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Development of a laser remote sensing instrument to measure sub-aerial volcanic CO_2 fluxes

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A thorough quantification of volcanic CO_2 fluxes would lead to an enhanced understanding of the role of volcanoes in the geological carbon cycle. This would enable a more subtle understanding of human impact on that cycle. Furthermore, variations in volcanic CO_2 emissions are a key to understanding volcanic processes such as eruption phenomenology.
However, measuring fluxes of volcanic CO_2 is challenging as volcanic CO_2 concentrations are modest compared with the ambient CO_2 concentration (∼400 ppm) . Volcanic CO_2 quickly dilutes with the background air. For Mt. Etna (Italy), for instance, 1000 m downwind from the crater, dispersion modelling yields a signal of ∼4 ppm only. It is for this reason that many magmatic CO_2 concentration measurements focus on in situ techniques, such as direct sampling Giggenbach bottles, chemical sensors, IR absorption spectrometers or mass spectrometers. However, emission rates are highly variable in time and space. Point measurements fail to account for this variability. Inferring 1-D or 2-D gas concentration profiles, necessary to estimate gas fluxes, from point measurements may thus lead to erroneous flux estimations. Moreover, in situ probing is time consuming and, since many volcanoes emit toxic gases and are dangerous as mountains, may raise safety concerns. In addition, degassing is often diffuse and spatially extended, which makes a measurement approach with spatial coverage desirable. There are techniques that allow to indirectly retrieve CO_2 fluxes from correlated SO_2 concentrations and fluxes. However, they still rely on point measurements of CO_2 and are prone to errors of SO_2 fluxes due to light dilution and depend on blue sky conditions.
Here, we present a new remote sensing instrument, developed with the ERC project CO_2Volc, which measures 1-D column amounts of CO_2 in the atmosphere with sufficient sensitivity to reveal the contribution of magmatic CO_2. Based on differential absorption LIDAR (DIAL) the instrument measures the absorption, and therefore path amount, of CO_2 in the atmosphere. The kit has been optimized to be rugged, man-portable and to use little power (∼ 70W). By flying the instrument over a volcanic plume we will be able to swiftly determine CO_2 fluxes. This opens the possibility of rapid, comprehensive surveys of both point source, open-vent CO_2 emissions, as well as emissions from more diffuse sources such as lakes and fumarole fields.
We present initial test results from the new instrument. We believe that the CO_2 LIDAR could make a major contribution to volcano monitoring. Potential follow-on applications include environmental monitoring, such as fugitive CO_2 detection in storage sites or urban monitoring of car and ship emissions.