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Poster No. XY0593

# Design of a multi-sensor enabled simulation module for tsunami early warning

## Abstract

The German Contribution to the Indian Ocean Tsunami Early Warning System in Indonesia (GITEWS) will comprise a simulation module which will assist the decision making process of disseminating tsunami warnings to the affected regions. This simulation module will mainly rely on pre-computed scenarios for response time optimization. Other than most of the simulation modules in tsunami early warning systems, the design of our system incorporates the utilization of multiple sensor types for continued improvements of scenario quality. Theses sensor types include seismic sensors, deep ocean pressure gauges, coastal water level gauges, and GPS measurements of the rupture.

## System Overview

- Decision support system with user interface, visualization, etc.
- Independent (sensor) sub-systems
- Centralized data storage
- Web-enabled interfaces (Tsunami service bus)
- Simulation module as "virtual" sensor

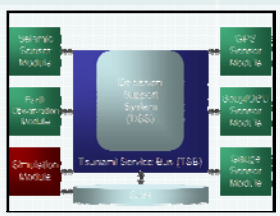


*Fig. 1 Early Warning System Overview*

## System Design

- Web-Services provide interfaces (OGC SWE compliant)
- Simulation System Controler (SSC) drives/steers system
- Selection Module selects best fit scenario
- Index database (IDB) contains indexed data from scenarios
- Index database updater (IDU) reads indexed data from scenarios
- Tsunami Scenario Repository (TSR) contains (compressed) NetCDF files with scenario data
- Fallback Model with Source Term Processing Unit provides fall-back option in case of unforseen events
- Java framework implemented

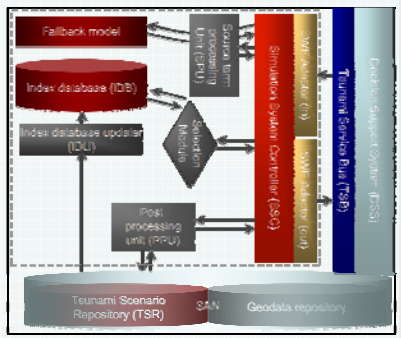


*Fig. 3 Simulation Module Overview*

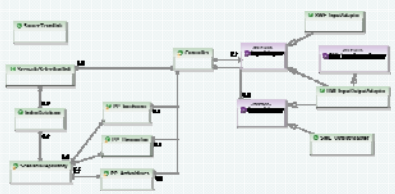

*Fig. 4 Java Framework of the Simulation System (Class Diagram)*

## Scenarios and Data Products

- Scenarios generated by TsunAWI
- Unstructured grid finite element non-linear shallow water code with inundation
- Mareograms for arbitrary positions
- Arrival time maps
- Inundation maps
- Evaluation (TsunAWI vs. Tunami-N3, Collaboration with BPPT, Indonesia)

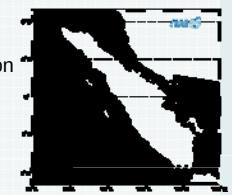

*Fig. 6 Triangular Grid*

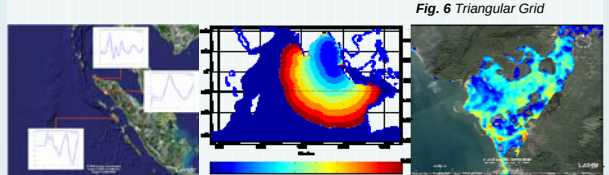

*Fig. 7 Data products of Simulation System: Mareograms, Arrival times, Inundation map (from left)*

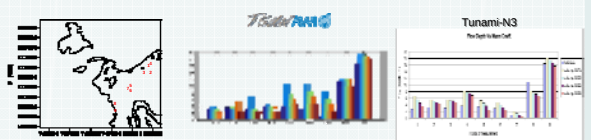


*Fig. 8 Comparison of water depths at selected positions: first column measured*

## Time requirements

- First information after 10 sec. (issued request from DSS)
- Qualified information after at most 240 sec.

⇨ **Results based on pre-computed scenarios**.

*Fig. 2 Early Warning Timeline*

## Selection

- Indexed data:
  - Epicenter/Magnitude $(\lambda, \phi) + M$
  - Gauge timeseries $\mathrm{ssh}_{\lambda,\phi}(t)$
  - GPS rupture vector $(x_\lambda, x_\phi)$
  - Max. Wave height $\mathrm{ssh}_{\lambda,\phi}$
  - Arrival time $t_{\lambda,\phi}$
- Selection by weighted least squares approach:

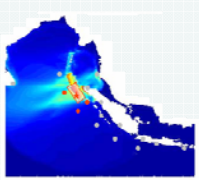

*Fig. 5 Indexing Example*

$$\min_{\text{all scenarios } s} \left[ w_{\text{loc}} \|(\lambda^0, \phi^0) - (\lambda^s, \phi^s)\|_2^2 + w_{\text{mag}} (M^0 - M^s)^2 + w_{\text{ssh}} \sum_i \|\mathrm{ssh}_{\lambda^i,\phi^i}(t) - \mathrm{ssh}^s_{\lambda^i,\phi^i}(t)\|_i^2 + w_{\text{GPS}} \sum_j \|(x^j_\lambda, x^j_\phi) - (x^{j,s}_\lambda, x^{j,s}_\phi)\|_2^2 \right]^{\frac{1}{2}}$$

## References

- Documentation for TsunAWI (on request)
- Web: http://www.awi.de/en/go/tsunami/

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