Detection of cyclic behaviors and characterization of magma storage at andesitic volcanoes using regional InSAR time series surveys

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Despite the threat posed to millions of people living in the vicinity of volcanoes, only a fraction of the worldwide 550 historically active volcanoes have geodetic monitoring. Indonesian and Mexican explosive arc volcanoes are sparsely monitored with ground-based methods but especially dangerous, emphasizing the need for remote sensing monitoring. In this study we use used over 1200 ALOS InSAR images to survey the entire west Sunda arc and the Trans Mexican volcanic belt (TMVB). We use 2 years of data to monitor the background activity of the west Sunda arc, and 4 years of data at four volcanic edifices (Sinabung, Kerinci, Merapi, and Agung), as well as 4 years of data to survey the entire TMVB. We derive time-dependent ground deformation data using the Small Baseline technique.

We show that while InSAR time series successfully constrain cyclic behavior at both regularly active and previously inactive Indonesian volcanoes, detecting pre-eruptive inflation and post-eruptive deflation, it fails to identify deformation at Mexican volcanoes. We thus identify 2 types of eruption cycles. The first type corresponds to closed volcanic systems where eruptions are preceded by inflation and followed by deflation detectable by InSAR. Observation of such cyclic deformation illustrates the traditional model of magmatic systems and eruption cycle assuming that overpressure in a reservoir eventually opens a conduit leading to eruption. The second type of eruption cycles corresponds to open-system volcanoes where no significant pressurization of the magmatic system is taking place prior to eruptions and thus no ground deformation can be detected. This is the case of regularly active, dome growing volcanoes such as Colima and Popocatepetl, in the TMVB, and Merapi, in the west Sunda arc.

We model the observed deformation in term of depth of magma storage, an important parameter for volcanic hazard assessment. We show that seven Indonesian volcanoes have shallow magma reservoirs at 1-3 km depth below the average regional elevation. We perform a global data compilation to evaluate the potential influence of regional parameters on the depth of magma storage beneath explosive andesitic arc volcanoes. By collecting data at 70 andesitic volcanoes in 8 continental and transitional arcs we show that volcanoes in extensional and strike-slip settings can develop shallow reservoirs whereas volcanoes in compressional settings lack them. Thus, magma ascent through the upper crust seems influenced by intra-arc tectonic settings.