A New Tsunami Numerical Model with the Polygonally Nested Grid System and its MPI-Parallelization for Real-time Tsunami Inundation Forecast on a Regional Scale

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1. Introduction

A real-time tsunami inundation forecast is expected to make disaster response activities shortly after earthquake occurrence more effective and efficient. Among technologies of real-time tsunami forecasts, "forward simulation" approaches, which simulate tsunami propagation and inundation after earthquake occurrence, has advantages over "database-driven" approaches. This is because the former can incorporate actual sensing data such as tsunami source models based on earthquake information and offshore tsunami observations, resulting in narrowing down the number of possible scenarios and increased precision. It is also a tremendous advantage to refrain from updating massive database of tsunami inundation scenarios. The fundamental bottleneck of the forward simulation approach, however, is computational load. Even adopting so-called supercomputers, it was possible to cover merely a certain city area with the coastline of 20 – 30 km[1), 2)]. A massive tsunami of the M9 level will devastate a series of coastal municipalities. Therefore, inundation forecasting should be conducted on a regional scale. This abstract summarizes our research regarding the development of an efficient tsunami inundation model for real-time tsunami inundation simulation in order to initiate the discussions in the workshop towards future collaborations.

2. A New Tsunami Numerical Model with the Polygonally Nested Grid System

As illustrated in **Fig. 1** (a), two-dimensional tsunami inundation simulation with the conventional rectangular domain will obviously face two obstacles in covering wider areas. Firstly, a computational domain includes high elevations that will not be inundated but increase a load of operation and memory. Secondly, deep waters are also included in the domain, leading to a stringent CFL condition. Therefore, we are obliged to cover the target region with lots of small domains and wastefully repeat computations as shown in **Fig. 2** (a). On the contrary, the newly-developed polygonally nested grid system extents the configuration of domains from conventional rectangular regions to polygonal regions so that deployment of high-resolution grids can be confined to coastal lowland as shown in **Fig. 1** (b), **Fig. 2** (b)[3)].

We also equipped the new model with functions for one-stop real-time forecasting and validated through the National Tsunami Hazard Mitigation Program benchmark problems, and named RTi (Real-time Tsunami inundation) model. **Fig. 3** shows the computational performance of RTi mode. It takes only 128 cores for 6-hour integration within 10 minutes, corresponding to over 10 times higher efficiency.

References

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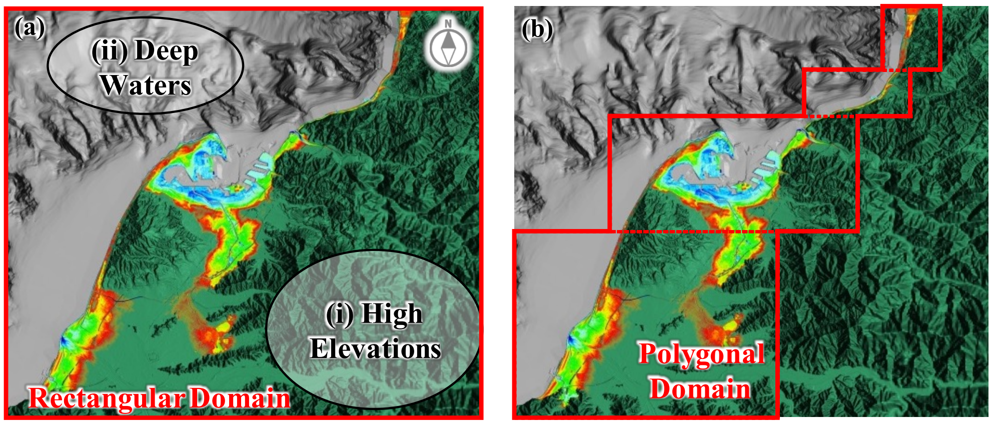

Fig. 1. Schematics of the two obstacles in a wide-area simulation (a) and extension to the polygonal domain (b). Solid lines in red designate borders of computational domain, and dashed lines are borders of polygonal blocks.

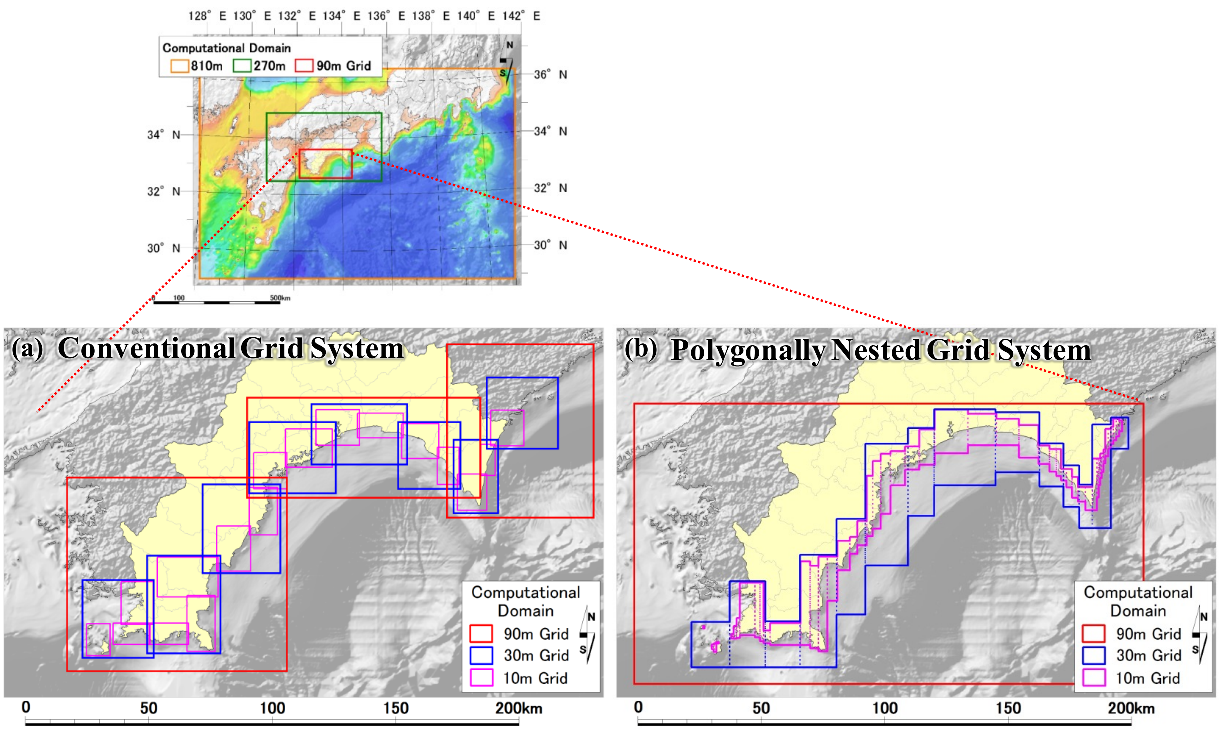

Fig. 2. Examples of grid systems for wide-area tsunami simulation regarding Kochi Prefecture in Japan, together with configurations of offshore domains with coarser grids. The panel (a) gives an example of a grid system with conventional rectangular domains. The polygonally nested grid system is shown in the panel (b). Dashed lines denote borders of polygonal blocks, and NS and EW directions are transposed in computation.

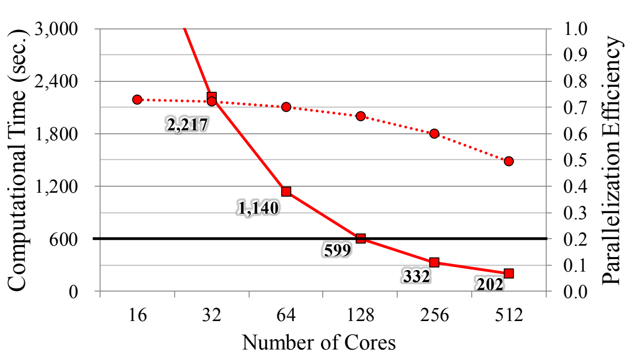

Fig. 3. Computational performance of the RTi model for the 10-meter resolution case of Kochi Prefecture with the coast line of 700 km. Duration of time integration is 6-hours. As a computational environment, SX-ACE, a vector supercomputer installed a Tohoku University is used. Square symbols denote computational time (left axis), and disks are parallelization efficiency (right axis), which is the rate of speed up compared to a single-core calculation normalized by the number of deployed cores.