Massive earthquake detection using matched filter and fingerprinting techniques.

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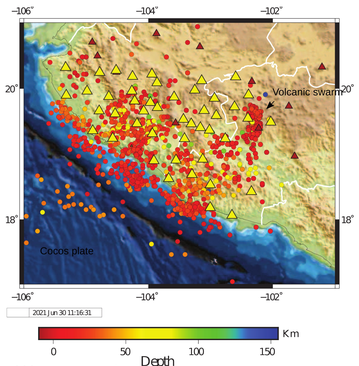
Abstract.

Seismology data analysis is becoming a challenge due to the exponential growth of continuous data being stored. In this study we present and compare two methods to massively detect earthquakes: the matched filter and fingerprinting. We have tested matched filter over several study zones of interest: in the Western part of Mexico (the Jalisco Block and nearby zones) to study general seismic activity using more than 2000 templates, in the Isthmus of Tehuantepec in Southern Mexico to track aftershocks from the September, 2017 Mw8.2 earthquake, and in the North Pole to study seismic activity mainly caused by ice cracking, or ice-quakes. We have demonstrated the accuracy of this technique especially detecting low amplitude signals hidden in the noise and coming out when we stack the resulting correlation coefficients over multiple stations. We are now testing fingerprinting, a technique much more efficient computationally, where we focus on extracting a fingerprint of the waveform for several templates in the frequency domain by compressing the resulting spectrogram. We then apply a hash function to create a hash table

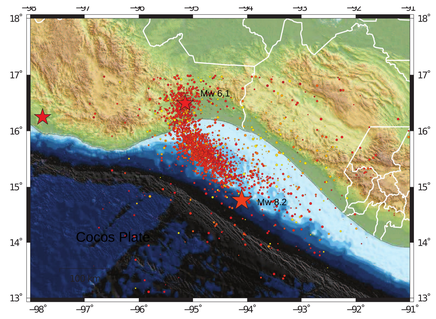
Matched Filter.

We have applied the Matched Filter technique for similar earthquake detection in two different zones in Mexico.

Western Mexico



Southern Mexico

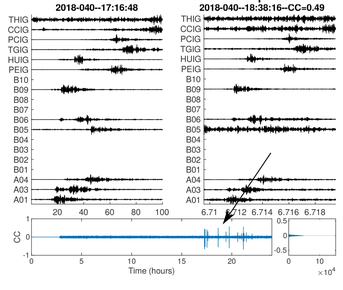


We proceeded in two ways:

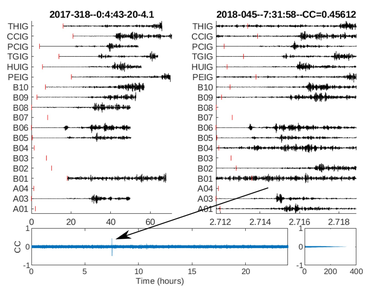
1.- Complete automatic detection method (building automatically multi-station templates with absolute time)

2.- Use existing catalogs as templates, taking into account time shifts (moveouts) as theoretical P wave travel times.

Absolute time template



template of a localized event

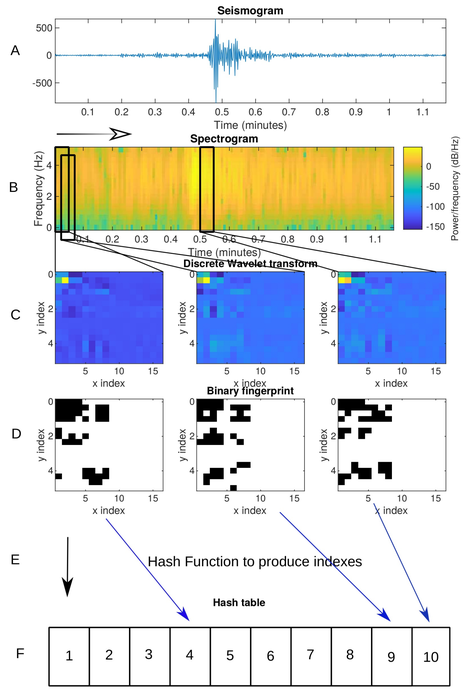


Using 2254 absolute time templates, we massively searched similar earthquakes in the Western part of Mexico, finding 13,115 unique detections.

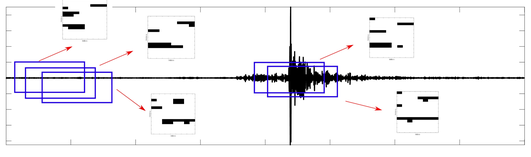
Using both, absolute and shifted time templates, we searched aftershocks following the 2017 Mw 8.2 Tehuantepec earthquake in Southern Mexico.

Fingerprinting.

With a moving window on the spectrogram we collapse it to scarce representation of each window (binary image or fingerprint) and to assign to each an index in a hash table from a hash function.



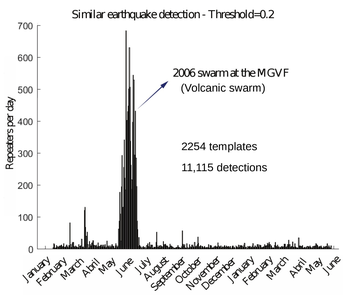
In order to search similarities, to each query signal we obtain systematically fingerprints in the same way as above, and get the number of hash coincidences with each template.



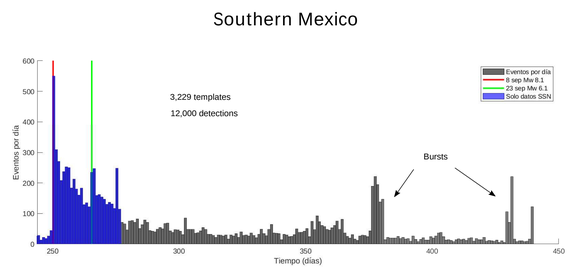
Using Fingerprinting and 3200 templates we search for similar earthquakes in Western Mexico

Results.

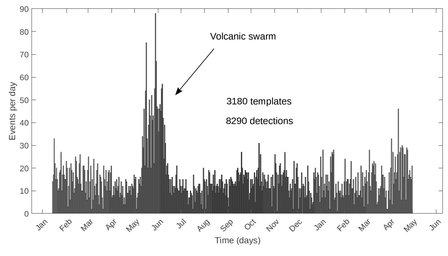
Western Mexico



Southern Mexico



Western Mexico



Conclusions.

The matched filter is powerful in detecting similar events, is easy to implement and very precise, but computationally is very intensive.

The Fingerprinting method is very efficient computationally since it does not do any redundant work. It is a very promising method, because if tunned properly, it can be used for automatic classification of earthquakes.

Regarding the computational time is: 1 week to process 500 days of data, 47 stations and 2254 templates using a GPU for the Matched Filter, while it took only 2 days for the same data and stations, but 3180 templates for the fingerprinting.