ARTIFICIAL SATELLITES, Vol. 57, No. SI1 – 2022
DOI: 10.2478/arsa-2022-0021

SECOND EARTH ORIENTATION PARAMETERS PREDICTION COMPARISON CAMPAIGN (2ND EOP PCC): OVERVIEW

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ABSTRACT. Precise positioning and navigation on the Earth's surface and in space require accurate earth orientation parameters (EOP) data and predictions. In the last few decades, EOP prediction has become a subject of increased attention within the international geodetic community, e.g., space agencies, satellite operators, researchers studying Earth rotation dynamics, and users of navigation systems. Due to this fact, many research centres from around the world have developed dedicated methods for the forecasting of EOP. An assessment of the various EOP prediction capabilities is currently being pursued in the frame of the Second Earth Orientation Parameters Prediction Comparison Campaign (2nd EOP PCC), which began in September 2021 and will be continued until the end of the year 2022. The new campaign was prepared by the EOP PCC Office run by Centrum Badań Kosmicznych Polskiej Akademii Nauk (CBK PAN) in Warsaw, Poland, in cooperation with GeoForschungsZentrum (GFZ) and under the auspices of the International Earth Rotation and Reference Systems Service (IERS). In this paper, we provide an overview of the 2nd EOP PCC five months after its start. We discuss the technical aspects and present statistics about the participants and valid prediction files received so far. Additionally, we present the results of preliminary comparisons of different reference solutions with respect to the official IERS 14 C04 EOP series. Root mean square values for different solutions for polar motion, length of day, and precession-nutation components show discrepancies at the level from 0.04 to 0.36 mas, from 0.01 to 0.10 ms, and from 0.01 to 0.18 mas, respectively.

Keywords: Earth Orientation Parameters, Length-of-Day, UT1-UTC, Universal time, predictions

1. INTRODUCTION

Real-time positioning and navigation with the means of Global Navigation Satellite Systems (GNSS) require accurate measurements and predictions of earth orientation parameters (EOP). EOP, comprising polar motion (PM), difference between universal time and universal coordinated time (UT1-UTC) or its time-derivative length-of-day (LoD) variation, and corrections dX and dY to the conventional precession–nutation model IAU 2000/2006, i.e., celestial pole offsets (CPO), are necessary elements of transformation matrices from the celestial reference frame to the terrestrial reference frame (IERS Conventions, 2010, Chapter 5). Due to unavoidable delays in providing accurate EOP estimates caused by latencies in processing space geodetic observations and in acquiring necessary correction models, EOP short-term prediction has become a subject of increased attention within the international geodetic community.

Apart from the International Earth Rotation and Reference Systems Service (IERS) Rapid Service/Prediction Centre that regularly generates EOP forecasts (McCarthy and Luzum, 1991), there are many other research groups around the world working on EOP predicting (e.g., Akyilmaz et al., 2011, Belda et al., 2018, Chin et al., 2004, Dill et al., 2019, Modiri et al., 2018, Nastula et al., 2020, Shen et al., 2017, Stamatakos et al., 2011, Wang et al., 2018, Xu et al., 2012). However, the forecasts delivered by these institutes differ in many aspects such as input data, predicting method, and forecast horizon, which results in different levels of accuracy for individual predictions. As shown in the study of Luzum (2010), EOP forecasting might benefit from improvements in terms of processing and delivering near-real-time EOP data, modelling of diurnal and semidiurnal tides, forecasting geophysical excitation of PM, and ameliorating real-time prediction procedures.

A first thorough comparison and evaluation of various EOP forecasts was conducted between 2006 and 2008 as part of the EOP Prediction Comparison Campaign (EOP PCC, Kalarus et al., 2010), organised by Vienna University of Technology and Centrum Badań Kosmicznych Polskiej Akademii Nauk (CBK PAN) and under the auspices of the IERS. The aim of this past campaign was to find the most optimal method for forecasting EOP as well as to develop a combined series of EOP predictions. The results of the first EOP PCC showed that it was useful as an initial attempt to evaluate the various existing prediction techniques under the same rules and conditions. The advantages of combination of submitted solutions were presented. It was also noted that accuracy of the predictions also benefits from using atmospheric forecasts data as an input. However, the best prediction technique was different for each parameter and prediction interval, i.e., no prediction technique was superior to others.

More than ten years after the end of the EOP PCC, noticeable progress has been made in the methods of processing geodetic observations for EOP estimation (Bizouard et al., 2019, Karbon et al., 2017, Nilsson et al., 2014) and in understanding the impact of the Earth's surficial fluid layers (atmosphere, oceans, hydrosphere) on orientation changes of the solid Earth (Bizouard, 2020, Chen et al., 2017, Dill et al., 2013, Gross, 2015, Nastula et al. 2019, Quinn et al., 2017). The number of research groups that are actively working on developing new advanced forecasting methods has also increased. In view of those improvements, it is now timely to re-evaluate the quality of present-day EOP predictions that are available so far.

The importance of this issue for the international community has been confirmed by the IERS which established a working group (WG) dedicated to conducting second EOP Prediction Comparison Campaign (2nd EOP PCC) (https://www.iers.org/IERS/EN/Organization/WorkingGroups/PredictionComparison/predictionComparison.html – accessed on 13 September 2022) in March 2021 to pursue a re-assessment of the various EOP prediction capabilities. The new campaign is led by the EOP PCC Office maintained by the CBK PAN in Warsaw, Poland, in cooperation with GeoForschungsZentrum (GFZ) in Potsdam, Germany, under the umbrella of the IERS. The specific goals of the WG are to supervise the EOP PCC Office in collecting and comparing operationally processed EOP predictions from different agencies and institutions over a representative period of time, evaluating the accuracy of final estimates of EOP, identifying both accurate and robust prediction methodologies, and assessing the inherent uncertainties in present-day EOP predictions.

The main idea of the 2nd EOP PCC is to compare the various methods, models, and strategies that can be used to predict EOP. The campaign will to some extent repeat the efforts made during the first EOP PCC, considering similar evaluation procedures and parameters, but also aims at going beyond the past efforts by incorporating new evaluation metrics and time-series analysis schemes. All the campaign details and updates are publicly available on the campaign's website (http://eoppcc.cbk.waw.pl/).

This article is the first work about the 2nd EOP PCC; therefore, it does not contain a detailed discussion of the results, as this will be included in the forthcoming papers prepared after the campaign ends. Instead, the current work provides information on the technical preparations of the campaign, most important events related to the campaign, and various statistics on the participants and EOP predictions received so far.

Additionally, in this study, we use the IERS 14 C04 EOP data (abbreviated here as C04) to assess a number of potential reference EOP solutions which are planned to be used in a final evaluation of EOP predictions. For this purpose, we use International VLBI Service (IVS) rapid data, rapid and final solutions from International Global Navigation Satellite Systems Service (IGS), solutions provided by International Laser Ranging Service (ILRS), data from Bulletin A provided by the IERS, and SPACE solution delivered by Jet Propulsion Laboratory (JPL). For precession-nutation, data from United States Naval Observatory (USNO) and Goddard Space Flight Center (GSFC) are used. These analyses are performed for the period between January 2020 and December 2021 to assess various reference EOP solutions.

This paper is organized as follows: In Section 2, we present campaign overview. In particular, Section 2.1 describes the preparation to the campaign; Section 2.2 presents some technical aspects regarding the format of prediction files and their submission; Section 2.3 shows the campaign statistics about, e.g., input data and prediction methods. In Section 3, we compare selected reference EOP series with IERS C04 (for PM in Section 3.1, for UT1-UTC and LoD in Section 3.2, and for precession-nutation in Section 3.3). Finally, Section 4 concludes the paper and gives an outlook.

2. CAMPAIGN OVERVIEW

2.1. Campaign preparations

At the international level, our activities started with the establishment of the IERS Working Group on the 2nd EOP PCC (IERS WG on 2nd EOP PCC), which was officially announced in March 2021 via IERS message no. 425 (https://datacenter.iers.org/data/2/message_425.txt – accessed on 13 September 2022). In the following months, preparations for the campaign were carried out in terms of defining the rules of participation and file format specification, providing instructions for participants, creating the official website of the 2nd EOP PCC (http://eoppcc.cbk.waw.pl/), and configuring servers for registration and data submission.

In June 2021, the pre-operational phase of the campaign began, which aimed at testing all technical matters. During that stage, interested participants had an opportunity to submit their predictions for testing purposes, and in response, the Office provided feedback on primarily formal issues (data formats, timeliness of submissions, file name conventions, etc.). Predictions submitted during the pre-operational phase were not taken into account in the official evaluation.

In July 2021, the call for participation in the operational phase of the 2nd EOP PCC was announced via IERS message no. 437 (https://datacenter.iers.org/data/2/message_437.txt – accessed on 13 September 2022). The official launch date of the campaign is 1st September 2021, when the Office received the first EOP predictions. In February 2022, the first online campaign workshop was held to present the status of the campaign and to obtain feedback from participants and members of the IERS Working Group. The most important events related to the campaign are presented in Figure 1. The 2nd EOP PCC is open to all participants and methods of prediction and new teams can join at any time during the campaign, which is expected to run until the end of 2022.

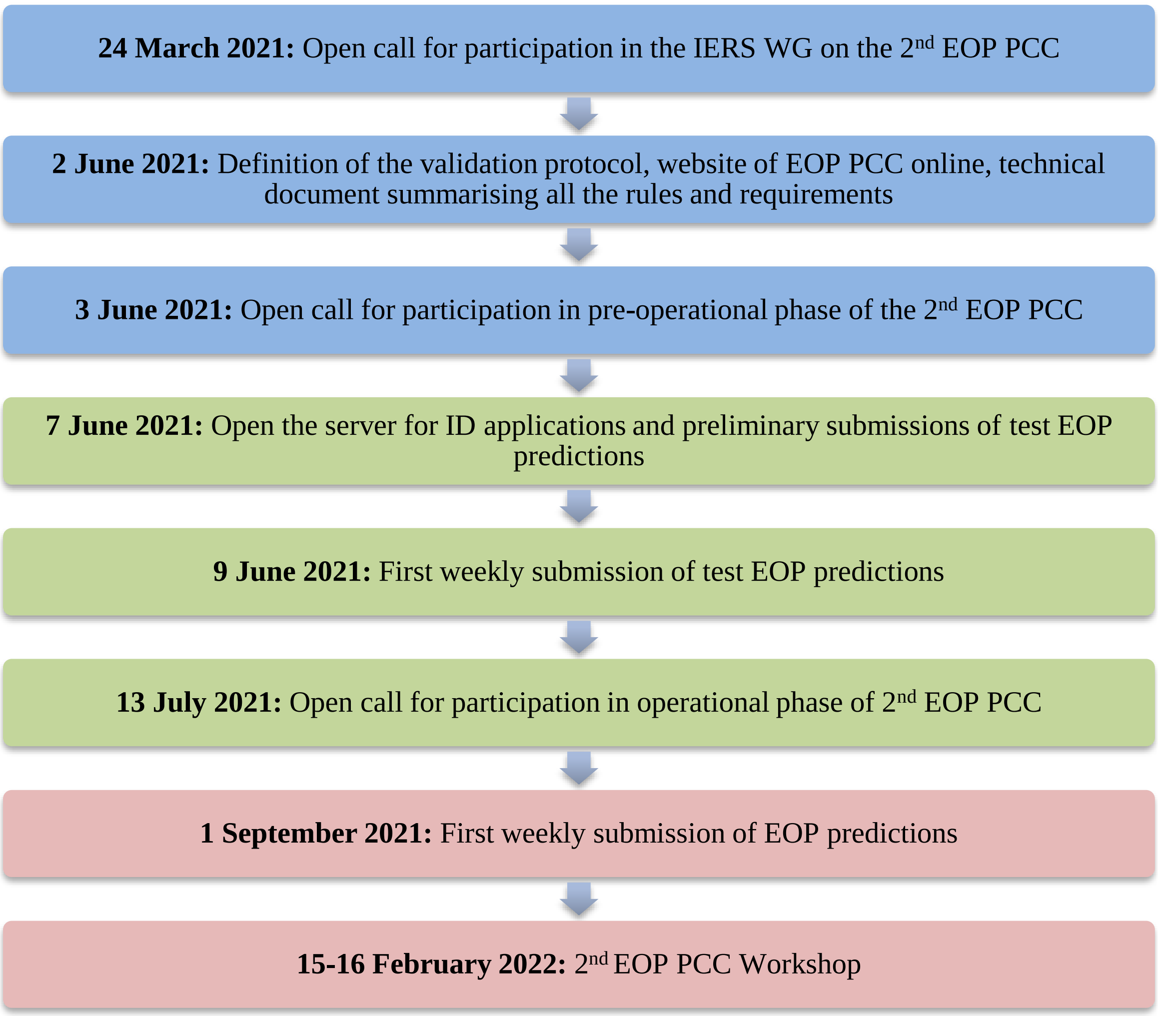

Figure 1. Deadlines and milestones of the 2nd EOP PCC: blue – preparation phase, green – pre-operational phase (test phase), and red – operational phase

2.2. Technical issues

All technical details including instructions for candidate registration, data submission rules, naming, and file formats convention have been made publicly available in the document with general rules for participation (http://eoppcc.cbk.waw.pl/wp-content/uploads/2021/06/EOPPCC_general_rules_2021.pdf – accessed on 13 September 2022). Until February 2022, 19 different participants have registered for the campaign, including both individual institutes and groups of several research centres. In total, the campaign involves 24 institutes from 8 countries with 58 individual persons, who regularly provide forecasts based on 38 different methods. There are clearly more participants and the methods exploited than in the previous campaign (Table 1). These numbers are still subject to (slight) increases, as the 2nd EOP PCC remains open to new participants and prediction methods until the end of the year. The participating teams are dominated by groups of either 4 people or individual researchers (six and five teams, respectively).

Table 1. Details on the 1st and 2nd EOP PCC participants and methods

	1st EOP PCC	**2nd EOP PCC**
Number of registered participants (institutes or groups of institutes)	13	19
Number of institutes	10	24
Number of countries of participants origin	7	8
Total number of all teams members	No data	58
Number of registered prediction methods (IDs)	20 (+1 combined prediction series)	38
Number of active participants	11	16

The EOP PCC Office has defined two formats of forecasts with a defined naming convention including individual candidate ID to enable automatic data processing. The file formats allow sending all of the EOP or only one parameter per file using the appropriate suffix in the name. The purpose of providing two forecast file formats is to allow the choice of the most convenient way to prepare forecast files.

Each participant must submit the forecasts on Wednesday before 20:00 UTC. The predictions are sent to a server in CBK PAN, from which they are then transferred to a repository available only to the EOP PCC Office. This prevents the data from being modified or replaced after the submission deadline. Subsequently, the forecast files are manually inspected by the EOP PCC Office for possible errors in formatting, i.e., file names or dates. Thus we have no automatic interference in the file format – any changes, e.g., in the name of the file, to be in line with our rules, are introduced manually with the consent of the participants. We do not interfere in any way with the values of the sent forecasts – these remain unchanged after submission. All approved files are loaded into the prediction database. During this stage, files are checked once again, e.g., if there is an appropriate number of columns with data or if the first forecast is given for the corresponding submission day. Only after successfully passing this quality check, we update statistics published on the campaign website.

For scientific assessments of the submitted predictions, the EOP reference series data are periodically updated on the basis of the EOP C04 files made available by IERS on its website. However, this data are available with a delay of several weeks, so that rapid solutions are also used for more timely checks. Those preliminary analyses are summarised in bi-monthly reports that are being shared with the participants in order to provide timely feedback. In addition, the results are discussed in dedicated workshops and presented at international conferences.

2.3. Campaign statistics

Until February 9th, 2022, the EOP PCC Office has received over 2,000 individual predictions, the most of which are forecasts for PM (497 predictions) and UT1-UTC (442 predictions). In turn, the fewest files were obtained for forecasts of precession-nutation given in dPsi and dEps components (41 predictions) (Table 2). The most frequently predicted parameters, depending on the number of participants and number of methods (denoted with IDs), are also presented in Table 2. It is noticeable that the most often forecasted parameter is PM, predicted by 16 participants with 25 different methods (IDs). UT1-UTC is also forecasted by more than a half of all participants and methods (15 participants and 21 different IDs). On the other hand, precession-nutation is considered by only very few research groups.

Table 2. Number of predictions submitted to the Office (as of February 9, 2022) with respect to the number of participants and the number of IDs

	x pole	**y pole**	**UT1-UTC**	**LoD**	**dPsi**	**dEps**	**dX**	**dY**	**Total**
Total number of predictions	497	497	442	348	41	41	142	142	2150
Number of participants	16	16	15	10	2	2	6	6	19
Number of IDs	25	25	21	17	2	2	7	7	38

The campaign Office collects information about the input data and forecasting methods used by participants to compute predictions. This information will be used in the final evaluation of all forecasts when analysing the effect of these factors on the prediction accuracy. As it can be seen from Figure 2, the diversity of observational data exploited in EOP forecasting is quite high. In terms of geodetic measurements used, data delivered by the IERS (both C04 final data and daily solutions) dominate as 23 out of 38 registered users declared the use of those solutions.

However, EOP observations provided by other data centres, such as SYstèmes de Référence Temps Espace (SYRTE) department of Paris Observatory, JPL, ILRS, IGS, European Space Agency (ESA), Goddard Space Flight Center Very Long Baseline Interferometry (GSFC VLBI) Group, are also applied in some prediction procedures. It can be also seen that most IDs use effective angular momentum (EAM) data (atmospheric angular momentum – AAM, oceanic angular momentum – OAM, hydrological angular momentum – HAM, sea-level angular momentum – SLAM) as an additional input.

An overview about the most popular methods is presented in Figure 3. Although there are a wide variety of algorithms exploited, two main groups of algorithms dominate, i.e., machine learning and least squares collocation. Both methods are used alone or in combination with other methodologies like, e.g., autoregression or convolution. When it comes to the programming languages used by participants to process EOP predictions, MATLAB and FORTRAN are the most frequently used (7 and 6 participants, respectively). Python is used by 4 participants and there are single users of C, Perl, and Julia.

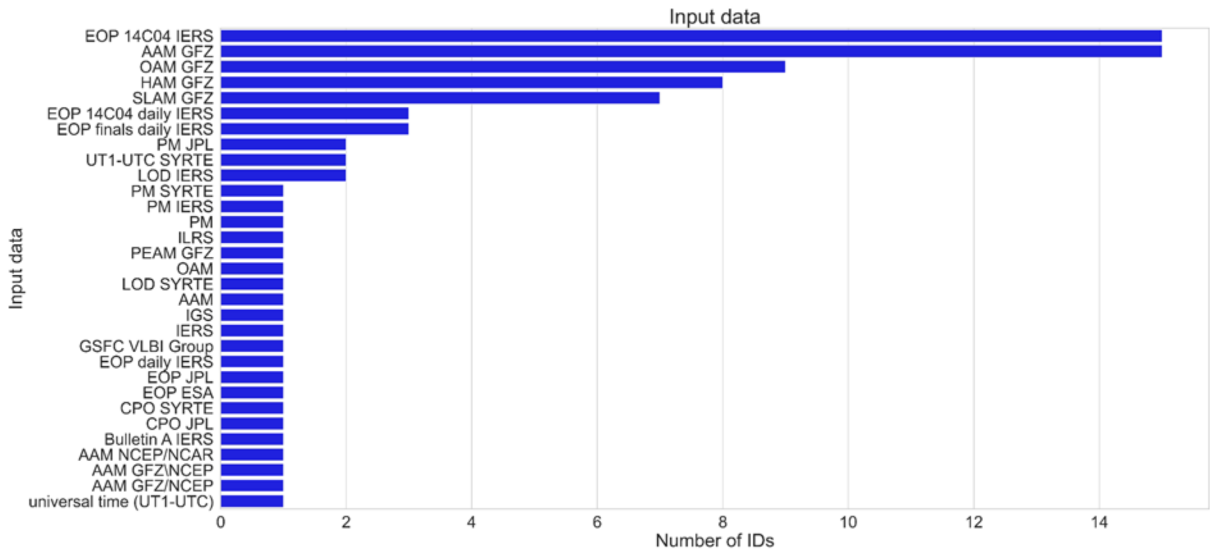

Figure 2. Input data used by participants to make the predictions

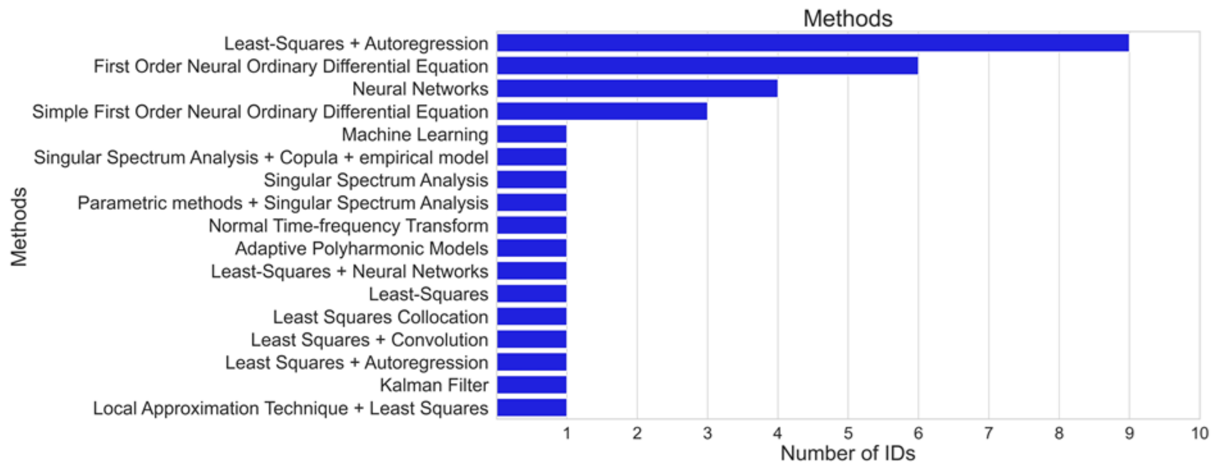

Figure 3. Methods used by participants to make the predictions

The EOP PCC Office regularly monitors the exact timing of data submissions as only files sent before the deadline (Wednesday 20:00 UTC) will be further processed. The histogram in Figure 4 shows that most of the predictions are delivered on time. A large part of the forecasts are submitted in the afternoon, between 16:30 and 19:00 UTC.

In contrast to the previous campaign, in the 2nd EOP PCC, participants are not required to send predictions of a specific length. The choice of the prediction horizon is up to each group, and the only requirement of the EOP PCC Office is that the forecasts should not be longer than a year into the future. The analysis of the length of files sent by participants shows that in the case of PM, UT1-UTC, and LoD, the most popular prediction horizon is 90 days into the future, and the second most popular prediction horizon is one year (Figure 5). For precession-nutation, the Office usually receives forecasts for 11 days, 3 months, 6 months, and 12 months into the future.

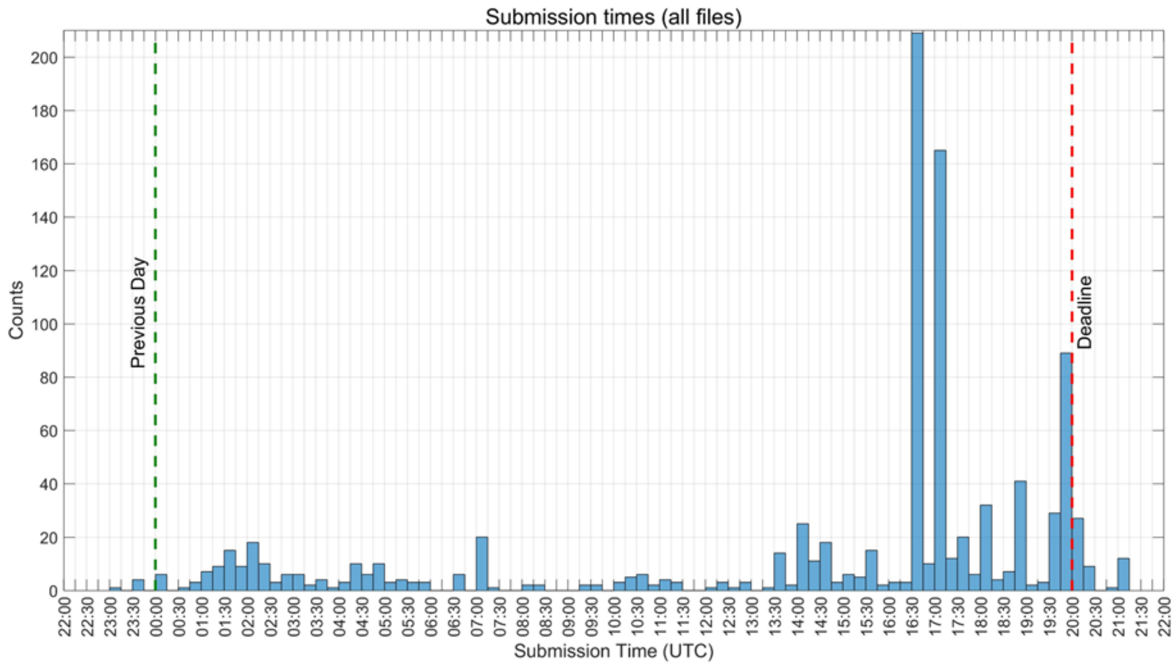

Figure 4. Times of submitting EOP forecasts by participants to the campaign Office

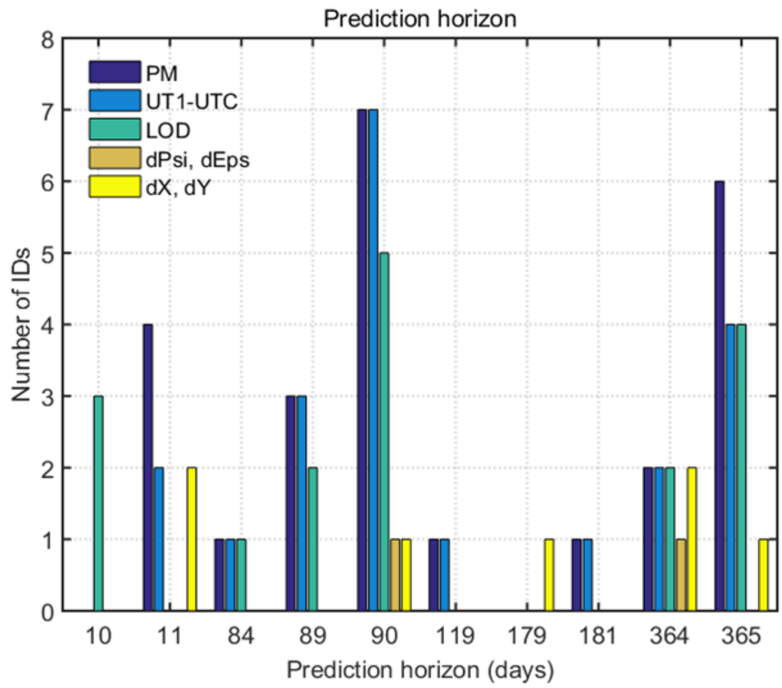

Figure 5. Prediction horizons used by participants in the forecasts and the number of methods in which a given forecast horizon is exploited

3. COMPARISON OF EOP REFERENCE SOLUTIONS

An essential part of our analysis is comparing submitted predictions against subsequently available final EOP estimates based on geodetic observations. For the sake of obtaining quick results, we usually use rapid solutions provided by IERS (https://datacenter.iers.org/products/eop/rapid/ – accessed on 13 September 2022). However, in future evaluation, we will not limit ourselves only to these but will also exploit other solutions, e.g., those supplied by Paris Observatory (https://hpiers.obspm.fr/eop-pc/ – accessed on

13 September 2022). We will focus on both combined results as well as on the single-technique reference data. In this section, we would like to present a comparison of possible reference series against the C04 solution to have a first insight into possible effects induced by the choice of data. As we mentioned in Introduction, apart from the C04 series, we use also IVS rapid data, IGS (rapid and final), ILRS, Bulletin A, and SPACE for the period between January 2020 and December 2021. For precession-nutation, data from USNO and GSFC are used (see Table 3 with details on each solution).

The IERS EOP C04 14 solution became the international reference EOP series on February 1, 2017, and it is the combination of operational series provided by the single-technique centres together with EOP solution associated with the International Terrestrial Reference Frame (ITRF) 2014 and operational solutions maintained by several IVS analysis centres and one IGS analysis centre (Bizouard el al. 2019). The C04 has been tied to two guide series, the IVS combination and the ITRF 2014 EOP solution, to ensure consistency with the conventional reference frames: second realization of International Celestial Reference Frame (ICRF2) (Fey et al 2015) and ITRF 2014 (Altamimi et al. 2016). Bizouard el al. (2019) state that the Allan standard deviation of differences between the C04 and the guide series revealed a stability on timescales between 10 days and 3 years below 20 µas for pole coordinates, 30 µas for precession-nutation offsets, and 3 µs for UT1.

The results of preliminary comparison of different reference solutions are presented in the following subsections. All the data sets were accessed from the website of the IERS Earth Orientation Center managed by Paris Observatory (https://hpiers.obspm.fr/eop-pc/ – accessed on 13 September 2022). Details of these solutions, including time span of records, their uncertainties and relevant references, are also available on this page.

Table 3. Details on EOP reference solutions compared in this study

Solution	Starting date	Provided EOP	Provider
C04	1 January 1962	x pole, y pole, UT1-UTC, LoD, dX, dY, dPsi, dEps	The Earth Orientation Center of the IERS (Bizouard et al. 2019)
SPACE	19 July 1993	x pole, y pole, UT1-UTC	JPL (Ratcliff and Gross 2019)
Bulletin A	1 September 1996	x pole, y pole, UT1-UTC	IERS Rapid Service Prediction Centre (Wooden and Gambis 2004)
ILRS	28 December 1997	x pole, y pole, LoD	ILRS (Sciarletta et al. 2010)
IGS rapid	30 June 1996	x pole, y pole, UT1-UTC, LoD	IGS (Kouba and Mireault 1998)
IGS final	30 June 1996	x pole, y pole, UT1-UTC, LoD	IGS (Kouba and Mireault 1998)
IVS rapid	4 January 2002	x pole, y pole, UT1-UTC, LoD, dX, dY, dPsi, dEps	IVS BKG/DGFI Combination Center (Malkin 2001)

Solution	Starting date	Provided EOP	Provider
GSFC	4 August 1979	x pole, y pole, UT1-UTC, LoD, dX, dY, dPsi, dEps	NASA GSFC (Technical description of solution gsf2014a, https://hpiers.obspm.fr/eoppc/series/operational/gsfc_r.txt – accessed on 13 September 2022)
USNO	4 August 1979	x pole, y pole, UT1-UTC, LoD, dX, dY, dPsi, dEps	USNO (Technical description of solution usn2015a, https://hpiers.obspm.fr/eoppc/series/operational/usno_r.txt – accessed on 13 September 2022)

3.1. Polar Motion

The plots of differences between C04 14 and other potential reference data for PM are shown in Figure 6, and the statistics for these differences are given in Table 4. For PM, the smallest differences with respect to C04 are present in Bulletin A and SPACE, whereas the highest discrepancies are found for ILRS and IVS solutions (Figure 6). This is confirmed by root mean square (RMS) values shown in Table 4. ILRS and IVS seem to be better compatible with each other for x pole, while in y pole, they are slightly shifted relative to each other. Mean differences between C04 and other possible reference data for x pole are between -0.050 and 0.028 mas, while for y pole, they range between -0.116 and 0.139 mas (Table 4).

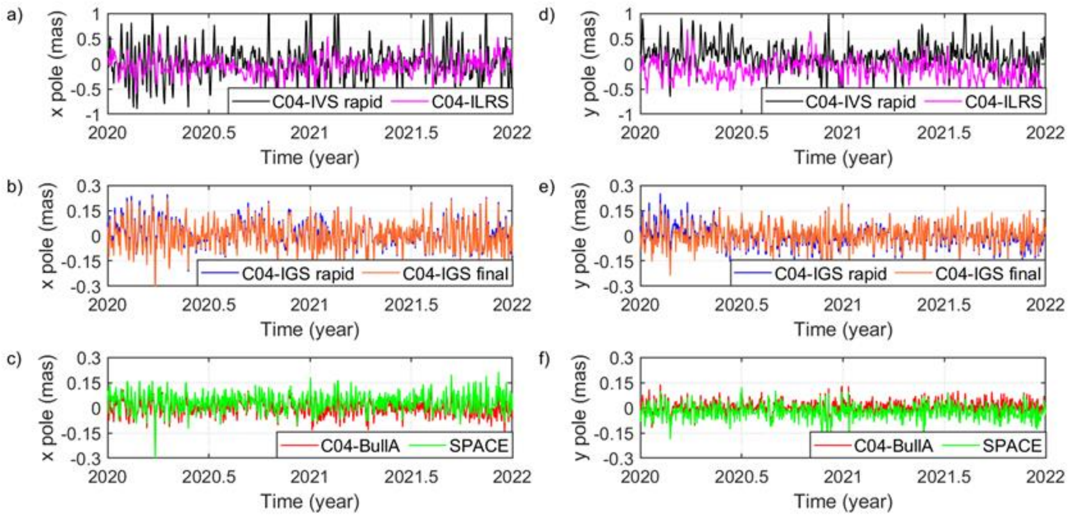

Figure 6. Differences between C04 and: IVS rapid, ILRS, IGS rapid, IGS final, Bulletin A, and SPACE solutions for x pole (a-c) and y pole (d-f). Note that for better visibility, the scale on y axis varies depending on the solution

Table 4. Root mean square (RMS), mean, minimum, and maximum of differences between C04 and Bulletin A, SPACE, IGS rapid, IGS final, ILRS, and IVS rapid solutions for x pole and y pole

Solution	RMS		Mean		Min		Max	
	x pole (mas)	y pole (mas)	x pole (mas)	y pole (mas)	x pole (mas)	y pole (mas)	x pole (mas)	y pole (mas)
C04 – Bulletin A	0.052	0.045	0.001	0.001	–0.312	–0.242	0.152	0.139
C04 – SPACE	0.066	0.051	0.035	–0.025	–0.307	–0.228	0.214	0.122
C04 – IGS rapid	0.084	0.070	0.006	–0.001	–0.413	–0.257	0.247	0.254
C04 – IGS final	0.080	0.065	0.001	0.000	–0.419	–0.254	0.227	0.194
C04 – ILRS	0.214	0.241	–0.050	–0.116	–1.656	–0.772	0.600	0.673
C04 – IVS rapid	0.360	0.299	0.028	0.139	–1.441	–1.144	2.268	1.263

3.2. UT1-UTC and LoD

In the case of UT1-UTC and LoD, the agreement with C04 is on a very good level for all solutions except IVS over the whole time span (Figure 7). All solutions are very stable, with the mean difference very close to zero (Table 5). Isolated anomalies and deviations from C04 series are found in the ILRS solution in the case of LoD, which could introduce systematic errors into the final evaluation. For UT1-UTC, the highest agreement with C04 is provided by SPACE and Bulletin A, while for LoD, the smallest deviation from C04 is observed for SPACE as well as final and rapid IGS solutions.

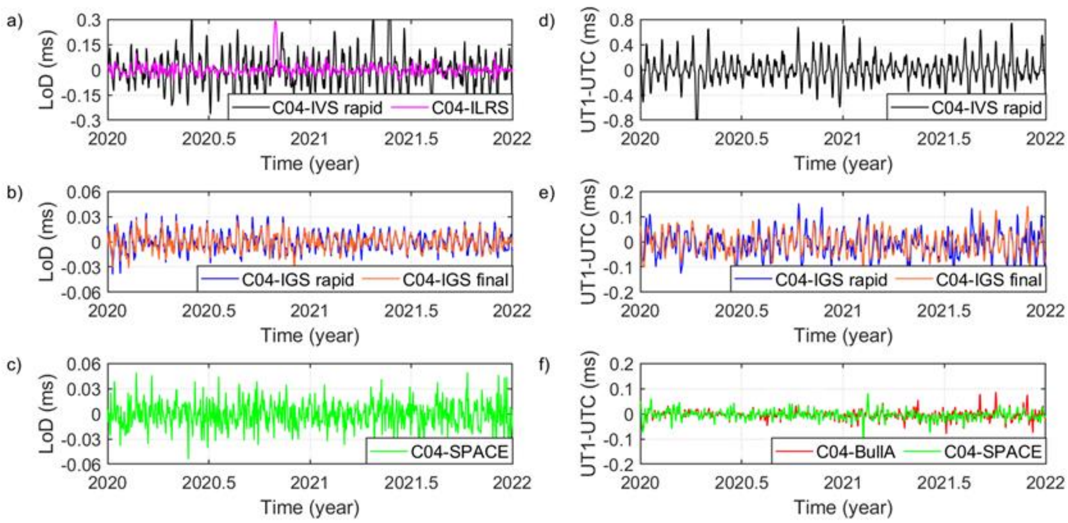

Figure 7. Differences between C04 and IVS rapid, ILRS, IGS rapid, IGS final, and SPACE solutions for LoD (a-c); differences between C04 and IVS rapid, IGS rapid, IGS final, Bulletin A, and SPACE solutions for UT1-UTC (d-f). Note that for better visibility, the scale on y axis varies depending on the solution

Table 5. Root mean square (RMS), mean, minimum, and maximum of differences between C04 and ILRS, SPACE, IGS rapid, IGS final, IVS rapid, and Bulletin A solutions for LoD and UT1-UTC

Solution	LoD				UT1-UTC			
	RMS (ms)	Mean (ms)	Min (ms)	Max (ms)	RMS (ms)	Mean (ms)	Min (ms)	Max (ms)
C04 – ILRS	0.035	0.000	–0.077	0.290	×	×	×	×
C04 – SPACE	0.015	–0.001	–0.054	0.050	0.019	–0.005	–0.113	0.082
C04 – IGS rapid	0.011	0.000	–0.039	0.034	0.051	–0.008	–0.167	0.153
C04 – IGS final	0.010	–0.001	–0.037	0.028	0.043	–0.006	–0.147	0.140
C04 – IVS rapid	0.098	–0.005	–0.391	0.502	0.212	–0.001	–1.035	0.744
C04 – Bulletin A	×	×	×	×	0.020	–0.004	–0.110	0.087

3.3. Precession-nutation

Although it is evident that IVS solution strongly differs from the others in case of PM, UT1-UTC, and LoD (Figures 6 and 7), the IVS series are fully in agreement with C04 data for precession-nutation (both dX, dY and dPsi, dEpsilon) which is shown in Figures 8 and 9, and indicated by very low RMS values in Table 6.

This simple analysis reveals possible differences between various EOP series, which might affect the results of the predictions evaluation. IERS solutions as the official products will be central to the routine analysis performed as a part of the ongoing campaign. However, we believe that the additional consideration of other solutions might be essential for a proper understanding of the performance of individual contributions, which might be more tailored to reference solutions other than C04. Despite the high variances of differences for some single-technique solutions visible in the figures, we aim at adopting those data as the study of the impact of the choice of reference data on prediction accuracy is one of the objectives of the 2nd EOP PCC.

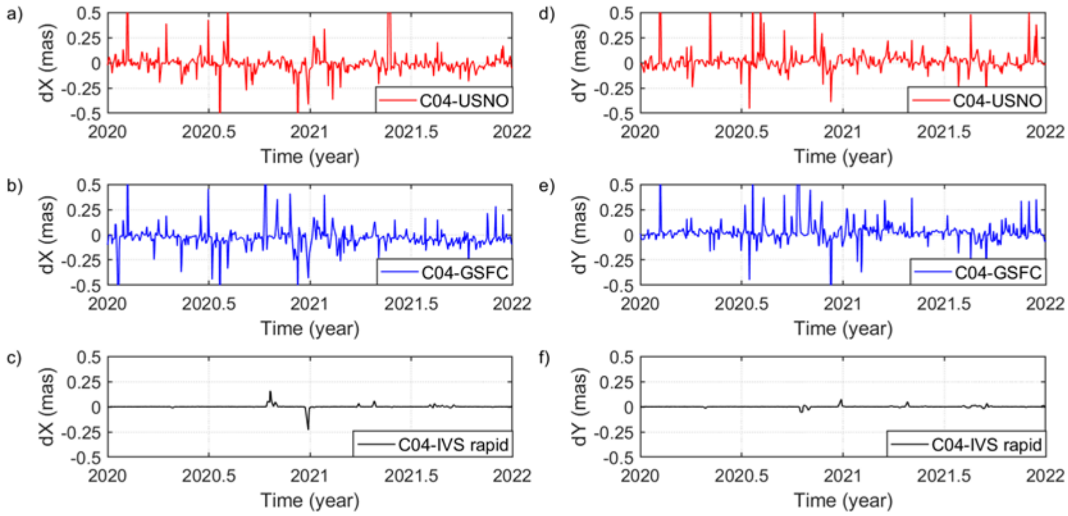

Figure 8. Differences between C04 and: USNO, GSFC, and IVS rapid solutions for dX (a-c), dY (d-f) components of precession-nutation

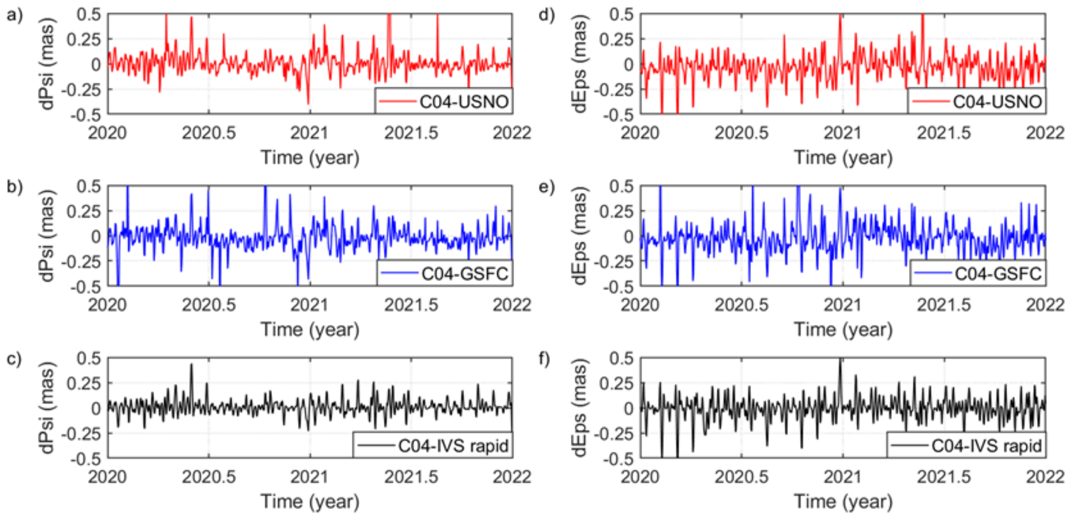

Figure 9. Differences between C04 and USNO, GSFC, and IVS rapid solutions for dPsi (a-c), dEpsilon (d-f) components of precession-nutation

Table 6. Root mean square (RMS), mean, minimum, and maximum of differences between C04 and: USNO, GSFC, and IVS rapid solutions for dX, dY and dPsi, dEps components of precession-nutation

Solution	RMS		Mean		Min		Max	
	dX (mas)	dY (mas)	dX (mas)	dY (mas)	dX (mas)	dY (mas)	dX (mas)	dY (mas)
C04 – USNO	0.178	0.117	–0.001	0.018	–0.913	–0.455	2.952	1.658
C04 – GSFC	0.114	0.146	–0.034	0.027	–0.885	–1.262	0.946	2.002
C04 – IVS rapid	0.018	0.008	0.001	0.000	–0.231	–0.055	0.159	0.076
Solution	**dPsi (mas)**	**dEps (mas)**	**dPsi (mas)**	**dEps (mas)**	**dPsi (mas)**	**dEps (mas)**	**dPsi (mas)**	**dEps (mas)**
C04 – USNO	0.130	0.139	0.010	–0.031	–0.466	–0.642	1.608	1.086
C04 – GSFC	0.135	0.181	–0.019	–0.024	–0.878	–1.297	0.954	1.965
C04 – IVS rapid	0.078	0.117	0.009	–0.008	–0.414	–0.634	0.440	0.498

4. CONCLUSIONS

The 2nd EOP PCC is conducted under the auspices of IERS from September 2021. The campaign registration is open to all interested scientists, and new submissions may be entered at any time until the expected end of the campaign in December 2022. Submissions of all different kinds of EOP for up to one year in the future are welcome. It is also possible for individual institutions to submit more than one forecast with sufficiently distinct methods.

A first summary of the statistics on the 2nd EOP PCC participants and predictions shows high interest in the campaign by the scientific community. We recorded a higher number of participating groups and forecasting methods used than in the previous campaign, which was carried out in the years 2006 to 2008. The presented statistics indicate a large variety of EOP forecasts in terms of the input data, forecasting methods, programming languages, and the forecast horizon. In terms of input data used, IERS C04 solutions are dominant. The most often forecasted parameter is PM, predicted by 16 participants with 25 different methods, wherein two main groups of algorithms dominate, i.e., machine learning and least squares collocation.

During the course of the campaign, we will continue evaluating the quality of predictions against various reference data and for different prediction horizons. A preliminary comparison of potential reference series for EOP prediction validation reveals some discrepancies that merit further scrutiny. RMS values for differences between IERS 14 C04 and selected EOP solutions show discrepancies at the level:

- for PM from 0.04 mas for Bulletin A to 0.36 mas for IVS rapid;
- for LoD from 0.01 ms for IGS to 0.10 ms for IVS rapid;
- for UT1-UTC from 0.02 ms for SPACE and Bulletin A to 0.21 ms for IVS rapid;
- for dX, dY components of precession-nutation from 0.01 mas for IVS rapid to 0.18 mas for USNO;

- for dPsi, dEps components of precession-nutation from 0.08 mas for IVS rapid to 0.18 mas for GSFC.

In the upcoming articles with detailed campaign results, we will focus more on the basic features of the input data and predicting methods used by participants, and their impact on the prediction accuracy. We will also study in detail various reference solutions, especially the way they are constructed, the time span of records and predictions, their uncertainties, and limitations. This will help to objectively assess the impact of the observational data used on the accuracy of the forecasts. The campaign will continue to discuss preliminary results with participants and other interested scientists in a series of online meetings and workshops. All details of these events will be announced publicly via https://eoppcc.cbk.waw.pl.

Acknowledgements. The work of T. Kur, J. Nastula, A. Partyka, and J. Śliwińska is financed from the statutory funds of the CBK PAN. J. Śliwińska is partially financed by the National Science Center, Poland (NCN), grant number 2018/31/N/ST10/00209. H. Dobslaw is supported by the project DISCLOSE as funded by the German Research Foundation (DO 1311/6-1).

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Received: *2022-06-14*

Reviewed: *2022-07-28 (undisclosed name); 2022-08-26 (undisclosed name)*

Accepted: *2022-11-17*