Atmos. Chem. Phys. Discuss., 9, C6762–C6783, 2009
www.atmos-chem-phys-discuss.net/9/C6762/2009/

Atmospheric
Chemistry
and Physics
Discussions

Interactive comment on "AMALi – the Airborne Mobile Aerosol Lidar for Arctic research" *by* I. S. Stachlewska et al.

I. S. Stachlewska et al.

iwonas@igf.fuw.edu.pl

Received and published: 5 November 2009

We would like to thank the Anonymous Referee # 2 valuable suggestions and comments, which helped us to improve this paper and to make it more concise and better structured. In the following we give detailed answers to the issues raised.

***

General comments

Referee: This paper provides a very detailed presentation of the airborne lidar and the data retrieval schemes. The level of detail is appropriate in case of the instrument description but should be extended in case of the iterative airborne inversion section.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Authors: The iterative airborne inversion section is extended as requested.

Referee: Several details discussed in the frame of the data analysis are well known and should be excluded to make the paper concise and more readable.

Authors: The data analysis section is rewritten and some of its parts are excluded according to the Referee's suggestions.

Referee: The presented instrument comparison with the KARL lidar shows only one case study and should be extended to give more credibility to the presented results. A detailed error assessment and a validation using independent instruments are missing.

We added the error discussion and gave references for the intercomparison and validation studies with in-situ instruments (Stachlewska et al. 2006c, Gayet et al. 2007, Lampert et al. 2009), other passive and active remote sensors (Stachlewska et al. 2005, Stachlewska 2006, Stachlewska and Ritter 2009), and models (Stachlewska et al. 2006a, Doernbrack et al. 2009).

Referee: The structure of the article needs to be revised.

Authors: It is revised, e.g. now chapter 3, chapter 4 and section 5.1 are combined to a one drastically shortened (< 4 pages). Former chapter 5 is now containing subsections: 1. the AMALi and the KARL intercomparison, 2. the iterative approach (were section 4.2.2 is now included) and 3. the combined nadir-aiming and zenith-aiming approach (former section 4.3). The eye-safety chapter is shortened and moved to an Appendix (however, we consider removing it).

Referee: The paper is recommended for publication subject to mandatory revisions which in my opinion include the shortening of the article and the revision of the error assessment / sensitivity analysis as stated below.

Authors: Thank you, we hope to fulfill these requirements.

Specific comments

Introduction:

Referee: p. 18747, 20: How was the system validated before the Artic campaigns?

Authors: We will consider to write more in detail about the validation, e.g. that prior to the ASTAR 2007 campaign (after the implementation of the THG crystal), we operated the AMALi next to the ComCal (Compact Cloud and Aerosol Lidar, description of the ComCal in Immler et al. 2006) in vicinity of Bremerhaven were both lidars observed the same boundary layer and cirrus structures.

Immler F., I. Beninga, W. Ruhe, B. Stein, B. Mielke, S. Rutz, Ö. Terli, and O. Schrems, A new lidar system for the detection of cloud and aerosol backscatter, depolarization, extinction and fluorescence, Reviewed and Revised Papers Presented at the 23rd International Laser Radar Conference (ILRC 2006), 1, 35–38, 2006.

Referee: A brief overview of recent airborne lidar developments should be given.

Authors: So far we considered mentioning the following airborne backscatter lidar systems:

POLIS - POrtable LIdar System, MIM-LMU / GCTO, Germany Modular design for 3 configurations: two backscatter signals at 355 nm and 532 nm, or backscatter at 355 nm and its Raman N2 shifted signal at 387 nm, or backscatter and depolarization at 532 nm or 355 nm. Was employed on board Cesna 207 and Dornier 288.

Heese, B., V. Freudenthaler, M. Seefeldner, M. Kosmale, M. Wiegner 2004, First results from the portable lidar system POLIS - Proceedings of the International Laser Radar Conference, Matera, Italy.

Heese, B., V. Freudenthaler, M. Seefeldner, M. Wiegner 2002, POLIS - A new POrtable LIdar System for ground-based and airborne measurements of aerosols and clouds, Proceedings of the International Laser Radar Conference, Québec, Canada.

CPL - Cloud Physics Lidar, NASA, USA Besed on 355, 532, 1064 nm and depolarization at 1064 nm, high repetition rate, low pulse energy transmitter, photon-counting detectors, nominal FOV 100 microrad, vertical resolution 30 m, horizontal resolution 1 s (∼200 m at nominal NASA ER-2 speed of 200 m/s)

McGill, M., D. Hlavka, W. Hart, V. S. Scott, J. Spinhirne, and B. Schmid (2002), Cloud Physics Lidar: instrument description and initial measurement results, App. Opt., 41, no. 18, 3725-3734.

McGill, M.J., D.L. Hlavka, W.D. Hart, E.J. Welton, and J.R. Campbell (2003), Airborne lidar measurements of aerosol optical properties during SAFARI-2000, J. Geophys. Res., 108, doi: 10.1029/2002JD002370.

ALEX - Aerosol LIDAR Experiment, DLR, Germany 355, 532, 1064 nm, 10 Hz, FOV 1mrad

Moerl, P., Reinhardt, M.E., Renger, W.. and Schellhase, R., The use of the airborne lidar ALEX-F for aerosol tracing in the lower troposphere. Contr. Atmas. Phys., 45.403-410, 1981.

Renger, W., Kiemle, C., Schreiber, H. G., Wirth, M., and Mörl, P.: Correlative measurements in support of LITE using the airborne backscatter lidar ALEX, in: Advances in Atmospheric Remote Sensing with Lidar, edited by Ansmann, A,. Neuber, R., Rairoux, P.,and Wandinger, U., Springer-Verlag, Berlin, 165–168, 1997.

LEANDRE, France 532 nm & depol, 1064 nm

Cyrille Flamant, Jacques Pelon, P Chazette, Vincent Trouillet, P Quinn, R Frouin, D Bruneau, J.-F Leon, T Bates, J Johnson, J Livingstone T, Airborne lidar measurements of aerosol spatial distribution and optical properties over the Atlantic Ocean during a European pollution outbreak of ACE-2,Tellus (2000), Volume: 52B, Pages: 662-677

LAUVA - Lidar Aérosol UltraViolet Aéroporté, CEA/CNRS, France Installed on ultra-light airplane for atmospheric applications and canopy measurements. Large footprint (∼2.4m diameter from 300m flight altitude). Based on 355nm wavelength, 16mJ, 20Hz

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

but eye-safe.

Chazette P., J. Sanak, and F. Dulac, New approach for aerosol profiling with a lidar on board an ultralight aircraft: application to the African monsoon, Multidiscipl. Anal. Environ. Sci. Technol. 41, pp. 8335-8341, 2007.

Chazette P., Sanak J., Raut J.-C. and S. Berthier, Mini-lidar for balloon-borne and aircraft-borne measurements, 24st International Laser Radar Conference (ILRC24), 23-27 June 2008, Boulder, CA, USA, 2008.

Cuesta J., P. Chazette, J.Sanak, T.Allouis, S.Durrieu, P.Genau, C. Flamant, and P. H. Flamant, New airborne lidar observes forest canopies, SPIE Newsroom. DOI: 10.1117/2.1200909.1732, 2009.

Instrument description:

Referee: Figure 2 can be left out because it does not provide relevant information.

Authors: Fig.2 is removed, the right hand side photo of the Fig. 2 (showing integration of the AMALi on board Polar 5 in zenith-aiming configuration) is moved to the Fig.1 (on request of the Referee #3). The caption for Fig.1 is changed to: ‘The AMALi in a nadir-aiming configuration on board the Polar 2 aircraft (left) and in a zenith-aiming configuration on board the Polar 5 (middle). The main AMALi elements are the optical assembly (1) with it’s interior (photo on the right), laptop (2), safety breaker box (3), laser control and cooling unit (4), and transient recorders (5).’

Referee: Figure 3 (left) should be larger and Figure 3 (right) can be left out. The differences in the setups can be explained in the caption. Figure 3 caption: ‘22. PMT for perpendicular 355nm detection’. The word ‘perpendicular’ is misplaced. This detector measures both perpendicular and parallel polarization components at 355 nm.

Authors: It is done as suggested. Only Fig.3 left remains and is enlarged. The caption for Fig.3 is changed to ‘The AMALi optical assembly with schematically drawn ray-tracking at 532nm (green) and 1064nm (red). The numbers indicate the main com-

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

ponents in the assembly; 1.laser head 2.directing mirror in piezo motor 3.window with Brewster's angle 4.off-axis parabolic mirror 5.first folding mirror 6.pinhole 7.second folding mirror 8.achromatic lens 9.beam splitter 10.interference filter for 1064nm channel 11.APD for 1064nm detection 12.interference filter for 532 nm channel 13.polarizing cube 14.thin film polarizing filter 15.PMT for perpendicular 532nm detection 16.PMT for parallel 532nm detection 17.optical bench 18.springs 19.posts 20.base plate. In present configuration the IR detection channel is replaced with the UV channel comprising interference filter and PMT for 355nm detection'.

Referee: p. 18751, 17: 'The waveplate is specially designed for 532nm and 355nm and shifts the polarization of the 532nm wavelength by lambda/2 to match the polarization of the 355nm wavelength, shifted by lambda.' The wording should be changed: The dual waveplate rotates the polarization of the 532nm wavelength to match the polarization of the 355nm wavelength.

Authors: It is changed as suggested to 'The dual waveplate rotates the polarization of the 532 nm wavelength to match the polarization of the 355 nm wavelength.'

Referee: How is the assembly of waveplate and polarizer adjusted? Can you comment on the degree of linear polarization of the transmitted 532 nm beam?

Authors: To clarify this point we add following sentence 'Prior to installation measurements of the laser beam shape, laser energy and degree of polarization using rotating lambda/2 plate were made. Output polarization of the 532nm was vertical in (x,y) with value of 99.9%. The 1064 nm was elyptical. To assure that the polarization of the 532nm remain unchanged when the laser beam is emitted via the window, the latter one was used at the Brewster angle and its position was set for strongest transmission. After the integration of the THG crystal, the linear polarization at 532 nm was found to be poor (> 90%). Therefore, additionally to the dual wavelength waveplate, a Glan Taylor polarizer was included. The waveplate was adjusted by maximizing the signal at the 532 nm parallel detector and minimizing the signal at the 532 nm perpendicular detector of the AMALi system. The Glan Taylor polarizer was then adjusted to minimize the signal at the 532 nm perpendicular detector. Although the degree of linear polarization of the transmitted beam was not measured after the adjustment we beleive it was high as due to the extinction ratio of the Glen Tylor polarizer of 5×10-5.'

Referee: p. 18752, 10: What is the required SNR? Does it vary from case to case?

Authors: To clarify this we add the following explanation on page 18752 in line 11: 'In the case of the AMALi system a SNR of 15 leads to errors of 5% in the determination of the backscatter ratio, which is acceptable. The SNR does not vary from case to case as we do not modify measurement parameters, i.e. the laser runs stable and the high voltage applied to the PMTs is kept unchanged. Hence, both the signal strength and the SNR are very similar from case to case. At a SNR of 15 or higher the total error in the retrieval of the backscatter coefficient is not dominated by the noise but it is dependent on the choice of the the boundary condition value, the precision of the atmospheric density profile and the choice of the lidar ratio. When the boundary condition (with the lidar constant C known) can be obtained using the iterative method described in this paper and the atmospheric density profile is retrieved from radiosonde launch in Ny Ålesund, only the choice of the unknown lidar ratio will be the dominant source of errors for the AMALi retrievals.' Further on page 18759 line 17 we replace 'sufficient signal-to-noise ratio' with 'SNR above 15' to avoid confusion and on page 18760 line 6 we cancel ' an acceptable' because it is now explained on p18752.

Referee: Detection range limitation: This chapter better fits after the description of the receiver system.

Authors: It is moved as required.

Referee: Eye-safety constraints: This section should be shortened significantly because it provides no scientific content. From a technical point of view it will suffice to mention that the instrument parameters and the values of the MPE go along with the respective law and regulations.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Authors: Actually, we consider the eye-safety calculations an important detail which can be of interest for technically oriented persons and a good reference for present/future airborne lidars. Indeed, this calculation do not contain scientific intent, so we shortened it and moved into an Appendix of this paper. However, after the second comment of the Referee #1 we consider removal of this section.

Referee: Receiver subsystem: p. 18755, 27: For clarity: Is there a benefit of a non circular aperture?

Authors: This is misleading and to clarify we replace 'In the AMALi system, it is not necessary to use an aperture that is completely rotationally symmetric, and hence we could use the off-axis optics to minimize the system size weight and costs, and at the same time to maximize its efficiency' by 'Generally for backscatter lidars it is not necessary to use a primary mirror that is completely rotationally symmetric. We used an off-axis primary mirror which was cut off a larger parabolic and rotationally symmetric mirror in a way that the focal point of it is outside the mirror and not in the center of the mirror. If we had used a symmetric parabolic mirror we would have to face astigmatism problems.The off-axis mirror itself has rotationally asymmetric aperture but it gives a rotationally symmetric aperture stop (pinhole). This choice assures a diffraction limited optical system without astigmatisms and at the same time it allows keeping small the lidar dimensions (size and weight) due to a compact folded optical design.'

Referee: p. 18757, 12: Can you comment on the overall depolarization extinction ratio, i.e. the minimal depolarization cross talk?

Authors: The cross talk contribution of the parallel 532 nm channel on the perpendicular 532 nm channel is 10-3 % and further reduced to 10-6 % by using the thin film polarizing filter.'

Referee: p. 18757, 26: What is a 'double plain mirror' ?

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Authors: To clarify we replace ‘A double plain mirror, with high reflectance for the two lidar wavelengths in use is mounded ...’ with ‘A planar mirror which is highly reflecting for the two wavelengths in use is mounted’

Referee: p. 18757, 27: Change ‘mounded’ to ‘mounted’

Authors: It is done.

Data acquisition subsystem:

Referee: p.18758, 12: The wording should be concretized: The lidar system provides highly resolved measurements of the spatial distribution of aerosol and clouds . . .

Authors: It is changed as suggested.

Referee: p.18758, 15: Do the laptop computer specifications have to be mentioned?

Authors: Specifications are reduced but most important we want to keep to point out that for the AMALi even for airborne applications in the Arctic there is no need to use an expensive and difficult to dismount industrial computer.

Referee: p.18758, 22: ‘For the detection of the 1064nm channel a Peltier cooled Si Avalanche Photo-Diode (APD) was used, and Hamamatsu R7400 photomultipliers (PMT) for the detection of the 355nm channel and the two 532 nm channels for the parallel and perpendicular component.’ This sentence fits rather in section 2.2.

Authors: It is moved to section 2.2 as suggested.

Referee: p.18759, 20-28: This paragraph can be moved to section 2.1.1. Again, please specify the acceptable SNR. A table listing typical integration times to achieve a specific SNR in the different modes of operation would be beneficial. It is confusing to read about different combinations of measurement range, SNR, and integration time at different places in the manuscript.

Authors: This paragraph is moved to section 2.1.1. The SNR is specified. As suggested by the Referee # 1 and Referee # 2 a table is now provided within the paper. It summarizes the different AMALi configurations, evaluation schemes (with references), and their limitations. Please look at this Table via ACPD Interactive Discussion were it is posted as a separate Authors Comment.

Quick-look data processing and display:

Referee: This section should be left out because it does not provide any scientific content. Figures 5 and 6 can be left out. It is worth to note that the on board visualization enables pathfinder missions during coordinated or sequenced research flights. This can be said in the introduction there is no need for an own chapter.

Authors: Concerning this chapter we removed it and we now give a short comment on the online display in chapter 'Data acquisition subsystem'. Concerning the figures we think that the online display is a very important and characteristic property of the AMALi and that there should be at least one figure showing these capabilities. Hence, we left two bottom screens of Fig. 6 which illustrate the ability of the quick-looks to detect an invisible cirrus cloud. The caption of the Fig. 6 is changed to 'The quick-look displays of the AMALi on-line software for the zenith-aiming configuration on board the Polar 2 aircraft. We show here the display of the range and background corrected signals evolution at 532 nm and the depolarization ratio at 532 nm which is provided in real-time during the flight. These quick-looks allowed for an 'in flight' detection of an ice cloud at 3 km.'

Referee: Sections 3.1, 3.1.1, and 3.2 contain basics that are all well known and should be shortened to the essential equations. The heading of section 3 is not applicable: There are no data evaluation algorithms described in this section. I suggest to combine sections 3 and 4.

Authors: Following the suggestions of Referee #1 and Referee #2 we reduced section 3 and combined it with section 4 and section 5.1 under the new heading 'Data evaluation methods'.

Qualitative and quantitative data analyses:

Referee: p.18764, 15: There is no need to paraphrase ‘range corrected signal’ and ‘particle backscatter /extinction coefficient’. These terms are more common and self-explanatory than ‘first/second type end-product’.

Authors: As suggested the terms ‘first / second type end-product’ are removed.

Referee: Sections 4.1, 4.1.1, 4.1.2, 4.2, 4.2.1 predominantly contain basics that are well known and should be left out. A table can be made listing the different modes of operation (ground-based zenith, ground-based horizontal, airborne nadir, airborne zenith) together with the respective retrieval algorithms and an appropriate reference.

Authors: As we already mentioned such a table summarizing the AMALi’s configurations, evaluation schemes and limitations is added to the paper and posted on the ACPD Interactive Discussion as a separate Authors Comment.

Nadir-aiming iterative airborne inversion:

Referee: p.18768, 26: ‘Using this approach the backscatter coefficient profiles are calculated from these profiles using an assumption of the lidar ratio B(h)’. The wording should be changed: . . . are calculated from the profiles of attenuated backscatter using . . .

Authors: As suggested we replace ‘these profiles’ with ‘the profiles of attenuated backscatter’.

Referee: How is the lidar constant C determined? Later on it is mentioned that C is determined using collocated Raman lidar measurements. How is the relative accuracy of 7% achieved, how many flight legs over KARL were analyzed?

Authors: Both lidar constant C_AMALi and C_KARL were found experimentally for seven overflights of the AMALi over the ground based KARL during the ASTAR 2004 and SvalEx 2005 campaigns in a stable clean and polluted weather conditions. The

KARL's signals (elastic and Raman) were analyzed according to Ansmann et al. 1992 to obtain the extinction coefficient profiles and compared with a photometer optical depth. The KARL's backscatter profiles were calculated with Klett-Fernald-Sassano approach with constraint on obtained optical depths. The lidar constant C_KARL was calculated at the height of aerosol free tropopause according to the method described in Appendix C in this ACP special issue 'ASTAR'. Then the C_AMALi was retrieved directly from the lidar equation. The spread of the lidar constant calculations was from 2.3% to 6.9% at different PMT setting. Hence, we took accuracy of 7%.

Referee: Please comment on the variability of C. How do pulse-to-pulse and long term power fluctuations of the flash-lamp pumped laser affect the constant C?

Authors: The AMALi was designed for the nadir-aiming measurements in low troposphere on board a unpressurised aircraft under a tough Arctic weather conditions. We made all efforts to build highly stable performance lidar which can be optimized, adjusted and kept with these settings throughout the campaign. We assess this stability by testing the pulse-to-pulse fluctuations of the lidar constant C before and during airborne missions in the Arctic. We utilize laser with a very low pulse-to-pulse variability (for 80% energy (NF 8) at 15 Hz laser power fluctuations are ∼10-2. We close the optical assembly entirely to achieve after 30 min the thermal stabilization at 35C (interior warm up due to switching on the laser) which is continuously measured using a temperature cube. The measurements are either started after the required warm up time or the higher errors are considered for first 30 min. Prior to the Arctic campaigns we tested the variability of the lidar constant C by taking ground based quasi-horizontal measurements during after the rain episodes during the night. The single shots measurements were acquired using software especially designed by LICEL Ltd. for the AMALi airborne applications. Signals were measured at an inclination angle of 2.5 deg aiming out from the laboratory window over about 6 h period (in total) obtained with two PMT settings (750V and 850V). The range and background corrected single-shot signals were plotted in a logarithmic scale and form the slope of the linear fit on these profiles the values of the lidar constant C were obtained. The spread of the lidar constant calculations was between 3% and 5% for the different PMT setting (the higher spread was obtained for the lower PMT setting). Similar was done for a period of about 30 min on one day of the single-shot horizontal ground-based measurements performed in the Arctic the lidar constant spread of ~2% for high (850V) PMT setting. For calculations using a method described in Stachlewska and Ritter, 2009 again the higher spread was obtained for the lower setting of the PMT voltage (2.3% to 6.9%). As for the long term power fluctuations of the flash-lamp we never considered this a problem. We are aware of the fact that this is a crucial issue for the regular long term measurements with the lidar. The AMALi is not used for monitoring of the atmosphere but for applications during dedicated campaigns of a duration of a month or two at most. We simply make sure that before each campaign the flashlamps are exchanged. As mentioned above, the fact that very similar lidar constants were measured in different years and with the different PMT's settings (1.43*e13 to 5.3*e13) show that no major drop of laser power occurred during measurements.

Referee: How do sensitivity variations of the detectors affect C?

Authors: The sensitivity variation on the detectors surface was of no concern. After the test described above no adjustments of the optical elements nor of the interference filters were applied during a particular campaign. During the campaign test flights we selected the final set of the measurement parameters (e.g. PMT voltage) and did not change these during the rest of the campaign to keep consistency. As optics realignment was not done during an entire campaign the position of the light focusing on the detector surface reminded unchanged. Also the optical assembly of the AMALI is entirely closed with shielding and its interior warms up to achieve the thermal stabilization there is no effect of the temperature on the optics and alignment of the system.

Referee: How does it change from flight to flight due to alignment?

Authors: As mentioned above we do not realign the optics during a particular campaign, so this is not an issue.

Referee: How is the depolarization of the 532nm channel accounted for?

Authors: As mentioned before we consider the cross-talk negligible (10-6 % parallel to perpendicular cross talk).'

Referee: Please comment on how the relative efficiency factor of both channels (cross-parallel / co-parallel) is determined.

Authors: We retrieve the linear particle depolarization ratio (Biele et al. 2000) by division of the perpendicular particle backscatter coefficient profile by the parallel particle backscatter coefficient profile. Both backscatter profiles being obtained with the Klett-Fermald-Sassano method with calibration in tropopause or the iterative airborne inversion described in this paper with calibration with the known backscatter coefficient value near the aircraft. Otherwise we use the calibration in clear air of 1.4% or less (depending on the spectral bandpass of the filter).

Referee: p.18769, 13: What is h_egc ?

Authors: This is typing error it should state 'h_gc'.

Referee: p.18769, 26: How is the transmittance of the layer [h_f, h_gc] estimated? You mentioned that the transmittance is assumed to be 1.

Authors: We do not estimate the transmittance for the application of the iterative method but we assume it is 1. We can do this because in the AMALi case the attenuation of the laser light within the overlap range is negligible in the Arctic atmosphere. Even if we assume an extinction coefficient of 6 e-5 per meter (very high aerosol load) and we take the maximum overlap range of 235 m, then the transmission term in the lidar equation T = exp (-2 * 6e-5 * 235) = 0.972 which results in only 2.8% loss due to extinction. This we consider as an error contribution to the iterative calculation of b_KFS(h_ref).

Referee: p.18770, 2: '. . . alpha-profiles calculated as precise as the choice of the lidar ratio B(h)'. The wording '. . . alpha-profiles with the uncertainty of the assumed lidar ratio' seems more appropriate.

Authors: It is changed as suggested.

Lidar signal calibration and instrumental constant estimation:

Referee: This section should be part of chapter 4.

Authors: It is. Actually, now chapter 3, chapter 4 and section 5.1 are combined to a one chapter, which is also drastically shortened (< 4 pages). Former chapter 5 is now containing following subsections: 1. the AMALi and the KARL intercomparison, 2. the iterative approach (were section 4.2.2 is now included) and 3. combined nadir-aiming and zenith aiming approach (which is a former section 4.3).

Referee: 1) Background light correction. This section can be shortened.

Authors: It is shortened.

Referee: 2) Rayleigh calibration. Is the instrumental constant for nadir observations determined by Rayleigh calibration during zenith observations?

Authors: No, the AMALi lidar constant was found experimentally for several atmospheric conditions accordingly the method described in Appendix C in Stachlewska and Ritter, 2009, this ACP special issue 'ASTAR'.

Referee: 3) Depolarization ratio calibration. It should be noted that the molecular depolarization ratio depends on the amount of rotational Raman scattering detected. The stated value is the minimum ratio. Moreover, even a small amount of background aerosol in the free troposphere can change the depolarization ratio significantly.

Authors: We added the Referee comment in the text.

Referee: p. 18772, 24: 'In our case both channels were checked for the cross talk in an experimental way, and it was found that cross talk is not an issue.' It is interesting to know how the cross talk was checked. If cross talk is no issue what is its value?

Authors: We added the explanation on p. 18757, 12: 'For the final installation the position of the polarizing cube was adjusted in the laboratory experiment and fixed in the optimal position to minimize the cross talk of the two 532 nm detection channels. Experiment was performed in dark conditions using the Nd:Yag laser itself. Energy of the laser beam was measured before it entered the detection block unit, then consecutively after the beamsplitter, after the interference filter, after the polarizing cube on the parallel and the perpendicular channels, and finally after the thin film polarizing filter on the perpendicular channel. Each optical element was successively adjusted and fixed. This adjustment gave on perpendicular channel contribution of 10-3 % parallel cross talk, finally reduced to 10-6 % by polarizing filter.'

Referee: 4) Lidar ratio assumption: Again, please shorten.

Authors: It is shortened.

Referee: p.18773, 17: 'An accurate inversion can be made only if the lidar ratio is adequately estimated' should be changed to 'An accurate inversion can be made only if the lidar ratio is known'.

Authors: It is done as required.

Referee: p. 18773, 26: 'In such cases the accuracy of the independently obtained information strongly depends on the quality of the inelastic measurement.' I suggest to skip this sentence.

Authors: It is removed as suggested.

AMALi intercomparison with KARL:

Referee: Why haven't both instruments been normalized between 4.8 and 5.0 km using the same backscatter ratio? There is no error analysis. Please add error bars to the measurements.

Authors: There is a mistyping in the text. We calibrated the AMALi in the range 4.8 km – 5 km with KARL's value of 1.26 (not 1.06). This value is corrected in the final version. Further, to avoid confusion we added the explanation: 'Generally, the calibration value made at the far range from lidar and in the clear air atmosphere where the lidar does not sense aerosol particles is to foretake (issue discussed in Klett, 1984; stable backward solution). As the KARL system provides the opportunity to calibrate the signal at the tropopause or even in the stratosphere, we used KARL's signals for the initial calibration (with backscatter ratio value of 1.05) to assure higher accuracy of the KARL's retrievals. At the altitude 4.8 km – 5 km where the AMALi profiles had SNR >15 we obtained realistic value of the KARL's backscatter ratio of 1.26 and we used this value to calibrate the AMALi's retrievals. It is worth noticing that although the Arctic is generally considered clear and sparse in aerosol the backscatter ratio 1.05 on that day would be too low for the free troposphere at 5 km.'

Referee: There is no error analysis. Please add error bars to the measurements.

In the case of the KARL at 4.8 km SNR about 140 leads to the error of the backscatter ratio < 0.01 due to noise. Similar holds for the AMALi. All remaining errors due to the choice of the lidar ratio, the choice of the reference value in the aerosol free stratosphere and the error in the air density profile are greater than the error due to noise in the signal. The errors added on the plots make them difficult to read. Hence, to clarify this we add the following explanation at the end of this section: 'None of the lidars have any specific problem with the raw signal. The error in the backscatter ratio due to the noise in the data is negligible (at 4.8 km < 0.01) and becomes weaker when the SNR becomes stronger, i.e. the closer it is measured from the lidar). The error due to the lidar ratio assumption is a main error source, by far. It affects both systems in the same way as we used identical and constant lidar ratio value of 30 sr (studied in detail by Sasano et al., 1985).'

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Referee: p. 18775, 15: More comparisons and statistics on the data correlation would be beneficial. Agreement of both instruments during only one case study provides only zeroth order credibility to the measurements. It is stated that the system was validated before the Arctic campaigns. The validation results could be added here.

Authors: We reckon that one example per case should be enough to illustrate the system abilities and hence we would rather not include more on the AMALI and KARL intercomparison. However, to fulfill the suggestion of the Referee, at the end of this section we add 'Further examples on the AMALi and the KARL intercomparison of their backscatter extinction profiles are discussed in Stachlewska 2006c, Ritter et al. 2006, Stachlewska and Ritter, 2009 (this ACP special issue 'ASTAR'). The AMALi results comparison with the in situ airborne measurements involving various cloud systems are discussed in Gayet et al. 2007 and Lampert et al. 2009.'

Referee: p. 18775, 16: Why is noise of no concern?

Authors: This is due to the high SNR. In the case of the KARL at 4.8 km SNR about 140 leads to the error of the backscatter ratio < 0.01 due to noise. Similar holds for the AMALi. All remaining errors due to the choice of the lidar ratio, the choice of the reference value in the aerosol free stratosphere and the error in the air density profile are greater than the error due to noise in the signal. The errors added on the plots make them difficult to read. Hence, to clarify this we add the following explanation at the end of the Section 5.2: 'None of the lidars have any specific problem with the raw signal. The error in the backscatter ratio due to the noise in the data is negligible (at 4.8 km < 0.01) and becomes weaker when the SNR becomes stronger, i.e. the closer it is measured from the lidar). The error due to the lidar ratio assumption is a main error source, by far. It affects both systems in the same way as we used identical and constant lidar ratio value of 30 sr (studied in detail by Sasano et al., 1985).'

Sensitivity study of the iterative airborne approach:

Referee: p. 18776, 5: 'permits the accurate estimation of'. Skip the word 'accurate'.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

This estimation is not accurate, because both the transmittance and the instrumental constant C are error-prone.

Authors: Word ‘accurate’ is removed as suggested.

Referee: p. 18776, 11: ‘Hence, the clearer the atmosphere and the better the knowledge of the molecular contribution to the extinction alphaËĘmol (for example from nearby meteorological sounding) the better the transmittance estimate, i.e. the lower uncertainty of the beta_h_gc calculation.’ This has been said before and can be skipped.

Authors: It is removed as suggested.

Referee: p. 18776, 26: How was C_A = (1.4 +- 0.1)*10ËĘ13 mVmËĘ3 sr with the relative accuracy of 7% determined?

Authors: The AMALi was designed and build in a way to assure low variation of the lidar instrumental constant C by assurig a stable and environment independent operation. Before the Arctic campaigns, this system was extensively tested in the laboratory and during several test flights for the stability of the operation (laser stability, temperature dependence, warmup time dependence, detector dependence, etc.) which gave confidence to the low variabilty of C. The lidar constant C was obtained using a method described in the Appendix C of Stachlewska and Ritter 2009, this ACPD issue ‘ASTAR’. The spread of the lidar constant calculations during the tests was from 2.3% to 6.9% at different PMT high voltage setting. The highest spread was obtained for the lowest applied PMT voltage. For more information of the lidar constant C please see the explanation given to Referee #4 (p.C6722, bottom line 5 up to end of p.C6723.

Referee: p. 18777, 5: Why did not you use the lidar ratio profile obtained by KARL for your retrieval?

Authors: the KARL’s lidar ratio profile is representative for a local vertical measurement at Ny Alesund which is a very specific location due to the orography influence (compare with Dörnbrack et al., 2009). Multiple inversion layers which are often observed in Ny Alesund are related to this orography (compare with Stachlewska and Ritter, 2009). They are not representative for the atmospheric conditions outside this fiord were we took the measurement on the investigated here day (and generally during the ASTAR campaigns).

Referee: The values listed in table 3 seem a little low especially in the case of pollution aerosol.

Authors: The lidar ratio value of 35 sr is not too little to be concerned as the aged polluted Arctic aerosol called the Arctic Haze as long as no pronounced soot component is mixed into this aerosol (compare with Ritter et al. 2004). The Arctic Haze predominatly consists of sulphate with a variing content of soot, depending on age internally or externally mixed (compare withy Hara et al., 2003). However, we added in Table 3 the error calculated for the case of the backscatter coefficient retrieval under an assumption of highly polluted aerosol characterised with lidar ratio of 60 sr which resulted in error Delta bata_part = 2,6 × 10–7 1/sr 1/m.

Hara, K., S. Yamagata, T. Yamanouchi, K. Sato, A. Herber, Y. Iwasaka, M. Nagatani, and H. Nakata (2003), Mixing states of individual aerosol particles in spring Arctic troposphere during ASTAR 2000 campaign, J. Geophys. Res., 108(D7), 4209, doi:10.1029/2002JD002513.

Referee: Figure 8. A flight path could illustrate the place and range of the measurement.

Authors: We added the flight path figure.

Referee: What I miss in this sensitivity study is a graph which shows the influence of several error sources (e.g. transmittance estimate, lidar ratio estimate, instrumental constant errors, depolarization errors) on the profiles of aerosol backscatter and extinction.

Authors: To clarify we added the explanation: 'The error of backscatter coefficient depends linearly on the transmission term, so that any difference between T=1 and T=0.99 can be neglected (error 1-3%) for the iterative method. Due to the iterative aproach the boundary condition can be estimated dependably on the accuracy of the determination of the lidar constant C (error 2-7%). Hence, only three sources of errors remain: a) error due to the choice of the molecular contribution – error proportional to the air density in our case known from radiosonding (error ∼5%), hence this error is negligible. b) error due to the signal noise in the lidar data – this error for SNR > 15 is negligible (error ∼5%). c) error due to the assumption of the lidar ratio LR (detailed study by Sassano, 1985) – this error dominates the accuracy of the solution, however, as the partial derivative delta beta/ delta LR can be calculated this error can be estimated (results are given in Section 5.3).'

Conclusion:

Referee: p.18778, 5-9: This has been already said in the introduction.

Authors: It is removed here.

Referee: p.18778, 13: I doubt that an iterative retrieval based on assumptions can be 'precise'.

Authors: We removed 'is precise and'

Referee: p.18778, 17: Here, as well, 'knowledge' should be changed to 'estimate'.

Authors: It is changed as required.

Referee: p.18778, 21: Please specify the error of the backscatter ratio instead of saying 'These assumptions were found to be not too critical to retrieve an accurate backscatter'

Authors: Replaced by 'These assumptions were applied to the short range AMALi measurements taken under a stable Arctic atmosphere under a quasi-uniform air-mass

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

transport.'

Referee: p. 18778, 27: What are the relative deviations of the backscatter coefficients?

Authors: The errors of the particle backscatter coefficient beta_part are given as a function of a chosen lidar ratio LR in the Bernoulli differential equation (as in Klett, 1985), i.e. Delta beta_part = delta (Klett solution) / delta LR * Delta LR

Please also note the Supplement to this comment.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 18745, 2009.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper