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Improved automatic detection and location of volcano-tectonic earthquakes beneath Uturuncu, Bolivia using Mutichannel Coherency Migration

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The occurrence and properties of (micro-) earthquakes within volcanoes yield a huge amount of information about physical processes occurring inside the volcanic system. Analysis of stress state, magma migration, source processes and more are derived in the first instance from the detection and location of earthquakes. Traditionally, human analysts manually pick phase arrivals in order to locate these events, but as data volumes increase this becomes insurmountably burdensome. Instead, automatic methods are required. We propose a novel method to migrate seismic energy back to its source, based on an improved imaging condition with greater noise tolerance, and use it to detect new earthquakes beneath Uturuncu, a volcano in Bolivia, where seismicity is induced by the passage of surface waves caused by the M 8.8 2010 Maule earthquake.

The multichannel coherency migration (MCM) sums the absolute correlation coefficients of traces between all stations pairs, using predicted P- and S-wave windows for each imaging point in the target volume. The maximum coherency point in time and space defines the most likely event occurrence. The only adjustable parameter here is the analysis time window—though this is determined by the dominant period of the signal—which is attractive since many migration schemes typically require several parameters to be optimised for each application. Because we use the cross-correlation between stations, incoherent noise is well suppressed, and even coherent noise can be minimised provided it doesn't occur at a majority of stations. Event location down to signal-to-noise ratios of 0.025 (1/40) is possible in tests.

We apply the MCM to synthetic tests, which show it more reliably finds the true event than the envelope, STA-LTA and kurtosis imaging functions, even with an inaccurate velocity model. We finally show the MCM in action beneath Uturuncu volcano, where we automatically detect and locate 98% of 114 hand-picked catalogue events, plus 322 verified additional events not previously detected. Our locations, coupled with post-hoc manual trace inspection show that seismicity is likely deeper than previously thought, down to 6 km below the surface. This improved catalogue can now be used to investigate b-values, tomography and any other seismic analysis based on microearthquakes below Uturuncu.