Anomalies in the Earth rotation and Syzygies in Perigee

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Abstract: *In 2022 the Erath rotation velocity reached its maximum and in 2017-2020 the Chandler wobble of the rotational axis disappeared for the second time in the history of observations. Unexplained modulations of 90 and 20-25 year periods are observed. They reflect geophysical processes in the atmosphere, ocean, and Earth's interior and can be linked to climate. It is important to understand their causes and predict them for navigation etc. We found out, that the orientation of the lunar orbital plain and position of perigee revolves in such manner, that their mutual positions repeat with 90-year semi-periods at the minimum of the Chandler wobble. At the same time synodic period of syzygies in perigee (every 412 days) with respect to the position of the Chandler pole (433 days) rotates within ~22-23 years. We have collected arguments in favor of the hypothesis that the mass flows and redistribution within the Earth systems under the influence of apsidal-nodal effects of luni-solar tide could be responsible for the above mentioned modulations in the Earth rotation.*
Keywords*: EARTH ROTATION, CHANDLER WOBBLE, LOD, LUNAR ORBIT*

1. Introduction

The rotation of the Earth is the subject of research in geodesy, astrometry, and geophysics. In the 19th century, an increase in the accuracy of observations made it possible to detect changes of latitudes (the polar motion, PM). With the advent of quartz clocks in the first half of the 20th century, the variations of the angular velocity of the planetary rotation also manifested itself [1,2]. Fig. 1 shows the anomalies of the length of the day, LOD, reflecting how much (in milliseconds of arc) the length of the day has changed due to acceleration (LOD decreases) or deceleration of the planet. Against the background of long-term (20-25 years) variations, annual and interannual fluctuations are observed.

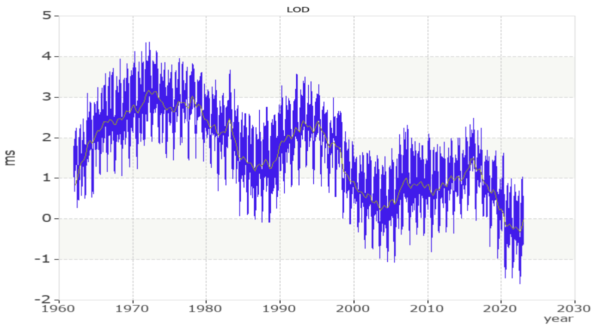

Fig. 1 *Variations of LOD from EOP CO4 bulletin.*

Figure 2 shows the trajectory of the Earth's pole since 1842 in the terrestrial reference frame (TRF). Its main components are the pole drift, the annual wobble, and the Chandler wobble (CW) with the period of 433 days and variable amplitude of about 100 ms of arc (3 m on the planet's surface). In the 1930s and 2020s, the CW disappeared.

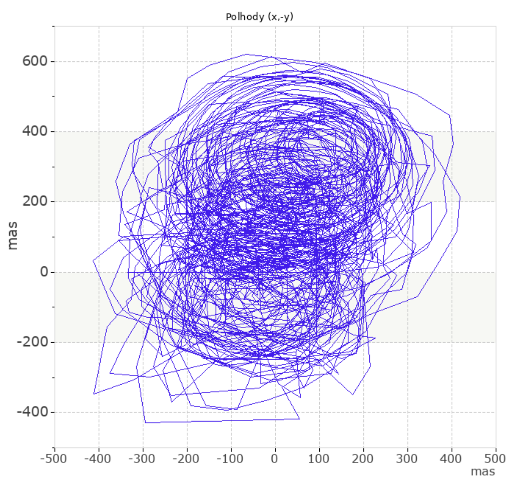

Fig. 2 *Polar motion from EOP CO1 bulletin (X up, -Y right).*

The Earth is a spinning top located in the gravitational field of the celestial bodies surrounding it. The moment of forces from the the Moon and the Sun causes precession and nutation of its axis in the inertial frame, well modeled by the IAU 2000 model [3] (former name MHB 2000). Observations show minor deviations of the real position of the planetary rotation axis in the celestial reference frame, CRF. These deviations are called Celestial Pole Offsets, CPO (dX, dY), and, along with LOD, x and y coordinates of the pole, constitute five Earth rotation parameters, ERP. Fig. 3 shows the CPO dX coordinate since 1985. Against the background of noise, a 430-day period of Free Core Nutation FCN appears. Its amplitude is at the level of ~0.3 milliseconds of arc, but in 2000 and 2022 it noticeably decreases [4].

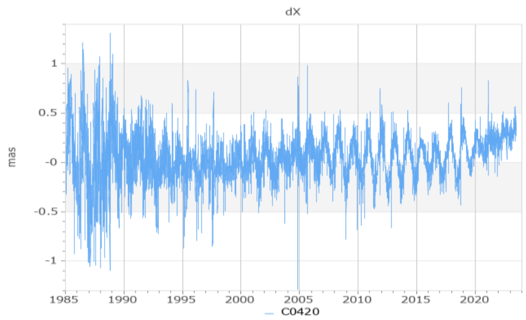

Fig. 3 *CPO dX from EOP C04 bulletin.*

From the presented ERP data, it can be concluded that a number of anomalies appeared in the Earth's rotation in the 2020s. The LOD reached minimum in 2022, comparable only with the minimum of 1930s, the Chandler oscillation died out, and the free core nutation signal disappeared. Features in the Chandler wobble of the pole can be revealed more clearly by filtering out other components of the polar motion. Figure 4 shows the CW extracted by various methods on example of its x-coordinate. One can see amplitude fluctuations with quasi-40- and 90-year periods [5].

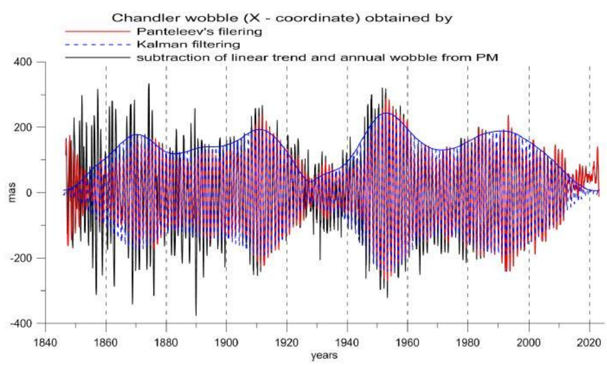

Fig. 4 *Chandler wobble filtered from EOP C01 bulletin.*

2. Approaches used to explain ERP variations and geometry of the tide

If the Earth were an absolutely rigid body, it would not change its shape and moment of inertia. Under the action of centrifugal forces, the planet acquired a spheroidal shape with a polar radius 21 km smaller than the equatorial one. The presence of many layers makes the Earth a complex system with viscoelastic properties.

Under the action of moments of external forces, the compressed top undergoes precession-nutation motions. The IAU 2000 theory allows to calculate them by passing the nutations of the solid Earth at different frequencies through the transfer function of the real Earth with resonant frequencies calculated theoretically in advance. Of these two, CW and prograde FCN eigen oscillations, are actually observed, while the inner core wobble (ICW) and near diurnal free wobble (NDFW), have not yet been detected [6].

Astronomers have divided the variations in the Earth's rotation into two frequency bands: precession and nutation and polar motion, PM. The first two processes are analyzed in the celestial reference frame CRF having periods more than two days. The PM lies outside the range from -0.5 to 0.5 cycles per day in CRF, but is conventionally considered in the rotating terrestrial reference frame TRF, which means that all the frequencies are shifted by one cycle per day. In TRF, the PM frequencies are outside the range from -1.5 to -0.5 cycles per day [3].

This was done taking into account that all the planets, the Sun and the Moon have slow motions in the celestial system and the components of their influences (torques) on the Earth are low-frequency in CRF. These effects can be studied both in Euler angles and in more general coordinates, for example, Andoyer variables, using the Lagrange or Hamilton equations.

It is more difficult to construct a theory of polar motions, since they occur mainly under the influence of geophysical factors, i.e. redistribution of the masses of the Earth, changes in the ocean currents, atmospheric winds, etc. Seasonal changes associated with the movement of the Earth around the Sun, causing variations in insolation and hemispheric heat transfer, are fairly regular and predictable. But difficult-to-predict phenomena, such as earthquakes, the El Nino climate oscillation, the passage of cyclones, also interfere and forces PM. It is very difficult to calculate the energy of these processes and construct the Lagrange equations for them. An approach based on the conservation of angular momentum, AM, law is used. If in one of the shells AM has changed, for example, increased, then the solid Earth should reduce its rotational speed. The Euler-Liouville equations for the motion of the pole and Earth's rotational velocity changes are trying to take into account in the form of excitaton functions all the redistributions of mass and proper motion in the shells, as well as changes in the inertia tensor components caused by deformations of the Earth's figure.

However, the question remains open: how the Sun, the Moon and other celestial bodies can influence the circulation in the ocean and atmosphere, processes in the depths and other geophysical phenomena, influencing the movements of the pole. We do not raise the question of why there are no clear manifestations of the 11-year solar cycle in meteorology, or why the 433-day Chandler period has not been revealed in other geophysical phenomena. We neither are trying to return to those views that existed at early steps of the scientific understanding of the world, when the influence of the planets on the fate of the world was of interest to astrologists. But we rise the following question as legitimate: is it possible that the precession-nutation theory, although taking into account the moments of forces from the planets that change the orientation of the axis of the gyroscope – Earth in inertial space, ignored the problem of the influence of celestial bodies on geophysics contributing to the PM? Here we meet the problem of divergence of the scientific branches, when even within one field the separate directions of the studies are isolated and do not elaborate the interdisciplinary problem.

The influence on the Earth from the celestial bodies comes through the tides. They attracted attention of many scientists: from Newton and Galileo to Laplace, Darwin, Lord Kelvin, Schrödenger, Jeffreys, Melchior, and others. The theory of the Earth’s response to the tidal potential, taking into account Love numbers, is well developed. The Laplace expansion of tides is a kind of approximation, when the ellipsoidal (second order) form of the tidal potential is approximated by a series of zonal, sectorial and tesseral harmonics [7]. In the harmonic theory of tides many frequencies arise in the diurnal, semidiurnal and long-periodic ranges. The complex nature of the Moon's movements is taken into account in the arguments of harmonics, including all the six orbital parameters changing in a long-period inequalities. Among them, the movement of the ascending node of the lunar orbit with a period of 18.6 years to the west and the 8.85-year drift of the perigee to the east.

Our attention was drawn to the combination of these processes by the works of N.S. Sidorenkov [8]. Obviously, depending on the location of the ascending node, the orientation of the lunar orbital plain and the declinations the moon reaches in its monthly course across the sky depend. The position of the perigee on orbit, when the Moon is moving faster and is closest to the Earth, determines both the time it takes for the moon to reach maximal declination and the strength of the tide. In syzygy, when the Sun, Moon and Earth are aligned along the same line, the tides from these two luminaries add up, leading to the maximum amplitude of the tidal wave. If at the same time the Moon is in perigee, then it will be even stronger.

Yu. N. Avsyuk [9] drew attention to the fact that the full moons, FM, in perigee (the same for new moons, NM) are separated by an interval of 412 days, very close to the 433-day period of the Chandler wobble. We plotted these events by blue (FM) and yellow (NM) stars in Fig 5. We noticed that the mutual synodic period of these two processes is about 22 years. If we take at every midnight (thereby demodulating the rotation of the planet) the direction in which the instantaneous pole of the Earth is displaced in the Chandler motion and determine the angle it makes with the direction to the perigee, then it turns out that the angle between them opens with 22-year period, i.e. directions along which the perigee full moons and new moons occur wrt CW shifts across the sky, describing a circle in 22-23 years. Similar quasi-periodicity is observed the decadal oscillations of LOD (Fig. 1) and antinodes (humps) of the amplitude of the Chandler oscillation (Fig. 4).

Considering the ascending node of the lunar orbit motion along the ecliptic, which determines the lunar orbit orientation relatively to it and equator, it turns out that in 22 years the perigee goes twice into one (for example, northern) hemisphere and thrice into the other. Vice versa in the next cycle. This leads to idea that the antinodes of the CW amplitude, which just reflect the untwisting of the axis in the interval of ~22 years and spiraling in the next interval [5,10], can be a consequence of the geometry of the tidal wave movement along the Earth’s shells.

The axis of symmetry of the tidal potential is directed from the center of the Earth to the tide-forming body (the Moon). Moving across the sky, the Moon deforms the Earth in different directions like pastry, changing its shape and the currents in the shells. The whole complex of accompanying redistributions of masses, friction of the material dragged by the tide is very complex, heterogeneous across the hemispheres and depends on the amplitude of the tide. The latter depends on how close the Moon is to the Earth and how the tides from the Moon and the Sun are mutually summed up. That is why syzygies in perigee attracted our attention: they reflect the sequence of mutual positions of the Moon, Sun, perigee and nodes.

Assuming that the Chandler wobble lows near 1927 and 2022 are not accidental, we have noticed from Fig. 5 that in 1927 the ascending node of the lunar orbit, located at the point of the summer solstice, formed a quadrature (right angle) with perigee, located at a point ~6^{o} north of the autumn equinox (due to the tilt of the lunar orbit). This year, the big full moon occurred near the date of the vernal equinox. Due to the fact that two rotations of the perigee 8.85*2=17.7 years last one year less than the precession cycle of 18.6 years, the ascending node lags behind and does not have time to return to the same point on the ecliptic, when the perigee again comes to where it was two cycles before. Therefore, the relative positions of the node and perigee grows, turning around the sky with a synodic period of ~180 years. Due to this, the dates of big full moons (in perigee) drift and after 90 years, a perigee new moon comes to the place (in a year) of the perigee full moon (compare tow panels of Fig. 5). Therefore, 90 years later - in 2020, when the node came back to the point of the summer solstice, the perigee came to a point 6^{o} south of the autumnal equinox (since this sector of the lunar orbit is inclined under the ecliptic) and formed a quadrature with the node again. The Chandler wobble has faded. The decay of the CW, as follows from the analysis of observations [4,5,10], is also accompanied by its phase change of 180^{o}, so, it flips. We found that due to the peculiarities of the inclination of the lunar orbit during the first 90 years, the series of big full moons go to the northern hemisphere sequentially to quite higher and lower declinations, while in the southern hemisphere they reach only the same very moderate ones. In the era of the disappearance of the CW, the situation reverses. This means that the described phenomenon be responsible for the changes in the amplitude of the polar motion. How this is synchronized with the LOD is not yet clear, but, in our opinion, the synchronization is seen from observations [10].

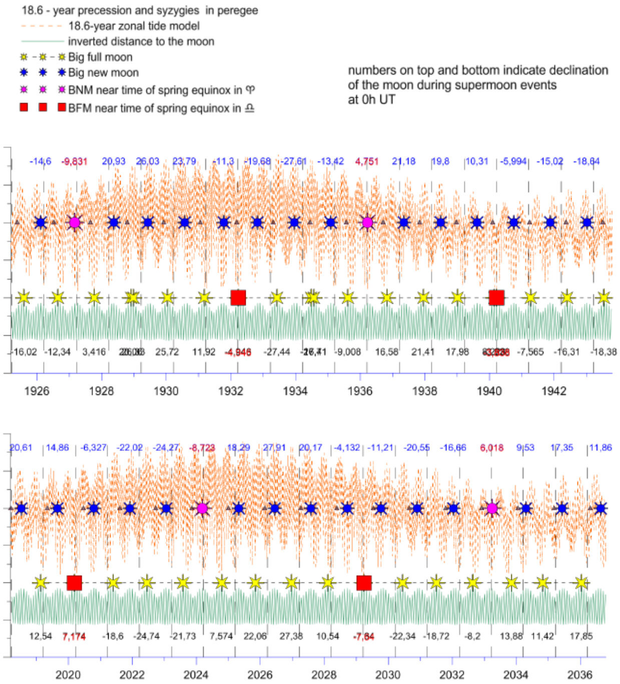

Fig. 5 Syzygies in perigee sequence on the background of 18.6-year cycle of tides.

3. Conclusions and Discussion

We presented considerations regarding the possible reasons of the appearance of 90-year and 20-25-year decadal modulations in the ERP: amplitude of the Chandler oscillation, LOD and CPO. The geometry (inclination) of the lunar orbit and its elongation are changing cyclically in the sky, and the interchange of syzygies in perigee reflects (measures) it. The revealed changes in mutual configurations of the Sun, Moon, perigee and nodes correspond to the epochs of anomalies appearance in the ERP. For a more convincing proof, it is necessary to carry out a detailed calculation of the components of inertia tensor changes, taking into account the subtle effects of the passage of a tidal wave over asymmetric (in terms of the distribution of water and land) hemispheres, the mutual addition of the lunar and solar tides, dissipation, and, possibly, the action of external moments of forces on the tidally elongated figure of the Earth.

Despite the fact that the movement of the nodes of the lunar orbit and perigee have been known for centuries and are taken into account in the harmonic theory of tides, the IAU2000 theory of precession and nutation, the tide models for LOD, etc., the author admits that the interaction of lunar orbital precession and perigee movement can cause unaccounted changes in the Earth's shells that affect the ERP. The mechanics of heaven, acting on the deformable Earth - a gyroscope, synchronizes the course of geophysical processes in the atmosphere, ocean, core on time scales of tens of years, causing long-term anomalies in the planetary rotation.

Long-term observations just started to allow us to identify such effects and their causes. The various superimposed irregularities hide from us what may be associated with the impact of regular cycles of the cosmic origin. The rotation of the Earth studies are at the intersection of astronomy and geophysics. Here we can expect a more noticeable manifestation of astronomical factors, which will make possible to trace their role in the local processes of meteorological, climatic, and hydrological nature [6,10]. In the near future, our specialized publication will appear, where we hope to give development of the presented impetus.

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