HDS26-16 Room:301B Time:May 21 11:45-12:00

High resolution tsunami inundation simulation using an unstructured mesh finite volume method and the K computer

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Simulations play an important role in tsunami hazard mitigation. For example, tsunami hazard maps are based on tsunami inundation simulations. In such simulations, a Leap-Frog finite difference method is usually applied to the shallow water equations and meshes with different resolutions are nested to have high resolution in the coastal region and lower resolution in the off shore region that covers the tsunami source region. The mesh resolutions are usually increased stepwise by keeping the ratio of the resolutions of the connected meshes at one third. Such simulations are usually performed on a relatively small computation system such as a workstation.

This study looks at future trends and discusses how high-speed computers can improve tsunami simulation technologies. For example, high-speed computers may make it possible to conduct tsunami inundation simulation much faster than real-time. Recently research on the instant analysis of high-resolution tsunami source distribution are being advanced, which use off-shore tsunami observations based on ocean bottom pressure gauges and GPS buoys. When almost-instant tsunami source data is used in the high-speed tsunami inundation simulations, accurate information on the inundated district can be obtained before the arrival of tsunamis. Another benefit of high-speed computation is that higher-resolution simulations can be conducted in a practical time scale. By applying a higher resolution at the coastline in a wider area, it becomes possible to accurately evaluate the waves that are reflected at the coastline and attack the coastline repeatedly, as observed in the 2011 Tohoku tsunami. Furthermore, the high-resolution simulations with high-resolution topography data (e.g., 2 - 5 km mesh spacing) provides accurate evaluations on urban inundation processes.

To efficiently conduct such high-speed and high-accuracy simulations using high-speed computers, an unstructured-mesh finite volume method is employed. We use the ANUGA software developed by the Australian National University and Geoscience Australia. In conventional tsunami simulations, the nested meshes basically have a rectangular shape. Therefore, deep ocean that does not need high resolution may be covered with a high-resolution mesh causing an unnecessary limitation on the time-step. And locations which are high above sea-level and never reached by the tsunami may be covered with a high-resolution mesh causing unnecessary calculations. Unstructured meshes can avoid such inefficiency by flexibly changing the mesh resolution depending on the topography. In addition, it is sometimes pointed out that artificial reflection may occur at the boundaries of higher and lower resolution nested meshes. Such problem can be avoided by using unstructured mesh that can change the mesh resolution more gradually.

In this presentation, we will explain the details of our tsunami model and the simulation results of the 2011 Tohoku tsunami. These results will be compared to the results from a conventional tsunami model based on the Leap-Frog finite difference method. These are followed by a report on the parallel computation performance on the K computer.