BOOK OF ABSTRACTS

THE SECOND INTERNATIONAL WORKSHOP ON COASTAL DISASTER PREVENTION

- Tsunami and Storm Surge Disaster Mitigation -

January 18 - 19, 2006

MIRAI CAN Hall, National Museum of Emerging Science and Innovation

THE SECOND INTERNATIONAL WORKSHOP ON COASTAL DISASTER PREVENTION

- Tsunami and Storm Surge Disaster Mitigation -

January 18 - 19, 2006
MIRAI CAN Hall, National Museum of Emerging Science and Innovation

One year has past since the catastrophic disaster of the Indian Ocean Tsunami on 26 December 2004. Reconstruction has begun in the disaster-affected countries. Following the last international workshop and symposium on tsunami disaster mitigation on 17-18 January 2005 at Kobe, this second workshop present comprehensive reports of field surveys on the Indian Ocean Tsunami. Also introduced are state-of-the-art technologies such as tsunami-monitoring techniques, numerical simulations, and experimental studies for tsunami disaster mitigation.

The extensive damage to the southern part of the United States caused by Hurricane Katrina in the end of the last August is still fresh in our minds. Field survey results on this hurricane disaster as well as disaster-prevention techniques against storm surges are reported.

In this workshop, the future of coastal hazard mitigation will be suggested through the discussions on the disasters due to these tsunamis and storm surges from scientific viewpoints.

Organizers:

- Port and Airport Research Institute (PARI), JAPAN
- Coastal Development Institute of Technology (CDIT), JAPAN
- Japanese Section of International Navigation Association (JS-PIANC)
- Asian Civil Engineering Coordinating Council (ACECC)

Co-sponsors:

- Ministry of Land, Infrastructure and Transport (MLIT), JAPAN
- Panel on Wind and Seismic Effects, U.S.-Japan Cooperative Program in Natural Resources (UJNR)

第 2 回　国際沿岸防災ワークショップ

～津波・高潮災害の軽減に向けて～

2006 年 1 月 18・19 日
日本科学未来館みらい CAN ホール

2004 年 12 月 26 日のインド洋津波による大災害から 1 年が経過し、被災国では復興が始められています。津波被害発生から 3 週間後に開催した前回の国際津波防災ワークショップに引き続き、第 2 回国際沿岸防災ワークショップでは、インド洋津波被害に関する現地調査等についてとりまとめるとともに、津波観測技術、被害予測のための数値計算技術や模型実験等の津波防災に関する最新技術を紹介します。

また、2005 年 8 月下旬にアメリカ合衆国南部を襲ったハリケーン・カトリーナは甚大な高潮災害を発生させました。本ワークショップでは、高潮・高波被害の実態に関する調査報告を行うとともに、これからの高潮防災のための技術についても紹介します。

本ワークショップは、津波や高潮によって発生した被害を科学的に受け止め、さらに津波や高潮防災に関する最新技術について議論を深めることにより、これからの津波・高潮に対する沿岸防災のあり方を考えます。

主　催：
独立行政法人 港湾空港技術研究所
財団法人 沿岸技術研究センター
国際航路協会日本部会
アジア土木学協会連合協議会

協　賛：
国土交通省
天然資源の開発利用に関する日米会議(UJNR)　耐風耐震構造専門部会

AGENDA OF THE SECOND INTERNATIONAL WORKSHOP ON COASTAL DISASTER PREVENTION

January 18 (Wednesday)

8:50 – 9:20 **Registration**

9:20 – 9:50 **Opening Ceremonies**

Opening Remarks by Mr. Makoto Owada, President, PARI, Japan

Remarks by Mr. Heizo Kito, Director-General, Ports and Harbours Bureau, Ministry of Land, Infrastructure and Transport, Japan

Remarks by Mr. Hisao Ida, Deputy Director-General, Research and Development Bureau, Ministry of Education, Culture, Sports, Science and Technology, Japan

Brief Introduction of the workshop by Takashi Tomita, WS Secretary

9:50 – 10:50 **Technical Session 1 – Tsunami (1), Experiment**

Chairman: Solomon Yim, Oregon State University, USA

Co-chairman: Toshihiko Nagai, PARI, Japan

9:50 *Large Model Test of Tsunami Pressure on a Seawall and on Land Structures*

Taro Arikawa, PARI, Japan

10:10 *Tsunami Wave Forces on Coastal Dike*

Fuminori Kato, National Institute for Land and Infrastructure Management, Japan

10:30 *Forces on a Container Due to Tsunami and Collision Force by Drifted Container*

Norimi Mizutani, Nagoya University, Japan

10:50 – 11:00 Break

11:00 – 12:00 **Technical Session 2 – Tsunami (2), Numerical Simulation**

Chairman: Saman Samarawickrama, University of Moratuwa, Sri Lanka

Co-chairman: Katsuya Hirayama, PARI, Japan

11:00 *Dispersion Effect in Tsunami Numerical Simulation*

Koji Fujima, National Defense Academy, Japan

11:20 *Application of Three-dimensional Numerical Model to Tsunamis*

Takashi Tomita, PARI, Japan

11:40 *Storm Wave and Tsunami Interaction with Structures*

Solomon Yim, Oregon State University, USA

12:00 – 13:00 Lunch

13:00 – 15:00 Special Session 1 – Indian Ocean Tsunami

Chairman: Byung Ho Choi, Sungkyunkwan University, Korea

Co-chairman: Tetsuya Hiraishi, PARI, Japan

13:00 *Damage and Impact on the Coastal Area Due to the 2004 Indian Ocean Tsunami*

Fumihiko Imamura, Tohoku University, Japan

13:30 *Indian Ocean Tsunami on the Srilankan Coast, Near Shore Processes and the Impact of Coral Removal*

Saman P. Samarawickrama, University of Moratuwa, Sri Lanka

14:00 *The 2004 Indian Ocean Tsunami Disaster and Building Re-construction in Thailand*

Panitan Lukkunaprasit, Chulalongkorn University, Thailand

14:30 *Disaster Impacts of December 2004 Indian Ocean Tsunami in Indonesia and Its Rehabilitation Efforts*

Subandono Diposaptono, Ministry of Marine Affairs and Fisheries, Indonesia

15:00 – 15:10 Break

15:10 – 16:30 Technical Session 3 – Tsunami (3), Countermeasure

Chairman: Fumihiko Imamura, Tohoku University, Japan

Co-chairman: Kenichiro Shimosako, PARI, Japan

15:10 *Tsunami Warning System in Japan*

Shin'ya Tsukada, Japan Meteorological Agency, Japan

15:30 *Concept of Tsunami Detecting System Using Remote Sensing*

Tomoyuki Takahashi, Akita University, Japan

15:50 *Offshore Tsunami Monitoring Network Design Using GPS Buoys and Coastal On-site Sensors*

Toshihiko Nagai, PARI, Japan

16:10 *Coastal Damage Due to the Indian Ocean Tsunami and Its Defense by Greenbelt*

Tetsuya Hiraishi, PARI, Japan

16:30 – 17:00 Technical Session 4 – Coastal Disaster Prevention (1)

Chairman: Fumihiko Imamura, Tohoku University, Japan

Co-chairman: Kenichiro Shimosako, PARI, Japan

16:30 *Technology of Tsunami Disaster Reduction*

Yoshiaki Kawata, Kyoto University, Japan

18:00 – 20:00 Reception

at National Museum of Emerging Science and Innovation (Miraikan)

Opening Speech by Mr. Yasuhiro Kawashima, President, JS-PIANC

Closing Speech by Dr. Tadahiko Sakamoto, Chairman, Japan-Side, Panel on Wind and Seismic Effects, UJNR

January 19 (Thursday)

8:50 – 9:20 Registration

9:20 – 9:40 Technical Session 5 – Coastal Disaster Prevention (2)

Chairman: Subandono Diposaptono, Ministry of Marine Affairs and Fisheries, Indonesia

Co-chairman: Koji Kawaguchi, PARI, Japan

9:20 *Business Continuity Management as a New and Holistic Framework for Flood Disasters Reduction*

Haruo Hayashi, Kyoto University, Japan

9:40 – 11:00 Technical Session 6 – Storm Surge and Waves

Chairman: Subandono Diposaptono, Ministry of Marine Affairs and Fisheries, Indonesia

Co-chairman: Koji Kawaguchi, PARI, Japan

9:40 *Recent Storm Surge Disasters in Japan and Korea*

Hiroyasu Kawai, PARI, Japan

10:00 *Operational Storm Surge Forecasting at Japan Meteorological Agency -Current Status and Future Outlook-*

Masakazu Higaki, Japan Meteorological Agency, Japan

10:20 *Tropical Cyclone Climatology in a Greenhouse Climate -Simulation with a Super-High-Resolution Global Atmospheric Model-*

Jun Yoshimura, Meteorological Research Institute, Japan

10:40 *Improvement of the Third Generation Wave Model for Coastal Wave Hindcasting*

Noriaki Hashimoto, Kyushu University, Japan

11:00 – 11:10 Break

11:10 – 12:10 **Special Session 2 – Hurricane Katrina Disaster**

Chairman: Katsuya Oda, National Institute for Land and Infrastructure Management, Japan

Co-chairman: Hiroyasu Kawai, PARI, Japan

11:10 *Impact of Hurricane Katrina on Southeast Louisiana*

Harley S. Winer, US Army Corps of Engineering, USA

12:10 – 13:10 Lunch

13:10 – 14:50 **Technical Session 7 – Coastal Disaster Prevention (3)**

Chairman: Norimi Mizutani, Nagoya University, Japan

Co-chairman: Fuminori Kato, National Institute for Land and Infrastructure Management, Japan

13:10 *Characteristics of Storm Surge Disasters in Japan and Countermeasures for Their Mitigation*

Tomotsuka Takayama, Kyoto University, Japan

13:40 *Coastal Disaster Mitigation in the U.S.*

Nobuhisa Kobayashi, University of Delaware, USA

14:10 *Counter Measures for Coastal Disasters in Europe*

Ahmet C. Yalciner, Middle East Technical University, Turkey

14:30 *Performance Design of Coastal Defense and Real-Time Prediction of Coastal Disasters Based on Prepared Scenarios*

Shigeo Takahashi, PARI, Japan

14:50 – 15:00 Break

15:00 – 16:00 **Technical Session 8 – Coastal Disaster Prevention (4)**

Chairman: Noriaki Hashimoto, Kyushu University, Japan

Co-chairman: Takehisa Saitoh, Kanazawa University, Japan

15:00 *Countermeasures Against Coastal Disasters In Mexico*

Jose Miguel Montoya Doriguez, Mexican Institute of Transport, Mexico

15:20 *Countermeasures Against Storm Surge and Tsunamis by Ministry of Land, Infrastructure, and Transport*

Yasuyuki Kajiwara, Ports and Harbours Bureau, MLIT, Japan

15:40 *Tsunami and Storm Surge Hazard Maps*

Tatsuyuki Shishido, CDIT, Japan

16:00 – 16:10 Break

16:10 – 17:10 **Panel Discussion**

Coordinator: Shigeo Takahashi, PARI, Japan

Panelists:

Yasuyuki Kajiwara, Ports and Harbours Bureau, MLIT, Japan

Nobuhisa Kobayashi, University of Delaware, USA

Panitan Lukkunaprasit, Chulalongkorn University, Thailand

Tomotsuka Takayama, Kyoto University, Japan

Harley S. Winer, US Army Corps of Engineering, USA

Ahmet C. Yalciner, Middle East Technical University, Turkey

Special Participants:

Subandono Diposaptono, Ministry of Marine Affairs and Fisheries, Indonesia

Jose Miguel Montoya Doriguez, Ministry of Communication and Transport, Mexico

Noriaki Hashimoto, Kyushu University, Japan

Masakazu Higaki, Japan Meteorological Agency, Japan

Fuminori Kato, National Institute for Land and Infrastructure Management, Japan

Norimi Mizutani, Nagoya University, Japan

Katsuya Oda, National Institute for Land and Infrastructure Management, Japan

Saman Samarawickrama, University of Moratuwa, Sri Lanka

Solomon Yim, Oregon State University, USA

Jun Yoshimura, Meteorological Research Institute, Japan

17:10 – 17:20 **Closing Ceremonies**

Remarks by Mr. Susumu Murata, President, CDIT, Japan

Contents

LARGE MODEL TEST OF TSUNAMI PRESSURE ON A SEAWALL AND ON LAND STRUCTURES

Taro Arikawa[1], Kenichiro Shimosako[2] and Fumihiko Imamura
[1] Project Researcher, Tsunami Research Center, Port and Airport Research Institute, 3-1-1 Nagase Yokosuka, 239-0826 Japan, arikawa@pari.go.jp
[2] Head, Maritime Structures Division, Marine Environment and Engineering Department, Port and Airport Research Institute, shimosako@pari.go.jp

1. INTRODUCTION

Although the research on Tsunami pressure has been conducted by many reseachers, comprehensive tsunami design methods for breakwaters, seawalls, and land structures have not been established. So, the purpose of the research is to make the tsunami design manuals for breakwaters, seawalls, and land structures, by taking into account results of the large model experimental test and the computational simulation.

2. LARGE MODEL TEST

Experimental Setup

The Large Hydro Geo Flume (see Figure 1) can generate 2.5m maximum height Tsunami with relatively long period by using the 14.0m stroke wave paddle.

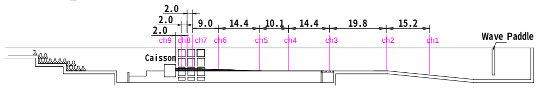


Fig. 1 The Large Hydro Geo Flume

Tsunami pressure acting on seawalls

As in Figure 2, a seawall was installed at the end of the slope and Tsunami pressure acting on it was measured. The testing was conducted for a total of 272 cases by combining gradients (1/30 and 1/50), depths (0.8 to 1.2m), offshore wave heights (0.05 to 0.8m), periods (14 to 60s), and whether the initial wave was a positive or a negative wave.

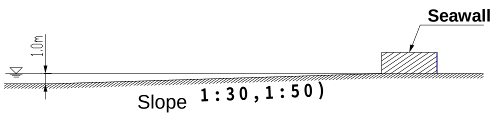


Fig. 2 Experimental setup for a seawall

The Figure 3 shows the relationship of the tsunami height (a_1), which is above the static water level in the offshore, with the sustainable pressure (P_s).

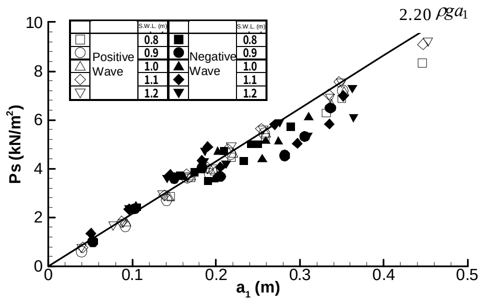


Fig. 3 Relationship of tsunami height with sustainable pressure

The figure shows that the relationship of the tsunami height above the static water level offshore with the sustainable pressure conforms to $2.2\rho g a_1$. It also reveals that there is no relationship with whether the initial wave was a positive or negative wave within the test range; it is also not dependent on the wave period.

Tsunami pressure acting on land structures

As shown in the Figure 5, a flat land area was formed beginning at the end of the 1/50 slope, a model house was installed and testing done for a total of 72 cases by varying test conditions.

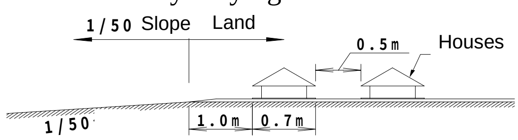


Fig. 5 Experimental Setup

The Figure 6 shows the relationship of the inundation height in front surface of a house (a_c) with the sustainable pressure (Ps).

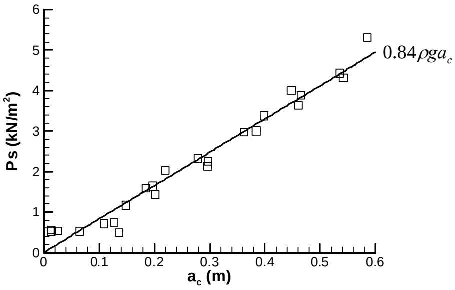


Fig. 6 Relationship of tsunami height in front of the seawall with sustainable pressure

In the case of a house near the shoreline, the wave force is approximately $0.84\rho g a_c$ of the tsunami height.

The relationship of the impulsive Tsunami pressure (P_I) with P_s reveals that it is in a range of 1.4 to 2.0 times. Differences in the Tsunami pressure acting on the house depending on whether or not there is another house in front of it. A comparison with a case shows that both P_I and P_s are reduced about 70%.

Impact loading Test

A larger Tsunami causes a lot of damage to structures with a strong impulsive load. The mechanism for destroying the structures by the impulsive Tsunami pressure should be clarified.

The 1/10 slope was installed in place of the 1/50 slope. A model wall made by wood was set up and was attacked by the 2.5m Tsunami. Photo 1 shows the state of destruction of wooden wall. The wall collapsed in an instant.

Photo 1 Destruction of wooden wall

Washing out body test

For the human body, even if the Tsunami height is less than 0.5m, people are maybe washed out. Therefore the criteria of sliding should be defined. In this test, the human stand on the floor in the wave flume. Photo 2 shows the state of experiments. Figure 7 shows the results by 10 adult men. From this result, less than 0.4m Tsunami washes out the body.

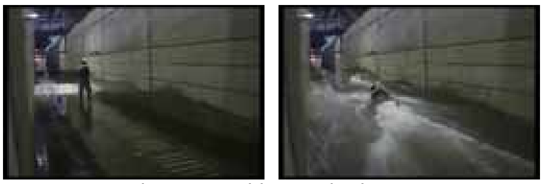


Photo 2 Washing out body test

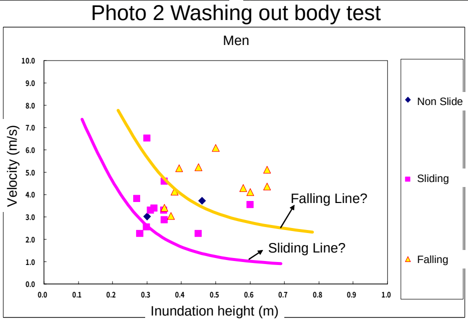


Fig. 7 the criteria of sliding

TSUNAMI WAVE FORCES ON COASTAL DIKE

Fuminori Kato, National Institute for Land and Infrastructure Management, Japan, katou-f92fr@nilim.go.jp
Shigeki Inagaki, ditto, inagaki-s924a@nilim.go.jp
Masaya Fukuhama, ditto, fukuhama-m92fc@nilim.go.jp

1. INTRODUCTION

In Japan, dikes are built along the coast to protect coastal areas against tsunamis, storm surges and high waves. Coastal dikes prevent tsunamis from infiltrating to the hinterland, although the expected tsunami height for earthquakes in the near future exceeds the height of coastal dikes in some areas.

Coastal dikes should be stable against tsunami run-up to minimize damage in the hinterland. Wave forces induced by tsunamis are one of the factors related to coastal dike failure. In shallow water, tsunamis sometimes make several bores and cause impulsive forces on structures, which cannot be easily simulated in numerical calculations.

In past studies, wave forces acting on offshore or onshore structures were evaluated through model experiments in which the structures were installed on a level bed. Since coastal dikes are usually built behind a sloping beach, wave forces on coastal dikes should be evaluated in consideration of tsunami transformation on the slope. Moreover, an upright wall was usually used as a model of the structures, while the seaward slope of a coastal dike is not always upright. Therefore, results of past experiments using an upright wall cannot be applied for sloping dikes without further examination.

To evaluate tsunami wave forces on coastal dikes, we conducted a series of large-scale experiments on wave pressure, taking wave transformation and dike slope into account.

2. EXPERIMENTAL SETUP

A fixed bed (slope: offshore 1/20, onshore 1/100) was built in a wave channel (length: 140 m, depth: 5 m, width: 2 m) of the National Institute for Land and Infrastructure Management, Japan. The channel is equipped with a piston-type wave-maker driven by a large servomotor. The wave-maker can produce solitary waves up to 0.4 m high. Five types of coastal dikes (scale: around 1/10) were installed on the bed. Type 1-4 dikes completely divided the channel. To measure the wave pressure near the edge of the dike, Type 5 (1 m wide) blocked half of the channel so that tsunami could run up on the other half of the channel.

As illustrated in Fig. 1, 23 pressure gages were fixed on the seaward slope, the crest and the landward slope of the coastal dike, and on the bed behind the dike at 10-cm intervals. To detect impulsive pressure, the sampling interval of the pressure gages was set at 0.002 s.

To take into account the effects of the beach on wave transformation into account, 5 water levels and 3 incident wave heights (0.2m, 0.3m, 0.4m) were combined.

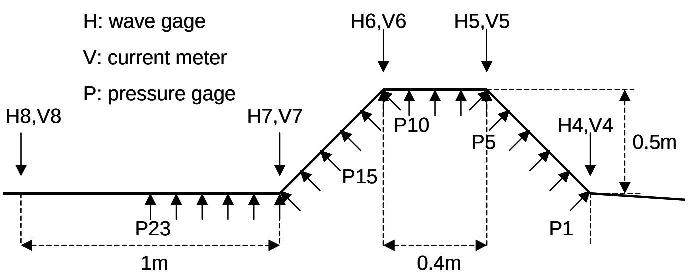


Fig.1 Arrangement of Gages (Type 1-4)

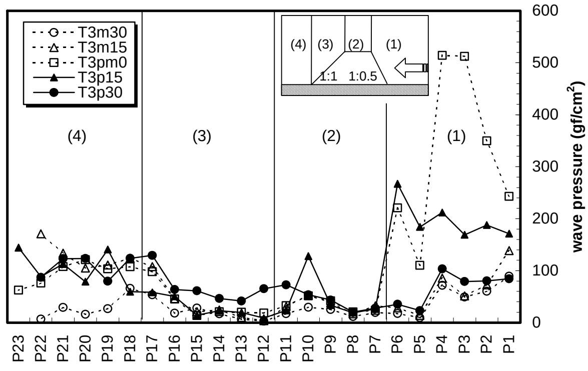


Fig.2 The Maximum Wave Pressure (Type 3)

3. RESULTS OF EXPERIMENTS

As a representative value, the maximum wave pressure at each point was extracted for cases in which the height of the incident wave was 0.4 m. Wave height increased to 1.1 m at H4 and 0.6 m at H5 because of wave transformation on the sloping bed. Current velocity at V5 exceeded 2 m/s before the peak water level at H5.

Figure 2 shows the spatial distribution of the maximum wave pressure for the type 3 dike (seaward slope 1:0.5, landward slope 1:1). For the case in which the shoreline was at the toe of the seaward slope (T3pm0 in Fig. 2), wave broke off the dike, and the maximum wave pressure exceeded 500 gf/cm^2 (49.0 kPa) at P3 and P4, and 200 gf/cm^2 (19.6 kPa) at P6. For the case in which the water level was 0.15 m lower than T3pm0 (T3m15 in Fig. 2), waves broke further offshore than T3pm0, resulting in the maximum wave pressure at the toe of the seaward slope being less than 140 gf/cm^2 (13.7 kPa) and smaller than that for Types 1 and 2. In contrast, for the case in which the water level was 0.15 m higher than T3pm0 (T3p15 in Fig. 2), the maximum wave pressure was relatively large at P6 because breaking waves collided heavily with the upper part of the seaward slope.

4. DISCUSSION

Figure 3 shows the vertical distribution of the maximum wave pressure on the seaward slope for cases in which the gradient of the seaward slope was 1:0.5. The vertical axis in the figure is the height from the still water level normalized by the wave height at the toe of the seaward slope. Plots are the results of this study, and the lines correspond to the equations proposed by past studies. Even the formulas by Ikeno et al. (2003) underestimated the measured wave pressures, especially for the cases in which the shoreline was at the toe of the seaward slope.

Fig.4 shows measured pressures near the toe of landward slope as well as values calculated with equations proposed by Mizutani and Imamura (2002). The measured pressures did not exceed the calculated values, which indicates that the equations can be applied to the experiment with solitary waves.

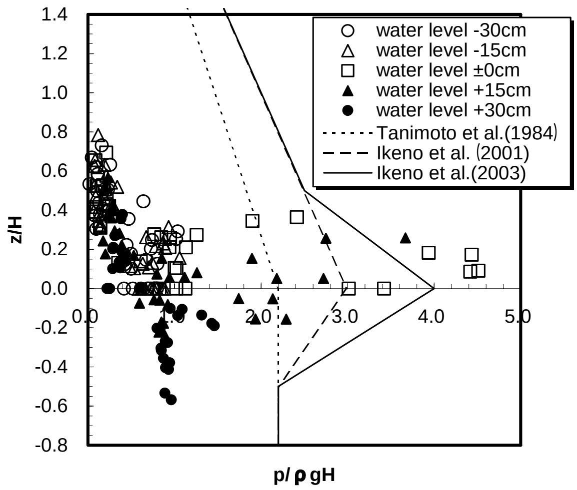


Fig.3 Vertical Distribution of the Maximum Wave Pressure (Type 3-4, Seaward Slope 1:0.5)

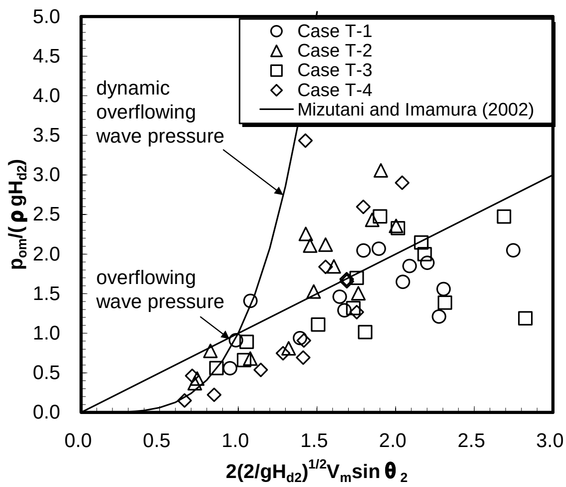


Fig.4 The Maximum Overflowing Wave Pressure (Type 1-4)

5. CONCLUSIONS

(1) Wave breaking in front of a coastal dike caused impulsive wave pressure in the lower part of the seaward slope.

(2) For the case in which the gradient of the seaward slope was 1:0.5, breaking waves collided with the upper part of the seaward slope, and produced large wave pressure there.

(3) The maximum wave pressure on the seaward slope was larger than that given by the formulas of past studies for some cases in which the shoreline was located at the toe of the seaward slope.

(4) The formulas of Mizutani and Imamura (2002) on overflowing wave pressure could be applied to this experiment with solitary waves.

6. REFERENCES

Ikeno, M. et al. Experimental Study on Tsunami Force and Impulsive Force by a Drifter under Breaking Bore like Tsunamis, Proceedings of Coastal Engineering, JSCE, Vol.48, pp.846-850, 2001.

Ikeno, M. and Tanaka H. Experimental Study on Impulse Force of Drift Body and Tsunami Running up to Land, Proceedings of Coastal Engineering, JSCE, Vol.50, pp.721-725, 2003.

Mizutani, S. and Imamura, F. Design of Coastal Structure Including the Impact and Overflow on Tsunamis, Proceedings of Coastal Engineering, JSCE, Vol.49, pp.731-735, 2002.

Tanimoto, K. et al. Tsunami Force of Nihonkai-Chubu Earthquake in 1983 and Cause of Revetment Damage, Proceedings of the 31th Japanese Conference on Coastal Engineering, JSCE, pp.257-261, 1984.

FORCES ON A CONTAINER DUE TO TSUNAMI AND COLLISION FORCE BY DRIFTED CONTAINER

Norimi Mizutani, Nagoya University, Nagoya, Aichi Japan, mizutani@civil.nagoya-u.ac.jp
Yusuke Takagi, PC Brigde Co.Ltd., Minato-ku, Tokyo Japan, y.takagi@pc-bridge.co.jp
Kazutomo Shiraishi, Nagoya University, Nagoya, Aichi Japan
Shogo Miyajima, Ministry of Land, Infrastructure and Transportation, Nagoya, Aichi Japan, miyajima-s852a@pa.cbr.mlit.go.jp
Takashi Tomita, Port and Airport Research Institute, Yokosuka, Kanagawa Japan, tomita@pari.go.jp

1. INTRODUCTION

In the Indian Ocean Tsunami, it has been revealed that the drifted objects by tsunami increased damages on the buildings and structures. Recently, major marine transports use containers and there are so many containers are placed on the container yards in the major ports in the world. As seen in Tokachi-oki Earthquake tsunami, some containers are drifted by tsunami. In Japan, huge earthquakes like Tokai Earthquake, Nankai and Tonankai Earthquakes are expected to occur. Thus, the drift of containers due to tsunami and resultant damages due to drifted containers are major concerns for the countermeasures against tsunamis. In this study, laboratory experiments have been carried out to measure the behavior of a container when tsunami runs up on the apron. Forces on a container due to tsunami has been measured and then decomposed into the drag and inertia forces. Also, collision force of drifted container to the vertical plate has been measured. Simple empirical formula to estimate the collision force is proposed based on the present results.

2. LABORATORY EXPERIMENTS

Experiments have been conducted using the wave basin of 28m long, 8m wide and 0.7m deep, which has the piston-type wave maker. The apron model of 0.25m in height above the still water level, 4m in width and 1.0m in length has been installed. Water depth was kept constant as h=0.22m. Containers of 20ft and 40ft scaled to 1:75 are used in the experiments. Six models with different mass of each length of container were prepared for the experiment. In the experiment, tsunami was modeled by solitary wave and solitary waves with different period were generated. Properties of run-up waves on the apron were investigated. Moreover, the critical condition of container movement due to tsunamis, forces due to tsunamis, behavior of drifting container and its collision forces were measured in the experiment. In the measurement of tsunami surface variation on the apron, the small pits filled with water have been installed. Water surface of the pit was set to coincide with apron surface and wave gages were set in the pit to ensure the linearity of the wave gages. Velocity of the run-up tsunami was measured by obtaining the tracks from video images of floats which were initially rested on the apron surface. Behavior of the container drifted by tsunami was obtained in the similar manner. In the measurement of the force on the container, the three component load cell was used. In this measurement, the container was fixed and water surface variations in front of the container and behind the container were also measured. The collision force due to tsunami was measured with a cantilever-type force meter developed for this experiment.

In the analysis, the time variations of the measured quantities and their maximum values are obtained. Moreover, the measured force on the container was decomposed into the drag and inertia forces using the Morison equation. In the analysis, the time variations of the velocity and acceleration at the position of container are necessary. However, the Eulerian velocity was not measured in the experiment, and then the linear transfer function method was employed in this study and the velocity was obtained by the time variation of the water surface variation.

3. RESULT AND DISCUSSIONS

(1) Crest height

Crest height at the given location η_m of run-up tsunami on the apron decreases with its propagation due to breaking. The variation along the propagation distance can be approximated by the linear relationship. Crest height of the run-up tsunami in front of the container η_{fm} is increased by a factor of 2 to 6 depending on the distance and incident wave height. Whereas the water level behind the container is very small.

(2) Velocity of run-up wave and drifted container

Velocity of run-up tsunami increases with increasing the crest height. As shown in Fig.1, the relationship between the velocity and the crest height is approximated by Cx= $2\sqrt{g\eta_m}$, which is similar to the results obtained by Matsutomi (1998) and Ramsden (1996). Drift velocity of the container is almost same as the velocity of the run-up tsunami when the mass of the container is small.

(3) Tsunami Force

Force exerted by tsunami on the fixed container is decomposed into the drag and inertia forces applying the Morison equation. Comparison of the drag and inertia forces acting on the container shows that the drag force dominates over the inertia force. Then, the forces acting on the container due to tsunami can be approximated by only the drag force as shown in Fig.2. However, the generation mechanism of the drag force may be different from the wave force on a small body as described below.

(4) Collision Force

Collision force generated by the drifting container depends much on the length of the container and less on the mass of the container. The collision force is well approximated by the model based on the impulse-momentum theorem as shown in Fig.3. Although the figure is not shown here, analysis based on the impulse-momentum theorem clearly shows that the contribution of the mass of the container to the collision force is small but the mass of the water behind the container is very large. This indicates that the added mass force of the drifting container plays an important role on the collision force due to the container.

Other important results will be presented at the presentation and the proceeding paper.

4. REFERENCES

Matsutomi, H. and H.Izuka : Tsunami Current Velocity on Land and Its Simple Estimation Method, Proc. Coastal Eng., JSCE, Vol.45, pp.361-365, 1988.

Ramsden J.D. : Forces on a vertical wall due to long waves, bores, and dry-bed surges, ASCE, Vol. 122, pp.134-141, 1996.

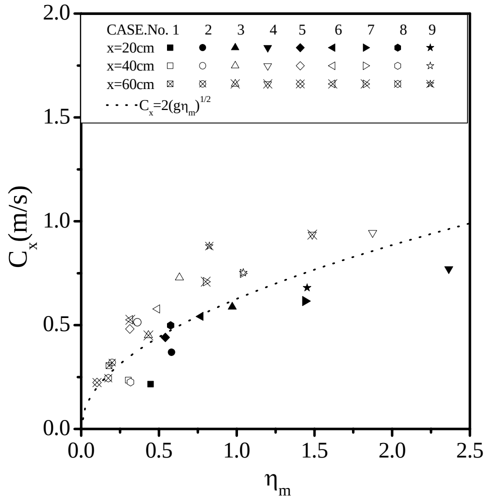


Fig.1 Relatioship between the crest height and velocity of run-up tsunami

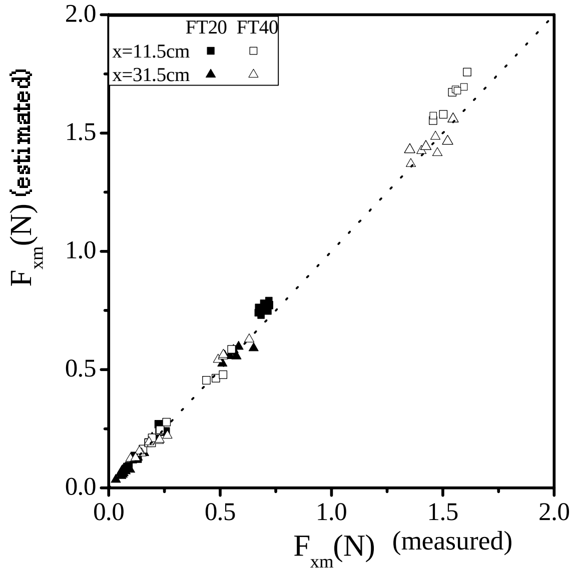


Fig.2 Comparison between tsunami force on the container and approximated value by the drag force

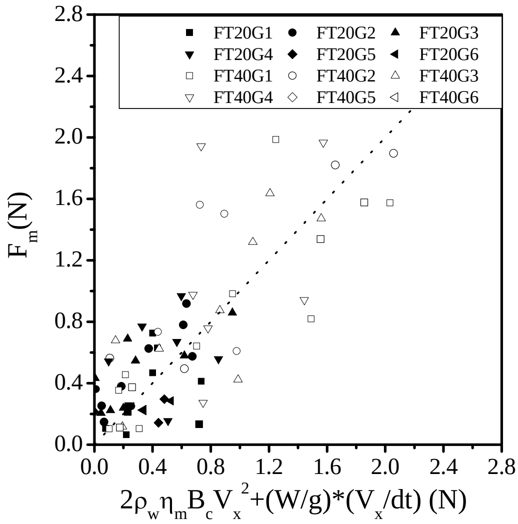


Fig.3 Collision force due to drifting container and its estimated value by proposed model

DISPERSION EFFECT IN TSUNAMI NUMERICAL SIMULATION

Koji Fujima, National Defense Academy, Yokosuka Japan, fujima@nda.ac.jp

1. INTRODUCTION

Dispersion effect plays an important role in trance-oceanic propagation of tsunami. Also in the case of near-field tsunami, dispersion effect is important if a tsunami propagates on a long shallow shelf and fissions to soliton waves. However, we do not have a standard numerical method for dispersive wave theory at the present. Fujima and Shigihara (2005) discussed the characteristics of some numerical schemes and equations, and proved that the leapfrog implicit method was stable and accurate. In addition, the selection of dispersion model (Boussinesq or Madsen-Sorendsen) was appeared not to be so important if the grid size was practical.

In this presentation, practical numerical method of leapfrog implicit scheme is proposed, where the potential function of dispersion term is solved implicitly, based on the method of Shigihara et al. (2005). In addition, effect of dispersion is shown by numerical simulation of Indian Ocean Tsunami.

2. NUMERICAL PROCEDURE

The governing equations are Eqs.(1) to (4), where f_x and f_y are the convection and the other terms. In the dispersion terms, the effect of variation of water depth is assumed to be small.

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

$$\frac{\partial M}{\partial t} + gd\frac{\partial \eta}{\partial x} + f_x = h\frac{\partial \phi}{\partial x} \tag{2}$$

$$\frac{\partial N}{\partial t} + gd\frac{\partial \eta}{\partial y} + f_y = h\frac{\partial \phi}{\partial y} \tag{3}$$

$$\phi = \alpha h\frac{\partial^2 M}{\partial t \partial x} + \beta h\frac{\partial^2 N}{\partial t \partial y} + \gamma g h^2\frac{\partial^2 \eta}{\partial x^2} + \delta g h^2\frac{\partial^2 \eta}{\partial y^2} \tag{4}$$

$$\phi - \alpha h\frac{\partial^2 \phi}{\partial x^2} - \beta h\frac{\partial^2 \phi}{\partial y^2} = -\alpha h\frac{\partial}{\partial x}[gd\frac{\partial \eta}{\partial x} + f_x] - \beta h\frac{\partial}{\partial y}[gd\frac{\partial \eta}{\partial y} + f_y] + \gamma g h^2\frac{\partial^2 \eta}{\partial x^2} + \delta g h^2\frac{\partial^2 \eta}{\partial y^2} \tag{5}$$

By substituting Eqs.(2) and (3) into Eq.(4), definition of the potential function, the governing equation of the potential function is obtained as Eq.(5).

Numerical Procedure is as follows:

(1) Water surface elevation is computed explicitly through Eq.(1).
(2) Potential function of dispersion term is solved implicitly through Eq.(5).
(3) Discharge rate in x- and y-direction is solved explicitly through Eqs.(2) and (3).

In procedure (2), because Eq.(5) is the differential equation of Poisson-type, the computation can be conducted effectively by a high-speed solver. The computation time is about 1/3 to 1/6 of that of simple SOR method. This numerical method is adaptable for the cases where there are nonlinear convection terms and the polar coordinates are used in the simulation.

3. NUMERICAL RESULTS

In the numerical simulation of Indian Ocean Tsunami, the coefficients of dispersion terms were set as those of Boussinesq model and the nonlinear terms were ignored. In the west side of tsunami source, e.g. Indonesia and Thailand, the dispersion effect was restricted. However, in the east and south side of the source, e.g. SriLanka and Maldives, the effect was not so small. Because wave celerity of high-wavenumber component becomes small by the dispersion effect, the simulation with dispersion terms provided the first wave profile without high-wavenumber component. If the dispersion effect was not considered in the simulation, the simulation provided the first wave profile with oscillation. However, in the numerical simulation without dispersion terms, the peak of the first wave and high-wavenumber component was not overlapped. Thus, the decrease of amplitude of the first wave was small, although the dispersive wave theory provides the smaller amplitude of the first wave generally.

4. REFERENCES

Fujima, K. and Shigihara, Y. Adequate Numerical Scheme for Dispersive Wave Theory, Proc. of Third International Conference on Asian and Pacific Coasts, pp.977-987, 2005.

Shigihara, Y., Fujima, K. Homma, M. and Saito, K. Numerical Model of Linear Dispersive Wave Equation for the Practical Problem, Proc. of Third International Conference on Asian and Pacific Coasts, pp. 998-1009, 2005.

APPLICATION OF THREE-DIMENSIONAL NUMERICAL MODEL TO TSUNAMIS

Takashi Tomita, Port and Airport Research Institute, Yokosuka, Kanagawa Japan, tomita@pari.go.jp
Kazuhiko Honda, Port and Airport Research Institute, Yokosuka, Kanagawa Japan, honda@pari.go.jp
Taro Kakinuma, Port and Airport Research Institute, Yokosuka, Kanagawa Japan, kakinuma@pari.go.jp

1. INTRODUCTION

The Indian Ocean Tsunami on 26 December 2004 caused severe damage in many coastal areas along the Indian Ocean. Tsunami fluid motion on the land was complicated on local topography and under the interaction with structures, and many structures suffered destructive damage by tsunami action. In this study a numerical tsunami simulator, STOC, which include a numerical flow model in three dimensions, is used to estimate such a non-hydrostatic feature of tsunamis.

2. NUMERICAL MODEL

The numerical tsunami simulator, STOC (Storm surge and Tsunami simulator in Oceans and Coastal areas), have been developed to estimate tsunami behavior from offshore to coastal areas. The simulator is a hybrid model consisting of a three-dimensional model, STOC-IC and a multilevel model, STOC-ML, referring to Fujima et al. (2002). The 3D model without assumption of hydrostatic pressure can be connected to the multilevel model in order to estimate minutely tsunami phenomena in the coastal areas where there are many structures and non-hydrostatic behavior of tsunami is induced.

Governing equations of STOC-IC is the Reynolds averaged Navier-Stokes equations in three dimensions and the porous model with the use of porosity and transmissivity by Sakakiyama and Kajima (1992) is introduced in each calculation cell to express configurations of the sea bottom and structure faces smoothly. The free water surface is defined by the vertically integrated continuity equation. The multilevel model, STOC-ML, uses the same equations as STOC-IC, and a different point from STOC-IC is the use of hydrostatic assumption in each level.

The governing equations are solved by the finite difference method in which a staggered mesh in space and leapfrog method in time are used.

3. APPLICATION TO TSUNAMI IN HYDRAULIC EXPERIMENTS

The accuracy of STOC was verified by comparing with hydraulic experimental results by Tanimoto et al. (1988). The comparison of the water surface variation in space around a tsunami breakwater which has a submerged breakwater in its open mouth to the sea is shown in Figure 1. In the figure, Cal (-2, -4), for example, indicates the numerical result using the horizontal and eddy viscosity coefficients of $10^{-2}m^2/s$ and $10^{-4}m^2/s$, respectively, and Cal(SGS) shows the numerical result with the SGS-type eddy viscosity in the same way as Fujima et al. (2002). The use of eddy viscosity coefficient like SGS-type depending on flow variation in space brings good results in the numerical simulation.

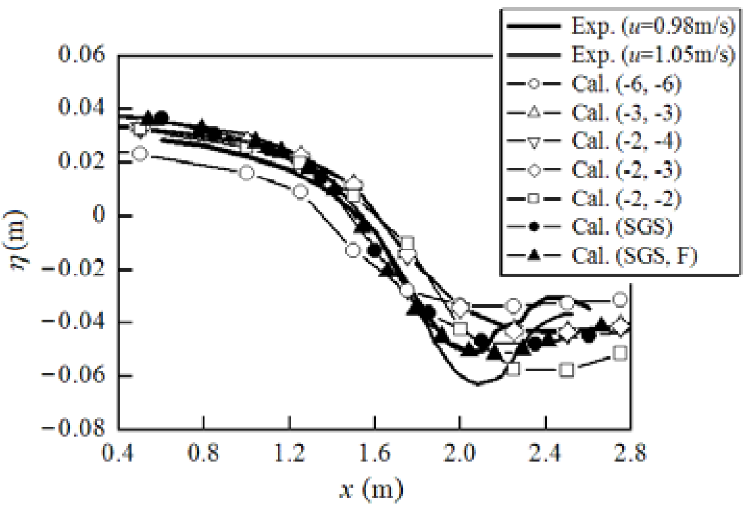


Figure 1. Experimental and numerical results on the free water surface variation in space around a breakwater

which has a submerged breakwater in its open mouth

As shown in Figure 2, the computed wave pressure of tsunami acting on a seawall could be also in good agreement with the experimental formula on the tsunami wave pressure by Tanimoto et al. (1983), which persists long time during the flooding tsunami after impulsive pressure and could be predominant for movement of massive structures like a breakwater.

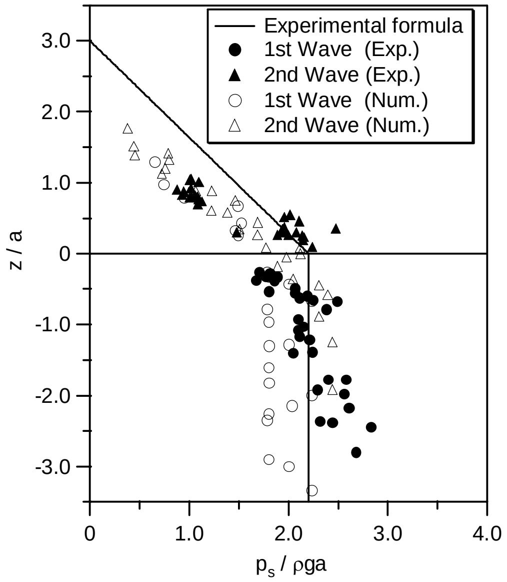


Figure 2. Experimental and numerical results on tsunami wave pressure acting on a vertical wall.

4. SUMMARY

The numerical tsunami simulator, STOC showed good performance in comparison with the hydraulic experiments. It also calculated tsunami force on structures directly considering not only hydrostatic but also dynamic wave pressures. The non-hydrostatic model can estimate the reduction of tsunami by structures using the suitable eddy viscosity model and then estimate the defense performance of the structures against tsunamis. Such visualization of numerical results as shown in Figure 3 should bring good understandings of danger of tsunami and safety against tsunamis in the coastal area where various structures exist. We are applying STOC to real topography to estimate tsunami flooding there.

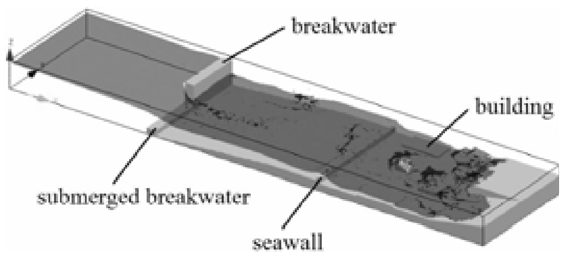


Figure 3. Example of a simulation result by STOC

5. REFERENCES

Fujima , K. et al. Development of the 2D/3D Hybrid Model for Tsunami Numerical Simulation, Coastal Engineering Journal, Vol. 44, No. 4, pp.373-397, 2002.

Sakakiyama, T. and R. Kajima. Numerical Simulation of Nonlinear Wave Interacting with Permeable Breakwaters, Proc. 23rd Int. Conf. Coastal Eng., pp. 1517-1530, 1992.

Tanimoto, K. et al. Field and Laboratory Investigations of the Tsunami caused by 1983 Nihonkai Chubu Earthquake, Tech. Note of PHRI, No. 470, 299 p., 1983.

Tanimoto, K. et al. Study on Stability of Submerged Dike at the Opening Section of Tsunami Protection Breakwaters, Rep. PHRI, 27(4), pp.93-121, 1988.

STORM WAVE AND TSUNAMI INTERACTION WITH STRUCTURES

Solomon C. Yim, Oregon Sate University, Corvallis, Oregon, USA, solomon.yim@oregonstate.edu
Kwok Fai Cheung, University of Hawaii at Manoa, Hawaii, USA, cheung@hawaii.edu

1. INTRODUCTION

Recent natural disasters caused by hurricanes and tsunamis are vivid evidence that the design codes of coastal structures, including those in the inundation zone, need to take these extreme events into account. However, current design codes (FEMA, CEM, UBC, etc.) in the US rarely mention hydrodynamic effects due to storm waves or tsunami. In an effort to mitigate the effects of tsunami on coastal cities, the US government is implementing a series of measures including the installing of additional tsunami measurement buoys in the Pacific and Atlantic oceans by NOAA. Intense research activities on various aspects of storm surge and tsunamis as well as their effects on coastal structures are underway. A complete account of these events is necessary to link the statistics of their occurrences to the mitigation efforts or design code revisions. These include modeling of generation at the source, propagation across the ocean, near-shore transformation, and fluid-structure interaction. In support of the experimental research at the Hinsdale Wave Research Laboratory at Oregon State University, 2-D and 3-D numerical models including tsunami runup and inundation effects on coastal structures are being developed. In the following sections, numerical modeling and its challenges are discussed.

2. STORM SURGE AND WAVES

Accurate modeling of coastal overwash due to hurricanes requires simultaneous simulation of physical processes that include surface winds and pressure, storm surge, astronomical tides, swell and seas, surf-zone processes, and wave runup onto dry land. These processes, with different time and length scales, have been modeled separately with reasonable accuracy. Cheung *et al* (2003) described linkages of the processes to produce a forecast package for storm-induced coastal flooding. The package produces good agreement with measured wind velocity, wave conditions, and storm-water levels in the Pacific and Atlantic basins as well as the overwash evidence in Hawaii and Southern New England.

In this comprehensive model package, hurricane wind and pressure fields, which can be generated by a parametric or numerical model, provide the environmental forcing over the ocean and coastal regions. A third generation spectral wave model generates and propagates the waves in the ocean region. The simulation results define the boundary conditions for another spectral wave model to describe transformation of the storm waves as well as the subsequent wave setup in the coastal region. A shallow-water model simulates the storm surge and astronomical tides, while a Boussinesq model provides wave-by-wave simulation of the surf and swash zone processes at the coastline.

3. TSUNAMIS

Modeling of tsunamis from seismic sources to runup is a challenging task. Deformation of the earth surface due to internal faulting is an idealization based on elastic theory of dislocation, in which the earth is treated as a homogeneous, isotropic, and elastic material. The determination of the initial tsunami waveform from the seafloor deformation is not trivial and depends on a number of factors. The most important is the rupture time, which affects the transfer of energy from the seafloor deformation to the water. The standard approach is to assume a short rupture time and as a results the initial tsunami waveform is identical to the vertical component of the seafloor deformation due to faulting. In the Hawaii Tsunami Mapping Project, recalibration of the seismic source intensity is necessary to reconcile errors from tsunami source modeling to match historical runup records.

Most nonlinear long-wave models do not conserve flow volumes and underestimate runup when breaking occurs. A fully conservative model with shock-capturing capability is a prerequisite to producing sensible runup results. Wei *et al* (2006) makes use of the surface-gradient method and a Godunov-type scheme with an exact Riemann solver to directly track the moving waterline and to capture flow discontinuities associated with bores or breaking waves, which are essential for runup calculations. This provides accurate descriptions of the conserved variables and small flow-depth perturbations near the moving waterline. The computed surface elevation, flow velocity, and runup show very good agreement with previous asymptotic and analytical solutions as well as laboratory data. The model accurately describes breaking waves as bores or hydraulic jumps and conserves volume across flow discontinuities.

4. FLUID-STRUCTURE INTERACTION

Modeling storm waves and tsunamis defines the boundary conditions at the coastline for more detailed analysis of fluid-structure interaction. The environmental loads on a structure include hydrostatic pressure, fluid impingement, form and viscous drag, and impact due to waterborne debris. These loads often induce large structural deformation, yielding, fracture, and collapse or dislodgement. The accurate numerical simulation of fluid-structure interaction is a very challenging problem since the study of coastal waves and structures have traditionally belonged to two different disciplines, namely, environmental hydrodynamics and structural mechanics. While the modeling of structures has been studied with success in the past, coupled wave-structure interaction is limited to special cases with often highly simplified assumptions. Since the inception of the Tsunami Wave Basin construction project in FY2000, researchers at OSU have been developing computational fluid-structure interaction software suitable for use by both tsunami and structural engineers (Yuk *et al* 2006). Selected developments related to the goals of this effort are briefly summarized here.

A number of commercial simulation software packages have been examined to determine their TWB experiment modeling capabilities. We found the LS-DYNA code, which contains modules for very large strain deformation, nonlinear materials, fracture, shearing detachment, contact and impact, the most suitable for our needs. Recently, a fluid model using the NS equations has been added to LS-DYNA. This fluid model can handle wave impact on flexible bodies as well as surface piercing and re-submergence of multiple flexible bodies. Recently a finite-element based formulation of the fluid domain, called the particle finite element method (PFEM), has shown promising signs for unifying the simulation of fully-coupled fluid-structure interaction. In this method, the continuity and momentum balance equations in the fluid domain are modeled using the Lagrangian formulation and discretized using the PFEM. The boundaries at the free surface and at the interface between the fluid and the structure can be modeled exactly with a moving FE grid that is remeshed at every time step. A combination using the CFD (computational structural dynamics) code from the industry for their proven robustness and nonlinear capabilities for the analysis of nonlinear structural behavior and the PFEM methods for modeling fluid motions in Lagrangian form may provide the best solution for the development of a sophisticated and robust code for simulation of tsunami wave basin experiments and prototype events. This choice allows a unified Lagrangian formulation and computation for both fluid and structural domains. More importantly, it allows for exact means of tracking the fluid-structure interfaces, which determines: (1) the energy input to the wave field by the wave generator; (2) the wave forces on the coastal structures and floating debris; and (3) energy dissipation at the bottom boundary and the beach which may contain porous media and/or movable sediments. Another issue that needs to be addressed is computational resources. To model a fluid-structural interaction experiment at the TWB using 1cm3 elements would lead to the number of fluid and structural elements on the order of 3×10^9. Using 20-node solid element with 3 degrees of freedom (d.o.f.) at each node would lead to approximately 4×10^{10} d.o.f.'s. An explicit computation of the numerical model for a typical transient experimental test of approximately 20 seconds would exceed the capability of many existing parallel computer systems. The use of high-end vector supercomputer will be necessary. Efficient unstructured grids generation software with judicial choice of grid density and some combination of explicit-implicit integration schemes is needed.

5. ACKNOWLEDGMENTS

Financial support from the National Science Foundation (CMS-0086571), NEESinc. (OMSA-2004-OSU), and from the Office of Naval Research (N00014-92-J1221 and N00014-04-10008) is gratefully acknowledged.

6. REFERENCES

Cheung, K.F., Phadke, A.C., Wei, Y., Rojas, R., Douyere, Y., Martino, C.D., Houston, S.H., Liu, P.L.F., Lynett, P.J., Dodd, N., Liao, S., and Nakazaki, E. "Modeling of storm-induced coastal flooding for emergency management," *Ocean Engineering*, 30(11), 1353-1386, 2003.

Yuk, D., Yim, S.C. and Liu, P.L-F., "Numerical Modeling of Submarine Mass-Movement Generated Waves Using RANS Model," Journal of Computers and Geosciences, in press, 2006.

Wei, Y., Mao, X.Z., and Cheung, K.F. "Well-balanced finite volume model for long-wave runup," W*aterway, Port, Coastal, and Ocean Engineering*, 132(2), in press, 2006.

DAMAGE AND IMPACT ON THE COASTAL AREA DUE TO THE 2004 INDIAN OCEAN TSUNAMI

Fumihiko Imamura, Shun-ichi Koshimura, Kazuhisa Goto and Hideaki Yanagisawa
Disaster Control Research Center, Graduate School of Engineering, Tohoku University
Aoba 6-6-11, Sendai 980-8579, Japan, imamura@tsunami2.civil.tohoku.ac.jp

1. DAMAGE DUE TO THE TSUNAMI

A tsunami caused by a great earthquake occurred in Indian Ocean on 26 Dec. 2004 and hit more than 10 countries around the ocean including Indonesia, Sri Lanka, India, Thailand and etc., which resulted in a death toll of nearly 300,000 people and great economic losses. The whole world was heavily shocked by the precipitate tragedy. The severest affected area of Indonesia is the Northern part of Sumatra, and it is reported that the coastal areas are completely destroyed by the strong shake and sudden attack of the huge tsunami more than 30 m. It was observed that the tidal surge had reached over 40 meters-height on the hilly area where the tsunami run over the top of the peninsula with a saddle shaped hill. The inland inundation mark at Banda Ache city was found up to 5 km from the coast, and there were lot of debris carried out by the tsunami wave into the center of the city, which should increase the destructive power of the tsunami. The nature of damages by this earthquake is similar to the great earthquakes with magnitude over 8 which will occur along the Nankai Trough Trance, but there epicenters are very close to the land. They will generate strong ground motion and great tsunami. In Thailand and Malaysia, many sightseeing spots were seriously damaged and a large number of foreign visitors also became victim of the tsunami disaster. It was a sudden major disaster to the resorts. This is serious issue to mitigate the tsunami damage in the coastal area because the most of visitors have large variety on the nation, knowledge, and response for natural disaster. The countermeasure at a tourist area is urgent issue even in Japan, Hawaii et al. In addition, India and Sri Lanka far from the source more than 1500 km were seriously damaged. Especially, in Sri Lanka, the number of death toll became (raised) nearly 40,000. The East and South coast in Sri Lanka were totally damaged; besides Colombo, the South-West Sri Lanka had been damaged too, even though the coast is located in the back for the direction of tsunami propagation from the source. In the coastal areas, the community villages were totally destroyed; and the train that stopped for evacuating in emergency basis, had lost more than one thousand of people who were passengers, which is one of new damages due to a tsunami.

2. EFFECTS OF TSUNAMI ON THE COASTAL ENVIRONMENTS

Large tsunami waves strongly affect the coastal environments, and damage severely to the agriculture and the fishery activities. For example, trees are fell down by the impact of tsunami waves, and vegetations within the inundation area were blighted due to the salty seawater. Moreover, the sea bottom, coastal topography and river drastically change due to the erosion and re-sedimentation of the sea bottom and the beach sediments. A large amount of sediments are transported landward and cover the wide area of the coastal area to form the tsunami deposits. In order to mitigate damages on the coastal environments and to make a future disaster prevention plan for at-risk countries, detail survey for understanding the damage of coastal environments by the 2004 Indian Ocean tsunami is required. We conducted the field survey on coastal vegetation such as mangrove, sediments and coral rocks, and coastal topography.

Fig.1 Affected area on the mangrove in Kao lak, Thai

3. IMPACT ON GREEN BELT SUCH AS MANGROVE

The tsunami provide us with an unprecedented opportunity to evaluate the impact on the environment and to assess the role of mangrove forests in reducing impacts of tsunamis or storm surge. We have made initial comparison of pre-tsunami mangrove cover and post-tsunami destruction by using paired satellite images. Mangrove forests, in particular, shield coastlines by reducing wave amplitude and energy. Coastlines fringed by mangroves were strikingly less damaged than those where mangroves were absent or had been removed. Field observations indicate that mangroves also prevented people being washed into the sea, which was a major cause of death. In addition, mangroves trapped driftwood preventing property damage and injury to people Green belts of other trees, coastal dunes, and intact coral reefs performed similar functions. On the other hand, coastal vegetations would be fell down and pulled up by the strong tsunami impact, and fragments of fallen trees convert to the dangerous floating materials. We try to get a criteria of fell trees/mangrove due to the moment/force of the tsunami, which is necessary to discuss an effective tsunami disaster reduction plan that uses coastal vegetations.

4. TSUNAMI DEPOSITS AND BLOCKS

A large tsunami can remove sediments from the sea bottom and the beach, and transport a large amount of sediments landward to form the tsunami deposits. Distribution of tsunami deposits and their sedimentological characteristics (e.g., thickness, grain size, sedimentary structures) are useful information to estimate the hydrodynamic force of the tsunami wave currents during their sedimentation. Thus, we preliminary investigated the distribution and their characteristics around the Khao Lak area (Goto et al., 2005). In Pakarang Cape near Khao Lak, there were abundant reef blocks, which were composed of fragments of coral up to 4 m in diameter. Reef blocks are scattered from 0 to about 400 m offshore and over a distance of about 1 km from north to south along the shore. No reef blocks are observed on land, suggesting that the hydrodynamic force of the tsunami wave currents have suddenly became weak near the shoreline. According to our field observation, flat, very shallow sea floor extends up to 300-600 m offshore from the high-tide line, and the gradient suddenly increased around the reef edge. We infer that tsunami waves probably impacted to the reef edge around 300-600 m offshore and transported reef blocks landward.

INDIAN OCEAN TSUNAMI ON THE SRI LANKAN COAST NEAR SHORE PROCESSES AND THE IMPACT OF CORAL REMOVAL

SP Samarawickrama[a], SSL Hettiarachchi[a] and HJS Fernando[b]
[a] Department of Civil Engineering, University of Moratuwa, Moratuwa, Sri Lanka, samans@civil.mrt.ac.lk
[b] Department of Mechanical & Aerospace Engineering, Environmental Fluid Dynamics Program, Arizona State University, Tempe, AZ 85287-980, j.fernando@asu.edu

1. INTRODUCTION

On 26th December 2004 the Sri Lankan coastline witnessed the devastating impact of a tsunami, hitherto to as the Indian Ocean Tsunami, which arose from a massive submarine earthquake 400 km west of northern Sumatra. The earthquake measured 9 on the Richter Scale and the fault length exceeded 1000km. The entire coastline with the exception of parts of the north-western coastline was severely affected. One of the important observations of the Indian Ocean Tsunami was that areas in the southern and western provinces that were in the shadow of the direct impact of the tsunami wave were severely affected and there were remarkable small scale spatial variation. This led to the investigations of understanding the propagation of the tsunami wave.

2. NEAR-SHORE WAVE TRANSFORMATIONS

From detailed studies of the tsunami wave witnessed around the island it was clearly evident that near-shore transformation processes and shoreline geometry increased the wave heights along many parts of the southern and western province which would have normally received only diffracted waves. The impacts of the combined transformation processes and the shoreline geometry contributed very heavily to the unexpected devastation at certain locations along the south west coast. The inland topography and lack of drainage facilities further enhanced the problem. Figures 1 and 2 illustrate the observed highest wave heights and arrival times of the highest wave. Arrival times of the highest waves given in the Figure 2 clearly indicate the complex transformation processes that occurred in the western coast. Some areas of the western coast received the highest wave much later than the rest due to the combined waves, ie the combination of reflected waves (reflection from India and Maldives) with the incoming incident waves (refracted and diffracted).

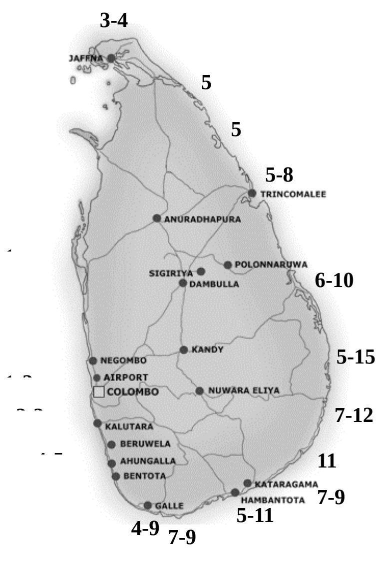


Figure 1: *Testified Tsunami wave heights in meters*

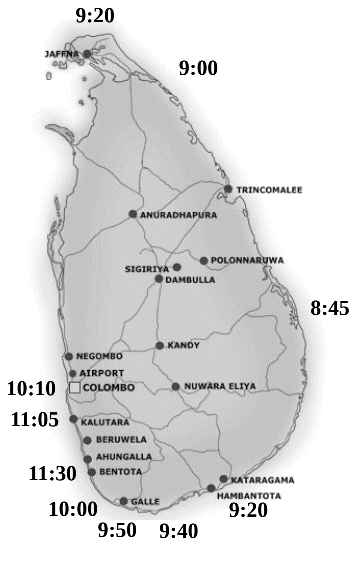


Figure 2: *Testified Tsunami arrival times (highest wave)*

3. IMPACT OF CORAL REEFS ON TSUNAMI WAVE PROPAGATION

Field investigations carried out on the southwestern coast indicate remarkable, small scale spatial variation of water inundation and destruction. For example, the town of Peraliya, where the passenger train was floated away, had 1.5km inundation whilst Hikkaduwa, about 3km south thereof, faced a mere 50m inundation. In the eastern, southern and southwestern coast upto Galle this inundation "pachiness" was very much related to the local geomorphologic features such as headlands, embayments and river/estuarine inlets whereas the stretch from Galle to Ambalangoda, this was completely unrelated to coastline features. This glaring absence of small-scale spatial features in wave and coastline records in the southwestern coast led to the investigation of inhomogenity of the ocean bottom as a candidate for spatial intermittency of destruction. It was evident that the north of Hikkaduwa up to Akurala where extensive coral mining had taken pace over the past few decades was under heavy attack from the tsunami wave. It is possible that the concentration of wave energy as a result of complex wave processes that happened in the southwestern coast may also have contributed to this significantly high local damage but the coral removal was thought to be the main contributor. The illegal coral mining has created a defenseless “low resistance paths” that allowed focused water jetting and intensified destruction. Similar jetting effect has observed in number of other locations in the Sri Lankan coastline where removal of sand dunes and coastal vegetation had taken place.

4. PHYSICAL MODEL SET UP

A physical modeling study was carried out in a 86cm wide, 30 m long flume to understand the effect of coral reefs on tsunami propagation, especially to understand the negative impacts of coral mining. A regular wave with heights of 8cm, 10cm & 12cm and a period of 2.5seconds was used in the 30cm water depth. A 20cm high, 60cm long porous media was selected to represent the coral reefs and the experiments were carried out for a loose structure (50% porosity) as well as for a tight structure (20% porosity). A narrow channel of 6.5cm and a wide channel of 16.5cm were left open to simulate the coral removal. It has to be noted here that this experimental setup represented realistic values for wave height, water depth and coral dimensions but only a short period wave was used in the study. Figure 3 gives the simulation of coral reefs in 2D physical modeling, a completed structure with a narrow opening.

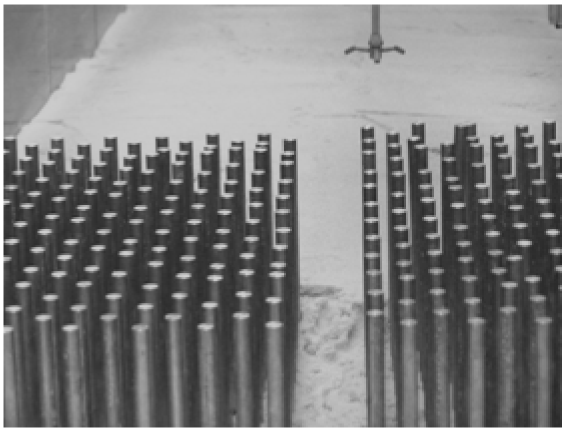


Figure 3: *Simulation of Coral Reefs in 2D Physical Modelling*

5. ANALYSIS OF RESULTS

Level from the bed (cm)	Velocity (cm/s)					
	No structure	Structure without an opening	Structure with a narrow opening		Structure with a wide opening	
			In the channel	Behind the structure	In the channel	Behind the structure
25	40	52	39	*45*	39	*34*
20	37	34	39	*34*	38	*32*
15	36	31	40	*31*	38	*31*
10	36	18	37	*5*	36	*4*
5	1	1	12	*1*	7	*1*

Table 1: *Velocity measurements for the tight structure (20% porosity)*

Table 1 gives the velocity measurements for H=12cm and T=2.5 seconds for the tight structure. It is clear from the table that there is a considerable reduction in velocity due to the presence of the structure throughout the water column apart from the surface velocity. On the other hand a considerable increase in velocity can be seen when there is a gap in the structure. It is also clear that a narrow opening in the structure gives a larger increase in velocity with compared to the wide opening due to the jetting effect.

THE 2004 INDIAN OCEAN TSUNAMI DISASTER AND BUILDING RE-CONSTRUCTION IN THAILAND

Panitan Lukkunaprasit, Chulalongkorn University, Patumwan, Bangkok, Thailand, lpanitan@chula.ac.th

1. INTRODUCTION

The unprecedented devastating Indian Ocean tsunami which struck the western coast of southern Thailand on December 26, 2004 caused more than 5,300 deaths, and heavy damage to buildings including ports in the affected areas. Prior to the event, the lack of historical records of destruction by tsunamis on Thai coastlines made the public, and even most academics, to be unaware of the possibility of tsunamis occurring along the coasts of the country. Consequently, the country was not prepared for the hazard, leading to great catastrophe and economic losses. Valuable but costly lessons have been learned from the seismological, engineering, environmental, social and economic viewpoints. This paper touches mainly on the structural damage in Southern Thailand, where run-up heights were 3-7 m above ground levels. Clues valuable for the safe and economical design of buildings against future tsunamis are outlined. Restoration and re-construction activities done after the disaster are also addressed.

2. BUILDINGS PERFORMANCE

The damage caused by the tsunami clearly reveals inadequate design and construction of foundations, columns, joints, as well as retaining structures. Excessive damage could be attributed to the non-seismic design and construction in Thailand, featuring relatively small columns with light transverse reinforcement. The prevalent scouring of the soil supporting retaining walls and footings of buildings suggests putting buildings on piles in locations close to the shorelines or water ways. The current practice of weakly connecting infill masonry panels to the boundary reinforced concrete frames with widely spaced dowels has proved to work well in detaching the brick walls from the frames under excessive water pressure, thereby releasing the force transmitted to the building. The superior performance of non-structural un-reinforced brick walls with openings has been observed, and reinforced concrete frames with such walls should be advantageous in providing a sound low cost structural system with strength and robustness. The collapse of pre-cast concrete slabs in a port structure due to uplift by the waves suggests that pre-cast systems are not suitable, since complicated design, detailing and construction are needed to provide uplift capacity to the structure.

Whereas most non-engineered buildings collapsed, it is interesting to note that a large number of engineered buildings, which have not been designed for seismic or tsunami loadings, have survived in water heights up to about 6 m above ground level.

3. RESTORATION AND RE-CONSTRUCTION

After the disaster, re-construction of buildings have been generally done in a haste in the affected areas using the normal construction practices which do not take into account the effects of tsunamis. However, a school has been re-built with the ground level raised by a few meters, and with the structural columns significantly stronger than the present standard of practice.

The disaster has also prompted amendment of the present ministerial regulations on seismic resistant design of buildings.

4. CONCLUSIONS

The Indian Ocean tsunami catastrophe has instantly changed the state of natural disaster in Thailand. It has also raised significant public awareness of natural disasters in the country.

The survival of a large number of non-seismic, non-tsunami resistant buildings in water heights of about 6 m suggests that it is possible to design tsunami resistant structures with reparability performance level. This assumes practical significance in that tsunami resistant buildings can be used as evacuation shelters for life saving in flat terrains. Concerted research efforts on tsunami loadings and tsunami resistant design of buildings should be a high priority.

DISASTER IMPACTS OF DECEMBER 2004 INDIAN OCEAN TSUNAMI IN INDONESIA AND ITS REHABILITATION EFFORTS

Subandono Diposaptono, Ministry of Marine Affairs and Fisheries, Indonesia, sbdn@cbn.net.id

1. INTRODUCTION

The world was made frighteningly more aware of the danger associated with population centres located in coastal areas by the devastating loss of live and setback of economic development due to the December 2004 tsunami disaster. The Indian Ocean Tsunami on 26 December 2004 caused severe damage in many coastal areas along the west and east coast of Nangroe Aceh Darussalam (NAD) provinces and Nias Islands,, North Sumatera provinces of Indonesia. The disaster in Indonesia was massive with record breaking earthquakes and tsunami waves. There was very short almost no time for alert and evacuation. The tsunami was deadly for a number of reasons :

- low-lying populated coasts within a short distance of the tsunami source (reaching Sumatra in less than half an hour)
- no tsunami warning system in the Indian Ocean
- little public awareness of tsunami hazards.
- un-proper spatial planning
- destruction of some natural protection, e.g. mangroves, coastal forests

The objective of this short paper is to provide an overview the impacts of tsunamis on the coastal areas and post tsunami disaster rehabilitation efforts in Indonesia

2. DISASTER IMPACTS ON COASTAL AREAS IN INDONESIA

The earthquake and tsunami wave damaged the most part of NAD's coastal areas, claiming heavy casualties, destroyed infrastructure, settlements, social facilities such as schools, health centers, security, social and public economic, and government buildings. This disaster also affected the social and economic condition of the people, including their psychological condition and welfare level.

The fatalities in 20 kabupatens (districts) in the Province of NAD are estimated to reach 126,602 people killed and interned, and 93,638 people missing. The number of fatalities in the Province of North Sumatra is estimated to reach 130 people killed and 24 people missing. The number of scattered refugees is 514,150 people in 21 kabupaten/kota of the Province of NAD. The total damage and losses are estimated to reach Rp 4l.4 trillion; most of them (78 percent) affecting non-public assets, with the remaining affecting government assets.

In general there are 3 zones affected by the tsunamis : Zone 1-direct tsunami impact, is the coastal areas which were destructed by the tsunami forces. Most victims are fishermen, survivors less than 20%, and survived by "miracle". In this zone, the wave heigh were so great, that almost all the structures are destroyed, no matter how they were built. Zone 2-tsunami flood impact, is the coastal areas which were inundated by tsunamis. This zone is characterized by physical damages to buildings and infrastructures. Most victims are farmer, trader, and informal sector; survivors more than 50%; survived by the efforts (running; climbing tress, high buliding etc.). And Zone 3-indirect tsunami impact, is the coastal areas which were suffered minor damaged by tsunami,. Debris were accumulated in this zone. Survivors more than 90%.

3. REHABILITATION AND RECONSTRUCTION

The disaster impacts are responsed through a comprehensive and integrated approach made in three stages, namely emergency response, rehabilitation and reconstruction to be going on simultaneously in the implementation, namely:

a. Emergency Response Stage (January 2005 - March 2005)

This is aimed at rescuing the surviving community members and to immediately fulfill their minimum basic needs. The main goal of this response stage is humanitarian rescue and aid. At this response stage, it is also endeavored to complete decent temporary phaces for refuge, and quick logistic arrangement and distribution that can reach the intended target namely the disaster survivors. At the outset of the disaster, the Stage of Emergency Response was set for 6 months since the disaster. Nevertheless, after the stipulation of Presidential Instruction Number 1 Year 2005, this Response Stage was shortened to 3 months and it will end on March 26, 2005.

b. Rehabilitation Stage (April 2005 - December 2006)

This is aimed at urgently recovering and restoring the functions of structures and infrastructures to follow up the stage of emergency response, such as the rehabilitation of mosques, hospitals, basic social infrastructures, as well as economic infrastructure and facilities that are badly needed. The main goal of this rehabilitation stage is to enhance public services up to an acceptable level. At this rehabilitation stage, it is also endeavored to solve various issues related to the legal aspect through settlement of rights on land, and to the psychological aspects through the handling of disaster victims' trauma.

c. Reconstruction Stage (July 2006 - December 2009)

This is aimed at reconstructing the areas of city, village and agglomeration of areas by involving all communities of disaster victims, the experts, representatives of non-government organizations, and the business community. Once the adjustment to spatial structure plan has been completed at provincial level and particularly at kabupaten and kota levels, particularly in coastal areas, infrastructure and facility construction must start. The main goal of this reconstruction stage is to reconstruct the areas and communities affected by the disaster directly or indirectly.

In April 2005, five months following the tsunami, the Indonesian government created the Aceh-Nias Reconstruction and Rehabilitation Agency (BRR). The Indonesian government has placed the BRR in charge of overseeing all projects and dealings with donor institutions and NGOs. The BRR is also responsible for checking whether NGOs are effectively functioning. There are currently 420 NGOs operating in Aceh and Nias. These NGOs are involved in various projects, including the construction of a functioning infrastructure. There are even several NGOs that had worked in Aceh before the BRR was established. The BRR itself is following a community-driven rehabilitation concept, aimed at giving the Acehnese people the freedom to determine and shape the development of their own region.

4. REFERENCES

Government of the Republic of Indonesia. Masterplan for Rehabilitation and Reconstruction for the Regions and People of the Province of Nangroe Aceh Darussalam and Nias Islands of the Province of North Sumatera, 2005.

Tempo. Special Edition the Tsunami, 1 Year On. 2005.

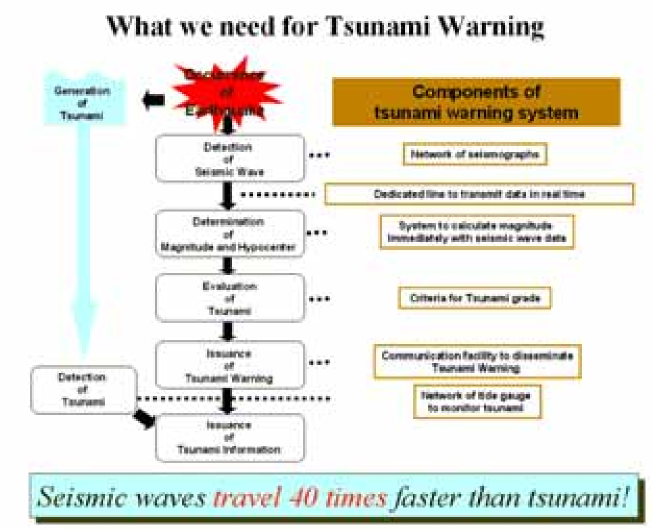
TSUNAMI WARNING SYSTEM IN JAPAN

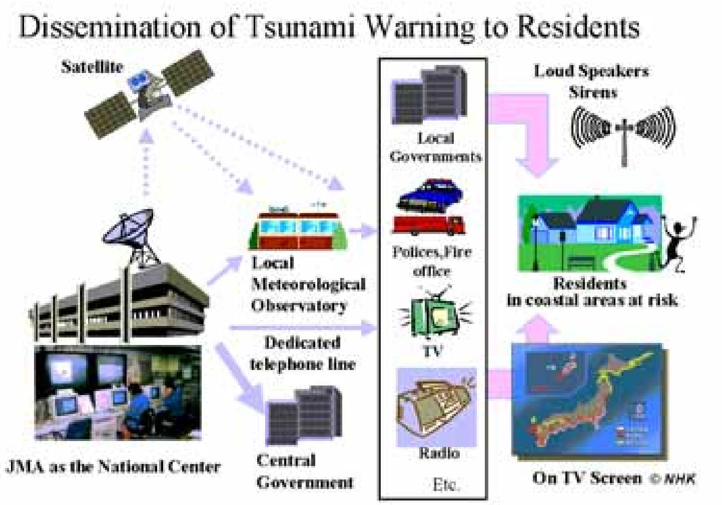
Shin'ya Tsukada, Seismological and Volcanological Department, Japan Meteorological Agency, 1-3-4 Ohte-machi, Chiyoda-ku, Tokyo, tsukada@met.kishou.go.jp

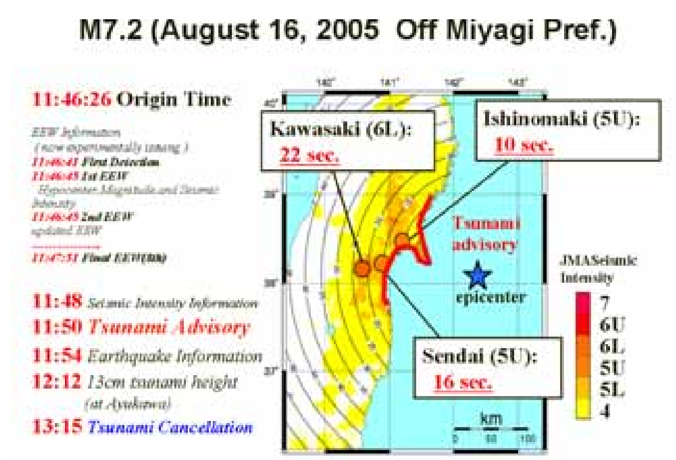
1. NATIONAL TSUNAMI WARNING SYSTEM

The Japan Meteorological Agency (JMA) continuously monitors the seismic activity in and around Japan. When an earthquake takes place, JMA immediately determines the location and magnitude of the earthquake. If the earthquake occurs in ocean area with tsunamigenic potential, JMA executes the tsunami forecast operation using the database containing tsunami heights and arrival times constructed by numerical-simulation. Tsunami forecasts are categorized into two; Tsunami Warning and Tsunami Advisory, and Warning is divided into two classes; Major Tsunami and Tsunami, depending on the forecast height of the tsunami. JMA issues Warnings and/or Advisories for 66 forecast coastal regions which cover all of coastal areas of the country. The elapsed time for tsunami warning has been reduced to 3 - 5 minutes since JMA started tsunami warning service in 1952. Tsunami forecast contains the expected maximum tsunami height and the arrival time of the tsunami. Warnings and/or Advisories are provided to the national and local authorities for disaster prevention and the broadcasting media. Mayors of cities, towns or villages are responsible for giving directions to residents for evacuation from tsunami hazardous areas. JMA monitors tsunami observed by the tide gauges installed on the coasts of Japan for re-evaluation of tsunami forecast. JMA cancels Warnings and/or Advisories for the forecast coastal regions where the safety is recovered due to diminishing the tsunami heights observed.

When a large earthquake occurs at a distant area from Japan, JMA determines the location and the magnitude using seismic data from global seismological observation network. In case of possibility of tsunami generation, JMA immediately executes the tsunami forecast operation in the same manner as the local tsunami. JMA uses the database derived from numerical simulation to judge whether the tsunami affects Japanese coast. Data of tsunami observations from foreign countries are also referred for the estimation of tsunami height.







Left upper: Procedure of Tsunami warning

Right upper: Dissemination of Tsunami warning

Left lower: Example of Tsunami Advisory

2. NORTHWEST PACIFIC TSUNAMI ADVISORY CENTER

The establishment of regional tsunami warning centers has been discussed by the International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU) since 1978. With regard to the Northwest Pacific region, the Republic of Korea proposed at the 14th session of ICG/ITSU in 1993 that Japan should take the responsibility of operating a regional center for the area. At the 17th session of ICG/ITSU in 1999, JMA submitted a proposal to provide the tsunami information when a tsunami is expected due to the earthquake occurred in the Sea of Japan, and started to provide the tsunami information to Russia and the Republic of Korea in January 2001. In addition, JMA was requested by ICG/ITSU to expand its responsible regions and include the Northwest Pacific Ocean and its adjacent seas region. In response to this request, JMA developed the system to provide the tsunami information for all Northwest Pacific Ocean regions. JMA held the technical meeting in March 2005 in order to start the operation of the Northwest Pacific Tsunami Advisory Center (NWPTAC) smoothly. At the 20th session of ICG/ITSU in 2005, JMA reported that the necessary preparations had been completed, and then NWPTAC started its formal operation.

NWPTAC determines the location and magnitude of an earthquake using data from global and domestic seismological networks and estimates arrival time and height of tsunami with the tsunami forecast system based on numerical simulation technique of tsunami. Moreover, when tsunami is actually observed, the observed tsunami height is also announced. NWPTAC provides the information to the relevant countries (Russian Federation, Republic of Korea, China, the Philippines, Indonesia and Papua New Guinea) as the first phase. NWPTAC issued the information four times as of 31 December 2005.

The targeted area of NWPTAC will be expanded into the marginal seas of the Pacific including the South China Sea on a step-by-step basis.

3. INTERIM PROVISION OF TSUNAMI WATCH INFORMATION FOR THE INDIAN OCEAN COUNTRIES

During the UN World Conference on Disaster Reduction (WCDR) held in Kobe, Japan, in January 2005, the Regional/Thematic Special Session entitled "Promotion of tsunami disaster mitigation in the Indian Ocean" sought the way to establish the early warning system in the Indian Ocean region through international coordination from the professional point of view.

JMA commenced to provide Tsunami Watch Information to countries around the Indian Ocean in cooperation with the Pacific Tsunami Warning Center (PTWC) as an interim measure to be carried out until the tsunami early warning system in the Indian Ocean region becomes fully operational. Tsunami Watch Information is issued in less than 20 to 30 minutes after the occurrence of an earthquake, depending on the availability of seismic data, and the Information contains earthquake information, tsunamigenic potential, and expected arrival times. Tsunami Watch Information should be regarded as a reference for taking preventive measure against possible tsunamis on the responsibility and initiative of the individual countries.

Tsunami Watch Information is provided to 26 countries and was issued eight times as of 31 December 2005.

CONCEPT OF TSUNAMI DETECTING SYSTEM USING REMOTE SENSING

Tomoyuki Takahashi, Akita University, Akita, Japan, tomoc@ce.akita-u.ac.jp

1. INTRODUCTION

Structural mitigation measures such as a seawall, a tsunami breakwater and a water gate are effective in tsunami disasters. These hardware solutions, however, cannot completely prevent the damages. Non-structural mitigation measures are also necessary. One of the most effective software solutions is a tsunami evacuation. Residents must escape from coastal region right after an earthquake. To support the tsunami evacuation, simple and useful information about arriving tsunamis should be provided for the residents. And to provide the information, precise and prompt tsunami detection should be carried out. Therefore, the tsunami detecting system is important in the tsunami disaster mitigation.

2. PROBLEM OF PRESENT TSUNAMI WARNING SYSTEM AND OBSERVATION SYSTEM

Because many tsunamis are generated by large earthquake, a present tsunami warning system is using a seismic wave to detect the tsunami generation as shown in Figure 1. The systems operated by such institutions as JMA and PTWC have been studied well and produced excellent results. However, there is a possibility of an underestimation of a tsunami magnitude in some cases of an extra large earthquake like the 2004 Sumatra event, a tsunami earthquake like the slow earthquake and a large asperity close to a coast.

A tsunami observation system has also been studied well and has been established such as NOWPHAS operated by PARI. The system has obtained many valuable data of past tsunamis and these data have contributed to a tsunami research. However, they are not yet sufficient for the tsunami generation detection, because they are located close to a coastal area and observe at each setup points. Many large tsunamis are generated along the plate boundary and their sizes get to a several hundred kilometers.

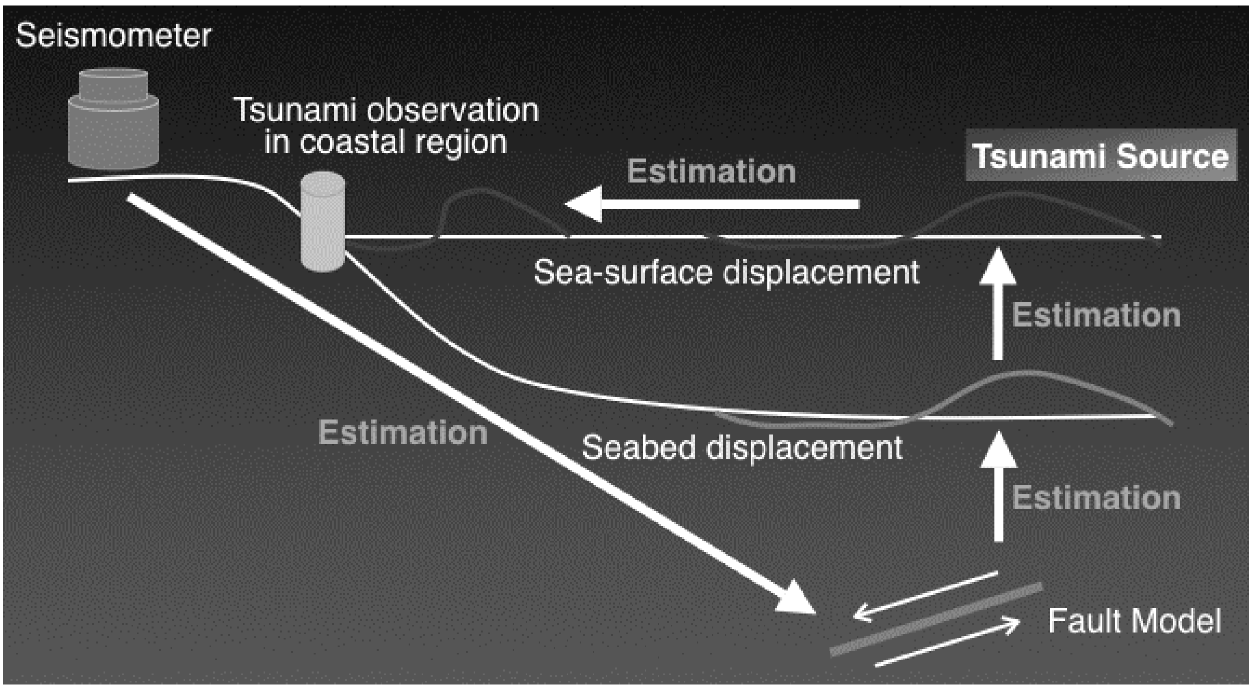


Figure 1. Example of the present tsunami warning system

3. IMPROVEMENT OF TSUNAMI DETECTING SYSTEM

The instructive systems mentioned above need to improve the tsunami detection performance for the advancement of tsunami disaster mitigation. Because tsunamis are huge phenomena occurred far from coasts, it is important to observe a very wide area and measure a sea surface directly. And furthermore, the real-time two-dimensional sensing is necessary to comprehend whole tsunami source and its propagation. To realize these functions, a remote sensing technique should be applied. As the remote sensing platform to detect tsunamis, ocean radar, a stratosphere platform and an artificial satellite should be applicable as shown in Figure 2. Especially, the ocean radar is the most promising, because it has already put to practice use in an ocean current observation. And it is inexpensive compared to other observation systems and easy to maintain itself.

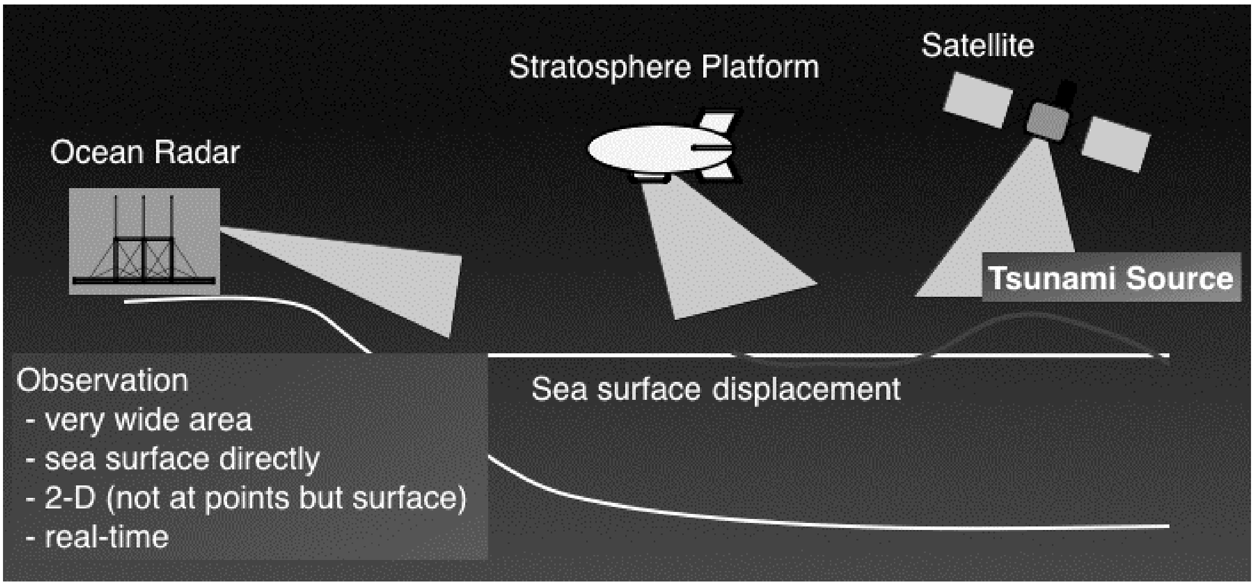


Figure 2. Diagram of the tsunami detecting system using remote sensing

OFFSHORE TSUNAMI MONITORING NETWORK DESIGN USING GPS BUOYS AND COASTAL ON-SITE SENSORS

Toshihiko Nagai, Port and Airport Research Institute, Yokosuka, Kanagawa Japan, nagai@pari.go.jp

1. INTRODUCTION

Establishment of the offshore tsunami monitoring network system is an urgent task for countries facing to ocean. Nevertheless, as a huge disastrous tsunami is a rare event, it is difficult to make understand the importance of maintaining and operating the network system, if the system is applicable only for tsunami events. Therefore, the network system needs to be applied to monitoring not only tsunami but also daily sea conditions such as coastal waves and tides. This presentation introduces a basic design of Japanese nationwide tsunami monitoring system, by improving the NOWPHAS (Nationwide Ocean Wave information network for Ports and HArbourS) system (Nagai, 2002), and by using the newly developed GPS buoy system (Nagai et al., 2005).

2. GPS BUOY OBSERVATION SYSTEM DEVELOPMENT

Recently, GPS buoy tsunami detection system has newly been developed as shown in the Figure 1 (Kato, et al., 2001). And the field experiment of the GPS buoy system proved its applicability to offshore waves, tides and tsunami observation (Nagai, et al., 2004). Real-Time-Kinematic (RTK) method is used in the system with on-land reference GPS station within 20km from the buoy, which is further offshore area than the existing NOWPHAS seabed installed sensor stations..

3. PROPOSED OBSERVATION NETWORK

Horizontal allocation of the sensors is also proposed. Figure 2 is the proposed offshore observation network. Offshore tsunami sensors are to be installed with intervals of about half length of the tsunami wave source zone in order to obtain offshore tsunami height distribution along the coast. Therefore, considering a possible horizontal scale of near-coast tsunami generating earthquakes (Hatori, 2004), tsunami detection stations should be installed at intervals of 50-100km along the Pacific coast as shown in the Figure 1. Small islands on the ocean are suitable points for long-distance tsunami detection, which will be helpful for international tsunami disaster reduction.

4. NECESSITY OF IMPROVEMENT OF THE NOWPHAS DATA CENTER SYSTEM

Development and improvement of the International Tsunami Monitoring System is getting more importance after the 2004 Sumatra-Off-Earthquake Tsunami disaster. This presentation intends to contribute to the international efforts to prevent tsunami disasters by using our experiences in offshore tsunami, wave, and tide observation and network data analysis. Up to present, tsunami monitoring system was developed and established based on earthquake vibration observation data only. Nevertheless, earthquake vibration data may give us incorrect tsunami forecasting, for the strength of the vibration and the tsunami energy are not exactly proportional. Therefore, offshore and coastal tsunami-wave profile observation system should be included in the monitoring system. This presentation introduced basic design of the future tsunami monitoring system using newly developed GPS buoy system and other coastal and on-site sensors. A new method of tsunami data processing system is also to be introduced.

5. REFERENCES

Hatori, T.[2005]. "Tsunami Source and Wave Energy Distribution along the Coast of Japan", Chikyu Monthly, Vol.27, No.3, Kaiyo-Syuppan Co., pp.166-170. (in Japanese)

Kato, T., Terada, Y., Kinoshita, M., Kakimoto, H., Isshiki, H., Moriguchi, T., Takada, M., Tanno, T., Kanzaki, M. and James Johnson [2001]. "A New Tsunami Monitoring System using RTK-GPS", ITS 2001 Proceedings, Session 5, Number 5-12, pp.645-651.

Nagai, T.[2002]. "Development and Improvement of the Nationwide Coastal Wave Observation Network", Techno-Ocean'2002, Paper-TI-1-2, 4p.

Nagai, T., Ogawa, H., Terada, Y., Kato,T., and Kudaka, M.[2004]. "GPS Buoy Application to Offshore Wave, Tsunami and Tide Observation", Proc. of the 29th International Conference on Coastal Engineering (ICCE'04), vol.1, pp.1093-1105.

Nagai, T., Kato,T., Nukada, K., Izumi, Y., Terada, Y., and Mitsui, M.[2005]. "Proposal of Coastal Tsunami Information System with Offshore, Nearshore and On-site Network Observation Equipments", Proceedings of the Ocean Vol.21, Japan Society of Civil Engineers, pp.61-66. (in Japanese)

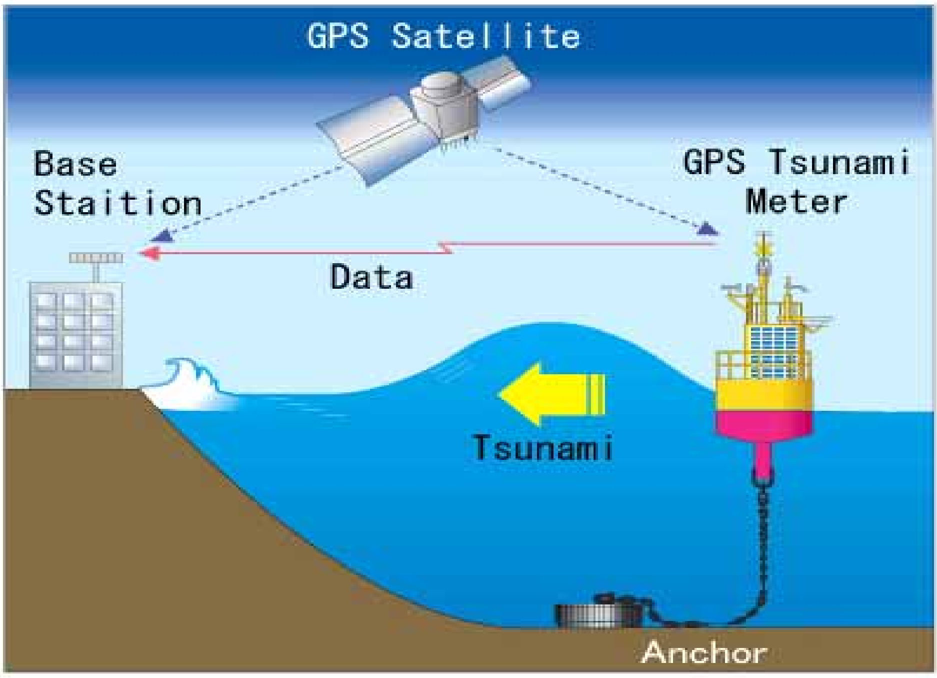


Figure 1. GPS Buoy Observation System

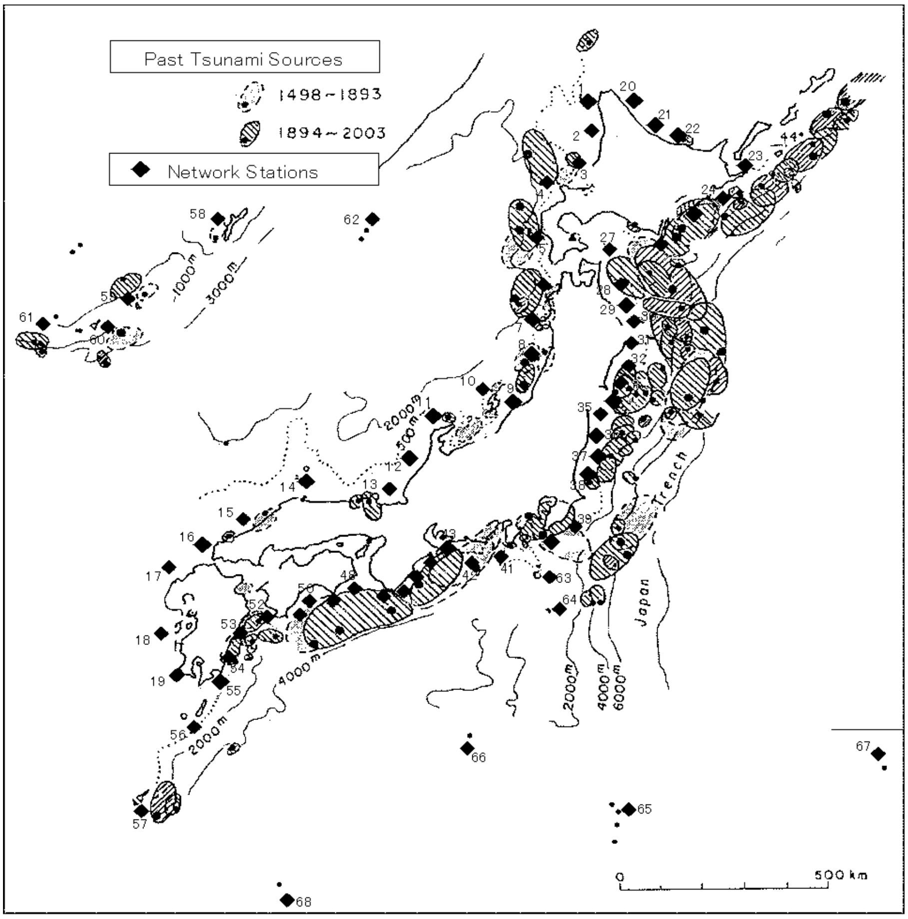


Figure 2. Proposed Offshore Observation Network.

COASTAL DAMAGE DUE TO THE INDIAN OCEAN TSUNAMI AND ITS DEFENCE BY GREENBELT

Tetsuya Hiraishi, Port and Airport Research Institute, Yokosuka, Kanagawa Japan, hiraishi@pari.go.jp

1. INTRODUCTION

The 2004 Indian Ocean Tsunami caused a catastrophic disaster in the coastal areas facing to the ocean. The break of residential areas were widely broadcasted and some field reports1) analyzed the tsunami run-up height distribution. The other characteristic of tsunami damage was the beach erosion and scouring at the foot of sea walls. The eroded volume became so large in the Banda Ache City, Indonesia that some coastal grounds disappeared after tsunami attack2). I conducted a field survey to measure the cross section of eroded beach in order to study on the relation between tsunami height and beach erosion in Thailand.

Meanwhile several reports3) described the effect of coastal forests composed of tropical pains and coconuts trees or mangroves to reduce the tsunami force destroying the coastal villages. The importance of greenbelt (coastal forest) as barrier against tsunami had been demonstrated mainly in the model experiments. I investigated the effect of greenbelt to reduce the coastal erosion as well.

2. FIELD MEASUREMENT

The measurement of cross section in a beach was carried out in a hotel resort area located in the Khao Lak Coast, Thailand. The tsunami run-up height in the hotel area was about 10m and the wooden cottages were completely washed out in the tsunami flow. Meanwhile the damage of main building composed of reinforced concrete was not severe and the second and third floors remained without little damages. The sandy beach in front of the main building, however, was heavily eroded compared with the neighboring beaches. Figure 1 shows the comparison of beach cross profile at the measurement lines 0, N and S. The line-0 represents that located at the front of hotel main building. The lines-N stands the measurement lines in the northern beach several ten meters apart from the main building and the lines-S in the southern.

The coastal forest with coconuts and pain trees was supposed to be located uniformly along the beach before the hotel construction. The width of coastal forest (greenbelt) became very narrow at the line-0 area because of the convenience in access to the beach and in viewing ocean from the hotel. The greenbelt remained without modification in the other lines location. Therefore the width of greenbelt in the N and S-lines are thick and its width is about 100m. Figure 1 demonstrates the depth of erosion in the line-0 becomes more than 2m while the depth of erosion in lines-N and –S are smaller than that in the line-0. The existence of greenbelts is seemed to reduce the erosion in the beach by tsunami run-up.

Several large holes inside the hotel ground were founded in the first survey which was conducted just after the tsunami attack to the Thailand coasts. The diameter and depth of a hole was 10 and 2m respectively. The location of holes was 200m away from the shore. The other reason of ground damage should be proposed because the beach erosion due to tsunami might be caused in the vicinity of the beach.

The liquefaction is supposed as one reason of such heavy ground sinking. The liquefaction due to sea wave was usually generated in the soft ground with silt materials. I analyzed the ground soil captured at the four deferent positions in order to study on the possibility of liquefaction due to tsunami flow. The central diameter of soil captured at the stage of hotel main building was 0.09mm and its silt contents was 48% while the diameter and silt contents of the beach sand was 0.44mm and 0.3% respectively. Therefore the high percentage of silt contents might cause the liquefaction of the ground soil which was employed as the reclamation of hotel ground.

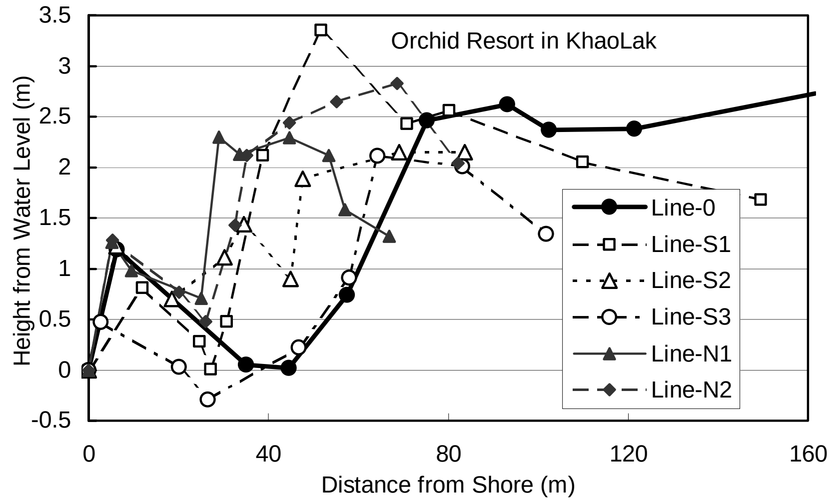
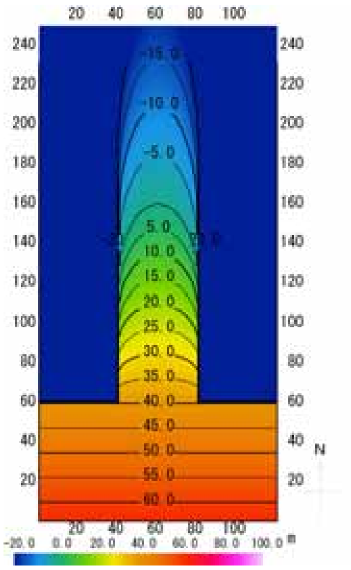


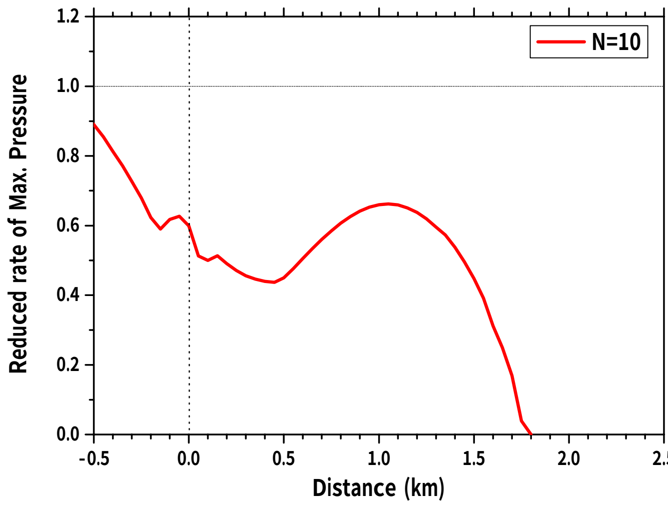
Figure 1 Beach profile measured in the damaged hotel area

3. EFFECT OF GREENBELT

The fields survey on the greenbelt effect demonstrated that the tsunami flow pressure was reduced by the dense greenbelt and the beach erosion depth became smaller in the beach with the greenbelt behind it than in the beach without. The reduction of tsunami flow pressure becomes important to prevent the washing out of village houses. In near future we have to establish the greenbelt tsunami prevention technique to reduce the human life and property. I conducted the numerical study to estimate the effect of greenbelt to reduce tsunami flow pressures. Figure 2(1) shows an example of U-shape bay model for simulation. The greenbelt is settled along the shore with the width of 100m. The number of trees with the diameter of 50cm included in the unit area ($100m^2$) N is changed from 0 to 30 in the simulation.

Figure 2(2) shows the variation of dimensionless tsunami flow pressure along center line in the U-shape bay. The computed tsunami flow pressure is divided by that simulated at the center and the distance of 0.0 for case without greenbelt. The maximum pressure rate is reduced by the effect of greenbelt. The reduction rate decreases when the distance increases. However the rate becomes higher when the distance becomes about 1.0knm from shore. Therefore the reduction rate of tsunami flow pressure varies for the location in the bay. The numerical simulation is necessary to design an appropriate with and dense of greenbelt.





(1) Depth contour of U-shape bay (2) Variation of tsunami flow pressure

Figure 2 Example of expectation of tsunami flow pressure reduction by greenbelt

4. REFERENCES

1) Hiraishi T., T. Arikawa, Y. Minami and M. Tanaka(2005): Field survey on Indian Ocean Earthquake Tsunami, Technical Note of The Port and Airport Research Institute, No.1106, 20p.

2) Homepage http://iahr/net/site/index.html

3) danielsen F. et al.(2005):The asian Tsunami: A protective role for coastal vegetation, SCIENCE, Vol.310, p.643.

TECHNOLOGY OF TSUNAMI DISASTER REDUCTION

Yoshiaki Kawata, Director and Professor, Disaster Prevention Research Institute, Kyoto University,
kawata@drs.dpri.kyoto-u.ac.jp

Tsunami disaster is one of the major disasters in Japan, therefore we have several countermeasures against this disaster. Recently, our social condition has remarkably changed as rapid urbanization, aging and decrease population. Moreover, gigantic tsunamis accompany with Tokai, To-Nankai and Nankai earthquakes will hit our southwest coastal areas along the Pacific.

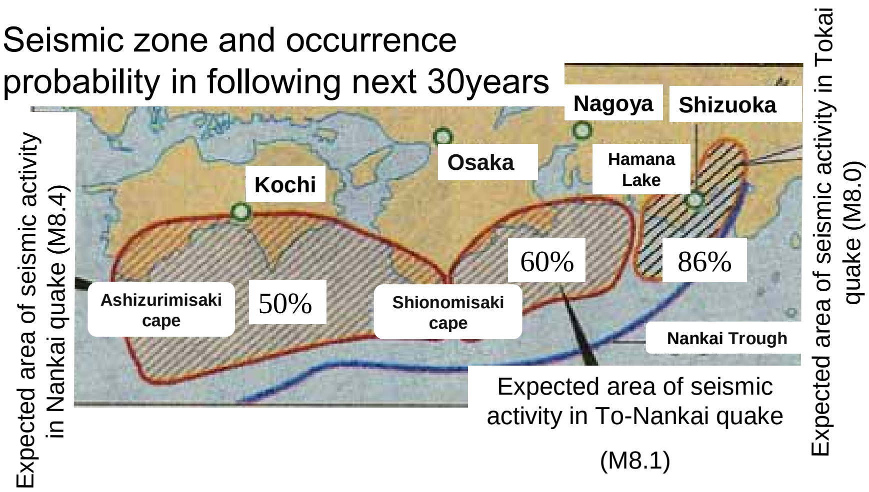


Figure 1

Figure 1 shows the expected seismic zone of Tokai, To-Nankai and nankai earthquakes and occurrence probability in following next 30 years. The 2004 Indian Ocean tsunamis showed that some segments moves simultaneously along the plate boundary. This is the most important lesson from the disaster. In order to reduce damage, an integrated technology has to be developed and improved before the disaster occurrence.

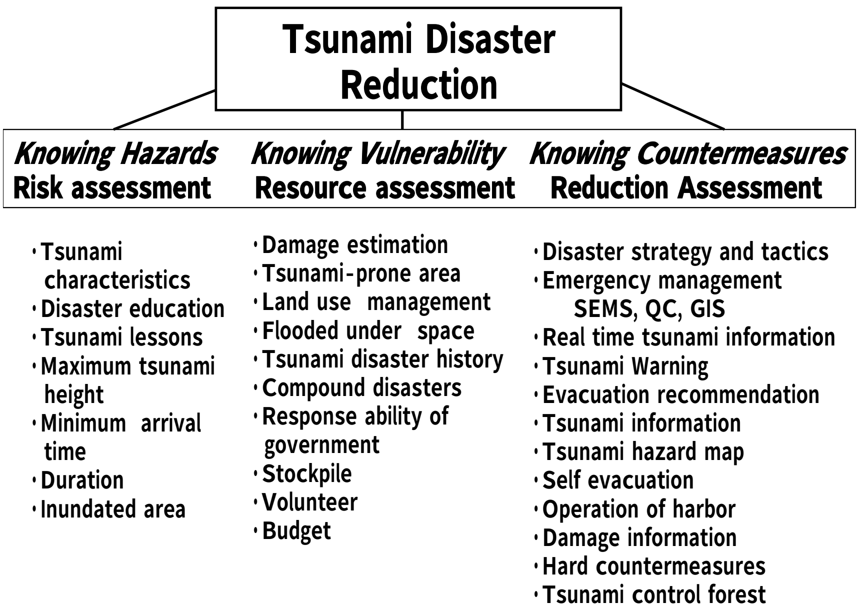


Figure 2

Figure 2 shows a diagram of tsunami disaster reduction systems. Some combination is very effective to reduce the damage. Figure 3 is the concept of disaster reduction systems with hard countermeasures and soft ones.

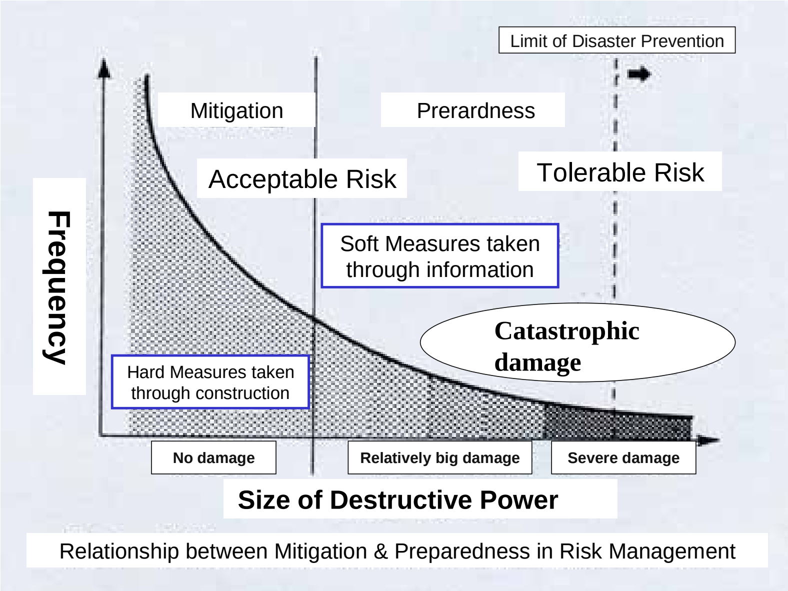


Figure 3

BUSINESS CONTTINUITY MANAGEMENT
AS A NEW AND HOLISTIC FRAMEWORK FOR FLOOD DISASTERS REDUCTION

Haruo Hayashi, Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan,
hayashi@drs.dpri.kyoto-u.ac.jp

1. INTRODUCTION

As indicated in recent disasters, urban floods could result in devastating disasters in terms of both casualties and losses. In Japan2000, the costliest flood occurred in and around Nagoya City in September of 2000 which losses amounted to as much as a total of 8 billion USD. In the U.S., the costliest flood ocuured as the results of levee breaches in New Orleans after Hurricane Katrina in August of 2005, which killed almost 800 people and as much as 80 % of the City was underwater for many weeks. These examples suggest that it is difficult or impossible to prevent urban floods completely by solely relying on engineering measures such as dykes and levees. In other words, a more holistic or multi-disciplinary approach should be taken to improve not only disaster resistance but also disaster resilience for urban flood disaster reduction. In this presentation, I would like to introduce a framework of holistic disaster reduction focused on "business continuity management". This idea comes from that it is indispensable for those organizations which have social responsibility to provide essential or necessary social goods and services to maintain their activities under any circumstances such as crises or disasters. To improve business continuity capability or business resumption capability shouke be the key for improving disaster resistance and disaster resilience.

2. BUSINESS CONTINUITY MANAGEMENT MODEL

Figure 1 shows a four step model for business continuity management: 1) Risk assessment, 2) Participatory Strategic Planning, 3) ICS based Crisis Management, and 4) Training and exercise. It is important these four steps form a cycle, which means the business continuity management is a continuous business improvement process. In what follows, let me describe briefly each of these four steps.

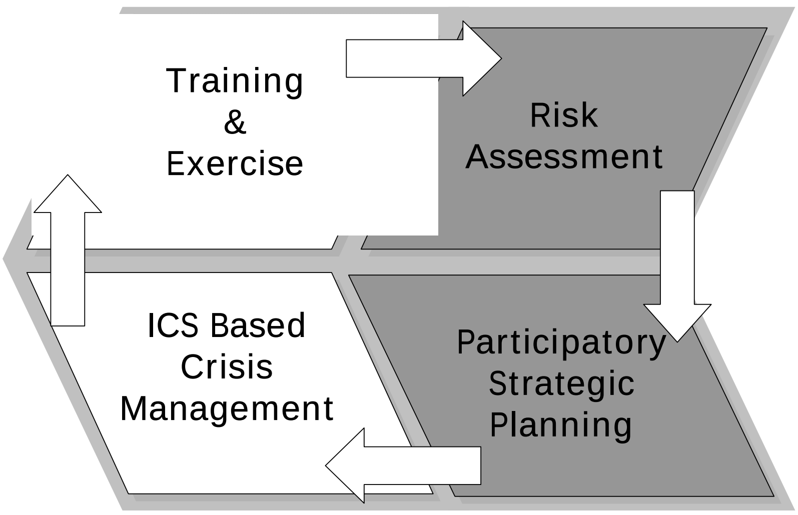


Figure 1 Four Step Model of Business Continuity Management

3. RISK ASSESSMENT

Business continuity management starts with identifying risks for which people should deal with. Even though the probability of its occurrence would be relatively low for a high impact event, urban floods due to storms, typhoons, or hurricanes, such as the category 5 Katrina of 2005, would results in enormous amount of impact for a quite wide region for a quite long time once they happen. Thus, it is indispensable element of disaster reduction effort for any major urban areas to create hazard map indicating the worst scenario of urban floods as the basis for holistic disaster reduction.

4. PARTICIPATORY STRATEGIC PLANNING

Once urban flood risk has been assessed both quantitatively and geo-spatially, it is a time to develop a strategic plan to reduce the expected damages and losses. The key word in strategic planning is “stakeholder participation”. Strategic planning is a planning method used widely by businesses, governments, and NGOs to reach goals and get better results. A strategic plan consists of the following element: 1) Identifying needs, 2) Clarifying goals, 3) Setting specific objectives, 4) Establishes an action plan & timelines, and 5) Provides for periodic progress review

By adopting strategic planning procedure to improve both disaster resistance and disaster resilience, it becomes easier to realize a most cost-effective disaster reduction by setting priorities among the following four major risk reduction methods for any objectives: 1) Risk Avoidance, 2) Risk Reduction, 3) Risk Transference, and 4) Risk Acceptance. Risk avoidance can be realized by adopting a wise land use planning. Risk reduction can be implemented by building river and coast protection facilities. Risk transference will usually take various forms of financial arrangement such as insurance and trust. Risk acceptance will be equal to improving crisis management or consequential management capabilities.

5. ICS BASED CRISIS MANAGEMENT

Once an urban flood occurs, it is an urgent and often confused business to start a wide range of new social activities called disaster response, relief, and recovery. In any emergency situations local people respond first. When a major incident happens, external help may be needed from all kinds of social sectors, and even from international communities This would create a lot of whole new problem of inter-agency coordination of cpost-event crisis management. Since 1970s, Incident Command System (ICS for short) has been developed as the template for inter-organizational coordination in wildfire situations. ICS makes possible 1)Unified approach to incident management and 2) Standard command and management structures. Because of its effectiveness, ICS becomes de facto standard for post-event consequential management. Even thought FEMA response has been severely criticized by mass media at the time of Hurricane Katrina, ICS has been used by all participating emergency response organizations and proved to be effective to provide a common framework for all kinds of disaster response, relief and recovery.

6. TRAINING AND EXERCISE

Since severe urban floods seldom occur, training and exercise should be used as the important methods to improve or maintain disaster resistance and disaster resilience for urban flood disaster in addition to learning by experience.

RECENT STORM SURGE DISASTERS IN JAPAN AND KOREA

Hiroyasu Kawai, Port and Airport Research Institute, Yokosuka, Kanagawa, Japan, kawai@pari.go.jp

1. INTRODUCTION

Each year a few typhoons make landfall on the Japanese main islands, and some of them cause severe storm surges and waves on the coast. This paper reviews major storm surge disasters in Japan and Korea from 1999 to 2004 and presents the result of storm surge and wave simulations. The typhoon tracks and the major places affected are shown in **Figure 1**.

2. RECENT STORM SURGE DISASTERS IN JAPAN

The Typhoon Vera in 1959, T5915, called the Isewan Typhoon in Japan, generated the storm surge of 3.5m at Nagoya on Ise Bay, inflicting a flood area of about 350km^2 and killing nearly 5,000 people. Then the Japanese Government rapidly constructed coastal defense facilities for the extreme storm surge and consequently no more fatal coastal disaster with loss of lives due to storm surge repeated.

The Typhoon Bart in 1999, T9918, however, took 12 lives due to a storm surge flood on the coast of Yatsushiro-kai Bay. Flooded marks at Matsuai Ward of Uki City near the innermost of the bay proved that the water level exceeded 6.5m above the chart datum line. The water level was due to an astronomical tide level of about 3m and a storm surge of about 3.5m. **Photo 1** shows a house standing on a ground lower than the astronomical high tide level. On the coast of Suo-nada Bay, impulsive wave pressure due to the combination of a high tidal level and high waves caused the collapse of seawall parapets. The Yamaguchi-Ube Airport, a sea front local airport, was flooded due to wave-overtopping and overflow of seawalls. For simulating the sea condition in these bays with large tidal level variation and rapid wave generation, the wave prediction model WAM C4 was modified for a small spatial and time resolution, and the model was coupled with a storm surge model. The marine surface wind field for the model was computed considering the pressure field distortion and the super gradient wind. The model gave the result that the tidal level variation and the tidal current affect the wave height and period while the young waves encourage the storm surge.

Ten typhoons made landfall on the Japanese main islands in 2004. Port and coastal facilities were damaged and their rearward urban areas were flooded. The board walks of the Itsukushima Shrine, a world heritage, were also covered with seawater. **Figure 2** shows the distribution of the storm surge by Typhoon Chaba, T0416, simulated by a conventional storm surge model, which is uncoupled with a wave model. The time of the maximum storm surge was so late that it goes east in Seto Inland Sea. Consequently the maximum storm surge met an astronomical high tide in the middle of the sea to flood the urban area of Takamatsu City. The astronomical high tide level is 2 to 4m high above the chart datum line.

3. RECENT STORM SURGE DISASTER IN KOREA

A severe typhoon rarely makes landfall on the south coast of Korea. The Typhoon Maemi in 2003, T0314, however, inflicted the most tremendous coastal disaster since the attack of Typhoon Sarah in 1959, T5914. According to the tide record at Masan Port in the innermost of a shallow and slender bay, the tidal level reached

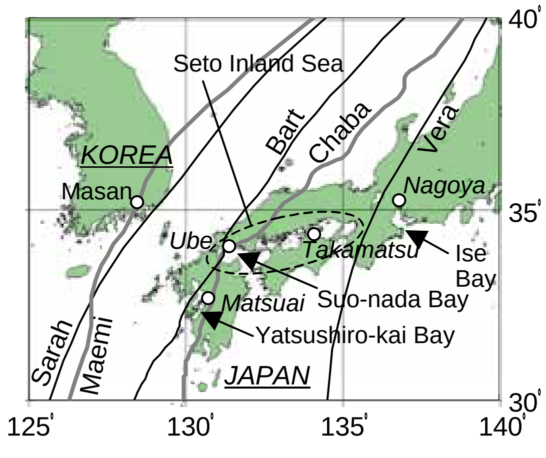


Figure 1. Major typhoon tracks and affected places

Photo 1. House flooded by storm surge

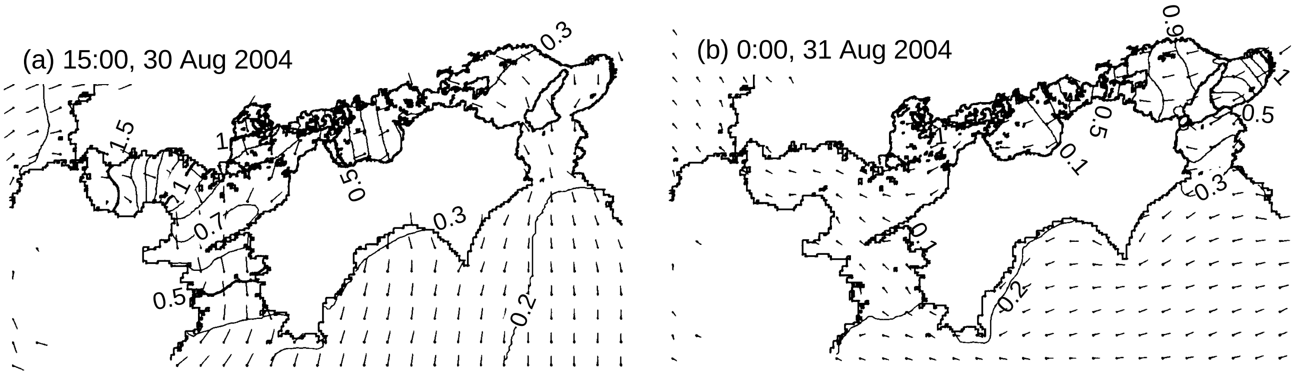


Figure 2. Distribution of wind (arrow) and storm surge (contour with digit) by Typhoon Chaba

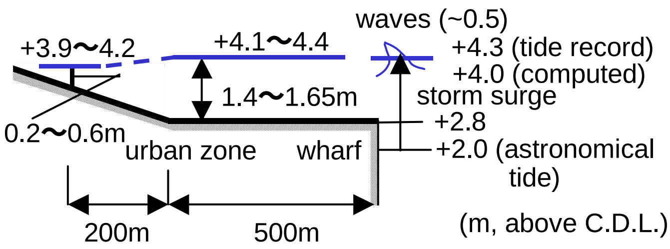


Figure 3. Cross section of flood in Masan City

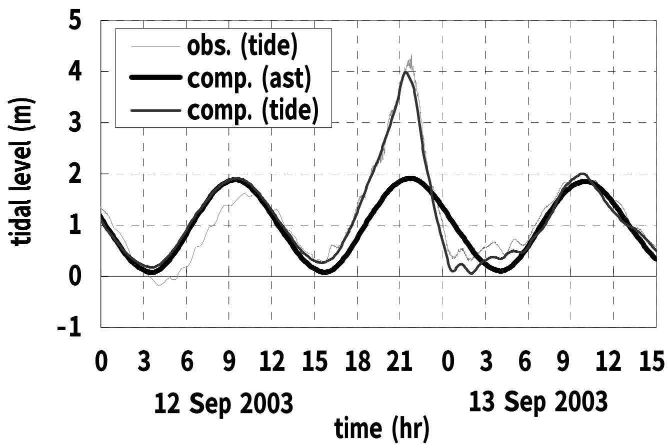


Figure 4. Variation of tidal level at Masan Port

4.3m above the chart datum line. **Figure 3** shows a typical cross-section of Masan City. There was no tide barrier between the wharf and the rearward urban zone with many underground parking spaces and shops because it was the first significant storm surge since the opening of the port. The area of 700m or more was flooded from the wharf and much timbers flowed out of the wharf into the urban zone. **Figure 4** shows that the tidal level computed by the coupled model is in good agreement with the observed.

4. REFERENCES

Kawai, H. et al. Field Investigation and Numerical Simulation of Storm Surge by Typhoon No. 9918, Tech. Note of PHRI, No. 971, 43p., 2000. (in Japanese)

Kawai, H. et al. Development of Storm Surge Model Coupled with Wave Model and Hindcasting of Storm Waves and Surges Caused by Typhoon 9918, ISOPE, 2004-NM-09, 8p., 2004.

Kawai, H. et al. Hindcasting of Storm Surges in Korea by Typhoon 0314 (Maemi), ISOPE, 2005-NM-03, 8p., 2005.

Kawai, H. et al. Characteristic of Typhoons in 2004 and Forecasting and Hindcasting Their Storm Surges, Tech. Note of PARI, No. 1103, 34p., 2005

Takahashi, S. et al. Storm Surge Disaster by Typhoon No.9918 - Performance Design of Coastal Defense -, Proc. of the Solutions to Coastal Disasters Conference 2002, ASCE, pp.735-749, 2002.

OPERATIONAL STORM SURGE FORECASTING AT JAPAN METEOROLOGICAL AGENCY – CURRENT STATUS AND FUTURE OUTLOOK –

Masakazu Higaki, Japan Meteorological Agency, Tokyo Japan, m-higaki@naps.kishou.go.jp

1. INTRODUCTION

Storm surges, especially associated with tropical cyclones, represent a major marine hazard, and result in the loss of life and property in many parts of the world on a regular basis. It is said that storm surges are responsible for approximately 90% of all deaths related to tropical cyclones.

In 1959, Typhoon VERA (T5915, called Isewan taifu in Japanese) hit the central part of Japan and inflicted more than 5,000 fatalities. Most of the fatalities came from the storm surge of 3.5m in Ise Bay area arising from the typhoon. Also in recent years, Japanese society has suffered from storm surge disasters continually. For example, in 1999, Typhoon BART (T9918) caused severe storm surges in the western part of Japan, which killed twelve people. Even two years ago, in 2004, more than 30,000 houses were flooded by the storm surges induced by Typhoon CHABA (T0416) in Seto Inland Sea, the western part of Japan.

Accurate and timely forecasts and warnings would contribute substantially to mitigating the threat to life and property from such storm surges. Japan Meteorological Agency (JMA), which has the responsibility of storm surge warning in Japan, has operated a numerical storm surge prediction model since 1998. Here, current status and future outlook of the operational storm surge forecasting in Japan are introduced.

2. MECHANISM OF STORM SURGE

The most important factors for generating a storm surge are inverted barometer effect associated with depression in tropical cyclones and the effect of wind setup due to strong winds on sea surface.

Inverted barometer effect: A 1hPa drop in atmospheric pressure raises the sea level by 1cm.

Wind setup due to strong winds: In general cases of significant storm surges, the effect of wind setup is much larger than that of inverted barometer. Under an idealized condition in which wind and water depth are constant, the rise of sea level due to wind setup is proportional to the square of wind speed, the width of shallow water and the inverse of water depth.

Additionally, high ocean waves contribute the rise of sea level along coasts facing open oceans. Shoaling and breaking of high waves near a coast yield a strong gradient of stress on sea water towards the coast and consequently raise the sea level at the coast. This effect is called “wave setup.”

3. FORECASTING METHOD OF STORM SURGE

To simulate the temporal and spatial variations of sea level in response to these meteorological disturbances, numerical models are commonly used in these years. JMA uses a numerical model based on the shallow water equations in operational storm surge forecasting. The equations are solved by numerical integration with finite difference method.

- Meteorological inputs

The model requires the fields of surface wind and atmospheric pressure as external forcing and these meteorological fields are obtained from mesoscale weather prediction models. Although the performance of typhoon forecast has been advancing constantly, the mean position error in typhoon track forecast is still around 100km for 24-hour forecast and 300km for 72-hour forecast. This implies that there is probably a large spread of possible forecast values of surface winds and atmospheric pressure at a certain location and the spread makes accurate storm surge prediction difficult even for 24-hour forecast. To take into account the position error in typhoon track forecast, five runs of the storm surge model are conducted with five possible typhoon tracks. These five typhoon tracks are prescribed at the center and at four points on the forecast circle within which a typhoon is forecast to exist with a probability of 70% (Figure 1).

The model also produces predictions of storm surges due to extra-tropical cyclones. In the cases of extra-tropical surges, it predicts a single scenario by using the meteorological fields only from NWP models.

- Calculation of astronomical tides

The model provides predicted storm surges alone but in issuing a storm surge warning we must know the whole sea levels including astronomical tides, periodical sea level changes driven by the body forces of the moon and the sun, as well. Astronomical tides can be predicted by using harmonic analyses of sea levels observed at tide stations. After the computation of storm surge, the level of astronomical tide for each station is added to predicted storm surge.

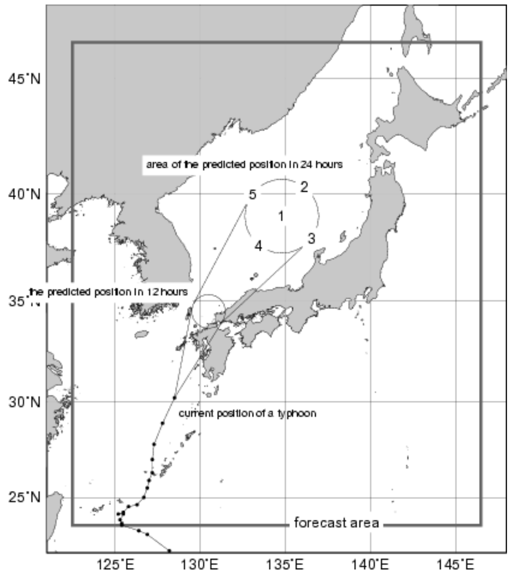


Figure 1. The model area and forecast typhoon tracks
Numerals in and on the forecast circle of typhoon position represent typhoon tracks used in the storm surge forecasting.

- Specifications and products of the model

The horizontal resolution of the model is one minute in longitude and latitude, corresponding to about 1.6km by 1.8km. The model area covers the entire Japan. The model runs four times a day, i.e. six-hourly, on the high performance computing system for numerical weather prediction in the headquarters of JMA and provides 33-hour prediction of storm surges (anomaly from the level of astronomical tides) and storm tides (storm surge plus astronomical tide) for about 280 locations on Japanese coasts. Then the predicted results are sent to local meteorological offices that have the responsibility of issuing storm surge warnings to their responsible areas and are used as the basic information for warning.

4. FUTURE IMPROVEMENT OF STORM SURGE FORECASTING

Although the storm surge forecasting system in JMA has provided useful information to weather forecasters, some issues such as the following are pointed out and need to be solved for further improvement of storm surge forecasting.

- Astronomical tides

The present system utilizes basically harmonic analyses of sea levels observed at tide stations to estimate astronomical tides. With this method, it is difficult to accurately estimate astronomical tides for arbitrary coastal points where sea level observation is not available. In this decade, many researchers developed ocean tide models by using satellite altimetry and tide gauge data. These tide models, however, have a larger amount of errors in shallow water areas while they provide good estimates for the tides in deep oceans. To predict accurate astronomical tides all around Japan, a data assimilation technique that combines estimates from a dynamical model and observations statistically should be exploited.

- Physical processes in storm surge model

Introducing a finer mesh to the storm surge model will lead to resolving complex topography and is expected to improve the forecast performance of the model. Besides, as mentioned above, “wave setup” raises sea levels along coasts facing deep oceans but the current version of the surge model does not include the effect. To improve the forecasts for these coasts, a method to estimate the effect should be implemented in the forecasting system.

- Meteorological inputs

Meteorological fields, particularly wind fields, have the biggest impacts on the performance of storm surge modeling. In recent years, a mesoscale weather model with 10km mesh has been put into operation and this contributes to the improvement of weather forecast. Furthermore, JMA plans the introduction of 5km-mesoscale model in March 2006. Utilizing meteorological fields derived from these models in storm surge modeling is likely to improve the accuracy of storm surge forecasting dramatically.

JMA is developing the techniques to address these issues, and will introduce them into the operation in the coming years.

TROPICAL CYCLONE CLIMATOLOGY IN A GREENHOUSE CLIMATE
– SIMULATION WITH A SUPER-HIGH-RESOLUTION GLOBAL ATMOSPHERIC MODEL –

Jun Yoshimura, Meteorological Research Institute, Tsukuba, Japan
junyoshi@mri-jma.go.jp

1. INTRODUCTION

Tropical cyclones, including typhoons and hurricanes, are probably the most devastating phenomena in the atmosphere, and sometimes cause large number of human deaths and huge economic losses in coastal areas. In a study by the author and collaborators, influences of the global warming on the tropical cyclone climatology are investigated by numerical experiments using a global atmospheric model with approximately 20-km grid size. This horizontal resolution is unprecedentedly high as a climate model for global warming simulation. The computation was performed on the Earth Simulator, one of the world's most powerful computers. The study has been conducted under the "Kyosei Project" funded by MEXT of the Japanese government, and will be published in a paper by Oouchi et al. (2005).

2. NUMERICAL EXPERIMENTS AND RESULTS

In this study, two types of 10-year climate experiments are conducted. One is a present-day climate experiment, and the other is a greenhouse-warmed climate experiment with a forcing of higher sea surface temperature (by about 1.7°C on an average) and increased greenhouse-gas concentrations of the year 2090 based on IPCC A1B emission scenario. The results of the experiments suggests that the tropical cyclone frequency in the warm-climate experiment is globally reduced by about 30% compared to the present-day-climate experiment. However, the number of intense tropical cyclones increases. The maximum surface wind speed for the most intense tropical cyclones generally increases under the greenhouse-warmed condition (by 7.3 m/s in the Northern Hemisphere and by 3.3 m/s in the Southern Hemisphere). On average, these findings suggest the possibility of higher risks of more devastating tropical cyclones across the globe in a future greenhouse-warmed climate.

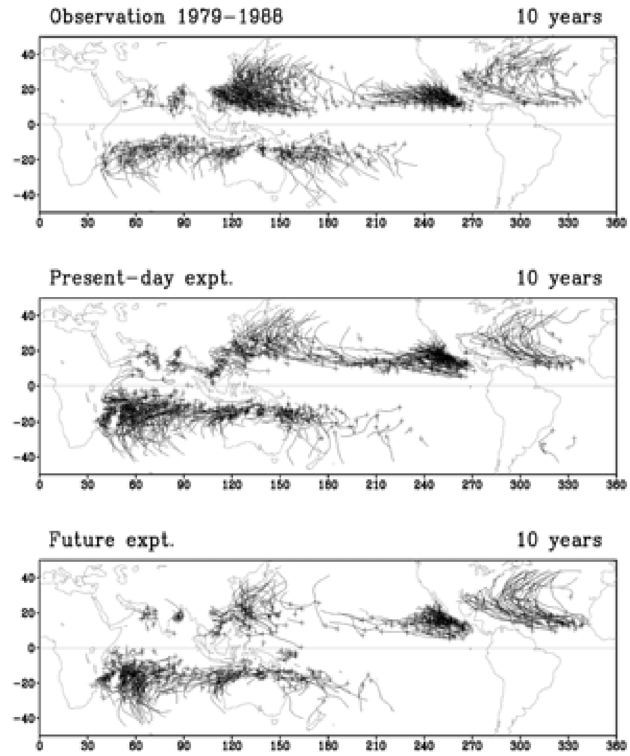


Figure. Tropical cyclone tracks of observational data (top), the simulations of the present-day (middle) and the global warming (bottom) experiments.

3. REFERENCE

Oouchi, K., J. Yoshimura, H. Yoshimura, R. Mizuta, S. Kusunoki and A. Noda. Tropical cyclone climatology in a global-warming climate as simulated in a 20km-mesh global atmospheric model: Frequency and wind intensity analyses. *Journal of the Meteorological Society of Japan,* accepted. (2005)

IMPROVEMENT OF THE THIRD GENERATION WAVE MODEL FOR COASTAL WAVE HINDCASTING

Noriaki Hashimoto, Kyushu University, Fukuoka, Japan, hashimoto-n@civil.kyushu-u.ac.jp
Hiroyasu Kawai, Port and Airport Research Institute., Yokosuka, Japan, kawai@pari.go.jp

1. INTRODUCTION

Recently, wave hindcasting models have been improved as seen in the successful development of the third generation wave models such as WAM, SWAN and Wave Watch III. In addition, accurate and reliable meteorological data for several decades has been supplied from several meteorological organizations such as ECMWF, NCEP and JMA. Thus the simulations of ocean waves with those wave models and meteorological data for the past of tens of years become easier. Now, accurate and reliable wave information can be obtained for a long term in various coastal areas where there is no wave observation data. Corresponding to these advancements, we have improved the third generation wave models for Japanese coastal wave hindcasting. We introduce some of these improvements of the third generation wave models, i.e., coupling WAM with a storm surge model, application of WAM with mesoscale meteorological model, MM5, and wave data assimilation with WAM.

2. COUPLING WAM WITH STORM SURGE MODEL

So far, waves and storm surges have been independently simulated in common investigations for coastal disasters. However, a wave model underestimated the wave height and a storm surge model also underestimated the storm surge caused by Typhoon 9918 in west Suo-nada Bay. The reason might be 1) underestimation of the marine wind speed and 2) neglect of wave-current interaction.

For such background, the wave model, WAM, was improved to take into account the effect of astronomical and meteorological tides, while the storm surge model was also improved to adopt the wave age dependent drag coefficient in the wave model and to take into account the effect of astronomical tide. Then these models were combined each other. The marine wind for the coupling model was estimated by considering the distortion of typhoon pressure field and super gradient wind near typhoon eye wall. The waves and the storm surges in Suo-nada and Yatsushiro-kai Bays were hindcasted by the coupling model. The Yatsushiro-kai Bay is narrow and its coastal line is very complex, therefore its spatial grid interval and time step in the computations were reduced to 0.6km and 20s, respectively.

Figure 1 shows the time variation of the significant wave height at Kanda in the innermost region of Suo-nada Bay. The coupling model with the modified wind gives the better hindcasting result than the previous model. Figure 2 shows the significant wave height at Ryugatake (relatively deep) in the middle region of Yatsushiro-kai Bay, and at Shiranui (shallow) in the innermost region. The modification of the wind field affected the wave height at both the points, while the effect of tides appeared only at Shiranui. The tidal level variation affected the wave height, while the tidal current affected the wave period. Therefore it is found to be necessary not only to estimate wind field exactly but also to apply the coupling model to the shallow bay where the astronomical tidal range and the storm surge are large.

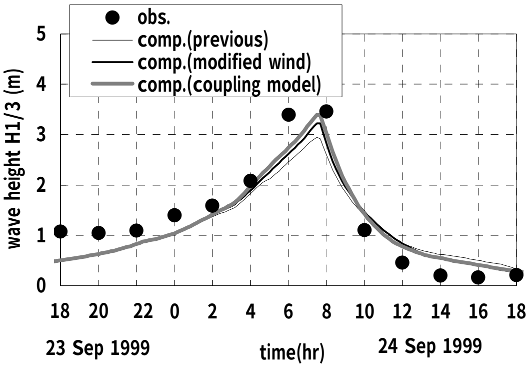


Fig. 1 Time variation of wave height at Kanda

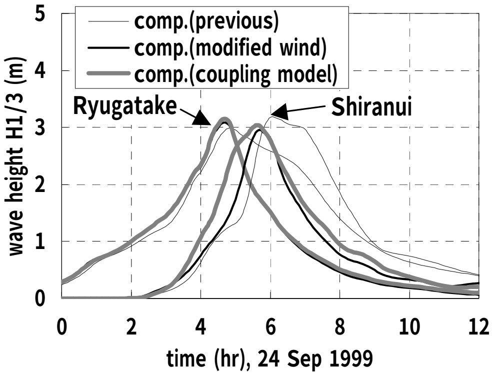


Fig.2 Time variation of wave height at Ryugatake and Shiranui

3. APPLICATION OF WAM WITH MM5 TO COASTAL WAVE HINDCASTING

The introduction of the third generation wave models to simulate the costal waves in bay area is still under development although most of the coastal engineering projects necessitate estimating wave information around the bay areas. One of the reasons of this delay is the difficulty of estimating accurate wind field around the bay area surrounded by the lands, where the wind field is sometimes very complicated. Accurate wind simulation with high spatial resolution is strongly required for accurate estimation of the waves around bay area.

We, therefore, applied the mesoscale meteorological models such as MM5 (PSU/NCAR) for wind simulation around Tokyo Bay and Seto Inland Sea. Then, we simulated coastal waves around the areas with the third generation wave models, WAM and SWAN, with the wind data simulated by the mesoscale metrological models. Figure 3 is an example of the simulated wave fields by the models, where the computations were carried out with the spatial resolution of about 2km for both areas. The boundary conditions were given by the coarse grid computations with the nesting technique. Four years simulations from 1998 to 2001 were carried out for Tokyo Bay and one year simulations of 2000 were carried out for Seto Inland Sea to investigate the wave characteristics around the areas.

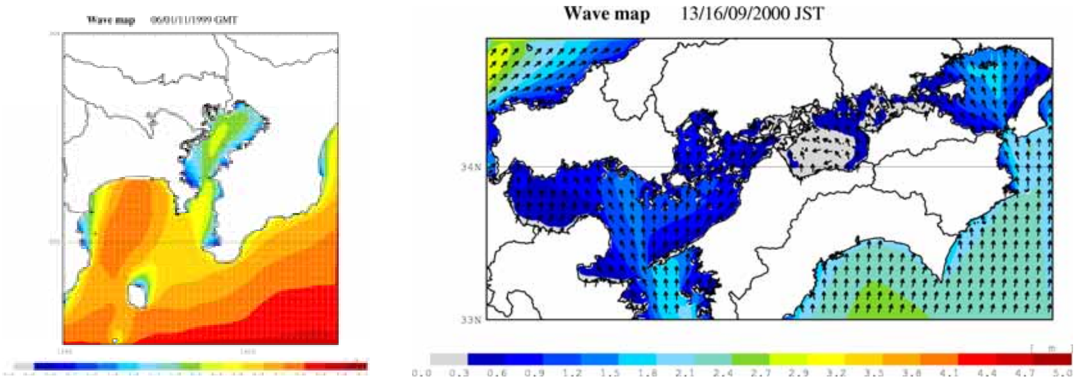


Fig.3 Examples of wind and wave simulations for Tokyo Bay and Seto Inland Sea

4. WAVE DATA ASSIMILATION WITH WAM

When we apply wave hindcasting models in practical applications and then the accuracy is not satisfactory, it is still common that we modify the parameters in the models or the wind field itself by trial and error manner by comparing the numerical results with the observation data. On the other hand, excellent data assimilation techniques have been developed, and have been used in various fields recently. The data assimilation is a vital technique to connect the model with the reality when we try to reproduce the natural phenomena by the model and verify them with the data. However, in order to utilize the maximum effect of the data assimilation technique and obtain reliable numerical results, not only the performance of a numeric model but also the performance of the data assimilation technique bears the key role. Figure 4 shows the examples of the estimated wave height at Akita and Sakata stations, where the data assimilations were carried out using the data obtained around the area. The accuracy of the final estimate (after assimilation) at both the stations is improved compared with that of the initial estimate.

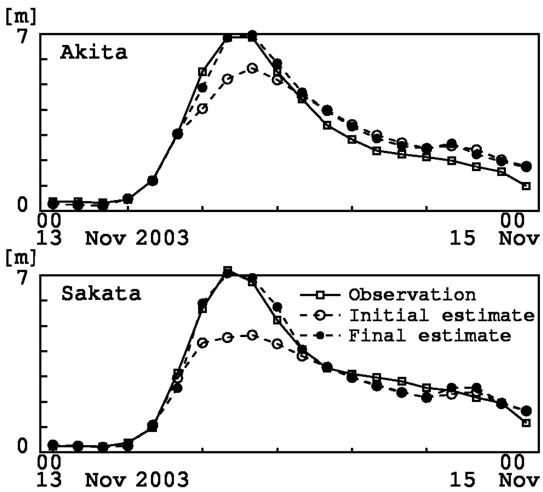


Fig.4 Comparison of time series of wave height

5. CONCLUDING REMARKS

Since 1988, the third generation wave models have replaced earlier the first and second generation wave models. We have carried out the research on the third generation wave models, and developed and improved some parts of the models for improving accuracy, versatility and applicability for deep and finite-water depth areas. We hope these results would be useful for coastal disaster prevention.

IMPACT OF HURRICANE KATRINA ON SOUTHEAST LOUISIANA

Harley S. Winer, Chief, Coastal Engineering Section, New Orleans District,
US Army Corps of Engineers, Harley.S.Winer@mvn02.usace.army.mil

ABSTRACT

On August 29, 2005 Hurricane Katrina made two landfalls along the coast of the northern Gulf of Mexico. The first landfall was as the storm crossed the Mississippi River in Plaquemines Parish near Buras, Louisiana. The second landfall was near the Louisiana Mississippi border near the mouth of the Pearl River. The winds and storm surge of this powerful storm inflicted tremendous damage on the Northern Gulf of Mexico from Louisiana to Alabama.

The presentation presents the history of Hurricane Katrina, and how the meteorology of the storm in combination with the local bathymetry and topography resulted in very high storm surges. The presentation goes Parish by Parish in southeast Louisiana depicting the extent of the damages to both the property and infrastructure as well as to the hurricane protection levees.

The presentation also covers the response of the Corps of Engineers to this disaster. The first task was unwatering of all of the areas that had been flooded by the storm and to provide interim protection in the event another hurricane should come before the end of hurricane season. In fact, Hurricane Rita arrived in the Gulf of Mexico less than a month after Hurricane Katrina but fortunately for southeastern Louisiana, did not make a direct hit. Hurricane Rita re-flooded some areas. Once interim protection and unwatering were successfully accomplished, the task shifted to providing hurricane protection for the upcoming 2006 hurricane season. Task Force Guardian was assembled to reconstruct the various hurricane protection features to their pre-Katrina authorized level by a June 1, 2006 deadline. In addition to these efforts, new efforts to design enhanced hurricane protection are being initiated. However, these efforts await Congressional authorization and funding.

The presentation also addresses the extent of the damage to the economy and the infrastructure of the region and the extent to which there has and has not been recovery to the date of the presentation.

CHARACTERISTICS OF STORM SURGE DISASTERS IN JAPAN AND COUNTERMEASURES FOR THEIR MITIGATION

Tomotsuka Takayama, Disaster prevention Research Institute, Kyoto University,
takayama@kaigan.dpri.kyoto-u.ac.jp

1. INTRODUCTION

Japan is located on the courses of typhoons. Therefore, she has much suffered from the disasters caused by storm surges and waves. This presentation derives the characteristics of storm surge disasters in Japan from the review of past disasters which occurred in Tokyo, Osaka and Ise bays, and Seto Inland Sea and describes the countermeasures which were employed to mitigate future disasters. The storm surge projects for disaster prevention in the above three main bays were established soon after the catastrophic disaster in Chukyo district caused by Ise-wan Typhoon in 1959. Some details of the projects are discussed in the presentation.

The present situations of these bays have become quite different from those at the time of the establishment of the projects. For examples, the differences are characterized as urbanization, constructions of man-made islands, and containerization of the ports. The presentation points out the necessary revise taking into account the difference.

2. CHARACTERISTICS OF PAST STORM SURGE DISASTERS AND COUNTERMEASURES

The past big storm surge disasters in three main bays of Tokyo, Osaka and Ise are described in this chapter. The typhoon which passed in the west side of Tokyo bay in 1917 and caused most disastrous abnormal tide due to the superimposition of storm surge of 2.1m and high astronomical tide. The abnormal tide inundated the area of Fukagawa, Suzaki and Shinagawa and took more than 500 human lives. Though the larger storm surge of 2.2m occurred in the same bay in 1938, no big damage was caused because of the occurrence of peak storm surge at low tide.

Muroto Typhoon which landed on Muroto in Shikoku in 1934 caused second severest disaster due to high storm surge of 3.1m. In the disaster the numbers of the dead and missing and the wounded reached 3,066 and 15,351, respectively and half of the former number was directly affected by the storm surge. The number of completely and half destroyed houses was about 42,000. After the typhoon, the information system of storm surge was improved to issue two types of warning and advisory.

Ise-Wan Typhoon which passed in the west vicinity of Ise bay in 1959 caused first severest disaster due to the highest storm surge of 3.5m in Japan. The number of the death reached 4,624. The lowest atmospheric pressure and highest mean wind speed were 954.3hPa and 37m/s at Nagoya. Levees and sea walls along the coasts were broken everywhere. Consequently inundation area was expanded up to several km to several 10kmfrom the coast. The disaster was enlarged by the ground settlement in whole coastal area along Ise bay.

Two years later than Ise-Wan Typhoon second Muroto Typhoon which took almost same track as Muroto Typhoon generated the big storm surge of 2.6m in Osaka bay, but no people were killed because of people’s learning of Ise-Wan Typhoon disaster. Soon after the Ise-Wan Typhoon disaster, the projects for mitigation of storm surge disasters in future was established for previously described three main bays. In the projects Ise-Wan Typhoon was employed as a standard magnitude of design typhoon. According to the projects the construction of sea walls and levees has been executed and is almost completed at the present.

No persons were killed by the storm surge in the period from Ise-Wan Typhoon to Typhoon 9918. Typhoon 9918 generated a big storm surge in Yatsushiro Sea in Kyushu and drowned 12 persons at Shiranui-Chou in Kumamoto Prefecture. Typhoons 0416and 0418 took the courses along Japan Sea coast and generated storm surges in Seto Inland Sea. Consequently some human lives were taken in Mizushima and Takamatsu because of the inundation by abnormal high sea level which was induced by the simultaneous occurrence of the peaks of storm surge and spring tide as shown in Fig.1. As shown in Photo.1 big damages were caused by high waves due to very high wind speed in Typhoon 0418 though the sea level rises were almost same between Typhoons 0416 and 0418. Thus storm surge disasters have become more frequent to occur in recent years.

3. PROBLEMS OF STORM SURGE MEASURES AT THE PRESENT

The projects against storm surge for three main bays were established about 45 years before. The countermeasures have been executed according to the projects and have almost been completed. However, the present situation is quite different from the past because of new construction of artificial islands outside storm surge barriers. The function of storm surge protection has become lost in some part of the barrier lines. Therefore, the master plan should be revised to correspond to the changed situation.

Three biggest cities of Tokyo, Osaka and Nagoya are located innermost part of the bays and utilize underground spaces for the urban functions like parking, shopping and subway. The storm surge generated by Typhoon 0314 drowned some Korean people in underground rooms of buildings in Masan Similar disaster occurred in river floods in Japan. Measures against flooding of underground spaces should be taken into account.

The storm surge disaster in New Orleans in 2005 showed that the destruction of the storm surge barriers which were expected to protect fully leaded to catastrophic damages. Therefore we should preliminarily estimate the state of damages, especially in the area under sea level when a storm surge bigger than design one is generated. If the damage becomes tremendous, the design condition for the barriers should be reconsidered.

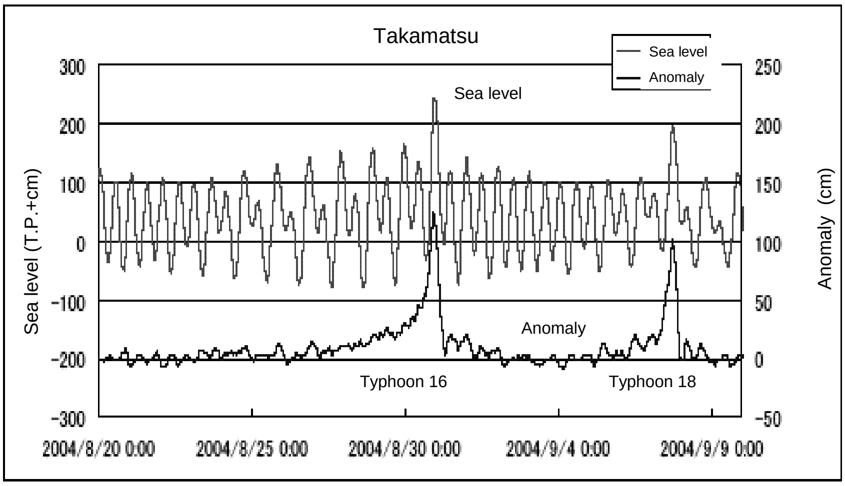


Fig.1 Observed time history of sea water level and storm surge anomaly

Photo.1 Seawalls and houses damaged by storm surge and waves generated Typhoon 0418 in Kure city

4. SUMMARY

The storm surge plans for three main bays in Japan employed Ise-Wan typhoon as the standard magnitude of design typhoon. The present degree of safety against storm surge should be checked by predicting disasters for different magnitudes of typhoon, because the present situation is quite different from the past one at the beginning of the project.

The evaluation of the present storm surge barrier system should be made for different magnitudes of typhoon. If fatal damages are predicted any countermeasure should be taken to mitigate the damage.

5. REFERENCES

Kobe Research and Engineering Office for Port and Airport of Chugoku Regional Development Bureau, Ministry of Land, Infrastructure and Transport, and Coastal Development Institute of Technology: Report on disaster prevention from storm surge and waves in Seto Inland Sea in 2004

COASTAL DISASTER MITIGATION IN THE U.S.

Nobuhisa Kobayashi, Center for Applied Coastal Research, University of Delaware,
Newark, DE 19716, U.S.A., nk@coastal.udel.edu

1. INTRODUCTION

Economic losses from natural hazards have been increasing exponentially in the U.S. since 1960 mostly because of population growth and migration to more hazard-prone locations such as coasts, while improvements in forecasting and warning systems and building codes have reduced human losses considerably (van der Vink et al. 1998; Cutter and Emrich 2005). Nevertheless, investment on coastal protection systems did not increase with the increasing economic losses. Hurricanes Charley, Ivan, Frances and Jeanne caused significant damage in Florida in 2004. Hurricanes Katrina and Rita inflicted catastrophe in Louisiana, Mississippi, Alabama and Texas in 2005. On the other hand, recent destructive tsunamis in the U.S. include the Hawaiian tsunami in 1946 and the tsunami generated by the Alaskan earthquake (magnitude 9.2) which caused considerable damage along the Pacific coast.

2. TSUNAMIS

Destructive tsunamis are rare in the U.S. and countermeasures are limited to relatively inexpensive methods such as risk assessment, detection, warning, evacuation, recovery planning, and public education. These measures will reduce the number of fatalities and the hardship on survivors if execution is satisfactory. After the Indian Ocean tsunami in December 2004, the Administration announced a plan to deploy 32 deep-sea buoys and other sensors to enhance tsunami detection and warning along the entire U.S. coast (U.S. Office of Science and Technology Policy 2005).

3. HURRICANES

The U.S. Army Corps of Engineers' shore protection program has shifted from hard structures to soft beach restoration and nourishment through placement of sand. The primary purpose of the Corps' shore protection program is to reduce the economic and physical impact of coastal storm damage from waves, inundation and beach erosion (Hillyer et al. 1997). This program covers only 8 percent of the nation's 4,300-km eroding sandy shoreline.

As for Louisiana located on the Mississippi River Delta, a coastal restoration plan, Coast 2050: Toward a Sustainable Coastal Louisiana was developed in 1998 (Izzo 2004). The goal of the plan is to restore the natural processes of the Mississippi River Delta. The levees protecting New Orleans have been rehabilitated and reinforced piecemeal against a design hurricane with a recurrence interval of 100-200 years. Hurricane Katrina caused dozens of breaches of the long levee system. Ongoing forensic studies for the levee failures and rebuilding efforts will be presented at the workshop.

4. REFERENCES

Cutter, S. and Emrich, C. (2005). "Are natural hazards and disaster losses in the U.S. increasing." *EOS Trans. AGU*, 86(41).

Hillyer, T.M., Stakhiv, E.Z. and Sudar, R.A. (1977). "An evaluation of the economic performance of the U.S. Army Corps of Engineers shore protection program." *J. Coast. Res.*, 13(1), 8-22.

Izzo, D. (2004). "Reengineering the Mississippi." *Civil Engineering*, ASCE, 39-45, July 2004.

U.S. Office of Science and Technology Policy (2005). "U.S. announces plan for an improved tsunami detection and warning system." Executive Office of the President, Washington, D.C.

van der Vink, G. et al. (1998). "Why the United States is becoming more vulnerable to natural disasters." *EOS Trans. AGU*, 79(44).

COUNTER MEASURES FOR COASTAL DISASTERS IN EUROPE

Yalciner Ahmet Cevdet, Middle East Techncial University, Civil Engineering Department,
Ocean Engineering Research Center, 06531 Ankara, Turkey, yalciner@metu.edu.tr

Population growth,, large utilization of coastal areas for several purposes, environmental degradation, climate change, poorly regulated industries, and continued economic uncertainty, cause the communities become more vulnerable to disasters. The life and property losses by earthquakes, tsunamis, floods, volcanic eruptions, landslides, wildland fires, droughts, cyclones, storm surges and erosion show that there still are long way in front us for assessment, preparedness for disasters and evaluation of disaster mitigation policies and tools.

Europe is 6th largest continent, 4,000,000 sq mi (10,360,000 sq km) including adjacent islands (1992 consensus. 512,000,000). It is actually a vast peninsula of the great Eurasian land mass. By convention, it is separated from Asia by the Urals and the Ural River in the east; by the Caspian Sea and the Caucasus in the southeast; and by the Black Sea, the Bosporus, the Sea of Marmara, and the Dardanelles in the south. The Mediterranean Sea and the Strait of Gibraltar separate it from Africa. Europe is washed in the north by the Arctic Ocean, and in the west by the Atlantic Ocean, with which the North Sea and the Baltic Sea are connected. Europe has a large continental shelf and a relatively long coastline (89 000 km) in relation to its land area. There is a wide variety of types of coastal zones, with different natural, cultural, economic and social characteristics. Europe has surrounded mainly by Baltic Sea, Atlantic Ocean, North Sea, Mediterranean, Aegean, Marmara and Black seas, and Caspian sea (See Figure 1). European coasts in Mediterranean have been utilized by humanity since antiquity, and where human impact has become greatest in the last century, consequently the changes in the environment have also been monitored and studied.

When the available meteorological, oceanographical, geographical, geological, geophysical and historical data about Europe have been examined, numerous disasters most of them have affected European coasts directly and/or indirectly can be determined. Those have endangered historical civilizations, human life and property, marine environment, economy and social life in the coastal zones. The documented earthquake and tsunami history in Europe covers 4000 years.

Figure 1: Europe and Surrounding Seas

There are active fault zones in Eastern Europe. The seismicity of Europe is characterized by various tectonic conditions expressed by the focal mechanisms of earthquakes with reverse faulting (Alps and Pyrennees), strike slip faulting (Alps, Pyrenees and Rhine graben) and normal faulting (Rhine graben). However, dip slip faults are predominant in these geological domains showing complexities and apparently no clear surface expression of coseismic faulting.. In Eastern Europe the North Anatolian Fault Zone (NAF), East Anatolian Fault Zone (EAF) and the Hellenic Arc are the most active Fault zones (Kuran and Yalciner, 1993).

The costal areas of Europe have experienced earthquakes and tsunamis many times in history (Altinok and Ersoy, 2000,Papadopoulos, 2000). The generation mechanisms and their characteristics have not been well described. According to the historical information, or distribution of fault zones, volcanos, and other probable tsunamigenic sea bottom formations, there are numerous source areas which may be considered responsible for those tsunamis (Yalciner et. al, (2003), Tinti et. al.(2005). One of the most important source areas of tsunamis in the eastern Mediterranean is the fault zone named Hellenic Arc which is a subduction zone of about 1000 km in length starts from south west of Greek mainland and follows a curve at south of Crete and south east of Rhodes island and directs towards Anatolia along North East direction near Dalaman town. The deepest region of Mediterranean with a depth of 4000 m and more is in between Rhodes and Dalaman region near Hellenic Arc. This region can be called Rhodes - Dalaman trench and might be one of the most important tsunami prone areas in the whole Mediterranean Basin (Minoura et. al. (2000).

Campi Flegrei - Etna - Lipari - Stromboli - Vesuvius – Vulcano, Methana, Milos, Santorini and Nisyros are active volcanoes in Eurpoe and have potential of disasters.

In this study the historical earthquakes, tsunamis, volcano activities, and other coastal related disasters in Europe are identified from the catalogues and from available historical data. The results of some paleotsunami studies are intrepreted to understand the location of probable source, and to determine approximate intensities of some historical earthquakes and tsunamis.

As for understanding historical events and estimating/comparing for future events the model studies are performed for numerous number of tsunami events. Some of tested events are based on the interpretetion of the historical data and results of paletsunami studies, and other events are selected as synthetic events based on scenarios related to hypothetical conditions. The maximum water level near the shore for each simulation at several different specified shore locations are computed and analyzed for each simulation in each sea in the Eastern Mediterranean Basin.

Earthquakes and tsunamis have taken role of mega events in history among the coastal disasters in Eurpoe. Earthquake is one of the most important natural hazards in the European region. Tsunamis are generally triggered by earthquakes and/or submarine-sub aerial landslides. There are recent considerable efforts establishing early warning system but still there are much work, time and efforts necessary to establish (Tinti, 2003). The risk analysis of coastal disasters, modelling, and mitigation measures are ongoing for establishing proper early warning systems, better preparedness and effective mitigation measures in the framework of interdisciplinary collaborations in Europe for coastal diasasters. As for the preparation and mitigation against coastal disasters the recent developments, countermeasures and motivation, the results of recent efforts will be presented and discussed.

Acknowledgement: Prof. Nobuo Shuto, Prof. Fumihiko Imamura, Prof. Costas Synolakis, Prof. Efim Pelinovsky, Prof. Stefano Tinti, Prof. Koji Minoura, Dr. Gerassimos Papadopoulos, Geophysicist Ugur Kuran are kindly acknowledged by the author for their long term, endless, valuable, cooperation, discussion and collaboration in several studies based on this presentation.

REFERENCES

Altinok, Y. and Ersoy, Ş. (2000). Tsunamis observed on and near Turkish Coasts. Natural Hazards, 21, 185-205.

http://europa.eu.int/comm/environment/iczm/situation.htm

http://www.infoplease.com/atlas/europe.html

http://www.infoplease.com/ce6/world/A0817876.html

http://www.astro.oma.be/PALEOSIS/metseis.htm

Kuran, U. and Yalciner, A.C. (1993). Crack Propagations Earthquakes and Tsunamis in the Vicinity of Anatolia. Paper in the Book, "Tsunamis in the World", in the book series of Advances in Natural and Technological Hazards Research by Kluwer Academic Publisher, (1993), Ed. Stefano Tinti, 159-175.

Minoura, K., Imamura, F., Kuran, U., Nakamura, T., Papadopoulos, G., Takahashi, T. and Yalçıner, A.C. (2000). Discovery of Minoan Tsunami Deposits. Geology, 28, 59-62.

Papadopoulos, G.A., 2001. Tsunamis in the Eastern Mediterranean: a catalogue for the area of Greece and adjacent seas. Proceedings of the Joint IOC–IUGG International Workshop: Tsunami Risk Assessment Beyond 2000: Theory, Practice and Plans, Moscow, Russia, June 14–16, 2000, pp. 34– 43.

Tinti, S., (2003), Needs and Perspectives of Tsunami Recearch in Europoe, NATO SCIENCE SERIES "Submarine Landslides and Tsunamis", Publisher Kluwer Academic Publishers , Editors Yalçıner A. C., Pelinovsky E., Synolakis C., Okal E.)

Tinti, S., Armigliato, A., Manucci, A., Pagnoni, G., Zaniboni, F., Yalçiner, A.C. and Altinok, Y. (2005). The Generating Mechanisms Of The August 17, 1999 Izmit Bay (Turkey) Tsunami: Regional (Tectonic) And Local (Mass Instabilities) Causes. Marine Geology (in press).

Yalçiner, A.C., Pelinovsky, E., Talipova, T., Kurkin, A., Kozelkov, A. and Zaitsev, A. (2003). Tsunamis in the Black Sea: Comparison of the historical, instrumental, and numerical data, J. Geophys. Res., 109, C12023, doi:10.1029/2003JC002113.

PERFORMANCE DESIGN OF COASTAL DEFENSES AND REAL-TIME PREDICTION OF COASTAL DISASTERS BASED ON PREPARED SCENARIOS

Shigeo Takahashi, PARI, 3-1-1, Nagase, Yokosuka, Japan 239-0826, takahashi_s@pari.go.jp
Hiroyasu Kawai, PARI, 3-1-1, Nagase, Yokosuka, Japan 239-0826, kawai@pari.go.jp
Takashi Tomita, PARI, 3-1-1, Nagase, Yokosuka, Japan 239-0826, tomita@pari.go.jp
Tomotsuka Takayama, Kyoto U, Goka-sho, Uji, Japan 611-0011, takayama@kaigan.dpri.kyoto-u.ac.jp

1. PERFORMANCE DESIGN AND DISASTER SCENARIOS

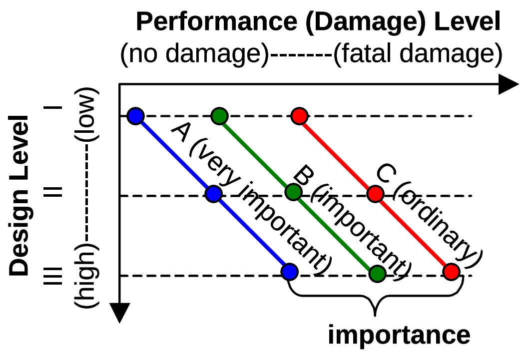
Figure 1 shows a photo taken during our visit to New Orleans to observe the aftermath of Hurricane Katrina. In order to be able to deal with disasters, we must learn from them. We must be able to recognize and prepare for the possible occurrence of extraordinary storm surges exceeding predicted levels used for construction design and the resultant disasters. We also have to be able to predict the possible failure of coastal defenses and the consequent devastating disaster.

Figure 1 Disaster due to Hurricane Katrina

Explained here is the performance design concept for coastal defenses which evaluates the performance for multiple design levels (i.e. heights of storm surges or tsunamis). The performance refers to the stability performance and the functional performance of coastal defenses, and therefore performance evaluation can reveal the actual nature of the disaster including those resulting from the failure of coastal defenses. Thus, the performance design can reveal the scenarios of disasters for different levels of storm surges or tsunamis.

Performance design has been introduced to the design of many kinds of civil structures. This paper presents a basic framework for the performance design of coastal defense facilities against storm surges or tsunamis. It is based on a performance matrix, which consists of design levels and performance levels depending on the importance (A, B and C) of the facility as shown in Table 1.

Table 1 Performance Matrix



2. REAL-TIME PREDICTION OF DISASTER BASED ON PREPARED SCENARIOS

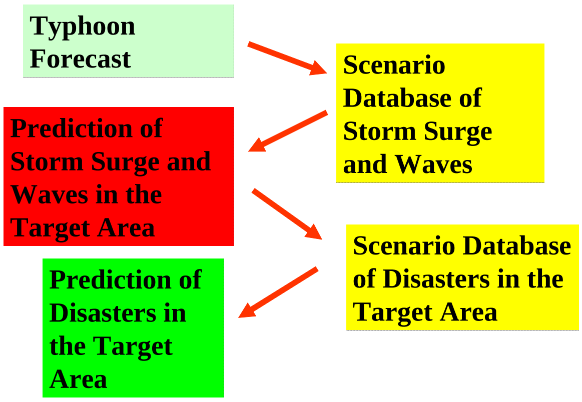
Figure 2 shows a fisherman interviewed during the damage survey just after a typhoon that hit Japan in 1999. The water had nearly reached the top of the seawall. The fisherman commented that prior to the typhoon, he had not understood why such a high seawall was needed. For engineers, it is encouraging to learn of people understanding the necessity for and effectiveness of coastal defenses. If the storm surge had been greater and/or the seawall had failed, that fisherman might not have survived. People in endangered areas should be given more information for detailed prediction of typhoon disasters, including the damages due to storm surges and waves.

Table 2 shows a conceptual flowchart of real-time prediction of storm surge disaster. The local tidal level and waves can be predicted from the forecast of the approaching typhoon using a scenario database of storm surges and waves. The stability and functional performance of coastal defenses and consequent inundation and other disasters in the local area (target area) can be estimated from locally forecast tidal levels and waves using the scenario database of disasters.

The procedure for the real-time prediction of tsunami disaster is similar to that in Table 2 although the time for the prediction is very limited. The scenario database of the disaster can be made using the similar technology that for the storm surge disaster. In Japan, the real-time prediction of the tsunami is currently made using a large amount of tsunami database by JMA (the Japan Meteorological Agency). The reliability should be increased using a real-time the monitoring of tsunami in offshore.

Figure 2 Fisherman and Storm Surge Seawall

Table 2 Flowchart of Real Time Disaster Prediction



3. PERFORMANCE DESIGN AND REAL-TIME PREDICTION

The scenario database of coastal disasters can be obtained from the performance design of coastal defenses. However, the number of design levels in the performance design should be increased to prepare for a complete scenario database. Economically feasible technology for performance evaluation and preparing scenario databases of coastal disasters are not yet satisfactory. Upgrading is needed based on intensive studies in this field.

Comprehensive mitigation measures of coastal disasters need to be prepared systematically using viable performance design concepts for coastal defenses.

4. REFERENCES

Takahashi, S., Kawai, H., Tomita, T., and Takayama, T. (2004): Performance design concept for storm surge defense, Proc. of the 29th International Conference on Coastal Engineering, pp.3074-3086.

Takahashi, S. (2005): Tsunami disasters and their prevention in Japan, - Toward the performance design of coastal defenses- Proc. of International Symposium of Disaster Reduction on Coasts, Monash Univ.

Takahashi, S., Kawai, H., Tomita, T., and Takayama, T. (2005): Proposal of real time prediction of storm surge based on prepared scenarios, Asian and Pacific Coasts 2005, September 4-8, 2005, Jeju, Korea.

COUNTERMEASURES AGAINST COASTAL DISASTERS IN MEXICO

José Miguel MONTOYA RODRÍGUEZ, Head of the Port and Coastal Engineering Division, Mexican Institute of Transport, Carretera Querétaro-Galindo Km. 12, Sanfandila, Mpio.de Pedro Escobedo, Querétaro, Qro., México, Post Code 76700, mmontoya@imt.mx

In Mexico the major coastal disasters are regarding with the action of the natural phenomenon such as hurricanes/tropical depressions, and tsunamis. The destruction caused by hurricanes in the Caribbean and Central America is a force that has shaped history and will shape the future of the region. The danger arises from a combination of factors that characterize tropical cyclonic storms: rise in sea level, violent winds, and heavy rainfall. Hurricanes also originate in the northeast Pacific, where they can affect the west coast of Mexico. Figure 1 shows the paths of the hurricanes originating in the Atlantic, the Pacific, and the Caribbean, Organization of American States et al. (1991). Some of the biggest storm attcak of the Mexican coast in the past years are the follow:

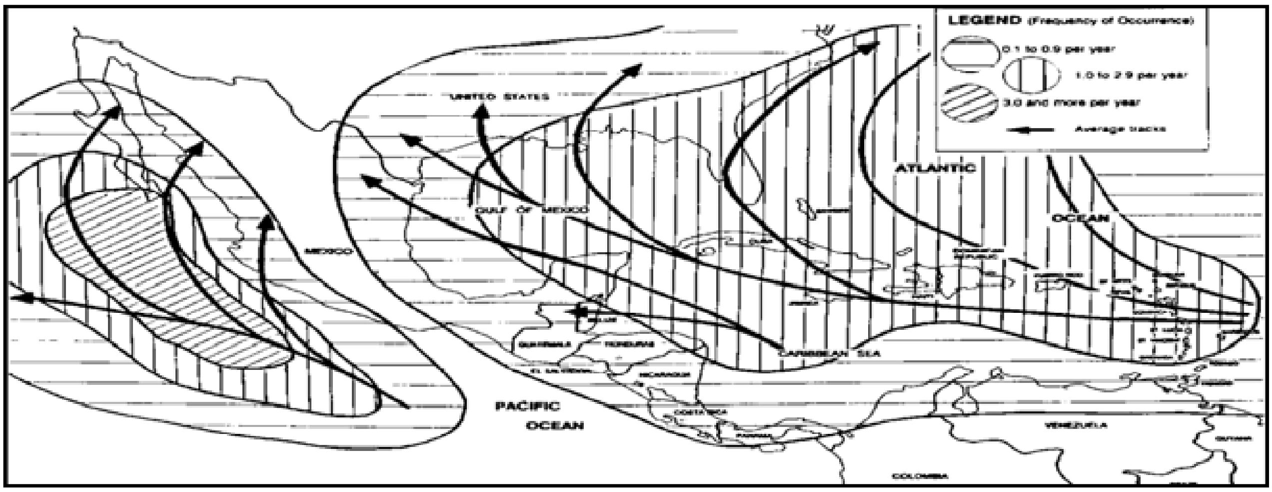


Figure 1 Map of nature risks on the Mexican coasts caused by hurricanes and tropical depressions; Source: Munich, Federal Republic of Germany, Munchener Ruckversicherungs: 1988.

(1) Hurricane Gilbert.

Gilbert (september 1988) was one of the strongest hurricanes ever seen in the Atlantic, Caribbean and Gulf of Mexico. Gilbert had winds up to 184 mph and a barometric pressure of 888 mb, which is the second-lowest pressure ever recorded for an Atlantic hurricane. Gilbert hit the Yucatan peninsula of Mexico shortly after recording the lowest pressure reading. After moving over the Yucatan, the strength of the hurricane diminished from a category 5 to a category 3. It caused serious flooding in the Monterrey region when it made landfall in Northern Mexico.

(2) Hurricane Wilma.

When Wilma became a hurricane on October 18, it tied the record dating back to 1969 for the most hurricanes in a season. However, when Wilma shot from a tropical storm to a Category 5 hurricane on the morning of October 19, it broke the all-time record for the lowest pressure ever measured in the Atlantic Basin. Wilma approaching the Yucatan Peninsula on October 21, 2005. Wilma was a Category 4 storm with maximum sustained winds reported at 240 kilometers per hour (150 miles per hour) by the National Hurricane Center. At its height, Wilma had sustained winds of 280 km/hr (175 mph). At this time Wilma attack Yucatan, Cozumel and Cancun in Mexico.

(3) Hurricane Stan.

On October 2005, Hurricane Stan made landfall in Mexico and generated separate tropical storms across southern Mexico and Central America. Stan spawned torrential rains that lasted for over five days causing widespread and severe flooding and deadly mudslides. Hurricane Stan has been reported to have been the cause of 610 deaths in southern Mexico and Central America.Hurricane Stan only reached category 1, but the loss off life looks like it might well exceed the figures quoted for Hurricanes Katrina and Rita put together.

Regarding with Tsunamis, the problem that exists in the pacific Mexican related with this phenomenon, One says to the presence of local events, that they have caused dead men and damages in the last hundred years, The mistake of a system of alert for tsunamis in Mexico, it forces the authorities of civil protection to develop works that allow to diminish the vulnerability of the population with regard to the impact of local tsunamis. We consider that by means of four principal lines of action, the risk will decrease for the population; the delimiting zone of risk and placement of signs, the training of the population, the elaboration of local plans and the establishment of a system of alarm, they are the actions to develop, Lopez Rivas et al. (2004).

Mexican Institute of Transport (IMT) of the Mexican Ministry of Communications and Transport (SCT, in Spanish) has been cooperated with Port and Airport Research Institute (PARI), Japan, for long years since 1984, when the technical cooperation project named as the "Mexico Port Hydraulic Center Project" started. Mexico Port Hydraulic Center Project was one of the project typed international cooperation activities financially assisted by the Japan International Cooperation Agency (JICA). The project term was in between 1984 and 1988. Irregular typed wave generators for hydraulic model experiment together with the field wave gauges were donated from Japan to Mexico during the project term; Some of those equipments are still used in the research activities of IMT now, although the Port Hydraulic Laboratory of the IMT moved from Mexico City to Querétaro City in 2001.

IMT has been trying to establish coastal wave observation network for long years, by introducing~ the Japanese NOWPHAS (Nationwide Ocean Wave information network for Port and HarbourS) system. And, after the 2004 Sumatra-Earthquake-Tsunami, IMT is now intending to add tsunami information to the coastal wave information system.

The purposes of this paper is to introduce the plan of a nationwide tsunami and information network in the Central and South Pacific Ocean (now under development in Mexico) as a part of the Nationwide Coastal Wave Information Network in Mexico, The development of this plan rests on the follow sources and studies:

Development of works in the short, medium, and long term for the nationwide coastal wave, meteorological and tsunami information network by means of installation of directional wave buoys, meteorological stations and pressure sensors respectively. The development of the plan in the short term (2004-2006) includes the following actions, Montoya et al. (2005):

- Development during 2004 of an history database for a set of offshore locations distributed along the Mexican coastline by means of the WAM numerical model, taking into account the recorded wind fields from the period of 1958 to 2001.
- Development during 2005 and 2006 of studies of wind and wave forecasting (in real time) for the main Mexican ports, by means of the MM5 numerical model and of the WAM and SWAN numerical models respectively.
- Installation during 2004, 2005 and 2006 of directional wave buoys, meteorological and pressure sensors for the tsunami and coastal wave monitoring.
- Development during 2006 and 2007 of hazards maps in coastal and ports areas regarding with Tsunamis actions in the central and South Pacific Ocean.
- Development during 2006 and 2007 of hazards maps in coastal and port areas regarding with storm surges in the Mexican littorals.

REFERENCES

Organization of American States et al. (1991): “Primer on Natural Hazard Management in Integrated Regional Development Planning”, Department of Regional Development and Environment Executive Secretariat for Economic and Social Affairs, Washington, D.C.

López Rivas and Pinto Aceves G. (2004): “Protección Civil y los Tsunamis”; Reporte de la Unidad Estatal de Protección Civil Jalisco, Gobierno del Estado de Jalisco, Tsunamis en México, evento organizado por el Centro Nacional de Prevención de Desastres y la Agencia de Cooperación Internacional del Japón , Ciudad de México, In Spanish.

Montoya Rodríguez José Miguel and Toshihiko Nagai (2005): Development of the Nationwide Tsunami Information Network in the Central and South Pacific Ocean In Mexico, Memorial Conference on the 2004 Giant Earthquake and Tsunami in the Indian Ocean, Tokyo University, Japan.

COUNTERMEASURES AGAINST STORM SURGE & TSUNMIS
BY MINISTRY OF LAND, INFRASTRUCTURE, & TRANSPORT

Yasuyuki Kajiwara, Ports and Harbors Bureau, Ministry of Land, Infrastructure, and Transport, Japan,
kajiwara-y23d@mlit.go.jp

As Japan is an island country whish is typhoon-prone and earthquake-prone, it has frequently experienced storm surge and tsunami disasters. Therefore, the national and local governments have focused on the development of coastal protection facilities such as seawalls and breakwaters. Particularly in three major bay areas where population and economic functions are dense, as the governments have concentrated on the development of coastal protection facilities, these areas have experienced no serious coastal disaster approximately during this half-century.

However, the aging of Japanese society accompanying population decrease as well as infrastructure aging makes government budgets for investing in facility developments rapidly tighten. Under such circumstances the Indian Ocean Tsunami and the Hurricane Katrina force the governments reexamine conventional countermeasures against disasters which have only focused on facility developments.

In addition to facility developments for projected disasters, countermeasures against storm surge and tsunamis by the Ministry of Land, Infrastructure, and Transport hereafter should emphasize the enhancement of damage reduction effectiveness by means of non-facility approaches such as information providing and evacuation guiding especially for low-probability disasters beyond projection.

TSUNAMI AND STORM SURGE HAZARD MAPS

Tatsuyuki Shishido, Coastal Development Institute of Technology, Tokyo, Japan, t_shishido@cdit.or.jp
Yoshiji Koyano, Institute of Technology for Disaster Management/CDIT, Tokyo, Japan, koyano@cdit.or.jp

1. INTRODUCTION

Humans have suffered from earthquakes, tsunamis, typhoons, storm surges, floods, and other disasters. We cannot escape from the menace of nature, but we can reduce the damage that disasters cause. Considering the fact that it is difficult to predict occurrence of natural disasters, it is important that we learn from experience in past disasters to prepare for disasters. One of the most fundamental requirements is that the people be fully aware of the risk of disasters in the region.

One tool that can play a big part in increasing public awareness of disaster risks is a hazard map, and earthquake, tsunami, volcano, and flood hazard maps are now prepared. This paper includes an introduction of the Manual for Tsunami and Storm Surge Hazard Maps, an overview of the present provision of hazard maps, mainly for tsunamis, in Japan, and an explanation of the significance and roles of hazard maps clarifies by the above.

2. MANUAL FOR TSUNAMI AND STORM SURGE HAZARD MAPS

The Cabinet Office, Ministry of Agriculture, Forestry and Fisheries, and the Ministry of Land, Infrastructure and Transport formed the Tsunami and Storm Surge Hazard Map Research Committee and prepared the Manual for Tsunami and Storm Surge Hazard Maps based on the study under this committee to publish the manual in March 2004. Aware that in order to reduce the damage caused by tsunamis and storm surges, not only physical measures such as construction of coastline protection structures, but non-physical measures such as providing local people with degree of danger information to enhance their ability to protect themselves from disasters must be introduced, the organizations above jointly prepared this manual by summarizing expertise in the preparation and use of hazard maps.

The manual defines hazard maps as “Geographical presentation of damage-prone areas with expected degrees of damage incase of possible tsunami or storm surge attack. As necessary, it includes the information for disaster mitigation such as evacuation location and evacuations routes”. The manual consists of five chapters, Chap. 1: Necessity of hazard maps against tsunami and storm surge and its function, Chap. 2: Outline of tsunami and storm surge hazard maps, Chap. 3: Method of assessing inundation-prone areas, Chap. 4: Method of preparing a tsunami or storm surge hazard map based on the results of the inundation prediction, and Chap. 5: Publicity, public awareness, utilization and promotion, and others of tsunami and storm surge hazard maps. Its reference materials include Inundation prediction based on a numerical time-domain simulation, Examples of the use of a tsunami or storm surge hazard map to prepare tsunami or storm surge protection measures and List of related web sites.

Seminars to explain the manual have been held for staff of administrations concerned with disaster prevention at ten locations throughout Japan. Considering that systems to prepare hazard maps are being established, the publication of this manual is counted on to encourage the wider provision and utilization of hazard maps.

3. PRESENT STATE OF TSUNAMI AND STORM SURGE HAZARD MAPS IN JAPAN

The results of a questionnaire survey concerning the state of provision of hazard maps concerning tsunamis and storm surges conducted by the government in coastal municipalities in August 2004 has shown that approximately 12.3% of coastline municipalities have provided tsunami hazard maps and about 1.2% have provided storm surge hazard maps. The promotion of preparation and wide use of hazard maps in more municipalities is expected.

Tsunami hazard maps are provided in 122 municipalities. Examining information of 95 hazard maps obtained in this questionnaire survey reveals that they were basically prepared by municipalities, while 35 were prepared with the cooperation of prefectural administrations and 6 with the cooperation of the national government. In these cases, the national government and prefectural administrations often prepared the fundamental data and carried out the inundation prediction. In 3 cases, it was done with the cooperation of voluntary disaster prevention organizations. By region, hazard maps have been provided by many municipalities along the Pacific Coast of Tohoku that has been struck by frequent tsunamis and in the Tokai region that is close to the center of the Tokai Earthquake. It is natural that many are provided in regions where there is great concern with disasters, but considering the fact that the almost entire coastline of Japan may be struck by a tsunami, they must be provided and popularized in other parts of Japan. These hazard maps have been published since 1994 and the number increased after 2001 and 20 hazard maps were prepared in 2004. This presumably reflects growing concern with disaster prevention.

The information presented in each hazard map varies according to circumstances in each region. On inundation, the inundation depth was indicated in 40 cases but not in 50 cases, and the predicted arrival time was indicated in 8 cases but not in 82 cases. Reasons for not presenting this information were a lack of the required data, fear that including the information without full explanations would lead to misunderstandings, and a high priority on the map being easy to understand. Numerical simulations were performed to predict the inundation in 37 cases, while it was set based on past inundations or ground height in the other cases. Workshops were held as part of the hazard map preparation process in cases of approximately 20%, allowing participants to express their views, suggesting revisions to the evacuation sites or requesting simplifications for example, and these are reflected in the final hazard maps. They were used for disaster prevention drill in about 1/3 cases but for education in only a few cases.

Experts evaluated 30 maps considered representative for use as a reference to prepare and to update hazard maps. Their comments concerning the method of representing the state of the inundation, ways to make them easier to understand, preparation of columns for local people to enter necessary information by themselves and so on, would be helpful when actually preparing a hazard map.

4. PREPARATION OF TSUNAMI HAZARD MAPS – THE CASE OF SUSAKI CITY

The procedure in preparing an hazard map have been examined based on the case of Susaki City in Kochi Prefecture where the people in the region worked together to prepare a hazard map.

Susaki City is a city with a population of about 28,000 facing the Pacific Ocean in the western part of Kochi Prefecture on the Island of Shikoku. Its urban area develops surrounding Susaki Bay that is open to the Pacific Ocean through a mouth approximately 1,500m wide. Because of its ria coast topography, it is susceptible to tsunami damage. Past tsunamis have claimed many precious lives of the citizen.

A tsunami simulation premised on a large-scale earthquake predicts that the present seawall and the tsunami breakwater under construction might be unable to prevent inundation. So, disaster prevention measures incorporating non-physical measures are required and a hazard map was noticed as an effective measure. Tsunami Countermeasure Study Committee was formed and deliberated on the results of the simulation and other technological challenges. In addition the views and desires of the local people were also obtained and a trial version of a hazard map was prepared. The final version has been completed based on detailed examination on the trial version under participation of the local people such as workshops at each district and trial evacuation drill.

Susaki City accompanied the preparation of the hazard map with the preparation of a Susaki City tsunami instruction booklet named Our Town and the Nankai Earthquake Tsunami – Understand and Protect Yourselves from Tsunamis –. These are distributed to the citizens and also posted on its web site.

5. SUMMARY

As concern for disaster prevention grows, it is important that municipalities throughout Japan take advantage of the hazard map manual that the government has published to provide and to promote the wide use of tsunami and storm surge hazard maps in their regions.

In order that hazard maps are used most effectively as risk awareness tools, it is important that the local people participate in their preparation, that advanced technology are introduced to increase the precision and clarity of the information they present, and that they are continuously applied as reference material for disaster prevention through their use in disaster prevention education etc., and that at the same time, efforts are made to make necessary improvements to hazard maps.

Hazard maps are tools that provide disaster prevention information that can be applied effectively for purposes other than the local people evacuation. The technology on simulation methods, presentation method and so on according to their purposes should be developed.

6. REFERENCES

Cabinet Office (Disaster Management), Rural Development Bureau MAFF, Fisheries Agency MAFF, River Bureau MLIT, Ports and Harbours Bureau MLIT, Manual for Tsunami and Storm Surge Hazard Maps, March 2004.

Cabinet Office (Disaster Management), Rural Development Bureau MAFF, Fisheries Agency MAFF, River Bureau MLIT, Ports and Harbours Bureau MLIT, In order that we do not encounter damage from tsunami and storm surge, June 2005.

Cabinet Office, White Paper on Disaster Management 2005, June 2005.

Takuya Masuyama, Hazard Assessment and Education Project for Tsunami Disaster Reduction in Susaki City, Report of the Coastal Development of Institute Technology No4, 2004.