Nonlinear wave modelling and analysis – Master's theses topics

Guillaume DUCROZET – guillaume.ducrozet@ec-nantes.fr

Ecole Centrale Nantes – LHEEA Lab.

CONTEXT

The marine and maritime sectors are of primary importance in the local industrial context of the Nantes regional area. At the local, national and international levels, those sectors are still facing several challenges, due to the complexity and severity of the ocean environment.

A prominent one is to account for the extreme wave conditions in the design of marine structures. These environmental conditions, as well as the induced responses, exhibit complex physical processes. In this context, the present procedures for the evaluation of extreme responses are known to be inaccurate. This forces the regulations of classification societies to introduce large safety factors that may be inadequate in some conditions.

The WASANO project, funded by the I-Site NExT initiative, intends to address the problem of an accurate and controlled description of extreme environmental conditions for ocean engineering. To overcome several identified scientific bottlenecks, the project proposes innovative methods to i) define the extreme sea states responsible for the ultimate responses of structures at sea and ii) reproduce them in water tanks or with high-fidelity numerical solvers. These will apply to environmental conditions in numerical simulations and physical experiments at the model scale.

The WASANO project will create a large international consortium in view of establishing reference procedures, which are expected to be part of the future of regulations at the international level. This international partnership involves for now 10 world-renowned international universities as well as 3 industrial partners.

MASTER'S THESES CONTENT

In this context, Ecole Centrale Nantes (ECN) is proposing two Master's thesis topics in the LHEEA Laboratory focusing on nonlinear wave analysis and modelling. Note that the content of the proposed topics can be adjusted according to the applicant's background and interest. More details on each of the topics can be provided if needed.

The expertise of ECN in the field of nonlinear waves is internationally acknowledged, especially with the development and open-source release of the numerical models based on the High-Order Spectral (HOS) named HOS-ocean and HOS-NWT. Those nonlinear wave models are now mature and widely used in the community to address ocean engineering problems and help understand the physics of nonlinear wave phenomena. Both models have been highly validated against experiments and measurements at sea. They allow for the simulation of different wave conditions, from regular waves up to complex irregular short-crested sea states.

Thanks to those numerical models, different physical phenomena can be studied. This includes the formation of extreme waves (aka rogue or freak waves) in different configurations. This is the topic of the first set of Master's theses proposed, with different possibilities in terms of the main research axis:

1. In order to understand the physical processes at play during the formation of extreme events, it is necessary to develop specific analyses. One of these methods that we want to investigate in detail in the course of a Master's thesis is the higher-order spectrum. This enables an in-depth analysis of the nonlinear wave interactions at play in a given wave field. The idea is to try to understand the formation of extreme waves in terms of those non-linear wave interactions. Preliminary work has been achieved to implement bi- and-tri-spectra analysis routines (Matlab). During this Master's thesis, the student will perform numerical simulations using HOS models in order to build a sufficiently large database for the bi- and tri-spectra analyses. Then, he/she will finalize the analysis routines and perform the corresponding analysis. Different irregular sea state configurations will be studied to investigate the effect of steepness, directionality, etc. Complementary, it is expected that the student studies the influence of wave generation methodologies known as i) random phases and ii) random phases and amplitudes on the wave statistics and nonlinear interactions.
2. Recent numerical work conducted in Univ. Oxford indicates that the wave statistics are possibly influenced by the high-frequency cut-off applied to the initial conditions of the wave field. For experiments in wave tanks, this cut-off can be related to the limitations in wave generation of the wave maker at high frequencies. It appears interesting to study if the same conclusions are drawn using the HOS-NWT numerical model. The Master's thesis successful applicant will perform the simulation of unidirectional irregular sea states with HOS-NWT, varying the cut-off frequency. The analysis of the results should confirm (or not) the recent conclusion of the literature in unidirectional configurations. Some experimental data are also available to try to conclude this phenomenon. Extension to directional sea states will be done during the second part of the Master's thesis.
3. From the literature, it is well known that when the relative water depth becomes small, the nonlinear resonant interactions (at the origin of the formation of extreme waves) disappear. This is then understood as a configuration that cannot lead to the formation of those rogue waves. However, this does not seem in line with some observations. This Master's thesis will investigate the formation of extreme waves with the numerical model HOS-ocean. The main idea will be to investigate irregular sea states in small relative water depths and different directional spreadings. The student will set up the numerical simulations and analyze the formation of large waves for a set of varying parameters.

Complementary to this analysis of numerical simulations, two other Master's thesis topics are also proposed on related topics:

4. Due to nonlinear wave interactions at play, a wave simulation performed using HOS-ocean does not exhibit a stable spectrum in time. This is an issue for the extraction of wave statistics in such simulations, even if some recent works seem to demonstrate that a 'steady state' can be reached after some time. The objective of this Master's thesis is to implement and validate a strategy in the existing numerical model that ensures the temporal stability of the wave spectrum. Comparison with the existing numerical model will be performed as well as with measurements at sea.
5. Recovery and analysis of existing databases with measurements at sea. The objective of this Master's thesis is to characterize the short-term statistics one can extract from the existing databases in different wind and wave conditions. The main topic of interest is the influence of those conditions (stable in time or not) on wave statistics. The student will try to answer the following questions: i) Develop a proper strategy to identify the unstable configurations (from the wind field point of view).ii) What is the probability of occurrence of unstable conditions

(with possible larger occurrence of extremes) compared to 'stable' ones? iii) How is it possible to include the existence of stable and unstable conditions in the design procedures?

All those works may lead to publication in an international conference.

PROFILE OF THE CANDIDATE

The candidate should be a 2nd-year Master's student (or equivalent degree) with a specialization in Ocean Engineering, Applied Mathematics, Mechanical Engineering or related topics. Appetence for numerical modelling is necessary and knowledge of the physics of the water waves is a bonus.

English fluency is mandatory.

SCHEDULE AND CONDITIONS

Schedule:

Candidates are invited to contact the supervisor, Dr. Guillaume Ducrozet (guillaume.ducrozet@ec-nantes.fr) via email, with a CV and a motivation letter.

Applications received after December 15th, 2023 will not be considered and the final decision should be available on December 22nd.

The successful candidate is expected to start by March 1st, 2024 at the latest.

Conditions

The candidate will be funded for six months (at the French legal level for MSc theses: around 600€/month) and hosted within the LHEEA Lab. of Ecole Centrale Nantes.

Centrale Nantes https://www.ec-nantes.fr/english-version

LHEEA Lab. https://lheea.ec-nantes.fr/english-version