RISK ASSESSMENT ON STORM SURGE FLOOD

by

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ABSTRACT

The method of risk assessment for hazard map on storm surge flood has not been established completely. For nationwide distribution of the hazard map, several research subjects in process of the risk assessment on storm surge flood will be investigated in this study. Probabilistic evaluation on tide level and wave overtopping rate, judgment on coastal dike break, and flood simulation are key elements in the risk assessment.

KEY WORDS: Flood, Risk Assessment, Storm Surges

1. INTRODUCTION

Typhoons have caused catastrophic damage by flooding due to storm surges in Japanese history. As shown in Table 1, large scale of storm surge disasters have occurred frequently until 1961. For example, about five thousands of people was dead with storm surge by a typhoon in 1959, which was called Ise Bay Typhoon. After 1970's, catastrophic flood disaster due to storm surges have been rare.

There are two main factors of small number of severe storm surge flood in recent 40 years. One is construction of coastal dike against storm surge, the other is improvement of weather forecast system. These factors made residents in coastal area feel as if their houses had been safe from storm surge flood.

Contemporary structure of great cities in coastal area is a complex including ground space and underground space. Storm surge larger than designed level in shore protection works may cause severe flood disaster of unexpected process in the great cities.

One of effective countermeasures against storm surge disaster is hazard maps on storm surge, however, the maps have not been distributed overall in Japan. The method of risk assessment for the map has not been established completely.

This study is to establish the method of risk assessment on storm surge flood.

2. FRAMEWORK OF RISK ASSESSMENT ON STORM SURGE FLOOD

There are some matters for making hazard maps on storm surge flood as shown in Figure 1.

One is how to set tide level and wave overtopping rate as boundary conditions of flood simulation. Return period of high tide level has not been evaluated accurately because of short period of tidal observation. Dependency of wave height on tide level also makes it difficult to evaluate return period of wave overtopping rate.

Second one is how to judge coastal dike break. Most of coastal area in Japan is protected from storm surges and high waves by coastal dikes in designed level. Although most of coastal dike is armored with concrete or asphalt, tide level and wave higher than designed level may break coastal dike.

From the viewpoint of mitigating fatalities, risk assessment on storm surge flood can be conducted as shown in Figure 2.

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Table 1 Storm surge disasters in Japan

Date	Major damaged area	Human casualties			Damage to houses			Typhoon
		Dead	Injured	Missing	Completely destroyed	Partially destroyed	Washed away	
1 Oct. 1917	Tokyo Bay	1,127	2,022	197	34,459	21,274	2,442	
13 Sep. 1934	Ariake Sea	373	181	66	1,420		791	
21 Sep. 1934	Osaka Bay	2,702	14,994	334	38,771	49,275	4,277	Muroto
27 Aug. 1942	Suo Sea	891	1,438	267	33,283	66,486	2,605	
17 Sep. 1945	Southern Kyushu	2,076	2,329	1,046	58,432	55,006	2,546	Makurazaki
3 Sep. 1950	Osaka Bay	393	26,062	141	17,062	101,792	2,069	Jane
14 Oct. 1951	Southern Kyushu	572	2,644	371	21,527	47,948	1,178	Ruth
7 Sep. 1959	Ise Bay	4,697	38,921	401	38,921	113,052	4,703	Ise Bay
16 Sep. 1961	Osaka Bay	185	3,897	15	13,292	40,954	536	Second Muroto
21 Aug. 1970	Tosa Bay	12	352	1	811	3,628	40	No.10
30 Aug. 1985	Ariake Sea	3	16	0	0	589	0	No.13

(1) Probabilistic evaluation on tide level and wave overtopping rate

Tide levels and wave overtopping rates are necessary for flood simulation in coastal zones as boundary conditions. Return period of tide levels and wave overtopping rates can be evaluated on results of numerical simulation with a probabilistic generation model for parametric properties of typhoon.

(2) Judgment on coastal dike break

Break of coastal dike increases inflow rate of seawater awfully. The break can be judged based on wave overtopping rate and type of coastal dike.

(3) Flood simulation

Inundation depth, velocity of flood flow, and arrival time of flood in coastal zone can be estimated with a numerical model.

(4) Risk assessment

From the viewpoint of need and safety of evacuation and safety of houses, risk of storm surge flood can be assessed based on results of the flood simulation.

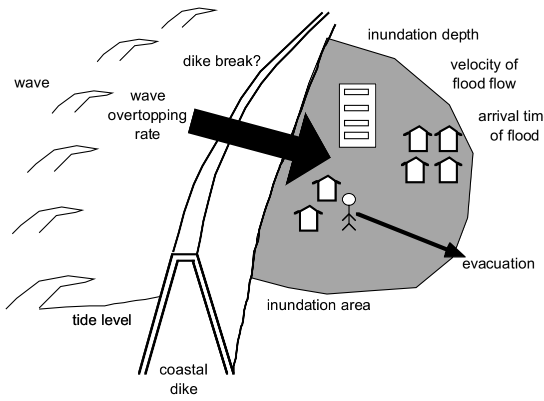

Figure 1 Schematic view of storm surge flood

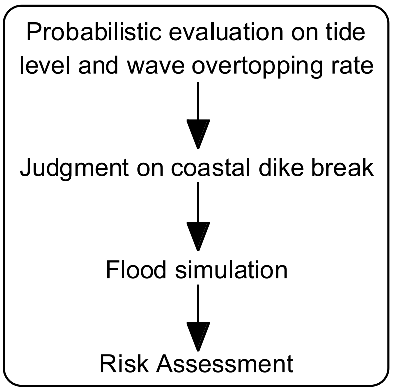

Figure 2 Flowchart of risk assessment on storm surge flood

3. PROBABILISTIC EVALUATION ON TIDE LEVEL AND WAVE OVERTOPPING RATE

Probabilistic evaluation on tide level and wave overtopping rate can be conducted as shown in Figure 3. First is making a probabilistic generation model for parametric properties of typhoon based on recorded data. Second is evaluating return period of tide level and wave overtopping rate based on Monte Carlo method.

Probabilistic generation model for parametric properties of typhoon can be made in methods by

Yamaguchi et al.(1994) and Hashimoto et al. (2001). In their method, probability of number, location and its variation, atmospheric pressure and its variation, and radius of typhoon are evaluated based on data of typhoon for the past fifty years.

In evaluating return period of tide level and wave overtopping rate, typhoons are supposed with the model for hundreds of years. After that, tide level and wave overtopping rate due to each supposed typhoon are calculated through numerical simulation. Finally, return period of tide level and wave overtopping rate are calculated.

Figures 4 to 9 show results of a typhoon simulation with the model. The simulation for past fifty years was conducted fifty times. It corresponds a simulation for 2,500 years. Although calculated standard deviations of atmospheric pressure at typhoon eye, typhoon speed and typhoon direction were smaller than observed ones, calculated

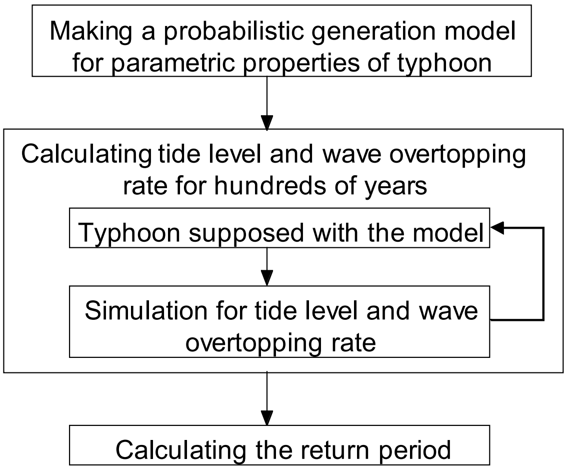

Figure 3 Flowchart of probabilistic evaluation on tide level and wave overtopping rate

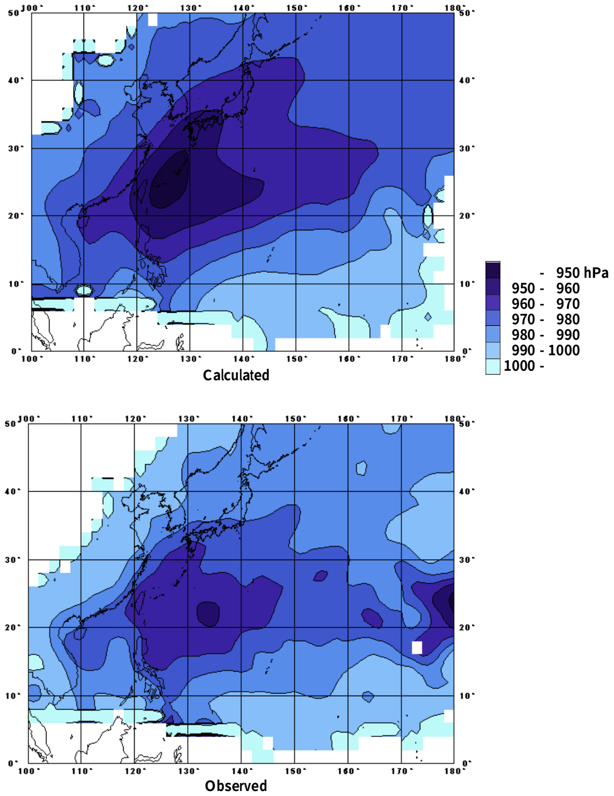

Figure 4 Average atmospheric pressure at typhoon eye

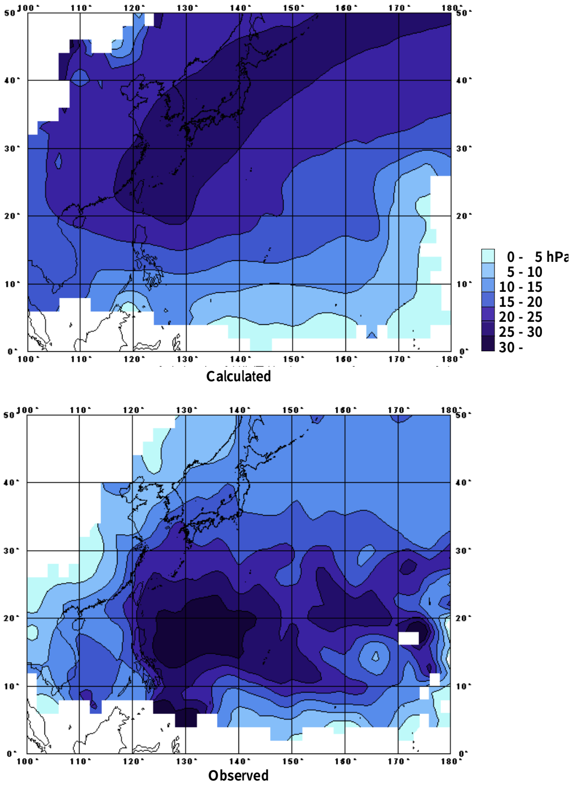

Figure 5 Standard deviation of atmospheric pressure at typhoon eye

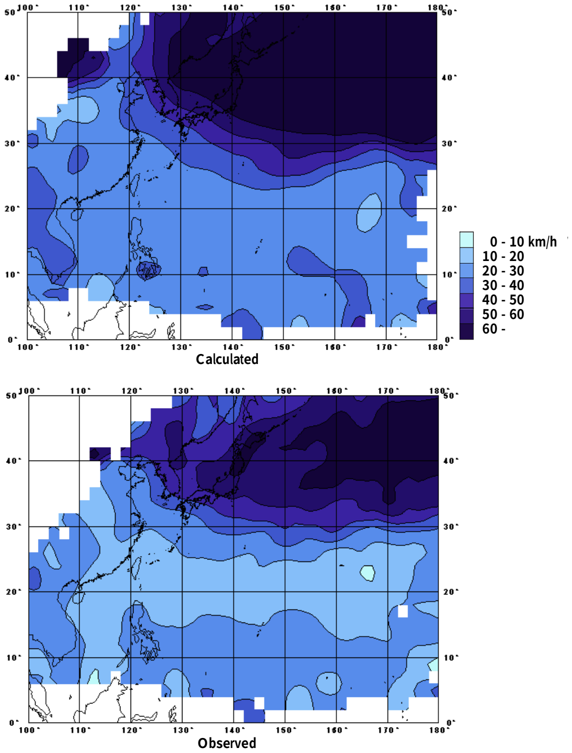

Figure 6 Average typhoon speed

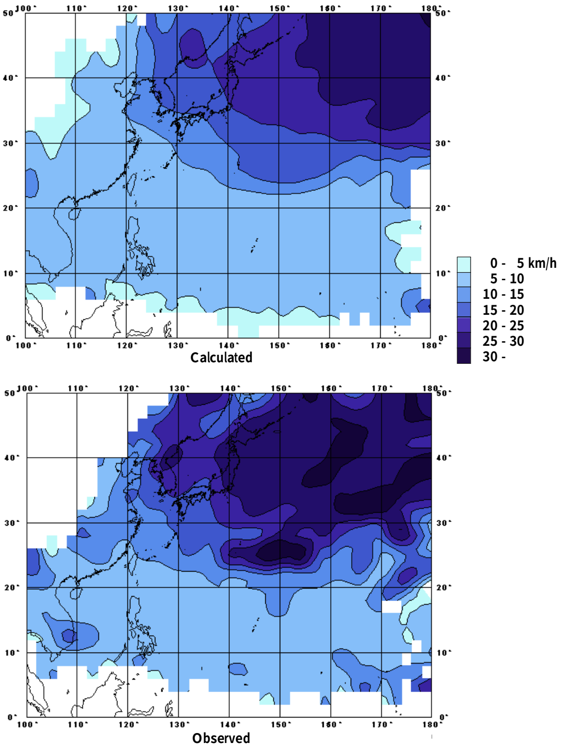

Figure 7 Standard deviation of typhoon speed

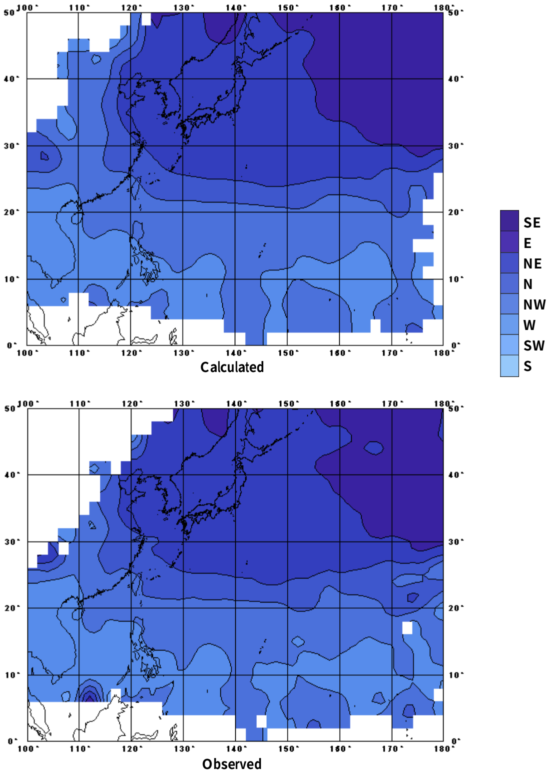

Figure 8 Average typhoon direction

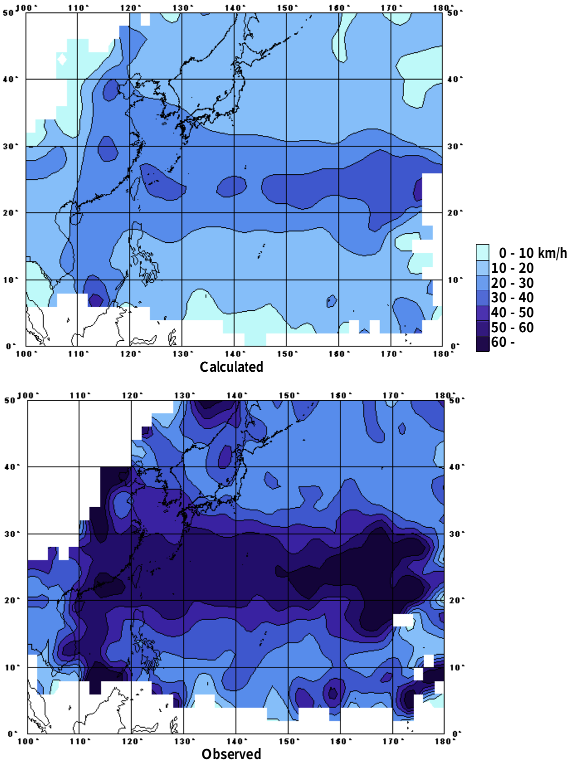

Figure 9 Standard deviation of typhoon direction

average values of them were almost equivalent to observed ones.

4. PROBABILISTIC EVALUATION ON COASTAL DIKE BREAK

Although most of coastal dike is covered with concrete or asphalt in Japan, coastal dike might be broken due to excess waves and/or cavern in fill. Table 2 shows an example of wave overtopping rate critical to destruction of dikes and revetments. Probability of coastal dike break should be evaluated for each wave overtopping rate based on breach examples and results of physical model experiments.

Table 2 Allowable wave overtopping rates (Goda, 1970)

type	crest of dike	landward slope of dike	wave overtopping rate (m^3/m/s)
1	not armored	not armored	<0.005
2	armored	not armored	0.02
3	armored	armored	0.05

5. RISK ASSESSMENT BASED ON FLOOD SIMULATION

If houses could be inundated due to a storm surge, the residents should evacuate to designated safe locations prior to any danger. Whether evacuation is required can be evaluated based on the maximum flood depth obtained from flood analysis using the worst scenario.

On the other hand, safety for evacuation depends on time for flood to reach each point as well as the maximum flood depth. In a low plain field, people in evacuation is safer at points far from the shoreline because it takes a long time for flood to reach there, although significant variation in the maximum flood depth is not observed throughout inundated area.

According to the criteria shown in Table 3, we ranked the relative hazards to human based on the

Table 3 Hazard ranking criteria for storm surge flood (Torii and Kato, 2001)

Hazard rank	Expected maximum flood depth	Houses	Expected time for flood to reach	Safe evacuation if residents begin to escape on becoming aware of the flood on their houses	Expected condition	Desirable action
A	above floor level		shorter than Tl and Tr	impossible	evacuation is possible if residents begin to escape before the onset of seawater invasion	escape prior to the onset of seawater invasion
B	above floor level		shorter than Tl, but longer than Tr	impossible	evacuation is possible in flood if residents begin to escape at the onset of seawater invasion	
C+	above floor level		longer than Tl and Tr	impossible	evacuation is possible in dry condition if residents begin to escape at the onset of seawater invasion, but impossible if residents begin to escape upon becoming aware of the flood on their houses	
C-	above floor level		longer than Tl and Tr	possible	evacuation is possible even if residents begin to escape upon becoming aware of the flood on their houses	escape on self-judgment
D	above floor level	high-rising, water-resist			safe in their houses	stand by in their houses
E	below floor level				safe in their houses	
(none)	no inundation				safe in their houses	

Tl: Time for residents to reach an evacuation location
Tr: Time for residents to reach a walkable evacuation road

maximum flood depth and the time for flood to reach obtained from flood analysis. The points where the maximum flood depth corresponds to the flood above floor level were assumed to be the evacuation-designated areas. Note that some of the houses that were not inundated completely or were not swept away even if flooded, might be ranked D indicating that evacuation is not required.

For the houses in the evacuation-designated areas, assuming that the residents began to escape when seawater overflowed the embankment, a comparison was made between the time required for evacuation and the time for flood to reach. If the time for flood to reach was longer, the houses were ranked C. Otherwise, the residents could escape when the flood depth was low by using the evacuation road, even if they began to escape at the onset of seawater invasion.

Further hazard ranking was made based on whether the residents could safely reach the walkable evacuation road even if they began to escape in case of a flood. The rank C houses were divided into subgroups based on whether residents could reach the safe evacuation road if they began to escape upon becoming aware of the flood on their houses.

This method allows us to evaluate the effects of improving evacuation locations and making the houses water-resistant inside the embankment. For example, if safe evacuation locations that are not inundated even during a flood, are improved into rank A or B locations, then the time required to escape is reduced and the houses in the vicinity of the locations are ranked C+ or C-.

Principal cities in Japan are in risk of riverine flood and flood due to drainage failure as well as storm surge flood. Flood risk should be assessed comprehensively for residents convenience.

We are now making a probabilistic generation model for parametric properties of typhoon. Evaluation on tide level and wave overtopping rate will be conducted for four coasts facing Tokyo Bay, Ise Bay, Osaka Bay and Tosa Bay, where severe storm surge has occurred.

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