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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Physical properties of High Arctic tropospheric particles during winter" *by* L. Bourdages et al.

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Below is our response to the detailed comments of Referee #1 (R1). The referee's comments are quoted, and our response follows. Please also see our "General Response" thread.

R1: "The authors present a winter climatology of four particle types at 80N, 86W (Eureka): aerosols, mixed-phase clouds, ice clouds and boundary-layer ice clouds. My recommendation of rejection is based on their apparent lack of an objective classification for the 4 particle types considered. We are given a one-day example in section 3, from which the manuscript immediately moves into the results of a 3 or 4 year climatology."

The classification scheme is described in Section 3 ("Methodology") of our manuscript, and clarifications to it are proposed in the "General Response". The classification scheme was made as objective as possible without presupposing the final result. The different categories are normally very clear in the measurement images, and this is demonstrated by inspection of Figure 3 in our paper. In the event of any mixing or uncertainty the data was not assigned a category. The statistical results that follow show how optical properties between categories are different, and also how they sometimes overlap. This overlap is real, and should be expected.

R1: "This is particularly troublesome because one of the main interesting findings is that small ice particles depolarize more than large ice particles - a counterintuitive finding. Yet we have little if any quantitative information on how the authors differentiate between large and small ice particles."

There is an entire section devoted to precisely this topic: "5.2 Mie theory computations of particle effective radius". The colour ratio determined from the measurements is converted into an effective radius using Mie scattering computations. Figure 9 shows the quantitative conversion of colour ratios to effective radius as determined from the model. High colour ratios imply large particles and low colour ratios imply small particles. A sensitivity analysis for different particle distributions was reported. The interpretation of the results for non-spherical ice particles is drawn from the work of Warren and co-authors.

R1: "I suggest the authors rescrutinize their classification scheme, describe it to the readers, describe the sensitivity to mis-classification, and evaluate it with data from other sites (SHEBA had a depolarization lidar, has the AHSRL being elsewhere?"

The categories are simple enough and applied with care so that mis-categorization is a non-issue. We categorized data using 1 km and 1 h resolution mask, and threw out bins that contained a mixture between categories (except aerosols). This approach limits interference between categories to a minimum, except for aerosols, which are

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described as ubiquitous in our manuscript and so are impossible to separate from the other types. We very carefully showed the impact of the aerosol interference on the other categories. These points would be clarified in any revision of our manuscript.

The SHEBA results were obtained with a less powerful lidar, and the kind of analysis we have done here would not be remotely possible with that instrument. The key feature of the AHSRL is that it obtains direct measurements of backscatter cross-section through its use of a molecular channel, which was essential for our analysis. An instrument like the lidar from SHEBA does not obtain such measurements.

R1: "Can data from other instruments be used to assess the AHSRL/MMCR-only classifications, such as a microwave radiometer for the mixed-phase classification, and the sun photometer for the aerosol classification?) before they resubmit this manuscript."

Depolarization lidar is a very well established technique for identifying mixed-phase clouds in the Arctic; see, for example, the paper by Intrieri and Shupe (2004, referenced in our manuscript) that used exactly the same approach. Sun photometers are of no use during the dark Arctic winter. The microwave radiometer provides a column-integrated measurement, and the condensed water content in a mixed-phase cloud is very low. The lidar/radar combination provides very clear classification information for our purposes, as shown by the example given in Section 3. More data would not be expected to result in significant re-classification, although it could lead to subdivisions of the current classification scheme. It is our opinion, however, the the simple classification scheme proposed, and the interesting results we have drawn from it, are essential to this paper.

R1: "- would recommend using winds from the radiosondes to assess how well boundary-layer ice clouds correspond to blowing snow."

This is not the topic of our manuscript. That result was established by the paper of Lesins et al. (2008).

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R1: “- the reflectivity of ice particles is actually a function of the 4th power of the ice particle size, rather than the 6th power, because of a density decrease with particle size increase (i.e. the Brown-Francis relationship, see also Matrosov et al. 2003 for further explanation).”

When we revise our manuscript, that information would be added. Note, however, that fourth power requires assumptions of the particle size distribution, which presupposes our results. In any event, the choice of power law would have no impact on our interpretation.

R1: “- the color ratio is not wholly independent of the number density as the particle size number distribution is still contained in the mean cross-sections.”

The mathematical formulation of the problem given in Section 3 (“Methodology”), which shows that the colour ratio is independent of the number of particles, has not been disputed. The sensitivity of the colour ratio to different particle distributions is explored in Section 5.2 (“Mie theory computations of particle effective radius”). From the different possible size distributions we considered, we identified a maximum systematic error in our particle effective radius measurements as +25%. Based on what we know about the particle size distribution (as discussed in the paper), the actual error is likely much lower.

R1: “- why the coarse vertical (1km) and time (1hr) resolution?”

We note first that this is an entirely different question from the measurement resolution we used, which was very high – 30 s and 15 m for the lidar. This high resolution is evident in the various distribution plots against altitude.

The 1 km and 1 hr resolutions are for the mask we applied to the data to categorize the different scattering events. The resolution used implies that there is at least 1 h in time and 1 km in space separation between the different categories. Masking at higher resolution would significantly increase the possibility for interference between

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categories, and so is not appropriate for our analysis. With an opportunity to revise our manuscript for ACP, we would clarify these points.

R1: "- does the study cover 3 or 4 years? 2005 to 2008 implies 4 years but 351 days total implies less."

There are only three complete winters between 2005 and 2008. As described in Section 4.1 ("2005-2008 data set") we used "the winter time months of December through March of 2005 to 2008".

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 7781, 2009.

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