Geophysical Research Abstracts
Vol. 21, EGU2019-15039, 2019
EGU General Assembly 2019
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A Method for Recovering an Initial Tsunami Waveform by Inverting Remote Measurements with DART Buoys Data: Case Study 2015 Illapel Chile Tsunami

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The numerical simulation is a powerful tool in the tsunami research aimed at the creation of a reliable tsunami warning system. The problem of recovering an initial tsunami waveform (called below the tsunami source) from remote measurements is considered to be an inverse problem of mathematical physics in the class of ill-posed problems. Unavoidable noise of real data contributes to the instability of the numerical solution of the inverse ill-posed problem and, thereby, it creates a serious obstacle in applying mathematical methods for solving these problems in any real application. In the approach proposed, the regularization is performed by means of the truncated Singular Value Decomposition (SVD) method. The solution obtained is a projection of the exact solution onto a subspace that is a linear hull of the first r right singular vectors of the direct problem operator. This subspace is chosen by analyzing the properties of the singular spectrum of the direct problem operator, which, in turn, is determined by the observation system and bathymetry. The location of tsunami waveform recorders affects the choice of number r in such a way: the better is the configuration of an observation system the longer is a weakly decreasing part of the singular spectrum. It is natural that as r increases, the information about the r -solution obtained also increases while its stability decreases. A comparison of the singular spectra of the matrices of the direct problem operators calculated by using the different sets of receivers makes it possible to highlight the most informative part of the observation system that provides the best recovery result. As an unknown initial tsunami waveform is represented as a part of the spatial harmonics series, the number of harmonics used is the key-point of the numerical simulation. The present study is focused on investigating the influence of the number of harmonics used on the inversion result. The complicated shape of a source requires a larger number of harmonics in the source representation, but this could cause increasing both the time of calculation and appearing the additional oscillations in the solution. The study of singular vectors allows one to obtain the desired balance with respect to the number of harmonics used.
The results of the numerical implementation of this approach using the real data of the 2015 Illapel Chile Tsunami do not contradict with the ones obtained from seismic data by other researchers.
Based on the numerical experiments, we can conclude that the method presented provides a good matching in the observed and calculated tsunami waveforms. Moreover, the algorithm provides a possibility to simultaneously restore the tsunami source and calculate tsunami waveforms even at the points where there are no observational data.