Geophysical Research Abstracts
Vol. 16, EGU2014-2282-3, 2014
EGU General Assembly 2014

Seismic Sensor orientation by complex linear least squares

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Poorly known orientation of the horizontal components of seismic sensors is a common problem that limits data analysis and interpretation for several acquisition setups, including linear arrays of geophones deployed in borehole installations, ocean bottom seismometers deployed at the sea-floor and surface seismic arrays. To solve this problem we propose an inversion method based on complex linear least squares method. Relative orientation angles, with respect to a reference sensor, are retrieved by minimizing the l2-norm between the complex traces (hodograms) of adjacent pairs of sensors in a least-squares sense. The absolute orientations are obtained in a second step by the polarization analysis of stacked seismograms of a seismic event with known location. This methodology can be applied without restrictions, if the plane wave approximation for wavefields recorded by each pair of sensors is valid. In most cases, it is possible to satisfy this condition by low-pass filtering the recorded waveform. The main advantage of our methodology is that, finding the estimation of the relative orientations of seismic sensors in complex domain is a linear inverse problem, which allows a direct solution corresponding to the global minimum of a misfit function. It is also possible to use simultaneously more than one independent dataset (e.g. using several seismic events simultaneously) to better constrain the solution of the inverse problem itself. Furthermore, by a computational point of view, our method results faster than the relative orientation methods based on waveform cross-correlation. Our methodology can be also applied for testing the correct orientation/alignment of multicomponent land stations in seismological arrays or temporary networks and for determining the absolute orientation of OBS stations and borehole arrays. We first apply our method to real data resembling two different acquisition setups: a borehole sensor array deployed in a gas field located in the Netherlands and a surface network including a seismic array in Chile. The first acquisition setup consists of a linear array of six three-component geophones within a single borehole. Sensor alignment is performed using seismic a regional seismic event occurred in the North sea. A second application focus on broadband seismic sensors deployed in Northern Chile. The sensors from the former Iquique Local Network have been recently reinstalled in a small-scale seismic array configuration, with a single station remaining at the same location in both old and new network geometry. We obtain here relative orientations for both network configurations, using this station as reference, performing the sensor orientation using both low-frequency coherent seismic noise, regional and teleseismic events. This work has been funded by the German BMBF “Geotechnologien” project MINE (BMBF03G0737A).