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Early Warning Systems at active volcanoes: trends and challenges

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Setting up an effective Early Warning System at potentially dangerous active volcanoes is the core issue in volcanic risk mitigation. Although the number of successful assessments at the global scale is increasing (the Merapi case, Indonesia, in 2010 stands as one such case in a developing country), we are overall still far from a satisfactory condition. The problem is particularly critical for explosive volcanoes close to highly urbanized areas, like Vesuvius and Campi Flegrei in Italy and others in many other countries. In all such cases evacuation of hundreds of thousands people requires a confident estimate of the eruption probability in order to reduce the risk of a false alarm that may by itself result in severe social and economic consequences. The key point here is to accept, by the volcanologists and by the society, that there is a substantial uncertainty in predicting both the occurrence of an eruption and its characteristics and impact. Such an uncertainty is mostly due to the large inaccessibility of the volcanic systems, that can not be observed directly, and to the highly non-linear nature of the volcanic processes. The uncertainty is inherent in the behaviour of the volcanic systems, and can not be totally ruled out. The scope of science must be therefore that of i) reducing the uncertainty to acceptable levels, and ii) managing it in a proper way, so to allow an effective cost/benefit analysis and lead to knowledge-driven actions (as opposed to emotionally-driven actions) by decision makers. Last ten years of volcano research at the global scale have brought about substantial progress along those lines, that may be summarized in: 1) the development and deployment at many potentially dangerous volcanoes of more advanced instruments covering a broad range of signal frequencies; 2) the development of numerical simulation techniques allowing more physically sound interpretation of the recorded signals; 3) the progressively increasing adoption in volcano science of the concepts and techniques of probability estimate and Bayesian event tree analysis. Furthermore, the occurrence of eruptions at some heavily monitored volcanoes in the world (e.g., Soufrière Hills at Montserrat Island, Western Indies, and Mount Etna and Stromboli in Italy) is providing new and more advanced clues on the pre-eruptive behaviour of different volcanic systems, bringing in new concepts and ideas and opening new perspectives in the set up of effective Early Warning Systems. While active volcanoes will continue to elude our understandable desire to predict their behaviour deterministically, the next decade will likely sees a prominent progress in the development and set up of probabilistic Early Warning Systems that will fully exploit knowledge deriving from a variety of sources, including previous experience, current observations, advanced modelling, and personal (subjective) opinion, the latter being currently experimented at a number of volcanoes through the methods of experts elicitation developed and commonly employed in fields as far to volcanology as those of politics and economics.