Influence of Source Constellations on UT1 Derived from IVS INT1 Sessions

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Abstract

We examined the influence of the spatial distribution of the observations on the quality of UT1 results derived from IVS INT1 sessions. The Kokee–Wettzell baseline midpoint is chosen as a reference point for the analysis. A Matlab code is written for classification of the topocentric source positions in different sections of the sky, as seen from the reference point. A combination of these key numbers is then used to classify the sessions with quality codes and compare them with their respective formal errors. Furthermore, we checked how many observations could not be used in the UT1 estimates, although they were included in the schedules.

1. Introduction

The parameter describing Earth rotation, dUT1, is needed for example when defining GPS orbits. The parameter can only be obtained from Very Long Baseline Interferometry (VLBI) observations. It is crucial to measure dUT1 with the best possible accuracy, thus we examine how the source constellations affect the quality of the results. IVS Intensive sessions INT1 with the baseline Kokee–Wettzell were chosen for the analysis because these sessions are measured five times per week, and thus there is enough data to attain reasonable results. A fictious baseline reference point is defined as the projection of the baseline midpoint onto the ellipsoid and serves as the origin of a topocentric system with the tangential plane being the equatorial plane of this system (Figure 1, left side). In a different projection, the baseline system can be interpreted as a hemisphere put on top of the ellipsoid at the baseline reference point (Figure 1, right side [1]).

Both the horizon limits of the two stations and the observations are best displayed in a stereographic projection, which is created by the SkyPlot program and described in Section 2.

2. SkyPlot Program

The SkyPlot program, written in GNU Octave, produces azimuth-elevation text files for the purpose of plotting station and baseline dependent sky-plots. As input files, skd files are used, which are produced with the software package SKED [2]. The skd files contain the scheduled observations of the current session and information about the station and source positions as well. The required information is parsed and used to calculate azimuth and elevation per scan for each participating station. These data are saved in ASCII files. Furthermore, such an output file is created per baseline as seen from the perspective of a fictive telescope placed at the baselines midpoint. In addition, the horizon limits of the stations are converted to the respective baseline midpoint by three sequenced single rotations. The common horizon of two stations at their baseline

Figure 1. Left: example of the midpoint based reference system (notice that this picture presents a baseline used in polar motion measurements, for dUT1 measurements a East-West placed baseline is needed). Right: geometry of baseline reference system and horizon mask are shown (pictures from [1]).

midpoint is the connecting line of the greatest elevation values per azimuth. Only radio sources above this border can be pointed at by both telescopes simultaneously. Plotting the baseline dependent sky-plot as a stereographic projection, like shown in Figure 2, the area of none visibility could be shaded in gray. At the cusps of the white area (sky sections 1 and 2 in Figure 2), which is the area of common visibility, are the lowest elevations for both stations. The azimuth-elevation text files created by the SkyPlot program, are used as the input files for the Matlab program written for the analysis described in Section 3.

3. Analysis Strategy

The stereographic projection from the SkyPlot program was divided into six sections as shown in the Figure 2. The azimuth and elevation limits are calculated on the basis of the azimuth-elevation files from the Skyplot. Quality codes AAA-D are given when 1 or more sources in two sections on opposite parts of the sky is seen from the midpoint of the baseline. Quality code AAA is given when there are three or more sources in both sections 1 and 2. This is assumed to be the best possible case, because the sources are as widely apart as they can be in the section pair. AA is given if there are two sources in one of the sections 1 and 2, and two or more sources in the other. Quality code A is given, if there is one source in one of the two sections, and one or more in the other. BBB is given if there are three or more sources either in sections 1 and 4, or 2 and 3. BB is given if there are two sources in one of the sections (1 and 4, or 2 and 3), and two or more in the other. B is given if there is one source in one of the sections, and one or more in the other. Quality code C is given, if there are three or more sources in sections 3 and 4, and D is given if there are the required number of sources in both sections 5 and 6. If any of the quality codes from AAA to D cannot be given (if there are not enough sources in any of the section pairs to enable the session to get a code AAA-D), quality code F is given. See Figure 3 for the section pairs.

600 INT1 sessions with the baseline Kokee–Wettzell from January 2009 to October 2011 were included in the analysis. 569 of these sessions were observed and correlated. Five of the remaining sessions were removed from the analysis due to large formal errors ($> 100\ \mu$s). Thus, 564 sessions were included in the analysis. Standard VLBI data analysis was performed following the IERS Conventions 2010 with the Vienna VLBI Software (VieVS [3]). A Matlab program to divide the
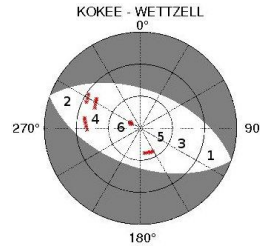
Figure 2. Stereographical projection with the division to different sky sections. Division to sections 1-6 was done with azimuth and elevation values obtained from the SkyPlot program.
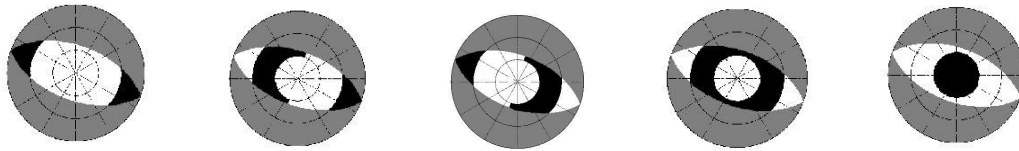

Figure 3. Stereographical projection plots with different section pairs marked for each quality code. From left to right: 1. The section pair for quality codes AAA-A. 2. and 3. The two possible section pairs for quality codes BBB-B. 4. The section pair for quality code C. 5. The section pair for quality code D. In the case that a session does not qualify for any of the codes (AAA-D), a quality code F is given.

data into different sections, to give quality codes and to calculate session counts, and to mean scan counts for each quality code was written.

4. Results

dUT1 estimates with respect to the a priori IERS C04 dUT1 and their formal errors were calculated with VieVS, and quality code error plots were generated to see at which level the formal errors of each category lay. Also mean values, session counts, and mean scan counts for the results in each category were calculated.

4.1. Quality Code Error Plots

Quality code error plots were drawn to see at which level the formal errors are in different quality categories. Also the session counts in each category can be evaluated based on Figure 4. The data was divided to nine quality categories. When the quality codes AAA: three or more sources in sections 1 and 2, AA: two or more sources in both sections (but less than three in one section), and A: one or more sources in both sections (but not two or more in both sections), were given, it was noticed that there were only 12 sessions in category AA. From Figure 4 it can also be seen that the variation in the formal errors grows from AAA to B. The variation is the smallest for formal errors of dUT1 for codes AAA to BB. The quality codes, session and mean scan counts are listed in Table 1. As can be seen the mean scan count is about 21-23 scans per session for categories AAA-AA and BBB-D, and for A about 20 and F about 19 scans per session.
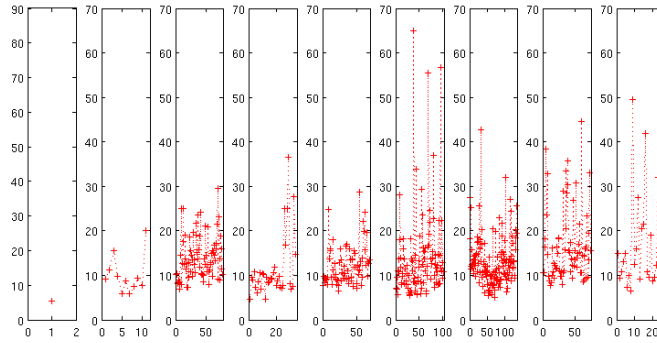
Figure 4. Formal errors of dUT1 estimates and quality code counts for categories AAA, AA, A, BBB, BB, B, C, D and F, in that order. On X-axis is the session count, and on the Y-axis the formal error in μs.

Table 1. Quality codes, the corresponding session and mean scan counts.

Quality code	AAA	AA	A	BBB	BB	B	C	D	F
Count	1	12	80	36	73	109	144	80	29
Scans	22.00	22.00	20.05	23.03	21.85	21.27	23.08	22.80	18.93

4.2. RMS Difference and Quality Code Counts

Table 2. Mean F.E. with RMS, RMS difference to IERS C04, and to IVS EOP-S, mean difference to C04 and to EOP-S, for each code, AAA-F in μs. * Only one session was included in the category.

Code	Mean F.E., RMS	RMS diff$_{C04}$	RMS diff$_{EOP-S}$	Mean diff$_{C04}$	Mean diff$_{EOP-S}$
AAA	5.37, −	14.75*	1.05*	14.75*	1.05*
AA	13.46, 4.66	13.78	30.46	-7.44	-5.57
A	15.48, 9.52	27.00	107.20	-8.24	8.86
BBB	11.10, 4.96	23.55	46.57	-2.78	12.58
BB	14.02, 9.36	27.40	82.93	-7.17	8.93
B	13.63, 6.95	28.60	153.31	-2.31	7.22
C	13.96, 6.91	34.95	63.76	-0.92	6.05
D	13.68, 6.62	32.03	103.78	-6.56	-15.03
F	14.71, 5.87	72.56	167.38	0.74	-16.13

RMS differences for dUT1 estimates for each quality code are listed in Table 2. Codes A and F have the largest mean values of formal errors of the dUT1 estimates with respect to the a priori IERS C04. The mean values of formal errors are the smallest with quality codes AAA and B. The five sessions that were removed due to large formal errors were from categories C and D. Category F has the largest RMS difference to IERS C04. Note that only one session has the quality code AAA, its dUT1 estimate relative to the IERS C04 a priori and its formal error have the value of

14.75 ± 5.37 μs, and it has a difference of 1.05 μs to IVS EOP-S dUT1. The RMS difference for dUT1 from the Intensive analysis with respect to the interpolated R1 and R4 dUT1 results from the combined solution from IVS EOP-S [4] are listed in the third column of Table 2. As can be seen the categories AAA, AA, and BBB give the best results. Also the mean differences to C04 and EOP-S are listed.

98.80% of the scheduled scans were observed and correlated. Failed sessions are not included in this percentage, only successfully correlated scans of successful sessions. The scheduled and observed scans were derived from SKD and NGS files, respectively.

5. Conclusions

We have categorized about 600 INT1 observing sessions with respect to their geometric distribution of observations in a baseline-fixed reference system. While category AAA with observations far down in the baseline sky map cusps seems to be the best one, categories from B to F with hardly any observations in the cusps or almost all observations close to the zenith of the baseline seem to be the worst. Looking at Figure 4, the formal errors seem to be convincingly low in categories AAA, AA, and BBB with only very few values larger than 12 — 13 μs. It is a bit surprising that category A does not show a similar behavior but this will be investigated. Nevertheless, the tendency of these groups not to show larger formal errors is quite striking. Larger formal errors definitely appear more in categories BB and below with formal errors often reaching 20 μs and above. With further analyses in this direction still pending we dare to conclude already that observations in the baseline sky map cusps are important for the geometric stability of the estimation of UT1-UTC from Intensive sessions because these observations seem to reduce the danger of large formal errors. They should, thus, be scheduled with highest priority.

Acknowledgements

References

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[4] IVS: International VLBI Service products available at http://ivscc.gsfc.nasa.gov/service/products 2012.