First results of an airborne release of volcanic ash for testing of volcanic ash plume measurement instruments

K. WEBER, C. FISCHER. A. VOGEL, T.POHL, C. BÖHLKE
Laboratory for Environmental Measurement Techniques (LEMT)
Duesseldorf University of Applied Sciences (FHD)
Josef-Gockeln-Str. 9, 40474 Duesseldorf
GERMANY
konradin.weber@fh-duesseldorf.de, http://mv.fh-duesseldorf.de/d_pers/Weber_Konradin

H. LAU
Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
Institute of Materials Research
Linder Höhe, 51147 Köln
GERMANY

J. ELIASSON
University of Iceland
Earthquake Engineering Research Centre
Austurvegur 2a, 800 Selfoss,
ICELAND

T. PALSSON
Reykjavik University,
101 Reykjavik
ICELAND

Abstract: - The eruption of the Icelandic volcanoes Eyjafjallajökull 2010 and Grimsvötn 2011 caused significant disruptions of the air traffic over Europe. The airspace of nearly whole Europe was closed for about a week in spring 2010 during the eruption of the Eyjafjallajökull. This caused an economic damage of several billion Euros. About one year later, in spring 2011, the Grimsvötn volcano erupted on Iceland. Because of this eruption the airports of many countries in North Europe were closed and caused therefore problems for the international air traffic as well. At the time of the Eyjafjallajökull eruption the decision of the legal authorities about the airspace closure were mainly based on the volcanic ash plume predictions of the Volcanic Ash Advisory Center (VAAC) in UK, which were gained by a numerical ash dispersion model. However, as it turned out later on, evidently the VAAC ash dispersion model could not always predict the dispersion of the ash plume precisely. Therfore the decision was taken to add so-called second sources of information like groundbased and airborne measurements of the volcanic ash plume as well as satellite observations for getting a more precise picture of the ash plume spread and concentration. However, at that point the question arises, how the accuracy of these measurement methods can be assured. Therefore in this paper a procedure is described for the production of an artificial ash plume, which is released from an aircraft. This ash plume simulates on a small scale the real world ash plume of a volcanic eruption. By these means systems for the measurement of ash can be tested and calibrated in a new and innovative way.

Key-Words: volcano, ash plume, aircraft measurements, ash particle measurement systems, research aircraft

1 Introduction

On 20 March, 2010 the Icelandic volcano Eyjafjallajökull erupted in the South of Iceland and continued its activity in several phases until 24 May 2010. This caused a tremendous ash plume, which was transferred because of meteorological conditions into the direction of Central Europe, Great Britain and Scandinavia. This plume was clearly visible by satellites. The Volcanic Ash Advisory Centre (VAAC) of the Meteorological

Office in London calculated on a regular basis ash dispersion forecasts, which were based on the results of model calculations for the ash dispersion over Europe and were released as maps of expected ash concentration. As volcanic ash of high concentrations is assumed to be hazardous to the air traffic, the airspace over Europe was closed from 15 April to 21 April, 2010, resulting in the cancellation of a huge number of flights [1-4]. A similar situation arose during the eruption of the Icelandic volcano Grimsvötn, in the period 21 – 28 May 2011 [3,5,6]. In this case only northern Europe was affected. However, due to adverse ash plume predictions of the VAAC UK many airports were closed temporarily in Northern Europe. However, during the period of the eruption of Grimsvötn real measured ash results were taken into account for the decision of the authorities about closure or re-opening of the airspace additional to the calculations of the VAAC dispersion model. The measurements were taken by in-situ aircraft measurement systems, Lidars, Ceilometers etc. [2,5,6].

However, in that situation it turned out, that it is important to validate the measurement systems and their results [2,5,6].

There are several possibilities and options to validate the measurement systems for ash particle determinations. In-situ measurement systems might be calibrated in ash loaded wind-tunnels. However, up to this date the calibration of the in-situ measurement systems were only performed in wind-tunnels with low speed, as the gravimetric reference samplers, which are used for reference and comparison, can be operated only at low wind speeds [1]. The isokinetic inlets of the measurement systems have to be validated with another independent method. For accurate Lidar- and Ceilometer measurements the optical parameters of the aerosols to be measured have to be known as accurate as possible, which is not always easy. Another possibility is, to validate these measurement systems during comparison flights with in-situ aircraft measurements.

However, in view of this situation it is an interesting approach to produce an artificial ash plume, released from an aircraft. First tests of this approach will be described in the following sections.

2 The ash used for generating the ash plume

The ash for the experiment was collected groundbased shortly after the eruption of the Eyjafjallajökull volcano on Iceland near the eruption vent. So this ash stems from the Eyjafjallajökull eruption. However, during the eruption mainly the bigger sized particles settled down to the ground on Iceland, whereas the smaller particles stayed in the air and travelled to central Europe.

We analyzed the ash collected on Iceland by several means:

- Electron microscope pictures
- EDX (for the chemical composition)
- Coulter counter (for determination the size distribution of the small particles)
- Sieving (for determination of the size distribution of the bigger particles).

Figure 1 and Figure 2 show electron microscope pictures of the collected ash. Both pictures show different representative ensembles of the collected ash. In both cases appear the bigger particles sizes of about 100-200 µm, whereas small particles down

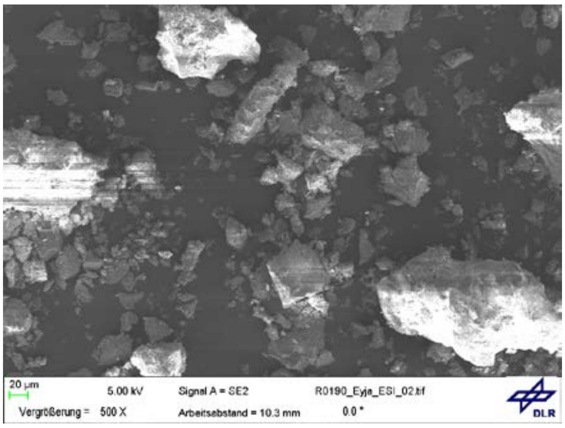

Fig. 1 : Electron microscope picture of the sample of Eyjafjallajökull ash, which was collected near the eruption vent

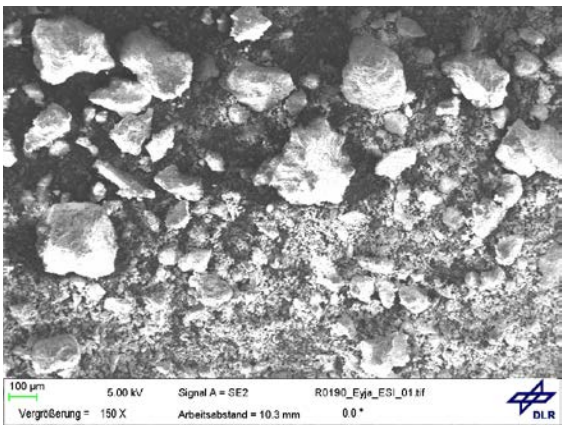

Fig. 2 : Electron microscope picture of the sample of Eyjafjallajökull ash, which was collected near the eruption vent

ISBN: 978-960-474-312-4

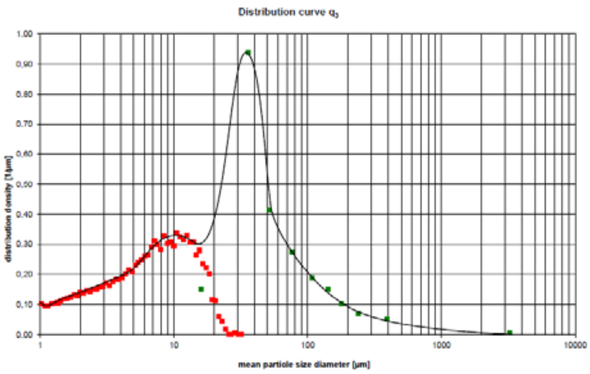

Fig. 3: Size distribution of the ash particles collected in the Eyjafjallajökull area. Red line: measurement results, taken with a Coulter Counter. Black line: measurement results gained by sieving.

to sizes of 1 µm and even below could be detected in the electron microscope as well. This seems to be typical
for the ash collected on Iceland. Moreover, the size distribution was verified directly in a Coulter counter for the small particles and by sieving of the bigger particles, which is shown in figure 3.

As it can be seen clearly in figure 3 the size distribution of particles has a maximum at 20 – 30 µm. This is supported by the visual impression of the particles in the pictures taken with the electron microscope.

3 Experimental setup for the airborne generation of an artificial ash plume

In order to test volcanic ash measurement systems under controlled conditions in the free atmosphere an ash plume generator was designed, which could operate on the ground as well as at a small aircraft. In this way an ash plume could be generated in the free atmosphere establishing a new method for testing and calibrating volcanic ash measurement systems. Figure 4 shows the schematic setup for the ash plume generator (ash disperser).

On the left hand side is a chamber with compressed gas under high pressure. This can be compressed air or compressed nitrogen. Moreover, other volcanic gases like SO_2 can be mixed into it, in order to get a realistic plume with ash particles and volcanic gas. By this means ash particle measurement systems as well as volcanic gas measurement systems can be tested.

The high pressure chamber feeds a low pressure buffer, from where the pressurized gas gets into the volcanic ash chamber (right hand side in figure 4). From the volcanic ash chamber the ash is blown out into the atmosphere by a pipe.

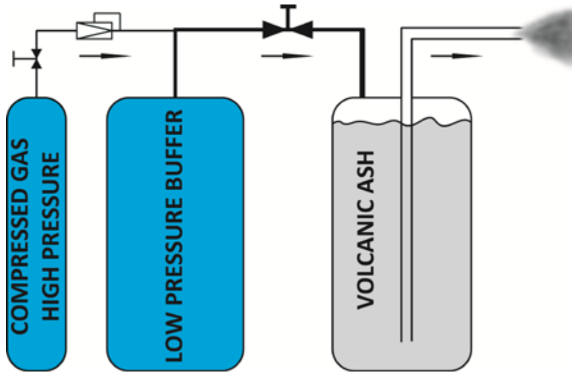

Figure 4: Volcanic ash plume generator (volcanic ash disperser)

4 Generation of the artificial volcanic ash plume

The volcanic ash plume generator was first tested on the ground for its efficiency. One of the first groundbased tests is shown in figure 5. It can be clearly seen that the ash plume generation works quite well.

Fig. 5: Volcanic ash dispersion ground test

During the ground tests the pressures in the different chambers, the amount of volcanic ash in the last camber and the exhaust pipe were varied to get optimal results for the generated ash plume. After sucessful testing and optimization of the ash plume generator on the ground it was mounted on a single engine light aircraft (Flight Design CT), which is used by the “Laboratory for Environmental Measurement Techniques (LEMT)” of FHD otherwise for volcanic research flights. Fig. 6 shows one example for the airborne generated volcanic plume as released from the aircraft. Additionally to releasing the ash plume from the one aircraft first ash measurement have been performed in the plume using an optical particle counter based on a second aircraft. Moreover, within these first tests the artificial ash plume turned out to be very useful for testing and comparing different types of isokinetic inlets for the measurement systems.

Fig. 6: Artificial ash plume released from the aircraft

6 Discussion

The experiments worked out quite well. Whereas first test releases of the ash plume produced a very inhomogeneous and strongly fluctuating ash plume, after some adjustments of pressure and ash in the chambers the ash plume could be released under controlled and stable conditions from the aircraft. In the next steps of development it is planned, to grind the ash, which was collected near the Eyjfjallajökull volcano on Iceland, to a size distribution, which LEMT has measured by aircraft measurements during the eruptions of Eyjafjallajökull und Grimsvötn over Europe [1,2]. In that case the ash plume would stay longer in the air. Moreover it is planned, to release bigger amounts of ash by using multiple exhaust pipes and larger quantities of dispersed ash from a bigger aircraft.

6 Conclusion

For the first time an artificial ash plume for testing of volcanic ash plume measurement instruments could be generated from an aircraft. This can serve now as an innovative tool for testing and validating different in-situ ash particle measurement systems, various ash sample inlets, Lidars, Ceilometer as well as IR-based and UV-based remote sensing systems for the detection of ash plumes. Similar experiments on a larger scale are planned in the near future.

References:

[1] Weber, K., Eliasson, J., Vogel, A., Fischer, C., Pohl, T., van Haren, G., Meier, M., Grobéty, B., Dahmann, D., Airborne in-situ investigations of the Eyjafjallajökull volcanic ash plume on Iceland and over North-Western Germany with light aircrafts and optical particle counters, Atmospheric Environment 48, 2012, 9-21, doi:10.1016/j.atmosenv.2011.10.030X2.

[2] Weber, K., Vogel, A., Fischer, C., Reichardt, R., Moser, H.-M., Eliasson, J., Löschau, G., Airborne Measurements of Volcanic Ash Plumes and Industrial Emission Sources with Light Aircraft - Examples of Research Flights During Eruptions of the Volcanoes Eyjafjallajökull, Grimsvötn, Etna and at Industrial Areas, Proc. „105nd Air and Waste Management Association Conference", A&WMA Pittsburgh, PA, USA, 2012, A 432

[3] Langmann, B., Arboledas, L.A., Folch, A., Matthias, F., (eds.), sepecial Issue: Volcanic ash over Europe during the eruption of Eyjafjallajökull on Iceland, April – May 2010, Atmospheric Environment 48, March 2012

[4] Bay Hasager,C., Birmili, W., Pappalardo, G., Prata, F. (eds.), Atmos. Chem. Phys., Special Issue: Atmospheric implications of the volcanic eruptions of Eyjafjallajökull, Iceland 2010

[5] Ansmann, A., Seifert, Teche, M., Wandinger, U., Profiling of fine and coarse particle mass: case studies of Saharan dust and Eyjfjallajökull/Grimsvötn volcanic plumes, Atmos. Chem. Phys., 12,9399-9415,2012

[6] Eliasson, J.; Palsson, A.; Weber, K.: Monitoring ash clouds for aviation; Nature 475, S. 455 28 Jul 2011, doi: 10.1038/475455b