Real-time Tsunami Inundation and Damage Forecasting with High-Performance Computing Infrastructure

Shunichi Koshimura[1], Yusaku Ohta[2], Takuya Inoue[3]

1. Introduction

In the aftermath of catastrophic tsunami disasters, identifying its impacts in a quantitative manner is crucial for disaster response and relief activities. With the lessons of the past events, the importance of developing technologies to forecast the regional impact of great tsunami disaster has been raised[1)]. However, the extensive scale of catastrophic tsunami makes it difficult to comprehend the whole picture of its impact along the long stretch of coastline, and may disable to prioritize how the limited resources for emergency response and relief should be deployed in such limited amount of time and information. We believe that fusion of high-performance computing and geo-informatics defeats this problem and lead to understanding the whole picture of the tsunami affected areas. This abstract summarizes our research to initiate the discussions in the workshop towards future collaborations.

2. Real-time Tsunami Inundation Forecasting

An automated system for real-time tsunami propagation and inundation forecasting, we established, first uses the information from Earthquake Early Warnings and GNSS crustal deformation monitoring[2), 3)] (Fig.1). Given the tsunami source, the system moves on to running tsunami propagation and inundation model which was optimized on the vector supercomputer SX-ACE and SX-Aurora[4)] (Fig.2) to acquire the estimation of time series of tsunami at offshore/coastal tide gauges to determine tsunami travel and arrival time, extent of inundation zone, maximum flow depth distribution. The implemented tsunami numerical model is based on the non-linear shallow-water equations discretized by finite difference method. The merged bathymetry and topography grids are prepared with 10 or 30 m resolution to better estimate the tsunami inland penetration.

3. Damage Estimation and Mapping

Given the maximum flow depth distribution, the system performs GIS analysis to determine the numbers of exposed population and structures using census data, then estimates the numbers of potential death and damaged structures by applying tsunami fragility curves[1)] (Fig.3), which is structural damage probability as a function of tsunami flow depth[1)]. Since the tsunami source model is determined, the model is to complete the estimation within 10 minutes. The results are disseminated as mapping products (Fig.4) to responders and stakeholders, e.g. national and regional municipalities, to be utilized for their emergency/response activities, e.g. identifying the number of exposed populations, potential damage on houses, road networks, critical infrastructures, search and rescue, and recovery.

4. Perspectives for Collaboration

With use of modern computing power and advanced sensing capabilities, we established a real-time tsunami inundation forecasting, damage estimation and mapping to enhance society's resilience in the aftermath of major tsunami disaster. Through the feasibility study, this system has started its operation since November 2017 as a function of tsunami disaster response system of the government of Japan. And we are willing to expand its capability to the other tsunami-prone areas. During the workshop, we aim to discuss how earth observations and modeling, in combination with local, in situ data and information sources, can support the decision-making process before, during and after a disaster strikes.

---

[1] Professor, International Research Institute of Disaster Science, Tohoku University, Japan (koshimura@irides.tohoku.ac.jp)
[2] Associate Professor, Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University, Japan (yusaku.ohta.d2@tohoku.ac.jp)
[3] Graduate Student, Department of Civil and Environmental Engineering, Tohoku University, Japan (takuya_inoue@kk-grp.jp)

Acknowledgments
The other contributors are; Yoichi Murashima[a, b], Takayuki Suzuki[b], Akihiro Musa[a, c], Ryota Hino[a], Hiroaki Kobayashi[a], Masaaki Kachi[d], Yoshihiko Sato[e] (a:Tohoku Univ., b:Kokusai Kogyo Co., Ltd., c:NEC Corporation, d:A2 Corp., e:NEC Solution Innovators, Ltd.)

References

1) Koshimura, S. and N. Shuto, Response to the 2011 Great East Japan Earthquake and Tsunami disaster, Phil. Trans. R. Soc. A, 2015, https://doi.org/10.1098/rsta.2014.0373
2) Ohta et al., Quasi real-time fault model estimation for near-field tsunami forecasting based on RTK-GPS analysis: Application to the 2011 Tohoku-Oki Earthquake (Mw 9.0), J. Geophys. Res., 2012, https://doi.org/10.1029/2011JB008750
3) Kawamoto et al., REGARD: A new GNSS-based real-time finite fault modeling system for GEONET, J. Geophys. Res., 2017, https://doi.org/10.1002/2016JB013485
4) Musa et al., Real-Time Tsunami Inundation Forecast System for Tsunami Disaster Prevention and Mitigation, Journal of Supercomputing, 2018, doi: https://doi.org/10.1007/s11227-018-2363-0

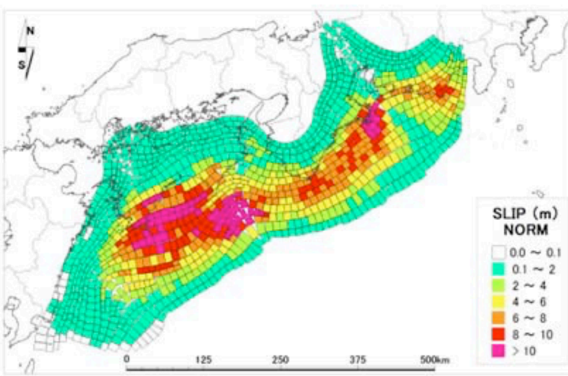

Fig.1 Example of estimated fault slip distribution by GNSS-based real-time finite fault modeling in Nankai Trough[3].

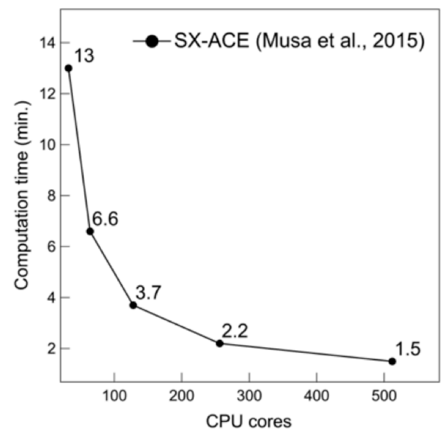

Fig.2 Performance of vector supercomputer SX-ACE in running tsunami numerical simulation for 3-hour forecast with 10 m grid[4]. This implies the advantage of high memory bandwidth and efficiency of vectorization in running tsunami simulation code.

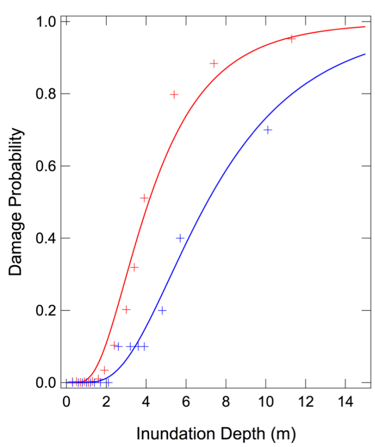

Fig.3 Tsunami fragility curves for estimating structural damage obtained from the 2011 Tohoku tsunami affected areas[1]. The plot shows the probability of structural destruction as a function of tsunami flow depth.

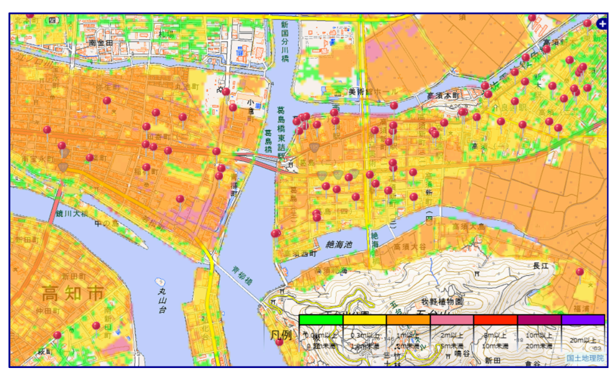

Fig.4 Example of mapping results at the test bed Kochi prefecture (Maximum tsunami inundation depth. The red pins represent the location of tsunami evacuation buildings).