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Editorial: External forcing on volcanoes and volcanic processes: Observations, analysis and implications

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Editorial on the Research Topic
External forcing on volcanoes and volcanic processes: Observations, analysis and implications

Volcanoes are complex systems that evolve in space and time as a result of their internal dynamics. These internal dynamics span both long and short time scales, reflecting the different steps for the magma to form, accumulate and evolve before being eventually erupted. All of these stages may be influenced by processes external to the volcano, although most of the evidence that has been gathered on this has considered influences on the magmatic fluids stored at crustal depths, or emerging at surface. External forcing acts either through the stress or gravitational fields that may accelerate or slow down the transfer of magma towards the surface. Changing tectonic stresses and Earth tides may induce changes in the dynamical state of volcanoes, ultimately providing the triggers that may lead to eruption. Water, which is ubiquitous on Earth, and present in its different fluid and solid envelopes, appears to play a key role, acting on volcanic systems from pore- to global-scale in various ways (hydrological modulation, ice cap loading), due to its physico-chemical properties.

This Research Topic brings together contributions, which provide new constraints and lines of evidence on the nature and variety of external processes influencing activity at quiet, restless and erupting volcanoes.

Seasonal hydrological variations can influence the evolution of volcanic systems, as suggested by Petrosino et al. who compare the behaviour of Vesuvius and Campi Flegrei (Italy). They find that part of the ground deformation reflects the seasonality of the hydrological cycles at both volcanoes, whereas part of the seismicity shows a seasonal

pattern only at Campi Flegrei. The authors conclude that rainfall patterns, through the combined action of water loading, diffusion processes in a fractured medium and interaction with the shallow hydrothermal fluids, play a role in modulating the dynamics of metastable volcanoes experiencing unrest, like Campi Flegrei.

Volcanoes with shallow hydrothermal systems may be subject to sudden increases in surface steam emission in response to external forcing, such as sudden decrease of atmospheric pressure or variation of meteoric water input. Bremond d'Ars and Gibert analyze the temperature fluctuations measured with 1 s resolution in the fumaroles at La Soufrière volcano (Guadeloupe, France). The authors observe temperature variations of more than 10°C with remarkable periodic patterns and compare them to rainfall measurements, finding a correlation between the two data sets.

In a study on the same volcanic system, Moune et al. synthesise the long term (5 years) high resolution dataset on volcanic gas compositions and fluxes from the hydrothermal systems of La Soufrière. They show how the influence of the inputs from the magmatic system at depth can be deconvolved from the processes acting within the shallow hydrothermal system, once the external influence of the tropical environment is accounted for.

Rowell et al. provide new insights on how water controls the evolution of explosive eruptions and especially the release of SO_2 into the stratosphere by a new model based on the coupling of one-dimensional models of conduit flow and atmospheric column rise. The comprehensive approach of the authors demonstrates that the predominant control factor of the jet behavior is the efficiency by which the water is incorporated into it and that hydrovolcanic eruptions have a rather reduced effect on climate forcing. This study also suggests that climate variations may impact the relative global frequency of hydrovolcanic eruptions on longer time scales.

More generally, the cryospheric environment has specific signatures on volcanic activity, as shown by Edwards et al. who provide a framework for understanding the impact of the cryosphere on glaciovolcanic systems, landforms and deposits. Their study, based on both observational data and numerical modeling, provides evidence for the modulations in eruptive style as well as rate and timing of eruptions in many volcanoes worldwide.

The investigation of the stability conditions of glacier-covered systems provides further insights on stress-related interactions at volcanoes. Lucas et al. study Westdahl Peak, a subglacial volcano on Unimak Island (Aleutian Arc, USA). The authors use thermomechanical finite element models to evaluate how the stability of a glaciated volcano is impacted by variations in ice cap thickness, magma chamber depth, geometry, magma flux rate, and seasonal changes in ice cover thickness. The results of the numerical experiments indicate that the presence of an ice cap increases the stability of the magma system. In addition, magma flux rates influence the timing of eruptions when the system is experiencing seasonal variations in ice thickness.

At a simple level, volcano-tectonic interactions are related to stress variations in the surrounding crust. Hedger and Gottsmann investigate stress transfer between the Akhisar-Kiliç fault segment (AKFS) in the Central Anatolian Volcanic Province and the active Hasan Dağ volcanic complex (Turkey). Using 3D finite element modelling, the authors show that progressive stress accumulation, quantified using the Coulomb Failure Stress change, promotes conditions favourable to failure and magma rising in the crust.

The stress field of volcanoes may also be altered by large scale processes such ocean loading, as suggested by Dumont et al. who investigated the existence of a possible link between the global eruptive activity and the global mean sea-level by analyzing the time-series of both data sets between 1880 and 2009. The authors found common decadal periodicities, ranging between ~20 and ~90 years, that have been also identified in the polar motion. By linking global processes and the worldwide eruptions, the authors provide a new angle to tackle external forcing on volcanoes acting on decadal scales.

Periodic signals have also been encountered in different geophysical parameters recorded at volcanoes on shorter time-scales, revealing variations of the volcano's gravitational field mainly related to lunisolar tides. Thus, seismic tremor generated by the hydrothermal activity at the two volcanoes of Ischia and Campi Flegrei (Italy) analyzed by Petrosino and Dumont using a time-series analysis technique, appears to be composed of periodic variations coinciding with those of long lunisolar Earth tides, ranging from ~5 to ~29 days. By extracting these tidal components, the authors suggest that the response of the hydrothermal system to this forcing depends on the source of the seismic tremor and the degree of hydrothermal alteration of the surrounding medium.

Sottili et al. present a wide-ranging historical perspective on the Research Topic, highlighting the development of ideas around oscillations of the fluid envelopes of the planet from their origins in Greek and Roman philosophy, to their re-emergence in arguments around different planetary-scale processes in the 19th and 20th centuries. Their essay highlights the interconnections between physical processes that act at different time scales, and links astronomical, climatic and geological phenomena, with a focus on volcanic activity.

Theoretical modeling offers a way to investigate the interplay between external forcing and internal dynamics at volcanoes which may favour transitions from stable to unstable regimes. From continuous deformation measurements at Akutan, Okmok (Aleutian arc, USA) and Piton de la Fournaise (La Reunion, France) volcanoes, Walwer et al. extract the temporal patterns by applying a data-adaptive statistical methodology which provides information on the underlying dynamics without *a priori* assumption on the physical mechanisms. Then, using phase portrait reconstructions, the authors formulate data-based mathematical models which concur to the definition of the

dynamical state of the volcanic systems and may help in distinguishing between stable/unstable conditions.

In summary, the works collected in the present Research Topic cover a wide range of methodologies mainly based on purely theoretical approaches and data analysis or both, providing new evidences on the influence and diversity of external processes acting on volcanic systems at different temporal and spatial scales.

Author contributions

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Conflict of interest

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