First test to locate the microseismicity induced at Rittershoffen geothermal field (France) using a migration-based technique

Emmanuel Gaucher (KIT), Alessia Maggi (EOST), Nicolas Cuenot (EEIG "Heat Mining"), Vincent Maurer (ESG)

Introduction

Seismic monitoring of Enhanced Geothermal Systems (EGS) is required because fluid circulation generally induces microseismicity, especially during reservoir stimulation where felt seismic events may occur and become a concern. Moreover, real-time processing of the seismic data becomes mandatory for setting up robust alarm systems. Hence, the development and application of reliable and automatic techniques for processing the data acquired by these local seismic networks are crucial.

Context

In Rittershoffen, Alsace, France, an EGS plant is being developed by the ECOGI joint venture (Baujard *et al.*, 2014). Once operational, the power plant should deliver 25 MWth to a bio-refinery plant located 15 km away. To reach this objective, a geothermal doublet is being developed at 2.5 - 3 km depth, into the Triassic sandstone and the Paleozoic granitic formations which constitute the reservoir formations. After drilling the first well, hydraulic stimulation was carried out in June 2013 to enhance the connectivity between the well and the geothermal reservoir. This operation induced seismicity which was continuously recorded by a surface network composed of 17 seismic stations (Maurer *et al.*, 2015).

Methodology

In the framework of this study, we replay the seismic record dataset through an automatic kurtosis-based migration detection and location technique, called Waveloc. The software, developed by EOST (University of Strasbourg) was applied successfully on volcano seismicity (Langet *et al.*, 2014). It first transforms the raw data into kurtosis-based waveforms which enhances the first arrivals of seismic events observed over the network. By considering only P-waves, the migration step consists in applying source-scanning, move-out and stack of the kurtosis waveforms over the target volume and over time. The resulting movie highlights the location and occurrence time of the seismic events associated to the maximum of the stacks in space and time (*Figure 1*). Such a procedure, which intrinsically integrates the detection, picking and location of the seismicity, automatically generates a catalogue of seismicity.

Results

The first test of this migration-based technique was done after calibration of the procedure. This necessary step consists, so far, in manually tuning the automatic processing parameters to the Rittershoffen seismic data. The parameters are related to the initial filtering of the raw data, to the kurtosis computation, to detection thresholds application, etc. In our well stimulation context, several events recorded during the first 6 hours of seismicity were used to select the best parameters. Over this period, the continuously recorded data were manually processed, which provides a reference seismic catalogue and allows us comparing the manual processing and the automatic Waveloc results.

Approximately 900 seismic events belong to the reference dataset, among which 12% were automatically detected by Waveloc. A ratio of 73% of good detections was reached. For fixed pre-processing parameters (raw seismogram filtering, kurtosis computing parameters), the percentage of good detections increases with the signal to noise ratio and, therefore, with the stacked kurtosis value; however, the absolute number of detected events decreases. This highlights a trade-off between both quantities. Location discrepancies between similar events of the two catalogues range between 100 m and 2100 m. However, these differences decrease with increasing signal to noise ratio. We also observe that seismic events are almost systematically located shallower using Waveloc and have later occurrence, thus emphasizing the well-known depth/origin time tradeoff. For a few stations, systematic delays between P-wave onset time arrival and the automatically picked arrival. This reflects discrepancy between the velocity model and the recorded waveforms and suggests possible improvement related to this matter with, for example, integration of station time corrections. Several other results need to be investigated such as the capability of Waveloc as a function of the magnitude of the events, etc.

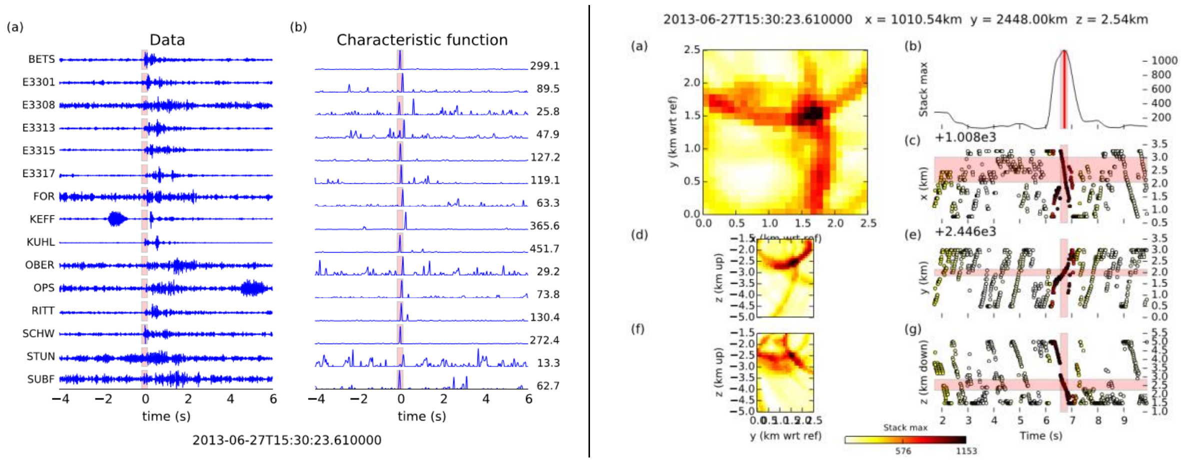

Figure 1: Micro-earthquake of 27 Jun 13 15:30:23 UTM. Left: Raw seismogram (a) and kurtosis derivative value (b) for each vertical sensor taken into account in the processing after move-out correction. Right: horizontal section (a), EW vertical section (d) and NS vertical section (f) of the spatial distribution of the stacked kurtosis (b) at the time indicated by the red line. The best location corresponds to the black color.

Conclusion and perspectives

The results of this first test show that, as expected, the detections and locations obtained by Waveloc are strongly dependent on the automatic processing parameters and therefore on the calibration procedure. This step is mandatory and unfortunately requires time both for manual processing of a reference dataset and for manual tuning of the automatic processing parameters. Hence, effective real-time processing would be possible only following such a first task. Nevertheless, a more systematic search of the optimal set of processing parameters in Waveloc may be considered. Dependency of the results as a function of the seismic event magnitude should be better investigated to quantify the real capabilities of the technique, especially in terms of increased detection capability compared to other techniques such as STA/LTA detection.

If we succeed in qualifying the Waveloc method for use at Rittershoffen, it will be possible to replay the whole dataset acquired on this site, which covers about 1.5 years, with the aim of enlarging the seismic catalogue by applying consistent processing over the period.

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