II－85 Numerical simulation of 2003 Tokachi earthquake tsunami and its current

Tohoku University Student member ○ Angela SANTOS
Tohoku University Member Fumihiko IMAMURA

1. Introduction

At 4:50 AM on the 26th September 2003 Mw 8.0 earthquake occurred at the Southwestern end of the Kuril Trench offshore Hokkaido [1]. It was followed by a tsunami that was observed at the tide gauges stations in Hokkaido and Tohoku regions. The maximum tsunami height was 4m [2] at the east of Cape Erimo. The epicenter was located at 144.64°E and 42.05° N and is represented in figure 1 by the star.

The objective of this paper is to calculate the water level history and the two components of the horizontal velocities in several stations.

2. Initial conditions

The study area is shown in figure 1, which includes the Pacific Ocean's bathymetric data near Hokkaido and Northern Honshu. The lower left corner corresponds to the geographical coordinates of 38°N, 140°E, and the upper right of 43.5°N, 146°E. This corresponds to a distance of 500 km in longitude and 611 km in latitude.

The tsunami was registered at several tide gauge stations along the Pacific Coast of Japan. However, in this study only three stations are considered: Tokachi River (#1), Tomakomai (#2) and Kuji (#3). They were chosen because these stations have records of the water level history as well as the velocities. For the first time in a tsunami event is possible to compare calculated and measured velocities.

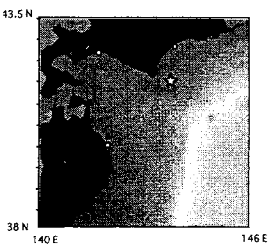

Fig. 1: Location of the three chosen stations in the study area: Tokachi River (#1), Tomakomai (#2) and Kuji (#3). The star represents the epicenter of the earthquake.

The Mansinha and Smylie Theory (1971) was used to calculate the initial sea surface displacement of the tsunami. The fault parameters of the earthquake are: fault length, L=31km; fault width, W=30km; strike angle, TH=230°; dip angle, DL=23°; slip angle, RD=114°; depth, HH=15.7km [3].

For the other hand, the dislocations for the non-uniform fault are (in meters): D1=3.0, D2=2.0, D3=3.0, D4=4.0, D5=5.0, D6=4.0, D7=1.0, D8=4.0, D9=4.0. In figure 2 is represented the location of each of these sub-faults.

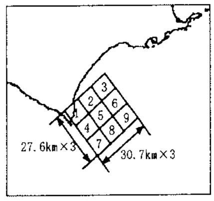

Fig. 2: Location of non-uniform fault for the 2003 Tokachi earthquake [3].

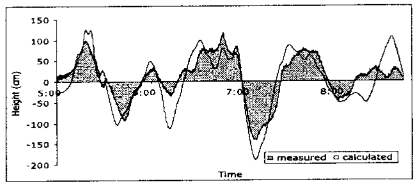

Fig. 3: Water level at Tokachi River station.

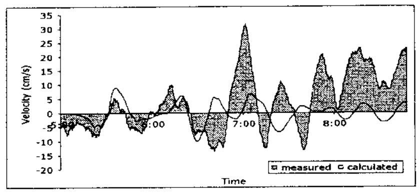

Fig. 4: Long-shore velocity at Tokachi River Station.

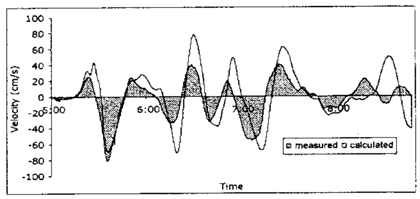

Fig. 5: Off-shore velocity at Tokachi River Station.

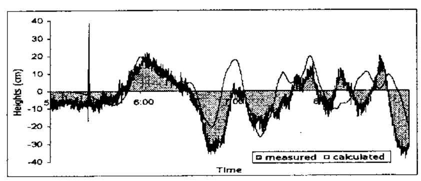

Fig. 6: Water level at Tomakomai Station.

3. Numerical model

The numerical simulation of the 2003 Tokachi tsunami based on the Non-Linear Shallow Water Equations [2] with a stage leap-frog scheme. It was considered a 501 m mesh size and a time step of 1s. The set of equations (1) - (3) are the mass equation and the momentum equations in the x and y directions.

In equations (1) to (3), M and N are the discharges fluxes in x and y directions, η is the sea surface displacement, D is the ocean's depth, g is the gravity acceleration and n is the Manning's roughness.

$$\frac{\partial \eta}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0 \quad (1)$$

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left(\frac{M^2}{D}\right)+\frac{\partial}{\partial y}\left(\frac{MN}{D}\right)+gD\frac{\partial \eta}{\partial x}+\frac{gn^2}{D^{7/3}}M\sqrt{M^2+N^2}=0 \quad (2)$$

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}\left(\frac{MN}{D}\right)+\frac{\partial}{\partial y}\left(\frac{N^2}{D}\right)+gD\frac{\partial \eta}{\partial y}+\frac{gn^2}{D^{7/3}}N\sqrt{M^2+N^2}=0 \quad (3)$$

4. Results

All the data was downloaded from the web site from Harbor and Airport Research Institute http://infosv2.pari.go.jp/bsh/ky-skb/kaisho/report/2003toka_j/2003toka_j.htm.
The stations belong to the newly developed Doppler-type Wave Directional Meter, which is the principle seabed installed gauge of the Nationwide Ocean Wave information network for Ports and Harbors [4]. This system is capable to obtain continuous sea-surface fluctuation, seabed pressure and two components of horizontal velocities [4] at Tokachi (23 m in deep), Tomakomai (50 m) and Kuji (50 m).

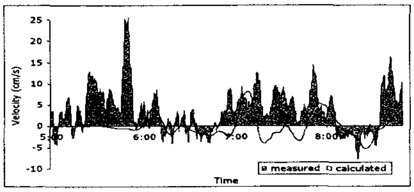

Fig. 7: Long-shore velocity at Tomakomai Station.

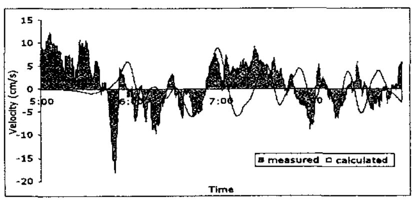

Fig. 8: Off-shore velocity at Tomakomai Station.

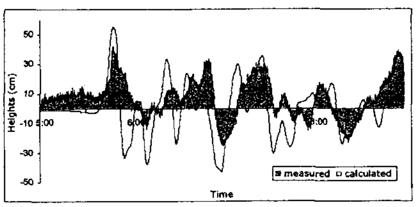

Fig. 9: Water level at Kuji Station.

Figures 3 to 11 show the results of the simulation in the three considered stations. The best results are at Tokachi River Station, for the water level (figure 3) and shore velocity (figure 5). The worst result was obtained at Kuji Station, where none of the calculated parameters are similar to the data. At Tomakomai station the water level has good agreement only in the first 2 hours.

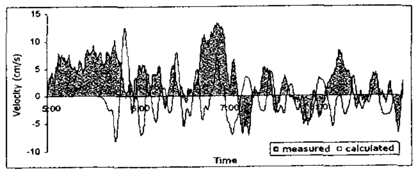

Fig. 10: Long-shore velocity at Kuji Station.

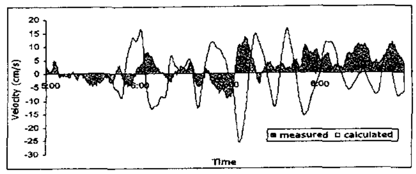

Fig. 11: Off-shore velocity at Kuji Station.

5. Conclusion

At Tokachi River Station there is a good agreement between measured and calculated water level for almost the 4 hours of computational time. This suggests that the initial tsunami source is correct. For the off-shore velocity it was also found good results, especially for the first 2 hours. On the other hand, at Tomakomai Station only the computed water level has some agreement with the data. At Kuji station none of the calculated values coincide with data.

A better knowledge of the data could allow a statistical treatment to get a filter to eliminate some noise. This could give better results especially in figures 6 to 10. Related to the velocity, maybe a finer mesh size could give better results. For example, using 100 m, instead of the actual 501 m.

References

[1] Hirata, K., Y. Tanioka, K. Satake, S. Yamaki, and E.L. Geist (2004): The tsunami source area of the 2003 Tokachi-oki earthquake estimated from tsunami travel times and its relationship to the 1952 Tokachi-oki earthquake, EARTH, PLANETS AND SPACE, vol. 56, no.3, pp. 367-372.

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[3] Ohgaki, K. and Imamura, F. (2004): Numerical analysis of the 2003 Tokachi-earthquake tsunami to understand its characteristics using field data, ANNUAL JOURNAL OF COASTAL ENGINEERING, JSCE, vol. 51(1) p271-275

[4] Nagai, T. and Ogawa, H., (2004): Characteristics of the observed 2003 Tokachi-off earthquake tsunami profile, COASTAL ENGINEERING JOURNAL, vol. 46, No. 3, pp 315-327.