

## **Comparative investigation of soil CO<sub>2</sub> flux measurements and geostatistical estimation methods on Masaya volcano, Nicaragua**

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Measurements of soil CO<sub>2</sub> flux ( $F_{CO_2}$ ) and its natural spatial and temporal variability in volcanic and hydrothermal environments are important for volcano monitoring, geothermal exploration, delineation of fault and fracture zones, and estimation of the contribution of CO<sub>2</sub> from volcanic and hydrothermal sources to the global carbon cycle. However, the choice of measurement and geostatistical methodologies may affect individual  $F_{CO_2}$  measurements and characterization of their natural spatial and temporal variability, the total CO<sub>2</sub> emission rate estimated, and the ability to assess the uncertainty associated with this estimate. We present a comparative study of  $F_{CO_2}$  measured by five research groups (Groups 1-5) at the 2003 IAVCEI-CCVG Eighth Workshop on Volcanic Gases on Masaya volcano, Nicaragua. Groups 1-5 measured  $F_{CO_2}$  using the accumulation chamber method at 5-m spacing within a 900 m<sup>2</sup> grid during a morning (AM) period. These measurements were repeated by Groups 1-3 during an afternoon (PM) period. Measured  $F_{CO_2}$  ranged from 218 to 14,719 g m<sup>-2</sup>d<sup>-1</sup>. The variability of the five measurements made at each grid point ranged from ±5 to 167%; however, the arithmetic means of fluxes measured over the entire grid and associated total CO<sub>2</sub> emission rate estimates varied between groups by only ±22%. All three groups that made PM measurements reported an 8-19% increase in total emissions over the AM results. Based on a comparison of measurements made during AM and PM times, this change is likely due in large part to natural temporal variability of gas flow, rather than to measurement error. To estimate the mean and associated CO<sub>2</sub> emission rate of one data set and to map the spatial  $F_{CO_2}$  distribution, we compared six geostatistical methods: arithmetic and minimum variance unbiased estimator means of uninterpolated data, and arithmetic means of data interpolated by the multiquadric radial basis function, ordinary kriging, multi-Gaussian kriging, and sequential Gaussian simulation methods. While the total CO<sub>2</sub> emission rates estimated using the different techniques only varied by ±1.1%,

the  $F_{CO_2}$  maps showed important differences. We suggest that the sequential Gaussian simulation method yields the most realistic representation of the spatial distribution of  $F_{CO_2}$ , but a variety of geostatistical methods are appropriate to estimate the total  $CO_2$  emission rate from a study area, which is a primary goal in volcano monitoring research.

Acknowledgement: Part of this work was completed at Lawrence Berkeley National Laboratory, under U.S. Department of Energy Contract No. DE-AC03765F00098.