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PRESENT AND FUTURE TSUNAMI AND STORM SURGE PROTECTIONS IN TOKYO AND SAGAMI BAYS

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ABSTRACT: On March 11, 2011, a large earthquake that occurred offshore the northeast coast of Japan generated a large tsunami which devastated extensive areas of the Tohoku coastline and large casualties were recorded. Based on the experiences, coastal protection works in Japan are now in the process of modifications. In the present paper, Tokyo and Kanagawa are taken as examples and new methodologies are explained in the area. For the case of storm surge, a new model is applied to predict the future behavior of storm surge. For the case of tsunami, Genroku Kanto Earthquake (1703), Keicho Earthquake (1605) and Meiou Tokai Earthquake (1498) were mainly discussed in the numerical analysis, since tsunamis caused by these three earthquakes gave strong damages to coastal area of Kamakura, and left influences to Yokohama and Tokyo. New tsunami flood maps over coastal land area based on numerical simulations were presented to the residents of coastal region on April 2012 in Kanagawa prefecture. For Kamakura area, Keicho Earthqueke takes 90 minutes to reach the Kamakura coast and the height is over 12 m. But for the case of Genroku Kanto earthquake it takes 25 minutes and the height is 8 m. It appears that there are two different types of risk, 1) high wave comes but we have time for evacuation and 2) relatively small wave comes quickly and time is limited for evacuation. New countermeasures including soft and hard techniques are also required.

Keywords: Tsunami, storm surge, coastal protection

STORM SURGE EVALUAYION IN TOKYO BAY

(Ohira et. al, 2012)

The purpose of this paper is to clarify the risk of storm surge and tsunami in Tokyo bay and Sagami bay by using three different numerical simulations, a storm surge simulation, a tsunami simulation and an overland inundation simulation. In the storm surge simulation, storm surge behaviors in Tokyo bay were calculated by numerical simulations. The simulation methodology developed by the authors (Ohira et. al, 2012) consists of 4 separate models that are coupled together: WRF (Weather Research and Forecasting model; Ver., 3.3.1) , SWAN (Simulating Wave Near-shore; Ver. 40.85) , STOM (STOrM surge model) and Nao99b (Matsumoto et al., 2000). All together, they have been designated as OSIS (Ohira and Shibayama Integrated Storm surge model). The model flow is shown in Figure.1.

Integrating the four models, (meteorology, wave, storm surge and tidal model) is important to simulate real wave conditions and to improve the accuracy of the calculation. The reason for integrating wave, storm surge and tide model is that the wave height due to the typhoon consists of a wave and storm surge (pressure surge and wind driven surge) components, together with the tide. Hence, it is important to calculate these 3 elements simultaneously to simulate real waves, as shown in Figure 1.

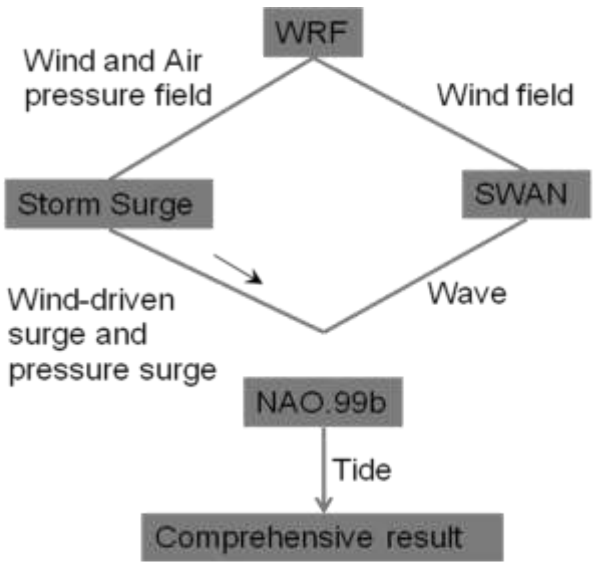

Figure 1 Flow of OSIS model.

In order to examine the accuracy of the models, the authors reproduced the storm surge and wave conditions that took place during the passage of Typhoon *Fitow* (2007). The typhoon passed through the Kanto region that surrounds Tokyo Bay, inflicting considerable damage along its path. It made landfall in the southern part of Izu Peninsula in Shizuoka Prefecture.

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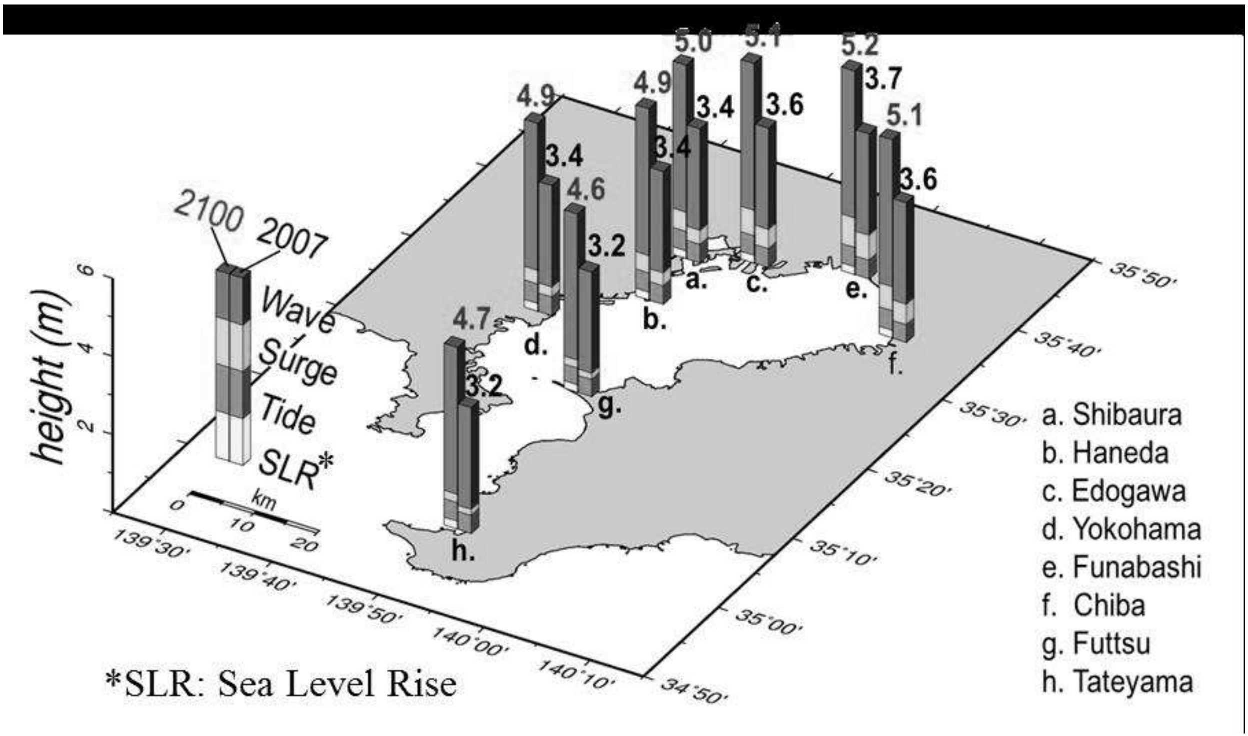

Figure 2: Comparison of storm surge components between Fitow2007 and Fitow2100 (Ohira et. al, 2012).

at 3pm on 6th Sep (UTC) and advanced northward straight through the Kanto region. The wave and storm surge caused by the storm resulted the collapse of the Seisho bypass into the sea, amongst other damage.

By using the methodology described in the previous part, it is possible to compare the damage potential between the present day Fitow typhoon ("Fitow2007") and the same typhoon in a future where Sea Level Rise (SLR) and Sea Surface Temperature (SST) effects are higher than at present ("Fitow2100"). Figure 2 shows the comparison between the maximum waters level (which results from the addition of the wave, storm surge, tide and SLR) between Fitow2100 and Fitow2007 at different points throughout Tokyo Bay. The total wave height at Shibaura, Edogawa, Funabashi and Chiba, which are located in the inner side of the Tokyo bay, are higher than those at Futtsu and Tateyama, which are situated in the entrance of the bay.

Figure 2 shows how for the entire extension of Tokyo Bay the water levels that result from the conditions in Fitow2100 are about 1.5m higher than those in Fitow2007. Much of these increases in water levels come from higher wave heights. Sea wave are generated by wind so as the wind increases in strength so do the waves increase in height. Although the present simulation did not increase the intensity (and hence wind speed) of typhoon Fitow before it reached the computational domain, the increase in SST inside the area studied results in a stronger typhoon compared to the historical event (2007), leading to stronger winds and thus higher waves. A more detailed assessment of the available countermeasures is needed in the future.

TSUNAMI IN TOKYO BAY AND SAGAMI BAY (Takabatake and Shibayama, 2012)

In the tsunami simulation, tsunami behavior in Tokyo bay and Suruga Bay are calculated under the consideration of three different earthquakes. The target earthquakes are Genroku (1703), Miura Peninsula and Kamogawa, Keicho (1605) and MeiouTokai (1498) earthquakes. Amongst them, the earthquake which induces the highest tsunami in Tokyo port is the Keicho earthquake. In that case, the tsunami height around Tokyo port is about 1.5m. In the simulation, the initial tsunami profiles were calculated by using the model of Manshinha and Smylie(1971) and tsunami propagations were calculated by using non-linear long wave equations. Overland inundation over coastal area is also simulated under the impact of the Keicho earthquake.

Figure 3 shows maximum tsunami height distributions in Tokyo bay for the case of Keicho earthquake. The results show the western Koto Delta, Southern Koto Delta, East Shinagawa and many other areas outside Tokyo port are under the risk of inundation. For the overland inundation simulation, a 5m mesh topography data was used, which enables the display of micro scale inundation. Around one meter inundations occur in maximum in low land area close to the shore line and along river. In Tokyo down town area, there are 124 km^2 low lands where the ground level is lower than the mean sea level and 1.5 million people are living in the area. The overall results show that it is necessary to reconsider disaster management plans in Tokyo metropolitan and Kanagawa prefecture, as current counter-measures might not be sufficient to protect certain areas against all foreseeable threats.

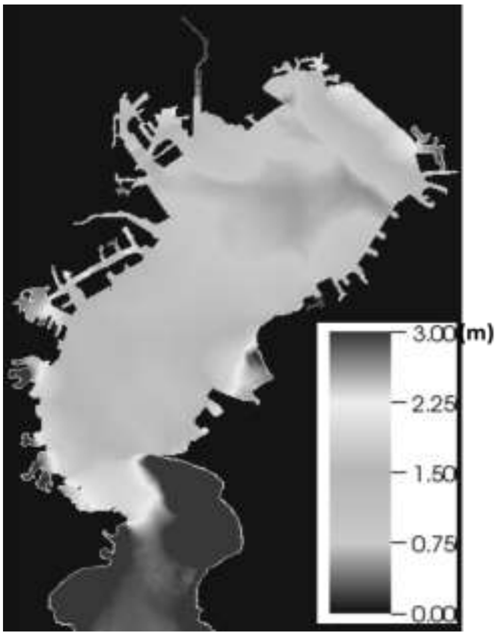

Figure 3: Maximum tsunami height in Tokyo bay for the case of Keicho earthquake (Takabatake and Shibayama, 2012).

KANAGAWA PREFECTURE TSUNAMI EVACUATION PLAN - A case study (Shibayama et. al, 2013)

An example of Kanagawa prefectural government is introduced since the first author is the chair of the committee for tsunami studies of the prefectural government. In the analysis of possible tsunamis in the prefecture, three different approaches were employed.

1) Analysis of records written in old documents, 2) Boring of ground to find out old layers of tsunami sediments and 3) Numerical simulations of historical old tsunamis. Based on the results of 1) and 2), Genroku Kanto Earthquake (1703), Keicho Earthquake (1605) and Meiou Tokai Earthquake (1498) were mainly discussed in the numerical analysis, since tsunamis caused by these three earthquakes gave strong damages to coastal area of Kamakura, and left influences to Yokohama and Tokyo. New tsunami flood maps over coastal land area based on numerical simulations were presented to the residents of coastal region on November 2011 and more precise information on April 2012.

In order to use the tsunami hazard map for evacuation planning, it is necessary to know both height and arrival time of tsunami waves. For Kamakura area, Keicho earthqueke tsunami takes 80 minutes to reach the Kamakura coast and the height is over 10 m. But for the case of Genroku Kanto earthquake it takes 51 minutes and the height is 6.5 m. For Minami Kanto earthquake (set scenario proposed by seismologist), they are 32 minutes and over 5 m. There are two different type of risks, 1) high wave comes but have time for evacuation and 2) relatively small wave comes quickly and time is limited for evacuation.

In Kamakura city, there are small scale town organizations for each small district (approximately 1,000 to 1,500 residents in population) and they make discussions for possible evacuation plans of each area by themselves and also do training activities for evacuation. In Kamakura, there are hills close to the coastal line but roads to go up to hill top is not well installed. Zaimokuza area will be isolated by coast line and Nameri river when tsunami comes and it will take more than 30 minutes to go to hill on foot for healthy adults. For this case, Genroku Kanto tsunami will be a problem because it comes 51 minutes after the earthquake. For Minami Kanto tsunami, the time condition is worse than Genroku Kanto tsunami.

For the case of Zaimokuza, number of buildings that have more than 4 stories are limited due to house construction code to keep good living conditions in the area. Buildings over 10 m in height are restricted in the housing area and over 15 m in commercial area. Designations of additional tsunami evacuation buildings and planning to build new evacuation buildings are also now in progress.

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