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Atmospheric Measurement Techniques Discussions



# *Interactive comment on* "Aerosol profiling using the ceilometer network of the German Meteorological Service" *by* H. Flentje et al.

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Authors' response to reviewer #2:

We are greatful for the reviewer's helpful comments

General reply:

We agree that this article must start a quantitative discussion of the contributing sources of uncertainty including estimations of their magnitude, relevance and discuss possible ways around. At the time being, however, this is work in progress as presently existing ceilometer networks are upgraded (as far as possible) from cloud height monitoring to aerosol monitoring. The community relevance follows from urgent requests from ministries of transport, aviation advisory and environmental security centres as well as WMO (e.g. GAW office) to foster scientific discussion on ceilometers' newly recognized potential contribution to the envisioned overarching international aerosol observation network part of which will be GALION.

Triggered by the Eyjafjöll eruption, ceilometer networks' mandate is to evolve towards a 24/7 aerosol plume alerting tool and to integrate into existing (inter)national aerosol observation networks. As this process will take several years, we consider it timely and important to highlight the potential of ceilometer networks in this context, even initially (unavoidably) with not elaborate characterisation – of course this limited scope has to be adequately claimed and the basic uncertainties and evolution paths must already now be discussed and outlined.

Thus our revision will:

- summarize and estimate the magnitude of uncertainties involved in ceilometer data evaluation at levels 0, 1,etc., based on literature, sensitivity studies and the signal/noise ratio

- clarify that the quantitative information about aerosol layers is not derived from the ceilometers, but stems from indispensable additional measurements

- focus our statements to the benefit achieved additionally by the use of ceilometers – in a network - rather than compete with lidars and drown in the complex bunch of considerations which will be discussed within the community during the next months and years.

- provide Germany-wide overview maps of backscatter intensity sections as zoomable electronic supplement files instead of stamp-size figures

- include a section on enlarging the footprint of lidar extinction profiles by use of ceilometer data for sufficiently coherent and passive plumes

- weaken the statements about estimated mass concentrations of the ash layer in a



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way that mass concentration were estimated to be of the order of up to 1 mg/m$^3$ which is not in contradiction to the values observed by the lidars.

Point by point:

Concerning multiple publication of results: After revision, the published ACP article by Flentje et al., 2010, does no more present results from the DWD ceilometer network but only refers to the measurements at Hohenpeißenberg. Thus the essential strength of cheap robust ceilometers, to enable an affordable synopsis of widespread aerosol profiles with high spatial coverage, is a novel aspect in this article that has not been previously published. A separation of the complex tasks of quantifying all uncertainties, into workpackages, executed by different groups, is obvious as is their assignment according to competence and experience. For this reason EARLINET groups were and will be engaged by the DWD to support the scientific development, characterisation of limitations and a subsequent acceptance of ceilometers for a final integration into aerosol observation networks.

3647/20: ok, will we rewritten -> The CHM15k provides profiles of total backscattering (particle+molecular) in an atmospheric column as described by the elastic backscatter lidar equation. Solving the lidar equation for the backscatter coefficient profile is discussed in the lidar literature \citep{Fernald84, Klett81, Klett85, Boeckmann04}. In case of elastically backscattered signals it requires independent information on the backscatter-to-extinction ratio (lidar ratio (LR) profile) and on the backscatter coefficient at a reference height. As mostly no height resolved particle information is available, the LR is usually taken from corresponding closure studies \citep{Mattis04, Mueller07, Papayannis08, Pappalardo10} and regarded as height-independent. For optically thin aerosols this causes relatively small errors scaling with their optical thickness. . .

3647/27: ok, this needs to be improved. We will discuss the height dependence of the LR using the example of the forest fire layers above the optically dominant PBL. In future (no more feasible for this study) the inversion algorithm will be expanded to



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accept more than on LR, as this is indeed a critical issue in deriving the extinction profile and cannot be solved without additional information. For the time being we will provide an error-range estimate and discuss corresponding hitherto literature results.

3648/10: corresponding discussion will be added -> obviously, (high altitude) contributions below the ceilometers SNR limit are missing and too large noise causes problems anyhow. But before purchasing, comparisons of JENOPTIK CHM15k, VAISALA LD-40 (ceilometers) and the DWD Raman lidar RAMSES have been performed at the DWD observatory Lindenberg. There the CHM15k proved to be capable to clearly detect thin Ci clouds at 12 km altitude with optical thicknesses less than 0.03. This constitutes an upper limit for contributions missing due to (high) aerosol layers. Part of this is shown in the ILRC 2010 abstract of Frey et al. and will be cited.

3651: the comparisons will be performed more quantitatively in order to yield an evaluation of the geometrical and optical information content of the ceilometer data.

3656: Yes. This is a sanity check of the profile rather than a validation of the absolute Extinction integral. The AOD from the sun photometer (SP) has been used to find the right backscatter reference value so that the integrated extinction = AOD of the ceilometer fits the SPs AOD. Then it was compared to the lidars backscatter profile. So the correspondence of the ceilometer's and SP's AOD is trivial.

3657: An obvious question – discussion like this will be added: The interpolation of profiles from lidar anchor stations with ceilometers will be feasible for aerosol plumes which are coherent on scales of the ceilometer network mesh-width. During the Eyjafjöll event (and in other cases as well) we recognized even details of the primary ash layer subsequently at different stations when crossing Germany. This means that the ceilometers are (at least in this case) close enough to each other to track internal changes of plumes and enable to link ceilometer and lidar observations. However, a thorough synopsis is a complex (kind of assimilation) issue which requires specialist efforts, planned e.g. for the upcoming German aerosol observation network. First steps are ongoing but not yet mature enough to be reported. For example simple interpolation between ceilometer and lidar stations is largely complicated or even useless in presence of clouds or relevant mixing/stirring. Against this, the footprint of precise extinction profiles measured by lidars may be enlarged significantly if a layer is as coherent as the volcanic ash on April 16/17, 2010 (c.f. corresponding figures which will also be supplied as zoomable electronic supplementary files to provide reasonable detailed overview maps). In Germany, Raman lidars are operated in the north, west, east and south such that interjacent ceilometer profiles allow to follow the identity of individual layers/plumes between a pair of lidar stations regardless of the transport pattern (if no substantial changes occur). More anchoring observations are available Europe-wide and are foreseen in specific occasions by means of aircraft-, drone, balloon- or dropsonde-borne in-situ instruments. The following topic then will be the user/application-oriented data processing and visualisation – i.e. a volcanic ash advisory centre needs information in a different way and at different accuraqcy than an environmental agency willing to subtract Saharan dust contribution from EU-legislated PM10 exceedances.

Simultaneously, the DWD (like other European) ceilometer network will be extended and upgraded. The manufacturer envisions the development of a depolarisation channel. If available, part of the network instruments will be equipped with it. For part of the instruments the optics module may be exchanged (already available) in order to reduce the overlap distance from about 1200 m to 150 m. At present, AOD measurements are available at only few stations (e.g. Hohenpeißenberg, Lindenberg, Hamburg). Several more will be upgraded and global radiation measurements will be investigated for their applicability (c.f. Gueymard, J. Appl. Met, 1996).

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Interactive comment on Atmos. Meas. Tech. Discuss., 3, 3643, 2010.