Evaluation of potential impact of tsunami-induced sediment transport in Kochi Prefecture during the Nankai Trough megathrust earthquake and tsunami

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Introduction

Strong flows due to giant tsunamis may cause large-scale sediment erosion, deposition and resulting morphological changes in coastal areas, in which sometimes alter the nature and size of tsunami hazards (e.g., Sugawara, 2017). The tsunamis flow loaded with a large amount of sediments possesses an increased hydrodynamic force, which causes not only loss of lives and properties but also incidental injuries to human healths, such as "Tsunami lung". Flush-out of coastal sediments into deeper sea often cause irreversible changes in sandy beaches, on which post-tsunami natural coastal processes may form an altered beach morphology. Sediment deposition on lands and shallow waters hampers not only emergent rescue and support, but also post-disaster recovery and reconstruction. Environmental pollutions due to chemical elements in sludge deposits are additional consequences of the tsunami-induced sediment transport.

In 2012, the Cabinet Office of Japan updated the tsunami risk assessment of the Nankai Trough earthquake and tsunami. However, influences of the sediment transport have not been included quantitatively in the tsunami scenarios. In this study, numerical simulations of tsunami sediment transport caused by the Nankai Trough earthquake have been performed to investigate the potential impacts of sediment erosion, deposition and morphological change in Tosa Bay, Kochi Prefecture, where severest damages are presumed by the Case 4 of the assessment of the Nankai Trough earthquake.

Numerical Calculation Methods

The tsunami sediment transport model (STM) proposed by Takahashi et al. (1999) was used. The STM takes into account exchange of bed- and suspended loads, in which parameters of the transport formula depend on the grain size of the sediment. Computational region covers a wide area of Tosa Bay including Kure Bay in Takaoka-gun to Hane Cape in Muroto City. To assess the uncertainties due to the grain size, three types of median size d_{50} were assumed, i.e., d_{50} = 0.127, 0.267 and 0.394 mm.

Results and Discussion

The numerical simulations demonstrated that in the mouths of class A (Niyodo and Mononobe) and B

(Shinjo, Aki, Ioki and Nahari) rivers, strong flows caused severe erosion greater than 10 m in depth, regardless of the choice of the grain size. A large amount of the sediments were flushed out to the offshore zone deeper than the wave base. In addition, extensive sediment deposition occurred on the lands neighborhood of the class A rivers. For example, deposit thickness near Niyodo River was as large as 1 m. Note that thickness of known paleotsunami deposits in this area is much smaller than the simulations. Further comparison of the field data and modeling results is needed to examine the assumptions of the size of the Nankai Trough earthquake. Based on the findings from the 2011 Tohoku tsunami, averaged deposit thickness is estimated at 4-5 cm. Choice of the grain size caused variations of the averaged deposit thickness ranging from 4.2 to 11.3 cm.

Sediment erosion and deposition were significant around harbors and bays along the coast. Bottom sediments of the mouth and inner part of Susaki Bay were eroded and that the sediments were deposited over a wide area of Susaki City. However, the simulated thickness of the deposit on Ikenouchi area including Tadasu-ike was quite thin compared to the paleotsunami deposits (Okamura and Matsuoka, 2012). Coastal defenses and changes in the land use might have affected to the difference between the deposits. In the mouth of Usa and Urado Bays, the simulations showed that part of the sediments were transported to the land near the source meanwhile most sediments were deposited on the seaward the bay mouth and the head of the bay.

The simulated morphological changes became larger with decreasing grain size. Increase in the maximum inundation heights was 2 and 1 m for d_{50} = 0.127 and 0.394 mm, respectively. In some of the investigated areas (i.g., Geisei-mura), effect of the morphological change to the inundation height was totally different. These results imply importance of sediment transport modeling for regional tsunami hazard assessments.

Conclusions

In Kochi Prefecture, tsunami-induced sediment transport may cause not only large-scale morphological changes of the coasts but also increase in tsunami hazards. Note that the influences of the sediment transport depend significantly on uncertainties in bed materials. Acquisition of detailed sedimentary data will benefit improved assessment of impacts from tsunamis. Further discussions are needed regarding countermeasures to tsunami hazards considering the regional characteristics of tsunami-induced sediment transport.

Keywords: tsunami-induced sediment transport, Nankai Trough earthquake and tsunami, Kochi Prefecture, Numerical simulation