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A new perspective on lava lake dynamics from thermal remote sensing

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Active lava lakes, large open-vent depressions filled with molten rock, are not well understood. Most lava lakes are in very remote locations such as Erta Ale and Nyiragongo in Africa, and Mt. Erebus in Antarctica. This makes remote sensing a very important tool (if not the only one) to study lava lake dynamics at these remote volcanoes. The radiant heat flux from lava lakes can be retrieved from thermal remote sensing and has been used as a proxy for magma supply rate. Interestingly, the radiant heat flux is still unknown for the current lava lake at Halemaumau, Kīlauea volcano, Hawaii, which formed in 2008. At Kīlauea, extensive ground-based monitoring including seismology, deformation and lake level measurements make Halemaumau lava lake an excellent site to assess the utility of satellite measurement. Here we used NASA's MODerate Resolution Imaging Spectroradiometer (MODIS) to estimate the radiant heat flux at Halemaumau based on the 4 μm spectral radiance (Wright and Pilger 2008) recorded by the MODVOLC algorithm. Since the lava lake existence, we have obtained a nine-year time series of daily radiant heat flux (2681 data points). These data show a ten-fold increase as the lake level rose and the crater widened. This disagrees with the gas data trend (also a proxy for magma supply rate), which first decreased with time and has recently plateaued at a lower level. We analyze for the effect of different variables on the estimated heat flux from space, including satellite viewing geometry, lake level, lake activity, crater area, and clouds and fumes. Synchronous abrupt increase in radiant heat flux and lava lake level is noticeable during 6/7 events at time scale of month to years. Interestingly, we found that the lake's surface activity did not correlate with high heat flux due to the larger contribution of calm lava lake with crusted surface and incandescent cracks compared to the localized spattering activity. We also observed the decrease in the measured radiant heat flux with larger satellite zenith angle (as well as clouds and fumes). We demonstrate that for at least one open-vent basaltic volcano, an increase in radiant heat flux is not directly related to magma supply rate but mostly depends on lava lake level and visible surface area.