LUNAR-SOLAR FORTNIGHTLY AND MONTHLY TIDES IN THE SEAS OF THE SOVIET ARCTIC

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Abstract

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LUNAR-SOLAR FORTNIGHTLY AND MONTHLY TIDES IN THE SEAS OF THE SOVIET ARCTIC

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Long-period tides in the World Ocean have as yet been studied comparatively little. Only in recent years has greater attention been paid to the study of this phenomenon. A number of works ([1–5]) have already indicated that fluctuations of mean sea level caused by long-period tides considerably exceed the magnitudes following from the static and dynamic theories of the long-period tide. Taking into account that the amplitudes of the constituent waves of the long-period tide increase with latitude, it becomes clear that the study of this phenomenon in the seas of the Earth' s high latitudes is of special interest.

As is known, the principal group of long-period oscillations of sea level consists of the lunar-solar fortnightly and the lunar monthly tides. In the expansion of the potential of the tide-generating force of the Moon and Sun ([6]), the group of terms with the indicated periodicities consists of 42 harmonic components. The most significant of this group are the lunar fortnightly wave M_f and the lunar monthly wave M_m. For these waves the harmonic constants are also calculated (phase angle K and semiamplitude H).

To characterize the fortnightly and monthly tidal waves, more than 100 annual cycles of level observations, carried out at 22 stations of the Soviet Arctic, were used. The observations were processed by the harmonic method of G. Darwin ([7]). The harmonic constants of the waves M_f and M_m obtained as a result of the analysis are given in Table 1.

The data presented in the table once again indicate that fluctuations of mean sea level in the Arctic caused by the long-period tidal waves under consideration exceed the magnitudes envisaged—

Table 1

Average values of the harmonic constants of the principal waves of the long-period tide at various stations of the Arctic
(K —phase angle of the wave; H —semiamplitude of the wave)

Observation point	Number of annual cycles of observations	M_f: K, deg.	M_f: H, mm	M_m: K, deg.	M_m: H, mm
Tikhaya Bay	3	215	22	183	26
Cape Zhelaniya	3	221	32	214	15
Cape Bolshevik Nos	4	224	31	205	28
Amderma	12	221	35	165	30
Dikson Island	16	257	35	235	36
Pravdy Island	2	247	45	240	36
Cape Chelyuskina	3	263	24	215	26
Solnechnaya Bay	3	216	26	238	26
Domashnii Island	2	214	18	145	5
Malyi Taimyr Island	2	233	34	190	32
Tiksi Bay	14	288	22	239	36
Kotel'nyi Island	3	289	20	268	28
Cape Shalaurova	4	310	44	254	49
Chetyrekhstolbovoi Island	9	336	28	301	45
Ambarchik Bay	5	346	37	230	39
Pevek	2	94	24	68	39
Wrangel Island	8	326	16	273	20
Cape Shmidta	3	358	31	282	37
Cape Vankarem	7	60	38	328	47
Cape Serdtse Kamen'	3	228	25	317	65

Observation point	Number of annual cycles of observations	M_f: K, deg.	M_f: H, mm	M_m: K, deg.	M_m: H, mm	Observation point	Number of annual cycles of observations	M_f: K, deg.	M_f: H, mm	M_m: K, deg.	M_m: H, mm
Cape Kosistyi	1	274	30	252	29	Ratmanova Island	9	329	38	296	42

···determined for these latitudes not only by the dynamic theory, but also by the static theory of the long-period tide.

On average, for the Arctic seas the ratios of the calculated amplitudes of the waves M_f and M_m to their static values proved to be: $\mu_{M_f} = 1.32$, $\mu_{M_m} = 2.80$, $\mu_{\text{av}} = 2.06$.

The obtained values of the coefficient μ agree well with the data of I. V. Maksimov and V. Munk. Thus, I. V. Maksimov ([1]) found the coefficients μ for the latitude interval 70–80° N: $\mu_{M_f} = 1.23$, $\mu_{M_m} = 2.24$, $\mu_{\text{av}} = 1.74$.

V. Munk ([8]), for the wave P_{14} (the polar tide wave), determined $\mu = 2.00$.

Thus, in the seas of the Soviet Arctic the fortnightly and monthly tides can change the mean sea level by 6–8 cm even on days when the phases of the indicated waves do not coincide, while on days of long-period syzygy, i.e., days characterized by coincidence of the phases of these waves, these oscillations may on average reach 12–15 cm.

The values of the phases of the long-period tide waves M_f and M_m, found from the analysis of observations, are in agreement with the static theory, i.e., the maximum height of the level is observed on the days of the greatest negative anomaly of the force. At the same time it should be noted that the fortnightly and monthly tides in the Arctic seas occur with some lag relative to the force exciting them, the magnitude of which increases from west to east.

Let us now consider how the fortnightly and monthly tides are manifested in the individual seas of the Soviet Arctic. For this purpose the mean wave amplitudes and mean values of the phase shift (level–force) were calculated for each sea; they are presented in Table 2.

Table 2

Mean amplitudes and phase shifts of long-period waves in the seas of the Soviet Arctic*

Sea	M_f H_{av}	M_f $(\varphi_y - \varphi_c)$	M_m H^*_{av}	M_m $(\varphi_y - \varphi_c)$
Kara Sea	30	53° (2.1)	25	24° (1.8)
Laptev Sea	26	89° (3.4)	31	54° (4.1)
East Siberian Sea	30	150° (5.7)	38	116° (8.9)
Chukchi Sea	33	231° (8.7)	48	125° (9.6)

* H_{av} is the mean wave amplitude in millimeters; $(\varphi_y - \varphi_c)$ is the mean magnitude of the wave-phase shift relative to the phase of the force, in degrees; in parentheses the magnitude of the phase shift in days is indicated.

It is evident from the table that the greatest amplitudes of the long-period waves M_f and M_m are observed in the Chukchi Sea. This makes it possible to draw a conclusion about the location of the antinode of the fortnightly and monthly tide waves in the Arctic Ocean. Earlier, on the basis of an analysis of the phase values of the astronomical components of ice drift in the Central Polar Basin, I. V. Maksimov showed that this characteristic zone is absent in the circumpolar zone of the ocean, where it should be located according to the static theory, and suggested that the antinode of the long-period tide wave is displaced toward the shores of Alaska, into the region of small depths separating the Arctic and Pacific oceans ([1]). The results of the analysis of level observations in the seas of the Soviet Arctic confirm this supposition.

The considerable magnitudes of the amplitudes relative to their theoretical values and the presence of a phase shift of the long-period waves relative to the act-

···of the acting force definitely indicate that the fortnightly and monthly tides in the Arctic seas are formed as free waves of the same periodicity and, consequently, cannot be computed from the equations of the theory of the long-period tide. This conclusion is confirmed by theoretical calculations made by J. Proudman ([9]), who showed that, at the continental margin of the ocean, the waves M_f and M_m must appear as free, not forced, waves. Therefore, in each particular case one should be guided by the study of observational results on oscillations of the mean sea level. In particular, for the calculation of long-period oscillations of the mean level in the Arctic seas one may use the data given in Table 2. The formula for computing the combined fortnightly and monthly long-period tides has the form

$$H_{M_f} + M_m = H_{M_f} \cos\left[2s - 180^\circ - (\varphi_v - \varphi_c)\right] +$$

$$+H_{M_m}\cos\left[(s-p)-180^\circ-(\varphi_v-\varphi_c)\right].$$

Here H is the mean amplitude of the long-period wave for the given sea; s is the mean longitude of the Moon; p is the longitude of the perigee of the lunar orbit; $(\varphi_v-\varphi_c)$ is the phase shift of the wave relative to the phase of the force, expressed in degrees.

The significance of the long-period tide for the hydrological and ice regime in the seas of the Soviet Arctic remains still unclear.

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CITED LITERATURE

[1] I. V. Maksimov, *Uch. zap. Leningradsk. vyssh. inzh. morsk. uchilishcha im. S. O. Makarova*, issue 13, 3 (1959). [2] I. V. Maksimov, *Problemy Arktiki i Antarktiki*, No. 3 (1960). [3] I. V. Maksimov, *Problemy Arktiki i Antarktiki*, No. 2 (1960). [4] I. V. Maksimov, *DAN*, 118, No. 5, 888 (1958). [5] E. Lisitzin, *J. du Conseil, permanent intern. explorat. mer.*, 22, No. 2 (1957). [6] G. Darwin, *Sci. Papers*, 1 (1907). [7] A. T. Doodson, *Proc. Roy. Soc.*, Ser. A, 100, No. 704 (1921). [8] W. Munk, R. Haubrich, *J. Geophys. Res.*, 64, No. 2 (1959). [9] J. Proudman, *Geophys. J. Astr. Soc.*, 3, No. 2 (1960).

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