SCENARIOS OF LOCAL TSUNAMIS IN CHNIA SEAS

Hua Liu[*a)], Xi Zhao[*], Yousheng He[*]
[*]*Department of Engineering Mechanics, Shanghai Jiao Tong University, Shanghai, 200240, China*

Summary The scenarios of the tsunamis originally generated by in submarine seismic movement at the Okinawa Trench in the East China Sea and at the Manila Trench in the South China Sea are simulated by the high order Boussinesq equations. It was found that, near the coastal area of the ESC, a train of solitary waves or an undular bore appears due to evolution of tsunami waves on the continental shelf of gentle slope, while a train of N-waves will be generated near the coastal areas around the SCS.

INTRODUCTION

Even though the cross Pacific Ocean tsunamis can be ignored for safety assessment of the coasts of China, the effects of local tsunamis on the coasts, potentially caused by the giant ruptures at the deep trenches near the continental shelf, have been received attention after the Indian Ocean tsunami in 2004 and the East Japan Ocean tsunami in 2011. It is believed that there are potential tsunami sources in the China Seas due to the fault ruptures along the Okinawa Trench in the East China Sea and the Manila Trench in the South China [1, 2].

Recent research shows that the nonlinearity and dispersion of tsunami waves play an important role in evolution of the tsunami waves propagating from the deep ocean to the shallow offshore. Motivated by observations on recent tsunamis events, it has been proved by field survey data and theoretical analysis of tsunami waves that, generally, the balancing law of nonlinearity and dispersion of tsunami waves could not been hold on in geophysical scales. For the case of a leading depressive wave train propagating into a shallow continental shelf may develop into an undular bore may split up into several solitary waves [3, 4]. Local resonant amplification phenomena may occur due to incoming and reflected wave interactions, which can be adopted to explain the why it is not always the first wave that causes the highest run-up, as well as why the tail of a single wave may produce leading-order run-up values appear runup [5].

The high order Boussinesq equations are used to simulate the tsunami generation and propagation in the ECS and the SCS. The mathematical formulation is introduced briefly. Several scenarios of tsunami waves moving on the continental shelf are provided. Characteristics of tsunami wave patterns are discussed.

MATHEMATICAL MODEL

We adopted the high order Boussinesq equations for modelling water waves from shallow water to deep sea [6]. The kinematic and dynamic free surface conditions are

$$\eta_t - \tilde{w} + \nabla\eta \cdot \tilde{\vec{u}} = 0 \tag{1}$$

$$\tilde{\vec{V}}_t + g\nabla\eta + \nabla\left(\frac{\tilde{\vec{V}} \cdot \tilde{\vec{V}}}{2} - \frac{\tilde{w}}{2}(1 + \nabla\eta \cdot \nabla\eta)\right) = 0 \tag{2}$$

where the fluid domain is bounded by the seabed at $z = -h(x, y; t)$ and the free surface at $z = \eta(x, y; t)$, t is the time, $\tilde{\vec{V}} \equiv \tilde{\vec{u}} + \tilde{w}\nabla\eta$, $\tilde{\vec{u}}$ and $\tilde{w}$ are the horizontal and vertical velocity components evaluated at the free surface, $\nabla = (\partial_x, \partial_y, 0)$ is the gradient operator in the horizontal space. The bottom boundary condition reads

$$w_b + \nabla h \cdot \vec{u}_b = -h_t \tag{3}$$

$\vec{u}_b$ and w_b are the velocity components at the bottom, h is the water depth. To establish a connection between the vertical and horizontal velocity variables at the free surface and the bottom, the exact solution of Laplace equation in the interior domain is introduced. Detailed information about the numerical aspects can be found for one dimensional case [5] and for two dimensional case [7]. A simplified approach for time-dependent bottom movement is adopted [2].

NUMERICAL RESULTS and DISDISCUSSION

Largest earthquake related tsunami threat to the communities along the SCS coast is coming from the Manila Trench. We adopted a plausible rupture scenario at the Manila Trench. The rupture extends over 1000 km and has a maximum

a) Corresponding author. Email: hliu@sjtu.edu.cn

width of 150 km. This scenario is identified as the worst-case and would generate an earthquake with MW above 9 [8]. The wavefields in the SCS are shown in figure 1. It turns out that there are different wave profiles at different locations along the coasts. At the south coast of Taiwan China, the leading depression N-wave occurs, while the leading elevation N-waves show up at the South coast of Mainland China.

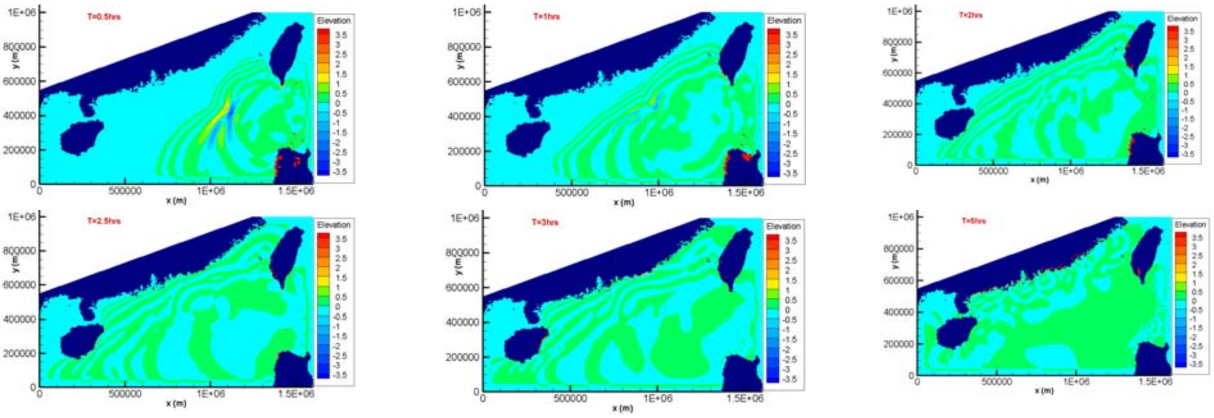

Figure 1 A scenario of tsunami wavefields in the South China Sea

It is an interesting phenomenon that the tsunami waves, originated from the Okinawa Trench in the ECS, develop into an undular bore and a train of solitary waves on the continental shelf of extremely gentle slope 1:6000, as shown in figure 2. Detailed discussion of the numerical results of the scenarios of tsunami waves in the ESC and the SCS will be presented in the Congress.

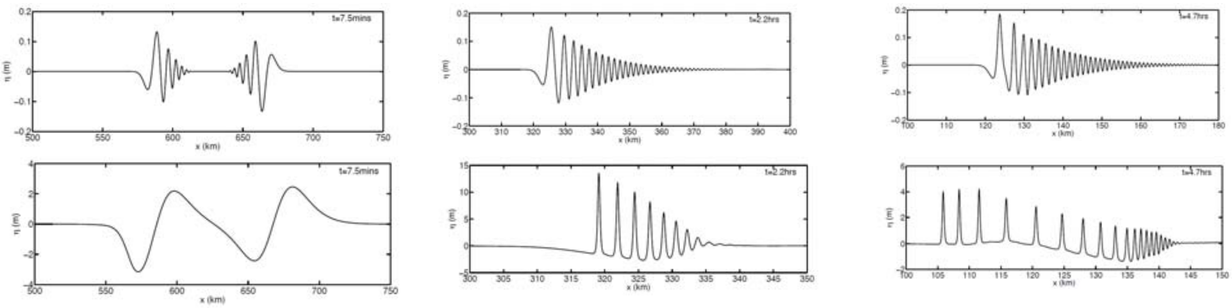

Figure 2 Tsunamis waves on the continental shelf of slope 1:6000 in the ECS.
Above panel: MW=7.0. Bottom panel: MW=9.0

CONCLUSIONS

Through numerical simulation of the scenarios of the tsunamis potentially motivated in the East China Sea and the South China Sea, it turns out that different wave patterns will appear for tsunami waves moving on continental shelf of different morphology, including N-waves, an undular bore and solitary waves. An accurate representation of both nonlinearity and dispersion is required for an accurate modeling of the evolution of tsunami waves over continental shelf of gentle slope.

References

[1] Ha D. M., Tkalich, P., *et al*. Tsunami Propagation Scenarios in the South China Sea. *J. Asian Earth Sciences* **36**:67-73, 2009.

[2] Zhao X., Wang B.L. and Liu H. Modelling the submarine mass failure induced Tsunamis by Boussinesq equations. *J. Asian Earth Sciences* **36**: 47-55, 2009.

[3] Madsen P. A., Fuhrman, D. R., Schaffer, H. A. On the Solitary Wave Paradigm for Tsunamis. *J. Geophys. Res*. **113**:C12012, 2008.

[4] Grue J., E. N., Pelinovsky D., et al. Formation of Undular Bores and Solitary Waves in the Strait of Malacca Caused by the 26 December 2004 Indian Ocean tsunami. *J. Geophys. Res*., **113**, C05008, 2008.

[5] Stefanakis, T., Dias, F. Local Run-Up Amplification by ResonantWave Interactions. *PRL* 107: 124502, 2011.

[6] Madsen, P. A., Bingham, H., Liu, H. A New Boussinesq Method for Fully Nonlinear Waves from Shallow to Deep water. *J. Fluid Mech.* 462:1-30, 2002.

[7] Wang B., Liu H. Solving a Fully Nonlinear Highly Dispersive Boussinesq Model with Mesh-less Least Square-based Finite Difference Method. *Intern. J. for Numerical Methods in Fluids* 52:213–235, 2006.

[8] Megawati K., Shaw F., *et al.* Tsunami Hazard from the Subduction Megathrust of the South China Sea: Part I. Source characterization and the resulting tsunami. *Journal of Asian Earth Sciences*, **36 (1)**:13-20, 2009.