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AMPLITUDE VARIATION OF THE CHANDLER WOBBLE USING IERS EOP C04 LONG-TERM POLAR MOTION TIME SERIES

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SUMMARY: We analyzed the Earth's long-term polar motion using the time series IERS EOP C04 (from 1984 to 2023) to determine the variation of amplitude of the Chandler wobble. To compare the results based on the C04 with the Belgrade latitude data (BLZ series 1949-1985) results, we calculated the variations of latitude at BLZ point using the C04 coordinates (x, y). The secular part of these latitude variations was determined by use of the least-squares method (LSM) and removed from the data to get residuals. We used the Fourier transforms (DFT) to obtain annual and semiannual oscillations and to remove them from the residuals (to get a new set of residuals). These new residuals were divided into 33 independent 1.2 years subintervals. For each subinterval, we calculated the amplitude, period and phase of the Chandler nutation using the LSM. The quasi-periodic instability of 33 values of the amplitude of the Chandler wobble is detected with a period of 54.5 years using LSM (it was 38.5 years from BLZ data 1949-1985); the amplitude of that quasi-periodic variation is $0.''087$ ($0.''06$ from BLZ data). The amplitude of the Chandler nutation varies with a minimum of $0.''012$ (at 2019.3) and a maximum of $0.''230$ (at 1994.1); the period is stable, but the phase is not stable. We applied the Abbe criterion to explain the variability in 33 values of the Chandler wobble amplitude, and the hypothesis that there is no trend in these 33 values is rejected. The obtained amplitude modulation is in accordance with other published papers about similar subject (and with our results based on BLZ data). Probably, the cause is lying in the hydro-atmospheric circulation that could influence calculated quasi-periodic variation. A possible explanation can be found in changes of core-mantle electromagnetic coupling (in line with the last few years investigations). In recent papers, it has been noticed that the effects of geomagnetic jerks are more important for exciting free nutation than the atmosphere and oceans.

Key words. Earth rotation – Polar motion – Chandler wobble

1. INTRODUCTION

The observations concerning the Earth rotation angles have been collected for more than a century: optical astrometry data are at the accuracy level of tens milliarcseconds (mas), the Earth Rotation Parameters (ERP) are at the level of about 0.1 mas because after 1980s these data started to be provided by space geodetic techniques. The stability in time of the amplitude and period (or phase) of the Chandler wobble, as important part of polar motion, could be investigated by using different series of classical and modern astrometry data. We did it (Damljanović et al. 1997) using the observations at one observatory (the Belgrade latitude data – BLZ); it enabled the studies of the Chandler wobble parameters. In the BLZ latitude series (from 1949 to 1985) the quasi-periodic changes of amplitude of the Chandler nutation were detected (near $0.''06$), and the period of these changes was about 38 years (Damljanović et al. 1997). Similar results were obtained in other papers (Rykhlova 1969, Zotov et al. 2022); the period of amplitude variations was about 40 years.

We wanted to check our results based on the BLZ data, because now there are the Earth's long-term polar motion data as very precise time series IERS EOP C04 from 1984 to 2023 (one-day intervals), and we did the same procedure using the C04 data to determine the variation of amplitude of the Chandler wobble. Moreover, in comparison with classical astrometry data (as BLZ latitude series), the C04 data are free of some systematic errors and local distortions. Because of it, the C04 data are particulary interesting for our investigation of amplitude variations of the Chandler nutation.

The time series IERS EOP C04 is a product of the International Earth Rotation and Reference Systems Service – IERS. The C04 is combination of EOP series derived from the various astro-geodetic techniques. These techniques are: Very Large Baseline Interferometry (VLBI) on extragalactic objects, Laser Ranging to the Moon (LLR) and to dedicated artificial satellites (SLR), and using GPS and DORIS systems. As part of the C04, the polar motion coordinates (x, y) describe the polar motion with respect to the crust.

Because of the lack of the physical explanation of mentioned phenomenon, the results about the observational evidence of variation of amplitude of the Chandler wobble (with period about 40 years) are not widely accepted as realistic ones. This is another challenge for our investigation, here. The homogenized and actual C04 data are a good opportunity for investigation of decades variations of the Chandler wobble parameters (amplitude A_C at the first place), and we wanted to give some contribution for a better description of these variations.

In the next section, our procedure of calculation of the parameters of the Chandler wobble is done, and the main features of variation of amplitude of the Chandler wobble are presented. In accordance with the Abbe criterion, the calculated values of A_C are not explainable with only formal errors, but this is possible in the case of the values of A_a (the amplitude of the annual wobble).

2. THE VARIATION OF AMPLITUDE OF THE CHANDLER WOBBLE

The annual term presented in the polar motion (in Fig. 2.) has a stable period (one year). The Chandler wobble is slightly elliptical (Guinot 1982) or nearly circular, and it is of importance to calculate the parameter of that wobble for some specific meridian (the BLZ meridian in this paper). The period of the Chandler wobble is variable (it could be from 1.06 years or 387 days to 1.21 years or 442 days), and the amplitude of that wobble varies from $0.''07$ to $0.''28$ (Vondrák 1985).

2.1. Latitude variations at BLZ point using the IERS EOP C04 polar motion data

First of all, we calculated the latitude variations ($\varphi - \varphi_0$) at BLZ point (in Fig. 1.) using the C04 polar motion coordinates (x, y) and Kostinski's formula Eq. (1) (Kulikov 1962). In this way, we can compare the obtained results (using C04 from 1984.0 to 2023.0) with our results based on the Belgrade latitude data (BLZ series from 1949 to 1985). Like that, the parameters of the Chandler wobble (amplitude, period and phase) refer to the Belgrade meridian $\lambda_{BLZ} = 20.^\circ5$. The value $20.^\circ5$ is calculated from the Greenwich meridian to the east. Kostinski's formula is:

$$x\cos(\lambda_{BLZ}) + y\sin(\lambda_{BLZ}) = \varphi - \varphi_0. \tag{1}$$

2.2. Secular term of the latitude variations at BLZ point

The coefficients of $a_1 = 0.''116 \pm 0.''002$ and $a_2 = (254 \pm 6.8)10^{-10}\ ''/y$ (secular term) in C04 latitude variations at BLZ point (see Fig. 1.) are calculated using the least-squares method (LSM) and $\varphi - \varphi_0 = a_1 + a_2 t$ model. The value t is time (in years, from 1984.0 to 2023.0). We calculated the residuals (the data of Fig. 1. without secular term). These residuals are our input to the Fourier transforms – DFT (see in Fig. 2.) to get parameters of the Chandler wobble, annual and semiannual variations (presented in Table 1.); the epoch for phases is $1984.^y0$.

2.3. Amplitude periodogram using the Fourier transforms

In Fig. 2., it is presented the amplitude periodogram, where the annual and Chandler wobbles are dominant. After applying the DFT, the standard deviations of amplitude and phase in Table 1. could be calculated using Eq. (2):

$$\sigma_A = \sigma_0\sqrt{(4-\pi)/N} = 0.''00009\ , \tag{2a}$$

$$\sigma_F \approx 57.^\circ296(\sigma_0/A)\sqrt{2/N}\ , \tag{2b}$$

where $N = 14245$ is the number of the C04 values (x, y) during 1984.0 – 2023.0, $\sigma_0 = 0.''012$ is the standard deviation of residuals (in Fig. 6.), A is the amplitude (the Chandler A_C, annual A_a or semiannual A_{sa}), σ_A is the amplitude standard deviation, and σ_F is the phase standard deviation ($\sigma_{Fc} = 0.^\circ07$ for the Chandler wobble, $\sigma_{Fa} = 0.^\circ08$ for annual one and $\sigma_{Fsa} = 3.^\circ34$ for semiannual one). The residuals (in Fig. 6.) are obtained after removing: the secular term, and three oscillations (the Chandler, annual and semiannual) from values presented in Fig. 1. After the DFT, the combined curve using the parameters (in Table 1.) of three harmonics (the Chandler, annual and semiannual) is $A_C\cos(360^\circ(t-1984.0)/1.2 - F_C) + A_a\cos(360^\circ(t -$

$1984.0)/1.0 - F_a) + A_{sa}\cos(360°(t - 1984.0)/0.5 - F_{sa}) = 0.''1135\cos(360°(t - 1984.0)/1.2 - 236.°07) + 0.''0951\cos(360°(t - 1984.0)/1.0 - 229.°64) + 0.''0024\cos(360°(t - 1984.0)/0.5 - 161.°83)$, where t (in years) starts from 1984.0.

Besides the DFT, the mean period $P_C = 0.^y184$ was calculated to get "the best fit" on the C04 interval (1984.0-2023.0) using the LSM. To do that, the value of P_C was varied to get the minimum of standard deviation $\sigma = 0.''7$ (the best fit) of suitable residuals; it means, minimum σ of the differences between the data and the fit. For that fit, the value of the Chandler amplitude is $A_C = 0.''1131 \pm 0.''0007$ and the phase is $F_C = 221.°5 \pm 0.°7$ (for the epoch 1984.0). As we expected, these values of the parameters of the Chandler wobble are close to the suitable values (using DFT) in Table 1.

2.4. Investigation of systematic variability of the Chandler wobble amplitude using the Abbe criterion

We wanted to check the trends and low-frequency variations in values of the Chandler wobble amplitude so we used the Abbe criterion (Malkin 2013, Damljanović et al. 2021). The Abbe criterion is aimed at testing the hypothesis that each of mathematical expectancies of the analyzed values A_C (in Table 2.) is equal, and the Abbe statistic is the ratio $R = a_1/a_2$. The value a_1 is the Allan variance and a_2 is the dispersion of the values A_C (see Eq. (3)). If there are trends and low-frequency variations in values A_C the value of a_2 is greater than that of a_1; it means, $R < R_0$ where R_0 is the critical value of the Abbe distribution. We can calculate the value R_0 via formula $R_0 = 1 + U_q/[n + 0.5(1 + U_q^2)]^{0.5}$, where U_q is the quantile of the order q of standard distribution of values A_C, and it is $U_{0.05} = -U_{0.95} = -1.64485$ for $q = 0.05$. In the case $R < R_0$, the hypothesis that there is no trend in values A_C is rejected. The conclusion is that there are statistically significant systematic variations in A_C values. We applied the Abbe criterion to the A_C values to explain variability in the A_C values (whether or not some variability could be explained by formal errors).

For probability level of 0.05, after applying the Abbe criterion to $n = 33$ values A_C (in Table 2.), the obtained values are: $R = 0.055$, and $R_0 = 0.721$; it is $R < R_0$ and in line with the Abbe criterion we conclude that the values A_C are not explainable with formal errors only. This means that there is some systematic part, and we can continue to investigate that systematic part; from Fig. 4., that systematic part is similar to a sinusoidal variation. We calculated the values a_1, and a_2 using formulas:

$$a_1 = \frac{1}{2(n-1)}\sum_{i=1}^{n-1}(Ac_{i+1} - Ac_i)^2 \ , \tag{3a}$$

$$a_2 = \frac{1}{n-1}\sum_{i=1}^{n}(Ac_i - A_{av})^2 \ , \tag{3b}$$

where A_{av} is the average of A_C values.

To check the annual wobble amplitude A_a using the Abbe criterion, we calculated the parameters of both wobbles (the Chandler and annual ones) over six years subintervals and obtained six independent A_C and A_a values: $A_{C1} = 0.''1767$ and $A_{a1} = 0.''0905$ (at 1987.0), $A_{C2} = 0.''2031$ and $A_{a2} = 0.''0600$ (at 1993.0), $A_{C3} = 0.''1526$ and $A_{a3} = 0.''0931$ (at 1999.0), $A_{C4} = 0.''1213$ and $A_{a4} = 0.''1047$ (at 2005.0), $A_{C5} = 0.''0731$ and $A_{a5} = 0.''1297$ (at 2011.0), $A_{C6} = 0.''0166$ and $A_{a6} = 0.''1038$ (at 2017.0). It was done using the LSM with two sinusoidal curves (as a model), where the annual period was just $1.^y000$ and the Chandler period was adapted near $1.^y180$ (with $0.^y001$ step) to get "the best fit". After applying the Abbe criterion to $n = 6$ values A_a, we get: $R = 0.910$, and $R_0 = 0.413$; it is $R > R_0$. In accordance with the Abbe criterion, we conclude that the values A_a can be explained with formal errors only. It is of importance that during the calculation of the 33 independent values A_C (in Table 2.), where the annual and semiannual wobbles were removed to get residuals (in Fig. 3.) and the annual amplitude was taken into the calculation as stable one. The amplitude A_{sa} of the semiannual wobble was very small and is unimportant here.

As for the 33 values of the period P_C and phase F_C of the Chandler wobble (in Table 2), after using the Abbe criterion it is obtained $R > R_0$ in the case of the period (because $R = 1.113$ and $R_0 = 0.721$) and $R < R_0$ in the case of the phase ($R = 0.395$ and $R_0 = 0.721$). Consequently, the hypothesis that there is no trend in the values F_C is rejected, but accepted for the values P_C. The value $R = 0.395$ is close to $R_0 = 0.721$, but still it is $R < R_0$ and the F_C is not stable during 1984-2023.

2.5. Parameters of the Chandler wobble of the 1.2 years subintervals long over the C04 period 1984.0-2023.0

After removing the annual and semiannual variations (obtained using DFT) we get the new residuals with mostly the Chandler variations (see Fig. 3.). These new residuals are useful for investigations of the Chandler wobble parameters. We calculated these parameters (so-called the "instantaneous" amplitude, period and phase for epoch 1984.0), on subintervals of 1.2 years long (of interval presented in Fig. 3.); the LSM was used. The results are presented in Table 2. (also, presented in Figs. 4. and 5.). The Chandler period P_C was adapted (from $1.^y1700$ to $1.^y2000$ with $0.^y0001$ step) to get "the best fit" (using the LSM) for each of 33 subintervals; it means, to get the minimum of standard deviation between the residuals (presented on Fig. 3.) and suitable sinusoidal approximation on each subinterval. A similar calculation was done (using the LSM) to get the fit presented by points in Fig. 4. (the results of parameters of the Chandler wobble are in Table 3.); the lines present the Chandler amplitude values for each of 33 subintervals (in Table 2.).

2.6. Variations of the Chandler amplitude

The first column of Table 2. contains the mid-subintervals (in years) of 1.2 years long subintervals over the period 1984.0-2023.0. Just the first subinterval is $1.^y1$ long (of the subperiod 1984.0-1985.1) and the last one is $0.^y7$ (2022.3-2023.0) because of some technical reasons. In the second column of Table 2., it is the number n (from 1 to 33) of each subinterval. The next three columns are (for each subinterval): the Chandler period P_C (years), amplitude A_C (arcseconds) and phase F_C (degrees) for epoch 1984.0. In Fig. 4., the variations of the Chandler amplitude (lines) and suitable sinusoidal approximation (black points) are presented. In Fig. 5., the changes of the Chandler phase (lines) and their average value (dashed horizontal line at 227°) are done. In Fig. 7., the residuals (between the Chandler amplitudes and suitable sinusoidal values over 1984.0-2023.0, in Fig. 4.) and their average value ($0.''12$) are presented.

As for the Chandler amplitude A_C values (see in Fig. 4.), the sinusoidal fit and the values A_C are close to each other. After removing the obtained sinusoidal part, the behavior of the suitable residuals is presented in Fig. 7. The period of those sinusoidal variations is 54.5 years and its amplitude is $0.''087$; it means, $f(A_C) = 0.''087\cos(360°(t - 1984.0)/54.5 - 49.°9)$, it is in line with the values in Table 3. where t is in years. The amplitude of the Chandler wobble varies with its minimum $0.''012$ at 2019.3 and maximum $0.''230$ at 1994.1. In the case of BLZ data (from 1949 to 1985), it was calculated the sinusoidal variations with time (Damljanović et al. 1997), also. From BLZ data, the period was 38.5 years and amplitude was $0.''06$. The period $54.^y5$ (based on C04 data) is much longer than $38.^y5$ (for about 42%), and the similar situation is in the case of the amplitude (about 45%). In line with the C04 data, the average value of amplitude of the Chandler wobble is $0.''1132$ and of the annual wobble it is $0.''0949$ (in the case of BLZ, the mentioned values are $0.''164$ and $0.''057$, respectively). The amplitude of the Chandler wobble from BLZ data (and for the period 1949-1985) is greater than one from C04 data (1984.0-2023.0) for amount about 31%, but in the case of the annual wobble it is opposite (it is less than for amount about 66%).

In the paper (Zotov et al. 2022) we can see that near 2019 the Chandler wobble amplitude reached its minimum since 1930s. Also, in the paper (Wang et al. 2016), using the interval 1900-2015 it was found that the amplitude of the Chandler wobble is currently at a historic minimum level. From our results here (based on C04 from 1984 to 2023), during the last few years of 1984-2023 the Chandler wobble amplitude is bigger than the minimum value $0.''012$ at $2019.^y3$ (in Figs. 3. and 4.), and it is $0.''076$ at $2022.^y7$ (in Table 2.).

The values of the period P_C are stable, and the period P_C varies within only a few days: its minimum is $1.^y1787$ at 1986.9 and 1989.3 (it is $430.^d52$), and maximum $1.^y1892$ at 1991.7 (it is $434.^d36$). The value $430.^d23$ (close to our results, here) is obtained from similar data and published in the paper (Vondrák and Ron 2020). Also, the value $432.^d3$ (from the interval 1962-2021) is close to our results and it is published in the paper (An and Ding 2022). The values of the phase F_C are not stable (in Fig. 5.).

After removing the Chandler wobble from residuals presented in Fig. 3. (using results of parameters of the Chandler wobble for each subinterval, in Table 2.), the final residuals are presented in Fig. 6.

3. CONCLUSIONS

We analyzed the variation of amplitude of the Chandler wobble using the polar motion coordinates (x, y) via time series IERS EOP C04 from 1984 to 2023 (one-day intervals); the coordinates (x, y) describe the polar motion with respect to the crust. Using the C04 coordinates (x, y) and Kostinski's formula we calculated the variations of latitude at BLZ point to compare with our results published in the paper (Damljanović et al. 1997) concerning the analysis of the BLZ data. The secular part of these latitude variations was calculated by LSM and removed from the data to get residuals. Using the DFT and these residuals, we obtained and removed the annual and semiannual oscillations to get a new set of residuals; those new residuals were divided into 33 independent 1.2 years subintervals. For each subinterval, using the LSM we calculated: the amplitude, period and phase of the Chandler nutation. Applying the Abbe criterion, we checked the trends and low-frequency variations in 33 values of the amplitude of the Chandler wobble; the Abbe criterion confirmed the existence of mentioned variations. Using the LSM and sinusoidal model, we calculated the parameters of the quasi-periodic instability of the amplitude of the Chandler wobble (in Fig. 4.) with the period of 54.5 years (it was 38.5 years from BLZ data 1949-1985) and amplitude of $0.''087$ ($0.''06$ from BLZ data). The minimum of the amplitude of the Chandler nutation was $0.''012$ (at $2019.^y3$) and maximum was $0.''230$ (at $1994.^y1$). Using the C04 (1984-2023), the period of the Chandler wobble varies only a few days with its minimum $1.^y1787$ or $430.^d52$ (at $1986.^y9$ and $1989.^y3$) and maximum $1.^y1892$ or $434.^d36$ (at $1991.^y7$). In line with the Abbe criterion, the P_C (in Table 2.) is stable during 1984-2023. It is in accordance with the result of $430.^d23$ from the paper (Vondrák and Ron 2020) and about the similar polar motion data. Also, the value $432.^d3$ is published in the paper (An and Ding 2022), about the interval 1962-2021, and it is close to our results. Conversely, the F_C (in Table 2. and Fig. 5.) is not stable during 1984-2023, after applying the Abbe criterion.

It was indicated in the paper (Zotov et al. 2022) that during the last few years the Chandler wobble amplitude reached its minimum since 1930s. Using the interval 1900-2015, in the paper (Wang et al. 2016) it was concluded that the Chandler wobble amplitude is currently at a historic minimum level. Here, based on C04 from 1984 to 2023, we see that the Chandler wobble amplitude (at the end of interval 1984-2023) is bigger than the minimum value $0.''012$ at $2019.^y3$ (in Figs. 3. and 4.), and it is $0.''076$ at $2022.^y7$ (in Table 2.).

The presented results concerning the amplitude modulation of the Chandler wobble (based on C04 data) are in line with the results based on only one instrument (the BLZ data) of optical astrometry data (Damljanović et al. 1997) and the other results concerning the similar subject (Zotov et al. 2022), but its cause is not clear. It necessitates future investigations because the geophysical explanation of that process remains elusive. Some results indicate that the cause is lying in the hydro-atmospheric circulation that could influence the calculated quasi-periodic variation (Zotov et al. 2022, Gross 2000), but in recent papers (Cui et al. 2020) a possible explanation can be found in changes of core-mantle electromagnetic coupling. It has been noticed that the effects of geomagnetic jerks are more important for exciting free core nutation than the atmosphere and oceans; it is in line with recent results (Vondrák and Ron 2020, An and Ding 2022). A further study is needed to throw more light on this controversy.

Table 1: The values of the Chandler nutation (amplitude A_C, period P_C and phase F_C), annual (A_a, P_a, F_a) and semiannual (A_{sa}, P_{sa}, F_{sa}) terms using DFT on C04 from 1984.0 to 2023.0; the epoch for phases is $1984.^y0$.

P_C (years)	$A_C('')$	$F_C(^\circ)$	P_a (years)	$A_a('')$	$F_a(^\circ)$	P_{sa} (years)	$A_{sa}('')$	$F_{sa}(^\circ)$
1.182	0.1135	236.07	1.000	0.0951	229.64	0.500	0.0024	161.83

Table 2: The values of the Chandler nutation (amplitude A_C, period P_C and phase F_C) for each of $n = 33$ subintervals 1.2 years long (from 1984.0 to 2023.0) obtained by LSM; the epoch for phases is $1984.^y0$.

Mid-subinterval (years)	n	P_C (years)	$A_C \pm \sigma_{A_C}('')$	$F_C \pm \sigma_{F_C}(^\circ)$
1984.55	1	1.1870	0.1822 ±0.0014	208.5 ±0.3
1985.7	2	1.1787	0.1733 ±0.0014	211.5 ±0.5
1986.9	3	1.1885	0.1666 ±0.0012	213.6 ±0.4
1988.1	4	1.1787	0.1872 ±0.0010	208.0 ±0.3
1989.3	5	1.1814	0.1801 ±0.0009	215.9 ±0.3
1990.5	6	1.1892	0.1618 ±0.0017	221.5 ±0.5
1991.7	7	1.1863	0.1857 ±0.0011	216.3 ±0.4
1992.9	8	1.1838	0.2260 ±0.0010	221.1 ±0.3
1994.1	9	1.1878	0.2299 ±0.0006	224.1 ±0.1
1995.3	10	1.1870	0.2080 ±0.0007	212.7 ±0.2
1996.5	11	1.1821	0.1702 ±0.0010	221.1 ±0.3
1997.7	12	1.1838	0.1359 ±0.0010	244.5 ±0.3
1998.9	13	1.1838	0.1390 ±0.0008	237.1 ±0.3
2000.1	14	1.1814	0.1335 ±0.0013	238.3 ±0.5
2001.3	15	1.1821	0.1824 ±0.0012	239.0 ±0.3
2002.5	16	1.1834	0.1569 ±0.0016	228.5 ±0.3
2003.7	17	1.1821	0.1174 ±0.0007	223.0 ±0.3
2004.9	18	1.1842	0.1289 ±0.0009	242.5 ±0.4
2006.1	19	1.1885	0.1147 ±0.0008	256.3 ±0.4
2007.3	20	1.1842	0.1192 ±0.0014	239.8 ±0.5
2008.5	21	1.1855	0.1258 ±0.0006	263.3 ±0.1
2009.7	22	1.1855	0.1061 ±0.0009	251.7 ±0.5
2010.9	23	1.1826	0.0920 ±0.0011	230.9 ±0.5
2012.1	24	1.1859	0.0506 ±0.0013	221.6 ±0.5
2013.3	25	1.1859	0.0420 ±0.0008	212.1 ±0.5
2014.5	26	1.1851	0.0408 ±0.0005	210.8 ±0.1
2015.7	27	1.1821	0.0205 ±0.0004	225.4 ±0.2
2016.9	28	1.1821	0.0254 ±0.0009	216.7 ±0.3
2018.1	29	1.1826	0.0178 ±0.0008	251.2 ±0.3
2019.3	30	1.1855	0.0119 ±0.0006	251.2 ±0.1
2020.5	31	1.1821	0.0156 ±0.0004	216.9 ±0.2
2021.7	32	1.1821	0.0408 ±0.0010	211.3 ±0.2
2022.65	33	1.1821	0.0755 ±0.0006	217.0 ±0.1
Average		1.1842 ±0.0005	0.1201 ±0.0116	227.4 ±2.7

Table 3: In line with amplitude variation of the Chandler nutation, the values of coefficients (C_1, C_2 and C_3 as harmonic terms) are obtained using LSM; the amplitude A, period P and phase F (the epoch is $1984.^y0$) of that variations are given for minimum of standard deviation (st.dev.) between the input 33 values (in Table 2.) and suitable sinusoidal fit (presented in Fig. 4.).

P (years)	$C_1('')$	$A('')$	$F(^\circ)$	$C_2('')$	$C_3('')$	$st.dev.('')$
54.5	0.115 ± 0.005	0.087	49.9	0.056 ± 0.008	0.066 ± 0.007	0.023

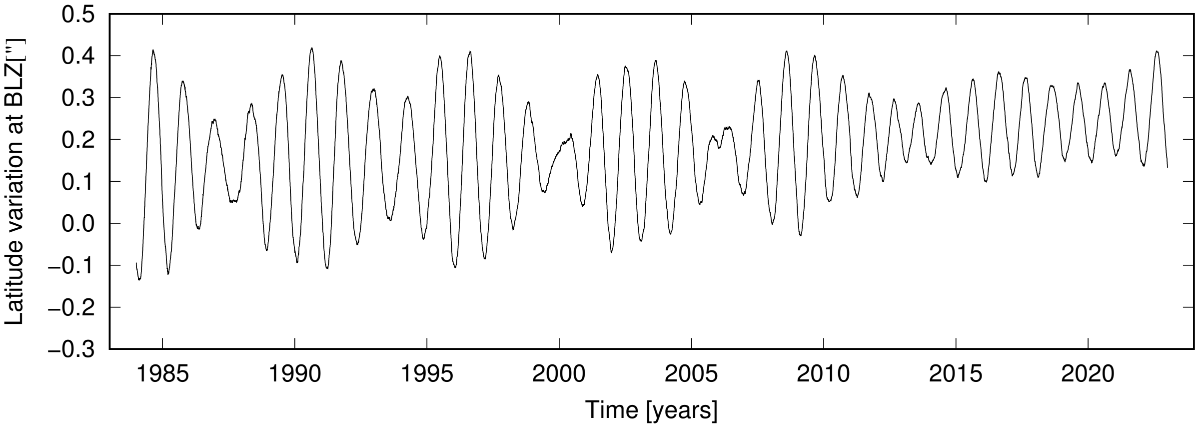

Fig. 1: Latitude variation at BLZ point (using IERS EOP C04 polar motion data).

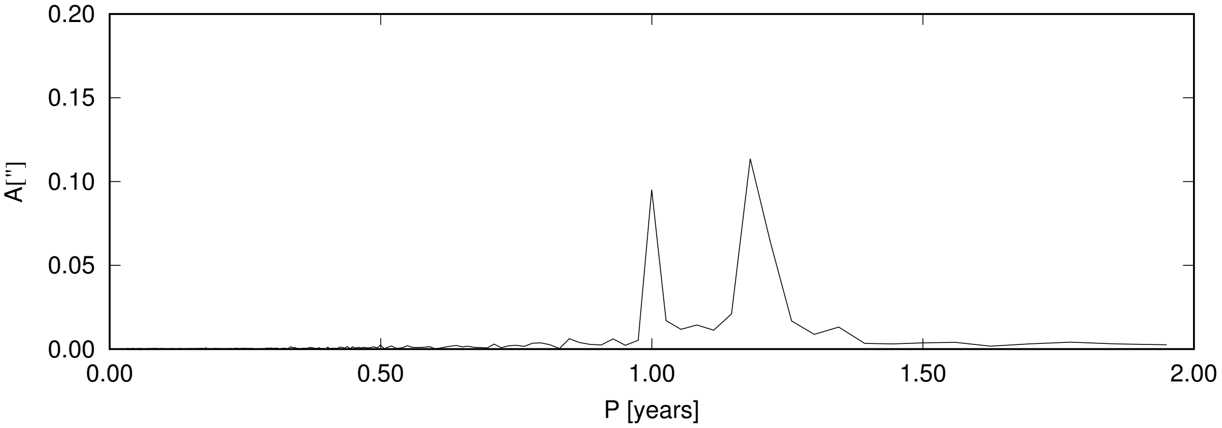

Fig. 2: Amplitude periodogram of latitude variation at BLZ point (using IERS EOP C04 polar motion data).

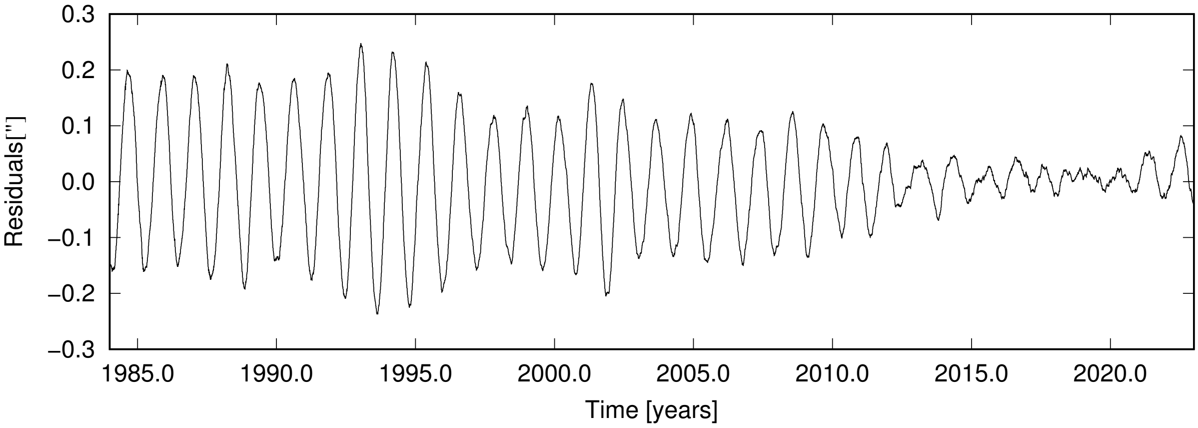

Fig. 3: Residuals (latitude variation at BLZ point without linear, semiannual and annual terms) during the period 1984.0-2023.0 .

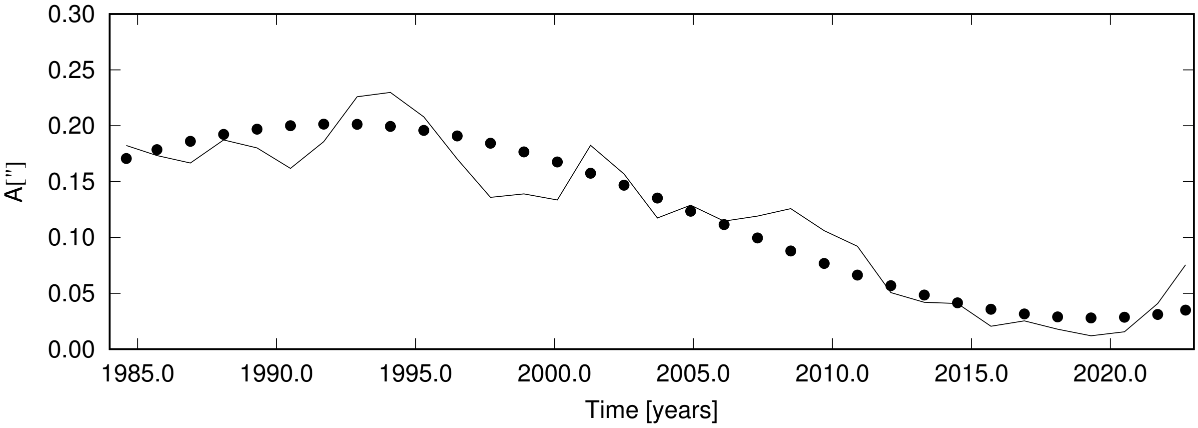

Fig. 4: Amplitude variation of Chandler nutation during the period 1984.0-2023.0 and suitable sinusoidal fit (using the LSM).

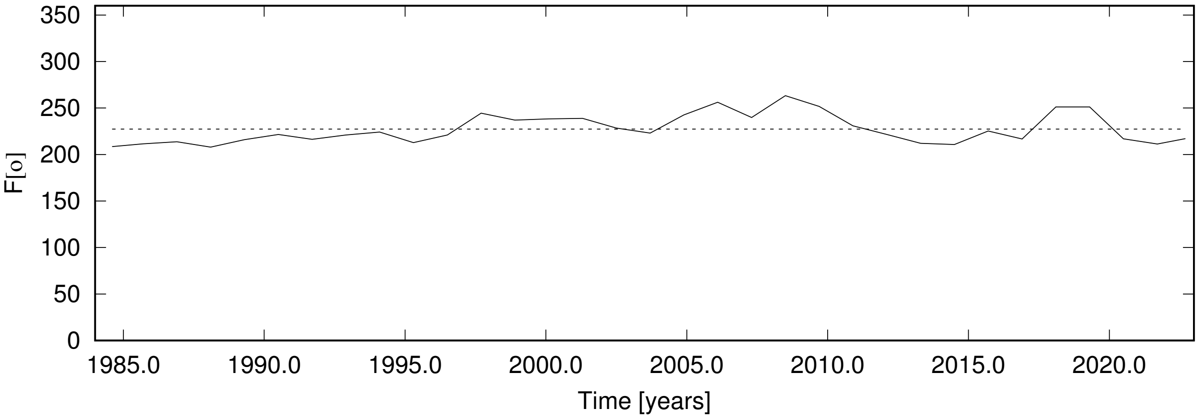

Fig. 5: Phase of Chandler nutation during the period 1984.0-2023.0 and the average value.

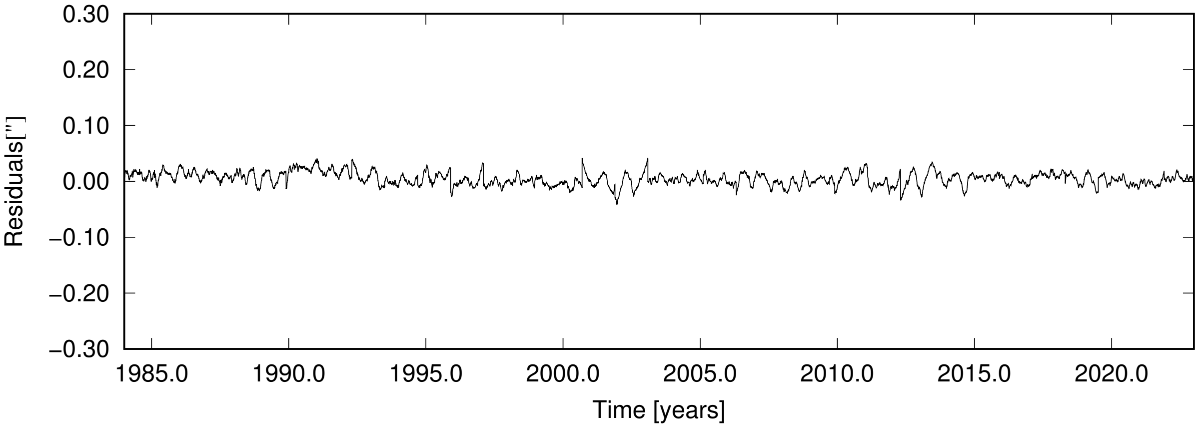

Fig. 6: Residuals (latitude variation at BLZ point without linear, semiannual, annual and Chandler terms) during the period 1984.0-2023.0 .

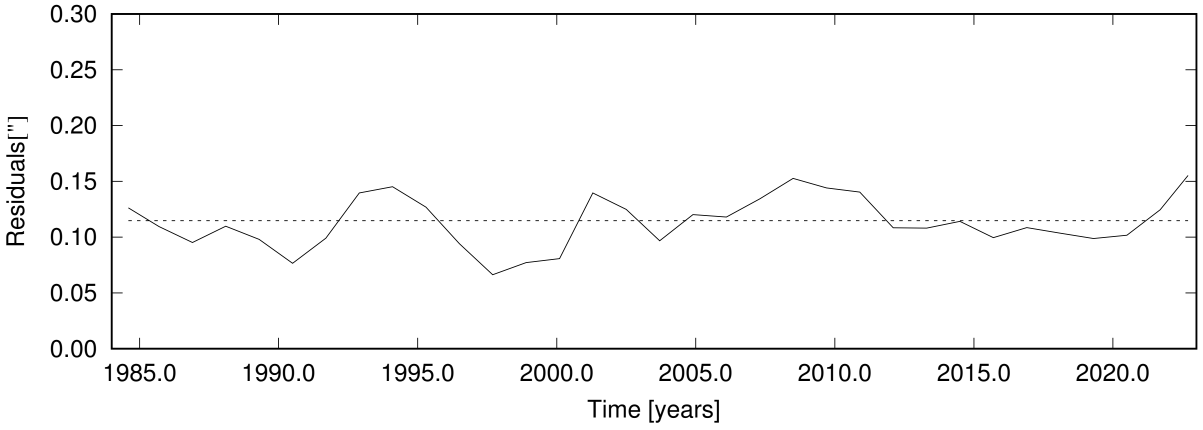

Fig. 7: Residuals of amplitude of Chandler nutation (differences between obtained values of amplitude of Chandler nutation and suitable sinusoidal values presented in Fig. 4.) during the period 1984.0-2023.0 .

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ПРОМЕНЕ АМПЛИТУДЕ ЧЕНДЛЕРОВЕ НУТАЦИЈЕ КОРИСТЕЋИ ВИШЕДЕЦЕНИЈСКЕ ПОДАТКЕ IERS EOP C04 ПОЛАРНОГ КРЕТАЊА

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Оригинални научни рад

Користили смо вишедеценијске податке поларног кретања Земље (x, y) серије IERS EOP C04 (од 1984. до 2023. године) да би испитали промене амплитуде A_C Чендлерове нутације. Да би поредили добијене резултате добијене из C04 са ранијим резултатима добијеним из ширинских података Београда (BLZ серија од 1949. до 1985. године) рачунали смо промене ширине за BLZ тачку користећи C04 координате (x, y). Секуларни члан смо израчунали користећи методу најмањих квадрата (LSM) и одстранили из промена ширине за BLZ тачку да би добили одговарајуће остатке. Применили смо на те остатке Fourier transforms (DFT) да би израчунали и одстранили из поменутих остатака годишњу и полугодишњу осцилацију. Добили смо нове остатке које смо поделили на 33 независна подинтервала од по 1.2 године. За сваки подинтервал смо рачунали амплитуду A_C, периоду и фазу Чендлерове нутације користећи LSM. Квазипериодичне промене A_C смо рачунали са LSM и добили периоду од 54.5 година (из BLZ је била 38.5 година за интервал 1949.-1985.) и амплитуду те промене од $0.''087$ ($0.''06$ из BLZ података). Вредности A_C су варирале од $0.''012$ (2019.3 године) до $0.''230$ (1994.1 године); период је стабилан, али не и фаза. Применили смо Abbe критеријум, и хипотеза да нема тренда у поменуте 33 вредности A_C је одбачена. Наши резултати су у сагласности са другим публикованим резултатима, као и са резултатима које смо добили користећи BLZ податке. Неки аутори узрок добијене квазипериодичне промене проналазе у воденим и ваздушним циркулацијама. У складу са новијим резултатима, могући узрок би могао бити у променама електромагнетне спреге језгра и омотача Земље. Последњих година се ефекат електромагнетних скокова (geomagnetic jerks) истиче као значајнији узрок поменуте појаве него атмосфера и океани. Неопходна су даља слична истраживања.