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The impact of strong precipitation and lithologic gradients on the evolution of post-eruption volcanic surfaces

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Volcanic edifices are dynamic landforms whose morphology encodes the long-term (thousands to millions of years) interaction between construction and erosion. Short-term episodes of volcanic activity that cumulatively build topography compete with long-term erosive processes associated with climate and mass wasting to degrade edifices, generating a variety of morphologies from simple, cone-like edifices to complex, non-axisymmetric volcanoes. However, separating the signatures of these processes using topography remains elusive as both volcanic and climatic processes are often spatially-heterogeneous and temporally-varying. Despite this, disentangling edifice morphologic histories provide new avenues to better discern an edifice’s volcanic record, assess potential hazards, and quantify the role of climate in landscape evolution.

Here, we aim to understand the long-term interaction between volcanic and erosional processes in driving edifice morphology using numerical landscape evolution modeling and comparing modeled landscapes to the morphology of the Kaua`i shield volcano. Kaua`i has been built over the past 5 Myr by series of lava flows that have non-uniformly altered both topography and surface erodibility. Coupled with this, a strong precipitation gradient across the island has influenced basin-scale erosion rates, impacting drainage development and making Kaua`i a natural laboratory to test the effects of spatially- and temporally-varying construction and degradation processes.

We analyze the interaction of these processes by first characterizing the impacts of lithology and precipitation gradients on edifice morphologies over 5 Myr timescales by employing the TopoToolbox Landscape Evolution Model. Starting with an initial, simplified edifice geometry, we test the effects of both singular and multiple parameter gradients through space and time over a broad parameter space. We then quantify edifice degredation and evolution using a series of metrics that include topographic hypsometry, basin geometries, drainage density, and , showing that such parameter gradients create asymmetric landforms with spatial heterogeneities related to the geometry and configuration of basins and channel networks. Afterwards, we consider edifice morphologic evolution within the framework of Kaua’i. By constraining the spatiotemporal model parameter configurations with the geologic and precipitation data of the volcano, and comparing modeled landscapes to the current morphology of Kaua’i, we determine likely parameter ranges that contribute to its evolution.