Credible Worst Case Tsunami Scenario Simulation for Padang

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Introduction

Padang in West-Sumatra (fig. 1) is one of the priority regions of the German-Indonesian Tsunami Early Warning System project (GITEWS). From 2006 onwards, Alfred Wegener Institute (AWI) as the lead organization within GITEWS for simulation products, has contributed simulation results and inundation map information to the community of Padang. In this memorandum, we intend to communicate latest results of our simulations.

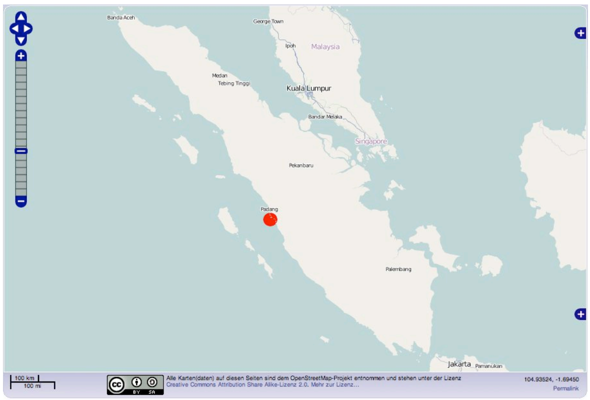

Fig. 1: Location of Padang (source: openstreetmap.de)

A report, published to the Padang authorities in September 2007, contains the results obtained with the geo-data available at that time. The worst cases, described in that report were heavily doubted in the scientific community, and a lot of effort has been put into coming up with better results based on more accurate geo-data (especially near-shore bathymetry and topography data), as well as more credible source data corresponding to a credible worst case earthquake. It turns out that the current credible worst-case does not differ significantly in the city center from the proposed planning basis in the mentioned report of 2007 (fig. 2).

In order to prepare for a follow-up of the “Padang Consensus Workshop” (International Workshop on Official Tsunami Hazard Map for Padang, August 25, 2008 at Andalas University, Padang), we present our latest simulation results in this short memorandum.

Source Parameters

At the mentioned workshop in August 2008 in Padang it was agreed among the scientific community that a credible worst-case approach should be taken for generating an official hazard map for Padang. The initial rupture for this credible worst-case were to be provided by Prof. Kerry Sieh and Prof. Danny Hilman Natawidjaja, based on their latest research on the locking situation and probable uplift amount. Natawidjaja presented his results in a PowerPoint presentation at the mentioned workshop, but could not make his source parameters available to the community at that point.

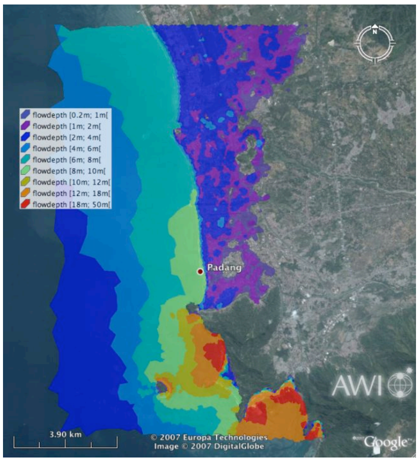

Fig. 2: Reference scenario from 2007 Report

Therefore, the tsunami modeling group at AWI generated their own initial uplift distribution and sources, using the software RuptGen by Dr. Andrey Babeyko (GFZ) with a hand-tailored uplift distribution based on the figures of Natawidjaja. An extension to the original claim of a maximum earthquake moment magnitude of 8.92, which takes the Benkulu 2007 earthquakes and stress release into

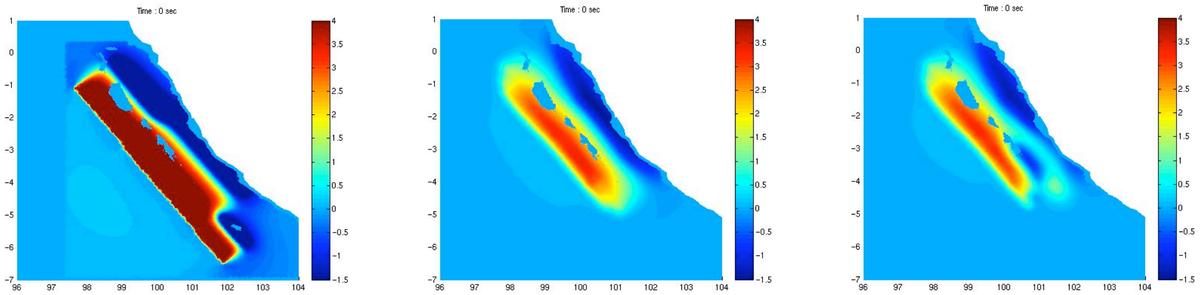

Fig. 3: Initial uplift distribution for the (from left) Borrero scenario, Natawidjaja 8.92 scenario, and Natawidjaja 8.87 scenario.

consideration, results in an earthquake with moment magnitude of 8.87. Initial conditions for both cases, together with the initial uplift for the originally proposed scenario from Borrero et al. (2006) are depicted in figure 3. All three scenarios are based on different states of assessing GPS based estimations of the locking situation south-west of Padang and historical data. The Natawidjaja scenarios represent the current state of the art knowledge with respect to the slip amount potential as well as the uplift modeling.

Figure 4 shows the energy distribution of all three scenarios for a 10-hour-simulation in the whole Indian Ocean domain.

Inundation Simulations

We conducted simulations based on the three available initial conditions with our unstructured mesh tsunami wave propagation and inundation simulation software TsunAWI. TsunAWI is well validated and tested and represents the state of the art of tsunami simulation at present (see e.g. Harig et al., 2008). With TsunAWI it is possible to simulate the propagation and inundation seamlessly, by using locally refined meshes.

Three different meshes are used for the simulations. The Indian Ocean mesh comprises

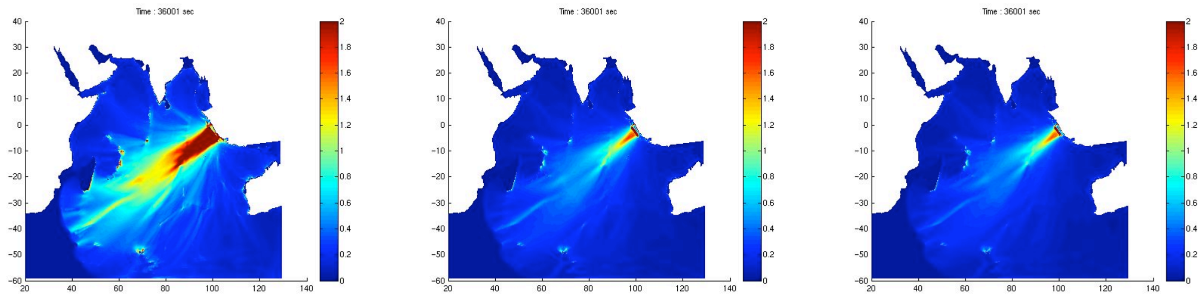

Fig. 4: Energy (max. wave height) distribution for the (from left) Borrero scenario, Natawidjaja 8.92 scenario, and Natawidjaja 8.87 scenario.

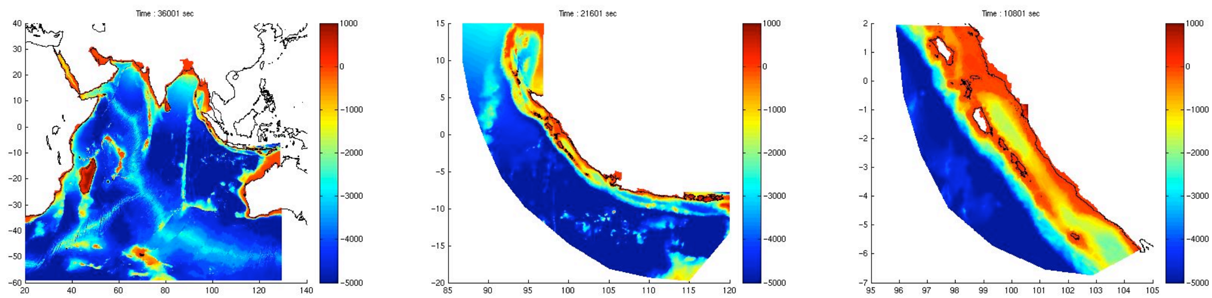

Fig. 5: Computational domains for three different meshes with bathymetry/topography (from left): indian_ocean, m003, and padang_hi.

approx. 5 million unknowns (or nodes), the regional mesh named m003 has approx. 2.3 million nodes and the local mesh named padang_hi has approx. 600.000 nodes. Extents of these meshes are shown in figure 5. The Indian Ocean mesh achieves a local resolution of approx. 500 m in Padang, while both other meshes locally resolve the inundation process with less than 100 m.

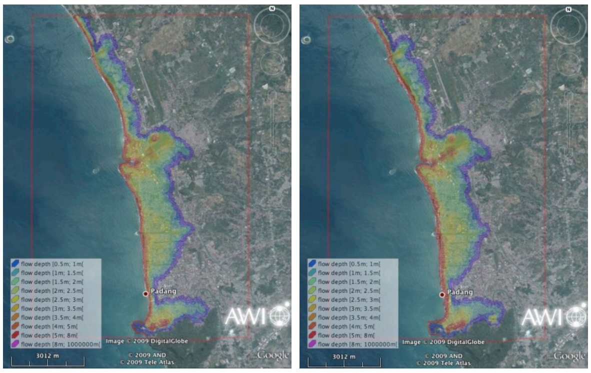

Fig. 6: Natawidjaja 8.87 scenairo on meshes m003 (left) and padang_hi, local resolution approx. 100 m.

We conducted simulations with differing sets of geo-data: Mesh m003 comes in two versions: Version “old” uses Gebco Bathymetry and SRTM (x-band) topography data with near-shore bathymetry composed of sea maps data and high-resolution bathymetric data acquired by Nils Goseberg from Franzius-Institute at University of Hannover. The “new” version of Mesh m003 uses the same bathymetry data, but superposes high-resolution and highly accurate HSRC data for topography in the city area of Padang, obtained from the “Last-Mile project” (http://www.last-mile-evacuation.de). The Indian Ocean mesh uses the same data as the m003 mesh, except for the high-resolution bathymetry from Franzius-Institute. Simulation of the Natawidjaja 8.92 scenario uses SRTM topography data, while Borrero and Natawidjaja 8.87 schenarios use HRSC topography. Finally, padang_hi grid simulations use HRSC topography in Padang, SRTM (X-band) everywhere else, Gebco 1-minute bathymetry and sea maps bathymetry near shore.

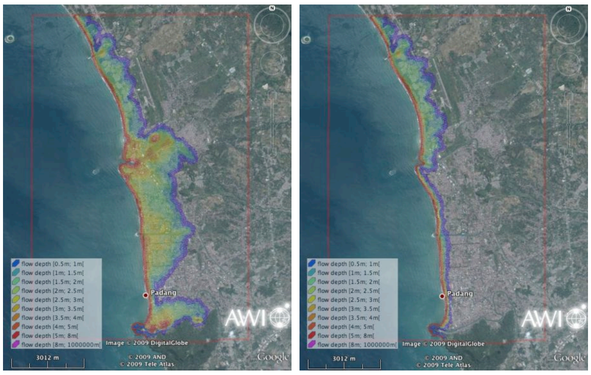

Fig. 7: Natawidjaja 8.92 scenario on mesh m003, with high resolution HRSC topography (left, new) and SRTM topography (right, old).

Since padang_hi and m003 grids have a similar resolution in Padang, the differing results are most likely due to the different bathymetries. Note, that the difference is very marginal (see figure 6). However, comparing old and new m003 grid simulations of Natawidjaja 8.92 scenarios makes quite a difference (fig. 7). The reason for this behavior is the high-resolution and accurate HRSC topography data set that can be used in this region. It is therefore recommended for future simulation efforts that high-resolution, and especially highly accurate, topography data be used, if possible. In the coarse resolution simulations with the Indian Ocean grid, highly accurate topography data are not sensitively determining the inundation behavior. However, for highly resolved and accurate simulation results (aka grids), the topography is crucially important for determining realistic inundation results (see figure 7).

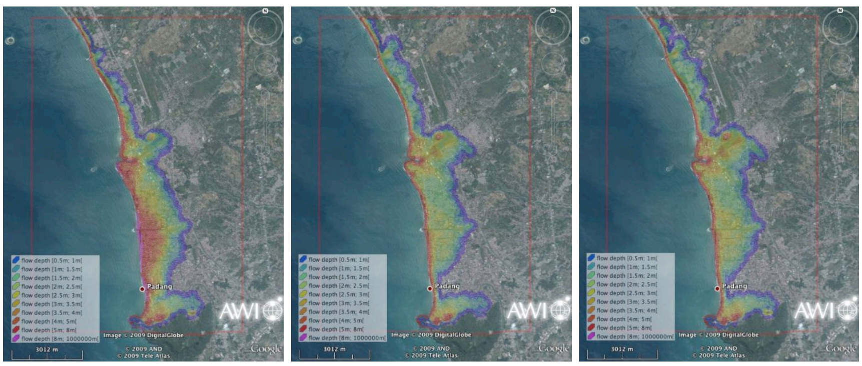

Fig. 8: Borrero, Natawidjaja 8.92, and Natawidjaja 8.87 scenarios (from left) on mesh m003.

Finally, the initial conditions are not as sensitive to the inundation results. Comparing the Borrero scenario, the Natawidjaja 8.92 and 8.87 scenarios, it turns out that all scenarios are qualitatively similar to each other (figure 8).

Conclusions

A credible worst-case tsunami scenario for Padang reveals a severe hazard potential for large portions of the central city area of Padang. It turns out that simulation results sensitively depend on highly accurate topography data, which should be provided to the modeling community. It is also important to note that sensitivity on initial conditions as well as on bathymetry data is by far not as sensitive as the topography.

All simulations in this memorandum are performed with exactly the same simulation software. It will be the task of the Padang Consensus scientific community to compare different simulation software systems in order to determine sensitivity to simulation tools.

The ultimate Padang Consensus Simulation based on the credible worst case for Padang is depicted in figure 9. Padang encounters flow depths of up to 8 m along the shoreline and close to the channels/rivers.

References

[1] Borrero, J. C., Sieh, K., Chlieh, M., Synolakis, C. E. (2006): *Tsunami inundation modeling for western Sumatra,* PNAS, **103**:19673–19677.

[2] Harig, S., Chaeroni, Pranowo, W. S., and Behrens, J. (2008): *Tsunami simulations on several scales: Comparison of approaches with unstructured meshes and nested grids,* Ocean Dynamics, **58**:429–440.

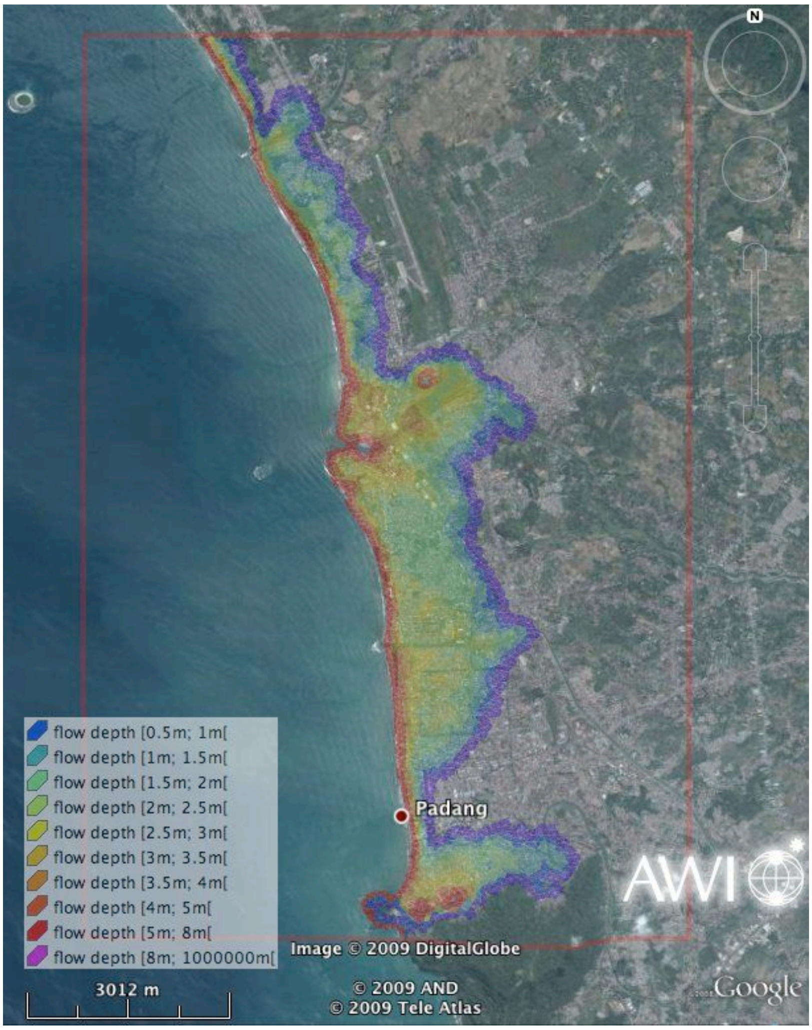

Fig. 9: Natawidjaja 8.87 scenario on mesh m003 – the credible worst-case.