Highly-resolved numerical modeling of tsunami run-up and inundation scenarios in the city of Padang, West Sumatra

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Purpose

The vastly exposed urban coastal agglomeration of Padang, West Sumatra, Indonesia, has recently been taken into consideration for further evaluation and risk assessment to the potential threat of tsunamis due to the amplified risk of future earthquakes in this region [McCaffrey 2007], aiming to improved recommendations on evacuation routes. The present work is one part of a large interdisciplinary research project and shows the results of hydrodynamic simulations of the inundation dynamics of a Tsunami in the urban coastal hinterland of Padang, Western Sumatra.

Fig. 1 sketches the computational domain and the positions of cross sections and analysed gauges. We considered two digital elevation models (DEM) for the conducted simulations differing basically from the spatial accuracy and resolution of the underlying geodatabase. The first DEM consists of coarsely resolved and adjusted SRTM topography and digitised nautical chart bathymetry. The second one is build from highly resolved HRSC topography and newly surveyed

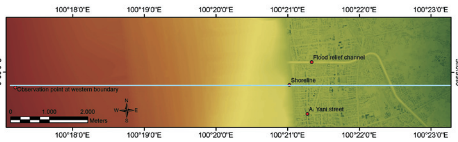

Figure 1: Sketch of computational domain, position of cross section and analysed gauges

multibeam bathymetry. Cross sections and elevations given in fig. 2 highlight the main differences between the two geometries. The primary advantage of the higher resolution is, that infrastructure and buildings are captured adequately. We found notably differences in height of both topography and bathymetry that influence the results of our numerical models significantly.

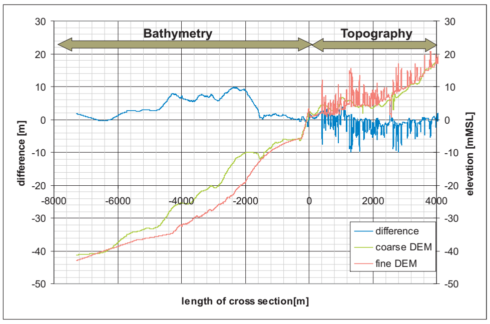

Figure 2: Cross sections for coarse and high resolved digital elevation model, differences in height

Model setup

We have chosen a hybrid approach where we coupled two numerical models in subsequent steps. At a first step the ocean-wide Tsunami propagation was modelled using TsunAwi [Harig et al. 2007]. Based on that results delivered from AWI, Bremerhaven, we secondly interpolated the results to our boundary as shown in fig. 3. The hydrodynamic inundation modelling tool used for the detailed near-shore simulation is constantly developed by the Australian National University and Geoscience Australia (ANUGA). Some features are:

- ✓ Nonlinear shallow water wave equations [Nielsen et. al. 2005], solved by finite-volume method
- ✓ Flexible mesh capabilities
- ✓ Robust wetting and drying algorithm allow modeling run-up, overtopping and inundation

The two compared model domains comprise between 400000 to 550000 cells with areas ranging between 3 - 2000m².

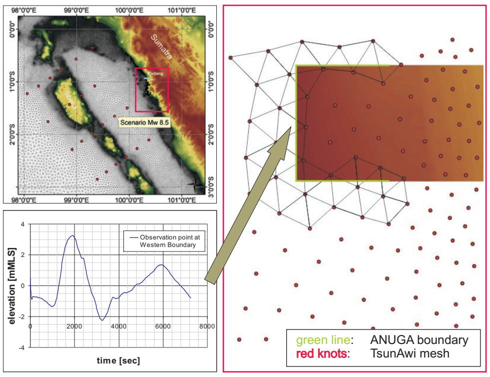

Figure 3: Boundary condition for the numerical simulation, coupling scheme between ocean-wide (TsunAwi) and near-field model (ANUGA)

Results

Initially the comparison of both results originating from the different geometries shows diverse inundation pattern. Figs. 4 and 5 demonstrate two snapshots of inundation for the model time 2040 sec. It is obvious, that by considering finer geometry, inundation is delayed and retarded. Differences in run-up for that particular time-step vary from 50m to 200m.

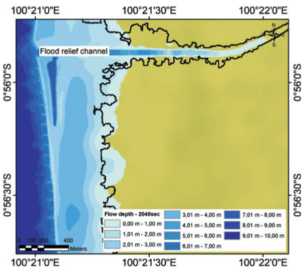

Figure 4: Inundation for the coarse DEM at t=2040 sec., black line indicates inundation limit of high resolved DEM at the same time-step

Figs. 6 and 7 illustrate maximum inundation for both geometries. Here differences in run-up are even more significant, ranging from 100m to 670m. The higher resolved geometry leads to a more uniform flow pattern whereas the coarser geometry effects areas to be inundated more easy. We found a noticeable time shift for the wave arriving at a distinct point of a few hundred seconds as well.

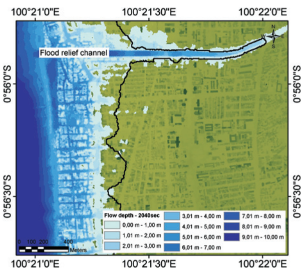

Figure 5: Inundation for the high resolved DEM at t=2040 sec., black line indicates inundation limit of coarse DEM at the same time-step

Additionally we compared time series at two locations as indicated in fig.1. For the A. Yasni street gauge we detected higher values for velocity as well as flow depth (fig. 8), when running the simulation with higher resolution.

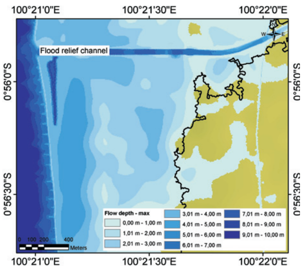

Figure 6: Maximum inundation for the coarse DEM at t=2520 sec., black line indicates inundation limit of high resolved DEM

This effect is mainly caused by friction and energy dissipation induced by infrastructure represented in the highly resolved DEM. Furthermore, this implies higher water stages near the coast and significantly higher velocities in the streets. By contrast this effect is absent at the flood relief channel where the quantities of velocity and flow depth are almost similar.

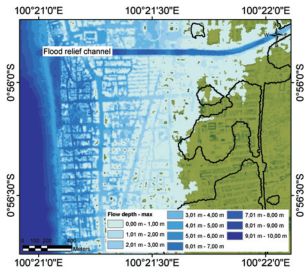

Figure 7: Maximum inundation for the high resolved DEM at t=3030 sec., black line indicates inundation limit of coarse DEM

Conclusions

Accuracy and resolution of digital elevation models used for small-scale hydrodynamics is a crucial component when detailed information about inundation dynamics and evacuation routes are needed. Hence, there is an urgent demand for highly resolved data.

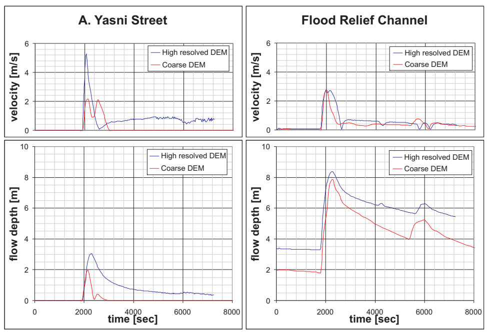

Figure 8: Time series for velocity and flow depth of analysed gauges *A. Yasni Street* and *Food Relief Channel* (blue line: high resolved vs. red line: coarse DEM)

Acknowledgements

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