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Detection of Low-Magnitude Seismic Events using Array-Based Waveform Correlation

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Correlation detection is a relatively new approach in seismology that offers significant advantages in increased sensitivity and event screening over standard energy detection algorithms. The basic concept is that a representative event waveform is used as a template (i.e. matched filter) that is correlated against a continuous data stream to detect new occurrences of a similar signal. These algorithms, therefore, are effective at detecting repeating events, such as explosions and aftershocks at a specific location.

We show that single-station waveform correlation can lower the detection threshold by 0.5 to 1 magnitude units over standard energy detection algorithms. By applying array processing, i.e. stacking the cross-correlation traces of the individual data channels of the array, we can obtain an additional lowering of the same order of magnitude. An important observation is that the cross-correlation traces are coherent across the array even when the waveforms are not.

We illustrate the power of the array-based waveform correlation using a much-analyzed seismic event that occurred in the Kara Sea, near Novaya Zemlya, on 16 August 1997. This event (of magnitude 3.5) was followed by a much smaller aftershock about 4 hours later. The aftershock was barely detected on the Spitsbergen seismic array using a conventional detector, but could readily be seen by applying waveform correlation on individual channels. The main event was also detected on the far more distant NORSAR array, but no conventional detection can be made for the aftershock, even when applying single-channel correlation. However, a clear detection is made when the correlation coefficients are beamformed over all sensors of the array.

We also describe a case study in which more that 1000 rockbursts at the Barentsburg coal mine on Spitsbergen were detected using signals from a major rockburst as a master event. In this connection, we demonstrate how spurious triggers (false alarms) can

be largely identified and eliminated by performing frequency-wavenumber analysis on the set of individual correlation traces.