Waseda Workshop on Theoretical and Computational Methods of Nonlinear Water Waves

An Introduction to the Mathematical Theory of Nonlinear Water Waves

Date: **May 16-17, 2016**, **Location:** Waseda University, large meeting room at Building No. 62

Intensive Lecture Speakers: Prof. Roberto Camassa（University of North Carolina），Prof. Wooyoung Choi（New Jersey Institute of Technology）

Other Speakers: Wataru Fujimoto (University of Tokyo), Yohei Onuki (University of Tokyo), Linyu Peng (Waseda University), Hidetaka Houtani (National Maritime Research Institute), Adrean Webb (University of Tokyo)

Schedule

	May 16	May 17
1:00pm -2:30pm	Fundamentals of fluid mechanics and free surface flows Roberto Camassa	Unidirectional wave propagation and integrable models in shallow water Roberto Camassa
2:45pm - 4:15pm	Asymptotic theories for nonlinear water waves Wooyoung Choi	Periodic waves and stability in deep water Wooyoung Choi
4:30pm- 5:00pm	A meshless numerical approach to spectral wave modeling Adrean Webb	Effect of phase modulation on parametric instability of oceanic internal waves Yohei Onuki
5:00pm- 5:30pm	On the wave geometry of unstable Stokes' waves in deep water Hidetaka Houtani	Multisymplectic structures and variational integrators for higher order field theories Linyu Peng
5:30pm- 6:00pm		Simulating observed freak waves in deep water near Japan using WAVEWATCH III and the higher order spectral method Wataru Fujimoto

Title: **Simulating Observed Freak Waves in Deep Water near Japan using WAVEWATCH III and the Higher Order Spectral Method**

Speaker: Wataru Fujimoto (University of Tokyo)

Abstract: We have investigated two freak waves observed by the JKEO K-Triton buoy in the Pacific Ocean near Japan. WAVEWATCH III was used to estimate the wave spectra at the time of the two freak wave occurrences, and then the HOSM was used to simulate the evolution of the two wave field initialized with the estimated spectra. The estimated wave spectrum of one freak wave is narrow, and the other one is broad. In wave fields simulated by HOSM, the large crest height occurrence probability of the narrow spectral wave field is significantly larger than the Tayfun distribution based on the second order nonlinear theory. In the broad spectral case, the occurrence probability is almost the same as the Tayfun distribution. These results imply that the freak wave for the narrow-spectrum wave field is caused by the third order nonlinear wave interaction while the broad one is generated by linear wave focusing.

Title: **Effect of phase modulation on parametric instability of oceanic internal waves**

Speaker: Yohei Onuki (University of Tokyo)

Abstract: Parametric instability of rotating internal waves is a key topic in recent physical oceanography, because it plays an important role in transferring energy from large-scale internal waves to small-scale mixing processes in the deep ocean. In recent studies, however, it is pointed out that numerical experiments obviously overestimate the dissipation of large-scale internal waves through parametric resonance with small-scale internal waves. One possible reason for this inconsistency is that these numerical experiments do not take into account the phase modulations of large-scale internal waves, for example, caused by eddy-like motions in the real ocean.

In this study, the effect of phase modulation of large-scale internal waves on parametric instabilities is investigated. We theoretically derive a simple expression of the growth rate of small-scale internal waves interacting with a large-scale internal wave with weak phase modulations. The obtained result reconciles a dispute among researchers in the past decade, smoothly connecting the two types of instabilities occurring in dynamic and kinetic time scales, which correspond to first and second orders of perturbation, respectively. It is expected that this theoretical study, combined with numerical and observational studies, provide a more detailed understanding of parametric instabilities in the real ocean.

Title: **Multisymplectic structures and variational integrators for higher order field theories**

Speaker: Linyu Peng (Waseda University)

Abstract: Symplectic structure plays essential role in particular geometric integrators for both Lagrangian and Hamiltonian mechanics. As a generalisation, during last decades multisymplectic structures have been developed for understanding partial differential equations from geometric viewpoints. In this talk, the conservation of multisymplecticity, for higher order field theories, is systematically interpreted as a divergence free expression on the variational bicomplex. A difference counterpart is also presented for multisymplectic integrators. Various illustrative examples are provided. This talk is based on collaborations with professors Peter Hydon (Kent) and Hiroaki Yoshimura (Waseda).

Title: **On the wave geometry of unstable Stokes' waves in deep water**

Speaker: Hidetaka Houtani (National Maritime Research Institute)

Abstract: It is well known that the Stokes' wave is unstable to the modulational perturbations. The modulational instability due to quasi-resonant interaction is thought as one of the mechanisms of freak wave generation.

We have conducted numerical simulations and laboratory experiments on modulational wave trains. The nonlinear long-term evolution of modulational wave trains was simulated with the HOSM (higher-order spectral method). HOSM is one of the efficient numerical methods to solve the nonlinear free surface boundary conditions derived by Zakharov (1968). The HOSM simulates the nonlinear temporal evolution of spatially periodic wave fields.

We have developed a method to reproduce a wave field simulated by the HOSM in an experimental wave tank (HOSM-WG). In the HOSM-WG, a spatially periodic wave field is generated because an output of the HOSM simulation is used in the calculation of the wave maker signal. The HOSM-WG experiments were conducted in a wave tank (50 m in length, 8 m in width and 4.5m in depth) of the National Maritime Research Institute. The spatial wave profile was measured by stereo imaging. Fully nonlinear numerical experiments of the HOSM-WG based on the boundary element method were also carried out.

The numerical and experimental results on the generation of modulational wave trains will be presented here. The geometric properties of spatially periodic and temporally periodic modulational wave trains will also be discussed.

Title: **A meshless numerical approach to spectral wave modeling**

Speaker: Adrean Webb (University of Tokyo)

Abstract: Ocean surface gravity waves are an important component of the atmospheric and oceanic boundary layer and the inclusion of such in a global climate model has the potential to correct model biases and improve air-sea interactions. Current existing spectral wave models used for short-term forecasting include extensive physics and parameterizations but are computational expensive for long climate runs. Here a new meshless prototype that uses RBF-generated finite differences to solve the wave action balance equation will be presented. This prototype is both an order magnitude faster and accurate than existing models and shows promise as a new numerical approach to global ocean wave modeling.