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Evolutionary full waveform inversion

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Standard full-waveform inversion (FWI) workflows rely on a static snapshot of available earthquake data, and it is not always obvious how information from new or previously not selected seismic events can be incorporated. In this contribution we introduce several methodological advancements which allow for the continuous inclusion of new data in an ongoing FWI, resulting in a dataset and model which “evolve” over time. In both synthetic and real-data applications, we show that such an approach substantially reduces the computational costs per iteration and leads to improved model recovery and waveform fits for a fixed computational budget.

The “evolutionary” workflow can be broken down as follows. First, seismic data centers are queried automatically to expand the current dataset, after which seismograms are processed and windows are selected. To accommodate the dynamic nature of an evolving dataset we compute model updates with the following strategy. Batches of events with a good spatial distribution are dynamically chosen from a complete set of events to compute the model update. Windows are picked every time an event enters the batch, this allows us to continuously expand the window length as the data fit improves. The batch size is adapted to the amount of additional information each individual gradient provides to the sum of gradients present in the batch. Previously calculated gradients can still be used to approximate the inverse Hessian in quasi-Newton optimization methods. The entire workflow from data acquisition to model update is fully automated.

These developments are highlighted in synthetic demonstrations of the workflow and prospective performance improvements, along with a real-data application to the African crust and mantle. In this context, seismograms from 125 earthquakes, filtered between 60 and 120 seconds were used. The data was obtained from the AfricaArray and NARS seismic arrays, as well as global networks. Over 100 iterations were performed with a minimum of 10 events per batch resulting in a new model that shows significant improvements in waveform fit as well detailed velocity structure of tectonic features such as the East African Rift System.