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
t
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 (η) 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 η. Eq (2): Is this function always valid?

Authors’ response

η 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 η.(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 $\widetilde{H}$ 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 $\tilde{P}(\widetilde{H})$ for specific h/H_s multiplied by probability of H_s ($\tilde{P}(\widetilde{H}) \cdot P(H_s)$), it's standard definition of conditional probability. Consequently, $P(h)$ can be determined as integral of $\tilde{P}(\widetilde{H}) \cdot P(H_s)$: 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 × 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^{-7} 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