Geophysical Research Abstracts
Vol. 19, EGU2017-892-1, 2017
EGU General Assembly 2017

Compositional variation in aging volcanic plumes - Analysis of gaseous SO_2, CO_2 and halogen species in volcanic emissions using an Unmanned Aerial Vehicle (UAV).

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Volcanoes are a large source for several reactive atmospheric trace gases including sulfur and halogen containing species. The detailed understanding of volcanic plume chemistry is needed to draw information from gas measurements on subsurface processes. This knowledge is essential for using gas measurements as a monitoring tool for volcanic activity. The reactive bromine species bromine monoxide (BrO) is of particular interest, because BrO as well as SO_2 are readily measurable from safe distance by spectroscopic remote sensing techniques. BrO is not directly emitted, but is formed in the plume by a multiphase reaction mechanism. The abundance of BrO changes as a function of the distance from the vent as well as the spatial position in the plume. The precursor substance for the formation of BrO is HBr with Br_2as an intermediate product. In this study we present the application of a UAV as a carrier for a remote-controlled sampling system for halogen species (Br_2, HBr, BrCl, etc), based on the gas diffusion denuder technique, which allows speciation and enrichment by selective organic reactions. For the analysis of gaseous SO_2 and CO_2 an in-situ gas monitoring system was additionally mounted. This setup was deployed into the gas plumes of Stromboli Volcano (Italy), Masaya Volcano (Nicaragua) and Turrialba Volcano (Costa Rica) in 2016, to investigate the halogen chemistry at distant locations in the plume further downwind to the emission source, which are in most cases not accessible by other approaches. Flights into the plume were conducted with ascents of up to 1000 m. From telemetrically transmitted SO_2 mixing ratios, areas of dense plume where localized to keep the UAV stationary for up to 10 minutes of sampling time. Additionally, ground based samples were taken at the crater rim (at Masaya and Turrialba) using alkaline traps, denuder and gas sensors for comparison with airborne-collected data. Herein we will present time and spatial resolved gas mixing ratio data for SO_2, CO_2 and halogen species for crater rim sites and a downwind plume age of about 3 to 5 minutes.