Numerical Simulation of Storm Surge Inundation in Yatsushiro Sea due to Typhoon No.18 in 1999

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1. Introduction

Kyushu Island is a region that often attacked by typhoons. The Yatsushiro Sea is located in the western part of Kyushu Island, which has a long and narrow shape along the northeastern direction, surrounded by a large area of lowland. In this region, the tidal range is large. The characteristics amplifies the storm surges due to typhoons. On September 23rd, 1999, Typhoon No.18 (T9918) was generated in the eastern China Sea and cut across the Kyushu Island as shown by blue line in Fig-1. It caused severe inundation on a large area, and left widespread damage behind it. 30 people died in the disaster, and thousands of people got hurt. Besides, the wealth lost was estimated at 100 billion yen, the worst ever in the Kumamoto. Therefore, it is very important to understand mechanism of the storm surge inundation by T9918.

2. Inundation Simulation

2.1 Numerical Model

Using a typhoon model with Myers' equation, the air pressure as well as the wind field is simulated. The route of typhoon is set based on the best-track-data from Japan Meteorological Agency (JMA). The water elevation and inundation are simulated by Finite Volume Coastal Ocean Model (FVCOM). FVCOM is an ocean current model proposed by Prof. C. Chen of Massachusetts Dartmouth University which use unstructured grid and quasi-3 dimensional finite volume method. It has been proved that unstructured grid can reproduce more details of complexed coastline with high accuracy. The wet or dry condition is judged. Thus, both water elevation and the inundation are simulated at the same time.

Fig-1 shows the computational mesh. The size of each grid near the eastern open boundary is about 16km, and gets smaller from 16km to 0.05km as getting closer to the Yatsushiro Sea. As for the land area, considering about the precision, the grid side length is also set 0.05km. Tab-1 shows the calculation condition.

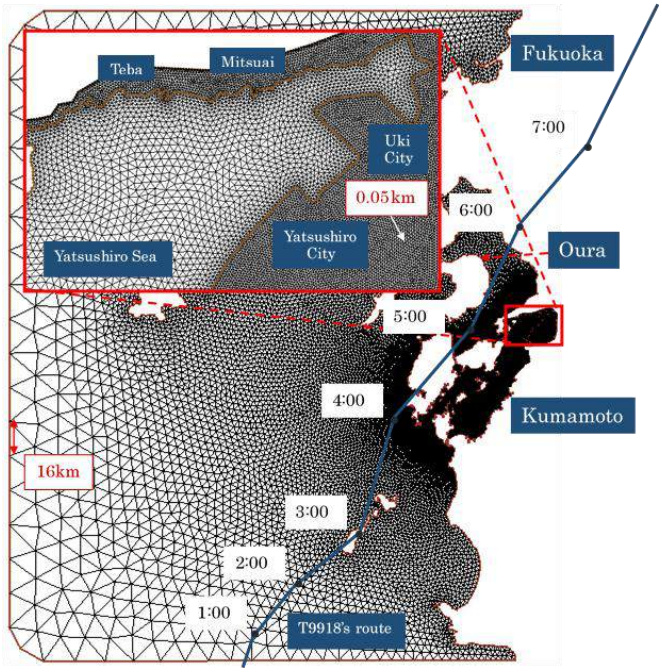

Fig-1. Computational mesh and T9918's route

Tab-1 FVCOM calculation condition

Horizontal mesh size	0.05~16km
Vertical layers	3
Sea water density	1025.99 kg/m^3 (20℃，35psu)
Open boundary condition	Water level boundary (tide)
Meteorological condition	Typhoon model (input time interval is 10min)
Calculating time interval	0.2s
Calculating time range	1999/9/23 20:00~9/24 20:00 (24h)
Initial tide	T.p. 0m

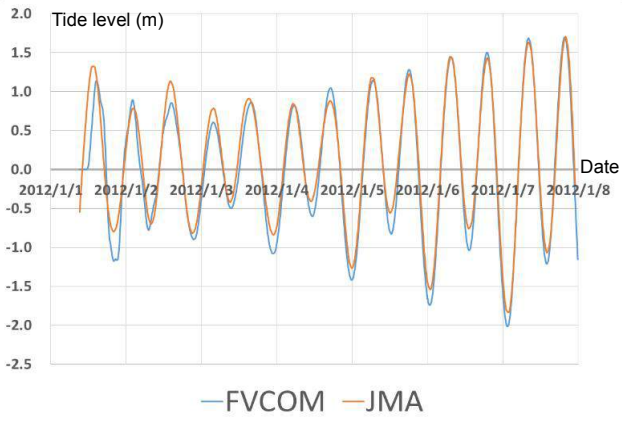

Fig-2. Verification of tide simulation at Oura

3. Simulation Results

3.1 Verification of tide simulation

Fig-2 shows the comparison of tidal change between astronomical data of JMA (2012 Jan 1st ~7th, Oura) and FVCOM simulation result without external force at the sea surface. In Fig-2, there are small differences at peaks, however, the simulation result agree with the JMA's data generally.

3.2 Storm surge and inundation

Fig-3 shows temporal change of tide level at Yatsushiro port according to the survey by researchers of Kumamoto University. There are 2 peaks of the tide level. First one (marked by red arrow) occurs at 6:03, and the other one (marked by blue arrow) shows up at 8:30. Fig-4 shows the simulated tide level at Yatsushiro port by FVCOM. The time of the peaks is roughly reproduced, though the first peak's height of the simulation is a little lower.

The survey also shows the inundation on the lowland around the Yatsushiro Sea. Fig-5 shows that, in Matsuai District, Nagao District, Kazuhara District, especially in the Uki City, large area of land was inundated. While in Fig-6, it shows the inundation happens in the same area.

4. Summary

The storm surge inundation of Yatsushiro area was simulated with FVCOM. Simulation results show that the tide level variation of Yatsushiro port with several peaks agrees with the survey.

On the whole, from the simulation, it was confirmed that FVCOM can reproduce the inundated area along the inner bay of the Yatsushiro Sea.

The future subject of the study is to investigate the influences of the mesh size for the inundation.

References

1) Chen, C., H. Liu, R. C. Beardsley. 2003. An unstructured, finite-volume, three dimensional, primitive equation ocean model: application to coastal ocean and estuaries, J. Atm. Oceanic Tech. 20, pp.159–186.

2) Takikawa K. 2001. Storm surge damage caused by Typhoon No. 9918 in the area of the Shiranui Sea, Civil Engineering, JSCE, Vol.31, pp.42-48.

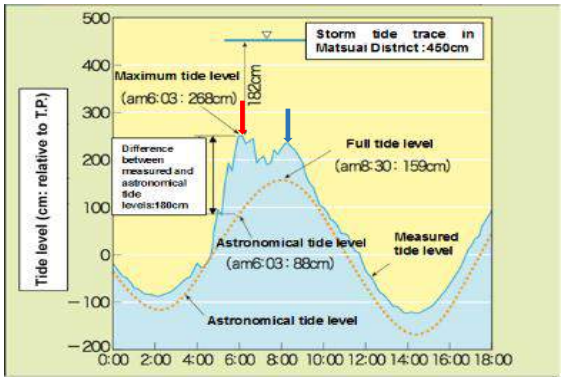

Fig-3. Tide level at Yatsushiro port (refer to storm surge damage caused by Typhoon No. 9918 in the area of the Shiranui Sea[2])

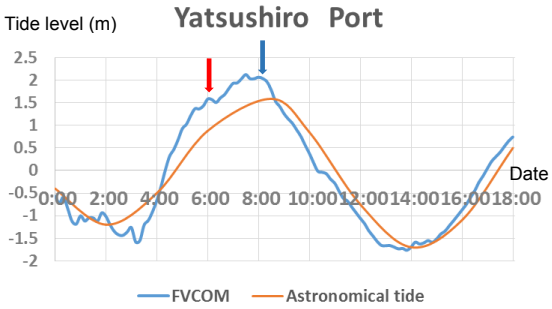

Fig-4. Tide level simulation

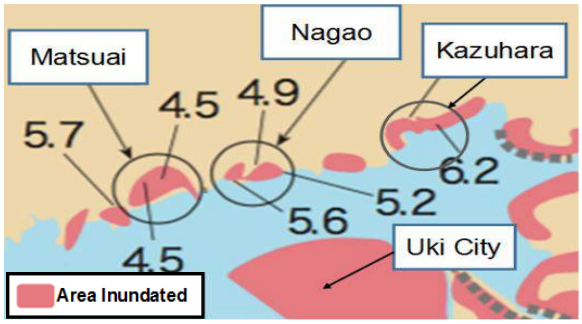

Fig-5. Inundated area of Yatsushiro (refer to storm surge damage caused by Typhoon No. 9918 in the area of the Shiranui Sea[2])

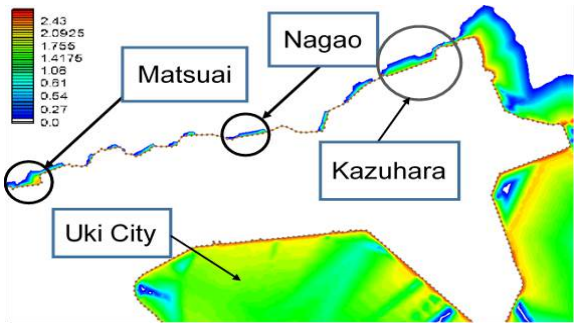

Fig-6. Distribution of inundation height