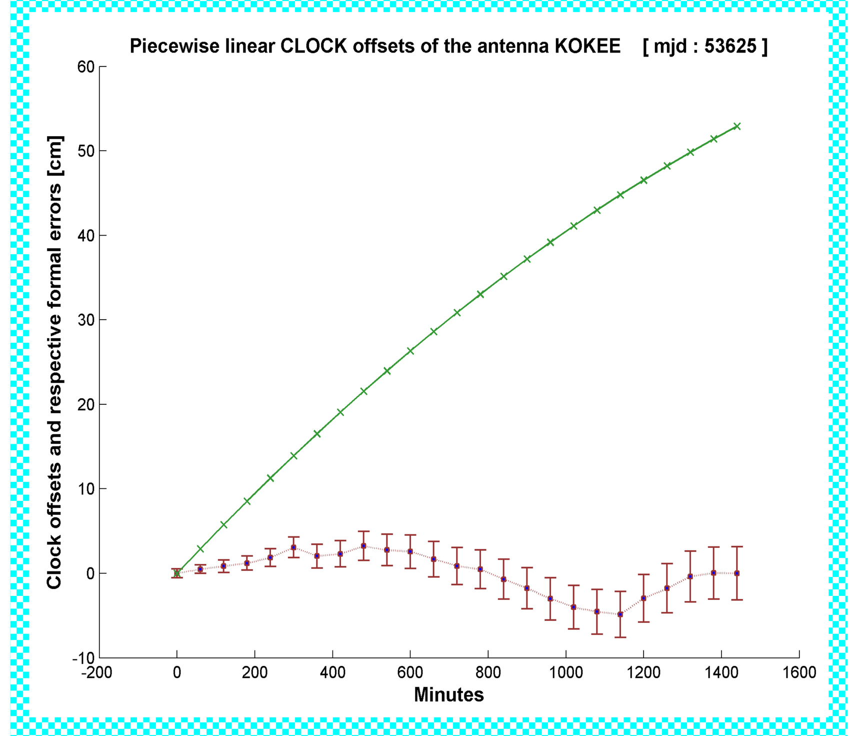

Figure 2. Quadratic clock function plotted in green and piecewise linear offsets in red for the Kokee Park clock.

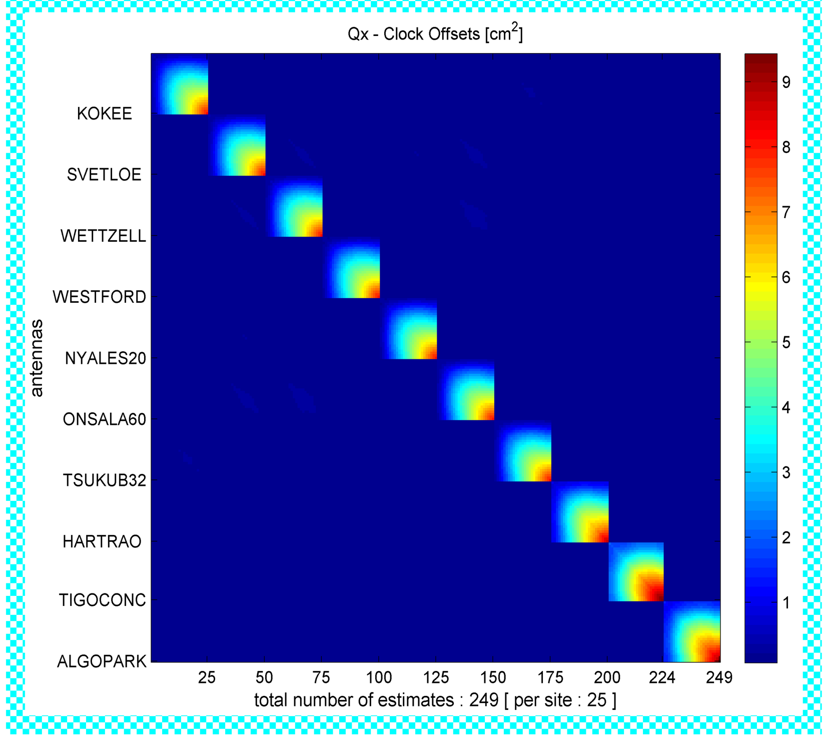

Figure 3. Covariance matrix of the piecewise linear clock offsets. Gilcreek clock is fixed. The offset errors increase proportionally to the elapsed time from the first scan time (t_0) of the session.

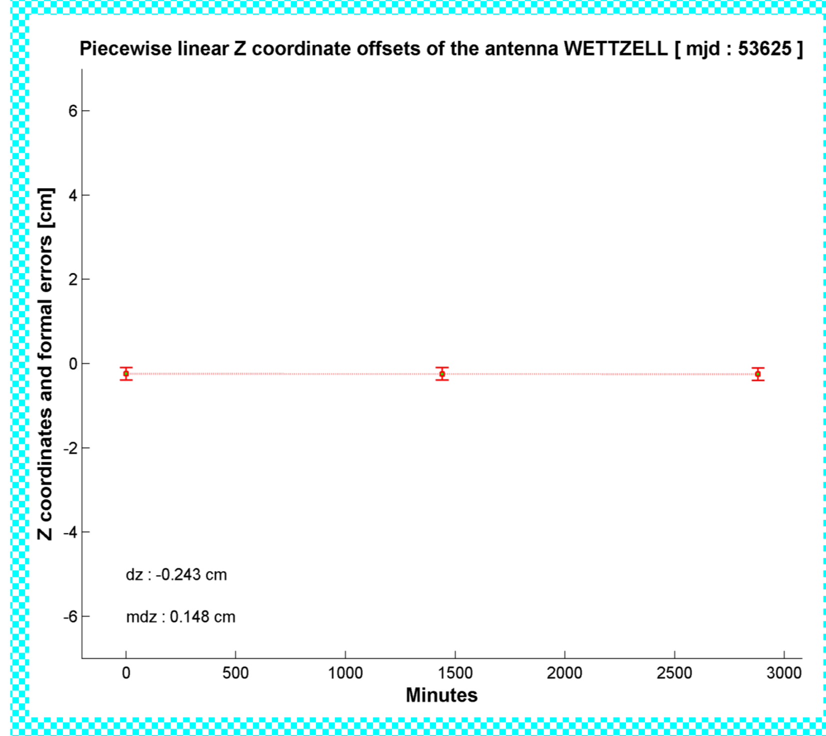

Figure 8. Tightly constrained piecewise linear offsets of the Z component of the Wettzell antenna coordinates (coordinates of 3 sites „Gilcreek, Kokee, Svetloe“ are fixed).

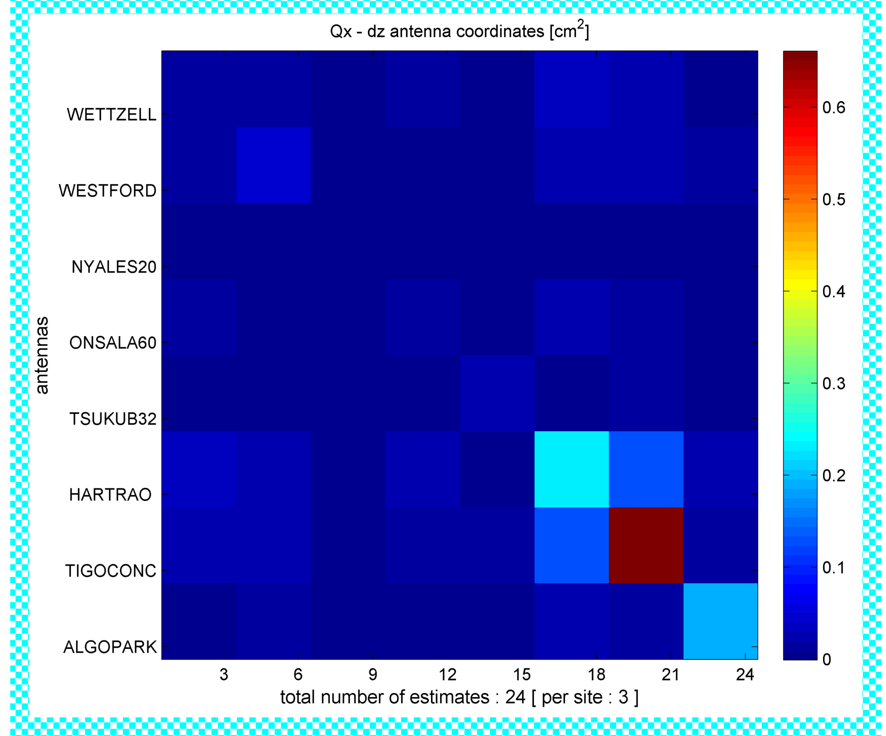

Figure 9. Covariance matrix of the tight constraint piecewise linear offset estimates of the Z coordinates of the antennas (coordinates of 3 sites „Gilcreek, Kokee, Svetloe“ are fixed).

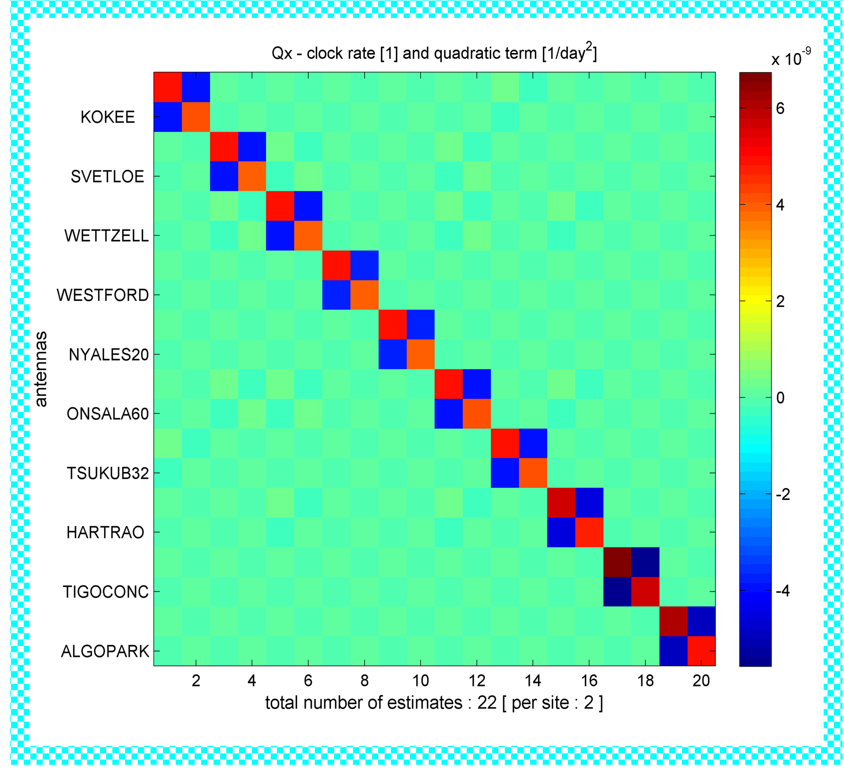

Figure 4. Covariance matrix of the rate and quadratic terms of the clock function.

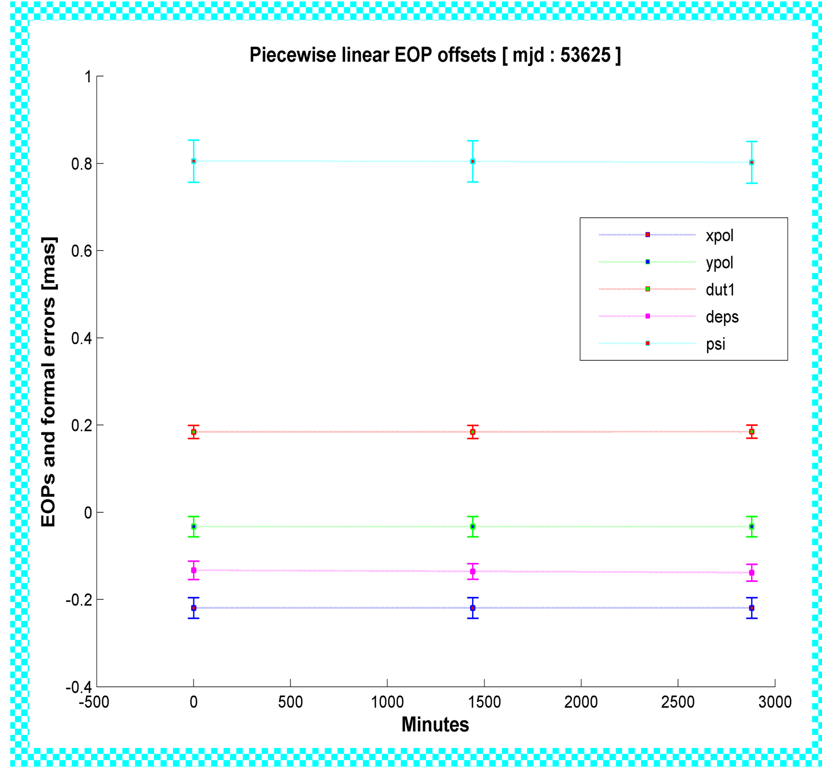

Figure 5. Tightly constrained piecewise linear EOP offset estimates (all antenna coordinates are fixed).

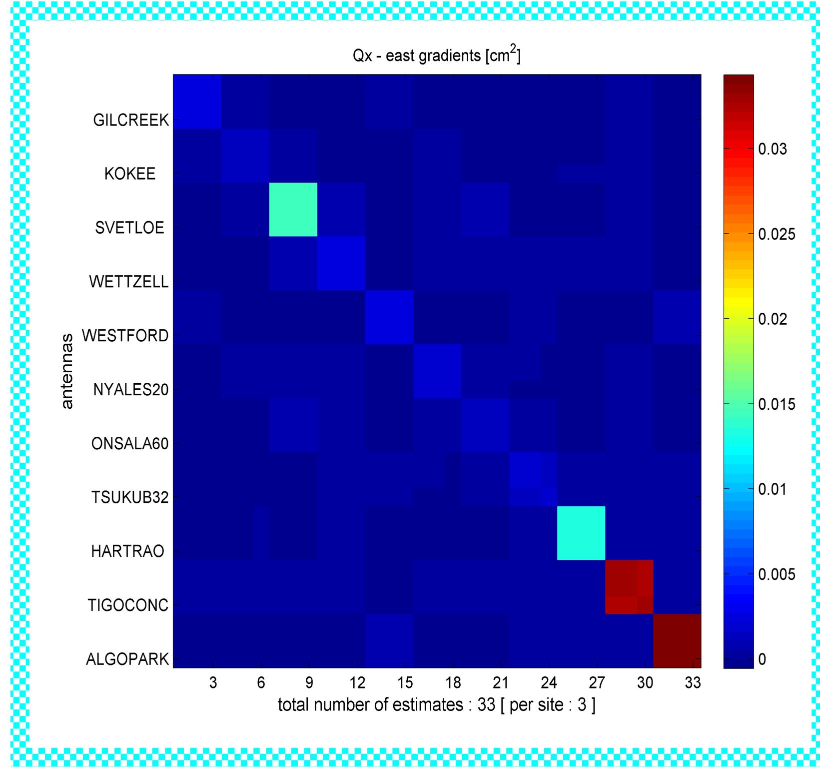

Figure 10. Covariance matrix of the piecewise linear east gradient offset estimates.

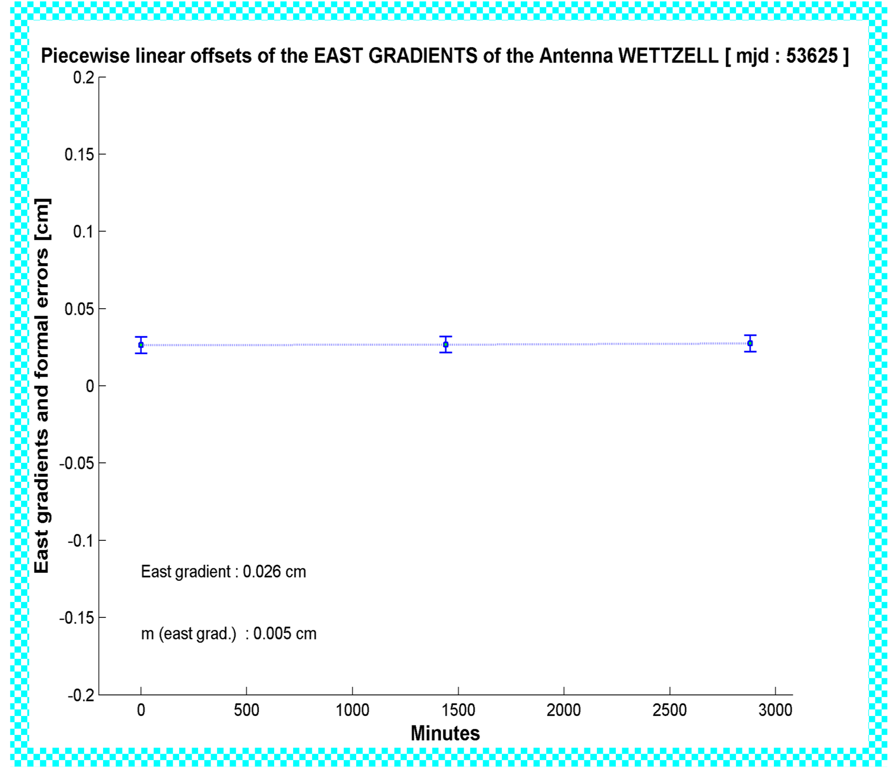

Figure 11. Piecewise linear tropospheric east gradient offset estimates of the Wettzell.

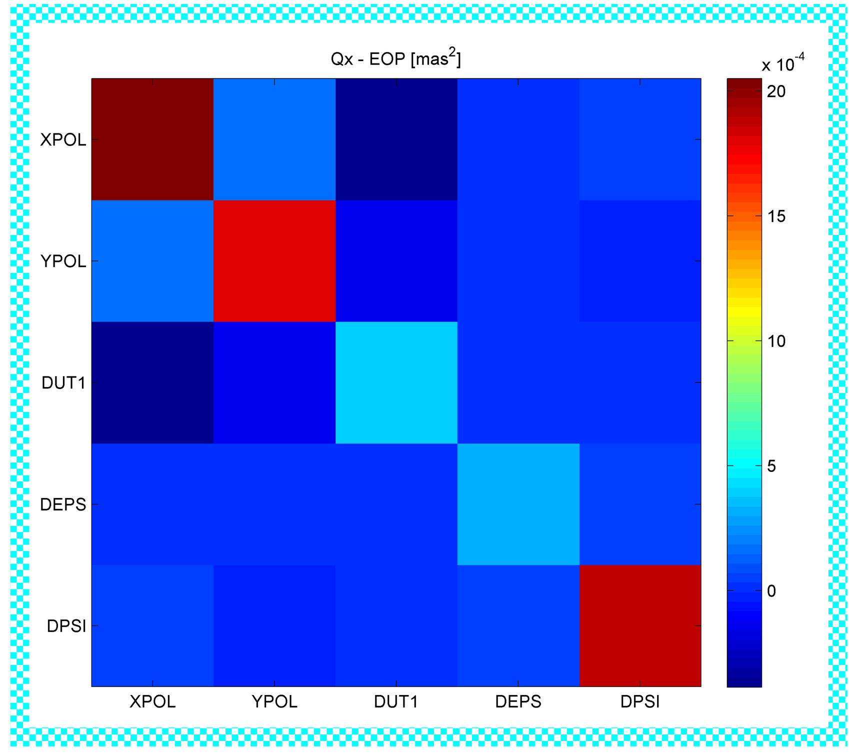

Figure 6. Covariance matrix of the EOP estimates (7 sites „Gilcreek, Kokee, Svetloe, Wettzell, Westford, Onsala60, Nyales20“ are fixed).

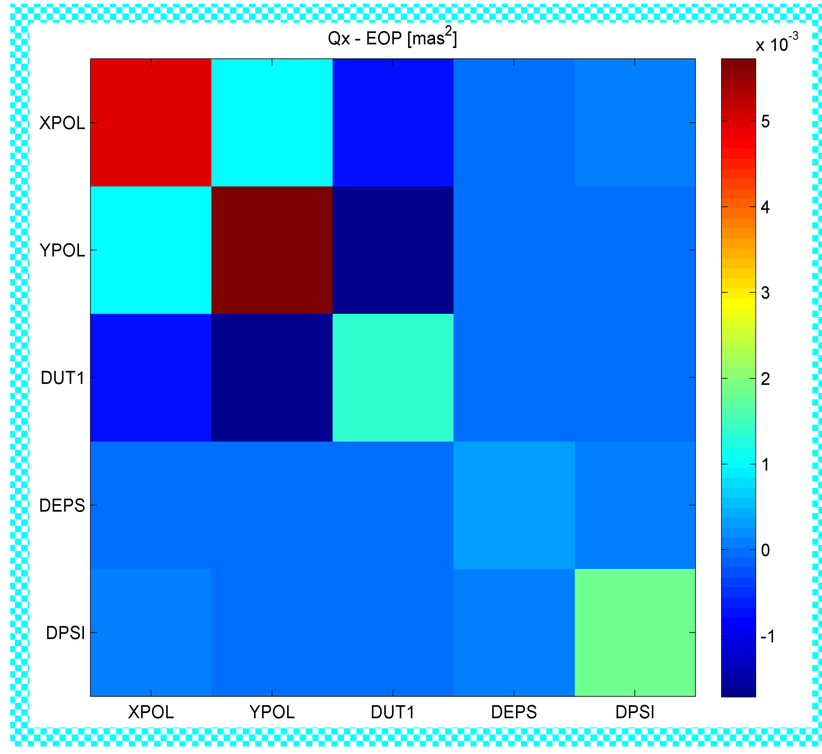

Figure 7. Covariance matrix of the EOP estimates (3 sites „Gilcreek, Kokee, Svetloe“ are fixed).

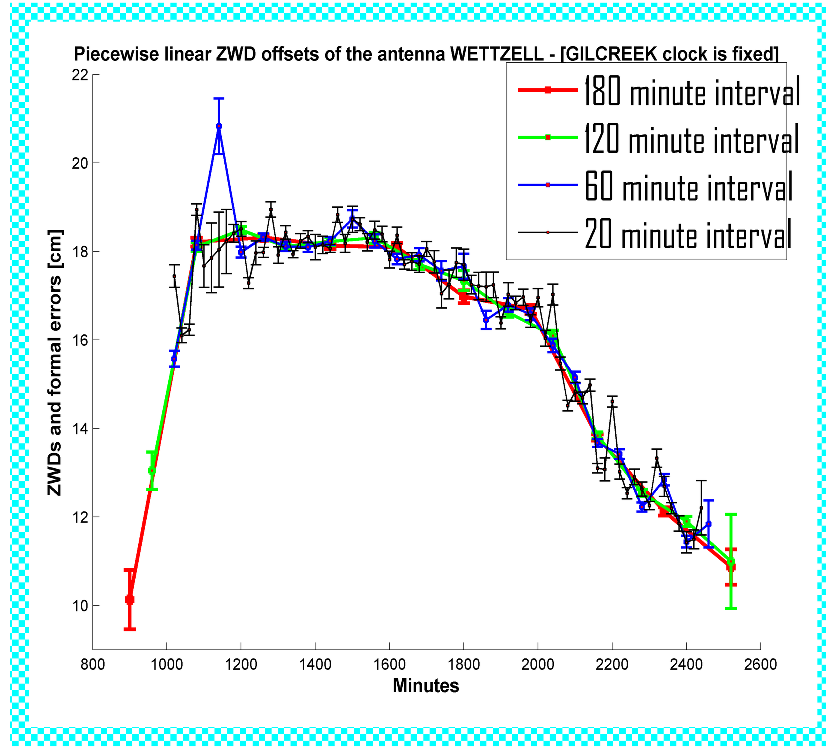

Figure 12. Piecewise linear zenith wet delay offsets of Wettzell (Gilcreek clock fixed).

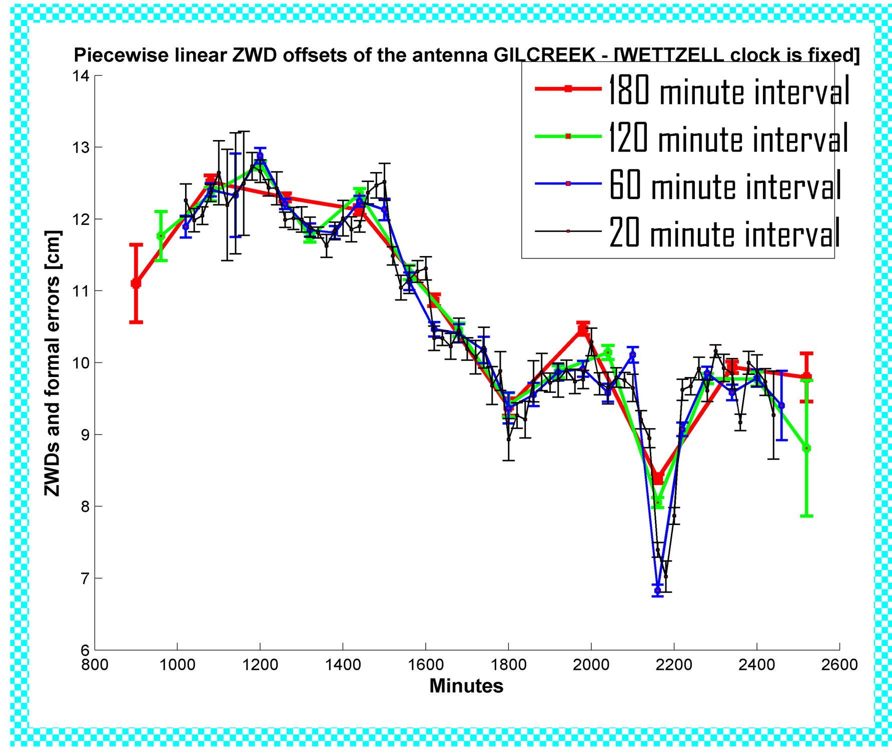

Figure 13. Piecewise linear zenith wet delay offsets of Gilcreek (Wettzell clock fixed).

Conclusion. From the investigations carried out within this study the following conclusions can be drawn:

- Piecewise linear offsets can be applied for all parameters, i.e. zenith wet delays, troposphere gradients, clocks, Earth orientation parameters, and station coordinates.
- The offsets should be determined at integer days, integer hours, or integer fractions of integer hours, respectively.
- The weights of the constraints (pseudo-observations) have to be chosen accordingly to those of the real observations.
- Clock parameterization and modelling should be improved.

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References.

• Kutterer, H. **The Role of Parameter Constraints in VLBI Analysis**, 16th Working Meeting on European VLBI for Geodesy and Astrometry, pp. 171-179, 2003.

•Titov, O., Tesmer, V., Boehm, J. **OCCAM v. 6.0 software for VLBI data analysis**. In International VLBI Service for Geodesy and Astrometry 2004 General Meeting Proceedings, Ed.; Nancy, R., Vandenberg and Karen D. Baver, NASA/CP-2004-212255, pp. 267-271, 2004.