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The use of synthetic master events for waveform cross correlation

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It has been clearly demonstrated that waveform cross correlation substantially improves signal detection, phase association and event building. These processes are inherently related to the Comprehensive Nuclear-Test-Ban Treaty (CTBT) monitoring. The workhorse of cross correlation is the set of seismic master events (earthquakes or explosions) with high quality waveform templates recorded at array stations of the International Monitoring System (IMS). For the monitoring to be globally uniform, these master events have to be evenly distributed and their template waveforms should be representative and pure. However, global seismicity is characterized by a non-uniform distribution. Therefore, the master events selected from the Reviewed Event Bulletin (REB) produced by the International Data Centre (IDC) can be found in the areas constrained by the global seismicity. There are two principal possibilities to populate the globe with master events: to replicate real REB events or to build synthetic events. Here we compare the performance of these two approaches as applied to the aftershock sequence of the April 11, 2012 Sumatera earthquake. To compute synthetic waveforms, we use AK135 teleseismic velocity model and local CRUST-2 models for source and receiver, and four different source functions representing three different source mechanisms for earthquakes and one for explosion. The synthetic modeling is performed for teleseismic events and based on the stationary phase approximation to a wave equation solution developed by J. Hudson.
The grid covering the aftershock area consists of 16 points. For each grid point, we find detections associated with real, replicated, and four versions of synthetic master events at seven IMS array stations, and then build event hypothesis using the Local Association (LA) procedure based on the clustering of origin times as estimated by back projection of the relevant arrival times with known master/station travel times. Then all conflicts between the hypotheses built by different masters for physically same events are resolved. There are two principal ways to compare the performance of actual, replicated, and synthetic master events: to compare the characteristics/distributions of detections (also station dependent) and those of event hypotheses. Both datasets have shown that the synthetic events provide the same overall performance as the real and replicated master events. The best performance is associated with the explosion source and the earthquake with the Harvard CMT solution for one of real events. When source mechanism and velocity model are appropriately chosen, the global grid of synthetic masters may allow a reduction in the magnitude threshold of seismic monitoring and improving the accuracy and uncertainty of event locations at the IDC to the level of the best located events. When a ground truth event is available, one can expand its influence over hundreds of kilometers.

Key words: array seismology, waveform cross correlation, synthetics, seismicity, master events, IDC, CTBT