Response to the comments of Referee #2:

First of all, we thank the referee for spending time and effort to perform a thorough review of our manuscript. Most of the comments were really helpful to improve the quality of our paper.

General comments on the lidar:

In the following, we give answers to the questions raised by the referee. Some specific statements have been used also to improve the respective parts of our paper:

The lidar presented in this article (with λ=532 nm as a shortest wavelength) can obtain information on aerosol particles larger than approximately 100 nm. The smaller the particle the weaker is its interaction with visible light. However, the lidar still does see the molecular background due to the high number concentration of air molecules. Therefore, a strict lower limit of particle size cannot be given. But as a rule of thumb for our Arctic conditions, aerosol particles smaller than 100 nm become difficult to see if their concentration is about 1000 cm^{-3}.

In the text, we basically talk about the depolarization ratio (see below) and the backscatter ratio. The backscatter ratio is dimensionless and is defined as the total backscatter coefficient (with contributions from molecules of clear air and aerosol particles, units: m^{-1} sr^{-1}) divided by the molecular backscatter coefficient, see Eq. for R_{532nm} in Appendix A of the paper. Hence, a value of R_{532nm} = 2 means that the aerosol particles contribute as much to backscatter ratio, as the molecules with their Rayleigh scattering do. In more absolute values: at ground level the molecular backscattering of the atmosphere at 532 nm is about 1.5 10^{-6} m^{-1} sr^{-1} and proportional to the air density.

One can derive an aerosol size distribution (assuming Mie theory) based on lidar observations if one have simultaneous measurements of the backscatter coefficient at 3 different wavelengths and the extinction coefficient (m^{-1}) at 2 additional wavelengths. The extinction can be derived for example by using the Raman-effect for molecules of Nitrogen present in the atmosphere. Such calculations are challenging and beyond the scope of the mobile AMALi detection chain, although they are possible with the multi-wavelength lidar KARL based at Ny-Ålesund.

The theory for deriving independent information on backscatter and extinction for lidars is explained in

A. Ansmann, U. Wandinger, M. Riebesell, C. Weitkamp, and W. Michaelis, "Independent measurement of extinction and backscatter profiles in cirrus clouds by using a combined Raman elastic-backscatter lidar," Appl. Opt. 31, 7113-7113 (1992)

The mathematically challenging (ill-posed) problem of the derivation of a size distribution was outlined by:

I. Veselovskii, A. Kolgotin, V. Griaznov, D. Müller, U. Wandinger, and D. N. Whiteman, 2002: "Inversion With Regularization for the Retrieval of Tropospheric Aerosol Parameters From Multiwavelength Lidar Sounding," Appl. Opt. 41, 3685-3699

and

Böckmann, C., 2001: Hybrid regularization method for the ill-posed inversion of multiwavelength lidar data to determine aerosol size distribution, *Applied Optics* **40**, pp 1329-1342

Unfortunately, large lasers, big telescope mirrors and very small field of views are required to retrieve the extinction from the aerosol-Raman lidar data, see:

P. Pornsawad, C. Böckmann, C. Ritter, M. Rafler, The ill-posed retrieval of aerosol extinction coefficient profiles from Raman lidar by regularization, Applied Optics, 47 (2008) 1649-1661

Thus we are left with the basic problem, that "size" and "concentration" cannot be detangled from the AMALi measurements. Roughly, a backscatter ratio of 2 at 3 km altitude corresponds to a backscatter coefficient of 1.0 10^{-7} m^{-1} sr^{-1} and this might be due to 200 particles per cm^3 of 0.2 µm radius or 10 particles per cm^3 of 1 µm radius. Therefore, the scattering efficiency sharply increases with particle radius in this range of sizes. If we made the assumptions that the aerosol particles under investigation have the same size, the same shape and the same chemical composition, then the quantity R_{532nm} - 1 (= β_{part}/β_{mol}) is directly proportional to the concentration.

However, with the conditions during the ASTAR 2004 flight over the orography of Spitsbergen the real aerosol distribution was really complicated. There, sea salt, ice crystals and the dust outflow from Adventdalen all entered together in the lidar signal. Our clearest profiles show a backscatter ratio of around 2 close to the ground. If we assume that this is predominantly due to sea salt we can estimate the extinction coefficient at the ground by assuming a lidar ratio of 20 sr according to:

S. J. Doherty, T. L. Anderson, and R. J. Charlson, "Measurement of the Lidar Ratio for Atmospheric Aerosols with a 180° Backscatter Nephelometer," Appl. Opt. 38, 1823-1832 (1999)

to be about 4.3 10^{-5}. Hence, we obtain a visibility of about 90 km with the lidar which documents that the undisturbed Arctic atmosphere is really clear.

Contrary, our high backscatter ratios $R_{532nm} \approx 10$ in 800 m altitude correspond to a particle backscatter of 1.27 10^{-5} $m^{-1}sr^{-1}$. As the particles are similar to desert dust particles and the depolarisation shows similar values as well, we can assume a lidar ratio of 55 sr according to:

Ansmann, A., et al. (2008), "Influence of Saharan dust on cloud glaciation in southern Morocco during the Saharan Mineral Dust Experiment", J. Geophys. Res., 113, D04210, doi:10.1029/2007JD008785.

As the result, we obtain a particle extinction (product of backscatter and lidar ratio) of 7.0 10^{-4} m^{-1}. If the particles were around 0.2 µm in radius this roughly corresponded to 7000 particles per cm^3 - again for larger particles a fewer number were sufficient.

So, this Adventsdalen event by far outreached typical Arctic haze events (which show around 200 particles of 0.2 microns, corresponding to a backscatter ratio of R_{532nm} = 2.5) in the vicinity of Spitsbergen, see for example

Ritter, C., Kirsche, A. Neuber, R., 2004: Tropospheric aerosol characterized by a Raman lidar over Spitsbergen, *ILRC22, ESA SP-561*, pp. 459-462

Regarding depolarisation: The laser in the AMALi lidar emits linearly polarised light at 532 nm. Spherical particles, according to Mie theory, do not alter the state of polarisation, while non-spherical particles almost always do. See: van de Hulst, H. C. "Light scattering by small particles" New York: Dover, 1981.

In the AMALi, the returning light from the atmosphere is separated by polarising beam splitter into the components "parallel" and "perpendicular" relative to the initial laser polarization. The depolarisation is simply the ratio of the signals "perpendicular" divided by "parallel". Due to the asphericity of the air molecules, the depolarisation of clean air is 1.4 %. Hence, a calibration of both channels in aerosol-free layers is possible without knowledge of the transmittance through all optical components in the lidar. Water clouds generally have very small depolarisation (unless they are so thick that multiple scattering occurs). As they are not perfectly spherical layers of water droplets they can have a depolarisation of about 0.6%. The highest depolarisation show cirrus cloud layers where values above 60% were found, especially at low temperatures.

Das, S.K., Chiang C.-W., Nee J.B., 2009: Characteristics of cirrus clouds and its radiative properties based on lidar observation over Chung-Li, Taiwan, Atmospheric Research, v. 93, iss. 4, p. 723-735

Typically, aged Arctic aerosol has a volume depolarisation of 2 – 5 % (see Hoffmann et al.), while desert dust shows a high depolarisation of 10 %, very similar to the values we found in Adventdalen. Depolarisation of more than 30% is due to cirrus clouds as described in Das et al., 2009.

A summary of aerosol/cloud statistics with depolarisation and backscatter values during the whole ASTAR2007 campaign was published in this same issue:

A. Hoffmann, C. Ritter, M. Stock, M. Shiobara, A. Lampert, M. Maturilli, T. Orgis, R. Neuber, and A. Herber: Ground-based lidar measurements from Ny-Ålesund during ASTAR 2007: ACP

as well in this issue in:

I. S. Stachlewska, R. Neuber, C. Ritter, G. Wehrle: AMALi – the Airborne Mobile Aerosol Lidar for Arctic research. ACPD 2009

A statistical overview and as well in this issue a detailed description of the AMALi system and its data evaluation schemes are given in:

I. S. Stachlewska, R. Neuber, C. Ritter, G. Wehrle: AMALi – the Airborne Mobile Aerosol Lidar for Arctic research. ACPD 2009

Typically, aged Arctic aerosol has a volume depolarisation of 2 – 5 % (see Hoffmann et al.), while desert dust shows a high depolarisation of 10 %, very similar to the values we found in Adventdalen. Depolarisation of more than 30% is due to cirrus clouds as described in Das et al., 2009.

It is difficult to assess a precise detection limit for lidar data as the lidar profile is a function of distance from the system. Stachlewska et al. (2009) determined a signal to noise ratio of the lidar profile to assure an evaluation with given error. In the case of this paper the biggest uncertainty of the depolarisation ratio retrieval is due to the calibration of the parallel and perpendicular signals which depends on the existence of aerosol-free layers. However, the only information we want to give here is a rough classification of aerosol due to its depolarisation.

Detailed Comments:

- p16443, L8: An additional sentence with number concentrations added.

- p16442, L20: valid point! The respective sentences are changed.

- p16444, L14: In the figure captions of Fig. 1 and 3 are hints. On the other hand, consulting online maps for readers of an online journal shouldn't be a problem to get orientation.

- p16446, L17: Unfortunately, only visual observations are available for this event. No in situ data for number and mass concentration exist.

- p16447, L 6: We added in appendix after the definition of R_{532}: "The backscatter ratio of 1 corresponds to the pure Rayleigh scattering by molecules of the air. In the Arctic typical values of backscatter ratio range from 1.01-1.6 for the clear free troposphere.". For Arctic haze in the free troposphere they can reach values up to 5 and near the ground up to 10. For the sea-salt aerosols in the Arctic marine boundary layer values range from 2 to 4 are found. For the Arctic subvisible clouds values reach up to 10 and for the optically thick water clouds they are exceeding 30, see above. The value R_{532} = 1.4 for altitude more than 400 m over ground comes from lidar observations at Ny-Ålesund (Hoffmann et al 2009). This is an average value for low tropospheric altitudes in the absence of clouds or aerosol layers and indicates clear air of the free Arctic troposphere.

- p16447, L16: Yes, this information can be retrieved from the caption of Fig. 4 and the location of respective profile areas in Fig 3b. The revised caption of Fig 3b explicitly points the reader to the Adventdalen.

- p16448, L10: First of all, the profile No 9 was averaged from six different samples in this area. Thus, extreme dust event which occurred at least during the 90 min of sampling time might explain the exceptional magnitude. Additionally, the particular location of the respective area with respect to the import of transported material from the different sources as stated in the text. As can be seen in the high-resolution MODIS images (not shown in the paper but available via the quoted webpage) the dust plume originating from the Adventdalen followed a curved trajectory at this location before it enters the Isfjorden.

- p16450, L5: the formulation has been changed: triangular is replaced by upward sloping layer. The white area mark regions with no data. This now stated in the figure caption.

- p16453, L3: The value of ρ^{α} = 3.2 10^{-3} kg m^{-3} was taken from Nivkovic and Dobricic (1996); it is now referenced in the text. Thanks for the careful checking of the unit!!

- p16457, L 23 This was a mistake: soot is nonsense and the term removed from the text.

- p16457,O28 – p16458, L1: The referee is right, we replace 'confirm that most of the backscattering particles consisted' with 'indicates existence'.

Fig. 2: We made the figure caption more expressive in order to point the reader to the west coast of Svalbard. As it is just a MODIS image taken from the web page, we have no means at hand to draw lat/lon grid or a scale. Alternatively, the figure could be removed completely.

Fig 3: The profile areas are associated with the boundaries set for calculating the average profiles and correspond to the values in Table 1.

Fig. 4-5: The oscillations in the volume depolarization are due the noise in the lidar signal.

Final remark: The number of figures has been reduced and, esp. Figs.5 and 6, have been redrawn.

The wind direction can be easily seen from the contour lines of the geopotential height in Fig. 1. The wind direction is always parallel to the contour lines and points in the direction when small values of the geopotential height are to the left.