REQUEST FOR A SPECIAL PROJECT 2019–2021

MEMBER STATE: UK…………………………………………………………………..…

Principal Investigator[1]**:** Prof V.I.Shrira………………………………………………………

Affiliation: Keele University…………………………………………………….……

Address: School of Computing and Mathematics, Keele ST5 5BG UK.…

…………………………………………………………………….……

…………………………………………………………………….……

Other researchers: Dr Sergei Annenkov……………………………………………..……

…………………………………………………………………….……

Project Title: **Direct numerical simulation of long-term evolution of wind waves: dynamics vs kinetics, with applications to freak waves prediction** ……………………………………………………….……

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SPGBSHRI**	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2019	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2019-2021: (To make changes to an existing project please submit an amended version of the original form.)		**2019**	**2020**	**2021**
High Performance Computing Facility	(SBU)	500	500	500
Accumulated data storage (total archive volume)[2]	(GB)	100	100	100

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.

[2] If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.

Principal Investigator: **Prof V.I. Shrira** ....

Project Title: **Direct numerical simulation of long-term evolution of wind waves: dynamics vs kinetics, with applications to freak waves prediction** ....

Extended abstract

Currently, all wave modelling is based on the Hasselmann equation, which describes energy exchange between wave motions of different scales and directions, energy input from wind and dissipation through wave breaking and other mechanisms. The part concerned with the redistribution of energy between spectral components, aka nonlinear interaction term, was considered to be established since it had been derived from first principles under very plausible assumptions used in other branches of physics, while the input and dissipation remained an issue of debates. In operational wave forecasting practice, in order to achieve agreement with observations the input and dissipation terms are tuned assuming the nonlinear interaction term to be correct. There was no possibility to verify to what extent this assumption is good. There were no alternatives to the Hasselmann equation or its generalisations/computational simplifications.

Until now direct numerical simulation (DNS) was possible only for short-term evolution of water wave spectra (about $O(10^2)$ characteristic wave periods). The DNS algorithm for random waves based on the Zakharov equation (Annenkov & Shrira 2013, 2018) has radically changed the situation. This algorithm does not invoke any statistical hypotheses, the statistical description being obtained by averaging over an ensemble of realisations. At present, this is the only DNS algorithm for simulating the evolution of random water wave fields (with or without wind forcing) that allows long-term simulations (up to tens of thousands characteristic wave periods).

Annenkov & Shrira (2018) demonstrated that for idealised situations with no wind and no wave breaking the Hasselmann equation does capture well the evolution of the bulk characteristics of a wave field (total energy, wave steepness, position of the spectral peak), but fails quite dramatically in other respects. In particular, it fails to capture the shape of the resulting spectra, the DNS spectra being considerably broader. Another major discrepancy was in the rate of angular broadening of spectra with initially narrow directional distribution, which is considerably overestimated by the Hasselmann equation.

Our preliminary DNS simulations of a "real" wind wave evolution over several hundred kilometres, compared with observations by Romero & Melville (2010) in the Gulf of Tehuantepec (which has produced the best data set so far), shows that indeed the DNS and observed spectra are very close, and differ significantly from those simulated on the basis of the Hasselmann equation. In the current wave modelling practice, the input/dissipation terms are chosen to complement the nonlinear interaction term, based on the Hasselmann equation, which is considered to faithfully represent the reality. The discrepancies found with the new DNS results and with observations suggest the necessity of radical revision of the whole edifice of modern wave modelling. The target of the project is to perform long term DNS simulations and to compare them with high quality observations. As shown by Annenkov & Shrira (2014), higher-order moments of a random wave field, and hence the probability of freak waves, are dependent on spectral shape, not just the on integral characteristics of a wave field. Preliminary estimates show that the found discrepancies in spectral shape can strongly affect higher-order moments, in particular kurtosis, and the difference is expect to be substantial (of the order of 100%). This has huge potential implications for the prediction of extreme wave events.

The DNS code is fully tested, highly parallelised and optimised for the supercomputing environment.

Specific objectives include:

1. To explore the discrepancy between the shape of the DNS (verified by observations) and the Hasselmann equation predictions. Examine implications for probability of freak waves, mixing via the vortex force and other processes sensitive to the shape of spectra.

2. To get new insights into the input and dissipation functions.

3. Explore the causes of the failure of the established approach.

References

Annenkov, S.Y. & Shrira, V.I. 2014 Evaluation of skewness and kurtosis of wind waves parameterized by JONSWAP spectra. J. Phys. Oceanogr. 44, 1582-1594.

Annenkov, S.Y. & Shrira, V.I. 2018 Spectral evolution of weakly nonlinear random waves: kinetic description versus direct numerical simulations. J. Fluid Mech. 844, 766-795.

Romero, L. & Melville, W.K. 2010 Airborne observations of fetch-limited waves in the Gulf of Tehuantepec. J. Phys. Oceanogr. 40, 441-465.