Optical Properties of Arctic Aerosol during PAMARCMiP 2018

Konstantina Nakoudi [a,b], Kim Janka Müller [a,c], Christoph Ritter [a], Roland Neuber [a]

a) Alfred-Wegener-Institute Foundation for Polar and Marine Research, Telegrafenberg A43, D-14473 Potsdam, Germany
b) Institute of Physics and Astronomy, University of Potsdam, Potsdam, Germany
c) Carl von Ossietzky Universität Oldenburg, Ammerländer Heerstraße 114, D-26129 Oldenburg, Germany

Motivation

Aerosol strongly affect the radiation balance, especially in the Arctic where climate change is significantly faster compared to lower latitudes, a phenomenon known as Arctic Amplification [1], [2]. The interaction between aerosol and radiation can be either direct (scattering and absorption) or indirect (aerosol serving as cloud condensation nuclei and ice nucleating particles).Aerosol concentration in the accumulation mode exhibits an annual maximum in the Arctic in springtime, forming the Arctic Haze [3], [4], [5], [6]. In this work, elevated layers from the European Arctic are analyzed in terms of their optical and hygroscopic properties.

Observations

In the springtime of 2018, persistent elevated aerosol layers have been identified in the free troposphere over Ny-Ålesund as well as over Greenland Sea (Fig. 1). The research aircraft Polar 5 (P5) was flying from Greenland Sea towards Station Nord.

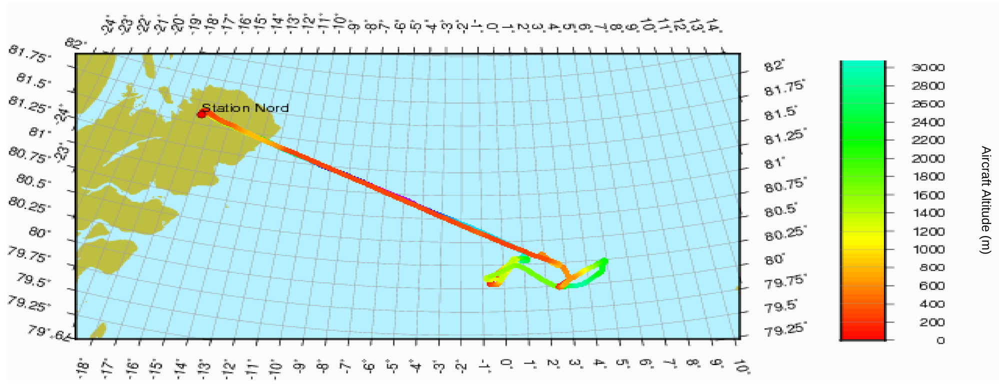

Fig. 1: P5 track on 2nd April, 2018.

Instruments and Methodology

AMALi is an elastic Lidar onboard P5. It provides backscatter profiles at 532 and 355 nm together with linear depolarization at 532 nm (temp. res. 5 min, vert. res. 7.5 m) [7]. During PAMARCMip2018 AMALi was used in zenith configuration.

KARL is a "3β+2α+2δ+2wv" system (temp. res. 2 min, vert. res. 7.5 m), located in Ny-Ålesund, Spitsbergen [8]. Retrievals of aerosol backscatter coefficient were performed according to the Klett method [9].

From March 1st until 13th radiosondes were launched from the same site at UT 5h, 11h, 17h, and 23h in order to determine additional properties as humidity, temperature and others.

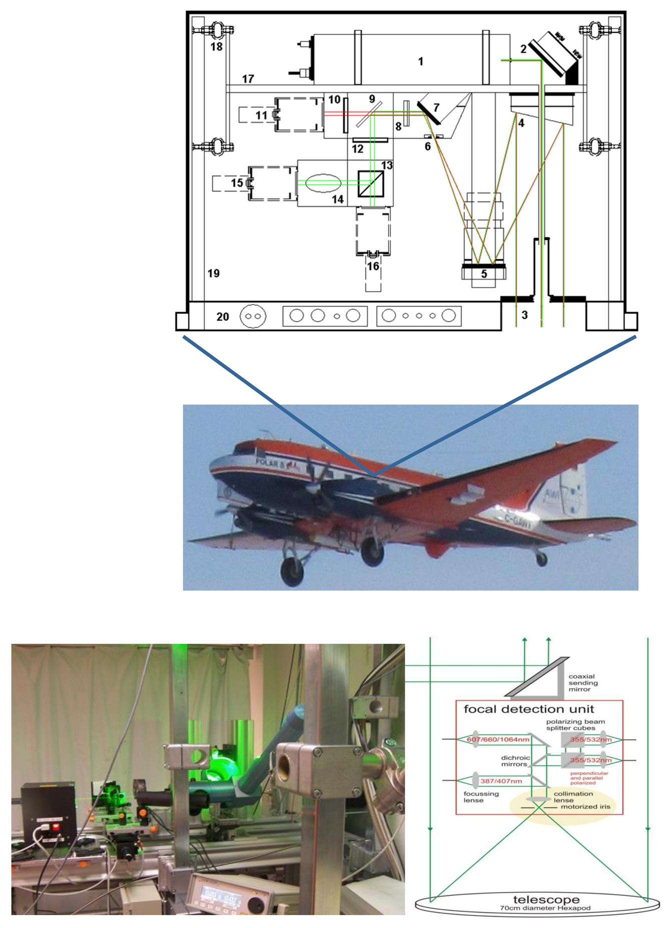

Fig. 2: Main components of AMALi (top) and KARL (bottom) Lidar systems.

Optical Properties of elevated layers

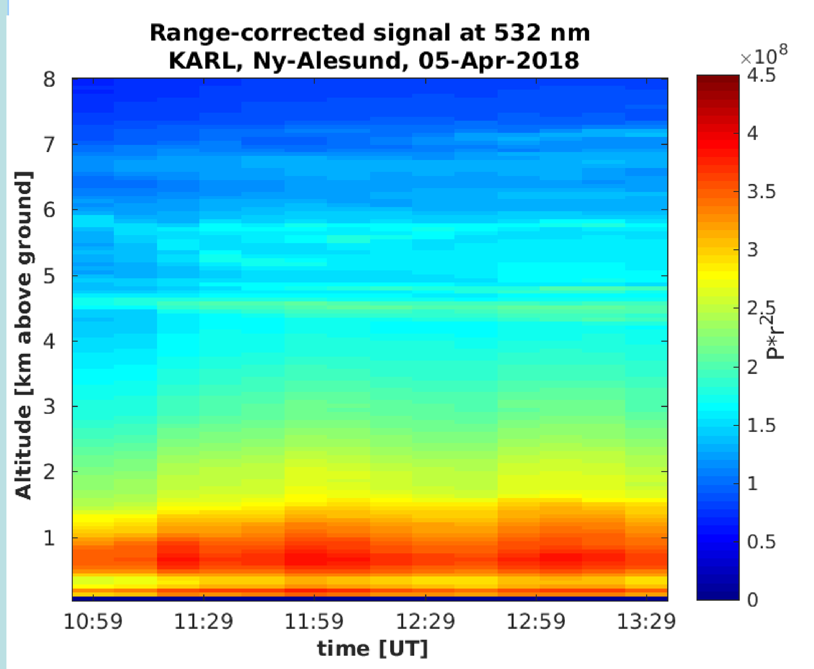

Fig. 3: Elevated layer in Ny-Ålesund.

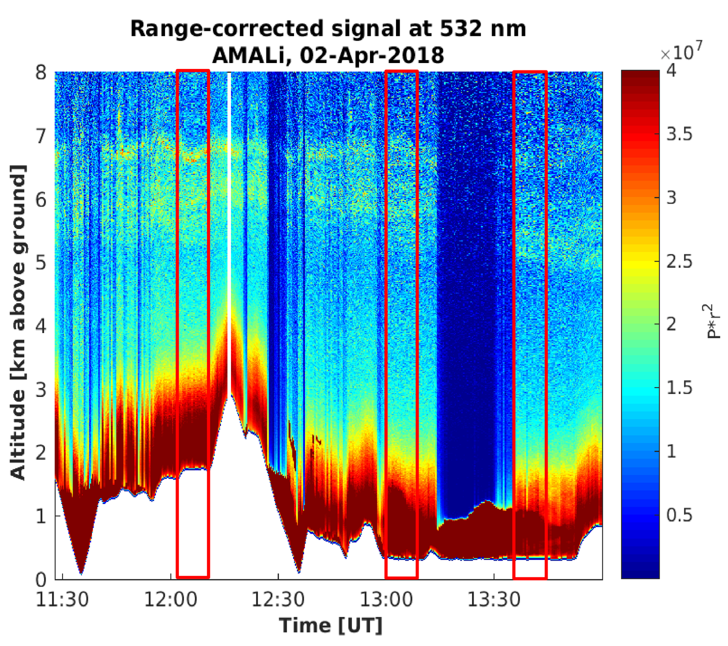

Fig. 4: Elevated layer over Greenland Sea.

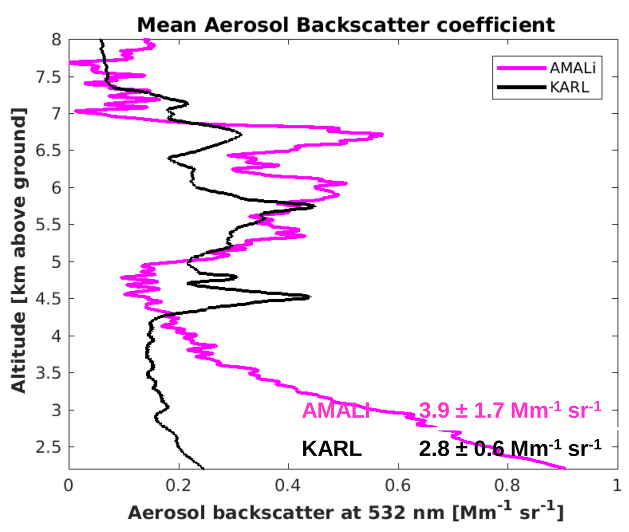

Fig. 5: Aerosol backscatter.

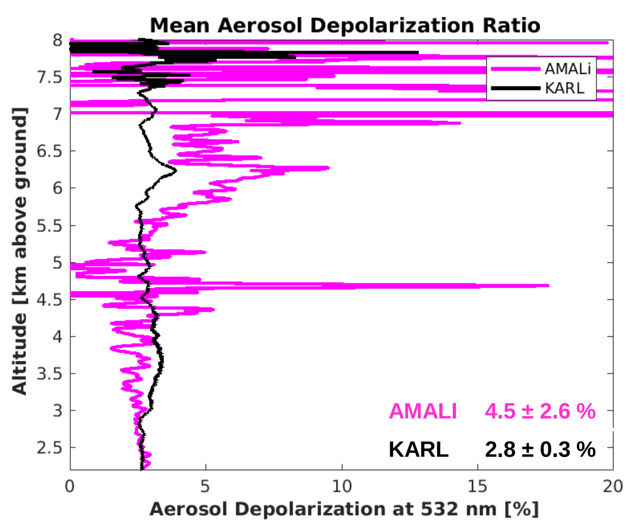

Fig. 6: Aerosol depolarization (δ=β532s/β532p).

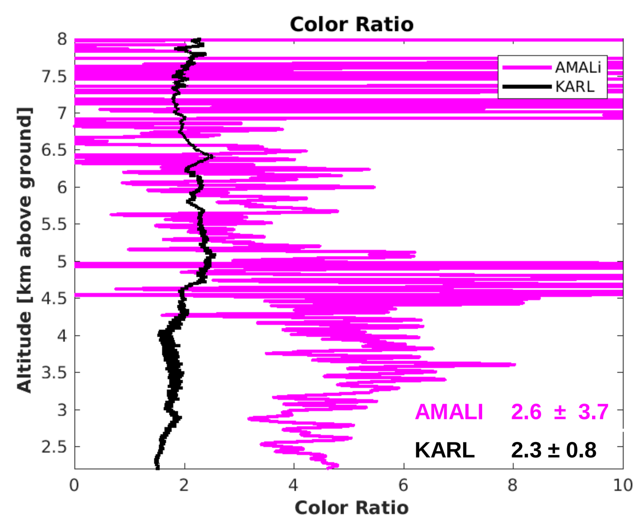

Fig. 7: Color ratio (CR=β355/β532).

Ground-based and air-borne Lidar observations revealed persistent layers in the free troposphere over Ny-Ålesund (Fig.3) and Greenland Sea (Fig.4).

Aerosol depolarization ratio (δ) indicated nearly spherical particles. This is in agreement with the Arctic Haze season of 2014 [8]. Slightly less spherical (higher δ) and larger (smaller CR) particles were observed during the evolution of the event (5th April, KARL) possibly due to an aerosol aging process. Aerosol mass concentration, which is roughly proportional to aerosol backscatter seems to decrease towards the end of the event.

Formula Appendix

$$CR(\lambda_1, \lambda_2) = \frac{\beta^{aer}_{\lambda_1}}{\beta^{aer}_{\lambda_2}}, \lambda_1 < \lambda_2$$

Eq. 1: Color ratio

$$\delta^{aer}(\lambda) = \frac{\beta^{aer}_{\perp}(\lambda)}{\beta^{aer}_{\parallel}(\lambda)}$$

Eq. 2: Aerosol depolarization

Hygroscopic Properties of Arctic Aerosol derived by Lidar - and radiosonde data

Furthermore, data from Lidar- and radiosonde measured from Ny-Ålesund in March are available. These were used to analyse amongst others hygroscopic properties of Arctic aerosols. Hygroscopic growth over water, but not over ice has been found.

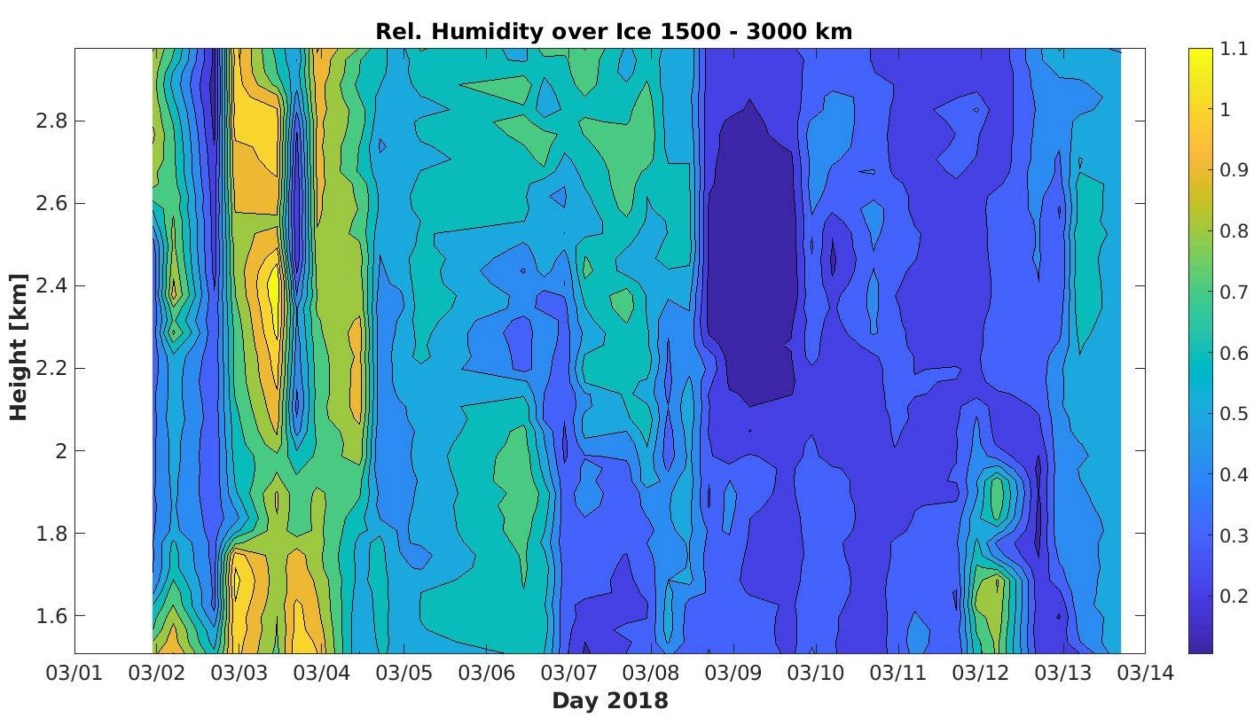

Fig. 8: Relative humidity over ice from 1st to 13th March 2018 measured by radiosonde (Vaisala RS41).

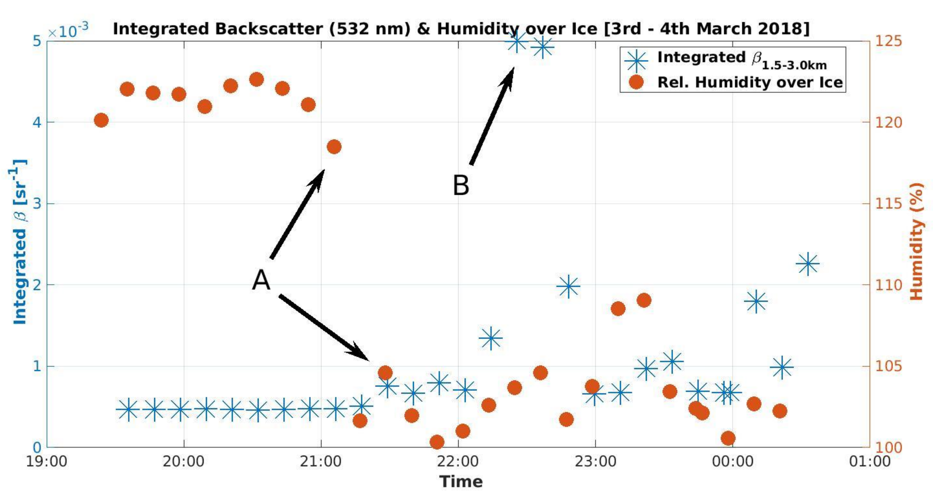

Fig. 9: Measured backscatter values and relative humidity over ice from 3rd – 4th March.

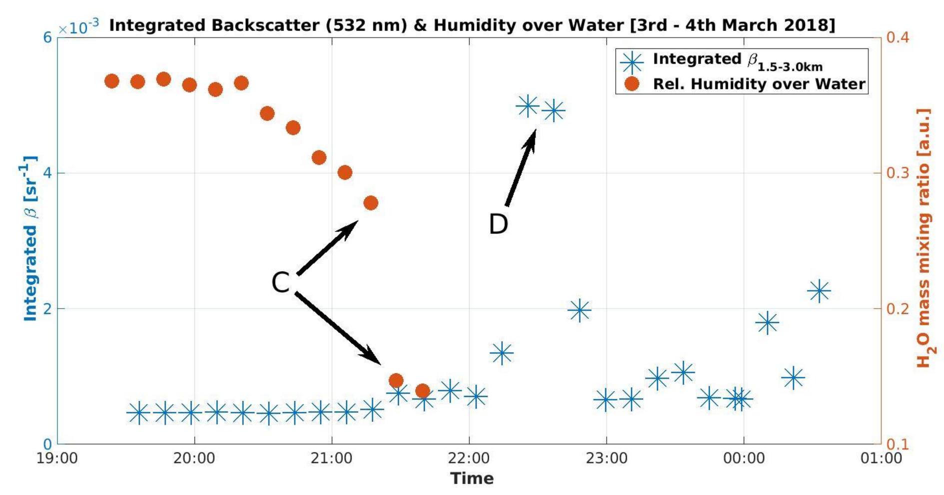

Fig. 10: Measured backscatter values and relative humidity over water from 3rd – 4th March.

Fig. 5 shows the development of relative humidity over ice for the height 1500 – 3000 m. Only high humid values (100% or higher) were distinguished.

Fig. 6 shows the data of measured backscatter represented as integrated values as well as the relative humidity over ice. At the beginning the backscattering has a lower value but rises during the evening to a certain maximum (B). The humidity is in general relatively high but decreases during the night (A). The diminishing of humidity occurs often simultaneously to the increase of backscatter.

Fig. 7 depicts the backscatter values against the relative humidity over water. The decrease of humidity is visible (C) as well as the increase of backscatter (D).

Conclusions

- In this work, the aerosol optical and hygroscopic properties during springtime of 2018 have been investigated.
- Layers over Ny-Ålesund and Greenland Sea exhibited similar geometrical and optical properties with a tendency towards bigger and less spherical particles during the end of event.
- An increase of backscatter simultaneously to a decrease of humidity was recognized. This might result to dry air masses being the origin of those aerosols concluding that in general a high amount of aerosols was present. A higher number causes a higher backscattering. On the other hand high humidity was observed, nevertheless no hygroscopic growth of aerosols have been seen.

References

[1] MC Serreze and RG Barry, 2011, Global and Planetary Change, Vol. 77, 85-96.
[2] M Wendisch et al., 2018, BAMS, doi: 10.1175/BAMS-D-18-0072.1.
[3] P Quinn et al., 2007, Tellus B, Vol. 59, 99-114.
[2] T Yamanouchi et al., 2005, Tellus B, Vol. 57, 141-52.
[3] K Hara. et al., 2003, J. Geophys Res. 108 (D7), 4209 doi:10.1029/2002JD002513.
[4] C Warneke et al., 2009,J. Geophys. Res. Lett., 36, L02813, doi:10.1029/2008GL036194.
[5] A Hoffmann et al, 2010, " A redesigned Raman Lidar for cloud and aerosol profiling in the Arctic", ILRC 25, St. Petersburg.
[6] I Stachlewska et al. 2010, Atmos. Chem. Phys., Vol.10, 2947-2963.
[7] J Klett 1981, Appl. Opt., Vol 20, 211-220.
[8] C Ritter 2016 et al. Atmos. Environ., Vol 141, 1-19.

Acknowledgements

This work was supported by the DFG funded Transregio-project TR 172 "Arctic Amplification (AC)³".

Ny-Ålesund Atmosphere Flagship open Workshop, Potsdam, October 15-19, 2018