Name of research institute or organization:

Institute for Aerosol and Sensor Technology,
University of Applied Sciences Northwestern Switzerland (FHNW)

Title of project:

Development of an airborne sensor for the reliable discrimination of volcanic ash particles from water droplets or ice crystals

Project leader and team:

Dr. Ernest Weingartner, project leader
Dr. Zsófia Jurányi*
Daniel Egli
Peter Steigmeier
Prof. Dr. Heinz Burtscher

* now at: Alfred-Wegener-Institut (AWI), Bremerhaven (zsofia.juranyi@awi.de)

Project description:

The DUWAS (DUal Wavelength Ash Sensor) is a new instrument development that allows in-situ monitoring of refractory particles such as mineral dust or volcanic ash. A special feature of the employed technique is that the measurement is not biased by the presence of hydrometeors (i.e. cloud droplets or ice particles).

Operated on an airplane, this technique can be used to quantify the exposure to hazardous volcanic ash. At aviation altitudes, water droplets and ice crystals are often present in the particle size region of the ash (> 1 micrometer) and their concentrations can reach the levels that are considered as the limits of the different volcanic ash contamination zones. An important difference to other laser based in-situ techniques is that the new method can quantify the volcanic ash exposure within water or ice clouds. Other techniques have difficulties in distinguishing ash particles from cloud droplets or ice crystals.

The new aerosol detection method is based on dual-wavelength light scattering. The requirement that the sensor can distinguish cloud droplets and ice crystals from the hazardous refractory ash particles is achieved by comparing the light scattering properties of individual aerosol particles simultaneously at two different wavelengths, i.e. at λ = 660 nm (visible) and at λ = 2750 nm (infrared, IR).

The envisaged component-specific particle differentiation makes use of the different scattering behavior of the aerosol components. Calculations have shown (Jurányi et al., 2015) that the unique behavior of the refractive index of water at the IR wavelength of λ = 2750 nm allows distinguishing water droplets from other aerosol particles (such as volcanic ash).

At the absorption band of water (in our case at λ = 2600 – 3400 nm), water droplets or ice crystals scatter much less radiation compared to their scattering further away from the absorption band. Mineral particles do not have such a distinct feature at 2750 nm. In the visible, water and volcanic ash show similar scattering intensities. Therefore, we calculate the ratio of the measured scattered light intensities at these two wavelengths. The ratio R is defined as follows:

$$R = \frac{\text{scattering intensity in the visible}}{\text{scattering intensity in the IR}}$$

R contains information on the particles nature because the ratio of the measured scattering intensities is much higher for water droplets and ice crystals than for volcanic ash ($R_{water} \gg$

R_{ash}). For more information, the reader is referred to Jurányi et al. (2015) and Weingartner et al. (2016).

The development of the DUWAS started in 2014, and its correct operation was first tested in the laboratory with various well-defined aerosols and water droplets. In December 2015, we installed the DUWAS at the High Altitude Research Station Jungfraujoch (3580 m asl). The instrument was placed outdoors on the terrace of the research facility (see Figure 1), 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 1. The DUWAS on the terrace of the Jungfraujoch research facility at 3580 m asl. The device is protected by a metallic cover. The instrument's inlet (entrance into the wind tunnel) is on the left side. (photo credit: Z. Jurányi)

During the outdoor operation, intermittently small amounts of dust and ash particles were manually injected into the DUWAS sampling line to test its proper functioning. Figure 2 shows the measured *R*-value distributions for hydrometeors, dust and ash particles at the Jungfraujoch. The distributions are well separated; one even sees two distinct peaks present at the same time (green dashed line) when test dust particles were injected during cloudy conditions. This analysis shows that the DUWAS can clearly differentiate dust or ash particles from ambient cloud droplets and ice particles.

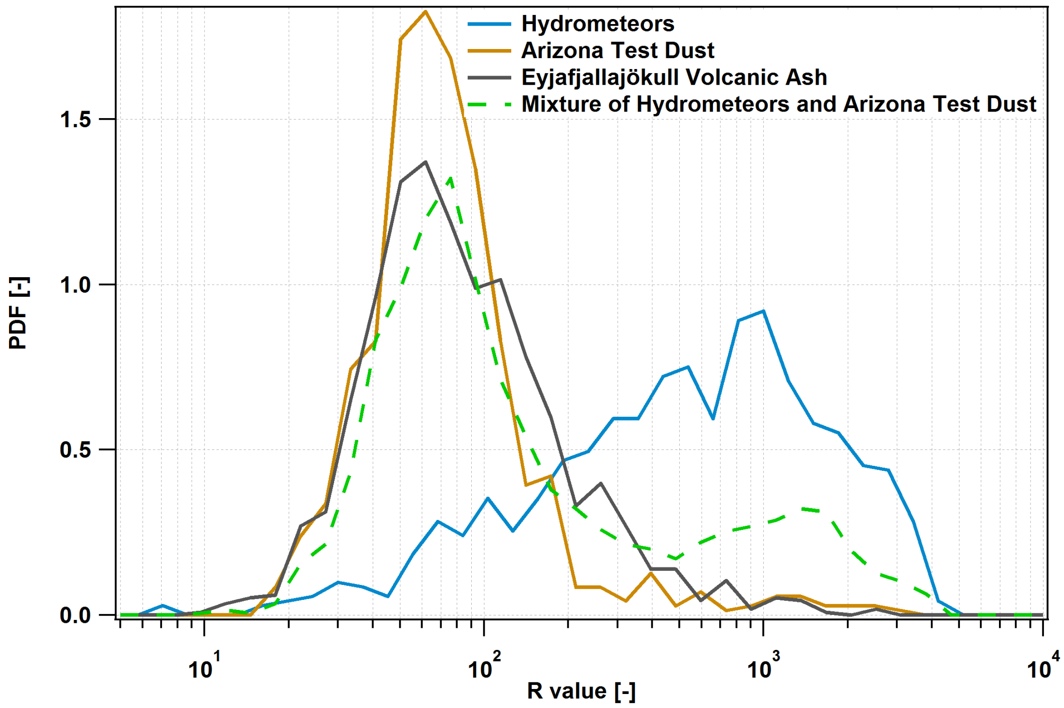

Figure 2. Measured R-value distributions at the high alpine site Jungfraujoch. Ambient hydrometeors (droplets and ice crystals) are characterized by relatively high R-values, in contrast to Arizona test dust and ash particles sampled at the Eyjafjallajökull volcano. These particles were injected into the DUWAS sampling line during normal operation at ambient temperatures. The envisaged differentiation works in natural mid-level clouds.

In a next step, the DUWAS was tested in summer 2016 on-board of the research aircraft METAIR-DIMO. We installed the instrument in the measurement pod of the airplane, and a flow channel was designed and implemented such that the ambient aerosol (ca. 100 km/h) was isokinetically directed to the DUWAS detection volume. Overall, four flights were conducted over the Swiss Plateau, and the ambient aerosol was characterized out-of-clouds as well as within natural cloud edges.

These airborne measurements confirm the findings from the Jungfraujoch: In flight, the DUWAS was able to discriminate cloud particles from other super-micrometer sized dust-like particles that were present at low concentration as a “natural background” in our ambient atmosphere. Calculations show that the instrument would be capable of measuring volcanic ash concentrations that are considered dangerous for air traffic.

Based on all these tests we plan to further develop the sensor. As a university, we are looking for future collaborations with companies that are interested in commercializing this new technique. A patent application on this method has been filed.

References:

Juranyi, Z., H. Burtscher, M. Loepfe, M. Nenkov, and E. Weingartner, Dual-wavelength light-scattering technique for selective detection of volcanic ash particles in the presence of water droplets, Atmos. Meas. Tech., **8**, 12, 5213-5222, doi: 10.5194/amt-8-5213-2015, 2015.
http://www.atmos-meas-tech.net/8/5213/2015/

Key words:

Optical particle sizer, dual-wavelength light scattering, volcanic ash, hydrometeors

Collaborating partners/networks:

Prof. Dr. Bruno Neininger, Centre for Aviation, School of Engineering, Zurich University of Applied Sciences (ZHAW), Winterthur, Switzerland
METAIR AG, Airfield LSZN, Hausen am Albis, Switzerland
Dr. Marcel Rattunde, Fraunhofer Institute for Applied Solid State Physics (IAF), Freiburg, Germany
Dr. Martin Gysel, Laboratory for Atmospheric Chemistry, Paul Scherrer Institut, Villigen, Switzerland

Scientific publications and public outreach 2016:

Refereed journal articles and their internet access

Weingartner, E., Z. Juranyi, D. Egli, P. Steigmeier, and H. Burtscher, Development of an airborne sensor for reliable detection of volcanic ash, IEEE Metrology for Aerospace (MetroAeroSpace), 19-24, doi: 10.1109/MetroAeroSpace.2016.7573179, 2016. http://ieeexplore.ieee.org/document/7573179/

Conference papers

Weingartner E., Z. Jurányi, H. Burtscher, Reliable detection of volcanic ash with dual-wavelength light scattering, European Aerosol Conference EAC 2016, Tours, France, September 4-9, 2016.

Weingartner E., Z. Jurányi, D. Egli, P. Steigmeier, H. Burtscher, Development of an airborne sensor for reliable detection of volcanic ash, 3rd IEEE International Workshop on Metrology for Aerospace, Florence, Italy, June 22-23, 2016.

Magazine and Newspapers articles

"Neuer Sensor soll vor Vulkanasche warnen", Sicherheitsforum, February 24, 2016.
https://www.sicherheitsforum.ch/neuer-sensor-soll-vor-vulkanasche-warnen/

Address:

Institute of Aerosol and Sensor Technology
University of Applied Sciences Northwestern Switzerland (FHNW)
Klosterzelgstrasse 2
CH-5210 Windisch, Switzerland

Contacts:

Dr. Ernest Weingartner
Tel.: +41 56 202 7918
e-mail: ernest.weingartner@fhnw.ch
URL: http://www.fhnw.ch/engineering/iast
http://www.fhnw.ch/people/ernest-weingartner/