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Source array configuration and applications in crustal structure studies

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Based on the reciprocity theorem of Green's function, a number of seismic sources recorded at single station are considered as a “source array" (SA), in analogy of a receiver array (RA). To compose an SA requires that the coordinates, origin times, and depths of the sources to be precisely known. Furthermore, akin to the waveform coherency requirement for a RA, SA waveform needed to be coherent. This implicitly implies that the source mechanisms of all events should be similar or the effect of waveform dissimilarity should be corrected.
The positive attribute of a SA is the possibility of forming a 3-D array, that allows for full slowness field calculation of the phases leaving the source region, the study of the near source structure and the wavefield travel pass. In addition, without bearing the extra cost of sensor installation, array processing methods are applicable. On the other hand, the fulfillment of all prerequisite conditions is difficult in practice.
In this work, the aim is to facilitate the use of seismic source array beamforming in order to image the crustal interfaces producing strong converted/reflected phases, given a well located events catalog. We propose the use of optimization technique to find the SA elements. Using optimization technique allows for quantitative evaluation of the related prerequisites by defining suitable criteria.
We suggest three criteria/objective functions: (1) to ensure the high resolution of SA beamforming in 3-D slowness spaces, that can be evaluated using either by synthetic or real data, (2) to check the waveforms similarity over the array elements, and (3) to select events with lower location error.
The location of the interface in the velocity model, that makes the converted/reflected phases, e.g. sp-phases, is retrieved by a grid search method once the SA elements are found. Considering each grid point as a hypothetical interface for all source element, theoretical travel time of the sp-phase is estimated by sum of s-phase and p-phase. The former travels the distance between the source and interface and the latter travels the distance between the interface and receiver. Then, sp-phases windows are selected from the waveforms and stacked and the corresponding semblance value is calculated and is assigned to that grid point. The procedure is repeated for all grid points and the maximum value of the semblance of all grids indicates the location of the interface.
We applied the approach in the North Bohemia Vogtland, for which evidences of converted phases have been approved from previous studies, and a well-located catalog of earthquake swarm is available. We locate the different segments of the interface with a population of source arrays and considering different station locations. The accuracy of the approach and the obtained results are convincing that the method is applicable to study the crustal structure and the location of crustal interfaces when the strong converted phases are observed in the data and a well-located catalog is available.