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Numerical reconstruction of tsunami source using combined seismic, satellite and DART data

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Recent tsunamis, for instance, in Japan (2011), in Sumatra (2004), and at the Indian coast (2004) showed that a system of producing exact and timely information about tsunamis is of a vital importance. Numerical simulation is an effective instrument for providing such information. Bottom relief characteristics and the initial perturbation data (a tsunami source) are required for the direct simulation of tsunamis. The seismic data about the source are usually obtained in a few tens of minutes after an event has occurred (the seismic waves velocity being about five hundred kilometres per minute, while the velocity of tsunami waves is less than twelve kilometres per minute). A difference in the arrival times of seismic and tsunami waves can be used when operationally refining the tsunami source parameters and modelling expected tsunami wave height on the shore. The most suitable physical models related to the tsunamis simulation are based on the shallow water equations.

The problem of identification parameters of a tsunami source using additional measurements of a passing wave is called inverse tsunami problem. We investigate three different inverse problems of determining a tsunami source using three different additional data: Deep-ocean Assessment and Reporting of Tsunamis (DART) measurements, satellite wave-form images and seismic data. These problems are severely ill-posed. We apply regularization techniques to control the degree of ill-posedness such as Fourier expansion, truncated singular value decomposition, numerical regularization. The algorithm of selecting the truncated number of singular values of an inverse problem operator which is agreed with the error level in measured data is described and analyzed.

In numerical experiment we used gradient methods (Landweber iteration and conjugate gradient method) for solving inverse tsunami problems. Gradient methods are based on minimizing the corresponding misfit function. To calculate the gradient of the misfit function, the adjoint problem is solved. The conservative finite-difference schemes for solving the direct and adjoint problems in the approximation of shallow water are constructed. Results of numerical experiments of the tsunami source reconstruction are presented and discussed. We show that using a combination of three different types of data allows one to increase the stability and efficiency of tsunami source reconstruction.

Non-profit organization WAPMERR (World Agency of Planetary Monitoring and Earthquake Risk Reduction) in collaboration with Informap software development department developed the Integrated Tsunami Research and Information System (ITRIS) to simulate tsunami waves and earthquakes, river course changes, coastal zone floods, and risk estimates for coastal constructions at wave run-ups and earthquakes. The special scientific plug-in components are embedded in a specially developed GIS-type graphic shell for easy data retrieval, visualization and processing.

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