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# Observation of the volcanic plume of Eyjafjallajökull over continental Europe by Multi-Axis Differential Optical Absorption Spectroscopy (MAX-DOAS)

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The recent eruption of Eyjafjallajökull Volcano (Iceland) and the emitted ash plume which disrupted commercial air traffic over Europe for an extended period of time has led to an intense debate on how to improve our ability to quantitatively determine the ash load in the atmosphere as a function of time and geographical location in the aftermath of future eruptions. A combination of satellite remote sensing instruments detecting ash and $SO_2$ in combination with ground-based LIDAR stations can help to constrain atmospheric transport and meteorology models used to predict ash dispersion. However, multi-axis Differential Optical Absorption Spectroscopy (MAX-DOAS) represents an additional and often neglected tool with considerable potential for the quantitative detection of elevated volcanic ash and $SO_2$ plumes. A MAX-DOAS network performs especially well during weather conditions in which satellites and LIDAR instruments are impeded in their effectiveness, e.g. in the case of dense cloud cover (above or below the plume). We discuss the advantages and disadvantages of the DOAS technique, and explore its potential for monitoring of volcanic ash hazards. Results of ash and $SO_2$ measurements of the Eyjafjallajökull plume as it passed over the city of Heidelberg, Germany in 2010 are presented as an example of a successful detection of a highly diluted volcanic plume. $SO_2$ was detected on several days with differential slant column densities (dSCD) of up to $(3.35 \pm 0.13) \bullet 10^{17}$ molec/cm$^2$. The occurrence of these high dSCDs is in good agreement with model predictions (FLEXPART), in-situ background (Schauinsland, Germany) and remote sensing measurements (GOME-2). Also aerosol extinction profiles and optical depths (AOD) at 477 nm were retrieved from the MAX-DOAS measurements. The retrieved AOD values of up to $1.20 \pm 0.01$ are in good agreement with Sun photometer (Mainz, Germany) measurements. Additionally, the qualitative comparison of the aerosol extinction profiles retrieved from MAX-DOAS shows good agreement with the diurnal development of the range corrected backscatter signal measured by the ceilometer (Rheinstetten, Germany).
Its relatively low cost and complementary nature in respect to other $SO_2$/ash detection techniques makes multi-axis DOAS a promising technology in the field of aviation hazard detection and management.