Report on International Workshop on Tsunami Inundation Mapping,

in Tokyo, Japan,
25-27 November 2015,

organized by

Hydrographic and Oceanographic Department,
Japan Coast Guard

in cooperation with

UNESCO/ Intergovernmental Oceanographic Commission (IOC)
Tsunami Program

and

Port and Airport Research Institute (PARI)

East Asia Hydrographic Commission

Group photo of the participants shot on the first day of the workshop

1. Introduction

In the Asia-Pacific region, many countries have suffered serious damage due to marine natural disasters. For example, Japan was hit by a massive tsunami caused by the Great East Japan Earthquake in March 2011, and the Philippines experienced a devastating storm surge caused by Typhoon Haiyan in November 2013. These types of marine natural disasters have been a persistent threat in coastal regions over many years. These disasters have occasionally caused serious damage to local economies and the environment and claimed many lives. Therefore, it is important to engage in day-to-day efforts to improve public awareness, preparedness, and regional cooperation to deal with marine natural disasters.

A tsunami inundation map (TIM) is a useful tool for increasing public awareness of tsunamis and preparedness against them. A TIM can also be applied to storm surge. To develop a TIM, it is important to obtain bathymetric information to calculate tsunami propagation and determine the tsunami inundation area. Hydrographic offices (HOs) are expected to contribute such bathymetric information for developing TIMs in each country.

The International Workshop on Tsunami Inundation Mapping was held by the Hydrographic and Oceanographic Department, Japan Coast Guard (JHOD), in cooperation with the UNESCO/International Oceanographic Commission (IOC) Tsunami Programme and Port and Airport Research Institute (PARI), at the JHOD office in Tokyo, Japan, on November 25–26, 2015, as part of the 2015 East Asia Hydrographic Commission (EAHC) Capacity Building Program using the International Hydrographic Organization (IHO) Capacity Building Fund.

The objectives of this workshop were to improve the capacity of HOs in mainly the East Asian countries for developing and utilizing TIMs and to discuss the way forward through sharing the latest knowledge and technology as well as experiences and challenges among participants.

The workshop program is shown in **Annex 1**.
In total, 45 people from nine countries participated in this workshop, as shown in **Annex 2**.

2. Opening Ceremony

The workshop was opened by Mr. Hideki Kinoshita, JHOD. Then, Vice Admiral Shigeru Kasuga, Chief Hydrographer of Japan, JHOD, made an opening address on behalf of the hosting organizations. He emphasized the possibility of HOs contributing to the development of TIMs in each country by using their capabilities to conduct bathymetric surveys and produce nautical charts. He also highlighted the importance of cooperation among the organizations concerned to improve their capacities. His opening address is shown in **Annex 3**.

After the opening address, Prof. Kenji Satake of the University of Tokyo, Japan, gave a keynote presentation entitled “Tsunami Generation and Propagation.” His presentation is shown in **Annex 4-1**. In his presentation, he said that in the last two decades, tsunami disasters with many casualties have occurred almost every year. Tsunami propagation is governed by bathymetry, and additional fine grid data of the bathymetry in coastal areas, rather than in offshore areas, are necessary for numerically modeling tsunami propagation. In the 2011 Japan Tsunami, the inundation area was larger than expected in some areas. He also emphasized the importance of efforts to obtain geological evidence from past events, because some studies have discovered that huge tsunamis in the past caused inundation on a scale similar to the 2011 Japan Tsunami.

In response to a question from a participant, he explained that information about the structures in coastal areas could be considered for precisely predicting the inundation area.

3. Session 1: International Framework and Cooperation on Tsunami

Mr. Tomoaki Ozaki, Japan Meteorological Agency, delivered a presentation on the activities of the IOC Tsunami Programme in the Pacific Region. His presentation is shown in **Annex 4-2**. He introduced the international tsunami warning and mitigation system under the UNESCO-IOC, International Tsunami Service Providers - Pacific Tsunami Warning Center (PTWC), and Northwest Pacific Tsunami Advisory Center (NWPTAC). The IOC Tsunami Programme was started in the Pacific Ocean in response to the 1960 Chilean Tsunami. Then, the 2004 Indian Ocean Tsunami accelerated the establishment of tsunami warning systems around the world. Tsunami warning systems have now been set up in the Indian Ocean, Caribbean Sea, Northeast Atlantic Ocean and Mediterranean Sea, in addition to the Pacific Ocean. He noted that "Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030." was listed in the seven global targets of the Sendai Framework for Disaster Risk Reduction 2015–2030 developed at the third UN World Conference on Disaster Risk Reduction, March 14–18, 2015, Sendai, Japan. He highlighted that the linkage of tsunami warnings and inundation mapping is important for effective evacuation orders/recommendations, tsunami disaster management planning, and other efforts. He said that the IOC Tsunami Programme now mainly focuses on tsunami warnings but it has also been working on issues such as tsunami hazard assessment and disaster management. He said that the international framework on TIMs is not adequate at present.

In response to a question from a participant, he explained that the Japan Meteorological Agency has set a target time of approximately 3 min for issuing a warning after the occurrence of an earthquake.

4. Session 2: Development of Tsunami Inundation Maps

Dr. Takashi Tomita, Asia-Pacific Center for Coastal Disaster Research, Port and Airport Research Institute (APaC-CDR/PARI), Japan, delivered a presentation on the Guideline for Development and Utilization of Tsunami Disaster Management Map. His presentation is shown in **Annex 4-3**. He said that the Tohoku region had been one of the regions in Japan best prepared for tsunamis, though the 2011 Japan Tsunami was bigger than expected from the viewpoint of tsunami disaster management. A combination of structured and unstructured measures had some effect on securing time for evacuation from the tsunami. In his presentation, he said that the important purpose of tsunami hazard maps, which identify safe zones for evacuation and the risk in a target community, is to build a tsunami-resilient community by preparing holistic and integrated measures. Then, with regard to tsunami hazard mapping, the results of the tsunami numerical simulation depend on the accuracy of the numerical models employed as well as the bathymetric and topographic data. We should prepare appropriate numerical models and suitably accurate bathymetric and topographic data and further structure these data to calculate tsunami propagation and inundation. The estimation results for disaster mitigation should be made easily available to residents, disaster managers, and officers to build a common awareness of tsunami damage. Hazard mapping is a good tool for this purpose. Additional information about disaster mitigation measures on the hazard map is effective for investigating and planning a holistic and integrated system for tsunami disaster mitigation. He concluded that we should understand and estimate the potential damage and disasters due to tsunamis, foster individuals who are well-prepared for tsunamis, and develop cities that are resistant and resilient to tsunamis.

Replying to a question from a participant, he explained that one of the low-cost structured measures against a tsunami is a soil embankment. He explained that guidelines have been developed in cooperation with experts in the ASEAN region and that these are now freely available via the Internet.

Speaking on the technical aspects and challenges of TIM development in Japan, Mr. Takashi Yanuma, PASCO Corp., Japan, presented a practical approach to develop a tsunami simulation and inundation map from PASCO's experiences. He divided the procedure for tsunami simulation and hazard mapping into four steps: preparing the digital topography, selecting a possible earthquake, performing tsunami simulation, and creating a tsunami hazard map. He said that in the tsunami simulation model, an accurate topographic dataset is important. Furthermore, the topography of rivers plays a major role in extending the tsunami inundation area. He also introduced some Web sites that are useful for validating tsunami simulation results.

In answering a question from a participant, he explained that, generally, Tokyo Peil (mean sea level of Tokyo Bay) has been used as the datum for topography in Japan.

5. Session 3: Latest Technology for Bathymetric Surveys in Shallow Water

Mr. Naohiro Miyasaku and Mr. Yutaka Kawamura of PASCO Corp. gave a presentation on coastal surveying using airborne LiDAR (light detection and ranging). Their presentation is shown in **Annex 4-5**. They introduced the concept and characteristics of airborne LiDAR and airborne laser bathymetry (ALB) along with some survey results. They summarized the capability of these methods to grasp the underwater surface topography as follows:

- For coastal zones, the seafloor, and rivers, wider coverage of underwater terrain data can be obtained.
- In contrast to acoustic sounding by ships, “shallow water depth range” measurement is possible by ALB.
- Temporal data acquisition for the quantitative understanding of sediment variation, such as peripheral structure, is possible.
- After correction of the area (grid) data obtained by ALB, a realistic simulation or evaluation can be performed.

They also emphasized that by using ALB for surveying a wider area of the seafloor and water bottom, it is possible to reduce the total cost compared with that of the conventional acoustic sounding measurement.

In response to a question from a participant, they explained that the ellipsoidal level is used as the datum for ALB, and measurements of the water surface position are performed at the same time in reference to ALB survey data.

Mr. Yoshihiro Matsumoto, JHOD, reported his study of satellite derived bathymetry (SDB). His presentation is shown in **Annex 4-6**. Considering that SDB is an efficient survey method for very shallow waters that allows for shorter survey periods, less use of survey vessels, and lower cost, he summarized the application of SDB to tsunami simulation and highlighted the following points:

- Rapid and low-cost methodology for unsurveyed or poorly surveyed areas.
- Even density of soundings, like in a digital elevation map, up to grid sizes of 1.8 m.

6. Session 4: Public Awareness and Collaboration for Disaster Management

Dr. Anawat Suppasri, International Research Institute of Disaster Science (IRIDeS), Tohoku University, Japan, gave a presentation on public awareness and collaboration for disaster management, as shown in **Annex 4-7**.

He introduced the lessons learned from previous disasters such as the 2004 Indian Ocean Tsunami, 2011 Japan Tsunami, and the storm surge caused by Typhoon Haiyan in 2013. He said that the key topics to address are the importance of understanding the generation mechanism of each disaster, the necessity of preparing for unexpected event and creating more accurate hazard maps considering uncertainty, and problems during an evacuation. The lessons learned and experiences of a disaster could result in reduced damage in future disasters. After reviewing some examples of successes and failures in the evacuation and emergency response in the case of the 2011 Japan Tsunami, he introduced a collaboration among Tohoku University, tsunami-affected areas, local governments, and local media to overcome these failures.

In response to a question from a participant, he explained that the participation rate of the local community in the tsunami evacuation drill conducted by a local municipality in Tohoku is now around 30%.

7. Session 5: Survey of Coastal Information

In this session, Mr. Takaya Ishizuka and Ms. Shiori Tamagami, PASCO Corp., presented case studies of natural disasters and remote sensing based on some earthquake, volcano, landslide, typhoon, and flood disasters. Their presentation is shown in **Annex 4-8**. They showed the effectiveness of remote sensing technology for understanding the damage caused by a disaster. In the 2011 Japan Tsunami, they detected floating objects in TerraSAR-X imagery acquired on March 13. Regarding the storm surge due to Typhoon Haiyan in Philippines in 2013, the damage analysis results and threedimensional elevation model data obtained using airborne LiDAR were provided to experts on a Japan International Cooperation Agency (JICA) project team to consider a reconstruction plan and countermeasures against a future disaster. The JICA project team also created a 1/5,000 scale base map from the high-resolution optical satellite image data. They introduced their experience in a field survey of the extent of damage in the Philippines, from which local people said they would have evacuated if they had been informed of the possible incursion of a tsunami-like surge.

8. Session 6: Case Studies in Japan

Mr. Satoshi Nagasaki and Mr. Naoto Takenoya, Kamakura City, Kanagawa Prefecture, Japan, provided examples of a TIM made by a local municipality in Japan. Their presentation is shown in **Annex 4-9**. Kamakura City has experienced several huge tsunami disasters in the past. After the 2011 Japan Tsunami, the city reviewed its countermeasures for tsunamis. Inland relocation of important buildings such as fire stations and schools was planned; however, countermeasures for the structural base are limited. Kamakura City has conducted various activities including publishing a booklet on disaster preparedness containing TIMs; installing signs to indicate elevation above sea level, evacuation sites, and evacuation routes along streets; and conducting tsunami evacuation drills with the local community. For tsunamis, the city has built a basic concept of *Jijo Kyojo*, which means “self-help and help each other” in Japanese.

In response to questions from participants, Mr. Nagasaki explained that the city has requested local residents be the first to evacuate because this attitude could lead to the evacuation of visitors including foreigners. He also noted that education including drills will be important for maintaining public awareness of tsunamis.

Mr. Takafumi Hashimoto, JHOD, discussed JHOD activities pertaining to TIMs for harbors and coastal areas. His presentation is shown in **Annex 4-10**. JHOD provides TIMs in the harbors and coastal areas where it is assumed that tsunami damage will occur in the event of a large earthquake. The maps are based on numerical simulations of tsunami behavior using the detailed bathymetric data obtained by JHOD, and they are used as basic information for preparing for and responding to tsunami disasters.

In his answer to a question about whether the TIMs by JHOD were intended for large ships, Dr. Suppasri said that the map would be useful for smaller ships, too, such as fishing boats.

In response to a question from a participant about what action is recommended for a container ship or tanker, he explained that the TIMs have been published to aid such considerationsby ship operators and port authorities. Japanese experiences shared from the floor suggested that some studies on ship evacuations were attempted, and the recommended actions differed from one case to the next, depending on the position and operating conditions of the ship, among other factors.

9. Session 7: Discussion of Tsunami Inundation Mapping for HOs in East Asian Countries

Before the discussion, Mr. Norio Baba, JHOD, presented survey results from the Questionnaire on Tsunami Inundation Map, which JHOD administered to EAHC members before the workshop. The details of the survey report are shown in **Annex 4-11**.

He reported that the tsunami disaster was the highest concern among eight countries in the EAHC. In many countries, another organization apart from the HO had the primary responsibility for developing TIMs, but the HO in these countries supported TIM development by providing bathymetric information and other assistance. All participating countries expected to improve their knowledge and techniques for TIM development at the workshop.

To stimulate further discussion, the situation and challenges in some EAHC members were reported by Ltjg. Rodel Guarte, National Mapping and Resource Information Authority (NAMRIA), the Philippines, and Lt. Dadang Handoko, Indonesian Hydro-Oceanographic Services, Indonesia. Their presentations are shown in **Annex 4-12** and **Annex 4-13**, respectively. Ltjg. Guarte noted that a training session by Regional Integrated Multi-Hazard Early Warning Systems for Africa and Asia

(RIMES) was conducted in the Philippines in 2013 by low-cost near-shore bathymetry using handheld GPS and sonar systems. An Internet-based Simulation Platform for Inundation and Risk Evaluation (INSPIRE) and Evaluation System for Computing Accessibility and Planning Evacuation (ESCAPE) by REIMS were also introduced.

Then, Mr. Kinoshita, JHOD, facilitated a discussion by participants about how to improve capacity for developing TIMs in the region, categorizing the discussion points into three stages: preparation, information collection, and utilization.

In the discussion of the **preparation stage**, it was found that the participants recognized the following through the workshop:

1. Several activities related to TIMs have been conducted internationally, such as the UNESCO/IOC Tsunami Programme, the ASEAN-Japan Transport Partnership in cooperation with PARI, and RIMES.
2. We need to further improve the recognition and utilization of TIMs.
3. There are differences in national policies, legal systems, and organizational structures for disaster management among the countries.
4. HOs could play an important role in many aspects of TIM development by utilizing their capacities, such as providing bathymetric data and coastal information and editing and printing TIMs. However, the role and tasks to be taken on by HOs differ among the countries owing to the different organizational structures and capacities of the HOs among the countries.

Then, the participants discussed how we can promote international cooperation and avoid duplicated efforts, how we can further improve recognition, and how we can promote the TIM utilization. Another topic of discussion was how HO involvement in the development of TIMs in each country can be improved. The participants made the following comments:

1. We should share knowledge and techniques relating to tsunamis and countermeasures including TIMs through capacity-building activities such as workshops, training, and education.
2. Because several international activities are being conducted, duplicated efforts should be avoided. HOs could serve as data providers.

In discussing the **information collection stage**, the workshop participants understood that the following information should be collected for TIMs:

1. High-quality bathymetric information coupled with land elevation information for precise estimation of tsunami propagation and inundation area.
2. Evacuation sites and routes and facilities essential for countermeasures against disasters that should be indicated on TIMs.
3. Information to be used to identify tsunami inundation areas, such as numerical models, historical records of past events, and historical records of tidal observations.

Then, the participants discussed the technical and governmental/legal problems faced in collecting this information and how HOs can contribute to the information collection. The participants noted the following:

1. HOs' Understanding of tsunamis and TIMs should be further improved.
2. In some countries, resources of HOs are too limited to conduct a hydrographic survey of the entire coastal area.
3. For TIM development, collaboration with other organizations/agencies is important, but role of each organization and agency should be clearly defined.
4. Knowledge and techniques for collecting accurate topographic information should be shared among HOs. A representative from Singapore introduced his new method for simultaneously surveying coastal structures and bathymetry by using a laser scanner and multibeam echosounder from a survey vessel.

In the discussion of the **utilization stage**, the participants recognized that TIMs have been used for several purposes, such as public awareness, and review and development of countermeasure plans. Then, the workshop participants discussed the problems faced in TIM utilization. It was pointed out by the participants that to improve the recognition of TIMs, the awareness of the tsunami threat should be increased first, and then, the recognition of TIMs could be improved along with the awareness of the tsunami threat.

10. Closing Ceremony

The workshop was closed by Mr. Kinoshita, JHOD, as shown in **Annex 5**. He expressed his appreciation for all the speakers and participants for their active participation and cooperation in the workshop.

Annex 1

Program of the Workshop

Opening Ceremony

- Opening Address
  Vice Admiral Shigeru Kasuga, Chief Hydrographer of Japan, JHOD
- Administration Arrangement
  Secretariat, JHOD
- Keynote: Tsunami generation and propagation
  Dr. Kenji Satake, University of Tokyo, Japan

Session 1: International Framework and Cooperation on Tsunami

- Activities of the IOC Tsunami Program in the Pacific Region
  Mr. Tomoaki Ozaki, Senior Coordinator for International Earthquake and Tsunami Information, Japan Meteorological Agency

Session 2: Development of Tsunami Inundation Maps

- Guideline for Development and Utilization of Tsunami Disaster Management Map
  Dr. Takashi Tomita, Asia-Pacific Center for Coastal Disaster Research, Port and Airport Research Institute (APaC-CDR/PARI), Japan
- Technical Aspects and Challenges on the Development of Tsunami Inundation Map in Japan
  Mr. Takashi Yanuma, PASCO Corp., Japan

Session 3: Latest Technology for Bathymetric Surveys in Shallow Water

- Coastal survey using Airborne Lidar
  Mr. Naohiro Miyasaku and Mr. Yutaka Kawamura, PASCO Corp., Japan
- Study on Satellite Derive Bathymetry
  Mr. Yoshihiro Matsumoto, Principal Ocean Research Officer, JHOD

Session 4: Public Awareness and Collaboration for Disaster Managment

- Public Awareness and Collaboration for Disaster Management
  Dr. Anawat Suppasri, International Research Institute of Disaster Science (IRIDeS), Tohoku University, Japan

Session 5: Survey of Coastal Information

- Identification of Land Use and Damaged Area using Remote sensing Technology
  Mr. Takaya Ishizuka and Ms. Shiori Tamagami, PASCO Corp., Japan

Session 6: Case Studies in Japan

- Example of Local Municipality in Japan
  Mr. Satoshi Nagasaki and Mr. Naoto Takenoya, Kamakura City, Kanagawa Prefecture, Japan
- Tsunami Information Map for the Harbors and Coastal Areas
  Mr. Takashi Hashimoto, JHOD

Session 7: Discussion of Tsunami Inundation Mapping for HOs in East Asian Countries

- Report on the Survey result by Questionnaire on Tsunami Inundation Map in the Member Counties of EAHC
  Mr. Norio Baba, JHOD
- Report by the EAHC member countries
  Ltjg. Rodel Guarte, National Mapping and Resource Information Authority (NAMRIA), Philippines
  Lt. Dadang Handoko, Indonesian Hydro-Oceanographic Services, Indonesia
- Discussion by the WS participants

Closing Ceremony

- Closing Remark

Annex 2

List of the Participants

Bangladesh

Mr. Anowar Hossain
Director General (Early Warnings)
Rural Mother & Child Health Care Society (RMCHCS)

Mr. S M Rafiqul Islam
Director General (Asia-Pacific & Oceania)
Rural Mother & Child Health Care Society (RMCHCS)

China

Ms. Liwen Liu
Surveying and Mapping Engineer
Shanghai Chart Center
Donghai Navigation Safety Administration
MOT, China MSA

Indonesia

Lt. Dadang Handoko
Staff Planning of Survey Division
Indonesian Hydro-Oceanographic Services

Japan

Mr. Norio Baba
Senior Liaison Officer for Hydrography and Oceanography,
International Affairs Office
Hydrographic and Oceanographic Dept.,
Japan Coast Guard (JHOD)

Mr. Yasuhiro Fuchita
PASCO Corp

Mr. Takafumi Hashimoto
Geodesy and Geophysics Office
Hydrographic and Oceanographic Dept.,
Japan Coast Guard

Mr. Tadashi Ishikawa,
Director for Volcano Research,
Hydrographic and Oceanographic Dept.,
Japan Coast Guard

Mr. Takaya Ishizuka
PASCO Corp

Dr. Yo Iwabuchi
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Mr. Koji Kawai,
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Japan Coast Guard

Mr. Shigeru Kasuga
Chief Hydrographer
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Mr. Yutaka Kawamura
PASCO Corp

Mr. Hideki Kinoshita
Director of International Affairs Office,
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Graduate student (Intern)
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The University of Tokyo

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Kamakura City

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Japan Coast Guard (JHOD)

Dr. Azusa Nishizawa
Director of Ocean Research Laboratory
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Mr. Mitsuhiro Numata
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Japan Coast Guard

Mr. Tomoaki Ozaki
Senior Coordinator for International Earthquake and Tsunami Information
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Associate professor
International Research Institute of Disaster Science,
Tohoku University

Mr. Michihiro Suzuki
Senior Officer, Geodesy and Geophysics Research Office,
Hydrographic and Oceanographic Dept.,
Japan Coast Guard (JHOD)

Ms. Hitomi Takahashi
Geodesy and Geophysics Research Office,
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Japan Coast Guard (JHOD)

Mr. Naoto Takenoya
Kamakura City

Ms. Shiori Tamagami
PASCO Corp

Dr. Takashi Tomita
Deputy Director of Asia-Pacific Center for Coastal Disaster Research,
Port and Airport Research Institute

Mr. Shin-ichi Toyama
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Mr. Naoto Ujihara
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Mr. Akio Yamamoto
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Japan Coast Guard (JHOD)

Mr. Ichiro Yamashita
Fugro Japan Co., Ltd

Mr. Takashi Yanuma
PASCO Corp

Malaysia

Mr. Musa Paiman
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National Hydrographic Centre

Philippines

LTJG. Rodel Guarte
Chief Survey Officer,
Brp Hydrographer Palma
National Mapping and Resource Information Authority (NAMRIA)

Republic of Korea

Mr. Chung ho Lee
Assistant director
Korea Hydrographic and Oceanographic Agency (KHOA)

Singapore

Mr. Weng Choy Lee
Senior Assistant Hydrographer
Maritime and Port Authority of Singapore

Thailand

Cdr. Supasit Kongdee
Head of Coastal Engineering Section
Hydrographic Department,
Royal Thai Navy

Annex 3

Opening Address by

Vice Admiral Shigeru KASUGA,

Director General of Hydrographic and Oceanographic Department,

Japan Coast Guard

Good morning, ladies and gentlemen. I am Shigeru Kasuga, Chief Hydrographer and Director General of the Hydrographic and Oceanographic Department, Japan Coast Guard.

First, we would like to welcome you from the bottom of our hearts.

It is a great honor and pleasure for us to host this workshop. We would like to express our gratitude to you for coming all the way to Japan.

This workshop is planned and organized as a capacity-building program of the East Asia Hydrographic Commission using the International Hydrographic Organization Capacity Building Fund, and it is supported by the UNESCO Intergovernmental Oceanographic Committee Tsunami program.

We greatly appreciate cordial cooperation for the workshop from the Port and Airport Research Institute, the Earthquake Research Institute of the University of Tokyo, the Japan Meteorological Agency, PASCO Corporation, the International Research Institute of Disaster Science of Tohoku University, and Kamakura City.

A tsunami inundation map is an indispensable tool for reducing the damage caused by a tsunami or storm surge. A technique to produce a tsunami inundation map is applicable to a storm surge inundation map as well. A tsunami or storm surge map is a useful tool for evacuation planning, developing countermeasure plans, and raising public awareness of such disasters.

In the Asian region, many disasters have occurred, such as tsunami disasters in Indonesia in 2004 and in Japan in 2011 and the storm surge disaster in the Philippines in 2013. We must be ready for disasters in the future.

To produce an inundation map, detailed bathymetry information and map compilation skills are necessary. Hydrographic offices that conduct hydrographic surveys and produce nautical charts for navigation safety can greatly contribute to the production of inundation maps in each country and should do so as part of their responsibility.

The main purpose of the workshop is to improve the capacity of hydrographic offices in mainly East Asian countries for the development and utilization of tsunami inundation maps. This is the first workshop conducted with the theme of tsunami inundation map in the International Hydrographic Organization.

Another theme that is no doubt important to everybody attending this workshop is to strengthen friendships with one another.

Lastly, we hope that this workshop will be successful and will contribute to improving the capacity for disaster management in East Asia.

Thank you very much for your kind attention.

Tsunami Generation and Propagation

Kenji Satake

Earthquake Research Institute

University of Tokyo

1

Outline

1. The 2004 Indian Ocean and 2011 Tohoku tsunamis
2. Tsunami generation by earthquakes
3. Tsunami propagation and computer simulation
4. Tsunami observation (instrumental, historical, geological)
5. Tsunami hazard maps

2

Outline

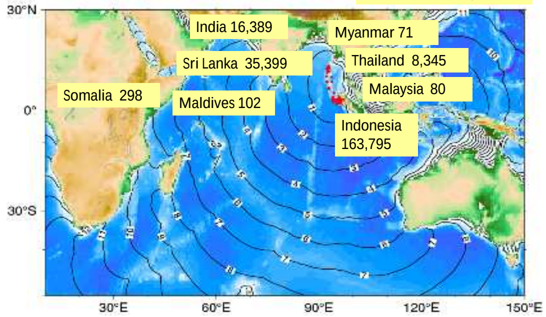
1. The 2004 Indian Ocean and 2011 Tohoku tsunamis
2. Tsunami generation by earthquakes
3. Tsunami propagation and computer simulation
4. Tsunami observation (instrumental, historical, geological)
5. Tsunami hazard maps

3

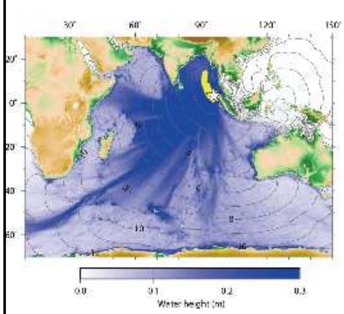
The 2004 Sumatra Earthquake and Tsunami

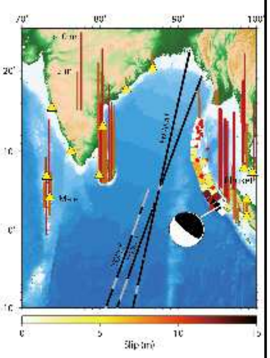
Worst tsunami disaster in history
>230,000 casualty in > 10 countries

Casualties from tsunami
World Disaster Report



The 2004 Sumatra Earthquake and Tsunami

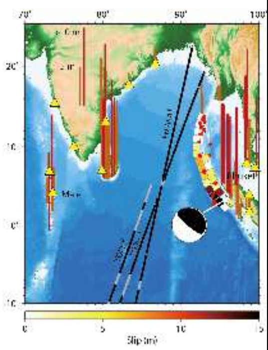




5

The 2004 Sumatra Earthquake and Tsunami

Thailand

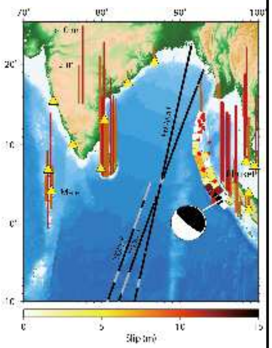


About 8,000 casualties
Including Royal family member
Nearly a half were foreign tourists

6

The 2004 Sumatra Earthquake and Tsunami

Banda Aceh, Indonesia



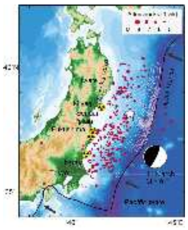
About 60,000 casualties
(original population 260,000)

Prof. Iemura, Kyoto Univ.

7

The 2011 Tohoku earthquake and tsunami

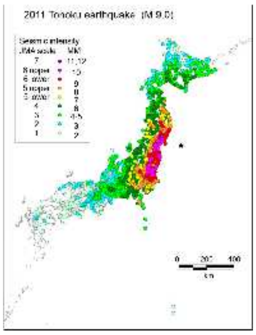
Sanriku coast
High tsunami
~ 30 min after the quake

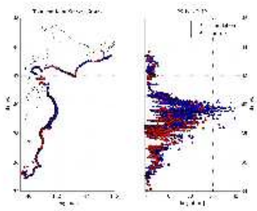


Sendai plain
Large inundation
~ 1 hour after eq.

Mainichi Newspaper 8

The largest earthquake in Japan's history





The 2011 Tohoku Earthquake Tsunami Joint Survey Group

The earthquake (by Japan Meteorological Agency)
"Off the Pacific Coast of Tohoku Earthquake"
"the 2011 Tohoku Earthquake"

The disaster by Cabinet Office
"The Great East Japan Earthquake Disaster"

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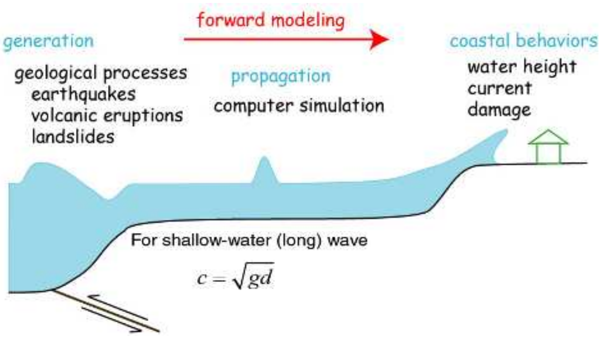
Tsunamis with > 100 fatalities in last two decades

Date	Region	Eq. M	Max hgt, m	Fatalities
2011/3/11	Tohoku, Japan	9.0	39	15,854
2010/10/25	Mentawai, Indonesia	7.8	7	431
2010/2/27	Maule, Chile	8.8	29	156
2009/9/29	Samoa	8.0	22	192
2006/7/17	Java, Indonesia	7.7	21	802
2004/12/26	Sumatra, Indonesia	9.1	51	226,898
1999/8/17	Kocaeli, Turkey	7.6	3	155
1998/7/17	Papua New Guinea	7.0	15	2,205
1996/2/17	Irian Jaya, Indonesia	8.2	8	110
1994/6/2	Java, Indonesia	7.8	14	250
1993/7/12	Hokkaido, Japan	7.7	54	208
1992/12/12	Flores, Indonesia	7.8	26	1,169
1992/9/2	Nicaragua	7.7	10	170

NOAA/NGDB 10

Tsunami Generation and Propagation



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Outline

1. The 2004 Indian Ocean and 2011 Tohoku tsunamis
2. Tsunami generation by earthquakes
3. Tsunami propagation and computer simulation
4. Tsunami observation (instrumental, historical, geological)
5. Tsunami hazard maps

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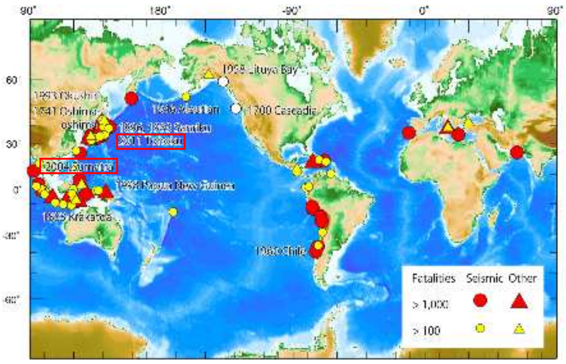
Tsunami Examples



NOAA/NGDC Tsunami Event Catalog

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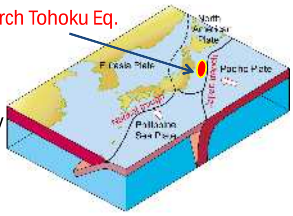
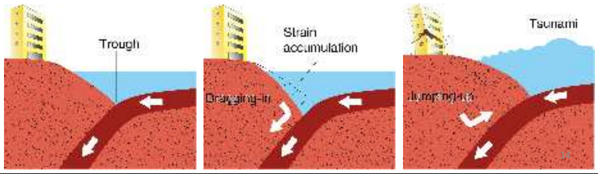
The 2011 Tohoku Earthquake

11 March Tohoku Eq.

- Interplate earthquake due to subduction of Pacific plate at 8 cm /year or 8 m / century
- Largest size (M=9.0) in Japan's history

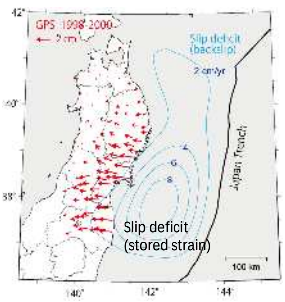




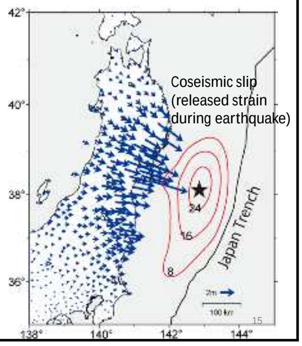
GPS data and slip distribution

About 1,300 GPS stations monitor the movement of Japan

Westward motion in 1998-2000



Eastward rebound on March 11



GSI (2010, 2011)

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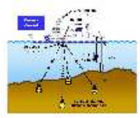
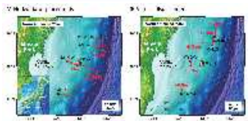
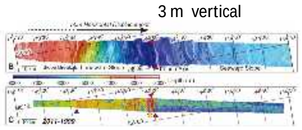
Seafloor displacement



Sato et al. (Science 2011)

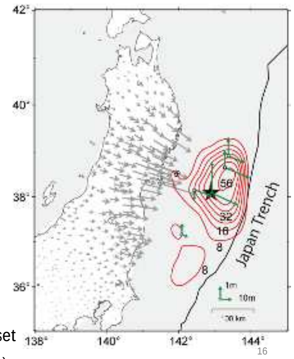


Max observed slip: 24 m horizontal
3 m vertical



Repeated bathymetry sounding: ~ 50 m offset

Max slip on fault (estimated): > 50 m



Fujiwara et al. (Science 2011)

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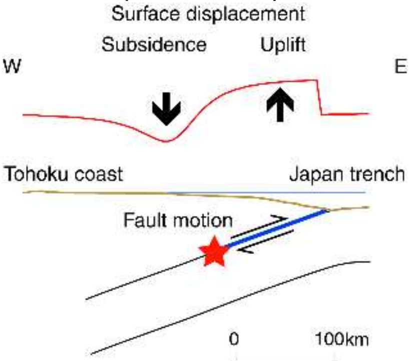
Seafloor displacement (cross-section)



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Earthquake Size

Surface Wave Magnitude

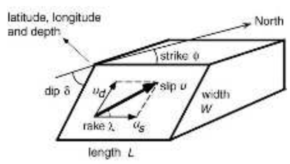
$$M_s = \log_{10}\frac{A}{T} + 1.66\log_{10}\Delta + 3.5$$

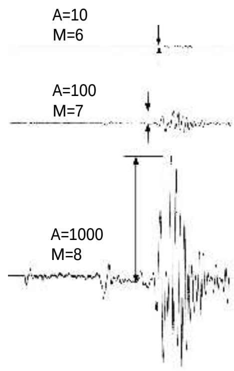
Moment Magnitude

$$M_W = (\log_{10} M_0 - 9.1)/1.5$$

Seismic moment $M_0 = \mu\, u\; L\; W$

μ : rigidity (elastic constant)





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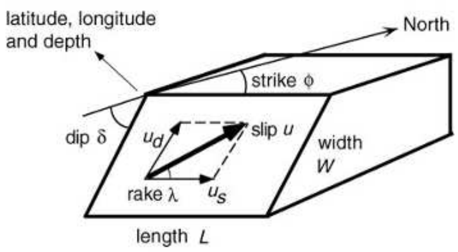
Fault Parameters



Seismic moment Mo = $\mu\, u\, L\, W$

μ : rigidity (elastic constant)

Moment magnitude Mw = (log Mo - 9.1) / 1.5

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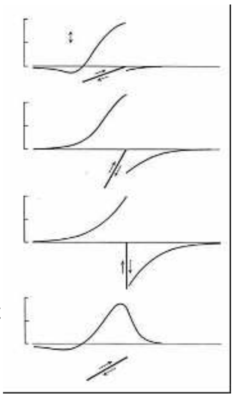
Vertical Deformation due to Reverse Fault



dip-slip fault δ=30 ° — Large uplift above fault plane Small subsidence in the left (hanging wall) side

δ=60 ° — Large uplift above fault plane Small subsidence in the right (foot wall) side

δ=90 ° — Uplift = Subsidence

buried fault δ=30 ° — No discontinuity

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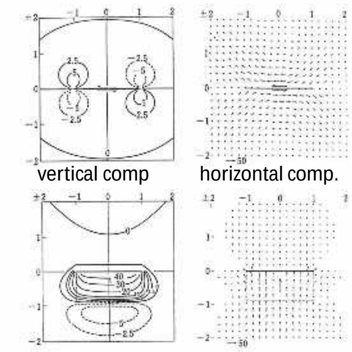
Crustal Deformation due to Faulting



strike-slip fault

vertical comp — horizontal comp.

dip-slip fault δ=30°

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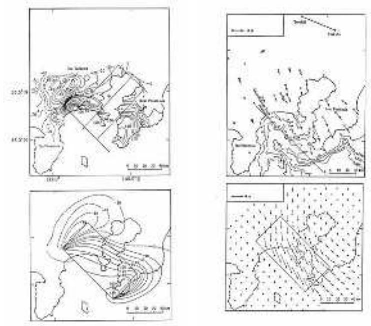
Crustal Deformation for the 1923 Kanto eq.

vertical comp — horizontal comp.

obs. data

model



Kanamori and Ando (1973)

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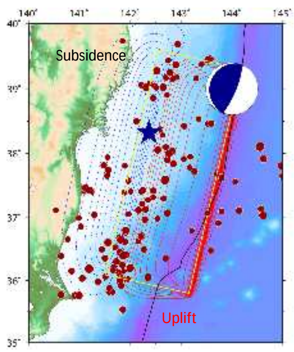
Seafloor deformation



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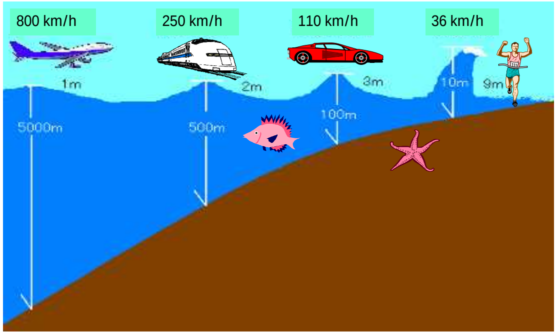
Tsunami Speed is Faster in Deeper Ocean



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Tsunami is a Gravity Wave

Phase velocity of gravity wave is

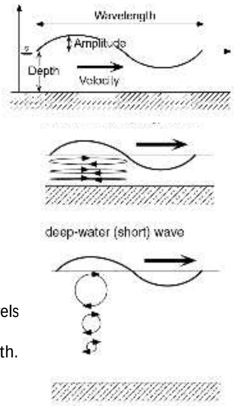
$$c = \left(\frac{g}{k}\tanh kd\right)^{\frac{1}{2}} = \left(\frac{g\lambda}{2\pi}\tanh\frac{2\pi d}{\lambda}\right)^{\frac{1}{2}}$$

(1) When λ/ 2π >> d (wavelength>> depth)
tanh x ~ x, so $c = \sqrt{gd}$

The velocity depends only on depth.
The particle motion is basically horizontal.
This is called shallow water-wave.

(2) When λ/ 2π ~ 2 d (wavelength ~ depth)
tanh x ~ 1, so $c = \sqrt{\frac{g}{k}} = \sqrt{\frac{g\lambda}{2\pi}}$

The velocity shows dispersion (longer wave travels faster than shorter wave).
Particle motion is circular, and decays with depth.
This is called deep-water wave.



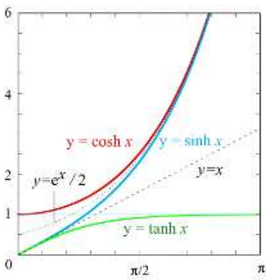
Hyperbolic Functions

$$\sinh x = \frac{e^x - e^{-x}}{2}$$

$$\cosh x = \frac{e^x + e^{-x}}{2}$$

$$\tanh x = \frac{\sinh x}{\cosh x} = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$

	$x \to 0$	$x \to \pi$
sinh x	x	$e^x/2$
cosh x	1	$e^x/2$
tanh x	x	1



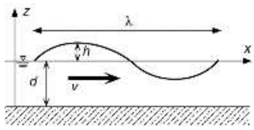
Tsunami is a Shallow Water Wave

For tsunami,

λ ~ 100 km (seafloor deformation)
d ~ 5 km (Pacific Ocean)
Because λ >> d, tsunami can be treated as shallow-water (long) wave

The velocity: $c = \sqrt{gd}$

g: gravitational acceleration
d: water depth



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Tsunami is a Shallow Water Wave

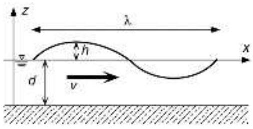
Long-wave (λ >> d)

Eq. of motion (momentum conservation

$$\frac{\partial V}{\partial t} + (V \bullet \nabla)V = -g\nabla h - C_f \frac{\mathbf{V}|\mathbf{V}|}{d+h}$$

Eq. of continuity (mass conservation)

$$\frac{\partial (d+h)}{\partial t} = -\nabla \bullet \{(d+h)\}\mathbf{V}$$



Linear Long-wave (λ >> d. h<<d, no bottom friction))

Eq. of motion

$$\frac{\partial V}{\partial t} = -g\nabla h$$

Eq. of continuity

$$\frac{\partial h}{\partial t} = -\nabla \bullet \{dV\}$$

Wave eq. $\frac{\partial^2 h}{\partial t^2} = gd\nabla^2 h$

Wave velocity $c = \sqrt{gd}$

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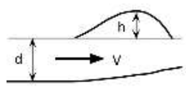
Finite-difference Computation



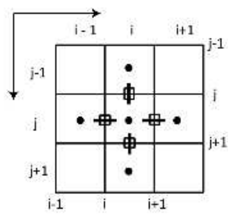
eq. of motion

$$\frac{\partial V_x}{\partial t} = -g\frac{\partial h}{\partial x}$$

$$\frac{V_y}{\partial t} = -g\frac{\partial h}{\partial y}$$

eq. of continuity

$$\frac{\partial h}{\partial t} = -d\left(\frac{\partial V_x}{\partial x} + \frac{\partial V_y}{\partial y}\right)$$



● water height (h)
□ water depth (d)
━ velocity (V_x)
┃ velocity (V_y)

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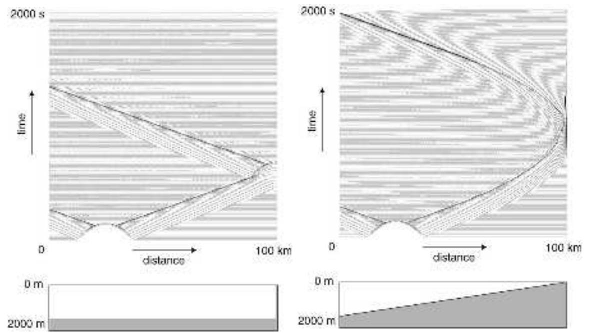
Tsunamis in Uniform and Sloping Seafloor



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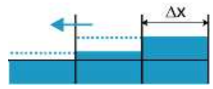
Finite Difference Computation

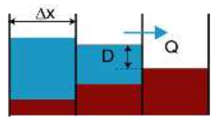
Boundary Conditions

Offshore Boundary
Transmission



Land Boundary
No inundation
velocity (flux) = 0

Inundation
Moving boundary
Flux
Total depth
Weir formula



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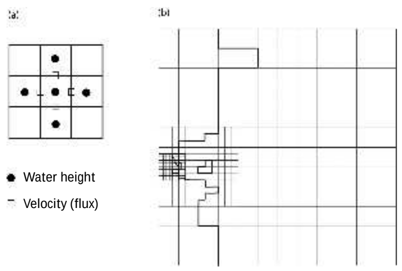
Topography/Bathymetry data

Offshore: coarse grid (a few km)

Near coast: fine grid (a few to a few tens of m)



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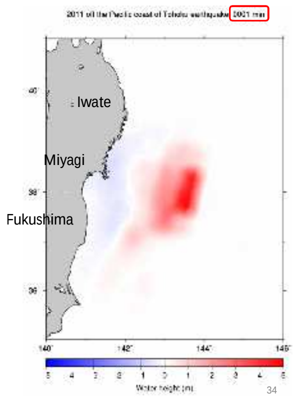
March 11, 2011 tsunami

Sanriku coast
High tsunami
~ 30 min after the quake

Sendai plain
Large inundation
~ 1 hour after eq.



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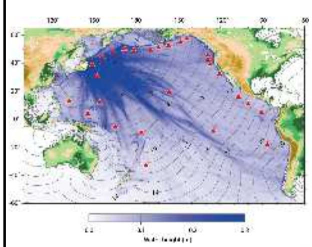
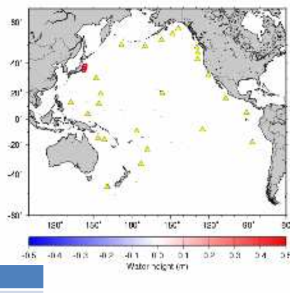
Effects to other countries





Area	time	heights	damage
Hawaii	7 hrs	5 m	$ 8 million
California	12 hrs	3 m	1 death, $20 million
Chile	22 hrs	3 m	$ 4 million
Indonesia	6 hrs		1 death

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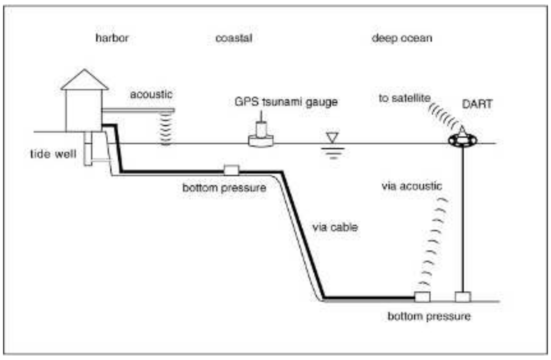
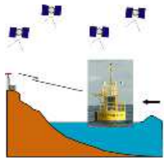
Tsunami Observation Systems



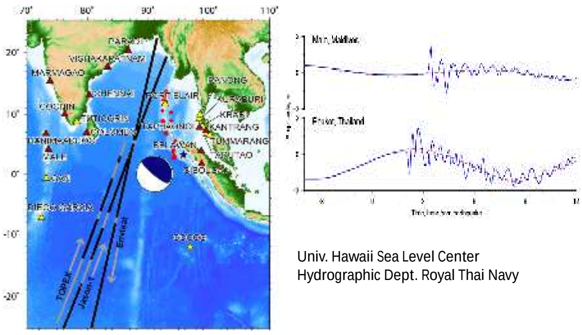
Tsunami Observation Systems

Coastal tide gauge GPS tsunami gauge DART buoys (NOAA)



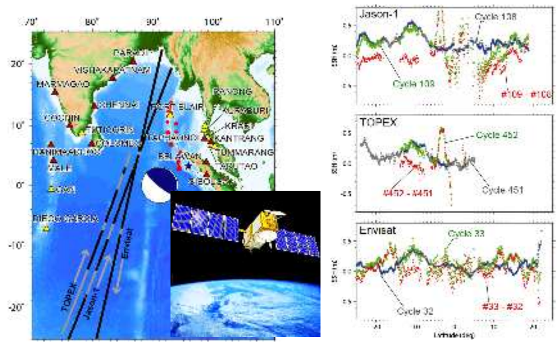
Bottom Pressure Gauges
on submarine cables

Tide Gauge Data

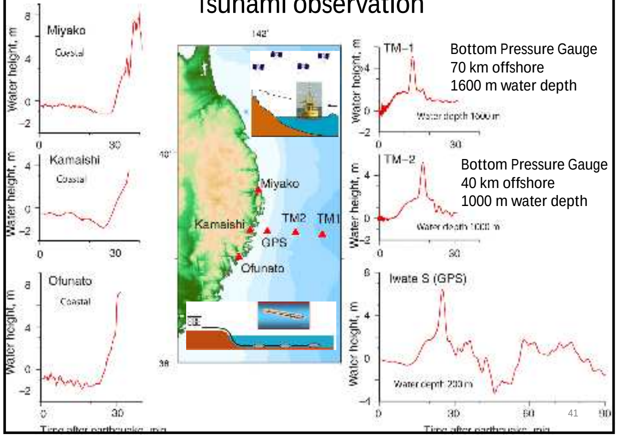


Univ. Hawaii Sea Level Center
Hydrographic Dept. Royal Thai Navy

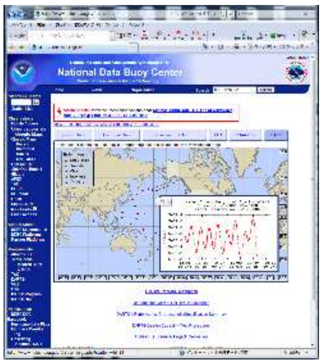
Satellite Altimetry Data



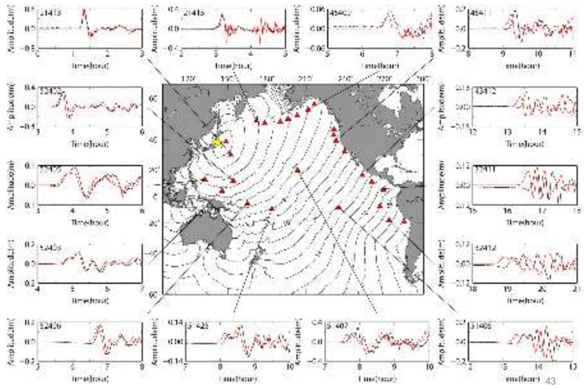
Tsunami observation



DART buoys (NOAA)



The 2011 Tohoku tsunami



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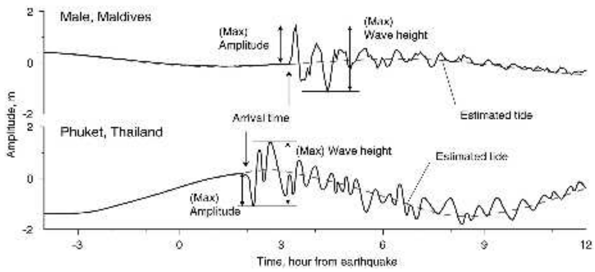
Amplitude and Wave Heights



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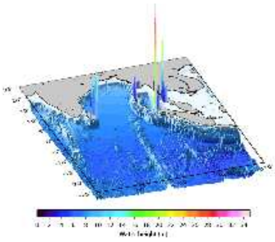
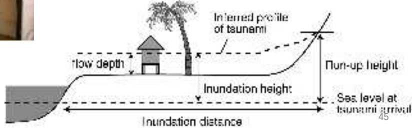
Survey of Tsunami Heights





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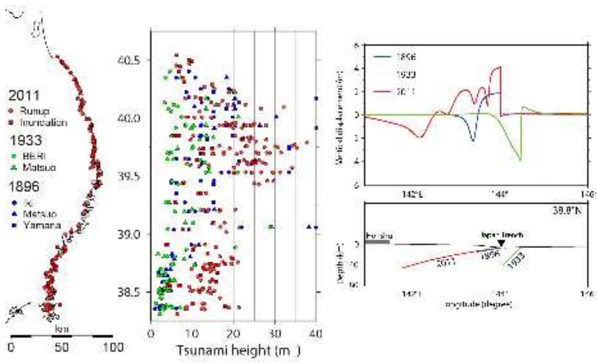
Past Tsunami Heights along Sanriku coast



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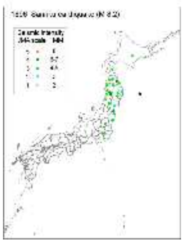
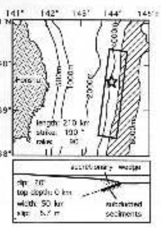
The 1896 Meiji Sanriku tsunami

1896 Meiji tsunami: 22,000 casualties (more than 2011 tsunami)





M 7.2, Max tsunami height 38 m
Weak shaking but large tsunami
"Tsunami earthquake"

Width: 50 km, slip: 10 m
Near trench axis

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AD 869 Jogan Earthquake

Nihon Sandai Jitsuroku (Chronicle of Japan)
- A large earthquake in Mutsu
- People, panic stricken by violent tremblings, lying on the ground
- Fallen houses, wide-opened ground fissured
- Roaring like thunder heard from the sea
- The sea rushed into the castle, a few hundred miles
- About 1,000 people were killed

Tsunami deposit studies
- Sand layer brought by tsunami below volcanic ash (AD915)
- distributed ~ 3 km from the coast

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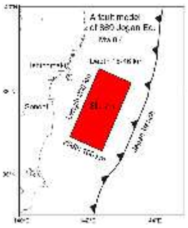
The 869 Jogan Earthquake

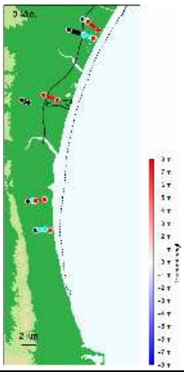
A fault model



Satake et al. (2008)
Namegaya et al. (2010)

- The 869 deposits
- Possible 869 deposits
- No deposits

869 Simulation



2011 inundation

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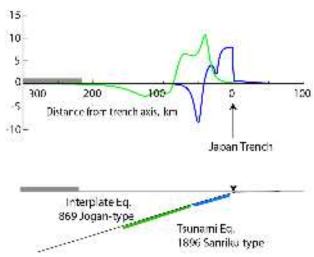
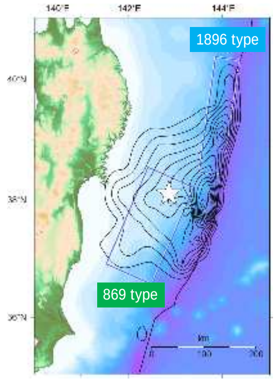
Deep and Shallow Subfaults





Ver. 8.0

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Past Tsunami in Taro, Miyako city

1896 Meiji tsunami: 1867 deaths (out of 2248 residents, or 83%)

1933 Showa tsunami: 972 deaths (out of 4945, or 20%)

Before and after the 1933 tsunami

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Past Tsunami in Taro, Miyako city

1896 Meiji tsunami: 1867 deaths (out of 2248 residents, or 83%)

1933 Showa tsunami: 972 deaths (out of 4945, or 20%)

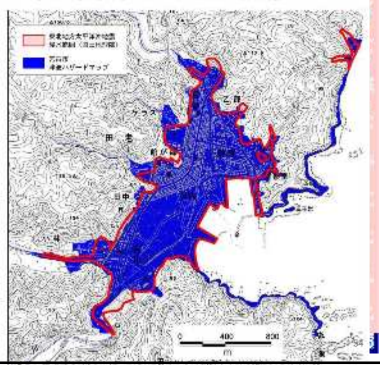
2011 Tohoku-oki tsunami: 230 casualties (out of 4000, or 6%)

10m high 2.5 km long breakwater around Town

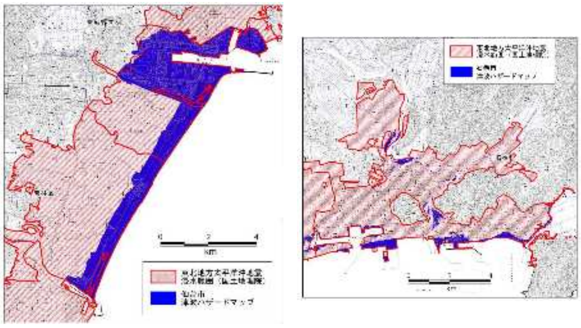
53

Tsunami hazard map (Iwate Pref. Miyako city, Taro)

Actual inundation area in 2011

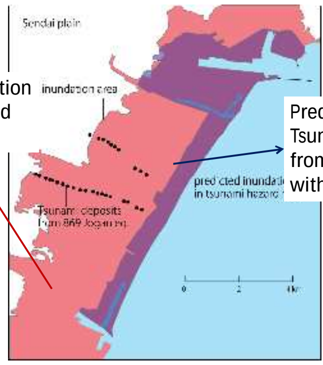


Tsunami Hazard Maps (Sendai and Ishinomaki)



Central Disaster Management Council

The 869 Jogan earthquake



Conclusions

1. The 2004 Indian Ocean and 2011 Tohoku tsunamis caused devastating damage.
2. Sources of earthquake-generated tsunamis can be modelled as seafloor deformation due to faulting.
3. Tsunami propagation can be modelled by shallow-water (long-wave) equation, and the velocity is determined by water depth. Computer simulation on actual bathymetry is a standard method.
4. Tsunami observation system includes instrumental (sea level measurements, bottom pressure gauges, satellite altimeter) as well as historical and geological data.
5. Tsunami hazard maps need to consider infrequent large earthquake source.

November 25, 2015

Activities of the IOC Tsunami Program in the Pacific Region

Tomoaki OZAKI
Senior coordinator for International Earthquake and Tsunami Information
Department of Seismology & Volcanology
Japan Meteorological Agency

1

Outline

- International tsunami warning and mitigation system under the UNESCO-IOC
- International Tsunami Service Providers - Pacific Tsunami Warning Center (PTWC) and Northwest Pacific Tsunami Advisory Center (NWPTAC)

2

Outline

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3

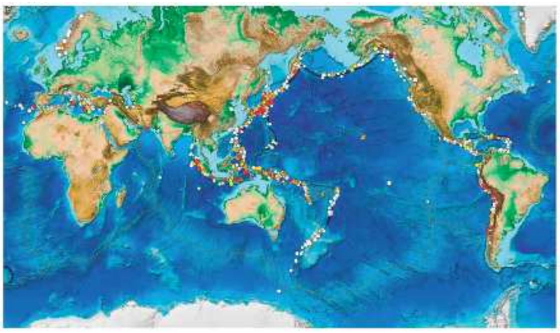
International tsunami warning and mitigation system is implemented under the coordination of the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO).

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

4

Global Tsunami Source Locations



Confirmed tsunami source locations from 1610 B.C. to A.D.2014.
(from Pacific Tsunami Warning System – A Half-Century of Protecting the Pacific 1965-2015, by PTWS)

5

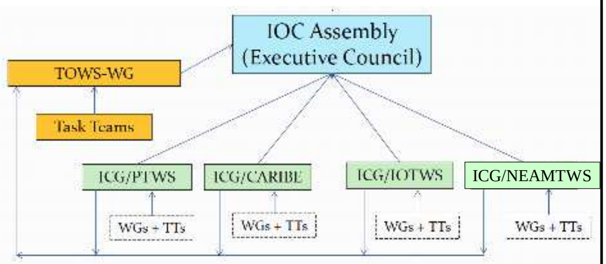
History of Pacific tsunami warning system

Year	Events	Tsunami warning system
1946	Aleutian Islands tsunami	
1948		U.S. established Seismic Sea Wave Warning System (SSWWS).
1949		JMA started a nationwide tsunami warning service.
1952	Kamchatka tsunami	USSR established Sakhalin and Kamchatka Tsunami Warning Centers.
1960	Chile tsunami	
1964	Alaska tsunami	
1965		ICG/ITSU and ITIC were established under IOC/UNESCO.
2004	Indian Ocean tsunami	
2005		ICG/ITSU was renamed to ICG/PTWS .
2010	Chile tsunami	
2011	Japan tsunami	

ICG/ITSU: Intergovernmental Coordination Group for the Tsunami Warning System in the Pacific
ITIC: International Tsunami Information Center
IOC/UNESCO: Intergovernmental Oceanographic Commission of UNESCO
ICG/PTWS: Intergovernmental Coordination Group of the Pacific Tsunami Warning and Mitigation System

6

International Tsunami Warning and Mitigation Systems

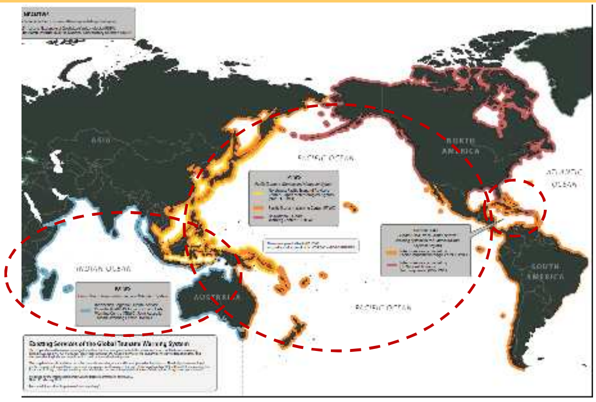


from UNESCO/IOC TOWS-WG Report, 26th ICG/PTWS

TOWS-WS: Working Group on Tsunamis and Other Hazards Related to Sea-Level Warning and Mitigation Systems
ICG/PTWS: Intergovernmental Coordination Group of the Pacific Tsunami Warning and Mitigation System
ICG/CARIBE: Intergovernmental Coordination Group for the Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions
ICG/IOTWS: Intergovernmental Coordination Group of the Indian Ocean Tsunami Warning and Mitigation System
ICG/NEAMTWS: Intergovernmental Coordination Group of the Tsunami Early Warning and Mitigation System in the North-Eastern Atlantic, the Mediterranean and Connected Seas

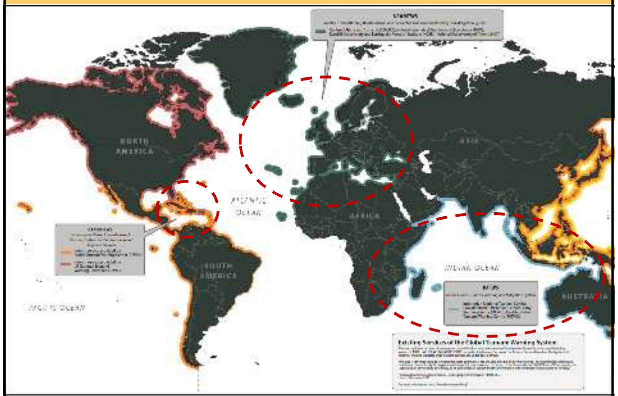
7

Global Tsunami Warning System (1)



8

Global Tsunami Warning System (2)



9

Current and proposed Tsunami Advisory Centers

Pacific:
Pacfic (US), North West Pacific (Japan), South China Sea (China), Central America (Nicaragua)

Indian Ocean:
Australia, India, Indonesia

North-Eastern Atlantic, the Mediterranean and Connected Seas:
France, Greece, Italy, Portugal, Turkey

Caribbean and Adjacent Regions:
Currently no specific center.
(PTWC and NTWC issues advisories instead.)

10

Tsunami Information Centers

Definition:
Centres that provide education, outreach, technical and capacity building assistance to Member States and the public in preventing, preparing, and mitigating measures for tsunamis. Among other activities, the centres manage post event performance surveys, serve as a resource for the development, publication, and distribution of tsunami education and preparedness materials and information on tsunami occurrences, and may support risk assessment and mitigation activities. A Tsunami Information Center has been established in each of the regional tsunami warning systems within the ICG framework.

Pacific:
ITIC (Hawaii, US)
Indian Ocean:
IOTIC (Jakarta, Indonesia)
North-Eastern Atlantic, the Mediterranean and Connected Seas :
NEAMTIC (Paris, France)
Caribbean and Adjacent Regions:
CTIC (Barbados)

11

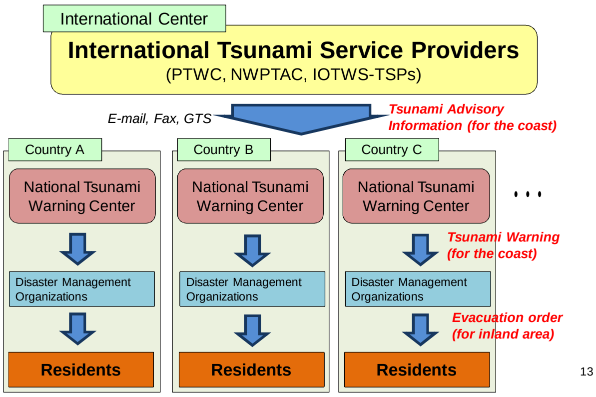
PTWS Member States

PTWS MEMBER STATES: 46
Australia, Brunei Darusalaam, Cambodia, Canada, Chile, China, Colombia, Cook Islands, Costa Rica, Democratic Republic of Korea, Ecuador, El Salvador, Fiji, France, Guatemala, Honduras, Indonesia, Japan, Kiribati, Malaysia, Marshall Islands, Mexico, Micronesia, Nauru, New Zealand, Nicaragua, Niue, Palau, Panama, Papua New Guinea, Peru, Philippines, Republic of Korea, Russian Federation, Samoa, Singapore, Solomon Islands, Thailand, Timor-Leste, Tokelau, Tonga, Tuvalu, United Kingdom, United States of America, Vanuatu, Vietnam

PTWS meeting is held every two years.

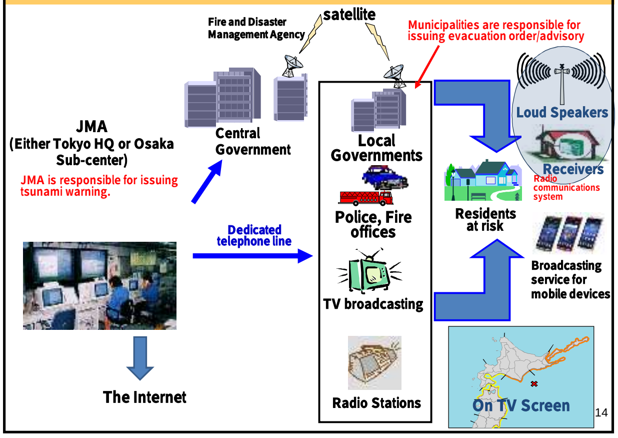
12

Tsunami information flow (Example)



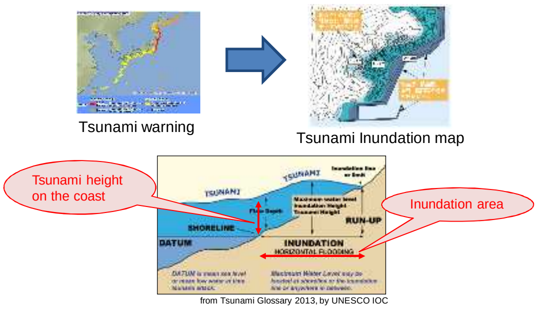
13

Tsunami Warning and Evacuation Order/Recommendation (Japan's case)



14

Tsunami warning and Tsunami inundation map



from Tsunami Glossary 2013, by UNESCO IOC

- Tsunami warning is issued based on coastal tsunami height prediction.
- Linkage of tsunami warning and inundation mapping is important for effective evacuation order/recommendation, tsunami disaster management planning, etc.

15

PTWS Governance

- ICG/PTWS meeting is held every two years. Last meeting, 26th Session of ICG/PTWS, was held in Honolulu, Hawaii, U.S. from 22 to 24 April 2015, just before the International Tsunami Symposium to commemorate the 50th Anniversary of the PTWS.
- Three Technical Working Groups
  - Tsunami Hazard Assessment
  - Tsunami Detection, Warning and Dissemination
  - Disaster Management, Preparedness and Risk Reduction
- Regional Working Groups
  - Central American Pacific Coast
  - South East Pacific Region
  - South West Pacific Region
  - South China Sea Region

16

WG1: Tsunami Hazard Assessment

1. Work toward developing standards for tsunami hazard assessment model products and methodology to ensure model products interoperability and consistency for use in hazard assessment and forecast application.

2. Work with IUGG and other scientific bodies to review and report on existing methods for tsunami hazard assessments. Develop recommendations for IUGG and other scientific bodies on science gaps in hazard assessment capability.

3. Explore procedures for use of coastal inundation models, including appropriate requirements for bathymetry.

4. Liaise with Working Groups from the other ocean basins, as well as other working groups within ICG/PTWS to coordinate and ensure use of data and new model forecast products for improvements and new development of hazard assessment and tsunami forecast models.

17

WG2: Tsunami Detection, Warning and Dissemination

1. Develop, coordinate and enhance operational implementation of interoperable tsunami threat information products and services.

2. Undertake studies to determine warning requirements for seismic and sea level data.

3. Monitor and report on the performance of key observational, warning and communication system components.

4. Contribute to the conduct of regular exercises and communication tests of the PTWS.

5. Identify areas of priority for action following assessments, communications tests, exercises and real tsunami events.

6. Develop and maintain relevant documentation, such as the PTWS Users Guide.

7. Provide advice to the International Tsunami Information Centre (ITIC) on educational materials about the warning systems and services.

8. Help strengthen the capacity and capability of Member States.

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WG3: Disaster Management, Preparedness and Risk Reduction

1. Facilitate in collaboration with TOWS Task Team on Disaster Management and Preparedness and organizations such as UNISDR, the exchange of experiences and information on risk reduction and preparedness actions, and matters related to disaster management;

2. Promote preparedness in coastal communities through education and awareness products and campaigns;

3. Facilitate SOP training across regions to strengthen emergency response capabilities of Member States and their Disaster Management Offices;

4. Develop and promote best practice preparedness material, programs and assessment Tools;

5. Develop and promote best practice tsunami risk reduction material, programs and assessment tools;

6. Support the ITIC of the ICG

19

Sendai Framework for Disaster Risk Reduction 2015-2030

Third UN World Conference on Disaster Risk Reduction, 14-18 March 2015, Sendai, Japan

Seven global targets

a. Substantially reduce global disaster mortality by 2030, aiming to lower average per 100,000 global mortality between 2020-2030 compared to 2005-2015.
b. Substantially reduce the number of affected people globally by 2030, aiming to lower the average global figure per 100,000 between 2020-2030 compared to 2005-2015.
c. Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030.
d. Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030.
e. Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020.
f. Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this framework by 2030.
g. **Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.**

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Outline

- International tsunami warning and mitigation system under the UNESCO-IOC

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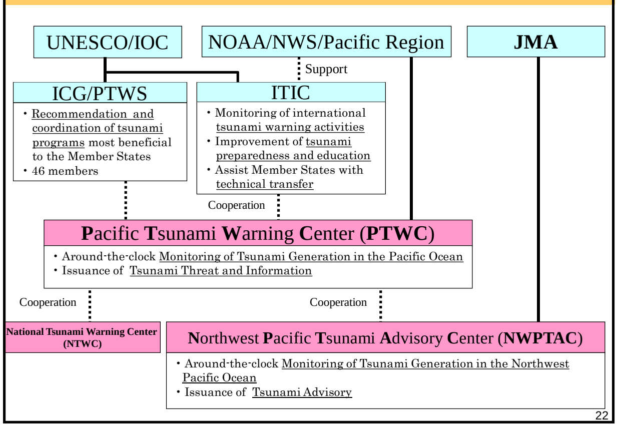
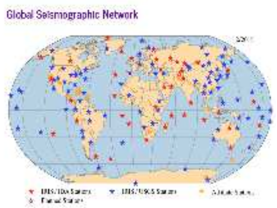
Organizations of Pacific Tsunami Warning System



22

Global seismic data network

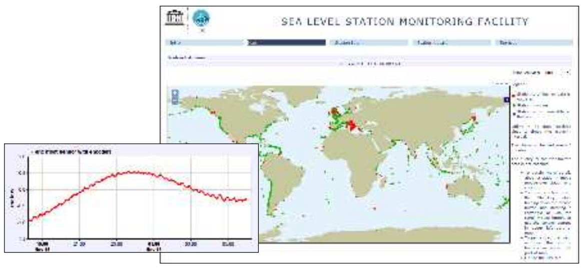


https://www.iris.edu/hq/programs/gsn

- The Global Seismographic Network (GSN) is a 150+ stations, globally distributed, state-of-the-art digital seismic network.
- The GSN provides free, realtime and open access data through the Data Management Center of Incorporated Research Institutions for Seismology (IRIS DMC) .
- GSN data is used for international tsunami warning center to monitor global seismic activities.

23

Global sea level data

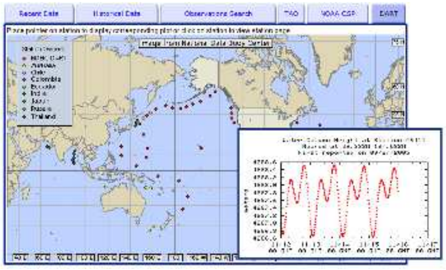


http://www.ioc-sealevelmonitoring.org/map.php

- Sea level monitoring data is exchanged under the framework of UNESCO/IOC.
- Global Telecommunication System (GTS) of the World Meteorological Organization (WMO) is effectively used for this exchange.

24

Offshore tsunami buoy data



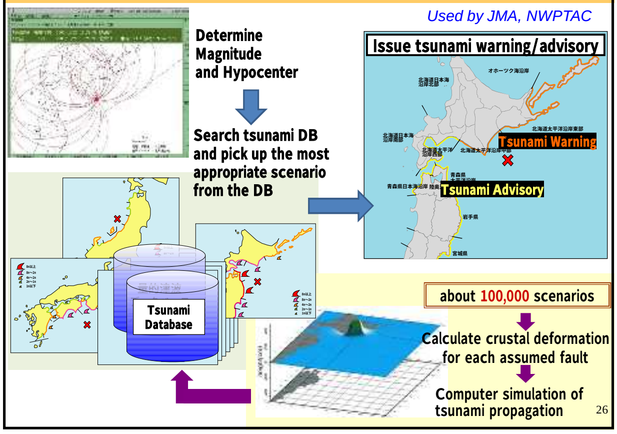
http://www.ndbc.noaa.gov/dart.shtml

Offshore tsunami buoy data deployed on the ocean is summarized on the website of National Data Buoy Center of the National Oceanic and Atmospheric Administration (NOAA).

25

Methods of tsunami forecasting - tsunami simulation DB

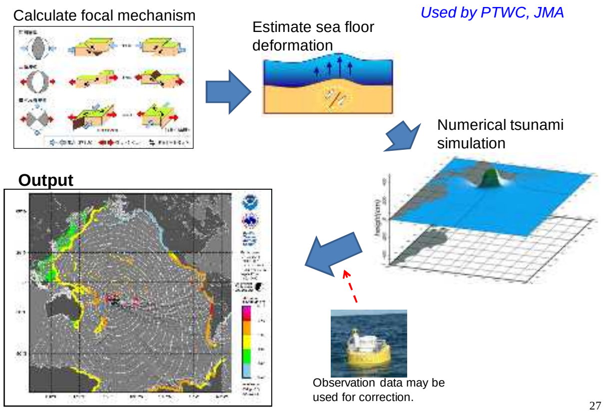
Used by JMA, NWPTAC



26

Methods of tsunami forecasting – Real time tsunami simulation

Used by PTWC, JMA



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PTWC Enhanced Tsunami Products

Background:

With an increase in seismic and tidal data availability and quality and better numerical models, it becomes possible to provide more accurate forecasts of tsunami impacts in real time.

PTWC new Enhanced Products:

- PTWC new Enhanced Tsunami Products has been implemented from 1 October 2014, fully replacing the former products.
- New products consists of text and graphic products, and are based on numerical tsunami forecast models.

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PTWC Website

PTWC text products are available at the PTWC website.
http://ptwc.weather.gov/

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Timeline for PTWC new product issuance

0 min. Earthquake occurs in the Pacific region

10min. Initial text products are issued according to the following general procedure. (Text only)
If the earthquake is shallow (< 100km depth) and undersea,

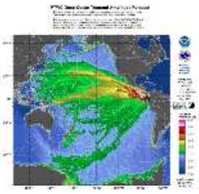
6.5 =< M =< 7.0	"Tsunami Information Statement", no tsunami
7.1 =< M =< 7.5	"Tsunami Threat Message", a possible tsunami threat to coasts located within 300km of the epicenter
7.6 =< M =< 7.8	"Tsunami Threat Message", a possible tsunami threat to coasts located within 1000km of the epicenter
7.9 =< M	"Tsunami Threat Message", a possible tsunami threat to coasts within 3 hours tsunami travel time

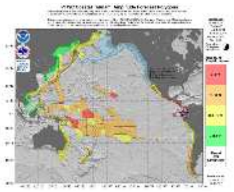
20min. If the earthquake parameters (M, location, depth) change significantly, the appropriate supplemental text product will be issued.

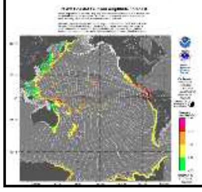
40min. After the forecast model run using earthquake's faulting mechanism, for events with forecast coastal amplitudes greater than 0.3m, text product of "Tsunami Threat Message" is issued along with graphic products.

30

PTWC Enhanced Tsunami Products (Graphic Products)



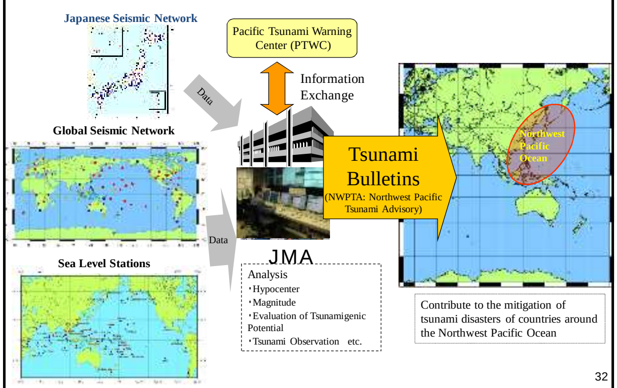




- Graphic products are disseminated only to Tsunami Warning Focal Points for use by National Tsunami Warning Centers in order to minimize potential confusion and misinterpretation by the public.
- Details for PTWC Enhanced Tsunami Products are available on the following website;
http://itic.ioc-unesco.org/index.php?option=com_content&view=category&id=2143&Itemid=2582

31

NWPTAC (North West Pacfict Tsunami Advisory Center)



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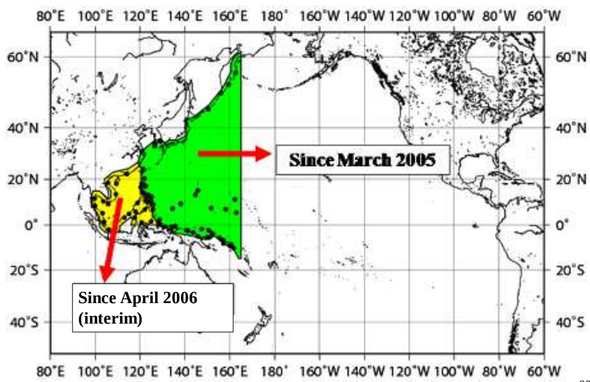
Area of Service of NWPTAC



33

History of NWPTAC

1993 Republic of Korea proposed at ICG/ITSU-XIV that Northwest Pacific regional tsunami warning center could be assumed by JMA.

1999 ICG/ITSU-XVII accepted the JMA's proposal to establish a regional tsunami warning center for the Northwest Pacific at JMA.

2003 JMA submitted a report at ICG/ITSU-XIX to demonstrate its readiness for the operation of the center.

2004 IOC/EC-XXXVII adopted a resolution to start the services of the regional center at JMA by March 2005.

2005 JMA initiated the operation of NWPTAC.

2006 JMA started the interim service for the South China Sea region.

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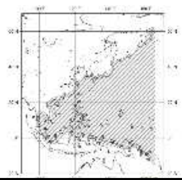
Geographical coverage, timing and criteria for NWPTA issuance

(1) The Northwest Pacific Tsunami Advisory (NWPTA) is issued when the NWPTAC detects occurrence of an earthquake of magnitude 6.5 or greater in its coverage area (see the bottom figure), which includes the northwestern and a portion of the southwestern Pacific and, on an interim basis, the South China Sea regions.

(2) When the NWPTAC receives reports of tsunami observations, the tsunami observational data is presented in the subsequent NWPTA messages as necessary.

(3) When the location and magnitude of the earthquake are re-estimated using seismic data subsequently obtained and/or an unexpectedly significant tsunami is observed, further NWPTA is issued to revise the previous advisory.



35

NWPTA contents (1)

NWPTA contains:

(1) Earthquake information
(2) Tsunami-genic potential of the earthquake
(3) Estimated tsunami arrival times and heights
(4) Observed tsunami arrival times and heights

Date and time: Universal Time Coordinated (UTC)

Expected tsunami arrival times and heights are estimated by pre-calculated simulation database.

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NWPTA contents (2)

Earthquake Information

- Origin time
- Epicenter (latitude and longitude)
- Name of geographical area
- Depth (only for the earthquake at a depth of 100 km or deeper)
- Magnitude

Earthquake parameters in NWPTA and PTWC bulletin are coordinated to harmonize with each other.

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NWPTA contents (3)

Tsunami-genic Potential

Tsunami-genic potential is evaluated according to the magnitude of the earthquake.

$M > 7.8$	Possibility of a destructive ocean-wide tsunami
$7.8 \geq M > 7.5$	Possibility of a destructive regional tsunami within 1,000 km of the epicenter
$7.5 \geq M > 7.0$	Possibility of a destructive local tsunami within 100 km of the epicenter
$7.0 \geq M \geq 6.5$	Very small possibility of a destructive local tsunami

No tsunami-genic potential is applied for earthquakes occurring in inland areas far enough from the coast, or at a depth of 100 km or deeper.

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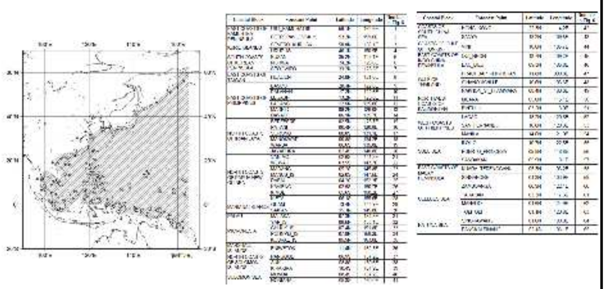
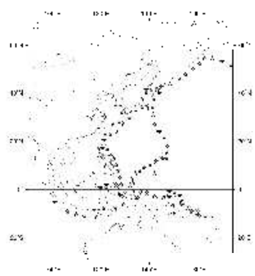
Forecast Points and Coastal Blocks



39

Tsunami Simulation Database for NWPTAC



Assumed Fault Points

Assumed faults points: As shown in the left figure

Magnitude: 7.0, 7.5, 8.0, 8.5

Depth: 0km, 20km, 40km, 60km, 80km, 100km

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NWPTA Sample Message

```
WEPA40 RJTD 191353
TSUNAMI BULLETIN NUMBER 001
   ISSUED BY NWPTAC(JMA)
   ISSUED AT 1353Z 19 APR 2014
HYPOCENTRAL PARAMETERS
ORIGIN TIME:1328Z 19 APR 2014
PRELIMINARY EPICENTER:LAT06.7SOUTH LON155.0EAST
 BOUGAINVILLE - SOLOMON ISLANDS REGION
 BISMARCK AND SOLOMON ISLANDS
MAG:7.8
BY PTWC

EVALUATION
 THERE IS A POSSIBILITY OF A DESTRUCTIVE REGIONAL TSUNAMI

THIS BULLETIN IS FOR
NORTH COASTS OF PAPUA NEW GUINEA
MICRONESIA
SOLOMON SEA

ESTIMATED TSUNAMI ARRIVAL TIME AND ESTIMATED TSUNAMI WAVE AMPLITUDE
NORTH COASTS OF PAPUA NEW GUINEA
 LOCATION              COORDINATES  ARRIVAL TIME  AMPL
 RABAUL                04.2S 152.3E 1356Z 19 APR  1M
 KAVIENG               02.5S 150.7E 1443Z 19 APR  0.5M
 KIETA                 06.1S 155.6E 1412Z 19 APR  1M
MICRONESIA
 LOCATION              COORDINATES  ARRIVAL TIME  AMPL
 POHNPEI_IS.           07.0N 158.2E 1606Z 19 APR  0.5M
 KOSRAE_IS.            05.5N 163.0E 1620Z 19 APR  1M
SOLOMON SEA
 LOCATION              COORDINATES  ARRIVAL TIME  AMPL
 MUNDA                 08.4S 157.2E 1358Z 19 APR  1M

AMPL - AMPLITUDE IN METERS FROM MIDDLE TO CREST

HOWEVER AT SOME COASTS, PARTICULARLY THOSE NEAR THE EPICENTER, HIGHER
TSUNAMIS MAY ARRIVE THAN OUR ESTIMATION AT THE NEARBY
FORECAST POINTS
AUTHORITIES SHOULD BE AWARE OF THIS POSSIBILITY.
…
```

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Plan of NWPTAC Enhanced Products (1)

First Message:

Database output based on an assumed fault (tectonic)

- Text which contains both estimated arrival time and height … basically no change to the present version

Second Message:

Real-time simulation based on a calculated fault

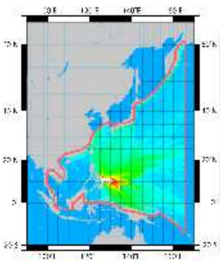
- Text (in the same format as First Message)
- Some graphics

Changeover to the Enhanced Products is planned to be in 2018.

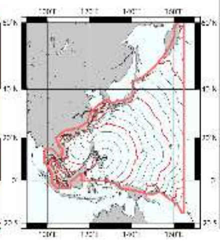
42

Plan of NWPTAC Enhanced Products (2)

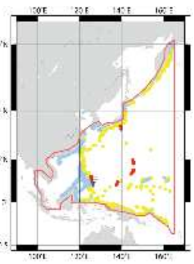
Graphic Products



Deep Ocean Tsunami Amplitude Forecast



Tsunami Travel Time Map



Coastal Tsunami Amplitude Forecast

43

Websites

UNESCO IOC Tsunami Program
http://www.ioc-tsunami.org/

Tsunami Glossary 2013
http://itic.ioc-unesco.org/index.php?option=com_content&view=article&id=1328&Itemid=1142&lang=en

Global Seismic Network
https://www.iris.edu/hq/programs/gsn

Global sea level data (IOC Sea level station monitoring facility)
http://www.ioc-sealevelmonitoring.org/station.php

Offshore tsunami buoy data (National Data Buoy Center of NOAA)
http://www.ndbc.noaa.gov/dart.shtml

PTWC
http://ptwc.weather.gov/

Details of PTWC Enhanced Tsunami Products
http://itic.ioc-unesco.org/index.php?option=com_content&view=category&id=2143&Itemid=2582

Details of NWPTAC products
http://unesdoc.unesco.org/images/0018/001800/180097e.pdf

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Thank you for your attention!

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1

Workshop on Tsunami Inundation Mapping
organized by Hydrographic and Oceanographic Department, Japan Coast Guard (JHOD)
in cooperation with the Intergovernmental Oceanographic Commission (IOC) Tsunami Program
and Port and Airport Research Institute(PARI)
in Tokyo, Japan, on 25-26 November 2015

Guideline for Development and Utilization of Tsunami Disaster Management Map

Dr. Takashi Tomita

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Lessons Learned form the 2011 Tohoku Tsunami Disaster

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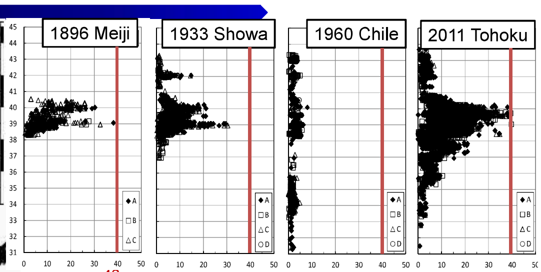
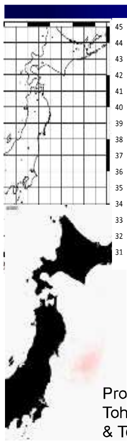
Devastating tsunamis in Tohoku region



Height of tsunami traces (m)



Propagation of the 2011 Tohoku tsunami (Takagawa & Tomita, 2012)

The 2011 Tohoku tsunami
- was higher than the historical tsunamis, and
- affected broad coasts like the 1960 Chile tsunami.

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Preparation for tsunamis in Tohoku region

The Tohoku region had repeatedly suffered tsunami disasters.

↓

People and communities had well prepared for tsunamis.

For example,
- Tsunami hazard mapping, based on the largest tsunamis at a site of interest
- Arrangement of evacuation buildings and heights
- Moving some residential areas to the places higher than tsunamis estimated
- School education on tsunamis and people's responses to them
- Support agreement in the event of a disaster between local government and private sectors
- Construction of defense structures to reduce tsunami impact

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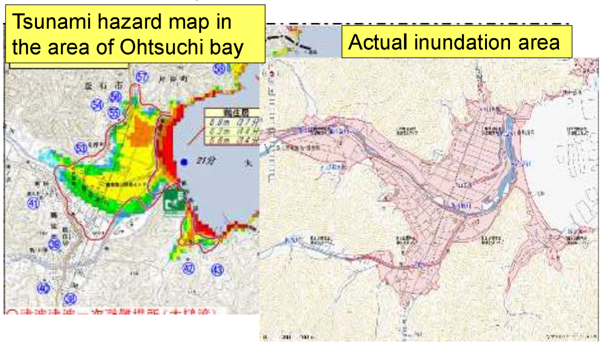
Actual inundation area wider than the estimated inundation area in a hazard map



Hazard map: Web site of Kamaishi City
http://www.city.kamaishi.iwate.jp/index.cfm/6,16801,c,html/16801/tsunami.pdf
Actual inundation area: Web site of the Association of Japanese Geographers
http://danso.env.nagoya-u.ac.jp/20110311/ecom.html

Multi-Level Estimation of Tsunamis

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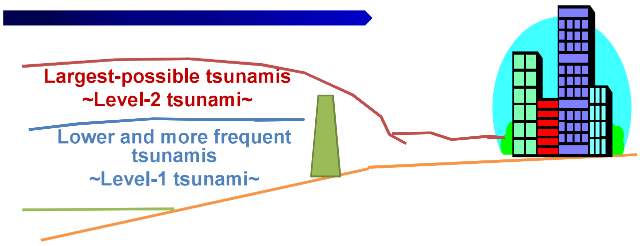

To save lives against largest-possible tsunamis

To protect individual and social property against tsunamis lower and more frequent than the largest-possible tsunamis

Multi-layered Defense System

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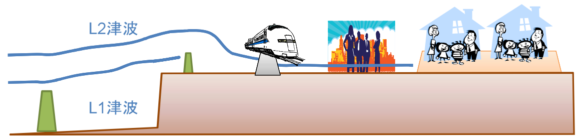
Defense infrastructures to reduce and prevent inundation by largest-possible tsunamis and lower tsunamis, respectively
Mounds of roads and railways

Evacuation support measures and land use plan to prevent loss of life



Various Damage by a Tsunami

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High tsunami caused various disasters:

- Inundation in wide areas
- Various debris: ships, boats, cars, logs, etc.
- Oil spill and fire
- Topographical change
- Destruction of infrastructures

Copyright limitation

Tsunami-induced debris

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Tsunami-induced debris

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Talcahuano in the 2010 Maule tsunami

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Port of Sendai-Shiogama

City of Miyako

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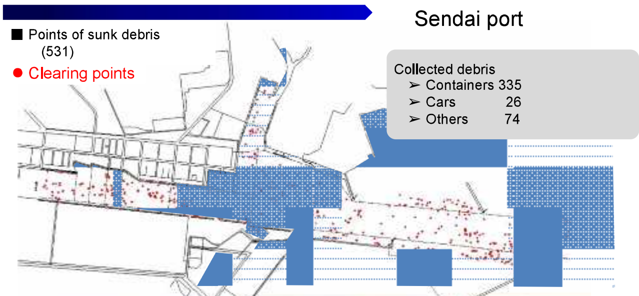
Obstacles to Navigation



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Oil Spill and Fire

Tsunami impacted oil tanks and the leakage oil from the tanks caused fire.

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Kadowaki Elementary School in Ishinomaki City

http://bbs10.fc2.com//bbs/img/_637100/637049/full/637049_1329679499.jpg

Fire incidence whose cause was probably cars

Evacuees came to the school by cars, and stopped the cars on the school ground.
The salty water came here by the tsunami, and affected car batteries to make fire.

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Topographical Change

Beautiful coastal forest was destroyed by the 15 m tsunami higher than trees in the forest, and beach and sand spit were eroded.

Rikuzen-Takada

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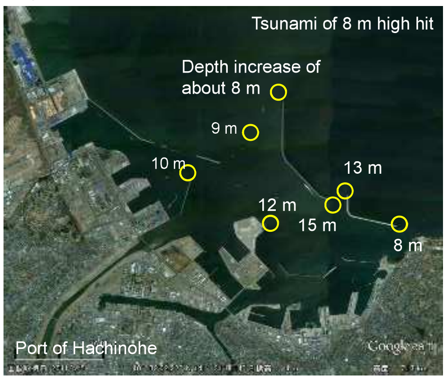
Scouring of Sea Bed

Scouring around head sections of breakwaters



Tsunami-Induced Damage in Farming Facility

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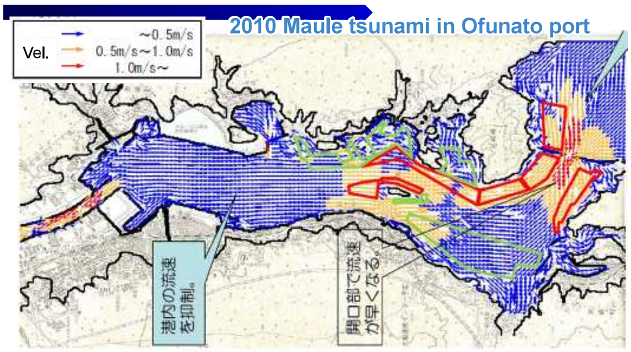

Current of 0.5 m/s or more damaged farming facilities

Damaged framing facilities

No damaged framing facilities

Mathematical Simulation of Tsunamis

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- To understand and predict the effect of a tsunami
- To evaluate the effect of a structure to reduce the impact of a tsunami, and the residual risk.

Calculation by a tsunami mathematical model (STOC)

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Measures to Mitigate Tsunami Disasters

Safe Zones for Evacuation

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Emergency height in or near a residential area

Evacuation Buildings

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1) Evacuation tower
2) Emergency height
3) Usage of an existing rigid building for emergency evac.

Guideline for Tsunami Evacuation Buildings

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- Structural requirements
  - Seismic resistant structure
  - Tsunami resistant structure
    - We need more study on tsunami impacts depending on configuration of a buildings.
    - A solution is buildings to be RC (Reinforced Concrete) or SRC (Steel Reinforced Concrete) whose evacuation floors are higher than the tsunami of the worst-case scenario estimated at each site of the buildings.
- Location requirements
  - Capacity of an evacuation building is determined by estimation of evacuee population in the cover area of the building

Various Signs to Support Evacuation

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Mitigation of Inundation

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- Cause of inundation: Intrusion of great volumes of water
- Tsunami energy is hard to be dissipated by wave-absorbing blocks, because the tsunami is very long in scale

➔ A line of structures higher than tsunamis is an essential measure to prevent inundation by them.
  - Seawall/levee (Protection wall along coasts and rivers) to prevent/reduce intrusion of water into land
  - Breakwater to reduce intrusion of water into a port and harbor

Mitigation of Inundation

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- If defense structures are destroyed by the tsunami or storm surge, inundation becomes terrible.
- ➔ Defense structures are expected
  - to be hard to break even by action of the tsunami or storm surge higher than the design one, and
  - to keep the function to reduce intrusion of water even if it is deformed.

Tsunami-Resilient Community

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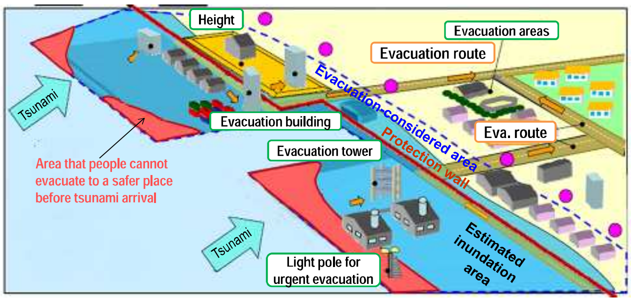
- To understand hazard &vulnerability in a target area
- To create holistic and integrated system to mitigate/prevent tsunami disasters



Guideline for tsunami evacuation measures in ports, Port and Harbour Bureau, MLIT, Japan, 2013

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Tsunami Hazard Mapping

Tsunami Hazard Mapping

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Simulation by appropriate mathematical model with bathymetric and topographic data

Tsunami hazard map

➔ First step to build a **tsunami-resilient community** through preparing holistic and integrated measures

- To identify safe zones for evacuation: Hazard map of largest-possible tsunami
- To identify a tsunami inundation risk in a target community: Collection and compilation of a number of hazard mapping

How to Estimate Tsunami Hazard

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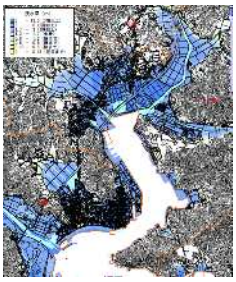
In a target area,

- To investigate historical data on tsunamis
- To calculate tsunami propagation and inundation from sources of historical tsunamis and estimated tsunamis

← Red-colored area indicates the inundated area by the largest tsunami in history

Blue-colored area indicates the inundated area by the estimated largest tsunami →



Data for Tsunami Hazard Mapping

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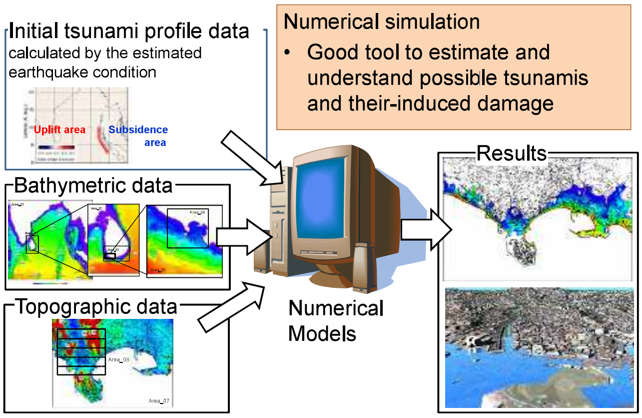
Numerical simulation

- Good tool to estimate and understand possible tsunamis and their-induced damage



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Guideline for Development and Utilization of Tsunami Disaster Management Map

Guideline

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- Tsunami Hazard Map Manual in Japan(2004)
- Guideline for Development and Utilization of Tsunami Disaster Management Map (TDMMap) (2008) was modified for developing countries
  - Including advices from experts of ASEAN countries, and Japanese technical committee including JICA.
    - To describe the contents for those who have less knowledge of tsunamis and tsunami numerical simulation to understand easily
    - To list actual examples of the utilization of disaster prevention maps in order to make it easy for those in charge of administration in developing countries to understand

Development of Hazard Map to Use Disaster Management

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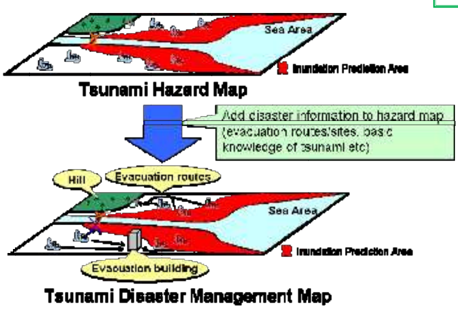
- Hazards
- Vulnerabilities
- Measures

} **Tsunami Hazard Map** } **Tsunami Disaster Management Map**



Tool to plan adequate measures to mitigate possible tsunami

Utilization of TDMMap results in achievement of disaster reduction and development of resilient community

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- In the guideline,
  - To estimate tsunami hazards, numerical simulations are recommended, because you can consider changes of topography and structure arrangement from the past to a future plan.
  - If bathymetry and topography data are not available, historical damage data helps to estimate possible tsunami disasters.
  - Depending on available data, step-by-step development of disaster estimation is also recommended.

You can download the guideline from

http://www.pari.go.jp/unit/trc/others/tdmm.html

Step-by-Step Estimation

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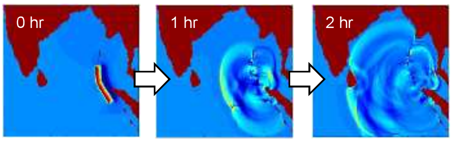
Tsunami feature	Needed data	Estimation result
Propagation in the oceans	Bathymetric data in the ocean	Tsunami height and arrival time near shore and in front of a port

Proceed to shore

The General Bathymetric Chart of the Oceans (GEBCO) provides global gridded bathymetry data with one arc-minute spacing freely through the web site (http://www.gebco.net/).
GEBCO operates under the auspices of the International Hydrographic Organization (IHO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO.



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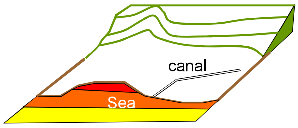
Tsunami feature	Needed data	Estimation result
Propagation and transformation in a shallow water region	Bathymetric data in the sea including near shore and a port	Accurate tsunami height and arrival time near shore and in the port

Proceed to land

Sea bottom configuration may be measured in some ports and harbors.

Tsunami heights increase dramatically in shallow water, and their distributions in ports and harbors are more complex than a plane beach.



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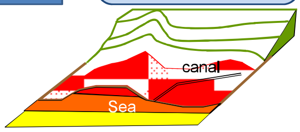
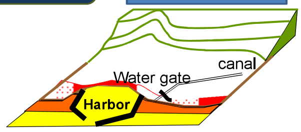
Tsunami feature	Needed data	Estimation result
Inundation and flooding on land	Topographic data	Inundation area and depth on land
Effects of structures	Structure data	Accurate Inundation area and depth, fluid velocity and defense function of structures





Users of Tsunami Disaster Management Map

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- TDMMap should be prepared corresponding to its purpose as well as intended users.
  - Different knowledge level of each user on tsunamis
- Expected users:
  - Administrative persons
  - General public including residents and non-residential works and tourists

Prime Information for Residents

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Priority measure of residents: Evacuation

- Locations of evacuation sites & routes
- Tsunami inundation areas
- Advanced information:
  - Tsunami arrival time
  - tsunami striking direction
  - inundation depth

Information for Residents

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Additional information for people resilient to tsunamis

- Basic knowledge of tsunamis
  - Effective in increasing people's self- and mutual defense capabilities when a tsunami will strike
- Tsunami evacuation tips
  - When the shaking stops, start to evacuate as quickly as possible.
  - Move quickly to higher ground away from the coast.
  - Don't return home before the local official gives the "All Clear" notice.
  - A tsunami does not always start to withdraw the sea surface.

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Information for Disaster Manager and Officer

- Various purposes as well as evacuation
  - Plan for evacuation
  - Plan for preventative measures
  - Evaluation of effects of structural measures
- Additional information
  - Protection line
  - Land use plan
  - Emergency transportation route
  - Authorities related to disaster control
  - Life line
  - others

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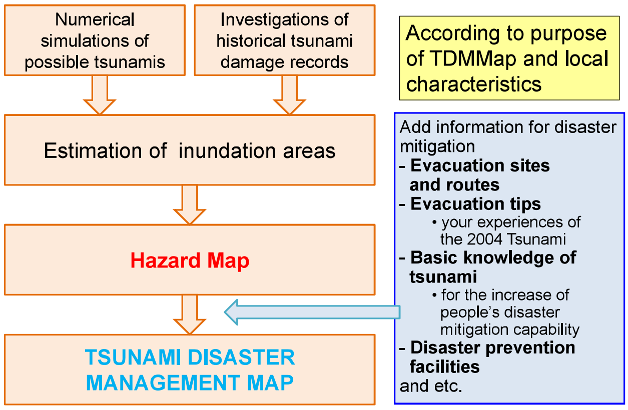
Flowchart to Make TDMMap



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Scenario Writing for Tsunami Hazard Estimation

- Tsunami generation conditions
  - Earthquake condition
    - Magnitude, location, …
  - Tide condition
    - High or low tide at the time of tsunami striking
- Tsunami propagation conditions
  - Bathymetric and topographic condition
    - Bathymetry and topography data
- Structure and land-use conditions
  - Conditions of structures such as seawalls
    - Seawalls withstanding or collapsing in the earthquake, Open or close gates, …
  - Density of buildings and housing in each district

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Utilization of TDMMap

- Residents
  - Educational opportunities
    - Workshops
      - To enhance residents' awareness of disaster prevention against tsunamis
      - To establish the importance of the map within the community.
    - School
      - To continuously educate people about disasters and related issues from childhood
      - To provide a chance for family members to talk about disaster prevention.
- Voluntary disaster prevention organization in each district
  - To promote more precious tsunami disaster management in the district

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Utilization of TDMMap

- Evacuation drills
  - Ex. On the way back home from school
    - Sounding a siren is scheduled when students are on the way home from school. The students who hear the siren evacuate to the nearest shelter indicated on an evacuation map.

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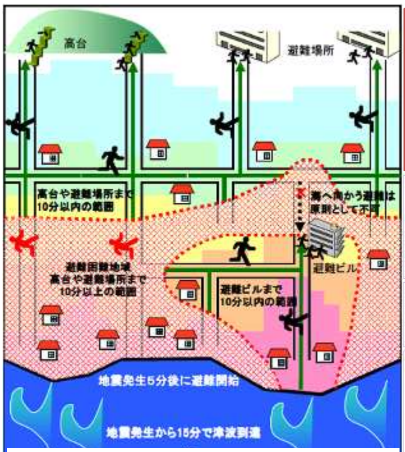
Utilization of TDMMap

- Drawing up evacuation plans
  - Information of evacuation sites/places as well as inundation area and striking time of the expected tsunami results in identifying areas where it is difficult for people to evacuate and planning of residents' and non-residential persons' evacuation.



The expected tsunami strikes 15 min. after the quake

Determination of areas where completion of evacuation is difficult within the specific time by Wakayama Prefecture, Japan

Condition 1:
Walking speed = 0.5 m/s
Considering elders and difficulty of evacuation due to destruction of houses

Condition 2:
Maximum distance of evacuation = around 1 km

Condition 3:
Maximum time spent for evacuation = 5, 7, 10 min.
Depending on tsunami arrival time and starting time of evacuation after the quake

Application to Storm Surge Disaster

- Storm surges are cased by the different mechanism from tsunamis.
  - Storm surges are generated mainly by suction due to low atmospheric pressure and shear stress due to high wind blowing on the sea water surface.
- Storm surges are able to be calculated by means of the same numerical model as tsunamis, if a hurricane/cyclone/typhoon model is installed in the simulation system.
- Estimation results such as height distribution of storm surge and inundation areas are utilized in the same way as tsunamis.
- Almost parts of the guideline is available for storm surge disaster management.

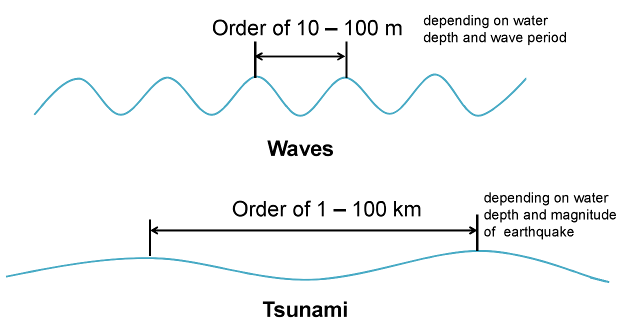
Basics of Tsunami

Difference from Waves

- The wavelength of tsunami is extremely long .
  - which is 200 km long in the cases of the 2004 Indian Ocean tsunami and 2011 Tohoku tsunami
  - which is much greater than the water depth
    - Tsunami feels the sea bottom even in the deepest ocean.
    - = Tsunami can be affected by the sea bottom change.

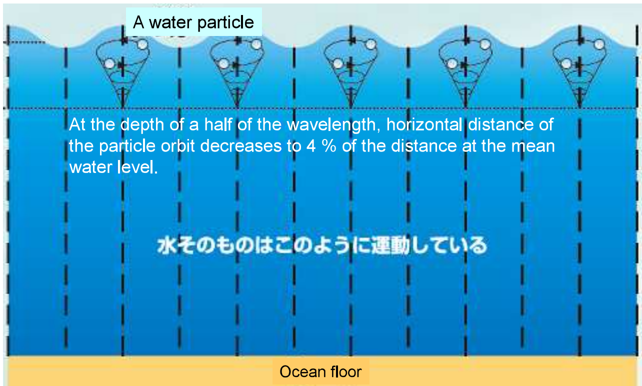
Difference from Waves

- Tsunami has a very long wave-length than the wind waves.



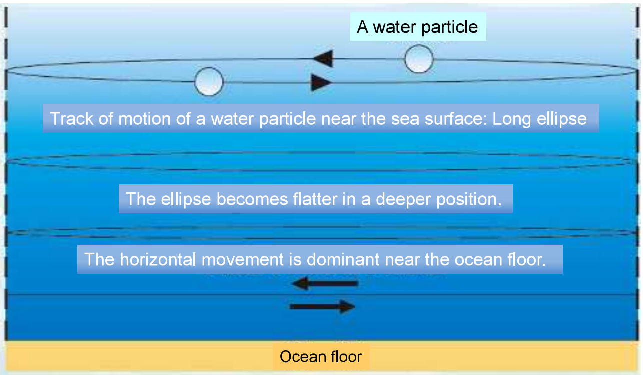
Movement of water under waves

Movement of water under waves



Movement of water under tsunami

Movement of water under tsunami



Hydraulic experiments

Waves with wave height of 0.5 m offshore and wave period of 4 s

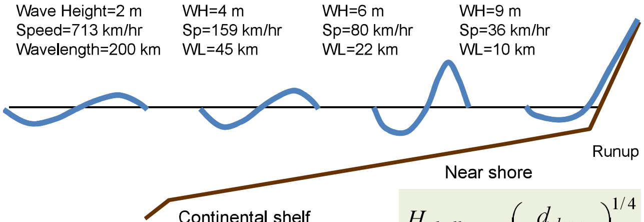
Tsunami with wave height of 0.5 m offshore and wave period of 20 s

Conducted by Dr. T. Arikawa, PARI

Increase of Tsunami Height

Tsunami height increases as the tsunami approaches coasts, because of decrease of the water depth.

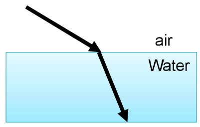
Depth 4000 m (average depth of the P. O)	Depth 200 m (on a continental shelf)	Depth 50 m (nearshore)	Depth 10 m (nearshore)
Wave Height=2 m Speed=713 km/hr Wavelength=200 km	WH=4 m Sp=159 km/hr WL=45 km	WH=6 m Sp=80 km/hr WL=22 km	WH=9 m Sp=36 km/hr WL=10 km



$$\frac{H_{shallow}}{H_{deep}} = \left(\frac{d_{deep}}{d_{shallow}}\right)^{1/4}$$

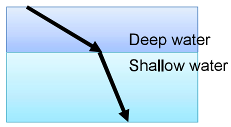
Refraction (Change of propagation direction)

Refraction of light



The change in direction of propagation (refraction) of light is caused by the moving speed of light slower in water than air.

Refraction of tsunami



The change in direction of propagation (refraction) of a tsunami is caused by the moving speed of the tsunami slower in a shallow water region than a deep water region.

$$c = \sqrt{gd}$$

c: moving seed of a tsunami
d: water depth
g: gravitational acceleration

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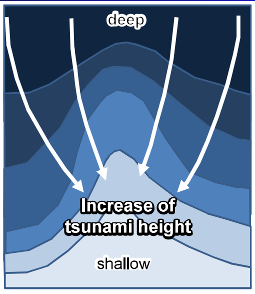
Refraction of Tsunami



Shallow water area projecting into a deep water area

Shallow water area in a deep water area

Tsunami energy is concentrated due to wave refraction produced by a local shallow water area, resulting in development of tsunami height.

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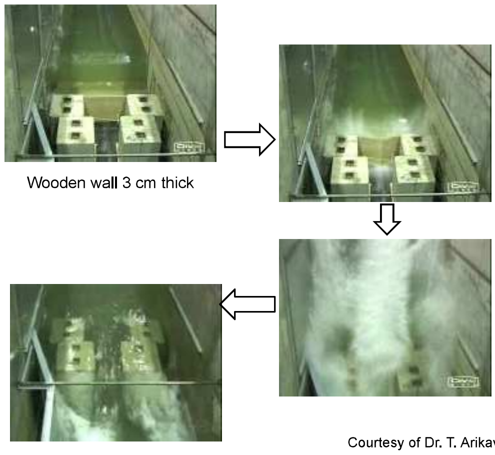

Wooden wall 3 cm thick

Courtesy of Dr. T. Arikawa, PARI

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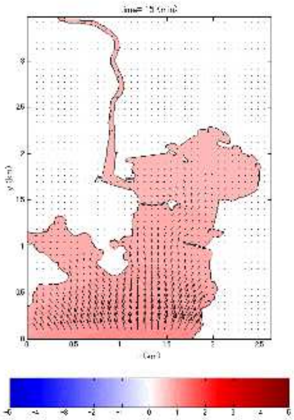
Structure effects on fluid velocity



Actual tsunami-induced vortex in a port

Vortices induced by Breakwaters and other obstacles

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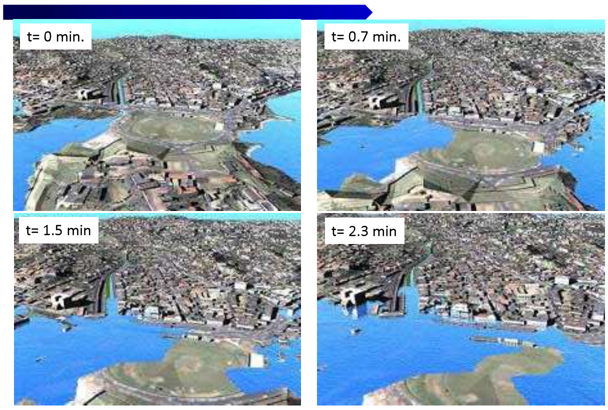
Tsunami Inundation



The 2004 Indian Ocean Tsunami in Galle, Sri Lanka, STOC calculation

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Tsunami Inundation

The 2004 Indian Ocean Tsunami in Galle, Sri Lanka, STOC calculation

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Summary

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Keys to Build Tsunami-Resilient Community

- Multi-level hazard estimation
  - Largest-possible tsunamis to consider measures for saving human lives
  - Tsunamis lower and more frequent than the largest-possible tsunamis to consider measures for protecting individual and social property as well as lives
- Multi-layered defense system
  - Against uncertain future tsunami, multi-layered defense system should be establish to build tsunami-resilient community.

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Keys for Tsunami Hazard Mapping

- Results of tsunami numerical simulation depend on accuracy of the numerical models employed as well as bathymetric and topographic data.
- We should prepare appropriate numerical models and suitably-accurate bathymetric and topographic data and further structure data to calculate tsunami propagation and inundation.
- If the suitable data is not available at present, we need to go forward the simulation step by step depending on preparation of the data.

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Utilization of the estimation results for disaster mitigation

- The estimated results should be indicated easily for residents, disaster managers and officers, to share the common awareness for tsunami damage.
- Hazard mapping is a good tool for the indication.
- Additional information of disaster mitigation measures on the hazard map is effective to investigate and plan a holistic and integrated system for tsunami disaster mitigation.
  - Ex. indication of evacuation sites on the hazard map is utilized to plan an evacuation procedure of each people.

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Conclusion

- We should understand and estimate damages and disasters by possible tsunamis, and then
- Develop well-prepared people to tsunamis, and
- Develop a city (town/village/community) to be resistant and resilient to tsunamis

PASCO
World's Leading Geospatial Group

Practical Approach to develop Tsunami simulation and Inundation Map

November, 2015
PASCO Corporation

What is "tsunami"?

• The word "tsunami" is a Japanese word meaning, "harbor wave". A tsunami is a series of traveling ocean waves of extremely long length generated by disturbances associated primarily with earthquakes occurring below or near the ocean floor.

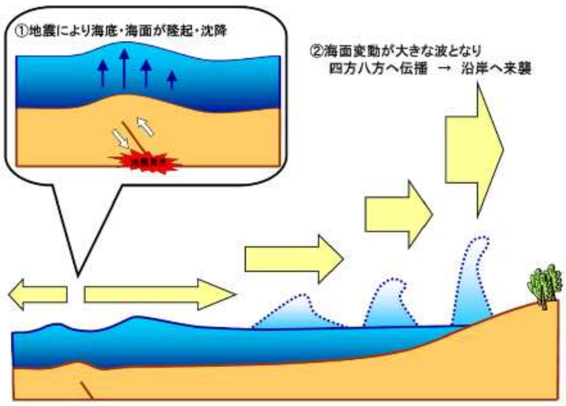
• Land slide due to land slides by volcanic eruptions or submarine land slides also can generate tsunami.

→An example of the land slide by volcanic eruption

Eruption of Unzen Hugen-dake volcano in Kyushu district, Japan (called "Shimabara taihen, Higo meiwaku", 1792.)

→An example of the submarine land slide:Due to the eruption of Oshima-ohsima island near Hokkaido district, Japan(year 1741)

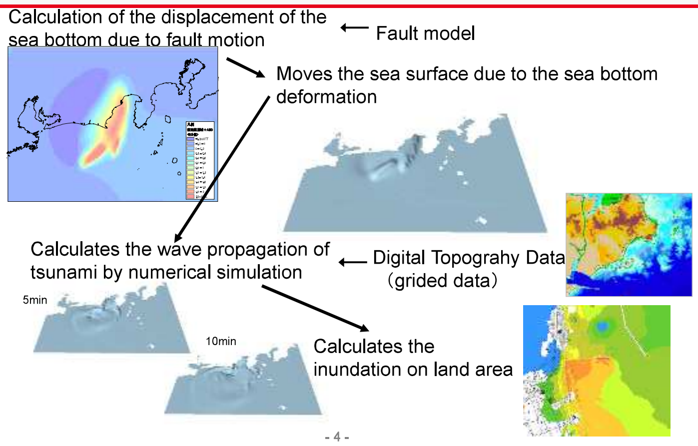
Tsunami due to the earthquake



Tsunami due to the land slide of the volcano

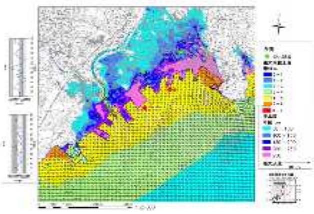
• Eruption of Unzen Hugen dake volcano in Kyushu district, Japan (called "Shimabarataihen, Higo meiwaku", 1792.)

Procedure for the tsunami simulation and hazard map

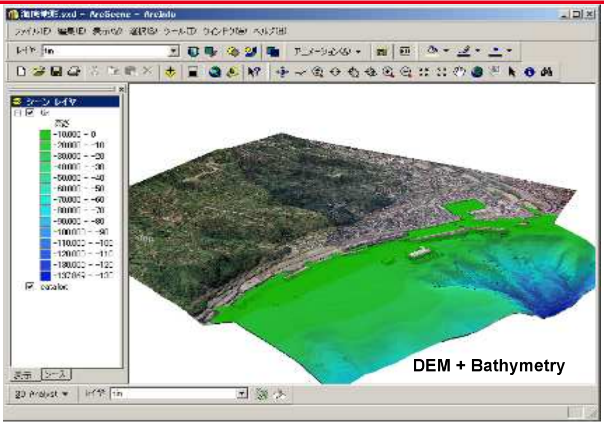


Procedure for the tsunami simulation and hazard map

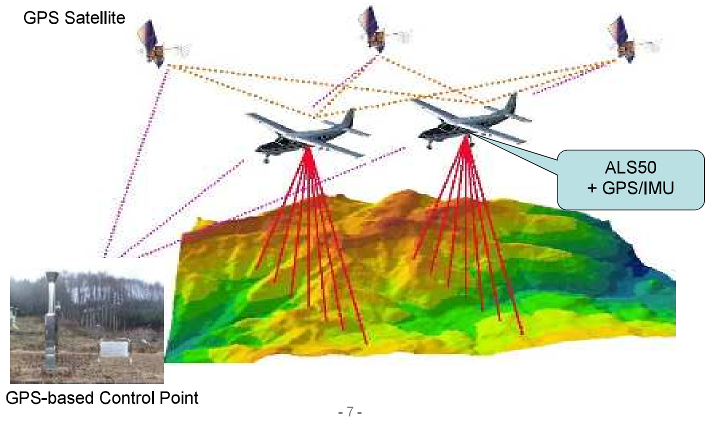
1. Digital topography
2. Selection of the possible earthquake
3. Tsunami simulation
4. Tsunami hazard map



1 Topography for Tsunami-simulation

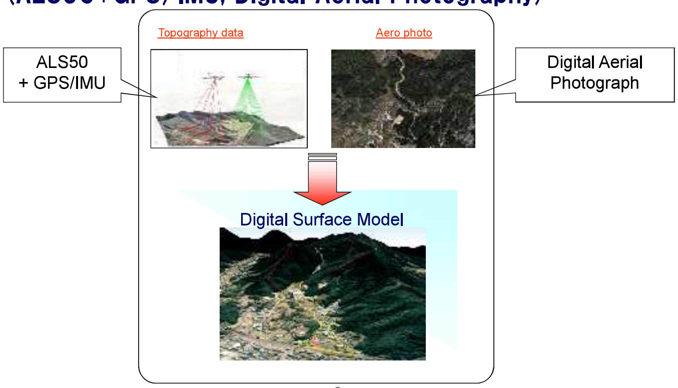


1-1 (1) Airborne Laser Scanner (land area)

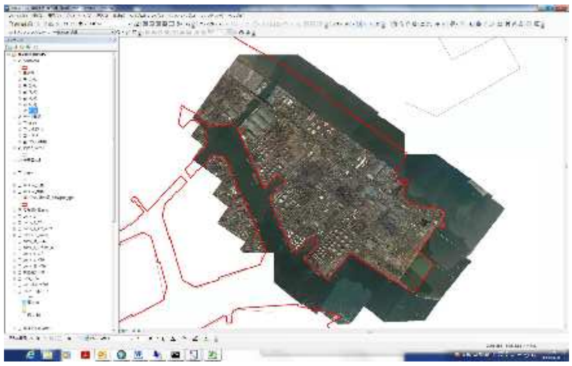


1-1 (2) Digital Surface Model

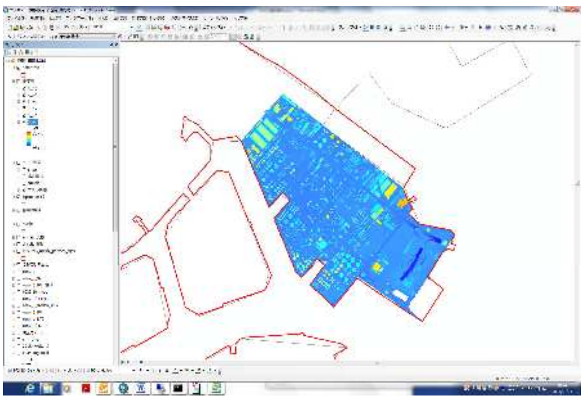
(ALS50+GPS/IMU, Digital Aerial Photography)



1-1 (3) An example of Airborne Laser Scanner data



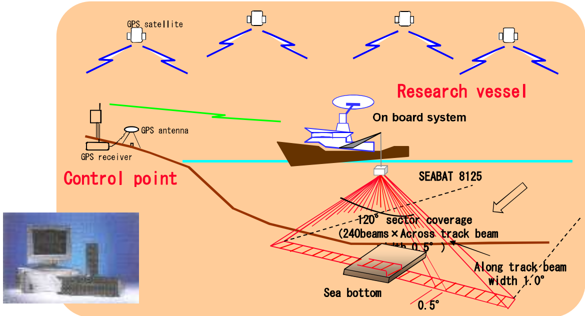
1-1 (3) An example of Airborne Laser Scanner data



1-1 (4) 5m mesh DEM provided from GSI

In Japan, 5m mesh DEM data can be obtained from Web site of Geospatial Information Authority of Japan (GSI)

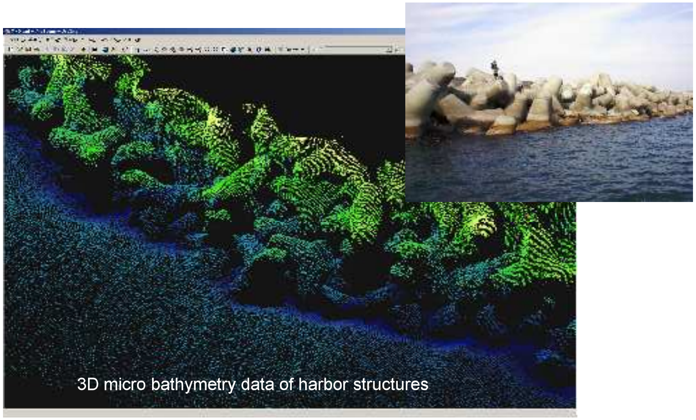
1-2（1）Narrow multi-beam sonar sounding



The integration of GPS-positioning and narrow multi-beam sonar sounding can produce 3-dimennsional bottom topography. The bathymetry data are offered in SHAPE file(GIS format).

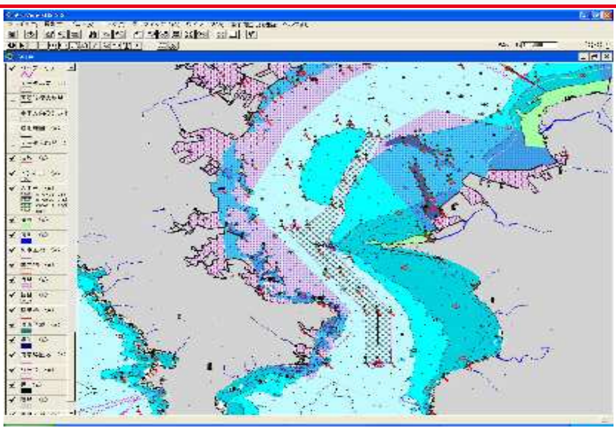
Accuracy RTK-GPS resolution : 2cm
Depth resolution : 6mm

1-2（2）Micro Bathymetry SEABAT8125



3D micro bathymetry data of harbor structures

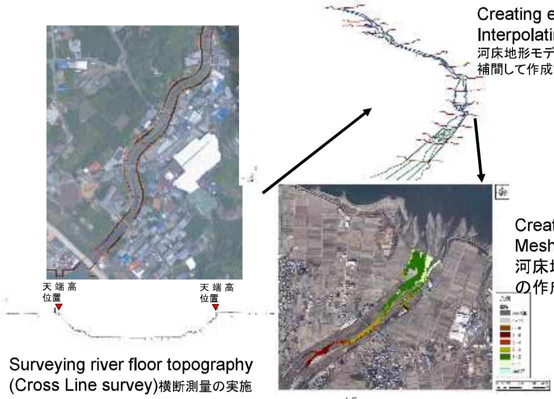
1-2（3）ENC(Electronic Navigational Chart)



1-3（1）Topography of Rivers

Tsunami inundation through rivers is very important

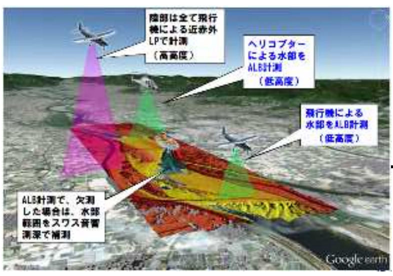
Creating elevation model by Interpolating Cross line survey
河床地形モデルを、横断測量成果を補間して作成する。

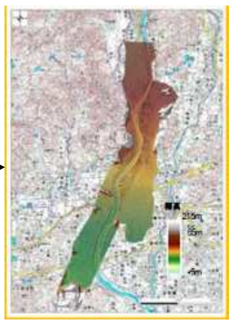


Creating elevation Mesh Data
河床地形メッシュデータの作成

Surveying river floor topography
(Cross Line survey)横断測量の実施

1-3（2）Topography of Rivers : Direct survey using ALB

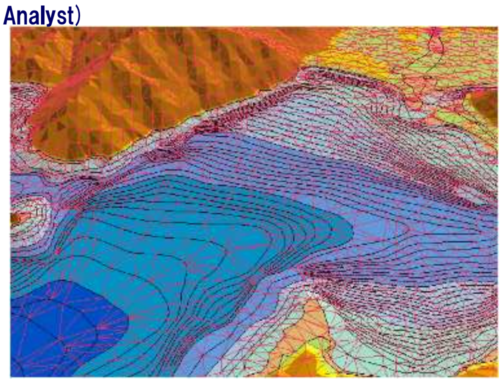




ALB:Airbone Laser Bathymetry
We can obtain river floor topography directry using ALB survey.

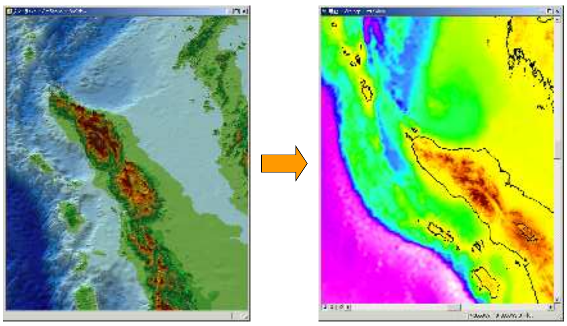
1-4（1）3D-terrain Model

GIS platform is used for 3D-terrain model(TIN) using ArcGIS (3D Analyst)

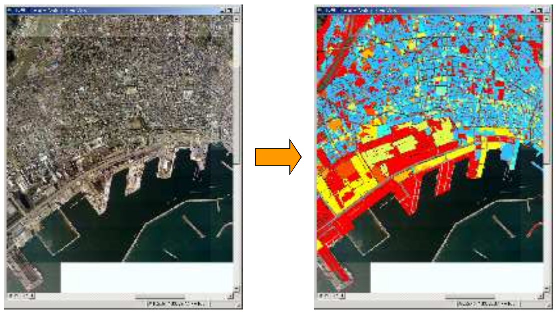


1-4 (2) 3D-terrain model

Example around Northern Sumatra



1-5 (1) Extracting Roughness data from land-use data

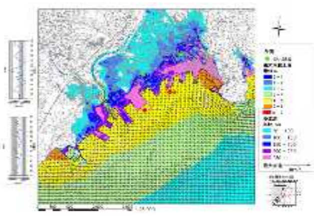


1-5 (2) Extracting Roughness data from land-use data

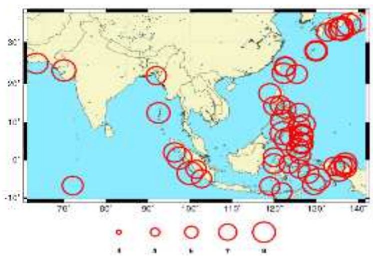
Land-use		Manning's roughness Coefficient
Residential district	density(80～100%)	0.080
	density(40～80%)	0.060
	density(10～40%)	0.040
Industrial plant, etc		0.040
Farm land (field, etc)		0.020
Forest (wood land, waste land, etc)		0.030
Water (river, lake, sea)		0.025
Others (open space)		0.025

Procedure for the tsunami simulation and hazard map

1. Digital topography
2. Selection of the possible earthquake
3. Tsunami simulation
4. Tsunami hazard map



2 Selection of the possible earthquake



Distribution of tsunami-generating earthquakes

Source: Utsu, T., "Catalog of Damaging Earthquakes in the World" (Through 2002)

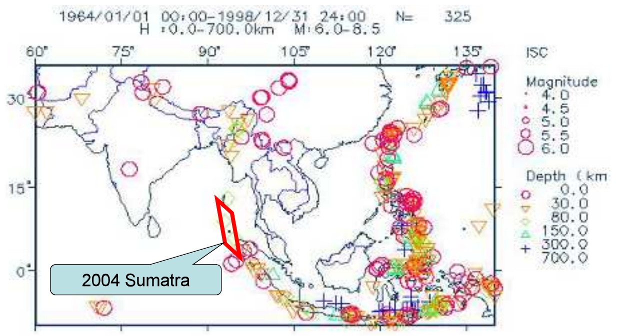
Setting up a hypothesis of earthquake epicenter

1) A place where seismic gap exists

2) Historical Earthquake

The largest scale earthquake occurred in the past

2-1 Seismic gap



Source: TSEIS web version 0.1 DATABASE ISC

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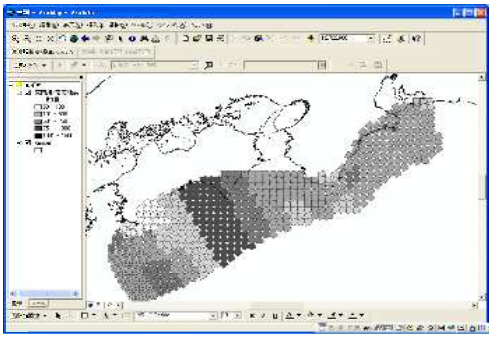
2-2 Historical earthquake



Tonankai and Nankai earthquake (Central Disaster Prevention Council)

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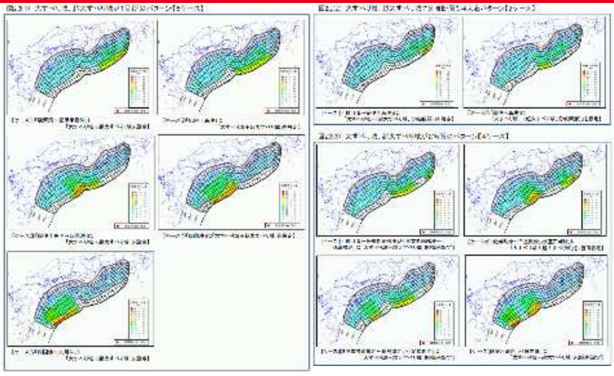
2-3 (1) Possible Earthquakes studied in the Government



Huge Earthquakes of Nankai-Trough:Provided
内閣府から提唱されている南海トラフの巨大地震

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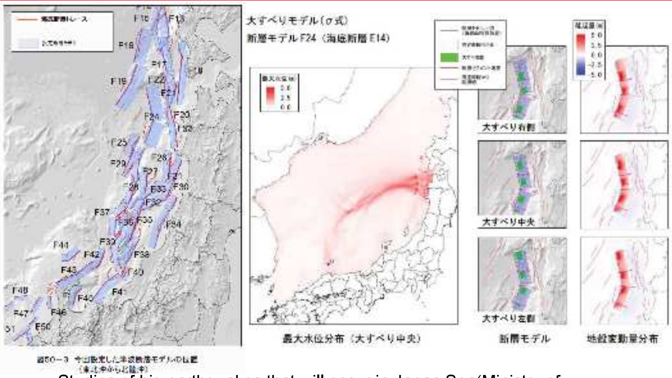
2-3 (2) Possible Earthquakes studied in the Government



Studies of big earthquakes that will occur in Japan Sea(Ministry of Land, Infrastructure, Transport and Tourism)
日本海における大規模地震に関する調査検討会(国土交通省)

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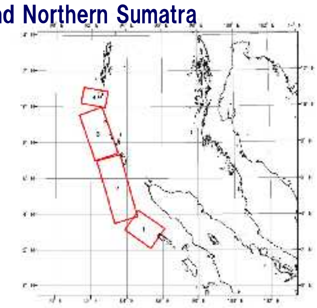
2-4 Selection of the possible earthquake

Example around Northern Sumatra



No	Strike (°)	Dip (°)	Slip (°)	length (km)	width (km)	Dislocation (m)
1	55.1	8	110	200	150	5.6
2	344.1	8	110	400	150	5.6
3	340.2	8	90	300	150	10.7
4	10.4	8	90	100	150	10.7

http://www.jamstec.go.jp/jamstec-j/sumatra/3_2/index.html

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Procedure for the tsunami simulation and hazard map

1. Digital topography
2. Selection of the possible earthquake
3. Tsunami simulation
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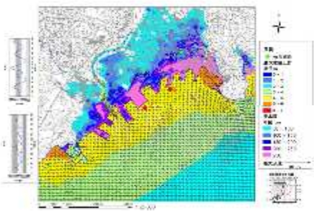

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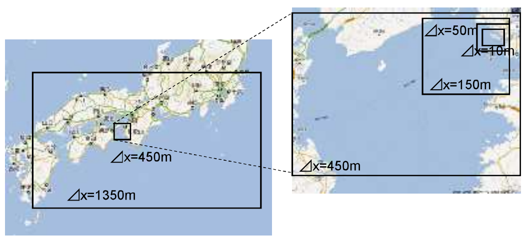
3 Tsunami Simulation for the Possible Earthquake

The extent of the outermost region is taken to cover the source region of the earthquake, and the size of mesh resolution is taken finer in the trage area.



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3-1 Methodology of data acquisition for different mesh resolution

Mesh Resolution	Water Depth	Elevation
10m (very high)	Hydrographic survey (required about 1m depth contour)←SEABAT	DEM(required about 1 m contour)←ADS50 Port facility ledger
50m (high)	Hydrographic survey (required about 5m depth contour)	DEM(required about 5 m contour)
150m (medium)	Hydrographic chart, Electrical navigational chart	basically not required
450m (low)	Hydrographic chart, Electrical navigation chart	
1350m (very low)	ETOPO2 , JTOPO30, Jegg500	

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3-2 Equations for tsunami simulation

$$\frac{\partial M}{\partial t} = -gD\frac{\partial \zeta}{\partial x} - \frac{gn^2}{D^{\frac{1}{3}}}\frac{M\sqrt{M^2+N^2}}{D^2} - \frac{\partial}{\partial x}\left(\frac{M^2}{D}\right) - \frac{\partial}{\partial y}\left(\frac{MN}{D}\right)$$

$$\frac{\partial N}{\partial t} = -gD\frac{\partial \zeta}{\partial y} - \frac{gn^2}{D^{\frac{1}{3}}}\frac{N\sqrt{M^2+N^2}}{D^2} - \frac{\partial}{\partial x}\left(\frac{MN}{D}\right) - \frac{\partial}{\partial y}\left(\frac{N^2}{D}\right)$$

$$\frac{\partial \zeta}{\partial t} = -\left(\frac{\partial M}{\partial x} + \frac{\partial N}{\partial y}\right) + \frac{\partial \eta}{\partial t}$$

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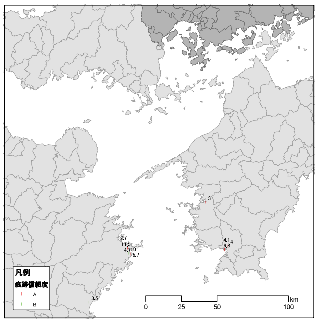
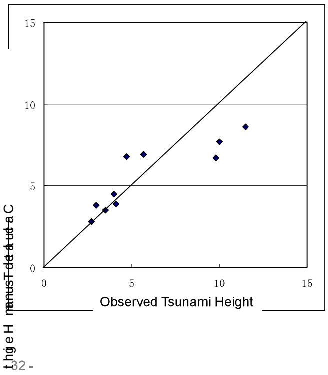
3-2 Validation of the simulation model

The validation of the simulation model is examined whether the model can reproduce well the actual observed tsunami height.





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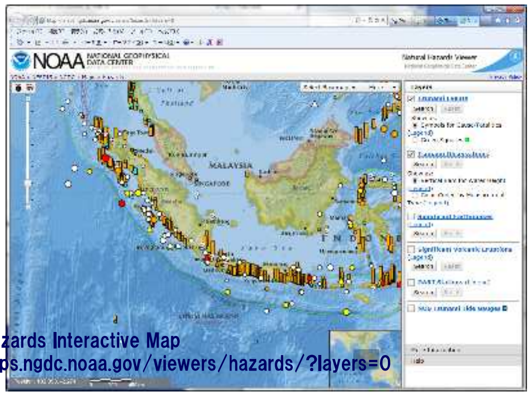
3-2 Validation of the simulation model



Natural Hazards Interactive Map
http://maps.ngdc.noaa.gov/viewers/hazards/?layers=0

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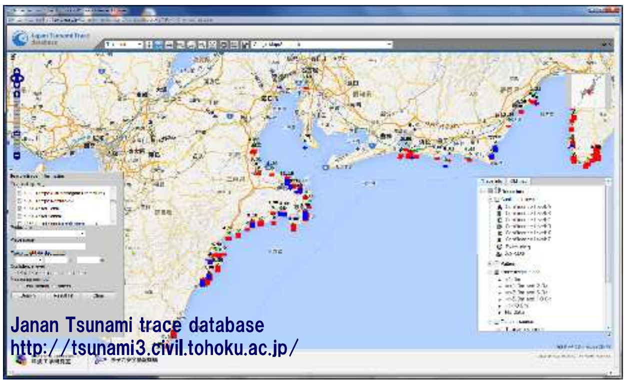
3-2 Validation of the simulation model



Janan Tsunami trace database
http://tsunami3.civil.tohoku.ac.jp/

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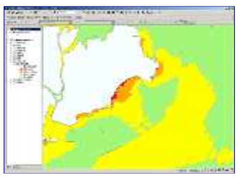
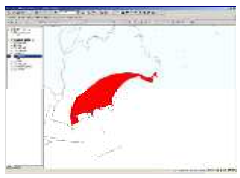
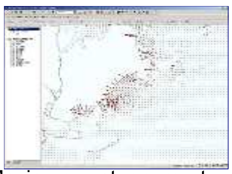
3-3 Tsunami simulation results



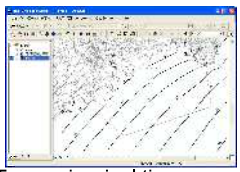
Maximum height of sea level
(for assessing the safety of vessels)



Inundation area
(for the estimation of damage)



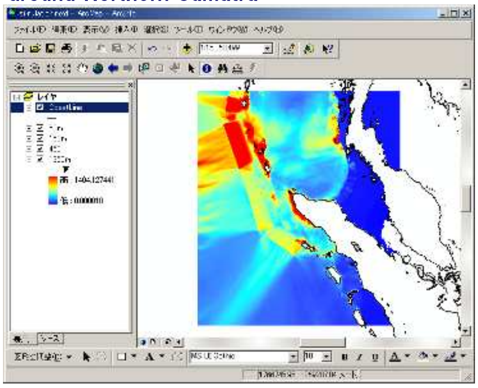
Maximum water current,
(for assessing the safety of vessels)



Tsunami arrival time
(to know when tsunami comes)

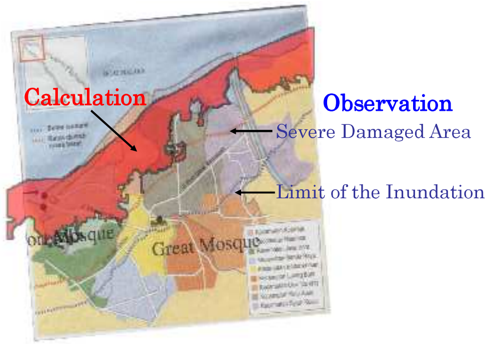
3-3 Tsunami simulation results

Example around Northern Sumatra



3-3 Tsunami simulation results

Example around Northern Sumatra



Procedure for the tsunami simulation and hazard map

1. Digital topography
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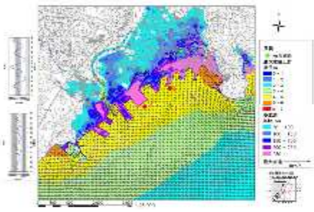
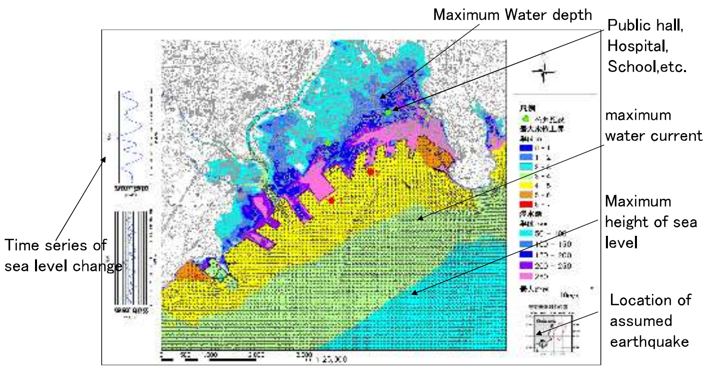
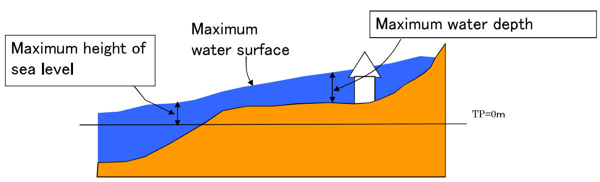


4 Tsunami Hazard Map

Type1 ; tsunami inundation map

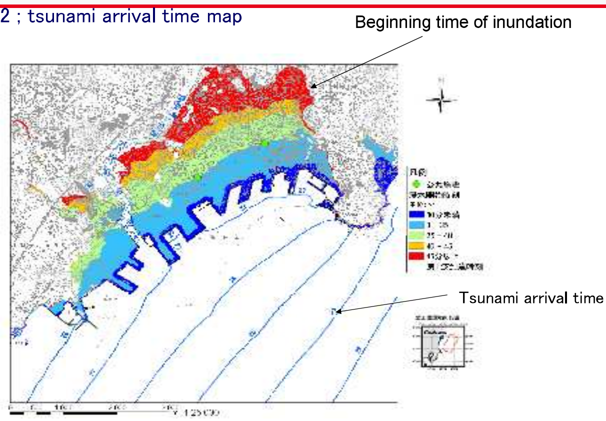


4 Tsunami Hazard Map



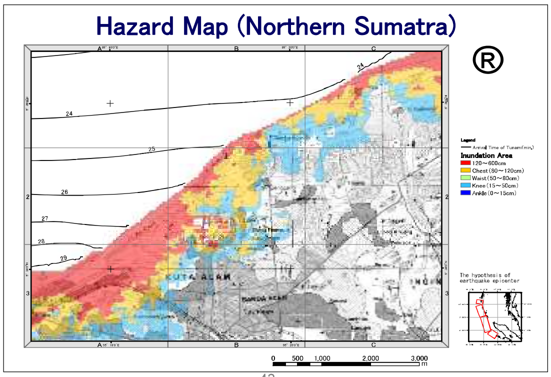
4 Tsunami Hazard Map

Type2 ; tsunami arrival time map



4 Tsunami Hazard Map

Example around Northern Sumatra



The International Workshop on Tsunami Inundation Mapping
Session 3: The Latest Technology of Bathymetric Survey in Shallow Water
25th November 2015, Tokyo, Japan

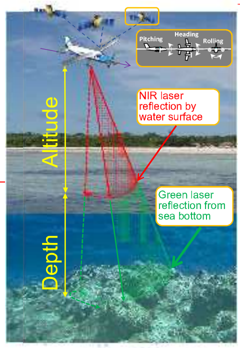
Coastal Survey Using Airborne LiDAR
(Airborne Laser Bathymetry)

Naohiro Miyasaku & Yutaka Kawamura

PASCO CORPORATION

Contents

1. ALB measurement concept



Green Laser reflection from the sea bottom

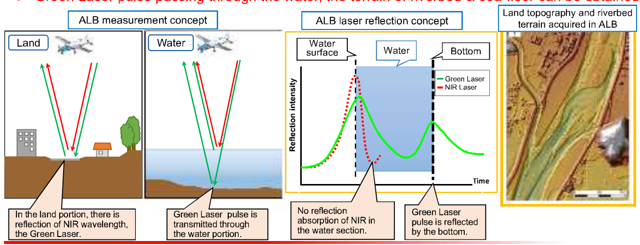
ALB measurement concept

Overview

- Capability of high-resolution & high-precision 3D topography of the land, river & sea-floor.
- Bathymetry is possible by Airborne survey.
- Surveying & monitoring of the sea-floor & rivers, utilization for disaster countermeasures etc.

Mechanism of basic measurement

- Basic measurement is the same as the conventional airborne laser survey.
- Measurement by transmitting 2 laser wavelength bands simultaneously (NIR, Green Laser).
- Green Laser pulse passing through the water, the terrain of riverbed & sea-floor can be obtained.

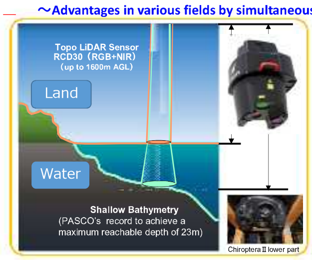


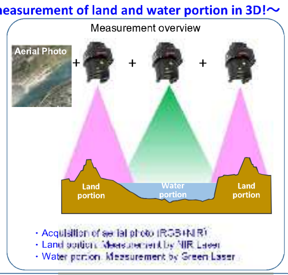
2. PASCO's introduced ALB system

(Taken under the fuselage of Chiroptera II)

Introduced system Chiroptera II

～Advantages in various fields by simultaneous measurement of land and water portion in 3D!～



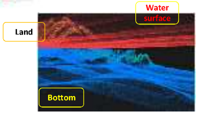


- ✓ First private-sector company in Japan to introduce ALB.
- ✓ Depth range: D_{max} = 2.2/K* (～ 1.5 Secchi depth)
  *K Value (Diffusion and attenuation coefficient)
  This coefficient is the indicator to estimate the ALB depth of bathymetry.
- ✓ NIR Laser (Land) + Green Laser (Water) + simultaneously mounted aerial camera.
- ✓ It is possible to capture land portion, aerial photographs at the same time, the ground Ortho can be also created.

 - 6 -

Features of Chiroptera Ⅱ

- Airborne NIR Laser and Green Laser sensors perform scanning into an elliptical shape. It is also effective for the walls and shaded areas.



- Even in the case of water waves, in order to scan from a different angle to the same place twice, there is improved accuracy of the water surface estimation.
- High reliability of the analyzed results for twice waveform analysis on the same target.
- Future possibility to mount on the helicopters and to fly domestically.

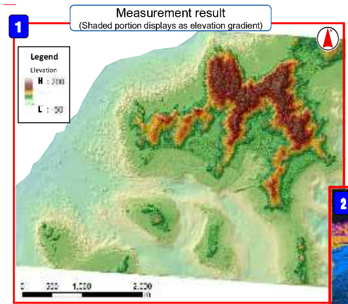
- Availability of Deep Bathy Sensor as an option on request. Depth range is D_{max} = 4/K, up to a depth penetration of 50m, compatible.*

* For some preparation time, the cost may increase to some extent.

3. Measurement cases of coastal zone and sea-floor

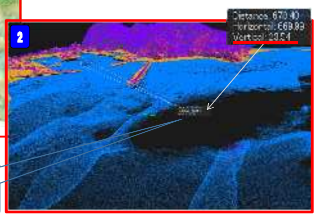
Measurement case of Japanese marine area 1

Measurement result (Shaded portion displays as elevation gradient)



Range (km²)	Flight ALT (from ground) (m)	No. of flying courses	ACQ date
33.7	500	22	Mar/8

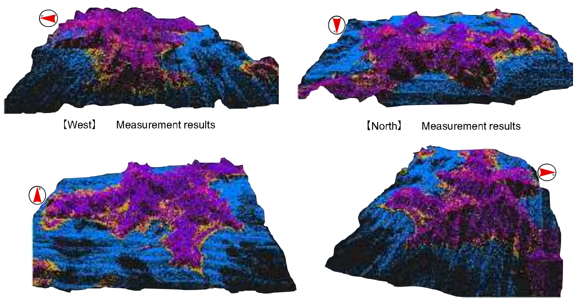
1 Up to a depth of 50m was measured by Chiroptera Ⅱ & optional Deep Bathy Sensor.



2 Since the water quality condition was good during observation, with the introduced Chiroptera Ⅱ, it could measure up to approximately 23m depth. A notable achieved depth record by PASCO!

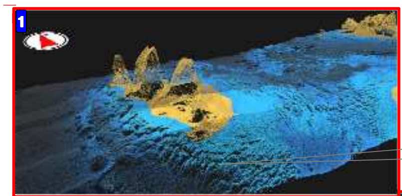
Measurement case of Japanese marine area 1

Measurement results – "Bird's-eye View" (*)



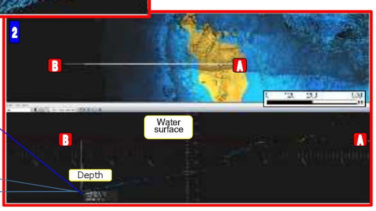
(*) Up to a depth of 50m was measured by Chiroptera Ⅱ & optional Deep Bathy Sensor.

Measurement case of Japanese marine area 2



Up to a depth of 50m was measured by Chiroptera Ⅱ & optional Deep Bathy Sensor.

1 It clearly captured the unevenness of the sea-floor coral.

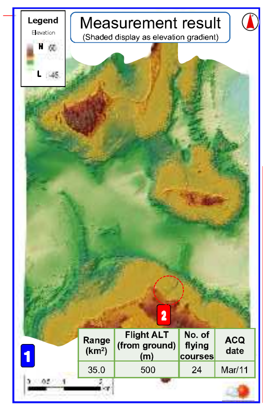


Distance: 51.43
Horizontal: 4.66
Vertical: 51.22

2 With optional Deep Bathy Sensor, it captured the sea-floor topography up to a depth of 51m.

Measurement case of Japanese marine area 3

Measurement result (Shaded display as elevation gradient)

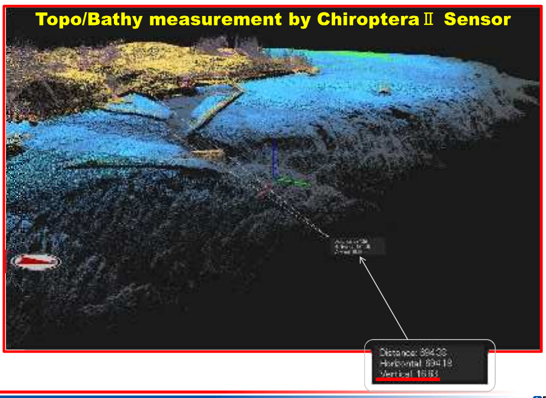


Range (km²)	Flight ALT (from ground) (m)	No. of flying courses	ACQ date
35.0	500	24	Mar/11

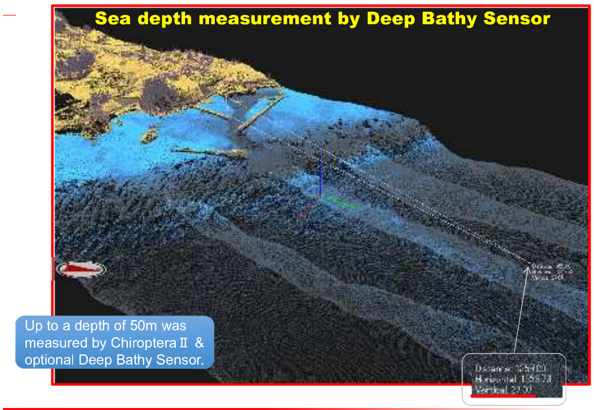
Up to a depth of 50m was measured by Chiroptera Ⅱ & optional Deep Bathy Sensor.

It was able to clearly capture uneven seabed of the harbor.

Measurement case of Japanese marine area 3

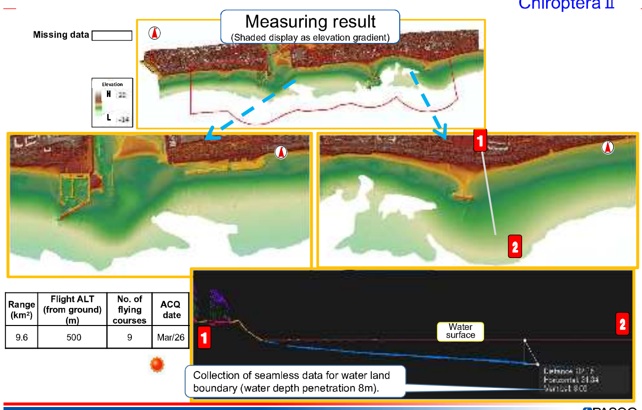


Measurement case of Japanese marine area 3



Measurement case of Japanese coastal area 1

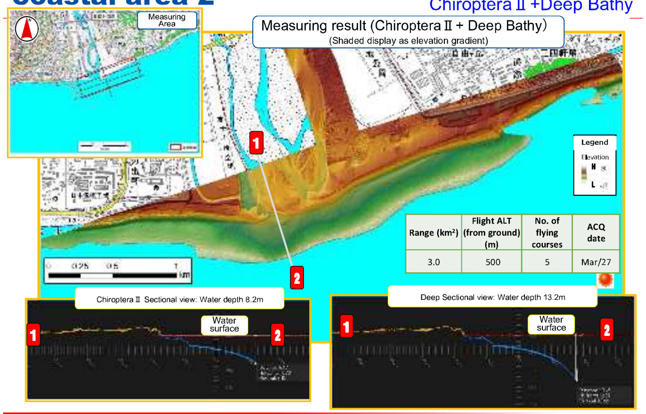
Utilized sensor
Chiroptera Ⅱ



Range (km²)	Flight ALT (from ground) (m)	No. of flying courses	ACQ date
9.6	500	9	Mar/26

Measurement case of Japanese coastal area 2

Utilized Sensor
Chiroptera Ⅱ +Deep Bathy

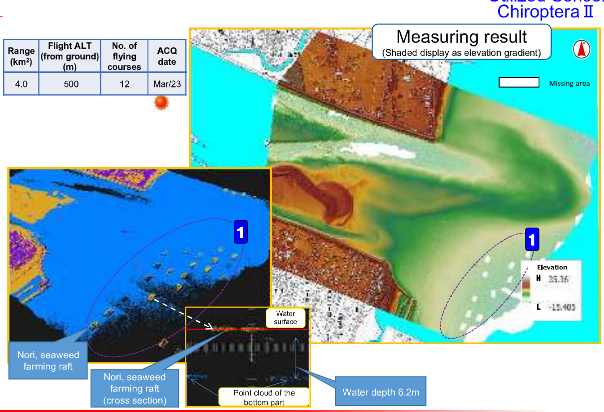


Range (km²)	Flight ALT (from ground) (m)	No. of flying courses	ACQ date
3.0	500	5	Mar/27

Measurement case of estuary

Utilized Sensor
Chiroptera Ⅱ

Range (km²)	Flight ALT (from ground) (m)	No. of flying courses	ACQ date
4.0	500	12	Mar/23



4. Accuracy verification

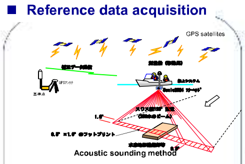
- Water portion position accuracy verification
- Land portion position accuracy verification

Water portion position accuracy verification **Water**

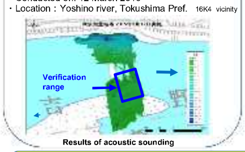
■ Verification contents: Comparison between data acquired by acoustic sounding & ALB

- Reference data: Shipborne acoustic sounding data (Conventional approach)
- Verification data: Collected data by the ALB Green Laser (Acquisition date: 14 March 2015)

■ Reference data acquisition



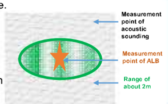
- Conducted on: 12 March 2915
- Location : Yoshino river, Tokushima Pref. 16K4 vicinity



Results of acoustic sounding

■ Verification methodology

1. Selection of a flat place as riverbed surface.
2. Extraction of ALB acquired data in (1).
3. Measurement point extraction of acoustic sounding from one point of ALB acquired data in the range of about 2m.
4. From 2 and 3 of superposition, comparison of the difference in the height direction.



■ Verification results

Item	Value (m)
Max difference	0.462
Average difference	-0.012
Standard deviation	0.037
Mean Square Error	0.039

Confirmation about equivalent to the acoustic sounding & it resulted same accuracy.

Japan Coast Guard hydrographic survey Water classification 1b Satisfaction archived according to the base of accuracy
Water classification 1b: Water depth is within 100 m

Land portion position accuracy verification **Land**

■ Verification contents: Comparison with actual and ALB measurement data

- Reference data: The acquired data in the actual measurement (Conventional approach) By Japanese public survey standard for airborne laser survey
- Verification data: Data collection by ALB NIR Laser (Acquisition date: 14 Mar 2015)

■ Reference data acquisition

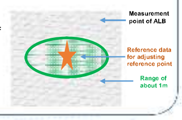
- Selection of 10 horizontal sites of no obstacles, e.g., ground, empty lots, roads, etc.
- The GNSS surveying, obtaining the positional coordinates (network-based GNSS-VRS observation method quaternary reference point or equivalent).

・Test site: Yoshino River, Tokushima Prefecture

Adjustment for reference point acquisition location

■ Verification methodology

1. Extract measurement point of ALB from the reference data in the range of about 1m.
2. From the superposition of the 1 and the reference data, compare the difference in the height direction.



■ Verification results

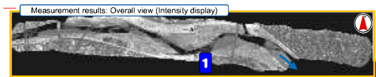
Item	Value (m)
Max difference	0.091
Average difference	-0.048
Standard deviation	0.025
Mean Square Error	0.054

Confirmation about equivalent or greater than accuracy with the airborne laser.

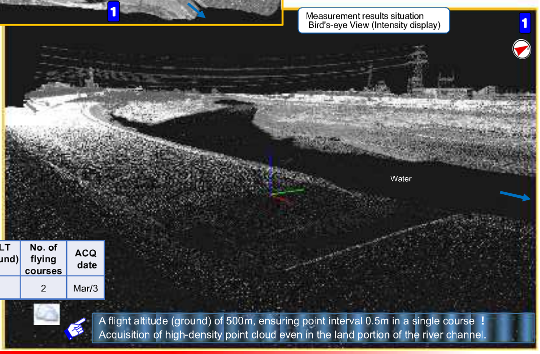
Japanese public survey standard
Error permission: Mean square error within 0.3m

PASCO

Reference: Data acquisition by Topo (NIR) Laser



SL: 70% Measurement situation



Range (km²)	Flight ALT (from ground) (m)	No. of flying courses	ACQ date
0.5	500	2	Mar/3

A flight altitude (ground) of 500m, ensuring point interval 0.5m in a single course !
Acquisition of high-density point cloud even in the land portion of the river channel.

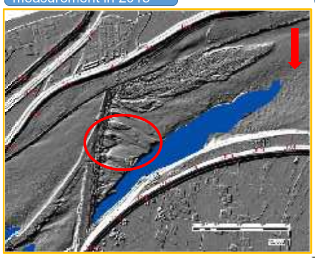
PASCO

5. Analyzed case (river) by ALB

PASCO

Yoshino riverbed situation comparison near floodgate, Tokushima Prefecture

Riverbed situation measurement in 2013 — Missing area



Riverbed situation measurement in 2015 — Missing area

By measuring the two periods, it is possible to grasp the changes of the riverbed terrain. Change of riverbed wave of bottom-wide and river structures (floodgate), the changes are observed in the large terrain on the downstream side.

⇒ For river maintenance, it is possible to grasp the whole local inspection of the rivers.

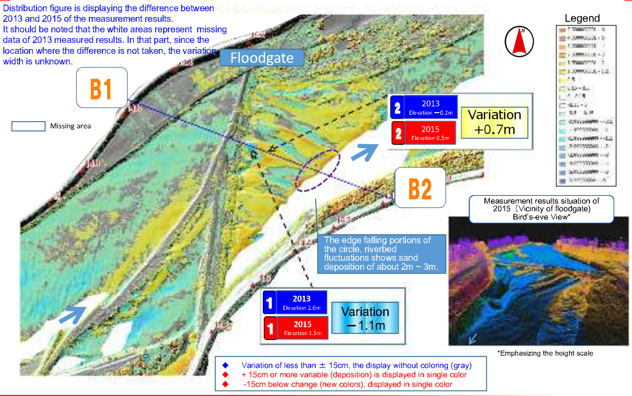
Ortho during 2015 measurement

Measurement site

PASCO

Riverbed variation distribution in the vicinity of floodgate

Distribution figure is displaying the difference between 2013 and 2015 of the measurement results.
It should be noted that the white areas represent missing data of 2013 measured results. In that part, since the location where the difference is not taken, the variation width is unknown.



- Variation of less than ± 15cm, the display without coloring (gray)
- + 15cm or more variable (deposition) is displayed in single color
- -15cm below change (new colors), displayed in single color

PASCO

6. Preparations before conducting ALB measurement

Water quality survey

Water quality conditions influence ALB measurement. At least 1-3 analysis items are usually performed.

1. Photon meter

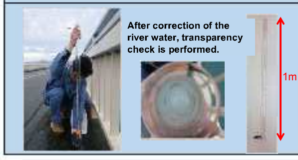
RBR Ltd. XR-620 (CTD+PAR profile logger)
RBR Ltd. concertoCTD +Licor PAR Quantum

Data correction of light energy in water.

2. Transparency version

Checking the depth by a white board in the water.

3. Transparency meter



4. Water sampler*

River water correction.

*Detailed analysis of the water quality after utilization for the environmental research.

※ Flight condition (a hurdle by low altitude flight) must be checked.

7. Effectiveness of ALB

Effectiveness of ALB

LiDAR Bathy

Effective to grasp underwater surface topography

- For the coastal zone, sea-floor & rivers, wider coverage of underwater terrain data can be collected.
- Due to acoustic sounding of the weakness of the ship, the "shallow water depth range" measurement is possible by ALB.
- Temporal data acquisition for the quantitatively understanding of the sediment variation, such as, peripheral structure is possible.
- After correction of the area (mesh) data collected by ALB, we can expect to analyze for the real simulation or real evaluation.

RCD30 (RGB)

Cost

Through the utilization of ALB measurement, for surveying wider area of the sea-floor & water bottom, it is possible to reduce the total cost as compared to the conventional acoustic sounding measurement.

Improvement of safety & rapidity

For conducting the actual measurement, the surveyors directly enter into risky locations. But by the application of ALB measurement, it is possible to secure a highly safe survey in a short period of time.

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www.global-pasco.com

Study on Satellite Derived Bathymetry (SDB)

Yoshihiro Matsumoto
Ocean Research Laboratory, JHOD

25-26 November 2015
Workshop on Tsunami Inundation Mapping

JAPAN COAST GUARD

1

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3

Background

1. What's SDB?

- High resolution bathymetric data is required for tsunami simulation
  - The shallower, the denser.
- Coverage of modern hydrographic surveys is poor in shallow waters.
  - Multibeam surveys are less efficient for very shallow waters. (ex: < 5 m)
  - Sometimes the survey boat cannot access.
  - LiDAR is efficient for coastal areas, but costly and poorly available.

-> HOs are focusing on SDB to cover the unsurveyed or poorly surveyed areas.

4

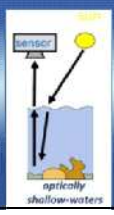
Principle

1. What's SDB?

SDB is a survey method founded on analytical modelling of light penetration through the water column in visible bands of satellites' hyper-spectrometers.

Bathymetry is retrieved simultaneously to
- Water quality/optical properties, and
- Benthos substrate composition

(Martin-Lauzer, 2013)



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Several methods for depth estimation by radiation analysis

1. What's SDB?

- Lyzenga's empirical method (1978) — France
  Uses multiple visible bands.
  Applicable to variable seafloor reflectivity.
- Banny and Dawson (1983)
  Uses one band only. Basic method.
- Stumpf and Holderied (2003) — GEBCO CookBook
  Uses blue and green bands.
- Lee's inversion method (1998, 1999, 2000) — Australia
  Requires multiple bands (>5) and high resolution.
  (applicable to airborne hyper spectral sensors)

6

y enga s empirical method

1. What's SDB?

Lyzenga's regressional equation:
(for green and red bands)

$$Z = A\ln(V_1 - V_{1inf}) + B\ln(R_2 - R_{2inf}) + C$$

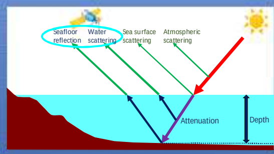
depth green red

- oe i ients and are determined b the re ations bet een radian es and depths
- The e uation an be e tended or more spe tra bands to a hieve more a ura

7

adiance measurement

1. What's SDB?

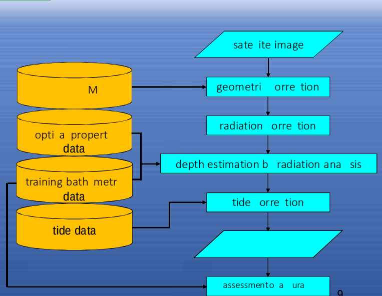


- adian e measurement b sate ite mu tispe tra imager
- Water depth is derived rom the attenuation o ight
- ma amount o training data sounding depths re uired

8

rocedure for producing S B

1. What's SDB?



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Contents

1. What's SDB?
2. Expected performance of SDB
3. Our study on SDB

10

erformance eedback precision

2. Expected performance of SDB

Horizontal precision:
- 2m locally, with HR images and dense network of control points

ertical precision:
- Up to 30 uncertainty in the 0 5m layer
- 10 average uncertainty in the 5 20m layer

Assessed from 99 satellite derived nautical charts (SHOM, 2012)

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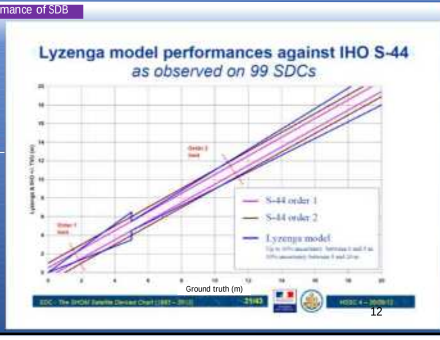
y enga model performances

2. Expected performance of SDB



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vailable Satellites for S B

2. Expected performance of SDB

	round resolution	vailable visible bands
Landsat 8	30 m	4
ALOS A R 2	10 m	3 (Blue, Green, Red)
S OT 6 7	8 m	3 (Blue, Green, Red)
O OS	3.28 m	3 (Blue, Green, Red)
leiades 1A,1B	2.8 m	3 (Blue, Green, Red)
uickBird	2.44 m	3 (Blue, Green, Red)
World iew 2	1.84 m	6 (Coastal, Blue, Green, ellow, Red, Red Edge)

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erformance Shortcomings

2. Expected performance of SDB

Bottom investigation remains incomplete:

➢Features not always detected and or difficult to determine

Depth of penetration: 20m on average, exceptionally 30m

➢Difficult or impossible to detect and measure 2m ob ects at 40m depth (S 44 order 1a)

Ground control (Control points Control survey lines):

➢ ndispensable and relatively costly.

(SHOM, 2012)

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Costs of surveys per s km

2. Expected performance of SDB

- LiDAR
  - Average: 1,500 to 2,000 euros
  - Greatly variable.
  - Depends on survey and quality of post processing
- MBES
  - Average: 1,000 to 2,400 euros
  - Up to 10 times these figures in the worst cases
- Satellite
  - 25 to 45 euros
  - (depends on quality of product)

(SHOM, 2013)

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Contents

1. What's SDB?
2. Expected performance of SDB
3. Our study on SDB

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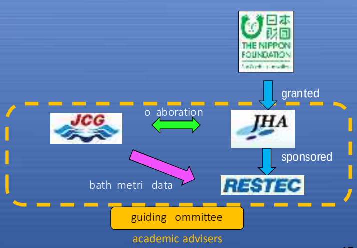
rame ork of S B study

3. Our study on SDB



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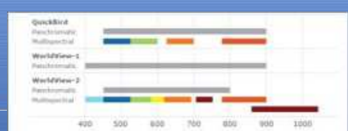
orld ie launched ct

3. Our study on SDB



igita obe 2010

- spe tra bands
  - ➢6 visib e bands oasta b ue green e o red red edge
  - ➢NI NI 2
- 1 m ground reso ution

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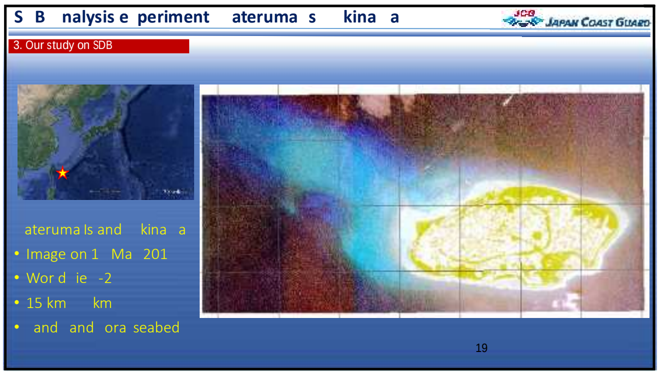

S B nalysis e periment ateruma s kina a
JAPAN COAST GUARD
3. Our study on SDB
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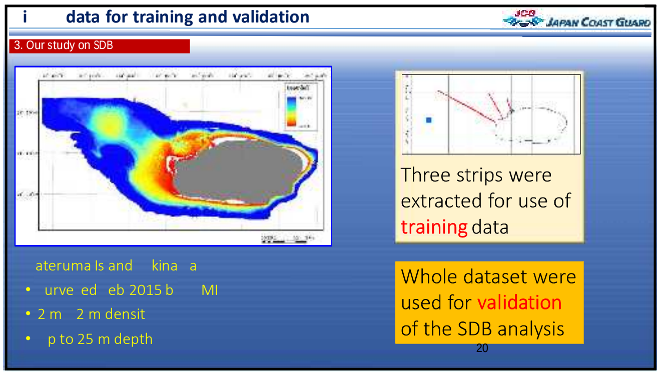
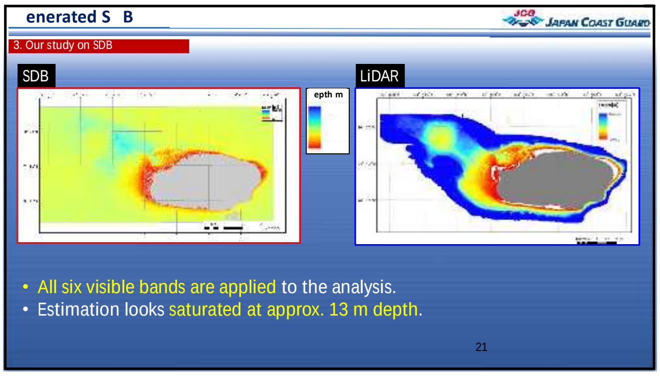
• Image on 1 Ma 201
• Wor d ie -2
• 15 km km
• and and ora seabed
19



i data for training and validation
JAPAN COAST GUARD
3. Our study on SDB
Three strips were extracted for use of training data
Whole dataset were used for validation of the SDB analysis
ateruma Is and kina a
• urve ed eb 2015 b MI
• 2 m 2 m densit
• p to 25 m depth
20



enerated S B
JAPAN COAST GUARD
3. Our study on SDB
SDB
epth m
LiDAR
• All six visible bands are applied to the analysis.
• Estimation looks saturated at approx. 13 m depth.
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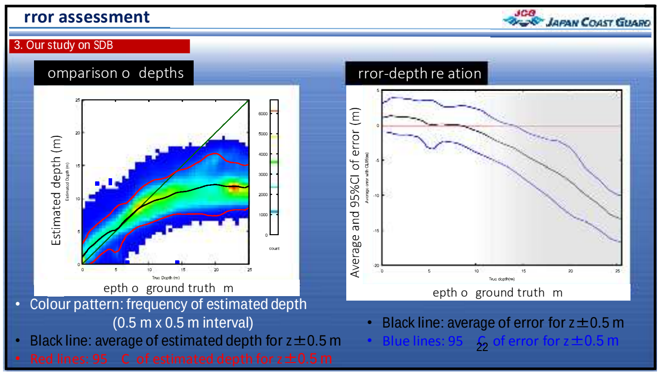

rror assessment
JAPAN COAST GUARD
3. Our study on SDB
omparison o depths
Estimated depth (m)
epth o ground truth m
rror-depth re ation
Average and 95%CI of error (m)
epth o ground truth m
• Colour pattern: frequency of estimated depth (0.5 m x 0.5 m interval)
• Black line: average of estimated depth for z±0.5 m
• Black line: average of error for z±0.5 m
• Blue lines: 95 C of error for z±0.5 m
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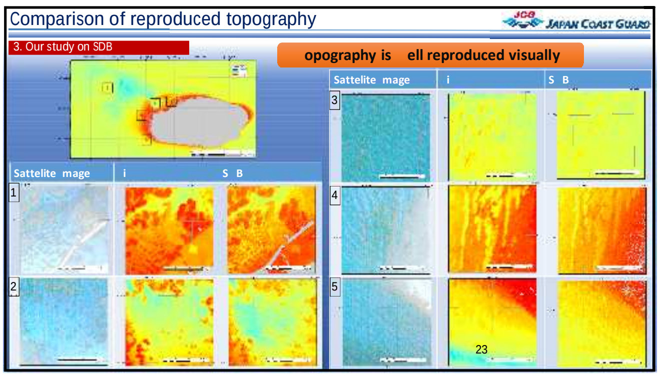
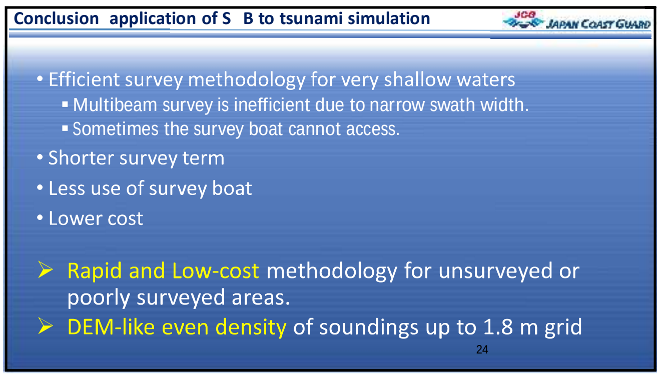


Comparison of reproduced topography
JAPAN COAST GUARD
3. Our study on SDB
opography is ell reproduced visually
Sattelite mage
i
S B
23



Conclusion application of S B to tsunami simulation
JAPAN COAST GUARD
• Efficient survey methodology for very shallow waters
▪ Multibeam survey is inefficient due to narrow swath width.
▪ Sometimes the survey boat cannot access.
• Shorter survey term
• Less use of survey boat
• Lower cost
➢ Rapid and Low-cost methodology for unsurveyed or poorly surveyed areas.
➢ DEM-like even density of soundings up to 1.8 m grid
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Public awareness and collaboration for disaster

Anawat Suppasri

Tsunami Engineering Research Field
International Research Institute of Disaster Science
Tohoku University

26 November 2015

Contents

2

The 2004 Indian Ocean tsunami: Situation in Thailand

Honor for young girl who saved tourists from tsunami

Tilly had studied tsunamis with her geography teacher, Andrew Kearney, shortly before flying to Thailand for a holiday with her parents and younger sister last year. As she watched the waves suddenly begin to recede, she warned her mother, Penny, that the beach was about to be struck by a tsunami. Mrs Smith and her husband, Colin, from Oxshott, Surrey, alerted other holidaymakers and hotel staff and scores of people were cleared from Maikhao beach at Phuket.

However, most of the tourists were likely or similar to this

Source: AFP/ The atlantic.com
http://www.theatlantic.com/photo/2014/12/ten-years-since-the-2004-indian-ocean-tsunami/100878

Regular sea level

Max. recession

Max. tsunami level

Source: Wikipedia
https://en.wikipedia.org/wiki/Effect_of_the_2004_Indian_Ocean_earthquake_on_Thailand

3

Situation in Sri Lanka

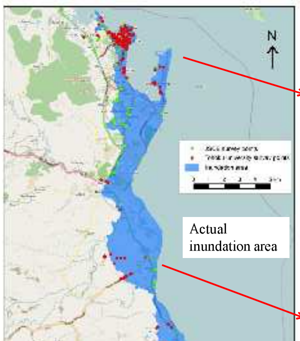
- known locally as the Queen of the Sea Line, was a regular train operating between the cities of Colombo and Galle.
- Only about 200 m inland from the sea
- The estimated no. of deaths is 1,700
- Employing the same guard who was on the train and survived the disaster
- The train, now restored with the same locomotive and two of its original carriages

Source: http://nalakagunawardene.com/2009/12/28/asian-tsunami5-how-a-packed-train-headed-to-disaster-with-no-warning/

Source: Digital globe, QuickBird satellite image

4

Storm surge inundation area in case of the 2013 Typhoon Haiyan



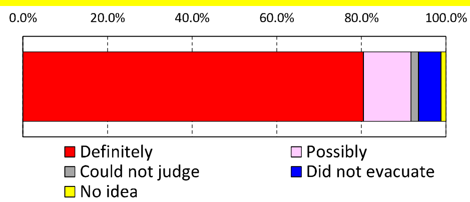
Developed inundation zone was much larger than that on the flood, storm surge hazard maps of Tacloban and Tanauan. (Mas et al., 2014 and Yi et al., 2014)

Terminology: Storm Surge VS Tsunami

✓ **Understood the meaning of "Storm Surge" *before* Yolanda?**

→ Yes = 12.8%

✓ **If you heard it was "tsunami", evacuated to anywhere else except your house?**



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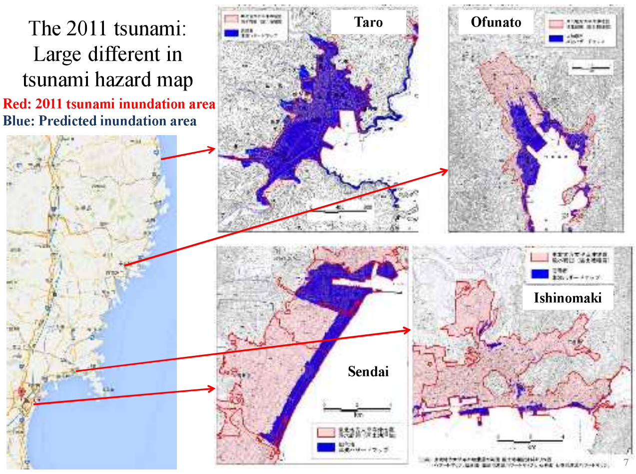
The 2011 tsunami: Large different in tsunami hazard map

Red: 2011 tsunami inundation area
Blue: Predicted inundation area



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Questionnaire survey related to tsunami evacuation (1)

By Cabinet Office, Fire Agency and Japan Meteorological Agency
-Total answers: 870 (Iwate = 391, Miyagi = 385 and Fukushima = 94), period: During July 2011
-A: Soon evacuated (57%), B: Evacuated after some actions (31%), C: Tsunami came during doing some actions (11%) and D: Did not evacuated (they were already in high ground) (1%)
-[A+B] Main reasons for starting evacuation: large shaking (48%), were asked to evacuate by family or surrounding people (20%) and surrounding people start their evacuation (15%)
→ Less amount of calling out for evacuation
-[B+C] Why they did not evacuated as soon as possible: Went back home (22%), looking for family or picking up family (21%), tsunami did not come in the past (11%) and did not think about tsunami coming (9%)
→ Have to reduce the amount of people going back home or seeking family

Condition of evacuation shelter
- C has the highest ratio of people who were inside the inundation area (38%)
- A and B are both mostly evacuated to designated evacuation shelters but C is large on the highest floor of the same building

Blue = outside inundation area
Red = inside inundation area
Green = could not identify

Source: Cabinet office of Japan

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Questionnaire survey related to tsunami evacuation (2)

Evacuation method
- In general, about 57% of people evacuated using car.
- Reason for using car: Not enough time without using car (34%), wanted to evacuate together with family (32%), far from safe place (20%)
- About 34% of them were trapped in the serious traffic.
- In general, limit distance for evacuation by walking was about 500 m and by car was 2 km.

Moving distance to the first evacuation shelter by evacuation method

		[illegible]	Median distance
Total	By walk	[illegible]	[illegible]
	By car	[illegible]	[illegible]
Iwate	By walk	[illegible]	[illegible]
	By car	[illegible]	1,775m
Miyagi	By walk	[illegible]	[illegible]
	By car	[illegible]	1,530m
Fukushima	By walk	12	[illegible]
	By car	[illegible]	[illegible]

Tsunami hazard map
- Number of people who had seen tsunami hazard map or had hazard map in their house was less than 20%

Source: Cabinet office of Japan

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Questionnaire survey related to tsunami evacuation (3)

By Weathernews
- Target area: Hokkaido, Aomori, Iwate, Miyagi, Fukushima, Ibaraki and Chiba
- Total answers: 5,296 (3,298 from survivors and 1,998 related to people who were casualty)

1) Time from earthquake generation to starting evacuation
- Survivor = 19 min and casualty = 21 min
2) Reason for starting evacuation
- Major tsunami warning or tsunami warning and only 28 % of the survivors soon evacuated
3) Evacuation condition
- Reason for not evacuated was they believe they were safe and 20% of victim could not evacuated
4) Selected evacuation place
- 75% of survivor could evacuated to safe place while 75% of victim could not
- 40% could not evacuate to high ground and 50% evacuated to non-designated evacuation place
5) Why they could not evacuate from the tsunami
- 18% of victim was because they were obstructed during their evacuation
6) Evacuated elevation from tsunami
- Approximately 2.9th floor for survivor and 1.7th floor for victim
7) Moving from evacuation place
- 60% of victim moved to tsunami inundation zone again
8) Reason for moving from evacuation place
- Looking for their family was the main reason

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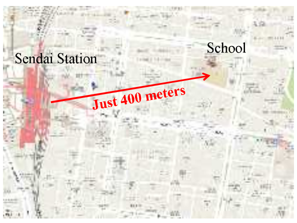
Lessons # 1: Tsutsujigaoka Elementary School

Number of evacuee = 2,500 !! (four times over than the estimation!!)

Source: Kahoku Shinpo
http://www.kahoku.co.jp/spe/spe_sys1071/20110726_01.htm

- Sendai station suffered serious damage → Failed to serve as evacuation shelter
- Just 10 min by walk from Sendai station
- Estimated no. of evacuee was only based on the local residence population which was 600
- About 1,200 meals were stored for 600 persons (1 person = 2 meals). After asking from other community, finally got 3,080 meals on the following day
- Most evacuee started leaving the school from 12th night
- The school served as evacuation shelter until 24th March



11

Lessons # 2: Arahama Elementary School

Most children survived excepted those who went back home with family

http://www.city.sendai.jp/fukko/__icsFiles/artimage/2011/09/09/c_70_70/110311tsunami2.jpg

http://pub.ne.jp/ebinet/image/user/1312539194.jpg

http://blog-imgs-36.fc2.com/j/o/s/josua1113/20110331204858158.jpg

12

Lessons # 3: Ogawa Elementary School

Tsunami from river: bad selection of evacuation shelter

http://blogs.yahoo.co.jp/eraser1eraser/62801660.html

- Dead: 74/108 children and 10/11 teachers
- Designated shelter but suffered damage → decided to move to the bridge in stead of high ground but steep slope. Tsunami will not reach the school in their estimation.
- Some survived by following family back home and climbed up hill but some could not

Lessons # 4: Hiyori Kindergarten

Leaving from high ground to death

- Located in high ground but decided to send children back home as some of them felt insecure and cold
- 7 children dropped at their home on the way but other 5 children got struck in the traffic and became casualty by the tsunami
- The court judged the kindergarten to pay children's parents 2.67 Million USD

http://memory.ever.jp/tsunami/higeki_hiyori.html

http://memory.ever.jp/tsunami/images-NP/0327-hiyori-NP.jpg

Lessons # 5: Kadonowaki Elementary School

Escaping from second disaster… fire

- The school was burnt by fire caused by sparking of car's battery and floating debris
- 230 of children could evacuated before tsunami arrival via stair next to the school while the rest 50 residence broke school glass and jumped from school to the high ground

http://memory.ever.jp/tsunami/higeki_hiyori.html

http://www.t01.com/11071205z.html

Lessons # 6: Unosumai Disaster Prevention Center

One actual disaster differ from million drills

- 34 survived and 128 or more becoming deaths
- Original evacuation places are on the high ground
- The center was newly opened on Feb 2010 and were used as a goal of tsunami evacuation drill on 3rd March 2011 or just 8 days before the event
- Tsunami reached almost the roof of the second floor
- As results, 150-200 residences selected this center as their evacuation destination

http://www.at-s.com/news/2012/03/07/images/11.jpg

http://www.chunichi.co.jp/article/earthquake/sonae/20120312/images/PK2012031202100063_size0.jpg

Lessons # 7: Unosumai Elementary and Junior high schools

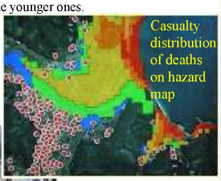
Miracle of Kamaishi… Awareness for expected event

- All nearly 3,000 students survived

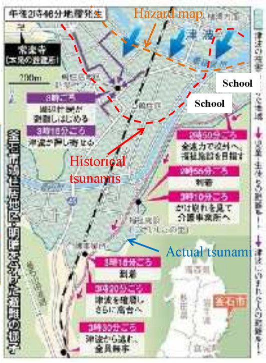
Three principles

- First, don't put too much faith in outdated assumptions. "In other words, don't trust hazard maps.
- The second rule of thumb is for people to make their best efforts to deal with the situation. They urged the teachers to keep moving higher, adding that the older kids also remembered to help the younger ones.
- And finally, to take the initiative in any evacuation.

http://mnj.gov-online.go.jp/kamaishi.html



http://insite.typepad.jp/.a/6a0120a6885bf1970b01543336c30e970c-320wi



http://www.chunichi.co.jp/article/earthquake/sonae/20120312/images/PK2012031202100063_size0.jpg

Our homepage

http://irides.tohoku.ac.jp/index.html

Connection between disaster areas and IRIDeS

Disaster prevention notebook for everyone

New disaster education tools and activities

Disaster digital archive

Deliver complicate science to simple knowledge

Tsunami evacuation drill

Kesennuma satellite office

To contribute to the recovery and the promotion of disaster mitigation measures in the areas affected by the Great East Japan Earthquake and Tsunami, the International Research Institute of Disaster Science (IRIDeS) has concluded comprehensive collaboration agreements with local governments affected by the disaster, strengthening commitments to local areas.

IRIDeS made an agreement with Kesennuma City in July 2013, and in October 2013, established the institute's first satellite office (branch office) within the city. The Kesennuma branch office (called Kesennuma Satellite) as its base, IRIDeS is passing on the latest research results and activities (by holding lectures on disaster risk reduction, exhibiting research results, etc.), as well as enhancing cooperative relationships and information sharing between IRIDeS and parties involved in recovery and disaster mitigation measures such as officials and other practitioners, citizens, and researchers.

Furthermore, Kesennuma Satellite is serving as a center for various action-oriented schemes such as collaboration with local governments on formation of regional disaster prevention plans and tsunami evacuation measures, and disaster digital archive projects that the institute is promoting (Michinoku Shinrokuden and Michinoku Ima o Tsutae-tai).

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Disaster notebook distributed in Japan

Details on how to prepare and what are important soon, 10 hours, 100 hours (4 days), 1,000 days (2 months) and 10,000 hours (1 year) after disaster

Iwate prefecture: 106,564 households

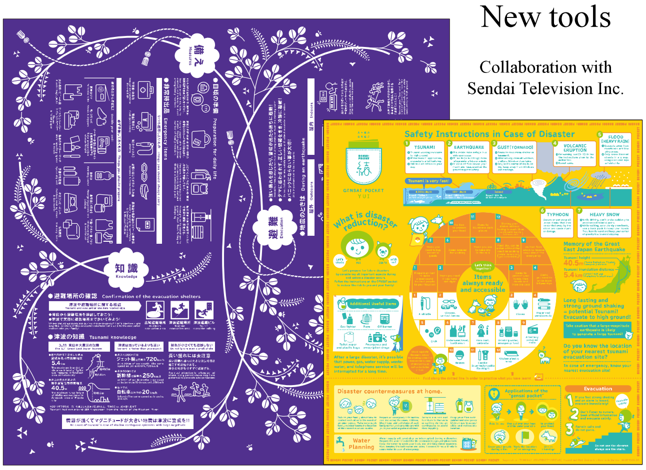
Tagajo city: 25,132 households

Takanabe town: 8,971 households

20

New tools

Collaboration with Sendai Television Inc.



Detail of disaster education program

みちのく震録伝 Tohoku University Disaster Archive project

http://shinrokuden.irides.tohoku.ac.jp/contents

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みちのく震録伝 Tohoku University Disaster Archive project

http://shinrokuden.irides.tohoku.ac.jp/contents

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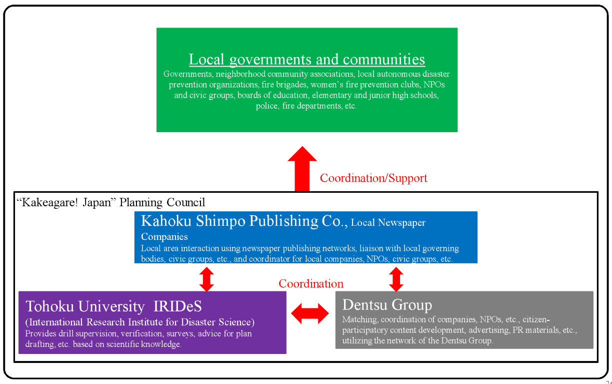
(勇気出して逃げろ / 「自らの命」と「地域」守る / 避難場所ごとのみ込まれ)

Kahoku Shinpo's special page on disaster prevention and reduction

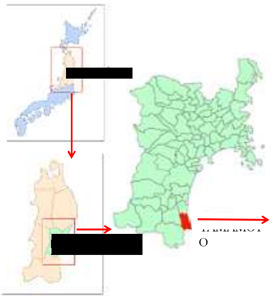
Kahoku Shinpo is the biggest newspaper company in Tohoku region. They put large effort and received some awards after the 2011 tsunami. This page is published every month on the 11th.

Implementation System



Yamamoto, Miyagi Prefecture(August 31,2013)

- The area is located on the Sendai plain, where there is no high ground and no tall buildings exist, requiring evacuation over a distance of several kilometers.
- A drill based on evacuation by car was carried out. (Those involved in recovery and reconstruction work also participated.)



KAKEAGARE! THAILAND(June 18,2014)

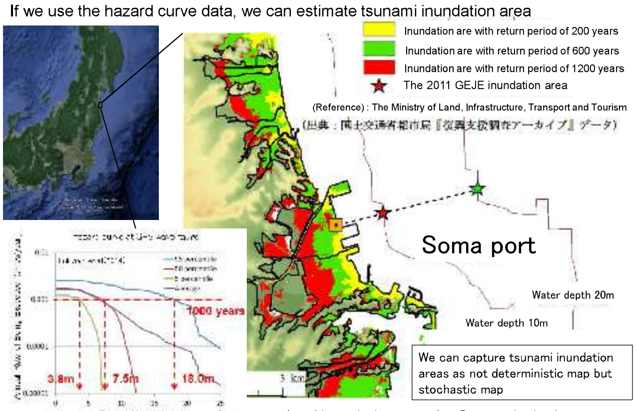
KAKE AGARE! THAILAND
Tsunami evacuation drill

Ban Kalim School
(Phuket, Thailand)

Incorporation with: Southern Meteorological Department (West Coast),TMD

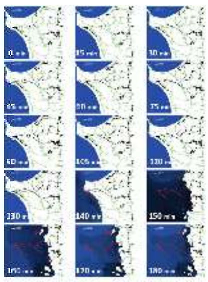
Stochastic tsunami hazard map

If we use the hazard curve data, we can estimate tsunami inundation area



An example of inundation map for Soma-city in Japan

Tsunami evacuation problems in Thailand

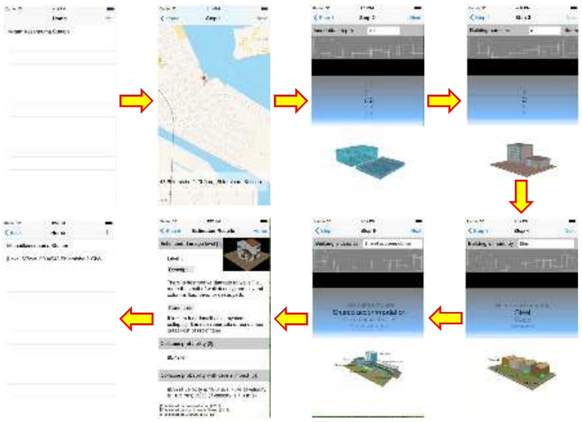


V (%)	E (μ) (min)	F (%)
0	30	23%
0	60	26%
0	90	30%
0	120	34%
25	30	9%
25	60	14%
25	90	21%
25	120	26%
50	30	7%
50	60	10%
50	90	16%
50	120	22%
75	30	6%
75	60	10%
75	90	16%
75	120	21%
100	30	7%
100	60	11%
100	90	15%
100	120	22%

"V" is the percentage of population using vehicles for evacuation. Either as driver or passenger. It is assumed that each car has four passengers.
"E" is the mean of the distribution (μ) used to construct the evacuation start time curve.
"F" is the Fatality ratio

Patong beach

DamageEstimateApp



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Summary

Lessons from the previous disaster such as the 2004 Indian Ocean tsunami, 2011 Japan tsunami and 2013 typhoon Haiyan showed us importance of public awareness and collaboration for disaster mitigation.

1. Understanding of generation mechanism of each disaster: Tsunami is not always followed by receding wave or strong typhoon can cause storm surge as high as 5-6 m.
2. Making and interpretation of hazard maps: We should prepare for unexpected events and more accurate hazard maps considering uncertainty should be provided.
3. Problems during evacuation are the most important topics to be solved: Late evacuation, using of vehicles, lower estimation of prepared items, going back home are common examples for the great loss.

We then put our effort for many collaborations with local governments, medias and other IT-related companies. We believe that these collaborative activities will help people to make better decision and safely evacuate.

1. Kesennuma satellite office and special column on Kahoku Shinpo will to transfer the most recent information among the researchers and locals (residents and governments)
2. Disaster prevention handkerchief, cloth warping and notebook are new education tools so that everyone can learn and increase their awareness during daily life
3. Disaster digital archive also helps recalling the disaster memories and lessons to next generations.
4. Kakeagare project performs many types of tsunami education drills so that locals will be ready for the next event.
5. Our new researches on hazard maps, damage estimation application and evacuation simulation are new tools for locals against disaster.

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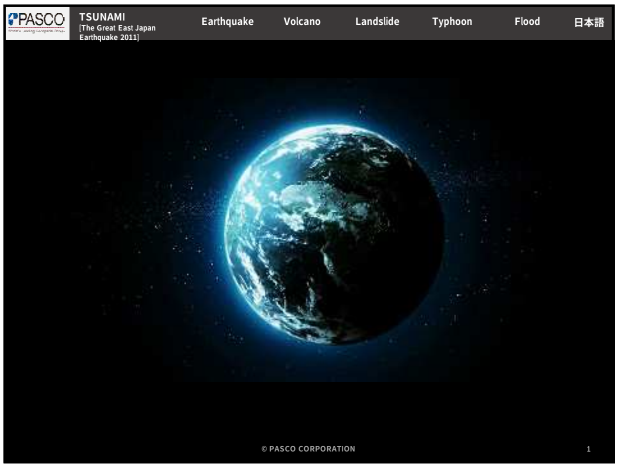
PASCO
TSUNAMI
[The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
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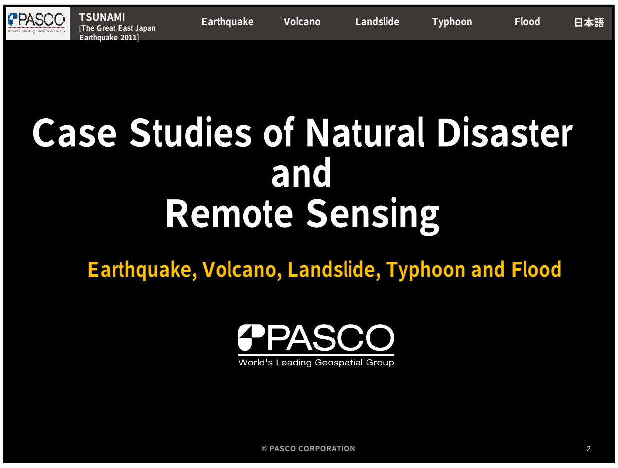
1


PASCO
TSUNAMI
[The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Case Studies of Natural Disaster
and
Remote Sensing
Earthquake, Volcano, Landslide, Typhoon and Flood
PASCO
World's Leading Geospatial Group
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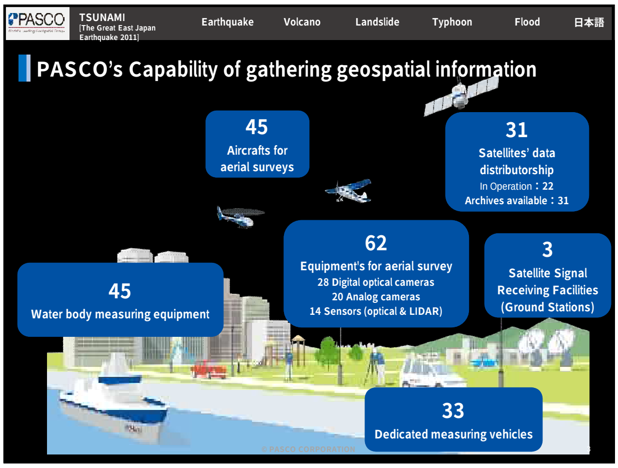
2


PASCO
TSUNAMI
[The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
PASCO's Capability of gathering geospatial information
45
Aircrafts for aerial surveys
31
Satellites' data distributorship
In Operation : 22
Archives available : 31
62
Equipment's for aerial survey
28 Digital optical cameras
20 Analog cameras
14 Sensors (optical & LIDAR)
3
Satellite Signal Receiving Facilities (Ground Stations)
45
Water body measuring equipment
33
Dedicated measuring vehicles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Volcano
Landslide
Typhoon
Flood
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TSUNAMI
3.11 The Great East Japan Earthquake
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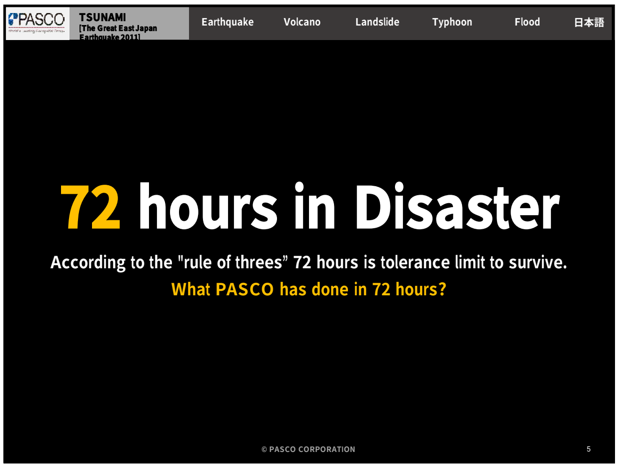
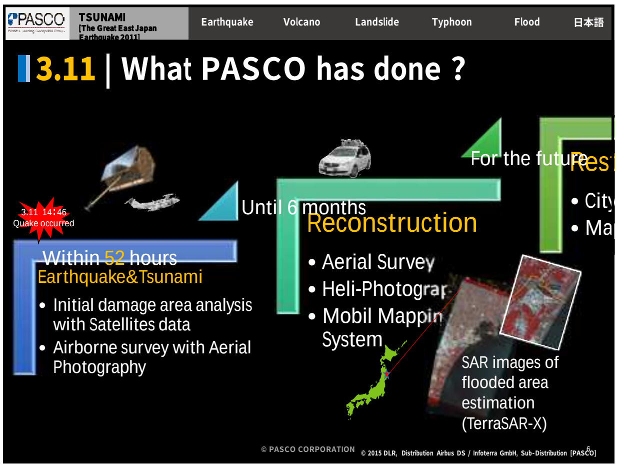
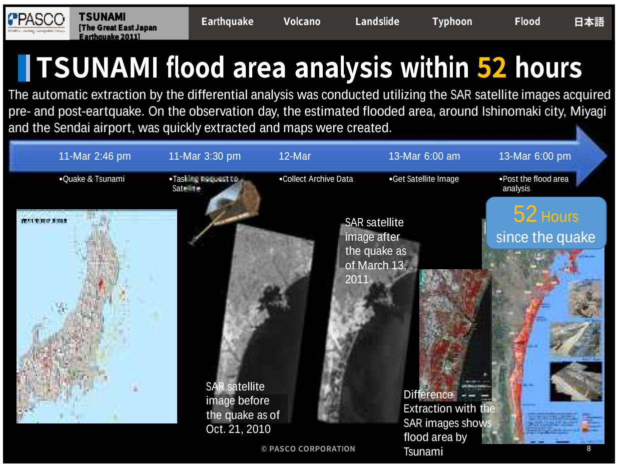
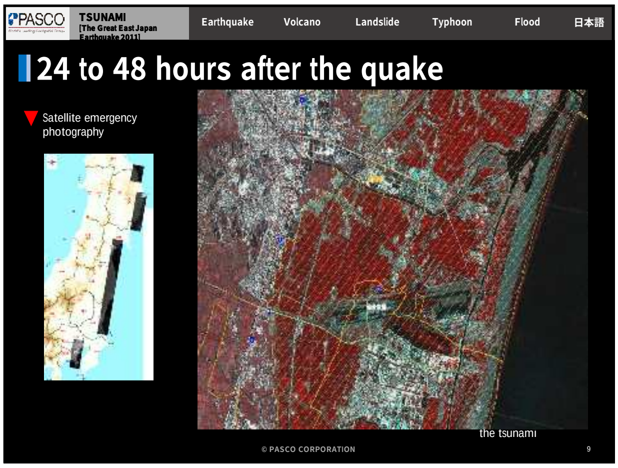

PASCO
TSUNAMI
[The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
72 hours in Disaster
According to the "rule of threes" 72 hours is tolerance limit to survive.
What PASCO has done in 72 hours?
© PASCO CORPORATION
5


PASCO
TSUNAMI
[The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
3.11 | What PASCO has done ?
3.11 14:46
Quake occurred
Within 52 hours
Earthquake&Tsunami
• Initial damage area analysis with Satellites data
• Airborne survey with Aerial Photography
Until 6 months
Reconstruction
• Aerial Survey
• Heli-Photograp
• Mobil Mappin System
For the future
• City
• Ma
SAR images of flooded area estimation (TerraSAR-X)
© PASCO CORPORATION
© 2015 DLR, Distribution Airbus DS / Infoterra GmbH, Sub-Distribution [PASCO]


PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
The First 72 Hours | What PASCO has done?
The 72 hours for first motion in disaster is the key
Quake & Tsunami
24 Hours
48 Hours
72 Hours
March 11 14:46pm
March 12
March 13
March 14
Order Tasking
First Satellite data acquisition after the quake
Continuous observation by satellites
Initial analysis of basic geospatial data
Uplink
Downlink
Estimated tsunami flooded area map
Preparing archive geospatial information;
Satellite images
Aerial photos
Population
Elevation data
Estimated seismic intensity distribution map 3/12 10:30
Extracted Area elevation under 10m 3/12 1:05 pm
Tsunami-Flooded area estimated map, Miyagi Coastal line 3/13 6:00 pm
52 Hours
Interpretation of the suspended & floating objects
© PASCO CORPORATION
7


PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
TSUNAMI flood area analysis within 52 hours
The automatic extraction by the differential analysis was conducted utilizing the SAR satellite images acquired pre- and post-eartquake. On the observation day, the estimated flooded area, around Ishinomaki city, Miyagi and the Sendai airport, was quickly extracted and maps were created.
11-Mar 2:46 pm
11-Mar 3:30 pm
12-Mar
13-Mar 6:00 am
13-Mar 6:00 pm
•Quake & Tsunami
•Tasking request to Satellite
•Collect Archive Data
•Get Satellite Image
•Post the flood area analysis
52 Hours since the quake
SAR satellite image after the quake as of March 13, 2011
SAR satellite image before the quake as of Oct. 21, 2010
Difference Extraction with the SAR images shows flood area by Tsunami
© PASCO CORPORATION
8


PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
24 to 48 hours after the quake
Satellite emergency photography
the tsunami
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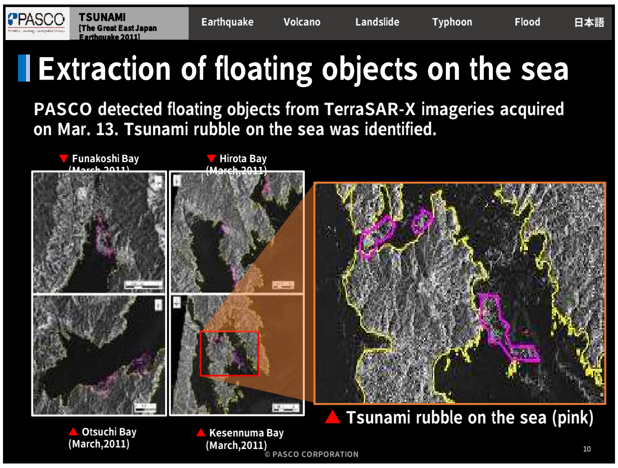
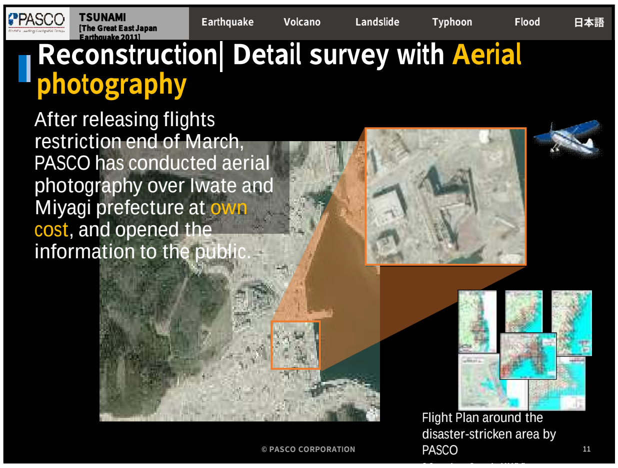
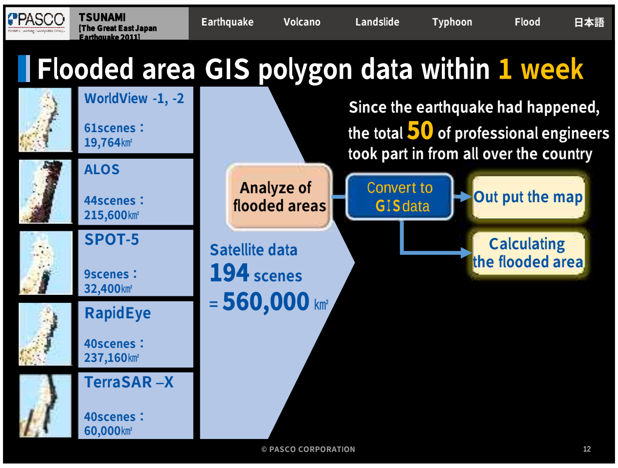
9


PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Extraction of floating objects on the sea
PASCO detected floating objects from TerraSAR-X imageries acquired on Mar. 13. Tsunami rubble on the sea was identified.
Funakoshi Bay (March,2011)
Hirota Bay (March,2011)
Otsuchi Bay (March,2011)
Kesennuma Bay (March,2011)
Tsunami rubble on the sea (pink)
© PASCO CORPORATION
10


PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Reconstruction| Detail survey with Aerial photography
After releasing flights restriction end of March, PASCO has conducted aerial photography over Iwate and Miyagi prefecture at own cost, and opened the information to the public.
Flight Plan around the disaster-stricken area by PASCO
© PASCO CORPORATION
11


PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Flooded area GIS polygon data within 1 week
WorldView -1, -2
61scenes : 19,764㎢
ALOS
44scenes : 215,600㎢
SPOT-5
9scenes : 32,400㎢
RapidEye
40scenes : 237,160㎢
TerraSAR –X
40scenes : 60,000㎢
Satellite data 194 scenes = 560,000 ㎢
Analyze of flooded areas
Convert to GIS data
Out put the map
Calculating the flooded area
Since the earthquake had happened, the total 50 of professional engineers took part in from all over the country
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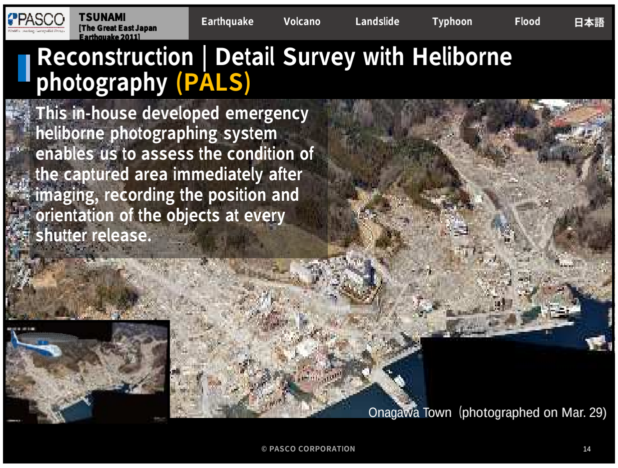
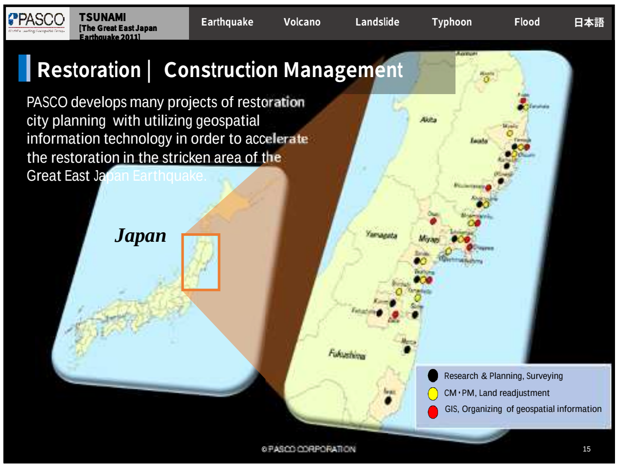
12


PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Reconstruction | Before/After the TSUNAMI (MMS)
At implementation of the emergency countermeasures, more detailed information has been demanded. PASCO collects the information by Mobile Mapping System (MMS) equipped with high precision GPS.
Before
After
Ishinomaki City
Nov.2008
April. 2011
© PASCO CORPORATION
13


PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Reconstruction | Detail Survey with Heliborne photography (PALS)
This in-house developed emergency heliborne photographing system enables us to assess the condition of the captured area immediately after imaging, recording the position and orientation of the objects at every shutter release.
Onagawa Town (photographed on Mar. 29)
© PASCO CORPORATION
14


PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Restoration | Construction Management
PASCO develops many projects of restoration city planning with utilizing geospatial information technology in order to accelerate the restoration in the stricken area of the Great East Japan Earthquake.
Japan
Research & Planning, Surveying
CM・PM, Land readjustment
GIS, Organizing of geospatial information
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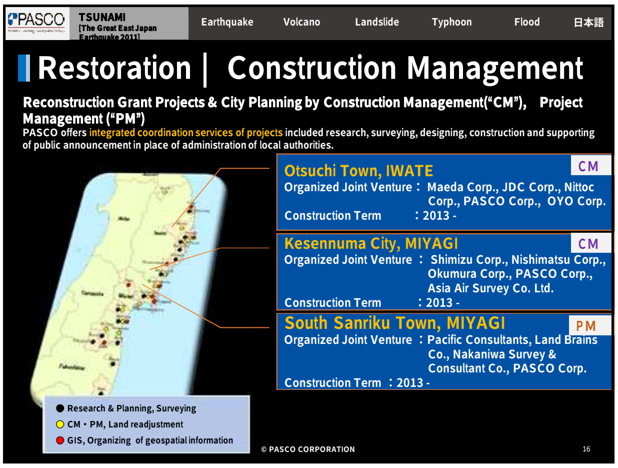
15


PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Restoration | Construction Management
Reconstruction Grant Projects & City Planning by Construction Management("CM"), Project Management ("PM")
PASCO offers integrated coordination services of projects included research, surveying, designing, construction and supporting of public announcement in place of administration of local authorities.
Otsuchi Town, IWATE
CM
Organized Joint Venture : Maeda Corp., JDC Corp., Nittoc Corp., PASCO Corp., OYO Corp.
Construction Term : 2013 -
Kesennuma City, MIYAGI
CM
Organized Joint Venture : Shimizu Corp., Nishimatsu Corp., Okumura Corp., PASCO Corp., Asia Air Survey Co. Ltd.
Construction Term : 2013 -
South Sanriku Town, MIYAGI
PM
Organized Joint Venture : Pacific Consultants, Land Brains Co., Nakaniwa Survey & Consultant Co., PASCO Corp.
Construction Term : 2013 -
Research & Planning, Surveying
CM・PM, Land readjustment
GIS, Organizing of geospatial information
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16


PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Restoration | Construction Management
City Planning projects in restoration land readjustment for the stricken city area
The project is to reorganize city infrastructure by land readjustment after the earthquake with improving efficiency of land use.
Shin Hebita, Ishinomaki City, MIYAGI
Construction Term : 2011 -
Source: Ishinomaki city website
Northern Gamou, Sendai City, MIYAGI
Construction Term : 2012 -
Source: Sendai city website
Surveying
CM・PM, Land readjustment
GIS, Organizing of geospatial information
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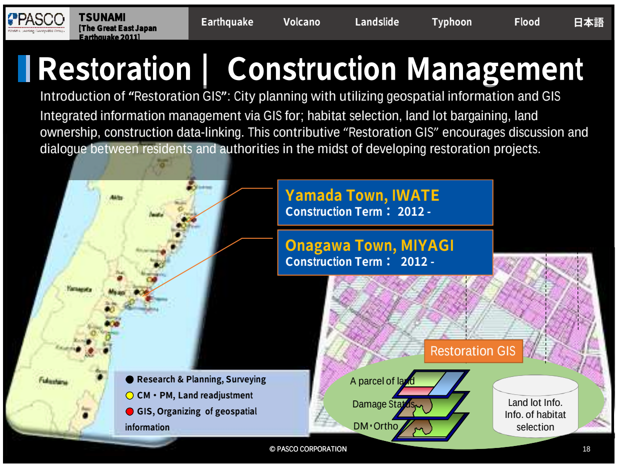
17


PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Restoration | Construction Management
Introduction of "Restoration GIS": City planning with utilizing geospatial information and GIS
Integrated information management via GIS for; habitat selection, land lot bargaining, land ownership, construction data-linking. This contributive "Restoration GIS" encourages discussion and dialogue between residents and authorities in the midst of developing restoration projects.
Yamada Town, IWATE
Construction Term : 2012 -
Onagawa Town, MIYAGI
Construction Term : 2012 -
Restoration GIS
DM・Ortho
Land lot Info.
Info. of habitat selection
Research & Planning, Surveying
CM・PM, Land readjustment
GIS, Organizing of geospatial information
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PASCO
TSUNAMI
[The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Case of Earthquake
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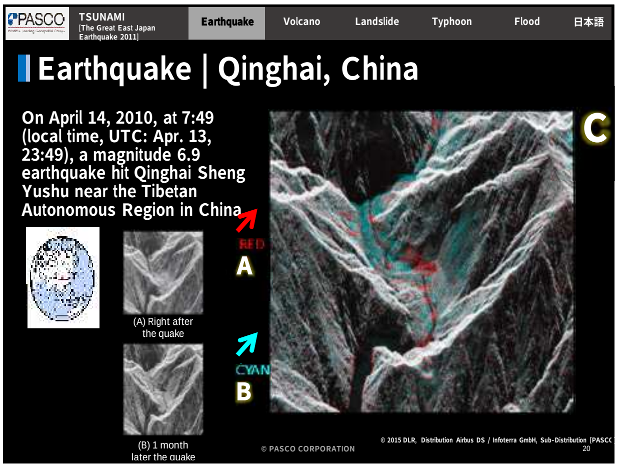
PASCO
TSUNAMI
[The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Earthquake | Qinghai, China
On April 14, 2010, at 7:49 (local time, UTC: Apr. 13, 23:49), a magnitude 6.9 earthquake hit Qinghai Sheng Yushu near the Tibetan Autonomous Region in China
C
RED
A
(A) Right after the quake
CYAN
B
(B) 1 month later the quake
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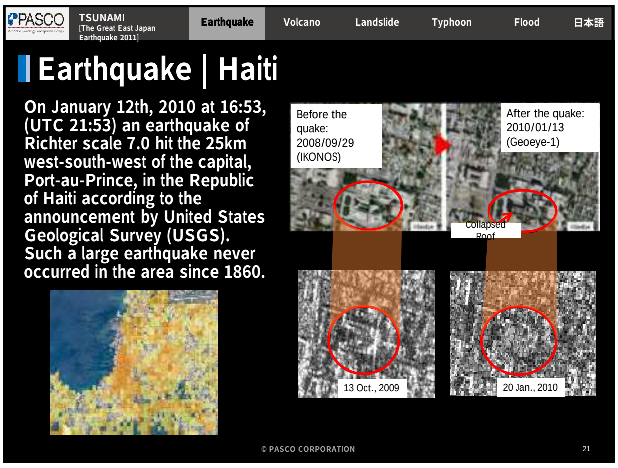
PASCO
TSUNAMI
[The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Earthquake | Haiti
On January 12th, 2010 at 16:53, (UTC 21:53) an earthquake of Richter scale 7.0 hit the 25km west-south-west of the capital, Port-au-Prince, in the Republic of Haiti according to the announcement by United States Geological Survey (USGS). Such a large earthquake never occurred in the area since 1860.
Before the quake: 2008/09/29 (IKONOS)
After the quake: 2010/01/13 (Geoeye-1)
Collapsed Roof
13 Oct., 2009
20 Jan., 2010
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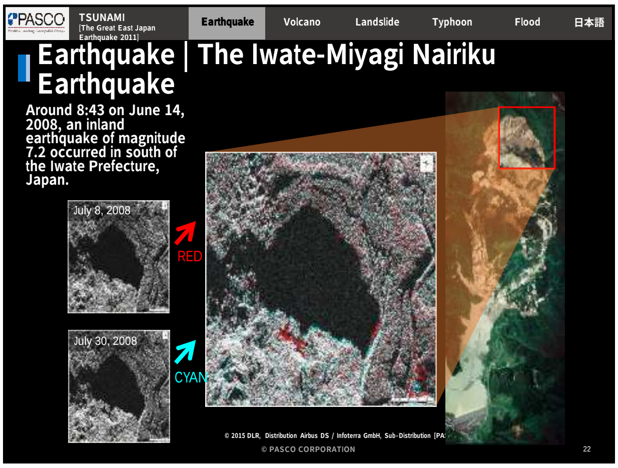
PASCO
TSUNAMI
[The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Earthquake | The Iwate-Miyagi Nairiku Earthquake
Around 8:43 on June 14, 2008, an inland earthquake of magnitude 7.2 occurred in south of the Iwate Prefecture, Japan.
July 8, 2008
RED
July 30, 2008
CYAN
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TSUNAMI
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Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Case of Volcano
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TSUNAMI
[The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Volcano | New Island "Nishinoshima"
Since November 20, 2013, PASCO has been observing a newly emerged island near Nishinoshima by satellites.The initial size was about 200 meters long, and the island is now larger than the pre-existing island.
西之島火山のモニタリング
PASCO
2013年11月30日
2013年12月14日
2013年12月24日
2014年1月5日
2014年1月16日
2014年1月29日
2014年2月18日
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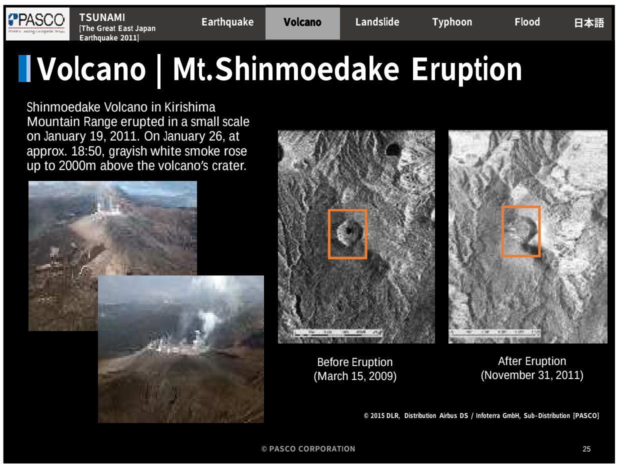
PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Volcano | Mt.Shinmoedake Eruption
Shinmoedake Volcano in Kirishima Mountain Range erupted in a small scale on January 19, 2011. On January 26, at approx. 18:50, grayish white smoke rose up to 2000m above the volcano's crater.
Before Eruption (March 15, 2009)
After Eruption (November 31, 2011)
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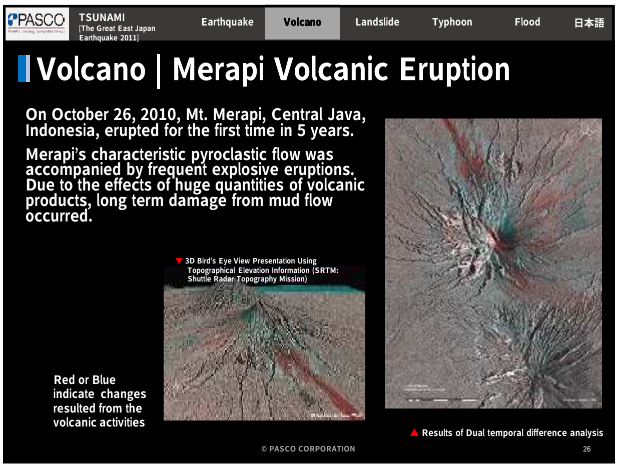
PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Volcano | Merapi Volcanic Eruption
On October 26, 2010, Mt. Merapi, Central Java, Indonesia, erupted for the first time in 5 years.
Merapi's characteristic pyroclastic flow was accompanied by frequent explosive eruptions. Due to the effects of huge quantities of volcanic products, long term damage from mud flow occurred.
▼3D Bird's Eye View Presentation Using Topographical Elevation Information (SRTM: Shuttle Radar Topography Mission)
Red or Blue indicate changes resulted from the volcanic activities
▲ Results of Dual temporal difference analysis
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TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Case of Landslide
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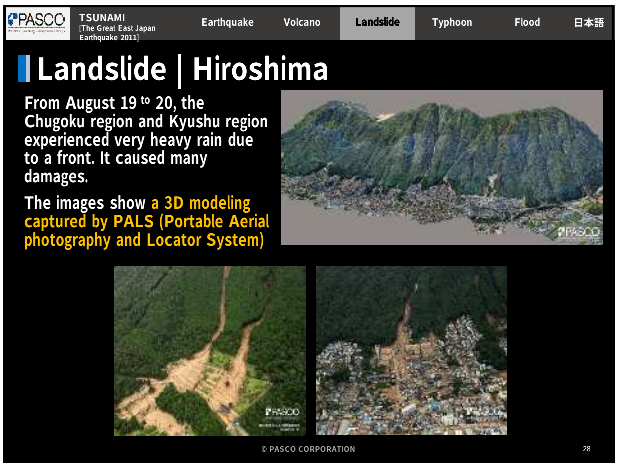
PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Landslide | Hiroshima
From August 19 to 20, the Chugoku region and Kyushu region experienced very heavy rain due to a front. It caused many damages.
The images show a 3D modeling captured by PALS (Portable Aerial photography and Locator System)
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TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Landslide | Hiroshima
2014年8月 広島市豪雨災害
PALS撮影による3次元モデリング
PASCO
© PASCO CORPORATION
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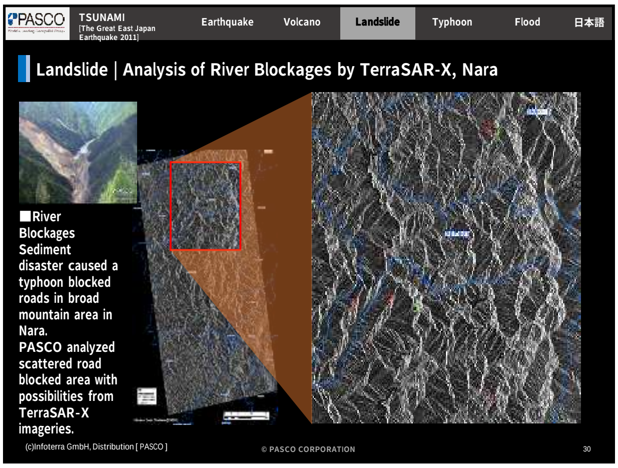
PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Landslide | Analysis of River Blockages by TerraSAR-X, Nara
■River Blockages
Sediment disaster caused a typhoon blocked roads in broad mountain area in Nara.
PASCO analyzed scattered road blocked area with possibilities from TerraSAR-X imageries.
(c)Infoterra GmbH, Distribution [PASCO]
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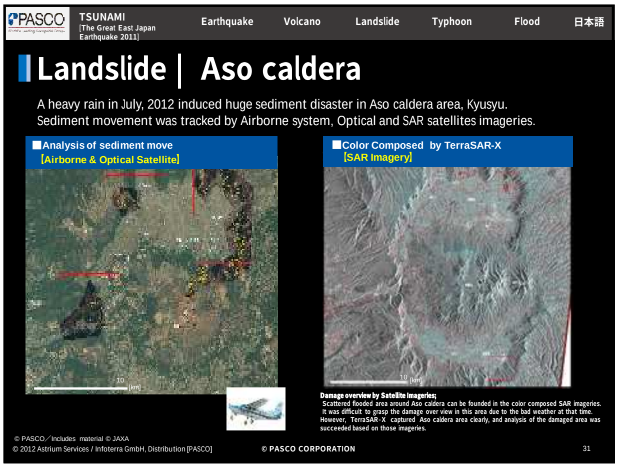

PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Landslide | Aso caldera
A heavy rain in July, 2012 induced huge sediment disaster in Aso caldera area, Kyusyu.
Sediment movement was tracked by Airborne system, Optical and SAR satellites imageries.
■Analysis of sediment move [Airborne & Optical Satellite]
■Color Composed by TerraSAR-X [SAR Imagery]
Damage overview by Satellite Imageries;
Scattered flooded area around Aso caldera can be founded in the color composed SAR imageries.
It was difficult to grasp the damage over view in this area due to the bad weather at that time.
However, TerraSAR-X captured Aso caldera area clearly, and analysis of the damaged area was succeeded based on those imageries.
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TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Case of Typhoon
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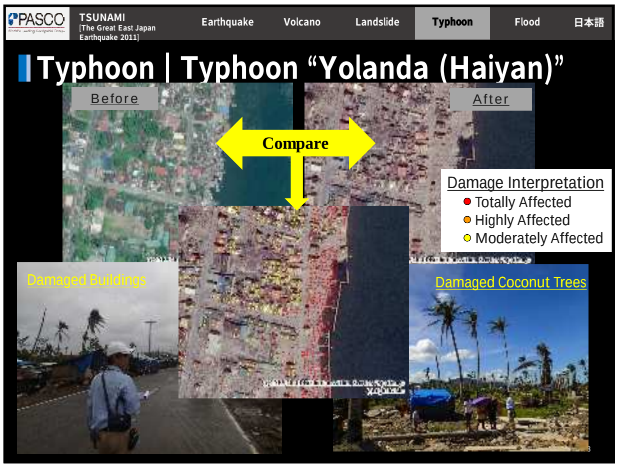
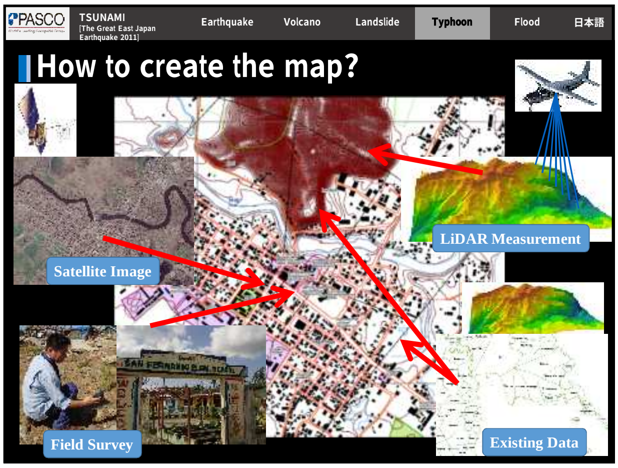


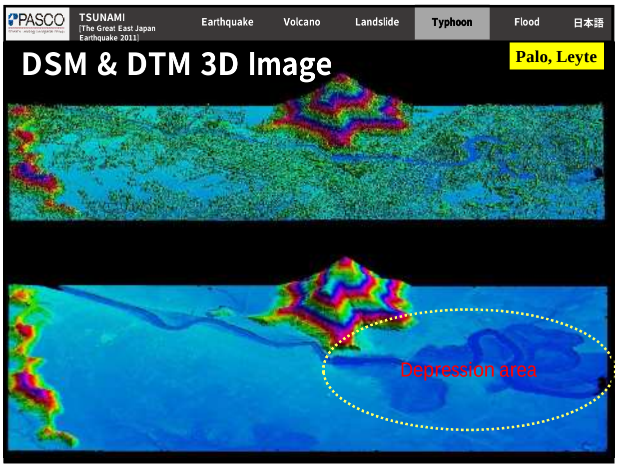
PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Typhoon | Typhoon "Yolanda (Haiyan)"
Before
After
Compare
Damage Interpretation
Totally Affected
Highly Affected
Moderately Affected
Damaged Buildings
Damaged Coconut Trees

PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Satellite Image Sample
Tacloban City, Leyte
(c)CNES 2014,Distribution Astrium Services / Spot Image
(c)DigitalGlobe

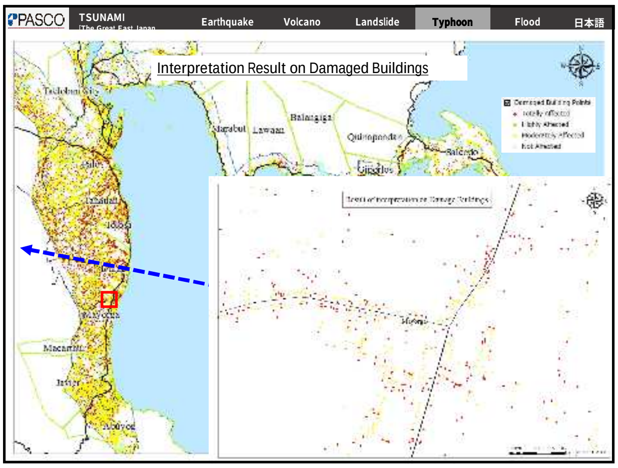


PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
How to create the map?
LiDAR Measurement
Satellite Image
Field Survey
Existing Data

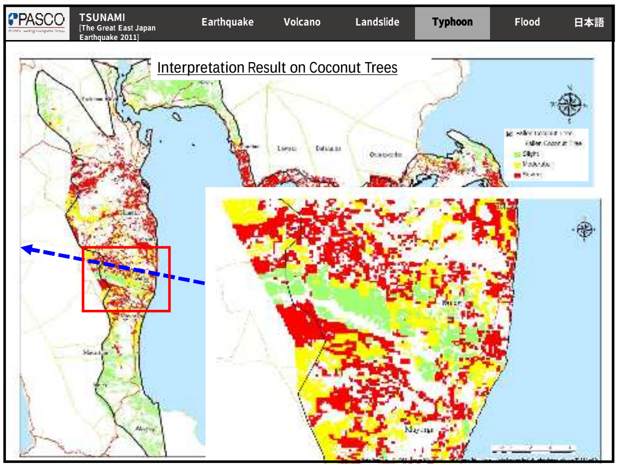
PASCO
TSUNAMI [The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
LiDAR Measurement Equipment
* Light Detection And Ranging
LiDAR sensor
Controlar & Disk for LiDAR



PASCO
TSUNAMI
[The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
DSM & DTM 3D Image
Palo, Leyte
Depression area



PASCO
TSUNAMI
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Interpretation Result on Damaged Buildings



PASCO
TSUNAMI
[The Great East Japan Earthquake 2011]
Earthquake
Volcano
Landslide
Typhoon
Flood
日本語
Interpretation Result on Coconut Trees

OIL

Case of Flood

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Flood | Chao Phraya River Basin, Thailand

Disaster Overview

The flooding that occurred in central Thailand from early October 2011 caused serious problems in 30 out of Thailand's 77 municipal districts (excluding southern Thailand), gravely impacting 2.34 million people in over 760,000 households (as announced by the Thai government on October 8), with the damage subsequently spreading even further.

Observe Industrial Estate with Satellites

These floods are believed to have had a major impact on Thailand's industrial zones, into which foreign companies have made considerable investments, as well as affecting the world economy.

- World well-known Japanese companies have industrial bases and brunches around central Bangkok. PASCO had observed Industrial estate area of Japanese companies with Satellites since the early phase of the flood.

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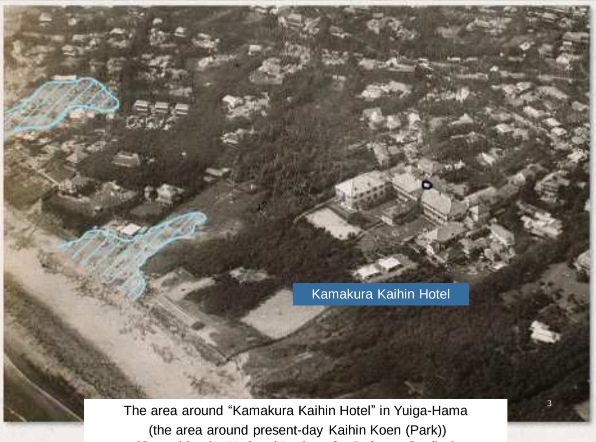
Example of Local Municipality in Japan

Nov. 26, 2015
Kamakura City, Kanagawa Pref.
Satoshi Nagasaki

Zaimokuza (Owned by the National Institute for Defense Studies)
(Tsunami struck up to the front of the main gate of Komyo-ji (temple))



The area around "Kamakura Kaihin Hotel" in Yuiga-Hama
(the area around present-day Kaihin Koen (Park))
(Owned by the National Institute for Defense Studies)

The Great Buddha of Kamakura
(A picture postcard)

THE GREAT EAST JAPAN EARTHQUAKE

- 11th March (Fri.), 2011 14:46 JST
- A massive earthquake of magnitude 9 (the largest earthquake ever recorded in Japan), off Sanriku, the Tohoku region
- Maximum JMA seismic intensity 7, Kurihara City, Miyagi Pref.
- Devastating damage by Tsunami in the greater area of the Pacific coast
- 9.3 m, the height of Tsunami in Soma, Fukushima Pref.
- A run-up height (at land) 40.5m, Miyako, Iwate Pref. The highest ever observed in Japan.
- Deceased and missing : Approximately 20,000 (90% of the casualties by Tsunami)
- JMA seismic intensity 4, Kamakura City. No human damage. Tsunami: About 2m by visual

A picture taken from the city office (11th March, 2011 15:27, Miyako city, Iwate Pref.)
(Presented by the Miyako City Office)

翻訳

The Tsunami striking the fire department headquarters office of Rikuzen-Takada city
(11th March, 2011 15:27, Rikuzen-Takada city)
Presented by the fire department headquarters of Rikuzen-Takada city

Sea level plate (height above sea level)

8

A sign for a Tsunami evacuation building

The following signs are placed on tsunami emergency evacuation buildings (Tsunami Evacuation Buildings) with which the city concluded a contract

9

A Tsunami evacuation drill
(An elementary school in Kamakura city)

10

Tsunami countermeasure training
in a seaside swimming area

11

A warning board of Tsunami

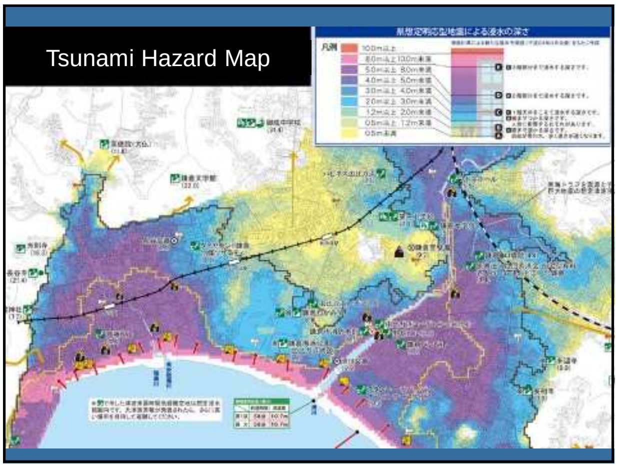
12

An embedded road sheet showing a Tsunami evacuation route

In order to secure a safe evacuation, a sheet showing a Tsunami evacuation route is laid on the road surface leading to evacuation facilities

13

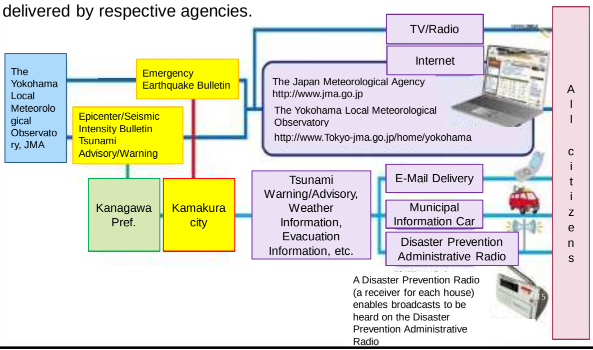
Tsunami Hazard Map



Communication Route for Disaster Prevention Information

Disaster prevention information is communicated by respective agencies through the following routes.

All citizens are advised to evacuate without delay utilizing information delivered by respective agencies.



Thank you for your attention

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Tsunami Information Map

Japan Hydrographic and Oceanographic Department
Geodesy and Geophysics Office

EAHC
Nov. 26, 2015

海上保安庁
JAPAN COAST GUARD

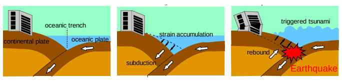
Outline

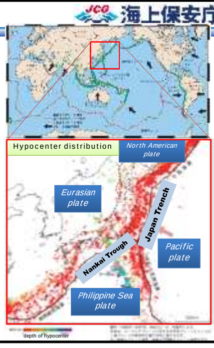
- Backgrounds
  - Earthquakes and Tsunami around Japan
  - Tsunami protection measures in Japan
  - The roles of Japan Coast Guard for Tsunami protection measures
- Tsunami information Maps for Mariners

1

Geological Setting of Japan

- Japan has historically suffered damage from huge earthquakes.
- The focal regions of such huge earthquakes usually lie beneath the seafloor, especially on the side of the Pacific Ocean.
- Two oceanic plate, the Pacific plate and the Philippine Sea plate, move under the Eurasian plate.

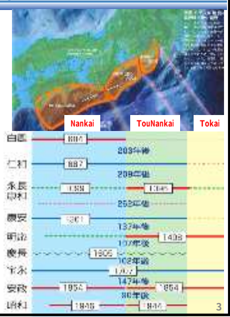




2

Huge earthquakes around Japan

- Nankai Trough
  - The Philippine Sea plate subucts under the Eurasian plate.
  - The huge earthquakes caused by the plate subduction occur periodically, 90-150 years interval.
  - The last earthquake of Tokai area occurred at 160 years ago.



3

Tsunami protection measures in Japan

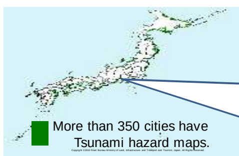
- Cabinet office (Central Disaster Management Council)
  - Developing the guideline for disaster prevention measures
  - Establishing the assumed fault models
  - Coordinating relevant ministries and agencies
- Japan Meteorological Agency
  - Issuing Tsunami warning
- Municipalities
  - Preparing Tsunami inundation Hazard maps and evacuation plans in the land area

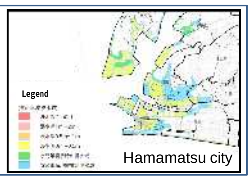
4

Tsunami Hazard Map

Tsunami Hazard Map

- Usually prepared by municipalities.
- Show the inundation area and the inundation height when predicted huge earthquake occurs.
- Used for making a residents' evacuation plan.
- Usually for the only land area.





5

For mariners…

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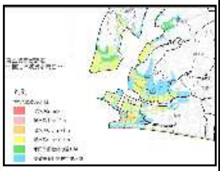
Difficult to use such Tsunami hazard maps

No information in sea area…

For making evacuation plan, we need current speed at least…



Tsunami Hazard Map for ships

6

Necessary information for making a ship evacuation plans

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- the arriving time of the first tsunami
  - Should departure from or stay at the port
- the distribution of the current speed / Tsunami height / current direction in the sea
  - Safer area in the sea
- the duration of Tsunami

7

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- To simulate of Tsunami requires both of the topographic model and the fault model.
  - Tsunami behavior depends on the topographic feature.
- Hydrographic and Oceanographic Department, Japan Coast Guard has collected a plenty of bathymetric data around Japan for making nautical charts and managing of the territorial water.
- HOD performs hydrographic surveys in order to provide the bathymetric data to help the disaster prevention.

8

Tsunami Information Map

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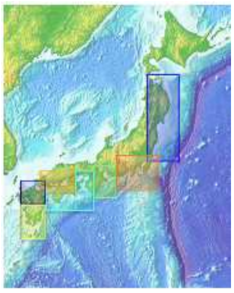

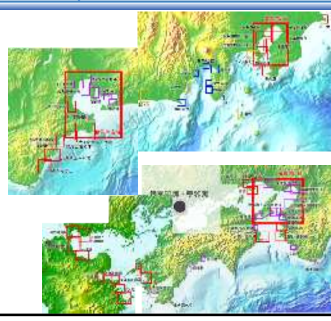

9

Tsunami Information Map

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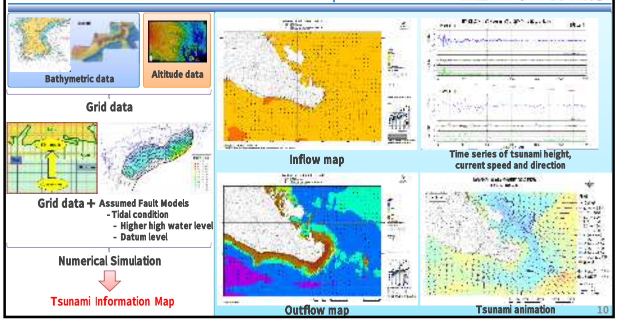

10

Inflow Map

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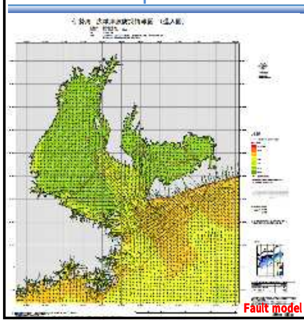
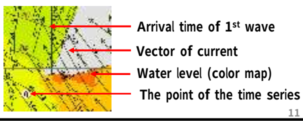


Infromation;

- Maximum water level
- Maximum current speed and direction
- Arrival time of 1st wave

Calculation conditions;

- higher high water level



11

Outflow Map

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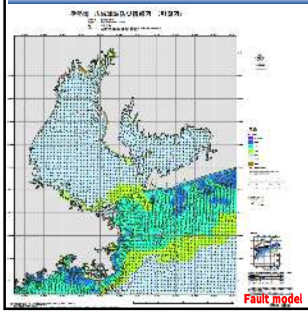
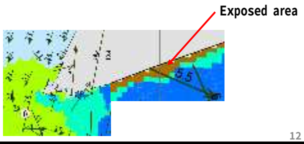


Infromation;

- Minimum water level
- Maximum current speed and direction
- Exposed area

Calculation conditions;

- Datum level



12

Animation and Time series

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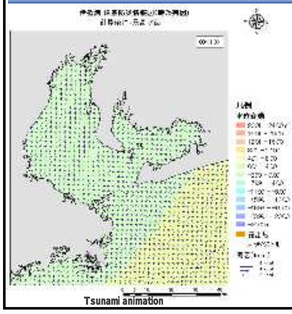

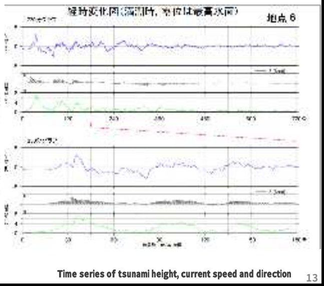

13

Usages of Tsunami Information Map

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14

Any questions…..?

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Thank you for your attention.

15

Summarised Result of the Questionnaire Survey for preparation of EAHC Tsunami Inundation Mapping Workshop

done by Japan Hydrographic and Oceanographic Department

1. Purpose of the Questionnaire Survey

In order to conduct the EAHC Tsunami Inundation Mapping Workshop fruitfully in Japan in November 2015, a questionnaire was circulated among the EAHC members by Japan Hydrographic and Oceanographic Department to know situation on tsunami inundation map and demands for the workshop in each member in advance to the workshop.

2. Results of the Questionnaire Survey

A response to the questionnaire was received from (8) members, China, Indonesia, Japan, Rep of Korea, Malaysia, Philippines, Singapore and Thailand.

The responses from the members were summarized as below, and details of the response were shown in Annex.

3. Summarized result of "Q 1. Which marine disasters are highly concerned in your country?"

The replies of the EAHC members to the questionnaire Q1 were summarized in table1. The highest concern of the members in marine disasters was tsunami. However, we can understand that, if we see the replies from the view on application of the inundation mapping, the members have a concern with the marine disasters to which the inundation mapping is applicable such as typhoon, heavy rain and storm surge.

Table 1. Type of Marine Disaster for that the EAHC members have high concern

Type of Marine Disaster	Number of the counties
Tsunami	6
Typhoon	3
Storm surges	2
Oil spills	4
Monsoon Squall / Tropical storm	2
Red tide	1

Q 1-1. If there is, let us know outline of the marine disasters happened in your country in recent years and, involvement and role of your Hydrographic Office against those marine disasters.

Each replied member had damages in recent years by the marine disasters which were shown high concern at the Q1.

Hydrographic Office of the replied members took the following actions against the marine disasters.

- ✓ Provision of information and materials to the responding organizations/agencies against the marine disaster, such as nautical charts, bathymetric information, sea condition (tide, current, water temperature etc.), trajectory prediction and other

reference information.
- ✓ Conducting monitoring activity of the sea condition in the damaged area.
- ✓ Conducting hydrographic survey to open approaches to the damaged area from the sea.
- ✓ Conducting hydrographic survey to search sunken ship.
- ✓ Provision of marine safety information (navigational warnings) for safety of navigation in the damaged area.
- ✓ Transport of relief supplies
- ✓ Did not prepare anything for the Indian Ocean tsunami in 2004. However after the disaster, tidal gauges for tsunami early warning system were installed and coastal hydrographic survey from coastline to the depth of 30 meters was conducted. (Thailand)
- ✓ Involved to establishment of Intern-Agency Committee on Risk Management Earthquake and Tsunami after the 2004 Indian Ocean Tsunami. The role of HO is to provide the bathymetry data as essential data in Tsunami Modelling. (Malaysia)
- ✓ Conducting sweeping survey after the disaster by typhoon in 2006. (China)

Q 1-2. If possible, please share with us about your faced problem and needs against the marine disasters.

The following issues were reported by the replied members as their faced problems and needs against the marine disasters.
- ✓ Cooperation among the organizations/agencies against the marine disasters
- ✓ Capability for the crisis management when the marine disaster was happened
- ✓ Capability of monitoring and provision of the precise and reliable sea level data.
- ✓ Understanding for mariners which navigational warnings are in effective within large numbers of the navigational warnings issued when a huge marine disaster was happened.
- ✓ HO will require continuous effort to resurvey the damaged area repeatedly after a huge disaster of earthquake and tsunami. The HO might need to re-determine a datum level and monitor a change of it, because a grand at the damaged area will move after the disaster in many case.
- ✓ Need to improve the nation's ability to alert populations in the specific marine disaster threatened area
- ✓ Lack of data and marine knowledge on preventions of the tsunami such as development of natural protection and human protection
- ✓ Sweeping survey after disasters and compilation of chart in the first time.

Q2. Dose National Contingency Plan for Disaster have been developed in your country?

All relied counties have established an organizational structure to cope with the disasters, and 6 counties have established a national contingency plan or a standard operating procedure for disaster.

Q2-1. If yes, dose it cover the marine disasters?

The marine disasters have been covered by the national contingency plan or the standard operating procedure of all the replied members.

Q2-2. Which organization has a primary responsibility on the National Contingency Plan for Disaster in your country?

A primary responsible organization for the national contingency plan or the standard operating procedure for disaster in the replied members were shown in table 2.

The national contingency plan or the standard operating procedure has been managed by another governmental body other than the organization to which HO has belong in the replied members except Singapore.

Table 2 Primary Responsible Organization for National Contingency Plan for Disaster in the replied members

Country	Primary Responsible Organization
China	Emergency management office of the state council For marine disasters, China Marine Search and Rescue Centre of MOT
Indonesia	National Disaster Management Authority (BNPB: Badan Nasional Penanggulangan Bencana)
Korea, Rep of	Ministry of Public Safety and Security
Malaysia	National Security Council and Malaysia Meteorological Department
Philippines	National Disaster Risk Reduction and Management Council (NDRRMC) under the Office of the President of the Philippines
Singapore	Maritime and Port Authority (within port waters)
Thailand	1. Department of disaster prevention and mitigation, Ministry of Interior (for tsunami and extreme weather) 2. Marine Department, Ministry of Transport (oil spill)
Japan	Central Disaster Management Council under the Cabinet Office

Q3. Does Tsunami Inundation Map or Storm Surge Inundation Map have been developed in your country?

Out of 8 replied members, 2 members have developed the tsunami inundation map or storm surge inundation map, 1 member has partially developed, 1 member has some pilot projects and 1 member has a plan to develop it.

Q3-1. If yes, which organization has a primary responsibility to develop such inundation map in your country? How is your Hydrographic Office involved in the development of inundation map?

As summarized in Table 3, Republic of Korea has plan that its HO, KHOA will take a primary responsibility to develop the inundation map from production, publicity and distribution. However, in other replied EAHC members, HOs provide bathymetry, sea level information to assist the development of inundation map by other responsible organization.

In Thailand, it is not clear which organization has a primary responsibility for the inundation map and there are several trial to develop the inundation map by some organizations. HO in Thai has supported those trials by providing bathymetric information and tidal data

although the HO has a plan of the own pilot project.

Table 3 Primary Responsible Organization for the Inundation Map and Role of Hydrographic Office in the Development of Inundation Map

Country	Development of Inundation Map	Primary Responsible Organization	Role of HO
China	Don't have much experience	MSA	Performing emergency survey and developing the related map from the acquired data
Indonesia	Research level		
Korea, Rep of	Plan	KHOA	production, publicity and distribution
Malaysia	Partially done	Malaysia Meteorological Department	Provision of bathymetry data
Philippines	Plan	PHILVOCS, PAGASA and NAMRIA	Provision of sea level data
Singapore	Yes	Singapore National Environment Agency	Provision of bathymetry and tide gauge info.
Thailand	Pilot Project	Not clear	Provision of bathymetry and tide gauge info.
Japan	Yes	Each local municipality	Provision of bathymetry

Q3-2. If your HO has been involved, please share with us about your faced problem and challenges to make the inundation map.

The following issues were listed by the replied EHAC members as the faced problem and needs to make the inundation map.

- ✓ Standardization of the inundation map
- ✓ Data and Information Collection
  - ➢ Accurate information
    - Coupling the vertical datums of land and sea for accurate inundation modelling
    - Determination of the extent of water inundation during a tsunami requires high-resolution topographic information and the numerical models using to represent flow through coastal area.
  - ➢ Lack of data
  - ➢ Numerical model
  - ➢ Sharing the related data among the agency.
    - Charging to the data due to the policy even the data is provided to the agency

of the inter-agency committee.

- ➢ Lack of accurate data related to the production of inundation map.
- ➢ Mobility
  - How to acquire the data immediately. For example, the shoreline changed after disasters.

Q4. What is your expectation to the EAHC Tsunami Inundation Mapping Workshop?

In terms of the technical views on the inundation map, the participating members are expecting to learn new techniques and methodology and share experiences and challenges in making tsunami inundation map at the EAHC Tsunami Inundation Mapping Workshop.

And they would like to know the following issues in addition to the knowledge and skill of the inundation map.

- ✓ Nature of Tsunami, such as effect to water column and duration of tsunami, and other factor to affect the landmass along the coastal area
- ✓ Sharing the experience of the EAHC members on countermeasures including how inter-agency work together to manage the resources for the recovery phase of the Tsunami.
- ✓ Education of the people with a medium being practice by the EAHC members

And then, some members are expected that after the workshop, the role of the Hydrographic Office will be clearly defined in terms of providing assistance during the occurrence of marine disasters.

Q5. Is there any request to the EAHC Tsunami Inundation Mapping Workshop?

The following issues are rose by the participating members;

- ✓ to provide a software to make Inundation Tsunami Map or numerical models for forecast tsunami propagation and inundation and,
- ✓ to promote further collaboration in the region to develop Tsunami Inundation Map in the member counties.
- ✓ to have more living instance.

Details of the Response by the EAHC members to the Questionnaire Survey for preparation of EAHC Tsunami Inundation Mapping Workshop

Q 1. Which marine disasters are highly concerned in your country?

[China]
Oil pollution, damage to ships, typhoon, and any other related to human life.

[Indonesia]
Earthquake and Tsunami Disaster

[Korea, Rep of]
Red tide phenomenon which appears frequently near Korean coast. Oil spill by which causes pollution of the sea

[Malaysia]
Malaysia has established the Inter-Agency Committee on Risk Management Earthquake and Tsunami in year 2010 in conjunction with the 2004 Indian Ocean Tsunami that claiming the lives of 68 Malaysians from among 220,000 worldwide.
Tsunami is known as one of the marine disasters which highly concerned in Malaysia, especially over the coastal areas of North region of Peninsular Malaysia (Kedah, Penang, Perlis and Perak) and Sabah.

[Philippines]
1. Typhoon
2. Storm surges
3. Tsunami
4. Oil Spills

[Singapore]
Storm Surges, Monsoon Squall and possible tsunami.

[Thailand]
- Tsunami
- Extreme weather such as typhoon, tropical storm and storm surge
- Marine accidents, oil spill

[Japan]
Tsunami disaster caused by a huge earthquake

Q 1-1. If there is, let us know outline of the marine disasters happened in your country in recent years and, involvement and role of your Hydrographic Office against those marine disasters.

[China]
Coastal areas in Fujian and Zhejiang province were hit by the typhoon saomai on August 10, 2006. The local people's lives and property suffered from huge losses. The emergency team from China maritime safety administration immediately went to Shacheng port for sweeping survey. The area of 28 square kilometres was surveyed and more than 140 wrecks were found, providing the strong technical support.

[Indonesia]
The role of our hydrographic office after tsunami happened, provides information about safe beach for landing ship to give humanitarian aid. We know that earthquake

and tsunami cause damage for some infrastructures such as: roads, bridges, ports and airport. Hydrographic Office have responsible for supporting the safety of navigation, for handling of marine disasters are handled by other institutes and coordinated by BNPB.

[Korea, Rep of]

The Sewol Ferry incident occurred on Apr. 14, 2014. The Korea Hydrographic and Oceanographic Administration took part in the disaster relief by giving information on the detailed topography and currents around Jindo where the ferry sank.

[Malaysia]

As the Malaysian National Authority for Hydrographic, National Hydrographic Centre of Malaysia involvement is aligning with the establishment of the Inter-Agency Committee on Risk Management Earthquake and Tsunami. The role of NHC is to provide the bathymetry data as essential data in Tsunami Modelling.

[Philippines]

1. Typhoon Yolanda (Haiyan) – 2013
2. Typhoon Pablo (Bopha) – 2012
3. Typhoon Sendong (Washi) – 2011
4. Typhoon Ondoy (Ketsana) – 2008
5. Guimaras Oil Spill – 2006

The Hydrography Branch of the National Mapping and Resource Information Authority (NAMRIA) conducted the following activities related to the disasters listed above:

- Transported relief goods to areas affected by typhoon Yolanda (Haiyan).
- Conducted hydrographic survey of Tacloban City after typhoon Yolanda (Haiyan) and after the earthquake in Bohol in 2013.
- NAMRIA tide stations were used to monitor the rise in sea level during the occurrence of an underwater earthquake.
- NAMRIA provided nautical charts and topographic maps and other data to government agencies and local government units for disaster relief and rehabilitation efforts.
- Search for M/T Solar 1 that sank of the coast of Guimaras that spilled 500,000 litres of oil using the multibeam system of the two survey vessels

[Singapore]

Nil

[Thailand]

- The Indian Ocean tsunami of 26 December 2004 hit the southwest coast of Thailand, which was about 500 km from the epicentre. The tsunami hit the coast at around high tide, there was dreadful tragedy, 5,400 people were killed and 3,100 people reported missing due to the tsunami in Thailand. The typical tsunami heights are 6 to 10 m. Thailand did not prepare anything for this tsunami. After this disaster, Hydrographic department installed tide gauges for tsunami early warning system and conducted coastal hydrographic survey from coastline to the depth of 30 meters by using multibeam technology in the area of southwest coast of Thailand.
- In Thailand storm surges have yearly occurred in both the east and west coastal areas of Thailand during monsoon season. The extreme weather affects coastal communities along the coast of Thailand and currents created by surge combine with waves to severely erode beaches and coastal highways.
- The Rayong oil spill occurred on July 27, 2013, in the Gulf of Thailand, off the coast of Ko Samet and Map Ta Phut in Rayong Province.

[Japan]

By the earthquake and the tsunami generated by the earthquake, 21,839 people are killed or missing (as of March 2015), wide area in the coast of the Tohoku region faced to the Pacific Ocean was devastated. JHOD as hydrographic office of Japan, has provided maritime safety information on failures of Aids to Navigation and driftage etc. caused by the earthquake and tsunami though issuing Navigational Warnings and Notice to Mariners. Furthermore, JHOD conducted surveys at 11 damaged major ports to open approaches for delivery of relief supplies, and then those ports were partially opened by the end of March 2011.

Q 1-2. If possible, please share with us about your faced problem and needs against the marine disasters.

[China]

The problems we face are the sweeping survey after disasters and compilation of chart in the first time.

[Indonesia]

Indonesian Waters is large that not all risk earthquake and tsunami region have landing beach. The need to improve the ability of management and mitigation of disasters that have cooperated with other offices as have been done in Japan.

[Korea, Rep of]

For the Sewol Ferry incident, we found some problem in the crisis response capability.

[Malaysia]

Lack of data and marine knowledge on preventions of the tsunami such as development of natural protection (e.g., replanting mangroves or coastal vegetation) and human protection (e.g., breakwaters, seawalls and dikes).

[Philippines]

The need to further improve sea level instrumentation and communication (e.g. internet connection) are important to deliver more accurate and reliable data and information during the occurrence of marine hazards.

[Singapore]

Nil

[Thailand]

Need to improve the nation’s ability to alert populations in the specific marine disaster threatened area.

[Japan]

At the disaster in 2011, many navigational warnings were issued. But, claim was made from some users that it was difficult to imagine which warnings were in effect and where the warning affect to. In response to the claim, JHOD tested providing information map as Navigational Warnings Location Map which visually summarized the effective navigational warning on the JHOD homepage. Through this experience, JHOD has started a new service that user can search Navigational Warnings issued by the JHOD on geographic map through the Internet since June 2014.

Because several bench marks and permanent tidal stations were destroyed in the damaged area, JHOD had to recover or install them. Furthermore, JHOD has continuously monitored a change of the ground level in the damaged area, because the ground level has been still changing gradually. When necessary, re-survey in those area will be conducted.

Q2. Dose National Contingency Plan for Disaster have been developed in your country?

[China]
Yes, it has been developed.
[Indonesia]
Our government has established a National Disaster Management Authority (Badan Nasional Penanggulangan Bencana/ BNPB) a body to act quickly and efficiently coordinates and manages disaster in a planned, integrated, and comprehensive.
[Korea, Rep of]
A new organization to response quickly and efficiently is established, controlling national disaster management systems chiefly.
[Malaysia]
Yes. National Contingency Plan was developed under the Inter-Agency Committee on Risk Management Earthquake and Tsunami. It was leaded by the Ministry of Science, Technology and Innovation (MOSTI) and supervised by National Security Council of Malaysia.
[Philippines]
Yes. The National Disaster Risk Reduction and Management Plan (NDRRMP) fulfills the requirement of RA No. 10121 of 2010, which provides the legal basis for policies, plans and programs to deal with disasters. The NDRRMP covers four thematic areas, namely, (1) Disaster Prevention and Mitigation; (2) Disaster Preparedness; (3) Disaster Response; and (4) Disaster Rehabilitation and Recovery, which correspond to the structure of the National Disaster Risk Reduction and Management Council (NDRRMC). By law, the Office of Civil Defence formulates and implements the NDRRMP and ensures that the physical framework, social, economic and environmental plans of communities, cities, municipalities and provinces are consistent with such plan.
[Singapore]
Singapore has a national inter-agency Tsunami Task Force with developed Standard Operating Procedures (SOP) on roles and responsibilities for responding to Tsunami in Singapore.
In addition, there are various SOP with various national agencies to address Search and Rescue, Ferry Mishaps, Oil/ Chemical Spills and other marine incidents.
[Thailand]
Yes
[Japan]
Yes, as national contingency plan for disaster, the Government of Japan has established Basic Disaster Management Plan under Disaster Countermeasure Basic Act.

Q2-1. If yes, dose it cover the marine disasters?

[China]
Yes, it does.
[Indonesia]
After earthquake and tsunami as Aceh in 2004, this agency has given its contribution to manage disaster at affected areas.

[Korea, Rep of]
Yes, the organization covers the marine disasters as well.
[Malaysia]
Yes. It covers all aspects related to marine disasters.
[Philippines]
The National Contingency Plan covers land and marine disasters.
[Singapore]
Yes
[Thailand]
Yes
[Japan]
The plan covers tsunami, storm surge and other marine disasters.

Q2-2. Which organization has a primary responsibility on the National Contingency Plan for Disaster in your country?

[China]
In China, emergency management office of the state council takes charge of the emergency affairs. For marine disasters, China Marine Search and Rescue Centre of MOT (Ministry of Transport of the People's Republic of China) coordinates the related issues. And China MSA is responsible for the rescue and the related technical support, such as emergency survey, emergency charting etc.
[Indonesia]
BNPB (Badan Nasional Penanggulangan Bencana) or National Disaster Management Authority. The agency is structured are in all provinces and districts / cities in Indonesia
[Korea, Rep of]
Ministry of Public Safety and Security
[Malaysia]
National Security Council and Malaysia Meteorological Department
[Philippines]
National Disaster Risk Reduction and Management Council (NDRRMC) under the Office of the President of the Philippines
[Singapore]
Within port waters, Maritime and Port Authority will be one of the main agencies responsible to coordinate efforts.
[Thailand]
There are two organizations responsible for marine disasters.
1. Department of disaster prevention and mitigation, Ministry of Interior (for tsunami and extreme weather)
2. Marine Department, Ministry of Transport (oil spill)
[Japan]
Central Disaster Management Council has been established in the Cabinet Office. The council consists of the Prime Minister as the chair, all members of the Cabinet, heads of major public corporations and experts. The Council develops the Basic Disaster Management Plan, establishes basic disaster management policies and deliberates important issues on disaster management.

Q3. Does Tsunami Inundation Map or Storm Surge Inundation Map have been developed in your country?

[China]

Some years ago, we made some typhoon track sketch-charts when we were suffering from the typhoon. Frankly speaking, we don't have much experience on Tsunami Inundation Map or Storm Surge Inundation Map. However, if needed, we would like to do the meaningful work after the disasters.

[Indonesia]

Research activities about tsunami seriously have be done in Indonesia, since tsunami happened at Flores in 1992. Researches were conducted on the two main purposes, such as research on the mechanism of tsunami generated, and research on tsunami wave propagation.

[Korea, Rep of]

We have a plan to develop the map.

[Malaysia]

Yes, however the tsunami inundation maps for Malaysia are not be fully delineated. Only suspected coastal region that are prone to tsunami hazard has been mapped especially for the coastal areas of Kedah, Penang, Perlis, Perak and Sabah.

[Philippines]

No. The Project Nationwide Operational Assessment of Hazards (NOAH) of the Department of Science and Technology (DOST) has nine components with different participating Philippine Government Agencies and organizations:

- Hydromet Sensors Development
- DREAM-LIDAR 3D Mapping
- Flood NET – Flood Information Network
- Strategic Communication
- Disaster Management using WebGIS
- Enhancing Geohazard Mapping through LIDAR and High-resolution Imagery
- Doppler System Development
- Landslide Sensors Development
- Storm Surge Inundation Mapping
- Weather Information Integration for System Enhancement (WISE).

[Singapore]

Yes

[Thailand]

Yes, some pilot projects of tsunami inundation map had been developed.

[Japan]

Yes.

Q3-1. If yes, which organization has a primary responsibility to develop such inundation map in your country? How is your Hydrographic Office involved in the development of inundation map?

[China]

China MSA. We are responsible for performing emergency survey and developing the related map from the acquired data.

[Indonesia]

Institutions active in research include BMKG, BPPT, LIPI, PPPG, PPGL, PU, ITS,

and ITB. Earthquake Monitoring System in Indonesia has been built by BMKG, it has 59 stations spread throughout Indonesia.

[Korea, Rep of]

The Korea Hydrographic and Oceanographic Administration is the primary organization for the inundation map; production, publicity and distribution.

[Malaysia]

The Malaysia Meteorological Department is the primary organization that responsibility for the development of tsunami inundation map in Malaysia. NHC as supporting organization in providing bathymetry data for uses in tsunami numerical modelling.

[Philippines]

The Philippine Volcanology and Seismology (PHILVOCS), the Philippine Atmospheric Geophysical and Astronomical Agency (PAGASA) and NAMRIA are the primary responsible agencies to develop such inundation map.

[Singapore]

Singapore National Environment Agency is primary responsible for the inundation map for Singapore. Singapore Hydrographic Office provided the bathymetry and tide gauges information for the development of the inundation map.

[Thailand]

- It is still not clear which organization has a primary responsibility to develop the inundation map. Several organizations such as Department of Disaster Prevention and Mitigation, Department of Mineral Resources and Educational Institution try to develop the inundation map.
- Hydrographic Department has supported bathymetric and tidal data to the organizations producing the inundation map and has a plan of pilot project for producing the inundation map in the area of Royal Thai Navy.

[Japan]

The Basic Disaster Management Plan requests each local municipality to prepare hazard maps which contain inundation areas by tsunami or storm surge. JHOD has provided the local municipality coastal bathymetric data, which is fundamental data for precise prediction of inundation by tsunami or storm surge.

Q3-2. If your HO has been involved, please share with us about your faced problem and challenges to make the inundation map.

[China]

Maybe the problem is how to acquire the data immediately. For example, the shoreline changed after disasters.

[Indonesia]

We do not yet to make the inundation map.

[Korea, Rep of]

Standardization of the inundation map

[Malaysia]

Sharing the related data among the agencies. Even the agency is under the Inter - Agency Committee on Risk Management Earthquake and Tsunami, but due to the policy, the data need to be paid for certain amount. Other things are the lack of accurate data related to the production of inundation maps.

[Philippines]

Other Branch of NAMRIA is responsible in the production of inundation map, however, the Hydrography Branch provided sea level data to the project.

[Singapore]
One of the main problems is the need to tie in the vertical datums for land and sea for accurate inundation modelling. In this regard, the Hydrographic Office coordinate effort with our Land Authority to address the challenges.
[Thailand]
Determination of the extent of water inundation during a tsunami requires high-resolution topographic information and the numerical models using to represent flow through coastal area.
[Japan]
JHOD has not been directly involved in making the inundation map.

Q4. What is your expectation to the EAHC Tsunami Inundation Mapping Workshop?

[China]
We expect to learn more about Tsunami Inundation Mapping and draw on the experience and good results from other Member States of EAHC, especially the high-risk natural disaster countries.
[Indonesia]
Our Hydrographic Office hopes to join the workshop and make Inundation Tsunami Map.
[Korea, Rep of]
Sharing of techniques to develop the mapping.
[Malaysia]
My expectations are as follows:-
a. To gain knowledge on the development made by EAHC members;
b. To reproduce the Tsunami Inundation Map developed by Malaysia to meet highly accurate forecast; and
c. To educate the people with a medium being practice by EAHC members.
[Philippines]
- The EAHC Tsunami Inundation Mapping Workshop would be a good opportunity to learn new techniques and methodology in making tsunami inundation map. It is expected that after the workshop, the role of the Hydrographic Office will be clearly defined in terms of providing assistance during the occurrence of marine disasters.

[Singapore]
- To understand what other factors could affect the land mass along coastal area during a Tsunami.
- Other than the extent of the inundation inland, how a Tsunami affects the surrounding water column and the duration of the Tsunami which is often overlooked.
- Sharing and learning from real life practical experience from Member States on their respond to natural disasters such as Tsunami
- To understand how inter-agency work together to manage the resources for the recovery phase of the Tsunami.

[Thailand]
The workshop will make me to know how to develop tsunami inundation map.
[Japan]
To share experiences and challenges of each member states among the participants.

Q5. Is there any request to the EAHC Tsunami Inundation Mapping Workshop?

[China]
We would like to have more living instance.
[Indonesia]
The workshop also discuss the tsunami mitigation ever implemented at Japan, and the participants get a software to make Inundation Tsunami Map.
[Korea, Rep of]
Mutual assistance for the development of inundation mapping.
[Malaysia]
Yes. Based on the achievement made by EAHC in knowledge and technologies. We are looking forward to further collaboration with EAHC in developing of Tsunami Inundation Mapping for Malaysia.
[Philippines]
Nil
[Singapore]
Nil
[Thailand]
Numerical models hoe forecast of tsunami propagation and inundation.
[Japan]
No.

------ End of Report ------

NATIONAL MAPPING AND RESOURCE INFORMATION AUTHORITY
HYDROGRAPHY BRANCH

Tsunami Inundation Mapping in the Philippine Hydrographic Office

LTJG RODEL G GUARTE

1

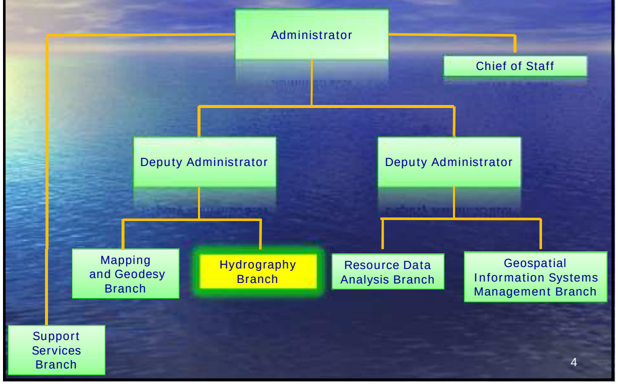
2

National Mapping and Resource Information Authority (NAMRIA)

- is mandated to provide the public with mapmaking services and to act as the central mapping agency, depository, and distribution facility for natural resources data in the form of maps, charts, texts, and statistics.
- NAMRIA's vision is to become a center of excellence, building a geospatially-empowered Philippines by 2020. Its mission is to provide accurate, timely and accessible topographic maps, nautical charts and other geospatial products and services.

3

NAMRIA Organizational Structure



4

HYDROGRAPHY BRANCH

- Conducts hydrographic and oceanographic surveys
- Provides nautical charts, tide and current predictions, and maritime publications
- Responsible for the delineation of the various maritime zones such as archipelagic waters, territorial sea and contiguous zone
- Maintain and operate tide stations (telemetry and non telemetry)

5

What is NAMRIA's participation in the Tsunami Risk Reduction and Management?

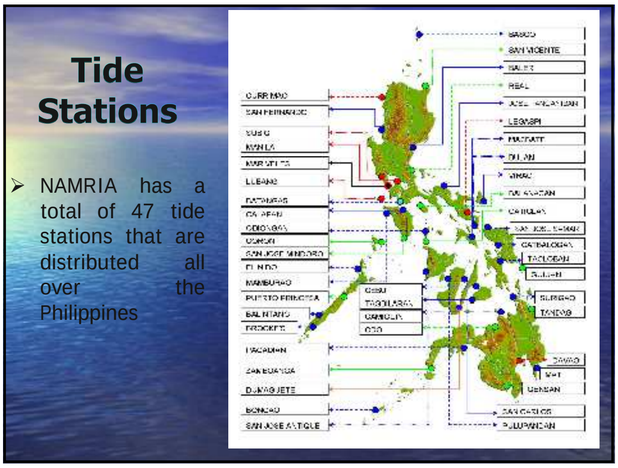
1. NAMRIA, thru its HYDROGRAPHY BRANCH, operates tide stations which provides near real-time sea level data to international programme and organizations such as:
   a. Intergovernmental Oceanographic Commission (IOC)
   b. Global Sea Level Observing System (GLOSS)
   c. University of Hawaii Sea Level Center (UHSLC)
   d. Pacific Tsunami Warning Center (PTWC)
   e. Regional Integrated Multi-hazard Early Warning System for Africa and Asia (RIMES)

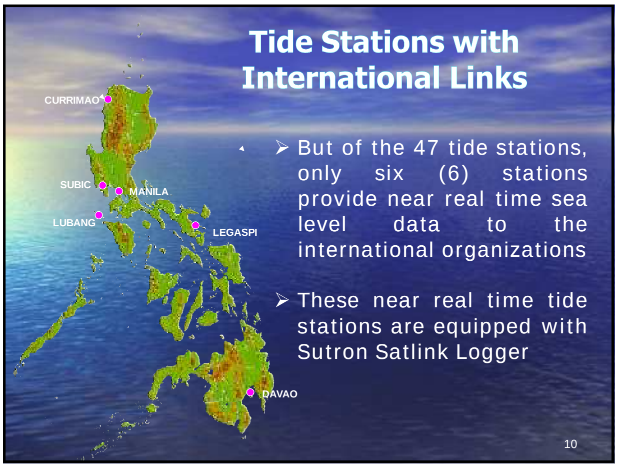
The above organizations use the sea level data gathered for near real time monitoring of tsunami and storm surge as well as in the study of sea level rise.

6

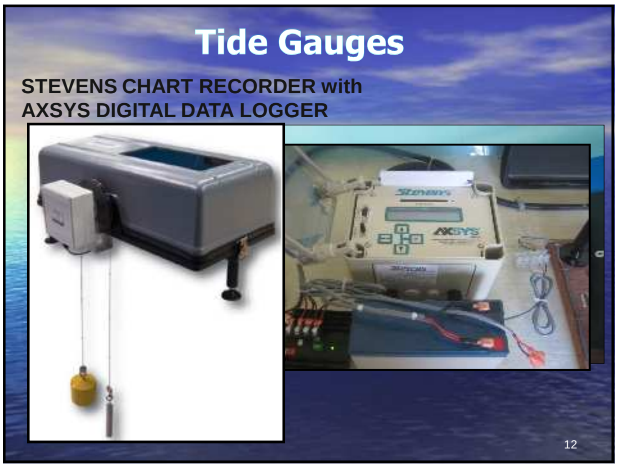

Tide Stations
BULAN
PRIMARY TIDE STATION
7


Physical Oceanography Division
BM-2
2007
NAMRIA
8


Tide Stations
NAMRIA has a total of 47 tide stations that are distributed all over the Philippines
SAN VICENTE
REAL
LEGASPI
BULAN
CATBALOGAN
TACLOBAN
SURIGAO
TANDAG
DAVAO
GENSAN
SAN CARLOS
PULUPANDAN
CURRIMAO
SAN FERNANDO
SUBIC
MANILA
LUBANG
BATANGAS
ODIONGAN
SAN JOSE MINDORO
MAMBURAO
PUERTO PRINCESA
CEBU
TAGBILARAN
CAMIGUIN
ZAMBOANGA
DUMAGUETE
BONGAO
SAN JOSE ANTIQUE


Tide Stations with International Links
CURRIMAO
SUBIC
MANILA
LUBANG
LEGASPI
DAVAO
But of the 47 tide stations, only six (6) stations provide near real time sea level data to the international organizations
These near real time tide stations are equipped with Sutron Satlink Logger
10

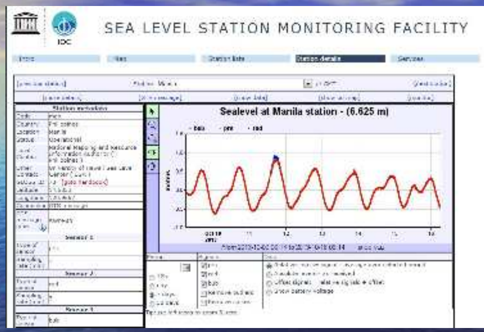

Tide Gauges
OTT STRIP CHART WATER LEVEL RECORDER
with OTT THALIMEDES DIGITAL DATA LOGGER
11


Tide Gauges
STEVENS CHART RECORDER with
AXSYS DIGITAL DATA LOGGER
Stevens
AXSYS
12

SUTRON SATLINK LOGGER

13

Tide Stations with International Links



IOC website: *http://www.ioc-sealevelmonitoring.org/*

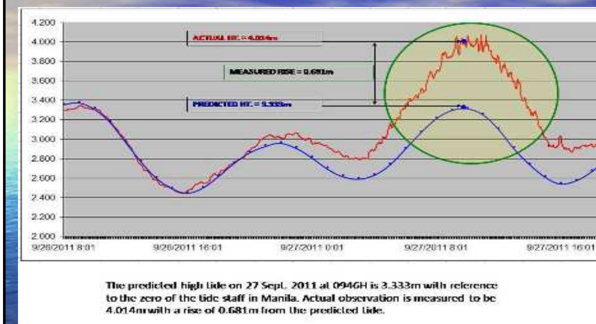
14

What is NAMRIA's participation in the Tsunami Risk Reduction and Management?

2. NAMRIA tide stations are also being used in the post-tsunami assessment.

15

Storm Surge Assessment



Storm surge effect observed at Manila Tide Station
during Typhoon NESAT (Pedring)

16

Tsunami Assessment

Tsunami effect observed at several tide stations
after Sendai/Tohoku Earthquake

17

What is NAMRIA's participation in the Tsunami Risk Reduction and Management?

3. In terms of tsunami inundation mapping, NAMRIA had participated in the RIMES training on low-cost near-shore bathymetric and topographic surveys, survey data processing and Digital Elevation Model (DEM) generation, and workshop on INSPIRE and ESCAPE software applications for tsunami hazard and risk assessment and evacuation planning.

This training was conducted in 2013 and was funded by UN Economic and Social Commission for Asia and the Pacific (ESCAP)

18

Highlights of the RIMES Training

The training was divided into 3 parts:

a. Low-cost near-shore bathymetric, topographic, and exposure survey methodologies

b. Data processing to generate Digital Elevation Model (DEM) required for tsunami risk assessment

c. Use of Internet-based tool for tsunami risk assessment (named INSPIRE), and computer-based evacuation mapping tool (named ESCAPE)

19

Highlights of the RIMES Training

A pilot site was selected in Olongapo City, Philippines wherein the survey data acquired during the training were used to generate tsunami risk assessment and evacuation mapping for the pilot site

20

Highlights of the RIMES Training

- Training on low-cost near-shore surveys
  - Actual bathymetric and topographic surveys were conducted last 18 January to 01 February 2013 in the Philippines
  - Purpose of the survey was to generate final DEM of the seabed and land area for tsunami risk and inundation assessment
  - Low-cost equipment were used (handheld GPS receiver, commercial fish finder sonar)

21

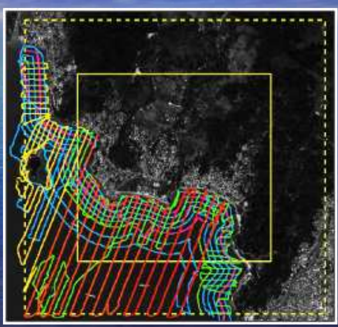
Highlights of the RIMES Training

- Training on low-cost near-shore surveys

22

Highlights of the RIMES Training

- Training on low-cost near-shore surveys



23

Highlights of the RIMES Training

- Training on low-cost near-shore surveys

24

Highlights of the RIMES Training

- Training on low-cost near-shore surveys

Highlights of the RIMES Training

- Training on survey data processing and DEM generation
  - Conducted in Thailand last 17 June to 20 July 2013

Highlights of the RIMES Training

- Training on the use of tsunami risk assessment and evacuation mapping software applications, INSPIRE and ESCAPE
  - Conducted in the Philippines last 24-28 September 2013
  - Near-shore DEM and exposure data, which were produced in the Thailand training, were used as inputs to INSPIRE and ESCAPE software applications
  - Tsunami inundation maps, evacuation routes, and shelter location capacity were generated

Highlights of the RIMES Training

- Training on the use of tsunami risk assessment and evacuation mapping software applications, INSPIRE and ESCAPE

INSPIRE web address: *http://inspire.rimes.int/page_login.php*

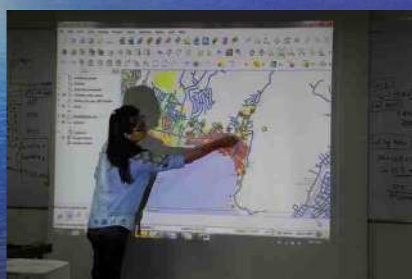
Highlights of the RIMES Training

- Training on the use of tsunami risk assessment and evacuation mapping software applications, INSPIRE and ESCAPE

ESCAPE web address: *http://escape.rimes.int/*

Highlights of the RIMES Training

- Training on the use of tsunami risk assessment and evacuation mapping software applications, INSPIRE and ESCAPE



Highlights of the RIMES Training

- Training on the use of tsunami risk assessment and evacuation mapping software applications, INSPIRE and ESCAPE

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Present Role of NAMRIA in Tsunami Inundation Mapping

- Although NAMRIA was involved in some of the trainings regarding tsunami inundation mapping, NAMRIA is not directly involved in the production of tsunami inundation maps and in the distribution of tsunami warning advisories.
- NAMRIA's present role is limited only to monitoring and evaluation of post-tsunami events. The Philippine Institute of Volcanology and Seismology (PHIVOLCS) is the Philippine institution dedicated in monitoring volcano, earthquake, and tsunami, and issues warnings as necessary. PHIVOLCS is mandated to mitigate disasters that may arise from such volcanic eruptions, earthquakes, tsunamis, and other related geotectonic phenomena

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- END -

Thank you!

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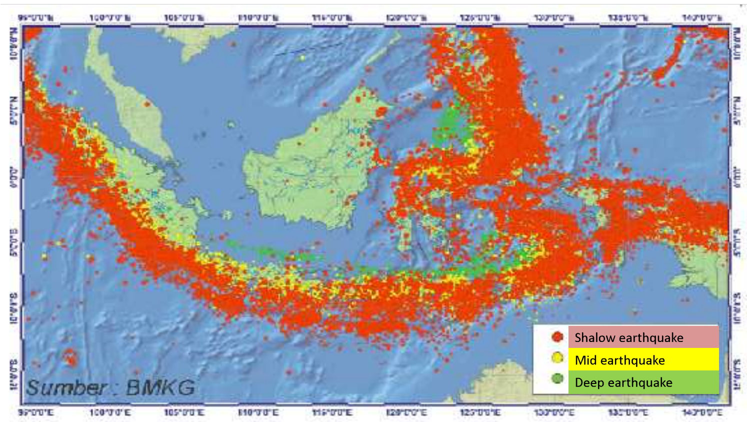
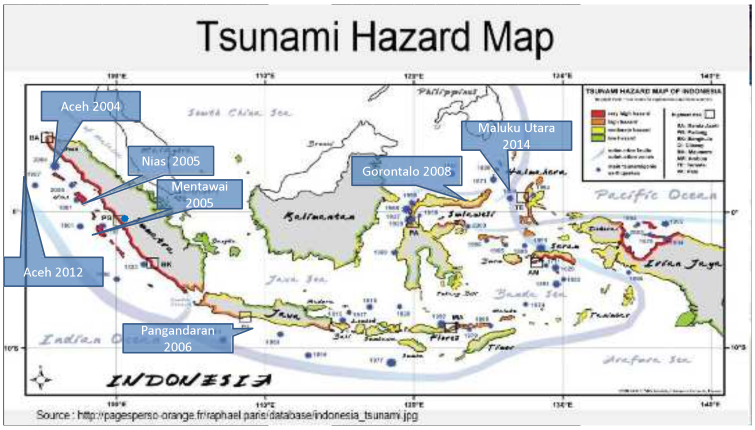
Dinas Hidro Oseanografi
TNI Angkatan Laut
Indonesia experience
in Tsunami
Tsunami Inundation mapping workshop
Tokyo, 25-26 November 2015

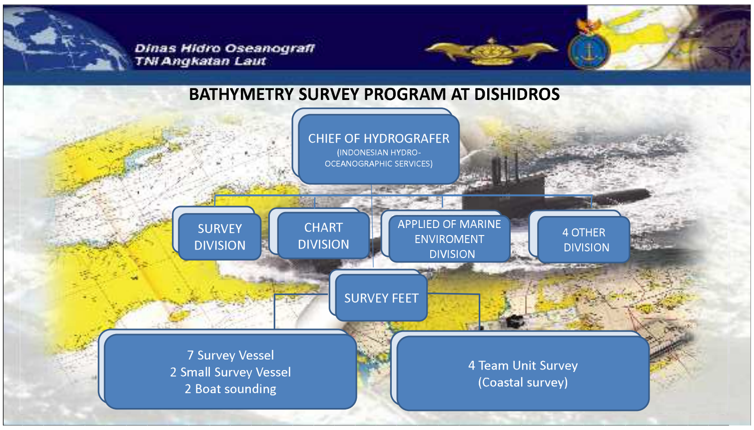

PETA ZONASI ANCAMAN BENCANA GEMPABUMI DI INDONESIA
Zona Ancaman Gempabumi Tahun 2010

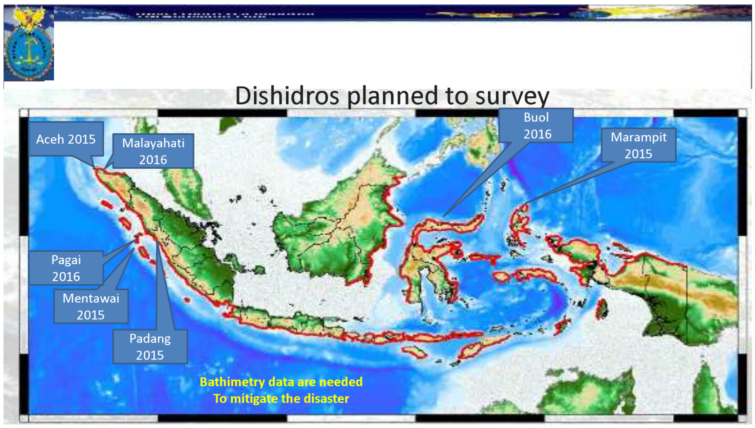

Shalow earthquake
Mid earthquake
Deep earthquake
Sumber : BMKG


Potential of Tsunami in Indonesia


Tsunami Hazard Map
Aceh 2004
Nias 2005
Mentawai 2005
Aceh 2012
Gorontalo 2008
Maluku Utara 2014
Pangandaran 2006
South China Sea
Pacific Ocean
Kalimantan
Sulawesi
Java Sea
Banda Sea
Arafura Sea
INDONESIA
TSUNAMI HAZARD MAP OF INDONESIA
Source : http://pagesperso-orange.fr/raphael.paris/database/indonesia_tsunami.jpg

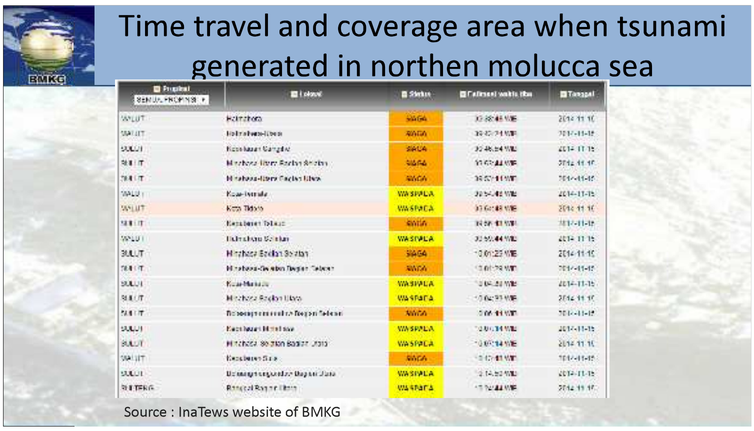

Related Institutions
DISHIDROS
(Hydro-Oceanographic Services)
LIPI
(Indonesian Institute of Science)
Badan Nasional Penanggulangan Bencana
(National Board For Disaster Management)
BNPB
BMKG
(Indoneisan Meteorogicy, Climatology and Geophysics Agency)
Badan Pengkajian dan Penerapan Teknologi
(Agency for The asesment and Aplication of Technology)
BPPT
BIG
(Indonesian Geospacial information Agency)
BADAN INFORMASI GEOSPASIAL

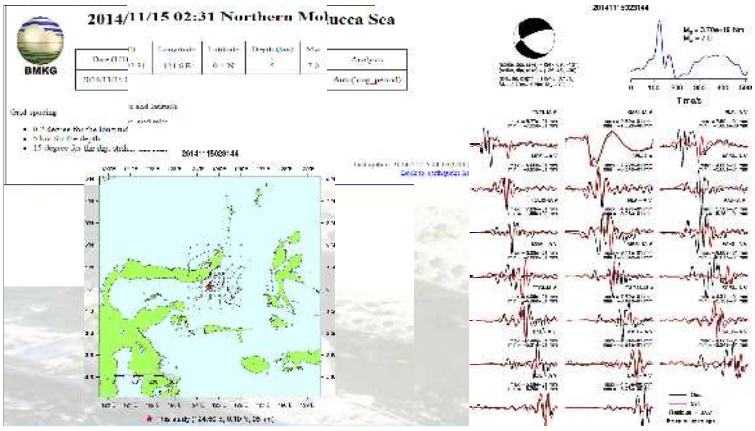

Dinas Hidro Oseanografi
TNI Angkatan Laut
BATHYMETRY SURVEY PROGRAM AT DISHIDROS
CHIEF OF HYDROGRAFER
(INDONESIAN HYDRO-OCEANOGRAPHIC SERVICES)
SURVEY DIVISION
CHART DIVISION
APPLIED OF MARINE ENVIROMENT DIVISION
4 OTHER DIVISION
SURVEY FEET
7 Survey Vessel
2 Small Survey Vessel
2 Boat sounding
4 Team Unit Survey
(Coastal survey)

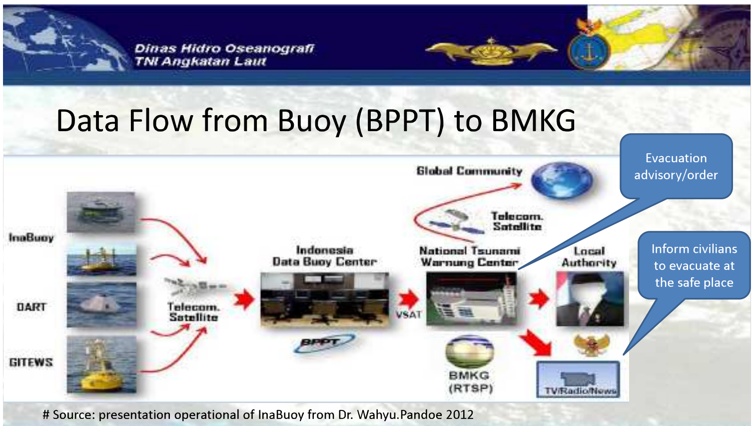

Dishidros planned to survey
Aceh 2015
Malayahati 2016
Buol 2016
Marampit 2015
Pagai 2016
Mentawai 2015
Padang 2015
Bathymetry data are needed
To mitigate the disaster


Dinas Hidro Oseanografi
TNI Angkatan Laut
Structure Design of
the Indonesian Tsunami Early Warning System
(InaTEWS)
Telecommunication Satellite
Control Center
BPPT
Buoy
Tide gauge
GPS
Seismograph
DISHIDROS
OBS
BIG
BMKG
© Jan Sopaheluwakan, 2005

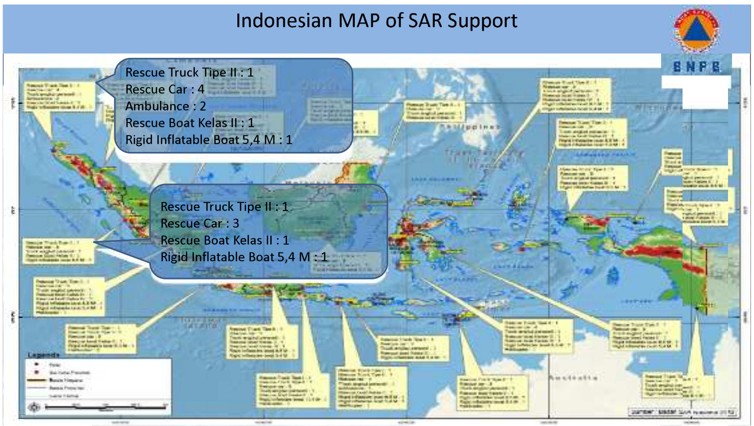

Website of BMKG : www.bmkg.go.id
earthquake at north moluccas sea in 15-11-2014
BMKG
Parameter Gempabumi
Magnitude
7.3


Time travel and coverage area when tsunami
generated in northen molucca sea
BMKG
Source : InaTews website of BMKG

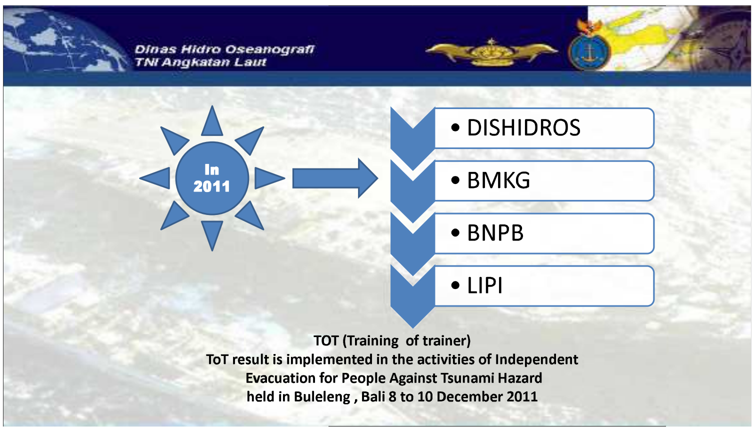

2014/11/15 02:31 Northern Molucca Sea
BMKG


Dinas Hidro Oseanografi
TNI Angkatan Laut
Data Flow from Buoy (BPPT) to BMKG
Global Community
Evacuation advisory/order
Telecom. Satellite
InaBuoy
Indonesia Data Buoy Center
National Tsunami Warning Center
Local Authority
Inform civilians to evacuate at the safe place
DART
Telecom. Satellite
VSAT
GITEWS
BMKG (RTSP)
TV/Radio/News
Source: presentation operational of InaBuoy from Dr. Wahyu.Pandoe 2012


BPPT
Badan Pengkajian dan Penerapan Teknologi
(Agency for The asesment and Aplication of Technology)
InaBuoy TEWS 2007-2012
Operational and Maintenance
Buoy Simeulue
Buoy ENGGANO
Buoy Halmahera
DART II - Standard
Buoy Mentawai
Buoy Komodo
Buoy Cilacap
Buoy Krakatau
Buoy Pelabuhan Ratu


Indonesian MAP of SAR Support
BNPB
Rescue Truck Tipe II : 1
Rescue Car : 4
Ambulance : 2
Rescue Boat Kelas II : 1
Rigid Inflatable Boat 5,4 M : 1
Rescue Truck Tipe II : 1
Rescue Car : 3
Rescue Boat Kelas II : 1
Rigid Inflatable Boat 5,4 M : 1


Dinas Hidro Oseanografi
TNI Angkatan Laut
InaTEWS
(Indonesian Early Warning System)
BMKG
BIG
BPPT
Good bathimetry data (DISHIDROS)


Dinas Hidro Oseanografi
TNI Angkatan Laut
In 2011
• DISHIDROS
• BMKG
• BNPB
• LIPI
TOT (Training of trainer)
ToT result is implemented in the activities of Independent Evacuation for People Against Tsunami Hazard held in Buleleng , Bali 8 to 10 December 2011


Dinas Hidro Oseanografi
TNI Angkatan Laut
Tsunami Drill & Workshop


Dinas Hidro Oseanografi
TNI Angkatan Laut
SOCIALIZATION OF TSUNAMI SIRINE IN BANYUWANGI BY BMKG at 18/11 2015
JAVA SEA
JAKARTA
Muncar distric
250 km
JAVA
INDIAN OCEAN
BMKG TSUNAMI SIRINE IN BANYUWANGI


Dinas Hidro Oseanografi
TNI Angkatan Laut
THANK YOU

Annex 5

Outcomes of the Workshop

Through the workshop, we recognized the following:

1. A tsunami inundation map is a very useful and essential tool for raising public awareness and developing countermeasure plans for tsunami as well as storm surge disasters.
2. Hydrographic offices are strongly encouraged to provide high-quality coastal bathymetric information coupled with land elevation data, which is essential for accurately estimating tsunami propagation and inundation.
3. It is important to strengthen collaboration among national organizations and agencies for promoting the development and utilization of tsunami inundation maps.

We confirmed that hydrographic offices can play a leading role in many aspects of developing and utilizing tsunami inundation maps in each country.

We recognized that various activities for tsunami inundation mapping are engaged in internationally, such as the IOC Tsunami Programme and the Asia-Japan Transport Partnership and the Regional Integrated Multi-Hazard Early Warning Systems for Africa and Asia (RIMES), and we recognized that further collaboration and active participation in international activities by each county should be encouraged.

We agreed that further capacity-building activities on tsunami inundation mapping should be requested for hydrographic offices.

Annex 6

List of Acronyms

ALB	Airborne Laser Bathymetry
APaC-CDR/PARI	Asia-Pacific Center for Coastal Disaster Research, Port and Airport Research Institute
DEM	Digital Elevation Model
EAHC	East Asia Hydrographic Commission
ESCAPE	Evaluation System for Computing Accessibility and Planning Evacuation of RIMES
HO	Hydrographic Office
IHO	International Hydrographic Organization
INSPIRE	Internet-based Simulation Platform for Inundation and Risk Evaluation of RIMES
IOC	UNESCO/ Intergovernmental Oceanographic Commission
IRIDeS	International Research Institute of Disaster Science, Tohoku University
JCG	Japan Coast Guard
JHOD	Hydrographic and Oceanographic Department, Japan Coast Guard
LiDAR	Light Detection and Ranging
MBES	Multi Beam Echo Sounder
NAMRIA	National Mapping and Resource Information Authority
NWPTAC	Northwest Pacific Tsunami Advisory Center
PARI	Port and Airport Research Institute
PTWC	Pacific Tsunami Warning Center
PTWS	Pacific Tsunami Warning and Mitigation System
RIMES	Regional Integrated Multi-Hazard Early Warning Systems for Africa and Asia
SDB	Satellite Derived Bathymetry
TIM	Tsunami Inundation Map
TDMMap	Tsunami Disaster Management Map