DYNAMIC EFFECTS OF THE SPATIAL MOVEMENT OF THE EARTH-MOON SYSTEM IN THE EARTH'S POLE OSCILLATION

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ABSTRACT. On the basis of a numerical-analytical approach, the irregular effects of the oscillatory process of the Earth's pole, associated with changes in the Chandler and annual component, are investigated. An approach to the study of oscillatory processes in the motion of the Earth's pole is proposed on the basis of joint consideration of the Chandler and annual components of its motion. Within the framework of this approach, a transformation to a new coordinate system has been found, in which the in-phase motion of the pole and the precession of the lunar orbit are shown.

1. INTRODUCTION

The trajectory of the motion of the pole at the Earth's surface forms a spiral curve that is traced out as the pole moves around its mean position. The drift of the mean pole has a long-period and secular character. The time dependence of the coordinates of the pole (x_p, y_p) can be represented by a superposition of the trend displayed by the coordinates (c_x, c_y), the Chandler and annual components with periods of 365.25 and 433 days, respectively, and small-scale oscillations, as a rule, having an irregular or quasi-regular character. As a consequence of the superposition of the Chandler and annual components, the radius of the trajectory varies, on average, from 70 to 230 milliarcseconds (mas) with a period of approximately 6.45 yrs, leading to a modulation of the oscillations.

The actual problem of studying the irregular behavior of the main components of the Earth pole oscillations is currently poorly understood. Of a significant interest are studies aimed at establishing the geophysical and celestial-mechanical reasons for such behavior of the Chandler and one-year components, and the construction of refined prediction models for the EOP required for solving high-precision satellite navigation problems.

2. THE OSCILLATORY PROCESS OF THE EARTH POLE AT THE FREQUENCY OF THE MOON'S ORBIT PRECESSION

We analyzed the variations of the main components of the polar oscillations by carrying out a transformation of the coordinates of the pole in several steps. This transformation of the coordinate system can be written in matrix form [1]:

$$\begin{pmatrix}\xi_p\\ \eta_p\end{pmatrix} = \Pi(w_{ch/h} - w_1)\left[\Pi(w_1)\begin{pmatrix}x_p - c_x\\ y_p - c_y\end{pmatrix} - \begin{pmatrix}a_0\\ 0\end{pmatrix}\right]. \qquad (1)$$

$$w_{ch/h} = \begin{cases} w_h, & \text{if} \quad a_h < a_{ch},\\ w_{ch}, & \text{if} \quad a_h > a_{ch},\end{cases}$$

$$w_1 = \begin{cases} w_{ch}, & \text{if} \quad a_h < a_{ch},\\ w_h, & \text{if} \quad a_h > a_{ch},\end{cases}$$

$$\dot{w}_{ch} = 2\pi(0.84 \div 0.85)\omega_*, \quad \dot{w}_h = 2\pi\omega_*.$$

Here, a_h and a_{ch} are the amplitudes of the annual and the Chandler oscillations of the pole and ω_* is the yearly frequency.

In (1), Π is the matrix for a planar rotation, a_0 the mean amplitude of the oscillations of the pole about its mean position (i.e., without the trend), c_x and c_y represent the mean position of the pole and contain constants, secular terms, and variations with periods exceeding six years, and $w_{ch/h} - w_1 = \pm\nu_T$ is the frequency of the six-year cyclic motion of the pole.

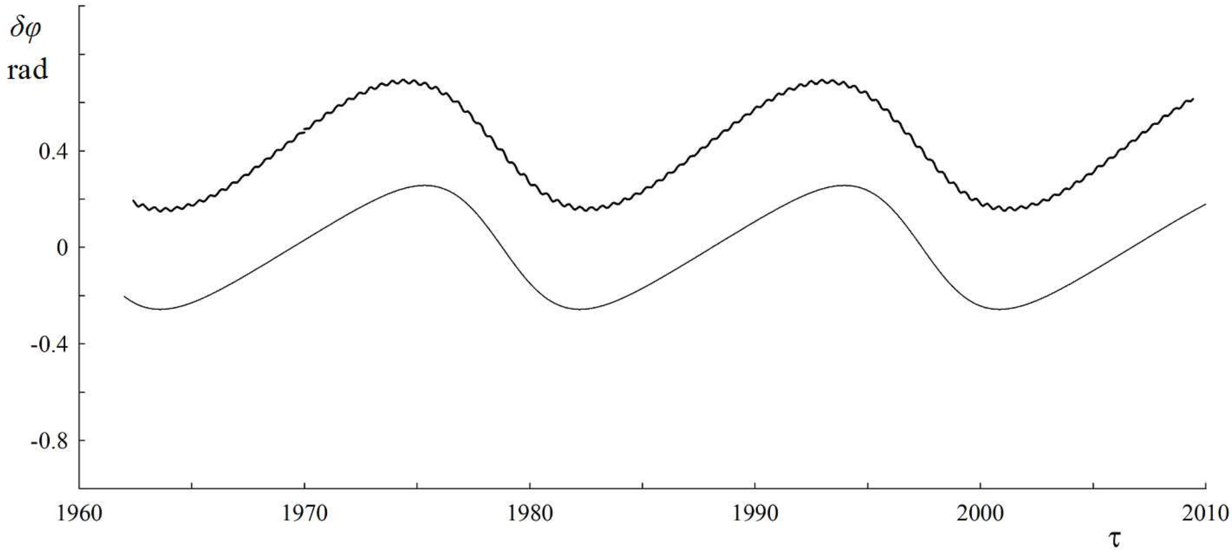

Figure 1: Comparison of the polar angle variations $\delta\varphi$ (bottom line) with the oscillations along the equator of the point of intersection of the lunar orbit and the equator (upper line), constructed using the lunar ephemeris.

We can illustrate oscillations of the Earth's pole synchronous with the precessional motion of the lunar orbit in the new coordinate system (ξ_p, η_p), and determine the regular component of the phase variations $\delta\varphi$.

In Figure 1 the polar angle $\delta\varphi$ is compared with the oscillations of the intersection point between the equator and the lunar orbit. The units of the oscillation amplitudes are radians, and τ is time in standard years. In the new coordinate system, it is possible to illustrate synchronous oscillations of the Earth pole with the precessional motion of the Moon orbit and to determine the regular component of the $\delta\varphi$ phase variation, which makes it possible to use lunar ephemeris when predicting additional terms in the model of Earth pole motion.

3. CONCLUSION

Based on the results of our numerical simulations and model verification on various time intervals, we conclude that, when the stability of the oscillations of the Earth's pole with a frequency close to the precessional frequency of the lunar orbit is preserved, the terms added to the model enable an enhancement of the precision with which the position of the Earth's pole can be determined by, on average, 30 cm in prediction intervals from two to eight years within a single oscillatory regime for the pole (before the change in the oscillation frequency of the additional harmonics).

4. REFERENCES

[1] Perepelkin V.V., Rykhlova L.V., Filippova A.S., 2019, "Long-Period Variations in Oscillations of the Earths Pole due to Lunar Perturbations", V. 63, N. 3, pp. 238–247, doi: 10.1134/S1063772919020070.