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Numerical simulation of an initial tsunami waveform based on sea-level data inversion: case study for the Shicotan event of the 4th October 1994

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The recent disaster of Japanese tsunami in March 2011, which caused nearly 16,000 deaths and estimated at US$35-billion to US$40-billion the insured cost, served as a last wake-up call to world community. Since then, the development of technology of an early warning system including methods for forecasting in real-time the tsunami waves propagation has provided a way to mitigate the adverse impacts of future tsunamis. The development of tsunami simulation models makes it possible to identify regions at tsunami risk. One of the most important issues of the tsunami modeling is gaining some insight of a tsunami source – the case in hand is the tsunami wave generated by the sea surface deformation. The latter is presumed to be equal to the co-seismic vertical displacement of the sea floor. This paper proposes an approach to recover initial tsunami waveform in tsunami source area based on the inversion of remote measurements of sea-level data. This inverse problem is treated as an ill-posed problem of hydrodynamic inversion with tsunami tide gauge records. Tsunami wave propagation is considered within the scope of the linear shallow-water theory. The direct problem is approximated by a finite-difference technique. The ill-posed inverse problem of recovering initial tsunami waveform is regularized by means of a least square inversion using the truncated SVD approach. The numerical simulating yields the so-called r-solution. The algorithm is verified with bathymetry data of the Sea of Okhotsk, synthetic and real records. In this paper, we make an attempt to answer the following questions: (1) How accurately can a tsunami source be recovered using recordings at a given tide gauge network? (2) Is it possible to improve the quality of recovering a tsunami source by distinguishing the "most informative" part of the given observation system? For answering these questions, we have carried out a series of numerical experiments. Based on the characteristics of a given tide gauges network the method proposed in the present paper allows one to control the numerical instability of the solutions obtained and therefore to get an acceptable result in spite of the ill-posedness of the problem, that is one of the major benefits of the method. The numerical experiments give promise that this approach can be a useful tool in tsunami early warning systems.