INDIVIDUAL FELLOWSHIPS

Project n°: 909389

Project Acronym: DeRogue Waves

Project Full Name: Deterministic Forecasting of Rogue Waves in the Ocean

Marie Curie Actions
IEF-IOF-IIF- IIFR -Final Report

FINAL PUBLISHABLE SUMMARY REPORT

Period covered: **from 1 August 2012 to 31 July 2013**

Period number: **1**

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The project creates the scientific basis for new methodologies for deterministic rogue wave forecasting (when it is possible) and for improvement of probabilistic forecasting. Its aims can be subdivided into two general tasks: **i)** scientific background for deterministic rogue wave forecasting and **ii)** deterministic forecasting for rogue waves on currents.

The combined simulations, by means of weakly and fully nonlinear models, and by means of laboratory measurements are performed in collaboration with European universities. Assembling the new and previously obtained within the project results, we end up with a clear picture of properties and dynamics of extreme short wave groups, which should enable establishing the short-term *deterministic rogue wave forecasting*. In particular, very steep structurally stable solitary wave groups over deep water are proved to exist, and were generated with the help of analytic weakly nonlinear solution, despite numerous opposite assertions and the consequent conventional contrary opinion.

The solitary groups form breather-like solutions when embedded in surrounding wave background. Locally, the weakly nonlinear theory is capable of description of these wave groups, though when long-term evolution is concerned or specific characteristics are wanted (such as maximum crest/trough amplification, growth time, apparent steepness, etc.), strongly nonlinear corrections must apply. The most interesting case of very steep, close to breaking waves was in the focus of our study. The strongly nonlinear stage of the self-modulation instability is studied in detail for the situations of a single and several (up to five) unstable modes.

The universal picture of the maximum attainable wave and wave group (nonbreaking case) is presented. The potential Euler equations framework is shown to describe the solitary waves perfectly. The key parameters for the extreme solitary wave groups are obtained (envelope shapes, wave asymmetry, propagation velocity). The quantitative estimations of maximum waves parameters prior wave breaking are obtained for the broad class of modulated waves. Significantly, the one-to-one mapping based on asymptotic solutions is shown possible even for the strongly nonlinear results.

An extensive study of rogue wave occurrence is completed on the basis of strongly nonlinear numerical simulations of the primitive water equations. The joint analysis of the surface elevations and velocity fields confined in the spatio-temporal domains of the size 20 min × 10 km is the distinguishing feature of the work performed. The fine data resolution in time and space allows us to conduct out of the common rogue wave analysis. The detailed pictures of individual rogue wave evolution and of intermittent rogue wave events, which last for a significantly longer time, are depicted. We found the specific practically important feature of rogue waves in strongly nonlinear sea conditions, which has not been noted so far: an extreme wave is more frequently a high crest followed by a deep trough. The question of relation between extreme wave kinematics and extremely high waves is discussed in the statistical sense.

The theory for trapped waves on jet current has been developed further. The developed asymptotic theory is verified through the direct comparison between the trapped modes of the original two-dimensional boundary-value problem and of the suggested tractable one-dimensional problem. The fully nonlinear three-dimensional solver for potential Euler equations taking into account the jet current (of any intensity) has been implemented.

Conducted simulations confirm existence of the effect, on which the project is focused: the self-modulation of trapped waves over deep water cause occurrence of essentially three-dimensional rogue waves.

The impact of the project should become apparent in many different ways: through contribution to development of the marine industry making seafaring safer, by establishing scientific links between European and Russian scientific institutions. The project results improve competitiveness of the European research concerned with rogue waves: the developed methodology has no analogues in the world, it will be an important element in establishing European leadership in dangerous sea wave forecasting and preventing fatalities and serious ship incidents in sea. The results are also applicable to many other physical contexts, where the underlying mathematics is the same or quite similar. The results will be also used in educational purposes, which might attract gifted students to science and engineering. During the re-integration phase the established scientific collaboration between the Return and Host institution researchers have not been diminished, interrelations between the fellow and European institutions have been deepened. Simultaneously the fellow has consolidated his position at Home institution, developing his scientific career, and occupied teaching position in a university.