General View of Dispersion in Tsunami Modeling

Ceren Ozer[(1)], Ahmet Cevdet Yalciner[(1)], Andrey Zaytsev[(2,3)], and Efim Pelinovsky[(3,4)]

(1) METU, Department of Civil Engineering, Ocean Engineering Research Center, Ankara, Turkey (cozer@metu.edu.tr, yalciner@metu.edu.tr), (2) Special Research Bureau for Automation of Marine Researches, Yuzhno-Sakhalinsk, Russia , (aizaytsev@mail.ru), (3) Applied Mathematical Department, State Technical University, Nizhny Novgorod, Russia, (4) Applied Physics Institute, Department of Nonlinear Geophysical Processes, Nizhny Novgorod, Russia (pelinovsky@hydro.appl.sci-nnov.ru)

Necessary Terms of Simulations Using Nonlinear Long Wave Equations

NONLINEARITY — DISPERSION — FRICTION

Linearity may be sufficient in deep water.

Nonlinearity is essential in shallow zone. The friction term becomes important in the shallow zone and at land.

The **dispersion** becomes **important** in long distance propagation and also when the wave amplifies in the shallow zones.

- There are numerious numerical approaches for assessment of tsunamis from source to target locations.
- Tsunami generation and propagation are solved by numerical modeling with a reasonable and acceptable error limit.
- **However, tsunami behaviour in shallow region and at land are not solved clearly because of**

  - **breaking**
  - **dispersion due to the increase of η at shallow region**
  - **Dispersion due to long distance propagation**
  - **shoaling**

NONLINEAR SHALLOW WATER EQUATIONS

$$\frac{\partial \eta}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0$$

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left(\frac{M^2}{d}\right)+\frac{\partial}{\partial y}\left(\frac{MN}{d}\right)+gd\frac{\partial \eta}{\partial x}+\frac{\tau_x}{\rho}=0$$

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}\left(\frac{MN}{d}\right)+\frac{\partial}{\partial y}\left(\frac{N^2}{d}\right)+gd\frac{\partial \eta}{\partial y}+\frac{\tau_y}{\rho}=0$$

Bottom Friction

$$\frac{\tau_x}{\rho}=\frac{fn^2}{D^{7/3}}M\sqrt{M^2+N^2}$$

$$\frac{\tau_y}{\rho}=\frac{fn^2}{D^{7/3}}N\sqrt{M^2+N^2}$$

NONLINEAR DISPERSIVE SHALLOW WATER EQUATIONS (BOUSSINESQ EQUATIONS)

$$\frac{\partial \eta}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0$$

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left(\frac{M^2}{d}\right)+\frac{\partial}{\partial y}\left(\frac{MN}{d}\right)+gd\frac{\partial \eta}{\partial x}+\frac{\tau_x}{\rho}=\frac{\partial \psi}{\partial x}$$

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left(\frac{M^2}{d}\right)+\frac{\partial}{\partial y}\left(\frac{MN}{d}\right)+gd\frac{\partial \eta}{\partial x}+\frac{\tau_x}{\rho}=\frac{\partial \psi}{\partial y}$$

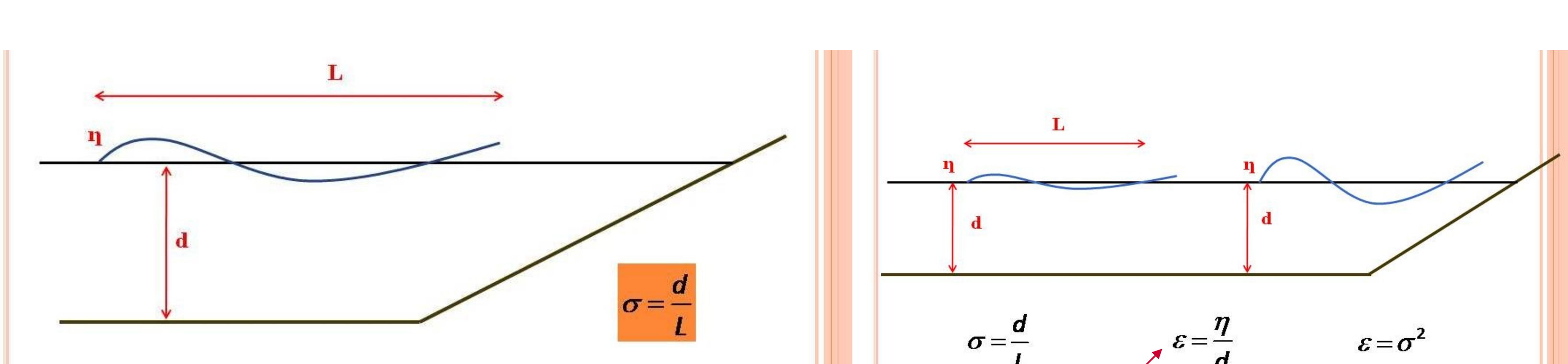
Dispersion Potential

$$\psi=\frac{h^2}{3}\left(\frac{\partial^2 M}{\partial x \partial t}+\frac{\partial^2 M}{\partial y \partial t}\right)$$

IMPORTANT RATIOS

Depth to wave length

Amplitude to depth



BOUSSINESQ'S APPROXIMATION

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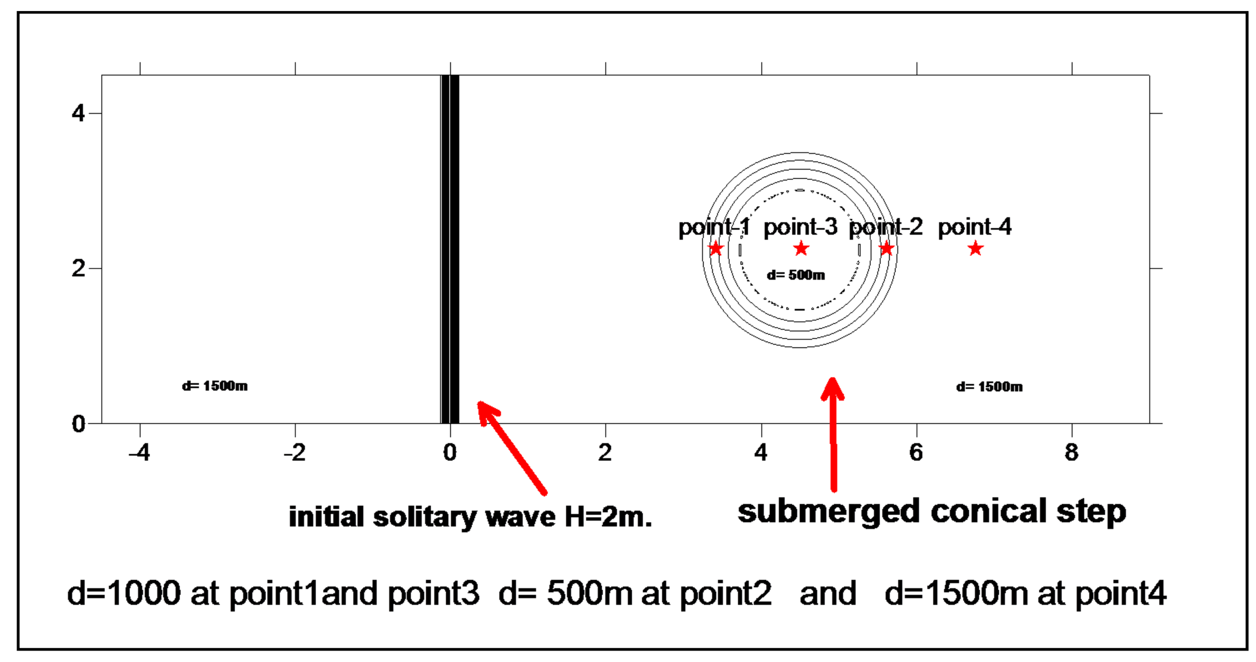
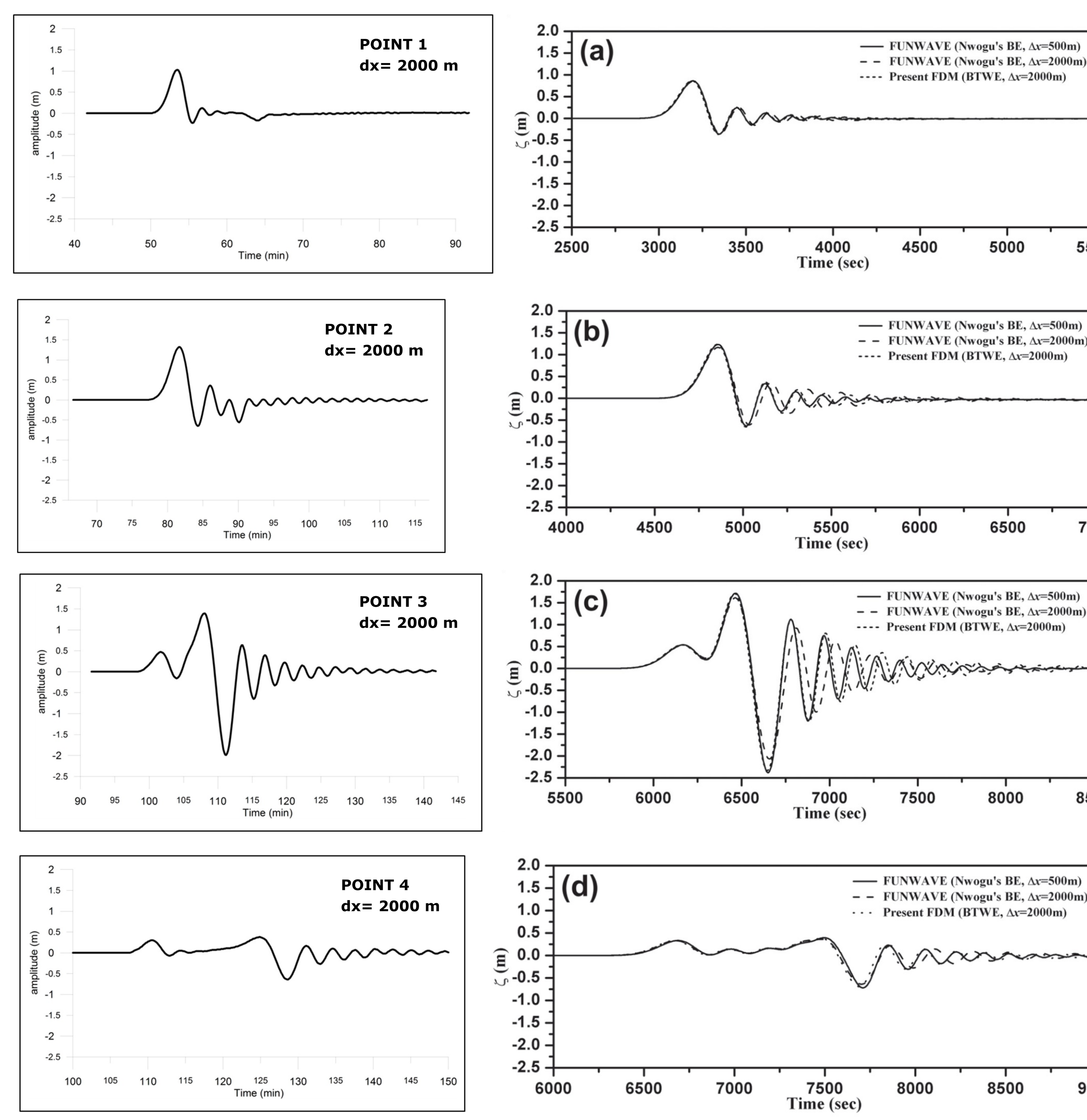
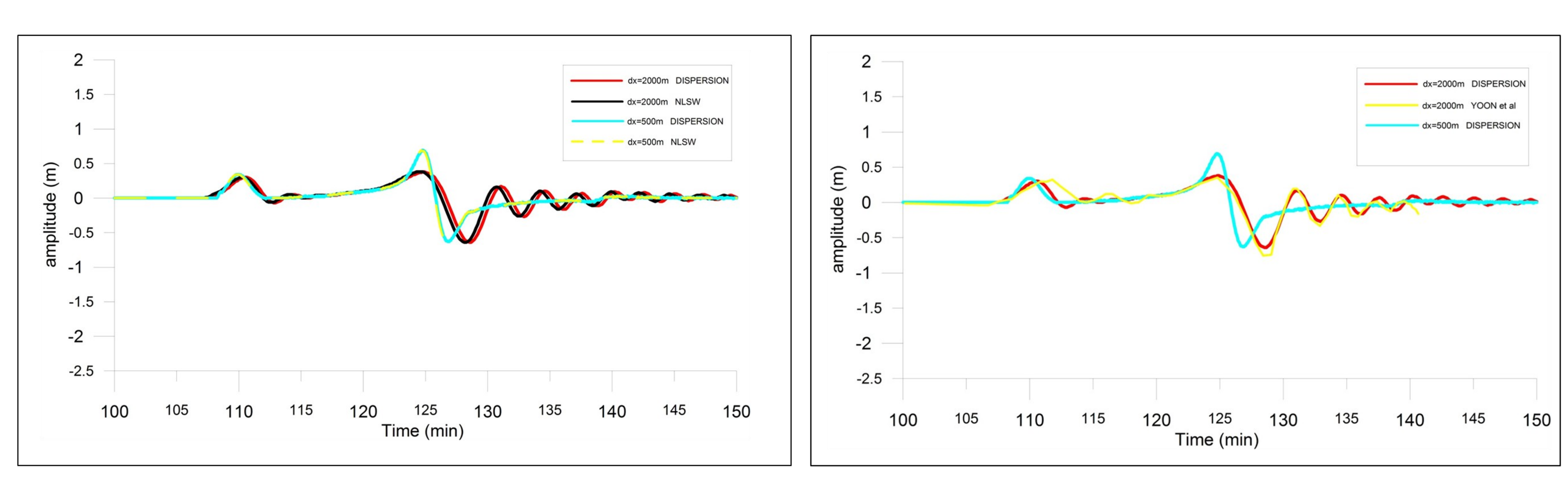
Results of NAMI DANCE– dispersion module Comparison with the results of Yoon et al (2007)







Shuto (1991) compared numerical results of three long wave theories (linear Boussinesq, Boussinesq and linear long wave) in deep water. He stated that linear Boussinesq and Boussinesq equations almost give the same solution with the linear surface wave theory, means that the nonlinear term is not essential in the tsunami propagation in deep water. Using coarser grid size in numerical dispersion makes the solution better than the same model at finer grid.

The incoming waves are divided into several waves due to dispersion in shallow region. Hence, the maximum amplitude of the wave decreases but the resulting water motion and tsunami forces may be still strong.

SUMMARY: IN WHICH STAGE OF TSUNAMI MODELING IS THE DISPERSION IMPORTANT??

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