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High-resolution catalog of the Maurienne Swarm (French Alps) based on template matching and double-difference relocation

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INTRODUCTION

THE MAURIENNE SWARM

Starting from October 2017, the Maurienne Valley (French Alps) experienced a period of intense seismic activity that lasted until December 2018. Several events of ML > 3 were recorded and a clear clustering of seismicity was observed.

DATASET

The data used for this study were acquired from March 2017 to October 2019 by a local seismic network of 6 broadband stations: one station part of AlpArray (A181A) and 5 stations installed by ISTerre after the largest event (see Figure 3). The SISmalp catalog contains information on about 5400 events that occurred in Maurienne. This catalog was built using standard techniques commonly employed in seismological centres. In this study we present the methods used to extend the SISmalp catalog in terms of number of detections, location accuracy and magnitude estimation.

DETECTIONS

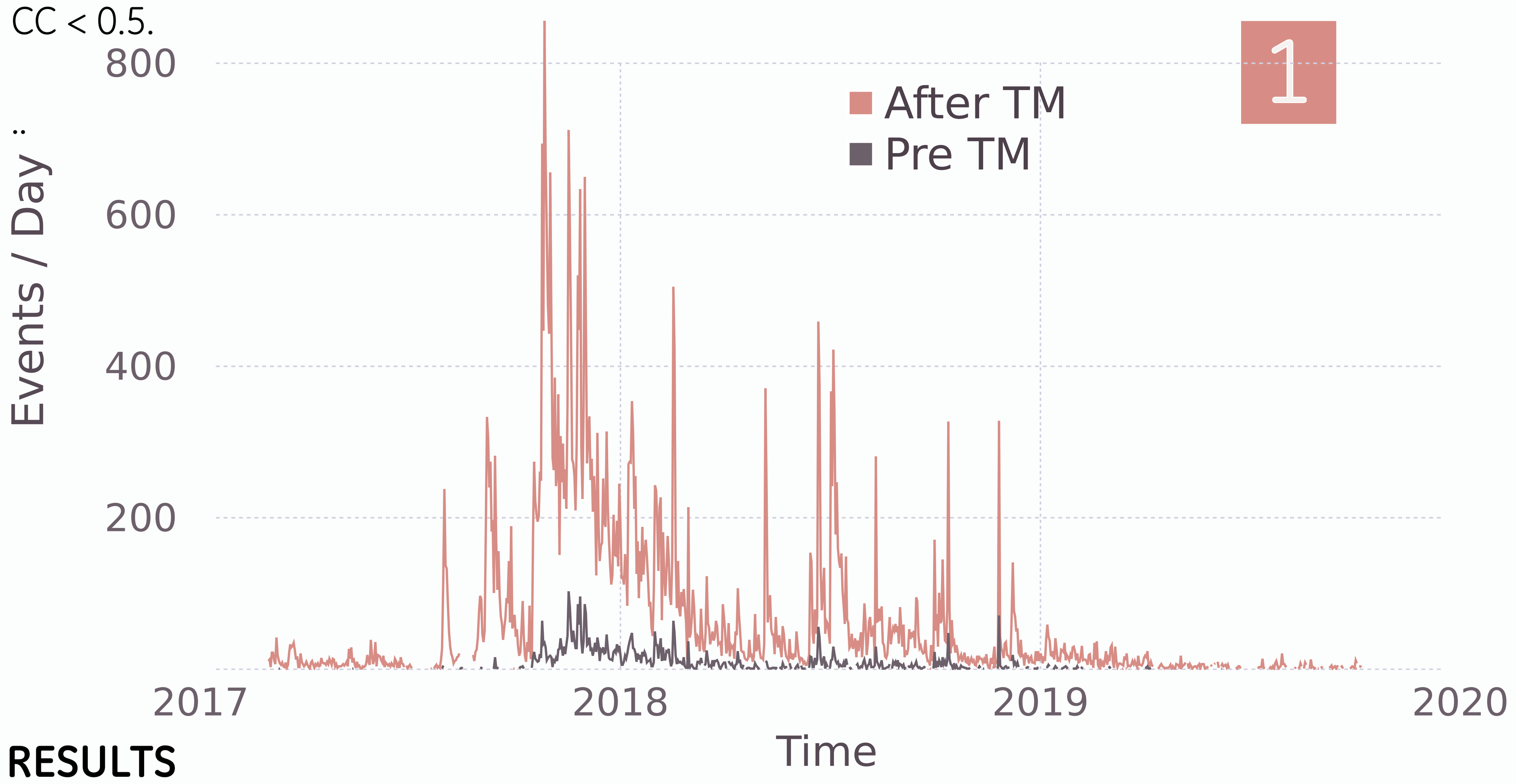
TEMPLATE SELECTION.

The events of the starting catalog were divided into clusters using hierarchical custering. A correlation coefficient (CC) of 0.75 was chosen as threshold. For each cluster, the event giving the best average CC was selected as template.

TEMPLATE MATCHING

With A181A as reference station (see Figure 3), we cross-correlated the templates with the continuous recordings. The waveforms were filtered between 3 and 40 Hz and the detection threshold was set at 0.40.

After applying template matching, false detections were removed using antitemplates . The antitemplates were obtained by considering detections with signal/noise > 9 and CC < 0.5.



RESULTS

1330 templates were defined after hierarchical clustering. Template matching allowed to detect **79000** events (Figure 1), 14 times more earthquakes than the original catalog.

RELOCATIONS

DOUBLE DIFFERENCE RELOCATION

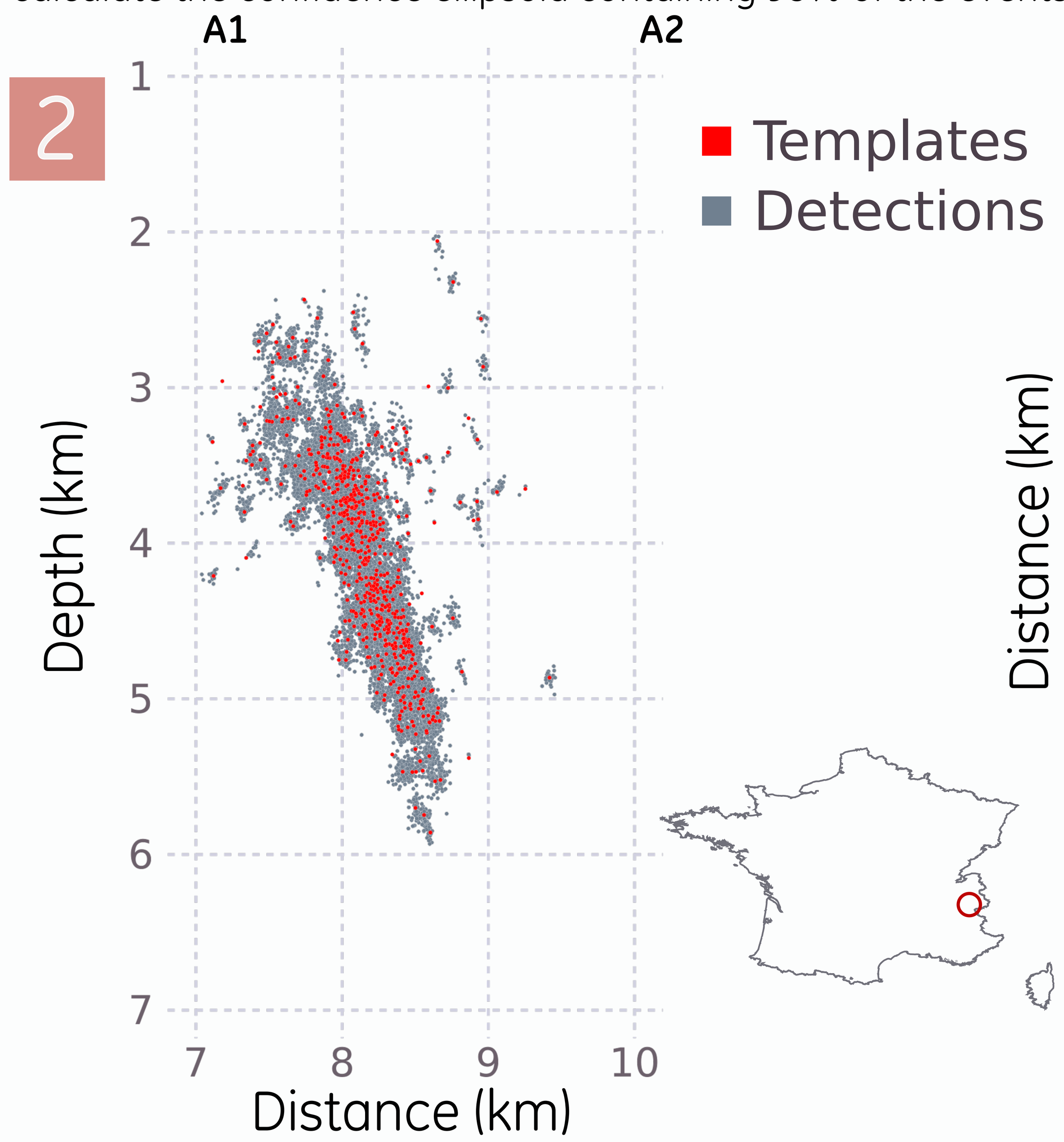
We employed double difference relocation to locate the detections with high accuracy. We assumed that the detections occured at the same location of the template that detected them. With this assumption, we used detection times to derive origin times and arrival times of P and S waves at all the available stations.

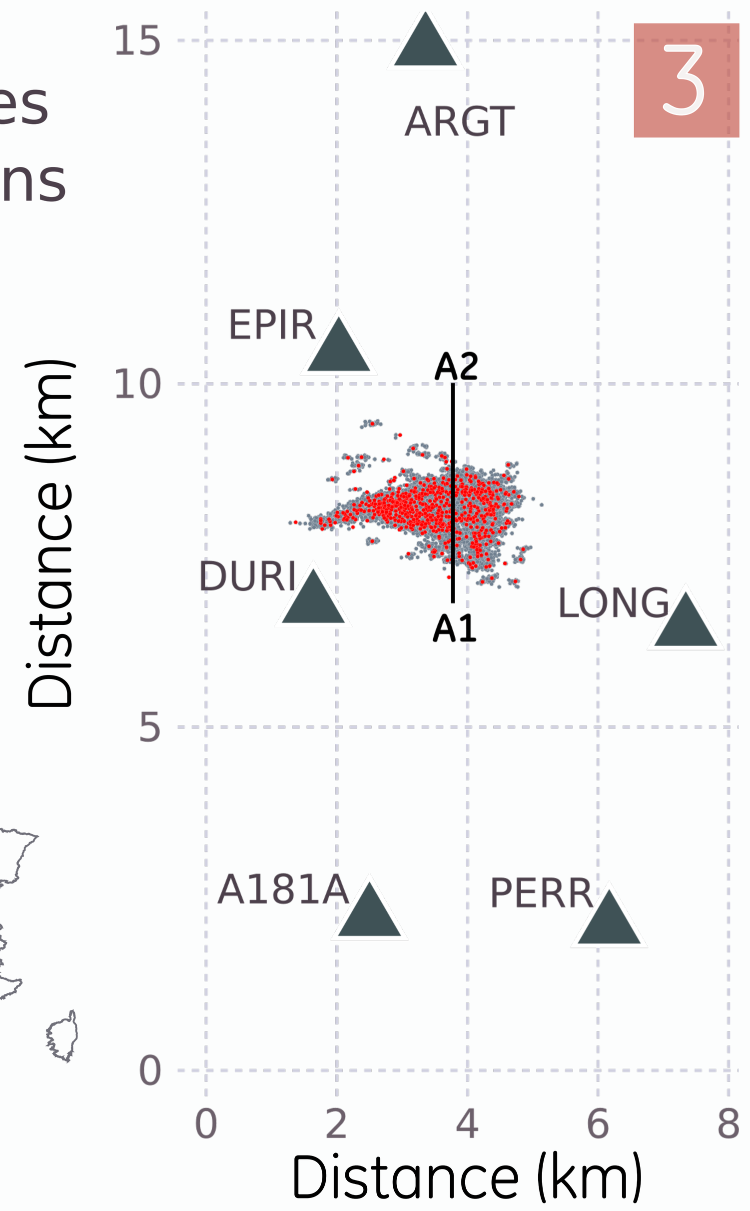
We first relocated the templates considering both catalog and cross-correlation differential times, The new locations were then used to relocate the detections using only cross-correlation times. In this last step, the detections were only linked to detections belonging to the same cluster.

When calculating differential times with cross-correlation, CC values of 0.65 and 0.55 (for templates and detections respectively) were set as threshold, Both P and S waves were taken into account. and only event pairs with at least 6 observations were kept.

BOOTSTRAP

Location errors were estimated with bootstrap, by sampling the residuals travel times of the relocated events. A total of 200 iterations were performed. The resulting locations were used to calculate the confidence ellipsoid containing 95% of the events.





RESULTS

24000 events were relocated (Figure 2 and 3). Part of the losses derive from the fact that only 700 out of 1300 templates were found suitable to be relocated.

The estimated location errors are 168, 150 and 65 m for depth, y, and x directions respectively.

MOMENT MAGNITUDES

SPECTRAL FITTING

We first calculated moment magnitudes (Mw) by fitting the observed displacement spectra with a theoretical one based on the source model of Boatwright. This is only possible for events with good signal/noise.

Mw - AMPLITUDE RELATIONS

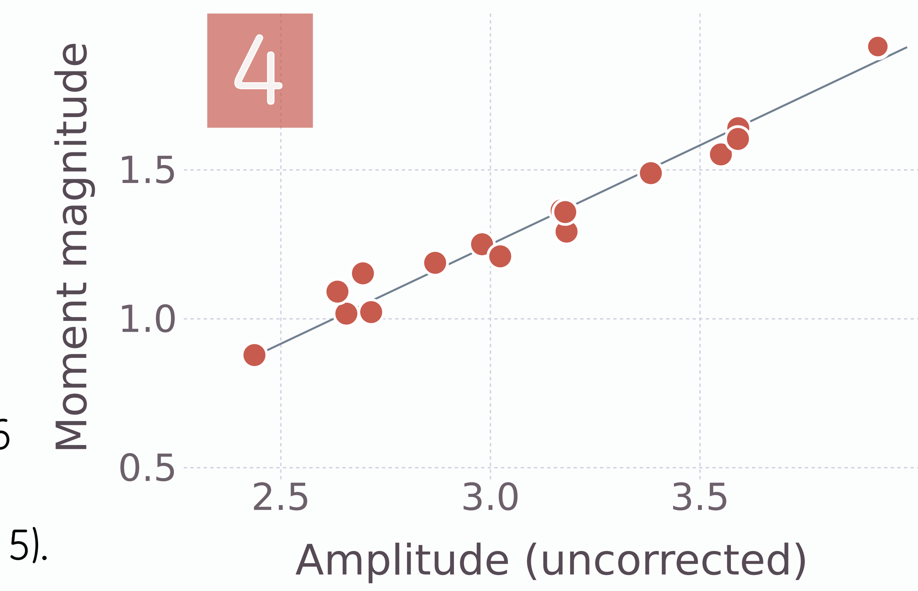
To calculate the Mw of small events, we took advantage of the fact that colocated earthquakes have identical normalized waveforms if their corner frequences are sufficiently high. In this case, Mw can be estimated from the maximum amplitude (A_{max}) of P or S waves by solving:

$$M_w = \frac{2}{3} A_{max} + C$$

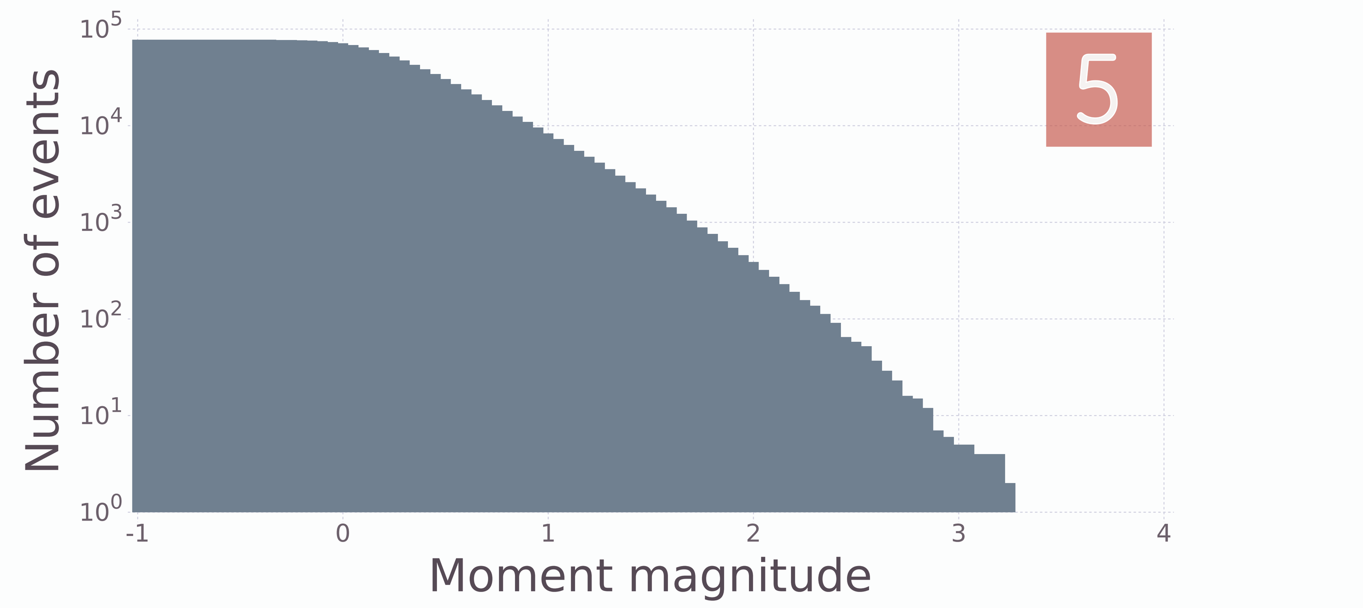
The intercept C has to be estimated for each cluster and it can be trivially obtained using the Mw values calculated with spectral fitting (FIgure 4).

RESULTS

The use amplitudes instead of seismic moment allowed us to calculate the moment magnitude for almost all detections (**77000**).



The estimated b value is 1.16 while the magnitude of completeness is 0.22 (Figure 5).



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