Indian Ocean Tsunami in 2004

-sharing experiences with Japanese

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Prof. Kazuo Nadaoka, Tokyo Institute of Technology

- **Mechanism of tsunami generation**
- **Predicting the propagation, run-up and inundation of tsunamis**
- **Countermeasure**
- **Field survey for the 2004 tsunami**
  - **Major damage caused by the tsunami**

006-25

DCRC TSUNAMI ENGINEERING

What is “tsunami”？ 津波とは？

- **津＋波 ~ “tsu” + “nami” = harbor+wave**
- **Accepted as an international academic word in 1946**
- **Tsunami committee in IUGG started in 1960**

Historical Tsunamis

- **14th BC in Santorini, the oldest record in the world**
- **Tsunamis in Japan have been well documented for more than 195 tsunamis over 1,321 years since Nankai-do tsunami in 684AD**

Typical historical tsunamis around Japan

- 1771 Ishigaki Is. 85m (M7.4)

- 1896 Sanriku tsunami in Meiji era 30m (Ayasato Bay)
(M7.6) Dead & missed: 27,122

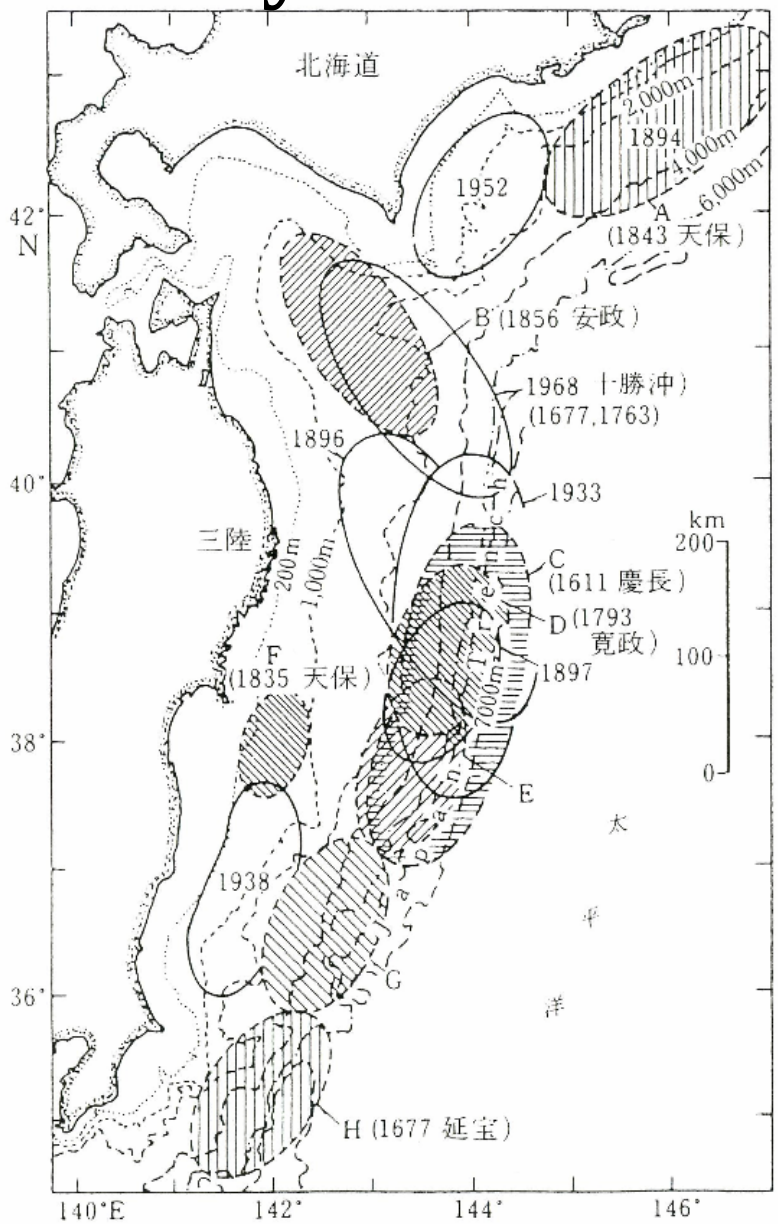
- 1923 The Great (Kanto) Earthquake 12m (Atami) (M7.9)

- 1933 Sanriku tsunami in Showa 29m (Ayasato Bay)
(M8.5) Dead & Misses: 3,051

- 1960 Chile tsunami 0.6～6.4m
Dead: 139人 (Sanriku coast) (M8.5)

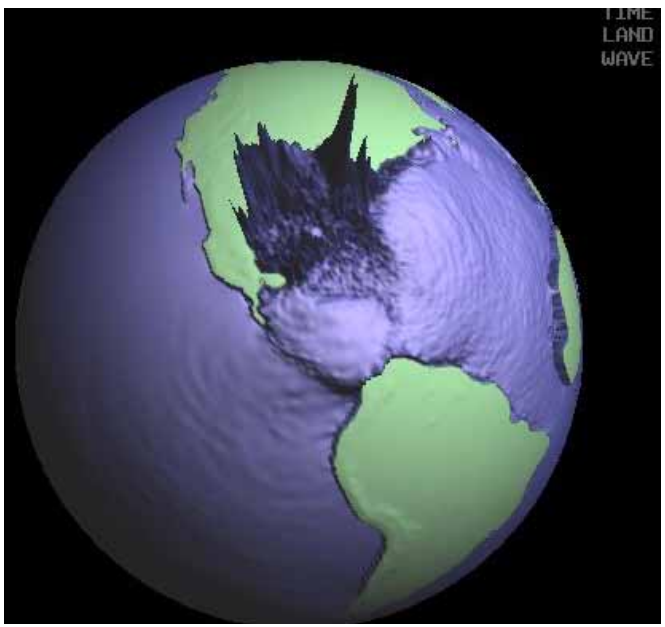
- 1968 Off Tokachi 5.3m (Miyako Bay) (M7.9)

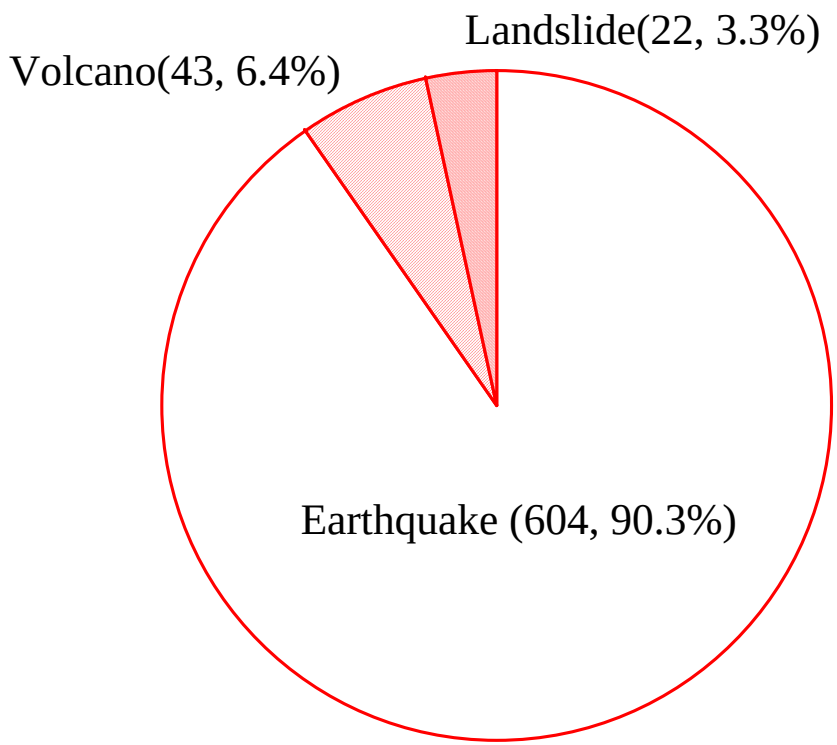
Historical tsunami source areas estimated by ancient documents



Several Phenomena to Generate Tsunami; Seismic and Non-seismic

- Fault movement
- Landslide
- Volcano
- Comet collision



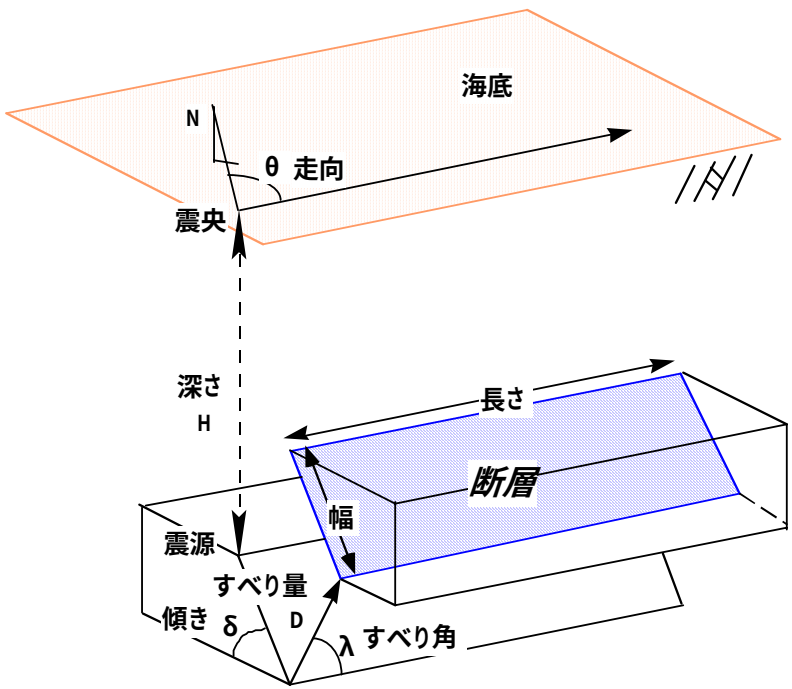


All tsunami data during 1790- 1990

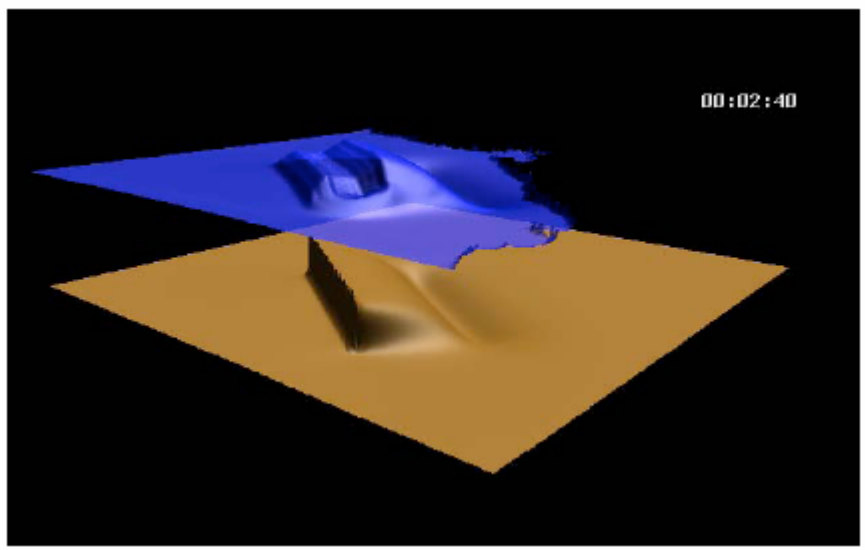
Estimation of a Seabed Movement-Deformation

A fault movement is described by its location including its depth,

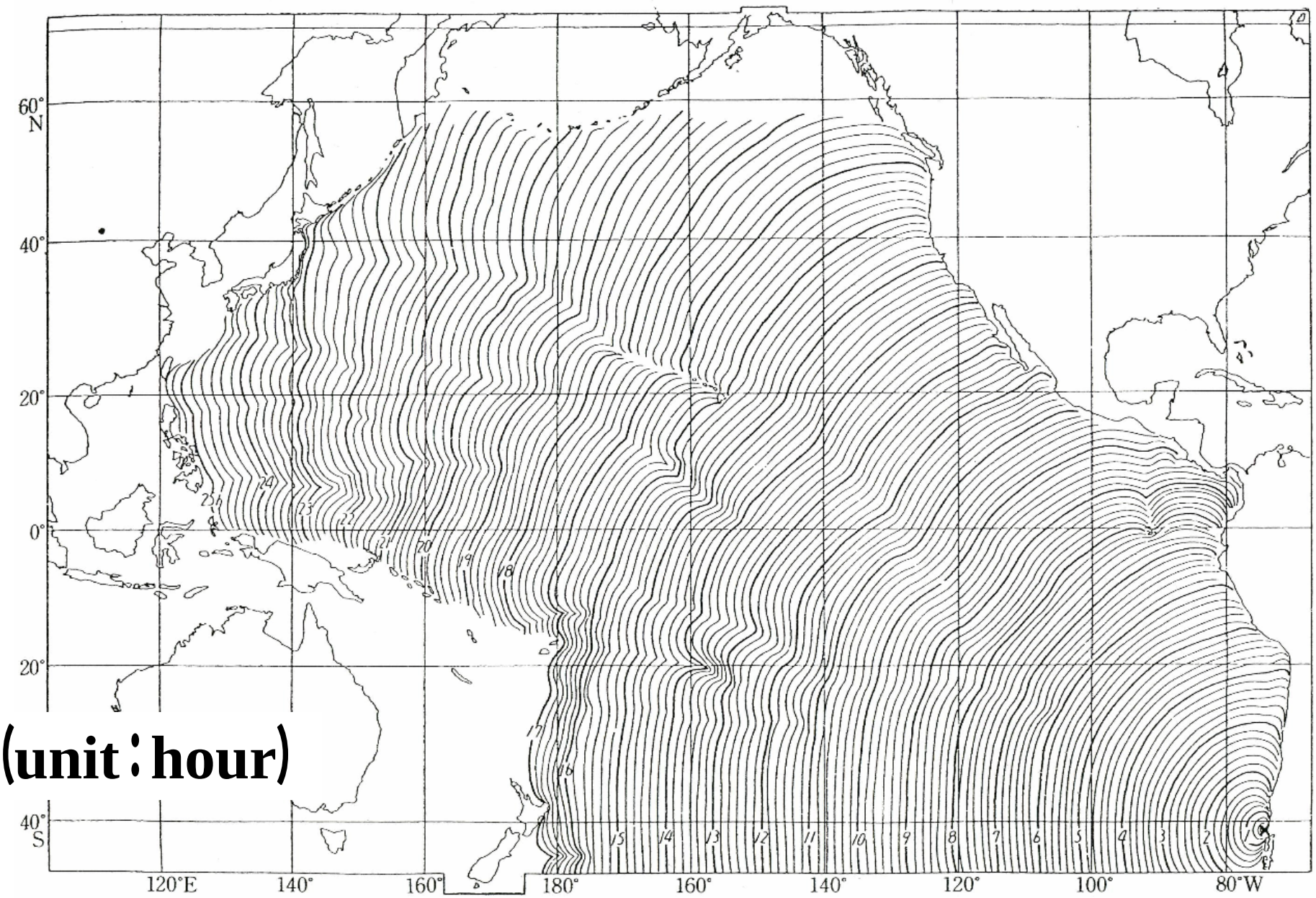
- **Mechanical characteristics; (strike, dip- and slip-angles of the fault plane),**
- **Geometrical characteristics (length, width and dislocation of the fault plane), and**
- **Dynamic characteristics(rupture direction, rupture velocity and rise time of the fault movement).**



- **Earthquake magnitude**
- **Depth of the fault**
- **Length and width of the fault plane**
- **Strike and dip angle of the fault plane**
- **Dislocation and slip angle**



Wave propagation of Chile tsunami



(unit：hour)

Tsunami as Long Waves

$$C=\sqrt{gh}$$

h=4km → C 713km/h

Cf.

For long waves

Comparable to a jet-plane speed !!

$$h / L < 1/20 \sim 1/25$$

$$\downarrow$$

$$L > 80 \sim 100 \text{ km}$$

$$\downarrow$$

$$T > 7\text{min} \sim 8 \text{ min}$$

• • • ok !

Distant Tsunamis

Wave system

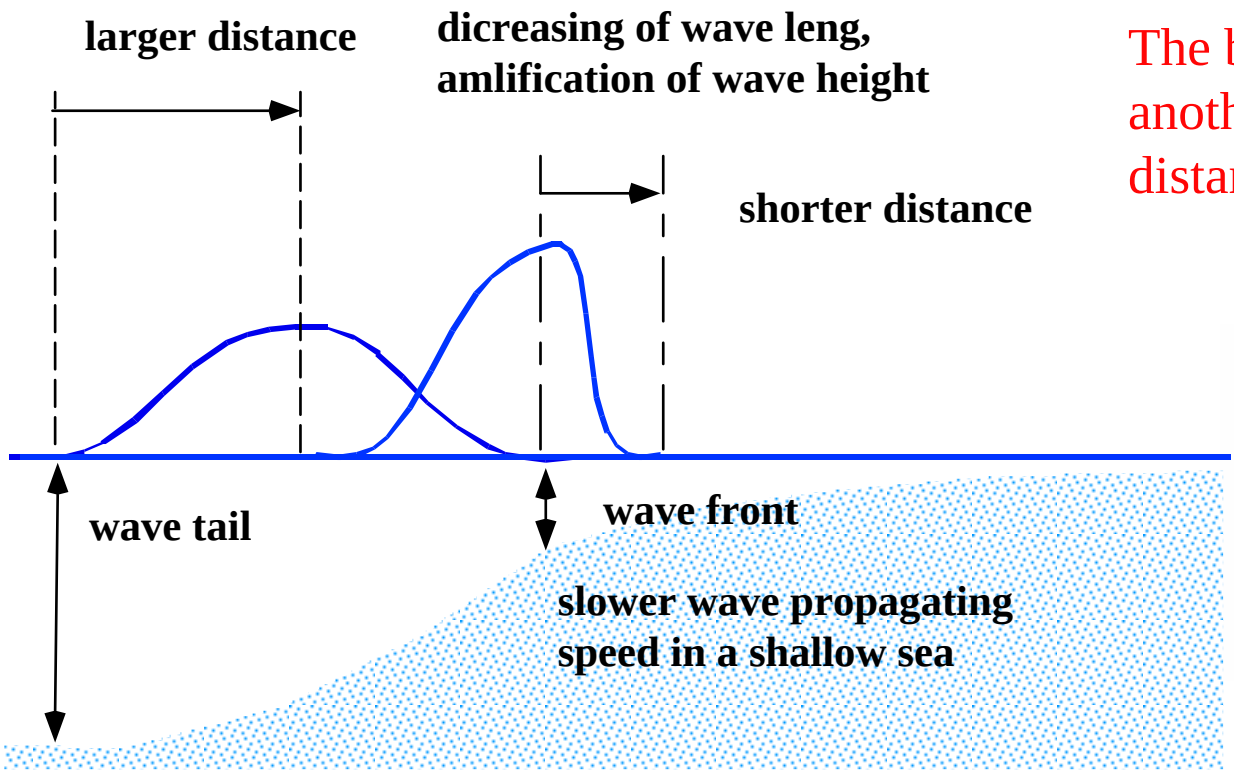
The fact that the wavelength of a tsunami is much longer than the water depth leads to the system of long waves.
The wave amplitude of a tsunami in the deep ocean is infinitesimally small compared to the water depth ; Linearity of the water wave .

A distant tsunami can be solved with the aid of liner equations for long waves with the Coriolis force , frequency dispersion included, described in the longitude-latitude coordinate system.

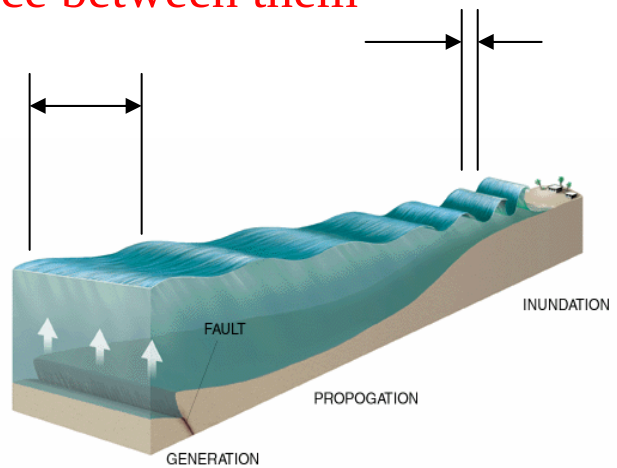
1996 Irian Jaya tsunami, made by DCRC Tohoku Univ.

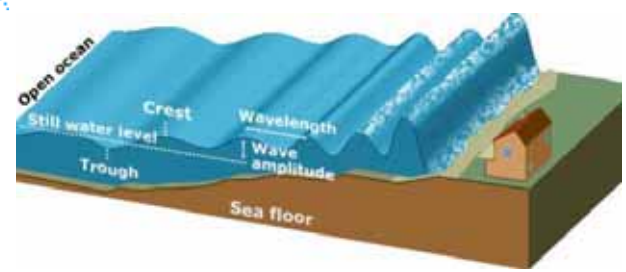
Tsunami Propagation : Shoaling Effect

The deeper the water and the longer the wave, the faster the tsunami propagate.

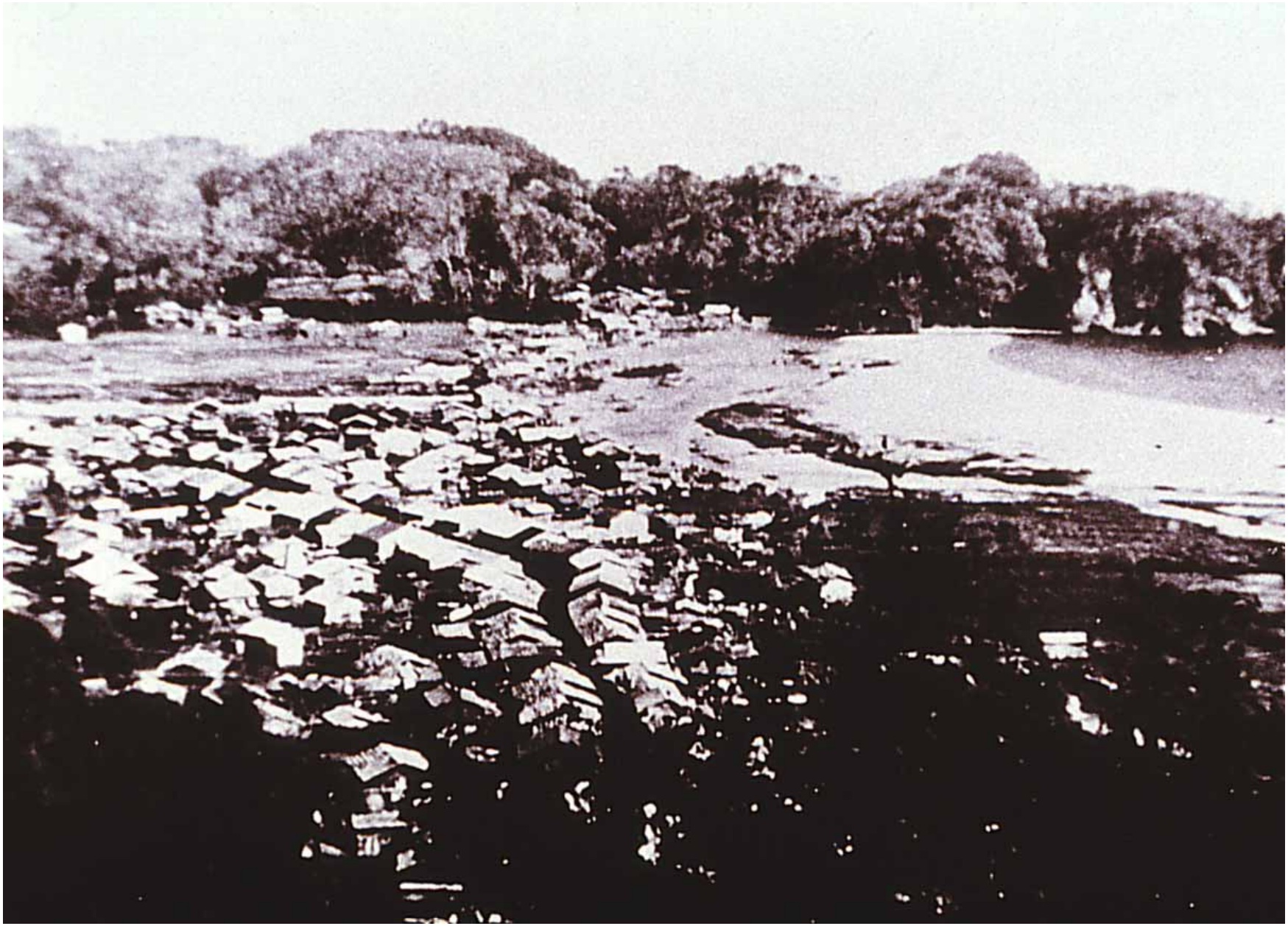


The back of wave overtake another,decreasing the distance between them





Sanriku tsunami (3.3.1933) Before tsunami attack



Sanriku tsunami (3.3.1933) After tsunami attack

北海道南西沖地震津波

Before

北海道奥尻島　来襲前

北海道南西沖地震津波

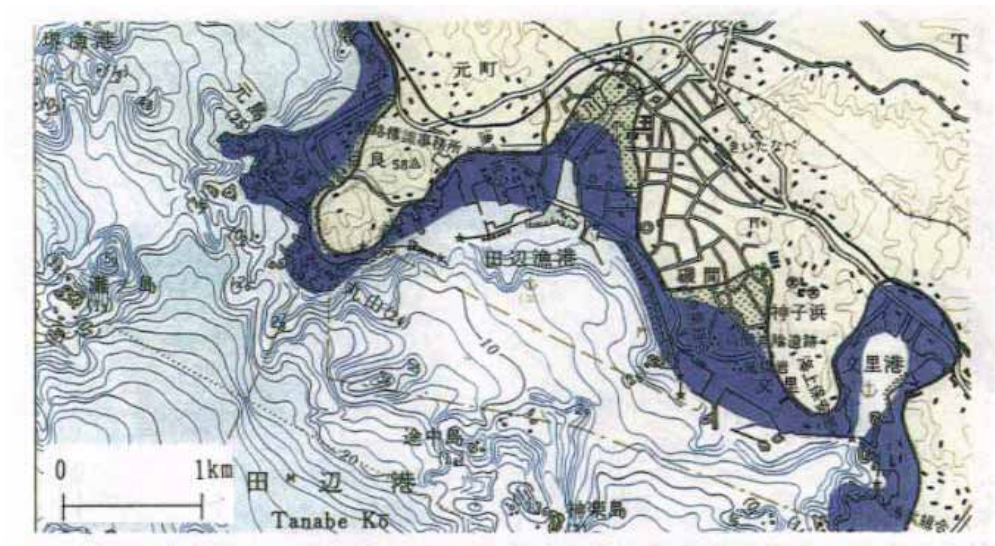
After

北海道奥尻島　来襲直後

Local Propagation

- **Locally generated tsunami waves may propagate from their generating source to the near shore area of a nuclear power plant site;**
- **hence, the wave propagation phenomena in shallow region become important.**
- **Numerical techniques,FDM, are applied to determine modification during propagation.**
- **The accuracy of bottom topography has a vital effect on the computed results**

TIME -project; Tsunami Inundation Modeling Exchange
By UNESCO/IOC and IUGG, manual 34



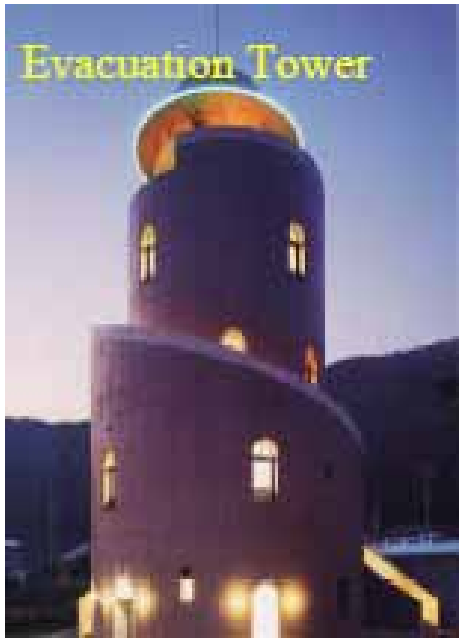
Countermeasures

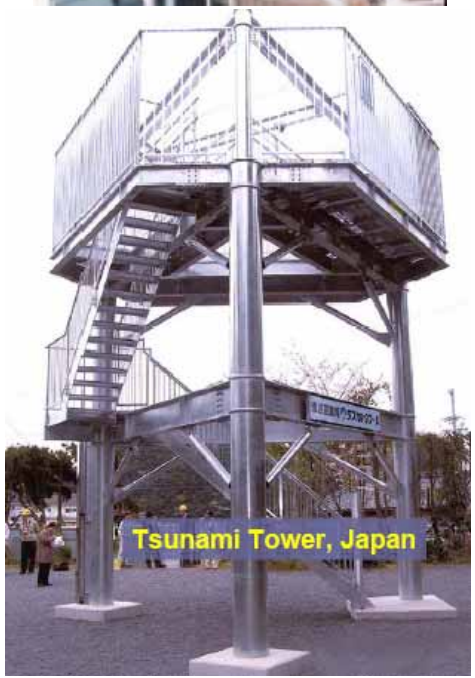
The offshore tsunami breakwaters were planned to reduce tsunami wave heights in Ohfunato Bay, as severe damage was caused by the Chilean Earthquake Tsunami in 1960. The breakwater was completed in 1967 after 4 years construction works.

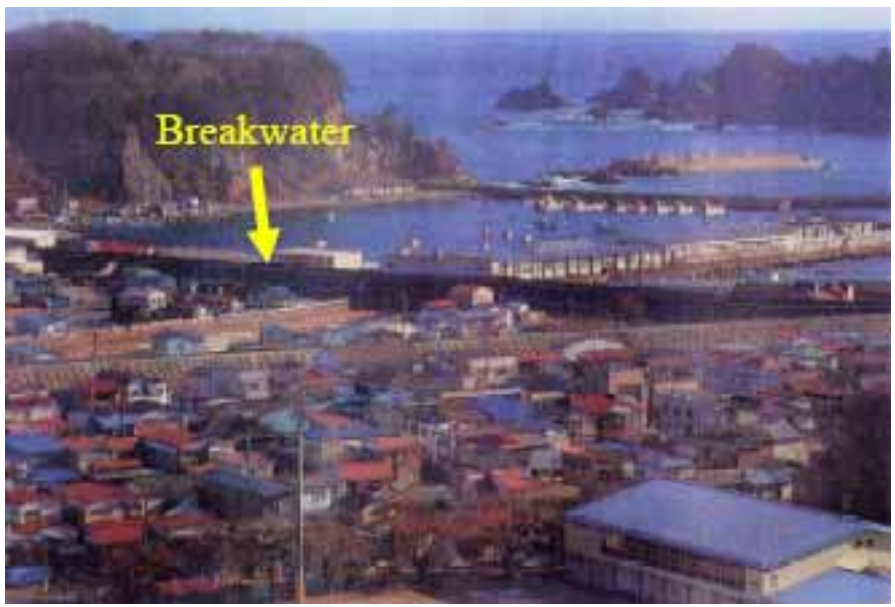
Countermeasures

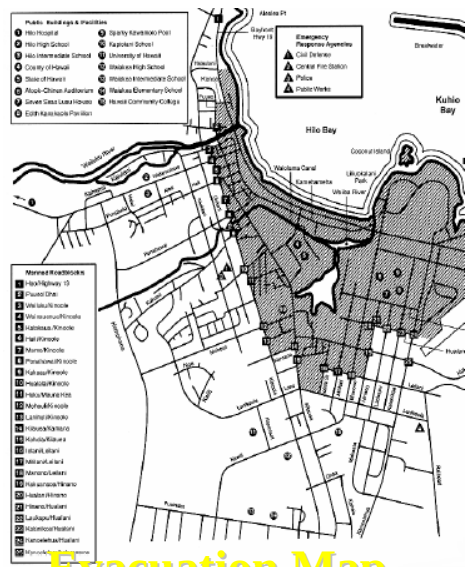
Kamaishi Harbor is located in the center of the Sanriku Coast. The harbor has suffered tsunami damage several times in its history, since it is situated at the head of a narrow bay. The photograph shows the construction of the breakwaters at depth in the bay mouth.

Countermeasures

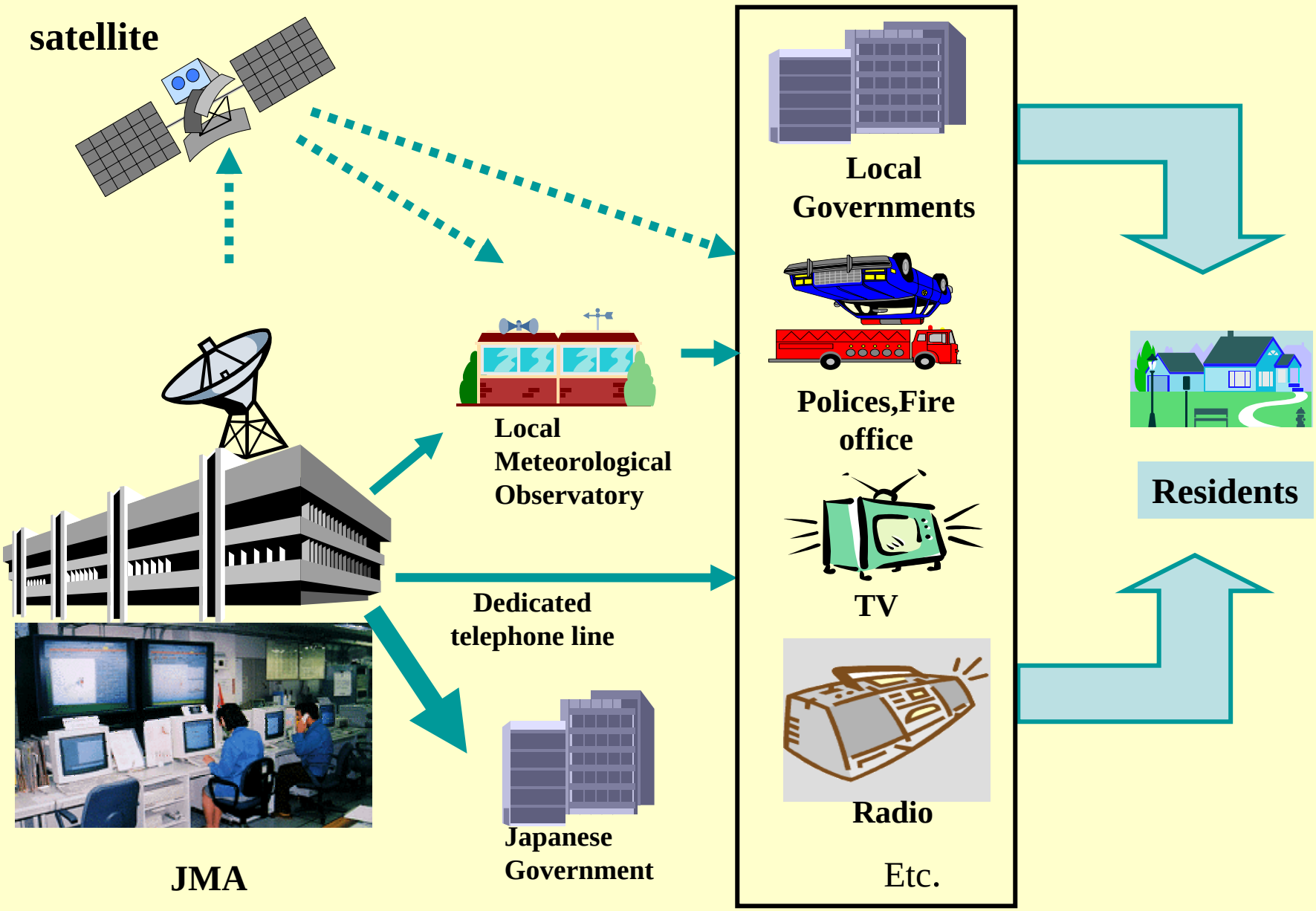








Dissemination of Tsunami Warning to Residents



(Source: Japan Meteorological Agency)

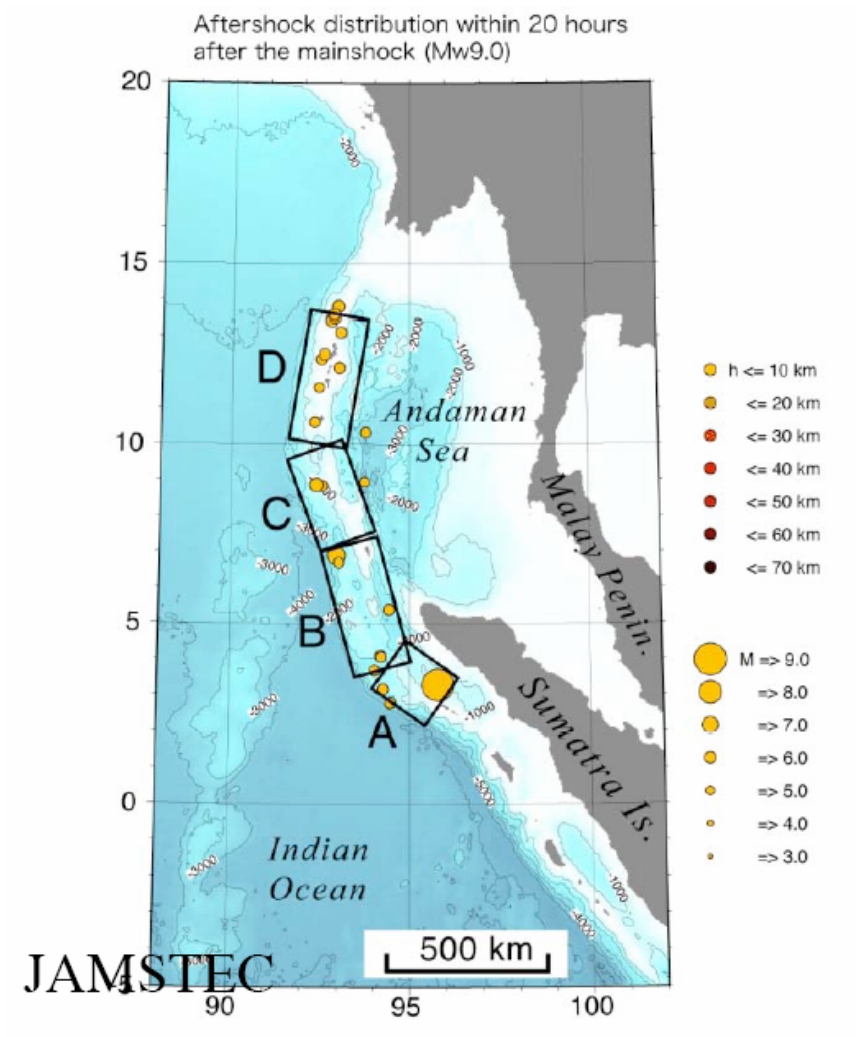
Research topics on the 2004 tsunami

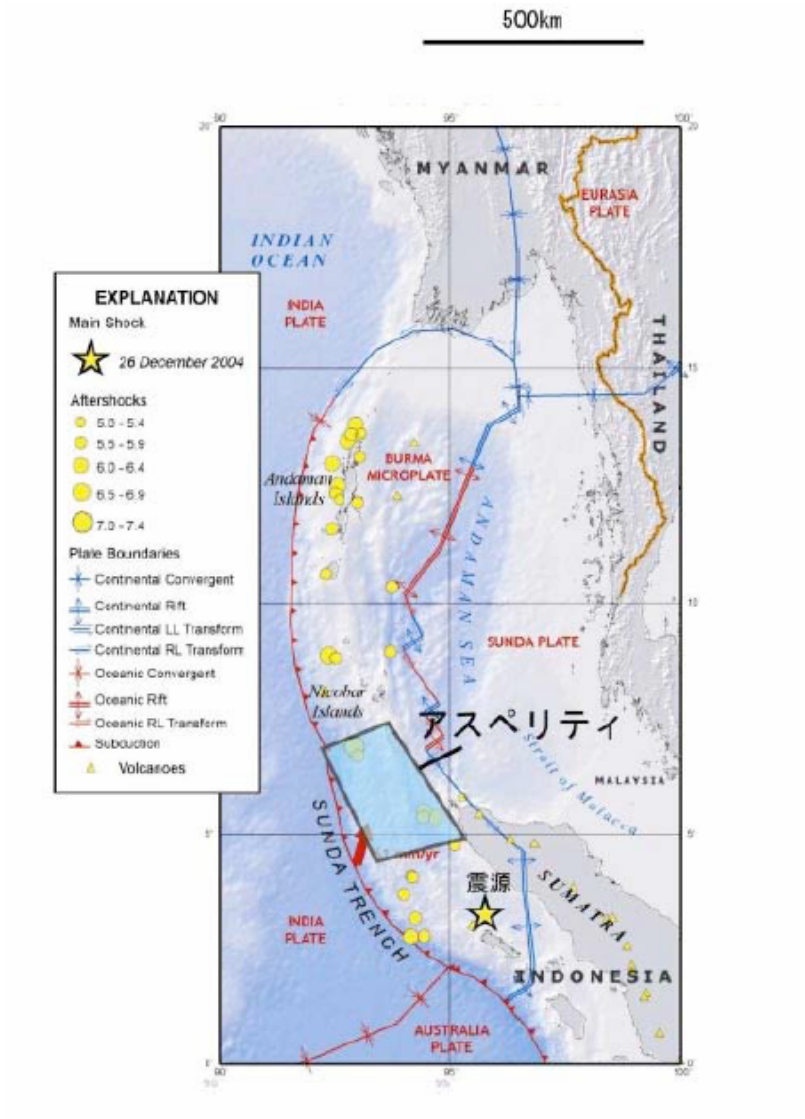
- To clarify the mechanism of the earthquake of M=9.0 for improving the numerical simulation of tsunami

- To investigate the cause of the devastating damage, which may be governed both by relative magnitude of hazards and prevention ability

- To compile tsunami impact on records; videos and photos recording the tsunami, aerial photos and satellite images

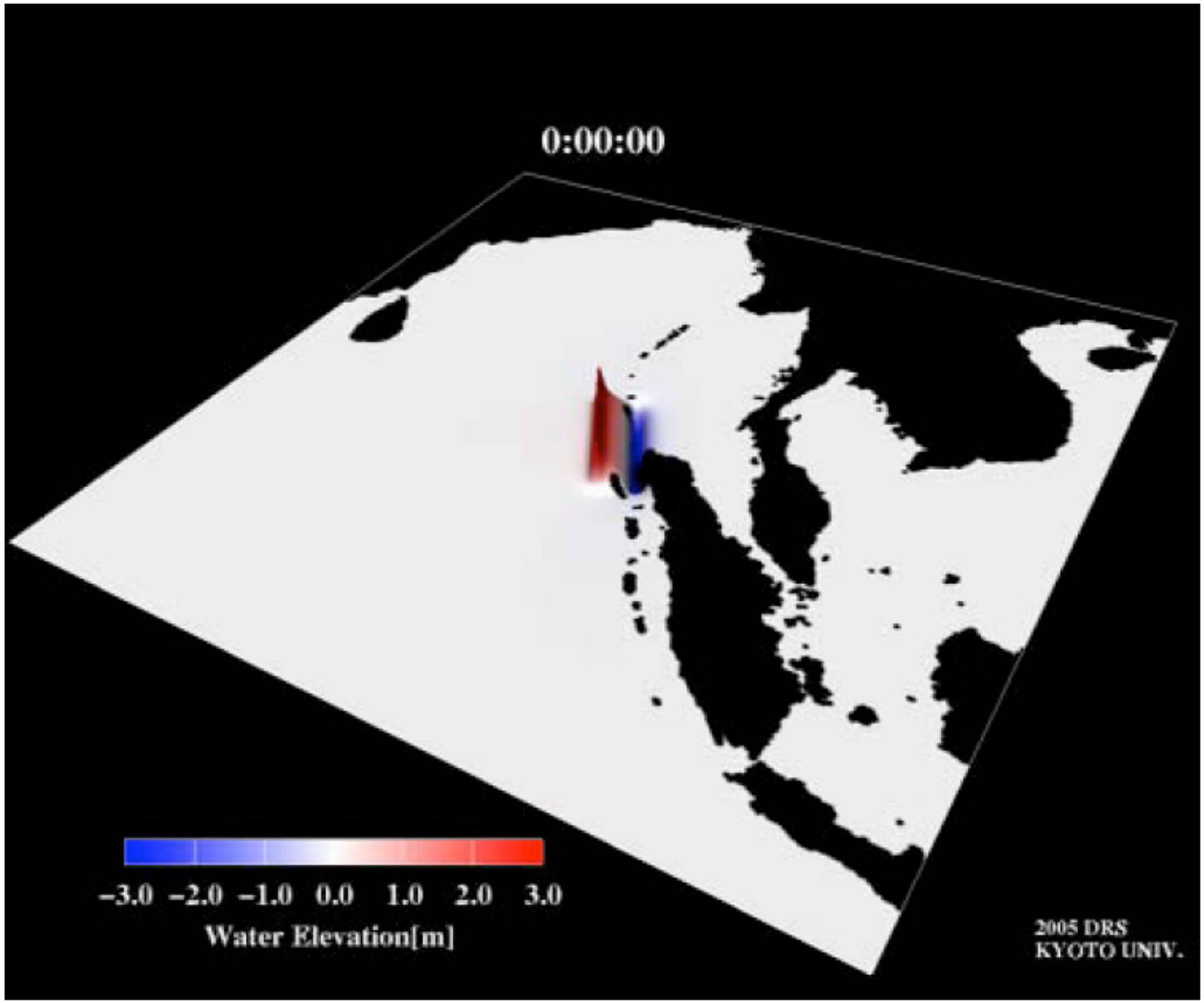
2004スマトラ沖地震の発生域
Aftershocks, faults model & tsunami source,





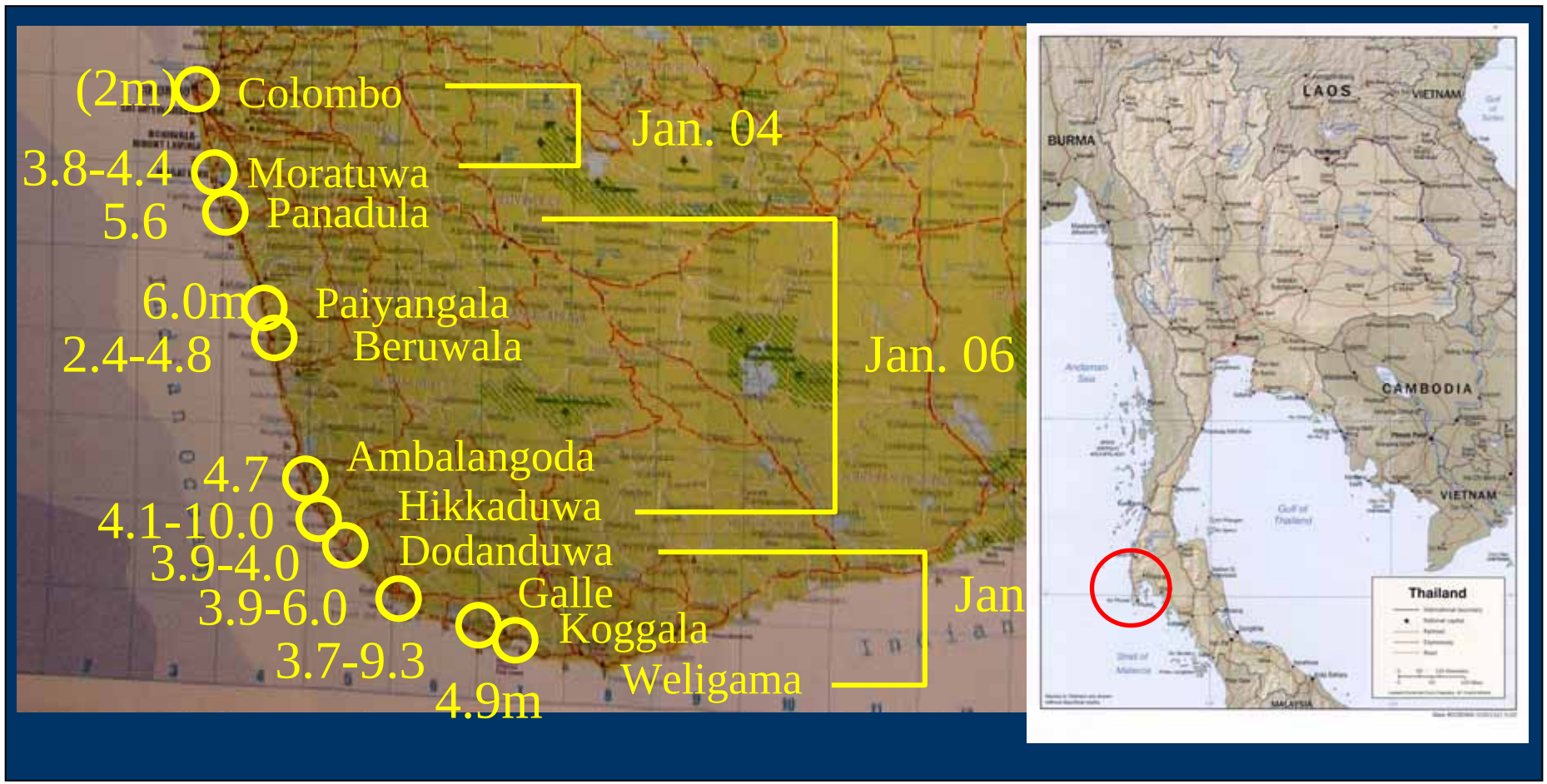
Indian Ocean Tsunami generation and propagation

made by DPRI, Kyoto University



Int.Tsunami Survey Team,
Indonesia, Sri Lanka, Thailand, India, Myanmar

South-West of Sri Lanka Island

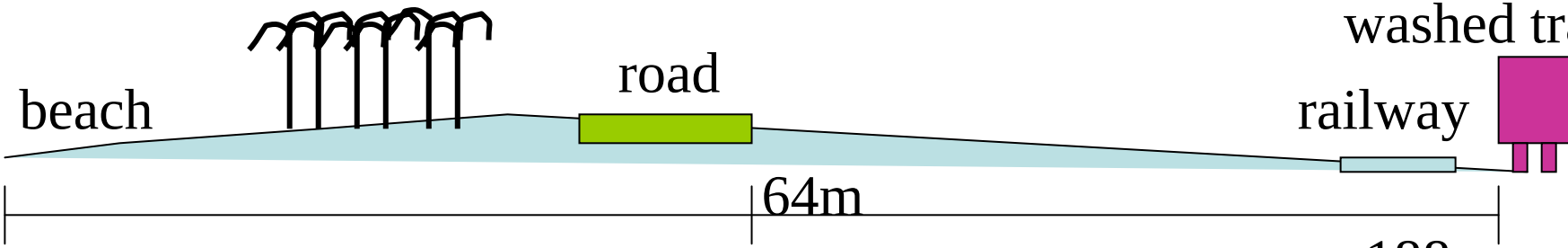


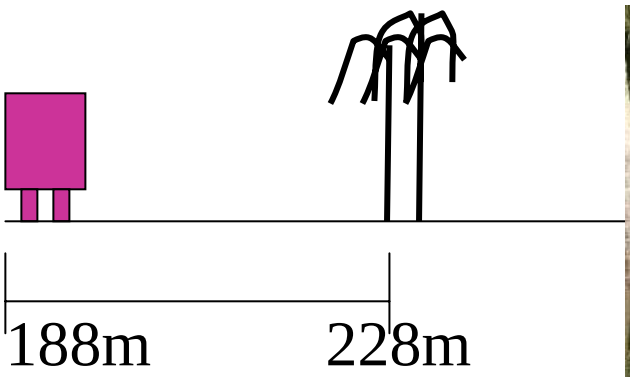
Temporal web; http://www.drs.dpri.kyoto-u.ac.jp/sumatorta/

Damage on the train in Sri Lanka causing 1,000 death

インフラ，交通機関への被害，津波による漂流物

KAHAWA, Hikkaduwa (1)





leaf tarnished

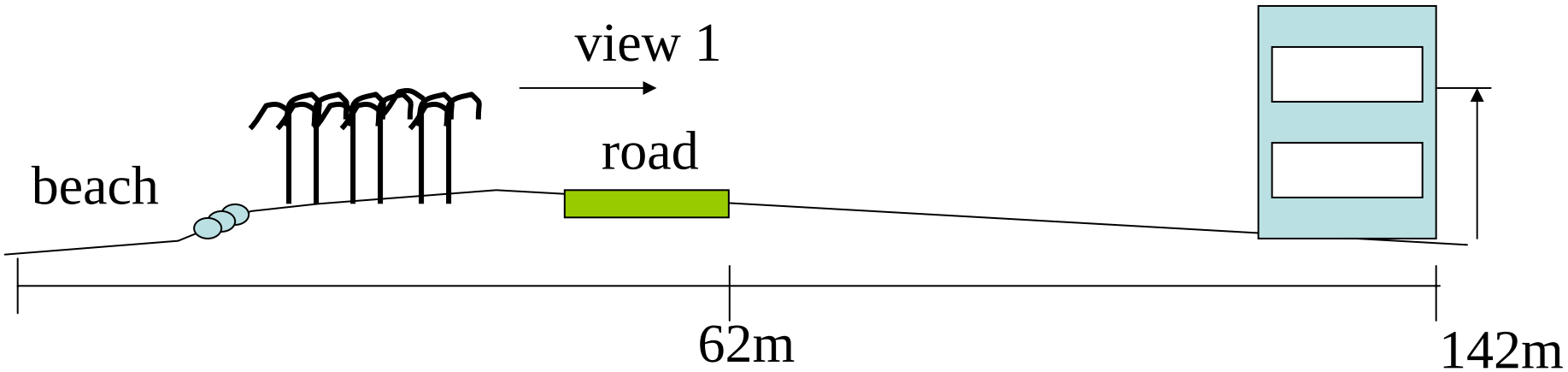
The most damaged area in Sri Lanka where the trains stopped 200m away from the coast were washed away by the 2nd tsunami attack.

列車事故と同じ地域で破壊された住宅（煉瓦造り）

All houses at Kahawa were destroyed completely by the tsunami

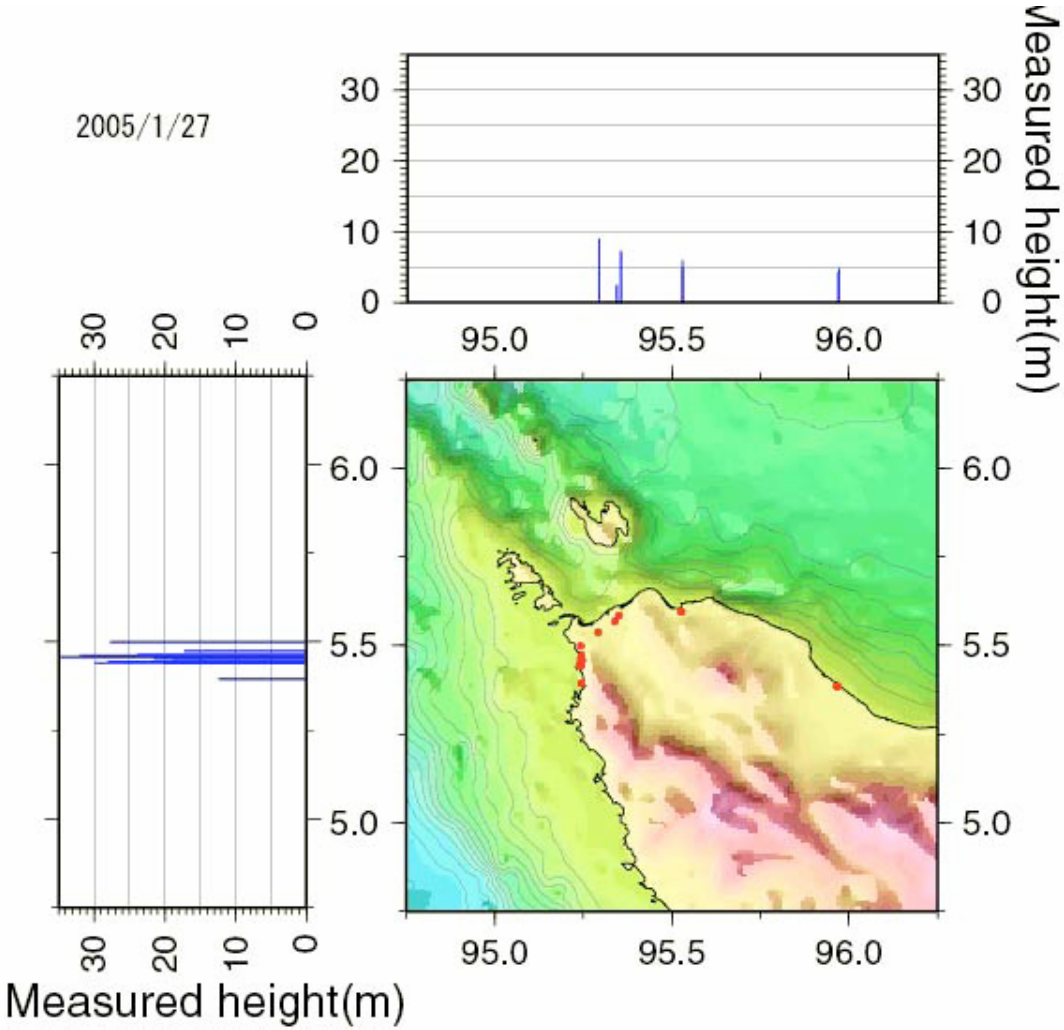
The most damaged area in Sri Lanka where the trains stopped 200m away from the coast were washed away by the 2nd tsunami attack.

KAHAWA, Hikkaduwa (2)



view 1

インドネシア・バンダアチェ周辺での津波遡上高さ
Measured tsunami runups at Banda Aceh and surround

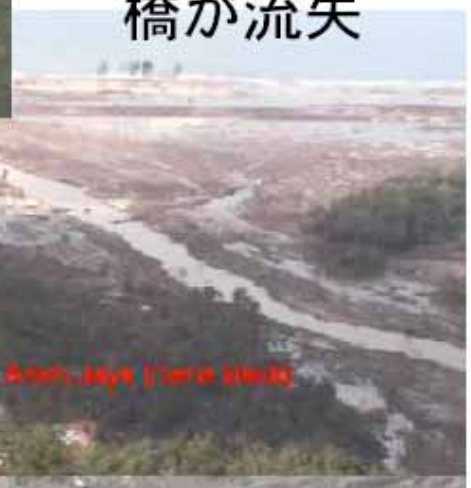


人工衛星データ(RADARSAT)

Tanggal : 10 Januari 2003
(Sebelum Tsunami)

Tanggal : 29 Desember 2004
(Sesudah Tsunami)

Sumatora**西海岸**, Lhok Nga; severe damage



セメント工場まで遡上

浸水域での被害状況

Indonesia, Sumatora, **Lhoknga**

Dr.Jose Borrero, USC

Sumatora, Banda Aceh ; severe damage

Baiturrahim Mosque

Jr. high school No.5 of Banda Aceh 8.8m

A boat carried by the tsunami attacking the hotel at downtown

Subjects for tsunami disaster prevention and mitigation

- Developing the monitoring and warning system with information technology
- Integrated disaster mitigation program for each region to mitigate tsunamis as well as typhoons, erosion and flood
- Data-base development to compile all relevant data
- International network for developing public awareness, GIS & hazard maps, risk management, etc.

Research and countermeasure, and recovery NOW

Towards the Establishment of a Tsunami Warning and Mitigation System for the Indian Ocean

- UNESCO/IOC; coordinating conference for the Indian ocean tsunami warning system
  - ✓ http://ioc.unesco.org/indotsunami//
- International Aid; JICA Since mid-January, JICA has dispatched survey teams and a number of experts to help the affected areas recover and reconstruct over the medium- to long-term.
  - ✓ http://www.jica.go.jp/english/resources/news/2005/jan.html
- Academic coordination; ICSU Natural and Human-Induced Environmental Hazards WG, & Inter Academy Panel WG
  - ✓ http://www4.nationalacademies.org/IAp/IApHome.nsf/(weblinks)/WWWW-5HUEH9
- Research groups in Japan;
  - ✓ JSCE, Special committee, tsunami committee
  - ✓ MEXT and Cabinet office providing the budget for the research