Two cross-correlation techniques applied to volcanic seismic waveforms

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Two cross-correlation methods that employ very different mathematical approaches are compared: bispectrum-verified relative lag estimates and cross-coherency-determined lags inverted for pick adjustments.

The bispectrum method is used to verify results from time-domain cross-correlation for cases in which correlation coefficients fall below pre-determined quality thresholds. Bispectrum cross-correlation, or cross-correlation in the third order spectral domain, identifies waveform similarity in cases where traditional methods fail due to correlated noise contamination such as wind or site effects. For correlations passed through verification, the method incorporates cross-spectral information for subsample precision in the output differential times. The algorithm produces differential times, intended for use with the double-difference family of earthquake relocation and tomography methods.

The cross-coherency correlator calculates adaptive, cross-coherency-weighted correlation lags. Both integer and subsample cross-correlation are employed. Following correlation, a dendrogram-based pair-group classification scheme identifies clusters of similar waveforms. Correlation lag differentials are inverted for consistent pick adjustments within clusters, using a 1-norm conjugate gradient solver, providing adjusted absolute phase picks for subsequent use in any location or tomography algorithm.

We apply the methods to local seismicity recorded at Redoubt Volcano from 1989-1994 during and after the 1989/90 eruption. Waveforms recorded at volcanoes are often noisy and contain distinct spectral components that arise from complex interactions of tectonic and magmatic processes. Volcano seismic networks typically have few stations and often marginal coverage, providing challenges for earthquake location in a complex, three-dimensional setting. We compare the performance of the two methods, measured primarily by a direct comparison of correlation lags and earthquake relocations, but also by the success of both techniques in robustly segregating families of repeating earthquakes.