Numerical simulation of tsunami using hydrostatic approximation approach (quasi-two dimentional model)

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1 Background

Tsunami is the sea wave brought by uplift or subsidence of the ocean bed . Motion of fluid flow including tsunami can be described by the equation of the Navier-Stokes. The equation of the Navier-Stokes is difficult to solve analytically because of its non-linearity. For numerical simulation of tsunami, the equation of the shallow-water approximation is generally employed. Provided that a wavelength of tsunami is much longer than a water depth, the shallow-water approximation can be used (long-wave approximation). However, all of the description of tsunami wave can not approximate to the shallow-water. For example, the shallow-water approximation cannot be used, when the wavelength is short or submarine topography is not uniform. Therefore, the shallow-water approximation neglected the calculation of vertical direction may not always give true solutions. Thus, in this study, we make a code for a numerical simulation of tsunami adopting the hydrostatic approximation approach and discuss its validity for tsunami wave propagation problems by comparing with the shallow-water approximation approach.

2 Model

For simplicity, we consider the two-dimensional Cartisian coordinate system (x-z plane). The equations of shallow-water approximation ignores the vertical velocity, that is, the equations to be solved are reduced to one-dimension (only horizontal direction). In this study, the hydrostatic approximation is applied in the vertical direction. Thus, the equations of hydrostatic approximation are treated in quasi-two dimension. To consider the topography, we adopt the z* coordinate system, in which water depth is normalized as a single constant value. To solve the basic equations, we adopt the central difference scheme in space and the forward difference scheme in time. As a initial condition, we give a sine curve. The side boundaries are assumed to be free end. First, varying water depth, we compare the result obtained by the hydrostatic approximation with those of the shallow-water approximation in uniform topography. We, then, compare both results for a at various topography.

3 Results

In cases that the depth of sea bed remains constant, calculated waveheight and propagating velocity for hydrostatic approximation shows a good agreement with those for shallow-water approximation, while the topography of sea bed is changing, the results using the equation of hydrostatic approximation demonstrate the larger waveheight and higher propagating velocity. The initial waveforms are also influenced on waveheight and propagating velocity.

4 Discussion and Conclusion

We find that the vertical components should not be ignored in solving the motion of tsunami, because the vertical component has influenced on the waveheight and propagating velocity in case of taking account of the changes of the topography of sea bed. Waveheight and propagating velocity are also affected by the initial waveforms. Vertical velocity component due to the uplift can not be neglected. These results indicate that, in particular, the hydrostatic approximation method may be useful against the numerical simulation of tsunami brought by near earthquake.