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Blind Source Separation of Seismic Events with Independent Component Analysis: CTBT related exercise

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Blind Source Separation (BSS) methods used in signal recovery applications are attractive for they use minimal a priori information about the signals they are dealing with. Homomorphic deconvolution and cepstrum estimation are probably the only methods used in certain extent in CTBT applications that can be attributed to the given branch of technology. However Expert Technical Analysis (ETA) conducted in CTBTO to improve the estimated values for the standard signal and event parameters according to the Protocol to the CTBT may face problems which cannot be resolved with certified CTBTO applications and may demand specific techniques not presently used. The problem to be considered within the ETA framework is the unambiguous separation of signals with close arrival times. Here, we examine two scenarios of interest: (1) separation of two almost co-located explosions conducted within fractions of seconds, and (2) extraction of explosion signals merged with wavetrains from strong earthquake. The importance of resolving the problem related to case 1 is connected with the correct explosion yield estimation. Case 2 is a well-known scenario of conducting clandestine nuclear tests. While the first case can be approached somehow with the means of cepstral methods, the second case can hardly be resolved with the conventional methods implemented at the International Data Centre, especially if the signals have close slowness and azimuth. Independent Component Analysis (in its FastICA implementation) implying non-Gaussianity of the underlying processes signal's mixture is a blind source separation method that we apply to resolve the mentioned above problems. We have tested this technique with synthetic waveforms, seismic data from DPRK explosions and mining blasts conducted within East-European platform as well as with signals from strong teleseismic events (Sumatra, April 2012 Mw=8.6, and Tohoku, March 2011 Mw=9.0 earthquakes). The data was recorded by seismic arrays of the International Monitoring System of CTBTO and by small-aperture seismic array Mikhnevo (MHVAR) operated by the Institute of Geosphere Dynamics, Russian Academy of Sciences. Our approach demonstrated a good ability of separation of seismic sources with very close origin times and locations (hundreds of meters), and/or having close arrival times (fractions of seconds), and recovering their waveforms from the mixture. Perspectives and limitations of the method are discussed.