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INVERSE METHODS AND UNCERTAINTY QUANTIFICATION: ROBUST IMAGING OF EARTHQUAKES AND ASEISMIC FAULT BEHAVIOR

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Abstract

Imaging subsurface slip behavior from surface observations is essential to increase our level of understanding of the physical processes controlling earthquake and tsunami occurrence. As the estimation procedure is inherently ill-posed, the adopted inverse methodology to obtain such estimates, in particular the chosen form of a priori information, plays a key role in this learning process. There are two general end member approaches to estimate the distribution of slip on a fault that deals with the inherent instability of the inverse problem: an unregularized, computationally expensive, fully Bayesian approach and a much more expedient but biased optimization approach using some form of regularized least squares. While we prefer the use of the fully Bayesian methodology, its high computational cost motivate us to pursue improvements in the regularized least squares inversion method. However, understanding regularization as a priori information that introduces a bias on fault slip estimates, that needs to be well understood before making a rigorous interpretation of the inversion results.

Here, we present a description of state-of-the-art methodologies used to infer fault slip behavior, and discuss the effects that a priori information, implied by common regularization schemes, have on fault slip estimates. In addition, we propose a novel Equal a Posteriori Information Content (EPIC) condition for Tikhonov regularization that generalizes the concept of a priori information by setting its errors based on a chosen form of the structure of a posteriori model parameter errors. The EPIC condition counterbalances the spatial variability of the (typically onland) observational constraints on fault slip, improving stability, quality and interpretation of slip estimates uncertainties in terms of their spatial distribution. We carry out our analysis performing thousands of least squares inversions constrained by data generated from synthetic slip distributions and test the proposed methodology inferring co-seismic slip for the 2011 (Mw 9.0) Tohoku-Oki earthquake. Also, through some examples, we show the applicability of the proposed regularization methodology to a wider variety of inverse problems in other fields, where the definition of the unknown model parameters through a spatial discretization makes sense.

SEMINARIO

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