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Quantitative Network Design Optimization

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SUMMARY

The capability to correctly interpret microseismic datasets depends strongly on the completeness of the event catalogue and reliability of measurements. Location accuracy of a microseismic event is strongly controlled by azimuthal coverage defined by the source-receiver geometry. Furthermore, the detection limit is determined by the noise level and the distance between source and each receiver. Economics drive the need to find the network geometry with minimum number of sensors that optimizes both location accuracy and catalogue completeness down to a desired event magnitude.

However, the geometry of a downhole sensor network is mostly controlled by available well locations and sensor spacing of standardized sensor strings. At the surface (or ocean floor) the design of a sensor network is constrained by accessibility, existing infrastructure, and a variety of noise sources (Kraft, 2013).

Introduction

The capability to correctly interpret microseismic datasets depends strongly on the completeness of the event catalogue and reliability of measurements. Location accuracy of a microseismic event is strongly controlled by azimuthal coverage defined by the source-receiver geometry. Furthermore, the detection limit is determined by the noise level and the distance between source and each receiver. Economics drive the need to find the network geometry with minimum number of sensors that optimizes both location accuracy and catalogue completeness down to a desired event magnitude. However, the geometry of a downhole sensor network is mostly controlled by available well locations and sensor spacing of standardized sensor strings. At the surface (or ocean floor) the design of a sensor network is constrained by accessibility, existing infrastructure, and a variety of noise sources (Kraft, 2013).

Method

We here present a target oriented network optimization tool. We borrow techniques from both, large array observatories and active seismic processing. The parameters we considered in the optimization are (1) location accuracy, (2) regularity of the magnitude of completeness in a target volume, and (3) inherent filter capacity of a network.

Location accuracy is described here essentially in terms of 3D spatial resolution, using an adapted version of the Point Spread Function (PSF) concept used in reflection seismics to model depth-migrated images (Lecomte, 2008). This corresponds to modelling the results of a stacking approach in micro-seismic event processing (e.g. Gharti *et al.* 2010). For a given velocity model, PSF allow for fast analysis of the potential focusing pattern of a network geometry, and can thus be translated into microseismic event location capabilities of the network for any give point. Ray-based (e.g., Gjøystdal *et al.* 2007) and/or eikonal-solver (e.g., Podvin and Lecomte, 1991) seismic modelling is used in potentially complex models to generate the necessary slowness vectors needed to estimate these PSFs. Additional Green's function parameters, such as traveltimes, amplitudes, etc, may be added for filtering and weighting options, to refine the analysis by including various wave-propagation and processing effects. The aim here is to find the design that leads to the best possible 3D spatial resolution for all points in the target volume.

Detection threshold, and thus magnitude of completeness, is based on source spectral amplitudes compared to a noise model. We consider attenuation and geometrical spreading to account for amplitude loss along the rays. The optimum design regarding detectability provides the smallest magnitude of completeness for all points in the target volume.

Finally, we evaluate the capacity of the design to filter-out or stack certain frequencies. Such techniques are regularly applied in the processing of large seismological observatories to filter-out coherent or directional noise. Such noise is often observed in OBC datasets and can be caused by platform noise or seismic shooting. Onshore surface systems can be contaminated by coherent noise of industrial sites. The filter capabilities of a network depend on the wavelength of the coherent noise. Additionally, array processing techniques such as beam-forming, provide further constraints on the location uncertainty.

These constrains are fed into an optimization routine, while allowing number of stations and location vary. Thus, this tool provides a robust method to balance network performance with external constraints and economics.

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