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Ground-based remote sensing of volcanic CO_2 and correlated SO_2, HF, HCl, and BrO, in safe-distance from the crater

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Remote sensing of CO_2 enhancements in volcanic plumes can be a tool to estimate volcanic CO_2 emissions and thereby, to gain insight into the geological carbon cycle and into volcano interior processes. However, remote sensing of the volcanic CO_2 is challenged by the large atmospheric background concentrations masking the minute volcanic signal. Here, we report on a demonstrator study conducted in September 2015 at Mt. Etna on Sicily, where we deployed an EM27/SUN Fourier Transform Spectrometer together with a UV spectrometer on a mobile remote sensing platform. The spectrometers were operated in direct-sun viewing geometry collecting cross-sectional scans of solar absorption spectra through the volcanic plume by operating the platform in stop-and-go patterns in 5 to 10 kilometers distance from the crater region. We successfully detected correlated intra-plume enhancements of CO_2 and volcanic SO_2, HF, HCl, and BrO. The path-integrated volcanic CO_2 enhancements amounted to about 0.5 ppm (on top of the $\sim$400 ppm background). Key to successful detection of volcanic CO_2 was A) the simultaneous observation of the O_2 total column which allowed for correcting changes in the CO_2 column caused by changes in observer altitude and B) the simultaneous measurement of volcanic species co-emitted with CO_2 which allowed for discriminating intra-plume and extra-plume observations. The latter were used for subtracting the atmospheric CO_2 background. The field study suggests that our remote sensing observatory is a candidate technique for volcano monitoring in safe distance from the crater region.