Geophysical Research Abstracts
Vol. 14, EGU2012-5540, 2012
EGU General Assembly 2012

On comprehensive recovery of an aftershock sequence with cross correlation

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We have introduced cross correlation between seismic waveforms as a technique for signal detection and automatic event building at the International Data Centre (IDC) of the Comprehensive Nuclear-Test-Ban Treaty Organization. The intuition behind signal detection is simple – small and mid-sized seismic events close in space should produce similar signals at the same seismic stations. Equivalently, these signals have to be characterized by a high cross correlation coefficient. For array stations with many individual sensors distributed over a large area, signals from events at distances beyond, say, 50 km, are subject to destructive interference when cross correlated due to changing time delays between various channels. Thus, any cross correlation coefficient above some predefined threshold can be considered as a signature of a valid signal.
With a dense grid of master events (spacing between adjacent masters between 20 km and 50 km corresponds to the statistically estimated correlation distance) with high quality (signal-to-noise ratio above 10) template waveforms at primary array stations of the International Monitoring System one can detect signals from and then build natural and manmade seismic events close to the master ones. The use of cross correlation allows detecting smaller signals (sometimes below noise level) than provided by the current IDC detecting techniques. As a result it is possible to automatically build from 50% to 100% more valid seismic events than included in the Reviewed Event Bulletin (REB).
We have developed a tentative pipeline for automatic processing at the IDC. It includes three major stages. Firstly, we calculate cross correlation coefficient for a given master and continuous waveforms at the same stations and carry out signal detection as based on the statistical behavior of signal-to-noise ratio of the cross correlation coefficient. Secondly, a thorough screening is performed for all obtained signals using f-k analysis and F-statistics as applied to the cross-correlation traces at individual channels of all included array stations. Thirdly, local (i.e. confined to the correlation distance around the master event) association of origin times of all qualified signals is fulfilled. These origin times are calculated from the arrival times of these signals, which are reduced to the origin times by the travel times from the master event.
An aftershock sequence of a mid-size earthquake is an ideal case to test cross correlation techniques for autiomatic event building. All events should be close to the mainshock and occur within several days. Here we analyse the aftershock sequence of an earthquake in the North Atlantic Ocean with mb(IDC)=4.79. The REB includes 38 events at distances less than 150 km from the mainshock. Our ultimate goal is to excersice the complete iterative procedure to find all possible aftershocks. We start with the mainshock and recover ten aftershocks with the largest number of stations to produce an initial set of master events with the highest quality templates. Then we find all aftershocks in the REB and many additional events, which were not originally found by the IDC. Using all events found after the first iteration as master events we find new events, which are also used in the next iteration. The iterative process stops when no new events can be found. In that sense the final set of aftershocks obtained with cross correlation is a comprehensive one.