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Bayesian Seismic Waveform Inversion with A Multilevel Markov Chain Monte Carlo approach

Anamika Pandey (1), Juan Pablo Madrigal Cianci (2), Fabio Nobile (2), and Raúl F. Tempone (1)

(1) Chair for Mathematics of Uncertainty Quantification, RWTH Aachen University, Germany., (2) SB-MATHICSE-CSQI, École polytechnique fédérale de Lausanne (EPFL), Switzerland., (3.) King Abdullah University of Science and Technology (KAUST), Computer, Electrical and Mathematical Sciences & Engineering Division (CEMSE), Thuwal, Saudi Arabia.

In this talk, we present the Bayesian formulation and a Multilevel Markov Chain Monte Carlo (ML-MCMC) sampling strategy inferring earthquake source location under the uncertainties of Earth's material properties. Most of the existing literature on earthquake source inversion show a large variability in their results for same seismic event, which indicates that the inherent uncertainties of the Earth's material should be taken into account.

In the Bayesian formulation, we first assume that the recorded/observed data are subjected to some noise and can be reproduced by providing some unknown input parameters to a mathematical model, which is known as forward map in the formulation. In the present work, this forward map is given by the initial-boundary value problem (IBVP) for seismic wave propagation in an inhomogeneous linear viscoelastic media with random wave speeds and densities, subject to deterministic boundary and initial conditions. The random parameters model the inherent uncertainties of the Earth's material. We then use the forward map (model) together with MCMC algorithm to generate samples from the posterior probability distribution of the earthquake source location. But this needs to simulate the IBVP a large number of times; and the approach becomes prohibitively expensive. This motivates to work on multilevel algorithms to accelerate seismic inversion addressing earthquake source estimation. We use a publicly available code `SPECFEM`, based on the spectral element method, to approximate solutions of IBVP for seismic wave propagation. We also study a noise model for Bayesian inverse problems by using recorded seismograms.

We validate our results by considering real seismological data. These data were recorded in seismic stations that belong to a small seismic network in the Ngorongoro Conservation Area on the East Rift, in Tanzania. Numerical results show that the large number of simulations of the underlying IBVP are performed at coarser discretizations where the computational cost of the IBVP solver is significantly cheaper. Moreover, samples generated by multi-level approach decorrelate faster compared to those obtained by single level and hence less number of samples are required to generate necessary samples. Therefore, multilevel approach reduces the computational cost of seismic inversion dramatically. We are interested in inferring parameters, which define seismic events, by a given set of data recorded at a seismic network. In this work, our main focus is to infer the epicenter of an earthquake. This approach can also be applied to general seismic inversion problems such as inferring magnitudes, slip-distributions and moment tensors.