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Probabilistic earthquake early warning in complex earth models using prior sampling

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In an earthquake early warning (EEW) context, we must draw inferences from small, noisy seismic datasets within an extremely limited time-frame. Ideally, a probabilistic framework would be used, to recognise that available observations may be compatible with a range of outcomes, and analysis would be conducted in a theoretically-complete physical framework. However, implementing these requirements has been challenging, as they tend to increase computational demands beyond what is feasible on EEW timescales.

We present a new approach, based on 'prior sampling', which implements probabilistic inversion as a two stage process, and can be used for EEW monitoring within a given region. First, a large set of synthetic data is computed for randomly-distributed seismic sources within the region. A learning algorithm is used to infer details of the probability distribution linking observations and model parameters (including location, magnitude, and focal mechanism). This procedure is computationally expensive, but can be conducted entirely before monitoring commences. In the second stage, as observations are obtained, the algorithm can be evaluated within milliseconds to output a probabilistic representation of the corresponding source model. We demonstrate that this gives robust results, and can be implemented using state-of-the-art 3D wave propagation simulations, and complex crustal structures.