Volcano monitoring in reducing volcano risk

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Since the 17^{th} century, volcanic disasters have killed more than 300,000 people and caused property damage and economic loss in excess of hundreds of millions dollars. Fortunately however, with the emergence of modern volcanology in the 20^{th} century, the risk from volcanic hazards can be anticipated and reduced by scientific studies and timely governmental actions. Volcanic eruptions are almost always preceded and accompanied by "volcanic unrest," as manifested by physical and (or) chemical changes in the state of the volcano and (or) its associated hydrothermal system. Such precursory activity (e.g., seismic, geodetic, gas emission), which provides early warning of possible impending eruption and attendant hazards, is readily detectable by ***volcano monitoring***—the systematic collection, analysis, and interpretation of visual observations and instrumental measurements at restless volcanoes. Data from volcano-monitoring studies constitute the only scientific basis for *short-term* forecasts of a future eruption, or of possible changes during an ongoing eruption. In general, the longer the time span of the pre-eruption *baseline* monitoring data, the more robust and reliable is the short-term forecast. Thus, in any effective hazards-mitigation program, a basic strategy in reducing volcano risk is the initiation or augmentation of volcano monitoring at historically active volcanoes and also at geologically young, but long-dormant, volcanoes with potential for reactivation. Experience worldwide indicates that the optimum volcano-monitoring approach is one that employs a combination of techniques rather than reliance on any single one.

Beginning with the 1980s, substantial progress in volcano-monitoring techniques and networks has been achieved. Although some geochemical monitoring techniques (e.g., remote measurement of $SO_2$and CO_2 gas emissions) are being increasingly used and show considerable promise, seismic and geodetic methods remain the techniques of choice, and these generally provide the most reliable diagnostic precursory data. Especially impressive are the recent advances in volcano seismology made possible by the wider use of broad-band seismometers and the development of sophisticated methodologies in the analysis and interpretation of long-period (LP) and very-long-period (VLP) seismicity, which nearly always precede and accompany magma intrusions, some of which culminate in eruptions. Major improvements have been realized also in the application of satellite-based or *space geodesy* [e.g., **G**lobal **P**ositioning **S**ystem (GPS), **I**nterferometric **S**ynthetic **A**perture **R**adar (InSAR)] in the detection and mapping of the areal extent of ground deformation at restless volcanoes. To the extent scientific and economic resources permit, volcano-monitoring data should be acquired and processed in a timely manner—ideally, in *real-* or *near-real-time* modes—for rapid communication of the hazards information to the responsible civil authorities. Availability of comprehensive volcano monitoring was a decisive factor in the successful scientific and governmental responses to the reawakening of Mount St. Helens (Washington, U.S.A.) in 1980 and, more recently, to the powerful explosive eruptions at Mount Pinatubo (Luzon, Philippines) in 1991. Still, volcano-monitoring data—no matter how complete and timely—cannot ensure the successful outcomes of future volcanic crises and mitigation of volcano risk. What is beyond doubt, however, is that, without adequate monitoring data, volcanic crises almost certainly will end in volcanic catastrophes.