On the Ellipticity of the Trajectory of the Free Motions of the Earth’ s Pole

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On the Ellipticity of the Trajectory of the Free Motions of the Earth' s Pole

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It is known from latitude observations that the motion of the Earth' s rotation pole is the result of the interaction of free and forced oscillations of the instantaneous axis of rotation. The free oscillations of the rotation axis have a period close to 1.2 years (the Chandler period) and are determined by the shape of the Earth and its elastic properties. The forced oscillations arise as a result of the seasonal redistribution of air masses over the continents and oceans and have an annual period.

Numerous works have been devoted to the study of the free and forced motions of the Earth' s rotation pole (see the surveys in ([1,2])). The present article is devoted to the investigation of the least-studied phenomenon in the motion of the poles–the ellipticity of the free motions. This question is directly connected with the shape of the Earth and with the position of the principal axes in its body. Previously, the elliptical character of the trajectory of polar motions was considered in works ([3–5]). At present it appears possible to investigate this phenomenon using the material of longer observations of the International Latitude Service.

For this purpose, the coordinates of the instantaneous rotation pole of the Earth for the period from 1900 to 1958 ([1]) were used. Usually the amplitudes of the free and forced motions of the pole are obtained by harmonic analysis of its coordinates, taken every 0.1 year over a 6-year period–an interval of time equal to 5 Chandler and 6 annual periods. Using the method of sliding harmonic analysis of 6-year series of pole coordinates, in which the beginning of each subsequent 6-year interval was shifted by 1.0 year, we obtained the amplitudes and phases of the free oscillations of both pole coordinates (X and Y).

Table 1

Elements of the mean ellipses of the free motions of the Earth' s rotation pole for the period from 1900 to 1958

Fig. 1

Figure 1: Fig. 1

Years	R_{max}	R_{min}	n	γ
1900–1905	14,11	12,03	1,17	127°E –53°W
1906–1911	21,29	20,80	1,02	104 E –76 W
1912–1917	18,99	17,77	1,07	78 E –102 W
1918–1923	12,11	9,81	1,23	18 E –162 W
1924–1929	4,21	4,10	1,03	42 W –138 E
1930–1935	7,71	6,37	1,21	166 E –14 W
1936–1941	6,25	4,96	1,26	158 E –22 W
1942–1947	15,12	13,83	1,09	170 E –10 W
1948–1953	29,53	27,29	1,08	166 E –14 W
1953–1958	26,97	23,18	1,16	124 E –56 W
Average	–	–	1,13	112 E –68 W

Note. R_{max} and R_{min} are in hundredths of a second of arc.

The data obtained were then used to compute the parameters of the elliptical trajectories of the free motions of the pole on average for each sliding 6-year period (54 periods in all). The major (R_{max}) and minor (R_{min}) semiaxes of the ellipses of the free motions were computed as the greatest and smallest of the radius vectors ($R = \sqrt{X^2 + Y^2}$), calculated

at intervals of 0.01 year within the period of free nutation. The values R_{max} and R_{min}, as well as their ratio η, characterizing the ellipticity of the trajectories, and the direction of the major axis γ for successive 6-year intervals are presented in Table 1, and for the entire period of observations in Fig. 1. All calculations were carried out on the BESM-2M electronic computer.

The values we obtained for the semimajor axis of the ellipse of free motions vary in accordance with the general character of the changes in the amplitudes of the free motions of the pole according to the data of ($^{6-8}$) and others. The major axis reached its largest values at the beginning of the 1900s (around 1906) and at the beginning of the 1950s (around 1952). In the period between 1925 and 1938 the free oscillations of the pole of rotation were unstable in character, and the semimajor axis of the elliptical trajectory attained a value of only $0''.04$. The ellipticity of the free motions of the pole is a variable quantity. During the period studied, η varied from 1.02 to 1.41, with a mean

Fig. 1. Change in the dimensions (1) and direction (3) of the major axis and the ellipticity (2) of the free motions of the pole of rotation of the Earth for the period from 1900 to 1958.

Fig. 2. Direction of displacement of the eastern half of the major axis of the

Fig. 2

Figure 2: Fig. 2

ellipse of the free motions of the pole of rotation of the Earth for the period from 1900 to 1958 (the arrow on the right shows the direction of motion of the pole of rotation)

value of 1.13; moreover, the change in this quantity obeys a definite regularity. As is seen from Fig. 1, the course of η in time is, in general, inverse to the change in $R_{\max}$. This means that at the maximum amplitudes of the free oscillations of the pole, its trajectory on the surface of the Earth is close to a circle ($\eta \simeq 1.00$); in the years when the free motions decay, the ellipticity of the pole trajectory increases ($\eta \simeq 1.40$).

According to present-day views, in which the Earth is regarded as a triaxial ellipsoid, the major axis of the ellipse of the free motions of the pole of rotation should, in direction, coincide with the minor axis of the equator ([1]). In accordance with the elements of F. N. Krasovskii' s ellipsoid, the eastern longitude of the largest meridian from Greenwich is $15^\circ \pm 2^\circ.4$. Hence the minor axis of the equator, and consequently also the major axis of the ellipse of the free motions of the pole, should lie in the plane of the meridian $105^\circ \pm 2^\circ.4$ E.

According to our data, on average for the period from 1900 to 1958 the direction of the major axis of the ellipse of the pole' s free motions is close to the indicated value and is 112° E longitude. In reality, however, the direction of the major axis changes continuously, and during the same period it fluctuated within considerable limits. As can be seen from Figs. 1 and 3, along with short-period fluctuations, three characteristic periods can be distinguished in the changes in the direction of the major axis of the ellipse of the pole' s free motions. On average from 1900 to 1924 the major axis shifted in the direction from east to west; then the direction changed sharply to the opposite one—from west to east. Motion in this direction continued until the end of the 1930s and again changed to the opposite one. Simultaneously with the change in the direction of the major axis, its dimensions also changed. A schematic representation of the displacement of the major axis of the ellipse of the free motions, taking account of its dimensions, is presented in Fig. 2.

As is known, the Earth' s rotation pole moves around the pole of inertia in the direction from west to east. The major axis of the elliptical trajectory of the free motions of the pole of rotation, as we see (Fig. 2), shifts either in the same direction or in the opposite one. Thus, on average from 1924 to 1939 the major axis shifted in the same direction as the instantaneous pole of rotation, while in the periods from 1900 to 1924 and from 1939 to 1956 it shifted in the opposite direction.

Thus, the ellipticity of the trajectory and the dimensions of the major axis of the ellipse of the free motions of the pole of rotation, as well as its direction, turn out to be variable quantities. This, evidently, was to be expected. The free motions of the Earth' s pole are closely connected with the figure of the Earth, with its internal structure and elastic properties. Within the Earth and in its crust there are constant displacements of masses associated with earthquakes, the subsidence and uplift of continents, and horizontal shifts of large blocks of the Earth' s crust. The redistribution of masses in the Earth changes its ellipsoid of inertia and changes the direction of the principal axes. Owing to the elasticity of the shell, the Earth appears as a weakly pulsating body with a variable position of the near-equatorial regions of flattening. To some extent this is also confirmed by our data on the change in the direction of the major axis of the ellipse of the pole' s free motions, which is associated with the position of the principal axes of inertia of the Earth.

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Note: Figure translations are in progress. See original paper for figures.