ILRC 25, Eyjafjallajökull Session, Tue, 6 Jul 2010, 18 – 20 h
(updated 2 July 2010)

	Invited Oral Presentations (20 min)	Affiliation of 1st author	Title
1	G. Pappalardo et al.	CNR-IMAA, Italy	EARLINET observations of the Eyjafjallajökull ash plume
2	U. Schumann et al.	DLR, Germany	Volcanic Ash Cloud Observations with the DLR-Falcon over Mid-Europe during Airspace Closure
	Oral Presentations (10 min)		
3	D. Winker et al.	NASA, USA	Observations of the Eyjafjallajökull volcanic plume from CALIPSO
4	F. Gao et al.	University of Nova Gorica, Slovenia	Remote Sensing of Icelandic Volcanic Ash above Slovenia
6	J. Gasteiger et al.	MIM, Germany	Microphysical properties of a volcanic ash plume over Munich derived from remote sensing measurements
7	M. de Graaf et al.	KNMI, NL	Mass loading estimates of the Eyjafjöll ash plume using principle component analysis applied to multi-wavelength Raman lidar data over The Netherlands
18	Simone Lolli et al.	Leosphere, France	Eyjafjallajökull volcano ash plume operational monitoring all over Europe with ground based and airborne mounted lidars.
	Poster Presentations		
5	A. Papayannis et al.	NTUA, Greece	Optical and chemical properties of ash particles observed over Athens, Greece using Raman lidar and in-situ sampling during the Eyjafjallajökull eruption
8	L. Alados-Arboledas et al.	University of Granada, Spain	Ground-based active and passive remote sensing of the Eyjafjallajökull volcanic aerosols at Granada, Spain
9	A. Behrendt et al.	Univ. of Hohenheim, Germany	Eyjafjallajökull ash observations over Stuttgart in spring 2010
10	V. D. Burlakov et al.	Institute of Atmospheric Optics, Russia	Traces of Eyjafjallajökull volcanic eruption according to data of lidar observations in Tomsk (56.5N, 85.0E)
11	D.P. Donovan et al.	KNMI, NL	Observations of the Eyjafjöll ash plume made at the Netherlands Cabauw site
12	E. Giannakaki et al.	University of Thessaloniki, Greece	Volcanic ash observations from Eyjafjallajökull eruption with a Raman lidar over Thessaloniki, Greece
13	S. Gross	MIM, Germany	Lidar measurements of the Eyjafjallajökull ash plume over Munich
14	F. Molero et al.	CIEMAT	Comparison of SPALINET network lidar measurements with model forecasts during the Eyjafjalla event
15	D. Nicolae et al.	INOE, Romania	Lidar derived optical properties of volcanic ash in Romania, during Eyjafjallajokull eruption
16	J. Preißler et al.	Geophysics Centre of Évora, Portugal	Ash from the Eyjafjallajökull volcano observed by lidar over Portugal
17	V. Simeonov et al.	Swiss Federal Institute of Technology-Lausanne, CH;	Lidar observation of Eyjafjallajoekull ash layer evolution above the Swiss Plateau

(1) EARLINET observations of the Eyjafjallajökull ash plume

Gelsomina Pappalardo[1], Aldo Amodeo[1], Albert Ansmann[2], Arnoud Apituley[3], Lucas Alados Arboledas[4], Dimitris Balis[5], Christine Böckmann[6], Anatoli Chaikovsky[7], Adolfo Comeron[8], Giuseppe D'Amico[1], Volker Freudenthaler[9], Ivan Grigorov[10], Ove Gustafsson[11], Stefan Kinne[12], Holger Linnè[12], Ina Mattis[2], Lucia Mona[1], Detlef Mueller[2], Valentin Mitev[13], Doina Nicolae[14], Alexandros Papayannis[15], Maria Rita Perrone[16], Aleksander Pietruczuk[17], Manuel Pujadas[18], Jean-Philippe Putaud[19], Francois Ravetta[20], Vincenzo Rizi[21], Valentin Simeonov[22], Nicola Spinelli[23], Kerstin Stebel[24], Thomas Trickl[25], Ulla Wandinger[2], Frank Wagner[26], Matthias Wiegner[9]

[1]Istituto di Metodologie per l'Analisi Ambientale CNR-IMAA, C.da S. Loja, Tito Scalo, Potenza, Italy I-85050, pappalardo@imaa.cnr.it
[2]Institut für Troposphärenforschung, Leipzig, Germany
[3]Rijksinstituut voor Volksgezondheid en Milieu, Bilthoven, The Netherlands
[4]Universidad de Granada, Granada, Spain
[5]Aristoteleio Panepistimio, Thessalonikis, Greece
[6]Institut für Mathematik der Universität Potsdam, Germany
[7]Institute of Physics, National Academy of Sciences, Minsk, Bjelarus
[8]Universitat Politècnica de Catalunya, Barcelona, Spain
[9]Ludwig-Maximilians-Universität, München, Germany
[10]Institute of Electronics, Bulgarian Academy of Sciences, Sofia, Bulgaria
[11]Swedish Defence Research Agency, Linköpig, Sweden
[12]Max-Planck-Institut für Meteorologie, Hamburg, Germany
[13]CSEM, Centre Suisse d'Electronique et de Microtechnique SA, Neuchâtel, Switzerland
[14]National Institute of R&D for Optoelectronics, Magurele-Bucharest, Romania
[15]National Technical University of Athens, Department of Physics, Athens, Greece
[16]Università degli Studi di Lecce, Department of Physics, Lecce, Italy
[17]Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland
[18]Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Madrid, Spain
[19]EC Joint Research Centre, Ispra (VA), Italy
[20]Université Pierre et Maris Curie-Institut Pierre Simon Laplace, Paris, France
[21]Università degli Studi dell'Aquila - Dipartimento di Fisica - CETEMPS, L'Aquila, Italy
[22]Ecole Polytechnique Fédérale de Lausanne, Switzerland
[23]Consorzio Nazionale Interuniversitario per le Scienze Fisiche della Materia, Napoli, Italy
[24]Norwegian Institute for Air Research (NILU), Kjeller, Norway
[25] Karlsruher Institut für Technologie, Garmisch-Partenkirchen, Germany
[26]Universidade de Évora, Centro de Geofísica de Évora, Évora, Portugal

EARLINET, the European Aerosol Research Lidar NETwork, established in 2000 is the first coordinated lidar network for tropospheric aerosol study on continental scale [1, 2].

The network activity is based on scheduled measurements, a rigorous quality assurance program addressing both instruments and evaluation algorithms, and a standardised data exchange format.

All EARLINET stations measure simultaneously on a predefined schedule of at least three dates per week, i.e., Monday afternoon, and Monday and Thursday after sunset. This data set is used to obtain unbiased data for climatological studies. The increasing number of automated EARLINET lidars drastically improves the overall measurement time. Additionally to these regular measurements, coordinated network observations are performed to address specifically important events like Saharan dust, forest fires, volcanic eruptions [3, 4], and photochemical smog. All measured profiles are stored in a centralized data base with a standardized data format which allow for an easy access to the complete data set for further scientific studies.

At present, the network includes 26 lidar stations distributed over Europe. Detailed locations and contact information can be found at www.earlinet.org.

Three of the stations operate fully automated lidars on the basis of round-the-clock observations. There are 9 simple backscatter lidars. Eighteen of the EARLINET stations operate Raman lidars which allow for the independent retrieval of profiles of the particle extinction and backscatter coefficients [6]. The particle extinction-to-backscatter (lidar) ratio contains information on particle size and particle light-absorption and thus allows for a rough separation among different aerosol types. Nine multi-wavelength Raman lidar stations belong to EARLINET. These lidars allow for the retrieval of three backscatter coefficients at 355, 532, and 1064-nm wavelength plus two extinction coefficients and lidar ratios at 355 and 532nm. The wavelength dependence of the backscatter and extinction coefficients and of the lidar ratios allow for a more detailed differentiation of aerosol types [7].

A coordinated network activity for the observation of the ash plume of the Eyjafjöll volcano over Europe started at April 15, 2010. Almost all EARLINET stations started intensive measurements and observed the evolution of the ash plume until April 24. The plume first reached the stations Cabauw and Hamburg during the morning hours of April 16. Later at this day the layer arrived at Leipzig and at Munich between 2.5 and 6 km height. The optical depth of this first plume at 500 nm was up to 0.7 [5]. Later, the ash plume was diluted and distributed over almost whole Europe. It reached, e.g., Italy at April 19 and Greece at April 21.

A second event was observed over Portugal and Spain (6 May) and then over Italy (8 May) and Greece (10 May). Volcanic plume was then observed again over Southern Germany on 11 May.

Detailed daily reports with summaries of the EARLINET observations of the the Eyjafjallajökull ash plume have been submitted to WMO.

REFERENCES

[1] J. Bösenberg et. al, “EARLINET: A European Aerosol Research Lidar Network to Establish an Aerosol climatology,” 2003, Tech. Rep. 348, Max-Planck-Institut für Meteorologie, Hamburg.

[2] Pappalardo, G., U. Wandinger, L. Mona, A. Hiebsch, I. Mattis, A. Amodeo, A. Ansmann, P. Seifert, H. Linné, A. Apituley, L. Alados Arboledas, D. Balis, A. Chaikovsky, G. D'Amico, F. De Tomasi, V. Freudenthaler, E. Giannakaki, A. Giunta, I. Grigorov, M. Iarlori, F. Madonna, R.-E. Mamouri, L. Nasti, A. Papayannis, A. Pietruczuk, M. Pujadas, V. Rizi, F. Rocadenbosch, F. Russo, F. Schnell, N. Spinelli, X. Wang, and M. Wiegner, 2010, EARLINET correlative measurements for CALIPSO: First intercomparison results, J. Geophys. Res., 115, D00H19, doi:10.1029/2009JD012147.

[3] Pappalardo G., A. Amodeo, L. Mona, M. Pandolfi, N. Pergola, V. Cuomo, 2004: Raman lidar observations of aerosol emitted during the 2002 Etna eruption, Geophys. Res. Lett., 31, doi:10.1029/2003GL019073.

[4] Wang, X., et al., 2008: Volcanic dust characterization by EARLINET during Etna’s eruptions in 2001-2002, Atmos. Env., 42, pp. 893–9056.

[5] A. Ansmann, M. Tesche, S. Gross, V. Freudenthaler, P. Seifert, A. Hiebsch, J. Schmidt, U. Wandinger, I. Mattis, D. Müller, M. Wiegner, 2010, “The 16 April 2010 major volcanic ash plume over central Europe: EARLINET lidar and AERONET photometer observations at Leipzig and Munich, Germany”, Geophys. Res. Lett., doi:10.1029/2010GL043809, in press.

[6] A. Ansmann, U. Wandinger, M. Riebesell, C. Weitcamp, and W. Michaelis, 1992, “Independent measurement of extinction and backscatter profiles in cirrus clouds by using a combined Raman elastic-backscatter lidar,” Appl. Opt. 31, pp. 7113–7131.

[7] D. Müller, A. Ansmann, I. Mattis, M. Tesche, U. Wandinger, D. Althausen, and G. Pisani, 2007, “Aerosol-type-dependent lidar ratios observed with Raman lidar,” J. Geophys. Res. 112(D16202), doi:10.1029/2006JD008292.

ACKNOWLEDGMENTS

The EARLINET-ASOS project is funded by the EC under grant RICA-025991.

The ESA financial support under the ESTEC Contract No. 21487/08/NL/HE and the ESRIN Contracts No. 21769/08/I-OL and 22202/09/I-EC is gratefully acknowledged.

(2) VOLCANIC ASH CLOUD OBSERVATIONS WITH THE DLR-FALCON OVER MID-EUROPE DURING AIRSPACE CLOSURE

Ulrich Schumann, Hans Schlager, Bernadett Weinzierl, Oliver Reitebuch, Stephan, Rahm, Andreas Minikin, Monika Scheibe, and Caroline Forster

Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany

The volcano ash plume originating from the Eyjafjallajökull volcano eruption in Iceland was probed during four flights with the DLR Falcon research aircraft in the region of Germany, the Netherlands, Denmark, Southern Norway, the Baltic Sea and Poland at 1-11 km altitudes between April 19 and 23, 2010.

The Falcon was instrumented with a downward looking, scanning 2-µm-Wind-Lidar (aerosol backscattering and horizontal wind, 100 m vertical resolution), and several in-situ instruments. The particle instrumentation, including wing station probes (PCASP, FSSP-300) cover particle number and size from 5 nm to some tens of µm. Further in-situ instruments measured O3, CO, SO2, H2O, and standard meteorological parameters.

Flight planning was based on numerical weather forecasts, trajectory-based particledispersion models, satellite observations and ground based Lidar observations, from many sources.

During the flight on April 19, 2010, layers of volcanic ash were detected first by Lidar and then probed in-situ. The horizontal and vertical distribution of the volcanic ash layers over Eastern Germany was highly variable at that time. Calculations with the particle dispersion model FLEXPART indicate that the volcanic ash plumes measured by the Falcon had an age of 4-5 days. The concentrations of large particles measured in the volcanic aerosol layers are comparable to concentrations measured typically in fresh (age < 2 days) Saharan dust plumes. Depolarization measurements of ground-based lidars indicate that the upper part of the heavily polluted boundary layer, in which the Falcon took in-situ samples, also contained volcanic ash. An estimation of the particle mass concentration in the elevated volcanic ash plume probed as part of a vertical profile over Leipzig at about 4 km altitude yields 60 µg/m3. Of the total mass only less than 10 percent was residing in the particle size range below 2.5 µm. This emphasizes the need for adequate instrumentation to fully capture the size distribution of volcanic ash.

During the flight on April 22, 2010, measurements on a route from Southern Germany to Southern Norway showed low-concentration remainders of volcanic ash over Germany, but two types of fresh and slightly aged aerosols around Southern Norway. According to FLEXPART the fresh plume was transported from Iceland within about 2 days. It was characterized by strongly enhanced sulfur dioxide concentration and many small particles, possibly due to previous new particle formation. The partly aged plume layers were inclined from 5.5 to 3.5 km altitude from north to south between Oslo and Hamburg. The ash mass concentration was lower than that found on the April 19 plume. For the purpose of aviation, the predictions of the ash plume locations were found generally close to what was observed. Details have still to be determined.

The results had been provided to the German Weather Service (DWD) and others partly during the flights by satellite telephone and within 24 hours as quicklooks, and made available to the public by internet. The results had immediate impact on the decisions of the responsible agencies in Germany and the Volcanic Ash Advisory Centre (VAAC) in London. After the flights the Falcon inspections showed no obvious damage due to volcanic ash impact.The results are now used for further scientific investigations (ash plume dispersion, aerosol ageing, mass concentration estimates, heterogeneous chemistry, comparison to other observations and models) and assessment of practical consequences (operational observation system, aircraft engine thresholds for maximum and integral critical ash loading, etc.).

(3)Observations of the Eyjafjallajökull volcanic plume from CALIPSO

Dave Winker, Jacques Pelon, Ali Omar, Zhaoyan Liu, and Jason Tackett

The eruption of the Eyjafjallajökull volcano beginning on 14 April 2010 and subsequent impacts on European aviation has emphasized the usefulness of lidar for monitoring volcanic aerosols and their transport. The ash plume was observed by a variety of ground-based and satellite sensors but lidars provided the most sensitive detection and the only remote sensing measurements from which vertically resolved mass concentration could be estimated. Ongoing activities are using lidar observations to verify dispersion models used by the ash advisory centers. While lidar provides highly sensitive detection of ash, classification of atmospheric features as having volcanic origin can be ambiguous from lidar alone. The unique signature of volcanic ash in the thermal infrared allows a clear discrimination of ash from cirrus, however. In combination, measurements from the CALIOP and IIR instruments on the CALIPSO satellite provide unique capabilities. This talk will present CALIPSO observations of the Eyjafjallajökull plume over the North Atlantic and across Europe and discuss capabilities for the identification and characterization of volcanic ash plumes using CALIPSO measurements.

(4) Remote Sensing of Icelandic Volcanic Ash above Slovenia

F. Gao (a), K. Bergant (a,b), T. Bolte (b), F. Coreno (c), T.-Y. He (a), A. Hrabar (b), J. Jerman (b), A. Mladenovic (d), S. Stanic (a), J. Tursic (b) and D. Veberic (a)

(a) University of Nova Gorica, Nova Gorica, Slovenia
(b) Environmental Agency of the Republic of Slovenia, Ljubljana, Slovenia
(c) Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy
(d) Slovenian National Building and Civil Engineering Institute, Ljubljana, Slovenia

The eruption of the Eyjafjallajökull volcano on 14 April 2010 caused considerable spreading of volcanic ash over the inhabited parts of Europe. With the aim to determine the exact altitude of the ash cloud above Slovenia and its arrival trajectories, we performed a number of remote sensing and in-situ measurements of aerosol loading of the troposphere. Based on the predictions of the ECMWF model, volcanic ash was expected to initially reach Slovenia from the north during the night of 17 April 2010. Due to the changing weather conditions in neighboring northern Italy air masses containing volcanic ash briefly left Slovenia towards the northeast on 18 April 2010 and returned at lower altitudes on 20 April 2010.

During the second arrival of air masses carrying volcanic ash on 20 April 2010, lidar based remote sensing and aircraft based in-situ measurements were performed in order to confirm the presence and the streaming patterns of volcanic ash over Slovenia. The two Mie scattering lidar systems that were used were positioned within 10 km radius at elevations of 107 m above sea level (a.s.l.) and 945 m a.s.l. Measurements of both systems revealed an elevated layer with increasing aerosol loading at an altitude of about 2600 m a.s.l. In parallel, atmospheric properties including aerosol concentration, temperature and relative humidity were measured in-situ using a Cessna 172 aircraft 30 km away from the lidar site. Temperature profile and relative humidity profile showed layering in the atmosphere, which implied significant physical changes between different altitude ranges. The distribution of 0.3 μm diameter particles also showed the layering, but in addition manifested a global maximum of aerosol loading (about 36 particles/mm2) at an altitude of about 2200 m a.s.l. After the flight, the structure and chemical composition of aerosol samples collected by the aircraft were investigated using a combination of low vacuum scanning electron microscopy (SEM) with the back-scattered electrons (BSE) image mode and the energy dispersive X-ray technique (EDS).

Analysis of the collected samples and comparison of the results to the properties volcanic ash obtained directly in Iceland confirmed the aerosols found in Slovenia to be ash of volcanic origin as the particles of Icelandic volcanic ash appeared in all of the collected samples.

(5) OPTICAL AND CHEMICAL PROPERTIES OF ASH PARTICLES OBSERVED OVER ATHENS, GREECE USING RAMAN LIDAR AND IN SITU SAMPLING DURING THE EYJAFJALLAJÖKULL ERUPTION

A. Papayannis[1], R. E. Mamouri[1], E. Remoundaki[2], P. Kokkalis[1], G. Tsaknakis[1], M. Tsezos[2]

[2]National Technical University of Athens, School of Mining and Metallurgical Engineering, Laboratory of Environmental Science and Engineering, Heroon Polytechniou 9, 15780, Zografou, Greece

[1]National Technical University of Athens, Physics Dept., Laser Remote Sensing Laboratory, Heroon Polytechniou 9, 15780, Zografou, Greece

The optical and chemical properties of ash particles from the Eyjafjallajökull eruption were obtained over Athens, Greece using a multi-wavelength Raman lidar and in situ data aerosol sampling. Ash was observed from 10 km down to ground for a total period of about 7-8 days, after a 3-5 days trajectory from the source region located in Iceland. Different ash layers were observed both in the form of filaments and in mixing state with locally produced aerosols.

(6) Microphysical properties of a volcanic ash plume over Munich derived from remote sensing measurements

Josef Gasteiger, Silke Gross, Volker Freudenthaler, Franziska Schnell, Matthias Wiegner

Meteorologisches Institut, Ludwig-Maximilians-Universität München, Theresienstr. 37, 80333 München, Germany

Contact: josef.gasteiger@lmu.de

Volcanic ash plumes over the EARLINET site Munich/Maisach (Germany), emitted by the Eyjafjallajökull volcano (Iceland) in April and May 2010, were observed by the lidar systems MULIS and POLIS, a CIMEL sun

photometer, and a Jenoptik ceilometer. The aim of the present study is to extract information about microphysical particle properties of the volcanic ash from these measurements, with focus on mass concentration because of its relevance for flight safety.

We use spectral optical particle properties from the lidar measurements, i.e. extinction coefficients, backscatter coefficients, and linear depolarization ratios, as input for an inversion. The basic idea of the inversion approach is that information about microphysical aerosol properties can be retrieved by comparing the optical properties of a large number of different model aerosol ensembles with the corresponding values from the lidar measurements. The optical properties are calculated using the T-matrix approach, supplemented by geometric optics calculations for large particles. The aerosol ensembles in the present study are defined by parameters for a mono-modal log-normal size distribution, by a wavelength-independent complex refractive index, and by parameters for the distribution of aspect ratios of prolate and oblate spheroids. The parameters of the aerosol ensembles are sampled within appropriate ranges using an Monte Carlo approach. Ensembles that agree with the lidar measurements within the uncertainty of the measurements are accepted as solutions of the inverse problem. As a large number of aerosol ensembles are compatible with the measurements, the result of the inversion is a distribution of aerosol ensembles. For each aerosol ensemble the quantity of interest, e.g. the effective radius or the mass concentration, can be calculated. This implies that the inversion result for the quantity of interest is also a distribution.

The application of this novel approach to the optical properties derived from lidar measurements of the pure volcanic ash plume in the morning of April 17th 2010 over Maisach results in an effective volume-equivalent radius of about one micrometer. The range of effective radii of the accepted aerosol ensembles is from about 0.7 to 1.8 micrometers. For the mass concentration the inversion suggests values of about one milligram per cubic meter (0.7 to 1.9 milligram per cubic meter) at the maximum of the ash plume, where the extinction coefficient was about 0.75 per kilometre. The ash mass density is assumed to be 2.6 gram per cubic centimetre.

Due to the complexity of the physical ash properties, several assumptions are necessary in the inversion. The assumptions can possibly bias the results. As a preliminary test for the effect of the assumption of spheroids, simulated optical properties of complex-shaped particles are used as input for the inversion. It is shown that the real part of the refractive index is underestimated, if these complex-shaped particles are present, but spheroids are assumed in the inversion. The imaginary part and particle sizes, however, are barely affected by the assumed particle shape.

Furthermore, it must be emphasized that optical properties from lidar measurements do not carry much information about particles that are much larger than the lidar wavelengths. In case of mono-modal size distributions, the amount of large particles is constrained by the shape of a log-normal function. However, a potential second mode with very large particles can not reliably be detected by lidar. Fortunately, for the ash plume in the morning of April 17th a comparison of effective particle sizes with information from an independent source is possible: We use sky radiance measurements of a CIMEL sun photometer in the aureole of the sun together with an radiative transfer code (disort2 in libRadtran) for an independent estimation of the effective radius. The two-layer structure of the aerosol, that was detected by the lidars, is taken into account in the radiative transfer simulations. The comparison shows that the effective radii derived from lidar and from sky radiance measurements are in the same range, which suggests that there was no second size mode with very large particles.

(7) Mass loading estimates of the Eyjafjöll ash plume using principle component analysis applied to multi-wavelength Raman lidar data over The Netherlands.

M. de Graaf (1)*, D. P. Donovan (1), A. Apituley (1,2) and K. M. Wilson (1,2)

(1) Royal Netherlands Meteorological Institute (KNMI), Wilhelminalaan 10, 3732 GK, De Bilt, The Netherlands
(2) National Institute for Public Health and the Environment (RIVM), The Netherlands.
* presenter and corresponding author. E-mail: graafdem@knmi.nl

A recently adjusted principle component analysis (PCA) method for the inversion of Raman lidar data to retrieve microphysical aerosol properties is a very useful tool to estimate mass loadings of volcanic ash. PCA performed on measurements of aerosol extinction and backscatter data is a stable and reliable way to infer integrated properties of the aerosol size distribution, like effective size radius or the total aerosol volume concentration. The latter can be translated into a mass concentration when the ash density is known.

In a recently submitted paper the PCA algorithm was adapted to account for varying aerosol refractive indices, to be applicable in the troposphere. Instead of using one inversion kernel set based on an *a priori* defined aerosol refractive index, the algorithm chooses between sets based on several aerosol models. The selection criterion is based on the accuracy with which the various kernel sets can reconstruct the original measurements when one the measurements is removed. It was shown that only a few different aerosol models need to be present in the algorithm to retrieve accurate estimates of the integrated size distribution of the ambient aerosols, provided that the aerosol models represent the entire range of aerosols found in the troposphere in terms of refractive index. I.e. the aerosol models need to represent a large range in real refractive index and absorption. In this case the retrieved refractive index is not so much an accurate indicator of the ambient aerosol type, although that could be improved by using more models, but the retrieved total volume concentration proved to be rather insensitive to the error in the retrieved aerosol refractive index.

After the Eyjafjöll eruption the PCA method described above was applied to Raman lidar measurements from Cabauw in central Netherlands, after a quick and dirty inclusion of a volcanic ash kernel set, based on a google search of volcanic ash refractive indices and ash densities. The results showed that

(1) volcanic ash mass densities can be retrieved with an accuracy of about a factor of three using Raman lidar measurements. The maximum mass loading, one day after the explosive eruption of Eyjafjöll when the initial plume reached The Netherlands, as retrieved from the Raman lidar measurements was about 0.1 mg/m^3 using a particle density of 2 g/cm^3,

(2) the volcanic ash kernel was indeed the aerosol model that was best at predicting the extinction and backscatter measurements inside the ash plume;

(3) the retrieved volume and mass concentration were not sensitive to the inclusion of the volcanic ash kernel: in the original algorithm a desert dust aerosol model, which has a refractive index that is close to that of included ash model, produced nearly similar results, supporting the conclusion that only a few models are needed in the algorithm to retrieve accurate integrated microphysical properties for a wide variety of aerosol types.

The PCA method is a mathematically stable inversion method, producing valuable, integrated estimates of the aerosol size distribution, without the need of *a priori* knowledge of the aerosol type. This method can be used to infer estimates of mass loadings from multi-wavelength extinction and backscatter profiles, independent of aerosol refractive index, which is different for various types of aerosols in the troposphere and can be different for different types of volcanic ash. The method might be further improved using more accurate kernel sets. When an estimate of the refractive index of the measured aerosol is present, it can easily be included to retrieve even more accurate results.

(8) Ground-based active and passive remote sensing of the Eyjafjallajökull volcanic aerosols at Granada, Spain

L. Alados-Arboledas[(1,2)], F. Navas-Guzmán[(1,2)], J.A. Bravo-Aranda[(1,2)], H. Lyamani[(1,2)], D. Pérez-Ramírez[(1,2)], J. L. Guerrero-Rascado[(1,2,3)], M. Antón[(1,2)] and F. J. Olmo[(1,2)]

[1]Departamento de Física Aplicada, Universidad de Granada, Fuentenueva s/n, 18071, Granada, Spain.
[2]Centro Andaluz de Medio Ambiente (CEAMA), Av. del Mediterráneo s/n, 18071, Granada, Spain
[3]Évora Geophysics Centre (CGE), University of Évora, Rua Româo Ramalho 59, 7000, Évora Portugal

The eruption of the Eyjafjallajökull volcano on April 14, 2010 has strongly affected Central Europe during the second half of April. Over the western part of the continent, particularly the Iberian Peninsula, the arrival of the volcanic ashes has been detected during the first week of May. At the Andalusian Center for Environmental Research (CEAMA) in Granada (Spain, 37.16°N, 3.6ºW, 680 m a.s.l.), we have monitored the ash layers originating from the eruptions of Eyjafjallajökull volcano using a combination of ground-based remote sensing, both active and passive, together with surface boundary layer instrumentation. The station is part of the multiwavelength European Aerosol Research Lidar Network (EARLINET, Bösenberg *et al.*, 2003), and the Aerosol Robotic Network (AERONET, Holben *et al.*, 1998). Analyses of the optical and microphysical properties of the atmospheric aerosol have been performed. The CIMEL C-318 retrievals suggested an increase in the micrometric mode. Under the presence of the volcanic ashes the aerosol optical depth for the total column reached 0.6 at 340 nm, with Angström exponent around 1. The night time Raman retrieval indicates an aerosol optical depth around 0.2 at 355 nm for a dense layer from 3 to 4 km a.s.l., where maximum extinction coefficients around 375 Mm^{-1} have been measured at the same wavelength. Lidar ratios at 355 and 532 nm are around 40 sr, with negligible spectral dependence. The volcanic ashes are characterized by backscatter-related Ängström exponent (355-532 nm) bellow 1 and aerosol depolarization at 532 nm in the range 6-10%.

Acknowledgements: This work is supported by Spanish Ministry of Science through grant CGL2007-28871-E/CLI and projects CGL2007-66477-C02-01, CSD2007-00067 and CGL2004-05984-C07-03; by Autonomous Government of Andalusia through the projects P08-RNM-3568 and P06-RNM-01503, and by EARLINET-ASOS project (EU-CA., 025991, RICA).

References

Bösenberg, J., *et al.* (2003), *Rep. 348*, Max-Planck-Inst., Hamburg, Germany.
Hess, M., Koepke, P., and Schult, I. (1998), *Bull. Am. Met. Soc.*, **79**, 831-844.
Holben, B. N., *et al.* (1998), *Remote Sens. Environ.*, **66**, 1-16.

(9) Eyjafjallajökull ash observations over Stuttgart in spring 2010

Andreas Behrendt, Volker Wulfmeyer, Andrea Riede, Gerd Wagner

University of Hohenheim, Stuttgart, Germany

Contact: andreas.behrendt@uni-hohenheim.de

We present observations of Eyjafjallajökull ash made at University of Hohenheim (Site Coordinates: 48° 42' 40.7" N, 9° 12' 15.5" E, Site Height: 370 m above sea level, ASL), near Stuttgart, Germany, in April and May 2010. For the observations, we used the scanning water differential absorption lidar (DIAL). The observations were synchronized with overflights of the Falcon aircraft of the German Aerospace Center (DLR). The DIAL emitted laser pulses near 820 nm with a pulse repetition rate of 250 Hz and puls energy of 8 mJ resulting in a laser power of 2 W. The receiving telescope has a primary mirror diameter of 80 cm and was used in different scanning modes. We found that between 18 and 21 April 2010, enhanced aerosol load was present in the atmospheric boundary layer (top height at ~2.8 km ASL) with particle extinction coefficient (PEC) up to (0.35 ± 0.05) 1/km, while the aerosol load in larger heights was much lower. The ash load above 3.0 km ASL was already quite weak over Stuttgart in the evening of 18 April with PEC < (0.06 ± 0.01)*1/km and did not increase significantly later in April; some free-tropospheric aerosol layers were observed but PEC always stayed below 0.06*1/km. On 18 May 2010, larger PEC values than in late April were found in the free troposphere: several ash layers were present over Stuttgart in heights between 2.0 and 6.0 km ASL and showed maximum PEC of (0.10 ± 0.02)*1/km on this day. In addition to the lidar measurements, our institute made also analyses of aerosols near the ground. The correlation of these data with the lidar measurements will also be discussed.

(10) Traces of Eyjafjallajoekull volcanic eruption according to data of lidar observations in Tomsk (56.5N, 85.0E)

V. D. Burlakov, S.I. Dolgii, G.P. Kokhanenko, A.V. Nevzorov, I.P. Penner

Institute of Atmospheric Optics, Siberian Branch of the Russian Academy of Sciences, Tomsk, Russia

Contact: dolgii@iao.ru

Since April 19, 2010, five days after eruption of Eyjafjallajoekull volcano, until late April the lidar measurements in the upper troposphere over Tomsk (56.5N, 85.0E) revealed well-defined aerosol layers at heights from 5 to 10 km. Occurrence of these layers may be associated with transport of eruption products of Eyjafjallajoekull volcano. The measurements were performed by lidar at the wavelengths 355 anf 532 nm. The report presents data of measurements of the scattering ratio and aerosol backscattering coefficient. We also measured the depolarization degree of the aerosol layers at wavelength 532 nm.

This work was supported by Ministry of Education and Science (contract No. 02.740.11.0674).

(11) Observations of the Eyjafjöll ash plume made at the Netherlands Cabauw site

D.P. Donovan(1)*, A. Apituley(1,2), M. de Graaf (1), K. M. Wilson (1,2), W. Knap(1).

(1) Royal Netherlands Meteorological Institute (KNMI), Wilhelminalaan 10, 3732 GK, De Bilt, The Netherlands
(2) National Institute for Public Health and the Environment (RIVM), The Netherlands.
* presenter and corresponding author. E-mail: donovan@knmi.nl

The Cabauw Experimetal Site for Atmospheric Research (CESAR) in the Netherlands was among the first sites within continental Europe to detect the ash plume using lidar measurements. The Eyjafjöll ash plume was observed by a continuously operating automated Leosphere UV polarization sensitive lidar system as well as a manually operated multi-wavelength Raman lidar system (CAELI).

The eruptions and their subsequent impact on air traffic generated a large demand for timely mass loading estimates. Data from both systems were used to produce quantitative estimates of the mass loading. The estimates from the multi-wavelength Raman system are considered to be the most accurate. However, the temporal coverage of the Raman lidar is limited and the data processing chain is not automated. In response to the demand for rapid estimates of mass loading (even with large i.e 2-3x uncertainty ranges) an experimental rapid automated ash processing system was implemented for the automated UV lidar. The procedure relies on the difference between the observed volume depolarization ratio and the expected aerosol-only depolarization ratio in order to estimate aerosol backscatter, extinction and (utilizing an aerosol scattering model) mass estimates.

In this presentation, the measurements made over Cabauw will be presented and discussed. The rapid ash processing product will be presented and compared with results from the Raman system as well as sun-photometer based results.

(12) Volcanic ash observations from Eyjafjallajökull eruption with a Raman lidar over Thessaloniki, Greece

Elina Giannakaki, Dimitris Balis, Alkiviadis Bais

Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki, Greece

Eyjafjallajökull is one of the smallest glacier in Iceland. After seismic activity recorded during December 2009, a first eruption started on March 20, between 22:30 and 23:30 UT. The transport of aerosol in the troposphere during the Eyjafjallajokul eruption is presented with the use of lidar observations, model simuations and sunphotometer measurements. The case study concentrates on the period between 16th of April and 16th of May.

The spatial and temporal evolution of volcanic ash layers are presented. Some layers are persistent but with variable thickness, while other layers seems to disappear after some hours. The main objective of this study is the presentation of the geometrical and optical properties of the observed volcanic ash layers over Thessaloniki.

(13) Lidar measurements of the Eyjafjallajökull ash plume over Munich

Silke Gross, Volker Freudenthaler, Josef Gasteiger, Franziska Schnell, Matthias Wiegner

Meteorologisches Institut, Ludwig-Maximilians-Universität, Munich, Germany

Contact: silke@meteo.physik.uni-muenchen.de

On April 16, 2010, at about 17 UTC the volcanic ash plume of the Eyjafjallajökull eruption in Iceland arrived at the measurement sites at Munich and at nearby Maisach. The plume was measured with the two Raman and depolarization lidar systems MULIS and POLIS in Maisach, and with a CIMEL sunphotometer and a JenOptik ceilometer in Munich. MULIS and POLIS are reference systems of the European Aerosol Research Lidar Network (EARLINET), and allow a comprehensive characterization of atmospheric aerosols including the backscatter coefficient at three wavelengths (1064 nm, 532 nm and 355 nm), and the extinction coefficient and particle linear depolarization ratio at 532 nm and 355 nm.

The Eyjafjallajökull eruption plume was monitored over 1 month, over the first 10 days continuously, to document the temporal evolution and the change of the optical properties with time and with the state of mixing. With this unique data set it is possible to investigate the potential of advanced lidar systems regarding the characterization of volcanic ash layers, especially in view of air traffic safety. In addition, almost real-time quicklooks of the range corrected signals and of the volume linear depolarization ratio on the web gave an overview of layer height and development supporting modellers and decision makers.

At its maximum the extinction coefficient of the ash plume was as high as 0.75 km^{-1} and wavelength independent. The extinction-to-backscatter ratio (lidar ratio) was found to be 55 ± 5 sr at 532 nm and 355 nm. The particle linear depolarization ratio of 0.35 – 0.37 at both wavelengths indicates non-spherical particles. The combination of both parameters, in particular as they are available at two wavelengths, is an excellent tool to discriminate volcanic ash from other aerosol types.

Furthermore, the Munich systems have a very low full overlap at 100 m (POLIS) and 300 m (MULIS) enabling accurate measurements without overlap corrections in the boundary layer. In the boundary layer a particle linear depolarization ratio larger than 0.06 at 532 nm was used as a clear indicator for volcanic ash. Such ash loaded air masses often showed wavelength dependent scattering coefficients with wavelength independent lidar ratios almost unchanged at 50 ± 10 sr, and varying wavelength dependencies of the particle linear depolarisation ratio.

On some days the particle linear depolarization ratio in the boundary layer showed a negative correlation with the relative humidity profile, with depolarisation values ranging between 0.02 to 0.2, which indicates hygroscopic growth of particles.

It is planned to use the optical data for a microphysical characterization, and to compare our data and results with simultaneous airborne measurements of the DLR.

(14) COMPARISON OF SPALINET NETWORK LIDAR MEASUREMENTS WITH MODELS FORECASTS DURING THE EYJAFJALLA EVENT

F. Molero[1], M. Sicard[2], J.L. Guerrero-Rascado[3-4], F. Navas-Guzmán[4], S. Tomás[2], J. Preißler[3], D. Kumar[2], F. Rocandenbosch[2], L. Alados-Arboledas[4], F. Wagner[3], A. Comeron[2], M. Pujadas[1]

[1]Grupo de Contaminación atmosférica, CIEMAT, Avda Complutense, 22. 28040 Madrid, Spain.
f.molero@ciemat.es
[2]Department of Signal Theory and Communications, Remote Sensing Laboratory, Univ. Politècnica de Catalunya / Institut d'Estudis Espacials de Catalunya, c/ Jordi Girona, 1-3, 08034, Barcelona, Spain.
msicard@tsc.upc.edu
[3]Évora Geophysics Centre (CGE), U. Évora, Rua Româo Ramalho 59, 7000, Évora Portugal
.fwagner@uevora.pt
[4]Centro Andaluz de Medio Ambiente (CEAMA), Av. del Mediterráneo s/n, 18071, Granada, Spain,
alados@ugr.es

An assessment of the model forecast for the Eyjafjalla volcanic event has been performed for the Iberian Peninsula. Vertical profiles measured by a network of lidar instruments have been compared with the predictions provided by two models. The event over the Iberian Peninsula, which occurred between the 5^{th} and 8^{th} of May, 2010, was reasonably well captured by both models, although some discrepancies in temporal and spatial accuracy respect to the lidar profiles are commented. The assessment is limited due to interference of the lidar measurements by low clouds and rain.

(15) Lidar derived optical properties of volcanic ash in Romania, during Eyjafjallajokull eruption

Doina Nicolae, Camelia Talianu, Razvan Radulescu, Emil Carstea

National Institute of R&D for Optoelectronics, 1 Atomistilor Str., Magurele, RO-077125, Romania

Due to the complex air mass circulation between April 17 and 28, Romania was exposed sequentially to volcanic ash and mixture of volcanic ash with continental aerosols. Five distinct episodes were identified and analysed during this period, based on lidar retrievals. Fresh ash particles with an average Angstrom exponent of 1.4±0.2 and an average particle depolarization value of 9.4 ±0.9 were measured at altitudes of 3Km on April 18, while mixed ash and continental particles, with a lower depolarization and increased color ratio were identified on April 28. This paper presents the alternate of these episodes, corresponding to the continental transport.

(16) ASH FROM THE EYJAFJALLAJÖKULL VOLCANO OBSERVED BY LIDAR OVER PORTUGAL

Jana Preißler, Frank Wagner, Juan Luis Guerrero-Rascado, Ana Maria Silva

Geophysics Centre of Évora, Physics Department, Rua Romão Ramalho 59, 7000 Évora, Portugal, E-mail:jana@uevora.pt

Volcanic eruptions are known to be a natural cause of climate change [1]. However, the influence of volcanic aerosol is hard to predict as volcanic eruptions occur only infrequently and with irregular spatial and temporal distribution. Thus measurements and observations can also only be made occasionally. The eruption of the Eyjafjallajökull volcano (63.6_N, 19.6_W) in Iceland in April and May 2010 provided a good opportunity for such measurements.

Ash plumes from Iceland could be detected in Évora, Portugal (38.57_N, 7.92_W, 290 m asl) by lidar in the beginning of May 2010. The measurements were performed with PAOLI (Portable Aerosol and clOud LIdar), a Raman lidar of the type PollyXT [2]. It emits light at the wavelengths 355, 532 and 1064 nm. Detection channels for those three wavelengths and for the two Raman-shifted wavelengths 387

and 607 nm, corresponding to 355 and 532 nm respectively, enable the determination of the profiles of the backscatter coefficients _ at three wavelengths and the extinction coefficients _ at two wavelengths.

Hourly averages of the lidar signal were used for the calculation of backscatter coefficient profiles. The Klett method [3] was applied for day-time profiles and the Raman method [4] for night-time profiles at 355 and 532 nm. For the profiles of the backscatter coefficients at 1064 nm, only the Klett method was used.

Data from GDAS model soundings from NOAA ARL (National Oceanic and Atmospheric Administration, Air Resources Laboratory), available at http://ready.arl.noaa.gov/READYamet.php, were used for the calculation of the Rayleigh coefficients.

For this work, measurements in the time period from the 5th to the 7th as well as on the 10th, 13th and 14th of May 2010 were analysed. No measurements were possible on the 8th of May due to low clouds and rain. The measurements on the 9th, 11th and 12th of May show low dense cloud layers and no volcanic ash and therefore were not further investigated.

During the whole period several thin filaments as well as strong layers with a vertical extension of about 1 km could be detected. Maximum values of the backscatter coefficient within the volcanic ash layers were found in the night from the 6th to the 7th of May. Besides, a decrease in height of several aerosol layers in process of time was found. However, no intrusion of ash into the boundary layer could be observed. More detailed information about the temporal distribution of the volcanic ash plume as well as geometrical layer properties and optical characteristics, such as profiles of the backscatter coefficients, will be presented at the conference.

REFERENCES

[1] Solomon, S. et al. (editors) Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA, 2007.

[2] Althausen, D. et al. (2009): Portable Raman Lidar PollyXT for Automated Profiling of Aerosol Backscatter, Extinction, and Depolarization. Journal of Atmospheric and Oceanic Technology, 26, doi:10.1175/2009JTECHA1304.1.

[3] Klett, J. D. (1981): Stable analytical inversion solution for processing lidar returns. Applied Optics, 20, pp. 211–220.

[4] Ansmann, A. et al. (1992): Independent measurement of extinction and backscatter profiles in cirrus clouds by using a combined Raman elastic-backscatter lidar. Applied Optics, 31, pp. 7113–7131.

(17) Lidar observation of Eyjafjallajoekull ash layer evolution above the Swiss Plateau

V. Simeonov[1], T. Dinoev1, M.Parlange[1], I. Serikov[1],[6], B.Calpini[2], F. Wienhold[3], I. Engel[3], M. Brabec[3], A. Cirisan[3], T. Peter[3], V. Mitev[4], R. Matthey[5]

[1] Swiss Federal Institute of Technology-Lausanne (EPFL), EPFL ENAC EFLUM Lausanne Switzerland; [2] MeteoSwiss, Payerne , Switzerland; [3] Swiss Federal institute of Technology Zurich (ETH), Institute for Atmospheric and Climate Science, Switzerland; [4] CSEM, Rue de l'Observatoire 58, Neuchâtel, Switzerland; [5] University of Neuchâtel, Dep. of Science, Neuchâtel, Switzerland; [6] MPI for meteorology Bundesstr. 53 Hamburg Germany

Contact: valentin.simeonov@epfl.ch

The Iceland volcano Eyjafjallajökull started to emit significant amounts of volcanic ash and SO_2 on 15th April 2010, following the initial eruption on 20th March 2010. In the next days, the ash was dispersed over large parts of Europe resulting in the closure of the major part of the European airspace. Information about spatial and temporal evolution of the cloud was needed urgently to define the conditions for opening the airspace. Satellite, airborne and ground observations together with meteorological models were used to evaluate the cloud propagation and evolution. While the horizontal extents of the volcanic cloud were accurately captured by satellite images, it remained difficult to obtain accurate information about the cloud base and top height, density and dynamics. During this event lidars demonstrated that they were the only ground based instruments allowing monitoring of the vertical distribution of the volcanic ash. Here we present observational results showing the evolution of the volcanic layer over the Swiss plateau. The measurements were carried out by one Raman lidar located in Payerne, two elastic lidars located in Neuchatel and Zurich, and a backscatter sonde launched from Zurich. The observations by the lidars have shown very similar time evolution, coherent with the backscatter sonde profiles and characterized by the appearance of the ash layer on the evening of 16th, followed by descend to 2-3 km during the next day and final mixing with the ABL on 19th. Simultaneous water vapor data from the Payerne lidar show low water content of the ash layer.

The CSEM and EPFL gratefully acknowledge the financial support by the European Commission under grant RICA-025991, EGU2010-15745

(18) Eyjafjallajökull volcano ash plume operational monitoring all over Europe with ground based and airborne mounted lidars.

Simone Lolli, Leosphere France (France); Patrick Chazette, LSCE(France), Conil, Andra (France); Alain Dabas, Meteo France (France); Dave Donovan, KNMI (Netherlands); Sven-Erik Gryning, Torben Mikkelsen, Risø (Denmark); Hugo Ricketts, University of Manchester (United Kingdom); Philippe Royer, LSCE (France), Laurent Sauvage, Leosphere France (France); Geraint Vaughan, University of Manchester (United Kingdom); Joerg Walter, University Leipzig (Germany); Frank Wienhold, ETHZ (Switzerland)

Eyjafjallajökull volcano eruptions of ash plumes starting on April 2010 paralyzed completely air traffic in Europe for several days. During the crisis, Leosphere has collected operational from Denmark to South of France in order to provide quick looks of the sky at regular intervals to different met agencies and to the VAAC coordinated by UK MetOffice. Moreover, Meteo France supported by other institutions as CNRS, CEA , CNES and Leosphere realized several test flights over France and North Atlantic with an airborne Lidar. In this work are presented some results of these measurements