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CPO Prediction: Accuracy Assessment and Impact on UT1 Intensive Results

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Abstract

The UT1 Intensive results heavily depend on the celestial pole offset (CPO) model used during data processing. Since accurate CPO values are available with a delay of two to four weeks, CPO predictions are necessarily applied to the UT1 Intensive data analysis, and errors in the predictions can influence the operational UT1 accuracy. In this paper we assess the real accuracy of CPO prediction using the actual IERS and PUL predictions made in 2007-2009. Also, results of operational processing were analyzed to investigate the actual impact of EOP prediction errors on the rapid UT1 results. It was found that the impact of CPO prediction errors is at a level of several microseconds, whereas the impact of the inaccuracy in the polar motion prediction may be about one order of magnitude larger for ultra-rapid UT1 results. The situation can be amended if the IERS Rapid solution will be updated more frequently.

1. Introduction

Rapid VLBI UT1 observations are vital for the accuracy of the rapid IERS EOP solution and its prediction. To decrease rapid UT1 latency, special single-baseline 1-hour sessions are conducted practically every day with a delay in processing from several hours to several days. As shown in previous studies [1–3] UT1 estimates obtained from the single-base Intensive programs heavily depend on the celestial pole motion model used during analysis. For the most exacting applications, the celestial pole coordinates are computed as the sum of theoretical values given by an adopted theory of precession-nutation, IAU2000A nowadays, and corrections called celestial pole offset (CPO) that are obtained from observations, exclusively VLBI nowadays. The CPO comprises trends and (quasi)periodic components, Free Core Nutation (FCN) in the first place, caused by the inaccuracy of Earth Rotation theory.

The most accurate CPO is obtained from 24-hour VLBI sessions and is available, as a rule, with a delay from two to four weeks[1]. Therefore CPO predictions are necessarily applied to the UT1 Intensive data analysis, and errors in the predictions can influence the rapid UT1 accuracy. In this paper the real accuracy of CPO predictions is assessed using the actual predictions made by IERS (USNO) and PUL IVS Analysis Center (Pulkovo Observatory). The required prediction length can be found from analysis of the IVS combination delay, i.e., the time between the date of publication of the IVS combined solution and the last EOP epoch in this solution. For 2009, the median delay was 18 days, while the maximum delay was 37 days. We extend our analysis to the longer length, which may be interesting for other applications. Of course, the IVS series is then updated with new observations processed, but these changes in the IVS data are small enough to significantly influence rapid UT1 results.

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[1] Strictly speaking, CPO results from individual Analysis Centers are available with lower delay, but we consider the IVS combined CPO series as the most suitable for the EOP service applications.

This paper is aimed at an accuracy assessment of the CPO predictions computed with different models. As usual, the prediction accuracy is derived from a comparison of predicted values with the final ones. For a proper interpretation of the results obtained in this study, the following circumstance should be taken into account. Each CPO model is a result of the fitting of observed CPO series. The models differ not only by the method of fitting, but also by the CPO data used in the analysis, which makes results from the accuracy assessment somewhat ambiguous. One may consider the prediction accuracy with respect to the model itself, which is, in fact, the accuracy of representation of the given model. However, we are interested in the accuracy of the representation of the actual celestial pole motion, which is the most important for the majority of users. For this reason we use a comparison of CPO predictions with the IVS combined CPO series, which is intended to be an official standard.

2. Data Used

In this study we present results of processing VLBI observations made in the framework of the IVS UT1 Intensive observing program with different delay and different CPO models. The following data were used:

- INT1 sessions, observed on the workdays on the stations KOKEE (Kk) and WETTZELL (Wz); the database is normally available in 2–5 days.
- INT2 sessions, observed on weekends on the stations TSUKUB32 (Ts) and WETTZELL; the database is normally available in 1–2 days.
- INT3 sessions, observed on Monday on the stations NYALES20 (Ny), TSUKUB32, and WETTZELL; the database is normally available on the same day.

The following actual and publicly available CPO models were tested:

- IERS final EOP series computed at the Paris Observatory (C04 series) [4]. It does not contain prediction and thus is equivalent to a zero model for rapid data processing.
- IERS rapid EOP series computed at the USNO (NEOS model) [4]. It is constructed from analysis of the NEOS combined CPO series and updated daily.
- Lambert's FCN series computed at the Paris Observatory (SL model) [5]. As a matter of fact, it can represent only the FCN contribution to CPO. However, this model is recommended by the IERS Conventions (2003) as the substitute for CPO. It is constructed from the analysis of the IERS combined series C04 and updated every several months.
- The author's ZM2 model computed at the Pulkovo Observatory [6]. It is constructed from the analysis of the IVS combined CPO series and updated daily.

Comparison of these models with IVS data is shown in Fig. 1.

3. Accuracy of CPO Predictions

As usual, the accuracy of CPO predictions was estimated by a comparison of predicted and final values. Predictions made in the period from December 30, 2006 through December 25, 2009 were used. Both the rms and maximum prediction errors were computed; the latter causes the maximum dilution in the UT1 accuracy and thus is very important. Results are presented in Figs 2 and 3. One can see that ZM2 model provides the best accuracy of CPO prediction.

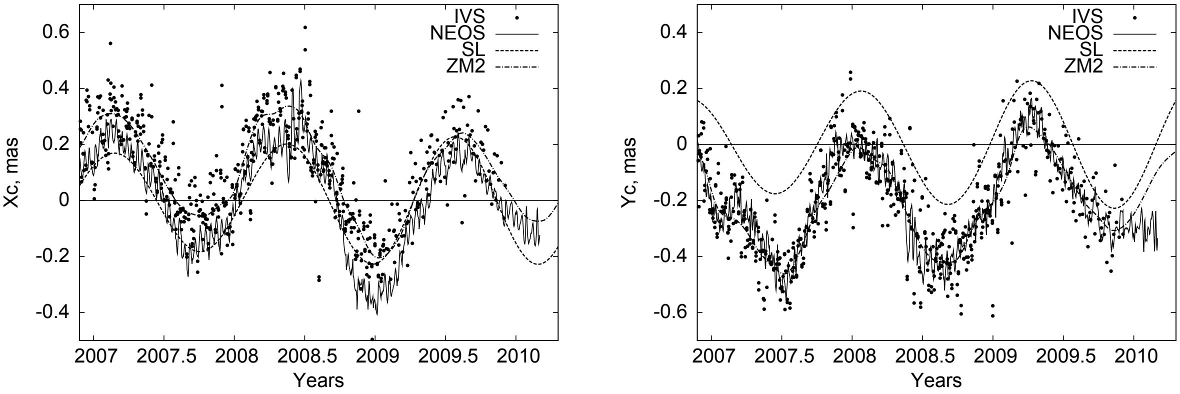

Figure 1. CPO models compared with the IVS combined CPO series.

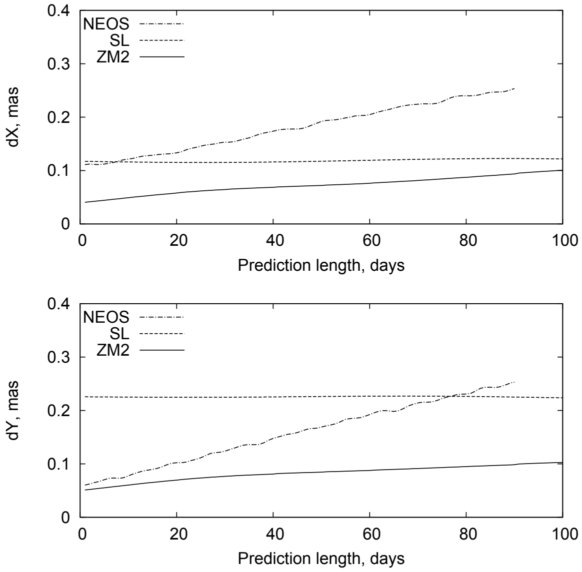

Figure 2. The rms error of CPO prediction for different models.

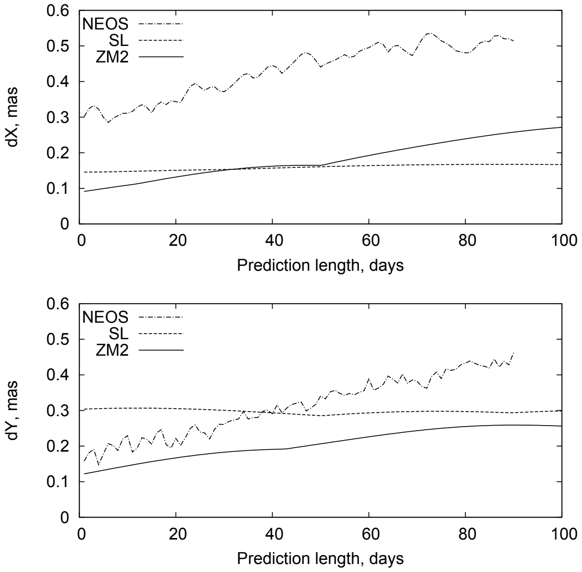

Figure 3. The maximum absolute error of CPO prediction for different models.

4. Impact of Prediction Errors on Rapid UT1

To investigate the impact of the CPO prediction error on the rapid UT1 estimates, we started an experimental processing of INT1, INT2, and INT3 sessions with different CPO models in October 2009. All the computations presented here were made with the ZM2 model. Using other models gave similar results. Each session was processed three times:

1. immediately after the database is available (O); during INT1 and INT2 processing interpolated polar motion (PM) and extrapolated CPO are used, and during INT3 processing both CPO and PM are extrapolated;
2. 5-7 days after the date of observations (O2); in this case practically the final PM is available, but CPO is still extrapolated;

3. at least 10 days after the IVS combined CPO for the date is available (F); during this processing practically both the final CPO and PM are available.

In the beginning of this work, only operational processing (O) was performed. The first O2 processing was made in December 2009. The differences between the UT1 estimates obtained with different delays for several sessions are shown in Tables 1 and 2. These results are quite representative for all the computations. Comparisons of F-O, O2-O, and F-O2 differences show that errors in extrapolated PM coordinates have a more significant impact on the UT1 estimates than on the CPO prediction errors. This can be explained by the fact that, while the maximum CPO 30-day prediction error during the last three months was about 0.15 mas (for ZM2 model), the maximum PM error for the IERS Bulletin A 1-day PM prediction during the same period was about 1.7 mas and 0.94 mas for X and Y pole coordinates, respectively. Consequently, the impact of the PM prediction errors is about one order of magnitude larger than the impact of the CPO prediction errors. The latter is at a level of a few microarcseconds, much less than the uncertainty of UT1 estimates. This result is in good agreement with Nothnagel's estimate of a single-baseline UT1 bias at the level of 1 microsecond for a 40-microarcsecond bias in CPO or PM [2]. One can see that INT3 results obtained for the whole 3-station network NyTsWz are similar to the single-baseline solutions TsWz for the same sessions.

5. Conclusion

The impact of a CPO prediction error on the rapid UT1 results seems not to be very significant, much less than the impact of the PM prediction error. The very rapid UT1 observations of the INT3 observing program that are correlated on the day of the observations—so that the database is normally available before the IERS Rapid combination used as a priori EOP is updated—sometimes show very large biases up to several tens of microseconds as compared with results of processing made after interpolated IERS PM data is published. The situation can be amended if the IERS Rapid solution will be computed and published more frequently, say every 6 hours, after the ultra-rapid IGS combination is ready. Such an approach seems to be much more preferable than a user doing a home-bred combination of the IERS and IGS data.

More details of this study are given in [7].

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Table 1. Differences between UT1 estimates obtained using different delays (μs): INT1 (KkWz). See text.

Session code	Week-day	UT1 differences			Session code	Week-day	UT1 differences		
		F-O	F-O2	O2-O			F-O	F-O2	O2-O
I09357	Wed	-2.0	-2.0	0.0	I09348	Mon	-2.2	-2.2	0.0
I09362	Mon	-1.5	-1.6	0.1	I09349	Tue	-2.1	-1.6	-0.5
I09363	Tue	-1.7	-1.5	-0.2	I09350	Wed	-0.2	-1.3	1.1
I09364	Wed	-1.5	-1.1	-0.4	I09351	Thu	-0.8	-0.8	0.0
I09365	Thu	-1.9	-1.6	-0.3	I09352	Fri	-0.9	-0.8	-0.1
I10004	Mon	-0.3	-1.6	1.3	I09355	Mon	-1.3	-1.3	0.0
I10005	Tue	-1.8	-1.8	0.0	I09356	Tue	-1.6	-1.6	0.0

Table 2. Differences between UT1 estimates obtained using different delays (μs): INT2 and INT3. See text.

Session code	Week-day	UT1 differences					
		TsWz (INT2)			NyTsWz (INT3)		
		F-O	F-O2	O2-O	F-O	F-O2	O2-O
K09299	Mon	-1.6					
K09304	Sat	-3.2					
K09305	Sun	9.4					
K09306	Mon	47.1					
K09311	Sat	-3.1					
K09312	Sun	1.6					
K09313	Mon	8.4					
K09318	Sat	1.5					
K09319	Sun	-0.4					
K09320	Mon	0.3					
K09325	Sat	-1.6					
K09326	Sun	-1.0					
K09327	Mon	20.8					
K09332	Sat	0.6					
K09333	Sun	5.7					
K09334	Mon	-1.6					
K09339	Sat	-1.0					
K09340	Sun	0.6					
K09341	Mon	-0.9					
K09346	Sat	-0.5	0.5	-1.0			
K09347	Sun	0.2	1.6	-1.4			
K09348	Mon	-9.2	0.1	-9.3			
K09353	Sat	-1.3	-0.6	-0.7			
K09354	Sun	0.2	0.0	0.2			
K09355	Mon	3.5	-0.6	4.1			
K09360	Sat	-1.0	-1.0	0.0			
K09361	Sun	1.7	-1.3	3.0			
K10002	Sat	-2.8	-2.7	-0.1			
K10003	Sun	-1.2	-2.7	1.5			
K10004	Mon	2.9	-1.7	4.6	0.5	-2.1	2.6
K10011	Mon	5.7	-3.0	8.7	6.4	-2.6	9.0
K10018	Mon	-15.3	-2.8	-12.5	-13.3	-2.7	-10.6
K10025	Mon	-4.7	-2.5	-2.2	-4.6	-2.5	-2.1
K10032	Mon	-11.9	-3.2	-8.7	-10.7	-3.1	-7.6