Tsunami Run-up problems treated by Modern Software Geoclaw: the Tohoku-Oki event as an Example

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Summary Tsunami models are proposed to study the transoceanic tsunami propagation, together with the inundation in small-scale coastal regions. The software package Geoclaw, which utilizes shock-capturing finite volume methods, is applied to model the tsunami propagation and run-up. Using the Tohoku-oki event as an example, the overall distribution of tsunami propagation, the area submerged by flood water, and maximum wave heights along the coast are obtained from numerical calculations.

INTRODUCTION

On March 11, 2011 a magnitude 9.0 earthquake occurred near the east coast of Honshu, Japan. Five minutes in duration, it triggered a Pacific-wide tsunami that was catastrophic along the northeast coast of Japan. According to the report by Bruce Jaffe from USGS of the International Tsunami Survey Team, the first tsunami wave arrived at the Honshu coastline within about 15 minutes of the earthquake. The subsequent waves 10m or more in height near the coast resulted in inundation distances larger than 4 km. Entire communities were flooded by the waves and substantial infrastructure was damaged.

Tsunami runup exhibits distinct flow characteristics compared to tsunami propagation. Run-up is measured by the difference between the elevation of maximum tsunami penetration (inundation line) and the sea level at the time of the tsunami. The prediction of runup is indispensable to evaluate the tsunami hazards in coastal regions. Two dimensional linear long-wave equations are widely used for tsunami propagation simulations, as these models provide adequate wave prediction with relatively smaller memory requirements and shorter computational time. However, as the water depth decreases in coastal areas the non-linearity gains relevance. The detailed modelling of inundation of small-scale coastal regions poses a number of algorithmic challenges distinct from trans-oceanic propagation.

Tsunami Propagetion and Run-up simulated by Geoclaw

Tsunami wave propagation is commonly modelled with the shallow water equations: depth-averaged equations for conservation of mass and momentum. The shallow water equations are a set of three coupled nonlinear hyperbolic equations. Geoclaw is a software package specially tailored for solving hyperbolic problems in the environmental sciences. Among the problems tackled by Geoclaw are tsunamis, storm surges, floods and landslides. The software is based on high-resolution Godunov shock-capturing finite-volume schemes with adaptive-mesh refinement (AMR). It employs a special Riemann solver for resolving the moving wet-dry interface problem at the inundation front. Geoclaw has now been parallelized using Open-MP.

Preliminary Results of the Numerical Simulation

We use the commercial software Amira to visualize the numerical simulation results. Fig 1 shows the visualization of the propagation in the first 15 minites of Tohoku-Oki event.

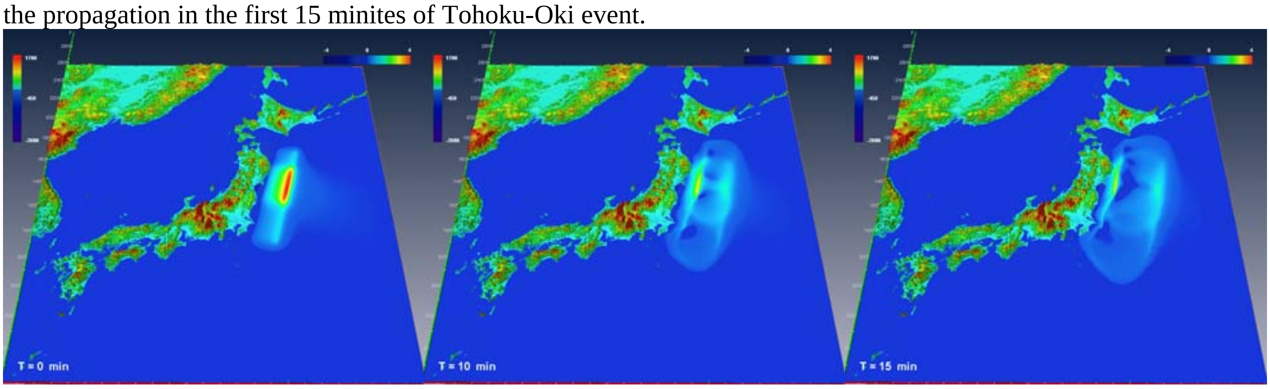

Fig 1. The results of our numerical simulation for the propagation process of Tohoku-Oki event.

Preliminary results pictures shown in figure 1 illustrate the basic characteristics of the tsunami waves' propagation, such as reflection, refraction and diffraction. The distribution of the maximum offshore tsunami wave amplitudes

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directly revealed the distribution of the potential hazards. By numerical simulation we can also get the overall distribution of maximum free-surface tsunami elevation and maximum wave heights along the coast.

CONCLUSIONS

We proposed tsunami models based on the modern software package Geoclaw to study the tsunami propagation and run-up. Using high-resolution Godunov shock-capturing finite volume methods and adaptive mesh refinement makes the software well-suited for such problems. Using the Tohoku-oki event as an example, we obtained the overall distribution of tsunami propagation and maximum wave heights along the coastline from the numerical calculations. The detailed modelling of inundation of small-scale coastal regions based on Geoclaw can be utilized to estimate the area submerged by flood water along the coast. Run-up heights at various sites and tsunami hazards will be evaluated.

References

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