Interactive comment on “Evaluation of extreme wave probability on the basis of long-term data analysis” by Kirill Bulgakov et al.

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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.

2nd 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 category of freak wave can be defined the wave with trough-to-crest height equals to .

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 prob-
ability of waves exceeding a specific value of wave height above mean level \( P(h) \) and
\( h \) below was developed using long-term data on \( H_s \).

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
1st comment from referee
Page 1 Lines 37-39: This sounds contradictory. It looks like this work does estimate
real wave heights probability from \( H_s \), while in this sentence authors say that “there are
not enough data on \( H_s \) to evaluate the probability of real wave heights”. Probably, it
needs to be rephrased.

Authors’ change in manuscript
\( H_s \) data are not enough to evaluate the probability of real wave heights

2nd 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
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)).

3rd 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.

4th 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.
5th 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 ).
6th comment from referee
Line 47 - The authors should specify 3 million values of what, Hs? 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).
7th 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. 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 H tilda 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.
8th 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 Hs equals Ptilda for specific h/Hs multiplied by probability of Hs (Ptilda(h/Hs)*P(Hs)) it’s standard definition of conditional probability. Consequently, P(h) can be determined as integral of Ptilda(h/Hs)*P(Hs) over all possible value of Hs
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
Dche 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 expectancy 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) (Ptilad (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

16th 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