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Figure 1

Figure 1: Figure 1

Abstract

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GEOPHYSICS

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THE POLAR TIDE IN THE BALTIC SEA

(Presented by Academician V. G. Fesenkov on 23 XI 1964)

The study of changes in the mean ocean level produced by free oscillations of the instantaneous axis of the Earth' s rotation is an important problem of modern oceanology. J. Darwin called this phenomenon the **polar tide**. V. Schweydar created a static theory of the polar tide ([16]). One of the first investigations of this phenomenon based on observational data was carried out by E. Przybyllok ([15]). Examining materials from long-term observations of oscillations of the Baltic Sea level, E. Przybyllok came to the conclusion that no real polar tide exists in the ocean. Later I. Bossan ([10]), I. V. Maksimov ([1−9]), and, more recently, W. Munk and G. Haurwitz ([11]) showed that E. Przybyllok' s conclusions were erroneous and proved the reality of sea-level oscillations of nutational origin. However, in these studies the question of the polar tide in the Baltic Sea was not addressed.

Fig. 1. Periodograms of changes in the component of the instantaneous pole of the Earth' s rotation on the axis 0—180° (X_{sum}) and of level oscillations in various ports of the Baltic Sea. The periodograms were computed on the BESM-2 machine for the period from 1900 to 1930.
1 –Dragschellan, 2 –Vyborg, 3 –Ventspils, 4 –Karskhamn, 5 –Świnoujście, 6 –Ratan, 7 –Gävle, 8 –Södersher, 9 –Baltiysk, 10 –Gedser, 11 –Oulu, 12 –Lypertö, 13 –Utö

To clarify the question of the magnitude and character of the polar tide in the Baltic Sea, we used observations of sea-level oscillations in 13 ports of the Baltic Sea over 30 years, from 1900 to 1930. These observations were used to compute sea-level heights for each tenth part of a year (for comparison with the latitude data) and were subjected to detailed periodogram analysis on the BESM-2 machine. At the same time, the values, taken from the data of the International Latitude Service, of the component of the instantaneous pole of the Earth' s rotation on the axis 0—180°, i.e., the values of the component X_{sum}, were subjected to the same analysis. The results are given in Table 1. Characteristic periodograms of sea-level oscillations and periodograms of the motion of the Earth' s rotation pole are shown in Fig. 1.

The data from the analysis of observations proved to be very indicative. They make it possible to draw the following essential conclusions about the dimensions and character of the polar-tide wave in the middle latitudes of the Earth:

1. The complete identity of the periodograms of the component of the radius-vector of the instantaneous pole of the Earth's rotation on the axis 0—180° longitude (X_{sum}) and the periodograms of level oscillations in various ports of the Baltic Sea convincingly proves the reality of the polar tide in the middle

Table 1

The polar tide in the Baltic Sea

Observation point	Coordinates	Period of oscillation, years τ^a	Phase of oscillation relative to January 1900 φ	Phase difference φ level − φ pole	Oscillation amplitude A_{14}
Component of the pole of the Earth' s rotation on the axis 0—180° (X)		1.20	109°	–	0.12″
Level oscillations of the Baltic Sea					
Oulu	65°02′ N, 25°26′ E	1.21	175°	66	41 mm
Ratan	64°00′ N, 20°55′ E	1.22	285	–	44

Observation point	Coordinates	Period of oscillation, years τ^a	Phase of oscillation relative to January 1900 φ	Phase difference φ level − φ pole	Oscillation amplitude A_{14}
Draghällan	62°20′ N, 17°28′ E	1.22	296	–	45
Vyborg	60°42′ N, 28°44′ E	1.21	165	56	52
Gävle	60°40′ N, 17°10′ E	1.21	174	65	40
Ljuppertö	60°36′ N, 21°14′ E	1.22	170	61	41
Söderhamn	60°07′ N, 25°25′ E	1.20	177	68	45
Utö	59°47′ N, 21°26′ E	1.22	175	66	51
Ventspils	57°24′ N, 21°33′ E	1.22	165	56	36
Karlshamn	56°06′ N, 15°35′ E	1.23	253	–	34
Baltiysk	54°38′ N, 19°54′ E	1.23	166	57	38
Gedser	54°34′ N, 11°58′ E	1.21	143	34	20
Świnoujście	53°56′ N, 14°17′ E	1.24	170	61	25

latitudes of the Earth, and E. Przybyllok' s conclusions concerning the absence in the Baltic Sea of a wave of the nutational tide were not confirmed.

The periodograms obtained showed that the level oscillations of the Baltic Sea contain two principal quasiperiodic components: annual and 14-month. Precisely such a structure has long been known also for latitude oscillations connected with the motion of the Earth' s pole. On average, from the data of the analysis, the following characteristic of the free motions of the Earth' s pole and of the level oscillations of the Baltic Sea created by these motions was obtained for 1900–1930.

	Period of oscillation τ^a	Phase φ	Amplitude A
Pole (X_{sum})	1.20 yr	109°	0.12″
Level of the Baltic Sea	1.22 yr	168°	39.4 mm

These results confirm earlier studies ([1,5]) and show that the polar tide is associated in the middle latitudes of the Earth with sea-level oscillations that are not only noticeable but also significant.

2. The forced wave of the polar tide, according to its static theory, must rotate around the pole from west to east with a longitudinal displacement speed of 25.71° of longitude per one mean month. The mean longitude of the Baltic Sea ports whose observations were used for the analysis is 20°. It follows from this that the phase shift pole—level is 39° for the Baltic Sea. This means that the maximum of the polar-tide wave passes through the longitudes of the Baltic Sea 1.5 months after the passage through the mean longitude of this sea of the radius-vector of the instantaneous pole of the Earth' s rotation.

3. Amplitudes were obtained for the polar-tide wave that considerably exceed its static value. To characterize this excess, the coefficient μ is used, representing the ratio of the mean observed amplitude of the polar-tide wave to its static value. For the Baltic Sea it was found that $\mu = 7.73$.

From the data of earlier determinations, the following values of the coefficient m have been found:

Polar-tide wave (P_{14}). Results of processing 160 seven-year series of observations of fluctuations in the level of the Atlantic and Pacific oceans, between 20 and 70° N and 20 and 50° S. Determination by I. V. Maksimov. 3.86

Polar-tide wave (P_{14}). Results of processing observations of sea-level fluctuations for the period from 1900 to 1954 north and south of latitude 40°. According to W. Munk' s data ([11]). 3.71

Semiannual solar-tide wave (S_{sa}). Results of processing 2551 annual cycles of observations at various points of the World Ocean north and south of latitude 40°. According to data published by I. V. Maksimov, I. Rossiter, and E. Lisitsina ([12]). 5.88

Wave of the 19-year lunar declinational tide (M_N). Results of processing long-term observations of level fluctuations in 59 ports of the World Ocean. According to data published by I. V. Maksimov, I. Rossiter, and E. Lisitsina ([12]). 3.74

Lunar monthly tide (M_m). Results of processing 327 annual cycles of observations at various points of the World Ocean north and south of latitude 40°. According to I. V. Maksimov' s data. 3.27

The data presented show that the high value of the coefficient μ found for the Baltic Sea is not unexpected and reflects what is characteristic of all long-period waves of the tidal type: the excess of their magnitudes in the real ocean over the magnitudes following from the static theory. The especially high value of this coefficient in the Baltic Sea is apparently connected with the fact that, as was established earlier, the polar-tide wave reaches especially significant magnitudes near 60° north and south latitude, i.e., precisely in latitudes close to the mean latitude of the Baltic Sea.

4. The results of works ([10,1,11]) and of the present study show that the polar-tide wave—a wave generated by free oscillations of the Earth' s axis of rotation—is very characteristically expressed in the World Ocean and is associated not only with perceptible but also with significant fluctuations of its mean level.

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