International Tsunami Warning Systems

International Institute of Seismology and Earthquake Engineering, Building Research IISEE

Tsukuba, Paris, May 7, 2010

Peter Koltermann, Head IOC Tsunami Unit
Hazard * Vulnerability = Risk

Advisory – Alert - Warning

Awareness – Preparedness - Mitigation
Reducing Tsunami Risk ...

... Requires end-to-end solution

1. Hazard assessment
2. Warning / guidance
3. Mitigation, Preparedness, Awareness
The threat and major source for tsunamis
Coastal inundation -> evacuation planning

Map 19: Airport to Waikiki

Note 1
When evacuation boundaries are drawn along streets and roadways, they are considered to be safe from wave action.

Note 2
Steel and/or concrete buildings of six or more stories in height may provide adequate protection if people are able to reach the third floor of the building.

Note
Maximum rise of water levels within Keahi Lagoon, Honolulu Harbor, and Kewalo Basin should not exceed 4 feet. However, all vessels should be secured, removed, or put to sea due to the probability of strong currents and wave action.
Warning Systems
dormant, continuous, jump start

The Concept of Early Warning
know the hazard, estimate the risk,
be prepared in time

“Saving time is saving lives”
IOC co-ordinates Tsunami Warning Systems globally as an end-to-end system

IOC’s mandate is to be there **before** marine disasters strike

**Tsunami Early Warning System**

- **upstream**
  - detection, verification, prediction of tsunami wave, dissemination of tsunami information, international, intergovernmental

- **downstream**
  - issue national warnings, initiate national warning command chain, prepare and implement standardized reaction
TSUNAMI Early Warning Overview

Earthquake
Tsunami

Tsunami Warning Center

National Government
Local Government

Mass Media

International/Regional Framework

National Warning System

Public Awareness & Preparedness

Community Based Disaster Reduction

Where is Evacuation Route?

What is Tsunami?
LOCAL / REGIONAL:
• Generated nearby
• Strikes shore quickly (in minutes)
  => NO TIME for official evacuation
➢ Education, Awareness
➢ People-centered response – recognize / act immediately

DISTANT / OCEAN-WIDE:
• Generated far away, instr detection
• Strikes shore later (2+ hours)
  => TIME for official evacuation
• Widespread Damage
➢ Tsunami Warning Centre, then
➢ People-centered response – locally-guided safety actions
Sequence and Components of Tsunami Warning System

- Occurrence of Earthquake
- Generation of Tsunami
  - Detection of Seismic Wave
  - Determination of Magnitude and Hypocenter
  - Evaluation of Tsunami
  - Issuance of Tsunami Warning
  - Re-evaluation of Tsunami
  - Detection of Tsunami
  - Components of Tsunami Warning System
    - Network of seismometers
    - Real time transmission of seismic data
    - Real time data processing system
    - Criteria for Tsunami grade
    - Communication facility to disseminate Tsunami Warning
    - Network of tide gauge to monitor tsunami

Source: JMA
Two major tasks:

- Identify, detect, verify and predict natural extrema, such as tsunami, cyclones, earthquakes with potential implications to mankind (upstream component)

- Raise awareness and preparedness to react appropriately to warnings of such extreme events (downstream component)
Generation mechanisms for tsunamis

EARTHQUAKES ---------LANDSLIDES----------VOLCANOES

All three can cause a tsunami!

Source: Office of Naval Research

http://www.onr.navy.mil/focus/ocean/motion/waves3.htm
Tsunamis are often no taller than normal wind waves, but they are much more dangerous.

Wind waves come and go without flooding higher areas.

Even a tsunami that looks small can be dangerous!

Any time you feel a large earthquake, or see a disturbance in the ocean that might be a tsunami, head to high ground or inland.
What is a tsunami?

- Not all earthquakes generate a tsunami
- Earthquakes are NOT predictable
- Tsunamis are, once generated....

- **Tsunamis**
  - deep ocean: travel fast ca. 900 km/h, amplitude ca. 0.50 m
  - shallow coastal seas: slow, wave steepens, ampl. 2 -4 m
  - inundated areas: fast currents, run-up up to 30 m
Behrens et al, 2008: Altimeter SL heights/modelled
Before Tsunami image, Banda Aceh, Indonesia
(Quickbird, June 23, 2004)
After tsunami image, Banda Aceh, Indonesia
(Quikbird image, December 28, 2004)
The 17th July South Java Tsunami Tidegauge Record at Cilacap
Mediterranean Seismicity
Historical Seismicity in the Mediterranean
Proposed network of sea-level stations for the NEAM Multi-Hazard EWS
Seismic Data Transmission Network in Japan

- Naha
- Okinawa
- Sapporo
- Fukuoka
- Osaka
- Sendai
- Tokyo

Legend:
- Green: Seismic Data Line
- Red: High-Speed Digital Line

Scale: 0 - 300Km
Seismic Stations and Networks Contributing to the Tsunami Warning System in the Pacific
Seismic Networks

- Academic, funded by research proposals
- FSDN, IRIS, GEOFON, GEOSCOPE

- CTBTO closed system, very reliable
  - Agreements between IOC and CTBTO for TWS purposes in place

- ACTION -> ensure continuous funding
Determination of Hypocenter

最終震源 発現時刻: 2005/09/09 18:27:00 ニューギニア付近
(hyposat) : 2005/09/09 18:27:00 南緯: 4.6 東経: 153.3 深さ不明 M: 7.3

震源マグニチュード

<table>
<thead>
<tr>
<th>震源マグニチュード</th>
<th>会津</th>
</tr>
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<tr>
<td>Mj</td>
<td>Ms</td>
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<tr>
<td>7.3</td>
<td>0.0</td>
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震源情報

<table>
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<tr>
<th>組合せ選択</th>
<th>地震例</th>
<th>地震例</th>
<th>組合せ設定</th>
<th>衝正種変更</th>
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<tbody>
<tr>
<td>2005/09/09 16:35:47</td>
<td>北西太平洋</td>
<td>本番</td>
<td>2系</td>
<td>トリガ起動</td>
</tr>
</tbody>
</table>

震源計算

- P-P法
- hyposat
- グリッドサーチ

震源情報

- 00年 00月 00日 00時 00分 00秒
- 距離 118 km

震源計算

- M_s
- M西前
- M坪井
three components of a TWS

Warning Guidance

Mitigation

Hilo Bay

Hazard Assessment
Warning Guidance

“Upstream” information flow
Quantitative Tsunami Forecast System of JMA

**Numerical Simulation**

Even a most-advanced computer needs much time to simulate tsunami propagation!
Tsunami Forecast Operation for Tsunamis from near-field origin

- Major Tsunami
- Tsunami Warning
- Tsunami Database
- Evaluation of Tsunami

・Quantitative Tsunami forecast (arrival time and Tsunami height)
・Tsunami warning for 66 regions
Event Distribution: Tsunamigenic regions

Whole historical period

- Pacific Ocean and marginal seas: 59%
- Mediterranean Sea (including the Black Sea): 25%
- Atlantic Ocean (including the Northern and the Baltic Seas): 12%
- Indian Ocean: 4%

20th century

- Pacific Ocean and marginal seas: 77%
- Mediterranean Sea (including the Black Sea): 9%
- Atlantic Ocean (including the Northern and the Baltic Seas): 4%
- Indian Ocean: 10%
Tsunami Sources in the World
(2180 events from 1628 BC to 2005)
GLOSS Core Network defined by GLOSS02
End–to–end Tsunami Warning System
Performance test of an operational TWS under scenario aspects

UNESCO Member States in the Pacific will stage tsunami drill

More than 20 countries* around the Pacific Rim will participate in a pre-arranged tsunami scenario from 28 to 30 October 2008. Testing the UNESCO-initiated Pacific Tsunami Warning and Mitigation System (PTWS), the drill aims to evaluate the system, increase preparedness and improve coordination throughout the region.
OFF EAST COAST OF HONSHU, JAPAN
Lat: 40.0° N  Lon: 143.0° E
Depth: 33 km / 20 mi
Mag: 9.2
Origin Time: 24 Oct 2008 12:00 Z
Current Time: 24 Oct 2008 14:24 Z
ΔTime: 2:24 hours
Exercise Pacific Wave 08

Tsunami Travel Times (15-min contours)
M9.2 Earthquake source (black line)
Tonga EQ 7.7 and Tsunami, 19 March 2009
Tonga EQ 7.7 and Tsunami, 19 March 2009

Niue Tide Gauge, 1911Z, 0.04m amplitude

source: PTWC, ITIC, 2040Z 19mar09
Computed Maximum Tsunami Wave Amplitude
(after NOAA/PMEL)
American Samoa, run-up after Sep 24, 2009
Am. Samoa: Poloa church shortly after tsunami (courtesy Hermann Fritz)
Haiti Tsunami: 12 Feb 2010

Note: The image contains a map showing the geographical spread of the tsunami, with annotations indicating different locations and markers for epicenters, coastal gauges, and deep-ocean gauges. The map is color-coded to represent different intensities of the tsunami's impact.
Chile Tectonics
Historical Earthquakes in Chile

- 1922 (8.4)
- 1943 (8.3)
- 1906 (8.6)
- 2010 (8.8)
- 1928 (8.4)
- 1939 (8.3)
- 1960 (9.5)
- 1730 (8+)
- 1751 (8+)
- 1835 (8+)
- 1922 (8.4)
- 1906 (8.8)
- 1939 (8.3)
- 1960 (9.5)
- 1700
- 1800
- 1900
- 2000

△ 現地で津波が観測されていない地震
Chile Earthquake 2010: vertical displacement

Concepcion: 2.1 m towards west

Santiago: 0.18 m towards west

San Fernandez Isl: 2.1 m UP
Chile Earthquake and Tsunami 27 Feb 2010: modelled and observed run-up heights

ALTURAS DE TSUNAMI MODELADAS Y OBSERVADAS. EVENTO DEL 27 DE FEBRERO DE 2010, CHILE

Altura máxima tsunami observada
Altura máxima tsunami modelado

Referencias

Escuela de Investigación en Terremotos (EITT - Instituto de Geografía de Chile)
Pontificia Universidad Católica de Chile
Instituto de Geografía

Collaborators:

Pontificia Universidad Católica de Chile
Instituto de Geografía
LOCATION: 100 KM FROM CONCEPCION; 330 KM FROM SANTIAGO
ELEVATED HIGHWAY COLLAPSE DETAIL
TALCAHUANO PORT: LOCAL TSUNAMI DAMAGE
TSUNAMI WAVES MOVE ACROSS THE PACIFIC
ISSUE TIME OF PTWC INITIAL BULLETINS FOR TELESEISMS

EVENT TIME (YEAR)

MINUTES SINCE QUAKE
Four regions to coordinate
System Constraints

- Culturally very heterogeneous regions
  - Language, custom, attitude
  - Language dominance
  - Solutions imposed
  - Stakeholders involvement entitles to a
    - Bottom-up approach
International Mechanisms and National Legislation

Disaster do not stop at a border

Emergency Management, Civil Defence,
All need clear legislation
  - information gathering, flow, access,
  - decision making, line of command
  - money: who pays every time?

“Where national sovereignty meets international needs”

- How can a country say yes or no, or stay silent?
International Rules and Mechanisms

- United Nations
- Consensus principle
- Everyone pays his own bill
- Open, free, neutral
Setting standards:

Norms: how to do things

Standards: how ALL do things

Establish references:

- ISO norms
- Guidelines
- Manuals and Procedures
- Zoning laws
- Building codes
Intergovernmental Oceanographic Commission

Established in 1960 in UNESCO

Purpose
to promote international cooperation and to coordinate programmes in research, services and capacity-building, in order to learn more about the nature and resources of the ocean and coastal areas and to apply that knowledge for the improvement of management, sustainable development, the protection of the marine environment, and the decision-making process of its Member States.
United Nations role: What is the System?

- Define the proper scale of the problem and its solution.
- The system must be:
  - Fully owned by countries in region
  - Based on international multilateral cooperation
  - Based on open and free data exchange
  - Protect all countries in region
  - Transparent and accountable to all members
1965: IOC established the ICG/ITSU International Coordination Group for the Tsunami Warning System in the Pacific (PTWC headquarters)

Successful & operational
Tsunami Warning & Mitigation System

Only in 2006 changed to intergovernmental status
IOC in UN partnership

- Warning guidance
- Hazard assessment
- Mitigation
- Communication (GTS)
- Multi-hazard
- Public awareness
- Preparedness
IMPLEMENTING an EFFECTIVE EWS

TWO ENTITIES CRITICAL (Pacific experience):

1. **WARNING CENTER** provides warning guidance
   incl Basin-wide warnings, sub-regional warnings; Local (educate), distant (monitor and warn)

2. **NDMO** (recognized authority) receives warning, immediately evaluates/translates, disseminates public message
   Additionally, hazard and risk, preparedness guidance

➢ BOTH MUST WORK CLOSELY TOGETHER

3. **EWS SUSTAINABILITY – ALL-HAZARDS APPROACH**

4. **COORDINATION AND DATA SHARING ESSENTIAL**, esp. for regional and distant tsunamis
Tsunami Warning Reliability Strategy  
*(no single points of failure)*

- REDUNDANT DATA SOURCES
- REDUNDANT COMMUNICATIONS PATHS
- REDUNDANT COMPUTER system (including UPS)
- ON DUTY 24X7
- BACKUP WARNING CENTRE
Designing a GLOBAL Tsunami Warning and Mitigation System

3 Oceans

4 Seas

INDIAN OCEAN

PACIFIC OCEAN

N. ATLANTIC

MEDITERRANEAN

ATLANTIC OCEAN

CARIBBEAN

SE Asia

NW Pac

SW Pacific

CA-Pac
Establish legal instruments!

- **UNGA Resolution 2006 and 2007:**
  - 2007: TNC and TWFP are institutionalized

- **European Union Council of Ministers (Dec 2007):**
  - NEAMTWS is the European System!
  - EU supports member states in its establishment
  - Member States are required (invited) to direct their own resources to this system
Moving towards ocean-hazard systems

**I-GOOS**
(IOC-WMO-UNEP)

**IPHAB**

4 regional TWS
TAKING ACTION - 7 steps

1. **KNOW and UNDERSTAND** tsunamis, risk
2. **RECOGNIZE** natural warning signals
3. **PLAN, and IMPLEMENT** warning system (monitor, detect, evaluate, warn)
4. **MONITOR and WARN** everyone
5. **MAKE AWARE** diverse audiences
6. **KEEP preparedness going forever**
   - System readiness - practice to improve
   - Personal responsibility
7. **PREVENT** damage by making stronger buildings
Beyond immediate response: Multi-Hazard Platforms

- Storm – surges (IOC, WMO, JCOMM)
- Tropical storms (WMO, JCOMM)
- Improving Storm and cyclones track forecasts (IOC, WMO, JCOMM)
- Ice Hazard (IOC, WMO, JCOMM)
- Oil Spills (IOC, WMO, UNEP)
Thank you for your attention

And thanks to all contributing to this presentation: JMA, PTWC, ITIC, IOC/TSU staff