A COMPARISON OF POLAR STRATOSPHERIC CLOUD LIDAR RETRIEVAL ALGORITHMS DEVELOPED AT AWI AND NILU

K. STEBEL[1], M. MÜLLER[2], G. H. HANSEN[1], R. NEUBER[2], and W. RUHE[3]

[1]Norwegian Institute for Air Research (NILU), Tromsø, Norway
[2]Alfred Wegener Institute for Polar and Marine Research (AWI), Potsdam, Germany.

[3] impres GmbH, Bremen, Germany

Keywords: polar stratospheric clouds, lidar, retrieval algorithm

INTRODUCTION

Polar stratospheric clouds (PSCs) play a pivotal role in the winter polar stratosphere due to the fact that heterogeneous reactions on cloud particle surfaces can lead to chlorine activation, which is the initial step for the catalytic destruction of stratospheric ozone. PSCs are generally classified depending on their backscatter/depolarization characteristics measured by lidar. The main types are: type Ia, solid particles below $T_{NAT,}$ the coexistence temperature of nitric acid tri-hydrate (weak to medium backscatter ratio (R), high depolarization (δ)), type Ib, liquid particles below T_{NAT} or T_{STS} (STS: super-cooled ternary solution) (medium R, low δ), and ice PSCs (high R, high δ).
Lidar measurements of PSCs and ozone have been preformed by AWI at the Koldewey station in Ny-Ålesund (78.9 ºN, 11.9 ºE), Svalbard, since winter 1991/92 (Neuber et al., 1992). At the Arctic Lidar observatory for Middle Atmosphere Research (ALOMAR, Andøya; 69.3 ºN, 16.0 ºE) the stratospheric ozone lidar, jointly run by FFI, NILU and the Andøya Rocket Range, has been used to detect PSCs since winter 1995/96 (Hoppe, 1995). Figure 1 shows an example of PSC observations from January 1996 at ALOMAR. The general aim of this study is the harmonization of AWI's and NILU's lidar data retrieval for PSCs, and aerosols in general.

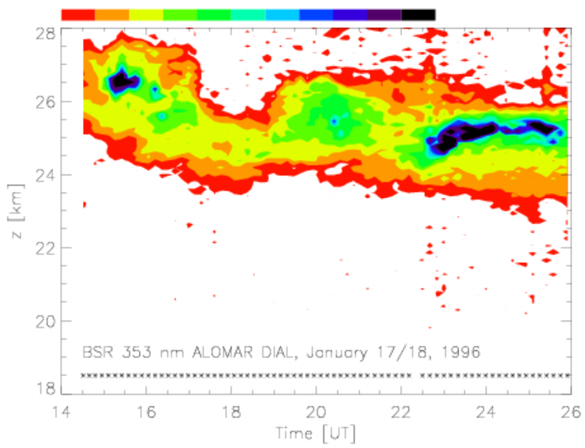

Figure 1. Polar stratospheric clouds observed by the ALOMAR DIAL during the night January $17^{th}/18^{th}$, 1996. Shown is the backscatter ratio at 353 nm [intervals between 1.1 (dark colour at the outer edge of the cloud) and 8 (around about 15 UT in 26.5 km altitude, and after ca. 22.30 UT around about 25 km altitude)].

METHODS

Different inversion algorithms are utilized by AWI and NILU to extract geophysical parameter from measured backscattered light intensities at different wavelengths. Both groups use external density and temperature data from radio-soundings as additional input data, which are available on a daily base only in Ny-Ålesund. Background substraction, as well as dead time correction are parts of both analyses. AWI's retrieval is based on Klett's inversion algorithm (Klett, 1981, 1985), while at NILU (see Hansen et

al., 1997) R is calculated from the ratio of the range- and Rayleigh extinction corrected lidar profile and a reference density profile taken from ECMWF data at the nearest grid- and time point. While AWI's software in general uses 30 km as an aerosol-free altitude (R = 1), at NILU the lower edge of the aerosol layer is determined visually, which is needed to minimize effects from beam misalignment and deviations between the local and the reference density profile. At NILU the ozone extinction contained in the R profile at 308 nm is corrected using an external ozone profile to derive a colour index.
Different raw data sets for comparison have been selected to cover the wide spectrum of PSCs observed. Cross-analyses of raw data sets from 15 days, 1 h each, have been preformed, and differences have been determined. An example of the comparison is shown in Figure 2. First results generally show good agreement between the AWI and the NILU data analysis.

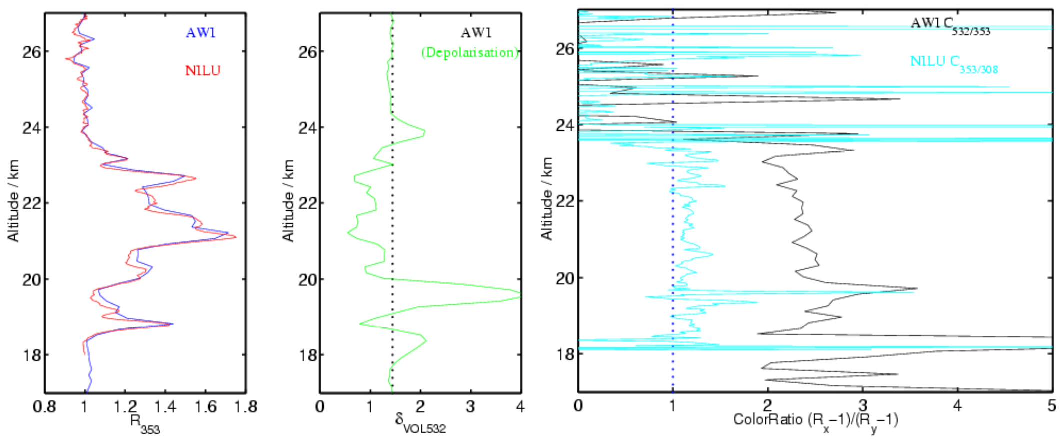

Figure 2.a. R at 353 nm measured in Ny-Ålesund, January 10th, 2000 (04.22 - 05.28 UTC) by the AWI lidar, and calculated with AWI (black line) and NILU (gray line) algorithms (left panel), b. volume depolarization at 532 nm for the same period, measured and analysed by AWI (middle panel), c. colour ratios for 532 nm / 353 nm calculated with AWI algorithm and colour ratios for 353 nm / 308 nm calculated with NILUs data analysis software.

We will describe both the data acquisition of the systems, the basic parts of the algorithm used at present, and modified algorithms used under special conditions, in more detail. We document the existing data retrieval depending errors in PSC parameters, and identify reasons as far as possible. In particular the usability of the O_3-correction algorithm for the 308 nm DIAL channel in order to obtain aerosol parameters (e.g. colour ratio) is studied further.

ACKNOWLEDGEMENTS

This work was partly financed via ENVINET by the EU 5th Framework Human Potential Program and by the EU project MAPSCORE.

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Measurements of polar stratospheric clouds (PSCs):

Lidar measurements of PSCs and ozone have been preformed by AWI at the Koldewey station in Ny-Ålesund (78.9ºN, 11.9ºE), Svalbard, since winter 1991/92 (Neuber et al., 1992). At the Arctic Lidar Observatory for Middle Atmosphere Research (ALOMAR, Andøya; 69.3ºN,16.0ºE) the strato-spheric ozone lidar, jointly run by FFI, NILU and the Andøya Rocket Range, has been used to detect PSCs since winter 1995/96 (Hansen and Hoppe, 1997).

Inversion algorithms used by AWI and NILU:

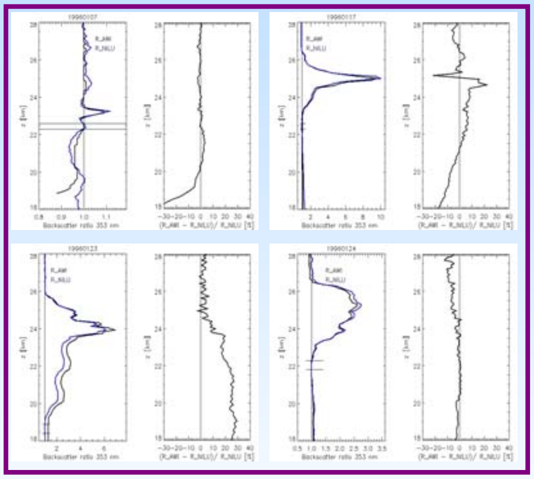
AWI's retrieval is based on Klett's inversion algorithm (Klett, 1981, 1985), while at NILU (see Hansen et al., 1997) R is calculated from the ratio of the range- and Rayleigh extinction corrected lidar profile and a reference density profile taken from ECMWF data at the nearest grid- and time point. While AWI's software in general uses 30 km as an aerosol-free altitude (R = 1), at NILU the lower edge of the aerosol layer is determined visually, which is needed to minimize effects from beam misalignment and deviations between the local and the reference density profile. At NILU the ozone extinction contained in the R profile at 308 nm is corrected using an external ozone profile to derive a colour index for 353/ 308 nm.

Discussion of results from algorithm intercomparison:

Cross-analyses of raw data sets from 15 days, 1 hour each, representing the wide spectrum of PSCs observed, have been performed, and differences have been determined.

In **Figure 2** calculated profiles for different PSC types are shown. The overall agreement in the altitude range of PSCs is good, showing differences of less than 5%. In case of PSCs with sharply changing gradients as in the case from 17 January 1996, small altitude uncertainties give – as to be expected - larger deviations (10–20%). There is a good agreement of the integrated values. Larger deviations occur when analysing optically thicker PSC, e.g. seen on 23 January 1996, which extended over the altitude range 19 – 26 km. The agreement is good above the peak of the PSCs, below, the data analyzed with Klett's algorithm, show a positive deviation from NILU's results, with deviations increasing to about 25% at the cloud base. This might be due to an underestimated aerosol extinction using Klett's formula. On the other hand, normalizing the lidar profile to R = 1 below the PSC, as done by NILU's, bears the risk to underestimate the value of the background aerosol content.

Figure 3 illustrates the results of the O_3-correction algorithm for the 308 nm channel of the DIAL system to calculate colour-ratios. Increased values of the volume depolarization and changes in the colour ratios at 532/353 nm reveal that the cloud is composed of different typs of PSC with varying sizes/phases. The size change is as well reflected in the colour-ratios calculated for 353/308 nm. NILU's approach seems to be suitable to obtain additional, qualitative information about the internal structure of the PSC.



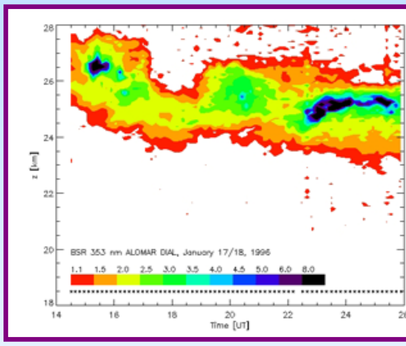


Figure 1 shows an example of PSC observations during the night January 17th/18th, 1996 at ALOMAR. Backscatter ratios at 353 nm are shown.

Figure 2: Backscatter ratio at 353 nm, analysed with AWI's and NILU's algorithm, and deviation between the two, for different types of PSCs, measured at ALOMAR during spring 1996: upper left panel: very weak PSC type I with R_{max}= 1.1; upper right panel: PSC type II with sharp maximum at about R = 10; lower left panel: thick PSC between 19–26 km altitude; lower right panel: medium strong PSC between 22.5 –26.5 km altitude.

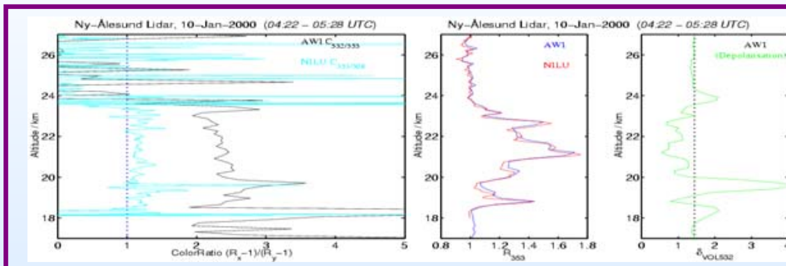


Figure 3 shows measurements from Ny-Ålesund, January 10th, 2000: left panel: colour ratios for 532 /353 nm (AWI's algorithm) and 353/308 nm (NILU's algorithm); middle panel: backscatter ratio at 353 nm (analysed by AWI/NILU); right panel: volume depolarization at 532 nm (AWI).

Conclusions:
In general we find a good agreement, better than 5 %, between the PSC results analyzed by AWI (using Klett's algorithm) and NILU (normalization of the lidar profile to a density profile). Larger deviations are seen for thick PSCs extending over a wide altitude range, with non-negligible extinction. Using an O_3-correction algorithm for the 308 nm DIAL channel in order to calculate colour-ratios seems to be a good tool to obtain additional qualitative information about aerosol sizes and the internal structure of PSCs.

ACKNOWLEDGEMENTS:
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Contact: Kerstin Stebel, NILU, Polar Environmental Centre, N 9296 Tromsø, Norway. Email: kerstin.stebel@nilu.no