# Impact of the Source Selection and Scheduling Optimization on the Estimation of UT1-UTC in VLBI Intensive Sessions

L. Kern[1], M. Schartner[2], J. Böhm[1], S. Böhm[1], A. Nothnagel[1], B. Soja[2]

**Abstract** With the help of Very Long Baseline Interferometry (VLBI), it is possible to determine a large number of parameters, including station and source coordinates as well as the Earth orientation parameters (EOP). Due to the limitation of observations of one-hour single baseline sessions, so-called *Intensive* sessions, only a few parameters such as clock offsets and zenith wet delays per station can be estimated in addition to the parameter of primary interest, which is the difference between UT1 (Universal Time 1) and UTC (Coordinated Universal Time).

Thus, the remaining parameters, including station and source coordinates, as well as EOP, are fixed to their a priori values, making the precision of the UT1-UTC estimate dependent on the accuracy of the a priori values used in the estimation process. Additionally, due to the daily rotation of the Earth and the revolution around the Sun, the source visibility and selection changes continuously, resulting in variations of the estimates of interest over time. Furthermore, the scheduling optimization process itself also has an impact on the results obtained by real observations or simulations. In this study, we show the variations of UT1-UTC estimates due to varying source selection and scheduling optimization strategies throughout the investigation period of one year using the simulation results of [7].

**Keywords** VLBI, Intensives, simulation, UT1-UTC

1. TU Wien
2. ETH Zürich

## 1 Introduction

The purpose of Very Long Baseline Interferometry (VLBI) observations includes the realization of the International Terrestrial Reference Frame (ITRF) [1] and the International Celestial Reference Frame (ICRF) [6]. Furthermore, it is possible to estimate the complete set of Earth orientation parameters (EOP) with VLBI [8]. So-called *Intensive* sessions, or shortly *Intensives*, are one-hour VLBI sessions between mostly two to three stations and are observed daily with the main goal of deriving the difference between UT1 (Universal Time 1) and UTC (Coordinated Universal Time) with a short latency. Due to the highly restricted number of observations, only a few parameters can be derived in addition to the main parameter of interest, namely zenith wet delays per station and a linear function for the clock differences. Thus, each of the remaining EOP, station, and source coordinates is fixed to its a priori value. As a result, the precision of the UT1-UTC estimate from *Intensives* is not only dependent on the baseline geometry (see [10]) but also on the accuracy of the a priori values used in the estimation process (see [7]). Furthermore, the overall scheduling process, including the source selection as well as the optimization strategies, influences VLBI observables. Based on our previous study [7], where we analyzed the impact of erroneous a priori information on the UT1-UTC estimate from *Intensives*, we are now taking a closer look at the differences in the UT1-UTC estimates themselves. By comparing the monthly estimates, the impact of the source visibility can be assessed, while the variations within one month represent the impact due to the scheduling process.

## 2 Data

The data were taken from our previous study [7], where we generated a 10 × 10 degree grid of artificial VGOS telescopes, which were assumed to have the same properties as the WETTZ13S telescope. In the course of the study, all possible baselines between so-called reference stations located at the reference meridian at zero degrees and any other artificial station were investigated, leading to almost 3,000 investigated baselines. In Figure 1 the gray dots represent the artificial antennas, and the red star highlights a reference station at 50 degrees latitude. For demonstration purposes, four random baselines are displayed using different colors.

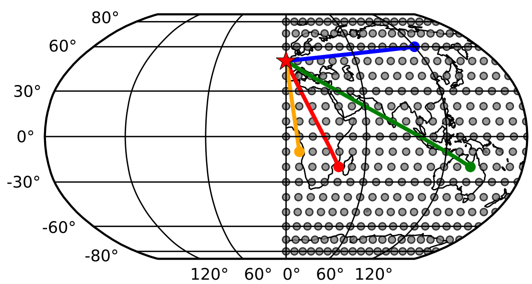


**Fig. 1** Experiment setup. All single baselines between the reference station (red star) and any other station (gray dot) are investigated. For demonstration purposes, four random baselines are displayed.

Highly optimized schedules per baseline and month were generated with the help of VieSched++ [11] over the investigation period of one year using different optimization strategies. In this respect, the weight factors for sky-coverage, scan duration, and low elevation observations as well as the corner switching cadences within the *Intensive* scheduling algorithm [10] are varied. Hence, per session, almost 100 schedules were created and simulated. In addition, a compact list of 125 suitable sources was used to mitigate the impact of varying source selection within the different schedules. However, as concluded in [7] and as can be seen in more detail in Section 3, changes in the source selection and thus scheduling results between the different months are still visible.

In this previous study, out of the 96 schedules per session, only the best performing schedule was selected for further processing, where we investigated the difference (ΔUT1) in the simulated UT1-UTC value of an unaltered evaluation, where no errors were introduced in the a priori information, and several modified evaluations. For this purpose, the remaining EOP, including the $x_p$- and $y_p$-components of polar motion and the $dX$- and $dY$-components of the nutation offsets, were taken from the IERS Rapid Service and Prediction Center (finals2000A.daily). The topocentric station coordinates of the second station of each baseline were compromised with an error of 162 µas or 5 mm. For more details on the impact of errors in the a priori information on the UT1-UTC determination with *Intensive* sessions, see [7].

Due to the high scatter of the monthly ΔUT1 values of some baselines, we found that the scheduling process itself, including the source visibility and selection as well as the optimization strategies, can have a significant impact on the precision of the estimates on the order of tenths of µs. In this additional study, we now want to analyze the results of all generated schedules per session created within the study [7] and show the variations of ΔUT1 per a priori error source within the 96 generated schedules and throughout the investigation period of one year.

## 3 Analysis

In the following Figures 2, 3, 4 and 5, the distribution of the ΔUT1 values of the different evaluations of all 96 generated schedules per month are displayed for four representative baselines. Comparing the monthly solutions makes it possible to quantify the impact of source visibility, while the distribution within one month represents scheduling-related impacts. The lines connect the medians of the monthly sessions to demonstrate the variations between the monthly sessions. The filled area represents the upper and lower quartiles of the 96 individual ΔUT1 estimates, while the whiskers show the total range of the estimates. Among the selected baselines are the northern INT1 baseline between Wz (Wettzell, Germany) and Is (Ishioka, Japan) (blue), the southern baseline between Ht (Hartrao, South Africa) and Hb (Hobart, Tasmania) (green), the INT9 baseline between Ag (Aggo, Argentina) and Wz (orange) with a midpoint close to the equatorial plane, and a north-south oriented baseline which is close to being parallel to the Earth's rotation vector between Wz and Ht (pur-

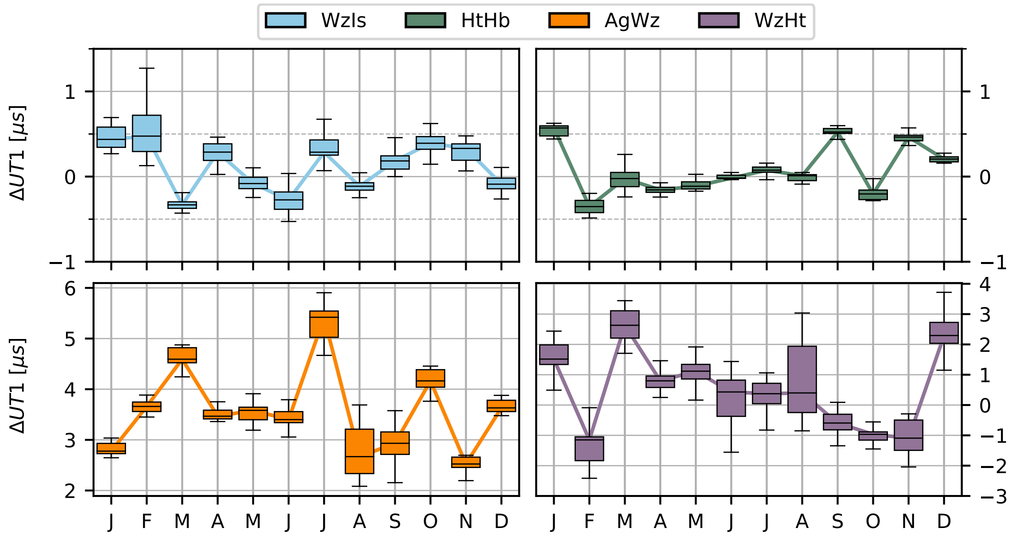


**Fig. 2** Effects on ΔUT1 by errors in the up–down direction of the a priori station coordinates.

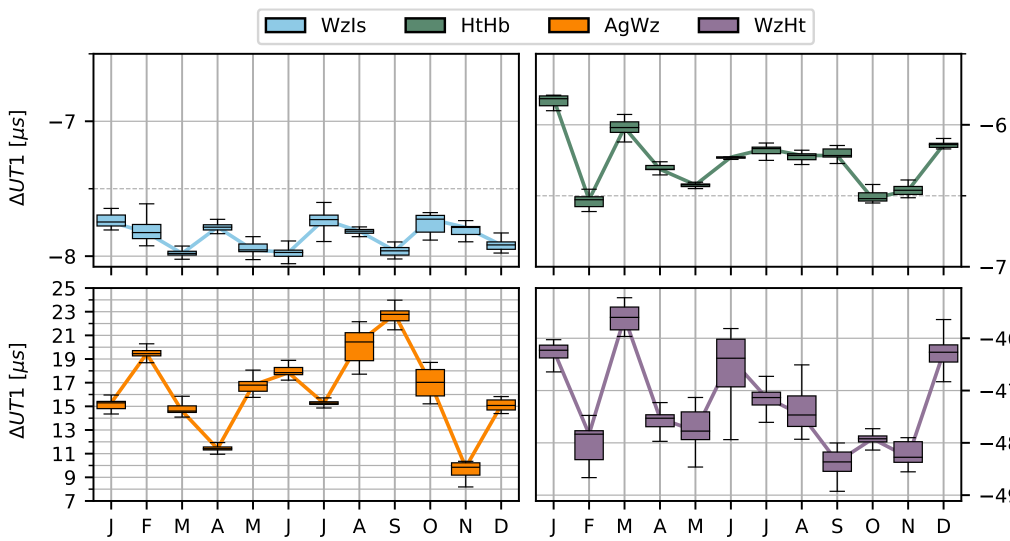


**Fig. 3** Effects on ΔUT1 by errors in the east–west direction of the a priori station coordinates.

ple). Except for the last baseline WzHt, all baselines are observed on a regular basis in *Intensive* sessions.

In Figure 2, an error of 5 mm was introduced in the up-component of the topocentric coordinates of the corresponding second station. In the case of the WzIs and HtHb baselines, the ΔUT1 values of about zero μs represent the high resistance against this a priori error. Furthermore, the overall scatter (standard deviation of all ΔUT1 biases) is rather low for both baselines ($\sigma$ = 0.3 μs), just as the variations within the individual sessions. In contrast, the differences in the UT1-UTC values for the AgWz and WzHt baselines are higher, and the standard deviations of all values are 0.8 and 1.4 μs. Moreover, the session-wise scatter is much higher, as noted by the different (larger) y-axis limits.

Figure 3 depicts the results of an evaluation with a modified east-component, which overall has a higher impact on the results compared to an error in up-direction. However, the baselines WzIs and HtHb are again more consistent throughout the year ($\sigma$ = 0.1 / 0.2 μs), although a clear bias due to the altered a priori coordinates is present, and within one session. In comparison, the individual plots of AgWz

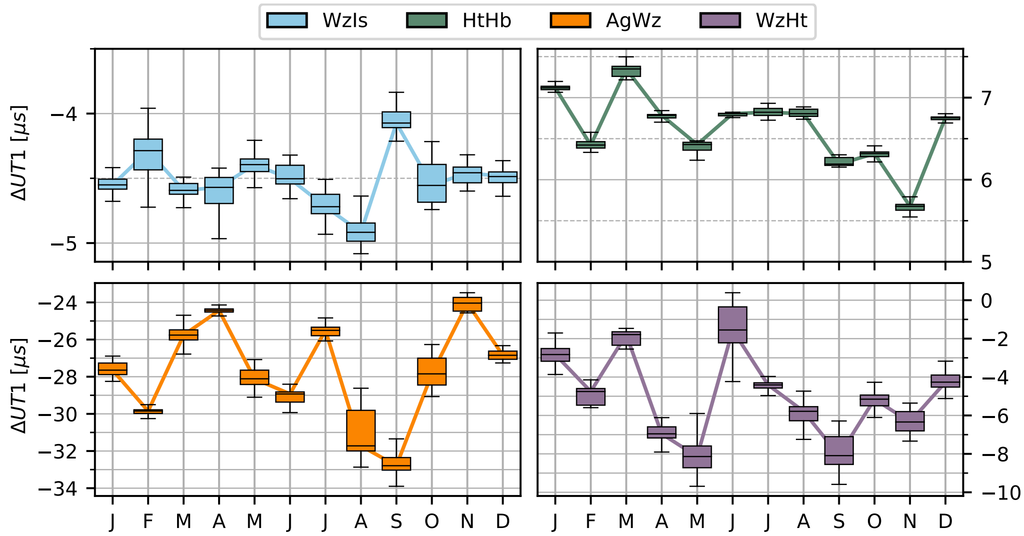


**Fig. 4** Effects on ΔUT1 by errors in the north–south direction of the a priori station coordinates.

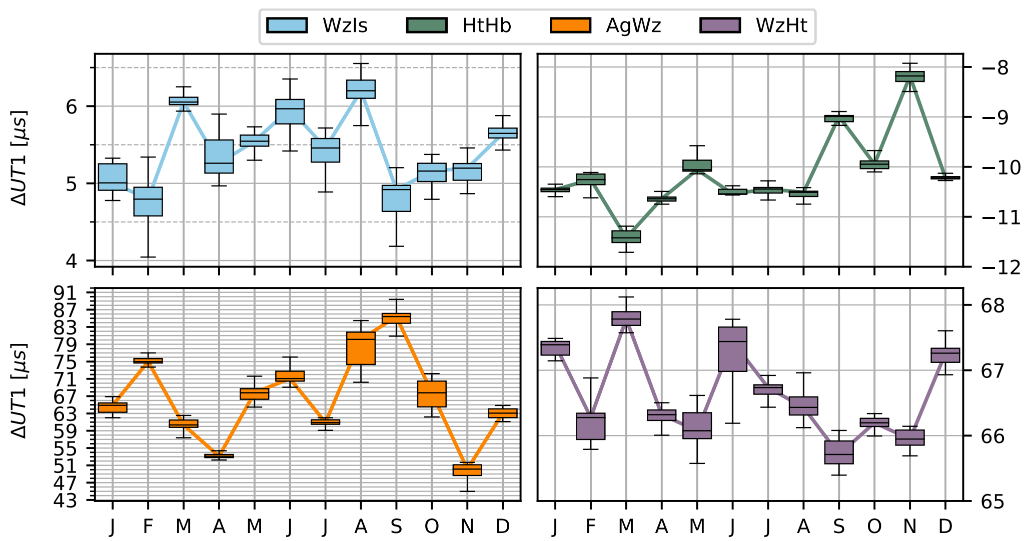


**Fig. 5** Effects on ΔUT1 by errors in the $x_p$- and the $y_p$-components of the a priori polar motion information.

and WzHt ($\sigma$ = 3.6 / 0.9 µs) depict how sensitive these baselines are against changes in the source selection.

Comparable results can be obtained if an error is introduced in the north-component (see Figure 4) with standard deviations of 0.2 (WzIs), 0.4 (HtHb), 2.6 (AgWz), and 2.2 (WzHt) µs.

In all cases with erroneous a priori station coordinates, the scatter between the individual months is greater than the scatter within one month. Therefore, one can conclude that the impact of source visibility is greater than the impact of scheduling.

Lastly, errors in the $x_p$- and $y_p$-components of the a priori polar motion information strongly affect the AgWz baseline, resulting in a standard deviation of 10 µs and ΔUT1 values of approximately 67 µs (see Figure 5). The other three baselines seem to be more resistant against changes in the source selection with standard deviations of 0.5 (WzIs), 0.8 (HtHb), and 0.7 (WzHt) µs.

## 4 Conclusions

*Intensives* are strongly influenced by the baseline geometry, errors in the a priori information, source visibility, and the scheduling process. While the baseline geometry and errors in a priori information were already studied in [10] and [7] respectively, this study reveals that the source visibility seems to have a larger impact compared to changes in the scheduling optimization. As can be seen from this study as well as in [7], some baselines (baselines with a midpoint close to the equatorial plane, e.g., INT9) are more affected than others (long east–west oriented baselines). This can be partly explained by the fact that baselines that exhibit a large scatter in the UT1-UTC estimates are also declared as not optimal for this determination due to their geometry or, more precisely, due to the restricted right ascension angles of observed sources [10]. Lastly, the examined southern baseline did not perform much worse than the northern baseline although fewer good sources are available in the southern hemisphere [6, 9]. More information on the performance of real southern *Intensives* can be found in [5].

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