MATHEMATICAL MODELING FOR TSUNAMI WAVES USING LATTICE BOLTZMANN METHOD

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To my mother and father

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My brother

AHMAD ZERGANI

For your infinite and unfading love, sacrifice, patience, encouragement and

Best wishes

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ABSTRACT

This research focuses on tsunami wave modelling. The nature of tsunami waves can be conditionally divided into three parts; generation, propagation and inundation (or run-up). General patterns and important characteristics of tsunamis can be predicted by various sets of governing equations and commonly used models which include elastic wave, nonlinear shallow water and forced Korteweg de Vries (fKdV) equations. In order to construct tsunami model, we divide this modelling into two parts; the first part contains seismic (earthquake) wave that focuses on the nonlinear elastic wave equation. The equation has been successfully applied to the tsunami generation part and is shown to give suitable complex flow simulation of elastic wave generation. The second part essentially deals with the nonlinear shallow water equations which are often used to model tsunami propagation and sometimes even the run-up part. This work specifically studies the properties of propagation of tsunamis. Shallow water equations have become the choice model of operational tsunami modelling for irrotational surface waves in the case of complex bottom elevation. The run-up part basically deals with the KdV and fKdV equations for unidirectional propagation and effects of external noise and damping terms for the studies of tsunami run-up. Several test-cases are presented to verify propagation and run-up model. The simulation algorithm of this research is based on the lattice Boltzmann method (LBM). The aim of this research is to use the LBM to solve tsunami waves modelling. Several problems for simulation of tsunami waves are generated with LBM. The appropriate equilibrium distribution function is selected and extended to solve the related three-dimensional problems and appropriate units are chosen and changed in accordance with lattice Boltzmann simulations and stability of lattice Boltzmann models. These models are solved and the solutions with different boundary conditions are analysed to produce relevant patterns and behaviours, assumptions and approximations for modelling tsunami and seismic waves. These analyses have been implemented via accurate, robust and efficient LBM for solving the tsunami sets of equations under complex geometry and irregular topography. The graphical output profiles are generated by using Matlab version 2012.

ABSTRAK

Kajian ini memberi tumpuan kepada model gelombang tsunami. Sifat gelombang tsunami boleh dibahagikan kepada tiga bahagian mengikut syarat; penjanaan, perambatan dan limpahan (atau *run-up*). Pola umum dan ciri-ciri penting tsunami boleh diramalkan dengan pelbagai set persamaan utama dan model yang biasa digunakan termasuk gelombang elastik, air cetek bukan linear dan persamaan Korteweg de Vries paksaan (fKdV). Dalam usaha membina model tsunami, pemodelan ini dibahagikan kepada dua bahagian; bahagian pertama mengandungi gelombang seismik (gempa bumi) yang memberi tumpuan kepada persamaan gelombang elastik bukan linear. Persamaan ini digunakan dengan jayanya untuk bahagian penjanaan tsunami dan terbukti memberi simulasi aliran kompleks penjanaan gelombang elastik yang sesuai. Bahagian kedua pada dasarnya adalah berkenaan persamaan air cetek bukan linear yang sering digunakan untuk memodelkan perambatan tsunami dan kadang kala juga bahagian limpahan. Kerja ini secara khususnya mengkaji sifat-sifat perambatan tsunami. Persamaan air cetek telah menjadi model pilihan dalam pemodelan operasi tsunami untuk gelombang permukaan tak berputar dalam kes dongakan kompleks bawah. Bahagian limpahan pada dasarnya berkaitan dengan persamaan fKdV untuk perambatan satu arah dan kesan bunyi luaran serta terma redaman dalam kajian limpahan tsunami. Beberapa kes ujian dibentangkan untuk mengesahkan model perambatan dan limpahan. Algoritma simulasi kajian ini adalah berdasarkan kaedah kekisi Boltzmann. Tujuan kajian ini adalah untuk menggunakan LBM dalam menyelesaikan pemodelan gelombang tsunami. Beberapa masalah untuk simulasi gelombang tsunami dijana dengan LBM. Fungsi taburan keseimbangan yang sesuai diambil dan dilanjutkan untuk menyelesaikan masalah tiga dimensi yang berkaitan dan unit yang sesuai dipilih serta diubah mengikut simulasi kekisi Boltzmann dan kestabilan model kekisi Boltzmann. Model ini diselesaikan dan penyelesaian dengan syarat sempadan yang berbeza dianalisis bagi menghasilkan corak yang relevan serta perilaku, andaian serta anggaran pemodelan gelombang tsunami. Analisis ini dilaksanakan menerusi LBM yang jitu, teguh dan berkesan bagi menyelesaikan set persamaan seismik dan tsunami di bawah geometri kompleks dan topografi yang tidak teratur. Profil hasil grafik dijana dengan menggunakan Matlab versi 2012.