Reliable detection of volcanic ash with dual-wavelength light scattering

E. Weingartner, Z. Jurányi and H. Burtscher

University of Applied Sciences Northwestern Switzerland, CH-5210 Windisch, Switzerland
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Presenting author email: ernest.weingartner@fhnw.ch

Background

A volcanic eruption emits a significant amount of hazardous ash particles into the air. If the eruption is strong enough, the volcanic ash plume can reach high altitudes and can be a serious security risk for airplanes.

We have developed a new prototype aerosol sensor for the reliable detection of volcanic ash. The envisaged application is the employment of this new technique on-board of passenger aircraft. It allows in-situ monitoring of the airplane's exposure to volcanic ash.

The challenge of this development is that the sensor has to be able to distinguish cloud droplets (or ice crystals) from the hazardous refractory ash particles. At aviation altitudes, water droplets and ice crystals are often present in the particle size range of the ash (1–20 micrometer) and their concentrations can reach the same concentrations that are considered as the limits of the different volcanic ash contamination zones. Therefore, it is crucial that the sensor can differentiate between volcanic ash and water or ice particles.

Experimental method

The setup of the new instrument, called DUWAS (DUal Wavelength Ash Sensor) is shown in Figure 1. It detects volcanic ash particles by measuring the backscattered light of individual aerosol particles, flying through the detection volume, simultaneously at two different wavelengths, i.e. at λ = 660 nm (Vis) and 2750 nm (IR). Calculations have shown (Jurányi et al. 2015) that the unique behavior of the refractive index of water at the specific IR wavelength allows distinguishing water droplets (and ice crystals) from other aerosol particles (such as volcanic ash) by evaluating the ratio R of detected light scattering intensities (Vis to IR) form individual particles at the two wavelength.

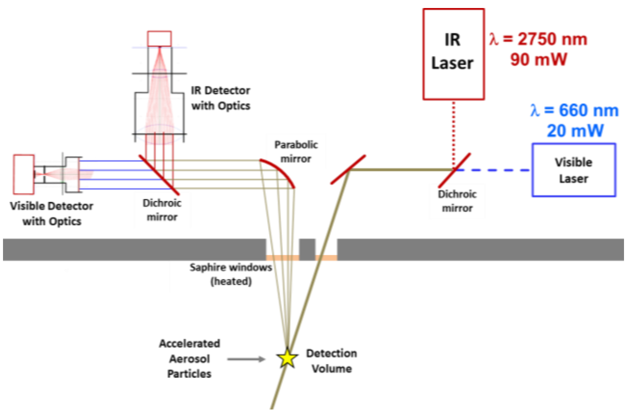

Figure 1. Schematic setup of the DUWAS

Results

The envisaged discrimination was successfully tested in the laboratory with various test aerosols: water droplets, cement dust, ISO test dust and ash collected at the Etna volcano (Jurányi et al. 2015).

In December 2015, we installed the DUWAS at the high alpine research station Jungfraujoch (3580 m asl) and made ambient tests. The instrument was placed outdoors on the terrace of the research facility, where it was fully exposed to the harsh weather conditions prevailing at this site. The station is often engulfed in clouds (supercooled, mixed-phase and ice clouds) and during the campaign the ambient temperatures were often below -20°C with extraordinary high wind speeds (up to 100 km/h).

Figure 2 presents the measured R-value distributions during the outdoor operation at the high alpine site. Dust and ash particles were injected into the DUWAS sampling line during normal operation at ambient temperatures. The analysis shows that the DUWAS can clearly differentiate dust or ash particles from ambient cloud droplets and ice particles.

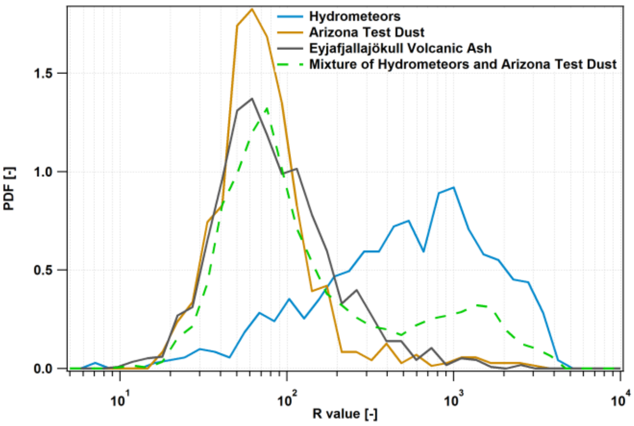

Figure 2. Measured R-value frequency distributions measured at the high alpine site Jungfraujoch. Ambient hydrometeors (droplets and ice crystals) are characterized by fairly high R-values, in contrast to Arizona test dust and ash particles collected at the Eyjafjallajökull volcano.

Outlook

We will continue to optimize the sensor. As a university, we are also looking for future collaborations with companies that are interested in commercializing this new technique.

Jurányi et al., *Atmos. Meas. Tech.*, 8, 5213–5222, 2015.