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The Geodetic Infrastructure Required to Study and Monitor Volcanoes

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Surface deformation observations play an important role in understanding the mechanical and dynamic properties of volcanic sources and as part of any comprehensive real-time monitoring strategy. In a number of cases volcano deformation has preceded seismicity or other significant precursory signals heralding renewed activity at a volcano, while in other cases deformation has been detected that, over a decade at least, leads to no eruption. Deformation measurements provide a primary observation for the estimation of volcano source properties, including the shape and volume change of the source, as well as its depth and location. These characteristics are essential, when combined with other observations such as gas and thermal emissions, gravity, or seismicity, for understanding properties of the magma that is injected and its dynamics during emplacement and ascent, and as part of a real-time monitoring program. While seismological and gravity measurements are necessarily in situ, deformation measurements, though traditionally made with instruments on or near the volcano, recent advances in satellite and airplane synthetic aperture radar (SAR) make remote sensing possible. Advantages of interferometric SAR (InSAR) measurements include large area coverage at approximately 1-100 m resolution from a single line-of-sight (LOS) direction. Satellite based systems provide the advantage of global coverage, although lacking continuous global coverage, airplane systems offer flexibility and mobility for responding to volcanic events. Disadvantages with respect to GPS include a time sampling that is discontinuous (i.e. 11-46 days for current satellite systems), one relative displacement component, and varying levels of coherence depending on vegetation conditions, relative topography, and the properties of the radar sensor. Future systems, such as UAVSAR, have the potential to reduce repeat time to sub-daily if warranted, though it requires a priori identification of the target volcano. GPS observations can provide continuous temporal sampling, and three-component displacements in a stable reference frame. Disadvantages of GPS include a lack of global coverage (sites must be established in advance), and the need for and cost of having a dense enough or extensive enough network to fully define the surface deformation. In the case of a very active volcano, there can also be the potential for loss of instruments in the field, so measurements for real-time response would be compromised. I will examine these issues through numerical models and examples from InSAR and GPS observations and analysis at a number of volcanoes worldwide.