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Wind Waves in the Northwestern Black Sea

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Abstract—The study presents the results of long-term monitoring of wind waves was carried out on the offshore fixed gas production platform in the northwestern part of the Black Sea in 1995–2011. The analysis of more than 31000 wave records provided reliable statistical characteristics of wind waves in the analyzed region. It was found that the maximum wave height reached 4.8 m in summer and 8.76 m in winter. The maximum hourly wave height exceeds significant wave height by 1.9 times in the vast majority of cases. The method of annual maxima revealed that in the Karkinit Bay the maximum wave height with the return period of 50 years is equal to 9.2 m.

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As the exploration and production of oil and gas expanded on the northwestern shelf of the Black Sea and navigation increased, reliable information on long-term characteristics of this basin became precious and actively sought.

Long-term instrumental observations of wind wave parameters are absent, so information on the return period of waves of various frequency and on the probability of their generation in the Black Sea has been obtained by calculations [5, 6] and in the recent years, using wave models such as SWAN [4, 9, 13] and WAM [3, 8].

Despite the great number of reference data on the mean characteristics of wind waves in the Black Sea ([1, 3] etc.), there are no publications based on long-term measurements in its northwestern part.

The objective of the present paper is to analyze long-term hydrometeorological monitoring data and to obtain the statistical characteristics of wind waves describing the wave regime in this region in 1995–2011.

Data and processing. In December 1995, the equipment for the hydrometeorological monitoring was installed on Golitsyno-4 offshore fixed gas production platform located on the northwestern shelf of the Black Sea at the point with the coordinates 45 42.5 N, 31 52.5 E (the distance from the shore is about 50 km) [10]. The twisted resistance wave gage with the sampling period of 4 Hz and with the possibility of recording the wave height to 10 m was used to measure wave height [7]. The measurement error did not exceed 1 cm. The registration of sea surface elevation was conducted during 1995–2002 and 2008–2011 (the observation period is 12 years); more than 31000 wave records with the duration of 20–60 minutes were collected. Currently, wind wave measurements on Golitsyno-4 platform are the longest for the Black Sea.

The quality of wave data was controlled, and unreliable fragments were rejected. In the present paper, the significant wave height H_s was determined as four values of standard deviation. The maximum wave height in the wave record H_{max} was found as the largest distance between the trough and the crest. The maximum of a thousand of waves $H_{1/1000}$ often considered as the maximum wave was calculated as $H_{1/1000} = 1.9H_s$.

The estimates (m) of extreme values of wave height of various probability for the northwestern part of the Black Sea

Parameter	Return period, years					
	5	10	20	30	40	50
H_{max}	6.68	7.42	8.18	8.64	8.95	9.2
(H_{max})	4.82–8.55	5.41–9.43	6.06–10.30	6.47–10.81	6.79–11.11	7.05–11.35
H_s	3.59	3.76	3.89	3.95	3.98	4.01
(H_s)	3.29–3.89	3.46–4.06	3.59–4.19	3.65–4.25	3.67–4.28	3.71–4.31

Note: is the 95% confidence interval.

To obtain wave characteristics with a low probability of occurrence (once in 5, 10, 20, 30, 40, 50 years), the analytical distribution function for the extremes of the analyzed parameters was constructed. The distribution function was obtained by the method of annual maxima using the Generalized Extreme Value (GEV) distribution [11]. The 95% confidence intervals were determined according to [12].

Results. The lowest mean values of significant wave height in the northwestern part of the Black Sea were observed in summer and were equal to 0.40–0.48 m. During summer storms the maximum height of significant waves reached 2.4 m, and that of single waves reached 4.8 m. In winter waves intensified: the mean significant wave height in winter was 0.85–1.00 m, that is, by 2–2.5 times greater than in summer. During storms in September to April, the significant wave height was >3 m, and the mean height of maximum waves exceeded 6 m. According to monitoring data, the highest wave was 8.76 m (January 22, 1998).

The comparison of theoretically calculated maximum height $H_{1/1000}$ and the measured maximum wave height H_{max} revealed that the above formula can be used with high accuracy (the correlation coefficient is 0.986, the bias ($H_{max} - H_{1/1000}$) is equal to –0.09 m) to determine the maximum wave height based on the known significant wave height.

Weak waves (0.1 m < H_s < 0.5 m) dominate from May to September, the highest probability (73.6%) is observed in July. In winter, the frequency of occurrence of waves with the height <0.5 m is equal to 20–26%. Slight waves (0.5 m < H_s < 1.25 m) were most frequently (47–57%) registered in October to March; in summer, their probability did not exceed 37%. Moderate waves (1.25 m < H_s < 2.5 m) were rather rarely (to 3%) observed in May to August; the probability of such waves in winter was 27%. The average annual percentage of measured waves with the height of 1.25–2.5 m is 13%. Rough waves (2.5 m < H_s < 4.0 m) were not registered in summer, their probability in winter was about 3%. Storm waves with the significant wave height above 4 m were not recorded in the analyzed region.

The calculated values of significant wave height and maximum wave height with the return periods of 5, 10, 20, 30, 40, and 50 years as well as the limits of 95% confidence intervals are presented in the table. It was found that the significant wave height with the return period of 50 years is 4 m, and the maximum wave height can reach 9.2 m. It should be noted that the obtained estimates are based only on measurement data from the offshore fixed platform in 1995–2002 and 2008–2011, and these data have some gaps. Therefore, higher values of wave height than those provided in the table should be expected for the northwestern Black Sea.

Thus, the hydrometeorological monitoring carried out in 1995–2002 and 2008–2011 on Golitsyno-4 offshore fixed platform in the Karkinit Bay allows the following conclusions:

—the monthly mean significant wave height H_s was equal to 0.4–0.48 m in summer and 0.85–1 m in winter;

—the maximum wave height during storms reached 4.8 m in summer and 8.76 m in winter;

—the highest frequency of occurrence was obtained for weak waves (H_s < 0.5 m) in summer and for slight waves (0.5 m < H_s < 1.25 m) in winter;

—the maximum hourly wave height for the northwestern Black Sea was equal to 1.9H_s in the vast majority of cases;

—the significant wave height with the return period of 10, 30, and 50 years is 3.8, 3.9, and 4 m, respectively, and the maximum wave height with the same return periods can reach 7.4, 8.6, and 9.2 m, respectively.

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REFERENCES

1. *The Atlas of Wind and Waves of the Black Sea* (Gidrometeoizdat, Leningrad, 1969) [in Russian].
2. *Wind and Waves in Oceans and Seas: Reference Data* (Transport, Leningrad, 1974) [in Russian].
3. V. V. Efimov and O. I. Komarovskaya, *The Atlas of Extreme Wind Waves in the Black Sea* (EKOSI-Gidrofizika, Sevastopol, 2009) [in Russian].
4. S. A. Myslenkov and V. S. Arkhipkin, "Analysis of Wind Waves in the Tsemes Bay of the Black Sea Using the SWAN Model," Trudy Gidromettsentra Rossii, No. 350 (2013) [in Russian].
5. A. B. Polonskii, V. V. Fomin, and A. V. Garmashov, "Characteristics of Wind Waves in the Black Sea," Dokl. Akad. Nauk Ukrainy, No. 8 (2011) [in Russian].
6. *Typical Fields of Wind and Waves in the Black Sea*, Ed. by E. N. Al'tman and G. V. Matushevskii (FOL SO GOIN, Sevastopol, 1987) [in Russian].
7. Yu. N. Toloknov, A. I. Korovushkin, and K. G. Kozlov, "Automated Hydrometeorological Complex," in *Environmental Control Systems* (1998) [in Russian].
8. M. V. Shokurov, V. A. Dulov, E. V. Skiba, and V. V. Smolov, "Wind Waves in the Coastal Zone of the Southern Crimea: Assessment of Simulation Quality Based on In Situ Measurements," Okeanologiya, No. 2, **56** (2016) [Oceanology, No. 2, **56** (2016)].
9. A. Akpinar and S. P. Leon, "An Assessment of the Wind Re-analyses in the Modelling of an Extreme Sea State in the Black Sea," Dyn. Atmos. Oceans, **73** (2016).
10. A. V. Garmashov and A. B. Polonskii, "Wind Variability in the Northwestern Part of the Black Sea from the Offshore Fixed Platform Observation Data," Meteorol. Gidrol., No. 12 (2011) [Russ. Meteorol. Hydrol., No. 12, **36** (2011)].
11. V. V. Kharin and F. W. Zwiers, "Changes in the Extremes in an Ensemble of Transient Climate Simulations with a Coupled Atmosphere–Ocean Model," J. Climate, **13** (2000).
12. R. J. Sobey and L. S. Orloff, "Triple Annual Maximum Series in Wave Climate Analyses," Coast. Eng., No. 3, **26** (1995).
13. G. P. van Vledder and A. Akpinar, "Wave Model Predictions in the Black Sea: Sensitivity to Wind Fields," Appl. Ocean Res., **53** (2015).