ABSTRACT

The algorithm for computing tsunami propagation from the initial source to the coastline that uses switching of computational grids has been developed. Computations that use Method of Splitting Tsunami (MOST) are carried out on a sequence of grids with various resolutions where one is embedded into another. Tsunami parameters are transferred from the larger domain to the embedded smaller one by means of boundary conditions. The 4-stage algorithm was used for numerical modeling the far-field tsunami propagation to the Sanriku coast harbors. The grid resolution decreases from approximately 4000 m in deep water down to 17 m near a coastline that provides a detailed tsunami description. Using of modern computer architecture and in parallel computations on several computers can significantly shorten the time of computations.

KEY WORDS: Tsunami; shallow-water model; numerical modeling; computational grid; grid step; boundary conditions.

INTRODUCTION

Recent tsunamis (of the last 10 years) show that the problem of the coastal zones protection against natural hazards is far from a reasonable solution. Achievements in the mathematical modeling and computer resources are not sufficient. Still, it is not possible to build proper constructions (e.g. dams or seawalls) in the open water to protect the shoreline. The only way to save human lives is to evaluate (timely and properly) the tsunami wave parameters and, if needed, to take measures for people notification and evacuation. A faster and more accurate prediction results in a larger amount of saving lives and reduction of economic and ecology impact. There are a number of algorithms and models developed for the tsunami risk mitigation. The most known and widely used are TUNAMI (Shuto et al., 1995) and MOST (Titov, 1988, 1989, 1998). These algorithms cover phases of generation, propagation from the deep ocean to the coastal areas. However, the quality of the warning systems is far from being efficient to provide the population security. Now it is necessary to develop original algorithms for the real time data processing and their adaptation in order to use the whole computational power of modern hardware. Modern reliable and fast algorithms will contribute to the task of human protection in shoreline areas. The only way to protect people living at the shoreline from catastrophic tsunami waves is to make an accurate estimation of expected tsunami wave parameters such as height near the shore, arrival times etc. To date, there exist several original algorithms which bring us closer to real time tsunami risk mitigation. The numerical modeling of tsunami wave propagation takes a significant time and should be accelerated as much as possible. Acceleration can be done with the help of hardware architecture or developing more efficient algorithms. Here, one of such methods for quick and precise estimation of the tsunami height near the shore is described.

MATHEMATICAL AND NUMERICAL MODEL

The long wave propagation in the ocean is governed by the so-called shallow-water differential equations:

$$H_t + (uH)_x + (vH)_y = 0,$$

$$u_t + uu_x + vu_y + gH_x = gD_x,$$

$$v_t + uv_x + vv_y + gH_y = gD_y,$$

where $H(x, y, t) = h(x, y, t) + D(x, y, t)$, $h$ is the water surface displacement, $D$ is depth, $u(x, y, t)$ and $v(x, y, t)$ are velocity components along the axis' $x$ and $y$, $g$ is acceleration of gravity. The initial conditions: still water at all grid points except a tsunami source where a surface displacement is not equal to zero. From the shallow-water equations it follows that the tsunami propagation velocity does not depend on its length and is expressed by the so-called Lagrange formula (Titov, 1989)

$$c = \sqrt{g(D + \eta)}.$$

This formula plays the key role for the long-wave (tsunami) kinematics. From the shallow-water equations the ratio between the running wave height and the water flow velocity can be derived. The horizontal flow velocity depends on the wave amplitude and water depth

$$u = \eta \sqrt{\frac{c}{D}}.$$

This relation between the tsunami wave parameters is used in the algorithm proposed.

The numerical algorithm is based on splitting the difference scheme, which approximates equations (1) by spatial directions. A finite difference algorithm based on the splitting method has been developed. To solve shallow wave equations, the splitting method reduces the numerical solution of equations with two spatial variables to the solution of two one-dimensional equations. It makes possible to