

Interactive comment on “The Eyjafjallajökull eruption in April 2010 – detection of volcanic plume using in-situ measurements, ozone sondes and a new generation ceilometer network” by H. Flentje et al.

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Authors' response to review #1:

Thanks for the valuable comments. We regret that a companion paper about the ceilometer network, designated for this special issue, was considerably delayed and published only recently in AMT. Nearly all questions concerning the ceilometers are answered there.

Therefore, all questions referring to the ceilometer results are absolutely justified and

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could largely have been avoided if the companion paper had been published beforehand as planned. The evaluation of the ceilometer data, especially for optical and micro-physical properties of the Eyjafjoll ash plume over Germany, are described in detail in that second paper (Flentje et al. 2010b). There the potential of the DWD ceilometer network to detect, track and identify different types of aerosols is described. It is available at AMT (<http://www.atmos-meas-tech-discuss.net/3/3643/2010/>).

Nevertheless, it seems necessary to make this paper more self-explaining and add more details about evaluation and data quality of the ceilometer data also in the revised version of the present manuscript. This will be done.

Detailed Response:

p. 14948: Will be revised. Main results and numerical values will be added to the abstract.

p. 14948, line 22: IES is Iceland Institute of Earth Sciences, will be added to text/references: http://www2.norvol.hi.is/page/ies_Eyjafjallajokull_eruption

p.14948., l.25: will be clarified. The centre of the high pressure system was south-west of Iceland on April 14th and moved further to the east. On April 15th air masses over Iceland (on the Northern edge of the high pressure system) were transported with westerly winds towards east, later (April 16th) the air flow changed and emissions were directly transported (with north-westerly winds) along the eastern flank of to high pressure system to Central Europe.

p. 14949, line 7: Removed “consequently” and split into two separate sentences.

p. 14949, l.12-17: The transport of the aerosol cloud is well documented by satellite images, trajectory calculations and a synopsis of ceilometer and lidar data from various platforms. It is discussed in our companion paper (Flentje et al., 2010). We will add further references, and add a brief discussion of the ash dispersion which however is beyond the scope of this paper.

page 14949 l. 18: OK, good point, will be added.

p. 13949, l. 26: see above

p. 14950, l.2: All these details are described in our companion paper Flentje et al, 2010.

We will refer to this but provide a brief summary of the ceilometers' sensitivity here as well. Actually, even extinction coefficient $< 5 \times 10^{-6}$ 1/m can be detected under favourable conditions (no clouds, only moderate scattering up to about 3-4 km altitude) averaging over 10 minutes horizontally and over 60-90 m vertically. Though we did observe the same thin layers on 19-23 April and thereafter in May, which were measured by EARLINET lidars we won't discuss them in our context. The optical properties of thin layers can only be estimated with a large uncertainty up to 50%.

Note that we calibrate our extinction profiles with co-located AOD measurements – thus it is the other way round than for 'Rayleigh-calibrated' lidar measurements: the backscatter coefficient is the inferred variable and is estimated from the extinction coefficient using a lidar ratio. The uncertainty of the extinction scales mainly with that of the AOD while the lidar ratio (backscatter/extinction ratio) is of minor relevance for an optically dominant layer as the one observed on April 17. As these faint layers are not clear in the composite plot from 16 April, we will remove this figure and will concentrate on those ceilometer measurements which directly support the in-situ observations at Hohenpeißenberg/Schneefernerhaus.

The uncertainty of the 1064nm backscatter coefficient is mainly determined by the signal/noise ratio, the backscatter ratio (the factor by which particle scattering exceeds molecular scattering) and by the availability of auxiliary data of e.g. aerosol optical depth. The molecular (Rayleigh) backscatter coefficient at 3 km altitude is about 8×10^{-8} 1/(m sr) which is of the order of the detectable signal. Thus, calibration with the molecular signal only is problematic. But for the ash case aerosol optical depth (extinction integral) measurements and surface measurements of the scattering coefficient

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were available which allow estimation of the extinction coefficient of the ash layer at $1.06 \mu\text{m}$ with an uncertainty of about 50%. This is described in Flentje et al, 2010. Also surface mass concentrations are available which allow estimating the specific extinction coefficient thus the particle mass concentration from the ceilometer profiles with an uncertainty of a factor of 2-3. The accuracy and detection limit of the ceilometers has also been investigated by B. Heese, IfT Leipzig, was meanwhile accepted for ACPD and will soon be published. Of course high power lidars, operating at a shorter wavelength or with a Raman channel can quantify the aerosol optical properties much more accurate! We do not claim that ceilometers are that good! Our strength is that we have ground-based in-situ measurements available which circumvents some of the assumptions that lidars/ceilometers need for data evaluation without auxiliary data. Admittedly we need assumptions about the homogeneity of the PBL after entrainment of the ash. But it is encouraging that our values agree reasonably well with both, lidar-derived as well as airborne in-situ measurements of particle mass concentrations reported during the ash period.

Page 14950 line 5, ok

Page 14950 line 7, is 100 mm, added to text.

Page 14950, line 13, this will be clarified: CHM15k ceilometers provide profiles of total backscattering which adds from molecular and particulate contributions but only in the lowest part of the profile is sensitive enough to detect Rayleigh scattering at 1064 nm.

Page 14950, line 15, ok, yes we use the usual Fernald-Klett method. Fernald, 84 will be added.

Page 14950, line 17: We use a lidar ratio 50, published by Pappalardo et al, 2010 at the EGU conference in Vienna, 2010. cf. Flentje et al., 2010.

Page 14950, lines 19-22: Yes that's what that sentences should tell: at 1064 nm molecular scattering is small compared to particle scattering. And using 1064 nm, Mie scat-

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tering efficiency drops as $\sim r^{*-6}$ when particle radii decrease. This means, we are rather 'blind' for very small particles.

Page 14952 lines 21: Figure will be removed and the reader shall refer to our companion paper where we did what you propose.

Page 14952 line 25: Figure 1 will be replaced as proposed by measurements from 3 stations in north, middle, and south Germany.

p. 14953, l.7, l.11-12 and following, Figure 3: Answers to nearly all these questions are provided in our companion paper about the ceilometer network. We will refer to it but also show selected examples from the week after arrival of the ash, in this paper (modifying Figure 3). There you'll see, that except from the optically thinnest ones the ash layers were also observed by the ceilometers all over Germany (under cloud-free conditions). Flentje et al. 2010 also provides two direct comparisons between EARLINET lidar and ceilometer. Meanwhile another manuscript from Heese et al. is accepted for this special issue at ACP and will soon be online. (Reference will be added). Detailed comparisons of ceilometer with lidar profiles is shown there. Clearly, the ceilometers' sensitivity and the information content of their data are significantly lower than that of sophisticated lidars and we strongly plead for an integration of both types of instrument, maybe in WMO's envisioned GALION. However, the faint layers were optically and micro-physically of minor relevance. We will modify Figure 3 to show examples of the thin layers observed at different times and locations.

Page 14954, lines 2-4: Concerning descent of the layer: ECMWF analyses indicate subsidence of about 1000-2000 m/day in 3-5 km altitude, CALIOP images indicate that the layer was strongly tilted (e.g. on 16 April over Belgium). We will modify the text to include this additional evidence. The layer observed at Zugspitze resembled the one at Hohenpeissenberg in detail indicating that it was the same layer. This is also clear due to its temporal and spatial scales and transport during that day.

Page 14955, line 2: Concerning particle diameter: A sudden concentration increase

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of particles with 1-4 μm diameter was observed by our in-situ measurements at surface level at Hohenpeißenberg after the ash particles had been mixed down to ground levels. This coincided with SO_2 increase. This surely means that some ageing took place. It is a matter of definition if we call this an aged air-mass. We will clarify this in the revised version, and add references / more information on particle sizes, e.g. from the Falcon flight, which is about to be published by Schumann et al. in this special issue.

Page 14956, line 21-29 and Page 14957, lines 19-27: See revised Figure 3 and accompanying text changes.

Page 14957, lines 10-12, 19-27: We are sure that you'll be more convinced now that our companion paper is available which detained essential information. We are sorry for this because the delay was not foreseeable. Has been reworded

Figure 2: yes the feature corresponds closely to that at Munich, Augsburg and other surrounding stations. addressed by revised Figure 3 and its description

Figure 4 comment: horizontal lines for particle concentration (percentiles) will be provided but are not as conclusive as for SO_2 because this event was not extraordinary at Hohenpeißenberg surface in terms of particle concentrations.

Figure 8: Actually the date in the plot is correct. What is misleading is the Figure caption. We have ozone soundings on many days, but only 4 selected ones are shown. Changed April 14 to April 16 and April 25 to April 23 in the caption, to better agree with what is plotted.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 14947, 2010.

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