## 1st Referee

# 1st comment from Referee

If I understand the paper of Chalikov and Bulgakov 2017 correctly than are the eta in the definition of H-tilde (H-tile =  $eta/H_s$ ) on line 35 op p.2 and the wave height h in formula 3 on page 3 the same variable. However in the paper it looks like h is the wave height (crest to through or through to crest) and eta is the height above mean water level and h is the wave height. As the authors state clearly in the introduction on p.2 (lines 12-24), the statistical properties of trough-to-crest wave height are quite different from those of the wave height above mean level. Please clarify and correct where necessary. Authors' response

h- is the wave height above mean level. It was said on lines 25-26 of p.25 of primary text. To clarify it fully, the addition in the text was made:

Authors' change in manuscript

In paper (Chalikov and Bulgakov, 2017) an algorithm for estimation of cumulative probability of waves exceeding a specific value of wave height above mean level (P(h) and h below) was developed using long-term data on Hs.

# 2nd comment from Referee

The authors do not mention the limitations of formula 2 (on page 2). It is not clear to me, if differences in directional distribution, multi-peak spectra (wind-sea and or 1 or more swell components) are taken into account. As far as I can see in a quick scan of the Chalikov and Bulgakov 2017 paper, equation (2) is only valid for a JONSWAP spectrum with a typical directional distribution and a typical peak enhancement factor. The authors should elaborate on this and make this clear in the introduction and/or discussion of the paper. In my opinion, the current analysis is not the ultimate answer to the probability of extreme waves, which does not mean that it does not contribute to the discussion. Therefore it is important to state the limitations of the current analysis.

## Authors' response

Approximation of cumulative probability (formula 2) was made for spectrum, which is similar to JONSWAP spectrum, but somewhat different since JONSWAP spectrum was used as initial condition for 3-D model of potential wave. and spectrum of wave field was changing a little during the numerical experiments. Initial spectrum undergoes the nonlinear transformation: it obtains a discrete nature (Chalikov et al, 2014) and changes the angle distribution. Naturally, it is impossible to take into account a great variety of situations and it is unclear how it can be done. However it is widely accepted that JONSWAP spectrum reflects the main features of wind wave field.

It is quite likely that for realistic statistics of extreme wave the wave field should contain sufficiently large number of modes, propagating in relatively narrow range of angles. It is unlikely that swell (if it is not too high) can influence the wave statistics. However, this problem deserves further investigation many models

Authors' change in manuscript

Abstract. A method of calculation of wind wave height probability based on the significant wave height probability is described.

Chalikov and Bulgakov (2017) suggested the algorithm for estimation of cumulative probability of waves exceeding a specific value h (P(h) below) using climate data on significant wave height  $H_s$ . The

algorithm was based on results of 3-D model of potential waves. The model used spectral definitions of fields, finite differences for vertical derivatives calculation, fourth-order Runge–Kutta scheme for time integration. Fourier resolution is 256X64 wave number, resolution in physical space is 1024\*256 (more detail in (Chalikov et al., 2014)). (more detail in (Chalikov et al., 2014)). The calculations were

done for 350 units of nondimensional time, i.e., for 70,000 time steps. The initial conditions were generated on basic JONSWAP spectrum. Totally 50 experiments were made (more detail in (Chalikov and Bulgakov, 2017)).

Currently, this approximation is considered as universal for wind waves fields where cases of freak waves are most likely. Waves of other types of spectrum (swells) have a small steepness and don't influence on extreme wave generation.

2nd Referee

General comments

1st comment from referee

Is this the only work that estimates the probability of extreme waves? If not, it might be worth mentioning the others and comparing with the proposed methodology.

## Authors' change in manuscript

The theoretical probability distribution for wave height was suggested by Weibull (1951). Later it was studied on a basis of observational data on nature and wave channels (see review by Kharif et al, 2009). Extended data for estimation of probability of wave height can be obtained with integration of nonlinear modes based on full potential equations (Touboul and Kharif, 2010; Chalikov et al, 2009). Methods of probability calculations were considered in many papers (see, for example Bitner-Gregersen and Toffoli, 2012; Toffoli et al 2010; Mori and Janssen, 2005; Dyachenko at all, 2016). The most popular method of trough-to-crest wave height detection is based on zero-crossing technique. Direct method is based on use of moving windows, which is applicable both for 1-D and 2-D cases.

2 nd comment from referee

In the introduction, the authors mention the definition of "freak" waves, is their work discussion paper somehow helping to improve the state-of-the-art definitions?

Authors' response

Improved definition of freak wave and discussion of this topic can be found in paper (Chalikov, 2009) where the moving window was suggested for detection of trough-to-crest wave height. Considering practical application of the theory of rare waves, it can be concluded that a strict unconditional 'definition' of freak waves is not required at all. Instead, it makes sense to introduce the categories of dimensional freak waves, like it had been done, for example, for classifications of hurricanes. For example, the  $n^{th}$  category of freak wave can be defined the wave with trough-to-crest height equals to 3n.

3th comment from referee

In the introduction, there is a section about the differentiation between "through-to-crest wave height" and "wave height above mean level", this terminology is then lost in the methodology.

Authors' response

h- is the wave height above mean level. It was said on lines 25-26 of p.25 of primary text. To clarify it fully, the addition in the text was made:

Authors' change in manuscript

In paper (Chalikov and Bulgakov, 2017) an algorithm for estimation of cumulative probability of waves exceeding a specific value of wave height above mean level (P(h) and h below) was developed using long-term data on Hs.

4th comment from referee

The methodology is presented as universal, how the authors can prove that? More information is needed better explaining eq. (2) and (3) and the data used.

Authors' response

The method is not presented as 'universal', approximation (2) is presented as universal for wind waves. It is presented as method developed on extraordinary large volume of data. More information about equation (2-3) and data used is below in answer on specific comments

5th comment from referee

The results are given in terms of  $10^{-7}$  probability, why specifically  $10^{-7}$ ?

Authors' response

The paper basically describes the method of calculation itself and the examples are given for probability  $10^{-7}$ .

6th comment from referee

Can the cumulative probability be given in terms of return period?

Yes, it can. But it's quite sophisticated problem. To make it, data of wave peak period is needed to use. Authors are planning to devote separate article to it.

Specific comments

1 st comment from referee

Page 1

Lines 37-39: This sounds contradictory. It looks like this work does estimate real wave heights

probability from Hs, while in this sentence authors say that "there are not enough data on Hs to evaluate the probability of real wave heights". Probably, it needs to be rephrased.

Authors' change in manuscript

Hs data are not enough to evaluate the probability of real wave heights

2 nd comment from referee

Page 2

Line 32 - It will make the paper more readable briefly explaining here what the 3-D model of potential waves is.

Authors' change in manuscript

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The algorithm was based on results of 3-D model of potential waves. The model used spectral definitions of fields, finite differences for vertical derivatives calculation, fourth-order Runge–Kutta scheme for time integration. Fourier resolution is 256X64 wave numbers in x and y directions, resolution in physical space is 1024X256 (more detail in (Chalikov et al., 2014)).

3 th comment from referee

Line 34 - It is not clear what " $H_s$  was calculated" means, is not  $H_s$  already provided by the numerical model?

Authors' response

 $H_s$  characterizes energy of waves in experiments considered  $H_s$  was fixed

Authors' change in manuscript

Each wave field of surface height above mean level ( $\eta$ ) reproduced by numerical model was normalized by the value of significant wave height corresponding to this field.

4 th comment from referee

Line 35 - It is missing the definition of  $\eta$ . Eq (2): Is this function always valid?

Authors' response

 $\eta$  is height of free surface above mean level. This function is valid for the wind waves. Definition of eta was added, see answer on comment above

Authors' change in manuscript

Currently, this approximation is considered as universal for wind wave fields where cases of freak

waves are most likely.

5 th comment from referee

Line 46 - The authors should explain better what it is the "precise 3-D model based on non linear equations".

Authors' response

Description of the 3D model was given in the text (see answer on 2th comment).

6 th comment from referee

Line 47 - The authors should specify 3 million values of what,  $H_s$ ? Spanning different years? Different locations?

Authors' response

There was a mistake.

Authors' change in manuscript

The volume of data used for approximation (2) includes more than 4.5 billion values of  $\eta$ .(number point in single field multiply number of record in experiment multiply number of experiments).

7 th comment from referee

Page 3

Line 1 - The author should better specify the data they were using (as well as limitations of Eq (2)), it could help to understand why this approximation is universal.

Authors' response

Data is fields of eta, which was calculate by 3D potential wave model. Initial condition was JONNSWAP spectrum. m It's generally believed that this spectrum describes field of wind waves. We can consider that eq 2 is universal for cases of wind waves. Limitation of eq (2) is maximal value H tilda in data (1.85).

Authors' changes in manuscript

The calculations were done for 350 units of nondimensional time, i.e., for 70,000 time steps. The initial conditions were generated on basic JONSWAP spectrum. Totally 50 experiments were made (more detail in (Chalikov and Bulgakov, 2017)).

The probability of wave higher than 1.85 (it's maximal value of  $\tilde{H}$  in data) can be considered as extremely low and therefore - neglected.

Currently, this approximation is considered as universal for wind waves fields where cases of freak waves are most likely. Waves of other types of spectrum (swells) have a small steepness and don't influence on extreme wave generation.

8 th comment from referee

Eq (3) - The authors should specify better from where this equation come from. It is a crucial part in this work.

Authors' change in manuscript

Probability of wave over specific *h* on condition specific  $H_s$  equals  $\tilde{P}(\tilde{H})$  for specific  $h/H_s$  multiplied by probability of  $H_s$  ( $\tilde{P}(\tilde{H}) \cdot P(H_s)$ ), it's standard definition of conditional probability. Consequently, P(h) can be determined as integral of  $\tilde{P}(\tilde{H}) \cdot P(H_s)$ : over all possible value of  $H_s$ :

9 th comment from referee

Line 7 - What is the initial data?

Authors' response

It was a mistake.

Authors' change in manuscript

 $P(H_s)$  is distribution of cumulative probability  $H_s$  for a specific point, while  $H_{smax}$  is the maximum value of  $H_s$  in the dataset for a specific point.

10 th comment from referee

Line 8 - More details about the WAVEWATCH III model should be added. Which wind forcing was used? What was the performance? How long is the model run? Even if it is in the referenced paper, a couple of words here would improve readability

Authors' change in manuscript

The data (Chawla et al., 2013) used were calculated with the latest version of WAVEWATCH III model (Tolman 2014) and GFS-2 wind analysis (Sasha at al., 2014). The hindcasts cover the period from August 1999 to July 2015. The spatial resolution of the dataset fields is  $0.5 \times 0.5$  degree.

11 th comment from referee

Line 10 - "Method 1-3". Author should not include Eq. (1) in their method that is the standard equation to calculate Hs from the wave spectrum.

Authors' change in manuscript

The method 2-3 can be also used for estimation of height of extreme waves of any given cumulative probability.

## 12 th comment from referee

Line 24/25 - Are the authors giving the probability of extreme waves in terms of expectance time? If not, why are they mentioning it here? Maybe it is worth plotting and commenting this information.

Authors' response

These lines were deleted. It will be subject of the next work.

13 th comment from referee

Page 4

Fig. 2 - If the significant wave height is the starting point of this method, the authors should show first Hs and then the results of their method (just to follow a more logical order).

Authors' response

From the authors point of view it's more convenient to show the results of methods firstly and then to compare it with data which was used.

14 th comment from referee Page 7 Line 8: "outside approximation area of (2)". Could the authors elaborate a bit more on this?

Authors' response

There was a mistake in value. The change was made.

Authors' change in manuscript

It is not expedient to use the values less than  $10^{-9}$  as this value is outside the approximation area (2) ( $\tilde{P}(1.85)$  is approximately  $10^{-9}$ ).

15 th comment from referee

Line 9/10 - "may have a certain practical importance". Could the authors explain why it has a practical importance?

Authors' response

Result of probability 10<sup>-7</sup> is just an example of calculations. From practical point of view was developing of methods of any probability

16 th comment from referee

Line 15 - statistical data? Is it not a long-term wave hindcast data (wave model data)?

Authors' response

It's a long-term wave hindcast data.

Authors' change in manuscript

The paper describes a method of calculation of extreme wave probability, based on long-term wave hindcast data on significant wave height

# Evaluation of extreme wave probability on the basis of long-term data analysis.

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Abstract. A method of calculation of wind wave height probability based on the significant wave height probability is described. An application of the method on the basis of long-term data analysis is presented. Examples of averaged annual and seasonal fields of extreme wave heights obtained by the above method are given.

#### 1. Introduction

Highest risks of economic and environmental damage for the sea-based human activities, i.e., cargo shipments, fishery, oil production etc., are mostly connected with extreme weather conditions on sea surface among which strong storms are the foremost. It is especially difficult to 20 predict emergency situations caused by extreme waves for those cases of the sea-based activities which require people's long stay at sea or prolonged use of the equipment in the ocean.

One of the methods to minimize such possible risks is use of climatic data based on longterm series of observations. At present there are archives consisting of the reanalysis data on surface waves based on wave forecast corrected by different methods, i.e., direct measurements 25 using accelerometers and GPS-buoys; remote measurements by satellite-borne altimetry and various types of radars. The main characteristic of wave field included in the archive is significant wave height  $H_s$  defined as a mean value (trough to crest) of one third of the highest of all the waves (Ochi 2005). The value of  $H_s$  is calculated in the following way:

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$$H_{s} = 4 \left( \int_{0}^{\infty} \int_{0}^{\infty} S(k_{x}, k_{y}) dk_{x} dk_{y} \right)^{1/2}, \tag{1}$$

where  $k_x$ ,  $k_y$  are wave numbers, while  $S(k_x, k_y)$  is wave spectrum.

It is evident that significant wave height does not provide any information on real wave height for a given wave field. Extreme waves of the same height can appear with different probability 35 for different values of  $H_s$ . For example, a wave 10 meters high can appear both in a wave field with  $H_s=10$  m and in a wave field with  $H_s=5$  M. Thus,  $H_s$  data are not enough to evaluate the probability of real wave heights.

Up to the present some vagueness of definition of extreme ('freak') wave has existed.

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The standard definition suggests that any wave exceeding two significant wave heights  $H_s$  can be 40 considered as "freak" wave (Chalikov 2016). Firstly, such definition is not universal, since it does not define real dimensional wave height. This definition makes sense for theoretical investigations only, as the adiabatic equations of wave dynamics are self-similar, i.e., when transformed to the nondimensional form, they do not contain any nondimensional parameters, which makes the whole approach quite convenient due to its universal character. The nonadiabatic factors (for example, input energy) violate self-similarity; anyway, since the time scale of wave energy transformation is by many orders of magnitude larger than the wave periods, a nondimensional approach in theoretical investigations is still acceptable. However, practical conclusions of the theoretical investigation should be formulated in a dimensional form.

Secondly, the value  $2H_s$  is large, which means that the definition refers to the full height of wave, i.e., trough-to-crest height. This definition is straightforward for linear monochromatic waves only when the trough-to crest height is simply equal to the doubled wave height above mean level. For a complicated multi-mode wave field the trough-to crest height should be defined as a vertical distance between crest and the closest wave trough. The question is what the term 'closest' means. The only way recommended in (Chalikov, 2009) (see also (Chalikov, 2016)) is based on the consideration of moving window with horizontal size  $L_w$ . Since extreme wave actually occurs at peak frequency, it is reasonable to assume  $L_w=1.5L_p$  (where  $L_p$  is the wavelength in peak of spectrum). Coefficient 1.5 is introduced to take into account the variability of length of 'wave' (which in fact is a transient local superposition of several modes).

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The nature of freak waves was investigated analytically (Onorato et al., 2009) and numerically (Chalikov, 2009). Recently it was found that the statistical properties of trough-tocrest wave height are quite different from those of the wave height above mean level. Paper (Chalikov and Babanin, 2016; Chalikov, 2017) shows that linear and nonlinear statistics of extreme waves (defined as trough-to-crest waves) are identical not only for broad spectrum but for one-dimensional wave field too. It means that generation of a trough-to-crest extreme wave is the result of simple superposition of linear modes, no matter how broad the spectrum is. This property is not found for the wave height above mean level. Thus, the statistical properties of trough-to-crest wave height can be investigated with no nonlinear modeling, but just by generation of large ensembles of superposition of linear modes with random phases and the spectrum prescribed. It is obvious that the problem of the trough-to-crest statistics becomes quite straightforward. Contrary to such approach, investigation of the statistics of wave height above mean level remains a subject of nonlinear wave theory.

The theoretical probability distribution for wave height was suggested by Weibull (1951).
Later it was studied on a basis of observational data in nature and wave channels (see review by Kharif et al., 2009). Extended data for estimation of probability of wave height can be obtained with integration of nonlinear modes based on full potential equations (Touboul and Kharif, 2010; Chalikov et al, 2009). Methods of probability calculations were considered in many papers (see, for example Bitner-Gregersen and Toffoli, 2012; Mori and Janssen, 2005; Dyachenko at all,

30 2016). The most popular method of trough-to-crest wave height detection is based on zerocrossing technique. Direct method is based on use of moving windows, which is applicable both for 1-D and 2-D cases.

This paper is devoted to investigation of the statistics and geographical distribution of wave height above mean sea level.

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### 2. Description of the method

In paper (Chalikov and Bulgakov, 2017) an algorithm for estimation of cumulative probability of waves exceeding a specific value of wave height above mean level (P(h) and h 40 below) was developed using long-term data on  $H_s$ .

The algorithm was based on results of 3-D model of potential waves. The model used spectral definitions of fields, finite differences for vertical derivatives calculation, fourth-order Runge–Kutta scheme for time integration. Fourier resolution is 256X64 wave number, resolution in physical space is 1024\*256 (more detail in (Chalikov et al., 2014)). The calculations were done for 350 units of nondimensional time, i.e., for 70,000 time steps. The initial conditions were

done for 350 units of nondimensional time, i.e., for 70,000 time steps. The initial conditions were generated on basic JONSWAP spectrum. Totally 50 experiments were made (more detail in (Chalikov and Bulgakov, 2017)). The results of the series of experiments were processed in the following way: Each wave field of surface height above mean level ( $\eta$ ) reproduced by numerical

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model was normalized by the value of significant wave height corresponding to this field. ( $\tilde{H} = \eta/H_s$ ). Then, a nondimensional wave field was used for calculation of cumulative probability of nondimensional wave height  $\tilde{P}(\tilde{H})$ . The distribution obtained was approximated by the following function:

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$$\tilde{P}(\tilde{H}) = \exp\left(-3.97\tilde{H} - 4.02\tilde{H}^2\right)$$
<sup>(2)</sup>

Note, that  $\tilde{P}(\tilde{H})$  is cumulative probability of the height of free surface above mean level. This probability for  $\tilde{H} = 1$  (the height of free surface equals significant wave height) is quite small (0.0003).

Also note, that  $\eta$  is variable of 3-D model of potential waves. It should be distinguished from *h* despites the fact that both ( $\eta$  and *h*) have the same physical sense.

The above expression can be used for the interval  $0 \le \tilde{H} \le 1.85$ . The probability of wave higher than 1.85 (it's maximal value of  $\tilde{H}$  in data) can be considered as extremely low and therefore neglected. It should be noted that approximation (2) was obtained with use of the precise 3-D model based on full nonlinear equations. The volume of data used for approximation (2) includes more than 4.5 billion values of  $\eta$  (number point in single field multiplied by number of record in experiment multiplied by number of experiments). Currently, this approximation is considered as universal for wind wave fields where cases of freak waves are most likely. Waves of other types of spectrum (swells) have a small steepness and don't influence on extreme wave generation.

The probability of wave exceeding specific height h, if significant wave height is in a small range  $dH_s$  around  $H_s$ , equals  $\tilde{P}(\tilde{H})$  for specific  $h/H_s$  multiplied by probability of  $H_s$  in this range  $(\tilde{P}(\tilde{H}) \cdot P(H_s))$ , by the standard definition of conditional probability. Consequently, P(h) can be determined as integral of  $\tilde{P}(\tilde{H}) \cdot P(H_s)$ : over all possible value of  $H_s$ :

 $P(h) = \int_0^{H_{smax}} \tilde{P}\left(\frac{h}{H_s}\right) P(H_s) dH_s, \qquad (3)$ 

where  $P(H_s)$  is probability distribution of  $H_s$  for a specific point, while  $H_{smax}$  is the maximum value of  $H_s$  in the dataset for a specific point.

The data (Chawla et al., 2013) used were calculated with the latest version of WAVEWATCH
III model (Tolman 2014) and GFS-2 wind analysis 2 (Sasha et al. 2014). The hindcasts cover the period from August 1999 to July 2015. The spatial resolution of the dataset fields is 0.5 × 0.5 degree. Calibration of the model and its validation are carried out using a great number of wave buoys.

The examples of the calculations using the method (2-3) are given in (Chalikov and Bulgakov, 2017) where space distribution of the extreme wave probability was investigated. The method 2-3 can be also used for estimation of height of extreme waves of any given cumulative probability.

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#### 3. Results



Fig.1 — Wave heights (m) with cumulative probability  $10^{-7}$ , annual average

Figure 1 shows an average annual field of wave heights with cumulative probability 10<sup>-7</sup>. It can be seen that waves with the height up to 20 m can appear with such probability, some of the extreme waves (16 m and more) being found in the areas of active navigation (eastern part of the Atlantic Ocean, East China Sea, Philippine Sea, Yellow Sea, south-western part of the Pacific Ocean).



Distribution of mean annual significant wave height calculated by data (Chawla et al., 2013) is shown in Fig. 2. As seen, the maximum value of significant wave height does not exceed 5 m, while the height of real extreme wave can reach 20 m. The data in Fig 1 have a more complicated structure, due, for example, to the periods with strong wind along trajectories of

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tropical storms. Consequently, the calculations of distribution of real wave height should be done for shorter periods, i.e., for seasonal or monthly averaged data on significant wave heights.





Figure 3. – Wave height (m) with cumulative probability  $10^{-7}$  for December-February.

In Fig. 3 the field of wave height with probability 10<sup>-7</sup> calculated by the data (Chawla et al., 2013)], averaged for December-February, is shown. When comparing Figs 3 and 1 it is seen that in mid-latitudes of the Northern Hemisphere wave heights become higher. In some areas appearance of extreme wave heights exceeding 16 m is possible. At the same time there are actually no extreme waves in the eastern part of the Arctic Ocean, which is connected with seasonal ice formation in the area. In equatorial and tropical areas of the World Ocean wave heights are less in winter (Northern Hemisphere), as compared with the average annual wave heights. It should be noted that in the western part of the Atlantic Ocean tracking trajectories of hurricanes disappeared while the number of such trajectories increased in the Indian Ocean.

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Figure 4. – Wave height (m) with cumulative probability  $10^{-7}$  averaged for March-May.

An increase of wave heights over March-May can be registered (Fig.4) in the Southern Hemisphere. Actually all the area of mid-latitudes from the latitude of 40 degrees S. to the latitude of 60 degrees S. is characterized by probability  $>10^{-7}$  of wave heights over 14 m. In mid-latitudes of the Northern Hemisphere in spring wave height values are more than the average annual values, though less than the winter values, while in some areas (Atlantic Ocean near Iceland, Pacific Ocean near Bering Sea) appearance of waves exceeding 14 m in height is quite possible.





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Fig.5 – Wave heights (m) with the cumulative probability of 10<sup>-7</sup>, for June-August

Summer months (Fig.5) are characterized by general decrease of extreme wave probability. It is especially noticeable in the northern areas of the Atlantic and Pacific Oceans.

Also, wave heights slightly decreased in the Southern Hemisphere. It should be noted that storm tracks appear off the eastern coast of North America and disappear in the southern part of the Pacific Ocean. Besides, quite distinct trajectories of storms appeared in the eastern part of the Pacific Ocean. Small wave heights can be observed in the Arctic Ocean, in the area free from ice.

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Figure 6. – Wave heights (m) with cumulative probability 10<sup>-7</sup>, averaged for September - November

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During autumn months (Fig. 6) an increase of wave heights is observed in the Arctic Ocean, the extreme wave height values sometimes reaching 20 m. Among other peculiarities is an increase of wave-free area in polar latitudes of the Southern Hemisphere, which is obviously connected with seasonal ice formation.

It is quite evident that the average monthly fields of cumulative wave-height probability will allow us to obtain more exact information on the areas of extreme wave probability.

The above approach can be used with different values of cumulative probability. It is not expedient to use the values less than  $10^{-9}$  as this value is outside the range of validity for equation (2) ( $\tilde{P}(1.85)$ ) is approximately  $10^{-9}$ ). Mapping of wave heights with the cumulative probability exceeding  $10^{-7}$  may have a certain practical importance (ensuring of safety cargo shipments for instance). Hence, on the whole, the method considered is suitable for estimation of extreme values of wave heights with minor probability.

### 4. Conclusions

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The paper describes a method of calculation of extreme wave probability, based on long-term wave hindcast data on significant wave height. Such method can be used for estimation of probability of extreme waves, which is important for designing of engineering constructions, as well as for other purposes. The maps of global distribution of wave heights of certain probability for main seasons illustrate the method.

Authors are thankful to Professor D. Chalikov for his useful consultations.

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References

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