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Summit CO_2 emission rates by the CO_2/SO_2 ratio method at Kīlauea Volcano, Hawaiʻi, during a period of sustained inflation

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ABSTRACT

The emission rate of carbon dioxide escaping from the summit of Kīlauea Volcano, Hawaiʻi, proved highly variable, averaging 4900±2000 metric tons per day (t/d) in June–July 2003 during a period of summit inflation. These results were obtained by combining over 90 measurements of COSPEC-derived SO_2 emission rates with synchronous CO_2/SO_2 ratios of the volcanic gas plume along the summit COSPEC traverse. The results are lower than the CO_2 emission rate of 8500±300 t/d measured by the same method in 1995–1999 during a period of long-term summit deflation [Gerlach, T.M., McGee, K.A., Elias, T., Sutton, A.J. and Doukas, M.P., 2002. Carbon dioxide emission rate of Kīlauea Volcano: Implications for primary magma and the summit reservoir. Journal of Geophysical Research-Solid Earth, 107(B9): art. no.-2189.]. Analysis of the data indicates that the emission rates of the present study likely reflect changes in the magma supply rate and residence time in the summit reservoir. It is also likely that emission rates during the inflation period were heavily influenced by SO_2 pulses emitted adjacent to the COSPEC traverse, which biased CO_2/SO_2 ratios towards low values that may be unrepresentative of the global summit gas plume. We conclude that the SO_2 pulses are consequences of summit re-inflation under way since 2003 and that CO_2 emission rates remain comparable to, but more variable than, those measured prior to re-inflation.

1. Introduction

Kīlauea Volcano, Hawaiʻi is an active and accessible hotspot volcano, conveniently providing a setting for numerous studies. These studies have led to extensive knowledge of its volcanic system (e.g. Tilling and Dvorak, 1993). The long-term and consistent geophysical and geochemical monitoring routines at Kīlauea contribute to an in-depth understanding of the magmatic system and provide valuable data with which to compare short and long-term studies of gas emissions. Kīlauea is located on the island of Hawaiʻi adjacent to the stable shield volcano Mauna Loa (Fig. 1).

Eruptions and intrusions at Kīlauea, whether within the caldera or along the rift zones, involve magma that first passes through a summit magma reservoir existing between 1–2 km and 7 km beneath the summit. The storage of primary magma supplied to the summit reservoir is temporary as magma is discharged either to the caldera surface or into the rift zones. Previous to 1924, volcanic activity at Kīlauea was characterized by nearly continuous eruptions in the summit caldera, but since then, eruptions and magmatic intrusions have most commonly occurred at locations along the east rift zone (ERZ) after summit reservoir storage.

The CO_2 emission rate of Kīlauea is of particular interest because variations in CO_2 emissions can be examined alongside a wealth of other measurements including deformation patterns to gain a better understanding of eruption precursors and dynamics. The primary mechanism for removing CO_2 from mantle-derived magmas at Kīlauea is quiescent degassing from magmas temporarily stored in the summit reservoir (Gerlach and Graeber, 1985; Greenland et al., 1985). CO_2-depleted magmas are transported down down-rift where the majority of SO_2 is exsolved as magma ascends toward the surface just prior to eruption. Here we provide further evidence that degassing trends and changes in emission patterns at Kīlauea's summit can be linked to changes in magma accumulation and eruptive behavior.

In the summit region of Kīlauea, gas emission measurements are conducted by cross-cutting and profiling the summit plume. Northeasterly trade winds transport summit gas emissions southwest across the southern portions of Crater Rim Drive (Fig. 2). This road section has been used regularly since 1979 for vehicle-based correlation spectrometer (COSPEC) measurements to constrain the summit SO_2 emission rate (Casadevall et al., 1987; Elias et al., 1998; Sutton et al., 2001).

A study by Gerlach et al. (2002) uses the volcanic CO_2-to-SO_2 concentration ratio of the plume along the summit traverse (Fig. 2) and the synchronous SO_2 emission rate obtained from COSPEC measurements to constrain Kīlauea's summit CO_2 emission rate. This method was first developed for aerial measurements at Kīlauea (Gerlach et al., 1998) and has been further established through research at Mount Etna (Aiuppa et al., 2006, 2007). In Gerlach et al. (2002) a CO_2 emission rate for Kīlauea's summit caldera of 8500 t/d (metric tons per day) is reported

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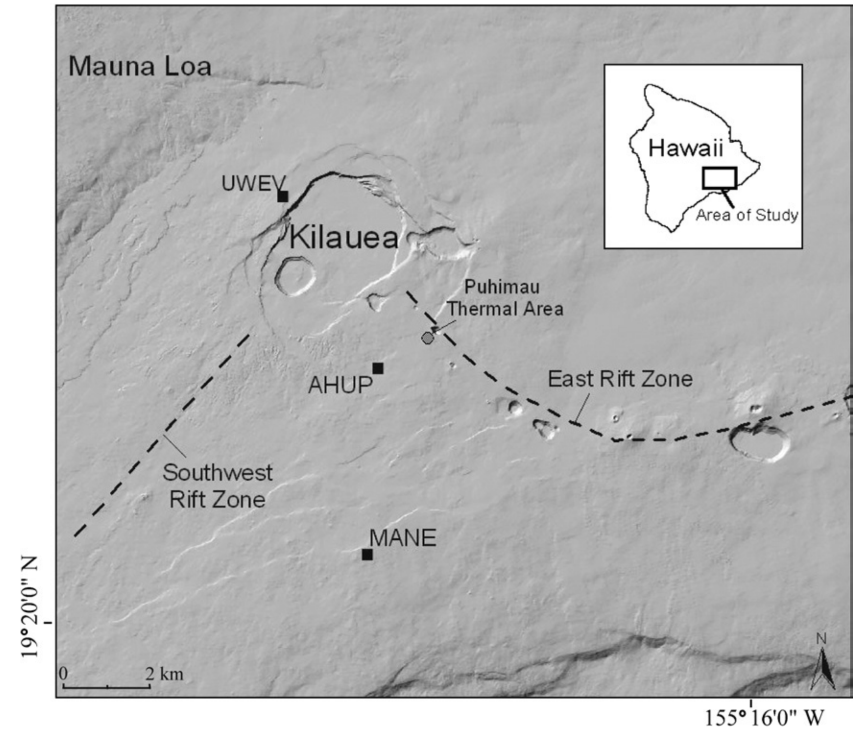

Fig. 1. Location map for Kīlauea Volcano. The dashed lines represent rift zone locations. Solid squares indicate the locations of three Global Positioning System stations (UWEV, AHUP, MANE) used to monitor deformation around the volcano. Also shown on this map is the Puhimau Thermal Area, a tree-kill site on Kīlauea's upper east rift zone.

based on three sets of data collected over a four-year time span (1995–1999), all measured under conditions of summit reservoir deflation. Previous to this study, only two measurements of Kīlauea's summit CO_2 emission rate were determined, both significantly less than 8500 t/d (Greenland et al. 1985). Earlier measurements, although made within just two months of each other, differ by over a factor of 2 (3600 and 1600 t/d in December 1983 and February 1984 respectively).

Past studies of summit CO_2 emission rates employed infrequent measurements over long time periods of months to years, but the

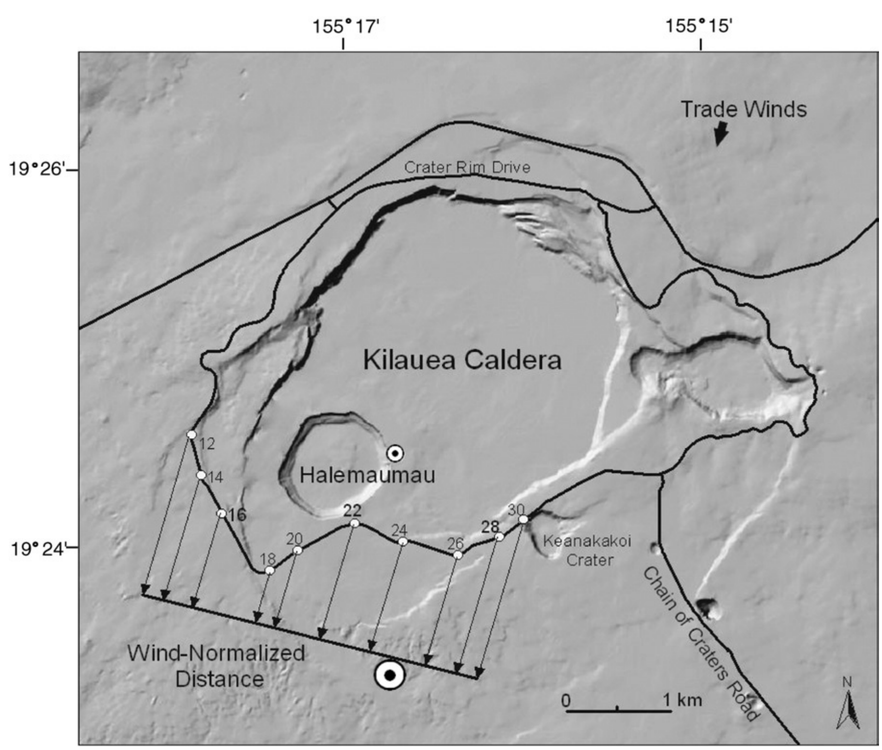

Fig. 2. Summit region of Kīlauea Volcano. Hillshade image shows the caldera and crater walls, fissures, and faults. The summit COSPEC traverse is the portion of Crater Rim Drive between checkpoints 12 and 30. White points along the traverse section show the locations and labels of multiple checkpoints used to distinguish straight road segments. Under typical trade wind conditions, the summit plume is blown across the road section. Vectors project road distances to wind-normalized distances. The locations of maximum vertical movement during deformation events at Kīlauea's summit are depicted by white and black circles (adapted from Cervelli and Miklius, 2003).