CENTER FOR MARINE AND OCEAN - ATMOSPHERE INTERACTION RESEARCH

Vietnam Institute of
Meteorology, Hydrology and Environment

Numerical Simulation of Tsunami Propagation and Runup: Case study on the South China Sea

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OBJECTIVES

1) Develop a Numerical Model for Simulation of Long Wave Propagation and Run up on beaches

2) Test the Model with Laboratory experimental data

3) Simulation of Tsunami on the South China Sea

MODEL

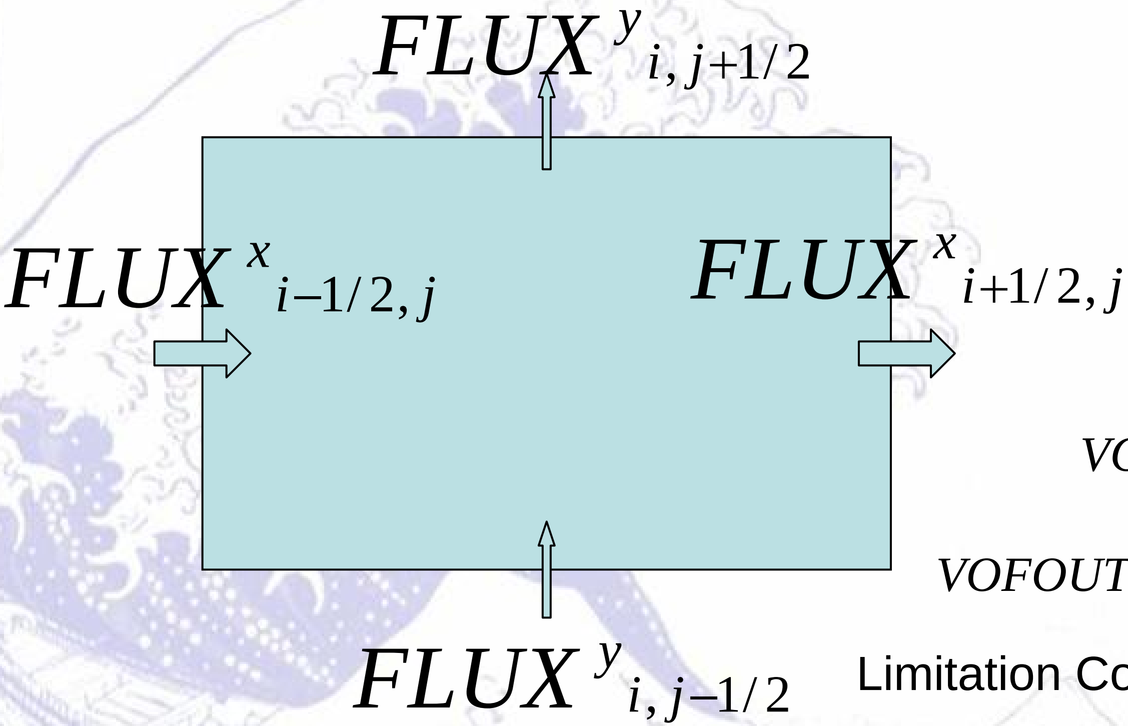
OKADA MODEL:
(Tsunami generation)

Shallow Water Equation
Finite Volume Method
(Godunov-type Second order)

+ (Splitting + VOF technique)

Boussinesq Term
(Madsen et al., 1997)
Finite Difference Method

VOF – Like Technique



$$VOF = (h+\eta)\Delta x \Delta y$$

$$VOFOUT = FLUX^{x}_{i+1/2,j} + FLUX^{y}_{i,j+1/2}$$

Limitation Coefficient (if **VOFOUT**>**VOF**)

$$C_l = \frac{VOFOUT}{VOF}$$

$$FLUX^{x}_{i+1/2,j} = FLUX^{x}_{i+1/2,j} / C_l$$

$$FLUX^{x}_{i,j+1/2} = FLUX^{x}_{i,j+1/2} / C_l$$

Need to adjust the outgoing fluxes

Calculation of Numerical Fluxes

1) Godunov method: HLL (Harten, Lax and Vanleer) Rieman Solver for Calculation of Numerical Fluxes at cell Interfaces of Shallow water Equation (Torro, 1999);
2) Muscl-Hancook method and Roe Limiter to get the second order of accuracy in space and time (Toro, 1999);
3) Crank-Nicholson Scheme of the Finite difference method for the Boussinesq Term

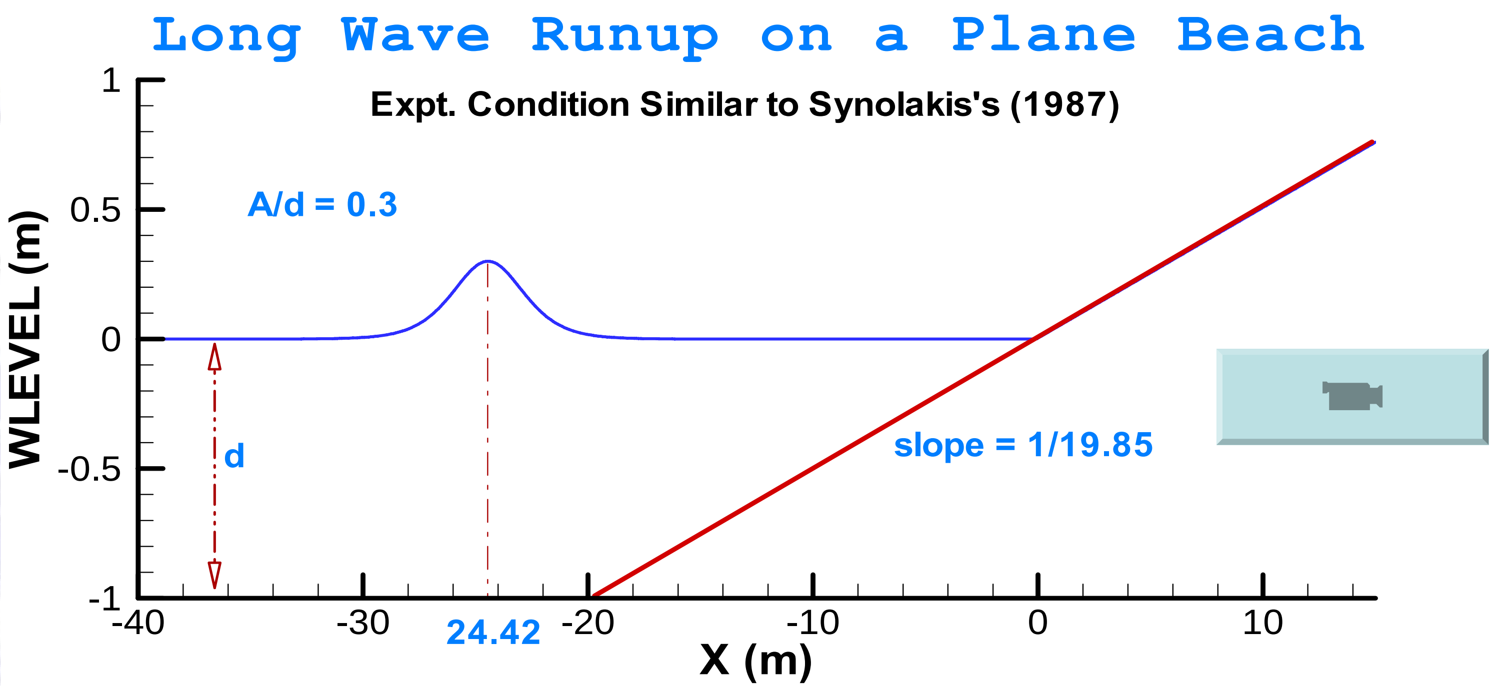
MODEL TEST:

TEST 1: Solitary Wave Run up on a Plane Beach (Synolakis's Exp.,1987)

TEST 2: Shock Wave Run up on a non-uniform Beach

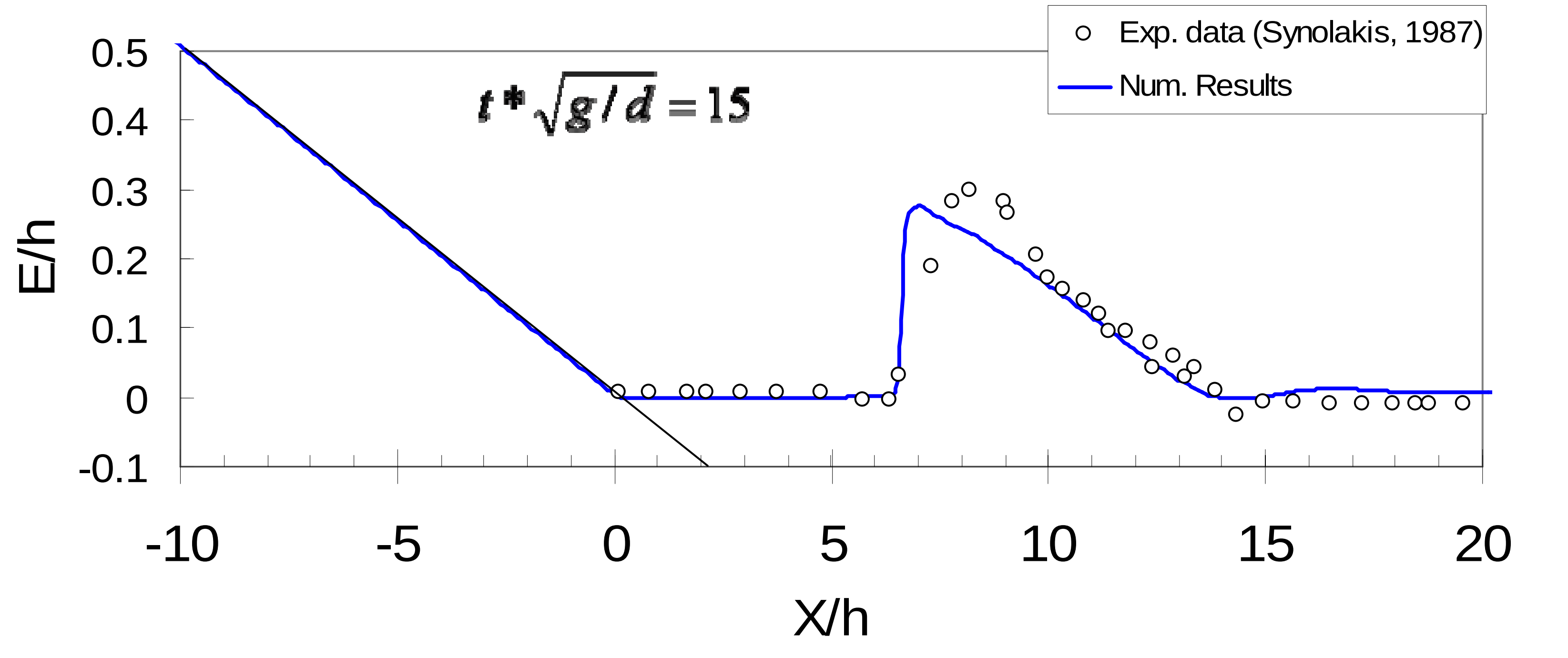
TEST 3: Solitary Wave run up on a Conical Island (Briggs et al.'s Exp, 1995)

TEST1: SOLITARY WAVE RUN UP ON A PLANE BEACH

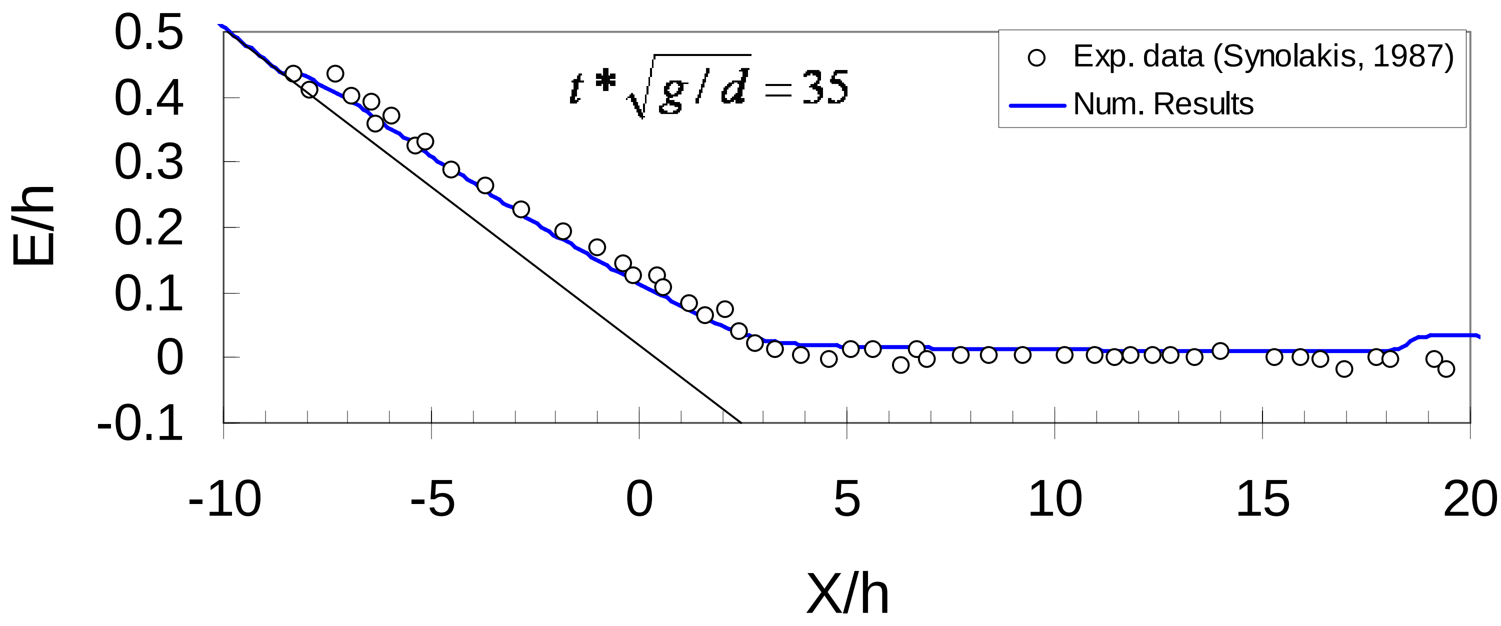


Experimental condition

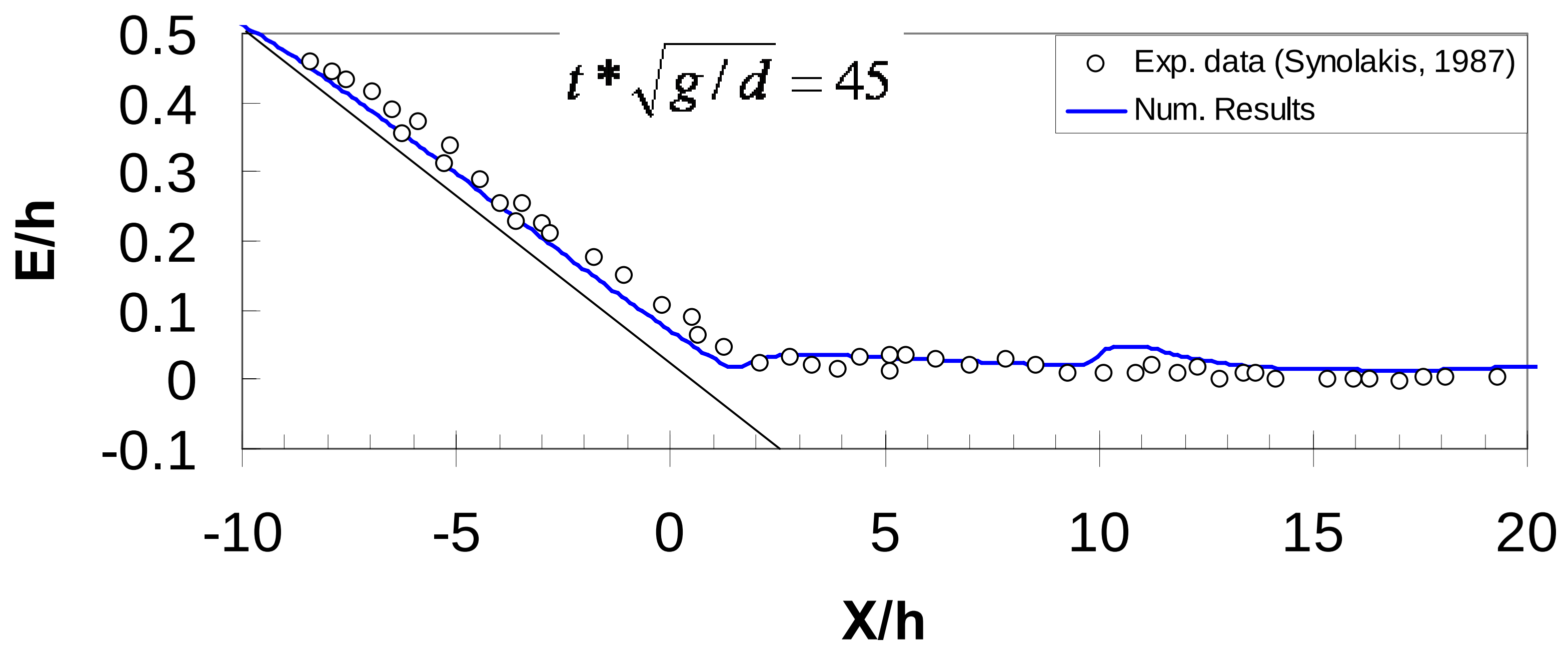
Test1 - Results: WATER SURFACE DISTRIBUTION



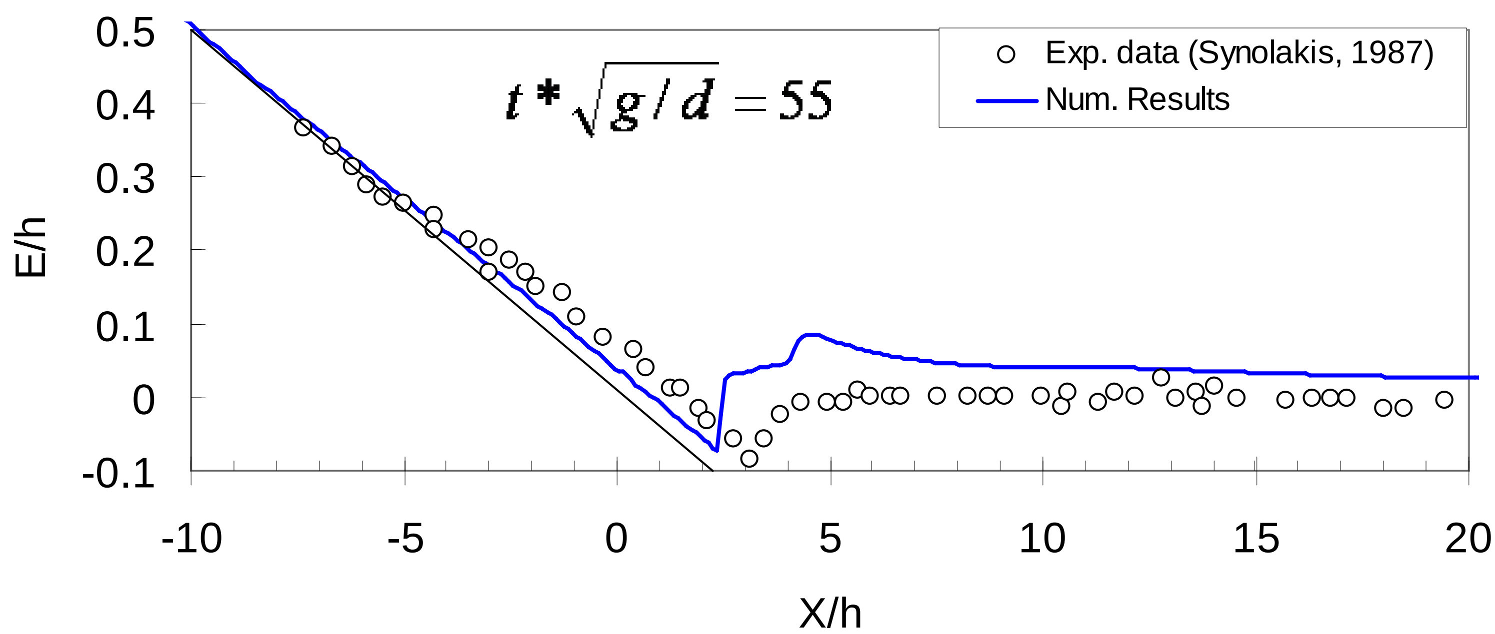
Test1 - Results: WATER SURFACE DISTRIBUTION



Test1 - Results: WATER SURFACE DISTRIBUTION

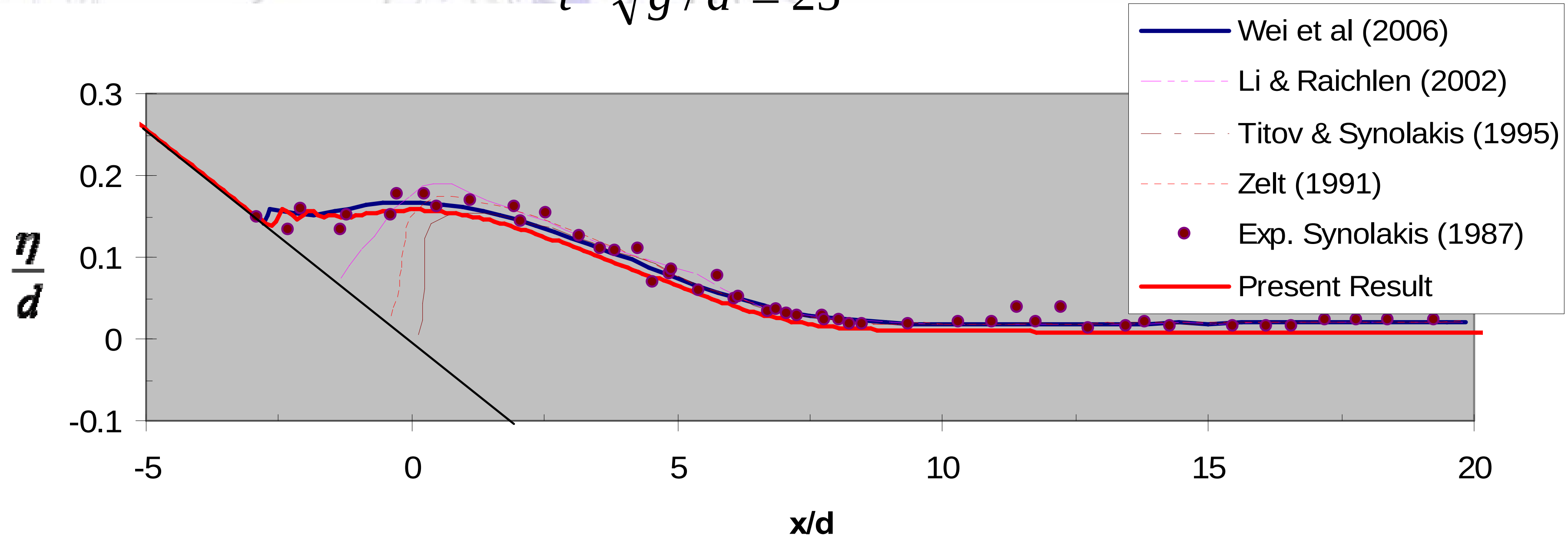


Test1 - Results: WATER SURFACE DISTRIBUTION



Test1 - Results: WATER SURFACE DISTRIBUTION

$$t * \sqrt{g/d} = 25$$

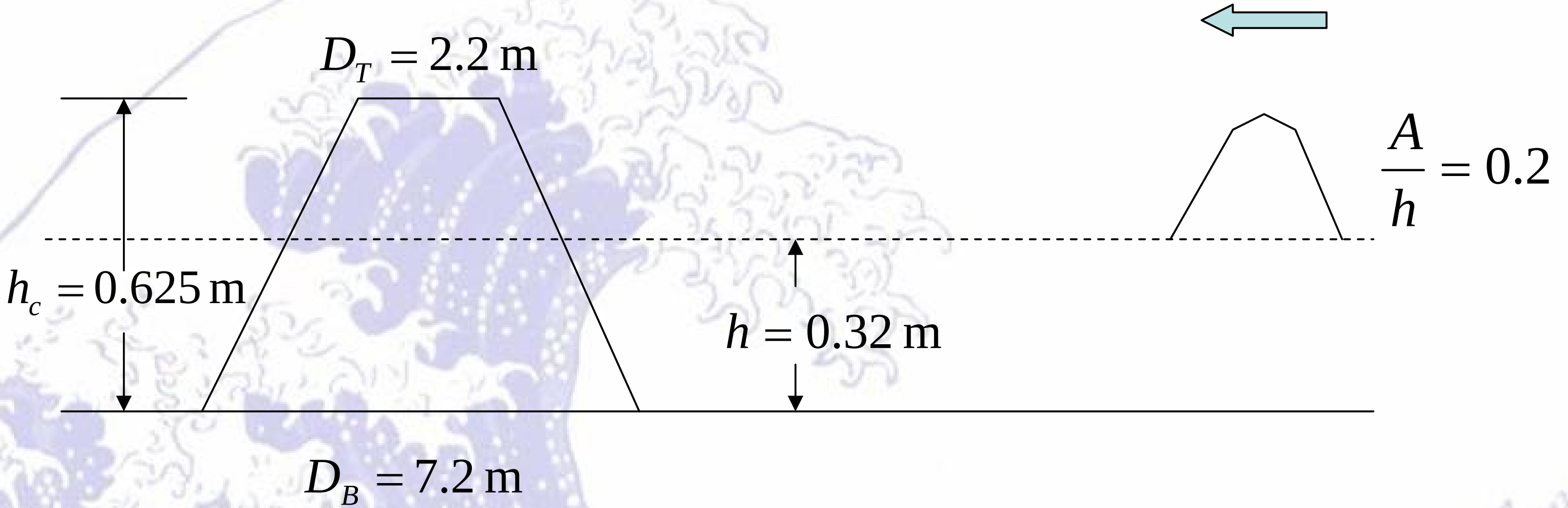


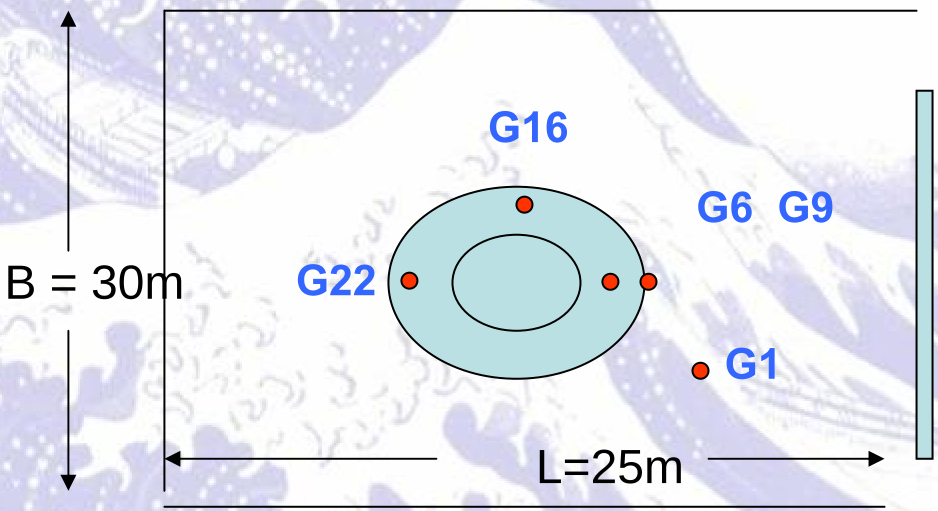
Comparison with other numerical results

Test2-Results: SHOCK WAVE RUN UP ON A NONUNIFORM BEACH

Results

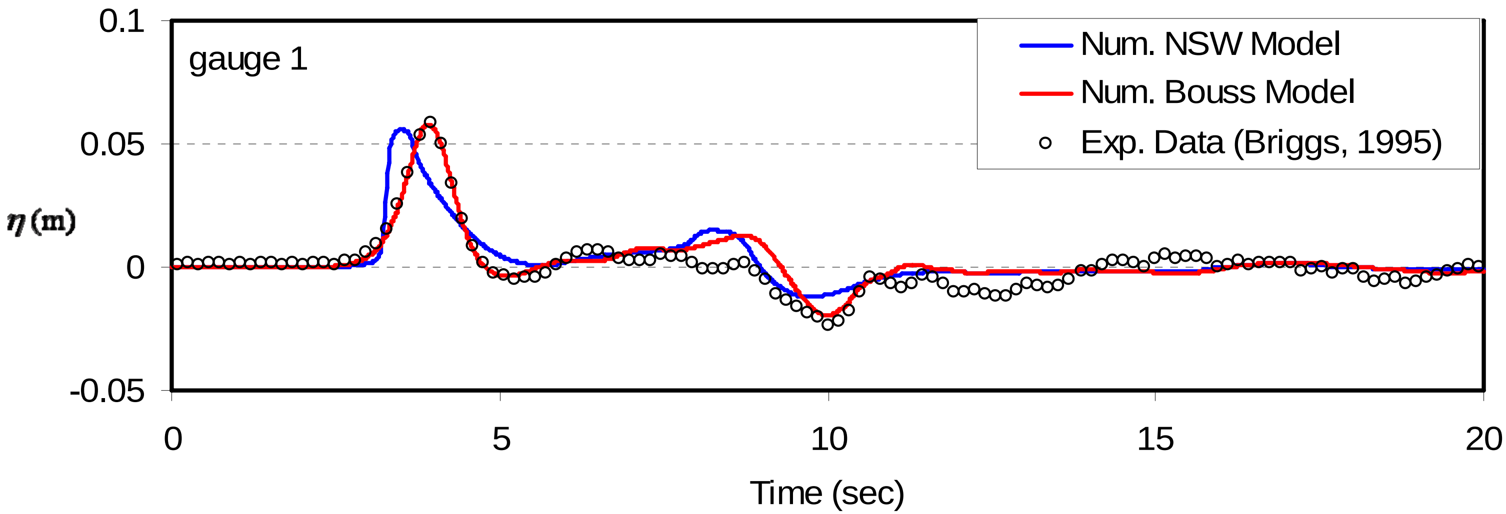
TEST3: SOLITARY WAVE RUN UP ON A CONICAL ISLAND (Briggs et al., 1995)

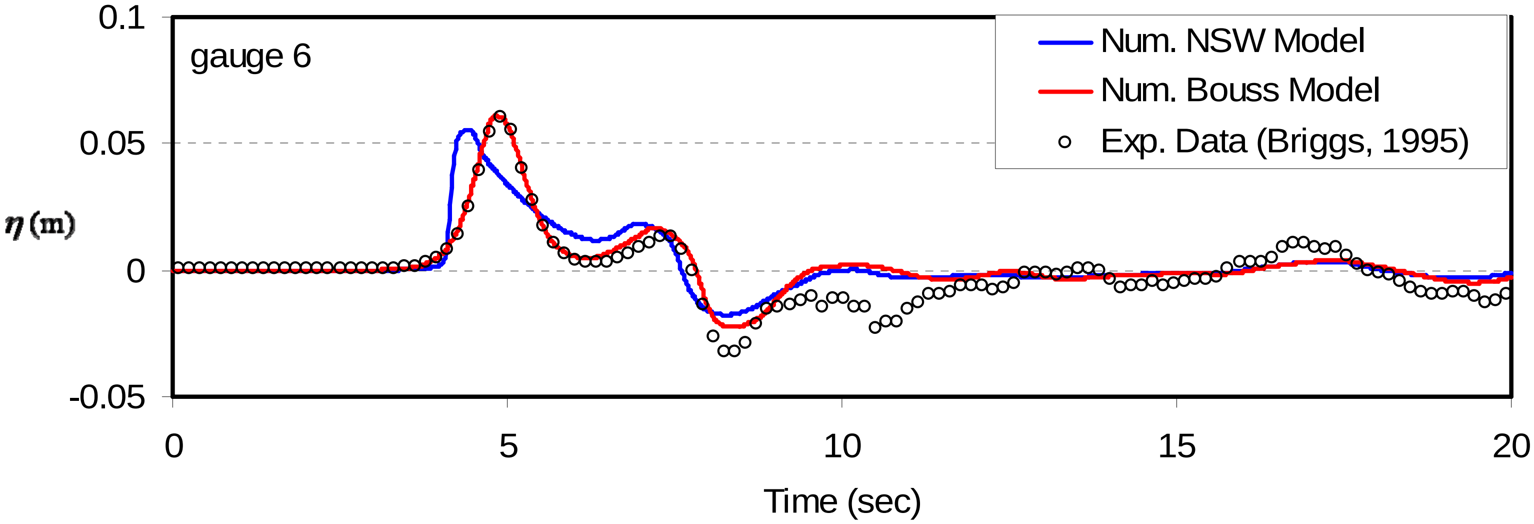




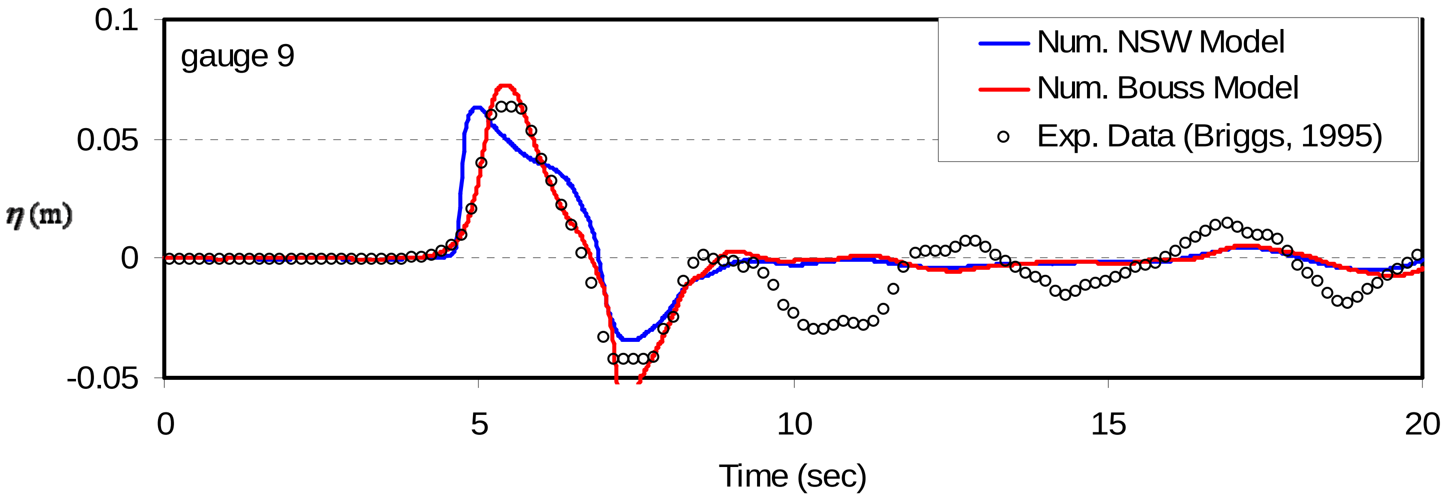
Schematic view of the experiment

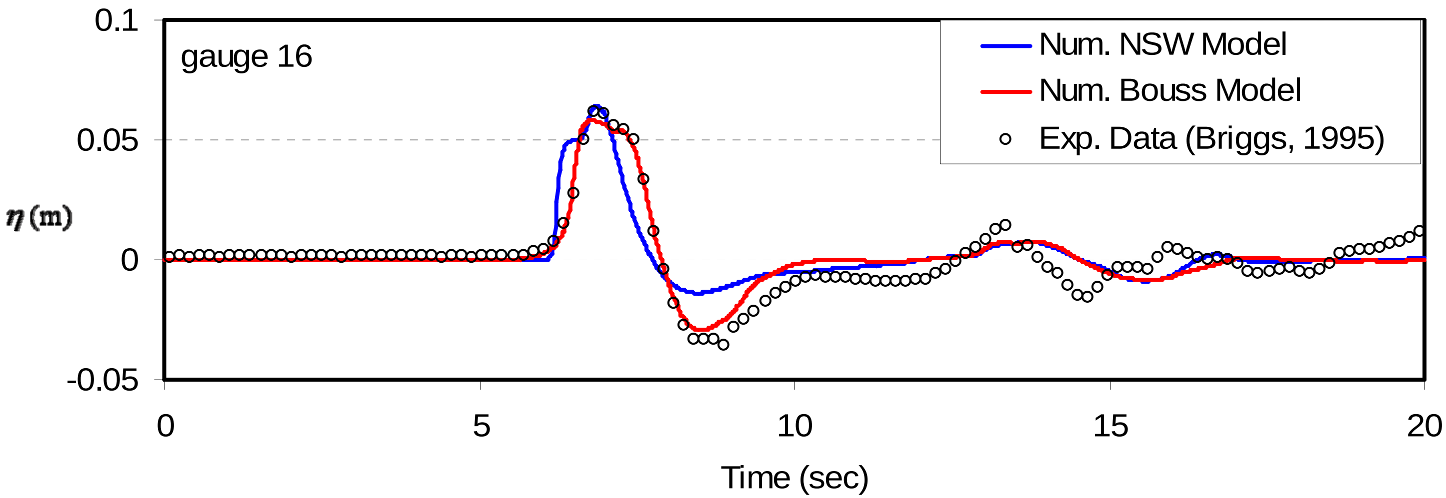
Test3-Results: WATER SURFACE ELEVATION



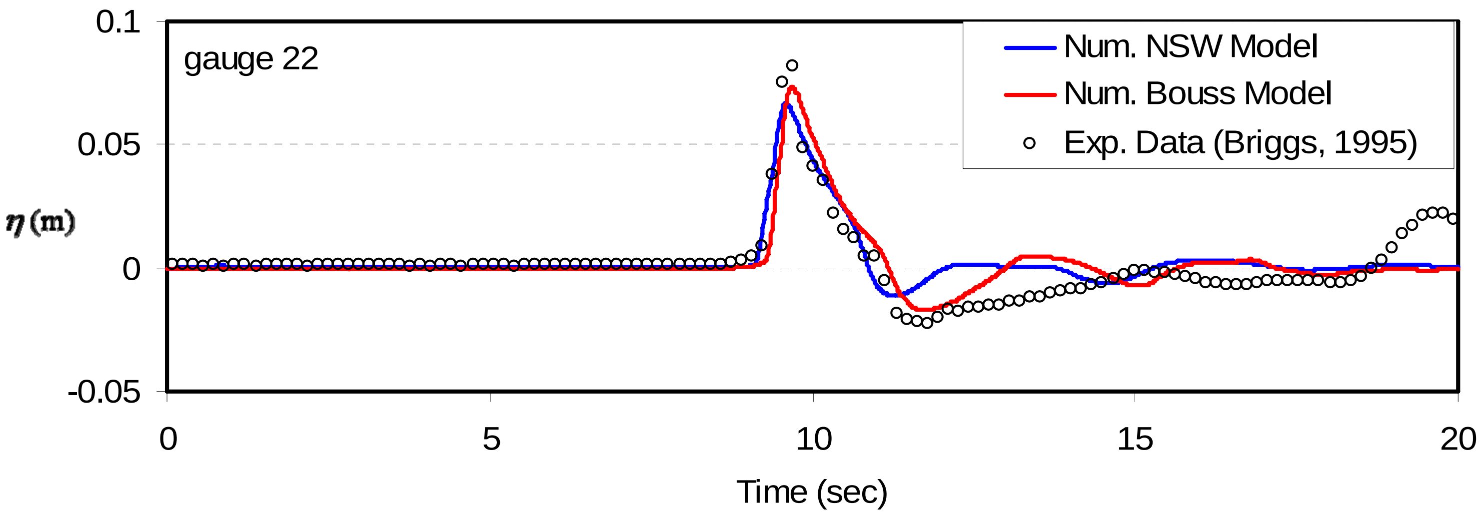


Test3-Results: WATER SURFACE ELEVATION

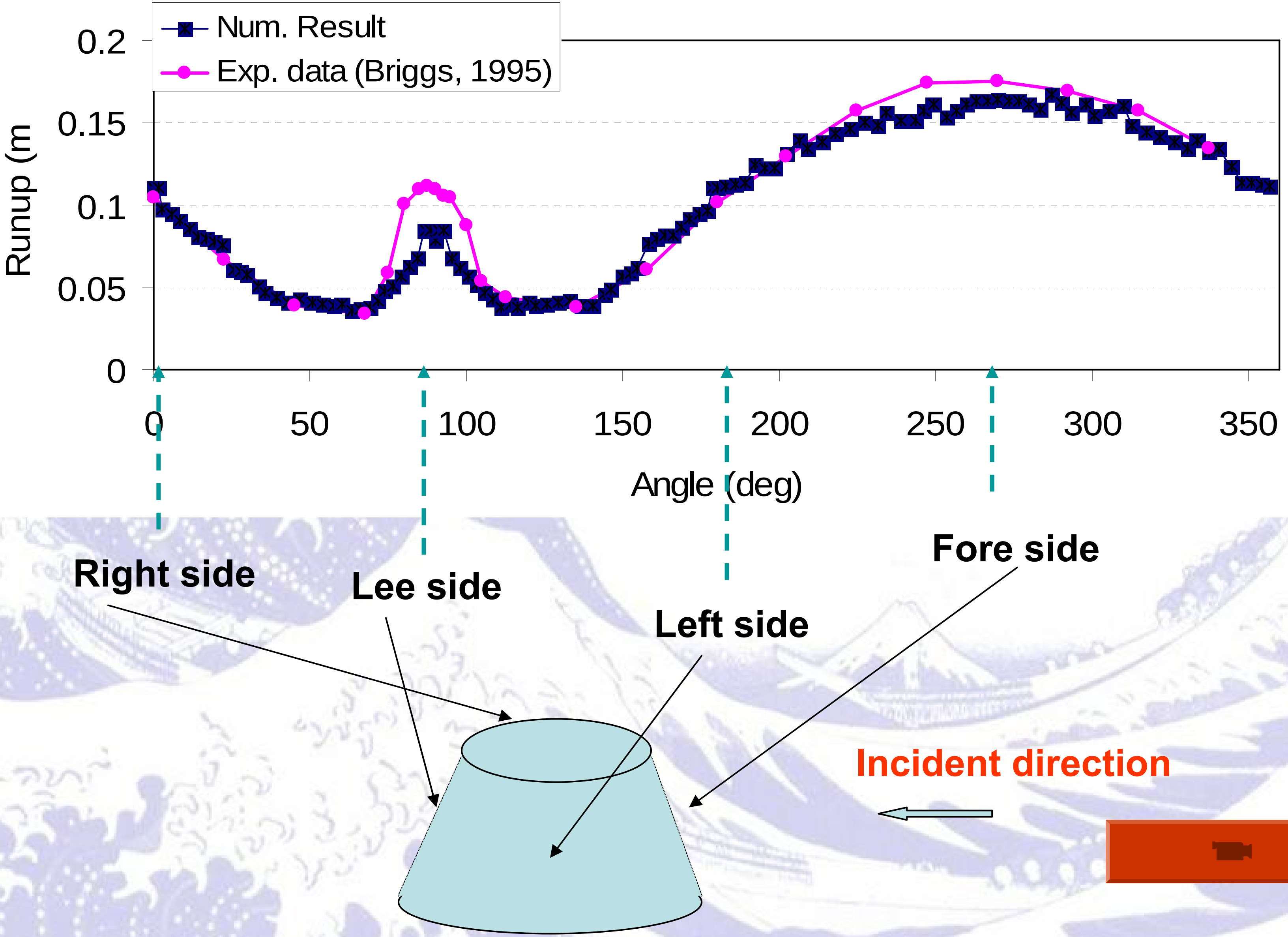




Test3-Results: WATER SURFACE ELEVATION



Test3-Results: Run up Height on Circular Island



Remarks

- The Numerical Model can simulate well the propagation of long wave and run up on a sloping beach;
- The Boussinesq Term added to the shallow water model can improve significantly simulated results for water surface elevation of long waves;
- The numerical model should be considered to the next step of verification with field case studies;

SIMULATION OF TSUNAMI ON THE SOUTH CHINA SEA

- Consider Earthquake with Magnitude M=8.5 at the Manila Trench;
- Consider Tsunami-Travel Time;
- Maximum Wave Height Distribution;

Simulation Condition

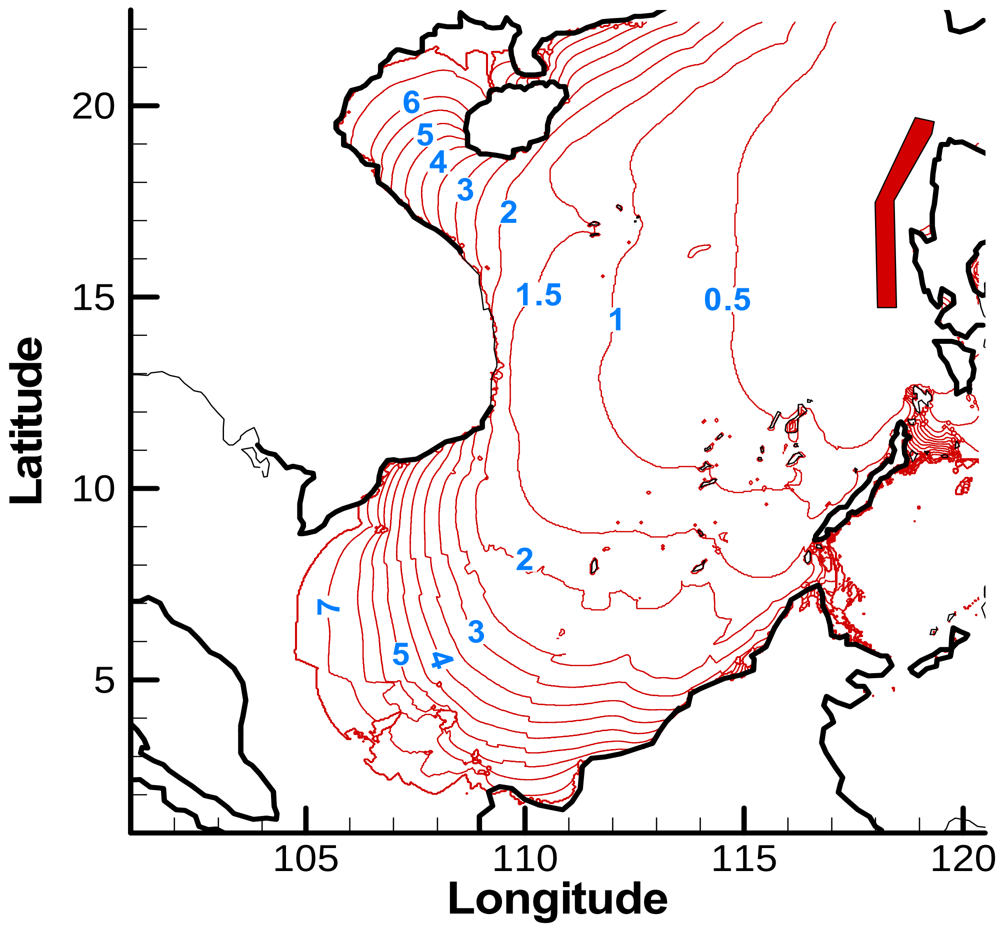
Topography: ETOPO 2

Mesh: Regular

Initial condition: OKADA Model (1985) with the earthquake parameters:

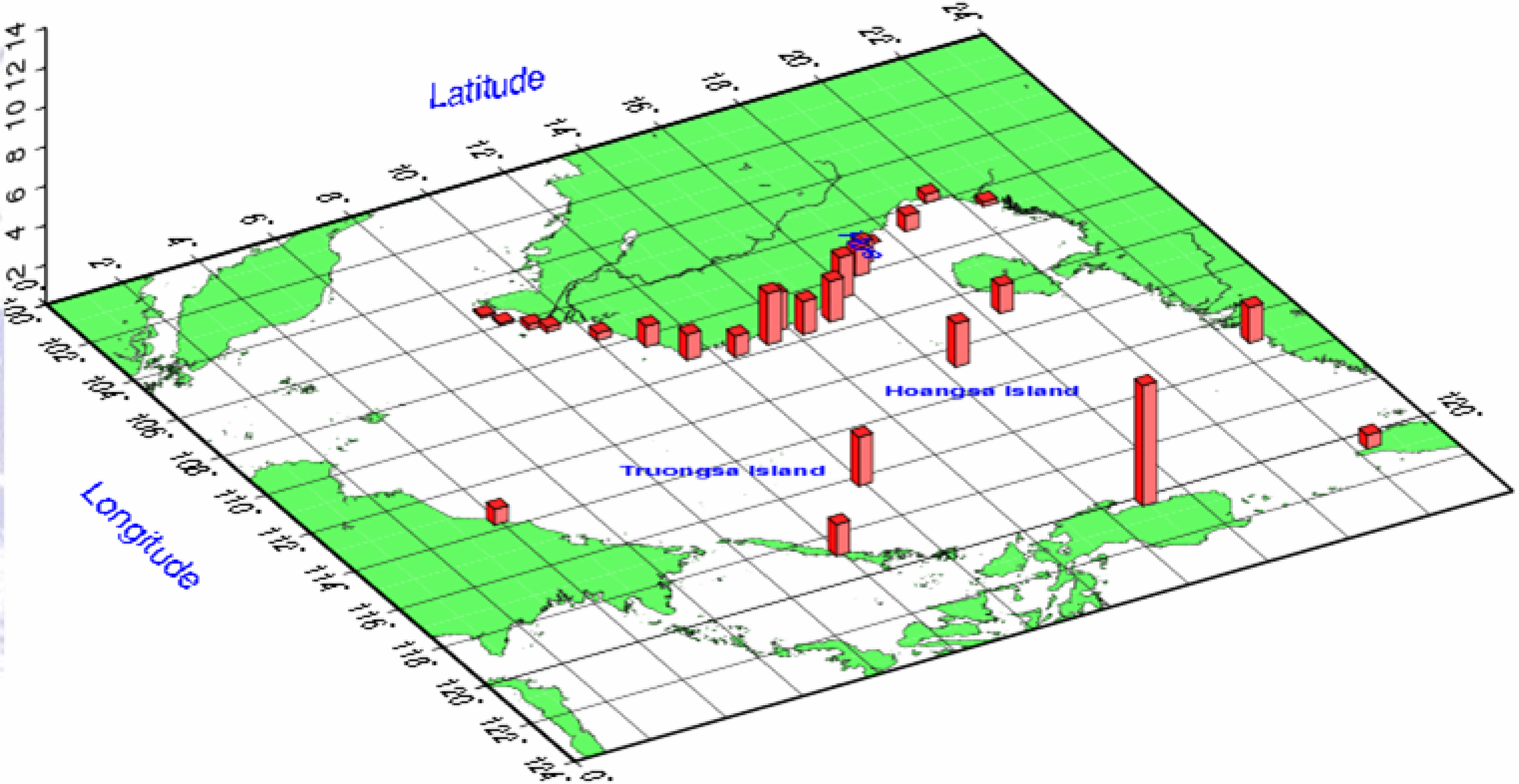
Scenarios	Magnitude	Strike (Deg)	Dip (Deg)	Rake (Góc trượt) (Deg)	Depth of Epicen tre (km)	Length of Fault (km)	Width of Fault (km)
1	8.5	177	15	90	18	313	68
2	9.0	87	15	90	24	646	101

Simulation Results: Travel Time

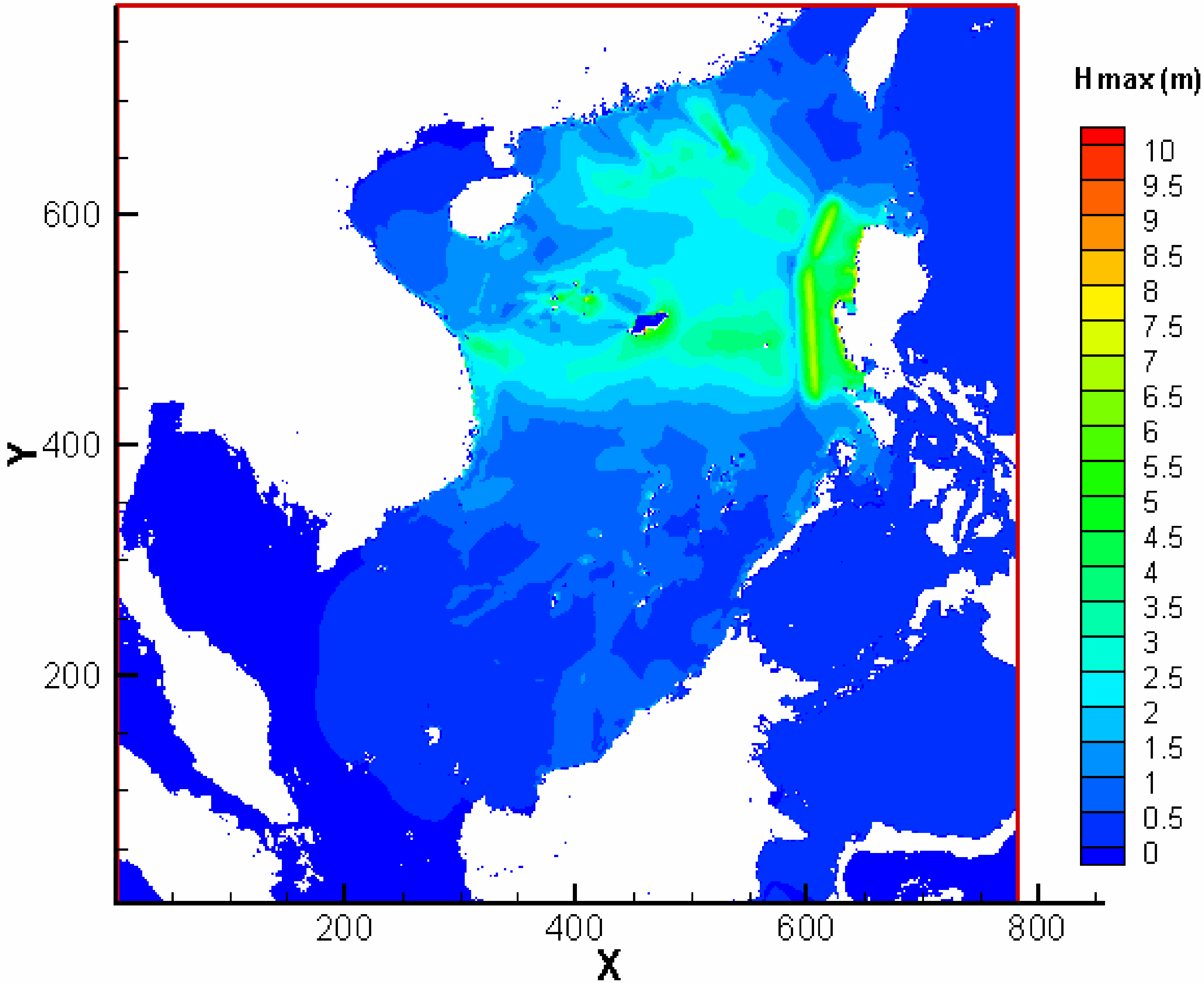


Simulation Results: Maximum Tsunami Height

M=8.5 at Manila Trench



Simulation Results: Maximum Tsunami Height Distribution



REMARKS

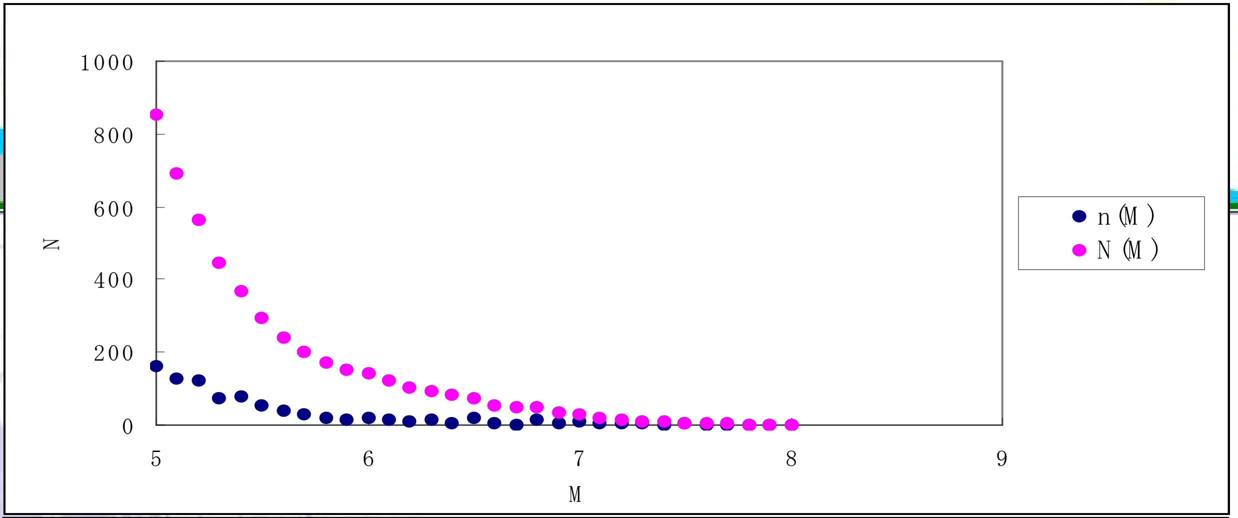
☺ **Boussinesq Equation is a good choice to improve simulation results for long wave propagation including tsunami;**

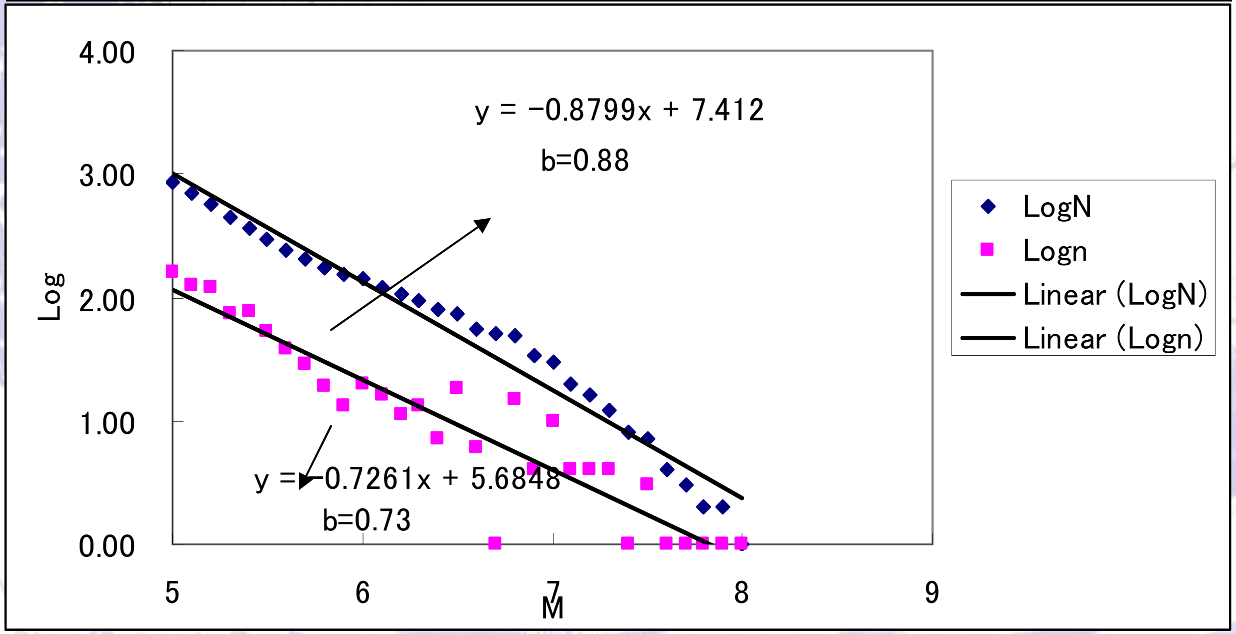
☺ **Tsunami travel time in the South China Sea is very short, only 20 minutes to reach the Taiwan Coast, 1.5 hours to Vietnam coast and immediately to Philippine Coast for the case of earthquake at the Manila Trench occurs;**

☺ **It is worth to build up maximum tsunami waning maps in advance before a real tsunami-earthquake occurs in the South China Sea in order to understand which area is potentially suffer from a destructive tsunami;**

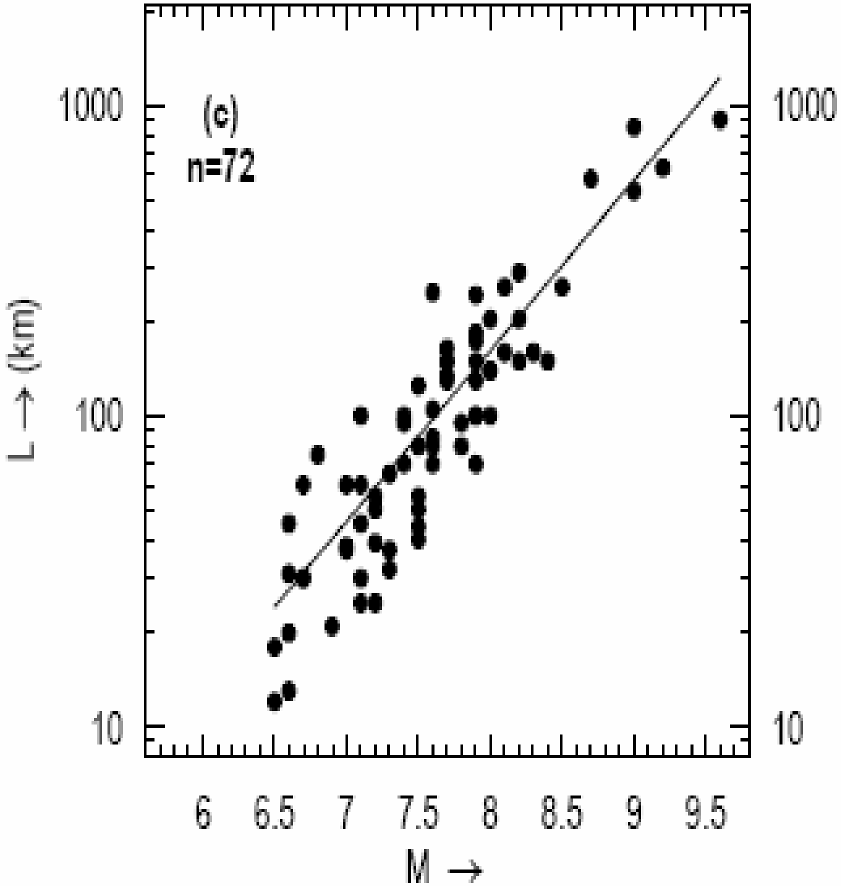
Thank you very much for your attention!

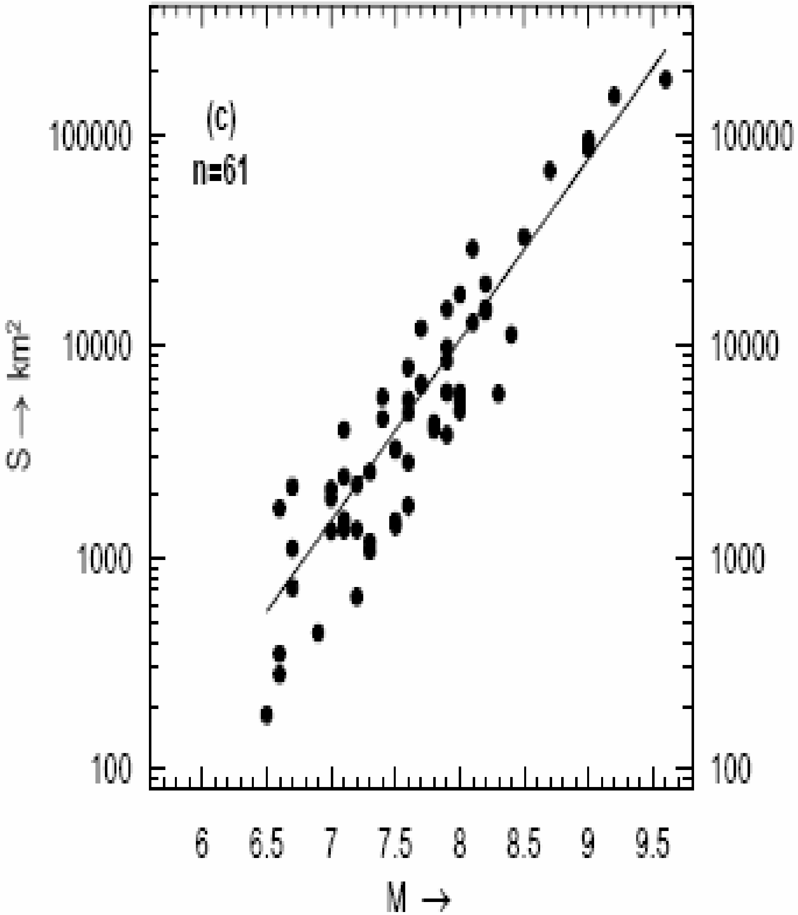
Mag	n(M)	N(M)	LogN	Logn
8	1	1	0.00	0
7.9	1	2	0.30	0
7.8	0	2	0.30	#NUM!
7.7	1	3	0.48	0
7.6	1	4	0.60	0
7.5	3	7	0.85	0.477121
7.4	1	8	0.90	0
7.3	4	12	1.08	0.60206
7.2	4	16	1.20	0.60206
7.1	4	20	1.30	0.60206
7	10	30	1.48	1
6.9	4	34	1.53	0.60206
6.8	15	49	1.69	1.176091
6.7	1	50	1.70	0
6.6	6	56	1.75	0.778151
6.5	18	74	1.87	1.255273
6.4	7	81	1.91	0.845098
6.3	13	94	1.97	1.113943
6.2	11	105	2.02	1.041393
6.1	16	121	2.08	1.20412
6	20	141	2.15	1.30103
5.9	13	154	2.19	1.113943
5.8	19	173	2.24	1.278754
5.7	29	202	2.31	1.462398
5.6	38	240	2.38	1.579784
5.5	53	293	2.47	1.724276
5.4	77	370	2.57	1.886491
5.3	74	444	2.65	1.869232
5.2	121	565	2.75	2.082785
5.1	127	692	2.84	2.103804
5	163	855	2.93	2.212188





(earthquake data from 1600-2005, 5.0<M<9.0)





LogL = 0.55M – 2.19,
6.7≤M≤9.3

LogS = 0.86M – 2.82
6.7≤M≤9.2

Relation between earthquake and rupture parameters