Tsunami Disasters
Tsunami and Storm Surge Comparison

**<Tsunami>**

- Tsunami Height (m)
  - Max: 3.3m
  - Min: -6.0m

**<Storm Surge>**

- Typhoon, Hurricane, Cyclone

Typhoon Yolanda (Haiyan) in 2013
<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>Chilean Tsunami, Chile</td>
<td>(Chile) 6,000 (Japan) 142</td>
</tr>
<tr>
<td>1964</td>
<td>Alaska Tsunami</td>
<td>119</td>
</tr>
<tr>
<td>1983</td>
<td>Sea of Japan Tsunami</td>
<td>101</td>
</tr>
<tr>
<td>1998</td>
<td>Papua New Guinea Tsunami</td>
<td>1,600</td>
</tr>
<tr>
<td>2004</td>
<td>Indian Ocean Tsunami</td>
<td>&gt;180,000</td>
</tr>
<tr>
<td>2006</td>
<td>Central Java Tsunami</td>
<td>700</td>
</tr>
<tr>
<td>2009</td>
<td>Samoan Islands Tsunami</td>
<td>200</td>
</tr>
<tr>
<td>2010</td>
<td>Chilean Tsunami, Chile</td>
<td>500</td>
</tr>
<tr>
<td>2010</td>
<td>Mentawai Tsunami, Indonesia</td>
<td>500</td>
</tr>
<tr>
<td>2011</td>
<td>Tohoku Tsunami, Japan</td>
<td>(deaths) 15,782 (unknowns) 4,086</td>
</tr>
</tbody>
</table>
## A Selected History of Tsunamis in Japan

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>684</td>
<td>Hakuho Tsunami</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>(The first tsunami recorded in Japan)</em></td>
<td></td>
</tr>
<tr>
<td>869</td>
<td>Jogan Tsunami</td>
<td></td>
</tr>
<tr>
<td>1498</td>
<td>Meio Tsunami</td>
<td>3~40,000</td>
</tr>
<tr>
<td>1605</td>
<td>Keicho Tsunami</td>
<td>5,000</td>
</tr>
<tr>
<td>1703</td>
<td>Genroku Tsunami</td>
<td>200,000</td>
</tr>
<tr>
<td>1707</td>
<td>Hoei Tsunami</td>
<td>20,000</td>
</tr>
<tr>
<td>1896</td>
<td>Meiji Sanriku Tsunami</td>
<td>26,360</td>
</tr>
<tr>
<td>1946</td>
<td>Showa Nankai Tsunami</td>
<td>1,330</td>
</tr>
<tr>
<td>1983</td>
<td>Sea of Japan Tsunami</td>
<td>104</td>
</tr>
<tr>
<td>1993</td>
<td>Hokkaido South-west Tsunami</td>
<td>198</td>
</tr>
<tr>
<td>2011</td>
<td>Tohoku Tsunami</td>
<td><em>(deaths)</em> 15,782</td>
</tr>
</tbody>
</table>
|      |                                 | *(unknowns)* 4,086
Tsunami Disasters
Inundation Height, Depth and Run-up Height
Water Level before Tsunami Arrival

Tsunami Inundation Height, Depth and Run-up Height

Inundation Depth

Inundation Height

Run-up Height
Tsunami Disasters
Risk Management Framework
Example of Tsunami Risk Management Framework

**Survey**

Survey the existing protection structures

Compare between existing structure height and necessary height based on historical records and preliminary simulations.

Identify the possible risk areas

**Off-shore simulation**

Assume the possible cases for tsunamis and storm surges

Simulate off-shore simulations for tsunamis and storm surges

Calculate the wave height in the study area for both tsunamis and storm surges

**Inland simulation (flood over land)**

Simulate the flood over land based on the wave heights from the off-shore simulation

Calculate the flood depth, velocity, momentum, time series for flood over land

**Risk analysis**

Calculate the time requirement for evacuation of residents

Calculate possible loss of lives

Identify risks in term of loss of lives
Tohoku Tsunami
A History
Tohoku Tsunami: Tsunami Height Distributions - Summary

- Wide area from Hokkaido to Chiba
- In Sanriku, two big tsunamis over 115 years (Once for a hundred years)
- In the Sendai plain, the biggest tsunami since the Jogan tsunami in 869 (Once for a thousand years)

Meiji, Showa, Chile Tsunami data: Japan Tsunami Trace Database, Tohoku University and JNES
2011 Tsunami: Tohoku Tsunami Joint Survey Group including Waseda University
Tohoku Tsunami
Tohoku Tsunami: Kamaishi City

There were three defense lines

- Outside the bay: Run-up height was more than 30m
- Inside the bay: Run-up height was around 10m

Data from the 2011 Tohoku Earthquake Tsunami Joint Survey Group (TTJS) (http://www.coastal.jp/tsunami2011/)
Tohoku Tsunami: Kamaishi Bay Breakwater
Tohoku Tsunami: Kamaishi Bay Disaster Area
Tohoku Tsunami: Kamaishi Bay – View from Evacuation Area

Designated evacuation building

Area full of buildings
Tohoku Tsunami: Breakwater in Onagawa City

The breakwater in Onagawa City disappears due to the tsunami

(a) 4th March, 2010

(b) 26th March, 2011
Tohoku Tsunami: Flooded Area of Sendai City - Arahama

Main Map: Geospatial Information Authority of Japan [http://www.gsi.go.jp/kikaku/kikaku60003.html]
Top Left Upper: Map Data © 2015 Google, SK planet, ZENRIN
Top Left Lower: Imagery © 2015 Google, Data SIO, NOAA, U.S. Navy, NGA, GEBCO, TerraMetrics, Map Data © Google, ZENRIN
Tohoku Tsunami: Wakabayashi Ward

Data from the 2011 Tohoku Earthquake Tsunami Joint Survey Group (TTJS) (http://www.coastal.jp/tsunami2011/)
Tohoku Tsunami: Wakabayashi Ward Inundation Height

Inundation Height 9.38m

Elementary School

1km

Inundation Height 9.38m

Arahama

Image © 2015 DigitalGlobe
Tohoku Tsunami: Arahama Flooded Area

The whole area was flooded in Arahama
Tohoku Tsunami: Elementary School in Arahama

Arahama: 700m from the shoreline

(4.62m from the baseline)
Tohoku Tsunami: Flooded Area of Natori River Mouth

Main Map: Geospatial Information Authority of Japan [http://www.gsi.go.jp/kikaku/kikaku60003.html]
Top Left Upper: Map Data © 2015 Google, SK planet, ZENRIN
Top Left Lower: Imagery © 2015 Google, Data SIO, NOAA, U.S. Navy, NGA, GEBCO, TerraMetrics, Map Data © Google, ZENRIN
Tohoku Tsunami: Natori River Mouth Coastal Erosion
Tohoku Tsunami: Yuriage Fishery Port – Inundation Height: 9.09m
Tohoku Tsunami: Typical View of Broken Coastal Bank
Tohoku Tsunami: LES for Tsunami Flood

Source: Mikami and Shibayma, 2013
Tohoku Tsunami
Coastal Engineering Viewpoint
Tohoku Earthquake Tsunami

High Momentum Bore Wave with Turbulence in Land

Destruction of Houses and Structures Coastal Erosion

Reconstruction of Local Society

Land Subsidence

Debris in Water and Land

Reconstruction of Industry (Fishery)

Release of Chemicals

Reconstruction of Coastal Ecosystem

Release of Radioactive Materials

Health Effects

Fukushima Nuclear Power Plant Accident
Tohoku Tsunami
Important Lessons
Important Lessons from the Survey: Tohoku Tsunami

1. The Tohoku coast:
   - Frequently attacked by tsunamis
   - Tsunami was predicted
   - Tohoku tsunami far bigger than predicted

2. Tsunami experiences in the north and south are different
   - North: big tsunami once in a hundred years
   - South: big tsunami once in a thousand years
   - North and south residents could approach rehabilitation differently

3. Japanese coastal engineers change their basic concepts of coastal protection
   - Hard measures alone cannot protect against the loss of life

Meiji, Showa, Chile Tsunami data: Japan Tsunami Trace Database, Tohoku University and JNES
2011 Tsunami: Tohoku Tsunami Joint Survey Group including Waseda University
Level I Tsunami Protection Height
1. Coastal structures protect property or help the evacuation process
2. For frequent but low-level events (several decades to 150 years)

Level II Tsunami Evacuation Height
1. Soft measures (evacuation) to protect lives
2. For infrequent higher level events (1,000 years)

→ Reconstruction and transfer to higher land are also discussed
→ Consensus formation meetings with residents
Tohoku Tsunami: Minami-Sanriku Aerial View

Photo: May 18, 2011

Top Right: Google Maps: Imagery © 2015 Google, Map Data © 2015 Google, ZENRIN
Tohoku Tsunami: Minami-Sanriku Evacuation Building

Tsunami flooded over 71 cm above the roof
Tohoku Tsunami: Evacuation Points Classification

Evacuation points in Japan are classified into three separate categories.

**Category A:**
- Higher terrain adjacent to the coast
- Elevation continues for a long distance
- Not be isolated low hills - part of a larger geographical area

**Category B:**
- Robust buildings with six or more floors
- Hills that are more than 20m high
- Risk of being isolated

**Category C:**
- Robust buildings over 4 floors high
- Risk of being overtopped
Tohoku Tsunami
Fukushima Nuclear Power Plant Disaster
Fukushima Nuclear Power Plant: Tsunami Height

Fukushima No.1 Nuclear Power Plant in March 11, 2011

Tsunami Run-up Height: 14-15 m
Tsunami Inundation Height: 13 m

----------------------------------------------
Tsunami Design Height: 5.7-6.1 m
# Fukushima Nuclear Power Plant: Accident Timeline in Reactor No. 1

## March 11, 2011

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:46</td>
<td>Earthquake</td>
<td>Electric supply from outside was shut down. The atomic power generator automatically stopped.</td>
</tr>
<tr>
<td>15:27</td>
<td>Tsunami: Wave 1</td>
<td>All electric power (AC) was shut down. Temperature of power station increased.</td>
</tr>
<tr>
<td>15:35</td>
<td>Tsunami: Wave 2</td>
<td>Cooling water level decreased. Big amount of hydrogen was generated.</td>
</tr>
</tbody>
</table>

## March 12, 2011 / March 14, 2011 / March 15, 2011

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:36</td>
<td>12\textsuperscript{th}: Generator No. 1</td>
<td>Hydrogen explosion occurred. Nuclear reactor container was destroyed.</td>
</tr>
<tr>
<td>11:01</td>
<td>14\textsuperscript{th}: Generator No. 3</td>
<td>Radioactive materials were released to environment.</td>
</tr>
<tr>
<td>06:00</td>
<td>15\textsuperscript{th}: Generator No. 4</td>
<td></td>
</tr>
</tbody>
</table>
Hamaoka Nuclear Power Plant, Chubu Electric Company

Prediction of Tsunami Height Distribution by the Japanese Government for the Nankai Trough

Tsunami Propagation: Nankai Trough

Data: The GEBCO Digital Atlas published by the British Oceanographic Data Centre on behalf of IOC and IHO, 2003
New Tsunami Barrier: Chubu Electric Company

Estimation of Tsunami Height: **19m** (Tokai-Tonankai Nankai Earthquake (Nankai Trough))

Multiple Tsunami Flood Countermeasures:
- Artificially protected by sand dunes (10~15m above MWL)
- Tsunami barrier (18 m)
- Water proofing of the main plant
- Setting an emergency dynamo in the hills (25m above MWL)

Cross-Sectional View

Sand Dune Height: 10-15 m, Width 60-80m, Length: 1.5km
Indian Ocean Tsunami
Sri Lanka
Field Survey: Indian Ocean Tsunami - Sri Lanka

Members
→ Prof. Shibayama (Team Leader)

Yokohama National University
→ Dr. Sasaki, Dr. Suzuki, Dr. Jayaratne (now University of East London)

Tokyo University of Marine Science and Technology
→ Prof. Okayasu

Ruhuna University
→ Dr. Wijayaratna
Indian Ocean Tsunami: Tsunami Simulation

\[ C = \sqrt{gh} = \sqrt{9.8 \text{ms}^{-2} \times 3000 \text{m}} = 620 \text{km/h} \]

tsunami simulation

Data: The GEBCO Digital Atlas published by the British Oceanographic Data Centre on behalf of IOC and IHO, 2003
Indian Ocean Tsunami: Sri Lankan Victims

Victims in Sri Lanka as reported by the WHO (18th Jan)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Killed</td>
<td>30,920</td>
</tr>
<tr>
<td>Missing</td>
<td>6,020</td>
</tr>
<tr>
<td>Refugees</td>
<td>431,224</td>
</tr>
</tbody>
</table>

© OpenStreetMap contributors
Indian Ocean Tsunami: Survey Groups

Group 1: Prof. Kawata et al.
- Kyoto University, Tohoku University and the Port and Airport Research Institute
- Southwestern Sri Lanka: 4\textsuperscript{th} ~ 7\textsuperscript{th} Jan, 2005

Group 2: Prof. Shibayama et al.
- Yokohama National University, Tokyo University of Marine Science and Technology, Ruhuna University
- Southern Sri Lanka: 7\textsuperscript{th} ~ 9\textsuperscript{th} Jan, 2005

Group 3: Liu et al.
- Cornell University, Southern California University, USGS
- Eastern Sri Lanka: 10\textsuperscript{th} ~ 14\textsuperscript{th} Jan, 2005
Indian Ocean Tsunami: Group 1 Findings

Map: © OpenStreetMap
Topography: The GEBCO Digital Atlas published by the British Oceanographic Data Centre on behalf of IOC and IHO, 2003
Indian Ocean Tsunami: Communication in Colombo

Sharing information between two of the groups and Sri Lankan researchers
Indian Ocean Tsunami: Group 2 Findings

Map: © OpenStreetMap
Topography: The GEBCO Digital Atlas published by the British Oceanographic Data Centre on behalf of IOC and IHO, 2003
Indian Ocean Tsunami: Location 1 – South Sri Lanka (Hambantota)

Hambantota

Map: © OpenStreetMap
Indian Ocean Tsunami: Hambantota Residential Area - Housing Foundations
Indian Ocean Tsunami: Hanbantota Residential Area – Water Mark House One
Indian Ocean Tsunami: Hanbantota Residential Area – Water Mark House Two
Indian Ocean Tsunami: Hambantota Residential Area Tsunami Height
Indian Ocean Tsunami: Run-up Height – Measured by Debris
Indian Ocean Tsunami: Run-up Height – Witness Testimony
Indian Ocean Tsunami: South Sri Lanka Tsunami Height

- Maximum height: 10.6m
- Maximum runup: 88m
- Maximum height in topography: 10.0m
Indian Ocean Tsunami: Location 2 – South Sri Lanka (Kirinda Fishery Port)

Kirinda Fishery Port

Map: © OpenStreetMap
Indian Ocean Tsunami: Kirinda Fishery Port before the Tsunami

1984: The port was constructed by Japanese ODA (Official Development Assistance). However, due to sedimentation, the port was filled with sand.

1992: Repair work was carried out.

2001: A dredging ship began working in the area.

Photo: Nov 27, 2002
Due to the tsunami, depositional sand was moved inland and outside of the port.
Indian Ocean Tsunami: Kirinda Fishery Port Cross Section

- 166 m
- 8.45 m
- 250 m
- 5.02 m
- 0.60 m
- 8.22 m
- 9.05 m
- 3.20 m
- 5.5 m

Dimensions and heights along the cross section of the port.
Indian Ocean Tsunami: Location 4 – South Sri Lanka (Polhena)

Polhena

Map: © OpenStreetMap
Indian Ocean Tsunami: Polhena

- The coral shelves extend from the shoreline for about few hundred meters offshore.
- ‘Polhena’ literally means “Coconut Land”
Indian Ocean Tsunami: Polhena
Indian Ocean Tsunami: Polhena Cross Section

Coral Shelf

- 2.60 m
- 2.00 m
- 1.50 m
- 1.10 m
- 1.36 m

389 m → 640 m
Indian Ocean Tsunami: Location 5 – South Sri Lanka (Gintota Bridge, Gin River)

Gintota Bridge and Gin River

Map: © OpenStreetMap
Indian Ocean Tsunami: Gintata Bridge

Gin River: 240m from the river mouth

4.0m from the water surface
Indian Ocean Tsunami: Gin River Tsunami Heights

4.6km from the river mouth

① First tsunami attack:
1.2m (24m from the river)

② Second tsunami attack:
(3 hours after the first attack)
1.6m (40m from the river)
Indian Ocean Tsunami: Measured Tsunami Height

Before tide correction
Indian Ocean Tsunami
Indonesia
Field Survey: Indian Ocean Tsunami - Banda Aceh, Indonesia

Members
→ Prof. Shibayama (Team Leader)

Yokohama National University
→ Dr. Sasaki, Dr. Suzuki

Tokyo University of Marine Science and Technology
→ Prof. Okayasu

Syiah Kuala University
→ Ir. Masimin, Ir. Zouhrawaty Atiff

Pacific Consultant
→ Mr. Matsumaru
Indian Ocean Tsunami: Survey Area

Map: © OpenStreetMap
Indian Ocean Tsunami: Indonesian Field Survey Locations – Syiah Kuala

1: Rhiting
2: Lepung
3: Site of Syiah Kuala
4: West side of the discharge channel
Indian Ocean Tsunami: Syiah Kuala Religious Monument
Indian Ocean Tsunami: Substantial Coastal Erosion in Syiah Kuala
Indian Ocean Tsunami: Syiah Kuala Coastal Destruction
Indian Ocean Tsunami: Indonesian Field Survey Locations – Rhiting

1: Rhiting
2: Lepung
3: Site of Syiah Kuala
4: West side of the discharge channel
Indian Ocean Tsunami: Rhiting – Flooding Between Hills
Indian Ocean Tsunami: Rhiting Area Washed Out
Indian Ocean Tsunami: Direction of Tsunami Propagation

Contour: 20m

Scale: 500m
Indian Ocean Tsunami: Rhiting/Legung Inundation and Run-up Height

<table>
<thead>
<tr>
<th>No.</th>
<th>Survey Point</th>
<th>Measured Height (m)</th>
<th>Shoreline Distance</th>
<th>Inundation or Run-up</th>
<th>Note</th>
<th>Corrected Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rhiting</td>
<td>49.43</td>
<td>70</td>
<td>Inundation</td>
<td>Dead tree and grass level. Fallen trees.</td>
<td>48.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21.35</td>
<td>940</td>
<td>Inundation</td>
<td>Dead tree level</td>
<td>21.39</td>
</tr>
<tr>
<td>2</td>
<td>Lepung</td>
<td>17.55</td>
<td>340</td>
<td>Inundation</td>
<td>A branch on a tree.</td>
<td>17.59</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18.66</td>
<td>350</td>
<td>Run-up</td>
<td>Timber on a tree.</td>
<td>18.70</td>
</tr>
</tbody>
</table>

![Map of Rhiting and Lepung survey points]

Measured Height (m)
Summary of Indian Ocean Tsunami

1. Tsunami attacked: Indonesia, Thailand, Sri Lanka, India, Maldives and Africa.

2. Tsunami run-up height:
   - Sri Lanka: >10 m
   - Aceh, Indonesia: 20m
   - Rhiting, Indonesia: 48.9m

3. Not predicted and not prepared
   Huge number of lives lost (180,000)

4. No knowledge of tsunamis
   Residents did not evacuate
Java Tsunami
Field Survey: Java Tsunami – 21-24 Jul, 2006

Members
→ Prof. Shibayama (Team Leader)

Yokohama National University
→ Dr. Sasaki, Dr. Takagi

Institute Technology of Bandung
→ Dr. Wurjanto, Dr. Hendra Achiari, Dr. Rildova
Java Tsunami: Java Coastline Tsunami Height Survey

Topography: The GEBCO Digital Atlas published by the British Oceanographic Data Centre on behalf of IOC and IHO, 2003
Java Tsunami: About the Java Tsunami

**Magnitude:**
7.7 (Major)

**Date:**
17 July, 2006

**Time:**
15:19:28 (local time)

**Location:**
200km from Java Island
- 9.222° S
- 107.32° E

Map produced by the U.S. Geological Survey
Java Tsunami: Adipala Buton

The speed of the tsunami was so fast, victims could not escape.
Interview with Local Residents

“I escaped with my Motorbike. [The] tsunami was just 7m behind me!”

“[The] tsunami rose to the middle of that tree. About 3m from ground level!”
Java Tsunami: Eroded Sand Dunes

Part of the sand dunes were artificially eroded as it was a foot path.
In an area located just behind the sea several people died.

The Tsunami surged from the upland to the lowland.
Java Tsunami: Field Survey Summary

1. 600 residents killed
2. Maximum tsunami height: 3.5 m
3. Permanent sand dunes (2-3 m high) were effective
4. Some sand dunes were erased
Samoan Tsunami
Field Survey: Samoan Tsunami  
October 28 – 31, 2009

Waseda University
→ Prof. Shibayama, Dr. Matsumaru, Dr. Takagi, Dr. Mikami

National University of Samoa
→ Mr. Latu, Dr. Chan Mow
Samoan Tsunami: Distribution of Tsunami Height

Topography: The GEBCO Digital Atlas published by the British Oceanographic Data Centre on behalf of IOC and IHO, 2003
Samoa Tsunami: Field Survey Area

Maps: © OpenStreetMap
Samoan Tsunami: Satitoa Survey (Oct 28) – Witness Testimony

- The tsunami approached between a small island and the mainland
- The wave looked unusual when breaking on the coral reef
Samoan Tsunami: Satitoa Survey (Oct 28) – Tsunami Height

6.07 m
6.45 m

the second floor
Samoan Tsunami: Poloa Survey (Oct 29) – American Samoa

Map: © OpenStreetMap

Image © 2015 DigitalGlobe

Survey Area
Samoan Tsunami: Poloa Survey (Oct 29) – Church

- Church: about 25 m, 8.97 m, 20.39 m
- About 80 m
- About 20 m
- 11.12 m
- 20.39 m
Samoan Tsunami: Ulutogia Tsunami (Oct 30)

- NUS student’s hometown
- Interviews with a teacher, student’s relative, and a minister of a church
Samoan Tsunami: Ulutogia Survey – Village Interview

Village Interview
- All residents evacuated to higher land
- Residents heard the warning and saw the tsunami wave
- Education was important

Tsunami Recovery
- Matai decided to relocate to higher land
- The land is owned by the community
- Adjusting the rights to the land was easy
- New villages are 1.5km further inland so it was easy to relocate
Relocation plan decided after one month

Up to November 2015 nobody had moved back to the coast
Samoan Tsunami: Saanapu Survey – Water Marks
Samoan Tsunami: Field Survey Summary

1. The effects of the wide coral reef
   - Residents saw the tsunami wave coming and evacuated

2. Recovery from the Tsunami
   - Residents relocated after just one month

3. Widespread education about tsunamis
   - Widespread education meant that residents evacuated
   - Education is improving since the Indian Ocean Tsunami
Chilean Tsunami
Field Survey: Chilean Tsunami – 2010    April 2 – 11, 2010

Waseda University
➔ Prof. Shibayama, Dr. Esteban, Dr. Mikami, Mr. Ohira

University of Tsukuba
➔ Dr. Takewaka

University of Chile
➔ Mr. Ayala

Catholic University in Concepcion
➔ Mr. Villagran, Dr. Aranguiz, Mr. Behrens
Chilean Tsunami: Numerical Simulation

**Seismic Parameters:**
- Fault length: 450 km
- Fault width: 100 km
- Strike: 16°
- Dip: 14°
- Slip: 104°
- Average slip: 10 m
- Position: (35.6S, 73.3E)
- Depth: 5 km
(from USGS)

**Tsunami Model:**
- Governing Equations
  - Non-linear shallow water equations
- Bathymetry Data
  - 1.5 arc-minute (GEBCO)

Topography: The GEBCO Digital Atlas published by the British Oceanographic Data Centre on behalf of IOC and IHO, 2003
Chilean Tsunami: Tsunami Propagation

Topography: The GEBCO Digital Atlas published by the British Oceanographic Data Centre on behalf of IOC and IHO, 2003
Chilean Tsunami: Wave Amplitude in Valparaiso and Constitucion

Valparaiso

Constitucion

Time (min)
Chilean Tsunami: Wave Amplitude Inside and Outside the Bay of Concepcion
Chilean Tsunami: Measured Tsunami Height
Chilean Tsunami (2010): Field Survey Summary

1. Tsunami energy was trapped due to resonance, or total reflection

2. Inundation height: 8-10m
   Run-up height: >20m.

Number of victims is low compared to Sri Lanka

Chilean Deaths: 350 (including those cause by seismic vibrations)
   *(Dichato city: 18)*

Sri Lankan Deaths: 35,322
   *(Hambantota city: 3,000)*

Reason for the difference:

1. Residents knew of the Chilean Tsunami (1960) and Indian Ocean Tsunami (2004)

2. The large earthquake meant residents knew about the tsunami
Mentawai Tsunami
Field Survey: Mentawai Islands Tsunami - 2010

Waseda University
→ Prof. Shibayama, Dr. Mikami, Mr. Ohira, Dr. Esteban

Yokohama National University
→ Prof. Sasaki, Dr. Suzuki

Bandung Institute of Technology
→ Dr. Achiari, Mr. Widodo

Topography: The GEBCO Digital Atlas published by the British Oceanographic Data Centre on behalf of IOC and IHO, 2003
Mentawai Islands Tsunami: Inundation and Run-up Height

Topography: The GEBCO Digital Atlas published by the British Oceanographic Data Centre on behalf of IOC and IHO, 2003
Mentawai Islands Tsunami: Tsunami Distribution Height

Topography: The GEBCO Digital Atlas published by the British Oceanographic Data Centre on behalf of IOC and IHO, 2003
Mentawai Islands Tsunami: Tsunami Propagation Simulation

Topography: The GEBCO Digital Atlas published by the British Oceanographic Data Centre on behalf of IOC and IHO, 2003
Mentawai Islands Tsunami: Satellite Images of the Effected Areas

(a) DESA BOSUA
   Bosua Utara
   Bosua Selatan
   Profile 1

(b) DESA BOSUA
   Gobik
   Profile 2

(c) KEC. SIPORA SELTAN
   Masokut
   DESA BOSUA

(d) KEC. SIPORA SELTAN
   Matalu
   Bere
   Bukkumonga
   Profile 3

Image © 2015 DigitalGlobe

Google Earth
Mentawai Islands Tsunami: Tsunami Trace Height

Surveyed villages and survey profiles

profile 1 (Bosua)

profile 2 (Old–Gobik)

profile 3 (Bere–Berilou)

- tsunami trace height
- ground level
- * at the time of the arrival of the tsunami

distance from the shoreline (m)
Mentawai Islands Tsunami: Bosua, Sipora Island (no casualties)

- People evacuated when the tsunami arrived
- A road connects to the inland so people could easily escape
Mentawai Islands Tsunami: Old-Gobik, Sipora Island (10 casualties)

- No connecting road to the higher inland area
- Evacuation was difficult
- Residents decided to relocate to higher ground ("New-Gobik")
Mentawai Islands Tsunami: Masokut, Sipora Island (8 casualties)

- The tsunami penetrated the village both from the river mouth and gap in the sand dune
- No connecting road to the higher inland area
- Evacuation was difficult
Mentawai Islands Tsunami: Bere-Berilou, Sipora Island (5 casualties)

- A road running downhill explains how the tsunami reached over 300m inland
- No higher ground or tall buildings
Mentawai Tsunami: Field Survey Summary

1. Houses are 2-3m above MSL
   No direct roads connecting the village to higher ground
   Rivers obstructed evacuation

2. 10-20 minutes from the earthquake to the tsunami
   Immediate evacuation is necessary