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Geodesy—the key for constraining rates of magma supply, storage, and eruption

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Volcanology is an inherently interdisciplinary science that requires joint analysis of diverse physical and chemical datasets to infer subsurface processes from surface observations. Among the diversity of data that can be collected, however, geodetic data are critical for elucidating the main elements of a magmatic plumbing system because of their sensitivity to subsurface changes in volume and mass. In particular, geodesy plays a key role in determining rates of magma supply, storage, and eruption. For example, surface displacements are critical for estimating the volume changes and locations of subsurface magma storage zones, and remotely sensed radar data make it possible to place significant bounds on eruptive volumes. Combining these measurements with geochemical indicators of magma composition and volatile content enables modeling of magma fluxes throughout a volcano's plumbing system, from source to surface.

We combined geodetic data (particularly InSAR) with prior geochemical constraints and measured gas emissions from Kīlauea Volcano, Hawai'i, to develop a probabilistic model that relates magma supply, storage, and eruption over time. We found that the magma supply rate to Kīlauea during 2006 was 35–100% greater than during 2000–2001, with coincident increased rates of subsurface magma storage and eruption at the surface. By 2012, this surge in supply had ended, and supply rates were below those of 2000–2001; magma storage and eruption rates were similarly reduced. These results demonstrate the connection between magma supply, storage, and eruption, and the overall importance of magma supply with respect to volcanic hazards at Kīlauea and similar volcanoes. Our model also confirms the importance of geodetic data in modeling these parameters—rates of storage and eruption are, in some cases, almost uniquely constrained by geodesy. Future modeling efforts along these lines should also seek to incorporate gravity data, to better determine magma compressibility and subsurface mass change.