HIGH-RESOLUTION TSUNAMI-BEDLOAD COUPLED COMPUTATION IN AMR ENVIRONMENT

Yasunori Watanabe, Hokkaido University, yasunori@eng.hokudai.ac.jp
Yuta Mitobe, Tohoku Gakuin University, y_mitobe@mail.tohoku-gakuin.ac.jp
Hitoshi Tanaka, Tohoku University, hitoshi.tanaka.b7@tohoku.ac.jp
Kazuya Watanabe, Akita University, kazuwata@gipc.akita-u.ac.jp

INTRODUCTION

Conventional tsunami computations on coarser grids have employed Manning's friction coefficients of subgrid equivalent roughness for buildings, vegetation and public facilities (roads, dikes and so on), depending on land-use at the grid location. This equivalent roughness macroscopically models to integrate all effects of resistances against the flow within the computational cells; that is, drag force and pressure reduction behind structures in addition to wall roughness defined in turbulent boundary layer theory. Recently high-resolution land elevation data (2-m resolution), measured by an aerial laser profiler, has been used for computing local inundation of tsunami flood. Since the high-resolution data resolves major buildings and facilities, the mechanical contributions of the structures, such as drag and pressure reduction, are included in the computed result. In this case, conventional equivalent friction may be unacceptable to use.

The 2011 Tohoku tsunami propagated along Kitakami River, Miyagi prefecture, Japan, and collapsed river dikes, causing significant flood over wide area and human damages including 84 deaths of school children. In order to understand the temporal extension of the tsunami inundation in the river basin, local overflow from the river dikes and the land erosion by the run-up tsunami need to be precisely estimated.

This study proposes the novel semi-Lagrangian computational model for computing comprehensive tsunami run-up process, fully coupled with bedload sediment transport computation, on high resolution elevation data under Adaptive-Mesh-Refinement (AMR) environment. The contributions of the computed local land erosion to the Kitakami River flood were discussed in this study. One important focus of this work is to assess grid-size dependencies of the flood evolution.

COMPUTATION

The nonlinear shallow water equation was solved in the semi-Lagrangian manner by using fractional step and CIP methods (Gotoh et al. 2013). Introducing color function C, indicating C=0 for non-inundation and 1 for inundation, the run-up wave front, defined by C=0.5, was tracked by computing an advection equation for C by the CIP method. A Meyer-Peter-Muller model for bedload sediment transport was used for computing sediment flux and local displacement of land elevation. The updated elevation was reflected to the shallow water computation, which achieves the simultaneous coupling between hydrodynamic and topographic computations.
AMR is a dynamic mesh refinement algorithm to attain efficient high-resolution computation at low computational cost. In the AMR environment, the run-up wave front was precisely resolved and tracked at highest resolution (1.2-m), to maintain a sharp wave profile of tsunami propagating on the river and overflowing from the dikes (See Fig. 1).The current model was applied to the flood case of Kitakami River. The computed results for fixed and movable bed cases were compared with experimental ones as well as the results computed by conventional Tohoku University Model (TU).

RESULTS & DISCUSSIONS

The current model provided consistent high-resolution estimates of tsunami propagation on the river, overflow from the dikes, rapid spreads of the inundation area, and flood into canals and roads (Fig. 1). In the fixed bed case, the computed results were identical to the both experimental and TU model results. In the movable bed case, the collapse of dikes and the erosions of sand bars were found to accelerate the inundation on the river basin. We also found that the computed maximum inundation area is insensitive to the resolution. However the computational and topographical resolutions significantly affect the timings and locations occurring overflow over the eroded dikes and spreading velocity of the floods. The current model has advantages to precisely compute divergence of the bedload flux, resulting from local gradients of the bottom shear, which provides reasonable estimates of the local deposition and erosion during the flood.

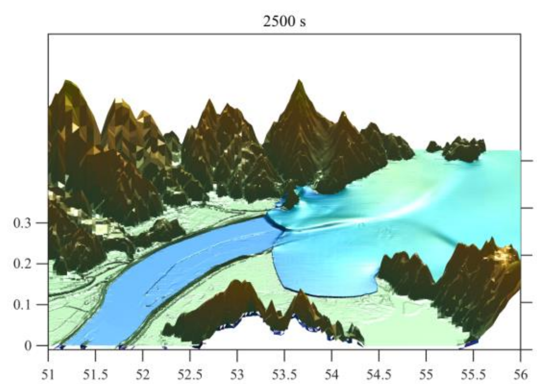

Figure 1 – Computed tsunami flood near the Kitakami River mouse (2500s after the 2011 Tohoku earthquake).

REFERENCES

Gotoh, Okayasu, Watanabe (2013): Computational Wave Dynamics, World Scientific.