Evolutionary full-waveform inversion with dynamic mini-batches

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We present an evolutionary full-waveform inversion based on dynamic mini-batch optimization, which naturally exploits redundancies in observed data from different sources and allows the model to evolve along with the amount of available information in the data.

Quasi-random subsets (mini-batches) of sources are used to approximate the misfit and the gradient of the complete dataset. The size of the mini-batch is dynamically controlled by the desired quality of the approximation of the full gradient. Within each mini-batch, redundancy is minimized by selecting sources with the largest angular differences between their respective gradients, and spatial coverage is maximized by selecting candidate events with Mitchell’s best-candidate algorithm. Information from sources included in a previous mini-batch is incorporated into each gradient calculation through a quasi-Newton approximation of the Hessian, and a consistent misfit measure is achieved through the inclusion of a control group of sources.

By design, the dynamic mini-batch approach has several main advantages: (1) The use of mini-batches with adaptive sizes minimizes the number of redundant simulations per iteration, thus potentially leading to significant computational savings. (2) Curvature information is accumulated and used during the inversion, using a stochastic quasi-Newton method. (3) Data from new events or different time windows can seamlessly be incorporated during the iterations, thereby enabling an evolutionary mode of full-waveform inversion.

To illustrate our method, we start an inversion for upper mantle structure beneath the African plate. Starting from a smooth 1-D background model for a dataset recorded in the years 1990 to 1995, we then sequentially add more and more recent data into the inversion and show how the model can evolve as a function of data coverage. The mini-batch sampling approach allows us to incorporate data from several hundred earthquakes without increasing the computational burden, thereby going significantly beyond previous regional-scale full-waveform inversions.