Tsunami Simulation for the warning and risk evaluation

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- Mechanism of tsunami generation
- Predicting the propagation, runup and inundation of tsunamis
- Runup and inundation information to be used for zoning and coastal planning
Tsunami Wave System

- **Generation**
  - A seafloor disturbance, such as motion along a fault, pushes up the overlying water.

- **Propagation**
  - The wave propagates across the deep ocean at jetliner speeds
  - Shoaling and refraction to amplify the wave

- **Inundation**
  - As the wave moves into shallower water, increased energy density increases both the wave height and the currents.
  - Runup on a land and run-down
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
Earthquake induced tsunamis

Tsunamis can be generated when the sea floor abruptly deforms and vertically displaces the overlying water.
Landslide/volcano induced Tsunamis

Caldera formation; surrounding water rushing into a cavity

10% of tsunamis over 100 years
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.

Faster wave propagating speed in a deep sea

Slower wave propagating speed in a shallow sea

Decreasing of wave length, amplification of wave height

Larger distance

Shorter distance

Wave tail

Wave front

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Wave fronts tend to align parallel to the shoreline so that they wrap around a headland.

Energy concentration

Crest line of wave
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 linear equations for long waves with the Coriolis force, frequency dispersion included, described in the longitude-latitude coordinate system.
An initial tsunami profile has many components of different period, which propagate with different velocities. This difference results in non-negligible deformation in wave profile, if the travel time becomes long as in case of a distant tsunami. A parameter $\text{Pa}$ (Kajiura, 1970) is used to judge whether the frequency dispersion effect should be included or not.

\[ \text{Pa} = (6h/R)^{1/3}(a/h) \]

where $h$ is the water depth, $a$ the horizontal dimension of the tsunami source and $R$ the distance from the source to the site of a nuclear plant.

$\text{Pa} > 4$, the linear long-wave equation with the Coriolis force
$\text{Pa} < 4$, the frequency dispersion effect should not be neglected.
the linearized Boussinesq equation should be used including the Coriolis force described in the longitude-latitude coordinates.
Tsunami Numerical Simulation

to be improve through the comparison with the several data

The 2004 Indian Ocean tsunami simulation by Tohoku Univ.

\[ dx = 2\text{min.}(2-4\text{km}) \]

in spherical coordinate

\[ dt = 2\text{ second} \]

Simulation of the tsunami for 8 hours needs CPU time of 1 hour using Pentium 4 computer system
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 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
Tsunami Warning System

1. Estimating the occurrence of a tsunami by seismic information (magnitude, location and depth)
2. Data base of the simulation with assumptions
3. Real time analysis with the tentative fault model
4. Revision of the tentative fault model by the observation data

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Accuracy of the simulation

Major causes of low accuracy induced by:

- Initial source; location and slip
- Modeling and Geometry data

For example.
The fixed epicenter and variety of locations in the fault
Possibility of the Tsunami Warning using by the Simulation

The Indian Ocean

Sea Bottom Topography

Under the TIME project

Cooperated with the Deployment of Asia-Pacific-Indian Ocean Hazard-mitigation Network for Earthquakes and Volcanoes: DAPHNE Project
To reduce damage and casualties

The “Three Helps” of disaster measures

The people could not see the impact/terror of tsunami only by warning with the tsunami information; arrival time and heights. They should understand its impact have the imagination before the tsunami attack through making hazards map and having workshop.
Advanced information – estimating potential damage

- Scenario
- Earthquake/tsunami source
- Simulation
- Tsunami heights, velocity, wave force, inundation area
- Estimating damage on the GIS

<table>
<thead>
<tr>
<th>Population</th>
<th>Estimated casualties</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>151,129</td>
<td>27,325</td>
<td>18.1</td>
</tr>
<tr>
<td>Total of houses</td>
<td>Damaged houses</td>
<td>(%)</td>
</tr>
<tr>
<td>57,344</td>
<td>469</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Criteria to estimate damage by tsunamis

Inundation depth
Human: killed >> 50cm
House: partially damaged >> 1.0m
totally damaged >> 2-3.0m
Building: damaged >> 5.0m
津波進上予測図 1

（津波予報 8 mのとき）

「宮城県地方に、沿岸での津波の高さが8m」という津波予報が出た場合には想定される30cm以上の浸水域の予測図です。

かなり遠方で巨大な地震が発生した場合に相当すると考えられます。西暦869年（貞観11年）の地震による津波が、この程度ではなかったかと考えられています。

この場合、名取市の沿岸部（仙台東道路より東側の閉上地区・下増田地区・北釜地区）の広い範囲で、ほぼ全域で0.3m以上の浸水があると、想定されます。

このような大津波は、予報発令から津波が来襲するまで2時間以上の時間的余裕があることが多いと考えられていますので、落ち着いて内陸部（市の中央部もしくは西部地区）へ避難してください。

自治会・町内会の対応は？

Tsunami Hazard Map to provide the inundation
According to the information of JMA tsunami warning
Making the original hazard maps

- In the past, the map was provided by the local government but no use for the people
- Original information should be included
- Selecting the base map
- Collecting the information of risk
- Discussion what information be included
- Checking them by town-walking
Powerful & future tool to support the awareness; Example of Hazards map and Data base Using the image from Sattelite on GIS

Damage in past

Safety area

Damage in past
Integrated Tsunami Countermeasure

**PAST**

No system

**PRESENT**

Structure & Facility; sea wall and breakwater

**FUTURE**

 Combination with; green belt and tsunami information

Public education for awareness and evacuation system with consideration of life and culture at reach region

Memorial day, International Tsunami Mitigation day; 26 December