Automatic classification of seismo-volcanic signals as a tool to improve eruption forecasting

Anais Boue[1], Philippe Lesage[1], Guillermo Cortes[2], Carmen Benitez[2], Jesus Ibanez[2], Isaac Alvarez[2], Angel de la Torre[2], Luz Gutierrez[2], Raul Arambula[3], Miguel Gonzalez-Amezcua[3], Gabriel Reyes-Davila[3]

[1]ISTerre, Universite de Savoie, France, [2]Universidad de Granada, Spain, [3]Universidad de Colima, Mexico

E-mail: Anais.Boue@univ-savoie.fr

Seismic activity is one of the main precursors of volcanic eruptions as it usually increases before crises. The material Failure Forecast Method (FFM) is the most common approach used for eruption prediction. It is based on empirical power laws applied to observables such as the rate or energy of the seismic activity. In most seismic studies, the observable mixes together numerous types of events that are associated to different physical mechanisms at the source : brittle rupture, resonance of fluid-filled cavities, degassing, collapse, regional earthquake, or noise. Brittle rupture is associated with volcano-tectonic (VT) events. In the framework of the FFM, the acceleration of this type of seismic activity is interpreted as resulting from damaging processes preceding ruptures and eruptions. Long-period (LP) events can be generated by different physical phenomena at the source. The acceleration of LP rate observed before some eruptions is probably associated with other processes than damaging. It is thus important to understand better this accelerated behaviour of LP seismicity in order to verify if it can be used as a reliable precursor.

In order to improve eruption forecasting, it appears necessary to process separately the different types of seismicity and to identify the most pertinent ones for this task. For this purpose, we use an automatic classification tool adapted from a voice recognition system based on continuous Hidden Markov Models (HMM). Various behaviour laws (among them power laws) are then applied on the classified seismic activity and their ability to give robust predictions is tested with a hindsight approach.

We calculate the seismic energy release and the seismicity rate for each type of events and we fit behaviour laws to these observables. Then we compare the time of divergence of the theoretical curves with the time of eruption. We pay special attention to the choice of the fitting window and we analyze the evolution of the estimated parameters (exponent of the power law, time of eruption) as a function of the starting and ending times of the window in order to test the robustness of the predictions.

We present applications of this procedure to the seismic activity associated to several eruptive crises of Volcan de Colima, Mexico. The results obtained with classified seismicity and with the complete raw signals are quantified and compared. They show that the precursory patterns for LP and VT events differ from an eruptive period to an other. This observation provides insight on the precursory eruption processes. Moreover, more consistent and more robust estimations of the eruption time are obtained when separating the different types of volcano-seismic events. Finally, the approach developed in this work has been conceived for real-time applications through automatic signal recognition and automatic fitting of behaviour laws. It is thus aimed at being integrated in monitoring systems.