Retrospect on the tsunami simulation efforts for the German-Indonesian Tsunami Early Warning System

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Outline

- GITEWS overview
- Evolution of TsunAWI and the scenario repository
- Focus: dataproducts
- Focus: scenario selection
- Focus: inundation sensitivity study
GITEWS Timeline

German-Indonesian Tsunami Early Warning System

2005-2011  GITEWS project funded by BMBF

Nov. 2008  Inauguration of the tsunami early warning system in Jakarta

Sep. 2010  Evaluation by international experts

March 2011  Transfer of Ownership to Indonesia

In a nutshell

- Non-linear SWE (sibling of full ocean model FESOM),
- Unstructured $P_1 - P_1^{NC}$ finite element grid, $\Delta x \leq \min \left( c_t \sqrt{gh}, c_g \frac{h}{\nabla h} \right)$
- Initial conditions: Okada parameters, source model, land slide model
- Leap-frog time stepping
- Modules for tides, non-hydrostatic pressure
- Fortran90, OpenMP, netcdf
- Visualization with Matlab, OpenDX, GIS
- Scripts for batch and post processing, shapefile output
TsunAWI scenario repository
Scenarios 2007-2010

**model physics**  linear shallow water

**source model**  by GFZ: RuptGen 1.0, 1900 sources
336 epicenters, Mw=7.5, 7.7, **8.0**, 8.2, **8.5**, 8.7, **9.0**

**bathymetry**  GEBCO 1’, accurate datasets for coastal regions
TsunAWI scenario repository
Scenarios 2007-2010 → since 2011

**model physics**  linear shallow water
→ nonlin. advection added, Smagorinsky viscosity, improved inundation scheme

**source model**  by GFZ: RuptGen 1.0, 1900 sources
336 epicenters, Mw=7.5, 7.7, **8.0**, 8.2, **8.5**, 8.7, **9.0**
→ RuptGen 2.1, 3470 sources
528 epicenters, Mw=7.2, 7.4, 7.6, . . . , 8.8, 9.0

**bathymetry**  GEBCO 1’, accurate datasets for coastal regions
→ GEBCO 30” instead of GEBCO 1’

**technical improvements**
→ faster calculation, reduced scenario file size
TsunAWI scenario repository
Model domain for scenarios 2011
TsunAWI scenario repository
Model domain for scenarios 2011 and extension 2013
## TsunAWI scenario repository

### Scenarios Comparison

<table>
<thead>
<tr>
<th></th>
<th>Scenarios 2011</th>
<th>Extension 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>#scenarios</strong></td>
<td>3450</td>
<td>New, East: 1100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Replace: 1100</td>
</tr>
<tr>
<td><strong>magnitudes</strong></td>
<td>7.2, 7.4, ..., 8.8, 9.0</td>
<td></td>
</tr>
<tr>
<td><strong>#grid nodes</strong></td>
<td>2.3 Mio</td>
<td>15 Mio</td>
</tr>
<tr>
<td><strong>reduced</strong></td>
<td>1.1 Mio</td>
<td>7.5 Mio</td>
</tr>
<tr>
<td><strong>resolution</strong></td>
<td>50m - 150m - 15km</td>
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<tr>
<td><strong>model time</strong></td>
<td>3 h</td>
<td>12 h</td>
</tr>
<tr>
<td><strong>compute time</strong></td>
<td>0:45 h</td>
<td>15 h</td>
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<tr>
<td></td>
<td>2 × 8 Core</td>
<td>1 × 8 Core</td>
</tr>
<tr>
<td></td>
<td>Xeon Nehalem</td>
<td>Xeon Westmere</td>
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<tr>
<td><strong>file size</strong></td>
<td>1.1GB</td>
<td>22GB → 500MB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>without timesteps</td>
</tr>
</tbody>
</table>
Scenario data products

ETA isochrones and maximum amplitude

Example: Magnitude 9.0 in the Eastern Sunda Arc
Scenario data products

Coastal forecast points

Example: Magnitude 9.0 in the Eastern Sunda Arc, zoom to Lembar, Eastern Lombok

- Maximum SSH and ETA at 134,000 coastal forecast points
- Time series at tide gauge locations
Scenario selection algorithm
Uncertainty reduction with multiple sensors

Regard each sensor type with its characteristics in mind!

- Epicenter and magnitude are derived from multiple sensor data by approved SeisComP3.

- Reliable GPS data comes fast, too. But little experience so far, limited number of stations.

- Tide gauges hard to use for early warning in a fully automated algorithm.
Scenario selection algorithm

Uncertainty reduction with multiple sensors

Regard each sensor type with its characteristics in mind!

- Epicenter and magnitude are derived from multiple sensor data by approved SeisComP3.
  → Use epicenter and magnitude to pre-select scenarios.

- Reliable GPS data comes fast, too. But little experience so far, limited number of stations.
  → Refine scenario selection by comparing GPS measurement and scenario data.

- Tide gauges hard to use for early warning in a fully automated algorithm.
  → Very valuable for all-clear and hind-casts.
Scenario selection algorithm

1. Step: Seismic pre-selection

**Magnitude uncertainty:**

\[ M - 0.5; M + 0.3 \],

\[ M_w + 0.2 \] for momentum tensor Magnitude

**Epicenter uncertainty:**

Ellipse parallel to the trench

\[ r_L = 10^{0.5[M+0.3]} - 1.8 \text{ km}, \]

\[ r_W = \frac{1}{2} r_L. \]
Scenario selection algorithm

2. Step: Refine selection with GPS data

- e.g., Benkgulu Sept. 2007

USGS Finite Fault: Tsunami source NW of the epicenter. Measured GPS-dislocations strong in the NW, but not SE.

GPS matching would reject all scenarios in the SE, and some very strong scenarios in the NW.
Inundation simulation
Sensitivity study on topography data

Three groups  AIFDR, ITB, AWI,
Three models  ANUGA, TUNAMI-N3, TsunAWI,
Three regions  Padang (Sumatra), Maumere (Flores), Palu (Sulawesi)
One conclusion  **High quality topography data is crucial!**

- Free SRTM data (90m horizontal resolution, \(<16m\) vertical accuracy) only for rough estimates,
- Intermap (5m; 0.7m) and LiDar (1m; 0.15m) comparable for shallow water models,
- Results more sensitive to varying data sets than to varying resolution.
Inundation simulation

Sensitivity study on topography data

Example: synthetic scenario for Maumere, Flores

Resolution: 2m

Data: LiDAR DSM
Data: SRTM90

Data: LiDAR DTM
Data: DSM

Data: DTM
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Thank You, Terima Kasih!

Poster: B238