Geophysical Research Abstracts
Vol. 20, EGU2018-16397-1, 2018
EGU General Assembly 2018

3-component array processing by polarization analysis – Method and application to USarray seismic data

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A seismic wavefield can be considered as a combination of polarized waves. These waves recorded by a 3-component array exhibit three kinds of coherency: a temporal coherency, a spatial coherency and a polarization coherency. Identifying and fully characterizing the waves in seismograms with simultaneously using the three mentioned coherency modes is a major challenge in the array seismology.

Standard one-component array processing methods can already simultaneously include the temporal and the spatial coherency modes, giving access to the propagation characteristics within the array range. One-component array processing algorithms can be directly applied to multi-component array data by averaging the contributions from each component [Inza, 2013], which permits to include complementary information brought by each component. This approach does not take into account the inter-component dependencies, described by the wavefield's polarization characteristics.

Recently, mathematical approaches to process records by multi-component arrays for the joint estimation of arrival directions and wave polarization parameters have been developed [Miron, 2005]. Without introducing limiting hypothesis on the polarization model, these extended methods are required to solve inverse problems by using heavy optimization schemes poorly adapted to the complexity of a 3D wavefield. The use of limiting hypothesis, such as a linear polarization model [Wagner 1996] or a limitation to a 2D case [Hobiger 2011] renders the extended methods feasible but limits their application domains.

Here we propose an alternative approach to bypass the tricky problem of optimization without limiting the polarization model. By assuming coherent polarization properties for plane waves propagating through a seismic array, the spatial coherency of polarization parameters is integrated in an advanced array processing techniques. The polarization is first estimated independently at each station of the array in the time-frequency domain and later those polarization estimations are used to find the propagation parameters that maximize the spatial coherency of the polarization through the array. The novelty of our approach is that it uses the signal coherency in polarization rather than in amplitude.

We applied our method to teleseismic data recorded by the USArray. Our first results are promising. The proposed algorithm is able to detect and to identify seismic phases according to their spatial coherency polarization parameters, with both polarization and propagation parameters being estimated for each detected waves.