Modeling Volcano Breathing: A Path to Forecasting Eruptions

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As a window into the Earth System, volcanoes are natural laboratories for advancing understanding of the dynamics of our planet. More than 50 volcanic eruptions are reported every year, including devastating eruptions which kill people, damage homes, change landscapes, and disrupt climate. Forecasting the onset of eruptions is one of the grand challenges in volcano science. Fortunately, many volcanoes generate signs of unrest ("breathing") prior to the eruptions, including surface deformation, earthquakes, temperature increase, and gas emissions. In combination with observations of this unrest, robust eruption forecasts require quantitative models to understand the processes driving the unrest and to identify critical thresholds for eruption phenomena. In this talk, I will present a framework for integrating multidisciplinary observations and numerical modeling to explain the thermal and mechanical processes driving the unrest of two volcanic systems: At Laguna del Maule, a large silicic volcano in the Chilean Andes, I show that the pressurization of its magma reservoir increases the hydraulic connectivity in a pre-existing fault zone. Consequently, pore fluids with high pressure are injected into this zone, and open fractures and trigger earthquakes that release stresses and delay the eruption. At Augustine volcano, a relatively small andesitic system in Alaska, I show that volcanic gases transfer heat from a deep magma reservoir to the surface through a fractured conduit system, causing a measurable thermal anomaly months before the eruption. Concurrently, interaction between magmatic gases and the volcano's conduit decreases the permeability of the uppermost conduit, resulting in a build-up of high pressure beneath the "sealed" conduit, generating surface deformation, triggering earthquakes, and finally leading to eruption. This modeling framework, constrained by multiparameter observations, provides a critical understanding of how volcanoes "breathe" prior to eruptions and advances our ability to accurately forecast volcanic eruptions.

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