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Numerical simulation of tsunami deposition by the 2011 Tohoku-oki earthquake in Sendai Plain

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Geological research on paleotsunami events is essential for reliable evaluation of risks from infrequent large-scale earthquake. Numerical simulation of tsunami sediment transport will give aid for quantification of the inundation area, hydraulic character and wave source of the past tsunamis. A lot of numerical studies have been carried out during the last decades, taking modern examples into account, such as the 2004 Indian Ocean tsunami. The 2011 off the Pacific coast of Tohoku (Tohoku-oki) earthquake may offer a valuable opportunity to enhance the utility of tsunami deposits and its numerical simulations, on the basis of abundant datasets such as densely-measured tsunami trace heights, high-resolution digital elevation model (DEM) and tsunami records from tide observations.

Numbers of previous studies have reported sedimentological feature of the 2011 Tohoku-oki tsunami deposits in the Sendai Plain (e.g. [1]). The tsunami deposited sandy to muddy sediments up to 30 cm in thickness, and distributed them up to several kilometers inland. It is notable that the maximum inland extent of the sandy tsunami deposit reached only 60-70% of the inundation distance, and the thickness of the sand layer showed significant variations across shore-normal transects [1][2]. Quite minor contribution from sea-bottom sediments to the onshore tsunami deposit have been confirmed through the grain-size, microfossil and geochemical analyses [3][4], implying that most of the onshore tsunami deposits are originated from the shallow sea closed to the coast, beach and inland areas. It is highly likely that the flow condition and also sediment transport would have been affected by natural and anthropogenic topography, such as dikes installed on the top of sand dunes, roadways on elevated mounds. Numerical simulation of the tsunami sediment transport in the Sendai Plain should incorporate the effects from such kinds of topographic features.

A numerical analysis on sedimentation by the Tohoku-oki tsunami is performed in the present study. The tsunami source is based on the fault model proposed by Sugino et al. [5], which reasonably reproduce the terrestrial geodetic data and tsunami records from offshore and nearshore tide stations. The tsunami propagation is calculated using a numerical code based on the shallow-water theory (TUNAMI-N2; [6]), and the tsunami sediment transport model by Takahashi et al. [7] is coupled with it. A high-resolution DEM (dx = 5 m) and land use map with same resolution are used to incorporate the effects from complex topographic features and land covers.

The preliminary result showed that entrainment of sediments from the beach and massive erosion around the engineering structures mainly accounts for the origin of sand layer deposited inland. Shore-normal distributions of the calculated thickness of sediments reasonably agree with the distribution trend and local variation of the tsunami deposits observed in the field. There are many issues to be resolved for direct comparison of numerical result and field data. In this presentation, applicability and limitation of the current tsunami sediment transport model is examined, and desirable strategy for data correction in the field will be discussed.

References

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