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ASSESSING THE COMBINED EFFECT OF HIGHER ORDER NONLINEARITY, DIRECTIONAL PROPERTIES AND FINITE WATER DEPTH ON THE STATISTICAL PROPERTIES OF SURFACE GRAVITY WAVES

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1. Introduction

It is not yet understood whether the combined effect of higher order nonlinearity, short crestedness and finite water depth may have a significant effect on the statistical properties of surface gravity waves. In deep water, the dynamics of surface gravity waves is dominated by the instability of wave packets to side band perturbations.

This mechanism, which is a nonlinear third order in wave steepness effect, can lead to a particularly strong focusing of wave energy, which in turn results in the formation of waves of very large amplitude also known as freak or rogue waves (Janssen 2003). In water of finite depth, however, the interaction between waves and the ocean floor induces a mean current. This subtracts energy from wave instability and causes it to cease for relative water depth $kh = 1.36$, where k is the wavenumber and h the water depth (Janssen - Onorato, 2007). A series of experiments in the MARINTEK Ocean Basin are planned in the summer of 2012. The experiments will focus on the nonlinear evolution of irregular wave fields in water of arbitrary depth. Concurrently, numerical experiments will be performed solving the Euler equation of motion with the Higher Order Spectral Method (HOSM) (West et al. 1987) and a conformal mapping technique (Chalikov and Sheinin 2005).

Statistical properties of the water surface (namely, the skewness and kurtosis) from the laboratory measurements and numerical simulations will be compared.

2. Experiment in the MARINTEK Ocean basin

Experiments to study the statistical properties of water surfaces elevation have already been carried out in different laboratories (e.g. at the University of Tokyo and at the MARINTEK Ocean Basin amongst others), but most, if not all, of these experiments were performed in deep water conditions. It is now well accepted that modulational instability, known as one of the main mechanisms for the formation of extreme waves when dealing with random and long-crested deep water waves, is quenched when shortcrested waves are considered (Onorato et al, 2008).

The main motivation to carry out a new set of measurements at the MARINTEK Ocean Basin is to understand whether, and for which relative water depths, nonlinearity of orders higher than third is statistically significant and to validate the results of numerical simulations.

3. Numerical model

Simulations of the sea surface elevation will be performed solving the Euler equation of motion with two different methods: HOSM approach by West et al. (1987) and a conformal mapping technique proposed by Chalikov and Sheinin (2005).

The HOSM method has already been successfully applied in deep and intermediate water conditions for the execution of a large number of simulations of the random see surfaces (Toffoli et al, 2008, 2009). The method is based on the expansion of the vertical velocity about the free surface under the assumption of weak nonlinearity. Its advantage is in allowing the activation or deactivation of different orders of nonlinearity. The conformal mapping method, on the other hand, enables transforming a complex physical region bounded by a wave surface to a regular computational domain, where a spectral computational scheme can be efficiently applied. The advantage of this method is that it handles fully nonlinear computations. Tests with a directional wave spectrum consistent with the laboratory experiments will be performed.

4. Comparing statistical properties of the water surface

The statistical analysis of both numerical and laboratory data will be based on the estimation of the density function of the surface elevation and its third and fourth statistical moments i.e. skewness and kurtosis.

The resulting parameters values will be compared.

5. Conclusion

A number of physical experiments are to be carried out at the Marintek Ocean Basin facility to look at the statistical properties of directional waves in limited water depth.

A numerical model based on the HOSM method has been adapted so that it can simulate wave evolution up to fifth order of nonlinearity on the one hand and in limited water depth on the other hand. First results of the comparison between the physical and the numerical experiments will be presented during the conference.

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References

Janssen, P.A.E.M.,Onorato, M 2007. 'The intermediate water depth limit of the Zakharov equation and consequences for wave prediction' *Phys.Ocean.* 37, no. 10, 2389-2400.

Janssen., P. A. E. M 2003, 'Nonlinear four-wave interaction and freak waves', *J. Phys. Ocean., 33(4):–* 33, no. 4, 863-884.

Onorato, M., Waseda, T., Toffoli, A., Cavaleri, L., Gramstad, O., Janssen, P., Kinoshita, T., Monbaliu, J., Mori, M., Osbourne, A., Serio, M., Stransberg, C., Tamura, H., and Trulsen, K. 2008, 'Statistical Properties of Directional Ocean Waves: The Role of the Modulational instability in the Formation of Extreme Events', *Phys. Rev.Lett. 102(114502).*

Toffoli, A., Fernández, L., Suslov, S., Monbaliu, J. 2011, 'Assessing the effect of finite water depth on modulational wave instability using a direct numerical simulation method of the Euler equations', *ACOMEN 2011.*

Toffoli, A.,Onorato, M., Bitner-Gregersen, E., Osborne, A.R:, Babanin, A.V. 2008, 'Surface gravity waves from direct numerical simulations of the Euler equations: a comparison with second-order theory', *Ocean Engineering* 35, no. 3-4, 367-379.

West, B.J., Brueckner, K. A., Jand, R. S., Milder, D. M. and Milton, R. L. 1987, 'A new method for surface' *J. Geophys. Res.*, 92, no. C11, 11803-11824.

Chalikov D. and Sheinin D. 2005, 'Modeling of extreme waves based on equations of potential flow with a free Surface'. *J. Comp. Phys.* 210, 247-273.

Toffoli A., Benoit M., Onorato M. and Bitner-Gregersen E. M. 2009, 'The effect of third-order nonlinearity on statistical properties of ransom directional waves in finite depth', *Nonlin. Process. Geophys,* 16, 131-139.