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The statistical signature and physical mechanism of quiescent volcanic degassing

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Non-eruptive or quiescent degassing is the most common modality of emission from volcanoes and it is responsible for a major part of the time-averaged global volcanic gas input to the atmosphere. The resulting plumes can be relatively small in size or much diffused and they are usually confined to tropospheric altitudes. For these reasons, ground-based remote sensing is particularly well suited for long-term monitoring of quiescent volcanic plumes.

Previous studies of time-series of quiescent volcanic degassing from different volcanoes have concentrated on interpreting the trends, usually in relation to the variation of other geophysical signals, or periodicities in the data. Long-term monitoring at the scale of minutes reveals that the gas emission rate at several volcanoes can occasionally exhibit abrupt changes, without necessarily showing concomitant changes in the eruptive state, thus with no correlation with other signals or without any clear periodic pattern.

We investigate the statistical distribution of emission pulses of SO_2 at a time scale of a few minutes obtained from scanning-DOAS measurements at several volcanoes of the NOVAC network during the last decade. The change in order of magnitude between consecutive emissions follows a mono-modal and symmetric distribution that is well modelled as alpha-stable. The stability parameter of the distribution is found to lie between 1 and 2, being larger for volcanoes of lower magma viscosity. The lower limit converges to a Cauchy-Lorentz distribution (akin to resonance), whereas the upper limit corresponds to a Gauss distribution (akin to randomness). The tail of the distribution converges to a scale-free (power-law) distribution.

To make sense of this finding we present a model of directed percolation that accounts in a natural way for the derived distribution and is compatible with known physics of the transport of gas through a porous medium. This suggests that quiescently degassing volcanoes can be understood as systems close to a critical state, where the governing parameter is the degree of percolation determined by a critical porosity. Transition to a different state can be indicated by a change in the statistical signature of degassing observed during a certain period of time.

This study is an attempt to find the common features of degassing from volcanoes of quite different characteristics, based on the information obtained from a large database. This gives not only understanding of the physical processes behind passive emission, but also helps to identify the nature of unusual emission changes (statistical or a change of state) and to improve the quantification of the emission budget of volcanoes at an individual and global basis.