A new three-dimensional regularization for finite fault source inversions

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The earthquake rupture process is often represented by a source function that defines slip in space and time. If we assume slip to occur on a planar surface, then the source function becomes a function of three independent variables: two spatial dimensions (slip down-dip and slip along-strike) and one temporal dimension (source time function at each point on the fault). Finite fault inverse problems aim at exploring this model space in order to find the source function that generates synthetic ground motion that best fits the observed data. This inverse problem is severely ill-conditioned. In order both to ensure a regular solution and to avoid over-fitting the data, both physical and mathematical constraints can be imposed. Common methods of finite fault source inversion typically apply a one-dimensional regularization in time, which gives preference to compacted-support source-time functions, like triangular or trapezoidal functions in time, or to two-dimensional regularizations that ensure smooth variations of slip over the fault plane (Mai et al., 2016). In this work, we propose an innovative three-dimensional regularization for kinematic source inversions in the frequency domain, which simultaneously requires smooth variations of slip over space (2D) and frequency (1D, smooth spectra). This new three-dimensional regularization selects the spatial slip distributions that are more similar to those of neighboring frequencies, thus effectively transferring knowledge from one frequency to another. In the framework of Tikhonov regularization, having more than one regularization condition requires more than one damping factor to be inserted in the inversion misfit. Additionally, no orthogonal decomposition (like Generalized Singular Value Decomposition) exists when more than one regularization conditions are imposed. Thus, we investigate a new 3D regularization method using a Bayesian approach with a Markov Chain Monte Carlo (MCMC) simulation. The new method is tested using the SIV-inv1 benchmark exercise. The proposed method is also preliminarily applied to study the rupture process of the 2019 M5.9 Torkamanchay, Iran, earthquake.