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Tsunami Inundation Simulation at the Yaene Port, Hachijo Island due to hypothetical South Sea of Japan Tsunami
일본남해의 가상지진에 의한 야에네항의 지진해일 범람시뮬레이션

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1. INTRODUCTION

The 2004 Indian Ocean earthquake was an undersea (subduction) earthquake that occurred on December 26, 2004, and damaged near the epicenter of the west coast of Sumatra, Indonesia and the opposite side of Indian Ocean. The moment magniude is estimated Mw=9.3 and it is almost same as the 1960s in Chile and Alaska. Such earthquake was not expected on the seismology.

The tectonic setting from the west-north of Japan to Ryukyu trench is very similar with the tectonic setting of Sumatra to Andaman Islands. relatively slow subduction is proceeded and a major slip fault is developed on islands in this region. And the half area has a back-arc basin with expanding axis. These affinity is not the evidence to cause similar massive earthquake, and the gigantic earthquake could not occur by the characteristic of these area in the traditional point of view. However, the gigantic earthquake can be occurred in any subduction area with very long interval (Furumoto, 2007).

Tokai-Nankai-Tonankai (east sea, south sea, east-south sea) hypothetical earthquake is a gigantic earthquake assumed that the 3 earthquake occur at less than 1 year. However the occurrence at the exact same time is possible. Fig. 2 shows the timeline of South Sea (Nankai), East-south Sea(Tonankai) and East Sea (Toaki) of Japan Earthquake. The return period is about 80 ~ 150 year, the theory of 200 year is exist also. The expected earthqake is the maximum magnitude of 8.7, and it will be one of the strongest earthqake.

This research simulated the hypothetical tsunami expected in the South Sea of Japan, and its focused inundation to the Yaene Port, Hachijo Island (Fig.3) using 2-D mode of Princeton Ocean Model (Mellor, 2003).

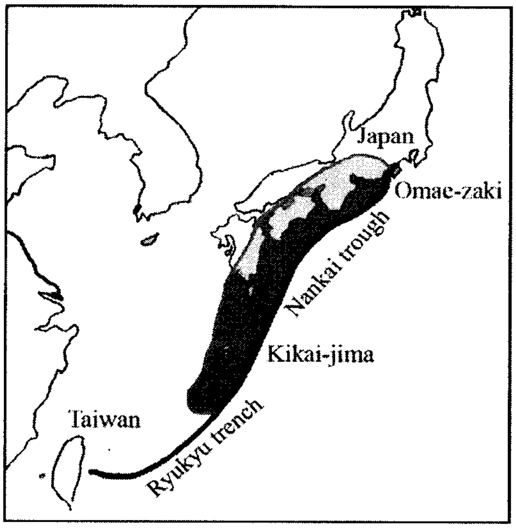

Fig. 1. The source region of the presumed hyper earthquake.

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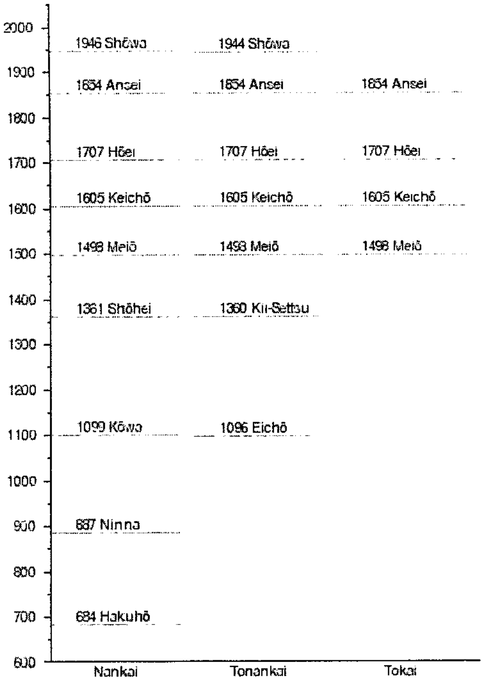

Fig. 2. Timeline of South Sea (Nankai), East-south Sea (Tonankai) and East Sea (Toaki) of Japan Earthquake. (Wikipedia)

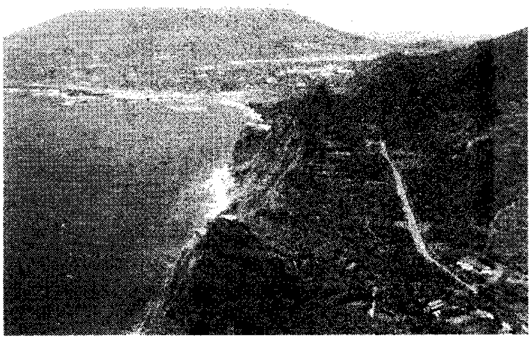

Fig. 3. Photo of Yaene Port, view from south

2. NUMERICAL SIMULATION

A finite difference method is applined to equations of fluid dynamics to simulate tsunami waves generated on the Nankai Trough in the North Pacific Ocean. The sytem of partial differential equations analyzed in this paper consists of a continuity equation and equations of motion. The surface elevation can be written as

$$\frac{\partial \eta}{\partial t}+\frac{\partial UD}{\partial x}+\frac{\partial VD}{\partial y}=0. \tag{1}$$

the momentum equations become

$$\begin{aligned}&\frac{\partial \overline{U}D}{\partial t}+\frac{\partial \overline{U^2}D}{\partial x}+\frac{\partial \overline{U}\,\overline{V}D}{\partial y}-\widetilde{F}_x-f\overline{V}D+gD\frac{\partial \eta}{\partial x}=\\&-<wu(0)>+<wu(-1)>+G_x\\&-\frac{gD}{\rho_0}\int_{-1}^{0}\int_{\sigma}^{0}\left[D\frac{\partial \rho'}{\partial x}-\frac{\partial D}{\partial x}\sigma'\frac{\partial \rho'}{\partial \sigma}\right]d\sigma' d\sigma,\end{aligned} \tag{2}$$

$$\begin{aligned}&\frac{\partial \overline{V}D}{\partial t}+\frac{\partial \overline{U}\,\overline{V}D}{\partial x}+\frac{\partial \overline{V^2}D}{\partial y}-\widetilde{F}_y-f\overline{U}D+gD\frac{\partial \eta}{\partial y}=\\&-<wv(0)>+<wv(-1)>+G_y\\&-\frac{gD}{\rho_0}\int_{1}^{0}\int_{\sigma}^{0}\left[D\frac{\partial \rho'}{\partial y}-\frac{\partial D}{\partial y}\sigma'\frac{\partial \rho'}{\partial \sigma}\right]d\sigma' d\sigma.\end{aligned} \tag{3}$$

The quantities and are defined according to

$$\widetilde{F}_x=\frac{\partial}{\partial x}\left[H2\overline{A_M}\frac{\partial \overline{U}}{\partial x}\right]+\frac{\partial}{\partial y}\left[H\overline{A_M}\left(\frac{\partial \overline{U}}{\partial y}+\frac{\partial \overline{V}}{\partial x}\right)\right] \tag{4}$$

$$\widetilde{F}_y=\frac{\partial}{\partial y}\left[H2\overline{A_M}\frac{\partial \overline{V}}{\partial y}\right]+\frac{\partial}{\partial x}\left[H\overline{A_M}\left(\frac{\partial \overline{U}}{\partial y}+\frac{\partial \overline{V}}{\partial x}\right)\right]. \tag{5}$$

The so-called dispersion terms are defined according to

$$G_x=\frac{\partial \overline{U}^2D}{\partial x}+\frac{\partial \overline{U}\,\overline{V}D}{\partial y}-\widetilde{F}_x-\frac{\partial \overline{U^2}D}{\partial x}-\frac{\partial \overline{UV}D}{\partial y}+\overline{F_x} \tag{6}$$

$$G_y=\frac{\partial \overline{U}\,\overline{V}D}{\partial x}+\frac{\partial \overline{V}^2D}{\partial y}-\widetilde{F}_y-\frac{\partial \overline{UV}D}{\partial x}-\frac{\partial \overline{V^2}D}{\partial y}+\overline{F_y}. \tag{7}$$

Fig. 3 show the 8 domains (domain A to domain H) of numerical simulation with one-way nesting system. The largest domain, domain A, has 716 x 498 mesh system with 1.28 km grid resolution, and time step of 1.2 sec. The sub-domains are nested in 1:2 grid interpolation. The smallest domain, domain H, has 144 x 170 mesh system with 10 meters grid resolution, and time step of 0.005 sec. Also domain H runs the inundation mode using the Wet-and Dry scheme by Oey (2005). Fig.4 shows the location of each domains, and Table 1 shows the information of grid and nesting system on all domains.

Table 1. Nesting and grid information

	A	B	C	D	E	F	G	H
NX	716	142	126	172	192	136	124	144
NY	498	224	126	152	228	148	180	170
DX	1280	640	320	160	80	40	20	10
DT	1.2	1.2	0.6	0.3	0.1	0.05	0.02	0.005

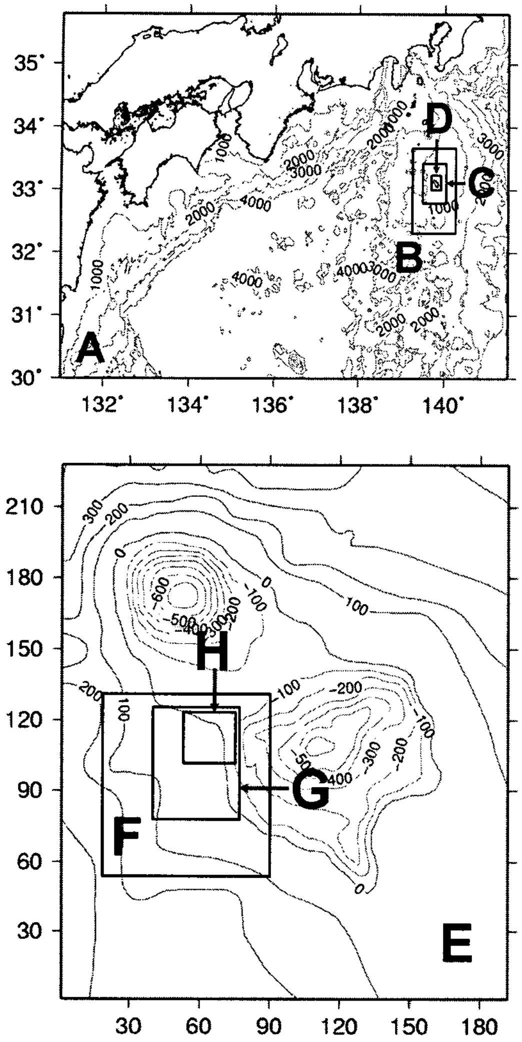

Fig. 4. Nesting grid system and water depth (negative value indicates elevation) for the South Sea of Japan

3. RESULTS

Fig. 5~8 show the snapshots of tsunami simulation result of domain A at 0, 5, 10 and 30 minutes later. The first image shows the initial surface profile of Tokai-Nankai-Tonankai hypothetical earthquake. The first tsunami wave reaches to Hachijo Island near 30 minutes but not reaches to Osaka, more closed from eruption area. Fig. 9~10 show the snapshots of tsunami inundation result in domain H at 30 and 32 minutes later. The initial water area is shown by blue shade, and the inundated area is shown by red in Fig. 11. Also black contours show maximum water elevations. The maximum water elevation on the barrier is over the 4 meters but the maximum water elevation in the port is about 3.8 meters. The issued point for inundation is the north area of central port (position about X=100 and Y=127). In this simulation it can be said that this area is safe on the Tokai-Nankai-Tonankai hypothetical earthquake.

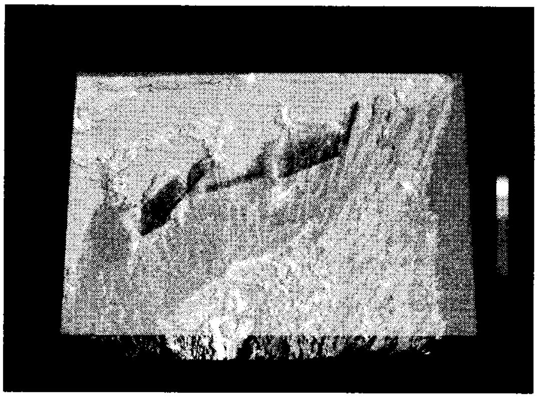

Fig 5. Sea surface elevation of domain A at t=0 min. Same as the initial condition)

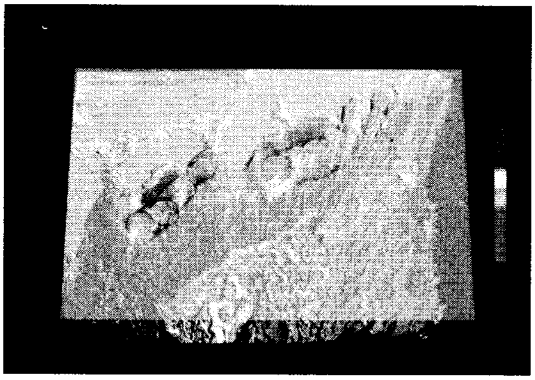

Fig 6. Sea surface elevation of domain A at t=5 min.

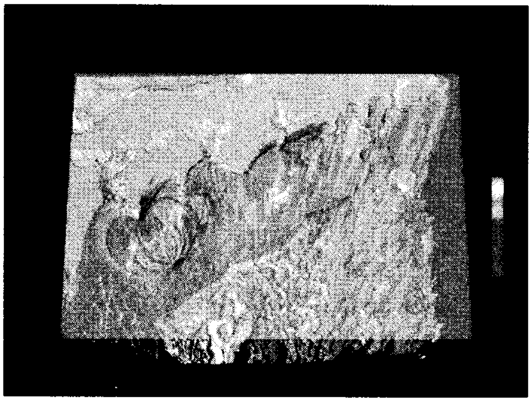

Fig. 7. Sea surface elevation of domain A at t=10min.

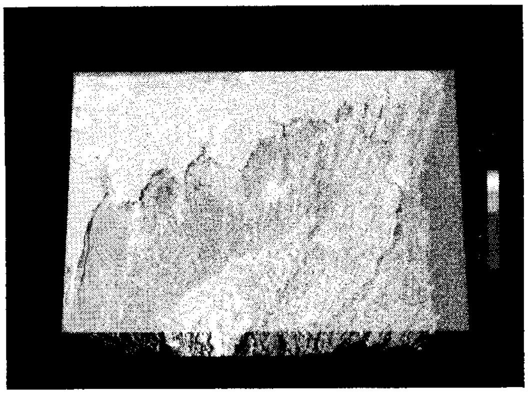

Fig. 8. Sea surface elevation of domain A at t=30min

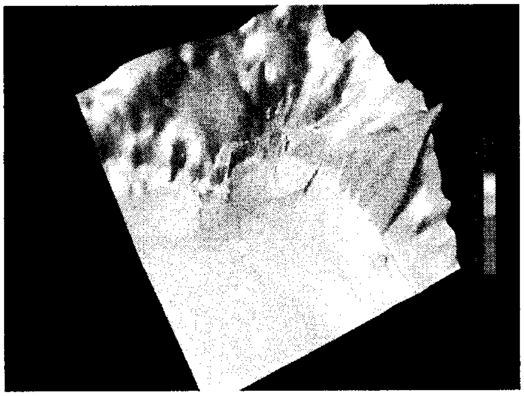

Fig. 9. Sea surface elevation of domain H at t=30 min

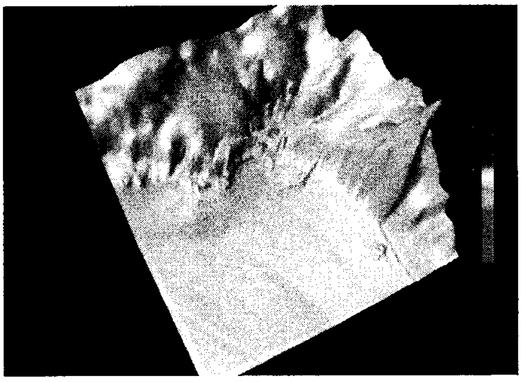

Fig. 10. Sea surface elevation of domain H at t=32 min

4. CONCLUSION

Tokai-Nankai-Tonankai (east sea, south sea, east-south sea of Japan) tsunami is the worst scenario when three earthquakes occur at the exact same time. These earthquakes are occurred within 1 year until now and the occurrence at the exact same time is possible.

This research simulated the hypothetical tsunami expected in the South Sea of Japan, and its focused inundation to the Yaene Port, Hachijo Island.

The first tsunami wave reaches to Hachijo Island near 30 minutes by simulation. The maximum water elevation on the barrier is over the 4 meters but the maximum water elevation in the port is about 3.8 meters. There is not so severe problems inside of port but wave is computed over the 4 meters in the barrier.

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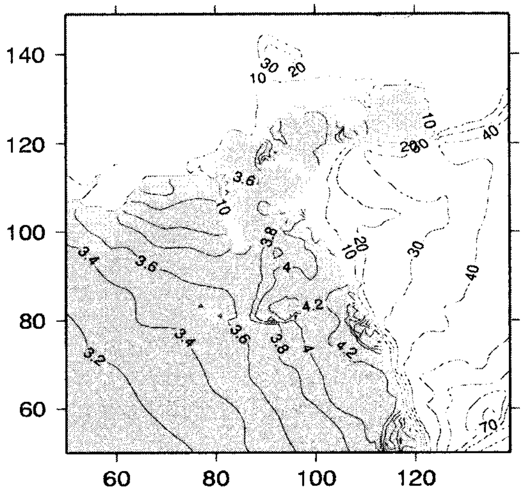

Fig. 11. Initial water area (blue) and inundated area (red). Black contours show maximum water elevations and red contours show land elevations.