NHESS_2018_238 'The occurrence of rogue waves in the interior of the oceans: A modelling and computational study'
by K. W. Chow, H. N. Chan, and R. H. J. Grimshaw
Date: November 12, 2018

Reply to Referee 2:

We thank the Referee for the constructive comments, and also for the assertion that the present work can be potentially an important contribution to ocean science. Before we submit a revised manuscript, we provide a few concise points in response:

(1) '*… occurrence of rogue waves, which makes me think that formation of internal rogue waves is discussed within a proper statistical framework…*'

Response: There are several review articles on rogue waves where various approaches of investigations are presented including deterministic and stochastic models. An example is 'Oceanic rogue waves' by K. Dysthe, H. E. Krogstad, P. Muller, *Annual Reviews of Fluid Mechanics* **40**, 287 (2008). From the various mechanisms discussed, the words 'nonlinear focusing' and 'modulational instability' are more appropriate for our paper. Hence we suggest a possible change to a new title 'Nonlinear focusing as a possible generation mechanism for rogue waves in the interior of the oceans: A modelling and computational study'.

(2) '*…There is an extensive literature discussing generation of internal rogue waves, but this is not discussed in details in the present manuscript. I am thinking, for example, to Grimshaw, R., Pelinovsky, E., Stepanyants, Y. and Talipova, T., 2006. Modelling internal solitary waves on the Australian North West Shelf. Marine and Freshwater Research, 57(3), pp.265-272; and Chapter 25 of Osborne, A.R., 2002. Nonlinear Ocean Wave and the Inverse Scattering Transform. In Scattering (pp. 637-666), and reference therein. To justify a rapid communication, more effort should be put to highlight the original contribution of the present manuscript…*'

Response: There is indeed an extensive literature on large amplitude oceanic internal waves. In particular, the two references quoted and many other related works are mainly on the topic of 'internal solitary waves'. These are spatially localized pulses propagating permanently, but they are not localized in time. We consider simple analytical description of a wave pulse localized in ***both*** space and time. In widely used phrase in this field, rogue waves are 'waves that appear from nowhere and disappear without a trace'. We shall emphasize on this point in the revised manuscript.

(3) '*…The authors mention that "classical" modulation instability would cease at kh<1.36. However, there is evidence that instability can survive for shallower relative depth if the wave field is sufficiently directional (Toffoli, A., Fernandez, L., Monbaliu, J., Benoit, M., Gagnaire-Renou, E., Lefevre, J.M., Cavaleri, L., Proment, D., Pakozdi, C., Stansberg, C.T., Waseda, T., Onorato, M., 2013. Experimental evidence of the modulation of a plane wave to oblique perturbations and generation of rogue waves in finite water depth. Phys. Fluids, 25, 09170). Also, effects of current have been discussed in detail in Onorato M., Proment D., Toffoli A., 2011. Triggering rogue waves in opposing currents. Phys. Rev. Lett.,107, 184502, doi: 10.1103/PhysRevLett.107.184502; and Toffoli, A., Waseda, T., Houtani, H., Kinoshita, T., Collins, K., Proment, D., Onorato, M., 2013. Excitation of rogue waves in a variable medium: An experimental study on the interaction of water waves and currents. Phys. Rev. E, 87, 051201(R), before Liao et al 2017…*'

Response: Thank you for these references, where the well-known constraint of $kh > 1.363$ was extended to lower numerical values. However, it is not clear (at least to us) how far can these numerical values go. In contrast,

► we are studying internal waves as opposed to surface waves, and

► our proposed constraint is very well defined, i.e. $kh < 0.766n\pi$. The limit of k or h tending is zero is explicitly included.

(4) '*…The theoretical framework, especially the NLS equation, seems to be already published. Nevertheless, the title mentions modelling study. What is the novel model the authors are proposing?…*'

Response: The word 'modelling' is used here as opposed to numerical simulations or field data comparison. When the paper by Liu and Benney (*Studies in Applied Mathematics* 1981) was published, the focus then was internal solitary wave. Our proposed contributions are:

(a) This formulation applied to the setting of internal rogue waves will provide a nonlinear focusing mechanism in the long internal waves (shallow water) regime, as opposed to the usual deep water scenario for surface waves.

(b) Numerical simulations from random and specially prescribed initial conditions, a practice frequently implemented only in the past ten years, is pertinent for internal wave investigations.

(5) '…Section 3, *Computational Simulations, is may major concern. It should be the core of the manuscript and yet it is reduced to 7 lines. This section does not convene a message at all and needs to be re-written and expanded…*'

Response: Please see point (6) below for a full explanation.

(6) We provide a response to each query individually. As an overview, the primary intention of this 'brief communication' is to demonstrate that unexpectedly large displacements (rogue waves) may occur in internal waves too. Indeed they can occur in the shallow water regime, in sharp contrast to the surface wave scenarios. Numerical presentations were condensed due to the 4-page limit, but we can expand this part if necessary, subject to editorial advice.

'…*What simulations did the author carried out?...*'
Response: We conduct simulations with random as well as specially selected initial conditions to determine how rogue-wave-like structures can emerge.

'…*What are the initial conditions? Are regular or irregular waves considered?...*'
Response: Specially selected conditions mean choosing a modulation instability mode with the optimized growth rate. Random conditions are generated by the computer.

'…*What are the values of key parameters? etc…*'
Response: For surface rogue waves described by the nonlinear Schrödinger equation, the key parameters are k, the wave number of the carrier wave envelope and h, the water depth. For the present wave packet dynamics in a stratified flow model, two additional parameters are N_0, the constant buoyancy frequency of the background stratification and n, the mode number of the internal wave.

'…*It also seems that no sensitivity analysis has been done and only one specific "lucky"case is discussed…*'
Response: Standard quality control processes were routinely performed for similar simulations in our papers in the past. Our present results, analogous to those of other research groups (e.g. Baronio et al, *Physical Review A* 2015), are that rogue-wave-like structures will emerge, and this is not a 'lucky' result. The goal of this portion of the paper is to convince the audience that such dynamics also holds true for internal wave scenarios too. We would be pleased to revise our paper to provide more detailed discussions.

'…*What is the effect of wave steepness? What is the threshold of relative water depth below which internal rogue waves do not occur? what is the effect of density gradient?...*'
Response: The wave steepness must scale with the small parameter describing the long modulation scale as given in any standard derivation of the nonlinear

Schrödinger equation (e.g. the paper by Liu and Benney, *Studies in Applied Mathematics*, 1981). The threshold of relative water depth for ***internal rogue waves to occur*** is $kh < 0.766n\pi$, four lines below Equation (7) of the text (strong contrast with $kh > 1.363$ of surface waves – this constitutes the theme of the paper). This new constraint means that internal rogue waves can thus occur for small h (or shallow water regime). The density gradient, or more precisely, the buoyancy frequency parameter N_0, will affect the horizontal length scale of the rogue wave and a precise description will constitute one of the long term objectives of this study.

'…*None of these points are discussed, leaving the reader completely unaware of the number computations. In addition, I am not sure to understand Figure 1. Or better, I can guess what it is and its meaning, but the authors did not put any effort to describe it*…'
Response: Again we wish to emphasize that we are constrained by the 4-page limit of a 'brief communication'. To address a relatively broad audience, we have described the dynamics of the nonlinear Schrödinger equation in the first half of the paper. If space permits, we can elucidate the numerical details in a revised paper if necessary.

(7) '…*Throughout the paper and in the title, it is mentioned that likelihood of occurrence of rogue waves is assessed. However, I do not see any discussion of a proper statistical framework that can justify new results on the probability of occurrence of internal rogue waves*…'

Response: As discussed earlier, it is beyond the scope of this paper to carry out a statistical assessment. To avoid confusion, we shall adopt the words 'nonlinear focusing mechanism' or similar terminology in the revised paper.

(8) Final paragraph:
'…*section 3 has to be significantly redeveloped and more details provided to support results*…'

Response: Again the motivation of writing this 'brief communication' is to show this rather unexpected parameter regime for nonlinear focusing for internal rogue waves. Due to the 4-page limit on a 'brief communication', we have of necessity condensed the numerical treatment. We can revise and expand the simulation portions, subject to editorial approval.

'…*If this is done properly, this manuscript has the potential to become a significant contribution to ocean science*…'

Response: Thank you for providing a very positive opinion on our work.