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

V. PERELPELKIN[1], A. FILIPPOVA[2], S. KRYLOV[3]

[1] Moscow aviation institute - Russia - vadimkin1@yandex.ru
[2] Moscow aviation institute - Russia - filippova.alex@gmail.com
[3] Moscow aviation institute - Russia - krylov@mai.ru

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 represented by the coordinates (c_x, c_y). The time dependence of the pole coordinates can be represented by the superposition of the trend, the 433 day Chandler wobble (amplitude a_{ch}, angular frequency $\dot{w}_{ch}$), the annual term (amplitude a_h, angular frequency $\dot{w}_h$), 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 years.

The irregular behavior of the main components, namely of the Chandler and annual oscillations, is poorly understood. Of a significant interest are studies aimed at establishing the geophysical and celestial-mechanical reasons for such behavior, 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 (Perepelkin et al, 2019) :

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

where $w_{ch/h}$ and w_1 are uniformly increasing angles at the frequencies $\dot{w}_{ch/h}$ and $\dot{w}_1$ determined by the set of relations

$$\dot{w}_{ch/h} = \begin{cases}\dot{w}_h, & \text{if} \quad a_h < a_{ch},\\ \dot{w}_{ch}, & \text{if} \quad a_h > a_{ch},\end{cases}$$

$$\dot{w}_1 = \begin{cases}\dot{w}_{ch}, & \text{if} \quad a_h < a_{ch},\\ \dot{w}_h, & \text{if} \quad a_h > a_{ch},\end{cases}$$

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

Here ω_* is the yearly frequency.

In (1) Π is a planar rotation matrix , 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 $\dot{w}_{ch/h} - \dot{w}_1 = \pm\nu_T$ is the frequency of the six-year cyclic motion of the pole.

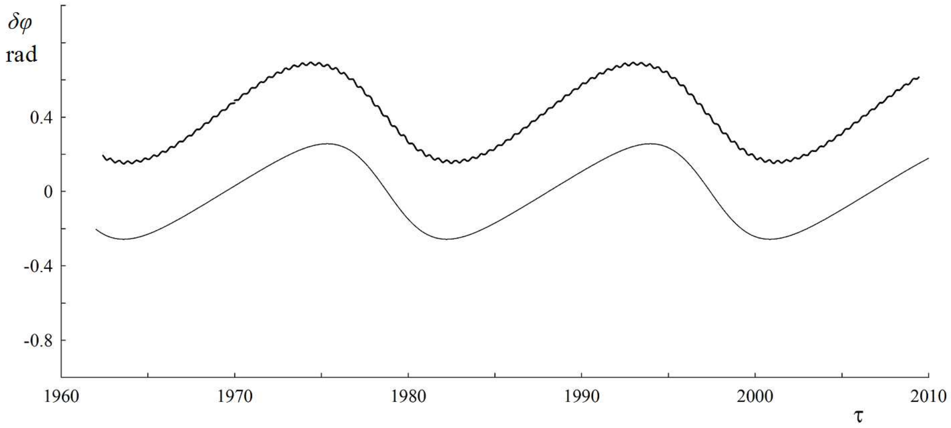

Figure 1: Comparison of the polar angle variations $\delta\varphi$ (bottom line) with the oscillations along the equator of the point of intersection of the lunar orbit and the equator (upper line), constructed using the lunar ephemeris.

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 predicted by, on average, 30 cm at horizon 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

Perepelkin V.V., Rykhlova L.V., Filippova A.S., 2019, "Long-Period Variations in Oscillations of the Earth's Pole due to Lunar Perturbations", Astronomy reports 63(3), pp. 238–247, doi: 10.1134/S1063772919020070.