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Combining VLBI Intensive with GPS Rapid Solutions for Deriving a Stable UT Time Series

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Abstract. Two different applications of the SINEX files for the intensive sessions will be shown in this contribution. In the first part, we demonstrate the benefit for the UT estimates if the intensive session is combined with the rapid GPS solution of the corresponding day. Secondly, we show their importance for deriving a combined long-time series of UT at daily intervals.

1. Introduction

In standard solutions for the intensive sessions, all parameters except for universal time (UT), one troposphere zenith delay per site and one clock parameter are fixed on their a priori values. The most critical parameters among the fixed parameters are polar motion (PM) and nutation [1]: as PM estimates often are not available in due time, they have to be fixed on predicted values. The nutation is fixed on the IAU2000 values so that the free core nutation is neglected. Recently, the IVS started to provide SINEX files for the intensive sessions, containing station coordinates, PM, UT and length of day (LOD), allowing for a rigorous combination with other data in order to have more reliable information than the predictions for PM. We assess the benefit of such a combination using normal equations derived from rapid GPS analysis. In general, if a combination of GPS- and VLBI-derived UT and LOD should be performed, the intensive sessions play a very important role as they fill many gaps between the 24-h sessions.

2. Daily Rapid ERP Combination

As the main intention of the intensive sessions is to have UT estimates with a very short latency, the rapid solutions from the International GNSS Service (IGS) are suitable for a combination. We use the normal equations from the rapid analysis at the CODE analysis center, containing station coordinates, PM, PM rates, UT1-UTC and LOD.

2.1. Impact of Fixed a Priori Pole Coordinates on UT

According to the Rapid Service and Prediction center of the IERS, the predicted values for PM have an accuracy of about 2.0 mas. In order to assess the impact of fixing pole coordinates that are wrong by this order of magnitude, we shifted the IERS-C04 series by 2.0 mas and estimated UT for the intensive sessions by fixing these falsified pole coordinates (one solution for shifting the x-pole only and a second solution for shifting the y-pole only). Additionally, we estimated UT for the same sessions by fixing PM on the original values of the IERS-C04 series. Comparing both resulting time series of UT (see Fig. 1 for the impact of the x- and y-pole, respectively), we see that the impact on UT is twofold: a mean bias and annual variations. However, the mean bias as well as the annual variation differ between the individual baselines. We can conclude that uncertainties in the y-pole have nearly no effect on UT derived from the baseline Wettzell-Tsukuba (XK-sessions), i.e., a bias of only 1.8 μs and almost no annual variation (i.e., 4.0 μs in terms of an RMS of unbiased residuals). But a wrong x-pole for this baseline will cause a large bias of about 64.3 μs in UT and only a small annual variation (RMS of 11.0 μs). The same is true for the impact of the y-pole for the baseline Wettzell-Kokee (XU-sessions) with a bias of 27.0 μs and an RMS of 5.3 μs. The largest variation in UT is visible for an error in x-pole in case of the baseline Wettzell-Kokee, resulting in a bias of 21.0 μs and an annual variation with an RMS of 16.2 μs. These results are in good agreement with the analysis carried out by [1]. It is clear that the predicted values for PM often are not as bad as 2 mas, and they are not wrong systematically as we assumed for our tests. However, the errors in the a priori PM have an impact on UT that should not be neglected.

2.2. Combination Results

For the last 16 months (November 2006 until February 2008), each normal equation of the intensive sessions is combined with the normal equation of the GPS rapid analysis of the corresponding day. Altogether, 287 XU sessions (Wettzell-Kokee) and 144 XK sessions (Wettzell-Tsukuba) are available. The combination is done in two steps: In a first step, only those parameters are combined that have to be fixed in a standard VLBI-only intensive solution, i.e., station coordinates and PM. In a second step, the contributions of GPS and VLBI to UT/LOD are combined additionally.

One pre-condition for the combination is that a co-located GPS site is

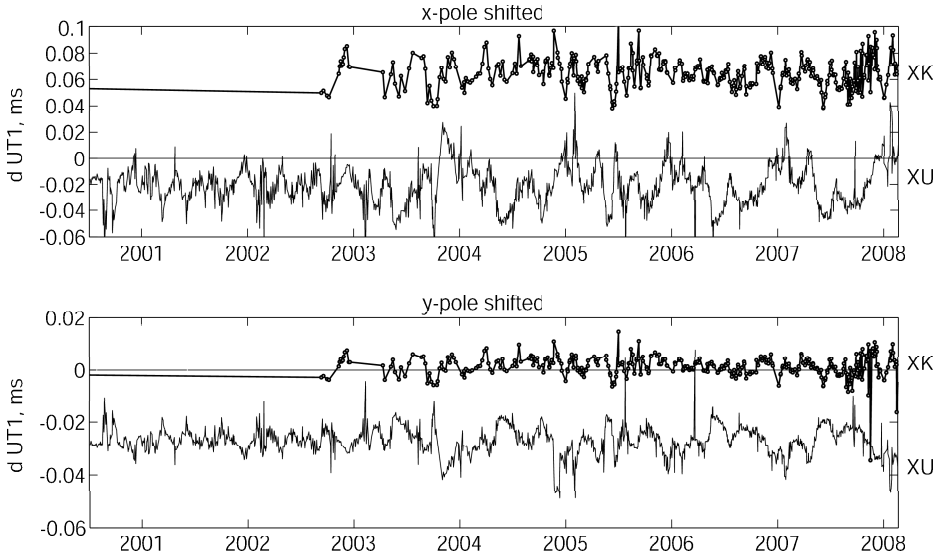

Figure 1. Impact on UT if pole coordinates shifted by 2.0 mas are fixed (XU: Wettzell-Kokee; XK: Wettzell-Tsukuba)

needed for both VLBI sites. However, the station priorities in the rapid GPS analysis did not yet consider the needs for the VLBI intensive sessions. Therefore, the site Tsukuba is often missing so that only 44 out of 144 XK sessions remain for the combination studies. The situation is much better for the XU sessions: 276 out of 287 sessions are usable. Another remark should be added regarding the GPS site at Wettzell. Normally, the site WTZR is included in the rapid solution, but due to the request for tracking GLONASS satellites, the site WTZZ was included (instead of WTZR) from July 2007 until mid of November 2007.

In order to assess the benefit of a combination, we first computed a VLBI-only solution for each intensive session by fixing the station coordinates to ITRF2005 and PM to the IERS-C04 series. The resulting VLBI-only time series is shown in Fig. 2. When combining station coordinates and PM, the resulting UT estimates are shown in Fig. 2 as well. The scatter of the residuals to IERS-C04 is reduced from 22.3 μs for the VLBI-only solution to 18.9 μs for the combined solution, demonstrating the benefit of a combination with GPS rapid solutions. However, the time series between July and November 2007 is striking. This is exactly the time span where the GPS site WTZZ instead of WTZR is included in the GPS rapid solution (see above). In an ideal case, this change should not have any impact on the results. However, as the solution heavily depends on the local tie information that is introduced, we can conclude from the results that there is a discrepancy between the local tie connecting VLBI with WTZR and that connecting VLBI with WTZZ. If

we consider only those combined sessions that are tied to WTZR, the RMS of the unbiased residuals is reduced to only 15.6 μs. The combined solution

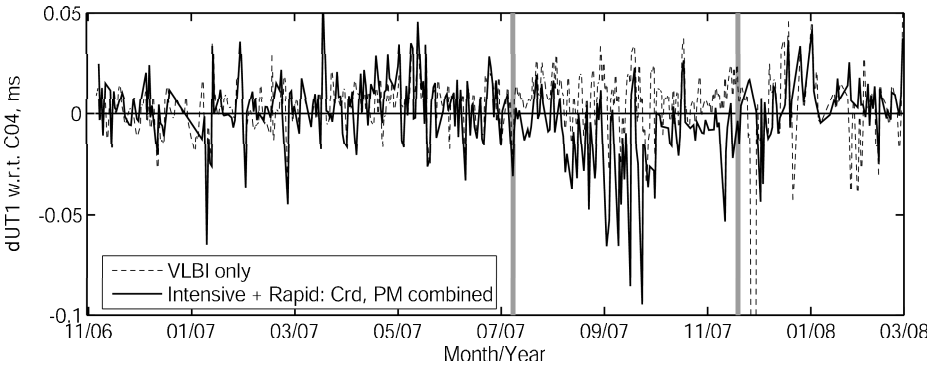

Figure 2. Differences of the UT1-UTC estimates compared to IERS-C04 for daily solutions. The two vertical lines delimit the time span with the site WTZZ

of the second step is not shown here because the results look similar to those of the first step (with identical RMS value). Thus, it can be concluded that the inclusion of the GPS-derived information about UT/LOD does not have a large impact, neither positive nor negative.

3. Combined Continuous Time Series of UT

In an ideal case, a time series of Earth orientation parameters (EOPs) contains estimates at equidistant epochs. This is problematic in the case of UT because VLBI does not have continuous observations but it is the only technique to determine UT in an absolute sense. Although the intensive sessions have no importance for the other EOPs, they are essential for UT. In order to show their importance, we combine normal equations for GPS and 24-h VLBI sessions generated within the project GGOS-D, and normal equations for the intensive sessions provided by BKG. All normal equations are combined into one full solution by estimating daily EOPs, station coordinates and velocities.

As our basic parameterization of the EOPs is a daily piece-wise linear polygon with functional values at epochs 00:00 UTC, we include the VLBI contribution by linearly transforming offset and drift given at the mean epoch of the session into two functional values at 00:00 UTC and 24:00 UTC of the corresponding day.

Considering the year 2004, we have only 129 24-h sessions, i.e., about two third of the daily UT values are derived solely from GPS and, thus, suffer from the systematic drifts induced when integrating GPS-derived LOD (Fig. 3, left plot). If we use the intensive sessions additionally, altogether 283 epochs in 2004 have a contribution by VLBI (Fig. 3, right plot). Comparing both figures,

it becomes clear that the intensive sessions fill many gaps between the 24-h sessions with valuable information. However, there are still about 80 epochs left that are determined solely by GPS. Tabl. 1 summarizes the RMS of the residuals compared to the IERS-C04 series. The benefit of combining the 24-h sessions with GPS can be clearly seen. The inclusion of the intensive sessions improves the full time series only slightly, but may be that the weighting still has to be optimized.

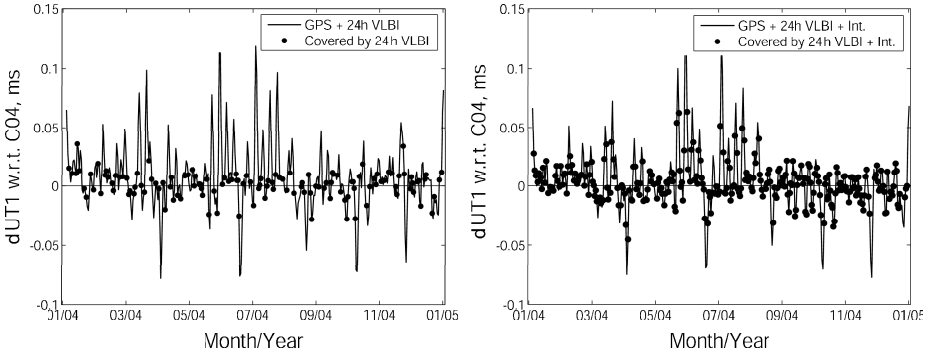

Figure 3. Combined time-series of UT at daily intervals (dots mark the epochs with a contribution of VLBI)

Table 1. RMS of UT residuals compared to IERS-C04 for the year 2004

Time series	RMS VLBI epochs	RMS all epochs
24-h VLBI	16.9 μs (129 epochs)	–
GPS + 24-h VLBI	10.8 μs (129 epochs)	26.4 μs
GPS + 24-h VLBI + Intensives	15.7 μs (283 epochs)	25.4 μs

4. Conclusions and Outlook

The impact of wrong fixed pole coordinates on UT for the VLBI intensive sessions has been demonstrated. An improvement compared to the VLBI-only solution can be seen if a combination with GPS is performed. However, it must be emphasized that the VLBI-only solution used here as a reference was computed with very good a priori PM (IERS-C04) instead of predicted values. Thus, we assume that the benefit of a rapid daily combination is even larger for the estimated UT values than it turned out in the studies presented here.

As regards GPS, the combination with VLBI intensive sessions will allow to derive daily rapid solutions with a correct alignment of UT. However, the benefit still has to be investigated.

The importance of the intensive sessions for a combined time series of UT at daily intervals has been shown for the year 2004. However, the combination should be extended to the whole time span where SINEX files are available.

Acknowledgements

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References

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