MMD Tsunami Modeling and Overview of Tsunami Models in Southeast Asia

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Tectonic Plates

**Philippines Sea plate moves westward and subducts under the Philippines with velocity 7cm/year**

**Indo-Australian plate moves northeast ward and subducts under the Sumatra with velocity of 7cm/year**

**Major tectonic plates around Malaysia**
Focal mechanisms distribution around Malaysia from January 2000 to July 2012, M>6.0
(Source: Intan, 2012 and Global CMT catalog)
The geometry of subduction slabs in Northern Luzon Philippines (Manila and Philippines Trenches)

Bautista et al., 2001
Overview of Tsunami Models in Southeast Asia

- **Malaysia (MMD):**
  - TUNAMI N2 & F1 codes (each unit source is at interval 0.5, fault parameter based on empirical equations)
  - TTT NOAA: to calculate the ETA

- **Singapore (NEA & local Universities):**
  - TUNAMI-N2-NUS code (modified TUNAMI-N2)

- **The Philippines (PHILVOCS):** TUNAMI code

- **Indonesia (BMKG & German):** TsuNAWI model
  - non-linear shallow water model
  - based on a finite element discretisation
  - gives estimated tsunami height, ETA, inundation

- **Vietnam (Institute of Geophysics)**

- **China (MNEFC)**
MMD Tsunami Modelling

- **Tsunami source model**
  - Prediction of fault parameters using empirical equations (Scaling Law, Tatehata 1997)
  - Fault Length, width and dislocation based on the magnitude of earthquake

![Diagram of fault parameters](image)

\[ d \quad \text{Depth of fault top edge} \]
\[ L \quad \text{Fault Length} \]
\[ W \quad \text{Fault Width} \]
\[ D \quad \text{Slip amount} \]
\[ \phi \quad \text{Strike angle (clockwise from North)} \]
\[ \delta \quad \text{Dip angle (from horizontal plane)} \]
\[ \lambda \quad \text{Slip angle (counterclockwise from horizontal line)} \]

- a) \( \log L = 0.5 M - 1.9 \), \( \log W = 0.5 M - 2.2 \), \( \log D = 0.5 M - 3.2 \)
  - where \( L \): length, \( W \): width, \( D \): slip, \( M \): magnitude
- b) \( \delta \): (dip angle) = 45° , \( \lambda \): (slip angle) = 90° : reverse fault
- c) the strike of a fault is parallel to the trenches or the coastlines
- d) the hypocenter is located at the center of a fault plane

JMA, 2006
MMD Tsunami Modelling

- **Tsunami source model**
  - Strike angle: set parallel to the trench axis
  - Dip and slip angle: 45 and 90 degree assigned assuming the most effective case for tsunami generation
  - The epicenter is set at the center of fault
  - Distance interval between each simulation points (source points) is $0.5^0$
MMD Tsunami Modelling

- **Initial deformation**
  - A crustal deformation of sea floor by the fault motion is calculated by the elastic theory (Okada, 1985)
  - An initial deformation of sea surface is assumed to be identical to the deformation of sea floor and it is given to the numerical simulation as an initial value.
MMD Tsunami Modelling

- **Tsunami propagation model**
  - Numerical modeling using two TUNAMI codes from DCRC, Tohoku University, Japan with some modification to obtained estimated tsunami wave height
  - Estimated tsunami arrival time: TTT NOAA model
  - Bathymetry/topography: 2 min & 5 min (modified from GEBCO 1 min resolution data)
  - Governing Equations: Non-linear (in Cartesian) & linear Shallow Water Equations (in spherical coordinate system)
  - The coriolis force and bottom friction are considered
MMD Tsunami Modelling

- **Tsunami propagation model**
  - Numerical Scheme: Leap-frog Finite Difference Method (TUNAMI-CODE of Tohoku University)
  - Spatial Grid Size: 2 min or 5 min (GEBCO modified)
  - Temporal Grid Size: 6 min
  - Green’s Law applied at 50m depth of Forecast Points (FP) to calculate the tsunami height at the coast (1m)
Location of CP and FP

**Coastal Point (CP)**
Bathymetry water depth ~ 1 m

**Forecast Point (FP)**
Bathymetry water depth ~ 50 m

CP and FP are located along the coastlines with random interval.

**Bathymetry Data**
GEBCO 1 arc min (~1852 m)
Indian Ocean

MMD Tsunami Forecast Points (FP) & Coastal Points (CP)
Forecast Points (99 points) ~ 50m
South China Sea
and surrounding waters
MMD Forecast Points (FP) & Coastal Points (CP)
Coastal Points (73 points) ~ 50m
Forecast Points (73 points) \( \sim 1m \)
## Magnitude and Depth

<table>
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<tr>
<th>Magnitude (M&lt;sub&gt;w&lt;/sub&gt;)</th>
<th>Depth (km)</th>
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<td>8.0</td>
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</table>
Simulation points in Makran Subduction zone (Arabian Sea)

Simulation points from surrounding subduction zones (Sunda, Manila, Philippine, Negros, Sulu, Cotabato, Minahassa Trenches)

Snapshot of tsunami propagation (Sunda Trench)

Snapshot of tsunami propagation (Manila Trench)

> 36,000 Existing tsunami Scenarios

MMD Tsunami Forecasting Database

MMD Tsunami Database
Tsunami Simulation - Manila Trench (M9.0)
Maximum Tsunami Height: Manila Trench (M9.0)

Note: Output was based on the GEBCO 1-min bathymetric grid.
MMD Tsunami Forecasting Database

> 6000
Additional tsunami simulations (in progress)

Estimated total scenarios by end 2012

> 40,000
Covering Indian Ocean, South China Sea, Arabian Sea and some part of the Pacific Ocean
Conclusion (some issues..)

- Linear model gives large tsunami heights due to negligible of bottom friction and convection terms in the tsunami calculation
- Application of Green’s law gives large tsunami height at the coast (CP)
- Coarse bathymetry data affect the accuracy of results, and difficult to locate the synthetic points location (to match with the tidal gauge stations location)
- Pre-computed scenarios were based on estimation fault parameters only for all the subduction zone earthquakes
Some recommendations and suggestions

- Identified potential tsunami source areas - moderate or high risk areas (any seismic gaps)
- High resolution near shore bathymetric and topographic data are required for better accuracy of tsunami height and inundation
- Rupture can be represented more realistically with multiple rupture zones, instead of a single uniform rupture zone (especially for large magnitude)
- Knowing the geometry of each subduction slabs: dip angles are varies
- Nested grid model with fine bathymetric resolutions
Malaysian National Tsunami Early Warning Centre
Thank You