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Estimating lava effusion rates from high temporal resolution satellite image time series

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We present a new method for estimating lava effusion rates from high temporal resolution satellite time series of thermal radiance from an advancing lava flow. Estimates of lava effusion rates have a number of applications, from placing constraints on the vent and magma chamber processes driving the eruption to predicting final lava flow length. Satellite observations of thermal radiance from a lava flow provide a synoptic view of the dominant mode of heat loss, which can be balanced against heat input from extruded material and used to calculate effusion rates. Previous methods have been limited by a long repeat time between successive observations and observations in a limited number of bands, and effectively assume a linear relationship between instantaneous thermal radiance and some average of effusion rate in the period prior to the acquisition of the radiance measurement, where the constant of proportionality is either calculated empirically from data for similar eruptions or derived from an analytical model (e.g. Wright et al, 2001). However high temporal resolution satellite data may capture the full variation in output thermal radiance over the course of the eruption, thus the radiance at a given point in time can be modelled as a function of the effusion rate up to that point and the rate at which the previously erupted material has cooled.

We assume that lava is extruded at the vent at uniform eruption temperature and constant thickness and flows away from the fissure maintaining its thickness, cooling by conduction at the base and radiation and convection at the top, and being internally heated by the latent heat of crystallisation. We assume there is no lateral heat conduction or advection. These assumptions give us the simplification that all points on the flow surface exhibit the same cooling history, just offset in time from one another. The 1D finite element lava flow cooling model of Kent and Pinkerton (1994) is then used to model the cooling of a point on the surface of the flow. Given the simplification described above, the deconvolution of the satellite radiance time series by the predicted radiance time series for a cooling point on the flow surface gives an area effusion rate, which can be converted into a volume effusion rate by multiplying by the assumed thickness of the flow. We test this new model using SEVIRI time series of a number of recent eruptions, and compare the total area of erupted material found from high resolution satellite images to that predicted by the area effusion rate curve.