Adaptive fault discretization for the inversion of geodetic data

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Abstract

The Recent development of geodetic observations allows us to image slip distribution on buried faults during interseismic, coseismic, and postseismic periods. The capability of imaging fault slips at depth from geodetic data is, however, limited because geodetic observations are almost always done at Earth's surface. Also, the absence of or limited offshore geodetic measurements makes detailed imaging of the slip on a shallow offshore fault difficult.
In geodetic inversions, the spatial distribution of fault slips is often obtained by applying smoothing constraints. However, the optimum choice of the smoothing parameter is not straightforward. Although several studies have proposed methods to choose the optimum smoothing parameter, they do not always give a definitive optimum parameter. Also, a single smoothing parameter cannot take the spatially variable resolution on the fault plane into account.

Here I propose a method to adaptively discretize a fault plane of arbitrary shape according to the spatial resolution on the fault plane. The method applies Singular Value Decomposition of the data kernel, a matrix that relates the observation to the fault slip, to truncate higher modes, and continues to discretize the fault plane by Voronoi diagrams as long as diagonal elements of the model resolution matrix are above a specified threshold. The only parameter that needs to be set in this method is the truncation threshold of eigenmodes that is determined roughly by the signal-to-noise ratio of the observation. Note that the real dataset is not necessary to evaluate the spatial resolution of the fault slip, but only the truncation threshold of eigenmodes needs to be preset.
I applied the method to the coseismic displacement field associated with the 2011 Tohoku earthquake. I evaluated the spatial resolution of the inverted fault slip with and without offshore GPS measurements. The spatial resolution at a depth of 50 km is about 30 km regardless of the presence of offshore GPS measurements. The spatial resolution at shallower depths near the trench, however, improves drastically from more than 100 km to about 20 km with them. Consequently, localized large slips near the trench inferred from seismic and tsunami studies are detectable only with offshore GPS measurements. This result demonstrates the utility of offshore GPS measurements to decipher the coseismic slip distribution associated with a large interplate earthquake, in which the shallow portion of the interplate fault is often offshore.

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