SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	**2016**…………………………………………………..……
Project Title:	**Direct numerical simulation of wind wave fields in a rapidly changing environment**
Computer Project Account:	**SPGBSHRI**…………………………………………….……
Principal Investigator(s):	**Prof V.I. Shrira**……………………………………..…
Affiliation:	**School of Computing and Mathematics, Keele University, Keele ST5 5BG UK**……………………..……
Name of ECMWF scientist(s) collaborating to the project (if applicable)	………………………………………………………..… ………………………………………………………..…
Start date of the project:	**01/01/2016**………………………………………..……
Expected end date:	**31/12/2018**………………………………………..……

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)			**300000**	**17500**
Data storage capacity	(Gbytes)			**100**	**30**

Summary of project objectives

(10 lines max)

This project aims at developing new models and algorithms for wind wave modelling, applicable for situations with fast changes of the environment, which are beyond the limits of applicability of the classical kinetic equation. Rapid changes of wind can lead to the increased probability of extreme wave events. The generalized kinetic equation (GKE) and direct numerical simulations (DNS) of wind wave fields, based on the Zakharov equation, allow tracing the evolution of spectra and higher-order moments of the field for many thousands of wave periods (at least an order of magnitude longer than with other DNS approaches). In this project, a direct comparison of the DNS and the GKE is performed, with the aim to understand the role of coherent processes, resolved by the DNS but completely filtered out in the statistical approach. These processes result in the difference in the timescales of the evolution of spectra, and affect higher statistical moments.

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Summary of problems encountered (if any)

(20 lines max)

No particular problems encountered……………………………………………………………………

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Summary of results of the current year (from July of previous year to June of current year)

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

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The project was started this year. Algorithms for the generalized kinetic equation and for the DNS have been both adapted for the efficient use in parallel supercomputing environment, and tested on a few model cases. Numerical experiments without wind forcing have revealed that both algorithms give essentially the same evolution of integral characteristics of a wave field, for large time tending to the known asymptotics of self-similar evolution. However, there are certain notable differences in the spectral shape (Fig. 1). It was shown that the scaling of spectral growth rates in the DNS evolution is different from that of the statistical model and corresponds to the dynamical scaling proportional to the fourth power of nonlinearity, which indicates the presence of coherent processes in the wave field, resolved by the DNS but filtered out in the statistical approach. There is a striking difference in the rate of angular broadening of the spectrum, which is much larger for the GKE than for the DNS. The di fference of growth rate scaling in the responsible for the
di fference in spectral shapes and rates of ang
Short-term evolution of these spectra was simulated numerically by Xiao et al (2013) using high-

order spectral method and the Dysthe equation. Thus, we were able to validate our algorithms against the short-term DNS simulations.

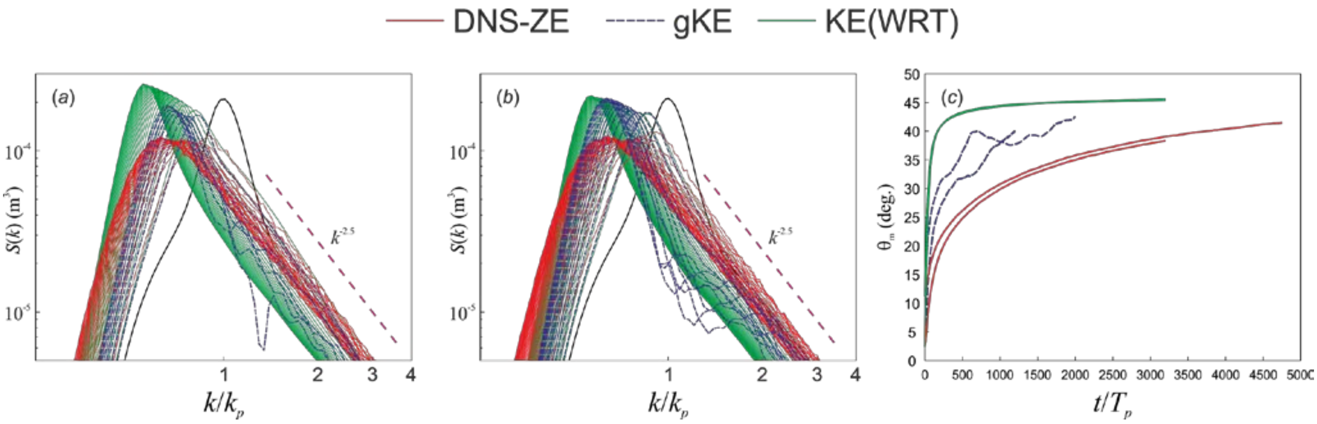

Fig. 1. Evolution of two initial spectra, with a direct comparison of 3 different numerical approaches. There is no wind forcing; dissipation is at high frequencies. Initially, spectrum I (a) and spectrum II (b) are both JONSWAP with the same frequency distribution ($H_s = 0.08$m, $T_p = 1$ s, and $\gamma = 6$), different only in the initial directional distribution. For spectrum I the directional distribution is very narrow, corresponding to width parameter $\Omega = 12^o$ in the cosine-squared directional model (approximately equivalent to *N*=840 in the cos^N model), and for spectrum II it is wider, corresponding to $\Omega = 62^o$ and *N*=24. The spectra shown are omnidirectional *S(k)*, with the slope $k^{-2.5}$. Black curve shows the initial condition, other curves - the corresponding spectra after every 150 periods of evolution. Red curve - DNS based on the Zakharov equation (DNS-ZE). Green curve - standard kinetic equation, WRT algorithm, KE(WRT). Blue dashed curve - generalized KE (GKE). (c) Evolution of directional spread θ_m (second moment of directional distribution) for both initial spectra and all numerical methods.

Simulations with constant wind forcing have been so far performed with the GKE only. We performed simulations for instantly increasing wind forcing, and for the case of squall, where wind forcing increases and then decreases to the initial value, and demonstrate joint evolution of spectra and of higher statistical moments. Thus, we show that it is feasible to simulate transient wave field evolution using the GKE. These results can be straightforwardly translated into quantifying the corresponding changes of the p.d.f. and estimating the likelihood of freak waves.

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List of publications/reports from the project with complete references

Annenkov S.Y., Shrira V.I. Spectral evolution of weakly nonlinear random waves: kinetic description vs direct numerical simulations. Geophysical Research Abstracts Vol. 18, EGU2016-10523, 2016

Annenkov S.Y., Shrira V.I. New approaches to numerical simulation of random wave field spectral evolution. Wave Interaction (WIN-2016) 25 - 28 April 2016, Linz, Austria http://www.dynamics-approx.jku.at/lena/Workshop2016/A_Annenkov.pdf

Annenkov S.Y., Shrira V.I. Spectral evolution of wind waves: classical vs generalised kinetic equations vs DNS. WISE Meeting 2016 CNR-ISMAR Venice, May 22-26, 2016

Summary of plans for the continuation of the project

(10 lines max)

We plan to continue the work on the DNS algorithm. First, the DNS algorithm requires a careful parameterization of wave breaking. A suitable parameterization will be found in a series of numerical experiments. Then, we will perform a detailed comparison of the two models with constant and changing wind forcing, identifying the situations when sharp changes of forcing may result in spikes of higher statistical moments of wave fields. Special attention will be paid to the evolution of two-dimensional spectra with the DNS and the GKE.